CURRENT ECONOMIC STATUS OF THE U. S. LMFBR PROGRAM

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It is well recognized that the United States is suffering from the absence of anything approaching a coherent federal energy policy. Nevertheless, let it not be said that progress is not being made in Washington. In 1971, the fast breeder reactor was touted as our best hope for meeting the Nation's growing demand for economical clean energy. Last month, when the new cost figures for the Clinch River LMFBR Demonstration Reactor were released Llewellyn King stated in his Weekly Energy Report, "the [LMFBR demonstration plant] project is woefully short of believers outside the AEC."[1] King reported that AEC Commissioner William Kriegsman "has expressed doubts about the desirability of the project at this time," and even Commissioner William Anders, who has emerged as an aggressive salesman of the breeder, was reported as "far from ready to admit defeat, but does acknowledge the dimension of the challenge."[2] In our view that's progress -- moving this uneconomical, high risk technology from its priority position to the point where the Commission is split and clearly on the defensive with respect to its commercialization, and where the program is undergoing major review on several fronts.

What has forced this turnabout? In the words of one OMB official, a few years ago it was thought that capital was plentiful and uranium scarce. Now just the reverse is true. In this paper I will explore some of the salient features of this shift.

1/ Weekly Energy Report, 23 September 1974, p. 5.

2/ Ibid.

R&D Imbalance

Between 1946 and 1973, approximately 85 to 90 percent of the federal energy R&D funding was channeled through the AEC for purposes of developing nuclear reactors. As a consequence, we find ourselves confronted by a bureaucratic fait accompli: we are told that we can generate electricity with either nuclear reactors or dirty coal plants. This misallocation of energy R&D fuels has also produced a large governmental, institutional and industrial base (e.g., AEC, GE, Westinghouse, Exxon, university departments of nuclear engineering) whose self-interests tend to perpetuate past priorities including those which, in retrospect, were mistakes.

Having developed commercial light water reactors, the AEC in 1967 accorded the liquid metal fast breeder reactor (LMFBR) the highest priority civilian reactor R&D program. In exchange for favorable consideration by Rep. Holifield of a government reorganization proposal,[3] Nixon gave his blessing to the LMFBR in his June 4, 1971 Energy Message to the Congress, stating, "Our best hope today for meeting the Nation's growing demand for economic clean energy lies with the fast breeder reactor." Between FY-1967 and FY-1974, the portion of federal energy R&D expenditures attributable to the LMFBR climbed to over 40 percent. Less than one percent of the federal energy budget was devoted to geothermal energy and solar energy with terrestrial applications. By far the greatest portion of public money and talent from 1945 to this date has gone into development of breeder reactors.[4]

3/ Barfield, Claude E., "Science Report/Nuclear establishment wins commitment to speed development of breeder reactor," National Journal 17 July 1971, pp. 1502-1503.

4/ Teller, Edward, as reported in Nuclear News, Vol. 17, No. 13, October 1974, p. 48.

At the height of last winters' oil embargo the administration acted as if the funds for energy R&D were unlimited and the federal energy R&D budget jumped by 80 percent from $1.0 billion in FY-1974 to $1.8 billion in FY-1975. The LMFBR budget climbed to $500 million in FY-1975, representing about 28 percent of the total energy R&D budget; against less than 3 percent ($50 million) to solar, less than 3 percent ($44.7 million) to geothermal, and one percent ($22 million) to energy conservation technologies. The amount currently allocated to solar energy R&D is only one-half of the amount required for an accelerated, orderly program having a high probability of early success according to a recent AEC panel chaired by Alfred Eggers of the National Science Foundation.

In order to curb inflation, however, OMB is now emphasizing austerity as opposed to energy supply. It has been reported that the AEC has been told to cut $140 million out of its civilian power budget for FY-1976. According to the same report the Clinch River Demonstration Plant and the Fast Flux Test Facility (FFTF), two key elements of the LMFBR program, along with certain enrichment programs, are most vulnerable to OMB's austerity axe. For reasons outlined below, in my view the LMFBR program can easily absorb this cut and more. As a rule of thumb it is probably safe to assume that any money now earmarked for the LMFBR program could be better spent by the World Bank.

In sum, the historic imbalance in energy R&D expenditures continues. While it is getting marginally better, this has been due to the force of external events -- the oil embargo, and not due to any coherent long-term energy strategy. There is no sign of a much needed reversal of energy priorities.

Cost Overruns

In 1969 the AEC was estimating that it would have to spend in excess of $2 billion in order to achieve LMFBR program objectives. The AEC already has spent approximately $1.6 billion on the LMFBR program (through FY-1974) and is currently spending $0.5 billion per year on this program alone. The AEC's last official estimate (late-1973) of the LMFBR cost to completion was $6.5 billion. This figure is considerably higher than the previous (late-1970) estimate of $4.5 billion (a $3.6 estimate converted to mid-1974 dollars). We are still searching for the peak in LMFBR program costs. Nucleonics Week quoted Commissioner Anders as saying the $1.7 billion for the Clinch River demo plant as "not an unreasonable hunk" of the total LMFBR program cost, estimated to be in the $8-$10 billion range.[5] Ten billion incidently is the AEC's last official estimate of the cost of the fusion program, the most expensive federal energy R&D program in history. Ten billion is also twice the amount President Ford suggested will be raised in one year with his 5 percent tax surcharge.

Currently the estimated additional LMFBR Program expenditures (in constant dollars) as a function of time are increasing rather than decreasing, and alarmingly they are increasing faster than cumulative expenditures to date (sunk costs).

The AEC's estimate of the LMFBR cost to completion probably understates the true cost by at least a factor of two, due principally to cost overruns. Significantly, the Fast Flux Test Facility (FFTF), a major component of the LMFBR Program, was authorized in 1966 at $87.5 million. The direct costs associated with the FFTF are now

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5/ Nucleonics Week, 19 September 1974, p. 6.

estimated at $420 million.[6] The total cost, with indirect costs last placed at $480 million,[7] is 10 times higher than the 1966 estimate of $87.5 million. Additional increases are anticipated as the FFTF schedule continues to slip. There are still unresolved FFTF safety issues related to its capability to withstand hypothetical core disruptive accidents that could be extremely costly.

The second most significant component of the LMFBR Program is the Clinch River Breeder Reactor (CRBR), the first LMFBR demonstration plant if you discount Fermi-I.[8] The first official estimate of its cost was about $400 million. In a 1972 Memorandum of Understanding its cost was estimated at $700 million, two-thirds coming from the AEC and with the AEC assuming an open-ended risk (i.e., all the cost overruns). This estimate was $150 to $200 million higher than an AEC estimate only six months previous. In March 1974, it was reported that CRBR project officials are "focusing on some major steps that they hope will hold the total cost of the plant under $1.0 billion."[9] In July, it was reported that the CRBR project would cost $1.8-$2.0 billion,[10] and in September it was pegged at $1.736 billion.[11] Unfortunately,

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6/ Nucleonics Week 15, 10 January 1974, p. 1.

7/ Barfield, Claude E., "Energy Report/U.S. retains commitment to breeder reactor despite environmental, economic challenges," National Journal Reports, 15 December 1973, p. 1868.

8/ Fermi-I, the first commercial LMFBR plant, experienced a partial core meltdown and has subsequencly been shut down.

9/ Nucleonics Week 15, 21 March 1974, p. 1.

10/ Weekly Energy Report 30, 2 July 1974, p. 1.

11/ Weekly Energy Report, 23 September 1974, p. 5. Given the cost trend the last three significant digits are a joke.

the demonstration plant of the federal government's priority energy program has a cost doubling time of one year and a fuel doubling time of 30 to 60 years, instead of the reverse (See Figure 1). (Those of you with a flair for arithmetic will note that if this trend continues until the projected project completion date - 1982 - the final cost could reach $500 billion.)

Why the increased costs? According to Commissioner Anders, as reported in Weekly Energy Report, there are a variety of factors that have added to the new cost. They include:

> "an implied criticism of those managing the project in the past who underestimated the cost in order to make it more attractive politically; the new high cost of money and general escalation in cost; more stringent regulatory requirements than first envisioned, such as the projection of a core catcher; and a large chunk of new money for development."[12]

The first reason Anders gives is a polite way of saying the Commission has been lying to the Congress and the public for the past couple of years in order to promote its priority program. Turning to the other reasons, the end is still not in sight with respect to cost increases due to the high cost of money and general escalation. The AEC is using an 8% per year escalation factor while the economy is experiencing double digit inflation. The same is true with respect to regulatory requirements and new money for development. The Project Management Corporation, Westinghouse and the AEC's Division of Reactor Research and Development are trying to force a plant design through AEC Regulatory that would require a fundamental shift in Regulatory's safety philosophy. So far Regulatory has stood its ground. As far as reactor safety and licensibility are concerned, the Clinch River demonstration plant is on even shakier ground than the FFTF.

12/ Ibid.

It is significant that the AEC's last official projection of LMFBR expenditures, the $6.5 billion, exceeds a recent FPC estimate of the total R&D costs (to the point of commercialization of all non-nuclear technologies, including coal gasification, solar (direct and indirect) and geothermal technologies, advanced steam cycles, MHD, fossil fuel effluent controls, and a variety of energy storage systems.[13] A NSF/NASA Solar Energy Panel recommended in late-1972 that a 15-year program to develop all solar energy options would cost $3.5 billion,[14] roughly one-half the AEC's last official estimate of the LMFBR Program cost. Thus, we see that LMFBR program cost overruns are completely out of hand with no end in sight. The total cost of this program alone has outpaced the total cost of all the attractive (and I might add unattractive) non-nuclear alternatives.

Uneconomic Performance

In 1967 the constant dollar cost of electricity generated by nuclear reactors was less than one-half what it is today. It was believed that the higher capital cost of the breeder reactor -- over conventional light water reactors -- would be offset by savings in the fuel cycle cost. Since 1967, the capital cost of electric power plants has doubled in constant dollars,[15] rising to the point where

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13/ Report of the Task Force on Energy Conversion Research to the Technical Advisory Committee on Research and Development, November, 1973, DRAFT.

14/ An Assessment of Solar Energy as a National Energy Resource, Prepared by the NSF/NASA Solar Energy Panel, Dec. 1972, Table 4, p. 11.

15/ Bupp, Irvin C. and Jean-Claude Derian, "The Breeder Reactor in the U.S.: A New Economic Analysis," Technology Review, July/August 1974, p. 33.

amortizing the nuclear plant cost represents over 80 percent of the total cost of electricity from these plants. The LMFBR, with its higher capital costs, can not now economically compete with other nuclear plants. It will not be able to do so until the price of uranium (in constant dollars) is substantially above its present price. By substantially, I mean by a factor of 5 or more.

The AEC has performed three cost-benefit analyses of the breeder program -- the first written in 1968, was released in 1969,[16] the updated (1970) analysis was released in 1972[17] and the latest (1973) analysis was included in the AEC Draft Environmental Impact Statement on the LMFBR Program.[18] It has been pointed out that the AEC's cost-benefit analyses are extremely sensitive to changes in several important input variables, capital cost, energy demand, uranium supply and discount rate. By making favorable assumptions with respect to these, the AEC was able to generate favorable benefit-to-cost ratios in each of these studies. These studies are classic examples of the manner in which uneconomical programs are sold to the public using fraudulent economic analyses.

I believe the key assumptions in the AEC's cost-benefit analyses are indefensible. For example, electrical energy demand is not expected to grow nearly as rapidly as the AEC expects.[20] Also, in my view the

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16/ U.S. AEC, Division of Reactor Development and Technology, WASH-1126, April 1969.

17/ U.S. AEC, Division of Reactor Development and Technology, Updated (1970) Cost-Benefit Analysis of the U.S. Breeder Reactor Program, WASH-1184, January 1972.

18/ U.S. AEC, Draft Environmental Statement: Liquid Metal Fast Breeder Reactor Program. Report in four volumes, WASH-1535, March 1974.

19/ Cochran, Thomas B., The Liquid Metal Fast Breeder: An Environmental and Economic Critique. Resources for the Future, Washington, D. C. March 1974, p. 222.

20/ Chapman, Duane, et al., Power Generation: Conservation, Health, and Fuel Supply. DRAFT Report to the Task Force on Conservation and Fuel Supply, Technical Advisory Committee on Conservation of Energy,

price of uranium is not expected to reach the levels required to make the LMFBR economical until well into the next century, decades after the AEC's planned "commercial introduction" date of the LMFBR, which has now slipped to about 1990.

Other independent investigators have been equally critical of the AEC's methods and conclusions.[21-25]

Bupp and Derian, economists from Harvard and MIT respectively, conclude,

> ". . . we still cannot be really confident about future LWR capital costs. . . . it does not seem reasonable to claim definitive economic benefits on the basis of an allowable cost differential which represents a decreasing fraction (now less than 20%) of the cost of a relatively well-known technology, whose real cost we still cannot confidently predict, and a completely new product whose cost is highly uncertain."[26]

Holdren, Assistant Professor in the Energy and Resources Program at the University of California, Berkeley, concluded:

> "It was the intention here, however, to focus on a much narrower question with a specified time horizon: whether uranium supplies are adequate to meet the most ambitious projections for the growth of nuclear power (irrespective of plausibility or desirability) for the next 30 to 50 years, without breeder reactors and without dramatic increases in the price of nuclear-generated electricity. The answer obtained here is yes, indicating, in turn, that the urgency that has been ascribed to the LMFBR program primarily on grounds of limited availability of uranium is illusory (47)." [27]

21/ Bupp, Irvin C. and Jean-Claude Derian, Op. cit.

22/ Holdren, John P., "Uranium Availability and the Breeder Decision."

23/ EPA Comments on the LMFBR Draft EIS.

24/ NRDC Comments on WASH-1535, Draft Environmental Statement, Liquid Metal Fast Breeder Reactor Program. Natural Resources Defense Council, Washington, D. C.

25/ Rose, David J., "Nuclear Eclectic Power," Science 184, No. 4134, 19 April 1974.

26/ Bupp and Derian, Op. cit., p. 33.

27/ Holdren, John P., Op. cit., p. 31-32.

And Rose, Professor of Nuclear Engineering at MIT wrote in Science,

> "I estimate that the breeder will almost surely be attractive when U308 reaches $50 a pound in 1974 dollars. That will not happen in the first few decades of the 21st century (see the "resources" debate). In the meantime, nuclear power is in no danger of losing out to other fuels, and there does not need to be a crash breeder program. Economic introduction at A.D. 2000 would be a sign of technological good fortune, not of resolving an energy crisis with a time limit." 28

Comments by the EPA and the Natural Resources Defense Council (NRDC) on the DRAFT LMFBR Environmental Impact Statement (EIS) point out numerous methodological errors and omissions that flawed the AEC's latest cost-benefit analysis of the breeder program. Noting its cost-benefit analysis of the breeder was particularly deficient, the EPA gave the AEC's DRAFT environmental impact statement on the LMFBR its lowest rating -- "inadequate."

If society chooses to place a heavy reliance on nuclear fission for energy generation and this continues well into the next century, then some form of breeder will undoubtedly be economical and necessary if we choose not to pay the environmental costs of mining very low grade uranium ores -- a penalty comparable to mining coal or even oil shale. A viable and preferable alternative in my view is to phase out the fission technology in an orderly manner with heavy reliance in the short run on energy conservation measures and a higher priority placed on other energy R&D programs.

Among proponents of fission, the breeder debate revolves around the timing of commercial introduction and a central issue in this debate is uranium supply. Actually uranium supply, properly viewed, is simply another economic variable with uncertainty in the economic analysis of

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28/ Rose, David J., Op. cit., p. 357.

the breeder. However, many energy planners, erroneously I believe, elevate the uranium supply issue and treat it independently, arguing for example, that the breeder is necessary as insurance against a shortage of low cost uranium in order to "guarantee the validity of the nuclear option." But even here the key is whether there is enough low cost uranium to allow us to delay the commercial component of this technology for 5 or 10 years and stretch out and restructure the breeder R&D program and invest in more promising alternatives. In this regard, the breeder economics and the uranium supply issue could be reassessed at 5 year intervals to see whether continued delays are warranted.

There are three major uranium supply studies in progress. One of these, a comprehensive AEC analysis, is not expected to provide results for another 3 to 5 years. The Electric Power Research Institute is conducting a second study under the direction of Milton Searl, Manager of the Energy Supply Studies Program. Results from a first comprehensive cut at the subject have been circulated in draft. Searl's effort is without question the best comprehensive analysis of domestic uranium supply to date. Searl's estimates of the high, intermediate and lower grade uranium (cost cut off of $100/lb U_3O_8) in conventional sandstone deposits are several times greater than AEC estimates. Based on Searl's analysis there is high probability that there is ample high grade uranium ore in <u>domestic sandstone deposits</u> to delay the LMFBR program for a decade or more without economic penalty and without going to low grade unconventional uranium ores such as the Chatanooga shale deposits.

Searl's analysis is supported by the testimony of J. C. Stephenson before the FEA's Project Independence hearings September 10, 1974, in Chicago.[29] Stephenson is president of the Mining and Metals Division of Union Carbide and was speaking as chairman of the Uranium Advisory Council of the American Mining Congress. According to Stephenson the fundamental resource uranium base in the United States is adequate although present exploration levels in the United States are not adequate to meet projected uranium requirements after 1980. Stephenson said that the majority of those active in the uranium production industry believe that levels of drilling and discovery necessary to be self-sufficient in uranium can be obtained provided the incentive is present to draw a rapid commitment of funds and trained manpower.

Batelle is currently conducting for the National Science Foundation a short term study of uranium resources in unconventional deposits i.e., other than sandstone. It is likely that this study will identify substantial additional domestic low cost uranium resources not included in Searl's study.

The point here is that these studies strongly support the view that commercial introduction of the LMFBR can be delayed for decades. Clearly, there is sufficient domestic uranium available to support delaying the commercial development component of the LMFBR program, the CRBR, for five years while more definitive uranium studies are completed.

29/ Statement of J. C. Stephenson on behalf of the American Mining Congress before the Federal Energy Administration Project Independence Public Hearings: "Role of Nuclear Power," Chicago, Illinois, September 10, 1974.

Program Disarray

In the mid-1960s the United States had the most advanced LMFBR program in the world with a commanding 5 to 10 year lead over foreign LMFBR programs. The United States did not proceed immediately to develop a commercial LMFBR demonstration plant as did the Europeans. The primary focus of the U.S. effort was directed at describing all the technological problems that could be identified and following a "Program Plan" defined to solve these problems. The Program Plan was based on the theoretical concept that when all of the problems were solved, the solutions could be assembled and used to construct a commercial LMFBR.[30] The Program plan included the FFTF, a sophisticated fuel test facility, which has been the primary focus of the program since it was authorized in 1966. In the early 1970's there was a prevalent, though not universal nor publicized, nuclear industry view that the 5 to 10 year lead over foreign LMFBR programs had shifted rapidly to a 5 to 10 year lag due to the misdirected program focus coupled with inept management on several levels.

The first strong public criticism of the United States breeder program came from an assessment of advanced nuclear power led by Nobel Laureate Hans Bethe. This was one of the Cornell Workshop reports which was part of AEC Chairman Ray's $10 billion energy study for the President. The Bethe report concluded that while a breeder is needed in order to guarantee the fission energy option, the present LMFBR program does not meet the "true national objective" of developing a good breeder with a high breeding gain.[31] In the same Cornell Workshop report,

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30/ Koch, Leonard J., "EBR-2 plus 10: Is the U.S. formula right for effective LMFBR development?" Nuclear News 17, No. 10, August 1974, p. 5

31/ "Report of the Cornell Workshops on the Major Issues of a National Energy Research and Development Program," (Sept. 14 - Oct. 17, 1973), published by the College of Engineering, Cornell, Ithaca, N.Y., Dec. 1973.

W. Kenneth Davis, Vice President of Bechtel Corporation and a leading nuclear industry spokesman stated,

> "I personally believe that an economic LMFBR could be achieved (versus LWRs with uranium at present price levels), but do not believe it will be done in the United States with the present program. The priorities and expenditures for the present LMFBR program need to be reexamined in light of the competing needs, including such things as coal conversion R and D and the probability of the present FBR program achieving a useful goal in the time required."[32]

A more recent industry criticism of the LMFBR program is contained in the trade journal, Nuclear News. Here Leonard Koch, a former project manager in the breeder program notes, "the Clinch River breeder reactor is unlikely to operate before 1986 - about 18 years after the successful EBR-2 operation." In Koch's view commercial operation of competitive breeders will begin much before the end of the century,[33] and he suggested the United States cannot afford eight more years of an LMFBR program that does not interest utility people."[34]

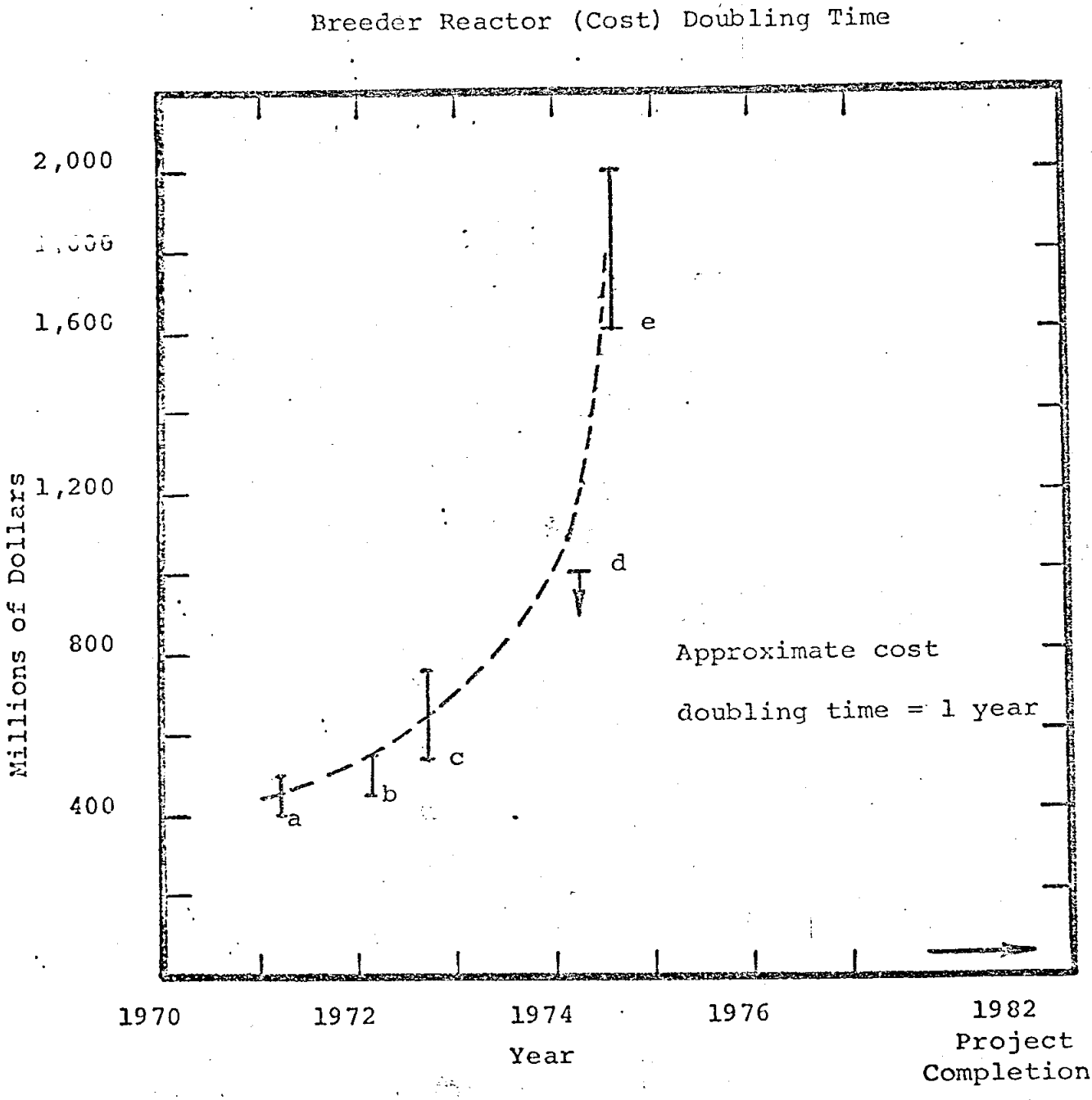
Conclusion

In conclusion, one of our best hopes for meeting our energy needs of the future is to perform surgical intervention on our present energy R&D policy, cutting to the bone the present priority program, the LMFBR. Priority should be shifted to energy conservation programs in the short run and the more attractive long run alternatives, solar and geothermal. What is needed is a clear and sufficient shift in energy R&D priorities and not simply a hodge podge of additions to the present imbalance. The raison d'etre for the present priority program, the LMFBR -- low cost energy, predicted shortage of uranium, high gain breeding -- have been lost, at least for the forseeable future.

32/ Ibid, p. 158-9.

33/ Koch, Leonard J., Op. cit., p. 57.

34/ Ibid.



AEC Estimates of the Range in the Cost of the Clinch River Breeder Reactor.

Sources:

(a) JCAE Hearings, AEC Authorizing Legislation - FY 1972, p. 702.
b) JCAE Hearings, AEC Authorizing Legislation - FY 1973, pp. 1156-1159.
c) JCAE Hearings, LMFBR Demonstration Plant, Hearings, p. 44.
d) Nucleonics Week, 15, March 21, 1974, p.1.
e) Weekly Energy Report, 30, July 29, 1974, p.1.