OESYS: A SIMULATION TOOL FOR NON-CONVENTIONAL ENERGY APPLICATIONS ANALYSIS

Theoretical and Operational Description with User Documentation

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MIT Energy Laboratory Report No. MIT-EL 80-022
August 1980
A method is developed for assessing both the operational and economic performance of variable mixes of energy conversion technologies within their specific service environments. This method is incorporated into OESYS (Optional Energy Systems Simulator), a computer model with the specific capability to assess conditions of economic viability and service reliability for energy project evaluation. OESYS is especially well suited to handle stochastic (weather-dependent) generation technologies, and will simultaneously handle the generation, transfer, and demand of multiple energy quality levels (electricity, high/low grade thermal, liquid/gaseous fuels, etc.). The model can be applied to most use sectors, including residential, commercial, industrial and institutional, or combinations of use sectors. A model summary description is given on page 13.

This paper includes a theoretical description of the types of energy applications handled by OESYS, an operational description of the model, user documentation, and three sample studies.
ACKNOWLEDGEMENTS

I would like to acknowledge the generous cooperation of three electric utilities for their giving of time and resource in supplying M.I.T. with customer load profile data. This data became the premise for the structure of this computer model. The utilities and their representatives include Roger Currier of the New England Electric System, Jim Watkins and Marilyn George of the Salt River Project in Phoenix, and Mike Anderson, Ron Frank, and John Walker of Wisconsin Power and Light.

In addition, I would like to thank Alan J. Cox, Lorrain Ferguson, and Dr. Richard Tabors.
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Optional Energy System Simulator (OESYS)

TITLE:
Optional Energy System Simulator (OESYS)

AUTHOR:
Tom Dinwoodie

PURPOSE:
Provides both technical/operational and economic performance assessments of variable mixes of energy conversion technologies in single or multiple demand settings. It is especially well suited to handle stochastic (weather-dependent) generation technologies, and will simultaneously handle the generation, transfer, and demand of multiple energy quality levels (electricity, high/low grade thermal, etc.). The model can be applied to most use sectors, including residential, commercial, industrial and institutional, or combinations of use sectors, providing characteristic energy demand profiles can be obtained.

METHOD:
The program performs hour by hour energy transfer accounting between pre-defined generation and load profiles. It will also accept user-supplied application load and/or generation models. The program is structured to accept both conventional and non-conventional utility rate setting practices.

SCOPE:
The model provides for specification of up to 20 energy load nodes and as many generation nodes defined by way of disk file data streams, and for unlimited additional load/generation nodes by way of user-supplied models. Energy storage is modeled as either system or dedicated where the latter is assumed to serve all generation units of like energy quality. Up to 10 levels of energy quality are acceptable (AC or DC electricity, various thermal grades, liquid fuel, etc.). Both utility interface and remote, stand-alone applications are possible and there is broad flexibility in defining the utility environment. The economics portion optionally examines homeowner, commercial/industrial and utility financing strategies and has the capability to examine the benefits of construction delay through a dynamic project appraisal method.

INPUT:
The model needs four types of information input:

1) Application load and unit generation figures in a pre-processed card image format or as user-supplied models.
2) Operating parameters, including load/generation node characteristics, unit efficiencies and utility characteristics.
3) Economic parameters, including market escalation rates, project financing characteristics, and unit cost figures.

4) Interactive input to specify program options.

**OUTPUT:** There are basically three forms of output which can be displayed in the form of output summaries and/or graphic plots:

1) System and component physical operation. Here, storage, generation, and demand characteristics are output at a four optional hierarchical levels corresponding to frequency of report. These range from hourly to end-run summaries.

2) A reliability summary is output subject to the selection of specific operating logics. It includes a total of 16 service indices, including service reliability index, loss of load probability, average loss durations, and total energy not met.

3) Economic Summaries reflect the option of homeowner, commercial/industrial, or utility financing. Reports include system and component breakeven capital costs, system profitability, the project rate of return, years to payback, and levelized energy costs. The dynamic project appraisal option computes all of the above as a function of construction delay beyond the year 1980 and up to the year 2000.
I. INTRODUCTION

I.1 Statement of Purpose

Sole dependence on traditional utilities no longer presents the only viable strategy for single or group consumers planning to meet their energy needs. The rising costs associated with the conventional means of producing energy are forcing a serious look at the numerous nonconventional and often inherently dispersed energy technologies. However, most alternative strategies are complicated by many uncertainties, both technical/operational and economic.

A method is developed for assessing the performance of variable mixes of energy conversion technologies within their specific service environments. This method is incorporated into OESYS (optional energy systems simulator), a computer model with the specific capability to assess conditions of economic viability and service reliability for energy project evaluation.

I.2 Description of the Model

OESYS is written in FORTRAN IV, is non-optimizing (not an LP) but rather an evaluative mechanism with broad capabilities for hourly energy transfer accounting between pre-defined generation and load profiles. It is employed by first explicitly defining the service environment. This is done by mapping all load and generation nodes, including storage points, for each specific level of energy quality being considered. Energy quality at each node is explicitly defined as either electricity, a specific grade of thermal energy, a gaseous or liquid fuel, etc. The model skeleton is that of a grand accounting routine which keeps track
of the pre-matched energy supply and demand nodes and assigns an economic value to all energy transfers.

The model can be applied to most use sectors, including residential commercial, institutional, and industrial, providing characteristic energy demand profiles as well as solar data for the specific cases can be obtained. Load profile data has been found to be available through a large number of utilities around the country, primarily as a result of studies by their rate departments on the effects of implementing time of day pricing schemes. This data has generally been in the form of quarter hourly to hourly energy demand figures for periods up to 2 and 3 years. It has and will continue to provide an essential data base for the purpose of examining the load profile characteristics of classes of utility customers. Where it is desired to examine particular applications where historical (recorded) data is unavailable, numerous models already exist (NECAP, NBSLD, etc.) which are capable of generating the appropriate energy demand data when supplied with the necessary physical and operational parameters.

Characteristics of the operating and market/finance environment are input in the form of parameter values. The program will also interface with user-supplied application or process models which generate energy consumption/production in actual simulation time.

The model capabilities include:

- utility interface and stand-alone operation; the utility environment allows both conventional and application (demand) dependent rate setting strategies.
- matching of energy supply technologies with like demand across the energy quality spectrum.
- specification of energy supply strategies to include:
- cogeneration
- forced generation (weather-dependent technologies)
- backup (utility, diesel, etc.)

- specification of the energy demand environment by
  - user load profiles
  - modeled application demand

- application of demand elasticities to individual users within the modeled site; treatment of demand elasticities is flexible and much to the discretion of the modeler.

- handling of dedicated or system storage

- economic accounting subject to specified market and financial parameters, including:
  - system Breakeven Capital Cost
  - component Breakeven Capital Costs
  - net profitability
  - rate of return
  - years to pay back
  - levelized costing
  - expense summaries

- a dynamic project appraisal capability for evaluating the profitability of various construction delay strategies.

- automatic simulation iterations for parameter sensitivity analysis.

- output summaries as follows:
  - run characteristics
  - economic accounting
  - reliability indices
  - graphic plots of both operating and economic/cost characteristics
  - demand-not-placed (on utility) tapes over any year within the run life of the system (for analysis in effecting load duration curves for utility capacity expansion models)

I.3 Organization of Documentation

OESYS is documented in sections II through VI of this report, with detailed information provided in the appendix. Section II establishes a
conceptual framework from which to view many of the problems associated with assessing the performance, both operational and economic, of different energy technologies. Section III presents the OESYS operating instructions. The user who is acquainted with the input definitions and requirements can proceed directly to this section. All first-time users will need to study, at minimum, sections IV.2-IV.4 for definition of logic options, data-input requirements, and program report options, respectively. It would serve the beginning user well to study section IV.1 in light of the discussion in section II to obtain an intuitive grasp of the program operating flow. Further assistance can be found with a careful study of the example application problems of section VI. With an advanced understanding of the program operating logic, the user will find section V helpful in defining his or her own iteration-study runs, operating logics, output changes as well as specific subroutine manipulations.
II. The Theoretical Model

II.1 The Physical System

The storage, conversion, and transmission of energy are three basic means by which we treat energy to satisfy our end-use needs. In physical terms, this translates into the construction of four types of facilities. First, conversion technologies which utilize the raw energy resource to generate a specific quality energy form. A coal or oil fired boiler, a reactor vessel, a solar collector or a wind turbine are examples of such primary conversion devices. If the point of resource conversion is not the point of end use, there is a need to construct some form of transmission network to carry either the raw resource, or the once converted energy to its point of application. This transmission structure may be a trucking or rail network, a gas pipeline, or an electrical distribution line. The end-use application generally entails an additional conversion to match the transmitted energy with the specific application load. This may require some translation amongst electrical, mechanical, hydraulic, or thermal energy firms such as for a pump, a high temperature industrial load, a stove, a television, and so on. Finally, we may optionally construct storage facilities to either reserve the primary energy resource, or to contain a specific form of once-converted energy. These options are simply depicted in figure 2-1.

![Diagram](figure 2-1)
The large centralized utilities of most developed countries are depicted in figure 2-2 by removing specific arrows from the previous figure. Here, energy storage takes place in the holding reserves of large oil tanks, coal piles, and uranium storage facilities and these reserves are depleted by primary conversion facilities, at a rate which is dependent upon the summation of a service regions end-use demands.

![figure 2-2](image)

The utilities in general are constrained to generate reliable power on call by the customers of their respective service region.

Most applications require multiple energy forms, such as gas for heat loads and electricity for lighting needs, and these applications are generally served by multiple utilities, as shown in figure 2-3.

![figure 2-3](image)
If the energy needs for that application can be proven to be more efficiently served by investment in its own conversion technology, then we have on-site generation as found in figure 2-4. Here, the primary energy resource is often the same as that supplied to the utility but generation is on a much smaller scale and often dedicated to the on-site load. On-site generation is proven most efficient when there is cogeneration of high and low quality energy forms. This is also depicted in figure 2-4 by the series generators, and can represent either a topping cycle (waste heat utilized as a by-product of electrical generation) or bottoming cycle facility (electricity produced from excessive heat generation).

It may be possible for an energy consumer to take advantage of a raw resource available on-site, such as a solar or geothermal resource, and it may prove practical to exchange any excess generated energy with an outside utility, in which case the application box can be expanded as found in figure 2-5.
Depending upon the availability of local energy resources, the application reliability constraints, and the possibilities for utility interaction, it may become advantageous for the utility and/or the customer to install storage facilities on-site. The storage unit may be dedicated solely to the generation facility or serve the system as a whole, as shown in figure 2-6.

![Figure 2-6](image)

Finally, if on-site resources are adequate and/or application reliability constraints forgiving (such as the case in many lesser developed countries), or if an alternative to the utility as backup looked more favorable (diesel generator, local hydro, etc.), the applications box may be closed with respect to outside connections as in figure 2-7. The application itself may be an irrigation water pump, a single family residence, or a small, isolated community. In the latter case, the application box may become a small utility in itself, with possible interconnections to a larger power pool.

![Figure 2-7](image)
It is obvious that as the number of load, resource, generation, and storage nodes increases, the possible permutations on interconnections both within and outside the application box multiply quickly. The arrangement of physical interconnections constrains the logic of energy flow between resource and end-use for modeling purposes. The model described in this paper is an attempt to realize a basic structure to accommodate as many application logics as is practical. The program simulates energy transfer conditions which are specific permutations of the applications depicted in the previous figures. It does so by providing a framework in which to simulate energy resource availability, application demands, physical and economic interactions with outside utilities, and the market/finance environment for evaluating the projects' economic worth. The structure of the model is presented in figure 2-8, and an update of specific application logics developed as options to this model is included in section IV.2a. The large dashed box in figure 2-8 is directly analogous to the applications boxes of the previous figures. Within this box, specification of energy demand sites is possible, whether for single appliances, residence or commercial needs, industrial facilities, or combinations of these. The user load profile can either be supplied in the form of hourly or sub-hourly tapes, or can be modeled, drawing upon simulation parameters of the operation logic as needed. Since user demand may vary as a function of operating or economic conditions, it is possible to apply elasticities to individual loads, with user elasticities estimated again on the basis of simulation parameters. The circled "E" designates the applied
elasticity in the figure. Energy production is specified also in the form of hourly or sub-hourly figures on tape, or modeled.

Since under real conditions production units will fail, it is necessary to account for the outage rates and periods of all production technologies. These failure rates are represented by the circled "F" in figure 2-8.
OESYS MODELING

- Central Utility
- On-Site Generation
- Application Load
- Energy Storage
- Load modification
- Generation unit failure

figure 2-8

kWh Transfer Summations
Economic Accounting
Once all user needs and resource availability are assessed for any single time interval, energy transfer losses can be estimated based on probable pathways for energy flow. For those applications with on-site generation and load, these losses may be insignificant. For small communities with an interconnecting distribution grid, such losses cannot be ignored.

Finally, a specific energy transfer logic is required to simulate the unique conditions of site interactions, including allocation to and from energy storage facilities. Interconnections with outside utilities are then modeled as interactions with the dashed box of figure 2-8.

It is possible to model all of the above, with the exception of the specific transfer logic, with a fair degree of generality, and this is the premise of the described model. The general programmatic flow logic for the operation portion of the model is shown in figure 2-9. Operation flow logic is further discussed in section IV.1c.

II.2 The Economic Market Finance Structure

All of the foregoing physical interconnection possibilities will largely effect, and be effected by, issues of the economic market environment and the means of finance. The market environment will determine such things as the cost of alternative available energy, inflation rates, escalation rates applied to the cost of conventional resources, utility purchase rates, short and long run expected capital and operating costs, and so forth. Financing means will vary with the investor type. In general, finance mechanisms require specification of
such parameters as construction start dates, tax rates, tax credits, depreciation schedules, fixed charge rates and others. The means of project finance will be peculiar to the objective of the investor, who may be broadly categorized as either private, public, or a utility. The private investor may range from a single homeowner to a commercial or industrial establishment with the common objective to maximize profit on investment. The objective of a public investor is most often the same, but where generally costs and benefits streams are more closely examined for their social worth, and where decision criteria may extend well beyond that of profitability. Although the utility also seeks to maximize its returns on investment, it is further contrained to invest specifically in energy projects which will assure a reliable supply of energy on demand by its customers.

The OESYS model allows for the strict definition of finance strategy by specification of investor type, whether that be homeowner, commercial/industrial/institutional, or utility. The object of financial modeling, the output figures for the purposes of project evaluation, are similar if not the same for all investor types. These include system profitability, system and component breakeven capital costs, rate of return, years to payback, fixed charge rates, and levelized costs and benefits. The remainder of section II.2 defines these quantities algebraically in the context of the specific investor's financing scheme.

II.2a Homeowner Financing

A private homeowner has the option to invest in an energy project either by outright purchase or by some form of amortized loan plan. The
criteria used by the homeowner is seldom clearly defined in accordance with economic rationale. Whereas the firm generally profit maximizes over a project's life, most homeowners are reluctant to wait longer than a year to realize an investment's returns and are neither willing nor able to consider any long-term investment where the costs are not somehow embedded and thus hidden within their current living expenses. To this end, it is necessary to speak to the homeowner not in terms of investment profit, but rather in terms of his or her cost per energy quantity, such as dollars per kilowatt hour, dollars per Btu and so forth. These figures are computed for alternative energy projects by means of levelized costing. OESYS is capable both of estimating levelized cost and of simulating mortgage financing. The methodology for doing so is discussed below.

**Mortgage Financing**

The mortgage finance method used by OESYS is a standard-practice schedule of constant monthly loan repayments. It is a current-year dollar arrangement where payments vary year to year in value but not number. The OESYS method discounts all payments beyond a chosen base year and models separately the effects of general and capital inflation. The formulation used is as shown in figure 2-10.

It is often convenient to compute some form of crude measure of "payback" as a numerical index of the short-term cash aspects of various investment options. Payback is defined as the number of years required for net cash flow to equal zero with no consideration of interest
Figure 2-10
The Mortgage Finance Method

\[ NB = \beta^{Y_s-Y_b} \ast S \ast D + \sum_{t=1}^{\max(L,1)} (FC_t \ast TR + \alpha^{Y-Y_b} r^{Y-Y_b} B_t - C) - \frac{\alpha^{Y-Y_b} OM_t - T}{(1+r)^t \alpha^{Y-Y_b}} \]

where;

- \( NB \) = net benefits to accrue to the project over its operating life
- \( L \) = project life
- \( l \) = mortgage life
- \( \beta \) = capital escalator computed for the construction year with respect to some base year.
- \( Y_s \) = construction year
- \( Y_b \) = base year
- \( S \) = total cost of installation
- \( D \) = percent down payment/100
- \( FC_t \) = Finance charge in project year t
- \( TR \) = tax rate for homeowner
- \( \alpha^{Y-Y_b} \) = general inflation rate computed for the current calendar year with respect to some base year
- \( y \) = current calendar year
- \( r^{Y-Y_b} \) = real price escalator applied to displaced conventional energy.
- \( B_t \) = returns on the project in year t of its life
- \( OM_t \) = operation and maintenance cost in year t
- \( T \) = sum of taxes applied to benefits
\[ r = \text{the homeowner's expected rate of return} \]

\[ C = \text{constant annual mortgage cost of the project computed as} \]

\[ C = \beta^{Y_s-Y_b} S \times (1-D) \times \frac{i}{1-(1+i/12)^{-12T}} \]

where

\[ i = \text{nominal annual interest rate computed as} \]

\[ i = (1 + \alpha_S)(1 + i_R) - 1 \]

\[ i_R = \text{the real interest rate} \]

\[ \alpha_S = \text{the inflation rate in the project start year} \]
charges. It is computed in OESYS as that year or year fraction where
the difference between the summation of benefits (less operating and
maintenance charges) and the initial installation price turns positive,
or \( t \) such that zero is just less than

\[
\max(L,1) \sum_{t=1}^{\max(L,1)} \alpha^y y_b (\gamma^y y_b a_t - OM_t) - S_b^y s^y y_b
\]

The expected rate of return is simply defined by equation 2-1 of
figure 2-10 as that \( r \) such that \( NB \) equals zero.

**Levelized Costing**

The OESYS method for levelizing the costs of energy produced by a power
generator is similar to that prescribed for photovoltaic worth analysis
by the U.S. Department of Energy.\(^\text{3}\) This method computes a levelized
constant dollar cost of energy produced (as opposed to the current year
dollars of most mortgage arrangements where payments vary year to year
in value but not number). Levelized costing is well-suited to the
homeowner-investor, as it provides a first year breakeven criterion for
project valuation. It therefore takes into account the reluctance of
most homeowners to place their investment dollars up front in the
anticipation of future returns. The levelized costing method advocated
by the DOE is extremely crude. It is computed as

\[
(2-3) \quad LEC = \frac{10^2 * C * F}{S} + OM/S
\]
where

\[ \text{LEC} = \frac{\text{levelized cost of energy produced (cents/kwh)}}{\text{C} = \text{installed cost of the generating unit(s) (dollars)}} \]

\[ \text{S} = \text{yearly energy generated (kwh)} \]

\[ \text{U} = \text{utilization coefficient} \]

\[ \text{OM} = \text{average yearly operation and maintenance cost (dollars)} \]

\[ \text{F} = \text{fixed charge rate} \]

\[ 10^2 = \text{converts dollars to cents} \]

The numerator of the above equation represents the annual cost to the homeowner while the denominator reflects the effective annual energy generated. The utilization coefficient \( U \) reduces the yearly energy generated as a result of several factors:

- power conditioning losses
- storage losses, if any
- efficiency losses resulting from aging
- temperature effects on unit operation
- utility purchase of excess generation

The drawback of this costing method derives from lumping so many parameters into this single utilization coefficient. For a typical photovoltaic array, the value computed after consideration of each of these factors is roughly .7, increasing by about 40 percent the cost of energy produced by that array. Other types of generating technologies will require special treatments of \( U \).
II.2b Commercial/Industrial/Institutional Financing

The methods employed for the modeling of commercial/industrial/institutional financing are taken from standard textbook procedures. Derivation of the financing method was borrowed from Myers [7].

Project finance by the commercial, industrial, and institutional sectors is performed by their means of income accounting for tax purposes. The costs stream for an investment includes an initial purchase cost followed by a stream of operation, maintenance and insurance charges related to that project. These costs are subtracted from the yearly benefits, generally defined as the annual value of displacing the closest energy alternative. Net annual profits are then taxed at the corporate income tax rate. This methodology is outlined in figure 2-11.

Financial modeling for the institutional sector (government facilities etc.) utilize the same formulation but all tax-related terms are removed.

Rate of Return and Years to Payback

OESYS computes the project rate of return after income taxes simply as that $R_i$ such that the two sides of the equation in figure 2-11 cancel when all costs are assumed. Years to payback is a crude measure of the short term cash payoffs of alternative investment options. It is generally computed without consideration given to interest charges and in OESYS is simply that year or year fraction when the difference between initial capital outlay and the summation of project benefits
Figure 2-11
Commercial/Industrial//Institutional Finance Method

\[
L \sum_{t=1}^{L} \frac{(1 - CT) \cdot (\gamma^t \cdot s_t - OPT) \cdot a^t}{(1 + r_f)^t \cdot a^t} = s^o \cdot i^u \cdot (1 - ITC - DEBT)
\]

\[+ \sum_{t=1}^{L} \frac{(1 - CT) \cdot r_b \cdot DEBT \cdot i^u \cdot s^o + CT \cdot D^u \cdot i^u \cdot s^o}{(1 + r_f)^t \cdot a^t} \]

\[+ \frac{DEBT \cdot i^u \cdot s^o}{(1 + r_f)^L \cdot a^L}\]

\[+ B \cdot i^k \cdot (-1 - ITC + DEBT) \]

\[+ \sum_{t=1}^{L} \frac{(1 - CT) \cdot r_b \cdot DEBT \cdot i^k \cdot s^o + CT \cdot D^k \cdot s^o}{(1 + r_f)^t \cdot a^t} \]

\[+ \frac{DEBT \cdot i^k \cdot s^o}{(1 + r_f)^L \cdot a^L}\]

where:

- \(L\) = life of the project
- \(a^t\) = general price inflator in year \(t\) computed with respect to the base year, i.e.,
  \[
a^t = \prod_{j=t_b}^{t} (1 + a_j)
\]
- \(a_j\) = general price inflator in year \(j\)
- \(t_b\) = base year
- \(g\) = escalation in capital costs in year \(t_0\) with respect to the base year, i.e.,
\[ s_0 = \prod_{j=t_b}^{t_0} (1 + s_j) \]

\[ t_0 = \text{year of investment} \]
\[ s_j = \text{escalation in capital costs in year } j \]
\[ \gamma^t = \text{real price escalator applied to project benefits computed from the base year to the year of investment, i.e.,} \]
\[ \gamma^t = \prod_{j=t_b}^{t} (1 + \gamma_j) \]
\[ \gamma_j = \text{real price escalator applied to benefits in year } j \]
\[ B_t = \text{energy savings in year } t \]
\[ CT = \text{corporate tax rate} \]
\[ \text{DEBT} = \text{the ratio of the firm's debt to debt plus equity} \]
\[ D_k^t = \text{depreciation fraction in year } t \text{ computed for the known portion of capital investment} \]
\[ D_k^u = \text{depreciation in year } t \text{ computed for the unknown portion of capital investment} \]
\[ I_k = \text{known portion of the initial investment} \]
\[ I^u = \text{unknown portion of the initial investment} \]
\[ \text{ITC} = \text{investment tax credit} \]
\[ OP_t = \text{operation and maintenance costs in year } t \]
\[ r_b = \text{nominal bond interest rate computed as} \]
\[ r_b = -1 + \sqrt{\frac{L}{\prod_{t=1}^{t} (1 + r_f)(1 + a_t)}} \]
\[ r_f = \text{real risk-free rate of return} \]
\[ r_i = \text{real rate of return which reflects the riskiness of the investment class.} \]
less operating and maintenance costs just turns negative, i.e., such that

\[ b^{Ys-Yb} \cdot c - \sum_{t=1}^{Life} (1-CT) \cdot (b - OP)^{a \cdot t} + C \cdot DEP \]

just turns positive.

**Project Delay**

A special option is featured in OESYS which allows the user to investigate the economic tradeoffs of project delay beyond a fixed calendar year reference date. The dynamic project appraisal method used here is based on the work of Marglin [6].

**II.2c Utility Financing**

The utility financing model is structured so as to be comptabile with the expected assessment practice of the utility. One standard utility criterion is to compute the levelized busbar energy cost based on output over a system life. Comparison with a "levelized annual energy benefit" derived from displacing conventional utility electricity is a convenient method of project evaluation. Derivation of these measures is based on the EPRI/JPL methodology described in reference [3]. Application of this methodology in the specific case of photovoltaic worth analysis for the commercial/industrial/institutional sector is presented by RTI [7]. The method used in OESYS is summarized below.
LEVELIZED ANNUAL COST (LEC)

The levelized energy cost is defined as:

\[
LEC = \frac{AC}{kWh_A}
\]

where

- \( LEC \) = levelized annual energy cost, \$/kWh;
- \( AC \) = annualized system cost, $;
- \( kWh_A \) = annual system energy output, kWh.

and

\[
AC = (1 + g)^{-d} \left[ FCR \cdot CI + CRF_{K,N}(OP + MNT + FL) \right]
\]

where

- \( g \) = general inflation rate (fraction);
- \( d = Y_{CO} - Y_b \);
- \( Y_{CO} \) = year of commercialization of the system
- \( Y_b \) = base year for LEC price;
- \( FCR \) = fixed charge rate, fraction;
- \( CRF_{K,N} \) = capital recovery factor
The Capital Recovery Factor (CRF) and fixed charge rate are computed as

\[
CRF_{k,N} = \frac{k}{1 - (1 + k)^{-N}}
\]

\[
FCR = \frac{1}{(1 - TR)(CRF_{k,N} - \frac{TR}{N})} + \beta_1 + \beta_2
\]

respectively, where

- \( TR \) = effective income tax rate, fraction;
- \( \beta_1 \) = annual "other taxes" as a fraction of CI;
- \( \beta_2 \) = annual insurance premiums as a fraction of CI.

The total capital investment is discounted to the present by

\[
CI = (1 + g_c)^m \sum_{t} CI_t (\frac{1 + g_c}{1 + k})^j
\]

where

- \( g_c \) = escalation rate for capital costs, fraction;
- \( m = y_{CO} - y_p \);
\( y_p \) = price year for capital investment

\( CI_t \) = capital investment in year \( y_t \);

\( y_t \) = years of capital investment stream;

\( j = y_t - y_{CO} + 1 \)

EPRI/JPL recommends computation of an appropriate discount rate from

\[ k = (1 - TR) k_d (D/V) + k_c (C/V) + k_p (P/V) \]

where

- \( k_d \) = rate of return on debt
- \( k_c \) = rate of return on common stock
- \( k_p \) = rate of return on preferred stock

\( D/V, C/V, P/V = \) ratio of debt, common stock, and preferred stock to total capitalizations respectively.

**Levelized Annual Energy Benefit (LEB)**

The EPRI/JPL methodology defined levelized annual energy benefit as:

\[
\text{LEB} = \left( \frac{1 + ge}{1 + g} \right) (y_t + 1 - y_b) \times E_o \left( \frac{1 + ge}{k + ge} \right) \left( 1 - \left( \frac{1 + ge}{1 + k} \right)^N \right) \text{CRF}_{k,N}
\]

where

- \( g_e \) = escalation rate of \( E_o \), fraction;
- \( E_0 \) = cost of electricity in the base year \( y_b \), proprietor ownership;
- \( \text{LEB} \) = worth of the system expressed in $/kWh, utility ownership;
- \( K \) = discount rate
- \( y_b \) = base year reference for dollars
Here, the first term converts all electricity costs in future years to the dollars of the base year $y_b$. The capital recovery factor converts to an annualized benefit the present value of the stream of electricity purchases over the system life.

The above is a utility compatible methodology. Special care must be taken to fix the above defined parameters to reflect the condition of utility, institutional, or commercial/industrial financing.
III. Operating Instructions

This section is intended for that user who is up to date on parameter input definitions and who wishes to proceed with the use of the model. The user who is unfamiliar with operating OESYS is referred to section IV in its entirety.

III.1 Data Checks

Figure 3-1 outlines a check list for data inputs to OESYS. Most users will only have reason to manipulate data on the level shown here. In this figure are shown the primary data inputs corresponding to the executive file, the physical and economic parameter file, and interactive input. All inputs are in card image format and fully defined in section IV.3. The user may select the operational or economic "study" option which allows multiple simulation runs to be carried through a specific set of physical and/or economic parameter charges. For example, a photovoltaic array may be varied in array size from 5 to 500m$^2$ while the start year for construction is delayed from 1 to 20 years from a chosen base year. Parameter studies of this sort must be fixed within specific subroutines, the setting of which is defined in section VI.1. Since type and availability of plot packages varies between computer systems, plot data is sent to various output files for user-defined post-processing. Description of the various plot files is given in section IV.4f.

A second level of data and program manipulation is possible with user definition of specific logics, including master operation logics
TAPE LOAD
TAPE GENERATION
FILE DEFINITIONS

Check List for Primary Data Inputs

figure 3-1

INTERACTIVE OR "LEAP"

PHYSICAL PARAMETERS
STUDY LOOP DEFINITION
SR STLOOP

ECONOMIC PARAMETERS

STUDY LOOP DEFINITION
SR STDYEC

OUTPUT

PLOT DATA
figure 3-2
Secondary Data Inputs
for specific applications, modeled loads and generation, treatment of user demand elasticities, generation outages, distribution losses, and alternative utility interaction. Also, additional output characteristics may be desired, especially as new master operating logics are added. A summary of possible programmatic additions and changes at this level are summarized in figure 3-2 and described in detail in section VI.

The user should be satisfied that both figures 3-1 and 3-2 are satisfied with respect to input requirements as defined in sections IV.3 and V before proceeding.

III.2 Running OESYS

Executing an OESYS run requires first defining 800K of virtual storage.

Following that, program execution and interaction procedes as follows:

(R: refers to user-typed response
(T: refers to terminal response)

R:  shine
T:  EXECUTION BEGINS ...

[Message is sent to TERMINAL
message can be user-structured in SR MSG2]
RUN NAME

(input an 8 character identification to head all output files)

T: A MULTIPLE RUN STUDY

R: YES: if an operation parameter study has been set up as described in V.1,
NO: one simulation run will occur over a single project life.

(If "yes" was typed in as the previous response, the program runs until completion, assuming all necessary interactive input has been pre-specified in the LEAP FILE, discussed in the next section. If "no" was the previous response, an asterisk prompter appears.

T: *

R: Type either "HELP", "GO", "LEAP", "END"

HELP: (explains the response options available for the * asterisk)

GO: Proceeds to a sequence of interactive questions

LEAP: Skips over interactive question sequence assuming all queried parameters are established by file. This is further explained below

END: Ends the program

III.3 Leap Option

In the event that it is necessary to perform many single or multiple run studies it is convenient to have the option to bypass the long question sequence by fixing all response parameters within a file. This option is allowed by OESYS by typing in "LEAP" after the * prompter. A description of how to set up the leap file is given in section IV.3g.
III.4 "Go" Option

Typing in "go" after the "*" prompter initiates an interactive question sequence. This question sequence proceeds as follows:

R: CREATE A NEW PV TAPE (Y/N/HELP)

HELP: Types the following:

YES: An hourly photovoltaic array output file is created drawing upon FI = 12 for meteorological data and upon the physical parameter file for array characteristics. The PV file is placed in FI = 14 (see SR DEFAULT).

For YES;

R: BE WARNED THAT ALL RUNS FOR THIS SESSION WILL RUN OFF THE TAPE YOU ARE ABOUT TO CREATE (FI = 14). TO AVOID DEVELOPING THIS SAME TAPE FOR LATER SESSIONS, TRANSFER ITS CONTENTS TO FI = 40 AT THE CLOSE OF THIS SESSION. OTHERWISE THE CURRENT FI = 40 FILE WILL BE USED FOR THE NEXT SESSION.

NOTE: YOU MAY WISH TO SAVE THE CONTENTS OF THE CURRENT FI = 40

T: INPUT LAST TWO INTEGERS OF RUN YEAR (e.g. 75,76)

R: (These two digits will be used in the leader description on each file of the PV tape — see section IV.3b)

T: INPUT A 4 LETTER ABBREVIATION FOR LOCATION

R: (to be placed on file leader — see IV.3b)

T: INPUT ARRAY SIZE IN SQUARE METERS (REAL .LT. 5 DIGITS)

R: (Input area of the collector: this is placed on file leader and is used as a base for linear multiplication of larger array areas — see section IV.3h and IV.3b)
T: INPUT ARRAY TYPE (INTEGER = 1-8)

R: Input: 1 for tilt angle = latitude
2 for tilt angle = latitude +10°
3 for tilt angle = latitude -10°
4 for tilt angle = latitude +15°
5 for tilt angle = latitude -15°
(tilt angle is specified in physical parameter file)

T: INPUT NUMBER OF DAYS OF DATA (DECIMAL .LT. 367)

R: Number of days of data provided on Meteorological tape in FI = 12 (see section IV.3d for file definitions)

T: [Long simulation pause]

T: TEST FOR TERMINAL DISPLAYED ENERGY VECTORS (Y/N/HELP)

R: NO: Skips to next question
HELP: types the following message:

THE FULL SUPPLY (SS), DEMAND (DD), MODELED DEMAND (DDM) AND COGENERATION (CGN) VECTORS CAN BE DISPLAYED AT VARIOUS SEQUENTIAL POINTS ALONG THE SIMULATION RUN. THE VECTOR OUTPUT CAN BE AT SPECIFIC POINTS, AT ALL POINTS, OR AT SOME POINTS, AND OCCURS AFTER A SPECIFIED HOUR. THE LEVELS OF OUTPUT ARE AS FOLLOWS:

1. FROM TEST 2 BEFORE CALLING PEAK
2. WITHIN SR PEAK, BEFORE CALLING SR MARX
3. WITHIN SR PEAK, BEFORE CALLING SR DEGR
4. WITHIN SR PEAK, BEFORE CALLING SR ELAS
5. WITHIN SR PEAK, BEFORE CALLING SR COGEN
6. WITHIN SR PEAK, BEFORE CALLING SR FAIL
7. WITHIN SR PEAK, BEFORE CALLING SR DSTRBN
8. WITHIN SR PEAK, BEFORE CALLING SR SUM
9. WITHIN SR PEAK, BEFORE CALLING SR UTILITY
10. WITHIN SR PEAK, BEFORE CALLING PK SPECIFIC SR
11. WITHIN SR PEAK, AFTER CALLING PK SPECIFIC SR
12. WITHIN TEST 2, AFTER CALL TO SR PEAK

YES: The following sequence is generated:
T: WHICH LEVEL OF OUTPUT (DECIMAL 1.-20. 0. = HELP)  
(parameter retrieved: KTSTI)
R: 0. types previous help message  
1.-20. fixes output according to series defined under HELP above.
T: 1 = ALL LEVELS UP TO LEVEL K INCLUSIVE  
2 = ONLY LEVEL k  
(where k is the level chosen as the level of output)  
(parameter retrieved: KTST2)
T: AFTER WHAT HOUR SHOULD TERMINAL OUTPUT BEGIN (DECIMAL)  
(parameter retrieved: TSTHR)
R: type in hour of the year after which you desire terminal displayed test output to begin where 1. applies to 1:00 a.m. January 1.

T: TEST OPTION: SPECIFIC SIMULATION CHECKS (Y/N)  
R: NO: Skips to next main question  
YES: Generates the following question sequence:
T: DISPLAY PHYSICAL SIMULATION CHECKS OUTSIDE HOURLY ITERATION LOOP (Y/N) (Parameter retrieved: KOPTS1)  
YES: Outputs pertinent parameters/variables at designated points of iteration not within the hourly iteration loop
T: DISPLAY PHYSICAL SIMULATION CHECKS OUTSIDE HOURLY ITERATION LOOP (Y/N) (Parameter retrieved: KOPTS1)  
YES: Outputs pertinent parameters/variables at designated points of iteration within the hourly iteration loop
T: DISPLAY ECONOMIC SIMULATION CHECKS OUTSIDE OF YEARLY ITERATION LOOP (Y/N) (Parameter retrieved: KECTS1)  
YES: Outputs pertinent economic parameters/variables at designated points of iteration outside of the yearly economic iteration loop
T: DISPLAY ECONOMIC ITERATION CHECKS INSIDE THE YEARLY ITERATION LOOP (Y/N) (Parameter retrieved: KECTS2)

YES: Outputs pertinent economic parameters/variables at designated points of iteration inside the yearly economic iteration loop

T: OUTPUT OPTION (1,2,3,4-5 for HELP)

R: (All output goes to FI = 7 (See section IV.3d); (Description of output summaries is given in section IV.4c)

5 (Outputs the following message: 1,2,3,4 FOR HOURLY, SECTIONAL, PERIOD, AND FINAL PRINTOUTS)

1 Outputs energy transfer summaries on an hourly or multi-hourly basis. If '1' is chosen, the following terminal query appears:

T: OUTPUT INCREMENT (FOLLOW BY A PERIOD)

R: (1. if hourly output is desired,
   2. if bi-hourly output is desired, 168 if weekly output is desired; 720 if monthly output is desired; etc.)

2 Outputs energy transfer summaries on a sectional basis (see description of project life breakdown in section IV.1d)

3 Outputs period energy transfer summaries (see section IV.1d)

4 Outputs energy transfer totals over the simulation life

WOULD YOU LIKE A GRAPHIC PLOT OF SELECTED DAYS

(Graphic plots are initiated by two means, through direct calling of the M.I.T. PRTPLT package and by output to plot files for use by graphics packages available to the user's system. The question here applies to use of the M.I.T. PRTPLT package. (parameter retrieved: PLTFLG)

NO: Skips to next main question

YES: Initiates the following question sequence:
T: INPUT A PLOT INCREMENT (DECIMAL HOUR)

R: (Type in an hour-multiple for graphic output, e.g. 24; 48; 720, for daily, bi-daily, monthly output. The number input must be divisible by 24).

Parameter retrieved: PLTINC

T: INPUT NUMBER OF DAYS EACH PLOT SHOULD COVER
(INT .LT. 4)

R: (Input on integer which specifies the number of days to be plotted at each plot interval)

(Parameter retrieved: NPER)

T: RUN TYPES (DECIMAL -5. for HELP)

(Specifies overall operating logic for this run:

(Parameter retrieved: RUN)

5. - Prompts the following message:

2. - UTILITY INTERFACES DISPERSED GENERATION
271. - UTILITY INTERFACES DISPERSED SYSTEM STORAGE
272. - UTILITY INTERFACES DISPERSED GENERATION-DEDICATED STORAGE
273. - STAND ALONE GENERATION/STORAGE
(Discussion of operating logics options is presented in section IV.2a)

(If options 2., 271., or 272. are selected the following is initiated:

T: WILL THE UTILITY PURCHASE EXCESS GENERATION

R: (Type in "yes" or "no")

(Parameter retrieved: BUYFLG)

COGENERATOR OPTION (0-NONE, 1-8, 9 FOR HELP)

(Parameter Retrieved: KCGN)

(the following options exist:

9 types the following message:
T: TYPE 0 TO IGNORE; TYPE 1-8 TO SPECIFY OPTION; OPTIONS ARE 1-8 NOT ESTABLISHED AS OF 5/80

ELASTICITY OPTION (0-NONE, 1-8, 9 FOR HELP)

(Parameter Retrieved: KELAS)

(the following options exist:
9 \hspace{1cm} types the following message:

T: TYPE 0 TO IGNORE; TYPE 1-8 TO SPECIFY OPTION; OPTIONS 1-8 ARE NOT ESTABLISHED AS OF 5/80

MODELED DEMAND OPTION (0-NONE, 1-8, 9 FOR HELP)

(Parameter Retrieved: KMDMD)

(the following options exist:
9 \hspace{1cm} types the following message:

T: TYPE 0 TO IGNORE; TYPE 1-8 TO SPECIFY OPTION; OPTIONS 1-8 ARE NOT ESTABLISHED AS OF 5/80

FAIL OPTION (0-NONE, 1-8, 9 FOR HELP)

(Parameter Retrieved: KFAIL)

(the following options exist:
9 \hspace{1cm} types the following message:

T: TYPE 0 TO IGNORE; TYPE 1-8 TO SPECIFY OPTION; OPTIONS 1-8 ARE NOT ESTABLISHED AS OF 5/80

DISTRBN LOSS OPTION (0-NONE, 1-8, 9 FOR HELP)

(Parameter Retrieved: KTD)

(the following options exist:
9 \hspace{1cm} types the following message:

T: TYPE 0 TO IGNORE; TYPE 1-8 TO SPECIFY OPTION; OPTIONS 1-8 ARE NOT ESTABLISHED AS OF 5/80
UTILITY DEFINITION (1-8, 9 FOR HELP)

(Parameter Retrieved: KUTL)

(the following options exist:

9 types the following message:

T: OPTIONS ARE:
1 PRICE SETTING UTILITY
2-8 NOT ESTABLISHED AS OF 5/80

INPUT NUMBER OF SUPPLY NODES (DECIMAL—MAX. 20)

(Parameter retrieved: NSS)

(A decimal number from 1 to 20 is input; there must be a
defined generation file for each supply node (see sections
IV.3c, IV.3d.) If supply node characteristics are not defined in the
physical parameter file, an error message is printed as follows:

T: NO RECORD OF SUPPLY NODE K IN PARAMETER FILE—SET 1
TO RETRY, 2 TO PROMPT

R: Either an error was made in communicating the number
of supply nodes (in which case, try again), or the
physical parameter file (see section IV.3e) needs
node characteristics specified, in which case hit 2
for * prompt and type "END" to end the program.

For each supply node, the following question will be asked;

T: FOR (NAMED) SUPPLY NODE, INPUT CAPACITY IN (UNITS)

(Parameter retrieved: SS(1,5)

(The supply node is named and units specified
according to the parameter fix specified in section
IV.3e)

R: (Input capacity; this number multiplies the energy
supply figure according to the ratio of SS(1,5) to
the capacity figure on the supply file leader
record. See section IV.3c for further description)
T: INPUT NUMBER OF DEMAND NODES (DECIMAL--MAX. 20)

(Parameter retrieved: NOD)

R: (input a decimal number from 1. to 20. according to the number of demand files specified in the physical parameter file and in the exec file (See sections IV.2b, IV.3d). If no record is provided for any load node from 1 to NDD, the following warning is issued:

T: NO RECORD OF DEMAND NODE "K" IN PARAMETER FILE; 1 TO RETRY, 2 TO ? PROMPT)

R: (Either an error was made in communicating the number of load nodes (in which case, try again) or the physical parameter file (section IV.3e) has no record of demand node "k's" characteristics, in which case, type 2, wait for * prompt, and program and fix the parameter file.)

T: INPUT NUMBER OF ENERGY QUALITY TYPES (INT. LT. 10)

Parameter retrieved: NEQUL

R: (Up to 9 energy quality types are allowed; default convention is as follows;

1 = AC electricity
2 = DC electricity
3 = High grade thermal
4 = Medium grade thermal
5 = Low grade thermal
6 - 9 = Undefined

However, the user can assign any number to any quality, or assign quality levels to specific utilities. If more than one electric utility were modeled at once, for example, it would be convenient to use the energy quality vector to keep allocation distinct. This issue is further explored in section V, and under the definitions for SS/DD vector parameters. Here it is only necessary to indicate the total number of distinct energy classifications being used. If the user indicated previously that the utility would purchase excess generated energy (parameter BUYFLG), then the following is issued;

T: UTILITY BUYBACK RATES CAN BE SET HERE AS CONSTANTS, OR CAN BE SET IN THE ECONOMIC PARAMETER FILE AS A FUNCTION OF CALENDAR YEAR (WHICH OVERRIDES WHAT IS HERE)

WOULD YOU LIKE TO SET THEM HERE (Y/N)
NO: Skips to next main question and assumed parameter SLBK(i) is set in the economic parameter file.

YES: For each energy quality (now assumed to represent an individual utility) the following is issued:

T: **INPUT BUYBACK RATE FOR E-QUALITY "K" (DECIMAL)**

(Parameter retrieved: SLBK(K, 1980-2010))

R: Input the utility buyback rate for that utility which services energy quality type "K."

T: **SINGLE YEAR SIMULATION (Y/N/HELP)**

(Parameter retrieved: STNORD)

R: HELP: Writes the following message:

T: YES: DEFAULT IS SINGLE YEAR RUN, SINGLE YEAR PERIOD, SINGLE SECTION YEAR, HOURLY SIMULATION FOR FULL YEAR

NO: RUN BREAKDOWN IS TAKEN AS EITHER SINGLE YEAR OR PARAMETER FILE

If "No" is answered, the following is initiated:

T: **TYPE: 0.0 FOR PARAMETER FILE RUN LIFE; 1.0 FOR FULL 20 YEAR RUN LIFE**

(See section IV.1.d for description)

T: **BEGIN HOUR (DECIMAL)**

( Parameter retrieved: IBGHR)

R: Input simulation start hour (hour of the year). Start hour must correspond to 1 a.m. of the first day of simulation (i.e. start hour minus 1 must be divisible by 24)
T: END HOUR (DECIMAL)

(Parameter retrieved: IENOHR)

R: Input final year hour of simulation run. If the begin hour is greater than the end hour the following is issued:

T: BEGIN HOUR IS GREATER THAN END HOUR—IT IS ASSUMED THAT GENERATION SUPPLY TAPES ARE SUPPLIED IN PAIRS TO ACCOMMODATE THIS—IS THIS THE CASE

R: NO: Request for end hour is reissued.
YES: Since begin dates are generally constrained by the application load file, and since generation tapes are generally a function of meteorological year and hence begin on January 1 and end Dec. 31, it is necessary to supply generation files for both years which the load file spans. This point is further refined in section IV.3c.

(Parameter retrieved: PVFLAG)

T: ECONOMIC EVALUATION (Y/N)

(Parameter Retrieved: KEV)

R: NO: The user desires only physical operation modeling, no economic summaries.
YES: The program assumes the economic parameter file contains all necessary market/finance/and cost characteristics for this project. The answer YES is followed by:

T: INVESTOR TYPE (1 = HOMEOWNER,
  2 = CMRCL/INDSTRL)
  3 = UTILITY

(Parameter retrieved: INVSTR)

(Here, homeowner, commercial/industrial/institutional, or utility finance means is modeled as described in section IV.2b)
T: CONTINUE
R: Answer "YES" to perform simulation
    Answer "NO," returns to * prompt.

At this point simulation begins. The terminal is flagged at the start of all period and all section iterations. In the event a multiple-run study has been selected, the program runs direct to completion. When the "leap" or "go" option are selected, the program finishes the simulation run by flagging the terminal with

T: RUN COMPLETE
  *

at which point the program has returned to the * prompt and the user has the option once again to END, GO, or LEAP, as described at the start of the interactive question sequence description.

III.5 Program Report Files

At the end of a run, all simulation reports are available by searching the simulation output files. The output file name and type characteristics are as defined in section IV.3d and the file listings themselves are explained in section IV.4c-f. Plot output is in the form of array values formatted in a manner which is easily accessed by the user's own plot packages. The file name and type characteristics are defined in section IV.3d and the format descriptions are presented in section IV.4f.
IV. The OESYS Simulator

IV.1 Program Structure

OESYS functionally described as a grand accounting routine specializing in the listing and evaluation of the performance characteristics of alternative energy supply/demand configurations. In describing OESYS as a user-interactive computer model, it is helpful to walk backwards through the program development by successively peeling structural layers. In this manner we arrive at an important intuitive understanding of how OESYS normally operates to combine user-oriented access with an applications oriented modeling structure.

IV.1a OESYS as a Black Box

A basic I/O description of OESYS is depicted in figure 4-1. There are two quasi-separable components to the model, the physical operation and the finance simulation. Each has been structured to accept a separate set of parameter inputs. The physical system model in addition requires interactive input as well as specific file definitions. The physical system portion operates independent of the finance package, although the reverse is not true.
IV.b Simulation Block Diagram

A user-oriented simulation block diagram is depicted in figure 4-2. There are basically three program levels, that of (1) entering the program environment, (2) entering a specific study loop, and (3) performance of an actual simulation. Once the study loop is entered program execution is automatic. Figure 4-3 goes one step further to reveal the program flow logic of the main routine.

IV.1c Operating Flow Logic

Section II.1 discussed in some depth the rationale behind what fills the system operation box of figure 4-2. A flow chart description of this box is shown in figure 4-4. Program execution entails hour by hour looping, retrieving all energy loads and accounting for the sum of energy generated, passing all values to a specific operating logic. All forced generation, cogeneration, modeled and tape loads are passed in the form of energy vectors, described in section IV.1e.

The operating logic simply prescribes the physical and logical constraints for energy transfers by specifically modeling system components, such as backup units (utility, diesel, etc.), storage units, conversion devices, and so forth. A description of alternative application logics including logic flow charts is given in section IV.2. The utility box of figure 4-4 represents a mechanism for valuing the energy generated, by generating a price for the closest available alternative energy supply. This can be an actual utility price, characterized by a predefined rate structure input to the physical
figure 4-2
SUBROUTINE PEAK
Physical Simulation Logic

figure 4-4
parameter file (section IV.3e), or it can be the cost of diesel fuel or any other desired means of backup. Utility rate setting is flexible and the program can handle flat or time-of-use rate structures. In addition, the option exists for the user to specify any alternative means of rate setting (see section VI.4d).

IV.1d Project Life Breakdown

Although OESYS defaults to a yearly simulation, the begin and end hour interactive parameter inputs allow for fractional year simulation. It may be desirable to break the year down into components (seasonal, monthly, weekly, etc.) to be simulated with data segments smaller than the chosen year fraction. In this way, a week may represent a month or season, a day represent a week, and so forth. This feature is particularly useful if continuous data is unavailable or of a nature such that fractional accounting is sufficiently accurate.

Precise specification of project life breakdown is made in the physical parameter file (section IV.3e). Limits to the project life split are as follows:

\[
P_i = \text{period } i \quad S_i = \text{year section } i \quad \text{inc} = \text{run increment}
\]

where:

- The run life may range from 1 to 25 periods (default is 1)
- Periods are generally, but not necessarily, a single year (range: 1 to 25)
- Sections are generally, but not necessarily, a full year and the maximum breakdown is weekly (1/52 year)
- Increments are hourly
The program default is to perform a single period (1 year), single section (1 year), hourly simulation. That single year is then extended to represent the entire project life in the economic modeling (section IV.3f).

IV.1e Energy Node Vectors

OESYS distinguishes energy load and generation nodes by the use of 4 "energy vectors." These energy vectors form the information core for the program energy transfer logic, testing procedures, and output reports. They are defined in figures 4-6 through 4-9.
Disk File Generation Node

Supply Vector SS(I,J)

I = 1, number of generation nodes

J = 1 - Energy Quality type

1 = AC electricity kWh
2 = DC electricity kWh
3 = High grade thermal
4 = Medium grade thermal
5 = Low grade thermal

etc.

2 = Energy Quantity Supplied this increment

3 = Probability of outtage

4 = Probability of outtage duration (hours)

5 = Unit capacity by standard rating. This number multiplies
    identifier on load data record. (See section IV.3c)

6 = undefined

7 = Node identifier (alphanumeric)

8 = Sizing units identifier (PV/m², WTG/kW, etc.) (alphanumeric)

9 = Number hours of this simulation run

10 = Peak generation over simulation period

11 = Year of peak generation

12 = Average generation over simulation period

13 = Total generation over simulation period

14 = Number hours of generation this simulation run

15 - 20 = Undefined

Figure 4-5
Disk File Load Node

DEMAND VECTOR DD(I,J)

I = 1, number of demand modes

J = 1 - Energy Quality Type

1 = AC electricity kWh_e
2 = DC electricity kWh_e
3 = High grade thermal
4 = Medium grade thermal
5 = Low grade thermal etc.

2 - Energy Quantity Demanded this increment

3 - undefined
4 - undefined
5 - undefined
6 - undefined
7 - node identifier (alphanumeric)
8 - demand units identifier (KWAC, KWDC, KWHT, KWMT, KWLT, etc.)
9 - number hours of this simulation run
10 - peak demand over simulation period
11 - yera hour of peak demand
12 - average demand over simulation period
13 - total demand over simulation period
14 - number hours of demand this simulation run
15 - 20 undefined

Figure 4-7
Modeled Cogeneration Node

Cogen Vector CGN(I,J)
I = 1, number of cogeneration modes
J = 1 - Energy Quality Type
  1 = AC electricity kWh
  2 = DC electricity kWh
  3 = High grade thermal
  4 = Medium grade thermal
  5 = Low grade thermal etc.

2 = Energy Quantity Demanded this increment
3 = probability of outage
4 = probability of outage duration (hours)
5 = unit capacity by standard rating
6 = undefined
7 - code identifier (alphanumeric)
8 - demand units identifier (PV/m², WTG/kW, etc.) (alphanumeric)
9 - number hours of this simulation run
10 - peak generation over simulation period
11 - year hour of peak generation
12 - average generation over simulation period
13 - total generation over simulation period
14 - number hours of generation this simulation run
15 - 20 undefined

Figure 4-8
Modeled Demand Node

Modeled Demand Vector DDM(I,J)

I = 1, number of demand modes

J = 1 - Energy Quality Type
   1 = AC electricity kWh<sub>e</sub>
   2 = DC electricity kWh<sub>e</sub>
   3 = High grade thermal
   4 = Medium grade thermal
   5 = Low grade thermal etc.

2 - Energy Quantity Demanded this increment

3 - undefined

4 - undefined

5 - undefined

6 - undefined

7 - node identifier (alphanumeric)

8 - demand units identifier (KWAC, KWDC, KWHT, KWMT, KWLT, etc.)

9 - number hours of this simulation run

10 - peak demand over simulation period

11 - year hour of peak demand

12 - average demand over simulation period

13 - total demand over simulation period

14 - number hours of demand this simulation run

15 - 20 undefined

Figure 4-9
IV.2 Selection of Application Types

OESYS requires the specification of a primary application logic to establish the physical and logical constraints in directing the flow of energy from source to point of destiny. Section II.1 discussed the myriad of possibilities for constraint logic and this section discusses those which are available on OESYS. In addition to a range of opportunities for specifying operating logic, there are numerous ways to deal with financial accounting. Those available on OESYS were discussed in section II.2 and section IV.2b here discusses their implementation within this model.

IV.2a Specific Operating Logics

IV.2a.a Utility Interface/Dispersed Generation

Figure 4-2-1 presents a conceptual schematic of dispersed generating units tied to a utility grid. Figure 7-1 of Section VII demonstrates the flow logic used by OESYS to simulate the performance of such an arrangement. The logic simply dictates that load is satisfied on a priority basis, first with available on-site generation and second with the utility as backup. Excess electricity is sold back to the utility at the utility purchase price according to whether the purchase flag (interactive option) has been set positive. The utility interface/dispersed generation logic is specified by fixing the parameter RUN = 2 in the interactive question sequence or by setting the same in the interactive bypass (LEAP) file discussed in section IV.3g.
IV.2a.b. Utility Interface/Dispersed System Storage

A conceptual schematic of this logic is drawn in figure 4-2-2. Figure 7-2 illustrates the OESYS flow logic. There exist numerous possibilities for determining the utility dispatch logic in operating dispersed storage devices. The logic used here is price-conditional. The value of stored energy when used on-site to satisfy load is simply the average purchase cost adjusted for average efficiency losses and utility buyback rate. The purchase price is the minimum price in a time-of-use utility rate schedule, where differential purchase rates are required in order to provide any incentive for investment in such a storage device. For low rate differentials in a time-of-use rate scheme and/or for low utility buyback rates, the storage unit may stand unused.
IV.2a.c. Utility Interface/Dispersed Generation and Dedicated Storage

Figure 4-2-3 presents a schematic of this operating logic and the simulation flow logic is as shown in figure 7-3. The priority schedule for satisfying on-site load is, in order, on-site generation, storage, and the utility as backup. The assumption is made that on-site generators have the least-cost cost operation, taking the advantage of a low cost solar or other resource. Since the storage unit is dedicated to on-site generation, remaining load is satisfied by storage. Finally, the logic makes the assumption that utility-level reliability is a requirement and that all additional demand is satisfied by the utility.
IV.2a.d. Stand-Alone/On-Site Generation and System Storage

The stand-alone (non-utility-connect) schematic logic is presented in figure 4-2-4. Figure 7-4 illustrates the simulation flow logic. Here, load is satisfied in order of on-site generation, storage which services this generation, and an on-site backup unit. The back-up unit is assumed most costly to operate, and therefore satisfies all loads which are not first satisfied by the other on-site generators. The logic makes the simplified assumption that the backup unit is load-following and is not served by the storage unit. It is required that the economics routine estimate costs of operating the backup unit based on the total load not served by the modeled generators.
IV.2b Selection of Financing Regimes

Alternative finance strategies are modeled on OESYS by specification of investor type. Justification for doing so is presented in section II.2. The finance strategy is fixed by inputting the appropriate response in the interactive question sequence or specifying the parameter INVSTR in the interactive bypass (LEAP) file. Each finance model has its own set of requisite parameters as described in section IV.3f.

IV.2b.a. Homeowner Financing

Section II.2a discussed the theoretical basis for homeowner financing, both in terms of mortgage financing and levelized energy costs. The necessary parameter inputs to these methods are described in section E.3 of the economic parameter file (IV.3f). Selection of this option requires that the INVSTR parameter be set to 1.
IV.2b.b. Commercial/Industrial/Institutional Financing

The theoretical rigor for commercial/industrial financing was established in section II.2b. Section E.4 of the economic parameter file (IV.3f) discusses the necessary parameter specifications. Selection of this finance strategy requires that the INVSTR parameter be set to 2.

IV.2b.c. Utility Financing

Section II.2c outlined one method by which utilities make their energy project evaluations. Specification of the necessary parameter inputs for this method is described in section E.5 of the economic parameter file (IV.3f). This option requires that parameter INVSTR be set to 3.

IV.3. Inputs Definition

IV.3a. Inputs Organization

This subsection describes the first order level of data inputs specification described in figure 3-1. There are six basic areas for inputs description; load profile data, generation profile data, the executive file for file definitions, the parameter file containing a physical description, a parameter file of market/finance figures, and the user interactive input. The load data may be hour-by-hour figures on a disk file, or modeled, drawing upon any of the simulation parameters for contingency logic. The same two options exist for energy generation data. Each of the above input requirements is taken in order here. Second and third level data and program manipulation are taken up in section V.
IV.3b. Application Load Data

Load data is supplied either in the form of hour-by-hour figures in card image on disk file, or by a user-defined model.

Tape Demand

Tape load data refers to disk file card image format. OESYS handles hourly, half hourly or quarter hourly sequential data of the format described in figure 4-3-1. Hourly sequential data requires 3 cards/day at 8 hourly figures/card. The file identifiers (filename and filetype) are specified in the executive file beginning at file 80 and ending at file 99 (see IV.3d). Hence, up to 20 separate disk files representing distinct application load nodes is allowed by OESYS.

Modeled Demand

The user may specify his/her own logic for simulating application load. The steps required to successfully implement a separate load model are as follows:

(1) Assign to the application load model an option number from one to eight which is not being used by any other modeled demand routine. Options currently existing are described in the interactive question sequence (IV.3g).

(2) Edit subroutine QS1, locate the "load model option" section and include a description of the new option under format statement number 6680.

(3) Edit subroutine MDMD and input a Fortran IF statement to call the new subroutine model subject to issuance of the appropriate flag option. For example, if the new model is defined in subroutine NMDL and is to be called when the load model option equals seven, then write in subroutine MDMD:

\[
\text{IF (KMDMD .EQ. 7) CALL NMDL(HOUR . . . )}
\]
format(1x,i3,1x,3i2,1x,i1,1x,i4,1x,i1,1x,i1,1x,2x,lf7.2)

a mtr i3 account meter number
b imo i2 number of current month
c ida i2 number of current day
d iyr i2 last two digits of current year
e icd i1 card number for this day's load data; icd ranges from
 1-3 if iddat=1 (3 data cards/day)
 1-6 if iddat=2 (6 data cards/day)
 1-12 if iddat=3 (12 data cards/day)
f iyrhr i4 year hour of 1:00 am of current day (i.e. 1, 25, 49, . . . 8737)
g iday i1 code number (1-8) for day of week, according to:
 1-7 monday through sunday
 8 holiday
h iddat i1
 1 if data stream shows hourly figures
 2 if data stream comes half hourly
 3 if data stream comes quarter hourly
l1 load f7.2 load data in units of kWh

figure 4-3-1
load profile data
disk file card image format

figure 4-3-2
application load model

energy load model

dom as defined in figure 4-9
The new load model must conform to a format compatible with OESYS. This requires little more than definition of an hourly load to be satisfied. The model is free to draw on any simulation parameters which are determined to affect its functioning. All parameters are defined in Appendix B with cross reference to their common designation. The user is free to define new parameters and place them in the physical parameter file along with their respective commons. Communication with the rest of the program of energy demanded at the modeled load node is made by way of the modeled demand vector, DOM(I,J), described in section IV.1e. The black box structure of the load model is described in figure 4-3-2.

Finally, the modeled demand node must be characterized according to the DOM energy vector notation in the physical parameter file. These are described in section IV.3e and are listed for convenience as follows:

- **NMOMD** = number of modeled demand nodes
- For each modeled demand node I:
  - **DDM(I,1)** = Energy Quality Type
    - 1 = AC electricity
    - 2 = DC electricity
    - 3 = High grade thermal
    - 4 = Medium grade thermal
    - 5 = Low grade thermal
    - 6 and above are correlated by the user
  - **DDM(I,7)** = 4 character alphanumeric node identifier
  - **DDM(I,8)** = 4 character alphanumeric demand units identifier

If these guidelines are followed, outputs description in the physical operation summary report (section IV.4c) is automatic, as are all testing (debug) reports (section IV.4b).

IV.3c. Point Generation Data

Node generation data is also supplied either in the form of hour-by-hour figures in card image on a disk file, or by a user-modeled generator.

**Tape Generation**

Tape generation implies a disk file card image format. OESYS handles only hourly sequential data, the format of which is described in figure 4-3-3.
FORMAT(1X,1J12,1X,1J4,1X,1J4,1A4,11,2X,8F7.3)

A  IMO (12) Number of current month
B  IDA (12) Number of current day 
C  IYR (12) Last two numbers of current year 
D  IYRHR (14) Year-hour of 1:00 am of current day (1, 25, 49... 8737)
E  ISCALE (14) Scale factor which is used with generator capacity specification (from interactive input SS(I,5)) to determine true output. For those units with linear production vs: capacity such as a PV array, ISCALE is set to the capacity of the modeled generator showing the values on the card. When the node capacity is called for (SS(I,5)) in the interactive question sequence, a scale factor is formed by

\[ SF = \frac{SS(I,5)}{ISCALE} \]

which multiplies all values on that disk file. For units not showing linear production vs: capacity curves, such as wind turbines, ISCALE should be set to 1 and the setting of the capacity should be understood to mean multiple generators of the modeled capacity.

F  TLOC (A4) 4 letter alphanumeric abbreviation for geographic locale
G  ITYPE (11) Code identifier of generating unit type (by user)
H  GEN(8) (F7.3) Generation figures in units of kWh

**figure 4-3-3**

GENERATION PROFILE DATA
Disk File Card Image Format

**figure 4-3-4**

Generation Model Requirements

physical params

GENERATION MODEL

CGN as defined in figure 4-8
The file identifiers (filename and filetype) are specified in the executive file beginning at file 40 and ending at file 79 (see IV.3d). Although 40 disk slots exist to accommodate generation files, only 20 are allowed by OESYS. The reason being that simulation begin and end dates are often restricted by available load profile data, which seldom start conveniently on January 1 while ending December 31. Generation files, on the other hand, are often established for a true calendar year, as they are often a result of a weather-dependent generation models, where weather data is most often available for the calendar year. Thus, it is necessary to provide two generation files for every load file if that load does in fact split a calendar year.

Generation Model

The user may specify a logic of his or her own devising for simulating a site generation node. The steps required to successfully implement a separate generation model are as follows:

1. Assign to the generator model an option number from one to eight which is not already being used by any other cogenerator logic. Options which currently exist are described in the interactive question sequence calling for cogenerator options, as well as in section VII.

2. Edit subroutine QS1, locate the "cogenerator option" section and include a description of the new option under format statement 6580.

3. Edit subroutine COGEN and input a Fortran IF statement to call the new subroutine model subject to issuance of the appropriate flag option. For example, if the new routine is defined in subroutine NMDL and is to be called when the cogenerator option equals four, then write in subroutine COGEN:

   IF (KCGN .EQ. 4) CALL NMDL(HOUR, . . .)
(4) The new cogenerator model must conform to a format compatible with OESYS. This requires little more than definition of an hourly generation quantity. The model is free to draw upon any simulation parameters which are determined to affect its functioning. All parameters are defined in appendix B with cross reference to their common designation. The user is free to define his or her own parameters and place them in the physical parameter file along with their respective commons. Communication with the rest of the program of energy supply at the cogeneration node is made by way of the cogeneration vector, CGN(I,J), described in section IV.1e. The black box structure of the cogeneration model is described in figure 4-3-4.

(5) Finally, the generation node must be characterized according to the CGN energy vector notation in the physical parameter file. These are described in section IV.3e and are listed for convenience as follows:

\[ \text{NCGN} = \text{number of modeled generation nodes} \]

For each generation node I:

\[ \text{CGN}(I,1) = \text{Energy Quality Type} \]

1 = AC electricity  
2 = DC electricity  
3 = High grade thermal  
4 = Medium grade thermal  
5 = Low grade thermal  
6 and above are correlated by the user

\[ \text{CGN}(I,7) = \text{4 character alphanumeric node identifier} \]

\[ \text{CGN}(I,8) = \text{4 character alphanumeric demand units identifier} \]

Outputs description for the cogeneration unit are displayed in the physical operation summary report (section IV.4c). Simulation-time reports of the CGN vector status are also made when the test (debug) option is specified.

IV.3d. The Executive File

The OESYS executive file, SHINE EXEC, is the source for all input/output file definitions as well as being that file which loads into core the main program. A sample copy of the executive file is shown in figure 4-3-5. Miscellaneous files are listed first, with allocations ranging from file 4 to 39. File slots 40 through 99 are
FILE: SHINE EXEC A

CONVERSATIONAL MONITOR SYSTEM

&CONTROL OFF
ERASE CII OUTPUT A
  * MISCELLANEOUS FILES . . .
FI 4 TERMINAL (LRECL 80)
FI 6 DISK PLOT OUTPUT A (RECFM FB LRECL 132 BLOCK 798)
  *FI 13 DISK EVP DATA A (DISP MOD LRECL 132 BLOCK 132 RECFM F PERM)
FI 14 DISK PV CREATE A (DISP MOD LRECL 80 BLOCK 800 RECFM FB PERM)
FI 9 DISK PP DATA A (LRECL 80 RECFM F PERM)
FI 12 DISK SOLAR DATA A (LRECL 80 RECFM F PERM)
FI 7 DISK CII OUTPUT A (DISP MOD LRECL 132 BLOCK 132 RECFM F PERM)
FI 16 DISK RELAB OUTPUT A (LRECL 132 BLOCK 132 RECFM F PERM)
FI 22 DISK OPPLOT OUTPUT A (DISP MOD LRECL 132 BLOCK 132 RECFM F PERM)
FI 28 DISK SYSECC PLOT A (LRECL 80 RECFM FB BLOCK 80)
FI 27 DISK PVSECC PLOT A (LRECL 80 RECFM FB BLOCK 80)
FI 29 DISK OTHER PLOT A (LRECL 80 RECFM FB BLOCK 80)
FI 31 DISK FYSEN OUTPUT A (LRECL 132 RECFM FB BLOCK 132)
FI 32 DISK OYCOS PLOT A (LRECL 132 RECFM FB BLOCK 132)
FI 33 DISK FYSEN INPUT A (LRECL 132 RECFM FB BLOCK 1320
  *FI 34 1A5
  *FI 35 IAS
  *FI 40-59 ARE GENERATION TAPES WHICH COME IN PAIRS (I.E. 40,41
  AND 42,43, ETC.). THE REASON BEING THAT LOAD TAPES OFTEN SPLIT
  INTO 2 WEATHER YEARS.
FI 40 DISK SOSTS 1PV100 A (DISP MOD LRECL 80 BLOCK 800 RECFM F3 PERM
FI 41 DISK SOSTS 1PV100 A (DISP MOD LRECL 80 BLOCK 800 RECFM F3 PERM
FI 42 DISK MA07S 25WTG A (DISP MOD LRECL 80 BLOCK 800 RECFM F3 PERM
  *FI 44
  *FI 45
  *FI 46
  *FI 47
  *FI 48
  *FI 49
  *FI 50
  *LOAD PROFILE TAPES . . .
FI 50 DISK BSSTBS 109 A (DISP MOD LRECL 80 BLOCK 800 RECFM F3 PERM
FI 81 DISK PGM Jan 167 A (DISP MOD LRECL 80 BLOCK 800 RECFM F3 PERM
  *FI 82
  *FI 83
  *FI 84
  *FI 85
  *FI 86
  *FI 87
  *FI 88
  *FI 89
  *FI 90
LOAD TEST2 (START NODUP CLEAR

FIGURE 4-3-5
OESYS Executive File
reserved for input files, the first 40 of which hold generation profile data streams while the latter 20 contain load profile data figures. File 5 is reserved for all terminal read (interactive sequence) input.

Correlation of all program file identifiers with location variables used in program I/O statements with their respective file locations is made in subroutine OFAULT FORTRAN

Miscellaneous Files

The files listed in figure 4-3-1 are defined as follows:

<table>
<thead>
<tr>
<th>File Number</th>
<th>File Record Length</th>
<th>File Name</th>
<th>File Type</th>
<th>File Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>80</td>
<td>(Terminal)</td>
<td>All</td>
<td>All terminal output.</td>
</tr>
<tr>
<td>6</td>
<td>133</td>
<td>PLOT OUTPUT</td>
<td>The object file for M.I.T. PRTPLT graphics package. This file is filled when the print option of the interactive question sequence is selected.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>132</td>
<td>C11 OUTPUT</td>
<td>The primary output file containing both physical operation run summaries as well as economic run summaries described in sections IV.4c, IV.4d.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>80</td>
<td>SOLAR DATA</td>
<td>Data file containing input for the photovoltaic preprocessor model described in section IV.3h.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>80</td>
<td>PV CREATE</td>
<td>Output data file for the photovoltaic preprocessor model. Output is in a format compatible with generation files 40-69. See section IV.3h.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>132</td>
<td>RELIAB OUTPUT</td>
<td>Output file containing service reliability summaries described in section IV.4e.</td>
<td></td>
</tr>
<tr>
<td>File Number</td>
<td>Record Length</td>
<td>File Name</td>
<td>File Type</td>
<td>File Description</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------------</td>
</tr>
<tr>
<td>26</td>
<td>80</td>
<td>SYBECC</td>
<td>PLOT</td>
<td>Plot data output file of system breakeven capital cost figures versus a specified parameter. For use with user's own graphics package. See section IV.4f.</td>
</tr>
<tr>
<td>27</td>
<td>80</td>
<td>PVBECC</td>
<td>PLOT</td>
<td>Plot data output file of component breakeven capital cost figures versus a specified parameter. For use with users' own graphics package. See section IV.4f.</td>
</tr>
<tr>
<td>28</td>
<td>80</td>
<td>NETBEN</td>
<td>PLOT</td>
<td>Plot data output file of project net benefit figures versus a specified parameter. For use with users' own graphics package. See section IV.4f.</td>
</tr>
<tr>
<td>31</td>
<td>132</td>
<td>FYBEN</td>
<td>OUTPUT</td>
<td>This file contains all energy transfer figures which are output from the physical operation model and which are utilized by the economics portion for project evaluation. Saving this file allows economic parameter sensitivity studies to be carried on without rerunning the physical operation portion.</td>
</tr>
<tr>
<td>32</td>
<td>132</td>
<td>DYCOS</td>
<td>PLOT</td>
<td>Plot data file which includes profit, system and component BECC, rate of return, and years to payback as a function of project start year for residential as well as commercial/industrial financing.</td>
</tr>
<tr>
<td>33</td>
<td>80</td>
<td>FYBEN</td>
<td>INPUT</td>
<td>This file contains all energy transfer figures which were once output from the physical operation portion of the model and which are now input to the economic evaluation portion alone.</td>
</tr>
</tbody>
</table>

Files 34-39 are available for further program development.
Generation Input

Files 40-79 are slotted for generation data files described in section IV.3c. Since in most cases the run simulation dates are limited to the monitor periods of utilities in collecting load profile data, and since those monitor periods seldom begin on January 1, it is often necessary to specify generation data for the years on either side of January 1. For instance, if load profile data was collected for the period September 7, 1978 through October 12, 1979, it would be necessary to supply both 1978 and 1979 generation data. Of course a single generation file which covers this same period is satisfactory, but often weather dependent technologies are most conveniently modeled in accordance with weather year as defined January through December. The user is flagged to this condition in the interactive question sequence if the simulation begin and end dates are set to cross January 1. If the LEAP option is selected, the user's option is communicated by way of the parameter PVFLAG, where if

\[ PVFLAG = 1 \quad \text{a single generation file per load file exists} \]
\[ PVFLAG = 2 \quad \text{2 distinct generation files per load file exist.} \]

Load Profiles

File locations 80-99 are reserved for load profile disk files described in section IV.3b.

IV.3e. The Physical Parameter File

This section defines all physical input parameters specified in the parameter file PARAM FORTRAN. OESYS parameters are defined in a program subroutine format rather than in a data read file as this saves an
expensive formatted I/O and is less prone to input error. The physical parameter file lists parameters by sections according to general topic. These topics include parameters which relate characteristics of the:

- P1) PHOTOVOLTAIC ARRAY
- P2) DEMAND NODE
- P3) SUPPLY NODE
- P4) RUN LIFE BREAKDOWN
- P5) HARDWARE
- P6) UTILITY PRICE SETTING
- P7) STORAGE

Input parameters are here defined by general topic.

**P1 PHOTOVOLTAIC ARRAY PARAMETERS**
(Used only if photovoltaic array preprocessor model is selected; see section IV.3h)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRATIO</td>
<td>F6.2</td>
<td>/ARRAY/</td>
<td>CRATIO signals the type of collector to be simulated. If CRATIO = 1.0, the flat plate photovoltaic array is assumed and there is no thermal collection. If CRATIO &gt; 1.0, the two axis tracking paraboloidal concentrating collector is assumed. When specifying a concentrating collector, CONEFF, the concentration efficiency, should be set to a value corresponding to the concentration ratio selected.</td>
</tr>
<tr>
<td>CEF28</td>
<td>F3.2</td>
<td>/ARRAY/</td>
<td>Rated photocell efficiency at 28°C.</td>
</tr>
<tr>
<td>CEFK</td>
<td>F3.2</td>
<td>/ARRAY/</td>
<td>Defines the temperature dependence of photocell electrical conversion efficiency. It is defined by the relation: operating efficiency = CEF28 (1.0 - CEFK(TCELL - 28.0)) in which the operating efficiency is the actual observable operating efficiency, CEF28 is as defined above, and TCELL is the cell temperature.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>PVCEFF</td>
<td>F3.2</td>
<td>/ARRAY/</td>
<td>An approximate average cell electrical conversion efficiency, used to arrive at a value for the thermal absorptivity of the cell.</td>
</tr>
<tr>
<td>PF</td>
<td>F3.2</td>
<td>/ARRAY/</td>
<td>The percent of collector area which is actually covered with photocells. For concentrators where the focal point is assumed to be 100 percent covered with cells, the packing factor would be the percentage of the collector field area which is actual concentrator aperture area.</td>
</tr>
<tr>
<td>RG</td>
<td>F5.2</td>
<td>/ARRAY/</td>
<td>For flat plate collectors, RG is the reflected portion of sunlight striking the ground. The directly received diffuse insolation is adjusted to include reflected diffuse insolation: $H_{de} = 1/2 \left( H_d + RG \right) [1 + \cos \theta (1+RG)]$ where $H_{de}$ is the effective diffuse insolation falling on the cells, $H_d$ is the diffuse not including ground reflection, and $\theta$ is the collector tilt angle as defined below.</td>
</tr>
<tr>
<td>ABSC</td>
<td>F5.2</td>
<td>/ARRAY/</td>
<td>The cell absorptivity. The percent of incident light which the photocells themselves absorb, including both light which is converted directly into electricity and the light which is absorbed in the form of thermal energy. $0.0 &lt; ABSC &lt; 1.0$.</td>
</tr>
<tr>
<td>ABSP</td>
<td>F5.2</td>
<td>/ARRAY/</td>
<td>Analogous to ABSC except that it represents the light absorptivity of the non-cell surfaces of a solar collector. Like ABSC, ABSP is used by subroutine SETSOL in calculating the thermal absorptivity of the collector as a whole: $TABSOC = PF(ABSC-PVCEFF)+ABSP(1.0-PF)$ $(0.0 &lt; ABSC &lt; 1.0)$.</td>
</tr>
</tbody>
</table>
### Parameter Format COMMON Description

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHI</td>
<td>F6.2</td>
<td>/ARRAY/</td>
<td>Site location latitude, decimal (°).</td>
</tr>
<tr>
<td>AA</td>
<td>F5.2</td>
<td>/ARRAY/</td>
<td>Array tilt angle between vertical and a flat plate array panel normal. Decimal, degrees (°).</td>
</tr>
<tr>
<td>BB</td>
<td>F6.3</td>
<td>/ARRAY/</td>
<td>Array azimuth angle of a flat plate collector surface normal. Decimal, degrees (°).</td>
</tr>
<tr>
<td>PO</td>
<td>F6.3</td>
<td>/ARRAY/</td>
<td>(kw/m²) PO (P zero) is used in conjunction with RO (R zero) as a reference power output level for estimating wiring and connections power losses at any given power output level. RO is the power loss at the reference power output level, PO. For flat plate arrays, PO is the reference power output per square meter of cell area.</td>
</tr>
<tr>
<td>RO</td>
<td>F6.3</td>
<td>/ARRAY/</td>
<td>(kw/m²). RO is used in conjunction with PO to estimate wiring and connections power loss at any given array power output level. At the reference power output level, PO, the losses are assumed to be RO. For flat plate arrays, RO is the power subtracted from theoretical output PO per square meter of actual cell area.</td>
</tr>
</tbody>
</table>

#### P2 DEMAND (LOAD) NODE CHARACTERISTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCUST</td>
<td>I5</td>
<td>/APPL/</td>
<td>Number of customers served in this application (for reliability index calculations).</td>
</tr>
</tbody>
</table>

For each load node i (see vector definition, section IV.1e)

| DD(i,1)   | F2.0   | /SSOD/ | Energy quality demanded at this node, where 1 = AC electricity 2 = DC electricity 3 = High grade thermal 4 = Medium grade thermal 5 = Low grade thermal 6 and above are correlated by the user |
Parameter | Format | COMMON | Description
--- | --- | --- | ---
OD(i,7) | A4 | /SSOD/ | 4 character alphanumeric node descriptor

**P3 SUPPLY (GENERATION) NODE CHARACTERISTICS**

--- For each generation node i (see vector definition, section IV.1e)

SS(i,1) | F2.0 | /SSOD/ | Energy quality supplied at this node (to correlate with OD(i,1) of P2 above)
SS(i,7) | A4 | /SSOD/ | 4 character alphanumeric node descriptor
SS(i,8) | A4 | /SSOD/ | 4 character alphanumeric description of capacity units (PV-m², WTG-kW, etc.)

--- Input a degradation function for each generation node i

DEGRD(IAGE,i) | F4.2 | /DEGR/ | IAGE=i to end of project life in years (X up to 30).
DEGRD(IAGE,i) multiplies the first year generation output to yield output during that year of project equal to IAGE.
DEGRD(IAGE,i) is generally 1 for IAGE = 1 and declines thereafter.

**P4 RUN LIFE BREAKDOWN**

(LOGICS: 2, 271, 272, 273)
(Required only if default simulation of single year/hourly simulation is not specified in the interactive questioning, or if STNDRD is unequal to 2.0 in the LEAP file (see section IV.3g))

(For description of project life breakdown, see section IV.1d)

Parameter | Format | COMMON | Description
--- | --- | --- | ---
INC5 | I4 | /BASIC/ | This value multiplies 5-minute base interval to set simulation interval. If INC5 = 12, simulation is hourly. OESYS is not currently structured to conveniently allow for INC5 other than 12. Modifications to SUBROUTINE MARX are required to interpolate hourly disk file load/generation data.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPERDS</td>
<td>I2</td>
<td>/SIM/</td>
<td>Total number of simulation periods where one period is at minimum 1 year.</td>
</tr>
<tr>
<td>NSECTS</td>
<td>I2</td>
<td>/SIM/</td>
<td>Total number of simulation sections in each period (maximum = 53)</td>
</tr>
<tr>
<td>NPYRS(i)</td>
<td>I2</td>
<td>/SIM/</td>
<td>Total number of years to be represented by period i.</td>
</tr>
<tr>
<td>DEGRA(i)</td>
<td>F4.2</td>
<td>/SIM/</td>
<td>Degradation factor to be multiplied by first year (undegraded) generation output to yield output in period i.</td>
</tr>
<tr>
<td>IBGSIM(i)</td>
<td>I4</td>
<td>/SIM/</td>
<td>Begin hour of section i simulation</td>
</tr>
<tr>
<td>IENSIM(i)</td>
<td>I4</td>
<td>/SIM/</td>
<td>End hour of section i simulation</td>
</tr>
<tr>
<td>IBGSXN(i)</td>
<td>I4</td>
<td>/SIM/</td>
<td>Begin hour of ith section simulated</td>
</tr>
<tr>
<td>IENSXN(i)</td>
<td>I4</td>
<td>/SIM/</td>
<td>End hour of ith section simulated</td>
</tr>
</tbody>
</table>

(If one week simulation is to represent one month, IBGSIM, IENSIM are the begin and end hours of the simulated week while IBGSXN and IENSXN are the border hours of that month.)

**P5**

**HARDWARE PARAMETERS (LOGICS: 2)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACAC</td>
<td>F4.2</td>
<td>/HDWR/</td>
<td>Inverter efficiency (AC to DC)</td>
</tr>
<tr>
<td>DCAC</td>
<td>F4.2</td>
<td>/HDWR/</td>
<td>Rectifier efficiency (DC to AC)</td>
</tr>
</tbody>
</table>

**P6**

**UTILITY PRICING PARAMETERS (LOGICS: 2,271,272,273)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTDMD</td>
<td>I4</td>
<td>/EC1/</td>
<td>Number of hours defined by utility as a customer's capacity charge period; monthly = 732, weekly = 168, etc.</td>
</tr>
<tr>
<td>MXNTO0</td>
<td>I2</td>
<td>/EC1/</td>
<td>maximum number of T.O.D. periods in a utility time-of-day rate structure.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>---------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ENDHR(i)</td>
<td>F5.0</td>
<td>/PRI/</td>
<td>Year hour corresponding to the end of price season i. All simulation hours between the hour ENDHR(i) and ENDHR(i-1) use the pricing schedule set for season i.</td>
</tr>
<tr>
<td>ENDTOD(ICSN, IDAYTYP, ITOD)</td>
<td>F5.0</td>
<td>/PRI/</td>
<td>ICSN = utility pricing season (1-12) IDAYTYP = type of day, where 1 = weekday 2 = weekend 3 = holiday ITOD = time of day period of current hour (up to 20) ENDTOD is the end hour for time of day period ITOD, for daytype given by IDAYTYP, in pricing season ICSN which ends at hour ENDHR(ICSN).</td>
</tr>
<tr>
<td>CPR(ICSN, IDAYTYP, ITOD)</td>
<td>F6.2</td>
<td>/PRI/</td>
<td>ICSN, IDAYTYP, ITOD as defined in ENDTOD; CPR(ICSN, IDAYTYP, ITOD) is cost of energy supplied by the utility during pricing season ICSN, during the IDAYTYP = (1) weekday, (2) weekend or (3) holiday, and in time-of-day period ITOD.</td>
</tr>
</tbody>
</table>

**ELECTRICAL STORAGE PARAMETERS (LOGICS: 271, 272, 273)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAP7</td>
<td>F12.1</td>
<td>/FLY/</td>
<td>Maximum storage capacity (in units of kWh_e)</td>
</tr>
<tr>
<td>EMIN7</td>
<td>F12.1</td>
<td>/FLY/</td>
<td>Minimum state-of-charge to be allowed on the storage unit (in units of kWh_e)</td>
</tr>
<tr>
<td>C7MX</td>
<td>F12.1</td>
<td>/FLY/</td>
<td>Maximum power (kw) charge allowed by the storage charging device</td>
</tr>
<tr>
<td>D7MX</td>
<td>F12.1</td>
<td>/FLY/</td>
<td>Maximum power (kw) discharge allowed by the storage discharge device</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>EST07</td>
<td>F6.4</td>
<td>/FLY/</td>
<td>Storage state-of-charge-related loss efficiency. This number multiplies the current storage state of charge to arrive at dissipation loss each hour.</td>
</tr>
<tr>
<td>FXLS7</td>
<td>F6.4</td>
<td>/FLY/</td>
<td>Constant power (kw) loss due to storage monitoring equipment, control, etc.</td>
</tr>
<tr>
<td>NEG</td>
<td>I2</td>
<td>/FLY/</td>
<td>Number of efficiency levels for inverter device output as a function of the fraction of maximum discharge (kw) capacity of that device. This parameter is used in conjunction with EG7.</td>
</tr>
<tr>
<td>NEM</td>
<td>I2</td>
<td>/FLY/</td>
<td>Number of efficiency levels for inverter device input as a function of maximum charge (kw) capacity of that device. This parameter is used in conjunction with EM7.</td>
</tr>
<tr>
<td>NEIN</td>
<td>I2</td>
<td>/FLY/</td>
<td>Number of efficiency levels for storage charging as a function of state of charge (kwh) of the storage unit. This parameter is used in conjunction with EIN7.</td>
</tr>
<tr>
<td>NEOUT</td>
<td>I2</td>
<td>/FLY/</td>
<td>Number of efficiency levels for storage discharging as a function of state of charge (kwh) of the electrical storage unit. This parameter is used in conjunction with EOUT7.</td>
</tr>
</tbody>
</table>
| EIN7(I,J) | F4.2   | /FLY/  | For storage state of charge interval I, given by storage state of charge between the values EIN7(I,1) and EIN7(I+1,1), the efficiency of charging the storage device is EIN7(I,2). Hence, if storage input efficiency is 93 percent from 0 to 50 percent of maximum storage capacity and 92 percent from 50 to 100 percent of maximum storage capacity, EIN7 reads as: EIN7(1,1) = 0. EIN7(1,2) = .93 EIN7(2,1) = .5 EIN7(2,2) = .92
### Parameter Description

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOUT7(I,J)</td>
<td>F4.2 /FLY/</td>
<td></td>
<td>For storage state of charge level ( I ), given by storage state of charge between the values ( EOUT7(I,1) ) and ( EOUT7(I+1,1) ), the efficiency of discharging the storage device is ( EOUT7(I,2) ) (see EIN7 definition above)</td>
</tr>
<tr>
<td>EG7(I,J)</td>
<td>F4.2 /FLY/</td>
<td></td>
<td>For inverter output level ( I ), given by output rates between the values ( EG7(I,1) ) and ( EG7(I+1,1) ) of the maximum output rate, the efficiency of output is ( EG7(I,2) ) (see EIN7 definition above)</td>
</tr>
<tr>
<td>EM7(I,J)</td>
<td>F4.2 /FLY/</td>
<td></td>
<td>For inverter input level ( I ), given by input rates between the values ( EM7(I,1) ) and ( EM7(I+1,1) ) of the maximum input rate, the efficiency of input is ( EM7(I,2) ) (see EIN7 definition above).</td>
</tr>
</tbody>
</table>

### IV.3f. The Economic Parameter File

This section describes all economic input parameters specified in the parameter file PARMEC FORTRAN. OESYS parameters are defined in a program subroutine format rather than in a data read file in order to save on expensive formatted I/O and to utilize a method which is less prone to input error. Also, many economic parameters need to be defined as values which are functions of either physical or interactive parameters or of physical operation output variables.

As in the physical parameter file, the economic parameters are also grouped according to general topic. These topics include:

- **E1)** CALENDAR DATE/PROJECT AGE AND OUTPUT PARAMETERS
- **E2)** FLAGS
- **E3)** HOMEOWNER FINANCING PARAMETERS
- **E4)** COMMERCIAL/INDUSTRIAL/INSTITUTIONAL FINANCING PARAMETERS
- **E5)** UTILITY FINANCING PARAMETERS
- **E6)** COST VECTOR PARAMETERS
- **E7)** BENEFIT PARAMETERS
Parameter definitions are made here according to the above grouping.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RLIFE</td>
<td>F3.0</td>
<td>/EC4/</td>
<td>Project life in years (up to 30)</td>
</tr>
<tr>
<td>ISYF80</td>
<td>I4</td>
<td>/EC4/</td>
<td>Project start year (in calendar notation: .gt. 1980)</td>
</tr>
<tr>
<td>JSYF80</td>
<td>I4</td>
<td>/EC4/</td>
<td>Project start year beyond 1980 (ISYF80 - 1980)</td>
</tr>
<tr>
<td>ILOOK</td>
<td>I4</td>
<td>/EC4/</td>
<td>Base year from which all economic discounting is carried out with respect to. ILOOK cannot be later than the construction start year (JSYF80)</td>
</tr>
<tr>
<td>LOOK</td>
<td>I4</td>
<td>/EC4/</td>
<td>Years beyond 1980 to which ILOOK is set. LOOK = ILOOK - 1980</td>
</tr>
<tr>
<td>GITC</td>
<td>F4.2</td>
<td>/ECON/</td>
<td>Income tax credit allowed on primary component</td>
</tr>
<tr>
<td>GITCIN</td>
<td>F4.2</td>
<td>/ECON/</td>
<td>Income tax credit allowed on infrastructure of primary component.</td>
</tr>
<tr>
<td>NSSBCC</td>
<td>I2</td>
<td>/ECOUT/</td>
<td>Gives the total number of generation technologies for which to compute the break even capital cost (up to 10)</td>
</tr>
<tr>
<td>ISSBCC(i)</td>
<td>I2</td>
<td>/ECOUT/</td>
<td>where i is from 1 to NSSBCC, gives the node number of the generation technology for which to compute the BECC.</td>
</tr>
<tr>
<td>NCGBCC</td>
<td>I2</td>
<td>/ECOUT/</td>
<td>Gives the total number of modeled generation technologies for which to compute the breakeven capital cost (up to 5)</td>
</tr>
</tbody>
</table>
CALENDAR DATE/PROJECT AGE AND OUTPUT PARAMETERS

ICGBCC(I) I2 /ECOUT/ Where i is from 1 to NCGBCC, gives the node number of the modeled generation technology for which to compute the BECC.

NSTBCC I2 /ECOUT/ Gives the total number of storage technologies for which to compute the BECC (up to 5).

ISTBCC(I) I2 /ECOUT/ Where i is from 1 to NSTBCC, gives the node number of the storage technology for which to compute the BECC.

Note: NSBCC + NSTBCC + NCGBCC must be less than 10.

FLAGS

Parameter | Format | COMMON | Description
--- | --- | --- | ---
KDC | I1 | /EC4/ | = 1 Chooses the dynamic costing option which repeats the financing routine for each year from ISYF80 to 2000.
| | | = 0 | No dynamic costing. The finance routine is run only for construction start year at ISYF80.

KCDLA | I1 | /EC4/ | Used only when KDC = 1
| | | = 1 | Cost of construction delay is computed and included as project cost.
| | | = 0 | Cost of construction delay is not computed.

KBECC1 | I1 | /EC4/ | = 1 Operating costs included in breakeven capital cost computations
| | | = 0 | Operating costs not included in BECC computations (hence, operating costs are assumed as set under E6 below).
### Parameter Format COMMON Description

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBECC2</td>
<td>I1</td>
<td>/EC4/</td>
<td>Component Balance of System costs included with primary unit in computing component BECC $= 1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Balance of system costs assumed as cost and component BECC includes the primary unit alone $= 0$.</td>
</tr>
</tbody>
</table>

#### E3 HOMEOWNER FINANCING PARAMETERS
(Used only when homeowner financing is requested in interactive question sequence, or if INVSTR = 1 in LEAP file.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXR</td>
<td>F5.2</td>
<td>/ECRS1/</td>
<td>The homeowner's tax rate</td>
</tr>
<tr>
<td>MRTLF</td>
<td>I2</td>
<td>/ECRS1/</td>
<td>The mortgage life</td>
</tr>
<tr>
<td>MRTLF</td>
<td>I2</td>
<td>/ECRS1/</td>
<td>Percent of the initial investment made as down payment</td>
</tr>
<tr>
<td>RAI</td>
<td>F5.2</td>
<td>/ECRS1/</td>
<td>Annual mortgage interest rate (real)</td>
</tr>
<tr>
<td>RTN</td>
<td>F5.2</td>
<td>/ECRS1/</td>
<td>Homeowner's expected rate of return (real)</td>
</tr>
<tr>
<td>UTC</td>
<td>F5.2</td>
<td>/ECRS1/</td>
<td>Utilization coefficient for the generator (see II.2a)</td>
</tr>
<tr>
<td>YEG</td>
<td>F5.2</td>
<td>/ECRS1/</td>
<td>Total kwh's of energy displaced by the generating unit.</td>
</tr>
<tr>
<td>FXCR</td>
<td>F5.2</td>
<td>/ECRS1/</td>
<td>Fixed charge rate applied to the capital investment (see II.2a).</td>
</tr>
</tbody>
</table>

#### E4 COMMERCIAL/INDUSTRIAL/INSTITUTIONAL FINANCING PARAMETERS
(Used only when CII financing is requested in interactive question sequence, or if INVSTR = 2 in LEAP file.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORPTX</td>
<td>F5.3</td>
<td>/ECON/</td>
<td>Corporate tax rate</td>
</tr>
<tr>
<td>BNDINT</td>
<td>F5.3</td>
<td>/ECON/</td>
<td>The Corporate bond interest rate</td>
</tr>
</tbody>
</table>
### Parameter Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEBTEQ</td>
<td>F5.3</td>
<td>/ECON/</td>
<td>Debt/debt plus equity ratio</td>
</tr>
<tr>
<td>RETURN</td>
<td>F5.3</td>
<td>/ECON/</td>
<td>Anticipated rated return on a non-risk-free corporate investment.</td>
</tr>
<tr>
<td>CONST</td>
<td>F3.1</td>
<td>/ECON/</td>
<td>Number of project construction years</td>
</tr>
<tr>
<td>IDEP</td>
<td>I1</td>
<td>/ECON/</td>
<td>Flag to identify the depreciation method for tax purposes: 1 = straight line, 2 = sum of the years digits, 3 = declining balance for first half of project life, sum of years thereafter, 4 = accelerated straight line</td>
</tr>
<tr>
<td>IDEPP</td>
<td>I1</td>
<td>/ECON/</td>
<td>Flag to identify the depreciation method for the firm's own books according to 1, 2, 3, 4 under IDEP.</td>
</tr>
<tr>
<td>IDEPPI</td>
<td>I1</td>
<td>/ECON/</td>
<td>Same as IDEP</td>
</tr>
<tr>
<td>IDEPGI</td>
<td>I1</td>
<td>/ECON/</td>
<td>Same as IDEPP</td>
</tr>
</tbody>
</table>

### C5 Utility Financing Parameters

(Used only when utility financing is requested in interactive question sequence, or if INVSTR = 3 in LEAP file.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>Effective income tax rate</td>
</tr>
<tr>
<td>DR</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>Annual average rate of return</td>
</tr>
<tr>
<td>AINFL</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>General inflation rate</td>
</tr>
<tr>
<td>BETA1</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>Annual &quot;other&quot; taxes as a fraction of capital investment</td>
</tr>
<tr>
<td>BETA2</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>Annual insurance premiums as a fraction of capital investment.</td>
</tr>
<tr>
<td>GC</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>Escalation rate for capital costs</td>
</tr>
<tr>
<td>GM</td>
<td>F5.3</td>
<td>/ECUTL2/</td>
<td>Escalation rate for operating and maintenance costs.</td>
</tr>
</tbody>
</table>
### Parameter | Format | COMMON | Description
--- | --- | --- | ---
EESC | F5.3 | /ECUTL2/ | Escalation rate for energy costs
IYB | I4 | /ECUTL2/ | Base year for constant dollars
IYCO | I4 | /ECUTL2/ | Construction start year
NBLDYR | I2 | /ECUTL2/ | Number of construction years (0,1,2,...)
AKWH | F12.2 | /ECUTL2/ | Annual energy (kwh) output of generation technologies.
DR | F5.3 | /ECUTL2/ | Expected rate of return for discounting purposes.

### COST VECTOR PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSSCC1(I,J,K)</td>
<td>F12.2</td>
<td>/CSS1/</td>
<td>Capital cost of primary component of generation unit I in year 0 of project as a function of calendar year of purchase. I = 1 to number of supply nodes (max 20) J = purchase year from 1980 (1 to 20) K = 1,2,3 for low, medium and high cost assumption.</td>
</tr>
<tr>
<td>CSSBS1(I,J,K)</td>
<td>F12.2</td>
<td>/CSS1/</td>
<td>Capital cost of balance of system aspect of primary generation unit I in year 0 of project as a function of calendar year of purchase, I = 1 to number of supply nodes max 20) J = purchase year from 1980 (1 to 20) K = 1,2,3 for low, medium and high cost assumption.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
<td>--------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CSSCC2(I,J,K)</td>
<td>F12.2</td>
<td>/CSS2/</td>
<td>Repurchase capital cost of primary component of generation unit I as a function of project age. I = 1 to number of supply nodes (max 20).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>J = purchase year from 1980 (1 to 20).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K = 1, 2, 3 for low, medium and high cost assumption.</td>
</tr>
<tr>
<td>CSSBS2(I,J,K)</td>
<td>F12.2</td>
<td>/CSS2/</td>
<td>Repurchase Cost of balance of system aspect of primary generation unit I as a function of project age.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I = 1 to number of supply nodes (max 20).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>J = purchase year from 1980 (1 to 20).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K = 1, 2, 3 for low, medium and high cost assumption.</td>
</tr>
<tr>
<td>CSSOP1(I,J,K)</td>
<td>F12.2</td>
<td>/CSS1/</td>
<td>Cost of operation, maintenance and fuel for generation unit I in year J where J = 1 corresponds to first year of operation after construction period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I = 1 to number of supply nodes (max 20).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>J = purchase year from 1980 (1 to 20).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K = 1, 2, 3 for low, medium and high cost assumption.</td>
</tr>
<tr>
<td>CGNCC1(I,J,K)</td>
<td>F12.2</td>
<td>/CGN1/</td>
<td>Same definition as for CSSCC1 except applies to modeled generation node and; I = 1 to number of modeled generation nodes (max 5).</td>
</tr>
<tr>
<td>CGNBS1(I,J,K)</td>
<td>F12.2</td>
<td>/CGN1/</td>
<td>Same definition as for CSSBS1 except applies to modeled generation node and I = 1 to number of modeled generation nodes (max 5).</td>
</tr>
<tr>
<td>CGNCC2(I,J,K)</td>
<td>F12.2</td>
<td>/CGN1/</td>
<td>Same definition as for CSSBS2 except applies to modeled generation node and I = 1 to number of modeled generation nodes (max 5).</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------</td>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CGNBS2(I,J,K)</td>
<td>F12.2</td>
<td>/CGN1/</td>
<td>Same definition as for CSSBS2 except applies to modeled generation node and I = 1 to number of modeled generation nodes (max 5)</td>
</tr>
<tr>
<td>CGNOP1(I,J,K)</td>
<td>F12.2</td>
<td>/CGN1/</td>
<td>Same definition as for CSSOP1 except applies to modeled generation node and I = 1 to number of modeled generation nodes (max 5)</td>
</tr>
<tr>
<td>CSTCC1(I,J,K)</td>
<td>F12.2</td>
<td>/C71/</td>
<td>Same definition as for CSSCC1 except applies to storage node and I = 1 to number of storage nodes (max 5)</td>
</tr>
<tr>
<td>CSTBS1(I,J,K)</td>
<td>F12.2</td>
<td>/C71/</td>
<td>Same definition as for CSSBS1 except applies to storage node and I = 1 to number of storage nodes (max 5)</td>
</tr>
<tr>
<td>CSTCC2(I,J,K)</td>
<td>F12.2</td>
<td>/C71/</td>
<td>Same definition as for CSSCC2 except applies to storage node and I = 1 to number of storage nodes (max 5)</td>
</tr>
<tr>
<td>CSTBS2(I,J,K)</td>
<td>F12.2</td>
<td>/C71/</td>
<td>Same definition as for CSSBS2 except applies to storage node and I = 1 to number of storage nodes (max 5)</td>
</tr>
<tr>
<td>CSTOPI(I,J,K)</td>
<td>F12.2</td>
<td>/C71/</td>
<td>Same definition as for CSSOP1 except applies to storage node and I = 1 to number of storage nodes (max 5)</td>
</tr>
<tr>
<td>CMSCC1(I,J,K)</td>
<td>F12.2</td>
<td>/C71/</td>
<td>Same definition as for CSSCC1 except applies to miscellaneous node and I = 1 to number of miscellaneous nodes (max 2)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>CMSBS1(I,J,K)</td>
<td>F12.2 /C71/</td>
<td>Same definition as for CSSBS1 except applies to miscellaneous node and I = 1 to number of miscellaneous nodes (max 2)</td>
<td></td>
</tr>
<tr>
<td>CMSCC2(I,J,K)</td>
<td>F12.2 /C71/</td>
<td>Same definition as for CSSCC2 except applies to miscellaneous node and I = 1 to number of miscellaneous nodes (max 2)</td>
<td></td>
</tr>
<tr>
<td>CMSBS2(I,J,K)</td>
<td>F12.2 /C71/</td>
<td>Same definition as for CSSBS2 except applies to miscellaneous node and I = 1 to number of miscellaneous nodes (max 2)</td>
<td></td>
</tr>
<tr>
<td>CMSOP1(I,J,K)</td>
<td>F12.2 /C71/</td>
<td>Same definition as for CSSOP1 except applies to miscellaneous node and I = 1 to number of miscellaneous nodes (max 2)</td>
<td></td>
</tr>
</tbody>
</table>

**E7 BENEFIT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXOGI(I,J)</td>
<td>F4.2 /PXG/</td>
<td>Price inflator for energy of quality type I in calendar year (from 1980) J. EXOGI(1,2) is the price inflator for AC electricity in 1982. I ranges from 1 to 10 and J ranges from 1 to 30 (i.e., from 1981 to 2010). I must match the energy quality definitions specified in the SS/DD vectors of section IV.1e.</td>
<td></td>
</tr>
</tbody>
</table>
Parameter       Format      COMMON      Description
SLBK(I,J)       F4.2       /WRTH/     For utility sale of energy quality I, the utility purchase price as a fraction of the going price in calendar year 1980 + J is SLBK(I,J). SLBK(1,3) = .54 refers to a utility buyback rate in 1983 for electricity of 54% of the utility sale price. This parameter is set here only if not set as constant in the interactive sequence (Section IV.3g).

IV.3g. User Interactive Input Parameters

By specification of the "LEAP" option described in section III.3, it is possible to bypass the lengthy interactive sequence of computer query and user response. With this option the program simply searches a third parameter file, LEAPME FORTRAN, for the otherwise interactively solicited parameters. Section III.4 steps through the interactive sequence, and it is the purpose in this section to define those parameters which are set as a result. Figure 4-3-6 presents the file LEAPME FORTRAN which must be set if the LEAP option is chosen.

Parameter definitions are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN</td>
<td>F6.0</td>
<td>/BASIC/</td>
<td>Application Logic Flag. This parameter should be set according to:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>271.0</td>
</tr>
</tbody>
</table>
FILE: LEAPME FORTRAN A

***** LEAPME *****

SUBROUTINE LEAPME(KIST1,KIST2,TSTEP,IOUPT,OUTINC,PLTFLO
1,PLTFIC,NNPER,RUN,BUYFLG,BUYRB,STYDHR,IVGHR,TENDHR
1,PVFLAG,INVSIR,REV)

COMMON/SSDQ/SS(20,20),DO(20,20),SSS(20),SSD(20),PS(20)

COMMON/N0/NSNO,KSNO,NOKS,KBOK,KOKS,KBOKS,KBOKS,KBOKS
COMMON/IS/IS1(10),IS2(10),IS3(10),IS4(10),IS5(10),IS6(10)
COMMON/CAPC/CAPC1,CAPC2,CAPC3,CAPC4,CAPC5

PVFLAG=2 MEANS JAN 1 SPLITS A YEAR

RUN=2,
BUYFLG=1.
IOUPT=4
OUTINC=725.
STYDHR=2.000
IVGHR=4753
TENDHR=IVGHR-1
PVFLAG=2,
PLTFLO=0,
PLTFIC=1440.
NNPER=1
REV=1
INVSIR=2
KST1=0
KST2=0
TSFIL=0.

KUP151=0
KUP152=0
KREL1=0
KREL2=0

KCGT=0
KELAS=0
KHAAD=0
KFAIL=0
KID=0
KUTL=1

FOR EACH ENERGY QUALITY...

NEQUL=1

FOR EACH ENERGY QUALITY TYPE WITH UTILITY BUYBACK, SET BUYBACK
RATE -- THIS CAN ALSO BE DONE IN PARMEC IF BUYBACK RATE IS

A FUNCTION OF CALENDAR YEAR

SLBK(1,1)=.85
CAPCHG=5.12

RETURN
END

figure 4-3-6
SAMPLE QUESTION BYPASS FILE
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUYFLG</td>
<td>F2.0</td>
<td>/FLAG/</td>
<td>= 1 If utility purchases excess generation in the first 3 logics above &lt;br&gt;= 0 if utility does not purchase excess generation.</td>
</tr>
<tr>
<td>IOUTPT</td>
<td>I1</td>
<td>/FLAG/</td>
<td>= For hourly or multiple-hourly output of physical operation &lt;br&gt;= 2 For section physical operation summaries &lt;br&gt;= 3 For period physical operation summaries &lt;br&gt;= 4 For final (total) physical operation summaries (see section IV.4a)</td>
</tr>
<tr>
<td>OUTINC</td>
<td>F6.0</td>
<td>/BASIC/</td>
<td>Used only when IOUTPT = 1, this is the hour-multiplier for physical operation output. If OUTINC = 1, output is hourly; if OUTINC = 168, output is weekly, if OUTINC = 732, output is monthly, and so on.</td>
</tr>
<tr>
<td>STNORD</td>
<td>F4.0</td>
<td>/FLAG/</td>
<td>Simulation Run Life flag. &lt;br&gt;IF STNORD &lt;br&gt;= 0.0 Run life is broken down into periods, sections and intervals according to physical parameter file specifications (see section IV.1d).</td>
</tr>
</tbody>
</table>
Parameter | Format | COMMON | Description
---|---|---|---
IBGHR | I4 | /BASIC/ | Simulation begin hour (hour of the year), corresponding to 1:00 a.m. of the day simulation begins (i.e., IBGHR-1 must be divisible by 24). If simulation begins on January 1, IBGHR = 1; January 2, IBGHR = 25; January 3, IBGHR = 49; etc.
IENDHR | I4 | /BASIC/ | Simulation end hour; since the maximum simulation interval is 1 year, IENDHR is set to IBGHR-1 for yearly simulations. If IENDHR is less than IBGHR, PVFLAG (below) must be set to 2 in order that the second generation disk file is switched over to January 1. See section IV.3d for discussion of why this is so.
PVFLAG | F2.0 | /FLAG/ | = 1.0 If a single generation file is used to match the application load file and if IBGHR is set less than IENDHR.
| | | | = 2.0 If energy generation figures are to come from a second file on January 1 (see IV.3d).
PLTFLG | F2.0 | /PLOT/ | = 1. If M.I.T. PRTPLT package is selected to plot generation, load, and net load over selected days.
| | | | = 0. If no plots are desired
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLTINC</td>
<td>F6.0</td>
<td>/PLOT/</td>
<td>Used only if PLTFLG = 1.0; Hourly multiple plot increment which must be divisible by 24. If PLTINC = 24., plots are daily; if PLTINC = 732., plots are monthly.</td>
</tr>
<tr>
<td>NPPER</td>
<td>I1</td>
<td>/PLOT/</td>
<td>Number of days plotted at each plot period. If NPPER = 2, 48 hours is plotted beginning at the hour specified by PLTINC.</td>
</tr>
<tr>
<td>KEV</td>
<td>I1</td>
<td>none</td>
<td>= 0 If only the physical operation portion of OESYS is to be run (i.e., no finance simulation is desired). = 1 If both the physical operation and finance simulation portions are to be modeled. = 2 If only the finance simulation portion is to be run. This option assumes that the pre-processor data exist in file 33 (FYBEN INPUT) in accordance with the specifications outlined in section IV.4g.</td>
</tr>
<tr>
<td>INVSTR</td>
<td>I1</td>
<td>none</td>
<td>Used only when KEV = 1 = 1 For homeowner financing = 2 For commercial/industrial/institutional financing = 3 For utility financing</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>KTST1</td>
<td>I1</td>
<td>/KTEST/</td>
<td>Test debug option for the physical operation model. If KTST1 = 0 The option is ignored = 1-12 The full SS/DD/CGN energy vectors are output to terminal according to location (1-12) within program (see section IV.4b)</td>
</tr>
<tr>
<td>KTST2</td>
<td>I1</td>
<td>/KTEST/</td>
<td>Used only if KTST1 is unequal to 0; = 1 Energy vectors are output at all levels up to level KTST1 = 2 Energy vectors are output only at level KTST1.</td>
</tr>
<tr>
<td>TSTHR</td>
<td>F6.0</td>
<td>/KTEST/</td>
<td>Used only if KTST1 is unequal to 0. Terminal debug output is printed beginning at this simulation year hour.</td>
</tr>
<tr>
<td>KOPTS1</td>
<td>I1</td>
<td>/TSOPEC/</td>
<td>Terminal display debug option for physical simulation: = 1 Display program-checks which are outside hourly iteration loop = 0 No display</td>
</tr>
<tr>
<td>KOPTS2</td>
<td>I1</td>
<td>/TSOPEC/</td>
<td>Terminal display debug option for physical simulation: = 1 Display program-checks which are inside hourly iteration loop = 0 No display</td>
</tr>
<tr>
<td>KECTS1</td>
<td>I1</td>
<td>/TSOPEC/</td>
<td>Terminal display debug option for finance simulation: = 1 Display program-checks which are outside yearly iteration loop. = 0 No output</td>
</tr>
<tr>
<td>Parameter</td>
<td>Format</td>
<td>COMMON</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>KECTS2</td>
<td>I1</td>
<td>/TSOPEC/</td>
<td>Terminal display debug option for finance simulation:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Display program-checks which are inside yearly iteration loop.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 No display</td>
</tr>
<tr>
<td>KCGN</td>
<td>I1</td>
<td>/KQ/</td>
<td>Modeled generation Option</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Bypass cogeneration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-8 Undefined as of 5/80</td>
</tr>
<tr>
<td>KELAS</td>
<td>I1</td>
<td>/KQ/</td>
<td>Application demand elasticity option:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Bypass elasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-8 Undefined as of 5/80</td>
</tr>
<tr>
<td>KMDMD</td>
<td>I1</td>
<td>/KQ/</td>
<td>Modeled application load option:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Bypass modeled load</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-8 Undefined as of 5/80</td>
</tr>
<tr>
<td>KFAIL</td>
<td>I1</td>
<td>/KQ/</td>
<td>Hardware unit outtage estimation estimation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Bypass outtage estimation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-8 Undefined as of 5/80</td>
</tr>
<tr>
<td>KTD</td>
<td>I1</td>
<td>/KQ/</td>
<td>Transmission/distribution losses estimation option:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Bypass outtage estimation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-8 Undefined as of 5/80</td>
</tr>
<tr>
<td>KUTL</td>
<td>I1</td>
<td>/KQ/</td>
<td>Utility type option:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Bypasses consideration of utility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Flat or time of use rate schedule is used to price AC and DC electricity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2-8 Undefined as of 5/80</td>
</tr>
<tr>
<td>NEQUIL</td>
<td>I2</td>
<td>/WRTH/</td>
<td>Number of energy quality types, or number of distinguishable servicing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>utilities.</td>
</tr>
<tr>
<td>SLBK(I,J)</td>
<td>F5.3</td>
<td>/WRTH/</td>
<td>Buyback rate for energy of quality (or from utility I) during the Jth year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>from 1980. If SLBK(1,3) = 0.54, the utility purchases excess electricity.</td>
</tr>
</tbody>
</table>
### IV.3h Preprocessor Models

All generation and load nodes which are to be modeled by use of load and generation profile data require the preprocessing of these data to correspond with the format specified in sections IV.3b and IV.3c. Load data is generally obtained from utilities engaged in customer monitoring practices, or from the output of application models, such as NBSLD, NECAP, TRNSYS, etc. Weather-dependent generation data is usually obtained from models interfacing with meteorological data for weather dependent technologies. OESYS is equipped with one such weather-dependent model — that of a photovoltaic array. The model requires 2 inputs: a file definition for meteorological data stored on

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>COMMON</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSS</td>
<td>I2</td>
<td>/SSDD/</td>
<td>Number of generation nodes modeled by sequential disk file data.</td>
</tr>
<tr>
<td>SS(I,5)</td>
<td>F10.1</td>
<td>/SSDD/</td>
<td>Capacity of generation node I where I = 1 to NSS. This figure, divided by the capacity figure of the generation disk file leader, multiplies all data figures on that disk file. For further explanation see section IV.3c &quot;TAPE DEMAND&quot;.</td>
</tr>
<tr>
<td>NDD</td>
<td>I2</td>
<td>/SSDD/</td>
<td>Number of application load nodes modeled by disk file data stream discussed in section IV.3b, &quot;TAPE DEMAND&quot;.</td>
</tr>
</tbody>
</table>
disk, and an interactive input following selection of the PV model option in the interactive question sequence. The program outputs hourly PV array generation in an OESYS compatible format. The specific steps required for array modeling are outlined as follows:

1) Specify in the executive file (section IV.3d) under disk file number 12, the filename and filetype of hourly meteorological data applicable to the time period and geographic location of interest. The data file must consist of hourly sequential data records of the following format:

\[ \text{YRHR, SOLHR, HDIF, HDIR, TAMB, WIND} \]
\[ \text{FORMAT(4x, F6.0, 2x, F5.2, 19x, 4(2x, F7.2))} \]

where:

- \( \text{YRHR} \) = Hour of the year for this record (1.-8760.)
- \( \text{SOLHR} \) = Solar hour of the day (0.00-23.99)
- \( \text{HDIF} \) = Diffuse component of solar radiation as found on a horizontal surface in Wh/m².
- \( \text{HDIR} \) = Direct component of solar radiation as found on a horizontal surface in Wh/m².
- \( \text{TAMB} \) = Ambient dry bulb temperature in °C.
- \( \text{WIND} \) = Ambient wind speed in m/s.

2) Set the array parameters as defined in the physical parameter file under "Array Parameters," P1 of section IV.3e.

3) The program should be entered and the "GO" option specified (see section III.)

The question sequence reads as follows:

T: CREATE A NEW PV TAPE (Y/N/Help)  
R: Type 'Yes'
T: THE MODELED PV SUPPLY FILE WILL BE WRITTEN IN FILE IPV2 (SEE SR DEFAULT). DO YOU WISH TO PROCEED? (Y/N/Help)

R: (F1 = IPV2 (file 14) in the executive file — this file should be renamed and saved at the end of this run. If a file which currently exists in file 14 should not be written over here, answer "NO", end program, and rename that file. Otherwise, type "YES")

(If 'YES' is typed in)

T: BE WARNED THAT ALL RUNS FOR THIS SESSION WILL RUN OFF THE TAPE YOU ARE ABOUT TO CREATE (FI = IPV2). TO AVOID DEVELOPING THIS SAME TAPE FOR LATER SESSIONS, TRANSFER ITS CONTENTS TO FI = IPVST AT THE CLOSE OF THIS SESSION. OTHERWISE THE CURRENT FI = IPVST WILL BE USED FOR THE NEXT SESSION. NOTE: YOU MAY WISH TO SAVE THE CONTENTS OF THE CURRENT FI = IPV.

T: INPUT LAST TWO INTEGERS OF RUN YEAR (E.G., 75, 76)

R: (input two digit year suffix)

T: INPUT A 4-LETTER ABBREVIATION FOR LOCATION.

R: (e.g., PHNX for Phoenix, JNSN for Jacksonville).

T: INPUT ARRAY SIZE IN SQUARE METERS (REAL .LT. 5 digits)

R: (Type in a decimal number)

T: INPUT ARRAY TYPE (INTEGER .LT. 10)

R: (Array types are coded as follows:)
   1 = tilt angle = latitude
   2 = tilt angle = latitude + 10°
   3 = tilt angle = latitude - 10°
   4 = tilt angle = latitude + 15°
   5 = tilt angle = latitude - 15°
   6-9 your choice

Note: Specification of array type only serves to identify the fixing of tilt angle parameter AA in the physical parameter file. The selection here does not force parameter AA to a value other than that set in the parameter file.
T: INPUT NUMBER OF DAYS OF DATA (Decimal .LT. 367.)

R: (Input a decimal number less than 367. The program assumes that the value selected times 24 is the number of data records in the meteorological data file discussed in instruction number 1.)

At this point, the program runs automatically, indicating to the terminal the passing of each week. If sufficient data was included in the meteorology data file, the program will resume the normal series of questions listed under the "GO" option of section III.

The PV generation output file is in FI = IPV2 of the executive file, under the format specified in section IV.3c, "TAPE GENERATION".

IV.4 Program Output

IV.4a Output Option Description

The OESYS final reports can be characterized under three headings: test facilities, performance summaries, and post-processor data files. All test reports result from test option selection in the interactive sequence and all reports for this option are displayed at the terminal. This can be changed by redefining the file definition IWT in subroutine DFAULT. All performance summaries go to disk files, although bottom line figures appear at the terminal at the end of the run. Performance summaries include physical operation characteristics, economic/finance reports, and a listing of service reliability indices. Characteristics of physical operation, operation summaries, and parametric economics are output in a data file format for convenient use by plot-packages and other post-processors.
IV.4b. Test Facilities

OESYS provides two distinguishable types of program output for simulation-time testing. The first is a full display of energy vectors, described in section IV.1e. at prescribed program locations and simulation hours. The second set of options provides variable checking within and without specific program loops. All options are set in the interactive question sequence, or in the question bypass (LEAP) file.

**Energy Vectors**

Referring to the definitions of interactive input given in section IV.3g, the following parameters affect the terminal display of energy node vectors:

- \( KTST1 \)
- \( KTST2 \)
- \( TSTHR \)

where,

- \( KTST1 = 0 \) if no energy vectors are to be displayed
- \( KTST1 = 1-12 \) depending on where in the program the display of energy vectors is desired. Locations correspond to the flow chart diagrams of figures 4-3 and 4-4 as follows:
  1. from the main program, prior to entering the sequence of figure 4-4.
  2. prior to calling subroutine MARX
  3. prior to calling subroutine DEGR
  4. prior to calling subroutine ELAS
  5. prior to calling subroutine COGEN
  6. prior to calling subroutine FAIL
  7. prior to calling subroutine DSTRBN
  8. prior to calling subroutine SUM
  9. prior to calling subroutine UTLTY
prior to calling Pk specific subroutine
after calling Pk specific subroutine
within TEST2, after call to subroutine PEAK

KTST2 = 1 if energy vectors are to be displayed only at the program point chosen in KTST1
= 2 for display at all program points up to and including KTST1

TSTHR = The simulation hour after and including which the program commences test display.

Figure 4-4-1 is a terminal listing of energy vector displays when KTST1 = 2, KTST2 = 2 and TSTHR = 5521. The output is first issued within the main routine (hence, HOUR = 0.) before the operation simulation loop. From then on, vectors are displayed in their entirety just prior to entering subroutine MARX in the hourly program loop.

Variable Checking

Referring again to the definitions of section IV.3g, the following parameters affect program checks at specific simulation intervals:

KOPTS1
KOPTS2
KECTS1
KECTS2

where

KOPTS1 = 0 No output
= 1 Terminal display of program location ("Entering Subroutine...") and variable indentification at points of the physical operation portion (non-economic) outside of hourly interval loop.

KOPTS2 = 0 No output
= 1 The above displayed for location and variables inside hourly interval loop of the physical operation portion.
EXECUTION BEGINS...

ALASKA . . .

RUN NAME? (6 CHARACTERS OR LESS)

Polly

A MULTIPLE RUN STUDY? (Y,N)

n

CONTINUE?

y

TEST AT HOUR 0.

POINTER PST PEAK

| SS NODE 1 |           |           |           |           |           |
|------------|-----------|-----------|-----------|-----------|
| 1/.20000E+01 | 2/.0   | 3/.10000E+01 | 4/.10000E+01 | 5/.20000E+03 |
| 6/.0       | 7/PV | 8/M2 | 9/.0 | 10/.0 |
| 11/.0      | 12/.0 | 13/.0 | 14/.0 | 15/.0 |
| 16/.0      | 17/.0 | 18/.0 | 19/.0 | 20/.0 |

DD NODE 1

|           |           |           |           |           |           |
|------------|-----------|-----------|-----------|-----------|
| 1/.10000E+01 | 2/.0   | 3/.0 | 4/.0 | 5/.0 |
| 6/.0       | 7/CII | 8/KWAC | 9/.0 | 10/.0 |
| 11/.0      | 12/.0 | 13/.0 | 14/.0 | 15/.0 |
| 16/.0      | 17/.0 | 18/.0 | 19/.0 | 20/.0 |

PLAYING PERIOD 1

START SCTN 1

TEST AT HOUR 5521.

POINTER B MARX

| SS NODE 1 |           |           |           |           |           |
|------------|-----------|-----------|-----------|-----------|
| 1/.20000E+01 | 2/.0   | 3/.10000E+01 | 4/.10000E+01 | 5/.20000E+03 |
| 6/.0       | 7/PV | 8/M2 | 9/.0 | 10/.0 |
| 11/.0      | 12/.0 | 13/.0 | 14/.0 | 15/.0 |
| 16/.0      | 17/.0 | 18/.0 | 19/.0 | 20/.0 |

DD NODE 1

|           |           |           |           |           |           |
|------------|-----------|-----------|-----------|-----------|
| 1/.10000E+01 | 2/.0   | 3/.0 | 4/.0 | 5/.0 |
| 6/.0       | 7/CII | 8/KWAC | 9/.0 | 10/.0 |
| 11/.0      | 12/.0 | 13/.0 | 14/.0 | 15/.0 |
| 16/.0      | 17/.0 | 18/.0 | 19/.0 | 20/.0 |

TEST AT HOUR 1.

POINTER B MARX

| SS NODE 1 |           |           |           |           |           |
|------------|-----------|-----------|-----------|-----------|
| 1/.20000E+01 | 2/.0   | 3/.10000E+01 | 4/.10000E+01 | 5/.20000E+03 |
| 6/.0       | 7/PV | 8/M2 | 9/.0 | 10/.0 |
| 11/.0      | 12/.0 | 13/.0 | 14/.0 | 15/.0 |
| 16/.0      | 17/.0 | 18/.0 | 19/.0 | 20/.0 |

DD NODE 1

|           |           |           |           |           |           |
|------------|-----------|-----------|-----------|-----------|
| 1/.10000E+01 | 2/.0   | 3/.0 | 4/.0 | 5/.0 |
| 6/.0       | 7/CII | 8/KWAC | 9/.0 | 10/.0 |
| 11/.0      | 12/.0 | 13/.0 | 14/.0 | 15/.0 |
| 16/.0      | 17/.0 | 18/.0 | 19/.0 | 20/.0 |

TEST AT HOUR 2.

SS NODE 1

| 1/.20000E+01 | 6/.0 |

FIGURE 4-4-1

Terminal Test Output
KECTS1 = 0  No output
= 1  Terminal display of program location and
variable identification at points of the
economic simulation portion outside of the
yearly interval loop.

KECTS2 = 0  No output
= 1  The above displayed location and variables
inside yearly interval loop of the economic
simulation portion.

IV.4c Physical Operation Summaries

A disk file (FI = IWF) copy of physical performance summaries is
output during each OESYS run. The detail of output is specified by the
following parameters, the values of which are declared as described in
IV.3g:

IOUTPT
OUTINC

where

IOUTPT = 1  Parameter echo and energy transfer summaries at
simulation intervals in hour multiples of
OUTINC. In addition to the following . . .
= 2  Section totals of energy transfer summaries in
addition to
= 3  Period totals of energy transfer summaries, in
addition to
= 4  Final totals of energy transfer summaries

OUTINC =  The hour multiple at which physical performance
summaries are output if IOUTPT = 1. If OUTINC = 1., output is hourly; 168., output is weekly,
etc.

Section and period run life breakdowns are described in section
IV.1d. An example of option IOUTPT = 1 is shown in figure 4-4-2. Only
the first page is shown since the output increment chosen was hourly. A
PARAMETERS ECHOED . . .

BASIC PARAMETERS
BEGIN HOUR: 5521 END HOUR: 5520 RUN INCREMENT: 12
LOAD NODES: 1/CII SUPPLY NODES: 1/PV

SECTION: 1 PERIOD: 1

<table>
<thead>
<tr>
<th>HOUR</th>
<th>PRICE</th>
<th>KWHSTL</th>
<th>KWHSTU</th>
<th>KWHUTL</th>
<th>KWHWST</th>
</tr>
</thead>
<tbody>
<tr>
<td>5521.0</td>
<td>1.0</td>
<td>.085000</td>
<td>0.0</td>
<td>30.000</td>
<td>0.0</td>
</tr>
<tr>
<td>SS</td>
<td>1/</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD</td>
<td>1/</td>
<td>30.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEN-</td>
<td>1/</td>
<td>0.0 2/</td>
<td>0.0 3/</td>
<td>0.0 4/</td>
<td>0.0 5/</td>
</tr>
<tr>
<td>DMD-</td>
<td>1/</td>
<td>30.0 2/</td>
<td>0.0 3/</td>
<td>0.0 4/</td>
<td>0.0 5/</td>
</tr>
<tr>
<td>5522.0</td>
<td>2.0</td>
<td>.085000</td>
<td>0.0</td>
<td>30.400</td>
<td>0.0</td>
</tr>
<tr>
<td>SS</td>
<td>1/</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD</td>
<td>1/</td>
<td>30.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEN-</td>
<td>1/</td>
<td>0.0 2/</td>
<td>0.0 3/</td>
<td>0.0 4/</td>
<td>0.0 5/</td>
</tr>
<tr>
<td>DMD-</td>
<td>1/</td>
<td>30.4 2/</td>
<td>0.0 3/</td>
<td>0.0 4/</td>
<td>0.0 5/</td>
</tr>
<tr>
<td>5523.0</td>
<td>3.0</td>
<td>.085000</td>
<td>0.0</td>
<td>30.400</td>
<td>0.0</td>
</tr>
<tr>
<td>SS</td>
<td>1/</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD</td>
<td>1/</td>
<td>30.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEN-</td>
<td>1/</td>
<td>0.0 2/</td>
<td>0.0 3/</td>
<td>0.0 4/</td>
<td>0.0 5/</td>
</tr>
<tr>
<td>DMD-</td>
<td>1/</td>
<td>30.4 2/</td>
<td>0.0 3/</td>
<td>0.0 4/</td>
<td>0.0 5/</td>
</tr>
<tr>
<td>5524.0</td>
<td>4.0</td>
<td>.085000</td>
<td>0.0</td>
<td>29.200</td>
<td>0.0</td>
</tr>
<tr>
<td>SS</td>
<td>1/</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
header repeats the selected run name as well as a description of the application type (parameter RUN). Selected parameters are echoed, including a description of all load, generation, modeled generation and modeled load nodes. In the figure, no modeled generation or modeled demand was chosen. For each output interval, the year hour (SOLHR) is followed by hour of the day, utility price for energy during the current hour, and a summary of energy transferred to load (KWHSTL), to utility (KWHSTU), utility to load (KWHUTL), and wasted (KWHWST). The selection of an application involving storage would extend the above list to include utility to storage (KWHUT7), storage to load (KWH7TL) and storage to utility (KWH7TU), as well as the current storage state of charge (SOC). Each energy vector is then displayed, listing over all nodes. For example, "DD 1/ 30.0" says 30 kwh's were demanded from load node 1 this interval. The GEN and DMD vectors then sum all generation and loads respectively for each energy quality type, 1 through 10. These are then repeated at each simulation multiple of OUTINC.

Output options IOUTPT = 2, 3, 4 are shown in figure 4-4-3. Output summaries now include a listing of the worth of equivalent energy displaced in the CSN-, CPD-, and CTO- vectors shown. The demand-charge accounting display (IOUTPT = 4) reveals the capacity savings resulting from generation coincident with peak demand over the interval specified by INTDMD of the physical parameter file (IV.3e). Generation, load, modeled load, and modeled generation node summaries are issued at the end of this summary.
**OTPT234 PARAMETERS**

**UTILITY INTERFACES DISPERSSED GENERATION**

**STANDARD RUN LIFE -- SINGLE YEAR**

### Sample Output File

**PARAMETERS ECHOED**

**BASIC PARAMETERS**
- **BEGIN HOUR:** 5521
- **END HOUR:** 5520
- **RUN INCREMENT:** 12
- **LOAD NODES:** 1/C11
- **SUPPLY NODES:** 1/PV 200. M2

#### SECTION TOTALS:

<table>
<thead>
<tr>
<th>Period</th>
<th>SECTION NO:</th>
<th>END HOUR: 5520</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S55-</td>
<td>1/</td>
<td>46597.0</td>
</tr>
<tr>
<td>SDD-</td>
<td>1/</td>
<td>283553.6</td>
</tr>
<tr>
<td>SGEN-</td>
<td>1/</td>
<td>0.0</td>
</tr>
<tr>
<td>SDD-</td>
<td>1/</td>
<td>0.0</td>
</tr>
<tr>
<td>SGEN-</td>
<td>1/</td>
<td>0.0</td>
</tr>
<tr>
<td>SDD-</td>
<td>1/</td>
<td>0.0</td>
</tr>
<tr>
<td>SNSTL</td>
<td>1/</td>
<td>40007.352</td>
</tr>
<tr>
<td>SNSTU</td>
<td>1/</td>
<td>997.937</td>
</tr>
<tr>
<td>SNUL</td>
<td>1/</td>
<td>243533.135</td>
</tr>
<tr>
<td>SHST</td>
<td>1/</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**EQUIVALENT ELECTRICITY COSTS**
- Csnstl 3400.799
- Csnstl 84.025
- Csnstl 20702.754

#### PERIOD TOTALS:

<table>
<thead>
<tr>
<th>Period</th>
<th>NO. YEARS:</th>
<th>CELL DEGR: 0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>P55-</td>
<td>1/</td>
<td>46597.0</td>
</tr>
<tr>
<td>PDD-</td>
<td>1/</td>
<td>283553.6</td>
</tr>
<tr>
<td>PGEN-</td>
<td>1/</td>
<td>0.0</td>
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<tr>
<td>PDD-</td>
<td>1/</td>
<td>0.0</td>
</tr>
<tr>
<td>PGEN-</td>
<td>1/</td>
<td>0.0</td>
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<tr>
<td>PDD-</td>
<td>1/</td>
<td>0.0</td>
</tr>
<tr>
<td>PDSTL</td>
<td>1/</td>
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</tr>
<tr>
<td>PDSTU</td>
<td>1/</td>
<td>997.937</td>
</tr>
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<td>PDUL</td>
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<tr>
<td>PDUST</td>
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<td>0.0</td>
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</table>

**EQUIVALENT ELECTRICITY COSTS**
- CPDSTL 3400.799
- CPDSTU 84.025
- CPDUL 20702.754
- CPDWST 0.0
## CONVERSATIONAL MONITOR SYSTEM

### FIGURE 4-4-3b

**DEMAND CHARGE ACCOUNTING AT 732 DEMAND INTERVALS**

---

**PERIOD 1**

**SECTION 1** WITH 12 DEMAND PERIODS

<table>
<thead>
<tr>
<th>Period</th>
<th>Demand Periods</th>
<th>Total Demand</th>
<th>Final Demand</th>
<th>Demand Charge Accounting</th>
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<tbody>
<tr>
<td>1/</td>
<td>94.800</td>
<td>94.800</td>
<td>94.800</td>
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</tr>
<tr>
<td>2/</td>
<td>96.000</td>
<td>96.000</td>
<td>96.000</td>
<td></td>
</tr>
<tr>
<td>3/</td>
<td>72.800</td>
<td>72.800</td>
<td>72.800</td>
<td></td>
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<tr>
<td>4/</td>
<td>68.000</td>
<td>68.000</td>
<td>68.000</td>
<td></td>
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<tr>
<td>5/</td>
<td>61.600</td>
<td>61.600</td>
<td>61.600</td>
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<tr>
<td>6/</td>
<td>61.600</td>
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<tr>
<td>7/</td>
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<td>70.000</td>
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**RUN TOTALS**

- **No. Periods:** 1
- **No. Sections per Period:** 1
- **Array Size:** 0

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<thead>
<tr>
<th>Item</th>
<th>Value</th>
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<tbody>
<tr>
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<td>ID0</td>
<td>28353.8</td>
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<tr>
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<td>ITWST</td>
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</table>

**Equivalent Electricity Costs**

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<tr>
<td>CTOSTL</td>
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<td>CTOSTU</td>
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<td>CTOWST</td>
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**Supply Node Summaries:**

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<tbody>
<tr>
<td>TTL SMTH HRS</td>
<td>1/ 8760.00</td>
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<tr>
<td>TTL GEN HRS</td>
<td>1/ 4721.00</td>
</tr>
<tr>
<td>Peak Generation</td>
<td>1/0.041900E+02</td>
</tr>
<tr>
<td>Year Hour of PK</td>
<td>1/ 4705.00</td>
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<tr>
<td>Avg Generation</td>
<td>1/0.331900E+01</td>
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<td>TTL Generation</td>
<td>1/0.485979E+05</td>
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</table>

**Demand Node Summaries:**

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<th>Item</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>TTL SMTH HRS</td>
<td>1/ 8760.00</td>
</tr>
<tr>
<td>TTL GEN HRS</td>
<td>1/ 4721.00</td>
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<tr>
<td>Peak Load</td>
<td>1/0.010270E+03</td>
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<tr>
<td>Year Hour of PK</td>
<td>1/ 4570.00</td>
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<tr>
<td>Avg Load</td>
<td>1/0.323059E+02</td>
</tr>
<tr>
<td>TTL Load</td>
<td>1/0.203554E+06</td>
</tr>
</tbody>
</table>
IV.4d. Economic Summaries

A parameter echo and performance summary for project financial characteristics follows the physical performance summary on disk file FI = IWF (CII OUTPUT). This output is subject to the specification of KEV = 0, 1 or 2 in the interactive sequence or LEAP file (IV.3g). There are three optional financing considerations, subject to the selection of INVSTR = 1, Homeowner; 2, commercial/industrial and 3, utility financing (IV.3g). Output from the selection of these options is depicted in figures 4-4-4 through 4-4-6. Parameter echoes include the run name, utility sellback for each energy quality, the construction year capital costs for the primary component and balance of system, as well as operation expenses for each generation node, all at low, medium, and high cost assumptions. The parameters specific to each financing method are then repeated, along with the yearly price inflators for each energy quality type. A summary of all worth figures transferred to the economics package from the physical operation model is then listed under FIRST YEAR BENEFITS. These are used later when operating solely the economics portion for economic sensitivity studies (IV. 4g).

Finally, in each of the figures is listed the bottom-line economics. For each of the financing mechanisms, these are defined as follows:

<table>
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<tr>
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<tr>
<td>1</td>
<td>low cost assumption</td>
</tr>
<tr>
<td>2</td>
<td>medium cost assumption</td>
</tr>
<tr>
<td>3</td>
<td>high cost assumption</td>
</tr>
</tbody>
</table>
CONVERSATIONAL MONITOR SYSTEM

**CONOMICS**

*HOMEN OWNER FINANCING*

**FIGURE 4-4-4**

**SHELLBACK FOR E-QUAL I**

1991/ 1.00 1992/ 1.00 1993/ 1.00 1994/ 1.00 1995/ 1.00 1996/ 1.00 1997/ 1.00 1998/ 1.00 1999/ 1.00 2000/ 1.00 2001/ 1.00 2002/ 1.00 2003/ 1.00 2004/ 1.00 2005/ 1.00 2006/ 1.00 2007/ 1.00 2008/ 1.00 2009/ 1.00 2010/ 1.00

**GENERATION NODE 1:**

1991/ 1.00 1992/ 1.00 1993/ 1.00 1994/ 1.00 1995/ 1.00 1996/ 1.00 1997/ 1.00 1998/ 1.00 1999/ 1.00 2000/ 1.00 2001/ 1.00 2002/ 1.00 2003/ 1.00 2004/ 1.00 2005/ 1.00 2006/ 1.00 2007/ 1.00 2008/ 1.00 2009/ 1.00 2010/ 1.00

**HOMEOWNER FINANCING PARAMETERS**

**PRICE INFLATOR FOR E-QUAL I**

1991/0.03 1992/0.03 1993/0.03 1994/0.03 1995/0.03 1996/0.03 1997/0.03 1998/0.03 1999/0.03 2000/0.03

**FIRST YEAR BENEFITS:**

1991/0.3400E+04 2/0.64025E+02 3/0.3000E+04 4/0.1434E+02 5/0.0 6/0.0 7/0.12302E+01 8/0.25344E+00 9/0.29150E+01 10/0.62000E+01 11/0.55999E+01 12/0.43153E+01 13/0.82000E+01 14/0.55660E+00 15/0.17513E+01 16/0.0 17/0.0 18/0.0 19/0.0 20/0.0

**SYFED ICST PROFIT:**

1996 1 0.31900E10 0.06099E00 0.59521E00 0.14347E02 0.25344E00 0.21545E04 0.41070E05 0.10893E01 0.42319E00

1996 2 0.10400E10 0.06099E00 0.17900E00 0.17933E02 0.14347E02 0.25344E00 0.21545E04 0.41070E05 0.10893E01 0.42319E00

1996 3 0.55913E02 0.79999E01 0.99980E01 0.21510E02 0.32110E04 0.43409E05 0.12942E01 0.42319E00
**Figure 4-4-5**

COMMERCIAL/INDUSTRIAL/INSTITUTIONAL FINANCING

---

**RUN NAME: HARVEY**

**SELCBACK FOR E-QUAL 1**

1991/0.54 1992/0.54 1993/0.54 1994/0.54 1995/0.54 1996/0.54 1997/0.54 1998/0.54 1999/0.54 2000/0.54 2001/0.54 2002/0.54 2003/0.54 2004/0.54 2005/0.54 2006/0.54 2007/0.54 2008/0.54 2009/0.54 2010/0.54

**GENERATION NODE 11: 200.00 M2 PV**

- **Primary Capital Component in 1986:** $/0.100215E+05
- **Balance of System in 1986:** $/0.145605E+05
- **Medium Operating Costs in (Proj Yr):** $/0.4912E+03
- **BOS Costs in $/M2 of Array (LHS):** 72.00 91.00 109.20

---

**FINANCING PARAMETERS**

- **A:** 0.07 **B:** 1.00 **C:** 0.40 **D:** 1.00 **E:** 0.05 **F:** 0.40
- **G:** 0.10 **H:** 0.10 **I:** 0.10 **J:** 0.01 **K:** 0.0

**PRICE INFLATION FOR E-QUAL 1**

1981/0.03 1982/0.03 1983/0.03 1984/0.03 1985/0.03 1986/0.03 1987/0.03 1988/0.03 1989/0.03 1990/0.03 1991/0.03 1992/0.03 1993/0.03 1994/0.03 1995/0.03 1996/0.03 1997/0.03 1998/0.03 1999/0.03 2000/0.01 2001/0.01 2002/0.01 2003/0.01 2004/2005/0.01 2006/0.01 2007/0.01 2008/0.01 2009/0.01 2010/0.01

**FIRST YEAR BENEFITS: WORTH**

1/0.34000E+04 2/0.8405E+01 3/0.0 4/0.0 5/0.0
6/0.0 7/0.33905E+07 8/0.67954E+07 9/0.81153E+07 10/0.90305E+07
11/0.01797E+01 12/0.1797E+01 13/0.15505E+02 14/0.21392E+02 15/0.30576E+01
16/0.5021E+01 17/0.0 18/0.0 19/0.0 20/0.0

**SYF-00 ICST PROFIT**

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<th>YEAR</th>
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<tbody>
<tr>
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<td>0.7653E+01</td>
</tr>
<tr>
<td>1590</td>
<td>0.7639E+01</td>
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<tr>
<td>1593</td>
<td>0.6492E+01</td>
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<tr>
<td>1596</td>
<td>0.3765E+01</td>
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<tr>
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<td>0.2153E+04</td>
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</table>

**SYF-00 ICST PROFIT**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ICST PROFIT</th>
</tr>
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<tbody>
<tr>
<td>1587</td>
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<tr>
<td>1590</td>
<td>0.000</td>
</tr>
<tr>
<td>1593</td>
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<td>1596</td>
<td>0.000</td>
</tr>
<tr>
<td>1598</td>
<td>0.000</td>
</tr>
</tbody>
</table>
### Utility Economics

#### Utility Financing Parameters

- **DR:** 0.07
- **AINFL:** 0.05
- **TR:** 0.48
- **BETA1:** 0.0200
- **BETA2:** 0.0025
- **EESC:** 0.0800
- **AKWH:** 0.465979E+05
- **GC:** 0.05
- **GM:** 0.06
- **NBLDYR:** 1

#### First Year Benefits

- **ISYFB0:** 1
- **ICST:** 0.3400080E+04
- **CFR:** 0.840251E+02
- **FCR:** 0.0
- **AC:** 0.0
- **CI:** 0.0
- **BLEC:** 0.0
- **BLEB:** 0.0

#### Laboratory Costs

- **1986:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1987:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1988:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1989:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1990:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1991:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1992:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1993:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1994:**
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  - **2:** 0.15797184
  - **3:** 0.15797184

- **1995:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1996:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1997:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1998:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **1999:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2000:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2001:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2002:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2003:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2004:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2005:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

- **2006:**
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  - **2:** 0.15797184
  - **3:** 0.15797184

- **2007:**
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  - **2:** 0.15797184
  - **3:** 0.15797184

- **2008:**
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  - **2:** 0.15797184
  - **3:** 0.15797184

- **2009:**
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  - **2:** 0.15797184
  - **3:** 0.15797184

- **2010:**
  - **1:** 0.09439343
  - **2:** 0.15797184
  - **3:** 0.15797184

---

**Figure 4-4-6**

**Utility Economics**

**Utility Financing**
The economic methodology used under each financing regime is discussed in section II.2.

If the dynamic costing option is selected in the economic parameter file (KDC = 1; see IV.3f), then the latter portion of figures 4-4-4 through 4-4-6 are extended to include computation of the above figures subject to a delay of construction beyond ISYF80 (as set in IV.3f) and up to the year 2000. Example output is shown in figure 4-4-7.

For commercial/industrial sector analysis, if the operational study option (III.2) is selected and dynamic costing is desired, then the optimum financial result (max profit, max rate of return, min years to payback, etc.) is displayed over the list of parameter changes as defined by the operational study. Figure 4-4-8 lists output which displays these optimum results, and the capacity figure of that optimum
## Dynamic Costing Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>SYFB</th>
<th>ICST</th>
<th>Profit</th>
<th>RCR</th>
<th>YPS</th>
<th>SYBECC</th>
<th>BECC-1</th>
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<td>0.178070E+01</td>
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<td>1988</td>
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<td>0.827658E+04</td>
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<td>0.182447E+01</td>
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<td>1988</td>
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<td>0.78197E+03</td>
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<td>1988</td>
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<td>0.214216E+01</td>
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<td>1988</td>
<td>4</td>
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<td>0.213691E+01</td>
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<tr>
<td>1988</td>
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<td>0.211792E+01</td>
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# Figure 4-4-8

**Dynamic Costing Results**

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<tr>
<th>JSYFBD IC</th>
<th>PROF (CAP)</th>
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<th>SECC (CAP)</th>
<th>C18ECC (CAP)</th>
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<td>200. 0.990365E+00</td>
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</table>

**Dynamic Costing Summary**

*Optimized*
value (in this case, the capacity of the generator at node 1, varied from a 0 to 500 m² PV array).

IV.4e Reliability Summaries

For the modeling of remote, stand-alone systems utilizing generation and storage, appropriate component sizing is important to maximize service reliability and minimize operating and capital cost. A reliability report is issued on disk file (FI= ISA) when such applications are modeled on OESYS (selected as RUN = 273). An example report is shown in figure 4-4-9. The output features four classes of simulation characteristics, (1) an echo of component sizing parameters, (2) run characteristics, (3) reliability indices, and (4) hardware sizing indices. The latter three are defined below and refer to figure 4-4-9:

1) RUN CHARACTERISTICS:

Peak hourly load (PKDMD) - peak hourly demand (kwh or kw) taken directly from the load profile.

Average Hourly Load (AVGL) - average load (kwh) as averaged over all hourly demand as taken directly from the load profile for the duration of the simulation life.

Average Daily Load (AVGOL) - simply AVGL multiplied by 24 hours (kwh).

Peak Nonsolar Interval Energy Demand (PkNL) - Maximum amount of energy demanded (kwh) from the list of nonsolar intervals. A nonsolar interval starts at sundown (no solar direct nor diffuse radiation) and ends at sunup (positive direct or diffuse radiation).

Average Nonsolar Interval Energy Demand (AVANL) - Average amount of energy demanded (kwh) from the list of nonsolar intervals as defined in (PkNL) above.

Peak Nonsolar Hour Power Demand (PkPk) - Peak power demand (kw) that occurred in a nonsolar interval as defined above under (PkNL).
FILE: RELIAB OUTPUT CONVERSATIONAL MONITOR SYSTEM

ASIA PARAMETERS

STAND ALONE GENERATION/STORAGE -- NO UTILITY
STANDARD RUN LIFE -- SINGLE YEAR

RELIABILITY SUMMARY

HARDWARE PARAMETERS

\[
\begin{align*}
\text{ACOL}: & \quad 1000.00 \\
\text{CAP7}: & \quad 200.00 \\
\text{E\text{H}7}\text{H}: & \quad 50.00 \\
\text{C7MX}: & \quad 140.00 \\
\text{D7MX}: & \quad 142.00 \\
\text{F}% 5\text{Y}: & \quad 0.2000 \\
\text{ES\text{OT}}: & \quad 0.0030 \\
\text{N\text{E}H}: & \quad 2 \\
\text{N\text{E}O\text{T}}: & \quad 2 \\
\text{N\text{E}M}: & \quad 2 \\
\text{N\text{E}G}: & \quad 2
\end{align*}
\]

RUN BEGIN HOUR: 5521 RUN END HOUR: 5520

SERVICE RELIABILITY SUMMARY

\[
\begin{align*}
\text{EAVG HOURLY LOAD (KWH)} & \quad 102.38 \\
\text{AVG DAILY LOAD (KWH)} & \quad 32.37 \\
\text{EPEAK NONSOLAR INTERVAL ENERGY DMD (KWH)} & \quad 1125.02 \\
\text{AVG NONSOLAR INTERVAL ENERGY DMD (KWH)} & \quad 259.99 \\
\text{PEAK NONSOLAR HOUR POWER DMD (KW)} & \quad 96.00
\end{align*}
\]

RELIABILITY

\[
\begin{align*}
\text{SERVICE RELIABILITY INDEX} & \quad 0.43 \\
\text{SERVICE UNAVAILABILITY INDEX} & \quad 0.57 \\
\text{LOSS OF LOAD PROBABILITY} & \quad 0.99 \\
\text{LOSS OF LOAD DAYS (YEAR AVG)} & \quad 361.00 \\
\text{AVG DURATION OF LOSS OF LOAD} & \quad 1.00 \\
\text{AVG DURATION OF CONTINUOUS LOAD} & \quad 0.78 \\
\text{CUSTOMER AVG INTERRUPTION FREQUENCY INDEX} & \quad 492.00 \\
\text{CUSTOMER AVG INTERRUPTION DURATION INDEX} & \quad 1.00
\end{align*}
\]

(CST HRS AVL/CST HRS SRVD) (UNAVL SRVC HRS/TOT CST HRS DMDD)

(TOT FAIL DAYS/TOT RUN DAYS) (EXPECTED LOL DAYS PER YEAR)

(HOURS DOWN/DOUTAGE) (HOURS UP/UP PERIOD)

(10T CST INTRT/10T CSTS) (10T CST INTRT DURATIONS/NO CSTS INTRTD)
## Conversational Monitor System

**FILE: RELIAB OUTPUT A**

**CONVERSATIONAL MONITOR SYSTEM**

**PAGE 002**

<table>
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<tr>
<td>Number of Demand Hours in a Period</td>
<td>8760 (HOURS)</td>
</tr>
<tr>
<td>Avg Demanded Energy Not Satisfied</td>
<td>25.71 (KWH/OUTAGE)</td>
</tr>
<tr>
<td>Avg Demanded Power Not Satisfied</td>
<td>25.71 (KW)</td>
</tr>
<tr>
<td>Max Energy Shortage over List of Outages</td>
<td>128366.12 (KWH/LARGEST OUTAGE)</td>
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<tr>
<td>Max Power Shortage over List of Outages</td>
<td>107.62 (KW)</td>
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<tr>
<td>Total Number Hours Energy was Demanded</td>
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</tr>
<tr>
<td>Number of Days There Occurred Loss of Load</td>
<td>361</td>
</tr>
<tr>
<td>Total Number Days of Demand</td>
<td>365</td>
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<tr>
<td>Total Hours Demand Not Satisfied</td>
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<tr>
<td>Number of Customers</td>
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### Hardware Sizing

**Figure 4-4-9b**

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<td>Avg Energy Lost</td>
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<td>Max Excess Charge Differential (KW)</td>
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<tr>
<td>Power Discharge Limiter</td>
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<td>Total Demand Not Met</td>
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<tr>
<td>Avg Demand Not Met (KWH)</td>
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<td>Energy Capacity Limiter (Overcharge)</td>
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<tr>
<td>Total KWH Wasted Due to Overcharge</td>
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<td>Avg KWH Wasted</td>
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<td>Max Overcharge (KWH)</td>
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<tr>
<td>Energy Capacity Limiter (Undercharge)</td>
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<tr>
<td>Total Energy Not Met (KWH)</td>
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<tr>
<td>Avg Energy Not Met (Each Hour)</td>
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<tr>
<td>Max Deficient Energy</td>
<td>107.62</td>
</tr>
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</table>
2) SUMMARY OF RELIABILITY INDICES USED IN SOLIPS

Service Reliability index (SRI) - total customer hours available over the customer hours served

Service Unavailability Index (FOR) - equivalent to 1-SRI and is greater than or equal to the forced outage rate (since Forced Outage Rate does not take into account maintenance.) Defined as the cumulative customer hours that service was unavailable during a run over the total customer hours demanded.

Loss of Load Probability (LOLP) - expected or long term average number of days on which daily peak load exceeds the available installed capacity. Defined as the total number of days there was a failure over the total number of days of run.

Loss of Load Days (LOLT) - expected number of days in a year when a load appears. (LOLP * 365)

Average Duration of Loss of Load (DURLOL) - average number of hours down when an outage occurs. (units of hours)

Average Duration of Continuous Load (DUREXP) - average duration of continuously supplied load before an outage interruption occurs.

Customer Average Interruption Frequency Index (CIFI) - average number of interruptions per customers served. Defined as the total number of customers interrupted over the number of customers served.

Customer Average Interruption Duration Index (CIDI) - average interruptions for customers interrupted during a specific time period. Defined as the total number of customer interruption durations over the number of customers interrupted.

Total Energy Not Met (TENM) - total kwh energy not satisfied over the simulation run life.

Average Demanded Energy Not Satisfied (DENS) - energy (kwh) sum which is not satisfied in an average outage.

Average Demanded power Not Satisfied (DPNS) - average power (kw) which is not satisfied during an outage.

Maximum Energy Shortage Over List of Shortages (ELOLMX) - maximum energy (kwh) not satisfied as summed over the list of outages.

Maximum Power Shortage Over List of Outages (PLOLMX) - maximum power demanded (kw) which went unsatisfied.

Total number of Hours Energy Was Demanded (NHRDMD) - total hours over simulation run life that there occurred a positive load.
Number of Days There Occurred Loss of Load (NDLOL) - total number of days over simulation run life that at least one outage occurred.

Total Number of Days of Demand (NDAYS) - total number of days over simulation run life (up to one year) that there occurred a positive load.

Total Hours Demand Not Satisfied (TOTOUT) - total hours over run life (up to a year) that demand was not satisfied.

Number of Customers (NCUST) - number of customers served in an application; defined as the number of separate billings made.

HARDWARE SIZING

Total Energy Lost (TOSA71) - total energy (kwh) wasted as a result of exceeding change rate capacity of the hardware.

Number of Power Overcharge Incidents (I2FA)

Average Energy Lost (TOSA71/I2FA) - average energy (kwh) wasted during an excess charge rate incident.

Maximum Excess Charge Rate Differential (SA71MX) - Maximum difference between power supplied and maximum charge rate C7MX.

POWER DISCHARGE LIMITS

Total Demand Not Met (TOSA72) - total (kwh) demand not met due to limitations on discharge capacity.

Number of Power Excess - Discharge Incidents (I2SLO) -

Average Demand Not Met (TOSA72/I2SLO) - average (kwh) not met as a result of demand exceeding discharge capacity of the hardware.

Maximum Excess Power Demanded (SA72MX) - maximum excess power demanded (kw) (difference between demand and maximum discharge capacity C7MX).

ENERGY CAPACITY LIMITS (overcharge)

Total kwh Wasted Due to Overcharge (TOSA73) - total kwh wasted due to overcharging of storage beyond the storage capacity (CAP7).

Total Number of Overcharge Incidents (I2HI)

Average kwh Wasted (TOSA73/I2HI) - average amount of energy wasted (kwh) as a result of exceeding the storage capacity.

Maximum Overcharge (SA73MX) - maximum difference between energy supplied and the capacity of the storage unit.
ENERGY CAPACITY LIMITS (UNDERCHARGE)

Total Energy Not Met (TOSA74) - total energy (kwh) that storage was deficient in satisfying over run life.

Total number of Undercapacity Incidents (I2LO) -

Average Energy Not Met (TOSA74/I2LO) - average energy (kwh) storage was deficient over the list of undercapacity incidents.

Maximum Deficient Energy (SA74MX) - maximum energy storage was deficient in satisfying for the duration of the outage over the list of outages (kwh).

IV.4f Plot Options

Specific parameter and variable values can be directed to OESYS plot files in a format readily adapted to post-processor plotting packages. OESYS is currently structured to output one set of physical performance characteristics and four types of economic performance relationships.

Physical Performance Characteristics

A Decision in favor of the plot option in the interactive sequence forces 3 parameters to be set, either in that sequence or in the interactive bypass file (IV.3g). Those parameters are

PLTFLG
PLTINC
NPPER

where

PLTFLG = 0 for no plots
= 1 to initiate plot option

PLTINC = Simulation interval multiple at which plot data is to be issued. If PLTINC = 168., plot data is issued weekly, etc.

NPPER = Number of days of plot data to be issued beginning at the start of each plot increment.
The plot data is output in file FI = IMAP (IV.3d) and is of the following format:

Line 1:  RUNNAM, YRHR  
Line 2-25: HOUR, VAL(1), VAL(2), VAL(3)

where

RUNNAM  Program run name
YRHR    Hour of the year at 1:00 a.m. of this plot day
HOUR    Hour of the day (1-24)
VAL(1)   Sum of all energy of energy quality 1 and 2 (IV.1e) demanded this hour, without generation
VAL(2)   Sum of all energy of energy quality 1 and 2 (IV.1e) demanded this hour, less all energy of the same quality generated
VAL(3)   All energy of quality 2 generated at node 1 this hour.

The first page of an example output file illustrating this format for a photovoltaic-matched bank in Phoenix, Arizona is shown in figure 4-4-10.

Economic Performance Summaries

OESYS currently outputs four economic functional characteristics when either the homeowners or commercial/industrial finance strategy is selected. The first three of these all relate system profit, system breakeven capital cost, and component breakeven capital costs according to the capacity of the generator at supply node 1. Figure 4-4-11 shows an example of these listings and identifies their respective files. The format used is as follows:

Line 1:  ID, NPTS, SLBK(1,1)  
Line 2 through SS(1,5), A1, A2, A3  
NSPS:  

where;

ID   =  1 if system Breakeven Capital Cost follows
    =  2 if component Breakeven Capital Cost follows
    =  3 if net benefit figures follow
## FIGURE 4-4.22
**DYNAMIC COSTING PLOT FIGURES**

<table>
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<tr>
<th>FILE</th>
<th>DCOS</th>
<th>PLOT</th>
<th>A</th>
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<td>5. 0.560000E-01</td>
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<td>105</td>
</tr>
</tbody>
</table>
NPTS = number of lines which follow
SLBK(1,1) = utility sellback price for energy quality 1 in 1981
SS(1,5) = capacity at generation node 1
A1 = estimate of SYSBECC/Unit BECC/PROFIT (corresponding to ID above) at low cost estimates
A2 = estimate of SYSBECC/Unit BECC/PROFIT (corresponding to ID above) at medium cost estimates
A3 = estimate of SYSBECC/Unit BECC/PROFIT (corresponding to ID above) at high cost estimates.

The fourth economic plot listing presents the output of the dynamic costing facility on OESYS. Figure 4-4-12 depicts this data summary, found in file FI=IA2. These data includes the optimal value criteria described in section IV.4d where figure 4-4-8 was described. The format used in this file is as follows:

JSY, IC, DPROF, CPROF, DROR, CROR, DYPB, CYPB, DSBECC, CSBECC, DCBECC1, CCBECC1, DCBECC2, CCBECC2

FORMAT(1x, I4, 2X, I1, 6(1X, E12.6, 1X F5.0)) Set in Subroutine OUTEC3

where;
JSY = year of project construction start
IC = cost assumption (1 = low, 2 = medium, 3 = high) upon which the remaining values in that row are calculated
DPROF = the maximum profit for the unit generation capacities studied in this run
CPROF = The capacity of the unit generator SS(1,5) at node 1 which yielded DPROF (i.e., the optimum capacity)
DROR = maximum rate of return for this study
CROR = SS(1,5) at DROR (optimum capacity)
DYPB = minimum years to payback for this study
CYPB = SS(1,5) at DYPB (optimum capacity)
DSBECC = maximum system breakeven capital cost for this study
CSBECC = SS(1,5) at DSBECC (optimum capacity)
DCBECC1 = maximum component breakeven capital cost of unit defined at supply node 1 of this study
CCBECC1 = SS(1,5) at DCBECC1
DCBECC2 = maximum component breakeven capital cost of unit defined at supply node 2 of this study
CCBECC2 = SS(1,5) at DCBECC2

By "study" is meant a physical operation study run which varies the capacity of the unit at generation node 1 (SS(1,5)) with each run iteration (see VI.1a).

IV.4g. First Year Benefit Data

The final example of post-processor data output is that of figure 4-4-13. This data is suited to the use of OESYS as the post-processor, as it represents that output of a physical operation run which is essential to a performance of the economic valuation. This data is output to file FI = IAI from subroutine OUT4C. The data format shown is as follows:

2 lines per run:

CAP, TOTSL WORTH(1-8) FORMAT(10E12.6)
WORTH(9-18) FORMaT(10E12.6)

where;

CAP = capacity of the unit at supply node 1
TOTSL = total energy output at that supply node
WORTH(1) = dollar worth of energy of quality 1 and 2 to be considered a direct benefit to the project
### FIRST YEAR COST/BENEFIT DATA

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<td>0.000000E+00</td>
</tr>
<tr>
<td>0.500000E+00</td>
<td>0.340306E+00</td>
<td>0.38027E+00</td>
<td>0.925101E+02</td>
</tr>
<tr>
<td>0.736373E+00</td>
<td>0.403178E+00</td>
<td>0.324234E+03</td>
<td>0.000000E+00</td>
</tr>
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</tr>
<tr>
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<td>0.625373E+00</td>
<td>0.995292E+00</td>
<td>0.324234E+03</td>
</tr>
<tr>
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</tr>
<tr>
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<td>0.936655E+00</td>
<td>0.171766E+00</td>
<td>0.182587E+00</td>
</tr>
<tr>
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</tr>
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<td>0.871243E+00</td>
<td>0.547310E+00</td>
<td>0.767038E+00</td>
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<td>0.000000E+00</td>
</tr>
<tr>
<td>0.500000E+00</td>
<td>0.340306E+00</td>
<td>0.38027E+00</td>
<td>0.925101E+02</td>
</tr>
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</tr>
<tr>
<td>0.500000E+00</td>
<td>0.340306E+00</td>
<td>0.38027E+00</td>
<td>0.925101E+02</td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
<td>0.205420E+01</td>
<td>0.911639E+01</td>
<td>0.581539E+01</td>
<td>0.179760E+02</td>
</tr>
</tbody>
</table>

![Figure 4-13](image-url)
WORTH(2) = dollar worth of energy of quality 1 and 2 to be multiplied by a utility buyback rate

WORTH(3) = dollar worth of energy of quality 1 and 2 to be subtracted from total benefits (energy purchased for storage)

WORTH(4) = undefined

WORTH(i) = i = 5-16
The capacity (kw) credit to be given the unit during interval i due to load displaced by the generator at time of peak load during that interval.

WORTH(17-20) = undefined

Although these values are defined here, they can be varied as the user chooses. What is important is that their values, set in subroutine OUT4A, be matched to the appropriate variables in subroutine FIBEN, where they are retrieved from that file to be used in the economic evaluation. Examples of figures passed are node capacities for use in estimating total capital costs, total generation output, the value of energy displaced, the value of energy sold to the utility, and the load displaced by a generator during that interval at which a capacity charge was determined for a user. To determine what variables are of significance to a user under these conditions, it is necessary to first identify those subroutines from the flowcharts of section IV.1c where these variables are likely set, then locate their common in the cross reference of appendix C, and rewrite the WRITE and READ statements of subroutines OUT4A and FIBEN, respectively. This is only necessary if it is desired to run the "economics only" option, however. For running that option, this output data file must be transferred to file FI = 1P3. The parameter KEV must be set to 2 in the interactive sequence or
interactivebypass file. If more than two lines are shown in this file and a multiple run study is chosen (for parameter sensitivity studies), it is necessary to match the study used in the economics-only study with that study used to generate the benefits output file. Specifically, CAP (above) for each run must match SS(1,5) calculated for that run in subroutine STLOOP.
V. Secondary Data Inputs and User-Designed Logics

OESYS was designed to provide a skeletal structure within which to model a wide range of energy applications. The design trade-off was against the constraints imposed by application detail. To maintain a high degree of modeling versatility, OESYS was modularly designed to accept user specified logics for various modeling systems. This section describes those options, as well as the format requirements for the user interface. It is first examined at how both physical operation and economic study options are implemented. Here, it is possible to fix the program to iterate through entire simulation runs, automatically incrementing a pre-specified parameter. This is a useful option for parametric sensitivity analysis. Application logics in addition to those of section IV.2 must be user specified, and the interfacing requirements are discussed here. A discussion of how to code for the characteristic output of each application logic follows. Since the user may wish to experiment with various user consumption elasticities, unit outage logics, formulations for transmission and distribution losses, and alternative utility pricing or backup characteristics, these have been modularly structured as black-box logics which readily accept user definition, and these are discussed. Finally, the characteristics of all OESYS post-processor output, including plot data, is provided.

V.1 Alternative Study Options for Parameter Sensitivity Analysis

In order to save computation time both modeling portions of OESYS, the physical operation model and the economic model, offer options for incrementing parameter values during run iterations. The options for each modeling portion are examined here.
V.1a Physical Parameter Iteration

The operational study option allows for sensitivity analysis to be carried out for parameters of the physical parameter file (IV.3e). This option is declared at the first question after specification of the run name in the interactive question sequence. Requesting this option assumes the following:

1) all interactive parameters have been fixed in the interactive bypass (LEAP) file.
2) the parameter iteration formula has been defined in subroutine STLOOP.

The first requirement has been discussed in section IV.3g. The second requirement is explained here.

When the study-iteration option is selected, the program reads both the physical and interactive parameter files and then passes through subroutine STLOOP to increment any parameter, or mix of parameters, desired. Thus, the parameter fix in SR STLOOP overrides the value set in either parameter file. At the end of a run, the program repeats this sequence. Limits are placed on incrementing within SR STLOOP and an end flag is issued when the final run is reached. A sample subroutine description is shown in figure 5-1. The dashed lines of this figure border that area where the incrementing variables are defined. The star lines enclose that area where parameters are incremented. The user will normally only need to reset values within the dashed lines once the increment logic is set outside of those lines. The logic used here is self-explanatory. The variables IQUIT and ILRUN must be set as follows:

\[
\text{QUIT} = 1 \quad \text{if the last iteration has been completed} \\
\text{ILRUN} = 1 \quad \text{if the last iteration is next to be run.}
\]
SUBROUTINE STLOOP(RUN, IQUIT, ILRUN)
COMMON/IOT/ IWT, IRF, IWF, IWH, IPI, IEV, IPV2, IPV3, ISA1
   1. ISA2, ISA3, IMAPI, IST, ID1, ID2, ID3
COMMON/SSO/ SS(20,20), CO(20,20), SSS(20), SOD(20), PSS(20)
   1. POD(20), TSS(20), TOD(20), NSS, NOD
COMMON/WRTM/ SLSK(0,30)
   1. ORTH(10,5), VALU(10), NEQU

IQUIT=0
ILRUN=0

C********************************************************************
C SET RUN PARAMETER CHANGES
C********************************************************************
C INCREMENT:
  AINC=100.
C START VALUE (AINC = ASTART IS START VALUE)
  ASTART=-95.
C END VALUE
  AEND=505.
C TOTAL NUMBER OF POINTS:
  NPTS=INT((AEND-ASTART)/AINC)
C ARUN=FLOAT(I RUN)
  SS(1.5)=(ARUN+AINC)+ASTART
  IF(SS(1.5).GT.AEND)IQUIT=1
  IF((SS(1.5)+AINC).GT.AEND)ILRUN=1
C WRITE TO PLOT FILES IF THIS IS THE FIRST TIME THROUGH
  IF(I RUN.NE.1)GO TO 10000
  I1=1
  I2=2
  I3=3

FIGURE 5-1
SUBROUTINE STLOOP
Physical Parameter Sensitivity Runs
V.1b Economic Iteration

The economic study option is declared by default, although parameters are set elsewhere in the parameter files which dictate the number of iterations performed. The study is structured in subroutine STDYEC, where the following variable must be set:

\[ IQUEC = 1 \text{ if this is the last iteration to be performed.} \]

\( (IQUEC = 0 \text{ before entering STDYEC}). \)

A sample STDYEC routine is shown in figure 5-2. The user inputs FORTRAN code between the star lines. Setting only the value \( IQUEC = 1 \) between the star lines would dictate that one economic finance simulation be performed according to the parameter values set in the economic parameter file (IV.3f). The routine shown in the sample figure is that used for the dynamic project appraisal option. The code is self-explanatory, \( JSYF80 \) (construction start years from 1980) by 1 year for every iteration. Since the call to SR STDYEC follows the reading of parameter values in the program sequence, specification of \( JSYF80 \) in SR STDYEC overrides that setting in the parameter file. The variable \( ISTEC \) is set exogenously to SR STDYEC and is a counter for the number of iteration runs.

V.2 Additional Operating Logics

Section IV.2a described the application types currently available on OESYS while section II.1 discussed the myriad possibilities of real world application types. OESYS has been designed to allow for the gradual addition of logics as discussed in section II.1. The following is a checklist outline of the necessary interface requirements for
SUBROUTINE STOYSC(ITSI, C:A, NSTEC, IOUEC)

CCVu=N/I/1:WT.I
RT, aF!, WF. 141PVLP7EL !PV2,IPV3.15AI
1.ISA2.ISA3. .IMAP.IST.
10D,.2.
03
WFK

COMMON/EC4/I LOOK.LQOX,I.SYP0,JSYF50.RLI9E.
KC.
I.vsTR,KSEC.1,KEC:
1,KCOLA
C SR STOYEC IS THE DRIVER FOR ECONOMIC STUDIES BASED ON THE
PREVIOUS APPLICATION SIMULATION. WHEN STOYEC RETURNS IOUEC=1
TO THE MAIN PROGRAM (TEST2), THE LAST ECONOMIC ITERATION IS
FLAGGED.
ISTEC IS THE NUMBER OF ECONOMIC ITERATION SO FAR.

IF(ITSI.EQ.1)WRITE(INT, 9)
FORMAT(' READING STOEC . . ')

100 FORMAT(' FROM STOYEC: ECONOMIC ITERATIONS EXCEED 20 — ',/1
' PROGRAM ENDING . . ')
IF(ITSI.GT.20)IF(ISTEC.GT.20)GO TO 10000

IF THIS IS A DYNAMIC COSTING RUN, ITERATE START YEAR FROM ILOOK
TO 2000 SO THAT J = ILOOK TO 21 AND SET END FLAG (IOUEC) WHEN
JSYFB0=21
IF THIS IS NOT A DYNAMIC COSTING RUN, PERFORM 1 ITERATION ON
THE GIVEN JSYFB0 AND END ECONOMIC STUDY

NIT IS NUMBER OF ECONOMIC ITERATION TO BE MADE

IF(KOC.EQ.1)NIT=2000-ILOOK
IF(KOC.NE.1)NIT=1
C SET START YEAR FROM 1980 ON THIS ITERATION: JSYFB0 IS USER
INPUT  —  BUT JSYFB0 IS WHAT ACTUALLY GETS USED IN THE STUDY.
C
IF(KOC.EQ.1)JSYFB0=(ILOOK=1980)=ISTEC
IF(KOC.NE.1)JSYFB0=JSYFB0=1980
IF(JSYFB0.GT.0.AND.JSYFB0.LT.21)GO TO 500
C WRITE(INT,510)JSYFB0
510 FORMAT(' FROM STOYEC: JSYFB0 = ',12,' OUT OF RANGE, ENDING .
CIAD=0.
GO TO 10000
C 500 CONTINUE
C CHECK FOR END OF ECONOMIC ITERATION: END FLAY (IOUEC=1)
C WRITE(INT,510)ISTEC
600 FORMAT(' FROM STOYEC: ISTEC.NIT.IOUEC = ',3(2X,12))
C 600 CONTINUE
C
C10000 CONTINUE
RETURN
END

FIGURE 5-2
SUBROUTINE STOYEC
Economic Parameter Sensitivity Runs
OESYS. A detailed discussion of those requirements immediately follows.

1) Logic coding according to OESYS specifications.
2) Option fix in SR QS1
3) Option fix in SR PEAK
4) Option fix in SR VALUE
5) Option fix in SR OUTC, OUT1C, OUT2C, OUT3C, OUT4C
6) Option fix in SR ECOX
7) Option fix in SR SUMBEN
8) Physical parameter file changes

1) Logic Coding According to OESYS Specifications

A thorough reading of section IV.2a is useful here for its presentation of examples of application logics used by OESYS. It is intended that the results of this task will be summarized as done for the other logics of sections IV-2a, b, c, and d.

The black box requirements of the new logic are portrayed in figure 5-3. All generation and load, whether from disk file or modeled, are transferred via the energy node vectors (SS, DD, DDM, CGN) as defined in IV.1e. Alternatively, the sum of all energy generation and supply differentiated only by energy quality type (or utility origin) can be utilized. These values are found in variables GEN(i) and DMD(i) of common /GENDMD/, where i refers to the energy quality code defined in section IV.1e. These can be passed either through the subroutine CALL statement or by common, as referenced in Appendix A. Other simulation variables can be passed according to the requirements of the new logic, such as the current utility prices for back-up energy, the current simulation hour, and so forth. Physical parameters can be defined as
additions to the physical parameter file of section IV.3e. These are passed via commons newly defined by the user. Output requirements during each simulation interval are those parameters which are pertinent for evaluation purposes. In the case of dispersed generation and system storage, the important variables include:

- TRNSFR(i,1) all energy of quality i displaced during that interval which otherwise would have been supplied by some other means (in this case, utility i)
- TRNSFR(i,2) all energy of quality i generated in excess of demand for energy of that quality which is sold back to utility i
- TRNSFR(i,3) all energy of quality i purchased for storage
- TRNSFR(i,4-20) subject to user's own definition.

Use of the TRNSFR vector allows the user to value the energy transfers according to his or her own requirements. Translation of these values into an economic benefit takes place in the VALUE and SUMBEN subroutines defined below. Any storage logics must be handled internally to the

![FIGURE 5-3](image)
NEW APPLICATION LOGIC
Interface Requirements

| SS  | Generation Supply Vector (fig 4-6) |
| DD  | Demand Vector (fig 4-7)           |
| CGN | Generator Model Vector (fig 4-8)  |
| DDM | Load Model Vector (fig 4-9)       |
| GEN(i) | Total generation of energy quality i |
| DMD(i) | Total demand for energy quality i |
| HOUR | Current simulation hour           |
| CPRICE(i) | Current price for backup energy of quality i |
| TRNSFR(i) | Energy transferred where i correlates WRTH(i), the manner in which that energy transfer is valued (in SR VALU) |
new logic. Opportunities for outputting variables for simulation summaries, whether at intervals, sections, periods, or end-of-run are discussed below.

2) Option Fix in SR QS1

Development of a new OESYS application option requires selection of an option number, specified for parameter RUN. Numbers 2., 271., 272., and 273. denote the 4 existing options on OESYS. Any decimal number is appropriate, providing the user is consistent in fixing that option number in this and the following subroutine changes. This first subroutine change is in the interactive question sequence, written in subroutine QS1. The section of interest is shown in Figure 5-4. When the terminal is prompted for RUNTYPE, the RUN option number input must be included with the IF statements after format statement 5030. If the application will consider a utility buy-back of excess generated energy, the terminal should be prompted further, as shown for option RUN=2, under statement number 5500. If no utility purchase is to be considered, the parameter BUYFLG must be set to 0.0, as under statement 5650.

3) Option Fix in SR PEAK

Figure 5-5 shows the segment of subroutine PEAK which calls the new operating logic from within the simulation interval loop. It is necessary to add the new option at the bottom of this list, passing all required parameters which are not carried over by common.
SUBROUTINE QSI(KTS1,KTS2,STWA,OUTPT,CUTINC,P1FLG,P2TINC,NNN)
1.RUN,BUFFLG,BUYFL,BTFOR,RO,EF,EF,PT,RO,PI,PNST,APV,TKPM,EF,EF,INT
COMMON/I0,I1,I,1F,M,1F,IF,1F,IPV,1F,1F,1F
1.IS2,IS2,IS2,LIST,131,13,113,1F
COMMON/K0,KCCN,KEAS,KOAM,KFAL,KP1A
COMMON/SP056/KOPTS1,KORF
KETS1,KETS2,KETS3

FIGURE 5-4
APPLICATION OPTION FIX IN SR QSI

CONTINUE

5000 CONTINUE
5001 CONTINUE
5002 CONTINUE

RUN TYPE

5010 WRITE(IWT,5020)
5020 FORMAT(IX,' RUN TYPE? (DECIMAL — 9. FOR HELP)')
READ(IRT,5030,ERR=5010)RUN
5030 FORMAT(F5.0)
C
IF(RUN.EQ.5.)GO TO 5090
IF(RUN.EQ.2.)GO TO 5500
IF(RUN.EQ.271.)GO TO 5550
IF(RUN.EQ.272.)GO TO 5600
IF(RUN.EQ.273.)GO TO 5650
GO TO 5090
C
5090 WRITE(IWT,5100)
5100 FORMAT(IX,'CHECK OPTIONS: ',
1 /' 2. — URENTY INTERFACES DISPERSED GENERATION.',
1 /' 271. — URENTY INTERFACES DISPERSED SYSTEM STORAGE.',
1 /' 272. — URENTY INTERFACES DISPERSED GENERATION/SYSTEM STORAGE.',
1 /' 273. — STAND ALONE GENERATION/STORAGE./')
C
GO TO 5010
C
5500 RUN=2.
BUFFLG=0.0
WRITE(IWT,6000)
READ(IRT,6010,ERR=5500)ANSS
IF(ANSS.EQ.YES)BUFFLG=1.0
GO TO 6500
5550 RUN=271.
BUFFLG=0.
WRITE(IWT,6000)
READ(IRT,6010,ERR=5550)ANSS
IF(ANSS.EQ.YES)BUFFLG=1.
GO TO 6500
5600 RUN=272.
BUFFLG=0.
WRITE(IWT,6000)
READ(IRT,6010,ERR=5600)ANSS
IF(ANSS.EQ.YES)BUFFLG=1.0
GO TO 6500
5650 RUN=273.
BUFFLG=0.0
GO TO 6500
C
6000 FORMAT(IX,'WILL THE UTILITY PURCHASE EXCESS GENERATION?')
6010 FORMAT(A1)
C
GO TO 6500
C
RETRIEVED:
RUN
BUFFLG
SUBROUTINE PEAK(RUNNAM)
REAL KWHSTU,KWHSTL,KWHSTT,KWHST5,KWHST8,KWHSTU
1,KWHST5,KWHST7,KWHSTL,KWHST0,KWHST7
REAL R1,R2,RATIO
REAL*S RSNAM1,SRNAM2,SRNAM3,SRNAM4,SRNAM5
DOUBLE PRECISION RUNNAM
INTEGER IAYHYP,IT,ICHK=10

CALL THE SPECIFIC PEAK LOGIC FOR THIS RUN

ICHK=10
DATA SRN10'/PEAK specifies'/
SRNAM1=SRN10
CALL TST(CIAO,HOUR,KTST1,KTST2,TSHR,ICHK,SRNAM1)
IF(RUN.EQ.2.)CALL PK2(GEN(2),CMO(2),OMO(1),CPRICE)
IF(RUN.EQ.2171.)CALL PK271(1271,INC,HOUR,OAYHR,GEN(2)
1,CMO(2),OMO(1),CPRICE)
IF(RUN.EQ.272.)CALL PK272(1272,INC,HOUR,AYHR,GEN(2)
1,CMO(2),OMO(1),CPRICE)
IF(RUN.EQ.273.)CALL PK273(1273,ISA,INC,HOUR,DAYHR,GEN(2)
1,CMO(2),OMO(1),CPRICE)

FIGURE 5-5
APPLICATION OPTION FIX IN SR PEAK

4) Option Fix in SR VALUE

Subroutine VALUE immediately follows the call for the new logic
within subroutine PEAK. Within this routine, each value passed by
parameter vector TRNSFR defined under (1) above (Logic Coding) is
multiplied by some figure to reflect economic worth. This figure is most
often the value of the closest available alternative, often the utility,
for that same energy unit. This multiplier is passed in parameter
vector VALU(i), where i varies from 1 to 10 and corresponds to the
utility supplying energy of quality i. Setting this vector is described
in section V.3d. The changes necessary to SR VALUE are described within
that subroutine. New logics begin at statement 400 and must end with a
GO TO 10000 statement.

5) Option fix in SR's OUTC, OUT1C, OUT2C, OUT3C, OUT4C

The output options described in section IV.4c are also run-option
dependent. Editing of these routines in the same manner described for
the above subroutines is required. Printouts of these routines will make editing requirements obvious.

6) Option Fix in SR ECOX

Subroutine ECOX is called when the economics portion of OESYS is desired (setting parameter KEV=1 or 2). Within ECOX the appropriate economics routine is called depending upon two parameters, the investor type, INVSTR, and the run option, RUN. A printout of this routine will make editing requirements obvious.

7) Option Fix in SR SUMBEN

This subroutine is called by each of the three finance models and is described in appendix A. Changes are required in this routine depending upon how the TRNSFR vector is defined in SR VALUE. This routine returns total yearly benefits to the finance model after buyback ratios and storage purchase charges have been applied to the TRNSFR vector. A printout of this subroutine will make editing requirements obvious.

8) Physical parameter file changes

All parameters required by the new logic should be placed in user-defined commons and the values set in the physical parameter file (IV.3e).

V.3 Additional User Options

V.3a Demand Elasticities

Figure 4-4 reveals at what point in the operation sequence energy consumption elasticities are applied to the hourly energy load figures.
There has been no major research effort to date which has attempted to quantitatively quantify consumer elasticities. As work continues in this area it will be possible to attempt some crude "behavior algorithms." OESYS allows for implementing future logics within subroutine ELAS. The interface requirements are as follows:

1) define an option number (1-9) for the elasticity model to be ascribed to parameter KELAS
2) fix the definition of KELAS under "ELASTICITY OPTION" in subroutine QSL
3) place a CALL statement to the subroutine which contains the new elasticity logic within SR ELAS using an IF(KELAS.EQ(option number)) statement.

Any elasticity logic is likely a function of a combination of parameters and variables. These include current energy price, hour of the day, day of the week, season of the year, expected future price of energy, available storage, and so forth. A black box description for a typical elasticity logic is shown in Figure 5-6. The single function of such a logic is to take as input the current energy demand at each load node and return as output the load actually expected. This is accomplished by manipulating parameter DD(i,2) of the load vector (IV.le). All simulation parameters and variables available for logic definition are listed in appendix B.

V.3b Generation Outages

No single generalized outage formula for generating unit failures was implemented on OESYS. This has been left as an option for the user's own devising, specific to the needs of any new application logic. The algorithm for unit failures is placed as part of SR FAIL
IN SR PEAK...

IF(KELAS.EQ.i)CALL ELAS_i

DD(i,2) /SSDD/ Energy demanded this interval at node i
DDM(i,2) /MDMD/ Energy demanded this interval at modeled demand node i
VALU(j) /WRTI/ Worth of backup energy of quality j this interval
HOUR Current hour of the year (1-8760)

Figure 5-6
ENERGY ELASTICITY OPTION

immediately after the call to subroutine MARX within SR PEAK, as shown in figure 4-4. The interface requirements are as follows:

1) define an option number (1-9) for the outage option to be ascribed to parameter KFAIL
2) fix the definition of KFAIL under "OUTAGE OPTION" in subroutine QS1
3) place a CALL statement to the subroutine which contains the new outage logic within SR ELAS using an IF statement: IF(KFAIL.EQ)[option number]CALL[logic routine]).

Unit failure logics will most often be a function of fail rate and fail duration probabilities specific to each unit. A first order probabilistic description of these is given in vector supply node characteristics (see IV.1e). More sophisticated logic may in turn make these a function of various weather conditions, previous (either extended or immediate) operating load, outage of support units, and so forth. The bottom line for such a logic is to output the supply node vector SS either unchanged or with the current interval generation
SS(i,2) set to zero and the foregone generation summed in SS(i,6), as described in IVle. Some units may in rare instances be capable of generation at a fractional output, in which case SS(i,2) would not be output at zero but rather at some percentage of the input figure. A black box description for the generation unit failure algorithm is provided in figure 5-7.

\[
\text{IN SR PEAK . . . IF(KFAIL.EQ.i)CALL FAIL}_i
\]

\[
\begin{align*}
\text{SR FAIL}_i \\
\text{SS(i,2) /SSDD/ Energy generated this interval at node i}
\end{align*}
\]

\[
\begin{align*}
\text{SS(i,3) /SSDD/ Probability of outage}
\end{align*}
\]

\[
\begin{align*}
\text{SS(i,4) /SSDD/ Probable duration of outage}
\end{align*}
\]

\[
\begin{align*}
\text{SS(i,6) /SSDD/ Sum of energy generation foregone due to unit outage}
\end{align*}
\]

**V. 3c Transmission and Distribution Losses**

Transmission and distribution loss functions are treated in much the same way as the previous two options. Again, no rigid formula has been fixed into OESYS. In some applications such losses will clearly not be an issue, whereas in others (small utility modeling) it may be some function of the particular magnitude and spatial qualities of the generation/load distribution.

The algorithm for transmission and distribution losses is placed in
a routine called by SR DSTRBN in the program sequence shown in figure 4-4. The interface requirements include:

1) define an option number (1-9) for the T and D loss option to be ascribed to parameter KTD
2) fix the definition of KTD under "DISTRIBUTION LOSSES" in subroutine QS1
3) place a CALL statement to the subroutine which contains the new outage logic for line losses within SR DSTRBN using an IF statement: IF(KTD.EQ.[option number])CALL[logic routine]).

Algorithm definitions must be provided within a subroutine with black box characteristics as shown in figure 5-8.

IN SR PEAK . . . 
IF(KTD.EQ.i)CALL DSTRB

SS(i,2) /SSDD/ Energy generated at node i this interval
GEN(j) /GENDMD/ Total energy generated of quality j this interval

FIGURE 5-8
LINE LOSSES OPTION
V.3d Alternative Utility Interaction

The utility option specified by KUTIL=1 (IV.3g) offers a price setting strategy for the closest alternative energy supply (the "worth" of energy generated) which is fixed by schedule. It allows fixed and time of use price setting, where the time of use schedule offers up to 53 pricing "seasons," three types of days for each season (weekday, weekend, holiday), and 20 available time periods for each day. The parameters which fix the rate schedule are defined in the physical parameter file (IV.3e). This utility feature offers substantial flexibility for modeling utility rate setting, whether computed by embedded, replacement or marginal costing methods. However, future utility service scenarios will likely involve much more complex rate setting strategies, such as rates computed on a real-time basis as a function of the current generation/load mix, forecasted weather conditions, available storage and so forth. Such rate "algorithms" may be implemented in an effort by the utility to smooth their load curve by directly affecting customer behavior. This algorithm is implemented into a subroutine and called by the program in much the same manner that the previously discussed options were. The interface requirements are:

1) define an option number (2-9) for the rate setting option to be ascribed to parameter KUTIL

2) fix the definition of KUTIL under "UTILITY OPTION" in subroutine QS1

3) place a CALL statement to the subroutine which contains the new rate algorithm within SR UTILITY using an IF statement: IF(KUTIL.EQ)[option number]CALL[logic routine]).

The black box characteristics of the rate logic required for interface with OESYS are as shown in figure 5-9.
IN SR PEAK...

IF(KUTIL.EQ.i)CALL UTIL

\[
\begin{align*}
SS(1,2) /SSDD/ & \text{ Energy generated at node } i \text{ this interval} \\
DD(1,2) /SSDD/ & \text{ Energy demanded at node } i \text{ this interval} \\
GEN(j) /GENDMD/ & \text{ Sum of energy of quality } j \text{ generated this interval} \\
DMD(j) /GENDMD/ & \text{ Sum of energy of quality } j \text{ demanded this interval} \\
\text{HOUR} & \text{ Current simulation hour}
\end{align*}
\]

FIGURE 5-9

UTILITY PRICING OPTION

V.4 Post Processor Output

It may be necessary to change the output characteristics of any one data file described in IV.4. The file descriptions and subroutine originsations for each set of data output are as follows (see IV.4f):

Daily Energy Transfer Characteristics (IV.4f)

FI=22 Data figures: SR PLOTIT

SYSTEM PROFIT (IV.4f)

FI=28 Header: SR STLOOP
Data figures: SR OUTEC3

SYSTEM BREAKEVEN CAPITAL COST (IV.4f)

FI=26 Header: SR STLOOP
Data figures: SR OUTEC3

COMPONENT BREAKEVEN CAPITAL COST (IV.4f)

FI=27 Header: SR STLOOP
Data figures: SR OUTEC3

DYNAMIC COSTING (IV.4f)

FI=32 Data figures: SR OUTEC3

FIRST YEAR BENEFITS DATA OUTPUT (IV.4g)

FI=31 Data figures: SR OUTEC3

FIRST YEAR BENEFITS DATA INPUT (IV.4g)

FI=33 Data READ: SR FIBEN
VI. Sample Studies

The studies which follow were all carried out on OESYS using the data inputs as defined in this documentation. The first example assesses the performance of a photovoltaic array mounted on the rooftop of a grocery store located in Boston. A comparison is made of six alternative utility rate schedules, and an investigation is made of the economic consequences of photovoltaic generation coincident with the application load profile by assessing a monthly capacity charge. The second study looks at an isolated Arizona residence equipped with a photovoltaic array, a flywheel energy storage unit, and a diesel generator as backup. The issues examined are criteria to establish optimum component sizing and the sensitivity to market uncertainties for both hardware costs and the future price of diesel fuel. The final study again looks at issues of optimal sizing, but now in a utility interfaced setting and with two generation devices, a photovoltaic array and a wind turbine generator. The load center for this study is a water pumping station in Sheboygan, Wisconsin.

VI.1 A Photovoltaic Assisted Grocery Store

A study was performed to examine the investment worth of photovoltaics in a commercial sector application. A photovoltaic array is assumed mounted atop a suburban grocery store in the general vicinity of Boston. Construction of the project begins in 1986 and the construction period lasts one year.

To model this application on OESYS, load profile data were obtained from a local utility and solar insolation data were obtained from the
**Figure 6-1**

**Market/Finance Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Life</td>
<td>20 years</td>
</tr>
<tr>
<td>Construction Start Year</td>
<td>1986</td>
</tr>
<tr>
<td>Number of Construction Years</td>
<td>1</td>
</tr>
<tr>
<td>Investors' Rate of Return</td>
<td>7.5 percent (real)</td>
</tr>
<tr>
<td>Tax Rate</td>
<td>.46</td>
</tr>
<tr>
<td>Bond Interest Rate</td>
<td>3 percent/year (real)</td>
</tr>
<tr>
<td>Debt to Debt Plus Equity Ratio</td>
<td>.4</td>
</tr>
<tr>
<td>Investment Tax Credit</td>
<td>10 percent</td>
</tr>
<tr>
<td>Depreciation</td>
<td>Sum of the Years</td>
</tr>
</tbody>
</table>

**General Inflation Rate:**

- 1980-12 percent; 1981-10 percent; 1982-9 percent;
- 1983-8 percent; 1984-6 percent; 1986-5 percent;
- 1987-2000-5 percent

**Capital Costs Escalation:**

- Same as general inflation rate

**Electricity Costs Escalation:**

- **Energy:** 5 percent/year in 1980 declining linearly to 0 percent/year in 2010
- **Capacity:** 1 percent/year in 1980 declining linearly to 0 percent/year in 2010
Figure 6-2

Alternative Time-of-Use Rate Structure

**Boston**

<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Capacity</th>
<th>Buyback</th>
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</thead>
<tbody>
<tr>
<td>FLAT EMBEDDED</td>
<td>35.4 m/kWh</td>
<td>$5.12/kW/mo.</td>
<td>.85</td>
</tr>
<tr>
<td>FLAT MARGINAL</td>
<td>35.4 m/kWh</td>
<td>$7.87/kW/mo.</td>
<td>.85</td>
</tr>
<tr>
<td>T.O.D. EMBEDDED</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equitable</td>
<td>Peak</td>
<td>37.1 m/kWh</td>
<td>$5.12/kW/mo.</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>35.3 m/kWh</td>
<td></td>
</tr>
<tr>
<td>3:1</td>
<td>Peak</td>
<td>98.209 m/kWh</td>
<td>$5.12/kW/mo.</td>
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<tr>
<td></td>
<td>Base</td>
<td>32.735 m/kWh</td>
<td></td>
</tr>
<tr>
<td>6:1</td>
<td>Peak</td>
<td>178.56 m/kWh</td>
<td>$5.12/kW/mo.</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>29.74 m/kWh</td>
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PEAK PERIOD: 1:00 p.m. - 3:00 p.m.

Monday-Friday All year
FINANCIAL CHARACTERISTICS
200m² PV Array for a Boston Grocery Store
Preliminary Results

<table>
<thead>
<tr>
<th>Profit</th>
<th>Rate of Return</th>
<th>Years to Payback</th>
<th>System BECC</th>
<th>PV BECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>-</td>
<td>-.044</td>
<td>.40</td>
<td>-.12</td>
</tr>
<tr>
<td>M</td>
<td>-</td>
<td>-.076</td>
<td>.38</td>
<td>-.90</td>
</tr>
<tr>
<td>H</td>
<td>-</td>
<td>-.096</td>
<td>.36</td>
<td>-1.17</td>
</tr>
<tr>
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<td></td>
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</tr>
<tr>
<td>L</td>
<td>-</td>
<td>-.044</td>
<td>.40</td>
<td>-.62</td>
</tr>
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<td>-.076</td>
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<td>-.90</td>
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<td>.36</td>
<td>-1.17</td>
</tr>
<tr>
<td>MARGINAL</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>-</td>
<td>-.044</td>
<td>.40</td>
<td>-.62</td>
</tr>
<tr>
<td>M</td>
<td>-</td>
<td>-.076</td>
<td>.38</td>
<td>-.90</td>
</tr>
<tr>
<td>H</td>
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<td>-1.17</td>
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<td>TIME OF DAY</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>EMBEDDED</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>-</td>
<td>-.044</td>
<td>.40</td>
<td>-.62</td>
</tr>
<tr>
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<td>.38</td>
<td>-.89</td>
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<tr>
<td>H</td>
<td>-</td>
<td>-.096</td>
<td>.37</td>
<td>-1.17</td>
</tr>
<tr>
<td>(EQUITABLE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>-</td>
<td>-.026</td>
<td>20.</td>
<td>.52</td>
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<td>M</td>
<td>-</td>
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<td>17.0</td>
<td>.68</td>
</tr>
<tr>
<td>H</td>
<td>-</td>
<td>-.08</td>
<td>17.0</td>
<td>.68</td>
</tr>
<tr>
<td>TIME OF DAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMBEDDED</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>L</td>
<td>-</td>
<td>-.006</td>
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<td>.68</td>
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<td>M</td>
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<td>H</td>
<td>-</td>
<td>-.062</td>
<td>17.0</td>
<td>.64</td>
</tr>
</tbody>
</table>

FIGURE 6-3
A commercial finance simulation was performed and the market/finance parameters used are as shown in figure 6-1. Utility rate structures were devised based upon alternative means of production costing and these are shown in figure 6-2.

A preliminary performance evaluation was made using an undersized array (i.e., an array serving a small fraction of the application load). Since all system costs are linear with array sizes, and since the utility buyback rate modeled was less than 100 percent of the utility sell rate, an undersized array will return the maximum breakeven cost figures.

The results for this preliminary study are shown in figure 6-3.

Given that the 1986 cost goals for photovoltaic modules is $3.70/Wp, it follows that photovoltaics will be too expensive for investment in that year. In fact, if the market/finance parameters are, in 1986, as fixed in this study, one would have to pay the investor to accept the photovoltaic modules. Examination of the rate of return column in figure 6-3 reveals that the economics of photovoltaics is highly sensitive to small changes in the investor's assumed discount rate.

In order to lend this study some interest, a time-of-day rate structure was used with four rate periods reflecting much higher overall energy costs than the previous rate policies. The rate structure used is as shown in figure 6-4. Such a rate structure helps out...
FIGURE 5-7

DEMAND CHARGE ACCOUNTING AT 733 DEMAND INTERVALS

PERIOD 1

SECTION 1 WITH 12 DEMAND PERIODS

DMM PO/MAX TOTAL DMM
1/ 730.350 2/ 730.350 3/ 890.750 4/ 590.750
5/ 533.250 6/ 533.250 7/ 533.250 8/ 464.400
9/ 495.000 10/ 519.300 11/ 690.750 12/ 730.350

DMM PO/MAX FINAL DMM
1/ 730.350 2/ 730.350 3/ 890.750 4/ 590.750
5/ 533.250 6/ 533.250 7/ 533.250 8/ 464.400
9/ 495.000 10/ 519.300 11/ 690.750 12/ 730.350

SAVINGS
1/ 0.0 2/ 0.0 3/ 0.0 4/ 0.0
5/ 0.0 6/ 0.0 7/ 0.352 8/ 0.0
9/ 0.0 10/ 0.0 11/ 0.0 12/ 0.004

FIGURE 6-8

DEMAND NODE SUMMARIES: (NODE NUMBER)/QUANTITY

TTL SMLTN MRS: 1/ 8750.00
TTL GMD MRS: 1/ 8750.00
PEAK LOAD: 1/ 0.730350E+03
YEAR MURH OF PK: 1/ 533.250
AVG LOAD: 1/ 0.398816E+03
TTL LOAD: 1/ 0.349363E+07
photovoltaics considerably, as shown in figures 6-5 through 6-7. In these figures, the array was varied in size from 3000 to 6000 meters square in order to demonstrate the effect which the buyback rate has upon excess generation. It is seen that when the array is sized at a peak capacity (kW) roughly equal to the average application load, the sizing is optimal. Figure 6-8 reveals that very little capacity credit was afforded by the photovoltaic array (PV generation at time of monthly peak load) and that the application peak to average load ratio was 1.8.

Finally, figure 6-9 was arrived at using the dynamic costing option available on OESYS. The results here show that for the fictitiously favorable conditions of financing and utility rate environment discussed, the optimal year in which to undertake construction of this project is 1991.
FIGURE 6-9a

FIGURE 6-9b
VI.2 Sizing for Photovoltaic/Flywheel Storage for a Remote Residence (Non-Utility Interface)

A remote applications analysis (parameter RUN=273.) was performed for a single-family residence equipped with a photovoltaic array, a flywheel energy storage unit, and a back-up diesel generator. The residence was located in the southwest portion of the U.S. and construction was assumed to begin in 1986. The issue under study included optimum sizing of the tri-component system, and the sensitivity of configuration sizing to two market parameters; 1) hardware costs and 2) diesel fuel costs in 1986. Figure 6-10 presents a summary of this analysis. With component size ranges set on each of the axes, and with the curves representing total energy met by the diesel, any point in the plane deterministically represents satisfaction of 100 percent of the total yearly application demand. In this figure, the boxes and circles represent economically optimal solutions. The boxes are a result of fixing diesel fuel costs at 3.07/kWh in 1980, applying a fixed 6.6 percent/year fuel price escalation factor for the years thereafter, and examining the effects of varying component cost assumptions on the configuration sizing solution.

The range of solutions here is dramatic, revealing that a low-cost assumption for the PV and flywheel dictates that fully 92 percent of the energy demand be satisfied by these components alone, whereas assuming the high cost range optimally yields an all-diesel system. On the other hand, fixing hardware costs at the medium projection and varying diesel fuel start costs for 1986 over a broad range yields a relatively minor, although significant, change in optimum system sizing.
FIGURE 6-10
REMOTE STAND ALONE PV FLYWHEEL DIESEL RESIDENTIAL SYSTEM
Sensitivity of Optimum Configuration Sizing to
- Diesel Start Costs in 1985
- Hardware Costs
- Low BOS Costs

ASSUMPTIONS

Utility Tie in
Costs as Benefits

- $.088/kWh
3%/Year Real
Price Escalator
- 30 Miles from Grid
$8712/Mile

Diesel Fuel Costs
Fixed at $.07/kWh
in 1985;
Hardware Costs Varied

Hardware Costs
Fixed at
PV = $.07/pk Watt
FW = Middle;
Diesel Fuel Costs
in 1986

<table>
<thead>
<tr>
<th>A</th>
<th>$0.07/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>0.097</td>
</tr>
<tr>
<td>C</td>
<td>0.133</td>
</tr>
<tr>
<td>D</td>
<td>0.169</td>
</tr>
</tbody>
</table>

After 1986
Escalate at
6.6%/Annum
FIGURE 6-11

STAND-ALONE PV FLYWHEEL DIESEL
SYSTEM NET BENEFITS VS ARRAY SIZE AND FLYWHEEL CAPACITY
MID-LENGTH HARDWARE COSTS ASSUMED
DIESEL FUEL START COSTS* IN 1985 VARIED
COST COMPARISON TO UTILITY TIE-IN 30 MILES FROM GRID

*Diesel Fuel Costs:
A = $0.07/kWh; B = $0.097/kWh; C = $0.133/kWh; D = $0.169/kWh
FIGURE 6-12
STAND-ALONE PV FLYWHEEL DIESEL

MAXIMUM SYSTEM NET BENEFITS AT GIVEN FLYWHEEL CAPACITY
- Cost Compared to Utility Tie-in
  2.065/kWh
  30 Miles from Grid:
- Middle Hardware Costs Assumed
- Diesel Fuel Start Costs in 1985 Varied

**Diesel Fuel Start Costs in 1985**
- A = $0.07/kWh
- B = $0.097/kWh
- C = $0.132/kWh
- D = $0.169/kWh

**Hardware Costs Assumed**
- PV = $7.70/Wp
- FW = Middle
- Benefits
  - $0.065/kWh
FIGURE 6-13

PV + FW + DIESEL STAND ALONE COMPARED AGAINST
UTILITY GRID CONNECT

PHOENIX RESIDENCE

PV ARRAY: 30 m²
FW CAPACITY: 20 kWh
DIESEL CAP: 3.55 kWh
DSL DEMAND: 4292 kWh

PV $0.70/Wp
FW Middle
3OS Low

Net Benefits ($'000)

Miles from the Grid
Examination of figures 6-11 and 6-12 reveals how figure 6-10 was arrived at as a result of OESYS runs. Considering for the moment only the circled optima of figure 6-10, figure 6-11 shows how net benefits accrued as a function of varying the array size parameters over various fixed storage capacities for different diesel fuel cost assumptions. Figure 6-12 maps out the maximum points of figure 6-11. The optimal sizing conditions merely fall out of figure 6-12 as the maximum points on each curve.

Taking the most likely configuration solution (i.e., reasonable diesel fuel and hardware cost assumption shown by the boxed circle (BB-A) of figure 6-10), the net benefits as a function of distance from the grid are charted in figure 6-13 where miles of distribution line not built now serve the benefits side of the equation. At just over one mile from the utility line, benefits rapidly begin to accrue to total energy residences equipped as described.

VI.3 Relative Photovoltaic/Wind Turbine Sizing for a Water Pumping Station*

A utility finance method was simulated to assess the worth of photovoltaics and/or wind turbine generators as an on-site generation means to assist a quasi-remote water pumping station near Sheboygan, Wisconsin. The utility currently supplies electricity to the pumping station via a transmission line at the expense of large line losses, and is considering either updating that transmission line or repairing on-site diesel generators which have been lying idle for seven years.

*The scenario described is make-believe.
The cost of electricity from the diesel generators is calculated to be 90/kWh and the cost to the utility of supplying electricity via the grid, taking account of line losses, is shown in figure 6-14.

![Figure 6-14](image)

The photovoltaic array consists of solar cells rated at 10 percent conversion efficiency and an inverter rated at 88 percent electrical efficiency. The power availability of the wind turbine varies as the cube of the wind speed and is simply estimated by:

\[
P(r/v_r)^3 \quad \text{for} \quad 0 \leq v < v_c
\]

\[
P_{r} \quad \text{for} \quad v_c \leq v < v_r
\]

\[
P_r \quad \text{for} \quad v \geq v_r
\]

where

- \(P_r\) = rated power (kW)
- \(v_r\) = rated speed (m/s)
- \(v_c\) = cutin speed = \(0.464 \times v_r\)

This study looked at wind turbines rated at 25 kW and assumed that larger capacities resulted from the construction of multiple mills.
The cost of the photovoltaic array is assumed equal to the 1986 DOE price target of $1600 per peak kW. The cost of the wind turbine was taken at $15,000 per mill. This figure is calculated from:\(^4\)

$$k = \left( \frac{v_{\text{ref}}}{v} \right)^2 \times C_c$$

where

$$\ln \left[ \frac{C_c}{P_r} \left( \frac{g}{\text{kW}} \right) \right] = 7.74 - 0.466 \ln (P_r) + 0.026 [\ln (P_r)]^2$$

$v_{\text{ref}} = 11.2$ m/s

$v = 9$ m/s

$k =$ cost of installation of a 25 kW wind turbine.

The worth analysis compared the levelized cost of energy production from PV and wind and compared that figure to the levelized energy benefit determined from the displacement of 1) grid-supplied electricity, and 2) electricity from the diesel generators. Comparison against grid-supplied electricity assumed a 65 percent buyback rate to reflect the worth of excess generation to the utility after losses. The utility finance parameters assumed for this study include:

- System Operating Lifetime: 20 years
- Rate of Return: .075 (real)
- General Price Inflator: .05
- Escalation Rate for Capital Costs: .05
- Tax Rate: .48
- Annual Insurance Premiums as a Fraction of the Initial Investment: .0025
- Annual "Other Taxes" as a Fraction of the Initial Investment: .02
SUPPLY NODE SUMMARIES: \((\text{NODE NUMBER})/(\text{QUANTITY})\)

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<tr>
<th></th>
<th>1/</th>
<th>2/</th>
</tr>
</thead>
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<td>8760.00</td>
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<tr>
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<tr>
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<td>2/0.319300E-05</td>
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</table>

DEMAND NODE SUMMARIES: \((\text{NODE NUMBER})/(\text{QUANTITY})\)

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<th>1/</th>
<th>2/</th>
</tr>
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</tbody>
</table>

**FIGURE 6-15**

![Graph showing Levelized Cost/Benefit of Electricity versus Number of 25 kW Wind Turbines]

- LEC -- High Cost
- LEC -- Medium
- LEC -- Low
- LEB -- Grid
- LEB -- Diesel

**FIGURE 6-16**
Construction Period 1 year
Construction Start Year 1986
Base Year for Constant Dollars 1980

Supply and load characteristics of the application are shown in figure 6-15 for a 1000 square meter photovoltaic array and a single 25 kW wind turbine. Results of the analysis are summarized in figure 6-16. Since the diesel option offers no opportunity for the sellback of excess generated electricity, the levelized energy benefit for displacing diesel generation is seen to drop rapidly with an increase in the number of wind turbines. No photovoltaic array is included in this figure since PV was not part of the optimum solution. The study which led to the optimal PV/wind mixing criteria is displayed in figure 6-17.

The results indicate that if the utility is constrained to operate its diesel generators, up to two 25 kW windmills would be chosen, whereas the use of wind power would offer only a marginal advantage over the grid supplied electricity even at a lower-bound cost assumption for wind turbines.
VII Update on Logic Development for Specific Application Types

The operation logics developed for this model which are specific permutations of figures II.1-II.9 are presented in this section. Logic selection is described in section IV.2a.

Logic 2:
Utility Interface/Dispersed Electrical Generation
completed 4/1/79
Author: T. Dinwoodie
Flowchart: Figure 7-1

Logic 271.
Utility Interface/Dispersed System Electrical Generation
completed 6/1/79
Author: T. Dinwoodie
Flowchart: Figure 7-2

Logic 272.
Utility Interface/Dispersed Electrical Generation with Dedicated Storage
completed 6/15/79
Author: T. Dinwoodie
Flowchart: Figure 7-3

Logic 273.
Remote Stand Alone Electrical Generation with SYSTEM Storage
completed 7/1/79
Author: T. Dinwoodie
Flowchart: Figure 7-4
FIGURE 7-1
UTILITY INTERFACE/DISPERSED GENERATION

RUN = 2.
Flow Chart
FIGURE 7-2
UTILITY INTERFACE/DISPERSED SYSTEM STORAGE
RUN = 271.
Flow Chart

* Value of stored energy is the average purchase cost adjusted for average efficiency losses
** Purchase price is the minimum price in a time of use rate structure
*** The value of stored energy for sellback to utility is the average purchase cost adjusted for efficiency losses and utility buyback rate
FIGURE 7-3
UTILITY INTERFACE/DISPERSED GENERATION AND DEDICATED STORAGE

RUN = 272.
Flow Chart

* Demand is satisfied with least cost alternative in order of 1) on-site generation, 2) storage, 3) utility backup

** A system storage unit would require additional logic at this point
Reports are for relative sizing of power conditioning, limits on storage charge/discharge capacities, state of charge conditions, and service reliability.
APPENDIX A

List of OESYS Subroutines

SHINE EXEC
CAPPSV FORTRAN
CSENV FORTRAN
CSUN FORTRAN
CTPVEG FORTRAN
OBUG1 FORTRAN
OBUG2 FORTRAN
OBUG3 FORTRAN
OFAULT FORTRAN
OFADE FORTRAN
OSTBNE FORTRAN
OYNCS FORTRAN
ECICT1 FORTRAN
ECX FORTRAN
ECRESI FORTRAN
ECUTL FORTRAN
ELAS FORTRAN
ETG FORTRAN
ETI1 FORTRAN
ETM FORTRAN
ETOUT FORTRAN
FAIL FORTRAN
FIBEN FORTRAN
HR FORTRAN
IRANG FORTRAN
JETZ FORTRAN
LEAPME FORTRAN
MARX FORTRAN
MODMD FORTRAN
MG2 FORTRAN
OUCO FORTRAN
OUTEC FORTRAN
OUTEC1 FORTRAN
OUTEC2 FORTRAN
OUTEC3 FORTRAN
OUTEUT1 FORTRAN
OUTEUT2 FORTRAN
OUTSA1 FORTRAN
OUTSA FORTRAN
OUT1C FORTRAN
OUT1C FORTRAN
OUT3C FORTRAN
OUT3C FORTRAN
OUT4C FORTRAN
OUT4C FORTRAN
PARAM FORTRAN
PEAT FORTRAN
PK2 FORTRAN
PK272 FORTRAN
PK272 FORTRAN
PK273 FORTRAN
PK273 FORTRAN
PLOTIT FORTRAN
PLT FORTRAN
PLTSA1 FORTRAN
PLTSA1 FORTRAN

PRID FORTRAN
PROPER FORTRAN
PVEG FORTRAN
PVEG273 FORTRAN
QEV FORTRAN
QS1 FORTRAN
RANCOM FORTRAN
RESI FORTRAN
RRANG FORTRAN
RRANGE FORTRAN
SA273 FORTRAN
SEASN FORTRAN
SETPAR FORTRAN
SOLTAP FORTRAN
SPOL1 FORTRAN
STO1 FORTRAN
STOY6C FORTRAN
STLCOP FORTRAN
SUM FORTRAN
SUMBEN FORTRAN
SUMCST FORTRAN
SUNCII FORTRAN
TC FORTRAN
TEST2 FORTRAN
TST FORTRAN
UTILITY FORTRAN
VALUE FORTRAN
LIST OF OESYS COMMONS

ADSL COMMON
APPL COMMON
ARRAY COMMON
ATO COMMON
BASIC COMMON
BOS COMMON
CCMG COMMON
CSS COMMON
CFLY COMMON
CJN COMMON
CJN1 COMMON
CSS1 COMMON
COST COMMON
CPOV COMMON
CSS1 COMMON
CSS2 COMMON
CT1 COMMON
DAT COMMON
DESRCR COMMON
DESNC COMMON
DOM COMMON
DYCS COMMON
ECQN COMMON
ECOUT COMMON
ECUTL COMMON
ECUTL2 COMMON
EC1 COMMON
EC3 COMMON
EC4 COMMON
EOQ COMMON
FIDES COMMON
FLAG COMMON
FLY COMMON
GENOMO COMMON
GOT COMMON
HOUR COMMON
INC COMMON
IO COMMON
KO COMMON
LOVE COMMON
LOVE2 COMMON
MO COMMON
PASS COMMON
PLOT COMMON
PRI COMMON
PXY COMMON
RNUN COMMON
SA COMMON
SA1 COMMON
SA2 COMMON
SIM COMMON
SSDD COMMON
STORK COMMON
ST7 COMMON
TO COMMON
TSOPEC COMMON
TSTVEC COMMON
TTLS COMMON
UFY COMMON
WRTH COMMON
Variables and Parameters in OESYS Commons

COMMON /ADSL/, CAPO, CDSLE, CDSLC, CDFUEL(4), DFCSC, IDPC
COMMON /APPLY/, VCUST
COMMON /ARRAY/, CRTG, SOLAR, WIND, TAMB, TCELL, CDF28, CEFX, XCEF
1, THCELL, ACOL, AQ, ABSC, ABSP, AVCEF, PHI, IA, BS
COMMON /ATOM, XT, XO, NSUB, NSUBO, NMET, CTDG, CTDQ, CTDCM
1, PTDG(4), PTDQ(4), PTDCM(4), PTDQCM(4), PTDQCM2(4)
1, PTDQX(4), ITOC
COMMON /BASIC/, INC, IENDHR, RUN, QUTINC, S3CHR
COMMON /BGST/, STRCT, FOUND, SFMAT, SFGAIL, SFFAS, GASKET
1, GROUND, ASSEM, FREINT, PUT
COMMON /CC4L/, CAPCHG
COMMON /CCSS/, SSBECC(20, 3), SSBECC(20, 3), PROFIT(3), ROR(3), YPB(3)
COMMON /CFLY/, CRTG(4), CMG(4), CMG(4), CVH(4), CELG(4), CELM(4),
CCNC(4), CTE(4), COTTAG(4), CTDC(4)
COMMON /CGN/, GN(5, 20), NCN
COMMON /CGN1/, GCNC(5, 20, 3), CNGC2(5, 30, 3), CNGS1(5, 20, 3)
CNGS2(5, 30, 3), CNGP1(5, 30, 3)
COMMON /CICS/, ABEC(3), ABEC(3)
COMMON /CMS1/, CMSSC1(2, 20, 3), CMSSC2(2, 30, 3), CMSB1(2, 20, 3)
CMSB2(2, 30, 3), CMSB2(2, 30, 3)
COMMON /COST/, CPOSTU, CPOSTL, CPOSTP, GPWST
1, CPOST5, CPOSTL, CPOSTU, CPOST5
2, CPOST7, CPOSTL, CPOSTU, CPOST7
COMMON /CPV/, CPOV(4)
COMMON /CSS1/, CSBECC(20, 3), SSBECC(20, 3), SSBECC(20, 3), CSSP1(20, 30, 3)
COMMON /CSS2/, CSS2(20, 20, 3), CSS2(20, 20, 3)
COMMON /CTC1/, CTC1(5, 20, 3), CTC2(5, 30, 3), CTC3(5, 20, 3)
CTC4(5, 30, 3), CTP1(5, 30, 3)
COMMON /DAT1/, WM(24), S5, PSL(24)
1, TDF(24), PST(24), TSD(24), TDD(24)
1, TMI(24), TID(24), TIA(24), TIA(24), TIA(24)
1, TIA(24), ITI(24), ITI(24), ITI(24), ITI(24)
1, TIP(24)
COMMON /DEGR/, DEGR(20, 30)
COMMON /DEGR/, DEGR(20, 30)
COMMON /DIM/, OSLFL, TOFL, NCST, TDFRAC
COMMON /DMG/, DMG(3), DFM(3), DFM(3)
COMMON /DYCS/, DPROF(15, 3, 3), DSSBECC(15, 3, 3), DSSBECC(15, 3, 3), DSSBECC(15, 3, 3)
DSSBECC(15, 3, 3), DSSBECC(15, 3, 3), DSSBECC(15, 3, 3), DSSBECC(15, 3, 3)
1, OC18CC(15, 3, 3), OC18CC(15, 3, 3), OC18CC(15, 3, 3)
COMMON /ECON/, ECON3, ECON4, CORPTX, DEBEO, OP, RETURN, CONE,
1, PEOXG, IDEP, IDEQP, GITC, GITC1
1, IDEP, IDEPP, GELV, IDEPG
COMMON /ECGUT/, NSBECC, SSBECC(10), NCBECC, ISBECC(5), NSBECC, ISBECC(3)
COMMON /ECLS/, CWC, RA, NMTL, RTN, UTC, YEG, FXGR, TXR
COMMON /ECRS2/, SP(3), DP(3), NAMAY(3), PRICPL(3), FING(3), AMP(3), ELC(3)
COMMON /ECUTL/, CI(3), BLEC(3), BLEB, CRP, CRP, VC(3), AC(3)
COMMON /ECUTL2/, AINFIL, TR, BETAI, BETAI, DR, QC, GM, AKWH, ESEC, IYB
1, IYCG, NLAYR
COMMON /ECG/, ECG1, ECG2, ECG3, ECG4
COMMON /ECG/, ECG1, ECG2, ECG3, ECG4
COMMON /ECG/, ECG1, INTCMD, XINTCO, SUMSK, RTFLG
COMMON /ECC3/, ECPFS, ISTART
COMMON /ECG4/, LOC, LOC, RSYFB, USYFB, RLFIE, KOC, INVT, XBECC1, XBECC2
1, KEDLA
COMMON /END/, ALPPV(23), ALLDMD, PKDMD, PKNL, DMONL, DKKHS, DKKP
COMMON /ENERGY/, TOTSQL
COMMON /ESK/, ESCAL(4, 30)
COMMON /FDEFINE/, ILPST, IPVST

cont'd
cont’d

COMMON/FLAG/ICUTPT, CIAO, STNORD, SUYFLG, PVFLAG
COMMON/FLY/CAPF, EM17, C74X, CTMX, FSTOP, FXS7, NEIN, NEOUT
1, NEM, NEIN7(10,2), EQUT7(10,2), EM7(10,2), EQ7(10,2)
COMMON/GENDMO/GEN(10), DOM(10), SGEM(10), SGMO(10), PGEN(10)
1, POMO(10), TGEN(10), TDOM(10), NEQUAL
COMMON/GQ/SAVL, SOC
COMMON/HOUR/ACDC, SDAC, PVTOP, ACOLM
COMMON/INC/NDAK, NVEK, NHR, DAYTYPE, PRICE
COMMON/I/O/ITLT, ITMT, IRF, ITW, IMW, IPV, ILP, IEV, IPV2, IPV3, ISA
1, ISA2, ISA3, IMAP, IST, ID1, ID2, ID3, IFW, IA1, IA2, IA3, IA4, IAS
COMMON/KQ/KCG, KCH, KM00, KFAL, KTO, KUTL, K1, K2, K3, K4, K5, K6
COMMON/LOVE/SECC, SECC2, ENETPV, SUMBE, DENBM
COMMON/LOVE2/SECC, PVBECC, ANB(3), SUMBS, DENBM
COMMON/MD/OMM(5,20), NMOOM
COMMON/PASS/IPHR, IPINC, IPGIN, IPEND
COMMON/PLTR/NPOL, PTINC, PLTFLG
COMMON/PR/ELOTDOI(12,3,24), DAYMR, CPR(12,3,24), ENOMHR(12)
COMMON/PXG/ECCGI(10,30)
COMMON/RNN/I RUN
COMMON/SAI/12H1, 12LD, 12SL, 12FA, SA7(75,3), SA7(75,3)
1, TOSAT1, SAT1MX, TOSAT2, SAT2MX, TOSAT3, SAT3MX, TOSAT4, SAT4MX
1, SAT3(75,3), SA7(75,3)
COMMON/SAS/12H1, 12LD, 12SL, 12FA, SA7(75,3), SA7(75,3)
1, TOSAT1, SAT1MX, TOSAT2, SAT2MX, TOSAT3, SAT3MX, TOSAT4, SAT4MX
1, SAT3(75,3), SA7(75,3)
COMMON/SAY/1CPIF(365,2), ALCPL, ALCUT, ACIF, ACFIF, FOR, SAI, TEM
1, TOSTUT, DENS, DPHS, PLCMX, ELCLMX, OURLOL, OURFPL, NHRMO
COMMON/SD/I DAYS
COMMON/SAI/12LD, 12SL, 12FA, 1CPIF, TOCLO
COMMON/SIM/NEPDS, NSECT, ICROSS(13), IENSIM(13), ISGOSXN(13)
1, IENSNX(13), DEGRA(25), NFRS(20)
COMMON/SSD/S5(20,20), S5(20,20), S5(20), SDD(20), SSD(20)
1, POD(20), TSS(20), TSS(20), NSS, NOD
COMMON/STORD/STIN, STOUT, STSCC, STIN, STOUT, SAVSOG
1, PSTIN, PSTOUT, PA/SOG, STIN, STOUT, TAVSOG
COMMON/STT/ST7(5,20), NST7
COMMON/TO/TOSTUT, TOSTL, TOUTL, TOWST
1, TOSTS, TOSTL, TOSTU, TOUTS
2, TOSTT, TOSTT, TOTTU, TOUTT
COMMON/TSPEC/KOPTS1, KOPTS2, KOPTS3, KOPTS4, KOPTS5
1, KECTS1, KECTS2, KECTS3, KECTS4, AECTS5
COMMON/TSTVEC/KTST1, KTST2, KTSTR
COMMON/TV/SC/NCM0, HACMO, HGEN, SOCMD, SACMD, SGEN
1, POCHMD, PAGMD, PGEN, TDDMO, TACMD, TGEN
COMMON/UPFL/SPRICE, ITODP, ITOCT
COMMON/WRTH/SLAK(10,30), WORTH(10,20), VALU(10), NEUL
BIBLIOGRAPHY


1. Whisnant (4).

2. This model was programmed by Jesse Tatum, then of the M.I.T. Energy Laboratory (reference 9).

3. The results of this study are taken from a study performed by the author and summarized in reference (3).

4. Shultis (8).
Work reported in this document was sponsored by the Department of Energy under contract No. EX-76-A-01-2295. This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately owned rights.