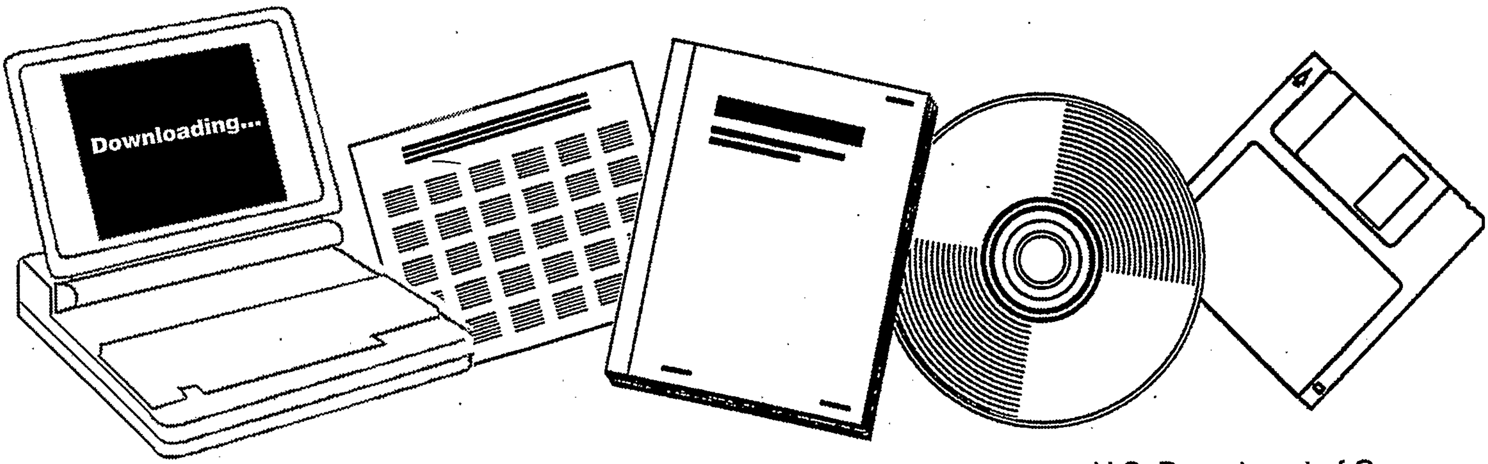
CAPITAL BUDGETING EXTENSION TO THE ECONERGY PORTFOLIO MODEL. ECONERY REPORT NO. 1-704

ECONERGY INC.
LOS ANGELES, CA

FEB 1977



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A CAPITAL BUDGETING EXTENSION TO THE ECONERGY PORTFOLIO MODEL

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ERDA Contract No. EX - 76 - C - 01 - 2517

Econergy Report No. 1-704

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February, 1977

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1. INTRODUCTION

There are two interrelated problems associated with making a selection for investment in a set, *or portfolio*, of new energy related projects. The first problem is to determine the best combination of projects from the point of view of overall economic benefits commensurate with the innate risks associated with them. Having done this, the second problem is to determine a suitable schedule for implementation.

The first question can be resolved by using the *Econergy portfolio model*. The basics of this model were developed and reported originally by English *et al* (1976) and extended and applied to actual coal demonstration plant projects in Econergy report No. 1-703, January, 1977. In this methodology, each candidate project is evaluated in terms of its time related schedule of capital costs, operating costs, revenues, and other benefits. These are all reduced to reference present values by means of the standard discounted cash flow (DCF) evaluations. Effects of probabilistic schedule changes (i.e., slippages or stretch out) are taken into account as *time* related costs. The net benefits of each project are then reduced to *normalized* reference *indices* by dividing by the present value of the related project investment. The uniqueness of the methodology then arises from the way risk is treated. Risks, both financial and technical, are assessed for each project separately as well as conjointly by pairs of projects to develop an interactive risk matrix. In principle this is a similar approach to that of the classical portfolio model of Markowitz (1952). These risks are also normalized by the investment scale of each project as was done for the net benefits. By plotting each acceptable combination (portfolio) of projects on an orthogonal coordinate system, the resulting *benefit/risk* map, Figure 1, may be examined to select the desired portfolio.

While each project is evaluated independently in terms of its unique expected *cash flow* streams, the presumption is that all projects will be started at the same zero time. This would require that no limit or budget constraint is imposed on the capital requirements in any year. Typically, a large scale energy project will require several years of study and engineering design. In addition, negotiations must proceed for approvals of environmental impacts, financing, and pricing regulation if the project comes under review by a utilities commission. During this time, which can stretch out over several years, expenditure levels are low. When construction is started, expenditures must increase by an order of magnitude and the schedule must be tightly controlled. Finally, there will be a shorter period for start-up before the project becomes fully operational and generates a positive cash-return flow.

The capital requirements for a portfolio of projects will be the sum, on a year by year basis, of the capital needed to fund each project. Because the total capital budget is limited, the various projects may have to be phased with respect to one another in such a way as to make the best use of available capital. The methodology for accomplishing this is called *capital budgeting* and provides the solution to the second problem in the economic evaluation of a portfolio of projects.

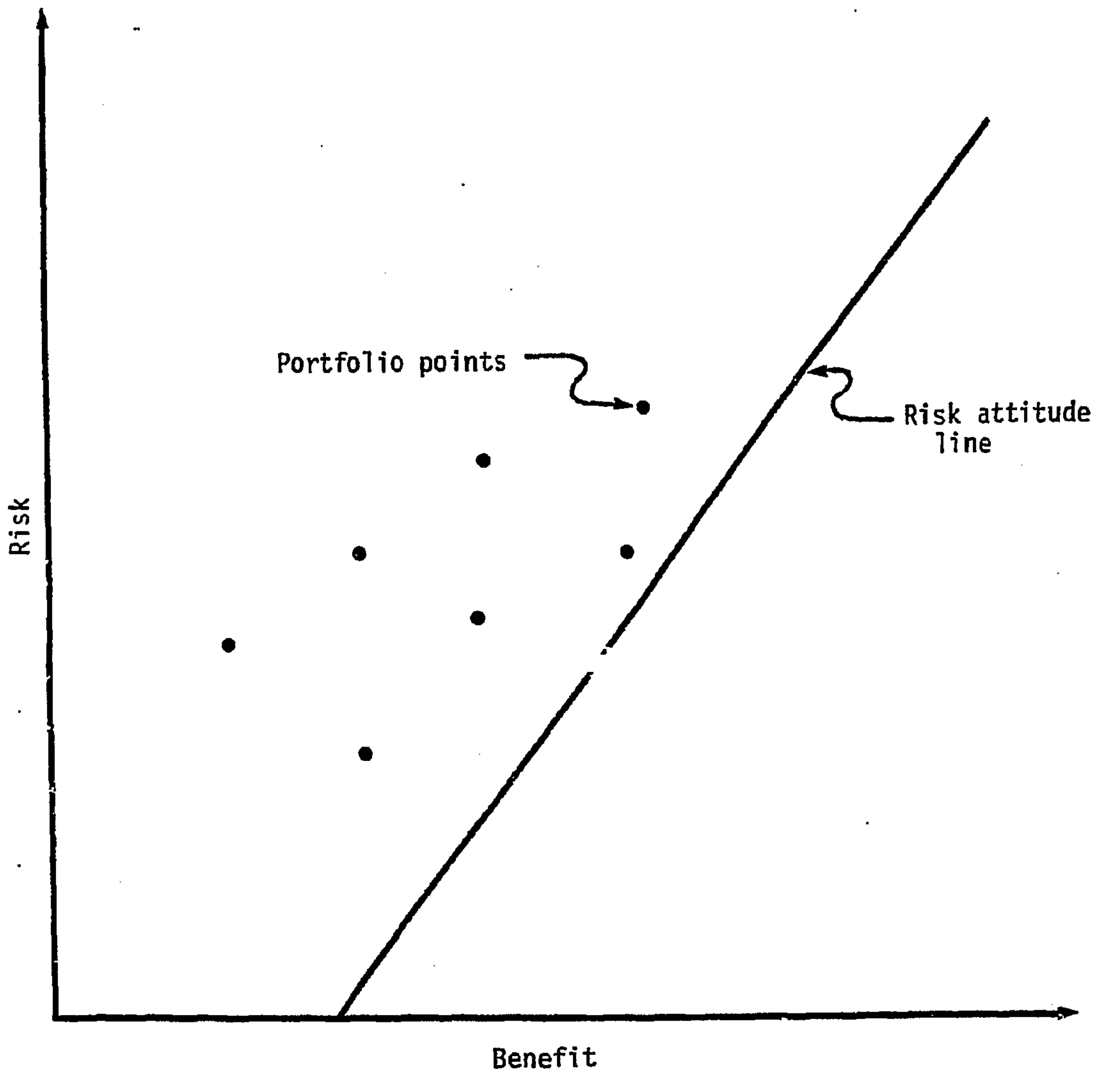

Figure 1. Typical Benefit/Risk Map

It will be evident that the two methodologies do not provide independent solutions. The solution of the Econergy portfolio model was predicated on a given schedule of expenditures for each candidate project in the portfolio. Given this solution for the desired eventual portfolio, the capital budgeting model will require a readjusted schedule. This, in turn, may require a modified portfolio. Thus, an iterative approach is indicated.

The basic approach to capital budgeting, with some unique features, was presented in the report by English et al (1976). The approach is extended in this paper to demonstrate how it may be utilized in conjunction with the Econergy portfolio model.

2. BASIC CAPITAL BUDGETING MODEL

The fundamental concepts of capital budgeting are quite straight-forward if risk is not considered. Simply stated, the objective is to allocate capital to all admissible projects in such a way as to maximize the total net present worth of the sum of all cash flows -- both negative cash flows as investment outlays and the return revenue-in-excess-of-cost cash flows-- subject to annual budget constraints. In mathematical form, the objective function is

$$\max PW = \sum_{i=0}^{\infty} \sum_{j=1}^{n} x_{ij} \alpha^{i} \tag{1}$$

subject to

$$L_i \geq \sum_{j=1}^{n} C_{ij} \tag{2}$$

where x_{ij} is the cash flow for project j in year i,

$$\alpha_i = \frac{1}{(1+r)^i} \quad \text{is the discount factor}$$

at the discount rate r for the i^{th} year,

$$C_{ij} = \begin{cases} x_{ij} \text{ if } x \leq 0 \\ 0 \text{ if } x > 0 \end{cases}, \text{ the capital expenditure for}$$

project j in year i, and

$$L_i = \text{budget limit in year i}$$

A problem arises from the intractability of practical solutions; the dimensionality of the programming routine becomes excessive. Weingartner (1963), as well as many others, have contributed extensively to the literature on this subject but practical solutions depend on how real world problems are simplified. The Econergy model is unique in its application to energy projects and the simplifying assumptions required for it are discussed below.

2.1 Postulations

1. *The Horizon.* Two separate planning horizons are used. The first is the capital planning period that, as a practical matter, is at most seven or eight years ahead. The second is long term. In a theoretical sense, all projects should be considered infinite because the decision to invest is fundamentally irreversible. However, it is customary to take some arbitrary cut-off time -- usually 20 years from start of operations.

Actually, comparison of projects requires consideration of a common terminal date for all projects. However, the DCF values of various projects will not be seriously influenced by discrepancies between terminal dates.

An example will illustrate this point. Consider the present worth of an annuity of $1.00 for 20 years versus one for 25 years, both at a discount rate of 12%. The PW of the first if $7.47 and the second is $7.84 -- a difference of only 5%. For a perpetuity the PW is $8.33.

If the projects considered for the capital budget allocations are all assumed to have a 20 year operating life and the time required from inception to start-up varies between 3 to 6 years, the discrepancy in horizon is then the difference between 23 and 26 years. This will amount to approximately a 2% effect.

2. *Project Continuity.* It will be assumed that once a candidate project has been funded, it will not be considered for abandonment in subsequent years, nor will the schedule of budget allocations for the project be changed after start of construction. However, expenditures for studies, investigations, various approval applications, and detailed engineering design may extend over several years. Postponement of project construction may occur at the conclusion of engineering with some allowance made for continuing engineering needed to keep the project viable.

3. *Budget Constraint.* The yearly budget constraint will be specified as a matter of policy for each year up to the capital budgeting horizon. The budget constraint will be defined as an inflexible limit for the first year. All projects that are candidates for funding in that year will be

specified. However, for subsequent years, new projects, presently unknown and unknowable, will be proposed. Because they are unknown, it will not be possible to include them in any explicit selection or ranking process. Nevertheless, it can be asserted with confidence that some of these future proposals will justify inclusion in the portfolio at some time in the future. In order to provide for these unknown candidate investments, a certain proportion of the budget will be reserved for them. The percentage allocation so reserved may be expected to start small in the second budget year but increase yearly to some maximum level that is determined on the basis of policy decision.

4. *Target Budget.* The target budget is the budget constraint reduced by future project reserves discussed under *Budget Constraints* above. Each year's project funding will be in discrete amounts that only coincidentally would add up to the target budgets. These target values are rough estimates that, based on judgement, may be extended to accommodate certain projects that otherwise might slip excessively. The use of this *fuzzy* constraint will be clear from a subsequent example. The principles on which such reserve budgets are justified have been demonstrated for the management of stock portfolios (Smith, 1971).

5. *Budget Carry-forward.* Any unused portion of the target budget will be considered lost. No carry-forward to subsequent years will be permitted. Except for possible loss of budget in the first year, such losses of budget will not necessarily be real. In effect, they become part of the reserve budget for presently unknown projects in the future. By similar reasoning, overruns of the target budget will not be borrowed from future years but simply be considered as reductions of reserve.

6. *Order Independence.* While there may be compelling reasons to fund projects in a particular order, no ordering sequence will be imposed. In other words, it will be assumed that each project may be started at any time without impacting the costs or benefits of any other project.

7. *Irrelevance of Sunk Costs.* Some projects of the portfolio will already be under way and expenditure incurred. These costs will not be relevant in themselves. Only future opportunity costs are of concern. However, the remaining capital costs, being reduced by virtue of earlier expenditure, will result in raising the relevant present worth of the project.

2.2 Method for Satisfying the Budget Constraint

The set of candidate projects are all members of a desired portfolio. As such, and in the absence of any budget constraint, they would be funded in the first year. Because there is an imposed budget constraint, some acceptable candidate projects(s) will have to be postponed. The budget constraint will not necessarily be limiting in the first year but may be so any year within the capital budgeting horizon. This might occur when the capital cost schedules for a number of projects tended to peak simultaneously. The problem is to select these projects for schedule slippage in such a way as to minimize the reduction in value of the desired portfolio by minimizing the costs of such slippage.

There will be a penalty for each year by which a candidate project slips. This penalty will be represented as an incremental reduction in net benefits. Concomitantly there may or may not be a change in risk. In most cases the delay of a project will be accompanied by a corresponding reduction in risk because more time will be available to gain experience.

There may be a number of ways in which all candidate projects comprising a portfolio can be slipped and still satisfy the budget constraints. Each change will, in effect, represent a revision of the portfolio point on the benefit/risk map, Figure 2. These changes result in different benefits and risks. The best revised final portfolio may be selected in relation to the risk attitude function represented by line AB in Figure 2.

The suggested procedure is to slip projects one year at a time to satisfy each year's budget constraint in turn and to do this in a way that will minimize the accumulated benefit penalty. These penalties are expressed in present worths. Having found the set of schedules that satisfy all budget constraints to minimize penalties, the changed risks are then assessed. The first step in effect moves the desired portfolio point, P_1, back to P_1'. The second step is to move it to the final portfolio point, P_1''. The procedure for doing this may be computerized and integrated with the program for the portfolio selection for fossil demonstration plants, English et al (1977).

It should be noted that P_1 was the best portfolio under zero budget constraints. Let us assume the next best portfolio is represented by P_2. This other portfolio may now be examined in the same manner to find its budget-adjusted value, P_2''. The characteristics of the processes in each portfolio may be such that after determining the budget-adjusted portfolios, P_2 will turn out to be the preferred portfolio, whereas P_1 was initially the best in the absence of budget constraints.

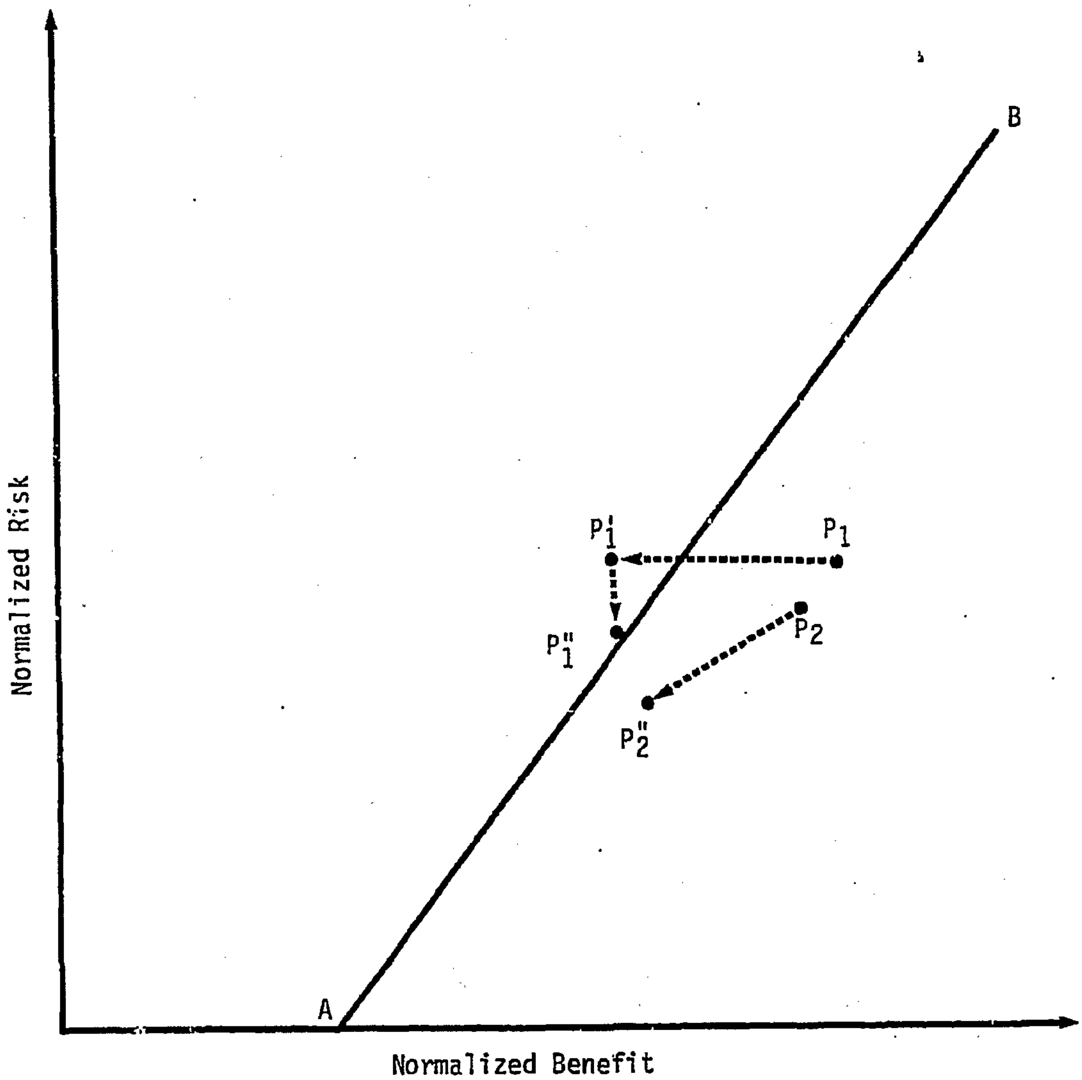

Figure 2. Movement of Portfolio Point Resulting from Budget Constraint

3. ILLUSTRATIVE EXAMPLE

The methodology for capital budgeting may best be explained by means of an example designed to illuminate the essential features of the methodology (Table I). For this purpose, hypothetical data for several projects have been selected. In actual practice, commercial scale data would be used to determine the best funding mix for candidate demonstration plants. Some of the candidate projects chosen are assumed to have been started as much as three years ago. As such, the original budgets during the earlier years already have been spent. These are now sunk costs. As a consequence of this history of expenditures, there is an implicit budget commitment for continuation of these projects.

Return cash flows that will be generated from the typical capital expenditure streams are not shown in the table but are assumed to be spread out over the life of the project to produce the net present worths indicated in the Column labeled PW. The discount rate for computing the present worths is taken to be 10%. This discount rate is currently required by the Office of Management and Budget (OMB) for government capital investment.

3.1 Net Present Worth

Net present worth (PW) at time zero is the discounted cash flow of both capital outflow streams and net cash return flows, i.e., PW's are DCF's of the cash flows in Column B, i.e., to the right of the current time line. Return cash flows are not shown because they do not influence the procedure. They are incorporated implicitly in the PW. The capital cash outflows of Column A are historical; they must be treated as sunk

	Projects	A Prior Years			B Future Years								Net Present Worth	Slippage Cost-1yr.	Sustaining Effort Cost
		-3	-2	-1	1	2	3	4	5	6	7	8	PW	ΔP	ΔS
Capital Expenses ($MM)	1	10	20	300	400	200	-	-	-	-	-	-	533.9	48.5	∞
	2	-	15	20	450	600	400	100	-	-	-	-	255.0	23.2	10
	3	5	10	200	300	300	100	-	-	-	-	-	350.0	31.8	∞
	4	-	5	10	120	400	60	-	-	-	-	-	150.0	13.6	4
	5	-	-	-	5	10	300	400	100	-	-	-	178.0	16.2	-
	6	-	-	-	10	15	600	600	100	20	-	-	211.0	19.2	-
	7	-	-	-	5	8	400	350	35	-	-	-	130.0	11.3	-
	8	-	-	-	2	5	100	50	-	-	-	-	80.0	7.3	-
Total Expenses		15	50	530	1292	1538	1960	1500	235	20	-	-			
Budget Constraint		-	-	-	1000	1200	1440	1600	1700	1800	1800	1800			
% Budget Reserve		-	-	-	0%	20%	40%	50%	50%	50%	50%	50%			
Target Budget		-	-	-	1000	960	864	800	850	900	900	900			
Budget Reserve		-	-	-	0	240	576	800	850	900	900	900			
Fuzzy Constraint		-	-	-	0	120	144	160	170	180	180	180			

Table I Basic Portfolio of Financial Data for the Eight Projects costs and are not relevant to the present capital budgeting decisions. However, it must be assumed that at the time Projects 1 through 4 were started, the DCF's of these projects were high enough to justify the initial decisions to proceed with them. Furthermore, the projected cash flows may have changed from the initial estimates. Such changes in estimated cash flow may be due to cost overruns or underruns, stretchouts in the schedules, and subsequent revenues and operating costs. Unless such revisions are of major significance, the PW's at the *present* zero time will be greater than the original PW's at the time the projects were started due to project capital investments which have already been made (sunk costs). If no revision has been made in estimates of future cash flow streams, the increase of the PW will be equal to the future worth of the sunk costs. It will be recognized from this that a project already under way tends to be upgraded in priority relative to newly proposed projects simply because of the increase in expected value.

To illustrate this, assume that the PW of Project 1 was \$125 MM at its start three years ago (t = -3) and that the actual expenditures were equal to those estimated during years t = -3, t = -2 and t = -1. Also, estimates of future expenditure and revenue streams remain unchanged. The reference present time has been shifted ahead by three years. Therefore, the original PW, which is really nothing more than a time-value index, must be shifted to the new zero time. Thus, the current PW using an r of 0.10 and before taking account of sunk costs will be

$$PW = 125(1+r)^3 = \$166.4$$

Now, adjusting for sunk cost, the current PW is \$166.4 plus the compounded amounts of the expenditures of \$10, \$20 and \$300 prior to $t = 0$. This is $166.4 + 10(1.1)^3 + 20(1.1)^2 + 300(1.1)^1 = \$533.9$.

For Project 2, cash flow estimates may have changed from the time of its inception but that change would be reflected in the PW for Project 2 listed in the column labeled PW. All other values of PW are merely chosen as representative of reasonably realistic situations.

3.2 Slippage Penalties

The Econergy portfolio model provided for unscheduled slippages of individual programs due to revisions of the capital expenditure schedule. Such revisions change the shape of the capital cash flow stream and, accordingly, affect the PW for the project but they do not allow for postponement of the project in its entirety. Thus, a separate slippage for an entire project may be scheduled to satisfy budget constraints. However, this type of slippage is not probabilistic and the shape of the expenditure stream will remain unchanged. There are two quite different ways in which such scheduled slippages can occur. The first is to move the entire cash flow schedule to the right. The penalty for doing this is recorded in Column ΔP, i.e., postponement. The amount shown is the reduction of PW for moving the start of the project one year. The value of this one year slippage is

$$\Delta P = \left(\frac{r}{1+r}\right) PW \qquad (3)$$

where r is the appropriate discount rate.

For m years the slip value is

$$\Delta P = \frac{(1+r)^m - 1}{(1+r)^m} PW \qquad (4)$$

The second penalty cost, ΔS, arises only if it is necessary to slip the schedule after the early lower cost years have elapsed. Typically the first few years of a large scale project are devoted to feasibility studies, engineering, financing arrangements, environmental impact studies, and obtaining of final regulatory approvals. Up to this point major construction contracts may be in negotiation but no commitment of funds for construction will have been made. This is not to imply that delays are without cost. There will be some sustaining effort for further investigation, maintenance of the engineering team, and the like. Therefore, postponement will entail an explicit expenditure beyond the time cost associated with the first type of slippage. Thus, the cost of slippage for one year, for a project already under way, will be

$$\Delta P = \Delta S + \left(\frac{r}{1+r}\right)PW \tag{5}$$

where ΔS is the estimated cost of the sustaining effort. ΔS would be supplied as data for each project as opposed to being calculated.

It should be noted that the present worth listed in all the tables are the PW's of the remaining cash flows with sunk costs excluded. The technique for doing this is shown in Table I-a for Project 6 and Table I-b for Project 2. Tables I-a and I-b are simply partial reproductions of Table I to show only one project at a time. The original schedule of Table I-a for the project is reproduced exactly from Table I and immediately below is the revised schedule showing the slip. Project 6 is only in the proposal stage, so that the revised PW is obtained by subtracting the ΔP for one year. A second years's slip is merely a repeat of the procedure.

Project	A Prior Years			B Future Years								Net Present Worth	Slipp. Cost	Sustain. Effort Cost		Prior Penalty	Accumulated Penalty
	-3	-2	-1	1	2	3	4	5	6	7	8	PW	ΔP	ΔS	ΔP+ΔS		
6	(No Slip) -	-	-	10	15	600	600	100	20	-	-	211.0	19.2	-	19.2	0	0
	(1 Year Slip) -	-	-	-	10	15	600	600	100	20	-	191.8	17.4	-	17.4	0	19.2
	(2 Year Slip) -	-	-	-	-	10	15	600	600	100	20	174.4	15.9	-	15.9	19.2	36.6

Table 1a Partial Table I Showing the Effect of Slippage of Project 6

Project	A Prior Years			B Future Years								Net Present Worth	Slippage Cost	Sustain. Effort Cost		Prior Penalty	Accumulated Penalty
	-3	-2	-1	1	2	3	4	5	6	7	8	PW	ΔP	ΔS	ΔP+ΔS		
2	(No Slip) -	15	20	450	600	400	100	-	-	-	-	255.0	23.2	10	33.2	0	0
	(1 Year Slip) -	15	20	10	450	600	400	100	-	-	-	231.8	21.1	9.1	30.2	0	33.2
	(2 Year Slip) -	15	20	10	10	450	600	400	100	-	-	210.7	19.2	8.3	27.5	33.2	63.4

Table Ib Partial Table I Showing the Effect of Slippage of Project 2

A slightly modified procedure is needed for Project 2 because it is impossible to slip the engineering costs already spent. In this case, a ΔS of 10 is added both as a penalty and as an expenditure to be budgeted in year 1. As in the single decision portfolio model, the net PW which actually is the net benefit measure, may be divided by the PW of the capital investment cost as adjusted for penalties, in order to non-dimensionalize or *normalize* the benefits for representation on the benefit/risk map. However, this normalization was not included in the present example to keep the illustration as straightforward as possible. The reader should be reminded that the normalizing value is the PW of projected capital investments *exclusive* of the sunk costs.

3.3 The Budget Constraints

The candidate projects of Table I are all acceptable projects in that the PW of each is positive. If unlimited resources could be made available, all projects of the desired portfolio would be funded to start in the first year. Because there is specified a budget limit, some projects must be postponed. The criterion for selection of those projects to be postponed is that collective penalties will be minimized. The dual of this will be that the retained projects must have the maximum PW (after adjustment for penalties).

As a matter of economic policy, the budget may be expected to grow from year to year at a suitable rate to ensure eventual funding of sufficient projects for achievement of the national goal. However, as discussed in Section 2, all the projects that eventually will need to be funded cannot possibly be foreseen at the present time. There can be a high degree of assurance that at least one or more new concepts will be proposed next year and the number of these will increase for the following and subsequent years. While specific future projects cannot be foreseen, let alone evaluated, there can be considerable confidence that when they are recognized they may have as high, or higher, priority than presently identified projects. For this reason and based on subjective evaluation, an increasing percentage of the budget must be reserved for unforeseen future projects. Therefore, it is desirable to provide a reduced target budget as shown in Table I (page 12).

It must be emphasized that such an arbitrary subdivision of the budget between unforeseen projects that are not assessable and identified projects that are assessable must, of necessity, be distinguished by a very fuzzy boundary. For this reason, an arbitrary rule may be chosen, *a priori*, that the indicated adjusted budget will be accepted if it falls within some specified plus or minus percentage of the target budget. In the illustrative example this will be taken as ± 10%. The fuzzy boundary is shown in Table I as "Allowable Overrun."

3.4 Process of Slippage

An examination of Table I indicates that, for the first year, the real budget limit (not flexible) is $1000 for a budget need of $1342. Therefore, $342 must be freed by selecting some project or projects to be moved to some future start time. Projects 1 and 3 are immovable because construction has been started and to slip them at this point would impose penalties that are clearly excessive. There is only one, Project 2, that is capable of satisfying the constraint by postponement. A revised table, Table II, is shown with the immovable projects, 1 and 3, now omitted. The budget limits are revised accordingly. Penalties for a one year slippage are shown in the right hand columns under ΔP and ΔS.

Now year 1 is under budget, but year 2 is $478 over budget. Again, it is not possible to accommodate this deficit except by moving Project 2 one more year, Table III.

At this stage, an option appears as to which projects to move. In year 3 with a deficit or overrun of budget amounting to $1146, we have the choice of slipping Project 2 again, but now Project 2 alone will not free sufficient budget. Some combination of 5, 6, 7, or 8 must be included. However, we could keep 2 and move 5, 6, 7, and 8. The decision will depend on meeting the fuzzy constraint of the target budget while minimizing slippage penalties. Greater emphasis will be placed on the latter criterion. It turns out that this minimum penalty occurs with slipping 2, 6, and 8. Clearly, if 6 and 8 slip at this stage and, thereby, require a ΔS penalty, it would have been preferable to have postponed the initial engineering study phases until such time that the schedule could be maintained without interruption. This would eliminate the need for an interim sustaining year. Furthermore, there will be better information available a year later and the engineering could be expected to result in a better design. Thus, Table IV is revised to reflect this effect by moving the schedules of Projects 2, 6, and 8. Further, Project 4 is beyond further consideration and may be eliminated from Table IV and the budget adjusted accordingly.

	Projects	Years								Net Present Worth	Slippage Cost	Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	2	10	450	600	400	100	-	-	-	231.8	21.1	9.1	33.2
	4	120	400	60	-	-	-	-	-	150.0	13.6	4	0
	5	5	10	300	400	100	-	-	-	178.0	16.2	-	0
	6	10	15	600	600	100	20	-	-	211.0	19.2	-	0
	7	5	8	400	350	35	-	-	-	130.0	11.8	-	0
	8	2	5	100	50	-	-	-	-	80.0	7.3	-	0
Total Expenses		152	888	2060	1800	335	20	0	0				33.2
Budget Constraint		300	700	1340	1600	1700	1800	1800	1800	Project Slippage Project 2/One Year Slip			
Target Budget		300	460	764	800	850	900	900	900				
Fuzzy Constraint		0	120	144	160	170	180	180	180				
Over Budget		-	428	1296	1000	-	-	-	-				

Table II Revised Table with Projects 1 and 3 Excluded and Project 2 Slipped One Year

	Projects	Years								Net Present Worth	Slippage Cost	Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	2	10	10	450	600	400	100	-	-	210.7	19.2	8.3	63.4
	4	120	400	60	-	-	-	-	-	136.4	12.4	4	0
	5	5	10	300	400	100	-	-	-	178.0	16.2	-	0
	6	10	15	600	600	100	20	-	-	211.0	19.2	-	0
	7	5	8	400	350	35	-	-	-	130.0	11.8	-	0
	8	2	5	100	50	-	-	-	-	80.0	7.3	-	0
Total Expenses		152	448	1910	2000	635	120	-	-				63.4
Budget Constraint		300	700	1340	1600	1700	1800	1800	1800	Project Slippage Project 2/Two Year Slip			
Target Budget		300	460	764	800	850	900	900	900				
Fuzzy Constraint		0	120	144	160	170	180	180	180				
Over Budget		-	-	1146	1200	-	-	-	-				

Table III Revised Table with Project 2 Slipped An Additional Year

	Projects	Years								Net Present Worth	Slippage Cost	Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	2	10	10	10	450	600	400	100	-	191.5	17.4	7.5	90.9
	5	5	10	300	400	100	-	-	-	178.0	16.2	-	0
	6	-	10	15	600	600	100	20	-	191.8	17.4	-	19.2
	7	5	8	400	350	35	-	-	-	130.0	11.8	-	0
	8	-	2	5	100	50	-	-	-	72.7	6.6	-	7.3
Total Expenses		20	40	730	1900	1385	500	120	-				117.4
Budget Constraint		180	300	1280	1600	1700	1800	1800	1800	Project Slippage			
Target Budget		180	60	704	800	850	900	900	900	Project 2/Three Year Slip			
Fuzzy Constraint		0	120	144	160	170	180	180	180	Project 6/One Year Slip			
Over Budget		-	-	26	1100	535	-	-	-	Project 8/One Year Slip			

Table IV Revised Table with Project 4 Excluded and Projects 2, 6, 8 Slipped One Year

While the budget requirements in year 3 can now be met by employing the fuzzy constraint of $144, still more slippage is needed because year 4 now becomes the problem, exhibiting a deficit of $1100. Year 3 has excess budget, but no project can be shifted back to year 2 without incurring an excessive budget overrun.

Some advantage may be realized by a trade-off between budget excess in year 3 versus budget deficit in year 2 quite apart from the net penalty of shifting to the right. At the same time, the budget deficit in year 4 is excessive and necessitates further shift to the right. In this case the deficit may be accommodated by again slipping Project 2 accompanied by a further slip in 6, Table V.

The problem has now shifted to year 5 where a deficit of $435 appears. In this case, it is again Project 2 that must suffer. Shifting it once more results in Table VI. Now all eight years are within prescribed budget limits and the process is completed. However, we cannot leave this example without emphasizing that the entire procedure was carried forward from the perspective of the current time zero. If all future costs and revenues as well as penalty assessments were fully deterministic, the resulting schedule for implementing projects would be as described in Table VI. The final planned schedule is recapitulated in Table VII.

It is interesting to note what develops if the decisionmakers were to consider accepting Project 2 after first letting it slip to year 3, Table III. This would necessitate an entirely different schedule

	Projects	Years 1	2	3	4	5	6	7	8	Net Present Worth PW	Slippage Cost ΔP	Sustaining Effort Cost ΔS	Accumulated Penalty
Capital Expenses ($MM)	2	10	10	10	10	450	600	400	100	174.1	15.8	6.8	115.8
	5	5	10	300	400	100	-	-	-	178.0	16.2	-	-
	6	-	-	10	15	600	600	100	20	174.4	15.9	-	36.6
	7	5	8	400	350	35	-	-	-	130.0	11.8	-	-
	8	-	2	5	100	50	-	-	-	72.7	6.6	-	7.3
Total Expenses		20	30	725	875	1235	1200	500	120				159.7
Budget Constraint		180	300	1280	1600	1700	1800	1800	1800	Project Slippage			
Target Budget		180	60	704	800	850	900	900	900	Project 2/Four Year Slip			
Fuzzy Constraint		0	120	144	160	170	180	180	180	Project 6/Two Year Slip			
Over Budget		-	-	21	75	385	300	-	-	Project 8/One Year Slip			

Table V Revised Table with Projects 2 and 6 Slipped One Year

	Projects	Years								Net Present Worth	Slippage Cost	Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	2	10	10	10	10	10	450	600	400	158.3	14.4	6.2	138.4
	5	5	10	300	400	100	-	-	-	178.0	16.2	-	-
	6	-	-	10	15	600	600	100	20	174.4	15.9	-	36.6
	7	5	8	400	350	35	-	-	-	130.0	11.8	-	-
	8	-	2	5	100	50	-	-	-	72.7	6.6	-	7.3
Total Expenses		20	30	725	875	795	1050	700	420				182.3
Budget Constraint		180	300	1280	1600	1700	1800	1800	1800	Project Slippage			
Target Budget		180	60	704	800	850	900	900	900	Project 2/Five Year Slip			
Fuzzy Constraint		0	120	144	160	170	180	180	180	Project 6/Two Year Slip			
Over Budget		-	-	21	75	-	150	-	-	Project 8/One Year Slip			

Table VI Revised Table with Project 2 Slipped One Year

	Projects	Years 1	2	3	4	5	6	7	8	Net Present Worth PW	Total Slipping Cost ΔP	Total Sustaining Effort Cost ΔS	Accumulated Penalty
Capital Expenses ($MM)	1	400	200	-	-	-	-	-	-	533.9	-	-	-
	2	10	10	10	10	10	450	600	400	158.3	96.7	41.7	138.4
	3	300	300	100	-	-	-	-	-	350.0	-	-	-
	4	120	400	60	-	-	-	-	-	150.0	-	-	-
	5	5	10	300	400	100	-	-	-	178.0	-	-	-
	6	-	-	10	15	600	600	100	20	174.4	36.6	-	36.6
	7	5	8	400	350	35	-	-	-	130.0	-	-	-
	8	-	2	5	100	50	-	-	-	72.7	7.3	-	7.3
Total Expenses		840	930	885	875	795	1050	700	420	1747.3	140.6	41.7	182.3
Budget Constraint		1000	1200	1440	1600	1700	1800	1800	1800	Project Slippage			
Target Budget		1000	960	864	800	850	900	900	900	Project 2/Five Year Slip			
Budget Reserve		0	240	555	725	850	750	900	900	Project 6/Two Year Slip			
Contingency Balance		160	30	0	0	55	0	200	480	Project 8/One Year Slip			

Table VII Summary of Revised Tables

adjustment as indicated in Tables IVa, Va, VIa and VIIa. While this is not necessarily the optimum solution, it does represent a different scheduling alternative. The accumulated penalty has been increased 6% from $182.3 to $193.5, although more years in the eight year planning period have positive contingency balances to offset unforeseen costs.

The schedule for implementing projects in Table VII is only made with respect to the current *prospects* for the future. It serves for making next years's allocation and must be subject to change one year hence. When commitments were made for expenditures one and two years ago, clearly Project 2, which has now slipped from year 1 to year 6, was expected to continue in year 1. The revision was occasioned by conditions different from those that had been predicted. Therefore, procedure must be repeated yearly.

3.5 Revised Benefit/Risk Map

The foregoing development for adjustment of net benefits was made without regard to the question of risk. The presumption was that risks were not influenced by the effects of slippage. This, of course, will not be the case, but it is enlightening to note the effect on the benefit/risk map of penalizing benefits to conform only to the budget constraint. The portfolio points in Figure 1 (page 3) will simply be moved to the left, compressing the horizontal positions of all the portfolios.

When the portfolio revisions for adjusted normalized benefits have been accomplished, the portfolio may then be adjusted for risk changes. This may be done by re-assessment of all risk parameters used in the Econergy

	Projects	Years								Net Present Worth	Slippage Cost	Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	2	10	10	450	600	400	100	-	-	210.7	19.2	8.3	63.4
	5	-	5	10	300	400	100	-	-	161.8	14.7	-	16.2
	6	-	10	15	600	600	100	20	-	191.8	17.4	-	19.2
	7	-	5	8	400	350	35	-	-	118.2	10.7	-	11.8
	8	2	5	100	50	-	-	-	-	80.0	7.3	-	-
Total Expenses		12	35	583	1950	1750	335	20	-				110.6
Budget Constraint		180	300	1280	1600	1700	1800	1800	1800	Project Slippage			
Target Budget		180	60	704	800	850	900	900	900	Project 2/Two Year Slip			
Fuzzy Constraint		0	120	144	160	170	180	180	180	Project 5/One Year Slip Project 6/One Year Slip			
Over Budget		-	-	-	1150	900	-	-	-	Project 7/One Year Slip			

Table IVa Alternate Revised Table with Project 4 Omitted and Projects 5, 6, 7 Slipped One Year

	Projects	Years 1	2	3	4	5	6	7	8	Net Present Worth PW	Slippage Cost ΔP	Sustaining Effort Cost ΔS	Accumulated Penalty
Capital Expenses ($MM)	2	10	10	450	600	400	100	-	-	210.7	19.2	8.3	63.4
	5	-	-	5	10	300	400	100	-	147.1	13.4	-	30.9
	6	-	-	10	15	600	600	100	20	174.4	15.9	-	36.6
	7	-	-	5	8	400	350	35	-	107.4	9.8	-	22.5
	8	2	5	100	50	-	-	-	-	80.0	7.3	-	0
Total Expenses		12	15	570	683	1700	1450	235	20				153.4
Budget Constraint		180	300	1280	1600	1700	1800	1800	1800				
Target Budget		180	60	704	800	850	900	900	900				
Fuzzy Constraint		0	120	144	160	170	180	180	180				
Over Budget		-	-	-	-	850	550	-	-				

Project Slippage

Project 2/Two Year Slip

Project 5/Two Year Slip

Project 6/Two Year Slip

Project 7/Two Year Slip

Table Va Alternate Revised Table with Projects 5, 6, 7 Slipped Another Year

	Projects	Years								Net Present Worth	Slippage Cost	Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	2	10	10	500	600	400	100	-	-	210.7	19.2	8.3	63.4
	5	-	-	5	10	300	400	100	-	147.1	13.4	-	30.9
	6	-	-	-	-	10	15	600	600	144.1	13.1	-	66.9
	7	-	-	-	5	8	400	350	35	97.6	8.9	-	32.3
Total Expenses		10	10	505	615	718	915	1050	635				193.5
Budget Constraint		178	295	1180	1550	1700	1800	1800	1800	Project Slippage			
Target Budget		178	55	604	750	850	900	900	900	Project 2/Two Year Slip			
Fuzzy Constraint		0	120	144	160	170	180	180	180	Project 5/Two Year Slip Project 6/Four Year Slip			
Over Budget		-	-	-	-	-	15	150	-	Project 7/Three Year Slip			

Table VIa Alternate Revised Table with Project 6 Slipped 2 More Years and Project 7 Slipped One More Year

	Projects	Years								Net Present Worth	Total Slippage Cost	Total Sustaining Effort Cost	Accumulated Penalty
		1	2	3	4	5	6	7	8	PW	ΔP	ΔS	
Capital Expenses ($MM)	1	400	200	-	-	-	-	-	-	533.9	-	-	-
	2	10	10	450	600	400	100	-	-	210.7	44.3	19.1	63.4
	3	300	300	100	-	-	-	-	-	350.0	-	-	-
	4	120	400	60	-	-	-	-	-	150.0	-	-	-
	5	-	-	5	10	300	400	100	-	147.1	30.9	-	30.9
	6	-	-	-	-	10	15	600	600	144.1	66.9	-	66.9
	7	-	-	-	5	8	400	350	35	97.6	32.3	-	32.3
	8	2	5	100	50	-	-	-	-	80.0	-	-	-
Total Expenses		832	915	765	665	718	915	1050	635	1713.4	174.4	19.1	193.5
Budget Constraint		1000	1200	1440	1600	1700	1800	1800	1800	Project Slippage			
Target Budget		1000	960	864	800	850	900	900	900	Project 2/Two Year Slip			
Budget Reserve		0	240	576	800	850	885	750	900	Project 5/Two Year Slip Project 6/Four Year Slip			
Contingency Balance		168	45	99	135	132	0	0	265	Project 7/Three Year Slip			

Table VIIa Summary of Alternate Revised Tables portfolio model. The risk parameters are adjusted in light of expected changes that may be realized from experience. Using these new risk parameters along with the reduced benefits dictated by the budget constraints, a solution of a new portfolio may then be found and the new benefit/risk map plotted.

The budget-adjusted benefit/risk map will now provide the basis for selection of the final portfolio. All initial portfolios that are admissable on the basis of no budget constraint must be viewed as tentative until after the capital budgeting exercise has been completed. The schedules for implementing the final portfolio are only planning schedules. Furthermore, the only budget that should be viewed as firm is the first year's allocation. The process must be repeated each year as other new projects become candidates for the portfolio and as revised benefit and risk data become available.

4. SUMMARY

This report has provided a simplified and practical tool for determining the schedule for capital allocations needed to implement a desired portfolio of energy projects. The Econergy portfolio model is a tool for determining what set of plants or processes will be best from the ERDA point of view. However, implementation of an engineering and construction program to obtain that portfolio will need to be scheduled in such a way as to keep within budget constraints determined by governmental policy. This means that schedules for various projects will need to be slipped in time. The Econergy capital budgeting technique provides a suitable means for doing this, thereby ensuring an optimal portfolio.

An example problem was worked out in some detail to demonstrate the methodology. A more sophisticated, computerized extension of this method could be developed and then be used in conjunction with the Econergy portfolio model.

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