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Report to Congressional Requesters

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U.S. Electricity Needs and DOE's Civilian Reactor Development Program

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Resources, Community, and
Economic Development Division

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The Honorable John Glenn
Chairman, Committee on
Governmental Affairs
United States Senate

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy
Research, and Development
Committee on Science, Space,
and Technology
House of Representatives

In response to your letters dated September 11, 1989, and August 30, 1989, and subsequent discussions with your offices, we agreed to provide information on (1) projected U.S. electricity needs until the year 1998 and (2) the status of the Department of Energy's (DOE) Civilian Reactor Development Program to meet future electricity needs. In addition, we agreed to obtain the views of selected utility company and nuclear industry officials on DOE's efforts to promote the development of advanced reactors.

Results in Brief

Electricity projections developed by the North American Electric Reliability Council (NERC) appear to be the best available estimates of future U.S. electricity needs. NERC, which represents all segments of the utility industry, forecasts that before 1998 certain regions of the country, particularly in the more heavily populated eastern half of the United States, may experience shortfalls during summer peak demand periods. These forecasts considered the utility companies' plans, as of 1989, to meet electricity needs during the period; these plans include such measures as constructing additional generators and conducting demand management programs.

Working closely with the nuclear industry, DOE is supporting the development of several reactor technologies to ensure that nuclear power remains a viable electricity supply option. In fiscal year 1990, DOE's Civilian Reactor Development Program was funded at $253 million. DOE is using these funds to support industry-led efforts to develop light-water reactors (LWR), advanced liquid-metal reactors (LMR), and modular high-temperature gas-cooled reactors (MHTGR) that are safe, environmentally acceptable, and economically competitive. The utility company officials do not expect these reactors to be operational until shortly after 2000.

Utility company officials in the Southeast and nuclear industry officials that we interviewed generally support DOE's approach to developing advanced nuclear reactors. However, the utility officials do not plan to purchase advanced nuclear reactors until after 2000 because of the high costs of constructing the reactors and public opposition to nuclear power. One official said that DOE should nonetheless continue its work in this area in the event these circumstances change and nuclear power becomes an option in the next 5 to 10 years.

Scope and Methodology

We performed our work between October 1989 and February 1990 in accordance with generally accepted government auditing standards. To assess future U.S. electricity needs, we relied, for the most part, on projections developed by NERC, an independent council representing all utility industry segments (including investor-owned, federal, state/ municipal, and rural electric cooperatives). DOE officials recommended that we use NERC's annual 10-year electricity needs forecast.[4] NERC developed its forecast by extracting data on the peak demand, capacity resources, generating unit planned additions, and retirements from data provided to DOE by utility companies, and from regional data submitted to it directly from its member councils. We interviewed NERC officials who prepared these projections.

To determine the status of DOE's Civilian Reactor Development Program, we reviewed planning documents, strategy papers, schedules, and other DOE reports related to the program. We also analyzed DOE budget data and verified this information with DOE officials. In addition, we interviewed officials in DOE's Office of the Deputy Assistant Secretary for Nuclear Energy, the Advanced Light Water Reactor Program, and the Advanced Reactor Program. We also discussed DOE's Civilian Reactor Development Program with officials representing five Southeastern utility companies and nuclear industry officials from General Electric, General Atomics, and Westinghouse.

We discussed this report with DOE and NERC officials, all of whom generally agreed with its contents, and incorporated their clarifications where

[4] 1989 Reliability Assessment: The Future of Bulk Electric System Reliability in North America 1989-1998 (Sept. 1989) and 1989 Electricity Supply and Demand for 1989-1998 (Oct. 1989).

As an end-use consumer of energy to fuel their generators, electric utilities consumed about 31 percent of the total U.S. energy consumption in 1979. This share of total U.S. energy consumption increased to 36 percent in 1988 and, according to the Department of Energy (DOE), is expected to rise to about 42 percent by 2000. When the amount of energy used in transportation is excluded from the total of all U.S. energy consumed, electricity made up about 49 percent of the total U.S. energy consumed in 1988 and is expected to increase to about 56 percent by 2000.

Current DOE electricity forecasts indicate that the industrial, commercial, and residential sectors are all expected to substantially increase their consumption of electricity during the decade. Table I.1 illustrates the actual and projected growth in electricity used in these sectors in 1988 and 2000.

Table I.1: Electricity Share of All Energy Consumed by the Industrial, Residential, and Commercial Sectors in 1988 and 2000

Percent of total energy consumption which is electricity

Sector	1988	2000
Industrial	14	18
Commercial	41	48
Residential	32	39

Source: Prepared by GAO from DOE data.

Utilities Are Taking Steps to Meet the Increased Demand for Electricity

U.S. utilities are undertaking efforts to meet this increased demand for electricity that may occur in the 1990s. Although many existing electrical generating units are projected to be retired by 1998, utilities are planning to construct additional electricity generating units and better manage their existing capacity by increasing the use of demand management programs.[5]

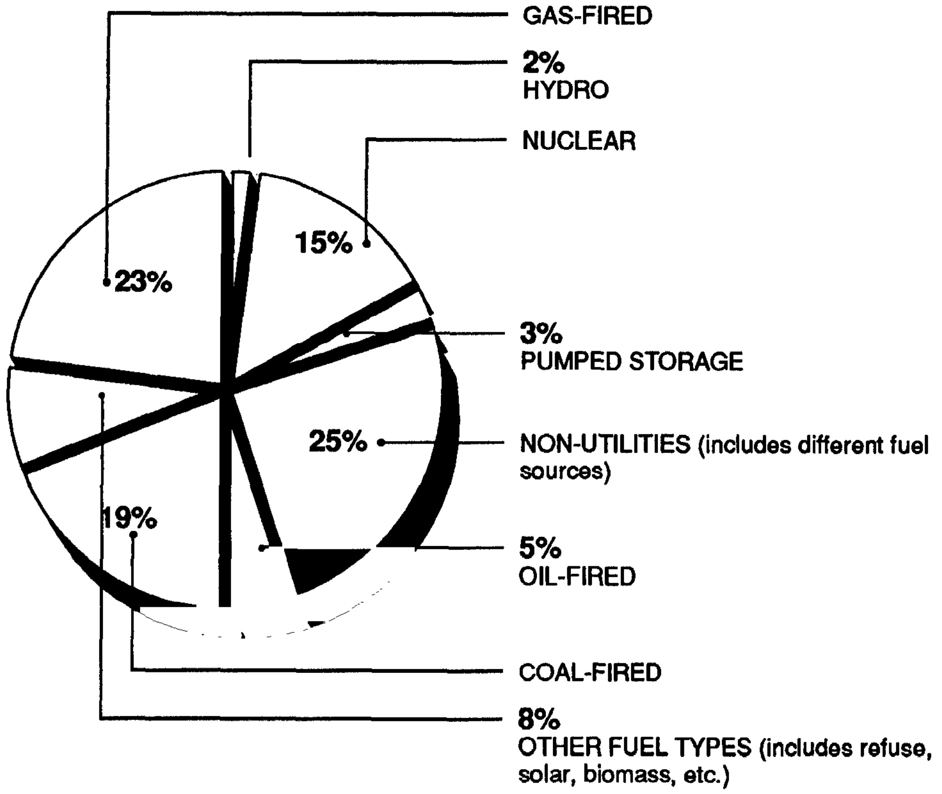
Generating Unit Additions and Retirements

According to NERC, approximately 729 new electrical generating units are planned to be added to the nation's supply system between 1989 and 1998, which will increase the supply by about 71,400 MW.[6] Nonutility

[5]Demand management programs include all activities undertaken by electric utilities or their customers to influence the amount and timing of electricity use to reduce peak demand.

[6]This total excludes the Shoreham nuclear plant. According to Long Island Light Company officials, Shoreham will not be permitted to operate as a nuclear facility in the state of New York, and power generation is not expected to occur in this assessment period.

Figure I.1: NERC-U.S. Additions by Fuel Source (1989 Through 1998 Forecasted Percentages)



Source: Prepared by GAO using NERC data.

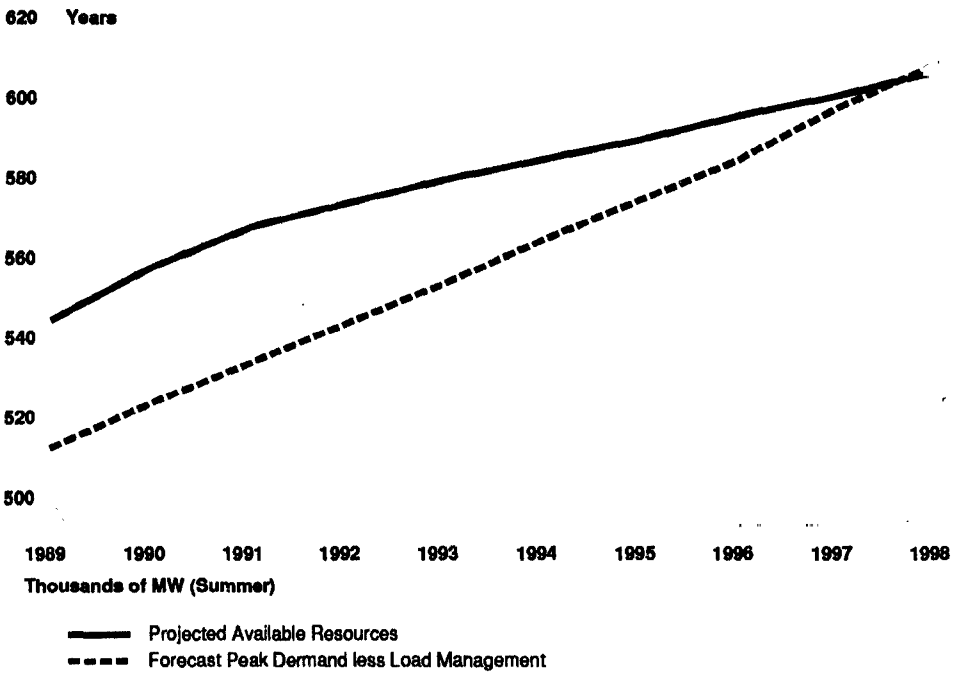
Demand Management Programs to Reduce Peak Demand

Demand management programs provide the utilities with the ability to reduce demand and to possibly delay the need for some future electric generating capacity. NERC projects that the utility companies' demand management programs will reduce the U.S. peak demand for electricity in 1998 from 623,000 MW to 608,000 MW. According to NERC's 1989 Reliability Assessment,

> Demand management includes conservation programs, improvements in the efficiency of both primary energy and electricity use, utility control of certain customer loads, economic incentives embodied in rate design, contractually interruptible customers, and many other similar activities.

Only that portion of demand management under the direct control of electric utility system operators or interruptible by the customer at the

Figure I.2: Peak Demand and Projected Available Resources (1989-98 Forecast)



Source: Prepared by GAO using NERC data.

Although figure I.3 indicates that, according to NERC's data, a shortfall nationally will not occur until 1998, forecasted electricity demand in some regions may exceed expected available capacity generation earlier than expected, particularly if peak demand continues to exceed forecasts. The following summarizes NERC's forecasts of anticipated electricity needs in some of its regions within the next 10 years. (App. III provides additional information about the NERC regions.)

East Central Area Reliability Coordination Agreement: A small decline in the availability of generating equipment, a slight increase in the rate of demand growth, or other factors such as implementation of mandated air pollution control strategies and transmission limitations, could quickly reduce the future electric system reliability to unacceptable levels.

Mid-Atlantic Area Council: More capacity additions are required in some years to provide adequate capacity margins, although planned capacity additions have been increased as a result of higher peak demands.

officials we spoke with, all of whom were in the Southeast, generally supported DOE's efforts in developing these technologies. However, most of the officials do not plan to purchase nuclear reactors until after 2000 because of the high costs of constructing nuclear reactors and current public opposition to nuclear power.[1]

Meeting the Nation's Electricity Needs Is a Concern

Electricity supply relative to demand remains an important area of concern. According to NERC, from 1989 to 1998 the U.S. summer peak demand for electricity is projected to increase approximately 2 percent per year from 522,000 megawatts (MW) in 1989 to 623,000 MW in 1998.[2] During this period, the projected available electrical generating resources will increase about 1 percent per year from approximately 544,000 MW in 1989 to 606,000 MW in 1998.[3] Certain U.S. regions, particularly in the more heavily populated eastern half of the country, may experience shortfalls during projected summer peak demand periods.

In 1989, when these forecasts were made, utility companies indicated that they were completing the construction of nuclear generators, as well as adding primarily oil-fired, coal-fired, and gas-fired generators. Also, they planned to use demand management programs, such as agreements with industrial users to interrupt their power supply during peak demand periods. Utility company officials we interviewed said they would take whatever measures were necessary to ensure that their areas had sufficient electricity during projected shortfall periods.

DOE Working With Nuclear Industry on Advanced Reactors

DOE, in partnership with the nuclear industry, is supporting the development of several reactor technologies to ensure that nuclear power remains a viable energy supply option. DOE expects to obtain Nuclear Regulatory Commission (NRC) design certification for a large-size LWR in 1991 and two mid-size LWRs in 1995. In addition to water-cooled reactors, DOE is also supporting the development of MHTGRs and LMRs. DOE

[1] Electricity Supply: What Can Be Done to Revive the Nuclear Option? (GAO/RCED-89-67, Mar. 23, 1989) contains a more detailed discussion of possible government actions to revive the nuclear option.

[2] According to NERC, many factors can influence electricity use and peak demand to the extent that the actual peak outcomes could vary from those projected. There is an 80 percent probability that the peak 1998 summer demand would fall within 565,000 MW to 673,000 MW.

[3] According to NERC, the possible loss of existing capacity, due to legislative changes such as amendments to the Clean Air Act (42 U.S.C. 7401, et. seq.) and to delays in completing construction of new generating capacity, could reduce projected available resources.

appropriate. However, as agreed with your offices, we did not obtain written agency comments on this report.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the Secretary of Energy. Copies will also be made available to others upon request. Please call me at (202) 275-1441 if you have any questions about this report. Major contributors to this report are listed in appendix VI.

Victor S. Rezendes
Director of Energy Issues

Contents

Abbreviations

DOE	Department of Energy
ECAR	East Central Area Reliability Coordination Agreement
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
GAO	General Accounting Office
LMR	liquid-metal reactor
LWR	light-water reactor
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interconnected Network
MAPP	Mid-Continent Area Power Pool
MHTGR	modular high-temperature gas-cooled reactor
MW	megawatts
NERC	North American Electric Reliability Council
NPCC	Northeast Power Coordinating Council
NRC	Nuclear Regulatory Commission
SERC	Southeastern Electric Reliability Council
SPP	Southwest Power Pool
WSSC	Western Systems Coordinating Council

Projected U.S. Energy Needs 1989-98

The North American Electric Reliability Council (NERC) projects that from 1989 to 1998,[1] U.S. electrical peak demand[2] will increase from 522,000 megawatts (MW) to 623,000 MW.[3] The utility companies' demand management programs will reduce this amount to 608,000 MW by 1998. Utility companies will also increase their electrical generating capacity to attempt to meet demand by taking such measures as constructing additional electrical generators and purchasing electricity from nonutility generators. Despite these efforts, NERC projects that by 1998, available resources in the United States will reach 606,000 MW, resulting in a possible 2,000 MW national shortfall. Prior to 1998, certain U.S. regions, particularly in the more heavily populated eastern half of the country, may experience shortfalls during summer peak demand periods.[4] Utility company officials told us they would take whatever measures were needed to ensure that their areas had sufficient electrical generating capacity during projected shortfall periods.

Electricity Demand Expected to Increase

The use of electricity has been growing, and this trend is expected to continue. In the United States, peak demand for electricity occurs during the summer months when businesses and residences make greater use of air conditioning. According to NERC, electrical peak demand is projected to grow at an annual rate of 2 percent over the 1989-98 forecast period, increasing from 522,000 MW to 623,000 MW. However, NERC pointed out that, because many factors can influence electricity use and peak demand, the actual peak demand could vary from that projected. According to NERC, there is an 80-percent probability that the peak 1998 summer demand would fall within 565,000 MW and 673,000 MW.

[1] 1989 Reliability Assessment: The Future of Bulk Electric System Reliability in North America 1989-1998 (Sept. 1989) and 1989 Electric Supply and Demand for 1989-1998 (Oct. 1989).

[2] Peak demand is the highest electrical requirement experienced by a power system in a year.

[3] Projections of peak demand and generating capacity are both subject to forecasting error. As a result, computations which rely on them are also subject to forecasting error. Based on NERC projections, the most likely outcome is a shortfall of the reported amount. However, because of the forecasting error, it is possible that the actual shortfall will be greater or smaller, or no shortfall will occur at all.

[4] We did not review the NERC statistical analysis or the baseline projections in detail. NERC aggregates the projections supplied by utility load forecasters from its member councils. Using a statistical analysis technique, NERC calculates the bandwidths that establish an 80-percent confidence interval around the baseline projections. This confidence interval represents a range in which the actual peak demand is expected to fall with an 80-percent probability. That is, NERC believes that there is a 10-percent chance that peak electricity demand will exceed the top of the bandwidth, and a 10-percent chance that peak demand will be below the bottom of the bandwidth. However, because the growth in demand for electricity is heavily influenced by the growth in the gross national product, we did compare NERC's gross national product base line forecast of 2.5 percent annual growth to that of the Wharton Econometric Forecasting Associates and found it to be generally consistent.

generators[7] are expected to provide about 18,100 MW, or about 25 percent, of this new generating capacity. The planned additions during the assessment period are shown in figure I.1 by fuel source. NERC estimates that of the total planned new capacity, approximately 15 percent of the power will be from nuclear power plants currently under construction.

The retirement of old generating units will offset the new capacity additions, reducing the total new capacity by about 6,540 MW. According to DOE data, plants to be retired will range in age from 40 to 46 years. According to NERC, the net gain in generating capacity over the 1989-98 time period will thus be about 64,860 MW. However, 63 percent of the total megawatt additions are not yet under construction and some of the planned capacity probably will not be completed on schedule.

[7]NERC defines nonutility generators as facilities for generating electricity that are not owned exclusively by an electric utility but which operate connected to an electric utility system.

utility's request is called load management. For example, a large industrial user, such as a chemical company, may enter into a contractual agreement that allows the utility to turn off a portion of its electrical power during peak demand periods. Usually, large industrial users have the capability to reschedule certain work, for example, from normal daylight hours to nighttime hours for this purpose. In its 1989-98 projections, NERC indicates that about 2.8 percent of the U.S. summer peak demand, or approximately 17,400 MW, will be under utility-controlled management or interruptible by the customer at the utilities' request by 1998 as compared to 2.2 percent in 1989. Currently, load management ranges from 0.9 percent to 3.2 percent of peak demand in the NERC regions, and this range is expected to increase to 1.1 percent to 5.3 percent of projected peak demands by 1998.

Projected Shortages

Many factors can affect the availability of electricity generation. Not all installed capacity is available at any given time due to full or partial forced outages,[8] deratings,[9] and downtime needed for maintenance requirements. Therefore, in making its projections, NERC reduced the planned capacity resources to reflect the unavailability of certain electrical generation equipment during peak demand periods. NERC refers to this reduction as the "projected available resources." Given the forecasted peak demand (minus savings from load management and demand management) and the projected available resources, figure 1.2 shows that NERC's data indicate that a capacity shortfall of approximately 2000 MW could occur in the United States by 1998. According to NERC, the possible loss of existing capacity, as a result of legislative changes such as amendments to the Clean Air Act[10] (42 U.S.C. 7401, et seq.) and delays in completing construction of new generating capacity, could cause this shortfall to occur by 1996.

[8]A forced outage occurs when a problem causes equipment to be taken out of service.

[9]Derating occurs when a unit's power is decreased because of modifications, such as the installation of environmental machinery on an older unit or changes in a fuel source, that may be necessary for economic reasons.

[10]New legislation could require reductions in the emissions from fossil-fueled electric power plants. The additional costs of installing emission control equipment may not be economical for the utilities, resulting in earlier than anticipated equipment retirements.

Transmission reliability to deliver emergency assistance is another concern wherein there could be significant shortfalls in planned capacity if peak demand continues to grow faster than projected. If this occurs, large amounts of additional capacity resources would be required in a short time period.

Mid-America Interconnected Network: Generating capacity may be less than required for adequate reliability in the mid to late 1990s. Additional load management or short-lead time capacity will be needed to ensure reliability. Another reliability concern in this region is the unknown effects that acid rain regulatory actions related to pollution control may have on future generating capability.

Northeast Power Coordinating Council: In the New York subregion, Long Island may experience shortfalls if required capacity resource additions do not materialize and capacity under construction and planned energy purchases are not available as scheduled. Continued marginal resource adequacy in the area will result from the closing of the Shoreham Nuclear Unit (809 MW) until additional generating capacity is added. In the subregion of New England, generating capacity now under construction, planned energy purchases, and demand management programs must be available as scheduled to provide for adequate capacity by the winter of 1993-94.

Southeastern Electric Reliability Council: Maintaining adequate capacity margins in the latter portion of the assessment period, particularly in Virginia, Florida, and the Carolinas, will depend on projected resources materializing as planned and continued high availability of existing generators. However, capacity may be less than required if conservation and direct control load management programs decrease and transmission systems are unable to supply the contracted power transfers.

Status of Civilian Reactor Development and Utility and Nuclear Industry Comments

The Department of Energy (DOE) is supporting the development of several reactor technologies to ensure that nuclear power remains a viable energy supply option. In fiscal year (FY) 1990, DOE's Civilian Reactor Development Program received an appropriation of $253 million to develop these technologies. To meet the nation's 5- to 10-year electricity needs, DOE, in partnership with the nuclear industry, is developing improved water-cooled reactor designs. DOE expects to obtain design approval from the Nuclear Regulatory Commission (NRC) for a large-size light-water reactor (LWR) in 1991. In 1995 DOE expects design approval of two mid-size LWRS, which incorporate passive safety features, such as natural coolant circulation and increased use of gravity for coolant supplies, and modular designs.[1] In addition to water-cooled reactors, DOE is also supporting the development of advanced reactors that have the potential to incorporate a greater degree of passive safety than water-cooled reactors. DOE's advanced reactor program is centered on developing modular high-temperature gas-cooled and liquid-metal-cooled reactor designs. According to DOE, neither the modular high-temperature gas-cooled reactor (MHTGR) nor the liquid-metal reactor (LMR) will be in operation until the next century.

Utility company and nuclear industry executives that we interviewed generally support DOE's approach in developing advanced nuclear reactor designs. However, some of these utility companies do not plan to purchase nuclear reactors to meet their electricity needs at least until after 2000 because of the high costs of constructing nuclear reactors and public opposition to nuclear power. According to these officials, light-water reactors will remain the leading candidate of choice until the advanced technologies have been successfully demonstrated.

DOE's Civilian Reactor Development Program

In the 1960s and early 1970s, nuclear power promised to be a safe, economical energy source. However, since then, safety concerns and soaring costs have clouded its future. As a result, the viability of nuclear power as an energy supply option is being increasingly questioned. To ensure that nuclear power remains a viable option, DOE, under its Civilian Reactor Development Program, is supporting industry-led efforts to develop

[1] Modular designs use factory-built, factory-inspected construction modules. These modules are then shipped to the site and joined together.

light-water reactors and advanced reactors that are safe, environmentally acceptable, and cost-effective.[2]

The Civilian Reactor Development Program, under DOE's Nuclear Energy Office, supports the development of improved light-water reactors to meet near-term energy needs and advanced reactor designs which will not be commercially available until after 2000. The light-water reactor program is part of a nationally coordinated effort to improve the technical, licensing, and institutional requirements to construct and operate water-cooled reactors. DOE's advanced reactor program supports the development of alternative designs that have the potential for breakthroughs in economics, safety, licensability, and waste management options. The primary emphasis of this program is to support continued work on LMRS and MHTGRS.

Historical Funding of Civilian Reactor Development Program

Actual Civilian Reactor Development Program expenditures declined 74 percent, from $978 million in fiscal year 1980 to $253 million in fiscal year 1990. In constant 1989 dollars, as shown in table II.1, the decline over this period was almost 84 percent. DOE has requested $219 million for the program in its FY 1991 budget request.

Table II.1: DOE Expenditures in Civilian Reactor Development Program

Millions of 1989 constant dollars

	Fiscal year										
Program area	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
High-Temperature Gas Reactor	65	55	46	44	36	37	34	22	24	20	22
Light-Water Reactor	42	55	66	49	65	60	54	37	33	27	23
Liquid-Metal Reactor	592	512	512	466	366	137	110	60	59	54	35
Facilities	411	308	296	204	188	166	148	138	137	140	163
Clinch River Breeder Reactor	276	257	241	280	101	20	0	0	0	0	0
Light-Water-Cooled Breeder	91	83	68	56	42	29	21	15	0	9	0
Total	**1,477**	**1,270**	**1,229**	**1,099**	**798**	**450**	**367**	**273**	**253**	**250**	**243**

Source: DOE data adjusted into constant dollars by GAO.

Note: All numbers do not total due to rounding.

According to a DOE official, the federal role in liquid-metal reactor development was restructured in 1985 to focus on resolving key technology

[2]Our report entitled Electricity Supply: What Can Be Done to Revive the Nuclear Option? (GAO/RCED-89-67, Mar. 23, 1989) contains a more detailed discussion of possible government actions to revive the nuclear option.

issues and uncertainties in order to enlist private sector involvement. Appendix IV contains a chronology of the major shifts and decisions in the Civilian Reactor Development Program since 1980.

Status of Civilian Reactor Development Program

DOE's Civilian Reactor Development Program currently focuses on developing designs for water-cooled, high-temperature gas-cooled, and liquid-metal-cooled reactors. Under the advanced LWR program, contractors working with DOE are currently developing LWRs that will incorporate passive safety features and modular designs. A DOE official said that these LWRs may become available for construction in the mid 1990s. DOE's advanced reactor program is centered on developing the MHTGR and LMR. (See app. V for descriptions of the LWR, LMR, and MHTGR.) These advanced reactors have the potential to provide additional degrees of safety. DOE officials do not expect these reactors to be operational until shortly after 2000. The following sections discuss the technologies and their current status of development.

Light-Water Reactor

Currently, nearly all of the nuclear power in the United States is generated from LWRs. Building on the vast experience gained from these existing LWRs, DOE and the utility industry are jointly sponsoring the development of advanced LWRs. The objectives of DOE's advanced LWR program are to

- support the Electric Power Research Institute (EPRI) and industry efforts to define the characteristics and performance parameters new plants will have to meet;
- demonstrate the improved standard plant-licensing process needed for all advanced reactors by certification of one or more large, evolutionary LWR standard plant designs; and
- support industry in developing and certifying greatly simplified mid-size (about 600 MW) LWRs that employ predominantly passive safety features and modular construction.

EPRI, under the direction of a utility steering committee, and with the support and direction of DOE, is preparing the requirements pertaining to the performance and design of future advanced light-water reactor designs. Drawing upon the experience gained from design features found in over 100 operating nuclear plants in the United States, specific regulatory guidelines, plant operator training methods, and specific hardware designs have evolved. The principles established by EPRI to govern the development of new designs are (1) a primary design emphasis placed on lowering the risk associated with a core-damaging incident;

(2) less dependence on electrical systems and mechanical components to achieve safety, relying instead on improved plant designs and passive safety systems; (3) greater design margins to allow more time to assess and deal with unusual conditions without jeopardizing or causing major damage to the plant; and (4) the advantage of having recent advances in human factors engineering in plant designs. According to an EPRI official, most volumes of the requirements document pertaining to large, evolutionary light-water reactor designs have been submitted to NRC for approval. EPRI plans to complete the remaining volumes of the document covering advanced mid-size light-water reactor designs and plans to submit them to NRC in 1990.

To demonstrate the viability of the nuclear plant standardization and licensing process, DOE is supporting, through a contractual cost-sharing arrangement, the efforts of General Electric and Combustion Engineering to obtain Nuclear Regulatory Commission (NRC) design certification of two large (1,250 MW and 1,350 MW) evolutionary LWRs. Evolutionary reactors, according to DOE, are reactors that incorporate simplified designs and state-of-the-art proven equipment. General Electric has submitted required safety analysis information for its reactor to NRC for review. In fiscal year 1990, required risk assessments and safety evaluations will be prepared, and revisions to the safety analysis and evaluations as needed to resolve NRC's comments will be submitted. According to DOE officials, final NRC design approval, which will initiate public hearings, is expected in about December 1990 and NRC design certification in September 1991.

As of February 1990 the status of Combustion Engineering's efforts to certify its evolutionary reactor design is unclear. Under its 1987 contract with DOE, Combustion Engineering was required to design only the nuclear island for NRC certification. However, in April 1989 NRC imposed new requirements that require the designs to encompass the entire plant, not just the nuclear island. Although Combustion Engineering has submitted the majority of its safety analysis information to NRC, DOE has been unable to provide additional funding to complete the certification process. According to a DOE official, during March 1990 DOE and Combustion Engineering are expected to meet to resolve this issue.

In addition to large-size evolutionary plants, DOE is also supporting the design, development, and certification of two mid-size (600 MW) light-water passive plant designs. These designs incorporate natural cooling mechanisms like gravity and natural convection rather than electric-powered core cooling equipment, resulting in greater simplification. It is expected that no operator action would be needed to keep the plant safe to the public for 3 days after a major loss-of-coolant accident, if it were to occur. On September 5, 1989, DOE selected General Electric and Westinghouse to complete designs of mid-size light-water reactors. On February 28, 1990, DOE and Westinghouse signed a contract for the development of an advanced pressurized-water reactor. DOE signed a contract with General Electric on April 2, 1990, for the development of a simplified boiling-water reactor. Under these contracts, DOE will match General Electric and Westinghouse on a 50/50 cost-share basis up to $50 million. These advanced mid-size light-water reactor designs are expected to receive NRC's design certification in 1995.

Modular High-Temperature Gas-Cooled Reactor

Modular high-temperature gas-cooled reactors have the potential to incorporate a greater degree of passive safety than water-cooled reactors. The safety characteristics of these reactors result from using helium, an inert gas, as the reactor coolant; coated fuel particles that are capable of retaining fission products under even severe conditions; and graphite core and support structures that have a high heat capacity and maintain their strength to temperatures beyond 5,000 degrees Fahrenheit. Further, passive cooling of the core can be achieved by conduction, radiation, and natural convection without the fuel reaching a temperature at which the coating would fail during an accident. According to a DOE official, the adoption of these design features offers the potential for enhancing safety margins, reducing the plant's reliance on electric-powered safeguard systems or operator actions.

Currently, MHTGR preliminary design work is being done under DOE contracts with General Atomics, Bechtel, Combustion Engineering, and Stone and Webster. In addition, materials, fuels, and fission product experimental programs that support the MHTGR are being conducted at DOE's Oak Ridge National Laboratory in Tennessee and at General Atomics. DOE is also assessing the MHTGR as one technology that could be used for a new reactor it plans to build for the production of tritium, which is used in nuclear weapons. A plan to coordinate and integrate this defense research and development program with the civilian reactor program has been developed, according to DOE. About $29 million of the funds DOE has requested for the New Production Reactor for FY 1991 has been earmarked for activities that are also in need of development under the civilian program. These areas of commonality include the validation of fuel performance and fission product behavior models and codes, materials development, and validation of the reliability of key components and system performance.

According to DOE, in September 1986 General Atomics prepared and submitted a Preliminary Safety Information Document to NRC. The objective of this effort was to obtain a Safety Evaluation Report from NRC that addresses the licensability of the MHTGR, the acceptance of the unique safety criteria, and agreement and concurrence with the overall safety assessment. NRC issued a draft Safety Evaluation Report in March 1989. Resolution of the issues identified by NRC will be completed in FY 1991. Completion of the civilian MHTGR preliminary design and submission of a Preliminary Standard Safety Analysis Report to NRC are expected to occur in FYs 1992 and 1993, respectively. Final design is scheduled to be completed in FY 1995 with a Final Standard Safety Analysis Report submitted in FY 1996. Final NRC design approval is expected in FY 1997.

Liquid-Metal Reactor

Like the high-temperature gas-cooled reactor, the passive safety characteristics of a liquid-metal reactor have the potential for reducing the plant's reliance on engineered safeguards equipment or immediate operator response should an accident occur. DOE initially considered the LMR's capability to breed more nuclear material than it consumes as its most important feature. However, the emphasis is now being placed on the LMR's capability to recycle spent fuel and convert long-lived actinide elements (plutonium and neptunium, and other radioactive elements) present in spent LWR, LMR, and MHTGR fuel. According to DOE, this would reduce not only the amount of nuclear waste requiring disposal but also the hazard of high-level waste destined for repository from hundreds of thousands of years to hundreds of years. DOE planned to design and construct a safety demonstration module because such a demonstration project should be completed before NRC can certify the design. However, because of funding constraints, DOE is not certain when a demonstration project, if any, will be constructed. According to one DOE official, the earliest date such a demonstration project could be built is 2005.

In January 1989 DOE awarded General Electric a 3-year contract for an advanced LMR conceptual design with an optional 2-year preliminary design phase. The engineering development work is on a 465 megawatts of electricity modular reactor.

According to DOE, the conceptual design of the LMR was completed in 1985, and a Preliminary Safety Information Document was submitted to NRC in September 1986. In October 1989 NRC staff issued a draft Safety Evaluation Report and licensing letter defining the outstanding safety issues. DOE expects to continue to update the LMR design features and to resolve key issues identified by NRC at least through FY 1991. DOE-supported research at its Argonne National Laboratory will continue to confirm the passive safety and improved economic potential of the LMR. According to DOE, current and anticipated funding constraints may limit its efforts to evaluate the capability of the reactor to recycle fuel and destroy long-lived actinide elements.

Nuclear Industry and Utility Company Comments

Executives representing five utility companies from the Southeast and officials from the nuclear industry generally support DOE's efforts to develop advanced nuclear reactors. Most of the utility company executives that we interviewed supported DOE's "two track approach" of funding the development of both the evolutionary, large LWR standard plant designs and the advanced mid-size LWR designs. One utility executive who was particularly impressed with the mid-size reactor concept said that mid-size reactors offer numerous advantages over evolutionary reactors. First, the smaller reactors will be less expensive and therefore utilities will have less difficulty in acquiring sufficient capital. Second, the mid-size reactors will be "different enough" from the older, larger reactors in service in the United States that the public will more readily accept the new reactors. Finally, if utilities purchase the smaller reactors, they will be in a better position to adapt to changes in growth patterns because the smaller reactors can be added incrementally to better respond to the public's demands for electricity.

Although the five utility industry officials we contacted supported DOE's development of light-water reactors, they said that they would not purchase advanced nuclear reactors during the next 10 years even though additional electrical generating capacity may be needed. Reasons cited by officials for their positions were the high costs of constructing nuclear reactors and public opposition to nuclear power. One official said that although there may not be a market for these advanced light-water reactors until after 2000, the designs should be made available as soon as possible in the event circumstances change and make nuclear power a viable near-term option. According to the Advanced Reactor Corporation,[3]

> It is the present judgment of the majority in the nuclear power industry that the LWR will remain the dominant nuclear power technology for the next several

[3]Advanced Reactor Corporation, Report of the ARC Ad Hoc Committee on U.S. Department of Energy Advanced Reactor Development Plan, January 10, 1990. This ad hoc committee was made up of officials from utility companies and the nuclear industry.

decades. . . . Thus, an improved version of the LWR is expected to be the leading candidate for the next increment of nuclear capacity ordered in the United States.

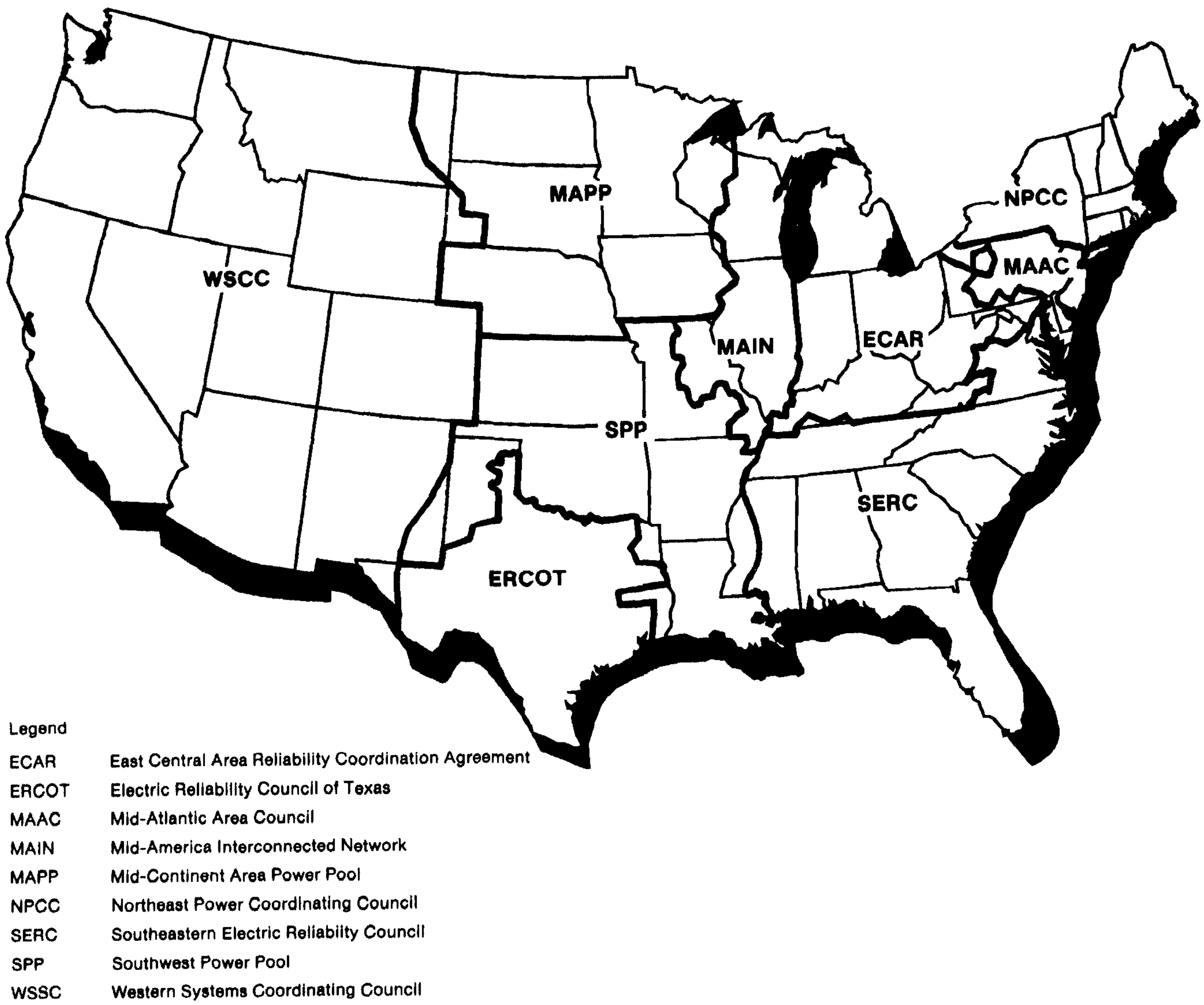
Utility industry officials generally concurred with this assessment, citing the industry's vast experience with light-water reactors.

With respect to the overall direction of DOE's light-water reactor program, officials from the nuclear industry who design LWRS and utility companies said that DOE is generally moving in the "right direction" in its support of the LWR program. Utility officials said that they are aware of DOE's involvement with EPRI and the utilities in establishing the Utilities Requirements Document. One utility company executive said that he was impressed that DOE has listened to the concerns of the individual utility companies about safety and was working with EPRI to incorporate this information into the requirements document.

Utility officials said that they are not as familiar with MHTGRS and LMRS as they are with LWRS because they have no "hands on" experience with these reactors. Although they recognized that these technologies have the potential to provide additional passive safety features not available on LWRS and that the LMR offers the capability to recycle waste products, they would be hesitant to select these technologies unless they had first been demonstrated.

North American Electric Reliability Council—U.S. Regions

Figure III.1: NERC-U.S. Map



Source: Prepared by GAO from NERC data.

East Central Area Reliability Coordination Agreement

The ECAR region bulk power membership currently consists of 27 companies (18 systems) which serve either all or part of the states of Michigan, Indiana, Kentucky, Ohio, West Virginia, Virginia, Pennsylvania, Maryland, and Tennessee.

Electric Reliability Council of Texas

ERCOT is composed of 25 municipalities, 51 cooperatives, 6 investor-owned utilities, and 2 state agencies which serve a total of 11 million customers. These systems operate 85 percent of the electric generation in Texas and serve approximately 195,000 square miles, or 73 percent of the area in the state.

Mid-Atlantic Area Council

MAAC consists of 11 member systems and 5 associates serving 20 million people in a 48,700 square mile area. The region includes all of Delaware and the District of Columbia; major portions of Pennsylvania, New Jersey, and Maryland; and a small portion of Virginia.

Mid-America Interconnected Network

MAIN is comprised of 12 regular member systems and 1 associate member serving a population of 18 million in a geographic area of 170,000 square miles. The region encompasses Illinois, the eastern third of Missouri, the eastern two-thirds of Wisconsin, and most of the upper peninsula of Michigan.

Mid-Continent Area Power Pool

The MAPP Region covers all portions of Iowa, Minnesota, Nebraska, North Dakota, Illinois, Michigan, Montana, South Dakota, Wisconsin, and the Canadian provinces of Manitoba and Saskatchewan. Membership includes 43 systems of 27 participants consisting of 11 investor-owned systems, 8 generation and transmission cooperatives, 3 public power districts, 4 municipal systems, and 1 federal agency. Associate participants include 2 Canadian Crown Corporations, 13 municipals, and 1 investor-owned system. The total geographic area covers 890,000 miles with a population of 16 million.

Northeast Power Coordinating Council

NPCC represents a total of 23 investor-owned and publicly owned utilities serving about 44 million people in a 1 million square mile area encompassing 2 areas in the northeastern United States and 3 areas in eastern Canada. In the United States, NPCC members participate in either the

New York Power Pool or the New England Power Pool. In Canada, the Ontario, Hydro, Hydro-Quebec, New Brunswick Power, and Nova Scotia Power systems make up the three Canadian areas of NPCC—Ontario, Quebec, and the Maritimes.

Southeastern Electric Reliability Council

SERC membership includes 29 systems located in 9 southeastern states that are divided into 4 diverse subregions covering 345,650 square miles. The subregions include the Florida peninsula, the Southern electric system, Tennessee Valley Authority area, and the Virginia-Carolina areas; they serve a population of about 26 million.

Southwest Power Pool

The SPP includes 43 electric power suppliers serving 6.6 million customers in the states of Kansas, Oklahoma, Missouri, Arkansas, Mississippi, Louisiana, Texas, and New Mexico. Its membership is composed of 17 investor-owned utilities, 12 municipal systems, 10 generating and transmission cooperatives systems, 3 state authorities, and a federal agency. The geographic area served spans 500,000 miles containing a population of 25 million.

Western Systems Coordinating Council

WSSC encompasses a total 1.8 million square miles of territory in 14 western states, 2 Canadian provinces, and a northern portion of Baja California, Mexico. The region is subdivided into four areas: the Northwest Power Pool Area, (including the states of Washington, Oregon, Idaho, Utah, portions of Montana, Wyoming, Nevada, and California and the two Canadian provinces of Alberta and British Columbia); the Rocky Mountain Power Area consisting of Colorado, eastern Wyoming, and a small portion of Nebraska and South Dakota; the Arizona-New Mexico Power Area consisting of most of New Mexico and the western-most part of Texas; and the California-Southern Nevada Power Area encompassing most of California, southern Nevada, and a northern portion of Baja California, Mexico. The council has 62 member systems and 3 affiliates.

Major Shifts and Decisions in DOE's Civilian Reactor Development Program

The following summarizes the major program shifts and decisions that have shaped DOE's Civilian Reactor Development Program since 1980.

Program Shift or Decision

1980

Congress passed the Nuclear Safety Research, Development, and Demonstration Act, resulting in the initiation of the Light Water Reactor Safety Research and Development Program.

1981

DOE completed the conceptual design study for a developmental liquid-metal fast breeder reactor.

President Reagan announced nuclear energy policies for:

- Establishing a high-level radioactive waste storage facility.
- Licensing and regulatory reform.
- Renewing breeder development program, including completion of the Clinch River Breeder Reactor project.

1982

DOE and the Electric Power Research Institute signed an agreement to cooperate on a large-scale prototype breeder.

1983

The U.S. Senate discontinued funding the Clinch River Breeder Reactor, thereby effectively terminating it.

The government's lead role shifted from developing a liquid-metal fast breeder reactor to a role of supporting and encouraging private sector initiatives and cooperating with foreign nations in research and development.

DOE reduced and consolidated the liquid-metal fast breeder reactor base program. DOE increased activities on licensing and regulatory reform.

1985

DOE continued the restructuring of breeder development to focus on resolving key technology issues and uncertainties prerequisite to private sector demonstration and development with no new federally funded energy system demonstration project. This restructuring placed major emphasis on:

- Technology necessary for a breeder system (including power plant and supporting fuel cycle) that is inherently safe, competitive with nuclear and nonnuclear alternatives, has predictable performance, and meets market needs of utilities.
- Development of advanced plant concepts competitive with alternative energy sources.
- Increased reliance on international cooperation.

DOE supported development of standardized requirements for advanced light-water reactors (LWR), i.e., the Electric Power Research Institute Utilities Requirements Document.

DOE shifted efforts from a steam cycle/cogeneration high-temperature reactor to an innovative modular high- temperature gas-cooled reactor (MHTGR) utilizing a prismatic fuel design with coated fuel particles; and integrated the program with efforts to encourage development of next-generation, innovative concepts for nuclear power.

1986

Liquid-metal reactor (LMR) activities focused on developing an advanced liquid-metal converter reactor incorporating major technology advances to improve competitive position.

DOE focused Advanced Converter Reactor technology (including LWR, MHTGR, and LMR activities) on developing advanced, high technology converter reactors capable of competing in the 1995-2020 timeframe; through innovative use of technology these reactors would be simpler, less expensive, safe, and secure.

DOE placed emphasis on small, modularized plant designs and greater use of passive safety features.

DOE initiated the development of reference high- temperature gas-cooled reactor design concept detail needed to support assessments of plant safety, operability, reliability, maintainability, constructability, licensability, and economics for process heat and defense applications.

DOE reshaped breeder technology development program to reflect commercial introduction sometime after 2000 emphasizing:

- Continued long-range technology and related fuel cycle development.
- Increased international collaboration and maintaining U.S. presence in discussions concerning nonproliferation and safeguards controls.
- Developing an advanced LMR breeder design capable of competing domestically and in the international market.

1987	DOE emphasized civilian reactor technology efforts to support industry/ government program on development of advanced light-water reactors with the objective to gain Nuclear Regulatory Commission final design approval and certification of at least two advanced LWR systems in 5 years. DOE shifted emphasis from primarily satisfying civilian needs for advanced reactors to space and terrestrial national security needs while maintaining technical, testing, analytical, and design infrastructure to ensure capability to respond to civilian needs.
1988	DOE selected General Electric's PRISM concept as the basis for further development of a national advanced liquid-metal reactor design program to begin in 1989. DOE shifted emphasis from an oxide fuel cycle to a metal fuel cycle in the liquid-metal reactor. DOE focused on passive safety and improved economic potential of a metal-fueled, modular liquid-metal reactor emphasizing the metal fuel/ Integral Fast Reactor concept at Argonne National Laboratory.
1989	DOE limited the scope of its work on liquid-metal reactor technology development in advanced instrumentation and controls, concept verification testing, and robotics because of reduced funding from the Congress. DOE increased its emphasis on the actinide recycle capability of LMRs and the potential to impact waste management solutions.

Descriptions of Civilian Nuclear Reactors

Light-Water Reactors

As the world's most dominant nuclear technology, light-water reactors use uranium as their fuel and ordinary water for cooling. In all reactors used for electricity generation, the final stage in the process is turning water into steam to turn the huge turbines that actually spin the generators. In designs known as boiling-water reactors, the steam is generated inside the reactor itself. In the pressurized-water reactors, hot water from the reactor is transferred to external steam generators where water is boiled to make the steam that drives the turbines.

Modular High-Temperature Gas-Cooled Reactors

The modular high-temperature gas-cooled reactor is a second-generation power system. Based on technology developed and demonstrated in the United States and the Federal Republic of Germany, the system makes use of refractory-coated nuclear fuel, helium gas as an inert coolant, and graphite as a stable core structural material. The MHTGR's fuel is made by forming uranium into billions of tiny grains and covering each of these with a tough ceramic shell that can withstand unusually high temperatures. This ensures that the fuel and its radioactive by-products are tightly sealed from the environment. Consequently, the safety and protection of the MHTGR is provided by inherent and passive features and does not depend on immediate operator actions or the activation of engineered systems in the event of an abnormal event.

Liquid-Metal Reactors

The liquid-metal reactor is a next-generation, sodium-cooled, modular nuclear power reactor. The concept of the LMR utilizes liquid-metal as a coolant and metallic fuel. The most significant property of liquid-metal cooling is that the LMR can operate near atmospheric pressures without requiring thick pressure vessels to contain the cooling system. Metallic fuel provides the critically important property of high thermal conductivity, which gives a high degree of inherent safety to the LMR.

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.

Judy A. England-Joseph, Associate Director
Robert E. Allen, Jr., Assistant Director
Duane Fitzgerald, Assistant Director/Nuclear Engineer
Edward E. Young, Jr., Assignment Manager
William P. Leavens, Evaluator-in-Charge
Jacqueline Bell, Staff Evaluator

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