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FINAL REPORT:
THE RAM2 RESOURCE ALLOCATION METHODOLOGY

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MASTER

Prepared for:

DIVISION OF BUILDINGS AND COMMUNITY SYSTEMS
OFFICE OF CONSERVATION AND SOLAR APPLICATIONS
UNITED STATES DEPARTMENT OF ENERGY

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The RAM2 Methodology is the second version of the BCS Resource Allocation Model. RAM2 utilizes a new and relatively unexplored concept of interproject competition. As a consequence, it is highly likely that substantial development and extension of the basic concept of the central idea will occur over the next several months and years. EEA and I are interested in further development of RAM2 and of the project competition construct. If you are interested in further developments or have new ideas to contribute, please contact me.

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INTRODUCTION

The Buildings and Community Systems Branch of the Department of Energy, Office of Conservation and Solar Applications is charged with the responsibility of developing energy conserving technologies for non-industrial applications in the private sector. The range of technologies which fall within this mandate is extremely broad. As a consequence, there is a great demand for the limited BCS resources.

The BCS research program has the potential of making available very efficient technologies in the coming decades which otherwise would not have been available for many more years, if at all. The energy savings can be very large if the technologies are both economically acceptable and energy efficient. If, however, the technologies are not acceptable to the ultimate consumer, no energy savings will result.

In addition to the risk of developing a technology which is ultimately uneconomical, BCS risks developing a technology which would have been developed by the private sector even in the absence of BCS involvement. In this case there is no net savings due to the BCS program -- more could have been accomplished had the BCS resources been directed toward developing a technology which was less acceptable to the private sector.

Properly directed, the BCS program can result in large energy savings, but there are risks. In order to avoid these risks and to maximize the effectiveness of the program, BCS has undertaken the development of a set of management tools to evaluate the worth of a proposed project both in isolation from and in concert with the other projects which constitute the program. This document describes one of those tools: the BCS Resource Allocation Model called RAM2.

The principal objective of this task has been to design and test a resource allocation model which identifies the most efficient research and development program for the buildings and community systems (BCS) group. The model provides a means of comparing the energy savings of various research portfolios which provide the greatest energy savings at various levels of research funding.

The model accomplishes this by associating the various technologies into market groups of competing products (e.g., space heating, water heating, etc.) Within each group the probable costs of the new technologies are compared with the cost of a competitive conventional product in order to determine the probability that the new technology will yield the energy savings. In conjunction with the expected market penetration and funding requirements, this allows the estimate of expected energy savings at various funding levels within a market group.

Successful portfolios within the various market groups can then be compared in a similar manner in order to develop the most effective comprehensive portfolios at various research funding levels. The details of the methodology for these analyses are presented in Section 1. The development of the data for the model is described in the first part of Section 2 which concludes the results of initial runs of RAM2.

1. RAM METHODOLOGY (VERSION 2)

1.1 INTRODUCTION

The BCS resource allocation methodology is an analytical tool for the evaluation, ranking, and selection of research portfolios. The analytical structure can be divided into two separate calculations -- first, the technique for the evaluation of a single portfolio, and second, the technique for comparing portfolios.

There are two general classes of inputs to the Resource Allocation Model (RAM). The first is a curve which relates the dollar value of resource savings in a functional use area to some measure of the cost of providing one unit of that function. For example, if a conventional furnace can supply 1 MMBtu of heat for $2, and a new technology can supply 1 MMBtu for $1, then the resource savings are $1 for each 1 MMBtu of the new type. If the cost of a new technology is greater than the cost of the conventional technology, then no resource savings will result from development of the new technology.

In the limit, every purchaser given a choice between the new and existing technology will select the new one as it is substantially less expensive. However, all new heating units installed will not use the new technology. Imperfect consumer information and an aversion to the risk and cost uncertainty associated with the new technology will have a negative impact on its adoption which can only diminish with an extended period of successful applications. Because there are non cost factors in the technology selection decision, cost is not a perfect determinant of market penetration. However, cost remains the single best parameter for forecasting technology adoption, especially when adjusted for risk.

The resource savings curves which are input to RAM relate total energy savings to cost. Total resource savings at one cost level is defined as the savings achieved per unit at that level of cost times the number of units which will be adopted which is also a function of cost. Thus, the market penetration estimates associated with RAM are made exogenously.

The optimal technique for assessing market penetration is very much a function of the dynamics of the specific market. As RAM must work across a broad range of markets, it is not practical to address each market endogenously.

A resource energy savings curve is shown in Figure 1.1. One such curve is developed for each functional use addressed by the research program being evaluated.

The second class of input to RAM is the technology cost curves. The technology cost curves describe the performance of the candidate technologies. Until the research is done, it is not possible to determine exactly how the technologies under development will perform. This technical uncertainty is manifested in the technology cost curves which are actually frequency distributions of technology cost. These curves do not include an uncertainty in cost due to market factors. Continuing with the example from above, a typical technology cost curve is presented in Figure 1.2. The horizontal axis is in $/MMBtu which is the same unit as the energy savings curve for the functional use which is addressed by the technology. The vertical axis is the probability that the technology will be able to deliver 1 MMBtu at less than the corresponding price. Example, there is a 50 percent chance that the technology will ultimately be able to deliver 1 MMBtu at $1.75 or less.

Together, the energy savings curve and the technology cost curve define the frequency distribution of the energy savings which will result from development of the technology. The technology cost curve defines the probability that the technology will achieve a certain price, while the energy savings curve describes the savings that will be achieved if a technology can meet the functional use at that price. The product of the two describes the probability that a level of energy savings will be achieved.

FIGURE 1–1

ENERGY SAVINGS CURVE

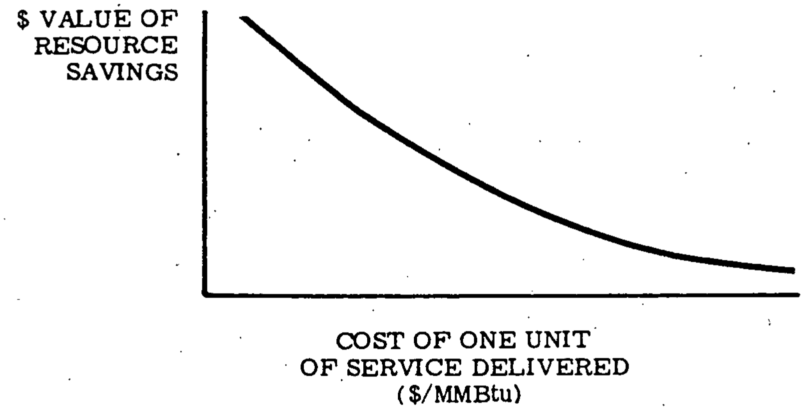
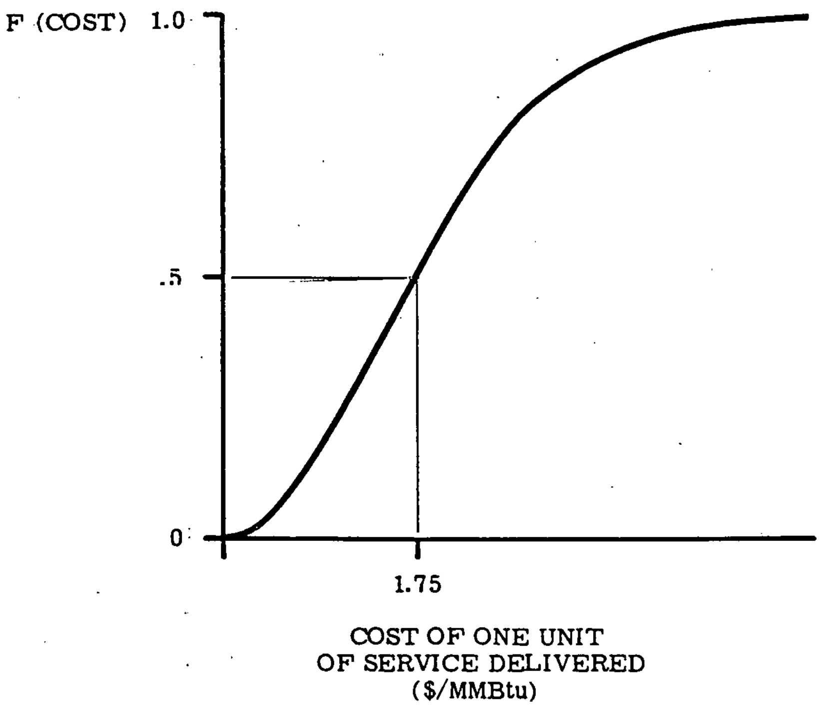


FIGURE 1–2

TECHNOLOGY COST CURVE



Evaluating a portfolio which addresses a single functional use involves calculating a cost curve for the entire portfolio from the separate technology cost curves. This curve, when multiplied by the functional use's energy savings curve, gives the frequency distribution and expected value of energy savings which will result from pursuit of the portfolio.

The current version of RAM assumes that there is no competition between technologies within different functional use areas except when a single technology addresses more than one functional use. Thus, heat pumps compete with both space heating and cooling devices, but insulation does not compete with either. Essentially, this assumption of independence between functional groups means that different functional areas are not regarded as alternative uses for the purchaser's capital. In some cases this assumption is very good. For example, few people are likely to consider whether to purchase a refrigerator or a lightbulb. But in some other cases, notably the decision whether to purchase better insulation or a new heating device, the assumption may introduce some error into the analysis.

Assuming independence, the evaluation of a portfolio which spans several functional use areas consists simply of adding the energy savings in the separate functional use areas which are determined by the evaluation procedure described above.

The number of possible research portfolios in the BCS program is very large and it is not feasible to evaluate every one separately for manual comparison. Therefore, RAM has the capability of evaluating a large number of portfolios, eliminating poor choices, and outputting potentially optimal portfolios in an interpretable manner.

The comparison of portfolios is done each time a new one is evaluated. After each portfolio evaluation, the new portfolio is compared to the current list of potentially optimal portfolios. First, the list is searched to determine if there are any less expensive portfolios which can save more resources. If there are, then the new portfolio is not added to the ranking. If the new portfolio does save more resources than any less expensive alternative, it is added to the list and another search initiated. This search eliminates from the ranking all portfolios which cost more than the new one but save fewer resources. The final result is a list of portfolios that shows which project selections should be made at each funding level to maximize the impact of the program. Funding levels beyond the one at which all input projects are included cannot be considered explicitly, but an extrapolation is made to indicate the value of adopting additional projects in each functional area. This estimate assumes that any new projects will be typical of those already adopted. The estimated cost and savings of each portfolio do not include costs of adoption given a baseline portfolio. They assume that no research is currently underway.

A more detailed description of each step in the methodology follows.

1.2 EVALUATING A SINGLE PORTFOLIO

Before a technology development project is completed, it is not possible to determine with certainty how well the technology will perform and how much it will cost. As performance and cost are major determinants of the technology's success in the end use market, the technical uncertainty makes it impossible to estimate precisely the potential resource savings which will result from development of the technology and, hence, the worth of pursuing the line of research.

The issue of technical uncertainty has often been ignored in evaluating a research program. Estimates of most likely cost and performance characteristics are formulated and market penetration estimates derived from these to produce an estimate of the most likely savings. While this approach is acceptable in screening work where the number of projects is large and the cost of a detailed probabilistic analysis cannot be justified, technical uncertainty cannot be ignored in final program evaluation.

A probabilistic treatment of technology cost and performance offers the advantage of enhanced realism, but there are complicating factors which make probabilistic analyses more difficult, time consuming, and expensive. Principal among these is the problem of estimating market penetration. Under the best of circumstances, the market penetration of technology with precisely defined characteristics can be estimated with only limited accuracy regardless of the effort put into market characterization. The state of the art of market performance forecasting is quite poor despite substantial research in the area.[1/] When the performance and cost of the technology are

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[1/] cf.

- Lenz, R.C. and H.W. Lanford, "The Substitution Phenomenon," Business Horizons, February, 1972, pp. 63-68.
- Mansfield, Edwin, "Technical Change and the Rate of Limitation," Econometrica, Vol. 29, No. 4 (October, 1961).
- Blackman, A. Wade, "A Mathematical Model for Trend Forecasts," Technological Forecasting and Social Change, Vol. 3, 1972, pp. 441-452.

not represented by a point, but rather by a frequency distribution, the task is even more difficult. To date, the only approach suggested has been to perform a probabilistic market analysis for numerous selected values of performance and cost in an attempt to derive some general relationship between savings and cost.

If the projects under evaluation are oriented to the development of different technologies or are aimed at different markets, a probabilistic analysis would follow a two step procedure. First, a frequency distribution of cost would be developed. This frequency distribution would describe the performance of the technology after completion of technical development. In the next step, selected values of cost would be selected from the distribution and input to a market penetration model. This market model would provide an estimate of the number of units of the technology which would be adopted for the input level of cost, which can be easily extrapolated into an estimate of savings. This estimate of savings is associated with the probability of the input level of performance occurring to yield a frequency distribution of savings and the expected value of savings. This procedure is illustrated in the example which follows.

<u>Example - Expected Savings</u>

This example is formulated for discrete probability distributions for simplicity. The entire procedure can be carried out using continuous mathematics by fitting a continuous function to the discrete energy savings estimates. Assume that the technology under study will most likely be able to deliver one unit of service at $10. There still remains the possibility that the technology will work out as well as expected and cost more or work out better than expected and cost less. The range of possible outcomes and associated probabilities is summarized as follows:

Cost Per Unit of Service ($)	Probability
≤ 6	0
7	.05
8	.05
9	.1
10	.3
11	.2
12	.1
13	.1
14	.1
TOTAL	1.0

For each possible cost of new technology, the market penetration is then estimated. Preparation of this estimate requires detailed knowledge about the market, the end user's needs and preferences, the user's ability to adopt the new technology, the performance of the technologies competing with the new one, and numerous other factors. For the purposes of this example, assume that all the necessary inputs are known and that good estimates can be prepared. The results are as follows:

Cost Per Unit of Service from the New Technology	Number of Units of Service Demanded by the Market
7	1.5 million
8	1.2 million
9	.9 million
10	.6 million
11	.4 million
12	.2 million
13	.1 million
≥ 14	0

The savings frequency distribution curve can be estimated from this table by multiplying the number of units of the new technology demanded times the savings per unit, which is the difference in price between the new and the conventional technology.

Cost Per Unit of Service ($)	Savings ($ x 10^6)	Probability
7	10.5	.05
8	7.2	.05
9	4.5	.1
10	2.4	.3
11	1.2	.2
12	.4	.1
13	.1	.1
14	0	.1

The expected savings is the sum of the products of the savings at each level of cost times their associated probabilities -- in this case, $2.34 million. This represents the maximum amount which can be allocated to research if the project is to show a net positive expected savings.

If there is more than one project devoted to developing a technology to provide the same service to the same set of customers, the simple procedure outlined in the example cannot be followed. Among the complicating factors which necessitate a modification of the methodology is competition between projects. If two technologies address the same functional use, the total savings attributable to both is likely to be less than the sum of the savings attributable to each, as estimated by the outline procedure, on the assumption that each is the only new technology available. For example, if there are two new heating plants that can provide 1 MMBtu of heat at $2 and

\$2.50, respectively, while a conventional heater can perform only at \$3/MMBtu, the savings due to the introduction of the \$2.50 heater will not be as large as they would have been had the \$2 heater also been introduced.

The RAM2 model was designed to address this sort of interproject competition for the case in which the end use market can be disaggregated into homogeneous segments. If the end use market can be broken down into pieces within which all end users exhibit identical preferences, they will all prefer precisely the same technology for a particular application. If selection is based on cost, then the technology which is least expensive in that segment will be purchased exclusively. Clearly this is an approximation.

It is possible to estimate the value of a portfolio of projects addressing the same market by using this construct. This is done through manipulation of the separate cost frequency curves for the projects that constitute the portfolio into one curve which represents the portfolio as a whole.

Basically, the total portfolio cost curve is a frequency distribution of the lowest cost. The probability associated with each cost value is the probability that the cheapest of all the technologies under development will cost that amount. This curve is defined by the relationship:

$$f_p(x) = \frac{d}{dx}\left(1 - \prod_{i=1}^{n_p} \{1. - \int_o^x f(x)dx\}\right) \qquad (1\text{-}1)$$

where x = a cost value

$f_p(x)$ = the cost frequency distribution of the entire portfolio

n_p = the number of projects in the portfolio

$f_i(x)$ = the cost frequqncy distribution of project i

The derivation of a portfolio cost curve and the evaluation of a portfolio of competing projects is illustrated in the following example.

Example:

Again, the example problem is done using discrete probability distributions for simplicity of illustration. Assume that there are three projects with cost frequency curves, $(f_i(x))$, as summarized below:

Cost Per Unit of Service	Probability: Project 1	Probability: Project 2	Probability: Project 3
6	0	0	0
7	.05	.05	.10
8	.05	.05	.15
9	.10	.10	.15
10	.30	.30	.10
11	.20	.20	.05
12	.10	.10	.05
13	.10	.10	.05
14	.10	.10	.35
TOTAL	1.00	1.00	1.00

Savings are estimated to vary as a function of cost. Assume that the same curve applies as in the earlier example. Here, however, the curve has a slightly different meaning. In the first case it represented the savings that would be achieved if the associated single technology were to become available at each price. Here, it represents the savings that will be achieved if the cheapest of all the technologies represented by projects A, B, and C were available at each cost. Recall the curve on page 1-9.

Cost Per Unit of Service	Savings which will Result if Cost at Left is Achieved (MM$)
7	10.5
8	7.2
9	4.5
10	2.4
11	1.2
12	.4
13	.1
14	0.0

To evaluate the probability distribution of savings, it is necessary to associate a probability with each of the cost values in the same manner as was done for the case where there was only one project. When there is more than one project, this probability is the total portfolio probability as calculated using the discrete form of equation (1).

The probability that the least expensive technology resulting from the development of the three projects A, B, and C will cost seven dollars is:

$$f_p(7) = \left(1. - \prod_{i=1}^{3}\{1. - \sum_{x=o}^{7} f_i\,(x)\}\right) - \left(1. - \prod_{i=1}^{3}\{1. - \sum_{x=o}^{6} fi(x)\}\right) \qquad (1\text{-}2)$$

$$\prod = 1. - (1. - f_1(7)) \times (1. - F_2(7)) \times (1. - f_3(7)) \qquad (1\text{-}3)$$

Substituting from the cost probability tape:

$$f_p(7) = 1. - (1. - .05)\ (1. - .05)\ (1. - .1) = .1875 \qquad (1\text{-}4)$$

.1875 is the probability that at least one of the new technologies will cost $7 per unit of service and that none will cost less.

Continuing this calculation for higher cost values, the entire f_p distribution is obtained. This can be used to calculate the expected value of savings for the portfolio.

Cost Per Unit of Service ($)	f_p (cost)	Savings which will Result if Lowest Cost is Value at Left
7	.1187	10.5
8	.1928	7.2
9	.3045	4.5
10	.2590	2.4
11	.0845	1.2
12	.0245	0.4
13	.0125	0.1
≥ 14	.0035	0.0

Again, the expected savings is the sum of the savings at each level of cost weighted by the associated probabilities. In this case, the value is \$4.63 million. Note that Project 1 in this example is the same as the project in the earlier example and that the saving curves were the same.

Because of this correspondence, comparing these two examples is equivalent to comparing two funding options. In the first example the outcome of funding only Project 1 was examined. The expected savings was \$2.34 million. In the second example the outcome of funding projects 1, 2, and 3 simultaneously was examined. The expected savings was approximately doubled. This increase illustrates the value of funding more than one project. Funding additional projects increases the probability that one or more will be successful in producing a technology at a low cost. This can be seen by noting that if only technology 1 was developed, the probability that the service would be available at \$7/unit was only .05, whereas if all projects were developed, the probability that one could provide the service at \$7 per unit was substantially increased.

The preceding pages present a fairly detailed description of how a portfolio is evaluated once the input data has been developed. The procedure can be summarized fairly simply. For the case where there is only one project addressing a market:

1. The outcome of a candidate project is expressed as a frequency distribution of the cost of the resultant technology.
2. A market penetration estimate is prepared for selected values of cost spanning the range of the technology's cost frequency distribution.
3. The market penetration point estimates are used to develop a function relating the savings to technology cost.
4. The frequency distribution of savings is determined by multiplying the savings function by the cost frequency distribution.

If there is more than one project addressing the same market, and therefore competing with each other, then the above procedure is slightly augmented though the general theme is the same.

1. The outcome of each project addressing the market is expressed as a frequency distribution of the cost of the resultant technology.
2. A market penetration curve is prepared for selected values of cost spanning the range of the cost distributions. Only one set of penetration estimates is prepared for each market group regardless of the number of projects addressing that market.
3. The market penetration estimates are used to derive a function relating savings to technology cost. This function expresses the savings which will result if any of the projects achieve the input cost and is not sensitive to the specific identity of the project which achieves that level.
4. The combined frequency distribution of cost is prepared for each portfolio that is to be evaluated.
5. The frequency distribution and expected value of savings for each portfolio is determined by multiplying the savings function times the cost frequency distribution of the portfolio.

1.3 EVALUATING MANY PORTFOLIOS

The procedures outlined in the previous section provide estimates of the value of a single portfolio. By reapplying these techniques, all candidate portfolios can be evaluated. However, the results of the individual evaluations are not sufficient in themselves as the total number is unmanageably large. It is necessary to process these results in some formal, mechanized way in order to screen out useless information about poor portfolios and to summarize the remainder in a comprehensible fashion.

The RAM2 Model does this by disaggregation, screening, and reaggregation, a sequence of steps that substantially reduces the number of portfolios which must be considered and, hence, the cost of using the model.

The first step is to disaggregate the entire BCS program into a number of smaller market groups. A market group is either a group of projects which addresses the same functional use and end users and thus competes in the end market, or a group of projects which has no competition within the BCS program but is administered by the same branch. Examples of both kinds of market groups follow.

Following this subdivision the analysis proceeds for each market group independently. Each portfolio within a group is evaluated and then ranked in order of increasing cost. At this point, all portfolios which cost more than others which save more are eliminated from the listing as they should not be adopted. This procedure is illustrated in the following example.

Example

Assume there are three projects, and thus $2^3 = 8$ portfolios. These portfolios are evaluated with the following results. The constituents of a portfolio are defined by the columns at the left of the Table. A "1" indicates that the project is included in the portfolio. An "0" indicates that the project is not included. Ranking in order of costs has already been completed.

Portfolio #	Constituent Projects			Research Cost (MM$)	Savings ($MM)
	1	2	3		
1	0	0	0	0.00	0.00
2	0	0	1	0.50	4.00
3	0	1	0	1.25	6.25
4	0	1	1	1.75	8.00
5 1/	1	0	0	2.00	7.50
6	1	0	1	2.50	9.20
7 1/	1	1	0	3.25	9.10
8 2/	1	1	1	3.75	10.00

The portfolios marked with a 1/ cost more than other portfolios which save more. Therefore, they should be eliminated from consideration. Portfolio 8, marked with a 2/, saves more than any less expensive portfolio, but the marginal savings over the next most expensive portfolio is less than the marginal cost. This portfolio should also not be considered. The final ranking is:

Portfolio #	Constituent Projects			Research Cost (MM$)	Savings ($MM)
	1	2	3		
1	0	0	0	0.00	0.00
2	0	0	1	0.50	4.00
3	0	1	0	1.25	6.25
4	0	1	1	1.75	8.00
6	1	0	1	2.50	9.20

The general procedure followed for each market group is illustrated in Figure 1-3.

Finally, after the portfolios in each market group have been evaluated, the RAM2 model constructs portfolios of portfolios. That is, it compares portfolios from the different market groups to determine priorities for funding increments. It does this in precisely the same combine, rank by cost, and screen procedure that is used within each market group, with the only change being that market group portfolios are added to the total portfolio rather than individual projects.

The overall procedure for comparing market groups is illustrated in Figure 1-4.

FIGURE 1–3

METHODOLOGY FOR EACH MARKET GROUP

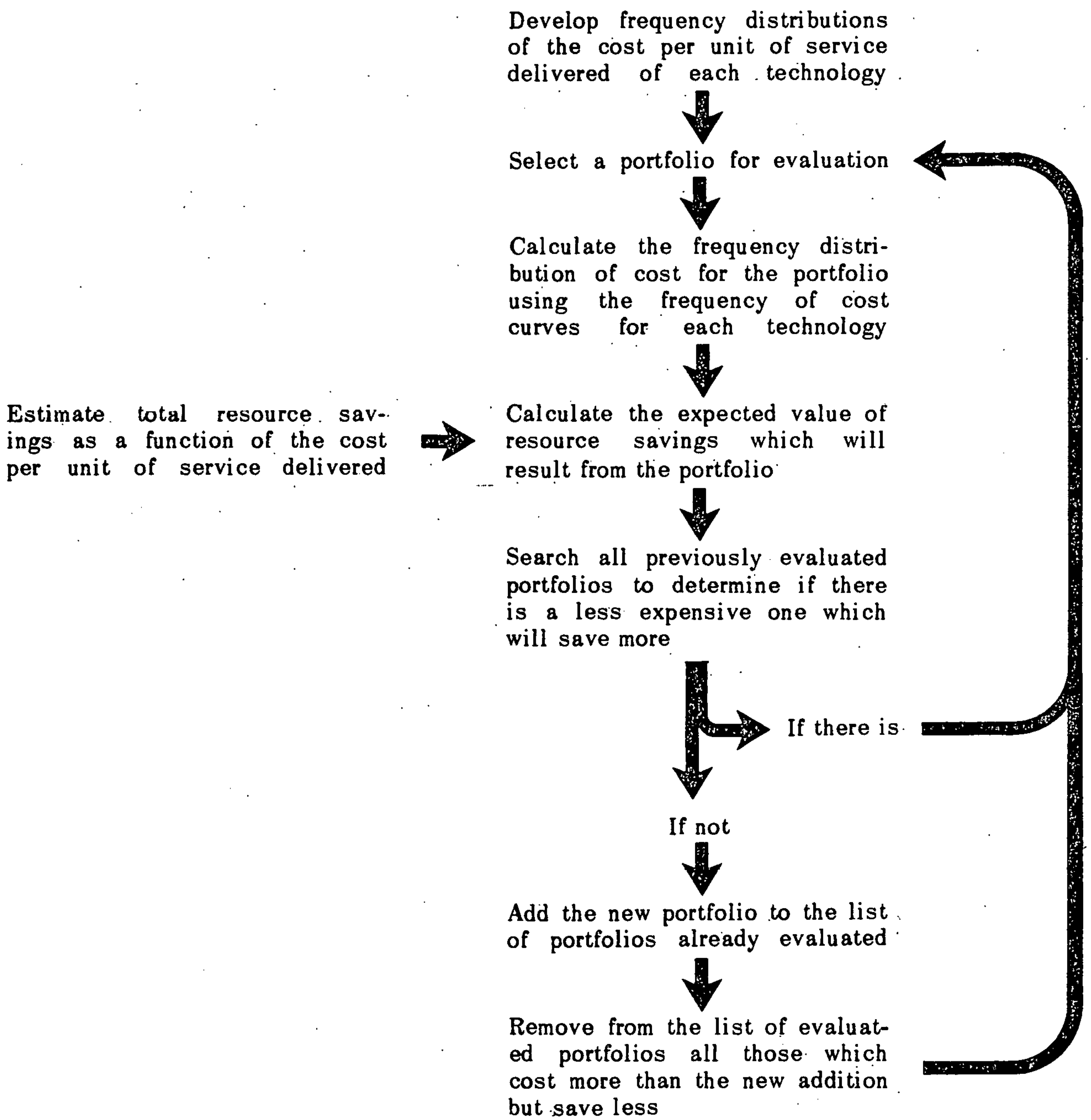
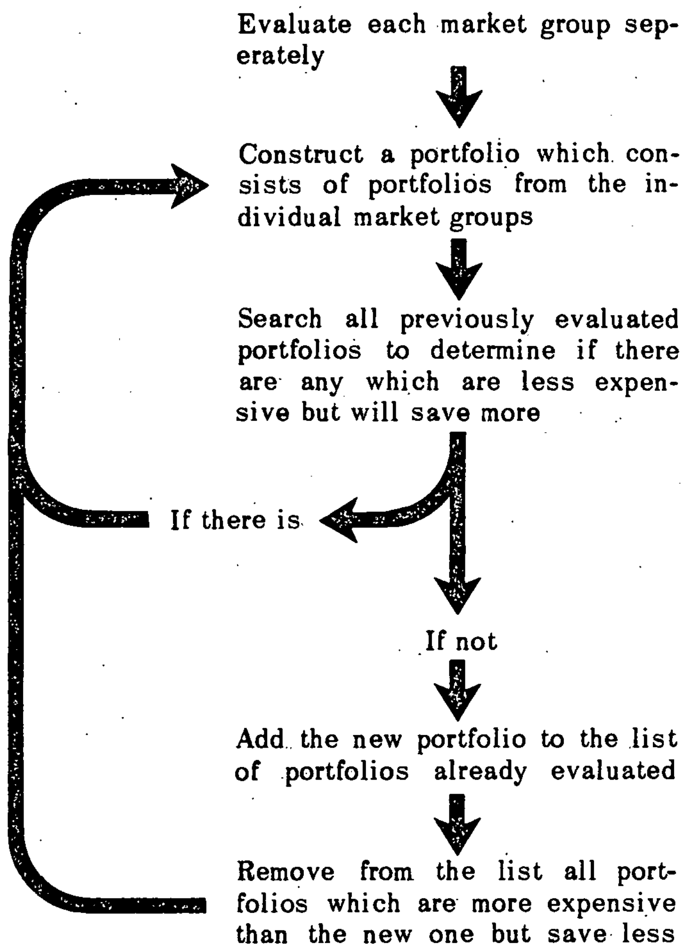


FIGURE 1-4

METHODOLGY FOR THE ENTIRE PROGRAM



1.4 INTERPRETING RAM2 OUTPUTS

The primary output of the RAM2 methodology is the market group portfolio sheet, an example of which is reproduced on the following page. This output contains most of the information necessary to determine the optimum project mix at various budget levels.

Line A of the report indicates the market group represented and the number of the market group. The market group number is always associated with a particular set of projects and is not reassigned between runs of the model.

Line B of the report shows the projects which are included in the market group. In this case there are eight projects, all devoted to space heating. The numbers of the projects are the same ones used in the threshold analysis in order to minimize confusion between RAM and threshold outputs.

Below line B is a matrix of zeros and ones. Each line of the matrix describes the constitution of a portfolio. A zero indicates that the project associated with that column is not in the portfolio corresponding to that line. For example, Portfolio 1 (portfolio numbers are in column D) consists of project 297 only. Portfolio 6 consists of projects 252, 297, 251, and 375.

Column E is the total time stream of research expenditures necessary to develop a portfolio discounted to the base year of the RAM2 execution. In this case, the base year is 1979.

Column F is the dollar value of energy savings which will result if the corresponding portfolio is developed. This savings is defined as the expected present value of the cost of meeting the total demand with a new technology minus the present value of meeting that demand with the conventional technology. Capital, installation, operating, and maintenance costs are included.

Column G is the value of savings divided by research expenditure. Note that this value generally decreases as the research expenditure increases as less efficient projects must be included in the portfolio. But the general trend toward decreasing returns to investment need not be maintained absolutely. The optimizing criteria in this application of RAM2 is that savings be maximized at each funding level, not that savings per dollar be maximized.

Reading down column E, research cost increases, and the corresponding value of savings also increases. The savings value represents the maximum savings which can be achieved at that funding level given the input set of projects from which to select. This value of savings can be obtained by funding the portfolio described at the right. For example, the maximum savings which can be achieved for an expenditure of $15 million is indicated by Portfolio 12. The savings value is $228 million which is achieved by developing projects 58, 297, 334, 251, and 375. The RAM2 output also shows that no additional savings can be achieved by selecting a different, more expensive portfolio short of doing the $18 million Portfolio number number 13.

The final line of the RAM2 market group output is the additional project evaluation, line H. This line shows the additional cost that will be incurred and savings that will be achieved if a typical additional project was added to the complete portfolio, number 18. This typical project is defined as having a cost which is the average of the costs of the existing eight projects, and a cost curve which is also an eight project average. This line attempts to show the value of adding an additional as yet undetermined project to the ones already selected. Of course, a better evaluation of a potential addition can be made if something is known about the cost and outcome of the project by rerunning RAM2 with the project included. Until more information is available, however, line H is a valuable indicator.

Note that the marginal value of adding the undetermined project in line H is greater than the marginal value of going from Portfolio 17 to 18. This is because project 53, which distinguishes Portfolio 17 from 18, is a poorer than average project and hence was added later, while the unspecified project is exactly average.

[redacted] [redacted] [redacted]

10/17/78

MARKET GROUP 1: SPACE CONDITIONING ← ROW A

	COLUMN G	COLUMN E	COLUMN F								
COLUMN D	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	FORTFOLIOS (FUNDING LEVELS)							
				53	58	252	297	334	335	251	375
1	0.548E+03	0.180E+00	0.987E+02	0	0	0	1	0	0	0	0
2	0.235E+03	0.800E+00	0.187E+03	0	0	0	0	0	0	1	0
3	0.245E+03	0.980E+00	0.240E+03	0	0	0	1	0	0	1	0
4	0.933E+02	0.297E+01	0.277E+03	0	0	0	1	0	0	1	1
5	0.458E+02	0.619E+01	0.283E+03	1	0	0	1	0	0	1	1
6	0.421E+02	0.682E+01	0.287E+03	0	0	1	1	0	0	1	1
7	0.352E+02	0.867E+01	0.305E+03	0	0	0	1	1	0	1	1
8	0.260E+02	0.119E+02	0.309E+03	1	0	0	1	1	0	1	1
9	0.250E+02	0.124E+02	0.310E+03	1	1	0	1	0	0	1	1
10	0.249E+02	0.125E+02	0.312E+03	0	0	1	1	1	0	1	1
11	0.241E+02	0.130E+02	0.313E+03	0	1	1	1	0	0	1	1
12	0.221E+02	0.149E+02	0.328E+03	0	1	0	1	1	0	1	1
13	0.184E+02	0.181E+02	0.332E+03	1	1	0	1	1	0	1	1
14	0.178E+02	0.187E+02	0.334E+03	0	1	1	1	1	0	1	1
15	0.160E+02	0.214E+02	0.343E+03	0	1	0	1	1	1	1	1
16	0.141E+02	0.246E+02	0.345E+03	1	1	0	1	1	1	1	1
17	0.137E+02	0.252E+02	0.346E+03	0	1	1	1	1	1	1	1
18	0.123E+02	0.284E+02	0.349E+03	1	1	1	1	1	1	1	1
	0.114E+02	0.320E+02	0.366E+03	<--- VALUES FOR COMPLETE FORTFOLIO PLUS ADDED AVERAGE PROJECT							

← ROW B

← MATRIX C

← LINE H

FIGURE 1-5

ANNOTATED OUTPUT

1.5 DEVELOPING INPUTS

The RAM2 methodology, as presented so far, uses two types of inputs: one which relates dollar value of resource savings to the cost of the technology and another which is frequency distribution of technology costs after completion of research. Though in all applications so far the model has been applied with these types of inputs, the structure is substantially more general and can be used without modification with other types of inputs in order to apply other optimization criteria. Current uses of the model follow Figure 1-6, the more general expression of which is Figure 1-7.

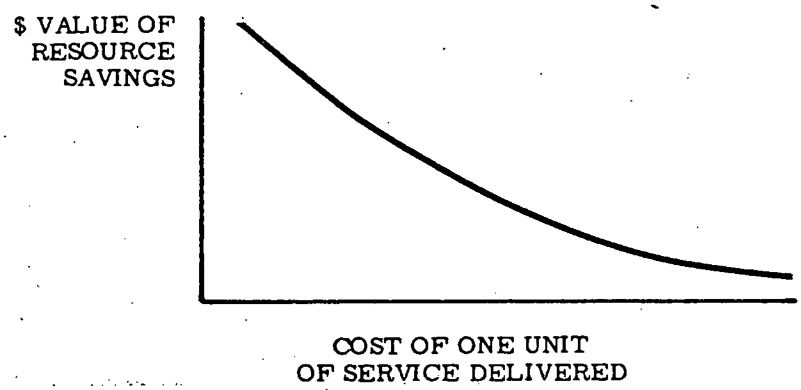
The vertical axis of the upper input curve is the optimization criteria. If this axis is the discounted value of savings, then portfolios will be selected to maximize the discounted value of energy savings. If the vertical axis is employment, then portfolios will be selected to maximize employment.

The horizontal axis of both input curves is a parameter which is left to the user's discretion. The single criterion for selection of this is that it be both a major determinant of the quantity which is to be maximized and a factor for which it is possible to assess each technology's post research frequency distribution. When the optimization criteria is resource savings, which is a strong function of market penetration, technology cost is a good decision variable as it is a strong determinant of market penetration.

Assessment of these two classes of inputs is the major area for further development in RAM-type methodologies. The technique used in applications to date is discussed in Section 2. However, the derivation shown there is only an example, and not a particularly advanced one. Elaborate models such as the Brookhaven Energy Conservation Optimization Model and the Oak Ridge residential and commercial models are ideal for developing the energy savings curves, but some effort is still needed to resolve differences in underlying assumptions and differences in the form of BNL and ORNL outputs and the form required by RAM2. Development of the cost frequency distributions is currently based on threshold information. This is not sufficient as the threshold input forms were not designed for assessment of frequency distributions and have not been verified adequately. Formal polling techniques, such as Delphi, are possible approaches for the future.

FIGURE 1–6

ENERGY SAVINGS CURVE



TECHNOLOGY COST CURVE

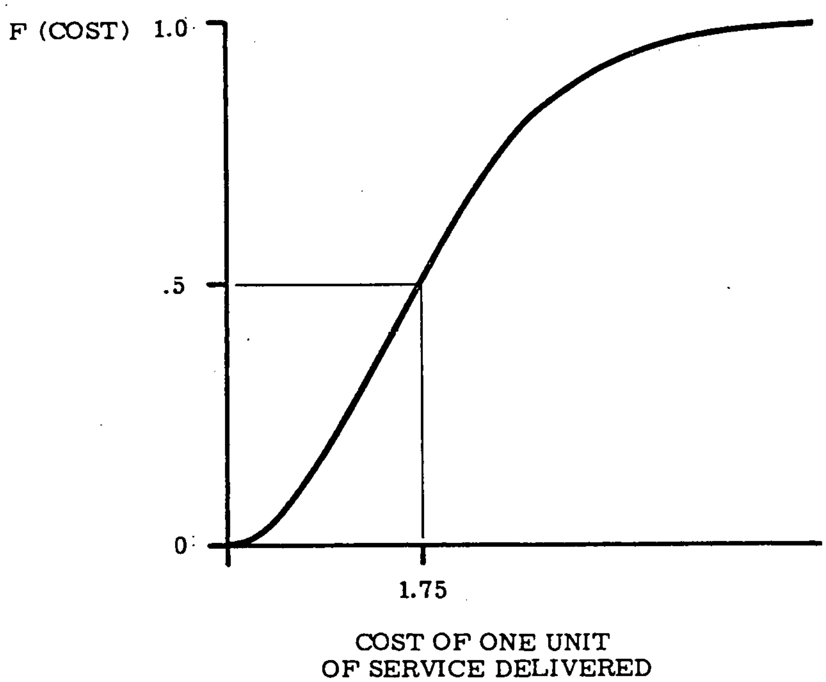
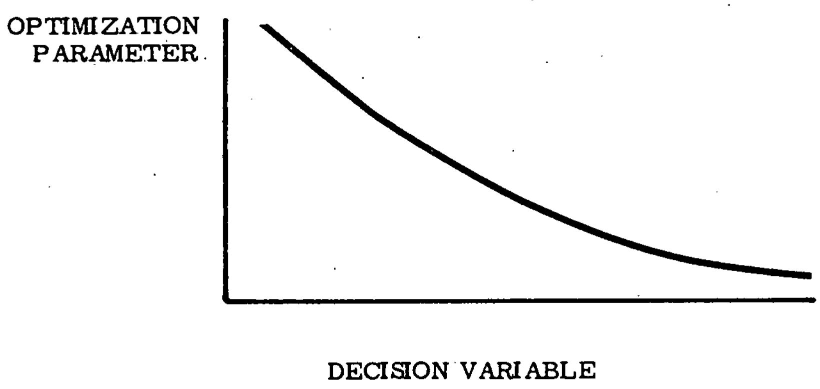
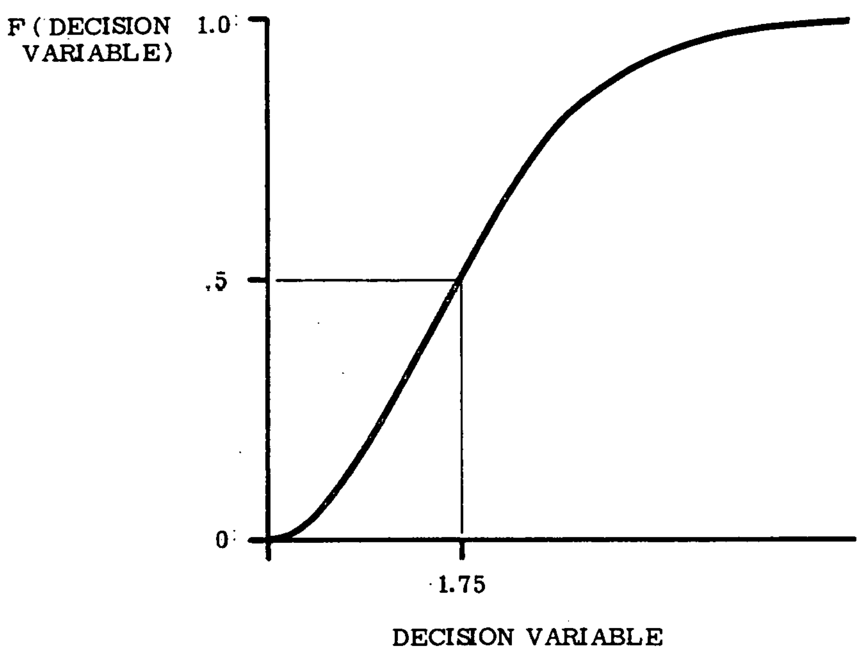


FIGURE 1-7

ENERGY SAVINGS CURVE



TECHNOLOGY COST CURVE



EXAMPLE APPLICATION

2.1 INTRODUCTION

The example application of the RAM2 methodology presented here is based on the current (as of October 1978) BCS program. Seven market groups are analyzed:

- Space Conditioning
- Windows
- A/E Non-Competing
- A/E Single Family
- A/E New Offices
- Appliance Packages
- Other Non-Competing

For each of these groups, frequency cost curves were developed primarily from threshold data. Energy savings curves were developed from a number of sources, but due to time limitations a substantial amount of threshold data was also used in this phase of the analysis. In subsequent applications of the RAM2 model, the dependence on threshold inputs for energy savings will be reduced.

Based on the input curves, market group summaries were prepared for each of the groups. These were used to develop estimates of the savings which can be achieved at proposed minimum, current, and enhanced budget levels. The results of the funding level analysis were calibrated to outputs of the Oak Ridge commercial and residential models to ensure consistency of scale in BCS forecasts.

The example application is presented in two parts: 1) development of the inputs, and 2) results. While this is an example application, the numbers used are realistic to the limits of the input data and are usable for planning. However, this is an example and there are other ways to develop the inputs than the one shown. As the RAM2 methodology is put into use the quality of the input data will improve substantially and the techniques by which the input curves are derived can be further developed, enhancing the accuracy of the methodology.

2.2 INPUTS

Several steps are involved in the preparation of data for input to the resource allocation model. These include:

- Determination of the market cost of each technology which is the present value of the purchase price plus operating costs over the lifetime of the equipment.
- Generation of cost probability curves estimating the probability that the technology will cost less than some amount.
- Estimation of market penetration for the various technologies.
- Development of the value of energy savings at various technology costs.

Each of these steps in the process of data preparation will be described and illustrated in the remainder of this section. The specific data input for each technology is presented at the end of Section 2.2.

2.2.1 Cost of Technology

The cost of each technology was developed from data submitted by the developers of the projects. For each technology, a capital cost and an annual operating and maintenance cost were submitted. The present value of these costs was determined over the lifetime of the equipment using a a discount rate of 10 percent.

In each market group a single conventional technology was used for comparison. The cost data for the conventional technology were sometimes taken from data submitted by the program developers. Occasionally other estimates were based on retail prices (e.g., the capital cost of a refrigerator in the Sears Roebuck Catalog) or statistical average costs (e.g., the average monthly residential electric bill, and the fraction thereof, which is due to refrigeration).[1/] The cost of the conventional technology was also expressed as present value with a discount rate of 10 percent.

1/ A useful reference in these matters was Liepens, et al, Buildings Energy Use Data Book, Oak Ridge National Laboratory, ORNL-5363, April 1978.

2.2.2 Cost Probability Curves

For any newly developed technology there is some probability that its cost will actually be greater or less than the developer's estimate. The cost probability curves were derived as a function of the risk of the new technology. For each new technology the lifetime cost based on the developer's estimate was taken as the tenth percentile. Thus, it was assumed that the actual cost has a ten percent probability of being less than the estimate.

The median cost was then estimated, based on the risk as estimated by the project developers. Technologies were said to be high risk if their probability of success was less than 80 percent; medium risk if the probability of success was between 80 and 90 percent, and low risk if the probability of success was greater than 90 percent. It was assumed that the median cost of high, medium, and low risk projects would be 2.0, 1.5, and 1.25 times their respective tenth percentile estimates. The relationship was assumed to be lognormal, illustrated in Figure 2-1.

It can be seen from this figure that although a high risk project has a higher probability of being prohibitively expensive, it also has a higher probability of being very inexpensive. This is taken into consideration when calculating the expected energy savings of the various projects.

2.2.3 Market Penetration

The market penetration for each market group represents the estimated number of innovative units in use by 1985. In most cases the developers' estimates were used directly, or an average of their estimates for several projects was used. It should be recognized that where a number of technologies are competing in a market, the total number of units in use will be an average of the estimates rather than a sum of the estimates. For example, if four electric heat pumps were developed and the market penetration of each one was estimated at one million units, the total market penetration of all four units would not be four million units. Rather, since the four technologies compete in a single market, the total penetration would be approximately one million units.

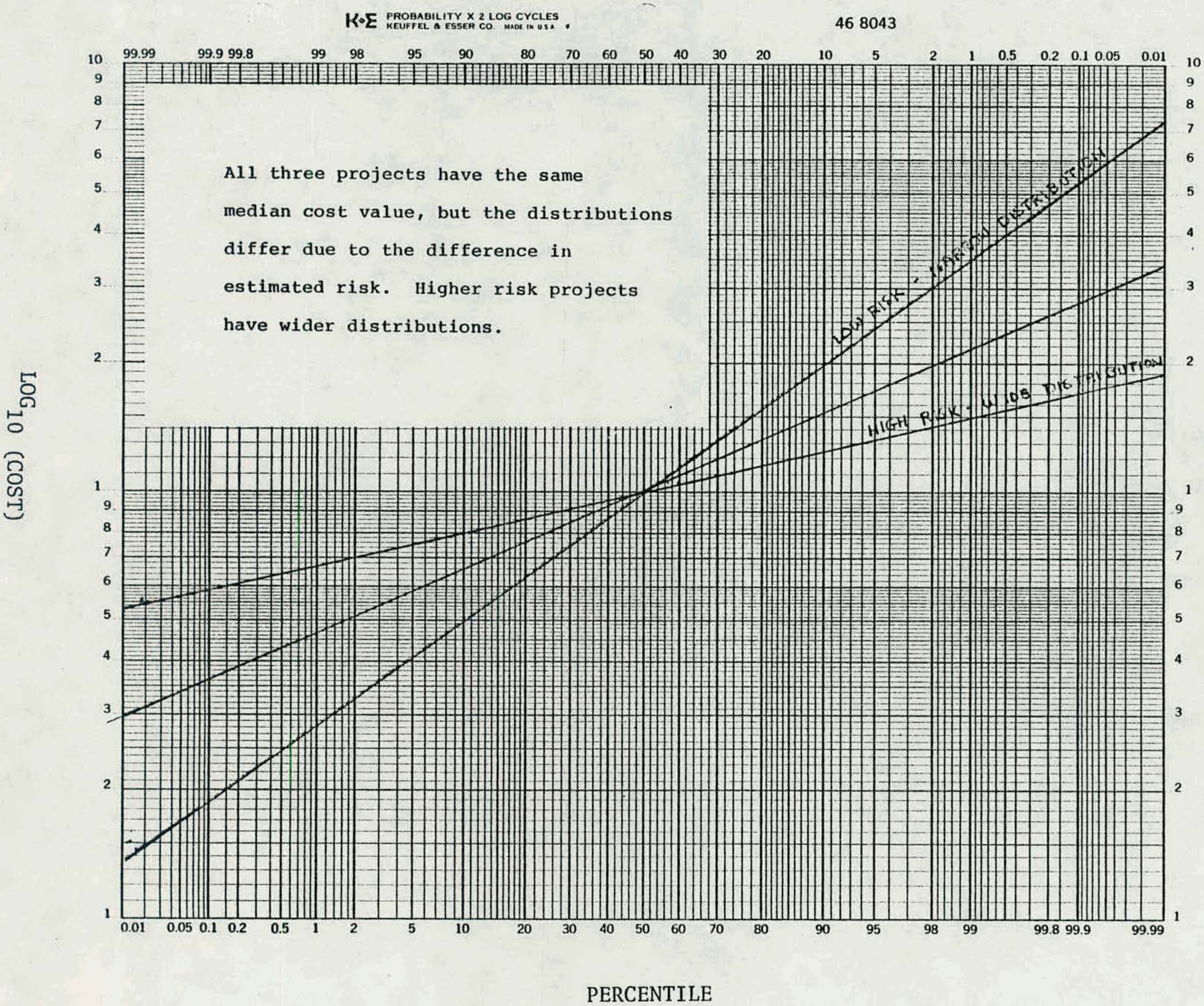


FIGURE 2-1

CUMULATIVE LOGNORMAL COST FREQUENCY CURVES

2.2.4 Input Data by Market Group

This section presents a summary of the input technology cost curves by market group. The tables which follow are all in the same format. The upper portion of the charts show the capital, operating and maintenance, and lifetime of the conventional and new technologies. Below these entries are the discounted present values of the technologies' costs and a rough estimate of the risk of each project. The risk estimate is developed, using the EEA risk methodology.[1/] A high risk rating, "H", means that the estimated chance of the project succeeding is less than 80 percent. A medium rating means an 80 to 90 percent chance of success, and a low rating means a chance of success greater than 90 percent.

The middle of the table describes the technology cost curves. Percentile values for each curve are given for up to the first decile value which exceeds the cost of a conventional technology. Below this table is the estimated probability that each technology will ultimately be available at a lower cost than the conventional technology. In the first chart, two technologies have a 70 percent chance and the third a 64 percent chance. Applying the function described in the preceding section for combining cost probabilities, if all three of the example technologies are developed, there will be a 94 percent chance that at least one will cost less than the conventional alternative. This is calculated by the expression:

$$.94 = 1 - (1-.70) \times (1-.70) \times (1-.66)$$

The research cost and estimated market size complete the technology input summary sheet.

1/ Project Evaluation Methodology Background Material, Energy and Environmental Analysis, Inc., March 15, 1978.

INPUTS

TABLE 2-1

WINDOW MARKET GROUP

ID's:

235 - Innovative Window Design
237 - Weather Resistant IR Mirror
238 - Sun Lighting Design and Controls

TECH #	CONV	235	237	238	AVG
CAP($)	0	240	240	50	
O&M($/YR)	80	2	2	50	
LIFE(YR)	20	20	20	20	
PV LIFE($)	681	257	257	426	
RISK	-	H	H	H	
PERCENTILES					
05		209	209	347	255
10		257	257	426	313
20		331	331	537	399
30		389	389	631	470
40		447	447	741	545
50		514	514	852	626
60		575	575	970	707
70		676	676		
80		794	794		
90					
P(S)		.70	.70	.34	
RESEARCH ($1,000)		710	675	520	635
1985 MARKET = 1.6 MILLION UNITS					

TABLE 2-2

SPACE CONDITIONING GROUP

ID's:

53 - Demo High SPF Gas Heat Pump
58 - Demo Sterling/Ranking Gas Heat Pump
251 - Advanced Electric Heat Pump
252 - Advanced Gas Furnace
297 - Variable Low Firing Rate Oil Burner
334 - SHEIP Program - Oil Units
335 - SHEIP Program - Gas Units
375 - Gas Heat Pumps

TECH #	CONV	53	58	251	252	297	334	335	375	AVG
CAP($)	350	604	587	400	430	250	530	450	583	
O&M($/YR)	300	262	186	153	250	238	208	225	172	
LIFE(YR)	15	15	15	15	15	15	15	15	15	
PV LIFE($)	2631	2596	2001	1564	2332	2060	2112	2111	1891	
RISK	-	H	H	M	L	L	L	L	M	
PERCENTILES										
05		2089	1622	1349	2138	1905	1950	1950	1514	1815
10		2596	2001	1564	2332	2060	2112	2111	1891	2083
20		3162	2512	1862	2399	2138	2188	2188	2692	2411
30		3800	3020	2089	2570	2332	2344	2343	3311	2726
40				2291	2818	2399	2454	2454		
50		5192	4002	2346	2915	2575	2640	2640	3782	
60				2754		2630	2754	2754		
70				3020		2818				
80										
90										
P(S)		0.11	.23	.56	.24	.63	.50	.50	.20	
RESEARCH										
($1,000)		3218	6195	800	3850	180	5700	6500	1990	3370
1985 MARKET = 550,000 UNITS										

[redacted]

TABLE 2-3

A/E NON-COMPETITIVE

ID's:

9 - Energy Conservation in Restaurants
13 - Retrofit Multi-Family Buildings, NYC
86 - New Schools

TECH #	CONV	9	CONV	13	CONV	86	CONV	87
CAP($)	51,000	76,000	0	85	4.4M	4.44M	4.4M	4.48M
O&M($/YR)	21,500	18,790	31	0	170K	163.5K	1.70K	163.5K
LIFE(YR)	15	15	10	10	30	30	30	30
PV LIFE($)	14.5K	218.9K	190	85	6.00M	5.98M	6.00M	6.02M
RISK		H		H		H		H
PERCENTILES								
05		173.8K		69		5.97M		6.00M
10		218.9K		85		5.98M		6.02M
20				107		5.99M		
30				129		6.00M		
40				148		6.01M		
50		437.8K		170		6.02M		6.10M
60				195				
70				229				
80								
90								
P(S)		.10		.58		.50		.05
RESEARCH ($1,000)		7400		1650		4200		1550
MARKET		19,000		400K		7310		16,270

TABLE 2-3 (cont)

A/E NON-COMPETITIVE

ID's:

89 - Food Stores Retrofit
156 - ACES Commercial Implementation
79 - Retrofit Municipal Buildings

TECH #	CONV	89	CONV	156	CONV	249	CONV	79
CAP($)	1.6M	1.89M	0	.50	0	200	0	250K
O&M($/YR)	165.6K	124.5K	.10	.01	200	86	70K	0
LIFE(YR)	10	10	20	20	20	20	10	10
PV LIFE($)	2.62M	2.65M	0.85	0.59	1703	932	430K	250K
RISK		H		M		H		H
PERCENTILES								
05		2.58		.42		759		204K
10		2.65		.59		932		250K
20				.66		1175		316K
30				.72		1380		363K
40				.79		1622		437K
50				.89		1864		500K
60				.93		2138		
70								
80								
90								
P(S)		.05		.48		.44		.42
RESEARCH								
($1,000)		1000		3140		1650		300
MARKET		800		154M		750K		600

[redacted] [redacted]

TABLE 2-4

A/E SINGLE FAMILY

ID's:

91 - Residential Retrofit
341 - Innovative Shelter Design
92 - Minimum Energy House
10 - ACES Single Family

TECH #	CONV	91	341	AVG	92	10
CAP($)	0	250	500		2400	2400
O&M($/YR)	200	177	58		15	80
LIFE(YR)	20	20	20		20	20
PV LIFE($)	1703	1757	994		2528	3081
RISK	-	H	H		M	H
PERCENTILES						
05		1412	794	1103	2239	2512
10		1757	994	1376	2528	3081
20		2188	1259	1723		
30			1514			
40			1738			
50		3514	1988		3792	6162
P(S)		.09	.39	.18	N/C	N/C
RESEARCH ($1,000)		1725	4868	3000	450	8290

1985 MARKET = 1.9 MILLION UNITS

[redacted] [redacted] [redacted]

TABLE 2-5

A/E NEW OFFICE*

ID's:

85 - GSA Manchester Demo
99 - Energy Use in Office Buildings
148 - ACES - New Office Buildings

TECH #	CONV	85	99	148	AVG
CAP($)	0	1.43	1.00	0.50	
O&M($/YR)	.40	.05	.27	.30	
LIFE(YR)	30	30	30	30	
PV LIFE($)	3.77	1.90	2.55	2.83	
RISK	-	H	H	H	
PERCENTILES					
05		1.55	1.70	1.86	1.70
10		1.90	2.55	2.83	2.43
20		2.40	3.24	3.55	3.06
30		2.82	3.80	4.27	3.63
40		3.31	4.47	4.90	4.23
50		3.80	5.10	5.66	
60					
P(S)		.50	.30	.24	
RESEARCH ($1,000)		1950	1436	2940	2109

1985 MARKET = 272 MILLION SQUARE FEET

*Competitive based on costs sq. ft.

TABLE 2-6

APPLIANCE PACKAGES

ID's:

67 - Other Residential Appliances: water-range-refrigerator-small appliance
319 - Integrated Electric Appliances: A/C-water heater

TECH #	CONV	67	319	AVG
CAP($)	800	950	1100	
O&M($/YR)	250	74	141	
LIFE(YR)	15	15	15	
PV LIFE($)	2702	1513	2172	
RISK	-	M	M	
PERCENTILES				
05		1349	1905	1627
10		1513	2172	1843
20		1698	2512	2105
30		1862	2754	2308
40		1995	2951	2473
50		2270	3258	2764
60		2344	3467	2906
70		2511	3715	
80		2754		
90				
P(S)		.76	.29	
RESEARCH ($1,000)		1905	400	1153

1985 MARKET = 3.5 MILLION UNITS

TABLE 2-7

NON-COMPETITIVE

ID's:

358 - 40 KW Fuel Cell
273 - High Efficiency Refrigerator/Freezer
316 - Range Hood Heat Recovery System

TECH #	CONV	358	CONV	273	CONV	316
CAP($)		24,000	450	527	0	1700
O&M($/YR)	3200	2913	35	22	1000	70
LIFE(YR)	20	20	15	15	20	20
PV LIFE($)	27,243	48,800	716	694	3513	2295
RISK		H		M		H
PERCENTILES						
05		43,651		661		1862
10				694		2295
20				724		2884
30				734		3467
40				741		3981
50				759		4591
60						5248
70						6026
80						7244
90						9120
P(S)		0		.18		.87
RESEARCH						
($1,000)				529		80
MARKET				5M		40K

TABLE 2-7 (cont)

NON-COMPETITIVE

ID's:

100 - Hospitals Retrofit
230 - Commercial Appliances
231 - Appliances with Storage

TECH #	CONV	100	CONV	230	CONV	231
CAP($)	0	250K	1700	2000	150	180
O&M($/YR)	80K	10K	505	375	97	81
LIFE(YR)	15	15	15	15	12	12
PV LIFE($)	608K	326K	5541	4852	811	732
RISK		H		H		M
PERCENTILES						
05		275K		3981		647
10		326K		4852		732
20		389K		6166		832
30		447K		7244		912
40		501K		8318		1000
50		576K		9704		1098
60		631K				
70		708K				
80						
90						
P(S)		.56		.15		.18
RESEARCH ($1,000)		2100		630		870
MARKET		2030		3000		2000

2.3 RESULTS

There are two types of outputs from the example application. The market group summaries are the direct output of the RAM2 computer code. These follow on the next several pages. The format was explained in Section 1.4.

The second output are plots of energy savings vs. funding curves for the seven market groups currently in the RAM2 system. These curves show how savings increase with funding level. They are prepared directly from the RAM2 market group outputs which present savings estimates for increasingly more expensive portfolios. These curves represent the maximum savings possible at each level. A lesser value of savings can be achieved by selection of a non-optimal portfolio. Such portfolios do not appear on the RAM2 outputs.

To aid in interpreting these curves, an annotated sample follows this page. The right hand vertical axis is the present value of the dollar value of cumulative resource savings through 1985, as estimated from threshold inputs. The left hand vertical axis is an estimate of cumulative energy savings through 2000 in Quads obtained from threshold inputs calibrated to Eric Hirst and Jerry Jackson's estimates, as presented in "Future Energy Use in Residential and Commercial Buildings: Energy Conservation and Economics," issued about 11 October 1978. The horizontal axis is the present value of the funding stream for all included projects. All present values are calculated with a ten percent discount rate.

The numbers, like those labeled "C", represent specific portfolios of projects taken from the RAM2 output. The current funding level, marked with a vertical line, corresponds to the total of all projects now funded, which is the last portfolio in the RAM2 ranking for each market group. Enhanced and minimum funding levels are also marked with vertical lines.

Following the current funding level, the savings curves have been extrapolated along two lines. The lower line, labeled "A", assumes that any funding above the current level will accrue savings at the same marginal rate per research dollar as the research portfolio at the current level. Because RAM2 is a ranking methodology, however, this extrapolation is equivalent to assuming that additional research will be no better than the poorest project now funded. This extrapolation represents a lower bound on the value of additional funding.

The higher extrapolation, labeled "B", assumes that any additional funding will go to a project which is the average in terms of cost and expected results of all projects currently funded. This represents a more reasonable estimate of the value of additional funding.

Note that the two savings trajectories are most different when the market group contains very heterogeneous projects. When the poorest project is closest to the average, the two curves are close together. Single projects with very large or very small savings can increase divergence. Substantial improvements in accuracy can be obtained from careful attention to the input data for these projects or isolation of these projects from the market group.

The final results presented are Table 2-15 and Table 2-16, which are summaries of the energy savings vs. funding curves.

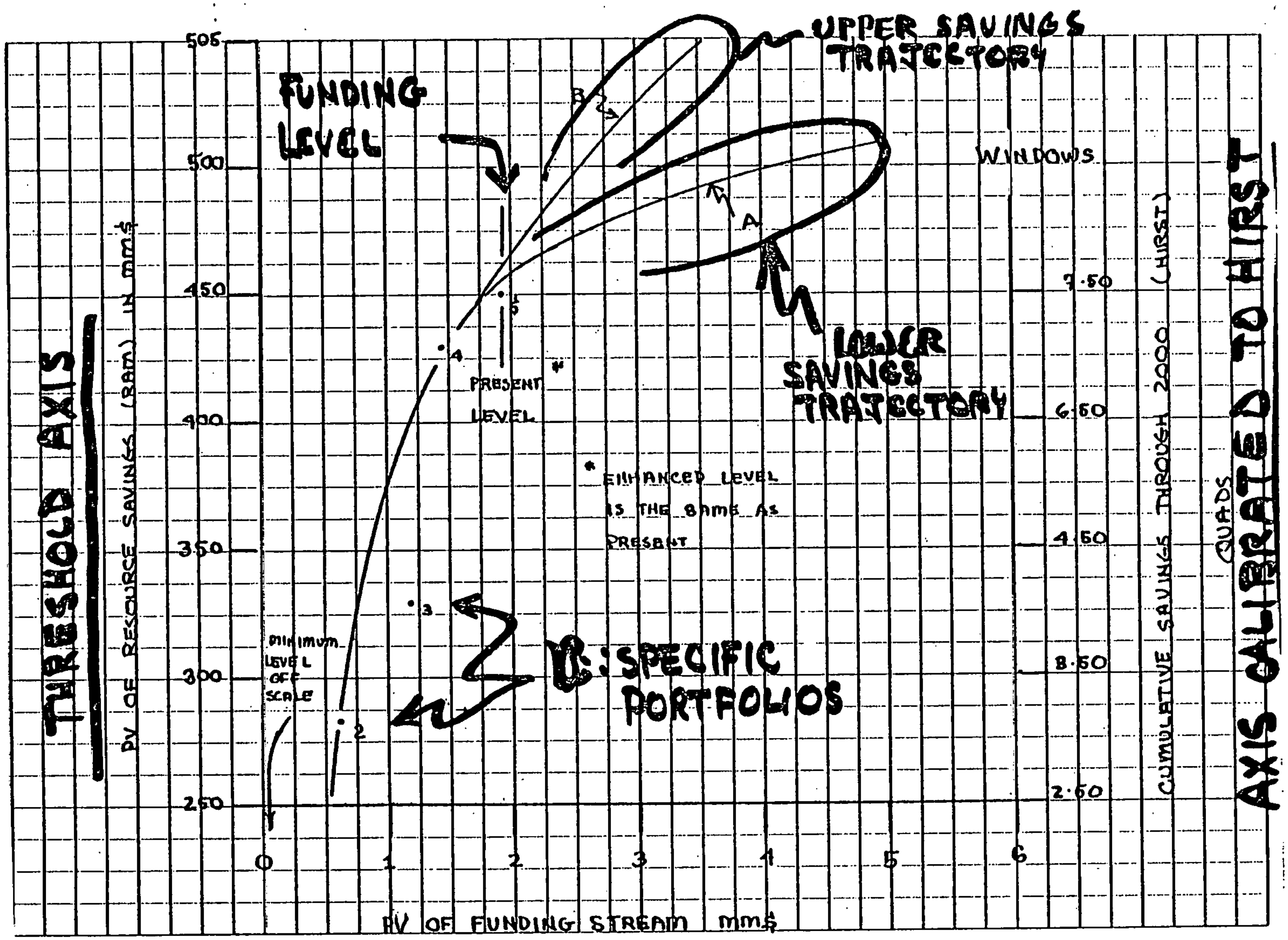


FIGURE 2-2

ANNOTATED SAVINGS CURVES

GROUP SUMMARIES

10/17/78

TABLE 2-8

MARKET GROUP 61 APPLIANCE PACKAGES

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS) 67	319
1	0.140E+03	0.400E+00	0.561E+02	0	1
2	0.139E+03	0.190E+01	0.265E+03	1	0
3	0.124E+03	0.230E+01	0.286E+03	1	1
	0.102E+03	0.346E+01	0.353E+03	<--- VALUES FOR COMPLETE FORTFOLIO PLUS ADDED AVERAGE PROJECT	

10/17/78

TABLE 2-9

MARKET GROUP 11 SPACE CONDITIONING

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS)							
				53	58	252	297	334	335	251	375
1	0.548E+03	0.180E+00	0.987E+02	0	0	0	1	0	0	0	0
2	0.233E+03	0.800E+00	0.187E+03	0	0	0	0	0	0	1	0
3	0.245E+03	0.980E+00	0.240E+03	0	0	0	1	0	0	1	0
4	0.933E+02	0.297E+01	0.277E+03	0	0	0	1	0	0	1	1
5	0.458E+02	0.619E+01	0.283E+03	1	0	0	1	0	0	1	1
6	0.421E+02	0.682E+01	0.287E+03	0	0	1	1	0	0	1	1
7	0.352E+02	0.867E+01	0.305E+03	0	0	0	1	1	0	1	1
8	0.260E+02	0.119E+02	0.309E+03	1	0	0	1	1	0	1	1
9	0.250E+02	0.124E+02	0.310E+03	1	1	0	1	0	0	1	1
10	0.249E+02	0.125E+02	0.312E+03	0	0	1	1	1	0	1	1
11	0.241E+02	0.130E+02	0.313E+03	0	1	1	1	0	0	1	1
12	0.221E+02	0.149E+02	0.328E+03	0	1	0	1	1	0	1	1
13	0.184E+02	0.181E+02	0.332E+03	1	1	0	1	1	0	1	1
14	0.178E+02	0.187E+02	0.334E+03	0	1	1	1	1	0	1	1
15	0.160E+02	0.214E+02	0.343E+03	0	1	0	1	1	1	1	1
16	0.141E+02	0.246E+02	0.345E+03	1	1	0	1	1	1	1	1
17	0.137E+02	0.252E+02	0.346E+03	0	1	1	1	1	1	1	1
18	0.123E+02	0.284E+02	0.349E+03	1	1	1	1	1	1	1	1
	0.114E+02	0.320E+02	0.366E+03	<--- VALUES FOR COMPLETE PORTFOLIO PLUS ADDED AVERAGE PROJECT							

12/10/78

TABLE 2-10

MARKET GROUP 7: OTHER NON COMPETITIVE

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS) 273	316	100	230
1	0.225E+04	0.800E-01	0.180E+03	0	1	0	0
2	0.302E+03	0.609E+00	0.184E+03	1	1	0	0
3	0.148E+03	0.124E+01	0.184E+03	1	1	0	1
4	0.155E+03	0.218E+01	0.339E+03	0	1	1	0
5	0.126E+03	0.271E+01	0.343E+03	1	1	1	0
6	0.103E+03	0.334E+01	0.343E+03	1	1	1	1
	0.103E+03	0.417E+01	0.428E+03	<--- COMPLETE PORTFOLIO WITH ADDED AVERAGE PROJECT			

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TABLE 2-11

MARKET GROUP 5: A/E NEW OFFICES

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS) 99	85	148
1	0.552E+01	0.144E+01	0.793E+01	1	0	0
2	0.253E+02	0.195E+01	0.493E+02	0	1	0
3	0.169E+02	0.339E+01	0.572E+02	1	1	0
4	0.978E+01	0.633E+01	0.619E+02	1	1	1
	0.978E+01	0.843E+01	0.825E+02	<--- COMPLETE PORTFOLIO WITH ADDED AVERAGE PROJECT		

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TABLE 2-12

MARKET GROUP 41 A/E SINGLE FAMILY

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS) 91	341
1	0.868E+01	0.100E+01	0.868E+01	1	0
2	0.762E+01	0.487E+01	0.371E+02	0	1
3	0.726E+01	0.587E+01	0.426E+02	1	1
	0.636E+01	0.880E+01	0.560E+02	<--- VALUES FOR COMPLETE PORTFOLIO PLUS ADDED AVERAGE PROJECT	

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TABLE 2-13

MARKET GROUP 2: WINDOWS

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS) 235	238	237
1	0.184E+03	0.520E+00	0.958E+02	0	1	0
2	0.423E+03	0.675E+00	0.285E+03	0	0	1
3	0.274E+03	0.119E+01	0.328E+03	0	1	1
4	0.311E+03	0.138E+01	0.431E+03	1	0	1
5	0.237E+03	0.170E+01	0.451E+03	1	1	1
	0.199E+03	0.254E+01	0.505E+03	<--- VALUES FOR COMPLETE PORTFOLIO PLUS ADDED AVERAGE PROJECT		

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TABLE 2-14

MARKET GROUP 3: A/E NON COMPETITIVE

	ENERGY SAVED/$	RES. COST ($X10**6)	ENERGY SAVED ($X10**6)	PORTFOLIOS (FUNDING LEVELS) 9	13	86	89	156	249	79
1	0.687E+02	0.300E+00	0.206E+02	0	0	0	0	0	0	1
2	0.163E+02	0.130E+01	0.212E+02	0	0	0	1	0	0	1
3	0.766E+02	0.165E+01	0.126E+03	0	0	0	0	0	1	0
4	0.754E+02	0.195E+01	0.147E+03	0	0	0	0	0	1	1
5	0.501E+02	0.295E+01	0.148E+03	0	0	0	1	0	1	1
6	0.447E+02	0.360E+01	0.161E+03	0	1	0	0	0	1	1
7	0.351E+02	0.460E+01	0.162E+03	0	1	0	1	0	1	1
8	0.263E+02	0.615E+01	0.162E+03	0	0	1	0	0	1	1
9	0.243E+02	0.674E+01	0.164E+03	0	1	0	0	1	1	1
10	0.213E+02	0.774E+01	0.165E+03	0	1	0	1	1	1	1
11	0.225E+02	0.780E+01	0.176E+03	0	1	1	0	0	1	1
12	0.201E+02	0.880E+01	0.177E+03	0	1	1	1	0	1	1
13	0.164E+02	0.109E+02	0.179E+03	0	1	1	0	1	1	1
14	0.150E+02	0.119E+02	0.180E+03	0	1	1	1	1	1	1
15	0.133E+02	0.135E+02	0.180E+03	1	0	1	0	0	1	1
16	0.129E+02	0.141E+02	0.182E+03	1	1	0	0	1	1	1
17	0.121E+02	0.151E+02	0.183E+03	1	1	0	1	1	1	1
18	0.128E+02	0.152E+02	0.194E+03	1	1	1	0	0	1	1
19	0.120E+02	0.162E+02	0.195E+03	1	1	1	1	0	1	1
20	0.107E+02	0.183E+02	0.197E+03	1	1	1	0	1	1	1
21	0.102E+02	0.193E+02	0.198E+03	1	1	1	1	1	1	1
	0.102E+02	0.221E+02	0.226E+03	<--- COMPLETE PORTFOLIO WITH ADDED AVERAGE PROJECT						

SAVING

PV OF FUNDING STREAM IN MM$

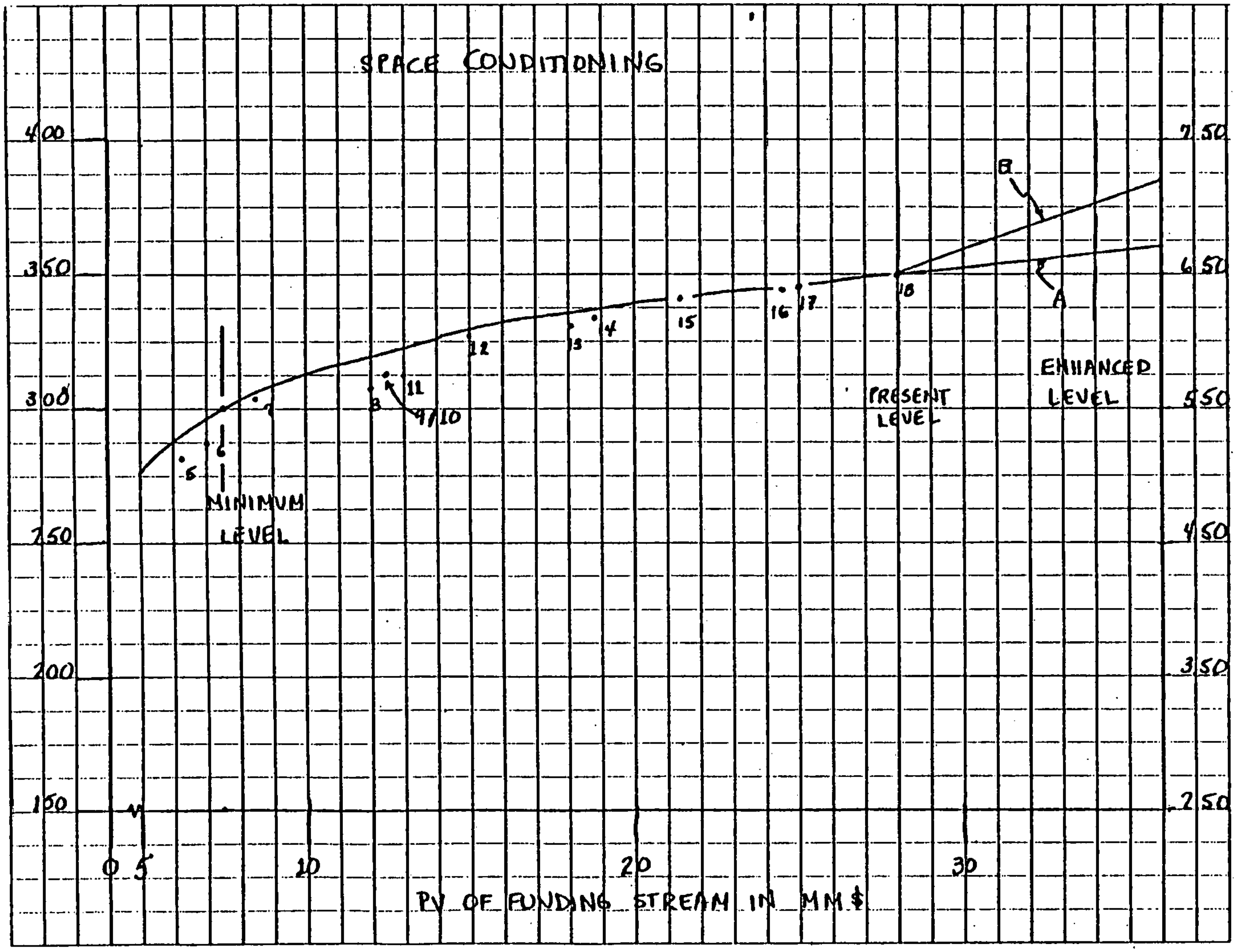
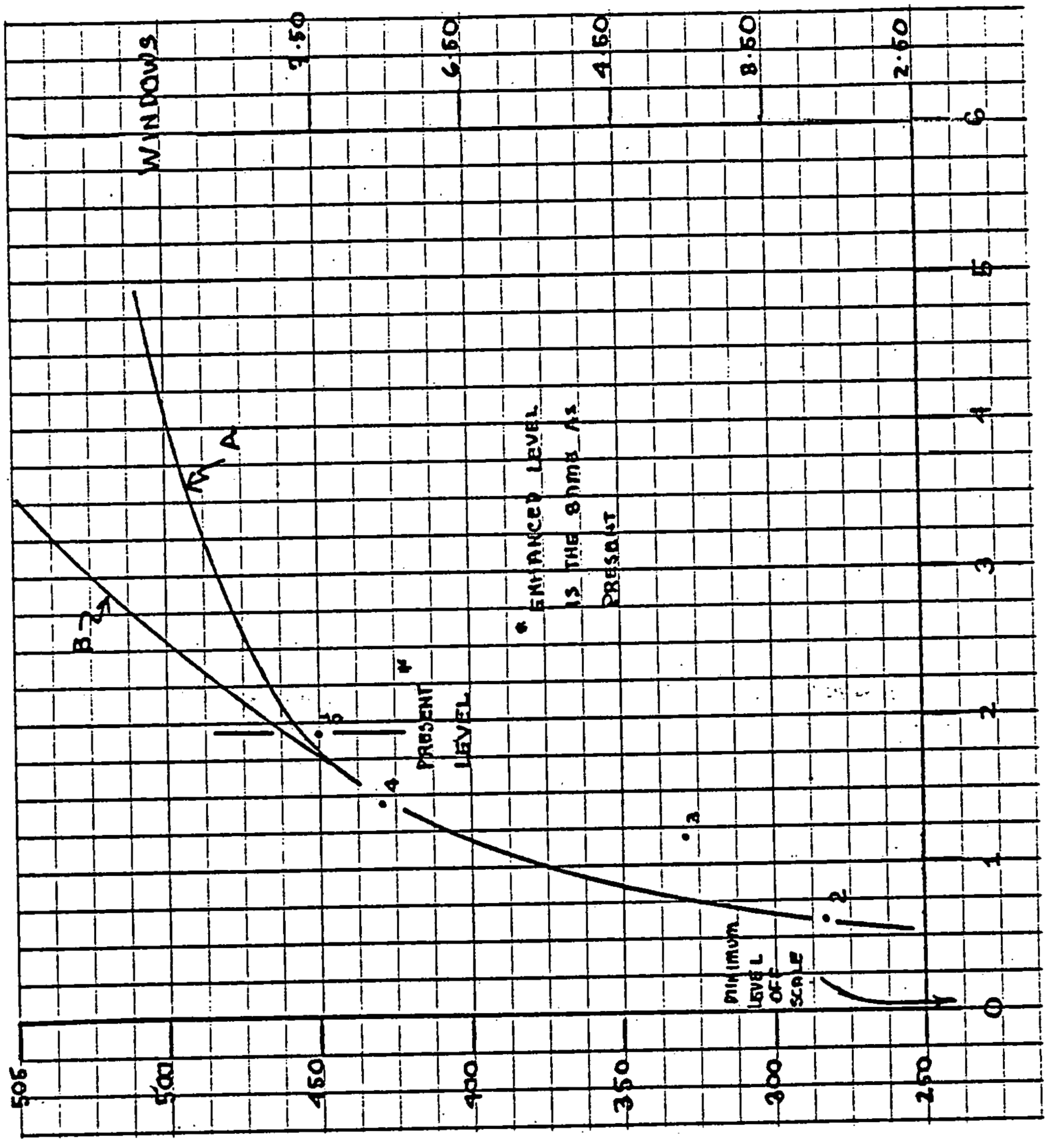


FIGURE 2-3

CUMULATIVE SAVINGS THROUGH 2000 (HIRST)
(QUADS)

FIGURE 2-4

CUMULATIVE SAVINGS THROUGH 2000 (HIRST)
(QUADS)



PV OF FUNDING STREAM MM$

PV OF RESOURCE SAVINGS (RAM) IN MM$

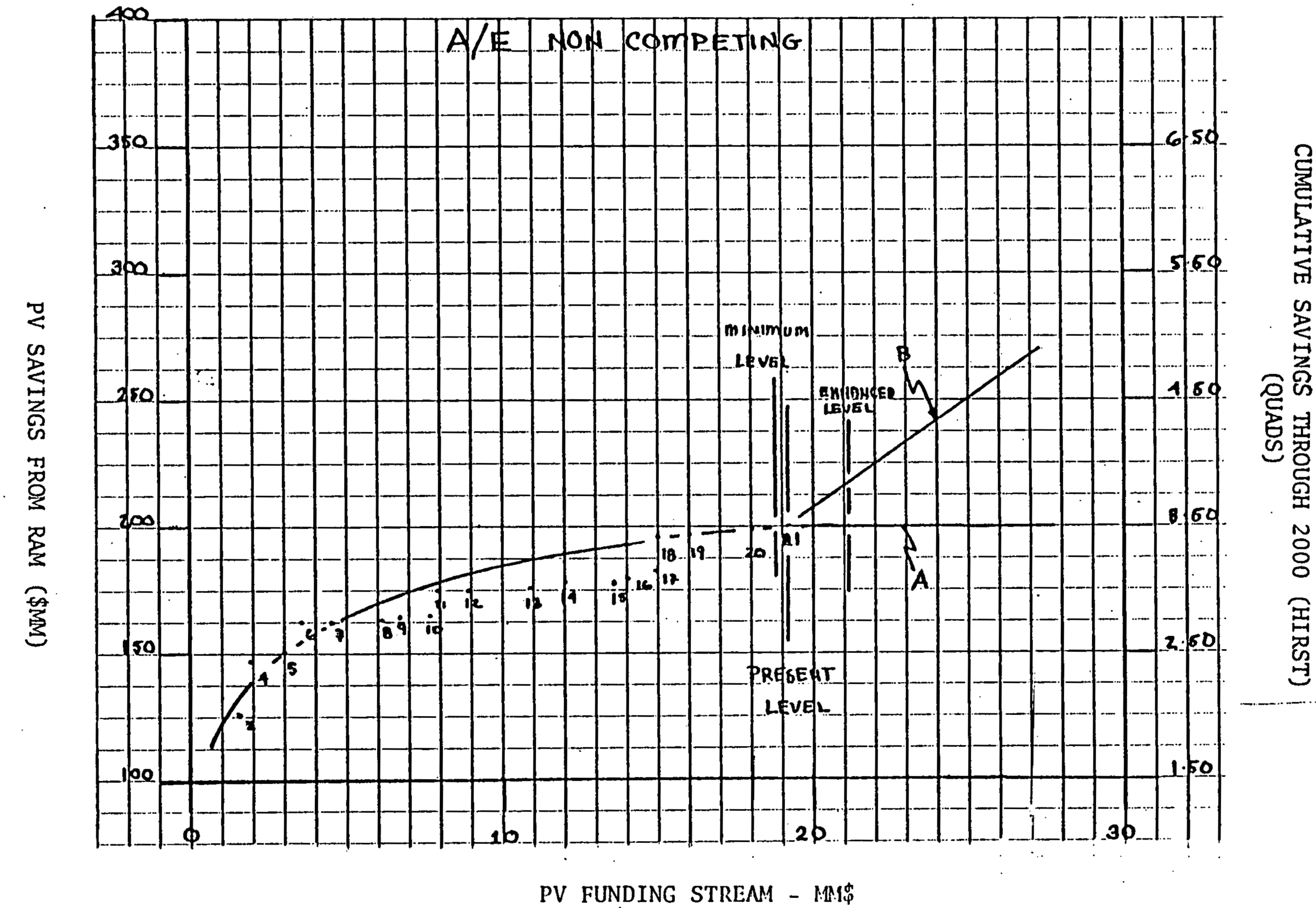
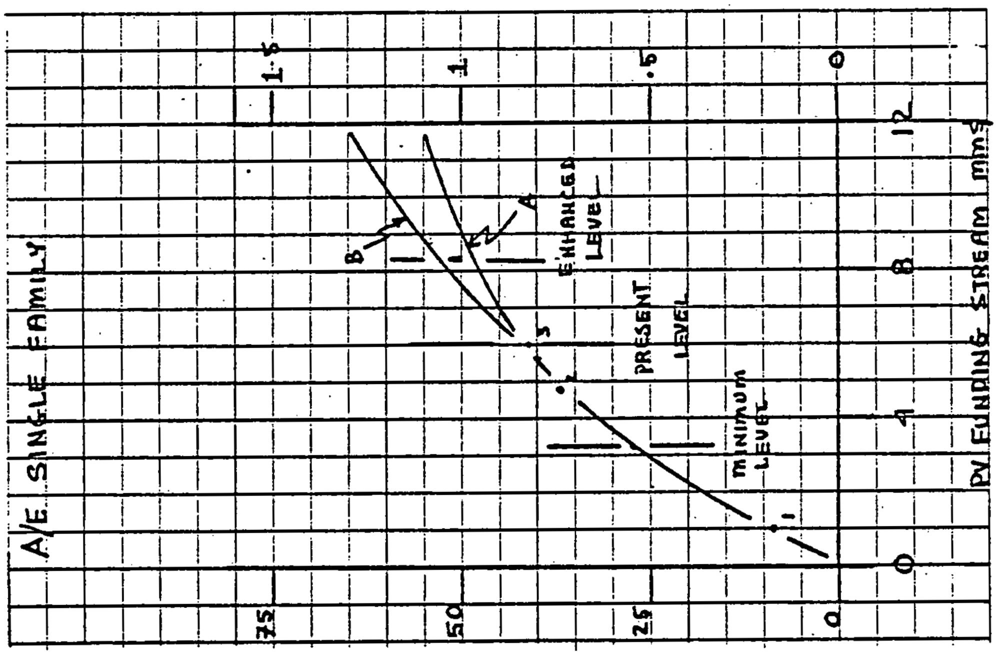

A/E NON COMPETING
400
350
300
250
200
150
100
6.50
5.50
4.50
3.50
2.50
1.50
0
10
20
30
MINIMUM LEVEL
ENHANCED LEVEL
PRESENT LEVEL
A
B
PV SAVINGS FROM RAM ($MM)
PV FUNDING STREAM - MM$
CUMULATIVE SAVINGS THROUGH 2000 (HIRST) (QUADS)

FIGURE 2-5

FIGURE 2-6

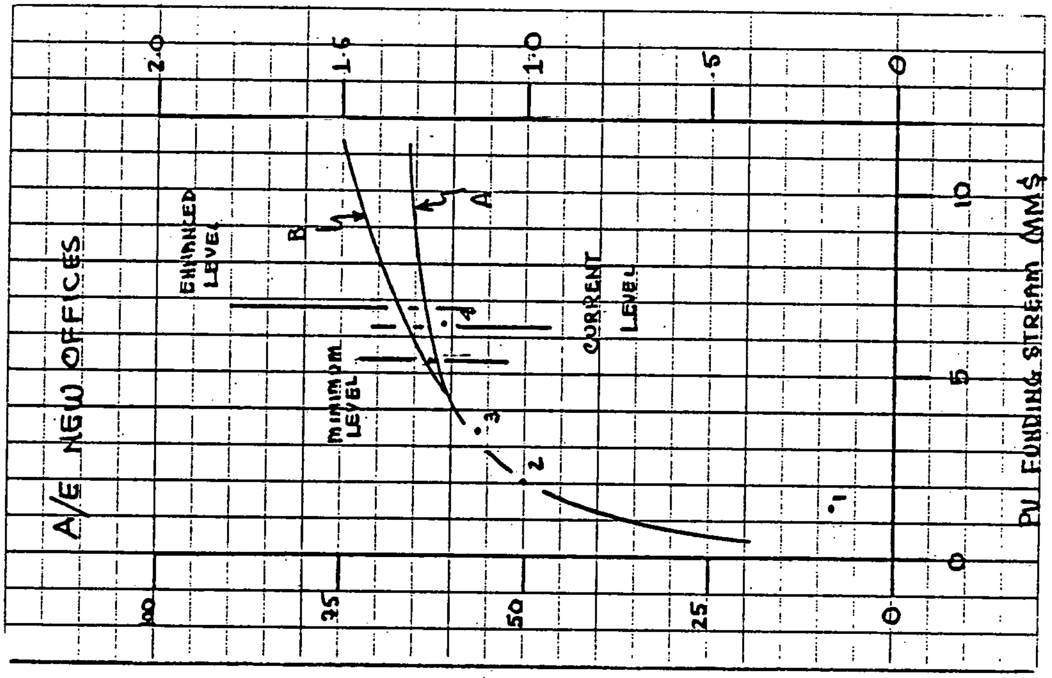
CUMULATIVE SAVINGS THROUGH 2000
(QUADS)



PV SAVINGS FROM RAM ($MM)

FIGURE 2-7

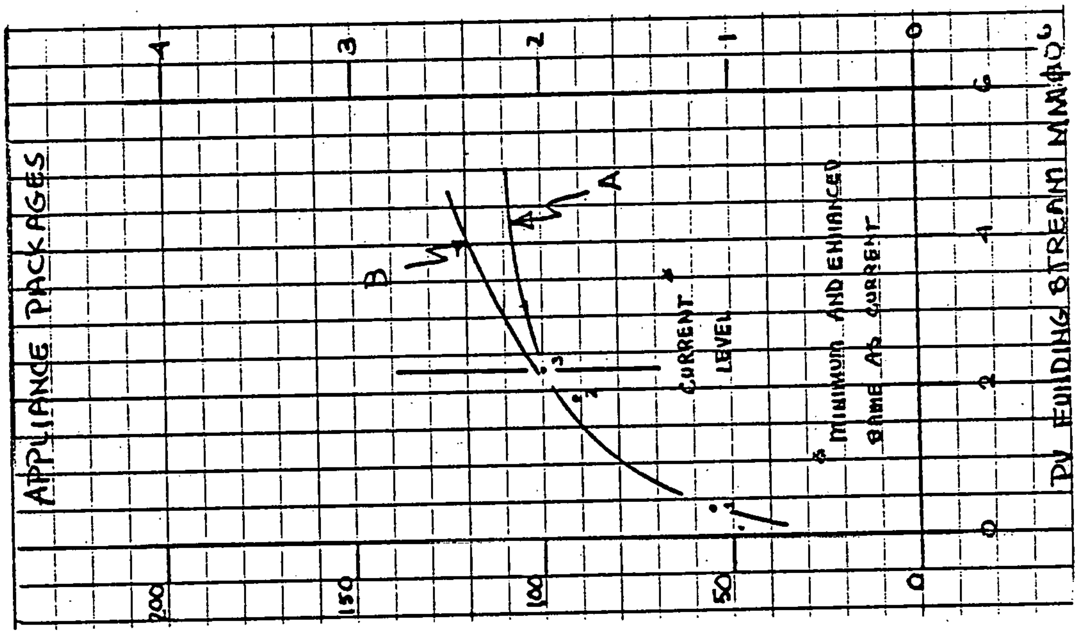
CUMULATIVE SAVINGS THROUGH 2000 (HIRST)
(QUADS)



PV SAVINGS FROM RAM ($MM)

FIGURE 2-8

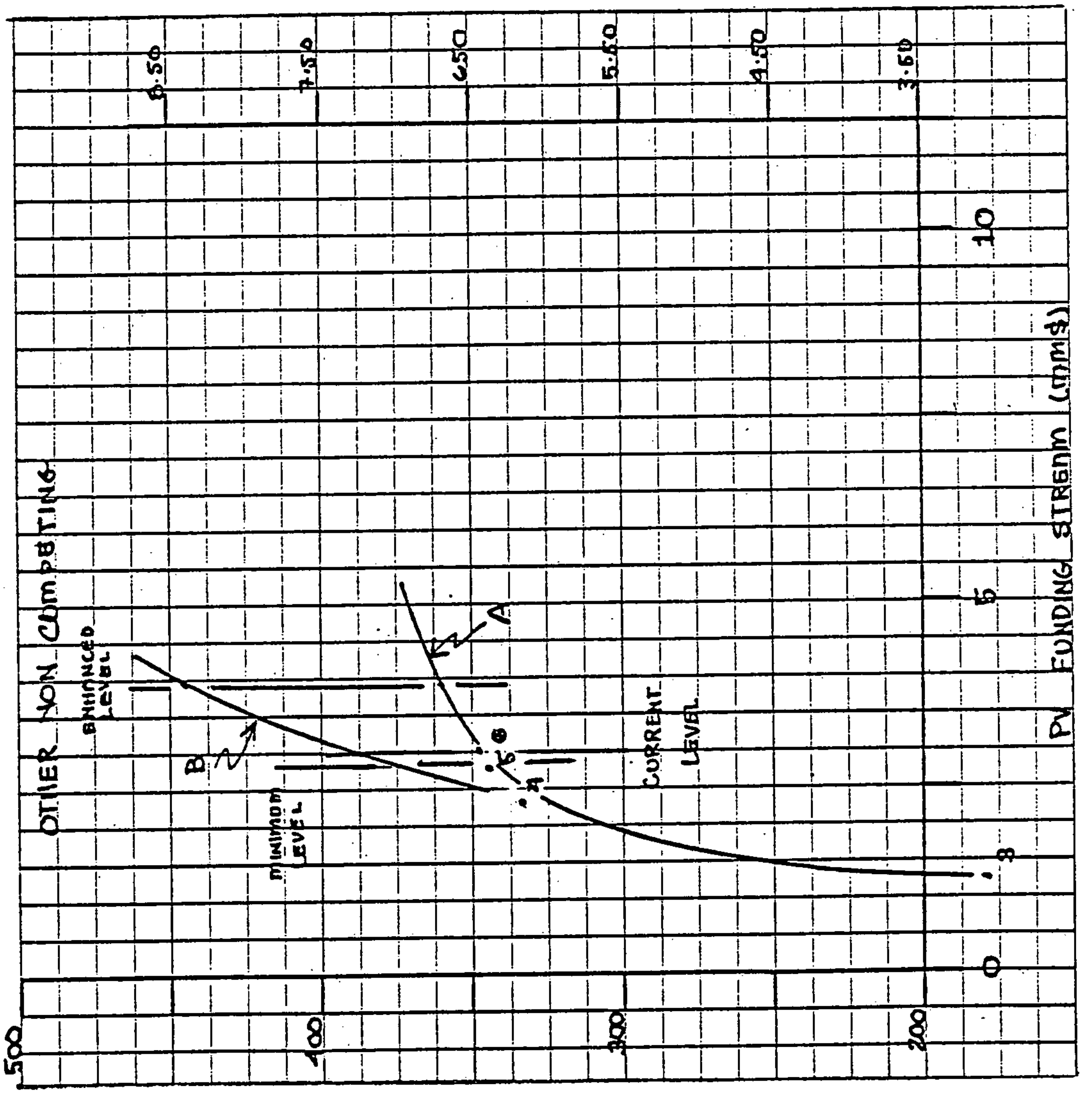
ENERGY SAVINGS THROUGH 2000 (HIRST)
(QUADS)



PV SAVINGS FROM RAM ($MM)

FIGURE 2-9

CUMULATIVE SAVINGS THROUGH 2000 (HIRST)
(QUADS)



PV SAVINGS FROM RAM ($MM)

SUMMARY TABLES

TABLE 2-15

PRESENT VALUE[1/] OF CUMULATIVE RESOURCE SAVINGS THROUGH 1985 ($MM)

(from threshold data)

Market Group	Minimum Level	Current Level	Enhanced Level	
			Low[2/]	High[3/]
Space Conditioning	300.0	349.0	355.0	375.0
Windows	12.2	451.0	451.0	451.0
A/E Non-Competing	196.0	198.0	200.0	214.0
A/E Single Family	27.5	42.6	48.3	53.0
A/E New Offices	61.3	63.5	64.2	67.1
Appliance Packages	111.0	111.0	111.0	111.0
Other Non-Competing (CP)	337.0	343.0	360.0	444.0
TOTAL	1045.0	1558.0	1589.0	1715.1

[1/] 1975 dollars discounted at 10 percent to 1978

[2/] Low values correspond to lower savings trajectories (labeled A)

[3/] High values correspond to higher savings trajectories (labeled B)

TABLE 2-16

CUMULATIVE ENERGY SAVINGS THROUGH 2000 (QUADS)

(from threshold data calibrated to Hirst and Jackson)

Market Group	Minimum Level	Current Level	Enhanced Level	
			Low[1/]	High[2/]
Space Conditioning	5.58	6.50	6.61	6.98
Windows	.23	8.40	8.40	8.40
A/E Non-Competing	3.65	3.69	3.72	3.98
A/E Single Family	.51	.79	.90	.99
A/E New Offices	1.14	1.18	1.20	1.25
Appliance Packages	2.07	2.07	2.07	2.07
Other Non-Competing (CP)	6.27	6.39	6.69	8.27
TOTAL	19.46	29.01	29.54	31.93

[1/] Low values correspond to lower savings trajectories (labeled A)

[2/] High values correspond to higher savings trajectories (labeled B)