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Cost of Energy from Some Renewable and Conventional Technologies

FY 1980 Progress Report

Strategic Planning Branch

Solar Energy Research Institute
1617 Cole Boulevard
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FOREWORD

This study is a 1980 snapshot of the current and anticipated costs of delivered energy from renewable resources and from competing conventional energy technologies. The results of the study are intended to provide U.S. Department of Energy (DOE) officials objective and comparable information to assist in developing policy guidance for DOE program offices.

This study was prepared for DOE's Office of Policy and Evaluation (PE). Although DOE program offices were not asked by PE for an official endorsement of the results of this study, staff members from a number of these offices commented on the methodology and reviewed the results. There seems to be general agreement among involved DOE staff about the methodology used, but there is wider variation of opinion about some of the specific numbers and assumptions employed. The information and analytical methodology used were the best available given the time and resources for the study. However, the large uncertainties inherent in projecting future energy costs, economic conditions, and consumer behavior naturally preclude attributing a high degree of significance to the numbers associated with each specific technology, especially as the analytical period extends to the year 2000. The study offers a common foundation for insight as to which renewable technologies appear to be strong economic competitors and points out others that do not seem to be particularly competitive.

As a follow-on to the study, SERI in FY 81 will expand the analysis to include an increased number of specific applications and sites for the more promising renewable energy technologies with the goal of better understanding their nationwide market potential. This work will include an analysis of the sensitivity of the comparative evaluations to economic uncertainties. In addition, SERI anticipates providing a technology characterization and economic analysis of applications where both conservation measures and renewable resources are used. This ongoing analysis will provide Department of Energy officials with a much improved basis for making technology tradeoff decisions crucial to efficient programming of DOE resources in the coming years.

Developing an accounting methodology that is uniformly applicable to a large number of different technologies, applying it to representative, well-documented cases, and coming up with timely and responsive results require the cooperation of many people. We wish to acknowledge particularly the guidance and support of Bill White and Alex Haynes of DOE in accomplishing this task. Jack Cadogan, also of DOE, provided valuable reviews and suggestions. The SERI Task Leader was Russell Hewett. The following SERI analysts contributed directly to the effort: Stella Krawiec, Prabhat Diksit, Anne Marie Neybert, Joel Swisher, and Deborah Buchanan.

Meir Carasso, Acting Chief
Strategic Planning Branch

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SECTION 1.0

INTRODUCTION AND SUMMARY

1.1 OBJECTIVE

The objective of this effort was to develop up-to-date, consistent, and transparent estimates of the cost of delivered energy from a selected number of solar and renewable technologies, and to compare these with the costs of conventional alternatives meeting the energy needs in comparable applications. The Strategic Planning Branch at SERI undertook, at the request of the AS/PE (Solar Office), an accelerated task of developing such estimates on the basis of currently available information, actual facilities where possible, or engineering cost estimates. As part of the project, SERI performed technology characterizations and cost assessments of representative systems relating to 23 solar and renewable resource technology/application pairs. For each pair, identical assessments were also made for representative conventional (e.g., fossil fuel) competing systems. Table 1-1 lists the 23 technology/application pairs.

This report documents the principal results of the assessments in concise, standardized fashion. Detailed backup information relating to each of the 23 assessments (e.g., engineering descriptions of the solar and conventional systems, technical performance data, economic analysis assumptions, sources of the data, etc.) is provided in the companion SERI report, Solar and Renewable Resource Technology Characterization and Cost Assessment Source Book.

Table 1-1. SOLAR AND RENEWABLE RESOURCE TECHNOLOGY/APPLICATION PAIRS ASSESSED FOR DOE/PE

Solar and Renewable Resource Technology	Application
1. Solar water heating	New single family homes (tract construction)
2. Solar water heating	Single family home retrofits
3. Solar water and space heating	New single family homes (tract construction)
4. Solar water heating	New commercial buildings
5. Solar water and space heating	New commercial buildings
6. Industrial process heat	Hot water
7. Agricultural process heat	Animal shelter heating
8. Solar thermal	Electric utilities
9. Wind	Large electric utilities
10. Wind	New single family homes
11. Low head hydroelectric	Electric utilities
12. Biomass	Gaseous fuels
13. Biomass	Liquid fuels
14. Photovoltaics	New single family homes
15. Photovoltaics	Central power plants
16. Geothermal	Industrial process heat
17. Geothermal	Electric utilities
18. Municipal solid waste	Industrial process heat
19. Photovoltaics	Industrial and commercial applications
20. Biomass (wood)	Electric utilities
21. Biomass (wood) cogeneration	Industrial steam and electricity
22. Passive	New single family homes (tract construction)
23. Biomass (wood)	Industrial process heat

1.2 SCOPE

For each of the 23 technology/application pairs, the following information is provided:

- Central Solar/Renewable Resource Systems (i.e., systems for utilities and systems for producing fuels--ethanol, etc.)
  - Brief engineering description and technical performance characteristics of a representative conventional alternative.
  - System installed cost estimates (in 1980 dollars) for both systems--assuming they were acquired in 1980, 1985, 1990, and 2000.
  - Life cycle cost and levelized cost of energy estimates (in 1980 dollars) for both systems--assuming they were acquired in 1980, 1985, 1990, and 2000.
- Distributed Solar/Renewable Resource Systems (i.e., systems for individual homes, farms, commercial buildings, industrial plants, etc., and cogenerating systems).
  - Brief engineering description and technical performance characteristics of a representative solar/renewable resource system for the subject application.
  - Technical performance characteristics of a representative conventional alternative.
  - End user energy-related requirements (e.g., annual energy requirements, temperature settings for space conditioning, etc.).
  - Conservation features of the building, as applicable.
  - System installed cost estimates (in 1980 dollars) for both the solar and conventional systems--assuming they were installed in 1980, 1985, 1990, and 2000.
  - Life cycle cost and levelized cost of energy estimates (in 1980 dollars) for both the solar and conventional systems--assuming they were installed in 1980, 1985, 1990, and 2000.

For each technology/application pair, the technical performance, first cost, and economic performance of both the representative solar/renewable resource system and the conventional alternative are determined assuming they are located at a specific site--which SERI clearly identifies.

To facilitate comparison, all cost data are given in constant 1980 dollars.

1.3 LIMITATIONS

DOE/PE needed results quickly for inclusion in its annual program planning process. Hence, SERI was faced with developing the standardized methodology and then using it to assess the 23 technology/application pairs under an accelerated schedule. Neither time nor funding was available to start from ground zero and do everything in an optimum manner--optimum in terms of analysis tools, analysis methods, and information identification and use. SERI found it necessary to identify and tie into the best available ongoing studies--inside and outside of SERI--relating to the 23 technology/application pairs. In many instances, even the "best available" studies had inadequacies.

The requirement to conduct the study under an accelerated schedule and the strategy of tying into the best available studies resulted in the following limitations:

- Economic Performance Measures: Life cycle cost (LCC) and levelized cost of energy (LCOE) were the only measures of economic performance developed. These are not necessarily the investment decision making criteria used by end users.
- Solar/Renewable System Sizing: Except for the systems relating to water and/or space heating for buildings, no attempt was made to develop a system sizing methodology and use it to determine optimum system size. SERI used the following approach for system sizing:
  - For those technology/application pairs where an existing system is used as the reference (i.e., representative) system, the system's size was maintained.
  - For those distributed technology/application pairs for which the representative solar/renewable system is a conceptual system, SERI used the system's size as specified by the designer.
  - For central technology/application pairs for which the representative solar/renewable system is a conceptual system, SERI used the size as specified (or recommended) by the designer.

- Solar/Renewable System Type: For each technology/application pair, only one type of solar/renewable system was investigated. For example, the representative system used for "solar water and space heating/new single family homes" was a system using hydronic, selectively surfaced, flat plate collectors. The following system types were not investigated:
  - Air flat plate
  - Evacuated tube
  - Water trickle.
- Technical Performance Error Analysis: System energy output values used at each site are expected values. Energy output ranges were not developed and used in subsequent sensitivity analyses.
- System Installed Cost Error Analysis: No attempt was made to estimate the range of possible system installed costs for each system at each site. Only expected cost estimates were generated.
- Economic Performance Sensitivity Analysis: Economic performance sensitivity analyses for each technology/application pair were not conducted. Neither time nor resources were available to assess the sensitivity of the LCC and LCOE for each system to parameters such as:
  - System installed cost
  - System annual energy output
  - Fuel cost escalation rate
  - Utility buyback rates (for distributed systems interconnected with utilities and cogenerating systems)
  - Discount rate.
- Societal/Environmental/Political Benefits: No attempts were made to assess any societal, environmental, or political benefits associated with the solar/renewable systems relating to the 23 technology/application pairs.

1.4 PRESENTATION OF RESULTS

Section 2.0 summarizes the standardized methodology developed by SERI to do the technology characterizations and cost assessments.

Assessments of technology/application pairs relating to distributed applications are presented in Section 3.0. Central system assessments are presented in Section 4.0.

Sections 3.0 and 4.0 consist of a set of three-page tables having a standardized format. All information relating to assessment of each technology/application/representative site combination appears in a separate table. For those technology/application pairs where two sites were investigated, two three-page tables are provided—one for each site.

1.5 SUMMARY

Table 1-2 presents a summary comparison of the levelized cost of energy produced from solar and renewable resources and compares it to the cost of energy produced from conventional resources required in the same application.

The table also provides a ready reference to the three-page summary sheets which comprise the main body of this report. Each three-page summary contains sufficient definition of end-use requirements; engineering definition of the solar and conventional systems; equipment lists; capital, O&M, and fuel cost data; and economic assumptions necessary to define the basis for the levelized costs shown in the table.

Table 1-2. SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980, 1985, 1990, AND 2000 INSTALLATIONS/ACQUISITIONS^{ac}
(1980 Dollars)

TECHNOLOGY/APPLICATION PAIRS (Representative Sites)	SYSTEM DESCRIP- TION REFERENCE TABLE (Page)	1980 INSTALLATIONS		1985 INSTALLATIONS		1990 INSTALLATIONS		2000 INSTALLATIONS	
		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy	
		SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL
Solar Water Heating/New Single Family Homes									
● Fort Worth, Texas	3-2	13.54	19.87	13.94	22.01	13.30	24.49	13.08	30.30
● Madison, Wisconsin	3-5	16.31	21.79	16.88	23.92	16.02	26.36	15.80	30.44
Solar Water Heating/Single Family Home Retrofits									
● Fort Worth, Texas	3-8	13.91	19.87	14.33	22.01	13.62	24.49	13.33	30.30
● Madison, Wisconsin	3-11	16.78	21.79	17.34	23.92	16.40	26.36	16.10	30.44
Solar Water and Space Heating/New Single Family Homes									
● Fort Worth, Texas	3-14	24.20	16.10	24.04	17.44	22.15	18.93	20.54	22.54
● Madison, Wisconsin	3-17	20.04	12.46	21.40	15.20	21.11	18.81	23.85	29.32
Solar Water Heating/New Commercial Buildings									
● Fort Worth, Texas	3-20	11.35	12.66	11.72	13.98	10.93	15.49	11.08	19.10
● Madison, Wisconsin	3-23	12.13	10.82	12.46	11.94	11.33	13.20	11.14	16.27
Solar Water and Space Heating/New Commercial Buildings									
● Fort Worth, Texas	3-26	17.42	15.23	18.15	18.26	16.99	22.18	18.22	34.00
● Madison, Wisconsin	3-29	13.31	16.94	14.14	8.42	13.32	10.32	15.18	16.09
Passive Solar/New Single Family Homes									
● Albuquerque, New Mexico	3-32	12.21	10.51	12.60	11.44	13.04	12.51	15.12	15.07
● Madison, Wisconsin	3-35	10.52	11.08	12.38	13.97	14.77	17.67	23.16	28.51
Wind/New Single Family Homes									
● Boston, Massachusetts	3-38	0.07/kWh	0.07/kWh	0.07/kWh	0.08/kWh	0.07/kWh	0.09/kWh	0.09/kWh	0.12/kWh
● Dodge City, Kansas	3-41	0.05/kWh	0.05/kWh	0.05/kWh	0.07/kWh	0.07/kWh	0.08/kWh	0.06/kWh	0.11/kWh
Photovoltaics/New Single Family Homes									
● Albuquerque, New Mexico	3-44	0.19/kWh	0.06/kWh	0.08/kWh	0.07/kWh	0.07/kWh	0.08/kWh	0.08/kWh	0.10/kWh
● Boston, Massachusetts	3-47	0.15/kWh	0.07/kWh	0.09/kWh	0.08/kWh	0.09/kWh	0.09/kWh	0.11/kWh	0.12/kWh

Table 1-2. SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980, 1985, 1990, AND 2000 INSTALLATIONS/ACQUISITIONS^{a,c} (continued)
(1980 Dollars)

TECHNOLOGY/APPLICATION PAIRS (Representative Sites)	SYSTEM DESCRIP- TION REFERENCE TABLE (Page)	1980 INSTALLATIONS		1985 INSTALLATIONS		1990 INSTALLATIONS		2000 INSTALLATIONS	
		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy	
		SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL
Photovoltaics/Industrial and Commercial Applications ● Oklahoma City, Oklahoma	3-50	0.31/kWh	0.05/kWh	0.08/kWh	0.06/kWh	0.08/kWh	0.07/kWh	0.07/kWh	0.09/kWh
Industrial Process Heat/ Industrial Hot Water ● Fresno, California	3-53	9.94	8.25	10.22	9.37	10.78	10.47	13.03	13.26
Geothermal/Industrial Process Heat ● Hooper, Colorado	3-56	6.03	3.26	5.90	3.51	6.11	3.83	7.15	4.43
Municipal Solid Waste/ Industrial Process Heat (Steam) ● North Little Rock, Arkansas	3-59	3.19	5.89	3.14	7.77	3.24	10.26	3.58	18.42
Biomass (Wood)/Industrial Process Heat (Steam) ● Escanaba, Michigan	3-62	4.24	4.84	4.30	5.14	4.52	5.47	5.05	6.23
Biomass (Wood) Cogeneration/ Industrial Steam and Electricity ● DeRidder, Louisiana	3-65	0.03/kWh (Elec.)	0.04/kWh (Elec.)	0.03/kWh (Elec.)	0.05/kWh (Elec.)	0.04/kWh (Elec.)	0.06/kWh (Elec.)	0.05/kWh (Elec.)	0.08/kWh (Elec.)
		5.13 (Steam)	7.67 (Steam)	5.29 (Steam)	8.11 (Steam)	5.48 (Steam)	8.59 (Steam)	5.95 (Steam)	9.69 (Steam)
Agricultural Process Heat/ Animal Shelter Heating ● Eastern Shore, Maryland ● Madison, Wisconsin	3-68	7.42	11.02	8.00	12.77	8.32	14.65	9.63	19.36
	3-71	6.72	10.08	7.39	11.56	7.93	13.31	9.68	17.74
Wind/Electric Utilities ● Goodnoe, Washington/ Government Utility ● Goodnoe, Washington/ Investor-Owned Utility	4-2	0.08/kWh	0.08/kWh	0.06/kWh	0.11/kWh	0.03/kWh	0.14/kWh	0.03/kWh	0.17/kWh
	4-5	0.11/kWh	0.09/kWh	0.08/kWh	0.11/kWh	0.05/kWh	0.15/kWh	0.05/kWh	0.18/kWh
Photovoltaics/Electric Utilities ● El Paso, Texas	4-8	0.67/kWh	0.09/kWh	0.32/kWh	0.11/kWh	0.08/kWh	0.15/kWh	0.06/kWh	0.18/kWh

Table 1-2. SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980, 1985, 1990, AND 2000 INSTALLATIONS/ACQUISITIONS^{ac} (Concluded)

(1980 Dollars)

TECHNOLOGY/APPLICATION PAIRS (Representative Sites)	SYSTEM DESCRIP- TION REFERENCE TABLE (Page)	1980 INSTALLATIONS		1985 INSTALLATIONS		1990 INSTALLATIONS		2000 INSTALLATIONS	
		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy		Levelized Cost ^b of Energy	
		SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL	SOLAR	CONVEN- TIONAL
Geothermal/Electric Utilities ● La Cueva, New Mexico	4-11	0.04/kWh	0.03/kWh	0.03/kWh	0.03/kWh	0.03/kWh	0.03/kWh	0.04/kWh	0.03/kWh
Biomass (Wood) Electric Utilities ● Montpelier, Vermont	4-14	0.05/kWh	0.05/kWh	0.05/kWh	0.05/kWh	0.05/kWh	0.06/kWh	0.06/kWh	0.07/kWh
Solar Thermal/Electric Utilities ● El Paso, Texas	4-17	0.20/kWh	0.16/kWh	0.16/kWh	0.15/kWh	0.12/kWh	0.14/kWh	0.07/kWh	0.13/kWh
Low Head Hydroelectric/ Electric Utilities ● Kennebec, Maine	4-20	0.06/kWh	0.16/kWh	0.05/kWh	0.14/kWh	0.04/kWh	0.14/kWh	0.03/kWh	0.12/kWh
Biomass/Gaseous Fuels (Medium-BTU Gas) ● Aiken, South Carolina	4-23	4.98	6.41	5.59	8.66	5.92	11.69	6.81	21.34
Biomass/Liquid Fuels (Ethanol) ● Carbondale, Illinois	4-26	1.21/Gal	1.22/Gal	1.36/Gal	1.38/Gal	1.53/Gal	1.57/Gal	1.94/Gal	2.03/Gal

^a In deriving the unit capital cost of systems installed in future years, use was made of estimates of the number of units deployed in 1985, 1990, and 2000, as well as estimates of the anticipated relationship between the unit cost, the scale of production, and other "learning effects. For details, See Sec. 3.0 and 4.0.

^b Costs are given in dollars per million BTU unless otherwise indicated.

^c This table is intended to be used for making pair-wise comparisons between a solar technology and the conventional alternative for the same application. It is not strictly designed for comparisons across different applications.

SECTION 2.0

STUDY METHODOLOGY

2.1 BACKGROUND

The development of a national energy strategy is based, in part, on estimates of resource availability, technology performance, and alternative energy systems costs.

The proliferation of solar systems, technologies, and applications, as well as that of the methods and assumptions used for the analysis of their performance, has resulted in comparisons that were often inappropriate and inconclusive.

SERI has undertaken a number of specific efforts to put the assessment of solar options on a solid footing: actual or detailed engineering assessments of system performance, actual or engineering estimates of the cost of energy, and uniform and transparent accounting. The effort reported here is a precursor to a considerably more extensive effort now underway at SERI. In order to provide a timely assessment of comparable cost estimates of the cost of energy from solar systems, SERI undertook an accelerated effort to provide the cost of energy from a mutually agreed upon set of 23 technology/applications.

Once SERI and DOE/PE reached agreement regarding the technology/application pairs to be characterized, SERI's strategy was threefold:

- Identify and tie into (or exploit) ongoing or completed studies relating to the 23 technology/application pairs:
  - Studies performed by SERI's Strategic Planning Branch.
  - Studies performed by other SERI branches.
  - Studies sponsored and funded by other SERI branches.
  - Ongoing DOE-funded studies by organizations outside SERI.
- Develop a structured, standardized methodology--consisting of standardized tools and procedures--for doing technology characterizations and cost assessments:
  - To insure uniformity of treatment.
  - To insure use of comparable economic analysis methods and parameters.
  - To facilitate meaningful solar-versus-conventional comparison.
  - To facilitate meaningful solar-versus-solar comparisons.
- Perform the 23 assessments using the standardized methodology.

2.2 SERI STANDARDIZED TECHNOLOGY CHARACTERIZATION AND COST ASSESSMENT METHODOLOGY

A detailed description of the SERI methodology--procedures, criteria, and tools--appears in the companion technical report, Solar and Renewable Resource Technology Characterization and Cost Assessment Source Book.

The methodology has nine components:

1. Twelve-step procedure of assessing each technology/application pair.
2. Set of standardized definitions.
3. Reference solar/renewable system selection criteria.
4. Conventional competing system selection criteria.
5. Site selection criteria.
6. Standardized procedure of performing solar/renewable and conventional system technical performance assessments.
7. Standardized system of accounts and formats for generating and documenting:
  - System installed costs
  - Annual O&M costs

8. Standardized procedure for performing economic performance assessment.

- Standardized sets of economic analysis parameters
- Standardized measures of economic performance

9. Rudimentary error analysis procedure.

The methodology centers around the 12-step assessment procedure (i.e., component 1) shown in Table 2-1. Components 2 through 9 are used in various steps of the 12-step methodology.

Table 2-1. 12-STEP PROCEDURE FOR ASSESSING SOLAR AND RENEWABLE RESOURCE TECHNOLOGY/APPLICATION PAIRS

FOR EACH TECHNOLOGY/APPLICATION PAIR, DO THE FOLLOWING:

1. Identify a specific application (e.g., 100-room motel in case of "solar water heating/new commercial buildings").
  2. Specify a reference solar system for that application (using the SERI system selection criteria).
  3. Select one or two representative sites where the system is assumed to be installed (using the SERI site selection criteria).
  4. Specify the competing conventional system for each solar system/site pair.
  5. Estimate the technical performance of the solar and conventional systems at each site.
  6. Estimate the system installed cost for the solar and conventional systems at each site for 1980 in 1980 dollars (using the SERI uniform system of accounts).
  7. Estimate the annual O&M cost for the solar and conventional systems.
  8. Compute the life cycle cost and levelized cost of energy for:
    - Reference solar system at each site
    - Conventional alternative at each site
  9. Specify the market penetration curve for each solar technology/application.
  10. Construct a unit cost curve for each solar technology/application--showing expected system cost as a function of experience, scale of production, and learning.
  11. Determine the expected system installed costs and annual O&M cost for the reference solar system and conventional competing systems for:
    - 1985
    - 1990
    - 2000
  12. Compute the life cycle cost and levelized cost of energy for the systems for:
    - 1985
    - 1990
    - 2000
-

Two measures of economic performance are calculated for each solar/renewable system and conventional alternative:

- Life Cycle Cost (LCC): Present value of the sum of the costs--over the useful life of the system--incurred by the owner.
- Levelized Cost of Energy (LCOE): Levelized annual cost of energy to the end user divided by annual energy delivered (\$/kWh or \$/million BTU).

$$LCC = IC + \sum_{n=1}^N \left\{ \frac{TC_n}{(1 + D)^n} \right\} - \left\{ \frac{S}{(1 + D)^N} \right\}$$

Where:

IC = Initial Cost
 TC_n = Total Cost Incurred in Year n
 (TC_n includes interest, fuel cost, insurance, maintenance cost, etc.)
 N = System Useful Life
 D = Discount Rate
 S = Salvage Value of System

$$LCOE = \left(\frac{LCC * CRF}{\bar{E}} \right)$$

Where:

LCC = Life Cycle Cost
 CRF = Capital Recovery Factor
 $\bar{E}$ = Average Annual Energy Production

SECTION 3.0

SOLAR/RENEWABLE RESOURCE TECHNOLOGY CHARACTERIZATIONS AND COST ASSESSMENTS: DISTRIBUTED SYSTEMS

Section 3.0 documents the results of the assessments for distributed* technology/application/site combinations and is organized as follows:

TECHNOLOGY/APPLICATION PAIRS (Representative Sites)	TABLE
1. Solar Water Heating/New Single Family Homes	
• Fort Worth, Texas	3-1
• Madison, Wisconsin	3-2
2. Solar Water Heating/Single Family Home Retrofits	
• Fort Worth, Texas	3-3
• Madison, Wisconsin	3-4
3. Solar Water and Space Heating/New Single Family Homes	
• Fort Worth, Texas	3-5
• Madison, Wisconsin	3-6
4. Solar Water Heating/New Commercial Buildings	
• Fort Worth, Texas	3-7
• Madison, Wisconsin	3-8
5. Solar Water and Space Heating/New Commercial Buildings	
• Fort Worth, Texas	3-9
• Madison, Wisconsin	3-10
6. Passive Solar/New Single Family Homes	
• Albuquerque, New Mexico	3-11
• Madison, Wisconsin	3-12
7. Wind/New Single Family Homes	
• Boston, Massachusetts	3-13
• Dodge City, Kansas	3-14
8. Photovoltaics/New Single Family Homes	
• Albuquerque, New Mexico	3-15
• Boston, Massachusetts	3-16
9. Photovoltaics/Industrial and Commercial Applications	
• Oklahoma City, Oklahoma	3-17
10. Industrial Process Heat/Industrial Hot Water	
• Fresno, California	3-18
11. Geothermal/Industrial Process Heat	
• Hooper, Colorado	3-19
12. Municipal Solid Waste/Industrial Process Heat (Steam)	
• North Little Rock, Arkansas	3-20
13. Biomass (Wood)/Industrial Process Heat (Steam)	
• Escanaba, Michigan	3-21
14. Biomass (Wood) Cogeneration/Industrial Steam and Electricity	
• DeRidder, Louisiana	3-22
15. Agricultural Process Heat/Animal Shelter Heating	
• Eastern Shore, Maryland	3-23
• Madison, Wisconsin	3-24

*For the purposes of this study, distributed systems, solar and non-solar, are systems for individual end-use applications: Single family homes, multifamily residences, industrial plants, office and commercial buildings, institutional buildings (e.g., schools, hospitals, etc.), and cogenerating systems.

TABLE 3-1
SOLAR WATER HEATING/NEW SINGLE FAMILY HOMES

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	New Single Family Residence/Water Heating
(3) REPRESENTATIVE SITE:	Fort Worth, Texas
(4) CONVENTIONAL ALTERNATIVE:	Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION

(1)

- Collector Area and Type: 54 ft² (5m²), Single Glazed Black Chrome Selective Surface, Flat Plate Collector
- Storage System: 82 Gallon (310 Liters) Hot Water Tank
- Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid
- Backup System: Conventional Electric Water Heater (40 Gallons) (151 Liters)
- Annual Solar Heat Output: 10.5 Million BTU (11.1 Million kJ)
- Annual Conventional Fuel Purchases:
Electricity - 775 kWh
for backup and 228 kWh
for parasitics

END USER REQUIREMENTS

(2)

- Annual Energy Requirement for Water Heating:
13.7 Million BTU (14.4 Million kJ)
- Service Hot Water Temperature:
120°F (49°C)
- Hot Water Requirement: 80 Gal/Day (300 Liters/Day)
- Average Water Supply Temperature:
66°F (19°C)

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc., 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-1 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Requirements:	13.7 million BTU (14.4 million kJ)
• Annual Energy Requirement Met by Solar:	10.5 million BTU (11.1 million kJ)
• Annual Energy Requirement Met by Electricity:	3.2 million BTU (3.3 million kJ)
• Net Solar Fraction:	77%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	2760	4050
(2) Levelized Cost of Energy	\$13.54/million BTU (\$12.82/million kJ)	\$19.87/million BTU (\$18.83/million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)
Collector	810	35	20	Electric Water Heater	240	10	10
Storage	288	--	20	Installation	86	--	--
Electric Wa- ter Heater	240	10	10				
Controls	60	--	20				
Misc. Hard- ware	264	--	20				
Installation	492	--	--				
TOTAL	2154	45	--	TOTAL	326	10	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE, AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	10.5	10.5	10.5
(2) Annual Solar System Output (Million kJ)	11.1	11.1	11.1
(3) Annual Electricity Requirements (kWh)	1003	1003	1003
(4) Annual O&M Cost (\$)	45	45	45
(5) System Installed Cost (Cost to End User)	2154	1858	1512
(6) Life Cycle Cost (\$)	2844	2709	2665
(7) Levelized Cost of Energy (\$/Million BTU)	13.94	13.30	13.08
(8) Levelized Cost of Energy (\$/Million kJ)	13.23	12.60	12.39

TABLE 3-1 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	326	326	326
(2) Annual O&M Cost (\$)	10	10	10
(3) Annual Electricity Purchased (kWh)	4084	4084	4084
(4) Life Cycle Cost (\$)	4486	4992	6175
(5) Levelized Cost of Energy (\$/Million BTU)	22.01	24.49	30.30
(6) Levelized Cost of Energy (\$/Million kJ)	20.86	23.22	28.71
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Owner-occupied Single Family Residence		
(2) Analysis Period:	20 years		
(3) First Year Cost of Electricity:	\$0.0385/kWh		
(4) Electricity Cost Escalation Rate:	10% annually (2.5% real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER HEATING/SINGLE FAMILY HOME, FORT WORTH, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-2

SOLAR WATER HEATING/NEW SINGLE FAMILY HOMES

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	New Single Family Home/Water Heating
(3) REPRESENTATIVE SITE:	Madison, Wisconsin
(4) CONVENTIONAL ALTERNATIVE:	Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION

END USER REQUIREMENTS

- (1)
- Collector Area and Type: 86ft² (8m²) Single-Glazed, Black Chrome Selective Surface, Flat Plate Collector
  - Storage System: 82 Gallon (310 Liters) Hot Water Tank
  - Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid
  - Backup System: Conventional Electric Water Heater 40 Gallon (151 Liters)
  - Annual Solar Heat Output: 12.3 Million BTU (12.9 Million kJ)
  - Annual Conventional Fuel Purchases:
Electricity - 1142 kWh
for backup and 189 kWh
for parasitics

- (2)
- Annual Energy Requirements for Water Heating: 16.5 Million BTU (17.4 Million kJ)
  - Service Hot Water Temperature: 120°F (49°C)
  - Hot Water Requirement: 80 Gal/Day (300 Liters/Day)
  - Average Water Supply Temperature: 50°F (10°C)

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating Cooling and Water Heating, Science Applications, Inc. 1979.
- (2) Booz, Allen, & Hamilton, Draft Report in Support of DOE/Office of Solar Applications.

TABLE 3-2 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Requirements:	16.5 Million BTU (17.4 Million kJ)
• Annual Energy Requirement Met by Solar:	12.3 Million BTU (12.9 Million kJ)
• Annual Energy Requirement Met by Electricity:	4.2 Million BTU (4.5 Million kJ)
• Net Solar Fraction:	75%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVES

(1) Life Cycle Cost (\$)	4004	5351
(2) Levelized Cost of Energy	\$16.31/million BTU (\$15.46/million kJ)	\$21.79/million BTU (\$20.66/million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System)				CONVENTIONAL SYSTEM COST: 1980			
Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)
Collector	1276	50	20	Electric	240	10	10
Storage	288	--	20	Water Heater	96	--	--
Electric Water Heater	240	10	10				
Controls	60	--	20				
Misc. Hardware	264	--	20				
Installation	616	--	--				
TOTAL	2744	60	--	TOTAL	336	10	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE, AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	12.3	12.3	12.3
(2) Annual Solar System Output (Million kJ)	12.9	12.9	12.9
(3) Annual Electricity Requirements (kWh)	1331	1331	1331
(4) Annual O&M Cost (\$)	60	60	60
(5) System Installed Cost (Cost to End User)	2744	2329	1848
(6) Life Cycle Cost (\$)	4146	3932	3879
(7) Levelized Cost of Energy (\$/Million BTU)	16.88	16.02	15.80
(8) Levelized Cost of Energy (\$/Million kJ)	16.01	15.18	14.98

TABLE 3-2 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE: 1985, 1990, 2000			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	336	336	336
(2) Annual O&M Cost (\$)	10	10	10
(3) Annual Electricity Purchased (kWh)	4928	4928	4928
(4) Life Cycle Cost (\$)	5871	6471	7471
(5) Levelized Cost of Energy (\$/Million BTU)	23.92	26.36	30.44
(6) Levelized Cost of Energy (\$/Million kJ)	22.67	24.99	29.09
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Owner-occupied Single Family Residence		
(2) Analysis Period:	20 Years		
(3) First Year Cost of Electricity:	\$0.0442/kWh		
(4) Electricity Cost Escalation Rate:	10% Annually (2.5% real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER HEATING/SINGLE FAMILY HOME, MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas		X			
(c) Escalation in Cost of Electricity		X			
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

- (1) TECHNICAL SOURCES
- 1 = Based on systems actually built and operating
  - 2 = Based on detailed designs of facilities similar to existing ones
  - 3 = Based on engineering designs of new facilities
  - 4 = Based on conceptual designs
  - 5 = Based on an analogy
- (2) ECONOMIC SOURCES
- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
  - 3 = Uncertain prices: Recent volatility on the order of 20% per year
  - 5 = Very uncertain prices and availability: Recent increases of more than 20% per year
- (3) SOCIETAL SOURCES
- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
  - 3 = Minor environmental or public acceptance issues
  - 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-3

SOLAR WATER HEATING/RETROFIT SINGLE FAMILY HOMES

- (1) REFERENCE SOLAR SYSTEM: Selectively Surfaced Flat Plate Collector with Water Thermal Storage
- (2) APPLICATION: Retrofit Single Family Residence/Hot Water Only
- (3) REPRESENTATIVE SITE: Fort Worth, Texas
- (4) CONVENTIONAL ALTERNATIVE: Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION

END USER REQUIREMENTS

- (1)
- Collector Area and Type: 54 ft²(5m²) Single-Glazed Black Chrome Selective Surface, Flat Plate Collector.
  - Storage System: 82 Gallon (310 Liters) Hot Water Tank
  - Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid
  - Backup System: Conventional Electric Water Heater 40 Gallon (151 Liters)
  - Annual Solar Heat Output: 10.5 Million BTU (11.1 Million kJ)
  - Annual Conventional Fuel Purchases: Electricity - 775 kWh for backup and 228 kWh for parasitics

- (2)
- Annual Energy Requirement for Water Heating: 13.7 Million BTU (14.4 Million kJ)
  - Service Hot Water Temperature: 120°F(49°C)
  - Hot Water Requirement: 80 Gal/Day (300 Liters/Day)
  - Average Water Supply Temperature: 66°F(19°C)

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc., 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-3 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Requirements:	13.7 million BTU (14.4 million kJ)
• Annual Energy Requirement Met by Solar:	10.5 million BTU (11.1 million kJ)
• Annual Energy Requirement Met by Electricity:	3.1 million BTU (3.3 million kJ)
• Net Solar Fraction:	77%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	2837	4050
(2) Levelized Cost of Energy	\$13.91/million BTU (\$13.19/million kJ)	\$19.87/million BTU (\$18.83/million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)
Collector	810	35	20	Electric Water Heater	240	10	10
Storage	288	--	20	Installation	86	--	--
Electric Water Heater	240	10	10				
Controls	60	--	20				
Misc. Hardware	264	--	20				
Installation	590	--	--				
TOTAL	2252	45	--	TOTAL	326	10	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	10.5	10.5	10.5
(2) Annual Solar System Output (Million kJ)	11.1	11.1	11.1
(3) Annual Electricity Requirements (kWh)	1003	1003	1003
(4) Annual O&M Cost (\$)	45	45	45
(5) System Installed Cost (Cost to End User)	2252	1941	1579
(6) Life Cycle Cost (\$)	2921	2775	2718
(7) Levelized Cost of Energy (\$/Million BTU)	14.33	13.62	13.33
(8) Levelized Cost of Energy (\$/Million kJ)	13.58	12.91	12.64

TABLE 3-3 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	326	326	326
(2) Annual O&M Cost (\$)	10	10	10
(3) Annual Electricity Purchased (kWh)	4084	4084	4084
(4) Life Cycle Cost (\$)	4486	4992	6175
(5) Levelized Cost of Energy (\$/Million BTU)	22.01	24.49	30.30
(6) Levelized Cost of Energy (\$/Million kJ)	20.86	23.22	28.71
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Owner-occupied Single Family Residence		
(2) Analysis Period:	20 years		
(3) First Year Cost of Electricity:	\$0.0385/kWh		
(4) Electricity Cost Escalation Rate:	10% annually (2.5% real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER HEATING/SINGLE FAMILY HOME RETROFIT, FORT WORTH, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-4

SOLAR WATER HEATING/SINGLE FAMILY HOME RETROFIT

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	Single Family Home Retrofit/Water Heating
(3) REPRESENTATIVE SITE:	Madison, Wisconsin
(4) CONVENTIONAL ALTERNATIVE:	Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

END USER REQUIREMENTS (2)

• Collector Area and Type: 86ft²(8m²) Single-Glazed, Black Chrome Selective Surface, Flat Plate Collector • Storage System: 82 Gallon (310 Liters) Hot Water Tank • Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid • Backup System: Conventional Electric Water Heater 40 Gallon (151 Liters) • Annual Solar Heat Output: 12.3 Million BTU (12.9 Million kJ) • Annual Conventional Fuel Purchases: Electricity - 1142 kWh for backup and 189 kWh for parasitics	• Annual Energy Requirement for Water Heating: 16.5 Million BTU (17.4 Million kJ) • Service Hot Water Temperature: 120°F (49°C) • Hot Water Requirement: 80 Gal/Day (300 Liters/Day) • Average Water Supply Temperature: 50°F (10°C)

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc. 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-4 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

- Total Annual Energy Requirements: 16.5 Million BTU (17.4 Million kJ)
- Annual Energy Requirement Met by Solar: 12.3 Million BTU (12.9 Million kJ)
- Annual Energy Requirement Met by Electricity: 4.2 Million BTU (4.5 Million kJ)
- Net Solar Fraction: 75%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION		
ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	4118	5351
(2) Levelized Cost of Energy	\$16.78/Million BTU (\$15.97/Million kJ)	\$21.79/Million BTU (\$20.66/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)	Component	First Cost(\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)
Collector	1276	50	20	Electric			
Storage	288	--	20	Water Heater	240	10	10
Electric Water Heater	240	10	10	Installation	96	--	--
Controls	60	--	20				
Misc. Hardware	264	--	20				
Installation	740	--	--				
TOTAL	2868	60	--	TOTAL	336	10	

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	12.3	12.3	12.3
(2) Annual Solar System Output (Million kJ)	12.9	12.9	12.9
(3) Annual Electricity Requirements (kWh)	1331	1331	1331
(4) Annual O&M Cost (\$)	60	60	60
(5) System Installed Cost (Cost to End User)			
	2868	2433	1929
(6) Life Cycle Cost (\$)	4260	4027	3953
(7) Levelized Cost of Energy (\$/Million BTU)	17.34	16.40	16.10
(8) Levelized Cost of Energy (\$/Million kJ)	16.45	15.55	15.26

TABLE 3-4 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	336	336	336
(2) Annual O&M Cost (\$)	10	10	10
(3) Annual Electricity Purchase (kWh)	4928	4928	4928
(4) Life Cycle Cost (\$)	5871	6471	7471
(5) Levelized Cost of Energy (\$/Million BTU)	23.92	26.36	30.44
(6) Levelized Cost of Energy (\$/Million kJ)	22.67	24.99	29.09
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Owner-Occupied Single Family Residence		
(2) Analysis Period:	20 Years		
(3) First Year Cost of Electricity:	\$0.0442/kWh		
(4) Electricity Cost Escalation Rate:	10% Annually (2.5% Real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER HEATING/SINGLE FAMILY HOME RETROFIT, MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-5

SOLAR WATER AND SPACE HEATING/NEW SINGLE FAMILY HOME

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector With Water Thermal Storage and Heat Pump
(2) APPLICATION:	New Single Family Home/Water and Space Heating
(3) REPRESENTATIVE SITE:	Fort Worth, Texas
(4) CONVENTIONAL ALTERNATIVE:	Air Heat Pump/Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION

(1)

END USER REQUIREMENTS

(2)

- Collector Area and Type: Single-Glazed, Black Chrome Selective Surface, Flat Plate Collector. Active Area 345ft²(32m²) - Storage System: -1700 Gallon (6400 Liters) Water Tank -82 Gallon (310 Liters) Domestic Hot Water Preheater Tank - Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid - Backup System: -Air-to-Air Heat Pump (40,000 BTU/hr) (42,200 kJ/hr) -Electric Water Heater (40 Gallons) (151 Liters) - Annual Solar Heat Output: 30.1 Million BTU (31.8 Million kJ) - Annual Conventional Fuel Purchases: Electricity - 2305 kWh for Backup and 1000 kWh for parasitics	- Single Family Residence - Ranch Home on a Slab Foundation, 1800 ft² (167 m²) of Living Space - Conservation Features: -R-12 Wall Insulation -R-19 Ceiling Insulation -R-5 Slab Foundation with One-Inch of Rigid Insulation Around Perimeter -Storm Windows - Annual Space Heating Requirement: 30.4 Million BTU (32.1 Million kJ) - Annual Energy Requirement for Water Heating: 13.4 Million BTU (14.2 Million kJ) - Service Hot Water Temperature: 120°F (49°C) - Hot Water Requirement: 80 Gal/Day (300 Liters/day)

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc., 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-5 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Load:	43.9 Million BTU (46.3 Million kJ)
• Annual Energy Load Met by Solar:	30.1 Million BTU (31.8 Million kJ)
• Annual Energy Load Met by Electricity:	13.8 Million BTU (14.5 Million kJ)
• Annual Electrical Requirement:	11.3 Million BTU (11.9 Million kJ)
• Net Solar Fraction:	63%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	15807	10522
(2) Levelized Cost of Energy	\$24.20/Million BTU (\$22.93/Million kJ)	\$16.10/Million BTU (\$15.27/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)	Component	First Cost(\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)
Collector Subsystem	6072	150	20	Heat Pump	1620	100	20
Storage	794	--	20	Electric Water Heater	240	10	10
Solar Hot Water System	720	40	20	Ductwork	480	--	20
Heat Pump	1620	100	20	Installation	890	--	--
Electric Water Heater	240	10	10				
Controls	696	--	20				
Ductwork & Piping	1885	--	20				
Installation	3780	--	--				
TOTAL	15807	300	--	TOTAL	3230	110	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	30.1	30.1	30.1
(2) Annual Solar System Output (Million kJ)	31.8	31.8	31.8
(3) Annual Electrical Requirements (kWh)	3305	3305	3305
(4) System Installed Cost (Cost to End User)	15807	13755	11223
(5) Annual O&M Cost (\$)	300	300	300
(6) Life Cycle Cost (\$)	15695	14466	13414
(7) Levelized Cost of Energy (\$/Million BTU)	24.04	22.15	20.54
(8) Levelized Cost of Energy (\$/Million kJ)	22.77	21.00	19.47

TABLE 3-5 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	3230	3230	3230
(2) Annual O&M Cost (\$)	110	110	110
(3) Annual Electricity Purchases (kWh)	8938	8938	8938
(4) Life Cycle Cost (\$)	11388	12364	14728
(5) Levelized Cost of Energy (\$/Million BTU)	17.44	18.93	22.54
(6) Levelized Cost of Energy (\$/Million kJ)	16.52	17.95	21.37
MAJOR ECONOMIC ANALYSIS ASSUMPTION			
(1) Ownership Pattern:	Owner-occupied, Single Family Residence		
(2) Analysis Period:	20 Years		
(3) First Year Cost of Electricity:	\$0.038 /kWh		
(4) Electricity Cost Escalation Rate:	10% Annually (2.5% Real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER AND SPACE HEATING/NEW SINGLE FAMILY HOME, FORT WORTH, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-6

SOLAR WATER AND SPACE HEATING/NEW SINGLE FAMILY HOME

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	New Single Family Home/Space and Water Heating
(3) REPRESENTATIVE SITE:	Madison, Wisconsin
(4) CONVENTIONAL ALTERNATIVE:	Gas Furnace, Gas Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION (1)	END USER REQUIREMENTS (2)
- Collector Area and Type: Single Glazed, Black Chrome Selective Surface, Flat Plate. Active Area - 570 ft²(53m²) - Storage System: -2800 Gallon (10,600 Liters) Water Tank -82 Gallon (310 Liter) Domestic Hot Water Preheater Tank - Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid - Backup System: -Gas Furnace (100,000 BTU/hr) (105,500 kJ/hr) -Gas Water Heater (40 Gallons)(151 Liters) - Annual Solar Heat Output: 43.9 Million BTU (46.3 Million kJ) - Annual Conventional Fuel Purchases: - Natural Gas - 67.3 Million BTU (71.0 Million kJ) for backup - Electricity - 833 kWh for backup and 183 kWh for parasitics	- Single Family Residence-Rambler with basement, 1700 ft² (158 m²) of living area - Conservation Features -R-12 Basement Floor Insulation -R-18 Wall Insulation -R-30 Ceiling Insulation -Triple Glazed Windows - Annual Space Heating Requirement: 68.6 million BTU (72.4 million kJ) - Annual Energy Requirement for Water Heating: 16.6 million BTU (17.5 million kJ) - Service Hot Water Temperature: 120°F(49°C) - Hot Water Requirement: 80 gal /day (300 Liters/Day) - Space Heating Temperature Setting: 70°F(21°C) - Annual Heating Degree Days (base 65°F): 7863

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc., 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-6 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Load:	85.2 Million BTU (89.9 Million kJ)
• Load Met by Solar:	43.9 Million BTU (46.3 Million kJ)
• Load Met by Natural Gas:	41.3 Million BTU (43.6 Million kJ)
• Net Solar Fraction:	52%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	25,411	15,795
(2) Levelized Cost of Energy	\$20.04/Million BTU (\$19.01/Million kJ)	\$12.46/Million BTU (\$11.82/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$) (Exc.Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$) (Exc.Fuel)	Life (Years)
Collector Subsys.	9868	300	20	Gas Furnace	840	50	20
Storage	1000	--	20	Gas Water Heater	270	10	10
Solar Hot Water Subsystem	720	40	20	Ductwork	450	--	20
Gas Furnace	840	50	20	Installation	743	--	--
Gas Water Heater	270	10	10				
Controls	696	--	20				
Ductwork & Piping	1855	--	20				
Installation	4604	--	--				
TOTAL	19,853	400	--	TOTAL	2,303	60	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	19853	16881	13288
(2) Annual Solar System Output (Million BTU)	43.9	43.9	43.9
(3) Annual Solar System Output (Million kJ)	46.3	46.3	46.3
(4) Annual Natural Gas Requirements (Therms)	673	673	673
(5) Annual Electricity Requirement (kWh)	1017	1017	1017
(6) Annual O&M Cost (\$)	400	400	400
(7) Life Cycle Cost (\$)	27133	26757	30225
(8) Levelized Cost of Energy (\$/Million BTU)	21.40	21.11	23.85
(9) Levelized Cost of Energy (\$/Million kJ)	20.29	20.00	22.60

TABLE 3-6 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	2303	2303	2303
(2) Annual O&M Cost (\$)	60	60	60
(3) Annual Natural Gas Purchased (Therms)	1387	1387	1387
(4) Life Cycle Cost (\$)	19336	23924	37293
(5) Levelized Cost of Energy (\$/Million BTU)	15.20	18.81	29.32
(6) Levelized Cost of Energy (\$/Million kJ)	14.41	17.83	27.79
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Owner-occupied Single Family Residence		
(2) Analysis Period:	20 years		
(3) First Year Cost of Natural Gas:	\$3.49/Million BTU (\$3.31/Million kJ)		
(4) First Year Cost of Electricity:	\$0.0442/kWh		
(5) Fuel and Electricity Cost Escalation Rate:	12.5% (5.0% real) annually for gas, 10% (2.5% real) annually for electricity		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER AND SPACE HEATING/NEW SINGLE FAMILY HOME. MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-7

SOLAR WATER HEATING/NEW COMMERCIAL BUILDING

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	New Commercial Building/Water Heating
(3) REPRESENTATIVE SITE:	Fort Worth, Texas
(4) CONVENTIONAL ALTERNATIVE:	Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

- Collector Area and Type: 43 ft² (4 m²) Single Glazed, Black Chrome Selective Surface, Flat Plate
- Storage System: 66 Gallon (250 Liters) Water Tank
- Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid
- Backup System: Conventional Electric Water Heater (52 Gallons) (197 Liters)
- Annual Solar Heat Output: 6.8 Million BTU (7.2 Million kJ)
- Annual Conventional Fuel Purchases: Electricity - 572 kWh for backup and 225 kWh for parasitics

END USER REQUIREMENTS (2)

- Building: Office building with 10,000 ft² (929 m²) of Floor Area
- Annual Energy Requirement for Water Heating: 9.3 Million BTU (9.8 Million kJ)
- Service Hot Water Temperature: 110°F (43°C)
- Hot Water Requirement: 94 Gal/ Day (362 Liters/Day) 5 Days/Week

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling and Water Heating, Science Applications, Inc. 1979
- (2) Booz, Allen & Hamilton, Draft Report in support of DOE/Office of Solar Applications.

TABLE 3-7 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

- Total Annual Energy Requirements: 9.3 Million BTU (9.8 Million kJ)
- Annual Energy Requirement Met by Solar: 6.8 Million BTU (7.2 Million kJ)
- Annual Energy Requirement Met by Electricity: 2.5 Million BTU (2.6 Million kJ)
- Net Solar Fraction: 73%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	1569	1752
(2) Levelized Cost of Energy	\$11.35/million BTU (\$10.74/million kJ)	\$12.66/million BTU (\$12.00/million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)	Component	First Cost(\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)
Collector	652	30	20	Electric	240	10	10
Storage	267	--	20	Water Heater			
Electric Water Heater	240	10	10	Installation	86	--	--
Controls	60	--	20				
Misc. Hardware	264	--	20				
Installation	452	--	--				
TOTAL	1935	40	--	TOTAL	326	10	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE :
FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 DOLLARS)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	6.8	6.8	6.8
(2) Annual Solar System Output (million kJ)	7.2	7.2	7.2
(3) Annual Electricity Requirements (kWh)	797	797	797
(4) Annual O&M Cost (\$)	40	40	40
(5) System Installed Cost (Cost to End User)	1935	1620	1388
(6) Life Cycle Cost (\$)	1621	1513	1533
(7) Levelized Cost of Energy (\$/Million BTU)	11.72	10.93	11.08
(8) Levelized Cost of Energy (\$/Million kJ)	11.10	10.36	10.50

TABLE 3-7 (Concluded)

CONVENTIONAL SYSTEM COST & ECONOMIC PERFORMANCE: FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	326	326	326
(2) Annual O&M Cost (\$)	10	10	10
(3) Annual Electricity Purchased (kWh)	2783	2783	2783
(4) Life Cycle Cost (\$)	1935	2142	2643
(5) Levelized Cost of Energy (\$/Million BTU)	13.98	15.49	19.10
(6) Levelized Cost of Energy (\$/Million kJ)	13.25	14.68	18.11
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Commercial		
(2) Analysis Period:	20 Years		
(3) First Year Cost of Electricity:	\$0.044/kWh		
(4) Electricity Cost Escalation Rate:	10% annually (2.5% real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER HEATING/NEW COMMERCIAL BUILDING, FORT WORTH, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas		X			
(c) Escalation in Cost of Electricity		X			
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-8

SOLAR WATER HEATING/NEW COMMERCIAL BUILDING

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	New Commercial Building/Water Heating
(3) REPRESENTATIVE SITE:	Madison, Wisconsin
(4) CONVENTIONAL ALTERNATIVE:	Electric Resistance Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION (1)	END USER REQUIREMENTS (2)
- Collector Area and Type: 65 ft²(6m²) Single Glazed, Black Chrome Selective Surface, Flat Plate - Storage System: 66 Gallon (250 Liters) Water Tank - Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix as Heat Transfer Fluid - Backup System: Conventional Electric Water Heater (52 Gallons) (197 Liters) - Annual Solar Heat Output: 8.4 Million BTU (8.9 Million kJ) - Annual Conventional Fuel Purchases: Electricity - 906 kWh backup and 194 kWh for Parasitics	- Building: Office Building with 10,000 ft² (929 m²) of Floor Area - Annual Energy Requirement for Water Heating: 11.9 Million BTU (12.6 Million kJ) - Service Hot Water Temperature: 110°F(43°C) - Hot Water Requirement: 94 Gal/Day(362 Liters/Day) - 5 Days/Week

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc., 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-8 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Requirements:	11.9 Million BTU (12.6 Million kJ)
• Annual Energy Requirement Met by Solar:	8.4 Million BTU (8.9 Million kJ)
• Annual Energy Requirement Met by Electricity:	3.5 Million BTU (3.7 Million kJ)
• Net Solar Fraction	69%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	2146	1917
(2) Levelized Cost of Energy	\$12.13/Million BTU (11.49/Million kJ)	\$10.82/Million BTU (10.26/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)	Component	First Cost(\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)
Collector	944	40	20	Electric			
Storage	267	--	20	Water Heater	240	10	10
Electric Water Heater	240	10	10	Installation	96	--	--
Controls	60	--	20				
Misc. Hardware	264	--	20				
Installation	568	--	--				
TOTAL	2343	50	--	TOTAL	336	10	--

Note -Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	8.4	8.4	8.4
(2) Annual Solar System Output (Million kJ)	8.9	8.9	8.9
(3) Annual Electricity Requirements (kWh)	1100	1100	1100
(4) System Installed Cost (Cost to End User)	2343	1930	1626
(5) Annual O&M Cost (\$)	50	50	50
(6) Life Cycle Cost (\$)	2207	2006	1973
(7) Levelized Cost of Energy (\$/Million BTU)	12.46	11.33	11.14
(8) Levelized Cost of Energy (\$/Million kJ)	11.82	10.74	10.57

TABLE 3-8 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)				
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)		1985	1990	2000
(1)	System Installed Cost (Cost to End User)	336	336	336
(2)	Annual O&M Cost (\$)	10	10	10
(3)	Annual Electricity Purchased (kWh)	3567	3567	3567
(4)	Life Cycle Cost (\$)	2114	2338	2879
(5)	Levelized Cost of Energy (\$/Million BTU)	11.94	13.20	16.27
(6)	Levelized Cost of Energy (\$/Million kJ)	11.32	12.52	15.42
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS				
(1)	Ownership Pattern:	Small Commercial		
(2)	Analysis Period:	20 Years		
(3)	First Year Cost of Electricity:	\$0.037 /kWh		
(4)	Electricity Cost Escalation Rate:	10% Annually 2.5% Real)		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER HEATING/NEW COMMERCIAL BUILDING, MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-9

SOLAR WATER AND SPACE HEATING/NEW COMMERCIAL BUILDING

(1) REFERENCE SOLAR SYSTEM:	Selectively Surfaced Flat Plate Collector with Water Thermal Storage
(2) APPLICATION:	New Commercial Building/Space and Water Heating
(3) REPRESENTATIVE SITE:	Fort Worth, Texas
(4) CONVENTIONAL ALTERNATIVE:	Gas Furnace and Gas Water Heater

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

END USER REQUIREMENTS (2)

- Collector Area and Type: Single-Glazed, Black Chrome Selective Surface, Flat Plate Collector-Active Area 400 ft² (37.2 m²) - Storage System: -2000 Gallon (7570 Liter) Water Tank -66 Gallon (250 Liter) Domestic Hot Water Preheater Tank - Heat Transfer: Closed Loop System Using Ethylene Glycol/Water Mix As Heat Transfer Fluid - Backup System: - Gas Furnace 160,000 BTU/hr (169,000 kJ/hr) - Gas Water Heater 52 Gallons (197 Liter) - Annual Solar Heat Output: 40.5 Million BTU (42.7 Million kJ) - Annual Conventional Fuel Purchases: (for Backup) - Natural Gas - 28.2 Million BTU (29.7 Million kJ) - Electricity - 967 kWh	- New Office Building-Single Story, 10,000 ft² (929 m²) Building With a Seven Zone Heating System - Conservation Features: -R-10 Wall Insulation -R-12 Ceiling Insulation -Double Glazed Windows with Solar Bronze Treatment - Annual Space Heating Requirement: 51.2 Million BTU (54 Million kJ) - Annual Energy Requirement for Water Heating: 9.3 Million BTU (9.8 Million kJ) - Service Hot Water Temperature: 110°F (43°C) - Hot Water Requirement: 94 Gal/Day (362 Liter /Day) 5 Days/Week - Space Heating Temperature Setting: 70°F (21°C) - Annual Heating Degree Days (Base 65°F) 2405

RESOURCES

- (1) P.J. Hughes and J.H. Morehouse, Comparison of Solar Heat Pump Systems to Conventional Methods for Residential Heating, Cooling, and Water Heating, Science Applications, Inc. 1979
- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-9 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Load:	60.5 Million BTU (63.8 Million kJ)
• Annual Energy Load Met by Solar:	40.5 Million BTU (42.7 Million kJ)
• Annual Energy Load Met by Natural Gas:	20.0 Million BTU (21.1 Million kJ)
• Net Solar Fraction:	66%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	15,684	13,706
(2) Levelized Cost of Energy	\$17.42/Million BTU (\$16.52/Million kJ)	\$15.23/Million BTU (\$14.44/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)	Component	First Cost	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)
Collector Subsystem	7422	400	20	Gas Furnace	1800	50	20
Storage	1085	--	20	Gas Water Heater	300	10	10
Solar Hot Water Subsystem	720	40	20	Distribution	2400	--	20
Gas Furnace	1800	50	20	Installation	3218	--	--
Gas Water Heater	300	10	10				
Controls	1535	--	20				
Distribution	4620	--	20				
Installation	7130	--	--				
TOTAL	24612	500	--	TOTAL	7718	60	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	40.5	40.5	40.5
(2) Annual Solar System Output (Million kJ)	42.7	42.7	42.7
(3) System Installed Cost (Cost to End User)	24612	21088	18508
(4) Annual Natural Gas Requirements (Therms)	282	282	282
(5) Annual Electricity Requirements (kWh)	967	967	967
(6) Annual O&M Cost (\$)	500	500	500
(7) Life Cycle Cost (\$)	16334	15300	16397
(8) Levelized Cost of Energy (\$/Million BTU)	18.15	16.99	18.22
(9) Levelized Cost of Energy (\$/Million kJ)	17.21	16.12	17.26

TABLE 3-9 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)				
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)		1985	1990	2000
(1)	System Installed Cost (Cost to End User)	7718	7718	7718
(2)	Annual O&M Cost (\$)	60	60	60
(3)	Annual Natural Gas Requirement (Therms)	938	938	938
(4)	Life Cycle Cost (\$)	16429	19972	30603
(5)	Levelized Cost of Energy (\$/Million BTU)	18.26	22.18	34.00
(6)	Levelized Cost of Energy (\$/Million kJ)	17.30	21.04	32.22
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS				
(1)	Ownership Pattern:	Commercial		
(2)	Analysis Period:	20 Years		
(3)	First Year Cost of Natural Gas:	\$7.00/Million BTU (\$6.64/Million kJ)		
(4)	First Year Cost of Electricity:	\$0.044/kWh (\$12.24/Million kJ)		
(5)	Natural Gas and Electricity Cost Escalation Rate	12.9% (5.0% real) annually for gas and 10% (2.5% real) annually for electricity		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER AND SPACE HEATING/NEW COMMERCIAL BUILDING, FORT WORTH, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas		X			
(c) Escalation in Cost of Electricity		X			
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

SOLAR WATER AND SPACE HEATING/NEW COMMERCIAL BUILDING

RESOURCES

- (2) Booz, Allen & Hamilton, Draft Report in Support of the DOE/Office of Solar Applications.

TABLE 3-10 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Load:	205.7 Million BTU (217.0 Million kJ)
• Annual Energy Load Met by Solar:	93.7 Million BTU (98.9 Million kJ)
• Annual Energy Load Met by Natural Gas:	112.0 Million BTU (118.1 Million kJ)
• Annual Natural Gas Requirements:	163.0 Million BTU (172.0 Million kJ)
• Annual Electrical Requirements:	6.6 Million BTU (7.0 Million kJ)
• Net Solar Fraction:	46%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	40,727	21,220
(2) Levelized Cost of Energy	\$13.31/Million BTU (\$12.61/Million kJ)	\$6.94/Million BTU (\$6.57/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$) (Exc.Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$) (Exc.Fuel)	Life (Years)
Collector Sub- system	25987	900	20	Gas Furnace	2160	50	20
Storage	2094	--	20	Gas Water Heater	300	10	10
Solar Hot Water Subsystem	720	40	20	Distribution	2400	--	20
Gas Furnace	2160	50	20	Installation	3562	--	--
Gas Water Heater	300	10	10				
Controls	1535	--	20				
Distribution	4620	--	20				
Installation	10243	--	--				
TOTAL	\$47659	1000	--	TOTAL	\$8422	60	--

Note - Costs shown include 20% overhead

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	93.7	93.7	93.7
(2) Annual Solar System Output (Million kJ)	98.9	98.9	98.9
(3) Annual Natural Gas Requirements (Therms)	1,630	1,630	1,630
(4) Annual Electricity Requirement (kWh)	1,934	1,934	1,934
(5) System Installed Cost (Cost to End User) (\$)	47,659	38,921	32,713
(6) Annual O&M Cost (\$)	1,000	1,000	1,000
(7) Life Cycle Cost (\$)	43,267	40,756	46,444
(8) Levelized Cost of Energy (\$/Million BTU)	14.14	13.32	15.18
(9) Levelized Cost of Energy (\$/Million kJ)	13.40	12.62	14.38

TABLE 3-10 (Concluded)

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE (FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)			
CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End User)	8422	8422	8422
(2) Annual O&M Cost (\$)	60	60	60
(3) Annual Natural Gas Requirement (Therms)	3023	3023	3023
(4) Life Cycle Cost (\$)	25734	31597	49232
(5) Levelized Cost of Energy (\$/Million BTU)	8.42	10.32	16.09
(6) Levelized Cost of Energy (\$/Million kJ)	7.12	9.79	15.24
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS			
(1) Ownership Pattern:	Commercial		
(2) Analysis Period:	20 years		
(3) First Year cost of Natural Gas:	\$3.42/Million BTU (\$3.24/Million kJ)		
(4) First Year Cost of Electricity:	\$0.037 /kWh		
(5) Natural Gas and Electricity Cost Escalation Rates	12.9% (5.4% real) annually for gas and 10% (2.5% real) annually for electricity		

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR WATER AND SPACE HEATING/NEW COMMERCIAL BUILDING, MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-11

PASSIVE SOLAR SPACE HEATING/NEW SINGLE FAMILY HOMES

- (1) REFERENCE SOLAR SYSTEM: Concrete Trombe Wall with Double Glazing and Night Insulation
 (2) APPLICATION: New All-Electric Single Family Home with Passive Solar System for Space Heating
 (3) REPRESENTATIVE SITE: Albuquerque, New Mexico
 (4) CONVENTIONAL ALTERNATIVE: Similarly Designed All-Electric Home Using Electric Heat Pump for Space Heating

Source: Ref. 5

SOLAR SYSTEM DESCRIPTION (3), (4)

- System Type: Vented Trombe Wall
- Glazing: 294 ft² (27m²) Double Glazed, R10 (0.5W/m²°C) Night Insulation
- Orientation: Vertical, Due South
- Storage Material: 12 Inch (30 cm) Thick Filled Concrete Block, Outside Painted Black
- Annual Load Met by Solar: 32 Million BTU (34 Million kJ), or (1,463 kWh)

END USER REQUIREMENTS (1)

- Home: Owner-Occupied One-Story, Three Bedroom House, 1600 ft² (150m²)
- Conservation Features:
  - All Windows Double Glazed
  - R-19 Wall Insulation
  - R-30 Ceiling Insulation
- Annual Heating Degree Days: 4290
- Annual Space Heating Load: 49 Million BTU (52 Million kJ)
- Space Heating Temperature Setting: 70°F (21°C)
- Space Conditioning Unit: 3 Ton Electric Heat Pump (COP = 2.25)

RESOURCES

- (1) Total Environmental Action, Determination of Passive System Costs and Cost Goals, Harrisville, NH, 1979.
- (2) Roach, F. and Noll, S., "Passive and Active Residential Solar Heating - A Comparative Economic Analysis", Energy, Vol. 4, 1979, pp. 623-644.
- (3) U.S. Department of Energy, Passive Solar Design Handbook, Vols. I and II, DOE/CS-0127, 1980.
- (4) Anderson, Bruce, The Solar Home Book, Harrisville, NH: Cheshire Books, 1977.
- (5) The First Passive Solar Home Awards. Prepared by Franklin Research Center for U.S. Department of Housing and Urban Development, January 1979.
- (6) Hughes, P. and Morehouse, J. Comparison of Solar Heat Pump Systems to Conventional Methods. Science Applications, Inc., 1979.

TABLE 3-11 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

- Total Annual Heating Load: 49 Million BTU (52 Million kJ)
- Annual Load Met by Solar: 32 Million BTU (34 Million kJ)
- Annual Load Met by Heat Pump: 17 Million BTU (18 Million kJ)
- Annual Electricity Requirement: 2250 kWh (COP = 2.25)
- Fraction of Load Met by Solar: 65%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	11,965	10,300
(2) Levelized Cost of Energy	\$12.21/Million BTU (\$11.58/Million kJ)	\$10.51/Million BTU (\$9.96/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 DOLLARS (2)					CONVENTIONAL ALTERNATIVE SYSTEM COST: 1980 DOLLARS (6)				
Component	Material Cost	Labor Cost	Total Cost	Annual O&M	Component	Material Cost	Labor Cost	Total Cost	Annual O&M
Masonry	\$ 900	\$1260	\$2160		Heat Pump	\$1400	\$ 650	\$2050	\$50
Paint	40	120	160		Controls	50	50	100	0
Glazing	890	280	1170	\$25	Distribution	250	150	400	0
Roofing	240	130	370						
Trim	200	250	450						
Framing	810	140	950						
Insulating									
Curtain	1170	270	1440						
Wall Credit	-500	-250	-750						
Heat Pump	1700	850	2550	50					
TOTAL	\$5450	\$3050	\$8500	\$75	TOTAL	\$1700	\$ 850	\$2550	\$50

REFERENCE SOLAR SYSTEM
COST AND ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN
1985, 1990, 2000

SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) System Installed Cost (\$)	8,500	8,500	8,500
(2) Life Cycle Cost (\$)	12,346	12,982	14,821
(3) Annual O&M Cost (\$)	75	75	75
(4) Levelized Cost of Energy (\$/Million BTU)	12.60	13.04	15.12
(5) Levelized Cost of Energy (\$/Million kJ)	11.95	12.36	14.33

CONVENTIONAL ALTERNATIVE
COST AND ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN
1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (FIXED 1980 \$)	1985	1990	2000
(1) System Installed Cost (\$)	2,550	2,550	2,550
(2) Life Cycle Cost (\$)	11,216	12,257	14,767
(3) Annual O&M Cost (\$)	50	50	50
(4) Levelized Cost of Energy (\$/Million BTU)	11.44	12.51	15.07
(5) Levelized Cost of Energy (\$/Million kJ)	10.85	11.86	14.29

TABLE 3-12
PASSIVE SOLAR SPACE HEATING/NEW SINGLE FAMILY HOMES

(1) REFERENCE SOLAR SYSTEM:	Concrete Trombe Wall with Double Glazing and Night Insulation
(2) APPLICATION:	New Single Family Home Space Heating
(3) REPRESENTATIVE SITE:	Madison, Wisconsin
(4) CONVENTIONAL ALTERNATIVE:	Similarly Designed Single Family Home Using Natural Gas Forced Air Furnace for Space Heating

REFERENCE SOLAR SYSTEM DESCRIPTION (3, 4)

END USER REQUIREMENTS (1)

• System Type: Vented Trombe Wall • Glazing: 408 ft² (38m²), Double Glazed, R10 (0.5W/m²-°C), Night Insulation • Orientation: Vertical, Due South • Storage Material: 12-Inch (30 cm) Thick Filled Concrete Block, Outside Painted Black • Annual Load Met by Solar: 41 Million BTU (43 Million kJ)	• Home: Owner-Occupied One-Story, Three Bedroom House, 1400 ft² (130m²) with 700 ft² (65m²) Finished Basement • Conservation Features: -All Windows Double Glazed -R-19 Wall Insulation -R-30 Ceiling Insulation • Annual Heating Degree Days: 7730 • Annual Space Heating Load: 103 Million BTU (109 Million kJ) • Space Heating Temperature Setting: 70°F (21°C) • Space Conditioning Unit: 40,000 BTU/hr (42,200 kJ/hr) Natural Gas Forced Air Furnace (75% Efficiency).

RESOURCES

- (1) Total Environmental Action, Determination of Passive System Costs and Cost Goals, Harrisville, NH, 1979
- (2) Roach, F. and Noll, S., "Passive and Active Residential Solar Heating: A Comparative Economic Analysis", Energy, Vol. 4, 1979, pp. 623-644
- (3) U. S. Department of Energy, Passive Solar Design Handbook, Vols. I and II, DOE/CS-0127, 1980
- (4) Anderson, Bruce, The Solar Home Book, Harrisville, NH: Cheshire Books, 1977
- (5) The First Passive Solar Home Awards. Prepared by Franklin Research Center for U.S. Department of Housing and Urban Development, January, 1979.
- (6) Hughes, P. and Morehouse, J., Comparison of Solar Heat Pump Systems to Conventional Methods. Science Applications, Inc., 1979.

TABLE 3-12 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

- Total Annual Heating Load: 103 Million BTU (109 Million kJ)
- Annual Load Met by Solar: 41 Million BTU (43 Million kJ)
- Annual Load Met by Furnace: 62 Million BTU (65 Million kJ)
- Annual Gas Requirement: 82 Million BTU (86 Million kJ) (75% Efficiency)
- Fraction of Load Met by Solar: 40%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	21,673	22,829
(2) Levelized Cost of Energy	\$10.52/Million BTU (\$9.97/Million kJ)	\$11.08/Million BTU (\$10.50/Million kJ)

REFERENCE SOLAR SYSTEM COST: 1980 (2)					CONVENTIONAL ALTERNATIVE SYSTEM COST: 1980 (6)				
Component	Material Cost	Labor Cost	Total Cost	Annual O&M	Component	Material Cost	Labor Cost	Total Cost	Annual O&M
Masonry	\$1250	\$1750	\$3000		Furnace	\$300	\$200	\$500	\$50
Paint	50	150	200		Controls	50	50	100	
Glazing	1250	380	1630	\$25	Distribution	250	150	400	
Roofing	380	160	540						
Trim	310	310	620						
Framing	1130	190	1320						
Insulating									
Curtain	1620	380	2000						
Wall Credit	-700	-350	-1050						
Furnace	600	400	1000	50					
TOTAL	\$5890	\$3370	\$9260	\$75	TOTAL	\$600	\$400	\$1000	\$50

REFERENCE SOLAR SYSTEM
COST AND ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN
1985, 1990, 2000

SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) System Installed Cost (\$)	9,260	9,260	9,260
(2) Life Cycle Cost (\$)	25,506	30,417	47,701
(3) Annual O&M Cost (\$)	75	75	75
(4) Levelized Cost of Energy (\$/Million BTU)	12.38	14.77	23.16
(5) Levelized Cost of Energy (\$/Million kJ)	11.74	14.00	21.96

CONVENTIONAL ALTERNATIVE
COST AND ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN
1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (FIXED 1980 \$)	1985	1990	2000
(1) System Installed Cost (\$)	1,000	1,000	1,000
(2) Life Cycle Cost (\$)	28,771	30,398	58,738
(3) Annual O&M Cost (\$)	50	50	50
(4) Levelized Cost of Energy (\$/Million BTU)	13.97	17.67	28.51
(5) Levelized Cost of Energy (\$/Million kJ)	13.24	16.75	27.03

TABLE 3-12 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership:	Homeowner
(2) Analysis Period:	20 Years
(3) Financing Period:	20 Years
(4) Interest Rate:	12%/Year
(5) General Inflation Rate:	7.5%
(6) First Year Fuel Cost:	\$6.29/Million BTU
(7) Fuel Cost Escalation Rate:	12.5%/Year
(8) Discount Rate:	10.5%/Year
(9) Income Tax Rate:	30%
(10) Property Tax Rate:	Solar System Exempt from Property Tax Through 1990
(11) Total Federal Tax Credits:	0.00
(12) Total State Tax Credits:	\$1,320 Through 1990

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: PASSIVE SOLAR HEATING - MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate	X				
(b) Operating Efficiency		X			
N/A (c) Capacity or Availability or Load Factor					
(2) ECONOMIC SOURCES					
N/A (a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas				X	
N/A (c) Escalation in Cost of Electricity					
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules				X	

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-13
WIND/NEW SINGLE FAMILY HOMES

- (1) REFERENCE SOLAR SYSTEM: 10 kW, 3-Bladed Wind Turbine Generator on a 40 ft (12.2m) Tower. No Onsite Electricity Storage System. Utility Interconnected
- (2) APPLICATION: New All Electric, Air Conditioned, Single Family Home
- (3) REPRESENTATIVE SITE: Boston, Massachusetts
- (4) CONVENTIONAL ALTERNATIVE: Electricity Purchased from Local Utility

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

END USER REQUIREMENTS (2)

• Peak Output: 10 kW at 25 mph (40.2 kmph) • System Characteristics: 3 Bladed WTG, 24.3 ft (7.4m) Rotor Diameter, On a 40 ft (12.2m) Tower Producing A.C. Electricity at 240 V, 60 hz. Operates between Speeds of 9-60 mph (14.5-96.6 kmph) • Onsite Electrical Storage System: None • Utility Interconnected: - Utility Serves as Backup - Excess Power Sold to Utility • Annual Energy Output: 13,200 kWh	• Home: Owner Occupied, Single Family, One Story, All Electric Home with 1,600 ft² (148.6m²) of Living Space. No Basement • Annual Energy Requirement: 23,300 kWh • Annual Energy Requirement for Space Heating: 8,725 kWh • Annual Energy Requirements for Hot Water: 4,384 kWh • Space Conditioning Unit: 3 Ton Heat Pump • Conservation Features: R-30 Attic Insulation, R-19 Walls. Double Glazed Windows

RESOURCES

- (1) Milville Wind and Solar Equipment Company, Milville, CA
- (2) Boston Edison Company, Boston, Mass. Personal Communication - George Day

TABLE 3-13 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Energy Requirements of Homeowner:	23,300 kWh
• Wind Machine Annual Energy Output:	13,200 kWh
• Annual Energy Requirements Purchased from Local Utility:	15,248 kWh
• Annual Systems Output Sold to Local Utility:	5,148 kWh
• Percentage of Load met by Solar:	35%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost	43,691	43,285
(2) Levelized Cost of Energy (\$/kWh) (Solar and Backup)	0.07	--
(3) Levelized Cost of Energy (\$/kWh) (Solar Only)	0.06	--
(4) Levelized Cost of Energy (\$/kWh) (Conventional Only)	--	0.07

REFERENCE SOLAR SYSTEM COST: 1980 DOLLARS (Including Backup From Local Utility)				CONVENTIONAL SYSTEM COST: 1980 DOLLARS			
Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)
Wind Turbine	10,750		30	No Incremental Systems Installed Cost is Incurred For Electricity Purchased from Local Utility			
Generator							
Tower	3,064		30				
Transportation	300		--				
Site Preparation	2,510						
& Installation							
Other	90						
TOTAL	16,714	100	30	TOTAL	0	0	

REFERENCE SOLAR SYSTEM COST, TECHNICAL AND ECONOMIC PERFORMANCE
FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) Annual Energy Output (kWh)	13,200	13,200	13,200
(2) Overall Capacity Factor	15.1%	15.1%	15.1%
(3) System Installed Cost (\$)	14,730	12,830	12,060
(4) Annual O&M Cost (\$)	110	112	149
(5) Electricity Purchased from Local Utility Annually (kWh)	15,248	15,248	15,248
(6) Life Cycle Cost (000 \$)	46,133	50,763	58,893
(7) Levelized Cost of Energy (Solar & Backup) (\$/kWh)	0.07	0.07	0.09
(8) Levelized Cost of Energy (Solar Only) (\$/kWh)	0.05	0.04	0.03

CONVENTIONAL ALTERNATIVE ECONOMIC PERFORMANCE FOR
SYSTEMS INSTALLED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (Constant 1980 \$)	1985	1990	2000
(1) Initial Cost of Purchased Electricity (\$/kWh)	0.074	0.083	0.107
(2) Life Cycle Cost (\$)	48,937	55,400	70,929
(3) Levelized Cost of Energy (\$/kWh)	0.08	0.09	0.12

TABLE 3-13 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS	
(1) System Ownership:	Homeowner
(2) System Expected Useful Life:	30 Years
(3) Downpayment:	20%
(4) Financing Period:	20 Years
(5) Mortgage Interest Rate:	12%
(6) General Inflation Rate:	7.5%
(7) Cost of Electricity During First Year:	0.065 (\$/kWh)
(8) Electricity Cost Escalation Rate (Real):	2.5%
(9) Discount Rate (Nominal):	10.5%
(10) Marginal Federal Tax Rate:	30%
(11) Property Tax Rate:	0.00%
(12) State Sales Tax Rate:	0.00%
(13) Federal Tax Credits:	\$4,000
(14) State Tax Credit:	\$1,000
(15) Price at Which Excess Electricity Produced is Sold to the Local Utility:	0.03 (\$/kWh)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: WIND/NEW SINGLE FAMILY HOMES, BOSTON, MASSACHUSETTS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate	X				
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-14
WIND/NEW SINGLE FAMILY HOMES

- (1) REFERENCE SOLAR SYSTEM: 10 kW, 3-Bladed Wind Turbine Generator on a 40 ft (12.2m) Tower. No Onsite Electricity Storage System. Utility Interconnected
- (2) APPLICATION: New All Electric, Air Conditioned, Single Family Home
- (3) REPRESENTATIVE SITE: Dodge City, Kansas
- (4) CONVENTIONAL ALTERNATIVE: Electricity Purchased from Local Utility

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

END USER REQUIREMENTS (2)

• Peak Output: 10 kW at 25 mph (40.2 kmph) • System Characteristics: 3 Bladed WTG Located on a 40 ft (12.2m) Tower Producing AC Electricity. 240 V, 60 hz. Operates Between Wind Speeds of (9-60)mph (14.5-96.6 kmph.) • Onsite Electrical Storage System: None • Utility Interconnected: -Utility Serves as Backup -Excess Power Sold to Utility • Annual Energy Output: 24,700 kWh	• Home: Owner Occupied, Single Family, One Story, All-Electric Home with 1,600 ft² (148.6m²) of Living Space. No Basement • Annual Energy Requirement: 23,800 kWh • Annual Energy Requirement for Space Heating: 8,675 kWh • Annual Energy Requirements for Hot Water: 4,384 kWh • Space Conditioning Unit: 3 Ton Heat Pump • Conservation Features: R-30 Attic Insulation, R-19 in Walls. Double Glazed Windows.

RESOURCES

- (1) Millville Wind & Solar Equipment Company, Millville, CA
- (2) Kansas Gas & Electric Co., Wichita, Kansas, Personal Communication with Wade Wright

TABLE 3-14 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Energy Requirements of Homeowner:	23,800 kWh
• Wind Machine Annual Energy Output:	24,700 kWh
• Annual Energy Requirements Purchased from Local Utility:	12,932 kWh
• Annual Systems Output Sold to Local Utility:	13,832 kWh
• Percentage of Load Met by Solar:	46%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	37,704	38,482
(2) Levelized Cost of Energy (\$/kWh) (Solar and Backup)	0.05	--
(3) Levelized Cost of Energy (\$/kWh) (Solar Only)	0.03	--
(4) Levelized Cost of Energy (\$/kWh) (Conventional Only)	--	0.06

REFERENCE SOLAR SYSTEM COST: (1980 DOLLARS) (Including Backup From Local Utility)				CONVENTIONAL ALTERNATIVE SYSTEM COST: (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)
Wind Turbine				No Incremental System Installed Cost Is Incurred for Electricity Purchased from Local Utility			
Generator	10,750		30				
Tower	3,064		30				
Transportation	250		--				
Site Preparation & Installation	2,340		--				
Other	90		--				
TOTAL	\$16,494	100	30	TOTAL	0	--	--

REFERENCE SOLAR SYSTEM
COST, TECHNICAL AND ECONOMIC PERFORMANCE
FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) Annual Energy Output (kWh)	24,700	24,700	24,700
(2) Overall Capacity Factor	28.2%	28.2%	28.2%
(3) System Installed Cost (\$)	14,730	12,830	12,060
(4) Annual O&M Cost (\$)	110	122	149
(5) Electricity Purchased from Local Utility Annually (kWh)	12,932	12,932	12,932
(6) Life Cycle Cost (\$)	38,947	40,953	48,219
(7) Levelized Cost of Energy (Wind & Backup) (\$/kWh)	0.05	0.05	0.06
(8) Levelized Cost of Energy (Wind Only) (\$/kWh)	0.02	0.01	0.002

CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) Initial Cost of Purchased Electricity (\$/kWh)	0.067	0.076	0.097
(2) Life Cycle Cost (\$)	44,320	49,273	63,039
(3) Levelized Cost of Energy (\$/kWh)	0.07	0.08	0.11

TABLE 3-14 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS	
(1) System Expected Useful Life:	30 Years
(2) System Ownership:	Homeowner
(3) Downpayment:	20%
(4) Financing Period:	20 Years
(5) Mortgage Interest Rate:	12%
(6) Cost of Electricity During First Year:	0.059 (\$/kWh)
(7) Electricity Cost Escalation Rate (Real):	2.5%
(8) Discount Rate (Nominal):	10.5%
(9) General Inflation Rate:	7.5%
(10) Federal Tax Credits:	\$4,000
(11) State Tax Credit:	\$1500
(12) State Sales Tax Rate:	3.0%
(13) Marginal Federal Tax Rate:	30%
(14) Property Tax Rate:	0.00
(15) Price at Which Excess Electricity Produced is Sold to the Local Utility:	0.02 (\$/kWh)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: WIND/NEW SINGLE FAMILY HOME, DODGE CITY, KANSAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate	X				
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-15

PHOTOVOLTAICS (PV) / NEW SINGLE FAMILY HOMES

- (1) SOLAR SYSTEM: PV Solar Array on Shingles, No Onsite Electricity Storage Subsystem, Utility Interconnected
- (2) APPLICATION: New All-Electric, Air Conditioned, Single Family Home
- (3) REPRESENTATIVE SITE: Albuquerque, New Mexico
- (4) CONVENTIONAL ALTERNATIVE: Electricity Purchased from the Local Utility

REFERENCE SOLAR SYSTEM DESCRIPTION (1), (2)	END USER REQUIREMENTS (1), (3)
• Peak Output: 4 kW • PV Array Type: Shingle Solar Cell/Glass Covered, Incorporated Into Roof • PV System Efficiency: 8.0% • PV Array Size: 237 Shingles -Collecting Area: 382 ft² (35.5m²) -Roof Area Covered By Solar Cells: 561.3 ft² (52.15m²) • Onsite Electrical Storage Subsystem: None • Utility Interconnected -Utility Serves as Backup -Excess Power from PV Cells Sold to Utility • Annual Energy Output: 9,587 kWh	• Home: Owner-Occupied, Single Family, One-Story Home with 1600 ft² (148.6m²) of Living Space. No Basement • Annual Energy (i.e. Electricity) Requirement: 14,766 kWh • Annual Energy Requirements for Space Heating: 5,264 kWh • Annual Energy Requirements for Space Cooling: 2,802 kWh • Annual Energy Requirements for Hot Water: 4,384 kWh • Space Conditioning Unit: 3 Ton Heat Pump • Conservation Features: R-38 Attic Insulation, R-19 Walls. Southern Windows Double Glazed. All Others Triple Glazed.

RESOURCES

- (1) General Electric Co., Detailed Residential Photovoltaic Systems Preferred Designs, Valley Forge, PA, Oct '79
- (2) ARCO Solar Corporation, City of Industry, CA.
- (3) Boston Edison Co., Boston, Mass., Personal Communication - George Day

TABLE 3-15 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Requirement of Homeowner:	14,766 kWh
• PV System Annual Energy Output:	9,587 kWh
• Annual Energy Requirement Met by Solar System:	5,273 kWh
• Annual Energy Requirement Purchased from Local Utility:	9,493 kWh
• Percentage of Load Met by Solar:	36%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	72,838	23,054
(2) Levelized Cost of Energy (\$/kWh) (Solar and Backup)	0.186	--
(3) Levelized Cost of Energy (\$/kWh) (Solar Only)	0.41	--
(4) Levelized Cost of Energy (\$/kWh) (Conventional Only)	--	0.062

REFERENCE SOLAR SYSTEM COST: 1980 (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$) (Excluding Fuel)	Life (Years)	Component	First Cost	Annual O&M Cost (\$) (Excluding Fuel)	Life (Years)
PV Arrays	\$32,000		30	No Incremental Systems Installed Cost is Incurred for Electricity Purchased from Local Utility			
Power Con- ditioning	4,140		20-30				
Remaining Balance of Systems	1,090		20-30				
Installation	950		---				
Indirect Cost	1,500		---				
TOTAL	39,680	\$150	---	TOTAL	0	0	---

REFERENCE SOLAR SYSTEM COST, TECHNICAL AND ECONOMIC PERFORMANCE
FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Energy Output (kWh)	9,683	9,779	9,875
(2) Overall Systems Efficiency	7.9%	8.0%	8.1%
(3) System Installed Cost (\$)	10,000	6,400	5,600
(4) PV Array Cost (\$/Peak Watt)	2.50	1.60	1.40
(5) Annual O&M Cost (\$)	154	158	166
(6) Electricity Purchased from Local Utility Annually (kWh)	9,344	9,192	9,039
(7) Life Cycle Cost (\$)	32,785	30,055	33,953
(8) Levelized Cost of Energy/PV and Backup (\$/kWh)	0.078	0.072	0.078
(9) Levelized Cost of Energy/Solar Only (\$/kWh)	0.094	0.056	0.041

CONVENTIONAL ALTERNATIVE ECONOMIC PERFORMANCE FOR SYSTEMS
INSTALLED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Initial Cost of Purchased Electricity (\$/kWh)	0.063	0.071	0.091
(2) Life Cycle Cost (\$)	26,077	29,491	37,762
(3) Levelized Cost of Energy (\$/kWh)	0.069	0.079	0.101

TABLE 3-15 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS		
(1)	System Ownership:	Homeowner
(2)	System Expected Useful Life:	30 Years
(3)	Downpayment:	20%
(4)	Financing Period:	20 Years
(5)	Mortgage Interest Rate:	12%
(6)	General Inflation Rate:	7.5%
(7)	Electricity Cost During First Year:	0.056 (\$/kWh)
(8)	Electricity Cost Escalation Rate (Real):	2.5%
(9)	Discount Rate (Nominal):	10.5%
(10)	Marginal Federal Tax Rate:	30%
(11)	Property Tax:	\$0.057 of Assessed Value
(12)	State Sales Tax Rate:	3.75%
(13)	Total Federal Tax Credit:	40% of 1st \$10,000
(14)	State Tax Credit:	-0-
(15)	Price at Which Excess PV Electricity is Sold to Local Utility:	0.025 (\$/kWh)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: PHOTOVOLTAICS/NEW SINGLE FAMILY HOMES - ALBUQUERQUE, NEW MEXICO

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate			X		
(b) Operating Efficiency			X		
(c) Capacity or Availability or Load Factor				X	
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-16

PHOTOVOLTAICS(PV)/NEW SINGLE FAMILY HOMES

- (1) SOLAR SYSTEM: PV Solar Array on Shingles, No Onsite Electricity Storage Subsystem, Utility Interconnected
- (2) APPLICATION: New All Electric, Air Conditioned, Single Family Home
- (3) REPRESENTATIVE SITE: Boston, Massachusetts
- (4) CONVENTIONAL ALTERNATIVE: Electricity Purchased from Local Utility

REFERENCE SOLAR SYSTEM DESCRIPTION (1), (2)

END USER REQUIREMENTS (1) (3)

• Peak Output: 4 kW	• Home: Owner Occupied, Single Family, One Story, All-Electric Home with 1600 ft ² (148.6m ²) of Living Space
• PV Array Type: Solar Cell Shingles Attached onto Roof	• Annual Energy Requirement: 16,429 kWh
• PV System Efficiency: 8.0%	• Annual Energy Requirements for Space Heating: 7,686 kWh
• PV Array Size: 237 Shingles -Collecting Area: 382 ft ² (35.5m ²) -Roof Area Covered by Solar Cells: 561.3 ft ² (52.15m ²)	• Annual Energy Requirements for Space Cooling: 2,043 kWh
• Onsite Electrical Storage Subsystem: None	• Annual Energy Requirements for Hot Water: 4,384 kWh
• Utility Interconnected: -Utility Serves as Backup -Excess Power from PV Cells Sold to Utility	• Space Conditioning Unit: 3 Ton Heat Pump
• Annual Energy Output: 5,480 kWh	• Conservation Features: R-38 Attic Insulation, R-19 Walls. Southern Windows Double Glazed. All Others Triple Glazed.

RESOURCES

- (1) General Electric Co., Detailed Residential Photovoltaic Systems Preferred Designs, Valley Forge, PA, October 1979.
- (2) ARCO Solar Corporation, City of Industry, CA.
- (3) Boston Edison Co., Boston, MA, Personal Communication-George Day

TABLE 3-16 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Energy Requirements of Homeowner:	16,429 kWh
• PV System Annual Energy Output:	5,480 kWh
• Annual Energy Requirement Met by Solar System:	3,014 kWh
• Annual Energy Requirement Purchased from Local Utility:	13,415 kWh
• Annual System Output Sold to Local Utility:	2,466 kWh
• Percentage of Load Met by Solar:	18%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	64,730	29,883
(2) Levelized Cost of Energy (\$/kWh) (Solar and Backup)	0.150	--
(3) Levelized Cost of Energy (\$/kWh) (Solar Only)	0.555	--
(4) Levelized Cost of Energy (\$/kWh) (Conventional Only)	--	0.071

REFERENCE SOLAR SYSTEM COST: 1980 (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)
PV Arrays	\$32,000		30	No Incremental Systems Installed Cost is Incurred for Electricity Purchased from Local Utility			
Power Conditioning	4,140		20-30				
Remaining Balance of System	1,090		20-30				
Installation	1,080		---				
Indirect Cost	1,500		---				
TOTAL	\$39,810	\$150	---	TOTAL			

REFERENCE SOLAR SYSTEM: COST AND ECONOMIC PERFORMANCE
FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Energy Output (kWh)	5,535	5,590	5,672
(2) Overall Systems Efficiency	8.0%	8.1%	8.2%
(3) System Installed Cost (\$)	10,000	6,400	5,600
(4) PV Array Cost (\$/Peak Watt)	2.50	1.60	1.40
(5) Annual O&M Cost (\$)	154	158	166
(6) Electricity Purchased from Local Utility Annually (kWh)	13,717	13,634	13,480
(7) Life Cycle Cost (\$)	39,904	38,020	46,238
(8) Levelized Cost of Energy/PV & Backup (\$/kWh)	0.089	0.090	0.107
(9) Levelized Cost of Energy/Solar Only (\$/kWh)	0.130	0.079	0.058

CONVENTIONAL ALTERNATIVE ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Initial Cost of Purchased Electricity (\$/kWh)	0.073	0.083	0.106
(2) Life Cycle Cost (\$)	33,800	38,249	48,965
(3) Levelized Cost of Energy (\$/kWh)	0.081	0.092	0.118

TABLE 3-16 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS	
(1) System Ownership:	Homeowner
(2) System Expected Useful Life:	30 Years
(3) Down Payment:	20%
(4) Financing Period:	20 Years
(5) Mortgage Interest Rate:	12%
(6) General Inflation Rate:	7.5%
(7) Electricity Cost During First Year:	0.065 (\$/kWh)
(8) Electricity Cost Escalation Rate (Real):	2.5%
(9) Discount Rate (Nominal):	10.5%
(10) Marginal Federal Tax Rate:	30%
(11) Property Tax Rate:	0.00
(12) State Sales Tax Rate:	0.00
(13) Total Federal Tax Credits:	40% of 1st \$10,000
(14) State Tax Credit:	\$1,000 (Maximum)
(15) Price at Which Excess PV Electricity is Sold to Local Utility:	0.031 (\$/kWh)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: PHOTOVOLTAICS/NEW SINGLE FAMILY HOME, BOSTON, MASSACHUSETTS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate			X		
(b) Operating Efficiency			X		
(c) Capacity or Availability or Load Factor				X	
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-17
PHOTOVOLTAICS (PV)/COMMERCIAL-INSTITUTIONAL FACILITY APPLICATION

(1) REFERENCE SOLAR SYSTEM:	350 kW Roof-Mounted Photovoltaic System Composed of Polycrystalline Solar Cells Augmented By Reflectors. No Onsite Storage. Utility Intertied
(2) APPLICATION:	Supplemental Electricity for the Oklahoma Center for Science and Arts (OCSA) Building, a 160,000 ft ² (14,860m ²) Facility
(3) REPRESENTATIVE SITE:	Oklahoma City, Oklahoma
(4) CONVENTIONAL ALTERNATIVE:	Electricity Purchased from a Local Utility

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

END USER REQUIREMENTS (2)

• Peak Output: 350 kW • Array Type: Polycrystalline Silicon Solar Cell Modules with Reflector Augmentation, Mounted on South Facing Roof. (Arrays Manufactured by Solarex) • Array Size: 3780 Modules of 2 ft by 4 ft (0.6 x 1.2m) Arranged in 45 Series Strings of 84 Modules Each • Subsystems: - Inverter: 350 kVA Windworks, Input Voltage of 400 Volts - Transformer: Isolation Transformer Raises Output to 480 Volts for Utility Interface • Onsite Electrical Storage: None • Utility Interconnected: - Utility Serves as Backup - Excess Sold to Utility • Annual Energy Output: 470,700 kWh	• Facility: 160,000 ft² (14,860 m²), Two Story Building. Electricity Used to Power Exhibits, Provide Illumination, Power Electric Trucks, Operate Elevators and Air Conditioners, Etc. • Annual Energy Requirement: 1,026,000 kWh • Operation: 364 Days A Year • Load Profile: -High Summer Demand -Moderate Winter Demand -Predominately Day-time Demand

RESOURCES

- (1) Science Applications Inc., A Solar PV Flat Panel Applications Experiment at the Oklahoma Center for Science and Arts, DOE/ET/23063-1, June 1980
- (2) Science Applications, Inc. (Dick Mole)

TABLE 3-17 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

• Total Annual Energy Requirements of Building:	1,026,000 kWh
• PV Systems Annual Energy Output:	470,700 kWh
• Annual Energy Requirement Met By Solar Systems:	435,700 kWh
• Annual Energy Purchased from Local Utility:	590,300 kWh
• Annual System Output Sold to Local Utility:	34,400 kWh
• Percentage of Load Met by Solar:	42%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	7,546,757	1,435,374
(2) Levelized Cost of Energy (\$/kWh) (Solar and Backup)	0.31	---
(3) Levelized Cost of Energy (\$/kWh) (Solar Only)	0.64	---
(4) Levelized Cost of Energy (\$/kWh) (Conventional Only)	0.054	0.054

REFERENCE SOLAR SYSTEM COST: 1980 \$ (Including Backup from Local Utility)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)
Arrays	3,569,620		30	No Additional System Installed Cost is Incurred for Electricity Purchased from Local Utility			
Power Conditioners	106,746		20-30				
Other Materials & Equipment	215,852						
Installation/ Preparation	640,007						
Miscellaneous	157,095						
TOTAL	4,689,320	23,446	--	TOTAL	0	0	--

REFERENCE SOLAR SYSTEM COST, TECHNICAL & ECONOMIC PERFORMANCE,
FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) Annual Energy Output (kWh)	490,560	551,880	613,200
(2) Overall Systems Efficiency	8.0%	9.4%	10.4%
(3) System Installed Cost (\$)	910,000	787,500	560,000
(4) Annual O&M Cost (\$)	18,200	15,750	11,200
(5) Electricity Purchased from Local Utility Annually(kWh)	569,840	508,520	447,200
(6) Life Cycle Cost (\$)	2,197,639	2,026,021	1,816,456
(7) Levelized Cost of Energy (Solar & Backup) (\$/kWh)	0.084	0.078	0.070
(8) Levelized Cost of Energy (Solar Only) (\$/kWh)	0.110	0.085	0.053

CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (Constant 1980 \$)	1985	1990	2000
(1) Initial Cost of Purchased Electricity (\$/kWh)	0.056	0.063	0.081
(2) Life Cycle Cost (\$)	1,607,619	1,808,571	2,325,306
(3) Levelized Cost of Energy (\$/kWh)	0.062	0.070	0.090

TABLE 3-17 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS	
(1) System Ownership:	Municipally Owned Non-Profit Organization
(2) System Expected Life:	30 Years
(3) Financing Period:	20 Years
(4) Bond Interest Rate:	8%
(5) General Inflation Rate:	7.5%
(6) Cost of Electricity During First Year:	0.050 (\$/kWh)
(7) Electricity Cost Escalation Rate (Real):	2.5%
(8) Discount Rate (Nominal)	10.5%
(9) Marginal Federal Tax Rate:	Not Applicable
(10) Property Tax Rate:	0
(11) State Sales Tax:	2.0%
(12) Federal Tax Credits:	0
(13) State Tax Credits:	0
(14) Price at Which Electricity is Sold to Local Utility:	0.016 (\$/kWh)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: PHOTOVOLTAICS/COMMERCIAL-INSTITUTIONAL FACILITY, OKLAHOMA CITY, OKLAHOMA

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate			X		
(b) Operating Efficiency			X		
(c) Capacity or Availability or Load Factor			X		
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-18
INDUSTRIAL PROCESS HEAT/HOT WATER

(1) REFERENCE SOLAR SYSTEM:	Flat Plate Solar Collectors to Preheat Process Water for an Industrial Laundry
(2) APPLICATION:	Industrial Laundry (ARATEX SERVICES, INC.) Requiring Approximately 65,000 Gallons/day (246,000 Liter/day)
(3) REPRESENTATIVE SITE:	Fresno, California
(4) CONVENTIONAL ALTERNATIVE:	Gas Fired Boiler Producing Low Pressure Steam

REFERENCE SOLAR SYSTEM DESCRIPTION (1)(2)

END USER REQUIREMENTS (3)

• Collectors: 140 Ying, Flat-Plate, Lexan Glazed Collectors, Which Provide an Effective Aperture Area of 6500 ft² (604 m²). Roof Mounted • Storage: 12,500 Gal (47,317 Liter) Insulated Fiber Glass Storage Tank • Pumps: 3 Pumps. One 150 GPM (569 LPM) and Two Pumps of 200 GPM (757 LPM) Capacity • Heat Recovery System: System for Running City Cold Water Through a Heat Exchanger Which Recovers Heat from Laundry Waste Water • Backup: Low Pressure, Gas Fired Boiler (250 boiler horse power) • Annual Solar Output: 1.7×10^9 BTU/yr (1.58×10^9 kJ/yr) • Annual Fossil Fuel Purchase: \$39,100	• End User: Large Industrial Laundry Operating Five Days a Week • Hot Water Requirements: 65,000 Gal/day (246,000 Liter/day) • Process Water Temperature: 170°F (77°C) • Annual Energy Requirements for Water Heating: 10,100 Million BTU (10,655 Million kJ) • Fuel for Boiler: Natural Gas

RESOURCES

- (1) Mueller Associates Inc., Solar Project Cost Report for Aratex Services, Inc. Industrial Laundry, Fresno, CA. Solar/2008-78/60, June, 1978
- (2) P.R.C. Energy Analysis Co., Solar Project Description for Aratex Services, Inc. Industrial Laundry, Solar/2008-78/50, June 1978
- (3) Aratex Services, Inc. (Erick S. Burnett and B. Miller, Fresno, CA.

TABLE 3-18 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

- Total Annual Requirements for Heating Hot Water: 10,100 Million BTU (10,655 Million kJ)
- Energy Contribution of Solar System: 1,700 Million BTU (1,793 Million kJ)
- Energy Requirements Provided by Auxiliary Boiler: 8,400 Million BTU (8,862 Million kJ)
- Percentage of Load Met by Solar: 17%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	1,374,180	1,152,558
(2) Levelized Cost of Energy \$/Million BTU (Solar and Backup)	9.94	—
(3) Levelized Cost of Energy \$/Million BTU (Conventional Only)	—	8.25

REFERENCE SOLAR SYSTEM COST: (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$)	Life (Years)
Collectors	67,197		20	Boiler	55,000		20
Support Structure	15,910		20	Heat Recovery System	68,000		—
Piping and Storage	63,972		20	Pumps, Storage	30,750		20
Other Equipment	18,045		—	Other Equipment	35,000		—
General Construction	5,742		—	Taxes & Freight	18,525		—
Conventional Backup	397,275		—	Site Preparations and Installations	150,000		—
TOTAL	568,141	10,000	—	TOTAL	397,275	8,000	—

REFERENCE SOLAR SYSTEM COST, TECHNICAL AND ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (CONSTANT 1980 \$)	1985	1990	2000
(1) Annual Energy Output (Million BTU)	1,700	1,700	1,700
(2) System Installed Cost (\$)	541,184	522,488	543,843
(3) Cost of Solar System Only (\$/ft ²)	20.35	15.75	15.75
(4) Annual Fuel Cost (\$)	52,874	71,427	130,350
(5) Annual O&M Cost (\$)	10,252	10,511	11,050
(6) Life Cycle Cost (\$)	1,421,935	1,508,417	1,872,437
(7) Levelized Cost of Energy (\$/Million BTU)	10.22	10.78	13.03

CONVENTIONAL ALTERNATIVE ECONOMIC PERFORMANCE FOR SYSTEMS INSTALLED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (Constant 1980 \$)	1985	1990	2000
(1) Initial Cost of Purchased Natural Gas (\$/1,000 ft ³)	6.30	8.50	15.52
(2) System Installed Cost	407,307	417,592	438,947
(3) Annual Fuel Cost (\$)	63,587	85,899	156,760
(4) Life Cycle Cost (\$)	1,281,263	1,439,516	1,866,112
(5) Levelized Cost of Energy (\$/Million BTU)	9.37	10.47	13.41

TABLE 3-18 (Concluded)

ECONOMIC ANALYSIS ASSUMPTIONS	
(1) System Ownership:	Privately Owned Corporation
(2) Expected Useful Life:	20 Years
(3) Financing Period:	20 Years
(4) Capitalization Structure:	30% Debt, 70% Equity
(5) Weighted Average Cost of Capital:	12.9%
(6) General Inflation Rate:	7.5%
(7) First Year Price of Natural Gas:	\$4.66/1000 ft ³
(8) Natural Gas Inflation Rate (Nominal):	13.7%
(9) Discount Rate:	10.5%
(10) Depreciation Algorithm:	Double Declining Balance for 1st 4 Years; Sum of Years Digits for Remaining Years
(11) Marginal Federal Tax:	48%
(12) State Income Tax Rate:	2%
(13) Property Tax:	4% (Assessed Value = 25% of Initial Investment)
(14) State Sales Tax Rate:	6%
(15) Federal Tax Credits (Conventional System):	10%
(16) Federal Tax Credits (Solar System):	25%
(17) State Tax Credits:	0.00

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR INDUSTRIAL PROCESS HEAT/HOT WATER, FRESNO, CALIFORNIA

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate	X				
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor	X				
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-19

GEOTHERMAL/INDUSTRIAL PROCESS HEAT

(1) REFERENCE GEOTHERMAL SYSTEM:	Liquid-Dominated Geothermal (Coury & Associates Design)
(2) APPLICATION:	Provision of Process Heat to Corn-to-Ethanol Plant
(3) REPRESENTATIVE SITE:	Hooper, Colorado
(4) CONVENTIONAL ALTERNATIVE:	Coal-Fired Boiler (R. Katzen Associates Design)

REFERENCE GEOTHERMAL SYSTEM DESCRIPTION (1) (2)	CONVENTIONAL SYSTEM DESCRIPTION
• Liquid-Dominated Geothermal (Coury & Associates Design) • Water Composition: 5800 Parts Per Million of Total Dissolved Salts • Well Bottom Temperature: 350°F (177°C) • Well Flow Rate: 334,000 lb/hr (151.5 Metric Tons/Hr) • Geothermal Heat Supplied: 37.4 Million BTU/Hr (11 MWt) • Number of Wells: 2 • Brine Disposal: Re-injection into Well • Plant Annual Production: 7.4 Million Gal (28 Million Liters) • Construction Period: 3 Years	• Coal-Fired Boiler (R. Katzen Associates Design) • Boiler Steam Output: 51 Million BTU/Hr (15 MWt) • Coal: High Sulfur Coal • Annual Coal Use: 18,160 Tons (16,470 Metric Tons) • Plant Annual Production: 10 Million Gal (38 Million Liters) • Feedstock: Corn • Construction Period: 3 Years

RESOURCES

- (1) K.L. Garing and G.E. Coury, "Assessment of the Geothermal Resource in Colorado As the Energy Source for a Process to Produce Alcohol from Agricultural Commodities," Prepared for Colorado Energy Research Institute under Contract Number 321-03 (1978).
- (2) R.W. Hardie and G.R. Thayer, "Ethanol from Corn-10 Million Gallon/Year Plant," Los Alamos Scientific Laboratory (to be published 1981).

TABLE 3-19 (Continued)

GEOTHERMAL SYSTEM COST (1980) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST (1980) (1980 DOLLARS)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Wells	10990	71	10	Boiler	2352	92	20
Lines & Pumps	323	142	20	Boiler Feed- Water	106	9	20
Additional Equipment	49	86	20	Deaeration	35	--	20
Design	564	--	--	Flue Gas Scrubber	1899	--	20
Preliminary Exploration & Royalties	1764	120	--	Boiler Aux- iliaries	412	--	20
TOTAL	13690	419	--	TOTAL	4804	101	--

REFERENCE GEOTHERMAL AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	GEOTHERMAL SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	35,560	26,220
(2) Levelized Cost of Energy (\$/Million BTU)	6.03	3.26
(\$/Million kJ)	5.71	3.09

GEOTHERMAL SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

RENEWABLE SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Energy System Installed Cost (000\$) (Includes Interest During Construction)	13,390	13,860	16,460
(2) Annual Energy Related O&M Cost, First Year (000\$)	422	420	454
(3) Expected Annual Energy Output (Million BTU)	295,000	295,000	295,000
(Million kJ)	311,000	311,000	311,000
(4) Capacity Factor (%)	90	90	90
(5) Life Cycle Cost (000\$)	34,794	35,973	42,165
(6) Levelized Cost of Energy (\$/Million BTU)	5.90	6.11	7.15
(\$/Million kJ)	5.59	5.78	6.78

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Energy System Installed Cost (000\$) (Includes Interest During Construction)	5,165	5,578	5,994
(2) Annual Energy Related O&M Cost, First Year (000\$)	141	156	190
(3) Expected Annual Energy Output (Million BTU)	402,084	402,084	402,084
(Million kJ)	424,600	424,600	424,600
(4) Life Cycle Cost (000\$)	28,260	30,800	35,660
(5) Levelized Cost of Energy (\$/Million BTU)	3.51	3.83	4.43
(\$/Million kJ)	3.32	3.63	4.20

TABLE 3-19 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Investor-Owned Industry
(2) Analysis Period:	23 Years (3 Years Construction, 20 Year Life)
(3) System Financing Period:	20 Years
(4) Percentage of System Financed by Debt:	60%
(5) Bond Rate:	11.5%
(6) Return on Equity:	17.6%
(7) General Inflation Rate:	7.5% Per Year
(8) Conventional System, First Year Cost of Coal:	\$1.03/Million BTU (0.98/Million kJ)
(9) Coal Escalation Rate:	1.3% Per Year (Real)
(10) Electricity Escalation Rate:	2.5% Per Year (Real)
(11) Discount Rate:	10.5%
(12) Depreciation Algorithm:	Sum-of-Years Digits
(13) Interest Rate During Construction:	10.5%
(14) State and Federal Income Tax Rate:	50%
(15) Property Tax Rate:	\$2/\$100 of Actual Value
(16) Federal Tax Credits (Renewable System):	\$301,772
(17) Federal Tax Credits (Conventional System):	\$188,900

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: GEOTHERMAL SYSTEMS/PROCESS HEAT, HOOPER, COLORADO

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor				X	
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity	X				
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-20

MUNICIPAL SOLID WASTE/INDUSTRIAL PROCESS HEAT

(1) REFERENCE SYSTEM:	Consumat Incinerator System with Heat Recovery
(2) APPLICATION:	Steam Supplied to an Industrial Plant
(3) REPRESENTATIVE SITE:	North Little Rock, Arkansas
(4) CONVENTIONAL ALTERNATIVE:	Natural Gas Burned in a Boiler at 80% Efficiency

REFERENCE SYSTEM DESCRIPTION (1)	CONVENTIONAL SYSTEM DESCRIPTION (1)
- Two Consumat Dual 1200 Continuous Burn Incinerator Modules with Heat Recovery - Rated Steam Production: 18,000 lb/hr (8165 kg/hr) - Steam Properties: 130 psig, 1174 BTU/lb (2728 kJ/kg) - Expected Annual Energy Output: 1.141×10^{11} BTU (1.203×10^{11} kJ) - Annual Waste Burned: 22,500 tons (20,412 metric tons) - Conventional Energy Usage: 10^{10} BTU/Year natural gas (1.05×10^{10} kJ/Year), 6×10^5 kWh Electric/Year - Capacity Factor: 90% (Based on 250 Days/Year) - Construction Period: 1 Year	- One Natural Gas Fired Boiler - Rated Steam Production: 18,000 lb/hr (8165 kg/hr) - Steam Properties: 130 psig, 1174 BTU/lb - Energy Purchased (To Give Energy Equivalent of Reference System): 1.43×10^{11} BTU/Year (1.51×10^{11} kJ/Year) - Efficiency Assumption: Natural Gas is Burned at 80% Efficiency - Energy Output is 10% of Plant Requirement - Boiler Make-up Water and Water Treatment Chemical Usage Equivalent to Reference System

RESOURCES

- (1) Richard Frounfelker, "Small Modular Incinerator Systems with Heat Recovery: A Technical, Environmental, and Economic Evaluation," EPA-SW-177c (1979).

TABLE 3-20 (Continued)

REFERENCE SYSTEM COST: (1980) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: (1980) (1980 DOLLARS)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Component	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Receiving	279.1	53.1	15	Boiler Sys.	61.0	37.9	15
Incineration	897.3	127.5	15	Miscellaneous	9.3	6.3	15
Heat Recovery	363.5	43.5	15	Design	9.0	---	--
General Plant	143.1	65.1	15	Site & Preparation	22.0	---	--
Design	47.5	---	--				
Site & Preparation	140.3	---	--				
TOTAL	1870.8	226.2	--	TOTAL	101.3	44.2	--

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	RENEWABLE SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	5,454	10,072
(2) Levelized Cost of Energy	\$3.186/Million BTU (\$3.022/Million kJ)	\$5.885/Million BTU (\$5.583/Million kJ)

RENEWABLE RESOURCE SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

RENEWABLE SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	1,896	1,993	2,180
(2) Annual O&M Cost, First Year (000\$)	261.1	281.3	326.5
(3) Expected Annual Energy Output (Million BTU) (Million kJ)	120,450 126,980	126,790 133,660	139,470 147,030
(4) Capacity Factor (%-250 Day/Yr)	90	90	90
(5) Net Waste Disposal Credit (\$/Ton) (Levelized Tipping Fee)	7.46	8.09	9.32
(6) Life Cycle Cost (000\$)	5,677	6,170	7,492
(7) Levelizee Cost of Energy (\$/Million BTU (\$/Million kJ)	3.14 2.98	3.24 3.08	3.58 3.40

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	106.9	112.9	125.8
(2) Annual O&M Cost, First Year (000\$)	45.1	48.6	56.4
(3) Expected Annual Energy Output (Million BTU) (Million kJ)	120,450 126,980	126,790 133,660	139,470 147,030
(4) Life Cycle Cost (000\$)	14,042	19,513	38,536
(5) Levelized Cost of Energy (\$/Million BTU (\$/Million kJ)	7.77 7.37	10.26 9.73	18.42 17.47

TABLE 3-20 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Municipally Owned Utility
(2) Analysis Period:	16 Years (1 year construction, 15 year life)
(3) System Financing Period:	15 Years
(4) Percentage of System Cost Financed by Debt:	100% (60% for conventional system)
(5) Bond Interest Rate:	10.5% (11.5% for conventional system)
(6) General Inflation Rate:	7.5% per year
(7) Conventional System, First Year Cost of Gas:	\$2.80/Million BTU
(8) Natural Gas Escalation Rate:	6.2% per Year (Real)
(9) Electricity Rate, First Year:	\$0.06/kWh
(10) Electricity Escalation Rate:	2.5% per Year (Real)
(11) O&M Escalation Rate:	1.5% per Year (Real)
(12) Discount Rate:	10.5%
(13) Depreciation Algorithm:	Straight-Line
(14) Tax Rate (All Taxes):	0% (50% for conventional system)
(15) Insurance Premium:	0.0025 of Capital Cost
(16) Credit for Waste Disposal:	40% of Cost of Incineration (\$6.94/Ton, Levelized Cost)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: MUNICIPAL SOLID WASTE/INDUSTRIAL PROCESS HEAT, NORTH LITTLE ROCK, ARKANSAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate	X				
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor	X				
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-21

BIOMASS (WOOD)/INDUSTRIAL PROCESS HEAT

(1) REFERENCE SOLAR SYSTEM:	Econergy Designed Wood-Fired Boiler
(2) APPLICATION:	Steam for a Pulp and Paper Mill
(3) REPRESENTATIVE SITE:	Escanaba, Michigan
(4) CONVENTIONAL ALTERNATIVE:	Coal-Fired Boiler

REFERENCE SOLAR SYSTEM DESCRIPTION (1)	CONVENTIONAL SYSTEM DESCRIPTION (2)
- Econergy Designed Wood-Fired Boiler - Rated Steam Production: 525,500 lb/hr (238,400 kg/hr) - Steam Properties: 600 psig, 1172 BTU/lb (2724 kJ/kg) - Expected Annual Energy Output: 4.6×10^{12} BTU (4.85×10^{12} kJ) - Conventional Energy Usage: 4.6 MW Electric - Non-Conventional Fuel Usage: 1000 Tons/Day Wood/Dry-Basis (907 Metric Tons/Day) - Capacity Factor: 85% - Construction Period: 2 Years	- Coal-Fired Boiler Plant - Rated Steam Production: 500,000 lb/hr (226,800 kg/hr) - Steam Properties: 600 psig, 1172 BTU/lb (2724 kJ/kg) - Expected Annual Energy Output: 4.36×10^{12} BTU (4.6×10^{12} kJ) - Conventional Energy Usage: 5.1 MWe - Fuel Type/Usage: High Sulfur Coal/ 190,000 Tons/Year (172,400 Metric Tons/Year) - Capacity Factor: 85% - Construction Period: 2 Years

RESOURCES

- (1) Econergy Associates, "Technology Characterization and Economic Evaluation of a 1000 tons/day (Dry) Wood-Fired Process Steam Plant," Report for LASL on Contract 4-L40-0745 M-1 (1980).
- (2) R. Katzen Associates, "Grain Motor Fuel Alcohol-Technical and Economic Assessment Study," Report for DOE, HCP/ J6639-01 (1978).

TABLE 3-21 (Continued)

REFERENCE SOLAR SYSTEM COST (1980 \$) (1980 Dollars)				CONVENTIONAL SYSTEM COST (1980 \$) (1980 Dollars)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Wood Handling	3534	410	20	Steam			
Generation	15341	2053	20	Generation	9127	1647	20
Utility Sys.	7664	890	20	Elec. & Water	1052	159	20
General	3941	473	20	Environmental	8575	1683	20
Contractor	942	--	--	General	671	100	20
Site &				Contractor	610	--	--
Preparation	1135	--	--	Site &			
Contingency	4883	--	--	Preparation	1135	--	--
Start-up & Work- ing Capital	3166	--	--	Contingency	3172	--	--
				Start-up & Work- ing Capital	3137	--	--
TOTAL	40,606	3,826	--	TOTAL	27,479	3,589	--

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: (1980)

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	389,988	420,652
(2) Levelized Cost of Energy	\$4.239/Million BTU (\$4.021/Million kJ)	\$4.842/Million BTU (\$4.591/Million kJ)

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

SOLAR SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	43,370	46,830	52,350
(2) Annual O&M Cost, First Year (000\$)	3,727	3,822	4,368
(3) Expected Annual Energy Output (Million BTU) (Million kJ)	4.60×10^6 4.85×10^6	4.71×10^6 4.97×10^6	4.87×10^6 5.13×10^6
(4) Capacity Factor (%)	85	87	90
(5) Life Cycle Cost (000\$)	395,617	425,549	492,438
(6) Levelized Cost of Energy (\$/Million BTU) (\$/Million kJ)	4.30 4.08	4.52 4.29	5.05 4.80

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	29,360	30,840	34,010
(2) Annual O&M Cost, First Year (000\$)	3,758	4,015	4,580
(3) Expected Annual Energy Output (Million BTU) (Million kJ)	4.36×10^6 4.60×10^6	4.46×10^6 4.70×10^6	4.62×10^6 4.87×10^6
(4) Life Cycle Cost (000\$)	447,998	487,995	575,186
(5) Levelized Cost of Energy (\$/Million BTU) (\$/Million kJ)	5.137 4.873	5.467 5.186	6.229 5.901

TABLE 3-21 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Investor-Owned Industry
(2) Analysis Period:	22 Years (2 Year Construction, 20 Year Life)
(3) System Financing Period:	20 Years
(4) Percentage of System Cost Financed by Debt:	60%
(5) Bond Interest Rate:	11.5%
(6) Equity Return Rate:	17.6%
(7) General Inflation Rate:	7.5% per Year
(8) Conventional System, First Year Cost of Coal:	\$55/Ton (Illinois coal delivered at Escanaba)
(9) Coal Cost Escalation Rate:	1.3% per Year (Real)
(10) First Year Cost of Wood:	\$25/Ton (Dry-Basis)
(11) Wood Cost Escalation Rate:	1% per Year (Real)
(12) First Year Electricity Cost and Escalation Rate:	\$0.05/kWh, 2.5% per Year (Real)
(13) O&M Escalation Rate:	1.5% per Year (Real)
(14) Discount Rate:	10.5%
(15) Depreciation Algorithm:	Sum-of-Years Digits
(16) Construction Period (Both Solar and Conventional Systems):	2 Years
(17) Interest Rate During Construction:	13.94%
(18) Marginal Federal Plus State Tax Rate:	50%
(19) Property Tax Rate:	\$2/\$100 of Actual Value
(20) Federal Tax Credits:	10% of Capital Cost

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: BIOMASS (WOOD)/PROCESS HEAT, ESCANABA, MICHIGAN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
1) TECHNICAL SOURCES					
(a) Capital Cost Estimate			X		
(b) Operating Efficiency		X			
(c) Capacity or Availability or Load Factor		X			
2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity	X				
3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-22

BIOMASS (WOOD) COGENERATION/INDUSTRIAL STEAM AND ELECTRICITY

- (1) REFERENCE SOLAR SYSTEM: Industrial Co-Generator Using Wood-Fired Boilers to Produce Steam and Electricity
- (2) APPLICATION: Integrated Pulp and Paper Mill (Boise Southern Company)
- (3) REPRESENTATIVE SITE: DeRidder, Louisiana
- (4) CONVENTIONAL ALTERNATIVE: Equivalent System Using Oil-Fired Boilers

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

CONVENTIONAL SYSTEM DESCRIPTION (1)

- System: An Integrated Pulp and Paper Mill Cogenerating Steam and Electricity Using Wood Waste as Fuel
  - Components:
    - Boilers: A. 1 Babcock and Wilcox Power Boiler with Rated Output of 725,000 lb/hr (329,000 kg/hr) of steam
    - B. 1 Combustion Engineering Power Boiler with Rated Output of 200,000 lb/hr (90,720 kg/hr) of Steam
    - Turbine Generator: A General Electric 56.4 MW Back Pressure Steam Turbine Generator Using 995,000 lb/hr (451,000 kg/hr) of 900 psig (6205 kPa) and 830°F (447°C) Steam
  - Annual Onsite Electricity Generated: 368,288 MWh
  - Annual Wood Fuel Requirements: 1,533,000 tons/yr (1,391,000 metric tons/yr)
- System: An Integrated Pulp and Paper Mill Cogenerating Steam and Electricity Using Gas/Oil as Fuel
  - Components:
    - Boilers: A. 1 Babcock and Wilcox Boiler with Rated Output of 725,000 lb/hr (329,000 kg/hr) of Steam (Oil Fired)
    - B. 1 Combustion Engineering Power Boiler with Rated Output of 200,000 lb/hr (90,720 kg/hr) of Steam (Oil Fired)
    - Turbine Generator: A General Electric 56.4 MW Back Pressure Steam Turbine Generator Using 995,000 lb/hr (451,000 kg/hr) of 900 psig (6205 kPa) and 830°F (447°C) Steam
  - Annual Onsite Electricity Generated: 368,288 MWh
  - Annual Fuel Requirements: 91.5 Million Gallons/yr (346.0 Million Liters/yr)

RESOURCES

- (1) Neil Sanders, Boise Southern Company, DeRidder, Louisiana

TABLE 3-22 (Continued)

REFERENCE SOLAR SYSTEM COST:1980 (Boiler Costs Based on C-E 200,000 lbs/hr Boiler)				CONVENTIONAL SYSTEM COST:1980 (Boiler Costs Based on C-E 200,000 lb/hr Boiler)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Boiler	10,500		30	Boiler	10,500		30
Fuel Handling & Storage	2,620		--	Oil Storage	800		--
Pollution Control	2,500		--	Pollution Control	2,500		--
Misc. Boiler Related Costs	1,700		--	Misc. Boiler Related Costs	1,700		--
Turbine Genera- tor	4,505		30	Turbine Generator	4,505		30
Auxiliary Turbine Equipment	1,550		--	Auxiliary Turbine Equipment	1,550		--
Indirect Costs	1,182		--	Indirect Costs	1,182		--
Contingency	1,057		--	Contingency	1,057		--
TOTAL	25,614	4,686		TOTAL	23,794	4,199	

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATIONS			
ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL ALTERNATIVE	
(1) Life Cycle Cost (000\$): Steam	115,912	175,240	
Electricity	273,131	387,615	
(2) Levelized Cost of Energy: Electricity(\$/kWh)	0.028	0.040	
Steam (\$/MBTU)	5.13	7.67	

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

SOLAR SYSTEM CHARACTERISTICS (1980 DOLLARS)	1985	1990	2000
(1) System Installed Cost (000\$)	30,127	34,071	43,619
(2) Annual O&M Cost	4,716	4,834	5,087
(3) Expected Annual Energy Output:			
A. Electricity (Megawatt Hours)	368,288	368,288	368,288
B. Steam (tons/yr at 830°F, 900 psig)	4,478,400	4,478,400	4,478,400
(4) Capacity Factor (Turbine-Generator)	0.77	0.77	0.77
(5) Life Cycle Cost (000\$) - A. Steam	119,189	123,035	132,715
- B. Electricity	311,113	356,330	474,888
(6) Levelized Cost of Energy:			
A. Busbar Cost of Energy (\$/kWh)	0.032	0.037	0.049
B. Cost of Steam (\$/Million BTU)	5.29	5.48	5.95

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE FOR
SYSTEMS ACQUIRED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 DOLLARS)	1985	1990	2000
(1) System Installed Cost (000\$)	28,070	31,740	40,640
(2) Annual O&M Cost (000\$)	4,305	4,413	4,645
(3) Expected Annual Energy Output:			
A. Electricity (Megawatt Hours)	368,288	368,288	368,288
B. Steam (tons/yr at 830°F, 900 psig)	4,478,400	4,478,400	4,478,400
(4) Capacity Factor (Turbine Generator)	0.77	0.77	0.77
(5) Life Cycle Cost (000\$) - A. Steam	185,168	195,935	220,302
- B. Electricity	453,676	532,731	741,868
(6) Levelized Cost of Energy:			
A. Busbar Cost of Electricity (\$/kWh)	0.047	0.055	0.077
B. Cost of Steam (\$/Million BTU)	8.11	8.59	9.69

TABLE 3-22 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Private Industrial Firm
(2) First Year Installed Cost (Solar System):	\$25,614,000
(3) Analysis Period:	33 Years
(4) System Financing Period:	20 Years
(5) Capitalization Ratio:	Equity: 50%
	Debt: 50%
(6) Weighted Average Cost of Capital:	12.9%
(7) General Inflation Rate:	7.5%
(8) Fuel Cost Escalation (Real):	2.5%
(9) Discount Rate (Nominal):	10.5%
(10) Depreciation Algorithm:	Sum of Years' Digits
(11) Construction Period (Conventional System):	3 Years
(12) Construction Period (Solar System):	3 Years
(13) Marginal Federal Tax Rate:	48%
(14) Other Taxes (Rate):	2%
(15) Federal Tax Credit (Solar System):	25%
(16) Federal Tax Credit (Conventional System):	10%

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: WOOD COGENERATION/INDUSTRIAL STEAM AND ELECTRICITY, DeRIDDER, LOUISIANA

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate	X				
(b) Operating Efficiency	X				
(c) Capacity or Availability or Load Factor	X				
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-23

AGRICULTURAL PROCESS HEAT/ANIMAL SHELTER HEATING

(1) SOLAR SYSTEM:	Air-Based System: Flat Plate Collector, Rock Bin Storage
(2) APPLICATION:	Pre-Heat Ventilation Air for New Chicken (Broiler) House
(3) REPRESENTATIVE SITE:	Eastern Shore, Maryland
(4) CONVENTIONAL ALTERNATIVE:	LP Gas

REFERENCE SOLAR SYSTEM DESCRIPTION

END USER REQUIREMENTS

• Collector Area and Type: Double-glazed, flat black surface, site-built flat plate collector. Active area 2000 ft² (185m²) • Storage System: 1000 ft³ (28.3m³) of washed stream-bed pebbles • Backup System: LP Gas Furnace • Annual Solar Heat Output: 109.7 Million BTU (115.8 Million kJ) • Annual Conventional Fuel Purchases (for backup): -LP Gas: 77.3 Million BTU (81.5 Million kJ) -Electricity (Parasitics): 5.6 Million BTU (5.9 Million kJ)	• Chicken House for Raising Broilers - 12,240 ft² (1,137 m²) Single Story • Annual Space Heating Requirements (mostly due to ventilation for humidity control): 163.8 Million BTU (172.8 Million kJ) • Broiler House Specifications: - 5 batches of 15,000 birds per year - required indoor temperature varies from 95-70 °F (35-22 °C) during 8 week growing cycle - ventilation requirements for temperature and moisture control increase as a function of live weight of birds - ventilation at any time is the maximum of that required for temperature, humidity and odor control

RESOURCES

- (1) Reece F.W. and Lott, B. D. Optimizing Poultry House Design for Broiler Chickens, Southcentral Poultry Research Laboratory, Mississippi State University.
- (2) Science Applications, Inc.

TABLE 3-23 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

Total Annual Energy Load:	163.8 Million BTU (172.8 Million kJ)
Annual Energy Load Met by Solar:	109.7 Million BTU (115.8 Million kJ)
Annual Energy Load Met by LP Gas:	54.1 Million BTU (57.1 Million kJ)
Annual LP Gas Requirements:	77.3 Million BTU (81.5 Million kJ)
Annual Electrical Requirements:	5.6 Million BTU (5.9 Million kJ)
Net Solar Fraction:	64%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	18,076	26,946
(2) Levelized Cost of Energy (\$/Million BTU)	7.42	11.02

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost (\$) (Exc. Fuel)	Life (Years)
Collector	8660	280	20	Propane Fur-			
Storage	4000	0	20	nace	1800	30	20
Blower	144	0	20	Plastic Dist.			
Controls	120	10	20	System	600	30	20
Dampers	256	0	20	Installation	600	0	
Plastic Dist.							
System	600	30	20				
Propane Fur-							
nace	1800	30	20				
Installation	1374	0	20				
TOTAL	16,954	350	--	TOTAL	3,000	60	--

Note - Costs assume majority of installation and maintenance performed by farmer

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Annual Solar System Output (Million BTU)	109.7	109.7	109.7
(2) Annual Solar System Output (Million kJ)	115.8	115.8	115.8
(3) System Installed Cost (Cost to End User)	16954	15353	13608
(4) Annual O&M Cost (\$)	350	350	350
(5) Annual Propane Requirements (Million BTU)	77.3	77.3	77.3
(6) Life Cycle Cost (\$)	19495	20276	23443
(7) Levelized Cost of Energy (\$/Million BTU)	8.00	8.32	9.63
(8) Levelized Cost of Energy (\$/Million kJ)	7.58	7.89	9.11

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (Cost to End Users in Dollars) (in Present Value 1980 \$)	3,000	3,000	3,000
(2) Annual O&M Cost (\$)	60	60	60
(3) Annual Propane Requirement (Million BTU)	234	234	234
(4) Life Cycle Cost (\$)	30,962	35,585	47,217
(5) Levelized Cost of Energy (\$/Million BTU)	12.77	14.65	19.36
(6) Levelized Cost of Energy (\$/Million kJ)	12.10	13.85	18.42

TABLE 3-23 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Commercial
(2) Analysis Period:	20 Years
(3) First Year Cost of Propane:	\$8.72/Million BTU (\$8.27/Million kJ)
(4) First Year Cost of Electricity:	\$16.61/Million BTU (\$15.75/Million kJ)
(5) Propane Gas and Electricity Cost Escalation Rates:	10.5% and 10% (3% and 2.5% real) annually

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: AGRICULTURAL PROCESS HEAT/ANIMAL SHELTER HEATING, EASTERN SHORE, MARYLAND

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency				X	
(c) Capacity or Availability or Load Factor				X	
2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 3-24

AGRICULTURAL PROCESS HEAT/ANIMAL SHELTER HEATING

(1) SOLAR SYSTEM:	Air-Based System: Flat Plate Collector, Rock Bin Storage
(2) APPLICATION:	Pre-Heat Ventilation Air for New Chicken (Broiler) House
(3) REPRESENTATIVE SITE:	Madison, Wisconsin
(4) CONVENTIONAL ALTERNATIVE:	LP Gas

REFERENCE SOLAR SYSTEM DESCRIPTION

(1) (2)

END USER REQUIREMENTS

(1) (2)

• Collector Area and Type: Double-glazed, flat black surface, site-built flat plate collector. Active area 2500 ft² (232m²) • Storage System: 1250 ft³ (35.4m³) of washed stream-bed pebbles • Backup System: LP Gas Furnace • Annual Solar Heat Output: 174.5 Million BTU (184.1 Million kJ) • Annual Conventional Fuel Purchases (for backup): - LP Gas: 173.3 Million BTU (182.8 Million kJ) - Electricity (parasitics): 8.4 Million BTU (8.8 Million kJ)	• Chicken House for Raising Broilers - 12,240 ft² (1,137 m²), Single Story • Annual Space Heating Requirements (mostly due to ventilation for humidity control): 295.8 Million BTU (312.1 Million kJ) • Broiler House Specifications: - 5 batches of 15,000 birds per year - required indoor temperature varies from 95-70 F (35-22 C) during 8 week growing cycle - ventilation requirements for temperature and moisture control increase as a function of live weight of birds. - ventilation at any time is the maximum of that required for temperature, humidity, and odor control.

RESOURCES

- (1) Reece, F. W. and Lott, B. D. Optimizing Poultry House Design for Broiler Chickens, Southcentral Poultry Research Laboratory Mississippi State University.
- (2) Science Applications, Inc.

TABLE 3-24 (Continued)

REFERENCE SOLAR SYSTEM ENERGY BALANCE

Total Annual Energy Load:	295.8 Million BTU (312.1 Million kJ)
Annual Energy Load Met by Solar:	174.5 Million BTU (184.1 Million kJ)
Annual Energy Load Met by LP Gas:	121.3 Million BTU (128.0 Million kJ)
Annual LP Gas Requirements:	173.3 Million BTU (182.8 Million kJ)
Annual Electrical Requirements:	8.4 Million BTU (8.8 Million kJ)
Net Solar Fraction:	59%

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (\$)	29,736	44,213
(2) Levelized Cost of Energy (\$/Million BTU)	6.72	10.08

REFERENCE SOLAR SYSTEM COST: 1980 (Including Backup System) (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)	Component	First Cost (\$)	Annual O&M Cost(\$) (Exc.Fuel)	Life (Years)
Collector	10825	333	20	Propane Furnace	1800	30	20
Storage	5000	0	20	Plastic Dist.Sys.	600	30	20
Blower	144	0	20	Installation	600	0	--
Controls	120	10	20				
Dampers	256	0	20				
Plastic Dist.Sys.	600	30	20				
Propane Furnace	1800	30	20				
Installation	1420	--	--				
TOTAL	20,165	403	--	TOTAL	3,000	60	--

Note - Costs assume majority of installation and maintenance performed by farmer.

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (Fixed 1980 \$)	1985	1990	2000
(1) Annual Solar System Output(Million BTU)	174.5	174.5	174.5
(2) Annual Solar System Output(Million kJ)	184.1	184.1	184.1
(3) System Installed Cost (Cost to End User)	20165	18261	16185
(4) Annual O&M Cost (\$)	403	403	403
(5) Annual Propane Requirements(Million BTU)	173.3	173.3	173.3
(6) Life Cycle Cost (\$)	32744	35195	42800
(7) Levelized Cost of Energy(\$/Million BTU)	7.39	7.93	9.68
(8) Levelized Cost of Energy (\$/Million BTU)	6.99	7.53	9.28

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS INSTALLED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost(Cost to End Users in Dollars)(in Present Value 1980 \$)	3,000	3,000	3,000
(2) Annual O&M Cost (\$)	60	60	60
(3) Annual Propane Requirements (Million BTU)	422.6	422.6	422.6
(4) Life Cycle Cost (\$)	50,985	58,784	78,415
(5) Levelized Cost of Energy(\$/Million BTU)	11.56	13.31	17.74
(6) Levelized Cost of Energy(\$/Million kJ)	11.02	12.64	16.94

TABLE 3-24 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Commercial
(2) Analysis Period:	20 Years
(3) First Year Cost of Propane:	\$8.72/Million BTU (\$8.27/Million kJ)
(4) First Year Cost of Electricity:	\$10.89/Million BTU (\$10.32/Million kJ)
(5) Propane Gas and Electricity Cost Escalation Rates:	10.5% and 10% (3% and 2.5% real) annually

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: AGRICULTURAL PROCESS HEAT/ANIMAL SHELTER HEATING, MADISON, WISCONSIN

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency				X	
(c) Capacity or Availability or Load Factor				X	
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

SECTION 4.0

SOLAR/RENEWABLE RESOURCE TECHNOLOGY CHARACTERIZATIONS AND COST ASSESSMENTS: CENTRAL SYSTEMS

Section 4.0 documents the results of the central* system assessments and is organized as follows:

TECHNOLOGY/APPLICATION PAIRS (Representative Sites)	TABLE
1. Wind/Electric Utilities	
• Goodnoe, Washington (Government-Owned)	4-1
• Goodnoe, Washington (Investor-Owned)	4-2
2. Photovoltaics/Electric Utilities	
• El Paso, Texas	4-3
3. Geothermal/Electric Utilities	
• La Cueva, New Mexico	4-4
4. Biomass (Wood)/Electric Utilities	
• Montpelier, Vermont	4-5
5. Solar Thermal/Electric Utilities	
• El Paso, Texas	4-6
6. Low Head Hydroelectric/Electric Utilities	
• Kennebec, Maine	4-7
7. Biomass/Gaseous Fuels (Medium BTU Gas)	
• Aiken, South Carolina	4-8
8. Biomass/Liquid Fuels (Ethanol)	
• Carbondale, Illinois	4-9

*For the purposes of this study, central systems, solar and non-solar, are systems for electric utility application and the generation of fuels.

TABLE 4-1

WIND/ELECTRIC UTILITIES (GOVERNMENT OWNED)

(1) REFERENCE SOLAR SYSTEM:	NASA/Boeing MOD-2 Wind Energy Conversion System (WECS)
(2) APPLICATION:	Electric Utilities/Fuel Saver
(3) REPRESENTATIVE SITE:	Goodnoe Hills, Washington
(4) CONVENTIONAL ALTERNATIVE:	50 MW Oil-Fired Gas Turbine Generator

REFERENCE SOLAR SYSTEM DESCRIPTION (1), (2)

- Solar Systems: Wind Farm Consisting of 25 NASA/Boeing MOD-2 Windmills
- Machine Rated Power: 2500 kW at a wind Speed of 27.7 mph (44.5 kilometers per hour)
- Expected Annual Energy Output per Machine: 8.32 Million kWh
- Annual Energy Output per Wind Farm (25 Machines): 208 Million kWh
- Transformers: 5 Step Up Transformers
- Capacity Factor: 38.0
- Construction Period: 3 Years

CONVENTIONAL SYSTEM DESCRIPTION (3), (4)

- Oil Fired Gas Turbine
- Rated Power: 50 MW
- Peak Power Output: 54.5 MW
- Time to Reach Rated Power Output: 15 Minutes
- Average Annual Energy Output: 157.68 Million kWh
- Annual Fuel Requirement: 7.44 Million Gallons (50.8 Million Liter) Residual Fuel Oil
- Capacity Factor: 36%

RESOURCES

- (1) Boeing Engineering and Construction Company, Seattle, Washington
- (2) National Aeronautics and Space Administration, MOD-2 Wind Turbine Systems Concept and Preliminary Design Report (NASA CR-159609), Cleveland, Ohio, July, 1979
- (3) General Electric Company, Schenectady, N.Y.
- (4) Public Service Company of Colorado, Denver, Colorado
- (5) Bonneville Power Administration, Portland, Oregon

TABLE 4-1 (Continued)

REFERENCE SOLAR SYSTEM COST-1980 (25 Wind Machines)(1980 Dollars)				CONVENTIONAL SYSTEM COST-1980 (1980 Dollars)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Hardware Costs	64,397		30	Turbine-Generator	4,618	(Excludes Fuel Cost)	25
Factory Assembly & Quality Control	9,481			Structures & Improvements	50		
Spares/Transportation	7,687			Access Electrical Equipment	105		
Site Preparation & Installation	10,703			Fuel Handling & Storage	478		
Checkout & Testing	13,446			Other	130		
Other Costs	2,461						
A&E Fee	10,666						
TOTAL	118,841	375	--	TOTAL	5,381	134	--

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL SYSTEM
(1) Life Cycle Cost (000 \$)	181,299	144,227
(2) Levelized Cost of Energy (\$/kWh)	0.077	0.082

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Systems Installed Cost (000\$)	87,585	51,795	51,795
(2) Annual O&M Cost (000\$)	876	518	544
(3) Expected System Annual Energy Output (Megawatt Hours)	208,050	208,050	208,050
(4) Capacity Factor (%)	38.0	38.0	38.0
(5) Life Cycle Cost (000\$)	133,094	78,403	78,433
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.057	0.034	0.034

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) Systems Installed Cost (000\$)	5,517	9,010	9,471
(2) Annual O&M Cost (000\$)	137	462	486
(3) Annual Fuel Cost (000\$)	4,690	5,135	6,901
(4) Expected System Annual Energy Output (Megawatt Hours)	162,060	166,440	166,440
(5) Life Cycle Cost (000\$)	168,654	216,147	350,536
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.105	0.136	0.168

TABLE 4-1 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Bonneville Power Administration
(2) Analysis Period:	33 Years
(3) System Financing Period:	20 Years
(4) Mortgage (Bond) Rate:	12%
(5) First Year Cost of Fuel for Conventional Systems (Net):	\$4,462,344
(6) Fuel Cost Escalation Rate (Real):	3.0%
(7) Discount Rate (Nominal):	10.5%
(8) Depreciation Algorithm:	Sinking Fund Deposit Factor and Compound Interest Method
(9) Construction Period (Conventional System):	2 Years
(10) Construction Period (Solar System):	3 Years
(11) Allowance for Interest During Construction:	\$35,282,231
(12) Interest Rate During Construction:	14.0%
(13) Marginal Federal Tax Rate:	0%
(14) Property Tax Rate:	0%
(15) Marginal State Tax Rate:	0%
(16) Federal Tax Credits (Solar System):	0
(17) Federal Tax Credits (Conventional System):	0

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: WIND/LARGE ELECTRIC UTILITIES, GOODNOE HILLS, WASHINGTON

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency		X			
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-2

WIND/ELECTRIC UTILITIES (PRIVATELY OWNED)

(1) REFERENCE SOLAR SYSTEM:	NASA/Boeing MOD-2 Wind Energy Conversion System (WECS)
(2) APPLICATION:	Electric Utilities/Fuel Saver
(3) REPRESENTATIVE SITE:	Goodnoe Hills, Washington
(4) CONVENTIONAL ALTERNATIVE:	50 MW Oil-Fired Gas Turbine Generator

REFERENCE SOLAR SYSTEM DESCRIPTION (1), (2)

- Solar Systems: Wind Farm Consisting of 25 NASA/Boeing MOD-2 Windmills
- Machine Rated Power: 2500 kW at a wind Speed of 27.7 mph (44.5 kilometers per hour)
- Expected Annual Energy Output per Machine: 8.132 Million kWh
- Annual Energy Output per Wind Farm (25 Machines): 208 Million kWh
- Transformers: 5 Step Up Transformers
- Capacity Factor: 38.0%
- Construction Period: 3 Years

CONVENTIONAL SYSTEM DESCRIPTION (3), (4)

- Oil Fired Gas Turbine
- Rated Power: 50 MW
- Peak Power Output: 54.5 MW
- Time to Reach Rated Power Output: 15 Minutes
- Average Annual Energy Output: 157.68 Million kWh
- Annual Fuel Requirement: 7.44 Million Gal (50.8 Million Liter) of Residual Fuel Oil
- Capacity Factor: 36%

RESOURCES

- (1) Boeing Engineering and Construction Company, Seattle, Washington
- (2) National Aeronautics and Space Administration, MOD-2 Wind Turbine Systems Concept and Preliminary Design Report (NASA CR-159609), Cleveland, Ohio, July '79
- (3) General Electric Company, Schenectady, N.Y.
- (4) Public Service Company of Colorado, Denver, Colorado

TABLE 4-2 (Continued)

REFERENCE SOLAR SYSTEM COST-1980 (25 Wind Machines) (1980 Dollars)				CONVENTIONAL SYSTEM COST-1980 (1980 Dollars)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Hardware Costs	64,397		30	Turbine- Generator	4,618	(Excludes Fuel Cost)	25
Factory Assembly & Quality Control	9,481			Structures & Improvements	50		
Spares/ Transportation	7,687			Access Electrical Equipment	105		
Site Preparation & Installation	10,703			Fuel Handling & Storage	478		
Checkout & Testing	13,446			Other	130		
Other Costs	2,461						
A&E Fee	10,666						
TOTAL	118,841	375	--	TOTAL	5,381	134	--

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL SYSTEM
(1) Life Cycle Cost (000 \$)	210,405	190,036
(2) Levelized Cost of Energy (\$/kWh)	0.107	0.093

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE, AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	87,585	51,795	51,795
(2) Annual O&M Cost (000\$)	876	518	544
(3) Expected System Annual Energy Output (Megawatt Hours)	208,050	208,050	208,050
(4) Capacity Factor (%)	38.0	38.0	38.0
(5) Life Cycle Cost (000\$)	154,665	91,230	91,253
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.079	0.047	0.047

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	5,517	9,010	9,471
(2) Annual O&M Cost (000\$)	138	462	486
(3) Annual Fuel Cost (000\$)	4,690	5,135	6,901
(4) Expected System Annual Energy Output (Megawatt Hours)	162,060	166,440	166,440
(5) Life Cycle Cost (000\$)	222,890	283,768	464,754
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.111	0.147	0.183

TABLE 4-2 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Private Investor-Owned Utility
(2) Analysis Period:	33 Years
(3) System Financing Period:	20 Years
(4) Capitalization Structure:	50% Debt 40% Common Stock 10% Preferred Stock
(5) Rate of Return:	12% Debt 12% Preferred Stock 14% Common Stock
(6) General Inflation Rate:	7.5%
(7) First Year Cost of Fuel for Conventional Systems (Net):	\$4,462,344
(8) Fuel Cost Escalation Rate (Real):	3.0%
(9) Discount Rate (Nominal):	10.5%
(10) Depreciation Algorithm:	Sum of Years' Digits
(11) Construction Period (Conventional System):	9 Months
(12) Construction Period (Solar System):	3 Years
(13) Allowance for Interest During Construction (Solar):	\$35,282,231
(14) Effective Interest Rate During Construction:	14.0%
(15) Marginal Federal Tax Rate:	46%
(16) Marginal State Property and Other Taxes:	3%
(17) Federal Tax Credits (Solar System):	10% (Investment Tax Credit)
(18) Federal Tax Credits (Conventional Systems):	10% (Investment Tax Credit)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: WIND/LARGE ELECTRIC UTILITIES (PRIVATELY OWNED), GOODNOE HILLS, WASHINGTON

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency		X			
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-3
PHOTOVOLTAICS/ELECTRIC UTILITIES

- (1) REFERENCE SOLAR SYSTEM: 10 MW Photovoltaic Central Station Power Plant Composed of Flat Plate, Silicon Solar Cells
(2) APPLICATION: Electric Utility/Fuel Saver
(3) REPRESENTATIVE SYSTEM: El Paso, Texas
(4) CONVENTIONAL ALTERNATIVE: 50 MW Oil-Fired Gas Turbine Generator

REFERENCE SOLAR SYSTEM DESCRIPTION (1)	CONVENTIONAL SYSTEM DESCRIPTION (2) (3)
• Solar System: Field of Flat Plate Silicon Cells Producing 10 MW of Peak Power • Land Requirements: 136 Acres (55 ha) • Annual Energy Output: 20,274,000 kWh • Subsystems: - Four 500 kW Arrays with 250/550 Voltage - Four 2000 kW Arrays with 500/100 Voltage - Power Conversion Subsystem - Central Transformer Station - Instrumentation and Control Subsystem - Lightning Protection Subsystem • Cooling: No Active Cooling of Cells • Capacity Factor: 23.2%	• Oil Fired Gas Turbines • Rated Power: 50 MW • Peak Power Output: 54.5 MW • Capacity Factor: 36% • Average Annual Output: 157.68 Million kWh • Annual Fuel Requirement: 7.44 Million Gal (50.8 Million Liter) of Residual Fuel Oil

RESOURCES

- (1) General Electric Company, Requirement Definition and Preliminary Design of a Photovoltaic Central Power Station Experimental Test Facility, SAND 79-7022, July 1979
(2) General Electric Company, Schenectady, NY
(3) Public Service Company of Colorado, Denver, CO

TABLE 4-3 (Continued)

REFERENCE SOLAR SYSTEM COST (1980) (1980 Dollars)				CONVENTIONAL SYSTEM COST (1980) (1980 Dollars)			
Component	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Component	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Solar Arrays	65,930		30	Turbine Genera- tor	4,618		25
Land	534			Structures and Improvements	50		
Structure & Site Facilities	4,809			Access Electrical Equipment	105		
Other Equipment	4,385			Fuel Handling and Storage	478		
Spares	1,513			Other	130		
Contingencies	7,566						
Sales Taxes	7,230						
Indirect Costs and Overhead	16,549						
TOTAL	108,516	1,085	--	TOTAL	5,381	134	--

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE - 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000\$)	189,777	190,036
(2) Levelized Cost of Busbar Energy (\$/kWh) 0.67		0.093

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE, AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN THE YEARS 1985, 1990, 2000)

SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	65,000	18,000	13,000
(2) Expected System Annual Energy Output (Megawatt Hours)	21,024	21,900	22,776
(3) Annual O&M Cost (\$)	660,000	216,000	169,000
(4) Capacity Factor	24%	25%	26%
(5) Cost per Peak Watt (\$/Wp)	6.5	1.80	1.30
(6) Life Cycle Cost (000\$)	113,563	32,126	23,326
(7) Levelized Cost of Busbar Energy (\$/kWh)	0.32	0.084	0.057

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED SUCCESSIVELY IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	5,517	9,010	9,471
(2) Expected System Annual Energy Output (Megawatt Hours)	162,060	166,440	166,440
(3) Annual O&M Cost (Including Fuel) (\$)	138,000	462,000	486,000
(4) Annual Fuel Cost	4,690	5,135	6,901
(5) Life Cycle Cost (000\$)	222,890	283,768	464,754
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.111	0.147	0.183

TABLE 4-3 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Investor Owned Utility
(2) Analysis Period:	33 Years
(3) Financing Period:	20 Years
(4) Capitalization Ratios:	Debt 50%
	Common Stock 40%
	Preferred Stock 10%
(5) Weighted Average Cost of Capital:	12.9%
(6) General Inflation Rate:	7.5%
(7) First Year Cost of Fuel (Conventional System):	\$4,462,344
(8) Fuel Cost Inflation Rate:	10%
(9) Discount Rate:	10.5%
(10) Depreciation Algorithm:	Sum of Years' Digits
(11) Construction Period (Conventional System):	2 Years
(12) Construction Period (Solar System):	3 Years
(13) Allowance for Funds Used During Construction (Solar System):	\$23,541,656
(14) Interest Rate During Construction:	14.0%
(15) Marginal Federal Tax Rate:	48%
(16) Other Taxes (Rate):	2%
(17) Federal Tax Credits (Solar System):	10%
(18) Federal Tax Credits (Conventional System):	10%

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: PHOTOVOLTAICS/CENTRAL POWER PLANT, EL PASO, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency				X	
(c) Capacity or Availability or Load Factor				X	
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products			X		
(b) Escalation in Cost of Natural Gas			X		
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-4

GEOHERMAL/ELECTRIC UTILITIES

(1) REFERENCE GEOHERMAL SYSTEM:	Liquid-Dominated Geothermal Electrical Plant
(2) APPLICATION:	Utility Base Load
(3) REPRESENTATIVE SITE:	La Cueva, New Mexico
(4) CONVENTIONAL ALTERNATIVE:	Coal-Fired Power Plant

REFERENCE GEOHERMAL SYSTEM DESCRIPTION (1) (2)CONVENTIONAL SYSTEM DESCRIPTION (3)

- Renewable System: Electrical Power Plant Utilizing Liquid-Dominated Geothermal Resource
- Steam Production: Single-Stage Flash
- Plant Capacity: 50MW electric
- Water Composition: 50,000 Parts Per Million of Total Dissolved Salts
- Resource: 92,500 lb/hr (11,568 g/s) at 464°F (240°C)
- Capacity Factor: 90%
- Expected Annual Energy Output: 16,425 MWh
- Brine Disposal: Re-injection into Well
- Construction Period: 5 Years

- Coal-Fired Base Load Plant
- Plant Capacity: 795 MW electric
- Capacity Factor: 70%
- Annual Energy Output: 4,875,000 MWh
- Annual Fuel Consumption: 2,560,000 Tons (2,320,000 metric tons)
- Construction Period: 6 Years

RESOURCES

- (1) J. R. Bartlit, et al., "Technology Characterization and Economic Evaluation of Energy Storage Systems, Geothermal Energy Systems, Electric Energy Systems," Los Alamos Scientific Laboratory, LA-UR-79-3495 (1979).
- (2) J. Leigh, A. Cohen, W. Jacobsen, and R. Trehan, "Site Specific Analysis of Geothermal Development: Vol. 1 and 2," Mitre Corp., HCP/T-4014-01 (1979).
- (3) Plant Capital Investment Cost Estimates: Current Trends and Sensitivity to Economic Parameters," Oak Ridge National Laboratory, DOE/NE-0009 (1980).

TABLE 4-4 (Continued)

REFERENCE GEOTHERMAL SYSTEM COST: (1980) (1980 Dollars)				CONVENTIONAL SYSTEM COST: (1980) (1980 Dollars)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
PRODUCER							
Wells	12918	129	10	Land	1917		30
Distribution	2610	388	20	Structures & Improvements	52732		30
Design	1669	--	--	Boiler Plant	148610		30
Exploration	26413	--	--	Turbine Plant	78619		30
Misc.	3363	1063	--	Electric Plant	35475		30
Subtotal	46973	1580		Misc. Plant	10546		30
UTILITY				Heat Rejec- tion System	13423		30
Generators	9478		30	Indirect	110259		--
Piping	4551		30	Contingency	45062		--
Electrical & Control	3610		30	Escalation & Interest	161074		--
Design	2422		--				
Misc.	16170		--				
Subtotal	36231	1087					
TOTAL	83,204	2,667	--	TOTAL	657,717	17,060	

REFERENCE RENEWABLE AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980

ECONOMIC MEASURE (1980 DOLLARS)	GEOTHERMAL SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle (000 \$)	424,816	3,620,800
(2) Levelized Cost of Energy (Busbar)	\$0.035/kWh	\$0.025/kWh

GEOTHERMAL SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

GEOTHERMAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	80,750	85,200	95,310
(2) Annual O&M Cost, First Year (000\$)	2,808	2,923	3,155
(3) Expected Annual Energy Output (MWh)	394,200	394,200	394,200
(4) Capacity Factor (%)	90	90	90
(5) Life Cycle Cost (000\$)	370,508	392,269	456,957
(6) Levelized Cost of Energy (\$/kWh)	0.03	0.03	0.04

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	654,000	686,000	738,000
(2) Annual O&M Cost, First Year (000\$)	17,060	17,060	17,060
(3) Expected Annual Energy Output (MWh)	4,857,000	4,857,000	4,857,000
(4) Life Cycle Cost (000\$)	3,696,720	3,880,000	4,230,000
(5) Levelized Cost of Busbar Energy (\$/kWh)	0.03	0.03	0.03

TABLE 4-4 (Concluded)
MAJOR ECONOMIC ANALYSIS ASSUMPTIONS

(1) Ownership Pattern:	Wells - Investor-Owner Industrial Firm; Power Plants - Investor-Owned Utility
(2) Analysis Period:	Geothermal - 35 years; Coal - 36 years
(3) System Financing Period:	30 years
(4) Percentage of System Installed Cost Financed Externally:	Well - 60% Power Plants - 50%
(5) Mortgage (Bond Rate):	11.5%
(6) General Inflation Rate:	7.5%
(7) First Year Cost of Fuel for Conventional System (Net):	\$42 x 10 ⁶
(8) Fuel Cost Escalation Rate (Coal):	1.3% (Real)
(9) Discount Rate:	10.5%
(10) Depreciation Algorithm:	Sum-of-Years-Digits
(11) Construction Period (Conventional System):	6 years
(12) Construction Period (Renewable System):	5 years
(13) Interest Rate During Construction:	10.5%
(14) Marginal Federal and State Tax Rate:	50%
(15) Property Tax Rate:	\$2/\$100 of Plant Capital
(16) Federal Energy Tax Credits (Renewable System):	\$6,007,100
(17) Federal Energy Tax Credits (Conventional System):	0

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: GEOTHERMAL/ELECTRIC UTILITIES, LA CUEVA, NEW MEXICO

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency		X		X	
(c) Capacity or Availability or Load Factor					
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity					
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules					X

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-5
BIOMASS (WOOD)/ELECTRIC UTILITIES

(1) REFERENCE SOLAR SYSTEM:	MITRE/Econergy Wood-Fired Power Plant
(2) APPLICATION:	Electric Utilities/Base Load
(3) REPRESENTATIVE SITE:	Montpelier, Vermont
(4) CONVENTIONAL ALTERNATIVE:	Grid Electric Power Purchased Wholesale

REFERENCE SOLAR SYSTEM DESCRIPTION (1) (2)

- MITRE/Econergy Designed Wood-Fueled Power Plant
- Plant Rated Power: 61 MW Electric (Net)
- Expected Annual Energy Output: 3.74×10^8 kWh Electricity
- Fuel Usage: 1000 tons/day Wood/Dry-Basis (907 Metric Tons/Day)
- Wood Is Partially Dried Using Hot Flue Gases
- Capacity Factor: 70%
- Construction Period: 3 Years

CONVENTIONAL SYSTEM DESCRIPTION

- Grid Electric Power Purchased Wholesale
- Power Is Generated in a Nuclear Power Plant
- Power Is Sold at Municipal/Total-Requirement Rates
- Energy Purchased (To Give Energy Equivalent to Reference System): 3.74×10^8 kWh Electric/Year

RESOURCES

- (1) Robert Geosits, "Electricity from Wood: A Technical and Economic Evaluation," Econergy Associates Internal Report (1980).
- (2) Econergy Associates, "Technology Characterization and Economic Evaluation of 1000 ODT/Day Wood-Fired Power Plant," Report for LASL on Contract 4-L40-0745 M-1 (1980).

TABLE 4-5 (Continued)

REFERENCE SOLAR SYSTEM COST: 1980 (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Component	First Cost (000\$)	Annual O&M Cost(000\$) (Exc. Fuel)	Life (Years)	Component	First Cost (000\$)	Annual O&M Cost(000\$) (Exc. Fuel)	Life (Years)
Wood Handling	3534	413	20	No Incremental Cost Incurred			
Steam Generation	18629	2321	20				
Turbine Generation	12810	1473	20				
Substation/ Transformers	1896						
Miscellaneous	8397	219	20				
Installation	14267	--	--				
Site & Preparation	1419	--	--				
Contingency	9142	--	--				
Start-Up & Working Cap.	3585	--	--				
TOTAL	73,679	5,485	--	TOTAL	0	0	--

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	371,232	336,263
(2) Levelized Cost of Busbar Energy	\$0.049 /kWh	\$0.045 /kWh

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

SOLAR SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	81,510	88,250	99,040
(2) Annual O&M Cost, First Year (000\$)	5,288	5,334	6,075
(3) Expected Annual Energy Output (MWh)	3.74x10 ⁵	4.01x10 ⁵	4.01x10 ⁵
(4) Capacity Factor (%)	70	75	75
(5) Life Cycle Cost (000\$)	375,848	404,537	453,111
(6) Levelized Cost of Energy (\$/kWh)	0.05	0.05	0.06

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	0	0	0
(2) Annual O&M Cost, First Year (000\$)	0	0	0
(3) Expected Annual Energy Output (MWh)	3.74x10 ⁵	4.01x10 ⁵	4.01x10 ⁵
(4) Life Cycle Cost (000\$)	380,451	430,446	551,007
(5) Levelized Cost of Energy (\$/kWh)	0.05	0.06	0.07

TABLE 4-5 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Municipally Owned Utility
(2) Analysis Period:	23 Years (3 Year Construction, 20 Year Life)
(3) System Financing Period:	20 Years
(4) Percentage of System Cost Financed by Debt:	100%
(5) Bond Rate:	10.5%
(6) General Inflation Rate:	7.5% Per Year
(7) Conventional System, First Year Electricity Cost:	\$0.036/kWh
(8) Electricity Escalation Rate (Conventional):	2.5% Per Year (Real)
(9) First Year Cost of Wood:	\$25 Per Ton (Dry-Basis)
(10) Wood Escalation Rate:	1% Per Year (Real)
(11) O&M Escalation Rate:	1.5% Per Year (Real)
(12) Discount Rate:	10.5%
(13) Depreciation Algorithm:	Straight-Line
(14) Construction Period (Solar System):	3 Years
(15) Interest Rate During Construction:	10.5%
(16) Tax Rate (All Taxes):	0%
(17) Insurance Premium:	0.0025 of Capital Cost

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: BIOMASS (WOOD)/ELECTRIC UTILITIES, MONTPELIER, VERMONT

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate			X		
(b) Operating Efficiency			X		
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity					
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-6

SOLAR THERMAL/ELECTRIC UTILITIES

(1) REFERENCE SOLAR SYSTEM:	Advanced Water/Steam Central Receiver Solar Thermal Power Plant
(2) APPLICATION:	Electric Utilities/Intermediate Load
(3) REPRESENTATIVE SITE:	El Paso, Texas
(4) CONVENTIONAL ALTERNATIVE:	Combined-Cycle Power Plant

REFERENCE SOLAR SYSTEM DESCRIPTION (1,2)

- Solar System: Advanced Water/Steam Central Receiver Solar Thermal Power Plant
- Rated Power: 100 MWe
- Thermal Storage Capacity: 635 MWh(th)
- Mirror Area: 7,480,980 ft² (695,000 m²)
- Annual Energy Output: 303.2 GWhe
- Capacity Factor: 35%
- Unit Life: 30 Years
- Construction Time: 5 Years

CONVENTIONAL SYSTEM DESCRIPTION (3,4)

- Conventional System: Combined Cycle Power Plant
- Rated Output: 250 MWe
- Fuel Type: #2 Fuel Oil
- Full Load Heat Rate: 8,345 BTU/kWh (8,804 kJ/kWh)
- Annual Energy Output: 875.0 GWhe
- Capacity Factor: 40%
- Fuel Consumption: 53.3 Million Gal/Year (201.3 Million Liter/Year)
- Unit Life: 30 Years
- Construction Time: 2 Years

RESOURCES

- (1) Solar System Description and Cost Information, Sandia Laboratories, Livermore, CA
- (2) DOE/SF-T0740-7/I Newman Unit 1 Solar Repowering Final Report, July, 1980
- (3) EPRI PS-1201-SR, Technical Assessment Guide, July 1979
- (4) Westinghouse Electric Corporation

TABLE 4-6 (Continued)

REFERENCE SOLAR SYSTEM COST: 1980 (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Collector	159,850	3,197	30	Combustion Tur-			
Receiver & Tower	27,600	828	30	bine	24,000	1,100	30
Storage	17,500	175	30	Boilers	7,350	444	30
EPGS	28,700	287	30	Steam Turbine/ Generator	9,000	222	30
Other Hardware	3,000	1,043	30	Condenser	1,200	55	30
Site Cost & Preparation	7,850	--	--	Controls	4,000	55	30
AFDC*	36,675	--	--	Power Electrics	2,500	55	30
				Cooling Tower	2,000	55	30
				Other Hardware	5,000	222	30
				Design Cost	6,500	--	--
				Site Preparation	3,000	--	--
				Installation	7,000	--	--
				AFDC*	3,450	--	--
TOTAL	281,175	5,530		TOTAL	75,000	2,218	

*AFDC: Allowance for Funds Used During Construction

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980
(SYSTEM ACQUIRED IN 1980)

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL SYSTEM
(1) Life Cycle Cost (000\$)	620,476	1,427,222
(2) Levelized Cost of Busbar Energy (\$/kWh)	0.20	0.16

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE FOR SYSTEMS ACQUIRED IN
1985, 1990, 2000

SOLAR SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Cost to End User in Dollars)	245,023	164,965	95,313
(2) Annual O&M Cost (000\$)	4,819	3,355	2,027
(3) Expected System Annual Energy Output (MWh)	303,200	303,200	303,200
(4) Capacity Factor (%)	35	35	35
(5) Life Cycle Cost (000\$)	540,699	366,320	213,479
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.16	0.12	0.07

CONVENTIONAL SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Cost to End User in Dollars)	70,803	61,700	46,854
(2) Annual O&M Cost (000\$)	1,933	1,685	1,279
(3) Expected System Annual Energy Output (MWh)	876,000	876,000	876,000
(4) Capacity Factor (%)	40	40	40
(5) Life Cycle Cost (000\$)	1,304,088	1,237,693	1,127,805
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.15	0.14	0.13

TABLE 4-6 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Investor-Owned Utility
(2) Analysis Period (Conventional System):	32 Years
(3) Analysis Period (Solar System):	35 Years
(4) System Financing Period:	30 Years
(5) Fixed Charge Rate:	18 %
(6) General Inflation Rate:	7.5 %
(7) Capital Escalation Rate:	7.5 %
(8) O&M Escalation Rate:	7.5 %
(9) First Year Cost of Fuel for Conventional System:	\$5.42/Million BTU
(10) Fuel Escalation Rate:	10.5 %
(11) Discount Rate:	10.5 %
(12) Construction Period (Conventional System):	2 Years
(13) Construction Period (Solar System):	5 Years
(14) Allowance for Funds Used During Construction (Conventional System):	4.8 %
(15) Allowance for Funds Used During Construction (Solar System):	15 %
(16) Interest Rate During Construction Period:	
(17) No Federal Tax Credits	

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: SOLAR THERMAL/ELECTRIC UTILITIES, EL PASO, TEXAS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency				X	
(c) Capacity or Availability or Load Factor				X	
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity					
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-7

LOW-HEAD HYDROELECTRIC/ELECTRIC UTILITIES

- (1) REFERENCE SOLAR SYSTEM: Low-Head Hydroelectric Power Plant
 (2) APPLICATION: Electric Utilities
 (3) REPRESENTATIVE SITE: Kennebec River, Maine
 (4) CONVENTIONAL ALTERNATIVE: Combined-Cycle Power Plant

REFERENCE SOLAR SYSTEM DESCRIPTION (1)

- Solar System: Low-Head Hydroelectric Power Plant
- Rated Power: 3,440 kW_e
- Expected Annual Energy Output: 18,000 MWh at an Average Net Head of 20.4 ft (6.21 m) and Average Mean Annual Flow of 2,370 CFS (67.0 CMS)
- Capacity Factor: 60%
- Unit Life: 40 Years
- Construction Period: 1.5 Years

CONVENTIONAL SYSTEM DESCRIPTION (2,3)

- Conventional System: Combined-Cycle Power Plant
- Rated Output: 250 MWe
- Fuel Type: #2 Fuel Oil
- Full Load Heat Rate: 8,345 BTU/kWh (8,804 kJ/kWh)
- Annual Energy Output: 1,314 GWhe
- Capacity Factor: 60%
- Fuel Consumption: 80 Million Gal/Year (302 Million Liter/Year)
- Unit Life: 30 Years
- Construction Time: 2 Years

RESOURCES

- (1) Central Maine Power Company, "Shawmut Redevelopment Project," Small Hydroelectric Demonstration Project Proposal Submitted to DOE in Accordance with PON/DE-PN-07-79-ID-12043, August 1979.
- (2) Personal Communications With the Westinghouse Electric Corporation Combustion Turbine Systems Division, November, 1980
- (3) EPRI Technical Assessment Guide, EPRI PS-866-SR, Special Report, June 1978

TABLE 4-7 (Continued)

REFERENCE SOLAR SYSTEM COST: 1980 (1980 DOLLARS)				CONVENTIONAL SYSTEM COST: 1980 (1980 DOLLARS)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Power House/ Waterways	1,035	3	40	Combustion Turbine	24,000	1,368	30
Turbine/Gener- ator	1,538	53	40	Boilers	7,350	547	30
Electrical Equipment	313	7	40	Steam Turbine/ Generator	9,000	274	30
Plant Auxiliaries	42	3	40	Condenser	1,200	68	30
Substation/ Transmission	47	1		Controls	4,000	68	30
Miscellaneous	28			Power Electrics	2,500	68	30
Contingencies	390			Cooling Tower	2,000	68	30
Design/Legal	900			Other Hardware	5,000	274	30
AFDC*	200			Design Cost	6,500		
				Site Preparation	3,000		
				Installation	7,000		
				AFDC*	3,450		
TOTAL	4,490	67	--	TOTAL	75,000	2,735	--

*AFDC: Allowance for Funds Used During Construction

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980
(SYSTEM ACQUIRED IN 1980)

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL SYSTEM
(1) Life Cycle Cost (000\$)	10,932	2,061
(2) Levelized Cost of Busbar Energy (\$/kWh)	0.06	0.16

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE FOR SYSTEMS ACQUIRED IN
1985, 1990, 2000

SOLAR SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Cost to End User in Dollars)	3,913	3,410	2,589
(2) Annual O&M Cost (000\$)	59	51	39
(3) Expected System Annual Energy Output (MWe)	18,000	18,000	18,000
(4) Capacity Factor (%)	60	60	60
(5) Life Cycle Cost (000\$)	9,526	8,302	6,304
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.05	0.04	0.03

CONVENTIONAL SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE FOR SYSTEMS
ACQUIRED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Cost to End User in Dollars)	70,803	61,700	46,854
(2) Annual O&M Cost (000\$)	2,384	2,078	1,578
(3) Expected System Annual Energy Output (MWe)	1,314,000	1,314,000	1,314,000
(4) Capacity Factor (%)	60	60	60
(5) Life Cycle Cost (000\$)	1,881,759	1,791,728	1,642,491
(6) Levelized Cost of Busbar Energy (\$/kWh)	0.14	0.14	0.12

TABLE 4-7 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Investor Owned Utility
(2) System Life and Financing Period (Solar System):	40 Years
(3) System Life and Financing Period (Conventional System):	30 Years
(4) Fixed Charge Rate (Solar System):	20 %
(5) Fixed Charge Rate (Conventional System):	18 %
(6) General Inflation Rate:	7.5 %
(7) First Year Cost of Fuel For Conventional System:	\$5.42/Million BTU
(8) Fuel Escalation Rate:	10.5%
(9) Discount Rate:	10.5%
(10) Construction Period (Solar System):	1.5 Years
(11) Construction Period (Conventional System):	2 Years
(12) Allowance for Funds During Construction (Solar System):	4.7 %
(13) Allowance for Funds During Construction (Conventional System):	4.8 %
(14) Interest Rate During Construction (Solar System):	
(15) Interest Rate During Construction (Conventional System):	
(16) Annual Capacity Factor (Solar System):	60%
(17) Annual Capacity Factor (Conventional System):	60%
(18) DOE Small Hydroelectric Demonstration Project Contribution:	\$850,000

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

APPLICATION: LOW-HEAD HYDROELECTRIC/ELECTRIC UTILITIES, KENNEBEC RIVER, MAINE

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate		X			
(b) Operating Efficiency		X			
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
N/A(a) Escalation in Cost of Refined Petroleum Products					
N/A(b) Escalation in Cost of Natural Gas					
N/A(c) Escalation in Cost of Electricity					
(3) SOCIETAL FACTORS					
(a) Environmental Issues	X				
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-8

BIOMASS (WOOD)/GASEOUS FUELS

- (1) REFERENCE SOLAR SYSTEM: Wood-fueled PUROX Process Gasification System
- (2) APPLICATION: Medium-BTU Gas For Central and/or Industrial Process Heat
- (3) REPRESENTATIVE SITE: Aiken, South Carolina
- (4) CONVENTIONAL ALTERNATIVE: Equivalent BTU of Purchased Natural Gas

REFERENCE SOLAR SYSTEM DESCRIPTION

(1) (2) (3)

CONVENTIONAL SYSTEM DESCRIPTION

- Wood Gasification Using the Union Carbide PUROX Process to Produce a Medium BTU Gas
- Rated Gas Production: 4.771×10^8 BTU/hr (5.03×10^8 kJ/hr)
- Medium BTU Gas Energy Content: 394 BTU/SCF (11.76 kJ/m³)
- Expected Annual Energy Output: 3.552×10^{12} BTU (3.744×10^{12} kJ)
- Conventional Energy Usage: 16 MW electric (Primarily for O₂ Plant and Compressors)
- Non-Conventional Fuel Usage: 800 Tons/Day Wood/Dry-Basis (725.7 Metric Tons/Day)
- Construction Period: 3 Years
- Purchased Commercial Natural Gas
- Energy Purchased (to Give Energy Equivalent of Reference System): 3.552×10^{12} BTU/Year (3.744×10^{12} kJ/Year)
- Natural Gas Energy Content: 1000 BTU/SCF (29.85 kJ/m³)
- Efficiency Assumption: Natural Gas and Medium BTU Gas are Burned at the Same Efficiency

RESOURCES

- Raymond E. Desrosiers, "Process Designs and Cost Estimates for a Medium Btu Gasification Plant Using a Wood Feedstock," SERI/TR-33-151 (1979).
- Robert Geosits, "A Technical and Economic Evaluation of Wood Gasification by the EA Biomass Gasification Process," Econergy Associates Internal Report (1980).
- Econergy Associates, "Technology Characterization and Economic Evaluation of Medium Btu Gas (MBG) from Wood," Report for LASL on Contract 4-L40-0745 M-1 (1980).

TABLE 4-8 (Continued)

REFERENCE SOLAR SYSTEM COST: 1980 (1980 Dollars) (2) (3)				CONVENTIONAL SYSTEM COST: 1980			
Component	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Component	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
• Gas Production	5387	1631	20	No incremental system cost is incurred for Commercial Natural Gas purchased from the local utility.			
• Oxygen Plant	8820	1672	20				
• Gas Purification	2295	703	20				
• Installation	5891	---	---				
• Design	1564	---	---				
• Site and Preparation	1121	---	---				
• Contingency	3748	---	---				
• Start-up/Working Cap	3656	---	---				
TOTAL	32392	4096	---	TOTAL	-0-	-0-	-0-

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	REFERENCE SOLAR	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000 \$)	354,063	455,224
(2) Levelized Cost of Energy	\$4.984/Million BTU (\$4.728/Million kJ)	\$6.408/Million BTU (\$6.079/Million kJ)

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

RENEWABLE SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	36,120	39,310	43,910
(2) Annual O&M Cost, First Year (000\$)	4,124	4,234	5,001
(3) Expected Annual Energy Output (Million BTU) (Million kJ)	3.552x10 ⁶ 3.744x10 ⁶	3.636x10 ⁶ 3.833x10 ⁶	3.761x10 ⁶ 3.965x10 ⁶
(4) Capacity Factor (%)	85	87	90
(5) Life Cycle Cost (000\$)	396,827	430,813	512,613
(6) Levelized Cost of Energy (\$/million BTU) (\$/million kJ)	5.59 5.30	5.92 5.62	6.81 6.46

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$) (Includes Interest During Construction)	0	0	0
(2) Annual O&M Cost, First Year (000\$)	0	0	0
(3) Expected Annual Energy Output (Million BTU) (Million kJ)	3.552x10 ⁶ 3.744x10 ⁶	3.636x10 ⁶ 3.833x10 ⁶	3.761x10 ⁶ 3.965x10 ⁶
(4) Life Cycle Cost (000\$)	614,962	850,397	1,605,263
(5) Levelized Cost of Energy (\$/million BTU) (\$/million kJ)	8.66 8.21	11.69 11.09	21.34 20.24

TABLE 4-8 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS

(1) Ownership Pattern:	Investor-Owned Industry
(2) Analysis Period:	23 Years (3-Year Construction, 20-Year Life)
(3) System Financing Period:	20 Years
(4) Percentage of System Cost Financed by Debt:	60%
(5) Bond Rate:	11.5%
(6) Equity Return Rate:	17.6%
(7) General Inflation Rate:	7.5% per year
(8) Conventional System, First Year Cost of Gas:	\$3.60/Million BTU
(9) Gas Escalation Rate (Conventional):	6.2% per year (Real)
(10) First Year Cost of Wood:	\$25/Ton (Dry basis)
(11) Wood Escalation Rate:	1% per year (Real)
(12) First Year Cost of Electricity and Escalation Rate:	\$0.028/kWh, 2.5% per year
(13) O&M Escalation Rate:	1.5% per year (Real)
(14) Discount Rate:	10.5%
(15) Depreciation Algorithm:	Sum of Years' Digits
(16) Interest Rate during Construction:	13.94%
(17) Marginal Federal + State Tax Rate:	50%
(18) Property Tax Rate:	\$2/\$100 of Actual Value
(19) Federal Tax Credits:	10% of Capital Cost

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: BIOMASS (WOOD)/GASEOUS FUELS, AIKEN, SOUTH CAROLINA

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate				X	
(b) Operating Efficiency			X		
(c) Capacity or Availability or Load Factor			X		
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity			X		
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules			X		

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
- 5 = Based on an analogy

(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues

TABLE 4-9

BIOMASS/LIQUID FUELS (ETHANOL)

- (1) REFERENCE SOLAR SYSTEM: Corn-to-Ethanol Plant (R. Katzen Associates Design)
- (2) APPLICATION: Production of 200 Proof Ethanol for Blending into 10/90% Gasohol
- (3) REPRESENTATIVE SITE: Carbondale, Illinois
- (4) CONVENTIONAL ALTERNATIVE: Unleaded Gasoline Consisting of a Blend of 10% Imported and 90% Domestic Stock

REFERENCE SYSTEM DESCRIPTION (1)(2)

- Corn-to-Ethanol Plant (R. Katzen Associates Design)
- Ethanol Use: Mix in 10%/90% ethanol unleaded gasoline blend
- Annual Corn Use: 19.35 Million Bushels (16.37 Million Cubic Meters)
- Annual 200 Proof Ethanol Output: 50 Million gallons (189 Million Liters)
- Annual Gasohol Production: 500 Million Gallons (1890 Million Liters)
- Annual Distillers Dried Grain's Output: 176,300 Tons (159,900 metric tons)
- Yearly Coal Use: 97,466 Tons (88,401 metric tons)
- Construction Period: 4 Years
- Annual Unleaded Gasoline Requirement: 450 Million Gallons (1700 Million Liters)

CONVENTIONAL SYSTEM DESCRIPTION

- 500 Million Gallons (1890 Million Liters) of Unleaded Gasoline Consisting of:
  - 50 Million Gallons (189 Million Liters) of Imported Gasoline
  - 450 Million Gallons (1700 Million Liters) of Domestically Produced Gasoline

RESOURCES

- (1) Econergy Associates, "Technology Characterization and Economic Evaluation - Ethanol from Corn, 50 Million Gallon/Year Plant," Report from LASL on Contract 4-L40-0745M-1 (1980).
- (2) A. Katzen Associates, "Grain Motor Fuel Alcohol - Technical and Economic Assessment Study," Report for DOE, HCP/J6639-01 (1978).

TABLE 4-9 (Continued)

REFERENCE SOLAR SYSTEM COST (1980 DOLLARS)				CONVENTIONAL SYSTEM COST (1980 DOLLARS)			
Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)	Components	First Cost (000\$)	Annual O&M Cost (000\$)	Life (Years)
Grain Handling	2699	--	20	No Incremental Cost Is Incurred			
Mash Cooking	3653	--	20				
Fungal Amylase	4511	--	20				
Fermentation	5428	461	20				
Distillation	6627	--	20				
Drying	16839	--	20				
Storage	5690	--	20				
Steam Prod.	19520	193	20				
Building & Site	2255	--	20				
Land & Misc.	22337	9764	--				
TOTAL	89,559	10,418		TOTAL			

REFERENCE SOLAR AND CONVENTIONAL SYSTEM ECONOMIC PERFORMANCE: 1980 INSTALLATION

ECONOMIC MEASURE (1980 DOLLARS)	SOLAR SYSTEM	CONVENTIONAL ALTERNATIVE
(1) Life Cycle Cost (000\$)	12,080,000	12,160,000
(2) Levelized Cost (FOB Terminal) (\$/gal) of 10/90 Blend	\$1.21 (\$/liter) \$0.32	1.22 0.32

SOLAR SYSTEM COST, TECHNICAL PERFORMANCE AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

SOLAR SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	88,620	94,070	106,000
(2) Annual O&M Cost (000\$)	10,303	11,013	12,588
(3) Expected System Annual Output (million gal)	500	500	500
(million liters)	1,890	1,890	1,890
(4) Capacity Factor (%)	90	90	90
(5) Life Cycle Cost (000\$)	13,570,000	15,290,000	19,390,000
(6) Levelized Cost (FOB Terminal) (\$/gal) for 10/90 Blend	1.36 (\$/liter) 0.358	1.53 0.404	1.94 0.512

CONVENTIONAL SYSTEM COST AND ECONOMIC PERFORMANCE
(FOR SYSTEMS ACQUIRED IN 1985, 1990, 2000)

CONVENTIONAL SYSTEM CHARACTERISTICS (1980 \$)	1985	1990	2000
(1) System Installed Cost (000\$)	0	0	0
(2) Annual O&M Cost (000\$)	0	0	0
(3) Expected System Annual Output (million gal)	500	500	500
(million liters)	1890	1890	1890
(4) Life Cycle Cost (000\$)	13,830,000	15,720,000	20,320,000
(5) Levelized Cost (FOB Terminal) (\$/gal) for 10/90 Blend	1.38 (\$/liter) 0.365	1.57 0.415	2.03 0.537

TABLE 4-9 (Concluded)

MAJOR ECONOMIC ANALYSIS ASSUMPTIONS	
(1) Ownership Pattern:	Investor-Owned Industrial Firm
(2) Analysis Period:	24 Years (20 yrs operating, 4 yrs construction)
(3) Percentage of System Installed Cost Financed Externally:	60%
(4) Bond Rate:	11.5% (for 20 years)
(5) Return on Equity:	17.6%
(6) General Inflation Rate:	7.5% per year
(7) First Year Cost of Gasoline from Imported Oil @ \$32/Barrel:	\$1.15/gallon
(8) First Year Cost of Domestic Unleaded Gasoline:	\$1.00/gallon
(9) Gasoline Escalation Rate Above Inflation:	2.6%
(10) First Year Coal Cost:	\$25/ton
(11) Coal Cost Escalation Rate Above Inflation:	1.3%
(12) Corn Price:	\$3.00/bushel
(13) Discount Rate:	10.5%
(14) Depreciation Algorithm:	Sum-of-Years' Digits
(15) Marginal Federal and State Tax Rate:	50%
(16) Property Tax Rate:	\$2/\$100 of Capital Plant Value
(17) Federal Tax Credits (Renewable System):	\$69,270,000
(18) Retailers Annual Tax Credits for Renewable System (not figured in above costs)	(\$20,000,000/yr Federal to 1992; \$0 to \$50,000,000/yr State, depending on state)

RUDIMENTARY ERROR ANALYSIS: MAJOR SOURCES OF ERROR

TECHNOLOGY/APPLICATION: BIOMASS TO LIQUID FUEL/CORN TO ETHANOL, CARBONDALE, ILLINOIS

TYPE/SOURCE OF ERROR	REASON(S) FOR ERRORS (CHECK APPROPRIATE BOXES USING KEY BELOW)				
	1	2	3	4	5
(1) TECHNICAL SOURCES					
(a) Capital Cost Estimate			X		
(b) Operating Efficiency		X			
(c) Capacity or Availability or Load Factor		X			
(2) ECONOMIC SOURCES					
(a) Escalation in Cost of Refined Petroleum Products					
(b) Escalation in Cost of Natural Gas					
(c) Escalation in Cost of Electricity	X				
(3) SOCIETAL FACTORS					
(a) Environmental Issues			X		
(b) Public Acceptance Issues; Delay in Schedules	X				

KEY:

(1) TECHNICAL SOURCES

- 1 = Based on systems actually built and operating
- 2 = Based on detailed designs of facilities similar to existing ones
- 3 = Based on engineering designs of new facilities
- 4 = Based on conceptual designs
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(2) ECONOMIC SOURCES

- 1 = Steady prices: Contracts may be written for long periods (15 years) with no escalation clauses
- 3 = Uncertain prices: Recent volatility on the order of 20% per year
- 5 = Very uncertain prices and availability: Recent increases of more than 20% per year

(3) SOCIETAL SOURCES

- 1 = No foreseeable increase in cost or reduction in operating efficiency or availability due to environmental issues or delay in schedule
- 3 = Minor environmental or public acceptance issues
- 5 = Major cost increases or delays may be anticipated due to public acceptance or environmental issues