Federal Energy Subsidies:

Energy, Environmental, and Fiscal Impacts

by Douglas N. Koplow
Lexington, Massachusetts

April 1993

The Alliance to Save Energy
Energy Price and Tax Program
Mary Beth Zimmerman, Program Manager

Largest 1989 Subsidies to Fission (Millions of 1989$)

Subsidy	High Estimate	Low Estimate
Direct and Grid		
Program		
Uranium Enrichment Corporation	1,026.8	279.1
DOE R&D and Waste Management	1,012.6	1,012.6
Bonneville Power Administration	381.5	354.5
NRC Regulation	347.4	287.2
REA Losses	321.6	316.5
Nuclear Waste Fund	181.7	0.0
TVA Cross-Subsidies	331.3	308.6
Total Program	3,602.9	2,558.5
Tax (General Capital and Other)		
Accelerated Depreciation (machinery and equipment)	2,074.8	605.0
General ITC (machinery and equipment)	427.0	167.8
Total General Tax	2,501.8	772.8
Tax (Energy)		
Tax-exempt Public Power Bonds	820.1	672.3
Utility Retention of Excess Deferred Taxes	489.3	0.0
Total Energy Tax	1,309.4	672.3
Total All Tax	3,811.2	1,445.1
Other (Indemnification)		
Price-Anderson	2,750.0	832.0
Underaccrual for Nuclear Decommissioning	197.3	0.0
Total Other	2,947.3	832.0
All Fission		
Total Large Program Subsidies	3,602.9	2,558.5
Total General Tax	2,501.8	772.8
Total Energy Tax	1,309.4	672.3
Total Large Tax Subsidies	3,811.2	1,445.1
Total Other Subsidies	2,947.3	832.0
Total All Large Subsidies	10,361.4	4835.6
All Other Subsidies to Fission	217.5	203.5
TOTAL SUBSIDIES TO FISSION IN 1989	**10,578.9**	**5,039.1**

Alliance to Save Energy and Douglas Koplow, April 1993

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APPENDIX B
Volume I

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Expensing of Construction Period Interest/AFUDC

STATUS: Repealed. Although projects for which construction was "substantially" underway prior to repeal were grandfathered, neither the JCT or the Treasury tax expenditure estimates show losses from this provision. Although privately-owned utilities are still allowed to include an allowance for funds used during construction (AFUDC) in their rate base, they apparently can not deduct it from the current year's taxable income any more. In this report, we view inclusion of AFUDC in the rate base as a proper manner to recover the financing costs of construction, and deferral of tax deductions as consistent with the general principal of matching expenses with the useful service life of the equipment.

DESCRIPTION: Allowed businesses to expense rather than capitalize the interest costs incurred during plant or project construction, yielding a mismatch of interest deductions and the property's useful life. This subsidy benefitted large scale capital projects that were heavily financed with debt (such as electric utilities) more than other types of projects. Projects that took more years to complete (such as nuclear utilities) benefitted more than projects with shorter lead times. The reduction of capital costs created a lower cost energy infrastructure and lower energy prices than would have occurred without the subsidy.

In addition, this provision allowed construction-period interest to be expensed for tax purposes (thereby reducing current tax liabilities), but capitalized for book and rate-making purposes (increasing the allowable capital base on which the utility can earn a return). Although this provision was eliminated in TRA of 1986, budgetary impacts continue as long as projects continue.

HISTORY: This provision was part of the original income tax law of 1913. A revision was added in 1942 which enabled taxpayers to voluntary elect capitalizing interest costs. The Tax Reform Act of 1976 required that construction period interest for non-corporate taxpayers be capitalized and amortized over a 10-year period. (OMB, FY 1982, Spec. Analysis G, 218).

The uniform capitalization rules of the Tax Reform Act of 1986 requires costs incurred after December 21, 1986 to be capitalized rather than expensed. Only "property constructed by the taxpayer for which substantial construction occurred before March 1, 1986" was able to delay capitalization. This includes direct costs, taxes, interest, pensions and other employee benefits, and a portion of general and administrative costs. (Kiefer, 3/18/87, 10). Capitalization requirements for interest expenses assumes that the project was financed 100 percent by debt.

BENEFICIARY ENERGY TYPES: The largest beneficiaries were the nuclear and fossil-electric utilities.

SUBSIDY MAGNITUDE: [PV(construction-period interest deduction) - PV(construction-period interest amortization deductions once facility opens)] x tax rate.

ELIGIBLE ACTIVITIES:

LIMITATIONS:

DEPARTMENT OF ENERGY: ATOMIC ENERGY DEFENSE ACTIVITIES

Activities Benefitting the Commercial Sector

Background

It is clear that without much of the early work on military applications of nuclear power, the commercial sector would never have evolved. For example, while the Atomic Energy Commission (AEC) divided early R&D into commercial and military sectors, both were critical in the development of light water reactors. "The civilian program used information and expertise developed in the more experimental military program. Further, the reactor prototype developed in the military program became the foundation for some of the AEC's later civilian reactor work as well as the basis for the commercial light water reactor." (Bowring, 16).

While there was significant spillover, to claim that military research directly subsidized the commercial sector is somewhat problematic since most of the military research would likely have occurred whether or not there were a commercial sector. However, it is likely that the staggering costs associated with military nuclear development led to an extensive search for ways to spread these costs over a broader base of recipients. Commercial nuclear power provided such an outlet.[27]

Some spending classified as "defense-related" does, in fact, directly benefit the commercial sector while at the same time using technology in excess of that needed to meet the military's requirements. One example is the $3.6 billion tritium facility planned for Idaho Falls, ID. Although ostensibly used solely for military purposes, the choice of reactor design relies on new, essentially untested, "fail-safe" reactors rather than the already refined light-water technology. As such, this expenditure seems, at least in part, to be a research expenditure for the commercial sector.[28]

For items clearly benefitting both the defense and commercial sectors, an arbitrary 5 percent of spending was allocated to the commercial sector as a first guess at the true level of support.

Current Spending

Materials Production. A small portion of the materials production budget supports the production of nuclear materials for use in civilian research and commercial applications, among others (DOE '92 Budget Request, v. 1, 175). It is unclear whether this accrues to energy research or other activities.

Naval Reactors Development Program. The tie between the naval reactor development program and the commercial sector continues today. As stated in the DOE Annual Report:

> The technology developed in the Naval Reactors Development program is directly applicable to, and an inherent part of, DOE's nuclear fission energy program. This program has been the source of much of the technology for the civilian nuclear energy industry." (DOE, ann rept., 297).

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[27]Joseph Bowring reasoned that a portion of the costs of military R&D were subsidies to commercial fission, and estimated their magnitude at $1,081 million (1989$) between 1950 and 1964. (Bowring, 31).

[28]Elmer-Dewitt, Philip. "Nuclear Power Plots a Comeback," Time, January 2, 1989, p. 41.

Technology Transfer. Many of the technologies developed for the nuclear weapons program have applications in other fields of national defense and industry. DOE and DOE research laboratories try to transfer these developments whenever possible (given national security constraints) to potential government and industrial users.

> Areas where the DOE weapons program has made and continues to make important contributions to the Nation's technology base include materials sciences, computer sciences and applications, and atomic and nuclear physics. For example, SNL [Sandia National Laboratory] recently has been transferring an average of approximately 50 research and development projects per year to industry." (DOE ann. rept, 268, 269).

Examples of energy-related technology transfers include:

- Computer codes originally developed to study the two-and three-dimensional hydrodynamics of nuclear weapons to electric utilities and well-drilling firms.
- Low-power hybrid circuits for nuclear instrumentation, a computer code for engine modeling, and components for a ceramic matrix material that has remarkable strength, as well as information exchange on high temperature superconducting materials. (DOE, ann. rpt. 268, 269).

Cleanup. Some federal facilities, such as the Uranium Enrichment Enterprise, provided services to both the military and the commercial sectors. As a result, responsibility for cleanup of those sites also belongs to both sectors. We were not able to estimate the degree to which the commercial sector benefitted from primarily-defense facilities that now face large cleanup bills.

Technology Development. This area includes applied research and development of methods to clean radioactively-contaminated soil and groundwater; handle and process radioactive wastes; incorporate waste minimization into production processes; and decommission concrete and metal structures. Although of immediate importance for the DOE military cleanup, the techniques and technologies are equally applicable to DOE sites serving commercial needs and commercial reactors. (DOE '92 Budget Request, v. 1, 587-629).

Waste Transportation and Site Management. Research into radioactive waste management which benefits the commercial sector to the same degree as technology development, shown above. ('92 Budget Request, v. 1, 644).

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DOE: URANIUM ENRICHMENT ENTERPRISE

Throughout the life of commercial nuclear power, DOE's uranium enrichment facilities have supplied the power plants with enriched uranium. For years after WWII, DOE was the only source in the world for fuel grade uranium. Although all production went to the military sector until 1969, commercial shipments grew dramatically in the ensuing years. Today, however, the enrichment facilities are under financial pressure from a number of other enrichment providers. Competition has put pressure on DOE's margins. Unrealized expected future demand, along with contracting procedures which placed all of the risk for changing market conditions on DOE, led to overcapacity and take-or-pay power contracts with the Tennessee Valley Authority running into the hundreds of millions of dollars per year.

In addition, extensive research into alternative enrichment techniques and incomplete capital recovery (exacerbated by poor accounting practices) have resulted in unrecovered federal investment running into the billions of dollars. Estimates of the unrecovered investment range from zero to $10 billion, although part of the disparity is due to capital write-offs which some parties argue should not be recovered in any future privatization of the enterprise. For our purposes, since the entire shortfall remains unpaid, the entire portion remains a subsidy to fission power which is reflected in reduced fuel costs.[31] Shortfalls in the accrual for decommissioning and decontaminating the enrichment facilities add still more to the overall level of subsidy. The main categories of subsidization are presented below.

<u>Below Market Purchases of Power</u>. Uranium enrichment is extremely energy-intensive, with electrical power costs comprising 70 to 80 percent of production costs and almost 100 percent of marginal costs. (Smith Barney, 35; '89 Uran. Enrichment Annual Report, 10). Power is supplied by the Tennessee Valley Authority and two other utilities formed solely to supply the enrichment facilities. This arrangement has led to allegations that the enrichment facilities receive power at below market rates.[32]

As shown in our estimate for TVA, power sales to UEE for much of the 1970s (until DOE had to make good on take-or-pay power contracts when demand for enriched uranium stopped growing) were 10-27% less expensive than the wholesale price to municipal and cooperative utilities. (TVA.WK1, 3). Any subsidized power sales are incorporated in the TVA section only to avoid double counting.

<u>Below Market Sales of Enriched Uranium</u>. Despite substantial market power and enormous unrepaid capital, DOE has historically sold enriched uranium far below its competitors.[33] For example, in 1986

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[31]Since DOE supplied enriched uranium to facilities all over the world, a portion of benefits from low cost fuel-grade uranium went to the foreign power sector. The source of this subsidy, however, was financed by the U.S. taxpayer. Through FY 1991, approximately 15% of the SWUs sold went to overseas utilities. This is equal to about 1/3 of the commercial fission share. (Warren, 10/13/92).

[32]Even if TVA does not lose money absolutely, power sales for uranium enrichment could be cross-subsidized by power sales to other sectors.

[33]While economies of scale could explain the ability to undersell competitors, this argument holds true only when fixed costs are being repaid. If fixed costs are not being covered by sales in a market where pricing to recover fixed costs is possible (UEE had a world monopoly for quite some time), selling more simply means losing more of the taxpayers capital investment. Excess capacity in the industry, exacerbated by recent increases in sales from the Soviet Union (Techsnabexport), explains much of the current pricing situation, but this competition did not always exist. With stagnant demand, huge fixed costs, and large unneeded capacity, prices are being cut far below levels necessary to recover sunk fixed plant. Such a scenario generally precedes market exit. However, the U.S. continues to spend money to bring a new enrichment technology, AVLIS, to market with the argument that it will reduce the price of enriched uranium. This perspective ignores the market realities that the producers using the older technologies will continue selling so long as <u>variable</u> costs are covered, rendering the new technology unneeded and more costly at this time. (GAO/RCED-91-88, pp. 38-40).

DOE's product sold for $119/Separative Work Unit (SWU)[34] while its competitors Eurodif (primarily France) and Urenco (Germany, Britain, and the Netherlands), which are also government-owned, sold theirs for $170-$190/SWU.[35] DOE's price was $12/SWU lower than average production costs, even excluding depreciation and a reasonable return on investment. (Montange, 8,11). By 1990, DOE enriched uranium was being sold for $118/SWU, a decline of 28 percent in real terms since 1984. (1989 Uranium Enrichment Annual Report, 9). Since DOE sells both to domestic and foreign buyers, a significant portion of the pricing subsidy (50% in 1979) accrues to foreign buyers.

We account for below-market sales of uranium through our tracking of operating losses and total unrecovered capital only. That is, low prices led to less revenue, which in turn was the major factor in UEE's poor financial performance. No effort has been made to estimate the historical opportunity cost of DOE's pricing strategy.

Unrecovered Government Investment. Unrecovered federal investments are the result of accrued operating losses, customer non-payment, funds invested in the gaseous diffusion enrichment facilities, and terminated research and development into gas centrifuge enrichment technology. Estimates of this loss vary by differing assumptions on the value of the initial plant at the time UEE began commercial operations and the cost of tied up funds to the government, as well as by differing decisions on when to recognize capital write-offs and how much to recognize. The impact of the timing of capital write-offs on the final subsidy estimate is mitigated by the process of amortizing the loss backwards over the period of loss.

For example, if no historical losses have been recognized and written off, the period of loss would run from 1969 (when UEE began commercial production) to our 1989 point of estimation. A larger measured loss (since nothing has been written off yet) would be spread over a longer period of loss, and the annual payment necessary to have covered that loss would be relatively smaller. Recognizing DOE capital write-offs would reduce both the current loss estimate and the period of loss significantly. Since interest was imputed on the unrecovered federal investment, we have amortized losses back using the imputed interest rate as a discounting factor.

While there is much debate over the magnitude of unrecovered investment, Congress, through the Energy Policy Act of 1992, has statutorily capped the value of recoverable federal investment at $3 billion. The remainder of the unrecovered federal investment has been converted to equity claims in the soon-to-be-privatized enterprise. As such, funds may be recovered only through dividends or stock appreciation -- should such stock have any value. (DOE, '92 Bill, 14).

The various estimates are evaluated below, and our rationale for making particular decisions with respect to the inclusion or exclusion of costs is presented.

The Edison Electric Institute (EEI) Estimate

The major difference between the EEI estimate and the others is that EEI considered the recoverable value of the initial plant and working capital to be zero. (Coopers & Lybrand, 24). The

[34] A separative work unit is a measure of the energy required to separate two isotopes of uranium.

[35] Part of this discrepancy emerges because Eurodif and Urenco both sell to domestic consumers at relatively high prices, while offering excess capacity on the U.S. market at substantially lower prices. (GAO/RCED-91-88, 37).

original investment in the three enrichment plants was $2.8 billion. (Bowring, 57). While much of the plant was depreciated prior to commercial use, the book value of the enrichment facilities plus net working capital on January 1, 1969 when service to commercial customers began was $1.5 billion. (Coopers & Lybrand, 24). The EEI estimate was deemed unusable because they valued the initial plant, equipment, and inventory at zero (in contrast to all other evaluators), and therefore have imputed no interest on this tied up capital over the past 20 years. In addition, where imputed interest calculations were done, EEI assumed that interest payments would not start until one year after incurring the expense. (Coopers & Lybrand, 20). We were unable to back out these assumptions to generate an estimate for our calculations.

The DOE Estimate

The main differences between the DOE estimate and the Smith Barney/Coopers & Lybrand, and GAO estimates are in the choice of interest rates used in imputed interest calculations, and in the exclusion of the costs of the abandonment of the gas centrifuge diffusion plant and excess gaseous diffusion capacity (the closure of the Oak Ridge facility). (Smith Barney, 62). Again, whether or not the capital write-offs are included in the recoverable asset base, they still constitute a subsidy to the enterprise since a private entity would have to write off the assets against pre-tax net income, and reflect the losses somehow in pricing or their future cost of capital (if current equity holders lost value future investors would charge a higher risk premium). Accepting both DOE's interest rate decision and past capital write-offs would yield a net subsidy of $3.0 billion over a period of loss from 1986 to 1989. The shorter period of loss more than offsets the lower capital loss figure, yielding higher annual payment estimates than in the GAO figures.

The GAO Estimate

The main difference in the GAO estimate is that GAO does not recognize historic write-offs of defunct assets and investments that DOE recognized in the early 1980s. Their resulting estimate of $10 billion includes four categories that bear adjustment for our purposes (Smith Barney, 62; Coopers & Lybrand, 25-33).

- Unexpended Appropriations: funds allocated but not spent should not be included as a subsidy. (Subtract $0.2 billion).
- Appropriations included in the uranium enrichment budget but not deemed related to the Uranium Enrichment Enterprise. (Subtract $0.85 billion).
- Exclusion of value of in-kind enrichment services provided to the federal government and subtracted from net unrecovered capital. (Subtract $0.8 billion).

These adjustments yield a revised GAO estimate of $8.15 billion ($10b-$1.85b) over a period of loss of 21 years (1969-1989, inclusive).

The Smith Barney/Coopers & Lybrand Estimate

One of the main differences between the adjusted GAO estimate above and the Smith Barney/Coopers & Lybrand (SB/C&L) estimate lies in the interest rate used on outstanding capital. Both methods are rational. The GAO estimate incorporates the annual cost to the government of having its funds tied up in the enrichment facility. The accounting firm assumption of the 1969 long-term bond rate treats the enterprise as a private facility which financed all of its capital needs in the least expensive manner at start-up. The SB/C&L estimate, including what they call "policy decisions" such as capital write-offs, is $4.5 billion. Since the recognition of capital losses in the mid-1980s reflects poor investments from the earlier time frame, the period of loss for the this estimate is 1986-1989. The shorter time frame yields higher annual payments.

Subsidy Accruing to the Commercial Sector

Until 1969, all enriched uranium produced by the Uranium Enrichment Enterprise was used for military purposes. (Coopers & Lybrand, 24). Since that time, a portion of production has continued to go to the defense sector. Although the civilian share of SWUs produced for civilian purposes to total SWUs is almost exactly 50 percent (Montange, 17), using this as an allocation factor would be erroneous since the subsidy calculations begin in 1969, not in the beginning of the enrichment facility life. Therefore, the allocation of costs to the commercial sector (both U.S. and foreign) is based on the 88.7% of SWUs produced since 1969 that went to commercial purposes. (Schmitt, 10/92).

Decommissioning and Decontamination (D&D)

The three enrichment facilities (all based on the gaseous diffusion technology) are extremely old. They were constructed and operated during a time when environmental issues were irrelevant. There are extremely large costs associated with both decommissioning (closing) the facilities and cleaning up the sites. There is also a wide range of estimates regarding the costs of this cleanup.

DOE estimates the total cost of decommissioning and decontaminating the three plants at $3 billion, with $1.404 billion to be paid by commercial customers via enrichment surcharges. This figure for some reason excludes costs such as pre-D&D maintenance and surveillance at the Oak Ridge Gaseous Diffusion Plant and Remedial Actions at all three enrichment plants. (UEE 1989 Annual Report, 35). Since DOE is accruing for these items also, our estimates of D&D shortfalls are net of these additional items.

An additional $2.25 billion charge on the commercial sector to cover enrichment D&D costs via a supplemental charge on nuclear utilities was included in the Energy Policy Act of 1992. The Act created a special $150 million/year inflation-adjusted charge earmarked for enrichment D&D. The charge lasts for 15 years, and is capped at total outlays of $2.25 billion (also adjusted for inflation). (DOE, '92 Bill, 17).

The Uranium Enrichment Enterprise is accruing funds to cover the $3 billion level of D&D costs over the projected lives of the facilities. Provision for closure and cleanup at the Oak Ridge Gaseous Diffusion Plant, which has already closed, is much greater. (FY 1989 Enrichment Annual Report, 35). As mentioned above, additional accruals for pre-D&D activities and remedial action are on-going as well. All of these accruals represent the total of a series of payments in nominal dollars. We convert them to 1989 constant dollars to make them comparable to our other estimates.

Since experience thus far suggests significant clean-up shortfalls if only $3 billion is available, we do not use the DOE estimate for our low estimate of total D&D costs. Alternative estimates of the total D&D cost are much higher than the DOE estimate. Initial site characterization is far from complete and has already found a wide range of problems. Furthermore, "past experience indicates that such costs increase as more information becomes available." (GAO, T-RCED-90-101,10). Problem areas include many leaking underground storage tanks, violations in the use of PCBs, out-of-compliance air emissions with asbestos and radionuclides, and potentially large problems with hazardous wastes. (Smith Barney, 68). Smith Barney estimates the cost of decommissioning the Oak Ridge plant alone could reach as high as $8 billion. Applying this standard to the three plants yields a potential liability for cleanup and decommissioning of $24 billion. (GAO, T-RCED-90-101, 10; Smith Barney, 82).

DOE contractor studies, done by firms involved in the cleanups, have estimated a range of $14 to $29 billion (1989$).[36] The Smith Barney estimate falls within this range. We view the contractor estimate to be far more likely than the current DOE estimate given current experience and the magnitude of unknowns on the site. Our high and low estimates for uncovered D&D costs are reduced by current accruals for D&D and for the recently added decommissioning surcharge. While the period of cleanup has been estimated to be between 25 and 37 years by two engineering firms who estimated the cost of D&D for DOE (TLG, p. 45; EBASCO, figure 5.4-1), we annualize the D&D shortfall over the commercial service of the facilities. This approach is consistent with our annualized estimates in many other program areas. The commercial life of the facilities is 36 years, from 1969 when commercial operations began through 2005 when the last facility is scheduled to close. (EBASCO, 2-1).

We follow the DOE allocation of D&D costs between the defense and commercial sectors in their annual reports. Forty-seven percent of the total D&D shortfall is allocated to the commercial sector. The D&D subsidy estimates on the UEE worksheet are net of special charges levied on nuclear utilities in the 1992 Energy Policy Act.

Gas Centrifuge Facilities. Cleanup costs for the abandoned gas centrifuge facilities are expected to total $187 million. (GAO/T-RCED-89-54, 3). The costs are incorporated in the contractor D&D estimate.

Other Subsidies to the Enrichment Enterprise

Nuclear Regulatory Commission Licensing. Being government-owned, the gaseous diffusion plants are exempt from NRC licensing. The cost of licensing and compliance, according to DOE, ranges between $5 million and $153 million per plant. (Smith-Barney, 87). Although the NRC suggests the lower end of the range is reasonable, the age and size of the facilities, in addition to their pivotal role in nuclear non-proliferation (since they can produce weapons-grade material), suggests the high end is a better figure. While the facilities are currently regulated for safety and compliance by government officials, the oversight appears to be less stringent than that required by NRC. (Smith-Barney, 87-89). Smith-Barney estimates that licensing costs and compliance fees are likely to run in the range of $181 to $379 million, and notes that

> principally due to the seismic issue and today's more restrictive safety criteria (compared to the standards applicable when the plants were built), there is some question as to whether or not the UEE's facilities can be licensed on any schedule at any cost. (Smith-Barney, 87).

The NRC will have oversight for the gaseous diffusion enrichment facilities once they are privatized, under conditions laid out in the 1992 Energy Policy Act. (DOE, '92 Act, 16). Since these costs will be borne through privatization, and since UEE did have some government oversight in the past, we do not ascribe a value to this subsidy here. However, it is clear that the laxer standards for UEE, since it was publicly owned, reduced compliance costs in the past. Had these costs been borne by UEE, rather than by the surrounding population and ecosystem through higher risks of accident or damage, the magnitude of unrecovered costs would likely be higher.

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[36] The contractors were EBASCO Services, Inc., Martin Marietta Energy Systems, and TLG Engineering. The General Accounting Office's audit of annual payments required to cover D&D yielded an estimate of $500 million/year, indexed to inflation, similar to our high estimate. (GAO, RCED-92-77BR, 2).

Insurance. Not being required to purchase environmental liability insurance reduces the costs of operating by placing risk on the taxpayers. In essence, the enrichment facilities are self-insured. Outlays for environmental remediation may be viewed as retrospective premiums. As mentioned at the beginning of this chapter, the impact of retrospective premiums on behavior and risk minimization may not be not optimal. However, financially it is an acceptable proxy since DOE has begun to incur the cleanup costs. Therefore, we treat the subsidy as zero.

Federal government indemnity from other forms of liability, such as for negligence, do confer subsidies to the enterprise. The Price-Anderson indemnification on liability, even for gross negligence, extends this liability subsidy further, to all contractors and suppliers. Subsidies from these programs to UEE could not be quantified.

Rate of Return and Tax-Exempt Status. The government investment, by not requiring a positive rate of return, reduces the cost of providing enriched uranium services for commercial utilities. The tax-exempt status of UEE reduces the cost structure still further. Since UEE competes with other providers of energy services (oil refineries and electric-utilities both upgrade fuel inputs for the final user, an analogous service to uranium enrichment), these factors provide a significant barrier to entry for substitutes.

The private market rate of return required on the Enrichment Enterprise, a multi-billion dollar, high risk investment, is likely to be quite high. Estimating this return is problematic. However, a recent study by the Energy Information Administration calculated that UEE would need to earn between $290 and $1.44 billion (1989$) more than it currently does in order to earn a 15% operating return on the value of depreciated assets. (EIA, 16).[37] The range of values reflects the controversy in measuring the book value of UEE's assets, as discussed in the above on unrecovered federal investment. Since the 15% rate of return is a pre-tax return (EIA, 65), it implicitly includes the value of UEE's tax-exemption as well.

However, it does not include the projected shortfall in D&D funds. Therefore, to generate an upper bound estimate of the subsidy to UEE, the $1.44 billion subsidy from UEE's tax-exemption and rate of return would need to be added to our high estimate of $142 million measuring the annual commercial D&D shortfall. This would yield a total 1989 subsidy of $1.58 billion.

Unsecured Long-Term Power Contracts. The uranium enrichment enterprise, anticipating burgeoning demand for enriched uranium during the 1970s and early 1980s from new power plant construction, entered a number of long-term take-or-pay contracts with the Tennessee Valley Authority for power necessary for enrichment. These contracts led TVA to construct new units. UEE, however, did not make similar requirements to purchase enriched uranium with its nuclear utility customers, for whom the new TVA capacity was ultimately being built. As a result, all risk for changes in market demand for enrichment services rested with UEE, rather than being shared by the beneficiary parties as would likely have occurred in private market transactions. When the market collapsed, UEE was forced to pay (after losing a court battle) TVA $1.8 billion, of which $465 million was due in 1989. (TVA Information Statement, F-15; 1990 Uranium Enrichment Annual Report, 32). Although these payments are already reflected in the UEE losses presented above, they are a good quantification of the subsidies associated with federal government uncompensated risk-bearing for private industry.

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[37]This price increase would not be supportable at current market prices. However, it demonstrates that UEE purchased too much capital or did not charge adequate prices when it could have passed them through to the market, or both.

Depreciation Rate of Uranium Stockpile. The enrichment of uranium involves increasing the ratio of $Uranium_{235}$ atoms to other forms of uranium (primarily $Uranium_{238}$), since U-235 is much more fissionable than the other isotopes. (EBASCO, 2-2). As more U-235 is removed from natural uranium to enrich the uranium fuel, the process of removing the remaining, more diluted, U-235 gets progressively more expensive. According to one analyst (Montange, 10/13/92), DOE has used a larger amount of natural uranium, but removing a smaller proportion of available U-235. Since the energy needed to remove U-235 increases as the concentration of U-235 in natural uranium decreases, the approach used by DOE saves money.

However, while the remaining uranium does have some recoverable U-235 remaining, the cost of recovery may be substantially higher than for the first increment. This makes the fuel-value of the semi-depleted stockpile lower. To reflect this lower value, the depreciation of the stockpile value in UEE's books would have to be accelerated rather than straight-line. According to Montange, UEE overstates the value of the stockpile, which is treated as an asset. This improves the apparent operating performance of the facility, partially justifying lower-cost sales of the final product. No subsidy estimate is included for this practice.

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Uranium Enrichment Enterprise

Part 1: Unrecovered Government Investment in the Enterprise

Estimator	Amount (Billions)	Period of Loss Start	Period of Loss End	# Yrs. for Accrual	Discount Rate (1)	Annual Charge (2)	Source
Revised General Accting. Office	8.42	1969	1989	21	0.0632	202.9	Smith Barney, 61; Coopers & Lybrand, 5,6. See accompanying text.
Department of Energy	3	1986	1989	4	0.0632	682.5	Smith Barney, 61; Coopers & Lybrand, 5,6.
Smith-Barney/Coopers & Lybrand	4.5	1986	1989	4	0.0778	1,001.9	Smith Barney, 63; Coopers & Lybrand, 5,6, 27; RATES2.WK1

	Low Est.	High Est.
Annualized Unrecovered Investment	202.9	1,001.9
Commercial Share (see Part 2)	88.27%	88.27%
Net Subsidy to Commercial Sector	179.1	884.4

Notes to Part 1:

(1) Since a significant portion of the unrecovered investment in UEE represents accrued interest on unrepaid capital, the various estimates were discounted using the same methodology employed in the calculation of imputed interest. Thus, DOE (after 1986) and GAO imputed interest based on the historical weighted average rate for all outstanding government debt. Smith-Barney, based on work by Coopers & Lybrand, felt that using the long-term bond rate available in the first year of the investment is more appropriate. The rate shown here for them is the 30-year T-Bond rate in 1986.

(2) The annual charge is the nominal payment needed each year to accrue the unrecovered capital during the period of loss. These payments accrue interest at the rate of the discount factor shown above.

Part 2: Derivation of Allocation Between Defense and Commercial Sectors

U.S. URANIUM ENRICHMENT ENTERPRISE SHIPMENTS OF SWU's FY1969-89
(SWU's in Thousands)

Year	Defense Enrichment Services	Civilian Enrichment Services	Year	Defense Enrichment Services	Civilian Enrichment Services
1969	2,580	1,247	1980	845	10,376
1970	2,416	3,265	1981	1,379	10,877
1971	1,845	8,410	1982	1,538	14,155
1972	253	6,173	1983	1,281	14,177
1973	521	7,912	1984	1,710	11,198
1974	346	15,763	1985	1,447	10,060
1975	606	8,366	1986	1,820	8,623
1976	927	11,654	1987	1,777	8,297
1977	1,652	10,917	1988	1,862	10,593
1978	1,332	12,730	1989	1,037	11,923
1979	909	14,661			
			Total	28,083	211,377
		% of Tot. Shipments		11.7%	88.3%

Notes to Part 2:

(1) SWU's refer to "Separative Work Units," the measure of enrichment services.

(2) Prior to 1969, all sales were defense-related. Some of these prior enrichment services were in inventory and may have gone to the commercial sector, although the above numbers do not reflect this. All estimates of unrepaid debt also begin in 1969.

(3) Data for 1990 were 541 SWU's to the defense sector and 10,182 to the civilian sector.

Source: Eugene Schmitt, Office of Uranium Enrichment, U.S. DOE, October 6, 1992.

Part 3: Decommissioning and Decontamination (D&D) Cost Sharing

Current DOE Accrual	$Billions	
Estimated Cost for D&D, all 3 plants	3	Summation of nominal past and future payments
Commercial Share	1.404	DOE Administrative Decision
Actual Ratio of Commercial/Defense Shares	46.80%	Note 1

Notes to Part 3:

(1) This estimate is used in the allocations below, and differs from the figure in Part 2 because D&D costs were incurred going back to the beginning of UEE, while the calculation of unrecovered costs began only in 1969. The breakout shown is from the 1989 UEE Annual Report, p. 35.

Part 4: Cost Estimates for Decommissioning & Decontamination

	$Billions	
A. DOE Estimated Cost, Nominal Value	3	From Part 3
DOE Accrual, Constant 1989$	2.46	Constant 1989$; From Part 5
Plus current accrual for site remediation not classified by DOE as D&D		
1. Pre-D&D maintenance and surveillance at Oak Ridge	0.43	Constant 1989$; From Part 5
2. Remedial Actions at all Three Sites	0.61	Constant 1989$; From Part 5
Total DOE Accrual*	3.50	

*Although little of this accrual has been paid out in cash, so long as it is reflected in UEE financial statements, the unrecovered federal investment shown in Part 1 would reflect the losses. The additional DOE accruals reflect associated costs to the civilian users of UEE for remediating the sites, but whic for no clear reason are excluded from DOE's total of current D&D accruals. These items are added to the $3 billion total to avoid double counting errors when netting the DOE D&D accrual from contractor D&D estimates below.

B. Smith-Barney Estimate

Est. Cost of Decommiss. the Oak Ridge Plant	8	1989$; from Smith Barney, p. 82; GAO/T-RCED-90-101, p. 10.
Extrapolation to Cleanup of 3 sites	24	

D. DOE Contractor Estimates	—Billions of 1992 Dollars— Lower Bound	Expected	High Est.	—Billions of 1989 Dollars*— Lower Bound	Expected	High Est.	Source
Cleaning of Buildings and Equipment	11.27	16.1	24.15	10.38	14.83	22.24	EBASCO Services, Inc., quoted in GAO/RCED-92-BR, p. 2.
Remedial Action, Surrounding Soil and Water	3	3	3	2.76	2.76	2.76	Martin Marietta Energy Systems, quoted in GAO/RCED-92-77BR, p. 2.
Conversion and Disposal of Low Level Radioactive Uranium Waste Streams	1.3	1.9	4.1	1.20	1.75	3.78	Martin Marietta Energy Systems, quoted in GAO/RCED-92-77BR, p. 2.
Total D&D Costs	15.57	21	31.25	14.34	19.34	28.78	
TLG Engineering Estimate	13.9		16.7	12.80		15.38	TLG Engineering, p. 5. Covers same scope as EBASCO study and TLG estimate is inside the EBASCO range.

*Estimates were converted to 1989$ using GDP implicit price deflator data from the "Survey of Current Business," Dec. 1992, p. 33. GDP rather than GNP deflators were used in this instance due to changes in federal data collection which stopped publishing GNP deflators in the early 1990s. The end-of-year 1991 price deflator was used since 1992 data are not yet complete, and since this better reflects prices in early 1992 when the contractors were assembling cost factor inputs for their studies.

E. High and Low Estimates - Most Likely to be Accurate Scenario: Contractor Estimates

	Low Est. (Billions of 1989$)	High Est.	
Total Estimated D&D Costs	14.34	15.38	
Less Current DOE Accrual for D&D	3.50	3.50	See Parts 4A and 6; includes future accruals through enriched uranium sales.
Net D&D Expected Shortfall	10.84	11.89	
Commercial Share	46.80%	46.80%	From Part 3B above.
Net D&D Subsidy to Commercial Fission	6.71	7.20	
Less Special D&D Charge on Utilities	2.07	2.07	The Energy Policy Act of 1992 levies a total of $2.25 billion (real 1992$) in D&D charges over 15 years.
Subsidy, net of special charges	4.64	5.13	
Period of Underaccrual	36	36	Note 1
Estimated Real Interest Rate	0.014	0	Reflects the payout of cash as it is collected; see Note 2.
Annualized Payment ($Millions)	100.0	142.4	Note 3

Notes to Part 3E:

(1) The Enrichment plants are began servicing the commercial sector in 1969, and are scheduled to close in 2005, a period of 36 years.

(2) The 1.4% rate is the historical, inflation-adjusted yield on long-term government bonds between 1925 and 1990 (Ibbotson, 76). The government yield was chosen since the deficit in UEE was financed through government borrowing. The zero rate of interest used to calculate the high estimate reflects the fact that D&D spending will be occuring as the funds are accrued for much of the accrual period. As a result, there may be no unspent collections on which to earn a return.

(3) This is the payment necessary to accrue the funds needed for facility D&D by the end of the planned D&D effort.

Part 5: Conversion of Nominal DOE Accruals For D&D and Related Costs to Constant 1989$

A. Current Nominal Accrual

Year Cost Accrued	D&D Accruals Nominal	1989$	Pre D&D work @ ORGDP Nominal	1989$	Remedial Action Nominal	1989$
1988	415	432	192	200	274	285
1989	58	58				
1990	58	56				
1991	58	53				
1992	58	51				
1993	58	49				
1994	58	47				
1995	58	45				
1996	58	43				
1997	58	41				
1998	58	40				
1999	58	38				
2000	58	36				
2001	58	35				
2002	58	33				
2003	58	32				
2004	58	31				
2005	58	29				
	1,404	1,151				

These payments are DOE's planned accrual of D&D funds over the remaining facility life.

Sources: DOE, UEE Annual Reports, 1988 (pp. 30,35) and 1989 (p. 30).

Discount Factor 0.0435 Equal to the cumulative average growth rate in the GNP implicit price deflator between 1950 and 1990.

B. Summary of Adjustments to D&D Inputs Shown in Part 3

Total DOE Accrual	Commercial Share Nominal	Commercial Share 1989$	Total Costs (1989$)	
Percentage of Total Costs Commercial			0.468	From Part 3
D&D	1,404	1,151	2,459	
Pre-D&D Work at Oak Ridge	192	200	427	Adjustments in Part 5A represent commercial share only. These are
Remedial Actions	285	285	610	scaled up to reflect the total cost, the needed input for Part 4E.
Total	1,881	1,636	3,496	

Adjustment of Energy Policy Act UEE Collections to 1989$

	Billions	
Total Collections, Real 1992 $:	2.25	
Total Collections, 1989$	2.07	See note in Part 3D for details on conversion.

Part 6: Summary of Annual Subsidies to Uranium Enrichment

	Low Est. (Millions of 1989$)	High Est.	
Unrecovered Capital	179.1	884.4	
Decommissioning and Decontamination	100.0	142.4	
NRC Licensing	NQ	NQ	See accompanying text for discussion.
Insurance	NQ	NQ	See accompanying text for discussion.
No Required Rate of Return	NQ	NQ	See accompanying text for discussion.
Tax-Exempt Operating Status	NQ	NQ	See accompanying text for discussion.
Total	279.1	1,026.8	

Notes to Part 6:

(1) A low estimate including an imputed rate-of-return was not done because our low estimates include direct costs to the government only. The absence of a rate-of-return, though it does reduce the cost structure of the enterprise, is not a direct cost to the federal government.

(2) "NQ" refers to "Not Quantified."

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DOE: NUCLEAR WASTE FUND

The Nuclear Waste Fund is a supposedly self-financing fund collected from generators of radioactive wastes and used to develop the technologies and facilities necessary to safely dispose of the nation's nuclear wastes.[38] The Fund is financed through a 0.1 cent/kWh fee on nuclear-generated electricity. In return for these payments, plus a one-time levy of $1.452 billion to cover the costs of wastes generated prior to the establishment of the fund in 1983, "utilities are relieved of further financial obligation for waste disposal." (GAO/RCED-90-65,2). Since the facility will also handle some defense-related nuclear wastes, the defense share of the facility has been set at 14.9% if there is one repository built, or 17.3% if there are two. (Nuclear Waste Fund Fee Adequacy, 11/90, 13).

Subsidies from the nuclear waste fund can take five forms: incorrect projections of receipts and facility costs; insolvency of contributors prior to payment; its tax-exempt status; its lack of a required rate of return on invested capital; and uncompensated risk bearing by the public and the States. For the facility cost projections, contributor insolvency, and uncompensated risk bearing, the current cost to nuclear utilities appears to be lower than the actual cost to the country, reducing the current private cost of providing nuclear power. The tax-exempt status and lack of a required rate of return also reduce the current cost to nuclear utilities, increasing the barriers to entry for non-nuclear energy alternatives.

Incorrect Projections of Receipts and Facility Costs

The Fund is intended to recover all costs associated with researching, constructing, and operating the nuclear waste depository, now limited to the Yucca Mountain site in Nevada.[39] Every year, the Department of Energy must estimate whether the current levy is sufficient to meet projected program needs as per the Nuclear Waste Policy Act of 1982. These assessments have, every year, determined that the current levy is, in fact, sufficient to meet facility needs.

This estimate is subject to a great deal of uncertainty, however. First, the estimates assume a program life of 100 years (GAO/RCED-90-65, 10), requiring that assumptions hold over an extremely long time period. This includes assumptions on real interest rates and inflation rates, both very difficult to predict with any accuracy. Since the fee is not indexed to inflation, incorrect inflation estimates can have serious repercussions. In addition, revenues are dependent on how many utilities generate how much electricity (thereby paying into the fund for each unit), over how long a period of time. DOE estimators assume that the average reactor will last 40 years (as of 1987); state regulators assume 30-35 years. DOE estimates assume no decline in performance as reactors get older, and that average industry capacity factor will increase gradually to 65% in 2000 and 70 percent in 2020. The capacity utilization table on the next page suggests that even capacity factors do not always move in a predictable manner. In fact, three government studies in the 1970s, and one in 1985, found dramatic declines in capacity factors as the plants

[38] The fund was originally earmarked for use only for nuclear waste disposal. Beginning in FY92, $19.7 million/year can be used to pay for Nuclear Regulatory Commission oversight costs of utilities (OMB '92, 4-1154 - 4-1157). In addition, there have been some violations that have recently come to light where money from the Fund has been used for discretionary (self-initiated) R&D by the DOE laboratories. In FY 1988, $1.3m was assessed from the fund for non-nuclear waste uses; in FY 1989, this rose to $1.42m. This amount is deducted from our high estimate of the Nuclear Waste Fund subsidy. (US GAO, Energy Management: Better DOE Controls Needed Over Contractors' Discretionary R&D Funds, December 1990, p. 41).

[39] There is some uncertainty whether there will be one or two repositories. The currently authorized capacity at Yucca Mountain (70,000 metric tonnes) is less than the projected need for disposal capacity (96,000 metric tonnes of waste) -- even if no new reactors are built. (Chapman, 252).

aged.[40] With no new plants built in the U.S. in over a decade, it appears that the industry average capacity factor will decline over time, rather than rising or staying stable as necessary to meet revenue projections. Interestingly, DOE studies after 1985 assume no decline in capacity factors of aging plants, though no study was done to support this revision.

DOE does make projections in a worst-case scenario in which no new reactors come on line to pay into the fund, reducing errors of underestimation in this area.

Historical Capacity Factors of United States Nuclear Reactors

Year	Capacity Factor
1973	53.7%
1974	47.9
1975	56.0
1976	54.9
1977	63.4
1978	64.7
1979	58.5
1980	56.4
1981	58.4
1982	56.7
1983	54.4
1984	56.3
1985	58.0
1986	56.9
1987	57.4
1988	63.5
1989	62.3

Source: "Nuclear Power Plant Operations," Energy Information Administration Monthly Energy Review, February 1990.

[40]U.S. Department of Energy, Update: Nuclear Power Program Information and Data, DOE/NE-0048/8, Feb. 1985, p. 57; and a 1972 study by the Atomic Energy Commission (WASH-1139), a 1975 update by the Energy Research and Development Administration (update to WASH-1139), and a 1970 Sandia National Laboratory study (NUREG/CR-0382 and SAND 78-2359). Cited in Kriesberg, 11/87, p. C-7.

In addition to uncertainty regarding model assumptions, there is uncertainty associated with the actual costs of facility construction. The estimated costs of the Yucca Mountain facility increased approximately $8 billion between 1983 and 1988.[41] (Chappie, 1453).

From the level of uncertainty involved with all aspects of projections it is clear that there is a significant possibility that it will be underfunded. Even DOE's own models show fund shortfalls if average inflation or real interest rates are off by even 1% over the 100 year model period. All net fund estimates include interest earned on the positive fund balance during the earlier years.

Low End Estimate. We assume DOE's model is correct and that there will be no shortfall in the fund, yielding zero-subsidy.

High-End Estimate. We assume that GAO's estimates of fund shortfalls, due to the items listed above, is correct. This yields an end of facility life fund deficit of $45.8 billion for a one-repository system and $80.2 billion for a two-repository system (in 1989$). (GAO/RCED-90-65, 39). Using information provided by GAO on the expected duration of fund collections, and the expected life of the facility, this large deficit is converted into annual payments which, if collected during the time the waste fund accepts waste, would provided enough funds to avoid a shortfall. (Our high-end estimate is based on a 1-repository system).

Insolvency of Contributors Prior to Repayment

Although current fees are collected on a current basis, payment of the one-time assessments to fund government handling of waste generated prior to 1983 was not. Utilities were given the option of paying in full by June 30, 1985 with no interest; in 40 quarterly payments with interest; or in a future lump-sum payment (including interest) by January 1998.[42] This payment method gives rise to subsidies through the interest rate charged, and through the potential default on obligations to pay.

Interest Rates. The unpaid balance accrues interest at the government's rate of borrowing until paid in 1998. The cost of capital for these utilities, especially those with insecure financial conditions (see below), would be higher. While the utilities who deferred payment are definitely being subsidized and should be included in our high estimate, we assume that our estimate of the subsidy to the Waste Fund overall would not change, and that the low interest payments are already reflected in the size of the fund deficit at closure.

Default on One-Time Payment. According to the Inspector General of the Department of Energy, 11 of the 17 utilities who chose to defer payments until 1998 are in uncertain financial position and may not be solvent to pay. (DOE/IG-0280 cited in GAO/RCED-90-65, 45). These 11 utilities owe a total of $2.1 billion in interest and principal by 1998. (DOE/IG-0280, p. 1).

Low-End Estimate: Zero; all utilities will pay their debt in its entirety.

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[41]Between 1983 and 1986, estimated cost of building a facility increased by between $2.1 and $10.4 billion (range estimates). This corresponds to a percentage increase of between 9.5 and 45.8%. (GAO/RCED-87-121, 48).

[42]The assessed interest rate is the 13-week Treasury bill rate compounded quarterly between April 7, 1983 and the first payment. Under the option of 40 quarterly payments, once the first payment is made, interest is calculated at the 10-year Treasury note rate in effect at the time. (Office of Civilian Radioactive Waste, 1989 Annual Report, 39). These interest rates are probably significantly lower than the utilities' costs of borrowing.

High-End Estimate: Based on the concerns expressed regarding utility solvency, we assume that only 50% of the amount required will be repaid. This generates an expected loss of $1.05 billion in 1998 at the facility opening. Using the period between 1985 (when utilities could pay in full without incurring any interest charges) and January 1998 when the payment is due, and a discount rate of 6.804% (the average of the monthly average 3-month treasury bill rates between 1985 and 1989 as a proxy for the interest rate on the 40 quarterly payments - see note 42), we calculate the annual payment that would be needed to avoid a shortfall.

Uncompensated Risk Bearing by the American Public

Upon payment into the waste fund, the power plant liability for nuclear waste shipments ends. It is the responsibility of the federal government to package the waste, ship it to the disposal site, dispose it, and monitor the disposal site. All of these activities involve risk; risk of spills, accidents, material loss, exposure of the population to radioactivity, etc. All of these risks are borne by citizens, especially by those on rail or highway transport routes to Yucca Mountain, essentially for free, since the government and all contractors are indemnified under the Price-Anderson Act. (Kehoe, 3,4). With one disposal site in Nevada, but with nuclear plants all over the nation, some of the wastes will be shipped for thousands of miles. It is clear that

> Government responsibility for ultimate waste disposal removes significant uncertainties from those investing in nuclear power production. (Bowring, 63).

The risks are not insignificant, and should be regarded as subsidies. We are, however, unable to quantify them and include them here.

Lack of a Required Rate of Return and Tax-Exempt Status. The lack of any required return on invested capital, along with an exemption from paying federal income taxes, both reduce the costs of handling nuclear waste. These benefits do not exist for competing fuels. Hazardous and combustion waste from coal burning, for example, must be disposed of at facilities which are often privately owned and operated. The disposal prices, unlike that for nuclear waste, must be high enough to provide an adequate after-tax return for the operator. As with uncompensated risk bearing, these subsidies do not appear in our total.

Decommissioning

Decommissioning one or more nuclear waste facilities at the ends of their productive lives is included in the DOE Waste Fund Fee Adequacy Assessments. We assume that the provisions for decommissioning are sufficient and that there is no additional subsidy in this area.

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DOE: Nuclear Waste Fund

Part 1: Shortfall in Accrual for the Nuclear Waste Facility Since Fund Initiation

	One Repository System	Two Repository System	
Future Value of Facility Shortfall	44,000	77,000	GAO, 39 - In Constant 1988 Dollars
	45,814	80,174	Inflated to Constant 1989 Dollars

(1) Assumes no new orders for nuclear reactors, capping the reactors paying into the fund at current capacity.

Part 2: Time Frame to Accrue for Shortfall

Beginning of Fund Collection	1983	1983	GAO, p. 9.
No new waste received	2027	2042	GAO, 32.
Projected End of Facility Life	2068	2089	GAO, 25
Years of Fee Collection	44	59	
Years of Administration After Waste Receipt (and fee collection) Ceases	41	47	

Part 3: Calculation of Shortfall At Point Fee Collection Ceases

Rationale: After the facility stops taking new wastes (and fee collection ceases), the remaining costs are primarily administrative according to GAO. These costs are small compared to the costs of facility construction. As a result, the shortfall at this point in time (more than 40 years prior to facility closure) will be almost as big (in present value terms) as at the end of the facility life. We therefore convert the end-of-facility life shortfall into the shortfall in 2027 and 2042, respectively. In addition, the entire deficit must be accrued by the time waste collection ceases since after that point a user fee would be impossible.

A. Discounting End-of-Facility Deficit to the Point at Which New Waste Collection Ceases in 2027 and 2042

Shortfall at Point of Facility Closure	45,814	80,174	From Part 1 above, in 1989$
Assumptions:			
Years between closure and cessation of waste fee collection	41	47	From Part 2 above
Real Rate of Growth of Surplus Funds	0.03	0.03	Note 1
PV of Shortfall in 2027 and 2042	13,635	19,984	

B. Annual Payments Needed to Make up Shortfall by 2027 and 2042

PV of Shortfall in 2027 and 2042	13,635	19,984	
Collection Start Date	1983	1983	
Collection End Date	2027	2042	
Number of Collection Years	44	59	
Real Rate of Interest	0.03	0.03	Note 1
Annual Payment (Millions of 1989$)	153.1	127.0	
Commercial Share of Shortfall	0.851	0.827	Administrative allocation; Nuclear Waste Fund Fee Adequacy, 11/90, 13.
Net Annual Subsidy to Commercial Sector	130.3	105.0	Note 2

C. High and Low Estimates

High Estimate	130.3	
Low Estimate	0	Note 3

Notes to Part 3:

(1) While this interest rate is higher than the historical real return on long-term corporate bonds and government securities between 1926 and 1990, we use it since it was the value used in the initial calculations of the Waste Fund shortfall. Since these initial calculations impute interest on the deficit at 3%, using any other discount factor would overstate the current value of losses.

(2) Calculations yield an average annual shortfall. Actual cash inflows and outflows on an annual basis would yield somewhat different results.

(3) Both scenarios shown in part 3B represent only two of the modeling results by DOE and GAO. Depending on the assumptions one makes regarding inflation, costs, and yields over the next 100 years, the Waste Fund may not run a deficit. Our low estimate, therefore, conservatively assumes that there will be no shortfall.

Part 4: Projected Default Rates on One-Time Payments

	Low Est.	High Est.	
Funds Owed ($Billions)	2.1	2.1	Principal plus interest due in 1998 (DOE/IG-0280, 1).
Date Due	1998	1998	
Date Interest Accrual Began	1985	1985	
Period of Accrual (inclusive)	13	13	Payments prior to 1985 could be paid with no interest charge. Payments due January 1998.
Discount Rate	0.06804	0.06804	Note 1
Implied Annual Accrual to Pay Lump-Sum Payment in 1998	105.6	105.6	
Expected Default Rate	0.00%	50.00%	Guess, based on DOE Inspector General Report
Annual Subsidy, 1-time payment defaults	0	52.8	Note 2

Notes to Part 5:

(1) This discount factor is the average of the monthly average 3-month Treasury bill rates between 1985 and 1989. This is the imputed interest rate used by the government to calculate interest on deferred payments by the utilities included in the total above who plan to pay their 1-time assessment for waste generated prior to 1983 in a lump sum payment in 1998. Since the rate is a nominal one, it incorporates inflation within it.

(2) The individual utilities that defer payment until 1998 receive an additional subsidy by the fact that their debt accrues interest at federal borrowing rates, which are significantly lower than their own. However, the net subsidy to the Waste Fund is unaffected since the interest rate subsidy simply increases the ultimate fund shortfall, and is incorporated in the value we use in Part 1.

Part 5: Summary of Annual Subsidies to the Commercial Users of the Nuclear Waste Fund

	Low Est.	High Est.	
Facility Shortfall	0.0	130.3	
Expected Defaults on 1-time Pymt.	0.0	52.8	
Less Fund Reciepts Used for Non-nuclear Waste Purposes	0	(1.4)	GAO, Dec. 1990, p. 41.
Tax-Exempt Status	NQ	NQ	See discussion in text
No Required Rate of Return	NQ	NQ	See discussion in text
Uncompensated Risk Bearing by Population Along Waste Transport Route	NQ	NQ	See discussion in text
Total Quantified Subsidies	0.0	181.7	

Sources:

(1) U.S. DOE, Office of Civilian Radioactive Waste. "Nuclear Waste Fund Fee Adequacy: An Assessment," November 1990.

(2) U.S. DOE, Office of the Inspector General. "Followup Review of Fees Paid by the Civilian Power Industry to the Nuclear Waste Fund," March 26, 1990. DOE/IG-0280

(3) U.S. GAO. "Energy Management: Better DOE Controls Needed Over Contractors' Discretionary R&D Funds," Dec. 1990.

(4) U.S. GAO. "Nuclear Waste: Changes Needed in DOE User-Fee Assessments to Avoid Funding Shortfall," June 1990. GAO/RCED-90-65.

NUCLEAR REGULATORY COMMISSION

The Nuclear Regulatory Commission was created in the Energy Reorganization Act of 1974 with the mission of assuring that civilian uses of nuclear materials in the United States are carried out to ensure proper protection of health, safety, environmental quality, and national security. The commission regulates nuclear materials in medical, industrial, and research applications as well as in power plants.

The NRC regulates reactor design, siting, and operations of nuclear power plants, including the licensing of transporters and disposers of radioactive materials. The Agency was also responsible for overseeing the clean-up at Three Mile Island.

Data on NRC spending by category was taken from the OMB Federal Budget. Detailed data on offsetting revenues is from the two page financial statements presented in the NRC 1990 Annual Report. Due to a range of values concerning the commercial utility share of radioactive waste, we generate high and low estimates for NRC.

The Omnibus Budget Reconciliation Act of 1990 required NRC to recover all costs from licensees for fiscal years 1991-1995. Renewal of the legislation in 1995 will be necessary to continue full cost recovery past that date. (Ingram, 3/1/93). For all years prior to 1991, the NRC provided hundreds of millions of dollars in uncompensated oversight to the commercial nuclear industry.

Reactor Safety and Safeguards Regulation

Tasks include all NRC licensing and inspection of civilian reactor facilities and designs. The NRC conducts reviews in the following areas: reactor operations reviews; human performance in reactor safety; reactor operations inspections; operating reactor license maintenance and regulatory improvements; reactor accident management; and reactor safeguards. (OMB, '91, A-1162).

Nuclear Safety Research

This area includes three main tasks: the provision of expertise and independent research (i.e., not from the licensees) on short-term problems; long-term research (5-10 years) in support NRC decisions and regulatory approaches; and the development of the regulations and guides necessary to implement policy or technical requirements of NRC programs.

Nuclear Material Safety, safeguards, and low-level waste regulation

This area of responsibility seeks to ensure that nuclear materials and fuel cycle facilities do not pose an undue health, safety, environmental, or national security risk. Tasks include all NRC licensing and inspection of nuclear fuel-cycle facilities, users of nuclear materials, the transport of nuclear materials, the safe management and disposal of low-level radioactive wastes, and uranium recovery activities and related remedial actions.

High Level Nuclear Waste Regulation

NRC licensing and oversight efforts to ensure the safe handling, transport, and management of high level radioactive wastes, including spent fuel.

Reviews, Investigations, and Enforcement

Review, evaluation, and investigation of NRC's licensees. Included are diagnostic evaluations of plant safety, evaluation of operational events (i.e., mishaps), and provision of advice in these areas. Also included is the NRC's emergency operations center.

Office of the Inspector General

An Office of the Inspector General was established in the NRC pursuant to the Inspector General Act Amendments of 1988. The purpose of this position is to review and appraise the integrity of NRC programs and operations. (OMB, '91, A-1164).

Sources:

Heede, Rick. Federal Energy Subsidies: Agency Obligations, Draft Report. Rocky Mountain Institute, 1986.

Ingram, Frank. Nuclear Regulatory Commission. Personal communication, March 1, 1993.

Office of Management and Budget. Budget of the U.S. Government, FY 1991, A-1161 - A-1164.

United States Nuclear Regulatory Commission. Annual Report 1988, June 12, 1989.

United States Nuclear Regulatory Commission. Annual Report 1990, 1990, pp. 199, 200.

NUCLEAR WASTE TECHNICAL REVIEW BOARD

The Board is directed to evaluate the technical and scientific validity of DOE's nuclear waste disposal program undertaken after the Nuclear Waste Policy Amendments Act of 1987. (OMB '91, A-1164). The Board is funded through the Nuclear Waste Fund, and is therefore not subsidized by taxpayers.

OFFICE OF THE NUCLEAR WASTE NEGOTIATOR

This position is created with the purpose and authority to attempt to find a State or Indian tribe willing to host a nuclear waste repository or monitored retrieval site at a technically qualified site. Funding began in 1990; therefore, it has no subsidy value for our 1989 snap-shot estimate.

PRESIDENT'S COMMISSION ON CATASTROPHIC NUCLEAR ACCIDENTS

The purpose of this Commission is to study the options for fully compensating victims (or their survivors) of a catastrophic nuclear accident. The study, which was to be completed by 1990, was authorized under the Price-Anderson Act Amendments of 1988. The Commission was abolished Oct. 1, 1990. (OMB '92, 4-1167). Funding was split evenly between commercial fission and the military sector.

Nuclear Regulatory Commission

Item	Amount ($mil) (a)	Commercial Fission Portion Low Est. (b)	Commercial Fission Portion High Est. (c)	Net Subsidy Low Est. (a*b)	Net Subsidy High Est. (a*c)	Notes
Reactor Safety and safeguards regulation	156.9	100.0%	100.0%	156.9	156.9	(1)
Nuclear safety research	109.9	100.0%	100.0%	109.9	109.9	(1)
Nuclear material and low-level waste safety and safeguards regulation	35.4	44.0%	88.3%	15.6	31.3	(2)
High-level nuclear waste regulation	17.7	2.5%	94.6%	0.4	16.7	(3)
Reviews, Investigations, Enforcement	33.8	100.0%	100.0%	33.8	33.8	(4)
Nuclear safety, management & support (NSMS)	63.9	44.0%	88.3%	28.1	56.4	(2)
Office of the NRC Inspector General	0.0	0.0%	0.0%	0.0	0.0	(5)
Reimburseable Program	3.6	0.0%	0.0%	0.0	0.0	
Total Program Costs	421.2			344.8	405.0	
Less Revenues (Notes 7 and 8)						
Reimburseable work for other agencies	(1.6)	0.0%	0.0%	0.0	0.0	(6)
Material Licenses	(3.7)	100.0%	100.0%	(3.7)	(3.7)	(6)
Facility Licenses	(48.0)	100.0%	100.0%	(48.0)	(48.0)	(6)
Other	(5.9)	100.0%	100.0%	(5.9)	(5.9)	(6)
Total Revenues	(59.2)			(57.6)	(57.6)	
Net Cost of Operations	362.0			287.2	347.4	

Notes:

(1) These areas of activity go almost entirely towards oversight of commercial reactors.

(2) Nuclear material and LLRW safety and safeguards and NSMS expenditures oversee nuclear fuel cycle facilites and low-level waste regulation. The low estimate is based on the volume of low-level radioactive wastes attributable to the utility sector (OTA, 84), assuming that costs are driven by the volume of LLRW. The high estimate reflects the percentage of uranium enrichment services going to the commercial sector (see section on DOE's Uranium Enrichment Enterprise), assuming that this pattern of activity is a fair proxy for the distribution of these costs. Allocating by the commercial share of radioactivity would yield a larger subsidy estimate than the one shown.

(3) The wide range here reflects the commercial share of high-level radioactive waste by volume in the low estimate and by radioactivity in the high estimate. We do not know which drives oversight costs more.

(4) Reviews and inspections of NRC licensees impacts commercial facilities.

(5) The Office of the Inspector General was not funded until FY91.

(6) Reimburseable work for other agencies is assumed to be unrelated to commercial fission. License fees are "other" fees are conservatively assumed all to be collections from commercial fission facilities. Data are from NRC 1990 Financial Statements, p. 200.

(7) Revenues are generally deposited into the U.S. Treasury, and then transferred to appropriations the following year. Revenue da 387.6 m for FY89 is used to scale

(8) In FY89 NRC fees were capped at 33% of the cost of running the Commission. Proposed legislation would have funded $19.7m in costs from the Nuclear Waste Fund, and the rest through license fees. In FY92, $19.7m did come from the Waste Fund; the status of fee collections is unknown. (OMB '91, A-1163; OMB '92, 4-1154).

Cumulative Generation of Radioactive Wastes to Jan. 1, 1989

	Vol. (000 cu yds	(%)	Radioactivity (Mil. curies)	(%)
Low Level Radioactive Wastes				
Nuclear Utility LLRW (Operating plus decommissioning)	9,335	44.03%	548	97.34%
Defense and Industrial LLRW	11,865	55.97%	15	2.66%
Total LLRW	21,200	100.00%	563	100.00%
High Level Radioactive Wastes				
Nuclear Utility HLRW	39	2.53%	20,430	94.56%
Defense and Industrial HLRW	1,500	97.47%	1,175	5.44%
Total HLRW	1,539	100.00%	21,605	100.00%

Source: Chapman p. 250, based on OTA.

Sources:

Chapman, Duane. "Decommissioning and Nuclear Waste Policy: Comprehensive or Separable?" The Energy Journal, V. 12, 1991.

Heede, Rick. "Federal Energy Subsidies: Agency Obligations." NRC section. Rocky Mountain Institute, 1986.

Nuclear Regulatory Commission. "Annual Report." For 1988, and financial statements for 1990.

Office of Management and Budget. "Budget of the U.S. Government, FY 1991," pp. A-1161 - A-1164.

Office of Management and Budget. "Budget of the U.S. Government, FY 1992," pp. 4-1154 - 4-1157.

Office of Technology Assessment. "Partnerships Under Pressure: Managing Commercial Low-Level Radioactive Waste," November 1989.

Other Federal Interventions Into Energy Markets

"Other" interventions is a catch-all category for the numerous remaining ways in which the federal government intervenes in energy markets. There are three main types of intervention covered in this chapter: the **Assumption of Legal Risks, Changes in Market Rules, and Federal Procurement of Energy Services for Internal Use.** Most of these interventions involve changing the rules under which private entities operate rather than the payment of direct financial subsidies from the federal government. The impact on market structure and the viability of emerging energy sources is extremely large nonetheless.

The assumption of legal risk reduces the costs of production for certain private entities in the energy sector by indemnifying them against accidents or other mishaps, or by shifting these risks from the producer to the public. Changes in market rules alter regulations governing the access to energy markets, pricing, and terms of sale. These changes can dramatically alter the risks and rewards (increase or decrease) of particular economic activity. Federal procurement of energy products and services affects energy markets through purchase preferences, and through the volume of products and services demanded. Each category is described in more detail below.

Assumption or Shifting of Legal Risks/Indemnification

Federal laws or actions may transfer private market risk to the federal government, or to the populace at large. Since private markets charge a price for risk-bearing, intervention in this arena to reduce the risks borne by particular energy producers can reduce (sometimes dramatically) the cost structure of the industry. Where risks are very difficult to predict or measure, such as with nuclear reactor accidents, federal intervention to limit or cap risks may be the main factor enabling the industry to develop.

The federal government reduces the legal risks for private industry in a number of ways. It may cap the amount of money that the private sector must pay in the case of an accident through statute, such as with the Price-Anderson Act covering nuclear reactor accident liability. It may also promise to pay for damages directly itself, through indemnification of the private party. The Price-Anderson Act also has an indemnification component.

The government may also run or finance insurance programs directly (as it does with crop-insurance), or guarantee repayment of loans (as it does with many loan guarantee programs). While all of these examples have some similarities, we separate them into federal indemnification, and federal insurance and loan guarantees. Insurance programs and guarantees are included under the federal agencies section of the report since risk assessments are done as a normal part of the on-going activities of a federal agency, and beneficiaries may be charged at least part of the cost of the services.

Indemnification or risk shifting is different. A statute says, in essence, if there is an accident, "the federal government will pay all/part of the damages," or "the company is not responsible for damages exceeding a certain amount." There is no charge for this service (although some conditions may have to be met). As a result, there are no on-going operations to measure risk, adjust the expected cost of these programs, etc.

Liability caps without federal indemnification reduce private risks by shifting them to surrounding populations, or to future taxpayers. In neither case do the unwilling recipients of the risks get compensated for their exposure. The Price-Anderson Act, for example, does not statutorily protect accident victims above the levels of private insurance and federal indemnification. The allowance for utilities to underaccrue funds to finance the decommissioning of their nuclear power plants shifts the risks for shortfalls to future ratepayers or taxpayers. Both actions reduce the costs of nuclear power today.

The implications of these risk-based subsidies are important. In addition to reducing the current cost of power generated by more risky methods, risk-subsidies hide the risks of current options. Current decision-makers may not be able to evaluate which of their current options pose the lowest societal risks. They may also have less of an incentive to make choices which minimize these risks, since they do not bear the full costs of poor decisions. This issue is worthy of additional research.

At least two areas are not included in this section due to data limitations, but should be examined in future research. These are the liability caps recently placed on transporters for oil spills, and issues associated with damages from coal mine subsidence, which historically were not always borne by the mine-owner.

Price-Anderson Act Nuclear Liability Cap and Contractor Indemnification

Background

The Price-Anderson Act was enacted in 1957 to facilitate the growth and expansion of the commercial nuclear industry. The perceived risk of enormous catastrophic losses in the case of a nuclear accident made private insurers unwilling to back the industry. The technology was new and much was unknown about the operating characteristics of commercial fission. Similarly, without any historic actuarial information on which to base rates, nuclear insurance seemed a dangerous proposition indeed for commercial insurance firms.

Price-Anderson solved much of this problem. First, the Act indemnified all contractors and suppliers who design and build commercial nuclear plants; or who operate federal nuclear fuel cycle, research, or disposal facilities from liability in the case of an accident - even in the case of gross negligence. This indemnification includes all parties involved with nuclear waste transport from commercial reactors all over the country to the proposed disposal facility in Nevada.[1] Second, the Act capped the losses for which the insurers and the utilities would be liable in the case of an accident.

A two-tier system of coverage was set up. The first tier is comprised of "normal" insurance, where utilities purchase coverage up to a certain limit, and pay annual premiums. Private insurance companies have been hesitant to increase their coverage for nuclear accidents. Thus, first tier insurance availability has remained constrained over the past 35 years. The second tier is comprised essentially of guarantees to pay a certain amount of money retrospectively in the case of an accident. These two components together now provide coverage up to the statutory limit set by the Price-Anderson Act. To the extent that losses exceed the insurance cap, the federal government would be the only source to pick up the tab. Since only the value of the liability cap for utilities has been estimated here (benefits to other contractors, operators, and transporters are excluded), the estimates which follow are likely to be too low.

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[1]According to an Office of Civilian Radioactive Waste Management in DOE, by the year 2020 there will be over 220,000 spent fuel assemblies to transport even if there are no new orders for reactors. With the assemblies grouped into shipping casks, tens of thousands of individual trips would be required to move the assemblies to disposal sites. These trips would cover between 27 and 65 million miles, depending on assumptions used regarding the available disposal points. (Rothwell, 12-14).

Table B5-1: Evolution of Price-Anderson Liability Coverage

	1957 Act	Reauthorization or Amendment Year		
		1965 and 1966	1975	1988
1st Tier: Private Insur. - Total Premium-Financed Insur. Available	$60m	Between $60 and $125m	$125m	$160m
2nd Tier: Retrospective Premiums	$0	$0	$5m x 53 reactors in 1975 = $260m	$63m x 110 reactors in 1988 = $6,930m; Since a maximum of $10m/yr. may be charged to each reactor, the present value of $63m over 6 1/2 years, discounted at 8.55%[2] is $51.2m.
Total Private Coverage, All Reactors in Operation[3]	$60m Plus fees utilities paid the Atomic Energy Commission for $500m in indemnification.	$60 - $125m, plus indemnification fees.	$385m, plus indemnification fees.	$7,090m nominal; $5,792m present value (adjusted for 6 1/2 yr. payout of retrospective premiums).
Additional Federal Indemnification				Subject to Congressional Action; nothing promised.
Other Conditions Added		-No fault feature added -Statute of limitations added		-No more than $10m/reactor of the retrospective premium would be assessed each year.
Indemnification of Contractors				
DOE Nuclear Contractors (including waste transport and disposal)	$500m, indemnified by the government even in cases of gross negligence			$7.2 billion liability limit via federal indemnification. Penalties for contractors who violate safety rules are possible.
At Commercial Reactors	Indemnified by utilities, up to utility insurance limit			
At Small Research Reactors	$500m, with damages above $250k indemnified			

Sources: Holt; Dubin and Rothwell

[2]The present value of the retrospective premium payment will fluctuate with the prevailing interest rates at the time the payments are made. This rate is the 3-year Treasury bond rate for 1989, and approximates the minimum discount factor for that year. Since the private utilities have much higher borrowing costs than the federal government, delaying the payment of the premium is more valuable to them. For example, the average bond rate grade BBB utilities (utilities with nuclear plant and past cost overruns would be more likely to be rated in this category) in 1989 was 9.993%. At this rate, the present value of the $63m premium is $49.7 million, and the total present value of private coverage for reactor accidents is $5,627 million.

[3]The Price-Anderson Act mandated a $560 million pool to cover accidents. The difference between this level and the sum of retrospective premiums and commercial insurance coverage was made up through government indemnification of the utilities in return for a fee. In 1984, this figure passed the required $560m level, at which point the minimum pool size increased by $5m with each new reactor that came on line. (Holt, 3).

The Liability Cap

The Price-Anderson Act liability limit has gradually increased over time (see Table below). The total private coverage available (first-tier plus second-tier insurance) increased from $60 million in 1958 to $7,153 million in 1988. This increase came from a number of sources. First, the amount of private, first-tier premium-financed insurance available has increased from $60m to $160m during this period. In addition, a second tier of liability coverage in the form of retrospective premiums was added in 1975 and increased in 1988. This provision created a statutory obligation for each utility to pay a set amount of money after an accident into the cleanup pool. The cleanup pool grew both due to statutory increases in the contribution per reactor and from an increase in the number of nuclear reactors in operation. The maximum payment was increased from $5 million in 1975 to $63 million per reactor in 1988.

The retrospective premiums are responsible for most of the growth in utility coverage for nuclear accidents. In fact, the "increase" in the first tier insurance availability is actually a decrease in real terms. Using the GNP implicit price deflator, $160 million in 1989 dollars is equivalent to only $36.9 million 1957 dollars[4] versus the $60 million available in 1957.

The 1957 Act mandated a minimum of $560 million in utility responsibility for an accident. This level was not actually achieved until 1984. Between 1957 and 1984, the shortfall was covered by the Atomic Energy Commission (and then the Nuclear Regulatory Commission beginning in 1975) in return for a fee from the utilities. (Holt, 2). We do not know how closely this "fee" resembled an insurance premium, although it can be safely assumed that it was less expensive to the utilities than the alternative of buying private coverage. Above the second tier coverage, no additional payments are guaranteed. Proposals for a third tier of coverage, in the form of an additional $8 billion in indemnification from the federal government, were defeated in the 1988 reauthorization. Congress stated only that it "will take whatever action is deemed necessary and appropriate" to provide additional compensation. (Holt, 3).

Subsidy to the Commercial Nuclear Power Sector

The commercial nuclear power sector receives a subsidy via the liability cap and indemnification provisions of the Price-Anderson Act. Without the law, the utilities would be forced to purchase private market insurance to cover far larger amounts - if such insurance were even available. The underlying assumption behind this claim is that many damage scenarios of a nuclear accident exceed the $7.2 billion in total coverage available. Thus, using a distribution of expected damages multiplied by the probability of those accident scenarios occurring, a number of researchers have generated estimates of the uncovered liability. To the extent that Congress steps in to pay damages in excess of $7.2 billion, these uncovered liabilities are borne by taxpayers. An absence of such action by Congress shifts the risk bearing to the citizens in the accident region.

Subsidy Estimates

1) Professor Jeffrey Dubin at the California Institute of Technology, and Professor Geoffrey Rothwell at Stanford University estimated the value of the Price-Anderson Act subsidy to nuclear utilities using NRC expected loss scenarios, and the implicit rate of return required by insurers on the first tier insurance provided. They differ from other researchers in that they include a range of accident severities, with more severe accidents having a lower probability.

Dubin and Rothwell calculate a liability subsidy of $60 million per reactor-year prior to the 1988 amendments and $22 million per reactor-year after. The value of the subsidies in 1989 was $2.746 billion,

[4]Implicit price deflator data are from the Economic Report of the President, 1991, p. 290.

and the cumulative subsidy between 1959 and 1989 was $128.5 billion.[5] (Dubin and Rothwell, 8). Their calculations use a $560 million limit for liability insurance between 1959 and 1982, although federal indemnification formed most of that coverage for much of that time (beginning at $500 million, and dropping finally to zero in 1984). (Holt, 3). To the extent that federal fees for indemnification represented token payments rather than risk premiums, the actual subsidy during this period (1959-1982) would have been even higher.

2) Pennsylvania Insurance Commissioner Herbert Dennenberg, using Atomic Energy Commission estimates for worst-case damages, calculated a subsidy of $23.5 million/reactor-year in testimony before the Atomic Safety Licensing Board in 1973. This is equivalent to $60.0 million in 1989 dollars. With 110 reactors, this amounts to $6.6 billion/year.[6] However, this estimate assumes that the probability of an accident with damages between $40 and $60 million is equal to the probability of a loss of $40 billion. (Dubin and Rothwell, 3). In addition, since it was done in 1973, the estimate does not reflect the increase in utility liability for accidents through retrospective premiums.

3) CIGNA insurance company studied the cost of providing limited nuclear risk policies (property loss only) to Pennsylvania homeowners at $25-$30 per home in 1984$. Using estimates of the number of homes (4.4m) and nuclear reactors in the state at the time (five), Bossong estimated the cost at $25.5-$31.1 million/reactor-year in 1989$. (Bossong, 7). Assuming similar insurance rates across the country, the CIGNA study yields a crude approximation of the value of Price-Anderson of ($25.5-$31.1) x (110 reactors) = $2.8 - $3.4 billion per year.

4) Other estimates presented by Bossong, but calculated by various other groups range from a minimum of $832 million to $10 billion per year. (Bossong, 9). We judged the $10 billion/year estimate, produced in a 1984 National Audubon study, to be problematic for two reasons. First, it ignores the probability distribution of an accident. Second, it does not accrue the payment for damages over a realistic time frame.

The $832 million estimate (1989$; scaled from $750m in 1986$) assumes that coverage for off-site damage (which is not required due to the Price-Anderson Act above statutory limits) costs the same as coverage for on-site damage (which the utilities currently buy). However, this estimate assumes coverage only to the amount of $1.7 billion. Since many accident scenarios project more than $1.7 billion in aggregate damage, full coverage, even using this estimation approach, would likely be higher. (Bossong, 8).

Summary

It is clear that Price-Anderson provides some form of a subsidy, though the estimates as to the magnitude vary. The estimate we judge most valid is the Dubin and Rothwell study for a number of reasons. First, it is the only estimate that incorporates the changes in the 1988 Reauthorization Act. Second, it most explicitly addresses the issue of a range of probabilities for accidents. However, even this estimate measures only the value of the Price-Anderson subsidy to utilities. Federal indemnification of contractors is not included. We estimate the value of the Price-Anderson insurance cap to nuclear utilities to be a minimum of $832 million per year, with our best guess estimate of $2.75 billion per year.

Sources

[5] Dubin and Rothwell estimates scaled to 1989 dollars using the GNP implicit price deflator.

[6] The total number of reactors is 110 since the Shoreham reactor never began operation. (EIA, Monthly Energy Review, Feb. 1990, p. 86.

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Kehoe, Keiki and Welch, Kathleen. $100 Billion in Contracts: Not a Penny at Risk: The Safety Implications of the Price-Anderson Act on the Department of Energy's Nuclear Contractors. Washington, DC: Environmental Policy Institute, February 1, 1988.

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Underaccrual for Nuclear Decommissioning Costs

With most industries, shutting down operations is not much of a problem. Rent the office space, sell off or throw away the leftover assets, and you're on your way. Nuclear fission stands in stark contrast to this. In addition to the radioactive waste, which must be monitored for hundreds of years, the utility plant itself must be carefully sealed or removed, a process called "decommissioning."

Decommissioning may be done three ways. *Immediate dismantlement* involves radioactive decontamination of the site as soon as the plant retires. *Temporary storage* "mothballs" the nuclear plant for a specified number of years to allow much of the shorter-lived radioisotopes to decay prior to dismantling the plant. *Entombment* encases all of the radioactive components in steel or concrete to shelter the surrounding population from radioactivity. The problem with entombment is that the radioactivity lasts far longer than the tomb. (Hindman, 5). Any of these methods require the expenditure of large sums of money at the end of the plant's life.

Financial problems with decommissioning arise if the nuclear utility does not have sufficient funds on hand at the time of decommissioning to pay the cost. Such a fund shortfall could be the result of either underestimating the costs of the decommissioning process, or of insufficient accrual of the funds necessary during the operating life of the plant. In either case, the decommissioning would have to be funded either by the taxpayers, or by a tax on the customers of the utility at that point in time. In neither case do those who used the nuclear-generated electricity pay the full private costs of providing that power (even ignoring environmental and health externalities).

Estimating the Underaccrual for Nuclear Decommissioning

Our interest in nuclear decommissioning is to estimate the likely size of the current underaccrual for decommissioning, at least a portion of which will probably be borne by the taxpayer. This estimate requires a number of parts, each which are addressed in more detail later.

- How much will plants cost to decommission? The higher the cost, the more money that should be put aside today.
- When will the plants be decommissioned? Depending on the method of decommissioning chosen, funds accrued during the plant's operating life can continue to earn interest (if the real interest rate is, in fact, positive) between the point of closure and the beginning of decommissioning expenses 0-60 years later. Further complicating the matter is the fact that the cost of decommissioning a plant and disposing of the radioactive waste could rise slower or faster than inflation in the interim.
- How much will decommissioning trust funds earn in interest? The higher the yields, the lower the current accruals need to be to build up the necessary decommissioning reserves.
- How much money do nuclear utilities plan to put aside, and how close is this to the amount likely to be needed?
- What portion of the decommissioning shortfall is likely to be borne by the general taxpayer rather than by the utility's future ratepayers?

How Much Will Decommissioning Cost?

Estimating the expected cost of decommissioning is complicated by a lack of industry decommissioning experience, different methods of estimating expected decommissioning cost, the type of decommissioning to be done (e.g., prompt dismantlement vs. entombment), rapid inflation in the cost of decommissioning, and differing assumptions regarding economies of scale and learning in the decommissioning process.

Lack of Experience. There have been no real examples of the decommissioning process on which to base cost estimates. The only fully decommissioned commercial plant in the United States was the Shippingport reactor in Pennsylvania. However, this reactor was very small. As a result, DOE entombed the reactor pressure vessel in concrete and shipped it by barge for burial in Hanford, WA. (Hindman, 10). Most of the reactors now in operation will have to be dismantled prior to shipping - a complicated and potentially costly process.

While experience with decommissioning is quite limited, it is interesting to note that utilities assume decommissioning will cost an average of $211/kW of capacity (Strauss and Kelsey, 60,61), while the actual amount paid for the supposedly easier to handle Shippingport reactor was a whopping $1361/kW (Fry, 96). Similarly, the weighted average expected decommissioning costs for reactors which are no longer in operation and are either being mothballed or in the process of being decommissioned, is $742/kW (Fry, 96,97), three-and-one-half times as big as the expected cost for the industry overall.[7] Even if the particularly expensive Three Mile Island plant is excluded, these utilities expect a weighted average decommissioning cost of $466/kW.

And even these figures may be too low. The estimated cost for decommissioning the Yankee Rowe plant increased after the plant was closed. In 1989 Yankee Atomic estimated that decommissioning of its Yankee Rowe plant would cost $116 million. When it announced the closure of the plant in summer of 1992, the decommissioning cost estimate had almost doubled in real terms, to about $220 million ($245 million in 1992$). This was due to "increased costs for staff and for disposal of the radioactive waste." (Chandler, 25). The expected costs of decommissioning the Fort St. Vrain Reactor, already included in the group of retired reactors above, has jumped from the $242 million cost included in our average to close to $300 million (1989$) currently. (Johnson and De Rouffignac). Neither of these plants are likely to be the last example of this type of cost escalation as the decommissioning date approaches.

Cost Estimation Methodology. There are two basic approaches to estimating the cost of decommissioning: site-specific estimates, and generic estimates. Historically, the generic estimates often assumed that decommissioning costs would be some proportion of plant construction costs. (Fry, 88). Site-specific estimates are essentially engineering studies of plant closure, and often yield very different results. In one study comparing the decommissioning cost estimates (Strauss and Kelsey, 67), site-specific estimates (in $/kW) were found, on average, to be 58 percent higher than the generic cost estimates. This discrepancy suggests that the current industry expectations, based on the generic method, are too low.

Type of Decommissioning. The costs for prompt dismantlement of reactors, versus temporary storage and mothballing differ. Mothballing may reduce final decommissioning costs but incurs interim security and maintenance costs. Since 95 percent of the reactor decommissioning estimates currently available assume prompt dismantlement and removal (Strauss and Kelsey, 65) we assume the same in estimating decommissioning shortfalls. It is important to note, however, that while reactors are now entering the decommissioning stage, no waste repository is yet operating. Therefore, immediate dismantlement is not be a viable option for utilities yet.

Depending on the real interest rate earned on funds (which may be either positive or negative), and on inflation rates in the cost of decommissioning operations and radioactive waste disposal, delaying dismantlement could either reduce or increase the present value cost of decommissioning. (See Rothwell for a model to calculate the optimal waiting time to decommission). The annual security costs to maintain

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[7]According to Fry (p. 92), "decommissioning cost estimates for retired reactors may be less uncertain than estimates for operating reactors" since many costs have already been incurred, radiation levels which must be handled are known, and the regulatory environment is also known.

and watch a mothballed nuclear plant during temporary storage are estimated at up to $15 million/year. (Johnson and De Rouffignac). Paying these costs for 60 years would eat through an initial principal of $443 million, even if that principal were earning our most generous expected real return of 2.7%. This is a level significantly higher than the current expected total decommissioning costs for most of the nation's reactors -- and this accrual would leave no money at the end to pay for the actual decommissioning. The "holding cost" of temporary storage erodes gains from additional interest or reduced costs from radioactive decay.

Economies of Scale and Learning. Implicit in many of the current estimates for decommissioning costs is the assumption that costs per kW of capacity fall for larger reactors (economies of scale), and that costs for reactors decommissioned later will fall due to lessons learned, and technologies developed, in earlier decommissioning efforts. While there clearly has not been enough operating experience to determine the likelihood of these gains with any accuracy, a number of researchers have suggested the gains are not likely to be that large.

Fry (p. 101) concludes that the "limited experience available shows a marked lack of scale economies," although he is careful to point out the the current sample is small and not necessarily representative. In contrast, Strauss and Kelsey found that "[s]maller plants cost more to decommission on a per kW basis than do larger plants." (Strauss and Kelsey, 65). One explanation for this difference is that Fry analyzed plants that have already been shut and in some cases began to be dismantled, while Strauss and Kelsey analyze the projected decommissioning costs for operating reactors.

Cantor compares the cost of decommissioning with the original cost of commissioning the nuclear reactors, and points out that both economies of scale and of learning were anticipated but not realized during plant construction. (Cantor, 110). She presents a number of possible explanations for why these gains were not realized, including regulatory uncertainty and operating problems leading to construction changes; and the clustering of reactor construction in time, as well as a lack of standard reactor designs, inhibiting the transfer of lessons learned. (Cantor, 111, 113).

According to Cantor, since decommissioning will be less clustered than plant construction was, learning may be more transferable. However, the non-standard reactor designs and the potential additional regulatory changes suggest that the degree to which decommissioning experience is transferable between reactors will be limited. (Cantor, 114).

The current utility estimated costs for decommissioning assume significant economies of scale and learning (Fry, 103). To the extent that these economies are not realized, current decommissioning accruals are likely to be too small.

Real Increases in Estimated Cost Components. Cost estimates for nuclear decommissioning have been rising dramatically over time. Since 1976, the average real rate of increase in decommissioning cost estimates has been about 16 percent per year. (Biewald and Bernow, 235). While utilities routinely include a contingency factor in their cost estimates for decommissioning, this factor is generally only 25%, a level that "would have allowed for only one-sixteenth of the cost growth that actually occurred" since 1976. (Biewald and Bernow, 235). While part of this increase is due to a lack of actual decommissioning experience, part is also due to a changing regulatory environment and rapidly rising costs of radioactive waste disposal.

When Will the Plants be Decommissioned?

Different methods of decommissioning require vastly different time frames. Prompt dismantlement begins at the end of the facility life. According to a NISA survey, the average facility had 31 years of its 40 year operating life remaining in 1989 (NISA, 12). Our calculations of annual decommissioning payments are based on this expected lifetime. However, the 15 U.S. units that have closed so far operated an average of only 12.7 years,

> and with the average per-kilowatt cost of running a nuclear plant now edging higher than the cost of a coal-fired plant, Department of Energy officials now say privately that 25% of the remaining reactors may be closed in the next decade for economic reasons. (Johnson and De Rouffignac).

To the extent that the average reactor life proves shorter than 40 years, our calculated annual underaccrual in decommissioning funds will be too low.

Temporary storage would keep the facility "mothballed" following shutdown for very long periods. Some arguments in favor of mothballing facilities for as long as 100 years have been made (MacKerron, 105), since during this time frame, the decay of Cobalt-60 may allow readier access to the reactor core. This would facilitate much simpler dismantling of the core. While a 100-year waiting period may have some technological benefits, the current NRC limit is 60 years.

If the nuclear decommissioning trust is earning positive real returns, the interim costs are small, and the expected costs and regulations associated with decommissioning are stable, the delay might also reduce the cost to rate payers. However, in line with our "beneficiary should pay" approach, we assume that the entire cost of decommissioning (excluding interest to be earned during any waiting period) should be paid during the operating life of the facility. Therefore, decommissioning payments in all cases are assumed to stop at the point of reactor shutdown, regardless of the method of decommissioning chosen.

The attached estimates assume further that all reactors will be promptly dismantled. This assumption was made because 95% of the utility decommissioning estimates make the same assumption. To the extent that real returns on decommissioning trusts, inflation of decommissioning costs, and regulatory certainty favor temporary storage over immediate dismantlement, our estimates may be too high. However, current trends in each of these parameters suggests that the opposite is true, and that most reactors will be immediately dismantled, so long as a waste repository exists at the time of closure.

How Much Will Decommissioning Trusts Earn in Interest?

The real (inflation-adjusted) yield on trust principal will have a dramatic effect on whether the fund ends up in deficit or surplus for any particular expected cost range. Real yields are affected by a few key variables: the type of securities held, the duration of investment, and the tax-treatment of trust earnings. These variables are, in turn, influenced by the type of decommissioning trust set up. We describe these trusts first, and then discuss each of the variables.

Types of Decommissioning Trusts

Decommissioning Trusts are special funds created by the nuclear utilities to accrue funds during the reactor's operating life in order to pay for reactor decommissioning at the end of the reactor life. Until the end of the 1970s, very few utilities made any provision to accrue for decommissioning. (MacKerron, 107). Prior to 1988, funds for decommissioning could be held internally. Thus, utilities could accrue the funds on paper, but there was no guarantee that the cash would actually be there when needed. In 1988, the Nuclear Regulatory Commission promulgated rules which required the creation of external trusts. This significantly reduced the risks of "commingled funds or default." ("Utilities Move Closer to Nuclear Decommissioning External Trust Compliance," 21).

The NRC rules created two types of allowable trust funds: a qualified nuclear decommissioning trust, and a nonqualified decommissioning trust. While these trusts differ in their tax treatment, and in the eligibility of utilities for each type of tax treatment, both are now external trusts, and recent changes in the law have made them more similar than they used to be.

Qualified Nuclear Decommissioning Trust. Qualified trusts enable utilities to deduct trust contributions from current taxes. In return, income generated by the trust investments is taxed. Prior to 1994, this income is taxed at the full corporate rate of 34%. Due to the Energy Policy Act of 1992, the tax rate on decommissioning trusts was reduced to 22% beginning 1994, and to 20% in 1996. (DOE, EPACT Summary, 25).

Prior to the Energy Policy Act of 1992 (EPACT), the allowable investments for qualified trusts were limited to the lowest risk securities (Treasury bonds, state and local municipal bonds, and demand deposits at banks or insured credit unions). These are often called "Black Lung" securities because they are the same family of investments allowed for Black Lung trust funds, as set out in the Black Lung Act. EPACT removed these restrictions, effective December 31, 1992. (DOE, 10/15/92, 25). However, the annual amounts which may be contributed into a qualified trust are limited by IRS rulings (Rogers, 70), and this limit may be too low to meet projected needs.

Nonqualified Nuclear Decommissioning Trusts. Prior to EPACT in 1992, nonqualified trusts were free to invest in a wider range of options than qualified trusts, including corporate bonds, stocks, and real estate. However, local law and regulatory agencies may restrict the expected risk level of the portfolio (Weinblatt et al, 207), and qualified trusts may now invest in the same types of investments.

The tax treatment of nonqualified trusts differs from that of qualified trusts in that no current deduction is allowed for contributions, but income earned by the fund is taxed at the utilities' actual tax rate, which may be below 34%. (Weinblatt et al, 207). In essence, income from nonqualified trusts may be offset by all the tax preferences the utility may have available (subject to limits such as the Alternative Minimum Tax). (Tuschen, 218). Once decommissioning begins, expenses paid from a nonqualified trust may be deducted against taxable utility income going back to 1984. (Tuschen, 221). Finally, as a corporate trust, 70% of dividend income is exempt from taxation. (Rogers, 70).

Which Type of Fund to Use. The choice of funds is determined by three main factors: the timing of the contribution, the size of the contribution, and the marginal tax rate of the utility. Since only contributions related to operations in the nuclear plant after 1984 may be put into a qualified trust, all prior decommissioning accruals must be held in a nonqualified trust. (Tuschen, 218). In addition, funds which exceed the IRS's annual allowable contribution must also be put into a nonqualified trust. (Rogers, 70).

The utility's marginal tax rate affects the choice of trust funds because the utility must balance the benefit of the current deduction of trust fund principal against the benefit from the lower tax rate on trust fund investment income. Where the value of the current tax deduction outweighs the higher tax rate on investment income, the utility will use a qualified trust, and vice-versa. (Weinblatt et al, 207). The recently passed reductions in the tax treatment of income from external qualified trusts and freeing up of investment choices will make the economics of qualified trusts much more attractive.

Type of Securities Held

Qualified trusts were limited by statute to very low risk municipal and Treasury bonds, and bank demand deposits, though, as mentioned above, this is no longer the case. The high marginal tax rate on income from qualified trusts at the 34% tax rate currently in effect suggests that most current investments will be in tax-exempt municipal bonds (Hiller, 194), although some may also go into Treasury securities. The reductions of the tax rate to 22% and then to 20% in the coming years may shift the desired mix of securities towards taxable securities somewhat.

Since income of public power and cooperatives is not taxed, their investment choices are not influenced by tax liability. As a result, they are more likely to invest in low-risk taxable securities, such as Treasury bonds. Overall, however, publicly-owned and cooperative power providers own only about 8% of the nation's nuclear capacity. (Tuschen, 219).

However, the past restrictions on the types of assets held do not seem to be the main reason that nuclear utilities are holding such low risk securities. According to the NISA survey, which was done before investment restrictions were removed in the Energy Policy Act of 1992, even if the restrictions were removed (as they are now), tax-exempt bonds (which are now mostly municipal) would remain the primary investment held by the decommissioning trusts, although holdings of higher yield bonds and equities would rise somewhat. (NISA, 18). Perhaps this risk aversion is due, in part, to the fact that a loss of principal in the fund's early years yields large interest losses during the life of the fund, and that this risk outweighs the incremental value of higher, riskier yields. (Hiller, 194).

Maturity of Securities Held

Although longer-term securities generally offer higher yields than shorter-term issues, this increased yield carries with it larger inflation and interest rate risk. Guessing the wrong inflation rate, and being locked into 30-year bond issues, could greatly hurt the ability of the fund to keep up with inflation.[8] Since the cost of decommissioning is rising so quickly, even above general inflation levels, most analysts recommend an investment strategy focused on shorter-term issues to avoid additional inflation risk. The trade-off here is one of lower yields in return for lower inflationary risk. (Hiller, 197). Following the analysis of Hiller and others, we assume that funds are invested into shorter-term securities in our calculation of decommissioning shortfalls.

Expected Yield

Following the above discussion, we use yields on shorter-term, low risk securities, adjusted for taxation and inflation (because our cost estimates are in real dollars). However, the pending reduction in the tax rate on qualified trusts reduces the incentive to invest in tax-exempt bonds, and the nonqualified trusts may also have significant holdings in corporate bonds.

An additional issue involves what historical period of real returns provides an appropriate proxy for the expected yields going forward on the decommissioning trusts. For decommissioning scenarios involving temporary storage, time frames of up to 100 years may be involved between now and the dismantlement of the reactor. With immediate dismantlement, the time frame of concern may be more like 30 years. We therefore include data on historical real returns for both 1926-1990, and for 1966-1990. Empirically, yields in the more recent time frame are lower than for the 1926-1990 period (see worksheet, part 2A).

A final issue involves the type of inflation adjustment done to nominal yields in order to generate the real return. Most figures are adjusted for the general inflation level. However, as mentioned above, nuclear decommissioning costs have been rising far more rapidly than general prices. We found one estimate that incorporated this into their yield estimate (Borson et al, 12), and this rate is significantly below the expected yield we use in our high estimate of the decommissioning underaccrual. We chose not to use this yield because it potentially double-counts decommissioning cost estimates, accounting for cost increases both in the expected yield, and in the expected decommissioning cost per kW.

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[8] Although secondary markets for long-term debt introduce liquidity into the holding of long-term bonds, if interest rates rise, the bonds could only be sold at a discount, and liquidity does not ameliorate the implications of mis-guessing inflation.

Analysts who have tried to estimate the likely returns on decommissioning trusts have not found them to be promising. For example, Weinblatt et al (pp. 209, 211) analyzed real returns on a variety of investments between 1960-1988 and concluded that only stocks provided real after tax returns during the period, investments which are generally considered riskier than municipal bonds, and would be unlikely to be used for any major part of the trust portfolio.

How Much Money do the Nuclear Utilities Plan to Put Aside?

The NRC requires a minimum decommissioning fund of $105 to $135 million, depending on the plant type or size. (GAO/RCED-88-184, 3). A General Accounting Office survey of decommissioning costs found that most experts believed the NRC figures were too low, and that estimates went as high as $3 billion per reactor. (GAO/RCED-88-184, 1). The Yankee Rowe plant, which is the oldest and smallest commercial reactor in the country, is expected to cost close to twice (the actual cost may rise still further) the top end of the NRC minimum fund requirement.[9] Larger plants are likely to cost even more. (Chandler, 25).

Above, we noted that the utilities estimate an average decommissioning cost of $211/kW, and that utilities closer to (or already in) the decommissioning phase expect costs which average between $466 (with Three Mile Island excluded) to $742/kW (TMI included) of capacity.

Their past and current contributions to decommissioning trusts, however, require optimistic assumptions at all levels in order to break even in time for decommissioning. According to the NISA survey in 1989, utility contributions would yield a pre-tax kitty of $355/kW if invested entirely in corporate bonds.[10] Incorporating even some of the expected real decommissioning cost increases, and yields which more closely match the portfolios that the utilities are currently holding would provide a much smaller kitty at the point of plant closure (see worksheet, parts 2B and 2C). Since the lower accrual is due, in part, to an expected negative real interest rate, holding the funds during a 30-60 year interim storage period would increase the shortfall, not decrease it.

Due to accruals which are most likely below even the current expected cost, and to costs which can be expected to rise significantly as time goes on, there is little chance that current accruals will be sufficient to cover the cost of decommissioning the nation's nuclear plants.

Who Pays the Shortfall?

Fear of large, uncovered decommissioning liabilities which had to be paid by the taxpayers was the driving factor behind the NRC regulations requiring that decommissioning trusts be held external to the utility. According to the NRC,

> in the event of bankruptcy there is not reasonable assurance that either unsegregated or segregated internal reserves can be effectively protected from claims of creditors and therefore internal reserves cannot be made legally secure.[11]

[9] Both the NRC requirements and the cost of Yankee Rowe used in this comparison are in nominal dollars. This contrasts to the use of 1989$ for all other parts of this section.

[10] As of early 1989, NISA estimated that $2.9 billion was held in decommissioning trusts, and that new funds were being collected at a rate of $583 million/year. (NISA). A recent NRC estimate placed the aggregate funds in early 1993 at about $4 billion (Johnson and De Rouffignac), suggesting that annual accruals may not be as high as NISA had anticipated.

[11] U.S. NRC, "General Requirements for Decommissioning Nuclear Facilities," Final Rule, Federal Register, V. 53, #123, June 27, 1988, p. 24033. Cited in Borson et al, p. 43.

The creation of external trusts alleviated much of the concern that accrued funds would not be available to actually decommission the facilities.. However, the NRC regulations did not address who pays the cost of decommissioning if the accrued funds, for whatever reason, are insufficient to do the job. Insufficient accruals may be paid either by customers, utility shareholders, or through increased returns on trust assets. In every case, the taxpayer is the residual risk bearer since decommissioning is not a discretionary expenditure, and the costs must be paid by somebody. These options are each addressed in turn.

Increasing the price of its power to consumers in order to make up any fund shortfall initially seems the most favorable option from the perspective of a taxpayer. However, this solution has two drawbacks. First, if charges are placed on current nuclear power users while more comprehensive power wheeling increases inter-regional competition, consumers have greater opportunity to avoid buying nuclear-generated electricity. This reduced demand could result in lower decommissioning collections than would have happened without the surcharge, increasing the risks of default on decommissioning obligations. Secondly, if charges are passed onto future power users (as would occur if accruals at plant closure were too low), than future users would be subsidizing current users. In addition, wheeling would enable future users to bypass the more expensive nuclear utility as well.

Shareholders may also pay for decommissioning shortfalls through a loss of their equity. This would occur if decommissioning shortfalls are not allowed into the rate base (or, indirectly, if consumers bypass the nuclear utility through wheeling). The "shareholder pays" scenario also has potential costs to the taxpayer. First, the unfunded decommissioning bill will alter the financial stability of the utility leading to a reduced bond rating, and possibly also to default. For example, the debt rating for Public Service of Colorado, the owner of the soon-to-be dismantled Fort St. Vrain reactor, has had its debt rating reduced four times since the reactor was shut down. (Johnson and De Rouffignac).

Shortfalls could also potentially be made up through investing in higher-yield, higher-risk securities. The strategy of investing in higher risk securities brings with it an increased risk of defaulting on the ultimate obligations. This strategy is as likely to increase the shortfall through defaults as it is to decrease it through higher real yields.

In all of these cases, the health, safety, and proliferation issues associated with bankrupt, undecommissioned power plants suggests that the federal government would have no choice but to pay the shortfall from general tax revenues. Whether the default is triggered by customer bypass of utilities owning nuclear capacity (made possible by wheeling), through a high risk investment strategy, or by default or bankruptcy, the unfunded liability rests with the taxpayer.

It would be unrealistic to assume that no nuclear utilities will default on their decommissioning liabilities. For example, 11 nuclear utilities (assuming only 1 reactor per utility, this equals 10% of the U.S. reactors) are considered to have a significant risk of defaulting on their nuclear waste lump-sum assessments for the Nuclear Waste Fund. It is unlikely that these utilities will be in any better shape to pay for decommissioning. This example provides strong evidence that at least some defaults are likely.

Increased competition in energy markets (which increases the risk of consumer bypass of traditional monopolies), coupled with rapidly escalating decommissioning cost estimates, suggests that the taxpayer liability for decommissioning may be substantial. A recent increase in premature reactor closures due to poor operating economics greatly increases the unfunded portion of decommissioning costs, increasing the risks of defaults still further.

In our low estimate, we assume that the taxpayer will bear no liability for decommissioning shortfalls. In our high estimate, we assume that 25 percent of the shortfall will be borne by the taxpayer. This 25 percent figure begins with the 10% of the industry considered likely to default on Nuclear Waste Fund obligations, and adds a 15% additional default rate on <u>unfunded</u> decommissioning costs to account for the competitive and regulatory pressures described above. Even in the high estimate, we implicitly assume a zero default rate on planned trust contributions.

Clearly, this estimate is uncertain. However, we consider the estimate to be extremely conservative. The market forces and trends outlined above suggest that the defaults could be very large. In addition, our estimate of the size of expected shortfalls does not incorporate the impact of premature plant closings. Since premature plant closures greatly increase the magnitude of unfunded decommissioning costs, and since up to 25 reactors may close prematurely over the next 10 years (Parshley et al, 1), a large portion of the planned trust contributions are at some risk of not being made. This risk, which would greatly increase the size of the decommissioning shortfall, offsets the risk of overstating the default rate on the unfunded liabilities.

About the Estimate

We estimated the underaccrual for decommissioning by comparing the expected future value of the current trust funds plus planned future payments through the average plant closure (based on data from the NISA survey) to various estimates for the expected cost of decommissioning. The period of trust accrual is based on the NISA survey, which reports the average reactor to shut in 2020. Different assumptions were made about real rates of return on invested assets and on the appropriate measure of decommissioning costs per kW of capacity, and these led to a wide range of estimates for the shortfall.

Our low estimate for the shortfall uses generous real rates of return on invested assets, assumes that the current utility projections for decommissioning costs are correct, that no utilities will default on their decommissioning obligations, and that decommissioning costs should be prorated downward based on the capacity factor of the reactor.[12]

Our high estimate uses the historical real interest rate on shorter-term government securities to better represent the actual types of assets held by the funds, and the utility decommissioning cost estimates for reactors which have already shut down. We also use the design capacity of all operating and closed reactors rather than the operating capacity of the reactors which remain open, since this entire capacity must be decommissioned. Even the high estimate does not incorporate the manner in which real cost increases in decommissioning will escalate the realized costs even for the subset of reactors already closed but not yet decommissioned.

Both high and low estimates spread the total decommissioning shortfall over the 40-year life of an NRC license. Licensing extensions or premature closure (which seems more likely at this point in time) will both impact the size of decommissioning shortfalls expected.

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Nuclear Decommissioning Shortfall

Part 1: Current Collection of Funds and Expected Accrued Funds by End of Plant Life

Industry Data, as of 1989:

	$/MW Capacity		Comments/Source
Average Trust Size	30,400		NISA, 9
Average Annual Collection	6,000		NISA, 12
Ave. Remaining Plant Life	31	Years	NISA, 12; assumes an average facility life of 40 years.
Expected Trust Size at Maturity	649,000		NISA, 12
Implied Annual Nominal Yield	5.68%		Calculated

Part 2: Calculation of Real Value of Current Accruals

A. Historic Real Yields on Invested Securities

Security Type	Period	Real Returns - Pre-Tax: Arith. Mean	Real Returns - Pre-Tax: Geomet. Mean	Real Returns - After-Tax: Arith. Mean	Real Returns - After-Tax: Geomet. Mean	Source
L-T Gov't Bonds	1926-1990	1.80%	1.40%	0.60%	0.20%	Siegel, p. 31
L-T Gov't Bonds	1966-1990	1.60%	0.90%	-0.70%	-1.30%	Siegel, p. 31
L-T Corporate Bonds	1926-1991	2.70%	2.20%			Ibbotson, p. 105.
S-T Gov't Bonds	1926-1990	0.60%	0.50%	-0.20%	-0.30%	Siegel, p. 31
S-T Gov't Bonds	1966-1990	1.30%	1.20%	-0.50%	-0.60%	Siegel, p. 31

Other Point Estimates of the Real Return on Nuclear Decommissioning Trusts

Return on Investments	1.00%	Borson, et al p. 4; based on interviews with utility analysts.
Return, net of expected cost increases	-1.93%	Borson et al, p. 4; assuming that cost estimates for decommissioning are likely to double over the remaining lives of the facilities (which is likely).

B. Plausible High and Low Returns on Decommissioning Trusts

(See Text for Discussion of appropriate interest rate proxies)

Maximum, from Part A	2.70%	This assumes the Trusts hold all corporate bonds, which seems unlikely given the current mix of assets and apparent risk preferences.
Minimum, from Part A	-0.60%	Uses short-term rates, per discussion in text of likely portfolio mix. Excludes lowest estimate of -1.93% since this would double-count some (though not all) of the decommissioning cost inflation.

C. Value of Current Trust Fund Contributions, Using Real Rather than Nominal Interest Rates

Average Trust Size	30.4	$/kW Capac.	NISA, 12
Average Annual Collection	6	$/kW Capac.	NISA, 12
Ave. Remaining Plant Life	31	Years	NISA, 12; assumes an average facility life of 40 years.

	Low Est.	High Est.	
Real Yield on Investments	2.70%	-0.60%	Higher interest rates will ultimately yield a smaller shortfall in accrued funds.
Value of Trust at End of Plant (per kW) Life Using Real Yields	354.8	195.4	Calculated

Part 3: Estimates of the Cost of Decommissioning

A. Based on Utility Decommissioning Studies (average) 211 1989$/kW of capacity; Standard deviation of 98 $/kW; Strauss & Kelsey, pp. 60, 61.

B. Based on Experience Decommissioning Shippingport

Total Cost (Millions of 1989$)	98	Fry, p. 96.
Size (kW)	72,000	
Decom. Cost/kW Capacity	1,361.1	

Unit cost may be too high due to higher cost for first reactors, and for smaller reactors in general.
Unit cost may be too low due to ability to move entire reactor core in one piece. This will not be possible with larger reactors.

C. Based on the Expected Costs to Decommission Reactors Already Removed from Active Production

Reactor	Capacity (MWe)	Est. Decom. Costs (Mil. 1989$)		Decom. Cost $/kW
Entombed Reactors				
Hallam	76	10.0		132
Piqua	11	3.1		282
BONUS	16	5.1		319
Fully Dismantled Reactors				
OMRE (approx. capacity)	4	0.9		225
SRE (approx. capacity)	6	24.5		4,083
Elk River	22	14.6		664
Shippingport	72	98.0		1,361
Fully Mothballed Reactors				
Dresden 1	220	129.0		586
Pathfinder	58	81.0		1,397
Humboldt Bay	65	73.6		1,132
Partly Mothballed Reactors				
Fermi 1	61	23.3		382
Peach Bottom 1	46	4.6		100
Three Mile Island 2	961	1,350.0		1,405
Fort St. Vrain	343	242.0		706
Reactors Not Yet Dismantled				
LaCrosse	65	24.3		374
Indian Point	275	96.1		349
Rancho Seco	963	242.0		251
Total	3,264	2,422.1	Wghtd. Ave.	742
			TMI 2 Excluded	466

Source: Gene Heinze Fry, "The Cost of Decommissioning U.S. Reactors: Estimates and Experience," in The Energy Journal, 1991, V. 12, pp. 96, 97.

	1989$/kW	1989$/kW	
Weighted Ave. Expected Cost of Decom. for Reactors Out of Prod.	742	466	Note 1: lower value excludes Three Mile Island
Expected Cost, All Nuclear Utilities	211	211	
Expected Cost, Retired Reactors/ Expected Cost-Operating Reactors	3.5	2.2	

Notes:

(1) Since these utilities are much closer to paying for decommissioning (and in some cases have already started to pay) one would expect their cost estimates to be more precise than for the general mix of operating nuclear utilities. If this is true, and if there are not enormous economies of learning (see text for discussion), then it suggests that operating utilities are likely to have large decommissioning shortfalls at the time of plant closure.

Part 4: Estimating Aggregate Shortfalls for Plant Decommissioning

A. Net kW of Nuclear Generating Design Capacity in the United States

	Mil. Net kW	
Peak Net Summer Operating Capability	100.5	EIA, MER, 3/92, p. 101. Peak capacity was July 1990. Undercounts since units shut prior to 7/90 excluded.
Komanoff and Roelofs, as of 12/91	102.5	Komanoff and Roelofs, p. 9.
Aggregate Domestic Plant Capacity*	104.2	Strauss and Kelsey, pp. 60, 61; plus excluded units from Fry, p. 96.

*Whether or not a plant operates up to its design capacity, all parts of the plant get radiated and must be decommissioned.

B. Fund Shortfall per kW of Nuclear Capacity

1. Based on Above Data		Utility Ave.	Shipping-port	Non-Operating Plants, Wghtd. Ave. Excluding TMI	
Estimated Decom. cost/kW capacity		211.0	1,361.1	465.5	From Part 3
Expected Value of Current Accruals					
	Low Estimate	354.8	354.8	354.8	From Part 2C. Since a higher accrual yields a lower expected deficit, the low estimate is ascribed the high end of the expected value of current collections.
	High Estimate	195.4	195.4	195.4	
Expected Shortfall (Surplus)/kW					
	Low Estimate	(143.8)	1,006.4	110.8	
	High Estimate	15.6	1,165.7	270.1	
Industry Size (mil kW)					
	Low Estimate	100.5	100.5	100.5	From Part 4A
	High Estimate	104.2	104.2	104.2	From Part 4A

		Utility Ave.	Shipping-port	Non-Operating Plants, Wghtd. Ave. Excluding TMI	
Projected Fund Shortfall (Surplus) (Millions of 1989$)					
Low Estimate		(14,447)	101,139	11,133	Aggregate shortfall in 1989$
High Estimate		1,624	121,465	28,145	Aggregate shortfall in 1989$
Calculated Annual Payment Necessary to Avoid Shortfall					
Low Estimate					
Years	40	(205)	1,435	158	While an average of 31 years remained until reactor closure in 1989 (NISA), we spread the decommissioning shortfall over the entire expected life of the reactor - 40 years.
Interest Earned	2.70%				
High Estimate					
Years	40	46	3,407	789	
Interest Earned	-0.60%				

2. Komonoff and Roelofs estimate:

Aggregate Deficiency in 1989 ($Millions)	186	Komonoff and Roelofs, p. 15 (top).

3. Public Citizen Estimates

	$Mils	
Annual Required Payment to Meet Utility Expected Cost	727	Borson et al, p. 4
Ave. Annual Funds Collected through 1989	399	
Annual Shortfall in 1989	328	
Annual Required Payment to Cover Expected Costs Using More Realistic Cost Inflators	1060	Borson et al, p. 47.
Ave. Annual Funds Collected through 1989	399	
Annual Shortfall in 1989	661	

C. Summary of 1989 Decom. Deficiency Estimates

	Low	High	Rationale for Including/Excluding in Estimate
Utility Projected Need	(205)	46	Included as low estimate; any surplus would be returned to rate payers or shareholders.
Shippingport Experience	1,435	3,407	Shippingport is averaged in with reactors no longer operating (below). This mix is a better cost indicator.
Expected Costs for Reactors no longer Operating	158	789	Used as high estimate. Best available cost indicator, given current experience.
Komonoff and Roelofs	186	186	Within chosen low/high range.
Public Citizen, based on utility assumptions	328	328	Within chosen low/high range.
Public Citizen, including projected cost escalation	661	661	Within chosen low/high range.
Minimum/Maximum	(205)	3,407	
Chosen range	(205)	789	See rationale for choices above.

Part 5: Share of Shortfall Paid by the Taxpayer, Rather than by the Future Ratepayer

	Low Est.	High Est.	
Estimated Annual Decomm. Shortfall (Surplus) for 1989	(205)	789	
Percent of surplus returned to ratepayers/shareholders	100.00%	N/A	
Net Shortfall	0	789	
Default Rate on Decommissioning Deficit	0.00%	25.00%	See discussion in text.
Expected Annual Cost of Defaults to Taxpayers	0	197	

Sources:

(1) Borson, Daniel et al. "Payment Due: A Reactor-by-Reactor Assessment of the Nuclear Industry's $25+ Billion Decommissioning Bill," (Washington, DC: Public Citizen Critical Mass Energy Project, Oct. 11, 1990).
(2) Fry, Gene Heinze. "The Cost of Decommissioning U.S. Reactors: Estimates and Experience," The Energy Journal, V. 12, 1991.
(3) Ibbotson Associates. "Stocks, Bonds, Bills and Inflation," 1992 Yearbook.
(4) Komanoff, Charles and Cora Roelofs. "Fiscal Fission: The Economic Failure of Nuclear Power," (Washington, DC: Greenpeace, Dec. 1992).
(5) National Investment Services of America. "Decommissioning Trust Survey," Jan. 1989. Prepared by Eager Assoc. Focus Marketing Research.
(6) Siegel, Jeremy. "The Equity Premium: Stock and Bond Returns Since 1802," Financial Analysts Journal, Jan./Feb. 1992.
(7) Strauss, Peter and James Kelsey. "State Regulation of Decommissioning Costs," The Energy Journal, V. 12, 1991.
(8) U.S. DOE, Energy Information Administration. "Monthly Energy Review," Feb. 1990.