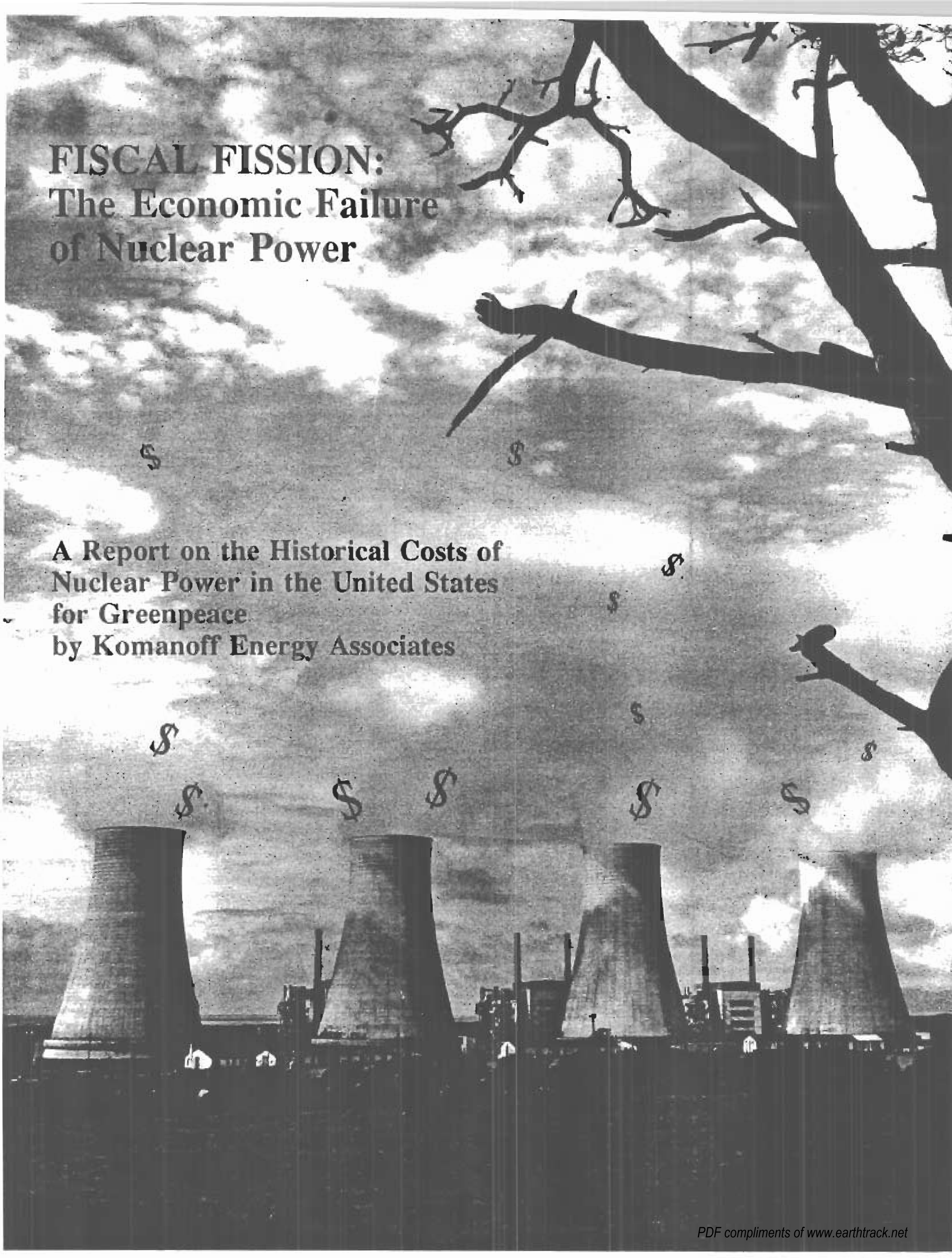
FISCAL FISSION:
The Economic Failure of Nuclear Power



A Report on the Historical Costs of Nuclear Power in the United States for Greenpeace by Komanoff Energy Associates

Although page numbers 30 and 70 have been inadvertently omitted, the text appears in its entirety.

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FISCAL FISSION: The Economic Failure of Nuclear Power

A *GREENPEACE* Report on the Historical Costs of Nuclear Power in the United States

Komanoff Energy Associates
Charles Komanoff
Cora Roelofs

with a Foreword by
Harvey Wasserman and Peter Grinspoon, ***Greenpeace***

December 1992

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Charles Komanoff, Cora Roelofs, Peter Grinspoon, Harvey Wasserman

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FOREWORD

by Peter Grinspoon and Harvey Wasserman, *Greenpeace*

Half a trillion dollars in known costs. Perhaps another half a trillion in additional costs and subsidies. And innumerable expenses which can never be fully accounted for, but which will burden generations to come. All this in exchange for an unstable and declining eight percent of our total energy. And for the potentially limitless liability of plant decommissioning, radioactive waste, unforeseen meltdowns and untraceable health impacts.

That's the bottom line for commercial atomic power.

In 1985, ***Forbes*** Magazine termed the nuclear reactor industry "the greatest managerial disaster in American business history." The editors conservatively estimated the price of the "Peaceful Atom" at $250 billion, which they compared to the total cost of the war in Vietnam and the space program combined, plus another $100 billion.

Now, thanks to Charles Komanoff and Cora Roelofs, we know that the tab is at the very least twice what ***Forbes*** estimated. The price is even higher when we figure in the value of several categories of federal support and societal costs that were excluded for conservatism. These include the value to the nuclear industry of the Price-Anderson Liability Act, which limits utility accountability in case of a catastrophic accident, federal support for uranium fuel production, ideological support, and environmental harms. And the full economic impact of nuclear power will never be known until the ultimate costs of dealing with plant decommissioning, radioactive waste, health costs or (God forbid) a future meltdown are factored in.

In the interests of brevity, we have not attempted to make firm estimates of all of these intangible and inestimable long-term costs. In this report, we have asked Komanoff and Roelofs to provide us only with the tangible and indisputable costs known to be associated with the delivery of nuclear-generated electricity since the quest began. The results are damning enough. It is clear beyond doubt that atomic power has proven to be the most expensive technological failure in American history.

It did not have to happen.

In 1952, the Paley Commission Report, assigned by President Harry Truman to investigate the feasibility of a renewable energy future, predicted there would be 11 million solar-heated homes in the U.S. by the year 1975. The key to America's energy future was with the sun.

But in December, 1953, President Eisenhower inaugurated an "Atoms for Peace" program that swept away the Paley recommendations. Civilian nuclear power was politically and economically bound to the American nuclear weapons program, a pillar of the Cold War. It would ultimately swallow the lion's share of federal dollars for energy research.

Komanoff and Roelofs begin to show us the extent of our government's tilt towards the nuclear option. The numbers lead us to conclude that had the Federal government not forced the nuclear industry into being, and subsidized it to the hilt, nuclear power would be merely a bad academic memory, a sideshow curiosity in the annals of failed technologies.

As Komanoff and Roelofs document here for the first time, this rush away from renewables and efficiency cost American taxpayers and ratepayers hundreds of billions of dollars. In research and development, in fuel production subsidies, in regulation, in security and public relations, in waste disposal, in melt-down insurance, in export subsidies, in tax incentives, and in a whole host of minor and major giveaways, the nuclear power industry has lived off the public dole for four decades, with no end in sight and, until now, with no one really counting. In construction and operating cost overruns, reactor down-time, equipment failure and the preoccupation of some of the best of the nation's technical minds for four decades, it has sapped the strength of our biggest utilities, bankrupted several others, and deprived our nation of the chance to build a solid, cutting-edge energy economy based on technologies with a safe, reliable future. Indeed, had only some of the money sunk into atomic power gone instead to develop renewables and efficiency, the American economy would be considerably more stable, stronger, more competitive, and far closer to full employment.

Despite this terrible failure, the reactor industry is now demanding taxpayer and ratepayer help to build yet another generation of atomic power plants, stumping hard for a new round of massive subsidies and public risk.

During his campaign for the presidency, Bill Clinton repeatedly told prospective voters there would be no new commercial reactors built in the United States under his administration.

As early as 1980, then-Governor Clinton, writing in the ***American Oil & Gas Reporter***, cited Charles Komanoff as "a leading nuclear power economist" who "dispelled the notion of 'cheap' nuclear power." Clinton went on to say that "on the conservation side, Mr. Komanoff has found that a modest improvement in U.S. energy efficiency from 1973 to 1978 has contributed three times the amount of energy generated by all U.S. nuclear power plants in 1978." Indeed, said Clinton, Komanoff's findings confirmed those of the famed Harvard Business School study ***Energy Future***, which urged "the rapid development of conservation and solar energy as the best alternative to the nation's dependence on foreign supplies." Clinton and Gore's 1992 ***Putting People First*** confirms too that today the winning ticket "oppose(s) increased reliance on nuclear power."

But Clinton's victory alone will not decide the case. The question of whether to build new reactors is certain to arise with all the added force the industry and its backers can muster, with all the desperation of an industry headed toward extinction.

So we turned to Komanoff Energy Associates (KEA) to put a price tag on nuclear power to help stave off a future energy financial disaster. Since the mid-1970s, Charles Komanoff, as then-Governor Clinton noted, has been the leading authority on the realities of U.S. nuclear power. KEA's database ranks as the most comprehensive and complete single source on national nuclear electric production data. This analysis will stand as the benchmark against which all future estimates of the true bottom-line "unchallengeable" costs of nuclear energy must be measured.

Nor does the Komanoff-Roelofs analysis stand alone. According to Joseph Colvin of the Nuclear Management and Resources Council, an industry group, "there's a broad recognition that the generation of nuclear power is at risk from an economic perspective." Indeed, in the 1990s it is becoming clear that this "largest managerial disaster in American business history" is becoming even larger by the minute. For example:

- As of 1992, no reactor ordered since 1973 had been completed — a stretch of almost twenty years.

- As of 1992, no new reactor orders had been placed since 1978. The two placed in 1978 were subsequently cancelled.

- A public opinion poll conducted by the firm of Frederick/Schneiders in March 1992, found 65% of Americans opposed to the construction of new commercial reactors.

- From 1989 through late 1992, five licensed, legally operable commercial reactors were shut prematurely. One, Long Island's Shoreham, was shut essentially due to public uproar over an unworkable evacuation plan. Another, Sacramento's Rancho Seco, was voted shut in a public referendum, in large part because its customers no longer believed it economic to operate. A third, Yankee Rowe, in western Massachusetts, was closed when its owners balked at the high cost of conducting major tests on its embrittled core. A fourth, Fort St. Vrain in Colorado, was shut because chronic equipment failure made it uneconomical to operate. And on November 30, 1992, as this report is being issued, the owners of California's San Onofre Unit One are voluntarily shutting it down because they deemed it too costly to continue operating.

- In the summer of 1992, Portland General Electric, owner of the Trojan reactor, agreed to shut it by 1996 because continued operations there were a poor investment.

Thus, in little more than three years, more than 5% of all licensed commercial reactors in the U.S. were marked for premature retirement by their owners. Yet the industry continues to press ahead for a "new generation" of atomic power plants, even though no working prototype of such a plant exists and the promise of its producing safer, cheaper electricity remains pure speculation, hauntingly similar to what was promised back in the "too cheap to meter" 1950s.

In desperation, the nuclear industry has turned away from economics to justify this new plunge into the atomic abyss and toward none other than its oldest nemesis: the natural environment. In attempting to paint this technology "green," the industry has used its $20 million annual advertising budget to sell nuclear power as a "clean" technology. Prime among its claims is the specious idea that atomic energy can alleviate global warming.

The claim is particularly ironic since many of the industry's chief backers, such as former White House Chief of Staff John Sununu, have vehemently argued for years that there is no global warming problem in the first place. Apparently untroubled, the claim that reactors will lessen CO_2 output and thus save our atmosphere has become a staple of the highly-financed atomic pitch.

But a host of leading energy experts, scientists and environmentalists bitterly dispute this contention. Energy expert Bill Keepin, for example, maintains that to replace coal-fired plants worldwide and thus significantly diminish greenhouse gas emissions from electrical generation, more than 1,000 large reactors would have to be built in the U.S. by the year 2025 and some 5,000 worldwide. (There are now 110 reactors in the U.S. and just over 400 worldwide).

These additional reactors would cost a minimum of $5 trillion — a conservative estimate. Yet global warming would still worsen because electrical generation accounts for just one-sixth of the greenhouse gas emission problem. The other five-sixths of the problem comes from cars, industrial processes, deforestation, agriculture and other sources, none of which can be curbed by increased reliance on nuclear power.

Overall the idea of atomic energy as an environmentally benign source of power is widely viewed as absurd. The problems of radioactive emissions and waste, the specter of Three Mile Island and Chernobyl, and other ecological impacts give the technology a well-deserved image as possibly the most dangerous and destructive humankind has ever produced.

Exclusive of this frantic new effort to revive it, atomic power is clearly on its way out. For one thing, the end of the Cold War and the halt in the construction of new nuclear weapons has undermined the commercial industry's primary base of trained personnel. The "Peaceful Atom" grew out of warhead production, and the two industries always operated side-by-side, sharing personnel, R&D and some infrastructure. In particular, promoters of a new generation of reactors were counting on the development of a new reactor to produce warhead tritium — funded by the Department of Energy — which would serve as a prototype for new commercial plants.

But in 1992, in the wake of the end of the Cold War, the New Production Reactor was cancelled. With the shutdown of much of the weapons production network, the commercial industry lost a major piece of its foundation. Moreover, since the 1986 Chernobyl reactor accident in Ukraine, nuclear power has been in rapid decline throughout Europe and the rest of the world, with the possible exceptions of Taiwan and Korea. Even the nuclear programs in France and Japan, often touted as exemplary, are running into serious technical and financial problems, plus rapidly mounting public opposition.

In the U.S., however, in the face of accelerating collapse, the industry won its greatest legislative prize since the 1950s. With the National Energy Bill, signed by George Bush on October 24, 1992, the industry won the legal right to shut citizens out of the reactor licensing process, with the new "one-step" licensing. It got the promise of substantial taxpayer money for research on new reactors. And it allows DOE to circumvent EPA regulations and limit citizens' rights to decide if they want a nuclear waste dump in their state's borders. Certainly, the 80% of Nevada citizens who oppose the high level nuclear waste dump slated for their state — a state without a commercial nuclear reactor — lost out on Bush's Energy Bill.

In the realest sense, the Energy Bill was the industry's ultimate admission that it cannot compete in a free society. Only by voiding the public's right to intervene in plant licensing, and by depriving Nevadans of the right to ban radioactive waste dumping could the industry proceed. Only with yet another round of massive taxpayer subsidies could it develop a new generation of plants.

For by the early 1990s, despite immense government subsidies, nuclear power could not compete with energy efficiency and renewables, such as solar power. In 1989, for example, the ratepayers of the Sacramento Municipal Utility District (SMUD) voted to shut their Rancho Seco nuclear plant and put the economics to the test. SMUD management was taken over by S. David Freeman, who formerly managed the Tennessee Valley Authority.

With support from the elected SMUD board, Freeman began replacing Rancho Seco's capacity with an aggressive program built around efficiency and renewables. Relying on a mix of solar, wind, natural gas, increased efficiency, conservation, and the planting of 500,000 shade trees to cut down air conditioning demand, Freeman in early 1992 termed his plan "ahead of schedule and under budget." Contrary to industry predictions, rates have held steady following the Rancho Seco shutdown, making Sacramento's success an example for other utilities around the nation to move away from nukes and toward renewables and efficiency.

Put simply — were the marketplace for electricity truly free and unfettered, atomic power at this price simply could not compete. Not with coal, not with oil, not with natural gas, not with wind, not with increased efficiency and conservation, and not with photovoltaic cells and other green technologies now dropping rapidly in price.

Increasing energy efficiency, using fully developed technology now available, is commonly estimated to cost from 0.5 to 4.0¢/kWh. Ancillary environmental "costs" are all on the plus side, while the production and installation of these technologies has been shown to produce two to ten times the jobs per dollar as reactor construction and operation. According to the Worldwatch Institute, "generating 1,000 gigawatt-hours of electricity per year requires 100 workers in a nuclear power plant and 116 in a coal-fired plant, but 248 in a solar thermal facility and 542 on a wind farm."

And the capacity is enormous. It has been widely established that all of the electricity which is currently generated by nuclear reactors could be rapidly displaced with increased efficiency alone, at enormous long-term cost savings.

Wind energy, using American-designed, American-built machines, has now been widely demonstrated, with unquestioned reliability, at five cents per kilowatt hour, including all financing and unseen environmental costs. ***Wind Potential in the United States***, a recent study by the Pacific Northwest Laboratory for the Department of Energy found that the windpower available in just a dozen states in the middle of the country is sufficient to provide a quarter of current U.S. electric power needs. With the next generation of ultra--efficient wind machines, these same sites could meet all U.S. electric power needs.

Other renewable production technologies fare almost as well. Photovoltaic cells, thin chips which transform sunlight directly into electricity, began coming into production in the early 1990s in the range of ten cents per kilowatt hour, with the price expected to drop rapidly. The U.S. had the lead in this technology in the late 1970s, but the Reagan-Bush administrations starved federal research in this area, handing the lead by default to the Japanese and Germans. Sanyo recently began marketing a photovoltaic device capable of transforming a rooftop into an electric generator. Should the Japanese dominate the solar market, they will become the "Saudi's of the sun."

Other renewable and efficiency technologies such as tidal power, ocean thermal, geothermal, co-generation, and biomass conversion could totally revolutionize energy and electricity production in the 1990s. In such a market, the most charitable term to apply to nuclear power is "obsolete." The complexity of the technology, the failure of the industry to make significant engineering or operational breakthroughs, the enormous expense, the mounting piles of radioactive waste and the rising tide of political resistance make the future of atomic power chancy at best.

But raw political power forced this technology into commercial application in the first place. And the immense clout of the industry could do it again. Such a strategy will succeed only if the public fails to comprehend the true costs involved. Until now, those numbers have never been compiled for all to see. Now that they are, we see clearly that atomic energy is the most expensive technological failure in human history. At 9¢/kWh — minimum — with half a trillion dollars invested already, with hundreds of billions more unaccounted for (possibly raising the price of nuclear power to at least 16¢/kWh), there is simply no prospect of economic success. As of 1992, these are the bottom-line numbers. But the meter is still running, and will for generations to come, even after the last reactor is shut.

As Komanoff and Roelofs have shown, a simple accounting would indicate we took a wrong turn back in 1953 when we turned away from the sun and toward the reactor. In the 1990s we are faced with a re-run of pretty much that same choice, except with forty years of experience and cost-accounting under our belts.

We'll have no one to blame but ourselves if the mistake is repeated again. And this time, the margin for error — economically and ecologically — is far smaller.

PREFACE

by Charles Komanoff

In May 1979, six weeks after the meltdown at Three Mile Island, Ralph Nader assailed nuclear power as fundamentally "too unsafe, too expensive and too unnecessary." Events in the intervening years have confirmed Ralph's pronouncement — the Chernobyl disaster, investor losses from reactor cost overruns, and the emergence of an energy-efficiency profit center within the utility industry, to name a few. As safe energy activists have grasped from the beginning — long before Three Mile Island — nuclear power's lack of safety, economics and necessity go together.

The fundamental nature of nuclear technology — the very radioactivity and energy density that mesmerized the first atomic physicists — makes it inherently dangerous and in need of an unprecedented and unaffordable degree of physical and social control. Nuclear power's high cost, in turn, undermines the need for it, as users, inventors and institutions develop more effective technologies and — yes — lifestyles, that allow us to function without it.

October 1993 will mark the 20th anniversary of the last order for a commercial U.S. nuclear power plant that made it through the pipeline. Old reactors are being retired faster than new ones are being brought on line. Capital that previously was funneled to new power plants is financing efficient light bulbs and machinery in factories, homes and offices. Increasingly, energy studies at the local, state, national and international levels are mapping energy paths that reduce fossil fuel use without nuclear power. Progressive utilities are coming to realize that their future lies in providing "least-cost" electricity services through maximal end-use efficiency.

Today, thanks to a resourceful safe energy movement, nuclear power is at bay. Nevertheless, while the reality of nuclear power grows ever dimmer, the idea of it refuses to die. Federal officials and reactor corporations persist in trying to dictate a nuclear future for U.S. energy policy. Through their influence, several hundred million federal taxpayer dollars still go each year to concoct new reactor models that, they promise, will be miraculously free of the problems that have plagued the hundred-or-so still running.

Thus, even as nuclear power atrophies, the nuclear debate is very much with us — courtesy of Bechtel, General Electric, Westinghouse and the Department of Energy. In this climate, it seems important to track down exactly what has already been spent on nuclear power to date; to chart the what, when and who of every dollar that ratepayers and taxpayers have been made to sink into the nuclear enterprise. Knowing the magnitude of these costs to date, the nation could be better positioned to avoid throwing more good money after bad. We would also have a solid benchmark to evaluate the considerable investments that must be made to fully develop efficiency and renewables; those squeamish about hundreds of millions should reflect that nuclear power has absorbed many hundreds of *billions*.

Although the idea for this report originated with Greenpeace, I grabbed at the opportunity to participate. Over the past 20 years I have probably paid more attention to nuclear costs than any other participant in the nuclear power debate. During this time, Komanoff Energy Associates has painstakingly compiled virtually every relevant cost datum on U.S. nuclear power — construction costs, operating costs, repair costs, downtime rates (capacity factor), and the like. These verifiable, empirical data on nuclear costs form a powerful antidote to the tendency of nuclear promoters to confuse expectation with fact, and hope with reality, as former Harvard Business School Professor I.C. Bupp once put it.

But for all my and others' data gathering, no one has ever assembled all of the costs of nuclear power in one place. No one has compiled industry-wide capital costs, operating costs, and "back-end" costs such as decommissioning set-asides and waste disposal payments, and combined these with entries such as cancellation write-offs that are usually relegated to footnotes but which are part of the cost of nuclear power just the same. Nor have I personally had a chance to delve into the notorious but murky area of federal subsidies, to determine how much taxpayers spent to launch the nuclear industry and keep it afloat.

Now, thanks to Greenpeace, and to KEA research analyst Cora Roelofs, who exhaustively researched the subsidies issue and organized the utility ratepayer figures as well, the full cost numbers are here for all to see. And they're worse — bigger — than I had expected.

During 1968-1990 — essentially the full history of U.S. commercial nuclear power for which data was available — utilities spent $389 billion to generate 5.4 trillion kilowatt-hours of nuclear power; this averages out to 7.2¢ per kWh (all figures here are in 1990 dollars). Over the same period, fossil-fuel power — electricity from coal, oil and gas — cost around 4¢/kWh to generate. This 3¢/kWh difference works out to an excess nuclear generating cost of $160 billion, not even counting federal subsidies. While part of this bill was picked up by unlucky investors who got caught up in regulatory disallowances or utility bankruptcies, most was paid by consumers and businesses through high utility bills.

Moreover, most of these costs came due within the past decade, when nuclear power costs really went through the roof. During this time, nuclear power has cost around $15 billion *extra* a year compared to fossil fuels, an amount equal in cost to the destruction from

Hurricane Andrew every 14 months. Since the early eighties, the equivalent of 1/300th of U.S. output — a big resource in a huge economy like ours — has been wasted by using nuclear power to produce electricity less efficiently than even through traditional fossil fuels. Equally important, the industry has imposed a one-dimensional energy policy that blocked a sustainable, least-cost path emphasizing a transition to renewables — the one energy option compatible with a healthy biosphere *and* atmosphere.

Industry policy and government policy have never been far apart on nuclear power. Over the 1968-1990 period, the federal government poured $83 billion (1990 dollars) into nuclear power, dispensing this largess through dozens of conduits from free R&D to outright tax breaks. This subsidy adds 1.6¢/kWh to the cost of nuclear power during 1968-1990, making an overall total cost of 8.8¢/kWh and a national *excess* nuclear cost (vis-a-vis fossil fuels) of almost $250 billion. Indeed, add the $20 billion that government and utilities spent on nuclear power during its 1950-1967 pre-commercial period, and the excess cost surpasses $250 billion. To sum up, **during 1950-1990, the United States spent around $500 billion to produce nuclear-powered electricity averaging at least 9¢/kWh and costing, in the aggregate, $250 billion more than equivalent fossil-generated power (all figures in 1990 dollars).**

No doubt some will blame these costs on the antinuclear movement for delaying licenses and coercing utilities into installing extra safety measures. In reality, these citizen heroes functioned as a vital market corrective, forcing an industry sheltered since birth to reduce the risks it imposed on the public. That reactors cost more to melt down less, indicates that high costs are intrinsic to nuclear power and not an artifact of "over-regulation."

We are more than fortunate that the safe energy movement struggled and eventually prevailed. Imagine if the nuclear industry had not been stopped in its tracks after a mere hundred or so reactors, but had expanded to the thousand envisioned by its government and corporate sponsors.... the half-trillion-dollar cost counted here, staggering though it is, would have been just a small down payment.

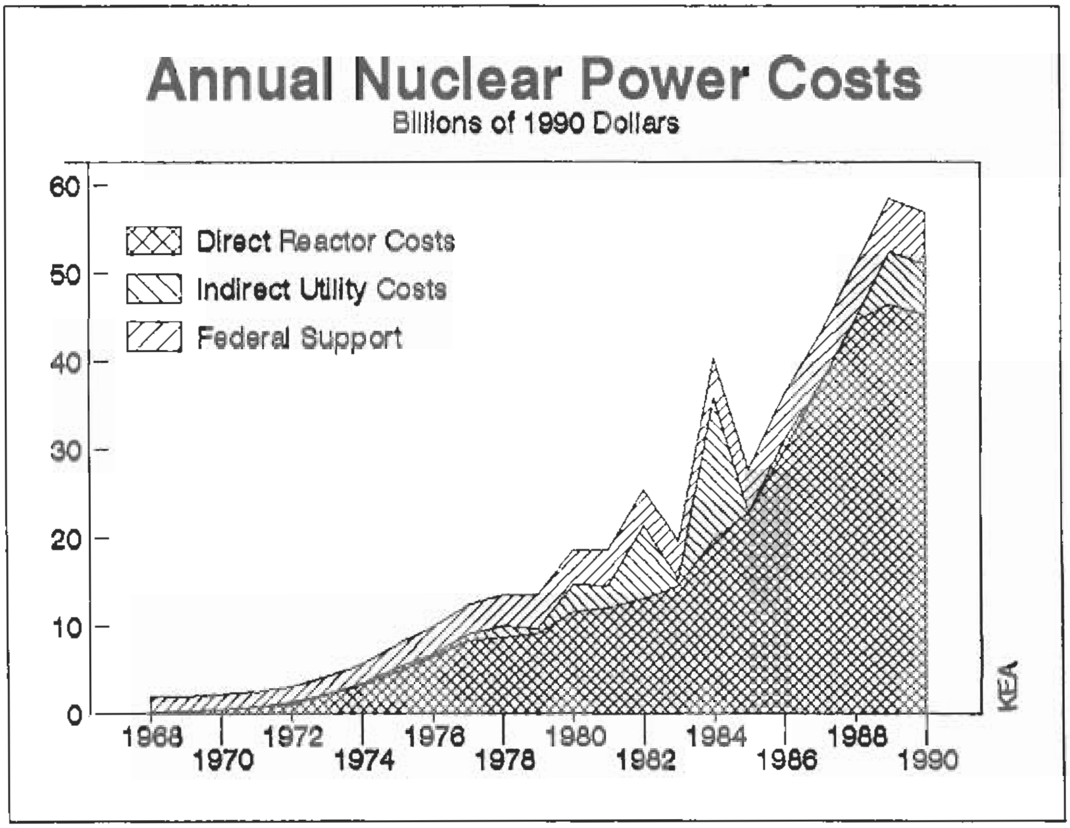
SECTION 1

HISTORICAL COSTS OF NUCLEAR POWER IN THE UNITED STATES

Introduction and Summary

From 1950 through 1990, U.S. taxpayers, consumers and investors spent an estimated $492 billion to develop and obtain nuclear power. Four-fifths of this amount, $396 billion, was expended by utilities; most of this was passed through, to and paid by, utility customers, except for a small portion of cancelled plant costs and construction cost overruns which was absorbed by utility investors. The remaining 20 percent, $96 billion, was spent by the federal government and, thus, borne by taxpayers. **(All cost figures are expressed in constant 1990 dollars, except where noted.)**

Figure A



These $492 billion in costs represent a minimum figure for resources spent on nuclear power through 1990. They reflect only current bare-bones estimates by government or industry of the ultimate cost to bury nuclear wastes and decommission nuclear plants. They include only governmental expenditures that were fully quantifiable and that directly assisted civilian nuclear fission technology, excluding some programs in DOE's military divisions that benefitted civilian power, and also excluding all support of nuclear fusion. The $492 billion cost figure also excludes the cost of the harms done by radiation released in nuclear plant operations, accidents and the fuel cycle. Nor does the cost capture the immense economic benefit conferred on nuclear power through its decades of government-enshrined status as the "official technology" for meeting future energy needs.

As discussed in this report, these excluded costs and subsidies could well total $376 billion (in 1990 dollars) — three-fourths as much as the $492 billion in directly quantified utility and government costs — even without counting the almost certain escalation in future waste and decommissioning costs. Nevertheless, because these costs cannot be pinpointed with the same precision with which we have established utility and direct government costs, we have not included them in the main conclusions of the report.

Of the $492 billion in thoroughly quantified costs, slightly under $20 billion, or 4%, was spent during 1950-1967 — the "pre-commercial" nuclear era. During this period, the federal government expended $13 billion in research and administrative funds, as well as considerable prestige, to nurture the fledgling nuclear power industry; utilities themselves spent $7 billion building and operating a dozen prototype reactors.

The remaining $472 billion was expended after Jan. 1, 1968. On that date, the country's first two commercial-size reactors, 575-megawatt Connecticut Yankee and 450-MW San Onofre 1, entered service, marking the beginning of nuclear power as a commercial enterprise in America.[1] Of this $472 billion, $83 billion (18%) has been expended by the federal government, and the remaining $389 billion by utilities. Moreover, although our detailed cost accounting stops at the end of 1990, it is apparent that total expenditures on nuclear power in the U.S. are still increasing at a rate of around $50 billion a year.

[1] This paragraph understates somewhat nuclear power outlays during 1950-67 as a share of the total, since both research expenditures and reactor capital investment are amortized here, resulting in allocating considerable expenditures to later years. Conversely, of the $6.6 billion in utility expenditures included in the $19.5 billion amount charged to 1950-67, some was incurred in operating small non-commercial reactors after 1967. Although these conventions make it hard to pinpoint the precise amount spent on nuclear power during 1950-67, the actual share was probably 4-6% of the 1950-90 total.

TABLE 1

U.S. NUCLEAR POWER COSTS (Millions of 1990 Dollars)

	Direct Reactor	Indirect Utility	TOTAL UTILITY	Federal Support	TOTAL
1950-1967	6,596		6,596	12,945	**19,541**
1968-1990	340,774	48,152	388,926	83,343	**472,269**
TOTAL	**$347,370**	**$48,152**	**$395,522**	**$96,288**	**$491,809**

Utility Costs

The utility costs fall into two categories: *direct reactor costs* and *indirect utility costs*.

Direct reactor costs include construction charges, operation, fuel, and decommissioning set-asides. Utilities have made these expenditures to build and run nuclear plants, and, for the most part, have recovered utility expenditures from customers in return for providing nuclear generation. During 1968-90, these direct reactor costs totaled $341 billion (again, costs are in 1990 constant dollars).

Utilities have incurred *indirect utility costs* on a company-wide rather than a plant-specific basis. Indirect utility costs in this report consist largely of money spent on plants that were cancelled. However, they also include levies that utilities have made — or have indicated they will need to make (per their own cost accounting) — to pay for nuclear waste disposal and reactor decommissioning, beyond the routine allowances built into rates through the fuel adjustment clause (spent fuel charges) and depreciation (decommissioning).

Because indirect utility costs aren't tied to specific nuclear electricity production, they are often ignored when nuclear per-kWh generating costs are compared with those of fossil fuels or renewables; yet they are also a real cost of the effort to deploy nuclear power. They total $48 billion during 1968-90.

In return for the expenditures itemized above and throughout this report, U.S. households and businesses obtained more than 5.4 trillion kilowatt-hours of electricity during 1968-90 — 12 percent of total utility power generation.[2] Averaged over the period, and expressed in 1990

[2] As tabulated in this report, commercial U.S. nuclear power plants generated 5,369,274 GWh of electricity during 1968-90; the smaller, non-commercial reactors whose costs are tabulated here generated an additional 63,137 GWh during 1961-90, for a total of 5,432,411 GWh. According to *Monthly Energy Review* (covering 1973-90) and U.S. DOE, *1981 Annual Report to Congress*, Vol. 2, Table 66 (for 1968-72), U.S. nuclear plants generated 5,798,568 GWh in the same period, exceeding the generation tabulated here by 366,157 GWh. This difference is accounted for by two categories of nuclear power generation: (i) generation

dollars, nuclear power cost 7.2¢/kWh — 6.3¢/kWh in direct utility costs, and 1.0¢/kWh in indirect costs (sum differs from total due to rounding).

Federal subsidies added another 1.6¢/kWh over 1968-90, resulting in a total average cost for commercial nuclear power of 8.8¢/kWh during 1968-90 (in 1990 dollars). ***When expenditures and generation from 1950-1967 are added, during the entire period 1950-1990 commercial nuclear power cost an average of 9.02¢/kWh (in 1990 dollars).*** Moreover, for 1990 alone — the last year for which reasonably complete cost information was available — the average cost of commercial nuclear power was 10.2¢/kWh.

As noted above, we have excluded several categories of likely costs, government subsidies and societal harms from our total. **Adding estimates of these difficult-to-quantify costs and subsidies to the tally of included costs would almost double our estimate of the average cost of a nuclear kWh.**

TABLE 2

U.S. NUCLEAR POWER COSTS (1990 Dollars)

	Cents Per Kilowatt-hour		
	1950-1990	**1968-1990**	**1990 Alone**
Direct Reactor Costs	6.37	6.35	8.06
Indirect Utility Costs	0.88	0.90	1.03
TOTAL UTILITY COSTS	**7.25**	**7.24**	**9.09**
Federal Support	1.77	1.55	1.07
TOTAL	**9.02**	**8.80**	**10.15**

Direct and Indirect Costs Over Time

Not surprisingly, both direct and indirect utility costs have varied widely over time as nuclear power itself has undergone changes in engineering, regulation and governance. Although generalizations can obscure year-to-year twists in the underlying data, an overall picture can be gleaned by separating the commercial nuclear power era into the following four periods (all costs are in 1990 constant dollars):

- **Early Commercial Era, 1968-73**: Direct reactor costs averaged 2.89¢/kWh. The largest component was capital and construction costs, accounting for 1.74¢/kWh.

"power ascension," i.e., prior to commercial operation; and (ii) commercial production prior to the start of the next calendar year. Category (i) generation, the larger of the two, is relected in this report as a credit against capital costs booked by utilities (based on the value of displaced fossil generation); however, our omission of category (ii) generation, which was dictated by our database convention, does bias our estimates of per-kWh nuclear costs upward slightly, perhaps by around one-tenth of a cent.

Indirect costs were 0.22¢/kWh (about equally for Nuclear Waste Fund One-Time Fees and cancelled plants), resulting in average total utility costs of 3.11¢/kWh.

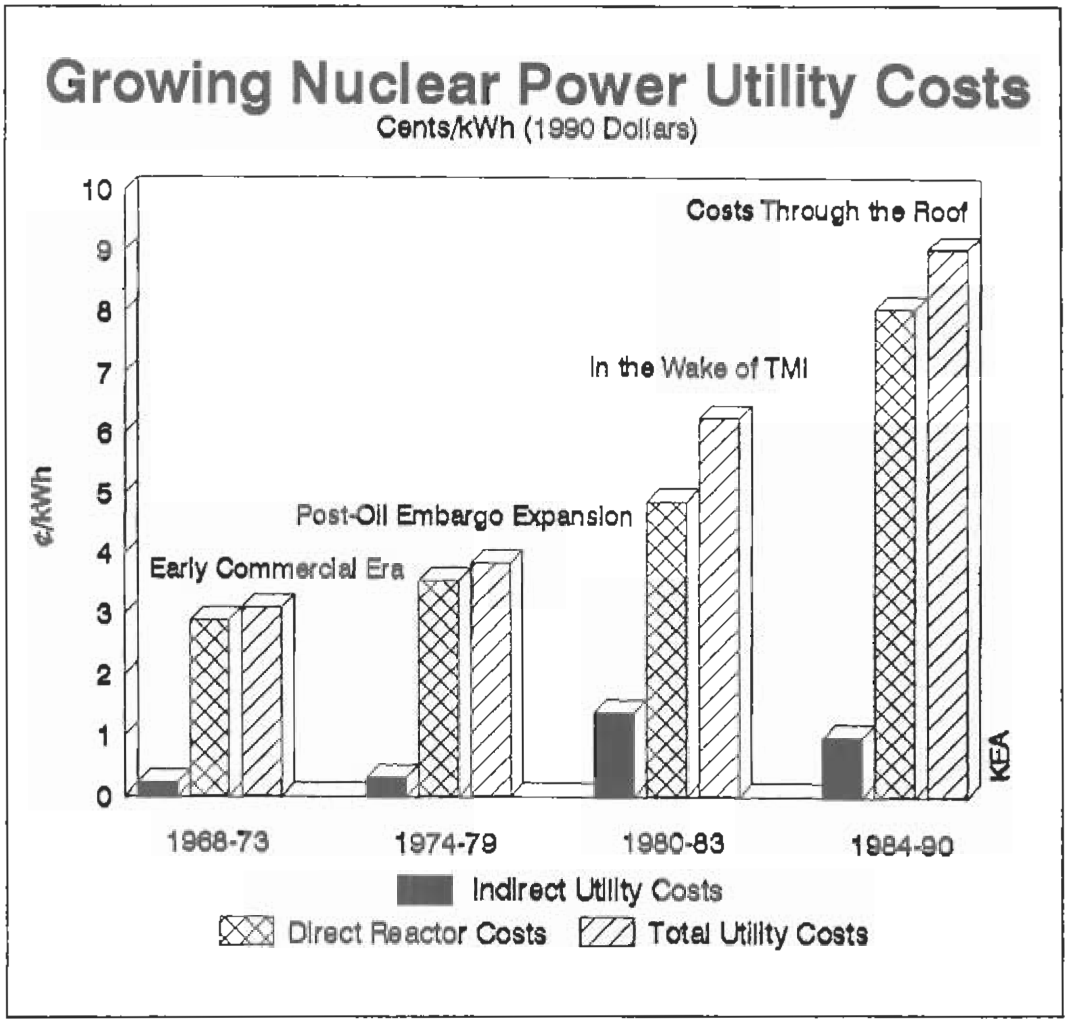
- **Post-Oil Embargo Expansion, 1974-79**: Costs averaged 3.55¢/kWh direct and 3.85¢/kWh total, or close to 25% higher than in 1968-1973. The increase was primarily due to O&M and Capital Additions costs, which more than doubled from the prior (1968-1973) period. Cancellation charges accounted for the largest share of indirect costs, which averaged 0.30¢/kWh.

- **In the Wake of Three Mile Island, 1980-83**: Capacity factors plummeted and O&M costs, capital additions, and plant cancellations skyrocketed, in the wake of the Three Mile Island accident. Utility costs rose to an average of 4.88¢/kWh direct and 6.27¢/kWh total. Average costs would have risen even more steeply but for the slowdown in plant completions which kept the rising costs of new reactors out of utility ratebases. Only 2,000 MW per year of nuclear capacity went on line during these four years, a mere one-third of the 6,000 MW annual completion rate during the prior (1974-79) period.

- **Costs Through the Roof, 1984-90**: Utility costs took their biggest jump, to an average of 8.08¢/kWh in direct costs and 9.06¢/kWh total. Several dozen extraordinarily expensive new reactors finally graduated from construction limbo and entered utility ratebases; as a result, construction charges leaped from 1.89¢/kWh averaged over the prior history of commercial nuclear power (1968-83), to 4.63¢/kWh. Plant cancellations and rising O&M and capital additions costs also took their toll. Indeed, charging cancelled plant costs to the year in which cancellations were announced — a simplifying convention adopted here — produces a record high total cost of 11.82¢/kWh for 1984, the year in which utilities scrapped 11 reactors with a sunk investment of almost $13 billion.

  Direct costs per kWh grew steadily during 1984-88 until leveling off in 1989 and declining somewhat in 1990, primarily because of improving capacity factors. Yet even in 1990, and even after adjusting for general inflation, a nuclear kilowatt-hour was costing utilities and their customers almost three times what it cost in 1973 — 9.1¢/kWh in 1990 versus 3.2¢/kWh in 1973.

Figure B



Federal Subsidies over Time

We estimate that the federal government subsidized the nuclear industry with $97 billion dollars (1990 dollars) of expenditures during 1950-1990. This estimate of federal outlays *excludes* vast categories of government support for nuclear power, most notably the Price-Anderson Act which shielded utilities from full liability for costs to society from reactor accidents. As well, we have excluded from our estimate a dozen other categories of public subsidy ranging from the ideological support which crowned nuclear power an "official technology" and won investor confidence, to the more concrete support the nuclear industry obtained from the U.S. Bureau of Mines uranium exploration programs. Likewise, we have omitted estimates of the harm to people and the environment from nuclear radiation released in fueling, operating and cleaning up nuclear power plants.

Although we have not included these categories in our tally (due to difficulties in pinpointing their costs), their value to nuclear power has been enormous. Based on painstaking analysis by experienced researchers, the total of these excluded categories could reasonably be estimated at $376 billion (1990 dollars) — or almost four times the $97 billion in federal support that we have included below. (See "Excluded Costs and Subsidies" in Section 2 for a full discussion.)

- **Establishing an Industry, 1950-1973** The goal of early government sponsorship of the nuclear power program was to launch a commercial nuclear power industry. However, it was not until 1973 — over two decades into the process — that utilities spent more on nuclear power than did the federal government; even then, federal support was almost 3 cents per kWh produced. During this period, federal support for nuclear power increased at an average annual real rate of 12%.

- **Post-Reorganization, 1974-1984** The "graduation" of civilian nuclear power to commercial status did not result in a lessening of federal aid. Indeed, the government's support for nuclear power escalated following the Energy Reorganization Act of 1974, which separated the promotional and regulatory duties of the Atomic Energy Commission. Even as utilities cancelled dozens of reactor orders during this period, thereby dampening the need for uranium, federal R&D dollars were aimed at developing the "next" nuclear technology — the breeder reactor — whose raison d'être was uranium conservation. Federal expenditures for nuclear R&D dipped only after cancellation of the Clinch River Breeder Reactor in 1984. During 1974-1984, federal support added an average of 1.58¢/kWh to the cost of nuclear power.

- **Institutionalizing the Subsidy, 1985-1990** In recent years, despite strong support for the nuclear path from the Reagan-Bush administrations, budgetary pressures have forced federal R&D expenditures down from the high levels of the late 1970s and early 1980s. Nevertheless, White House and "DOE support for [nuclear] technologies has insulated them from major reductions," according to a 1987 General Accounting Office report, even as non-nuclear energy R&D suffered severe cutbacks in the 1980s. In 1990, DOE spending for civilian nuclear power (fission) R&D was more than five times that for renewable energy resources. Moreover, due to sustained growth in tax breaks to nuclear utilities, the federal subsidy to nuclear power actually grew at an average annual rate of 10% during 1984-1990. In 1990, forty years after the federal government began subsidizing commercial nuclear power, 10.5% (1.07¢) of the cost of a nuclear kWh was still being funded by the federal government.

Nuclear Costs vs. Fossil Fuel Costs

As noted earlier, nuclear power costs averaged 9.0¢/kWh (in 1990 dollars) during 1950-1990, and 8.8¢/kWh during 1968-1990. Also as noted, in the latter period, approximately 7.2¢/kWh was for direct costs — brokered through electric utilities — and the other 1.6¢ provided by federal taxpayers. Although a comparable analysis of fossil fuel generating costs is beyond our scope, it is safe to say that **the 8.8¢/kWh average cost of nuclear power during 1968-1990 is *twice* the comparable cost of electric power generation from coal, oil or gas during the same period.**

Consider the early 1970s, for example. In 1971, production expenses — fuel plus O&M — for the nation's "steam-electric" fossil-fueled utility stations averaged only 4.7 mils/kWh, or a mere ½¢/kWh.[3] Capital charges probably averaged even less; based on rough average capital costs of $150/kW, a nominal 12% "fixed charge rate" and an assumed average 60% capacity factor, plant capital charges were even less, around 3-4 mils/kWh. Thus, total average fossil power costs in 1971 were around 0.8¢/kWh, or roughly 2.5¢/kWh converted to 1990 dollar terms. This is slightly less than utility generating costs for nuclear plants for 1971, and two-thirds less than the average utility nuclear cost for the full 1968-1990 period.

To be sure, fossil generating costs rose throughout the 1970s, as prices rose to pay for plant pollution controls, mine safety and health measures, and oil and coal producers' windfall profits. In 1980, for example, fossil production expenses averaged 23.5 mils/kWh, or 5 times the 1971 level.[4] Average capital charges probably tripled as well, to around 10 mils, implying total 1980 fossil generating costs of 3-3½¢/kWh, or 5¢/kWh in 1990 dollars. Real fossil generating prices have dropped since then, however. Fuel costs, which accounted for around 40% of fossil power costs in 1980, fell by one-sixth in nominal terms and by almost one-half in real terms to 1990. In round numbers, fossil generating costs appear to have averaged 4-5¢/kWh in 1990, or half of the 9.1¢/kWh utility cost for nuclear electricity in that year.

For 1968-1990 as a whole, while nuclear averaged 7.2¢/kWh (in 1990 dollars, exclusive of federal taxpayer subsidies), the fossil average is probably around 4¢/kWh (in the same terms). Taxpayer subsidies for fossil power during 1968-1990 were probably only several mils/kWh. Thus, counting subsidies, nuclear costs averaged 8.8¢/kWh, as noted, while fossil power costs were in the range 4-4½¢.

Based on the foregoing, the typical nuclear kilowatt-hour produced during the 1968-1990 period cost utility ratepayers around 3¢/kWh more than comparable fossil-generated electricity. When this difference is aggregated across the 5.4 trillion kWh from commercial nuclear plants tabulated in this report for 1968-1990, the excess ratepayer costs caused by nuclear generation equates to approximately $160 billion (in 1990 dollars), or $650 for every American adult and child now living.

This excess nuclear power cost does not include direct federal support, which we estimate

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3 U.S. Federal Power Commission, *Steam-Electric Plant Construction Cost and Annual Production Expenses — 1971*, p. xiv.

4 U.S. DOE, *Thermal-Electric Plant Construction Cost and Annual Production Expenses — 1980*, p. 8.

totaled $96 billion (1990 dollars) through 1990; nor does it count nuclear costs still to come due, ranging from high capital and O&M costs built into utility rate structures over the remaining life of today's reactors, to the almost certain bailout of decommissioning and waste disposal costs by taxpayers and/or ratepayers. Nor does this estimate of $160 billion excess nuclear costs reflect the $376 billion in further government support and public harms that has been estimated by other researchers but which we have excluded from our main conclusions. Nor does it reflect the extraordinary waste, both economic and environmental, from the failure of the federal government and the utility industry to provide energy through increased efficiency (at 0-4¢/kWh) and renewables rather than fossil *or* nuclear power.

Nuclear Power Costs Since 1990

Because most of the data-gathering and "number crunching" for this report took place in the first half of 1991, the report covers only U.S. nuclear power experience through 1990 — the most recent year for which reasonably complete information was available. This section gives a brief overview of cost and performance since then.

Direct Utility Costs

1. ***Number of Reactors*** Three new nuclear units have entered commercial service — Limerick 2 (January 1990) and Comanche Peak 1 and Seabrook (both August 1990). (Note that in this report we excluded units prior to their first full calendar year of commercial operation; note also that no U.S. reactor went commercial in 1991.) These bring the total number of reactors of 400 MW or greater capacity to 110 (including TMI-2, but excluding Rancho Seco which was voluntarily retired in 1989). On the horizon for 1992-93 are commissioning of Comanche Peak 2 and retirement of San Onofre 1. Yankee Rowe, a "pre-commercial" reactor, was retired in 1992.

2. ***Total Reactor Capacity*** The three new reactors have design electrical ratings of 1055, 1150 and 1150 MW, respectively; added to the prior total of 99,130 MW, U.S. commercial units had a combined capacity of 102,485 MW.

3. ***Capacity Factor*** The U.S. nuclear power sector achieved an average 68.4% capacity factor in 1991. This exceeded the previous high-water mark of 66.1% set in 1978, and the 1990 value of 65.0% (not counting the industry average of 69.2% in 1969, which covered only two reactors, Connecticut Yankee and San Onofre 1).

4. ***Capital Cost of New Plants*** Estimated capital costs at completion were $3.0 billion for Limerick 2, $6.9 billion for Seabrook and $7.2 billion for Comanche Peak 1 (exclusive of an

estimated $4.4 billion for Comanche Peak 2).[5] These plants were approximately 50% more costly (in unadjusted dollars/kW) than other plants finished after the early 1980s.

5. ***Construction Charges*** These were $27 billion in each 1989 and 1990. In lieu of a detailed calculation, it's likely that 1991 first-year charges on the three expensive new reactors added in 1990 offset 1991 depreciation in charges on the prior 107 commercial plants. Thus, it's probably safe to say that construction charges were approximately $27 billion in 1991 as well, and close to that figure for 1992.

6. ***Average O&M Cost*** Average per-kW nuclear O&M costs appear to have increased by 4.7% from 1990 to 1991, or roughly in line with general inflation. We infer this from Utility Data Institute figures published in *Nucleonics Week* (Aug. 15, 1991 for 1990 data, July 2, 1992 for 1991 data), giving industry-wide O&M costs exclusive of fuel of $8.435 billion in 1990 and $8.949 billion in 1991. Installed capacity increased as well, although less rapidly, from an estimated 101,335 MW in 1990 to 102,485 MW in 1991. (The 1991 figure is shown directly above; the 1990 figure was estimated by adding all of Limerick 2's capacity and half of Comanche Peak 1 and Seabrook to the prior total of 99,130 MW.) Combining these figures yields a 4.7% increase, or approximately $97/kW.

7. ***Average Capital Additions*** With the continued decline in comprehensiveness and accuracy of utility cost reporting to DOE (e.g., in the annual *Electric Plant Cost and Production Expenses* books), it has become increasingly difficult to compile definitive capital additions data. The $45/kW value for 1990 is a reasonable rough estimate for 1991 and 1992, with slight declines in scope offsetting slight inflationary pressures.

8. ***Average Fuel Cost*** According to UDI data in *Nucleonics Week*, July 2, 1992, U.S. nuclear fuel costs for 1991 averaged 6.8 mils/kWh.

9. ***Decommissioning Set-aside*** The linear growth pattern assumed for 1980-1990 probably applies for 1991-92 as well.

10. ***Total Costs, this year*** From the foregoing, a rough estimate of total direct reactor costs for 1991 is as follows:

- Construction Charges: **$27 billion.**
- O&M: At an assumed **$97/kW,** the **102,485** MW of commercial capacity had an estimated total O&M cost in **1991 of $9.9 billion.**

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[5] Seabrook figure from telecom August 3, 1992 with Paul Gunter of Nuclear Information and Resource Service. Limerick figure from *Nucleonics Week*, Dec. 1, 1988. Comanche Peak 1 from Clarence Johnson of the Texas Office of Utility Counsel (telecom August 4, 1992). Comanche Peak 2 figure from Texas Utilities 10-K form filed for 1991.

* Capital Additions: Assuming $45/kW, the 1991 cost is **$4.6 billion.**
* Fuel: Assuming a unit cost of 6.8 mils/kWh, the estimated 614 TWh of nuclear generation for 1991 had a fuel cost of **$4.2 billion**.
* Decommissioning Set-aside: **$0.5 billion.**

The calculated total direct U.S. nuclear generation cost for 1991 is then approximately **$46.2 billion**.

11. ***Average Cost per Nuclear kWh*** Dividing the prior total by the 614 TWh generated by commercial reactors in 1991 yields an average 1991 direct reactor cost for U.S. commercial nuclear generation of 7.5¢/kWh — the lowest in four years and the lowest in real terms since 1985.

Note that no plants on order or under construction were cancelled in 1991 (or 1992 to date) — indeed, the only reactors now left "in the pipeline" are TVA's Watts Bar 1/2 and Bellefonte 1/2 plants, which the authority is doggedly pursuing toward completion sometime before 2000.

Discussion of the progress of other costs in 1991-92, including "back end" deficiencies and governmental subsidies, is beyond our scope.

Notes on Methodology and Assumptions

Please note that:

* We have rounded figures.

* We have calculated annual growth rates for certain categories of costs using regression analysis. This produces a more fully representative portrait of cost changes than simply calculating from the first and last data points in a series.

* Federal research and development expenditures have been amortized over a 10-year period in order to show the cost of each year's nuclear kWhs. Section 2 shows actual annual federal expenditures. Thus, federal expenditures do not directly compare between Section 1 and Section 2.

* Costs encompass all reactors of 400 MW or greater capacity, beginning with the first full calendar year for which a unit was in commercial service for the entire year. The first reactors meeting these criteria both entered service on 1-1-68 — Connecticut Yankee and San Onofre 1. Smaller and/or earlier reactors such as Yankee Rowe, Dresden 1 and Indian Point 1 are not included in year-by-year data but are itemized separately (see below). Several nuclear units entering service during 1990, including Seabrook, are not included in the analysis. Rancho Seco is included through 1989, the year in which it was retired. Three

Mile Island Unit 2 is included throughout.

- As of the end of 1990, the KEA nuclear capacity factor database included 1,239 unit-years from 108 commercially operating reactors, extending from 1968 through 1990. Note that the annual averages are weighted by plant capacity, i.e., they represent the average capacity factor for the nuclear sector as a whole, rather than the mean of the different reactors' capacity factors.

- Pre-commercial reactors are defined as plants of less than 400 MW capacity. Our analysis includes 10 such units, ranging from 50 MW to 330 MW, and installed between 1960 and 1975. We have estimated their generation and costs for the entire 1960-90 period, in 1990 dollars only, and on an aggregate basis, to avoid the excessive effort that would have been required to calculate each plant's generating cost in each year.

  Key assumptions include: average original cost in end-of-1971 $/kW of approximately 360 (based on data available for five of the 10 reactors in the 1971 Federal Power Commission Steam-Plant Cost Book); inflation factor to 1990 dollars of 3.0; estimated ratio of lifetime fixed charges to original capital cost of 2.0, reflecting return, depreciation and taxes; estimated annual O&M and capital additions costs of $75/kW (1990 dollars); estimated fuel and decommissioning costs of 1.0¢/kWh and $1000/kW (1990 dollars). These assumptions produced aggregate generating costs for the 10 reactors of $6.6 billion in 1990 dollars.

- Risk-free interest rate is taken as the 10-year Treasury Bond prices from the *Economic Report of the President*, Feb. 1990, Table C-71. Because costs of capital are not listed therein until 1953, capital costs for 1950-52 were assumed equal to 1953. Similarly the 1989 value was used for 1990. (The *Economic Report of the President*, Feb. 1992 shows a 1990 10-year Treasury Bond rate of 8.55%. The 1989 price was 8.49%.)

- GDP Deflator is calculated from *Economic Report of the President*, Feb 1992, Table B-3, "Implicit Price Deflators for GDP, 1959-1989." 1950-1958 from *Economic Report of the President*, Feb. 1990, Table C-3, "Implicit Price Deflators for GNP, 1929-1989."

- For greater detail on our calculations, please refer to **Appendix C: Calculation Detail Spreadsheets**.

TABLE 3
ANNUAL NUCLEAR POWER COSTS
(Millions)

	DIRECT REACTOR COSTS		INDIRECT UTILITY COSTS		FEDERAL GOV'T SUBSIDIZED COSTS		TOTAL	
	Current	1990$	Current	1990$	Current	1990$	Current	1990$
1968	40	141	1	4	486	1,729	526	1,875
1969	47	160	2	6	501	1,699	550	1,866
1970	119	383	4	12	523	1,683	646	2,078
1971	219	668	8	24	569	1,737	796	2,429
1972	352	1,024	75	219	620	1,803	1,047	3,047
1973	753	2,059	26	72	713	1,949	1,493	4,080
1974	1,229	3,090	115	290	856	2,154	2,201	5,534
1975	2,069	4,748	186	427	1,129	2,590	3,384	7,765
1976	3,024	6,528	89	192	1,390	3,001	4,503	9,721
1977	4,052	8,184	338	683	1,665	3,362	6,055	12,229
1978	4,592	8,598	670	1,255	1,918	3,592	7,181	13,444
1979	5,305	9,143	329	567	2,156	3,715	7,789	13,426
1980	7,325	11,534	1,945	3,062	2,481	3,906	11,751	18,503
1981	8,337	11,930	1,792	2,564	2,770	3,964	12,899	18,458
1982	9,673	13,033	6,110	8,231	3,079	4,148	18,862	25,412
1983	11,177	14,472	582	753	3,331	4,313	15,090	19,538
1984	15,839	19,651	12,993	16,119	3,605	4,472	32,437	40,243
1985	18,991	22,713	112	134	3,961	4,738	23,064	27,584
1986	25,498	29,709	1,092	1,272	4,447	5,181	31,037	36,162
1987	32,760	36,986	149	168	4,919	5,553	37,828	42,708
1988	40,951	44,498	188	204	5,507	5,984	46,646	50,687
1989	44,454	46,299	5,893	6,137	5,842	6,085	56,189	58,521
1990	45,223	45,223	5,754	5,754	5,982	5,982	56,959	56,959
TOTAL	**$282,031**	**$340,774**	**$38,452**	**$48,152**	**$58,451**	**$83,343**	**$378,934**	**$472,269**
			ADDITIONAL COSTS 1950-1967					
	2,500	**6,596**			**3,146**	**12,945**	5,646	19,541
TOTAL	**$284,531**	**$347,370**	**$38,452**	**$48,152**	**$61,597**	**$96,288**	**$384,580**	**$491,809**

TABLE 4
ANNUAL NUCLEAR POWER COSTS
(Average Costs/kWh)

	DIRECT REACTOR COSTS		*INDIRECT UTILITY COSTS*		*FEDERAL GOV'T SUBSIDIZED COSTS*		*TOTAL*		*Electricity*
	Current	*1990¢*	*Current*	*1990¢*	*Current*	*1990¢*	*Current*	*1990¢*	*Generation*
1968	0.93	3.32	0.03	0.10	11.41	40.62	12.37	44.04	4,257
1969	0.76	2.57	0.03	0.10	8.02	27.20	8.81	29.87	6,246
1970	1.01	3.26	0.03	0.11	4.46	14.34	5.50	17.70	11,738
1971	0.96	2.92	0.03	0.11	2.49	7.59	3.48	10.62	22,878
1972	0.85	2.47	0.18	0.53	1.50	4.35	2.53	7.35	41,454
1973	1.12	3.07	0.04	0.11	1.06	2.91	2.22	6.08	67,087
1974	1.48	3.72	0.14	0.35	1.03	2.59	2.65	6.66	83,049
1975	1.43	3.28	0.13	0.30	0.78	1.79	2.34	5.37	144,717
1976	1.68	3.62	0.05	0.11	0.77	1.66	2.50	5.39	180,437
1977	1.86	3.75	0.16	0.31	0.76	1.54	2.78	5.61	217,965
1978	1.75	3.28	0.26	0.48	0.73	1.37	2.74	5.14	261,802
1979	2.13	3.68	0.13	0.23	0.87	1.49	3.13	5.40	248,532
1980	3.02	4.75	0.80	1.26	1.02	1.61	4.84	7.62	242,860
1981	3.22	4.61	0.69	0.99	1.07	1.53	4.99	7.14	258,554
1982	3.56	4.79	2.25	3.03	1.13	1.52	6.93	9.34	272,063
1983	4.11	5.33	0.21	0.28	1.23	1.59	5.55	7.19	271,732
1984	5.23	6.49	4.29	5.33	1.19	1.48	10.72	13.30	302,624
1985	5.40	6.45	0.03	0.04	1.13	1.35	6.55	7.84	351,968
1986	6.84	7.97	0.29	0.34	1.19	1.39	8.33	9.70	372,756
1987	7.57	8.55	0.03	0.04	1.14	1.28	8.74	9.87	432,709
1988	8.26	8.98	0.04	0.04	1.11	1.21	9.41	10.23	495,577
1989	8.59	8.95	1.14	1.19	1.13	1.18	10.86	11.31	517,227
1990	8.06	8.06	1.03	1.03	1.07	1.07	10.15	10.15	561,041

Note: Average Costs per kWh prior to 1968 are excluded due to minuscule electrical generation 1950-1967.

TABLE 5
DIRECT REACTOR COSTS
(Millions)

	Capital/ Construction		O&M		Capital Additions		Fuel		Decommissioning Set-Aside		TOTAL	
	Current	1990$	Current	1990$	Current	1990$	Current	1990$	Current	1990$	Current	1990$
1968	29	104	4	14	0	0	7	23			40	141
1969	31	104	4	14	2	7	10	35			47	160
1970	79	253	10	32	10	31	21	66			119	383
1971	146	445	20	63	10	30	43	130			219	668
1972	207	602	43	127	23	68	78	228			352	1,024
1973	424	1,160	98	267	89	244	142	389			753	2,059
1974	753	1,893	175	441	122	307	179	449			1,229	3,090
1975	1,244	2,854	324	744	133	306	368	843			2,069	4,748
1976	1,767	3,815	481	1,038	290	626	486	1,050			3,024	6,528
1977	2,253	4,550	585	1,181	593	1,198	621	1,255			4,052	8,184
1978	2,400	4,493	819	1,533	530	993	843	1,578			4,592	8,598
1979	2,699	4,652	1,082	1,865	597	1,028	927	1,598			5,305	9,143
1980	3,244	5,108	1,600	2,519	1,070	1,685	1,367	2,153	44	69	7,325	11,534
1981	3,129	4,477	1,999	2,861	1,513	2,166	1,608	2,301	87	125	8,337	11,930
1982	3,368	4,537	2,620	3,530	1,749	2,356	1,806	2,434	131	176	9,673	13,033
1983	4,011	5,193	3,018	3,908	1,991	2,578	1,984	2,568	174	225	11,177	14,472
1984	6,644	8,242	3,769	4,676	2,997	3,718	2,212	2,745	218	270	15,839	19,651
1985	9,309	11,133	4,349	5,202	2,503	2,993	2,569	3,073	261	312	18,991	22,713
1986	13,993	16,304	5,181	6,037	3,298	3,842	2,721	3,170	305	355	25,498	29,709
1987	19,023	21,477	6,616	7,470	3,614	4,080	3,159	3,566	348	393	32,760	36,986
1988	25,687	27,912	7,631	8,292	3,624	3,938	3,618	3,931	392	426	40,951	44,498
1989	27,399	28,537	8,708	9,069	4,136	4,307	3,776	3,932	435	453	44,454	46,299
1990	27,004	27,004	9,194	9,194	4,451	4,451	4,096	4,096	479	479	45,223	45,223
TOTAL	$154,840	$184,848	$58,333	$70,077	$33,345	$40,953	$32,640	$41,614	$2,873	$3,283	$282,031	$340,774

TABLE 6
DIRECT REACTOR COSTS
(Average Cents/kWh)

	Capital/ Construction		O&M		Capital Additions		Fuel		Decommissioning Set-Aside		TOTAL		Electricity Generation
	Current	1990¢	Current	1990¢	Current	1990¢	Current	1990¢	Current	1990¢	Current	1990¢	
1968	0.68	2.44	0.09	0.33	0.00	0.00	0.15	0.55			0.93	3.32	4,257
1969	0.49	1.67	0.07	0.23	0.03	0.11	0.16	0.56			0.76	2.57	6,246
1970	0.67	2.16	0.09	0.27	0.08	0.27	0.17	0.56			1.01	3.26	11,738
1971	0.64	1.94	0.09	0.27	0.04	0.13	0.19	0.57			0.96	2.92	22,878
1972	0.50	1.45	0.10	0.31	0.06	0.16	0.19	0.55			0.85	2.47	41,454
1973	0.63	1.73	0.15	0.40	0.13	0.36	0.21	0.58			1.12	3.07	67,087
1974	0.91	2.28	0.21	0.53	0.15	0.37	0.22	0.54			1.48	3.72	83,049
1975	0.86	1.97	0.22	0.51	0.09	0.21	0.25	0.58			1.43	3.28	144,717
1976	0.98	2.11	0.27	0.58	0.16	0.35	0.27	0.58			1.68	3.62	180,437
1977	1.03	2.09	0.27	0.54	0.27	0.55	0.29	0.58			1.86	3.75	217,965
1978	0.92	1.72	0.31	0.59	0.20	0.38	0.32	0.60			1.75	3.28	261,802
1979	1.09	1.87	0.44	0.75	0.24	0.41	0.37	0.64			2.13	3.68	248,532
1980	1.34	2.10	0.66	1.04	0.44	0.69	0.56	0.89	0.02	0.03	3.02	4.75	242,860
1981	1.21	1.73	0.77	1.11	0.59	0.84	0.62	0.89	0.03	0.05	3.22	4.61	258,554
1982	1.24	1.67	0.96	1.30	0.64	0.87	0.66	0.89	0.05	0.06	3.56	4.79	272,063
1983	1.48	1.91	1.11	1.44	0.73	0.95	0.73	0.95	0.06	0.08	4.11	5.33	271,732
1984	2.20	2.72	1.25	1.55	0.99	1.23	0.73	0.91	0.07	0.09	5.23	6.49	302,624
1985	2.64	3.16	1.24	1.48	0.71	0.85	0.73	0.87	0.07	0.09	5.40	6.45	351,968
1986	3.75	4.37	1.39	1.62	0.88	1.03	0.73	0.85	0.08	0.10	6.84	7.97	372,756
1987	4.40	4.96	1.53	1.73	0.84	0.94	0.73	0.82	0.08	0.09	7.57	8.55	432,709
1988	5.18	5.63	1.54	1.67	0.73	0.79	0.73	0.79	0.08	0.09	8.26	8.98	495,577
1989	5.30	5.52	1.68	1.75	0.80	0.83	0.73	0.76	0.08	0.09	8.59	8.95	517,227
1990	4.81	4.81	1.64	1.64	0.79	0.79	0.73	0.73	0.09	0.09	8.06	8.06	561,041

TABLE 7
INDIRECT UTILITY COSTS
(Millions)

	Sunk Cost, Cancelled Reactors		Decommissioning Set-Aside Deficiency		Nuclear Waste Fund 1-Time Fees		TOTAL	
	Current	1990$	Current	1990$	Current	1990$	Current	1990$
1968	0	0			1	4	**1**	4
1969	0	0			2	6	**2**	6
1970	0	0			4	12	**4**	12
1971	0	0			8	24	**8**	24
1972	60	175			15	44	**75**	219
1973	0	0			26	72	**26**	72
1974	80	201			35	88	**115**	290
1975	120	275			66	152	**186**	427
1976	0	0			89	192	**89**	192
1977	223	450			115	233	**338**	683
1978	520	974			150	281	**670**	1,255
1979	173	298			156	269	**329**	567
1980	1,756	2,766	19	29	170	267	**1,945**	3,062
1981	1,549	2,216	37	53	206	295	**1,792**	2,564
1982	5,809	7,826	56	75	245	330	**6,110**	8,231
1983	436	564	74	96	71	93	**582**	753
1984	12,900	16,004	93	115			**12,993**	16,119
1985	0	0	112	134			**112**	134
1986	962	1,120	130	152			**1,092**	1,272
1987	0	0	149	168			**149**	168
1988	20	22	168	182			**188**	204
1989	5,706	5,943	186	194			**5,893**	6,137
1990	5,550	5,550	205	205			**5,754**	5,754
TOTAL	**$35,863**	**$44,385**	**$1,229**	**$1,404**	**$1,360**	**$2,363**	**$38,452**	**$48,152**

TABLE 8
INDIRECT UTILITY COSTS
(Average Cents/kWh)

	Sunk Cost, Cancelled Reactors		Decommissioning Set-Aside Deficiency		Nuclear Waste Fund 1-Time Fees		TOTAL		Electricity Generation
	Current	1990¢	Current	1990¢	Current	1990¢	Current	1990¢	
1968	0.00	0.00			0.03	0.10	0.03	0.10	4,257
1969	0.00	0.00			0.03	0.10	0.03	0.10	6,246
1970	0.00	0.00			0.03	0.11	0.03	0.11	11,738
1971	0.00	0.00			0.03	0.11	0.03	0.11	22,878
1972	0.14	0.42			0.04	0.11	0.18	0.53	41,454
1973	0.00	0.00			0.04	0.11	0.04	0.11	67,087
1974	0.10	0.24			0.04	0.11	0.14	0.35	83,049
1975	0.08	0.19			0.05	0.10	0.13	0.30	144,717
1976	0.00	0.00			0.05	0.11	0.05	0.11	180,437
1977	0.10	0.21			0.05	0.11	0.16	0.31	217,965
1978	0.20	0.37			0.06	0.11	0.26	0.48	261,802
1979	0.07	0.12			0.06	0.11	0.13	0.23	248,532
1980	0.72	1.14	0.01	0.01	0.07	0.11	0.80	1.26	242,860
1981	0.60	0.86	0.01	0.02	0.08	0.11	0.69	0.99	258,554
1982	2.14	2.88	0.02	0.03	0.09	0.12	2.25	3.03	272,063
1983	0.16	0.21	0.03	0.04	0.03	0.03	0.21	0.28	271,732
1984	4.26	5.29	0.03	0.04			4.29	5.33	302,624
1985	0.00	0.00	0.03	0.04			0.03	0.04	351,968
1986	0.26	0.30	0.03	0.04			0.29	0.34	372,756
1987	0.00	0.00	0.03	0.04			0.03	0.04	432,709
1988	0.00	0.00	0.03	0.04			0.04	0.04	495,577
1989	1.10	1.15	0.04	0.04			1.14	1.19	517,227
1990	0.99	0.99	0.04	0.04			1.03	1.03	561,041

TABLE 9
FEDERAL GOVERNMENT SUBSIDIZED COSTS
(Millions)

	R&D Amortized and Regulation		Capital Charges Avoided Via Tax Breaks		Unrecovered Enrichment Costs		Nuclear Waste Fund Shortfall True-up		TOTAL	
	Current	1990$	Current	1990$	Current	1990$	Current	1990$	Current	1990$
1968	476	1,695	4	13	5	16	1	5	**486**	**1,729**
1969	488	1,653	5	17	7	22	2	7	**501**	**1,699**
1970	495	1,592	12	39	12	40	4	12	**523**	**1,683**
1971	514	1,570	23	72	24	74	7	22	**569**	**1,737**
1972	527	1,533	36	105	44	128	13	38	**620**	**1,803**
1973	550	1,504	71	193	71	194	21	57	**713**	**1,949**
1974	621	1,562	121	305	88	221	26	65	**856**	**2,154**
1975	732	1,680	198	454	153	352	45	104	**1,129**	**2,590**
1976	845	1,823	298	643	191	413	57	122	**1,390**	**3,001**
1977	968	1,954	398	803	231	467	68	138	**1,665**	**3,362**
1978	1,089	2,038	470	880	278	520	82	154	**1,918**	**3,592**
1979	1,257	2,167	557	960	264	454	78	134	**2,156**	**3,715**
1980	1,479	2,329	668	1,052	258	406	76	120	**2,481**	**3,906**
1981	1,697	2,428	718	1,027	274	392	81	116	**2,770**	**3,964**
1982	1,925	2,594	780	1,050	289	389	85	115	**3,079**	**4,148**
1983	2,095	2,713	862	1,117	288	373	85	110	**3,331**	**4,313**
1984	2,112	2,621	1,077	1,336	321	398	95	118	**3,605**	**4,472**
1985	2,151	2,573	1,326	1,586	373	446	110	132	**3,961**	**4,738**
1986	2,182	2,543	1,752	2,041	395	461	117	136	**4,447**	**5,181**
1987	2,071	2,338	2,253	2,544	459	518	136	153	**4,919**	**5,553**
1988	2,011	2,185	2,816	3,060	526	571	155	169	**5,507**	**5,984**
1989	1,918	1,998	3,213	3,347	549	571	162	169	**5,842**	**6,085**
1990	1,707	1,707	3,505	3,505	595	595	176	176	**5,982**	**5,982**
TOTAL	**$29,911**	**$46,800**	**$21,163**	**$26,149**	**$5,694**	**$8,023**	**$1,683**	**$2,371**	**$58,451**	**$83,343**

TABLE 10
FEDERAL GOVERNMENT SUBSIDIZED COSTS
(Average Cost/kWh)

	R&D Amortized and Regulation		*Capital Charges Avoided Via Tax Breaks*		*Unrecovered Enrichment Costs*		*Nuclear Waste Fund Shortfall True-up*		*TOTAL*		*Electricity*
	Current	*1990¢*	*Current*	*1990¢*	*Current*	*1990¢*	*Current*	*1990¢*	*Current*	*1990¢*	*Generation*
1968	11.18	39.82	0.09	0.31	0.11	0.38	0.03	0.11	11.41	40.62	4,257
1969	7.81	26.46	0.08	0.27	0.11	0.36	0.03	0.11	8.02	27.20	6,246
1970	4.22	13.56	0.10	0.33	0.11	0.34	0.03	0.10	4.46	14.34	11,738
1971	2.25	6.86	0.10	0.31	0.11	0.32	0.03	0.10	2.49	7.59	22,878
1972	1.27	3.70	0.09	0.25	0.11	0.31	0.03	0.09	1.50	4.35	41,454
1973	0.82	2.24	0.11	0.29	0.11	0.29	0.03	0.09	1.06	2.91	67,087
1974	0.75	1.88	0.15	0.37	0.11	0.27	0.03	0.08	1.03	2.59	83,049
1975	0.51	1.16	0.14	0.31	0.11	0.24	0.03	0.07	0.78	1.79	144,717
1976	0.47	1.01	0.17	0.36	0.11	0.23	0.03	0.07	0.77	1.66	180,437
1977	0.44	0.90	0.18	0.37	0.11	0.21	0.03	0.06	0.76	1.54	217,965
1978	0.42	0.78	0.18	0.34	0.11	0.20	0.03	0.06	0.73	1.37	261,802
1979	0.51	0.87	0.22	0.39	0.11	0.18	0.03	0.05	0.87	1.49	248,532
1980	0.61	0.96	0.28	0.43	0.11	0.17	0.03	0.05	1.02	1.61	242,860
1981	0.66	0.94	0.28	0.40	0.11	0.15	0.03	0.04	1.07	1.53	258,554
1982	0.71	0.95	0.29	0.39	0.11	0.14	0.03	0.04	1.13	1.52	272,063
1983	0.77	1.00	0.32	0.41	0.11	0.14	0.03	0.04	1.23	1.59	271,732
1984	0.70	0.87	0.36	0.44	0.11	0.13	0.03	0.04	1.19	1.48	302,624
1985	0.61	0.73	0.38	0.45	0.11	0.13	0.03	0.04	1.13	1.35	351,968
1986	0.59	0.68	0.47	0.55	0.11	0.12	0.03	0.04	1.19	1.39	372,756
1987	0.48	0.54	0.52	0.59	0.11	0.12	0.03	0.04	1.14	1.28	432,709
1988	0.41	0.44	0.57	0.62	0.11	0.12	0.03	0.03	1.11	1.21	495,577
1989	0.37	0.39	0.62	0.65	0.11	0.11	0.03	0.03	1.13	1.18	517,227
1990	0.30	0.30	0.62	0.62	0.11	0.11	0.03	0.03	1.07	1.07	561,041

Note: Average Costs per kWh prior to 1968 are excluded due to minuscule electrical generation 1950-1967.

1. Construction/Capital Costs

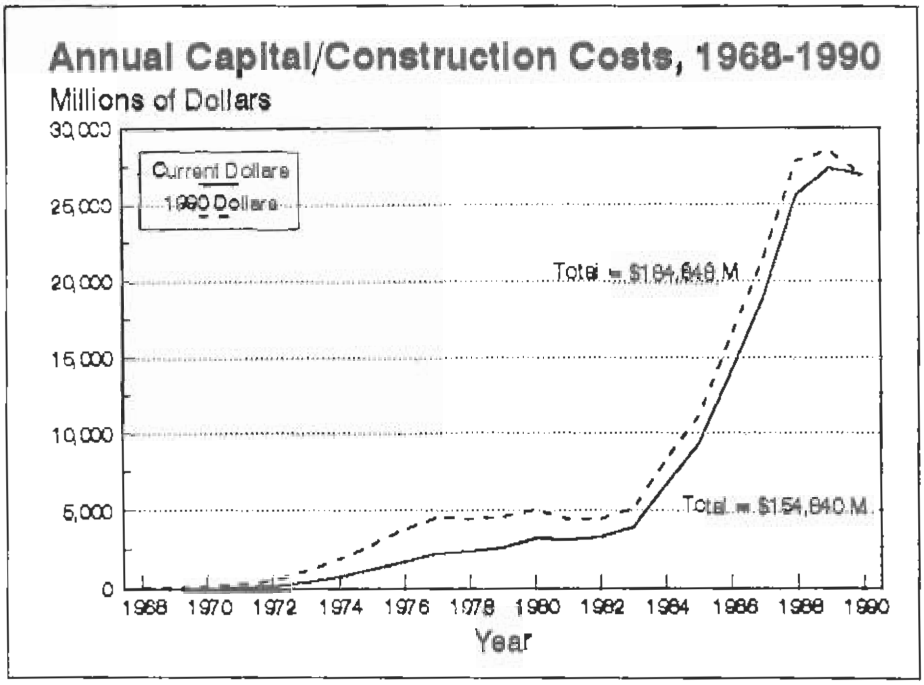
Highlights

•Construction/Capital costs represent 54% of direct reactor costs, 48% of all utility costs, and 39% of total costs 1968-1990; 47% of total costs for 1990.

•In the 1970s, Construction/Capital Costs averaged 1.95¢/kWh (1990$) and increased by an average of only 0.5% a year.

•In the 1980s, Construction/Capital Costs averaged 3.51¢/kWh (1990$). Their average annual rate of increase was a staggering 14.4%. Over the period 1970-1990, these costs increased 5.7% annually and averaged 2.76¢/kWh (1990$).

•Real costs per kWh were 80% higher in the 1980s than in the 1970s.



U.S. nuclear power's cost problem is most spectacularly illustrated by construction/capital costs — construction costs plus related financing charges. Astonishingly, nuclear plants finished in the mid or late 1980s cost twenty times as much as reactors built in the early 1970s — equivalent to a 6-fold increase in "real" (inflation-adjusted) terms. A reactor costing $4000/kW — not atypical for plants completed in the late 1980s — and operating at 65% capacity factor, had first-year capital charges of over 13¢/kWh, or around twice the current national average *retail* price of electricity. Costs spiraled as utilities fell victim to ever-changing designs, increasingly stringent regulatory requirements, and their own construction mismanagement. Publicly, the nuclear industry blamed high costs on general economic conditions (high inflation and interest costs), or disguised them in skewed comparisons with coal power costs, which were actually rising much less rapidly. In the end, utilities misled investors into financing reactors based on shockingly inaccurate cost assessments.

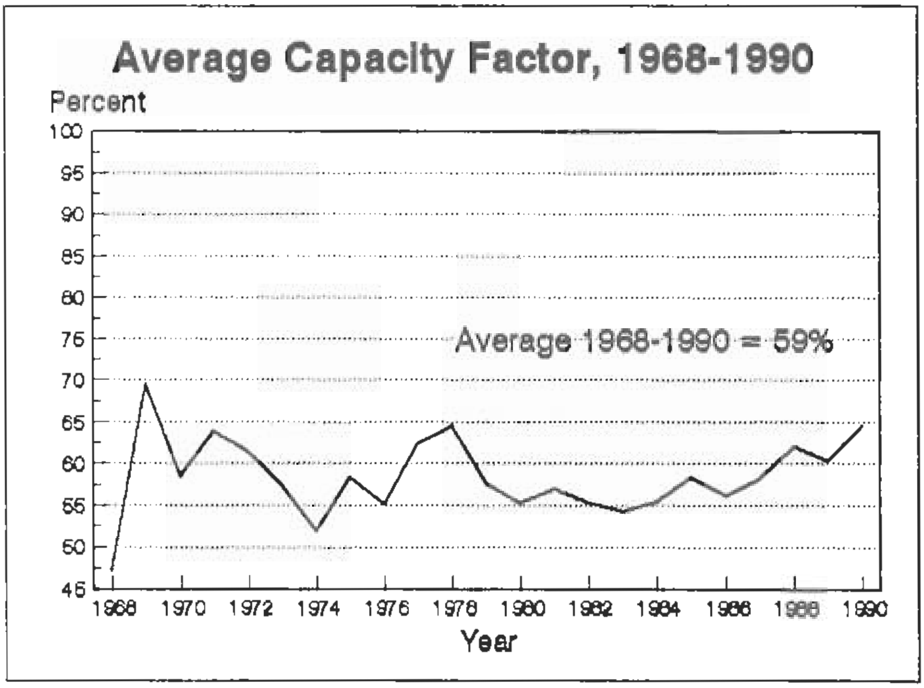
Source: *Construction/Capital Costs are based on the KEA Nuclear Capital Cost Database and include AFUDC (interest during construction), depreciation, return on investment, utility income taxes on construction (capital) costs, taxes on plant property, and insurance charges. They are amortized over a 30-year period and calculated using fixed charge rates. Because it was beyond our scope to calculate actual fixed charges incurred in each year by each reactor, our calculations employed typical annual fixed charge schedules for four vintages of nuclear plants — 1968-73, 1974-79, 1980-85, 1986-90. These periods were selected to correspond to differences in federal tax treatment and in average utility costs of capital. New plants are charged only for their fraction of year in ratebase. Property tax rate is assumed to be 1% of the plant's capital cost — a standard approximate value for power plants. Insurance rate is assumed to be 0.25% of the plant's capital cost. This value approximates utility costs for damage to utility property as well as utility contributions to federally mandated nuclear insurance pools.*

2. Nuclear Power Plant Performance

Highlights

•62 plants were operating at the end of the 1970s. Average capacity factor 1970-1980 was 58.7%.

•By 1990, the number of plants had grown to 107; the average capacity factor 1980-1990 remained the same as the previous decade — 58.7%.



Capacity performance powerfully affects nuclear economics. Because nuclear fuel is relatively cheap, a high-performing reactor can rack up significant fuel savings to offset some of the plant's initial cost. Conversely, poor performance magnifies a reactor's high fixed costs. For each successive ten percentage point drop in capacity factor below 80%, nuclear generating costs increase by 13%, 15% and 18%. (These figures are sequential and assume that non-variable expenses — capital, decommissioning, O&M and interest on fuel costs — account for 90% of total costs.)

Until the mid-'70s, reactor boosters assumed that U.S. nuclear power plants would average 80% capacity factor. The reality has been only a 59% capacity factor 1968-1990, with little discernible improvement until recently. This poor performance record has seriously damaged nuclear power's competitiveness and driven up costs across the board. Although plant maturation and growing utility experience have aided reactor performance somewhat, their influence has been less than expected. Three primary hurdles have stood in the way of steady improvement in performance: (i) the lingering impact of the Three Mile Island accident, which for a while led the NRC to pay closer attention to reactor risks; (ii) the inherent complexity and danger of nuclear plants, almost assuring a steady sequence of accidents, equipment failure and extended repair times; and (iii) aging, a factor increasingly affecting reactors placed in service two decades ago. Attention to these problems has necessitated frequent plant shutdowns.

Source: *Nuclear performance data are from the KEA Capacity Factor Database. Capacity factor measures a plant's electrical output as a percentage of its design capability. Capacity factor is measured using the original net design electrical rating reported by the utility to the NRC. As of the end of 1990, the KEA database included 1,239 unit-years from 108 commercially operating reactors, extending from 1968 through 1990 (including Three Mile Island 2 for all years and Rancho Seco until its retirement). Annual averages here are weighted by plant capacity, i.e., they represent the average capacity factor for the nuclear sector as a whole, rather than the mean of the different reactors' capacity factors. The capacity factor average for both 1970-1980 and 1980-1990 — 58.7% — is fractionally lower than the 1968-1990 average (58.8%), because both decade averages include 1980, a particularly poor year for plant performance.*

3. Operating and Maintenance

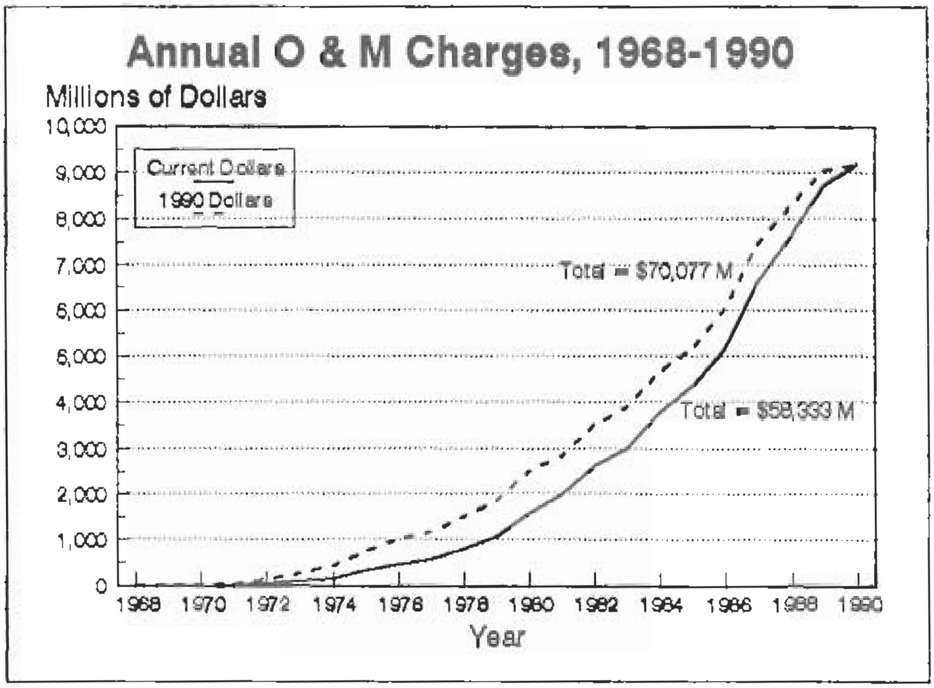
Highlights

- O&M costs are 21% of direct reactor costs, 18% of all utility costs, and 15% of total costs, 1968-1990; 16% of total costs for 1990.

- In the 1970s, O&M costs averaged 0.53¢/-kWh (1990$) and increased by an average of 12.9% a year.

- In the 1980s, O&M costs averaged 1.48¢/-kWh (1990$). Their average annual rate of increase was 4.9%. Over the period 1970-1990, O&M costs increased by 10.9% annually and averaged 1.00¢/ kWh (1990$).

- Real O&M costs per kWh were 182% higher in the 1980s than in the 1970s.



Operating and maintenance costs are the expenses, other than fuel costs, incurred in running a power plant, e.g., labor and supplies such as lubricants and water. These "routine" reactor costs have risen steadily over the past two decades as utilities have continually overhauled their nuclear operations to cope with the increased complexity of reactor design and regulation. Staffing, security, use of consultants/contract personnel and overall administrative efforts to reduce reactor risks and improve plant performance have all grown apace. Only in the past few years have real per-kW nuclear O&M costs shown signs of stabilizing, at a level 6-7 times that of the early '70s. Still, the average nuclear kilowatt-hour now has an O&M cost of around 1.5¢, or 3-4 times the (non-fuel) operating costs of fossil-fuel plants.

Source: *Operating and Maintenance Costs are from the KEA Nuclear O&M and Capital Additions Database. The few datapoints for 1968 and 1969 data were unavailable; these were estimated as 6% less than in the succeeding year. 1989 and 1990 data were also unavailable: 1989 was estimated from 1988 at an assumed annual growth rate of 6%, 1990 as 4% above 1989. Latter per-kW increase is consistent with estimate by Utility Data Institute that nuclear per-kWh O&M fell by 2.7% (Nucleonics Week, 20 June 1991, p. 1), when 6.8% increase in per-kW generation (capacity factor) is taken into account. Fossil plant non-fuel operating costs are Utility Data Institute's estimates of 4.5 mills/kWh for 1990 (Nucleonics Week, Oct. 31, 1991).*

4. Capital Additions

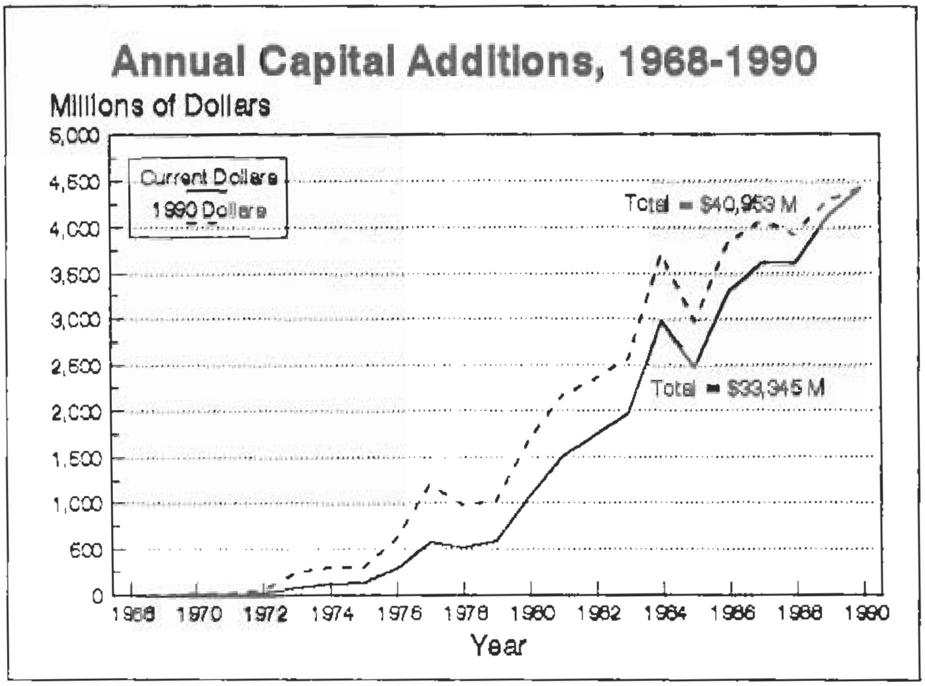
Highlights

•Capital Additions are 12% of direct reactor costs, 11% of all utility costs, and 9% of total costs, 1968-1990; 8% of total costs for 1990.

•In the 1970s, Capital Additions averaged 0.35¢/kWh (1990$) and increased by an average of 12.1% a year.

•In the 1980s, Capital Additions averaged 0.89¢/kWh (1990$). Their average annual rate of increase was 0.2%. Over the period 1970-1990, these costs increased 9.4% annually and averaged 0.62¢/kWh (1990$).

•Real costs per kWh were 152% higher in the 1980s than in the 1970s.



Capital additions are utility investments — expenditures with a time horizon beyond one year — made after a plant has entered commercial service. Although real reactor capital additions costs headed upward during the 1970s, the 1979 accident at Three Mile Island contributed to an approximate doubling in these costs. Heightened safety concerns meant plant repairs and modifications. Sometimes these were relatively small, routine "backfits" — design and equipment changes to improve operational performance and reduce accident risks. In some instances, however, plants underwent expensive, time-consuming outages to remedy generic design flaws such as pipe cracks or overstressed containment structures in General Electric designed reactors, or corroded, cracking tubes in Westinghouse steam generators. Although capital additions costs appear to be diminishing somewhat in real terms of late, they are still on the order of 0.7-0.8 ¢/kWh. Combined with O&M costs, they imply an average cost exceeding 2¢/kWh simply to maintain reactors in operational readiness, without even counting fuel or decommissioning costs.

Source: *Capital Additions are from KEA Nuclear O&M and Capital Additions Database. 1968 was assumed zero, since capital additions generally do not apply to initial year of commercial operation. 1969 data were unavailable, so were estimated by KEA. Data were not available for 1989 and 1990, so were estimated by assuming annual growth of 6% from 1988. For simplicity's sake, we allocate all capital additions costs to the year in which they were booked, rather than amortizing them over the remainder of plant life.*

5. Fuel Costs

Highlights

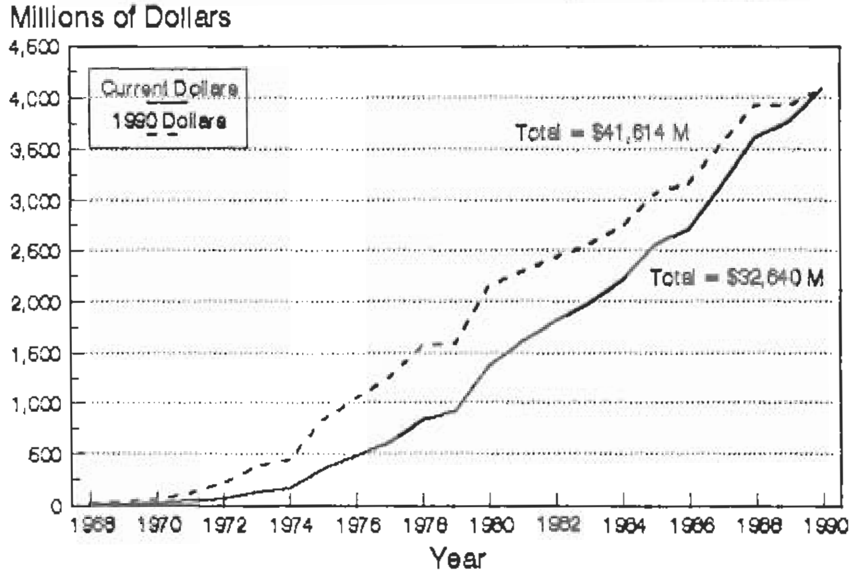
- Fuel Costs represent 12% of direct reactor costs, 11% of all utility costs, and 9% of total costs 1968-1990, 7% of total costs for 1990.

- In the 1970s, fuel costs averaged 0.61¢/kWh (1990$) and increased by an average of 2.9% a year.

- In the 1980s, fuel costs averaged 0.85¢/kWh, but decreased 2.1% a year on average. Over the period 1970-1990, these costs averaged 0.72¢/kWh (1990$) annually and increased 2.6%.

- Real fuel costs per kWh were 40% higher in the 1980s than in the 1970s.

Annual Nuclear Fuel Costs, 1968-1990



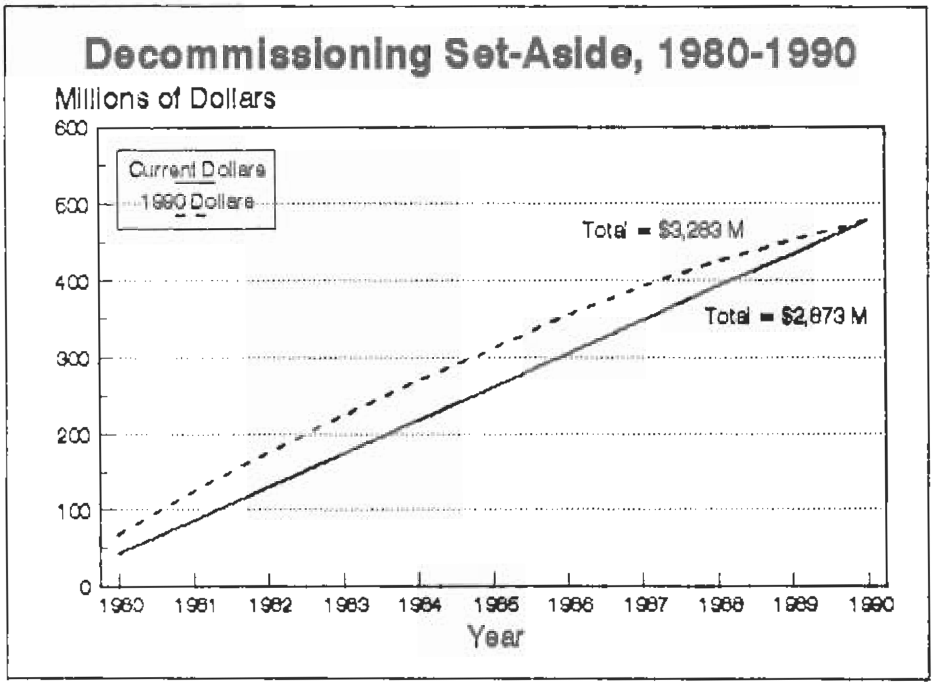
Nuclear fuel costs encompass uranium mining and milling, enrichment, fuel rod fabrication, and storage and disposal of irradiated (spent) fuel. The "front-end" charges — all steps to prepare fuel for the reactor — increased in the 1970s and stabilized or fell in the mid-1980s; back-end costs — post-reactor processing — went the opposite way, rising after being virtually ignored through the '70s. Uranium processing costs rose due to stricter mining safety and environmental standards and resource depletion (declining quality of the ore mined), until a uranium glut and a partial waiving of import quotas brought on a long, steady crash. Enrichment prices soared from $32/SWU in 1972 to $120/SWU in 1984 (a SWU, or Separative Work Unit, is a measure of enrichment work), mostly from increases in the cost of power to run the enrichment plants; but here too foreign competition and oversupply have brought prices down. Since early 1983, utility nuclear fuel costs have included 0.1¢/kWh to pay into DOE's Nuclear Waste Fund for fuel rod disposal.

Source: *Annual Nuclear Fuel Cost was derived by multiplying the Annual Average Fuel Cost per KWh by net electricity generation for each year. 1986-90 data were not available; costs were assumed same as 1983-85, to reflect apparent stability in nuclear fuel pricing. 1980-85 and 1975 data are from Atomic Industrial Forum annual nuclear cost surveys, calculated as weighted averages by KEA. 1977-79 are from U.S. DOE, Office of Nuclear Reactor Programs, "Update, Nuclear Power Program Information and Data," July/August 1980. 1976 was estimated as average of 1975 and 1977. 1973-74 are from AIF News Release, Dec. 3, 1974, "Nuclear Power Producing Electricity for 40% Less than Fossil Fuels" (but note that 1974 data therein were first half-year only). 1971-72 were calculated by KEA from all commercial plants reporting "steam-electric plant" cost data to FERC (formerly FPC). 1968-70 data were not available, so each year was estimated at 6% less than succeeding year. Note that beginning on April 7, 1983, utilities were to contribute 1 mil/kWh of nuclear generation to the Nuclear Waste Fund. No special allowance was made here for such contributions, i.e., they are assumed to be reflected in the 1983-90 estimates.*

6. Decommissioning Set-Aside

Highlights

- The Decommissioning Set-Aside represents 1% of direct reactor costs, 1% of all utility costs, and 1% of total costs 1968-1990; 1% for 1990 as well.
- Throughout the 1980s, the Decommissioning Set-Aside has averaged 0.08¢/kWh. See Source note for rate of annual increase.



In the mid-1980s, the NRC ruled that retired reactors must eventually be dismantled — rather than entombed or sealed — and subsequently directed utilities to establish dedicated, "external" funds to pay for it. Nevertheless, roughly one-third of decommissioning funds collected to date are maintained in internal utility accounts which in the event of bankruptcy might be divided among creditors. Moreover, the decommissioning cost estimates toward which utilities are collecting funds must be considered suspect on many grounds: lack of decommissioning experience, unknown costs of untried technology, persistent construction cost mis-estimation, reliance on generic rather than site-specific estimates, and exclusion of spent fuel costs. Although utilities' estimates of real decommissioning costs have more than doubled since 1985, many authorities still consider these costs under-estimated. (See, for example, *Energy Journal*, Special Nuclear Decommissioning Issue, Vol. 12, 1991.) Indeed, the decommissioning set-aside may be one of the few reactor costs which has not escalated fast enough.

Source: *Utility contributions to decommissioning funds are based on data in "Payment Due," a comprehensive report on nuclear decommissioning published by Public Citizens' Critical Mass Energy Project (Oct. 11, 1990). Our estimate assumes that (i) utilities began setting aside decommissioning funds in 1980, and (ii) annual industry-wide set-asides increased stepwise linearly, so that the 1981 set-aside (nominal dollars) = 2 x 1980 set-aside, 1982 = 3 x 1980, etc., until 1989 (lastyear) = 10 x 1980. The hypothetical value of the 1980 set-aside was calculated such that the total value of decommissioning funds at the end of 1989, with accumulated interest @ 7.5%/yr, would equal $3.352 billion. This is the value of utility decommissioning accounts as of the end of 1989, for the 108 plants in the annual calculations, as compiled in the Critical Mass report. The 1990 set-aside was assumed to be 11 x the 1980 set-aside, continuing the assumed linear growth pattern.*

7. Sunk Costs, Cancelled Reactors

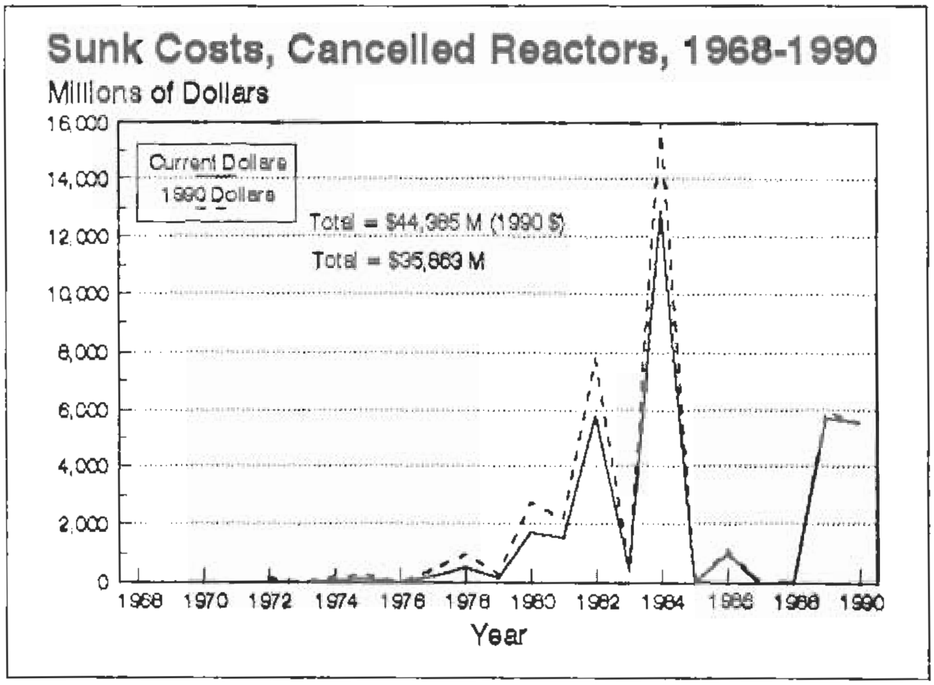
Highlights

- Sunk Costs of Cancelled Plants are 92% of indirect utility costs, 11% of all utility costs, and 9% of total costs, 1968-1990; 10% for 1990.

- Not until 1980 did utilities write off significant sums for cancelled reactors. In that year, for every kWh produced, 1.14¢ (1990$) was spent on cancelled reactors.

- In the 1980s, Sunk Costs of Cancelled Reactors averaged 1.16¢/kWh (1990$), produced.

- A wave of cancellations in 1984 produced a cost of 5.3 cents/kWh (1990$) making 1984 the most costly year (per kWh) for nuclear power.



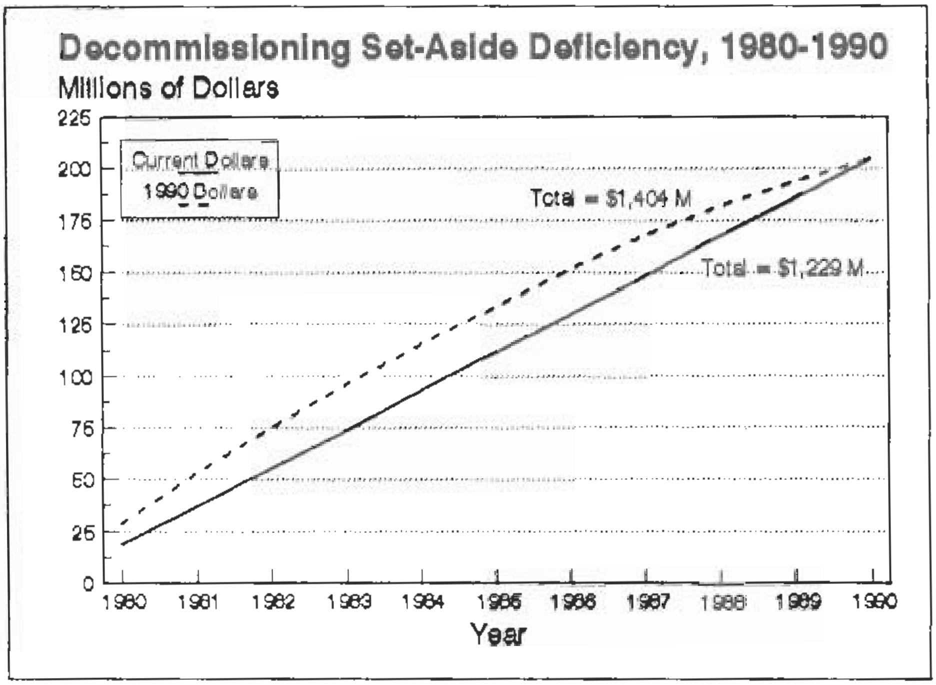
Utilities have cancelled at least 121 reactors (not counting others that they "ordered" without spending money), as nuclear over-optimism and utility growthmania ran afoul of cost escalation and market realities. In 1974 President Nixon predicted that one thousand U.S. reactors would be operating by the year 2000, providing half of a greatly expanded electricity supply. But recessions, customer conservation, embarrassing accidents, public opposition, cost overruns and dwindling utility capital precipitated waves of cancellations in the 1970s and 1980s. In 1985 *Forbes* Magazine marvelled: "The Tennessee Valley Authority cancelled 8 out of 17 nuclear projects, Public Service Electric & Gas 5 out of 8, Duke Power 6 out of 13, Detroit Edison 3 out of 4. The cancellations continue." A notorious example is the Shoreham reactor, which the Long Island (NY) Lighting Company cancelled in 1990 after spending $5.5 billion.

Source: *Sunk Costs of Cancelled Reactors adds costs expended on 121 cancelled reactors — 62 for which at least $50 million was invested at cancellation, and 59 for which smaller amounts were invested. For the former, cost data were drawn from numerous sources compiled by KEA, including DOE/EIA reports, trade journals, and direct communications with utilities; total cancellation costs were $35.3 billion. For the latter, per-reactor costs of $10 million were assumed, resulting in abandoned sunk costs of $590 million. Total cancellation costs for the two categories were thus approximately $36 billion. Although most utilities amortized cancellation costs over 10 years, we have applied the full sunk cost of each cancelled plant to the year in which it was cancelled, to simplify the calculations.*

8. Decommissioning Set-Aside Deficiency

Highlights

- The Decommissioning Set-Aside Deficiency is 3% of indirect utility costs 0.4% of all utility costs, and 0.3% of total costs 1968-1990; 0.4% for 1990.
- The Decommissioning Set-Aside Deficiency averaged .03¢/kWh (1990$) 1980-1990.



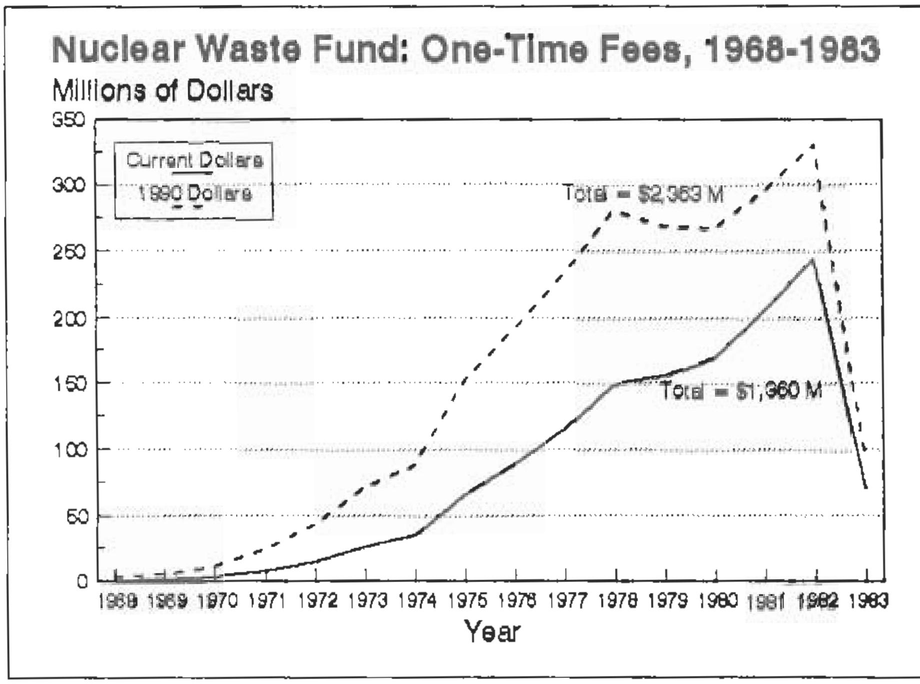
In 1990, Public Citizen reported that while U.S. nuclear plants had operated for about a third of their expected (30-year) operating lives, utilities had collected just 14% of the funds estimated to be necessary to decommission their plants. Based on the utilities' own estimates of decommissioning costs, utilities had under-funded their decommissioning reserves by $1.8 billion. Indeed, as of 1989, no decommissioning funds had been set aside for eight reactors and utilities had collected less than 5% of their estimated decommissioning costs for another 23 reactors. The set-aside deficiency — what utilities would have had to "squirrel away" to keep their decommissioning reserves on track — is almost half as great as utilities' actual payments into their decommissioning funds. Additionally, several sources suggest that utility estimates may prove grossly over-optimistic. A 1992 study by Moody's Investor Service noted, "In Moody's opinion, the cost is likely to be significantly higher as the reactors mature, and as the NRC continues to revise its (decommissioning) guidelines."

Source: *The Decommissioning Set-aside Deficiency is the additional amount that utilities would have had to set aside in decommissioning accounts, beginning in 1980, if the accumulated decommissioning funds at the end of 1989 (counting interest) were to be in the same proportion to utility estimates of ultimate decommissioning costs, as plant age at the end of 1989 was to an expected 30-year life. Note that the deficiency is based on utility estimates of decommissioning costs, and makes no allowance for likely further escalation in such costs.*

9. Nuclear Waste Fund One-Time Fees

Highlights

- Nuclear Waste Fund One-Time Fees are 1% of indirect utility costs, 1% of all utility costs, and 5% total costs 1968-1983.
- Nuclear Waste Fund One-Time Fees averaged 0.10¢/kWh (1990$) 1968-1983.



The 1982 Nuclear Waste Policy Act requires utilities producing electricity with nuclear power to contribute 1 mil (0.1 cent) per nuclear-generated kWh to a federal Nuclear Waste Fund, starting with power produced after April 7, 1983. (Utilities must also pay into the fund equivalent fees for nuclear wastes produced prior to that date.) In return, the Department of Energy relieved utilities of responsibility for spent fuel and high-level radioactive waste. Utilities must pay their one-time fees by 1998 by remitting either (i) quarterly payments with interest, (ii) a one-time future lump-sum payment with interest, or (iii) a payment in full by 1985 without interest.

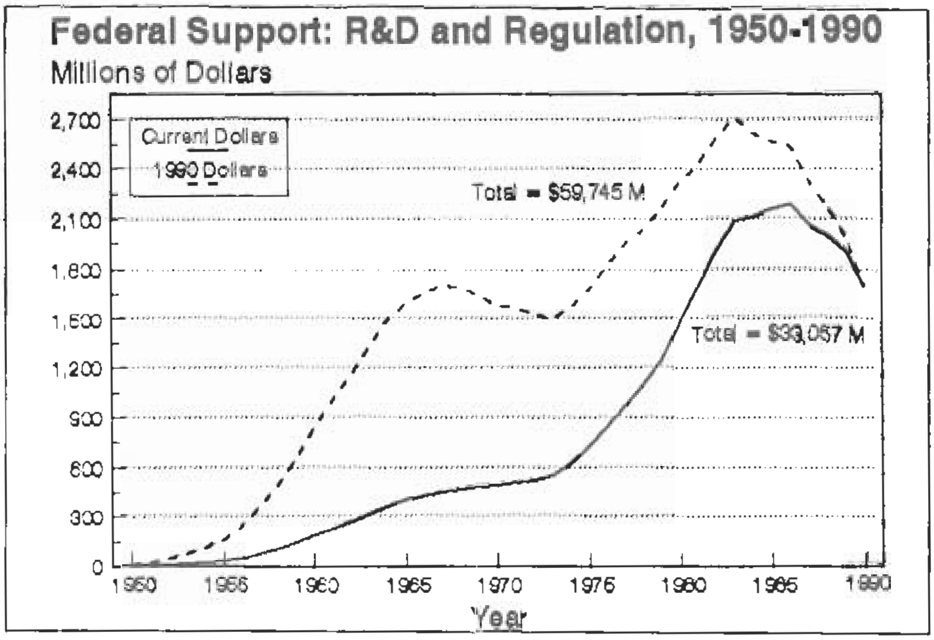
By the end of 1989, DOE had collected $1.5 billion in one-time fees. However, 17 utilities elected to defer their payments, and DOE estimates that these utilities will owe $3 billion in interest and fees by January 1998. GAO now warns that $2 billion of the deferred fees and interest may never be collected because 11 of the 17 utilities are in "uncertain financial position." Our estimate reflects amounts utilities should have paid prior to 1983, not what they have actually paid or may pay in one-time fees.

Source: *Pursuant to the 1982 Nuclear Waste Policy Act, utilities are required to pay into the federal government's Nuclear Waste Fund for nuclear generation prior to April 7, 1983. Nuclear Waste Fund One-Time Fees are what those payments would have been, had they been built into the fuel cost of each kWh at the time it was generated. It is calculated by ascribing interest at a risk-free cost of capital to generate 1 mil/kWh as of 4-7-83. Note that this estimate does not reflect future shortfalls likely to result from (i) the lack of an inflation adjustment for the 1 mil/kWh charge, or (ii) increases in estimated disposal cost since 1982, the time at which the 1 mil/kWh charge was instituted.*

10. Amortized R&D and Regulation

Highlights

- R&D and Regulation is 56% of government support and 10% of total costs 1968-1990; 3% for 1990.
- R&D and Regulation averaged 3.08¢/kWh (1990$) during the 1970s and 0.50¢/kWh (1990$) in the 1980s.
- Although R&D and Regulation costs have decreased significantly per kWh (12.1% annually) 1970-1990, real dollar amounts have increased at an average annual rate of 2.2% over the same period.
- DOE's 1990 nuclear R&D budget was almost five times greater than the budget for renewable energy R&D.



Federal support for research and development of civilian nuclear power dates from 1946, when the Atomic Energy Act created the Atomic Energy Commission. During the early years of the program, civilian and military nuclear power research were closely related. In fact, it was early military research into naval propulsion systems that led to the development of the first civilian nuclear light water reactor in Shippingport, PA. Since that time, the government's R&D efforts have ranged from the (abandoned) breeder technology program and the ever-elusive quest for electricity from nuclear fusion, to measures to reduce the dangers of nuclear waste and current reactors' operating mishaps. The AEC and its successor agency, DOE, have worked to cultivate a close partnership with private industry to develop nuclear power as a force in commercial power production. This relationship persists, as reactor vendors continue to rely on government funding for R&D on so-called Advanced Light Water Reactors.

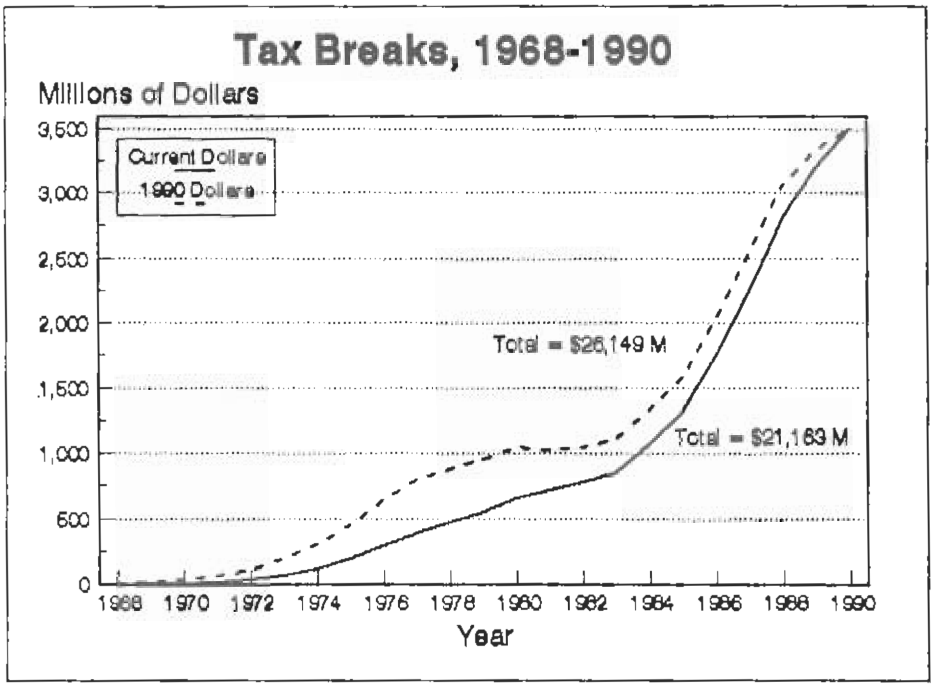
Over the years, the federal government has also assumed the majority of costs for the "supervision," or regulation, of nuclear power. Through licensee fees, utilities have paid only a fraction of the cost of this necessary service. In 1990, Congress passed a law requiring that the Nuclear Regulatory Commission begin recovering 100% of its budget from licensees. This ruling implicitly recognizes the substantial subsidy the NRC and its predecessor, the AEC, have provided to the nuclear power industry since the 1960s via federally funded regulation.

Source: R&D and Regulation include direct federal support for R&D as estimated by DOE in the late 1970s and by Sissine of the Congressional Research Service for the 1980s; waste R&D; "other" R&D including the allocable portions of DOE general programs; and AEC/NRC regulatory expenditures minus revenues from licensing fees. KEA converted these amounts from fiscal to calendar years in order to treat R&D expenditures as investments — amortizing them over a 10-year period. In so doing, each 1/10 annual share of a year's R&D investment was increased per the cost of capital between the expenditure year and the amortization year, to reflect the time value of money to the federal treasury between the R&D expenditure and its creation of value in the amortization year. Note that R&D and regulation both pre-date the 1968 start of the year-by-year commercial-plant data.

11. Capital/Construction Costs Avoided Via Tax Breaks

Highlights

- Capital/Construction Costs Avoided Via Tax Breaks are 31% of government support costs, 10% of total costs 1968-1990; 6% for 1990.
- Costs Avoided Via Tax Breaks averaged 0.34¢/kWh and increased by an average of 3.2% during the 1970s.
- In the 1980s, Capital Charges Avoided Via Tax Breaks averaged 0.50¢/kWh (1990$) and increased 5.7% annually. Over the period 1970-1990, these costs averaged 0.42¢/kWh (1990$) and grew at annual rate of 4.1%.
- Real Tax Breaks per kWh were 48% higher in the 1980s than in the 1970s.



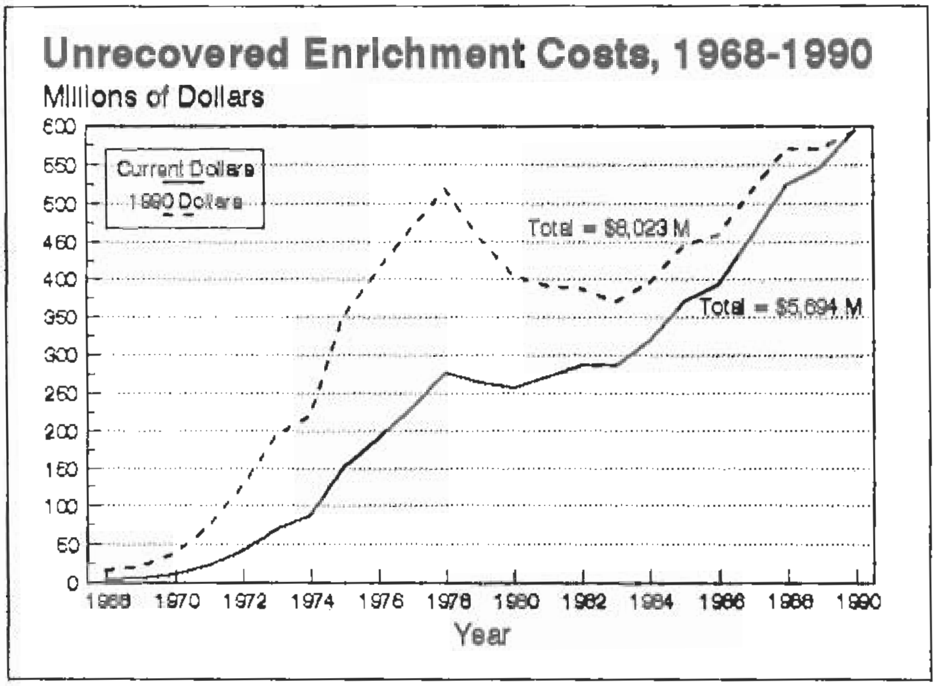
Utilities investing in nuclear power receive tax "incentives" ("tax breaks" in common parlance) through reduced payments of corporate income taxes on their nuclear investments. The chief accounting mechanisms through which these tax breaks have been conferred are the investment tax credit, accelerated depreciation and artificially short plant lifetimes assumed for tax purposes. These subsidies averaged around 3% of depreciated capital cost per year in the late 1960s and 1970s, roughly 2.8% during 1980-86, when the investment tax credit was reduced by 20%, and around 1.5% of depreciated plant value after passage of the 1986 Tax Reform Act. Although most of these loopholes are available to other industries, the extreme capital-intensive nature of commercial nuclear power bestowed a particular "tax-break windfall" on nuclear utilities.

Source: *Capital Charges Avoided via Tax Breaks are the estimated tax advantages realized by electric utilities that purchased nuclear plants. It is calculated by comparing (i) actual taxes paid by utilities (estimated via typical fixed charge rates), which reflect reductions via accelerated depreciation and the investment tax credit, to (ii) the rates utilities would have paid under straight line depreciation, and without the investment tax credit.*

12. Unrecovered Enrichment Costs

Highlights

- Unrecovered Enrichment Charges are 10% of government support costs and 2% of total costs 1968-1990; 1% for 1990.
- Unrecovered Enrichment Charges are estimated to be 0.11¢/kWh (1990$) 1968-1990.



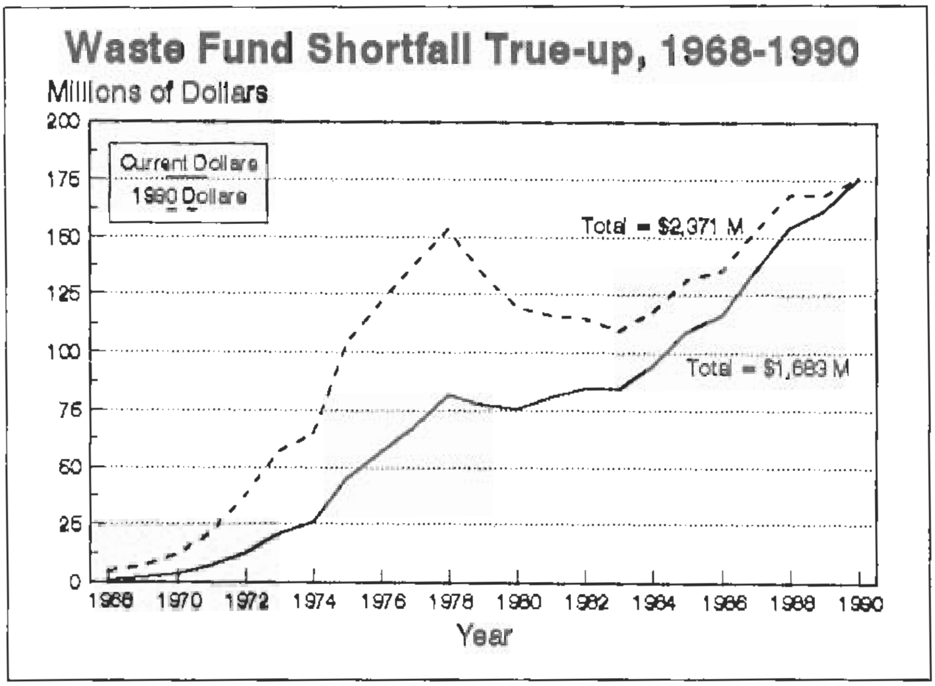
Enrichment is the process of increasing the concentration of fissile isotopes in uranium to make it usable as fuel for nuclear reactors and weapons. Since the mid-1970s, the three government-owned enrichment facilities have been used predominantly to enrich uranium to the specifications of individual commercial domestic and foreign power plants on a contract basis. The Atomic Energy Act of 1954 required that the government recover the costs of providing enrichment services to commercial customers. In practice, however, DOE has rarely, if ever, charged enough for enrichment services to recoup the government's costs. Thus, the federal government has subtly subsidized the nuclear industry by consistently undercharging electric utilities for enriched uranium; in September 1988, the GAO established that the "unrecovered costs" of enrichment were at least $9.6 billion. Interest accumulated after this estimate would put the government's subsidy to the commercial nuclear power industry via its enrichment services at $11.5 billion at the end of 1990. Using a different methodology, based on the amounts utilities would have had to pay during 1968-1990 to pay the full share of enrichment costs, we estimate that utilities avoided $8.0 billion in enrichment charges over that period.

Source: *Unrecovered Enrichment Costs are estimated here as the unrecovered enrichment charges incurred by the federal treasury because utilities have not been required to pay for them. It is estimated by applying a charge of 1.06049 mils/kWh to each kWh generated in each year. This charge, which was estimated through "back-calculation," is the per-kWh charge that, with interest accumulation to the end of 1990, would have summed to $11.549 billion by 12-31-90; that figure equals, with interest, the $9.6 billion estimate by the General Accounting Office of unrecovered enrichment charges as of 9-30-88. Interest accumulation on the enrichment charges is calculated by imputing risk-free interest (at 7.5%/yr) beginning with the succeeding year and extending through 1990.*

13. Nuclear Waste Fund Shortfall True-up

Highlights

- The Nuclear Waste Fund Shortfall True-up represents 3% of government support and 1% of total costs 1968-1990; 3% for 1990.
- In the 1970s, the Nuclear Waste Fund Shortfall True-up averaged .07¢/kWh (1990$).
- In the 1980s, the Nuclear Waste Fund Shortfall True-up averaged .04¢/kWh (1990$).



GAO estimates that unless the current 1 mil/kWh waste fund fee is raised, DOE will spend $4.1 billion (1988 dollars) more than it will collect to dispose of high-level waste. The 1982 Nuclear Waste Policy Act requires that DOE annually assess the adequacy of the fee, and GAO has repeatedly urged Congress to raise the fee to offset this potential shortfall. DOE, however, has never recommended an increase, despite real program cost escalation in addition to inflationary pressures; instead the Department is counting on chronic program delays to cover the shortfall by generating sufficient interest on unspent funds. Our skepticism led us instead to formulate a true-up account, based on a uniform per-kWh payment on all nuclear generation during 1968-90. The per-kWh amount required is about 3/10 of a mil, or 30% as much as the actual fee. Although the federal government may attempt to recoup this shortfall from utilities in the future, collecting funds from utilities that have ceased operating nuclear plants will likely be difficult; accordingly, we have assumed that taxpayers will end up absorbing the costs.

Source: *Nuclear Waste Fund Shortfall True-up is the estimate of the payments utilities would have had to make into the Nuclear Waste Fund, beginning in 1968, in order to accumulate, with interest, by the end of 1990, an amount equal to GAO's estimate of the shortfall in the Nuclear Waste Fund ($3.569 billion in 1990 dollars). For simplicity, we made the assumption that the per-kWh payment would have been equal for all kWh's generated, and that all nuclear generation would have been dunned in this fashion (rather than generation after 7 April 1983, the effective date of the Fund). The constant per/kWh amount is 0.31 mils.*

SECTION 2

A DETAILED LOOK AT FEDERAL SUBSIDIES TO THE U.S. NUCLEAR POWER INDUSTRY 1950-1990

SUMMARY

From 1950 through 1990, the federal government subsidized the U.S. commercial nuclear power industry by at least $62 billion. Adjusted for inflation, this figure is equivalent to approximately $97 billion in 1990 dollars.

These figures comprise federal expenditures during 1950-1990 for research and development of commercial nuclear power, regulation of the commercial nuclear industry, nuclear waste research programs and support for the commercial nuclear fuel cycle. They also include underpayment of taxes on nuclear power investment by electric utility companies, via investment tax credits and accelerated depreciation.

Excluded Categories

Our subsidy estimate does *not* include several types of federal support which, though significant, are not easily quantified. In this category are: the Price-Anderson Liability Law (limiting utilities' liability in the event of nuclear accidents); military nuclear power R&D; nuclear fusion R&D; market intervention on behalf of the uranium industry; contributions to the nuclear program from agencies other than the principal energy agencies' nuclear departments or from state governments; U.S. support for foreign reactor development; ideological support and government confidence in nuclear power; environmental damages; cost of low-level waste and uranium mill tailings disposal and clean-up; any assumption by the government of costs of high-level nuclear waste disposal beyond current government estimates of the cost of disposal; and any assumption by the government of costs of reactor decommissioning beyond current utility estimates of the cost of decommissioning. We have estimated roughly that the value of these excluded categories is $376 billion dollars (1990 dollars). (See Table 11)

Research & Development

The federal government's nuclear power R&D program from 1950 to 1979 included expenditures for fission research and development of conventional and breeder reactors, military program expenditures applicable to the civilian nuclear industry, and a portion of supporting AEC/DOE programs — biology and medicine, education and training, physical research and program management — applicable to civilian nuclear R&D. Less detail is available about R&D expenditures from 1980 to 1990. Program expenditures during this period fall into the general category of fission research and development.

Our tally includes the nuclear waste R&D subsidy from 1979 through 1990, although we have estimated the subsidy for 1989-1990 based on data for prior years. We have excluded waste R&D expenditures prior to 1979 for lack of data.

Federal research and development for commercial nuclear power 1950-1990 totals approximately $21.2 billion in unadjusted dollars,

$47.7 in 1990 dollars. R&D expenditures for commercial nuclear power have dipped somewhat in the past decade as research for military applications of nuclear power has come to dominate the field. Still, nuclear power remains the most consistently well-funded energy research program. In 1990, the Department of Energy R&D budget for civilian nuclear power (fission and fusion) was six times the budget for renewable energy resources.

Regulation

Government regulation of commercial nuclear power facilities has cost taxpayers $5.9 billion in unadjusted dollars -- $9.2 billion in 1990 dollars. This subsidy for regulating the commercial nuclear power industry is government expenditures for this activity minus what the industry paid back to the federal government nuclear regulatory agencies through licensing and other fees.

In 1990 Congress recognized the extent of the subsidy to the nuclear industry through government expenditures for its regulation, and ordered the Nuclear Regulatory Commission to begin recovering 100% of its budget from the users of its services.

Uranium Enrichment

The federal subsidy for uranium enrichment totalled approximately $11.6 billion as of the end of 1990. This figure was derived by making an interest adjustment to the 1989 estimate by U.S. General Accounting Office that unrecovered government costs to enrich uranium for nuclear power plants had reached $9.6 billion through the end of the 3rd Quarter of 1988. The enrichment subsidy includes commercial customers' share of operating costs, depreciation, interest on unrecovered investment and capital improvements on enrichment facilities, minus utility payments to the government for enrichment services.

The government's uranium enrichment program is one of the most controversial elements of the U.S. nuclear power program. Its future depends on even greater federal expenditures to bail out past debts and eventually decommission the three government-owned plants.

Waste Fund Shortfall

In 1990, the GAO estimated that the Nuclear Waste Fund is likely to be under-funded by $4.1 billion by the end of the program. Our Nuclear Waste Fund shortfall subsidy is an estimate of what utilities should have been contributing (beyond what they did pay) during 1968-1990 so that the Fund could adequately cover full high-level waste disposal costs. This subsidy estimate is $1.7 billion, or $2.4 billion in 1990 dollars.

There has been no visible progress in the government's high-level nuclear waste disposal program in Nevada. As the start-up date of a permanent repository for commercial nuclear waste continues to recede, its costs are likely to escalate.

Underpayment of Taxes

Utilities purchasing nuclear power plants have been allowed to reduce payments of corporate income taxes on their nuclear investments via investment tax credits, accelerated depreciation and artificially short plant lifetimes for tax purposes. Such tax breaks — although generally available to other industries — have been a particular windfall to the nuclear industry because of its extreme capital-intensiveness. From 1968 though 1990, underpayment of taxes on nuclear investment has totaled $21.2 billion ($26.1 billion in 1990 constant dollars).

Total Subsidy

Through 1990 the federal subsidy to nuclear power stood at $61.6 billion, or $97.0 billion in 1990 dollars (Table 16, p. 53). As noted, these figures exclude significant categories of federal support. Even so, they represent a substantial commitment of resources to the commercial application of nuclear power technology. Furthermore, our assessment of the nuclear power's costs to the public does not include some of the most severe potential liabilities, such as the costs to the health and safety of present or future generations, or the cost of under-allocating research dollars to renewable energy alternatives. The value to electric utilities of the federal government's unfailing support for nuclear power should not be underestimated. The federal government has insulated commercial nuclear from the rigors of the market and has protected reactor operators from the liabilities that industries face, such as waste disposal and insurance. The result has been a biased and misleading portrait of nuclear power's cost to electricity consumers and to society as a whole.

INTRODUCTION

According to economic theory, subsidies are required when market forces alone fail to deliver a desired societal product, such as a "public good." Government must then either provide the good itself through taxation and disbursement, or take other actions such as legislation, to remove barriers to the supply of that product. For the past four decades, the federal government has prioritized the commercialization of electric power supplied by atomic fission. It has given birth to and sustained nuclear power in the face of an "imperfect" market which wouldn't do so itself. The provision of government subsidies to the nuclear industry was critical to its development and has made nuclear power appear substantially cheaper in the market than it actually was.[1]

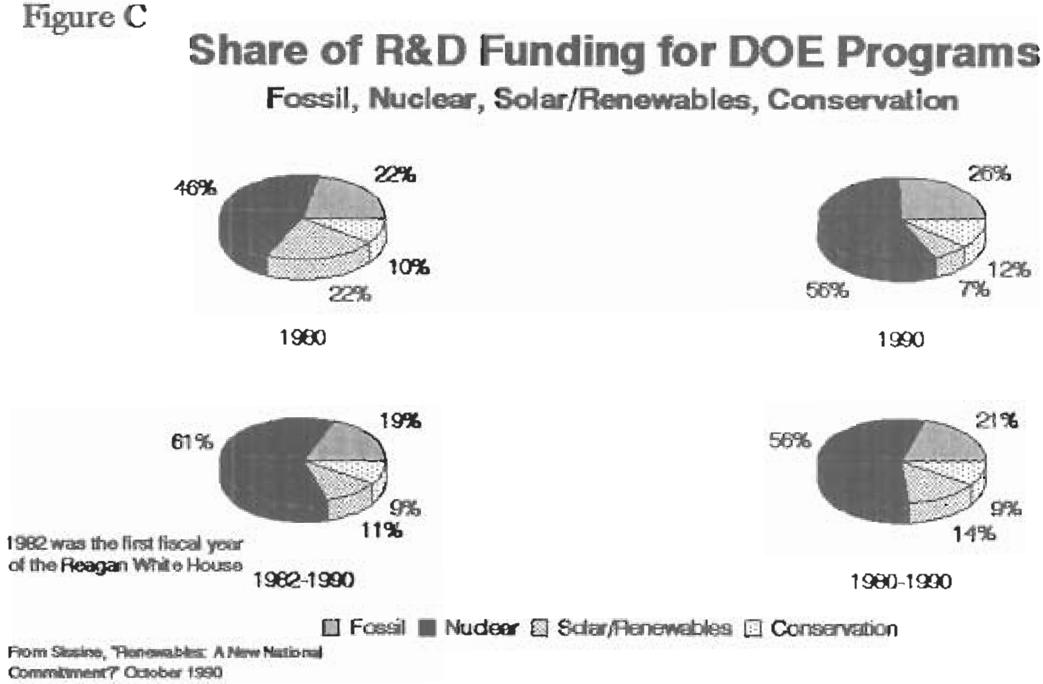
The energy sector, in general, has received high levels of federal support. In addition to the nuclear industry, the coal and oil industries have received massive amounts of state support. However, nuclear power has long held a privileged position in the federal energy hierarchy and, thus, has been the greatest beneficiary of federal energy support. (See Figure C.) A 1987 GAO report, ***Energy R&D***, concluded that while non-nuclear energy R&D suffered cutbacks in the 1980s, executive office and "DOE support for [nuclear] technologies has insulated them from major reductions."[2] The host of motivations for this policy — political, ideological, economic or even psychological — fall beyond the scope of this report.[3] Rather, this study details the form and extent of governmental support for the nuclear path.

Beginning in the early 1950s, the federal government committed itself to a policy of inducing private companies to enter the nuclear power business. In 1951 the Atomic Energy Commission's Industrial Participation Program surveyed companies which might potentially produce and deploy reactor technology to determine what it would take to get them involved in nuclear power development. Three decades later the AEC's successor agency, the Department of Energy, reflected, "A key conclusion ... was that private industry could not bear the projected capital costs of nuclear power plants in light of the risks involved."[4] The government then acted to reduce those costs and risks, and has continued its support of the program beyond the "long-term, high-risk, high-payoff" criteria for federal energy R&D support established in the 1980s. Layers of economic insurance have been added and modified to support the industry, from price supports for uranium to the removal of barriers to plant licensing. **We estimate that the federal government's assumption of responsibility for the viability of nuclear power has cost the public treasury at least $97 billion, in 1990 dollars, over the period 1950-1990.**

TYPES OF SUBSIDY

Federal government subsidies of commercial nuclear electric power fall in the following categories:

Figure C



■ **Direct subsidies** — These are payments to reactor manufacturers to produce technology which will generate electricity, or to firms engaged in various aspects of the nuclear fuel cycle. They include as well, expenses incurred by the federal government for its own efforts in direct support of commercial nuclear power. **All direct subsidies are included in our estimate.**

■ **Indirect subsidies** — These comprise government-supported research, development and demonstration on related technologies that have helped lay the groundwork for commercial reactors. Examples are materials research, naval reactors and future technologies such as fusion reactors. **Our subsidy estimate includes only those indirect subsidies which played a significant role in development of the commercial industry, e.g., early military-related R&D on Light Water Reactor (LWR) technology, and breeder reactor R&D.** Our estimate excludes R&D on fusion reactors.

■ **Reduction in taxes** — Utilities generating electricity with nuclear power have received sizeable tax breaks via tax provisions such as investment credits and accelerated depreciation. **Our subsidies estimate includes all such tax reductions.**

■ **Market intervention** — This pertains to government policy to create a fertile economic environment for the nuclear industry. Prominent examples are the Price-Anderson Act, which provided federal indemnification of the nuclear industry in the event of reactor accidents; the embargo on uranium imports for use in U.S. plants from 1964 to 1984; and loan guarantees for rural electric co-operatives investing in nuclear power plants. **We have not quantified, and therefore not applied, a dollar figure for market intervention to our subsidy estimate.**

■ **Deferred and/or external costs** — waste disposal, radiation leakage and other damage to workers, the public or the environment; such costs have been excluded from the monetized cost of nuclear power, with either the implicit assumption of responsibility by the government or the expectation that society will ignore or absorb them. **We have included a Nuclear**

Waste Fund True-up estimate. This represents utilities' share of the *government-estimated* shortfall in the Nuclear Waste Fund — the additional amount utilities should have been contributing so that the Fund can cover the cost of high level waste disposal for commercial nuclear power. We have excluded other external or deferred costs.

We estimate that the total federal subsidy to the civilian commercial nuclear power industry has been *at least* $97 billion from 1950 to 1990, in 1990 constant dollars.[5] The federally supported activities which we include in our estimate are:

- ***nuclear fission research and development (R&D)***
- ***licensing and regulation of commercial nuclear power plants (net of utility payments and fees)***
- ***enrichment of uranium for fuel for nuclear-generated electricity***
- ***nuclear waste R&D***
- ***utilities' share of the projected shortfall in the Nuclear Waste Fund, according to government estimates***
- ***tax reductions.***

Our subsidy estimate excludes several types of federal support and public costs which are not easily quantified. In this category are:

- *the Price-Anderson Liability Law (limiting utilities' liability in the event of a nuclear accident)*
- *exclusively military nuclear power R&D*
- *fusion R&D*
- *market intervention on behalf of the uranium industry*
- *contributions to the nuclear program from agencies other than the principal energy agencies, from non-nuclear divisions within DOE, or from state governments*
- *U.S. support for foreign reactor development*
- *the benefits of ideological support for and government confidence in nuclear power*
- *environmental harms, including short- and long-term damage to human health and the environment from routine operation and reactor accidents*
- *any assumption by the government of costs for disposal of nuclear wastes except for the government-estimated shortfall in the Nuclear Waste Fund, and*
- *any assumption by the government of costs of reactor decommissioning beyond current utility set-aside payments and beyond utility estimates of the cost of decommissioning.*

SOURCES

We have tried to base our estimates as much as possible on information from government sources. Three comprehensive studies of federal support for nuclear power were released in the late 1970s, covering roughly the same time period, 1950-1978. Much of the basic research for these reports appears in the one prepared by the Battelle Memorial Institute for DOE.[6] It was first published in 1978, but didn't appear in its final version until February 1980. The other studies are by GAO and by in-house analysts at DOE. There is general congruence among the reports in terms of their estimates of federal support; however, they differ over the proportion of the expenditures for nuclear power that should properly be termed subsidy.

In particular, the first and final versions of DOE's in-house study — ***Federal Support for Nuclear Power*** — differ markedly in their estimates of the federal subsidy to nuclear power: the final version's estimate is two-thirds less than the earlier version. (The texts of the two versions are similar — the difference is in which costs they choose to characterize as subsidies to the nuclear power industry.) Joseph Bowring, the DOE staff member who authored the first version, is not mentioned or credited in the final published report.[7]

No comprehensive government report has investigated government subsidies during the 1980s. We have relied on federal agency budget and expenditure reporting and non-governmental sources such as the Rocky Mountain Institute and U.S. Council on Energy Awareness to estimate the federal subsidy over the past decade.

See **Appendix D: Comparative Sources**, for a survey of alternative sources of information available on this subject.

Research and Development

DOE's ***Federal Support for Nuclear Power*** is our source for nuclear power R&D expenditures through 1979. For more recent subsidy data we present figures gathered by Fred Sissine of the Congressional Research Service, Science Policy Research Division. Although spending on civilian nuclear power was only a small part of Sissine's research on government energy spending and prospects for a federal commitment to renewable energy sources, his figures are the only government source of which we are aware that estimates nuclear R&D subsidies from 1980 to 1990.[8] [9]

Regulation

We have used the Battelle report, ***An Analysis of Federal Incentives Used to Stimulate Energy Production***, to tally the federal subsidy for the regulation of nuclear power through 1978. We have drawn our figures from fiscal statements in the Nuclear Regulatory Commission's annual reports for data for 1979 through 1990.

Enrichment

Our analysis of subsidy via uranium fuel enrichment relies on a 1990 report authored by Charles Montange, consultant to the National Taxpayers Union, and also on GAO estimates.

Radioactive Waste R&D

The nuclear waste R&D subsidy is calculated from the U.S. Council on Energy Awareness report, ***Right on the Money: The Costs, Benefits and Results of Federal Support for Nuclear Power***. Table 14 of the report shows civilian radioactive waste R&D from 1979 to 1988 according to DOE. We have excluded expenditures prior to 1979 for lack of data.

Nuclear Waste Fund Shortfall

The source of our Nuclear Waste Fund Shortfall subsidy estimate was ***Nuclear Waste: Changes Needed in DOE User-Fee Assessments to Avoid Funding Shortfall***, General Accounting Office, 1990.

In addition to these sources, we have relied on the works cited in the bibliography (**Appendix B**) to develop our subsidy estimates and provide the context of federal support for nuclear power.

SUBSIDIES AND COSTS EXCLUDED FROM OUR ESTIMATE

Before presenting our detailed analysis of the categories of subsidy making up our $97 billion subsidies total, we offer comments regarding forms of support for nuclear power which we excluded from this figure:

Price-Anderson Liability Act

The Price-Anderson Liability Act, enacted in 1957, originally provided federal indemnification of utilities in the event of nuclear accidents, thus removing a substantial (and perhaps insurmountable) barrier to nuclear power plant development. Congress reasoned that since the private market would not insure utilities against a nuclear plant accident, the government would have to assume the cost of damages beyond what commercial insurers would offer the industry. For the first several decades of commercial nuclear power, utilities paid for $60 million worth of insurance, while the government set the liability limit at $560 million; thus, the federal government assumed responsibility for $500 million worth of damages, and any claims beyond $560 million would simply go unpaid.

As amended in 1988, the Price-Anderson Act requires utilities to maintain $1.6 billion in utility property insurance and $200 million worth of insurance to cover public liability claims in the event of an accident. Additionally, utilities must join the industry-wide deferred premium plan — at the time of an accident each utility would pay its prorated share of public liability claims above $200 million, up to $63 million per reactor. Thus, in the event of a serious accident, approximately $8 billion of insurance would be available — $1.8 billion, plus $6 billion or more from the industry-wide pool. Damages in excess of this amount will not be covered unless Congress intervenes. While the 1988 amendments removed any government assumption of the nuclear industry's liability to the public, they continued to protect utilities from "free" market prices in nuclear plant accident insurance by maintaining a liability ceiling.[10]

A 1987 report by Public Citizen/Critical Mass Energy Project, ***The Price-Anderson Act: A Multi-Billion Dollar Annual Windfall for the Nuclear Industry***, noted:

> Numerous estimates ... suggest that the value of the Price-Anderson Act to just the electric utilities which operate nuclear power plants may be in the range of $1 to $5 billion annually or more. It is considerably higher if the companies which design, build and supply commercial nuclear plants or which operate government research, weapons and waste facilities are factored in. (p. 1)

In a 1990 article, Dubin and Rothwell estimate that "the cumulative value of the subsidy to the industry was $111 billion (in 1985 dollars) by 1988 and will grow to $131 billion by 2001."[11] This is the cumulative difference between what utilities actually paid annually for insurance, and what their premiums should have been in order to be sufficient to cover expected losses from a nuclear accident. The authors emphasize that this is a conservative estimate because it only includes property damages and excludes damages payable due to health effects. The value of damage to life and health resulting from a nuclear accident is discussed below under Environmental Externalities.

Nuclear advocates argue that because no money has been paid out by the government under Price-Anderson, the Act conferred no subsidy to the industry. However, as noted above, without government indemnification which helped mask the level of risk — both financial and in safety terms — commercial nuclear power would likely have never left the drawing boards.

Exclusively Military Nuclear Power R&D

In the 1950s and early 1960s, in particular, nuclear R&D for commercial purposes was thoroughly intertwined with nuclear military research and development. According to Battelle,

> In the early years of atomic energy the weapons program developed many aspects of the emerging commercial nuclear power program. Methods of handling radioactive materials, neutron diffusion codes, critical experiment technology, and other information from the military program] were largely applicable to the commercial program.[12]

We include in our subsidy estimate only the portion of military work — estimated by Battelle — which benefitted the civilian program. (This estimate is also given in the DOE report.) Yet, the *entire* military nuclear program pushed along the civilian program, lending it invaluable technological findings and proving ground. Thus, our subsidy estimate understates the total benefit to the civilian program provided by military nuclear reactor and fuel cycle R&D.

Fusion R&D

Fusion and fission power share certain key features, including origin in military applications, reliance on centralized high technology, and harnessing and generating radiation in the process of producing energy. Still, their differences, from both technical and political standpoints, seem wide enough to justify excluding fusion R&D expenditures from our tally of federal investments and other monetary support for nuclear (fission) power.[13] However, if fusion were to be commercialized, utilities would be the commercial beneficiaries of the government-sponsored research.

Market Intervention — The Uranium Industry

Nowhere was the federal government's interventionist economic policy toward the nuclear industry more apparent than in the uranium market. The Atomic Energy Act of 1946 made the AEC the sole owner of uranium in the U.S. This required the early nuclear utilities to secure their fuel by leasing uranium from the government. Even after passage of the Private Ownership of Special Nuclear Materials Act of 1964, many utilities continued this arrangement because it was cheaper than purchasing uranium outright. The leasing program ended in 1970 and all leases were terminated in 1973.

Additionally, the government has offered generous contracts, guaranteed prices, provided bonuses for discoveries, paid for haulage, undertaken extensive geological exploration programs and pledged to purchase utility plutonium at guaranteed buy-back prices. DOE estimated that the civilian portion of AEC uranium purchases and related programs from 1950 through 1979 was $2.5 billion in 1979 dollars.[14]

In 1964, in order to protect the domestic uranium industry, the government instituted an embargo prohibiting and then limiting importation of foreign ores, a policy that lasted until 1984. While this may have increased utilities' uranium costs — the opposite effect of typical subsidies — it was another aspect of the government's action to smooth the path for nuclear power by ensuring that all components of a nuclear industry were in place.

The DOE report notes that the issue of fuel supply was critical to utility decisions between coal and nuclear. Government actions which reassured utilities that uranium would be available, helped tip the balance toward nuclear.[15] However, the value to the nuclear industry of such market intervention cannot be readily quantified.

Non-Energy Agency, Non-Nuclear Division, and State Government Contributions

Our compilation of government spending for nuclear power is not exhaustive. Spending related to commercial nuclear power has come via many departments — from the National Science Foundation's funding of advanced materials R&D to the Bureau of Mines' support for access roads to uranium mines; from the Environmental Protection Agency's expenditures on research related to power-plant employees' health, to the arranging of foreign reactor sales by the Export-Import Bank. "Special Projects" such as the Three Mile Island accident clean-up cost DOE and the states of New Jersey and Pennsylvania $124 million.[16]

The exhaustive study of energy-related government agency expenditures for 1984 by Rick Heede of the Rocky Mountain Institute found that spending on activities supporting nuclear power by the major government agencies other than DOE and NRC equaled 7.6% of his estimate of DOE/NRC expenditures for commercial nuclear power for that year.[17] However, lacking definitive estimates of such spending for years other than 1984, we have excluded all such expenditures from our subsidy estimate.

Additionally, we do not include any contribution from DOE's General Sciences budget from 1980 through 1990. Through 1979, Battelle applied a portion of AEC/DOE general programs to its estimate of federal subsidy, on the grounds that part of these programs augmented the nuclear power R&D program. We have not estimated a nuclear subsidy from the General Sciences DOE budget for the 1980-1990 period.

State governments have also spent on nuclear-related programs. For example, the Uranium Mill Tailings Radioactivity Control Act of 1978 required affected states to pay 10% of the clean-up cost for uranium mill tailings (processing wastes). In the 1980s, many states with nuclear plants, waste and other nuclear material established agencies to address and oversee policy concerning nuclear dangers and emissions.

However, it is beyond the scope of this study to examine all government sources of funds. Instead we included only funds for civilian nuclear power disbursed from the principal energy agencies: the Department of Energy; its predecessors, the Atomic Energy Commission (1950-1975) and the Energy Research and Development Administration (1975-1977); and the Nuclear Regulatory Commission. We do believe, however, that these principal agencies disbursed the vast majority of funds in support of nuclear power development.

U.S. Support for Foreign Reactor Development

The federal government's continuing encouragement of foreign reactor development contrasts with the lack of any extant domestic reactor orders since October 1973. Support for foreign reactor development may have established a lifeline for domestic reactor producers faced with negative demand for their products at home. U.S.-sponsored international aid and promotional projects like the Atoms for Peace Program included grants and loans to industrialized and developing countries for reactor development, waivers of fuel use charges, discounted enrichment services, and research and training programs.

DOE reported in 1980 that the U.S. provided one-third of the operating budget of the International Atomic Energy Agency, plus disbursements of cash and in-kind of materials and research contracts. Additionally, as of 1979, 77 loans to foreign governments had been made through the U.S. Export-Import Bank totalling $4.7 billion in 1979 dollars.[18] India received the largest single loan — $72 million in 1960s-era dollars — for purchase of U.S. companies' services, materials and equipment to build the Tarapur nuclear power plant. According to DOE's ***Federal Support for Nuclear Power,*** "The international nuclear programs ... indirectly helped domestic producers of nuclear power plants by increasing foreign demand for U.S. reactor technology [and by] creating and maintaining the basic technical infrastructure that is required in order to maintain nuclear generating stations."[19] However, it was not possible to determine the dollar benefit to domestic companies from these expenditures to develop nuclear power around the world.

Ideological Support

Steve Cohn, a professor of economics at Knox College in Illinois, has written incisively about the ways in which the U.S. government's aggressive seal of approval for nuclear power — enshrining it as the "official technology" — dampened the perceived risk of nuclear power and other barriers to the commercialization of a new technology, thereby reducing costs across the board.[20] Cohn writes, "The goal of nuclear promotion was to 'create' rather than 'discover' economic efficiency by capturing contingent economies, such as scale economies, learning curve cost reductions, credit costs reductions, etc. for nuclear power." He estimated that the total value of nuclear power's official-technology status (direct and indirect benefits) was 5.1 cents/kWh (1987 dollars).[21] Indirect Effects of "Official Technology Status" alone are estimated in Table 11 as $80 billion (1990 dollars). Although we regard Cohn's thesis as extremely significant, for conservatism we have not included the value of the benefits that utilities operating nuclear power plants derived from this authoritative official signal to proceed.

Environmental Damages

Through 1990, nuclear power generated an estimated $131 billion (1990 dollars) in unaccounted-for environmental effects. This figure is calculated by multiplying nuclear generation through 1990 by 2.4¢/kWh — the nuclear power "externality value" estimated by the Pace University Center for Environmental Legal Studies.[22]

Pace's 2.4¢/kWh estimate is comprised of two major components: (i) costs related to a potential accident and (ii) damage to humans and the environment from the routine operation of nuclear power plants. The possibility of a major accident — predicted by the U.S. Nuclear Regulatory Commission to occur at a rate of 1 in every 3,333 reactor-years[23] — results in cost of 2.3¢/kWh for expected health and non-plant property damage. Pace derived this figure from the costs resulting from the Chernobyl Nuclear Plant accident in 1986 in the former Soviet Union.[24]

The routine operation of nuclear power plants causes an estimated 0.03¢/kWh for non-radiation-related injury and death to nuclear plant workers and 0.07¢/kWh in radiation-related deaths to workers and the public. (Pollution effects on wildlife from the routine operation of nuclear plants are valued at an additional 0.01¢/kWh.) The resulting estimate of 2.4¢/kWh for the costs to humans and the environment from nuclear power generation excludes all environmental effects from the extraction and transportation of uranium and the storage, transportation and disposal of nuclear waste.

We exclude environmental damages from our estimate because, although some of these costs have already been absorbed by society, it is not known who will pay them in the future. Although the Nuclear Power Plant Owners Insurance Fund, mandated under the Price-Anderson Act, would cover a portion of costs resulting from an accident, the Fund would not adequately cover the public's damages.

Other Waste Disposal and Decommissioning Costs

Our estimate does not include several radioactive waste subsidies. These exclusions are mentioned here and detailed in the section of this report on Nuclear Waste.

Waste R&D and Disposal Prior to 1979

DOE estimated that the federal government spent $1.8 billion (mixed current dollars) on waste R&D and disposal through 1979. This amount was for both civilian and military applications. R&D on waste disposal would have applied to the civilian program, as a waste disposal solution would have served both sectors. However, we do not include the $1.8 billion in our total because we do not have data indicating the portion that covered R&D and not military disposal costs.

Low-Level Waste

The Nuclear Waste Fund does not cover low-level radioactive waste R&D or disposal. Since passage of the 1980 Low-Level Waste Policy Act, DOE has expended funds to help states develop low-level waste sites which will ultimately contain commercial low-level waste. We do not have data indicating how much the federal government has or will expend to cover these costs.[25] We have also excluded the millions of dollars being spent by state governments to either encourage or prevent siting of low-level waste dumps within their boundaries.[26]

Enrichment Plant Waste

GAO estimated in its 1989 report, ***Uranium Enrichment***, that bringing the three gaseous diffusion uranium enrichment plants into compliance with environmental standards would cost $2 billion.[27] In the same report GAO estimated that decommissioning the three plants and the abandoned gas centrifuge project could cost

$4 billion.[28] Smith Barney, the consulting firm hired by DOE to evaluate the enrichment situation, estimates that decommissioning could actually cost $20 billion.[29] No money has been collected from commercial customers — the utilities — to cover these liabilities. We do not include the potential $6 billion (at least) expenditure for enrichment plant environmental compliance and decommissioning costs in our subsidy estimate because it is not certain how much of this future obligation will be assumed by government.

TABLE 11
Estimates of the Value of Some Excluded Costs and Subsidies
Billions of Constant 1990 Dollars

1.Price-Anderson Liability Act	$132.8
2.Exclusively Military Nuclear Power R&D	n/a
3.Fusion R&D	9.5
4.Uranium Production	4.3
5.Non-Energy Agency Contributions	4.3
6.DOE General Sciences Contribution	1.7
7.State Government Contributions	n/a
8.U.S. Support for Foreign Reactor Development	0.4
9.Ideological Support	80.1
10.Environmental Externalities	131.4
11.Other Waste Disposal and Decommissioning Costs	11.1
Total:	$375.5 billion

Notes:

1. See p. 36 of this report. $111 billion in 1985 dollars inflated to 1990 dollars.

3. See p. 37.

4. See p. 38. $2.5 billion in 1979 dollars inflated to 1990 dollars.

5. 7.6% of our R&D and Regulation subsidy estimate 1950-1990, following Heede's analysis.

6. 16% of Energy Supply Budget from 1980 through 1990 following Battelle's finding that "additional program" contributions were 16% of R&D budget from 1950 to 1979.

8. DOE, "Federal Support," (1981) p. 25. $237 million in 1979 dollars inflated to 1990 dollars. Represents expenditures, not value to domestic nuclear industry.

9. See p. 39. Cohn estimated that the value of Indirect Effects of Official Technology Status, i.e., the capture of critical mass efficiencies was 1.3¢/kWh. 1.3¢ multiplied by net nuclear electricity generation through 1990 (5,455 billion kWh) inflated from 1987 to 1990 dollars.

10. See p. 39. 2.41¢ multiplied by net nuclear electricity generation through 1990. (1) and (10) do not overlap, because the Price Anderson subsidy estimate excludes damages payable due to the health effects of an accident - the principal component of the externality value.

11. See p. 40. $1.8 billion waste disposal prior to 1979 (inflated to 1990 dollars), $6 billion anticipated enrichment plant environmental action and decommissioning costs, $1 billion uranium waste clean-up.

Uranium Mining Waste and Decommissioning Costs

Additionally, DOE has estimated that it will have spent $1 billion dollars by 1994 to clean up the radioactive waste products of uranium mining and processing. The eventual amount may be much greater as new environmental standards come into effect. Costs which the government may assume to cover the decommissioning of its own experimental reactors (the decommissioning of the Shippingport experimental reactor cost $91.3 million) or to aid utilities in decommissioning commercial nuclear power plants have also been excluded from our estimate.

Summary of Excluded Categories

The categories excluded from our subsidy calculation indicate that **our estimate of $97 billion is extremely conservative — perhaps by as much as several hundred billion dollars** — as shown in Table 11. Although some of the excluded subsidies mentioned here might be quite small, such as the $11 million New Jersey taxpayers paid for the clean-up the Three Mile Island accident, the aggregate effect of such diverse support for nuclear power has been substantial. Each subsidy added to nuclear power's leverage in the planning process and tilted the scales against alternatives lacking such institutional support.

INCLUDED SUBSIDIES
RESEARCH AND DEVELOPMENT

A Brief History of the Federal Research and Development Program[30]

The Atomic Energy Act of 1946 marked the official beginning of the civilian nuclear power program. The Act created the Atomic Energy Commission (AEC) and charged it with conducting R&D, encouraging private R&D, and regulating fissionable materials. The Act also established the Congressional Joint Committee on Atomic Energy to oversee development of nuclear power "for peaceful purposes." Until the Energy Reorganization Act of 1974, the AEC regulated and promoted both civilian and military R&D, although in the early years of nuclear power development military and civilian projects were barely distinguishable. Civilian work focused on nuclear materials testing and breeder reactor technology, while military work was primarily concerned with naval propulsion systems. The Light Water Reactor (LWR) developed for nuclear aircraft carrier propulsion in 1952 (which itself was developed from nuclear submarine LWR research) led to the first civilian power plant in Shippingport, PA. While breeder R&D continued, the Commission reoriented the civilian program toward commercialization of LWR because of its initial success with the LWR and technical problems with breeder technology.

Private companies including General Electric and Westinghouse were heavily involved in the early programs aimed at developing nuclear submarines and aircraft carriers. DOE concluded in 1980:

> These relationships gave the firms extensive experience in nuclear technology and assured their place in future reactor development and commercialization. It was a relatively short step for these companies to pursue civilian research on their own or under Government contract in an area which held some potential to become a significant private market in the future.[31]

To further promote industrial involvement, Congress passed the Atomic Energy Act of 1954. The Act took away two substantial barriers to the commercialization of nuclear power. For the first time private firms were permitted to operate and own nuclear facilities (though not nuclear materials), and essential information was declassified and made available to potential investors. However, these two steps alone did not set off a wave of commercial involvement because investment in nuclear power still carried too much associated risk. The AEC's Power Reactor Demonstration Program initiated in 1955 directly mitigated the costs and risks to private firms. The program encouraged joint government/industry projects through heavy government subsidies.[32] The success of the program was reflected in the construction of three relatively large (200-MW-class) commercial LWRs — Dresden I, Yankee Rowe and Indian Point I, in 1960, 1961 and 1962, respectively.

After 1962, the AEC and its industrial partners assumed that LWR technology was "mature" and shifted R&D back to breeder reactors. The Liquid Metal Fast Breeder Reactor was to be the standard model for the second generation of nuclear power plants and, via plutonium recycle, help provide a solution to the waste problem. However, continual economic, technical and political problems precluded development of commercial breeder reactors. Technical failures led to the closing of the West Valley plutonium reprocessing facility in 1976. The next year, President Carter placed a moratorium on breeder reactor commercialization and fuel reprocessing due to concerns over nuclear weapons proliferation. Several billion dollars had been poured into civilian breeder research when in 1984 Congress finally axed the Clinch River Breeder Reactor project out of the nuclear R&D budget.

Throughout the 1980s, as the market for new reactors collapsed and advanced technologies fell by the wayside, nuclear R&D concentrated on what was on its plate — keeping commercial reactors going. The Energy Reorganization Act of 1974 had separated the regulatory and promotional activities of the AEC, and distributed these duties to the Nuclear Regulatory Commission and the Energy Research and Development Administration. The Department of Energy, which succeeded ERDA in 1977, explained:

The overriding concern in the commercial sector now is assuring that the existing nuclear technology remains a viable competitor and that the underlying industry infrastructure remains intact. Questions regarding which new nuclear technology to pursue are of lesser interest.[33]

TABLE 12
Federal Research and Development Expenditures for Civilian Nuclear Power
1950-1979
Millions of Current Dollars

	Conventional Fission	Breeder Fission	Civilian-Related Military	General Programs: Bio/Med	General Programs: Ed/Train	General Programs: Phys Rsrch	General Programs: Prog Mgmt	Annual Total
1950	$3.1		$5.1			$0.7	$0.3	$9.2
1951	5.1		17.7			1.9	0.8	25.5
1952	6.3		24.5			2.5	1.1	34.4
1953	10.1		38.8			4.0	1.7	54.7
1954	18.8		35.5			4.5	1.9	60.8
1955	26.4	3.5	32.8			5.2	2.2	70.1
1956	48.9	6.2	51.4			8.8	3.8	119.1
1957	90.7	6.8	99.0			16.3	6.9	219.7
1958	142.2	5.9	103.6			20.8	8.9	281.4
1959	175.9	8.8	96.5			23.3	9.9	314.4
1960	243.8		79.3			26.7	11.4	361.2
1961	282.2		82.3			30.2	12.8	407.5
1962	271.8		47.7			26.4	11.3	357.2
1963	265.4		54.5			26.5	11.3	357.6
1964	295.8					24.5	10.4	330.7
1965	298.9					24.7	10.5	334.2
1966	235.9	42.0		13.3	4.5	23.0	9.8	328.5
1967	231.1	54.6		13.7	4.6	23.7	10.1	337.7
1968	253.5	81.1		16.1	5.4	27.7	11.8	395.6
1969	204.9	97.9		14.5	4.9	25.1	10.7	358.0
1970	176.6	104.1		13.5	4.5	23.2	9.9	331.8
1971	195.2	105.8		14.4	4.9	24.9	10.6	355.8
1972	217.3	138.8		17.1	5.8	29.5	12.5	421.0
1973	256.4	161.0		20.0	6.8	34.6	14.7	493.4
1974	384.8	215.5		28.3	9.7	49.7	21.1	709.7
1975	69.0	538.0		29.1	9.8	50.2	21.4	717.6
1976	188.5	504.5		33.3	11.2	57.4	24.4	819.2
1977	205.5	717.5		44.3	14.9	76.4	32.5	1,091.1
1978	186.0	729.0		43.9	14.8	76.7	32.2	1,080.5
1979	184.0	758.0						942.0
Totals:	$5,173.2	$4,279.0	$768.7	$302.0	$101.9	$768.2	$326.8	$11,719.7

R&D SUBSIDY 1950 - 1979 $11,719.7 millions of current dollars

Sources:
DOE, "Federal Support," (1981), Table 1, p. 19
'General Programs' from Battelle, "Federal Incentives," (1980), Table 21, p. 116. We have prorated back Battelle's totals for these programs into current dollars, in proportion to the R&D budget for each year. Battelle's figures cover the period 1950-1978.

Although work went forward on Advanced LWRs (ALWR), nuclear R&D more and more took on the character of "maintenance" work — trying to solve basic problems such as prolonged construction periods and poor operating performance. The accidents at Three Mile Island and Chernobyl also forced DOE to devote a larger share of its R&D dollars to research on reactor dangers. Nuclear power was on the defensive. In 1987, a large chunk of civilian R&D was shifted back over to the military program, whence it had come (to the Strategic Defense Initiative, specifically).

Despite 40 years of trying, and despite achieving the objective of establishing a commercial nuclear power industry, the federal government has failed to wean the private sector from federal support or assuring the expansion — or even the survival — of commercial nuclear power.[34]

Accounting for Federal R&D Support: 1950 - 1979

Table 12 shows figures from ***Federal Support for Nuclear Power: Reactor Design and the Fuel Cycle***, published by DOE in February 1981. Our estimate of the R&D subsidy through 1979 relies on the figures reported in this investigation. The DOE report shows expenditures for four principal areas of R&D and construction-demonstration:

- civilian converter, or conventional, reactor
- breeder reactor
- applicable military projects, i.e., nuclear submarine, and
- general supporting programs.

Civilian R&D constituted only 1% of the AEC R&D budget in 1950. The remainder of the R&D budget was presumably devoted to military R&D. The percentage of the AEC nuclear budget devoted to civilian R&D climbed to its highest — 25.2% — in 1975, prior to reorganization. These small percentages support the argument that the civilian power program was quite modest compared to the military program. At the same time, however, both the percentag-es and absolute amounts allocated to civilian nuclear R&D were increasing.

TABLE 13
Federal Research and Development Expenditures for Civilian Nuclear Power
1950 - 1979
Millions of Constant 1990 Dollars

	Conventional Fission	Breeder Fission	Civilian-Related Military	General Programs: Bio/Med	General Programs: Ed/Train	General Programs: Phys Rsrch	General Programs: Prog Mgmt	Annual Total
1950	$17.4		$28.6			$3.8	$1.6	$51.4
1951	27.2		94.5			10.1	4.3	136.2
1952	33.1		128.8			13.4	5.7	181.0
1953	52.3		200.8			21.0	8.9	283.0
1954	96.3		181.0			23.0	9.8	310.0
1955	130.1	17.3	161.7			25.6	10.9	345.5
1956	233.3	29.6	245.2			42.1	17.9	568.1
1957	417.9	31.3	456.1			74.9	31.9	1,012.1
1958	641.9	26.6	467.7			94.1	40.0	1,270.3
1959	775.7	38.8	425.6			102.7	43.7	1,386.5
1960	1,058.7		344.3			116.1	49.4	1,568.5
1961	1,211.4		353.3			129.6	55.1	1,749.5
1962	1,145.0		200.9			111.4	47.4	1,504.8
1963	1,101.6		226.2			109.9	46.8	1,484.5
1964	1,205.6					99.8	42.5	1,347.9
1965	1,188.2					98.4	41.8	1,328.4
1966	905.9	161.3		51.2	17.3	88.3	37.6	1,261.6
1967	861.1	203.4		51.1	17.2	88.1	37.5	1,258.5
1968	902.8	288.8		57.2	19.3	98.7	42.0	1,408.8
1969	694.7	331.9		49.3	16.6	85.0	36.2	1,213.6
1970	568.0	334.8		43.3	14.6	74.7	31.8	1,067.4
1971	595.6	322.8		44.1	14.9	76.0	32.3	1,085.8
1972	632.3	403.9		49.7	16.8	85.8	36.5	1,224.9
1973	700.9	440.1		54.8	18.5	94.5	40.2	1,348.9
1974	967.6	541.9		72.4	24.4	125.0	53.2	1,784.4
1975	158.3	1,234.6		66.8	22.5	115.3	49.0	1,646.6
1976	406.9	1,089.1		71.8	24.2	123.8	52.7	1,768.5
1977	415.0	1,449.1		89.5	30.2	154.3	65.6	2,203.8
1978	346.4	1,364.9		82.1	27.7	141.7	60.3	2,023.0
1979	317.2	1,306.5						1,623.7
Totals:	**$17,808.7**	**$9,616.8**	**$3,514.8**	**$783.3**	**$264.2**	**$2,427.0**	**$1,032.4**	**$35,447.2**

R&D SUBSIDY 1950 - 1979 $35,447.2 millions of constant 1990 dollars

Sources:
DOE, "Federal Support," (1981), Table 1, p. 19
'General Programs' from Battelle, "Federal Incentives," (1980), Table 21, p. 116. We have prorated back Battelle's totals for these programs in proportion to the R&D budget for each year. Battelle's figures cover the period 1950-1978.
GDP Deflator calculated from "Economic Report of the President 1992," Table B-3, "Implicit Price Deflators for GDP, 1959-1989." 1950-1958 from "Economic Report of the President 1990" Table C-3, "Implicit Price Deflators for GNP, 1929-1989."

Conventional Reactor — Expenditures for conventional reactor operating, equipment and construction R&D programs fall into the following categories: nuclear fission, advanced isotope separation, reactor safety, "other applied energy," resource assessment and nuclear materials. Most expenditures for conventional reactor research were under DOE's Civilian Reactor Development Program. These expenditures were direct subsidies aimed at developing commercial nuclear power. Conventional reactor R&D totals $5.2 billion in mixed current dollars, $17.8 billion in 1990 constant dollars.

Breeder Reactor — From the early days of nuclear power development until the 1970s, the breeder was the *sine qua non* of nuclear fission development. Nuclear plants would be so numerous, and uranium reserves were considered so limited in comparison, that the light water "phase" was intended as a mere transition to a breeder economy. While the GAO includes breeder technology R&D in its estimate in its 1979 report, ***Nuclear Power Cost and Subsidies***, DOE excludes expenditures on breeder technology from its final estimate. We chose to include this category of R&D spending, and to adopt the DOE-reported expenditures as our estimate of breeder R&D. The fact that the breeder reactor did not come to fruition in the United States does not negate the fact that industry and government regarded it as the indispensable premise on which nuclear power would be built. Breeder reactor R&D totals $4.3 billion in mixed current dollars, $9.6 billion in constant 1990 dollars. (Note that from 1950 through 1954, and 1960 through 1965, no separate listing is shown for this category because breeder expenditures are included in the conventional reactor R&D figures.)

Military Projects — DOE includes applicable military spending from 1948 (included with 1949 in the amount for 1950) through 1963. According to DOE:

> For the period 1948 through 1955, the military and civilian implications of the AEC programs on submarine and aircraft carrier reactors are so bound together that it is impossible to separate them. Although the military programs were formulated solely for military application, the technology developed was to the advent [sic] of commercial applications.[35]

Beginning in 1964, the civilian portion was completely segregated; thus, no military expenditures are reported from 1964 forward. Although these expenditures are categorized as indirect, their contribution to the development of commercial nuclear power is hardly questionable. Civilian-related military R&D totals $0.8 billion in mixed current dollars, $3.5 billion in 1990 constant dollars.

General Supporting Programs — DOE supplements its year-by-year R&D figures with the portion of the sum spent on DOE-wide supporting programs applicable to the civilian nuclear program. DOE cites the Battelle report as the source of this analysis. Battelle added $2.6 billion (1978 dollars) for R&D on biology and medicine, nuclear submarine development, education and training, physical research, and program management. DOE affirms Battelle's findings:

> While not directly relevant to the development of commercial reactors, these programs were broadly relevant to the commercialization of nuclear power. The expenditures on these programs were attributed to the development of civilian nuclear power by the Battelle study (and here) in proportion to the civilian component of the AEC and ERDA budets.[36]

Where Battelle included work on the nuclear submarine in its supporting programs subsidy, DOE has included this program in its military-related R&D subsidy. Expenditures on biology and medicine and education and training are recorded for the years 1966 through 1977 (from 1950 to 1965, these programs mostly supported military applications), while physical research and program management expenditures span the life of the program — 1950 to 1977. The civilian-nuclear portion of the expenditure for these programs was $1.5 billion in mixed current dollars, $4.5 billion in constant 1990 dollars.

Although DOE calculated a total federal expenditure for fusion R&D, we have not included this amount in our subsidy compilation for the reasons cited in the Excluded Costs and Subsidies section of this report.

1950-1979 Summary

The DOE subsidy including conventional, breeder and civilian-related military and general supporting program R&D totals $11.7 billion in mixed current dollars, or $35.4 billion in 1990 dollars.

Accounting for Federal R&D Support: 1980 - 1990

Table 14 shows federal civilian nuclear R&D estimates from 1980 to 1990 compiled by Fred Sissine of the Congressional Research Service. His figures are based on federal budget and expenditure reports and DOE databases recording spending on civilian fission programs. Expenditures fall under the "Energy Supply" heading. Sissine does not show which categories, e.g., breeder or reactor safety research, are included. Sissine also does not include a portion of the General Sciences budget or an amount for other general programs such as program management, as did the Battelle analysis. We could assume that the amounts would be higher if relevant programs were included. However, we might also suppose that DOE accounting became more accurate and came to include all applicable programs under "nuclear fission."

The amounts allocated to civilian nuclear power research have declined from the high levels characteristic of the late 1970s, averaging $700 million annually since 1981. However, nuclear power continues to receive the lion's share of energy R&D funding, and has managed to hold onto most of its budget while R&D on other energy sources has been severely scaled back. (See Figure C.)

Civilian radioactive waste R&D is also shown in Table 14. These amounts for generic waste (high and low-level) R&D are from the U.S. Council on Energy Awareness' report, ***Right on the Money: Costs, Benefits and Results of Nuclear Power.*** For 1984, their figure is similar to that of Heede's for that year's waste R&D. The USCEA reports "U.S. Department of Energy" as their source.

TABLE 14
Federal Research and Development Expenditures for Civilian Nuclear Power
1980 - 1990

Millions of Current Dollars

	Energy Supply	Civilian Radio-Active Waste
1980	$1,097.3	$411.7 *
1981	1,127.2	246.5
1982	1,062.7	237.1
1983	849.5	42.2
1984	758.1	25.7
1985	600.6	39.4
1986	589.6	16.1
1987	605.3	6.5
1988	582.8	5.0
1989	609.1	2.5
1990	600.0	1.0
Totals:	$8,482.2	$1,033.7

R&D SUBSIDY 1980-1990 $9,515.9 millions of current dollars

Millions of Constant 1990 Dollars

	Energy Supply	Civilian Radio-Active Waste
1980	$1,727.8	$648.3
1981	1,612.9	352.7
1982	1,431.7	319.4
1983	1,099.9	54.6
1984	940.5	31.9
1985	718.3	47.1
1986	687.0	18.8
1987	683.4	7.3
1988	633.3	5.4
1989	634.4	2.6
1990	600.0	1.0
Totals:	$10,769.2	$1,489.2

R&D SUBSIDY 1980-1990 $12,258.4 millions of constant 1990 dollars

Sources:

'Energy Supply' from Sissine, "Renewable Energy," (1990)

'Civilian Radioactive Waste' from USCEA, "Right on the Money," (1991), Table 3, p. 11. DOE cited as original source. Figures for 1989 and 1990 are from telecom with Andy Gray, Office of Civilian Radioactive Waste Mangement, Feb. 7, 1991.

GDP Deflator calculated from "Economic Report of the President 1992," Table B-3, "Implicit Price Deflators for GDP, 1959-1989." 1950-1958 from "Economic Report of the President 1990," Table C-3, "Implicit Price Deflators for GNP, 1929-1989."

* Figure for 1979 ($174.3) waste R&D included in 1980 figure.

The 82% decrease in funding for civilian waste R&D in 1983 was a result of the creation of the Nuclear Waste Fund in that year. The utility-supported Fund took over the responsibility for most high-level waste R&D. See our Section on Radioactive Waste.

The total R&D subsidy for 1980 through 1990 is $9.5 billion in mixed current dollars, $12.3 billion in constant 1990 dollars.

REGULATION

Battelle notes that the purpose of the AEC regulatory program was

> to carry out the Commission's statutory responsibilities for assuring that the possession, use and disposal of radioactive facilities be conducted in a manner consistent with public health and safety and the common defense and security, and with proper regard for environmental quality.[37]

In February 1975, the Nuclear Regulatory Commission assumed the regulatory duties of AEC — the licensing and safety oversight of civilian nuclear power plants and the nuclear fuel cycle (except for uranium mining which is regulated by affected states, and enrichment which is regulated by DOE).

In November 1990, Congress passed a law requiring that the Nuclear Regulatory Commission begin recovering 100% of its budget from those it regulates — power reactor operators, fuel manufacturers, uranium recovery facilities, fuel and waste transporters, spent fuel storage facilities and other fuel cycle licensees. This ruling implicitly recognizes the substantial subsidy the NRC and its predecessor, the AEC, have provided to the nuclear power industry since the 1960s via services rendered through federally funded regulation. Over the years, the federal government has assumed the majority of costs for the "supervision" of nuclear power. Through licensee fees, utilities have paid for only a fraction of the cost of providing this necessary service. In 1979 GAO quoted an NRC official to the effect that revenues from licensing covered only 20% of actual licensing costs, excluding completely the costs of safety regulation.[38]

TABLE 15
Federal Expenditures for Regulation of Civilian Nuclear Power
1960 - 1990
Millions of Dollars*

	Current Dollars	Constant 1990 Dollars
1960	$3.3	$14.1
1961	3.5	15.0
1962	3.8	16.0
1963	12.5	51.9
1964	22.3	90.9
1965	25.1	99.6
1966	30.3	116.2
1967	36.9	137.3
1968	41.4	147.3
1969	46.0	156.0
1970	50.3	161.6
1971	60.5	184.6
1972	58.5	170.2
1973	51.4	140.4
1974	74.8	188.0
1975	135.6	311.2
1976	186.0	401.5
1977	220.3	444.9
1978	254.9	477.3
1979	314.1	541.4
1980	370.6	583.6
1981	408.7	584.9
1982	442.9	596.6
1983	480.8	622.5
1984	425.1	527.3
1985	373.2	446.4
1986	362.6	422.5
1987	347.1	391.8
1988	369.8	401.8
1989	370.0	385.4
1990	370.0	370.0
Totals:	$5,951.8	$9,198.0

REGULATION SUBSIDY 1960 - 1990
$5,951.8 millions of current dollars
$9,198.0 millions of constant 1990 dollars

Sources:
1960-1978: Battelle, "Federal Incentives," (1980), Table 26.
1978-1988: NRC, Annual Reports 1978-1988, Statement of Operations: Government Investment in the NRC, p. 201
1989-1990: Estimated by KEA
GDP Deflator calculated from "Economic Report of the President 1992," Table B-3, "Implicit Price Deflators for GDP, 1959-1989."
* Amounts for regulation have been converted by KEA from a fiscal year basis to a calender year basis.

Table 15, showing our estimate of the regulation subsidy, employs Battelle's figures through 1978, and the NRC fiscal statements (from their annual reports) thereafter. Our subsidy estimate is the sum of the Battelle estimates from 1960 to 1978 and the entire NRC budget minus revenues from licensing and fees from 1979 through 1990. We have not included AEC regulatory expenditures from the 1950s, because the AEC primarily regulated military nuclear power activities prior to 1960. From 1960 to 1965, regulation was not reported as an item separate from general administrative costs. For those years, Battelle estimated the portion of administrative costs devoted to regulation and licensing (approximately 6% of AEC administrative costs). The figures for 1979-1990 may include small expenditures for the regulation of nuclear materials used for medical or industrial applications.

We estimate that the subsidy to the nuclear industry through federal regulation is $6.0 billion in mixed current dollars, $9.2 billion in constant 1990 dollars from 1960-1990.

ENRICHMENT

> "Perversely, DOE's pricing strategy appears designed to maximize losses rather than profits," Charles Montange, ***Stopping a Budget Meltdown: Reorganizing the Federal Uranium Enrichment Program***, National Taxpayers Union, 1990.

Enrichment is the process of increasing the concentration of fissile isotopes in uranium to make it usable as fuel for nuclear reactors and weapons. Between 1943 and 1956, the federal government built three large gaseous diffusion enrichment plants — in Tennessee, Ohio and Kentucky — to provide highly concentrated fuel for weapons. Construction of the three enrichment facilities cost $2.4 billion in actual (nominal) dollars expended during the years of construction.[39] The facilities are still owned by the government, but they are operated under a fixed-fee contract by Martin Marietta, which succeeded Union Carbide in the mid-1980s.

In the 1950s, a small percentage of enrichment capacity was dedicated to producing fuel for small-scale demonstration power reactors. Over time, as the commercial nuclear industry developed, the percentage of enrichment applied to nuclear power increased, and the percentage used for weapons fuel decreased. Since the mid-1970s, the three facilities have been used predominantly to enrich uranium to the specifications of individual commercial domestic and foreign power plants on a contract basis. The plants have rarely operated at capacity, however, and the Tennessee plant was shut down in 1984.

The Atomic Energy Act of 1954 required that the government recover the costs of providing enrichment services to commercial customers — primarily, electric utilities. The Act states that "any prices established under this subsection shall be on the basis of recovery of the Government's costs over a reasonable period of time." This language was interpreted by the Joint Committee on Atomic Energy to mean that all direct and indirect costs including depreciation and a return on investment should be recouped from commercial customers in proportion to their use of enrichment capacity.[40]

In practice, however, DOE has rarely, if ever, charged enough for enrichment services to recover the Government's costs. In recent years, the disparity between enrichment price and cost has increased as DOE has lowered the price to retain customers in the face of foreign competition. In 1989, for example, DOE charged its enrichment customers an average price of $109 per SWU. (A SWU, or Separative Work Unit, is a unit of uranium isotope separation, i.e., enrichment work. A 1,000 MW reactor typically uses 100,000 SWUs a year.) In the same year, according to GAO, the government's cost of production per SWU was $131; including depreciation and a return on government investment would bring the price to $172 per SWU. Thus, the government lost between $22 and $63 per SWU sold, depending on whether only direct costs or both direct and indirect costs are counted. Montange estimated that the government's losses were running at an annual rate of half a billion dollars by the late 1980s.

In September 1988, GAO's Director of Energy Issues testified before a House Subcommittee that the "unrecovered costs" of enrichment were at least $9.6 billion. That estimate reflected the following costs, net of payments from utilities:

- operating costs: direct costs of enrichment services for commercial customers;

- the commercial customers' share of depreciation on enrichment facilities;

- commercial customers' share of imputed interest on the federal government's unrecovered investment in enrichment;

- $1 billion in capital improvements to the original gaseous diffusion plants;

- $2 billion spent on the abandoned gas centrifuge enrichment plant project (a newer-technology facility intended to provide additional enrichment capacity in the period when the federal government projected a shortage).

Based on this analysis, **the total enrichment subsidy to utilities through 1990 is $11.6 billion.**[41]

In 1989 Duke Power and two other U.S. utilities in cooperation with a European enrichment firm (Urenco) formed Louisiana Energy Services and announced their intention to build a private enrichment facility without federal support. This move suggests that a commercial facility might have been generated by the market earlier if the government had not subsidized enrichment services. Indeed, as GAO notes: "According to the Senior Vice President, Duke Power's objectives are to compete with DOE and diversify its sources of supply because the company is concerned about increasing DOE enrichment prices, and the potential that prices could go higher as DOE identifies and pays for needed environmental compliance and decommissioning activities."[42]

WASTE MANAGEMENT

Four types of waste result from the nuclear fuel cycle:

- uranium mine and mill tailings
- low-level radioactive waste
- high-level waste/spent fuel
- decontamination/decommissioning wastes.

Federal policy toward nuclear waste was formally established by the Uranium Mill Tailing Radiation Control Act of 1978, the Low-Level Radioactive Waste Policy Act of 1980 and the Nuclear Waste Policy Act of 1982. Although federal research and development on waste disposal, both civilian and military, has proceeded since the beginning of the nuclear program in the early 1950s, waste R&D remained "not a high priority effort" and at low funding levels until the mid-1970s.[43]

We have included in our R&D subsidy estimate the amount reported for civilian radioactive waste disposal R&D from 1979 through 1990. (See the discussion in Excluded Costs and Subsidies: Waste Disposal and Quantified Subsidies: R&D 1980-1990 above.)

In the following section we detail the waste disposal problem in order to demonstrate that most of the costs for waste disposal have been deferred. Government "permission" for this deferment has had a dramatic "subsidy effect" — allowing nuclear power to appear cheaper than it is — not only by putting off the payment of known costs, but also by ignoring expected, but unknown, future costs.

Mining and Mill Tailings

Mining and mill tailings are the sand-like waste products which result from the processing of natural uranium ore into "yellowcake" — blocks of concentrated enrichable uranium. The Southwest Research and Information Center has labeled these wastes "the source of the most chronic emissions of radioactivity in the nuclear fuel cycle."[44] The 1978 Uranium Mill Tailings Radiation Control Act requires that the federal government pay 90% of clean-up costs at inactive mill sites (the affected states pick up the remaining 10%). Mine and mill owners are responsible for active sites, even if they produced uranium under federal contract. In the United States, 24 mill sites are inactive and 29 mills are classified as active. However, only 4 of the 29 active sites are currently operating.

GAO estimated in 1989 that it will cost mill owners between $1 and $2 billion to clean up the active sites.[45] GAO also cited a DOE estimate that cleaning up the inactive sites will cost $1 billion by the time it is completed in 1994. As of 1989, DOE had spent $584 million and states had spent $41 million on actual clean-up activities. GAO further indicated that new environmental legislation mandating additional actions to purify groundwater resources could send the clean-up cost higher.

Low-Level Waste

There is no clear-cut definition of low-level waste. Generally, radioactive waste is classified as low-level if it contains less than 10 nanocuries (10 billionths of a curie — a curie is a measurement of radioactive emissions per second) of high-level transuranic wastes. It is also defined as "all radioactive waste which does not fit in another category." The majority of low-level waste is generated by commercial and research nuclear reactors. Pharmaceutical companies and hospitals also generate low-level waste, but it is of much lower toxicity than power-related low-level waste. 75% of radioactivity in medical waste (medical waste constitutes 25% of all low-level waste) has a half-life of only one week. Radioactive sludges from power plants contain radioactive isotopes which must be isolated for 300 years.[46]

Low-level radioactive waste is currently disposed of at three shallow burial sites in Hanford, Washington; Beatty, Nevada; and Barnwell, South Carolina. All three sites have experienced chronic leakage and storage problems which have caused temporary shutdowns and capacity shortages.[47] The Low-Level Radioactive Waste Policy Act of 1980 mandated that states form regional compacts to develop several secure low-level facilities. A 1988 study by Rogers & Associates estimated in 1988 that building and maintaining one new Low-Level Waste facility would cost $5.2 billion over its lifetime.[48] Ten years after passage of the act, only one facility (in Needles, California) has reached the licensing stage. Attempts to site LLW facilities have faced opposition, delays and cost overruns (and in the case of the Central States Compact — embezzlement of compact funds by the executive director) in Connecticut, Maine, Michigan, Nebraska, New York, North Carolina and Texas.[49]

High-Level Waste

Spent fuel and other commercial high-level radioactive waste are presently stored on-site at nuclear plants and research facilities. Spent, or irradiated, fuel assemblies result from the "using-up" of fuel in the reactor. The 1982 Nuclear Waste Policy Act required utilities producing electricity with nuclear power to contribute 1 mil (0.1 cent) per nuclear-generated kWh to a federal Nuclear Waste Fund. Utilities must also pay into the fund equivalent one-time fees for nuclear wastes produced before 1983. In return, utilities are relieved of all responsibility for spent fuel and high-level radioactive waste.

The Nuclear Waste Fund is intended to cover DOE's program costs including: R&D and program administration; transportation of wastes; construction and operation of one or two permanent repositories; construction and operation of a monitored retrievable storage facility to hold wastes until permanent disposal is possible; and benefit payments (buy-offs) to states and Indian tribes bordering or on prospective waste disposal sites. Through 1989, the Nuclear Waste Fund had collected $5.1 billion — $1.5 billion in one-time fees, $2.7 billion in on-going fees and $0.9 billion in interest. Disbursements totalled $2.7 billion. Thus, there was a balance of $2.4 billion, reflecting the lack of visible progress in high-level waste management. Indeed, political, managerial and technical problems have delayed even the selection of a disposal site, and the target date for construction of a repository has been pushed back to 2004, with start-up in 2010. (The original 1982 Nuclear Waste Policy Act envisioned that the first high-level waste dump would start to receive waste in 1998.)

DOE is also responsible for wastes generated by its own civilian and military R&D projects. Military wastes, with the exception of transuranic waste (high-level wastes produced in military-fuel reprocessing centers) will be commingled with commercial power plant wastes in the high-level repositories. DOE is required to make payments into the Nuclear Waste Fund out of its operating budget to cover its share, but thus far has deposited only $22.5 million toward its estimated $4-6 billion obligation.

GAO is skeptical about the adequacy of the Nuclear Waste Fund to cover the full cost of waste R&D and disposal. In 1989, DOE estimated that the total cost to dispose of military and civilian wastes would be $32 billion (1988 dollars).[50] This is $12 billion (1988 dollars) more than its 1982 cost estimate. Two-thirds of the increase are attributable to increased program costs, the remainder is accounted for by inflation. GAO notes:

> Considering how cost estimates have increased over the last 6 years and the uncertainties that must be considered in estimating costs over nearly a 100-year period, it is reasonable and prudent to assume that the actual cost of the nuclear waste program will be much higher than currently estimated by DOE. Major uncertainties include inflation, schedule delays, and the number and location of repositories to be built. Despite such major uncertainties, DOE does not include a liberal, system-wide contingency allowance in its cost estimates.[51]

GAO estimates that unless the current fee of 1 mil/kWh is raised, DOE will spend $4.1 billion (1988 dollars) more than it will collect from utilities and from itself to build two repositories.[52] GAO has repeatedly recommended to Congress that the fee be adjusted to account for the potential shortfall. The 1982 Act requires that DOE annually assess the adequacy of the fee and recommend to Congress if the fee should be raised. However, in the eight years of the Fund, DOE has never recommended an increase. Based on the GAO's $4.1 billion shortfall estimate, we have estimated that from 1968-1990 utilities should have contributed $2.4 billion (1990 dollars) more than they will have done in order to meet the final costs of disposal of their waste.

Adding to the projected inadequacy of the fee per kWh is the additional shortfall the Fund may face if utilities default on their one-time fees for wastes generated prior to the creation of the Fund. GAO noted that "DOE's Inspector General reported in 1986 and again in 1990 that collection of some of the one-time fees is doubtful." Approximately $2 billion of the $3 billion in one-time fees owed by January 1998 may never be collected because 11 of the 17 utilities that deferred payment of their one-time fees are in "uncertain financial position." However, we have not included in our estimate of the Nuclear Waste Fund True-up the one-time fees which DOE has suggested may never be paid.

Decommissioning

Decommissioning costs are expected to be absorbed by utilities without government support. However, DOE must decommission its own facilities — used to develop commercial nuclear power. DOE spent $91.3 million from 1985 to 1989 to decommission the Shippingport Experimental Reactor. Furthermore, the federal government may be called upon to assist utilities if the amounts they have set aside for this purpose prove insufficient.

Waste Summary

Our nuclear waste subsidy estimate comprises costs which have been paid by the government for nuclear waste R&D. It includes:

- generic waste R&D expenditures from 1979 to the present not covered by the Nuclear Waste Fund: $1.0 billion in current dollars or $1.5 billion in 1990 dollars, as shown in Table 14 page 46.

- utilities' share of the anticipated shortfall in the Nuclear Waste Fund at the completion of the high-level waste disposal program.

Our estimate *excludes*:

- R&D expenditures before 1979, for which we have no reliable data.

- any past, current or future federal expenditure for waste management (as distinct from waste R&D).

- 50% (the civilian portion) of the $1 billion (mixed current dollars) estimated cost of mine and mill tailings clean-up at inactive sites over the years 1979-1994.

- anticipated groundwater clean-up costs for radioactive contamination by uranium mill tailings.

- R&D on military-specific waste disposal.

- the Nuclear Waste Fund and deferred one-time fees and interest.

- state funding for LLW disposal and expenditures related to siting.

- the decommissioning and disposal costs of DOE research reactors, enrichment plants and experimental facilities or federal support for utility decommissioning of private sector reactors and facilities.

TAX BREAKS

Utilities have been able to reduce payments of corporate income taxes on their nuclear investments by taking advantage of two components of the Internal Revenue Code: investment tax credits and accelerated depreciation.

Construction charges — contruction costs plus finance charges — dominate nuclear generating costs, accounting for roughly half of all reactor power costs paid for directly by consumers. In turn, income taxes levied on the profits earned from the utility's investment account for 15-20% of these construction charges — no small sum. Nevertheless, these taxes would have been greater, if not for certain provisions of the federal tax code which permitted utilities to obtain tax deductions and credits for capital investments, particularly for investments in new nuclear plants.

Under accelerated depreciation, utilities were permitted to write off investment as if the nuclear plant had only a 16-year life, rather than the expected 30 years. This resulted in lower taxes, a benefit particularly magnified in each reactor's early years, through the time value of money. Under the investment tax credit, utilities enjoyed direct tax reductions equal to 10% of the plant's direct construction cost, exclusive of AFUDC (reduced to 8% in the late 1980s). Although these credits were returned to the Treasury over the course of plant life, again the time value of money caused the net benefit to utilities (which was flowed through to ratepayers) to be considerable.

We estimated what the fixed charge rates would have been, assuming 30-year straight-line depreciation rather than accelerated depreciation, and with no investment tax credit. The difference between taxes owed under this method and taxes owed using accelerated depreciation and the investment tax credit equals our estimate of the "tax break" subsidy, or construction charges avoided through tax breaks. 1950-1990 the nuclear industry has avoided tax obligations in the amount of $21.2 billion in current dollars, or $26.1 billion in 1990 dollars.[53]

CONCLUSION

Thus, the total subsidy to commercial nuclear power from 1950 through 1990 is **$97 billion in 1990 dollars**, as shown in Table 16. This amount is a conservative estimate of federal support for commercial nuclear power. As shown in Table 11 on page 41, we have excluded categories that might have added several hundred billion dollars to our subsidy estimate.

TABLE 16
FEDERAL SUBSIDIES TO NUCLEAR POWER
1950 - 1990
Millions of Dollars

	Current Dollars	Constant 1990 Dollars
Research and Development		
Conventional*	$13,655.4	$28,577.9
Breeder	4,279.0	9,616.8
Civilian-Related Military	768.7	3,514.8
General Programs	1,498.9	4,506.9
Waste	1,033.7	1,489.2
Total R&D	**21,235.7**	**47,705.6**
Regulation	**5,951.8**	**9,198.0**
Enrichment	**11,550.0**	**11,550.0**
Waste Fund Shortfall	**1,683.0**	**2,371.0**
Tax Breaks	**21,163.0**	**26,149.0**
TOTAL	**$61,583.5**	**$96,973.6**

Sources:
R&D Tables 12, 13, 14; Regulation Table 15; Enrichment p. 48; Waste Fund p. 50; Tax Breaks p. 52.

Subsidies to the nuclear industry are sometimes characterized as "incentives," implying that initial government support was necessary to permit development of an economically independent industry. Indeed, many industries receive the benefit of subsidies in the early stages of their development. However, the federal government has sustained high levels of financial and policy support for nuclear power for 40 years. Clearly, nuclear power subsidies can no longer be explained as "infant industry" incentives.

Instead, it is simply that utilities have gotten a substantial price break in nuclear power. The federal government made commercial nuclear power possible by intervening at whatever points it became economically untenable for the utilities to plan, build and operate reactors. The unsolvable problems created by nuclear power such as waste disposal or liability insurance have been absorbed by the federal government and thus by the citizen. Had the Internal Revenue Service identified nuclear power on citizens' tax forms as the beneficiary of so much of their dollars, would the public have agreed to pay the high price twice — first through taxes and then again through rates?

ENDNOTES

1. Rick Heede of the Rocky Mountain Institute elucidates this definition of subsidy in his 1985 report for the Center for Renewable Resources, *The Hidden Costs of Energy* and in his June 21, 1985 testimony before the U.S. Senate Subcommittee on Energy and Agricultural Taxation.

2. GAO, *Energy R&D: Changes in Federal Funding Criteria and Industry Response*, RCED-87-26, 1987 p. 26.

3. Swedish researcher Asa Moberg makes an appealing argument with regard to the question of motivation for support for nuclear power from official quarters in her 1986 book, *Nuclear Power in Crisis*:

   > Nuclear power provides 13% of the world's electricity, but receives more than 90% of the money available [for energy R&D]. There must be some explanation for this remarkable imbalance in the division of research resources. The most obvious one is that nuclear power is the only source of energy with direct military connections. Weapons cannot be made out of biomass [...] Nuclear power began life as a bomb. The civilian developments came later, as a kind of excuse for the bomb... (p. 99)

4. U.S. Department of Energy, *Federal Subsidies to Nuclear Power: Reactor Design and the Fuel Cycle*, DOE/EIA-0201/13, February 1981, p. 10.

5. Current or nominal dollar values are the dollar amounts spent in each year on a cash basis. These amounts do not represent the true value of money as we reflect back from the present time. Because of inflation, today's dollar buys less than yesterday's. Constant or 1990 dollars have been adjusted for inflation to reflect their value in today's terms. Constant dollars are calculated by multiplying current dollar amounts by the Gross National Product Deflator for each year. The deflator may be found in the annual *Economic Report of the President*.

6. Battelle Memorial Institute for the Department of Energy, *An Analysis of Federal Incentives Used to Stimulate Energy Production*, PNL-2410 UC-59 Rev. II, February 1980.

7. See Joanne Omang, *The Washington Post*, "Nuclear Energy Subsidy Estimate Slashed by DOE," April 8, 1981. The principal difference between the Bowring draft and the final report (aside from the absence of Bowring's name) is that the DOE, while reporting Bowring's figures, limits the definition of subsidy in its final analysis to direct benefits to the current generation of exclusively civilian, domestic nuclear plant projects. Among the categories excluded in the final version's estimate are "future" technologies (breeder and fusion) and joint military/civilian projects.

8. In 1984, the Rocky Mountain Institute tried unsuccessfully to persuade Congress to authorize another study on the scale of the Battelle Institute's 1980 several-volume energy subsidies report, to determine the effect of energy subsidies on energy production.

9. The U.S. Council on Energy Awareness report *Right on the Money: The Costs, Benefits and Results of Federal Support for Nuclear Power*, released in 1991, also estimates federal support for nuclear power for this later period. The report cites "Department of Energy" as the USCEA's source. Their figure for 1984 does not differ significantly from Sissine's. See Appendix A of this report for a detailed discussion of the USCEA report. (USCEA serves a public relations function for the nuclear industry.)

10. It is important to note that the $7 billion pool of insurance for public liability claims shrinks as plants retire. This is especially worisome given that as nuclear plants across the board age, they are more susceptible to accidents.

11. Dubin, Jeffrey and Geoffrey Rothwell, "Subsidy to Nuclear Power Through Price-Anderson Liability Limit," *Contemporary Policy Issues*, July 1990. The authors' figure is based on an estimate of $60 million per reactor-year "above the liability limit of $560 million from 1959 to 2001 and below the NRC's worst-case loss of $10 billion. The increase in coverage to above $7 billion due to the 1988 amendments to the Price-Anderson Act reduces the subsidy to $22 mil-

lion." The product of 111 reactors and $63 million (the liability limit set forth in the 1988 Price-Anderson Act amendments) is approximately $7 billion.

12. Battelle, *Federal Incentives*, p. 114. See discussion in Battelle, pp. 114-117.

13. We estimate that $9.4 billion (1990 dollars) in federal funds has been spent on controlled nuclear fusion from 1956 through 1990, based on DOE, *Federal Incentives*, for 1956-1979, and Sissine, *Renewable Energy*, 1980-1990.

14. DOE, *Federal Support*, Table 3, p. 33.

15. The uranium purchase programs put uranium producers in a position to expand their output without large price increases when commercial demand increased. This helped reduce the uncertainty about uranium supply which served as an impediment to utility purchases of nuclear powerplants. Even then, estimated nuclear costs were very close to those of coal fired plants. For this reason, the decision by a utility to build a nuclear plant was very sensitive to other factors. The adequacy of uranium supplies was one of the more important of these other factors. The AEC purchase programs provided assurance that fuel would be available, which, by reducing the uncertainty, made investment in nuclear power more attractive to manufacturers and engineering firms as well as utilities. DOE, *Federal Support*, p. 36-37

16. General Public Utilities Nuclear Press Release No. 485N, January 10, 1985.

17. See Note 1. The USCEA adopted this analysis in their report 1990 *Right on the Money*. They estimate "All Other Federal Support Activities" to be 5% of the AEC/ERDA/DOE civilian nuclear power R&D budgets -- $1.7 billion from 1950 to 1988 in 1988 dollars. We have not adopted this approach for estimating non-energy agencies' contributions because we suspect that the proportion of support probably varied greatly over the four decades of the nuclear program.

18. DOE, *Federal Support*, p. 22.

19. DOE, *Federal Support*, p. 24.

20. Steve Cohn, *Journal of Economic Issues*, "The Political Economy of Nuclear Power 1945-1990: The Rise and Fall of an Official Technology," Sept. 1990.

21. Cohn explains the "Economic Impact of Official Technology Dynamics" in Table 5 of the above cited article. 5.1 cents/kWh (or 75 mills/kWh) equals the sum of the value of the Direct Effects of "OT Status" comprised of the following: R&D Assistance (4.5 mills/kWh); Subsidy & Cost Deferment Assistance (11 mills/kWh); Benefits of Infant Industry Regulation (23 mills/kWh) and the Indirect Effects: the Capture of Critical Mass Efficiencies (13 mills/kWh). The indirect aid excludes the systematic tendency for nuclear cost under-estimation of more than 2 cents per kilowatt hour which greatly enhanced nuclear competitiveness. All figures in 1987 dollars. See Note 9 in our Table 11.

22. *The Environmental Costs of Electricity*, Pace University Center for Environmental Legal Studies, Oceana Publications, 1990. Table 4, "Starting Point Values for Nuclear Power Externality Costs," p. 34. Pace estimates the value of human life at $4 million per premature death and $400,000 for non-fatal illness. See pp. 365-390 for detailed explanations of the calculation, e.g. cancer incidence in relation to radiation exposure, etc. The $131 billion estimate of nuclear power generation externalities is obtained by multiplying the per-kWh estimate of 2.41¢ (1990 dollars) by the total number of nuclear kWhs.

23. Ibid. At p. 379 Pace cites *Nucleonics Week*, "NRC Minimizes Significance of Core Meltdown Risk Estimate at Markey Hearing," April 25, 1985 as the source of this NRC estimate of accident probability. The article notes that a 45% chance of a core melt accident before the end of the century (upon which Pace based its estimate of a 1 in 3333 reactor-year accident probability) does not imply that each core melt would release radiation off-site.

24. Pace relied on a 1987 DOE report which estimated deaths, illnesses and genetic defects likely to follow from the Chernobyl accident. Applying the NRC's accident probability and Pace's "health values," Pace calculated a per-kWh externality cost of 3.1 cents for accident damage to human health. Because of differences between the Chernobyl-type reactors and U.S. LWRs, Pace elected to lower the health damage externality value to 2 cents/kWh. Damage to agriculture (property damage) is derived from estimates of the value of the wheat crop destroyed by the accident.

25. Richard Iager, General Accounting Office, Telecom, August 13, 1991. Mr. Iager noted that DOE expenditures for this purpose were probably less than $150 million from 1980 to 1990.

26. See, for example: *Nucleonics Week*, "Central Interstate LLW Generators Move to Tighten Financial Controls," June 27, 1991.

27. U.S. General Accounting Office, *Uranium Enrichment: Some Impacts of Proposed Legislation on DOE's Program*, GAO/RCED-89-170BR, July 1989.

28. GAO, *Uranium Enrichment*, p. 29.

29. Charles Montange, *Stopping a Budget Meltdown: Reorganizing the Federal Uranium Enrichment Program*, National Taxpayers Union, 1990, p. 1.

30. The information in this section relies on the history provided in the DOE's 1980 *Federal Support* report.

31. DOE, *Federal Support*, p. 7.

32. DOE, *Federal Support*, pp. 11-12 give detailed description of this program.

33. DOE, *Nuclear Proliferation and Civilian Nuclear Power: Report of the Nonproliferation Alternative Systems Assessment Program*, June 1980. Cited in GAO/RCED-87-26, *Energy R&D*, p. 41. Our synopsis of nuclear R&D in the 1980s relies on the GAO document.

34. This assessment is reflected in the 1987 GAO report *Energy R&D* which describes the lack of private industry interest in picking up the slack in curtailed federal R&D funding. (p. 40)

35. DOE, *Federal Support*, p. 9

36. DOE, *Federal Support*, p. 18. Since these are "mixed" programs — combining military and civilian R&D, Battelle estimated their civilian component by prorating at the ratio of other civilian nuclear R&D to the total nuclear budget. The exception is education and training, of which Battelle allocated one-third as a civilian subsidy.

37. Battelle, *Federal Incentives*, p. 139, citing AEC authorizing legislation for 1973.

38. GAO, *Nuclear Costs*, p. 15.

39. Battelle, *Federal Incentives*, p. 132.

40. The Atomic Energy Commission, with the approval of the powerful Joint Committee on Atomic Energy of the U.S. Congress, provided that the cost recovery requirement applied to both direct and indirect costs, including depreciation and a return on investment. Under the "Conway Formula," worked out with the Joint Committee, non-government customers were required to pick up all depreciation costs when private toll enrichment began absorbing 75% of the capacity of the enrichment plants. That point was reached in 1976. When the [DOE] appeared to diverge from this basic approach, Congress amended [the Atomic Energy Act of 1954] in order to confirm an opinion by the General Accounting Office that the statute required the federal government to price uranium enrichment services so as to secure full cost recovery. *Stopping a Budget Meltdown*, p. 5. Information in this section comes from this document, unless otherwise noted.

41. Interest accumulation on the enrichment charges was calculated by imputing risk-free interest (at 7.5%/yr) beginning with the succeeding year and extending through 1990.

42. GAO, *Uranium Enrichment*, p. 41

43. DOE, *Federal Support*, p. 48.

44. "The Nuclear Legacy - How Safe Is It?" *The Workbook*, Southwest Research and Information Center, July-October 1983, p. 152.

45. GAO, *Uranium Enrichment*, p. 20.

46. *A "Low-Level" Nuclear Waste Primer*, Sierra Club, Buffalo, New York, 1981 p. 1.

47. For several weeks in 1979, for instance, the Hanford and Beatty sites were shut, and the Barnwell facility raised its fees and limited the amount of waste it would accept during this crisis period. This incident brought attention to the inadequacy of low-level waste facilities and led to the passage of the Low-Level Radioactive Waste Policy Act the following year.

48. *Nucleonics Week*, "Study Says LLW Sites Could Have a Lifetime Cost of $5.2 Billion," February 18, 1988, p. 5

49. For recent examples see *Nucleonics Week*, "US Ecology LLW Siting Commended But Voters May Have Last Word," (Aug. 29, 1991); "California Grants Draft License for LLW Repository," (Jun. 27, 1991); "Central Interstate LLW Generators Move to Tighten Financial Controls," (Jun. 27, 1991); "Connecticut Picks Possible Sites for LLW Facility," (Jun. 20, 1991); "LLW Authority's Siting Delays Cost Overruns Seen Justified," (Jun. 20, 1991).

50. U.S. General Accounting Office, *Nuclear Waste: Changes Needed in DOE User-Fee Assessments to Avoid Funding Shortfall*, GAO/RCED-90-65, June 1990, p. 19.

51. GAO, *Nuclear Waste*, p. 17. See also Footnote 14 in Appendix A *Wrong on the Money* citing the GAO's testimony to Congress regarding the need for a higher fee.

52. (Minus) $4.1 billion represents the anticipated revenues available in the Nuclear Waste Fund at the end of the program minus the projected costs. The result has been deflated to 1988 dollars (assuming 4% inflation rate) and to account for the time value of money. GAO, *Nuclear Waste*, p. 4. The GAO analysis assumes no new reactor orders. Under this scenario, all plants will be retired and have ceased producing electricity by 2037. Because utilities stop contributing to the fund when they are no longer producing electricity by nuclear power, all contributions to the fund will end in 2037. However, the waste program will run through 2087. Thus, sufficient fees must be collected before 2037 to fund the remaining 50 years of the program.

53. The following table summarizes the assumptions used to estimate tax reductions enjoyed by utilities owning operating nuclear power plants.

TAX BREAKS: SUMMARY OF KEY ASSUMPTIONS				
Plants Completed in Year Shown	1968-73	1974-79	1980-86	1987-90
Ratio of Direct to Total Costs	90%	80%	70%	65%
Depreciation Method	DDB-16	DDB-16	ACRS-16	ACRS-16
Investment Tax Credit	10%	10%	8%	6.5%
Cost of Debt	7.5%	9%	12.5%	10%
Cost of Preferred Stock	8.5%	10%	13.5%	11%
Cost of Common Equity	10.5%	12%	15.5%	13%
Federal Income Tax Rate	48%	48%	46%	35.5%

Notes: DDB-16 denotes Double Declining Balance method of depreciation, calculated for 16-year tax life. ACRS-16 denotes Accelerated Cost-Recovery System for depreciation, also calculated for 16-year tax life. All fixed charge rates calculated with capitalization ratios of 50% debt, 15% preferred, 35% equity, and state income tax rates of 4%. 1987-90 tax rates are averages reflecting transition rules in Tax Reform Act of 1986.

APPENDIX A

WRONG ON THE MONEY...
A Response to USCEA'S *Right on the Money: Costs, Benefits, and Results of Federal Support for Nuclear Energy*[1]

In April 1991 the nuclear industry public relations and lobbying arm, the U.S. Council on Energy Awareness, released a report asserting that the federal government's investment in the nuclear industry will ultimately be paid back 7 to 9 times in increased GNP. ***Right on the Money: Costs, Benefits, and Results of Federal Support for Nuclear Energy***, prepared for the USCEA by Management Information Services, also estimates that the total government subsidy of nuclear power from 1950-1988 has been only $39 billion in 1988 dollars — considerably less than our estimate of $80 billion in 1988 dollars for the same period.[2] The USCEA's lower estimate of governmental support for nuclear power is key to its conclusion that the benefits from nuclear power have greatly outweighed its costs to society.

The preceding sections of our study of government investment and other direct and indirect costs of nuclear power clearly contradict these claims. This section of our report directly addresses some of the points raised in the USCEA study.

Right on the Money begins with an explanation of why government incentives were required to inaugurate and sustain the development of commercial nuclear power. According to the USCEA, the market failed to deliver nuclear power just as it is unable to provide other desirable public goods such as parks or police. Private firms were unlikely to invest in the development of the industry without government support because competing energy sources were less heavily regulated, giving them an unfair advantage.

Of course, the notion that subsidies were required to jumpstart a risky but eventually self-sustaining industry falls flat when we observe that nuclear power continues to receive subsidies 40 years later. USCEA justifies continued government support by its analysis that nuclear power provides vast benefits which flow to the public rather than investors; hence, it should be "made" economical to investors by means of public subsidy.

NUCLEAR POWER COSTS

Right on the Money limits its characterization of federal subsidies to nuclear power from 1950 through 1988 to the following categories (all figures given in 1988 constant dollars):

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[1] The views in this appendix do not necessarily reflect the organizational views of Greenpeace.

[2] We estimated the total 1950-1990 federal subsidy to nuclear power at $97 billion in 1990 dollars, in Section 2, Table 16. The 1950-1988 portion of this is $79.8 billion in 1988 dollars.

- Research and development on programs "directly supportive of nuclear energy as an electricity generation source": ***$33.1 billion***[3]

- Federal regulation, net of user fees: ***$6.6 billion***

- "Other" supporting activities from federal government departments other than the principal energy agencies: ***$1.7 billion***[4]

The USCEA subtracts from these costs the positive balance of the Nuclear Waste Fund — $2.4 billion.[5] **Thus, the USCEA estimates that the federal government has invested $39.0 billion (1988 dollars), or approximately $42.4 billion in 1990 dollars, in commercial nuclear power.**

Further below we itemize the omissions in the subsidy compilation in the USCEA report and also critique the report's estimates of nuclear power benefits. Interestingly, the USCEA subsidy estimate appears to be off by almost $8 billion through a computational error alone. Inflating the annual nuclear R&D costs in the USCEA report to 1988 dollars and summing the results yields a $40.7 billion cost for R&D alone (1988 dollars), rather than the $33.1 billion reported in the USCEA report.[6] Although the Management Information Services consultants who prepared the report admitted that "a major mistake" had been made, the USCEA has so far done nothing to correct the $7.6 billion undercount in their reported total.[7]

The USCEA's subsidy estimate for 1950-1988 of $39.0 billion, or, alternatively, $46.6 billion, compares to our estimate of $79.8 billion for the same period (both figures in 1988 dollars).[8] Our estimate includes:

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3 USCEA's source for expenditures through 1978 was *An Analysis of Federal Incentives Used to Stimulate Energy Production* (1980) published by Battelle Pacific Northwest Laboratory. For years 1979 through 1988, USCEA cites "U.S. Department of Energy."

4 The "other" category is based on *The Hidden Costs of Energy*, Rick Heede, Center for Renewable Resources, 1985. That report covered the year 1984, and estimated that federal government departments other than the principal energy agencies contributed an amount equal to 7.6% of his estimate of the subsidy from DOE and NRC. The USCEA has elected to add 5% of R&D expenditures for "all years" (we assume since 1950) through 1988 to the total subsidy estimate as "Other Supporting Programs."

5 See discussion of the Nuclear Waste Fund below.

6 We derived $40.7 billion by inflating to 1988 dollars the yearly figures reported in the USCEA's Tables 1 and 3 for general and civilian radioactive waste R&D from 1950 through 1988. The sum of these figures is $40.7 billion in 1988 dollars.

7 Telecom with Bob Wendling, Management Information Services, July 24, 1991.

8 Our estimate through 1990 is $70.8 billion in government agency outlays, plus $26.1 billion in tax breaks for a total subsidy of $97 billion (1990 dollars).

- Research and development applicable to the development of commercial nuclear power, including R&D on fission and breeder reactor technologies, early military-related research on Light Water Reactors, a portion of general science and technology research carried out by the Atomic Energy Commission (AEC), and radioactive waste R&D: ***$42.8 billion***

- Federal regulation, net of user fees: ***$7.8 billion***

- The federal government's unrecovered costs resulting from its investment in commercial nuclear fuel enrichment, including operating costs net of utility payments, depreciation on enrichment facilities, and capital improvements and additions: ***$9.6 billion***

- Capital charges avoided via tax breaks taken by utilities which own and operate nuclear power plants: ***$17.8 billion***

- Nuclear Waste Fund shortfall: ***$1.9 billion.***

Our total subsidy estimate is higher than the USCEA's because we have included in our estimate two crucial subsidy categories which the USCEA has excluded (enrichment and tax breaks), and because we do not subtract the positive balance of the Nuclear Waste Fund from the total subsidy, but rather *include* the U.S. General Accounting Office-projected shortfall in the Fund. In addition, we have identified other categories of subsidies which we have not quantified and therefore not included in our dollar estimate. The USCEA does not even consider these items to be subsidies. The differences are detailed below.

ENRICHMENT

The USCEA analysis excludes any cost to the government for uranium enrichment services provided to electric utilities, concluding that "federal incentives for commercial nuclear energy through the enrichment program were negligible."

The USCEA acknowledges that the dominant market for enrichment services is the commercial nuclear power industry and that several expensive efforts have been undertaken (though never completed) to expand U.S. enrichment capacity to meet projected commercial sector demand.[9] However, the USCEA claims that because the plants were originally built to meet military enrichment needs, it is unfair to characterize the GAO's estimate of $9.6 billion in unrecovered government investment in commercial nuclear fuel enrichment as a subsidy to the nuclear industry.[10] The USCEA reasons that because the government did not anticipate the commercial sector and therefore did not *plan* to subsidize commercial power's enrichment needs, no

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9 USCEA, p. 14.

10 U.S. General Accounting Office, *Uranium Enrichment: Some Impacts of Proposed Legislation on DOE's Program*, GAO/RCED-89-170BR (July 1989).

subsidy can be attributed now.

As we stated in Section 2, we agree with Congress that enrichment charges properly include capital recovery, including depreciation. Moreover, unrecovered federal government costs for enrichment services provided to the commercial nuclear industry are growing at an estimated $0.5 billion a year.[11] Federal legislation requires that DOE recover its investment in the plants, but DOE is following in the AEC tradition of undercharging commercial customers for enrichment services.

OTHER SUBSIDY CATEGORIES

The USCEA's summary of costs also excludes government support for commercial uranium production, nuclear accident liability insurance, military applications of atomic power and radioactive waste management.[12] Although we have excluded dollar figures for these areas of federal support in our analysis, this was because of the difficulty of quantifying the level of support. Unlike the USCEA, we believe that these types of federal support are, in fact, subsidies to the commercial nuclear industry.

WASTE FUND BALANCE

USCEA counts the positive balance of the Nuclear Waste Fund (NWF) — $2.4 billion — as an industry-supplied asset (or subsidy) to the government, and therefore subtracts this amount from the total subsidy. In reality, the positive balance is strictly temporary. The GAO has estimated that the total costs at completion of the high-level waste disposal facility(ies) will be far in excess of the expected revenues in the NWF.[13] The positive balance in the NWF is explained by chronic delays in program deployment which will ultimately escalate the total cost of secure high-level waste disposal and will almost certainly require further government investment to complete the project.[14] Based on the GAO assessment of fund inadequacies,

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[11] Montange, Charles, *Stopping A Budget Meltdown: Reorganizing the Federal Uranium Enrichment Program*, National Taxpayers Union Federation, 1990.

[12] While not all military-related R&D on nuclear power has had commercial applications, military and civilian R&D continues to overlap (as has been the case historically), sharing personnel and information. (See our discussion of Excluded Costs and Subsidies in Section 2.)

[13] U.S. General Accounting Office, *Nuclear Waste: Changes Needed in DOE User-Fee Assessment to Avoid Funding Shortfall*, GAO/RCED-90-65 (June 1990), p. 19. (See our discussion of Waste Management in Section 2.)

[14] In May 1991, a GAO representative testified before the Subcommittee on Energy and Power, Committee on Energy and Commerce of the House of Representatives that the NWF fee structure is not adequate. She also directly addressed the issue of the positive balance in the NWF:

> Large fund balances in the early years of the program should not influence decisions about fee adequacy. Surpluses, such as the $3 billion in the Fund at the end of April 1991, are to be ex-

we have estimated the amount that utilities should have contributed in order that the Fund does not face a shortfall at completion of the program.

TAX BREAKS

The USCEA takes the unique position that no tax "breaks" have been enjoyed by the nuclear industry. In contrast, we have estimated that through 1990 utilities have already taken advantage of $21.2 billion (mixed current dollars) in tax breaks.[15]

The USCEA reasons that the industry has received no subsidy via tax breaks because "there are no provisions of the federal tax code that apply uniquely to nuclear energy or that were enacted for the specific purpose of subsidizing the development of commercial nuclear power." In other words, because other industries enjoy subsidies via tax breaks, this practice is too standard to be considered a subsidy to the nuclear industry. The USCEA considers it "ludicrous" to view deductions taken by the industry as anything more than the standard meals and entertainment deductions available to every Mom and Pop store.

Yet in 1990 alone, nuclear utilities took advantage of $2.6 billion dollars worth of tax breaks. It stretches the dictionary for the USCEA to defend such an astronomical sum as "standard." While nuclear power is by no means the only sector of the economy to benefit from accelerated depreciation and investment tax credits, it has benefitted especially heavily due to its extraordinary capital-intensiveness.[16]

NUCLEAR POWER BENEFITS

As our study indicates, the public and private sectors have invested roughly half-a-trillion dollars in commercial nuclear power over the last 40 years. The USCEA's primary message is that this investment through our taxes and electric bills has been paid back many times over in societal benefits — from cleaner air and reduced foreign oil dependence to jobs and increased GNP.

However, the USCEA is only able to present this cornucopia of nuclear good things by:

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pected early in the program, when expenditures are relatively small, as contrasted with later years, during construction and operation of one or two repositories. *Nuclear Waste: Changes Needed in DOE User-Fee Assessments*, GAO/T-RCED-91-52.

[15] Tax breaks through 1990 total $17.9 billion in 1990 constant dollars. See Section 2, FN 53.

[16] The 1980 DOE report, *Federal Support for Nuclear Power: Reactor Design and the Fuel Cycle* (DOE/EIA-0201/13), writing about the history of nuclear power R&D, describes tax breaks available to firms participating in the AEC Power Reactor Demonstration Program: "Utilities involved had access to low-cost capital, a result, in one case, of Rural Electrification Administration loan guarantees and, in the other case, because of the tax-exempt status of municipal bonds." p. 13

- disguising costs as benefits
- ignoring significant costs
- making excessively favorable comparisons with fossil fuels, and
- ignoring conservation or renewables as alternative energy sources.

Some of the societal benefits that the USCEA alleges have been produced by nuclear power are elaborated below, along with brief rejoinders.

Benefit 1. *Nuclear power plants have displaced anticipated fossil fuel plants "and since the cost of nuclear-generated power has generally been lower than that of fossil fuel plants, significant savings have accrued to electricity consumers over the past two decades." The USCEA estimates this savings at $55 billion.*[17]

The USCEA may be the only group left in America suggesting that nuclear-generated electricity has generally been cheaper than other power sources.[18] Other authorities, including DOE, *Forbes* (with its 1984 "$100 Billion Meltdown" cover story) and even USCEA's predecessor, the Atomic Industrial Forum, have long since thrown in the towel and conceded that nuclear power is far costlier than fossil fuel power.[19]

To be sure, some U.S. reactors — one to two dozen — have managed to combine reasonably good plant performance and moderate capital and operating costs. These plants stand out as

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[17] USCEA, p. iv.

[18] The USCEA report cites seven studies in support of its economic savings claims for nuclear power; all seven are by one firm, Science Concepts, which has long been associated with USCEA and its predecessor, the Atomic Industrial Forum. (See USCEA, Notes 49 and 50.) Although we have not reviewed the Science Concepts studies in detail, their methodology for calculating nuclear power "savings" is questionable at best. For example, Science Concepts computes fossil plant costs on a per-kWh basis, with fixed (capital) costs divided, in effect, by plant capacity factor; in calculating what it would have cost to increase fossil generation (in the absence of nuclear power), these capacity factors should be adjusted upward, since low-utilized plants, particularly oil-fired plants, would have taken up much of the slack. Science Concepts makes no adjustment, however, and thereby acts as if utilities would have built new fossil plants in preference to increasing output from existing plants with 25% capacity factors! This is one way in which Science Concepts inflates the value of nuclear power.

[19] The Atomic Industrial Forum's annual *Economic Survey* for 1984 reported average nuclear generating costs of 4.1¢/kWh, and 3.4¢/kWh for coal; the prior year's *Survey* indicated a nuclear-coal tie, at 3.5¢/kWh. As unfavorable to nuclear power as these figures are, they still understated nuclear costs and inflated coal costs by omitting some reactor "back-end" (decommissioning and waste disposal) costs, and including only the minority of U.S. coal plants operated by ***nuclear*** utilities -- a criterion biased toward regions where coal was more expensive and where coal plants tended to be underutilized. See Note 20. The AIF's final survey, covering 1985 power costs, showed nuclear plants averaging 4.3¢/kWh and coal plants 3.4¢. Both the AIF's coal and nuclear cost estimates omitted environmental externalities.

low-cost, reliable electricity suppliers. Perhaps another one or two dozen reactors are roughly comparable in cost with fossil plants. But the vast majority of the 108 commercial U.S. nuclear units have cost, and continue to cost, considerably more to own and operate than fossil fuel plants.

For a brief period in the 1970s, starting directly after the Arab oil embargo (and the concurrent runup in U.S. coal prices), nuclear power was competitive with, and sometimes cheaper than, coal-fired electricity. This period was short-lived, however. By 1978 — the year before Three Mile Island — rising capital costs and poor plant performance had driven the average nuclear generating cost above that of coal.[20] The gap widened dramatically after TMI, as every key category of nuclear costs (excepting fuel) — capital, O&M and capital additions — was launched into a spectacular cost upward spiral. Thus, the period of nuclear power's competitiveness — roughly 1973-77 — was an anomaly, accounting for only 13% of total nuclear power generation to date (1968-1990).

Our analysis shows that U.S. nuclear power plants ran up an average cost during 1990 of 9.1¢/kWh. This average spans a wide range, from as little as 3¢/kWh for low-capital-cost, high-capacity-factor 1970s-era plants such as Point Beach and Prairie Island, to 12-15¢/kWh for mid- and late-1980s reactors that cost $2,000 to $5,000 per kW to construct. The closest "competitor" is oil at 5¢/kWh average, while coal and gas-fired plants probably average around 4¢/kWh (slightly more for the newest plants). Indeed, nuclear's current 9¢/kWh average (8¢ in direct reactor costs and 1¢ in indirect costs — mostly the sunk cost of cancelled reactors), easily exceeds the 1990 average U.S. retail electricity price of 6.6¢/kWh, a figure that includes not only generating costs but also transmission, distribution and reserve capacity.

Benefit 2. *"Investments in R&D pay themselves back with increased GNP by a factor of between 7 and 9 to one over an 18 year period. This analysis estimates that through 1988 the return to the economy of the $33.1 billion investments in commercial nuclear energy R&D programs between 1950 and 1988 totalled $150 billion, and that through 1988 the payback to the economy (thus far realized) of the Federal government's commercial nuclear energy R&D program was about 5 to 1."*[21]

To establish this "benefit," the USCEA applies a general rule-of-thumb for returns from scientific and technological R&D, with no direct evidence that it applies specifically to nuclear power. Indeed, Benefit 2 is based on studies of NASA investments — a realm with little parallel to nuclear power. Furthermore, using this general approach, the argument can easily be

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[20] See C. Komanoff, *Power Propaganda* (Environmental Action Foundation, Washington DC, 1980) for a comprehensive debunking and recalculation of the Atomic Industrial Forum's survey of 1978 nuclear and fossil generating costs, and the conclusion that 1978 nuclear generating costs, at 2.0¢/kWh, slightly exceeded those of coal (1.9¢/kWh). The AIF conceded most of the criticisms in *Power Propaganda* in an article in *The New York Times*, "Group Says Study Distorted Nuclear Power Costs," March 6, 1980. All subsequent AIF surveys, similarly corrected, showed nuclear generation costing more than coal-fired power.

[21] USCEA, p. iv.

made that R&D investment in any alternate energy technology such as solar or hemp fuel would produce the same effect on GNP.

Moreover, much of the nuclear industry's contribution to GNP has been through monies committed to non-productive and non-sustainable projects, e.g., the 120 or so reactors which were partially built, but subsequently cancelled. Utilities spent $44.4 billion through 1990 (constant 1990 dollars) on these plants which never will produce a drop of nuclear-generated electricity.[22] This amount alone represents more than a fourth of what the USCEA claims in returns to society through future increases in GNP.

Another large share of "increased GNP" can be attributed to escalated costs, expensive replacement power and finance charges incurred as a result of construction delays and plant outages. The nuclear industry has increased GNP with such investments as the reconstruction of Diablo Canyon after the discovery that plant accident systems had been built backwards, the $5.5 billion sunk into Shoreham before it was cancelled, and litigation fees paid to lawyers after a decade of financing Seabrook bankrupted the Public Service Company of New Hampshire. The billions expended on the Clinch River Breeder Reactor project or the Gas Centrifuge Enrichment Plant, both cancelled in 1984, might also be characterized by the USCEA as being good for the economy. Any rational observer would consider it a waste.

Benefit 3. *"The environmental benefits of nuclear energy are clear: unlike the burning of fossil fuels it causes little air or water pollution. This analysis estimates that through 1988 the environmental benefits of nuclear energy resulting from the reduction of SO_2 emissions totalled $83 billion."*[23]

Right on the Money vastly overstates the size of any environmental benefits that may result from the use of nuclear power, through these four errors:

1. assuming that the demand for electricity in the absence of nuclear power would have been met entirely by burning fossil fuels;

2. assuming that high-sulfur coal, rather than average-sulfur coal, would have been burned in the absence of nuclear power;

3. imputing an air pollution "price tag" from the 1990 Clean Air Act to air pollution from the prior two decades;

4. ignoring the death, disease and danger introduced through nuclear power generation.

Point 1: The USCEA is probably on target in estimating that a little less than half (47%) of the fossil fuel electricity displaced by nuclear power was from coal-burning plants. What is

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[22] See Section 1 on Cancelled Plants. 121 reactors have been cancelled.

[23] USCEA, p. iv.

questionable is the implicit assumption that, without nuclear power, the amount of electricity generated in the U.S. would have remained the same, and would have employed precisely the technologies that were deployed in the '70s and '80s. If not for the seduction of U.S. utilities and policy-makers by nuclear power, a wide array of technologies — ranging from low-emitting coal plants such as fluidized-bed boilers, to fuel cells, wind turbines, and energy-efficient end-use lighting, appliances and motors — would almost certainly have gained funding, political favor and at least a foothold in utility applications.[24] These sources would have taken up at least some of the slack left by nuclear power, with far less environmental pollution than the coal plants assumed by USCEA.

Point 2: According to the USCEA, the coal burning displaced by nuclear power would have generated 55 million tons of sulfur dioxide emissions during 1973-1988. A simple back-calculation indicates that the average coal sulfur content assumed by the USCEA was slightly under 3%. Yet at least as far back as the late 1970s, U.S. utility coal has averaged around 2% sulfur. Moreover, the effective average in the 1980s, the period in which most of nuclear power's coal displacement occurred, has probably been even less, due to the increasingly widespread use of SO_2-capturing scrubbers on utility boilers. Thus, even with the USCEA's static perspective on alternatives to nuclear power, its SO_2 savings in tons and dollars are probably overstated by about 50%.[25]

Point 3: If reduced air pollution is a benefit of nuclear power, then "routine" emissions of radioactivity, emissions during accidents, the various levels of nuclear waste, and public unease and fear are all nuclear power costs. These are ignored by the USCEA report.

Benefit 4. *"Cumulatively through 1988 the construction and operation of nuclear energy plants generated $1,161 billion in economic product, created 10.5 million man-years of employment, and generated $345 billion in federal state, and local government tax revenues."*[26]

This statement gives an estimate of the cost of the resources expended in the nuclear adventure. Refer to the response to Benefit 2 (above). Presumably, if nuclear power plant cost overruns had averaged 10-fold rather than the actual 5 times projected costs, we could double

[24] For an incisive analysis of how an officially sanctioned technology derives a wide range of economic benefits via access to capital, risk reduction and technological momentum, see Cohn's "The Political Economy of Nuclear Power 1945-1990: The Rise and Fall of an Official Technology," *Journal of Economic Issues*, September 1990.

[25] The $1500/ton value (1988 dollars) that the new Clean Air Act places on reducing SO_2 emissions was only established in 1990. While we personally believe that acid rain and airborne sulfates are extremely damaging to human health and the environment, the fact remains that society, as intermediated by government, apparently did not arrive at such a conclusion until 1990, when the $1500/ton value was codified into law. A more appropriate measure of the value of displaced SO_2 in the '70s and '80s would rely on implicit valuations derived from the less-aggressive regulatory and legislative rules in place during that period. Such a value would be less than $1500/ton.

[26] USCEA, p. v.

the USCEA's estimate of nuclear power's contribution to the economy. And then we would also have had even less money left over to spend on clothes, books, bicycles and everything else not being poured into the design, construction, repair, monitoring and cleanup of nuclear power plants. The notion that such appropriation of funds is a "benefit" of nuclear power reflects a narrow perspective typical of nuclear power boosters.

Benefit 5. *"[This] analysis estimates that between 1973 and 1988 nuclear energy displaced nearly 4 billion barrels of imported oil valued at $115 billion."*[27]

Refer to Benefit 3, Point 1 above, regarding the fallacy that electricity demand in the absence of nuclear power would have been (i) constant and (ii) supplied only by the limited fossil fuel technologies that remained to fight over the crumbs after nuclear power had taken the lion's share of energy R&D and expectations for several decades.[28]

USCEA Benefit 5 reflects tunnel vision in another respect, in the unspoken assumption that nuclear power was the only resource or policy available to displace oil consumption on a large scale. Yet, to cite just one counter-example, from 1978 to 1982, while U.S. nuclear generation rose a mere 2%, petroleum consumed to produce electricity fell by a resounding 61%, as coal and conservation took up the slack. More broadly, the failure of the Reagan-Bush Administrations to pursue policies that could have sustained the 1976-1986 rate of improving U.S. energy efficiency had led, by 1990, to U.S. oil over-consumption of roughly 1.6 million barrels per day — or over half-a-billion barrels in 1990 alone.[29]

Finally, the nuclear industry continually cites nuclear power as the antidote to foreign oil dependency and an asset to national security. The U.S.-Iraq war belies this argument, insofar as nuclear power was a partial motivation for American military action. Iraq's experimental nuclear power reactor (built with western technology and support) generated justifiable fears regarding Iraqi nuclear weapons capability. Even though Iraq was a signatory to the Nuclear Non-Proliferation Treaty, the safeguard system imposed by the International Atomic Energy Agency was insufficient to prevent Iraq from developing a partial nuclear weapons capability under the cover of civilian use. Whether oil was at stake in the Gulf or not, nuclear weapons most certainly were.

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[27] USCEA, p. v.

[28] The USCEA's 4 billion barrel figure also appears overstated, even on its own premises. At 6.3 million Btu per barrel (#6 oil) and a 10,400 Btu/kWh heat rate, the 1,974 billion kWh that USCEA estimates were displaced from oil-fired plants in 1973-1988 would have required approximately 3.25 billion barrels.

[29] Calculation assumes that 50% of the energy that would have been saved in 1990 (by continuing the average 1976-1986 rate of improvement (2.8%/year) in the U.S. GNP/Btu ratio beyond 1986) would have been in the form of petroleum. See Matthew Wald, "America is Still Demanding a Full Tank," *The New York Times*, August 12, 1990.

SUMMARY

As with its close cousin, the military sector of the U.S. economy, commercial nuclear power in the United States has absorbed vast amounts of financial, natural and human resources, required the public to sustain its detrimental economic and environmental effects, and provided little which couldn't have been gotten cheaper and better from alternative strategies.

The USCEA study appears intended to distract our attention from this assessment and prepare us for another costly stroll down the nuclear path. The American public can make a more informed decision of this "option" by having full knowledge of the true costs from the first time around.

APPENDIX B

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APPENDIX C

CALCULATION DETAIL SPREADSHEETS

Annual Costs of Commercial U.S. Nuclear Power, 1968-1990 (+ Pre-1968 Summary)

SUMMARY RESULTS, 1968-1990 ONLY	Unadjusted Dollars	
Consumer spending on Operating Plants	$282 Billion	5.25 ¢/kWh
Consumer spending on Operating+Cancelled Plants	$318 Billion	5.92 ¢/kWh
Total Expenditures, incl. Subsidies	$379 Billion	7.06 ¢/kWh
	1990 Constant Dollars	
Consumer spending on Operating Plants	$341 Billion	6.35 ¢/kWh
Consumer spending on Operating+Cancelled Plants	$385 Billion	7.17 ¢/kWh
Total Expenditures, incl. Subsidies	$472 Billion	8.80 ¢/kWh

COST OF SAVING EACH BARREL OF OIL WITH NUCLEAR POWER

kWh Generated by Commercial Reactors 1968-90	5,369 Billion
Barrels of oil displaced if all kWh from oil	8.5 Billion

COUNTING ONLY CONSUMER SPENDING ON OPERATING PLANTS

If all kWh were from oil (in nominal dollars)	$33
If all kWh were from oil (in 1990 constant dollars)	$40
If 50% of kWh were from oil (in nominal dollars)	$66
If 50% of kWh were from oil (in 1990 constant dollars)	$80

COUNTING ALL NUCLEAR COSTS, INCLUDING SUBSIDIES

If all kWh were from oil (in nominal dollars)	$44
If all kWh were from oil (in 1990 constant dollars)	$55
If 50% of kWh were from oil (in nominal dollars)	$89
If 50% of kWh were from oil (in 1990 constant dollars)	$111

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Consumer Spending on Operating Plants, 1968-1980													
Number of Reactors	2	2	4	7	12	20	26	38	48	51	58	61	62
Average Reactor Capacity (MW)	513	513	571	583	638	666	701	744	774	780	796	805	804
Total Reactor Capacity (MW)	1,025	1,025	2,285	4,081	7,653	13,310	18,218	28,264	37,134	39,761	46,175	49,088	49,872
Average Capacity Factor, %	47.28	69.56	58.64	64.00	61.67	57.54	52.04	58.45	55.32	62.58	64.72	57.80	55.44
Electricity Generation (million Net kWh)	4,257	6,246	11,738	22,878	41,454	67,087	83,049	144,717	180,437	217,965	261,802	248,532	242,860
Capital Cost of Year's New Plants ($million)	179	257	83	782	643	1,211	3,280	2,718	2,973	2,922	715	4,489	633
Total Capital Cost to Date ($million)	179	436	519	1,301	1,944	3,155	6,435	9,152	12,126	15,048	15,763	20,251	20,884
Average New Plant CO Date (weighted by cost)	68.00	69.92	70.17	71.46	72.89	73.31	74.53	75.60	76.50	77.46	78.92	79.65	80.17
Capital/Construction Costs ($million)	29	31	79	146	207	424	753	1,244	1,767	2,253	2,400	2,699	3,244
Average O&M Cost ($/kW)	3.9	4.1	4.4	5.0	5.7	7.3	9.6	11.5	13.0	14.7	17.7	22.0	32.1
O&M Costs, this year ($million)	4	4	10	20	43	98	175	324	481	585	819	1,082	1,600
Average Capital Additions, this year ($/kW)	0	2	4.3	2.4	3.0	6.7	6.7	4.7	7.8	14.9	11.5	12.2	21.5
Capital Additions Costs, this year ($million)	0	2	10	10	23	89	122	133	290	593	530	597	1,070
Average Fuel Cost, mils/kWh	1.54	1.64	1.75	1.86	1.89	2.12	2.15	2.54	2.70	2.85	3.22	3.73	5.63
Fuel Costs, this year ($million)	7	10	21	43	78	142	179	368	486	621	843	927	1,367
Decommissioning Set-aside, this year ($million)													44
Total Costs, this year ($million)	40	47	119	219	352	753	1,229	2,069	3,024	4,052	4,592	5,305	7,325
Average Cost per Nuclear kWh (cents)	0.93	0.76	1.01	0.96	0.85	1.12	1.48	1.43	1.68	1.86	1.75	2.13	3.02
Total Costs, this year (90$, million)	141	160	383	668	1,024	2,059	3,090	4,748	6,528	8,184	8,598	9,143	11,534
Average Cost per Nuclear kWh (90¢)	3.32	2.57	3.26	2.92	2.47	3.07	3.72	3.28	3.62	3.75	3.28	3.68	4.75
Add: Cancelled Plants, 1968-1980													
Sunk Costs, Cancelled Reactors ($million)					60	0	80	120	0	223	520	173	1,756
Total Costs, including Cancelled Plants ($million)	40	47	119	219	412	753	1,309	2,189	3,024	4,275	5,112	5,478	9,081
Average Cost (+Cancel $) per Nuclear kWh (cents)	0.93	0.76	1.01	0.96	0.99	1.12	1.58	1.51	1.68	1.96	1.95	2.20	3.74
Total Costs, Counting Cancel $ (90$, million)	141	160	383	668	1,199	2,059	3,292	5,023	6,528	8,634	9,571	9,442	14,299
Average Cost (+Cancel $) per kWh (90¢)	3.32	2.57	3.26	2.92	2.89	3.07	3.96	3.47	3.62	3.96	3.66	3.80	5.89
Add: Accounting Adjustments for Waste, Decommissioning, 1968-1980													
Decommissioning, Set-aside Deficiency ($million)													19
Nuclear Waste Fund, 1-Time Fees ($million)	1	2	4	8	15	26	35	66	89	115	150	156	170
Nuclear Waste Fund, Shortfall True-up ($million)	1	2	4	7	13	21	26	45	57	68	82	78	76
Add: Utility Avoidance of Taxes + Enrichment Charges, 1968-1980													
Unrecovered Enrichment Costs ($million)	5	7	12	24	44	71	88	153	191	231	278	264	258
Capital/Construction Costs Avoided via Tax Breaks ($million)	4	5	12	23	36	71	121	198	298	398	470	557	668
Total -- All costs w/o Direct Federal Support ($ million)	50	63	151	282	520	942	1,580	2,652	3,659	5,087	6,092	6,532	10,271
All costs w/o Direct Federal Support, avg cost per kWh	1.19	1.01	1.29	1.23	1.26	1.40	1.90	1.83	2.03	2.33	2.33	2.63	4.23
Total -- All costs w/o Direct Federal Support (90$, million)	180	213	486	859	1,514	2,576	3,972	6,085	7,898	10,275	11,406	11,259	16,173
All costs w/o Direct Federal Support, avg cost per kWh (90¢)	4.22	3.41	4.14	3.76	3.65	3.84	4.78	4.20	4.38	4.71	4.36	4.53	6.66

Add: Federal Support Through R&D + Regulation, 1968-1980

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Nuclear R&D Subsidies, Amortized ($million)	435	442	445	454	468	499	546	597	659	747	834	943	1,109
Nuclear Power Regulation ($million)	41	46	50	61	59	51	75	136	186	220	255	314	371
R&D Amortized + Regulation ($million)	476	488	495	514	527	550	621	732	845	968	1,089	1,257	1,479
R&D Amortized + Regulation (90$, million)	1,695	1,653	1,592	1,570	1,533	1,504	1,562	1,680	1,823	1,954	2,038	2,167	2,329
Total cost adding R&D+Regulation ($million)	526	550	646	796	1,047	1,493	2,201	3,384	4,503	6,055	7,181	7,789	11,751
Avg Cost (adding R&D+Regulation) per Nuclear kWh	12.37	8.81	5.50	3.48	2.53	2.22	2.65	2.34	2.50	2.78	2.74	3.13	4.84
Total cost adding R&D+Regulation ($90, million)	1,875	1,866	2,078	2,429	3,047	4,080	5,534	7,765	9,721	12,229	13,444	13,426	18,503
Avg Cost adding R&D+Regulation per Nuclear kWh (90¢)	44.04	29.87	17.70	10.62	7.35	6.08	6.66	5.37	5.39	5.61	5.14	5.40	7.62

Add: Federal Support Through R&D + Regulation, 1981-1990

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1968-90	Pre-1968	1950-90
Nuclear R&D Subsidies, Amortized ($million)	1,288	1,482	1,614	1,687	1,778	1,820	1,724	1,641	1,548	1,337	24,096	3,009	27,105
Nuclear Power Regulation ($million)	409	443	481	425	373	363	347	370	370	370	5,814	138	5,952
R&D Amortized + Regulation ($million)	1,697	1,925	2,095	2,112	2,151	2,182	2,071	2,011	1,918	1,707	29,911	3,146	33,057
R&D Amortized + Regulation (90$, million)	2,428	2,594	2,713	2,621	2,573	2,543	2,338	2,185	1,998	1,707	46,800	12,945	59,745
Total cost adding R&D+Regulation ($million)	12,899	18,862	15,090	32,437	23,064	31,037	37,828	46,646	56,189	56,959	378,934	3,146	382,080
Avg Cost (adding R&D+Regulation) per Nuclear kWh	4.99	6.93	5.55	10.72	6.55	8.33	8.74	9.41	10.86	10.15	7.06		7.12
Total cost adding R&D+Regulation ($90, million)	18,458	25,412	19,538	40,243	27,584	36,162	42,708	50,687	58,521	56,959	472,269	19,541	491,809
Avg Cost adding R&D+Regulation per Nuclear kWh (90¢)	7.14	9.34	7.19	13.30	7.84	9.70	9.87	10.23	11.31	10.15	8.80		9.16

Other Parameters for the Analysis, 1968-1980

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
GDP Deflator, 1987=100	31.7	33.3	35.1	37.0	38.8	41.3	44.9	49.2	52.3	55.9	60.3	65.5	71.7
GDP Deflator, 1990=100	28.1	29.5	31.1	32.8	34.4	36.6	39.8	43.6	46.3	49.5	53.4	58.0	63.5
Risk-Free Interest Rate (10-Yr Treasury Bonds)	5.7%	6.7%	7.4%	6.2%	6.2%	6.8%	7.6%	8.0%	7.6%	7.4%	8.4%	9.4%	11.5%

Other Parameters for the Analysis, 1981-1990

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
GDP Deflator, 1987=100	78.9	83.8	87.2	91.0	94.4	96.9	100.0	103.9	108.4	112.9
GDP Deflator, 1990=100	69.9	74.2	77.2	80.6	83.6	85.8	88.6	92.0	96.0	100.0
Risk-Free Interest Rate (10-Yr Treasury Bonds)	13.9%	13.0%	11.1%	12.4%	10.6%	7.7%	8.4%	8.9%	8.5%	8.5%

Property tax rate: 1.0%
Insurance rate: 0.25%

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1968-90	Pre-1968	1950-90
Consumer Spending on Operating Plants, 1981-1990													
Number of Reactors	64	68	69	74	80	86	94	100	106	107		10	
Average Reactor Capacity (MW)	808	823	828	838	859	879	900	907	921	926			
Total Reactor Capacity (MW)	51,691	55,963	57,111	62,028	68,702	75,555	84,554	90,698	97,643	99,130		1,314	
Average Capacity Factor, %	57.10	55.50	54.31	55.54	58.48	56.32	58.42	62.20	60.47	64.61			
Electricity Generation (million Net kWh)	258,554	272,063	271,732	302,624	351,968	372,756	432,709	495,577	517,227	561,041	5,369,274	85,858	5,455,132
Capital Cost of Year's New Plants ($million)	1,659	0	10,378	11,738	15,407	30,475	17,762	32,074	8,437	15,335	164,149		164,149
Total Capital Cost to Date ($million)	22,544	22,544	32,922	44,660	60,067	90,542	108,303	140,377	148,814	164,149			
Average New Plant CO Date (weighted by cost)	81.96	NA	83.68	84.62	85.68	86.65	87.76	88.21	89.06	90.78			
Capital/Construction Costs ($million)	3,129	3,368	4,011	6,644	9,309	13,993	19,023	25,687	27,399	27,004	154,840		154,840
Average O&M Cost ($/kW)	38.7	46.8	52.9	60.8	63.3	68.6	78.2	84.1	89.2	92.7			
O&M Costs, this year ($million)	1,999	2,620	3,018	3,769	4,349	5,181	6,616	7,631	8,708	9,194	58,333		58,333
Average Capital Additions, this year ($/kW)	29.3	31.3	34.9	48.3	36.4	43.6	42.7	40.0	42.4	44.9			
Capital Additions Costs, this year ($million)	1,513	1,749	1,991	2,997	2,503	3,298	3,614	3,624	4,136	4,451	33,345		33,345
Average Fuel Cost, mils/kWh	6.22	6.64	7.30	7.31	7.30	7.30	7.30	7.30	7.30	7.30			
Fuel Costs, this year ($million)	1,608	1,806	1,984	2,212	2,569	2,721	3,159	3,618	3,776	4,096	32,640		32,640
Decommissioning Set-aside, this year ($million)	87	131	174	218	261	305	348	392	435	479	2,873		2,873
Total Costs, this year ($million)	8,337	9,673	11,177	15,839	18,991	25,498	32,760	40,951	44,454	45,223	282,031		282,031
Average Cost per Nuclear kWh (cents)	3.22	3.56	4.11	5.23	5.40	6.84	7.57	8.26	8.59	8.06	5.25		5.25
Total Costs, this year (90$, million)	11,930	13,033	14,472	19,651	22,713	29,709	36,986	44,498	46,299	45,223	340,774	6,596	347,370
Average Cost per Nuclear kWh (90¢)	4.61	4.79	5.33	6.49	6.45	7.97	8.55	8.98	8.95	8.06	6.35	7.68	6.37
Add: Cancelled Plants, 1981-1990													
Sunk Costs, Cancelled Reactors ($million)	1,549	5,809	436	12,900	0	962	0	20	5,706	5,550	35,863		35,863
Total Costs, including Cancelled Plants ($million)	9,886	15,482	11,613	28,739	18,991	26,460	32,760	40,971	50,160	50,772	317,894		317,894
Average Cost (+Cancel $) per Nuclear kWh (cents)	3.82	5.69	4.27	9.50	5.40	7.10	7.57	8.27	9.70	9.05	5.92		5.92
Total Costs, Counting Cancel $ (90$, million)	14,146	20,859	15,036	35,655	22,713	30,829	36,986	44,520	52,243	50,772	385,159	6,596	391,755
Average Cost (+Cancel $) per kWh (90¢)	5.47	7.67	5.53	11.78	6.45	8.27	8.55	8.98	10.10	9.05	7.17		7.18
Add: Accounting Adjustments for Waste, Decommissioning, 1981-1990													
Decommissioning, Set-aside Deficiency ($million)	37	56	74	93	112	130	149	168	186	205	1,229		1,229
Nuclear Waste Fund, 1-Time Fees ($million)	206	245	71								1,360		1,360
Nuclear Waste Fund, Shortfall True-up ($million)	81	85	85	95	110	117	136	155	162	176	1,683		1,683
Add: Utility Avoidance of Taxes + Enrichment Charges, 1981-1990													
Unrecovered Enrichment Costs ($million)	274	289	288	321	373	395	459	526	549	595	5,694		5,694
Capital/Construction Costs Avoided via Tax Breaks ($million)	718	780	862	1,077	1,326	1,752	2,253	2,816	3,213	3,505	21,163		21,163
Total -- All costs w/o Direct Federal Support ($ million)	11,202	16,937	12,995	30,324	20,913	28,855	35,757	44,635	54,271	55,252	349,023		347,340
All costs w/o Direct Federal Support, avg cost per kWh	4.33	6.23	4.78	10.02	5.94	7.74	8.26	9.01	10.49	9.85	6.50		6.50
Total -- All costs w/o Direct Federal Support (90$, million)	16,030	22,818	16,825	37,622	25,012	33,619	40,370	48,502	56,524	55,252	425,469	6,596	432,065
All costs w/o Direct Federal Support, avg cost per kWh (90¢)	6.20	8.39	6.19	12.43	7.11	9.02	9.33	9.79	10.93	9.85	7.92	7.68	7.92

APPENDIX D

A COMPARISON OF SOURCES: Federal Subsidies to the U.S. Nuclear Power Industry

Section 2 of this report, Federal Subsidies to the U.S. Nuclear Power Industry, surveys the history and extent of federal support for commercial nuclear power. We have derived an estimate of this support from the several documents mentioned in the body of the report. This appendix surveys the resources which we *did not* use to develop our estimate, but which nevertheless helped shape our analysis.

The appendix presents alternative estimates for federal support for nuclear power R&D, regulation, uranium enrichment and waste disposal. These estimates are shown in Table 17 in mixed current dollars and Table 18 in 1990 constant dollars. The appendix also provides further rationale for the figures we ultimately included in our estimate of federal backing for nuclear power.

TABLE 17
Appendix D: Comparative Sources
Federal Subsidies to the Nuclear Power Industry
Millions of Current Dollars

	RESEARCH & DEVELOPMENT					REGULATION		ENRICH	WASTE
	[1] GAO	[2] Battelle	[2a] Battelle	[3] D/S	[4] Budget	[5] GAO	[6] NRC	[7] Bowring	[8] DOE
1950	7.2	7.2	7.2	13.8					
1951	14.5	14.8	14.5	20.3					
1952	19.9	20.3	19.9	31.4					
1953	23.4	23.8	23.4	46.2					
1954	36.7	38.5	36.7	43.8					
1955	51.0	57.1	51.0	58.1					
1956	75.2	82.6	75.2	79.7					
1957	124.2	135.8	124.2	77.2					
1958	136.3	165.1	136.3	110.9					
1959	170.6	199.5	170.6	135.5					
1960	227.1	260.8	227.1	167.3		3.1		76.1	
1961	232.2	262.2	232.2	179.4		3.4		76.1	
1962	226.4	251.2	226.4	188.6		3.6		76.1	
1963	227.7	254.4	228.7	194.8		4.0		76.1	
1964	210.3	235.2	211.5	207.6		21.0		76.1	
1965	213.6	238.7	214.3	207.4		23.6		76.1	
1966	205.6	231.6	207.3	193.4		26.5		76.1	
1967	208.8	238.9	213.6	205.8		34.0		76.1	206.0
1968	256.2	286.4	258.5	242.2		39.7		76.1	21.0
1969	243.4	278.6	246.8	218.7		43.0		29.7	26.0
1970	243.6	286.9	249.4	213.8		49.0		80.0	28.0
1971	284.9	333.1	291.7	214.8		51.5		194.9	32.0
1972	347.4	404.5	354.4	260.4		69.5		160.0	46.0
1973	422.1	488.2	431.1	293.0		47.5		220.0	50.0
1974	558.5	659.0	558.5	497.3		55.2		723.7	61.0
1975	689.2	771.0	676.0	630.4		94.3	50.8	447.7	94.0
1976	721.3	752.0	613.0	960.6		221.0	188.2	437.8	158.0
TQ	214.8	238.0	188.0						
1977	988.7	1109.0	898.0	1065.0		213.6	218.1	685.5	235.0
1978	1195.8	1355.0	1078.0	1051.0		240.2	280.2	641.3	362.0
1979				1081.1			298.9	717.5	483.0
1980				1097.3	145.5		359.8		369.9 *
1981				1127.2	1127.2		403.0		256.8 *
1982				1062.7	1088.5		425.9		143.6 *
1983				849.5	856.5		493.7		30.5
1984				758.1	697.7		442.0		14.2
1985				600.6	612.9		374.2		25.9
1986				589.6	816.8		370.3		16.0
1987				605.3	598.6		339.5		6.5
1988				582.8	604.6		369.7		5.0
1989				609.1	617.7				2.5
1990				595.9					1.0
Totals:	8,577	9,679	8,264	17,368	6,967	1,244	4,594	5,023	2,674

* Estimated by KEA based on spending patterns.

RESEARCH & DEVELOPMENT

General Accounting Office, *Nuclear Power Costs and Subsidies*, EMD-79-52, June 1979

The first column of Tables 17 and 18 show R&D expenditures from 1950 to 1978, according to the General Accounting Office report. The GAO provides annual nuclear R&D expenditures by the Atomic Energy Commission (from the beginning of the program in 1946 until reorganization in 1975), the Energy Research and Development Administration (folded into the DOE in 1977), and the Department of Energy. The report makes an annual tabulation in the following six categories of R&D subsidies:

- nuclear materials
- civilian reactor development (fission)
- advanced isotope separation (enrichment)
- waste management
- reactor safety research
- uranium resource assessment

The annual figures in the GAO report total $8.6 billion, of which $7.0 billion was spent on the Civilian Reactor Development Program, including $4.4 billion for the Liquid Metal Fast Breeder Reactor. Converted to constant 1990 dollars, the GAO annual subsidy compilation for 1950-1978 translates to $25.0 billion.

The comments solicited from DOE on GAO's findings indicated that DOE was in "general agreement" with GAO's results, with one key exception: GAO's inclusion of funds spent on the liquid metal fast breeder reactor. DOE officials believed that "fast breeder reactor expenditures are not directly related to the present generation of nuclear power." The GAO countered that though the technology had not yet been commercialized, the breeder reactor is "widely regarded as a nuclear fission technology" and therefore should be counted as part of federal support for civilian power.[1] We concurred with the GAO analysis and have included breeder technology R&D expenditures in our subsidy estimate.

The GAO report also cites

TABLE 18
Appendix D: Comparative Sources
Federal Subsidies to the Nuclear Power Industry
Millions of constant 1990 dollars

	RESEARCH & DEVELOPMENT					REGULATION		ENRICH	WASTE
	[1] GAO	[2] Battelle	[2a] Battelle	[3] D/S	[4] Budget	[5] GAO	[6] NRC	[7] Bowring	[8] DOE
1950	40.4	40.4	40.4	77.4					
1951	77.5	79.1	77.5	108.4					
1952	104.6	106.7	104.6	165.1					
1953	121.1	123.2	121.1	239.1					
1954	187.1	196.3	187.1	223.3					
1955	251.4	281.4	251.4	286.4					
1956	358.8	394.1	358.8	380.3					
1957	572.2	625.7	572.2	355.7					
1958	615.3	745.3	615.3	500.6					
1959	752.4	879.8	752.4	597.6					
1960	986.1	1132.5	986.1	726.5		13.5		330.4	
1961	996.8	1125.6	996.8	770.1		14.6		326.7	
1962	953.8	1058.2	953.8	794.5		15.2		320.6	
1963	945.1	1055.9	949.3	808.6		16.6		315.9	
1964	857.1	958.6	862.0	846.1		85.6		310.2	
1965	849.1	948.9	851.9	824.5		93.8		302.5	
1966	789.5	889.4	796.1	742.7		101.8		292.2	
1967	778.0	890.2	795.9	766.8		126.7		263.6	767.6
1968	912.5	1020.0	920.7	862.6		141.4		271.0	74.8
1969	825.2	944.6	836.7	741.5		145.8		100.7	88.2
1970	783.5	922.8	802.2	687.7		157.6		257.3	90.1
1971	869.3	1016.4	890.1	655.4		157.1		594.7	97.6
1972	1010.9	1177.0	1031.2	757.7		202.2		465.6	133.9
1973	1153.9	1334.6	1178.5	801.0		129.8		601.4	136.7
1974	1404.3	1657.0	1404.3	1250.4		138.8		1619.7	153.4
1975	1581.5	1769.2	1551.2	1446.6		216.4	116.6	1027.3	215.7
1976	1557.1	1623.3	1323.9	2073.6		477.1	406.3	945.1	341.1
TQ	463.7	513.8	405.8						
1977	1996.9	2239.8	1813.7	2151.0		431.4	440.5	1384.5	474.6
1978	2238.9	2537.0	2018.3	1967.8		449.7	497.2	1200.7	677.8
1979				1863.5			515.2	1236.7	832.5
1980				1727.8	229.1		566.5		582.5
1981				1612.9	1613.0		576.7		367.5
1982				1431.7	1486.5		573.8		193.5
1983				1099.9	1108.9		639.2		39.5
1984				940.5	865.6		548.4		17.6
1985				718.3	733.0		447.5		31.0
1986				687.0	718.6		431.4		18.6
1987				683.4	676.9		383.3		7.3
1988				633.3	657.0		401.7		5.4
1989				634.4	643.3				2.6
1990				595.9					1.0
Totals:	25,034	28,287	24,449	35,238	8,712	3,115	6,534	12,387	5,350

[1] GAO, *Nuclear Power Costs and Subsidies*, EMD-79-52, June, 1979, p. v.

an additional $1.1 billion dollar "mixed program" R&D subsidy as calculated independently by Battelle in their 1980 report. This comprises $600 million from the Biology and Environmental Sciences program and the Education Information and Training program, and $500 million in program management and administrative costs (based on the applicable civilian component of these mixed programs). GAO's final estimate of subsidy is therefore $9.7 billion, or approximately $27.1 billion in constant 1990 dollars.[2] Again, this covers the period 1950-1978.

Our R&D subsidy estimate for the period 1950-1978 is $10.8 billion in mixed current dollars, $33.8 billion in constant 1990 dollars. The differences between the two estimates are accounted for by

- civilian-related military contribution included our estimate (excluded in the GAO's), totalling $0.8 billion in mixed current dollars, $3.5 billion in constant 1990 dollars,

- different strategies to account for inflation — we prorated an annual share of the mixed program contribution proportional to the annual civilian R&D budget over the years the program applied, GAO added a lump sum in 1978 dollars.

Battelle Memorial Institute/DOE, *An Analysis of Federal Incentives Used to Stimulate Energy Production*, PNL-2410 REV II UC-59, February 1980

The Battelle report covered the same period as the GAO report, 1950-1978. It appeared in its first version in December 1978, six months before the GAO report. Battelle's estimate of federal R&D support is slightly greater than that of GAO. Battelle's estimates appear in Column 2 of the table. Unlike GAO, Battelle includes an estimate of federal expenditures for nuclear fusion R&D in its report, though not in its final estimate. Column 2a shows the Battelle amounts minus fusion research. These figures are less than, but still

NOTES FOR TABLES 17 AND 18

TQ=Transition Quarter. In 1976 the federal government changed from a July-June fiscal year to October - September, thus creating an extra quarter in the transition year. Where a column has no entry for 1976 TQ, its 1976 FY is 5 quarters, 7-1-75 - 9-30-76.
GDP Deflator calculated from "Economic Report of the President 1992," Table B-3, "Implicit Price Deflators for GDP, 1959-1989." 1950-1958 from "Economic Report of the President 1990" Table C-3, "Implicit Price Deflators for GNP, 1929-1989."

1. GAO, "Nuclear Power Costs and Subsidies," EMD-79-52, June 1979, Appendix IV.
2. Battelle Memorial Institute/DOE, "An Analysis of Federal Incentives Used to Stimulate Energy Production," PLN-2410 Rev. II, 1980, Tables 19 and 20.
2a. Battelle totals minus amounts spent on Laser Fusion and CTR (Magnetic Fusion).
3. Figures for 1950 to 1973 are from Fred Sissine, Congressional Research Service, based on Warren Donnelly, "Federal Expenditures Relating to Civilian Nuclear Power," CRS 1973. Figures for 1974 to the present are from Sissine, "Renewable Energy: A New National Commitment?", CRS, Oct. 1990. For 1973, Donnelly's figure of $293 million in his 1950-1973 compilation is used instead of the $397.9 million reported by Sissine in his 1973-89 figures.
4. Office of the President, Budget of the United States, Appendix Section I-J5 for Fiscal Years 1982, 1984-1991; Section I-F43 for 1983.
5. GAO, "Nuclear Power Costs and Subsidies," EMD-79-52, June 1979, Appendix V.
6. NRC, Annual Reports 1976-1988, Statement of Operations: Government Investment in the NRC, p. 201. (Figure represents expenses minus revenues excepting revenues from other federal agencies.)
7. Energy Information Administration, Joseph Bowring, Unpublished Report, "Federal Subsidies to Nuclear Power: Reactor Design and the Fuel Cycle," March 1980. *Table 4, p. 59*. Also, final report issued Feb. 1981, Table 4, *p. 45*.
8. DOE, "Nuclear Power: Reactor Design and the Fuel Cycle," EIA-0201/13, Feb. 1981, Table 5, p. 52. Figures from 1980 through 1982 are estimated by KEA. Figures for 1983 to 1990 are from telecom with Andy Gray, Office of Civilian Radioactive Waste Management, Feb. 7, 1991.

[2] We inflated the "additional" mixed program amount ($1.1 billion mixed current) to constant 1990 dollars using the 1978 deflator. Thus, presuming that $1.1 billion is in 1978 dollars, it is $2.1 in 1990 constant dollars.

close to, the GAO estimates. Battelle's 1950-1978 total is $9.7 billion in mixed current dollars including fusion; $8.3 billion without fusion. This translates into 1990 dollars as $28.3 billion with fusion, and $24.5 billion without.

In addition to the total cited, Battelle adds $2.6 billion (1978 dollars) for R&D on biology and medicine, nuclear submarine development, education and training, physical research, and program management. Since these are "mixed" programs — combining military and civilian R&D, Battelle estimates their civilian component by prorating at the ratio of other civilian nuclear R&D to the total nuclear budget. (The exception is education and training, of which Battelle allocates one-third as a civilian subsidy.) Adding this amount brings the total R&D subsidy according to Battelle, excluding fusion, to $9.8 billion in mixed current dollars, $29.4 billion in constant 1990 dollars. Battelle included a contribution from the military program, thus, their estimate is closer to ours.

Warren Donnelly, Congressional Research Service, *Federal Expenditures Relating to Civil Nuclear Power Fiscal Years 1948-1974*, 1973

The Donnelly figures for 1950 through 1973 (Column 3) serve as the basis for estimates in *Renewable Energy: A New National Commitment?*, by Fred Sissine, also of the Congressional Research Service (October 1990). We have adopted Sissine's figures for the period 1980-1990. The Donnelly/Sissine amounts average 14% less than the Battelle amounts (2a — without fusion) for comparable years, except for the 1950-1954 period where Donnelly exceeds all other estimates. The Donnelly/Sissine figures are 23% lower than Battelle's from 1957 to 1963, 4% lower from 1964 to 1968, and 11% lower from 1969 to 1978.

Donnelly provides detailed information about programs funded in the early years of the civilian atomic power program. The source of Donnelly's information was AEC budget reports and correspondence with the AEC Controller. His analysis confirms that the military and civilian nuclear power programs were closely intertwined even into the 1970s.

On a yearly basis, Donnelly's figures break down into the following categories:

1950-1954: 50% of the total reactor development program is estimated to be civilian or allocable to civilian nuclear R&D. Civilian spending was not separated from military in these early years. Donnelly based his 50% estimate on the 1955-1957 average of 53% of the reactor budget devoted to civilian purposes. Donnelly's 1950-1954 figures are somewhat higher than other researchers' figures.

1955-1957: Donnelly includes the full amounts reported by the AEC for reactor development for segregated civilian purposes. These are an average of 53% of the total military and civilian reactor development program. Specific programs include: civilian power reactors, "advanced development," commercial ship reactors, and program support. A note indicates that work in the category of "advanced development" was related in part to work on power for defense, in other words, a mixed program. Donnelly therefore included only a portion of this program in the civilian total.

1958-1960: Reactor development in this period included R&D on the "government program," the Cooperative Power Reactor Demonstration Program (in which the AEC supported early reactor acquisition by utilities), the cooperative program with Euratom and "general supporting R&D." A note indicates that this last item was related to defense power research.

1961-1965: The categories of advanced systems and nuclear safety were added to the tally for these years. A notes says these categories also are related to nuclear power for defense.

1966-1971: The same programs were active as in the previous period minus the merchant ship.

1972-1973: The accounting for this period includes the program categories: central station power development, Cooperative Power Reactor Demonstration Program, nuclear safety, and technology and engineering (defense related, in part). Naval reactors, applied energy technology and controlled thermonuclear research are excluded.

Physical research and biological and environmental research are excluded from all years reported. As indicated in the Battelle and DOE reports, a portion of these programs could reasonably be applied to an estimate of a commercial power subsidy.

An estimate of federal support for nuclear power R&D based on Donnelly and Sissine's estimates from 1950 through 1990 would be $17.4 billion in mixed current dollars, or $35.2 billion in 1990 constant dollars. This compares with our R&D estimate for the same period of $21.2 billion in mixed current dollars, $47.7 in 1990 constant dollars. (See Table 5.) Although Donnelly's annual estimates for the 1950s are higher than ours, later years show his annual estimates taking a decisive nosedive.

Office of the President, *Budget of the United States*, Appendix Section I-J5 FY1982, FY1984-91; Section I-F43 FY1983

Column 4 shows the R&D figures for civilian fission research reported by DOE's Energy Research and Technology Branch, as listed in the Appendix to the U.S. Budget. These amounts are roughly equivalent to Sissine's amounts from 1974 to 1990; they are based on the same source. However, Sissine's figures reflect an estimate of actual spending, while the amounts in Column 4 are allocations. Column 4 totals $7 billion ($8.7 billion constant 1990 dollars) for 1980 through 1989. For the same period Sissine reports $10.2 billion in constant 1990 dollars.

REGULATION

For the period 1950 through 1978, there are two identical estimates of the subsidy provided via regulation. These estimates are by the GAO and Battelle. We cite the Battelle report as our source. Column 5 references the estimate by the GAO.

Column 6 shows regulatory expenditures net of user fees from annual reports of the Nuclear Regulatory Commission. For 1975 through 1978, when the comparative data are available, the NRC amounts are $79 million lower for this period, or 11% less. We have adopted the Battelle/GAO figures for 1960-1978, the NRC's reporting for 1979-1988, and we have estimated the subsidy for 1989 and 1990.

ENRICHMENT

DOE calculated in its 1981 report that the direct enrichment subsidy was $2.75 billion as of 1979.[3] This is equivalent to $5.1 billion in 1990 dollars, or less than half of Montange's estimate of total unrecovered costs of enrichment. (See section on Enrichment.) However, DOE applies only half of its total estimate toward its nuclear subsidy calculations, on the premise that only half of U.S. enrichment services went to U.S. utilities. Foreign utilities purchased the other 50%, in effect capturing half of the overall subsidy for *their* customers.[4] A rationale for charging overseas customers less than full price was maintenance of loyalty to U.S. nuclear technology, which was expected to (and to some extent did) aid the U.S. domestic reactor industry by providing markets. Foreign subsidies of enrichment appear to have been largely a consequence of efforts to develop civilian nuclear power, and in any event, it was U.S. taxpayers who footed the bill. The DOE estimate also excludes subsequent investment in capital improvements and the gas centrifuge project which was abandoned in 1984.

The pre-publication draft of the DOE report by Joseph Bowring estimated $5.0 billion in mixed current dollars as the subsidy from 1960 to 1979.[5] Bowring included a depreciation calculation of $76.1 million per year from 1960 to 1969 attributable to commercial customers. Bowring also included foreign contracts. Bowring's estimate is $12.4 billion in 1990 constant dollars. Our estimate, which included expenditures for 1980-1990 (excluded in Bowring's estimate), is $11.6 billion.

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[3] DOE, *Federal Support for Nuclear Power: Reactor Design and the Fuel Cycle*, DOE/EIA-0201/13, Feb. 1981, p. 45.

[4] This estimate of 50% foreign commitments may have been an all-time high. With the development of European and Soviet enrichment facilities, foreign contracts with the U.S. enrichment facilities have decreased to between one-half and one-third of SWUs enriched. The GAO's 1989 *Uranium Enrichment* report noted "Between 1974 and 1985, DOE's share of the free world's enrichment market fell from 100% to about 47% because of foreign competition, rising costs and other problems." (p. 38).

[5] Joseph Bowring, *Federal Subsidies to Nuclear Power: Reactor Design and the Fuel Cycle*, March 1980. Prepublication draft. Pp. 50-56.

ABOUT THE AUTHORS

Charles Komanoff has researched and written on the economic and environmental impacts of energy supply and demand, especially nuclear and coal power, since the early 1970s. He has published three books including *Power Plant Cost Escalation*; authored numerous articles in technical journals including *Nuclear Safety* and *Journal of the Air Pollution Control Association*; written on energy policy for the country's leading newspapers including *The Wall Street Journal, The New York Times* and *The Washington Post*; and consulted on nuclear costs for the U.S. Department of Energy, several agencies of Congress and half the States in the Union.

Komanoff is credited with being the first analyst to establish the true dimension of U.S. nuclear power cost escalation. His work is cited frequently in news, financial and scientific periodicals; the General Accounting Office of Congress has cited Komanoff Energy Associates as "a leading authority on nuclear power costs," and Arkansas Gov. Bill Clinton called Komanoff "a leading nuclear power economist." Through Komanoff Energy Associates, and as senior consultant to Boston-based Resource Insight, Inc., Komanoff assists state, local and federal agencies in energy conservation implementation and on other issues including nuclear power costs and utility air pollution.

Komanoff is also president emeritus and research director of Transportation Alternatives (T.A.), a New York-based environmental advocacy organization. Under Komanoff's leadership, T.A. has expanded bicyclists' rights and become New York City's leading grassroots force for non-motor transportation and clean air. He is currently completing two major reports for T.A., *Win-Win Transportation: A No-Losers Approach to Financing Transport in New York City and the Region*, and *The Bicycle Blueprint: Mainstreaming Bicycle Transportation in New York City*. Komanoff graduated with honors from Harvard College in 1968, with a B.A. degree in Applied Mathematics.

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In 1978, Battelle estimated the enrichment subsidy through 1978 as $2.1 billion in 1978 dollars. This estimate consisted of the difference between the government's and fair-market prices ($0.6 billion) plus unrecovered costs expended to increase capacity ($1.5 billion). Fair-market prices were based on a GAO estimate of the difference between what the government charged for enrichment services and what a new commercial operation would charge.[6]

WASTE MANAGEMENT

DOE estimates that $1.8 billion was spent on waste R&D through 1979.[7] This is equal to $5.4 billion in 1990 dollars, and includes expenditures for both military and civilian applications.

The Office of Civilian Radioactive Waste Management, created by the 1982 Nuclear Waste Policy Act, spent an estimated $101.6 million on waste R&D since the Act's passage — from 1983 through 1990 ($123.1 million in 1990 dollars).[8] KEA estimated that $770.3 million was spent from 1980 through 1982 based on DOE's estimate of expenditures prior to that period, and OCRWM spending in the following period. If we were to accept DOE's estimates, add our own for the period 1980 through 1982, and the OCRWM's expenditures from 1983 through 1990 — the total waste R&D subsidy would be $2.7 billion in mixed current dollars, or $5.4 billion in 1990 dollars as shown in Column 8.

This compares with the $1.5 billion figure (1990 constant dollars) we have estimated for this subsidy (see Table 16). We have not adopted the DOE's figures for the period prior to 1979 because we suspect that the bulk of these expenditures were for containment of military wastes. (See Section on Nuclear Waste.)

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[6] Battelle, *An Analysis of Federal Incentives Used to Stimulate Energy Production*, DOE/PNL-2410, Feb., 1980, p. 138.

[7] DOE's estimate begins with 1967, although a note indicates that the 1967 figure includes expenditures for prior years. The DOE estimate is the total military and civilian waste R&D program. DOE notes:

> Although there is some difference in the form of the high-level waste, a satisfactory solution for the storage of high-level military waste also will be a solution for storage of high-level civilian waste. It is, therefore, virtually impossible to disentangle the two programs. (p. 51)

[8] Telecom with Andy Gray, Office of the Budget, DOE Nuclear Energy Research Branch, February 7, 1991.