Chapter 7

Survival of the Nuclear Industry in the United States and Abroad

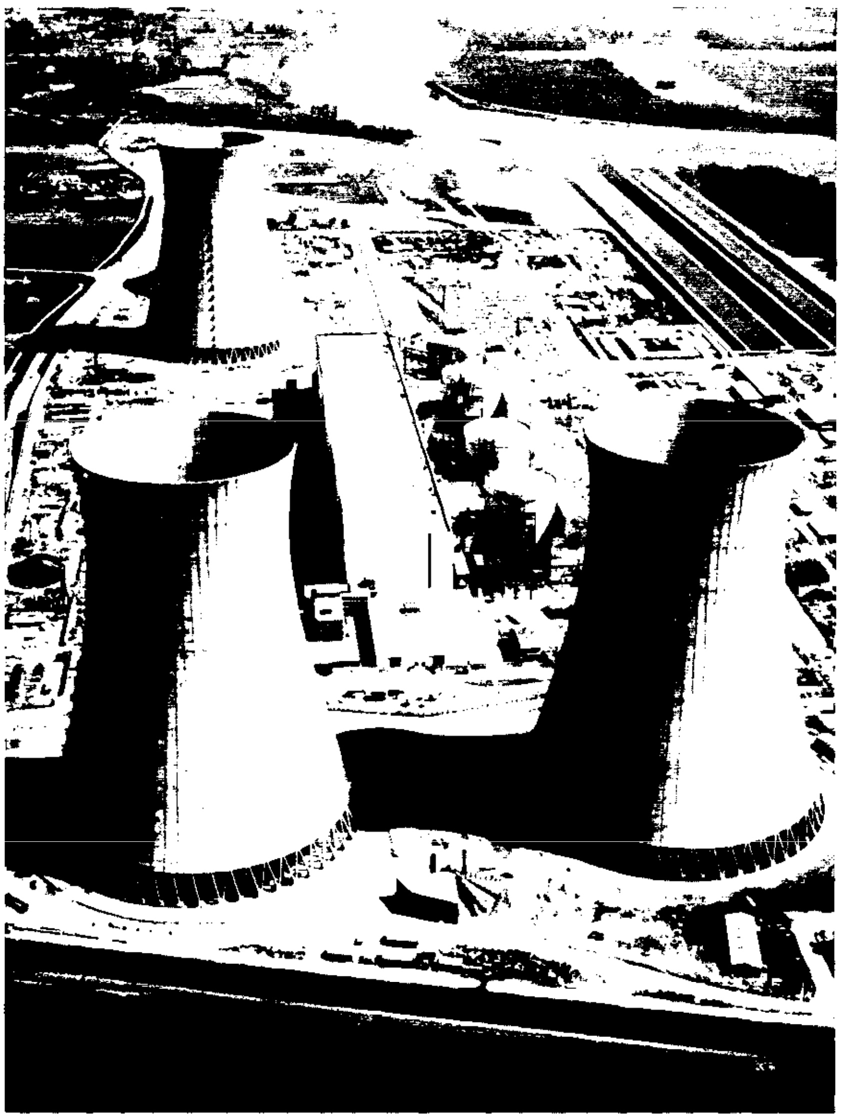

Photo credit: **Electricite** *de France*

Four nuclear units at Dampierre, France

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INTRODUCTION

Whether or not utility executives order more powerplants (given all the uncertainties and disincentives described in earlier chapters) has direct implications for the U.S. nuclear industry and its ability to remain viable as a source of nuclear powerplants both within the United States and abroad. This chapter examines the consequences for different parts of the U.S. industry of a long period with no orders for new plants or a period in which orders for new plants follow a long delay. The chapter then surveys the prospects for nuclear power abroad and the likelihood of U.S. exports as well as the possibility that the United States might be able to turn to foreign suppliers as future sources of the technology.

Although there are no strict parallels between the U.S. nuclear industry and that of any other country, there nonetheless is much to be learned from foreign experience. Many of the same problems faced by the U.S. industry are being faced elsewhere: public opposition to nuclear power, slow demand growth, and the difficulty of controlling cost and time overruns in nuclear plant construction. Understanding how these and other problems are being coped with in each country, provides some perspective on the U.S. situation and information on approaches that might be successful in the United States.

THE EFFECTS IN THE U.S. NUCLEAR INDUSTRY OF NO, FEW OR DELAYED NEW-PLANT ORDERS 1983 TO 1995

The nuclear industry may be portrayed as a monolith by its critics. In fact, however, it has always been a loose-knit group of several hundred businesses and organizations, given what cohesion it has by the demands of a difficult technology and the need to develop a coordinated response to critics. Today, the industry consists of the 59 public and private utilities that are the principal owners of nuclear powerplants in operation or under construction, 4 reactor manufacturers also known as nuclear steam supply systems (NSSS) vendors, 12 architect-engineering (AE) firms with a specialty in nuclear design and construction, about 400 firms in the United States and Canada qualified to supply nuclear components, and several hundred nuclear service contractors. Table 23 shows the combinations of reactor manufacturers and AE firms for plants under construction or on order as of the spring of 1981.

Of about 90,000 employees of the nuclear industry, about half operate and maintain commercial power reactors (as well as some test and research reactors), a quarter are engaged in reactor and reactor component manufacturing, and a quarter are engaged in design and engineering of nuclear facilities (other than design associated with reactor manufacture) (4).

Companies and organizations in each of these sectors must develop strategies for coping with the likelihood of no new orders for nuclear plants for 3 to 5 years and the possibility of no or very few orders for 5 or more years after that. In a comprehensive study for the U.S. Department of Energy (DOE), the S. M. Stoner Corp. (37) assessed the impact on NSSS vendors and component suppliers of three possible futures:

- a slowly increasing projection of: no orders until 1986, an average of two to three a year

Table 23.—NSSS/AE Combination of Light Water Reactors Under Construction or On Order As of 1981

Architect/ engineering firms	Reactor vendors: Westinghouse	General Electric	Combustion Engineering	Babcock & Wilcox
Bechtel	6	10	6	5
Burns & Roe	—	1	1	—
Black & Veatch	—	2	—	—
Brown & Root	2	—	—	—
Ebasco	4	1	4	—
Gilbert/Commonwealth	1	2	—	—
Gibbs & Hill	2	—	—	—
Gilbert Associates	—	—	—	—
Utility Owner	7	—	6	—
Fluor Power Services	—	—	—	—
Sargent & Lundy	8	7	—	—
Stone & Webster	5	6	2	2
United Engineers	2	—	—	2
Tennessee Valley Authority	3	6	2	2

SOURCE *Nuclear Powerplant Standardization* Light Water Reactors (Washington, D.C. U.S. Congress, Office of Technology Assessment, OTA-E-134, April 1981)

until 1989, and six to eight orders a year after that;

- no orders until the early 1990's; and
- no orders until 1988 or 1989 and an average of one a year for 5 years after that.

The findings of the Stoner study are echoed in the results of 35 interviews conducted by OTA with representatives of reactor vendors, nuclear suppliers, AE firms, utilities with nuclear plants, and industry analysts and regulators. Further insights are available from several assessments of personnel needs for the industry **(4,9,16,18).**

Reactor Vendors

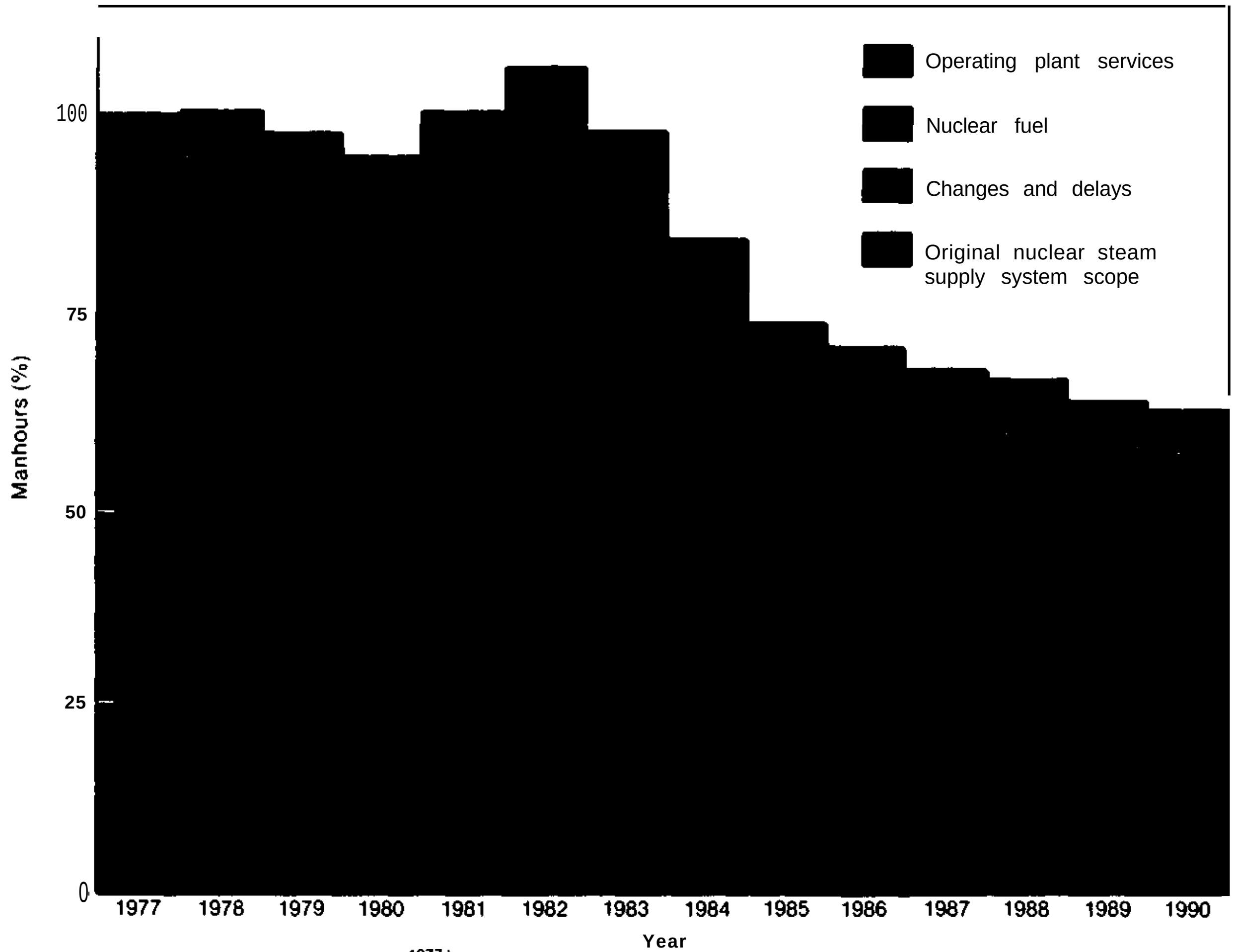
No new nuclear reactors are now being built. The nuclear business for the four reactor vendors currently consists of assembling at site, fuel loading and services, and the latter two will continue regardless of what happens to new orders. Figure 34 shows one vendor's prediction of the need for engineering manpower through the 1980's. Engineers will be needed for services to operating plants and fuel loading. Manpower to handle changes in existing plants, and rework in plants under construction, will initially increase but then diminish. The need for engineering manpower to design new NSSS will practically disappear.

Refueling, which occurs in each plant approximately every 18 months, is a demanding task requiring sophisticated skills and a sound knowledge of nuclear physics. Used fuel rods are removed and new fuel rods are inserted among partially used fuel rods, and the array of both fresh and older fuel rods is then reconfigured to provide maximum nuclear energy. Vendors expect also that spent fuel management will also be a continuing source of business.

Vendors are now competing for the nuclear service business in an arena once dominated by the nuclear service consultants. The Stoner report estimates further that backfits and rework may require 30 to 50 man-years of contracted engineering work per operating plant with a total demand of 3,000 to 6,000 technical people per year. (37) The vendors are uncertain, however, if the current level of backfits, stimulated largely by requirements following the Three Mile Island accident, will continue beyond the next few years, and, at the same time realize that over the long run the continued cost of backfits will discourage new orders.

The only current new plant design activities are joint ventures by both GE and Westinghouse with Japanese companies. The Westinghouse project is being aimed at both the domestic and export markets and is being developed in consultation with the Nuclear Regulatory Commission (NRC). (See ch. 4.) The GE project is being developed for Japan only and not for future U.S. licensing.

Figure 34.-Engineering Manpower



[a]As estimated by one NSSS supplier, (Base year is 1977.)

SOURCE A *Study of the Adequacy of Personnel for the U S Nuclear Program* (Washington, D C.: Department of Energy, November 1981)

Both companies hope that an export market will sustain some of their design and manufacturing capability. The likely export market (described later in this chapter), however, has shrunk to only a fraction of what was projected 5 years ago and is currently substantially less than what can fully use worldwide manufacturing and design capability.

For U.S. companies to compete successfully requires not only continued technical success (as is being attempted in these joint ventures) but also possible modifications in U.S. export financing and nonproliferation policies (25). There is evidence that some orders have already been lost because U.S. vendors are losing their reputation for up-to-date technology. As a Finnish source told ***Nucleonics Week:*** "Why should Westinghouse put in millions (of dollars) for R&D if they don't have business prospects. That is one reason why we are not studying their (U. S.) reactors in a [plant-purchase] feasibility study" (29).

Moreover, future export orders are likely to involve reduced U.S. manufacturing demand since many of the countries most likely to pursue nuclear programs have nuclear import policies designed to promote domestic industries. Other ad-

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vanced countries with nuclear programs, especially Japan, are also likely to bid successfully for component manufacturing business (25,37).

The current backlog of NSSS manufacturing work is scheduled for completion in 1984. All U.S. vendors have taken steps to close or mothball many of their manufacturing facilities, or to convert them for other uses. It has been estimated that announced facilities closings and consolidations have already reduced by two-thirds the U.S. capacity to supply nuclear powerplants. Some vendors are maintaining their technical capability with nuclear work for the U.S. Navy, DOE, or research and development (R&D) sponsored by the Electric Power Research Institute (EPRI) (37).

Vendors are already feeling the effects of a shrinkage in nuclear component suppliers on which they base future standardized NSSS designs. Currently, each vendor purchases components from about 200 qualified nuclear suppliers. Several vendors estimate that the number of suppliers will drop by two-thirds in 3 tos years, leaving the vendors dealing with a much higher proportion of sole source suppliers (37). Vendors faced with this situation are considering various responses, such as manufacturing their own components, encouraging less qualified suppliers to upgrade their products and get them certified, and developing new sources of foreign supply.

Nuclear Component Suppliers

The impact of the shrinkage in new orders is most dramatic on component suppliers. Some companies supply components used both for new plants and for backfit and spare parts for plants in operation. These companies expect to keep their businesses going. Many companies, however, supply only components for new plants. Some of these produce nuclear components that are identical or very similar to nonnuclear components except for quality-control documentation. These companies can be expected to maintain their nuclear supply lines. Others, however, produce very specialized nuclear components that require separate testing and manufacturing facilities. Many of these facilities are now closed or mothballed (37).

At present the number of component suppliers appears to be declining slowly. One clear sign is the decision by suppliers not to renew the "N-stamp," a certificate issued by the American Society of Mechanical Engineers (ASME) for the manufacturer of nuclear plant components. N-stamps are not specifically required by the NRC for the manufacture of safety-related nuclear-plant components. However, they are required by some States, and their use certifies that certain NRC quality-assurance requirements have been met.

The number of domestic firms holding N-stamps has dropped by about 15 to 20 percent since 1979, the year of the accident at Three Mile Island, and the drop would probably be greater if the renewal were annual instead of triennial **(21). By contrast, foreign N-stamp registration has held steady. By** the end of 1982, some 400 companies in the United States and Canada held about 900 N-stamps, according to ASME. An additional 50 companies held about 100 certificates for Q-system accreditation on nuclear-grade materials. Overseas, about 70 companies held about 100 N-stamps, and about 20 companies held about so Q-system certificates (21).

Maintaining an N-stamp requires both personnel and money. Thus, in the absence of new nuclear business, many smaller companies have decided they cannot justify the costs. In addition to the $5,000 to $10,000 that must be spent for ASME certification (renewable at the same cost every 3 years), there is also the need to dedicate part of the plant and at least one or two employees to the intricate paperwork that accompanies each N-stamp component. In total, cost estimates for maintaining a stamp range from $25,000 to $150,000 a year (21). Suppliers say that no other work, including contracts for the National Aeronautics and Space Administration (NASA) and the U.S. Navy nuclear program, requires such a detailed paper trail. "1 make a valve that sells for about $300" one supplier said. "If it has an N-stamp I have to charge $4,000 for the same valve. And with low volume, I suppose I should charge even more" (21).

So far, the reduction in N-stamps has not been as rapid as the lack of new orders might suggest. Part of the reason may be a habit of looking to the future that has been characteristic of the nuclear industry since the beginning. Some suppliers evidently believe that the N-stamp imparts a certain status to a nuclear supplier's operations, and those who must consider letting their certification expire say they would do so reluctantly. "It's a nice marketing tool," one supplier said, "even when you're selling non-nuclear items. And it's good discipline for a company to have it" (21). Some suppliers and utilities report that they must persuade their subcontractors to keep the stamp. "We're giving companies [with N-stamps] our nonnuclear business, just to help them along, " one utility executive said. Another challenge is to prevent market entry by foreign companies. "If equipment from overseas becomes standard," one supplier said, "we'll never get that business back" (21).

For many suppliers it will be almost impossible to obtain nuclear qualification for new product lines. For some product lines, 1 to 5 years would be needed to carry out the necessary tests. Maintaining an older nuclear-qualified product line alongside a newer nonnuclear product line will be difficult for those suppliers with a preponderance of nonnuclear business. Since nonnuclear business is likely to respond more quickly to an increase in general business investment of the recession than is nuclear business, there may be pressure to drop the nuclear product lines. The existence of nuclear components in 35 gigawatts (GW)* of partially completed but canceled nuclear plants is viewed as a further damper on the nuclear component business even though only some of this equipment is expected to be sufficiently maintained and documented enough to be usable (see advertisement). For all these reasons, there may be a far more rapid decrease in suppliers over the next 3 to 5 years than over the past 3 years, possibly down to a third of the present number (37).

Architect= Engineering Firms

AE firms have substantial work for the next few years finishing the plants under construction, installing backfits and dealing with special problems such as steam generators. One promising concept for interim survival involves "recommissioning" nuclear stations—installing some new components to extend their operating lives by 10 to 20 years. Like the reactor vendors, AE firms complain of reduced sources of supply for nuclear-grade components and materials. And, like the reactor vendors, they are moving outside their specialties to bid on nuclear services (e. g., emergency planning) and rework proposals.

Most AE firms also have large amounts of business stemming from major construction projects other than nuclear: cogeneration, geothermal, and coal technologies; petrochemical plants; industrial process heat applications; and conventional fossil powerplants. During the 1981-83 recession, business in these areas was no more robust than the firms' nuclear work. One AE executive said, "As it is now, we can't move our nuclear people to nonnuclear projects just to keep them in-house. There isn't much nonnuclear work around either" (21). Several firms reported they expected their nonnuclear work to pick up long before their nuclear work (21).

Much of the project management and construction skills used on other types of large construction projects are also required for nuclear projects. These skills will be available as long as the AE firms have experience in major construction projects. The design and project management skills unique to nuclear projects area small proportion of the total work force.

Some firms are taking losses to keep their skilled nuclear people employed because they estimate that retraining would ultimately cost more. Architects are working as draftsmen, for example, and skilled machinists are cutting and stacking sheet metal. Layoffs have not been necessary, one AE executive said, because employees are retiring early or quitting to move to fields with more growth potential and less regulation, such as military R&D **(21).**

The Impact on Nuclear Plant Operation

The halt in nuclear plant orders and uncertain prospects for new orders have had discernible

"One GW = 1 GWe = 1,000 MWe (1 ,000,000 kWe) or slightly less than the typical large nuclear powerplant of 1,100 to 1,300 MW.

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Photo credit: Engineering News Record

Advertisement for nuclear component auction appearing in *Engineering News Record,* Feb. 21, 1983 effects on the utilities' experience in keeping their existing nuclear plants staffed and maintained. The effects are most noticeable in two areas: obtaining component parts and services, and filling certain key jobs.

Component Costs and Delays. -With the decrease in nuclear component suppliers described above, utilities report an increase in the number of sole source suppliers and a resulting upward pressure on prices. One utility reported that sole source suppliers received 40 to 50 percent of 1982 contract dollars. A more typical range reported by utilities was 25 to 30 percent, an increase from 15 to 20 percent a decade ago (21).

In a few cases, utilities report that prices of services and components are falling because of increased competition. Generally, however, prices are expected to rise partly because of lack of competitive pressures on the increased number of sole source suppliers and partly because the fixed cost of nuclear quality assurance must be spread over dwindling sales.

Delays are also expected to be more of a problem for similar reasons. With less nuclear work to do, suppliers are more likely to arrange production schedules to use qualified craftsmen and their 'special machinery only when a number of orders are in hand, postponing work on some projects for months. Or they could require premiums for deadlines that are more convenient for the utilities. "He'd get the part for you, when you wanted it," one utility executive said of a supplier, "but you'd have to pay for a whole shift to go on overtime" (21). Suppliers report that utilities are placing more "unpriced" orders, for which the supplier alone sets the costs, and choosing other than the lowest bid to get the schedule and quality they need **(21).**

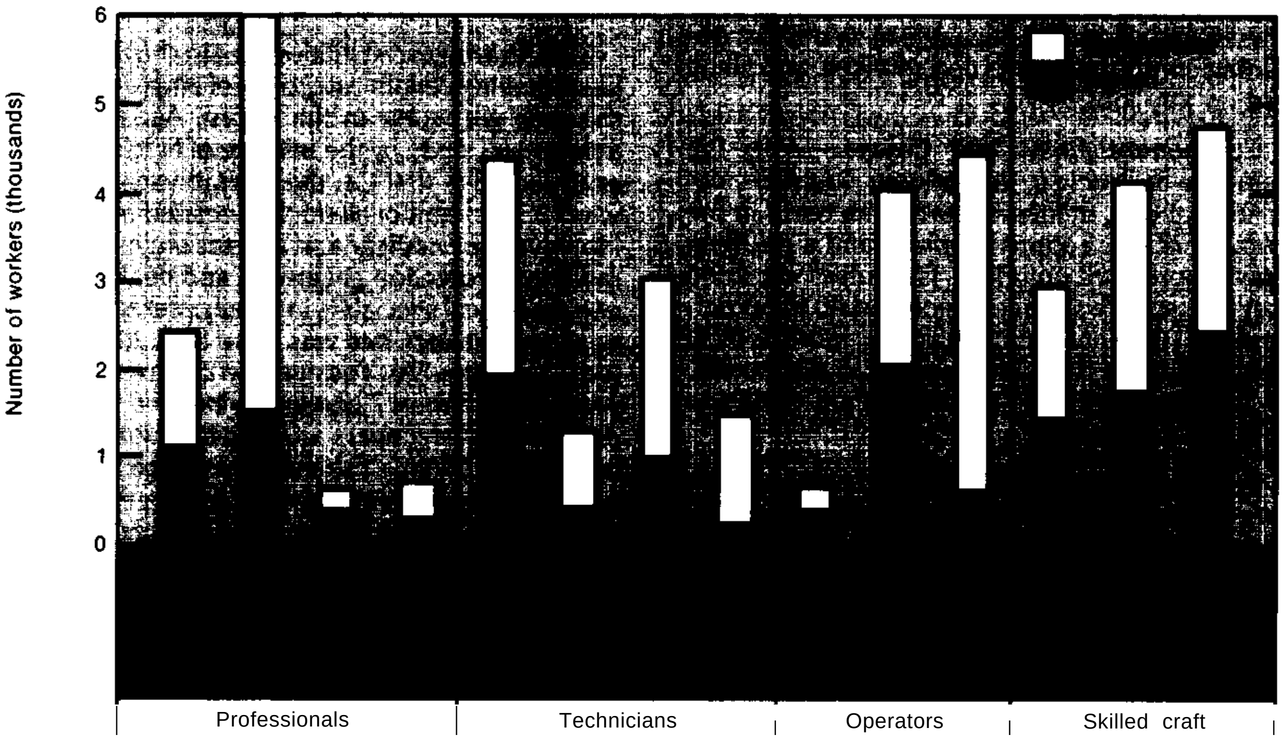
In addition to possible increased prices and delays, utilities are also experiencing some greater confusion in the bidding process for rework and nuclear services as more and more firms attempt to diversify in the face of falling profits. "Anything in an RFP [request for proposal], that's at all related to our business, we'll bid on it," one nuclear consultant said. "We've got to try for anything out there, just to survive" (2]).

Skill Shortages.– Utilities are also having trouble recruiting certain categories of employees and this may get worse in the future. According to a personnel study by the Institute of Nuclear Power Operations (INPO), the overall vacancy rate was 12.5 percent of all nuclear-related positions. However, for nuclear and reactor engineers, for radiation protection engineers, and health physicists (technical specialists in health effects of radiation), the vacancy rate was more than 20 percent (see app. table 7A). The average turnover rate for engineers is almost 7 percent a year, and, for most categories of engineers, quitting their jobs in utilities means leaving the industry altogether (16). For the nuclear utilities as a group, an estimated 6,000 additional engineers will be needed between now and 1991. Almost 5,000 of these will be needed to replace those that leave the industry (see fig. 35). About 3,000 technical level health physicists will be needed, about 2,000 of these for replacement **(18).**

Despite the availability of ample jobs for nuclear specialists, degrees and enrollment in nuclear-related fields are stable or declining (see fig. 36 for nuclear engineering degrees). There is some evidence that students are being discouraged from enrolling in programs leading to employment in nuclear power by a perception that the industry is declining and by parental concern and some peer pressure against nuclear power careers. A recent DOE study of personnel for the nuclear industry contrasted steadily increasing enrollment in medical radiation physics programs with declining enrollments in technically similar health physics and radiobiology programs aimed at work in the field of nuclear electricity generation (9).

INPO which has developed demanding training requirements for utility personnel has also taken some modest steps to help with recruiting by setting up a fund for graduate nuclear training (see ch. 5). Individual utilities have also taken steps to fund nuclear programs at local community colleges. More, however, may be needed if

Figure 35.–Estimates of Additional Manpower Requirements for the Nuclear Power Industry, 1982-91



SOURCE: **Ruth C. Johnson,** *Manpower Requirements in the Nuclear Power Industry, 1982-91,* **September 1982, ORAU-205.**

current turnover and recruiting trends continue, or worsen.

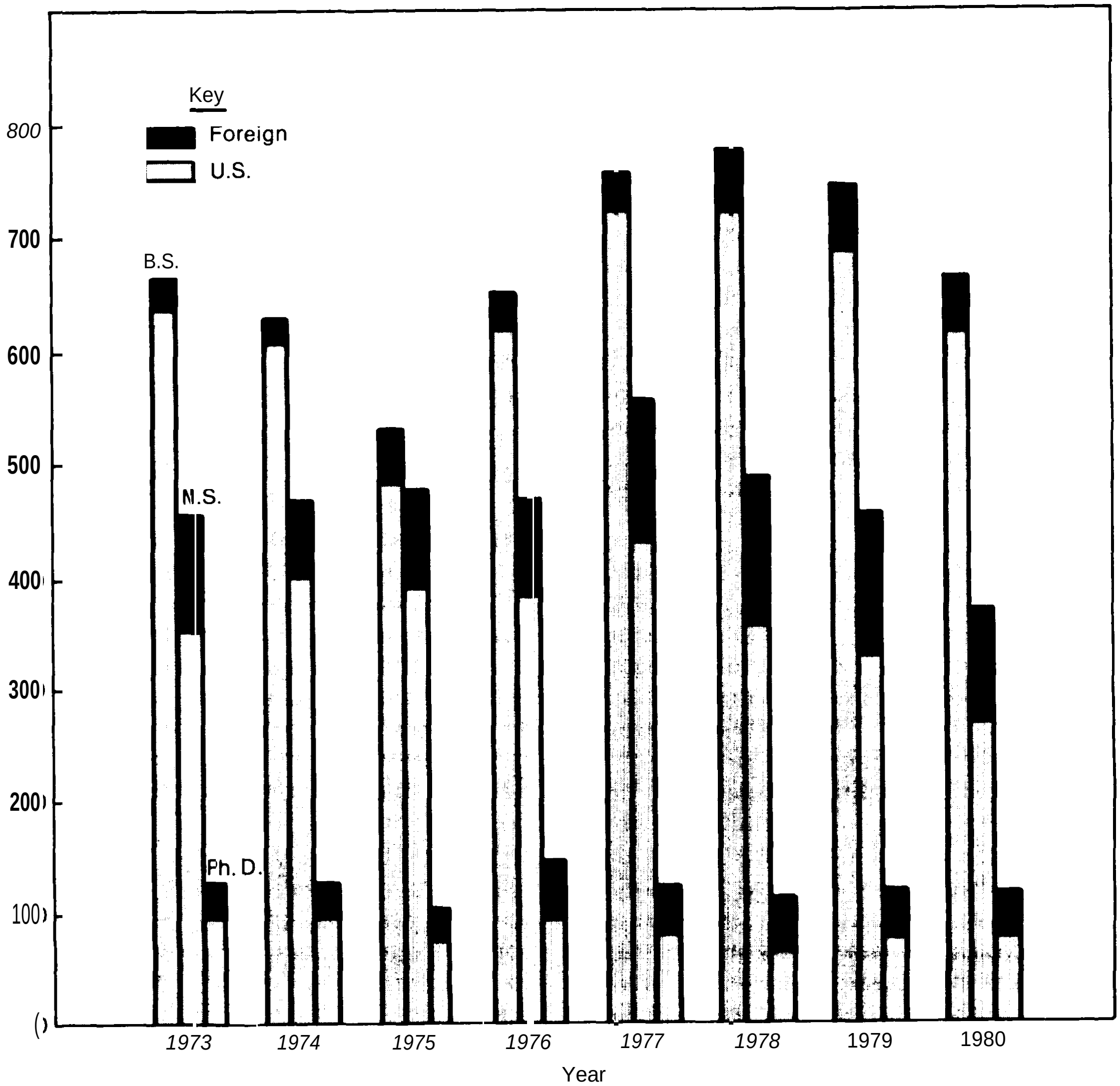
The Impact on Future New Construction of Nuclear Plants

There are several ironies in the current situation of much of the nuclear industry. Many companies are sustaining themselves on backfits and rework, which over time increases the cost of nuclear power to utilities and consumers alike and makes it less likely that utilities will place orders soon for more nuclear powerplants. Some companies are maintaining their nuclear business because the rest of their business has not yet been affected by the improvement in the economy. As business investment picks up, the rate of companies leaving the nuclear business may accelerate. The recovery is likely to create work and jobs in most other industries before utilities see their reserve margins shrinking and begin ordering again (see ch. 3). As one supplier said, "If the economy revives, I'm not sure I can wait around for the nuclear contracts to roll in. I maybe doing something else in the meantime" (21).

Some effects of a hiatus in new plant orders are inevitable even if the optimistic projection of nuclear orders after 3 to 5 years occurs. There are likely to be fewer reactor manufacturers (two or three rather than four) and some initial delays for vendors in securing all the necessary suppliers and encouraging their renewal of N-stamps. Even under this optimistic projection, foreign sources would probably be used for some specific areas of supply.

Component suppliers estimate a delay of 1 or 2 years in obtaining N-stamp qualifications and additional delays once they are operating because of unfamiliarity with support services. "Right now," one said, "my people know just who to call for an interpretation of the regulations. They know which seismic stress labs are the best. If we had to start over [several years hence], a question that takes an afternoon on the phone to answer today would take three to four months to answer" (21).

Figure 36.—Nuclear Engineer Degrees: Foreign Nationals and U.S. Citizens



SOURCE: *A Study of the Adequacy of Personnel for the* U.S. *Nuclear Industry* (Washington, D. C.: Department of Energy, November 1981).

Despite these difficulties, it is probable that even after a hiatus, a realistic 8-year project schedule (under conditions assuming no hiatus) would be delayed only about a year, and perhaps less, if utilities were to freely allow overseas purchasing. If utilities insisted on U.S. sources for all or most components, the delay could be longer (37).

With a hiatus of 10 years or longer, there will be a much bigger problem in new plant construction. Unless there have been at least some overseas orders, the reactor vendors are likely to provide designs for initial plants that were developed overseas in joint ventures with foreign countries, perhaps even as licensees of foreign companies (37). With a longer passage of time, there will be more critical areas with no qualified U.S. supplier and more dependence on overseas component suppliers. Since licensing and quality-control requirements for foreign nuclear programs are quite different it could prove time-consuming and difficult to obtain nuclear qualification and licensing for the design and components of the initial plant (37). Under these circumstances it is unlikely that there would be more than two U.S. vendors. It is also conceivable that foreign companies might bid directly for the design and supply of the initial units (37).

After a period of 10 years or more without nuclear plant construction some skills would still be available from other industries. Control and instrumentation designers and workers would probably be available from the electronics and aerospace industries. Construction contractors expect that semiskilled construction and maintenance workers would also be available. Of the construction skills, a shortage of welders with nuclear certification might pose the greatest staffing problem. But one AE executive said that the biggest difficulty "would be administrative;" learning again to control "the thousands of decisions and tasks" needed to construct and test a nuclear plant (21).

Still another possibility, a very low volume of orders beginning in the late 1980's, is the situation most likely to encourage evolution in the nuclear industry structure to permit the necessary economies of scale in design and construction management experience (37). In this situation, it is likely that utilities or others will form regional or national nuclear generating companies to obtain the economics of scale from multi-unit sites and standardized construction. This is also the situation that is likely to encourage "turnkey" construction, a practice used for the earliest plants constructed in the late 1960's and still used for some exports of nuclear plants (e.g., a plant being constructed by Westinghouse in the Philippines). In turnkey construction, a company or consortium, often headed by an NSSS vendor, offers to construct and warranty an entire nuclear island, * or even a complete nuclear plant, for a fixed price, ready for the operating utility to "turn the key" and operate the plant. Such fixed-price agreements may be the only way for vendors to convince utilities that their costs for nuclear power are predictable. It is quite possible that foreign vendors might offer turnkey plants in the United States. It is perhaps more likely that U.S. vendors may attempt to form consortia with foreign designers and component suppliers to offer turnkey plants.

Conclusion.–As of 1983 the nuclear industry is still intact although somewhat reduced from 3 to 4 years ago. The industry probably would survive a short hiatus of 3 to 5 years in new orders with only some increase in costs and delays in obtaining some components from U.S. sources and perhaps little or no increase in costs and delays if foreign component sources are used.

Predicting the consequences of a hiatus of 10 years or more is more difficult but it is **unlikely** to mean the end of the nuclear option in the United States. If vigorous, economical, and safe nuclear programs survive in several foreign countries, they are likely to provide designs and some components for the initial plants of a new round of nuclear construction if one occurs. (The survival of foreign nuclear programs is the subject of the next section of this chapter.) Many U.S. businesses would still supply nuclear components because they supply very similar nonnuclear components. Many others probably would get recertified to supply nuclear components. U.S. vendors of NSSS will still have large nuclear service and fuel-loading businesses and probably some foreign nuclear work as well. They are likely to be active in any consortia or joint ventures involving foreign sales of nuclear powerplants in the United States.

Under some circumstances, AE firms could end up with less nuclear business after a long hiatus, depending on what restructuring might occur in the industry. A shift to turnkey construction of entire plants or the formation of a few generating companies with their own design and construction management staffs would sharply reduce the role of the architect-engineer. The number of utilities directly involved in nuclear construction would also be drastically reduced under such circumstances.

***Nuclear island refers to all the equipment that directly or indirectly affects the safety of nuclear operations. In addition to the reactor vessel itself and the primary cooling system it usually includes the secondary cooling system and the steam generators (in a pressurized water reactor).**

THE PROSPECTS FOR NUCLEAR POWER OUTSIDE THE UNITED STATES

Many of the problems that have threatened the nuclear power industry in the United States have also weakened nuclear power prospects abroad. However, a few countries–with somewhat different institutional structures for producing electricity and stronger motivation to avoid dependence on energy imports-may be able to nurture their nuclear industries to survive the 1980's in stronger condition than the U.S. industry. This section surveys the highlights of the foreign nuclear experience–economic, technical, and political–and points out a few aspects of foreign experience that provide a perspective on U.S. experience. The section also assesses the likely competitive situation of the U.S. industry vis a vis its competitors abroad.

The Economic Context for Nuclear Power

Worldwide forecasts of the future role of nuclear power have experienced the same boom and bust cycles as have U.S. forecasts. In 1975, OECD* countries forecast a total of 2,079 GW of nuclear power by the year 2000. As of 1982 the OECD countries forecast for the same year had fallen by 75 percent, to only 455 GW of nuclear power (table 24). The reasons for this drastic reduction in expected nuclear capacity are familiar to anyone acquainted with the U.S. nuclear industry: slower-than-expected electricity demand growth, high interest rates that increased the cost of capital for nuclear powerplants and stronger-than-expected public opposition in many countries.

Just as in the United States, the rate of growth of electricity demand slowed from the 1960's to the 1970's in France, West Germany, and the United Kingdom (except for demand from French households) (10) (see fig. 37).

Given the slower-than-expected growth rates in electricity demand, many countries are now lowering their forecast growth rates for 1990 and 2000 and finding themselves with adequate generating capacity, West Germany expects to need new powerplants only if oil and gas capacity is to be replaced (24). A Government commission in France estimated that completion of the present construction program should provide most of the electricity forecast to be needed before 2000. As of mid-1983, the Government had not

*OECD means Organization for Economic Cooperation and Development, a Paris-based organization of industrialized countries.

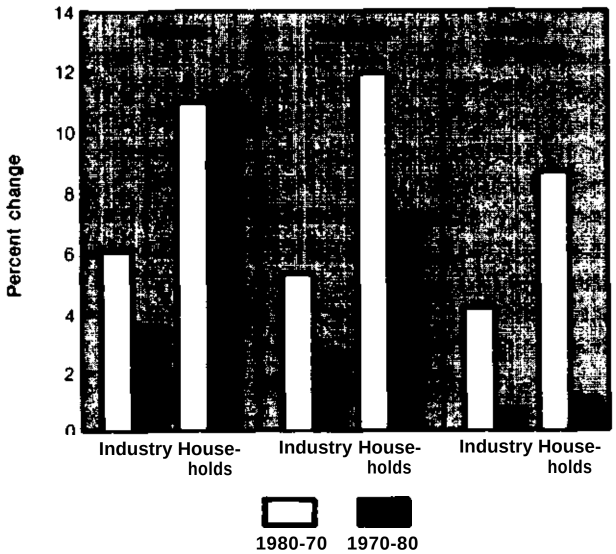
Table 24.–Forecasts of Installed Nuclear Capacity in OECD Countries (GW)

Regions and countries	Forecasts for the year 2000: OECD, 1975	INFCE, 1980[a]	OECD, 1982[a]	Nuclear capacity installed: 1980	1990[b]	Installed public generating capacity of all types: 1979[c]
Western Europe:	798	341	214	43.8	126.6	371
France	170	96	86	16.1	56.0	47
Germany	134	63	34	8.6	23.5	66
United Kingdom	115	33	31	6.5	11.1	69
North America:	**1,115**	**384**	**173**	**60.2**	**131.2**	**671**
Canada	115	59	22	5.2	15.0	72
United States	1,000	325	151	55.0	116.2	599
West **Pacific:**	**166**	**130**	**68**	**15.8**	**28.0**	**153**
Japan	157	130	68	15.8	28.0	126
Australia/New Zealand	9	0	0	0.0	0.0	27
OECD total	2,079	855	455	119.8	285.8	1,195

[a]Figures are the averages of high and low estimates.
[b]Capacity installed or due to be commissioned by Jan 1, 1990 Source SPRU turbine generator data bank
[c]Source: United Nat Ions, 1981.

SOURCE Mans Lonnroth, "Nuclear Energy in Western Europe," a paper for the East-West Center, Honolulu Conference on Nuclear Electric Power in the Asia Pacific Region, January 1983.

Figure 37.–Average Annual increase in Electricity Demand: France, West Germany, and United Kingdom



SOURCE: OECD.

yet accepted the report because of the drastic implications for the future of the nuclear power industry.

Other conditions, familiar to observers of the U.S. nuclear industry, were described by Mans Lonnroth, and William Walker in a 1979 paper, ***The Viability of the Civil Nuclear Industry (26).*** Although the rapid increases in oil prices after 1973 made nuclear power appear relatively less expensive over the long run, it made it harder to finance in the short run because the resulting high rates of inflation increased interest rates. In those countries where the government approves electricity rates it became harder to get political support for rate increases to compensate for inflation. Inflation and the several recessions of the decade also put pressure on governments providing financing to electric utilities to restrict the extent of their support ***(26).***

Public Acceptance

In most European countries and some other countries, there has been considerable public opposition to nuclear power. This sometimes arises from specific concerns about plant siting, design and management, and sometimes from much broader philosophical concerns about the future direction of a society based on high technology which requires extensive central control (24,30).

In a few countries, public opposition to nuclear power has become directly involved in political and administrative decisions that affect the growth of nuclear power. The most dramatic of these is Sweden. in a referendum held in March 1980, 57 percent of the public voted that 3 plants under construction should be completed but the total of 12 reactors then in existence should be operated only until economical means are found to replace them and should not be replaced with more nuclear powerplants if there is any feasible alternative. Parliament subsequently adopted this position as official Government policy. A similar referendum, which halted nuclear power-

Photo credit: OTA Staff

In West Germany, construction of nuclear plants has been stopped in the courts while in France the more centralized decision-making system has kept nuclear construction going without **delays,** despite public opposition.

plant construction in Austria, was passed following a period of widely publicized debates among nuclear experts. In West Germany, citizens can sue in State courts to stop the construction of powerplants. Four plants were stopped in the mid-1970's and brought nuclear construction in Germany to a virtual halt. Subsequent extensive Parliamentary Commissions have recommended caution but not a halt. In the United Kingdom, a public inquiry was conducted throughout 1983 to consider the general adoption of a modified Westinghouse light water reactor (LWR) design. (This is the Sizewell B design, discussed in ch. 4.) This technology would be in addition to the existing series of advanced gas-cooled reactors that until now have formed the basis of the United Kingdom's nuclear technology.

In France, there have been infrequent Parliamentary discussions of policy with respect to nuclear power; otherwise decision making has been treated as a technical and administrative rather than a political matter (31). Public opposition has been expressed in anti-nuclear demonstrations, in demonstrations at particular sites, and in the formation of ecology parties which have challenged candidates in local and regional elections. None has had any substantial impact on the French nuclear program. In part, this appears to be because public opinion surveys have shown increasing support for nuclear power (36).

Foreign Technical Experience: Plant Construction and Reliability

Many foreign countries have experienced delays in building nuclear powerplants similar to those experienced in the United States, but some have built all their plants as fast or faster than any U.S. plant (see table 25). In France, the slowest plants have taken 7 or 8 years from reactor order to commercial operation, while the fastest plants take 5 to 6 years (14). In Japan, slower plants have taken 9 or 10 years while faster plants have also been built in 5 or 6 years. In Japan most of the delay occurs at the site-approval stage, prior to the start of construction. For the other countries with at least several nuclear plants the fastest construction times are comparable (6 to 8 years) with the fastest construction schedules in the United States.

Typical nuclear plants in several foreign countries can also be constructed more cheaply than typical U.S. plants. Based on information obtained in an NRC survey of foreign licensing practices, U.S. costs are comparable with those of Sweden and West Germany but about 30 percent higher than in Japan and about 80 percent higher than in France (38). *In* France, a nuclear plant can be constructed for about half the man-hours/kW required for a nuclear plant in the United States. The other three countries use about 30 percent fewer man-hours/kW than in the United States (fig. 38). Most of the savings occurs in two categories: the nuclear increment over man-hours needed for constructing a non-nuclear powerplant, and the engineering man-hours used during construction, which is almost 10 times higher in the United States than in any other country (38) (see ch. 3).

Performance of U.S. reactors falls at, or slightly below, average in cumulative load factors for world reactors* (see table 26). Several countries, such as Finland, Switzerland, Belgium, and the Netherlands, with only one to four reactors, have very high average cumulative load factors. Canada's nine heavy water CANDU reactors have the highest load factors of all, averaging over 80 percent (see ch. 4). In other countries, however, with large numbers of reactors, average reactor performance does not differ substantially from the United States. At the same time, a smaller share of U.S. reactors can be found among the top-ranking reactors. Among the top 25 percent are 96 percent of Canada's reactors, 32 percent of Sweden's reactors, 44 percent of West Germany's reactors, 16 percent of Japan's reactors, but only 10 percent of U.S. reactors. Many U.S. reactors can be found at the bottom of the list; 27 percent of U.S. reactors rank in the lowest 25 percent of world reactors.

Licensing and Quality Control

West Germany has as complex a licensing process as the United States. Licensing of nuclear plants is governed by seven State (Lander) licens-

***World reactors excluding reactors in Eastern Europe, the U. S. S. R., and several third-world countries for which cumulative load factor data is not available (see appendix table 7B for listing of nuclear capacity in all countries).**

Table 25.—Sample Construction Times for Nuclear Plants in Various Countries

	Faster		Slower	
	Date of com operation	Years Sine; reactor order	Date of com operation	Years since reactor order
France:				
St. Laurent B1, B2	1981	—	—	—
Gravelines C5	1984	5	—	—
Dampierre 2,3,4	—	—	1981	
Cattenom 2	—	—	1986	8
Germany:				
KKU, Unterweser.	1978	7		—
KKI-1, Ohu	1977	6		—
KKG, Grafenrheinfeld	1981	6		—
KKK, Krummel	—	—	1983	11
KBR, Brokdorf	—	—	1987	12
Italy:				
Caorso	1978	8		—
Montalto 1	—	—	1986	12
Japan:				
Ikata 2.	1982	5		—
Fukushima 11-2	1984	6		—
Fukushima 11-3	1985	5		—
Genkai 2	1981	5		—
Ohi 1,2	—	—	1979	9
Fukushima 11-1	—	—	1982	10
Sweden:				
Barseback 1	1975	6		—
Barseback 2.	1977	5		—
Ringhals 3,4	—	—	1982	10
Forsmark 1	—	—	1980	9
Spain:				
Almaraz 1	1981	9		—
Valdecaballeros 2	—	—	1988	13
Lemoniz 1	—	—	1983	11
Switzerland:				
Goesgen.	1979	6		—
Leibstadt	—	—	1984	14
Taiwan:				
Kuosheng 1	1981	8		—
Chin-Shan 1	1979	9		—
Maansham 2	—	—	1985	11
Canada:				
Pickering 1	1971	6	—	—
Bruce 5	1983	7		—
Gentilly 2	—	—	1983	9
Darlington 1	—	—	1989	12
United Kingdom:				
Torness 1, 2	1986	8	—	—
Heysham 3,4	1986	7		—
Dungeness B-1, B-2.	—	—	1982	17
Heysham 1,2	—	—	1983	13
United States[a]:				
St. Lucie 2	1983	6		—
Hatch 2.	1979	7	—	—
Diablo Canyon 1	—	—	1984	16
Midland 1	—	—	1985	13

[a]Starting time is construction permit rather then reactor order.

SOURCES: December 19S1 Atomic Industrial Forum List of Nuclear PowerPlants Outside the United States; ch. 5, table for U.S. nuclear plants.

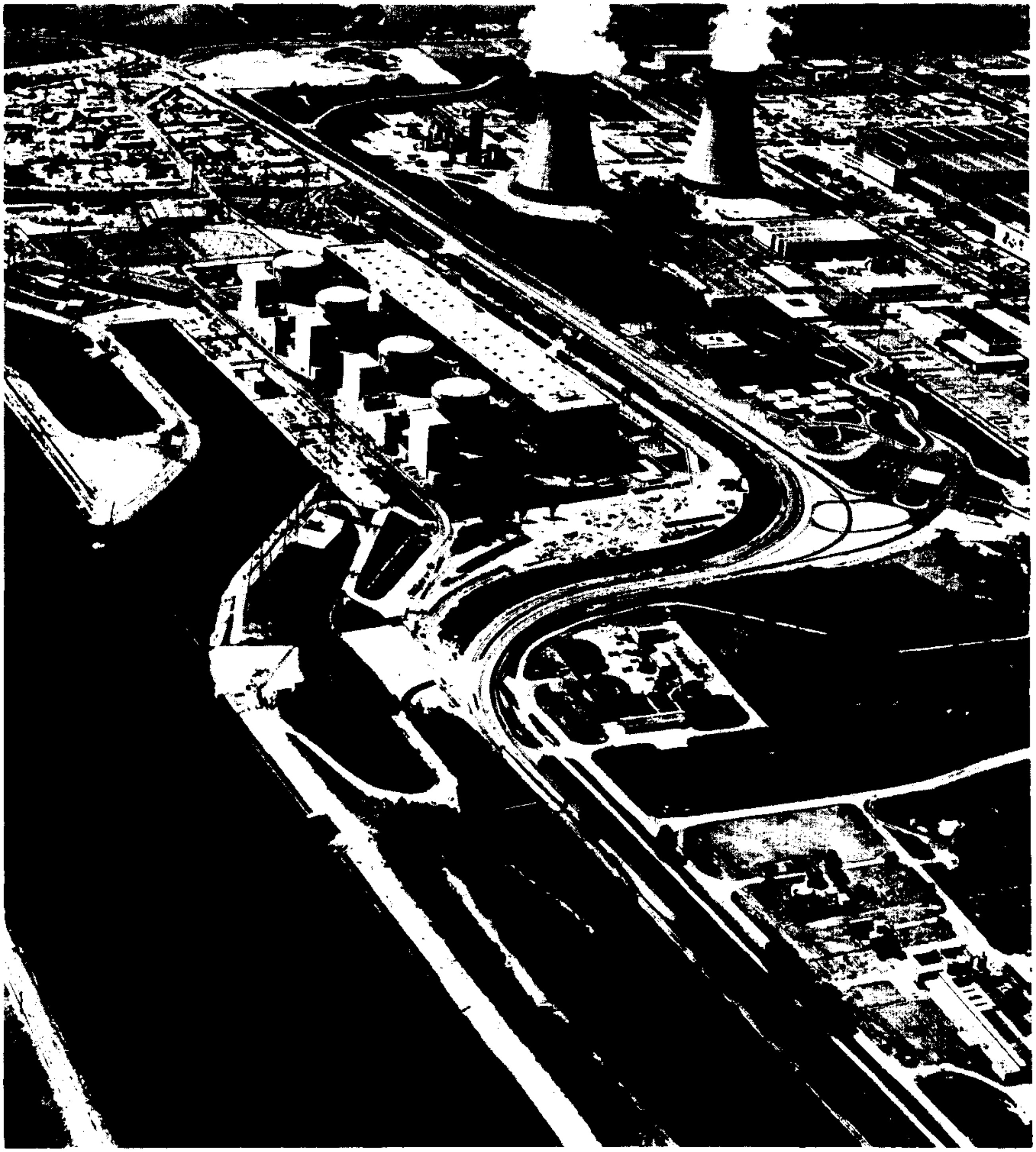
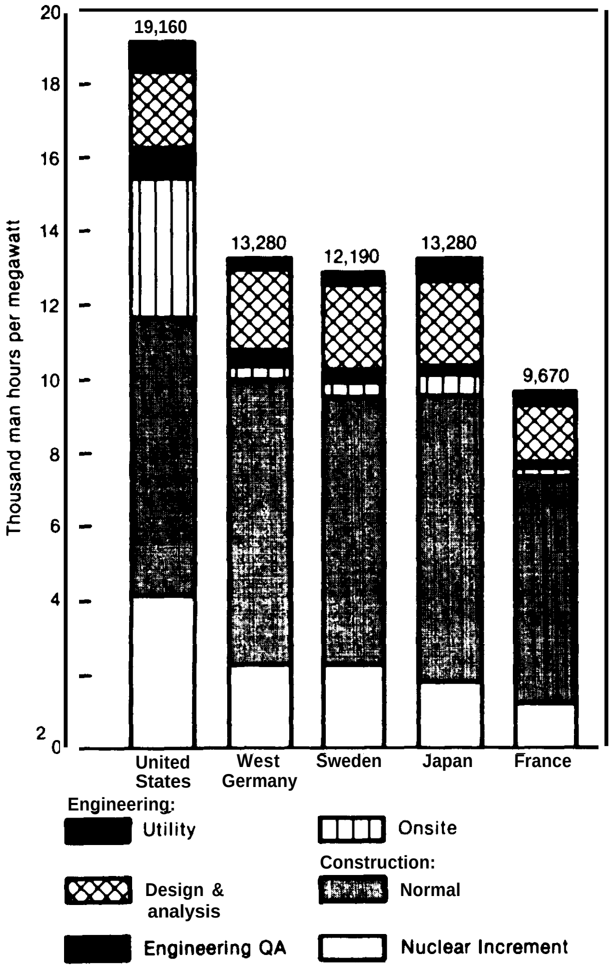


Photo credit: Electricite de France

Each of the four identical 925-MW units at Tricastin in France averaged 6.5 years construction time. Work force and engineering experience with the standard design and with the site accounted for the short construction time

Figure 38.-Engineering and Construction Man-Hours per Magawatt of Capacity (typical nuclear plants)



SOURCE: J. D. Stevenson end F. A. Thomas, *Selected Review of Foreign Licensing Practices for Nuclear Power Plants*, NUREG/CR-2664. These estimates were made from estimates of staffing patterns, project duration, end other Information obtained from interviews with about 50 people in the United States end foreign countries. The interviews are listed In the front of the report.

ing agencies each of which in turn depends on one of seven independent inspection agencies (TUV) for technical licensing requirements. In the 1970's, West German licensing and quality-control requirements imposed on nuclear plants increased in much the same fashion as they did in the United States (19). Engineering work tripled, quality-assurance documentation quintupled, and there was a 50-percent increase in the time required for component manufacture.

In France, Japan, and the United Kingdom, the consideration of siting and environmental issues is clearly separated from the consideration of safety issues. In all three countries the only opportunity for public intervention occurs at the earliest site-approval stage. This process can take 2 to 3 years in Japan (17). In France, the site-approval process can take place as much as 8 years before application for a construction license. In fact, sites have been approved for all nuclear construction until 1990 (36). In England, there is an option to hold a public inquiry at this early stage. The public inquiry for the Sizewell B covers a broad range of issues concerning development of pressurized water reactors (PWRs) in England (32).

Once site approval has been obtained, the licensing process in all three countries involves a technical exchange of information between licensing entity and licensee. In Japan and the United Kingdom, there is only one license (a construction license) but there is a series of technical requirements—for tests, safety analyses, and operating procedures—that must be met before the plant is allowed to operate. In practice, this amounts to a multistage licensing procedure. In France, there is an additional operating license, but the process is similar. The plant must pass a series of tests and have proposed operating procedures approved before an operating license can be issued (36).

Overall Nuclear Development

There are significant differences among countries in the probable future course of nuclear development. Table 27 classifies countries with actual or possible nuclear power programs into six categories based on the prospects for further nuclear construction.

Five countries–France, Japan, Canada, Taiwan, and Korea—have Government-supported programs of constructing and operating nuclear plants. Three—France, Japan, and Canada–have emphasized standardization to minimize construction cost and increase reliability. All three have ambitions for major export programs in the 1990's when demand picks up again, although Canada has had several setbacks in its efforts to make the CANDU heavy water reactor (HWR) a viable export, when sales failed to go forward in Mexico, Korea, and Rumania. In addition, Can-

Table 26.—Operating Performance by Country (average reactor cumulative load factor, to end of 1933)

	Reactor types									
	PWRs		BWRs		Magnoxs		Heavy water		HTRs &AGRs	
Country	Load factor, 0/0	Number of units	Load factor, %	Number of units	Load factor, 0/0	Number of units	Load factor, %	Number of units	Load factor, 0/0	Number of units
United States	54.8	48	56.1	23	—	—	—	—	17.9	1
Argentina	—	—	—	—	—	—	75.3	1		—
Belgium	75.6	3	—	—	—		—	—	—	—
Brazil	2.3	1	—	—	—		—		—	—
Canada	—	—	—	—	—	—	80.1	9	—	—
Finland	75.0	2	62.7	2						—
France	56.0	23	—	—	52.8	5	—	—	—	—
Germany, West	71.2	7	44.1	4						—
Great Britain	—	—	—	—	58.5	18	-	-	40.6	4
India	—	—	49.1	2	—		33.4	2		—
Italy	44.1	1	30.3	1	59.3	1	—	—	—	—
Japan	56.2	11	61.0	12	62.6	1	49.8	1	—	—
Netherlands	77.9	1	—	—	—	—	—	—		—
South Korea	55.2	1	—	—			—	—	—	—
Spain	36.8	2	62.0	1	72.0	1	–	—	—	—
Sweden	38.3	2	65.1	7	—		—	—	—	—
Switzerland	75.1	3	80.5	1	—		—	—	—	—
Taiwan	—		51.9	4	—		—	—	—	—
Yugoslavia	53.1	1	—	—	—	—		—	—	—
World	56.7	106	56.6	57	57.8	26	76.0	13	38.0	5

Notes: 1. All plants operating less than a year as of July 1983 were excluded from this calculation.
2. The USSR and several countries in Eastern Europe with substantial numbers of nuclear plants are not listed, (See appendix table 7B)
3. Graphite-water and fast breeder reactors are not included,
4. Plant load factors were weighted by plant rated capacity to get country and reactor-type averages.

SOURCE: Nuclear Engineering International, "Nuclear Station Achievement 1983," October 1983.

Table 27.—Categories of Foreign Nuclear Programs in Western Europe and the Asia-Pacific Region

	Category	Countries in category
I.	More nuclear plants planned and under-construction backed by Government policy	France, Japan, Taiwan, Canada, Korea
II.	More nuclear plants planned but may be stopped by public opposition	United Kingdom, West Germany, Italy
III.	More nuclear plants planned but delayed due to economic difficulties	Spain, Yugoslavia, Greece Portugal, Turkey
IV.	Nuclear plants in existence with de facto and de jure halt on further construction	Sweden, Switzerland
V.	Nuclear plants begun but indefinitely halted	Philippines, Indonesia
VI.	Government policy prohibits nuclear plants	Australia, Austria, Norway Ireland, Denmark

SOURCES: Off Ice of Technology Assessment categorization based on papers presented at conference on Nuclear-Electric Power in the Asia Pacific Region Jan 24-28, 1982; and Måns Lönnroth and William Walker *Nuclear Power Struggles. Industrial Competition and Proliferation Control,* George Allen and Unwin, London, 1983.

ada has entered into negotiations with U.S. utilities to build plants whose output is primarily intended for the U.S. market (20,24). Several characteristics of the nuclear industry in Canada, France, and Japan make it far easier to maintain momentum in the nuclear industry than it is in the United States. In Canada and France, the nuclear-using utilities are Government-owned (see table 28). With only one nationalized utility in France and three nuclear-owning utilities in Canada, the institutional coordination for an effective standardization program is fairly easy. In Japan, the nine utilities are investor-owned and depend on private financing. However, planning for nuclear power development takes place within the overall framework of private-public cooperation established by the Ministry of International Trade and Industry (MITI). Of these coun-

Table 28.—Structure of Electric Utility in Main Supplier Countries and the Distribution of Authority Over Key Decisions Influencing Financial Health of Utilities

Ownership of utilities	Choice of generating mix	External financing of investments	Rate regulation	Comments
United States: Large number of utilities, mainly privately owned	In principle utility, but, State governments tend de facto to influence decisions	Capital market (bonds, stocks). Bonds rated by independent rating agencies; State finance for public utilities	Public utility commissions in each State	Fragmented authority over utility financial health. Role of Federal Government very weak
France: State owned, EdF	Government, at recommendation from EdF	National budget, international capital market (e.g. US) for bonds	National Government approves rate change	National Government controls financial health
West Germany: Several utilities, the larger ones having mixed State (land) and private ownership	Utility, but regional government makes final licensing decisions	Capital market, regional government	Federal Government has to approve rate changes	Local, regional, and Federal governments all influence, and have interest in, financial health of utilities due to ownership and rating responsibilities
Canada: Mainly provincially owned (Ontario, Quebec, etc.)	Utility recommendation, provincial government final decision	Budget of provincial government, capital market (bonds)	Provincial government approves rate changes	Provincial government controls financial health
United Kingdom: State owned, CEGB and SSEB	National Government, after recommendation from generating boards	Budget of National Government	National Government approves rate changes	National Government controls financial health
Japan: Private investor owned (9)	Safety assessments carried out by central government, environmental assessment by local government. Final authority rests with Prime Minister	Mixed (bonds, equity ...)	Ministry of International Trade and Industry (MITI)	Financial health generally good. Utilities with nuclear investments have developed substantial in-house technical capabilities
Sweden: State owned (50)%) Privately owned (35%) Local government (15°10)	National Government final licensor after pro. posals from utilities	National budget (for State-owned utility), bonds for utilities not owned by the state	Almost none. Electricity producers allowed to compete for large-scale customers and distributors	Financial health generally good, due to large share of inflation resistant hydro. Competition between utilities said to hold rates down

SOURCE. Mans Lonnroth and William Walker, *The Viability of the Civil* Nuclear Industry, a working paper for the International Consultative Group on Nuclear Energy Published by the Rockefeller Foundation and the Royal Institute of International Affairs in 1979.

tries, France and Japan have substantial domestic markets for nuclear powerplants and are thus in stronger position to sustain nuclear industries.

The United Kingdom, West Germany, and Italy have nuclear powerplants underway, but these could still be stopped by public opposition. Further construction of LWRs in the United Kingdom will depend on the outcome of the Sizewell B Inquiry. The case for new construction is greatly weakened by the very low electricity demand growth in the United Kingdom over the decade of the 1970's (32).

in West Germany, a group, called a "convoy," of six similar nuclear powerplants was started through licensing review in the spring of 1982 (7). There are indications that political and public opposition may have peaked although there have been no changes in legal structure (24). Construction stoppage is still a possibility, however, because citizens retain the legal right to sue to stop the plants and the courts are independent.

In Italy, two nuclear plants are under construction in addition to four in operation. Local opposition to the two under construction caused extensive delays. The State electricity corporation, EN EL, will begin a vigorous campaign of local public education at each site of four plants proposed to be built by 1990. Success of such efforts in avoiding site delays is still unknown; similar site public relations efforts in France were targets of protestor bombings.

Of the countries with nuclear plants in existence and nearing completion, but with a hold on further construction, Sweden has the most explicit moratorium. Switzerland also appears to have halted further construction beyond plants scheduled to begin commercial operation in 1985. Several countries have avoided nuclear power in developing a national energy policy. Despite possessing some of the world's richest uranium supplies, Australia is dedicated to basing its electricity generation on coal. Austria and Norway have decided against building nuclear plants but are able to use abundant hydropower. New Zealand has surplus electricity from hydropower and coal; and Ireland will increase coal-fired electricity (12).

Implications for the U.S. Nuclear Industry

Implications for the U.S. industry can be drawn from the experience of other countries in developing nuclear power. Probably the most powerful lessons will come from countries more like ourselves.

The West German "Convoy" Experiment.– The German licensing system for nuclear power appears every bit as cumbersome as the U.S. system; in fact it involves even more regulatory man-years per regulated megawatt (38). With seven State licensing authorities, assisted by seven different independent engineering review organizations (TUVs), the West German system adds State-to-State inconsistency to the several stages of hearings and the independent court reviews of the U.S. system.

In an effort to halt the cycle of delays, requirements for rework, and increasing engineering manpower and paperwork, Kraftwork Union (KWU), the chief German reactor vendor, has negotiated a plan with State licensing authorities and technical agencies (TUVs) for a series of powerplants to be ordered and licensed in groups of five or six or "convoys" over the next 10 to 12 years (19). The basic process is modeled on the successful French program. Each series would have a standard design. Improvements on the design would be saved for a subsequent series.

The various parties to the construction and licensing of powerplants have agreed to several changes in procedure designed to reduce the cost and delays in plant construction. Documentation requirements have been simplified. Technical reviews of different aspects of the convoy plants have been assigned each to a separate technical review agency. KWU will make maximum use of computer-assisted design and develop a convoy management system that controls the critical features of the design of each plant.

The legal framework has not changed in West Germany in order to facilitate the convoy concept. As KWU concluded in its report on the concept, "without the broad consensus of all the parties involved (namely the customers, licensing authorities, authorized inspection agencies, and manufacturers) the concept will remain nothing more than a collection of odds and ends, with every chance of real success denied it" (19).

Although the institutions are different, the problems of getting a large number of different organizations to work together to streamline an increasingly cumbersome process is similar to what would have to be accomplished in the United States. Success of the West German effort would demonstrate that such an effort is possible.

Backfits.—In both West Germany and France there are policies that restrict backfits. In West Germany, utilities are supposed to be compensated for the costs of implementing any backfits after the State licensing authority has given its approval (38). In practice, this provision has not been carried out very often and has not prevented the escalation in required engineering man-hours described above.

In France, backfits are restricted once each standardized design has been approved. Occasionally, certain backfits (e.g., several following the Three Mile Island accident) may be judged

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important and then they are implemented on all plants of a certain design (36,6).

Standardized Training.–In West Germany there is a single institution for certifying powerplant operators. This school, called the Kraftwerkschule is owned by a joint organization of 116 utility members in six countries. Operators complete a 3-year course including supervised operation of an actual powerplant. Such training is a minimum requirement for a deputy shift supervisor. The shift supervisor must be an engineer (33).

Siting of Nuclear Powerplants.–In Japan and Italy, land is constrained, and finding sites for nuclear plants is difficult. In Japan, the most difficult part of the licensing process is the series of negotiations with local governments. MITI has in its budget about $60 million for public works grants to local governments that accept nuclear powerplants nearby. Additional funds are used to reduce electric bills of local residents (12,36,38). More funding is available if power is exported from the local area.

A similar approach is used in France where electric bills in areas surrounding nuclear plants are reduced by 15 percent, and funds to build housing, schools, and other public facilities are lent by the utility to nearby towns which repay the loan in utility property tax abatements. In Italy, there is an 18-month site review and approval process. Special public education centers are set up at each proposed site well in advance to help educate the public about the benefits and risks of nuclear power (12).

Financial Risk.—There is far less financial risk to utilities investing in nuclear power in other countries than in the United States. In West Germany, utilities set their own electric rates subject

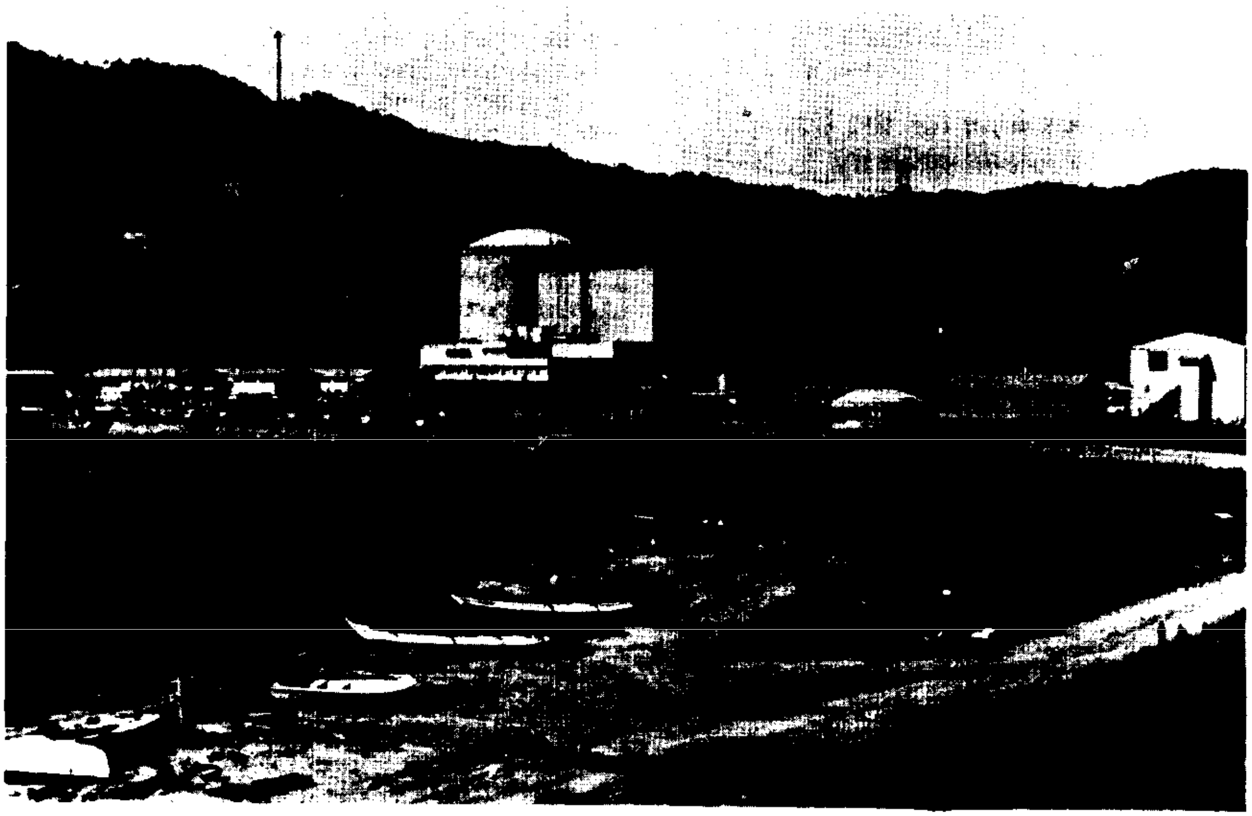

Photo credit: Atomic Industrial Forum

For citizens living near Japanese nuclear powerplants, electricity rates are reduced and grants are made available for public works

to general Federal approval for household rates and subject to antitrust provisions for industrial rates. Financing is provided not only by the private sector market but also by regional governments, which are pat-t-owners of the largest utilities. In Sweden where utilities also use private financing for investments, electric rates are generally not regulated, and utilities are in good financial shape (see table 28) (26). Similarly, in Japan, privately financed utilities are strong financially. Electric rates in Japan are the highest in the world and reflect the full costs of producing power, in order to encourage conservation (12). In France, on the other hand, the Government approves electric rates; in 1982 they were not increased enough to prevent a deficit of about $1 billion in the account of the electric utility (36).

Timing and Balance.—There are some indications that public opposition outside the United States has been intensified by very rapid development of nuclear power in Sweden and West Germany (26). At the same time, public acceptance for nuclear power in many countries seems to be more solid if nuclear power is included as part of an overall national energy plan that includes a strong emphasis on energy conservation, renewables, and other sources of electricity. Such plans have been formally announced in Japan, France, West Germany, and Italy, all countries with potentially important roles for nuclear power (1 **2).**

Shift to a New Reactor Technology.–As consideration is given in the United States (see ch. 4) to the desirability of shifting to a whole new reactor technology—heavy water reactors (HWRs), gas-cooled reactors (GCRs), or “forgiving” LWRs, several lessons can be learned from foreign experience. One is that it is quite possible to shift to a new technology. France shifted from GCRs to PWRs for plants ordered in the early 1970’s. The United Kingdom is now considering the shift to PWRs in a formal public inquiry. In both cases, the shift has been towards a “standard” technology now in use in the United States and elsewhere, Clearly, this is a different situation from a shift to a relatively untested technology described as a possibility in chapter 4.

The public inquiry into the Sizewell B PWR now underway in the United Kingdom has been one of the most extensive public debates on nuclear power ever held. Beginning in January 1983, it lasted most of 1983. Much of the argument focused on the economics of the proposed project. In all but one of the five electricity demand scenarios proposed by the Central Electricity Generating Board (CEGB), electricity demand in the United Kingdom is forecast to decline between 1980 and 2000. The argument for building the Sizewell B powerplant is that cheaper nuclear power will substitute for increasingly expensive oil and coal, but there is much official skepticism about the economic plan from other government agencies. The public inquiry has addressed questions of the likelihood of cost overruns and of public pressure for expensive safety improvements to match those being required in the United States and West Germany (32).

The Sizewell B debate should provide a thorough exploration of many of the issues now facing the U.S. nuclear industry. Furthermore, it will provide one more example of a possible approach to involving the public in decisionmaking on nuclear power. Conceivably such a full inquiry could precede the launching of a “convoy” of new advanced design LWRs when orders pick up again.

The U.S. Industry in an International Context

Although the United States has by far the largest number of nuclear plants of any country, future prospects for the U.S. nuclear industry are regarded as dimmer than those of several other countries, at least by some observers. Mans Lonnroth, a Swedish author of a book on the worldwide nuclear industry (25), describes the coming decade as tough for all nuclear countries since the industry will have to demonstrate that it is a “safe, reliable and economic energy source. ” Success will depend in part on the coherence of each country’s response to this challenge (24).

The French have been very successful at constructing nuclear plants quickly and cheaply.

They have a large design, manufacturing, and construction capacity much of which has no other alternative use. Among French industries, the nuclear industry has been successful, and there will be considerable pressure to keep it operating even in the face of slower growth in electricity demand than anticipated. The French nuclear industry, however, has had less success in exporting sales than has West Germany or the United States. This is the big challenge for the next decade (24).

By contrast, Lonnroth claims, in the United States a "collapse of the nuclear industry would not seriously affect either the public authorities, the industry at large, or the American society" (24). The U.S. social and political system is more fragmented than either the French or West German system and for this reason may have difficulty developing a coherent long-range strategy in the absence of full consensus. West German governmental processes are as complex and open as those in the United States, but the German nuclear industry acts far more as a single industry. It "views itself as one industry, with one collective will and one identity" (24). For this reason Lonnroth suggests that the technical and economic coordination necessary for a long-range nuclear strategy in West Germany is possible within a series of "interlocking ownerships among the main industrial actors" under the long-range guidance of key West German banks (24).

Japan has had its difficulties with nuclear power, including prolonged siting processes and construction delays. However, Japan has very strong motivation to develop its nuclear industry because it has no indigenous fossil fuels. Japan has also demonstrated the ability to coordinate long-range industrial strategy in other areas and to develop an export-oriented strategy. Japan has become the single most important exporter of heavy electrical equipment and is expected to provide about 25 percent of all exports in this sector from 1975-87 (24). This gives Japan a very strong industrial base on which to develop a nuclear exports business. For the moment the nuclear industry still needs government support. However, such support will not be available indefinitely.

Thus West Germany, France, Japan, and the United States–and perhaps Canada as well–will be competing for a nuclear export market in the 1980's and 1990's. They will be competing for a market that is far smaller than worldwide nuclear industrial capacity and far smaller than previous estimates had projected (see table 29 and appendix table 7B). Several importing countries—Korea, Taiwan, Argentina, and Spain–are working to develop domestic supply capabilities and will be curtailing imports. Many countries are importing far less equipment and engineering and construction management services than they did earlier in the decade.

Given the softness of the export market, it will be difficult for suppliers of nuclear equipment and services to be sustained through the next two decades unless they have some domestic base. Although U.S. firms are involved in 31 plants still under construction, all major components will have been delivered by the end of 1984. For those overseas plants engineered by U.S. AE companies, the basic design is now complete (37). If U.S. suppliers begin to get new domestic orders in about 5 years, they will provide a new basis for maintaining design teams and manufacturing facilities capable of sales abroad. If new reactor orders are delayed for 10 years or more, U.S. firms may find themselves looking to the Japanese, West Germans, or French for joint ventures or licensing arrangements in which the foreign company is an equal, or even dominant, partner. This would be the reverse of the situation in each of these countries early in the history of the nuclear industry.

Nuclear Proliferation Considerations

U.S. and worldwide efforts to restrict proliferation of nuclear military technology are an important influence on the development of international trade in civilian nuclear power (25). The perceived link between the civilian and military uses of nuclear power has stimulated much of the opposition to nuclear power (see ch. 8). The reasoning is straightforward: commercial nuclear power requires the production of nuclear fuels, and some of these fuels and facilities that pro-

Table 29.-Estimated Reactor Export Market (1983-87 inclusive) in Units

	Orders		Industrial capability	Hardware market		Software market		Previous suppliers 1960-80 (no. of units)
	Low	High		Low	High	Low	High	
Europe:		**12**						
North	(0	**3)**						
Belgium	0	1	**'/2**	0	0	0	0.5	U.S. *(6),* France (2)
Finland	0	1	2	0	***0.5***	0	0.75	Sweden (2), USSR (2)
United Kingdom	0		**'/2**	0	***0.25***	0	0.5	—
South	(3	9)						
Greece/Turkey/Portugal	0	1	***3***	0	1	0	1	
Italy	2	**4**	1	0	0	0.5	1	U s . (I)
Spain	1	**2**	1	0	0	0.25	0.5	U.S. (12), Germany (2)
Yugoslavia	0	**2**	***2***	0	1	0	1.5	Us. (1)
Latin America:	0	**5**						
Argentina	0	**1**	***2***	0	0.5	0	0.75	Germany (2), Canada (1)
Brazil	O	**2**	***2***	0	1	0	1.5	Germany (2), U.S. (1)
Mexico	O	**2**	**2/3**	0	1.5	0	2	Us. ***(2)***
As/a and Pacific:	***2***	10						
China	O	***2***	***2/3***	0	1.5	0	2	
Indonesia	0	1	3	0	1	0	1	
Pakistan	0	1	**2/3**	0	0.75	0	1	Canada (1)
South Korea	2	**4**	**'/2**	0.5	1	1	2	U.S. (6), France (2), Canada (1)
Taiwan	O	**2**	2	0	1	0.75	1.5	U.S. (6)
Africa and Mid-east:	0	**5**						
Egypt	**O**	**2**	***3***	0	2	0	2	
Israel	**O**	**1**	***3***	0	1	0	1	
South Africa	O	**2**	**2/3**	0	1.5	0	2	France (2)
Total	5	**32**		0.5	15.5	2.5	22.5	
Average annual rate	1.0	**6.4**		0.1	3.1	0.5	4.5	

SOURCE: Mans Lonnroth, "Nuclear Energy in Western Europe," based on research for *Nuclear Power Struggles,* **Allen and Unwin, London, 1983.**

duce them can be used for nuclear weapons. The fundamental premise of U.S. and worldwide efforts to avoid proliferation to additional nations has been to keep civil uses of nuclear energy distinctly separated from military applications, and to try to erect barriers to prevent diversion or misuse of civil nuclear materials and facilities. Technical and institutional aspects of nuclear proliferation were the subject of a previous OTA study and a recent Congressional Research Service paper which is reprinted in full as an appendix to this report (1 1,34).

Although it is technically possible to make crude nuclear weapons from the plutonium in spent fuel from nuclear power reactors, it is more likely from the higher grade plutonium manufactured in spent-fuel reprocessing, and in the operation of breeder reactors (see appendix table 7C). Economic prospects for commercial reprocessing have decreased worldwide as well as in the United States and no nation is currently producing and using plutonium commercially for nuclear fuel. A few countries, most notably France, are working with plutonium for use in breeder reactors.

Current worldwide and U.S. concern about nuclear power and proliferation stems from these considerations about the potential use of civilian nuclear fuels. One fear is that a rapidly industrializing state with a nuclear power base in a troubled part of the world might be tempted to use its civilian program as a base for developing nuclear weapons. The second concern is that some underdeveloped countries with nominal nuclear power programs might obtain enough technology and equipment on the world market to build facilities to produce weapons-usable materials. The grave concern in the 1960's that many nuclear powerplants worldwide would give rise to the wholesale spread of nuclear arsenals has given way in the 1980's to the concern that a few nuclear powerplants and related facilities scattered among some developing countries could bring them much closer to an ability to make nuclear weapons. It is this concern that drives proposals for restrictions on international nuclear cooperation and trade.

Concern about the spread and use of nuclear weapons has led to several international initiatives. The Non-Proliferation Treaty (NPT) pledges its members that do not have nuclear weapons to forego future acquisition of them, and requires verification of the use of civilian facilities by international inspection. It further stipulates that all the nuclear facilities in signatory states without nuclear weapons will be safeguarded, even those that are developed indigenously. This treaty represents a significant departure from practices prior to 1970, and is an important element of the international proliferation regime. However, it has not been as effective as it might have been because a number of nations have refused to participate in the treaty. As shown in table 30, the nonsignatory states include India, Pakistan, Brazil, Argentina, and South Africa.

After NPT took effect, other events stimulated further proliferation concerns. **In 1974, India tested a nuclear explosive that was derived from civilian facilities. Shortly thereafter, France and West Germany agreed to supply enrichment and/or reprocessing plants to nations (Pakistan and Brazil) which had refused to sign the NPT. By the late 1970's, the nuclear supplier countries had** become concerned enough to agree informally to exercise additional restraint in nuclear cooperation and trade, particularly in the area of the transfer of sensitive technology. The United States imposed even more severe restrictions than the other suppliers with the passage of the Nuclear Non-Proliferation Act of 1978.

U.S. policies and controls that guide nuclear cooperation and exports include the following

Table 30.-No-Nuclear Weapons Pledges in Effect in 1981

	Treaty and data of entry into force			
State	Antarctic Treaty, 1961	Limited Test Ban Treaty, 1963	Treaty Prohibiting Nuclear Weapons in Latin America, 1 966a	Nuclear Non-Proliferation Treaty, 1970
Argentina.	P	s	S[b]	
Australia	P	P	P	P
Belgium	P	P	P	P
Brazil	P	P	s[c]	
Canada	P	P	P	P
Cuba.		—	—	—
Egypt	—	P		P
F.R.G, , ...	P	P	P	P
India		P	—	
Iran		P	—	P
Iraq		P		P
Israel		P		
Italy	P	P		P
Japan	P	P		P
Libya		P	—	P
Netherlands.	P	P	P[d]	P
Pakistan.		s	—	
South Africa	P	P		
South Korea		P		P
Spain		P		P
Sweden		P		P
Taiwan		P		P
Yugoslavia. . . . .,		P		P

P = Party.
S = Signatory.
[a]Not yet in force for all signatories.
[b]Ratified Subject to preconditions not Yet met.
[c]Additional Protocol II applying to Dutch territories in Latin America.
[d]There is some difference of opinion as to whether one small unsafeguarded laboratory should be considered a facility.

SOURCE: W. Donnelly and J. Pilat, "Nuclear Power and Nuclear Proliferation: A Review of Reciprocal Interactions," Congressional Research Service for the Office of Technology Assessment, April 19S3.

items: restrictive conditions for licensing exports of nuclear materials, equipment, and reactors; restrictive conditions for providing technical assistance and transferring technology; restrictions on export of dual-use items that can be applied to weapons programs as well as to legitimate nuclear power programs; post-export controls, or prior rights over what may be done with or to U.S. nuclear exports, such as reactors or fuel; and cutoff of nuclear cooperation and exports to states which violate safeguards agreements with the United States. These restrictions are embedded in U.S. law, particularly in the Non-Proliferation Act of 1978 mentioned above, the Atomic Energy Act of 1954, and the Symington and Glenn amendments to the Foreign Assistance Act of 1961.

Nuclear cooperation and trade has been circumscribed in many aspects by the restrictive conditions and controls intended to prevent the development of nuclear weapons. Specifically, the supply of sensitive nuclear technology to countries that have little visible economic need for it is discouraged by the nuclear suppliers, and particularly by the United States. The supply of items that can be used for both civilian and military purposes has been little affected in the past, but is likely to be more restricted in the future since export control lists are being made more detailed and specific. Importing countries most likely to feel the effects of such additional restrictions include Argentina, Brazil, India, and pakistan.

Pressures from both formal and informal nonproliferation regulation can be viewed as stimulating some nuclear customer countries to seek independence of the major suppliers, either by building up their own nuclear industries indigenously or by finding suppliers who offer less demanding conditions. This could give rise to the emergence of a second tier of suppliers from the more industrialized developing nations, such as Argentina and India, who might not comply with the guidelines of the major suppliers. This could significantly change the character of nonproliferation control.

In part because of fears of loss of U.S. nonproliferation influence and trade, the Reagan administration has shifted emphasis somewhat from the policies of the Carter administration. Rather than emphasize across-the-board denial of nuclear supply, the Reagan administration has promoted the concept that the United States is a reliable supplier of nuclear equipment to trusted countries who are not viewed as proliferation risks.

Conclusion

For economic, political, and technical reasons, the 1980's will be a difficult decade for the nuclear power industry in all countries. Those most likely to survive are those with the political and industrial cohesion to develop a long-range strategy for demonstrating that nuclear power is a safe, reliable, and economic energy source. France, Japan, and possibly West Germany and Canada have a combination of national motivation and institutional coherence that makes it quite possible they will survive the decade with a more viable nuclear industry than will the United States. In the worst case, therefore, if the U.S. industry emerges weakened from a long period with no new orders, these countries may reverse earlier roles and provide some of the expertise and hardware to U.S. companies during the early years of a revival of the U.S. industry.

Appendix Table 7A.–Onsite and Offsite Nuclear-Related Job Vacancies at INPO Member Utilities Mar. 1, 1982

Occupations	Positions[a]	Vacancies: Number	Vacancies: Percent of positions
Managers and supervisors	5,765	432	7.5
Engineers:			
Chemical	179	30	16.8
Civil	872	40	4.6
Electrical	1,518	239	15.7
Instrument and control	506	91	18.0
Mechanical	2,844	327	11.6
Nuclear and reactor	1,427	287	20.1
Quality assurance/control	791	147	18.6
Radiation protection	140	30	21.4
All other engineers	2,229	420	18.8
	10,506	1,611	15.3
Scientists:			
Biologists	144	6	4.2
Chemists	269	37	13.8
Health physicists	404	83	20.5
Other scientists	235	28	14.6
	1,052	154	14.6
Training personnel			
SRO/Relicensed/certified instructors	405	109	26.9
Other technical/scientific instructors	576	100	17.4
Other instructors	188	52	27.7
Support staff...	135	17	12.6
	1,304	278	21.3
Operators:			
Shift technical advisors	416	93	22.4
Shift supervisors	735	119	16.2
Senior licensed operators (SRO)	385	117	30.4
Licensed operators (RO)	1,094	230	21.0
	2,214	466	21.1
Non-licensed operators assigned to shift	2,286	242	10.6
Other non-licensed operators	351	102	29.1
	2,637	344	13.1
Individuals ingraining for SRO licenses	495	22	4.4
Individuals ingraining for Relicenses	878	66	7.5
Individuals ingraining for non-licensed positions	838	246	29.4
	7,478	1,237	16.6
Technical and maintenance personnel:			
Chemistry technicians	1,004	161	16.0
Draftsmen	1,209	98	8.1
Electricians	1,609	172	10.7
Instrument and control technicians	2,463	320	13.0
Mechanics	3,554	244	6.9
Quality assurance/control technicians	793	88	11.1
Radiation protection technicians	1,792	266	14.8
Welders with Nuclear Certification	415	48	11.6
Other technical and maintenance personnel	3,883	312	8.0
	16,742	1,709	10.2
All other professional workers	1,304	125	9.6
Other technical personnel	1,061	114	10,7
Total	45,212	5.660	12.5

[a]This includes persons employed by INPO member utilities, Including holding company positions allocated to the utilities, vacant positions, and contractor positions used in normal operations.

Note: Fifty-five utilities providing offsite information; onsite data comes from 82 plants representing 58 utilities, except onsite vacancy data, which was provided by only 81 piants representing 57 utilities.

Appendix Table 7B.—Nuclear-Generating Capacity Outside the United States

	1980			1981		1985		1990		1995		2000	
	Net MWe installed	Percent of capacity	Percent of generation	Net MWe installed	Percent of capacity	Net MWe installed	Percent of capacity	Net MWe installed	Percent of capacity	Net MWe installed	Percent of capacity	Net MWe installed	Percent of capacity
Argentina	344	3.7	na	344	na	944	8.5	1,642	12.0	2,842	na	3,442	23.0
Austria	0	0	0	0	0	na	na	na	na	na	na	na	na
Belgium	1,667	15.0	23.3	1,667	14.9	5,427	38.0	na	na	na	na	na	na
Brazil	0	0	0	0	0	626	1.0	1,871	4.0	5,606	7.0	10,586	10.0
Bulgaria	1,320	na	na	1,320	na	2,760	na	4,760	35.0	na	na	na	na
Canada	5,498	8.0	9.0	5,498	7.7	10,347	10.5	14,502	13.0	na	na	na	na
China, People's Republic of	0	0	0	0	0	0	0	0	0	3,000	na	16,000	na
Cuba	0	0	0	0	0	0	0	1,320	na	na	na	na	na
Czechoslovakia	992	na	na	992	na	3,192	17.0	10,952	32.1	na	na	18,952	50.0
Denmark	0	0	0	0	0	0	0	0	0	2,600	na	na	na
Egypt, Arab Republic of	0	0	0	0	0	0	0	900	6.7	3,600	na	8,400	28.6
Finland	1,080	12.0	16.5	2,160	22.0	2,160	20.0	2,160	19.0	3,160	25.0	na	na
France	14,400	23.0	24.0	21,930	31.0	38,200	43.0	58,000	54.0	na	na	na	85.0
Germany, Democratic Republic of	1,400	na	na	1,400	na	5,360	na	9,000	na	9,000	na	na	50.0
Germany, Federal Republic of	8,625	12.0	14.3	9,850	10.0	17,700	na	26,704	na	na	na	na	50.0
Greece	0	0	0	0	0	0	0	600-900	5.0	na	na	na	na
Hungary	0	0	0	0	0	1,760	na	4,760	10.0	na	na	11,000	48.0
India[a]	640	2.1	2.7	860	2.7	1,330	2.6	1,800	na	4,030	na	10,000	8.3
Israel	0	0	0	0	0	0	0	0	0	1,800	na	2,700	30.0
Italy[b]	1,424	3.0	1.5	1,424	3.0	1,462	3.1	4,462	6.1	11,462	na	na	na
Japan[c]	5,511	12.0	15.9	15,511	11.7	28,000 – 30,000	15.6 – 16.8	51,000 – 53,000	22.1 – 22.9	74,000 – 78,000	26.7 – 28.2	na	na
Korea, Republic of (South)	587	6.3	9.3	587	6.0	3,815	20.0	11,216	41.5	na	na	na	na
Libya	0	0	0	0	0	0	0	na	na	na	na	na	na
Mexico	0	0	0	0	0	1,308	5.0	2,300	5.0	na	na	20,000	25.0
The Netherlands	505	3.3	7.0	505	3.2	505	3.0	505	3.0	450	2.0	450	2.0
Pakistan	125	na	7.1	125	na	725	na	na	na	na	na	na	na
The Philippines, Republic of	0	0	0	0	0	620	10.5	620	7.2	620	na	620	3.5
Poland	0	0	0	0	0	0	na	4,000	9.0	na	na	23,000	na
Portugal	0	0	0	0	0	0	0	0	0	na	na	2,790	18.0
Romania	0	0	0	0	0	440	na	3,960	20.0	na	na	na	na
South Africa, Republic of	0	0	0	0	0	1,844	7.0	na	na	na	na	na	na
Spain	1,100	3.7	4.7	2,030	6.2	7,655	20.3	2,000	26.1	18,000	32.1	27,000	40.0
Sweden	4,600	16.8	27.0	4,600	na	8,380	26.3	9,430	28.2	na	na	na	na
Switzerland	1,926	17.5	28.4	1,926	17.5	2,871	21.9	na	na	na	na	na	na
Taiwan (China)	1,212	14.5	19.1	2,163	22.4	4,928	31.0	8,728	na	11,578	na	na	na
Thailand	0	0	0	0	0	0	0	0	0	900	10.1	na	na
Turkey	0	0	0	0	0	0	0	0	0	1,000	na	na	na
Union of Soviet Socialist Republics	10,505	na	na	15,790	na	34,135	10.0	90,000	25.0	na	na	130,000 200,000	33.0
United Kingdom	6,457	9.0	12.0	6,457	9.4	9,835	na	10,311	na	na	na	na	na
Yugoslavia	0	0	0	632	na	632	na	632	na	na	na	na	na

[a]Gross MWe.
[b]Percent of capacity for 1985 and 1990 includes share of Super Phenix.
[c]Gross MWe (excluding Fugen). 1980 figures for fiscal year Apr. 1, 1980 to Mar. 31, 1981.

SOURCE: Atomic Industrial Forum List of Powerplants Outside the United States, December 1981.

Appendix Table 7C.—Usability of Nuclear Materials for Nuclear Weapons or Explosives

	Usability		
Material and form	Direct	Indirect	Processing required
Plutonium:			
Metal	Yes		
Oxide	Possibility	Yes	Chemical separation
Oxide with uranium in nuclear fuels	No	Yes	Do
Oxide or other forms in spent nuclear fuels	No	Yes	Reprocessing
Thorium: Ore, metal, chemical forms	No	No	
Uranium-235:			
Normal ore, metal, chemical forms	No	No	
Slightly enriched (3-6 percent) metal	No	Yes	Chemical processing to produce uranium hexafluoride for enrichment to weapons grade
Oxide in nuclear fuels	No	Yes	Do
Oxide or other forms in spent nuclear fuels	No	Yes	Reprocessing, chemical processing and enrichment
Moderately enriched (20 percent) metal	Unlikely	Yes	Chemical processing and enrichment
Oxide	No	Yes	Do
Oxide in nuclear fuels	No	Yes	Do
Oxide or other forms in spent nuclear fuels	No	Yes	Reprocessing, chemical processing and enrichment
Highly enriched (90 percent):			
Metal	Yes		
Oxide	Yes		
Oxide in nuclear fuel	No	Yes	Chemical separation
Oxide or other forms in spent nuclear fuels	No	Yes	Reprocessing
Uranium-233:			
Metal	Yes		
Oxide	Yes		
Oxide in nuclear fuels	No	Yes	Chemical processing and enrichment
Oxide or other forms in spent nuclear fuels	No	Yes	Reprocessing, chemical processing and enrichment

SOURCE. W. Donnelly and J. Pilat, "Nuclear Power and Nuclear Proliferation: A Review of Reciprocal Interactions," Congressional Research Service for the Office of Technology Assessment, April 1983.

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