Overview of the alternative power system economic analysis model

by RICHARD B. DAVIS
Jet Propulsion Laboratory
Pasadena, California

and

JEROME V. V. KASPER
UCLA
Los Angeles, California

INTRODUCTION

The Alternative Power System Economic Analysis Model (APSEAM) is an interactive computer model which can be applied in three ways: (1) the model projects the annual, after-tax costs of capital investment in various conventional and non-conventional energy technologies for each and every year in the investment time horizon; (2) the model serves as an investment analysis tool; and (3) the model serves as a tool which can be used for evaluating the impact of specific policies on specific investors.

The basic model premise is that the valuation of investment alternatives should have a "lifecycle cost" perspective in addition to the usual "first-cost" perspective. The needed "lifecycle cost" perspective is obtained through use of a cash flow methodology. Detailed cash flow information is projected for each investment alternative for each and every year in the investment time horizon. This annual cash flow information is then aggregated to produce various measures of the lifecycle costs of each of the investment alternatives. The model can be used to quantify the impact on annual cash flows and on lifecycle costs of variations in technology cost (capital costs and operations and maintenance costs), general economic conditions, investor-specific financial conditions, technology performance over time, supply and demand matching, incremental plant start-up, and component replacement scenarios.

As an investment analysis tool, the model aggregates the projected cash flow information to produce an investor-specific "investment profile" for each investment alternative—a set of figures of merit which include net present value, levelized energy costs, liquidity requirements, and fractional return on investment. As an investment analysis tool, the model produces investor- and application-specific projections of how specific investors are likely to perceive the worth of a particular investment alternative relative to others.

The specific investor types which can be treated include private utilities, municipal utilities, corporations, and individuals. In addition, various types of joint ventures and leasing arrangements can be modeled.

As a tool for analyzing policies, the model quantifies the impact of specific state and federal actions on the perception of specific private sector investors concerning the economic viability of the various investment alternatives. For example, the model can quantify the implications of utilizing various methods of depreciation accounting, various provisions for tax credits, various rules concerning the carry-back and carry-forward of tax credits and/or operating losses. Insofar as the model is a year-specific cash flow model, these governmental actions can be year-specific.

The model has been applied to a study of the economics of a homeowner in Phoenix either buying or leasing a photovoltaic system rather than relying on the utility grid for all electricity needs. The model is currently being applied to evaluate the financial viability of solar thermal technology in an island utility system (Catalina) and in a thermal stimulation scheme for heavy oil recovery (Kern County).

Cash flow model

The basic model premise is that the evaluation of investment alternatives should be based upon a "lifecycle cost" perspective. The relative worth of the various investment alternatives in conventional and non-conventional energy technologies is particularly difficult to judge when the various cost elements associated with the investment alternatives change at varying rates over the time horizon of interest. In general, the costs of the various investment alternatives over the entire time horizon of interest must be recognized. The needed "lifecycle cost" perspective is obtained through use of a cash flow methodology. In a cash
flow model, detailed cash flow information is projected for each investment alternative for each year in the investment time horizon. Within APSEAM, this annual cash flow information is aggregated to produce various measures of the lifecycle costs of each of the investment alternatives.

The model is capable of quantifying the effects of variations in the cost of various technologies (capital costs and operations and maintenance costs), general economic conditions, investor-specific financial conditions, the method of financing of the capital investment, the resource (e.g., solar insolation levels), technology performance over time, supply and demand matching, incremental plant start-up, and component replacement scenarios.

**Investment analysis tool**

The Alternative Power System Economic Analysis Model also functions as an investment analysis tool. As such, it seeks to answer the question: "What is the relative worth of different investment alternatives to a specific investor?" This question is much broader than the question "What are the lifecycle costs of different investment alternatives?" for it takes into account a specific investor's financial environment (for example, his ability to take advantage of tax credits, his cost of capital, etc.) as well as the specific investment alternatives available to that investor. As applied to energy system investments, the investment alternatives can include: (a) capital investments in various energy technologies (conventional or non-conventional) to meet specified requirements (electrical and/or thermal); or (b) purchase of all energy needs (electrical energy from the utility grid, thermal energy from combustion of purchased fossil fuel in fossil-fired boilers); or (c) cessation of those activities which create energy needs—investment in some alternative with no energy demands. **

The model "massages" the projected cash flow information and then aggregates it to produce an investor-specific "investment profile" for each investment alternative—a set of figures of merit which enable that investor to make an informed decision.

**Investor-specific policy analysis tool**

In addition to functioning as a lifecycle cost model and as an investment analysis tool, the model also functions as a policy analysis tool. As such, it seeks to answer the question: "What is the impact of various governmental policies on specific private sector investors concerning the relative worth of various investment alternatives?"

The model quantifies the impact of specific state and federal policies on the perception of specific private sector investors concerning the economic viability of the various investment alternatives. For example, the model can quantify the implications of utilizing various methods of depreciation accounting, various provisions for tax credits, various rules concerning the carry-back and carry-forward of tax credits and/or operating losses. Insofar as the model is a year-specific cash flow model, many of these governmental policies can be year-specific. Thus, time-phased incentive strategies can be evaluated. This is an important feature of the model insofar as the government will likely use time-phased strategies to encourage the use of alternative, non-conventional energy systems: large incentives in the near-term, with a tapering off of the incentive size as the desired energy technologies penetrate the marketplace by natural mechanisms.

**Ownership options**

The specific investor types which can be treated include private utilities, municipal utilities, corporations, and individuals. In addition, various types of joint ventures and leasing arrangements can be evaluated.

**Alternative uses of model output**

As an investment analysis tool, the model produces projections of how specific investors are likely to perceive the worth of a particular investment alternative in a specific application relative to other investment alternatives. This information, coupled with the market size potential which those specific investors represent, provides the basis for meaningful estimates of expected market penetration. Hence, model-derived information can serve as valuable input to macro-market penetration models. In like manner, as a policy analysis tool, the model specifies what the impact of specific policy decisions is on the perceptions of specific investors in specific applications concerning the relative worth of various investment alternatives. Aggregated, this information enables the effects of alternative governmental policies and incentive strategies on the market penetration potential of various energy technologies to be quantified. In this way, the costs and the expected benefits associated with alternative policy options can be related and optimal trade-offs identified, both from the standpoint of the government and of individual investors.

**Model execution**

In actual operation, the model is a highly interactive program which possesses graphical capabilities. Internal doc-

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* It is of course true that the calculation of the lifecycle costs of an investment alternative requires assumptions about the investor's opportunity cost of investment and his state and federal tax rates.

** This last investment alternative is included to reflect the fact that, all other things being equal, private sector investors seek to maximize profit. If being in a business which produces or consumes energy is not as profitable as being in another type of business, an investor might be expected not to opt for investments involving energy production or consumption.

† Actual market penetration will depend on largely subjective behavioral considerations and institutional/political factors as well as upon the purely financial, profit-maximizing decision-making criterion specified here. 
It has many user-oriented features to allow for easy input/output formatting, internal calculations and sensitivity analyses. In addition, its graphical capabilities enable the user to readily perceive trends and relationships.

OVERVIEW OF MODEL METHODOLOGY AND OPERATIONAL CAPABILITIES

The model compares each capital investment alternative to a "business-as-usual" option. This "business-as-usual" option is the status quo.

The energy production systems associated with each capital investment alternative are designed so that a uniform degree of energy production reliability†‡ is realized by the investor in his application. In this way, the various investment alternatives can be directly compared in terms of the financial aspects alone.

The comparison of a specific capital investment alternative to the "business-as-usual" option is realized by: (1) projecting the expected annual after-tax cash flows associated with that investment alternative; (2) projecting the expected annual after-tax cash flows associated with the "business-as-usual" option; and (3) calculating the annual differential after-tax cash flows.

The input data required to effect this comparison falls into one or more of the following categories:

- Purchased power costs (PP)
- Capital investment costs (CI)
- Capital funding costs (CF)
- Recurrent expenditures (EX)
- Revenues (RV)
- Taxes (TX)
- Escalation rates (ER)
- Economic parameters (EP)
- Performance (PR)
- Demand (DE)
- Timing (TI)

The major steps in the process are as follows:

1) The matching of supply (the performance of the Capital Investment Alternative) and the demand (the Load Profile)
2) Determination of the pre-tax cash flows for the Capital Investment Alternative
3) Determination of pre-tax cash flows for the Business-As-Usual Option
4) Determination of the Subsystem Replacement Requirements
5) Determination of state and federal taxes for the Capital Investment Alternative and for the Business-As-Usual Option

MODEL APPLICATION

Lifecycle costing

APSEAM is a cash flow model which projects, for each investment alternative considered, all of the revenues and expenses to be experienced by an investor over the entire investment time horizon. These annual cash flow streams are summed to determine the lifecycle costs for each investment alternative. Four different measures of lifecycle costs are calculated, corresponding to the four different types of "dollars" which the model considers. These four types of "dollars" are: (1) nominal dollars; (2) real dollars; (3) energy dollars; and (4) discounted dollars.

Nominal dollars are dollars actually "in hand." In inflationary times, they possess less and less purchasing power over time. Real dollars are nominal dollars from which the effects of inflation have been decoupled. Real dollars have constant purchasing power over time for the "general mix" of consumer goods. Energy dollars are real dollars in which the effects of inflation and of a real escalation of energy costs have been decoupled. When energy costs escalate at a rate above the general inflation rate, a constant number of real dollars possesses less and less purchasing power over time for "energy goods." Hence, there is a need to work with "energy dollars": dollars of constant energy purchasing power over time. Discounted dollars are nominal dollars which have been "interpreted" to reflect the time value of money to a specific investor and to account for the alternative uses he might make of his investment dollars. Assume that an investor has an opportunity cost of investment, in nominal after-tax dollars, of OCIN. This is that investor's time value of money, his "discount rate." If that investor were to receive A after-tax dollars one year from the present, he would be indifferent between that and receiving A/ (1 + OCIN) dollars today; therefore the present worth of a cash flow, A, one year in the future, is A/(1 + OCIN). In general, for the cash flow stream, Ci , and an investor discount rate, OCIN, the present worth of that cash flow stream extending over N years is:

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\text{present worth} = \sum_{i=1}^{N} \frac{C_i}{(1 + OCIN)^i}
\]

Assuming no risk, an investor is indifferent between receiving the actual cash flow stream over time or having the pres-

† The term "reliability" here refers to the probability that a power system will be able to satisfy the investor's demand for energy. Uniform reliability implies that the power system configuration which constitutes each of the investment alternatives has the same loss of load probability (as expressed in terms of the number of days within a given time period that the demand cannot be satisfied). Hence, for example, sufficient back-up or standby capacity is provided in the definition of an insolation-dependent technology alternative so that its reliability is equal to that associated with all other investment alternatives and with the "business-as-usual" alternative.

‡ The opportunity cost of capital contains an opportunity cost component and a risk premium component.
ent worth of that cash flow stream today—they are financially equivalent.

The lifecycle cost for each investment alternative is calculated in terms of these four types of dollars by expressing the after-tax cash flow stream for each investment alternative valued in each type of dollar and by then summing each of them.

The discounted life cycle cost of an investment alternative is perhaps the most informative of the four different types of lifecycle costs to a potential investor. The discounted lifecycle cost specifies the effective amount of money the investor must have on hand, today, invested at his discount rate, OCIN, so that he can "cover" the costs associated with that investment alternative as they come due over the investment time horizon.

INVESTMENT ANALYSIS TOOL

The information contained in the annual differential cash flows must be aggregated in order for a potential investor to more readily evaluate the relative worth of the various investment alternatives. In acting as an investment analysis tool, the model aggregates the annual differential cash flow data to produce an "investment profile." This investment profile contains the type of information which enables a decision maker to make an informed decision. This investment profile contains five different figures of merit, each of which is expressed in terms of one or more of the four different types of "dollars" described above.

These figures of merit are:
1) Net Present Value
2) Absolute, Levelized Energy Costs (after-tax)
3) Liquidity Requirements
4) Fractional Return on Investment
5) Payback Period.

POLICY ANALYSIS TOOL

The model can be used to determine the impact of certain types of governmental actions on the cash flow stream and resultant figures of merit associated with the alternative investment choices by specific investors. A series of options exist in the model which the user can specify when executing the program.

These options were chosen insofar as they represented various means whereby the government could alter the perceptions of the private sector concerning the economic viability of various investment alternatives. These options fall into the following major categories:

- Depreciation accounting
- Tax credit accounting
- Income tax brackets
- Income tax deductions accounting
- Taxable income
- Property taxes

In the depreciation accounting category, options exist both as to method and application. The user must specify the depreciation method to be used at the federal and state level for initial investments as well as for replacements. The methods available are: (1) sum of the years digits; (2) straight line; (3) double declining balance; and (4) declining balance at a user-specified rate. The user must also specify if depreciation is to be taken at the federal level and/or at the state level and, if so, on what fraction of capital costs. Finally, the user must also specify if the special federal first year 20 percent depreciation allowance is to be taken.

In the tax credit accounting category, options exist both as to method and application. The user must specify the terms of any tax credit, the size of the tax credit (usually a percentage of the capital cost) and the limit on the monetary amount of the credit (for example, the federal energy tax credit is 30 percent of the first $2000 and 20 percent of the next $8000 for a limit of $22000). The user must also specify whether the tax credit is to be taken at the federal level and/or at the state level. Finally, if applicable, the user must specify the year the availability of the tax credit ends.

Also included in this category are options with respect to the carryback and carryover of unused investment tax credit. Presently, at the federal level,† any part of the investment tax credit which is not applied as a credit, because of the limitations with regard to the maximum credit in any given year, can be carried back three years and carried over seven years. These time periods can be adjusted in the model, to allow for evaluation of the impact of variations in them on specific investors.

Two options exist with respect to the income tax bracket category: the income tax brackets can be assumed to remain fixed (the status quo) or they can be assumed to be indexed, that is, to inflate at the standard rate of inflation.

In the income tax deduction category, options exist which are pertinent to both businesses and homeowners. With respect to businesses, the user can specify if fuel costs should be allowed as a tax deduction or not. Presently, they are, of course. The model allows this deduction to be either allowed or disallowed. With respect to homeowners, the user can specify that costs associated with buying and operating a power system are deductible, in addition to the usual interest costs. Homeowner costs, some fraction of which can be allowed as deductions at the user's discretion, include fixed costs, variable costs, other annual costs, and insurance costs. These deductions must be specified for both the state and federal levels. The rationale for allowing these options with respect to homeowners will become evident when the taxable income category is discussed.

When a company has more deductions than gross taxable income in a given year, it has a net operating loss in that year; these net operating losses can be carried back three years and carried over seven years at the federal level.‡

Within the model, the time limits allowed for carryback or carryover of net operating losses are input parameters.

† The State of California has no provision for investment tax credits.
‡ The State of California has no provision for carryback or carryover of net operating losses.
The options which exist in the taxable income category apply to homeowners.* They were incorporated in the model because homeowners purchasing power systems will frequently have excess electricity to sell back to the grid and will thereby realize revenues. What is the impact if these revenues are taxed at either the federal or state levels? The user must specify, for both the state and federal levels, what fraction of those sell-back revenues are taxed. In conjunction with this, as mentioned above, the user must specify what portion of homeowner costs are deductions at both the federal and state levels against those revenues.

The property tax option category requires the user to specify the tax rate base on both land and improvements, the escalation rate of that tax rate base, and the property tax rates on the land tax base and on the improvements tax base. Thus, property taxes can be realized only on capital improvements, only on new land acquisitions, on both, or on neither.

SUMMARY


Two major uses of these case study analyses are:

1. Determination of appropriate inputs for market penetration studies of various advanced energy systems: market penetration models for energy technologies typically assume that investment occurs when the levelized energy cost for the new investment alternative (such as solar) is less than or equal to the levelized energy cost from conventional alternatives (such as purchased power, oil-fired energy generation, etc.). This assumption ignores the many other financial considerations/figures of merit which an actual investor would consider in making a capital investment decision. The alternative approach is to consider a particular investor/application whose characteristics are typical of a particular segment of the market. A case study for that particular investor/application is then prepared, generating the appropriate figures of merit for capital investment decision-making, and evaluating the financial feasibility of any particular investment decision. Correlation of the predicted investment choices of particular application/investor sets with the market share which each represents then provides a good basis for estimation of the market penetration of new energy technologies.

2. Identification of optimal candidates for government-sponsored technical experiments and demonstrations. Due to the highly visible nature of demonstrations and the importance of creating a positive image of new energy systems, it is imperative that government-sponsored experiments and demonstrations be sited where the new energy systems are projected to be perceived as financially favorable as possible.

Model development is continuing. The process of applying the model to various case studies has served to identify areas of necessary/desirable model refinement. The continued application of the model to other case studies will undoubtedly identify additional model development needs.

Validation of the model has been initiated and is proceeding in two phases. Phase I is in process and involves the review of the model code/documentation by a Certified Public Accountant (CPA). Suggested/required changes are being incorporated into the model. Phase II of the validation process involves a review of the model by an accounting firm, selected through the competitive procurement process. This contract will be initiated in mid-1980.

It is anticipated that the model will be available for public use within a year. A user's manual is in preparation. The model is presently on a DEC VAX-11/780 system. It will soon be modified to be usable on an IBM 370/3032 and a UNIVAC 1108.

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* These are inappropriate for a business, for which these costs are already acceptable deductions.