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METHODS FOR EVALUATING AND RANKING
TRANSPORTATION ENERGY CONSERVATION
PROGRAMS

Final Report

MASTER

April 30, 1981

Work Performed Under Contract No. AC01-80CS50226

Wilson Hill Associates
Washington, DC

U. S. DEPARTMENT OF ENERGY

Division of Transportation Energy Conservation

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**METHODS FOR EVALUATING
AND RANKING
TRANSPORTATION ENERGY
CONSERVATION PROGRAMS
FINAL REPORT**

CONTRACT NO: DE-AC01-80CS50226

April 30, 1981

Prepared For:

**U.S. DEPARTMENT OF ENERGY
OFFICE OF TRANSPORTATION PROGRAMS
Washington, D.C. 20585**

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Louis C. Santone
Principal Investigator
Wilson Hill Associates

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EXECUTIVE SUMMARY

The Office of Transportation Programs of the Department of Energy administers a variety of programs designed to help achieve significant reductions in the consumption of petroleum by different forms of transportation while maintaining public, commercial and industrial mobility. The programs are diverse in nature, ranging from the electric vehicle and advanced propulsion programs to outreach programs such as the MPG mileage guide in which the Department pays for the preparation and distribution of booklets that list the fuel economy of all automobiles sold domestically.

This report presents methods for comparative evaluations of the programs. Assessments of the programs in terms of petroleum savings, incremental costs to consumers of the technologies and activities, probability of technical and market success, and external impacts due to environmental, economic and social factors are all inputs to the evaluation methodologies presented in this report. A computer program developed by the Argonne National Laboratory is the main source of inputs involving petroleum savings and aggregated incremental consumer costs.

The methods for evaluating the programs on a comparative basis are three ranking functions and a policy matrix listing important attributes of the programs and the technologies and activities with which they are concerned. The first of the ranking methods is the traditional net present value measure. This method computes the present worth of petroleum savings less the present worth of costs. This is modified by dividing by the present value of DOE funding to obtain a net present value per program dollar, which is the second ranking function. The third ranking function is broader in that it takes external impacts into account and is known as the comprehensive ranking function.

The underlying rationale for the selection of ranking functions and attributes for the policy matrix is that no small number of attributes is sufficient to provide comparative evaluations for all purposes. Some of the 30 attributes simply describe the programs and are used to provide a quick reference for administrative purposes.

This report, in addition to presenting the policy matrix and the ranking functions, describes procedures for making computations of the ranking functions and the attributes that require computation. In addition, computations are made for four of the OTP programs. These are the electric vehicle, Stirling engine, gas turbine and MPG mileage guide programs.

The four programs, electric vehicle (auto and truck), Stirling engine, gas turbine and MPG mileage guide are ranked on the following basis:

- a. Net Present Value (NPV)
- b. Net Present value divided by discounted DOE funding (NVPM)
- c. Comprehensive ranking function (CRF).

The ranks and scores are as follows:

	NET PRESENT VALUE (Billions of 1980 \$)		NET PRESENT VALUE MODIFIED (\$ per DOE funding) (Divided by 2)		COMPREHENSIVE RANKING FUNCTION	
	RANK	SCORE	RANK	SCORE	RANK	SCORE
Electric Vehicle	1	50	1	84	1	98
Stirling Engine	2	22	2	56	2	86
Gas Turbine	3	14	4	28	3	80
MPG Mileage Guide	4	1	3	45	4	77

NOTE: NPVM is divided by 2 to allow plotting on a scale from zero to one hundred.

FIGURE 1. GRAPHICAL REPRESENTATION OF SCORES AND RANKS

These rankings were all made using inputs from the Argonne Computer program for savings and costs.

In Figure 1, the scores that were obtained by evaluating the ranking functions are plotted. The programs are ranked according to the scores, i.e., the program that receives the highest score according to a given ranking function is said to rank number one according to that ranking function.

The electric vehicle program, primarily because of the large volume of petroleum savings, scores highest on all three of the ranking functions, and is accordingly the highest ranking of the four programs. The three vehicle programs, electric vehicle, Stirling engine and gas turbine have the same rankings relative to each other on all three of the ranking functions. That is, if the MPG mileage guide program were not included in the rankings, the Stirling engine would be ranked second on all three ranking functions, and the gas turbine would be ranked third. As it is, the MPG mileage guide program is ranked third on the net present value modified (NPVM) ranking function and the gas turbine is ranked fourth. In the case of the net present value (NPV) function, the MPG mileage guide is clearly inferior to the other three programs, whereas in the case of the other two ranking functions, the MPG mileage guide program is better than or just about equal to the gas turbine program. The low government costs and the fact that no consumer costs are assigned causes the MPG mileage guide program to have a competitive scoring on the latter ranking functions.

In the graph in Figure 1, it appears that the scores for the programs relative to the comprehensive ranking function (CRF) are bunched. The significance of the bunching should not be overestimated. Part of the comprehensive ranking function, as described in Section 3, is a term consisting of the number 94 that is added to the score of each program

to keep the score of any program from being negative. The selection of the term, as is the desire to avoid negative values, is arbitrarily selected as the largest negative value that a program could possibly receive. A term such as 30 would have served as well in the case of the four sample programs. If the term would have been selected as 30, there would be a much wider apparent spread.

SECTION 1. INTRODUCTION

1.1 OTP POLICY MATRIX

One of the purposes in the administration of an organization or activity is to allocate available resources in such a way as to best meet goals. For many government programs, there are multiple goals that may conflict with each other. They may not always be agreed upon at levels of decision-making above and below the level of the manager of a particular organization, and may change over time. Compared with many government programs, the principal goals of the Office of Transportation Programs (OTP) are relatively free from conflict and are generally agreed upon. The principal goal of the program is to reduce the amount of petroleum consumed by the transportation sector of the economy by an amount that is a significant percentage of projected petroleum imports. Other goals relate to cost effectiveness and maintenance of mobility.

Selecting a set, or portfolio, of programs based on their contribution toward meeting the goal of reducing petroleum consumption is conceptually straightforward. Taking costs into account is less straightforward but manageable, provided that only costs to the consumer and costs to the government program are included. Other costs, particularly external costs such as those from adverse economic, environmental and social impacts and costs to be borne by industry, are more difficult to determine.

As a practical matter, evaluation relative to the goals of petroleum saving and cost effectiveness is difficult because of the need to forecast a large number of factors, most of which are difficult to forecast precisely and accurately.

Even in cases where precision and accuracy of forecasting are adequate for evaluation purposes, there is a need to demonstrate adequacy to decision makers at a number of levels of government, i.e., the Department of Energy, the Office of Management and Budget, and the Congress.

The uncertainty concerning the precision of forecasts of measures of petroleum savings and costs together with the requirement to demonstrate the level of precision and accuracy that has been achieved requires that as much information as is available and useful concerning the OTP programs be conveyed in a concise manner. The OTP Policy Matrix presented in this report is designed to give this information in terms of attributes that describe program inputs, expected outputs, and some external impacts of the programs. The policy matrix is one of the tools for arriving at a portfolio of projects for the Office of Transportation Programs.

Most of the attributes that are listed in the policy matrix have been adopted from other sources. These sources are indicated in the reference list and in the presentation of the matrix. Few of the sources have included specific definitions of the attributes. They are defined specifically in this report and may vary from what the original proposers had in mind.

1.2 METHODS FOR RANKING OTP PROGRAMS

The program ranking function is another tool for program selection. The ranking function makes use of combinations of some of the attributes defining the OTP Policy Matrix. Section 3 of this report describes a comprehensive ranking function (CRF). It is realized that a traditional benefit cost measure such as net present value (NPV) has utility

in ranking programs for portfolio selection. Net present value is presented both as a matrix attribute in its own right and as a potential alternative ranking function. It is also used to provide some of the rationale for the comprehensive ranking function. The net present value ranking function is further modified by dividing by DOE program cost to yield a measure of net present value per program dollar. This is also used as a ranking function.

One of the guiding principles in selection of the evaluation criteria in the ranking function (and the attributes in the policy matrix) was that the OTP Evaluation Group's current or planned work should provide inputs for calculating values of the criteria or that quantitative values can be placed on external impacts.

1.3 AUTOMATION PROCEDURES

The program ranking function and many of the matrix attributes are functions of expected petroleum savings and costs. The Argonne National Laboratory has developed a computer program for computing costs and savings. These are primary inputs to an automated procedure for calculating the matrix attributes and evaluating the ranking function.

Mathematical formulations are given for all of the matrix attributes that are not direct inputs to the policy matrix or the ranking function. (Those that are direct inputs do not need calculation.) All of the required inputs are indicated as are their sources. It is intended that a computer program be implemented according to the automation procedures given in Section 4. The purpose of the computer program is to allow rapid calculation of attributes and ranking functions when new estimates of costs and savings are made and when

there is a need to change some of the assumptions concerning discount rates, real fuel price escalators and other scenario elements. The computer database also serves as a means to store the policy matrix and the results of the ranking function for ad hoc inquiry and display.

1.4 METHODS FOR DISCOUNTING TO PRESENT VALUE

Most energy conservation measures are such that savings take place over a period of time after the investment in the measure is made. The value of future savings at the time of investment depends on the real rate of increase in energy prices and on the time value placed on money. Methods for making the calculations of present value of energy savings and recommendations concerning the discount rates are given in Appendix D.

1.5 LIMITATIONS OF THE STUDY

The purposes of this study are to develop methods for evaluating energy conservation programs and present evaluation results. Examples are used for purposes of illustrating the methods and concepts. While the examples chosen are valid in that input data and information are results of studies performed for the Department of Energy, the studies were not conducted as part of this study. Hence, both the inputs and methods for deriving them are inputs to this study.

The evaluation methods are useful primarily for inter-program comparisons. Consequently, the evaluation is not at a high level of detail. Evaluations at more detailed levels are contemplated, and when they are completed and results become available, they can become inputs for the methods presented in this report since the attributes in the policy matrix.

can be modified to reflect the increased level detail. It is probable, however, that the attributes defined in this report are adequate for almost all results that may be derived in future studies.

Most of the terms in the ranking functions have to do with amounts of energy saved and the costs to consumers and government of attaining the savings. The objectives of the OTP may change from what they were when this study was completed. That is, policy may be formulated to assist industry in cases where the costs of research and development must be shared because of the high risks. The methods presented in this report are still useful regardless of policy shifts because any program must, ultimately, given technical success, lead to high energy savings at competitive costs to consumers and hence have some policy elements in common with the goal as stated in Section 1.1. The comprehensive ranking function illustrated in the report gives a high weight to petroleum savings and a lower weight to consumer costs. It also includes provisions for terms that can reflect changing emphasis on different objectives. The methods for determining the terms and the weights are illustrated in Appendix C to this report and can be used to incorporate new policy initiatives as necessary.

The attributes in the policy matrix were also selected to allow for evaluation of programs in the event of policy changes. Under certain policy changes, however, it will be necessary to at least review the attributes and some attributes may have to be added.

1.6 RECOMMENDATION FOR FURTHER WORK

The comprehensive ranking function (CRF) relies on subjective methods for determining inter-attribute weights and intra-attribute scaling factors. The weights used in this report are

the results of a very brief exercise as described in Appendix C. The intra-attribute scaling factors were developed by the authors of this report. These should be developed in a more methodical fashion and should take policy changes into account.

The computer program for automating the development and use of the policy matrix and the rankings should be implemented. In addition to providing a tool for analysis and maintenance of an evaluation data base, records of all of the assumptions made in computing attributes, measures of effectiveness, and rankings can be displayed with the results.

Finally, as more detailed evaluations are conducted and the results become available, the methods presented in this report should be tested using the new results. This will determine whether the attributes in the policy matrix and/or the ranking functions should be modified.

SECTION 2. THE OTP POLICY MATRIX

2.1 INTRODUCTION

The policy matrix is presented in the form of four matrices that emphasize the grouping of attributes in a way that can be of most interest to decision makers and others. The four matrices are:

- Program Matrix
- Savings Matrix
- Industry Input Matrix
- Impact Matrix.

In each of the matrices, the column headings are the OTP programs and the row headings are attributes which apply to the programs.

The Program Matrix is intended to give a description of the programs in terms of DOE inputs, target markets and other agency participation. The Savings Matrix gives the primary outputs of the programs, the time frames in which they are expected to occur and the measures that account for different time frames in which resources are expended and that savings accrue. The Industry Input Matrix includes attributes that describe inputs by industry that are required to implement technologies and activities. The Impact Matrix includes impacts that are essentially external but must be considered. The adverse impacts may be internalized in the cost attributes found in other matrices but are also indicated explicitly in this matrix.

ATTRIBUTES	OTP PROGRAMS					
	P_1	P_2	.	.	.	P_n
1 FY 1981 DOE Funding	References 1, 2, 3, 6					
2 Present Value Cum. DOE Funding	Reference 1					
3 FY 1981 DOE Manpower	References 1, 2, 6					
4 Final Year of DOE Funding						
5 Percent Other Agency Funding, FY81						
6 Market Definition	References 2, 6					
7 Percent Market Penetrated	References 2, 6					
8 First Year of Saving	Reference 6					
9 Probability of Technical Success	References 1, 4, 6					
10 Probability of Commercial Success	References 1, 2, 6					
11 Years of Accelerated Program						

FIGURE 2-1. PROGRAM MATRIX

ATTRIBUTES	OTP PROGRAMS				
	P_1	P_2	.	.	P_n
1 Cum. Petroleum Saved In Quads Thru Year Given	Reference 6				
2 Value Cum. Petroleum Savings in 1980 \$	Reference 1				
3 Present Value Petroleum Saved/Present Value DOE Funding	Present value of petroleum saved divided by Attribute 3 in Program Matrix				
4 Present Value Petroleum Saved/Present Value Cum. Cap. Invest.	Present value of petroleum saved divided by Attribute 1 in Input Industry Matrix				
5 Petroleum Saved in Quads, 1985	Reference 6				
6 Petroleum Saved 1985/Petroleum Saved 2000	Reference 2				
7 Marginal Cost to Consumer in 1990 and 2000	References 3, 4				
8 Percent Cum. Savings Attrib. to OTP Programs	Reference 6				
9 Payback Period to Consumer (Years) in 1985, 2000	References 2, 6				
10 Discounted Net Present Value	Reference 9				

FIGURE 2-2. SAVINGS MATRIX

ATTRIBUTES	OTP PROGRAMS				
	P_1	P_2	.	.	P_n
1 Cum. Cap. Invest. Thru Years Given in 1980 \$	References 3, 5				
2 Cap. Invest. in Years 1990 and 2000, in 1980 \$					
3 Cap. Cost per Unit, in 1980 \$	Reference 3				
4 Industry Providing Capital	Reference 5				
5 Ratio of Industry to DOE Funding for R&D, FY81	Ratio of Industry to Attribute 1 in Program Matrix				

FIGURE 2-3. INDUSTRY INPUT MATRIX

ATTRIBUTES	OTP PROGRAMS				
	P ₁	P ₂	.	.	P _n
1 Prob. of Adverse Environmental Impact (L, M, H)	References 2, 6				
2 Prob. of Adverse Economic Impact (L, M, H)	References 2, 6				
3 Institutional Barriers (Yes, No)	References 5, 6				
4 Technology Contribution (Yes, No)	Development of new technology or enhancement of existing technologies				
5 Technical Solution Required (Yes, No)	Solution required before implementation				

FIGURE 2-4. IMPACT MATRIX

2.2 ATTRIBUTES LISTED IN THE PROGRAM MATRIX

2.2.1 FY 1981 DOE Funding

In the OTP evaluation effort currently being conducted, this figure is given in mid-1980 dollars. For the example computations of ranking functions and matrix attributes given in Appendices A and B constant dollars always means mid-1980 dollars. When the matrices are used in future evaluations, new definitions may be given for constant dollars.

2.2.2 Present Value of Cumulative DOE Funding

Present value refers to the time at which the evaluation is taking place. For the present evaluation, it means mid-1980. It is not necessary that constant dollars and present value refer to identical points in time.

2.2.3 FY 1981 DOE Manpower

This attribute refers to the number of OTP staff assigned to administer the program. It may have some bearing on the manner in which the Director of OTP would select some of the smaller programs but is mainly useful as general information concerning the program.

2.2.4 Final Year of DOE Funding

This figure is a projection and may vary in the future. It is also an informational item that describes the program.

2.2.5 Percent Other Agency Funding

Some of the OTP programs are funded jointly with other agencies. This attribute simply conveys such information.

2.2.6 Market Definition

This attribute refers to the identity of the market for which the particular OTP program provides a technology or activity. It is important that the market be defined in the policy matrix because it makes the savings and cost estimates more understandable. In addition, it gives meaning to the attribute percent of market penetrated.

2.2.7 Percent of Market Penetrated

This figure is given for the year during the evaluation period in which there is maximum market penetration. This year should also be noted in the matrix. The matrix element for a given program would then read, for example, "20 percent penetration in 1999."

2.2.8 First Year of Savings

This means the first year in which savings are projected to occur or in which savings have occurred.

The purpose of listing this attribute is to represent the time frame for which the program is intended in a more comprehensive manner than is afforded by the simple designation of short- and long-range programs.

2.2.9 Probability of Technical Success

Refers to probability of meeting technical goals. For heat engine programs, this refers to the probability of meeting efficiency goals. For outreach programs such as DECAT, this refers to the probability of reaching the stated fraction of the target population to be reached.

2.2.10 Probability of Commercial Success

Means the probability of penetrating the target fraction of the market given technical success.

2.3 ATTRIBUTES LISTED IN THE SAVINGS MATRIX

2.3.1 Cumulative Petroleum Saved in Quads Through Given Year

This is the single most important program attribute. It is the primary measure for comparing with other energy conservation or production programs and is directly related to the primary goal of OTP.

2.3.2 Value of Cumulative Petroleum Savings in 1980 Dollars

This attribute gives the value of cumulative petroleum savings based on increases in price, and net of inflation. Hence, a real fuel price escalator is used in computing this attribute. The value is not discounted. The reason is that discounted values are used for other attributes, but the values without discounting would otherwise not appear. As a point of information, this is a useful attribute.

2.3.3 Present Value of Petroleum Saved Divided by Present Value of DOE Funding

The primary importance of this attribute is that analogous measures are used in evaluating other government programs and it may be desired to compare the OTP programs on the same basis. For the current evaluation, present value refers to mid-1980. Computing this attribute requires a forecast of petroleum prices and selection of discount factors for the value of petroleum and DOE funding. Since savings occur far into the future for some of the programs, the values

obtained for this attribute are sensitive to the discount factor selected, and to the forecast of real fuel price.

2.3.4 Present Value of Petroleum Saved Divided by Present Value of Cumulative Capital Investment

For some OTP programs, there is no identifiable capital investment. This is the case with the MPG mileage guide in which all of the costs are DOE costs. For other programs, there may be a capital cost but it is difficult to estimate with any reasonable accuracy. For programs such as the electric vehicle, Stirling and turbine engine programs, capital cost is amenable to estimation and is an important attribute because the capital investments are large. The size of these capital requirements and normal capital requirements in the industries that have to make the investments are among the determinants of when and at what rate particular technologies can be introduced.

2.3.5 Petroleum Saved in Quads, 1985

Only a few of the OTP programs have near term savings. The purpose of this attribute is to represent those programs that have near term savings.

2.3.6 Petroleum Saved in 1985 Divided by Petroleum Saved in the Year 2000

Discounting the value of petroleum saved in later years to present value takes the importance of near term savings relative to long-term savings into account for the most part. The effects of discounting are not easily visualized, however, this attribute is intended to portray in a more explicit manner the effects of short-term versus long-term savings.

2.3.7 Marginal Cost to Consumer in 1990 and 2000

In its simplest form, the marginal cost to the consumer of saving a gallon of gasoline is the incremental cost of the vehicle divided by the number of gallons of gasoline saved. The incremental cost of the vehicle is the difference between the cost of the vehicle of the new technology and the cost of the vehicle of the old technology that the consumer might otherwise have purchased. In the case of the Stirling vehicle, this cost is \$1500 in 1980 dollars. Hence, if the consumer were to save 1500 gallons of gasoline over the life of the vehicle, the marginal cost to the consumer of saving a gallon of gasoline would, in its simplest form, be one dollar.

Computing the marginal cost to the consumer of saving a gallon of gasoline is, however, somewhat more complicated. The fact that the savings take place over a number of years means that the value of the gasoline saved in future years is not as great as the value of gasoline saved in the year that the vehicle is purchased even if the real price of fuel stays the same. Therefore, the value of fuel saved in future years is discounted at some rate. In the case of the sample computation the discount rate is seven percent. On the other hand, the real price of fuel is assumed to continue to escalate after the vehicle is purchased. For this reason, a price escalator, three percent per year for the sample case, is applied.

For vehicle technology programs, marginal cost to the consumer is an important attribute because it can be used to compare fuel economy programs with energy production programs. In the case of the energy production programs, an easily understood concept is the cost to the consumer of a gallon of gasoline produced from coal, for example. The concept of cost of saving a gallon of gasoline is somewhat more abstract but still easy to understand.

2.3.8 Payback Period to Consumer

The main purpose of this attribute is to allow more insight into consumer costs. It is also useful for comparing OTP programs with energy conservation and production programs outside of OTP. For example, it is a commonly used and well understood measure of effectiveness for evaluating solar energy technologies. When it is used for comparing with other energy conservation programs, it is important to ascertain that discount rates and real fuel price escalators are comparable for all programs to be compared since payback period is sensitive to these factors. This is particularly true with the rate at which the value of savings is discounted.

2.3.9 Discounted Net Present Value

This attribute is also suggested as a ranking function. It is discussed in Section 3.2. It may not always be desirable that it be chosen for use as a ranking function and for this reason it is important that it at least be listed as a policy matrix attribute.

2.4 INDUSTRY INPUT MATRIX

2.4.1 Cumulative Capital Investment Through Years Given

Capital investment requirements for implementing the technologies for which there are OTP programs have been estimated.

In some cases, there is either no identifiable capital investment or it has not been estimated. It is important that estimates be made and reported in the policy matrix since the timing and size of the capital requirements can determine whether a technology will be implemented.

2.4.2 Capital Investment in Years 1990 and 2000

The preceding attribute includes only capital investment cumulative to a given year. Both of these attributes are listed because it may be that only cumulative estimates are available for some technologies whereas a better breakdown is available for others. This will be indicated by listing the capital investment for two selected years in the policy matrix.

2.4.3 Capital Cost Per Unit

This attribute is obtained from the two preceding attributes in the industry input matrix. Its purpose is simply to give a figure to compare with the incremental consumer cost per unit. This figure is not available for all of the technologies of the OTP programs but even the indication that it is not available gives some information about the reliability of the incremental cost figures.

2.4.4 Industry Providing the Capital

It is not immediately obvious which industries are to provide the capital for implementing the technology or activity that is the subject of the OTP program. The voluntary truck and bus program, for example, may require that some industry provide capital for manufacturing an energy saving device. The industry may be the automobile industry or a supplier industry. Likewise, the electric vehicle may be produced by some industry other than the automobile industry. It is at least useful to know which industry is to supply the capital to determine if such factors as supply side limitations are placed on market penetration.

2.4.5 Ratio of Industry to DOE Funding for R&D, FY 1981

The precise ratio may not be known for all programs where there is both the industry and government funding for R&D but an estimate would be useful for some of the purposes of program evaluation. For example, if evaluation on attributes exclusive of this attribute shows that a particular program is ranked high compared with the other programs, it is useful to know whether industry is spending large or small sums on research and development for the technologies that are a subject of the program.

2.5 ATTRIBUTES LISTED IN THE IMPACT MATRIX

2.5.1 Probability of Adverse Environmental Impact

A considerable amount of research has been conducted concerning potential adverse environment impacts associated with the technologies and activities that are subjects of the OTP programs. For many of the programs, it is possible to determine whether the probability of at least one adverse environmental impact is low, medium, or high. In the ranking function proposed in this paper, one of the attributes for ranking the programs is probability of adverse environmental impact. It is used in such a way that high probability of at least one adverse environmental impact lowers the score for ranking the program. It is important, however, that the attribute also be included in the policy matrix because it has more meaning when taken together with the other information about the program. A program with an otherwise high payoff that has a potential adverse environmental impact could be ranked higher because of the existence of the high probability of adverse environmental impact. It could be reasoned that government involvement is needed to help mitigate

the adverse environmental impact or to help indirectly by assuming some of the other costs. At the other end of the ranking, a program with a small payoff may be dropped altogether if it has a potential environmental impact even if it otherwise scored higher than one or more of the other programs.

2.5.2 Probability of Adverse Economic Impact

This refers primarily to the loss of jobs and is associated with programs where there is a reduction in the manufacturing requirements or a major shift in the industry structure resulting in a loss of jobs. It also refers to changes in industry structure that are adverse in nature. For most of the OTP programs, determining this attribute can be done by analyzing the work already done in evaluating the programs. For others, more research is required. It is an important attribute particularly because the goals of the OTP can only be met if there are some programs that save large amounts of petroleum. These are the very programs that may cause large shifts in industry structure, jobs and other economic factors.

2.5.3 Institutional Barriers

This refers to the requirements for change in institutions if the program is to be implemented. The changes may include new legislation, change in current legislation, cooperation on a large scale as in the case of the trucking industry or the airline industry, or structural changes in manufacturing industries.

Institutional barriers also include the requirement to obtain the agreement of institutions such as manufacturers to adopt radically new technology or fleet owners to cooperate in programs.

2.5.4 Technology Contribution

Refers to a positive byproduct of a program in which a new technology is established. A program may make a technology contribution even if there is no requirement to solve a specific problem in order for the program to succeed. The efficiency devices being developed for the voluntary truck and bus program are examples in which new technology may be established even if there is no specific problem that must be solved for the program to succeed. Ceramics technology in the case of the Stirling and turbine programs are examples of a required technology contribution for full success of the programs.

2.5.5 Technical Solution Required

Refers to the need for solving a technical problem before the program can fully succeed. This may be the case in the electric vehicle program and in the case of ceramics in the Stirling and turbine programs.

SECTION 3. METHODS FOR RANKING OTP PROGRAMS

3.1 INTRODUCTION

A number of the attributes listed in the policy matrix may be used directly to rank OTP programs. The rankings obtained by using different attributes would, of course, be different but may have utility for particular purposes. Generally, however, such rankings, like the attributes themselves, are more useful as part of more general analyses.

In discussing ranking functions, it is useful to think of attributes in two categories; as basic attributes and attributes that are combinations of basic attributes in which the combinations are specified by a mathematical relationship. For example, an attribute that may be thought of as a basic attribute is the cumulative petroleum saving in Quads through the year 2000. Another basic attribute may be the cumulative DOE funding for the entire program. Dividing the cumulative saving by the cumulative funding gives another attribute. Clearly, this measure, sometimes called a benefit/cost ratio, may be used to rank programs for some purposes. As a ranking function, it should be noted that no further factors or terms are needed.

The net present value and the net present value modified ranking functions discussed in this section are also such that no additional factors or terms are needed. The net present value measure is given as both a program attribute and a ranking function in this report.

The problem with ranking functions that make use of attributes only and no additional factors is that when attributes must be derived by a rating scheme, they cannot be used directly with other attributes that can be estimated in given units

such as gallons or the value of savings that can be estimated and given in dollar value. An attribute such as environmental impact can conceptually be given in monetary terms also. When monetary estimates of environmental impact are not available, however, it is necessary to put environmental impact on some sort of scale. Such attributes are called rated attributes. When this is done, the only way to include them in a ranking function that includes estimated attributes such as petroleum savings is to normalize the estimates in some fashion. Even when all of the attributes are amenable to estimation, it may be that some of the attributes used in the ranking function are deemed to be more important than some of the others. This requires some sort of weighting scheme. When rated attributes and attributes for which estimates can be made are used, together in a ranking function, there is said to be a need for intra-attribute scaling and inter-attribute weighting. This is the case for the comprehensive ranking function. Scale factors and weights have been developed for it and are discussed in this section and Appendix C.

3.2 RANKING ON NET PRESENT VALUE (NPV)

Net present value is a commonly used measure for evaluating or ranking programs. For OTP programs, it is suggested as both a policy matrix attribute and a ranking function. For these purposes, it is defined as follows:

Net present value equals the present value of petroleum saved minus the present value of costs. Present value refers to value in mid-1980 dollars in mid-1980.

There are three possible cost components depending on the OTP program for which the measure is evaluated. These are

DOE program costs, incremental costs of the technology or activity to the consumer, and electric power costs in the case of the electric vehicle.

Net present value, like all measures for ranking or evaluating programs, has advantages and disadvantages. The following are some of these advantages and disadvantages as applied to the OTP programs.

One of the major advantages is that it is a commonly used measure. Accordingly, some of the programs with which it may be wished to compare the OTP programs may have been evaluated according to this measure.

Other costs that may be added are environmental, economic and social costs that have not been internalized in the originally estimated cost of the product or service. These must not only be given in monetary terms but the timing of the costs must be forecast so that discounting can be properly accounted.

The net present value can be made to give more insight for ranking by dividing it by the present value of program funding. This gives a discounted present value per program dollar. This ranking function is the net present value modified ranking function (NPVM).

For OTP programs, net present value has disadvantages that result from the fact that it is a cost benefit measure and requires that any factors be represented in monetary terms consistent with all other costs and benefits. At this time, adding environmental, social and economic costs also requires subjective determination of costs. Any alternative for taking these into account, such as the one proposed in the next

section, must also make use of subjective estimation. In the case of the net present value measure, the requirements to give the additional costs and benefits in monetary terms and at the time these are to occur, together with the requirement to apply discount rates for all costs and benefits as well as to forecast the real price of fuel renders the measure very sensitive to assumptions.

In spite of the disadvantages, it is recommended that the measure be used as a policy matrix attribute and that it also be used to rank OTP programs along with the comprehensive ranking function in the following section. Computational procedures for net present value in a form not including the import premium or the environmental, economic or social costs are given in Section 4 of this report and sample calculations of net present value and net present value per program dollar are given in Appendix A.

3.3 COMPREHENSIVE RANKING FUNCTION (CRF)

The following ranking function is designed to alleviate some of the deficiencies of the net present value measure. It appears to be more arbitrary than the net present value measure, but considering that it does not include discount factors, price escalators or import premiums, it may not be as arbitrary in the long run. Moreover, it is suggested that it be viewed as a tool for use in addition to the net present value measure and other attributes in the policy matrix.

The comprehensive ranking function is as follows:

$$R = 6.1(aS) - 2(bC_1) - 3(cC_2) \\ - 1.4(EN) - 1.7(I) - 1.3(EC) + 94$$

The constants for which numerical values are given (6.1, 2, 3, 1.4, 1.7, 1.3) were derived from an exercise conducted by the OTP Evaluation Group during the meeting of Oct. 29, 1980. The procedures for arriving at these constants are given in Appendix C. The number 94 is added to assure that R does not become negative for any of the programs. The factors a, b and c are to be determined by setting aS, bC₁, and cC₂ equal to ten for the programs that have the highest value of S, C₁ and C₂.

These measures are defined as follows:

- S = cumulative petroleum savings in Quads to the year 2000 for short-range programs and 2010 for long-range programs.
- C₁ = cumulative DOE funding from FY1981 to the final year of funding.
- C₂ = cumulative cost to the consumer. For some programs, there is no additional cost to the consumer beyond the cost of DOE funding, or it is assumed that this is the case. In the case of vehicle programs, this cost is made up of the sum of incremental vehicle costs. For the electric vehicle programs it includes the cost of electric power. In cases where the purchaser is a commercial or industrial concern, their cost is a component of C₂.

- EN = a rated criterion that takes into account adverse environmental impacts. The values assigned are 10, 5 or 1, depending on whether there is a high, medium or low probability of adverse environmental impacts associated with implementing the results of the program.
- I = a rated criterion that takes into account the existence of insitutional barriers that must be overcome. The value assigned is 10 if there is more than one barrier that requires new legislation, modification of existing legislation to permit program implementation, cooperation of institutions in a manner that requires them to establish a new activity, or structural changes in industry. The value assigned is 5 if there is one barrier and 1 if there are no barriers.
- EC = a rated criterion that takes into account adverse economic impacts such as increased unemployment or substantial shifts of production that result in industry dislocation. The values assigned are 10, 5 or 1, depending on whether the probability of one or more adverse economic impacts is high, medium or low.

This ranking function may be more consistent with the goals of the OTP in that it weights petroleum savings more heavily. The weight is subjectively determined but the determination is done on the basis of the importance of saving petroleum relative to costs to consumers and other environmental, social and economic costs.

The requirement for subjective estimates of coefficients is a disadvantage and it is in this requirement that the potential for comparing OTP programs with other programs outside of OTP is reduced.

SECTION 4. AUTOMATION PROCEDURES

4.1 SUMMARY OF REQUIRED INPUT, OUTPUTS AND SOURCES

4.1.1 Introduction

Most of the computations required for determining values of the policy matrix attributes and evaluating the ranking functions are straightforward and can be done using a desk calculator. Some, such as marginal cost to the consumer, are more complex and almost all require computations that are tedious. Moreover, some intermediate results are of interest in addition to the rankings, ranking scores and matrix attributes.

A computer program for making the computations on an electronic computer will allow a large number of runs to be made for various assumptions. Furthermore, a database and record of previous runs can be of major utility to the OTP evaluation effort.

A review of the computational procedures described in Sections 1, 2 and 3 shows that determination of numerical values of the attributes of policy matrix and ranking function scores can easily be handled with a desk calculator. Further, the review would indicate that the computation of these numerical values for policy matrix attributes and ranking functions scores depends upon two factors. First, there are certain types of parameters which are considered as inputs to the analysis and for which values are assigned outside of the evaluation and ranking analysis framework. Examples of such parameters include: unit price of gasoline in mid-1981,

yearly savings of petroleum consumption owing to market penetration of different technologies, and coefficient values of the ranking function. The second type of factor for computing policy matrix attributes may be described as the specification of methodology, procedures and analytical formulas. (These are given as explicit algebraic statements in Appendix A.2).

The specification for the procedure to be followed to calculate policy matrix attributes and ranking scores remains, for the most part, invariant over time. (Some changes might be tried to realize computational efficiencies.) Different values of the input parameters might be considered, however, for at least two reasons. First, at a latter time, more information might become available to determine a value of an input parameter. For example, the discount rate to be applied to monetary value of energy savings might rise or fall depending on the success of alternative fuel developments.

Second, it is sometimes desirable to evaluate "what if" types of questions. Decision makers at DOE might like to know how sensitive the ranking analysis is to coefficient values in order to see if additional work is justified to more accurately determine these values. While it is possible, in principle, to compute both matrix attributes and ranking scores for varying input by value sets, the desk calculator method used to calculate the sample examples in this report are that computation task will quickly grow quite burdensome if multiple input value sets are desired.

To accommodate the possibility of multiple input sets in a computationally efficient procedure, a scheme to automate the process is outlined in this section. It is envisioned that an environment where the actual program will be designed and run would be a small computer. The specification is

kept general enough, though, to accommodate any number of environments.

This section describes an automated procedure for the policy matrix and the ranking functions. Formats for input are also described. Figure 4-1 presents a framework for the flow of information and computations. Appendices A and B, in addition to presenting sample computations, present algebraic formulations for the policy matrix attributes in the savings matrix and the ranking junctions.

4.1.2 Inputs to the Automated Procedure

As indicated in Figure 4.1 most of the inputs are outputs of the Argonne computer program. Some are direct inputs to the policy matrix and are not processed at all except to be displayed as part of the policy matrix as output of the computer program. In some cases, the inputs to the automated procedure are factors used in the Argonne computer program. These include vehicle miles travelled (VMT) and survival fraction (S_q). Finally, some inputs are factors that can be assumed and are meant to be varied for purposes of sensitivity analysis. These include discount factors and real fuel and electric power price escalators.

The following is a description of the inputs to the automated procedure.

4.1.2.1 Fuel Savings

Fuel savings on a year-by-year basis are inputs to the automated procedure and represent the petroleum savings realized from the introduction of more fuel efficient technologies

FIGURE 4.1 AUTOMATION PROCEDURE FRAMEWORK

into the marketplace or the introduction of outreach programs such as the MPG Mileage Guide. The annual savings expressed in Quads (PS)_i and millions of gallons of fuel (GS)_i are available as outputs from the Argonne program. In the case of vehicle programs, these savings are realized from fuel efficient vehicles bought and driven in that year as well as fuel efficient vehicles bought in prior years and driven in that year. The figure is thus the savings for the cumulative new fleet and reflects both survival rate and yearly differences by age of vehicle in miles driven by the average driver.

4.1.2.2 Vehicle Technology Characteristics

For the vehicle technologies, single value parameter inputs include: annual incremental capital cost (ICC), to be incurred by consumers, operating efficiency of vehicle (in mpg), electric power requirements (if any in kwh permile), number of years prior to technology market penetration that capital costs by industry is required, and number of years prior to market introduction that DOE funding, and year of market penetration.

4.1.2.3 Miles Driven

The year-by-year distribution of vehicle miles travelled by vehicles with the energy efficient technology (MPV). This figure is for the entire fleet and thus represents vehicle miles travelled (VMT) for vehicles purchased in the year for which the data pertains as well as vehicles purchased in previous years. The sum of vehicle miles driven by new technology vehicles (MT)_i is also an input from the Argonne Computer program.

4.1.2.4 Discount Rates

There are two discount rates of interest in this analysis. The first d_1 , is applied to savings which are brought about through use of a more energy efficient technology. The second discount rate, d_2 , pertains to the cost of borrowing money or determining the current value of future expenditures. For the sample calculations in Appendix A, seven percent was used for both of these factors. However, it may be desirable to have discount rates for savings different from discount rates for costs in sensitivity analyses.

4.1.2.5 Fuel Escalator Rates

For the conservation program considered in this sensitivity analysis, two types of fuels are important. They are petroleum and electric. On data records, values of the fuel escalator for petroleum are input by the following format. Year escalator rate starts, year escalator rate ends, escalator rate; year rate starts, ends, escalator, ... For example, if petroleum prices were expected to increase by 3% per year -- in real times -- from 1980 to 1990, and by 1% over the next decade, and then decrease by .5% per year indefinitely, then data record would be as follows:

1980	1990	+3.0	1991	2000	+1.0	20001
	2020	-0.5				

where 2020 is the last year of the analysis.

The data record for the electric power price escalator is similar except that the escalator rate would be indicative of electric fuel cost changes and the dates would change accordingly. The symbols used for these rates are E_1 and E_2 , for petroleum fuel and electric power respectively.

4.1.2.6 Other Inputs Required for Computing Savings Matrix Attributes and Ranking Function Values

In addition to the inputs mentioned above, there are other inputs that are required to compute attributes in the savings matrix. These are $P(1980)$, the price of fuel in 1980, $(DOEF)_i$, program funding in year i by DOE, and $(CC)_i$, a capital investment required of industry in year i .

4.1.2.7 Inputs for the Ranking Functions

Inputs for the net present value and net present value divided by DOE funding, when these measures are used as ranking functions, are the same as the inputs for the policy matrix.

For the broader ranking function, the inputs are the coefficients of the terms and the constant term added, (94 in the version of this report) to prevent negative scores. For the impact terms in this ranking function, it is also required to assign, as inputs, values for each program and each impact term. These values are 1, 5 or 10, depending on probabilities of adverse impacts being high, medium or low.

4.1.2.8 Input Data Sources

The sources from which data were obtained for the sample calculations in this report are as follows:

1. Computer program developed by the Argonne National Laboratory
2. NBS Handbook 135, Life Cycle Costs Manual for the Federal Energy Management Program, Dec. 1980
3. Transportation Energy Data Book, Edition 4, Oak Ridge National Laboratory, Feb. 1979
4. OTP Evaluation Group Data.

Figure 4-2 indicates which inputs are used for calculating each of the attributes in the savings matrix. For this purpose, the attributes are numbered one through ten in the same order in which they appear in Figure 2-2. That is, number one is cumulative petroleum saved in Quads through the year given and number ten is discounted net present value. It also indicates the source listed above, numbered one through four, from which the inputs were obtained.

4.1.3 Formats for Displaying Inputs

Inputs to be displayed are:

$(PS)_i$	=	petroleum saved in Quads in year i
$(GS)_i$	=	millions of gallons of fuel saved in year i
$(MT)_i$	=	billions of miles travelled by new technology vehicles by program in year i
$(ICC)_i$	=	total incremental costs for technology units sold in year i
E_i	=	real fuel price escalator in year i
E'_i	=	electric power real fuel price escalator in year i
S_q	=	survival fraction by age of vehicle
MPV	=	miles per year driven by each vehicle by age of vehicle

For $(PS)_i$, $(ES)_i$, $(VMT)_i$, $(ICC)_i$, E_i and E'_i , the formats are the same except for the title. For the purpose of illustration, $(PS)_i$ is chosen.

INPUTS		SAVINGS MATRIX ATTRIBUTES									
Symbol	Source	1	2	3	4	5	6	7	8	9	10
$(PS)_i$	1	X				X	X				
$(GS)_i$	1		X	X	X				X		X
$(MT)_i$	1								X		
$(ICC)_i$	1										X
E_i	2		X	X	X			X	X	X	X
E'_i	2							X	X	X	X
S_q	1							X		X	
MPV	1							X		X	
P(1980)	4			X	X			X	X	X	
d_1	2								X	X	X
d_2	2										X
ICC	1							X		X	
EP	3							X	X	X	X
$(DOEF)_i$	4			X							X
$(CC)_1$	4				X						

FIGURE 4-2. INPUTS AND SOURCES FOR SAVINGS MATRIX ATTRIBUTES

Title: (PS)_i Input this run

Date: (of run)

Run No.:

YEAR	<u>ELECTRIC VEHICLE</u>	<u>STIRLING</u>	<u>TURBINE</u>	<u>MPG</u>
1981				
1982				
.				
.				
.				
.				

For S_q and MPV, the formats are the same except for the title.
For the purpose of illustration S_q is chosen.

Title: S_q Input this run

Date: (of run)

Run No.:

YEAR	<u>ELECTRIC VEHICLE</u>	<u>STIRLING</u>	<u>TURBINE</u>	<u>MPG</u>
1				
2				
3				
.				
.				
.				
.				

4.1.4 Formats for Displaying Outputs

Policy Matrix Attributes

The principal output format for the policy matrix attributes are the four policy matrices themselves. There is also a set of outputs from the database that should be available at the user's option.

It is anticipated that the computational procedures from the policy matrix and the ranking functions will be implemented on the Four-Phase system or on a comparable system that can present outputs on a CRT as well as hard copy (see Figure 4-3).

The ranking function output formats are as follows:

Title: Ranking on Net Present Value (NPV) and Net Present Value Modified (NPVM)

Date: (of run)

Run No.:

OTP PROGRAM NAME	RANK NPV	SCORE NPV	RANK NPVM	SCORE NPVM
Electric Vehicle (Truck & Auto)	1	50	1	84
Stirling Engine	2	22	2	56
Gas Turbine	3	14	4	28
MPG Mileage Guide	4	1	3	45

Title: Ranking on Comprehensive Ranking Function (CRF)

Date: (of run)

Run No.:

OTP PROGRAM	RANK CRF	SCORE CRF
Electric Vehicle (Truck & Auto)	1	98
Stirling Engine	2	86
Gas Turbine	3	80
MPG Mileage Guide	4	77

FIGURE 4-3. RANKING FUNCTION OUTPUT FORMATS

4.2 DATABASE

4.2.1 Database Elements

The available database is made up of the following information:

1. All attributes found in the policy matrix
2. The ranking functions evaluated for selected sets of programs
3. Inputs as listed in Section 4.1.3
4. Intermediate outputs as follows:
 - a. Price of electric power by year from 1981 through 2030
 - b. Price of fuel (gasoline) from 1981 through 2030
 - c. Present value of electric power for electric vehicle programs.

APPENDIX A
SAMPLE CALCULATIONS FOR POLICY MATRIX

A.1 INTRODUCTION

Sample calculations were made for the attributes in the policy matrix. These are illustrated in the following tables. The net present value attribute is used as a ranking function and sample calculations are given in Appendix B rather than in this appendix.

A.1.1 Description of Tables

Table A-1 gives the seven percent discount factor and real price of fuel. Real price of fuel is given based on \$1.23 per gallon in 1980 and the real price escalator given in NBS Handbook 135 where the value for residential distillate is used as approximating the price escalator for gasoline.

The primary purpose of Table A-1 is to provide easy reference in using the rest of the tables.

Table A-2 gives incremental consumer costs and discounted cumulative costs in selected years for the electric vehicle, Stirling engine powered vehicle (Stirling), the gas turbine engine powered vehicle (turbine), and the MPG Mileage Guide. These costs are for total number of vehicles sold based on outputs of the Argonne computer program. Consumer costs are discounted at a seven percent rate.

Table A-3 gives electric power costs for the electric vehicle.

TABLE A-1. REAL PRICE OF FUEL AND DISCOUNT FACTOR

YEAR	REAL PRICE OF FUEL (1980 Dollars)	⁷ / ₈ DISCOUNT FACTOR (d_1)
1980	1.23	1.000
1990	1.72	.508
1995	2.05	.362
2000	2.52	.258
2005	3.07	.184
2010	3.60	.131
2015	4.30	.094
2020	5.00	.067
2025	5.80	.048

Real Price Escalator for Fuel

.0338, mid-1980 to mid-1985

.0285, mid-1985 to mid-1990

.0401, mid-1990 to mid-1995 and beyond.

(for residential distillate, national average)*

All price escalators are from NBS Handbook 135.

*The NBS Handbook 135 does not list a price escalator for gasoline. It is recommended that the value for residential distillate be used.

TABLE A-2. INCREMENTAL CONSUMER COSTS (ICC)_i
(Millions of Dollars)

YEAR	ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1986	300	0	0	0
1990	669	0	0	0
1995	3118	295	601	0
2000	8318	2400	2799	0
2005	14214	11906	4442	0
2010	17605	12919	4875	0
2015	0	0	0	0
2020	0	0	0	0
2025	0	0	0	0

CUMULATIVE DISCOUNTED CONSUMER COSTS (DCC)
(Millions of Dollars)

YEAR	ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MILEAGE GUIDE
1990	1311	0	0	0
1995	5019	107	454	0
2000	13384	2632	2906	0
2005	26657	11816	7253	0
2010	39044	21249	10796	0
2015	39044	21249	10796	0
2020	39044	21249	10796	0
2025	39044	21249	10796	0

TABLE A-3. ELECTRIC POWER COSTS (AUTO PLUS TRUCK)
(Millions of Dollars)

YEAR	ANNUAL COSTS	CUMULATIVE DISCOUNTED COSTS
1986	8	8
1990	81	123
1995	388	595
2000	1377	1956
2005	3242	4700
2010	4769	8102
2015	2235	9988
2020	388	10464
2025	0	10464

- Based on 1.5¢ per mile driven
- Real price escalator is taken as zero for these computations

- Cumulative Discounted Costs =
$$\sum_{i=1}^m (EPC)_i \frac{1}{(1+d_1)^i}$$

Table A-4 gives annual petroleum savings and discounted value of savings for electric vehicle Stirling, turbine, and MPG. These are based on a seven percent discount rate.

These computations are for vehicles sold up to and including the year 2010.

For MPG, savings end in the year 2000.

Table A-5 gives sample calculations for marginal cost to the purchasers of Stirling and turbine vehicles in the year 2000. This is the cost of saving a gallon of fuel in 1980 dollars. The incremental cost per vehicle is \$1500 for Stirling and \$1000 for turbine in 1980 dollars. The fuel price escalator of .03 was used.

Table A-6 gives marginal cost to purchasers of electric vehicles in the year 2000. The incremental costs were \$3628 and \$6645 respectively.

The computation of marginal cost to the consumer of saving a gallon of gasoline can best be explained by proceeding on a year by year basis. For the Stirling vehicle, the consumer saves, in the first year after purchase of the vehicle, 151 gallons of gasoline based on 15,894 miles driven and on fuel useage at the rate of 31.30 miles per gallon compared with the fuel useage at 24.12 miles per gallon that the alternative car that the consumer might have purchased would achieve.

This amount of saving takes place over the whole and is discounted at the rate of seven percent for that year and each year thereafter. The real price of fuel is assumed to stay constant during the first year and to increase at a rate of three percent each year thereafter . The total gallons saved each year are multiplied by these factors.

TABLE A-4
ANNUAL PETROLEUM SAVINGS (GS)_i
(Millions of gallons)

YEAR	ELECTRIC VEHICLES	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1981				11
1985				41
1990	231			67
1995	1173	30	144	78
2000	4246	895	1060	85
2005	10488	4715	2823	92
2010	15450	8182	3891	98
2015	7150	3702	1687	41
2020	1611	792	358	9
2025	0	115	52	1

CUMULATIVE DISCOUNTED VALUE OF SAVINGS (PVPS \$1980)
(Millions of dollars)

YEAR	ELECTRIC VEHICLES	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1981				150
1985				420
1990	546			715
1995	3162	22	182	998
2000	12658	1399	2188	1265
2005	36119	10009	8543	1509
2010	70540	27596	17476	1645
2015	93082	39476	22978	1680
2020	99617	42699	24439	1685
2025	100065	43142	24638	

$$PVPS (1980) = \sum_{i=1}^n (GS)_i \frac{1}{(1+d_1)^i}$$

d_1 is 7% discount rate.

TABLE A-5. MARGINAL COST TO CONSUMER IN
YEAR 2000 (MCC) STIRLING AND TURBINE
(1980 dollars)

YEAR	SURVIVAL FRACTION (F_i)	R	DISCOUNT FACTOR 7 % ($1/(1+D_1)^i$)	PRICE ESCALATOR ($1.04)^{i-1}$)	PRODUCT
2000	.999	1.00	.935	1.00	.93
2001	.997	1.02	.873	1.03	.91
2002	.992	.95	.816	1.06	.82
2003	.982	.82	.763	1.09	.67
2004	.963	.77	.713	1.13	.59
2005	.925	.73	.666	1.16	.52
2006	.859	.70	.623	1.19	.44
2007	.758	.63	.582	1.23	.34
2008	.627	.65	.544	1.27	.28
2009	.490	.60	.508	1.30	.19
2010	.366	.55	.475	1.34	.13
2011	.266	.55	.444	1.38	.09
2012	.191	.51	.415	1.42	.06
2013	.136	.49	.388	1.46	.04
2014	.096	.46	.362	1.51	.02
					6.04

$$\text{MCC, Stirling} = \frac{1500}{6.04 \times 151} = \$1.64 \text{ per gallon saved}$$

$$\text{MCC, turbine} = \frac{1000}{6.04 \times 119} = \$1.39 \text{ per gallon saved}$$

TABLE A-6
MARGINAL COST TO CONSUMER IN YEAR 2000 (MCC)
ELECTRIC VEHICLE (Auto)
(1980 dollars)

YEAR	ELECTRIC POWER COSTS DISCOUNTED	R	SURVIVAL FRACTION	REAL PRICE FUEL ESCALATOR	DISCOUNT FACTOR FUEL	PRODUCT
2000	125	1.00	.999	1.00	.93	.93
2001	119	1.02	.996	1.03	.87	.91
2002	95	.95	.991	1.06	.82	.82
2003	82	.82	.980	1.09	.76	.97
2004	71	.77	.960	1.13	.71	.59
2005	61	.73	.921	1.16	.67	.52
2006	50	.70	.854	1.19	.62	.44
2007	37	.63	.753	1.23	.58	.34
2008	29	.55	.626	1.27	.54	.24
2009	20	.60	.491	1.30	.51	.20
2010	13	.55	.370	1.34	.47	.13
2011	9	.55	.270	1.38	.44	.09
2012	<u>5</u>	.51	.196	1.42	.41	<u>.06</u>
	716					5.94

$$MCC = \frac{ICC - EPC}{CDS (2000)} = \frac{716 + 3628}{(5.94) (479)} = \$1.53 \text{ per gallon}$$

CDS based on $\frac{13460}{28.1} = 479$ gallons, where 28.1 is mpg for the technology replaced.

There are two other factors that are included in the product. These are the factor for the survival rate and the factor that takes into account the different number of miles driven each year after purchase of the car. The latter is given as a fraction because the number of miles driven in a particular year is included in the computation of the number of miles driven in the first year. It is necessary that these two factors be included because the marginal cost can only be estimated for an average user. That is, historical survival rates are the only available figures for basing expected lifetimes of vehicles and an aggregate measure such as average miles driven is the only available basis for estimating miles driven.

In Table A-5, the survival fraction by age of car and the ratio of miles driven in each year to miles driven in the first year after purchase are given in the first two columns. The discount factor and the price escalator factor are given in the next two columns. The last column, labelled "product," is the product of the four columns. The sum of products, 6.04, is given at the bottom of the last column. This sum of products is the same for both the Stirling car and the gas turbine car.

Multiplying the sum of products, that is multiplying 6.04, by the number of gallons saved in the first year gives the cumulative discounted savings in the year 2000. This result is then divided into the incremental cost to the consumer to give the marginal cost of saving a gallon of gasoline to the consumer. The gas turbine car saves 119 gallons of gasoline in the first year and costs an additional 1000 dollars compared with a saving of 151 gallons of gasoline saved in the first year for the Stirling car and an additional cost of 1500 dollars. For the Stirling car, the cost of saving

a gallon of gasoline is \$1.64 and for the gas turbine car the marginal cost is \$1.39.

While the average driver is assumed for these sample computations, it is probable that the average purchaser of fuel efficient vehicles are those that drive much more than the average driver. Even though the survival fractions may reduce more quickly over the years, the savings will be realized sooner and the effects of the discounting will, accordingly, be less pronounced. This will lead to a slight reduction in the marginal cost to the consumer.

For the electric automobile, the computation is the same except that the cost of electric power is to be added to the incremental cost of the vehicle. The electric power cost is discounted at seven percent since it is paid over the years that the vehicle is driven. Computation of electric power costs also take into account the expected number of miles driven each year.

Tables A-7 through A-10 give payback period in years for purchases of Stirling, electric vehicle, and turbine. Payback period in years is the number of years it takes a purchaser to recoup the incremental cost of the vehicle.

In calculating the payback period to the consumer, the computational procedure has many of the same features. That is, the product of the survival fraction, the ratio of miles driven in years after the year of purchase to the miles driven in the year of purchase, the discount factor, and the fuel price escalator is computed in the same manner. In addition to multiplying the product for each year by the number of gallons of fuel saved in the first year after purchase, the price of fuel in the first year is also included in the factor.

TABLE A-7
PAYBACK PERIOD, STIRLING, YEAR 2000 (PBP)

YEAR	SURVIVAL FRACTION	R	DISCOUNT FACTOR 7%	PRICE ESCALATOR	DISCOUNTED VALUE OF SAVINGS
1	.999	1.00	.93	1.00	353
2	.997	1.02	.87	1.03	347
3	.992	.95	.82	1.06	312
4	.982	.82	.76	1.09	254
5	.963	.77	.71	1.13	226
6	.925	.73	.67	1.16	200

PBP = 5.0 years

Discounted value of savings = \$2.52 x 151, where \$2.52 is the

price of fuel in the year 2000,
in 1980 dollars, 151 is the
number of gallons saved in 2000

PBP = number of years it takes for discounted value of savings to add up to 1500

TABLE A-8
PAYBACK PERIOD, TURBINE, YEAR 2000 (PBP)

YEAR	SURVIVAL FRACTION	R	DISCOUNT FACTOR 7%	PRICE ESCALATOR	DISCOUNTED VALUE OF SAVINGS
1	.999	1.00	.93	1.00	279
2	.997	1.02	.87	1.03	273
3	.992	.95	.82	1.06	246
4	.982	.82	.76	1.09	200
5	.963	.77	.71	1.13	178

PBP = 4.0 years

Discounted values of savings = \$2.52 x 119 where \$2.52 is the price of fuel in the year 2000 in 1980 dollars and 119 is the number of gallons saved in the year 2000.

PBP is the number of years it takes for discounted value of savings to equal \$1000.

TABLE A-9

PAYBACK PERIOD, ELECTRIC VEHICLE (AUTO), YEAR 2000 (PBP)

YEAR	SURVIVAL FRACTION	R	DISCOUNT FACTOR	REAL FUEL PRICE ESCALATOR	DISC. VALUE OF SAVINGS	DISC. ELEC. POWER COSTS	DIS- COUNTED NET SAVINGS
1	.999	1.00	.93	1.00	1121	125	996
2	.996	1.02	.87	1.03	1099	119	980
3	.991	.95	.82	1.06	988	95	893
4	.980	.82	.76	1.09	804	82	722
5	.960	.77	.71	1.13	716	71	645

PBP = 4.1 years

Discounted net savings = Discounted value of savings minus (-)
discounted electric power costs

PBP is the number of years it takes for discounted net savings
to equal \$3628

Gallons saved in first year = 479

TABLE A-10

PAYBACK PERIOD, ELECTRIC VEHICLE (TRUCK), YEAR 2000 (PBP)

YEAR	SURVIVAL FRACTION	R	DIS-COUNT FACTOR	REAL FUEL PRICE ESCALATOR	VALUE OF SAVINGS	ELEC-TRIC POWER COSTS	DIS-COUNTED NET SAVINGS
1	.995	1.00	.93	1.00	1657	133	1524
2	.987	1.00	.87	1.03	1610	123	1487
3	.977	.89	.82	1.06	1398	106	1296
4	.964	.89	.76	1.09	1336	93	1243
5	.946	.73	.71	1.13	1057	66	991
6	.923	.73	.67	1.16	1011	58	953

PBP = 5.1 years

Discounted net savings = Discounted value of savings minus (-)
discounted electric power costs

PBP is the number of years it takes for discounted net savings
to equal \$6645

Gallons saved in first years = 707

A.2 COMPUTATIONAL PROCEDURES FOR THE POLICY MATRIX

A.2.1 Introduction

The following computational procedures have been designed for calculating the attributes of the policy matrix. Except for present value of cumulative DOE funding, all of the attributes in the program description, industry input and impact matrices, are inputs to the automated program and will not be addressed further. The attributes in the savings matrix require additional computation once the inputs are given. Present value of cumulative DOE funding is a component of one of the savings matrix attributes and the computational procedure for that attribute will be presented with the savings matrix attribute.

The principal inputs to the computations are outputs of the Argonne program for computing benefits and costs of the OTP programs. The Argonne program has undergone some revision since these computational procedures have been developed. In particular, in the version to which these procedures apply, fuel savings by year for each program are computed to the year 2010. Incremental consumer costs are also given to the year 2010. For some of the programs and certain attributes, savings due to vehicles sold in 2010 and in previous years that are still operating in years beyond 2010 must be included to be consistent with the costs to consumers.

A.2.2 Mathematical Representation

The mathematical representations that follow are given for all of the attributes in the savings matrix except for attributes 1, 5 and 6.

For attribute 1, cumulative savings in Quads, the values are direct outputs of the Argonne Computer Program.

Attribute 5, petroleum savings in Quads in 1985, is also a direct output of the Argonne Computer Program.

Attribute 6, petroleum saved in 1985 divided by petroleum saved in 2000, requires only that the ratio of outputs from the Argonne Computer Program be found.

2. Attribute:

Value of cumulative petroleum savings (VCPS)
in constant (1980) dollars

Mathematical Representation:

$$VCPS = \sum_{i=1}^n P_i (GS)_i$$

$(GS)_i$ = fuel saved in year i in gallons for all units
(vehicle) of the program on the road in the
year i and is a direct output of the Argonne
Computer Program

$$P_i = P_{i-1} (1 + E_i)$$

for $i = 2, \dots, n$

P_i = price of fuel in mid period 1980 dollars

E_i = real fuel price escalator in decimal form for
year i

n is the last year of savings listed in the Argonne Computer
Program.

3. Attribute:

Present value of petroleum saved (PVPS) divided
by the present value of DOE funding (PVDOEF)

Mathematical Representation:

$$\frac{PVPS(1980)}{PVDOEF(1980)}$$

$$PVPS(1980) = \sum_{i=1}^n \frac{P_i (GS)_i}{(1 + d_1)^i}$$

$(GS)_i$ and P_i are as in VCPS in calculated attribute No. 2.

d_1 = discount rate for value of savings.
n is last year of savings listed in Argonne
Computer Program

$$PVDOEF(1980) = \sum_{i=1}^k \frac{(DOEF)_i}{(1 + d_2)^i}$$

d_2 = DOE funding at discounted rate

$(DOEF)_i$ = DOE funding in year i in constant (1980) dollars

k = final year of DOE funding

PVPS(1980) = present value in 1980 of petroleum savings.

4. Attribute:

Present value of petroleum saved (PVPS) divided
by present value of cumulative capital investments
(PVCCI)

Mathematical Representation:

$$\frac{PVPS(1980)}{PVCCI(1980)}$$

PVPS(1980) as calculated in attribute No. 3.

$$PVCCI = \sum_{i=1}^t \frac{(CC)_i}{(1 + d_1)^i}$$

$(CC)_i$ = capital investment in year i

t = the last year for which capital costs are expended.

d_1 as calculated in attribute No. 3.

7. Attribute:

Marginal cost to consumer (MCC) in 1990 or 2000

Mathematical Representation:

$$MCC = \frac{ICC + EPC}{CDS(1990 \text{ or } 2000)}$$

ICC = incremental cost of a vehicle to 1990 or 2000 purchaser in 1980 dollars

EPC = discounted electric power cost over the life of a vehicle. This is represented as follows:

$$= \sum_{i=1}^m \frac{(EP)_i}{(1 + d_1)^i}$$

where:

$(EP)_i$ = cost to purchaser of electric power in year i .
This is represented as follows:

$(EP)_{i-1} (1 + E_i) R_i F_i$, for $i = 2, \dots, m$

and $(EP)_1$ for $i = 1$

E_i = electric power real price escalator

R_i = ratio of miles driven by vehicle in year i to miles driven in $i=1$ (2000 or 1990)

F_i = survival probabilities in year i (from survival fraction)

$CDS(1990 \text{ or } 2000)$ = cumulative value of savings discounted to 1990 or 2000. This is represented as follows:

$$\sum_{i=1}^m \frac{(CS)_i (1 + E_i)^i}{(1 + d_1)^i}$$

$(CS)_i$ = number of gallons of fuel saved in year i .
This is represented as follows:

$(CS)_i, R_i F_i$

m = the last year in which probability of survival is not zero.

E_i = Price of fuel escalator.

8. Attribute:

Percent of cumulative savings attributable to program (CSOTP)

This is either a direct input or, as in the case of advanced propulsion in electric vehicle, it is assumed that all savings are attributable to the OTP program, in which case:

$$\text{CSOTP} = 100\%$$

or that savings begin earlier because of the OTP program. For this case:

$$\text{CSOTP} = \frac{\text{CPS}_a - \text{CPS}_n}{\text{CPS}_n}$$

where:

CPS_a = cumulative petroleum saved by the accelerated program

and

CPS_n = cumulative petroleum saved by the technology given a normal introduction date.

9. Attribute:

Payback period (PBP) to consumer in year

Mathematical Representation:

$$PBP = t-1 + \frac{ICC-f(t-1)}{f(t)-f(t-1)}$$

where:

t = first year in which

$$f(t) = \sum_{i=1}^t \frac{P_i(CS)_i - (EP)_i}{(1 + d_1)^i}$$

where:

$P_i(CS)_i$, $(EP)_i$, d_1 are all as defined in computing MCC in Attribute 7.

10. Attribute:

Net present value (NPV)

Mathematical Representation:

Attribute = present value of petroleum saved minus
the present value of costs

Present value of petroleum saved is as calculated
in Attribute 3

Present value of incremental costs to the consumers
is represented as follows:

$$\sum_{i=1}^n (LCC)_i \frac{1}{(1 + d_2)^i}$$

Present value of DOE costs (funding) is represented
as follows:

$$\sum_{i=1}^n \frac{(DOEF)_i}{(1 + d_2)^i}$$

Present value of electric power costs is represented as follows:

$$\sum_{i=1}^n \frac{(EPC)_i}{(1 + d_2)^i}$$

where:

$(EPC)_i$ = electric power costs in year i

$(EPC)_i$ = (stock x miles per car x electric power cost
per mile) in year i

A.3 SAMPLE POLICY MATRIX

The following matrices are intended to illustrate the way in which the attributes are entered into the matrices. The values for the attributes listed in the savings matrix were derived from actual studies and the assumptions that went into the computation of the attributes are though to be valid. The same is true of those attributes for which values are given in the program matrix. Not all of the cells in the matrix are filled out because the information was not made available for this study or because estimates have not been made.

The attribute values given in the impact matrix are examples and are not intended to be particularly valid. None of the cells in the industry impact matrix were filled in because the information is not generally available. The area of industry impact is an important area for future study and the number and definition of attributes in the matrix should be the subject of future work for revision.

TABLE A-11 SAVINGS MATRIX

		OFFICE OF TRANSPORTATION PROGRAMS			
ATTRIBUTES		ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1	Cumulative petroleum saved in Quads through given year 2025, 2000	24.5 (2025)	11.2 (2025)	6.1 (2025)	.16 (2000)
2	Value of cumulative petroleum savings in 1980 \$ 2025, 2000	2000 12658 2025 100065	2000 1399 2025 43142	2188 24638	998 1685
3	Present value of petroleum saved / present value of DOE funding				
4	Present value of petroleum saved / present value of cumulative Capital Investment				
5	Petroleum saved in Quads, 1985 0 MPG	0	0	0	.005
6	Petroleum saved in 1985/Petroleum saved 2000 MPG	0	0	0	.005/011
7	Marginal cost to consumer in 1990 and 2000	\$1.53 per gallon for auto 2000	\$1.64 per gallon saved 2000	\$1.39 per gallon saved 2000	NA

TABLE A-11. SAVINGS MATRIX (CONT'D)

		OFFICE OF TRANSPORTATION PROGRAMS			
ATTRIBUTES		ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
8	Percent cumulative savings attributable to OTP Programs 100%	100%	100%	100%	100%
9	Payback period to consumer (years) in 1985, 2000	5.1 Years truck 2000 4.1 years Auto 2000	5.0 years 2000	4.0 years 2000	NA
10	Net present value.	\$50 billion	\$22 billion	\$14 billion	\$1 billion

TABLE A-12. PROGRAM MATRIX

ATTRIBUTES	OFFICE OF TRANSPORTATION PROGRAMS			
	ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1 FY 1981 DOE funding	22 million	22 million	35 million	1
2 Present value of cumulative DOE funding	151 million	206	239 million	13
3 FY 1981 DOE Manpower				
4 Final year of DOE funding	1991	2000	1999	2010
5 Percent other agency funding, FY81				
6 Market Definition	Autos and LT trucks	Medium & Large Cars and Light Trucks	Large Cars and Light Trucks	NA
7 Percent Market Penetrated	10%	50%	50%	NA
8 First Year of Funding				
9 Probability of Technical success				
10 Probability of Commercial success				
11 Years of accelerated program	5 years			NA

TABLE A-13. IMPACT MATRIX

ATTRIBUTES	OFFICE OF TRANSPORTATION PROGRAMS			
	ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1 Probability of adverse environ- mental impact (L,M,H)	M	L	L	L
2 Probability of adverse economic impact (L,M,H)	L	L	L	M
3 Institutional barriers (yes, no)	NO	NO	NO	YES
4 Technology contri- bution (yes, no)	YES	YES	YES	NO
5 Technical solution required (yes, no)	YES	YES	YES	NO

TABLE A-14. INDUSTRY INPUT MATRIX

		OFFICE OF TRANSPORTATION PROGRAMS			
ATTRIBUTES		ELECTRIC VEHICLE	STIRLING ENGINE	GAS TURBINE	MPG MILEAGE GUIDE
1	Cumulative capital investment through given year in 1980 \$				
2	Capital investment in years 1990 and 2000, in 1980 \$				
3	Capital cost per unit, in 1980 \$				
4	Industry providing capital				
5	Ratio of industry to DOE funding for R+D, FY 81				

APPENDIX B

SAMPLE CALCULATIONS FOR RANKING FUNCTIONS

B.1 INTRODUCTION

The following sample calculations are made for purposes of illustration. Inputs to the ranking function such as cumulative value of petroleum savings, cumulative incremental costs to the cosumer and cumulative DOE funding are results of estimates made using the Argonne computer program which has inputs based on extensive studies and projections made by the OTP Evaluation Group. Consequently, they are thought to be valid. The coefficients of the comprehensive ranking function are the results of an exercise involving the OTP Evaluation Group as described in Appendix C. These coefficients are derived in an abbreviated exercise and are subject to improvement. The values for EN, EC, and I in the comprehensive ranking function are not well determined for this exercise.

B.2 NET PRESENT VALUE COMPUTATIONS

Net Present Value (NPV) is given by the following equation:

$$NPV = PVPS - ICC - EPC - DOEF$$

where:

PVPS = Cumulative Value of Petroleum Savings, Discounted
ICC = Cumulative documented Cosumer Costs, Discounted
EPC = Cumulative Electric Power Cost, Discounted
DOEF = Cumulative Disconted DOE Funding

All discount rates are at seven percent annually.
Inputs and results for NPV and NPVM are shown in Table B-1.

TABLE B-1.

NET PRESENT VALUE (NPV)

PVPS = Cumulative Value of Petroleum Savings, Discounted
 ICC = Cumulative Incremented Consumer Costs, Discounted
 EPC = Cumulative Electric Power Costs, Discounted
 DOEF = Cumulative Discounted DOE Funding

Program	PVPS (\$Billion)	ICC (\$Billion)	EPC (\$Billion)	DOEF (\$Billion)	NPV (\$Billion)
Electric Vehicle	100.0	38.9	2.7	.20	50.7
Stirling Engine	43.1	20.6	0	.20	22.3
Gas Turbine	24.6	10.8	0	.24	13.5
MPG Mileage Guide	1.0	0	0	.01	1.0

NET PRESENT VALUE PER PROGRAM DOLLAR (NPVM)

Program	DOLLARS PER FUNDING DOLLAR
Electric Vehicle	168
Stirling Engine	112
Gas Turbine	56
MPG Mileage Guide	89

B.3 COMPREHENSIVE RANKING FUNCTION COMPUTATION

The Comprehensive Ranking Function (CRF) is given by the following equation:

$$R = 6.1 (aS) - 2 (bC_1) + 3 (cC_2) \\ - 1.4 (EN) - 1.7 (I) - 1.3(EC) + 94$$

Inputs for the Comprehensive Ranking Function are given in Table B-2 and the computations are illustrated in Table B-3. The values for a, b and c are derived by setting the largest aS, bC₁, and cC₂ all equal to 10 for the longest values of S, C₁, and C₂. Where S is petroleum savings in Quads, C₁ is DOE costs, and C₂ is the sum of incremented consumer costs and electric power costs. The computations are as follows:

$$a(24.5) = 10; a = .41$$

$$b(320) = 10; b = .03$$

$$c(247) = 10; c = .04$$

TABLE B-2

COMPREHENSIVE RANKING FUNCTION INPUTS

Program	Pet Saved Quads	DOE COSTS Million	Inc. Consumer Cost (Billion)	Electric Power Costs (Billion)
Electric Vehicle	24.54	302	186	61
Stirling Engine	11.24	300	116	0
Gas Turbine	6.10	320	54	0
MPG Mileage Guide	.16	20	0	0

Program	EN	EC	I
Electric Vehicle	5	1	1
Stirling Engine	1	1	1
Gas Turbine	1	1	1
MPG Mileage Guide	1	5	5

TABLE B-3
COMPUTATION OF SCORES USING
THE COMPREHENSIVE RANKING FUNCTION

$R(EV) = 6.1(.41)(24.5) - 2(.03)(302) - 3(.04)(247)$ $- 1.4(5) - 1.7(1) - 1.3(1) + 94 = 98$
$R(\text{Stirling}) = 6.1(.41)(11.2) - 2(.03)(300) - 3(.04)(116)$ $- 1.4(1) - 1.7(1) - 1.3(1) + 94 = 86$
$R(\text{Gas Turbine}) = 6.1(.41)(6.1) - 2(.03)(310) - 3(.04)(54)$ $- 1.4(1) - 1.7(1) - 1.3(1) + 94 = 79$
$R(\text{MPG}) = 6.1(.41)(.16) - 2(.03)(20)$ $- 1.4(1) - 1.7(5) - 1.3(5) + 94 = 77$

B.4 COMPUTATIONAL PROCEDURES FOR THE RANKING FUNCTION

B.4.1 Introduction

The components of the ranking function are direct inputs from the policy matrix or they are derived from intermediate calculations of the attributes.

B.4.2 Computational Procedures

Mathematical Representation:

$$R_p = 6.1(a S_p) - 2(bc_{1p}) - 3(cc_{2p}) \\ - 1.4(EN_p) - 1.7(I_p) - 1.3(EC_p) + 94$$

where:

R_p = the value of the ranking function for program p and the programs are ranked according to the values of R_p

S_p = cumulative petroleum savings in Quads from program p.

This is Attribute 1 in the savings matrix (Section 2)

Cl_p = cumulative DOE funding from FY1981 through to the final year of funding

$$= \sum_{c=1}^n (DOE)_i$$

C_{2p} = cumulative cost to the consumer, which is represented as follows:

$$\sum_{i=1}^n (ICC)_i + \sum_{i=1}^n (EPC)_i$$

where:

$(ICC)_i$ = incremental cost to the consumer in year i

and

$(ECP)_i$ = electric power costs in year i.

The values of a , b , c are found by setting

$$S_p, C_{1p} \text{ and } C_{2p} = 10$$

for programs where S_p , C_{1p} and C_{2p} have the largest values.

EN_p , I_p and EC_p are found as indicated in Section 3.3 and 94 is a constant that is added to keep R_p from becoming negative for any program.

APPENDIX C

IDENTIFYING, RANKING AND WEIGHTING EVALUATION CRITERIA

INTRODUCTION

The comprehensive ranking function (CRF) in Section 3 is in the form of a linear combination of terms. This is also the form of the net present value. However, in order to make the comprehensive ranking function broader, it is necessary to provide terms for economic, and environmental impacts as well as institutional barriers. To include these terms on a common basis with the savings and cost terms, it is necessary to develop a set of coefficients. These coefficients must be determined subjectively. One of the approaches to subject determination of such coefficients is to have a group of individuals make subjective judgements in a systematic way on various factors that can then be converted to numerical values for the coefficients. These coefficients are derived from the weights found by the following procedures. In practice, it is convenient to find the coefficients by dividing all of the weights by the lowest weight. Since the scores for programs to which the ranking function is applied are meaningless except on a relative basis, dividing by the lowest score is done simply for computational convenience.

During the meeting of the OTP evaluation group, held October 29, 1980, an initial attempt was made at selecting and weighting evaluation criteria. The original plan was to have each attendee at the meeting to rank a set of criteria, indicating those they considered not to be pertinent or of any importance in the process of evaluating OTP programs. The second step in the original plan consisted of each individual involved in the exercise distributing 100 points over the criteria according to the importance that they attached to each. Following this step, the high and low scores assigned to

each of the criteria would be noted and the individuals assigning the high and low scores would be asked to comment on the reasons for their assignments. This would be followed by a second and final round of scoring. Final weights would then be derived by averaging the assigned weights.

One of the most important aspects of the procedure would have been the discussion that would result. In particular, those comments made by the individuals giving the high and low assignments would have been useful.

Due to time limitations, the plan could not be implemented as designed. However, ranks and weights were assigned by the attendees. The rankings and weightings were done in a very short time period, approximately fifteen minutes. Nevertheless, the results were processed as described in the following discussion and they have proved interesting. It should be noted that there is no reason that the procedure cannot be conducted again at a later date.

The details of the procedure and the analysis of the results are presented in terms of a discussion of the attached tables. In Table C-1, a list of proposed evaluation criteria and their sources is given. The first of the criteria, DOE funding, was dropped from the list because it was contained in the criteria numbered 13, 14, and 15 in Table C-1. The remaining criteria, in a different order and modified slightly, are listed in Table C-2.

This table was used as shown in the October 29 meeting. Instructions above and below the list were followed in filling out the spaces at the left.

All of the criteria in Table C-2 are listed again in Table C-3 with the exception of the criterion listed as "Cumulative

energy savings through 2000." This was left out because relative weighting of cumulative petroleum savings and cumulative energy savings are best handled in a separate comparison. They were both included in the ranking exercise to provide information for the separate comparison exercise. Instructions for use of Table C-3 are given above and below the list.

Table C-4 gives the individual distributions of 100 points. It was desired to keep the number of points distributed by each of the individuals filling the forms to the range of 95 to 105. Because of the extremely short time allotted to the exercise, three of the seven individuals for which sheets were collected allotted more than 105 points. The split boxes indicate the adjustments that were made. In the first two cases, one point was subtracted from each of the point assignments that were greater than zero. In the third case, two thirds of the assigned numbers were taken.

Table C-5 lists the modified points again for convenient reference, the totals across the columns, the averages and the averages divided by 2.9, the lowest of the averages. It should be noted that any of the last three columns are suitable for weighting purposes.

TABLE C-1

PROPOSED EVALUATION CRITERIA AND THEIR SOURCES

A - Policy Matrix - Transportation Initiatives

B - Transportation Program Evaluation Methodology

C - CS Ranking

1. DOE funding	A B C
2. Cumulative petroleum savings	A ¹ B C
3. Cumulative energy savings	A ¹ B C
4. Near term savings	B C
5. Commercial success	A ² B C
6. Technical success	A B C
7. Capital requirements	A
8. Institutional barriers	A
9. DOE manpower	C
10. Environment impact	B
11. Social impact	B
12. Economic impact	B
13. Savings per DOE dollar	A B C
14. Savings per government dollar	B
15. Savings per total dollar	B
16. Payback period to ultimate user	Professional judgement*
17. Cost sharing in R&D	Private communication with various DOE persons**
18. Benefit to country and government responsibility	Professional judgement**

¹ not explicitly² uses "risk"

* Phil Patterson, DOE

** Louis Santone, Wilson Hill Associates

TABLE C-2

REVISED EVALUATION CRITERIA

Rank the following criteria. If you do not think that a particular criterion should be included in an evaluation function (indexing function), place an "X" in the space provided. If you think two or more are equally important, give them the same rank.

- ___ Cumulative petroleum savings through 2000.
- ___ Cumulative energy savings through 2000.
- ___ Near term petroleum savings.
- ___ Petroleum savings per DOE dollar.
- ___ DOE manpower, DOE funds per manager.
- ___ Petroleum savings per government dollar (cumulative).
- ___ Petroleum savings per total dollar, government plus consumer (cumulative).
- ___ Payback period to consumer.
- ___ Environmental impact.
- ___ Social impact.
- ___ Economic impact.
- ___ Institutional barriers.
- ___ Cost sharing with industry in R&D.
- ___ Capital requirements.
- ___ Technical success.
- ___ Commercial success (given technical success).
- ___ Degree of government responsibility.

Add any other criteria you think ought to be added for use in an indexing function.

COMMENTS:

TABLE C-3

SCORING SHEET ON EVALUATION CRITERIA

Distribute 100 points over the following criteria. If you think that a particular criterion should not be included, assign zero as the number of points. Think of the points as weighting factors that reflect the importance of the criteria relative to each other.

POINTS

- ___ Cumulative petroleum savings through 2000.
- ___ Near term petroleum savings.
- ___ Petroleum savings per DOE dollar (cumulative).
- ___ DOE manpower, DOE funds per manager.
- ___ Petroleum savings per government dollar (cumulative).
- ___ Petroleum savings per total dollar, government, and direct consumer cost (cumulative).
- ___ Payback period to consumer.
- ___ Environmental impact.
- ___ Social impact.
- ___ Economic impact.
- ___ Institutional barriers.
- ___ Cost sharing of R&D with industry.
- ___ Capital requirements.
- ___ Probability of technical success.
- ___ Probability of commercial success (given technical success).
- ___ Degree of government responsibility.

It is not necessary that the number of points add exactly to 100, but they should add to a number between 95 and 105.

COMMENTS:

TABLE C-4

INDIVIDUAL DISTRIBUTION OF 100 POINTS							
Cum. Pet. Savings Through 2000	7	14 15	15	30	18	14 15	26 40
Near Term Petroleum Savings	4	0 0	20	5	8	0 0	13 20
Pet. Savings/DOE \$	6	14 15	8	10	12	14 15	7 10
DOE Manpower	3	0 0	6	0	8	0 0	3 5
Pet. Savings/Gov't. \$	10	9 10	6	0	8	0 0	7 10
Pet. Savings/Total \$	10	9 10	4	5	7	12 13	7 10
Payback Period	10	5 6	3	10	6	4 5	7 10
Env. Impact	2	5 6	3	1	5	5 6	7 10
Social Impact	3	5 6	1	2	4	4 5	3 5
Economic Impact	4	5 6	3	3	4	4 5	3 5
Institutional Barriers	6	5 6	3	0	5	12 13	3 5
Cost Sharing R&D w/ind.	7	3 4	3	4	4	5 6	7 10
Capital Requirements	8	5 6	4	5	4	5 6	7 10
Prob. of Tech. Success	8	5 6	8	10	5	7 8	3 5
Prob. of Comm. Success	8	5 6	4	10	3	9 10	3 5
Deg. of Gov't. Resp'ty.	0	9 10	4	5	2	2 8	0 0
TOTAL	96	98 112	95	100	103	102 115	106 160

TABLE C-5
WEIGHT COMPUTATIONS

	MODIFIED POINT DISTRIBUTIONS							TTL	AVG	WGT
Cum. Pet. Savings Through 2000	7	14	15	30	18	14	26	124	17.7	6.1
Near Term Petroleum Savings	4	0	20	5	8	0	13	50	7.3	2.4
Pet. Savings/DOE \$	6	14	8	10	12	14	7	71	10.1	3.5
DOE Manpower	3	0	6	0	8	0	3	20	2.9	1.0
Pet. Savings/Gov't. \$	10	9	6	0	8	0	7	40	5.7	2.0
Pet. Savings/Total \$	10	9	4	5	7	12	7	54	7.7	2.7
Payback Period	10	5	3	10	6	4	7	45	6.4	2.2
Env. Impact	2	5	3	1	5	5	7	28	4.0	1.4
Social Impact	3	5	1	2	4	4	3	22	3.1	1.1
Economic Impact	4	5	3	3	4	4	3	26	3.7	1.3
Institutional Barriers	6	5	3	0	5	12	3	34	4.9	1.7
Cost Sharing R&D w/ind.	7	3	3	4	4	5	7	33	4.7	1.6
Capital Requirements	8	5	4	5	4	5	7	38	5.4	1.9
Prob. of Tech. Success	8	5	8	10	5	7	3	46	6.6	2.3
Prob. of Comm. Success	8	5	4	10	3	9	3	42	6.0	2.1
Deg. of Gov't. Resp'ty.	0	9	4	5	2	7	0	27	3.9	1.3

Table C-6 lists the average points again and gives the range between the high and low number of points assigned to each of the criteria. The ranges are probably much higher than would be desired. If successive rounds of the weighting process were carried out, sharing results between rounds among participants would tend to cause results to converge to a smaller range.

Table C-7 gives the individual rankings of the criteria assigned by the group. In some cases, the individuals marked an "X", indicating that they did not think that the criterion should be included. For purposes of analysis these were assigned a rank of 18. Had there been more rounds, it is possible that these criteria would be altogether. The rankings were then totalled across the columns and these totals were then ranked to produce the final rankings.

Table C-8 lists the sixteen criteria and gives the total weighting scores, the average weights, the average weights divided by 2.9 and two rankings. The first ranking is the ranking of the scores and the second is the result of the direct ranking exercise.

TABLE C-6

AVERAGE AND RANGE FOR POINTS ASSIGNED IN EACH CRITERIA

	AVG.	RANGE
Cum. Pet. Savings Through 2000	17.7	23
Near Term Petroleum Savings	7.1	20
Pet. Savings/DOE \$	10.1	8
DOE Manpower	2.9	8
Pet. Savings/Gov't. \$	5.7	10
Pet. Savings/Total \$	7.7	8
Payback Period	6.4	7
Env. Impact	4.0	6
Social Impact	3.1	4
Economic Impact	3.7	2
Institutional Barriers	4.9	12
Cost Sharing R&D w/ind.	4.7	4
Capital Requirements	5.4	4
Prob. of Tech. Success	6.6	7
Prob. of Comm. Success	6.0	7
Deg. of Gov't. Resp'ty.	3.9	9

TABLE C-7
INDIVIDUAL RANKINGS OF CRITERIA

									TTL	RNK 'G
Cum Pet Savings	1	18	1	1	2	1	1	1	26	1
Near Term Pet Savings	15	1	2	6	1	4	3	2	34	3
Pet Savings/DOE \$	1	2	18	2	3	2	2	3	33	2
DOE Manpower	17	18	18	5	6	15	15	12	106	16
Pet Savings/Gov't. \$	1	18	18	3	7	12	5	4	68	5
Pet Savings/Total \$	1	7	4	8	11	3	4	5	43	4
Payback Period	7	18	14	14	14	5	7	6	85	10
Env. Impact	7	3	8	4	13	14	17	9	75	6
Social Impact	7	5	13	13	17	13	16	14	98	14
Economic Impact	7	4	12	12	16	11	8	15	96	12
Institutional Barriers	7	6	3	15	12	16	13	13	85	11
Cost Sharing R&D w/ind.	16	18	11	16	15	10	9	8	103	15
Capital Requirements	7	18	10	11	10	8	10	7	81	9
Technical Success	14	18	6	10	3	6	11	11	79	8
Commercial Success	7	18	5	9	8	7	12	10	76	7
Deg. of Gov't. Resp'ty.	6	18	7	17	9	9	14	17	97	13

TABLE C-8

TOTAL WEIGHTING, AVERAGING AND RANKING OF INDIVIDUAL CRITERIA

	<u>TTL WGT SCR</u>	<u>AVG</u>	<u>AVG ÷ 2.9</u>	<u>RNK BY SCR</u>	<u>RNK DRTLY</u>
Cum Pet Savings through 2000	124	17.7	6.1	1	1
Near Term Pet Savings	51	7.3	2.5	4	3
Pet Savings/DOE \$	71	10.1	3.5	2	2
DOE Manpower	20	2.9	1.0	16	16
Pet Savings/Gov't. \$	40	5.7	2.0	8	5
Pet Savings/Total \$	54	7.7	2.7	3	4
Payback Period	45	6.4	2.2	6	11
Env. Impact	28	4.0	1.4	12	6
Social Impact	22	3.1	1.1	15	14
Economic Impact	26	3.7	1.3	14	12
Institutional Barriers	34	4.9	1.7	10	10
Cost Sharing R&D (w/ind)	33	4.7	1.6	11	15
Capital Requirements	38	5.4	1.9	9	9
Prob of Tech Success	46	6.6	2.3	5	8
Prob of Comm Success	42	6.0	2.1	7	7
Deg. of Gov't. Resp'ty.	27	3.9	1.3	13	14

APPENDIX D

METHODS FOR DISCOUNTING TO PRESENT VALUE

For energy conservation programs, it is necessary to determine the value of energy saved and costs of achieving the savings at a common point in time or in a common year since the investments are made before the savings occur. For an individual, a dollar saved this year, even net of inflation, is worth more than a dollar saved next year. Likewise, a dollar spent by an individual consumer in the future is less valuable than a dollar spent this year. Determining the value of savings and costs at a common point in time such as the present is called discounting to present value.

The rates at which savings and costs are to be discounted are usually subject to a great deal of discussion. Unfortunately, for OTP programs, the results of evaluation are sensitive to the selection of discount rates. The reason is that the savings and costs, in this case incremental costs to consumers, are twenty to thirty years off. For some programs, discounted savings can differ by more than twenty percent from choosing seven percent rather than ten percent. Obviously, measures for evaluating programs that depend on discounted costs and savings can vary greatly as combinations of different discount rates are applied.

In this report, program costs and aggregate incremental costs to consumers are discounted at seven percent rate. The value of savings and electric power costs to individual purchasers are also discounted at seven percent. These are discount rates net of inflation, consequently fuel prices and costs are all given in constant (1980) dollars.

One of the resources available to the OTP program evaluation effort is NBS Handbook 135, "Life-Cycle Cost Manual for the Federal Energy Management Program." This manual also gives real fuel price escalators and electric power price escalators.

NBS Handbook 135 is designed for use in evaluating energy conservation in building systems. It cites OMB directives for selecting discount rates for certain purposes. The seven percent discount rate for savings and for costs is consistent with the manual. Using seven percent for discounting electric power costs to individuals is clearly less consistent with the manual and it may be decided that a ten percent rate is more appropriate. It should be pointed out, however, that the discount rate for electric power costs to individuals only applies to discounting the costs of electric power over the life of electric vehicles and is used in computing payback period and marginal cost to the consumer.

APPENDIX E

USE OF TERMS

A number of terms have been used interchangeably in the process of program evaluation to characterize programs and the technologies and activities involved in the programs. The most common are attribute, criterion, and measure of effectiveness.

It usually does not matter which term is used if the elements to which the terms refer are defined and the manner in which the element is to be used is described.

One of these terms, attribute, has a mathematical meaning in a set of methodologies called multidimensional scaling. Used in this sense, the term would have a scope closer to that of criterion and measure of effectiveness. In the mathematical connotation, the attribute has an attribute dimension and an attribute position in some of the methodologies. As such, only the attributes of importance are included. In a broader sense, the term refers to any characteristics that describe an element. In this sense, the terms criterion and measure of effectiveness are attributes.

Some program attributes are not by themselves measure of effectiveness or criteria, but are used to calculate measures of effectiveness. An example is the market that a technology or activity is expected to penetrate. This is a program attribute that is used to calculate measures of effectiveness such as amount of petroleum saved.

Since attribute is the broader term, it is recommended that it be used in connection with the policy matrix. In this way, even if an element such as the market penetrated is

not by itself a criterion or measure of effectiveness, it may be included in the matrix along with attributes that are measures of effectiveness or criteria.

The terms criterion and measure of effectiveness are typically used interchangeably. In systems analysis, the term is used in connection with alternatives evaluation. That is, once alternatives are generated, they are to be evaluated on the basis of a single criterion or some combination of measures or two or more criteria. Sometimes, a measure of effectiveness is a combination of measures of criteria also. For example, the term cost effectiveness means cost of some unit of outcome. In the case of energy conservation programs, the measure of effectiveness in this regard may be cost per barrel of energy saved. The two components of this measure may be cost and energy saved. It could, of course, be argued that cost is by itself a measure of effectiveness. The two components, cost and amount of energy saved are, however, evaluation criteria that can be combined or weighted for purposes of evaluation.

It is probably not very important that the terms criterion and measure of effectiveness not be used interchangeably. However, the term criterion may best be used when a single component or attribute is used for evaluation and the term measure of effectiveness may best be used when some combination of components is used.

APPENDIX F
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