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Methodology for Site Selection of a Solar Total Energy Large Scale Experiment

Robert W. Hunke

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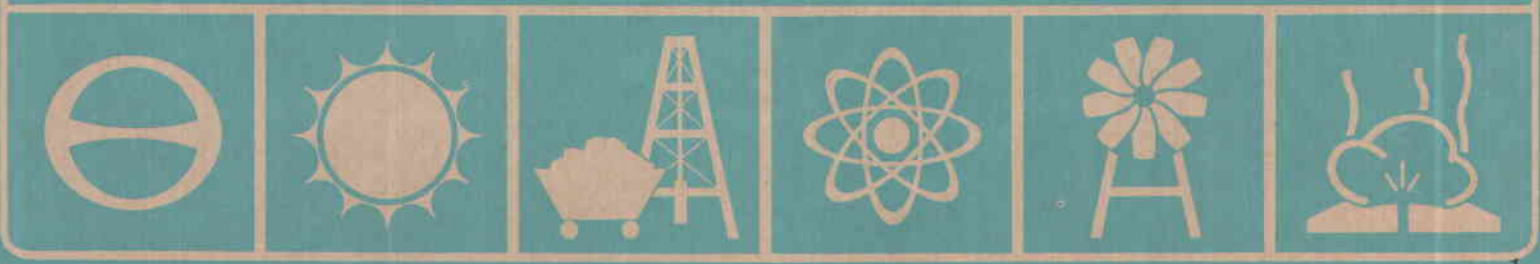

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METHODOLOGY FOR SITE SELECTION OF A SOLAR TOTAL ENERGY LARGE SCALE EXPERIMENT

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ABSTRACT

This report describes the development of the evaluation criteria for a site (a parcel of real property with a development--apparatus, equipment, facilities, etc.) for a Solar Total Energy, Large Scale Experiment. The Large Scale Experiment's desired characteristics are described. The evaluation criteria are given together with an algorithm for the calculation of the expected value of proposals.

ACKNOWLEDGMENTS

This work represents the contributions of many individuals at Woodward-Clyde Consultants, ERDA and Sandia Laboratories. At Woodward-Clyde Consultants Alan Sickerman, Rakish Sarin and Keshavan Nair provided the decision analysis techniques and consultation necessary to the work. At ERDA George Rhodes, Arnold Tepper, Gil Cordova and J. E. Rannels (ERDA Headquarters) provided preference inputs. At Sandia Laboratories many people provided input, among these were Bob Stromberg, Bill McCulloch, Billy Marshall, Jim Leonard and Ray Harrigan. John Zimmerman in particular provided valuable assistance in preparation of the preference structure and prepared the programs for implementation of the algorithms.

CONTENTS

METHODOLOGY FOR SITE SELECTION OF A SOLAR TOTAL ENERGY LARGE SCALE EXPERIMENT

I. Introduction

The Energy Research and Development Administration (ERDA) Solar Total Energy Program (STEP) is a separate activity of the National Solar Thermal Power Systems Program. ERDA's Solar Program is briefly described in a publication designated ERDA 76-1, a National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future. The National Solar Thermal Power Systems Program seeks to develop the technology for the practical and economic collection and conversion of solar irradiation into electricity and to apply this technology to suitable applications.

A Solar Total Energy System (STES) is defined as an energy system which uses collected solar energy by supplying high-grade (electrical/mechanical) and low-grade (low temperature thermal) energy needs for selected applications. The STEP is primarily concerned with solar energy systems which use heat engines or photovoltaic devices to produce electricity and/or mechanical energy and use the conversion process rejected energy for useful purposes.

Sandia Laboratories in its role of Technical Project Manager for ERDA's STEP has prepared a program plan[1] for ERDA that describes implementation of the STEP. An important part of STEP is the design, construction and operation of a series of Large Scale Experiments (LSE). The objective of these LSE is to move the Solar Total Energy technology from the laboratory environment into conditions found in private sectors for the purpose of: (1) assessing the interaction of the technology with the nonlaboratory environment; (2) narrowing the prediction uncertainty of the cost and performance of STES; (3) expanding solar engineering capability and experience with large-scale hardware systems; and (4) disseminating information on STES.

Selection of a site was undertaken by ERDA in January, 1977.[2] The purpose of this report is to describe the methodology developed to aid in the evaluation of site proposals submitted to ERDA. In performing this work, the emphasis has been on providing a means (1) to reduce the subjectivity or at least identify the subjectivity in evaluating the proposal so that the sensitivity could be analyzed, (2) to provide a means for rapid testing of the ranking of proposals by variation of any evaluation parameter, and (3) to provide a vehicle whereby proposers could have high visibility into the process used in the site proposal technical evaluation.

II. Description of the STE-LSE to be Located on the Selected Site

A. Objective

The objective of this Large Scale Experiment (LSE) is to design, construct, test, evaluate, and operate a STES for the purpose of obtaining experience with large-scale hardware systems and to establish engineering capability for subsequent Solar Total Energy Demonstration Projects. The LSE is to be large enough to encounter the problems of a full-scale demonstration. An important objective of the LSE is that all collected energy be used in a cost-effective manner.

B. System Description

The STES to be located on the selected site will be tailored to meet the specific STES engineering needs. The site must be compatible with the desired LSE systems characteristics. The system characteristics of the STES are as follows:

- It will be designed to produce 1 to 3 MW thermal and 200 to 500 kW electrical. The developed site must meet these average load requirements.
- The LSE may be a scaled portion of a larger load, in which case, the design will be based on the scaled load and the STES built to supply the scaled load.
- The STES will be installed to operate in parallel with conventional energy supplies and will be designed to operate on a day-to-day basis to reduce conventional energy demand.
- Thermal storage will be included in the design of the STES to handle conditions peculiar to the electrical and thermal loads of the developed site, and to the local meteorological conditions. Thermal storage to accommodate extended periods of operation, such as overnight operation is not contemplated.
- High temperature storage will not include sensible heat of water unless this concept shows superior cost and/or performance advantages because of factors peculiar to the developed site.
- The STES will be designed to achieve maximum cost benefits while supplying 60 to 90 percent of the thermal load of the developed site (or the scaled load) using an average annual predicted meteorological simulation.
- The input temperature to the heat engine of the thermal conversion system will be approximately 600 degrees Fahrenheit. The input temperature to the thermal application may range between 150 and 350 degrees Fahrenheit.
- The size of the electrical power generation subsystem will be based on the collected solar energy. A base load will be supplied by the local utility if the developed site requires more electrical power than is available from the collected solar energy. (Load peaks will be supplied by the STES.)

- A standby fossil fuel system will be included and will be capable of supplying the thermal energy equivalent of the collected solar energy.

C. Overall STE-LSE Outline

A seven-phase STE-LSE project is planned. The project phases are summarized in the following paragraphs. The estimated schedule for the STE-LSE is shown in Figure 1.

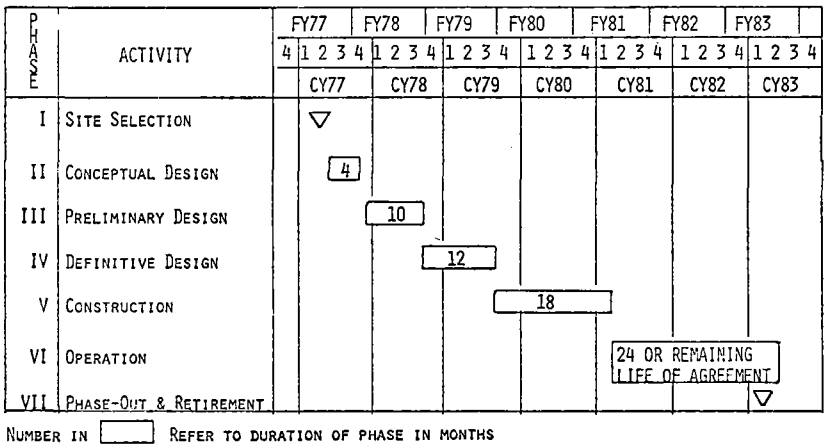

Figure 1. Large Scale Experiment Schedule

Phase I - Site and Development -- A site will be selected which is compatible with the LSE objective of applying proven laboratory technology to large scale use in the private sectors. The following information is to be provided in the proposal for each site:

Site and Development Description
Compliance with Laws and Ordinances
Health and Safety
Environmental Assessment
Load Analysis
Energy Displacement
Utility Interface

Phase II - Conceptual Design -- A solicitation will be issued for up to three contracts to prepare conceptual designs of the STES for the selected site. This project phase will result in a site specific design description, containing as a minimum, the following elements:

System Requirement Analyses
Site Description
System Conceptual Design
Conceptual Test and Operational Plans
Needed Development
Procurement Concept
Cost Estimate
Plans for Subsequent Phases

Phase III - Preliminary Design -- This phase may be an extension of selected Phase II contract(s) and will result in the following elements. (More than one preliminary design contract may be awarded.)

Preliminary System Requirements Analyses

Site Description

System Description (including flow chart with outline specifications for components and subsystems, interface specifications, and characterization of components and subsystems by date.)

Projections of System Operational Performance

Preliminary Test and Evaluation Plan

Operating Plan

Development Data Needed (including project risk attendant with this development)

Preliminary Procurement Plan

Cost Estimates, (including cost breakdown and schedule for each phase of the LSE)

Project Management Plan (including work-breakdown structures, schedule, and milestones for Phase IV and major milestones for subsequent LSE phases)

Phase IV - Definitive Design -- From the preliminary design(s), a design will be selected for definitive design. The definitive phase may be an extension of a Phase III contract and will result in:

Construction Plan, Drawings, and Specifications

Procurement Plan (including long lead time items)

System Requirements Analysis

Interface Definition

System Test and Evaluation Plan

Test Data Management Plan

Operating Plan

System Acceptance Test Plan

Detail Cost Estimates

Project Management Plan (including work-breakdown structures, schedules, and milestones for Phase V and major milestones for subsequent LSE phases)

Phase V - Construction -- The LSE will be constructed and all equipment installed during this phase. The LSE will be operational at the completion of construction. A Project Management Plan and a Test and Evaluation Plan for Phase VI will be included in the Phase V deliverables.

Phase VI - LSE Operation and Projected Use -- The LSE will be operated by the ERDA or its designee for at least two years to gather performance data under actual operating conditions. Operating and economic data will be gathered and evaluated. An analysis of the system's requirements versus operating experience will be made. Alternative plans will be developed during this phase including: (1) the retirement of the LSE, and disposition thereof, or (2) the continued operation of the developed site as part of an ERDA Solar Total Energy Demonstration.

Phase VII - LSE Disposition -- An alternative identified during Phase VI will be selected and implemented for disposition of the LSE.

III. Development of Proposal Evaluation Criteria

The evaluation criteria provided in the Request for Proposal[2] (RFP) were developed by making a list of attributes, Table I, then condensing the attributes into a composite list for inclusion in the RFP. Throughout the preparation of the RFP, attention was directed toward assuring that the information requested from the proposer addressed the required criteria and that the proposal structure provided for ready identification of this information.

Five areas are considered from the standpoint of the Proposer's real property and its developments (site) offered for use in connection with the proposed Solar Total Energy--Large Scale Experiment. The factors to be considered in evaluating the criteria are as follows:

1. Suitability of the site

   a. Climate, including direct normal solar radiation, storms, and relevant winds and similar phenomena.

   b. Relationship of available solar radiation to the site's electrical and thermal load profile and requirements.

   c. Ratio of thermal-to-electrical consumption with a view to maximizing use of all solar energy collected for the proposed STES.

   d. Amount and type of fossil fuel energy proposed to be displaced.

   e. Topography and land use of surrounding areas and subsurface conditions as they may affect design, construction and cost of construction of the STES.

   f. Degree to which the site is representative of extensive application of Solar Total Energy.

2. Compatibility of the site.

   a. The degree to which the energy characteristics of the proposed site effectively interface with the STES characteristics.

   b. The degree to which the time and events necessary to accomplish interface of the proposed site with the Solar Total Energy--Large Scale Experiment is consistent with the events and schedule.

3. Availability of the site.

   The degree to which the proposed site is made available for free access and use by ERDA and its designees for purposes of constructing, operating and maintaining the STES, and conducting and evaluating the LSE.

4. Organizational approach, management and financial capability to perform obligations of the Cooperative Agreement

   a. Resources, experience and commitment of Proposer's organization to effectively perform obligations of the Cooperative Agreement and to promote the development and use of the solar total energy concept.

TABLE I

Site Selection Attributes

1. Site
   - direct normal solar radiation
   - level of precipitation
   - level of wind activity
   - quality of topography
   - subsurface conditions (load bearing)
   - land availability
     - quantity
     - schedule
     - sun-look angle
     - restrictions
     - existing obstructions
     - restrictions against future sunlight
     - obstructions (assurances)
2. Application (load)
   - size
   - operation cycle
   - storage requirements
   - load partitioning (peak and off-peak)
     - utility
     - solar
     - fossil fuel
   - fossil fuel requirements
   - thermal-to-electric applications
   - collected energy to waste heat ratio
   - energy displacement
   - utility interface
3. Schedule
4. Socio-Institutional
   - building codes and standards
   - sun rights
   - architectural restrictions
   - zoning codes
   - building restrictions
   - community and local government support
   - reflected light restrictions
5. Environmental
   - setting before construction
   - impact of proposed action by project phase
     - physical environment
     - biological environment
     - socioeconomic environment
   - effects that cannot be avoided
   - enhancement of man's environment
   - alternatives
6. Health and Safety
   - physical security of plant
   - reflected light
   - safety plan
   - health factors
7. Ownership Proposal
   - financial
   - manpower
   - materials and services
8. Organization and Management
   - competence
   - personnel
   - cooperative agreements
     - interest and commitment
     - effectiveness
   - work plan
9. Cost of Total Project
10. Financial Capability
11. Information Dissemination
    - visibility of site/application to public
    - planned technology dissemination

b. Availability and qualifications of Proposer's personnel to be responsible for administering the Cooperative Agreement on schedule and in a cost-effective manner.

c. Adequacy of the proposed financial resources to accomplish all tasks proposed.

5. Proposer cost-sharing proposal.

From the criteria developed for inclusion in the RFP, a list of evaluation factors was developed and ranges were assigned to the various factors. A number of Sandia Laboratories and ERDA personnel were consulted in developing the range of each factor. The particular factors and the ranges are given in Section IV, and the functions are shown graphically in Figure 2.

IV. Site Selection Evaluation Factors

A. Suitability of Site

1. Climate, including direct normal solar radiation, storms, and relevant winds and similar phenomena. (Places which have less than 20% clear days or excessively harsh climates are excluded.)

   a. Clear days (the mean sky cover between sunrise and sunset is less than or equal to 3/10 as measured by the National Oceanic and Atmospheric Administration (NOAA). Range: 20 - 70 %

   b. Presence of climatic factors for maintenance and operational testing (wind, snow, hail, dust, pollutants).

      (1) little opportunity of testing under most factors (e.g., 0 - 1 of 5)

      (2) opportunity to test under several factors (e.g., 2 - 3 of 5)

      (3) opportunity to test under most factors (e.g., 4 - 5 of 5)

2. Relationship of available solar radiation to the site's electrical and thermal load profile and requirements.

   a. Yearly average percent of load occurring in sunshine hours. Range: 25 - 100 %

   b. Load profile (control testing)

      (1) load follows sun closely

      (2) flat profile

      (3) single peak not following sun closely

      (4) peaks and valleys

      (5) several real profiles available

3. Ratio of thermal-to-electrical consumption with a view to maximizing use of all solar energy collected for the proposed STES.

   a. Thermal-to-electric consumption ratio. Range: 3 - 15 %

   b. Percent utilization of collected energy. Range: 60 - 100 %

4. Percent natural gas displaced. Range: 0 - 100 % (fuel oil is considered at 50 % natural gas)

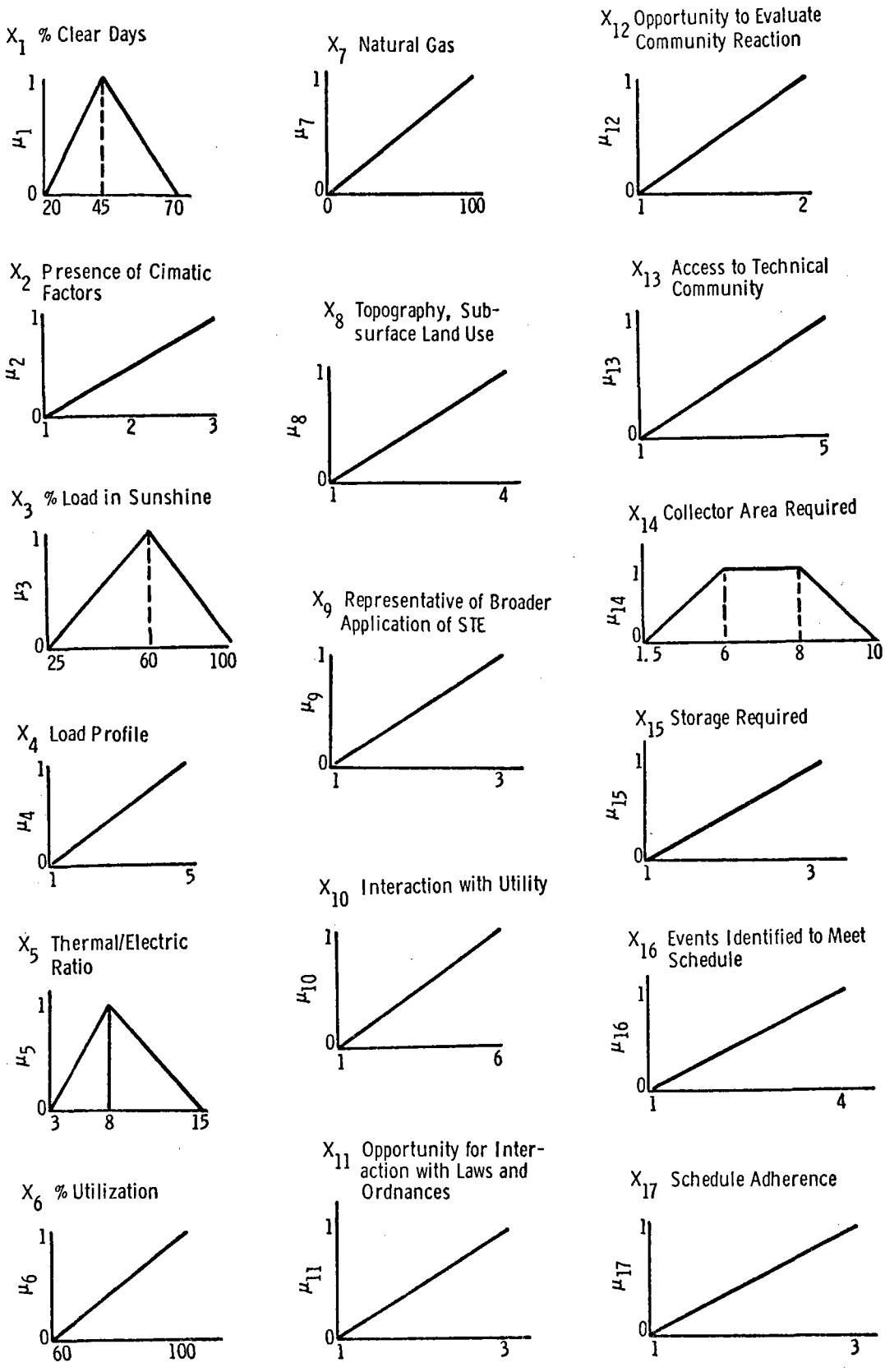

Figure 2. Utility Functions

5. Topography and land use of surrounding areas and subsurface conditions as they may affect design, construction, and cost of construction of the STES.

   Subjective scale: 1 - 4

   4 - Excellent (flat or south facing, free of sun obstructions)

   3 - Good (level, free of sun obstruction, less than ideal load bearing)

   2 - Fair (earth moving required, significant foundations)

   1 - Poor (north facing, poor load bearing, not free of sun obstructions, poor drainage)

6. Degree to which the site is representative of extensive application of STE.

   a. Attractiveness of application in terms of application to a broad sector.

   3 - { commercial (e.g., shopping centers)
       { industrial (e.g., manufacturing, processing)
       { residential (including motels)

   2 - { special institutions (universities, hospitals)
       { agricultural (irrigation, feedlots)

   1 - special applications only (almost unique application)

   b. Interaction with Utility

   Electric utility interface testing:

   (1) little utility interface (isolated, stand alone system)

   (2) utility surcharge for electricity produced (since backup must be kept available)

   (3) passive acceptance of interface by utility

   (4) "A&E" operated with utility participation (consultation, oversight)

   (5) utility operated but ERDA funded

   (6) utility operated

   c. Opportunity to interact with regulations and zoning.

   (1) little opportunity to test interaction with regulations and zoning

   (2) some interaction with very mild regulations and zoning

   (3) interaction with not too atypical regulations and zoning

   d. Opportunity to examine some community reactions to the plant.

   (1) little opportunity to measure reaction of community

   (2) opportunity to measure reaction from community

   e. Accessibility to Technical Community

   Population of community or metropolitan area which is a reasonable commute to the site, e.g., 20-mile radius maximum; population is a good proxy for airport facilities, amenities, accessibility, etc., e.g., Albuquerque - 316,000; Phoenix - 968,000; Lubbock, TX - 149,000.

5 - metropolitan area (> 200,000 people)

4 - locale of major interest to tech community

3 - town < 200,000 with scheduled airline service

2 - town without scheduled airline service or more than 40 miles from major airport

1 - remote, limited accessibility

B. Compatibility of the Site

1. The degree to which the energy characteristics of the proposed site effectively interface with the STES characteristics described in Attachment A.

   a. Collector Area Required $\left(\frac{\text{kW}\cdot\text{hr/operational day}}{\text{kW}\cdot\text{hr/m}^2\text{/day) (0.35)}}\right)$

      Range: 1500 - 10,000 square meters

   b. Storage Capacity Requirements

      3 - 2 hours to 4 hours

      2 - 4 hours to 6 hours

      1 - more than 6 hours or less than 2

2. The degree to which the time and events necessary to accomplish interface of the proposed site with the STE - LSE is consistent with the events and schedule set forth in the RFP.

   a. Identifies Events to Meet Schedule

      4 - PERT-time or equivalent

      3 - Detailed outline

      2 - Broad outline

      1 - Starting and completion dates only

   b. Adherence to Schedule

      3 - meets schedule

      2 - within 2 months

      1 - within 4 months

C. Availability of the Site

1. The degree to which the proposed site is made available for free access and use by ERDA and its designees for purposes of constructing, operating and maintaining the STES, and conducting and evaluating the LSE.

   3 - no restrictions

   2 - some restrictions

   1 - many restrictions

D. Organization and Management

Organizational approach, management and financial capability to perform obligations of the Cooperative Agreements.

1. Resources, experience and commitment of Proposer's organization to effectively perform obligations of the Cooperative Agreement and to promote the development and use of the Solar Total Energy Concept.

   a. Availability of equipment, facilities required to execute the Cooperative Agreement

      Range: 0 - 10 points

   b. Experience of offeror on similar projects

      Range: 0 - 25 points

   c. Commitment and participation of offeror's top management

      Range: 0 - 25 points

   d. Commitment to development of Solar Total Energy Concept

      Range: 0 - 15 points

2. Availability and qualifications of Proposer's personnel to be responsible for administering the Cooperative Agreement on schedule and in a cost-effective manner.

   a. Availability of the numbers and skill mixes of personnel required to accomplish the Cooperative Agreement

      Range: 0 - 30 points

   b. Qualifications of offeror's personnel assigned to the project, i.e., demonstrated experience in similar projects.

      Range: 0 - 45 points

3. Adequacy of the proposed financial resources to accomplish all tasks proposed.

   Screening Criteria: Yes or No.

V. Determination of the Weighting for the Evaluation Factors

Having developed a list of factors believed to adequately describe the criteria needed, decision analysis techniques formulated by Woodward-Clyde Consultants[3] were used to establish the preference structure for the various factors. The technique for accomplishing this was to determine attitudes toward risks and the tradeoffs of various factors against one another. The base criteria used were the percent of the solar collected energy used and percent clear days although any factor could be traded off against another factor. Other factors were considered to verify consistency. The techniques used will be described in the final report from the site selection algorithm contract.[3] In establishing the preference structure, a panel of Sandia Laboratories' personnel were used as well as other people knowledgeable in the field of Solar Total Energy. The preference structure technique was used only on the technical categories, A and B, of the criteria given in the RFP. The other categories, C and D were included in the algorithm but their numerical value was determined by the more traditional method.

The final preference values relative to X_6, the percent utilization of solar energy collected is shown in the following form. Evaluation Form, STE - LSE, Site Selection.

SOLAR TOTAL ENERGY LARGE-SCALE EXPERIMENT - SITE SELECTION

Paragraph Reference			Elements	I.D. No.	Range	Worst	Best	X_i/X_6	Proposal Value	Totals	Element Value
A			Suitability of site	-				-	• • • • •		
	1		Climate	-				-	• • • • •		
		a	% Clear days	X_1	20-70	20-70	45	0.63			
		b	Climatic factors	X_2	1-3	1	3	0.25			
	2		Load profile	-					• • • • •		
		a	Yearly average	X_3	25-100	25-100	60	0.38			
		b	Load profile	X_4	1-5	1	5	0.38			
	3		Energy consumption	-					• • • • •		
		a	Thermal-to-electric ratio	X_5	3-15	3	8	0.25			
		b	% Utilization	X_6	60-100	60	100	1.0			
	4		Natural gas displaced	X_7	0-100	0	100	0.5			
	5		Topography, subsurface, etc.	X_8	1-4	1	4	0.25			
	6		Application	-					• • • • •		
		a	Broader application	X_9	1-3	1	3	0.63			
		b	Utility interaction	X_{10}	1-6	1	6	0.43			
		c	Laws & ordinances	X_{11}	1-3	1	3	0.25			
		d	Community reaction	X_{12}	1-2	1	2	0.5			
		e	Technical community	X_{13}	1-5	1	5	0.125			
B			Compatibility of site	-					• • • • •		
	1		With STE System	-					• • • • •		
		a	Collectors required (KM^2)	X_{14}	1.5-10	1.5-10	6-8	0.38			
		b	H.T. Storage	X_{15}	1-3	1	3	0.125			
	2		Timeliness and completeness	-					• • • • •		
		a	Events identified	X_{16}	1-4	1	4	0.38			
		b	Schedule adherence	X_{17}	1-3	1	3	0.25			650
C			Availability of site	-	1-3	1	3				200
D			Organization and Management	-	-				• • • • •		
	1		Resources, experience, commitment	-	-				• • • • •		
		a	Availability	-	0-10	0	10	-			
		b	Experience	-	0-25	0	25	-			
		c	Commitment to Project	-	0-25	0	25	-			
		d	Commitment to STE	-	0-15	0	15	-			
	2		Availability and qualification	-	-				• • • • •		
		a	Personnel available	-	0-30	0	30				
		b	Personnel qualification	-	0-45	0	45				
	3		Financial adequate	-	YES OR NO						150
			TOTAL SCORE								1000

COMMENTS ON PROPOSAL EVALUATION

Comments should identify the following areas in particular, if applicable and deficient.

1. Proposer's understanding of requirements of the RFP
2. Inherent drawbacks for the overall project.
3. Major technical or business deficiencies or omissions including cost estimates.
4. Other factors which should be called to the attention of the Source Evaluation Board.

Particular strong points of a proposal should be noted.

COMMENTS: (Use additional pages if necessary)

Proposal Identification

Evaluator: ______________________________

Date: ________________________

VI. Site Evaluation Algorithm

Calculation of the value of the individual proposals uses an algorithm based on multiattribute utility theory. The reader is referred to the final report resulting from the Site Selection Algorithm contract for information on the multiattribute utility theory employed.[4] Evaluation of the attributes, and the preference structure indicated that the multiplication form was preferred to the addition form of the utility function and hence was used. Sensitivity tests to verify this selection were made. For criteria elements A and B of the RFP, the point value was determined using:

$$(\text{value})\,(650) = \frac{\prod_{n=1}^{17} [1 + kk_i\mu_i(x_i)] - 1}{k}$$

where

650 = points allocated by the SEP for categories A and B

k_i = scaling constant $(0 < k_i < 1)$

k = non-zero scaling constant $(k \neq 1)$

$U_1(x_i)$ = the utility of an evaluation element

n = number of evaluation elements

The value of k is determined by solving the polynominal:

$$1 + k = \prod_{i=1}^{17} (1 + kk_i), \quad -1 < k \neq 0 \quad .$$

To aid in evaluation of the proposals, these two relationships were programmed for the Hewlett-Packard HP-67 calculator.

VII. References

1. Solar Total Energy Program Plan, SAND76-0167, August, 1976.

2. Request for Proposal EG-77-R-04-0025, Cooperative Agreement for the Conduct and Evaluation of a Solar Total Energy Large Scale Experiment.

3. Sandia Laboratories Contract 05-4566, Solar Total Energy Algorithm, Woodward-Clyde Consultants, November 19, 1976.

4. Final Report, Site Selection Algorithm, Contract 05-4566, Woodward-Clyde Consultants, February, 1977.

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