NUREG-0001
Part II of V

Nuclear Energy Center Site Survey – 1975

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POOR ORIGINAL

The U. S. Electric Power System and the Potential Role of Nuclear Energy Centers

United States Nuclear Regulatory Commission

UNITED STATES NUCLEAR REGULATORY COMMISSION

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NUREG-0001
Part II

NUCLEAR ENERGY CENTER SITE SURVEY-1975

PART II: THE U.S. ELECTRIC POWER SYSTEM AND THE POTENTIAL ROLE OF NUCLEAR ENERGY CENTERS

Other Volumes:

Part I	Summary and Conclusions
Appendix A	United States Map--Coarse Screening Results
Part III	Technical Considerations
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January 1976

U.S. NUCLEAR REGULATORY COMMISSION

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SECTION 1

THE UNITED STATES ELECTRIC POWER SYSTEM TODAY

1.1 INTRODUCTION

The electric power industry's role and manner of development in the future is an issue which deserves the most serious consideration by everyone, whether he or she be a legislator, government official, private planner, utility official, a manufacturer, an environmentalist or a consumer.

In less than 100 years the electric power generating industry has become the Nation's largest industry in terms of capital investment. It is our most capital-intensive industry; the privately owned sector alone controls assets in excess of $100 billion, and it generates revenues in excess of $25 billion. In 1974, for example, public utilities accounted for 15.7% of total business expenditure in new plant and equipment as compared to 8.1% in 1965.

1.2 INDUSTRY GROWTH

Since the beginning of this century the industry almost without exception has doubled its production every decade; its production increased at about twice the rate in overall industrial production. According to Federal Power Commission figures, by 1920 the average annual per capita consumption was 540 kWh. This grew to 1,380 kWh in 1940, 4,760 kWh in 1960 and an expected 8,179 kWh in 1975. There is significant debate on the rate of future growth.

1.3 INDUSTRY STRUCTURE

Over 3,500 separate entities participate in the supply of electric energy directly to consumers or for resale to consumers in the United States. Those include six Federal systems, nearly 1,000 cooperatives, more than 2,200 non-Federal publicly-owned systems and over 300 privately-owned systems. Many of these systems are quite small, supplying total loads of only a few thousand kilowatts; others are exceedingly large such as the TVA system which generates about 18 million kilowatts in order to satisfy demand.

The electric power industry has been moving toward consolidation over the past several decades. For example, in 1947 there were approximately 4,000 electric utilities in operation in the United States of which 858 were privately owned. In 1974 the number was 3,115 with 260 privately owned systems remaining. Most of the consolidation has come about through corporate merger and integration. For the most part the electric power industry is vertically integrated. That is to say that a single utility generates, transmits and distributes electricity. In addition, most utilities are interconnected with neighboring utilities. The historical trend and current ownerships of power systems in the contiguous United States are indicated in Table 1.1.

TABLE 1.1

OWNERSHIP OF U.S. POWER SYSTEMS

Ownership	1927	1937	1947	1957	1974
Investor Owned	2,135	1,401	858	465	260
Public Non-Federal	2,198	1,878	2,107	1,890	1,880
REA Cooperatives	192	887	1,026	960	969
Federal Power Agencies	1	3	4	5	6
Total	4,526	4,169	3,995	3,320	3,115

Source: Federal Power Commission

Investor-owned utilities. There is considerable diversity of ownership types as well as a wide variation in sizes and functions, though the private sector continues to dominate the industry as it has for many decades. The 217 Class A and B privately owned systems* provided over 75% of the generating capacity, served about 80% of the ultimate customers and collected over 80% of the total revenues of the electric power industry in 1973. Nearly all of these systems perform all of the functions of generation, transmission and distribution. In a growing number of instances they are also seeking to perform the function of fuel supply and fuel transportation. The majority of these systems are independently owned with securities that trade on the national stock exchanges. About 80 systems in the private sector are subsidiaries of 18 operating electric utilities or 14 non-operating holding companies.** In most instances these groups operate as integrated systems, often with central dispatch of their generating facilities.

The fifty largest investor owned utilities by operating revenues for 1974 are shown in Table 1.2. In addition to rank, the table shows the composition by operating revenue for electricity, gas, or other (mainly steam).

Tennessee Valley Authority. In the 1930s the Federal government began to assume a major role in electric power supply and transmission business. Since that time, there has been established six Federal systems accounting for roughly 10% of the total industry generating capacity. The largest and best-known is the Tennessee Valley Authority (TVA) which was established in 1933 to develop the resources of the Tennessee River basin, including navigation, flood control and hydroelectric power. TVA was authorized to market surplus hydroelectric power that was developed in conjunction with the construction of navigation and flood control projects. TVA's

*Class A and B are ratings of the Federal Power Commission. Class A utilities are those having annual operating revenues of $2.5 million or more. Class B utilities are those with annual operating revenues of $1 million or more but less than $2.5 million. On the basis of assets and revenues, these Class A and B utilities comprise nearly 100 percent of the privately owned sector of the electric light and power industry.

**Holding companies are defined as those companies which directly or indirectly control 10 percent or more of the outstanding voting securities of a public utility (or of a holding company) or which, in the judgment of the Securities Exchange Commission, can exercise a sufficient influence over such an entity as to make regulation appropriate.

TABLE 1.2

FIFTY LARGEST INVESTOR OWNED UTILITY COMPANIES
RANKED BY OPERATING REVENUES FOR THE YEAR 1974

Rank	Company	Company Type[a]	Operating Revenues ($ Millions)	Composition of Revenues: Electric %	Gas %	Other (Steam) %
1	Consolidated Edison	E	2,439	86.0	7.0	7.1
2	Pacific Gas and Electric	C	1,727	64.0	36.0	0.0
3	Southern	E	1,489	100.0	0.0	0.0
4	Southern California Edison	E	1,484	100.0	0.0	0.0
5	Commonwealth Edison	E	1,460	100.0	0.0	0.0
6	Public Service Electric and Gas	C	1,456	75.6	24.4	0.0
7	American Electric Power	E	1,316	100.0	0.0	0.0
8	Consumers Power	C	1,105	56.1	43.8	0.1
9	Philadelphia Electric	E	1,012	86.3	10.8	2.9
10	Florida Power and Light	E	951	100.0	0.0	0.0
11	Detroit Edison	E	898	96.1	0.0	1.9
12	General Public Utilities	E	862	99.8	0.0	0.2
13	Niagara Mohawk Power	C	831	80.8	19.2	0.0
14	Duke Power	E	823	100.0	0.0	0.0
15	Middle South Utilities	E	822	94.0	4.7	1.4
16	Virginia Electric and Power	E	764	96.3	3.7	0.0
17	Texas Utilities	E	727	100.0	0.0	0.0
18	Northeast Utilities	E	653	99.4	0.0	0.6
19	Baltimore Gas and Electric	C	609	77.3	21.8	0.8
20	Central and Southwest	E	595	100.0	0.0	0.0
21	Long Island Lighting	C	586	82.9	17.1	0.0
22	New England Electric System	E	586	98.8	0.0	1.2
23	Northern States Power	C	545	83.7	15.3	0.9
24	Allegheny Power System	E	501	100.0	0.0	0.0
25	Ohio Edison	E	498	99.2	0.0	0.8
26	Houston Lighting and Power	E	487	100.0	0.0	0.0
27	Pennsylvania Power and Light	E	472	99.1	0.0	0.9
28	Union Electric	E	469	94.5	3.8	1.7
29	Cleveland Electric Illuminating	E	464	98.4	0.0	1.6
30	Carolina Power and Light	E	461	100.0	0.0	0.0
31	Boston Edison	E	46[illegible]	93.9	0.0	6.[illegible]
32	Northern Indiana Public Service	C	449	46.7	53.3	0.0
33	Potomac Electric Power	E	442	100.0	0.0	0.0
34	Wisconsin Electric Power	C	432	80.5	18.2	1.3
35	Cincinnati Gas and Electric	C	416	65.7	34.3	0.0
36	Florida Power	E	405	100.0	0.0	0.0
37	Gulf States Utilities	E	370	91.3	2.1	6.6
38	Public Service of Colorado	C	364	62.0	37.1	0.9
39	Illinois Power	C	330	67.0	33.0	0.0
40	Duquesne Light	E	325	97.6	0.0	2.4
41	Dayton Power and Light	C	300	71.6	26.8	1.6
42	New York State Electric and Gas	C	296	80.4	19.6	0.0
43	San Diego Gas and Electric	C	290	76.7	23.1	0.2
44	South Carolina Electric and Gas	C	280	81.8	17.4	0.7
45	Arizona Public Service	C	274	78.0	22.0	0.0
46	New England Gas and Electric	C	269	69.4	27.9	2.6
47	Delmarva Power and Light	E	262	87.4	9.1	3.5
48	Public Service of Indiana	E	261	100.0	0.0	0.0
49	Rochester Gas and Electric	C	234	60.8	32.2	7.0
50	Oklahoma Gas and Electric	E	227	100.0	0.0	0.0

Source: Office of the President-Finance, Pacific Gas and Electric Company, Comparative Financial Data, Fifty Largest Companies, Year 1974, (San Francisco: Pacific Gas and Electric Company), July 25, 1975.

[a]E: electric; C: combination (a company that sells a substantial amount of gas).

power operations were later expanded to include fossil fuel and nuclear generation and today it is the largest producer of electric energy in the United States. In 1974 TVA delivered around 106 billion kilowatt-hours of electric energy. Such energy is marketed by TVA to major industries and to local municipal and rural electric cooperative power systems for resale to the end user. The low cost of electric power in the TVA area is considered to have been a major stimulus to the area's industrial and agricultural development since the depression years of the 1930s.

Bonneville Power Authority. In 1937 the Bonneville Power Authority (BPA), under the Secretary of Interior, was established for the purpose of marketing hydroelectric power produced by Federal multipurpose reservoir projects being constructed in the Pacific Northwest by the Corps of Engineers and the Bureau of Reclamation. The low cost of this hydroelectric power has attracted major industries sensitive to power cost, i.e., aluminum reduction plants, and made electricity a primary energy source for the entire region. In FY 1974 BPA marketed around 63 billion kilowatt-hours of electric energy. The Pacific Northwest and the TVA area lead the Nation in the use of electricity for home heating as a result of its low cost.

Rural Electrification Program. In a further effort to spread the use and benefits of electricity to rural areas that were below the economic range of the private sector, the rural electrification program was initiated by Presidential Executive Order in 1935, and in 1936 legislation was passed establishing the Rural Electrification Administration as a lending agency. At the present time there are some 1,000 rural electric distribution cooperatives owned by the members ranging in size from less than a hundred members to as many as 35,000. These cooperatives delivered around 100 billion kilowatt-hours of electricity in 1974 or around 5.5% of the total consumed in the contiguous United States. Around 30% was self generated; the remainder was purchased from Federal marketing agencies and investor owned utilities. In recent years a large number of the distribution cooperatives have organized area generation and transmission cooperatives (G&Ts) on a wide regional basis to construct major generating stations and transmit wholesale power to the distribution load centers. The distribution cooperatives are thereby enabled to obtain the economic benefits of large generating plants and favorable financing and to take delivery of wholesale power at the most feasible location on their distribution systems. The G&Ts are expected to become the major source of power supply for the rural electric cooperatives as their loads continue to grow and have been incorporated in the overall interconnected power system of the Nation.

Other Federal power systems. Over the past four decades the Federal Government has pursued an extensive dam building program for controlling flood waters and developing navigation and hydroelectric power in the Nation's major river basins. In 1944, the Secretary of the Interior was given a general marketing authority for power produced from such multipurpose projects (excluding TVA) constructed by the U.S. Army Corps of Engineers, in addition to those built by the Department's own Bureau of Reclamation. In accord with that authority, the Secretary established the Southwestern Power Administration (SPA) and the Southeastern Power Administration (SEPA) to develop and administer Federal hydroelectric power marketing programs in their respective designated areas as well as the previously established Bonneville Power Authority.

During FY 1974 SPA marketed about 7.9 billion kilowatt-hours and SEPA marketed about 7.5 billion kilowatt-hours of electric energy. The Bureau of Reclamation marketed directly around 49 billion kilowatt-hours of electric energy during FY 1974.

Other non-Federal public power systems. The other major segment of the electric power supply industry in the Nation consists of the public non-Federal power systems, most of which are municipally owned and operated. The number of these systems reached a peak in the mid 1920s with nearly 3,100 electric systems. The number declined rapidly to about 2,200 by 1927. In 1974, there were around 1,880 such systems. Municipal utilities are the most common form of public non-Federal power systems. They vary in size from very small systems, with a few hundred customers, to the Los Angeles Department of Water and Power with over a million customers. During the 1930s and 1940s other government entities such as Public Utility Districts were established to produce and sell electric power, many of which are located in the State of Washington. Also, in some states special authorities were established, such as the Arizona Power Authority and the Power Authority of the State of New York. The latter organization is a major supplier of wholesale power in New York, Vermont and to a limited extent in Pennsylvania. More recently, it has undertaken to purchase a nuclear plant from Consolidated Edison in addition to the one it already has in operation.

1.4 GENERATION AND OPERATION

Size of generating units. In the 1930s the largest steam-electric generating unit was about 200 megawatts. In 1975 the largest is about 1,300 megawatts.* The movement to larger size units began to accelerate around 1955 when the size had increased to about 300 megawatts. Until the late 1960s, the larger size units and the associated transmission system made it possible for the utilities to keep unit production costs from escalating since capital costs per kilowatt and operation and maintenance cost per unit of energy generated are less for large units than small ones. In more recent years, however, the increasing size of units has leveled off at about 1,100 megawatts while the industry seeks to improve the performance of these larger units, both fossil and nuclear. The trend of increased size of fossil fueled generating units is indicated in Figure 1.1

Base and peak loading. Power demands can vary widely on electric power systems, with early morning loads frequently less than half the peak loads of late afternoon, and with winter peaks on some systems as much as 40 percent below the summer peaks. To meet these load variations electric utilities use a combination of various types of generating plants, including coal, oil and gas-fired steam plants, nuclear steam plants, hydroelectric plants, oil and gas fired combustion turbines, and oil and gas fired internal combustion engines. In California, geothermal steam is used by Pacific Gas and Electric in a limited way as an energy source.

*Currently, there is a Nuclear Regulatory Commission guide that limits the thermal power for nuclear powered units to 3,800 MW. For light-water reactors, this translates to an electric power of about 1,300 megawatts.

Source: Federal Power Commission

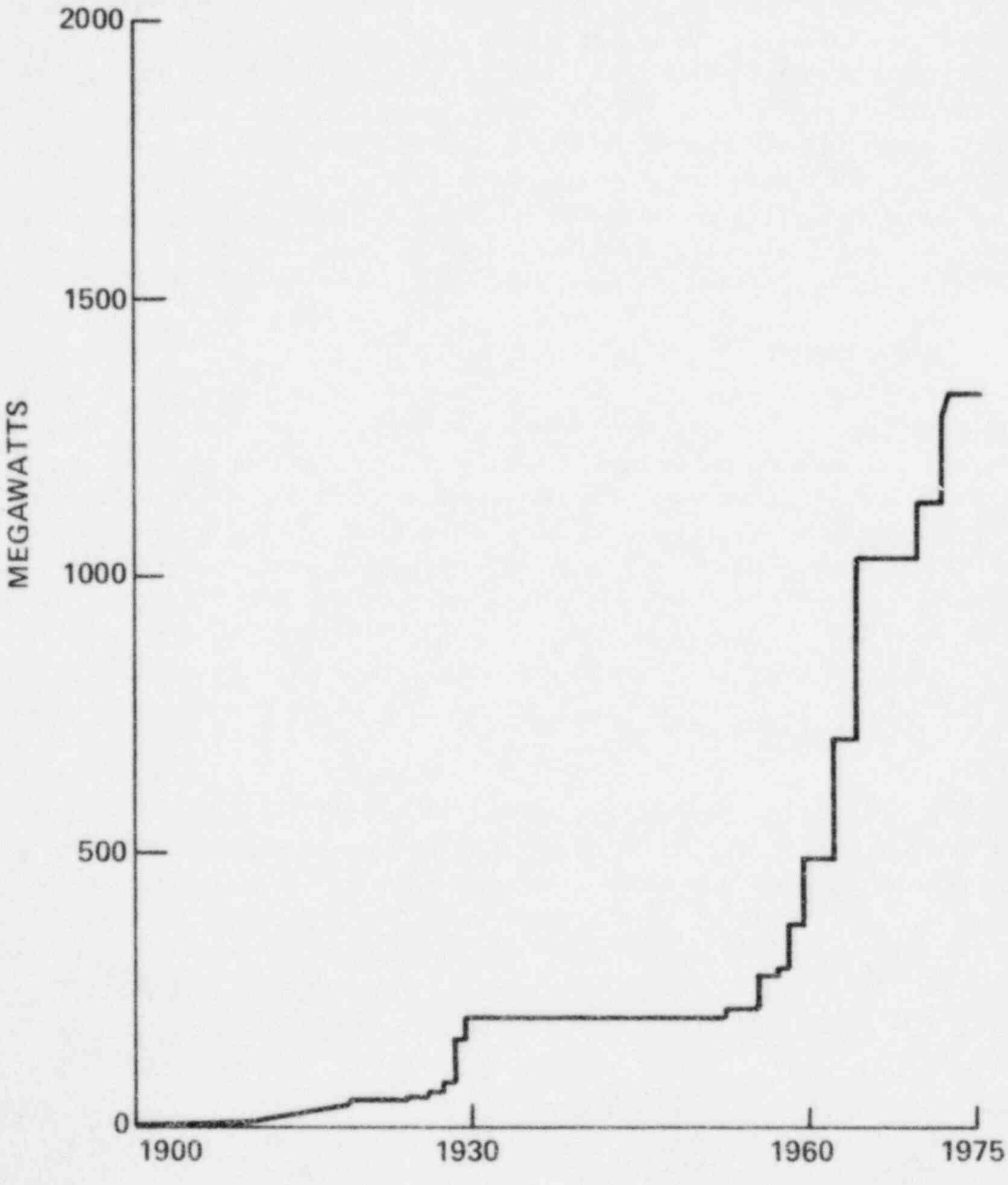

FIGURE 1.1 LARGEST FOSSIL-FUELED STEAM-ELECTRIC TURBINE-GENERATORS IN SERVICE, 1900-1975

Economics. Typically, the coal fired and nuclear steam plants have the highest first costs but the lowest direct operating and fuel costs of all thermal plants. Consequently these plants are utilized as much as possible. If they can be used at essentially full power, 24 hours a day, they are said to be "base loaded." To meet the part-time higher load levels utilities employ generating units which can be readily started and stopped and which can operate satisfactorily from full load down to less than half of full load. Such units are termed "cycling units" and often consist of older, smaller units. The economics of such units allows acceptance of higher fuel and operating costs, because of the limited operating periods, provided the capital charges are lower than those of base load units. To meet the peak loads, which may exist for only ten percent of the time, utilities in recent years have turned increasingly to combustion turbine generating units, which have capital costs only a third of a coal-fired plant, but considerably higher fuel consumptions, and consequently higher operating costs. However, these can be readily started and stopped on very short notice. Hydroelectric plants also make excellent peaking units where the water flow is insufficient for continuous operation. Pumped storage hydroelectric plants are being constructed specifically for peaking operation. In such units water is pumped from a lower reservoir to an upper reservoir in off-peak hours, using energy from base load plants. During peak electrical demand periods the water flows down again, providing the needed extra generation.

An approximate tabulation of U.S. generating capacity, as of the end of 1974, is provided in Table 1.3. The classifications of primary fuel in the steam plant category are approximate because a number of units can burn more than one fuel.

1.5 INTERCONNECTION, TRANSMISSION AND REGIONAL COORDINATION

Interconnection and transmission. Although the electric utilities recognized the advantages of interconnected systems operations as early as 1914, when two systems in New England were interconnected - one with only hydroelectric power and the other with only steam-electric generation - the major effort toward the interconnection and coordination of the Nation's major power systems came during and after World War II. The World War II production effort placed a great strain on the electric utility industry to meet the power requirements of war production plants. One of the measures used to meet the demand was the establishment of additional interconnections between major power systems and the displacement and transmission of power from areas with surplus generation to areas with generation deficiencies.

As the electric utility industry expanded following World War II, particularly during the late 1950s and in the 1960s, the economies and system reliabilities achievable through strong interconnections and coordinated operations of power systems became key factors in the planning and construction of extra high voltage transmission lines and of generating units having a higher generating capacity. The need to transport electric energy in greater amounts led to higher transmission voltages. While the maximum alternating current (a.c.) transmission voltage operating during World War II was 230 kV, by 1975 345-kV and 500-kV lines had become commonplace and 765 kV had started to play a role, the latter having a transmission capacity in the order of five to seven times that of a 230 kV line. Studies and development work are now underway on transmission voltage levels as high as

TABLE 1.3

TYPES OF U.S. GENERATING CAPACITY, DECEMBER 31, 1974
(Megawatts)

Fossil Steam		336,414	70.6%
Coal	(197,588)[a]		(41.4)
Oil	(66,124)[a]		(13.9)
Gas	(72,291)[a]		(15.2)
Geothermal	(411)		(0.1)
Nuclear Steam		31,662	6.7
Hydroelectric (including pumped storage)		63,589	13.4
Combustion Turbine		39,292	8.3
Internal Combustion		5,001	1.0
		475,958	100.0%

Source: Federal Power Commission

[a]estimated

1,500 kV. The economies and operating advantages of high voltage direct current (d.c.) transmission are making it a feasible alternative to high voltage alternating current in some cases. The first such direct current transmission line in the United States, a $\pm$ 400-kV d.c. line reaching from Oregon to southern California, was placed in service in May 1970. The industry is interested in dc transmission compared to ac because reliability is increased, transmission right-of-ways are reduced, and regional instabilities that arise from weak interconnections are reduced. An indication of the trend of increased transmission voltage levels is shown in Table 1.4.

TABLE 1.4

TRANSMISSION LINE MILEAGES -- 230 kV AND ABOVE

	230 kV	345 kV	500 kV	765 kV	$\pm$ 400kV (d.c.)
1940	2,327	-	-	-	-
1950	7,383	-	-	-	-
1960	18,701	2,641	13	-	-
1970	40,600	15,180	7,220	500	865
1974	55,470	38,407	13,451	1,139	865

Nearly all the electric systems in the continental United States are interconnected with one or more other systems, and, for the most part, operate in parallel. On a broad basis, there are three primary systems. The largest of these extends from the East Coast to the Dakotas, Nebraska, Kansas and Oklahoma. To the west of this system there is the Northwest Interconnected Systems Group which is tied together by a large a.c. and d.c. interconnection with the Pacific Southwest systems. The remaining system is located in Texas which for the most part operates independently of the rest of the country.

Over the last fifteen years, major steps have been taken to strengthen the interconnected system with stronger tie lines and, in some cases, brand new interties. For example, Detroit Edison and Consumers Power Co. have interconnected with their neighbors to the south. The New York and Pennsylvania-New Jersey-Maryland (PJM) interconnections have been strengthened and the ties between the TVA system and its neighbors have been strengthened. These steps have meant that electrical energy can be transferred instantaneously from one system to another allowing the systems to participate in the bulk power supply market in which electricity is purchased or sold for purposes of resale. Participation in this market may enable a system having only distribution facilities to obtain its entire power supply from one or more other sources; it may also enable a largely vertically integrated power supplier to coordinate the operation and planning of its bulk power supply facilities with one or more neighboring systems in such a way as to reduce capital and operating costs and improve system reliability.

Regional coordination. Many types of formal and informal organizational arrangements have been developed for the purpose of enabling utilities to obtain the advantages of coordination. The formal arrangements vary from a simple two-party agreement between neighboring systems covering the exchange of emergency and economy energy to a complex power pooling agreement among as many as a dozen or more systems including systems of various types of ownerships. At the present time there are about 20 formal pools in operation including five holding company pools.

In addition to the coordinating agreements and power pools discussed above, which have been developed primarily for purposes of economy, the electric utilities with the encouragement of the Federal Power Commission have found it essential for assurance of reliability of bulk power supply to coordinate their system planning and operation on a broader scale. Following the Northeast Power Failure in 1965, systems in New York and New England formed the Northeast Power Coordinating Council to improve adequacy and reliability of bulk power supply in that region. Subsequently, similar reliability councils were formed in other regions so that at the present time there are nine councils whose members include virtually all major electric utilities in the 48 contiguous States (see Figure 1.2). These are voluntary organizations which, although they have no authority to make decisions involving the planning or installation of new bulk power facilities, review proposals for the installation of such facilities from the point of view of their effect on regional power supply reliability.

In 1968, a further step in self-organization was taken by the industry in forming its National Electric Reliability Council (NERC). The members of NERC include the nine regional councils. While the Councils do not have any authority to make and enforce regulations or to issue directives to their members, the mutual disclosure of plans and the discussion of regional issues has been helpful in resolving regional problems and promoting more effective use of utility resources. Each year the Councils submit to the Federal Power Commission a detailed projection of electric power loads ten years into the future, with a listing of major generation and transmission facilities which are planned to meet the loads who review the projections and comments publicly thereon.

FIGURE 1.2 REGIONAL ELECTRIC RELIABILITY COUNCILS

1.6 REGULATION OF THE ELECTRIC POWER INDUSTRY

Principal responsibility for the regulation of electric utilities has been vested for many decades in the state utility commissions. Such commissions now function in nearly all states, the principal exception being Nebraska which is served entirely by publicly owned systems. Although all of these Commissions regulate investor-owned systems, less than half have authority to regulate cooperatives or publicly owned systems.

The scope of authority of state commissions generally includes establishment of allowable rates for the cost of electricity and service, approval of securities issuances, and required accounting practices; in many cases it also includes certification of major property additions, initiation and abandonment of service and territorial allocation and in some cases, certification of rights-of-way. Over 90 percent of the revenue of electric utilities, namely that portion representing sales of electricity at retail, is subject to State regulation. The balance, representing sales at wholesale for resale, is regulated by the Federal Power Commission.

The principal responsibilities of the Federal Power Commission include the licensing of all non-Federal hydroelectric projects which in its judgment are best adapted to a comprehensive plan for improving or developing a waterway for the use or benefit of interstate and foreign commerce. In addition, as to those utilities which are engaged in the transmission of electric energy in interstate commerce, the FPC regulates their wholesales and service, approves their accounting systems and reviews other various corporate activities such as issuance of securities, etc. While under Sec. 202(a) of the Federal Power Act it has the responsibility to assure "an abundant supply of electric energy throughout the United States with the greatest possible economy and with regard to the proper utilization and conservation of natural resources," it does not have authority to direct an interconnection except upon request in the case of an emergency. Nor does the FPC have any authority over the licensing of, the construction of, or operation of interstate transmission lines or fossil fuel or nuclear generating stations; jurisdiction is fragmented over a number of different Federal and/or State agencies. However, in response to the mandate of Section 202(a), the Commission has initiated several National Power Surveys, such as the one in 1964 and again in 1970.

Among the several other Federal administrative and executive agencies, the Securities and Exchange Commission regulates the activities of public utility holding company systems engaged in the electric power business. These include accounting, securities issuances, service company arrangements, mergers and intercompany transactions.

The Nuclear Regulatory Commission is responsible for regulating nuclear power plants with respect to radiological safety and environmental impact and for monitoring, in collaboration with the Department of Justice, the antitrust issues that arise in the generation and distribution of electric energy from nuclear plants. A more detailed description of NRC's responsibilities is given in Section 7.

In addition, the Environmental Protection Agency, the Federal Energy Administration, and the Rural Electrification Administration have differing degrees of responsibility for the regulation of certain activities of the industry. The functions of these agencies will be further discussed in later sections.

SECTION 2

ELECTRICITY DEMAND HISTORY AND FORECASTS

2.1 FORECASTING GROWTH IN ELECTRICITY DEMAND

2.1.1 Forecast Types and Characteristics

Electric power growth projections have been prepared for many years by individual utilities, by industry associations, by publications serving the industry, by government agencies and by various research organizations. In recent times, these various projections have become a subject of some debate. In the eyes of some conservationists, industry projections are sometimes regarded as self-fulfilling plans for the wasteful and irreversible expenditure of natural resources. To others, growth projections are essential instruments in helping the Nation plan adequately to meet the economic and social needs of its population.

Some protagonists offer a projection of electric energy use as a national goal to limit resource depletion, which in their view, should be enforced by various governmental measures. Such a 'goal' projection, however, differs from the more usual projection, which is an attempt to forecast what the market for electric power will be, assuming the continuation of the same economic system we have been using, bu . allowance for the effects of changes in living patterns, shifts in the price of electricity in comparison to other things, the availability of alternate energy forms, and other factors influencing electricity use. An understanding of such uses is, however, essential to an evaluation of the relative merits of the various projections.

For the utilities, the most fundamental purpose of electric power load forecasts should be to assist the planning and scheduling of new electric generating, transmission and distribution facilities. This electric energy is presumably needed for new industrial, commercial and residential construction, as well as the energy for the continued addition of electric equipment by existing consumer; the facilities and the capital for their construction must be committed in advance of the demand. If the facilities of a utility fall short of the demand, there can be electric power shortages; interruptions could, of course, have serious economic and social consequences. If the utility meets the demand by purchasing energy from its neighbors, the higher incremental costs of such purchases, as compared to self-generation, also generally reduce net income. On the other hand, if facilities are constructed substantially in advance of demand, they are not fully utilized and the capital charges on the facilities also represent a loss of net income. Thus, the economic optimum for any utility is to bring new facilities into service just as they are needed. The advantages of accurate forecasts for this purpose are obvious.

Major generating facilities, the most expensive capital items, now require 5 to 10 years to plan and construct, a period during which the demand may change considerably. Consequently, a relatively small error in the demand growth rate forecast could result in a substantial undershoot or overshoot of capacity if the long-term facility plans were left unchanged. Utilities have generally been able to avoid large overcapacity or undercapacity situations by adjusting the schedules of facilities under construction.

For government, financial, and other institutions a second major purpose of electric growth forecasts, which has become more important in recent years, is for national energy planning. In contrast to the individual utility's shorter term interests, this focus tends to be on periods 20 or 30 years into the future. Because of the close relationships between electrical energy use and economic activity, the scenarios painted by long-term economic models can be strongly influenced by variations in electricity growth forecasts. Thus, a projection accuracy adequate for the needs of the utilities often may not serve the desires of the economists and planners. The utilities methods emphasize short-term load forecasting for several years ahead. Their forecasts focus on local conditions in the areas they serve, including such definable load-builders as new factories and housing. Essentially, these are "bottom-up" forecasts, in which estimates of individual load components are aggregated to produce a total load forecast. The forecasts do make use of generalized projections of national, regional and local economic growth prepared by governmental, financial and academic institutions, but the principal concern is with the utility's own service area (Ref. 1, 2).

Utility forecasts, which usually assume long-term trends of the past, are sometimes termed "trending forecasts," with an implication that they blindly extrapolate the past into the indefinite future. Actually, much of the value of the short-term utility forecasts is in identifying the detail of probable loads--their location, character and relative timing--although the very large generating units now being built obviously serve the aggregate demand and are committed on the basis of total load growth.

Long-term load growth projections, ten and twenty years into the future, tend to be less accurate than short-term forecasts because of the evident greater opportunity for unforeseen events to markedly shift the demand patterns. Also, electric demand has a quality akin to inertia; its patterns usually can change only slowly. In a short time period, electricity demand is governed by the usage made of electric equipment already in place, which is usually subject to only small variations. Long-term demand growth, in contrast, is governed by the installation of new electric equipment. Such installations represent reasoned decisions, and the decisions can be influenced by many factors, especially the comparative economics of electric equipment versus other ways of achieving the functions desired. Thus, electricity growth patterns over the long term can be affected by the economics of electricity and availability of alternatives.

Over the long term, electricity can be regarded as just one of a number of commodities available to achieve economic goals. To predict the effect of various sets of economic parameters upon electric demand growth, econometric models have been constructed. These mathematical models depend in part upon what are known as "price elasticity coefficients," that is, the incremental change in demand resulting from an incremental change in price, as well as "cross-elasticities," the effect of changes in the use of one energy form, such as natural gas, upon the demand for another, such as electricity. The use of these models has provided much insight into the relationships between energy and the economy, but the forecasts made by the models are critically dependent upon the price elasticity assumptions. Data to determine these coefficients have been lacking in the past, but some economists believe that the recent sharp electricity price increases have now provided the basis for determining reasonable values of the coefficients, and are offering long-range econometric forecasts of electricity demand.

For many years, electric utilities could plan, construct and bring into service a major new power plant over a period of four years, or less. Thus, load projections beyond five years were not critical and a utility could adjust its construction plans fairly well to meet changes in forecast demand. However, the lead time for a coal-fired power plant is now approximately 6 years, and for a nuclear power plant is in the neighborhood of 10 years. The longer lead times result from several factors, a trend to much larger generating units, 500-1,300 MWe as compared to the 50-300 MWe units formerly employed, to the addition of complex environmental control equipment, labor problems, late delivery of major equipment; and to the increased number and duration of reviews needed to secure local, Federal and State approvals (Ref. 3). As a consequence, electric power planning now requires reasonably good demand projections approximately ten years ahead, where once five years was adequate. Thus, the electric utilities are showing more interest in long-term "econometric" projections than they once did.

All forecasts and projections are actually extrapolations of prior experience, including the econometric projections, because the coefficients are derived from experience. Furthermore, the econometric models can provide internally consistent projections of the consequences of various assumptions regarding the future, such as limitations on oil supplies, the price of coal, the availability of synthetic natural gas, etc. Nevertheless, the fact is that no projection can anticipate the unknowable and all projections should be regarded as aids to decision-making, rather than as highly accurate bases for detailed commitments.

In the current environment, there are more uncertainties regarding the future growth of electric demand than has been the case for many decades. A primary cause is that future economic growth patterns are not clear, particularly the effects of the Nation's yet-to-be-established energy policies.

A final important point concerning electric load forecasts is that regions have differed markedly from one another in the past in rates of growth and surely will do so in the future. This will be discussed further in Section 4, Regional Notes. Thus, a national growth projection of good accuracy may be quite misleading if applied to a local or regional area.

2.1.2 Historical Trends

Since all forecasts and projections are actually extrapolations of prior experiences, the actual statistics on the use of electricity in the past and for the present are extremely important in developing the best forecast possible. As noted earlier, the electric power industry has been growing at a sustained rate of around 7%, or a doubling of loads about every ten years. This is around two times the average annual growth rate of the Nation's total energy requirements. This growth rate is related to two basic trends--a population growth rate of about 1.3 percent per year, and the mounting use of electricity per capita. Population growth has been a significant factor in the ultimate size of the total energy market. Other major factors which have affected the demands for goods and services, including electric energy, are technological advances, increases in personal income and the manner that available income was used. Some of the major factors that have influenced the preference for electricity, leading to the phenomenal growth in its use include:

1. The availability of an abundant and reliable supply of relatively low cost electricity.

2. The convenience and cleanliness in the use of electricity.

3. Newly level developed applications of electricity in residential uses that are labor-saving and comfort-oriented, including washing machines, clothes dryers, refrigerators, freezers, kitchen appliances, lighting, heating and air conditioning, televisions, hair-dryers, and numerous other personal conveniences; many of which have high, short-term power demands.

4. Newly developed applications of electricity for use in the commercial and industrial segment of the economy including electronic processes, heating and air conditioning, automation, lighting, electric drive, advertising, refrigeration, food processing, transportation, and other labor and cost-saving and convenience applications.

It is standard practice to break the market for electric power into three main classes, residential, commercial and industrial. The industry uses these categories for pricing purposes, market strategy and future expansion plans. Table 2.1 summarizes the retail market for electricity served by the privately-owned sector of the industry in 1973, including number of customers, kilowatt-hours sales and revenues.

Recent Experience since the Embargo. The use of electricity dropped off immediately after the oil embargo of October 1973. This is evident as shown in Fig. 2.1. This figure also shows that electrical usage has recovered somewhat since that time. By late 1974, electricity use was exceeding year-earlier levels, despite the fact that the average electricity prices had risen by 35 percent and economic activity, measured by real gross national product, had become severely depressed (Ref. 4).

An estimation of the impact of depressed economic conditions versus non-economic factors which have caused a change in the trend of electric energy production is shown in Fig. 2.2. The depression of kilowatt-hour production below the trendline appears to be the result of two factors acting simultaneously, i.e., conservation and the depressed economy. A comparison of the weekly output for 1975 (until Sept. 27) shows little growth with respect to 1974 or 1973 as shown in Fig. 2.3. To what extent this situation may change in the long term is discussed in the following subsections.

Source: (Ref. 4)

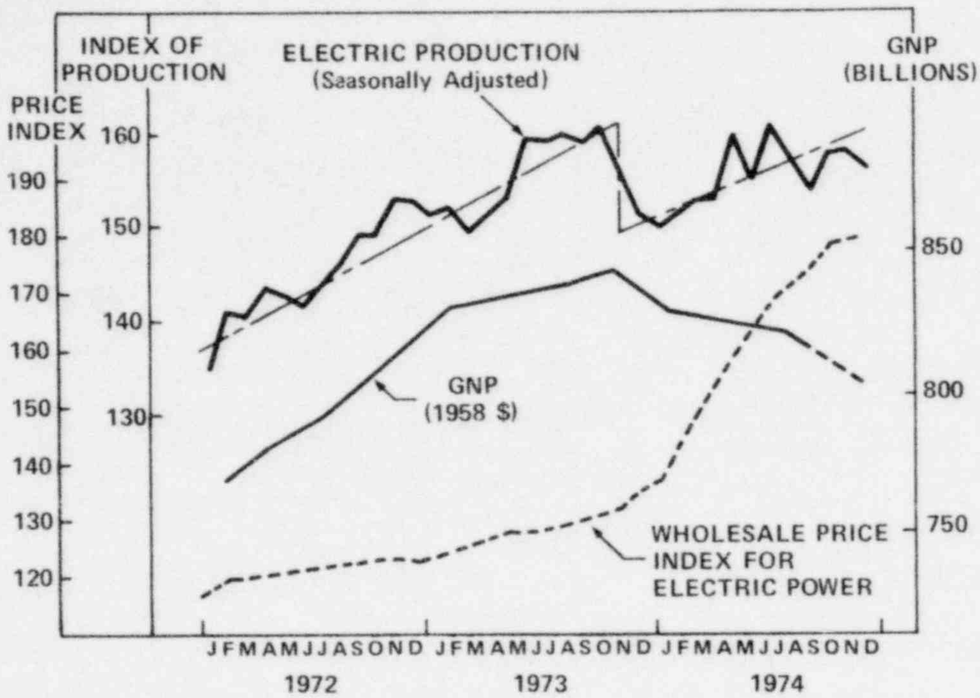

FIGURE 2.1 MONTHLY ELECTRIC POWER PRODUCTION, REAL GROSS NATIONAL PRODUCT AND WHOLESALE PRICE INDEX ELECTRIC POWER, 1972-1974

Source: (Ref. 4)

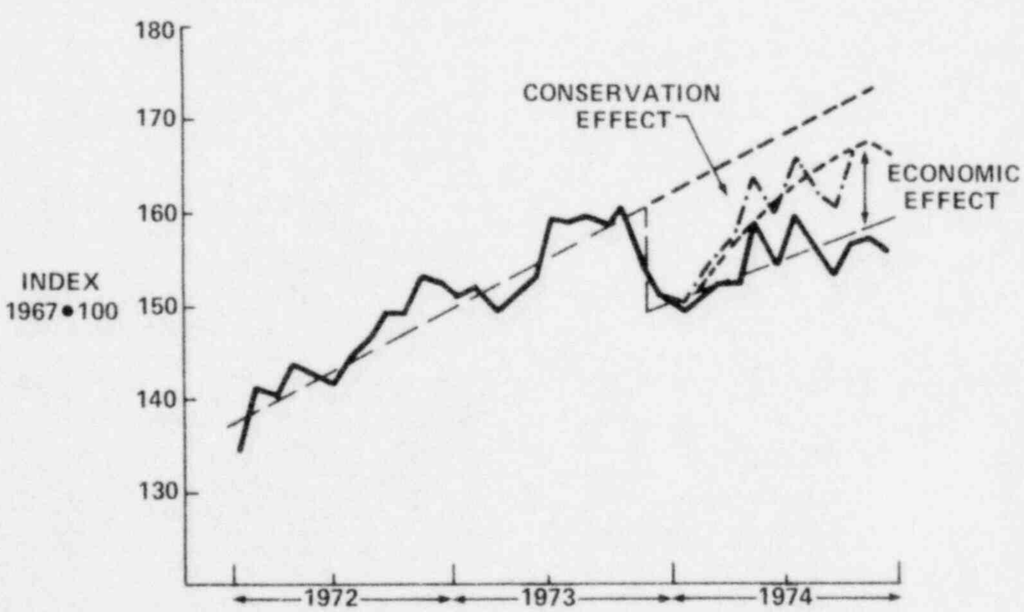

FIGURE 2.2 MONTHLY INDEX OF ELECTRIC PRODUCTION, FOR 1972-1974 TOGETHER WITH ESTIMATED EFFECTS DUE TO CONSERVATION AND ECONOMIC CONDITIONS

Source: Electrical World

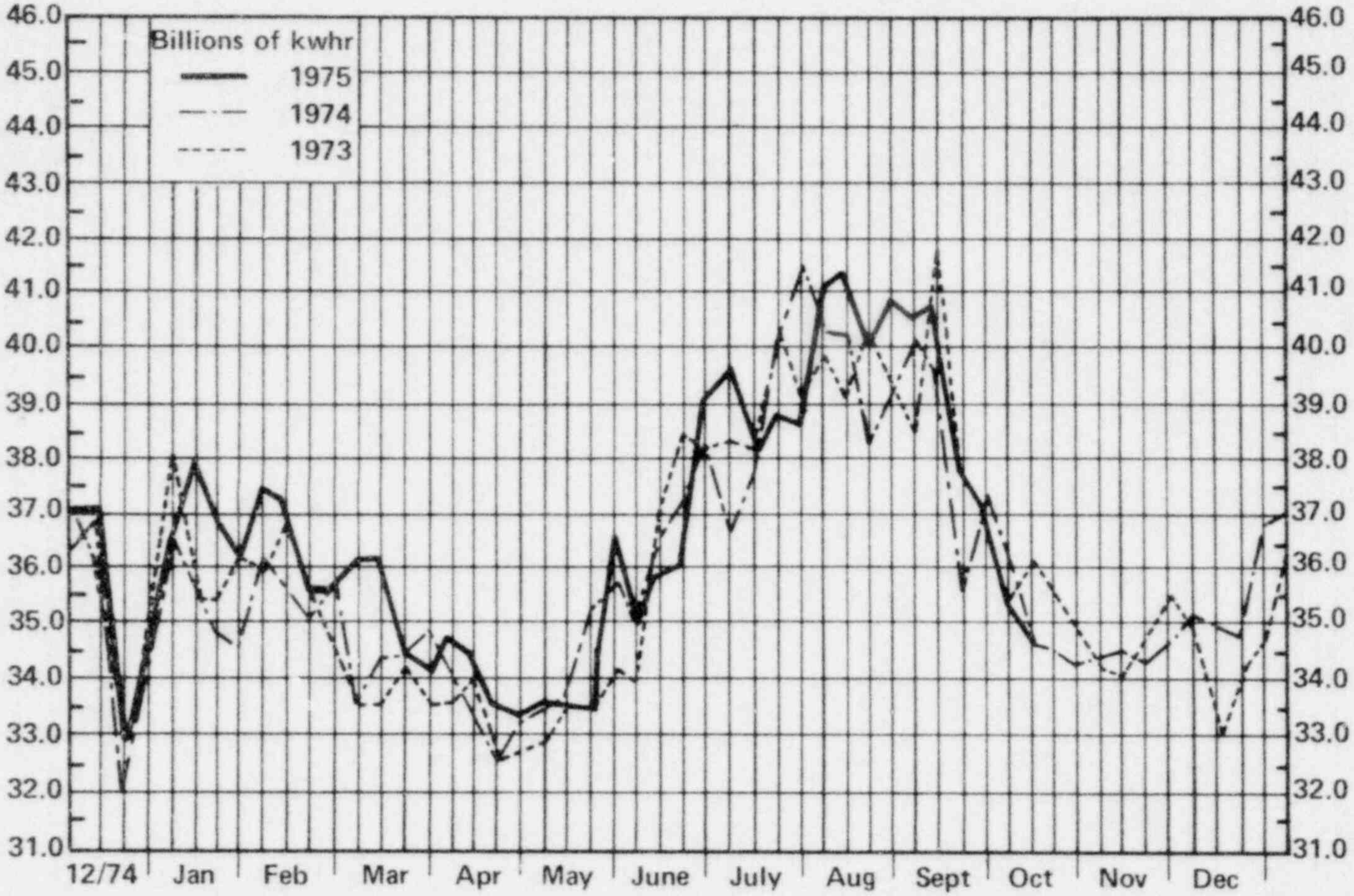

FIGURE 2.3 WEEKLY ELECTRICAL PRODUCTION OUTPUT FOR 1973, 1974, AND 1975 UNTIL SEPTEMBER 27

TABLE 2.1

NUMBER OF ULTIMATE CUSTOMERS, SALES AND REVENUES OF CLASS A AND B PRIVATELY OWNED ELECTRIC UTILITIES,[a] 1973

Item	Customer Classification				
	Residential	Commercial	Industrial	Other	Total
Number of Ultimate Customers	53,759,712	6,753,829	295,429	217,174	61,026,204
Percent of Total	88.1	11.1	0.5	0.3	100.0
Sales to Ultimate Customers (millions of kWh)	416,188	323,909	550,783	49,802	1,340,682
Percent of Total	31.0	24.2	41.1	3.7	100.0
Revenues from Ultimate Customers (millions of dollars)	10,566	7,822	6,865	1,048	26,301
Percent of Total	40.2	29.6	26.1	4.1	100.0

Source: Federal Power Commission

[a]See Footnote, p. 1-3, for definition.

2.1.3 Future Demand Factors

Technological, economic, political, and social factors will continue to play an important role in the future energy markets in the U.S. Energy prices have risen dramatically within the past two years and will have to be given increased attention by long run energy planners and forecasters. Most observers believe that energy conservation by users will reduce total energy consumption below levels indicated by extrapolation of historic data. This reduction will be a consumer response to higher energy prices and implementation of technical measures designed to conserve energy.

The future demand trends may be markedly different for electrical energy demand growth than for total energy growth. Two opposing forces are at work. Consumers can be expected to reduce electrical energy demand in response to higher electricity prices. On the other hand, restricted current and future supplies of natural gas and heating oil may more than offset the demand reducing force of energy conservation in certain regions. Thus, electrical energy may substitute on the demand side for fuels with restricted or uncertain supply.

At the national level, consumption of electrical energy has in the past, been closely associated with the level of macro-economic activity. Given the complex nature of economic factors at work, simple historical correlation of this type probably does not constitute an adequate basis for long run electrical energy forecasting.

Regional and local factors are also important and should be considered in preparing electrical energy forecasts. There are important regional differences in the supply prices of electricity which result from regional resource availability, transportation costs, and other factors. In response to local conditions, consumer demand for electrical energy varies regionally. Two important regional parameters of electrical energy demand growth are population and real total personal income.

Past forecasts of electrical energy comsumption have tended to emphasize extrapolation of historic data. A separate analysis of the demand impact of energy price changes was neglected. More recent energy forecasts tend to give more weight to energy prices and other variables believed to affect both electrical and total energy demand.

2.2 LONG TERM FORECASTS

A number of long term forecasts of electricity demand have been made by both governmental and non-governmental groups. Sometimes these forecasts are called scenarios or projections. A simple summary of the most widely known ones for the years 1985 and 2000 is illustrated in Figures 2.4 and 2.5 respectively. As a reference point, the estimated 1975 electrical production is given. Because of the significant impact of the oil embargo of October 1973, only those forecasts that were published afterwards are included. For additional forecasts the reader is referred to the literature (Ref. 4, 5). The results of the forecasts depend highly on the nature of the assumptions. For this reason, a brief description of the assumptions for the various forecasts is given.

Atomic Energy Commission (AEC): WASH-1139(74) (Ref. 6)

The Atomic Energy Commission, Office of Planning and Analysis, published in February 1974, four long-term projections identified as Cases A, B, C, and D that are noted in Figure 2.4 for 1985 and in Figure 2.5 for the year 2000. Case A is the base case used in the Nuclear Energy Center Site Survey - 1975. These forecasts are based on assessments of possible changes in technologies and relative prices, structural changes in the economy and in relations with the rest of the world, as well as changes in the needs and desires of American society. The population and economic projections are linked to a level of total energy resource consumption modified by such considerations as the effect of successful conservation measures, the potential for greater use of electricity in the economy, and the existence of energy resource supply constraints. These considerations have been examined in an analytical framework which facilitates a systematic examination of the patterns of energy use and energy supply. A brief description of the four cases is presented:

Case A. A slower rate of economic growth, compared to the compound rate of 3.9 percent annually of real GNP which was assumed as a basis for WASH-1139(74), owing to a decreased emphasis on the production of goods, coupled with higher energy prices relative to other commodities characterizes Case A. Maximum efforts are made to conserve energy by increasing utilization efficiencies in all sectors including residential and commercial space heating and cooling, oil use for air and ground transportation, coal used in steel making, electrical use in aluminum production, and in industrial process heat applications. Actual reductions in demand also

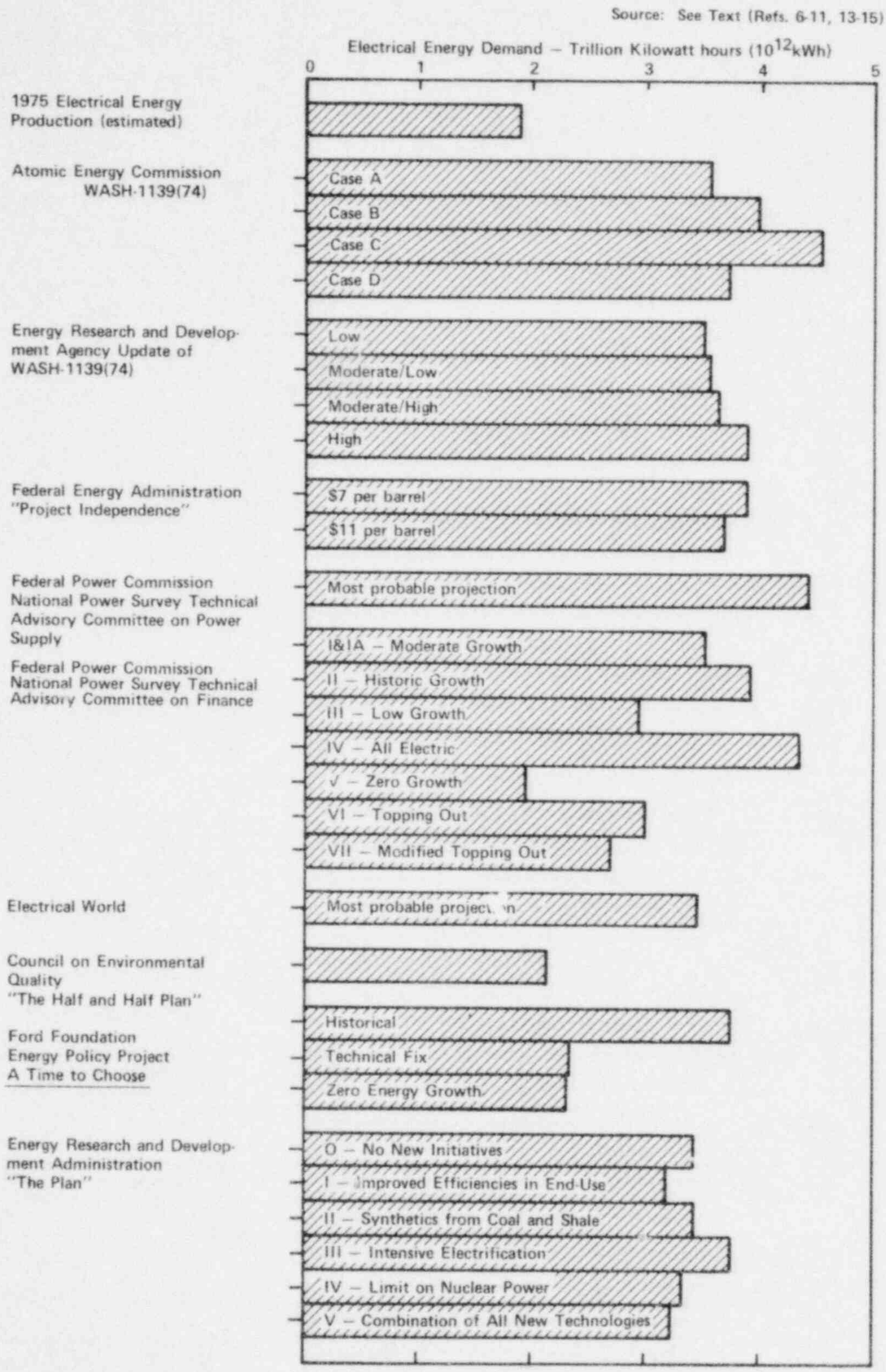

FIGURE 2.4 FORECASTS, SCENARIOS AND PROJECTIONS OF U. S. ELECTRICAL ENERGY DEMAND FOR THE YEAR 1985

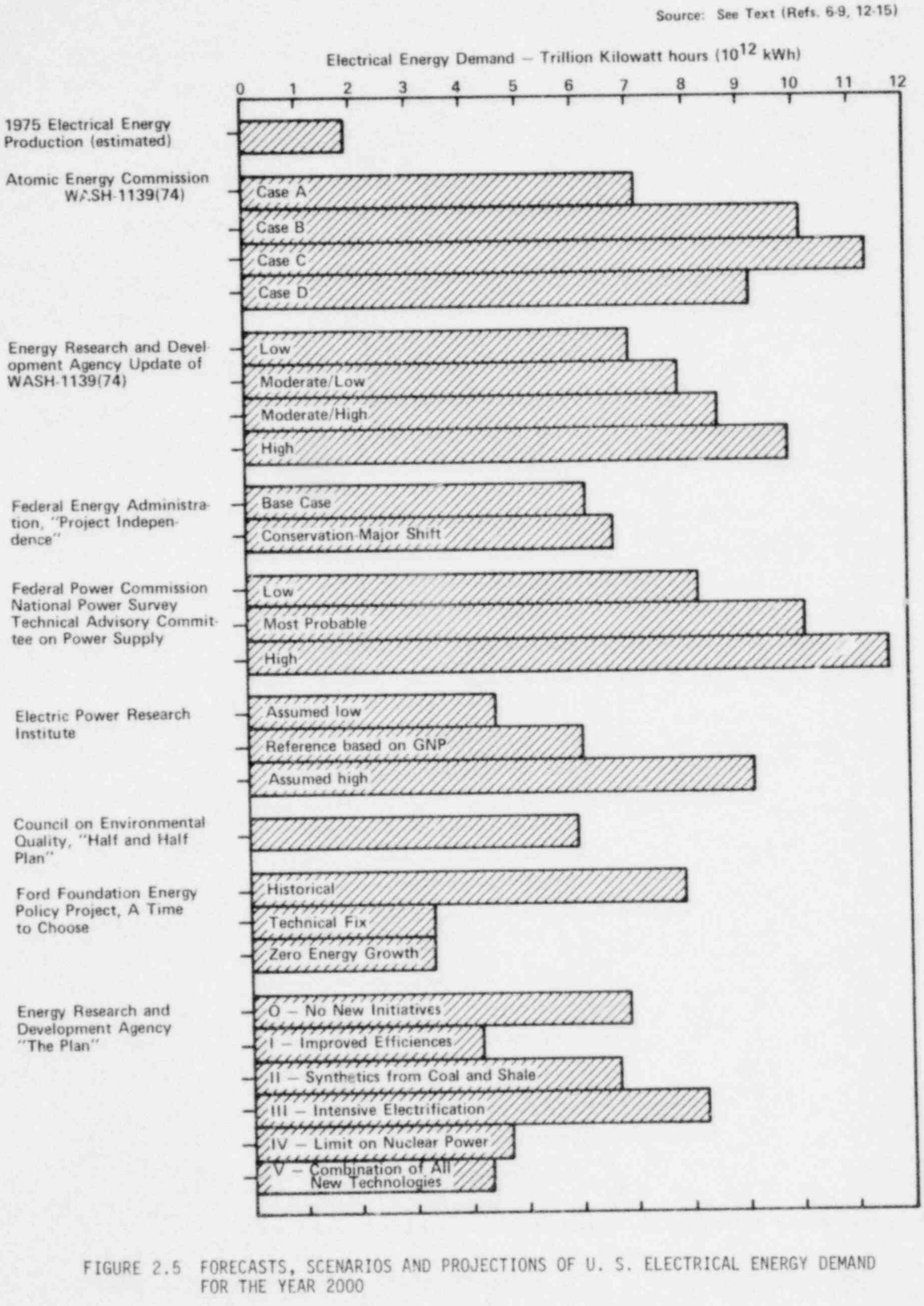

FIGURE 2.5 FORECASTS, SCENARIOS AND PROJECTIONS OF U. S. ELECTRICAL ENERGY DEMAND FOR THE YEAR 2000

occur in several sectors, notably in petrochemical requirements and process heat use, as a result of a slower rate of economic growth. High energy costs result in less demand for heating and cooling in homes through adjustments in temperature and expenditures for more household insulation. Internalization of pollution control costs, coupled with electric rate structure revisions to discourage peak use, are expected to affect electricity consumption. Similarly, the high energy costs assumed in this case will cause shifts away from inefficient transportation modes such as private vehicles and airplanes and increase the use of buses and railways.

Case B. Case B inherently assumes that factors historically important in shifting the pattern of energy use in favor of electricity will influence future demand. Electricity is expected to remain a useful, convenient, and inexpensive form of energy relative to available substitutes. Technological innovation will proceed so that the rate of introduction of devices, processes, and other end uses for electricity will not change from past experience.

Case C. Case C may be characterized as based on a continuation of the same general long-term historical trend in total energy consumption as Case B, but with a different means utilized to satisfy demand. In this case it is assumed that electricity will remain cheap relative to oil and natural gas, but that energy prices on the whole will not change significantly relative to other commodities. As a result, it is expected that a more rapid shift to electricity would occur where technically feasible. Specifically, it is assumed that all new housing added beyond 1977 are all-electric homes, that electricity is substituted for heating and cooling in the commercial sector and in certain industrial end-uses particularly for process heat, and further that electric vehicles and electric transportation constitute an important fraction of transportation needs by the end of the century.

Case D. Case D considers the situation where total consumption of all forms of energy is reduced through conservation measures, but where these measures are not so stringent as to limit improvements in standard of living or economic development. In this view, all end use energy demands are met, but fewer energy resources are consumed because higher energy prices relative to other commodities cause industrial and other energy consumers to improve the efficiency with which they use energy.

ERDA Update of WASH-1139(74) (Ref. 7)

On April 28, 1975, Roger Legassie, Assistant Administrator for Planning and Analysis, ERDA, presented in Congressional testimony an update WASH-1139(74) that was completed in March 31, 1975. These updated projections do not specifically address the future impact of expanded Federal energy research and development programs. The alternative projections presented should be viewed as such rather than a forecast or set of forecasts. They are the following:

Low Case. The stringent conservation measures in the total energy situation are combined with an electric energy situation that continues to capture an increasingly larger portion of final demands. While kilowatt-hour growth is only 5.8% through 1985 and an even lower 4.75% for the latter part of the century, electric energy inputs rise to account for 51% of total energy inputs.

Moderate/Low Case. Within the moderate energy case, the situation of electric energy for direct energy use occurs at a more modest rate, reflecting that relative prices for electricity are not so advantageous and other fuels are more readily available. Kilowatt-hour production grows at 6.0% per annum through 1985 then declines to a 5.4% per annum growth through 2000.

Moderate/High Case. This case postulates within the moderate energy case, while rising electricity prices cause reductions in expected future demands, the availability and prices of other fuels are such as to cause continuing substitution of electric energy for direct energy uses. Kilowatt-hour production grows at a 6.25% per annum rate through 1985 and at a 5.85% per annum rate through the last 15 years of the century.

High Case. Electricity production resumes growth near historic rate of 7% per annum through the middle 1980's, then declines 6.4% per annum growth through the end of the century. Electric energy inputs increase to 50% of total resource consumption by 2000.

Federal Energy Administration (FEA): Project Independence (PI) (Ref. 8)

The Federal Energy Administration, in November 1974, published its report on Project Independence known as the Blueprint. The purpose of the Blueprint was to analyze alternative strategies for developing a national energy policy to meet U.S. energy needs in an economically and socially efficient manner, consistent with national security. An evaluation of alternative strategies requires an analysis of the interactions between the supply and demand sides of the relevant markets, and therefore requires a demand model which approximates the response of these markets to changing economic circumstances. The forecasts of demand generated by the simulation model used depends critically upon the assumed values of energy prices, of the level of real output, and of other economic and demographic variables. Two major petroleum price scenarios were used and can be described as follows:

> $7 per barrel. This scenario assumes an imported- and domestic-oil weighted price of $7.00 per barrel in 1973 prices. The constant $7.00 price assumes the post-embargo price will continue through 1985.
>
> $11 per barrel. All $11.00 price of crude oil in 1973 constant dollars is assumed in the second scenario. The price of crude oil approaches $11.00 per barrel by 1985, with approximately 87 percent of the adjustment occurring by 1980.

The electricity demand at $7 per barrel and $11 per barrel oil for 1985 is shown in Figure 2.2. The report outlines alternative conservation strategies and the amount of electrical energy saved assuming each is implemented. However, an aggregate is not given. These two prices are the most frequently cited in the report. The estimated electricity demand for the year 2000 for two cases is shown in Figure 2.5. The first one is the Base Case which represents a continuation of the trends emerging in the near term case that continues present policies with only minor changes. The second one is called Conservation-Major Shift and combines conservation with a shift to energy sources that are not in short supply and a major shift to electric power.

Federal Power Commission (FPC): Technical Advisory Committee on Power Supply (TACPS) (Ref. 9)

The National Power Survey Technical Advisory Committee on Power Supply, in February 1974, reported three projections of electricity demand. Most probable projections were given for 1985 and the year 2000. In addition, upper and lower estimates were presented for the year 2000. See Figures 2.4 and 2.5 respectively. The projections include a consideration by the task force of the net effect of two important conflicting factors. The first, acting to reduce electricity growth, is the pressure for conservation of energy in all its forms resulting from the impending depletion of domestic oil and gas resources, increased environmental protection, and sharply higher energy costs and prices. The second factor, acting to increase electricity growth, is the recognition that a greater fraction of future energy needs must be supplied by coal and nuclear energy, and for many applications electricity is the only practical form in which to utilize those energy sources.

Federal Power Commission (FPC): Technical Advisory Committee on Finance (TACF) (Ref. 10)

The National Power Survey Technical Advisory Committee on Finance, in December 1974, published seven different possibilities with respect to annual rates of future growth in electricity demand. They were given to 1990 and the results for 1985 and are shown in Figure 2.4. The seven cases are:

Case I and IA - Moderate growth. This is a moderation of past growth trends, following the sharp 1974 slowup.

Case II-Historic growth. A brief slowup followed by a resumption of past trends, moderating somewhat in the 1980s.

Case III-Low growth. This is lower than the moderate growth assumptions.

Case IV-All electric. This is an acceleration of historic patterns resulting from the assumed substitution of electricity for oil and gas should these become very scarce.

Case V-Zero growth. This is extremely low (virtually zero) growth. As with the all-electric case, it is not considered to be among the most likely to occur, but it was included in order to make the range of cases complete.

Case VI-Topping out. This is a brief period of moderate growth followed by declining rates in the 1980s.

Case VII-Modified topping-out. This is a somewhat lower rate of growth in the late 1970s and a lower rate of decline thereafter.

Electrical World (EW) (Ref. 11)

The Electrical World, in September 1975, published its 26th annual electrical industry forecast. A most probable forecast is presented which stops at 1995. The one for 1985 is shown in Figure 2.4. The forecast is based on a variety of inputs, such as population growth, new households, gross national product, consumer disposable income, inflation, personal savings, industrial sales, commercial sales, and residential sales.

Electric Power Research Institute (EPRI) (Ref. 12)

The Electric Power Research Institute, in November 1974, published a long-range estimate of electricity demand to the year 2040. Three forecasts are given for the year 2000 which are shown in Figure 2.5. According to the authors, the reference estimate is based on an excellent correlation between real gross national product and total electricity generation. No allowance is made for changed conditions in the future as compared to the historical period. An assumed high figure is used which is regarded as highly improbable on the basis of the demographic and GNP projections used. Also, an assumed low is given. Both the assumed low and high are believed to be unlikely to become reality compared to the reference case.

Council on Environmental Quality (CEQ): The Half and Half Plan (Ref. 13)

The Council on Environmental Quality, in March 1974, published "A National Energy Conservation Program: The Half and Half Plan". This plan calls for a serious long-term national program to conserve energy and meet the needs of a growing economy.

The major elements of the Half and Half Plan are:

1. The target for gross energy consumption in the year 2000 should be 121 quadrillion BTUs, an increase of 49 quadrillion BTUs over the 1972 consumption of 72 quadrillion BTUs. This represents an annual growth rate of 1.8 percent.

2. This target is based on growth in net per capita energy consumption of 0.7 percent per year and on a continuing conservation effort which would, through improved efficiency and elimination of waste, save energy at a rate of 0.7 percent per year. This program--half growth and half conservation--would provide an effective increase in usable energy of 1.4 percent per year, equal to the average rate of growth experience from 1947 to 1972.

The forecasts for electricity demand for the years 1985 and 2000 are given in Figures 2.4 and 2.5 respectively.

Ford Foundation: Energy Policy Project (EPP) (Ref. 14)

The Energy Policy Project, in 1974, published three electricity demand scenarios in its report, A Time to Choose, America's Energy Future. The three scenarios that were analyzed are:

Historical Growth. The Historical Growth scenario examines the consequences of continuing growth in energy consumption for the remainder of the century at the 1950-1970 average rate of 3.4 percent per year.

Technical Fix. The Technical Fix scenario is an attempt to anticipate the results if long-term energy prices and government policies were to encourage greater efficiency in energy consumption.

Zero Energy Growth. The Zero Energy Growth scenario represents a modest departure from the Historical Growth Scenario. It would not require austerity, nor would it preclude economic growth. The real GNP in this scenario is approximately the same as in Technical Fix, and it actually provides more jobs. It includes all the energy-saving devices of Technical Fix, plus extra emphasis on efficiency. Its main difference lies in a small but distinct redirection of economic growth, away from energy-intensive industries toward economic activities that require less energy. An energy excise tax, by making energy more expensive, would encourage the shift.

The electricity demand forecasts for the three scenarios is shown for 1985 and the year 2000 in Figures 2.4 and 2.5 respectively.

Energy Research and Development Adminstration (ERDA): The Plan (Ref. 15)

The Energy Research and Development Administration Plan, published in June 1975, examined six scenarios of the future, each one of which is extreme in form but taken together illuminate key strategic energy research, development and demonstration problems and options. The electricity demand for the six scenarios is shown in Figure 2.4 for 1985 and in Figure 2.5 for the year 2000. These scenarios are not forecasts or predictions. They are intended as illustrations or analytic tools. A brief description of the six scenarios from the demand side is presented:

Scenario 0 - No New Initiatives. This was designed to provide a reference point against which to assess the potential of major energy research, development and demonstration options analyzed in the subsequent scenarios. The demand assumptions are:

- Current consumption patterns continue with no improvement in residential, commercial, or industrial end-use and most transportation efficiencies.

- A 40 percent efficiency improvement for energy use in automobiles is realized by 1980 because of a trend toward smaller autos.

Scenario I - Improved Efficiencies in End-Use Scenario I was designed to show the potential of an intensive program of (1) energy conservation through efficiency (i.e., no reduction in services or products) and (2) parallel use of energy resources already potentially available and characterized by considerations of efficiency (e.g., recovery of energy from waste materials and enhanced recovery of oil and gas). Consequently, energy demand is reduced from that projected in Scenario 0. The demand assumptions are:

- Residential and commercial sector technologies are improved with regard to
  - The structure itself in order to reduce heating and cooling requirements
  - Improved air conditioners, furnaces, and heat pumps
  - Appliances and consumer products
- Industrial process efficiency improvements are achieved in
  - Process heat and electric equipment
  - Petrochemicals
  - Primary metals
- Efficiencies of electricity transmission and distribution are increased
- Improved transportation efficiencies derived from new technologies (in contrast to efficiencies from smaller vehicles) are assumed for land and air transportation
- Waste heat (e.g., from electric generation) is employed for other low-grade uses now requiring separate energy input
- Also, the demand assumptions of Scenario I.

Scenario II - Synthetics from Coal and Shale. Scenario II is based on increasing the limited supply of liquids and gases. The scenario assesses the impact of drawing on abundant coal and shale resources to produce liquids and gases as direct substitutes for conventional fuels. Of all the scenarios, this approach requires the least disruption of end-use technologies and existing distribution infrastructure. The key demand assumptions for the analysis are:

- No end-use efficiency improvements are assumed.
- The assumptions, unless otherwise stated, are those of the previous scenarios to ensure that comparisons are being made only of the impacts of stated energy options.

Scenario III - Intensive Electrification. Scenario III examines how the total energy picture would be affected by an intensive shift to electrification, with (1) maximum use of all sources to generate electric power and (2) maximum reliance on electricity for end-uses. The key demand assumptions are:

- Improved electric conversion efficiencies are introduced

- Widespread use of electric autos begins

- Technologies to improve efficienty of electricity transmission and distribution are implemented

- Demand assumptions are consistent with Scenario 0 unless otherwise stated.

Scenario IV - Limit on Nuclear Power. The analysis represented by Scenario IV examines what might be required if for any reason (technological or political) the development of a major technology were constrained. This scenario is constructed to ask the question: "If a large block of new energy production capability, such as nuclear, were unavailable, how many other new technologies would have to be simultaneously and successfully introduced so as to produce about the same import results as the preceding three scenarios?"

In this example, nuclear power is limited to essentially the num of plants already built or on order. Coal is arbitrarily directed toward synthetics, as cenario II, rather than toward electricity production which would also be a feasible resp The specific demand inputs assumptions are:

- Industrial effieiency aspect of conservation scenario (Scenario I) is included

- Electric transmission efficiencies are not included, as electricity use grows too slowly to justify changes.

Scenario V - Combination of All New Technologies. Scenario V analyzes a case in which a combination of all major energy packages, including nuclear, are simultaneously commercialized (i.e., improved end-use, synthetic fuels, and electrification). The specific demand assumptions for this scenario are the same as Scenarios 0 through IV.

Overview

The WASH-1139(74) Case A NECSS-75 study assumption of about 7 trillion kilowatt-hours of electrical energy demand for the year 2000 is a representative forecast compared to the many forecasts, scenarios and projections shown in Figure 2.5. Case A is very high under the unlikely assumption that the United States were to follow a Zero Energy Growth or Technical Fix Scenario envisioned by the Ford Foundation Energy Policy Project. Also, Case A is high compared to the ERDA Scenario I - Improved Efficiencies in End Use, Scenario IV - Limited Nuclear Power, or Scenario V - Combination of All New Technologies. All three of these scenarios would likely require heavy government involvement to attempt to bring these about with no assurance of success. When viewed in the context of the high forecasts of electrical energy demand, Case A is relatively low. However, it appears unlikely that these higher ones will come about. Futher discussion on how electrical energy demand and supply are interrelated will be treated in Sections 3 and 5.

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SECTION 3

HISTORY AND FORECASTS OF THE ELECTRIC UTILITY INDUSTRY

3.1 INTRODUCTION

A good deal of the historical background of the electric utility industry was discussed in Sections 1 and 2. They should give the reader some overall perspective. The principle objective of this section is to supplement the earlier discussion where necessary with the view to discussing the supply of electricity, the reliability and the reduction of outage risks, capacity plans, potential capacity limiting factors all of which finally leads to a discussion of long-term forecasts of future capacity.

3.2 LIMITED ELECTRICITY SUPPLIES

Traditionally, the United States has not had to deal with electricity shortages which have been common in other countries. The demand has always been satisfied so that usage equalled the demand. Therefore, the term 'demand forecast' has become synonymous with 'usage forecast', however, utility spokesmen indicate possible future shortages of either installed capacity or fuel supplies or both.

A basic goal of central station electric power operations is to provide uninterrupted service to all customers. Generally speaking, the bulk power supply reliability of electric power systems has been and continues to be very high. Service interruptions due to major losses of generation, capacity shortages or transmission failures affecting large numbers of customers are relatively infrequent.

This high reliability of bulk power supply is achieved in large part through the application of the principle of redundancy. That is, the system is designed and operated as much as possible so that no single failure will result in dropping load.

The capacity requirements for such a system include, over and above the maximum load expected, the following considerations:

1. An operating or spinning reserve, consisting of connected capacity which can pick up load within a few seconds should there be a failure of a generating unit. This operating reserve is also necessary to achieve stability of the electrical system. One of the common criteria is that the spinning reserve be at least equal to the capacity of the largest unit connected to the system. With interconnections, this reserve margin can be provided in part by neighboring systems.

2. An available and operable capacity reserve to cover possible miscalculations in the peak load estimate.

3. An allowance for the generating units which can be expected to be out of service, both because of scheduled maintenance work and because of forced outages. Statistically, forced outages are certain to occur, but the exact times and amounts of capacity affected are not predictable. There is considerable variation in the outage rates for different types of generation equipment; typically hydroelectric plants have low rates while coal-fired steam plants tend to have relatively high rates. However, the outage rates are strongly influenced by maintenance practices, age of equipment and other variables.

The total reserve margin objective is determined for a particular system on the basis of that system's characteristics and experience so as to provide a low statistical probability of experiencing a capacity shortage--typically on the order of one instance in ten years. The Federal Power Commission reports that electric power systems in recent years have been planning for gross capacity reserve margins (i.e., the difference between the total capacity in commercial status and the expected peak load) of between 15 and 25 percent of the peak load, with most systems adopting a margin of 20-25 percent, somewhat higher than in earlier years. No set figure can be considered adequate for all systems; for example, on one system with a high percent of hydro generation, 12 percent may be fully adequate while other systems may experience difficulties with a 30 percent margin, particularly if the system can not rely upon a widely interconnected network for emergency supply.

The 1975 Regional Council projections, which include systems of all kinds, indicate that the national average reserve margin planned by the utilities for the early 1980s is approximately 20 percent. In the summer of 1975 the national reserve margin was about 30 percent, caused principally by the down turn in economic growth since the oil embargo.

Over the past 15 years many utilities have experienced a greater rate of growth in peak load, which establishes capacity requirements, than in total energy demand, because of the rapid adoption of air conditioning. The annual load factor for the industry as a whole is now about 62 percent.

3.3 RELIABILITY AND THE REDUCTION OF OUTAGE RISKS

Electric system reliability, as seen by the user of electricity, is measured by continuity of service at normal levels of frequency and voltage. It is generally accepted that power systems have three well-defined segments: generation, transmission, distribution. Only the transmission and generation aspects are considered here; these together constitute the bulk power supply facilities.

Reliability of supply to the substations on the transmission system, at which points the distribution portion of the system begins, is a composite of generating plant reliability and transmission facility reliability. Not only is the reliability a function of the reliability of the physical elements themselves, but it is dependent upon the organization of the facilities, the design of the features which integrate power plants, transmission systems and customers, and the operating procedures. Regulatory oversight must not be over looked.

"Outages," when applied to power system facilities, refer to equipment being out of service and may also refer to failure of the system to deliver power to a user. In the latter case, the user is said to be "out." Power systems are so designed that some bulk power facilities can be out of service without affecting continuity of supply to the user. Sufficient generating capacity is installed or purchased by an electric utility to match the largest demand expected, with some allowance for failures of generating facilities. Transmission circuits, similarly, are so designed that failure of one line will not usually interrupt service to customers. Much of the engineering effort expended in the planning of power systems is directed toward answering the questions "How much generating capacity is needed?" and "How much transmission capacity is needed?" Related questions are "Where shall the generating plants be built?" "When shall the generating plants be built?" and "How shall the transmission system be arranged?"

It is well known to system planners that most of the problems met within the design of power supply networks cannot be solved purely sequentially or in isolation one from the other. A given answer to "How much generating capacity" affects the solutions to "Where shall the plant be built" and "How best arrange the transmission system." If the choice of plant sites is made first, the amount of generating capacity will be affected, as will the transmission system arrangement. The magnitude of base load capacity installed, and its cost, must be balanced against the need for peaking capacity. Also, within those two categories, the types of generating units available must be considered. Economy of operation, unit reliability, time required for construction, capital costs, and fuel considerations including the type of fuel are some of the factors involved in the complex decision-making procedures that lead to reliable power plants. Each choice must be considered in relation to the options available for solving the other problems. In addition to the technical and technological problems, economic factors must be considered continuously to develop a reliable bulk power supply system at reasonable cost.

The reduction of outage risks to a very low level could be achieved, probably, by installation of excessively large amounts of generating capacity and many redundant transmission lines of large capacity. Based on cost considerations, a more reasonable approach is to select a level of outage risk that is satisfactory to most users in consideration of the cost burden they will be asked to assume. Within certain limits, their eduction of outage risks is dependent upon the cost of the system. Certainly, for a given cost, the risk of outage will be a function of the engineering expertise brought to bear upon the planning, construction, and operation of the system. But given equally sound engineering, greater reliability can be achieved at greater expense.

The standard of reliability of supply currently used by many systems in determining the amount of generating capacity needed is based on probability mathematics. The criterion is the probability that demand will not exceed supply capability on more than one occasion in ten years. The mathematics of the procedure result in the criterion having the probability value of 1/2,600 = 0.0003846. Other measures of reliability can be used and are discussed in the literature; they relate to frequency of occurrence and duration of low capacity levels, probability of not meeting peak demand, probability of energy shortage, among others. However, these other measures have not yet been as widely used or accepted as the "one time in ten years" measure.

Once the reliability level has been established, decisions must be made as to the number, size and type of generating units to be installed during the specified period. A ten-year advance period is not uncommon for planning purposes. Load patterns must be established for each year, and choices of generating units must be made as to time of installation, type of unit, and size of unit. Each different choice will result in different loss-of-load probability and different costs. One of the critical factors in the selection of generating units is the reliability to be associated with each unit in the probability studies. The unit reliability is usually quantified as the "forced outage rate". A forced outage rate is an occurrence which requires that a unit be taken out of service. The forced outage rate is the ratio of hours in service to the sum of hours in service plus hours of forced outage. This decimal number is used as the probability that a unit will fail when in service. In general conversation, the decimal is multiplied by 100% to obtain the "percent forced outage rate."

It has been the industry experience that, as steam generating units whether fueled by oil, coal or uranium became larger, their forced outage rates increased; that is, larger units have proved to be less reliable than smaller units. Average nationwide statistics of generating unit forced outage rates have been published annually by Edison Electric Institute for several years. The trends are not clearly established, because the statistics are cumulative and combine data from "mature" units with data from "immature" units. Some two to four years may be required before a large unit can be considered as having reached an approximately constant annual forced outage rate. However, it does appear that generating units of ratings 300 MW and larger are significantly less reliable than those of smaller size. All this has had a consequence of reducing earlier estimates about increases in sizes of generating units and the lower costs which were anticipated as a result. Furthermore, this trend toward use of large steam units forces as increase in the generating capacity required for a given reliability level for two reasons: 1) the units are less reliable than smaller units; and 2) outage of a large unit requires a large unit as replacement capacity. It is necessary, therefore, to direct the attention of the electric utility industry and their manufacturers toward the improvement of generating unit reliability. The Federal Power Commission has done this with a 17-point program of actions that could improve reliability, in its Report on Electric Generating Plant Availability (Ref. 1). The Federal Energy Administration has also published a report that discusses reliability, A Report on Improving the Productivity of Electric Power Plants (Ref. 2). The consensus of both reports is that much can be accomplished to improve the reliability of generating facilities and thereby reduce the risk of outages.

Measures of transmission system adequacy are not quantified to the same degree as is the case with power plants. The one-occasion-in-ten-years criterion for generating capacity relates to capacity and load only; the transmission system is not a factor in the calculations. Consequently, the risk of power supply failure at a specified point will be greater than once in ten years because of the less-than-perfect reliability of the transmission system. Transmission systems are so diverse that no simple computational procedure for determining outage risk has been devised that will be generally applicable. However, transmission facilities are considered to be much more reliable than large generating units, although when something goes wrong, there may be difficulty in confining the problem to any one area. Choice of voltage levels, routing of lines, substation and generating plant bus arragements, and protective relaying schemes have significant effects of the reliability of transmission systems so that there is great incentive to do a good job of planning.

3.4 CAPACITY PLANS

As noted in the discussion of load forecasts, electric load does not grow smoothly but exhibits considerable variation in year to year increases. Capacity plans are generally based on the long term trend of the peaks of the load growth curve, because the utilities, and generally regulators as well, consider the consequences of insufficient capacity to be greater than the costs of idle capacity. However, within the past year some utilities have found it difficult to finance their desired new construction because of the extreme escalation of costs, the high price of money and the erosion of return on equity. In many cases, planned additions turned out to be unnecessary because of unexpected decline in growth. Consequently, planned capacity additions on some systems have been delayed or cancelled. As a result, there are widely differing reserve margins forecasted for the future, from a low margin of 10 percent to a high of 40 percent.

The selection of the form of planned capacity additions has been traditionally an economic evaluation with the objective of achieving the lowest power costs. Such evaluations, however, are now critically dependent on the forecast price of fuels and costs of construction as well as the forecast cost of environmental protection measures. Further, the issue in more and more cases is simply the availability of adequate primary fuel supplies. Oil and natural gas for varying reasons have been difficult to come by.

It is clear that only a limited amount of further primary hydroelectric development will be possible; most of the remaining good sites are not available because of other uses or a public desire to preserve a river in its natural state. Natural gas supplies are dwindling and the electric power industry recognizes that it must drastically reduce gas use over the next decade. Three-fourths of the oil for electric power generation used principally on the East coast is imported and national policy is to limit oil imports. As a consequence, practically all planned base load as contrasted to peak load capacity is either coal fired or nuclear. Most new peaking units, however, continue to be oil fired for the next decade because of the absence of other fuel alternatives and the limited opportunities for pumped storage units. New cycling units are somewhat an enigma. Oil fired units have lower first costs and better operating characteristics, but if oil is unavailable, or there is a large continuing price spread between oil and coal, many such units will be coal fired.

At this time it appears that in many cases there will be only small differences in the cost of power between base loaded coal plants and nuclear plants. Both coal and uranium prices seem to be escalating rapidly and are being set more and more on a competitive Btu basis. Variations in coal transportation costs or judgments that nuclear costs are likely to be more stable can swing the selection one way or the other. A more detailed discussion of the future of the nuclear industry appears in Section 5.

Most of the electrical generating plants expected to be in use by 1985 are already on the drawing boards. Table 3.1 shows the planned capacity additions, 1975-1984, reported to the FPC by the Regional Reliability Councils on April 1, 1975. The types of generating capacity as of December 31, 1974 were given on Table 1.3 of Section 1.

TABLE 3.1

PROJECTED GROWTH OF GENERATING CAPACITY IN THE ELECTRICAL UTILITY INDUSTRY OF THE CONTIGUOUS UNITED STATES, 1975-1984

Type	Total Capacity To Be Added		Total Units To Be Added	
	MWe	%	No.	%
Fossil Steam	138,257	40.44	301	34.08
Combustion Turbine	12,477	3.65	166	18.80
Diesel	75	0.02	17	1.93
Combined Cycle	6,684	1.96	44	4.98
Geothermal	1,172	0.34	11	1.25
Fuel Cell	468	0.14	18	2.04
Nuclear Steam	144,663	42.31	137	15.52
Conventional Hydro	13,154	3.85	118	13.36
Pumpeo Hydro	10,110	2.96	44	4.98
Type not reported	14,790	4.33	27	3.05
TOTAL	341,850	100.00	883	100.00

Source: Federal Power Commission

3.5 POTENTIAL CAPACITY LIMITING FACTORS

Capacity growth will be basically governed by demand growth; however, other factors,* i.e., mainly financial difficulties and siting problems have the potential of limiting capacity to less than the needed levels. A discussion of financing follows; siting is considered in Sections 6 and 7.

Financing. The production of electric power is very significant to the United States economy. In terms of size, the privately owned sector controls assets which are substantial in excess of $100 billion, generates annual revenues in excess of $25 billion, and is considered to be our most capital intensive industry. The capital intensiveness of an industry can be measured as the amount of investment in assets required to generate a dollar in sales or revenues. Approximately a 3-1/2 dollar investment in assets is required to generate one dollar in revenues. Furthermore, the investment in plant accounts for more than 90% of the industry's assets.

Other industries are substantially less capital intensive. A recent study found the communications, railroad, and gas utility and pipeline industries to have ratios of assets to revenues

*Not including energy limiting factors, e.g., inadequate supply of oil, gas, or uranium.

in the 2 to 2-3/4 range, while industries such as steel and chemicals had ratios of less than one (Ref. 3).

The capital intensiveness of the electric utility industry is further accentuated by examining the industry's expenditures on new plant and equipment as a percentage of the total national business expenditures on new plant and equipment. The electric utility industry accounted for 8.1% of the total business expenditures on new plant and equipment in 1965 as shown in Table 3.2. However, increased demand for electricity and rising construction costs, led to a substantial increase in the electric utility industry's portion of the total. Electric utilities accounted for the 13.4% in 1970 and 15.7% in 1974 of total business expenditures on new plant and equipment.

TABLE 3.2

BUSINESS EXPENDITURES ON NEW PLANT AND EQUIPMENT
($ Billions)

	1965 Amount	1965 Percent	1970 Amount	1970 Percent	1974 Amount	1974 Percent
Total	54.41	100.0	79.71	100.0	112.40	100.0
Public Utilities						
Electric	4.43	8.1	10.65	13.4	17.63	15.7
Gas and Other	1.70	3.1	2.49	3.1	2.92	2.6
Communications	5.30	9.7	10.10	12.7	13.96	12.4
Miscellaneous[a]	13.19	24.2	16.59	20.8	22.05	19.6
Manufacturing						
Durable	11.50	21.1	15.80	19.8	22.62	20.1
Non-durable	11.94	21.9	16.15	20.3	23.39	20.8
Mining	1.46	2.7	1.89	2.4	3.18	2.8
Transportation						
Railroad	1.99	3.7	1.78	2.2	2.54	2.3
Air	1.22	2.2	3.03	3.8	2.00	1.8
Other	1.68	3.1	1.23	1.5	2.12	1.9

Source: Federal Reserve Bulletin, selected issues.

[a]Includes trade, service, construction, finance, and insurance.

The degree of capital intensivity, coupled with increasing total demand for electric power (all compounded by inflation), will require tremendous future expenditures for plant and equipment. Investor-owned utilities historically have been able to generate approximately 40% of their need for funds from internal sources and 60% from external sources. However, as is shown in Table 3.3, electric utilities relied more heavily on stock and bond issues during the 1970s to meet their financing needs. This occurred because the retention of earnings and depreciation and amortization sources did not grow proportionally with recent financing requirements.

The Technical Advisory Committee on Finance (TACF) has provided estimates of future construction expenditures (Ref. 4). Some perspective on future financing requirements can be gained by examining the financing requirements associated with the TACF's "moderate growth" forecast (which corresponds reasonably well with the WASH-1139(74) Case A forecast.) Table 3.4 indicates

TABLE 3.3

SOURCES OF FUNDS FOR CLASS A AND B ELECTRIC UTILITIES

		Long-Term External Funds				Internal Funds			
Year	Total Amt. ($ Millions)	Common Stock	Preferred Stock	Debt	External Total	Retained Earnings	Deferred Taxes	Deprec. & Amorti.	Internal Total
1965	4,078	9.3%	3.5%	30.9%	43.7%	14.0%	1.2%	41.1%	56.3%
1966	5,551	5.2	6.1	43.4	54.7	12.5	0.8	32.0	45.3
1967	6,160	8.5	7.5	42.7	58.7	9.6	0.9	30.8	41.3
1968	7,101	8.8	6.7	44.5	60.0	10.5	0.9	28.6	40.0
1969	7,983	10.8	5.0	44.5	60.3	10.8	1.2	27.6	39.7
1970	11,043	16.3	10.1	44.1	70.4	6.8	1.0	21.7	29.6
1971	12,550	19.1	14.1	38.0	71.1	6.1	1.8	20.9	28.9
1972	14,167	19.3	15.3	34.2	68.7	8.2	2.6	20.4	31.3
1973	15,076	22.4	11.0	34.0	67.4	7.2	3.7	21.6	32.6

Source: Federal Power Commission, Statistics of Privately Owned Electric Utilities in the United States, selected annual issues.

expenditure requirements under the assumption of moderate growth in demand (5.5%-6.5%) along with high escalation of construction costs and either high or low environmental costs.

According to TACF, construction expenditures are expected to range between $660 billion and $690 billion (depending on environmental cost trends) over the 1975 through 1989 period. External financing will be about $400 billion or approximately 60% of the total financing requirements. An important assumption in these projections is that returns on common equity will be on the order of 14%--a level not currently being achieved by the electric power industry. Future capital requirements are also placed in greater perspective when compared to the $83 billion spent for construction during the first-half of the 1970s (1970-74) (Ref. 4, pages 23-24).

As stated above the electric utility industry currently accounts for over 15% of total business expenditures on new plant and equipment. In addition, it is important to the industry to raise new debt and equity funds in the capital markets. Consequently, in light of the magnitude of recent capital expenditure forecasts and the present national financial climate, there is concern about the availability of adequate future supplies of capital for the industry. And, to complicate matters, there exists some contention that the United States is facing an overall capital shortage due to a change in the rate of savings formation in our society.*

*For example, the New York Stock Exchange recently estimated $650 billion shortage of investment capital over the 1974-85 period unless efforts are made to improve the investment climate. See: New York Stock Exchange, "The Capital Needs and Savings Potential of [illegible] Economy," September 1974, and "Demand and Supply of Equity Capital," June 1975.

TABLE 3.4

FORECAST OF EXPENDITURE REQUIREMENTS FOR
THE U.S. ELECTRIC POWER INDUSTRY
($ Billions)

MODERATE GROWTH IN DEMAND[a]

	High Environmental Costs		Low Environmental Costs	
	Construction Expenditures	External Financing	Construction Expenditures	External Financing
1975-79	$ 129	$ 80	$ 116	$ 69
1980-84	218	132	208	128
1985-89	341	200	332	197
1975-89	688	412	656	394

Note: These expenditures are expressed in "future" dollars (i.e., actual dollars, reflecting expected inflation, that are expected to be spent in a future period). External financing includes short-term borrowings, but excludes refundings.

Source: Federal Power Commission (Technical Advisory Committee on Finance - National Power Survey), The Financial Outlook for the Electric Power Industry, December 1974, p. 26.

[a]This is approximately equal to WASH-1139(74), Case A.

Some perspective on the electric industry's role in future capital markets can be gathered indirectly by examining the relationship of external funds needed by the industry to Gross National Product. The TACF contents that, although external financing by the electric utility industry as a percentage of GNP increased substantially since the early 1960s it will remain at about 1% level through the next decade--an acceptable and workable level. On the other hand, if rapid inflation remains, the capital markets may continue to deteriorate resulting in a restriction of the future supply of capital funds. This, in turn, might force the electric power industry to resort to alternative strategies involving conservation, rationing, or government aid (Ref. 4, pp 118-128).

3.6 LONG TERM FORECASTS OF FUTURE CAPACITY

Forecasts, projections and scenarios of future electrical generating capacity for 1985 and the year 2000 are compared in Figures 3.1 and 3.2 respectively. For reference, the total installed capacity of 476,000 MWe as of December 31, 1974 is given. The sources of the forecasts, projections and scenarios are the same as the ones for which electrical energy demand were given in Section 2. Some of the studies did not report total capacity and are not included here. All of the cases reported in Section 2 are similar except for the demand management (DM) forecast of FEA's Project Independence Report which requires heavy government involvement. As before, conservation effects were not included in the FEA forecasts. As in the case of electrical energy demand, the base case for NECSS-1975 is WASH-1139(74), CASE A and is considered to be a representative forecast in view of the little likelihood that the considerably higher and lower ones will come about. Nuclear capacity forecasts, projections and scenarios will be discussed in Section 5.

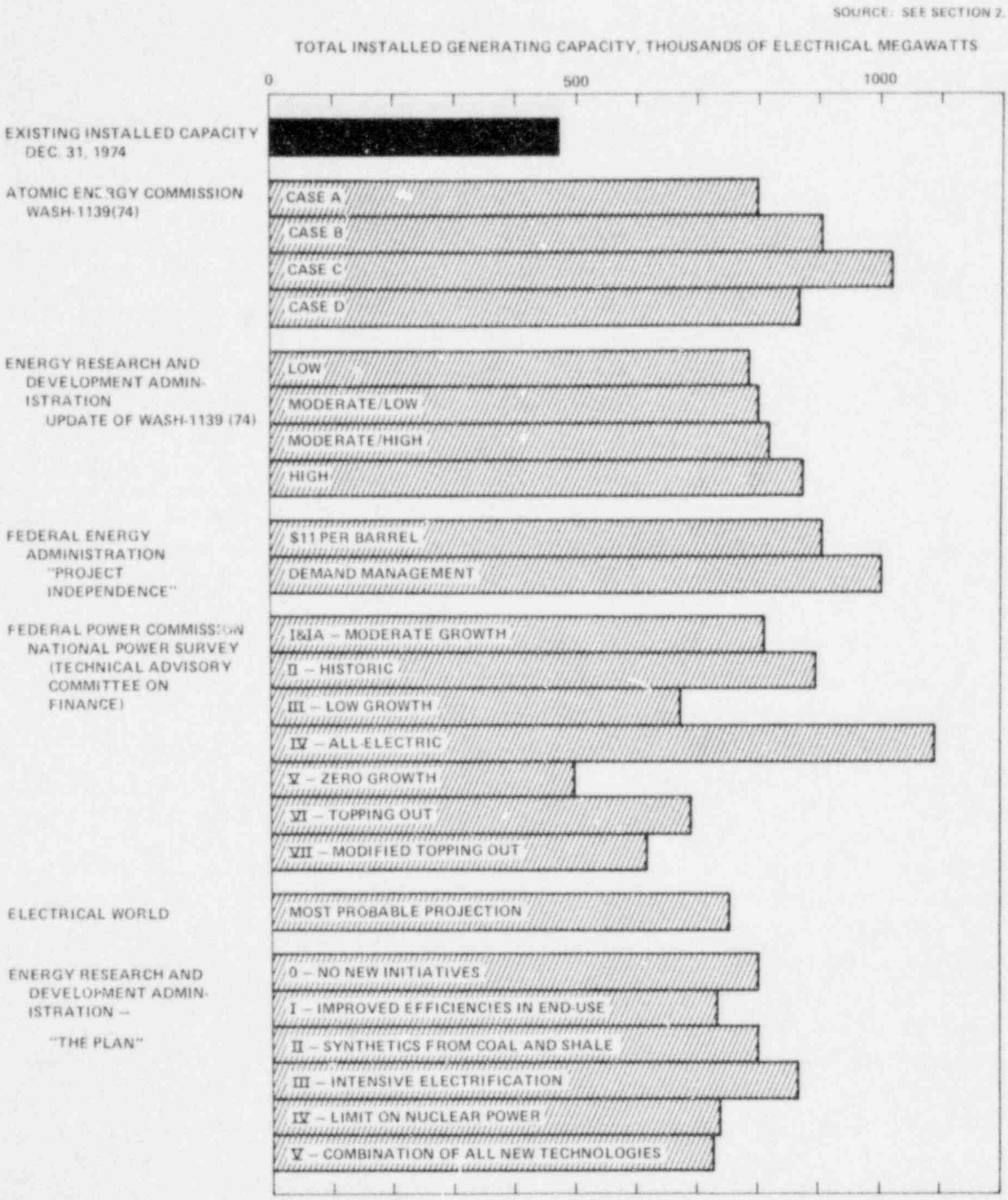


FIGURE 3.1 FORECASTS, PROJECTIONS AND SCENARIOS OF TOTAL INSTALLED GENERATING CAPACITY FOR THE YEAR 1985

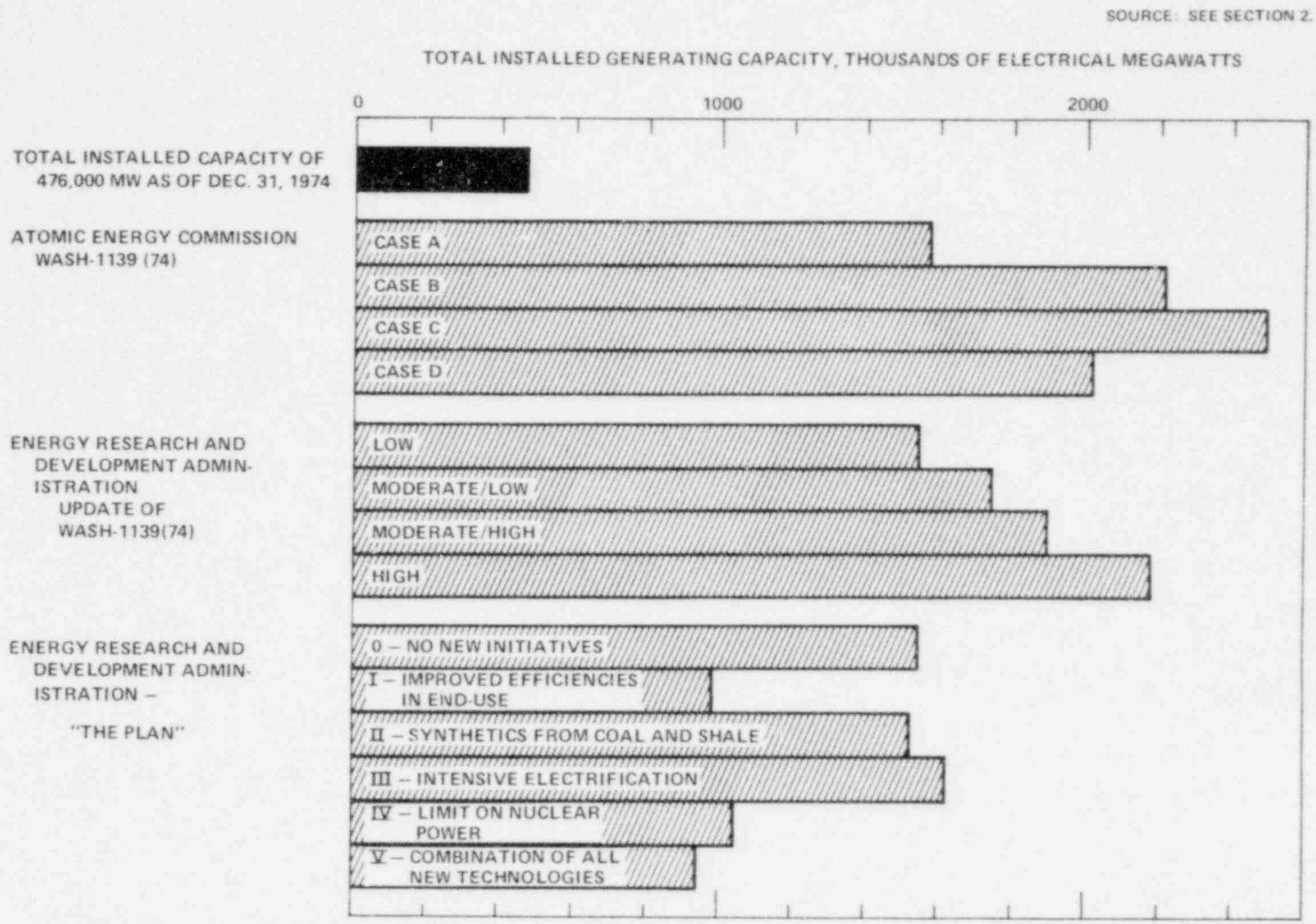


FIGURE 3.2 FORECASTS, PROJECTIONS AND SCENARIOS OF TOTAL INSTALLED GENERATING CAPACITY FOR THE YEAR 2000

REFERENCES

1. Federal Power Commission. May 1975. *New release no. 21430*.

2. Federal Energy Administration Office of Energy Conversion and Energy Resource Department. March 1975. *A report on improving the productivity of electric powerplants*.

3. Weidenbaum, Murray L. September 1974. *Financing the electric utility industry*. Edision Electric Industry, New York.

4. Federal Power Commission, Technical Advisory Committee on Finance--National Power Survey. December 1974. *The financial outlook for the electric power industry*.

SECTION 4

REGIONAL NOTES

4.1 REGIONAL CONSIDERATIONS IN ELECTRICAL ENERGY DEMAND

Regional considerations are important in the historic and the future growth in electrical energy demand. Some areas of the country have had abundant supplies of low cost energy. In these areas, energy producers could supply electricity and other energy forms at relatively low prices. Table 4.1 indicates a wide variation in recent monthly electricity bills around the country. Residents in Seattle currently pay the lowest monthly electricity bill of about $7 for 500 kWh consumption. This is attributable to substantial reliance upon low cost hydro-electric power available in the Columbia river basin. The highest monthly electricity bill for 500 kWh is over $37 in the New York-Newark area. In large measure, high electricity prices in New York can be attributed to the use of high cost oil-fired generating capacity. In response to local economic, climatic, and other conditions, electricity usage varies significantly from one region to another in the U.S. as shown in Table 4.2. The 1973 national average annual use per residential customer was 7,981 kWh. However, annual usage in the east-south central region of the country (Kentucky, Tennessee, Alabama, and Mississippi) was 11,475 kWh, or roughly 44 percent above the national average. At the low end, the Middle-Atlantic Region (New York, New Jersey, and Pennsylvania) average annual usage per residential customer was 6,050 kWh, or approximately 24 percent below the national average. These are broad averages for comparatively large regions of the country. Even larger divergences from the U.S. average usage patterns would result from comparative data disaggregated to metropolitan areas.

Differences among regions within the U.S. in economic and population growth rates will result in different rates of growth in electrical energy demand. (See Table 4.3) Historically for 1950-71, the mid-continent electric reliability council (roughly: Minnesota, Iowa, North Dakota, South Dakota, and Nebraska) had the lowest rate of growth in population (0.8 percent per year) and total personal income (3.3 percent per year). The regions projected to have the lowest growth rates 1971-90 of 0.4 percent per year for population and 3.6 percent per year for total personal income are the mid-continent again and the southwest (roughly: Oklahoma, Arkansas, Louisiana, and Kansas). The highest growth during 1971-90 is expected to occur in the south-east reliability council region (roughly: Tennessee, North and South Carolina, Georgia, Florida, Alabama, Mississippi, and Virginia). In the southeast the population growth rate is expected to average 1.4 percent per year and real personal income is expected to increase at an annual rate of 4.5 percent. Regions with higher than average growth rates should experience higher than average growth in electrical energy demand.

4.2 NATIONAL AND REGIONAL GENERATION AND CAPACITY

In general discussions of the national economy, of the national industrial complex, and of bulk power supply and demand, data are often cited on a total national basis. References may be made

TABLE 4.1

1973 AVERAGE CONSUMPTION OF ELECTRICITY PER CUSTOMER FOR REGIONS WITHIN THE UNITED STATES

	Residential Customer, kWh	Large Light and Power Customers, kWh
Total U.S.	7,981	1.66×10^6
New England	6,447	1.04×10^6
Middle Atlantic	6,050	1.08×10^6
East North Central	7,094	2.44×10^6
East North Central	7,416	1.41×10^6
South Atlantic	9,758	1.95×10^6
East South Central	11,475	2.69×10^6
West South Central	9,445	1.06×10^6
Mountain	7,699	1.30×10^6
Pacific	7,978	2.81×10^6

Source: Edison Electric Institute, Statistical Year Book of the Electric Utility Industry for 1973 (New York: 1973), pp. 33 and 38.

TABLE 4.2

NET MONTHLY COST TO CUSTOMER FOR 500 KWH OF ELECTRICITY, IN SELECTED AREAS, MARCH 1975

Atlanta	$19.76
Chicago - N.W. Indiana	19.68
Cleveland	19.69
Houston	14.48
Los Angeles - Long Beach	20.16
New York - N.E. New Jersey	37.18
Philadelphia	26.94
St. Louis	18.07
San Francisco - Oakland	14.81
Seattle	6.93
Washington, D. C.	22.00

Source: Bureau of Labor Statistics, U.S. Department of Labor, Retail Prices and Indexes of Fuels and Utilities (March, 1975), p. 4.

TABLE 4.3

HISTORIC AND PROJECTED GROWTH
RATES FOR POPULATION AND TOTAL PERSONAL INCOME
BY ELECTRIC RELIABILITY COUNCIL REGIONS, 1950-1990

Electric Regional Reliability Council		Population			Total Personal Income		
			Average Annual Growth Rate		1971	Average Annual Growth Rate	
Abbreviation	Area	1971 Mid-year (millions)	1950-71 (%)	1971-90 (%)	(billions of 1976 dollars)	1950-71 (%)	1971-90 (%)
ECAR	East Central	30.0	1.2	0.9	104.5	3.8	3.9
ERCOT	Texas	11.4	1.8	0.9	36.3	4.5	4.0
MAAC	Mid-Atlantic	23.8	1.3	0.9	88.7	3.8	3.9
MAIN	Mid-America	20.4	1.1	0.7	76.6	3.5	3.7
MARCA	Mid-Continent	9.6	0.8	0.4	31.7	3.3	3.6
NPCC	Northeast	30.5	1.1	0.7	124.5	3.6	3.7
SERC	Southeast	33.9	1.6	1.4	101.4	5.3	4.5
SWPP	Southwest	10.6	0.9	0.4	30.9	3.9	3.6
WSCC	Western	34.3	2.7	1.0	127.5	5.0	4.0

Note: Historic and projected data aggregated from the State level into regional totals approximating Electric Reliability Councils. Projections are from information in: Bureau of Economic Analysis, U.S. Department of Commerce, "State Projections of Income, Employment, and Population to 1990," Survey of Current Business, (Volume 54, Number 4, April, 1974), pp. 19-45.

to such items as "Total U. S. Annual Electric Energy Consumption," "Total U. S. Summer Peak Demand," or "Total Installed Generating Capacity in the U. S." Such data may be useful for making gross estimates of economic factors. It is also used for comparing the economies of the U. S. and other countries. However, these data are not of great value in an evaluation of the reliability of bulk power supply, since reliability of supply must be viewed in a smaller context than that of the Nation as a whole. Nevertheless, for the purpose of setting a frame of reference, some data concerning bulk power supply and demand on a national scale are given in Table 4.4.

For the purpose of examining the reliability of supply, and for the purpose of planning system expansion, it is necessary to delineate specific regions or areas. There is no mathematical, rigid rule that can be used to determine the boundaries of an area suitable for power system planning. Existing electric utilities have grown in accordance with demands placed upon them by industry, commerce, and population growth. Cities, centers of population, and industries have been established, fostered, and increased by circumstances of geography and politics as well as by unpredictable events. An appropriate step, then, in discussing power supply, is to start with the existing facilities.

Small utility systems were established in response to local demands. As the systems increased in capacity and extent in response to customer demands, utility engineers found it expedient to connect (or "interconnect") the separately owned systems. The reasons for interconnection were two-fold: economic and reliability-based. Interconnected systems found they were able to

TABLE 4.4

INSTALLED CAPACITY AND SEASONAL
PEAK DEMANDS, CONTIGUOUS UNITED STATES, 1972-74

CONTIGUOUS UNITED STATES

Peak load Period	Installed Capacity (MWe)	Peak Demand (MWe)	Gross Reserve (MWe)	Ratio of Gross Reserve to Peak Demand (%)
Summer 1972	382,133	307,218	74,915	24.4
Winter 1972	398,204	282,274	115,430	40.8
Summer 1973	426,569	334,174	92,395	27.7
Winter 1973	438,101	282,300	155,801	55.2
Summer 1974	452,961	336,339	116,622	34.7
Winter 1974	474,175	282,646	191,529	67.8

Source: Federal Power Commission

effect savings in capacity installation through sharing and interchanging generating capacity, and were able to provide more reliable service by having available the resources of other utilities. In some instances, interconnected utilities merged into a single system under single ownership. In some instances, individual companies became subsidiaries of a holding company. In other instances, the interconnected utilities agreed to maintain their separate corporate structures but to plan and operate their physical power-producing facilities with some degree of coordination, through "pooling" contracts.

Following the Northeast Power Failure in November 1965, the Federal Power Commission, recognizing the need for better coordination of power supply planning and operation on a large scale, urged the industry to form regional coordinating groups (Ref. 1). Several such groups, somewhat limited in scope, had been in existence for some time, and following the Commission's recommendation, additional ones were formed. By 1974, nine such organizations, referred to as Regional Electric Reliability Councils, covered the contiguous United States and a tenth is in existence in Alaska. A map showing the names and geographic boundaries of the Councils was given in Figure 1.3 of Section 1. Coordination of planning among the utilities that are members of a Council is effected by means of a Planning Coordination Committee. Operating practices are reviewed and standardized to some extent by an Operating Coordination Committee. Each Council establishes, from time to time, committees or task forces to make special studies involving its member utility systems.

The Councils differ in their geographic size, their loads, and their installed capacity, among other factors. The boundaries have evolved from a more or less natural grouping of adjacent utilities having service areas of similar characteristics. Several of the Councils have well-defined sub-regions within their boundaries.

Interconnections among utilities existed long before the Councils were organized, and have continued to increase in number and power transfer capacity. The advantages of interconnections, as regards both reliability and economy, encourage utilities to continually strengthen their networks. At the present time, interconnections among utility systems have resulted in the creation of three large networks that supply power to all regions of the contiguous United States.

The largest network consists of the seven reliability council areas that are strongly interconnected: ECAR, MAAC, MAIN, MARCA, NPCC, SERC, and SPP (see Figure 1.3). These seven councils form a network of approximately 1,000 generating plants, public and private, supplying power to all or part of 40 states and the District of Columbia; the output of these plants flows into a system of transmission lines operating at voltages as high as 765 kilovolts, connecting the major load centers and power sources, both in U. S. and Canada. To varying extents for different councils, power is often moved in emergencies, or for economic reasons, from one council area to another.

The next largest interconnected area, embracing all or part of 14 Western states, is WSCC, which is connected to the seven-Council area by only a few transmission lines not regarded as reliable for transferring significant amounts of power or energy. WSCC meets its own loads with its own resources and cannot contribute with any degree of reliability to meeting demand in the seven-Council area. Technical and economic factors* have so far precluded strengthening the ties between WSCC and the seven-Council group; studies now in progress, however, are expected to result in a 100-megawatt direct current interconnection that will increase the reliability of the East-West interconnection by 1976.

The third and smallest area, ERCOT, covers most of Texas. Texas now has no interconnections between any other Council area, and thus cannot depend upon other regions for power supply in emergencies. While the possibility of interconnection between ERCOT and SPP has been explored, no plans by the ERCOT systems to become part of the national power supply network have been put forth (Ref. 2). The ERCOT systems generate and supply power only within the State of Texas. Most generators have been using natural gas as the primary fuel.

Most of the individual Councils differ in geographical size, installed generating capacity, total peak demand, and other characteristics. Some Council areas have highly concentrated industrial loads, some have large agricultural areas. Native fuel supply is non-existent in some, plentiful in others. For example: New England must rely upon imported oil or the Appalachian coal as its primary fuels or go to uranium. In WSCC, there is believed to be significant potential for geothermal power plants. In the southwestern region of the country, solar energy may be a feasible substitute for electric energy in heating and cooling applications. In the far West, extensive use is made of hydroelectric sources, but thermally powered plants are now under deveopment. The New England states, having no indigenous fuel resources, have utilized hydro plants, nuclear plants, and oil-fired plants to produce power. In the

* The major load centers in the Midwest and the West are half a continent apart, with the Rockies in between. Reliable ties to carry economic quantities of power would have to be of extra-high-voltage construction and would be very costly.

Southwest, natural gas has been used extensively to fuel power plants. However, because of shortages, the use of natural gas is being phased out of utility planning. The demographic and geographic conditions within each region have a large effect on the location of power plants, their type, and the arrangement of the transmission system. Moreover, in many cases, the regions are finding that traditional patterns are changing dramatically.

4.3 CAPACITY BY COUNCIL REGIONS

Table 4.5 shows the total generating capacity and peak demands projected for meeting the summer peak load in each Council region, as forecast in early 1975. For this table, capacity and load data have been tabulated only for the summer peak load p riod because all council areas except WSCC, the western system region, experience their greatest annual demands in summer. For WSCC the projected summer and winter peak demands are approximately equal. New England is a winter-peaking area and New York is a summer-peaking area. Because New York's demand is greater than that of New England, thus NPCC as a whole is summer-peaking. TVA is another winter-peaking sub-region of a Council (SERC) which as a whole is a summer-peaking. In both cases, however, interties have made possible sales of excess capacity to the adjoining utilities in the region.

4.4 GENERAL REGIONAL DEVELOPMENT

The availability of natural resources historically has affected the growth and development of each region as a whole as well as influenced the individual development of each utility. For example, New England's ample water supplies led to early development of its hydro potential. Since in many cases the most promising sites were located inland some miles away from the load centers, transmission lines were built to bring the power to the market, and it was not too long until New England was crisscrossed by an interconnected system. In New York the need to tie the ample hydro generating capacity available on the St. Lawrence of Niagra Rivers led to the development of its statewide 345-kV interconnected network.

This pattern was also somewhat typical of early development along the East coast. The early development of hydro not only provided ample supplies of power for industry but also was relatively inexpensive. It wasn't long, however, before demand exceeded the capacity available from hydro facilities in the East, and the utilities looked westward to the Appalachian coal fields to supplement their hydro generating facilities.

An abundance of rail lines provided the transportation, and soon many utilities were relying heavily upon coal as a major fuel supply for their generating stations. In the late fifties and early sixties, many of the utilities along the East coast began to turn to oil in lieu of coal Cheap oil prices and lower construction costs together with fewer air pollution problems caused a substantial shift to foreign oil as a substitute for coal. Then, additional concern about air pollution and a desire to seek a long-term stable fuel supply led the New England utilities to explore the development of nuclear energy. As early as 1960, one of the Nation's first nuclear stations came on line; and by the end of the decade New England was heavily dependent upon nuclear energy. From then on many utility executives felt that, since conventional fuel supplies were becoming more and more scarce and more expensive, the New England region would be more competitive nationwide as to the cost of electricity.

TABLE 4.5

PROJECTED SUMMER GENERATING CAPACITY AND PEAK DEMAND FOR ELECTRICITY
CONTIGUOUS UNITED STATES
BY REGIONAL ELECTRIC RELIABILITY COUNCILS

Electric Reliability Council Region	Summer Generating Capacity 1975	1984	Summer Peak Demand 1975	1984
ECAR	71,946	115,026	55,682	99,192
ERCOT	32,873	59,288	25,273	50,276
MAAC	41,760	62,757	31,930	50,650
MAIN	36,193	66,425	31,956	57,053
MARCA[a]	18,684	32,525	14,300	25,571
NPCC[a]	48,237	68,325	33,761	53,084
SERC	97,437	185,286	78,947	158,254
SWPP	41,309	81,180	34,735	70,522
WSCC	82,030	143,988	64,822	109,196
Total US	470,469	814,800	371,406	673,798

Source: April 1, 1975 response to Appendix A-1 of FPC Docket R-362, Items 1 and 3.

[a] Includes only United States portion of Council.

In the other regions of the country the utilities sought to develop their natural resources. The American Electric Power (AEP) system, for example, sitting on top of tremendous coal reserves in the Appalachian and Ohio Valley regions, quite logically looked to coal after initial development of the more promising hydro facilities. AEP has now constructed a significant number of coal fired generating stations in the Nation; new transmission systems have brought electricity to those areas without adequate coal supplies.

Another interesting development occurred in the Tennessee Valley. As was noted earlier, development of the hydro capacity along the rivers in the Tennessee Valley at very attractive rates led to rapid development of the region. Before too long, hydro generation was not sufficient to meet demand and the TVA system turned first to coal generation, then in recent years, to nuclear generation.

Throughout central United States the utilities sought at first to develop the native fuels which seemed to be so ample, namely oil and natural gas. Utilities in Texas, Oklahoma, Louisiana, Arkansas, Kansas, and Illinois concentrated on developing their sources, but in very recent years there has been a very significant change. Natural gas, bought for so many years at an interruptible rate, is running out. Oil was more valuable for other uses, although some of the utilities sought sources [illegible]nada. Now we find utilities in the Southwest looking to the Rocky Mountains for coal to supply their generating stations and starting to build nuclear plants as well. Utilities in Texas no longer can count on continuing to use oil and natural gas as the principle fuels.

On the West coast it was believed that years would elapse before the demand would exceed the capacity that could be developed on the large rivers of the region. Huge dams with large generating stations gave the Pacific Northwest an abundant supply of power at very low rates. Industry flocked to the region. Ties were built to transmit excess capacity to the Pacific Southwest in exchange for excess fossil fuel capacity. Now the region finds itself turning to Wyoming and Montana for coal to fuel its stations. Here the utilities are faced with a problem which increasingly is dictating plant location, the availability of cooling water.

In summary, it would seem that coal and uranium through necessity have already become the paramount sources of fuel. Table 4.6 shows the present reliance of all regions on fossil fuel, the relatively small but important amount of hydro electric generation, and the more recent introduction of nuclear generation.

In the longer term, however, there are developments being undertaken to supplement these types of generation. In large urban areas efforts such as those in St. Louis are underway to use waste products as an energy source. The most optimistic forecast is, however, that only 5 percent of the projected requirements will be supplied by recycling waste products.

In the Pacific and Rocky Mountain areas geothermal energy is considered as another very important, though again relatively small, supplementary source of power generation. It is and has been for some time the primary source of fuel at its "Geysers" plant in California. This plant, with a total capacity of 440.6 megawatts (as of Dec. 31, 1974) is the only geothermal plant in the United States. Operation of the Geysers plant began in 1960 with one unit; several more have been added since. Although some of the factors in geothermal plant design and operations are similar to those of fossil-fuel-burning facilities, others such as steam supply pressure, temperature, purity and quantity are major elements in geothermal plant design which require engineering consideration of novel aspects, and mineral content of steam drawn from underground sources may pose environmental problems. However, geothermal energy is a natural resource, and continuing development of it is envisioned for the West and is under way. It does not appear that usable geothermal sources adequate for significant power production exist elsewhere in the U.S.

Again, in the longer term, it is expected that solar energy will provide an important contribution to the solution of the Nation's energy dilemma. Already the Energy Research and Development Administration projects that it might be possible, provided funds are available for research and development so that product on costs can be reduced, that electric energy will be produced from solar energy, (see Section 6 of Part V). At the moment the greatest attention is being given to those regions which are blessed with more than adequate hours of sunlight, though this is not expected to rule out solar heat in other regions. Even in the northern regions today, solar heat is being used as a supplementary source of space heating.

Along with development of solar energy, many scientists are optimistic that our vast fossil fuel resources, namely, coal, oil shale, and tar sands, may be converted to gaseous and liquified form and used for power generation. hould this be the case, then the fuel could be transported to other regions for use in generatio , i.e., those regions which have adequate supplies of cooling water.

TABLE 4.6

PERCENTAGE DISTRIBUTION OF GENERATING CAPACITY
BY PRIMARY ENERGY SOURCE
CONTIGUOUS UNITED STATES
DECEMBER 31, 1974

Electricity Reliatility Council Region	(% of Total Council Capacity) Fossil	Hydroelectric	Nuclear
ECAR	93	3	4
ERCOT	99	1	0
MAAC	85	5	10
MAIN	80	5	17
MARCA	69	14	17
NPCC	71	16	13
SERC	81	9	10
SWPP	92	2	6
WSCC	52[a]	45	3
TOTAL U.S.	80	14[b]	6

Note: Percentages are approximate and have been rounded.

Source: Federal Power Commission

[a]Includes about 0.6% for geothermal energy.

[b]About 15% of the total hydro-electric capacity is pumped storage capacity.

Whatever the kind of fuel, because of the strong regional networks and interregional ties which have been built up, it is now possible to build generating stations in almost any area and transmit the output reasonable distances to other areas both economically and reliably.

REFERENCES

1. Federal Power Commission. July 1967. *Prevention of power failures, a report to the President. Vol. 1, p. 88.*

2. Federal Power Commission, Bureau of Power. October 1972. *Study of proposed interconnection between electric reliability council of Texas and Southwest Power Pool.*

SECTION 5

THE NUCLEAR ROLE: STATUS, HISTORY AND FORECAST

5.1 INTRODUCTION

The advent and large scale use of nuclear energy is probably the most important single change in the electric power industry during the past fifty years, and perhaps the most controversial. The promise of low cost nuclear energy, however, has brought with it many questions, most of which are related in one way or another with public health and safety. As a result, Congress has developed a very extensive Federal regulatory program which monitors and governs the development of the industry. In light of the fact that many of the problems are unique to this industry, progress has been slow at times and in recent years quite controversial among certain groups. However, the Nation's energy policy includes the further development of nuclear fission energy and, in the more distant future, nuclear fusion energy.

If recent experience can be a guide, it is going to be difficult to forecast the future accurately. The early optimism of the 50's with the advent of several experimental projects gave way to a more cautious outlook. By 1964 the Federal Power Commission projected 70,000 megawatts of capacity to be in operation by 1980. At that time only 1,000 megawatts was in commercial operation and 3,000 MWe under construction or on order. Shortly thereafter the manufacturing industry went on a marketing offensive, and in the late sixties and early seventies almost 200 nuclear units were ordered. Competing fuel prices were under pressure to remain level, and great economies of scale were expected to result in continuing reductions in rates from nuclear generation. However, problems became apparent. Delays in construction, caused by a number of factors raised costs considerably. Overly optimistic capacity factors had to be reduced. Inflation exceeded all forecasts. The so-called fuel cycle problems complicated things further. Also, uranium fuel costs have risen substantially. New environmental health and safety questions have been posed and addressed. Security and safeguard problems have taken on new dimensions. Some legislatures, such as Vermont, seek to regain control over site location which in past times they have delegated to administrative bodies. Demands for a nuclear moratorium are voiced. Even the scientist has become involved. Through all this churning, the general consensus is that nuclear energy will play an increasing role in our energy future.

5.2 HISTORICAL AND CURRENT TRENDS

Under the leadership of Chairman Lewis L. Strauss, the Atomic Energy Commission began early in 1954 to revitalize its program for developing civilian power reactors. The AEC announced plans to build, within 5 years, five experimental reactors to test basic reactor designs then under study. Of the AEC's five reactor prototypes, the one to have the most immediate impact on nuclear power development was the Pressurized Water Reactor (PWR)* built at Shippingport, Pa., with a power of 90 MWe. Stemming from the development of nuclear propulsion systems for naval ships, the PWR was completed on schedule late in 1957 as the Nation's first full-scale nuclear generating station. The cooperative agreement with the Duquesne Light Co. provided for the AEC's ownership of the reactor and company ownership of the generating facilities.

To take advantage of the industrial participation provisions of the Atomic Energy Act of 1954, the AEC early in 1955 invited industry to submit proposals for building power demonstration reactors. Industry responded with four proposals using all but one of AEC's five basic designs, and all four projects were completed. Subsequent invitations elicited a dozen additional proposals which resulted in four small generating stations. Two large utility companies also elected to build central-station nuclear plants independent of government support.

By the end of 1957, the AEC had seven experimental power reactors in operation, and American industry was participating in nine independent or cooperative projects capable of producing almost 800 megawatts of electricity by the mid-1960s. By 1961 two nuclear plants built by industry--the Commonwealth Edison plant at Dresden, Ill., having a Boiling Water Reactor (BWR)* with a power of 200 MWe, and the Yankee Atomic Electric plant at Rowe, Mass. a PWR with a power of 175 MWe--had joined the Shippingport plant in producing nuclear power for commercial use.

The amount of nuclear steam generator capacity placed on order grew rapidly as shown in Figure 5.1. This growth was both in absolute amount and also with respect to conventional steam generator capacity and was due to a variety of reasons two of which were the relative economics and the fuel availability.

Since the late 1950s, both the number of units that became operable and the size of the units grew. As of August 31, 1975 there were 54 units with total rated capacity of 37,000 MWe. The largest operating units are now approximately 1,100 MWe.

One of the primary reasons that units became large is the economy of the scale in construction cost that larger units offer. This is historically illustrated in Figure 5.2 where the unit costs in constant 1971 dollars are shown to decrease from about $500 per kilowatt of capacity for 100 megawatt plants to around $150 to $200 per kilowatt for plants with capacity in the range of 500 to 800 megawatts. The degree that the construction costs will continue to decline with size is controversial (Ref. 1, 2, 3). Current indications of construction savings for units as large as 1,300 MWe is shown in Figure 5.3. Note that economies of scale also apply to coal and oil units and explains the trends to larger sizes for them also.

Another important trend is the clustering of more than one unit at a site. This has been done for both economic and siting reasons. The siting aspects are discussed in Section 6. From an economic point of view, the major portion of the savings depends on the units being essentially identical and the schedule of the second unit lagging the first by about one year. An obvious

*In addition to the pressurized water reactor (PWR) and the boiling water reactor (BWR), another type of reactor concept has come into commercial use, the High Temperature Gas Cooled Reactor (HTGR). These are discussed in Appendix A.

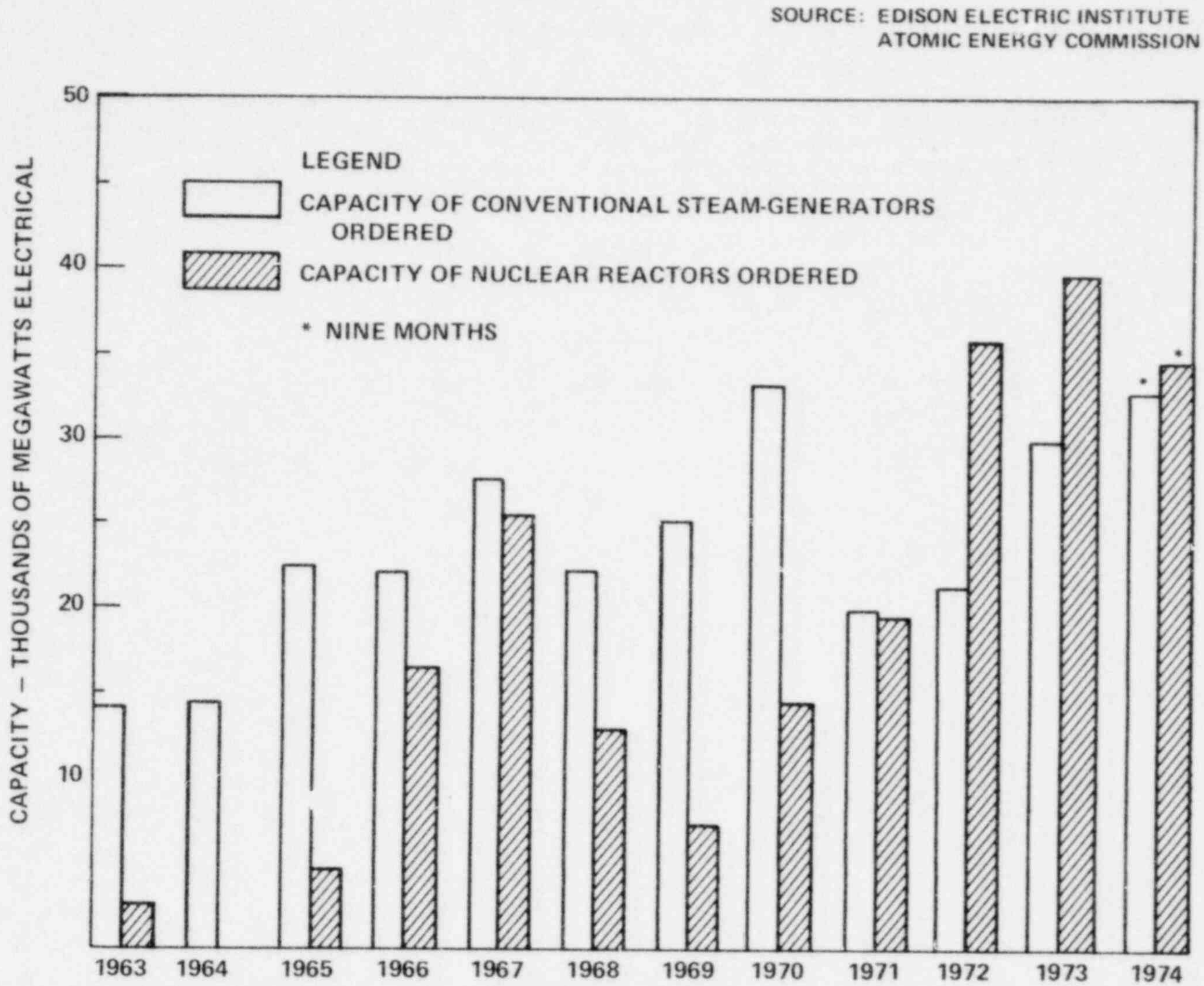
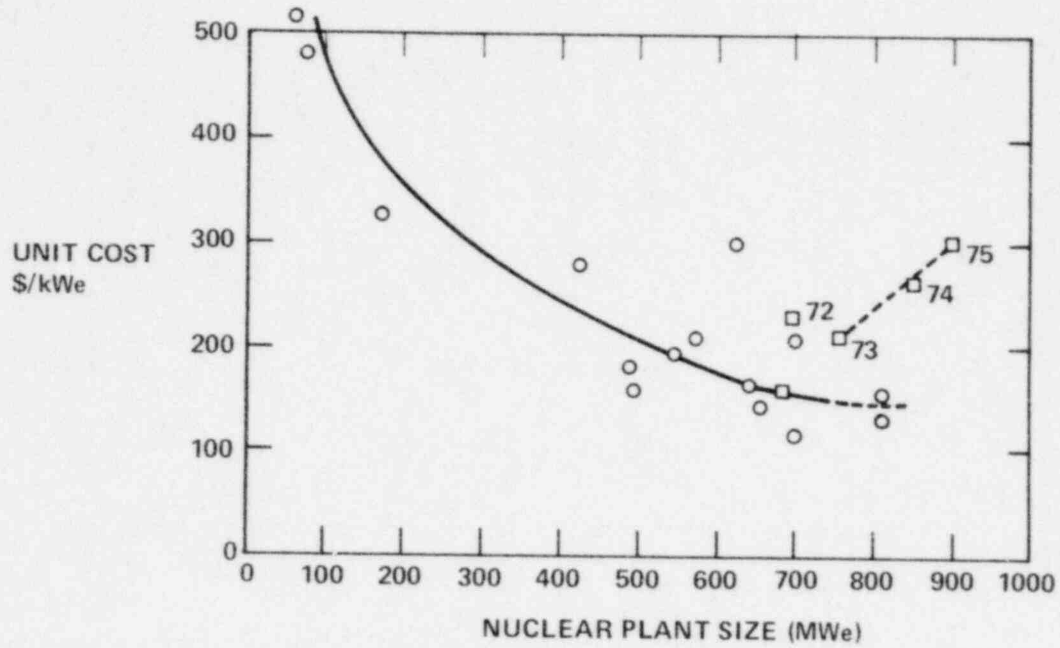


FIGURE 5.1 CAPACITY OF STEAM GENERATORS PLACED ON ORDER WITH DOMESTIC MANUFACTURERS OF U.S. ELECTRIC POWER SYSTEMS, 1963-1974

SOURCE: F. C. OLDS, SEE REF. 1.



NOTE: CIRCLED POINTS ARE UNIT COSTS, $/kWe, FOR 15 LIGHT WATER NUCLEAR POWER PLANTS (LWR) THAT WENT INTO COMMERCIAL SERVICE IN 1961 THROUGH 1971. POINTS IN SQUARES ARE THE AVERAGE UNIT COSTS OF LWRs GOING INTO COMMERCIAL OPERATION IN THE YEARS 1971 THROUGH 1975. ALL COSTS ARE ADJUSTED TO CONSTANT 1971 DOLLARS AND INCLUDE INTEREST DURING CONSTRUCTION.

FIGURE 5.2 UNIT COST TRENDS OF LIGHT WATER NUCLEAR POWER PLANTS FROM 1961 THROUGH 1975

SOURCE: POWER PLANT CAPITAL COSTS, CURRENT TRENDS ANDSENSITIVITY TO ECONOMIC PARAMETERS (REF. 3)

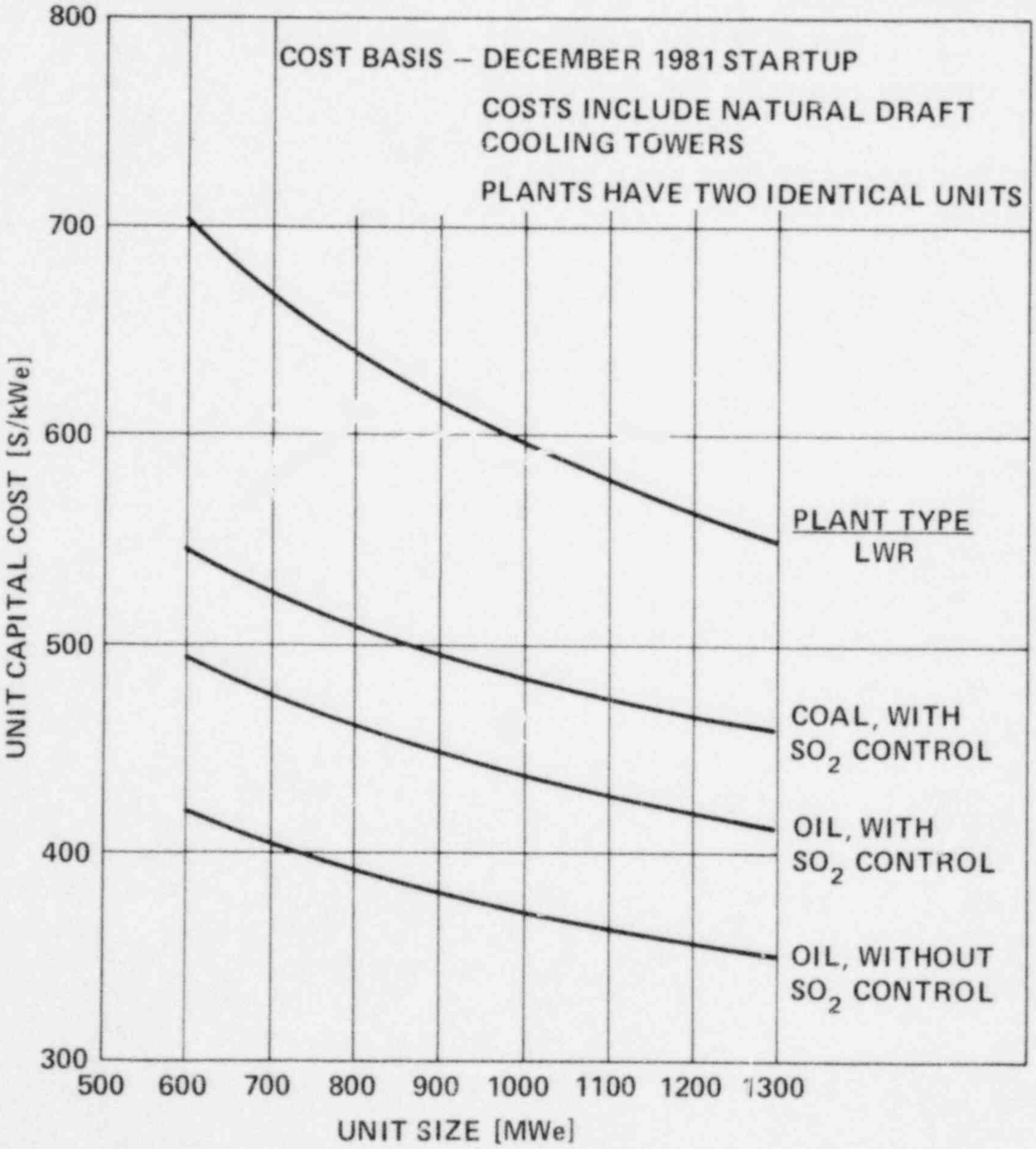


FIGURE 5.3 UNIT CAPITAL COSTS OF POWER PLANTS AS A FUNCTION OF UNIT SIZE
(These costs include interest during construction)

large savings result from the use of a developed site, since most of the site preparation costs for the first plant would also be adequate for the second. Both reactors could be served by the same roads, railroads, etc. with only minor cost increases. The total savings in cost of an identical second unit lagging the first one by one year is estimated to be about 10 to 15 percent (Ref. 3, p.74). The clustering trend has also been extended to more than two units at a site. Currently, there are five sites with four units each in the planning stage. They are: Harris 1-4, Alabama; Hartsville 1-4, Tennessee; North Anna 1-4, Virginia; San Joaquin 1-4, California; and Surry 1-4, Virginia. Barton 1-4, Alabama and Vogtle 1-4, Georgia were orginally planned for four units but 3 and 4 have been cancelled recently.

5.3 CURRENT STATUS AND SHORT TERM FORECASTS

Recent increases in fuel costs have increased substantially the supply price of electricity. Other costs of doing business have also risen. An important component of the future supply price of electricity is the cost of new capital equipment such as generating capacity, transmission lines and distribution equipment. The costs of past additions to capital equipment are reflected in the financial accounts on which electricity rates are based. The purchase of new equipment has a twin impact tending to increase electricity supply price: higher initial price per unit and higher interest rates used to finance such equipment.

In spite of the fact that the unit costs in constant dollars are decreasing, as was suggested in Figure 5.2, the average cost in current dollars has increased substantially as shown in Figure 5.4. These increases have come about for a variety of reasons, such as, environmentally related costs; safety-related costs; miscellaneous costs like the expanded scope of supply and increased requirements for design, engineering analysis, quality assurance, and construction management; and indirect costs like engineering, quality assurance and control, inflation, etc. (Ref. 2, pages 11-17).

In addition to capital costs increasing, fuel costs have increased for oil, coal and uranium. This is shown in Figure 5.5. There was a precipitous increase at the time of the oil embargo in the fall of 1973.

Although capital and fuel costs have increased for nuclear power, they also have increased for coal and oil fired units so that nuclear generated steam has remained competive. It should be noted, also, that there are many other considerations in selecting a power plant in addition to cost, such as siting, environmental impact and fuel availability. Taking these factors into account, the utility industry expects to add 137 nuclear units during the time frame 1975-1984. This amounts to about 145,000 MWe of capacity or about 42 percent of the total capacity to be added. (See Table 3.1, Section 3)

At the end of 1974, forty-five nuclear units representing a total capacity of 28,964 megawatts were in commercial operation (See Table 5.1). The total generating capacity for the contiguous United States at that time was 474,143 megawatts; nuclear generating capacity represented 6.1 percent of the total. By 1984, 185 nuclear units, representing 175,754 megawatts or 21.2 percent of the total capacity of 830,719 megawatts for the United States, are expected to be in commercial operation.

SOURCE: F. C. OLDS, SEE REF. 5.

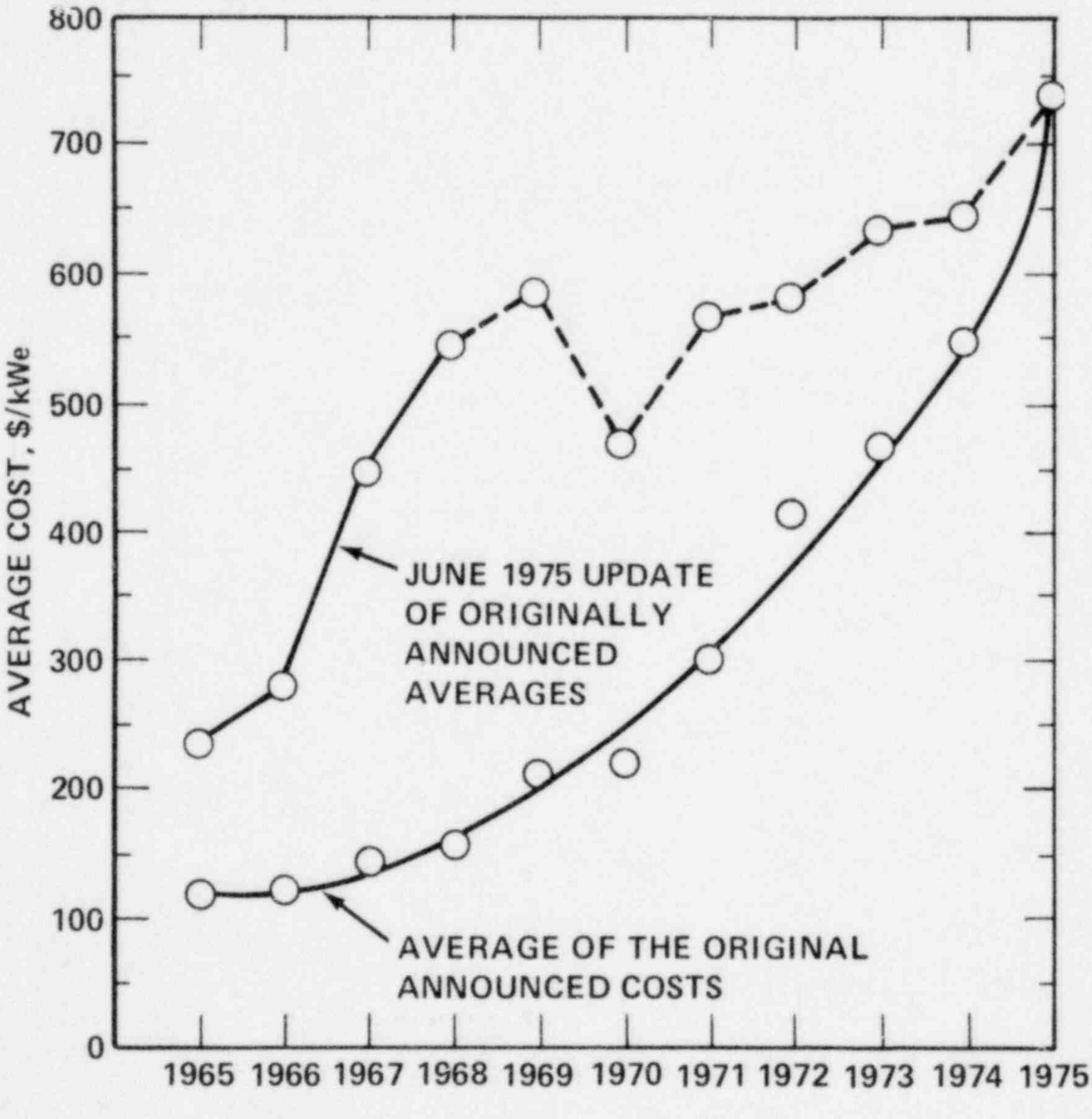


FIGURE 5.4 NUCLEAR PLANT COST TRENDS.
(The average plant costs, including interest during construction in $/kWe, are calculated in the year of plant order and fall along the lower curve. Updated estimates or actual finished costs as of June 1975 are shown by the higher points. The dotted line indicates no plants for these years are yet on line.)

SOURCE: FREMONT FELIX, "POINT-OF-USE EFFICIENCY GIVES ELECTRIC ENERGY AN EDGE IN GENERATING HIGH PER-CAPITA GNP," ELECTRICAL WORLD, NOV. 1, 1975.

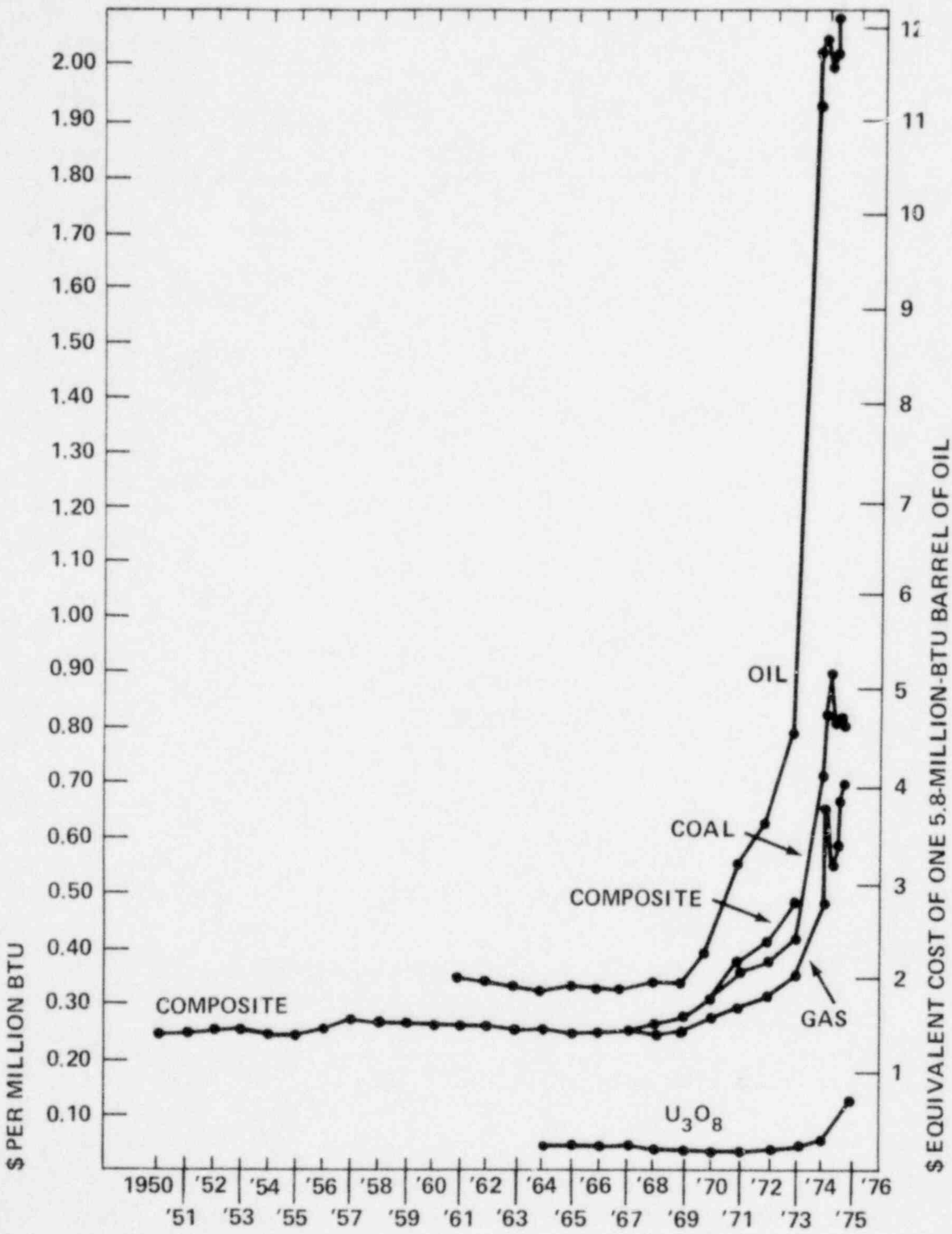


FIGURE 5.5 FUEL COSTS FOR OIL, COAL AND URANIUM, 1960-1975

TABLE 5.1

INSTALLED GENERATING CAPACITY IN THE CONTIGUOUS UNITED STATES, NUCLEAR AND TOTAL, 1970-1984

Commercial Operation	Number of Nuclear Units		Nuclear Capacity (Megawatts)		Total Capacity (Megawatts)		Percentage of Nuclear to Total Capacity
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	
1970	-	14	-----	5,771	-----	339,776	1.7
1971	6	20	3,456	9,227	26,266	366,042	2.5
1972	8	28	5,525	14,752	32,162	398,204	3.7
1973	7	35	5,235	19,987	38,515	436,719	4.6
1974	10	45	8,977	28,964	37,424	474,143	6.1
1975	14	59	11,163	40,127	16,951	491,094	8.2
1976	7	66	6,931	47,058	26,617	517,711	9.1
1977	9	75	8,605	55,663	33,076	550,787	10.1
1978	7	82	7,058	62,721	27,903	578,690	10.8
1979	8	90	8,666	71,387	32,624	611,314	11.7
1980	14	104	15,775	87,162	42,177	653,491	13.3
1981	18	122	18,694	105,856	37,852	691,343	15.3
1982	26	148	28,698	134,554	54,151	745,494	18.0
1983	19	167	21,382	155,936	34,453	779,947	20.0
1984	18	185	19,818	175,754	50,772	830,719	21.2

Note: 1970-1974 figures are actual; others are estimates.

Source: Capacity figures for 1970-74 obtained from Federal Power Commission data; 1975-1984 capacity estimated by Northeast Power Coordination Council.

The geographical location of commercial nuclear power reactors is indicated in Figure 5.6. They are listed under various categories, i.e., licensed to operate, under construction, and application under review. In addition, a table of the status of nuclear power plants as of August 31, 1975 is shown in Table 5.2. In total, there are 241 units with a rated capacity of 242,000 MWe.

5.4 LONG TERM FORECASTS, PROJECTIONS AND SCENARIOS OF NUCLEAR CAPACITY

A number of long term forecasts, scenarios and projections of nuclear capacity have been published recently. They are shown for the years 1985 and 2000 in Table 5.3 and include LWR, HTGR, LMFBR and fusion reactors. As in the case of demand for electricity, which was described in some detail in Section 2, the magnitude of the forecasts of nuclear capacity depends highly on the assumptions that are made. For that reason, the assumptions for the various forecasts are summarized here. There is no real attempt to assess the likely probability of the various forecasts, scenarios or projections coming into being. This study should only be viewed as an abbrievated tabulation of the more pertinent results.

Atomic Energy Commission (AEC); WASH-1139(74)(Ref. 5)

Each of the near-term nuclear growth projections in Cases A through D, could be combined with various long-term resul' . The near-term problems in plant construction do not necessarily determine long-term programs or their ultimate degree of success. However, in order to calculate meaningful ranges of the possible implications of nuclear power, the near-term forecasts of low capacity have been tied to long-term forecasts of low demand, and high near-term capacities, have been tied to high future demands. The demand projections have been described in Section 2. The assumptions for the near-term forecasts for nuclear capacity are the following:

Case A. This is the study case for NECSS-1975. This case presents the lowest forecast of nuclear capacity. The assumption is made that delays in bringing nuclear plants on line continue to plague the industry. The sources of delay are manifold including late equipment deliveries, construction delays, strikes, poor labor productivity and regulatory problems. It is not assumed that any particular source of delay is predominant or that any particular source is corrected, but rather that some of these sources of delay will remain.

Case B. This case assumes that there will be some improvement over recent experiences in construction and regulation. Specifically, project times will average 8 years with about 15 months for planning and design, license application and environmental report preparation; 15 months for construction permit issuance; and about 5-1/2 years for construction and start-up.

Case C. This case assumes additional improvements in construction performance and regulatory processess. New legislation and rules would permit construction to begin prior to completion of the construction permit application safety review. The site environmental review would be completely separated from the safety review. This presupposes that standardized plant designs would be used in the license application. The project time would be about 6 years with 1 year for design and planning, license application preparation and environmental review and 5 years for construction and start up with concurrent operating license review and approval.

FIGURE 5.6 COMMERCIAL NUCLEAR POWER REACTORS IN THE UNITED STATES AS OF AUGUST 1, 1975

TABLE 5.2

STATUS OF NUCLEAR POWER PLANTS - NOV. 30, 1975

Number Of Units			Rated Capacity (MWe)
* 55	LICENSED TO OPERATE		38,000
** 63	CONSTRUCTION PERMIT GRANTED		63,000
26	Under Operating License Review	25,000	
37	Operating License Not Yet Applied For	38,000	
78	UNDER CONSTRUCTION PERMIT REVIEW		87,000
**23	Site Work Authorized, Safety Review in Process	24,000	
55	Other Units Under CP Review	63,000	
23	ORDERED		27,000
19	PUBLICLY ANNOUNCED		23,000
238	TOTAL		238,000

* In addition, there are two operable ERDA-owned reactors with a combined capacity of 940 MWe.

**Total of units under construction (Construction Permit Granted plus Site Work Authorized): 86 units, 87,000 MWe.

Source: NRC

TABLE 5.3

COMPARISON OF FORECASTS, PROJECTIONS AND SCENARIOS OF TOTAL NUCLEAR GENERATING CAPACITY FOR 1985 AND THE YEAR 2000

Forecast	Case	Total Nuclear Capacity (Thousands of MWe)	
		1985	2000
Atomic Energy Commission			
WASH-1139(75)	A	231	850
	B	260	1,200
	C	275	1,400
	D	250	1,090
Energy Research and Development Administration			
Update of Wash-1139(74) March 31, 1975	Low	160	625
	Low/Moderate	185	800
	Moderate/High	205	1,000
	High	245	1,250
Federal Power Commission Technical Advisory Committee on Power Supply[a]	Base	not given	982
	Conservation	not given	818
	Substitution	not given	1,520
Federal Energy Administration "Project Independence"	$11 per barrel	234	not given
	Demand Management	275	not given
Council on Environmental Quality "The Half and Half Plan"[a]		140	571
Ford Foundation Energy Policy Project[a]	Historical		
	Domestic Oil and Gas or High Import	162	653
	High Nuclear	194	818
	Technical Fix		
	Self Sufficiency	130	180
	Environmental Protection	81	49
	Zero Energy Growth	81	49
Energy Research and Development Administration "The Plan"	0-No New Iniatiatives	185	720
	I-Improved Efficiencies in End Use	185	368
	II-Synthetics from Coal and Shale	185	720
	III-Intensive Electrification	225	801
	IV-Limited Nuclear Power	185	201
	V-Combination of All New Technologies	225	449

[a] Estimates based on fuel requirements that were given with assumed heat rates of 10,000 BTU/kWh and capacity factor of 0.7.

Case D. This case assumes a general reduction in the growth rate of electricity use which for the near-term means a reduction in non-essential and extravagant uses.

ERDA UPDATE OF WASH-1139(74)(Ref. 6)

On April 28, 1975, Roger Legassie, Assistant Administrator for Planning and Analysis, ERDA, presented in Congressional testimony an update WASH-1139(74) that was completed in March 31, 1975. These updated projections do not specifically address the future impact of expanded Federal energy research and development programs which is done later in "the Plan." The alternative projections presented should be viewed as such rather than a forecast or set of forecasts. They are the following:

High Case. This case reflects the Preside tial objectives for 200 new nuclear power plants through 1985 and a continuation of a conc ed nuclear effort in the longer term coupled with continued high rates of growth in electric energy. For 1985 this case would require that all plants maintain schedule as currently announced for operation by that date plus an additional 30,000 MWe be scheduled for installations in the same period.

Moderate/High Case. This case is primarily based on counting plants ordered in the short run with some allowance for additional slippage in schedules. The longer-term presumes that nuclear power plants maintain an economic advantage over other type central station power plants and therefore capture the largest portion of new additions.

Moderate/Low Case. Within a setting of slower growth of electricity, the need for new central station plants is reduced, and consequently, a similar type reduction in nuclear power plants. While nuclear power maintains an economic advantage, the problems of high capital costs and long lead times cause some shifting to fossil-fuel plants.

Low Case. Associated with low total and electric energy scenarios, a low nuclear growth case is postulated. The case presumes that in the short-term, nuclear power plants continue to be plagued by numerous problems creating large slippages in announced schedules. During the long-term, nuclear power plants are presumed to have only a marginal economic advantage over new technology fossil-fuel plants.

Federal Power Commission (FPC): Technical Advisory Committee on Power Supply (TACPS)(Ref. 7)

The National Power Survey Technical Advisory Committee on Power Supply published three hypothetical forecasts. The full implications of the forecasts were not evaluated.

Base. A hypothetical situation occurring if prior conditions of plentiful supplies of low-cost oil and gas were to continue.

Conservation. Higher prices of energy supplies but still having adequate oil and gas supplies available at those prices.

Substitution. The authors claim that this is the one the most likely to occur. This case recognizes that the principal shortages will be concentrated in oil and natural gas; and that these fuels will become increasingly unavailable at any price; and that coal and nuclear energy must be substituted for applications which currently use oil and natural gas.

Federal Energy Administration (FEA): Project Independence (PI) (Ref. 8)

The FEA has prepared two projections of future nuclear electrical capacity for 1985. There was none for the year 2000. There was no substantive discussion of relative likelihood of the final result.

$11/B. This is the Business-As-Usual case with oil at $11 per barrel.

Demand Management. This case entails greater Government participation in demand management. It assumes an acceleration of nuclear construction schedules.

Council on Environmental Quality (CEQ): The Half and Half Plan (Ref. 9)

No assessment of the likelihood of the Half and Half Plan was stated. Some of the implications for energy supply are that:

1. Major reliance must be placed on coal and nuclear fission. Coal will increase from 12.6 quadrillion BTUs in 1971 to 33.4 quadrillion BTUs in 2000; nuclear power from 0.4 to 35 quadrillion BTUs.

2. Over 42 percent of total energy inputs will be used to produce electricity. This will result in substantial conversion losses--as much as 30.7 quadrillion BTUs in 2000.

3. Limited petroleum resources must increasingly be reserved for transportation uses.

4. Major research and development should be carried out on new energy resources such as nuclear fusion, solar and geothermal energy. Even with a major effort, however, we cannot reasonably expect more than 3 percent of our total needs from these new sources by the year 2000.

Ford Foundation: Energy Policy Project (EPP)(Ref. 10)

Three basic scenarios were examined which are described below. The relative likelihood of them coming into fruition should be judged by the individual reader by consulting Ref. 12 to understand the full implications of the scenario.

Historical. If a conservative view of the likely fruits of energy research and development is taken there are three major sources of future supplies for the rest of the century: domestic fossil fuels, including synthetic oil and gas; nuclear power; and oil imports. The relative importance of these various sources depends upon such factors as environmental acceptability, relative price, and government policy concerning reliance on imports. To illustrate the breath and High Imports. A basic feature of all supply options under Historical Growth is that the supply mix shifts away from oil and gas. Today gases and liquids make up more than three-quarters of our energy supply. But in the year 2000 they would account for only about half the total supply in the Historical Growth scenario. In contrast, an even greater role is expected for coal and nuclear power, whose share of the energy supply increases from 20 to 50 percent between now and 2000. Roughly two-thirds of the growth in energy between now and 2000 in the Historical Growth scenario is due to coal and nuclear power.

Technical Fix. A basic advantage of the Technical Fix scenario is that through energy conservation, this country gains considerable flexibility in putting together an energy supply mix. It is important to emphasize, however, that even the low rate of growth in this scenario requires substantial additional energy supplies, and expansion of a number of sources will be required. With the lower growth rate, however, it is possible to forego development of some major energy sources, or alternately, to meet demand by expanding various sources at about half the rate required in the Historical Growth scenario.

There are two options in the Technical Fix scenario:

1. Self-sufficiency. In this option, the objective is to cut imports in half, from the present level of about six million barrels per day to three million barrels per day for the period 1985-2000. Half the growth in this option would come from nuclear power and coal.

2. Environmental protection. The thrust of this supply mix is to minimize demands on environmentally controversial sources of energy: developments in presently underdeveloped offshore area; in Western coal and shale where water is scarce and reclamation difficult; and in nuclear power.

Zero Energy Growth (ZEG). The energy supplies required for ZEG are not simply scaled down versions of the supply schedules for higher growth scenarios. Some of the motivations that curtail growth in demand are reflected in the supply mix for ZEG.

A decision to level off energy consumption a decade hence might stem in part from a desire to avoid development that causes serious environmental problems. This means avoiding the Atlantic and Pacific coasts, oil shale, and much western coal. It also means avoiding the expansion of nuclear power. Similarly, concern over climatic alterations from burning fossil fuels would motivate a limit on the growth in fossil fuels. Further, a concern over the "big brother" syndrome would lead to the de-emphasis of large energy technologies in favor of small scale total energy systems, roof top solar systems, organic waste energy systems, and wind power. And use of solar energy could help alleviate chronic air pollution.

Energy Research and Development Administration (ERDA): The Plan (Ref. 11)

The six scenarios are the same as those discussed in Section 2. One has to evaluate the ultimate consequences of the various scenarios in order to appraise the relative likelihood of their occurrence. Since the matters are quite complex it is advised that each reader do it for him- or herself by consulting Ref. 11. The supply assumptions for the scenarios are discussed below.

Scenario 0--No New Initiatives

. Oil and gas production draws on remaining recoverable domestic resources
  - According to lower estimates by the U.S. Geological Survey (1975) and the National Academy of Sciences.
  - Without tertiary or other new recovery.
. Coal and nuclear converter reactors continue to expand to meet electricity demand, limited by ability to construct or convert plants.
. Other energy sources (e.g., geothermal, hydroelectric, and urban wastes) expand according to historic projections of existing technologies which do not reflect recognition of a serious energy problem.

Scenario I--Improved Efficiencies in End-Use

. Domestic oil and gas production is increased above the base case (Scenario 0) by new enhanced recovery technologies.
. Solar heating and cooling are introduced.
. Geothermal heat is used for process and space heating.
. Waste materials are employed as fuels or are recycled to save new energy in production.
. Other assumptions are those of Scenario 0.

Scenario II--Synthetics from Coal and Shale

. Substantial new synthetic fuels production is introduced from
  - Coal
  - Oil Shale
  - Biomass
. Enhanced oil and gas recovery levels of Scenario I are included.
. Under-used solar, geothermal, and waste sources included in Scenario 0 are not included here.
. The assumptions, unless previously stated, are those of the previous scenarios.

Scenario III--Intensive Electrification

. Electric power is intensively generated by coal and nuclear power as in prior scenarios.
. New technology energy sources are introduced as available to generate electricity.
  - Breeder reactors
  - Solar electric (wind, thermal, photovoltaics and ocean thermal)
  - Fusion
  - Geothermal electric
. A minimal contribution is assumed from waste materials (as in Scenario 0).
. Supply assumptions are consistent with Scenario 0.

Scenario IV--Limit on Nuclear Power

- Converter reactor energy levels are constrained to 200,000 megawatts electric.
- Coal electric is at the levels in other scenarios to permit coal to be employed for synthetics.
- Additional sources of electricity depend on
  - -Accelerated geothermal development (more than a factor of two over Scenario III)
  - -Accelerated solar development (a factor of two over Scenario III)
  - -Fusion as in Scenario III
- Solar and geothermal heating are used (as in Scenarios I and III).
- Synthetic fuels are produced from coal, shale, and biomass at the level of Scenario II.

Scenario V--Combination of All New Technologies

Scenario V analyzes a case in which a combination of all major energy packages, including nuclear, are simultaneously commercialized (i.e., improved end-use, synthetic fuels, and electrification). Complete success in all these complex endeavors is highly unlikely. The specific supply assumptions for this scenario are the same as Scenarios 0 through IV.

Overview

The WASH-1139(74) Case A NECSS-1975 study assumption of 850,000 megawatts of nuclear capacity for the year 2000 is a representative forecast, scenario or projection compared to the many shown in Table 5.3 which appear likely to occur. Case A is very high under the assumption that the United States were to follow a Zero Energy Growth or Technical Fix Scenario envisioned by the Ford Energy Policy Project. Also, Case A is high compared to the ERDA Scenario I -Improved Efficiencies in End Use, Scenario IV - Limited Nuclear Power, or Scenario V - Combination of all technologies. All three of these scenarios would likely require heavy government involvement to attempt to bring this about with no assurance of success.

For the purposes of NECSS-1975, a sensitivity analysis is performed on WASH-1139(74) Case A in Section 6, Part V, in order to determine whether the results of NECSS-1975 would be altered significantly should the nuclear growth be significantly different from-WASH-1139(74) Case A.

5.5 REGIONALIZATION OF NUCLEAR ELECTRIC CAPACITY

The regionalization of Case A projections of the total need for nuclear generating capacity may be developed by assuming that regional preferences for nuclear power, as expressed in completed plants through 1974 and planned additions during 1974-1984, will persist in the future albeit scaled to Case A nuclear for the nation as a whole. Estimates of the regional need for nuclear capacity under these assumptions for 1985 and the year 2000 appear in Table 5.4. They are based on regionalization of the projections of the Federal Power Commission Task Force on Forecast Review (Ref. 9) and the Water Resource Council (Ref. 12). A detailed explanation of the calculations and the derivation of the results is given in Section 6, Part V.

TABLE 5.4

COMPARISON BETWEEN REGIONAL NUCLEAR CAPACITIES
DERIVED FROM FEDERAL POWER COMMISSION AND WATER RESOURCES COUNCIL
SHARES OF TOTAL CAPACITY

Region	1985		2000		Growth 1985-2000	
	FPC	WRC	FPC	WRC	FPC	WRC
ECAR	28	28	91	93	63	65
ERCOT	10	10	41	39	31	29
MAAC	27	27	83	91	56	64
MAIN	17	17	71	68	54	51
MARCA	10	10	32	29	22	19
NPCC	28	28	70	99	42	71
SERC	70	70	294	251	224	181
SPP	14	14	76	64	62	50
WSCC	27	27	92	116	65	89
Total	231	231	850	850	619	619

Note: National total electric and total nuclear electr : capacities from WASH-1139(74) Case 4.

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SECTION 6

POWER PLANT SITING PRACTICES AND PROBLEMS - GENERAL

6.1 INTRODUCTION

A society as technologically oriented and demographically crowded in some of its areas as the United States cannot exist without energy--much of it in the form of electricity--to drive its machinery and provide mobility. There is general expectation that the demand for electricity will continue to grow as time goes on, though there can be debate--and there is--on what the rate of that growth should and will be. However, the need is inescapable for additional plants in which this incremental electricity can be generated.

The purpose of this section is to identify on an introductory basis the resources, issues, and conditions that must be recognized in providing sites for these incremental generating facilities. The claim for generating sites, which continuously trend toward larger sizes, intrudes on an increasingly crowded environment. As the size of the facilities increases, with the welcome expectation of economy-of-scale advantages, the impacts on the environment also tend to increase, with the likelihood of undesirable consequences. This comes at a time in history when society's very timely and proper concern for protection of environmental amenities is at a high level.

This also comes at a time when, for all practical purposes, two of our Nation's favorite and more favorable fuels for generation of electricity, oil and natural gas, can no longer play a significant role for this purpose. There is mounting pressure to use what is left of these fuels for more valuable purposes. Furthermore, there are only a small number of hydroelectric sites that remain to be developed. Thus, there remains only coal and nuclear fuel from which the required additional electrical energy can be obtained. It follows then, in exploring the issues involved in the selection of sites for electricity generating facilities, that attention will be focussed on sites that will accommodate either coal or nuclear generating units.

Many factors are involved in the choosing of a site for a power plant or station. In focusing on features that would best accommodate a typical electricity plant or even the bare minimum that would permit such a facility, a large number and wide variety of issues must be considered. There is considerable comparability in requirements as to accommodations for coal and for nuclear station sites, but also a number of differences. The more important differences will be separately discussed in Section 7 of this Part. All references to specific generating units, unless otherwise specified, is for a 1200-MWe coal fired plant or for a 1200-MWe light water reactor (LWR), approximately the largest sizes in service or expected to go into service. Also, to the present time, most generating stations consist of only one or two generating units though the trend, influenced by the increasing difficulty of obtaining and developing sites, is toward multiple unit stations.

Whereas the following discussion is of an introductory nature, the reader is referred to a number of pertinent documents that give the history and current status of power plant siting practices and problems (Refs. 1-10). Other directly related material is provided in Section 7.

6.2 GENERAL ORIENTATION: HISTORICAL PERSPECTIVES

6.2.1 Dominant Role of Utilities in Site Selection

Traditionally, from the beginning of commercial electricity and continuing to the present, the electric utility companies play a dominant role in the selection of sites for power stations. Being by nature essentially a monopoly in their respective service areas, utilities have traditionally been regulated by State's Utility Commission and the Federal Power Commission as to consumer rates, etc., but have had relatively broad latitudes in choosing sites for the power plants in management and operation of plants and in distributing electricity.

Power plants, at least in earlier times, were always on waterways--and preferably still are. Hydroelectric power was the first energy source. Then followed wood and the fossil fuels (coal, oil and gas)--in the thermal steam cycle, all of which still required cooling water. Finally there is nuclear, where for the present LWR reactors there is need for even more cooling water.

From the 1930s to the 1960s, there was a great spread of electricity generating plants. Utilities became a dominant industry with a large visability in towns and cities and rural areas. As good power plant sites became harder to find and more costly, and as citizens began to oppose the location of power plants, certain utility siting practices in behalf of economy resulted in considerable public resentment and hostility. A company, in order to purchase at low prices, would secretly locate a site, purchase it, and then present it to the community as an established fact. Concomitantly, there was a very large and long-term growth of public concern for the impact on the environment from the large scale industrialization of the nation. The utilities, particularly in the use of coal and in discharge of cooling water into rivers and streams, contributed significantly to this overall environmental impact. This concern has persisted well into the early nuclear power plant era.

6.2.2 Early Regulation

Because of the prevalent choice of electricity generating plant sites on waterways, the U.S. Corps of Engineers was given certain Federal regulatory authority over the construction of power plants by utilities. These controls related primarily to dikes, dams, and other impediments that would interfere with other uses of navigable waterways. Individual States also exercised regulatory control, including limitation in some cases on the extent of temperature rise and various other environmental requirements. However, until after the passage of National Environmental Policy Act of 1969 (P.L. 91-190), there was no uniform or extensive environmental controls existing on fossil fueled power plants, and there is still substantially less extensive regulation of private utility owned fossil fired plants in comparison with those applicable to nuclear plants.

6.2.3 Early Atomic Energy Commission (AEC) Regulatory Controls on Nuclear Power Plants

Because of the well recognized radiological risks inherent in nuclear power plants, a rigorous regulatory control in behalf of siting requirements, engineering design, and safety systems have been practiced from the beginning. Among other provisions, criteria were established on the physical characteristics of site for advance guidance of prospective applicants for licenses.

Public hearings were also established at the construction permit and operating license stages prior to the issuance of these respective authorizations. At earlier stages of nuclear authorizations these hearings were at times used more as an opportune forum for expressing public concern for environmental protection in general than for opposition to nuclear plants per se, though significant opposition has later developed on certain issues. (A more detailed discussion of the current Nuclear Regulatory Commission's role in siting is presented in Section 7.)

6.2.4 The Landmark National Environmental Policy Act

Passage of the National Environmental Policy Act (NEPA) of 1969 imposed through its requirements a more extensive and uniform emphasis on all types of power plant facilities, among others, for attention to environmental amenities. The Act is invoked only when Federal agencies are involved in major action roles affecting the quality of the human environment, or when Federal lands are involved, etc. An important aspect is the requirement for consideration of alternatives to the proposed Federal action. Its provisions are not mandatory per se where non-Federal actions are at issue.

The provisions of this Act has had a profound effect on the detailed examination that must be given to many aspects and consequence of power plant operations and in turn on the physical characteristics and design features of facilities subject to the requirements. The demand of environmental impact statements required by NEPA assures that due consideration of the environment will be accommodated as the choice of site and design features are developed.

NEPA was followed by the Clean Air Act in 1970, the Federal Water Pollution Control Act Amendments of 1972, and the Safe Drinking Water Act in 1973. These Acts, under the Environmental Protection Agency (EPA) implementing authority, are broadly applicable to all types of power plants.

These several successive environmental protection acts, in response to the national concern for reducing the harmful impacts on the environment, have greatly altered the procedures, the factors that must be taken into account, the criteria that must be observed, and regulatory surveillance that must accompany choice of site location, design, construction, and operation of electricity generating plants. The discussion of factors affecting the siting of electricity generating plants will reflect the impact of these environmental protection acts.

6.3 GENERAL CONSIDERATIONS OF POWER PLANT LOCATION

It is obvious that power plants should be located as close to their services area as possible. However, for a variety of reasons compromise for much more remote sites may be necessary. There is increasing public opposition to nearby industrial facilities; the size of the sites are becoming much larger, and more expensive when not remote. As the sizes of generators, boilers, condensers, and associated equipment have enlarged, the problem of site location have increased. A certain amount of opposition may be expected at almost any site because people do not want to be displaced and prefer industrial projects "in somebody elses back yard"! Any adverse environmental effects or a perceived adverse effect associated with the plant can sharply increase the scope of opposition. Land acquisition costs may tend to make the plant site more remote. There is likely competition from other industries for any good sites--especially waterfront sites. The ultimate in remoteness of sites is realized when for example a coal plant is located at the mine mouth and electricity is transmitted all the way to the service area.

In a number of States, the State itself is assuming a larger role in the determination of power plant location; in Maryland, the State may purchase a site and control the selection location of sequential construction. Other States are in various stages of organizing and implementing power plant siting procedures.

Further, some States require the utilities to publish annually each utility's projection of anticipated power needs for 10 future years. Such projections are also required of each Regional Electric Reliability Council. The open availability of such information may serve to ease the problems of power plant siting as constituents become better informed of needs. The general trend toward openness and candor in the common concern for needed energy should in general permit more meaningful public consideration of proposed sites.

6.4 GENERAL PHYSICAL PREREQUISITES OF SITE

6.4.1 Foundations

An important factor in choosing a site for fossil and nuclear generating units is a thorough examination to assure the presence of sound and sufficient geological conditions relative to the heavy structures to be placed thereon. This examination should extend to the nearby region and to historical records to determine whether or not there is evidence of earthquake faulting. For nuclear sites, active faulting in the plant site itself would not be acceptable. If there is faulting nearby, the distance of the site from the nearest fault, historical magnitude of earthquakes and other factors would determine the protective design criteria to be applied in the design of the plant.

6.4.2 Hydrology

Flooding: The power plant should have ample elevation or protective arrangements such as levees to escape flooding from any inundations that might be anticipated by past records. Cognizance should be taken of any upstream dams that could fail.

Security of water supply: The cooling water source for all thermal steam cycle plants should be ample even during the lowest anticipated fluctuations in flow. A nuclear plant, after initial operation, requires continued water flow--at lower rates--to remove decay heat when the plant is shut down.

Quality of water: Temperature ranges, mineral content, and other factors must be carefully assessed to determine the most appropriate cooling systems.

6.5 METEOROLOGY AND AIR POLLUTION

A careful assessment of the meteorology of a site area, by current observation and historical records, is important to numerous important issues. Directional wind and weather patterns are significant factors in relation to release of air pollutants, to drift directions of spray from cooling towers, and to possible radioactive releases from plants.

The prevalence and direction of hurricanes, tornados, ice storms, sand storms, and other meteorological phenomena have significant implications for various design features. Hence an assessment of current and historical meteorology is a good point of departure for the projection of possible meteorological alteration of local weather patterns due to the subsequent plant operations.

Nuclear Stations: The operation of nuclear generating stations is accompanied by the release of very small amounts of radioactive materials from the radioactive waste handling system within the permissible range and under carefully controlled conditions. Normal radioactive releases and permissible doses to individuals under the "as low as is reasonably achievable" concept are spelled out in NRC's regulations (10 CFR 50, Appendix I). Generally speaking, these regulations specify that the annual total body dose to any individual per reactor in an unrestricted area should not exceed 3 mrem from liquid effluents and 5 mrem from gaseous effluents (10 mrem and 15 mrem organ doses, respectively). The radioactive release design objectives for NECs have not yet been determined.

Coal Fired Plants: The combustion of coal unavoidably produces noxious effluents which may produce environmental consequences and possible hazards to health. The principal ones listed below together with the recently published EPA standards as an implementation of the Clean Air Act.

Sulfur dioxide (SO_2)	1.2 pounds (max. 2-hr average) per 10^6 Btu heat input
Particulates	0.2 pounds (max. 2-hr average) per 10^6 Btu heat input
Nitrogen oxides	0.7 pounds (max. 2-hr average) per 10^6 Btu heat input

Small amounts of radioactivity are also released to the atmosphere. Considerable efforts are underway to develop improved technology for additional controls on the effluents from coal plants to the atmosphere.

6.6 FUEL SUPPLY

For coal fired plants: Availability of an adequate and assured supply of competitively priced fuel is of vital importance. The method of delivery should be assured. Coal fired plants are often located so that more than one field can be considered a source of fuel.

For nuclear power plants: Some of the same principles would apply in this case as in coal fired plants. The infrequent delivery of fuel to a nuclear plant is of minor concern. A much larger concern in this case is the question of where and when the spent fuel supply can be reprocessed, the ultimate disposal of the radioactive residues, and the associated costs. Policies in these areas are in development.

6.7 ACCESS TO TRANSPORTATION FACILITIES

Coal Fired Stations: A continuous daily supply of coal is vital to a coal plant. Huge inventories are stored on the site, but daily burnup is also large. Therefore, a reliable routine supply is necessary. Prevalent supply methods of conveyance are discussed below.

The principal area of concern for the industry will be the movement of these tens of thousands of tons of coal from the mines to new coal burning power plants. This would pertain especially to the Rocky Mountain region, where there are abundant reserves of low sulfur coals. There are three methods that could be utilized to move this energy source to electric load centers. One would be the construction of mine-mouth power plants in the Rocky Mountain region and the transmission of electricity by wire to load centers. Although some power plants, up to 1,500 MWe each, are being constructed in this region, the limited supplies of water could restrict any future large scale developments. A second would be the movement of coal as a slurry (approximately 50% water and 50% coal) via pipe lines from the Rocky Mountain region to power plants constructed near electrical load centers. One such system, Black Mesa-Mohave Coal-Pipeline, is being successfully operated in the United States. This system moves the coal requirements of a 1500-MWe power plant a distance of 275 miles through an 18-inch pipeline. Four other slurry pipelines are currently being planned in the United States ranging in volume from 9 to 25 million tons per year and in length from 180 to 1,036 miles. Some of these plants are also being faced with the problem of an adequate supply of water in the semi-arid region of the Rocky Mountains where most of the deposits of coal are located. One proposed solution to this problem, although expensive, would be a double pipeline to recirculate the water. Also, securing rights-of-way for pipelines in some areas has become a problem. Federal legislation has been proposed to give slurry coal pipelines the right of eminent domain in securing rights of-way which, if enacted, would be a help in resolving this problem. The volume of coal to be moved by this method would at the present also appear to be limited. The third method, and the one which would probably move the bulk of these coal deposits, would be by rail utilizing the unit train concept. Such unit trains have around one hundred 100-ton cars or about 10,000 tons of coal per train. Turn around time for either loading or unloading is in the order of two to four hours.

The maximum volumes of coal the rail industry can move from a region will depend on a number of factors including the location of new coal burning power plants, location and number of mines, and the expansion and reinforcing of railroad lines. If one assumes, for example, that 500,000 MWe of coal generating capacity were added by the year 2000 (probably a low estimate), and half of the coal required was supplied from the Rocky Mountain region via railroad unit trains, around 225-unit trains would need to load and leave the coal mines in this region each day, or one train approximately every seven minutes. Thus, more than 20 mines with each having the capability of loading 10 unit trains a day (100,000 tons/day) would be required.

Access to transport is also necessary during the construction period of the plant for the delivery of the transformers, generators and other heavy components. Railroad, truck and barge--some or all are used in transporting and assembling a fossil plant.

Nuclear Stations: The most demanding transportation needs of the nuclear generating station are:

- Transport, delivery and assembly of the heavy components of the plant itself; the pressure vessels weighing as much as 500 tons, the transformers, turbines, generators, and other components. Not only is transport to the site a major item, but assembly and transport on site is also a matter of major engineering attention.
- Rail haul of the spent fuel casks is also an important requirement. These massive casks, with shielding to absorb the radioactive decay radiation, may weigh as much as 200,000 pounds.
- Delivery of the infrequent fuel elements is a minor problem.

In summary, however, while transportation access for nuclear plants is important, transportation costs are not a major siting consideration.

6.8 TRANSMISSION OF ELECTRICITY

There is no practical way, other than pumped storage, to store electricity in the quantities required for general household, commercial, and industrial use; it must be used essentially as it is generated, and the consumer must be connected to the generating source by an electrical conduit. Delivery of electricity is by copper or other metallic cable which must be rigorously isolated from contacts with electric pathways to ground.

A number of factors dictate a necessity for the transmission lines to be as short as possible:

- The conduit cable is expensive.
- The cable normally is suspended on tall towers for isolation. These also are expensive. In some high density areas there is aesthetic demand for underground cables--which is even more expensive and is currently practiced only in densely populated areas.
- The conduit and towers are on right-of-way land of widths up to 200 or more feet. The total investment in rights-of-way is normally a significant item in relation to the total cost of the project.

- A small percentage of the electricity being transmitted is lost by cable resistance, electromagnetic effects, etc. Thus the longer the transmission distance, the larger the loss of electricity.

- Very long lines tend to have stability problems, may be less reliable, and are more difficult to protect from terrorist or sabotage.

The line losses are reduced if electricity is transmitted at higher voltages. Transmission voltages have periodically escalated as technology and equipment permitted: 10 kV (thousand volts) in 1880; 138 kV in 1920; 287 kV in 1940; 500 kV in 1970.

Some electricity is now being transmitted at 765 kV, and this may become prevalent for longer transmission distances. As a penalty, the right-of-way must be wider and at these and higher voltages, and the public may need to be excluded from access to the right-of-way because of possible health effects from the electrical perturbations in the immediate vicinity.

Encouraging results are being obtained from transmission as direct current rather than the prevalent alternating current. Line losses are significantly less; but, since the electricity is generated as alternating current and undoubtedly will continue to be used as alternating, transmission as direct current requires two transformations, one into d.c. for transmission, the other back to a.c. for consumer use. Each of these exact a large capital cost and a penalty loss of power--hence d.c. is not used except for very long distance transmission. Exploration is also being made of transmission by cryogenically cooled (very low temperature) cables in which resistance losses are minimized. Thus, many factors relating to transmission must be considered in selecting a site and in considering how the electricity can be most economically distributed in each particular situation.

6.9 THE NEED FOR WATER: CONSEQUENCES OF HEAT DISSIPATION

6.9.1 Dissipation of Waste Heat

All systems for conversion of thermal energy into electricity by the familiar steam pressure-turbine-generator system works on the same basic principles and uses similar equipment, whether the fuel is wood, coal, oil, gas or uranium. Heat is generated in a "combustion chamber," or "pressure vessel" for a nuclear reactor; a fluid--water for coal plants and for LWRs, but it may be other "working fluids"--heated. A high temperature is generated and this steam, directed through a turbine, drives a rotating generator which produces electricity. The steam, after being cooled from passage through the turbine, is condensed back to water and is continuously recycled through the system.

The continuously circulating water, which is alternately heated to very high pressures and then cooled again, must meet most exacting specifications of purity and chemical characteristics; even minor impurities or alteration of chemistry could ruin the turbine and other components. On the other hand, the cooling water on the other side of the condenser can be of almost any quality, just so long as it absorbs the heat through the condenser tubes. Raw water directly from streams or ponds, sewage treatment plants, or other sources can be used.

If circumstances permit, the simplest heat dissipation system is water pumped from some natural source, through large pipes screened to exclude debris, to and through the condenser (where it picks up heat through the condenser tubes that keep it separated from the reactor water), and back to the source from which it was taken. This is at a point somewhat downstream. In its passage through the condenser this water is heated up by a few degrees, depending on what can be tolerated environmentally. If only small temperature increases can be tolerated environmentally, larger volumes of water must be used. The total volume of this "once-through" cooling system is very large. The flow is on the order of a billion gallons per day and more in some cases for a 1200-MWe LWR station. If only small temperature increases can be tolerated and sufficient cooling water flow is not available or would be environmentally unacceptable, then some other form of cooling system (other than "once-through") is required.

6.9.2 Relative Efficiency of Fossil and Nuclear Plants

A nuclear generating station requires about 50% more condenser cooling water than that for a coal fired station of comparable size of current design. The overall efficiency of a current mode coal generating plant is about 38%, and some of the waste heat goes directly to the atmosphere in the stack. For nuclear generating, the efficiency is 31% to 34%. Thus, reactors must transfer to the environment more heat per MWe of electricity produced, and all of the waste heat comes from the condenser. These factors are very important in choosing sites, and methods of heat removal.

6.9.3 Cumulative Thermal Impact on Streams; Consequences

Prior to passage of the NEPA, it was not uncommon for once-through cooling water to be returned to a stream 10, 20, or more degrees warmer than ambient temperatures. The consequences that this has on aquatic life depends on many complex parameters--the size of the steam, the flow velocity, and many others. Eventually the waste heat transferred to the river goes to the atmosphere, i.e., at some distance downstream, all of the heat will have been transferred to air by evaporation or radiation.

In the meantime, however, major disruptions and displacements of the native aquatic life may occur. Some species may vanish and others take their places, spawning beds may be disturbed, the body of heated water may constitute a block to up or downstream migration, and extensive secondary and tertiary effects may result--some adverse, some beneficial.

As an aftermath of NEPA, the Federal Water Pollution Control Act Amendments of 1972, and the follow-on environmental protection legislation, the utilization of most once-through cooling in large power plants is likely to phase out in preference to other alternate cooling systems, except for stations located on large bodies of water.

6.9.4 Other Methods of Heat Dissipation

In all the alternate cooling systems, the internal working fluid system remains in principle exactly the same: the thermal process (combustion or fission) heats the recycled water to high temperatures and pressure; the steam drives the turbine, expending most of its energy, which drives the electricity generator; and the low pressure steam is then condensed in the condenser and recirculated to the combustion or fission area to be reheated again. What is different is the mechanism of removing the waste heat from the cooling water leaving the condenser. Once-through cooling carries the heat into the natural body of water: other types carry it more directly to the atmosphere onsite, through some type of air or water heat transfer mechanism.

Evaporative Natural Draft Cooling Towers: In this cooling system the hot water from the condenser is piped to a large "chimney" or tower of parabolic shape. This tower may be a couple of hundred feet wide at the bottom and several hundred feet tall. The hot water is sprayed into this tower, and the rising heated air pulls outside air in from the bottom (natural draft). Heat is transferred from the hot air primarily by evaporation of the water, but also by direct heat transfer. Thus, some of the heat is not released immediately to the atmosphere, but is released sometime later (offsite) as the water vapor condenses through contact with the environment.

As mentioned, much of the water sprayed into the tower is evaporated and is carried into the air through the tower. Each evaporated droplet leaves its residue of impurities, particles, dissolved salts, minerals, etc. Therefore the reservoir of cooling water is diminished by the evaporated droplets that do not fall back into this reservoir. Also, there is a gradual buildup of impurities in the reservoir. In consequence, the reservoir must be continually replenished in proportion to the water evaporated. Also, a certain additional portion of the reservoir must be continually bled off and discharged to keep the impurities in the reservoir sufficiently low so that pumps and spray nozzles do not become inoperative. This purposefully bled-off portion is called blowdown.

Another phenomenon associated with evaporative cooling towers is called "drift." Tiny droplets of liquid spray are carried by air currents into the atmosphere, where they fall to earth. Any impurities carried within the droplet are deposited--insignificant when counted one by one, but in the cumulative total over a year a considerable amount of salts and mineral impurities could be deposited on surrounding areas, in the direction of prevailing winds. However, extensive study is being given to this problem and the state of the art in drift eliminators is being improved.

Two other phenomena associated with heat dissipation through cooling towers are important to consideration of site selection for generating stations:

- The quantity of moisture injected into the atmosphere is sufficient to cause alteration in meteorological phenomena in local and at times extended areas: increased fogging, cloud planes, snow, and humidity.

- The amount of heat may enhance the prevalence or severity of such climatic events as storms, and possibly tornados in local areas, depending on the basic climatic circumstances.

Other Types of Cooling Alternatives:

- A mechanical-draft wet cooling tower is basically similar to a natural-draft system, with the addition of fans to expedite the upward natural draft of the tower. The consequence would be generally similar, though not in detail. They are shorter in height, since they do not require the buoyancy effect of the heated air to draw a draft.

- Dry cooling towers function as do the radiators of autos. The hot liquid circulates in finned tubes located in the natural or mechanically assisted convective draft in a tall stack. This has less efficiency than that of the evaporative principle in spray system (thus requiring larger towers), but has a major advantage in eliminating the water requirement siting constraint; also, the moisture injection into the atmosphere and the drift on land areas are eliminated. However, this method of cooling costs more, is less efficient (i.e., requires more energy to operate), and is in the developmental stage for large power stations.

- There can be cooling ponds or lakes which cool by natural evaporation and radiation. These require very large land areas.

- There can be spray systems in a single or sequential series of reservoirs with vertical sprays for evaporative cooling systems without the superimposed tall cooling towers. These systems require substantial land area, however, and enhance ground fogging.

- There can be various combinations of the above systems, dry towers arrangements and others.

In selecting sites for nuclear plants the area under consideration must be carefully examined and assessed as to the most advantageous heat dissipation system for that particular area.

6.10 LAND AREAS CURRENTLY REQUIRED FOR POWER PLANT SITES

Nuclear Generating Stations: Land areas for individual nuclear generating stations range from about 200 acres to 1,000 acres or more depending on the preferences of the owner, the cooling systems utilized, and other factors. Some cooling lake arrangements cover several thousand acres or more.

It is required by Nuclear Regulatory Commission regulation that there be an "exclusion" area in which the licensee has authority to control all activities, including personnel and property, in the area. Normally no residents are in the area; but a highway, railroad, or waterway may traverse the area, provided the operator has authority to act freely within his discretion anywhere in the area in case of necessity.

There is also a second (low population) zone immediately surrounding the first, which may contain residents, the total number and density of which are so situated as to provide reasonable assurance that appropriate protective measures in their behalf could be taken in case of serious accident.

Coal Fired Stations: A modern coal plant requires about 1,200 acres of suitable land. The plant itself would require only a hundred or so acres. Some three or four hundred acres is required for the fuel inventory storage area on which the fuel would be 25 feet in depth. An area almost as large would be needed for cumulative storage of ashes--to about the same depth. Rail terminal and switchyards are necessary to accommodate the delivery of coal, as in the usual case. Some documents indicate that the public has in some cases brought pressure on the utility to improve the aesthetics of coal plants, even to the extent of providing underground location of these facilities.

6.11 OTHER FACTORS IN SITING

Among the other kinds of factors posing problems in power plant siting (common to both nuclear and coal stations) are:

- impairment of recreational values
- impairment of aesthetic values
- impairment of natural conservation values
- loss of property values
- loss of certain kinds of regional income, and
- a host of temporary stresses on community identity and cohesion or the overloading of public services and social facilities during the period of plant construction. These factors are becoming more important; and the utilities and Federal, State, and local governments are placing more weight on them.

6.12 PUBLIC ACCEPTANCE

It is anticipated that the practices, problems, and perspectives discussed above in relation to the selection of sites for nuclear and coal generating stations will extend into the foreseeable future. Also, the utilities, Government authorities at all levels, and the public will continue to seek improvement in these practices to more effectively protect the environment and to better serve the overall public interest as defined by NEPA and other laws. This cooperation is being demanded by the public. A further discussion of public acceptance is given in Section 7.

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SECTION 7

NUCLEAR FACILITIES SITING PRACTICES AND PROBLEMS

7.1 INTRODUCTION

The objective of this section is to provide an overview of past and current nuclear power-plant and facilities siting practices and problems. The perspective developed is primarily from the NRC point of view, because it is the primary Federal Agency responsible for regulating nuclear activities. The materials presented in this discussion are drawn largely from the Annual Report to Congress (1971-1974) by the Atomic Energy Commission and the 1975 Annual Report to the President and the Congress by the Nuclear Regulatory Commission.

7.2 LAW, REGULATION AND PUBLIC ATTITUDES

7.2.1 The Requirements of the Law

The Atomic Energy Act of 1954 as amended and the Energy Reorganization Act of 1974 place upon the NRC the responsibility for regulating and licensing commercial atomic energy activities, and for carrying out inspections to assure compliance with the NRC's regulations. Such activities include the possession, transportation and use of radioactive materials and the design, construction and operation of nuclear facilities. In developing the basic regulations in this field, the NRC seeks to impose no unnecessary restrictions upon the developing industry.

At the present time separate licenses are issued for construction and for operations of facilities, also for use of nuclear materials and radiation sources. Such licenses are issued only after the NRC has reasonable assurance that operations would comply with NRC regulations to assure public health and safety and protect the common defense and security. These requirements have been expanded in recent years to include protection of the environment within NRC's area of responsibility and compliance with antitrust laws.

The Calvert Cliffs Nuclear Power Plant, in Calvert County, Md., became a pivot point in 1971 for a major revision of the AEC's procedures for licensing nuclear power plants (Ref. 1 and 2). On July 23, 1971, the U.S. Court of Appeals ruled that the AEC's regulations for implementing the National Environmental Policy Act of 1969 (NEPA) in licensing proceedings did not comply in several respects with NEPA.

The court held that, under NEPA, the AEC was required to make an independent review and evaluation of all environmental effects at each relevant decision point in the nuclear power plant licensing process, whereas the AEC had earlier relied on the judgments and recommendations of other cognizant agencies in their areas of expertise. The court's decision affected AEC licensing actions on 103 nuclear power reactors then in operation, under construction, or under review in the licensing process, many of them retroactively.

The Commission decided not to appeal the decision but rather to move swiftly to implement the court's ruling. Compliance took the form of two substantive environmental review changes: (1) the environmental matters required to be fully considered by a license applicant and the AEC were enlarged to include the full range of environmental effects of the proposed plant including its effect on water quality; and (2) the addition of a cost-benefit analysis which considers and balances the environmental and other effects of the facility and the alternatives available for reducing or avoiding adverse environmental and other effects, as well as the environmental, economic, technical and other benefits of the facility. Significant changes were made in the Regulatory organization to expedite the reactor licensing functions in the area of the expanded environmental reviews resulting from the Calvert Cliffs decision.

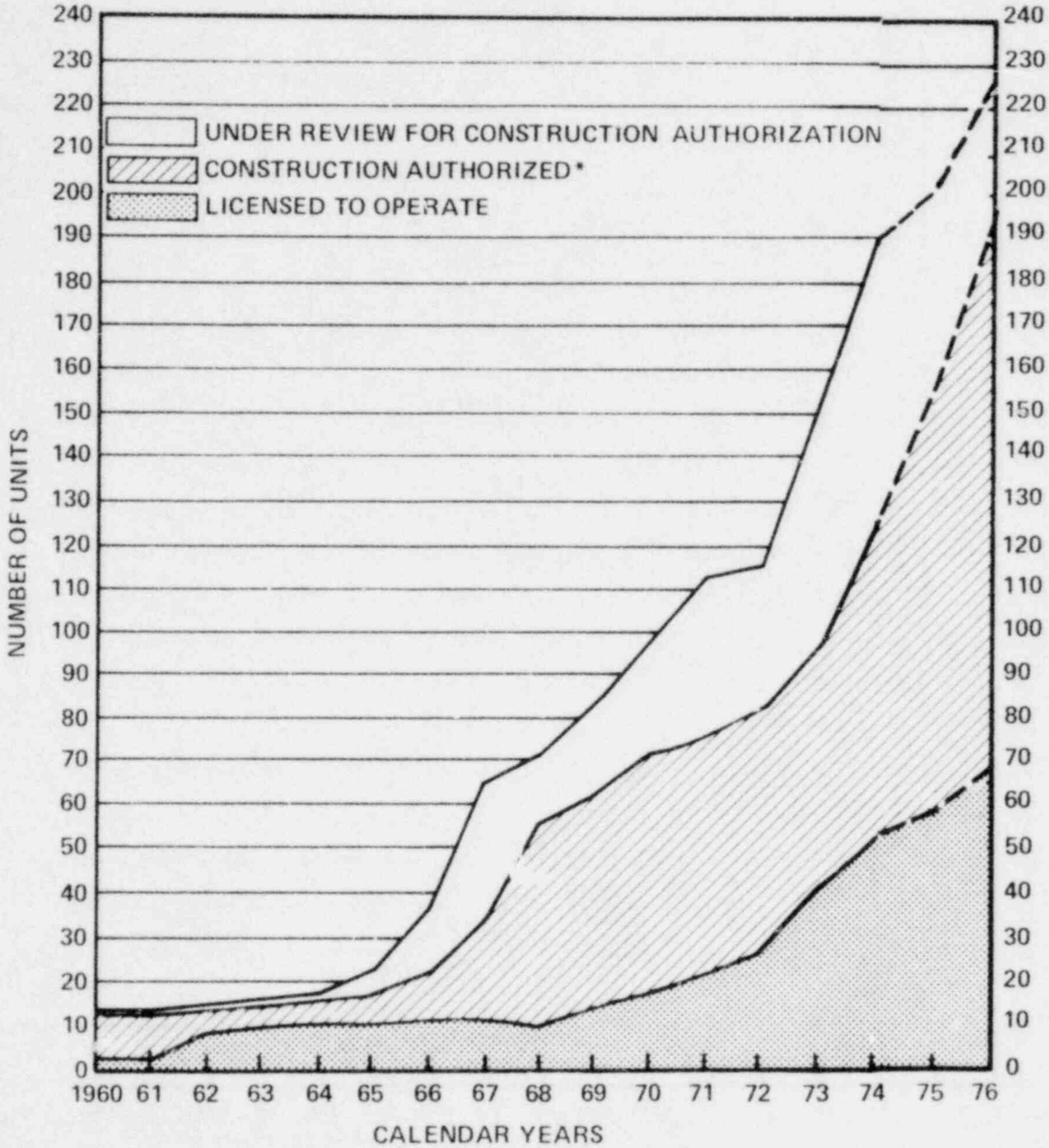
7.2.2 The Licensing Process

The licensing of power reactors and other major nuclear facilities (such as fuel reprocessing plants) involves a series of technical reviews and public hearings. A construction permit application is first reviewed by the NRC staff as to health, safety, common defense and security, and environmental quality considerations, and where appropriate, antitrust aspects. During the course of the environmental review, the staff prepares a draft environmental statement which is published for review and comment by other Federal, State and local agencies and by the interested public. Their comments are considered by NRC staff prior to publication of the final evaluation of environmental impact. ..so an independent technical safety evaluation is conducted by the Advisory Committee on Reactor Safeguards (ACRS). After these two reviews, a public hearing is conducted in the vicinity of the proposed site by an Atomic Safety and Licensing Board (ASLB). The ASLB's initial decision on issuance of the permit is subject to review by an appeal board, or by the Commission, before becoming final. Upon request for an operating license, the NRC staff and the ACRS again conduct extensive technical reviews and evaluations, and a public hearing is held if requested. The NRC's surveillance of licensed reactors continues throughout their operating lifetime. Their decommissioning is also subject to NRC regulation.

7.2.3 Regulation

The major share of nuclear regulatory effort is focused on the growing use of nuclear energy to generate electric power. A primary objective is to shorten the design-licensing-construction cycle for nuclear plants as much as possible to help attain the national goal of energy self-sufficiency, while maintaining the rigorous safety, health and environmental standards required for these facilities. Substantial progress is being made toward this objective. The number of nuclear power plants under NRC surveillance is shown in Figure 7.1. Their rated capacity is shown in Table 5.2 of Section 5 and in Figure 7.2 on a monthly basis.

Regulation of nuclear power involves not only safety evaluations and licensing decisions on reactor applications and surveillance of plant construction and operations, but also the regulation of steps in the nuclear fuel cycle from the milling of uranium ores through their chemical conversion, fabrication into fuel elements, reprocessing and transportation, to final



*Includes Limited Work Authorizations in 1974—1976

FIGURE 7.1 NUCLEAR POWER PLANTS UNDER NRC SURVEILLANCE, 1960-1976

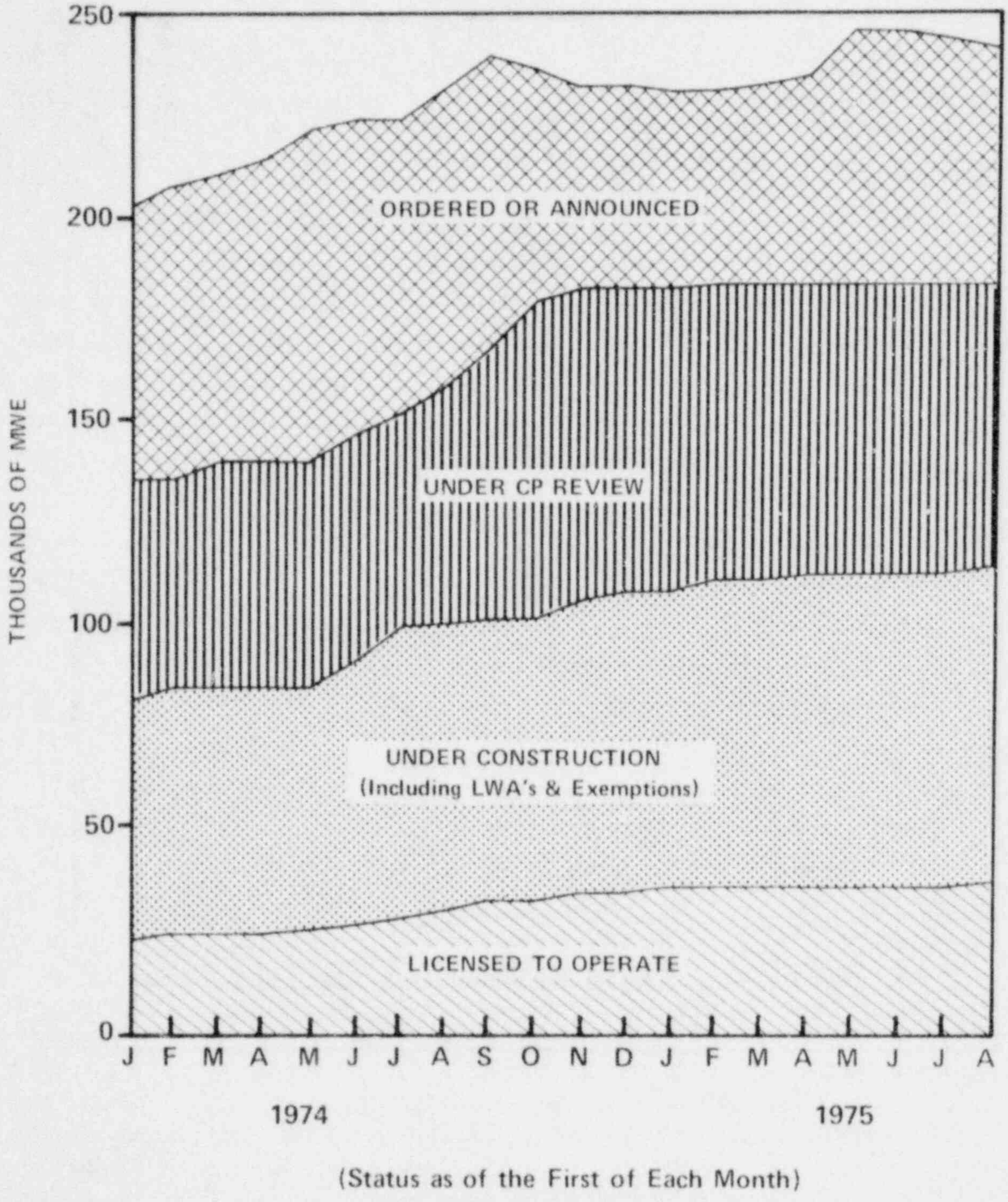


FIGURE 7.2 MONTHLY NUCLEAR POWER CAPACITY, 1974-1975

safe disposition of the radioactive wastes. The regulatory function also includes development of effective working relationships with the 50 States and with foreign governments regarding nuclear energy regulation.

These activities require broad programs of standards setting, technical safety reviews, assessment of safety research needs, environmental impact evaluations, public hearings (providing opportunity for participation of the interested public), inspection, and enforcement.

7.2.4 Bringing Nuclear Power On Line

The utility industry's reliance on nuclear power to assist resolving continuing energy supply problems, and increasing public interest concerning nuclear issues, have brought into sharper focus the challenge of making licensing decisions in a timely manner while at the same time assuring safe and reliable operation of these facilities.

More than half the steam electric generating capacity ordered in the United States since 1970 was nuclear; however, financial difficulties due to raising the necessary capital for power plants encountered during 1974 and 1975 prompted a number of utilities to defer construction of many nuclear and fossil plants and to cancel a few. The impact of these deferrals for the near term has been decreased somewhat by the slowdown in the growth of electric power demand resulting from current economic conditions and by the implementation of conservation measures. Despite continuing construction delays plaguing the industry, 14 new nuclear units were licensed to operate in 1974, adding 11,800 electrical megawatts (MWe) of capacity to the U.S. total. These units, combined with 13 licensed in 1973 and 9 licensed in 1972, brought nuclear electrical capacity to some 36,000 MWe. As of November 30, 1975, 55 nuclear power units were licensed to operate with total capacity of 37,690 MWe.

7.2.5 Limited Work Authorization

One recent step to reduce the time that the licensing process occupies the critical path of the nuclear plant cycle was the institution of limited work authorizations (LWA). Under NRC regulations, limited amounts of work may be authorized to be carried out in appropriate cases prior to a decision on the construction permit application. This authorization may be granted only after a full environmental impact review and a site suitability review have been completed by the staff. In addition, an Atomic Safety and Licensing Board must determine, after a public hearing on environmental and site suitability matters, that there is a reasonable assurance that the proposed site is a suitable location for a nuclear power reactor of the general size and type proposed.

As a result of this procedure a utility could, by also availing itself of plant standardization, expedited site selection, and improved quality assurance measures, design and bring a nuclear power plant on line in 8 years or less for plants ordered today. (See Figure 7.3). Since institution of the LWA procedure in April 1974, it has resulted in an average improvement of seven months in initiation of construction for 18 projects representing 33 nuclear units.

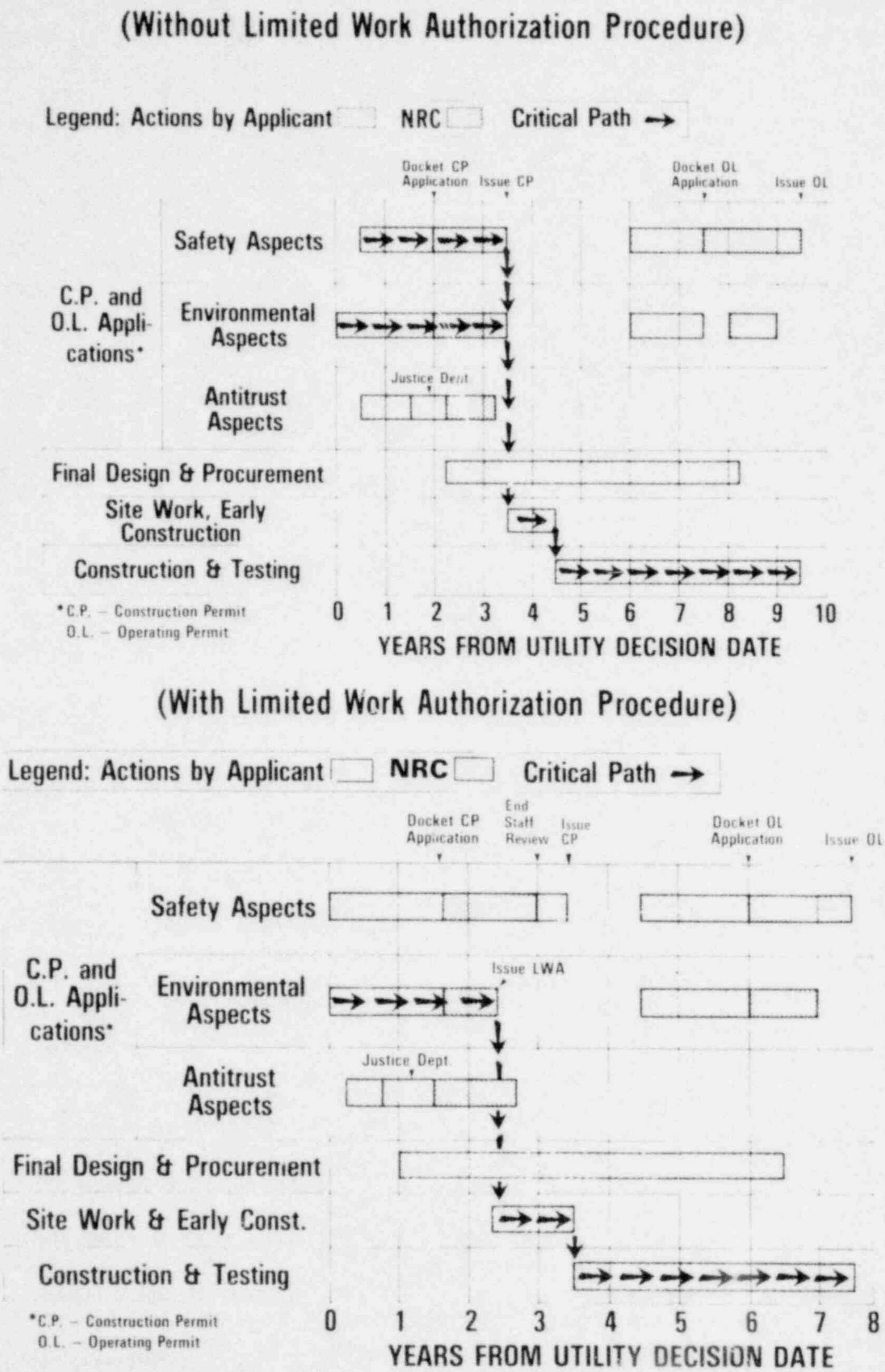


FIGURE 7.3 TIME REQUIRED FROM CONCEPTION TO OPERATION OF NUCLEAR PLANTS

7.2.6 Improvements Through Legislation

In May, 1974 the Commission forwarded to the Congress a legislative proposal to improve the licensing process for major nuclear facilities, which was introduced as S. 1717 and H.R. 7002. In hearings conducted in June by the Joint Committee on Atomic Energy, the Commission strongly supported the proposed licensing reform legislation as a measure that could lead to reduction of the time now required to bring a nuclear power plant on line from 8 or more years to about 6 years. (See Figure 7.4)

The basic concepts of early site resolution and standard plant designs are at the heart of the proposed legislation. The Commission noted it would provide a more efficient framework for siting and licensing without impairing the quality or thoroughness of the NRC's safety, common defense and security, or environmental reviews, or depriving the Commission or the public of the benefits of full public participation in the process. It would make a major contribution to attainment of more efficient, effective regulation which is essential, if nuclear power is to be a viable option in meeting the country's demand for electric energy.

Highlights of Legislation

Main features of the proposed legislation are:

1. Provision for separate and early site review for nuclear plants. Site permit applications could be filed by interested States as well as by persons proposing to construct plants. An inventory of approved sites could be developed. There would be a complete environmental review and opportunity for formal hearing before issuance of any site permit.

2. Would encourage standardization of nuclear plants by providing for combined construction permits and operating licenses, by encouraging early public participation in the resolution of plant design questions, and by avoiding duplicate hearings.

3. Public participation would be enhanced by providing for hearings on site suitability and design questions at early points in time when they can be most effective, and by providing for certain assistance to hearing participants.

7.2.7 The Impacts of Standardization

During 1975, further significant progress was made toward the goal of nuclear power plant standardization which was enunciated by the Commission in April 1972. The NRC regards standardization of plant designs, complemented by the early review of sites planned for the location of nuclear plants, as one of the most important means for improving the efficiency and effectiveness of the licensing process.

The procedural options made available to applicants by the Commission to facilitate the standardization of nuclear power plants are:

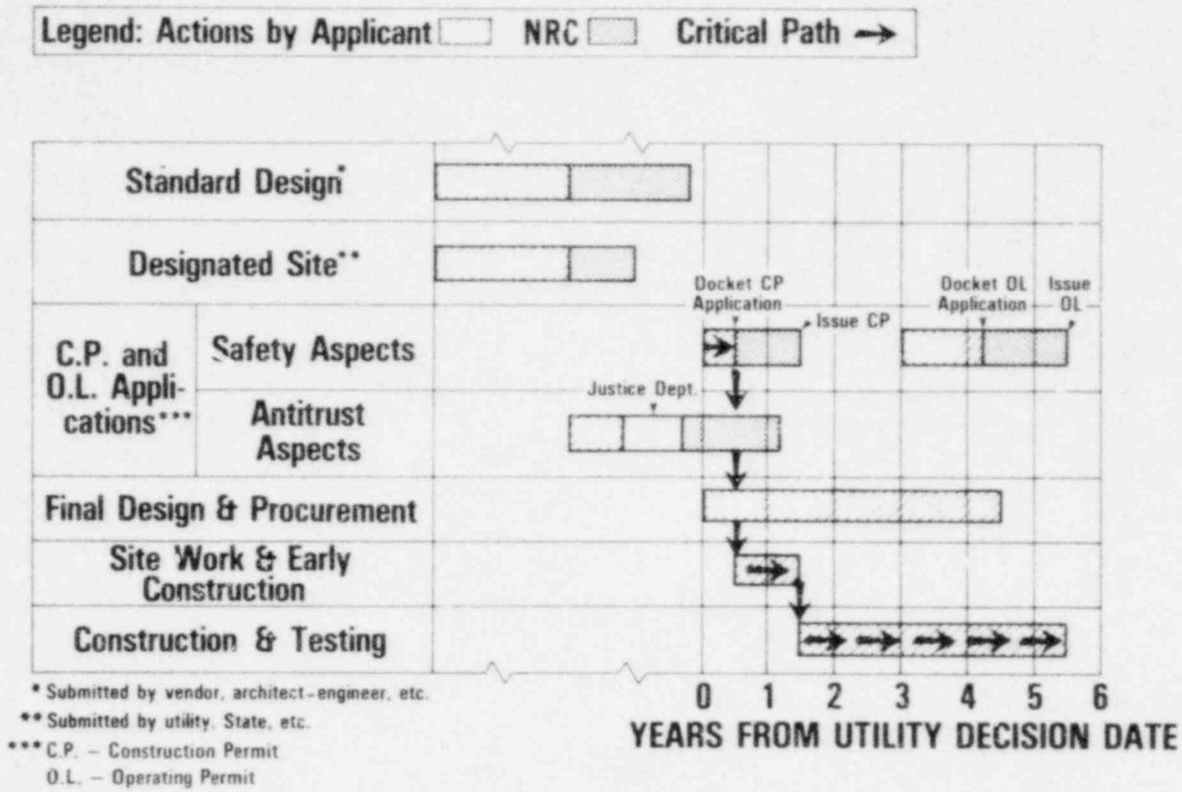


FIGURE 7.4 TIME REQUIRED FROM CONCEPTION TO OPERATION OF NUCLEAR PLANTS
(Assuming standardized plants and designated sites)

- Reference System--a generic design of an entire facility or major portion thereof can be reviewed once and utilized repeatedly by reference without further review in individual applications for licenses.

- Duplicate Plants--the design for several identical plants that would be constructed within a limited time by one or more utilities at one or more sites can be reviewed once.

- License to Manufacture--the design of an entire facility can be reviewed once for manufacture at a central location. The preapproved facilities can then be moved to specific utility sites for construction and operation. These sites must be compatible with the site parameters postulated in the plant design.

As an expansion of the duplicate plant option, a policy for "replication" was established in 1974. Replication provides for the reuse of an approved custom plant of recent design. The NRC regards replication as an interim approach to standardization until a sufficient number of reference system designs is accumulated, estimated to occur 2 to 4 years hence. Each of these standardization approaches is based on the reuse of approved plant designs. Table 7.1 indicates standardization applications under review as of November 30, 1975.

TABLE 7.1

STANDARDIZATION APPLICATIONS UNDER REVIEW
(As of November 30, 1975)

PROJECT	APPLICANT	DOCKET DATE	COMMENTS
Reference Designs			
GESSAR-238	General Electric	7-30-73	Nuclear steam supply system (NSSS) standard design and containment
CESSAR	Combustion Eng.	12-19-73	NSSS
RESAR-41	Westinghouse	3-11-74	NSSS
B-SAR-241	Babcock & Wilcox	5-14-74	NSSS (Withdrawn)
SWESSAR	Stone & Webster		Standard balance-of-plant
RESAR-41		6-28-74	(BOP) design matched to RESAR-41
CESSAR		10-21-74	BOP matched to CESSAR
RESAR-3S		a	BOP matched to RESAR-3S
B-SAR-205		a	BOP matched to B-SAR-205
BWR		a	BOP matched to BWR-NSSS
C.F. Braun SSAR	C. F. Braun	12-21-74	Turbine Island matched to GESSAR-228
GASSAR	General Atomic	2-5-75	NSSS
GESSAR-251	General Electric	2-14-75	NSSS
RESAR-3S	Westinghouse	8-1-75	NSSS
GESSAR-238 (NSSS)	General Electric	a	NSSS
B-SAR-205	Babcock & Wilcox	a	NSSS (replaces B-SAR-241)
F-P SSAR	Fluor Pioneer	a	BOP matched to RESAR-41
Utility Application Using Reference Systems			
Cherokee 1-3	Duke Power	5-24-74	References CESSAR
Perkins 1-3	Duke Power	5-24-74	References CESSAR
South Texas 1 & 2	Houston Light & Power	7-5-74	References RESAR-41
WNP-3 & 5	Washington Public Power Supply System	8-2-74	References CESSAR
Palo Verde 1-3	Arizona Public Service	10-7-74	References CESSAR

TABLE 7.1 (Cont.)

PROJECT	APPLICANT	DOCKET DATE	COMMENTS
Hartsville 1-4	Tennessee Valley Authority	11-11-74	References GESSAR-238
Black Fox 1 & 2	Public Service of Oklahoma	Tendered 8-08-75	References GESSAR-238 (NSSS)
Phipps Bend 1 & 2	Tennessee Valley Authority	Tendered 10-1-75	References GESSAR-238
Duplicate Plants			
Byron/Braidwood	Commonwealth Edison	9-20-73	Two units at each of two sites
SNUPPS	Kansas Gas & Electric		Five units at four sites
Wolf Creek	Kansas City Power & Light	6-21-74	
Callaway 1 & 2	Union Electric	6-21-74	
Tyrone 1	Northern States Power	6-21-74	
Sterling	Rochester Gas & Electric	6-21-74	
WUPS	Wisconsin Electric Power		As many as six units on three sites
Koshkonong 1 & 2	Madison Gas & Electric Wisconsin Power & Light Wisconsin Public Service	8-09-74	
License to Manufacture			
Floating Nuclear Plant (FNP) 1-8	Offshore Power Systems	7-05-73	Entire plant design
Utility Applications Using License to Manufacture			
Atlantic 1 & 2	Public Service Electric & Gas	3-01-74	Reference FNP
Replication			
Jamesport 1 & 2	Long Island	9-06-74	Replicates Millstone 3
Marble Hill 1 & 2	Public Service of Indiana	9-17-75	Replicates Byron/Braidwood
UEA 1 & 2	Alabama Power	a	
NEP 1 & 2	New England	a	

[a]Future application

7.2.8 Public Participation in Regulation

As a result of policies and procedures adopted over the years, particularly during the last five years, a regulatory process has been developed in which determined efforts are made to involve the public from a conviction that public participation and understanding are necessary for the effective regulation of nuclear energy.

Pursuant to these policies, virtually all safety information possessed by the NRC staff is publicly available, either in public document rooms or on request. This availability has been extended to many internal memoranda and draft documents which could have been withheld from public disclosure under Freedom of Information Act provisions.

Information about each licensing case is deposited in public document rooms in Washington, D.C., and in communities near the sites of the facilities. With respect to individual licensing cases the information includes the complete, multivolumed license applications and amendments thereto; NRC staff correspondence with the applicant, staff memoranda and reports; records of meetings of the Advisory Committee on Reactor Safeguards and of ACRS reports relating to each case; correspondence with interested members of the public or public organizations, and transcripts of public hearings. Also released are written documents prepared by the staff, NRC contractors, reactor manufacturers, and others relating on a generic basis to reactor safety and other topics important in nuclear energy regulation.

After a nuclear plant is licensed to operate, every interruption in power generation and every malfunction or incident which has safety significance is announced promptly by the NRC. Such announcements are made regardless of whether the licensee issues a similar announcement.

For certain categories of proprietary data (i.e., information considered by its originators to have competitive commercial value), it is not possible to make all information public. The AEC published in November 1974 proposed changes to its regulations which would sharply restrict the circumstances under which information claimed as proprietary may be withheld from the public.

In some instances involving national security matters, it is not possible to make all information public. These instances usually deal with government owned installations or activities that have national defense or security involvement.

Along with the availability of information, there is opportunity for interested members of the public to make their views known through participation in the regulatory process, beginning with the earliest stages of the application review. This includes opportunities to meet informally with the NRC staff, to participate in public hearings held on each case, and to attend meetings of the Advisory Committee on Reactor Safeguards. To facilitate public participation, licensing hearings are normally held in communities near to reactor sites. In addition, the Commission has made it a practice to conduct public rulemaking hearings to deal with broad safety and environmental issues on a generic basis. These, too, are open to public participation.

In licensing and certain other Regulatory activities, the public can make itself heard before the independent Atomic Safety and Licensing Boards. The Boards' decisions are subject to further review by Appeal Boards and possibly the Commissioners themselves. Ultimately, of course, recourse through the courts is available for judicial review of NRC decisions.

7.2.8.1 Atomic Safety and Licensing Boards

Public participation in the licensing of nuclear facilities is part of proceedings conducted by three-member Atomic Safety and Licensing Boards (ASLBs). It is in these proceedings that the public may place its concerns and beliefs on the record for consideration by an independent tribunal of experts.

Boards are drawn from an Atomic Safety and Licensing Board Panel made up of lawyers, nuclear physicists and engineers, environmentalists, and economists. Appointments to the Panel are made by the Commission. The selection criteria emphasize independence, experience and recognized achievement in the individual's field of endeavor. Assignments of Panel members to serve on an individual hearing board are based on the issues expected to be tried before that board.

ASLBs are required to conduct hearings on all construction permit applications and imited work authorizations. The boards hold hearings on operating license applications and certain other matters when such hearings are demanded by interested persons.

Hearings before ASLBs consumed 222 days in 1974, 194 of which were held in the vicinity of the plant site. During the first six months of calendar year 1975 there were 192 days of hearing. The hearing procedure facilitates participation as parties by interested local citizens and organizations, as well as permitting the local public to express its views through the means of limited appearances, and to attend the hearings.

7.2.8.2 Atomic Safety and Licensing Appeal Boards

Under Commission regulations Atomic Safety and Licensing Appeal Boards are authorized to exercise the authority and perform the review functions which would otherwise have been exercised and performed by the Commission in facility licensing proceedings. The Atomic Safety and Licensing Appeal Boards for individual proceedings are selected. Such selection is made by the permanent chairman of the Panel or, in his absence, the permanent vice-chairman.

7.2.8.3 Commission Review Activities

The Commission participates actively in the licensing review process, issuing a number of memoranda and orders directly affecting individual proceedings. Energy conservation strategies and, as a consequence, electric power forecasts are important considerations in siting. In 1973, the Commission, noting that it shared the deep national concern over energy sources and supply, instructed the Licensing Board in the proceeding concerning Nine Mile Point Unit No. 2 (New York), to allow presentation of evidence on the contentions regarding energy conservation alternatives framed by intervenors.

7.3 GENERAL SITING GUIDANCE

The development of siting guides for nuclear facilities is important to shortening the licensing process by assuring site suitability relative to the potential impacts from these plants on the environment and on the health and welfare of man. The AEC regulation, "Reactor Siting Criteria" (10 CFR Part 100) has provided guidance since 1962 for site selection based on considerations of the safety and protection of human health and welfare. It does not however, include guidance on site selection based on considerations of potential impacts of the plant on the environment.

Regulatory Guide 4.7, General Site Suitability Criteria for Nuclear Power Stations, (September 1974) discusses the major site characteristics related to safety, public health, and environmental issues which the Regulatory staff considers in determining the suitability of sites for nuclear power stations. The guidelines are intended to be used in a screening process to identify suitable candidate sites for nuclear power stations. The decision that a plant may be built on a specific candidate site is based on a detailed safety evaluation of the proposed site-plant combination as discussed in Subsection 7.2.2 and described further in 10 CFR Part 50, and a cost-benefit analysis comparing the proposed site with alternative site-plant combinations as discussed in Regulatory Guide 4.2, Preparation of Environmental Reports for Nuclear Power Plants, Revision 1, January 1975.

The safety issues of concern in site selection are primarily the relation of the geologic/seismic, hydrologic, and atmospheric characteristics of proposed sites and the design of the plant, particularly the capability of the plant to cope with potential site related conditions, such as earthquakes, tornadoes, floods, that might result in an unreasonable risk to the public health and safety. The size and distribution of population and the projected growth of population in an area around the plant are important factors in selecting a site. Protective measures are taken to guard the general public from the potential radiation hazards of postulated accidents, in spite of the low probability of occurrence.

The environmental issues considered in site selection relate to potential impacts of plant construction and operation on biological and ecological systems, land and water use, the atmospheric effects, aesthetics, and socioeconomics. Numerous environmental observations must be made over extended periods to obtain necessary information for site evaluation.

An extensive commitment of time and resources is required to select a site for a nuclear power station and to develop a design for that site. Site selection involves considerations of public health and safety, engineering and design, economics, institutional requirements, and environmental impacts. The potential impacts of the construction and operation of nuclear power stations on the physical and biological environment and on social, cultural, and economic features are similar for the site of any major industrial facility, but nuclear power stations are unique in the degree to which potential impacts of the environment on their safety must be considered.

More extensive discussion of the current utility siting practices and a suggested process for siting NECs in the future is presented in Section 8, Part V: Methodologies and Site Selection Considerations for Identifying and Confirming Specific Sites. Some of the major siting criteria are now discussed.

7.3.1 Population Density Criteria

As set forth in 10 CFR Part 100, a nuclear power plant site must have a low population zone (LPZ) immediately surrounding the exclusion area in which the population is sufficiently limited in number and distributed in such a way that there is a reasonable probability that appropriate measures could be taken in their behalf in the event of a serious accident. A proposed site will also have a "population center distance," defined as the distance from the nuclear reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents. The population center distance must be at least 1-1/3 times the distance to the outer boundary of the LPZ. It is required by 10 CFR Part 100 that the boundaries of the exclusion area and LPZ be sufficiently remote that a release of fission products (calculated as a consequence of a postulated major accident) will not result in radiation doses to an individual at any position on the exclusion area boundary or on the outer boundary of the LPZ greater than certain specified values. The basic purpose of these requirements is to assure that the protective measures that could be established would with considerable assurance provide protection against the potential accidents visualized. The general layout of a typical site is shown in Figure 7.5.

A reactor licensee is required by 10 CFR Part 100 to designate an exclusion area and to have authority to determine all activities within that area, including exclusion and removal of personnel and property. Usually the authority is exercised through ownership of the designated exclusion area. In some cases, such as where the designated exclusion area includes water bodies or transportation corridors which are routinely accessible to the public, the authority has to be obtained through arrangements with the local, State, Federal or other public or private agency having authority over the public accessible areas.

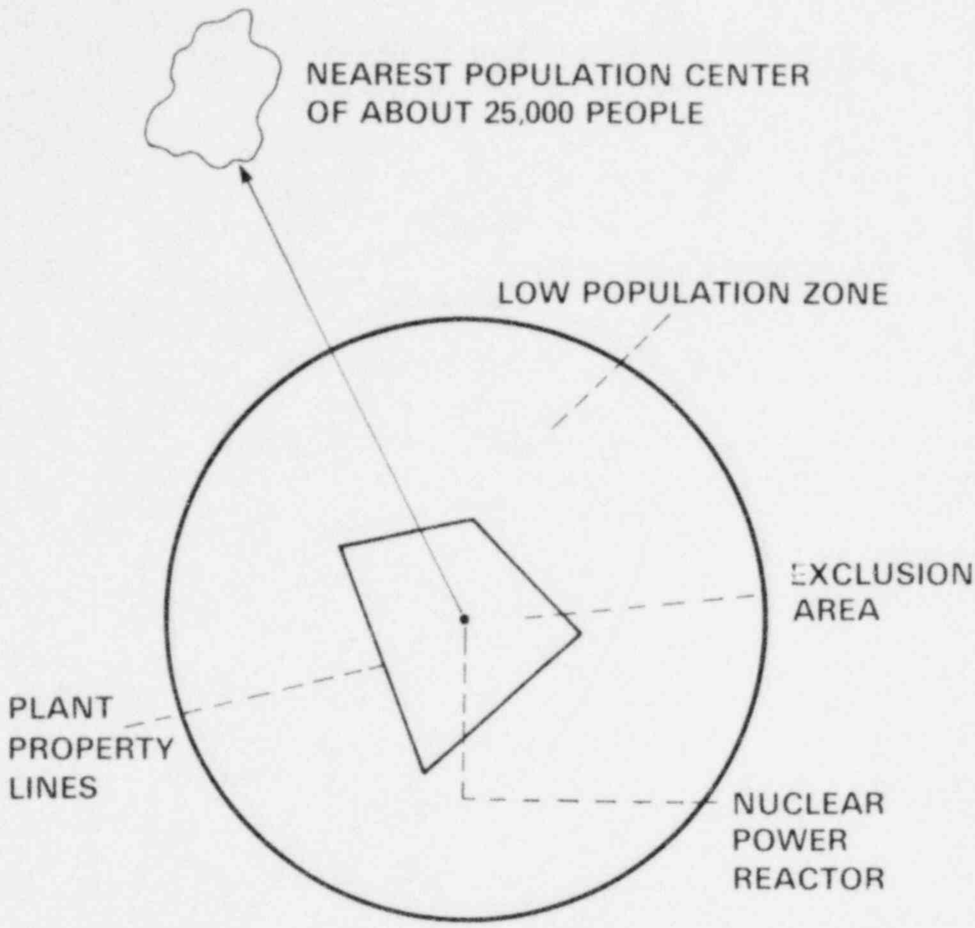
7.3.2 Seismic and Geologic Criteria

In November 1973, the AEC added to Part 100 an Appendix A, "Seismic and Geologic Criteria for Nulcear Power Plants." Adoption of these criteria culminated several years of effort in which the AEC enlisted help of the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the ACRS, and other consultants, and conducted an industry conference on the subject.

The Part 100 amendment, first proposed in November 1971, sets forth the principal seismic and geologic considerations used by the NRC to evaluate the suitability of proposed sites for nuclear power plants and the suitability of plant designs in relation to the seismic and geologic characteristics of proposed sites. The criteria reflect advances in the state-of-the-art geologic investigations achieved since late 1971 by giving more credit to three-dimensional investigations, such as those obtained from offshore geologic surveys, in determining the extent of the zone requiring detailed faulting investigations. The criteria describe the investigations required to obtain the geologic and seismic data necessary to determine site suitability and to provide reasonable assurance that the proposed nuclear power plant can be constructed and operated at a proposed site without undue likelihood that tectonic events would result in radiological risks from the nuclear installations.

Information obtained from the investigations is to be used to determine the design requirements for withstanding earthquake-produced ground motion and seismically-induced floods and water waves. This information is also to be used to determine whether, and to what extent, the nuclear power plant needs to be designed for surface faulting.

Important illustrative cases are Mendocino (California), Bodega Head (California), San Onofre (California), and North Anna (Virginia). For the first three proposed nuclear power plant



- At Boundary of Exclusion Area, No Member of Public May Exceed 25 rem Whole-Body Dose for Design Basis Accident
- Timely Evacuation of Low Population Zone Must be Planned
- Population Center Must Be at Least 1-1/3 Times Farther Away than LPZ Boundary

FIGURE 7.5 PART 100 DISTANCE REQUIREMENTS
(Typical plant)

sites, the issue was the relative proximity to the San Andreas fault. For Mendocino, the application was withdrawn. For Bodega Head, the construction permit was never issued. For the San Onofre site, NRC has laid down requirements which significantly increase the design seismic loadings for any additional plants that may be located there to 0.67g. This would significantly increase construction costs. Most plants west of the Rocky Mountains are designed to 0.3g or higher. For North Anna in Virginia, the issues were whether a fault found in the containment excavation was capable (i.e., exhibit recent movement) and the manner in which the utility reported the findings to NRC.

7.3.3 Water Quality Criteria

Cooling water discharges to waters are governed by the 1972 Amendments to the Federal Water Pollution Control Act (FWPCA, PL 92-500). It will be necessary to determine regulations current at the time particular sites are under consideration. Section 401(a)(1) of that Act requires, in part, that any applicant for an AEC construction permit for a nuclear power station provide to the AEC certification from the State that any discharge will comply with applicable effluent limitations and other water pollution control requirements. In the absence of such certification, no construction permit can be issued by the AEC, unless the requirement is waived by the State or the State fails to act within a reasonable period of time. A permit pursuant to Section 402 of that Act may be required for a nuclear power station to operate in compliance with the Act, but is not a prerequisite to an AEC license or permit.

The application of the NEPA review procedures has resulted in many plant design modifications and/or changes. Examples of plant design changes that have been made include:

1. Intake structure redesign (many plants);

2. Major cooling system redesign (e.g., Indian Point 2, Peach Bottom, Brunswick);

3. Modification of the thermal plume (e.g., Crystal River, Waterford, Dresden 2 & 3, Millstone, LaSalle, North Anna, Vermont Yankee);

4. Augmentation of radwaste systems (e.g., Cooper, San Onofre, Arkansas, Waterford, Vermont Yankee, Grand Gulf, Limerick);

5. Modification of chemical waste systems (e.g., Midland, Waterford, Point Beach, Davis-Besse, Vermont Yankee, Fermi, Trojan, Zion);

6. Rerouting of transmission lines (e.g., Midland);

7. Installation of fish screens (e.g., Surry);

8. Modification of circulation in receiving body by causeway redesign (e.g., Maine Yankee);

9. Preconstruction, preoperational, and operational environmental monitoring plans (many plants);

10. Ongoing studies of alternative cooling systems requiring adoption if monitoring of operations indicate reduction of impacts necessary (e.g., Indian Point 2, Turkey Point); and

11. Adoption of environmental monitoring techniques that reduce mortality of biota (e.g., modification of screen arrangements in intakes).

7.4 INSTITUTIONAL ASPECTS OF SITING

7.4.1 NRC-EPA Coordination

In November, 1974, the AEC issued for public comment a proposed second memorandum of understanding with the Environmental Protection Agency on carrying out each agency's responsibilities under the Federal Water Pollution Control Act amendments of 1972.

In view of some duplication of information needed in NRC and EPA licensing proceedings, the proposed memorandum provides for development of EPA regulations and procedures for issuance of "preliminary determinations" on the water quality and biota impacts of nuclear projects. These determinations would be made as far as possible in advance of NRC actions authorizing construction or operation, in contrast to the present practice of requiring such determinations when a plant is ready for operation--some six years after the start of construction. In this way, significant changes in plant design or location subsequent to NRC's environmental review, and possibly after construction has begun, could be avoided.

The proposed agreement provides for procedures to see that environmental reports submitted to the NRC with nuclear facility applications contain sufficient data to meet both NRC's and the States' need for FWPCA review purposes and the NRC's needs for evaluating the potential environmental impacts. It also provides for consideration of holding combined or concurrent hearings on EPA's preliminary determinations and NRC's construction permits; close contact between the agencies in environmental reviews; and cooperation with State and regional authorities to assure timely issuance of required water quality certifications under Section 401 of FWPCA and discharge permits under Section 402. The proposed agreement is still under negotiation and has not been finalized.

7.4.2 NRC-Justice Department Coordination

The NRC is required by the 1970 amendments to the Atomic Energy Act to conduct prelicensing antitrust reviews of all applications for nuclear reactors or other production or utilization facilities for commercial use. The NRC holds a hearing when recommended by the Attorney General and also considers whether antitrust issues raised by other persons should be the subject of a hearing. Antitrust hearings are held separately from those on environment and radiological health and safety matters. Antitrust reviews are conducted concurrently with other licensing reviews to prevent this activity from becoming the controlling factor in the time required for the licensing process. The antitrust review by the NRC and the Attorney General focuses on whether or not the activities under the license will create or maintain a situation inconsistent with antitrust laws or policy underlying those laws.

7.4.3 NRC-State and Local Governments Coordination

One of the factors complicating the licensing process for nuclear power plants has been the necessity for utility applicants to obtain not only the required Federal government authorizations, but also approvals of certain aspects of project proposals from various State and local certification agencies.

In January 1971, Governor Mandel of Maryland responded to a letter from the AEC Director of Regulation, Mr. Harold Price (which contained a policy statement for AEC implementation of the NEPA Act of 1969) by suggesting that "to ensure orderly governmental processes, it is suggested that consolidated Federal and State public hearing procedures should be investigated." In response the Commission stated: "We are interested in your suggestion about the feasibility of consolidating Federal and State public hearing procedures in the review and licensing of nuclear power facilities. We would like to explore this concept with you..."

Since that time the NRC has moved steadily toward closer collaboration with States in general and with Maryland in particular in this matter. In the meantime, Maryland has developed one of the most advanced programs of any State in selecting sites for power plants and has developed procedures for collaboration with NRC relative to joint efforts in licensing.

Some other joint NRC-State activities are the State sponsorship of the conference of State radiological directors, sponsorship of the National Governor's Energy Conference, the initial ad hoc collaboration with States on predesignated sites, the Agreement State program, and NRC training of State personnel.

7.5 NUCLEAR FUEL CYCLE FACILITIES--A STATUS REPORT

One of the most critical economic and technological questions faced by the nuclear power industry in planning for future operations is under what condition "plutonium recyle" will be permitted.

During the uranium fissioning process in today's light water-cooled nuclear power plants, the fissionable element plutonium (as well as highly radioactive fission products which are generally treated as wastes) is formed within the fuel elements. This plutonium and the unconsumed uranium remaining in the spent fuel can be separated from the fission products and recovered at fuel reprocessing plants. While the plutonium thus recovered can be manufactured into fuel oxides for these same nuclear power plants, such recycling of plutonium has not yet been approved. Resolution of this question involves important health and safety, environmental, and safeguards issues. The economic concept of the breeder reactor program now under development by the government and industry also depends on the recovery and recycling of plutonium as essential parts of the breeding process, which creates more new fuel than the reactor consumes.

Shortly after formation of the NRC, the Commissioners accorded high priority to consideration of all the factors involved and, during 1975, developed a provisional view of steps to be taken in reaching a timely decision on plutonium recycle. (The fuel cycle is described in Section 13 and Appendix B.)

Draft Environmental Statement. A draft generic environmental statement, prepared by the regulatory staff of the former AEC in accordance with the provisions of the National Environmental Policy Act, was published in August 1974 for public comment as a basis for deciding whether the large-scale recycle of plutonium as reactor fuel should be authorized. The technical report (WASH-1237, four volumes totaling 1,100 pages) was titled "Generic Environmental Statement on Use of Mixed Oxides," and became widely known throughout the industry by the acronym, GESMO.

The tentative staff report concluded that the use of nuclear fuels containing mixed oxides of uranium and plutonium would, with upgraded security measures, provide the maxium benefits at minimum cost and would be environmentally the most desirable alternative in producing nuclear electric power. The draft report stated that the recycle program, if approved, could be implemented by the nuclear industry at an early date.

The detailed analyses in the report led to the following staff conclusions (1) the recycling of plutonium in LWR nuclear fuel would result in a slight decrease in the environmental effects of the total fuel cycle; (2) there would be no significant change in factors affecting the safety of nuclear plants and operations; (3) safeguards considerations need not delay the approval of plutonium recycle, since there would be little change in plutonium production or utilization for several years; and (4) plutonium recycle would result in decreased resource requirements for meeting U.S. energy demands because plutonium's use as a fuel would reduce uranium ore mining requirements by millions of tons toward the end of this century.

Although the GESMO report did not set forth detailed cost-benefit analyses of alternative programs to protect against loss or diversion and illicit use of plutonium associated with such wide-scale use, it did review in considerable depth the current safeguards program and noted numerous measures which, in the staff's view, could contribute to upgrading of that program. From this assessment, the staff concluded that the safeguards problem would be manageable and should not delay recycle. The AEC staff report noted that decisions on safeguards upgrading were expected within one year after issuance of the final GESMO statement. At that time, the staff estimated that a decision on such measure could be reached by mid-1976; however, this did not consider time for completing environmental statements on safeguards or any public proceedings on the matter. When these factors are taken into account, the approach proposed by the AEC staff might have led to a decision on safeguards in late 1977 or early 1978, assuming that the earlier decision on other matters was favorable.

CEQ Recommendation. In a January 20, 1975 letter to the Commission, the President's Council on Environmental Quality expressed the following views:

> "Although the draft environmental statement is well done and reflects a high quality effort, it is incomplete because it fails to present a detailed and comprehensive analysis of the environmental impacts of potential diversion of special nuclear materials and of alternative safeguards programs to protect the public from such a threat.
>
> "The Nuclear Regulatory Commission, the Executive Branch, the Congress, and the American people should have the benefit of a full discussion of the diversion and safeguards problems, its impacts, and potential mitigating measures, before any final decisions are made on plutonium recycle.

"The Nuclear Regulatory Commission should take care to avoid actions which would result in unnecessary 'grandfathering' during the period in which the safeguards issue is being resolved."

NRC Definitive Plan. On May 8, 1975, the NRC announced its provisional view that a decision on plutonium recycle should await preparation of a cost-benefit evaluation of alternative safeguards programs to protect the public from the consequences of a possible diversion of special nuclear materials, in accord with the recommendation of the President's Council on Environmental Quality which is cited above. Comment on the matter was solicited from all interested parties and the general public. More than 200 organizations and individuals responded, and their judgments were carefully considered by the Commission and NRC senior staff in developing the procedures announced on November 12.

There are six basic steps set forth in the definitive plan, which is designed to make a final decision possible by early 1977, some 18 months earlier than was projected in the provisional plan. The six steps are:

- A cost-benefit analysis of alternative safeguards programs for the widescale use of mixed oxide will be prepared on an expedited schedule. A draft of the analysis is expected to be completed early in 1976, as is a partial final statement on health and safety and environmental matters. The final portion of the impact statement, expected in mid-1976, will include the NRC cost-benefit analysis on safeguards and the overall cost-benefit balance on the wide-scale use of mixed oxide fuel for light water nuclear power plants.

- Proposed rules for the use of mixed oxide fuel will be published and public comment solicited as final portions of the environmental statement are issued. The Commission expects to issue the final rules at the time of its decision on wide-scale use.

- The public will have the opportunity to participate in the decision-making process not only by submitting written comments on the draft environmental impact statement and proposed rules, but also by taking part in the public hearings which will be held on the final impact statement and on any rules to be implemented. These legislative-type hearings will begin as soon as practicable after issuance of the non-safeguards portion of the final statement early in 1976. These may be followed by adjudicatory-type hearings on particular issues, if the need for such is demonstrated to the Commission. If no such need arises, a final decision could be reached by early 1977.

- The NRC staff will continue reviewing applications already submitted for mixed oxide fuel related activities and will commence review of any new application received.

- Eligibility criteria have been established for considering the interim licensing of such operations as fuel reprocessing and mixed oxide fuel fabrication. The Commission noted that very little mixed oxide fuel is being made in the United States and that, at present, there is no reprocessing facility for commerical fuel in the country; thus, it is not likely that there could be any substantial use of mixed oxide fuel before the early to mid-1980s, regardless of licensing and construction activities. The Commission stated its confidence that the current safeguards framework is adequate for existing plants and for interim licensing of facilities to chemically separate spent fuel and to convert recovered uranium to a usable form. Upgraded safeguards requirements may be imposed in any interim licensing of facilities which convert recovered plutonium to a usable form and which fabricate mixed oxide fuel. Safeguards rules for these activities are expected to be published when the Commission publishes the draft safeguards supplement in early 1976; final interim rules will be published when the final portion of the statement appears in mid-1976, after consideration of all public comment on the proposed rules and safeguards.

- Operating licenses and amendments to operating licenses may be issued which authorize the interim use of mixed oxide fuel in light water reactors; such use would fall far short of "wide-scale" use because of the limited mixed oxide fuel fabrication capacity available. The Commission believes that such use would produce useful additional technical and economic data regarding this fuel.

The Commission, in reaching it decision on safeguards, will have the benefit of the results of a special study on safeguards needs for recycled plutonium as well as two additional one-year studies related to safeguards which were mandated by the Energy Reorganization Act.

7.5.1 Spent Fuel Reprocessing Plants

These heavily shielded facilities were designed to separate the highly radioactive fission products from spent fuel, purify the recovered uranium and plutonium for reuse in reactors, and concentrate the radioactive wastes for storage onsite pending solidification and transfer to the government for disposition. As with nuclear power reactors, the NRC conducts exhaustive safety and environmental reviews and will maintain surveillance over operations to assure radiological protection of workers, the public, and the environment.

Currently, there are three commercial spent fuel reprocessing facilities in various stages of development in the U.S.:

- The West Valley, N.Y., reprocessing plant owned by Nuclear Fuel Services, Inc., the first and only commercial facility of its type to be placed in operation, has been shut down since early 1972 for major modifications, including an increase in capacity from 300 to 750 metric tons of irradiated uranium per year (capable of supporting 20 1000-MWe power reactors). The NRC safety and environmental reviews for these changes continued during the year, with public hearings projected for 1976. In a separate licensing action, NFS requested authority to increase the capacity of its fuel storage pool.

- Licensing reviews continued on Allied-General Nuclear Services' reprocessing plant at Barnwell, S.C., on which construction was over 90% complete at the end of the fiscal year. A public hearing on environmental impact, being conducted by an Atomic Safety and Licensing Board, was expected to continue into calendar year 1976. A separate hearing will be held on Allied-General's request for approval to use its spent fuel receipt and storage station prior to final action on the facility operating license application. The Barnwell plant is designed to reprocess 1,500 metric tons of irradiated uranium per year (capable of supporting 50 1000-MWe power reactors).

- General Electric Co., which completed a reprocessing plant in 1974 at Morris, Ill., designed to handle 300 metric tons of spent fuel annually, decided not to place the facility in operation due to technical difficulties; the receiving and storage portion has been utilized, however, and GE has requested authorization to substantially expand storage capacity. The application is under review.

7.5.2 Fuel Fabrication

The final steps in producing fuel for nuclear power reactors are the conversion of the enriched uranium hexafluoride to uranium dioxide (UO_2) and the processing of the UO_2 into pellets which are enclosed in long pencil-like tubular rods manufactured of zirconium. These steps are generally performed in the same facilities that fabricate the finished fuel assemblies. Currently, there are five firms actively engaged in the processing and fabrication of UO_2 fuel for nuclear power reactors.

Significant fuel fabrication licensing actions in fiscal year 1975 included:

- Full-Term operating license (5 years) issued in July to Exxon Nuclear Co. for its uranium fuel fabrication plant and plutonium mixed-oxide laboratory at Richland, Wash., and subsequent amendment authorizing doubling the capacity of uranium fuel fabrication. Separate environmental impact statements were issued in connection with the uranium and mixed oxide fuel operations.

- Babcok & Wilcox Co. was authorized, in May, to use a new high-capacity fuel pellet line at its Commercial Nuclear Fuels facility at Lynchburg, Va.

- General Atomic Co. was permitted to terminate its license covering light-water reactor fuel fabrication at New Haven, Conn., and plutonium mixed-oxide fabrication research at Pawling, N.Y. The license was terminated after decontamination of the facilities in accordance with NRC guidelines.

7.5.3 Waste Burial

Wastes generated in the civilian uses of nuclear fission energy range from slightly contaminated trash to wastes with very high-level radioactive content produced in the fuel elements of nuclear power reactors after a long period of irradiation.

Where and how to store and dispose of highly radioactive wastes produced from nuclear reactor spent fuel reprocessing operations has been a matter of national concern for some time. The research and development program to resolve this problem, formerly carried out by the AEC, is now the responsibility of ERDA.

The Energy Reorganization Act of 1974 charged the NRC with responsibilities to license the safe storage and/or disposal of high-level radioactive wastes from the commercial reprocessing industry, whether stored at the reprocessor's facilities or at a Federal repository. To meet these, as well as other nuclear waste responsibilities conferred by the Atomic Energy Act, the Commission established a Waste Management Branch in the Office of Nuclear Material Safety and Safeguards. It is responsible for the necessary safety analyses and licensing activities as well as for the development of a comprehensive waste management policy for the Commission.

During the year, the NRC undertook preparation of a broad program plan for nuclear waste regulation and management concerning all types of wastes ranging from tailings at uranium mills to the decontamination of nuclear facilities upon decommissioning at the end of their useful lives.

Scope of the program will include standards development, backup research, and the licensing actions required to protect public health and safety in all aspects of the handling, treatment, shipping, storage and disposal of nuclear wastes.

High-Level Wastes. Under current NRC regulations, high-level radioactive wastes must be solidified within five years of generation and shipped to ERDA within another five years for storage or disposal. Of the many options proposed for the disposition of these wastes, ERDA is actively developing an interim storage technique (called a Retrievable Surface Storage Facility) and a geological disposal system in bedded salt, while studying other promising operations.

The NRC is charged by law with making licensing decisions on all such types of disposal facilities. The Commission is developing detailed standards and performance criteria for high-level waste disposal to help guide ERDA's waste management research and development program, while providing flexibility to include any additional options that may be developed as the program progresses.

Waste Burial Facilities. Low-level radioactive wastes are generally handled at commercial burial grounds located in six States. Two of these are regulated by the NRC, and the remaining four by the States in which they are located under the terms of an Agreement with the NRC.

In September 1974, the AEC proposed a new rule to prohibit commercial underground burial of transuranium elements (those with atomic numbers above that of uranium, such as plutonium) in order to provide an added margin of safety and further assurance of environmental protection. The regulation would require that these wastes be solidified (if liquid), packaged, and transferred to ERDA as soon as practicable, but no later than five years after their generation. At the end of fiscal year 1975, the NRC was evaluating public comments received on the proposed rule. Some delay in the rulemaking action has resulted from the withdrawal by ERDA of an environmental impact statement covering these wastes and the preparation of the broader NRC program. Both NRC and ERDA expect to have full documentation on the matter in readiness by spring of 1976.

7.6 PUBLIC ACCEPTANCE

The degree of public acceptance of nuclear power is difficult to assess in a definitive way. There is no question that there are strong advocates of no nuclear power or a slow growth policy.* Also, there are strong advocates for nuclear power.** Nevertheless, there have been attempts to make an assessment of public acceptance. For example, in 1974, the Interagency Task Force on Nuclear Energy examined this subject for Project Independence (Ref. 3). The principle issues identified in the study are:

- "Public concern about nuclear power could increase and could become more of a constraint on the expansion of the civil nuclear power system, though the general public is not, at present, strongly negative and tends to favor nuclear power over coal."
- "Events, and actions taken to influence public acceptability, can change public views and actions concerning nuclear power, particularly views of scientist-critics and local citizens affected by power plant decisions."
- "Opposition to nuclear power has been centered in a group of scientist-critics, public interest organizations, and concerned citizens in affected localities rather than the general public."
- "The safety record of the industry, the recent strengthening of regulatory activity, and other steps underway to deal with key nuclear power issues have not been adequately communicated to the public."
- "The relative health, safety and economics of various alternative energy sources have not been fully analyzed so that decision makers and the public have insufficient basis for rational choice."

More recently, a major survey conducted by Louis Harris and Associates for Ebasco Services Incorporated was conducted from March 21-April 3, 1975 (Ref. 4). The study was designed as a measure of attitudes of the public and their leaders--political leaders, business leaders, officials of regulatory agencies, and environmentalists--toward the development of nuclear energy in the United States. Some of the highlights of the study are the following:

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*A recent sampling of major works in opposition to nuclear power include the following:

Center for Responsive Law, A Citizens Manual on Nuclear Energy 1974 (Washington: Center for Responsive Law, 1974).

Union of Concerned Scientists, The Nuclear Fuel Cycle (San Francisco: Friends of the Earth, 1974).

John W. Gofman and Arthur R. Tamplin, Poisoned Power, The Case Against Nuclear Power Plants (Emmans, Pa.: Rodale Press, 1971).

Petitions have also been presented to the President of the United States. A recent one is titled, "Declaration on the Thirtieth Anniversary of Hiroshima," which was organized by Union of Concerned Scientists, and signed by 2,300 scientists according to the Washington Post. See letter dated June 18, 1975 from Union of Concerned Scientists to Dear Colleague and signed by John T. Edsall, James D. Watson, Henry W. Kendall, Harold C. Urey and George B. Kistiakowsky; and Thomas O'Toole, "Scientists Urge A-Power Slowdown," Washington Post, August 7, 1975, p. A3.

** Two examples of statements of support for nuclear power are those issued by 32 Scientists (the so called Bethe Manifesto named after its organizer Dr. Hans Bethe); and by the Board of Directors, American Nuclear Society. (See Nuclear News, February 1975, p.18; and December 1975, p.18).

- "The American public believes strongly that this nation is facing a serious energy shortage today, and that it will not disappear overnight. Four steps to ease the crisis received majority public support: speeding up the construction of the Alaskan oil pipeline, offshore drilling for oil, increasing efforts to produce oil shale in the Western States, and speeding up the building of new nuclear power plants. By a smaller margin, the public would also favor allowing more strip mining of coal. The public is not willing, however, to sacrifice the environment to the energy cause; by 65 to 26% Americans oppose slowing down the clean-up of air and water pollution as a step to help solve the energy shortage."

- "The public identifies some "major" problems connected with nuclear power plants. By far the biggest drawback in the public's mind is the disposal of radioactive waste materials, considered a "major" problem by 63% of the public (and comparable numbers of all leadership groups as well). In addition, other problems include the escape of radioactivity into the atmosphere (49% consider this "major"), followed by the chance of an explosion in the case of an accident (47%), the discharge of warm water into lakes and rivers that could endanger fish and other water life (47%), the threat of sabotage (39%), giving off polluting fumes (36%), and the possibility of theft of plutonium (34%)."

- "The public identifies some real advantages of nuclear energy over coal and oil. Nuclear energy and coal are felt to enjoy two main advantages over oil: that they make the U.S. less dependent on foreign sources and that they could be obtained almost entirely within the United States. While oil is felt to enjoy one plus over coal or nuclear energy--it raises fewer health hazards and dangers--nuclear energy is credited with surpassing coal and oil on some major counts: it will not run out of supply, it is a reliable form of energy in the long run, it can be produced in almost unlimited quantities, it is a cleaner source of energy and a cheaper form of energy."

In the future as in the past, it is expected that the public will continue to struggle with the overall assessment of nuclear power compared to alternative sources of electrical energy production.

7.7 SUMMARY

The major challenge to the NRC is arriving at licensing decisions in a timely manner, while at the same time assuring safe and reliable operation of these facilities and protection of environmental values. To achieve this goal, NRC has modified its regulations, encouraged the nuclear industry to adopt standardized plants, and proposed legislation that will permit decisions on power plant site to be made well in advance of any construction proposed. If these actions are successful, it may be expected that the time required from conception to operation of nuclear power plants may be as short as five and one-half years, which is at least two years less than has been possible in recent years.

Public participation in regulation has been and will continue to be an integral part of the NRC decision making process on nuclear power plant siting. This is important because each siting decision is a major Federal action which significantly affects the environment and must be made within the framework of the National Environmental Policy Act of 1969. To serve the public interest, siting decisions must be made in public proceedings that provide for participation of all interested parties.

The Commission has published siting guidance for nuclear power plant siting that takes into account all the relevant safety, environmental, and socioeconomic considerations. Some of the more prominent ones are population density, seismic and geologic, and water quality criteria.

Institutional aspects of siting will continue to play a significant role in power plant site selection, and there will be increasing coordination between NRC and other Federal, State, and local agencies in siting decisions.

Important decisions with regard to future plans for nuclear fuel-cycle facilities, (reprocessing plants, mixed-oxide fuel fabrication plants, and waste burial sites), currently await resolution of certain cost-benefit issues and especially those pertaining to safeguards considerations.

Finally, the public acceptance of nuclear power will remain a challenging area for government, industry, and public discussion in the future.

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SECTION 8

ORIGIN AND EVOLUTION OF THE NUCLEAR ENERGY CENTER CONCEPT

8.1 HOW THE IDEA AROSE AND PROGRESSED

The idea of nuclear energy centers (NECs) has been proposed and considered in various forms since the middle of the last decade, and to some extent anticipated earlier (Refs. 1 and 2). In its earliest forms the NEC idea was motivated by considerations different from those underlying the present study, and the concept itself took different forms. The NEC idea underlying the present study is that of a siting concept for nuclear power plants and related nuclear facilities that would in any event be built--if not in centers, then on dispersed sites. In the present concept, NECs are being evaluated as a potentially advantageous mode of responding to a power demand that--by and large--would in any event arise. By contrast, the earliest forms of NECs were considered not primarily as reactor siting concepts, but rather, to a large extent, as concepts for stimulating regional economic development.

The early nuclear energy center concepts involved complexes in which concentrations of nuclear electric generating capacity would serve as leaven for raising regional industrial and agricultural production and community living standards.

A study initiated in 1965 and reported on in 1968 (Ref. 3) involved nuclear power and desalting plants for the Southwest United States and Northwest Mexico. The study was pursued as a cooperative project by the International Atomic Energy Agency (IAEA) and the two countries involved. The study evaluated the feasibility of constructing centers near the U.S.-Mexico border, to serve both countries with electricity and desalted water. The report concluded that such centers were technically feasible. Thermal powers involved were taken as 10,000 MWe initially, with growth to an estimated 50,000 MWe by 1995.

In 1968 the Oak Ridge National Laboratory (ORNL) reported on a broad study of the potential use of nuclear energy for the generation of electricity and desalted water for industrial and agricultural/industrial complexes (Ref. 4). Power levels considered ranged upward from about 12,000 thermal megawatts. The study concluded that the technical and economic merits were sufficient to warrant further consideration.

A specific application of the idea of synergistic energy-water-industrial-agricultural complexes in arid regions of the Middle East (based on energy sources which would not necessarily be nuclear) was studied in detail by ORNL--reported in 1970 (Ref. 5).

A specific situation study for Puerto Rico, also reported in 1970 (Ref. 6), involved a small nuclear plant to provide electricity, desalted water, and process heat for a small diversified industry. The study was done jointly by the Atomic Energy Commission, the Department of

Interior, and the Commonwealth of Puerto Rico. The study concluded that the project, while technically feasible, would have only marginal economic merit in the then forecast economic environment, and that that merit was not sufficient to outweigh disadvantages.

The idea of nuclear energy centers as a reactor siting concept was first put forward in October 1971 by Alvin M. Weinberg, then Director of Oak Ridge National Laboratory and subsequently Director of the Energy Research and Development Office of the Federal Energy Administration (Ref. 7)

The idea would represent a planned sharp accentuation of trends already evident, since as many as four reactors are already in the plans for a few sites, and even larger numbers are under consideration.

Dr. Weinberg's original argument for nuclear parks" proceeded from a broad overview of a probable course of growth for the nation's and the world's electrical energy establishment in the decades immediately following the 1970s. These decades, in Dr. Weinberg's view, would see a world population growth continuing to proceed towards a leveling off at perhaps 15 billion, an increase in worldwide per-capita energy consumption gradually assimilating towards present U.S. standards, coupled with the prospect of eventual exhaustion of fossil fuels and no alternative clearly in sight to massive use of nuclear fission as an energy source. While recognizing a huge band of uncertainty in the forecasts, he argued that a large number of reactors, many spent fuel shipments, large plutonium and radioactive fission product inventories would make continued dispersed siting increasingly unsatisfactory. Clustering reactors and associated fuel-cycle facilities in "nuclear parks" was viewed as a means of greatly alleviating the increasingly severe problems that would otherwise exist. Specific advantages envisaged .ere mainly in four important respects:

1. Reactor safety This was Dr. Weinberg's first and principal argument for the parks. He said:

   > "The point here is that if, say, 10 reactors are sited close by, then the entire installation, by virtue of its size, might be expected to possess technical and engineering resources that would be impractical in a small installation. Should a serious accident occur in one of the reactors, the resources of the entire installation could be mobilized to deal with the incident, and to confine the spread of radioactivity. I realize that such nuclear parks may be more vulnerable to common-mode failure such as enemy action or earthquake; nevertheless, the balance seems to me to lie on the side of easily mobilized resources. This, at any rate, is the impression I get from the experience at Hanford and Savannah River: nuclear parks which are able to mobilize with impressive swiftness and efficiency." (Ref. 7)

   He argued that as the number of reactors increased, further improvements in the already extremely low major accident probabilities would be both appropriate and possible, and nuclear parks would be an important means to that end.

2. Plutonium inventory and shipment With forecast plutonium inventories, especially as breeder reactors reach industrial maturity, reaching many thousands of tons and potential annual shipments of spent fuel eventually exceeding a million, Dr. Weinberg sought a basic strategy that would concentrate nuclear activities in as few places as possible and keep the transportation lines internal, for both safety and safeguarding against clandestine diversion.

3. Old reactor sites. With uncertainties as to the extent to which decommissioned reactor sites can be decontaminated for free re-use for other purposes, nuclear parks would offer a low limit to the number of sites potentially committed in perpetuity.

4. Waste heat. Even the highest energy consumption projections would pose little heat dissipation difficulty on a global scale. (Dr. Weinberg cites asymptotic projections of ratio of nuclear to solar heat of 1/24,000 to 1/400 at low and high nuclear-energy assumptions.) But local heat dissipation limits are another matter. Such limits are already being encountered. Nuclear parks could be located where "heat islands" are of little consequence.

Dr. Weinberg expanded discussion of the nuclear energy concept in a number of subsequent papers (Refs. 8, 9, 10, 11).

John C. Sawhill, FEA Administrator, saw nuclear energy centers as a means of responding to public concerns about safety, diversion of nuclear material and waste disposal, concerns which would be exacerbated by proliferation of hundreds of sites throughout the country in the decades ahead (Ref. 12)

Integrated fuel cycle facilities were the subject of a 1974 study by an AEC Ad Hoc Study Group, formed through the interest and initiative of then AEC Commissioner C.E. Larson. (Ref. 13). The group considered integrated versus dispersed fuel cycle facilities, including reprocessing, fuel fabrication, and the storage, handling, and disposal of radioactive wastes. Enrichment topping plants were also addressed.

It was against this background that several major studies of nuclear energy centers were undertaken and the U.S. Congress acted to create the present Nuclear Energy Center Site Survey. Those studies and legislative action are discussed in Subsections 8.2 and 8.3.

The interest of some electric utility companies in the NEC concept is indicated by the Pennsylvania utilities' study discussed in Subsection 8.2 and by the following two recent actions:

- Application by Pacific Power and Light to the Washington State Planning Council for a ruling on the proposed Roosevelt site as to whether they can apply for an incremented number of power units, or whether they must apply for the intended potential capacity (10 units).

- Announcement by Florida Power and Light of their intention to evaluate two sites for small energy centers (approximately 12 GWe total generating capacity). One site is adjacent to the existing Turkey Point site south of Miami, to be cooled by mechanical draft cooling towers; the other is about 40 miles south of Tampa, to be cooled by a cooling lake with a two-year water capacity.

There is also interest in the nuclear energy center concept abroad:

- Japan has a strong clustering trend for nuclear power units. The Fukushima Power Station, in Fukushima Prefecture, about 500 miles north of Tokyo, has three power-reactor units operating, three under construction, and three or four more under consideration. In another location in the north of Japan's main island, in Niigata Prefecture, development of a nuclear power complex of approximately similar size is under consideration (Ref. 14).

- Germany has tentative plans for fuel-cycle terminal facilities, involving collocation of fuel reprocessing facilities with ultimate waste disposal. The recovered fuel would be shipped elsewhere (Refs. 15, 16).

- The International Atomic Energy Agency has engaged in informal talks since mid-July 1975 to sound out its members concerning a regional fuel cycle center. The queries for comment have received, on the whole, favorable response; and on this basis, IAEA is now proceeding in structuring a method by which to study all aspects of a regional fuel cycle center (Ref. 15).

8.2 STUDIES PRIOR TO THE PRESENT SURVEY

8.2.1 General

A number of studies of nuclear energy centers, both generic and with respect to specific potential locations, were initiated prior to the survey documented in this report. From some of the studies substantial findings, at least of an interim nature, were available to NRC at the outset of the present study or became available during the study. Such results were considered, and utilized as appropriate, in the conduct of NRC's present study. Specific citations will be found under the pertinent topical portions of this report.

An overview of the highlights of those studies is presented in the paragraphs that follow. Where conclusion or recommendations are cited in Subsections 8.2.2 to 8.2.6 they reflect entirely those of the referenced studies. They are presented at this point for background only, and without comment. They may or may not coincide with conclusions and recommendations that emerged from the NRC study.

8.2.2 AEC Study

A broad study of NECs was initiated by Dixy Lee Ray, Chairman of the Atomic Energy Commission in December 1973. The initiation of the study was motivated partly by a thrust towards energy self-sufficiency for the United States by 1980, as part of Project Independence. A report on this AEC work was issued in January 1974 (Report WASH-1288, Ref. 17). But more detailed follow-on studies of specific subject areas were still in progress at this writing, under the auspices of the Energy Research and Development Administration, the AEC's R&D successor.

The AEC study task force concluded that the project did not meet the criteria for energy independence by 1980, since nuclear energy centers could not be expected to have a significant impact till after 1985. However, the concept was viewed as offering sufficient potential advantages to warrant further study.

The AEC study defined nuclear energy centers as large concentrations of nuclear power at a single geographical site. In addition, they might have an appropriate combination of related facilities such as waste management and storage facilities, fuel reprocessing plants, recycled fuel fabrication plants, new fuel fabrication plants, uranium enrichment plants, and industries using process energy. A possible initial ("demonstration") nuclear energy center was thought of as involving a capacity of 10,000 to 20,000 MWe at maturity.

The AEC study included preliminary conceptual studies of two potential sites for nuclear energy centers: one at Hanford, Washington, the other at the Gulf States Utilities' River Bend site, north of Baton Rouge, Louisiana. In addition, it included generic consideration of a range of topics deemed relevant, including:

Electricity transmission considerations
Organizational, institutional, and financial implications
Radiological impact
Waste management
Use of process energy
Choice of reactor types for nuclear energy centers
Regulatory aspects of siting nuclear energy centers
Nuclear-industry growth-rate considerations.

The AEC task force's conclusions included the following:

1. Nuclear energy centers (NECs) are technically feasible.

2. They should provide nuclear power cheaper and more effectively than dispersed sites.

3. NECS of power-only types would evolve through normal utility growth by the year 2000, with some centers perhaps including fuel-cycle and/or other supporting nuclear facilities. When and how such unchanneled developments would occur are the major uncertainties.

4. NECs improve potential for good land management.

5. NECs offer the possibility of large permanent sites for baseload power production, with long-term programs of generating facilities renewal as equipment becomes obsolete.

6. Potential for reduction of concern about diversion of nuclear materials for unauthorized uses is a major merit of NECs.

7. Electricity would have to be transmitted over large distances.

8. Problems would include:

    a. Organization of cooperative ventures for NECs serving areas so large that they encompass a group of utilities.

b. Institutional problems of financing the largest centers. (No unusual difficulties with smaller ones.)

c. Potential problems with antitrust aspects.

The task force recommended follow-on studies to extend and round out both the Hanford and River Bend studies and the generic studies. The follow-on would extend through fiscal years 1975 and 1976. Follow-on activities, partly reflecting the WASH-1288 (AEC) task force's recommendations, are in fact proceeding (Refs. 18, 19, 20, 21) These follow-on studies center primarily on a possible nuclear energy center at Hanford, and include broad conceptual studies, fuel-cycle studies, and transmission considerations, as well as other factors.

8.2.3 National Science Foundation Sponsored Study

In 1974 the General Electric Company, under a grant from the National Science Foundation, began a study addressed to "assessment of energy parks vs. dispersed electric power generating facilities." The GE study includes consideration of coal as well as nuclear power. While final phases of the GE study overlapped in time the initial and middle phases of NRC's survey, a final report (Ref. 22) and informal contacts (Ref. 23) permitted NRC consideration of many of GE's results.

The overall purpose of the study has been to compare the advantages and disadvantages of meeting U.S electrical power needs via the energy park concept, i.e., aggregating large blocks of generating capacity and associated facilities and functions at a single suitable location to obtain possible benefits of common facilities, economies of scale, and other advantages, versus meeting those needs by present practices of distributed siting of power generating units. Included in this comparison is the evaluation of technical, institutional, economic and other issues in the implementation of the park concept. As a concomitant objective the study was to identify major research and development needs, both technological and institutional, and indicate alternative approaches to resolution of major policy issues that evolve from consideration of the energy park concept.

The study included nine tasks:

1. Development of energy park elements data and information, unit planning factors and unit cost models.

2. Characterization of energy parks.

3. Analysis of transmission requirements and transmission technology alternatives and evaluation of systems reliability for both parks and dispersed siting.

4. Evaluation of fuel cycle integration in the energy park concept.

5. Evaluation of the collocation of industry with energy parks.

6. Delineation and analysis of alternative resolutions of major institutional, social, financial and legal issues associated with the energy park concept.

7. Overall consideration of environmental issues related to energy parks.

8. Consideration of role and relation of advanced technologies to energy parks.

9. Comparative assessment of energy park concept versus conventional dispersed siting of electric power generating plants and associated facilities.

Task 6 was carried out for GE by the National Academy of Public Administration, supported by a workshop discussion managed by The Mitre Corporation.

For the nuclear comparisons GE used assumed sites with 2, 4, and 20 nuclear power plants of 1,300 MWe capacity. The baseline heat dissipation mode for the centers was via cooling lakes although evaporative cooling towers were also considered.

The GE study laid heavy emphasis on economic comparison. For the nuclear comparisons, a finding of an approximately 10% overall cost advantage for 20-unit centers over 2-unit dispersed sites (4-unit sites being about halfway in between) was contingent on quite rigid, long-term standardization and modular construction for the large center, a course that the GE study team judged to be only partially applicable to dispersed sites, to their considerable economic disadvantage. The net savings for centers were the result of substantial estimated construction cost savings diminished by increased transmission costs, due to greater average transmission distances (175 miles for centers vs. 25 for dispersed sites).

8.2.4 Pennsylvania Studies

8.2.4.1 Energy Park Development Group

An energy park siting study for Pennsylvania, covering both nuclear and fossil power plants, was started in 1974 and was continuing at the time of this writing. The study is being conducted by an Energy Park Development Group, organized for the purpose by a group of four utilities--Philadelphia Electric Company, Pennsylvania Power and Light Company, Metropolitan Edison Company, and Pennsylvania Electric Company. The group was assisted by Gilbert Associates, as engineers/consultants (Ref. 24).

Power capacities primarily considered were in the range of 10,000 to 20,000 MWe.

The group's interim conclusions included the following:

1. Numerous sites exist within Pennsylvania capable of supporting up to 20,000 megawatts of mixed fossil and nuclear capacity.

2. Transmission can be developed to deliver the energy from the energy park or parks to the major load centers.

3. No insurmountable technical problems which would block the development of the Energy Park are apparent at this time.

4. Significant technical obstacles included:

   . development of an acceptable economically and environmentally compatible cooling system

   . potential meteorological impact of massive relatively concentrated heat dissipation.

5. The solution of these and most other technical problems is site dependent or related and must be addressed in the detailed site studies.

6. Significant non-technical potential problems include:

   . antitrust implications

   . need to obtain regulatory approval for full park development even though it will be done in stages

   . initial financing and early "excess investment required in common facilities not fully utilized initially

   . public acceptance.

7. Considerable potential savings are apparent in the energy park concept versus dispersed siting of an equivalent amount of capacity.

8.2.4.2 Commonwealth of Pennsylvania

The Commonwealth of Pennsylvania through the Governor's Energy Council sponsored a study on energy parks that was conducted by the Center for the Study of Environmental Policy at the Pennsylvania State University (Ref. 25). The goal of the study, published in July 1975, was to specify a comprehensive set of questions and key issues that must be addressed in the formulation of a position for the Commonwealth of Pennsylvania on the energy park concept.

The following is a partial list of conclusions cited in the Center's report:

. The energy park siting alternative is not likely to significantly reduce the consumer's kilowatt-hour cost of electricity.

. Including land devoted to additional transmission line rights-of-way, the park alternative may require additional land commitments to power generation.

. The environmental consequences of a park do not differ qualitatively from the dispersed alternative, although such effects will be more intense at the site.

- The park's local socioeconomic impact is anticipated to be less serious than forecasted by previous studies within the Commonwealth.

- The dissipation of reject heat from the park's generating units will place substantial demands on the involved watershed.

- No final assessment of the park concept or its various characteristics is possible without specific sites considered relative to dispersed siting alternatives.

A two-point action program was recommended as deserving immediate attention by Commonwealth officials:

1. Work should be initiated to develop the necessary data and knowledge concerning the impact of energy center complexes.

2. A reassessment should be made of the ability of existing state agency structures to respond to intra- and interstate concerns on energy facility siting.

8.2.5 Federal Energy Administration Studies

The Federal Energy Administration has commissioned four energy park feasibility studies. The Camp Gruber, Oklahoma study and the Glasgow Air Force Base, Montana study have been completed. The Tularosa Basin, New Mexico study and the Central Michigan study will not be finished until the end of 1975.

These FEA site specific studies are to be viewed primarily as siting exercises. The closest possible cooperation and participation between Federal, State and local siting authority has been incorporated into them. It was not intended that the commissioning of a study at a specific site was tantamount to FEA encouragement or endorsement of the construction of some complex of facilities, either nuclear or non-nuclear. Rather, the purpose of the studies has been to generate, collect, analyze, and publicize information which could have an important effect upon future siting plans and actions at all levels of siting authority, and also upon public acceptance of those plans and actions.

Each Energy Park study has three major objectives. First, site description: a compilation and preliminary analysis of the basic and readily available data on the site. Second, facility description: a compilation of the basic criteria for the siting of various kinds of energy facilities and a comparison of the studies site's characteristics to those criteria. Finally, impact analysis: a projection of the socioeconomic and environmental impact on the surrounding region from the construction and operation of some representative energy complex.

Camp Gruber Oklahoma (Ref. 26). The Camp Gruber Military Reservation is a 65,'0J-acre United States Army training camp established in eastern Oklahoma in 1941. Since then about half of this land has been transferred to the State of Oklahoma, and an additional part has been recently declared "surplus" by the Federal Government. It is possible that the entire reservation could be transferred to the State. It is a policy of the Federal Government that the use of such property for energy resource development should be encouraged. One possible use for some of the land would be to site energy facilities.

The results of the study were that Camp Gruber would make an excellent site for many different kinds of energy facilities. There is a large quantity land, low cost, with good foundation characteristics, good drainage, favorable topography, and low probability of major earthquake and flooding damage. There is an ample supply of poor quality water which could evidently be made available for energy facility use (at least 12,000 MWe capacity during the worst expected conditions). The meteorological conditions at the site are good, dispersion and wind rose features being favorable. The construction and operating labor costs are low in comparison with the rest of the country and worker productivity is high. The site is uninhabited, not a habitat of rare and endangered species, not an historical or archaeological site, and not an "ecologically important" region. Good highway, railroad, and air transportation facilities are available. Most municipal utilities, facilities, and services are already available for an Energy Park size work force. There is a favorable local citizen attitude to what they perceive to be the socioeconomic and environmental impact of the siting of an energy park at Camp Gruber.

Glasgow Air Force Base. The 5,815-acre Glasgow Air Force Base, established in 1955, is located in northeastern Montana. The Base, worth $140 million in replacement cost, was closed in 1968 and is a potential Federal Surplus Property. Approximately 15,000 acres of range land of marginal utility owned either by the Federal Government or the State of Montana, is contiguous to the Base.

The results of the study were that Glasgow AFB would make an excellent site for many different kinds of energy facilities. There is a large quantity of land suitable for facility siting, of low cost, good foundation characteristics, good drainage, favorable topography and low probability of major earthquake. However, there is some evidence of faulting near the site and additional seismic studies would need to be conducted. There is a very large source of good quality water in Ft Peck reservoir, 24 miles distance from the AFB. There are very large deposits of strippable coal available within 70 miles of the AFB The meteorological conditions at the site are good, with large temperature extremes (50° below to 113° above, F), low rainfall (12" per year), modest occurrence of extreme weather, and prevailing winds from the northwest quadrant. No air quality data is available, but few sources of pollutants were identified. Good highway, railway, and air transportation facilities are available. Most municipal utilities, facilities, and services are already available, including housing, for an energy center size work force and their families. The report concentrated on the possible use of coal for conversion to other energy carriers, particularly high BTU gas and syncrude.

Tularosa Basin. The Tularosa Basin, in southern New Mexico is a 6,500 square mile structural trough bordered by mountain ranges. The area is sparsely populated, semi-arid, undeveloped desert with broad expanses of dry alkali lakes and beds. Most of the land is under Federal ownership or jurisdiction. A great brine acquifer, with proven reserves of several hundred million acre feet; underlines the basin. The purpose of this study is to determine the feasibility of mining brine from this acquifer, desalting it using waste heat from powerplants or other types of energy intensive facilities and using the resulting good quality water for powerplant cooling, slurry pipelines, coal gasification, municipal, industrial, or agricultural use. Preliminary estimates are that a half million acre feet a year can ultimately be economically mined. There are no surface waters available for energy resource development in this part of the country, and there is much energy resource to be developed.

Michigan Industrial. The State of Michigan has considerable energy re... ements in the industrial sector. And although there is adequate water for energy facility use, almost all fuels must be imported. Although industry has in the past generated some of its own electricity and has purchased process steam from public utilities, the long term trend has been to purchase more and more of its electricity and to generate its own steam using oil or gas fired "package" boilers. It i. probably necessary, from the standpoint of energy resource conservation and from the standpoint of maximizing energy production while minimizing capital investment, to reverse this long term trend. The purpose of this study is to determine the feasibility of an energy facility complex which takes the fullest possible advantage of savings that may accrue when facilities are designed to accommodate the total energy needs of a region. Preliminary estimates are that by 1985, even without the establishment of centers expressly designed for this purpose, industry could be generating 32.5% of its electricity and obtaining over 50% of its process steam requirements from dual-purpose facilities. The savings in oil are estimated to be about a million barrels a day.

8.2.6 The National Governors Conference and SINB

A joint preliminary study of power parks from the States' perspective was completed in March 1975 by the National Governors' Conference Energy Project and the Southern Interstate Nuclear Board (Ref. 27)

The study included preliminary consideration of site selection factors, mutual State radiological assistance, State radiological emergency response planning, and provisions of State power plant siting laws.

8.3 LEGISLATIVE ACTION

A provision to create a "Nuclear Power Park Site Survey" was introduced in the House of Representatives by Congressman Mike McCormack, of Washington, as Section 277 of H.R. 12823, on February 14, 1974. (H.R. 12823 dealt primarily with "improved procedures for planning and environmental review of proposed nuclear power plants.")

At the time of writing H.R. 12823, Mr. McCormack had available to him a draft of WASH-1288, the AEC white paper on nuclear energy centers (Ref. 17).

The McCormack bill, modified, was reintroduced as H.R. 13705 on March 25, and again, with significant modifications of the nuclear energy center provision, as part of H.R. 16700 ("Price licensing bill") on September 17, 1974.

Meanwhile, a similar bill was introduced in the Senate, by Senator Bellmon, of Oklahoma, as S. 3385, on April 25, 1974. The Bellmon bill was reintroduced on August 15, by Senator Baker, of

Tennessee, on behalf of Senator Bellmon, as an amendment to the Energy Reorganization Act of 1974.

The Administration submitted comments, coordinated by the Office of Management and Budget, with inputs from various interested agencies, including the AEC, FEA, and FPC.

There were no Congressional hearings on the subject.

The Nuclear Energy Center Site Survey provision ultimately became Section 207 of the Energy Reorganization Act of 1974 (P.L. 93-438). The final language was worked out in the Senate-House Conference on the Act and its preparatory staff work. The following is excerpted from the Conference Report (Ref. 28):

NUCLEAR POWER PARK SITE SURVEY

"The Senate amendment (section 112) made a finding that it is in the national interest to locate regional nuclear power park sites. The Administrator was authorized to make a survey and report to the Congress within one year.

"The conference substitute replaces the Senate language with a more comprehensive provision for a nuclear energy center site survey based on legislation drafted by the Joint Committee on Atomic Energy and moves this provision to title II of the Act (section 207). This provision requires that the study be undertaken by the Commission rather than by ERDA and that the survey "identify rather than "designate" possible sites for nuclear centers. The study is to be completed within one year from date of enactment of the Act rather than not later than June 30, 1976.

In adopting this provision, the conferees recognize the potential value of nuclear parks as well as the complex problems associated with designation of sites and requiring that nuclear power plants to be located in them. But it is apparent that much more information is needed before a nuclear power park site proposal can be adopted and sites actually can be designated."

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SECTION 9

CONCEPTUALIZED DESCRIPTION OF NUCLEAR ENERGY CENTERS

9.1 INTRODUCTION

Nuclear Energy Centers (NECs) represent geographic aggregates of nuclear power plants or fuel cycle facilities or both that are substantially larger than those presently being planned. Implementation of the nuclear energy center concept could begin in the late 1970s, if such centers are shown to be feasible, practical and desirable. Operation of the first facilities in a center could begin in 1985. Aggregation of facilities into a single site can intensify the local environmental, economic, and social impacts resulting from construction and operation of the facilities. A brief conceptualized technical description of the nuclear energy center models evaluated in the Nuclear Energy Center Site Survey (NECSS-75) is given below, together with a brief statement of the environmental, economic and socioeconomic characteristics.

The numbers and discussions presented in this section do not necessarily represent only the results of the NECSS. They represent a range of judgments drawn from many studies, but for the most part are reflective of and are not inconsistent with the information developed in the NECSS. They are provided for general reader perspective and not as a summary of NECSS results.

9.2 GENERAL TECHNICAL DESCRIPTION OF NUCLEAR ENERGY CENTERS

Nuclear energy centers may be grouped into the following three categories:

- Power center--A center that consists only of a large number of nuclear generating units with its associated electrical transmission facilities.

- Fuel cycle facilities center--A center that includes an integrated nuclear fuel cycle complex consisting of fuel reprocessing, mixed oxide fuel fabrication, and possibly waste management facilities.

- Combined facilities center--A center that contains various combinations of nuclear power generating units and fuel cycle facilities.

9.2.1 Power Centers

9.2.1.1 Generation Facilities

For the purposes of this study, a power center consists of from 10 to 40 reactors generating 1,200 MWe each (12,000-48,000 MWe). A 10-reactor model was chosen as the lower limit for a power only center because it represents a substantial size increase over the 2- and 4-reactor stations presently in the licensing process. An upper limit of 40 reactors or 48,000 MWe appears to represent the largest feasible conceivable size after the year 2000, considering electric demand and other technical considerations. The 48,000 MWe represents a block of capacity that is roughly twice that currently available to the metropolitan New York area.

The reactors primarily considered as a study assumption were the present generation of light water-cooled reactors. High temperature gas-cooled reactors and advanced concept reactors, such as the liquid metal fast breeder reactors, were also considered in order to determine whether they could be accommodated into nuclear energy centers.

If a national policy of power centers were to be adopted, there would typically be several power centers per Electric Rel ability Council region in various stages of development.

The ultimate size and rate of development of an individual nuclear energy center or combination of centers is dependent on a number of factors, such as electrical demand, fuel prices unit availability, and substitute technology.

9.2.1.2 Transmission Systems

In many areas of the country, the aggregation of generating facilities into a limited number of centers will increase the investment and right-of-way requirements significantly over those required for dispersed sites. Primarily this is because of the distances between the center and the loads are likely to be greater for dispersed sites. The need for additional interties to maintain reliability will also tend to increase the transmission facilities. However, the transmission requirements do not appear to place technical limits on center size.

Advanced transmission technology will have some benefit by reducing cost and the number of lines, but it should not be expected that equipment improvements will have a material effect on redundancy requirements for reliability. Fundamentally, the use of centers can be expected to intensify transmission problems including long-range planning, rates, right-of-way acquisitions, and environmental considerations.

9.2.2 Fuel Cycle Facilities Centers

As a possible means of improving the safeguarding of plutonium, collocation of fuel reprocessing (the step in which plutonium is recovered from spent nuclear fuel) and mixed oxide fuel fabrication (the step in which plutonium and uranium are mixed and manufactured into reactor fuel assemblies) facilities were evaluated. Two levels of aggregation of facilities were considered: a single fuel reprocessing plant capable of servicing 50-100 reactors collated with a matching mixed oxide fuel fabrication capability, and a regional integrated fuel cycle facility (IFCF) capable of servicing up to 300 reactors, and consisting of several reprocessing plants and mixed oxide fuel fabrication plants.

Federal waste management facilities are assumed to be a part of any integrated fuel cycle facilities; in addition, optimal location of Federal waste management facilities at two sites in the collocation model has been evaluated relative to the use of a single Federal waste management facility.

For an installed domestic nuclear power base of 850,000 MWe by the year 2000, a base assumption of this report, two to three regional integrated fuel cycle facilities could be adequate to service the national requirements (there are dispersed facilities presently under licensing review).

Possible restrictions on the shipment of plutonium offsite would result in constraint of fuel fabrication competition for collocated facilities unless plutonium is determined to be a fully fungible commodity.

9.2.3 Combined Facilities Centers

An additional level of aggregation of nuclear facilities is represented by the case in which fuel cycle facilities are located on the same site as reactors. Two basic models were evaluated, one in which the reactors can be fueled with mixed oxide fuel, the other in which the reactors would be fueled normally only by plutonium oxide fuel. The combined centers minimize the shipment of both plutonium and mixed oxide fuel elements (by locating plutonium recovery and fabrication facilities on the reactor site at which the plutonium would be used). Restrictions on the shipment of mixed oxide fuel offsite would have a tendency to constrain fuel fabrication competition, regardless of whether plutonium is fully fungible or not.

For the purposes of this study, the collocated fuel cycle facilities in a mixed center were assumed to be located sufficiently far away from the reactors so that environmental impacts could be considered separately.

9.3 ENVIRONMENTAL CHARACTERISTICS

9.3.1 Land Impacts

The land area for power centers will range from 20 to 75 square miles for the power site. This estimate is closely related to yet undetermined limits of heat dissipation intensity. The regional integrated fuel cycle facility (IFCF) might require from 8 to 25 square miles, if it were constructed separately. The land requirements for electrical transmission will vary with location. For a 40-reactor center located 75 to 100 miles from an array of electric demand centers, the transmission right-of-way land requirements might be as large as 250 square miles using conventional transmission concepts, down to perhaps 150 square miles using advanced concepts.

9.3.2 Air Impacts

While it is anticipated that evaporative cooling towers will be used as the primary means of heat dissipation from power NECs, other means may be demonstrated to be feasible. The concentration of heat dissipated from nuclear energy centers can be expected to raise issues involving weather modification, e.g., increased rainfall and local cloudiness, even severe turbulence. The present level of research and development in atmospheric heat dissipation is not able to provide precise working tools for decision making. Decisions on the feasibility of large aggregations of units will require considerable caution, subject to new direction as a better factual base is developed. The public reaction to possibly large, persistent visible plumes extending for many miles has not been evaluated.

9.3.3 Water Impacts

The availability of water is critical to operation of economically feasible generating facilities using conventional technology. If water is not plentifully available and dry cooling systems are needed, significant economic penalties can be expected. Therefore, it appears that access to water of sufficient quantity is important (a 40-unit center would consume water at about twice the amount of water withdrawn for use by the city of Chicago). It is not clear that, with exception of limited areas near major water sources, quantities of this sort can be developed without extensive impoundments and institutional conflicts. This limits siting flexibility and may force siting locations of diminishing economic attractiveness, principally because of additional transmission. Dispersed reactor siting may be much more attractive from a water availability standpoint, because the point demand requirements are more readily related to local stream capacity; the aggregate regional consumption of water would be the same.

9.4 ECONOMIC CHARACTER'STICS

9.4.1 Capital Costs

The capital costs of nuclear energy centers is directly related to the size of the center, and indirectly to factors which either increase or decrease the capital costs. Major factors that increase capital costs are transmission networks, right-of-way purchases, and environmental protection equipment. Major factors that decrease cost are plant standardization, construction efficiency, commonality of facilities for waste management, and fuel cycle. Capital costs would amount to billions of dollars for a center over a 20-year or longer period of time, but these capital costs would not be substantially different than the costs of building the same number of facilities using dispersed siting. For reader perspective, however, these estimated costs are shown in Table 9.1.

9.4.2 Cost of Electricity

There appears to be no major cost difference for the cost of electricity from power centers compared to dispersed siting. Any differences would largely be regional in nature and are not expected to exceed plus or minus ten percent in 1975 dollars. Likewise, there appears to be no major cost differences for fuel from IFCFs or combined facilities compared to dispersed facilities.

TABLE 9.1

NEC DATA FROM CURRENT STUDIES AND CONCEPTUAL DATA

	Capital Costs ($ Billions)(1975 dollars)		
	Generation	Transmission	Fuel Cycle
Large Power Center (40 reactors-48,000 MWe)	30-40	1-2	None
Small Power Center (10 reactors-12,000 MWe)	8-10	.3-.5	None
Regional IFCF	NA	NA	4-5
Combined Facilities: Power Center and collocated fuel cycle facilities	8-40	0.3-2	1

9.5 SOCIOECONOMIC CHARACTERISTICS

9.5.1 Construction and Operating Forces

The construction of large power centers can require a peak construction force of up to 12,000 people, depending on the construction rate. Since a 40-reactor unit site may take decades to complete, it could result in developing a quasi-dedicated construction force. Hence, many of the problems of trailer camp living and impact on schools and hospitals associated with di rsed sites having construction periods of roughly eight years can be reduced. Operating for for the 30- to 40-reactor unit site could reach 4,000 people when the site is filled, not including nonroutine maintenance forces.

The regional integrated fuel cycle facility could require a peak construction force of about 4,000 people, and an operating force of about 5,000 people. The predicted growth of the nuclear power industry is such that a regional integrated fuel cycle facility could be completely constructed in about 10-20 years. Hence, a more transient construction population would result than would be the case for the large power center, but the time period of construction would still be r tively long.

The impact of large combined facilities center is much like that of a power center with construction forces peaking at up to 13,000 people, and operating forces at up to 5,000 people.

9.5.2 Population Considerations at the Site

For a large power center, the presence of a large, stable construction force and a several thousand person operating force could result in the development of a population increase ranging from 70,000 to 100,000 persons or larger, if some employment diversification is achieved. The range depends on the existing infrastructure. Significantly smaller population increases would occur for smaller centers where there is established infrastructure and an existing labor pool in the area. New towns could be created, or alternatively, there could be an equivalent population increase in a number of adjoining communities. If one assumes that a power center is dedicated to power production for many years, with new units replacing ones taken off line, then the new and expanded communities could have a relatively long-term stable employment: otherwise diversification of employment becomes even more important.

It is important to note that, although there would be community disruptions occasioned by nuclear energy centers, the concentration of required personnel with their sophisticated capabilities may also attract a substantial intellectual community and result in an increased standard of living. The creation of expanded and new communities, or alternatively the revitalization of decaying ones, has the possibility of improving the quality of life provided that management that promotes this objective is instituted.

9.5.3 Ownership Patterns

Each power center probably may be comprised of several investor owned and public utilities. The many utilities involved and the large land areas that would need to be set aside could result in the establishment of large companies or complex and long-term agreements regarding the supply of power.

For fuel-cycle facilities centers, a wide variety of ownership patterns are expected which range from the current way the fuel cycle industry operates to possible joint private-public involvement. Combined facilities may even involve joint ventures of industry, government, and private and public utilities.

9.6 SUMMARY

This section has described the various conceptual models of NECs, i.e., power centers, fuel-cycle facilities centers and combined facilities centers. Also, a brief description of the technical, environmental, economic, and socioeconomic characteristics that define NECs was presented. These are summarized in Table 9.2 for the perspective of the reader.

TABLE 9.2
CHARACTERISTICS OF NUCLEAR ENERGY CENTERS, AS USED IN NECSS STUDY

Defining Characteristics of NECs	Large Power Center	Small Power Center	Regional Integrated Fuel Cycle Facility (IFCF)	Combined Facilities: Power Center and Collocated Fuel-Cycle Facilities
1. Technical				
Electric Power, MWe	48,000	12,000	None	12,000-48,000
Number of Reactors	40	10	None	10-40
Reactor Type	LWR-HTGR-LMFBR	LWR-HTGR-LMFBR	None	LWR-HTGR-LMFBR
Cooling Systems	Combination of all types	Combination of all types	No power units	Combination of all types
Transmission Voltage, (kV-ac)	500, 765, 1,200	500, 765, 1,200	None	500, 765, 1,200
Fuel Cycle	None	None	Several Reprocessing and Mox. Fab., 1-low level Waste Management, 1-high level Waste Management	Fuel Reprocessing, MOX Fabrication, Waste Management
2. Environmental				
Land Area, Miles^2	75[a]	19[a]	8-25	25-80
Water Consumption, gpm	530,000	130,000	Small Amount	130,000-530,000
Thermal Discharge, MWt	100,000	25,000	200	25,000-100,000
Transmission Lines (Single Circuit)	11 to 15	4 to 7	Not Applicable	4 to 15
Transmission Corridor Area, Miles^2	150 to 250	40 to 70	Not Applicable	40 to 250
3. Economic (1975 Dollars)				
Capital Cost, $ Billion				
Generating	30-40	8-10	Not Applicable	8-40
Transmission	1-2	0.3-0.5	Not Applicable	0.3-2.0
Fuel Cycle	None	None	4-5	1
Annual Operating and Maintenance Cost, Million $	200-250	50-60	500	150-350
4. Socioeconomic				
Construction Forces	12,000 Peak[b]	6,000 Peak[b]	4,000 Peak	13,000 Peak
Operation Forces	4,000 Peak	1,000 Peak	5,000 Peak	5,000 Peak
Population Increases[c]	70,000-100,000 Peak	10,000-35,000 Peak	10,000-35,000 Peak	75,000-120,000 Peak
Ownership	Public-Private	Public-Private	Public-Private	Public-Private

[a]Based on 1.0 acre/MWe.

[b]Based on 2 LWRs per year for large centers, 1 per year for small centers.

[c]Highly variable from region to region, depending on labor supply and existing infrastructure.

SECTION 10

POTENTIAL ROLE OF NUCLEAR ENERGY CENTERS

10.1 INTRODUCTION

Representative forecasts of nuclear power capacity (as discussed in Section 5) would involve something on the order of 1000 nuclear power plants in operation or under construction in the United States by the year 2000. In addition, there would be the associated fuel-cycle facilities: for uranium enrichment, uranium and plutonium-bearing fuel fabrication, fuel reprocessing, radioactive waste handling and storage.

In a substantially dispersed pattern of siting these power and fuel-cycle facilities would involve several hundred separate sites. The number of sites could be greatly reduced, while still avoiding having "too many eggs in one basket" from the reliability standpoint, by establishment of several nuclear energy centers in each of the nine electric reliability regions (or similar regional patterns). Integrated fuel-cycle facility centers could be separate from power centers or combined with selected ones.

The potential role of nuclear energy centers is not viewed as one of exerting a significant impact on the overall nuclear capacity to be built. Rather, their potential role is envisaged as an alternative siting concept for facilities that would in any event be built, as a result of forecast energy demand and basic technological and economic trade-offs and energy policy choices.

10.2 PROPOSED POSSIBLE ADVANTAGES

The motivation for considering NECs as a siting concept stems from perception of present and anticipated problems of siting nuclear facilities--problems that could possibly be dealt with more effectively or more advantageously by planned clustering. Listed below are factors that have been put forward as possibly creating a favorable role for NECs and factors recognized as possible significant obstacles. These lists are not study results. Rather, they reflect some of the important considerations that :ave created interest in NECs and some concerns that have led to recognition of a need for feasibility and practicality evaluations which are addressed in this report.

Proposed possible advantac ,' NECs, which to the extent of their reality could be important, have included the follow

- Improved nuclear ... t ·ial safeguards against sabotage, or theft or diversion and misuse.

This would stem both from reduced offsite transportation and from the possibility of stronger protective measures at larger sites. Safeguards advantages would be of increased importance as plutonium-bearing fuels come into wide use. The superior safeguards thesis is an argument for fuel-cycle centers and combined centers for power plants and fuel-cycle facilities.

. A more practical and manageable solution to nuclear plant siting problems.

In many parts of the country it has been becoming increasingly difficult to find generally acceptable sites for proposed nuclear power plants. While NEC sites would have more stringent requirements than dispersed sites (water and land requirements, heat dissipation to atmosphere, etc.), the site-finding problem would have to be solved several times less often, and would remain solved for many years, while the center is gradually built up to its ultimate capacity by periodic addition of units.

One way of viewing the NEC concept is that it would rationalize and systematize a trend to clustering nuclear plants which is already evident and would be projected to continue in a less orderly and less desirable way under a "laissez-faire" policy. The clustering trend is partly a reflection of overall regional electric capacity growth, which motivates the economics of multi-unit siting without excessive fractions of regional capacity on any single site.

. Greater institutional strength.

Greater technical and management strength and better "in-house" ability to respond to unusual or emergency situations could enhance safety and reliability.

. Lower construction and operating costs.

Savings would stem from economies of scale, construction methods geared to service multi-unit construction, the possibility of a more or less stable construction force, and easier attainment of a high degree of standardization.

Better waste management and storage.

Improvement would come through less extensive transportation and fewer places to manage. The prospect of eventually fewer old reactor or radioactive material processing sites is a related consideration.

Aid to plant standardization.

A greater degree of standardization would lead not only to construction economies, but also to better reliability and a more timely and efficient decision-making process in licensing and regulation.

- Lesser total radiological impact on society and lesser total environmental impact.

  This would be a total diminished effect of locally exacerbated impacts in fewer places.

- Greater ease of coordinated energy planning and easier attainability of effective land-use and water management.

  The fewer, larger sites would make sound planning both more necessary and more possible.

10.3 PROPOSED POSSIBLE DISADVANTAGES

There are some technical and technically-related economic disadvantages that may put bounds on sizes and conditions for which NECs may be considered feasible. Among such possible determinants of feasibility, analyzed in the present study, are the following:

- Heat dissipation.

  The "heat island" effect and meteorological impact are involved from heat rejection at approximately twice the power generation rate under the thermodynamic conditions of current and foreseeable reactor technologies. The heat dissipated from large centers would approximate or exceed that dissipated by cities occupying comparable land areas.

- Water needed for cooling.

  Cooling would be typically by "wet" cooling towers. While a significant quantity of water would be "consumed," by evaporation, this would represent only a small fraction of the available water source. Analysis involves consideration of water resource quantities, proximity (which is economically important), availability in competition with other possible demands, and quality impacts, such as those of return of cooling-tower "blowdown." (Water-poor areas that are otherwise attractive for NECs would not necessarily be ruled out, but they would involve a prima facie disincentive, because dry cooling towers make plants less efficient and are expensive and have unresolved environmental impacts.)

- Transmission.

  Concentration of generating capacity in larger blocks in fewer places would mean longer average transmission distances and possible need for special provision to maintain acceptable electric reliability. Longer transmission lines involve higher capital and operating costs and increased land requirements for rights-of-way.

- Potentially higher probability of common-mode failures.

  E.g., storm damage to cooling towers or transmission towers from a single incident could conceivably affect a greater fraction of a region's electric power supply.

- Greater local environmental impact and potentially higher local exposure to radiation.

Analysis wouid have to show that under the conditions contemplated the increased and potentially increased local impacts would be small enough to be acceptable.

Whether NECs are a practical and appropriate siting concept is not a question that can be resolved on technical considerations alone. The question also involves issues of great practical importance in the human, social, institutional spheres. Broad interactions of technology and policy are involved here, in the channeling of the nuclear power industry, an enterprise with far-reaching national, regional, and local implications. Factors in the following categories may influence the practicality of NECs or circumscribe their possible roles:

- Institutional constraints.

  These include Federal-State-regional-local interfaces, and current and customary and preferred division of jurisdictions and roles; manpower, indsutrial, and community interface considerations; government and industry relationships with respect to ownership, financing, management, and control; etc.

- Economic/financial constraints.

  These groups of factors include higher front-end costs for land, water-impoundments, transmission, infrastructure facilities and services, etc.; possible anti-competitive aspects of NECs and available countervailing measures; insurance and indemnity needs of the larger facility clusters; etc.

- Social, socioeconomic, and sociopolitical impacts.

  As new foci of large and important economic activity, with the attendant newly formed population clusters, probably in relatively thinly populated areas, NECs could exert much more substantial local and regional impact than dispersed sites. The impacts or perceptions may be considered favorable or unfavorable, but it is in any event appropriate to attempt to identify and characterize them for rational evaluation.

- National security considerations.

  The questions here involve the possible national security implications of loss of substantial blocks of electric power, as well as potential target attractiveness and vulnerability and defensibility with respect to sabotage or attack.

10.4 NUCLEAR ENERGY CENTER SITE SURVEY

The practicality and role of nuclear energy centers will also depend on availability of feasible and suitable sites in each electric reliability (or similar) region of the country.

The present report deals with evaluation of conditions for feasibility and practicality of nuclear energy centers, including a coarse screening of each electric reliability region for areas that are likely to contain potentially suitable sites.

SECTION 11

ASSUMPTIONS, CRITERIA AND BASES

11.1 INTRODUCTION

The purpose of this section is to describe the study assumptions that are used for evaluating and comparing Nuclear Energy Centers (NECs) with dispersed siting and the criteria used to select promising areas which may contain potential sites for NECs. The study assumptions may be grouped into three categories:

1. Assumptions regarding those physical characteristics of NECs which would have real or perceived impact on society. These assumptions concern the size, number, and cost of the NECs, the resource commitment required, and the impact on the environment resulting from effluents.

2. Basic assumptions underlying selection of issues and the conduct of the study. These assumptions concern institutional factors; Federal, State and local government involvement and responsibility; social, political, community, and economic impacts; safeguards, natural disasters, and national security; and national energy policy considerations.

3. Criteria used in the coarse screening, identifying potential areas where NEC sites may be found. These criteria include the factors deemed most important from a resource requirement and use point of view and relate mainly to land, water, seismicity, and population.

The assumptions and criteria stated here have been selected only for the purposes of the study, viz., for generic evaluation of the feasibility and practicality of nuclear energy centers and for a preliminary, coarse site screening. They are not licensing criteria; they would most likely vary on a site-specific basis; and they are not (without further development) suitable as definitive guides to evaluation of specific candidate NEC sites or features. Identification of these assumptions and a discussion of the basis for their adoption are provided in the following subsections.

There are many interrelated factors that determine the feasibility and practicality of nuclear energy centers. In selecting a set of assumptions, care has been exercised to provide a set of boundary conditions which reflect expected state-of-the-art through the year 2000. In some instances assumptions that were arbitrarily established in order to initiate studies were found to be inappropriate or unsupportable and were subsequently changed; in some instances "sensitivity analysis" was performed to show what effect changing an assumption would have.

Furthermore, in establishing the assumptions an attempt has been made to anticipate conditions, factors, and general environment that may exist in the utility industry 20 to 40 years hence. In the body of the report, assumptions which are sensitive to changing conditions have been discussed to the extent possible, and these should be addressed in greater detail during the planning phase of the NEC siting concept. The factors that argue for and against NECs are fluid, and the attractiveness of the NEC siting concept for a particular region of the country may change with developing technology, public attitude, and regulatory (State and Federal) requirements. For example, the availability of water is region-dependent. Also, the rate of building generating units at NECs, the number and location of NECs, and the timing for initiating NECs depend to a great extent on the nature and character of the various regions. Thus, the assumptions must accommodate a wide range of regional characteristics and practicality considerations, of which growth in power demand is of key significance.

For purposes of this study, NECs include only nuclear power units and related fuel cycle facilities. Fossil energy facilities might be sited with reactors in some cases, but the depth of investigation required was deemed beyond the scope of the NECSS. While it is recognized that certain energy-intensive industrial processes may be located near an energy center, the beneficial and adverse impacts of integrating industrial processes with energy centers are not evaluated.

The assumptions and basis relating to the physical characteristics of NECs are set forth below.

11.2 FACILITIES AND SCHEDULES

This section describes the types of facilities assumed for location on NEC sites used. The assumed characteristics take into account the state-of-the-art expected to be available in the early 1980s when the earliest centers could be initiated.

11.2.1 Power Reactor NEC

Assumption: A power-only NEC in which:

- The basic unit is a 1200-MWe light water reactor (LWR)
- Minimum size - 12,000 MWe (10 LWRs)
- Maximum size - 48,000 MWe (40 LWRs)
- Later phase-in of the HTGR and LMFBR is considered.

Basis: Power-only centers consisting of 10 to 40 nuclear generating units with a capacity of 1,200 MWe each are considered to span the range of interest over the next 20 to 30 years. The 10-unit, 12,000-MWe minimum size NEC is considered to be a reasonable extrapolation from the 2- and 4-unit power stations now being licensed using LWRs. At least three 10-unit centers are being studied by two major utilities. The 40-unit, 48,000-MWe, NEC is believed to be the maximum size of energy center likely to be considered in the next 20 to 30 years. The number of regions in which an NEC with 40 units could seriously be considered by the year 2000 is relatively limited; also a center that large might incur excessive differential penalties except under ideal load distribution circumstances.

The relation of 10-, 20- and 40-unit NECs to the projected power needs by Electric Reliability Council (ERC) for year 2000 is shown in Table 11.1.

The data show that the potential of NECs to meet regional demand in the year 2000 ranges from a small fraction of the regional demand to a relatively large fraction (for large NECs) which may exceed reliability and system security criteria. The tabulation provides a perspective and the relative impact of NECs by region.

TABLE 11.1

PERCENT OF POWER NEEDS WHICH COULD BE SUPPLIED BY AN NEC, BY REGION, FOR THE YEAR 2000

Electric Reliability Council Region[a]	Projected Generating Capacity		Power Needs Supplied by One NEC		
	Nuclear (GWe)	Total (GWe)	10-Unit 12 GWe (%)	20-Unit 24 GWe (%)	40-Unit 48 GWe[b] (%)
ECAR	91	207	6	12	23
ERCOT	41	151	8	16	32
MAAC	83	126	10	19	38
MAIN	71	125	10	19	38
MARCA	32	55	22	44	87
NPCC	70	115	10	21	42
SERC	294	413	3	6	12
SPP	76	181	7	13	27
WSCC	92	202	6	12	24
NATIONAL TOTAL	850[c]	1,575[c]	0.8	1.5	3

[a] The nine Electric Reliability Council regions are:

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

[b] Theoretical, because a 40-unit NEC could not be completed by the year 2000.

[c] Total generating capacity is based on WASH-1139(74) Case A; allocation to ERC regions is based on FPC, Task Force on Forecast Review (1973).

The capacity forcasts of WASH-1139, Case A, address the retirement of oil- and gas-fired units. A national policy to retire oil- and gas-fired units to the greatest extent possible could increase the potential requirement for nuclear units.

11.2.2 Fuel Cycle NEC

Assumption: Energy centers not including power reactors would contain only those fuel-cycle facilities involving strategic special nuclear materials (SSNM) and/or Federal waste management facilities.

Basis: The Energy Reorganization Act of 1974 defined the elements of the nuclear fuel cycle that might be considered, if appropriate, for location at a nuclear energy center as:

uranium enrichment facilities,
nuclear fuel fabrication facilities,
nuclear fuel reprocessing facilities,
and retrievable waste storage facilities.

The analyses presented in WASH-1327, Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in LWRs (GESMO) showed that, with the exception of radiological exposures, the environmental impacts of LWR fuel-cycle operations were generally less than those of the reactors served by the fuel-cycle facilities.

The major emphasis in NECSS-75 on the technical considerations for locating fuel-cycle elements at energy centers has been placed on the LWR fuel cycle operations of spent fuel reprocessing, mixed uranium and plutonium oxide fuel fabrication, and federally operated waste management facilities.* The technical considerations involved in selecting LWR fuel reprocessing and MOX fuel fabrication operations for inclusion in the NECSS-75 are that the operations involve strategic special nuclear materials and that they generate high-level and transuranic (TRU) waste.

Waste management facilities have been included because the fuel reprocessing and mixed-oxide fuel fabrication facilities are the sources of waste required to be shipped to waste management facilities. In addition, waste management facilities may require the dedication of land for very long periods of time.

Fuel Reprocessing and Recycle Fuel Fabrication--LWRs generate plutonium, a fissionable material, which is recovered by reprocessing and then fabricated into fuel at mixed-oxide (MOX) plants. Plutonium is a strategic special nuclear material (SSNM) requiring safeguards. Collocation of fuel reprocessing and MOX fuel fabrication facilities at one site reduces plutonium dioxide shipments, a consideration with respect to safeguards.

Locating several fuel reprocessing plants and MOX plants at a single site (IFCF) is a possible extension of the collocation concept.

Waste Management--Three types of radioactive waste must be transferred to the Federal government for disposal and if necessary, storage prior to disposal. These are high level waste (HLW), hulls generated at reprocessing plants, and TRU waste generated at fuel reprocessing plants and MOX fuel fabrication facilities. TRU waste-generation rates are estimated to be tens of millions of cubic feet per year by the year 2000. Economics requires application of a volume reduction

*The waste management operation for high-level waste is projected to involve storage and ultimate disposal. Transuranic (TRU) waste may require treatment to minimize their volume and recover plutonium prior to storage and ultimate disposal. Although the volume reduction step may be a part of the Federal Waste management operation, it may also be accomplished as a part of the fuel reprocessing plant operation or it may be carried out by private contractors before the TRU waste is transferred to Federal control.

step at the earliest time. Mechanical compaction processes will probably be applied at all plants regardless of size, but combustion either by incineration or chemical decomposition may not be economical at dispersed sites. Collocation or the IFCF would permit use of a combustion process onsite, thus reducing the volume of TRU wastes transferred to Federal management. In addition, it may be possible to locate IFCFs at Federal waste management disposal sites.

The other LWR fuel cycle facilities, and the considerations involved in their potential location at energy centers are as follows:

Uranium Mining--Energy centers are not likely to be located in areas where uranium is mined. The location and relatively short life of the mines would make it impractical to use their sites for energy centers.

Uranium Milling--Extracting uranium from ore and producing a concentrate is now done largely at mills located adjacent to mines. Transportation of large masses of ore to distant mills is not economical, and tailing disposal is best done near mining and milling operations. Hence, mills are unlikely candidates for location at fuel cycle centers.

UF_6 Production--This operation converts the production of the uranium milling operation to uranium hexafluoride (UF_6) the feed to the enrichment operation. Optimal location of these facilities lies between the mills and the enrichment facilities; therefore, they could be located at energy centers.

Enrichment (LWR fuels)--No elaborate safeguards measures are required at enrichment plants making fuel for LWRs. The existing enrichment process (gaseous diffusion) is energy-intensive, making siting of enrichment plants dependent on an available source of power. Future enrichment plants may use other processes that are less dependent on energy. A detailed analysis of both the site and power reliability would be required before a decision to mass the major source of LWR fuel supply at one or two locations could be made. Although there is some economic advantage to onsite location of enrichment plants near power facilities, because of lower transmission losses, no detailed evaluation of such siting has been made.

UO_2 Fuel Fabrication (LWR Fuels)--The enrichment of uranium fuels for LWRs is less than 5% ^{235}U. This material does not require elaborate safeguards. Projections of existing fuel fabricators imply that existing facilities will be expanded to the extent that they can be licensed and justified economically. New plants could be candidates for location at energy centers.

The major driving forces to consider fuel cycle centers are concerns for safeguards and waste management. The generic siting of UF_6 production, LWR enrichment or UO_2 fuel fabrication, on a site that contains a fuel reprocessing plant or a mixed-oxide fabrication facility, or both, appears not to require substantive evaluation of the technical feasibility beyond those evaluations required to site the reprocessing and/or mixed oxide plants. Hence the LWR fuel cycle operations considered in the NECSS-75 have been limited to those involving SSNM and the Federal waste management facility.

LMFBR fuel cycle operations (mixed oxide fuel fabrication and fuel reprocessing) and HTGR fuel cycle operations (topping enrichment and fresh ^{235}U fuel fabrication, and fuel reprocessing and recycle fuel fabrication) have been evaluated in the NECSS because they require handling of SSNM and may involve Federal Waste Management facilities.

11.2.3 Combined Nuclear Energy Centers (Plutonium Management)

Assumption: Plutonium management, and commercial incentives, are potential motivating factors in the development of combined reactor and fuel-cycle facility centers.

Basis: If a large number of reactors are located in a limited geographic area, fuel reprocessing plants could be sited close to these reactors so that spent fuel shipping costs could be minimized, control over plutonium shipments could perhaps be improved and any potential safeguards advantages of energy centers could be extended.

Recycle of plutonium to LWRs may require shipping of bulk plutonium dioxide and mixed oxide fuel assemblies. LWRs known as "plutonium burners" operate with 100% PuO_2 fuel. These reactors consume more plutonium than they generate; hence plutonium recovered from all LWRs could be concentrated in fewer plutonium burners.

A single site with reactors, fuel reprocessing, and MOX fuel fabrication facilities could eliminate the need for offsite shipments of plutonium in any form. Hence, in the analysis of mixed centers and their development, the plutonium management option has been emphasized.

11.2.4 Four-Unit Dispersed Siting

Assumption: The basic comparison for power only NECs is with the equivalent number of reactor units located at four-unit sites (Quads) dispersed throughout the country.

Basis: The 4-unit dispersed site was selected as a basis for comparison because: 1) four-unit sites are being licensed at the present time, and it is anticipated that the trend will be to four units or more per site; 2) the difficulty of finding a suitable number of sites for single- and twin-unit stations to meet projected power demands by the year 2000 is expected to encourage the siting of several units on dispersed sites; 3) preliminary study of conventional construction practice for stations ranging from one to four units per site reveals that a substantial part of the savings derived from multiple unit construction is achieved by the time the fourth unit is built. Therefore, assuming a base case of four reactors per site would result in a conservative estimate of economics that could be achieved from the construction of an NEC.

11.2.5 Reference Heat Dissipation System

Assumption: Wet natural-draft cooling towers are used as a conceptual reference system for dissipating waste heat.

Basis: The preferred heat dissipation system for an NEC depends on the specific site characteristics. For comparing NECs with dispersed siting, and for determining water requirements, wet cooling towers are used as a reference. Wet cooling towers are suitable for most, if not all, potential NEC sites and dispersed sites, while other cooling systems (once-through, cooling lakes/ponds, spray canals, etc.) are dependent on favorable site conditions. In addition because NECs using wet cooling towers are expected to have the greatest climatic impact, any limiting constraints associated with waste heat dissipation would be revealed. While wet cooling towers are used as a reference, all heat dissipation systems are analyzed. The results of this analysis are presented in Section 3, Part III, Heat Dissipation.

The use of dry towers, which may be necessary where water resources are limited, is also reviewed in Section 3, Part III. The general application of dry towers is considered to be economically unattractive due to high station heat rate and capacity losses.

Dry towers also deliver all of the dissipated heat as sensible energy directly contributing to bouyant convective forces. The concentration of dry towers on an NEC is expected to have a greater and less predictable climatic impact than wet towers.

11.2.6 Initial Generation Date

Assumption: Power generation at an NEC could start in 1985.

Basis: From a practical viewpoint, the earliest that a power plant on an NEC could come on line and begin producing power is between 1985 and 1990. Depending on the number of units planned, regional power needs, and other considerations, NEC construction activities could take from a minimum of about 15 years to 30 or more years.

11.2.7 Plutonium Recycle

Assumption: Plutonium recycle to LWRs is licensable and would begin in the early 1980s. LMFBRs become a commercial reality in the 1990s. Plutonium burners become available in the late 1980s.

Basis: The Nuclear Regulatory Commission is presently considering whether plutonium recycle in LWRs may be licensed. The NECSS makes no judgment of the outcome of this consideration, but makes the assumption of plutonium recycle since the center concept for fuel-cycle facilities appeared to be primarily related to those fuel-cycle elements which are specifically associated with the use of plutonium in reactors. The provisional NRC policy on Pu recycle implies no additional licensing actions on Pu recycle prior to about 1977. A delay of about 5 years beyond that date has been assumed for large-scale recycle based upon considerations of licensing and construction of the necessary fuel cycle facilities.

The date for LMFBR commercialization (about 1993) is based on ERDA projections.

With substantial amounts of plutonium available in the early 1980s, it may be possible to demonstrate the validity of the proposed plutonium burner design by the mid-1980s. Reactors designed to operate on either UO_2 or PuO_2/UO_2 fuel (at some loss of efficiency in plutonium use) could be brought on line in the late 1980s.

11.3 POWER PROJECTIONS

It is necessary to investigate the growth in electric power demand in order to gain a perspective on the possible role of NECs in providing generating capacity.

The number of NECs, the rate of their development, and their ultimate size must be related to ERC regional electric systems. For the NECSS it was necessary to select a forecast of electric power growth. Then a sensitivity analysis was made to determine whether there is a minimum installed capacity and growth rate which would make NECs impractical for any region and to identify those ERC regions where NECs would be most attractive. The results of this analysis are presented in Section 6, Part V.

The assumptions relating to power projections are presented below.

11.3.1 Projection of Energy Consumption

Assumption: The projection of energy consumption, electric generating capacity, and growth of nuclear power as contained in Case A of WASH-1139 (74), Nuclear Power Growth 1974-2000, is used as the base case.

Basis: Numerous forecasts of energy and electricity have been prepared over the years by responsible forecasters. Because of uncertain conditions (such as increased environmental concerns, awareness of the need to conserve energy and natural resources, increased emphasis on alternative energy sources, and the effect of substituting one energy source for another) the forecasts for electric generating capacity, both nuclear and fossil, vary widely. The approach taken for the NECSS study was to analyze these forecasts and to select as a base case one that is in the range of generally accepted forecasts and that also contains sufficient background information on projected nuclear plants and the nuclear fuel cycle requirements.*

11.3.2 Regionalization of Case A of WASH-1139

Assumption: The capacity projections in Case A of WASH-1139 can be allocated to the ERC regions by using FPC 1973 National Power Survey data and population projections.

Basis: The allocation to ERC regions of Case A forecasts for nuclear generating capacity is based on the capacities of nuclear plants in existence and those expected to be completed as

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*Recently, R. LaGassie, ERDA Assistant Administrator for Planning and Analysis, testified before the House of Representatives and presented a low case of 625 GWe of nuclear capacity out of a total national electrical projection of 1550 GWe. The difference between 625 GWe and 850 GWe does not appear to lessen the conceptual feasibility of NECs based on sensitivity analysis in Section 6, Part V.

indicated by the nine Regional Electric Reliability Councils' forecasts of nuclear power. These forecasts are presented in the FPC 1973 Task Force on Forecast Review. The methods used to regionalize the forecasts are described in Section 6, Part V. The regionalized data for nuclear and total generation are shown in Table 11.2.

TABLE 11.2

ESTIMATED ELECTRIC GENERATING CAPACITY BY REGION, NUCLEAR & TOTAL

	1975 GWe		1985 GWe		2000 GWe[a]	
Region	Nuclear	Total	Nuclear	Total	Nuclear	Total
ECAR	2.4	77	28	117	91	207
ERCOT	0	34	10	63	41	151
MAAC	6.0	46	27	70	83	126
MAIN	5.9	42	17	65	71	125
MARCA	3.9	20	10	30	32	55
NPCC	7.9	52	28	66	70	115
SERC	12.0	104	70	185	294	413
SPP	0.8	45	14	78	76	181
WSCC	4.1	90	27	126	92	202
TOTAL	43	510	231	800	850	1,575
	(8.43%)		(27.12%)		(53.90%)	

Note: National total from WASH-1139(74) Case A, regional share of total and nuclear capacity based on FPC, Task Force on Forecast Review (1973).

[a]One gigawatt = 1,000 megawatts. Divide GWe values by 12 to obtain equivalent number of smallest NECs, and by 48 to obtain equivalent number of largest NECs.

WASH-1139 uses the Census Bureau's "Series E" population projections as a basis for energy and economic growth forecasts. The U.S. Water Resources Council uses as a planning assumption the OBERS projections which are also based on the Census Bureau's "Series E" population projections. Since the FPC uses ERC forecasts in its National Power Survey Forecast, the views and interests of ERCs are recognized. The power projections are intended as indicators of a region's economic activity and do not reflect regional goals.

11.4 COST ASSUMPTIONS

The cost assumptions associated with comparing NEC siting with dispersed siting of nuclear power plants are as follows:

11.4.1 Price Estimate Basis

Assumption: To the extent possible, cost and price estimates are in December 1974-January 1975 dollars.

Basis: Cost and price estimates are based for the most recent data available. Generally these were for December 1974 or January 1975. In instances where cost data were taken from other reports the costs were escalated, when possible, to January 1975.

11.4.2 Discount Rate

Assumption: The discount rate used throughout the NECSS is 10%.

Basis: NRC uses a discount rate of 10% for its economic analysis; also, the Office of Management and Budget (OMB) used 10% in their analysis of Federal agency projects (Circular 94-A). The use of the 10% discount rate and the inclusion of a sensitivity analysis allow identification of cost relationships between NEC siting and dispersed siting that are sensitive to discount rates.

11.4.3 Nuclear Generating Unit Lifetime

Assumption: Nuclear generating unit economic lifetime is 30 years.

Basis: A lifetime of 30 years for nuclear units is generally used by NRC in benefit/cost evaluations. Specific lifetimes of units differ in various regions of the country, depending on utility practice and State regulatory policy.

11.4.4 Reference Generating Unit Cost Basis

Assumption: Nuclear generating unit costs are based on light-water reactors.

Basis: Data are readily available for LWRs, and many of these generating units are operating or are being built.

11.4.5 Transmission Facilities Lifetime

Assumption: The lifetime of the transmission facilities is 50 years.

Basis: A lifetime of 50 years is generally accepted by the utility industry and the FPC in treating the value of interstate power transfer.

11.5 TRANSMISSION

The goal of the transmission studies of NECSS is to analyze and compare the electrical power system that might develop, if nuclear energy centers are developed, with a system which is based on dispersed sites. The studies are intended to identify the different approaches to transmission systems that might be used for NECs vs. those used for dispersed sites. The possibility that NECs may require different transmission systems than do dispersed sites should not be overlooked. The influences of the different transmission approaches on technological developments and R&D needs are assessed. Assumptions used for the transmission studies are set forth below.

11.5.1 Transmission Voltage

Assumption: The principal voltage used for the development of transmission overlays for NECs in this study is 765 kV a.c.

Basis: Other voltages and methods may be feasible, but the 765 kV system is the best practicable, proven technology. Systems using 500 kV are in operation and are generally accepted as environmentally acceptable. While there is opposition in some regions to the installation of higher voltages, at 765 kV the power-handling capacity of transmission lines is large enough to minimize the required number of lines and rights-of-way. Also, for regions with relatively low mean transmission distances the cost of transmission using current technology indicates that 765 kV is an appropriate choice. UHV systems of 1200 kV are not state-of-the-art practice, and may have environmental problems involving induction and clearances.

The 400 kV d.c. line between Oregon and California (800 miles) has been a pioneer application of direct current transmission, but has unique operating efficiency problems. High-voltage d.c. systems may be attractive for transmission distances of 400 miles or greater and in the future may be an economically and environmentally favorable alternative for NECs where large point-to-point power transfers fit the regional system.

11.5.2 NEC Capacity

Assumption: For the purpose of assessing the number of NECs that might be used to meet regional power needs and determining likely rates for adding generating units to NECs it was assumed that, for reasons of reliability, no more than 15% of an electric reliability region's total generating capacity at any given time would be located at any one energy center. The effect of an NEC on the regional reliability would be the same as that of the equivalent dispersed four-unit stations.

Basis: As a general rule utilities do not put more than about 15% of their total capacity at any one site. This factor varies from utility to utility, depending primarily on the strength of the transmission system and the intertie system within pools. The assumption of a 15% factor may be low because it may be possible to design the NEC transmission system to permit parts of the center to function independently of other parts in the event of multiple unscheduled outages. The validity of the 15% assumed limitation must be evaluated for each region and adjusted to provide the desired reliability.

11.5.3 Switchyards and Transmission Lines

Assumption: Groups of four or five 1200-MWe generators will be serviced by one switchyard and at least two, and preferably three, transmission lines, depending on transmission distance and reliability/stability requirements. For maximum reliability, four-unit clusters within an NEC may have selective load segregation.

Basis: Because no single fault nor the loss of any one line from a switchyard should be able to directly affect the entire NEC or in turn, a load center, only the units within a four-unit cluster would be selectively bussed together. The power-handling capacity of two 765 kV lines exceeds the power generated by four or five 1200-MWe units. On a regional basis, the proper combination of lines can be selected to provide reliable offsite power by selective isolation of problems without involving the entire NEC.

11.6 CONSTRUCTION

The objective of the construction study for power centers is to identify "strong difference" trends between the NEC and dispersed power plant projects from the construction point of view.

11.6.1 Basic Site Layouts for Study Cases

Assumption: The following four basic site layouts are selected for analysis of power-only NECs.

- Nuclear Energy Center Case I--single cluster of 20 and 40 units
- Nuclear Energy Center Case II--two and four clusters of 10 units each
- Nuclear Energy Center Case III--five and ten four-unit groups scattered throughout the site
- Nuclear Energy Center Case IV--five and ten four-unit groups in an elliptical pattern.

Basis: The four site layouts cover a broad spectrum of possibilities and provide a basis for determining whether site layout is a significant factor to consider in designing NEC sites. The study has included consideration of the number of units which might be constructed in a series and the means by which changes in the series, or adaptation to reactor designs other than LWRs, might be accommodated. Also included are construction methods, the alternatives contributing to the construction environment, standardization, labor cost savings from a "levelized" craft work force and central management, specialized central shops, assembly areas, and fabrication facilities for modularization. Also, the four-site layouts provide at least four options for heat dissipation systems. The four cases are used to test the sensitivity of different configurations to heat dissipation systems and radiological doses. The construction activities with respect to time are also evaluated.

11.6.2 Dispersed Quad-Unit Station

Assumption: The dispersed site is a quad-unit station composed of two twin-units. Also, the quad-unit was selected as the unit module for building the NEC cases.

Basis: Construction experience and detailed data are plentiful for 1200-MWe single-unit and 2400-MWe twin-unit stations. This formed the basis for the quad-unit and the NEC estimates.

11.6.3 NEC Site Size

Assumption: The maximum NEC case is a 48,000-acre rectangular site (75 square miles in area) and includes a 4000 ft exclusion zone.

Basis: This is based on 40 units and one MWe per acre normalized power density for heat dissipation. The one MWe per acre is based on heat dissipation considerations discussed in Section 3, Part III.

11.6.4 Heat Dissipation System

Assumption: For each light water reactor unit, the main condenser heat dissipation system is a single 450-foot diameter wet natural draft cooling tower requiring 45 cfs of water for evaporation and blowdown. The emergency core-cooling system uses a Class I dry cooling tower. The shutdown cooling would be done by an evaporative system using stored water.

Basis: Because the use of pond cooling in the closed cycle mode, or the use of once-through cooling, is site-specific, the NECSS uses proven technology which can be examined on a generic basis. Wet evaporative cooling, while incurring some economic penalty, meets this guideline. Within classes of wet evaporative tower systems, the hyperbolic natural draft tower is technically and environmentally feasible in many regions of the country. It is recognized that wet natural draft towers will not operate efficiently in dry regions. However, for study purposes this factor is not considered as of overriding significance, because the areas of greatest potential application for NECs offer acceptable ambient conditions.

Most LWRs use natural water bodies or ponds for shutdown and emergency cooling. However, these applications are all site-specific. The study assumptions offer the best means of treating ancillary cooling without site-specific design study. The assumed systems are licensable under NRC regulations.

11.6.5 Power Center Arrangements

Assumption: All power center arrangements are designed to: 1) avoid concentrating transmission lines in any one area; 2) space the switchyards around the nuclear energy center perimeter; and 3) limit to 12 the number of generating units connected to one cooling water makeup/blowdown system.

Basis: Design considerations will govern the detailed arrangement of NECs. These can be expected to vary widely with respect to site-specific conditions. The three factors in the layout assumption permit generic treatment of centers without detailed site data; they are not sensitive components in the cost analysis of NECs.

11.7 RADIOLOGICAL ASSESSMENTS

NRC has recently published "as low as reasonably achievable" (ALARA) rules for radiological commitments for LWRs (40 CFR 19439), dated May 5, 1975. The Commission has not specified site limitations; ALARA limitations have been specified on a per reactor basis for the dispersed siting concept. No ALARA criteria for nuclear energy centers have been published.

11.7.1 Effluent Control

Assumption: Effluent control technologies presently available are used to estimate radiological effluents from facilities.

Basis: Source terms which are realistic under the present licensing conditions are used as a basis for all calculations in order to have a consistent and conservative approach.

11.7.2 Meteorological Conditions

Assumption: Average meteorological conditions for river basins are used to estimate atmospheric dilution between source and receptor.

Basis: The WASH-1258 Final Environmental Statement concerning proposed rulemaking action contains numerical guides for design objectives and limiting conditions for operation to meet the criteria "as low as practicable" for radioactive material in light-water cooled nuclear power reactor effluents. The average conditions used are drawn from this source.

11.7.3 Radiological Dose Commitments

Assumption: Annual radiological dose commitments from all pathways are the 50-year dose commitments received in the last year of plant operations, so that long-lived isotopes in the environment are at or near their equilibrium or maximum concentration.

Basis: This assumption offers a conservative means of treating the ultimate commitment without the bias that might be introduced by intermediate assessments in time.

11.8 LAND USE

The land requirements for NECs are sensitive to considerations involving heat dissipation, radiological assessment, and transmission corridors. The decision to construct a center requires a commitment for land use which extends for many years. The areas used in existing nuclear power stations provide some guidance, but the special nature of an NEC requires a special basis which is both site-specific and capable of evolutionary adjustment.

11.8.1 Land Area Required

Assumption: The area required for a power center is set at one acre per MWe. A 40-unit center requires about 75 square miles. If power generating units are grouped in clusters of four units, the clusters will be about 2.5 miles apart.

Basis: While the one acre per MWe is used for NECSS study purposes, there is insufficient scientific knowledge of both meteorological and environmental effects to provide a firm technical basis for this assumption. The one acre per MWe has been estimated as a large enough area to minimize possible problems attributable to injection of heat and water vapor into the atmosphere. With further research it may be possible to reduce the area needed for an NEC site. In order to permit assessments on a conservative basis, the value used for land requirements appears to offer a means to make the assessment generically.

11.8.2 Land Area Required for a Quad-Unit

Assumption: The assumed design of a quad-unit station consists of a rectangular site with the generating units occupying about 500 acres in the center and an additional 4000-foot exclusion zone on all sides, for a total area of about 3,700 acres. (1.3 MWe per acre)

Basis: Based on WASH-1255, a study of siting parameters for existing stations, the actual land areas for dispersed sites range from 300 acres to about 7,000 acres. The large sites, above 1,500 to 2,000 acres, are those which have cooling lakes or which are intended to accommodate a number of generating units (including fossil-fueled units). The area assumed for the dispersed case is in the midrange of areas for stations either operating or under construction.

11.8.3 Fuel Cycle Land Requirements

Assumption: The space required for dispersed fuel cycle facilities is assumed to be 9 square miles for a chemical reprocessing plant and 3.25 square miles for a mixed-oxide (MOX) fabrication plant. An integrated fuel cycle facility (IFCF) consisting of several chemical reprocessing plants and fuel fabrication plants requires about 24 square miles.

Basis: These estimates are based on requirements of existing plants or plants under licensing consideration.

11.9 WATER USE

In order to perform a survey of possible NEC sites, it was first necessary to establish criteria or guidelines for the NEC requirements and for the necessary resources to meet these requirements.

11.9.1 Consumptive Use of Water For Power NECs

Assumption: For a 1200-MWe LWR it is assumed that the consumptive use of water is 30 cfs. The cooling water is drawn from local surface waters, and some percentage of this intake is returned as blowdown from the NEC cooling system.

Basis: The water requirements for an NEC will depend on the type of cooling system used. This survey uses the wet natural-draft evaporative cooling tower. The consumptive water use of wet towers for one 1200-MWe unit during extreme summer conditions is 30 cfs. This represents a demand placed on the integrated basin water resources in the vicinity of an NEC; it is proportional to the number of units at an NEC. The consumptive water requirements for fuel-cycle facilities are minor, compared to the cooling water needs of power plants; thus, the water use assessment is based on the needs of power-only NECs.

11.10 AIR USE

11.10.1 Climatic and Air Quality Conditions

Assumption: The assessment of the impact of an NEC on climatic and air quality conditions will consider:

- meteorological, topographic, and air quality characteristics;
- amount of heat to be dissipated;
- type of heat dissipation system(s) (wet or dry, natural or forced draft, cooling ponds, spray ponds, etc.);
- area over which heat is dissipated and;
- configuration of the heat dissipation system(s).

Basis: These are the main factors to be considered. All of these are directly related to the alteration of the ambient environment. Secondary factors include the relationship of the ambient environment to the ecological ambient, including forest cover and general terrestrial conditions. Most factors are site-specific, and the comparison of a given NEC to equivalent four-unit sites is incomplete without expansion to regional perspective. Other considerations include types and amounts of industrial, commercial, agricultural, and residential development to be expected, or allowed, in the immediate vicinity of an NEC.

11.11 ENVIRONMENTAL

The primary environmental factors considered are thermal, chemical, ecological, social and economic.

11.11.1 Water Discharge

Assumption: The water discharged into rivers and lakes from NEC cooling systems must meet the regulations of EPA, the States and local governments.

Basis: For study purposes the requirements for new sources under EPA guidelines in 40 CFR Part 423 are applied to both centers and dispersed four-unit stations.

11.11.2 Discharge to Air

Assumption: The discharges of hot air and water vapor into the atmosphere are those from an operating 40-unit NEC.

Basis: Discharges of heat and water vapor into the atmosphere from an operating 40-unit NEC, will have the maximum impact on the local meteorology. These discharges are not currently regulated, but it is anticipated that they will be in the future.

11.11.3 Chemical Discharges

Assumption: The chemicals which are discharged with the effluent water will meet the regulations of EPA, the States and local governments.

Basis: It is anticipated that discharges of chemicals with cooling water will meet the applicable regulations. Blowdown control and zero-liquid-discharge systems are available for potential sites where salinity increase of the water source must be limited.

11.11.4 NEC Operation Schedule

Assumption: For purposes of the environmental assessment, it is assumed that the 40-unit NEC first produces power in the late 1980s and is completed with all facilities operating by the year 2020. For the ecological impacts the NEC is considered completely built (as a 40-unit NEC might look in the year 2020).

Basis: The 40-unit NEC provides the most conservative assessment of local impact in comparison to dispersed four-unit stations. Other intermediate sizes would have intermediate effects compared to dispersed sites.

11.11.5 Social and Economic Impact

Assumption: For the social and economic impact assessment it is necessary to forecast the changes that will occur during the entire period from initial construction in the early 1980s to final completion when all facilities are in operation. For this assessment various completion times based on a construction rate of one plant per year are selected for 10-, 20- and 40-unit NECs.

Basis: The most concentrated and relatively severe initial economic and social impacts of any large construction project occur in the immediate environs of the construction site. The economic impacts include effects on the local economy, governmental services, and finances; while the social impacts include effects on human activity patterns, health, safety, recreation, aesthetics, and noise. The assessment of impacts is expected to be sensitive to the region, the rate of construction, and the number of units at an NEC. In studying these factors, centers will have to be compared with the equivalent capacity of dispersed four-unit stations.

11.12 MANPOWER ASSUMPTIONS

The manpower requirements assumed to be necessary for the construction, operation, and support of the various NECs are discussed below:

11.12.1 Power Reactor NECs

Assumption: A power-only NEC could require a peak construction labor force of 5,000-10,000 people, depending on its ultimate size and construction rates. Operating manpower for a 40-reactor NEC would be about 4,000 workers.

Basis: A recent study by the National Science Foundation and manpower data on 1973-1974 construction and operations by TVA are the source material for the above assumption.

11.12.2 Fuel-Cycle Facility NEC

Assumption: An integrated fuel cycle facility (IFCF) could require a peak construction force of about 4,000 people, and an operating force of 4,000-5,000 people. At anticipated construction rates a regional integrated fuel cycle facility could be completed in about 10 to 20 years. Hence, a somewhat less permanent population than for a large power-only nuclear energy center might result.

Basis: Judgments, based on other studies and knowledge of recent construction and operation manpower experience.

11.12.3 Secondary Population

Assumption: Accommodations for up to 50,000 people or more could be needed for a large NEC project.

Basis: Since a 40-reactor-unit site would take decades to complete, both construction and operating personnel would be on the site fairly continuously. Housing and services for construction workers, operators and their families will need to be provided in existing villages or towns, or in "new towns."

11.13 SURROGATE SITES

Assumption: The surrogate site analysis technique was adopted to study many of the issues important to the evaluation of technical feasibility and practicality.

Basis: Surrogate site analysis is a valid technique for using specific site data to verify the generic evaluations and conclusions developed in the study. As used in this context, a surrogate site is defined as a "substitute" or a "representative" site, and the technique is used exclusively for developing assessment methodology, identifying problem areas, quantifying judgments, and minimizing any study bias that might occur from purely generic evaluations. The use of a surrogate does not mean that the specific site is recommended for the location of a nuclear energy center.

11.14 BASIC ASSUMPTIONS RELATING TO ISSUES

Selection of issues for conducting the study of the practicality of NECs as compared to dispersed siting was based on the considerations discussed below.

11.14.1 Consideration of Institutional Factors

Institutional arrangements made for a specific purpose, such as NECs, almost always have consequences in broader areas than the specific purposes for which they are set up. It is important to trace and evaluate the potential broad consequences of any institutional arrangements set up specifically for NECs.

11.14.2 Governmental Involvement and Responsibility

The interests and viewpoints of different levels and entities of government that will be involved in implementing nuclear energy centers, or that would be affected by the consequences of having them, were sought out and carefully considered. The study includes consideration of the viewpoints and concerns of various Federal agencies, States, possible regional groupings, and local government entities.

11.14.3 Social, Political, Community and Economic Impacts

Costs and benefits may accrue indirectly as a consequence of having NECs. These may be important factors in evaluating the practical merits of NECs. Examples of these indirect consequences include population shifts involved in assembling work forces for center planning, construction, and operation, as well as supporting services for these work forces; and the necessity of institutional adaptations to large clusters of economic and political power which may result from the greater degree of clustering of facilities.

The direct and indirect costs and benefits may be unequally distributed among the different groups that contribute to the enterprise, use it, or are affected by it through circumstances of location or otherwise. Measures that might be effective in achieving reasonable equity can be an important practical concern.

Indirect impacts on social, economic, and political life around NECs can be complex and significant. Those impacts occur at secondary, tertiary, and even more remote levels. Tracing the many interactions between a large technological enterprise and its social impact over all the anticipated decades of the life of the enterprise is too complex for dependable analysis. Nevertheless, attempts at evaluation may be valuable as aids to relevant policy formulation.

11.14.4 Allocation

There are economic consequences of proceeding with the implementation of NECs which cannot be quantified or included in the economic and cost analyses. For example, allocation of public land for an NEC does not make that land "free" in an economic analysis that is truly meaningful on a macroeconomic level. Similarly, the allocation of "free" water, which consequently would be withheld from possible competing uses in agriculture, other industry, or domestic or commercial use, must also be recognized as representing a quite real part of a total cost, even though these costs are not included in an accounting sense.

11.14.5 Natural Disasters and National Security

Loss of a power NEC could conceivably affect electric reliability to such a degree that it would have an impact on society or national security. Such loss could occur either from the effects of natural disasters on transmission facilities and cooling towers, or from sabotage or enemy attack (which could also result in additional considerations of radiological impact). While the impact is expected to have limited significance because the NEC would generate only a small fraction of national or regional generating capacity, it is felt that the subject merits detailed analysis.

11.14.6 Strategic Nuclear Material Safeguards Considerations

The study assumes that a certain level of protection against the diversion of strategic nuclear material must be attained for any siting option selected. This involves transportation, facility protection, and accountability. Adequate alternative methods of safeguarding need to be identified and their costs and benefits factored into the overall assessment of NEC siting in comparison with dispersed siting.

11.14.7 National Energy Policy

The broad issues of national energy policy, plans and projections for power demand, peak demand leveling, population projections, regional shifts of population and power demand, the desirable and proper role of nuclear power will all have a bearing on the practicality of NECs. Such issues are generally beyond the scope of the study, but there is a basic underlying assumption that it is possible to make a valid and meaningful comparison of NECs with dispersed sites without resolving these broad issues.

11.15 COARSE SITE SCREENING

In this section coarse screening criteria are presented for the factors deemed most important with respect to resource requirement and use. These criteria are used to select areas which may contain potential nuclear energy center sites. (This preliminary coarse screening is not necessarily equivalent to the initial screening effort applied by a utility in its choice of areas for site selection consideration.) More detailed analyses of these areas may subsequently reveal portions that are unsatisfactory for nuclear energy centers. On the other hand, some presently excluded areas may prove to contain satisfactory nuclear energy center sites.

11.15.1 Land

11.15.1.1 Land Area Location

Criteria: Land area to be considered for nuclear energy center sites must lie within the 48 contiguous States. The projected demand for electric energy in the area for which an NEC is being considered must be great enough to support a small NEC by the year 2000.

Basis: Virtually all of the immediate energy problems in the U.S. are associated with the 48 contiguous States. Area power demands of less than 12 GWe by the year 2000 are considered to be too low and futuristic to be considered as likely for energy center development. Offshore siting, still in the early development stages, was not considered in the NECSS; at present, one proposal for twin offshore nuclear generators is being evaluated by the NRC staff.

11.15.1.2 Topography

Criterion: In areas to be considered, at least 20% of the land must have a slope of less than 8%.

Basis: Nuclear energy centers require large blocks of relatively level land, ranging from an estimated 20 to 75 square miles. Areas with excessive land slope are more costly to develop.

11.15.1.3 Excluded Land

Criterion: National parks, national forests, national wilderness areas and national historic monuments are excluded from consideration. (These areas are shown in green on the U.S. map which is bound separately and is being circulated with Part I of this report and on the 11 regional maps in Section 7, Part V.)

Basis: Section 207 of the Energy Reorganization Act of 1974 specifically excludes these areas.

11.15.1.4 Wilderness Areas

Criterion: Wilderness areas are generally not acceptable for NECs.

Basis: The Congress has designated certain areas as wilderness (78 Stat. 890). "These areas are to be preserved as an enduring resource of wilderness which shall be managed to promote and perpetuate the wilderness character of the land and its specific value of solitude, physical and mental challenge, scientific study, inspiration and primitive recreation..." (Congressional Record, 93 Cong., 2nd Session, 19 December 1974, (daily ed.) 120:S22138.)

11.15.1.5 Public Lands

Criteria: Certain types of publicly owned land, Federal or State, if it is available in parcels of 8,000 acres or more, may be considered for NEC sites.

Basis: Section 207 of the Energy Reorganization Act of 1974 provides for consideration of federally owned lands. For purposes of this survey, State-owned lands have also been included. For planning purposes, one MWe per acre was used to size the land areas required for an NEC. Therefore, a 10-reactor energy center generating 12,000 MWe would require a 12,000-acre site. To assure that potentially desirable publicly owned land was not overlooked in the coarse screening, Federal and State land in excess of 8,000 acres is identified to the extent possible on all of the regional maps at the end of Section 7, Part V.

11.15.2 Water

11.15.2.1 Water Flow Requirements for Rivers

Criteria: The water resources required for a 10-unit NEC using wet cooling towers are based on the following:

For Category I (preferred areas):

- The Mississippi River, rivers in States bordering the west bank of the Mississippi River, and rivers to the east of the Mississippi River having a mean annual flow of 6,000 cfs or greater, and a 30-day, 20-year low flow of no less than 3,000 cfs.

- Rivers west of the western borders of the Mississippi River west-bank States having a mean annual flow greater than 15,000 cfs, and a 30-day, 20-year low flow of no less than 6,000 cfs.

For Category II (next best), these criteria would be applied to rivers that currently do not meet the 30-day, 20-year low flow requirements listed above, which means that impoundments would have to be added to accommodate seasonal variances in flow:

- The Mississippi River basin, as defined in Category I, and rivers to the east with a mean annual flow of 6,000 cfs or greater, and a 20-year annual low flow no less than 3,000 cfs.

- Rivers west of the western borders of the Mississippi River west-bank States with a mean annual flow of 15,000 cfs or greater and a 20-year annual low flow no less than 6,000 cfs.

For Category III (least desirable):

- All sources not in Categories I or II.

Basis: To evaluate the adequacy of a river to supply an NEC, with or without water management (storage), the mean annual flows and 20-year low flows were considered.

Category I criteria apply to rivers which may or may not have water management but whose existing flow characteristics appear to be adequate to supply sufficient cooling water during seasonal variances without undue impact on the environment or on other users. Category II criteria apply to rivers that might meet the Criteria I flow requirements if additional water management practices were employed.

If water is stored for use during periods of low river flow, many additional areas can be considered potential NEC sites. In determining the river flow requiring additional impoundments, neither the feasibility of building the particular reservoir nor its required capacity is considered in this study since conditions vary from site to site.

Water may be stored by on-stream reservoirs or by pumping to special single-purpose off-stream reservoirs.

To determine the flow required, it is assumed that the water consumption rate must not exceed 5% of the annual 20-year low flow in the western part of the country, and 10% in all other parts. The impact of this amount of consumption on the ecology of the river and the water available for other uses generally is not believed to be significant. However, it is recognized that these criteria might be too conservative in some cases while in other cases, where the river is totally committed to some other use, it may be difficult to allocate this amount of flow or consumptive use to an NEC. River-by-river analyses are required to determine actual water "available" for use.

11.15.2.2 Oceans and Great Lakes

Criterion: The oceans, including the Gulf of Mexico, are considered to be infinite sources of water. The Great Lakes are treated as large reservoirs in a river basin.

Basis: Nuclear energy centers located in the vicinity of oceans and the Great Lakes need not have the constraints of those located near flowing streams. However, all bodies of water are subject to local ecological damage which must be fully considered.

11.15.2.3 Estuaries

Criterion: Estuaries are excluded from consideration.

Basis: The importance of estuaries to the marine life cycle may severely restrict their use as either a water source or point of discharge for "blowdown" (the water which a cooling system returns to the river after evaporation has reduced its volume and concentrated the dissolved materials in it).

11.15.3 Seismicity

11.15.3.1 Seismic Zones

Criteria: For the purposes of coarse screening to identify potential nuclear energy center siting areas, the United States is divided into three seismic zones as follows (see Plate 4.1, Section 4, Part V):

- Zone I--This zone includes areas of low seismicity with no known capable faults. It is expected that seismically suitable sites will be found with little difficulty.

- Zone II--This zone includes two categories: (1) areas with moderate seismicity and complex geological structures, having numerous, old, incapable faults, and (2) areas close to zones of high seismic risk, which may lend to controversial risk assessment. Detailed site specific studies will be necessary to determine geologic/seismic site suitability.

- Zone III--This zone is characterized by high seismicity, accompanied in most cases by intense, recent faulting. It is expected that the cost and time required for investigation of site suitability would make it impractical to consider these areas for nuclear energy centers at this time.

Basis: The three zones represent NRC staff judgment with respect to the seismic stability of various land areas. The zones differ according to the relative difficulty of establishing the design value for the horizontal motion of the ground at the foundations of Category I structures at a nuclear energy center. The judgment is based on relative seismic risk maps and licensing experience. Consideration is given only to historical earthquake activity and known faulting. Other geological factors such as karst regions and subsidence are not considered.

Nuclear power reactors are designed to prevent loss of functions affecting the safety of the operation. Generally, the most restrictive safety-related characteristics considered in determining the suitability of a site are surface faulting, potential ground motion and foundation conditions (including liquefaction, subsidence, and landslide potential), and seismically induced floods. Criteria that describe the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability are provided in "Seismic and Geologic Criteria for Nuclear Power Plants," Appendix A to 10 CFR Part 100. Safety-related site characteristics are identified in U.S. Nuclear Regulatory Commission Regulatory Guides 1.70, Section 2.5, and Regulatory Guide 1.59. In addition to providing geologic and seismic evaluations for assessing seismically induced flooding potential, Section 2.4 of Regulatory Guide 1.70 and Regulatory Guide 1.59 describe the hydrologic criteria that should be considered, including coincident flood events.

In general, nuclear facilities can be designed to accommodate many site conditions. For example, plants in the western United States have been designed for acceleration values of up to 0.67 times the acceleration due to gravity (0.67g). However, the economic penalties associated with restrictive site conditions must be taken into account in the overall cost benefit analysis when alternative sites are being considered.

For coarse screening purposes it is appropriate to restrict siting of NECs to Zones I and II.

11.15.4 Population

11.5.4.1 Population Density and Distribution

Criteria: Areas having a site population factor (SPF) of less than 0.2 for 30 miles (numerically equivalent to having a population density of less than 200 persons per square mile uniformly distributed over a 30-mile radius) are generally considered to be most acceptable for the siting of nuclear energy centers.

Areas having a site population factor of 0.2 to 0.5 for 30 miles are probably acceptable but are subject to careful assessment of alternative siting.

Areas having a site population factor of greater than 0.5 for 30 miles (which includes all U.S. metropolitan areas) are least acceptable.

Basis: The site population factor (SPF) is a useful measure for comparing population distributions around potential nuclear generating sites, since it weights population by its distance from the nuclear reactor. Thus, sites which have the lowest population densities and are farthest from the centers of population concnetration have the highest probability of meeting this criterion. The SPFs were developed using 1970 census figures. A more detailed description of the SPF concept, is presented in "A Technique for Consideration of Population in Site Comparison," WASH-1235, Regulatory Staff, U.S. Atomic Energy Commission, October 1974."

SECTION 12

TYPICAL EVOLUTION OF A NUCLEAR ENERGY CENTER

12.1 INTRODUCTION

If nuclear energy centers are built, it is most likely they will be built in stages with gradual achievement of full capacity. The phased evolution of an NEC must be considered in the overall and long-term planning that such a venture requires. Various scenarios could be developed. A likely scenario for power centers at the present time is one which the construction of nuclear plants on the NEC would commerce in the late 1970s and the first power plant would commence operation some time after 1985. Construction activities and plant operations would continue for a number of years and possibly indefinitely. The number of plants and the rate at which plants would be added to an NEC would depend on the need for power and to a lessor extent on other factors associated with the Electric Reliability Council regions. The demand for power would be sufficient to support NECs in most, if not all, of the Electric Reliability Council regions even with low forecasts of nuclear capacity needs. The number and character of NECs would of course depend on many other factors, most of which are region-dependent, such as economics, water availability, competing energy sources, the availability of suitable sites and the distribution of load centers.

This section does not examine the evolution in detail. Rather, it is intended to give the reader a broad, composite view of how an NEC might be initiated, how sites might be selected, how an NEC might be designed, constructed and operated, and how an NEC might evolve, including the decommissioning of old plants and replacing them with new plants. The major social, environmental, economic and technical factors which shape the character of an NEC and which must be addressed in the long-term planning of an NEC will be highlighted.

While NECs may be composed of power plants only, fuel cycle facilities only, or combinations of both power plants and fuel cycle facilities, the emphasis here will be on power centers. The term NEC will refer to power centers in this section. The fuel cycle and the combined facilities centers are addressed in some depth in Sections 8 and 9 of Part III.

The institutional and practical aspects of NECs are presented in Part IV. The actual organizational structure, management, and responsibility for the implementation of an NEC are very site specific. It is envisioned that an NEC could be initiated in a number of ways depending on the utilities and States involved, and the national or regional desire to implement the NEC concept. The realization of the full benefits of the NEC concept would require coordinated planning and development among a region's utilities, States, regional planning agencies--particularly water and land resources planning groups which may overlap Electric Reliability Council regions. Electric bulk power system reliability must have as its basis the adequate planning of facilities, their proper maintenance, and their prudent operation. This would require the extensive study and analysis of alternative programs of system additions before construction of an NEC can begin. Except for a few large utilities, the implementation of an energy center would probably require several utilities to join forces. The concept of joint venture in ownership and operation of generating facilities and related transmission is not new. There has been a long history of coordination among the electric utilities involving every aspect of power system planning and operation.

12.2 SITE SELECTION

In order to gain perspective, a few possible ways an NEC may be initiated are described. Existing sites could, over a number of years, evolve naturally into energy centers. Such sites could be owned and operated by a single large utility or cooperatively by several utilities. Such an evolution would involve plant by plant additions, including safety and environmental reviews. This method of sub-optimization may not realize the potential social, economic, and environmental benefits of long-range planning that could be obtained from the NEC concept.

A second approach which could provide for long-range planning, and the realization of benefits that may be associated with the NEC concept, is similar to that taken by a group of Pennsylvania utilities. This group (Metropolitan Electric Company, Pennsylvania Electric Company, Pennsylvania Power and Light Company and Philadelphia Electric Company) established "The Energy Park Development Group" to study energy centers, identify potential sites, and establish the organization to carry out the group objectives. While this group's scope of activities and interest are confined to the State of Pennsylvania, the general approach could apply to an Electric Reliability Council or some other regional grouping, such as the initiatives by a single utility in the states of Washington and Florida.

A third approach could involve the States or Federal Government acquiring sites with sufficient land and water, preparing the necessary impact statements, and constructing the necessary head-end facilities. Individual sites in the NEC could then be leased to the utilities in the region on a long-term basis or made available under some other arrangements. Some States already have site programs for acquiring dispersed sites, each suitable for a limited number of power plants. These programs could be expanded and coordinated with other States to include the siting and subsequent initial development of an NEC. Several utilities would use these predesignated sites to construct and operate the generating plants required to meet their load growth needs in much the same fashion as present practice.

A fourth and perhaps more extreme approach could involve the establishment of a Federal bulk power generation and transmission agency or other entity (regional State compact, government corporation, etc.) to design, construct and operate NECs and their interconnecting transmission systems. The agency or other entity would be established by the Federal Government.

12.3 DESIGN, CONSTRUCTION AND OPERATION

The rate of building power plants at NECs, the number of NECs, and the timing for initiating NECs are dependent to a great extent on the nature and character of the various regions. The most significant long-range planning factors are the regional need for electric power, the rate of growth of nuclear generating capacity, the distribution of population and load centers within a region, the availability of suitable sites with cooling water, as well as institutional and political considerations which may be region-dependent. The growth rate and ultimate size of an NEC also will be constrained by site characteristics (such as cooling method, meteorology and topography) and regional characteristics (such as availability of craft labor, number of utilities involved, number of states involved, and State and local regulations). These will have an influence on the overall design and layout of an NEC, the construction approach, operation, infrastructure requirements, and the societal impacts. Recognizing that there are many possible combinations and alternatives for the design, construction and operation of NECs, only a very general description of an NEC is possible. It should be recognized that each NEC will assume its own particular characteristics and that possibly no two NECs will be very similar.

The information that follows is intended to aid visualization of power centers and their evolution by presentation of example layout and construction approaches. The reader should not infer preference for the approaches that are described here.

One possible layout for a 20-unit NEC is shown in Figure 12.1. In this layout the basic module for building the NEC is a quad unit composed of two twin units with a temporary construction facility located between the twin units. A bridge crane would lift large modules, assembled sections, and equipment from the construction facility area and set them in place at the site. Construction would perhaps begin on one of the outside units. About one year later construction on the second unit would begin, and a year later the third and so on. After construction was initiated on the fourth unit work on another quad site would be started so that a generating unit could be completed each year.

The site layout could be arranged around other groupings instead of a quad unit. The quad units could be grouped in a more symmetric array instead of random dispersed arrangement shown in Figure 12.1. The spacing is site-dependent on major factors such as heat dissipation and radiological impacts. Overall, the site and regional characteristics will determine the site layout and the most appropriate groupings.

In general it is envisioned that an NEC would consist of one or more design series consisting of perhaps 4 to 12 generating units of the same general design. Each design series would perhaps be constructed by one work force. The rate of construction could vary from a minimum of about one generating unit every 18 months to one every 12 months. If a construction rate greater than one every 9 months is required to meet power needs, two or more design series with separate work forces might be constructed at the same time. In order to provide a reliable and stable electric power supply to a region it may be necessary to limit the amount of power generation at an NEC to some fraction of the total regional power needs; thus it is envisioned that several NECs could be developed concurrently to meet a region's power needs.

To obtain maximum economies, the construction of energy centers could consist of a semi-factory type of operation having a stable work force for an extended construction period of 15 years or longer. Under these conditions the design of the generating unit would have to be somewhat standardized; the units would have to be designed so that components and major sections of the plant could be modularized; the construction would be automated to a degree unachieved to date;

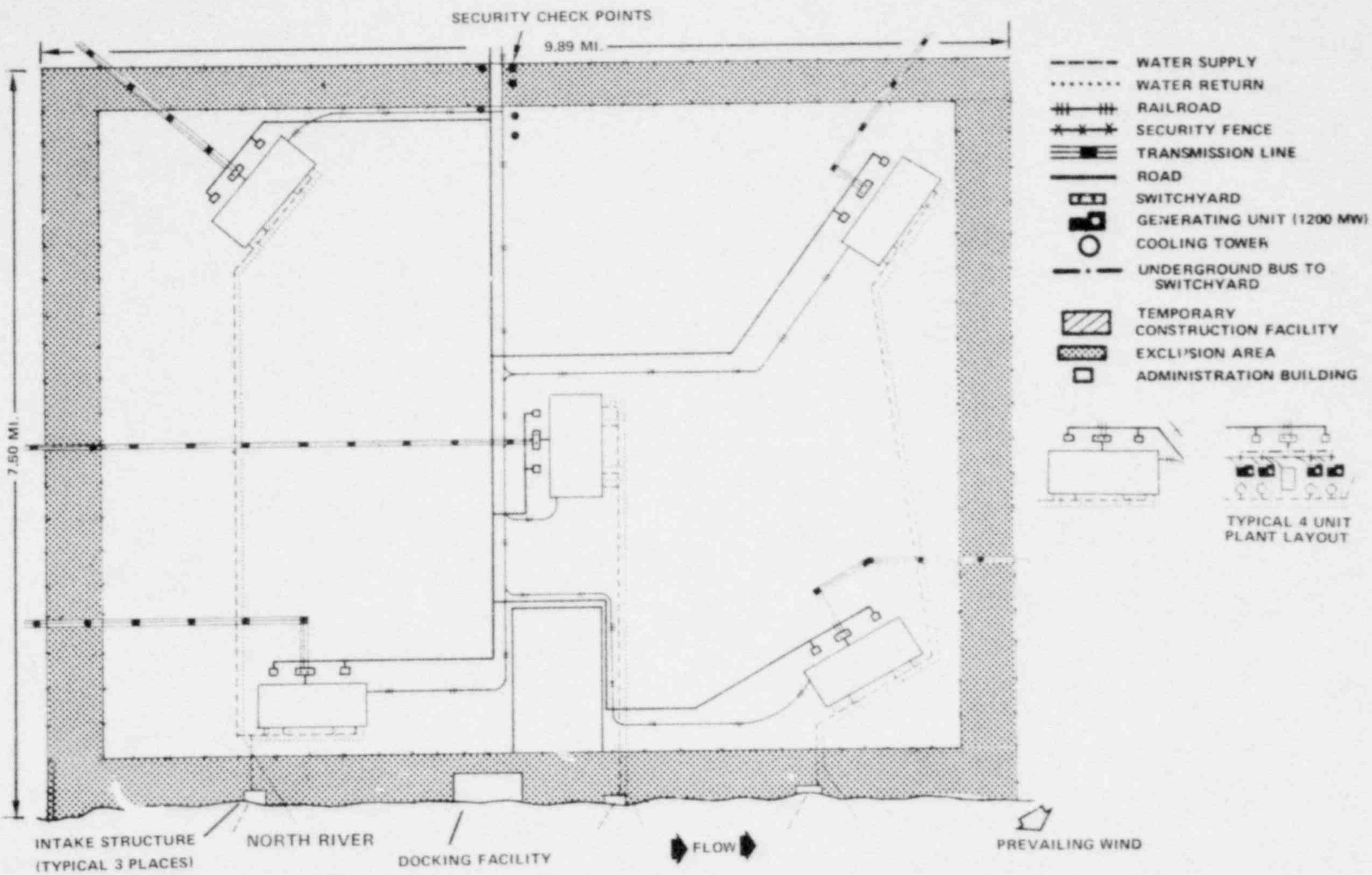


FIGURE 12.1 ONE POSSIBLE LAYOUT FOR A 20-UNIT POWER CENTER

and extensive use would be made of large bridge cranes, mechanized equipment and fabrication tools and fixtures. An artist concept of a bridge crane lifting a containment shell into place is shown in Figure 12.2.

It is envisioned that permanent fabrication facilities would be located on or near the NEC site. These facilities could be owned and operated by private firms and would provide services and fabricated assemblies for the construction of generating units on the center. Special transporters might be used to move fabricated assemblies to the temporary construction facilities located at each quad unit, where they would be lifted into place by large heavy-lift cranes. The central fabrication facility is shown in the lower center of the NEC site arrangement in Figure 12.2.

The transmission system would be designed to be constructed and placed into operation as the generating units are completed and begin generating power. It is envisioned that groups of 4 to 6 generating units would be supplying ower to a pool over a transmission system consisting of two or three transmission lines. To provide a reliable power supply each transmission line would be routed over a different corridor; however, each corridor may contain transmission lines serving other groups of generating units. To the extent possible, groups of generating units will be electrically isolated from the remainder of the NEC site. The design of the transmission system will be governed by the NEC site characteristics and the general regional electric power group patterns.

12.4 AGING OF NECs

It is envisioned that the time period of construction and operational lifetime of NECs will extend a considerable number of years. If an NEC with twenty five generating units is considered, on the basis of constructing one 1200-MWe unit per year, the construction period alone will extend for approximately 30 years; and if the operational lifetime of nuclear generating units is assumed to be 30 years then NEC construction activities could extend for more than 30 years. The first generating unit constructed on the NEC site might be scheduled for retirement about the time the 25th unit was being placed into operation. If old units could be dismantled and a new generating unit constructed in its place, then construction activities devoted to maintaining the center might continue over an extended time period. Of course, this depends on no changes in technology or regional plans that would preclude the continuation of the NEC as a source of electricity.

Many scenarios could be postulated and, in general, all involve a long period of time. The certainty of energy demand forecasts extending beyond 10 or 15 years becomes very speculative. The real purpose of addressing the aging or evolutionary aspects of NECs is the identification of key factors which might affect the long-term planning of such a venture. The planning process itself must be capable of evolution, since the plans must have built in flexibility. Inevitably, the effects of an NEC on its environs--be hey environmental, sociological, technical, or economic--will be dynamic in nature. Likewise, the evolution of an NEC will be affected by its environment.

Technological developments in areas such as energy storage, transmission, breeder reactor, other energy sources, and agro-industrial complexing could have a significar impact on the NEC

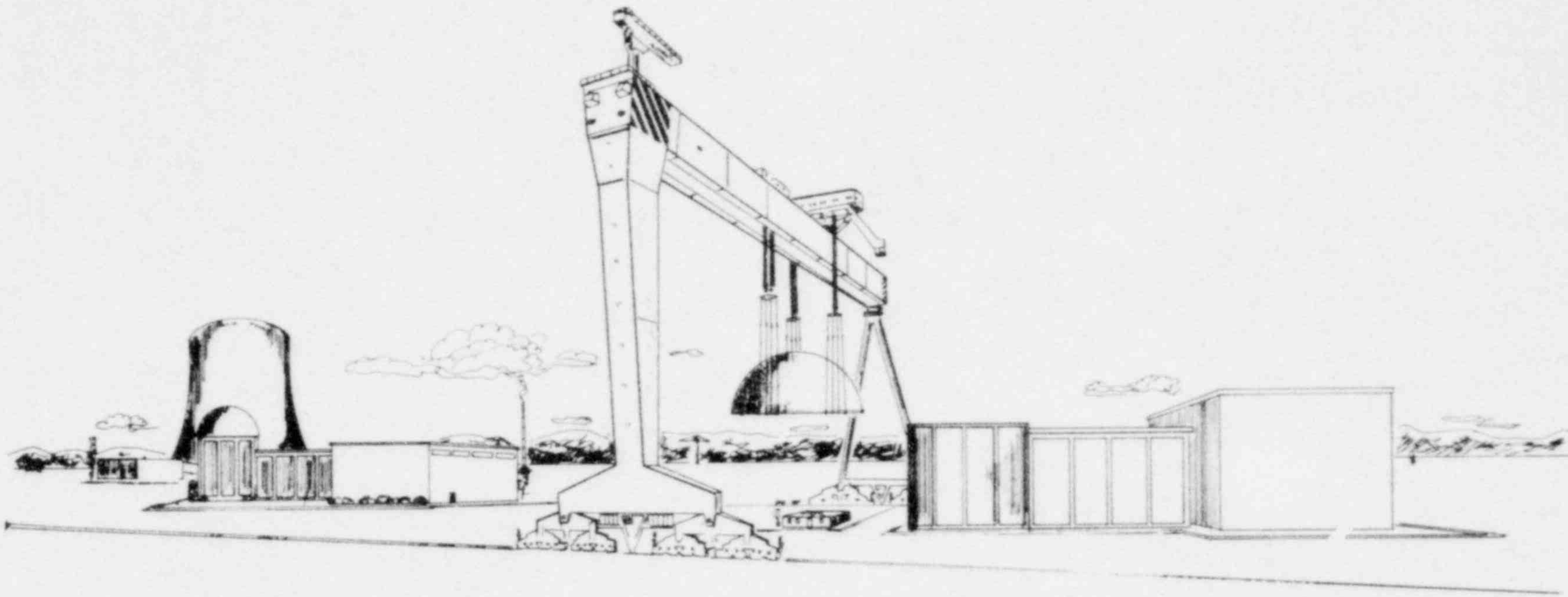


FIGURE 12.2 A BRIDGE CRANE LIFTING A CONTAINMENT SHELL INTO PLACE

siting concept in ways unforeseen today. Also, developments in the regulatory field, including new legislation to encourage the development of NECs, could have an impact on the way an NEC evolves.

The very fact that flexibility is necessary in planning NECs makes forecasting the evolution of the NEC concept difficult. For example, the economics of nuclear generation are dominated by capital investment. If savings are to be accrued in aggregate siting of units, then innovative construction methods as well as standardization must be utilized. On the other hand, the evolution of technology over the planning horizon of an NEC, if used to advantage, tends to limit the scope of this possibility; and there is risk to the use of innovative construction methods, especially if large front-end costs are required and there is large uncertainty with regard to electrical demand forecasts, changes in technology, or new sources of energy.

A set of guidelines and assumptions for this NECSS are identified in Section 11, Part II. With these as a basis and recognizing that alternatives may be equally viable in many instances, the factors which may affect the sensitivity of the evolution of an NEC are considered here as in the center life cycle. In terms of planning, better understanding of the conditions, factors, and general environment that may exist 20 to 40 years after a center is initiated is an important input to an understanding of the aging of an NEC. This discussion of the aging of NECs attempts to identify the major factors which may affect the way an NEC evolves. The following are considered to be the key factors that may impact on the evolution of an NEC.

12.4.1 Time

The construction time horizon commences in the late 1970s and may extend well past the year 2000. The expected lifetime for a single unit is approximately 30 years. To date no LWR has actually been decommissioned due to age, hence the expected lifetime is to some extent hypothetical.

12.4.2 Forecasted Capacity Factors

In terms of either national or regional load growth rates, an increasing portion is forecasted to be met by nuclear generation either at NEC sites or dispersed sites. Nuclear generation becomes an increasingly larger share of total generation according to WASH-1139(74) Case A. This forecast is used as a study assumption as discussed in Section 11, Part II. In the year 2000 over 35% of the generation capacity for any particular region is projected to be nuclear.

As the share of nuclear generation increases, the profile of nuclear capacity may have to change from one of base loaded plants to one of base load plus cycling, or else some form of energy storage must be added. The degree to which this change may take place is a function of many factors. One of these, however, is operating a nuclear plant in a daily cycling mode. The possibility of operating a nuclear unit at anything less than its full capacity has not been given detailed safety, environmental, technical and economic analysis. This potential change in philosophy may affect the comparison of NECs and dispersed generation. It is not presently clear that the predicted proportional increases in nuclear generation capacity will evoke differences in operation of centers versus dispersed generation, but the notion must be included in the planning of either.

12.4.3 Load Following

Load following is the generating system's response to short term variations in demand. Traditionally, these have been met by standby and gas turbine reserves. As discussed in the above subsection, the mix of nuclear and nonnuclear generating capacity may affect the philosophy of satisfying variations in demand.

As an alternative to the difficulties of load following in future power systems, new actions are presently under consideration aimed at smoothing out load curves. Two possibilities are being considered in this area. First is shaping the load to reduce peaks, such as by adjusting rate structures to persuade consumers to transfer the loads to off-peak hours. Second is in the area of energy storage to supply the peaks. At present, the only operating systems are pumped storage. Among other energy storage concepts being developed are batteries, hydrogen storage, compressed air storage, flywheels, and heat storage systems. These various concepts are presently under study by a number of different organizations.

The shaping of the load to reduce peaks and developments in energy storage concepts could have a significant impact on the nuclear industry and may influence the design and evaluation of energy centers.

12.4.4 Transmission

The transmission system is one of the key elements of a nuclear energy center. The evaluation of an NEC will entail a new perspective in transmission expansion planning. It is within this area that the determination of new transmission reliability criteria and possible improvements in transmission technology will come to bear.

If predicted generation requirements are to be accepted to some degree, the overall transmission system in the year 2020, for example, will bear little resemblance to that seen today. Simply stated, the transmission system developed from here on, particularly if NECs are adopted, will be the major system, and the present system will be auxiliary to it.

Generating plant development usually involves installation of several units at reasonable intervals so that no significant economic penalty, in terms of the total project investment, is involved in the initial construction of the transmission increments. In a nuclear energy center, however, a major problem exists because transmission is rarely optimal at any point in time. The total transmission system would not be required for the first few units.

At present, transmission systems expansion is quite site specific. The specifics for NECs would be similar in that the nature of the expansion would depend upon the distances to load centers, the underlying system capability in the area, and the relative economics of alternatives. However, with the extended horizon associated with NECSS the problem is compounded by possible technological developments and by the fact that the optimal system may have little resemblance to the underlying system.

12.4.5 Generation Technology and the Nuclear Fuel Cycle

The guidelines for the stud' the NEC concept assumes initially a light water reactor (LWR) dominated generation technology. The only reactor designs presently expected to be commercially available at the beginning for NECs besides LWRs are high temperature gas reactors (HTGRs).

No changes in the basic design of light water reactors are required for nuclear center application at this time. In the future the LWR plutonium-burning (PuB) reactor may also be available.

Technological and regulatory developments in the nuclear fuel cycle could significantly influence the way an NEC might evolve. Also, the breeder reactor concept is some distance upon the horizon, but within the time frame for NECs. The impact of introducing liquid metal fast breeder reactors (LMFBRs), HTGRs, and plutonium burning LWRs into the NEC concept was studied. The mixing of reactor concepts and integrated fuel cycle facilities (IFCFs) will be constrained by the environmental and regulatory climate surrounding the evaluation of the NEC concept. Future technology developments will start to play a role during the lifetime of a given NEC, but the planning must allow such flexibility. Within the time frame of NECs the entire energy environment will undoubtedly take on new perspectives.

12.4.6 Water Supply

Another possible limiting factor in the evolution of an NEC is the future availability of water resources. Obviously, the need for water for an NEC at maturity must be considered in the selection of potential sites. The reorientation of priorities for water resources as a center grows may affect the subsequent development of the NEC. Both the growth rate of electric power generation and development of the potential cooling system technology are directly related to the projection of the water requirements for NECs. Water supply problems will probably become more difficult as water use for other needs increases.

The possibility that priorities for water resources may change as a center evolves must be considered. If at some point in the construction of an NEC the available water suppliers were restricted beyond the requirements of a few additional units, the economic evaluation of an NEC could be significantly altered. Possibilities such as this should be included in the planning of an NEC and contingencies such as retrofitting with alternative cooling technologies must be considered.

These potential difficulties with altered water resources as a center develops are some- -t region-specific. As a national energy policy evolves, some future uncertainties in water supply allocation may be resolved.

12.5 DECOMMISSIONING

Forty years is the maximum period for which a license to operate a nuclear power plant is issued (10 CFR Part 50). Under present NRC regulations this period is applicable to all nuclear power plants. At the end of the forty-year period the operator of a nuclear power plant must renew the license for another time period or apply for termination of the license and for authority to dismantle the facility and dispose of its component parts. If prior to the expiration of the operating license, technical, economic or other factors are unfavorable to continued operation of the plant, the operator may elect to apply for license termination and dismantling authority at that time. In addition, at the time of applying for a license to operate a nuclear power plant, the applicant must show that he possesses "or has reasonable assurance of obtaining the funds necessary to cover the estimated costs of permanently shutting the facility down and maintaining it in a safe condition." These activities, termination of operation and plant dismantling, are generally referred to as "decommissioning."

As mentioned in the preceding subsection, to date no LWR has been decommissioned due to age, hence the expected lifetime of a single unit is somewhat hypothetical. A nuclear energy center is best viewed as a dynamic entity, growing and evolving in response to societal demands. If an NEC is envisioned as dedicated for an indefinite future then as units reach the limits of their useful lifetime they are replaced with new generation units. Such a view could be envisioned for an NEC at maturity, although it is not clear that such would be the case, because of factors as technological change and variations in forecasts for electrical demand and load center distribution.

SECTION 13

THE NUCLEAR FUEL CYCLE

The nuclear fuel cycle consists of a series of steps involved in supplying fuel for nuclear power reactors. To understand the fuel cycles for the major reactor types expected to be used in the United States--the Light Water Reactor (LWR), the High Temperature Gas Cooled Reactor (HTGR) and the Liquid Metal Fast Breeder Reactor (LMFBR), it is necessary to know what fuels are used, and what their functions are.

Nuclear reactors generate power from heat produced by the fissioning of specific isotopes. These isotopes include: ^{235}U, predominantly plutonium isotopes ^{239}Pu and ^{241}Pu, and ^{233}U.

^{235}U--^{235}U is the only fissionable isotope found in nature, constituting about 0.7% of the element uranium. The residual portion of uranium is predominantly ^{238}U, non-fissionable in the above reactors.

Plutonium--In the fissioning process, initiated by neutron bombardment of fissionable isotopes, an excess number of neutrons are released (over those required to sustain the fission process). These excess neutrons can be absorbed by certain non-fissionable isotopes to produce fissionable isotopes. The chemical element plutonium consists of a series of isotopes, formed predominantly from neutron absorption in ^{238}U. Of these plutonium isotopes, Pu-239 and Pu-241 are fissionable in LWRs (and HTGRs). These isotopes and other plutonium isotopes such as Pu-240 are fissionable in LMFBRs.

^{233}U--^{233}U is formed by neutron absorption in natural thorium. The HTGR is the only reactor operating on the thorium cycle today.

Uranium-238 and thorium-232 are known as fertile isotopes. The fuel for all three U.S. reactor types is a mixture of fissile and fertile materials. LWRs can operate on uranium fuel or a fuel manufactured from mixtures of plutonium and uranium. LMFBRs are also fueled with plutonium-uranium fuel of different composition than LWR fuel; additional fertile uranium material is placed in the reactor to increase the amount of plutonium formed in the LMFBR. (LMFBRs are designed to produce more plutonium than they consume.) Existing HTGRs are fueled with ^{235}U thorium fuels; in the future, ^{233}U fuel may also be used. Table 13.1 shows the comparative fuel characteristics for the initial fuel for the three reactor types. The bred fissile material in the spent fuel can be recovered and recycled to the type of reactor in which it was formed. In the case of LWRs and LMFBRs, bred plutonium can be interchanged between the two types of reactors.

TABLE 13.1

COMPARATIVE FUEL CHARACTERISTICS FOR LWR, LMFBR
AND HTGR REACTORS
(1200-MWe reactors)

	LWR		LMFBR		HTGR
	BWR	PWR	Core	Blanket	(Th Cycle
Initial Fuel					
Fissile Material	^{235}U	^{235}U	Pu	^{235}U	^{235}U
Chem. Composition	UO_2	UO_2	PuC	UO_2	UC
%Enrichment: ^{235}U	2.8	3.2		~0.2	93
Pu_f(Fissile)	a	a	12		
Fertile Material	^{283}U	^{238}U	^{238}U	^{238}U	^{232}Th
Bred Fissile Material	Pu	Pu	Pu	Pu	^{233}U

[a] If mixed-oxide fuel is used in LWRs instead of uranium fuel, the fissile plutonium content of the fuel is about 3% Pu_f.

The facilities of the nuclear fuel cycle and the logistical flows between them are shown schematically in Figure 13.1. A general discussion, applicable to any of the various nuclear fuel cycles expected to be used in the United States, follows.

Referring to Figure 13.1, the path labeled 1 represents the flow of natural uranium (as U_3O_8 "yellowcake") extracted from mined ore by the uranium mills. In path 2 the natural uranium has been converted to uranium hexafluoride (UF_6) and is being sent to the separation plant for enrichment, that is, to have the ^{235}U content increased over its naturally occurring concentration of 0.7%. In the enrichment process, uranium enriched in the fissile ^{235}U isotope is sent by path 3 to fuel element fabrication facilities, and the residual uranium tails (depleted in ^{235}U) are sent to storage via path 10. Whereas natural uranium contains 0.7% ^{235}U, the material in path 3 is enriched to 2 to 5% for use in LWRs and is highly enriched (~93%) for use in the HTGR. In the latter case, the fertile thorium is supplied by path 11.

In path 4, fresh fuel assemblies are shipped to the reactor site for initial cores or reloads. In the reactor, the fuel roads containing the fissionable and fertile materials generate heat for one to three years. The heat results from the fissioning of uranium or plutonium into highly radioactive fission products. After discharge from the reactors, the spent fuel assemblies are stored at the reactor site for cooling and subsequently shipped via path 5 to the reprocessing site where they may be stored for later reprocessing or reprocessed on arrival. The spent fuel in path 5 contains the residual fissile material (e.g., ^{235}U), the residual

Source: Adapted From General Electric Company, May 1975. Assessment of Energy Packs vs. Dispersed Electric Power Generating Facilities.

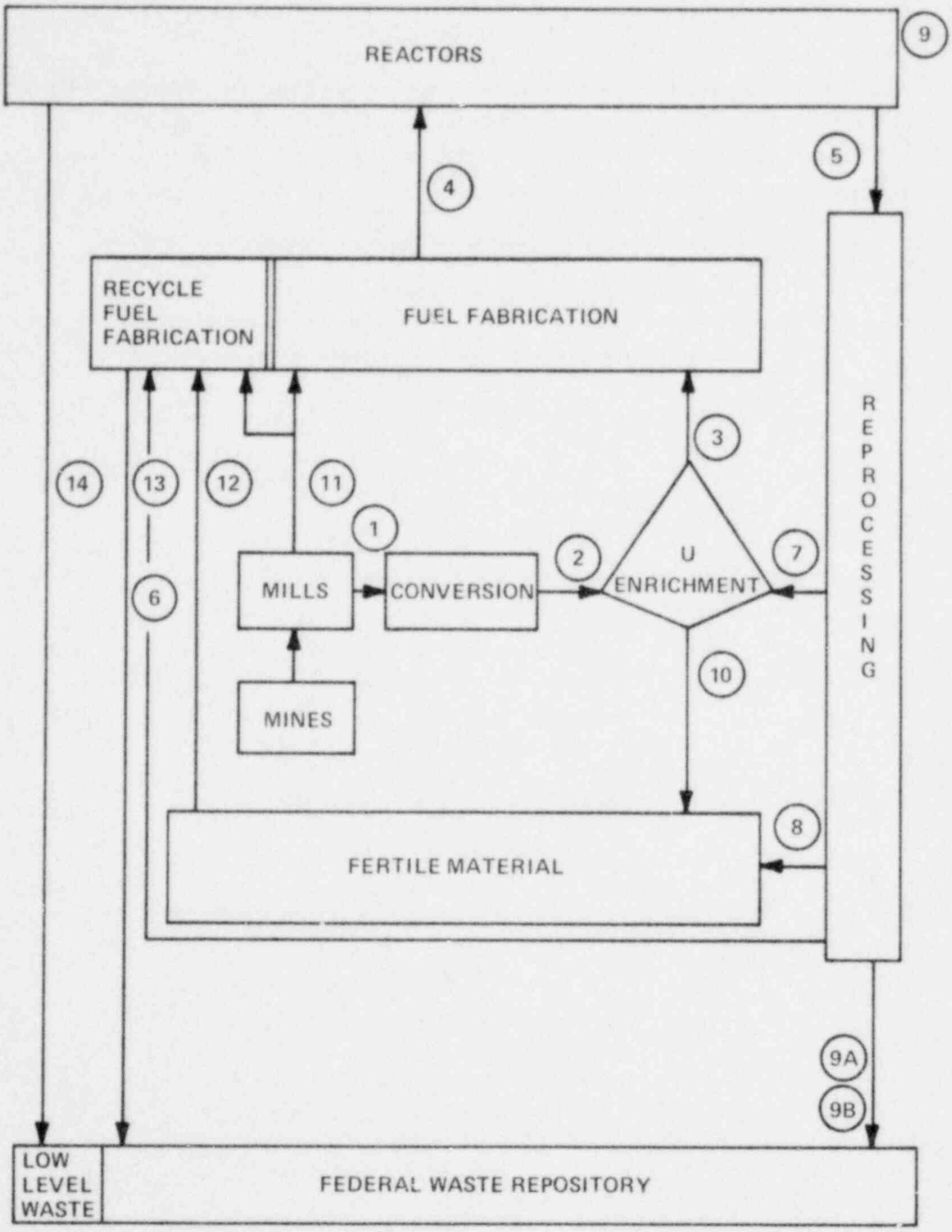


FIGURE 13.1 THE NUCLEAR FUEL CYCLE

fertile material (e.g., ^{235}U), and the fissile material (e.g., Pu-239) "bred" from neutron adsorptions during reactor operation.

In order to "close" the fuel cycle, radioactive fission products are removed in the reprocessing operation and stored or shipped via path 9, and the recovered fissile material, plutonium or ^{233}U (and once recycled ^{235}U in the case of HTGRs) is returned via path 6 to the fuel fabrication facility for "recycle" back through the reactors. The residual uranium from LWRs typically is still slightly enriched in ^{235}U and can be returned via path 7 to the separation plant for reinsertion into the enrichment process, or it can be stored via path 8 or possibly used via path 12 in the mixed oxide (MOX) fabrication of plutonium recycle fuel assemblies. (The term "mixed oxide" denotes a mixture of the dioxides of uranium and of plutonium, UO_2 and PuO_2.)

Paths 9, 13 and 14 represent the transfer of wastes generated in fuel cycle operations. The waste streams represent high level wastes, 9A, transuranic wastes, 9B and 13, and low level wastes 14. High level wastes (HLW) are required to be, and transuranic wastes (TRU) are expected to be required to be, transferred to the Federal Government for storage and disposal. Reactors generate relatively large volumes of low level wastes (LLW) that may be buried in commercially operated burial grounds.

Figure 13.2 shows the "interrelation of the three fuel cycles. The LWR fuel cycle requires the operations of uranium mining, uranium milling, UF_6 conversion, uranium enrichment, and UO_2 fuel fabrication. Mixed plutonium and uranium (MOX) fuel is manufactured from plutonium recovered from LWR fuel reprocessing and can be used to fuel LWRs. To start the LMFBR industry, plutonium recovered from LWRs can be used to manufacture the plutonium-uranium fuel for LMFBRs, the uranium being the depleted material from the enrichment plant. With a large scale LMFBR industry, plutonium recovered from spent LMFBR fuel can be used to fuel either LMFBRs or LWRs.

The HTGR thorium-uranium fuel cycle is relatively independent of the LWR and LMFBR fuel cycles. The only link between the fuel cycles is the supply of uranium from the (LWR) enrichment plant as feed to the topping enrichment plant required in the HTGR fuel cycle. The product from the topping enrichment plant is fabricated into ^{235}U-thorium fuel used in the HTGRs. Spent fuel is reprocessed to recover ^{233}U and once-recycled ^{235}U. These materials are fabricated into fuel and recycled to the HTGR.

Of the three fuel cycles, only the LWR can be described as existing on a commercial scale. The LMFBR fuel cycle and HTGR fuel reprocessing and recycle fuel fabrication steps are presently under development. Exhibit B contains a more detailed description of the LWR fuel cycle, together with a discussion of fuel requirements for nuclear reactors between 1985 and 2000.

Figure 13.2 shows five types of shipments required in the three fuel cycles. They are:

- Uranium (non-strategic) shipments
- Thorium shipments
- Spent fuel shipments
- Shipments involving strategic special nuclear materials
- HL and TRU waste shipments

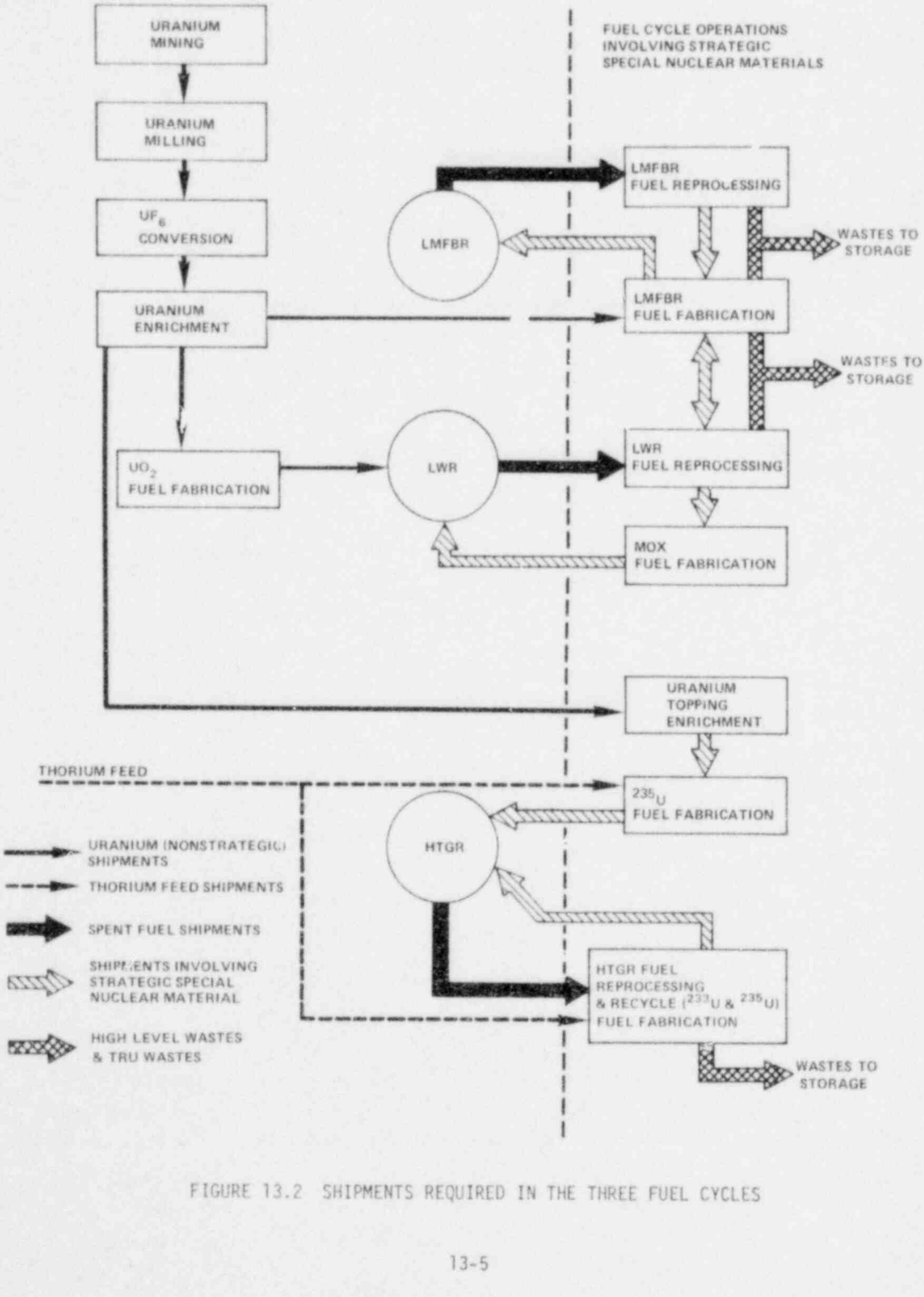


FIGURE 13.2 SHIPMENTS REQUIRED IN THE THREE FUEL CYCLES

Non-strategic uranium and thorium shipments involve materials of low specific activity (low levels of radioactivity) and of non-strategic value.

Spent fuel shipments and HL waste shipments involve materials of high specific activities (high levels of radioactivity) and TRU wastes contain plutonium.

In addition, Figure 13.2 shows the fuel cycle operations involving strategic special nuclear materials (SSNM). SSNM is plutonium, ^{233}U, and uranium enriched to greater than 20% in the isotope ^{235}U. SSNM is material that can be used to manufacture nuclear explosives and, as such, requires safeguards.

Of the three types of SSNM, plutonium is of particular significance. Like many other elements that undergo radioactive decay, plutonium isotopes are hazardous and require special handling. Plutonium-239 decays by emitting alpha particles; other plutonium isotopes emit gamma and beta radiation.

Plutonium poses a health hazard if it is inhaled. On the skin and in the gastrointestinal tract, it is a smaller problem. The alpha radiation does not penetrate to the sensitive basal layer of the skin. Since the gastrointestinal tract absorbs only a small fraction of the plutonium passing through it, the probability of accidentally ingesting enough to do any harm is small.

If plutonium is inhaled, its specific physical and chemical characteristics determine its behavior in the body. Soluble forms pass relatively quickly from the lung to bone and the liver; insoluble forms, which are retained longer in the lung, are transported principally to lymph nodes in the chest. Reactor fuel is an insoluble form.

On the basis of experimental evidence, maximum permissible airborne concentrations of plutonium have been set for the public. Based on experience with radium, limits have been set also for concentrations of plutonium in the lungs and in the body of plutonium industry employees.

The fissile characteristics that make plutonium a valuable fuel also make it useful in nuclear weapons. In addition, the radiotoxicity of plutonium makes dispersion of plutonium an event to be avoided. The properties of plutonium mitigate against successful dispersion events. Plutonium does not travel readily in air. The density of plutonium oxide is about the same as lead. Consequently, most of the plutonium would quickly settle on the ground. Only particles with diameters of less than ten microns (.00000039 inch) are capable of lodging in the lung.

If plutonium compounds were to be dispersed by adding them to surface water, the plutonium would react to farm insoluble plutonium compounds that would probably settle out.

The NECSS-1975 is an evaluation of siting modes for nuclear facilities; particularly on energy centers. At the present time, fuel cycle facilities shown in Figure 13.2 tend to be located at dispersed sites. There is an economic incentive to minimize those transportation links susceptible to minimization; particularly spent fuel shipping. This shipping cost minimization results in fuel reprocessing plants being located near large aggregations of reactors.

The questions of safeguarding of strategic special nuclear material have led the NECSS to focus on those operations of the fuel cycle that involve SSNM, notably LWR fuel reprocessing and mixed oxide fuel fabrication. LMFBR and HTGR fuel reprocessing and recycle fuel fabrication operations have been considered briefly, as have the HTGR fuel cycle operations of topping enrichment and ^{235}U fuel fabrication.

Locating an LWR fuel reprocessing plant and mixed oxide fuel fabrication facility (a collocation siting modes) on a common site can reduce transportation of plutonium between sites and concentrate the facilities requiring safeguards. Extending the concept of collocation such that several LWR fuel reprocessing plants and mixed oxide fuel fabrication plants results in the Integrated Fuel Cycle Facility siting concept. The IFCF concentrates the facilities handling SSNM onto a few sites.

Combining LWR fuel reprocessing and mixed oxide fuel fabrication, facilities and LWR reactors on a single site (a combined center) could result in reducing shipments of plutonium in any form.

In addition to considering siting modes for fuel-cycle facilities involving SSNM, the NECSS-1975 has evaluated possible alternative arrangements for locating the Federal Waste Repository for high level and transuranic waste storage. Aggregating the sources of these wastes onto a few sites permits consideration of these few sites for Federal Waste Management facilities. Hence, the IFCFs considered in this study have been assumed to have onsite Federal Waste Management Facilities.

The evaluations of the technical feasibility of siting nuclear fuel cycle facilities on energy centers are contained in Sections 8 and 9, Part III, of this study. Part IV contains the evaluations of the practicability of such siting.

APPENDIX A

DESCRIPTION OF A FOUR UNIT NUCLEAR GENERATING STATION

1.0 INTRODUCTION

The four-unit nuclear generating station is used as the primary basis for comparison for the Nuclear Energy Center arrangements considered in this study. This appendix provides a brief description of such stations.

Prior to 1970 nearly all reactor stations possessed single units with modest power ratings. Since then, power plants of up to 3,800 MWt have been proposed, with as many as four such plants at a single site. Based on the applications for licenses during the 1970s, a continuation of the trend towards multiple large plants is likely.

At this point, four applications for four-unit stations have been received, and are under varying stages of review. Environmental statements have been issued by NRC staff for each project (Ref. 1-4) and provide considerable detail on the characteristics of four-unit generating stations.

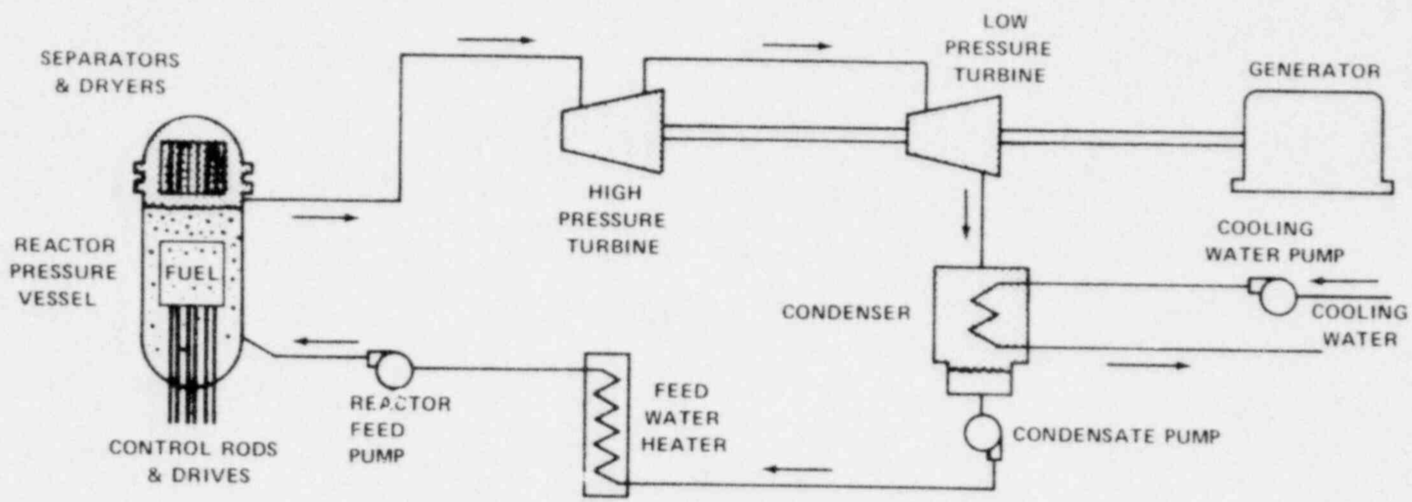
2.0 SUMMARY DESCRIPTIONS OF NUCLEAR POWER PLANTS

2.1 THE BOILING WATER REACTOR (BWR)

As far as power generation activity is concerned, the use of a reactor is not too different from using a conventional fossil fuel-fired boiler. In the nuclear case, the heat to convert water to steam is from the fission within the nuclear reactor vessel. Water enters the reactor core which consists of many fuel bundles (732 in the latest plants). The flow passes along fuel rods within the bundles, removing energy from the fuel rods which are being heated by the fission processs. Thus, the flow passing through the core is heated and then partially evaporated as steam is formed. This water and steam flow from all of the fuel bundles mixes in the area just above the core and then enters a bank of steam separators. The separators direct the steam toward steam dryers and then out of the vessel to the turbine. The water fraction is returned from the separators to be recirculated with the feedwater flow. The feedwater enters the vessel by means of flow header to equalize flow distribution. The mixed flow then passes through jet pumps within the reactor vessel in order to develop enough additional pressure to pass through the reactor core.

The principal parameters and design features of a BWR are listed in Table A.1. Figures A.1 and A.2 illustrate the concept.

The fuel rods are composed of uranium dioxide pellets enclosed in Ziracaloy tubes with welded end plugs. The tubes are spaced and supported in assemblies or arrays by upper and lower plates.



FUEL Slightly enriched uranium oxide clad with zirconium alloy
MODERATOR Boiling water
COOLANT Boiling water
PRESSURE OF PRIMARY SYSTEM 1,000 psi
OUTLET TEMPERATURE 550° F

FIGURE A.1 BOILING WATER REACTOR POWER PLANT

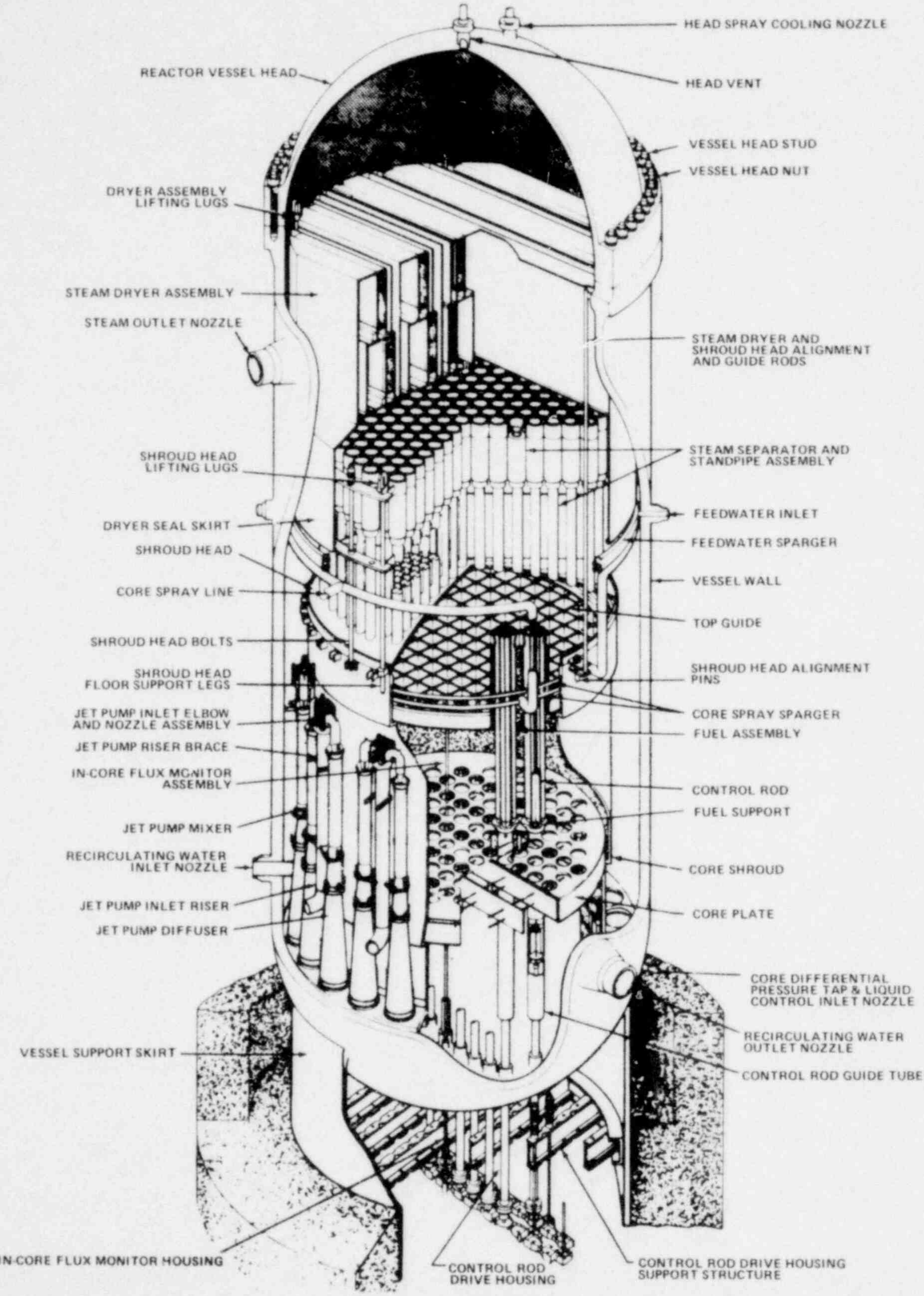


FIGURE A.2 CUTAWAY OF BOILING WATER REACTOR, BWR-6 AND PRESSURE VESSEL

TABLE A.1

PRINCIPAL PARAMETERS AND DESIGN FEATURES OF A BWR

Parameter or Feature	
Rated Power Level	3579 MWt
Net Electrical Output	1220 MWe
No. Fuel Assemblies	732
Fuel Rod Array	8x8 (63 rods)
No. Control Rods	177
Max. Linear Power	13.4 kW/ft
Reactor Vessel ID	19' 10"
Reactor Vessel Height (Inside)	70' 10"
No. Recirc. Loops	2
Recirc. Pump Flow Rate	35,400 gpm
No. Jet Pumps	20
No. Steam Lines	4
Steam Line ID	26"
Core Water Flow	105×10^6 #/hr
Steam Flow	15.4×10^6 #/hr
Nominal Steam Pressure	1040 psia
Feedwater Temperature	420°F

Source: "Safety Evaluation of the General Electric Standard Safety Analysis Report"; Docket No. STN-50-447; U.S.A.E.C., Directorate of Licensing, November 5, 1974.

Coil springs are provided at the top of each fuel rod to take care of expansion. Cruciform-shaped control rods containing stainless steel tubes filled with compacted boron carbide, are located within the fuel assemblies to control reactivity within the core. They are positioned by hydraulic drives with redundant features for fail-safe operation.

Load following is normally accomplished by varying the recirculation flow to the reactor. The reactor coolant recirculating pumps are vertical, single stage centrifugal pumps equiped with controlled leakage shaft seals. Equipment is provided to control the speed of the pumps (and therefore flow) to moderate reactor reactivity in accordance with plant power demands, as necessary in combination with control rod positioning.

Auxiliary systems are provided to perform the following functions:

a) Remove radioactive contaminants from reactor coolant water

b) Cool system components

c) Remove residual (decay) heat when the reactor is shut down

d) Remove residual heat from the spent fuel storage pool

e) Provide for emergency core cooling in the event of a loss-of-coolant-accident (LOCA)

f) Collect any condensation or leakage into reactor containment drains

g) Provide containment spray to help cool the containment and remove iodine in the event of a loss of coolant accident (LOCA)

h) Provide containment ventilation and cooling during normal operations and in the event of accidents

i) Process liquid, gaseous and solid wastes

j) Assure maintenance of a low leakage containment following LOCA

k) Provide redundant means of removing hydrogen from containment following LOCA (as might result from reactions between fuel cladding and water at high temperatures)

l) Provide systems for detecting leaks in the reactor coolant system

m) Inject borated water by a standby emergency liquid control system to assure the capability to safely shutdown the plant even during accident conditions.

Turbine and Auxiliaries

The steam and power conversion system converts heat energy in the steam by means of turbine generators. A portion of the unconverted heat energy is removed by the condenser cooling water system and discharged, ultimately to the environment.

The turbine is a tandem-compound unit, typically comprising one high pressure and three low pressure cylinders at 1,800 rpm having 43-inch exhaust blading in the low pressure cylinders. To assure optimum performance, six combination moisture separator-reheater units are employed to remove condensed water and superheat the steam between the high and low pressure turbine cylinders. The turbine auxiliaries include deaerating surface condensers, steam jet air ejector, turbine driven main feed condensate pumps, and a variety of pumps and equipment to process condensed steam and to discharge unused heat to an ultimate heat sink (a river, lake, ocean, or a cooling tower).

Electrical System

The plant systems are supplied necessary power from two independent sources for reliability and safety reasons. The main generator feeds electrical power through an isolated phase bus to two half-sized main power transformers. Station auxiliaries receive power during normal operation from the unit auxiliary transformer connected to the isolated phase bus and the station auxiliary transformer connected to an outside source, for example, 138 kV.

The Auxiliary Electrical System provides power to those auxiliary and engineered safeguards components which are required to operate during any of the plant's normal and emergency conditions of operation.

Power required for plant start-up and after reactor trip is furnished by a 138 kV system from an offsite source. Diesel generator capacity is adequate as an alternate onsite source for black startup.

Emergency power supply for vital instruments and controls is from two or more 125 volt d.c. station batteries.

The system design provides sufficient independence, isolation capability, and redundancy between the different power sources to avoid complete loss of auxiliary power.

Control Room

The plant is provided with a reactor and turbine-generator control room in a weather control building designed according to seismic, missile, tornado and flooding criteria, and contains all the necessary instrumentation and control for the plant's operation under normal and accident conditions.

Adequate shielding and air conditioning facilities permit occupancy during all normal operating and 30-day post-accident conditions.

Diesel Generators

Diesel generator sets supply emergency power for plant shutdown and essential safeguards operation in the event of the loss of all other a.c. auxiliary power simultaneously with a loss-of-coolant-accident (LOCA) or any such low-probability incident requiring safeguards operation and achieving and maintaining a safe shutdown of the reactor plant.

Waste Disposal System

The Waste Disposal System collects and processes liquids, gases and solid wastes from plant operation for removal from the plant site. All removals are made in accordance with applicable rules and guidelines for radioactivity disposal to the environs.

Fuel Handling System

The fuel handling system provides the ability to fuel and refuel the reactor core. Administrative procedures carefully established plus the design of the system minimize the probability of fission product release during the refueling operation.

The system also includes the following features:

a) Safe accessibility for operating personnel

b) Provisions for preventing fuel storage criticality

c) Visual monitoring of the refueling procedures at all times.

Structures

The major structures (Figure A.3) are the outer reactor containment building, the radwaste building, the control building, the diesel generator building, and the service water pump area, all designed to withstand, withstand failure, the safe shutdown earthquake. The reactor containment building provides a final barrier against the release of radioactivity in the event of an accident such as a LOCA.

General Electric Company is currently marketing a containment and nuclear design designated the Mark III, which is a complex of three buildings--the reactor building, the auxiliary building, and the refueling building. The Mark III concept uses pressure suppression with the dry containment layout. The drywell, a concrete cylinder which surrounds the reactor and primary coolant system, is a boundary (30 psig design pressure) that channels steam from the blowdown following a postulated loss-of-coolant accident through a pool of water (to suppress or condense the steam and thereby mitigate the effects of a LOCA).

The containment structure is similar to a standard dry containment and is nominally a free-standing steel containment (15 psig design pressure) surrounded by a concrete shield building or as a concrete pressure vessel with a liner. Auxiliary buildings are provided to house the spent fuel storage and handling facility and the core standby cooling systems and other reactor auxiliary equipment.

2.2 SUMMARY DESCRIPTION OF A PWR

A PWR is a dual-cycle boiler in which a closed pressurized water system accepts heat from the reactor; and a separate water system removes that heat to produce steam for the turbine generator. There are several manufacturers of this type of nuclear steam supply system (NSSS) but all have similar characteristics. Table A.2 provides a list of typical nuclear design characteristics; Figures A.4 and A.5 illustrate the concept.

Nuclear Steam Supply Steam

The nuclear steam supply systems consist of a pressurized water reactor, Reactor Coolant System and associated auxiliary fluid systems. The Reactor Coolant System (RCS) is arranged as four closed reactor coolant loops, each containing a reactor coolant pump and a steam generator, connected in parallel to the reactor vessel. Reactor power is controlled by (1) permanent devices such as full and partial length rod cluster control assemblies, (2) burnable poison assemblies used only in the initial core, and (3) a soluble chemical neutron absorber, boric acid, used for long-term control changes.

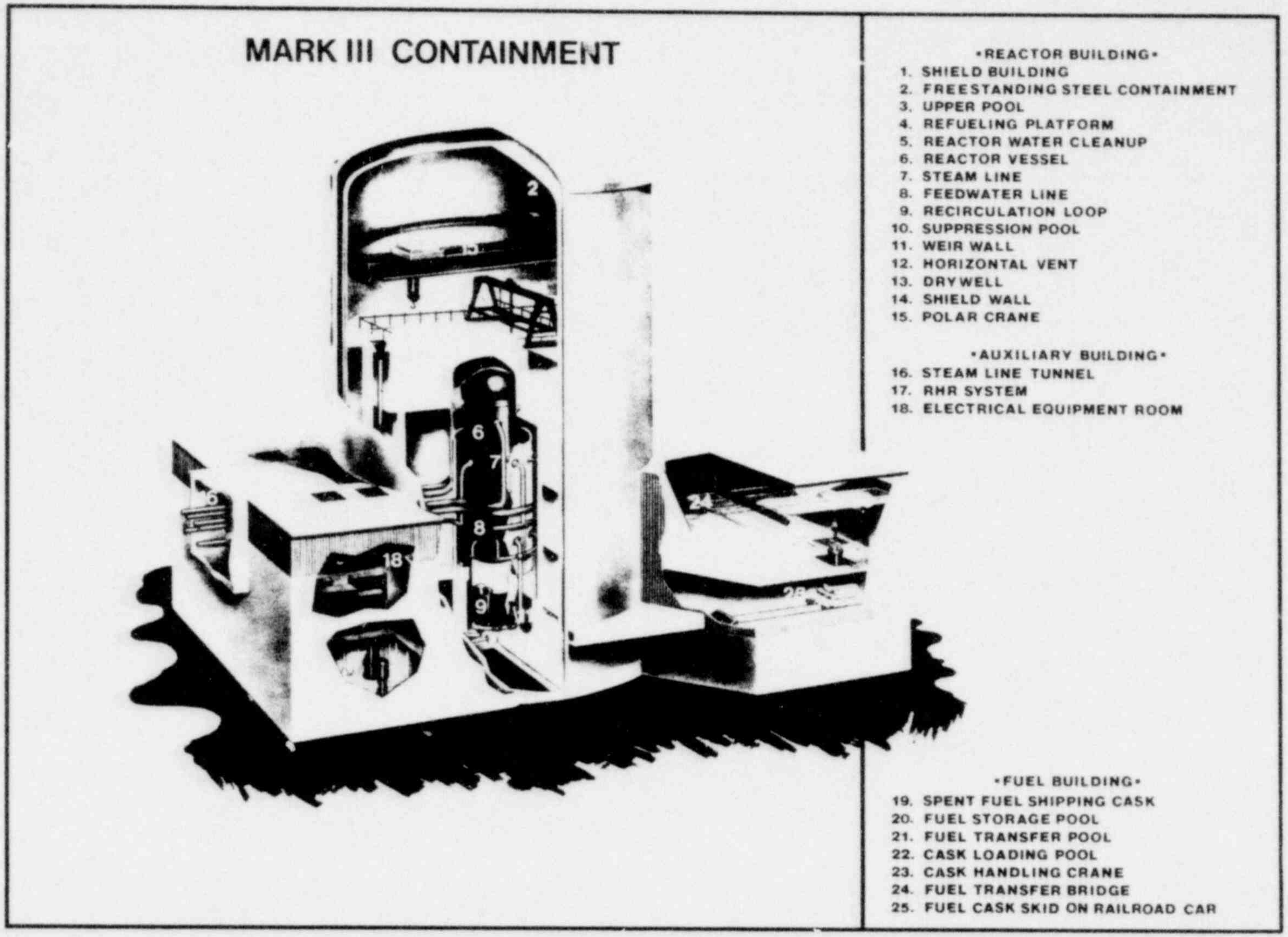
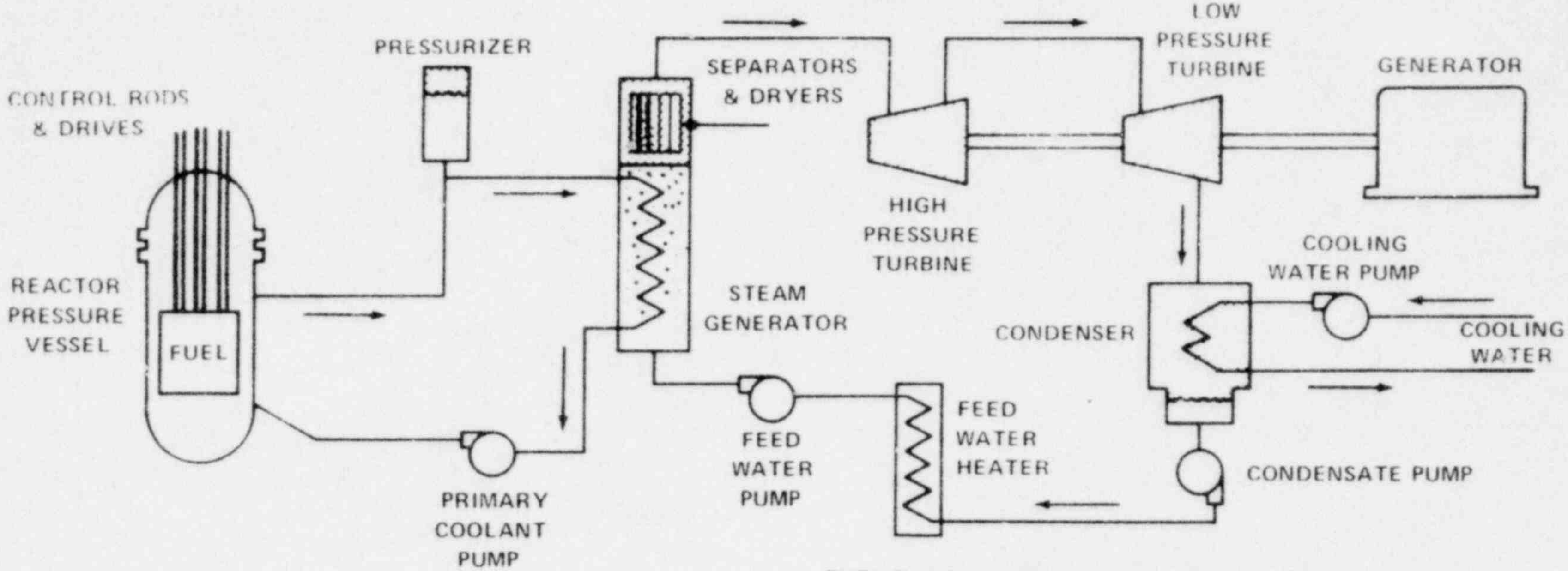


FIGURE A.3 THE GENERAL ELECTRIC MARK III MAJOR STRUCTURES



FUEL Slightly enriched uranium oxide clad with zirconium alloy
MODERATOR Water
COOLANT Water
PRESSURE OF PRIMARY SYSTEM 2,250 pounds per square inch
REACTOR OUTLET TEMPERATURE 605° F

FIGURE A.4 PRESSURIZED WATER REACTOR POWER PLANT

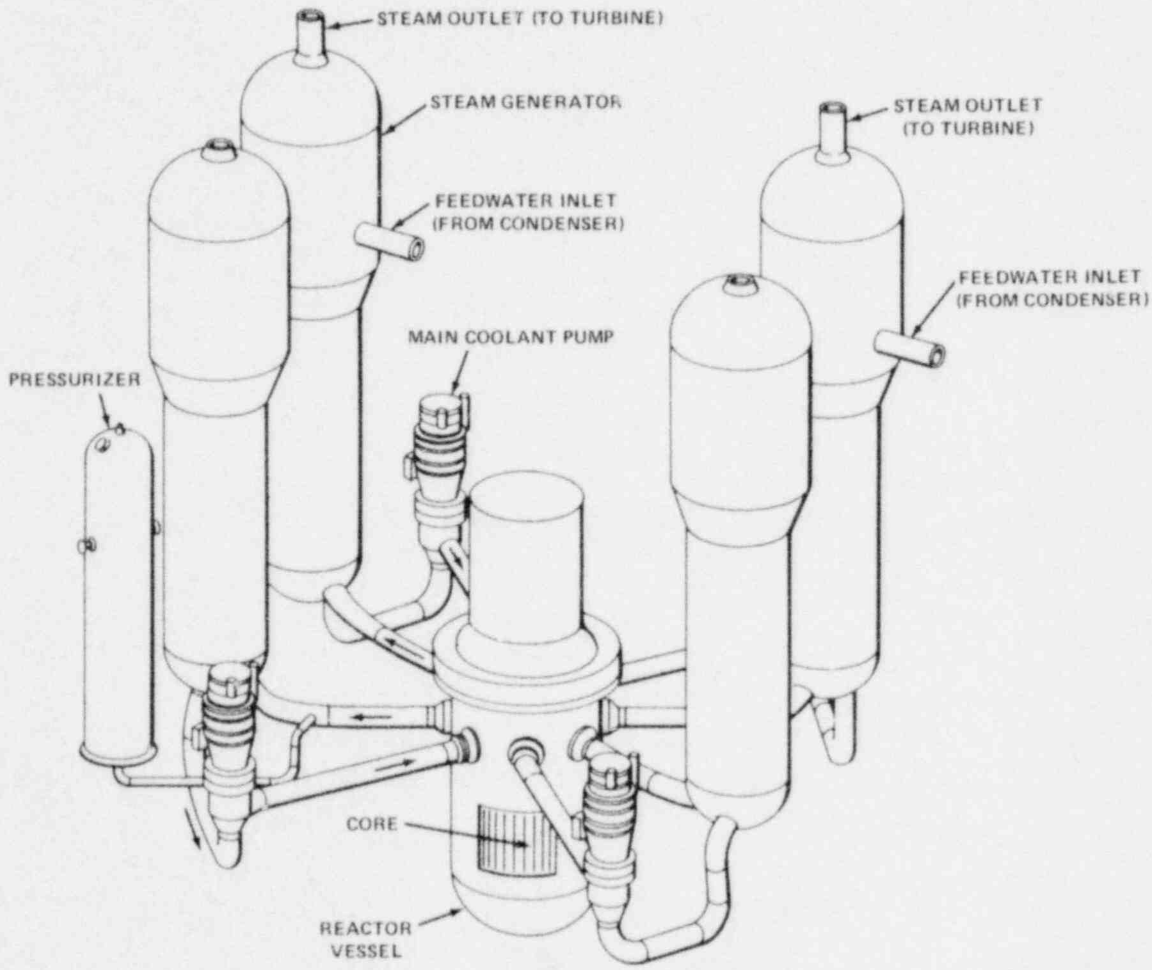


FIGURE A.5 SCHEMATIC OF REACTOR COOLANT SYSTEM FOR A PRESSURIZED WATER REACTOR

TABLE A.2

PRINCIPAL PARAMETERS AND DESIGN FEATURES OF A PWR

Parameters or Feature	
Power Level	3,800 MWt
Net Electrical Output	1,295 MWe
No. Fuel Assemblies	193
Fuel Rod Array	17 x 17 (264 rods)
No. Control Rods Assemblies	61 full length, 8 part length
Max. Linear Power	13.3 kW/ft
Reactor Vessel ID	14' 5"
Reactor Vessel Height (Inside)	43' 10"
No. of Loops	4
Coolant Flow Rate (Total)	144.7×10^6 lbs/hr
Nom. Coolant Pressure	2,235 psia
Nom. Reactor Vessel Outlet Temperature	624°F
Total Steam Flow	17×10^6 lbs/hr
Steam Temperature	603°F
Steam Pressure	1,100 psia
Feedwater Temperature	473°F

Sources: "Report to the Advisory Committee on Reactor Safeguards in the Matter of Westinghouse Electric Corporation Reference Safety Analysis Report RESAR-41"; Docket No. STN-50-480, U.S.N.R.C., Office of Nuclear Reactor Regulation, July 3, 1975. A similar report on the Combustion Engineering, Incorporated, Standard Safety Analysis Report CESSAR; Docket No. STN-50-470, was also published on the same date. Information on a Babcock and Wilcox 3600-MWt plant may be found in the Greenwood 2 and 3 Construction Permit Application (FES issued 11-25-74, Docket No. 50-452).

The reactor core is composed of slightly enriched (2%-3% U-235) uranium dioxide pellets enclosed in Zircaloy tubes with welded end plugs. The tubes are supported in assemblies by a spring clip grid structure. The mechanical portion of control rods consists of clusters of stainless steel-clad absorber rods and guide tubes located within the fuel assembly. To maximize fuel utilization, the core is initially loaded in three regions of different enrichments with new fuel being introduced into the outer region at successive refuelings, moved into the inner regions, and discharged to spent fuel storage.

After being heated in the core, the coolant will be circulated through the four steam generators. It is here that heat will be transferred to the secondary system to form steam to be used in turn to drive the turbine-generator. Reactor coolant pressure is established and maintained by an electrically-heated pressurizer connected to the hot leg piping of one of the loops. The reactor coolant pumps return the cooled liquid to the core.

Auxiliary systems are provided, much as in a BWR. For example, to:

a) Add makeup water

b) Remove radioactive contaminants from reactor coolant water

c) Provide chemicals for corrosion inhibition and reactor control

d) Cool system components

e) Remove residual (decay) heat when the reactor is shut down

f) Remove residual heat from the spent fuel storage pool

g) Provide for emergency core cooling in the event of loss-of-coolant accident (LOCA)

h) Dispose of liquid, gaseous and solid wastes

i) Provide systems for detecting leaks in the reactor coolant system.

Balance of Plant

The balance of plant equipment is similar to that for a BWR.

The containment structure completely encloses the entire reactor and reactor coolant system; a typical plant has a concrete containment structure with an inside diameter of approximately 135 feet and an overall inside height of approximately 67 feet. It is, together with support systems such as containment spray, capable of withstanding the effects of a LOCA and still provide a low leakage barrier to prevent any major release of radioactivity.

The control building houses the control room, auxiliary equipment, ventilation equipment, and reactor plant cooling water system. It is a missile-protected building since it houses safety-related equipment. The diesel-generator building is designed to withstand short-term tornado loading, including tornado-generated missiles. It houses the diesel generators that provide standby power. The turbine-generator building contains the turbine generator and other equipment related to the conventional portion of the plant. Building design is based on the same criteria as used for a fossil-fired plant turbine-generator building.

Miscellaneous structures are required for such uses as fuel storage, chemical storage, maintenance shops, and water intake equipment housing. Other balance-of-plant equipment and systems are similar to those required for a conventional fossil-fired plant. Included are items such as the condensers, feedwater pumps, makeup water treatment system, circulating water systems, and electric plant equipment.

2.3 SUMMARY DESCRIPTION OF AN HTGR

The high-temperature gas-cooled reactor is relatively new to the electric utility industry in this country. The concept employs a closed-cycle reactor cooling system as in a PWR. In the HTGR, pressurized helium gas is used as a coolant, and the fuel is graphite-coated, highly enriched uranium. Table A.3 provides a list of typical nuclear design characteristics; Figures A.6 and A.7 illustrate the concept.

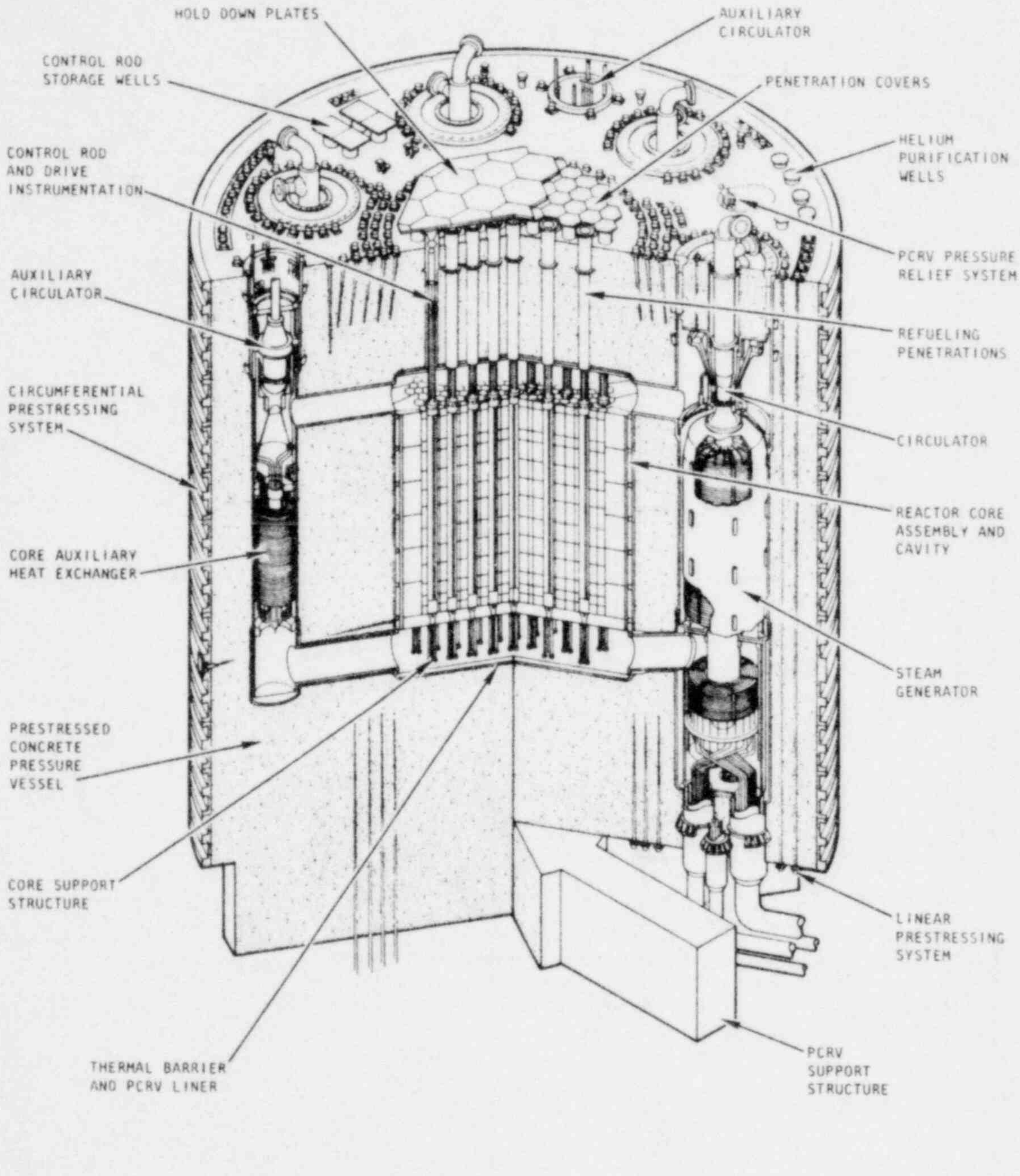


FIGURE A.6 GENERAL ARRANGEMENT OF A HIGH TEMPERATURE GAS COOLED REACTOR

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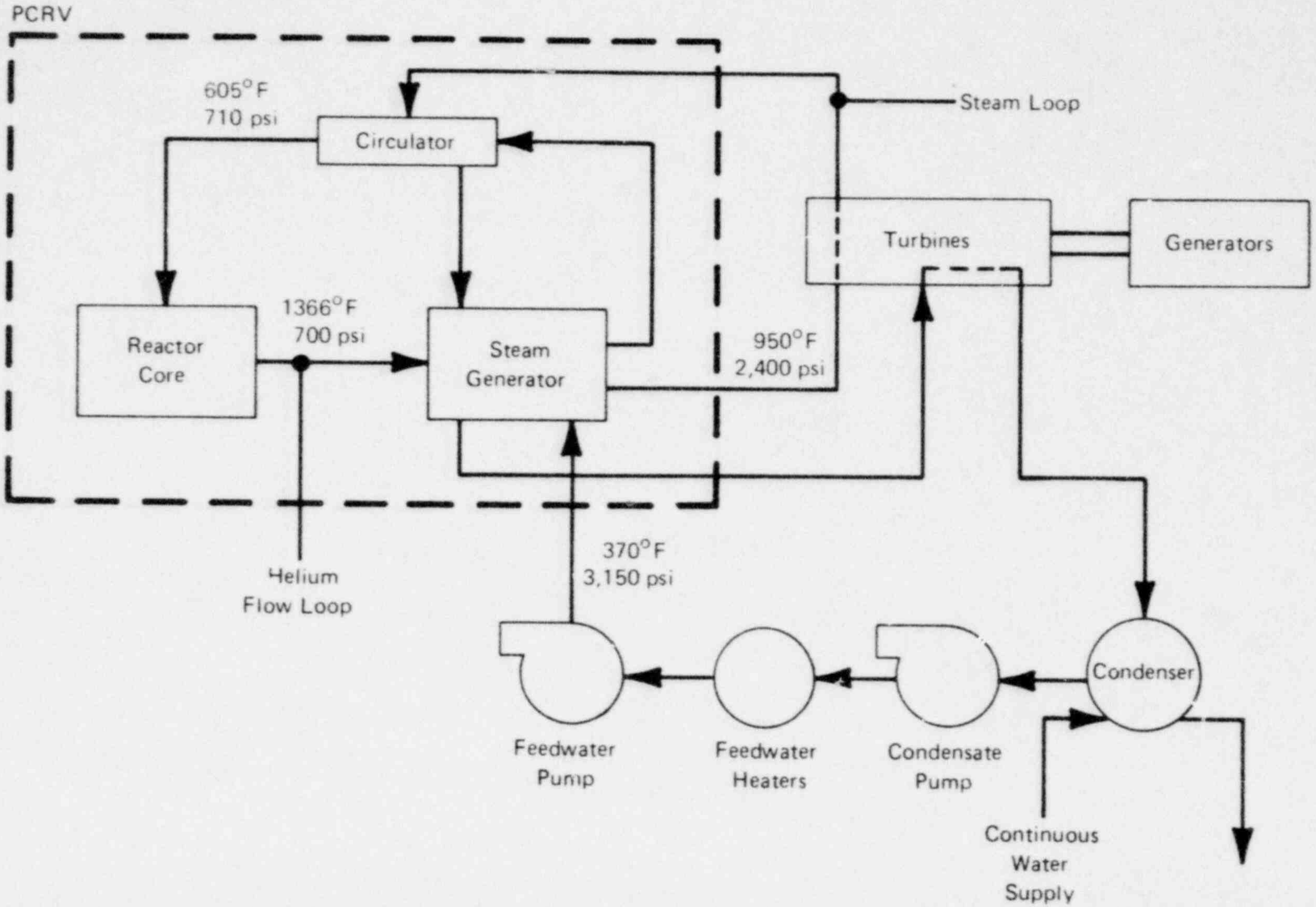


FIGURE A.7 TYPICAL HIGH TEMPERATURE GAS COOLED REACTOR STEAM PLANT FLOW DIAGRAM

TABLE A.3

PRINCIPAL PARAMETERS AND DESIGN FEATURES OF AN HTGR

Parameter or Feature	
Rated Power Level	3,000 MWt
Net Electrical Output	1,160 MWe
No. Fuel Elements	3,944
Fuel Rod Array	Stacked in Hex Array
No. Control Rods	146
Power Density	8.4 kW/ft
PCRV Diameter	105' 4"
PCRV Height	91' 2"
No. of Circulating Loops	6, /3 auxiliaries
Helium Pressure	710 psig @ circ. discharge
Core Inlet Temperature	607°F
S.G. Inlet Temperature	1,366°F
Total He Flow to S.G.	11×10^6 lbs/hr.

Nuclear Steam Supply System

The nuclear steam supply system consists of a high-temperature, pressurized helium gas reactor coolant system and associated auxiliary fluid systems. In current concepts, the reactor core and the entire primary coolant system, including the steam generators and helium circulators, are contained within a thick-walled, multicavity prestressed concrete reactor vessel (PCRV).

The active core is composed of vertical columns of hexagonally-shaped fuel elements, with graphite as the principal structural material.

Fuel materials are composed of highly enriched uranium carbide and fertile thorium oxide in the form of particles bonded together with a graphite binder to form fuel rods. Unlike LWRs, the fuel is not clad with a metal alloy. Instead the uranium carbide particles are coated with pyrolytic carbon and silicon carbide (TRISO), while the thorium oxide kernels are coated with layers of pyrolytic carbon (BISO). These layers serve to prevent the release of fission products into the coolant.

The thermal energy produced within the core is removed by a downward flow of pressurized helium circulated by the six main helium circulators. From the core outlet plenum, the primary coolant flows through cross ducts to the steam generators, where energy is transferred to the secondary coolant system, and returned to the suction side of the main helium circulators.

Auxiliary Systems are provided to perform the following functions:

a) Charge the reactor coolant system

b) Add makeup helium

c) Purify helium

d) Cool system components

e) Monitor coolant for moisture content (important to assure that no reactions take place with the graphite)

f) Remove residual heat when the reactor is shut down

g) Provide for emergency core cooling in the event of an accident

h) Provide containment ventilation and cooling

i) Process liquid, gaseous and solid wastes.

Reactor control and trip are provided by 73 top entry control rod pairs inserted in channels in the central column of each refueling region. Each rod pair is operated by an independent drive mechanism housed in the refueling penetrations in the top head of the PCRV. An independent reserve shutdown system is provided for the release of neutron absorbing material into the core.

Turbine and Auxiliaries

Steam produced by the NSSS is used to drive two turbines, of approximately 600 MW(e) rating each, arranged in parallel. Because an HTGR operates at high temperature, the turbines are of a conventional, reheat design. The main steam from the superheaters passes through the high pressure (H.P.) turbine. The steam from the H.P. exhaust is used to drive the main helium circulators before being reheated and returned to the intermediate pressure (I.P.) turbine. The exhaust steam from the I.P. turbine flows through the low pressure (L.P.) turbine to a condenser located beneath each L.P. turbine. The condensate is recycled to the feedwater pumps through a cleanup and reheat train. The condenser cooling water is a recirculating system with a cooling tower as the heat sink. Makeup water is provided as required.

Structures

The reactor containment building provides a barrier against fission product release to the atmosphere in case of an accident such as a failure of the liner or penetrations in the PCRV. It is a concrete cylindrical structure, the total height of which is 125 feet, with an inside diameter of 126 feet for an 1160-MWe NSS. The inner surface is lined with a carbon steel liner to ensure leak tightness.

The reactor service building houses new and used fuel storage wells and reactor auxiliary systems that are not located inside the containment building. Provisions are also made for storage of reactor moderator parts in this building, which is a multi-story structure adjacent to the containment building.

The control building houses the control room, auxiliary equipment, ventilation equipment, and reactor plant cooling water system. It is a missile-protected building since it houses safety-related equipment.

The diesel-generator building is designed to withstand short-term tornado-loading, including tornado-generated missiles. This building houses the diesel generators that provide standby power.

The turbine-generator building contains the turbine generator and other equipment related to the conventional portion of the plant. Building design is based on the same criteria as used for a fossil-fired plant turbine-generator building.

Miscellaneous structures are required for such uses as storage of helium bottles, chemicals storage, and water intake equipment housing.

The turbine generator and its controls act integrally with the NSS for turbine load control. The type of turbine selected is subject to variations; however, a typical heat balance diagram for a 3600-rpm tandem-compound turbine using four feedwater heaters is shown in Figure 8. The circulating water system provides the major means of plant heat rejection.

Other balance-of-plant equipment and system are similar to those required for a conventional fossil-fired or LWR plant. Included are items such as the condensers, feedwater pumps, makeup water treatment system, circulating water systems, and electric plant equipment.

2.4 SUMMARY DESCRIPTION OF A LIQUID METAL FAST BREEDER REACTOR

An LMFBR generates power in a manner analagous to a PWR or HTGR, in that one system is used to extract heat from the reactor and a separate system uses that heat to convert water to steam. The LMFBR uses uranium enriched with 15%-20% plutonium as the fuel base; the reactor coolant is sodium. These features permit design of a core which is much more efficient, in terms of uranium utilization than LWRs or HTGRs. The term breeder comes from the fact that fission able fuel is created than is burned during power generation.

This concept has been under development for several decades and has reached the point where the ERDA is seeking a license to construct and operate a 350 MWe demonstration plant. The concept is expected to be commercially available in the late 1980s. An environmental statement for the entire LMFBR R&D program has been prepared (Ref. 5) and provides considerable information on the various types of liquid metal reactors that may ultimately be used.

As in the case of HTGRs, the LMFBR operates with relatively high coolant temperatures (around 1,000°F) permitting thermal efficiencies approximately that of contemporary fossil boilers. A plant of approximately 3,000 MWt could generate about 1,200 MWe. A typical flow diagram for an LMFBR is as shown in Figure A.8.

In most respects the LMFBR will have similar general requirements and features as other reactor types. Equipment within the reactor building (Figure A.9) will of course be substantially different but the balance of plant will not.

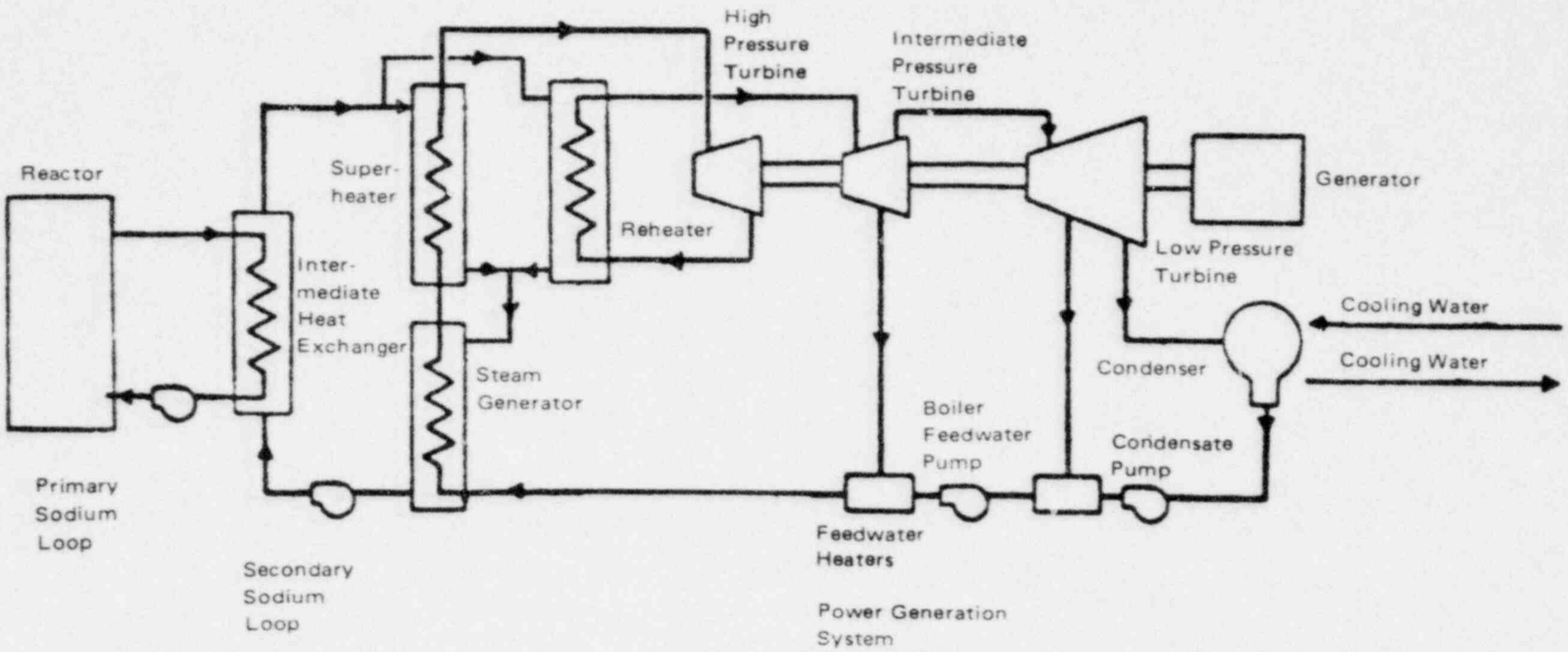


FIGURE A.8 MODEL LIQUID METAL FAST BREEDER REACTOR (LMFBR) PLANT FLOW DIAGRAM

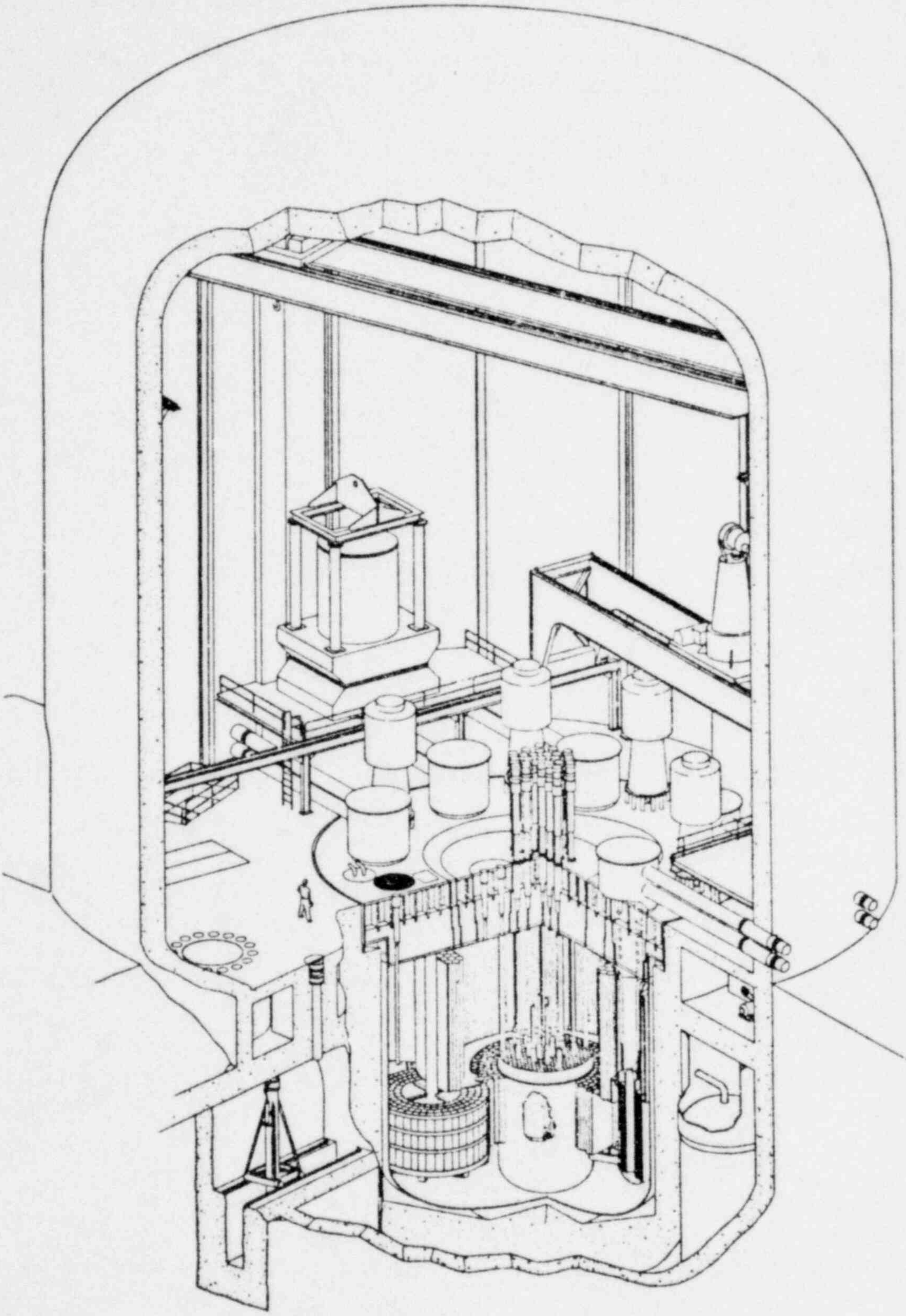


FIGURE A.9 SECTIONAL VIEW OF LIQUID METAL FAST BREEDER REACTOR BUILDING

3.0 ADDITIONAL ATTRIBUTES OF A FOUR-UNIT STATION

Since only LWRs have been proposed at this point for the four-unit stations, the description that follows is specific to LWRs but is considered to be generally applicable to other reactor types. It is assumed that the nuclear station will be built as two essentially identical plants, each with two generating units. The standardized portion of each unit consists of the following structures and associated systems and components:

a. Reactor building (containment)

b. Turbine building

c. Control building

d. Auxiliary building

e. Diesel generator building

f. Fuel building

g. Radwaste building

h. Storage tanks important to safety.

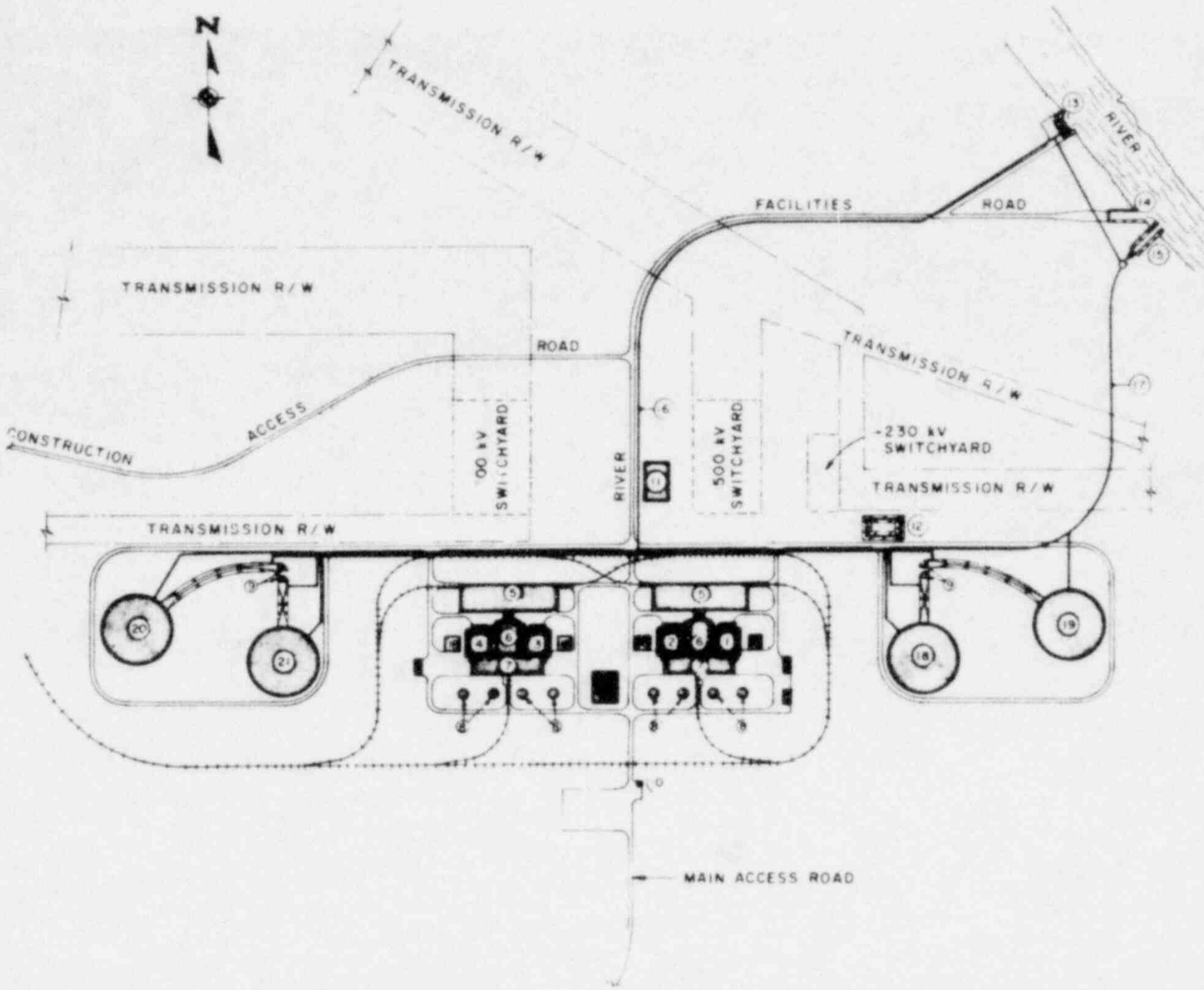
The remainder of the balance-of-plant equipment will be designed based on site conditions and will be shared to the extent practicable among all four units.

A significant amount of space and equipment, such as the Control Building, will be shared by Units 1 and 2 and by Units 3 and 4. Physical separation of Units 3 and 4 from Units 1 and 2 is provided and during initial operation of Unit 1 (or 3) prior to completion of Unit 2 (or 4), the construction area will be separated from the operating area. A representative site plan and view are shown in Figures A.10 and A.11.

With a station power of about 5,000 MWe (or 15,000 MWt), capability for heat dissipation is a major factor. For sites located on rivers, closed-cycle cooling systems are required. For a four-unit station, such a system will require a capacity of up to 5×10^{10} Btu/hr. Assuming that natural-draft cooling towers are used, roughly 100,000 gpm of makeup water will be required (60,000 gpm evaporative and drift losses and 40,000 gpm blowdown to the river).

A heat dissipation system for an essential service water system will be employed. If the system has spray ponds, four will be employed, each about three or four acres, and will be located between the two plants. A holdup pond and canal to the river will accommodate blowdown from this system (1,000 gpm).

For both systems, intake and discharge systems are provided, similar to those for two-unit stations (see WASH-1355, "Nuclear Power Facility Performance Characteristics for Making Environmental Impact Assessments").



INDEX

1) UNIT 1 REACTOR BLDG
2) UNIT 2 REACTOR BLDG
3) UNIT 3 REACTOR BLDG
4) UNIT 4 REACTOR BLDG
5) TURBINE GENERATOR BLDG
6) CONTROL & FUEL HANDLING BLDG
7) AUXILIARY BLDG
8) NUCLEAR SERVICE COOLING TOWER
9) CIRCULATING WATER INTAKE STRUCTURE
10) GUARD STATION
11) PLANT WAREHOUSE & TEMPORARY OFFICES
12) TEMPORARY RETENTION BASIN
13) RIVER MAKE-UP INTAKE STRUCTURE
14) BARGE UNLOADING FACILITY
15) DISCHARGE STRUCTURE
16) RIVER MAKE-UP WATER LINE
17) COOLING WATER BLOWDOWN LINE
18) UNIT 1 COOLING TOWER
19) UNIT 2 COOLING TOWER
20) UNIT 3 COOLING TOWER
21) UNIT 4 COOLING TOWER

FIGURE A.10 A TYPICAL SITE PLOT PLAN

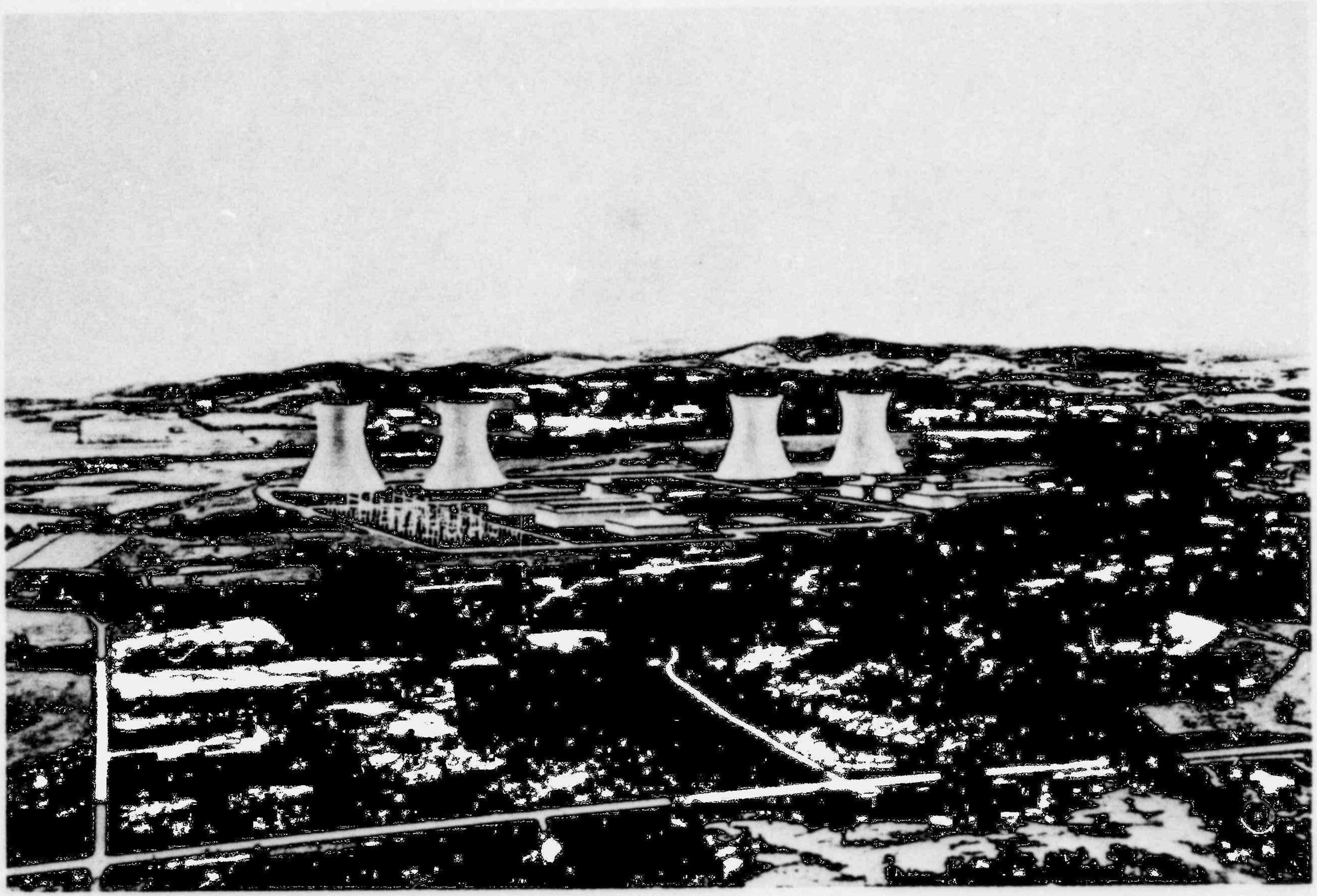


FIGURE A.11 AERIAL PERSPECTIVE OF HARTSVILLE PLANT

The overall site is likely to be 2000-4000 acres. The site area occupied by the four units will be about 500 acres. Several hundred acres will be covered by parking lots, roads, power lines, the meteorology tower, detention basins, and the railroad spur. Another 300 or 400 acres will be utilized during construction activities (such as borrow areas and land used for stockpiling of building materials).

Transmission lines will be provided connecting to a 230, 365, 500, or 765 kV line. The land needed for such lines may vary widely, but probably would be of the order of 5000 acres.

Construction at the site will occur over about a ten-year period, with a peak force of 3000-4000 and an average work force of about 1500. The units will be brought on line at the rate of one a year.

REFERENCES

1. United States Nuclear Regulatory Commission. June 1975. *Final environmental statement related to construction of Hartsville nuclear power plants of the Tennessee Valley Authority.* Docket Nos. STN 50-518 through 50-521. NUREG-75/039.

2. United States Nuclear Regulatory Commission. April 1975. *Draft environmental statement related to the proposed Alan R. Barton nuclear plant units 1, 2, 3 and 4, Alabama Power Company.* Docket Nos. 50-524 through 50-527. NUREG-75/029.

3. United States Atomic Energy Commission. March 1974. *Final environmental statement related to the proposed Alvin W. Vogtle nuclear plant units 1, 2, 3 and 4, Georgia Power Company.* Docket Nos. 50-424 through 50-427.

4. United States Atomic Energy Commission. March 1974. *Revised final environmental statement related to construction of Shearon Harris nuclear power plant units 1, 2, 3 and 4, Carolina Power and Light Company.* Docket Nos. 50-400 through 50-403.

5. United States Atomic Energy Commission. December 1974. *Proposed final environmental statement, liquid metal fast breeder reactor program.* Volume II. WASH-1535.

APPENDIX B

THE NUCLEAR FUEL CYCLE

Introduction

The nuclear fuel cycle encompasses those physical and chemical activities necessary to produce the fuel for use in the reactor, recover and process fissionable and fertile materials for reuse, and manage the radioactive waste generated in the activities. The major steps are those necessary to:

1. Discover, extract from their places in nature, and purify the naturally occurring fertile materials (Uranium Mining and Milling);

2. Convert this material to the proper chemical form for enrichment (Conversion of Feed Material);

3. Prepare the proper mixtures of fissile and fertile material by either isotopic enrichment or physical blending (Uranium Enrichment);

4. Physically convert the mixture into the proper form and containment for reactor operation (Nuclear Fuel Processing and Fabrication);

5. Separate and purify the unburned fissile and fertile values of spent fuel, as well as the fissile values generated in such fuel by reactor operation, for reuse (Spent Fuel Processing); and

6. Manage the resultant radioactive waste (Radioactive Waste Management).

The three types of nuclear reactors expected to dominate the nuclear power industry between the present and the year 2000 assuming that they have or will become appropriately licensed by the Nuclear Regulatory Commission are:

1. The LWR, operated UO_2 and mixed $(U,Pu)O_2$ fuel;
2. The HTGR, operated on U-Th; and
3. The LMFBR, operated on (U,Pu) oxide or carbide fuels.

Of course, this expectation rests on a variety of assumptions, such as the economic, environmental, and social viability of the concepts in addition to the fact that all elements of the fuel cycle must be appropriately licensed by NRC as well as the various concepts of nuclear power plants. Throughout the following discussion the above stated assumptions should be borne in mind and for these reasons some of the elements described may indeed change at some time in the future.

Not all reactor concepts require the same fuel cycle. For example, gas-cooled reactors use thorium rather than uranium-238 as the fertile material. Fast reactors use plutonium-239 as well as uranium-235 and uranium-233 as the fissile material. Some water-cooled reactors may use plutonium as well as uranium-235 for the fissile material in reload cores.

Extensive publications describe the operations of the various processes forming the nuclear fuel cycles for the three major reactor types. An NRC Environmental Impact Statement may be prepared for each new facility being licensed. These statements describe the process used, the effluents, and the resulting environmental impact. In addition, such survey documents as: WASH-1248, Environmental Survey of the Uranium Fuel Cycle; WASH-1327, Generic Environmental Impact Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in LWRs; WASH-1535, Proposed Final Environmental Statement Liquid Metal Fast Breeder Reactor Program; WASH-1539, Draft Environmental Statement, Management of Commercial High Level and Transuranium-Contaminated Wastes; and EPA-520/9-73-003, Environmental Analysis of the Uranium Fuel Cycle contain relatively detailed descriptions of the nuclear fuel-cycle plants and processes.

Only a brief description of the fuel-cycle facilities considered in the NECSS-1975 is given in this appendix. Readers are referred to the above documents, the general technical literature, or textbooks on nuclear energy for additional technical information.

Table B.1 categorizes the out-of-reactor fuel-cycle elements for the three reactor fuel cycles, and Figures B.1, B.2, and B.3 illustrate the fuel-cycle operations.

TABLE B.1

OUT-OF-REACTOR FUEL-CYCLE ELEMENTS

	Reactor Type		
Operation	LWR	LMFBR	HTGR
U Mining	x	-	x
U Milling	x	-	x
Nat'l UF_6 Manu.	x	-	x
Enrichment	x	-	x
U Fuel Element Manu.	x	-	-
U/Pu Fuel Element Manu.	x	x	-
U/Th Fuel Element Manu.	-	-	x[a]
Fuel Reprocessing	x	x	x
Waste Management	x	x	x

[a]Three types of elements will be manufactured--virgin $^{235}U/Th$; recycle $^{235}U/Th$, and $^{233}U/Th$.

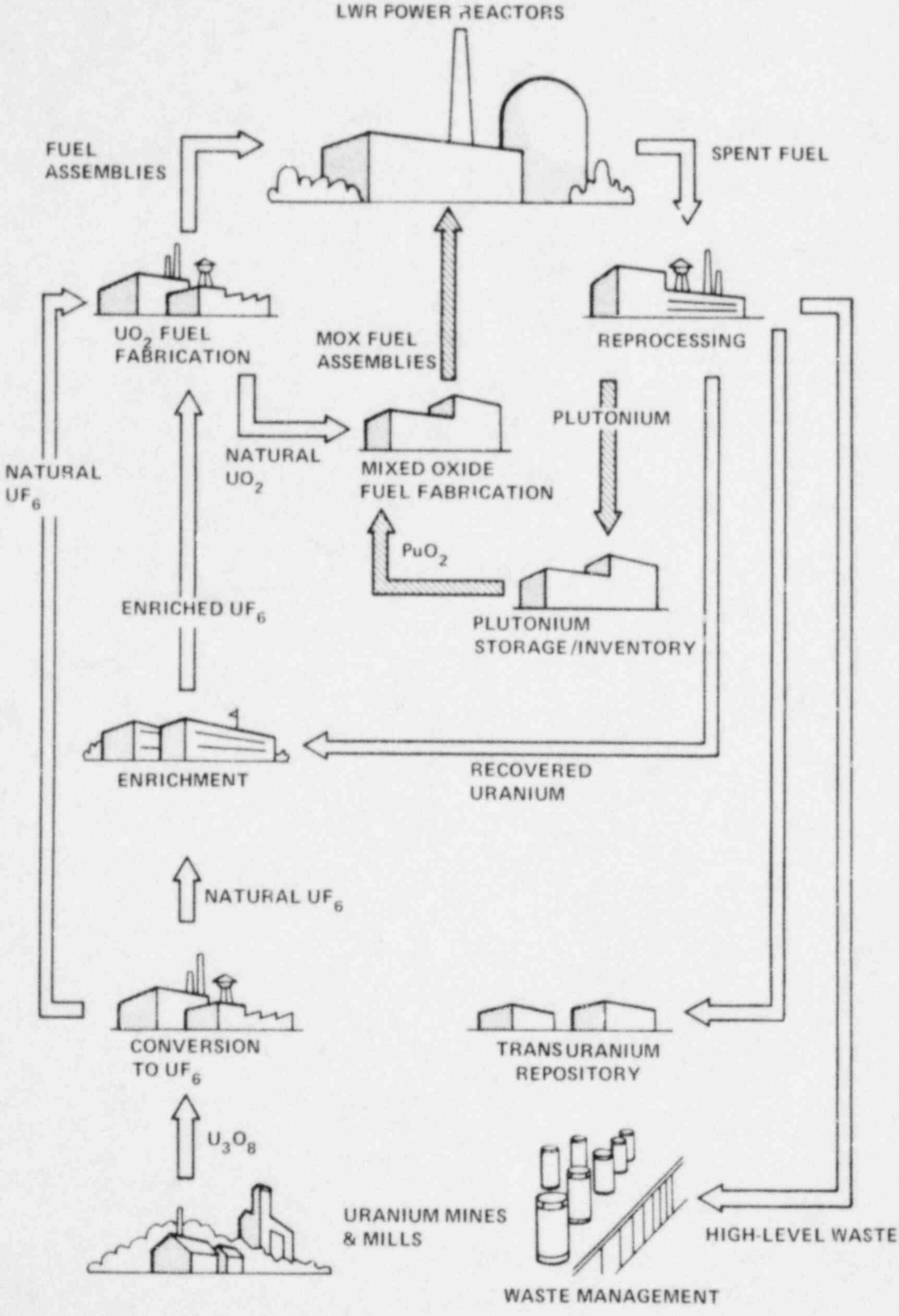


FIGURE B.1 LIGHT WATER REACTOR FUEL CYCLE

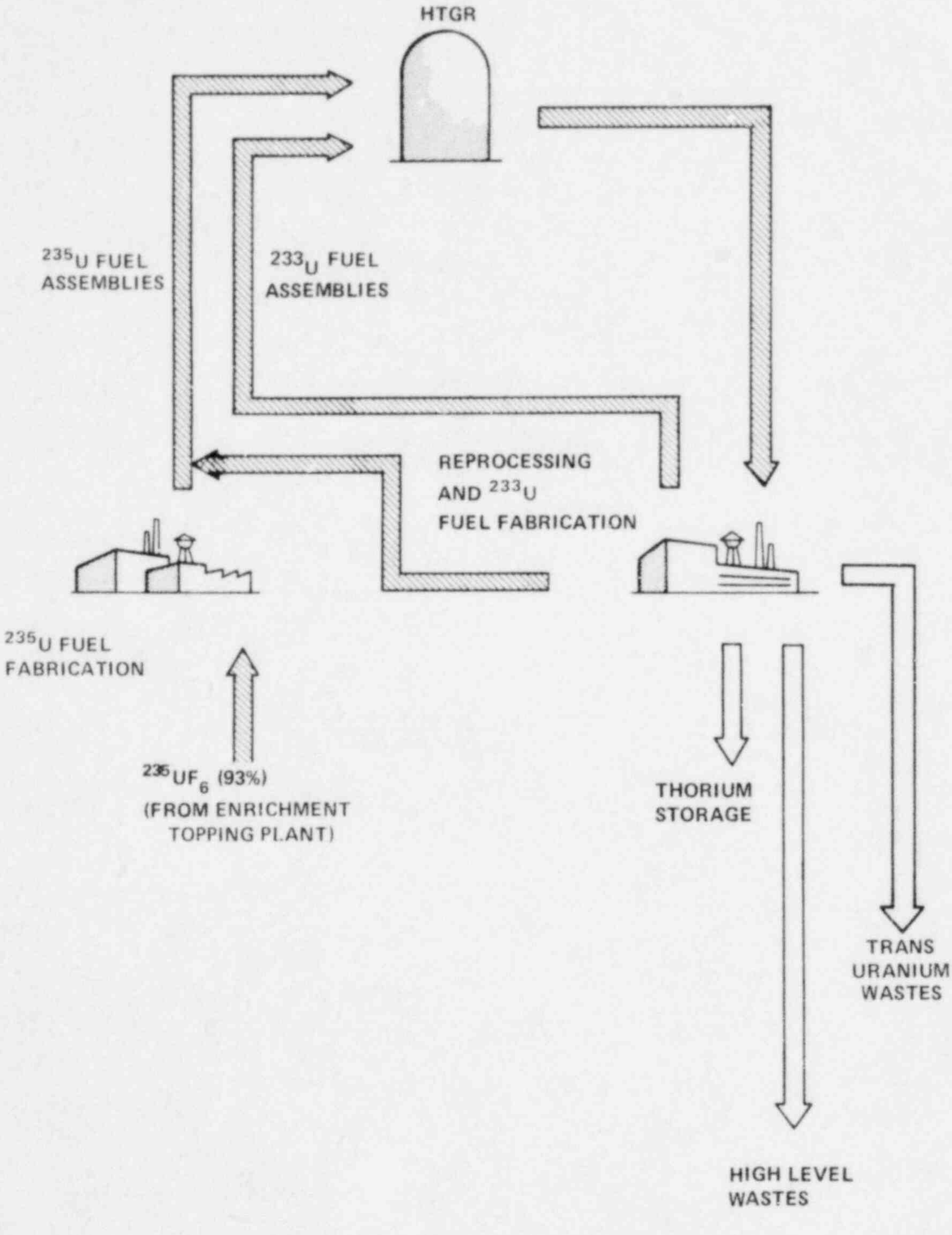


FIGURE B.2 HIGH TEMPERATURE GAS COOLED REACTOR FUEL CYCLE

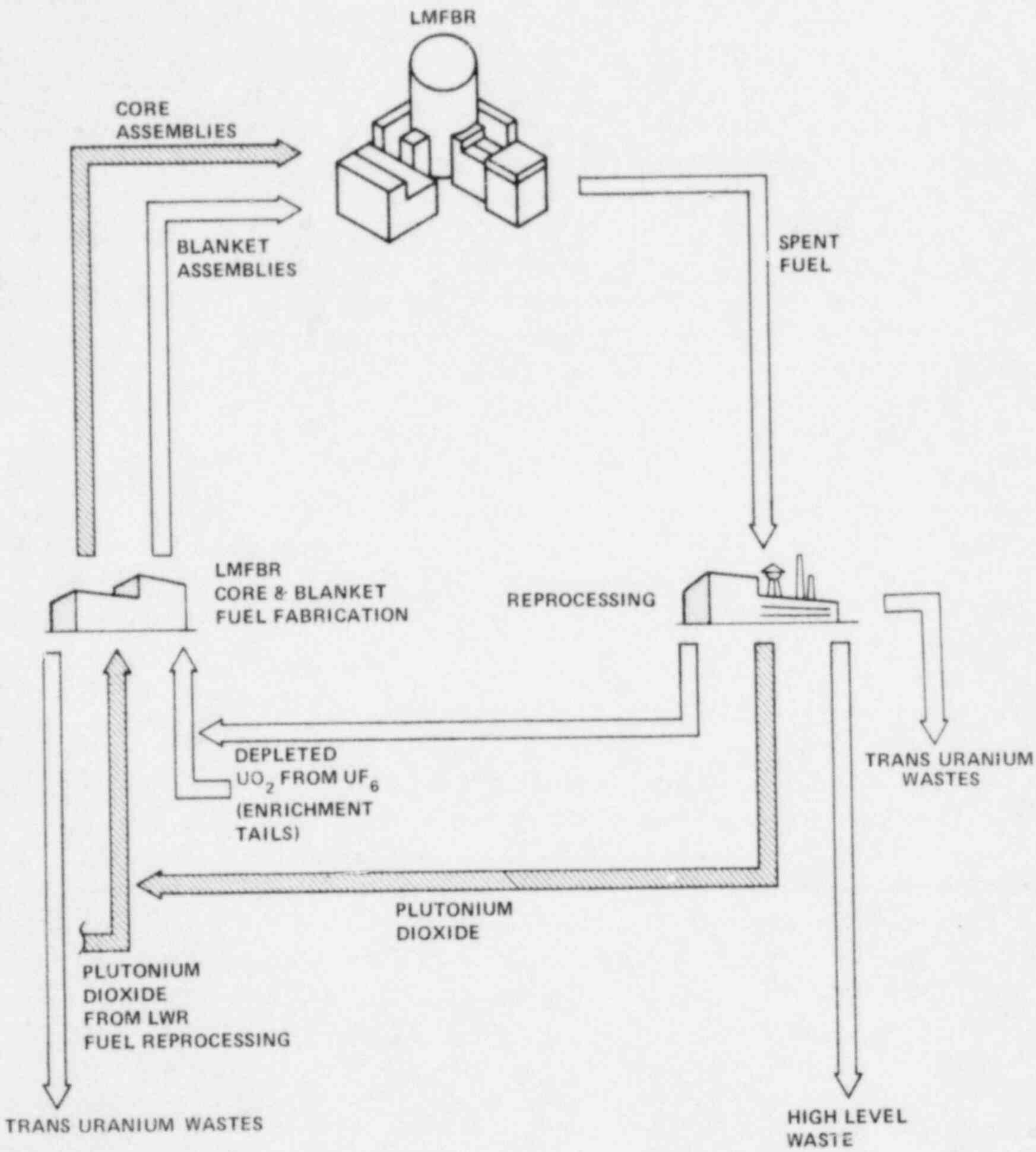


FIGURE B.3 LIQUID METAL FAST BREEDER REACTOR FUEL CYCLE

The brief discussions of the fuel cycle that follows uses the slightly enriched light-water cooled reactors (LWR) as a reference case since this system is the reactor chosen for NECSS-1975.

Nuclear Fuel Cycle - Present

Uranium Mining and Milling

In the first step of the fuel cycle, uranium-bearing ores are removed from the earth by underground or open-pit mining methods similar to those for extracting many other kinds of metal ores. In general, in the United States, the average uranium content of the extracted ores has been about one-quarter of one percent. To minimize the costs of shipping these ores, the uranium mills have usually been built fairly near the mines. At the mills, the ores are crushed and ground and the uranium extracted with acid leaching or with an organic solvent. The uranium fraction is generally converted to oxide form (U_3O_8) for shipment and the remainder of the ore is a waste product generally called mill tailings.

Conversion of Feed Material

The concentrates from the mill are sent to a plant where the uranium values are converted to uranium hexafluoride. This material still has its natural isotopic composition of 0.7 percent uranium-235 and 99.3 percent uranium-238. Since many reactors are designed to operate with fuel of a higher relative abundance of uranium-235, an isotopic enrichment step is the next operation in the fuel cycle.

Uranium Enrichment

The enrichment process in use today is gaseous diffusion using uranium hexafluoride as the feed material. This is a compound which is a solid at room temperature, but can be maintained as a gas by heating. In a gaseous diffusion plant, UF_6 is forced through a series of thin, porous barriers. Because of the difference in molecular weight, the uranium-235 hexafluoride diffuses through each barrier at a rate which is slightly faster than the rate for the uranium-238 hexafluoride. By using many barriers, a significant enrichment in uranium-235 is obtained. The UF_6 is withdrawn from the gaseous diffusion process with a uranium-235 content in the two to three percent range for use in light-water cooled nuclear power plant fuels. Fuel for HTGRs is enriched to more than 90% uranium-235. The residual uranium, which is correspondingly depleted in its uranium-235 content, is not a waste and is stored at the diffusion plant for possible later use.

Nuclear Fuel Fabrication

The enriched UF_6 is converted to usually uranium dioxide (UO_2) at a fuel element fabrication plant. The UO_2 is formed into pellets that are then sealed in tubes, or sleeves, made of Zircaloy, stainless steel, or some other material which will resist corrosion under the condition of heat coolant elements, are mounted in assemblies for use in the reactor.

Reactor Operation

During the reactor operation, fissile materials are destroyed in the fission chain reaction and fertile materials are converted into fissile materials by absorption of fission neutrons. The heat released in the fission reaction is conducted through the walls of the fuel elements into a coolant and converted in part into useful power. Some of the neutrons escape from the fuel elements and are absorbed in the coolant or in the shielding. Since materials created by neutron absorption are generally radioactive, this is a source of radioactive waste which must be handled either fairly soon (as in the treatment of coolant for recirculation or discard) or on a deferred basis (as in repair or eventual removal of reactor components).

The radioactivity induced by neutron capture is the major source of radioactive waste at the reactor site. However, far larger quantities of radioactive waste are created at the reactor within the fuel elements and are retained in the fuel until they are separated and packaged elsewhere. This larger waste volume is made up of the fission products, or materials into which fissile material splits up in the fission chain reaction.

Most of the fission products are radioactive. Those which undergo rapid radioactive decay within the fuel elements will come to an equilibrium point at which the creation of new atoms of a specific fission product is essentially balanced by the losses of that fission product through decay and burnout. For example, in a reactor operating at a constant power level, the quantity of the fission product iodine-131 will reach an approximate equilibrium after 40 days of operation (five times the radioactive half life). Other fission products which decay more slowly (such as strontium-90) will continue to accumulate with exposure within the fuel element throughout its use in the reactor. The absorption of neutrons by these fission products interferes with the chain reaction to the point where it is necessary to remove the fuel elements even though they still contain unburned fissile material. To conserve these materials, and the fertile material which has been created, the partly spent fuel is reprocessed.

Spent Fuel Reprocessing

The reprocessing is done at specialized plants, to which the irradiated fuel is shipped, intact, in heavily shielded casks. The first step is usually to mechanically chop the fuel elements into small pieces so that the fuel is no longer protected by the corrosion-resistant cladding. The fuel is then dissolved in nitric acid. An organic solvent, usually tributyl phosphate, is used to extract the plutonium and uranium from the acidic solution. The remainder of this acidic solution, containing almost all the fission products, is the "high level wastes" as defined in NRC regulations. Additional steps separate the uranium and plutonium from each other and purify them. They are then converted to a solid form. The plutonium is converted to plutonium dioxide and the uranium to UF_6 for recycle to reenrichment.

Radioactive Waste Management

Uranium milling generates a type of waste (mill tailings) which is unique to that step of the cycle. In terms of physical mass, uranium mill tailings are many times greater than any other type of radioactive wastes; the quantity now stored in the United States is about ninety million metric tons.

Another general type of radioactive wastes, not unique to any step of the fuel cycle, is generated to some extent in each of the steps. This type, usually called "low-level solid wastes," consists of a wide variety of solids which are not usually radioactive themselves but have radioactive materials present within them or upon their surface. Examples are: used processing equipment; used protective clothing; used nuclear reactor equipment; residues or scrap from chemical or metallurgical operations; precipitates, sludges, or ion exchange resins containing radioactive materials; and used high-efficiency particulate filters from ventilation exhaust systems.

A third classification of radioactive wastes is high level. These wastes contain more than 99 percent of the radioactivity in all radioactive wastes, although they are relatively small in volume. In physical form, they are originally acidic solutions. Under interim storage conditions, they may be present as acidic solutions, neutralized solutions, sludges or slurries, or dry solids. Typical individual tanks or containers of these wastes require massive shielding for the penetrating radiation emitted, and provisions for conduction away the radioactive decay heat.

A fourth class of radioactive wastes is TRU wastes, materials contaminated with plutonium or other transuranium isotopes.

Before returning to the beginning of the fuel cycle to discuss the techniques for managing solid wastes, a few words on radioactivity in gaseous and liquid effluents are in order. At present, filtration, ion exchange, and chemical treatments have been developed to the point of routinely decontaminating these effluents to a small fraction of the internationally-accepted concentration standards for almost all of the radionuclides. The exceptions are the fission products argon, krypton, and tritium. Argon and krypton are gases that are chemically inactive (like helium and neon) which makes it difficult to remove them from a gas stream. Tritium behaves chemically like hydrogen, which makes it extremely difficult to remove tritium oxide when it has been mixed in a water effluent. Although it appears that population exposures from effluents containing these radionuclides will continue to be well within standards, even under projected nuclear power growth, technology to remove them from effluents at the source is being investigated.

The low-level solid radioactive wastes generated in the various parts of the fuel cycle are managed in several ways. In the United States, the usual method has been burial in relatively shallow trenches after evaluations of the local geology and hydrology have indicated extremely low probabilities that the radioactivity would migrate. In the usual evaluations, the waste containers are assumed not to remain intact after the burial, with the soil itself being considered as the primary container. Contaminated solid wastes from the ERDA's operations are buried at 11 ERDA sites, and similar burials for wastes from commercial activities are buried at a total of six sites operated by three private companies.

High-level wastes are required to be transferred to the Federal Government for disposal. Proposed regulations would also require TRU wastes to be transferred to the Federal Government for disposal.

The Nuclear Fuel Cycle - 1975-2000

ERDA's Office of Planning and Analysis published projections of annual fuel requirements for the nuclear power base from the present to the year 2000. These fuel cycle requirements for enrichment services; LWR UO_2 and mixed oxide fuel fabrication; HTGR fissile and fertile fuel fabrication; LMFBR mixed oxide and blanket fuel fabrication; and spent fuel reprocessing for each of the reactor types are given in Table B.2, B.3, B.4, B.5, and B.6, respectively. The requirements are derived from the installed nuclear power capacity of Case A WASH-1139(74), with the assumption that plutonium recycle to LWRs begins in about 1982, and that commercialization of the liquid metal fast breeder begins around 1993. LWR fuel cycle requirements without plutonium recycle are given in Table B.2 and B.3. No data are presented on mining or milling since these operations were not considered candidate operations for location at energy centers.

TABLE B.2

ENRICHMENT SERVICES

Separative Work Units Metric Tons Per Year

Year	No Pu Recycle	With Pu Recycle
1985	25.4	20.7
1990	42.2	35.8
1995	59.3	50.3
2000	72.9	62.6

Source: WASH-1139(74) Case A.

TABLE B.3

LWR FUEL FABRICATION REQUIREMENTS

LWR Fuel, Metric Tons Per Year

Year	Total Fuel	Mixed Oxide Fuel
1985	7,700	6,400
1990	12,200	14,100
2000	20,000	16,800

Note: Total fuel = UO_2 Fuel and Mixed Oxide Fuel. With no Pu Recycle, Total fuel is all UO_2.

Source: WASH-1139(74) Case A.

TABLE B.4

HTGR FUEL FABRICATION REQUIREMENTS

Fuel Fabrication, MTHM/Yr

Year	HTGR Fissile[a]	HTGR Fertile[b]
1985	12	210
1990	28	410
1995	47	620
2000	63	770

Source: WASH-1139(74) Case A.

[a]Uranium

[b]Thorium

TABLE B.5

LMFBR FUEL FABRICATION REQUIREMENTS

Fuel Fabrication, Metric Tons Heavy Metal Per Year

Year	Core (Mixed Oxide)	Blanket (Depleted UO_2)
1985	4	3
1990	4	3
1995	114	130
2000	510	510

Source: WASH-1139(74) Case A.

TABLE B.6

FUEL REPROCESSING REQUIREMENTS

Fuel Reprocessing Metric Tons Heavy Metal Per Year

Year	LWR	HTGR Fissile	Fertile	LMFBR Mixed Oxide
1985	7100	-	-	-
1990	8000	-	-	-
1995	12100	25[a]	500[a]	-
2000	16100	25[a]	500[a]	500

Source: WASH-1139(74) Case A.

[a]Projected Plant Capability.

Most LWR fuel-cycle facilities exist at some scale ranging from experimental to large production level in the United States today. The only LWR facility that does not exist is the Federal Waste Management Facility for high-level wastes.

The status of the LWR industry is outlined below:

Uranium Enrichment--all of the enrichment services in the United States are performed by the three Government-owned gaseous diffusion plants. The present capacity of the three-plant complex is 17.5 million separative work units per year. Expansion programs to increase the capacity of the gaseous diffusion plants to 27.7 million separative work units by 1979 to 1980 are planned. The projected domestic and foreign enrichment requirements for United States facilities appear to require additional facilities for LWRs in the 1980s. These new facilities are expected to use the gaseous diffusion process for enriching, and to be industry-owned and financed. In addition, ERDA has issued requests for proposals for a demonstration centrifuge enriching facility (DCEF). The DCEF would be a small facility that would receive a subsidy from the Government.

In addition to facilities for enriching uranimum for use in LWRs, topping enrichment facilities to provide fully-enriched uranium for the HTGRs may be required at a somewhat later date than the enrichment facilities for the LWR.

LWR UO_2 Fuel Fabrication Facilities

The existing LWR UO_2 fuel fabrication facilities consist of ten commercial plants, each one of which performs all or part of the fuel fabrication operations from conversion of enriched UF_6 to UO_2 to fabrication of UO_2 into fuel assemblies. The ten existing plants have an estimated current capacity of 3000 metric tons per year of LWR fuel assemblies. (See Table B.7 for location and ownership of the plants.) Some of the existing sites may have substantial capability for increased production. For example, General Electric Company has indicated that their Wilmington, North Carolina, LWR UO_2 fuel fabrication facility capacity could quadruple between 1971 and 1981. NRC estimates, from GE's data, that the Wilmington facility could have the capacity to produce 3000 metric tons per year of fuel by 1980.

The data on LWR UO_2 fuel fabrication requirements given in Table IIB2 show increased production to be required prior to 1985, with additional increases in requirements at least through the year 2000. Some part of this increased UO_2 fuel fabrication will undoubtedly come from expansion of existing facilities, consonant with NRC regulations, as well as the manufacturing economics. NRC estimates that 4 to 7 new plants will be required by the year 2000.

Mixed Oxide Fuel Fabrication

The existing private facilities in the United States for fabricating mixed oxide fuel (uranium-plutonium) can be classed as pilot plant or semiworks scale facilities. The nine facilities having licenses to process plutonium into fuel rods have a total estimated annual production capacity of the order of 50-75 metric tons per year of fuel. (See Table B.8.) Two of the

TABLE B.7

LWR FUEL FABRICATION PLANTS

Licensee	Plant Location	Plant Feed Material	Plant Product
Babcock & Wilcox	Lynchburg, Va.	UO_2 Pellets	Fuel Assemblies
Combustion Engineering	Windsor, Conn.	UO_2 Powder	Fuel Assemblies
General Electric	Wilmington, N.C.	UF_6	Fuel Assemblies
Gulf United Nuclear	Hematite, Mo.	UF_6	UO_2 Powder or Pellets
Gulf United Nuclear	New Haven, Conn.	UO_2 Pellets	Fuel Assemblies
Jersey Nuclear	Richland, Wash.	UF_6	Fuel Assemblies
Kerr-McGee[a]	Crescent, Okla.	UF_6	UO_2 Powder or Pellets
Nuclear Fuel Services[a]	Erwin, Tenn.	UF_6	UO_2 Powder or Pellets
Nuclear Materials Div. (NMD) B & Pellets formerly NUMEC	Apollo, Pa.	UF_6	UO_2 Powder or
Westinghouse	Columbia, S.C.	UF_6	Fuel Assemblies

[a]Kerr-McGee and Nuclear Fuel Services data are from USNRC Regulatory files.

facilities, Kerr-McGee and the Nuclear Materials Division of Babcock and Wilcox (NMD) have fabricated mixed oxide fuel for the fast Flux Test Reactor. This fuel is similar to that used in a liquid metal fast breeder reactor. (See Section 7 for present status.)

LWR Fuel Reprocessing

There are two LWR fuel reprocessing plants: the Allied General Nuclear Services (AGNS) plant at Barnwell, South Carolina, presently under construction, and the Nuclear Fuels Service (NFS) plant at West Valley, New York, presently shut down for modifications and expansion. Total capacity of the two facilities is 2,250 metric tons per year, with NFS at its expanded capacity of 750 metric tons per year. Approximately 14,000 metric tons heavy metal per year fuel reprocessing plant capcity will be required by the year 2000; this capacity will require that about seven additional plants be built.

At the present time, the only element of the HTGR fuel cycle that exists is the ^{235}U-Th fuel fabrication facility, and General Atomics (GA) is the only fuel fabricator. The existing HTGR fuel fabrication facility is a small, semi-works facility located in San Diego, California; GA has applied for a license to build a production plant, potentially expandable to 26 cores/year at Youngsville, North Carolina. By the year 2000, ERDA projects an installed HTGR base of about 95,000 MWe, a sufficiently larger base to require additional uranium fuel fabrication

TABLE B.8

EXISTING $(U,Pu)O_2$ FUEL FABRICATION PLANTS

Licensee	Plant Location	Feed Material	Plant Product	Pu Possession Limit (kg)	Est. Prod. Cap. Mt/yr
Atomics International	Canoga Park, Calif.	-	-	4	-
Babcock & Wilcox[a]	Lynchburg, Va.	-	-	2	-
Exxon Nuclear	Richland, Wash.	UO_2 + PuO_2	$(U,Pu)O_2$ fuel assemblies	10 unencapsulated; 100 total	15
General Electric	Pleasanton, Calif.	Nitrate solution (U and Pu)	$(U,Pu)O_2$ fuel rods	15	3
Gulf United Nuclear[b]	Elmsford-Pawling, New York	UO_2 + PuO_2	$(U,Pu)O_2$ fuel rods	1	-
Kerr-McGee	Crescent, Okla.	Nitrate solution (U and Pu)	$(U,Pu)O_2$ fuel rods	360	5-10
Nuclear Fuel Services[c]	Erwin, Tenn.	Nitrate solution (U and Pu)	$(U,Pu)O_2$ fuel rods	2 unencapsulated 100 total	-
Nuclear Materials Div. (NMD) of B & W formerly NUMEC	Parks Township, Pa.	Nitrate solution (U and Pu)	$(U,Pu)O_2$ fuel rods	2000	20
Westinghouse	Cheswick, Pa.	Nitrate solution (U and Pu)	$(U,Pu)O_2$ fuel rods	120	10-15

[a] All work performed by NMD.

[b] Presently shut down for decontamination; will not be reopened by GUNF.

[c] License application states unencapsulated plutonium is for research and development.

facilities. These additional facilities will not be required until late in the 1980s or early 1990s.

ERDA is finalizing the programmatic, environmental impact statement for the LMFBR, with the issue date being about October 1975. If penetration of the commercial nuclear power market by the LMFBR occurs by the early 1990s, then fuel fabrication capability will be required by the late 1980s, and fuel reprocessing justifiable in the late 1990s.

The LWR and LMFBR fuel cycles discussed above generate high level wastes in the fuel reprocessing step, and transuranic (TRU) wastes in the fuel reprocessing and mixed oxide fuel fabrication facilities. The HTGR fuel cycle generates high level waste in its reprocessing step. These high level and TRU wastes, according to existing or proposed NRC regulations must be sent to ERDA-managed Federal Waste Repositories pending the availability of an ultimate disposal method. The interim storage facilities (waste repositories) do not exist at present; ERDA schedules call for the facilities to be available in 1985 or so.

The management of high-level radioactive waste is a shielding and confinement problem, but not a volume problem. A nuclear power reactor generating 1,000 megawatts of electricity discharges about 30 tons of partly spent fuel per year. After eventual processing, this can be expected to yield about 65 cubic feet of solidified high-level waste, or 10 canisters of one-foot diameter and 10-foot length (a possible practical size). From past projections of nuclear power growth, the cumulative inventory by the year 2000 would be about 80,000 such containers. This waste could be handled in a single repository of practical working size, although multiple (regional) repositories might be sought to reduce transportation costs.

Breeder reactor fuels will be irradiated to a higher degree than light water reactor fuels, and processing plant wastes may thus have a higher radioactivity content per unit volume. This might require longer interim storage for decay of short-lived activity, or more shielding; however, these are differences in degree of technology only, so that no new basic technology would be required. The use of metallic sodium as a reactor coolant will require expansion of present sodium safety technology to include handling of contaminated solid wastes generated during breeder reactor repairs. The potential exploitation of low-grade uranium (and possible thorium) deposits for breeder reactor programs may generate large volumes of mill tailings containing very low concentrations of radium. These tailings could be stabilized by methods in use today to prevent dispersion to air and water.

The major emphasis on fuel-cycle facilities in the NECSS-1975 has been on the LWR fuel-cycle operations of fuel reprocessing and mixed oxide fuel fabrication.

NRC has elected not to consider aggregating new enrichment capacity into nuclear energy centers for this site survey for the following reasons:

- the type of process selected for the enrichment process will be a dominant consideration in plant siting;

- the commercial plant capacity postulated (8.25 million separative work units (SWU)) is sufficient to supply about 60-1,200 MWe reactor reloads, and this size plant represents about 20% of the projected private uranium enrichment industry of year 2000 (i.e., each commercial enrichment plant may be considered an energy center);
- no safeguards problems are involved; and
- aggregation of enrichment capacity into larger blocks might result in reduced electrical system reliability, if the enrichment capacity were .. t for protracted periods because of strikes, etc.

NRC did not consider use of nuclear energy centers for LWR UO_2 plant siting for the following reasons:

- a substantial portion of the year 2000 industry may be represented by the existing UO_2 fuel fabrication sites;
- plants capable of handling 1,500 metric tons of uranium per year can service about 40 reactors; and
- no safeguards problems are involved in LWR UO_2 fuel fabrication.

The NECSS-1975 evaluates the location of LWR reprocessing and mixed oxide fuel fabrication plants at nuclear energy centers. Collocation of a fuel reprocessing plant and mixed oxide fabrication facilities at a single site could reduce plutonium shipments and might reduce overall plutonium diversion risk. Location of several reprocessing plants and mixed oxide fabrication plants at a single site (the so-called Integrated Fuel Cycle Facility) has the same potential advantages as the collected siting above, but may offer increased safeguards protection. In addition, the small releases for plutonium and high specific activity radioactive materials would be limited to a smaller number of sites.

LMFBR fuel-cycle facilities include mixed oxide fuel fabrication and fuel reprocessing. LMFBR fuel will be manufactured initially from plutonium recovered from LWR fuel; the early LMFBR fuel fabrication facilities may be discrete, or separate facilities, on a common site with LWR mixed oxide fabrication plants.

The LMFBR fuel fabrication facilities considered in the NECSS are assumed to be indistinguishable in terms of environmental impacts per unit of plutonium throughout from LWR mixed oxide fuel fabrication facilities. The relative environmental impact of their location at a nuclear energy center relative to that at a dispersed site has been subsumed into the evaluation of LWR mixed oxide fuel fabrication plant siting.

LMFBR fuel reprocessing requirements are projected to be met by a single plant coming on line in the 1990s. The incremental effect of locating that projected LMFBR fuel reprocessing plant at an integrated fuel-cycle facility to replace an LWR fuel reprocessing plant has been addressed in the NECSS.

The HTGR fuel-cycle operations of topping enrichment and ^{235}U fuel fabrication have been considered as candidates for collocation at an energy center, and the incremental effect of locating the HTGR fuel reprocessing and recycle fuel fabrication facilities at an integrated fuel-cycle facility has been considered.

The NECSS-1975 has addressed the relative effects of locating the Federal Waste Repositories for high-level waste and TRU waste at integrated fuel-cycle facilities.