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Planning for a Program Design for Energy Environmental Analysis

Progress Report

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DISCLAIMER

Abstract

The work reported in this first quarterly progress report is focussed on the use of interactive operational gaming in a regional assessment study program. There are three fundamental facts that must be brought into a study of the future of a region. First, the future evolution is fundamentally unknowable without interactive coupling with the decisive actors of the region. Second, the actors act upon their perception of the probable evolution attendant upon each of their decision options. Third, the actual evolution is determined through a continual resolution of conflicts between the objectives of different interests, both intra- and extra-region. A tentative structure of a regional energy environment game is presented and methodology is discussed.

Introduction

This investigation is directed at planning for a program design for energy environmental analysis. The central theme of the investigation is the use of interactive operational gaming in a regional assessment study program. By contrasting the applicability of the gaming approach with that of other approaches, one is able to address the question of the "most useful" program design for energy environmental analysis. The use of interactive operational gaming in a regional assessment study addresses three fundamental facts. First, the future evolution of a region is fundamentally unknowable without interactive coupling with the human decision-makers. Second, the human decision-makers act upon their perception of the probable evolution of the region following upon each of their decision options. Third, the actual evolution of the region is determined through a continuing resolution of the conflicts between the objectives of different interests intra- and extra-region. Interactive operational gaming seeks to couple the human decision-makers with an operational model of the evolution of a region under a variety of policy options so that they can witness the probable evolution of the region under each policy option. It is intended that the game may be played interactively with a single decision-maker or multiple decision-makers interacting with each other in order to simulate conflict resolution between different interests. Appendix A shows the scope of activity that is being employed.

Scope of Investigations

The work during this first quarter (January 1 - March 31, 1975) was directed at four tasks which encompass all of the six tasks of Appendix A but serve to emphasize the operational gaming approach during this time period. Toward the end of the project attention will be refocussed on attaining the balance indicated by Appendix A. The four tasks are described as follows.

Task 1. Definition of scopes, purposes, goals, and objectives of a regional assessment study program (Appendix A, Task 1).

Task 2. Definition, description, and analysis of the role of interactive operational gaming in a regional assessment study program (Appendix A, Task 2).

Task 3. Methodology for a regional energy environment game (Appendix A, Tasks 3 and 4).

Task 4. Description of special requirements in large scale implementation of regional energy environment gaming (Appendix A, Tasks 5 and 6).

Results

Intensive effort was focussed on a review and evaluation of previous gaming efforts and their relative merits for this application were assessed. A number of major deficiencies were found in previous efforts, with reference to this application, and these are being used to identify the pitfalls which must be avoided in this study. An essential weakness of previous efforts has to do with the ability of the game to accommodate a rich variety of options per player with complex conflicts between players.

A scenario approach to describing the context within which the game will be played has been adopted and outlined. A decision has been made to develop an actual small-scale game that will be built on the scenario approach. It is clear that the small-scale game will be very limited in its capability, but it will serve the useful purpose of allowing the investigators to explore the various ramifications associated with the interacting elements of game structure, policy options, objectives set, number of players, and conflicts resolution. The scenario approach is developed in a manner which serves to limit the game so that it fits the scope of a regional assessment study program.

In general, the major goals of the small-scale game are to explore the applicability of interactive operational gaming to:

1. Educate the game players in the complex mechanisms governing the evolution of a regional energy environment system (applicable to Tasks 2, 3, and 4 of Appendix A).
2. Serve as a potential policy selection tool that brings into account the conflicting interests of the important actors in a regional energy environment system (applicable to Tasks 2, 3, and 4 of Appendix A).
3. Scope, and set purposes, goals, and objectives for a regional assessment study program (applicable to Task 1 of Appendix A).

The first goal is being emphasized at this point in the investigation. It is greatly enriched by the scenario approach to constructing the game.

The role of interactive operational gaming is being studied concurrently with the development of the methodology for the game. The methodology development is being approached in two phases.

The first phase might be characterized as a "first generation" approach in that one attempts to encompass, in a highly aggregated sense, the essential elements of a regional energy environment system and its evolution while retaining the ability to enrich the elements in a subsequent generation. This phase serves as a tool to assist in the development of more meaningful games. The "first generation" approach employs the scenario technique mentioned earlier. A reference scenario has been described. This is the present state of the energy environment system under study. A set of decision scenarios have also been described which specify the future states of the system but which require action or actions on the part of a set of identified actors if the future state is to be attained. Naturally, these future states involve a variety of system evolutionary characteristics and the element of time. The Technology Transform Analysis methodology serves to organize the comparison between the elements of the decision scenarios and the corresponding elements of the reference scenario in order to assess the costs and benefits attendant upon the decision scenario.

A weighting methodology, based upon the Eigenvalue Prioritization Model, is used to weigh the factors of (1) an actor's objectives, (2) an actor's relative influence on the state variables of the regional energy environment system, and (3) the relative effect each state variable has in realizing a possible future scenario. The final relative weights of the future scenarios describe the composite scenario, or resulting state of the regional energy environment system, as a consequence of the interactions between actors in pursuing their objectives.

This "first generation" approach is nearing completion and a report is planned to present its findings. Appendix B is a tentative outline of the contents of the planned report.

The second phase, or "second generation" approach, is an attempt to quantify the mechanisms identified in the "first generation" approach. The three key activities in the transition from first to second generation are to set limits on the mechanisms, to quantify them, and to particularize the mechanisms to the region under study in order to construct an adequate operational game within the time frame of the study and which is consistent with the goals of a regional assessment study program. The schema for operationalizing the decision scenarios, actor policies, and impact models are under investigation. Appendix C gives the structure of the regional energy environment game and presents a time horizon chart for this portion of the study. Appendix D is a working paper on phase 1 methodology (first generation) which is provided to describe and illustrate the methodology being employed in this phase.

Level of Effort

During the quarter the total professional manpower utilized is about eleven man-months of which about one man-month of the principal investigators' time was used in organizing, guiding, and directing the project. This level of effort will continue for about two more months.

Components

The components of a Regional Energy Environment Game (REEG)

i) Reference Scenario

This is the current state of every variable which would be an important input to the decision making of the major actors who play important roles in the energy and/or environmental activity in the region and the nation.

ii) Decision Environment/Decision Scenario

This is the environment in which decisions by major actors are required. This decision environment consists of all current state variables described in (i) and announced or anticipated actions of some actors. For example, the decision environment could be that of an extensive program of rationing of natural gas. Natural resources can be defined as a passive actor (in the sense that his action is completely determined by others). Under this convention another decision environment could be that the "natural gas resources" actor announces that his resources would be depleted by 1990.

iii) Energy Environment Game

This is a simulation of how actors interact and take actions. The decision environment provides each actor with a set of (a) state variables relevant to him, (b) relevant announced or anticipated actions of some actors, and (c) influence exerted on him by other relevant actors and impact of these actions on relevant state variables as judged by him.

Then an actor makes two sets of decisions - (a) decisions to influence other actors in their decision making, (b) decisions to take certain actions (e.g., prescribe regulations, build fewer nuclear power plants).

iv) Impacts on the Present State

These are the net impacts or changes of current state variables as a result of the final actions made by the actors in the environment energy game.

v) Resultant State

This is the state resulting from impacts on the present state, with an updated set of values of every state variable. It enables a new iteration of the environment energy game to be played.

Methodology for the Regional Energy Environment Game

The regional energy environment game development is divided into two phases of study. Phase I takes a concise global approach to REEG gaming. The basic goal is to grasp quickly the important elements of REEG gaming. It will serve as a foundation for a more detailed model to be developed in Phase II.

Methodology for Phase I

1. Identification and Quantification of Present State (Reference Scenario)
   Here the task is to identify all state variables as defined in (i). These state variables are then quantified in Phase II.
2. Construction of Decision Environment(s)/ Decision Scenario(s)
   The decision environment will be that of dwindling supplies of oil and gas.
3. Identification and classification of major actors, their goals, objectives and policies, and their relationship with other actors.
   A. This entails the construction of a matrix as follows:

Actors

	Major Actors_1	Actors_2	Actors_i (identified in Task 3)
Objectives	Objectives, goals & policies identified in Task 3		

   B. Fill in the above matrix with each column indicating the relative importance of each goal to the actor, for example, $U_{i\,k}$ = relative importance of i to actor k

4. Identification and Quantification of Future States/Future Scenarios

A. Future states will be identified and described:

Scenario I: management of energy demand via conservation

Scenario II: increasing energy supply via significant expansion of nuclear generating capacity

Scenario III: increasing energy supply via significant expansion of domestic production of oil and gas

B. A matrix with entries from a scale will be constructed as follows:

	Scenario I	Scenario II	Scenario III (Task 4A)
State variables (Task 1)	a_{js}		

Note that a_{jS} is the degree that the value of a state variable will be judged to deviate (up or down) from that of the Present State (Reference Scenario).

5. Energy Environment Gaming with a Weighting Model

A. For each future state S, V^S is a matrix with entries, V^S_{ik} (= a measure of how much actor $\underline{k}$ would rate the relative importance of future state S according to his goal/objective i). We represent the weighted or aggregated importance of future state S to actor k by

$$r_{ks} = \sum_i (V^s_{ik})\ (U_{ik})$$

and put $W_s = \sum_k \underline{r_{ks}}\, x_k$ as the weighted desirability of future state (scenario) S accomodating all actors, where x_k is the weight of actor k relative to other actors.

B. Determination of Composite (desired) Future State

The state variables of the desired future state are described by the following:

$$d_j = \sum_s a_{js} \cdot W_s$$

The results of Phase I will provide the following inputs to Phase II of the study:

1. Identification and Quantification of relevant variables of the Present State (Reference Scenario).
2. Identification of Decision Environment(s) / Decision Scenarios
3. Description and understanding of major actors, their goals, objectives and policies, their relationship and influence on other actors, and their range of possible reactions.
4. Estimation of final decisions of the actors and the resultant Future State corresponding to the decision environment.

Methodology for Phase II

Phase II is a more thorough modeling approach to the simulation of the Regional Energy Environment Game. Its purpose is to demonstrate the feasibility of gaming for regional energy environment assessment. Phase II will focus on a limited number of actors (their interactions and decision making) i.e., a number large enough to demonstrate the feasibility and value of gaming and small enough for a computer simulation of actors' interaction within the scope of this study.

1. Impact Model Synthesis

A collection and documentation of impact models will be performed to be used in the decision impact analysis. Appropriate models will be selected from those that most efficiently address the changes in the defined set of state variables developed in Phase I.

2. Refinement and Quantification of State Variables

The set of state variables defined in Phase I will be refined in terms of the restricted set of actors and their relevant state variables. Then this restricted set of state variables will be quantified in terms that are compatible with a computerized interactive gaming scheme.

3. Model of Interaction

A preliminary investigation is being made of the state-of-the-art in the context of the present application, so that the groundwork for a suitable energy/environment game management computer program can be developed. This preliminary investigation, in concert with the characterization of actors, relationships, and policies developed in Phase I, will be used to construct the computerized gaming model. This model will also include coordination with the impact assessment models, so that the resulting system state, determined as a result of actor actions, can be measured. It is anticipated that refinement of the model of interaction (the game) will proceed along with the refinement of the characterization of actors, relationships and policies. The number of actors involved in the interactive gaming will be a restricted set of those considered in Phase I. Restricting the number of actors consequently restricts the scope of the state variables and the decision environment as well as making the computerized implementation of the game more practical.

4. Quantification of the Decision Scenario

The decision scenario discussed in Phase I must be quantified in terms of the defined state variable.

5. Model Implementation and Testing

Finally the model will be implemented in an interactive computer language and a testing of the game given several different decision scenario/environments will be performed. The results will be compared with the estimated results of the Phase I study in order to check consistency of the interactive gaming results.

III. Methodology for Regional Energy Enviroment Game (REEG)

PHASE I -

1. Reference Scenario Description

2. Decision Scenario Construction

3. Ident. and Class. of Actors, Relationships, and Policies

4. Future Scenario Description and Quantification

5. Development and Application of Weighting Methodology to REEG

PHASE II -

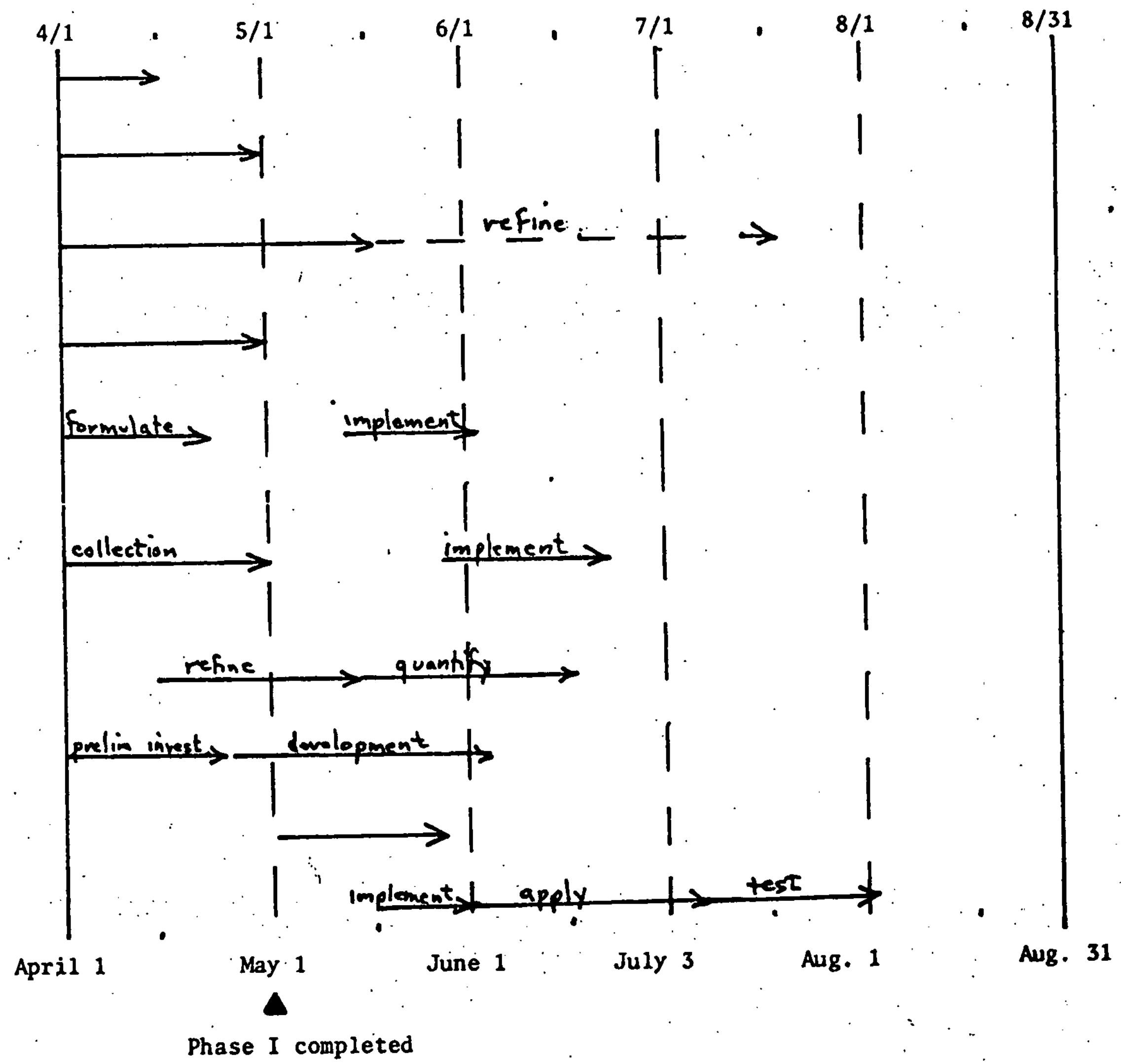
1. Impact Model Synthesis

2. Refinement and Quantification of State Variables

3. Model of Interaction

4. Quantification of Decision Scenario

5. Model Implementation, Testing and Refinement



Appendix A

Activity to be Performed

The scope of activity is unclassified and shall consist of the Contractor's assisting BER/ERDA in program planning. In furtherance thereof, the Contractor shall prepare a final report on a regional assessment study program which shall include the following items:

1. Describe and discuss how one scopes, sets purposes, goals, and objectives for and initiates a regional assessment study program suitable for BER/ERDA.
2. Analyze, describe, and discuss whether and how operational gaming might play a key and central, and perhaps unique, role either within a regional assessment study program or in the management and direction of one.
3. Describe, discuss, and analyze how a regional assessment program with or without the methods of operational gaming might affect the achievement of a higher level of public understanding with respect to the environmental and health and safety problems of nuclear energy in the context of alternative energy systems. Note that "safety" as used here does not refer to nuclear reactor accidents.
4. Describe, discuss, and analyze how a regional assessment study program with or without the methods of operational gaming might relate to the possibly serious needs that ERDA might discover for adequately trained manpower, nuclear and nonnuclear.
5. Describe and discuss any special requirements that a regional assessment study program and possibly operational gaming places with respect to such areas as computerized information systems, computerized data management systems and file management systems; computerized display systems, including graphics systems; etc.
6. Discuss and analyze the role of computer simulation in a regional assessment program with due attention to the current state of the art.

The Contractor shall also consult with BER/ERDA within the general area of scope of work as otherwise described above, and as set forth in the Contractor's informal budget to the Administration.

Appendix B

Tentative Contents - First Generation Game

I. Introduction

II. Methodology and Illustration

III. Reference Scenario

IV. Decision Scenarios (3)

V. Future Scenarios (3)

VI. Identification of Actors, Relationships, and Policies

VII. Judgmental Comparison - Application of the Weighting Methodology

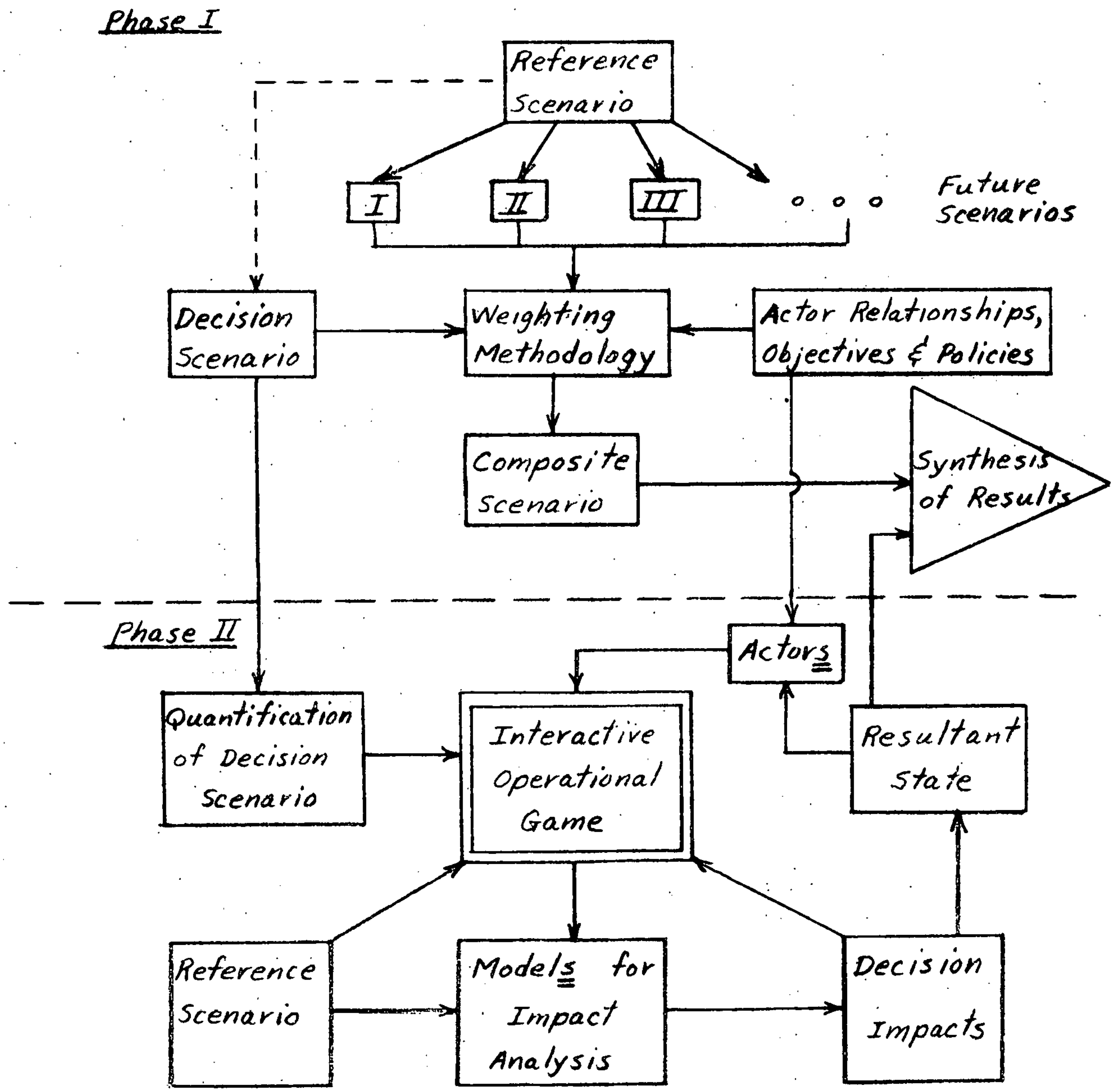
VIII. Results

IX. Sensitivity

X. Conclusions

Appendix C

Structure of the Regional Energy Environment Game



Appendix D

Working Paper on Phase I Methodology

As mentioned in the Introduction to the report the purpose of the Phase I study is to construct a concise global approach to Energy Environment gaming. The development in Phase I will facilitate:

1. Construction of important scenarios that provide the framework within which the Regional Energy Environment Game (REEG) can be played.
2. Characterization of the important actors that will become participants in the Game.

Since these two components are crucial in developing the final structure of the REEG game (Phase II), a test of their consistency must be made in order to insure that Phase II proceeds using reliable characterizations of actors, relationships among those actors, and the important factors involved in the Energy Environment system.

This test of consistency is based on the Eigenvalue Method for Prioritization and Planning. In this application the Eigenvalue approach is employed to determine a future based on the objectives of identified actors and relative overall influence each of these actors has in fulfilling his objectives. In particular we consider a region in which decision-makers may want to shape the energy environment future of the region and are concerned with the interaction of various interests in the regional socio-economic system as an input to this energy environment policy making process.

The Eigenvalue Model comprises a weighting methodology by which we can account for the objectives of relevant actors, as well as the relative overall influence each actor has in realizing his objectives, and then yield a derived future or composite scenario. This derived future scenario is a composite scenario in that it is selected from a set of possible future scenarios, or is constructed as a combination of this set of futures.

Let us demonstrate the technique in an example to illustrate how the eigenvalue approach can be applied in determining a composite scenario.

The following are required to apply this weighting methodology in the composite scenario construction:

1. A set of relevant actors whose interests determine the state of the existing energy environment system.
2. The state of the energy environment system is measured in terms of a set of factors or system variables.
3. Each actor has control over a number of the system factors and exercises this control in a manner that is consistent with his objectives which may be individual, which relate to his own interests, or global, which relate to the interests of society as a whole.
4. A set of future scenarios describe the possible consequences of actor interaction in pursuit of objectives and a combination of a number of these future scenarios comprises a composite scenario.
5. The context within which one makes decisions in pursuance of goals can be termed the decision scenario. This simply describes a state of affairs that requires action of the involved actors in the energy environment system. The characterization of the decision scenario along with a reference state (a reference scenario) of the energy environment system constitutes a decision environment which, in effect, sets the stage for interaction in the energy environment game or, in this first case, a shorthand description of the game by the weighting methodology.

Let us now look at the mechanics involved in deriving the composite scenario for a simple example which will, in the process, illustrate the weighting methodology.

Consider three actors in a simple energy environment system:

1. The government - which regulates the consumption of energy, the maintenance of environmental quality, and influences the level of reserves of energy resources.

2. A private profit-motivated utility which generates electricity at the rate demanded by a consuming public and which is subject to the regulatory influence of the government.

3. Consumers of electrical energy who are concerned about the price of energy, as well as the quality of the environment in which they live.

The actors can pursue any or all of the following objectives, some of which will be pursued more vigorously than others:

1. minimizing the cost of producing and consequently consuming energy
2. maintanence of a high standard of environmental quality
3. preservation or conservation of precious natural energy resources

Let us presume that the factors or variables that measure the state of the energy environment are the following:

1. the cost of energy in dollars
2. the quality of the environment in pollution units (e.g., concentration of SO_2)
3. the proven reserves of natural energy resources as a measure of availability of reserves

Suppose now that the above energy environment system has three alternatives for producing electric power in the future. These three alternatives constitute the possible future scenarios of the energy environment system:

1. use of oil-fired plants.
2. use of coal-fired plants.
3. use of nuclear plants.

Given this information, how can we determine the most desirable future of the energy environment system based on the interaction of the defined actors who are pursuing individual as well as global goals? In the terms of the eigenvalue approach we can first construct a matrix of pairwise comparisons of a particular actor's influence (effectiveness in realizing his goals) as compared to the relative influence of other actors. In the simplest application, these comparisons can be obtained by judgment, or perhaps observed from data empirically determined. The eigenvalue model requires that the judgments be based on a scale from zero to nine, with the inverse relationship defined by the reciprocal.

In this case, for instance, the government may exert more influence on the state of the energy environment system as compared to the utility by, say, a factor of 3. Accordingly, then the influence of the utility as compared to the government is 1/3. An example of these comparisons for all actors constructed in a matrix might be the following:

$$
\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \end{array}
\begin{array}{c} \begin{array}{ccc} A_1 & A_2 & A_3 \end{array} \\ \begin{bmatrix} 1.00 & 3.00 & 2.00 \\ .33 & 1.00 & 4.00 \\ .50 & .25 & 1.00 \end{bmatrix} \end{array}
$$

A_1 = government
A_2 = utility
A_3 = consumers

According to the theory of the eigenvalue method the normalized eigenvector corresponding to the dominant eigenvalue of this matrix can be used as a measure of dominance of one actor compared to another with respect to relative influence on the energy environment system.

Let us call this matrix W, the dominant eigenvector of which is A.

$$
A = \begin{bmatrix} .5317 \\ .3320 \\ .1463 \end{bmatrix} \begin{array}{l} \text{government} \\ \text{utility} \\ \text{consumer} \end{array}
$$

A is then the measure of the actor's relative influence.

Each actor pursues the defined objectives with varying degrees of emphasis. Pairwise comparison of the defined objectives of each actor can accordingly be made to determine the priority with which an actor views each of the sets of objectives.

Let us call the matrix of comparisons of objectives for the government actor A1, that for the utility A2, and that for the consumers A3.

A typical set of matrix constructions of these comparisons might be:

A1 = government

	O_1	O_2	O_3
O_1	1.00	3.00	3.00
O_2	.33	1.00	.33
O_3	.33	3.00	1.00

A2 = utility

	O_1	O_2	O_3
O_1	1.00	8.00	4.00
O_2	.13	1.00	.17
O_3	.25	6.00	1.00

A3 = consumer

	O_1	O_2	O_3
O_1	1.00	2.00	3.00
O_2	.50	1.00	2.00
O_3	.33	.50	1.00

O_1 = minimizing energy cost
O_2 = maintaining environmental quality
O_3 = preserving natural resources

The dominant eigenvectors of A1, A2, and A3, which we can call g_1, g_2, and g_3, respectively, describe the relative priorities of the objectives for each actor:

$$g_1 = \begin{bmatrix} .584 \\ .135 \\ .281 \end{bmatrix} \begin{matrix} O_1 \\ O_2 \\ O_3 \end{matrix} \qquad g_2 = \begin{bmatrix} .691 \\ .060 \\ .249 \end{bmatrix} \begin{matrix} O_1 \\ O_2 \\ O_3 \end{matrix} \qquad g_3 = \begin{bmatrix} .540 \\ .297 \\ .163 \end{bmatrix} \begin{matrix} O_1 \\ O_2 \\ O_3 \end{matrix}$$

Concatenation of these vectors in a matrix G and multiplication by A yields a vector B which is a weighting of objectives based on the relative importance of each objective to each actor and the relative influence of each actor.

$$\underline{B} = \underline{\underline{G}}A = \begin{bmatrix} .584 & .691 & .540 \\ .135 & .060 & .297 \\ .281 & .249 & .163 \end{bmatrix} \begin{bmatrix} .0584 \\ .2966 \\ .6450 \end{bmatrix} \begin{bmatrix} .5871 \\ .2172 \\ .1957 \end{bmatrix} \begin{matrix} O_1 \\ O_2 \\ O_3 \end{matrix}$$

We can again apply the scheme in the next hierarchy to determine the importance of a particular factor in pursuing an objective. This requires pairwise comparison again, this time of the three factors with respect to each objective. Let us call the comparison matrices for objective 1 (minimizing energy cost) O1, for objective 2 (maintaining environmental quality) O2, and for objective 3 (preserving natural resources) O3, and their respective dominant eigenvectors h_1, h_2, h_3, (concatenated to yield A).

O1 = minimize energy cost	f_1	f_2	f_3
f_1	1.00	8.00	3.00
f_2	.13	1.00	.14
f_3	.33	7.00	1.00

O2 = maintain quality environment	f_1	f_2	f_3
f_1	1.00	.14	.33
f_2	7.00	1.00	5.00
f_3	3.00	.20	1.00

O3 = preserve energy resources	f_1	f_2	f_3
f_1	1.00	6.00	.33
f_2	.17	1.00	.13
f_3	3.00	8.00	1.00

f_1 = cost of energy
f_2 = environmental quality
f_3 = energy reserves

$$H = \left[h_1 \vdots h_2 \vdots h_3 \right] = \begin{array}{c} \\ \\ \\ \end{array}\begin{array}{c} O_1 \quad\quad O_2 \quad\quad O_3 \\ \begin{bmatrix} .645 & .081 & .285 \\ .058 & .731 & .062 \\ .297 & .188 & .653 \end{bmatrix} \end{array} \begin{array}{c} \\ f_1 \\ f_2 \\ f_3 \end{array}$$

Multiplication of this matrix $\underline{\underline{H}}$ by $\underline{B}$ gives a weighting of the factors based on all of the following:

1. relative influence of actors
2. relative ranking of objectives
3. relative importance of factors for each objective

Let us call the result of multiplying $\underline{\underline{H}}$ by B the vector C, which is a weighting of factors.

$$\underline{C} = \underline{\underline{H}}B = \begin{bmatrix} .452 \\ .205 \\ .343 \end{bmatrix} \begin{array}{c} f_1 \\ f_2 \\ f_3 \end{array}$$

Finally we can extend the analysis to include the importance of a particular factor in realizing a possible future scenario. That is, for each factor what are the pair-wise comparisons of the contribution of this factor to the possible future scenarios (S1 = using oil, S2 = using coal, and S3 = using nuclear).

F1 = cost of energy

	S1	S2	S3
S1	1.00	.33	.14
S2	3.00	1.00	.20
S3	7.00	5.00	1.00

F2 = environmental quality

	S1	S2	S3
S1	1.00	6.00	5.00
S2	.17	1.00	.50
S3	.20	2.00	1.00

F3 = level of energy reserves

	S1	S2	S3
S1	1.00	.11	.33
S2	9.00	1.00	6.00
S3	3.00	.17	1.00

S_1 = use of oil
S_2 = use of coal
S_3 = use of nuclear

Let us define the corresponding dominant eigenvectors to the matrices F1, F2, and F3 to be i_1, i_2, and i_3, which when concatenated for the matrix I yields

$$\underline{\underline{I}} = \left[i_1 \vdots i_2 \vdots i_3 \right] = \begin{bmatrix} & F1 & F2 & F3 \\ S_1 & .081 & .726 & .068 \\ S_2 & .188 & .102 & .770 \\ S_3 & .731 & .172 & .162 \end{bmatrix}$$

Multiplication of $\underline{\underline{I}}$ by the vector $\underline{C}$ yields the vector $\underline{D}$ which is the overall weighting of the possible future scenarios (the composite scenario) that is based on the hierarchal weighting of actors influence, objectives intensity, and factors importance.

$$\underline{D} = \underline{\underline{I}}\underline{C} = \begin{bmatrix} .209 \\ .370 \\ .421 \end{bmatrix} \begin{matrix} S_1 \\ S_2 \\ S_3 \end{matrix}$$

In this particular example, as one might expect, the use of nuclear energy in producing the future's electric power returned the highest weight. We must recall that this result is determined by judgmental priorities throughout the hierarchal structure of the system. The judgments are made in the context of the decision environment and therefore, in some sense, measure the response of the actors in the energy environment system to the problems presented in that environment.

In this illustration the present "state of the world" was taken as the decision environment. This included such factors as recession and a financial dilemma for utilities which emphasizes the cost factor in the judgmental priorities and leads one to suspect that nuclear would come out with the highest weight, particularly in light of the present state of high fuel costs for the fossil alternatives. Indeed the nuclear alternative did yield the highest weight, but the coal alternative was next (actually very close to the nuclear) and, as expected, both coal and nuclear received much higher weights than the oil alternative.

The result to some extent depends upon the consistency of the judgmental priorities matrices. In the theory behind the Eigenvalue method it is asserted that the value of the largest eigenvalue is a measure of the matrix consistency. The theory says that the closer the highest eigenvalue is to the dimension of the matrix the higher the measure of consistency. In our case, the dimension of all the judgmental matrices is 3, the corresponding eigendata for the 11 judgmental matrices in the example are the following:

MAT	LAMBDA	EIGENVECTOR		
WX	3.104	.058	.297	.645
A1	3.136	.584	.135	.281
A2	3.136	.691	.060	.249
A3	3.009	.540	.297	.163
O1	3.104	.645	.058	.297
O2	3.065	.081	.731	.188
O3	3.074	.285	.062	.653
F1	3.065	.081	.188	.731
F2	3.029	.726	.102	.172
F3	3.054	.068	.770	.162