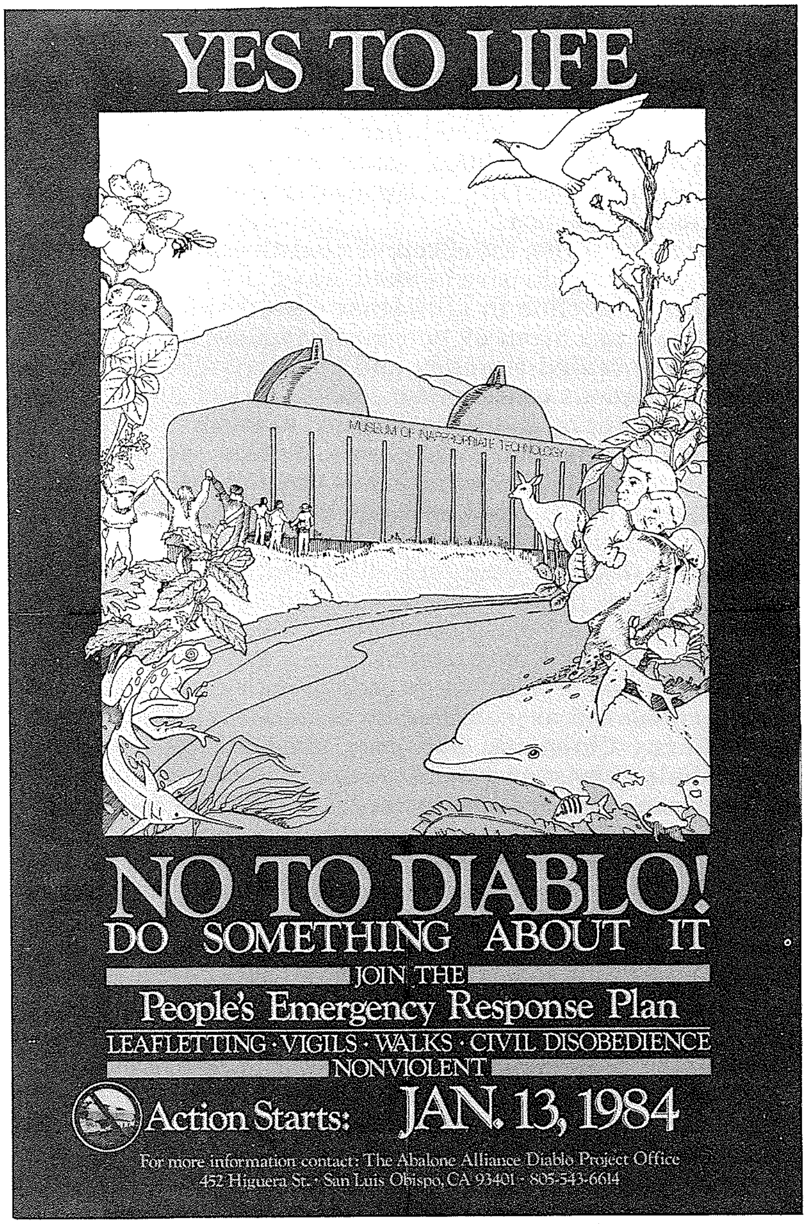


In the United States today, the atom produces as much electricity as the entire country used 25 years ago. Reactors supply about one-third of the power in New England and the Chicago area, and large amounts elsewhere. Yet opposition persists. The target of this 1984 poster: California's Diablo Canyon plant, first planned to start up in 1973.

Nuclear Power In America

It was just 40 years ago this season, soon after Hiroshima and the end of World War II, that the U.S. Congress began debating the future of the extraordinary new technology developed by the Army's secret Manhattan Project. Atomic power has since been widely tapped as a key source of energy. At last count, there were 342 nuclear power plants in 26 countries, among them such unrich states as South Korea, India, Pakistan, Yugoslavia, and Spain. Some 146 more are being built, and others are contemplated: China is planning a dozen plants. Reactors supply about one-half of the electricity in France and Belgium, more than 40 percent in Finland and Sweden, more than 20 percent in Switzerland, Taiwan, West Germany, Japan, and Bulgaria. Yet, in the United States, where the atomic age began, the news has been about high costs, court fights, cancellations. Just in the last year, plants have been abandoned in Indiana, Ohio, Texas, and Washington state. What passes for success is the completion recently of New York's Shoreham plant (after 12 years and $4.2 billion) and of California's Diablo Canyon (17 years, $5.6 billion). Here, William Lanouette examines what clouded the promise of the atom in America, and what might redeem it.

ATOMIC ENERGY, 1945–1985

by William Lanouette

At 4:00 A.M. on Wednesday, March 28, 1979, just 12 weeks after it had been put on line, a nuclear power plant on Three Mile Island (TMI) in Pennsylvania's broad Susquehanna River began to misbehave.

The plant was Metropolitan Edison's Unit 2, a Babcock & Wilcox pressurized-water reactor supplying steam to a generator producing 880 megawatts of electricity for the area around Harrisburg, the state capital, 10 miles away. Suddenly, several pumps stopped; they were needed to circulate the cooling water that keeps the 100-ton radioactive core at its normal 582-degree temperature.

Alarm bells sounded.

Scanning their instruments, the control room operators saw that back-up pumps had switched on automatically. They did not notice that two valves had been shut two days before, blocking the vital flow of water. In minutes the plant overheated, triggering an automatic reactor shutdown and the start of the Emergency Core Cooling System; it dumped tons of water onto the core. But, misreading the signals, operators shut down vital emergency cooling pumps.

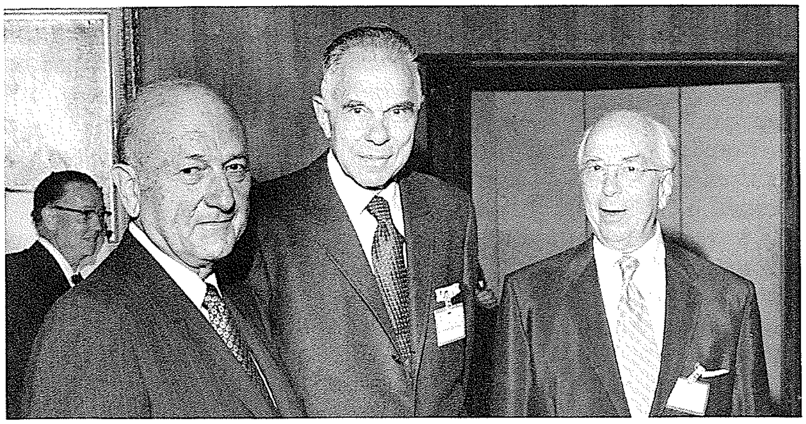
Now more than 100 alarms were blaring, and warning lights turned the room-long control panels into a technicolor light show. It was clear that the plant's troubles were multiplying: By 5:30 A.M., more than one-third of the cooling water, 32,000 gallons, had gushed through a faulty valve, releasing radioactive gas over surrounding buildings and pastures.

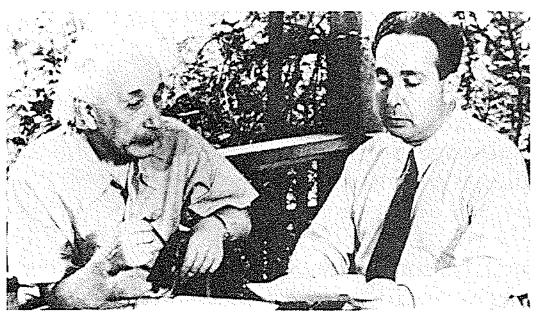
A public alarm was first sounded more than four hours after the accident began—not by officials but by "Captain Dave," the roving traffic reporter for pop-music station WKBO in Harrisburg. He wondered why volunteer firemen had mustered near the plant and called his station; the staff checked and reported the accident at 8:25 A.M. Soon the nation, and the world, knew of America's costliest commercial nuclear accident.

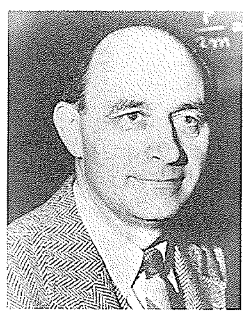
Most American pundits now date the country's ambivalence toward nuclear power to the ensuing week-long drama at TMI. The public found the words of the "experts" and "officials" as alarming as the malfunctions of the rogue reactor.

Pennsylvania governor Richard Thornburgh urged pregnant women and children to leave the area. Federal authorities flew in anticancer drugs, in case the sporadic radioactive leaks became worse. For days federal and utility spokesmen warned (mistakenly) that a hydrogen "bubble" trapped in the reactor's steel-sheathed, four-foot-thick concrete containment dome—designed to withstand the crash of a Boeing 747—might explode and spew fallout far and wide. During one of his newscasts, CBS's Walter Cronkite solemnly declared that "the danger faced

William Lanouette, 45, is Senior Associate at the World Resources Institute, a center for research on energy and environmental issues in Washington, D.C. Born in New Haven, Connecticut, he received an A.B. (1963) at Fordham College in New York City and an M.Sc. (1966) and Ph.D. (1973) at the London School of Economics. A former correspondent for National Journal *and frequent writer on atomic energy, he contributed to* Nuclear Power in the Age of Uncertainty *(1983), a report by Congress's Office of Technology Assessment. He is writing a biography of Leo Szilard.*







Some founding fathers (top to bottom): Three early chairmen of the Atomic Energy Commission, David Lilienthal, Glenn Seaborg, and Lewis Strauss, at a 1971 gathering; physicists Albert Einstein and Leo Szilard in 1939, as they wrote the letter that led to the Manhattan Project; Enrico Fermi.

by man for tampering with natural forces, a theme familiar from the myths of Prometheus to the story of Frankenstein, moved closer to fact from fancy."

But the officials played down the chances of a core "meltdown," although perhaps one-third of the core, with its 37,000 pencil-thin rods of nuclear fuel, *did* melt. Later, investigators found that the Emergency Core Cooling System, though shut down by confused operators, had cooled the core within half an hour before it reached the 5,000 degree temperature at which it might have begun to destroy the plant.

Joseph Hendrie, then head of the federal Nuclear Regulatory Commission (NRC), said later that he and his colleagues "were like blind men stumbling around in the dark." (Hendrie subsequently apologized to the blind, noting that in the dark they do *better* than others.) President Jimmy Carter, visiting the site to show that it was safe, grimaced a lot and wore yellow plastic booties that appeared to belie his faith. TMI was, in nuclear jargon, a LOCA, a "loss of coolant accident." To the public, millions of whom had seen the new Jane Fonda film *The China Syndrome,* about a near-meltdown at a California plant, it also seemed a LOCA—a "loss of confidence accident."

Later probes supported the claims of both foes and advocates of nuclear power. The LOCA was compounded by staffers who were inexcusably ill-trained and poorly supervised, as critics noted. But then the safeguards built into the system did limit the damage to the plant itself.* Yet while Carter urged Americans to view the accident "with care and reason," antinuclear spokesmen were quick to assert that, as Ralph Nader put it, TMI was "the beginning of the end of nuclear power in this country."

101 Scratches

The support that nuclear power long enjoyed had eroded. Just before TMI, a Cambridge poll showed that those who approved more nuclear plants outnumbered opponents by 53 percent to 29 percent; after, the antis rose to a majority for the first time. (Today, ambiguity reigns: Cambridge finds that about 60 percent oppose the construction of new plants, but 54 percent believe that nuclear energy should still be used and 73 percent consider atomic power "important" to the nation.)

Actually, the U.S. nuclear energy program had stalled well before TMI. Forty reactor orders were cancelled during the four years before the accident. Another 61 have been scratched since. At mid-year, 86 nuclear plants were supplying some 14 percent of the nation's electricity, or about three percent of total energy consumption. Thanks to design difficulties, cost overruns, weakening consumer demand, and other once unforeseen problems, fewer than one-half of the 36 plants still being built are likely ever to operate. Barring a national emergency and a renewed federal commitment to nuclear power, that may be it.

In the words of the Edison Electric Institute, representing the 175 investor-owned utilities that generate 76 percent of America's electricity, "The costs and risks of nuclear development have become unacceptably high."

*Though authorities have held that TMI posed no public hazard, as of last summer the number of damage suits had climbed well above 1,300. The filings surged this year following news that the plant's insurers had settled more than 250 early claims out of court for at least $3.9 million and that $1 million was paid to a child with Down's syndrome. The insurers now promise "vigorous" defense against the suits, which blame TMI for such ills as tumors, gallstones, vertigo, and acquired immune deficiency syndrome (AIDS).

I

IN THE BEGINNING

What happened?

With the benefit of hindsight, and of newly available documentation, it is now clear that the U.S. nuclear power program was fated for trouble even before President Dwight D. Eisenhower's December 1953 Atoms for Peace speech at the United Nations, which pledged America's "entire heart and mind" to the development of the new technology for civilian purposes. The U.S. effort would be afflicted by its sponsors' overoptimism, fights between the public and private sectors, personal and ideological struggles, and decisions postponed or, worse, never made on issues of safety, technology, and economics.

The saga of nuclear power is usually said to have begun at the University of Chicago's Stagg Field on December 2, 1942, a year after America entered World War II. In a squash court under the stands, scientists working on the Army's Manhattan Project, led by Enrico Fermi, created the first self-sustaining nuclear chain reaction.

It was a stunning feat. All matter is composed of tiny "building blocks" called atoms. Each atom has a core, or "nucleus," of positively charged particles called protons and neutral particles called neutrons. Around the nucleus fly as many electrons as there are protons. In a few large atoms containing more than 230 protons, such as uranium-235 and plutonium-239, it is possible for a stray neutron to bombard the nucleus and split, or "fission," it into two or more parts. More neutrons can then fly off to split other atoms in a chain reaction. In milliseconds, millions of atoms are burst, releasing the "binding energy" giving them (and all matter) structure. Thus matter becomes energy, released as heat and radiation.

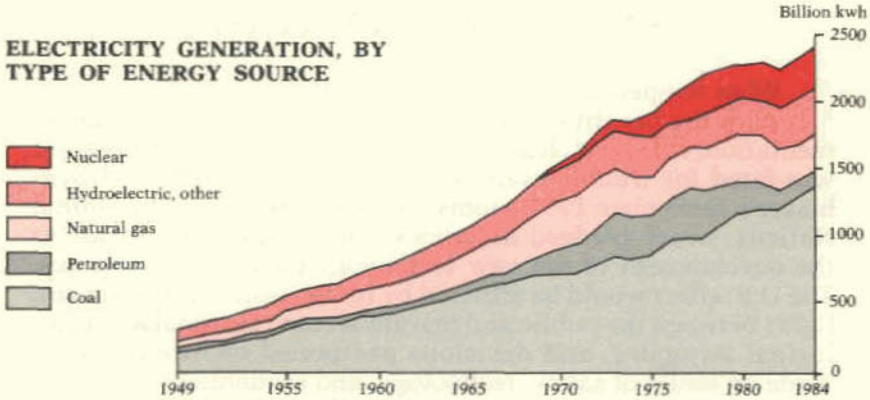
The 19-foot-high "pile" of dirty graphite blocks and uranium spheres at Stagg Field was the first reactor. It proved that atoms could be fissioned continuously to release energy. Knowing this, scientists could go on to design bombs. As Fermi remembered it, the 1942 test "was not spectacular. No fuses burned, no lights flashed. But to us it meant that release of atomic energy on a large scale would only be a matter of time."

Actually, the atomic power story begins in September 1933, on a London street corner. There, as he was watching a traffic light change, Leo Szilard, a Hungarian physicist who had become a refugee from Hitler, first conceived that the chain reaction would be the basic process for freeing the atom's energy.

Szilard's teacher in Germany, Albert Einstein, regarded

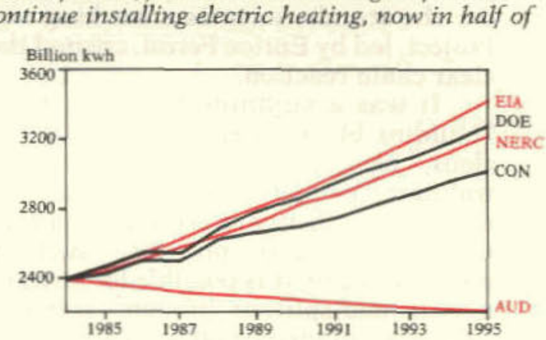
THE U.S. POWER PICTURE: PAST, PRESENT, AND FUTURE

ELECTRICITY GENERATION, BY TYPE OF ENERGY SOURCE

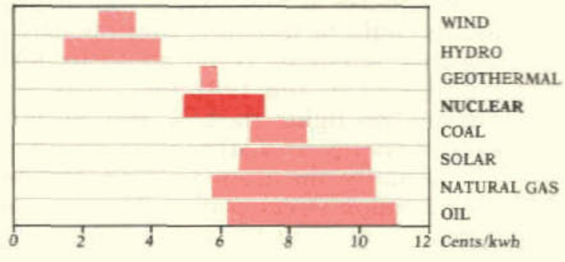


PROJECTING DEMAND. *The need for new power plants, nuclear or otherwise, will depend on many hard-to-predict factors, from the overall strength of the economy to Americans' desire to continue installing electric heating, now in half of new homes, and air conditioning, now in 70 percent. So forecasts of electricity vary widely, as these examples show.*

EIA: U.S. Energy Information Administration
DOE: U.S. Department of Energy
NERC: North American Electric Reliability Council
CON: Conoco, Inc.
AUD: National Audubon Society



COMPARING COSTS. *This chart projects electricity costs by energy type in California. Generally, nuclear plants completed by the mid-1970s have produced power considerably more economically than coal facilities. But rising construction bills have eroded the atomic advantage. A study done for Congress's Office of Technology Assessment concluded that nuclear can be cheaper—but not when the price tags on coal plants are lower by more than 20 to 40 percent.*



Sources: Energy Information Administration; California Energy Commission.

atomic energy as not "obtainable." The British physicist Lord Ernest Rutherford saw it as "moonshine." Yet by 1934, Szilard worked his chain reaction idea into a patent. He secretly assigned it to the British Admiralty, so as not to alert the Nazis.

All this is familiar to the A-bomb's historians. What is less well known is that five days after Szilard filed his patent, he began to promote atomic energy for peaceful uses.

Szilard first wrote to Sir Hugo Hirst, founder of the General Electric Company Ltd. (U.K.), about new "industrial applications" of modern physics. Meeting in London with G.E. researchers, he gave them a paper on "methods" that might be used for "liberating atomic energy." Through them, he said, power might be produced "on such a large scale" that coal and oil production would collapse in "a couple of years."

Eclipsing the Sun

Though dismissed as a crackpot, Szilard did not give up.

In 1936, he tried to interest Fermi, again unsuccessfully; the Italian physicist would not realize for another three years that anomalies in uranium experiments that he had conducted in 1934 were actually caused by nuclear fission. Then, in 1938, Szilard met American financier Lewis L. Strauss, a partner at the Kuhn, Loeb investment banking house in New York. Strauss had invested in research on radioactive isotopes. But with him, as with G.E. and Fermi, Szilard failed; he seemed both too visionary and too secretive. Few scientists, *Fortune* observed that year, saw a "serious or practical use for atomic energy."

Who needed it? King Coal, having reigned since the 19th century, was being challenged by an adaptable new fuel, oil. It was abundant in the United States and had been found in quantity in the Middle East. By 1929, oil already supplied about one-third of America's energy needs; its share would reach 60 percent by the mid-1940s, when the country first became a net importer of oil. With such cheap alternatives (even during the early 1970s Middle East crude would be *produced* for 10 cents a barrel), who needed another power source?

Szilard and Fermi first met at Columbia University in New York in January 1939, a month after the uranium atom had been fissioned for the first time, by scientists in Berlin. This fissioning offered what Szilard had sought for almost five years: a mechanism for his chain reaction concept.

Fermi considered nuclear explosives far-fetched and focused on fundamental questions of atomic physics. When he briefed U.S. Navy officials about atomic fission in March 1939, he inspired a young engineer, Ross Gunn, to propose research not on weapons but on nuclear propulsion for warships.

That summer, with war in Europe imminent, Szilard proposed the concept for the first reactor, which Fermi agreed to study, and which became the device used at Stagg Field. Szilard also told Einstein, who had fled from the Nazis to the United States, about chain reactions. Einstein, now a believer, was captivated by an implication: Fission could be the first energy source that did not come directly or indirectly from the sun.

Szilard proposed and drafted the August 1939 letter from Einstein to President Franklin D. Roosevelt that led to the Manhattan Project, the six-year, $2 billion effort to beat Germany to the A-bomb. Though the Army imposed strict secrecy, some hints of what was afoot appeared. A 1941 article about uranium-235 in the picture magazine *PIC* warned that "*this war will be won or lost in the laboratory*." But the weapon *PIC* envisioned was not a bomb but radioactive "death dust."

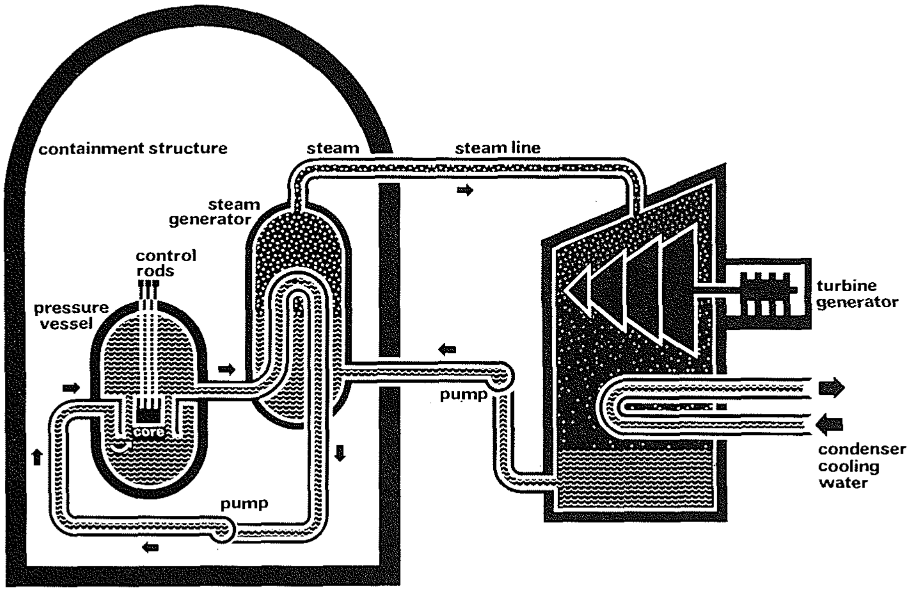
The Alchemist's Dream

After the United States entered World War II, Szilard became chief physicist at the Manhattan Project's "Metallurgical Lab" in Chicago, charged with finding ways to make fissionable materials for bombs. He not only joined Fermi in designing the first reactor (their U.S. patent was issued publicly in 1955) but conceived and named the "breeder," a reactor intended to make more nuclear fuel than it consumes.

By 1944, more than a year before the A-bomb was first tested in New Mexico, fissionable materials were being produced at two secret sites: an Oak Ridge, Tennessee, facility processed uranium, while a Hanford, Washington, plant turned out plutonium, a man-made element developed in 1941 by Berkeley chemist Glenn Seaborg. It became the core of the first A-bomb.

With all this underway, the Stagg Field scientists explored other uses for the atom. At weekly seminars in the University of Chicago's Eckhart Hall, they dreamed up different reactors and ways of handling radioactive fuel and waste. Indeed, what became the grand design for the U.S. nuclear power program was first outlined at an April 1944 session attended by Fermi, Szilard, Eugene Wigner, Alvin Weinberg, and other pioneers.

Because uranium was scarce—raw ore for the first A-bombs had to be brought from the Belgian Congo—they thought that atomic power had a future only if another fuel could be found. So they focused on the breeder; it was supposed to turn nonfissionable isotopes of thorium and uranium into fissionable



In a pressurized-water plant, water flows in a "loop" between the reactor core (left), where it assists the nuclear reaction and is heated, and a heat exchanger; there it produces steam to drive generators (right). About 90 percent of the world's reactors are of this or similar "light-water" designs.

uranium-233 and plutonium-239. The breeder—an "alchemist's dream" that would enthrall scientists and Washington policymakers long after uranium became plentiful during the 1950s—would both generate power and make plutonium for smaller plants. The result: "endless" energy.

For some of the Manhattan Project scientists, work on peaceful uses of the atom would become a form of atonement for their roles in creating The Bomb. "We all hoped that with the end of the war," Fermi later recalled, "power plants would become the paramount objective." Seaborg, as chairman of the Atomic Energy Commission, would champion not just atomic energy but the creation of a "plutonium economy" to succeed the eras of coal and oil.

Others would forsake the atom entirely; Szilard plunged into microbiology and arms control. Though it was not widely noted at the time, after World War II, when nuclear power first won wide attention, many researchers had already decided that its problems—high cost, the radiation hazard—outweighed its promises. Wigner lamented in 1949 that reactor development had "suffered" from a lack of attention of "first-rate scientists." Still, for a variety of reasons, Washington would strive to make atomic power a commercial reality.

II

GETTING ORGANIZED

During the autumn of 1945, following Hiroshima and the end of World War II, Congress debated how the government's nuclear technology should be managed. Nuclear power was being hailed in books, magazines, even pop music. In *Atomic Energy in the Coming Era*, Pulitzer Prize winner David Dietz forecast autos that would run for a year on a nuclear pellet "the size of a vitamin pill"; there would be "perpetual peace," because nations would have no need to fight over oil and coal.

A September 1945 National Opinion Research Center poll found that 56 percent of Americans thought atomic power "the greatest invention in over 1,000 years."

But who should manage the marvel? The nuclear genie, a creation of government with peacetime commercial possibilities, was unlike anything U.S. policy-makers had confronted before. Some military men wanted the Army to keep control of the atom, but President Harry S Truman would not hear of it. Thus the debate focused on a bill sponsored by Sen. Brien McMahon (D.-Conn.), under which the atom would remain a government monopoly but managed by a five-member civilian Atomic Energy Commission (AEC). This stirred ideological passions in Washington like nothing since the Tennessee Valley Authority (TVA), the burgeoning federal venture in the power business.*

While Democrats embraced a continued federal monopoly of the atom, Republicans railed about "socialism." McMahon's bill, said Rep. Clare Boothe Luce (R.-Conn.), "might have been written by the most ardent Soviet Commissar." The National Association of Manufacturers asked Congress to prevent "the atomic revolution from swamping the free-enterprise system." Detroit Edison chief James W. Parker urged development by "a plurality of producers." But then, a big firm might monopolize the technology no less than Uncle Sam. Could the nation afford,

*TVA was chartered in 1933, during Roosevelt's Hundred Days, to harness the Tennessee River for flood control and hydroelectric power. By the postwar era it was a major producer of electricity—most of it from coal-fired plants. Conservatives resented not just TVA's push into a free-enterprise realm but its privileges: Supported by Congress, it had no need to borrow funds and paid no taxes. During the 1960s and '70s, TVA began building 17 reactors in three states; as of last summer, the five that were completed were shut down.

the AEC's historian asked in his summary of the hearings, to put the atom "in the hands of a single individual or company"?

In a way, the bill that Truman signed into law as the Atomic Energy Act in August 1946 did just that.

Congress trusted the keeping of all of the nation's nuclear secrets to the AEC, whose first chairman was to be David Lilienthal, the 1933–36 head of the TVA. Indeed, the lawmakers held matters atomic in such awe that they sealed off their own oversight body, the Joint Committee on Atomic Energy (JCAE), from the pressures (public, presidential, and otherwise) that normally affect government. The JCAE, first chaired by Brien McMahon, held sole jurisdiction over nuclear research and development; it quartered itself in hard-to-find Capitol offices guarded by armed police.

Declaring weapons and power to be "two sides of the same coin," Lilienthal imposed a tight lid on all atomic technology and gave priority to making bombs. The only two in existence in 1945 had been dropped on Japan. The stockpile, according to the *Nuclear Weapons Databook* (1983), grew to nine in 1946; 13 in 1947; 50 in 1948—when Communists took power in Czechoslovakia, securing its uranium mines for the Soviets. Then, in August 1949, the Soviets tested a nuclear device. The brief U.S. monopoly was broken, and security grew even tighter. Overshadowed by the arms race, the power program languished.

Blue Sky Years

Even so, private industry was intrigued. Echoing the Manhattan Project scientists' ideas, Fermi in a 1946 speech declared that in 20 or 30 years "there will be large central installations" producing power and plutonium for smaller plants around the country. In 1947, a *Business Week* writer insisted that commercial power from "atomic engines" may be "five years away." Cost? The official estimate was about eight mills per kilowatt-hour, one-third higher than coal-generated power in areas where coal was plentiful. But many specialists still believed atom power could compete right from the start.

Lilienthal appointed the Industrial Advisory Group, headed by Detroit Edison's Parker, and began a power research program. But instead of defining a bold development agenda, the AEC became mostly occupied in refereeing competition among the federal laboratories at Oak Ridge, Los Alamos, and Argonne (Illinois). Each wanted test reactors, and the AEC obliged—usually to further arms production, not power. Congress also stressed the military side, moving in No-

THE ATOM ABROAD: "TOUTE NUCLEAIRE!"

After the 1979 accident at Three Mile Island, one nation pointedly *affirmed* plans to build nine new atomic plants over the next five years. "France has no choice," said André Giraud, a high Paris official. "It's either nuclear energy or economic recession."

That nuclear plants have spread from Finland to Australia to Taiwan is chiefly because they widely proved their worth as providers of relatively cheap power. During 1973, for example, the 10 European Community nations got 62 percent of their energy from imported oil. They halved that in a decade, mostly through a commitment to nuclear power that now has brought 120 reactors into service (due to rise to about 150 by 1990). The Community, which obtains one-fourth of its electricity from the atom, finds *coal* generation to be 30 to 88 percent more costly, depending on the country.

To be sure, while 23 reactors went on line abroad last year, overcapacity looms and orders for new plants have declined. Antinuclear agitation persists: The Austrians built a plant, then voted never to use it; Sweden (12 reactors) has imposed a moratorium on new facilities. Still, most nuclear programs continue. The major ones:

- FRANCE (42 reactors, 19 being built) has the most ambitious program of all. The country derives 23 percent of its energy (58 percent of its electricity) from the atom and aims for 30 percent by the year 2000. The state-owned utility Electricité de France began promoting "*toute nucléaire!*" (all nuclear!) power a decade ago. Bypassing French gas-graphite reactors as uneconomical, the utility obtained licenses to build Westinghouse light-water designs in standard 800 and 1,300 megawatt models. Citizen "intervention" in the approval process is not allowed, and plants are built in half the time (about six years) and at one-third the cost of the typical U.S. facility.

Seeking independence from foreign fuel suppliers,* the French have one commercial breeder plant and will soon open a larger one, called Super-Phénix. In Normandy, they also plan to open in 1989 the first fully commercial plant for reprocessing spent reactor fuel. Financed by utilities in Japan and five West European countries, this facility will "close the nuclear fuel cycle." That is, France will realize the 40-year-old vision, all but discarded in the United States,

*Once dominant, America now sells less than one-half of the Free World's nuclear fuel.

vember 1947 to authorize the development of a submarine and an aircraft powered by nuclear reactors.

Only the submarine project, guided by then Capt. Hyman G. Rickover, succeeded.* Alvin Weinberg and Eugene Wigner, both now at Oak Ridge, devised a pressurized-water reactor (PWR) to

*The airplane idea was finally dropped in 1961. Engineers could not solve the problem of the heavy shielding needed to protect the crew from radiation. In a last attempt to save the project, Air Force and AEC planners suggested that shielding could be decreased if veteran pilots were used: They would die of old age before the radiation they absorbed became lethal.

of dealing with both spent reactor rods and the need for new fuel through recycling. (Britain and Japan are building similar plants.)

- WEST GERMANY (20 reactors, seven on the way) produces six percent of its energy from the atom. Its plants, mostly powered by light-water reactors made by Siemens AG, are notably efficient. Yet citizen opposition grew during the 1970s, bogging down new projects in a complex federal and regional approval process that only recently has been streamlined. Meanwhile, the West Germans have focused on sales to (so far) Spain, the Netherlands, Austria, Switzerland, Argentina, Brazil, and Iran. Indeed, Siemens has become the U.S. manufacturers' chief rival abroad.
- BRITAIN (38 reactors, four under construction) is pushing ahead with nuclear power to conserve its North Sea oil and to help tame its strike-prone coal miners' unions. But the British gas-cooled reactor has proved costly; the government-run Central Electricity Generating Board may next buy a Westinghouse reactor.
- JAPAN (32 reactors, eight on the way), which must import nearly all of its conventional fuel, launched its nuclear power program in 1966. With government encouragement, two private utilities have bought Westinghouse and General Electric reactors; they produce 21 percent of the nation's electricity. Japanese firms are working with the two U.S. manufacturers on improved light-water plant designs. But no Japanese nuclear exports are in sight, as yet.
- THE SOVIET UNION (perhaps 46 reactors, nine under construction) has much uranium—and large nuclear-power ambitions. The country's light-water plants now supply around 6.5 percent of its electricity, although the current Five Year Plan calls for 12 percent. The Atomenergoexport sales agency has shipped 30 reactors to six East Bloc nations, and two to Finland. (The Finns call those reactors, which contain some Western components, their "Eastinghouse" plants.)

By Western standards, the Soviets have been cavalier about safety. They did not adopt emergency core cooling until recently, for example, and they locate their reactors without fear of public reaction. (Moscow has two plants *within* the city limits.) The state permits no citizen protest and, hence, no antinuclear movement. As a Soviet nuclear engineer once boasted to a group of touring U.S. journalists in Moscow, "We have no Jane Fonda here."

power the first nuclear sub, USS *Nautilus*, launched in January 1954. The PWR consumed much uranium but was compact and simple; it used "light water," ordinary H_2O, under high pressure, both as a "moderator," to slow the neutrons flying about the core and thus enhance a chain reaction, and as a coolant to control temperatures. This and another light-water reactor (LWR) type developed for the Navy, called a boiling-water reactor (BWR), would play large roles in the U.S. power program.

Congress's awe of the AEC would turn to jealousy of its powers, leading to fissures between the commission and its congressional overseer. Still, the JCAE's legislative monopoly, along with the AEC's dual mandate both to promote and regulate atomic energy, foreclosed outside scrutiny of the federal management of the atom. There was scant press or public questioning of AEC pronouncements about atomic power, which were little more than blue-sky promises.

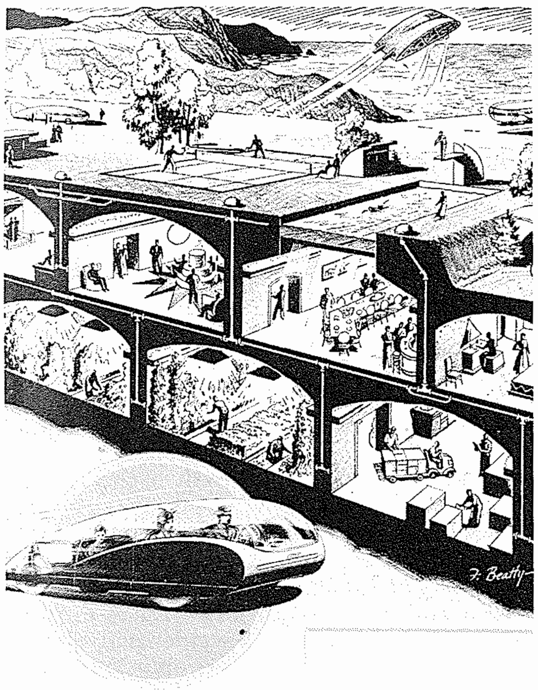
During 1947, for example, J. Robert Oppenheimer, the physicist from the University of California and the California Institute of Technology who had overseen the building of the first A-bombs in New Mexico and now headed the AEC General Advisory Committee, drafted a statement saying that the technical problems of commercial nuclear power would take "decades" to solve. Szilard's old acquaintance Lewis Strauss, by now an AEC commissioner and strong nuclear power booster, thought such candor might discourage Congress from funding research. The commission's final statement to the Congress said merely that it could be 20 years before the atom provided "any considerable portion" of the world's electricity.

III

THE ATOM GOES COMMERCIAL

The industrial firms that first entered the field of atomic power, such as Westinghouse, General Electric, Monsanto, and Union Carbide, were no less secretive than the officials in Washington; their initial endeavors supported defense projects, such as processing uranium and designing reactors. Their only potential customers for nonmilitary hardware were the utilities, which were themselves shielded by law from many political and economic pressures. As monopolies regulated by appointed state commissions, the utilities earned guaranteed returns on their investments and could pass most costs on to their customers. Although no risk-takers, their executives would be drawn to atomic power by a combination of unrealistic promises and enticing subsidies, from both the AEC and reactor suppliers.

The stage for this evolution was set when the public-private issue entered the 1948 presidential campaign. New York's governor Thomas E. Dewey, the GOP challenger, argued that the atom would benefit the nation only if the technology were transferred to private hands. After Harry Truman's upset victory, the AEC's Republican-dominated Industrial Advisory Group urged that the federal know-how be shared with business.



"The uranium age," as envisioned by Popular Mechanics *in 1941. With cheap power, the author wrote, "most activities" could be moved underground, even farming. The surface world could be devoted to recreation and such joys as "the U-235 automobile."*

At this point, the only firm designing a commercial nuclear plant—a breeder—was General Electric. And of the dozen research reactors being built at federal facilities, only one, a breeder in Idaho, was intended to generate power. More than five years would pass before ground was broken at a new commercial plant site.

The delay did not stem only from a lack of urgent need for nuclear power. Washington had other nuclear priorities. After the 1949 Soviet A-bomb test, the AEC assigned G.E.'s power reactor to the Navy's submarine program.* And soon, following a bitter debate among scientists and politicians over the need for "The Super," the hydrogen bomb was under development.

Rising military demand for plutonium sparked a three-year wrangle among manufacturers and utility officials over what kind of reactors should be built. "Single-purpose" plants that only generated power? Or "dual-purpose" reactors that would also turn out weapons-grade plutonium? Monsanto touted the

*This reactor eventually powered the second nuclear sub, USS *Seawolf*, commissioned in 1957. It was soon nicknamed "Twenty Thousand Leaks under the Sea" by sailors because of problems with its liquid sodium reactor coolant.

THE ATOM AND THE U.S. PRESS

For one important segment of the U.S. news business, Three Mile Island (TMI) was pivotal: It finally made nuclear power a "story."

Television had long all but ignored the subject. During the decade before TMI, a Media Institute study found, the networks devoted just one-quarter of one percent of their evening news time to atomic energy. With the 1979 accident, coverage rose sharply for a while and changed in tone from largely neutral to mostly negative. Critics got more exposure than advocates, and TV's big guns seemed to echo them. ABC's Howard K. Smith once declared himself "convinced" that nuclear generation was "better" than coal; now he put himself among "those who fear" atomic plants.

After analyzing several years of TV coverage, psychiatrist Robert L. DuPont found the "motif" of nuclear reporting to be "fear." A 1975 NBC special was titled *The Nuclear Threat to You*; a 1977 ABC report intoned that each reactor creates "wastes equivalent to 300 Hiroshima bombs each year." *The Fire Unleashed*, a "comprehensive" look at nuclear issues aired by ABC last June, spoke luridly of the "lethal legacy" of wastes and of the "hulks of the nuclear promise" (i.e., unfinished plants) now "scattered across the country."

Yet print editors, too, have found the "threat" theme compelling. A study conducted by University of Pittsburgh physicist Bernard Cohen of the *New York Times* and other major newspapers during 1974–78 found an average of 200 items a year on accidents involving radiation, though no deaths resulted; but there were only 25 items a year on industrial mishaps (which kill 4,500 annually) and 120 on vehicular accidents (50,000 deaths).

dual-purpose idea as a way finally to marry private enterprise to the federal atomic technology.

Eventually Lilienthal called for amending the Atomic Energy Act to ensure commercial development "in accord with the American system." Military secrecy could be maintained, he said in *Collier's* in 1950, while we "free the atom for America's industrial genius." The AEC began talks with eight firms about dual-purpose reactors. Still, there would be no *public* debate on commercial nuclear power until 1952, when Congress's JCAE held open hearings on the AEC's private-company talks.

One question on the JCAE's agenda was "Is it desirable to start a new industry dependent upon government for the purchase of plutonium?" Many equipment builders and utility men thought it was; they could gain experience with reactors that could "pay their own way" from plutonium sales even if the power they produced was uneconomical.

But how to begin commercialization? Various ideas emerged. Monsanto and Union Electric wanted government to

Early on, "mainstream" journalism, both broadcast and print, was mostly positive about nuclear power. In 1947, soon after airing *Hiroshima*, John Hersey's radio reprise of the first A-bomb attack, CBS ran a documentary titled *The Sunny Side of the Atom*. A *New York Times* piece that year hailed ways in which "nuclear energy is already at work for *good*." Later, especially as ecology issues and antinuclear groups gained force, many print editors took sides. While far-left periodicals (e.g., the *Guardian, Ramparts*) had long been anti-atom, liberal journals began showing concern. The *Nation* wrote in 1968 that reactor sales were spreading "too far, too fast" for safety; the *New Republic* warned in 1970 about the plants' "vast potential for destroying the environment." On the proindustry side, *Time* worried in a 1978 essay, "The Irrational Fight against Nuclear Power," that the anti-nuke movement "reflects a doubt that growth, once the watchword of the can-do American philosophy, is good."

Newspaper reporting on atomic energy has been uneven. Nuclear advocate Samuel McCracken argues that the U.S. debate over the atom has been "extraordinarily parochial" in part because the press slights foreign developments: One does "not often find coverage of the thriving British and French nuclear programs, or even the troubled Soviet breeder program." At the same time, few U.S. papers have come out against nuclear power. Early in 1984, for example, when Byron 1, Marble Hill, and other failures were news, most editorials took the long view. In New Orleans, close to the heart of oil and gas country, the *Times-Picayune* concluded that atomic energy was still "important." And the "pause" in its growth, the *Boston Globe* decided, was better seen as a chance to deal "with some of its problems than as the foreboding of its end."

build a pilot plant that industry could scale up. Dow Chemical and Detroit Edison wanted industry to build a dual-purpose plant on its own (which Edison later did). Lawrence Hafstad, director of the AEC's Division of Reactor Development, sought "all-government" financing of nuclear generation. Commonwealth Edison proposed a compromise—federal reactors coupled with commercial generators. Walker Cisler, president of the Detroit Edison Company, suggested building plants in "friendly foreign countries" where power was costly; this might combat "Communistic influence."

Most firms expected the federal laboratories to continue to do the main research. The economics was no secret. Commonwealth Edison reckoned that while coal-fired capacity cost about $77 per kilowatt to install, the cost of nuclear would be $277. But to the new Eisenhower administration, such numbers would be no deterrent. It believed that, as a National Security Council memo said, a strong nuclear industry was "a prerequisite to maintaining [the U.S.] lead in the atomic field."

IV

ENTER FREE ENTERPRISE

As his AEC chief, Eisenhower in 1953 named Lewis Strauss, the financier who as a charter commission member (1946–50) had championed the commercialization of atomic energy. Now backed by the first Republican administration in 20 years and a GOP majority in both houses of Congress, Strauss promised "an era of vigorous progress" for "this great natural force."

No one knew what the best power reactor might be, the light-water type or something else. But the Cold War was blowing hot. Mao Zedong had triumphed in China in 1949; the Communist takeover of Czechoslovakia had been followed by the Berlin blockade (1948) and the Korean War (1950–53). Strauss, wrote his biographer Richard Pfau, saw the East-West conflict "as a struggle between good and evil." And almost as threatening as the Red Menace abroad was Big Government at home. Strauss heated up the old struggle between those who—like senators Clinton Anderson (D.-N.M.) and Albert Gore (D.-Tenn.) on the JCAE and other New Deal Democrats—thought atomic energy should remain a federal monopoly and those who sought to make it private. Strauss's goal was to plug atomic plants into the existing national power grid, and he was eager to start.

Strauss urged that a Westinghouse PWR being built to power a prototype nuclear aircraft carrier be directly adapted for civilian use. To consider another contractor, as some urged, would waste "much time and momentum." He played matchmaker between Westinghouse and the Duquesne Light Company, which agreed to build a small (60 megawatts) nuclear plant at Shippingport on the Ohio River northwest of Pittsburgh—with the government paying most of the cost. Thus in July 1953, the AEC received its first atom plant application.

Some study of various competing reactor designs had to be done, however. Early in 1954, two months after Eisenhower announced the Atoms for Peace plan, which promised that the United States would share its nuclear know-how with countries that pledged to use it only for nonmilitary purposes, Strauss's AEC announced a program under which reactor-makers would build five experimental plants; as with Shippingport, the government would pay most of the cost. (A second round of proposals for "demonstration" plants was announced the next year.)

The GOP-controlled Congress then revised the Atomic Energy Act to let utilities finance, build, and own their reactors to produce power for consumers; they would receive fuel for up to seven years from the AEC, which would still control nuclear

Part of Adm. Hyman Rickover's nuclear Navy in 1964: the atom-powered carrier Enterprise, *cruiser* Long Beach, *and destroyer* Bainbridge. *Crews now live near reactors aboard 147 U.S. Navy ships.*

technology and all fissionable material. This was a defeat for Democrats on the JCAE who wanted federal development and operation of reactors, and it came at the hands of coal industry representatives. They saw federal atomic plants as rivals and lobbied Congress to include in the act a ban on the sale of power generated at government research or military facilities. The private sector had its way.

Eisenhower officiated at the September 1954 groundbreaking for Shippingport from a Denver television studio, where he waved a "radioactive wand" that (as *Life* reported) turned the "bright hope of atomic power" into a "solid certainty." Duquesne Light still expected to lose money on the plant, although the AEC would pay 85 percent of the cost. But Strauss predicted that as other utilities went nuclear, competition would cut the price of atomic power to the level of coal, oil, and perhaps even hydropower. Possibly, he said, "our children" will enjoy electricity "too cheap to meter."

Pronuclear utilities and makers of nuclear equipment formed a promotional group, the Atomic Industrial Forum (AIF). General Electric's president, Ralph Cordiner, predicted that half the nation's power stations would be nuclear by 1976.

Nonetheless, hints of future trouble appeared. Radiation first emerged as a public concern during 1953, after AEC weapons tests in Nevada. While the Soviets were pressing a campaign to abolish nuclear arms, intended to snatch the propaganda initiative from Atoms for Peace, foes of the AEC testing made "fallout" an issue, one that would be fanned by "Ban the Bomb" protests in Europe and the United States and by such works as Nevil Shute's 1957 nuclear war novel, *On the Beach.*

A Capitol Idea

At the AIF'S 1954 meeting, physicist George Weil raised the safety issue. He noted the danger of an overheating core, a particular problem with water-cooled reactors, which had many pumps, pipes, and valves that could malfunction. Weil cited the worry of Edward Teller, his Manhattan Project colleague and the first head of the AEC's Advisory Committee on Reactor Safeguards, that no matter what might be devised to prevent a release of radiation, "There is still no foolproof system that couldn't be made to work wrongly by a great enough fool."

Safety questions prompted the JCAE to order an accident-probability study. The result, published early in 1957, emphasized the "remote" chance of a serious accident but also estimated that a "worst-case" disaster might cause 3,400 deaths, 43,000 injuries, and $7 billion in property damage.

The AEC continued research. In fact, the nation's first power reactor accident occurred in 1955 at the Idaho National Reactor Testing Station: The EBR 1, a small breeder being used to test the consequences of a rise in heat, suffered a partial meltdown. At this point, however, the AEC's main drive was to nudge commercial nuclear power into being.

At the time of the first UN conference on Peaceful Uses of Atomic Energy, held in Geneva in 1955, America's program was lagging. The Soviets had begun operating the first civilian nuclear station, a five-megawatt plant south of Moscow, during 1954; the British would soon start up a 100-megawatt plant at Calder Hall. Strauss dismissed these as *government* projects; the first truly civilian station would be Shippingport. When the Soviets at Geneva announced plans for a power-generating breeder, Strauss got Detroit Edison's Walker Cisler, a member of the U.S. delegation, to fly home to apply for an AEC license for what would be the 61-megawatt Fermi 1 plant on Lake Erie at Monroe, Michigan, 29 miles from Detroit and 30 miles from Toledo. Strauss hailed that as the first *commercial* breeder.

The AEC wanted to keep most of the privately run test plants small, in the five- to 40-megawatt range. With safety and other questions still unresolved, the commission was wary of "scaling up" the technology too quickly. Yet by this time utility men and reactor manufacturers were persuaded that only large plants affording "economies of scale" could pay their way, and the AEC did not argue. Thus in February 1955, when the only U.S. plant actually being built was the 60-megawatt Shippingport facility, New York's Consolidated Edison ordered a 265-megawatt Babcock & Wilcox pressurized-water reactor for Indian Point, 24 miles from New York City.

In July 1955, Commonwealth Edison applied to the AEC for a license to build Dresden 1, a 200-megawatt G.E. boiling-water reactor in central Illinois—the first plant built without direct federal assistance. Then a group of New England utilities ordered a 175-megawatt Westinghouse PWR for a Massachusetts site. Few warnings about design difficulties or cost were heard. Indeed, back in Washington, D.C., two JCAE members proposed a $200,000 feasibility study of a reactor under the U.S. Capitol to supply heat and power. Everyone, said Rep. W. Sterling Cole (R.-N.Y.), is "confident that the idea is not only feasible and practicable," but also economical. (Wags quipped that the plant should be *in* the Capitol, which already had a handsome containment dome.)

Freezing the Future

Despite the strong start, more utility projects were slow in coming, and toward the end of Eisenhower's first term the public-private struggle flared anew—with important results.

Democrats, who had regained their Capitol Hill majorities, charged that America was losing the nuclear energy "race." Clinton Anderson, now the JCAE chairman, said that Strauss had made it easier for "a camel to pass through the eye of a needle" than for a utility executive to get data from the AEC. In 1956 he moved to step up research on plant design via the so-called Gore-Holifield Amendment, named after sponsors Albert Gore and Rep. Chet Holifield (D.-Calif.); it would have the AEC—not private firms—spend $400 million on six different prototype reactors, one in each region. To Strauss, this was a start toward a restoration of the federal monopoly of nuclear power that he had long fought.

Gore-Holifield passed the Senate but was defeated in the House, thanks to lobbying by coal companies, reactor suppliers, and utilities—all of whom feared federal control of the atom. This, as Strauss biographer Pfau would write, "saved" commer-

AMID THE LOSERS, SOME WINNERS

The woes of the U.S. nuclear power program, said *Forbes* this year, reflect "the largest managerial disaster in business history." While that is debatable, the U.S. failures *have* been numerous.

By the mid-1980s, for instance, a half-dozen major utilities with nuclear projects were skirting with bankruptcy, and poor planning and/or execution had scarred a number of projects. During 1984 alone: the Nuclear Regulatory Commission found it had "no confidence" in the construction quality at Byron 1 in Illinois and made that $3 billion facility the first new plant ever to be denied an operating license; work was stopped on Marble Hill, a half-finished, two-reactor Indiana plant that stood to be distinguished by the highest ever completion cost, $7.5 billion; and the builder of the nearly finished William H. Zimmer plant near Cincinnati moved to convert it to *coal*. Meanwhile, other undertakings established grim records:

- Biggest bust: The Washington Public Power Supply System. WPPSS, formed by a group of utilities led by the government-chartered Bonneville Power Authority, skipped payments on $2.25 billion in bonds—the largest default in U.S. history—after scrapping a five-plant program whose cost had risen to $23.9 billion. The WPPSS debacle was challenged in size only by that of the government-chartered Tennessee Valley Authority, which was forced by safety questions to shut down all five of its operating reactors this year.
- Longest drama: Diablo Canyon, a two-reactor California plant planned in 1969 to cost $350 million. It produced its first commercial power in 1985, after a 17-year struggle enlivened by the discovery of a nearby earthquake fault, multiple sieges and suits by opponents, and building errors that delayed licensing for 10 years. Final cost: $5.6 billion, a record—so far.
- Poorest performer: Beaver Valley 1 in Pennsylvania. Partly due to safety problems, the plant has produced just 34 percent of its potential power since 1977. That is the lowest "capacity factor" among veteran U.S. plants and one of the worst anywhere.

Yet despite such embarrassments, the U.S. nuclear program has its standouts. Among operators, North Carolina's Duke Power Com-

cial nuclear power. But ultimately it would be a setback. In effect, Gore-Holifield's defeat removed the government from research on new atomic power technology, which would now be left to industry. Yet "industry" basically meant the emerging leaders, Westinghouse and G.E., who were *already* committed to the light-water reactor designs developed for the Navy.

For all the money poured into prototype programs, only four non-LWR models were ever tried: A sodium-cooled, graphite-moderated reactor ordered by a Nebraska utility; a gas-cooled, graphite-moderated plant built by Philadelphia pany, which currently runs five reactors (along with eight coal plants), has consistently built the country's cheapest, most efficient nukes. A rare utility that does its own engineering and construction, Duke put its latest atomic plant, McGuire 2, on line last year for just $878 per kilowatt—well under the average for coal-fired capacity and on a par with the costs of the efficient French nuclear program. Adept also at dropping dubious projects, Duke has cancelled six nuclear units since 1978.

Among the 86 operating U.S. nuclear power plants, there have been a number of stars, old and new. As of this fall, for example, the Yankee Atomic Electric Company's small, 175-megawatt plant at Rowe, Massachusetts, has produced power reliably for a quarter-century. Over the years, the Wisconsin Electric Power Company's 15-year-old Point Beach 2 facility, one of two 485-megawatt units on Lake Michigan, 25 miles from Green Bay, has quietly achieved the nation's highest lifetime capacity factor, 80.4 percent. (The current U.S. average: 58 percent.) Point Beach also boasts the lowest rate of forced shutdowns (Unit 1 operated for all but one day during 1984); despite the modifications ordered after the Three Mile Island (TMI) accident, the cost of Point Beach's installed capacity is just $253 per kilowatt—one-twentieth that of the Shoreham plant in New York. Wisconsin Electric customers last year paid only 1.4 cents per kilowatt-hour (the U.S. average for residential power: 7.23 cents). The utility has *cut* its rates three times since January 1984.

Another such success is Florida Power & Light's St. Lucie plant north of Palm Beach. Despite a hurricane and post-TMI design changes, the 810-megawatt St. Lucie 2 unit was completed in the planned six years and went on line in 1983 at a well-below-average cost of $1,753 per kilowatt. St. Lucie 2 and its twin, completed in 1976, produce power for 0.8 cents per kilowatt-hour, about one-sixth of what the electricity from the company's oil-fired plants costs.

St. Lucie's success, argue Florida Power & Light officials, derives from the high competence of the plant's 550 staffers (who are organized under Japanese-style "quality circle" principles) and a simple corporate goal. The company, they say, wants "to become recognized as the best managed utility in the U.S."

Electric; an Ohio plant cooled and moderated by a liquid hydrocarbon called terphenyl; and a South Carolina reactor using "heavy water" (deuterium) as a moderator. These plants were never refined and scaled up to commercial size. For all practical purposes, U.S. reactor development was now frozen in a basic design that would require costly safety systems and especially careful operation. Except for two gas-cooled reactors in Pennsylvania and Colorado, all U.S. orders placed after 1959 were for light-water reactors; two-thirds of these would be of the particularly sensitive pressurized-water type.

Other 1950s wrangles would also affect the course of U.S. nuclear power development.

JCAE members were furious to learn that Strauss's AEC approved construction of the Fermi 1 after the AEC's own Advisory Committee on Reactor Safeguards warned that the breeder might pose a "public hazard" in the Detroit and Toledo area. In response, Congress made the safeguards group a statutory body whose reports on individual plants had to be made public. The lawmakers also opened decisions on plant-licensing, which had involved only AEC and utility officials, to intervention by citizens. The public could now take their objections to court, paving the way for the legal license-blocking tactics that would become perhaps the nuclear utilities' greatest single headache in getting plants started, completed, and put on line.

Nuclear power advocates also had victories to cheer, however. Suing on behalf of members in the Fermi 1 area, the United Auto Workers challenged the AEC's right to permit plant construction before safety issues were resolved. Ultimately the U.S. Supreme Court, in its first big decision on a nuclear issue, backed the AEC; the court ruled 7 to 2 that the law gave the AEC wide discretion to regulate atomic power as it saw fit.

Earlier, in 1957, Congress awarded a key concession to commercial nuclear power, the Price-Anderson Act. This provided for limited damage liability and federal no-fault insurance for the atomic utilities and their contractors: No one could take claims for nuclear accident injuries to court; awards would be set by insurance company pools and passed out on a first-come, first-served basis until they reached the limit, a relatively low $560 million. Thus today insurance policies on homes and autos exclude claims for radiological damage.

In effect, the law freed the utilities and their suppliers from what seemed their greatest deterrent to using the atom. But the measure was also one more government "assist" that would encourage many utilities to order nuclear plants without looking hard at the real costs and benefits of owning them.

V

THE BANDWAGON SIXTIES

With the Price-Anderson protections in place, the stage was set for a rise in plant construction. The 1960s would be dubbed—wryly, by utility men who remained skeptical about the atom—as "The Great Bandwagon Years."

Going into the decade, the atom had lost some of its luster. For all the agonizing over nuclear power, by the end of 1960 the nation had only Shippingport and one commercial plant operating, and 10 under construction. Costs were still high on utility executives' worry lists. When Shippingport began operating in 1957, its reactor's cost had risen to $110 million, more than double the original estimate, and it turned out power for 6.4 cents per kilowatt-hour, about 10 times the average for coal. (When reporters questioned all this, Admiral Rickover airily told them, "You people are asking for conception without sex.")

A 400-Foot Solution

Glenn Seaborg, named AEC chief by President John F. Kennedy in 1961—and still an ardent believer in breeder reactors and a "plutonium economy"—was determined to light a fire under the nuclear energy programs. But new problems surfaced.

After Sputnik carried the U.S.-Soviet competition into space in 1957, the AEC began to lose its pre-eminence in federal scientific research to the National Aeronautics and Space Administration. And now, JFK's vow to put an astronaut on the moon would allow the rocket men to command public attention in a way that the laboratory physicists and engineers working on atomic energy never could. Moreover, Kennedy's science adviser, Jerome K. Wiesner, later president of the Massachusetts Institute of Technology, would be the first White House official to question AEC forecasts of nuclear power needs.

Undaunted, Seaborg argued in 1962 that atomic power was not only "on the threshold" of competitiveness but becoming vital to the nation's well-being. Extrapolating from the seven percent annual rise in electricity use that the nation had experienced since World War II, he saw a rapidly expanding need for nuclear generating capacity: By century's end, the atom should be supplying one-half of America's electricity. How Kennedy, had he not been assassinated, would have handled Seaborg's call for aggressive breeder development is unknown.

Direct federal subsidies would end with Shippingport, Fermi 1, and the 11 prototype plants nursed along by Strauss's AEC during the 1950s. What finally started the bandwagon was a combination of promises. The sweeteners offered by Washington were all indirect—the Price-Anderson cap on liability; assurances that government would take care of the costly matters of safety research and reactor-waste disposal and that fuel would be in ample supply. (The AEC plants that enriched uranium for weapons and Navy reactors could turn out the far less

Polls show a steady erosion of public acceptance of nuclear power, but key support remains. A 1980 survey conducted for the Connecticut Mutual Life Insurance Company found that leaders in religion, business, the military, government, science, education, and the law thought the benefits greater than the risks. In a 1982 poll of Congress, 76 percent of the members favored greater use of atomic power.

potent fuel used by power plants with ease.)

For their part, G.E. and Westinghouse stirred up orders by offering utilities "turn-key" plants that would be built and made ready to run for a fixed price that was well below their cost. By the end of 1966, 10 utilities had bought 21 such loss-leaders from the firms, which thereafter would sell plants only on a cost-plus-fee basis. The companies also offered 20-year contracts to supply cheap fuel, which they thought would eventually be produced in abundance by breeder reactors.

Meantime, the great scale-up had begun. Bigger plants, insisted the manufacturers, meant lower costs all around. In December 1962, a Connecticut utility ordered a 582-megawatt plant. The next year brought four orders from 436 to 850 megawatts. The first proposal for a 1,000-megawatt plant, made in December 1963 by New York's Consolidated Edison, was less remarkable for its size than its site—in Queens, across the East River from Manhattan. Edward Teller wryly assured the public that the site would be safe, if the plant were buried 400 feet underground. Con Ed was persuaded to drop the idea.

As plants were growing in size, Congress took another fateful step. By 1964, the coal industry had decided that *commercial* nuclear power was a threat, so the Atomic Energy Act was amended once again. This time, most of the research funds that remained in the AEC budget after the defeat of the Gore-Holifield plan in 1956 were shifted away from support for light-water reactors to two types whose commercial promise was remote, breeders and plants using the "fusion" technology employed in H-bombs. Now, contrary to prior federal promises to the utilities, research on the safety of commercial reactors was almost entirely in the hands of the diverse firms which made, sold, and bought the reactors. As problems appeared, the AEC would order "engineered safeguards" to deal with them; a strategy of often costly multiple systems (containment structures, emergency core cooling devices, etc.) evolved that eventually became known as "defense in depth."

Bigger and Bigger

Still another government promise to the utilities was withdrawn. The AEC was making enough plutonium for weapons on its own by the early 1960s, so it cancelled its standing offer to buy plutonium made during the operation of both LWR and breeder plants. The AEC's new plan, later discarded, was that nuclear utilities would send their spent fuel to "reprocessing" plants to recover uranium and plutonium for their own use. In any case, the breeder concept showed some flaws. In 1966, three months after Fermi 1 went on line at Monroe, Michigan, it suffered a core-melt. Fermi 1 would not fulfill its promise. It produced neither salable plutonium nor reliable power. Yet Seaborg's faith in breeders remained strong.

While President Lyndon B. Johnson focused on other concerns—Vietnam, Great Society legislation, the peace movement, Watts, Detroit, and Vietnam again—Seaborg continued to promote nuclear power. By 1967, he was arguing that the atom would account for almost one-fifth of U.S. generating capacity in 1980, requiring around 100 plants. Without them, the nation would not meet its demand for electricity, which Seaborg thought would continue to increase by over four percent annually until the year 2000. Domestic uranium supplies might not last long; breeders would be essential.

With the war in Indochina and the War on Poverty commanding federal resources, Washington was not yet ready to fund new breeder projects. But private forecasts echoed Seaborg's view of the future. The Edison Electric Institute predicted about 117 investor-owned nuclear plants by 1980; G.E. saw some 125 plants; Westinghouse 150. Indeed, seven were ordered in 1965, the largest 873 megawatts. The first firm order in the 1,000-megawatt range came in 1966, for the TVA's three-reactor site at Browns Ferry, Alabama. Six of the 20 plants ordered in 1966 exceeded 1,000 megawatts, as did eight of the 29 booked in 1967. After 1968, when more than half of the 14 orders placed were for these big plants, they became standard. There was talk of 2,000-megawatt giants, and G.E. executives considered 8,000 megawatts possible, but in 1972 the AEC set a limit of 1,300.

VI

THE SOBERING SEVENTIES

Reactors were being scaled up faster than experience gained from smaller ones could be applied. By 1968, manufacturers were taking orders for plants six times larger than the biggest one then operating.

Construction times grew—from an average of six years during the 1960s to 12 years for plants begun during the 1970s. The same was true of costs. By 1971, when the nation's first 21 commercial plants were completed, their capital costs were roughly twice the original estimates. The utilities absorbed much of the pain, but G.E. and Westinghouse, who lost as much as $800 million on their turn-key deals, also suffered.

The economics was daunting. Almost everywhere, under existing regulations, utilities could not begin recovering their costs from their customers until the plants started running. Whenever a plant's operating date was delayed—by construction mistakes, government-ordered safety changes, citizen protests, and litigation—the utility's expenses would rise enormously.* Thus while the utility industry as a whole prospered during the 1960s, many companies that had undertaken to build nuclear plants would soon be sorely strapped for cash.

The big plants required so much capital (and produced so much power) that utilities often had to combine forces to purchase them. For example, in New England, where dependence on foreign oil was high and the air pollution from coal-fired plants was seen as a blight, 16 utilities joined during 1972 to buy two 1,150-megawatt reactors for a site at Seabrook, New Hampshire. A herd of 115 utilities in eight states grouped together with the Bonneville Power Administration to form the Washington Public Power Supply System (WPPSS), which was to build five atomic plants. As the later troubles of such consortia would show, group

*For example, even at today's moderate rates of inflation and interest, a growth in building time from eight to 12 years can add 40 percent to a plant's cost; price rises and debt service would account for more than 60 percent of the final bill.

THE NON-PROLIFERATION PUZZLE

The Nuclear Club remains just the superpowers, Britain, France, and China. It has been more than 20 years since a new country has declared itself nuclear-armed, more than 10 since any has set off a first atomic test. Yet "proliferation" is a problem.

There are nonclub nations with an undeclared or "veiled" weapons-making capability. Israel reached this point as early as 1968. India, South Africa, and perhaps Pakistan have followed. Brazil, Argentina, Libya, and Iraq (whose "research" reactor was bombed by Israel in 1981) are known to want to catch up.

The 1968 Non-Proliferation Treaty (NPT) permits the transfer of atomic technology only to countries that forgo nuclear weapons and allow inspection by the International Atomic Energy Agency (IAEA). But the treaty's 128 signatories do not include Israel, India, Pakistan, South Africa, Brazil, and Argentina, which have pursued their nuclear goals nonetheless. President Jimmy Carter sought to tighten the loose NPT "safeguards" with the 1978 U.S. Nuclear Non-Proliferation Act; it requires *any* country making nuclear purchases from the United States to accept IAEA inspection of *all* of its facilities. But among nuclear exporters, only Canada, Australia, and Sweden have followed suit. And America, critics say, has lost sales and influence in many nations with atomic power programs; they can turn to European or other suppliers that insist on safeguards only for the items being sold.

In any case, the nuclear nations' arms-curbing zeal has been uneven. During the 1970s, notes Leonard Spector, author of *Nuclear Proliferation Today* (1984), Washington fought to stop South Korea and Taiwan from announcing plans to make atomic weapons; it was less forceful with such undeclared nuclear states as Israel and Pakistan. The moral, he writes: If a state does not "openly" flaunt its aim, "it may approach and actually cross the nuclear weapons threshold with virtual impunity."

ownership complicated matters for management (not always strong in the utility industry). It became clear that big plants had poor operating records; complex safety systems made maintenance difficult, and when "downtime" was needed for repair or refueling, much replacement power had to be bought.

As these realities were becoming clear to utility executives, the old vision of steadily rising demand for electricity became a bit cloudy. What Seaborg and other planners had not seen was that in the past, electricity use had risen because, for four decades, its cost had declined—the result of softening prices for fuel *and* the efficiency of new coal- and oil-powered plants. (They, too, were scaling up.) When costs rose again during the early 1970s, propelled partly by Vietnam era inflation, demand leveled off.

And so did the need for new plants, though this reality sank in slowly. The 1973 AEC estimate was that by the year 2000 America would still get half its power from perhaps 400 breeders and 600 other nuclear plants. With lead times growing, many utility men felt pressed to move fast—and did, to their later regret.

Thus in 1973, the Long Island Lighting Company (Lilco) would break ground in Shoreham, New York, for an 820-megawatt plant expected to cost $300 million; soaring interest, construction difficulties, safety modifications, and assorted legal wrangles would push the price to $4.2 billion by the time the plant was finished in 1985. If and when commercial operation is allowed and Lilco can begin passing Shoreham's costs on to its rate-payers, the customers could in theory see a 38 percent rise in their monthly bills. This is called "rate shock."

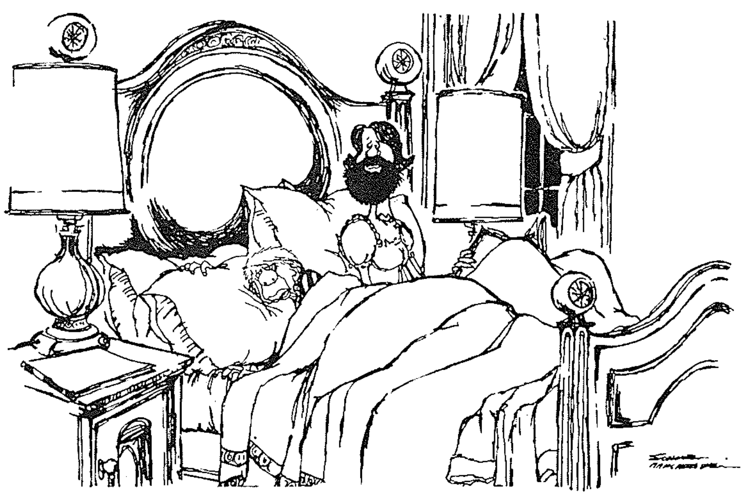
Even worse was what befell the WPPSS and its customers. It had been allowed to pass some of its work-in-progress costs on to its rate-payers. By 1983, when slack demand, debt, and other problems forced cancellation of the ill-advised plants, the state's residential rates had risen by about 80 percent.

While the new realities of soaring costs and softening demand worked their way through utility balance sheets, other developments would sour the prospects for nuclear power.

Arabian Nightmare

At first, concern about the environment had been a plus for the atom: Nuclear plants do not foul the air. Then, spurred in part by a 1969 *Sports Illustrated* piece ("The Nukes Are in Hot Water"), "thermal pollution" became an issue. The polluter was reactor cooling water, which can be 11 to 25 degrees hotter than the lakes and rivers into which it is pumped, and thus affect nearby fish and flora. Though the hazard was often exaggerated, the rumpus led to the tall cooling towers which have become a symbol of atomic power.

By the time of the Earth Day demonstrations of 1970, the atom's clean energy halo was gone. NO NUKES was a rallying cry, and the ralliers were handed a weapon. In a case concerning Calvert Cliffs, a proposed nuclear plant in Maryland on the Chesapeake Bay, a federal court ruled in 1971 that the 1969 National Environmental Policy Act's call for "environmental impact statements" on all large construction projects applied to nuclear plants. The AEC could no longer award licenses solely with regard to "public health and safety." The utilities' vulnerability to antinuclear protestors increased.



"Relax Rosalynn . . . The Nuclear Regulatory Commission said it was safe to go into that plant. . . ." *This cartoon ran after the Carters toured Three Mile Island in 1979. Only about 16 curies of iodine-131 radiation were released at TMI; a 1957 accident in England released 20,000 curies.*

President Richard M. Nixon was at least nominally pronuclear; in part to gain congressional support for other White House goals, he backed the 1971 funding of Clinch River, a federal project in Tennessee near Oak Ridge that was to be a prototype for big breeder plants. But Nixon's blunt AEC chief, James M. Schlesinger, warned that in the new national climate the commission could no longer be expected to solve the nuclear industry's "commercial" problems. These had to be settled with "Congress and the public." Atomic power was on its own.*

Other jolts followed. During 1972, a cartel led by Canadian and Australian producers raised the price of uranium ore. (It went from about $8 a pound to above $20 in 1975.) The manufacturers who had made long-term uranium deals were caught off guard. Westinghouse, whose pressurized-water reactor plants now commanded two-thirds of U.S. reactor sales, managed to renegotiate pacts and take cartel members to court to avoid default on 20 contracts. The uranium hold-up had no great effect on nuclear utilities; even today fuel accounts for only about 20 percent of their operating costs, versus 52 percent

*In 1974, Congress abolished the AEC, largely because it seemed to do more to promote nuclear power than to regulate it. The new, five-member Nuclear Regulatory Commission became the industry watchdog, while a new Energy Research and Development Administration took over weapons programs and the modest remaining efforts at improving nuclear power technology.

for coal-fired plants. But the episode did not help the argument that cheap fuel might easily offset nuclear's steep capital costs.

The year 1974, which brought the culmination of Watergate and Nixon's resignation, was also significant for nuclear power. It was the first year that *none* of the new plants ordered—28 were contracted for that year—would be completed. Orders then fell sharply, to four in 1975; three in 1976; four in 1977. The last U.S. order, later cancelled, was placed late in 1978, three months before TMI.

It is now clear that this stunning reversal was brought about partly by the crisis that was supposed to save nuclear energy: the 1973 Arab oil embargo and the four-fold rise in petroleum prices that followed. At the time, 17 percent of America's power was generated in oil-fired plants, at costs competitive in some areas with both coal and nuclear power. So builders of reactors and those who had bought them had reason to cheer as worries about cost and supply drove utilities away from petroleum. (No new plants using oil, or natural gas for that matter, were to be ordered after 1975.) They had further cause to smile in October 1973, when Nixon announced "Project Independence," a $22 billion energy development scheme designed to make the breeder reactor the dominant U.S. power source.

But the Nixon administration had expected half the research and development (R&D) money to come from private industry, which traditionally had spent little for such purposes. Industry did not break with tradition. Inflation, spurred by rising oil prices, further raised the cost of capital while the "oil shock" sparked a recession that cut demand for all energy. After 1972, electricity use grew by only 2.5 percent a year, mocking prior projections.

Enter the No Nukes

While orders were collapsing, an episode occurred that saddled the utilities with new expenses: An accident at TVA's Browns Ferry complex, the worst U.S. mishap prior to TMI.

This showed that even trivial events could threaten "defense in depth." A fire started by careless workers—testing for air leaks with a candle—raged for seven hours. It burned key power cables. Operators lost control of the core coolant; only by sending men into the reactor building to turn valves by hand was a meltdown averted. The NRC ordered rewiring at most plants, a job some utilities have still not completed. Retrofits, redesigns, and corrections have been common for more than a decade, partly because the AEC scaled back its work on developing and testing safety advances for commercial light-water reactors after the defeat of Gore-Holifield during the 1950s.

After Browns Ferry, the diverse antinuclear forces began to coalesce and devise new tactics. Proposals to curb atomic plants went on the ballots in seven states during 1976; though all were defeated, environmentalist Barry Commoner, author of *Poverty of Power*, a hymn to solar energy, declared "victory." During his brief White House sojourn, President Gerald R. Ford supported private development of nuclear power (while further cutting federal research). But he wound up suspending the commercial reprocessing of spent fuel as a way to attack "proliferation," the spread of nuclear materials and techniques that might enable more countries to obtain atomic weapons.

The $5,202 Kilowatt

Ford's motive was largely political. His Democratic challenger in 1976 had made an issue of proliferation and happened to be the nation's first presidential candidate who had hands-on experience with the atom. Jimmy Carter, the Annapolis graduate who had served in Rickover's nuclear Navy as a submarine officer, was sensitive to both the proliferation problem and environmental issues. As President, in his April 1977 energy message to Congress, he turned established U.S. policy upside down by declaring the atom to be a "last resort" energy source. He also reaffirmed the Ford ban on reprocessing and tried to cancel the Clinch River breeder project (thus spurring Congress to keep it going another few years).

While polls still showed majority support for atomic power, Carter seemed in tune with the antinuclear movement—though the movement's tactics were about to change from ballot initiatives to civil disobedience. In April 1977, some 5,000 protesters held the first mass demonstration against an atomic plant: a siege of Seabrook, New Hampshire, where 1,400 were arrested. Then came more Seabrook protests and the 1979 drama at TMI—to which the new NRC reacted by issuing a river of new regulations* and accelerating its two-year-old plan to post inspectors at all U.S. nuclear plants. In May 1979, some 100,000 antinuclear protesters gathered in Washington to chant slogans ("Two, four, six, eight, we don't want to radiate") and commune with rocker Jackson Browne, Ralph Nader, Dr. Benjamin Spock, and Jane Fonda. To a *New York Times* reporter, the crowd seemed like "graduates of an earlier [Vietnam protest] era re-

*By the Edison Institute's count, the total of various NRC directives reached nearly 2,000 as of the early 1980s. Post-TMI orders for new safety equipment are reckoned to have added some $3.5 billion to the nuclear utilities' capital costs.

TRYING TO BURY THE WASTE PROBLEM

A 1,000-megawatt coal-fired plant burns about 2.5 million tons of coal a year. Much of the residue goes into the atmosphere; the rest is carted away as ash, up to 500,000 tons of it. The fuel wastes from a comparable nuclear plant are piddling—30 tons or so annually. And if it could be compacted, the very radioactive "high-level" detritus involved would fit into a couple of steamer trunks.

Then, too, the high-level waste generated by the military—in making warheads and powering the nuclear Navy—is much greater in volume (though less radioactive) than that produced by atomic power generation. Yet the plant wastes are what concern the public most about nuclear power. Seventeen states have placed restrictions on how much or what kinds of spent fuel or other nuclear trash they will accept, and three will permit no such wastes at all; 12 states, moreover, have banned reactor construction pending a permanent solution to the waste problem.

The thousands of rods of mildly enriched uranium that make up a 100-ton reactor core are virtually harmless when delivered to a plant. After a year in the core, however, they generate much heat and are irradiated with cesium-137, strontium-90, plutonium-239, and other fission products, some of which remain dangerous for hundreds of years. Each year, one-third of the rods are removed and replaced. Because no final repository for such high-level wastes yet exists, spent rods are kept at the plants, left to cool slowly in large pools of water. By now some 7,000 metric tons of rods are thus stored, and space is running out. The waste problem will intensify as the plants themselves reach the end of their useful life.

The commercialization of atomic power began with the assumption that government would solve the waste problem. For a while, the answer seemed to be spent-fuel "reprocessing." In theory, 97 percent of some fission products can be turned into forms of uranium and plutonium that can be used again, as reactor fuel or for weapons. A commercial plant for this purpose did open, at West Valley, New York, in 1966. But the recycling effort died during the 1970s, a

turning for a 10-year reunion."

Later, the realities of the U.S. energy situation softened Carter's antinuclear stance. With imports now accounting for about one-half of America's oil consumption, Carter in his post-TMI energy message called for decontrol of domestic crude prices ("Use less oil and pay more for it") and conservation steps. By then, he had decided that the "last resort" atom should be used not just *if* other sources failed but *until* alternatives arrived. Said a Carter aide: "There's no way to turn our back on it now."

But by then the decisions, nondecisions, and random events of the previous 30 years had had their effect. The policy-makers had rushed to develop nuclear power—quickly settling on an victim of problems at West Valley and of the Ford-Carter ban on commercial reprocessing as a way to limit nuclear proliferation. Though this ban has been lifted, commercial recycling is uneconomical: There is scant nonmilitary demand for plutonium, and the cost of reprocessed uranium (more than $400 a pound) is prohibitive.

Thus the focus is on disposal. In theory, this is manageable. Suggestions have been made that all the high-level waste be fired toward the sun aboard rockets or buried 20,000 feet down in "superdeep" holes; but these solutions would be costly and would rule out the possibility of retrieving the spent fuel for reprocessing in the future. The French are pioneering a promising disposal method in which wastes are "vitrified," fused into glass and then sealed in stainless steel canisters for burial one-third of a mile underground.

In the United States, *where* to deposit high-level wastes has been as much of an issue as *how*. An abandoned salt mine in Kansas was considered during the 1960s, but it was later dropped when scores of drilling holes were discovered and doubts about the mine's "integrity" surfaced. The federal high-level waste site (for weapons material) at Hanford, Washington, was ruled out for spent fuel when the Nuclear Regulatory Commission, the Yakima Indians, and other groups raised objections involving uncertainties about the movement of underground water. With the Nuclear Waste Policy Act of 1982, Congress told the president to choose two new high-level dumps and ordered nuclear utilities to start contributing funds (now totaling $300 million a year) toward their support. But while government geologists have narrowed their choices to nine locations in Arizona, New Mexico, Utah, Texas, Mississippi, and Louisiana, the Department of Energy has asked for a delay in making its recommendations.

It now seems that no White House decision will be made before 1990, and even then the issue may not be settled. Congress has given the states the opportunity to veto the site selections—an offer that many state officials will find hard to ignore.

early military spin-off, the light-water reactor, that may or may not have been appropriate. The building and operation of nuclear plants were left to overoptimistic commercial suppliers and utilities—who increased reactor size too quickly. Pushed by Congress, the government pulled out of nuclear power R&D—which ended research on other designs and led to the piecemeal retrofits that helped drive costs to the skies. In tune with the neoprogressive ethos of the 1970s, Congress and the courts opened up licensing procedures—making the utilities easy game for all sorts of opponents just as their managers were struggling to get on top of the most demanding and costly projects they had ever undertaken.

And then came the "Reagan Recession" of 1980–81, which mocked all the demand forecasts once again. (Only two new *coal*-fired facilities have been ordered since 1982.) By 1985, various utilities had stopped several large nuclear works-in-progress (Marble Hill, Midland, Zimmer, the WPPSS plants) and were straining to finish others (Perry, South Texas, Seabrook 2, Grand Gulf 2). The final bills of some projects that did struggle to completion were awesome. When Shoreham was finished, the cost of its generating capacity turned out to be a record $5,202 per kilowatt; almost a dozen other projects still under construction stood to come in at well above the nuclear average of about $3,000 per kilowatt, not to mention the estimated $1,200 of a comparable coal plant.

VII

A NEW NUCLEAR FORMULA

What now?

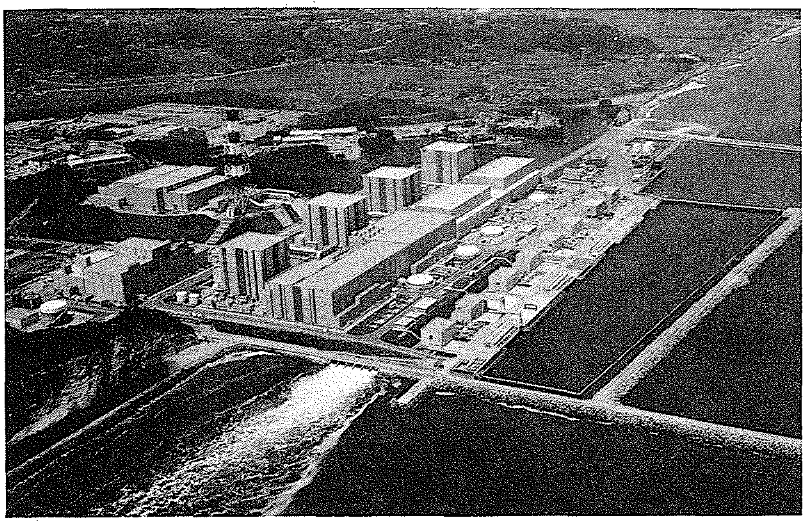
As Jimmy Carter eventually conceded, there is a clear need for nuclear power. Even at the present low level of demand growth, America will need to add new generating capacity—perhaps the equivalent of 100 large plants—by the end of this century. But oil and gas are uneconomical, and in any case federal law has barred their use in new plants since 1978. Coal, abundant as it is, presents environmental problems (smog, acid rain,* the physical ravages of strip-mining). Substantial help from solar power and other sources is still remote.

Fortunately, the need for new plants is not yet urgent. Power is short in the Northeast, but help is at hand. Canada, whose utilities are run by the provincial governments (they operate 16 nuclear plants), has made it policy to sell excess electricity to the United States; New Brunswick has one nuclear station primarily devoted to export and is planning another. All in all, U.S. generating companies may enjoy a breather lasting into the 1990s before they must build new capacity.

This interim period constitutes a time of opportunity, and a debate is underway in industry, academe, and government on how it might be used to revive the U.S. nuclear power "option."

Would a "technical fix" help? A Massachusetts Institute of Technology (MIT) study team led by nuclear engineer Richard

*A product of the sulfur dioxide released into the air by coal-burning plants. A 1980 study by the National Academy of Sciences estimated that the effluent of one large plant may cause as many as 60,000 cases of respiratory illness a year.



The Fukushima I plant of the Tokyo Electric Power Company, the world's largest private utility, has six General Electric reactors. Forgoing nuclear weapons, Japan has welcomed nuclear power.

K. Lester has concluded that the commonly used light-water reactor could be improved—but that even so, it may never "regain commercial acceptance." The MIT group, while endorsing further LWR refinement, also urges the development by the mid-1990s of two "fundamentally different" reactor types that might be smaller, cheaper, and pose fewer safety concerns.

One type might be the high-temperature gas-cooled reactor (HTGR), on which research has been done in Britain, West Germany and (to a limited extent) the United States. The HTGR is designed not only to produce nearly as much fuel as it uses (a mix of uranium and the plentiful element thorium) but also to close down safely even if it loses its helium coolant. Another possibility is the so-called PIUS, an "inherently safe" light-water reactor of Swedish design; its core, held in a pool of pressurized cold water that is itself contained in a pressure vessel, is supposed to shut down automatically upon encountering any problem, from human error to an earthquake. But federal help would be needed for new-reactor research. "Left to itself," says the MIT group, "industry will almost certainly fall short."

Do utilities need a redesign? Publicly, spokesmen for generating companies say that the U.S. nuclear power industry can flourish in its present configuration—once demand for electricity picks up again. They want costs to be reduced through standardized plants* and less onerous federal regulation: fewer change orders, streamlined plant approval. (Utilities now must obtain a construction permit *and* an operating license.)

Yet a new look for nuclear utilities is also under wide discussion. At present, nearly 60 utilities, from Maine and Florida to California and Washington, are involved in atomic projects, and about 40 of them operate only one or two plants. Many utilities are small: Two-thirds of the private companies now building atomic plants have more than 30 percent of their assets tied up in construction. The Edison Institute wants more plants run by syndicates and even "separate nuclear companies."

Bad Blend

Alvin Weinberg, who believes that the present light-water reactor can be retained in its essentials (though work should proceed on "inherently safe" alternatives), argues that worries over cost and safety would diminish if new plants were grouped in remote "energy parks" and run by well-paid, highly trained specialists. A 1984 study by Congress's Office of Technology Assessment, commissioned by a pronuclear House subcommittee, also urged the concentration of plant ownership and operation, à la Weinberg, in fewer, more skilled hands.

Should reactor manufacturing be reorganized? Eric R. Zausner, a former deputy administrator of the Federal Energy Administration, urges nuclear equipment suppliers and engineering firms to form a combine like the Texas-based Microelectronic & Computer Technology Corporation, chartered in 1982 by Control Data, Honeywell, RCA, and 10 other firms to pool the cost of developing supercomputers. Such an undertaking, says Zausner, might yield new designs that would compete with other countries' advancing nuclear technology.

The interest in concentration, standardization, and streamlined regulation reflects the envy of utility executives and others for the programs of nations such as France and Britain. But these countries operate their nuclear plants as *state* enterprises, with a single national manufacturer, utility, and regulatory agency. This is the model that Congress rejected, for the last time, with the defeat of the Gore-Holifield amendment in 1956.

During the 1940s, an aide on the staff of Congress's JCAE

*Nearly all U.S. facilities are custom designed, which complicates both regulation and operation. An egregious example is Millstone in Connecticut, where a consortium of six utilities runs three reactors; each was designed by a different manufacturer, each powers a plant built by a different architect-engineer, and each requires different operator training and supplies of spare parts.

wrote a study predicting that for nuclear power to thrive in America, it would need to be "a socialist island" in a sea of free enterprise. The technology and safety factors were so demanding, he reasoned, that no business would or could invest in the necessary research or manage staff training and the protection of radioactive material with the required military rigor. Utility executives have rejected this notion ever since the battles over the original Atomic Energy Act. But today, while the utilities are at the center of most nuclear power issues—they alone are the "customers" who choose what reactors to buy and how to run them—policy seems to be set in agencies, commissions, the courts, almost everywhere *but* in the utility board rooms.

All utilities are regulated state monopolies, but without the redeeming value of unified national authority. Lacking competition, utilities run state-sanctioned monopolies at rates (and for rates-of-return) set by state commissioners, not by the marketplace. In terms of advancing nuclear power technology, this is the worst possible blend of state and private enterprise; it makes utility executives responsible to stockholders, whose first concern is quarterly dividends, but with added homage to their customers and to more state and federal regulators than any other industry endures.

It thus may be that what the U.S. nuclear enterprise needs is not deregulation, as the Edison Institute argues, but a fundamental "re-regulation"—one that would require a scrapping of the Atomic Energy Act and a new beginning.

Like the Navy

Under one such approach, the government might become the operator of last resort of any nuclear plant a utility wishes to abandon, and no new nuclear plants would be built or designed under private auspices. Public and private utilities could continue to transmit and sell power to their customers, but eventually the operation of all *reactors* would become a federal responsibility. With this might come the simplicity that foreign nuclear regimes now have. (A small step in this direction came this year, in the form of a Senate bill that would make the five-member NRC a federal executive agency with one head.)

New statutes could set priorities; they might state that "national security" *requires* the atom's use as an energy source of "last resort," just as a strategic oil reserve might be, or a subsidized gasohol or synthetic fuel industry. Federal supervision would allow a chain of command that would be direct and efficient, embracing research, development, construction, and operation, as it is in the expensive but efficient nuclear Navy program.

Some regulators and industry officials believe that all nuclear plants must be turned over to specialized operators that would be created and chartered by Washington, along the lines of the TVA and the Bonneville Power Administration. Others who favor large nuclear operating entities of some sort have doubts; Alvin Weinberg has suggested that public authorities might be "harder to regulate than private ones." There is serious (if still off-the-record) discussion among utility executives about regional *private* utilities that would manage nuclear plants and sell power wholesale to existing companies; bureaucratic oversight could be shifted from the 50 state utility commissions to the Federal Energy Regulatory Commission, which already deals with bulk and international electricity sales.

Buying the Dream

Looking back, a top Wall Street utility analyst, Goldman, Sachs vice-president Ernest S. Liu, has noted that nuclear industry leaders did not just overestimate power needs and fail to foresee inflation, new regulations, and cost run-ups. They also saw too late "that nuclear power is an unforgiving technology, and plants have to be built right regardless of the cost." They "did not invest enough management in their programs early on."

Management preoccupied the Kemeny Commission, the presidential panel that studied TMI. It noted that Met Edison equated safe operations with meeting NRC rules, not with mastering nuclear operations on its own. After the accident, Met Edison sued the NRC for $4 billion, charging that the agency had not supervised it closely enough. Several pronuclear studies have concluded that utilities generally have not treated the atom with the respect it deserves. Fission is not "just another way to boil water," as some utility men were heard to say prior to TMI.

This attitude has affected basic efficiency. One way to rate a plant is by its "capacity factor," the power it produces as a percentage of its potential. In a 1983 survey by the Atomic Industrial Forum, 18 non–East Bloc foreign countries operated 149 reactors with an average capacity of 63.4 percent, compared with 57.5 percent for the 72 U.S. reactors running at the time. The foreign averages ranged from Switzerland's 84.2 percent to Pakistan's seven percent. The U.S. numbers for that year ran from 94.8 percent, for Florida Power & Light's St. Lucie 1, to 13.5 percent, for Pacific Gas and Electric's San Onofre 1 in California.

If nuclear energy had been developed solely as a commercial enterprise during the early years, rather than as a secret defense project, several companies would have built dozens of experimental reactors. Most would have failed. That is the nature of R&D. But the survivors would have been tested thoroughly, then scaled up only gradually to meet the demands of utilities and other users of high-energy heat. Only designs that met the test of market interest would have flourished.

This never happened, however, thanks to the exigencies of wartime. The government developed nuclear fission for weapons and only later sponsored research for the Navy equipment that became the model for most of today's power reactors. And the generalized boosterism that accompanied the power program made honest appraisal of what research there was impossible. Manufacturers who were themselves struggling to make money with their two basic light-water reactors had little incentive to see benefits in the development of new designs. The driving commercial pressure behind nuclear power became one of finding new ways to keep the basic reactors selling and running.

Indeed, that pressure is one reason that the TMI accident occurred. Investigators now believe that the plant's safety systems were compromised by the utility's rush to start operating on December 31, 1978, to qualify for the year's state and federal tax benefits.

There was an unhappy echo of TMI last June: Another Babcock & Wilcox reactor, Davis-Besse in Ohio, suffered 14 successive equipment failures that paralleled the early hours of the TMI accident. This time operators knew they should check the faulty valve that let water escape unnoticed at TMI, and they found it stuck open. Good. But this event also dismayed the industry and its regulators because Davis-Besse had a similar unpublicized accident in 1977—a direct precursor to TMI.

Such lapses underline the moral of the U.S. nuclear saga that NRC commissioner Peter Bradford drew in a 1982 speech. Assured by the AEC and the suppliers of reactors that the future lay with safe, reliable, and cheap atomic power, many utilities (and public officials) bought into the dream without studying the details. "It is precisely this sort of societal failure to face reality that our system of checks and balances is designed to avoid," Bradford observed. But that system, he added, "has never been applied very effectively to nuclear energy." Until now, that is.