FROM:
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TO:
William J. Dircks

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INTERIM REPLY	
FINAL REPLY	Case
FILE LOCATION	7/21/77

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DATE OF DOCUMENT 6/30/77

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DESCRIPTION ☒ LETTER ☐ MEMO ☐ REPORT ☐ OTHER

Discusses areas on which NRC disagrees with his report to the Arizona Corporation Commission re costs of the Palo Verde plant

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June 30, 1977 ltr dtd 7-21-77 filed in Env 3

William J. Dircks, Assistant Executive Director for Operations
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Dircks:

In late April of this year, I had sent a copy of my report (Palo Verde Economics--APS Projections Versus National Averages, 4 April 77, Encl. #1) to my representative, Mr. John Rhodes, which he kindly forwarded to the NRC. I received a copy of the reply you sent to Mr. Rhodes (Docket # 50-528-30) May 25, 1977. The reply contained many points that I wish to comment upon at this time.

In this letter, I will discuss these areas which we disagree on: (a) construction cost; (b) fuel efficiency; (c) fuel availability; (d) capacity factor; and (e) decommissioning costs.

In your letter your office stated that "It is in the staff's view, implausible to add further escalation of $1.6 to $6.2 billion as Mr. Lowes does." I am assuming that your staff projects a final construction cost of $2.9 billion with a maximum cost escalation cost of $1 billion, thus giving a base cost of $1.9 billion. Given this estimate, then this $1.9 figure is less than what the plant would have cost had it been finished in 1975. I must point out that at the $2.9 billion cost, the per kWe (installed) cost would be $761.15 per kWe.

The Federal Energy Administration states the cost of building a plant would be $640 per kWe in 1975 dollars. (Robert I. Hanfling, Deputy Assistant Administrator, Energy Resource Department of the F.E.A., Washington, D. C.; taken from letter sent to Rep. Eldon Rudd, 7 June 77). At $761.15/kWe, the escalation rate would be approximately 2%.

I should note here that I made a miscalculation in my report. I reported that Edward Cowan of the New York Times stated that the 1976 cost of building a reactor was $773/kWe. I have since discovered that Mr. Cowan meant the $773 figure as the <u>average</u> cost projection. He also stated that the average cost projection in 1967 was $134. So, using that $134 figure for '67 and the $773 figure for '76, it can be seen that the average projected cost escalation over that period ('67-'76) is approximately 21.5%.

Thus, I find it unacceptable to assume over the next eight years a mere 2% annual escalation rate. In my report I listed the reasonable annual escalation rate as 5% to 15%. That projection should stand--or both figures should be raised.

As an additional note, I received a reply to my report from the F.E.A., quoting a $1245/kWe construction cost figure for a plant in New York. (Completion date 1985.)

Applying that figure to Palo Verde, I come up with a construction cost of $4.45 billion completed (calculation includes a 6.9% deduction to bring it down to 1984--6.9% is the F.E.A.'s calculated escalation rate.)

Enviro.
Hearing

The NRC, AEC and utility companies have been notorious for making economic estimates that unrealistically post a benefit to nuclear costs, in the environmental impact statements released for the now-completed plants and even the nuclear plants now being built. In fact, a study by the Massachusetts Institute of Technology states that the average total cost escalation for nuclear plants from the original projected price to the final construction cost has been 100%. The Koshkonong plant in Wisconsin and the Consumers' Dow plant in Michigan have both increased in projected price by over 100%. The Wisconsin plant has not even been started, while the Michigan plant is still in the construction stage.

The NRC's Office of Operations did not respond to the subject of fuel efficiency in the reply, but I would like to turn your attention to it since I have recently uncovered some new findings. I stated in my report that the average fuel efficiency is 14 million kilowatt hours of electricity (MMWhe) per short ton of milled uranium (yellowcake). These points will support my conclusion that 14 MMWhe per short ton of milled uranium (yellowcake) is the average fuel efficiency ratio.

F. B. Baranowski, Director of the Division of Production and Materials Management of the former Atomic Energy Commission, says that for 1971 through 1973, the ratio was 14 MMWhe per short ton of yellowcake (M. C. Day, Bulletin of the Atomic Scientists, Dec. '75, p. 53). Also, according to Morgan Huntington, Director of the U.S. Bureau of Mines, the average ratio is about 14 MMWhe. Mr. Huntington states that the maximum to be expected should be 22, which is significantly lower than the approximate 25 MMWhe per ton of uranium used by the NRC in the Palo Verde Final Environmental Statement.

A report by Ron Carstens and Robert Lamson (Oct. '76, Box 37, Anacortes, Wash. 98221) titled Realistic Uranium Energy Yields and Cost (Encl. #2) concerns energy yields of reactors already in operation. The team requested information on uranium requirements from companies with reactors five years and older. Seven companies replied. Carstens and Lamson concluded that the average energy yield from yellowcake is 12.36 MMWhe (weighed average by length of operation).

The report, "Uranium Reserves, Resources and Production" (June 15, '76) cited by your office states that the amount of uranium ore available in the United States is enough to fuel three hundred 1,000-megawatt reactors over their entire lifetimes.

Since you state also that there are 1.84 million tons of reserves, it can be deduced that by dividing the amount of electricity that the units would produce (at the NRC projected 75% capacity factor for the Palo Verde) by the amount of known and probable reserves (1.84 million tons) yields an energy efficiency ratio of 32 MMWhe per short ton of milled uranium. Using a more reasonable capacity factor of 40% for the average 1,000-megawatt reactor, the fuel shortage cannot be alleviated but only relieved temporarily.

Also the report cited by your office states that there is enough uranium to fuel any reactors which may be placed in service by 1990. This statement does not address the time-span used in my report. Using a 35-year life span for the Palo Verde plant, the reactor units will operate up to 2017 to 2021. This means the Palo Verde will be operating 27 to 31 years after the 1990 date.

James Schlesinger of the Carter administration announced that 550 nuclear plants would be on line by the year 2000. According to the Chicago Tribune (April 24, '77), "Schlesinger proposed construction of 200-300 new nuclear plants in the next fifteen to 20 years."

As for the reliability of previous federal government estimates on fuel reserves, the expected costs for low-grade uranium have gone up from $50/lb. of yellowcake at 60-80 parts per million (see Encl. #3) to $100/lb. at 100 ppm in a two-year period. (John Klemenic, "An Estimate of the Economics of Uranium Concentrate from Low Grade Sources", Monograph, Planning and Analysis Division, Grand Junction office, USACE, Grand Junction, Colo., Oct. 22, '74).

Concerning my projected price of fuel for the Palo Verde, Carstens and Lamson project a fuel cost of 20 mills per kWhe in 1985--neglecting any possibility of a fuel shortage. My report projects a somewhat severe fuel shortage and assumes a minimum cost of 28.57 mills per kWhe.

Saunders Miller, in a just-released comprehensive study of nuclear and coal power economics, concludes "Unless more 'known reserves' are found, some of these reactors may have to shut down before their economic lives are completed. Prudence would dictate that no more new reactors be started until 'potential resources' become additional 'known reserves'".

The book, "The Economics of Nuclear and Coal Power" by Miller, was reviewed by Baron's May 30, 1977. (Enclosure #4.) The review author calls this study very reliable and "very conservative" in estimates.

Saunders states that the amount of 1000 MWe reactors that could be fueled from the "known", "probable", "potential", "possible", and "speculative" reserves would be 624 for their 30-year lifetimes. It is important to note that Saunders assumes a 65% capacity factor and a fuel efficiency ratio of approximately 30 million MMWhe per short ton of yellowcake. If the 65% capacity factor is brought down to 40% and the fuel efficiency is brought down to 14 MMWhe per short ton, the number of reactors is changed to 464. It must be emphasized that the "'potential resources' at this time--'probable', possible', and 'speculative'--are only 'maybe's'", Saunders reiterates.

Concerning Capacity Factor, by negating the poor performance of the Brown's Ferry reactors in the total sample of reactors over 1000 MWe in size, your office conveniently deduces that the presently existing reactors are performing much better than they, in a complete sample, actually are. It has been suggested by both industry and government agencies that the poorly performing reactors such as the Brown's Ferry and Palisades plants, be dropped from the sample when projecting capacity factors of future nuclear units. The following are reasons why exclusion of such reactors would constitute a poor sample:

1) One-of-a-type incidents are consistently occurring that decrease the performance of individual reactors.

2) There still, after years of commercial reactor experience, is no large-scale standardized design for reactors presently being built or reactors planned for the future. The plants that are now performing poorly are supposed to have been better than their predecessors--just as the reactors being built now are supposed to be better than their predecessors. In this view, the expected capacity factors for the reactors under construction should not be any better than the capacity factors of the reactors already in operation.

3) There has been no significant learning curve for the capacity factor, in that recently installed units have not improved in capacity factor over the older reactors. (Council on Economic Priorities, Power Plant Performance, N.Y.; Council on Economic Priorities, 1976, p. 18.)

See Enclosure #5 for more detailed discussion on the inclusion of all reactors in commercial operation of commercially viable size.

4). As you well know, the safety problems in nuclear reactors have not been solved.

In Power Plant Performance, which is probably the best study on capacity factors in the nation, the Council on Economic Priorities projects that the average capacity factor for a 1300 MWe pressurized water reactor (PWR) will perform at a 42.6% capacity over the first ten years of operation. The study also concludes that the capacity factor of PWR's declines 3.21% per 100 MWe increase in size; thus the Palo Verde reactors would be projected to obtain a capacity factor of 43.563% for the first ten years of operation. Margen and Lindhe, two Swedish engineers, project that the capacity factor of the average plant in the U.S. in operation today will obtain an average capacity factor of 42.7 over their lifetimes. (Peter Margen and Soren Lindhe, "The Capacity of Nuclear Power Plants", Bulletin of the Atomic Scientists, Oct. '75, p. 40). They project that the capacity factor of the average plant will decline to 25% in a graphical line. Using the approximate slope of the record of capacity factors of nuclear plants in 1973-74 (as the age increases, the capacity factors decrease) (Encl. #6)--I have estimated the average foreseeable lifespan for the three reactors at the Palo Verde (Encl. #7).

Using your figure of $2.3 million for one unit's decommissioning, the cost of mothballing all three units of Palo Verde would be $8.6 million including contingencies. Furthermore, the Palo Verde reactors are to be the largest in the U.S. upon completion. The annual upkeep expense was not stated in the letter to Mr. Rhodes. I personally question the wisdom of using as a source the Atomic Industrial Forum. History shows that this forum has exaggerated the benefits of nuclear power consistently. Your letter did not discuss the fact that experience in Europe (see Encl. #8) shows that dismantling may cost much more than projected by the Atomic Industrial Forum.

With the exception of the error on construction cost of the Palo Verde ($4.35 billion should be replaced by the minimum cost of $3.78 billion), the cost projections for the report, "Palo Verde Economics--APS Projections Versus National Averages" have been found to be accurate and perhaps even a little low for nuclear power. I believe the efficiency projections (fuel efficiency and capacity factor) made in the report will withstand any kind of scrutiny.

I would like to conclude with a quotation that will undoubtedly become well-known in future. In Mr. Saunders Miller's new book, he says "from an economic standpoint alone, to rely upon nuclear fission as the primary source of our stationary energy supplies will constitute economic lunacy on a scale unparalleled in recorded history, and may lead to the economic Waterloo of the United States."

Sincerely yours,

Russell J. Lowes

Russell J. Lowes
Arizonans for Safe Energy
618 N. Central Ave.
Phoenix AZ 85004

cc: The Hon. John J. Rhodes

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Encl.#1

PALO VERDE ECONOMICS --

APS PROJECTIONS VERSUS NATIONAL AVERAGES

Submitted to the Arizona Corporation Commission
April 4 ~~March 5~~, 1977

Russell J. Lowes
for
Arizonans for Safe Energy
618 N. Central Ave.
Phoenix, Arizona 85003

Chapter I

APS' ECONOMIC PROJECTIONS FOR THE PALO VERDE PLANT

The following report will deal with Arizona Public Service (APS) economic projections for the Palo Verde Nuclear Generating Station, in contrast with national averages and trends for reactors already in operation.

Up to this time APS has never released to the public a thorough comparative report on the costs of nuclear vs. coal energy. For the Palo Verde, APS has made an estimation on the economics based on studies done elsewhere in the nation. The company projects that electricity from the Palo Verde plant will be 38 per cent cheaper than coal-fired electricity. They project nuclear at 40 mills* per kilowatt hour, and therefore coal at 64.52 mills per kilowatt hour.[1]

APS' prediction for nuclear generated electricity is based on false assumptions to such a degree that nuclear is made to look economically better than coal, when in actuality coal energy is more economical in Arizona.

It should be assumed that the cost for coal-fired electricity as projected by APS is fairlyaccurate. The company has been building coal-fired plants for years, and is presently involved in construction of such plants.

In order to conduct a comparative economic study on nuclear energy, there must be a breakdown of the costs, and a computation of the energy output. The utilities' major cost categories directly concerning electrical production from the Palo Verde plant are

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*1 mill equals 1/10th of one cent.

[1] Arizona Corporation Commission, Arizona Public Service Rate Hearing Transcript, (Phoenix, Arizona: Hardy W. Scott & Associates, March 1977), p. 1222.

capital investment, fuel costs, operation and maintenance, and decommissioning (see Table I). Then there are hidden costs such as waste storage; police protection of the wastes, fuel in transport, and the plant; and research and development--of which the utility pays only a small part.

The electrical output must then be figured. This output is expressed in terms of kilowatt or megawatt hours of electricity (kWhe or MWhe). Although APS owns only a portion of the Palo Verde plant, this report will deal with the economics of the entire plant. Interest charges will be neglected, as will taxes. The plant life will be assumed at 35 years. (The Final Environmental Statement by the Nuclear Regulatory Commission states the plant life at both 30 and 40 years.)

Table I

APS PROJECTIONS FOR PALO VERDE
GENERATED ELECTRICITY
(over a 35-year lifetime)

Cost Category	Mills per kWhe	Total Cost (billions $)
Capital investment[a]	3.17	2.78
Operation & maintenance[b]	4.0	3.5
Fuel[c]	5.89*	5.16
Decommissioning	(not figured)	----

SOURCES:

[a]Final Environmental Statement--Palo Verde Nuclear Generating Station, Units 1, 2, and 3, NUREG-75/078 (Washington, D. C.: Government Printing Office, September 1975);

[b]Arizona Corporation Commission, Arizona Public Service Rate Hearing Transcript (Phoenix, Arizona: Hardy W. Scott & Associates, March 1977, p. 1222).

[c]Ted Dando, Nuclear Information Representative for Arizona Nuclear Power Project; personal letter, March 18, 1977.

*5.89 mills is the estimated average for the year 1990. Estimations after 1990 are unavailable.

Costs for operation and maintenance (O&M) and the hidden costs will not be discussed in detail in this report. O&M figures are unavailable on a nationwide basis; however the "19th Steam Station Cost Survey" showed that O&M costs of nuclear power are slightly higher than coal.[1]

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[1]Leonard M. Olmsted, ed., "19th Steam Station Cost Survey", Electrical World, 15 November 1975, p. 47.

Chapter II

PROJECTIONS FOR CAPITAL INVESTMENT

Capital investment for power plants is the amount of money required to build them. The capital costs for a nuclear plant are higher than those for a coal plant.[1]

Arizona Public Service projects that Palo Verde will cost $2.8 billion; or $730 per kW (installed). Construction of the nuclear plant probably could not have been finished at that cost today.

The average construction cost per kW in 1976 was $773 for plants completed that year.[2] The Palo Verde should cost more than the average plant because cooling towers are being installed. Cooling towers add an additional $85 per kW as compared to the average cooling system.[3]

Nuclear plant capital investment has increased on an average of fifteen percent per year since 1965, while in the same time the cost of building a coal plant has gone up less than ten percent per year. Even the Atomic Energy Commission (which usually underestimated the costs of nuclear energy, compared to the national averages) increased nuclear capital projections 500 percent from 1968.[4]

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[1]Leonard M. Olmsted, ed., "19th Steam Station Cost Survey," Electrical World, 15 November 1975, p. 47.

[2]Edward Cowan, "Economics of Nuclear Power Are No Longer Optimistic," New York Times, 18 July 1976, sec. 4, p. 6.

[3]James J. O'Connor, "Why Industrials Must Favor Coal," Power, September 1976, p. 7.

[4]Marvin Cooke and Mike A. Males, "Analysis of Public Service Company's Projections for the Black Fox Nuclear Stations", presented to the Oklahoma Public Service Commission, Tulsa, Oklahoma, 22 August 1976, p. 2.

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If the average escalation rate continues throughout the building period of the nuclear station, assuming there are no schedule delays, the cost per kW would total $2365; the plant cost would total $9 billion--3.2 times APS' estimate of $2.8 billion.

The fifteen percent escalation figure may decrease substantially in the future, but the costs are definitely expected to soar. Edward Cowan of the New York Times writes,

> The unwillingness of nuclear engineering companies to promise delivery of a $1 billion to $1.5 billion plant six or seven years in advance for a fixed price is symptomatic of the run-away economics --an unanticipated surge of capital, labor, and uranium costs--and other shocks that have buffeted the nuclear power industry in the last few years.[1]

The Bank of America predicts that kW costs for nuclear plants will range from $1620 to $1907 in 1985.[2]

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1 "Economics of Nuclear Power Are No Longer So Optimistic", New York Times, 18 July 1976, sec. 4, p. 6.

2 John Berger, "Nuclear Power--No Solution to Energy Crisis", San Francisco, 1976, p. 8. (Mimeographed).

Chapter III

FUEL COSTS

Fuel Performance

In obtaining an accurate picture of uranium costs for a nuclear plant, a net energy gain per unit of uranium must be projected. Then the cost of the fuel must be projected.

The energy gain for nuclear fuel is expressed as millions of kWhe per ton of milled uranium, known as yellowcake. There has been no official governmental wide-scale survey of this energy gain, but there have been estimates and small-scale surveys.

APS is projecting a lifetime use of 4819.62 tons (based on the assumed 35-year lifetime of the plant) of uranium dioxide (UO_2).[1] There is a conversion ratio of 1:7.3, of UO_2 (which is the finished product) to yellowcake, with a margin of error. In other words, for every pound of UO_2 used for fuel in a reactor, it takes 7.3 pounds of yellowcake (approximately).[2] (NOTE: The reason that this step was used, instead of just using APS' figures on yellowcake, was because the author has been unable to obtain such figures from the Public Service Company.) Multiplying 4819.62 tons by 7.3 yields 35,183.226 tons of yellowcake.

Dividing the total APS estimation of energy output by the amount of uranium to be used gives a projected 25 million kWhe per ton of yellowcake.

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[1]U.S. Nuclear Regulatory Commission, Final Environmental Statement - Palo Verde Nuclear Generating Station, Units 1, 2 and 3, NUREG-75/078 (Washington, D.C.: Government Printing Office, September 1975), sec. 3, p. 4.

[2]Phone interview, Jim Harding, Special Advisor, California Resources Agency, Sacramento, Calif., 9 March 1977.

According to M. C. Day, professor of chemistry at Louisiana State University, 14 million kWhe per ton of yellowcake is about the average ratio.[1] In a report to the Bulletin of the Atomic Scientists, civil engineer Ralph G. Kazmann and Joel Selbin, professor of chemistry, apparently agree. They state that omitting such plants as the Yankee Rowe and the Dresden 2 (which have poor performances), the average output is about 18 million kWhe per short ton of yellowcake.[2]

Fuel Costs and Availability

To accurately project costs for uranium, the supply must be determined. The supply is nearing depletion on a worldwide as well as a nationwide basis; ie., the supply that is reasonably obtainable.

When the amount of uranium reaches a certain dilution, the energy required to process the ore outweighs the amount of energy obtainable. Before this dilution occurs, the volume of earth to be mined becomes economically and environmentally unfeasible.

Tennessee Shale is such an example. It has been considered mineable by the U.S. Government. Yet this shale has a very low energy gain. To obtain the equivalent gross amount of electrical energy, it would be necessary to move about 2.3 times as large a volume of uranium ore as coal. The energy per short ton mined would be 980 kWhe for uranium, and 2,250 kWhe from bituminous coal.[3] Uranium is running short in the United States, and this is the type of reserves the suppliers will have to turn to.

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1. M. C. Day, "Nuclear Energy: A Second Round of Questions", Bulletin of the Atomic Scientists, December 1975, pp. 53-54.

2. Ralph G. Kazmann and Joel Selbin, "Letters", Scientific American, April 1976, P.8.

3. M. C. Day, "Nuclear Energy: A Second Round of Questions", Bulletin of the Atomic Scientists, December 1975, p. 58.

But what about finding more uranium? There have been no major uranium deposits identified in this country in the last seventeen years, according to Robert Ninninger of the U. S. Geological Survey Uranium Branch.[1] William C. Carley of the Wall Street Journal writes, "Geologists are especially concerned because they think most of the easy-to-find uranium deposits near the surface have already been discovered."[2]

M. A. Lieberman, associate professor of electrical engineering and computer sciences and a member of the Energy and Resources Group at the University of California at Berkeley, estimates that the total amount of uranium that can be assumed to exist in the United States is 1,134,000 short tons. He concludes: "It will be shown that, if the expansion of nuclear power proceeds as planned, a serious shortfall in uranium will develop during the late 1980's."[3]

Most of the uranium in the U.S. comes from two geological formations known as the Colorado Plateau and the Wyoming Basins. We will need to discover new uranium supplies equal to nine Colorado Plateaus or twenty Wyoming Basins. Hans Adler, Geologist for the Energy Research and Development Administration Nuclear Fuel Cycle and Production Division, states: "The major question confronting exploration geologists, is where in the U.S. will facsimiles of these two regions be found once, much less 9 or 20 times."[4]

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[1]Ralph E. Lapp, "We May Find Ourselves Short of Uranium, Too", Fortune, October 1975, p. 151.

[2]William C. Carley, "Uranium Drain. Fuel Shortage Forecast for U.S. Nuclear Plants Within Decade or Two", Wall Street Journal, 7 June 1976, sec. 1, pp. 1, 10.

[3]M. A. Lieberman, "United States Uranium Resources--an Analysis of Historical Data", Science, 30 April 1976, p. 435.

[4]David Dinsmore Comey, "The Uneconomics of Nuclear Energy", Skeptic, July 1976, p. 21.

Utility companies are unsure of their future sources. The suppliers are not consenting to long-term contracts, unless there is allowance for them to increase costs in the event their costs go up. Such is the case in APS' contract.[1]

Commonwealth Edison of Chicago, the nation's largest nuclear utility, admitted it had no idea where its uranium would come from after 1980; its fuel manager could only say, "We must believe the resources will be there to keep those monsters running."[2]

There have been large companies defaulting on contract prices already. Westinghouse, the nation's leading uranium supplier, found itself unable to provide 50 million pounds of natural uranium to utilities at the contracted prices and defaulted, prompting lawsuits.[3] APS has contracted with Westinghouse for its uranium, even though the supplier will find it hard to meet other contracts through the 1990's. Other companies have also announced deficits, such as General Electric, the second largest supplier in the U. S.

To top it all off, there is now an OPEC-like uranium cartel that is expected to purposely jack prices up.[4]

What about the Breeder--or Recycling?

It has been rumored that the breeder reactor will relieve resources requirements for uranium. That would be partially true if the breeder program is okayed. Many conserva-

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[1] Ariz. Corporation Commission, APS Management Study (Phoenix, Arizona: Peat, Marwick & Mitchell, Inc., 1976), sec. 4.6, p. II-14.

[2] William J. Lanouette, "Nuclear Fuel: Will It Run Out?", National Observer, 24 April 1976, p. 1.

[3] "Westinghouse: the Waiting Period", Forbes, 1 December 1975, pp. 24-36.

[4] "It Worked for the Arabs", Forbes, 15 January 1975, pp. 19-21.

tive political leaders who support the current nuclear program are opposed to the breeder. If the program survives, the cost is expected to be tremendous. A General Accounting Office report, revealed by columnists Jack Anderson and Les Whitten, states that if the program comes on line, it would cost $153 billion to build the same energy capacity that could be constructed for $128 billion with conventional reactors and $95 billion with coal-fired power plants.[1]

If the nation turns to the breeder, it would have no significant effect on uranium requirements in the year 2000, according to Dr. Ralph Lapp, a breeder proponent. The program would possibly depress uranium prices later on.[2]

The situation on recycling is similar; it just may never be gotten around to. In this case too, there are dangers involved. But, if recycling becomes a reality, the most that the uranium supply could be boosted would be 50 percent, but probably less than 25 percent, according to M. C. Day.[3]

Because of the shaky grounds on which the breeder and the recycling program stand, because of the complications in implementing either, and due to the lengthy lead time in constructing either type of plant, it is evident that even both together will not relieve our uranium shortage.

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[1] Jack Anderson and Les Whitten, "Secret GAO Report gives Nuclear Energy Dim Look", Scottsdale (Az.) Daily Progress, 3 November 1976, p. 4.

[2] Ralph E. Lapp, "We May Find Ourselves Short of Uranium, Too", p. 199.

[3] M. C. Day, "Nuclear Energy: a Second Round of Questions", pp. 53-54.

Chapter IV

CAPACITY FACTORS

In figuring the costs of power from any plant, a comparison must be made between how much money is put into producing the electricity and how much electricity is delivered. What is actually produced from a plant is referred to as electrical output, and is expressed as a percentage of the amount of electricity that could have been produced, had the plant been in perfect running order at all times. This percentage is called the "capacity factor" of the plant.

To be more specific, the capacity factor of a power plant refers to the number of kWhe a plant produces in a given amount of time, divided by the number of kWhe that the plant could have produced, if the plant had been operating 100 percent of the time at full performance.

If two plants require the same cost for building, operating, maintaining, and fueling, but one has an average capacity factor of 80 percent over the life of the plant, while the other has an average of 40 percent, the first plant generates electricity for one-half the cost required by the second plant.

Palo Verde will have three separate reactors, each producing 1270 MWe at full performance. APS has predicted an average capacity factor of 75 percent over the life of the three reactors.

This projection is totally unrealistic. There has never been a reactor over 1000 MWe in size to operate at this high percentage for a full year. The larger the reactor, the lower the average capacity factor will be. The Palo Verde reactors are to be the largest reactors in the United States.

In the U.S., the average nuclear plant size is between 700 and 800 MWe. Two Swedish engineers calculate an average capacity factor of 42.7 percent for the average size reactor.[1]

Evidence of the lower capacity for larger plants exists in the record of actual performance of nuclear reactors. Jim Harding, Special Advisor to the Energy Resources Conservation and Development Commission of California, has calculated the total lifetime commercial reactor capacity factor to be 53.7 percent.[2] The average capacity factor for plants over 1000 MWe is about 44.5 percent.[3]

It is not likely that capacity factors will improve for plants over 1000 MWe. In fact, the cumulative-to-date capacity factor average for plants over 1000 MWe went down from 46 percent in 1974 to 44.5 percent in 1975.[4] There has been no significant improvement--or learning curve--for nuclear performance since 1973, the first year that the U. S. Government started releasing reactor performance records. Furthermore, a retrogression of capacity factors is expected. All plants over 1000 MWe in the U.S. are less than eight years old, and after the eighth year of operation, capacity factors decline throughout the rest of the reactors' lifetimes.

There is not enough statistical information available to give more than a general estimate on the capacity factor that nuclear reactors will decline to, by the time they are shut down. But they are expected to go down to about 25 percent for the average plant.[6]

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1 David Dinsmore Comey, "Points Vs. Trends", Bulletin of the Atomic Scientists, Oct.75, p.45

2 Jim Harding, personal letter, Special Advisor, Calif. Energy Resources Conservation & Development Comm., 8 February 1977.

3 David Dinsmore Comey, "No Improvement, Capacity Factors Stay Constant in 1975", _Not Man Apart_, March 1976, p. 11.

4 Ibid.

5 Charles Komanoff, Power Plant Performance (New York: Council on Economic Priorities, 1976), p. 4.

6 Peter Margen and Soren Lindhe, "The Capacity of Nuclear Power Plants", _Bulletin of the Atomic Scientists_, October 1975, p. 40.

The Council on Economic Priorities, a consulting firm based in New York, did a detailed study on nuclear and coal capacity factors and projected performances for a range of different sizes of reactors for the first ten years of performance (see table 2).

Table 2

LEVELIZED AVERAGE PWR* CAPACITY FACTORS
Ages 1 - 10

Unit Size	Projected Capacity Factor
500 MWe	69.5%
600	66.2
700	62.8
800	59.4
900	56.1
1000	52.7
1150	47.6
1300	42.6

SOURCE: Charles Komanoff, Power Plant Performance (New York: Council on Economic Priorities, 1976), p. 32.

*PWR is the abbreviation for pressurized water reactor, which is the type being built at Palo Verde.

DECOMMISSIONING

The costs of decommissioning have almost been ignored by APS, and certainly have not been figured into the total cost. There are several figures for decommissioning costs that are circulating. The most common figures are $1 million, plus $100,000 per year indefinitely.

Indefinitely, indeed! "Because of the very long half-life of nickel-59, exposure from gamma rays and X-rays from this source in a commercial reactor would not decline to the permissible level of 0.2 millirems per hour in a 40-hour week for 19.28-80,000 year half-lives, or 1.56 million years," according to the New York Public Interest Research Group at the State University of New York at Buffalo.[1]

Decommissioning has proven to be much more expensive than most utilities estimate. The Elk River reactor, which was 22 MWe as compared to the three 1270 MWe reactors of the Palo Verde, cost $6 million to construct and $6.9 million to dismantle. This ratio should not be casually scaled up to present-day prices, but dismantling is expected to cost much more for commercial sized reactors. The Public Interest Research Group stated that dismantling will certainly amount to tens of millions of dollars per reactor.

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[1] Steven Harwood et al, "The Cost of Turning It Off", Environment (December 1976), p. 18

Jersey Central Power and Light, a New Jersey utility company, is seeking permission from the state's Board of Public Utility Commissioners to boost its rates so it can start building a $100 million fund for the purpose of decommissioning a nuclear power plant. The plan is to raise $1.35 million a year, to be set aside in the form of tax-free government securities. This would raise $100 million by 2033.[1]

The funds that this utility is seeking to obtain may be well under the amount required for decommissioning. In reference to the costs at the Elk River reactor, Chemical and Engineering News reports:

> Similar experience in Europe indicates that the cost of this procedure runs about 45% of the value of the initial investment. In any event, there are no unique technical problems associated with taking a facility out of service.[2]

Because a large reactor has never been decommissioned, it is hard to tell how much the price should be scaled down.

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1 "In Place Entombment", Stevens Point (Wis.) Daily Journal, 14 January 1977, Sec. 1, p. 4.

2 "Experts Mull Over Radioactive Waste Disposal", Chemical and Engineering News, 2 August 1976, p. 23.

Chapter VI

HIDDEN COSTS

There are many hidden costs of the Palo Verde. The government will eventually carry the burden of storing the high level wastes, and will probably share costs of decommissioning.

There are other government costs that have already indirectly gone into the Palo Verde plant. Committee for Nuclear Responsibility has estimated "For each nuclear plant licensed to operate so far (about sixty plants), taxes provided almost $100 million in government research and development."[1]

For 1977 alone, the Nuclear Regulatory Commission will receive a quarter of a billion dollars in tax money.[2] None of this money is for the military nuclear program. The Energy Research and Development Administration will spend around $5.8 billion for their total nuclear program, some of which is for commercial purposes.

The water requirement for a nuclear plant is much higher than the requirement for a coal plant. The Palo Verde will require 75,000 acre-feet per year. A coal plant of similar size requires 45,000 acre-feet per year. Since Arizona is not getting all of the power from the nuclear plant, much of Arizona's water will be used for out-of-state power. Arizona will lose a tremendous amount of water, without a fight.

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[1] "Nuclear Power -- Bad for the Economy": Committee for Nuclear Responsibility, Inc., Yachats, Ore., Nov. 15, 1976.

[2] Executive Office of the President, The Budget of the United States Government, Fiscal Year 1977: Appendix (Washington, D. C.: Government Printing Office, 1976), Section 2, Page 8.

Chapter VII

PROJECTIONS BASED ON EXPERIENCE

APS' claims are not supported by the facts documented in this study.

Taking into account the data in Table 2, and the expected decline in capacity factors, it appears that the average capacity factor for reactors the size of Palo Verde's will average about 35 percent over the lifetimes of the reactors. This is 2.14 times lower than the estimate given by APS.

Concerning fuel, it would appear that because of the lowered capacity factor, the amount of fuel purchased should be less than one-half the amount that APS originally projected, thus cutting costs. This, however, is not the case. The apparent saving is nearly cancelled by the fact that the fuel efficiency ratio claimed by APS is 75 percent higher than the actual national average.

It seems obvious that yellowcake will go into the hundreds of dollars per pound, and will cost at least $200 per pound by the 1990's[1] when our mineable domestic reserves near depletion. At this minimum price, the cost for fuel would be 28.57 mills per kilowatt-hour of electricity, instead of the APS claimed figure of 5.89 per kilowatt-hour.

Noting that the costs of construction have gone up drastically and are apparently continuing to climb, this would indicate that the costs of the nuclear plant will finally run between $4.35 billion and $9 billion--assuming that the inflation rate does not increase.

Based on the projected costs of decommissioning the plant in New Jersey, the cost

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[1] M. C. Day, "Nuclear Energy: A Second Round of Questions", Bulletin of the Atomic Scientists (December 1975) p. 54.

of the Palo Verde plant's decommissioning (because Palo Verde is to be the largest plant in the nation) will probably run to over $200 million--the equivalent of 0.49 mills per kilowatt-hour of electricity.

These total costs have been grossly understated by the public service company (see Table 3), as the capacity factor has been overstated.

Table 3

POSTULATIONS VERSUS AVERAGES AND TRENDS
(Over a 35-year Lifetime)

Cost Category	Mills Per kWhe APS	Mills Per kWhe Probable	Total Cost (Billions $) APS	Total Cost (Billions $) Probable
Capital investment*	3.17	10.63 - 22.02	2.78	4.35 - 9.01
Fuel	5.89	28.57 - 71.43	5.16	11.69 -29.22
Decommissioning	(not figured)	0.49+	----	0.2+

*disregarding extra cost for cooling towers

Consolidating APS' exaggerated projections on investment input and electrical output boosts the costs per kilowatt hour from both ends. Subtacting APS' estimates on capital investment and fuel cost from the minimum probable estimate yields an increase in cost of 8.3 billion dollars. Dividing APS' projected electrical output into 8.3 billion gives 9.467 mills per kWhe, in additional costs. This gives 49.467 mills per kWhe at the estimated 75 percent capacity factor.

The above figures concern only capital investment, fuel, and decommissioning costs--they do not include operation and maintenance, or interest.

Using the 35 percent capacity factor boosts the cost of electricity 2.14 times to 106.0 mills/kWhe. Nuclear energy from the Palo Verde plant will cost at least 165.0% more than APS has been projecting. With coal at 64.52 mills/kWhe, nuclear energy will be at least 64.29 percent more expensive than coal-fired electricity.

Encl #2's

REALISTIC URANIUM ENERGY YIELDS AND COSTS

by
Ron Carstens, Robert Lamson

Nuclear power plants have always been known to have high "front end" capital costs, and since 1970 the escalation in capital costs has posed an increasingly serious economic problem for nuclear power. However, nuclear power advocates in government and industry have attempted to counteract these high capital costs by emphasizing the "practically negligible" uranium fuel costs of nuclear power. The uranium fuel cost component of electricity produced from nuclear power has received scant attention outside of cost estimates for specific situations[1] and individual power plants.[2] In almost all cases, these "official" costs for the uranium fuel component have been around 3 mils per kwh, with recent figures put at 5 to 6 mils.[3,4] Utility industry officials have been led to believe that this was the primary advantage of nuclear over coal power and offset nuclear's higher capital costs. However, there seems to be a lack of published operating data on which to base such fuel cost calculations, particularly electricity yield from uranium. On the other hand, there is a great deal of information published on expected or projected yields.[1,4,12]

This investigation was undertaken to establish what uranium fuel cost component utilities could expect for a nuclear power plant in the near future, based upon actual operating data. All utilities operating nuclear power plants for more than five years were invited to submit their uranium fuel loading record, including dates of loading, amount of fuel charged and its enrichment. We obtained data from startup for five utilities (5,6,7,8,9) and the ten-year record of two other plants from ERDA.[10] The total electrical generation for these plants from startup date to the latest fuel loading date was derived from data in

the Federal Government publication "Monthly Operating Plants Status Report" known as the "Gray Book." Utilizing the fuel loading record and its enrichment, the uranium oxide "yellowcake" required to fuel each plant was calculated from a material balance on the enrichment step, using uranium ores naturally occurring 0.711 wt% U235 in the feed and a tails assay of 0.3 wt%.[1,4,11] The fuel charges used were the sum of the individual loadings charged to the plant from startup until the fuel cycle just prior to the last one submitted by the utility. In this way, the electricity generated from the last fuel load charged to the plant would be included to give maximum credit for generation from this last load. These overall electricity yields, as summarized in Table I, were simply calculated by dividing the total electricity generated over the periods described by the net fuel charged converted to uranium yellowcake (100% U_3O_8 basis). The individual plant's yields were then averaged by weighting the yield with the operating life to give more weight to the plants operating the longest in order to de-emphasize the yield-dampening effect of the initial core loading. The average yield obtained was 12.36 MMkwh per short ton yellowcake, which is astonishingly low by previous statements, being less than 40% of the lowest previous official government and industry statements. In official Federal Government publications[1,12] as well as private[4,13] and industry[3] manuscripts, the energy yield from uranium is represented as "unchallengeable and immutable" at around 32,600 Megawatt (thermal) days per metric ton uranium metal in the fuel. This calculates out to something over 32 MMkwh per short ton yellowcake over a ten-year operating period without reprocessing, depending upon reactor type, etc. Additionally, in 1970 the AEC stated that reactors yielded 34 MMkwh per short ton yellowcake, without reprocessing.(14) Just last year, an ERDA official testified that light water nuclear reactors in the United States routinely contributed 32 MMkwh per

short ton yellowcake [15] to the United States energy needs (without reprocessing). Some have claimed over 60 MMkwh per short ton yellowcake as the energy yield.[4] On the basis of the data revealed here, it appears that present generation light water reactors may use at least two-and-one-half times as much uranium fuel as has been heretofore assumed by Federal planners.

As can be noted in Table I, the electrical yields vary a great deal, with the highest being over twice the lowest yielding plant. Attempts were made to correlate these data with capacity factor, plant size, plant type, % enrichment, and between short and long-operating plants, all with no result. Capacity factor would be a logical correlating factor since the plants are charged with a designated amount of fuel and the rods are regularly changed even though the electrical output may be below design for various reasons. However, there is no correlation with any factors these authors could identify. We also considered the relatively brief operating time for the plants considered here (average life 7 years) with respect to the dampening effect of the initial core loading. However, using the Government's energy yield figures for the initial core and replacement loadings,[12] we calculated the yield difference between a plant operating seven years (average for this study) and those operating 15 years, or one-half the plant's expected operating life. The difference in yield obtained was only 3% and thus would not account for the differences revealed here. Meager published data on BWR[29] fuel rods performance would seem to be in agreement with this data. Actually, these electrical yields as derived here are high by 6% to 10% because no account was taken of transmission losses[17] which are real due to the large and remote nature of these plants. Therefore, for a utility that is concerned with buying uranium yellowcake and delivering "billable" electricity to its customers, the

actual electrical yield based upon these operating data is well below 12 MMkwh per short ton yellowcake. This analysis, of necessity, did not include the effect of recycling uranium or plutonium as these are not commercially practical at present. There is considerable doubt if there ever will be commercial reprocessing and recycling.[16] Even given the unlikely event of recycling becoming a commercial reality, it would at best increase the yield 20% to 25%[12] which may never be realized due to the doubtful economics of reprocessing and recycling.[18] In any event, it is questionable that reprocessing and recycling can be operational fast enough to help the United States from exhausting domestic uranium reserves in the near future.

Utilizing the electrical yield derived herein, the official ERDA figures on proven uranium reserves,[19] and the projected installation of nuclear plants,[12] the United States could theoretically run out of uranium fuel for its scheduled plants well before 1990 assuming no imports. Thus it is peculiar indeed that the nation is being asked to go nuclear in order to be self-sufficient in energy. In a day when the United States has problems with petro-dollars and an Organization of Petroleum Exporting Countries, we can expect to have problems tomorrow with uranodollars and an Organization of Uranium Exporting Countries.

The next portion of this study considered the effect of this lowered electrical yield upon the fuel cost component of nuclear generated electricity. There are many costs associated with uranium fuel which are not considered in traditional cost calculations for individual utilities' plants. These associated costs--spent fuel reprocessing to ultimate waste management and subsidies on reactor development and fuel enrichment--have caused some nuclear proponents to seriously re-evaluate cost estimates.[20] However, for purposes of this discussion these costs are not considered here, and we restrict our analysis to the

fuel cost component strictly from the standpoint of an individual utility operating a nuclear fueld generating station which will be on stream in 1985. The components of this fuel cost reflect only the operations of fuel gathering and preparation in order to prepare the fuel rods for light water nuclear plants. These include the cost of uranium yellowcake itself, transportation and conversion to UF_6 for fuel enrichment, the enriching process (to allow the natural 0.711% U_{235} to be upgraded to about 3.2%, reconversion to U_3O_8 and fabrication into fuel elements to be placed in a reactor.

The cost of yellowcake has undergone enormous increases in the past few years, from a market price of just 7$/lb in 1973 to the present contract price of 40$/lb.[20] Current long-term uranium contracts are written tied to market price at delivery or 7% per year escalation, whichever is greater. Therefore, the future price of uranium cannot be less than present prices (about 40$/lb) plus 7% per year escalation. This yields a 1985 price of about 80$/lb which is as low as a utility can expect to pay. Others have anticipated even higher prices,[22] some well over 100$/lb[23] for the mid 1980's. The uranium supply situation is so serious that some utilities have been forced to invest in uranium mines as a defense against further escalation.[24,25] Further aggravating the situation will be the lower-than-expected electricity yields observed here.

At the enriching plant step, we can also see the effect of inflation and rising electricity prices on the tremendous amounts of power it takes to enrich the uranium. Even considering ERDA's heavily-subsidized operation and using tax-free TVA power, the Government charge for enriching has climbed from $28.70/kgSWU in 1971 to the recently announced $67.25/kgSWU[25] which is almost a 20% annual increase. Further cost increases will be forthcoming due to the increasing cost of electricity, lack of added

Government subsidy or private enriching plants, and the normal forces of inflation. With an escalation rate of 7% per year for inflation, costs double every ten years. Therefore, we estimated a 1985 enriching cost of $135/kgSWU, which is probably on the low side given past and future expected electrical cost increases, the real costs of government subsidy, and/or a shortage of enriching capacity. The final step of reconversion of UF_6 back to the oxide and fuel rod fabrication has been estimated at $100/kgU,[2] but a realistic estimate puts the figure at $125/kgU,[27] which yields an escalated figure for 1985 of $250/kgU.

Combining these cost elements with the average operating electrical yield derived in Table I gives the uranium fuel costs in Table II. These 1985 basis costs total 19.8 mils per kwh just for the uranium fuel component alone into nuclear power plants. This is some 400% to 600% higher than previous estimates by government[1,2,3,4] and industry.

These costs do not include nuclear fuel financing charges which will add at least 20% and as much as 50% to the Table II figure of 19.8 mils per kwh. Financing costs vary greatly and depend upon actual vs. expected fuel rod life, how much fuel reserve a utility likes to have and their financing costs. Any economic advantages which may come to pass from reprocessing or "breakthroughs" in enrichment technology will be completely overshadowed by these financing charges and by transmission line losses which were also not included. Therefore there is reasonable assurance that a utility in 1985 will have pay at least 20 mils per kwh for nuclear fuel costs alone.

It would appear, based upon this analysis, that the nuclear fuel costs pass-throughs of the 1980's will make those of the '70's seem low indeed. Furthermore the

highly touted fuel cost advantage of nuclear power will very soon turn out to be a disadvantage. Even if we escalate the present average U.S. price of coal ($16.90/ton)[28] to 1985 (at 7%per year, yielding $33.80/ton), and use an average energy yield of 3000 kwh/ton for coal, we can see that the 1985 fuel cost of coal power is only 11.3 mils per kwh, or 57% of the uranium fuel cost component in Table II. The present lower charges for nuclear plant's fuel is evidently a short-lived utopia that will be shattered as we enter the 1980's.

TABLE I

SUMMARY OF ELECTRICITY YIELDS FROM OPERATING NUCLEAR POWER PLANTS

	1	2	3	4	5	6	7
Reactor	First Date of Commercial Operation	Latest date of fuel loading received from utility	Total uranium fuel charged to latest date, excluding last fuel load (metric tons)	Average wt% enrichment U_{235}	Total yellowcake (100% U_3O_8 required to fuel reactor, calculated from reactor fuel charge (short tons)[a]	Cumulative electrical production, startup to latest date of fuel loading, MM KWH	Gross energy yield, MM KW per short ton yellowcake
onnecticut Yankee	1/68	8/73	152.9	3.64	1,637	27,400	16.75
esden 1	7/60	9/71	139.2	1.88	695	10,700	15.40
inna	3/70	3/75	245.9	2.82	1,946	13,700	7.04
.Crosse	9/69	8/75	15.5	3.68	169	1,290	7.63
onticello	7/71	10/75	146.8	2.34	947	13,300	14.04
.R. Robinson 2	3/71	12/75	140.6	2.64	1,042	19,850	19.02
ankee-Rowe	8/60	9/71	111.6	4.20	1,378	12,300	8.93
						Weighted average by length of operation	12.36

a. Calculated from individual fuel loadings and enrichments supplied for each reactor and from enrichment section material balance at .3 wt% tails assay and 1.3 short tons 100% U_3O_8 per metric ton U fuel charged.

Note: Total uranium fuel, Col. 3, and average % enrichment, Col. 4, will not necessarily calculate out to Col. 5 because of the non-linearity of the enrichment material balance function. Col. 5 was calculated from actual individual fuel loadings received from the utilities, and Cols. 3 and 4 summarize their data for ease of presentation.

TABLE II

COST SUMMARY
URANIUM FUEL COST COMPONENT OF NUCLEAR ELECTRICITY
1985 BASIS

	Cost/Unit	Units/short ton yellowcake	Cost per short ton yellowcake	Mils/KWH[d]
100 % U_3O_8 yellowcake	80$/lb[a]	2,000	$ 160,000	12.95
Transportation and conversion to UF_6	7.30$/lb U[b]	239	1,750	0.14
Enrichment	135$/SWU[e]	413.7[c]	55,850	4.52
UF_6 reconversion to U_3O_8, fabrication into fuel rods	250$/kgU[e]	108.7	27,180	2.20
			TOTAL	19.81 mils/kwh

a - Present NUEXCO contract price escalated @ 7% per current contracts to 1985.

b - Approximate estimate includes $2.86/lb U for conversion and 27¢/lb yellowcake equivalent, for transportation to and from conversion and enrichment and final delivery, both escalated at 7% per year.

c - At average 3.2% enrichment, requiring 3.80 kg SWU for U fuel enrichment, and 9.2 short tons U_3O_8 per metric ton U.[I, II]

d - At Table I average yields of 12.36 MMkwh per short ton U_3O_8 yellowcake.

e - Current market prices escalated to 1985 at 7% per year.

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U.S. URANIUM RESOURCES AT $ 10 TO $200+? PER LB. U_3O_8

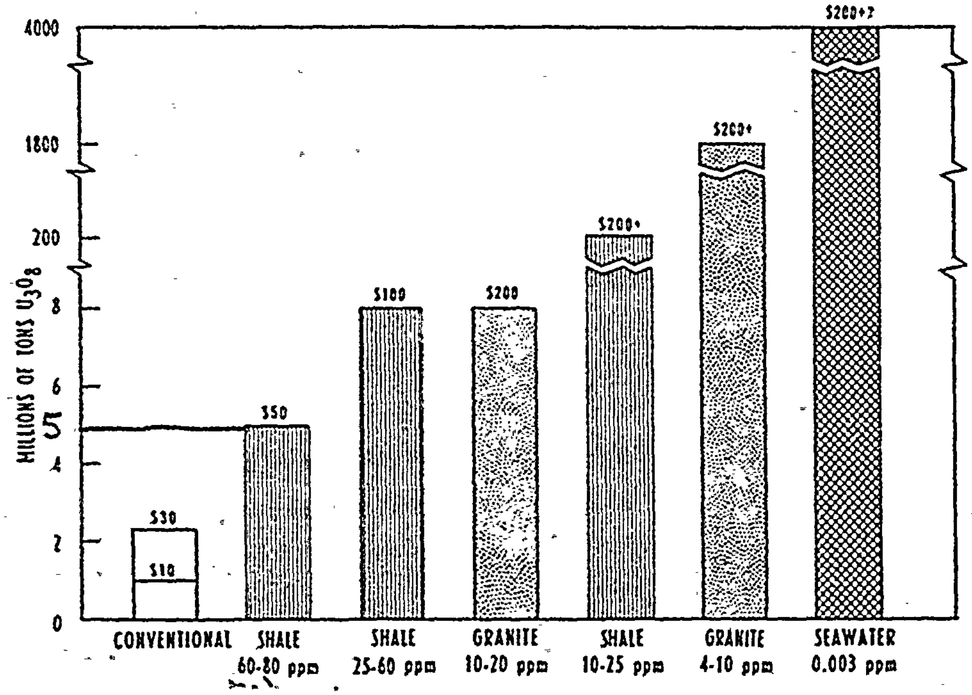


Figure 4

Encl. #3

Saunders Miller, The Economics of Nuclear and Coal Power (New York: Praeger Publishers—111 Fourth Ave., New York, NY 10003). 1977.

With limited resources, a more cogent method of comparing supply and demand might be to calculate the number of reactors that can be fueled for their entire life cycles. For a 1,000 MWe reactor with a 30-year life, 5,069 metric tons (MT) are needed. This estimate is based on an initial charge of 545 MT and an annual reload of 156 MT (at a 65 percent capacity factor).[8] Dividing the tons of uranium available by 5,069 will yield the number of 1,000 MWe reactors that can be fueled for their lifetimes.*

It will be noted from Table 1.7 that, at most, 117 plants of 1,000-MWe capacity can be supported for their lifetimes by known domestic reserves. However, as of September 1975, the Nuclear Regulatory Commission had already

*At an efficiency rate for converting heat to electricity of 32.6 percent (known as 32.6 MWD_{th}/kg U), 1 kilogram (kg) of enriched uranium produces 258,200 kilowatt hours (kwh) or 0.2582×10^6 kwh. (MWD_{th} = thermal megawatt days.) Thus a reactor operating at 65 percent capacity would require 22,052 kg of enriched uranium per year.

(8760 hours/yr.) (1,000 MWe) (65% Cap. Fac.) =

$(8.76 \times 10^3)(10^6 \text{ KW})(.65) = 5.694 \times 10^9$ KWH/yr.

$(5.694 \times 10^9)/(.2582 \times 10^6) = 22{,}052$ kg.

At 0.30 tails assay 7.08 kg. of natural uranium (U_3O_8) are required to produce 1 kg. enriched uranium.

1,000 kg = 1 MT

$(22{,}052 \times 7.08)/(1{,}000) = 156$ MT/ur. of natural uranium

Assuming a 30-year life for a plant, we have the following equation:

(initial load) + (years × reloads) = life cycle requirements for one plant.

545 MT + (29 × 156) = 5,069 MT

It should be noted that an efficiency rate of 32.6 percent is an assumed conversion rate utilized by ERDA in its computations, and our methodology has paralleled theirs. Whether or not this high an efficiency rate is justifiable is open to question. In the Bulletin of the Atomic Scientists of December 1975, M. C. Day ("Nuclear Energy: A Second Round of Questions") cites testimony of F. B. Baranowski of ERDA as testifying to Sen. Frank E. Moss on July 1, 1974, that the conversion ratio was 14 million kwh per short ton of uranium oxide, compared with the more commonly used value of 32 million kwh per short ton. Day does not draw any definitive conclusions, but if the efficiency rate is indeed less than 32.6 percent, the ability of uranium resources to sustain nuclear plants will be considerably less than indicated in this chapter which is based on ERDA assumptions.

End. #4

TABLE 1.7

Reactors Supportable by Uranium Resources
65 Percent Capacity with no Plutonium Recycle

Resource Base	MT U_3O_8	Number of 1,000 MWe Plants Supportable: Without Reprocessing	Number of 1,000 MWe Plants Supportable: With Reprocessing*
Known reserves	543,000	107	117
Plus potential: probable	1,034,000		
Total	1,577,000	311	341
Plus potential: possible	1,215,000		
Total	2,792,000	550	604
Plus potential: speculative	372,000		
Total	3,164,000	624	684

*If the reprocessing capability projected by ERDA does, in fact, turn out to provide 10 percent of the uranium needed, the life cycle demand is reduced to 4,620 MT. According to D. E. Saire (CONF-750209, pp. 67-72), reprocessing is expected to provide from 1.4 to 23 percent of total feed requirements between 1976 and 2000. In reality, reprocessing capability is far short of any projected targets, but an average of 10 percent is being utilized for discussion purposes.

Source: Compiled by the authors.

granted operating licenses to 37,000 MWe of nuclear capacity, construction permits for 65,000 MWe, and limited work authorization (ground breaking permits) for 18,000 MWe—a total of 120 GWe of committed nuclear capacity. Unless more "known reserves" are found, some of these reactors may have to shut down before their economic lives are completed. Prudence would dictate that no more new reactors be started until "potential resources" become additional "known reserves." However, ERDA projections show that by 1985, between 43 and 128 plants will have been built, which, based on known reserves, will not be able to function for their full economic lives. Table 1.8 illustrates this.

In fact, all projections forecast plants coming on stream *after* the known reserves would be fully committed (were producers to sign 30-year contracts). Under the moderate/high case (considered the "reference" case by ERDA) demand created by plants begun through 1990 would exceed all resources by 32 percent. It should be understood that the "potential resources" at this time—"probable," "possible," and "speculative"—are only "maybe's."

tors at other plants.

However, the suggestion that outages at these two units were not size-related but nevertheless cause the appearance of a size impact on capacity factor, is credible and worth considering. The trend equations through 1975 are indeed sensitive to inclusion of data for the two units. The PWR size-and-age equation through 1975 has a size effect of 3.4% per 100 Mw, with 99.9% statistical confidence (one-tailed) for the size term. Dropping Palisades, the size effect falls to 1.8% per 100 Mw, with only 97% confidence (but with a goodness of fit of 27%, vs. 21% for the all-PWR equation). For BWRs, the size effect through 1975 of 3.3%/100 Mw falls to 1.6%/100 Mw without Browns Ferry #1, with the confidence level falling from 98% to 87% when the unit is excluded. Clearly the size effect on capacity factor is extremely sensitive to inclusion of Palisades and Browns Ferry #1 (althouth Commonwealth Edison is incorrect in stating that "there is no significant correlation of unit size" to PWR capacity factors without Palisades).

Nevertheless, we believe it was proper to include these units' data in the Power Plant Performance trend equations, for the following reasons.

(i) Exclusion of some data opens the door to subjective decisions in defining the appropriate data base. If the worst performing PWR is removed from the sample, should Robinson #2, a reliably performing 707-Mw PWR, be similarly excised in a kind of trade? (Robinson #2 has the greatest cumulative positive divergence from the capacity factors predicted by the trend equation for a PWR of given size and age.) The arbitrariness in such decisions is eliminated by including all the data.

(ii) It is likely that the duration of outages affecting Palisades and Browns Ferry #1 capacity factors was size-related, even if initial outage causes were not. Large plants such as Browns Ferry #1 have more complex instrumentation than smaller units, so it is likely that the Browns Ferry fire caused cable damage which was more extensive and required more repair work than a comparable hypothetical fire at a smaller unit. Similarly, the major problem at Palisades -- chronic steam generator tube leaks -- is probably somewhat size-related, since the number of steam generator tubes is proportional to unit rating. It is thus not warranted to drop all of the size impact of the Browns Ferry #1 and Palisades data from the trend equations.

(iii) A look ahead at 1976 half-year data during preparation of the CEP study demonstrated to us that not only was 1976 full-year data likely to increase the significance of the PWR and BWR capacity factor/size correlations, but also that the magnitude of the size impacts was becoming less sensitive to inclusion of Palisades and Browns Ferry data. Sure enough, through 1976, the average size effect on PWR capacity factors is 2.5% per 100 Mw without Palisades (with 99.9% confidence), and 3.3%/100 Mw with Palisades. Through 1975, the size effect on PWR capacity factors was 1.8%/100 Mw without Palisades. Projected PWR capacity factors are only half as sensitive to Palisades' inclusion through 1976 as they were through 1975. (See Appendix C for PWR trend equations without Palisades.)

Similarly, the BWR size impact through 1976, omitting the new Browns Ferry #2 data as well as Browns Ferry #1, has only a 1.7%/100 Mw size effect (vs. 1.6%/100 Mw through 1975, without Browns Ferry), but the confidence level is 92% (one-tailed test), compared to 87% previously. BWRs admittedly do not show a conclusive size effect on capacity factor without the three Browns Ferry unit-years in 1975-76. Still, the BWR mean capacity factor is so low, at 55.6% through 1976, that the

allowance of even a small BWR size effect leads to sub-50% capacity factor projections for new 1150-Mw BWRs.

In short, the exclusion of Palisades and Browns Ferry data, as suggested by the study critics, is not only not fully justified, but in addition such exclusion does not have a confounding impact on the study's capacity factor projections, when 1976 data is added.

SOURCE:

Charles Komanoff and Nancy A. Boxer. Nuclear Plant Performance/Update: Data Through December 31, 1976 (New York: Council on Economic Priorities, 1977).

CRITICISM #2: The CEP capacity factor trend equations are said to be overly sensitive to removal of several poorly performing units from the sample.

Palisades, an 821-Mw PWR with a 1975 cumulative capacity factor of 23.2% (4 unit-years) and Browns Ferry #1, a 1098-Mw BWR with a 1975 one-year capacity factor of 14.0%, are large units which have suffered from allegedly non-recurrent, non-size-related outages. Their inclusion in the data base not only depresses the mean but, according to the industry, creates a spurious negative correlation between capacity factor and unit size.

The suggestion that Palisades and Browns Ferry #1 data be excised in computing the projection mean is self-serving and without merit. "One-of-a-kind" outages are a continuing fact of life in the nuclear power industry. Their putative uniqueness in each particular case has not prevented other one-of-a-kind outages from causing low capacity fac-

Encl #5

Vol. XXXI "On Cooking Curves," David Comey
Bulletin of the Atomic Scientists Oct., 1975 p. 41

Encl. #6

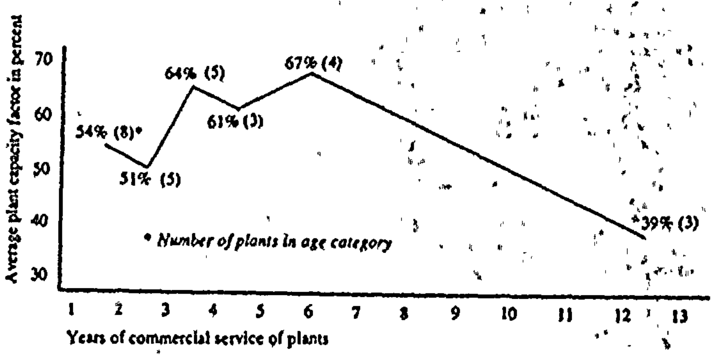
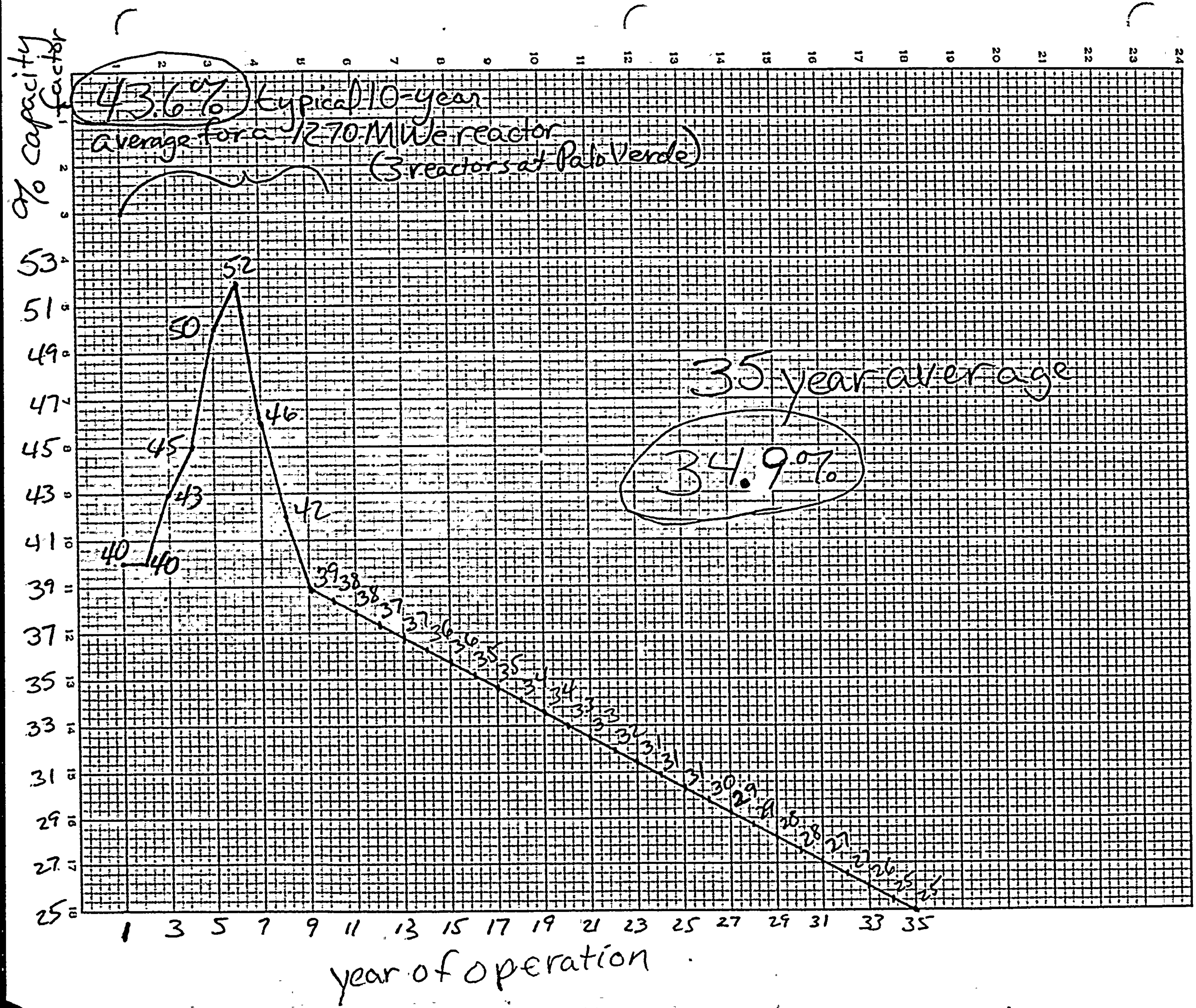


Fig. 1—Capacity factors of nuclear plants vs. age of plant, 1973-1974


43.6% typical 10-year average for a 1270 MWe reactor (3 reactors at Palo Verde)
35 year average
34.9%
% capacity factor
year of operation

Encl. #7

2, July 1977

William J. Dircks, Assistant Executive Director for Operations
US Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Dircks:

Concerning the letter that I sent you on 30 June 1977, on the subject of fuel efficiency, I made the same error in the letter several times consistently, so as not to affect the real proportions of electricity delivered. Every time the term "MMWhe" was used, the term should have read, "MMkWhe." A silly error, sorry.

Sincerely,

Russell J. Lowes

Russell J. Lowes
7501 E. Hubbell
Scottsdale, AZ 85257

Ref EDO-2174

Refer to
EDO-2174

That Joe Youngblood
brought up to
Regan yesterday

Marie