How soon will the lights go out?

The crisis in electrical power generation must be reversed, using superconductivity and nuclear energy. A report by Thoula Frangos, an engineer with the Fusion Energy Foundation.

Brownouts and blackouts in the electrical power system of the United States will become more and more frequent in the near future, if urgent measures are not taken to modernize and expand the nation's power grid. Last year, the Long Island
oratory if physics experiments would be damaged, if power were suddenly shut off due to shortages in the area. The Nevada Power Company is waiting for the next power outage on the overloaded Pacific Northwest Transmission grid. Presently, transmission lines are operating at full capacity a high percentage of the time, as utilities wheel in power from areas of lower generation costs to areas of higher costs. This short-term solution is lowering the reliability of the electric system and postponing the necessary effort to create new generating capacity.

To turn this situation around,
commercialize superconducting cable to improve transmission efficiency, and must abandon once and for all the environmentalist legacy of the Jimmy Carter years, and begin mass production of nuclear power plants to increase the nation's available power capacity.

Most people take its availability for granted, but our reliable supply of electric power, which is vital to economic growth and national security, will be threatened as early as the end of this
American Electric Reliability Council, "The reliability of electric supply will decline over the next 10 years. By the mid-1990s, electric generating capacity margins will be near minimum acceptable levels in some parts of the U.S., even if electricity demands grow no faster

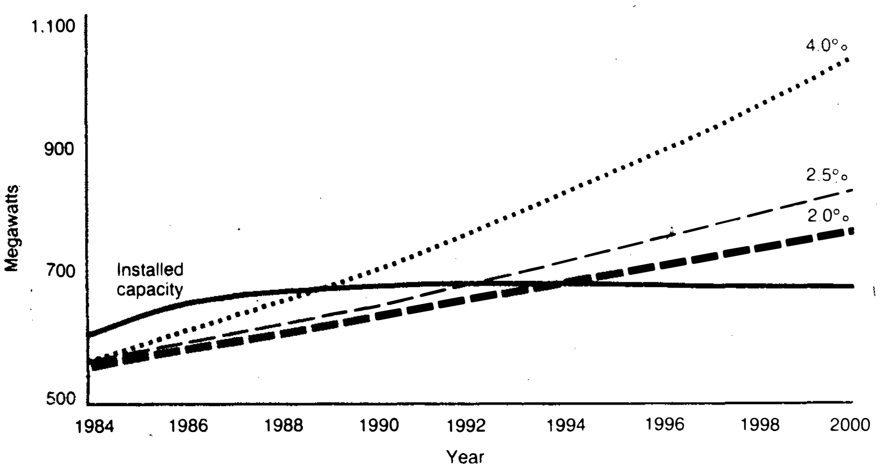


FIGURE 1
U.S. electricity supply and demand

Whether the U.S. demand for electricity grows at a slow 2% or a more optimistic 4%, demand would outstrip current installed capacity by 1992.

Source: Edison Electric Institute

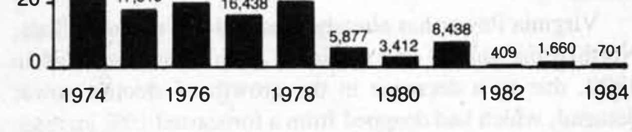
NSIPS/Carlos de Hoyos

The Three-Mile Island nuclear power plant in Pennsylvania. The political sabotage of the nuclear industry over the past 15 years, and particularly after the accident at TMI, means higher electricity costs and a threatened economy.

rate of 2.2% per year. . . . Some of the generating capacity that will be needed 10 years from now has not yet been committed to by utilities. Actual commitments have virtually stopped in the U.S. . . . Thus, the industry is in a precarious position to react to a growth in demand higher than the present forecast."

Electricity is unique among energy sources, in that it must be produced at the precise moment that it is required; it cannot be produced in excess at times of low demand and stored for use at times of peak demand. A reliable supply of electricity is vital to the modern economy. But at present there is a minimum of redundancy, making the system very vulnerable.

FIGURE 2
New orders for U.S. power plants
Megawatts



Source: Edison Electric Institute

Installed capacity has dropped drastically since the early 1970s. By the 1990s, electric generating capacity margins will be near minimum acceptable levels.

Assuming a 3% annual growth in electricity demand, the U.S. generating capacity would have to increase by over 50% of its current capacity by the year 2000. This represents an increase in capacity of 250,000 to 300,000 MW (megawatts, or a million watts) to meet increasing demands, the Department of Energy estimates.

Through 1994 the installed generating capacity "will be near minimum acceptable levels," reports the National Electric Reliability Council. Peak demand is expected to rise from 465,100 MW to 566,800 MW by 1994. In the United States, according to NERC, power companies are planning to install 107,000 MW of capacity by 1994, bringing the total capacity to 704,300 MW. This is a marked reduction from the 175,000 MW of new capacity that were scheduled only two years ago.

Lack of available capacity

The forecasted increase in demand for electricity in the next 10 years is a low 2.2% annually, according to NERC. Already in 1984, the annual electric energy use surprised everyone by increasing by 4.4% over 1983, instead of the forecasted 2.1% for that year. This was said to be an anomaly, probably due to a spurt of economic growth that was not expected to continue through the decade.

Due to this minimal demand forecast, planned capacity additions in the United States made in 1985 for the 10-year period from 1985 to 1994 were about 17,600 MW (or 13.5%) less than reported in 1984. Reductions in plans for coal and nuclear units account for essentially all of the cutback. This means that reserve margins for actual demonstrated capacity will fall below 21%. This is the minimum reserve margin utilities usually need to deal with weather-related spurts in demand, sudden shutdowns, and scheduled maintenance.

Electric power needed for economic growth

A recent study supported by Los Alamos National Laboratory shows a strong correlation between the growth of the national economy and consumption of electricity.

The study, conducted by the National Academy of Sciences for the Department of Energy, examined the relationship between electric demand and Gross National Product. "The objective was to estimate both the effect of GNP on electricity use and the effect of electricity supply on productivity and economic growth," Ronald Sutherland, a Los Alamos economist, reported. "The study concluded that there's a strong cause-and-effect relation in each direction."

The report called for federally sponsored research into new methods of producing electricity and ways to lower production costs. Robert Drake, leader of the Lab's Economics Group, emphasized, "The government has an important role in doing this research, because the cost of supplying electricity has an impact on economic growth."

The Committee on Electricity in Economic Growth included academic researchers and representatives of utilities, regulatory agencies, environmental groups, and the financial community. Its report makes three recommendations:

- Federal and state governments should design policies that stimulate greater efficiency in using electricity, develop and promote new technologies, and remove regulatory barriers to lowering costs.
- The relationship between electricity and productivity should be addressed in making policy decisions, since productivity is a key factor in such areas as the federal budget deficit and balance of trade.
- Further research is needed to identify and measure specific factors affecting the relation between the use of electricity and the economy.

The results of this report overturn the econometric theory, which gained prominence over the last 10 years, that energy consumption could be "decoupled" from economic growth. This view first received widespread political recognition with the 1977 report, "Energy and Economic Growth," by M. H. Ross and R. H. Williams, done at the request of the Joint Economic Committee of the U.S. Congress. This theory was used to promote the idea that the decrease in available power supply caused by the shutdown of nuclear reactors, would not affect economic growth.

"The Industry is in a precarious position to cope with demand that exceeds forecasts for the 1990s," notes NERC. Their analysts adds that, with time, capacity reserves will erode further, because plant efficiencies and availability deteriorate with age.

Utility planners are increasingly worried about brownouts and blackouts during peak periods of power demand as early as the late 1980s. There is not enough capacity being planned to replace aging plants and to support economic growth. "To avoid trouble in the near future," says William McCollam, Jr., president of the Edison Electric Institute, "utilities must start new projects soon."

U.S. electric utilities canceled 23,000 MW worth of new generating capacity in 1984. They are planning to install 113,200 MW of generating capacity in the 10-year period from 1985 through 1994. Coal and nuclear-fueled capacity additions amount to 42,200 MW and 46,000 MW, respectively.

Planned retirements over 1985-94 total 12,600 MW. The composite age of our fossil-fueled steam electric generating capacity is 17 years and, in 1995, will be 25 years. Even with the addition of all planned units over the next 10 years, the utilities will be entering 1995 with more than 100,000 MW of fossil-fueled steam capacity that is over 30 years old.

Electric utilities, according to NERC, are adopting a "minimum capital outlay" policy and "avoiding commitments to large power projects." Their strategy for resource planning is: 1) maximize availability and utilization of existing resources; 2) purchase power from other utilities, cogenerators, and small power producers; 3) implement load management and conservation programs; 4) install small, short lead-time generating units. It is clear that this approach reduces drastically reliability, by reducing redundancy.

The case of Virginia

This short-sighted approach prevails among all the utilities around the country. The way one Virginia Power official, Jim Buck, put it, "Growth and demand must be reduced. For utilities everywhere, the name of the game is not to be in the business of building generating power facilities, but in distribution facilities." The only new electric infrastructure planned now in the state of Virginia will be to upgrade an existing 7.2-mile transmission line in Loudoun County and to install a new 12.5-mile line around Washington, D.C. But with no firm plans for new capacity, Virginia Power will depend on "existing self-generation and purchasing power," he said.

Virginia Power has already canceled two nuclear plants, North Anna units 3 and 4. North Anna 4 was canceled in 1980, due to a decrease in the growth of electric power demand, which had dropped from a forecasted 10% increase in 1979, to 4% in 1980. North Anna 3 was canceled in 1982, when Virginia Power could no longer take the financial risk involved in redesigning and reworking the plant, as required by new regulations that came into effect after the Three Mile

Island
In
the utility decided to wheel in power from other utilities in the
Though this has made the
less than it would have been with the "risk" of building a new facility, the solution is only short-term.

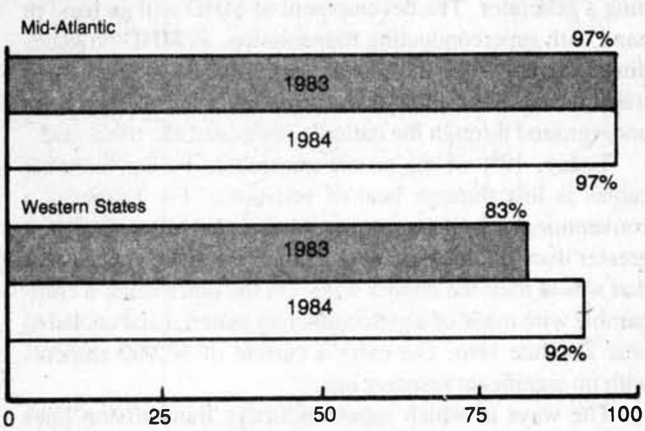
What Virginia Power is relying on the most, emphasized Buck, is "conservation and load management to reduce demand from now to the year 2000." This is being done by such programs as the "energy-saver home program" and the "dual fuel program." But such "solutions" only put off the time when the real problem of lack of capacity must be faced.

Overloaded transmission lines

Over the past few years, utilities in many regions have resorted to wheeling power among themselves, and from Canada, as a way of minimizing their costs. For example, northeastern utilities rely heavily on imports of electricity from Canada. Southeastern systems transfer large amounts of electricity among subregions. The mid-Atlantic area imports from the central United States, and vast amounts of Pacific northwest hydro-generated energy are transferred to the Pacific southwest.

Based on present estimates of load growths, fuel prices, and generator
continue to be loaded heavily with economy energy transfers through the mid-1990s. When electric transmission systems are continuously loaded to their maximum safe limits, little

FIGURE 3
Capacity utilization of transmission lines



Source: NERC

Many transmission lines around the country are operating continuously at almost full capacity, leaving very little spare for emergencies. Shown here is transmission use in the Mid-Atlantic, and Western States regions, compared to their transmission capabilities.

margin remains to handle the unexpected. This is seen in **Figure 3,** which shows actual 1983 and 1984
use in the Mid-Atlantic Area (M
Western States area (W
pabilities in those regions.

Such unexpected phenomena can include
conditions. For example, the state of New York, during a major heat wave in 1984, reached a record level of peak demand of electric power—21,940 MW. The entire New York Power Pool system (N
capacity. During the month of June, the NYPP had scheduled 7,900 MW of capacity to be undergoing routine maintenance, leaving 22,100 MW available when the heat wave began. There was then less than 3% of capacity left on reserve, when compared to the federal law requiring a 21% reserve margin to maintain a nationally reliable system. In order to keep at least reserve in case a plant on the system broke down, which is very likely in hot weather, when generators and transformers overheat, power was wheeled in from Canada.

The NERC has emphasized that though this wheeling of electric power has kept East Coast electric rates down, by not burning expensive imported oil, it has also cut down on the flexibility of the U.S. system, and has made states like New York dependent

Due to the increasing magnitude of these transfers, and the fact that they are taking place a high percentage of the time, the risk of system disturbance and customer service interruption is greatly increased. In
of existing transmission and generation systems with minimal capital expenditures, utilities are increasing the use of Special Protection Systems to allow them to operate their transmission systems at higher levels than normally considered acceptable.

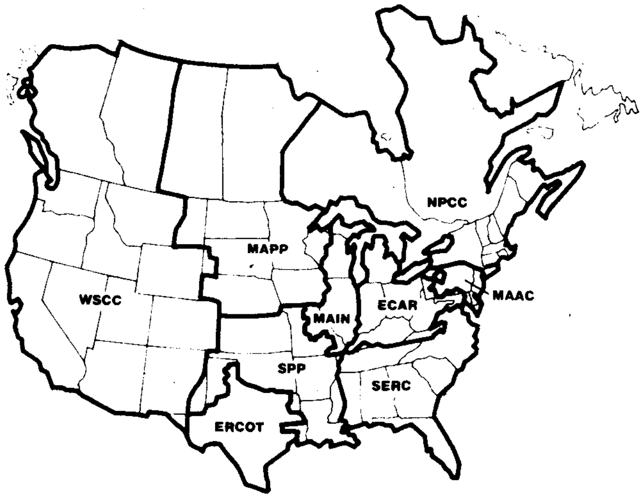
Economic transfers are causing utilities to expand their transmission capacity. Finding that new transmission lines are more costly in time and money, utilities are taking the strategy of upgrading and uprating their existing transmission lines. Uprating refers to any change that increases the power transmission capacity of a line. This may not be a physical change, but simply allowing the line to run hotter, or it can involve replacing the conductor and strengthening the towers. Upgrading refers to structural modifications, which can be done either for uprating a line or correcting a weakness.

The Electric Power Research Ins
out that it is cheaper and faster to uprate
and upgrade the tower structures than to build a new one. It is easier and faster to get licenses for an upgrade than for new construction, due to environmentalist obstruction. Such a project can typically be licensed in less than a year, as opposed to the usual two years for getting approval to construct a new transmission line. In
generally take less time.

EPRI points out that "in rare cases, these projects

FIGURE 4

The North American power grid



ECAR—East Central Area Reliability Coordination Agreement

ERCOT—Electric Reliability Council of Texas

MAAC—Mid-Atlantic Area Council

MAIN—Mid-America Interpool Network

MAPP—Mid-Continent Area Power Pool

NPCC—Northeast Power Coordinating Council

SERC—Southeastern Electric Reliability Council

SPP—Southwest Power Pool

WSCC—Western Systems Coordinating Council

The North American Electric Reliability Council (NERC) was formed by the electric utility industry in 1968 to promote the reliability of bulk power supply in the electric utility systems of North America. NERC consists of nine Regional Reliability Councils and one affiliate encompassing virtually all of the power systems in the United States and Canada.

dramatically cost-effective." As the result of a $100,000 upgrade of a short stretch of line from 69 to 115 kv (kilovolts), Niagara Mohawk is saving $5 million a year because the upgrade allowed it to tap inexpensive Canadian hydroelectric power. In
less. The upgrades don't always mean less expensive electricity per kilowatt than new construction, but they do require much less capital investment.

Wherever possible, it is necessary to maximize system redundancy, to deal with the unexpected. Building a new parallel line tends to increase system redundancy, whereas an upgrade tends
system capacity as much as a new line, and the remaining life of the modified facility will be less than that of new construction.

The solution, rather than the band-aid measures utilities are currently using, would be to go with the most advanced technologies available, to meet the future demands on the power system. We will now look at the most effective technologies available.

For the distribution of power, the most efficient known way to transmit large loads of power for long distances, with minimal power loss and placed conveniently underground, is known as *superconductivity*. This has been demonstrated at Brookhaven National Lab, and just
to complete the last mile of testing. Secondly, to immediately increase electric power capacity and provide clean, abundant, and cheap energy for the long-term future, we must mass-produce nuclear power plants. Nuclear power is still the most efficient and least expensive way of supplying energy. The United States will have the capability to mass-produce small standarized module units very soon. By 1990, based on design plans existing on the drawing boards today, the United States could turn out 300 or more small and medium reactors per year.

Superconductivity

A new kind of underground transmission line has been tested at Brookhaven National Laboratory, exploiting the phenomenon of superconductivity, which creates the equivalent of a world without friction. The principle behind this is an old one, discovered by the Dutch physicist Heike Kamerlingh Onnes, 78 years ago. While experimenting with metals at low temperatures, he confirmed his theory that the electrical resistivity of metals becomes zero, a superconductor, at temperatures close to absolute
mendous practical significance of his discovery, which promised lossless high-field magnets and electrical machines.

This principle is used in superconducting magnets for magnetohydrodynamics (MHD),
directly from heated gases, rather than by mechanically spinning a generator. The development of MHD will go hand in hand with superconducting transmission, as MHD produces direct current from the power plant, and superconductive transmission lines allow it to travel hundreds of kilometers underground through the

Today, 10% of the power transmitted by conventional cables is lost through heat of resistance. For example, a conventional 12-gauge copper wire cannot carry a current greater than 20 amperes, because
that would melt the copper wire. On the other hand, a comparable wire made of superconducting material and cooled to near absolute zero, can carry a current of 50,000 amperes with no significant resistive loss.

The ways in which superconductive transmission lines would revolutionize electric power distribution are numerous. The superconducting cable can deliver current, even if it is hundreds of miles long, to remote areas of the country, against a maximum of 15 to 20 miles for today's
cable. It
whereas present cables are limited. And while today's cables dissipate their heat to the surrounding soil, which limits the

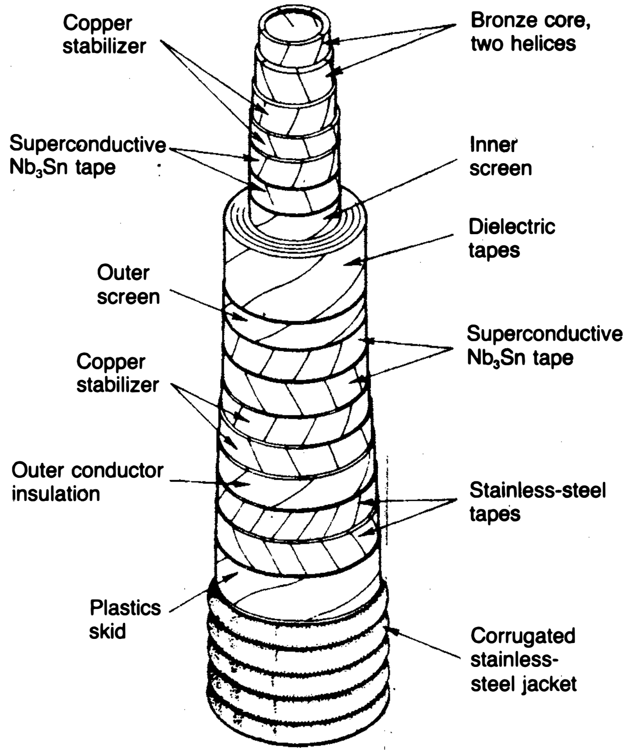
power they can carry, superconducting cable is not affected by soil conditions.

Superconducting transmission is much less expensive than conventional underground cable and is the only choice for long distances underground. A study by the Philadelphia Electric Co. compared various transmission line technologies for a proposed 66-mile 10,000 MW-capacity line. The overhead transmission line through this partly urban area was $600 million. The Brookhaven superconductive line was twice that, $1.2 billion. If
reach the length of 66 miles, it would have cost 10 times that of the overhead line. In
is greater than 15-20 miles, conventional underground cable simply is not technically
ductive cables fills the "technical gap."

The material used at Brookhaven for superconducting cable, is niobium-tin; it is cooled to temperatures of 6.5 to 8.5° Kelvin (above
along the cables. Niobium-tin was chosen because it can carry a very high current and has the highest operating temperature of the easily available superconductors. Since it is very brittle, it must be sandwiched between normal metals to add strength. The Brookhaven tape, shown in **Figure 5,** is a laminate of stainless steel, niobium-tin, and copper, with a total thickness of 0.125 millimeters. The Power Transmission Project facili-
ty's two superconducting cables could carry full power. With each cable carrying 330 megavolt amperes (M
ity had an output equivalent to 1,000 MVA in a three-phase system, or about the output of a nuclear generating plant.

There are only five large research projects
ductivity in the world today, three in the Soviet Union, one in Graz, Austria, and one in the United States, at Brookhaven National Laboratory. Due to continuing budget cuts, and most recently the effects of the Gramm-Rudman bill, this project
next year, according to Eric Forsyth, the project
1980, there was $3.5 million for the project,
declined to $1.5 million, in 1986, it was only $.7 million, and Forsyth expects the project
1987, due to "Gramm-Rudman's blind cutting of vital research."

FIGURE 5
Brookhaven's superconducting cable



Source: Brookhaven National Lab

Superconducting cable has no power loss and carries five times as much power capacity as conventional cables. The Brookhaven tape, shown here, is a laminate of stainless steel, niobium-tin, and copper with a total thickness of 0.125 millimeters.

The nuclear option

Today, 100 nuclear plants provide almost 16% of America's electric power, representing a total of 84,000 MW. This was as great as the total amount generated by the country's electric power supply system in 1952. It
be the cheapest form of energy. In
power has saved U.S. consumers $35-65 billion, when compared to the cost of the same amount of electricity generated by oil and coal.

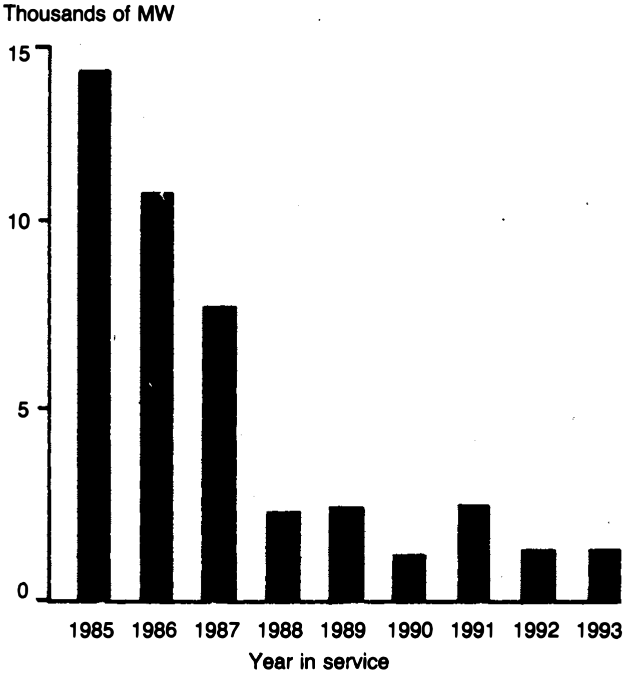
The only way to meet the electric power capacity necessary to ensure reliability and safeguard economic growth, is to expand the use of nuclear power. Nuclear power plants, standarized and mass-produced, can supply the cleanest, most abundant energy for the future.
changes in
struction time to three years, and lessen
as is being done in France today.

The capacity to meet future needs is simply not being planned today. If
electricity demand growth, and rely on equal coal and nuclear resources, approximately 346 GW of nuclear capacity will be required by the year 2020. That is about four times the 1985 nuclear capacity.

But today, as Secretary of Energy John Herrington explained, "There are no new orders for nuclear reactors in this country today, and that's very troubling if you're worried about the future of this country. . . . What we're doing, is we're mortgaging what's going to
2000. . . . We're going to need nuclear power to move forward into the next century." **(Figure 6)**

FIGURE 6

Nuclear power units under construction

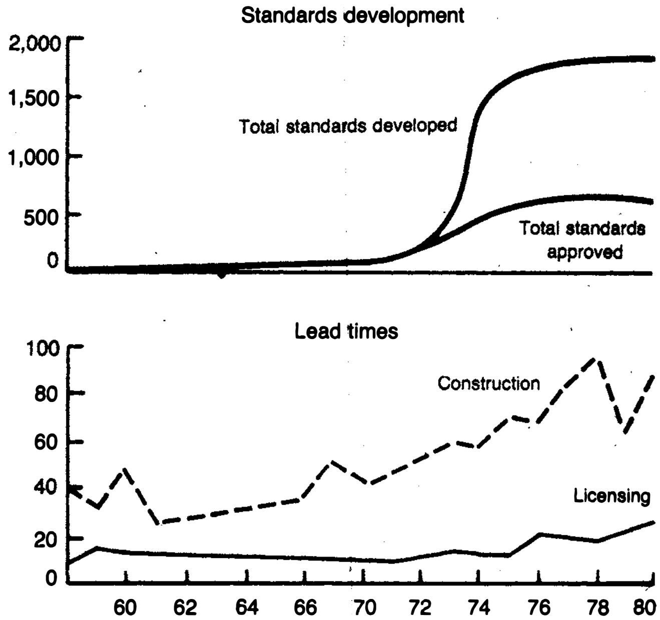


Source: NERC

"There are no new orders for nuclear reactors in this country today, and that's very troubling if you're worried about the future, of this country . . . . What we're doing is mortgaging what's going to happen after the year 2000 . . . . We're going to need nuclear power to move forward into the next century" —John Herrington, secretary of energy.

FIGURE 7

Delays mount in nuclear power plant construction



Source: Department of Energy

The number of regulations for nuclear power plants has multiplied in the recent past, causing longer lead times for licensing and construction.

Since 1972, one hundred U.S. nuclear power plants have been canceled. That is as many as are operational today in the United States! The consequences of the political sabotage of the nuclear industry over the past 15 years, and particularly after Three Mile Island, are being paid with higher electricity costs and a threatened economy.

Following the Three Mile Island incident in 1979, the Nuclear Regulatory Commisssion, under pressure of environmentalist protests, implemented major changes in regulation that resulted in increased plant costs and lead times (**Figure 7**). Design complexity and analysis requirements increased with such items as a greater number of safety systems, more complex seismic design criteria, related pipe support structures, changing standards, and quality assurance requirements. This caused plants, already designed or in the process of construction, to be redesigned and reworked, resulting in increased capital costs and construction times (**Figure 8**).

For example, in 1984, new nuclear plants went into service after an average licensing and construction time of more than 13 years, compared with 5 years for nuclear plants in the early 1970s, according to a survey by the Atomic Industrial Forum. During 1984, 3 units totaling 2,383 MW were indefinitely delayed and 8 units totaling 9,040 MW were canceled. In addition, 26 units had their service dates delayed an average of 7 months each. Of the 16 units scheduled for commercial operation that year, only 7 (totaling 7,566 MW) were placed in service.

These regulatory changes and project delays have caused a tenfold increase in capital costs over the past decade. Figure 8 shows that the interest on construction alone has gone from 17% in 1973 to 40% in 1983, and will be 67% for plants which start operation in 1993.

This has caused a situation in the United States where, for the first time, the cost of nuclear electricity, on average, has risen above that of coal. In 1981, the average production cost of nuclear, coal, and oil were 2.7¢, 3.2¢, and 6.9¢ respectively, compared to 1984 costs of 4.1¢, 3.4¢, and 7.4¢. As Carl Walske, president of the Atomic Industrial Forum, emphasized, this is the result of "the impact of the previous decade's nuclear construction stretchouts, high interest rates, inflation, and the escalation of regulatory requirments. . . .

FIGURE 8

Cost composition of a nuclear plant

Cost component	1973	Start of operation 1983	1993
Indirect/contingency	13%	17%	12%
Craft labor	14%	14%	8%
Factory equipment/ site material	56%	29%	13%
Escalation/interest on construction	17%	40%	67%

Source: EPRI

Today it takes 10 to 15 years to build a nuclear power plant. Delayed plant construction results in increased costs in escalation and interest on construction.

A nuclear power plant, built in eight years or less and regulated in a business manner, is still the most efficient way known to produce electricity. This is being routinely demonstrated outside the United States."

If U.S. plants were simplified and standarized, as they are in France, then nuclear power would again become the cheapest energy source in the United States. The Electric Power Research Institute made a study to compare U.S. plants with those being built in France. Two significant differences could be seen: The French construction manhours per kW were one-third to one-half of the U.S. experience; and French non-manual manhours per kW were one-fourth to one-sixth of U.S. The reasons for this include the fact that the French design is more complete at the start of the construction and fewer changes are made. The construction process is better organized and benefits from repetitive operations. The replication of identical units on a site and multiple ordering of a series of standarized units, allow fixed-costs contracting and better control of actual cost, manhours, and raw materials.

The United States has the capability of rapidly meeting the urgent demand for new capacity, by ushering in the next generation of nuclear plants. The concept is similar to Henry Ford's plan to produce Model T's: Mass-produce modular nuclear plants, using standarized parts and assembly-line shop fabrication. These units can be transported by rail, barge, or truck, and installed on site with the potential of adding more modular units when the need arises.

The main advantage of these smaller plants is the speed by which they would come on line—three years by estimates of U.S. nuclear suppliers. These smaller reactors would be about 350 MW, compared to today's 1,000 MW plants.

U.S. nuclear suppliers like GA Technologies and General Electric already have on the drawing board designs for smaller, modular plants—from modular light water reactors, to high temperature gas reactors (HTGRs), to breeder reactors that produce enough fuel to supply themselves. The modular HTGR and breeder are the optimal choices for mass production, because of their increased efficiency and versatility, but initially all designs available should be used.

Some of the advantages of small reactors reported by the International Atomic Energy Agency are: lower absolute capital cost with smaller financial burden, distribution of economic risk through several smaller plants, better-controlled construction schedule due to less on-site work and smaller size components, better past performance records than larger plants, high degree of shop fabrication and potential for series production.

The production and operation of small modular plants will be significantly simpler, resulting in reduced costs. Small reactors allow for greater flexibility of design, and their standarization allows for simplified training of operatives. They can be produced in factories using prestressed concrete or steel containments and standarized subsystems, creating higher rates of production. Greater reliability of operation can also be achieved with the new designs now being pioneered. The present hand-tailored method of construction in the United States, to individual specifications, not only is uneconomical, but also means that safety requirements have to be reviewed on-site. Using one basic design to guide the mass production of reactors, most regulatory questions can be solved at the point of production.

A survey by the Fusion Energy Foundation concluded that 10 firms, including the nuclear giants like General Electric, are preparing a capability, now in the conceptual design phase, to factory-produce reactors ranging from 10 MW to 335 MW. On the basis of these plans alone, it should be possible, by constructing 100 nuclear-plant-producing factories, to turn out 300 or more small and medium reactors per year by 1990.

There is no objective reason why the first factory-produced modules could not start rolling off an assembly-line in the United States at the beginning of the 1990s.

Environmentalist protest against nuclear power in 1980.