A Comparative Business Analysis of the Atomic Vapor LIS and Gas Centrifuge Uranium Enrichment Processes

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Summary

We compare the alternative advanced enrichment programs on the basis of realistic cost and performance analyses. The gas centrifuge program currently allows no leeway for either reduced performance or increased costs over current projections. In fact, with the most optimistic performance analysis the cost/SWU could be brought down to less than the current market price, recently, only by increasing the capital amortization time from 10 years to 25 years. Compare this with the atomic vapor laser isotope separation (AVLIS) process with only 1/5 the projected cost/SWU. Clearly, this process not only has substantially higher economic benefit but has inherently lower risk because of the ability to insure against uncertainties in realized enrichment performance. By constructing excess capacity at a total capital cost still much lower than that of GCEP, a desired production rate can be guaranteed even if the design performance is not achieved.

Introduction

In an era in which rising energy costs vie with rising capital costs a switch from an energy intensive gaseous diffusion enrichment industry to the capital intensive gas centrifuge enrichment process is too much akin to a frying pan/fire decision option. As energy costs escalated during the past decade, the pressure built for immediate and highly visible cutbacks in energy consumption. Unfortunately, the crisis atmosphere engendered by this "moral equivalent of war" has resulted in premature decisions on the basis of insufficient technical and economic analysis.

The emerging recognition of the true magnitude of the capital investment associated with a gas centrifuge enrichment plant has shifted the focus from the energy savings to the size of the capital outlay. To minimize the perceived impact of GCEP's capital cost, the amortization time used to calculate cost per SWU for gas centrifuge plants was increased from 10 to 25 years, at a time when the new tax law recognizes the reality of inflation by drastically shortening the capital recovery period for depreciation of capital investments. Figure 1 shows how the lengthened amortization period changed the apparent cost per SWU for GCEP so that it again becomes less than the selling price of ~$125/SWU. This figure also shows the impact of a more realistic interest charge than the 10% rate currently used in capital amortization.

A careful study of the energy and economic environment motivates the search for an enrichment alternative with lower capital requirements as well as lower energy consumption. The Atomic Vapor Laser Isotope Separation Program (AVLIS) has achieved such a process. As seen in Figure 2, at $20/SWU the cost is projected to be 1/5 that of GCEP at less than 1/8 the capital outlay. Stated another way, even with 1/5 the expected performance factor (and hence the same, ~$100/SWU, cost as GCEP) an AVLIS plant would cost only about 5/8 as much as the same capacity GCEP plant, and in addition provide the potential bonus capacity of up to 36 MSWU/yr, as seen in Figure 3. Figure 1 also shows that AVLIS, being much less capital intensive than GCEP, is not dependent on unrealistic financial analyses for its economic justification. High interest rates and short amortization time increase the relative benefit of AVLIS over GCEP. However, neither the amortization period nor the interest rate used have a significant effect on the AVLIS cost per SWU.

Background

The near term uranium enrichment supply and demand picture is summarized in Fig. 4. With the completion of the gaseous diffusion CIP/CUP upgrading program approximately 25.2 MSWU/yr of enrichment capacity will be available to meet the projected 1990's requirements of 30-40 MSWU/yr. This leaves a requirement for about 10 MSWU/yr of new capacity before 1995. The first two buildings of GCEP are planned to provide 2.2 MSWU/yr by 1989. With the roughly 35 MSWU of current inventory even the highest projections for domestic requirements (Fig. 5) are easily satisfied in the foreseeable future. Hence, no issues of national emergency need interfere with a studied decision based on a sound business analysis of the enrichment alternatives.

Furthermore, the Atomic Energy Act of 1954 directs that the selling price of SWU's is to provide for the recovery of all costs within a reasonable time frame. When government competes with the private sector for capital there are additional costs beyond those included in the simple amortized capital plus operating cost equation used in Figure 1. Figure 6 summarizes some considerations which must underlie a realistic economic analysis. It must be recognized that the cost to society of any goods or services depends only on the required quantity of resources such as labor, materials and capital, and on the skill and efficiency with which these are applied (the productivity). A product cannot be made and sold more cheaply simply because the government, which is controlling the endeavor, agrees to forego a reasonable profit. All this accomplishes is to transfer the profit "cost" (the cost of entrepreneurial initiative and risk taking) to other parts of the economy. In the case of a labor

intensive enterprise this may take the form of higher prevailing wages as government competes with an apparent advantage for a segment of the labor force. In the case of a capital intensive enterprise, such as the gas centrifuge enrichment scheme, the transferred cost may appear as higher interest rates and increased inflationary pressures. Hence, it is reasonable that all government projects be evaluated on a business basis. Otherwise government, if incorrectly deemed able to produce more cheaply than the private sector, will progressively enlarge its activities. This means, in particular, that capital should command a reasonable risk- and inflation-adjusted return, so that the true national costs of alternative programs can be compared.

That the U.S. government may wish to sell SWU's cheaply in order to maintain control of the international enrichment business, retarding nuclear weapons proliferation and helping our balance of payments, does not justify selling SWU's in foreign markets at less than their true cost. Rather, it means that the motivation for finding less expensive alternative enrichment processes is that much more urgent.

Finally, it must be borne in mind that inflation is only beneficial for capital intensive projects, such as GCEP, when a large portion of the capital can be borrowed long-term at fixed rates which do not include an inflation premium. Any new indebtedness certainly includes such a premium in the present high interest rates. In any case, from a national standpoint, this capital is largely borrowed from the American people so there could be no net national gain from inflation. In fact, high capital projects only add to the perception of government's vested interest in increasing levels of inflation.

Analysis

Having discussed the merits of judging alternative enrichment projects using a consistent, business analysis, we present the results of an economic study of the gas centrifuge and AVLIS programs. With implementation of each projected for roughly the same time frame, and no issues of national emergency involved, there are clearly just two major parameters to be considered, namely performance and total cost. Figure 7 is a decision diagram for selection of an enrichment process choosing the lower cost/SWU, based on the projected performance factor. This factor is the realized capacity of an enrichment plant divided by the design capacity, where the realized capacity is 8.8 MSWU/yr in each case. The parameters used to determine cost/SWU are those in Figure 2, including the optimistic amortization of capital over 25 years. Use of a more realistic capital amortization would clearly favor the less capital intensive AVLIS program even more than is shown in the figure. Note that the AVLIS plant is favored for all credible performance projections, even down to 20% of the performance currently projected. Furthermore (c.f. Figure 3), even for the case of equal cost/SWU AVLIS would still have a significantly lower capital cost than a gas centrifuge plant of the same realized capacity.

Figures 8 and 9 display the cost/SWU and plant capital cost for each process as a function of their performance factors. Note that these costs are not only much greater for the gas centrifuge process relative

to AVLIS, but for a given performance factor the GCEP costs are much more sensitive to its performance factor than are the AVLIS costs. Hence a 20% decrease in performance for GCEP carries a significantly greater cost penalty than it would for AVLIS.

Consider a worst case scenario in which AVLIS is selected assuming a 20% performance factor. The performance growth resulting from successive generations of separator design results not only in lower cost/SWU but in significantly increased separative work capacity. Figure 10 compares advanced gas centrifuge costs with those for advanced AVLIS separator designs. Each AVLIS set corresponds to more efficient isotope separation resulting from an RD & D program followed by retrofitting of the separators. AVLIS clearly holds the promise of obtaining significantly lower cost/SWU from performance growth. Advanced sets of AVLIS have successively greater advantage over advanced sets of gas centrifuge.

Having seen how achieved process performance influences the relative merits of AVLIS and GCEP, we turn now to a financial analysis of the costs from a business point of view, and compare their merits based on achievable return on investment. Figure 11a shows a comparison of the selling price/SWU required for GCEP in order to realize a given after tax annual return on capital (the impact of plant capital cost is somewhat lessened by allowing a 10% investment tax credit). Figure 11b shows the payback period for the plant investment corresponding to the sales price for separative work. A more detailed discounted cash flow calculation of real return on capital with allowance for inflation confirms the results shown here. An investor seeking an after-tax return on capital (ROC) of 15% (and under 7 year payback period) would have to sell GCEP enrichment

services for ~$200/SWU. However, the market requirement for a selling price of approximately $125/SWU would allow only about 9% ROC, corresponding to an 11 year payback period. This is to be compared with AVLIS which provides an after tax return on capital of 15% at a sale price of under $35/SWU or, alternatively, over 70% ROC at the current sales price.

Figure 12 shows for comparison the results of a more detailed discounted cash flow calculation allowing for an inflation rate of 8%. Here the required first year sales price for enrichment is even greater than the above $200/SWU in order to realize a 15% real (i.e., inflation adjusted, after tax) return on capital. We see that AVLIS does indeed become even more attractive when capital demands a reasonable return.

Conclusions

Figure 13 summarizes the results of our discussion. Although GCEP successfully avoids the high energy requirements of gaseous diffusion, the enrichment plant capital costs are even higher. Since, as we've discussed, no issues of national security are involved, the high cost/SWU and resulting low return on capital at present market prices of both GCEP and gaseous diffusion are the material factors motivating implementation of AVLIS. Finally, although the performance risk inherent in the AVLIS process can be made low, the financial risk for GCEP remains quite high because of the very low margin for profit with even the most ideal GCEP performance factor. This leaves no leeway for either increasing costs or degraded performance with the gas centrifuge program. On the other hand,

with an AVLIS program based on a guaranteed minimum 20% performance factor, as shown in Figures 3 and 8, the likelihood is that both lower cost/SWU and increased enrichment capacity will be achieved.

COST PER SWU VS CAPITAL AMORTIZATION

Cost/SWU = (Yearly capital amortization + operating costs) / Yearly Production

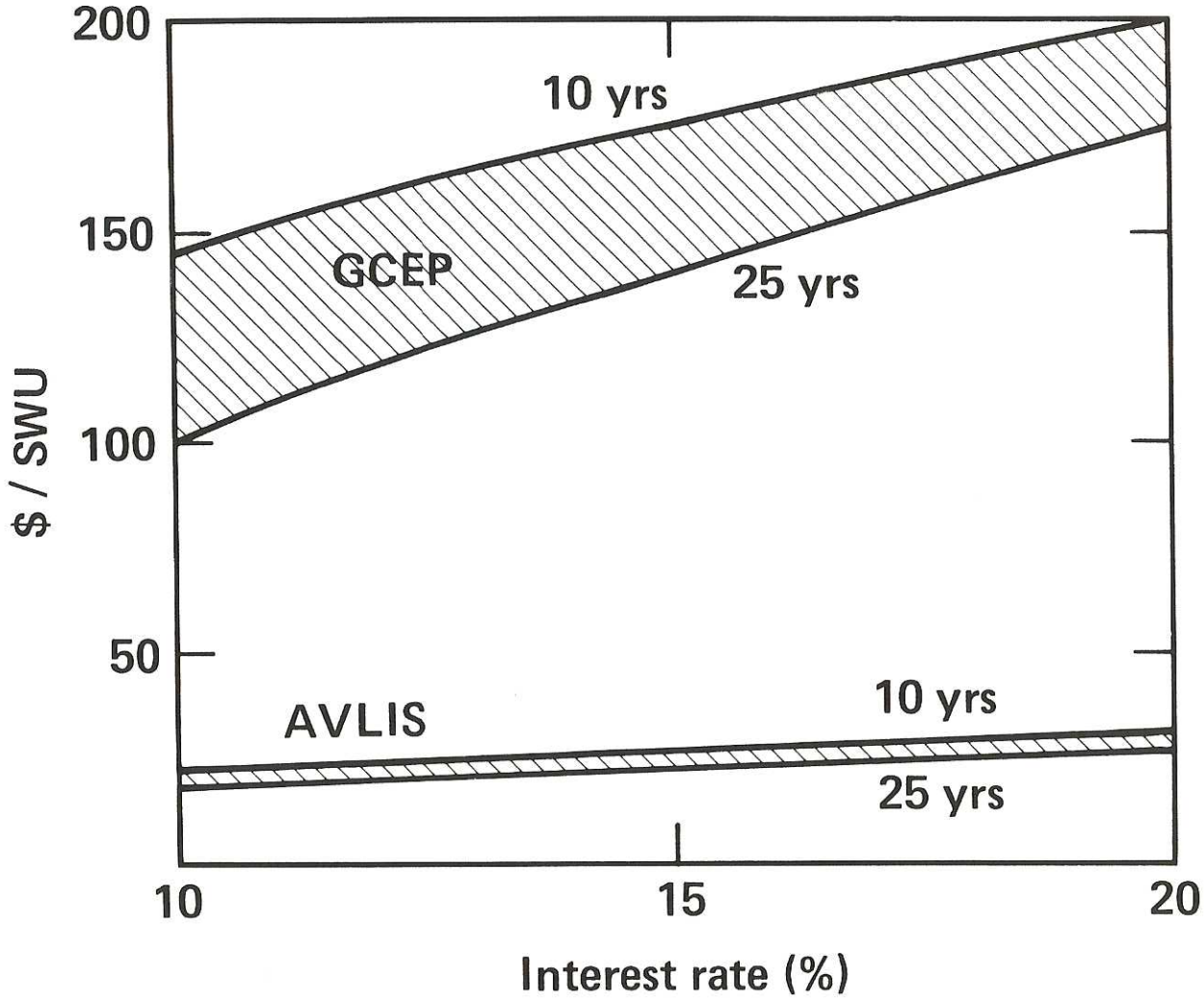

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FIGURE 1

SEPARATIVE WORK COST COMPARISON – 9 MILLION SWU/YR CAPACITY

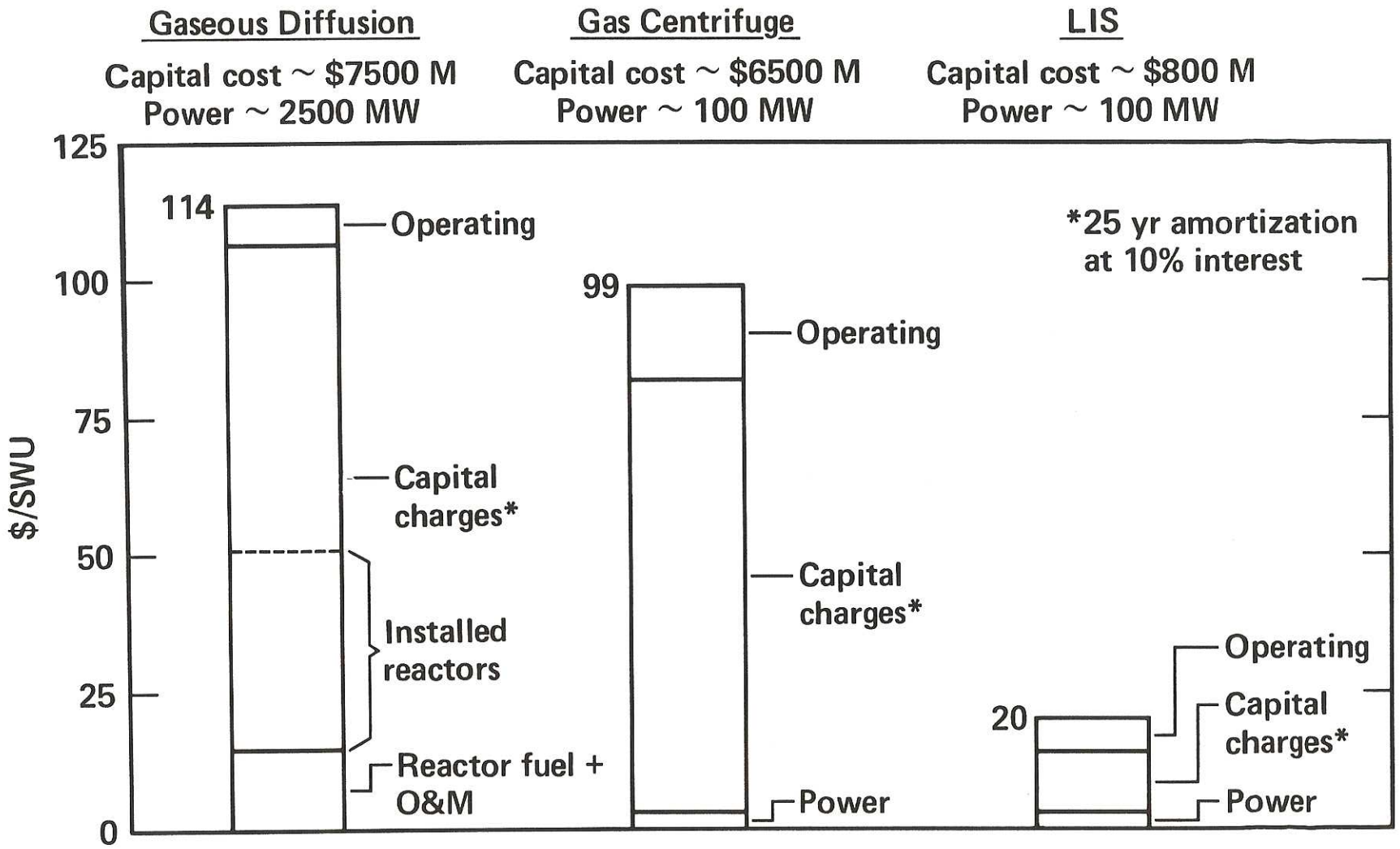

FIGURE 2

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AVLIS GUARANTEES PRODUCTION WITH CAPITAL SAVINGS

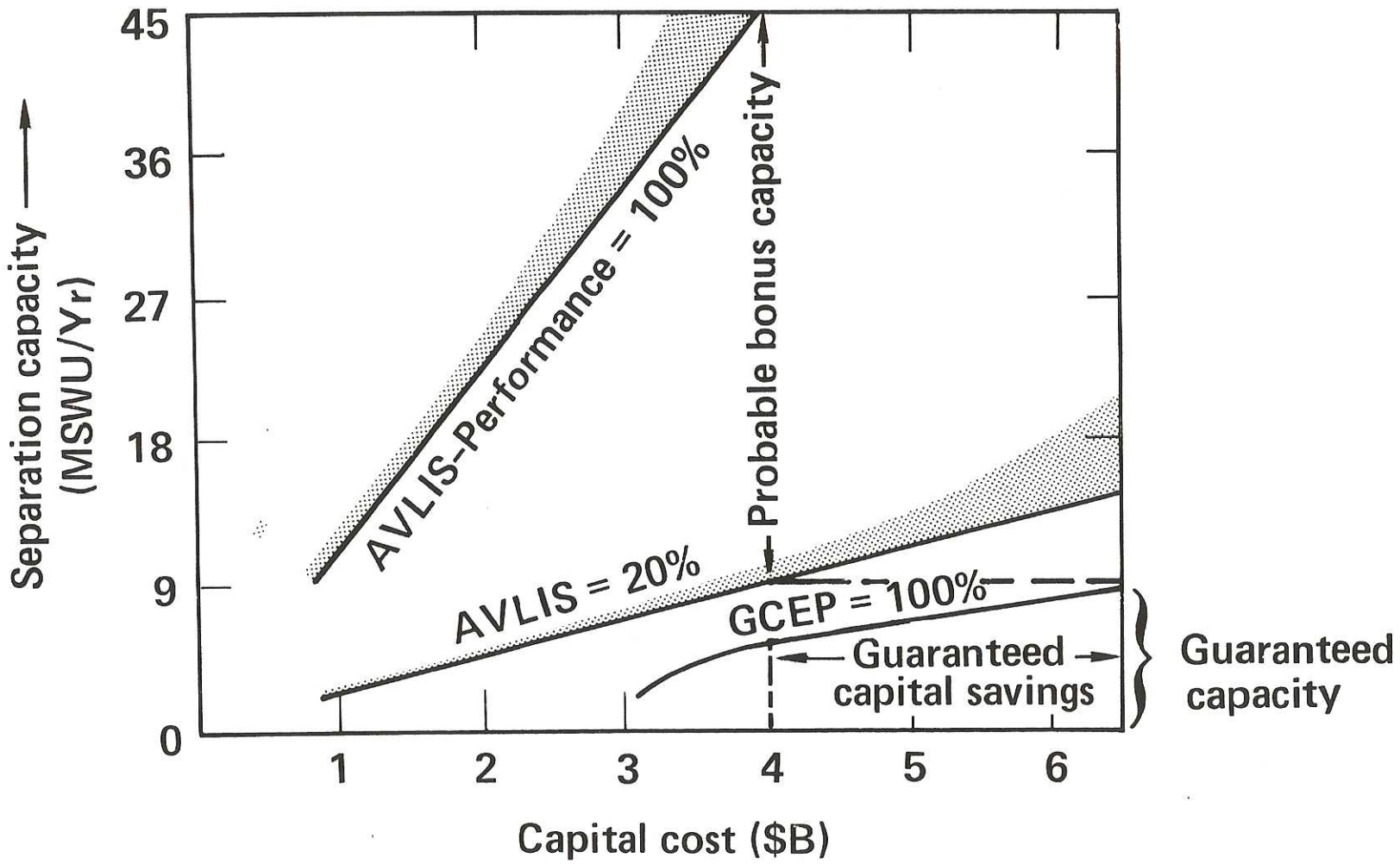

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FIGURE 3

NEAR-TERM URANIUM ENRICHMENT STATUS

- Installed capacity: 27.3 MSWU/yr
- Available capacity: 25.2 MSWU/yr
- Current production: ~10 MSWU/yr
- Current inventory: ~35 MSWU
- Current selling price: ~$130 (±10)/SWU
- Projected 1990s demand: 30-40 MSWU/yr

Requirements on New Capacity:

- Additional ~10 MSWU/yr before 1995
- Production costs ≲ $100/SWU (FY81$)

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FIGURE 4

PROJECTIONS OF DEMAND FOR DOE SEPARATIVE WORK*

(MSWU/YR)

	U.S.			Non-U.S.			Total		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
1980	7.2	7.4	7.8	5	5	5.1	12.1	12.3	12.9
1985	12.3	14	15.3	7.2	7.7	9	19.5	21.6	24.3
1990	18.5	19	20.7	8.3	9.6	12.5	26.7	28.7	33.2
1995	19.5	21.3	22.7	10.5	13.4	15.2	30	34.7	37.8
2000	22.1	24.8	27.5	12.9	16.2	18.8	35	41	46.2

*Source: Uranium Enrichment Strategy Study, Oct. 1980 scaled down proportional to DOE Uranium Enrichment 1980 Annual Report.

FIGURE 5

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NATIONAL POLICY ISSUES

- Not including a reasonable profit in government project evaluations merely transfers this "cost" to private sector
  - Higher interest rates
  - Inflationary pressure (hidden tax)
  - All social projects must be evaluated on common basis
- U.S. government may wish to sell SWU's cheaply
  - Maintain control of enrichment business
  - Retard proliferation
  - Help balance of payments
  - But, policy is to recover costs
- High capital projects add to government's vested interest in inflation

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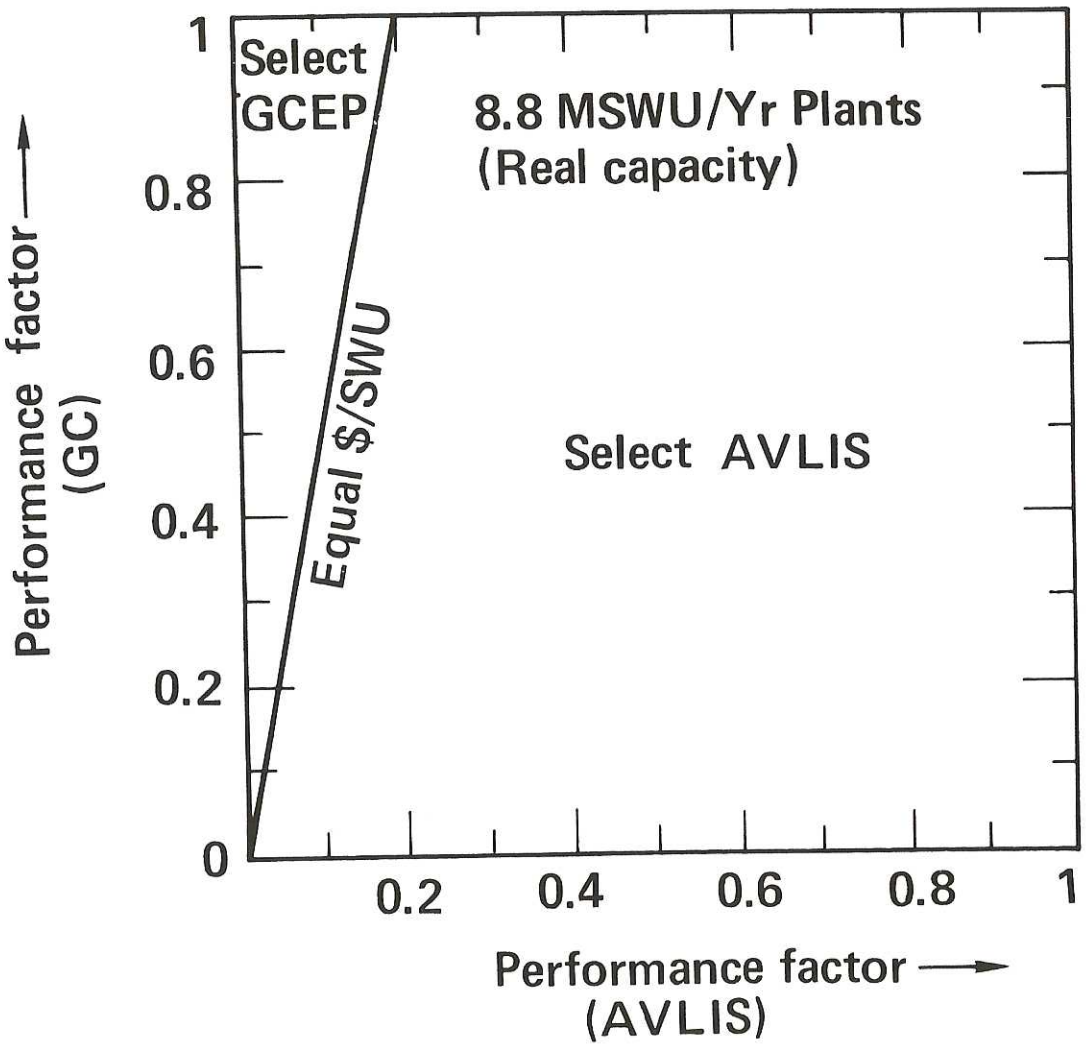
FIGURE 6

DECISION DIAGRAM : GCEP VS AVLIS



- AVLIS with ≳20% performance factor is preferred
- AVLIS always has lower capital cost for the same $/SWU

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FIGURE 7

COST PER SWU VS PERFORMANCE

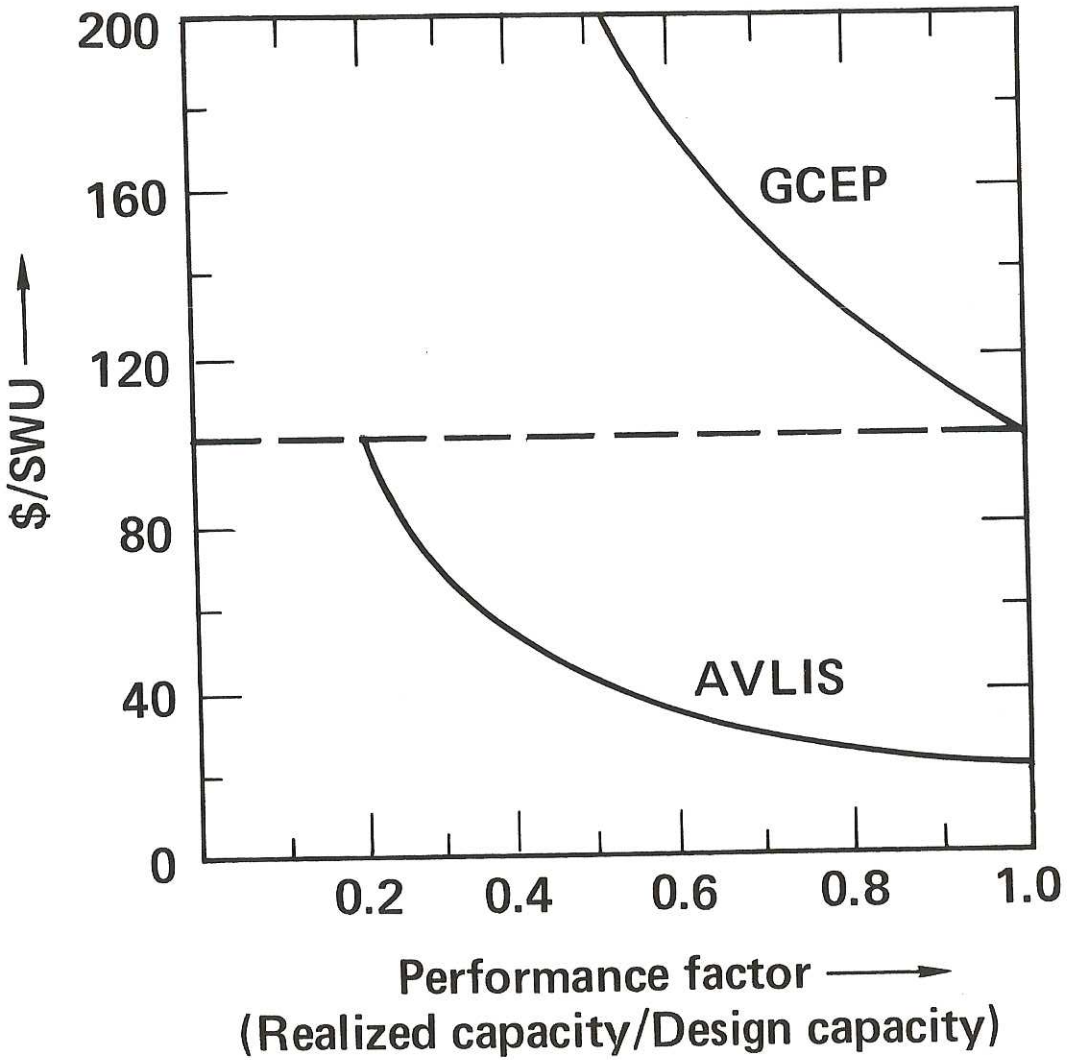

FIGURE 8

CAPITAL COST FOR 8.8 MSWU/YR PLANT

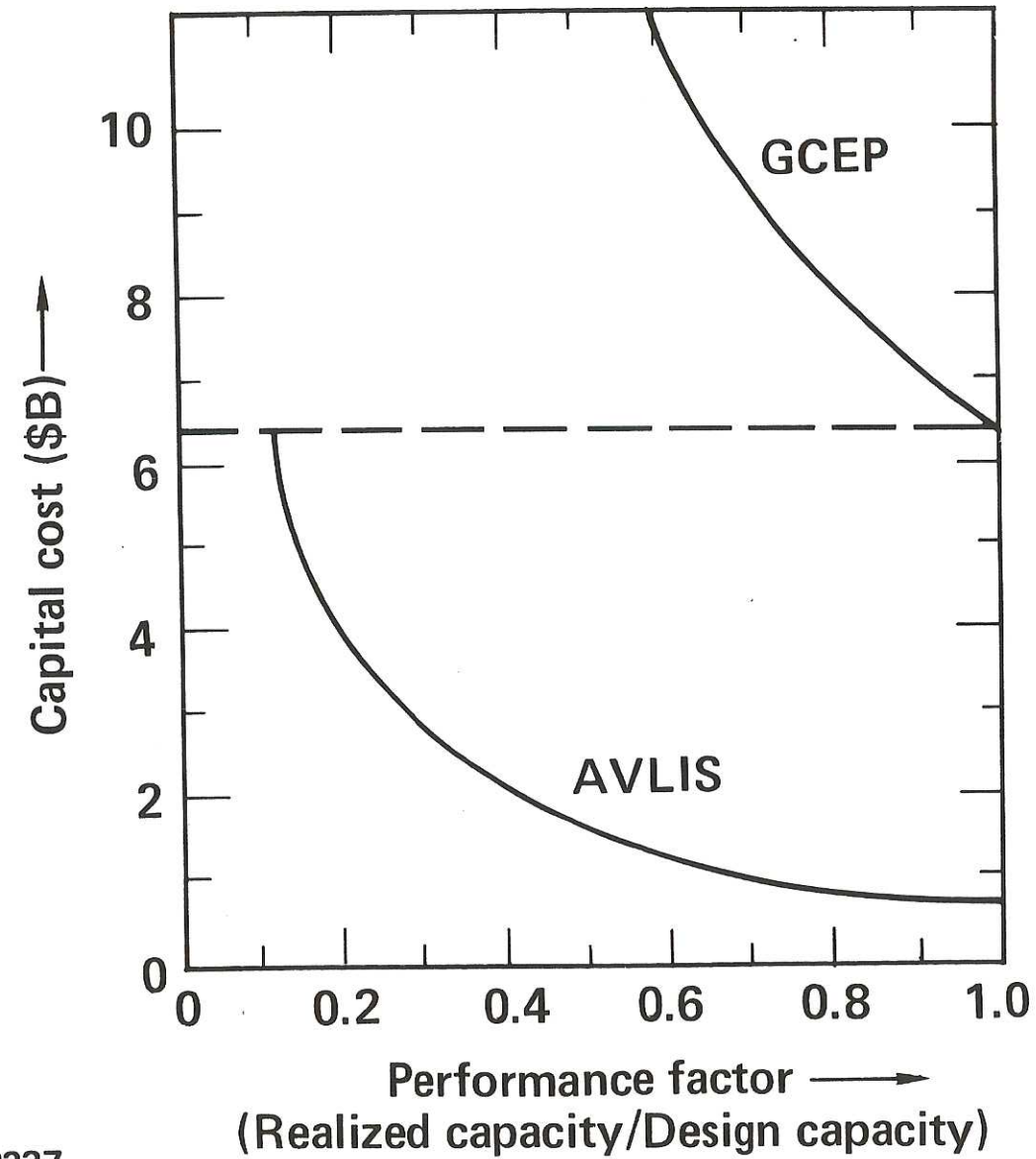

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FIGURE 9

PERFORMANCE GROWTH YIELDS REDUCED $/SWU

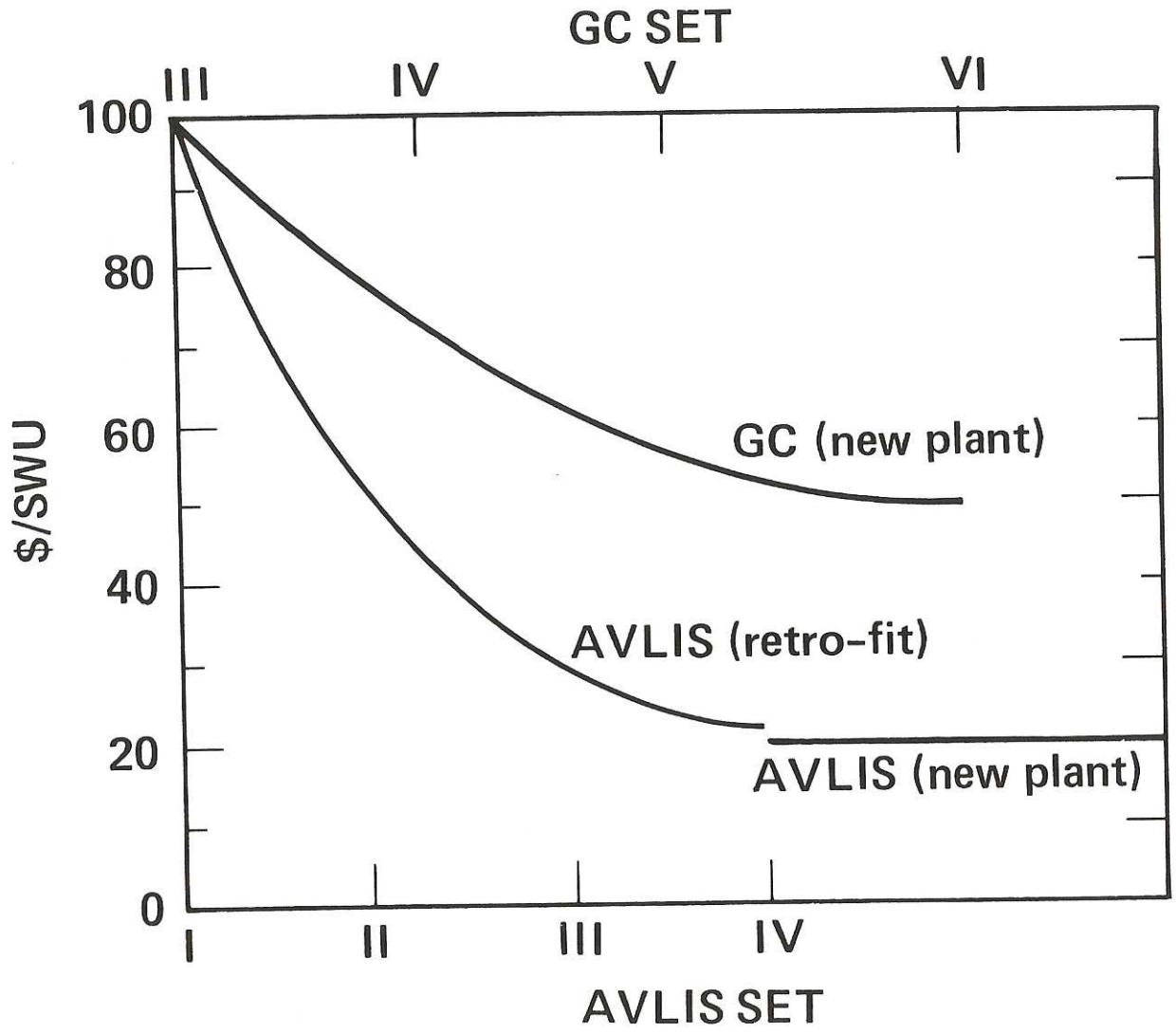

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FIGURE 10

INVESTOR AND MARKET REQUIREMENTS CONFLICT

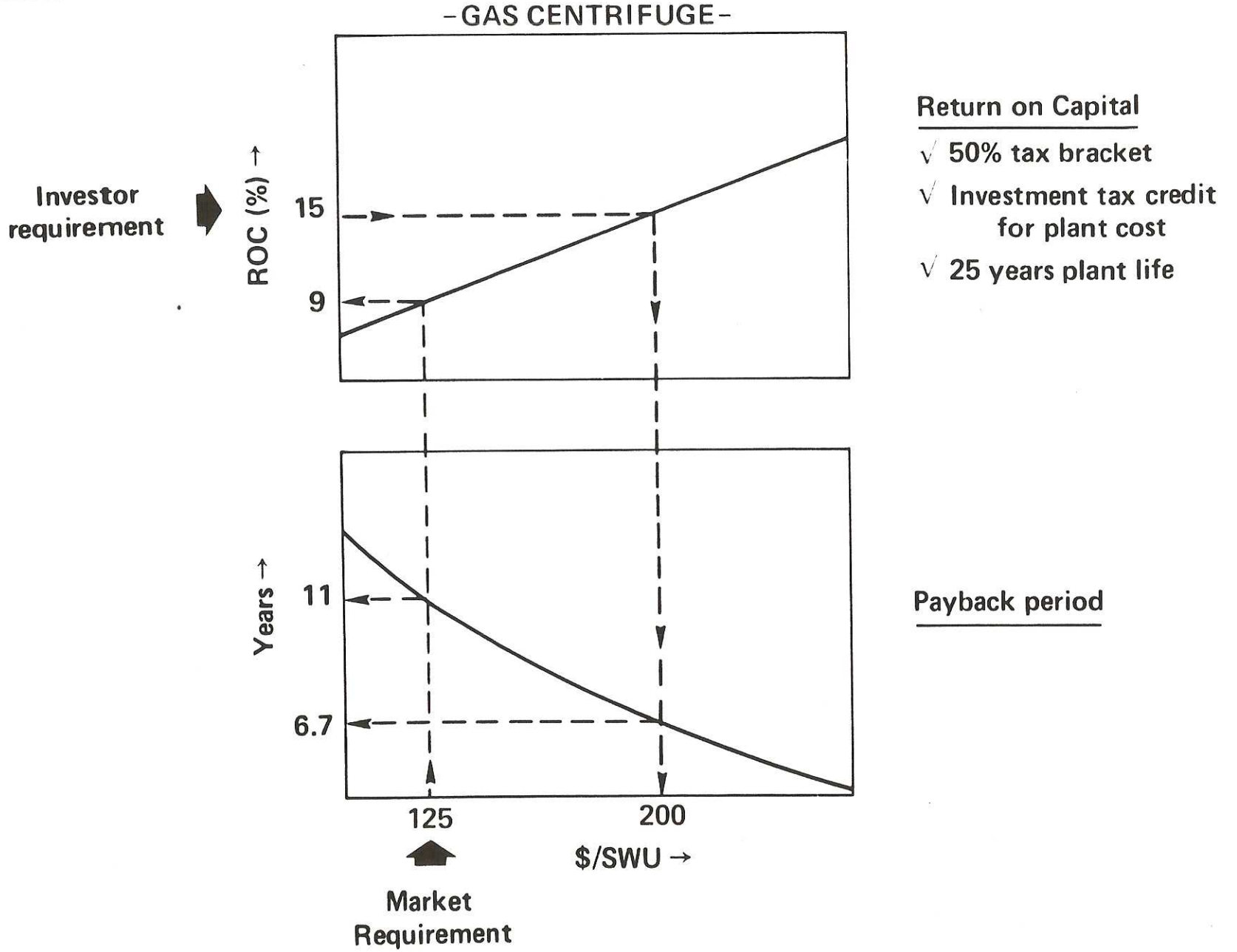

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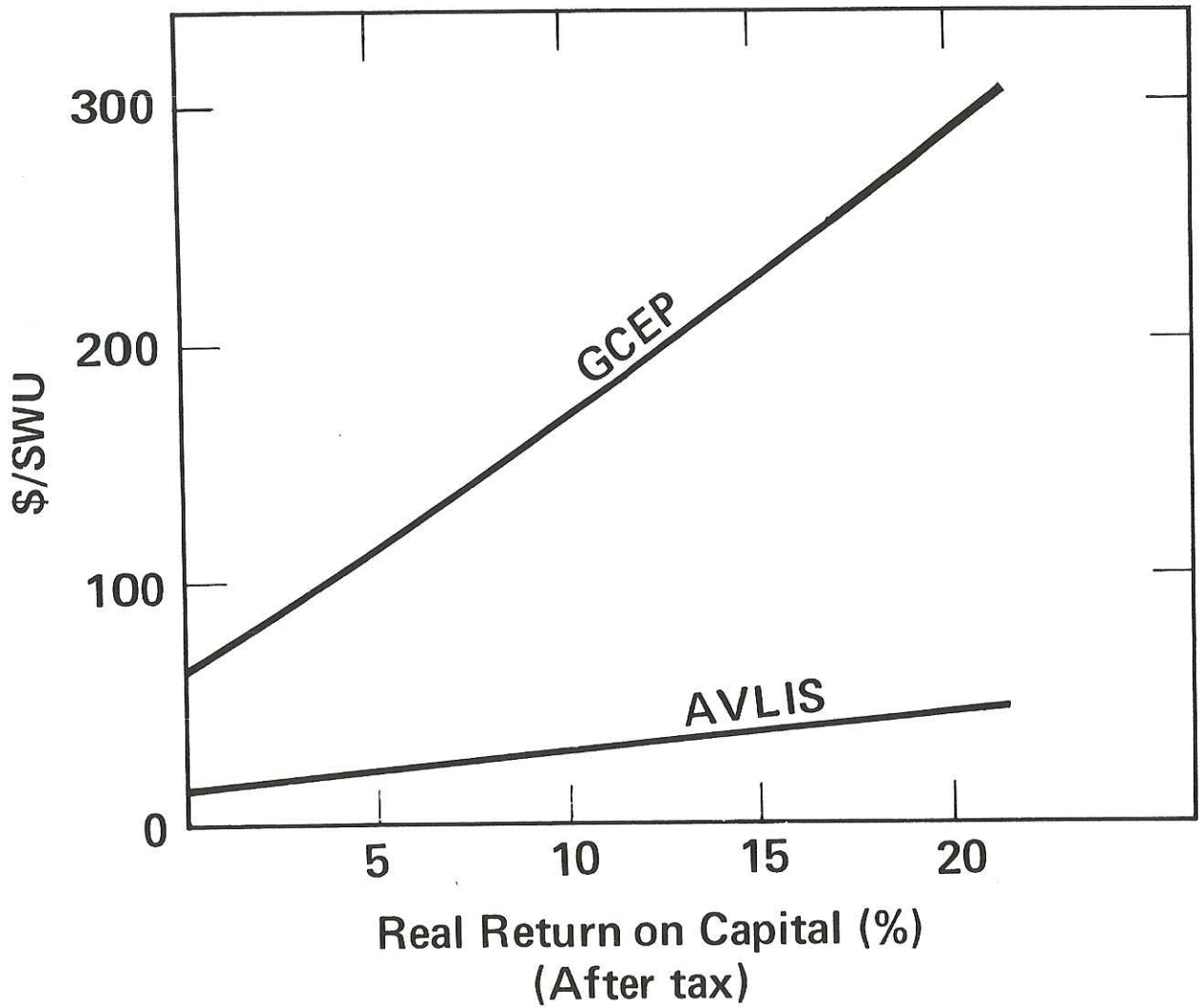
FIGURE 11

AVLIS IS EVEN MORE ATTRACTIVE WHEN CAPITAL DEMANDS A REASONABLE RETURN



- Discounted cash flow analysis, adjusted for inflation at 8%

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FIGURE 12

SUMMARY

	Energy Requirements	Capital Cost	$/SWU	Return on Capital	Performance Risk	Financial Risk
Diffusion	High	High	High	Low	Low	High (escalating energy costs)
GCEP	Low	High	High	Low	Low	High (escalating capital costs)
AVLIS	Low	Low	Low	High	Low*	Low

*Build required capacity at guaranteed minimum performance factor.

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FIGURE 13