27/7/30/79
24 to NT 15

MASTER

ALO-3787-4
Dist. Category UC-62

APPLICATION ANALYSIS OF SOLAR TOTAL ENERGY SYSTEMS TO THE RESIDENTIAL SECTOR

Volume IV. MARKET PENETRATION

Project 8987 Final Report

**Prepared by
Institute of Gas Technology
IIT Center, 3424 S. State Street
Chicago, Illinois 60616**

Date Published — July 1979

**Prepared for the
UNITED STATES DEPARTMENT OF ENERGY**

Under Contract No. EG-77-C-04-3787

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represent that its use would not infringe privately owned rights.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy	\$ 9.75 (domestic)
	\$12.25 (foreign)
Microfiche	\$ 3.00 (domestic)

APPLICATION ANALYSIS
OF SOLAR TOTAL ENERGY SYSTEMS
TO THE RESIDENTIAL SECTOR

Volume IV.
MARKET PENETRATION

Project 8987 Final Report

Approved by:

T. P. Whaley
T. P. Whaley
Program Manager

Prepared for the

UNITED STATES DEPARTMENT OF ENERGY
Under Contract No. EG-77-C-04-3787

Prepared by the

INSTITUTE OF GAS TECHNOLOGY
3424 S. State Street
Chicago, Illinois 60616

July 1979

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

PREFACE

This is the final report of the Institute of Gas Technology (IGT) on "Application Analysis of Solar Total Energy Systems to the Residential Sector," sponsored by the Department of Energy under Contract No. EG-77-C-04-3787. The period of performance was from 1 February through 30 April 1978.

The work is reported in four volumes, as follows:

- Volume I. Executive Summary
- Volume II. Energy Requirements
- Volume III. Conceptual Design
- Volume IV. Market Penetration.

The study was conducted by the following IGT personnel and subcontractors/consultants:

IGT Personnel

H. Abbasi
N.P. Biederman
R.B. Foster
T.M. Goff
J.E. Lamson
M. Novil
T.P. Whaley
J. Wurm
B.D. Yudow

Subcontractors/Consultants

Gamze-Korobkin-Caloger, Inc. (Design)	: M. Gamze, L. Korobkin, and N. Malik
Southern California Gas Co. (Design Performance):	D. Devoe
Honeywell (Solar Components)	: G. Smith
Sundstrand (Solar Components)	: W. Adams
Ormat Turbines, Ltd. (Solar Components)	: L. Bronicki

The ERDA-DOE Program Managers were Mr. J. Rannels and Mr. M. Resner. The Technical Monitor was Dr. R.W. Harrigan of Sandia Laboratories, Albuquerque, New Mexico.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

HIGHLIGHTS

- MARKET PENETRATION OF CENTRALIZED SOLAR TOTAL ENERGY SYSTEMS (STES) IN THE RESIDENTIAL SECTOR UNLIKELY TO BE SIGNIFICANT WITHOUT MAJOR REDUCTION IN CAPITAL COSTS.
- FACTORS THAT RESTRICT MARKET PENETRATION POTENTIAL OF STES IN THE RESIDENTIAL SECTOR ARE:
 - WIDESPREAD USE OF LOWER-COST UNITARY SYSTEMS FOR HEATING AND COOLING IN RESIDENTIAL SECTOR
 - PRIVILEGED POSITION OF RESIDENTIAL SECTOR WITH RESPECT TO SUPPLY OF FOSSIL FUEL
 - USE OF LARGE CENTRAL RECEIVER SYSTEMS LESS APPROPRIATE TO RESIDENTIAL SECTOR THAN OTHER SECTORS.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

LIST OF ABBREVIATIONS

a.c.	-	Alternating Current
A.G.A.	-	American Gas Association
BAU	-	Business-As-Usual
BEA	-	Bureau of Economic Analysis
Btu	-	British thermal unit
CF	-	Cubic feet
CIA	-	Central Intelligence Agency
COP	-	coefficient of performance
CPC	-	compound parabolic collector
CR	-	Concentration ratio
DOE	-	Department of Energy
EER	-	energy efficiency ratio
E-W	-	east-west horizontal (parabolic trough)
FEA	-	Federal Energy Administration
FPC	-	Federal Power Commission
GATE	-	Group to Advance Total Energy
G.E.	-	General Electric Co.
H.U.	-	household unit, or housing unit
IGT	-	Institute of Gas Technology
kW	-	kilowatt
kWhr	-	Kilowatt hour
LPG	-	liquified petroleum gas
MW	-	megawatt
N-S	-	north-south horizontal (parabolic trough)
O&M	-	operating and maintenance (costs)
OPEC	-	Organization of Petroleum Exporting Countries
ORC	-	Organic Rankine Cycle
OTA	-	Office of Technology Assessment
psia	-	pounds per square inch (absolute)
PV	-	photovoltaic
R&D	-	research and development
SFA	-	single-family - attached
SFD	-	single-family - detached
STE	-	solar total energy
STES	-	solar total energy systems(s)
WOS	-	world oil shortfall

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY

A solar total energy system (STES) is defined as an energy system designed to maximize the efficient use of collected solar energy by supplying both the low-grade (low-temperature thermal) and high-grade (electrical and/or mechanical) energy needs of selected applications. ERDA's (now DOE) Solar Total Energy Program is concerned primarily with those STES that use heat engine or photovoltaic devices to produce electricity (and/or mechanical work) and apply the residual thermal energy from the conversion process to some useful purpose. The solar total energy is backed up and supplemented to the extent required by conventional fossil-fuel-derived energy for periods when solar-derived energy is inadequate.

This project analyzed the application of solar total energy to appropriate segments of the residential sector and determined the residential market penetration potential for STES in the 1985-1990 time frame, and beyond.

This volume (Volume IV) first describes the residential consumption of energy in each of the 11 STES regions^{*} by fuel type and end-use category. Fuel categories are natural gas, fuel oil, LPG, electricity, and coal. The electrical energy consumption is broken down into point-of-use and primary energy for each region further broken down into the following sources: natural gas, fuel oil, hydro, coal, nuclear, and other minor sources. End-use categories are:

- Space heating
- Cooling
- Water heating
- Clothes drying
- Lighting
- Refrigeration
- Air conditioning, window
- Air conditioning, central
- Home food freezing
- Other.

* Regionalization described in Volume II.

The current and projected costs and availability of fossil fuels have been determined for the various STE regions, based on the FEA National Energy Outlook and other sources. Projected oil prices beyond 1985 are discussed in the light of two possible scenarios, one involving a world oil shortfall and one involving no shortfall.

Based on a projected U.S. population of nearly 250,000,000 and 88,753,000 households, new construction throughout the U.S. is projected to be approximately 13 million single-family houses, about 9.4 million townhouse dwelling units (not buildings), and about 7.3 million low-rise apartments (not buildings) in the 1980 to 1990 time frame. If as much as 10% of these units are suitable candidates for solar total energy systems, then nearly 3 million dwelling units could be considered as a potential residential market for STES over the 10-year period from 1980 to 1990, or about 300,000 units annually. Nearly half of this potential market is represented by single-family detached homes, and these are considered much less likely candidates than townhouses and low-rise apartments for the central STES analyzed in this project; consequently, a more likely target should be between 150,000 and 200,000 dwelling units annually.

The effects of STES ownership options, institutional constraints, and possible government actions on market penetration potential have been considered. In general, it would appear that the satisfactory resolution of these effects may be a major factor in developing the market penetration of STES in the residential sector. Past experience with fossil-fueled total energy systems suggests that the utility interface may be particularly important.

Capital costs for two types of STES were determined, those based on organic Rankine cycle (ORC) heat engines and those based on flat plate, water-cooled photovoltaic arrays. Both types of systems utilized parabolic trough collectors, either in the north-south horizontal or the polar mount configuration. System costs were based on projected installed costs of approximately \$20/sq ft for the N-S horizontal trough, approximately \$22/sq ft for the polar mount, \$600/kW for the ORC unit, and \$1,86/sq ft for photovoltaic arrays (by 1990). Based on these costs and those costs associated with storage, heat exchangers, thermal distribution systems, chillers, etc., total system costs were determined and compared with capital costs of conventional systems, which were base

on unitary (rather than central) systems for supplying space heating/cooling and hot water. The capital cost differential between conventional and STE systems was calculated on an incremental cost per dwelling unit for comparison with projected fuel savings in the market penetration analysis.

The market penetration analysis was planned in two phases, a preliminary analysis of each of the geographical regions for each of the STE systems considered; and a final, more precise analysis of those regions and systems showing promise of significant market penetration.

However, the preliminary analysis revealed no geographical regions in which any of the STES considered promised to be competitive with conventional energy systems using utility services at the prices projected for future energy supplies in the residential market. This conclusion may be due in part to the fact that future projections of energy availability indicated no future shortage of energy in the residential market and necessitated the requirement that future STES would necessarily have to compete with conventional energy services on a price basis.

Because no promising situations were found, the analysis was directed toward an examination of the parameters involved in an effort to identify those factors which make a residential STES less attractive than similar systems in the commercial and industrial areas. The following factors were identified:

- The availability of residential fuel supplies will not be curtailed.*
- There is a predictable trend toward applying a greater portion of increased fuel costs to commercial and industrial customers leaving residential fuel and electricity costs less affected.*
- An STES requires a central system which is common in industry and commercial buildings but has become less common in all but high-rise apartments in the residential market. The dispersed unitary systems becoming commonplace have lower capital costs which serve to increase the difference in cost between an STES and conventional energy systems in most of the residential market.
- The advantages of scale in 36- to 48-unit residential complexes is more than offset by very high costs for transmission and distribution of heat and cold.
- The most important factor, however, is the very high capital cost of solar collectors and on-site electric generation equipment. Until substantial reductions in these costs can be achieved, it does not appear that competitive STES can be offered.

* Based on current or projected Government policies.

Collector costs represent only 40% to 50% of the total capital cost of an ORC-based STE system, with ORC costs representing approximately 20%. Consequently, a drastic reduction in collector costs would not necessarily ensure a cost-competitive system unless improvements were also made in the costs of the other components of the system.

In view of these problems, it may be desirable to pursue the development of STES in industrial and commercial situations until future systems can be demonstrated to have cost performances more acceptable to the residential market.

TABLE OF CONTENTS

	<u>Page</u>
Section 1. INTRODUCTION	1
Section 2. IDENTIFICATION OF COMPETITIVE ENERGY SOURCES	4
2.1 Methodology	4
2.2 Heating	11
2.3 Water Heating	17
2.4 Air Conditioning	20
2.5 Escalation of 1975 Data	20
2.6 Primary Fuels Used in Electricity Generation	26
2.7 IGT Residential Energy Model	26
2.8 Projections of Energy Consumption (1985 to 2020)	26
Section 3. AVAILABILITY AND PRICES OF FUELS AND ELECTRICITY	44
3.1 Availability	44
3.1.1 Natural Gas	44
3.1.2 Oil	45
3.1.3 Liquified Petroleum Gas (LPG)	48
3.1.4 Electricity	50
3.2 Energy Prices	51
3.2.1 Current Energy Prices	52
Natural Gas	52
Fuel Oil	52
LPG	53
Electricity	53
3.2.2 Projected Energy Prices	54
Oil Price Projection	54
World Oil Shortfall (WOS)	54
Business-As-Usual (BAU) Scenario	56
Gas Price Projection	61
Effects of World Oil Shortfall (WOS)	61
Business-As-Usual (BAU)	62
LPG Price Projections	63
Electricity Price Projections	63
3.3 General Comments	64

TABLE OF CONTENTS, Cont.

	<u>Page</u>
Section 4. RESIDENTIAL BUILDING PROJECTIONS	65
4.1 Methodology	65
Section 5. OWNERSHIP	70
5.1 Fossil Fuel Total Energy Systems	70
5.2 Single-Family Dwelling Market	71
5.3 Multi-Family Dwelling Market	74
5.3.1 Rental Units	74
STES Owned by Building Owner	74
STES Operation	76
STES Service	76
Utility Ownership of STES	77
Siting Problems	77
Maintenance and Service	78
Service Problems With Other Total Energy Systems	79
STES Owned by Commercial Company	80
5.3.2 Owner Occupied Units	80
Section 6. REVIEW OF INSTITUTIONAL ASPECTS	82
6.1 Financial	82
6.1.1 Taxes	82
6.1.2 Earnings	83
6.2 Material	83
6.2.1 Reliability of Service	83
6.2.2 Building Codes	85
6.2.3 Development Timing	85
6.3 Technological	86
6.3.1 Training	86
6.3.2 Technical Obsolescence	86
6.4 Regulatory	87
6.4.1 Solar Systems/Utility Interface	87
6.4.2 Gas Utility Interface	88
6.4.3 Electricity Utility Interface	88
6.4.4 Technical Problems	88
6.4.5 Utility Viewpoint	89
6.4.6 Alternatives to Utility Interchange Connections	91

TABLE OF CONTENTS, Cont.

	<u>Page</u>
Section 7. IDENTIFICATION OF PERTINENT GOVERNMENT ACTION	94
7.1 Tax Relief	94
7.2 Support of Research and Development	94
7.3 Revision of Codes and Laws	95
Section 8. SYSTEM COSTS	96
8.1 Costs of Conventional Systems	96
8.2 Capital Cost of ORC-Based STE Systems	97
8.2.1 Pipefield Cost for Thermal STES	103
8.2.2 Future Capital Costs of ORC-Based STES	106
8.3 Cost Estimates for Photovoltaic Solar Total Energy Systems	107
8.3.1 Photovoltaic Cells	107
8.3.2 Thermal Collector Module	107
8.3.3 Collector System Fixed Cost	110
8.3.4 Pipefield Cost for Photovoltaic STES	110
8.3.5 Batteries and Power Conditioning Equipment	110
8.3.6 Battery Prices	111
8.3.7 Power Conditioning Costs	112
8.3.8 Building and Other Costs	112
8.3.9 Thermal Storage	113
8.3.10 Cooling, Heating, and Distribution Equipment	113
8.3.11 Thermal Energy and Domestic Hot Water Distribution System	114
Section 9. MARKET PENETRATION ANALYSIS	116
9.1 Preliminary Market Penetration Analysis	116
9.1.1 Methodology	116
Assumptions	116
Basis for Analysis	116
Preliminary Evaluation	118
9.1.2 Projected Cost of Conventional Utility Service	120
Gas-Heated Dwellings	120
Oil-Heated Dwellings	121
LPG-Heated Dwellings	121
All-Electric Dwellings	122

TABLE OF CONTENTS, Cont.

	<u>Page</u>
9.1.3 Annual Capital Cost Ratio	122
9.1.4 High-Temperature Organic Rankine Cycle System	123
Back-Up Energy Costs	124
Conventional Utility Back-Up Energy	124
Independent Back-Up Energy	124
Net Utility Energy Savings	125
A. Thermal Tracking ORC System	125
Energy Distribution Costs	131
Other Capital Costs	132
B. Independent (Stand-Alone) ORC System	134
9.1.5 Stirling Engine System	134
9.1.6 Photovoltaic System	135
9.2 Parametric Analysis	137
9.2.1 High-Temperature ORC System	137
Energy Flow Through STES	137
Variation of Collector Area	139
Comparison of Solar and Fuel Energy Costs	145
Electric Generation Costs	149
Time-of-Day Electric Rates	154
9.2.2 Photovoltaic System	155
9.3 Hybrid Systems	159
9.4 Potential Market Penetration	160
9.4.1 Market Capture	160
9.4.2 Impact on Energy Use	163
Section 10. MARKET STRATEGY	166
10.1 Site Selection Criteria	167
10.1.1 The Prioritization System	167
10.1.2 The Criteria	169
10.1.3 Regional Evaluation	170
Market Penetration Potential	170
High Visibility	170
Physical Feasibility	170
10.1.4 Site Evaluation	171

TABLE OF CONTENTS, Cont.

	<u>Page</u>
Market Penetration Potential	171
High Visibility	171
Technical Feasibility	171
10.1.5 Region and Site Selection	172
10.1.6 Entering the Marketplace	173
Section 11. GENERAL CONCLUSIONS	174
Section 12. RECOMMENDATIONS	176
REFERENCES CITED	177
Appendix A. State Tax-Relief Legislation	A-1
Appendix B. Collector Costs	B-1
Appendix C. Projected Annual Costs of Conventional Utility Energy Service	C-1
Appendix D. Estimated Net Savings Over Conventional Systems	D-1
Appendix E. Methodology for Determining Market Penetration	E-1

**THIS PAGE
WAS INTENTIONALLY
LEFT BLANK**

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	Diagram of Program Approach	2
2	Approximate Temperature of Water, in °F, From Nonthermal Wells at Depths of 30 to 60 Feet	18
3	Number of Hours Dry Bulb Temperature Reaches 80°F or Over in Average Year	21
4	Percentage of Single-Family Detached Dwellings, 1970	67
5	SFD Piping Layout	104
6	Low-Rise, 2-Story Piping Layout	105
7	Learning Curve for Cell Cost Per Unit Array Area	108
8	Annual Cost of STES Vs. Energy Saving	119
9	Overall Annual Savings — Los Angeles	126
10	Overall Annual Savings (By Year) — Los Angeles	127
11	Overall Annual Savings — Los Angeles	128
12	Overall Annual Savings — Boston	129
13	Overall Annual Savings — Raleigh	130
14	Overall Annual Savings — Dallas	136
15	Energy Flow Chart — Boston	138
16	High-Temperature ORC System — Los Angeles	141
17	High-Temperature ORC System — Boston	142
18	High Temperature ORC System With Thermal Tracking (Los Angeles)	143
19	High Temperature ORC System With Thermal Tracking (Boston)	144
20	Breakeven Solar Collector Cost — Los Angeles	147
21	Breakeven Solar Collector Cost — Boston	148
22	ORC Capital Cost to Breakeven	151
23	Savings From Time-of-Day Rates	156
24	Historical Adoption Curve	161
25	Historical Diffusion Curve	161

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Residential Energy Use	2
2	States in STES Regions	5
3	Region 1 Tabulation of the Number of Households by End-Use Category and Fuel Type, 1970	7
4	Region 10 Tabulation of the Number of Households by End-Use Category and Fuel Type for Northern Minnesota, 1970	9
5	Residential Energy Consumption, 1970	12
6	Average Residential Gas Consumption by State	16
7	Average Regional Gas Heating Energy Consumption	17
8	Average Temperatures of Well Water	19
9	Estimated Disposition of the Annual Energy Input to Residential Water Heaters	19
10	Approximate Cooling Degree-Day Hours Above 80°F	22
11	Inputs to Calculation of Saturation Level	22
12	Residential Saturation of Air-Conditioning Units	23
13	Residential Saturation of Home Food Freezers	23
14	Residential Saturation of Clothes Dryers, 1975	24
15	Residential Energy Consumption Inputs for Clothes Drying, 1975	24
16	Residential Energy Consumption for Air Conditioners, 1975	25
17	Residential Energy Consumption for Home Food Freezing, 1975	25
18	Residential Households, 1975	25
19	Total Electric Utility Industry, Generation by Fuel	27
20	Other Energy Consumption, 1975	28
21	Residential Use of Energy, 1975: Region 1	29

LIST OF TABLES, Cont.

<u>Table No.</u>		<u>Page</u>
22	Residential Use of Energy, 1975: Region 2	30
23	Residential Use of Energy, 1975: Region 3	31
24	Residential Use of Energy, 1975: Region 4	32
25	Residential Use of Energy, 1975: Region 5	33
26	Residential Use of Energy, 1975: Region 6	34
27	Residential Use of Energy, 1975: Region 7	35
28	Residential Use of Energy, 1975: Region 8	36
29	Residential Use of Energy, 1975: Region 9	37
30	Residential Use of Energy, 1975: Region 10	38
31	Residential Use of Energy, 1975: Region 11	39
32	Residential Consumption of Primary Energy, By End Use, 1975	40
33	Percentage of Housing Units Using Various Fuels, 1975	41
34	Estimated Gas Consumption by State and Class of Service, 1985	46
35	U.S. Propane Supply	49
36	Comparison of Recent Electric Demand Growth Studies	50
37	Residential Energy Prices - 1975	53
38	Estimated Cost of Energy From Coal	55
39	Residential Energy Prices - 1985	57
40	Residential Energy Prices - 1990 (Business-As-Usual)	57
41	Residential Energy Prices - 1990 (World Oil Shortfall)	58
42	Residential Energy Prices - 2000 (Business-As-Usual)	58
43	Residential Energy Prices - 2000 (World Oil Shortfall)	59
44	Residential Energy Prices - 2010 (Business-As-Usual)	59
45	Residential Energy Prices - 2010 (World Oil Shortfall)	60
46	Residential Energy Prices - 2020 (Business-As-Usual)	60
47	Residential Energy Prices - 2020 (World Oil Shortfall)	61
48	Regional Population (Households) Projections	66
49	Projected Breakdown of Housing Types, %	68
50	Regional In-Place Housing Projections	69
51	Projected 1980-1990 New Construction	69
52	STES Ownership Options	70
53	Breakeven Costs of Solar Capacity	93

LIST OF TABLES, Cont.

<u>Table No.</u>		<u>Page</u>
54	Estimated Capital Costs, Conventional System	98
55	Estimated Capital Costs, 300°F ORC STE System	99
56	Estimated Capital Costs, 600°F ORC STE System	100
57	Estimated Regional STES Costs, 300°F ORC System, \$	101
58	Estimated Regional STES Costs, 600°F ORC System, \$	102
59	Installed Collector Pipefield Costs for Thermal STES	106
60	Capital Cost Summary — Variable Costs	109
61	Thermal Collector Module Costs	109
62	Battery System Costs Estimates	111
63	Capital Cost Summary of Fixed Costs for Single-Family Detached Dwellings and Townhouses	115
64	Capital Cost Summary for Fixed Costs for Low-Rise Dwelling	115
65	Comparison of Capital Costs Per Dwelling Unit	132
66	Projected Cost of Heat And Electricity Provided by Photovoltaic STES	157
67	Incremental Payments and Capital Cost Differential	162
68	Summary of Incremental Payment and Capital Cost Differential	163
69	Energy Savings Per Dwelling Unit With High-Temperature ORC	164

Section 1.
INTRODUCTION

This is the Institute of Gas Technology's (IGT) report on Market Penetration, part of the Final Report on the Application Analysis of Solar Total Energy to the Residential Sector, sponsored by the U. S. Department of Energy under Contract No. EG-77-C-04-3787.

The overall program approach, described in Volumes II and III, is illustrated in Figure 1 and shows how the market penetration task fits into the overall project.

The objective of the market penetration assessment task was to identify and evaluate the conditions under which solar total energy systems (STES) would reasonably penetrate the market segments identified under the energy requirements effort. To achieve this objective, it was first necessary to identify the types and quantities of fuel used in these market segments in each of the STE regions and to project the availability/price of these fuels to a 1985 to 1990 time frame (and beyond), so as to determine the cost of providing the necessary energy to these market segments with conventional fuels. By projecting the cost of supplying this energy (or a substantial portion of it) to the market segments by STES, the potential cost benefits of STES can be determined and used as a basis for determining potential market penetration of STES in the residential sector.

The residential sector consumes 19.6% of the primary energy consumed in the United States, compared with 41.3% by the industrial sector, 24.6% by transportation, and 14.5% by the commercial sector. Consequently, the residential sector is the third largest consumer of energy in the U.S. and represents a major potential market for STES if they can compete economically with conventional energy systems. Obviously, then, a major goal of this study was to assess the comparative economics of STES so as to determine what share, if any, of this large potential market could be captured by solar total energy.

The breakdown of energy use in the residential sector is shown in Table 1.

A78073351

Figure 1. DIAGRAM OF PROGRAM APPROACH

Table 1. RESIDENTIAL ENERGY USE

Space Heating	55.0%
Water Heating	14.5%
Refrigeration/Freezing	7.7%
Lighting	5.7%
Cooking	5.1%
Air Conditioning	4.6%
Drying	1.7%
Other	5.7%
	<hr/>
	100.0%

This table indicates that thermal energy needs amounting to approximately 75% of the total (space heating, water heating, and air conditioning) would be the target for reject heat from a residential STES, with the remaining 25% (refrigeration, freezing, lighting, cooking, drying, and others) to be supplied by the electrical output of the STES.

By projecting the new residential construction^{1,2,3} for the time frame under consideration and estimating what portions could be considered likely candidates for competitive STES, the residential market potential for such systems can be estimated. The extent to which this potential could be realized is obviously dependent upon the net savings (i.e., monetary value of fuel and electricity savings over the system costs) that a buyer can realize by comparison with conventional systems. This can be translated into a net effect on the energy resource base of the country.

Section 2.

IDENTIFICATION OF COMPETITIVE ENERGY SOURCES

In order to determine STES market potential and the estimated rate of market capture, one must calculate the size of the market for conventional devices serving the same function. Market penetration can only be achieved if the incremental life-cycle costs of STES's compared with conventional energy systems are equivalent to, or less than, the value of fuel saved. In order to estimate the rate of market capture, one must know the market potential beforehand, then determine the spread between fuel savings and incremental capital costs. This portion of Volume IV provides estimates of regional households, all of which are potential STES buyers given favorable economic comparisons with conventional systems; future projections are given in a later section.

Another objective is to identify energy consumption in the residential sector by end use and fuel type so that STES displacement of scarce conventional fuels can be estimated. Further, in the case of electricity, the mix of primary fuels used for electrical generation, by region, must also be identified in order to calculate primary energy savings from STES displacement of utility generated electricity.

2.1 Methodology

The only definitive residential energy consumption data available are those provided by the decennial Census of Housing, which is carried out by the U.S. Bureau of the Census. This information, which lists the number of households and the types of fuels which are used for major end-use consumption categories, provides the base upon which this effort is carried out.

The census data provide information on major end-use categories which include: space heating and cooling, water heating, cooking, clothes drying, and home food freezing. Under each end-use category, the type of primary fuel used to fuel that device is identified. These include utility gas, distillate oil, liquefied petroleum gases (LPG) and electricity. Other energy forms are also included (wood and coal); however, since it is not our intent to calculate the displacement of these fuels they are grouped together in the "other" category.

However, immediately upon beginning the reformation of the 1970 data,⁴ it became apparent that the initial regionalization scheme, which used Bureau of Economic Analysis (BEA) regions, would require significant effort to re-apportion the 1970 Census data. This is primarily because the BEA regions cross state lines and would require a county-by-county analysis for each state in the STES region. Therefore, the regionalization scheme was revamped along state lines rather than BEA regions to facilitate easier manipulation of the census data (Table 2). This regionalization scheme required county-by-county tabulation of the census data for only two states, Florida and Minnesota (Tables 3 and 4). To facilitate this reformation of the census data, county names were listed for the smaller of the two parts of the two states (Region 1 in the case of Florida and the Region 10 portion of Minnesota) and a tabulation of the saturation of major energy consumption devices and households was performed. Since the two states, Florida and Minnesota, were represented in only two regions, once the absolute numbers representing one region were identified, subtraction of those from state totals yielded the remainder, which was allocated to other regions. Specifically, these were Region 6 for northern Florida and Region 9 for southern Minnesota.

Table 2. STATES IN STES REGIONS

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
S. Florida	California	Nevada Arizona	Utah Colorado New Mexico	Oklahoma Texas	Alabama N. Florida Georgia Louisiana Mississippi S. Carolina N. Carolina
<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	
Arkansas Delaware District of Columbia Kentucky Maryland Tennessee Virginia W. Virginia	Pennsylvania New Jersey New York Vermont New Hampshire Maine Massachusetts Michigan Connecticut Rhode Island	Kansas Nebraska Wisconsin Illinois Indiana Iowa Ohio Missouri S. Minnesota	Idaho Montana Wyoming N. Dakota S. Dakota N. Minnesota	Oregon Washington	

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Table 3. REGION 1 TABULATION OF THE NUMBER OF HOUSEHOLDS BY END-USE CATEGORY AND FUEL TYPE, 1970⁴

REGION 1	Home Food Freezer	Clothes Drying		Utility Gas	Space Heating			Coal and Other	Water Heating				Total Households	Air Conditioning			Cooking					
		Natural Gas	Electric		Fuel Oil	LPG	Electric		Utility Gas	Fuel Oil	LPG	Electric		Coal and Other	1 Unit	2 or More	Central Unit.	Utility Gas	Fuel Oil	LPG	Electric	Coal and Other
FLORIDA COUNTIES																						
Monroe	3,794	102	3,953	148	760	2,358	7,392	64	391	22	1,789	13,916	---	19,834	5,645	3,404	1,854	937	21	5,718	10,039	----
Dade	52,472	12,036	94,119	63,749	31,763	63,225	203,023	1,869	75,952	14,458	30,766	299,315	1,935	450,116	130,685	105,548	82,346	96,149	822	67,112	259,701	301
Broward	25,686	4,094	65,990	32,828	8,962	28,727	142,114	701	34,830	1,572	13,954	169,353	126	246,205	64,423	35,583	89,024	23,072	422	20,724	177,839	79
Palm Beach	18,544	2,372	30,147	20,060	10,620	23,191	62,162	563	21,267	569	11,811	86,610	125	135,074	34,741	17,344	34,550	18,617	885	18,679	84,263	158
Hendry	972	120	753	232	922	1,415	681	62	139	---	895	1,854	---	3,827	557	252	535	270	23	1,945	1,132	----
Glades	467	----	222	83	146	483	206	82	----	---	209	715	---	1,344	136	107	134	48	39	498	372	51
Martin	2,182	120	2,566	891	1,259	3,501	4,294	22	344	23	1,402	7,849	---	11,696	3,054	921	2,286	587	134	3,422	5,907	20
St. Lucie	3,521	213	3,167	4,061	1,948	4,905	5,589	79	2,954	84	3,197	10,004	---	18,781	3,647	1,475	2,992	3,262	145	5,694	7,604	18
Indian River	2,505	97	2,553	636	2,835	5,210	3,411	43	506	100	2,488	8,425	19	13,714	2,949	944	3,223	586	67	4,264	7,283	----
Okeechobee	1,082	----	763	108	706	1,060	1,170	89	33	75	301	2,604	31	3,722	521	348	292	118	115	959	2,039	----
Collier	2,422	39	4,541	282	1,004	2,394	8,630	79	371	105	1,031	11,146	---	16,004	3,230	882	7,146	346	49	3,053	9,457	----
Lee	5,888	365	10,297	4,276	4,876	9,703	17,828	156	3,666	166	4,607	27,517	---	42,157	9,252	2,499	14,289	3,567	248	9,580	23,784	----
Charlotte	1,497	66	2,408	2,006	1,695	1,953	5,784	30	1,950	23	1,038	8,365	---	12,877	4,062	756	3,304	816	---	2,007	8,687	----
De Soto	1,501	158	680	176	1,412	1,911	372	44	161	21	1,095	2,202	---	4,148	794	256	289	260	173	1,872	1,610	----
Highlands	2,624	25	1,860	656	2,088	4,935	2,967	134	444	124	2,086	7,450	23	12,616	2,419	840	1,542	411	148	4,536	5,708	46
Hardee	1,543	80	839	344	1,243	2,308	441	98	271	36	1,658	1,965	---	4,878	605	204	379	243	---	2,496	1,748	----
Sarasota	6,217	229	12,405	4,838	16,106	9,876	17,499	95	3,879	420	5,420	38,689	---	54,878	12,154	4,570	21,343	3,897	349	8,179	36,044	40
Manatee	5,790	315	7,239	3,991	12,049	11,100	11,017	115	3,348	401	6,905	26,539	21	41,793	10,414	3,071	8,847	3,976	418	12,088	21,815	40
Polk	21,498	814	17,127	8,027	27,500	20,950	15,193	622	4,475	594	8,667	55,289	87	79,576	17,877	6,083	12,782	6,660	382	18,406	47,236	78
Hillsborough	34,694	1,491	38,610	11,654	88,034	19,954	36,634	870	10,089	1,832	8,724	131,837	562	168,267	41,423	16,340	30,568	16,115	1,464	23,608	116,810	179
Pasco	4,880	189	4,662	969	7,810	8,083	13,186	170	677	234	4,055	24,492	---	34,235	9,834	1,106	6,436	1,287	244	9,298	19,415	20
Hernando	1,305	118	1,110	920	1,328	2,514	787	113	727	84	1,170	3,077	52	7,224	1,348	200	783	637	176	2,571	2,278	----
Citrus	1,686	47	1,338	313	2,063	2,254	2,507	144	138	89	1,091	5,800	43	9,802	2,587	501	1,160	342	116	2,898	3,989	29
Pinellas	23,616	2,296	44,763	21,131	111,487	17,548	59,764	744	22,839	4,853	10,135	169,619	184	225,786	65,268	25,189	56,447	28,209	1,135	26,984	153,962	237
Sumter	1,944	17	753	185	2,540	1,597	255	167	75	18	651	3,405	---	5,395	909	322	388	295	95	2,283	2,131	----
Lake	6,175	366	4,867	5,431	9,770	5,470	3,533	324	3,924	415	3,756	14,971	---	28,008	5,700	1,772	4,381	4,484	218	6,914	12,754	70
Flagler	674	19	339	38	793	615	65	45	16	---	302	1,038	---	1,921	329	60	220	40	---	876	617	----
Volusia	9,991	640	13,378	9,015	35,012	8,215	9,760	658	9,794	1,371	7,558	42,536	159	70,483	14,136	3,467	18,027	9,621	620	11,805	40,537	120
Seminole	6,591	373	8,169	2,482	14,150	3,403	5,378	324	2,396	228	2,014	19,525	20	28,408	5,833	2,198	8,820	1,991	283	4,759	18,697	----
Orange	22,818	1,395	33,661	12,645	57,653	11,663	25,567	385	11,121	980	8,196	86,539	---	116,931	29,184	12,638	30,877	10,979	608	13,395	83,210	40
Osceola	1,524	194	1,247	251	2,994	4,436	1,186	188	233	45	2,653	5,755	---	10,267	2,325	605	1,043	317	38	4,658	4,047	32
Brevard	16,097	3,215	25,214	17,064	22,465	7,161	20,948	393	13,130	268	3,669	50,843	19	77,672	15,066	4,379	34,461	7,438	172	8,633	52,101	----
TOTAL	292,200	31,605	439,740	229,490	483,993	289,118	689,343	9,472	230,140	9,210	153,293	1,339,244	3,406	1,957,639	501,107	253,864	480,768	245,577	9,609	309,914	1,222,816	1,558

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Table 4. REGION 10 TABULATION OF THE NUMBER OF HOUSEHOLDS BY END-USE CATEGORY AND FUEL TYPE FOR NORTHERN MINNESOTA, 1970⁴

	Home Food Freezer	Clothes Drying		Space Heating					Water Heating					Total Households	Air Conditioning			Cooking				
		Natural Gas	Electric	Utility Gas	Fuel Oil	LPG	Electric	Coal and Other	Utility Gas	Fuel Oil	LPG	Electric	Coal and Other		1 Unit	2 or More	Central Unit	Utility Gas	Fuel Oil	LPG	Electric	Coal and Other
Cook Lake	597	179	387	21	538	492	83	21	38	57	456	423	---	1,364	---	6	---	62	---	559	480	54
St. Louis	1,526	499	1,622	1,554	1,758	364	82	108	1,532	239	500	1,423	17	4,340	36	13	24	1,152	---	642	2,047	25
Itasca	24,889	4,798	29,373	13,163	43,343	2,765	1,300	9,474	24,656	3,578	4,305	29,464	5,852	74,595	1,307	133	650	16,603	98	6,837	45,212	567
Carlton	5,705	550	4,725	730	8,187	777	196	652	450	556	1,110	7,719	63	12,080	144	7	113	339	98	3,211	6,791	103
Koochiching	3,941	524	3,982	1,780	5,106	863	141	223	1,246	331	753	5,328	19	8,774	173	9	35	850	49	1,648	5,383	115
Lake of the Woods	2,387	276	2,240	89	4,194	591	---	446	61	851	808	2,866	209	5,923	55	6	36	124	---	1,438	3,614	65
Beltrami	644	117	461	---	800	179	35	227	---	18	268	730	21	1,479	28	---	---	21	---	643	480	97
Hubbard	3,114	401	2,784	527	5,340	796	349	452	583	574	988	4,323	37	8,871	146	14	29	859	---	2,387	3,973	218
Cass	1,820	207	1,089	61	1,802	779	168	349	40	61	617	1,956	48	4,089	48	---	28	208	---	1,254	1,584	66
Wadena	2,712	542	1,441	31	3,481	1,226	187	500	79	106	1,284	3,074	66	6,903	120	31	26	181	90	2,800	2,093	261
Crow Wing	2,369	147	1,589	534	2,650	237	212	202	313	20	201	3,060	24	4,224	81	20	29	252	---	993	2,523	45
Aitkin	5,492	885	4,165	3,513	5,533	1,309	320	271	2,461	332	1,636	5,927	41	12,569	771	70	119	2,369	23	3,027	5,413	114
Otter Tail	2,353	326	1,166	68	1,941	1,224	77	511	162	110	1,213	1,666	54	5,128	99	21	60	184	57	2,360	1,071	149
Wilkin	9,502	1,148	6,256	2,117	10,242	1,076	352	641	2,219	1,117	2,140	7,737	21	15,991	597	73	256	1,651	106	4,162	8,205	272
Clay	1,983	223	1,620	231	2,158	228	146	---	260	177	400	1,823	---	3,055	363	56	38	97	---	690	1,958	18
Becker	6,282	779	6,502	3,984	8,271	466	328	57	3,018	498	1,010	8,340	---	13,872	2,519	117	520	1,062	---	1,550	10,416	23
Norman	3,576	715	2,362	1,459	4,107	1,271	95	442	1,462	280	1,809	2,739	115	8,139	248	42	84	1,353	---	2,489	3,278	254
Mahnomen	2,089	185	1,434	546	2,336	235	154	90	511	55	600	1,780	---	3,743	208	13	20	374	55	998	1,914	20
Clear Water	1,005	39	640	60	1,087	182	43	151	77	38	349	744	---	1,841	71	---	5	98	21	671	661	50
Polk	1,368	37	838	48	1,979	57	105	266	---	---	143	1,644	---	2,916	28	---	29	26	---	1,107	1,147	151
Pennington	5,116	643	4,532	2,103	7,504	463	205	146	3,060	546	1,076	5,014	25	11,403	464	29	178	2,163	37	1,933	6,081	131
Red Lake	2,004	414	1,710	1,297	2,463	238	164	43	1,324	127	474	1,988	---	4,453	213	17	37	742	---	831	2,533	40
Marshal	731	34	725	75	1,139	191	48	31	---	47	282	1,037	---	1,639	73	---	6	22	---	370	1,092	---
Kittson	2,676	486	1,901	751	2,531	645	64	121	699	181	741	1,870	---	4,582	90	19	33	503	---	1,613	1,920	59
Roseau	1,274	55	977	233	1,341	375	21	121	166	21	422	1,246	---	2,620	91	6	38	90	21	618	1,289	73
Total	2,063	189	1,592	100	2,420	764	45	171	25	39	644	2,221	---	3,898	79	9	13	39	51	1,411	1,939	40
	97,218	14,398	86,113	35,075	132,251	17,793	4,920	15,716	44,431	9,959	24,229	106,142	6,612	228,491	8,052	711	2,406	31,424	706	46,242	123,097	3,010

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Once the tabulation shown in Tables 3 and 4 was completed, it was linked to the other data taken from the "Detailed Housing Characteristics, United States Summary"⁴ to form the tabulation of households by end-use energy consumption category and total households which is a part of Table 5, Parts A through G. However, the census data provided only the number of end-use devices, by STES region, and not the average energy consumption, by device, which is necessary for a calculation of overall energy consumption.

In addition to the number of energy consuming devices by region, Table 5 also lists average energy consumption data for each end-use category. This average consumption data is taken directly from a recent Rand Corporation publication entitled "Energy Use and Conservation in the Residential Sector: A Regional Analysis."⁵

However, three of the end-use categories required additional effort to be estimated according to consumption and STES region. These were space heating, cooling, and water heating.

2.2 Heating

The Rand report residential heating calculations compared favorably with those done recently at IGT;⁶ however, since the STES regions did not correspond with the calculations done using any other study we were familiar with, some means of re-apportioning heating data had to be found. A recent American Gas Association report by Kang S. Hu⁷ lists comparative energy consumption by state for the 1974-75 heating season (Table 6). While the calculations are presumably valid, the estimated heating consumption is considerably below that of any other we have seen. This may result from the relatively short period for which the calculations were performed and because of special circumstances which may have affected consumption during the 1974-75 heating period (i.e., energy conservation and mild weather). Therefore, the Hu analysis was used to apportion heating consumption into the STES regions then "scaled-up" to achieve parity with the national average heating consumption figure calculated by Rand (Table 7).

Table 5, Part A. RESIDENTIAL ENERGY CONSUMPTION FOR SPACE HEATING, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Utility Gas	229,490	5,650,839	486,836	1,055,405	3,378,087	3,116,951	2,764,186	7,405,427	9,678,112	475,400	422,303
10 ⁶ Btu Average Consumption/HU *	21.007	58.873	56.738	104.250	68.964	61.968	107.526	132.395	133.328	124.233	87.496
Fuel Oil	483,993	44,464	29,370	30,678	15,096	1,542,710	1,511,076	8,326,133	2,551.672	416,937	712,844
10 ⁶ Btu Average Consumption/HU	24.826	69.577	67.054	123.205	81.503	73.235	127.076	156.467	157.569	146.821	103.404
LPG	289,364	204,297	41,887	96,359	509,504	975,398	326.503	224,725	966,719	113,887	38,647
10 ⁶ Btu Average Consumption/HU	21.007	58.873	56.738	104.250	68.964	61.968	107.526	132.395	133.328	124.233	87.496
Electricity	689,343	565,956	121,553	40,006	325,213	700,746	813,402	493,255	460,813	50,055	541,725
10 ⁶ Btu Average Consumption/HU	10.924	30.614	29.504	54.210	35.861	32.223	55.914	68.845	69.331	64.601	45.498
Coal or Other	9,472	59,048	15,449	54,751	43,558	479,485	660,070	732,323	630,736	72,592	80,319
10 ⁶ Btu Average Consumption/HU	24.826	69.577	67.054	123.205	81.503	73.235	127.076	156.467	157.569	146.821	103.404
TOTAL HOUSEHOLDS	1,702,487	6,573,861	699,209	1,278,251	4,284,799	6,918,336	6,090,003	18,132,731	14,273,286	1,151,775	1,797,218

* Average annual consumption per household unit (HU).

Table 5, Part B. RESIDENTIAL ENERGY CONSUMPTION FOR COOKING, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Utility Gas *	245,577	4,350,357	340,256	513,320	2,669,576	2,052,216	2,397,538	10,147,309	7,594,654	210,658	123,576
10 ⁶ Btu Average Consumption *	9.5										
Fuel Oil	9,609	3,086	1,059	1,144	8,959	38,631	25,784	148,305	36,558	3,972	7,648
10 ⁶ Btu Average Consumption *	9.5										
LPG	429,914	164,848	46,751	79,508	444,480	763,101	609,983	1,165,288	1,302,062	150,481	49,128
10 ⁶ Btu Average Consumption	9.5										

* Assumed constant for all regions.

Table 5, Part C. RESIDENTIAL ENERGY CONSUMPTION FOR WATER HEATING, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Utility Gas	230,140	5,740,154	474,122	994,917	3,301,224	2,423,505	2,691,720	8,362,726	9,625,162	403,884	195,427
10 ⁶ Btu Average Consumption	26.03										
Fuel Oil	29,210	8,813	5,220	3,028	2,527	62,299	314,822	5,857,059	189,122	22,492	42,427
10 ⁶ Btu Average Consumption	27.19										
LPG	153,293	209,987	40,663	81,992	400,530	588,914	272,243	516,090	860,382	92,236	24,721
10 ⁶ Btu Average Consumption	26.03										
Electricity	1,339,244	580,694	157,301	160,569	370,191	3,055,558	1,994,762	2,771,783	3,060,686	550,538	1,510,096
10 ⁶ Btu Average Consumption	15.03										
Coal or Other	3,406	8,056	1,225	7,436	5,849	20,863	45,476	243,775	201,187	4,819	10,578
10 ⁶ Btu Average Consumption	27.19										
Regional Heat Requirements Factor	.8	.93	.98	1.07	.89	.89	1.01	1.13	1.07	1.13	1.07

Part D. RESIDENTIAL ENERGY CONSUMPTION FOR HOME FOOD FREEZING, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Electricity	292,200	1,377,225	167,547	450,924	1,351,279	2,604,248	1,912,068	3,434,316	4,637,480	582,902	781,656
10 ⁶ Btu Average Consumption	4.8										

Table 5, Part E. RESIDENTIAL ENERGY CONSUMPTION FOR AIR CONDITIONING, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Window Units											
1 unit	501,107	974,420	75,222	160,612	1,109,427	1,523,497	1,742,713	2,910,762	2,609,963	109,441	107,014
2 or more units	253,864	156,246	21,414	21,481	648,931	727,308	585,043	1,465,815	702,675	11,030	13,852
10 ⁶ Btu Average Consumption	6.8	4.7	5.8	4.7	7.9	5.8	5.2	2.6	4.2	3.1	2.1
Central Unit	480,768	612,071	306,036	150,476	1,237,522	1,052,808	432,498	709,208	1,355,812	47,358	61,334
10 ⁶ Btu Average Consumption	18.8	13.0	16.1	13.0	21.9	16.1	14.4	7.2	11.6	8.6	5.8

Part F. RESIDENTIAL ENERGY CONSUMPTION FOR LIGHTING, REFRIGERATION, AND OTHER, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Households	1,702,487	6,573,861	699,209	1,278,251	4,284,799	6,918,336	6,090,003	18,132,731	14,273,286	1,151,775	1,797,218
Average Energy Consumed For:											
10 ⁶ Btu Lighting *	3.9										
10 ⁶ Btu Refrigeration *	3.9										

Part G. RESIDENTIAL ENERGY CONSUMPTION FOR CLOTHES DRYING, 1970

NUMBER OF HOUSEHOLDS USING EACH TYPE OF FUEL	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10	REGION 11
Natural Gas	31,605	1,089,154	43,022	107,403	420,788	333,938	376,605	2,512,167	2,781,201	58,749	23,763
10 ⁶ Btu Average Consumption *	4.3										
Electricity	439,740	1,662,834	150,491	451,645	1,079,224	1,727,926	1,893,038	4,474,225	4,608,072	552,972	1,116,339
10 ⁶ Btu Average Consumption *	3.4										

* Average annual consumption per household unit, assumed to be constant for all regions.

Table 6. AVERAGE RESIDENTIAL GAS CONSUMPTION BY STATE*

	Average Space Heating Consumption	Average Degree Days	Number of Residential ⁵ Customers, 1000's		Approximate Non-Space Heating Residential Load, Million Btu/Customer
	Million BTU		Total	Space Heating	
Alabama	50.318	2,370	603.2	591.5	16.097
Arizona	37.139	2,053	518.7	502.7	12.487
Arkansas	51.744	2,858	406.4	405.3	17.264
California	43.461	2,075	6,185.4	5,872.0	20.213
Colorado	72.662	5,145	646.7	646.3	13.583
Connecticut	83.886	4,798	361.8	196.9	14.740
Delaware	87.118	3,947	77.5	46.6	15.882
Florida	15.508	660	382.9	278.0	9.990
Georgia	59.893	2,358	836.2	808.0	15.599
Idaho	65.720	5,095	95.2	93.1	9.598
Illinois	94.717	4,955	2,905.6	2,399.5	25.966
Indiana	87.320	4,646	1,092.6	955.9	23.620
Iowa	100.666	5,571	618.4	575.9	16.426
Kansas	85.268	4,167	625.5	612.9	16.631
Kentucky	93.810	3,694	583.1	544.9	15.333
Louisiana	40.672	1,560	873.7	864.5	17.250
Maine	53.019	5,942	16.7	4.8	6.539
Maryland	74.818	3,968	719.2	528.9	16.747
Massachusetts	80.564	4,855	977.4	530.9	13.091
Michigan	110.560	5,285	2,065.0	1,915.7	19.545
Minnesota	112.214	6,841	662.1	600.1	18.521
Mississippi	50.262	2,158	349.1	348.8	13.778
Missouri	90.547	4,259	1,087.3	1,032.1	17.456
Montana	92.382	5,867	156.3	149.4	18.528
Nebraska	87.913	5,174	353.1	342.9	19.057
Nevada	57.714	3,466	104.5	98.2	16.047
New Hampshire	86.496	5,714	41.8	28.5	12.736
New Jersey	97.657	4,372	1,628.4	793.4	14.264
New Mexico	71.195	3,851	252.5	245.4	14.970
New York	102.879	4,688	3,799.5	1,662.6	17.543
N. Carolina	66.813	2,900	303.3	283.6	10.521
N. Dakota	102.828	7,308	64.6	58.3	15.458
Ohio	108.988	4,631	2,558.3	2,489.2	19.086
Oklahoma	68.785	3,130	665.2	662.2	15.480
Oregon	58.380	3,587	222.6	210.9	12.829
Pennsylvania	99.009	4,579	2,159.9	1,649.1	18.246
Rhode Island	87.007	4,563	150.9	84.9	11.054
S. Carolina	63.967	2,384	260.5	231.5	9.821
S. Dakota	90.853	6,055	83.3	79.6	15.189
Tennessee	72.887	3,244	443.6	423.8	12.653
Texas	46.178	1,866	2,714.6	2,592.4	17.193
Utah	92.732	5,001	285.4	282.4	20.812
Virginia	83.595	3,582	480.6	377.1	16.014
Washington	68.324	3,922	309.0	298.5	15.412
West Virginia	99.129	4,109	362.6	356.9	18.040
Wisconsin	101.639	5,911	874.3	724.3	17.633
Wyoming	94.620	5,693	87.1	86.0	17.112

* 1974/1975 heating season.

Table 7. AVERAGE REGIONAL GAS HEATING ENERGY CONSUMPTION

Region	AGA Average Gas Consumption, Million Btu	Regional Population Fraction	Rand Average Gas Consumption, Million Btu
1	15.508	0.03	21.007
2	43.461	0.105	58.873
3	41.885	0.011	56.738
4	76.885	0.021	104.250
5	50.910	0.072	68.964
6	45.746	0.112	61.968
7	79.377	0.099	107.526
8	97.736	0.273	132.395
9	98.425	0.229	133.328
10	91.711	0.19	124.233
11	64.591	0.29	87.496
U.S. Average	76.590	1.000	103.750

Escalation Factor $\frac{103.75}{76.590} = 1.355$. (See Section 2.2.)

2.3 Water Heating

Water heating energy consumption was assumed to vary only with the inlet temperature of the water to be heated. The approximate average temperatures of well water in the Contiguous 48 States are shown in Figure 2, which is taken from a report by Mutch.⁸ These were taken as representative of average annual temperatures of water delivered to residences, some areas of the country using almost 40% more energy to heat water than others. The average water supply temperature for the United States is estimated to be 58°F and the regional energy requirements per household relative to the national average are shown in the last column of Table 8.

Regional estimates of energy consumption for water heating were calculated as follows: U.S. average energy consumption for households using fuel oil, gas, and electricity for water heating were taken from Mutch,⁸ who determined that 11.85 million Btu/year were required in the average residence. His estimates of heat losses, efficiencies, and energy requirements are given in Table 9. It was assumed that "coal and other fuels" has the same performance characteristics as fuel oil. For each fuel type in each region, the energy for water heating is the product of total heat input by fuel type, the number of households using that fuel type, and the regional heat requirements factor.

Figure 2. APPROXIMATE TEMPERATURE OF WATER, IN °F, FROM NONTHERMAL WELLS AT DEPTHS OF 30 TO 60 FEET

Table 8. AVERAGE TEMPERATURES OF WELL WATER⁸

Region	Range, °F	Estimated Weighted Average, °F	Heat Required to Raise Water Temperature to 140°F, Btu/lb	Regional Heat Requirements Factor
1	72-77	74	66	0.8
2	57-72	64	76	0.93
3	52-72	60	80	0.98
4	42-67	52	88	1.07
5	57-72	67	73	0.89
6	62-67	67	73	0.89
7	52-62	57	83	1.01
8	37-57	47	93	1.13
9	42-57	52	88	1.07
10	37-47	47	93	1.13
11	47-52	52	88	1.07
U.S. Average		58	82	1.00

Table 9. ESTIMATED DISPOSITION OF THE ANNUAL ENERGY INPUT⁸
TO RESIDENTIAL WATER HEATERS*

Type of Water Heater	Total Heat Input	Heat Lost Through Tank Surface	Heat Lost Up Flue		Net Usable Heat
			Burner Firing	Pilot Light†	
50-gallon Electric					
Therms††	150.3	31.8	- -	- -	118.5
%	100.0	21.2	- -	- -	78.8
40-gallon Gas/LPG					
Therms††	260.3	91.0	31.1	19.7	118.5
%	100.0	35.0	12.0	7.6	45.5
40-gallon Fuel oil					
Therms††	271.9	95.0	36.7	21.7	118.5
%	100.0	35.0	13.5	8.0	43.5

* These are end-use amounts of energy. Because electricity is largely generated from fossil fuels at an efficiency of about 30%, an electric water heater actually requires about 500 therms per year of raw energy, for which the net efficiency is about 24%.

† Assuming a 750 Btu/hr pilot and efficiency of heat transfer to the water of 70% for gas/LPG units and 67% for oil units.

†† A therm is equal to 100,000 Btu.

2.4 Air Conditioning

The methodology for calculating average air-conditioning consumption is the same as used in the Rand study⁵ after reformulating regional degree days above 80⁰ into STES regions. The energy efficiency ratio (EER)* is taken at 6.5 Btu/hr and 7.0 Btu/hr per watt of electricity consumed for window and central units, respectively. The use factor for each was estimated at 85%. Figure 3 shows areas of the United States and their average degree days in excess of 80⁰. A list of regions and average cooling degree days was developed from this and is shown in Table 10. Simple multiplication of these factors yields average window air-conditioning consumption. Central unit consumption was then developed as a ratio to window unit consumption using the data from Rand.⁵

2.5 Escalation to 1975 Data

Several years have passed since the 1970 census; population has grown and the density of energy consuming devices has changed. These divergences from the situation represented by the 1970 census data require that these data be updated to more current status. It was assumed that most of the major energy consumption categories vary with the increase in population, that is, densities of home heating equipment, refrigeration, cooking devices, and lighting were assumed to be 1.0 or close to 1.0 in 1970 and unchanged in 1975. However, a review of the annual sales figures¹⁰ for air conditioners, clothes dryers, and home freezers shows marked increases in national saturation density. Therefore, adjustment to the 1975 level for these three consumption categories required a compilation of increased saturation across the nation which was allocated to each region in the same proportion as the 1970 level. This was done by estimating the average replacement units and incremental gains using the inputs in Table 11. Tables 12 through 14 were then calculated using annual sales statistics taken from Appliance Manufacturers.¹⁰ These data were then allocated to each region, resulting in Tables 15 through 17. The remainder of the saturations and resulting energy consumption data are estimated from population changes. Since electricity customers are assumed to include nearly all or all of the residential households, calculations of residential electric customers, by state, were taken from the Edison Electric Institute's Annual Yearbook¹¹ and used as surrogates for population projections (Table 18).

* EER = $\frac{\text{cooling capacity (Btu/HR)}}{\text{power consumption (watt)}}$.

Figure 3. NUMBER OF HOURS DRY BULB TEMPERATURE REACHES 80°F OR OVER IN AVERAGE YEAR
 (Based on Weather Bureau Records for 41 Cities Covering
 the Years 1932 to 1937 Which Included an Unusually Hot Summer)⁹

Table 10. APPROXIMATE COOLING DEGREE-DAY HOURS ABOVE 80°F

<u>Region</u>	<u>Average Cooling Degree Days</u>
1	1300
2	900
3	1100
4	900
5	1500
6	1100
7	1000
8	500
9	800
10	600
11	400

Table 11. INPUTS TO CALCULATION OF SATURATION LEVEL
(Appliance Expected Service Life)

	<u>Assumed Average Life, years</u>	<u>Appliance Retention*</u>	
		<u>5 yr</u>	<u>10 yr</u>
Space Heating	15	0.69	0.42
Gas			
Oil			
Electricity			
Bottled Gas			
Water Heating	5	0.22	0.01
Gas			
Oil			
Electricity			
Bottled Gas			
Cooking	12	0.61	0.30
Gas			
Electricity			
Bottled Gas			
Drying	12	0.61	0.31
Gas			
Electricity			
Air Conditioning			
Room	8	0.44	0.12
Central	15	0.69	0.42
Food Freezing	12	0.61	0.30

* Fraction of appliances retained for 5 and 10 years, respectively.

Table 12. RESIDENTIAL SATURATION OF AIR-CONDITIONING UNITS¹⁰

<u>Window Air Conditioners</u>				
<u>Year</u>	<u>Sales</u>	<u>Replacement Units (50%)</u>	<u>Incremental Units (50%)</u>	<u>Units in Place</u>
Base				21,795,000
1970	4,298,000	2,149,000	2,149,000	23,944,000
1971	3,965,000	1,982,000	1,983,000	25,927,000
1972	3,285,000	1,642,000	1,643,000	27,570,000
1973	3,738,000	1,869,000	1,869,000	29,439,000
1974	3,192,000	1,596,000	1,596,000	31,035,000
1975	1,876,000	938,000	938,000	31,973,000

<u>Central Air Conditioners</u>				
<u>Year</u>	<u>Sales</u>	<u>Replacement Units (30%)</u>	<u>Incremental Units (70%)</u>	<u>Units in Place</u>
Base				7,263,000
1970	1,053,000	316,000	737,000	8,000,000
1971	1,725,000	517,000	1,208,000	9,208,000
1972	1,661,000	498,000	1,163,000	10,371,000
1973	1,958,000	587,000	1,371,000	11,742,000
1974	1,642,000	493,000	1,149,000	12,891,000
1975	965,000	289,000	676,000	13,567,000

Table 13. RESIDENTIAL SATURATION OF HOME FOOD FREEZERS¹⁰

<u>Year</u>	<u>Sales</u>	<u>Replacement Units (75%)</u>	<u>Incremental Units (25%)</u>	<u>Units in Place</u>
Base				17,591,800
1970	1,358,300	1,018,725	339,575	17,931,375
1971	1,436,500	1,077,375	359,125	18,290,500
1972	1,576,200	1,182,150	394,050	18,684,550
1973	2,414,600	1,810,950	603,650	19,288,200
1974	3,219,700	2,414,775	804,925	20,093,125
1975	2,457,100	1,842,825	614,275	20,707,400

Table 14. RESIDENTIAL SATURATION OF CLOTHES DRYERS, 1975¹⁰

Year	Sales	Replacement Units (60%)	<u>Electric</u>	
			Incremental Units (40%)	Units in Place
Base				18,156,506
1970	2,129,400	1,277,640	851,760	19,008,266
1971	2,527,400	1,516,440	1,010,960	20,019,226
1972	2,988,700	1,793,220	1,195,480	21,214,706
1973	3,330,400	1,998,240	1,332,160	22,546,866
1974	2,844,700	1,706,820	1,137,880	23,684,746
1975	2,197,700	1,318,620	879,080	24,563,826

Year	Sales	Replacement Units (60%)	<u>Natural Gas</u>	
			Incremental Units (40%)	Units in Place
Base				7,778,395
1970	851,500	510,900	340,600	8,118,995
1971	849,700	509,820	339,880	8,458,875
1972	936,200	561,720	374,480	8,833,355
1973	925,700	555,420	370,280	9,203,635
1974	738,900	443,340	295,560	9,499,195
1975	671,800	403,080	268,720	9,767,915

Table 15. RESIDENTIAL ENERGY CONSUMPTION INPUTS FOR CLOTHES DRYING, 1975¹⁰
(Million Btu)

Region	<u>Electric Dryers</u>		<u>Gas Dryers</u>	
	<u>Total</u>	<u>Average*</u>	<u>Total</u>	<u>Average*</u>
1	589,532	3.4	39,072	4.3
2	2,284,436	3.4	1,367,508	4.3
3	196,511	3.4	58,607	4.3
4	614,096	3.4	136,751	4.3
5	1,449,266	3.4	527,467	4.3
6	2,358,127	3.4	420,020	4.3
7	2,554,638	3.4	468,860	4.3
8	6,042,701	3.4	3,155,037	4.3
9	6,239,212	3.4	3,487,146	4.3
10	736,915	3.4	78,143	4.3
11	1,498,393	3.4	29,304	4.3

* See Table 5, Part G.

Table 16. RESIDENTIAL ENERGY CONSUMPTION FOR AIR CONDITIONING, 1975
(Million Btu)

<u>Region</u>	<u>Window Units</u>		<u>Central Units</u>	
	<u>Total</u>	<u>Average*</u>	<u>Total</u>	<u>Average*</u>
1	1,469,857	6.8	1,014,851	18.8
2	2,203,015	4.7	1,288,576	13.0
3	189,882	5.8	640,728	16.1
4	353,044	4.7	314,262	13.0
5	3,421,245	7.9	2,604,775	21.9
6	4,379,922	5.8	2,213,549	16.1
7	4,534,578	5.2	909,612	14.4
8	8,510,483	2.6	1,492,530	7.2
9	6,451,920	4.2	2,851,245	11.6
10	229,258	3.1	97,206	8.6
11	229,653	2.1	132,545	5.8

* See Table 5, Part E.

Table 17. RESIDENTIAL ENERGY CONSUMPTION FOR HOME FOOD FREEZING, 1975
(Million Btu)

<u>Region</u>	<u>Total</u>	<u>Average*</u>
1	343,743	4.8
2	1,621,389	4.8
3	196,720	4.8
4	530,109	4.8
5	1,590,328	4.8
6	3,064,695	4.8
7	2,250,894	4.8
8	4,042,084	4.8
9	5,458,471	4.8
10	685,415	4.8
11	919,409	4.8

* See Table 5, Part D.

Table 18. RESIDENTIAL HOUSEHOLDS, 1975

<u>Region</u>	<u>Number of Households</u>
1	2,469,027
2	7,363,496
3	948,674
4	1,647,710
5	4,936,677
6	8,806,650
7	7,256,285
8	19,178,595
9	16,084,543
10	1,407,550
11	2,148,672
Total	72,247,879

2.6 Primary Fuels Used in Electricity Generation

Electricity consumption displaced by STES's must be delineated as to the primary energy used in its generation. The EEI Statistical Yearbook lists electric generation for the entire electric utility industry by primary fuel and state.¹¹ These data were simply reorganized into the STES regions as shown in Table 19.

2.7 IGT Residential Energy Model

A descriptive energy model presenting the data developed in this task serves two purposes. First, it provides a convenient means of presenting all these data together, in terms of energy consumption by end use, fuel type, and STES region. Secondly, it allows one to vary all the inputs used to calculate energy consumption making it a convenient tool for extrapolating energy consumption over the time frames used to assess market penetration.

Actually, all the data previously presented in Table 5 are used to calculate 1970 energy consumption, then updated to the 1975 level using Tables 15 through 18. The "other" or catch-all category energy consumption is taken from the Rand report⁵ and updated to 1975 by the increase in population (Table 20). This may result in a slightly lower calculation of energy consumption than actually occurs; however, there are no actual calculations of overall residential energy consumption which would allow us to "back in" to the calculation in a fashion other than the methodology used in the Rand report. Tables 21 through 31 are model outputs showing energy consumption by fuel type and end-use category for the 11 STES regions. Overall energy consumption for the Contiguous 48 States is presented in Table 32 and is a simple addition of Tables 21 through 31.

2.8 Projections of Energy Consumption (1985 to 2020)

The household data presented in Table 18 are increased by the use of scenarios resulting from trends in population growth estimated by the U.S.

Table 19. TOTAL ELECTRIC UTILITY INDUSTRY, GENERATION BY FUEL
(Million kW, 1975)

Region	Total Generation	Hydro	Total Thermal	Coal	Fuel Oil	Natural Gas	Nuclear Fuel	Heat Rate, Btu	Other*
1	35,805	108	35,697	5,784	20,225	5,839	3,850	10,505	--
% of Total Region		0.3	99.7	16.2	56.5	16.3	10.7		
2	125,388	40,102	85,286	--	48,311	27,639	6,070	10,093	3,266
% of Total Region		32	68		38.5	22.1	4.8		2.6
3	35,360	8,930	26,430	17,653	4,745	4,032	--	10,897	--
% of Total Region		25.3	74.7	49.9	13.4	11.4			
4	41,869	2,642	39,227	27,477	1,496	10,254	--	11,130	--
% of Total Region		6.3	93.7	65.6	3.6	24.5			
5	181,034	4,868	176,166	11,420	1,084	163,573	--	10,344	--
% of Total Region		2.7	97.3	6.3	0.6	90.4			
6	281,082	28,184	252,898	132,721	38,390	50,607	31,180	10,312	--
% of Total Region		10	90	47.2	13.7	18	11.1		
7	250,237	22,755	227,482	172,113	34,068	3,068	18,233	10,290	--
% of Total Region		9.1	90.9	68.8	13.6	1.2	7.3		
8	376,705	34,780	341,925	155,510	121,445	5,577	59,393	10,438	--
% of Total Region		9.2	90.8	41.3	32.2	1.5	15.8		
9	397,590	6,268	391,322	302,600	12,940	27,161	48,426	10,922	195
% of Total Region		1.6	98.4	76.1	3.3	6.8	12.2		0.05
10	55,851	32,301	23,550	21,137	286	665	1,462	12,658	--
% of Total Region		57.8	42.2	37.9	0.5	1.2	2.6		
11	128,099	118,646	9,453	6,093	51	--	3,309	13,241	--
% of Total Region		92.6	7.4	4.8	0.04		2.6		

* Generation by geothermal, wood or waste.

Table 20. "OTHER" ENERGY CONSUMPTION, 1975*
(Trillion Btu)

<u>Region</u>	<u>Natural Gas</u>	<u>Electric (Point of Use)</u>
1	8.5905	2.9386
2	29.5894	10.1217
3	4.2330	1.4480
4	8.2585	2.8250
5	27.2239	9.3126
6	37.1009	12.6912
7	42.4129	14.5083
8	126.7823	43.3688
9	107.4848	36.7676
10	9.0885	3.1089
11	14.1930	4.8550

* Miscellaneous energy consumption not included under the other categories.

Bureau of the Census.¹² Saturation levels and average energy consumption for these periods are IGT's judgment as to the level of sales and improvements in efficiency which may occur over this time span. These inputs to extrapolation are given in Table 33. The computer program used to generate these data contains the capability of projecting this information to future time frames, based on projections of increased saturation and/or population (i.e., households) growth.

Table 21. RESIDENTIAL USE OF ENERGY, 1975: REGION 1
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	8.66	19.09	10.94	0.38	15.03	46.25	54.10	85.32
Cooking	3.38	0.13	5.92	0.02	7.27	22.38	16.73	31.84
Water Heating	5.61	0.84	3.75	0.10	16.97	52.24	27.28	62.54
Clothes Drying	0.17	0.00	0.00	0.00	2.00	6.17	2.17	6.34
Lighting	0.00	0.00	0.00	0.00	9.63	29.64	9.63	29.64
Refrigeration	0.00	0.00	0.00	0.00	9.63	29.64	9.63	29.64
Air Conditioning (Window)	0.00	0.00	0.00	0.00	10.00	30.76	10.00	30.75
Air Conditioning (Central)	0.00	0.00	0.00	0.00	19.08	58.72	19.08	58.72
Home Food Freezing	0.00	0.00	0.00	0.00	1.65	5.08	1.65	5.08
Other	8.59	0.00	0.00	0.00	2.94	9.04	11.53	17.64
End Use Totals	26.41	20.06	20.62	0.50	94.20	289.93	161.78	357.52
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	47.28	163.77	0.87	46.83	31.17	0.00	289.93	
Total	73.69	183.83	21.49	47.33	31.17	0.00	357.52	

Table 22. RESIDENTIAL USE OF ENERGY, 1975: REGION 2
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	372.63	3.48	13.48	4.61	19.41	57.40	413.61	451.60
Cooking	46.30	0.03	1.76	0.08	9.23	27.29	57.40	75.46
Water Heating	155.65	0.24	5.69	0.22	9.09	26.88	170.89	188.68
Clothes Drying	5.88	0.00	0.00	0.00	7.77	22.97	13.65	28.85
Lighting	0.00	0.00	0.00	0.00	28.72	84.92	28.72	84.92
Refrigeration	0.00	0.00	0.00	0.00	28.72	84.92	28.72	84.92
Air Conditioning (Window)	0.00	0.00	0.00	0.00	10.35	30.62	10.35	30.62
Air Conditioning (Central)	0.00	0.00	0.00	0.00	16.75	49.54	16.75	49.54
Home Food Freezing	0.00	0.00	0.00	0.00	7.78	23.02	7.78	23.02
Other	29.59	0.00	0.00	0.00	10.12	29.93	39.71	59.52
End Use Totals	610.04	3.76	20.92	4.92	147.94	437.49	787.59	1077.14
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	96.43	168.56	139.92	0.00	21.18	11.40	437.49	
Total	706.48	172.32	160.84	4.92	21.18	11.40	1077.14	

Table 23. RESIDENTIAL USE OF ENERGY, 1975: REGION 3
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	37.48	2.67	3.22	1.41	4.86	15.53	49.65	60.31
Cooking	4.39	0.01	0.60	0.14	1.65	5.27	6.80	10.41
Water Heating	16.41	0.19	1.41	0.05	3.14	10.04	21.20	28.09
Clothes Drying	0.25	0.00	0.00	0.00	0.67	2.13	0.92	2.39
Lighting	0.00	0.00	0.00	0.00	3.70	11.81	3.70	11.81
Refrigeration	0.00	0.00	0.00	0.00	3.70	11.81	3.70	11.81
Air Conditioning (Window)	0.00	0.00	0.00	0.00	1.10	3.52	1.10	3.52
Air Conditioning (Central)	0.00	0.00	0.00	0.00	10.32	32.94	10.32	32.94
Home Food Freezing	0.00	0.00	0.00	0.00	0.94	3.01	0.94	3.01
Other	4.23	0.00	0.00	0.00	1.45	4.62	5.68	8.86
End Use Totals	62.76	2.87	5.24	1.59	31.54	100.59	104.00	173.15
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	11.48	13.51	25.43	50.27	0.00	0.00	100.69	
Total	74.24	16.39	30.66	51.86	0.00	0.00	173.15	

Table 24. RESIDENTIAL USE OF ENERGY, 1975: REGION 4
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	141.83	4.87	12.95	8.69	2.80	9.12	171.14	177.45
Cooking	6.29	0.01	0.97	0.28	3.48	11.34	11.03	18.89
Water Heating	35.72	0.12	2.94	0.28	3.33	10.85	42.38	49.91
Clothes Drying	0.59	0.00	0.00	0.00	2.09	6.81	2.68	7.40
Lighting	0.00	0.00	0.00	0.00	6.43	20.96	6.43	20.96
Refrigeration	0.00	0.00	0.00	0.00	6.43	20.96	6.43	20.96
Air Conditioning (Window)	0.00	0.00	0.00	0.00	1.66	5.41	1.66	5.41
Air Conditioning (Central)	0.00	0.00	0.00	0.00	4.09	13.32	4.09	13.32
Home Food Freezing	0.00	0.00	0.00	0.00	2.54	8.30	2.54	8.30
Other	8.26	0.00	0.00	0.00	2.82	9.21	11.08	17.47
End Use Totals	192.68	5.00	16.87	9.25	35.65	116.27	259.46	340.08
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	28.48	4.15	7.34	76.31	0.00	0.00	116.27	
Total	221.16	9.16	24.20	85.56	0.00	0.00	340.08	

Table 25. RESIDENTIAL USE OF ENERGY, 1975: REGION 5
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	268.41	1.41	40.48	4.10	13.47	40.84	327.88	355.24
Cooking	29.22	0.10	4.86	0.23	5.33	16.16	39.74	50.57
Water Heating	88.12	0.07	10.69	0.17	5.71	17.29	104.76	116.34
Clothes Drying	2.27	0.00	0.00	0.00	4.93	14.93	7.20	17.20
Lighting	0.00	0.00	0.00	0.00	19.25	58.35	19.25	58.35
Refrigeration	0.00	0.00	0.00	0.00	19.25	58.35	19.25	58.35
Air Conditioning (Window)	0.00	0.00	0.00	0.00	27.03	81.92	27.03	81.92
Air Conditioning (Central)	0.00	0.00	0.00	0.00	57.04	172.89	57.04	172.89
Home Food Freezing	0.00	0.00	0.00	0.00	7.63	23.14	7.63	23.14
Other	27.22	0.00	0.00	0.00	9.31	28.22	36.54	55.45
End Use Totals	415.24	1.58	56.04	4.50	168.97	512.09	646.32	989.45
Primary Energy For Electricity Generation	<u>Gas</u> 462.93	<u>Fuel Oil</u> 3.07	<u>Hydro</u> 13.78	<u>Coal</u> 32.32	<u>Nuclear</u> 0.00	<u>Other</u> 0.00	<u>Total</u> 512.09	
Total	878.17	4.65	69.81	36.82	0.00	0.00	989.45	

Table 26. RESIDENTIAL USE OF ENERGY, 1975: REGION 6
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	245.85	143.82	76.95	44.70	28.75	86.85	540.07	598.17
Cooking	24.81	0.47	9.23	2.18	19.06	57.60	55.75	94.29
Water Heating	71.47	1.92	17.36	0.64	52.03	157.21	143.42	248.60
Clothes Drying	1.81	0.00	0.00	0.00	8.02	24.22	9.83	26.03
Lighting	0.00	0.00	0.00	0.00	34.35	103.77	34.35	103.77
Refrigeration	0.00	0.00	0.00	0.00	34.35	103.77	34.35	103.77
Air Conditioning (Window)	0.00	0.00	0.00	0.00	25.40	76.75	25.40	76.75
Air Conditioning (Central)	0.00	0.00	0.00	0.00	35.64	107.68	35.64	107.68
Home Food Freezing	0.00	0.00	0.00	0.00	14.71	44.45	14.71	44.45
Other	37.10	0.00	0.00	0.00	12.69	38.35	49.79	75.45
End Use Totals	381.04	146.21	103.54	47.51	265.00	800.66	943.30	1478.96
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	144.15	109.35	80.28	378.06	88.82	0.00	800.66	
Total	525.20	255.57	183.82	425.57	88.82	0.00	1478.96	

Table 27. RESIDENTIAL USE OF ENERGY, 1975: REGION 7
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	354.15	228.77	41.82	123.19	54.21	163.43	802.14	911.36
Cooking	27.14	0.29	6.91	1.92	14.03	42.29	50.29	78.55
Water Heating	84.32	10.30	8.53	1.49	36.07	108.76	140.72	213.41
Clothes Drying	2.02	0.00	0.00	0.00	8.69	26.19	10.70	28.20
Lighting	0.00	0.00	0.00	0.00	28.30	85.32	28.30	85.32
Refrigeration	0.00	0.00	0.00	0.00	28.30	85.32	28.30	85.32
Air Conditioning (Window)	0.00	0.00	0.00	0.00	23.58	71.09	23.58	71.09
Air Conditioning (Central)	0.00	0.00	0.00	0.00	12.83	38.67	12.83	38.67
Home Food Freezing	0.00	0.00	0.00	0.00	10.80	32.57	10.80	32.57
Other	42.41	0.00	0.00	0.00	14.51	43.74	56.92	86.15
End Use Totals	510.04	239.36	57.26	126.61	231.31	69.39	1164.58	1630.66
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	8.55	94.94	63.42	479.66	50.81	0.00	697.39	
Total	518.59	334.31	120.67	606.27	50.81	0.00	1630.66	

Table 28. RESIDENTIAL USE OF ENERGY, 1975: REGION 8
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	1036.99	1377.98	31.49	121.23	35.91	109.83	2603.60	2677.52
Cooking	101.96	10.53	11.72	0.91	15.59	47.69	140.71	172.80
Water Heating	260.17	190.33	16.08	7.90	49.80	152.32	524.28	626.79
Clothes Drying	13.57	0.00	0.00	0.00	20.55	62.83	34.11	76.40
Lighting	0.00	0.00	0.00	0.00	74.80	228.75	74.80	228.75
Refrigeration	0.00	0.00	0.00	0.00	74.80	228.75	74.80	228.75
Air Conditioning (Window)	0.00	0.00	0.00	0.00	22.13	67.67	22.13	67.67
Air Conditioning (Central)	0.00	0.00	0.00	0.00	10.75	32.87	10.75	32.87
Home Food Freezing	0.00	0.00	0.00	0.00	19.40	59.34	19.40	59.34
Other	126.78	0.00	0.00	0.00	43.37	132.64	170.15	259.42
End Use Totals	1539.47	1578.84	59.28	130.04	367.09	1122.68	3674.71	4430.30
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	16.62	361.94	103.65	463.46	177.01	0.00	1122.68	
Total	1556.09	1940.77	162.93	593.50	177.01	0.00	4430.30	

Table 29. RESIDENTIAL USE OF ENERGY, 1975: REGION 9
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	1454.20	453.16	145.18	112.02	36.02	115.27	2200.58	2279.83
Cooking	81.31	0.40	13.94	0.67	24.28	77.70	120.59	174.02
Water Heating	302.08	6.22	27.01	6.60	55.46	177.48	397.37	519.39
Clothes Drying	14.99	0.00	0.00	0.00	21.21	67.89	36.21	82.88
Lighting	0.00	0.00	0.00	0.00	62.73	200.74	62.73	200.74
Refrigeration	0.00	0.00	0.00	0.00	62.73	200.74	62.73	200.74
Air Conditioning (Window)	0.00	0.00	0.00	0.00	27.10	86.72	27.10	86.72
Air Conditioning (Central)	0.00	0.00	0.00	0.00	33.07	105.84	33.07	105.84
Home Food Freezing	0.00	0.00	0.00	0.00	26.20	83.85	26.20	83.85
Other	107.48	0.00	0.00	0.00	36.77	117.66	144.25	225.15
End Use Totals	1960.06	459.78	186.13	119.29	385.57	1233.88	3110.84	3959.15
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	84.29	40.16	19.45	939.09	150.29	0.61	1233.88	
Total	2044.36	499.93	205.59	1058.38	150.29	0.61	3959.15	

Table 30. RESIDENTIAL USE OF ENERGY, 1975: REGION 10
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	72.18	74.81	17.29	13.02	3.96	14.67	181.26	191.98
Cooking	2.45	0.05	1.75	0.18	3.72	13.79	8.14	18.21
Water Heating	14.52	0.84	3.32	0.18	11.43	42.38	30.29	61.24
Clothes Drying	0.34	0.00	0.00	0.00	2.51	9.29	2.84	9.63
Lighting	0.00	0.00	0.00	0.00	5.49	20.36	5.49	20.36
Refrigeration	0.00	0.00	0.00	0.00	5.49	20.36	5.49	20.36
Air Conditioning (Window)	0.00	0.00	0.00	0.00	0.71	2.64	0.71	2.64
Air Conditioning (Central)	0.00	0.00	0.00	0.00	0.84	3.10	0.84	3.10
Home Food Freezing	0.00	0.00	0.00	0.00	3.29	12.20	3.29	12.20
Other	9.09	0.00	0.00	0.00	3.11	11.53	12.20	20.62
End Use Totals	98.57	75.70	22.36	13.38	40.53	150.32	250.54	360.33
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	1.79	0.77	86.94	56.89	3.93	0.00	150.32	
Total	100.36	76.47	109.29	70.27	3.93	0.00	360.33	

Table 31. RESIDENTIAL USE OF ENERGY, 1975: REGION 11
(Trillion Btu)

End Use	Utility Gas	Fuel Oil	LPG	Coal and Other	Electricity		Total	
					Point of Use	Primary Energy	Point of Use Basis	Primary Energy Basis
Space Heating	44.18	88.12	4.04	9.93	29.46	114.31	175.74	260.58
Cooking	1.40	0.09	0.56	0.17	7.82	30.34	10.03	32.55
Water Heating	6.51	1.48	0.83	0.37	29.03	112.64	38.21	121.81
Clothes Drying	0.13	0.00	0.00	0.00	5.09	19.76	5.22	19.89
Lighting	0.00	0.00	0.00	0.00	8.38	32.51	8.38	32.51
Refrigeration	0.00	0.00	0.00	0.00	8.38	32.51	8.38	32.51
Air Conditioning (Window)	0.00	0.00	0.00	0.00	0.48	1.87	0.48	1.87
Air Conditioning (Central)	0.00	0.00	0.00	0.00	0.77	2.98	0.77	2.98
Home Food Freezing	0.00	0.00	0.00	0.00	4.41	17.12	4.41	17.12
Other	14.19	0.00	0.00	0.00	4.85	18.84	19.05	33.03
End Use Totals	66.41	89.68	5.43	10.47	98.69	382.88	270.67	554.86
	<u>Gas</u>	<u>Fuel Oil</u>	<u>Hydro</u>	<u>Coal</u>	<u>Nuclear</u>	<u>Other</u>	<u>Total</u>	
Primary Energy For Electricity Generation	0.00	0.15	354.63	18.21	9.89	0.00	382.88	
Total	66.41	89.83	360.05	28.68	9.89	0.00	554.86	

Table 32. RESIDENTIAL CONSUMPTION OF PRIMARY ENERGY, BY END USE, 1975
(Trillion Btu Per Year)

End Use	Region											U.S.	Percent of Total
	1	2	3	4	5	6	7	8	9	10	11		
Space Heating	85.3	451.6	60.3	177.5	355.2	598.2	911.4	2677.5	2279.8	192.0	260.6	8049.4	52.4
Cooking	31.8	75.5	10.4	18.9	50.6	94.3	78.6	172.8	174.0	18.2	32.6	757.6	4.9
Water Heating	62.5	188.7	28.1	49.9	116.3	248.6	213.4	626.8	519.4	61.2	121.8	2236.8	14.6
Clothes Drying	6.3	28.8	2.4	7.4	17.2	26.0	28.2	76.4	82.9	9.6	19.9	305.2	2.0
Lighting	29.6	84.9	11.8	21.0	58.4	103.8	85.3	228.8	200.7	20.4	32.5	877.1	5.7
Refrigeration	29.6	84.9	11.8	21.0	58.4	103.8	85.3	228.8	200.7	20.4	32.5	877.1	5.7
Air Conditioning (Window)	30.8	30.6	3.5	5.4	81.9	76.8	71.1	67.7	86.7	2.6	1.9	459.0	3.0
Air Conditioning (Central)	58.7	49.5	32.9	13.3	172.9	107.7	38.7	32.9	105.8	3.1	3.0	618.5	4.0
Home Food Freezing	5.1	23.0	3.0	8.3	23.1	44.4	32.6	59.3	83.8	12.2	17.1	312.1	2.0
Other	17.6	59.5	8.9	17.5	55.4	75.4	86.2	259.4	225.1	20.6	33.0	858.7	5.6
Total	357.5	1077.1	173.2	340.1	989.4	1479.0	1630.7	4430.3	3959.1	360.3	554.9	15351.6	100.0

Table 33, Part 1. PERCENTAGE OF HOUSING UNITS USING VARIOUS FUELS, 1975

Region	Utility	Fuel Oil	LPG	Coal and	Electricity	Total
	Gas			Other		
	Space Heating					
1	13.48	28.43	17.03	0.56	40.49	99.99
2	85.96	0.68	3.11	0.90	8.61	99.26
3	69.63	4.20	5.99	2.21	17.38	99.41
4	82.57	2.40	7.54	4.28	3.13	99.92
5	78.84	0.35	11.89	1.02	7.59	99.69
6	45.05	22.30	14.10	6.93	10.13	98.51
7	45.39	24.81	5.36	13.36	13.36	102.28
8	40.84	45.92	1.24	4.04	2.72	94.76
9	67.81	17.88	6.77	4.42	3.23	100.11
10	41.28	36.20	9.89	6.30	4.35	98.02
11	23.50	39.66	2.15	4.47	30.14	99.92
Total (Contiguous U.S.)	54.90	24.44	6.31	4.81	8.08	98.53
	Cooking					
1	14.42	0.56	25.25	0.09	71.83	112.15
2	66.18	0.05	2.51	0.12	30.57	99.43
3	48.66	0.15	6.69	1.58	42.44	99.52
4	40.16	0.09	6.22	1.81	51.46	99.74
5	62.30	0.21	10.37	0.48	26.35	99.71
6	29.66	0.56	11.03	2.60	52.80	96.65
7	39.37	0.42	10.02	2.79	47.15	99.75
8	55.96	5.78	6.43	0.50	19.83	88.50
9	53.21	0.26	9.12	0.44	36.82	99.85
10	18.29	0.34	13.07	1.34	64.43	97.47
11	6.88	0.43	2.73	0.81	88.77	99.62
Total (Contiguous U.S.)	47.88	1.76	8.48	0.99	37.63	96.74
	Water Heating					
1	13.52	1.72	9.04	0.20	78.66	103.14
2	87.32	0.13	3.19	0.12	8.83	99.59
3	67.81	0.75	5.82	0.18	22.50	97.06
4	77.83	0.24	6.41	0.58	12.56	97.62
5	77.05	0.06	9.35	0.14	8.64	95.24
6	35.03	0.90	8.51	0.30	44.17	88.91
7	44.20	5.17	4.47	0.75	32.75	87.34
8	46.12	32.30	2.85	1.34	15.29	97.90
9	67.43	1.33	6.03	1.41	21.44	97.64
10	35.07	1.95	8.01	0.42	47.80	93.25
11	10.87	2.36	1.38	0.59	84.02	99.22
Total (Contiguous U.S.)	54.26	9.70	5.28	0.85	25.70	95.79

Table 33, Part 2. PERCENTAGE OF HOUSING UNITS USING VARIOUS FUELS, 1975

<u>Region</u>	<u>Utility Gas</u>	<u>Fuel Oil</u>	<u>LPG</u>	<u>Coal and Other</u>	<u>Electricity</u>	<u>Total</u>
<hr/>						
	<u>Clothes Drying</u>					
1	1.58	0.00	0.00	0.00	23.88	25.46
2	18.57	0.00	0.00	0.00	31.02	49.60
3	6.18	0.00	0.00	0.00	20.71	26.89
4	8.30	0.00	0.00	0.00	37.27	45.57
5	10.68	0.00	0.00	0.00	29.36	40.04
6	4.77	0.00	0.00	0.00	26.78	31.55
7	6.46	0.00	0.00	0.00	35.21	41.67
8	16.45	0.00	0.00	0.00	31.51	47.96
9	21.68	0.00	0.00	0.00	38.79	60.47
10	5.55	0.00	0.00	0.00	52.35	57.91
11	1.36	0.00	0.00	0.00	69.74	71.10
Total (Contiguous U.S.)	13.52	0.00	0.00	0.00	34.00	47.52
<hr/>						
	<u>Lighting</u>					
1	0.00	0.00	0.00	0.00	100.00	100.00
2	0.00	0.00	0.00	0.00	100.00	100.00
3	0.00	0.00	0.00	0.00	100.00	100.00
4	0.00	0.00	0.00	0.00	100.00	100.00
5	0.00	0.00	0.00	0.00	100.00	100.00
6	0.00	0.00	0.00	0.00	100.00	100.00
7	0.00	0.00	0.00	0.00	100.00	100.00
8	0.00	0.00	0.00	0.00	100.00	100.00
9	0.00	0.00	0.00	0.00	100.00	100.00
10	0.00	0.00	0.00	0.00	100.00	100.00
11	0.00	0.00	0.00	0.00	100.00	100.00
Total (Contiguous U.S.)	0.00	0.00	0.00	0.00	100.00	100.00
<hr/>						
	<u>Refrigeration</u>					
1	0.00	0.00	0.00	0.00	100.00	100.00
2	0.00	0.00	0.00	0.00	100.00	100.00
3	0.00	0.00	0.00	0.00	100.00	100.00
4	0.00	0.00	0.00	0.00	100.00	100.00
5	0.00	0.00	0.00	0.00	100.00	100.00
6	0.00	0.00	0.00	0.00	100.00	100.00
7	0.00	0.00	0.00	0.00	100.00	100.00
8	0.00	0.00	0.00	0.00	100.00	100.00
9	0.00	0.00	0.00	0.00	100.00	100.00
10	0.00	0.00	0.00	0.00	100.00	100.00
11	0.00	0.00	0.00	0.00	100.00	100.00
Total (Contiguous U.S.)	0.00	0.00	0.00	0.00	100.00	100.00

Table 33, Part 3. PERCENTAGE OF HOUSING UNITS USING VARIOUS FUELS, 1975

Region	Utility	Fuel Oil	LPG	Coal and	Electricity	Total
	Gas			Other		
	Air Conditioning (Window)					
1	0.00	0.00	0.00	0.00	59.53	59.53
2	0.00	0.00	0.00	0.00	29.92	29.92
3	0.00	0.00	0.00	0.00	20.02	20.02
4	0.00	0.00	0.00	0.00	21.43	21.43
5	0.00	0.00	0.00	0.00	69.30	69.30
6	0.00	0.00	0.00	0.00	49.73	49.73
7	0.00	0.00	0.00	0.00	62.49	62.49
8	0.00	0.00	0.00	0.00	44.37	44.37
9	0.00	0.00	0.00	0.00	40.11	40.11
10	0.00	0.00	0.00	0.00	16.29	16.29
11	0.00	0.00	0.00	0.00	10.69	10.69
Total (Contiguous U.S.)	0.00	0.00	0.00	0.00	44.25	44.25
	Air Conditioning (Central)					
1	0.00	0.00	0.00	0.00	41.10	41.10
2	0.00	0.00	0.00	0.00	17.50	17.50
3	0.00	0.00	0.00	0.00	67.54	67.54
4	0.00	0.00	0.00	0.00	19.07	19.07
5	0.00	0.00	0.00	0.00	52.76	52.76
6	0.00	0.00	0.00	0.00	25.13	25.13
7	0.00	0.00	0.00	0.00	12.54	12.54
8	0.00	0.00	0.00	0.00	7.78	7.78
9	0.00	0.00	0.00	0.00	17.73	17.73
10	0.00	0.00	0.00	0.00	6.91	6.91
11	0.00	0.00	0.00	0.00	6.17	6.17
Total (Contiguous U.S.)	0.00	0.00	0.00	0.00	18.77	18.77
	Home Food Freezing					
1	0.00	0.00	0.00	0.00	13.92	13.92
2	0.00	0.00	0.00	0.00	22.02	22.02
3	0.00	0.00	0.00	0.00	20.74	20.74
4	0.00	0.00	0.00	0.00	32.17	32.17
5	0.00	0.00	0.00	0.00	32.21	32.21
6	0.00	0.00	0.00	0.00	34.80	34.80
7	0.00	0.00	0.00	0.00	31.02	31.02
8	0.00	0.00	0.00	0.00	21.08	21.08
9	0.00	0.00	0.00	0.00	33.94	33.94
10	0.00	0.00	0.00	0.00	48.70	48.70
11	0.00	0.00	0.00	0.00	42.79	42.79
Total (Contiguous U.S.)	0.00	0.00	0.00	0.00	28.66	28.66

Section 3.

AVAILABILITY AND PRICES OF FUELS AND ELECTRICITY

3.1 Availability3.1.1 Natural Gas

It has been a policy of the Federal Government to assign the highest priorities for natural gas use to essential residential uses. Thus, during recent periods of gas shortages, industrial boiler fuel and other easily transferable gas loads have been curtailed in order to preserve the available supplies for residential, commercial, and public need applications.

While there have been some local and temporary shortages of gas that have threatened the supply to high priority customers, emergency curtailments and transfers of gas from other areas have prevented the forced shutdown of any distribution systems due to low gas pressures. It does not appear that such shutdowns are likely to occur in the foreseeable future because of the large volumes of industrial gas loads that can be diverted to high priority use, as alternative fuels such as oil and coal are phased into industrial plants.

The Federal Power Commission issued a priority-of-service category listing for use during periods of curtailed deliveries by a transmission company. The priority-of-service categories are —

1. Residential, small commercial (less than 50,000 CF on a peak day)
2. Large commercial requirements (50,000 CF or more on a peak day), firm industrial requirements for plant protection, feedstock and process needs, and pipeline customer storage injection requirements
3. All industrial requirements not specified in (2), (4), (5), (6), (7), (8), or (9)
4. Firm industrial requirements for boiler fuel use at less than 3 million CF/day, but more than 1.5 million/day, where alternative fuel capabilities can meet such requirements
5. Firm industrial requirements for large volume (3 million or more CF per day) boiler fuel use where alternative fuel capabilities can meet such requirements
6. Interruptible requirements of more than 300,000 CF/day, but less than 1.5 million CF/day, where alternative fuel capabilities can meet such requirements
7. Interruptible requirements of intermediate volumes (from 1.5 million/day through 3 million CF/day), where alternative fuel capabilities can meet such requirements

8. Interruptible requirements of more than 3 million CF/day, but less than 10 million CF/day, where alternative fuel capabilities can meet such requirements
9. Interruptible requirements of more than 10 million CF/day, where alternative fuel capabilities can meet such requirements.

The problem is one of political administration of end-use allocation rather than a physical limitation on the availability of natural gas for residential users.

The Gas Requirements Committee of the gas utility industry has prepared a detailed projection of future gas consumption by state and by category of sales out to 1985.¹⁸ The 1985 projection is presented in Table 34. It is apparent that the residential sector is projected to consume about 5.93 trillion CF of gas or about 29% of the 20.6 trillion CF total consumption for all uses projected for 1985.

It is currently uncertain if the total gas production in 1985 will equal this projected total consumption by all sectors. A large number of gas supply projections have been made by various authors. Most projections predict nearly constant or slightly declining gas supply. None have been made that predict declines in supply sufficient to encroach upon the 6 trillion CF needed to supply the residential market. We can therefore conclude that the future natural gas supply will be more than adequate to serve the residential market demand to 1985.

There is less definitive data available on the time period from 1985 to 2000. Some projections, particularly those of the FEA, tend to peak sometime after 1985 and to decline slowly thereafter. Others show fairly constant annual gas production to the year 2000. The uncertainty of future gas production rests not with the existence of gas reserves, but with the economics of production relative to other forms of energy. Nevertheless, the future projections are so far above the requirements of the residential market alone, that as long as present allocation priorities are enforced, we can foresee no shortage of natural gas for the residential market. In fact, the availability of natural gas for the residential market should improve with time as adjustments are made to shift gas consumption away from low priority boiler fuel loads.

3.1.2 Oil

The increase in OPEC oil prices in 1973 and the resulting market incentive to reduce the demand for oil has created a worldwide surplus of crude oil.

Table 34. ESTIMATED GAS CONSUMPTION BY STATE AND CLASS OF SERVICE, 1985
(Million CF at 1000 Btu/CF at 14.73 psia)

	Firm			Electric Utilities for Power Generation		Interruptible		Other	Total Consumption
	Residential	Commercial	Industrial	Firm	Interruptible	Commercial	Industrial		
UNITED STATES TOTAL	5,933,504	2,691,333	4,829,287	1,083,724	507,077	357,189	1,548,569	1,456,667	20,603,350
FIELD USE									2,196,000
TOTAL EXCLUDING FIELD USE									18,407,350
1. NEW ENGLAND	177,597	71,327	43,864	-	3,975	1,306	10,234	16,327	324,630
Connecticut	36,231	17,400	12,187	-	-	-	625	3,783	70,226
Maine	904	714	602	-	-	-	-	150	2,370
Massachusetts	116,709	44,421	24,567	-	3,360	1,006	8,145	10,808	209,016
New Hampshire	4,610	2,773	945	-	-	-	-	530	8,858
Rhode Island	17,113	4,971	5,487	-	-	-	10	838	28,419
Vermont	2,030	1,048	76	-	615	300	1,454	218	5,741
2. APPALACHIAN	1,701,887	669,797	1,044,221	4,980	9,532	18,347	74,827	262,377	3,785,968
Delaware	8,670	3,106	4,216	-	-	-	-	834	16,826
District of Columbia	14,551	11,400	-	-	-	-	-	665	26,616
Kentucky	83,687	32,687	50,547	-	-	117	6,702	36,928	210,668
Maryland	80,083	22,910	28,221	-	-	-	17,886	7,280	156,380
New Jersey	179,633	84,250	41,434	-	3,030	2,517	15,248	12,720	338,832
New York	383,848	148,830	115,063	2,650	6,502	14,194	10,667	33,739	715,493
Ohio	498,151	187,868	392,439	2,219	-	674	3,092	37,734	1,122,177
Pennsylvania	333,586	124,547	308,457	111	-	10	12,400	52,630	831,741
Virginia	57,999	30,877	26,229	-	-	755	8,744	19,571	144,175
West Virginia	61,679	23,322	77,615	-	-	80	88	60,276	223,060
3. SOUTHEAST	316,101	185,502	243,450	52,830	1,939	27,336	54,409	90,479	972,046
Alabama	66,059	24,773	75,640	3,500	-	2,601	8,220	18,511	199,304
Florida	26,886	23,352	5,722	49,330	1,939	4,240	20,846	3,544	135,859
Georgia	106,700	58,757	63,457	-	-	20,354	4,459	23,104	276,831
North Carolina	30,122	23,420	19,780	-	-	-	3,459	8,964	85,745
South Carolina	33,757	12,707	19,142	-	-	-	15,085	6,643	87,334
Tennessee	52,577	42,493	59,709	-	-	141	2,340	29,713	186,973
4. GREAT LAKES	1,335,216	681,295	838,940	14,677	3,783	25,107	83,225	112,186	3,094,429
Illinois	603,059	310,075	322,057	3,149	2,173	267	7,458	46,863	1,295,101
Indiana	184,558	79,647	181,511	2,117	-	689	12,004	19,580	480,106
Michigan	403,100	213,320	272,680	7,170	-	5,280	21,180	43,110	965,840
Wisconsin	144,499	78,253	62,692	2,241	1,610	18,871	42,583	2,633	353,382
5. NORTHERN PLAINS	324,975	156,912	139,883	2,127	4,737	47,642	44,677	60,574	781,527
Iowa	111,124	50,880	68,836	2,056	3,284	16,469	11,953	33,199	297,801
Minnesota	128,344	46,403	42,066	71	-	20,993	17,803	14,438	270,118
Nebraska	60,060	36,510	28,055	-	1,363	6,660	10,521	11,917	155,086
North Dakota	12,995	15,041	62	-	90	1,168	1,255	598	31,209
South Dakota	12,452	8,078	864	-	-	2,352	3,145	422	27,313
6. MID-CONTINENT	371,031	160,468	166,756	189,529	45,956	32,803	253,186	130,086	1,349,815
Kansas	104,019	47,826	15,268	-	26,694	10,825	75,825	85,457	365,441
Missouri	176,645	68,893	39,159	-	6,979	13,429	34,560	17,025	356,690
Oklahoma	90,367	43,749	112,329	189,529	12,283	9,022	142,801	27,604	627,684
7. GULF COAST	478,082	242,855	2,012,486	775,286	291,084	120,424	400,748	503,095	4,824,060
Arkansas	46,641	20,579	163,781	104,400	-	-	9,595	65,123	410,119
Louisiana	126,343	25,429	349,878	233,456	20,025	120,424	868	73,017	949,440
Mississippi	35,157	22,189	47,584	1,100	8,215	-	22,189	50,501	186,935
Texas	269,941	174,658	1,451,243	436,330	262,844	-	368,096	314,454	3,277,566
8. ROCKY MOUNTAIN	240,662	153,123	31,354	2,750	11,736	22,059	80,414	30,934	573,032
Colorado	142,670	102,845	14,784	2,250	9,964	13,522	28,835	14,410	329,280
Montana	24,871	17,999	3,500	500	-	-	12,900	4,310	64,580
Utah	57,581	22,302	3,724	-	1,272	7,664	19,919	4,340	116,802
Wyoming	15,540	9,977	9,346	-	-	873	18,760	7,874	62,370
9. PACIFIC SOUTHWEST	892,085	306,297	186,757	41,545	134,335	38,848	452,920	128,376	2,181,163
Arizona	38,461	17,729	11,488	9,565	-	-	-	13,117	90,360
California	801,054	259,064	136,108	3,075	110,375	38,848	452,408	67,600	1,868,531
Nevada	19,072	21,542	9,588	6,579	-	-	-	2,753	59,534
New Mexico	38,367	17,143	29,573	22,326	23,961	-	512	45,196	177,078
10. PACIFIC NORTHWEST	95,868	63,757	121,576	-	-	23,317	93,929	5,223	403,670
Idaho	13,312	10,168	29,891	-	-	540	4,271	-	58,182
Oregon	32,495	19,675	38,482	-	-	499	27,576	1,909	120,636
Washington	50,061	33,914	53,203	-	-	22,278	62,082	3,314	224,852
11. PACIFIC*	-	-	-	-	-	-	-	117,010	117,010
Alaska	-	-	-	-	-	-	-	111,830	111,830
Hawaii	-	-	-	-	-	-	-	5,180	5,180

* Alaska and Hawaii's data and category of use statistics cannot be shown separately without revealing confidential data.

Most industry analysts have projected this condition to continue until sometime in the mid 1980's or 1990's when the worldwide demand for oil is expected to exceed the oil producing capabilities of the world.¹⁹⁻²² This expectation is based upon present projections of oil use and future rates of oil production from known oil resources. Middle East oil production is a primary consideration in these forecasts. While there is much uncertainty in these projections, it would be prudent to assume that by the year 2000, the world supply of oil will fall short of demand. A recent study by the CIA¹⁹ predicts that a world oil shortage may occur as early as 1983. Some of the major oil companies have mentioned dates between 1985 and 1995.²²

Although it is uncertain when this shortfall may occur, it is inevitable that it will bring about a substantial increase in the world price of crude oil.

The International Energy Agency has been organized for the specific purpose of administering some form of control among the oil consuming countries in the event of a future shortage of world oil supply. However, the task of securing the cooperation of over 20 individual sovereign states under such circumstances is formidable. If successful, it can only administer the shortage, allocating supplies and policing purchase agreements.

Regardless of what can be done to share the shortage, a market will be created for synthetic oil and gas at whatever price is necessary to produce them. Natural gas and oil prices will tend to increase to this level. They may be higher for a period of time until synthetic gas and oil supplies become readily available. Various forecasters have mentioned price ranges of \$5.00 to \$6.00 per million Btu for gas and oil when this transition occurs. Much will depend upon the timing between now and then.

Thus, the long range outlook for heating oil is that supplies will be adequate until 1985 or possibly later. During the period following the development of a worldwide oil shortage, the total supply of heating oil may become restricted. However, as in the current gas situation, we anticipate that government allocations will ensure adequate supplies for the residential market, while industrial users are encouraged to convert more heavily to coal and synthetic gas and oil.

The duration and severity of a future oil shortage in the United States, as a result of a world oil shortfall, can be mitigated by deliberate efforts to develop alternative oil supplies before such a shortage occurs. It is also possible that energy conservation worldwide, and the development of oil resources not known at present, could delay a world oil shortage and permit a smoother transition to other sources of energy.

In any case we do not anticipate a shortage of heating oil in the residential sector during the remainder of this century, except for possible short term politically motivated interruptions in supply. If such interruptions occur, they may have a psychological effect upon energy markets by stimulating efforts to avoid dependence on oil where the resulting economic penalty can be accepted. This effect is difficult to anticipate but it could perhaps influence the choice of back-up fuel selected for a solar total energy system.

However, for planning purposes we can assume that heating oil will be available and can be used either as a back-up fuel supply or as a potentially competitive energy source to solar energy.

3.1.3 Liquified Petroleum Gas (LPG)

A small portion (5%) of the residential energy market is currently served by LPG. Most of this consumption is in rural areas where natural gas service is not available. This market segment offers a potentially attractive area for solar total energy systems because of the relatively high energy distribution costs in rural areas.

About 75% of the LPG consumed is stripped from natural gas, the remainder is produced by oil refineries and is referred to as liquified refinery gas (LRG). Because of the currently declining supply of natural gas, the availability of LPG from domestic sources is declining also.

However, worldwide supplies of LPG have not been fully developed. As much as 7 trillion CF of natural gas is being flared in oil producing countries throughout the world. Most of this gas contains gas liquids that could be stripped and marketed along with the natural gas itself. Some of the new oil revenue of the OPEC countries is being used to procure facilities to capture and market these gas and gas-liquid supplies, which are currently being wasted. As these facilities come on stream they will add large increments to the world

supply of LPG and they should be carefully scheduled to avoid flooding world LPG markets. Saudi Arabia alone plans to increase its LPG production by 500,000 bbl/day by 1985. Others will add more on their own schedules.

These additions will probably not be well coordinated and we can expect that there will be temporary shortages and surpluses throughout the next several years as consumption increases to absorb the added supply at an uneven pace.

A short-term projection made by the FEA's LPG Industry Advisory Committee in June 1977²³ presented the following supply projection to 1980 (Table 35):

Table 35. U.S. PROPANE SUPPLY (1000 bbl/day)

<u>Year</u>	<u>Total</u>	<u>Refinery Production</u>	<u>Gas Plant Production</u>	<u>Imports</u>
1976	840	256	521	63
1977	908	277	502	129
1978	982	294	482	206
1979	1037	310	463	264
1980	1090	321	446	323

It is apparent that imports of LPG are expected to increase sharply as OPEC countries begin to market their supplies of LPG. The increase in refinery production results from the shift to lead-free gasoline production.*

Beyond 1980, projections are heavily dependent upon worldwide LPG production and international market demand. The quantities imported into the United States will depend upon the price U.S. users are willing to pay in competition with other world markets. There are very few reliable long-range projections of this very volatile segment of the energy market.

However, we expect that the availability of LPG in U.S. markets will continue to increase until after a shortfall in world oil supply develops. Beyond that point LPG will be subject to end-use restrictions on a worldwide basis much as it is currently restricted in the United States.

At present the residential and commercial uses of LPG in the United States total about 34% of the total LPG consumption. Federal regulations are designed to ensure that this segment of the market receives adequate supplies and receives the highest priorities for available supplies. If we assume that this

* More LPG is produced by refinery processes used to produce lead-free gasoline.

policy is continued, we can be assured that LPG supplies for the residential market will continue to be available even after it becomes necessary to restrict LPG usage in other areas such as industrial and chemical feedstock markets.

Thus the outlook for LPG is much like that of gas and heating oil. While there may be foreseeable shortages in total supply, the Federal Government has already taken measures to ensure that the residential market will receive its required shares of these fuels. It is therefore prudent to assume that solar total energy systems must compete with fossil fuel energy systems throughout the remainder of this century, at least.

3.1.4 Electricity

Although electricity is not a primary fuel it is an alternative source of energy that is widely available and can be expected to compete with solar-generated electricity for residential uses throughout the period covered by this study.

During the period from now until 1985 the electric utility industry is projected to grow at about 5.6% per year. This is an average of growth rates projected by various sources as shown in Table 36.

Table 36. COMPARISON OF RECENT ELECTRIC DEMAND GROWTH STUDIES
(Source: FEA, National Energy Outlook, 1976)

<u>Source and Year of Study</u>	<u>1974-85 Projected Growth Rate, %</u>
Oak Ridge National Laboratory - 1974	4.4
Arthur D. Little, Inc. - 1974	6.4
Lawrence Livermore Laboratory - 1974	5.6
Hudson Jorgenson - 1974	5.5
Technical Advisory Committee, FPC - 1974	6.0
Oak Ridge National Laboratory - 1975	5.1
Westinghouse - 1975	5.0
Electrical World - 1975	5.8
Average *	5.6

* The average given by FEA; probably reflects rounding.

Beyond 1985 electric utility growth will continue as required to supply increased electricity demand. The electric utility industry has in the past maintained generating plant capacities sufficient to meet demand, and there appears to be no reason for doubting that it will be able to continue to do so throughout the foreseeable future. While there may be temporary periods during which brownouts may occur locally, these will be caused by the inability to foresee 5 to 8 years in advance the increases in electricity demand that may occur. This increased lead time for utility plant construction makes system planning more difficult and uncertain. However, we see no reason why utility electricity need be restricted for residential use in the foreseeable future. Thus electricity also must be considered as a competitive alternative to solar energy.

3.2 Energy Prices

Although forecasting of prices is at best a hazardous and uncertain venture, in the energy field there are certain foreseeable trends, in particular cost elements of each fuel form, that lend some degree of confidence to future predictions. These "hard" cost elements, such as labor rates, capital costs, taxes, etc., are not likely to reverse their historic trends. Thus, where technology is stable and the items required to provide energy supply service remain constant, the price of energy must reflect the escalating rates of labor, capital, material, taxes, etc. It is only changing technology or patterns of demand that can bring about reductions in price that may run counter to the now accepted trend of generally inflating energy costs.

Depletion of certain fuel supplies causes shifts to other, usually more expensive, sources and contributes to higher real costs. New regulations requiring additional equipment or more costly procedures also result in increased real fuel costs as seen by the residential user. These increases are theoretically step functions that should result in sudden one-time cost increases. However, in practice they are implemented over extended periods of time and their cost impacts are difficult to distinguish from the effects of labor, capital, and tax increases.

Future price projections must take into account all of these cost factors. However, available energy price projections using computer techniques, while attempting to account for changing parameters, have not yet begun to treat the

problem in the detail necessary to simulate the real world of energy price competition. Computer models do not readily handle step functions or diffused step functions which are characteristic of legislative edicts such as changes in pricing regulations, environmental control laws, fuel allocation, etc.²⁴ Such models usually assume constant rates of change based on current or near-term experience. Extrapolation of these rates to long-term future dates can lead to unrealistic projections unless modified by wisdom and judgment.

We have attempted to make use of available energy price projections made by various groups and have relied most heavily upon the pricing projections of the Federal Energy Administration which were used in preparing the 1977 national Energy Outlook.²⁴ However, we have modified these projections where the work of others, or considered judgment, suggested that revision should be made.

The underlying rationale used was that future fossil-fuel prices will be dictated largely by world oil prices and electricity prices will be determined largely by capital cost increases associated with increasingly stringent environmental costs both directly and indirectly in the form of increased coal mining costs and nuclear fuel handling costs. Since no forecasts of future LPG prices were available, the above rationale was used to project LPG prices on the assumption that current relationships to light heating oil prices would be maintained as world oil prices continue to escalate.

3.2.1 Current Energy Prices

The base point used for projecting future energy prices was the 1975 price of residential fuels and electricity in 11 states representative of the geographical regions used in the study. Each of the applicable fuels is discussed in turn below.

Natural Gas

Residential prices for natural gas are taken from data compiled by the American Gas Association²⁵ and are presented in Table 37.

Fuel Oil

Data for heating oil prices were taken from the annual Gas Househeating Survey of A.G.A.²⁶ These data are presented in Table 37 for various cities, and prices representative of the states selected were chosen.

Table 37. RESIDENTIAL ENERGY PRICES — 1975 (1975 Dollars)

<u>Region</u>	<u>State</u>	<u>Electricity</u> ^a	<u>Gas</u> ^b	<u>Oil</u> ^c	<u>LPG</u> ^c
		<u>\$/10⁶ Btu</u>			
1	Florida	9.99	2.78	3.66	6.04
2	California	9.75	1.52	2.81	4.50
3	Arizona	10.66	1.83	2.60 ^d	5.61
4	Colorado	9.08	1.16	2.53	3.29
5	Texas	8.00	1.47	2.67	3.84
6	Georgia	8.23	1.75	2.66	3.87
7	Kentucky	7.15	1.30	2.76	4.16
8	New England	13.18	3.22	2.81	4.94
9	Illinois	10.43	1.58	2.74	4.44
10	N. Dakota	8.41	1.50	2.68	3.51
11	Washington	3.60	2.12	2.96	5.97
Average		8.95	1.84	2.81	4.56

^a Data from EEI Statistical Yearbook.

^b Data from A.G.A. Gas Facts.

^c Data from A.G.A. Househeating Survey using representative cities within state or region.

^d Estimate based on surrounding states.

LPG

Price data at the retail level for LPG were also taken from the Gas Househeating Survey by A.G.A.²⁶ using city prices representative of the state shown in Table 43.

Electricity

Residential electricity prices for 1975 were taken from the Statistical Yearbook of Edison Electric Institute for 1975.¹¹ In choosing a state representative of Region 8, the total New England area was used. This was done because the electricity prices in New York State, which would have been the logical choice, are relatively high because of Consolidated Edison prices, which include unusually high tax levies.

3.2.2 Projected Energy Prices

The 1975 energy prices were projected to 1985 using annual price escalation rates higher than those reported in the 1977 U.S. Energy Outlook.²⁴ The reasons for using the rates selected are presented in the following sections, addressed to each energy form. Oil is discussed first because of its importance in setting other fuel prices. Prices are given in 1975 dollars.

Oil Price Projection

While No. 2 heating oil prices have increased about 1% per year during the period from 1974 through 1976 they are tied to crude oil prices, which are increasing more rapidly for several reasons. OPEC has increased crude oil prices about 10% during the past year alone. Present indications of U.S. oil pricing policy allow increasing domestic oil prices to reach parity with world oil prices sometime before 1985. In real terms the refinery acquisition cost of crude oil increased about 3% per year between 1974 and 1976. It will probably continue to increase at some such rate regardless of the final form of the National Energy Plan.

Recent studies by IGT of future gas and oil prices resulting from market pressures tempered by Government controls²⁷ project a No. 2 heating oil price of \$3.96/million Btu (\$0.55/gallon) in real terms by 1985. This represents a 3.8% annual increase from the \$0.377/gallon 1975 average price reported by FEA in its Monthly Energy Review,²⁸ and appears to be consistent with current trends of crude oil prices which will dictate future No. 2 heating oil prices. We have, therefore, projected No. 2 heating oil to reach an average price of \$3.96/million Btu and have set the regional prices according to the relative prices existing in 1975. It is assumed that there will be no significant shift in the regional price patterns of heating oil relative to the national average.

The possibility of a shortfall in world oil supply beyond 1985 has already been discussed. To accomodate this possibility two price scenarios are presented for the time period beyond 1985.

World Oil Shortfall (WOS)

This scenario assumes a shortfall in world oil around 1985 which results in oil prices increasing to the level of synthetic fuel prices by 1990.

Current estimates of synthetic fuel prices range from \$3.00 to \$4.00/million Btu depending upon the conversion process and other factors including an allowance for transportation costs to the point of use. Synthetic crude and high-Btu gas tend to be closer to the \$4.00/million Btu level while low-Btu gas and solvent refined coal are closer to the \$3.00/million Btu level. Some of these costs are tabulated in Table 38, which was prepared by IGT staff to summarize synthetic fuel price projections that have been made by various groups doing work in the area of synthetic fuel processes.

Table 38. ESTIMATED COST OF ENERGY FROM COAL (1975 Dollars)

Energy Form	At Mine Mouth	Delivered 1000 Miles From Mine Mouth	
		Transport Coal	Transport Product
		\$/Million Btu	
1. Raw Coal	.65	1.00	--
2. Combustion and Stack Gas Clean-Up To Generate Steam for Large Installations (Commercial)	1.75	2.15	--
3. Fluidized-Bed Combustion to Generate Steam for Industrial Boilers (Not Yet Commercial)	1.90	2.30	--
4. 300 Btu/cu ft Gas Commercial Technology (Small Plant)	3.60	4.10	--
Commercial Technology (Large Plant)	2.90	3.40	3.60
2nd Generation Technology (Large Plant)	2.25	2.70	2.85
5. Solvent Refined Coal (Not Yet Commercial)	3.00	--	3.30
6. High-Btu Gas Commercial Technology	3.75	--	4.05
2nd Generation Technology	3.05	--	3.35
7. Synthetic Crude-Pipelineable (Not Yet Commercial)	3.90	--	4.00
8. Electricity, Mine Mouth Plant Bus Bar Cost Ship	11.00	--	--
Coal 1000 Miles, plus Bus Bar Cost	--	12.00	--
Bus Bar Cost, plus Cost to Transmit Electricity 1000 Miles	--	--	15.00

We have assumed that the \$4.00/million Btu price level will increase to \$5.00/million Btu in real terms by 1990, which implies an annual escalation rate of 1.5%. Thus, crude oil in 1990 would be priced at \$5.00/million Btu or about \$28/bbl. Beyond 1990 crude oil is assumed to escalate in step with increasing synthetic fuel prices — in real terms. This increase, if any, will occur as a result of increased costs of coal and costs associated with water supply and plant siting. Since these are expected to be similar to the cost increases facing electric utilities we have assumed an annual cost escalation rate of 0.5%/yr for both in real terms.

The addition of projected refining costs increasing at 0.25%/yr in real terms beyond 1990 to allow for increasing environmental and siting costs permits projection of No. 2 oil costs to the end of the forecast period. However, it must be recognized that the projection of energy prices forty years into the future is necessarily arbitrary and subject to possibly drastic revision as the future unfolds.

Business-As-Usual (BAU) Scenario

This scenario assumes that conservation combined with additional discoveries of oil are sufficient to put off a shortfall in world oil supply indefinitely. That is, domestic oil prices are dictated by world oil prices and continue to escalate at a rate of 2% per year in real terms as OPEC continues to press for increased revenue at slightly more than increasing inflation rates in order to approach the projected costs of synthetic fuels. It is assumed that the present prices of world oil will stimulate exploration and production in other parts of the world, but the quantities found and the cost of producing will not result in any downward pressure on OPEC oil prices. That is, the price of such oil will track world oil prices as set by OPEC. This rationale is based upon the experience already obtained in the North Sea, Prudhoe Bay, and southeastern Mexico.

In this scenario there is no sudden increase in world oil price, but it is assumed that there will be continued pressure to raise oil prices to the level of synthetic fuel price levels. We have assumed that this will result in an annual rate of increase of 2% in real terms exclusive of inflationary effects.

This results in world oil prices reaching a parity with synthetic fuel prices within the forecast period. This may appear to be unrealistic in view of the world oil outlook. However, the two scenarios have been designed to reflect the two alternatives of adequate natural oil supply and the necessity for supplemental synthetic fuel to meet the demand. It is hoped that the two scenarios will bracket the range of fuel prices that may prevail in the time period when solar total energy systems are being offered for sale.

The resulting fuel oil prices are presented in Tables 39 through 47.

Table 39. RESIDENTIAL ENERGY PRICES — 1985 (1975 Dollars)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u>	<u>Oil</u>	<u>LPG</u>
			$\$/10^6$ Btu		
1	Florida	13.01	5.52	4.75	7.13
2	California	12.70	3.31	4.02	5.71
3	Arizona	13.89	3.75	3.72	6.73
4	Colorado	11.82	3.31	3.63	4.39
5	Texas	10.40	3.00	3.82	4.99
6	Georgia	10.70	3.58	3.81	5.02
7	Kentucky	9.29	3.05	3.94	5.34
8	New England	16.20	5.64	4.02	6.15
9	Illinois	13.59	3.33	3.92	5.62
10	N. Dakota	10.94	3.16	3.83	4.66
11	Washington	<u>6.73</u>	<u>4.35</u>	<u>4.07</u>	<u>7.08</u>
Average		11.75	3.82	3.96	5.71

Table 40. RESIDENTIAL ENERGY PRICES — 1990 (1975 Dollars)
(Business-As-Usual)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u>	<u>Oil</u>	<u>LPG</u>
			$\$/10^6$ Btu		
1	Florida	13.35	6.01	5.23	7.61
2	California	13.03	5.23	4.55	6.24
3	Arizona	14.25	4.83	4.20	7.21
4	Colorado	12.13	4.72	4.10	4.86
5	Texas	10.67	4.97	4.32	5.49
6	Georgia	11.00	4.96	4.31	5.52
7	Kentucky	9.57	5.13	4.46	5.86
8	New England	16.51	6.23	4.55	6.68
9	Illinois	14.00	5.11	4.44	6.14
10	N. Dakota	11.22	4.98	4.33	5.16
11	Washington	<u>7.92</u>	<u>5.15</u>	<u>4.48</u>	<u>7.49</u>
Average		12.15	5.21	4.45	6.21

Table 41. RESIDENTIAL ENERGY PRICES — 1990 (1975 Dollars)
(World Oil Shortfall)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u> \$/10 ⁶ Btu	<u>Oil</u>	<u>LPG</u>
1	Florida	13.35	7.00	7.00	9.38
2	California	13.03	6.59	6.59	8.28
3	Arizona	14.25	6.38	6.38	9.39
4	Colorado	12.13	6.31	6.31	7.07
5	Texas	10.67	6.45	6.45	7.62
6	Georgia	11.00	6.44	6.44	7.65
7	Kentucky	9.57	6.54	6.54	7.94
8	New England	16.51	6.59	6.59	8.72
9	Illinois	14.00	6.52	6.52	8.22
10	N. Dakota	11.22	6.46	6.46	7.29
11	Washington	7.92	6.74	6.74	9.75
Average		12.15	6.55	6.55	8.30

Table 42. RESIDENTIAL ENERGY PRICES — 2000 (1975 Dollars)
(Business-As-Usual)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u> \$/10 ⁶ Btu	<u>Oil</u>	<u>LPG</u>
1	Florida	14.03	7.33	6.38	8.76
2	California	13.70	6.38	5.55	7.24
3	Arizona	14.98	5.89	5.12	8.13
4	Colorado	12.75	5.75	5.00	5.76
5	Texas	12.22	6.06	5.27	6.44
6	Georgia	11.56	6.04	5.25	6.46
7	Kentucky	10.06	6.25	5.44	6.84
8	New England	17.35	6.38	5.55	7.68
9	Illinois	14.72	6.22	5.41	7.11
10	N. Dakota	11.79	6.07	5.28	6.11
11	Washington	9.33	6.28	5.46	8.47
Average		12.95	6.24	5.42	7.18

Table 43. RESIDENTIAL ENERGY PRICES — 2000 (1975 Dollars)
(World Oil Shortfall)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u>	<u>Oil</u>	<u>LPG</u>
			$\$/10^6$ Btu		
1	Florida	14.03	7.36	7.36	9.74
2	California	13.70	6.93	6.93	8.62
3	Arizona	14.98	6.71	6.71	9.72
4	Colorado	12.75	6.63	6.63	7.39
5	Texas	12.22	6.78	6.78	7.95
6	Georgia	11.56	6.77	6.77	7.98
7	Kentucky	10.06	6.87	6.87	8.27
8	New England	17.35	6.93	6.93	9.06
9	Illinois	14.72	6.85	6.85	8.55
10	N. Dakota	11.79	6.79	6.79	7.62
11	Washington	9.33	7.08	7.08	10.09
Average		12.95	6.88	6.88	8.64

Table 44. RESIDENTIAL ENERGY PRICES — 2010 (1975 Dollars)
(Business-As-Usual)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u>	<u>Oil</u>	<u>LPG</u>
			$\$/10^6$ Btu		
1	Florida	14.75	7.74	7.74	10.12
2	California	14.40	7.28	6.77	8.46
3	Arizona	15.74	7.05	6.24	9.25
4	Colorado	13.40	6.97	6.10	6.86
5	Texas	12.84	7.13	6.42	7.59
6	Georgia	12.15	7.12	6.40	7.61
7	Kentucky	10.57	7.22	6.63	8.03
8	New England	18.23	7.28	6.77	8.90
9	Illinois	15.48	7.20	6.59	8.29
10	N. Dakota	12.39	7.14	6.44	7.27
11	Washington	9.81	7.44	6.66	9.67
Average		13.61	7.23	6.61	8.37

Table 45. RESIDENTIAL ENERGY PRICES — 2010 (1975 Dollars)
(World Oil Shortfall)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u> \$/10 ⁶ Btu	<u>Oil</u>	<u>LPG</u>
1	Florida	14.75	7.74	7.74	10.12
2	California	14.40	7.28	7.28	8.97
3	Arizona	15.74	7.05	7.05	10.06
4	Colorado	13.40	6.97	6.97	7.73
5	Texas	12.84	7.13	7.13	8.30
6	Georgia	12.15	7.12	7.12	8.33
7	Kentucky	10.57	7.22	7.22	8.62
8	New England	18.23	7.28	7.28	9.41
9	Illinois	15.48	7.20	7.20	8.90
10	N. Dakota	12.39	7.14	7.14	7.97
11	Washington	<u>9.81</u>	<u>7.44</u>	<u>7.44</u>	<u>10.45</u>
Average		13.61	7.23	7.23	8.99

Table 46. RESIDENTIAL ENERGY PRICES — 2020 (1975 Dollars)
(Business-As-Usual)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u> \$/10 ⁶ Btu	<u>Oil</u>	<u>LPG</u>
1	Florida	15.49	8.14	8.14	10.52
2	California	15.13	7.65	7.65	9.34
3	Arizona	16.54	7.41	7.41	10.42
4	Colorado	14.08	7.33	7.33	8.09
5	Texas	13.49	7.49	7.49	8.66
6	Georgia	12.77	7.48	7.48	8.69
7	Kentucky	11.11	7.59	7.59	8.99
8	New England	19.16	7.65	7.65	9.78
9	Illinois	16.27	7.57	7.57	9.27
10	N. Dakota	13.02	7.51	7.51	8.34
11	Washington	<u>10.31</u>	<u>7.82</u>	<u>7.82</u>	<u>10.83</u>
Average		14.31	7.60	7.60	9.36

Table 47. RESIDENTIAL ENERGY PRICES — 2020 (1975 Dollars)
(World Oil Shortfall)

<u>Region</u>	<u>State</u>	<u>Electricity</u>	<u>Gas</u>	<u>Oil</u>	<u>LPG</u>
			$\$/10^6$ Btu		
1	Florida	15.49	8.14	8.14	10.52
2	California	15.13	7.65	7.65	9.34
3	Arizona	16.54	7.41	7.41	10.42
4	Colorado	14.08	7.33	7.33	8.09
5	Texas	13.49	7.49	7.49	8.66
6	Georgia	12.77	7.48	7.48	8.69
7	Kentucky	11.11	7.59	7.59	8.99
8	New England	19.16	7.65	7.65	9.78
9	Illinois	16.27	7.57	7.57	9.27
10	N. Dakota	13.02	7.51	7.51	8.34
11	Washington	10.31	7.82	7.82	10.83
Average		14.31	7.60	7.60	9.36

Gas Price Projection

There is growing recognition that gas should be priced at parity with oil under continued regulation. Under deregulated conditions, there are reasons to believe that gas would command a premium of 15% to 20% in price over light distillate heating oil. In either case the price of natural gas by 1985 should be much closer to the price of oil at the retail level than the pricing levels projected by the 1977 U.S. Energy Outlook.²⁴

We have therefore chosen to use Dr. Lemon's analysis²⁷ to provide the basis for the 1985 gas projections as well as the 1985 oil projections. Using the same source for both provides some consistency in the projection and, we feel, may be more realistic as well.

Beyond 1985 the future projection of gas prices becomes more uncertain, and it is necessary to discuss them in the context of the two scenarios already defined for oil prices.

Effects of World Oil Shortfall (WOS)

In the event that crude oil prices increase to the price of synthetic fuels, utility gas will be competitive with heating oil in virtually all regions.

The present state of technology of synthetic gas and oil production suggests that gas can be made from coal at slightly lower cost than oil because of inherent differences in the conversion processes. This advantage for gas combined with the premium value mentioned above of 15% to 20% should offset any higher distribution cost of gas relative to oil that may occur. Thus, synthetic gas will be at parity with synthetic oil priced to the residential consumer in real terms. If synthetic gas and oil are placing a ceiling on the price of natural gas and oil, these will be priced no higher than synthetic fuels, and the average rolled-in (or incremental) price of gas will be competitive with unregulated natural gas or world oil.

This rationale permits a projection of gas price at parity with oil beyond 1985 in this scenario. Both are assumed to be at parity with synthetic oil and gas, thus resulting in higher prices than many other energy price forecasts.

Business-As-Usual (BAU)

If the world oil supply remains adequate to meet demand, its price, as shown in our projections for this scenario, will remain below the price of synthetic gas.

Under these circumstances we have assumed that the price of natural gas will reach a parity with natural oil after 1985 whether gas prices at the well-head are deregulated or not. However, the availability of imported oil will discourage synthetic gas development as it does now and prices of gas will be dictated by world oil prices.

In gas producing areas gas prices will be about 15% higher than No. 2 oil at the retail level because of differences in user costs such as inventory and storage costs incurred by the user in the case of oil. Gas prices away from the gas producing areas will be higher by the transportation cost to the region less the 15% premium where the total cost of gas exceeds the price of oil by more than 15%.

Gas transportation costs will tend to increase as throughput declines, but will also tend to be reduced as capital invested is depreciated. These tend to offset each other and it has been assumed that no change in transmission costs will occur in real terms.

There will be some production of synthetic gas at prices above natural gas and oil prices. Where synthetic gas can be produced at less than the total

cost of natural gas plus its transport cost to a region, the local supply will be augmented by SNG. This will not affect the overall market price pattern, however. Using these guidelines the prices of utility gas have been projected as shown in Tables 39 through 47.

LPG Price Projection

Although LPG prices are currently regulated and will probably continue to be controlled throughout the foreseeable future, the prices set must be competitive to avoid disrupting the present balance of energy supplies.

LPG stripped from natural gas streams must generate sufficient revenue to justify its extraction from natural gas. As the price of natural gas increases, the price of LPG must be increased also to maintain the economic incentive for extraction.

Since LPG competes primarily with light distillate oil for heating in the residential market, its price can be increased in step with light heating oil prices to maintain the necessary incentive for extraction. The existing prices shown in Table 37 show that LPG commands a substantial premium over heating oil at the residential retail level in all regions of the country. This is due to the fact that LPG can be used for cooking, small unit space heaters, and other applications unsuited to light oil. The residential user can use LPG for a number of applications that would require electricity if only heating oil were available; electric bills for such a user, particularly in rural areas, can be reduced by using LPG for cooking, etc. We expect that this premium for LPG will continue to exist, and have projected LPG prices to continue to escalate with No. 2 oil prices throughout the forecast period, preserving the current premium value. The resulting values are presented in Tables 39 through 47.

Electricity Price Projections

The projection of residential electricity prices is based largely on a recent projection of residential electricity prices made by Electrical World magazine.²⁹ However, that projection assumes that most of the increases in real costs of electricity due to environmental costs are already reflected in current prices. We have increased the projected rates of increase shown in the study, 1.4%/yr through 1985, to 2.25%/yr in real terms to reflect further increases in fuel and environmental costs not yet fully implemented.

Beyond 1985 we have used an escalation rate of 0.5%/yr in place of the 0.25%/yr used by Electrical World. The projected escalation of oil prices at 2%/yr in the "Business-as-Usual" scenario would alone require a 0.25%/yr increase in electricity prices if coal prices continue to track oil prices as they have for the past 3 years. This would provide no allowance for increased transmission and generation costs to reflect increasingly stringent environmental regulations upon the generation, transmission, and distribution of electricity.

This rationale was used to project residential electricity prices throughout the forecast period, and the resulting prices are presented in Tables 39 through 47.

A comparison of these electricity prices with fossil-fuel prices shows a considerable reduction in the present spread between electricity and fossil-fuel prices — in real terms. However, when inflationary effects are added the present spread may not be reduced as much and may even be increased because of the serious effects of inflation upon capital costs, which are greater for electricity than for fossil fuels even including synthetic fossil fuels made from coal.

3.3 General Comments

A knowledge of future energy costs is essential to the evaluation of solar total energy systems. Because of the lead time required for development, energy prices must be anticipated far into the future.

The above discussion concedes that future energy price projections are uncertain and lack precision. Nevertheless, some attempt at defining future energy costs must be made. The prices presented represent, we believe, a reasonable projection based upon foreseeable trends and developments.

However, later in the study when it becomes possible to compare owning and operating costs of solar total energy systems with the alternative of conventional utility energy service, it will be necessary to review the assumptions made in projecting future energy prices.

In cases where the choice hinges on a close comparison of conventional energy costs with STES costs it may be difficult to recommend a choice because of the uncertainty of future energy prices, as well as future STES costs. An effort will be made, however, to relate the choice to those factors in the energy industries that will have significant impact upon future energy prices.

Section 4.

RESIDENTIAL BUILDING PROJECTIONS

In order to determine the market penetration potential of STES in the residential sector, projections have been made for new construction of each building type in the various regions. These projections, appropriately modified to reflect buildings where STES would not be applicable, represent the theoretical base (i.e., 100%) against which to make market penetration projections. Although retrofit installations theoretically could represent a potential market for STES, this would be much less likely than new construction specifically designed for STES and should be considered only after the potential for new construction has been assessed.

Several studies have projected the housing inventories, by building types, for the 1985 time frame and beyond. Both TRW³⁰ and G.E.³¹ projected regional population growth and single-family/multi-family inventories for 1970 to 2000 as part of "Solar Heating and Cooling of Buildings (Phase Zero)" contracts; Westinghouse³² addressed the issue in programs on photovoltaic systems; and Brookhaven National Laboratory² made similar projections for the Northeastern United States as part of a 1976 study on "Future Residential and Commercial Energy Demand in the Northeast." Although considerable variation exists among the projections of the various studies, they generally continue the single-family dominated pattern that currently exists but predict a future trend to: a) a decrease in the percentage of single-family dwellings, and b) an increase in the percentage of mobile homes. Some of the assumptions used in the G.E. study were applied to the current study.

4.1 Methodology

The methodology used to project new housing construction for the four market segments (single-family detached, townhouses, low-rise and high-rise apartments) to the 1980 to 1990 time frame was as follows:

1. Aggregate 1980 and 1990 population projections (of the Census Bureau) according to the selected STES regions. (See Table 48.)
2. Using projected values for persons/household, determine the number of households represented by the population projections. (See Table 48.)

Table 48. REGIONAL POPULATION (HOUSEHOLDS) PROJECTIONS

Region	Representative City	1970	1980	1990
1	Miami	3394 (1044)	4140 (1403)	4813 (1713)
2	Los Angeles	19953 (6139)	24226 (8212)	28496 (10141)
3	Phoenix	2260 (695)	2837 (962)	3359 (1195)
4	Albuquerque	4282 (1318)	4958 (1681)	5602 (1994)
5	Fort Worth	13756 (4233)	15599 (5288)	17387 (6188)
6	Charleston	24965 (7682)	27329 (9264)	29546 (10515)
7	Nashville	20000 (6154)	22251 (7543)	24362 (8670)
8	Boston	58644 (18136)	64236 (21775)	70103 (24948)
9	Chicago	45414 (13974)	49525 (16788)	53897 (19180)
10	Bismark	3956 (1217)	4327 (1467)	4590 (1633)
11	Seattle	5500 (1692)	6379 (2162)	7238 (2576)
Persons/household		3.25	2.95	2.81

3. Using 1970 Census Bureau data and Rand Corp.³⁴ aggregation, divide 1970 housing inventory into single-family detached, single-family attached (or townhouses), low-rise multi-family, high-rise multi-family, and mobile homes. Project these values to 1980 and 1990 using G.E. assumptions, i.e., the percentage of single-family detached will decrease by one-third between 1970 and 2000; the percentage of mobile homes will double between 1970 and 2000; multi-family units will account for the difference. (See Figure 4 and Table 49.)
4. Once single-family detached and mobile home inventories for 1980 and 1990 are projected, apportion the remainder of households to various multi-family categories according to the 1970 ratio of single-family attached/multi-family. This will give projected townhouses and apartment buildings.
5. Use G.E. Phase Zero projections for high-rise multi-family, convert to individual units, and subtract from total multi-family projections to arrive at low-rise apartment inventory projections. (See Table 50).
6. Once the inventories of the various housing categories are projected for 1980 and 1990, the new construction needed in each category can be calculated from the formula:

New Construction = 1990 Inventory - 1980 Inventory + 1980/90 Removal.
 (Removal rates were estimated from G.E. Phase Zero values to be approximately 2.6% single-family detached, 2.9% low-rise and townhouse, and 2.8% high-rise removals during the 1980 to 1990 period.) (See Table 51.)

Figure 4. PERCENTAGE OF SINGLE-FAMILY DETACHED DWELLINGS, 1970

Table 49. PROJECTED BREAKDOWN OF HOUSING TYPES, %*

Region	Representative City	Year	Single-Family Detached	Single-Family Attached	Low-Rise	High-Rise	Mobile
1	Miami	1970	70	13	12 [†]		5
		1980	62	16	11	4	7
		1990	55	19	13	4	9
2	Los Angeles	1970	67	12	18 [†]		3
		1980	60	14	21	1	4
		1990	53	16	22	1	6
3	Phoenix	1970	73	10	10 [†]		7
		1980	64	13	14	<1	9
		1990	56	17	17	<1	10
4	Albuquerque	1970	72	11	10 [†]		7
		1980	64	14	13	<1	9
		1990	56	17	17	<1	10
5	Fort Worth	1970	81	8	8 [†]		3
		1980	72	13	11	<1	4
		1990	63	17	15	<1	5
6	Charleston	1970	70	13	12 [†]		5
		1980	62	16	13	2	7
		1990	55	19	15	2	9
7	Nashville	1970	75	11	9 [†]		5
		1980	67	16	10	1	6
		1990	59	21	12	1	7
8	Boston	1970	50	28	20 [†]		2
		1980	45	31	19	3	2
		1990	40	34	20	3	3
9	Chicago	1970	70	16	11 [†]		3
		1980	62	19	13	2	4
		1990	57	21	16	2	4
10	Bismark	1970	73	10	10 [†]		7
		1980	65	14	13	<1	8
		1990	58	17	17	<1	8
11	Seattle	1970	67	12	18 [†]		3
		1980	60	15	21	<1	4
		1990	54	18	23	<1	5

* Estimated from 1970 "Census of Housing" and extrapolated to 1990, based on a doubling of mobile homes and a one-third decrease in percentage of single-family houses by the year 2000. High-rise estimates taken from G.E. Phase Zero report "Solar Heating and Cooling of Buildings."

[†] Total of low-rise and high-rise buildings.

Table 50 . REGIONAL IN-PLACE HOUSING PROJECTIONS

Region	Representative City	Time Frame	SFD	SFA	Low-Rise	High-Rise
			Thousands of Dwelling Units			
1	Miami	1980	870	224	154	56
		1990	942	325	223	69
	1980-1990 New Construction*		298	166	114	30
2	Los Angeles	1980	4927	1150	1725	82
		1990	5375	1724	2136	101
	1980-1990 New Construction		1729	908	911	42
3	Phoenix	1980	616	125	135	<10
		1990	669	203	203	<12
	1980-1990 New Construction		213	114	107	< 4.8
4	Albuquerque	1980	1076	235	219	<17
		1990	1117	339	339	<20
	1980-1990 New Construction		321	172	184	< 7.8
5	Fort Worth	1980	3807	687	582	<53
		1990	3898	1052	928	<62
	1980-1990 New Construction		1081	564	515	<24
6	Charleston	1980	5744	1482	1204	185
		1990	5783	1998	1577	210
	1980-1990 New Construction		1532	946	722	77
7	Nashville	1980	5054	1207	754	75
		1990	5115	1821	1040	87
	1980-1990 New Construction		1375	964	505	33
8	Boston	1980	9799	6968	3920	653
		1990	9979	8482	4990	748
	1980-1990 New Construction		2728	3535	2207	278
9	Chicago	1980	10409	3358	2015	336
		1990	10933	4028	3069	384
	1980-1990 New Construction		3230	1644	1638	142
10	Bismark	1980	954	205	191	<15
		1990	947	278	278	<16
	1980-1990 New Construction		241	132	142	< 5
11	Seattle	1980	1297	303	476	<22
		1990	1391	464	592	<26
	1980-1990 New Construction		431	249	254	<10

* New construction is based on the following removal rates: 2.6% for SFD, 2.8% for high-rise, and 2.9% for low rise and townhouses, per year.

Table 51 . PROJECTED 1980-1990 NEW CONSTRUCTION
(Thousands of Dwelling Units)

Region	Representative City	Single-Family Detached	Townhouses	Low-Rise	High-Rise
1	Miami	298	166	114	30
2	Los Angeles	1729	908	911	42
3	Phoenix	213	114	107	< 4.8
4	Albuquerque	321	172	184	< 7.8
5	Fort Worth	1081	564	515	< 24
6	Charleston	1532	946	722	77
7	Nashville	1375	964	505	33
8	Boston	2728	3535	2207	278
9	Chicago	3230	1644	1638	142
10	Bismark	241	132	142	< 5
11	Seattle	431	249	254	< 10

Section 5. OWNERSHIP

There are many factors which determine the effectiveness and, in fact, the economic feasibility of a solar total energy system, and these factors vary considerably depending upon whether the system is installed and owned by the building owner himself or whether it is owned by a commercial firm or a public utility serving the area. The possible options are listed in Table 52.

Table 52. STES OWNERSHIP OPTIONS

<u>Ownership</u>	<u>Operation</u>	<u>Service</u>
Building Owner	Building Operator	Building Operator
Building Owner	Building Operator	Service Company
Building Owner	Service Company	Service Company
Utility Ownership	Utility	Utility
Utility Ownership	Building Operator	Utility
Utility Ownership	Building Operator	Service Company
Utility Ownership	Service Company	Service Company
Commercial Company	Commercial Company	Commercial Company
Commercial Company	Building Operator	Commercial Company
Commercial Company	Building Operator	Service Company

These options and certain variations of them are discussed below to present the various aspects of STES ownership and operation that must be considered in the subsequent market penetration analyses of each residential market segment.

5.1 Fossil Fuel Total Energy Systems

Much of the background for these discussions is drawn from past experience with gas- and oil-fired total energy systems. The gas utility industry under Project GATE (Group to Advance Total Energy) made a concerted effort to develop the market for gas-powered total energy systems during the 1960's. A great many alternatives of ownership, operation, and service were tried in actual service as well as planned on paper. The experience obtained can be applied directly to the marketing analyses of solar-powered total energy systems. Reference will be made to that experience in the course of the discussion.

5.2 Single-Family Dwelling Market

This study has avoided the consideration of solar total energy systems in individual single-family dwellings. Some discussion of the problems of STES ownership in the single-family dwelling market may suffice to show why this market segment is considered to be the least promising area for STES application in the residential market.

About 55% of the total housing units in the United States are owner-occupied, single-family dwellings. Thus, a major segment of the market for solar total energy systems falls in this category of housing. The problems of financing a large capital investment by the prospective owner of a new home are unique to this market and require careful consideration before projecting the salability of solar total energy systems to the individual home owner. The same can be said for the installation of solar systems in existing privately owned single-family dwellings.

The prospective new home owner is generally shopping for the maximum house he can afford to buy as judged by the ability of his family income to cover the monthly expenses associated with ownership of the dwelling. When his ability to do this is limited, he is likely to place greater emphasis on location and essential features of the house and to sacrifice costly items that can be avoided or added later, such as air conditioning, extra bedrooms, landscaping, etc. From this point of view an STES is an item he may be willing to forego unless it can be shown that the installation of such a system will result in lower monthly living expenses. This point is of fundamental importance to the acceptance of an STES in this segment of the residential market.

An additional factor of considerable importance to the prospective new home owner is the resale value of his property. Since the average life of a home mortgage in the United States is on the order of five years, it is evident that most home owners will resell their property to others at a time when the economic value of an STES installed in the home may be an important consideration in the sale of the property. A number of difficult questions can be posed.

- Will the prospective buyer want the STES that is installed in the house?
- Will the economics of the system still be attractive at the time of resale when operating costs are a matter of record?

- Will technical obsolescence require that considerable investment be made by the owner to update the system to make his home competitive at the time of resale?

One alternative that has been suggested is ownership of the STES by a utility, which will avoid some of these problems.

However, while utility ownership may be desirable from the point of view of the homeowner, it requires that the utility own and install a significant amount of capital equipment that is, to some degree at least, built into some one else's property. While utilities in the past have leased appliances such as heating furnaces, hot water heaters, air conditioners, etc., to homeowners, these items are readily removable in the event that the homeowner fails to fulfill his financial obligations to the utility. The expense of removing an STES from a residence may be prohibitive unless the system is designed with this in mind, and even then may entail design compromises that may increase the cost and impair the efficiency of operation of the system.

At the present time in the field of leased appliances, a person who buys a home in which, let us say, a leased hot water heater is installed, may decline to accept the lease for the hot water heater and direct the utility to remove it from the premises. The Washington Natural Gas Company in Seattle, Washington, reports that its experience in leasing hot water heaters has been that the number of occasions in which they have been requested to remove hot water heaters because of change in ownership have been relatively small and it has been possible to accept this additional cost as part of the overall leasing program.

At the present time there is, of course, no way of estimating what the experience will be in the case of solar total energy systems. Moreover, the relatively high cost of removal virtually precludes this alternative. It would seem to be necessary for a utility to write its lease contract in such a way that later resale of the property be contingent upon acceptance of the solar total energy system by the new owner. This could present a serious deterrent to the installation of STES's in individual homes.

In the case of the private dwelling, the problem of resale of a home containing a utility-owned solar total energy system presents some uncertain possibilities. There is no way to judge what the acceptability of a utility-owned total energy system will be in the house resale market. It is possible that

such installations will be readily acceptable by new homeowners who may even seek them out if the economics of the system are more favorable than conventional energy supply costs. On the other hand, if experience with such utility-owned systems is less than satisfactory, homeowners may be reluctant to accept an agreement with the utility that may restrict their use or disposition of the property. In any case, private dwelling resales could become very much more complicated when a solar total energy system is installed whether owned by the homeowner or by someone else.

If the homeowner owns his own solar total energy system, he alone is responsible for its maintenance and service to ensure reliable operation. The complexity of the system requires that such work be done by skilled personnel. Moreover, the fact that the STES provides lighting as well as heating and cooling means that the homeowner will be much less willing to tolerate interruptions in the service than he has been with his heating and cooling system. When the power goes off, he is accustomed to calling the local electric utility and becomes impatient if immediate action is not taken to restore power.

If the STES relies upon electric utility back-up electricity supply, electricity loads may be supplied automatically in the event of a failure of the STES; but if the unit is independent of the electric utility system, the homeowner is left to the resources of his maintenance and service contractor.

Experience with fossil-fuel total energy systems independent of utility power has clearly demonstrated the need for sophisticated and responsible maintenance and service under the direction of one person or organization. If the system ceases to function, it may not be obvious to the homeowner whether the services of a plumber, an electrician, or another technician is necessary. He will want to call someone who will assume responsibility for correcting the trouble and who will bring to the home a crew of technicians who are skilled in all aspects of the STES and can quickly correct the problems and place the system back in service. This caliber of maintenance and service will be more expensive than the usual cost of service for heating, plumbing, and electrical repair services. This kind of service is usually handled most effectively on an annual contract basis which permits the service contractor to do preventive maintenance in order to minimize the number of emergency repairs, nighttime, and weekend service calls. In any case, the annual cost of such maintenance

and service charges must be included in the projected annual operating costs for a solar total energy system. If the homeowner is not aware of these costs before committing himself to such a system, he may become dissatisfied with the system and discourage others from installing them.

Quite aside from actual cost, the problem of maintenance and service is a psychological problem to many homeowners. They have been accustomed to extremely reliable electric utility service as well as heating system reliability. The additional complexity involved in an STES suggests that there will be inherently lower levels of reliability and longer periods of interrupted or impaired service. This will be a very critical item, particularly during the early stages of the development of solar total energy systems, when there are a small number of scattered installations and relatively few trained and experienced service personnel.

These problems relating to personal ownership of an STES in a single-family dwelling appear to be more formidable than in multi-family dwellings. For this reason we expect that prospective manufacturers of STES's will prefer to explore and develop the multi-family dwelling segments of the residential market before attempting to penetrate the single-family dwelling market.

For this reason, much of this study is addressed to the multi-family dwelling market where larger units can be applied and where business accounting practices acknowledge depreciation costs, limited liability, etc.

5.3 Multi-Family Dwelling Market

From the point of view of ownership there is little difference between high-rise apartments, low-rise apartments and attached town houses. Some distinction must be made between rental units and condominiums, however.

5.3.1 Rental Units

STES Owned by Building Owner

When the solar total energy system is owned by the building owner he can define all of the characteristics of both and can also control the operation and servicing of the system. Since the occupants of the building are tenants, they have no control over the system except to accept it or to relocate. Thus, this option probably represents the maximum of centralized control of all aspects of the STES.

Experience in gas-powered total energy systems a decade ago generally showed that the rate of return from a total energy system was less than the rate of return from the building investment alone. Thus, the investor usually preferred to put his money into the building structure and minimize his investment in the major capital items necessary to provide utility services. Basically, the savings from using exhaust heat from prime movers (to provide electric power) for space heating and cooling did not offset the added capital investment by an amount sufficient to provide a more attractive alternative than the use of conventional utility services.

A solar total energy system is, of course, a different type of system than a gas (or oil) fired total energy system. The solar energy cost includes only the fixed cost of the collection and conversion system. A greater saving in energy costs can be made which can in turn offset a greater amount of capital facilities. Nevertheless, a large capital investment is involved and the building investor must decide whether his rate of return is improved by the addition of the STES. With a given amount of capital he can build a larger building using utility service or a smaller building with an STES.

This is the form of ownership which the developer of STES's would most prefer to work with for several reasons:

- There is one central authority to make decisions regarding any and all aspects of the system and the building.
- The owner must take a balanced view of the total installation including not only cost factors in the building, as well as the STES, but also the operating and maintenance costs and the resale value of the property.

However, this situation is obtained only in a relatively small number of instances in which some individual, or group, designs and builds a structure to use an STES, and plans to continue ownership and operation of the building as residential rental property throughout the economic life of the building. Public housing is a good example.

More often, the building owner is an investor interested primarily in maximizing the return on his investment in the building. Since the rates of return on rental income property are generally higher than the rates of return on utility services, an STES installed in rental property must provide a rate of return as attractive as that on the building itself to justify its use by a building investor.

STES Operation

The owner of a multi-family rental property may be an individual who lives in the building, or nearby, and assumes the role of landlord. Such an owner can be presumed to have some understanding of an STES that has been installed and sufficient knowledge to operate it in an effective manner. The system should not require 24-hour supervision but certain manual adjustments may be necessary to obtain efficient performance under varying operating conditions.

Other buildings may be owned by a group of investors or a corporation which employs a professional staff to perform janitorial services. Experience with fossil-fuel total energy systems has shown that janitorial personnel are often incompetent to operate such systems in an efficient manner if technical judgment is required in selecting various modes of operation.

Thus the STES must be almost completely automatic, using building personnel simply to report malfunctions; otherwise, professional staff must be maintained on at least a part-time basis. This requires the designer of the STES to trade off labor costs against the cost of automatic equipment. This usually results in selection of automatic controls plus periodic monitoring by skilled service personnel.

STES Service

Regardless of who monitors the operation of the STES, its service and maintenance will require the use of skilled technicians. Again, experience has shown that in other total energy systems as well as in heating, ventilating, and air-conditioning systems, an annual service contract permits the most effective service arrangement. This permits the service contractor to periodically inspect and service each system, thus minimizing the number of actual breakdowns and interruptions in service.

For this reason most building owners will probably contract for system service with companies specializing in such work. Exceptions to this may be small installations and those where the building owner takes a personal interest in the system. The annual service contract will be an important part of

the operating expense of the STES and a responsibility of the building owner. Until actual experience is obtained, the cost of an annual service contract will be an uncertain element in the annual cost of an STES.

Utility Ownership of STES

The building owner can preserve his own capital by subcontracting the utility service provided by an STES to someone else, as he does now by providing conventional utility service. The logical choice is the local utility itself.

The local utility may be either a gas utility, an electric utility or a joint utility providing both gas and electricity. A gas utility has an exclusive franchise to distribute gas but is excluded from distribution of electricity by the exclusive franchise of the electric utility serving the same area. Thus, the operation of a total energy system by either utility alone raises some legal questions regarding possible infringement of the other's franchise, or at least, imposes certain possible restraints on these utilities. A joint utility holding both franchises does not have the same problems as the straight gas or electric utility.

The experience with gas-utility-owned total energy systems tested many of the legal questions, and it is generally permissible for a gas utility, for example, to supply electricity provided that transmission of the electricity across public property is not involved. Some electric-utility franchises prohibit the resale of electricity to others, however, and it may be necessary to examine this problem carefully in individual cases to ensure that utility franchises are not violated by the manner in which tenants are metered and billed.

Electric utilities have less severe problems because even where gas must be the back-up fuel it will probably be converted to heat in the STES and there are no restrictions on the distribution of heat (or cold). Moreover, the STES may be all-electric or use oil as the back-up fuel.

Siting Problems

Assuming that the utility is willing to provide the STES, there may be difficult problems of locating utility-owned facilities on the property of the building owner. The rooftop is the logical location for solar collectors and

either rooftop or basement locations have been favored for energy conversion and storage facilities. Some complex legal agreement is necessary if a utility-owned STES is to be integrated into the building it serves.

A simpler alternative is to locate the system on utility-owned property adjacent to the building (or buildings) and to distribute heating, cooling, and electricity to the building. This alternative has an influence upon the design of the system and may favor an all-electric system to facilitate the distribution of energy to each residential unit. In this case either electricity storage or an electric-utility interconnection is necessary. The problems relating to the interface between the STES and the utility are discussed in a later section because of its importance and the significance of some of the broader aspects of the problem.

There is also the possibility that a utility-owned STES may serve more than one building, permitting benefits of scale and perhaps more efficient use of utility property. Nevertheless, the problem of locating the solar collectors owned by the utility is still a problem that may have considerable influence upon the design and economics of the entire installation.*

Maintenance and Service

Maintenance and service problems are greatly simplified by utility ownership. It is relatively easy to ensure that trained and experienced personnel are available to keep solar total energy systems in operation and to supply emergency power during any interruptions, either scheduled or unscheduled, through the use of utility power connections or with temporary mobile power supply systems designed for that purpose. While such services would be part of the cost to the residential user, such costs should be no more expensive than any other contracting arrangement. It is not likely that a utility would allow operation of the system by others except for the possibility of subcontracting service to a qualified contractor, initially. However, the existence of the normal service organization should permit a utility to expand and provide its own service economically after it acquires or trains sufficient personnel for the work.

* Some groups and individuals are lobbying to prohibit utility involvement in the manufacture and sale of solar components, particularly in California.

Service Problems With Other Total Energy Systems

Some comments on past experience with fossil-fuel total energy systems may be in order at this point. A number of years ago gas distribution utilities made an extensive effort to promote the use of gas-fired total energy systems in large residential and commercial installations such as apartment houses, shopping centers, schools, and commercial business establishments. A number of problems arose. The components of such systems were supplied by a variety of manufacturers, each with his own terms for warranties and guarantees. When maintenance and service was required, it had to be furnished by a representative of the manufacturer as long as his equipment was under warranty. This meant that a utility could not assume responsibility for maintenance service entirely and was dependent to a considerable extent on the service personnel of the various manufacturers involved. As might be expected, some were better than others.

It was not unusual for a total-energy plant user to call his local utility when he had difficulty and experienced the following sort of routine: The utility would send a service man who would determine that there was a problem with a gas engine. The gas-engine service man would be called and he would determine that the engine was functioning satisfactorily, but that a circuit-breaker on the control panel was tripping it out. The circuit-breaker service man would be called, and he would determine that the circuit breaker was functioning properly, but that the installer had wired it improperly. The contractor who installed the circuit breaker might report that he was no longer in the business. This problem of fixing responsibility before corrective action can be taken is time-consuming and expensive. If solar total energy systems are to be made attractive to the residential market, some means must be found to make repairs and part replacement directly without the delay of implicating servicemen of each manufacturer who may be involved. Since the utility is not a manufacturer, it does not ordinarily assume responsibility for the warranties of equipment that it may install and use. On the other hand, the manufacturer is not likely to allow the utility serviceman to service its equipment in the field unless there is some prior agreement with the manufacturer. This situation presents a difficult problem in providing prompt service on a complex system such as a solar total energy system involving many component suppliers. This leads us to the consideration of non-utility ownership.

STES Owned by Commercial Company

Another alternative available to the building owner is to subcontract the STES to a company specializing in the ownership and operation of STES systems but not operating as a utility. In the past a number of companies have engaged in the business of building total energy systems for commercial buildings, shopping centers, etc., and either operating them for others or operating them while retaining ownership.

This situation would generally be similar to utility ownership but would have some significant differences.

The franchise infringement hazard would be similar to the utility case, but there are precedents for such operations.

The commercial company would have this function as its main line of business rather than a sideline as may occur in the case of the utility. The utility interface problem is different in that the utility is involved in the interchange of power only and is similar to the situation when the STES is owned by the building owner.

The commercial company would, in all probability, provide maintenance service itself, although operating staff might be building service personnel responsible only for reporting operating difficulties.

However, such companies would become substantial customers of component manufacturers because of the number of STES plant they would build and operate. They could obtain agreements with suppliers to permit them to replace or service components without involving manufacturer's service personnel. This would greatly simplify and expedite the repairs necessary to reduce unscheduled outages.

5.3.2 Owner Occupied Units

Where multi-family dwellings are owned by the occupants of each unit, as in the case of condominiums, the problems of STES ownership favor utility or commercial ownership rather than ownership by the building owners.

In most condominiums a separate corporation contracts to provide landscaping service, swimming pool operation, and maintenance and operation of other common facilities such as health clubs, tennis courts, and other recreation facilities. These companies are not generally staffed to manage an STES.

Thus it would be more practical for a utility or a commercial firm specializing in this business to own and operate an STES serving a condominium.

In the event that a multi-family rental project, containing an STES owned by the building owner, is converted to condominiums, the problem of ownership and operation of the STES could be a serious deterrent, particularly if the system is highly integrated into the building structure.

Section 6.

REVIEW OF INSTITUTIONAL ASPECTS

6.1 Financial

Certain financial aspects of the ownership of an STES have been discussed in the preceeding section. Certain other aspects are worthy of note here.

6.1.1 Taxes

One of these is the increased property taxes that may be assessed on private real estate containing an STES. Since the capital cost of a total energy system may be substantial, it can result in a corresponding increase in the assessed value of a property and result in significant higher property taxes. This can be a very significant item in the single-family private dwelling market that would effectively deter the homeowner from considering the installation of an STES unless some specific provision is made for this particular item of taxation. In the multi-family dwelling market, this additional tax load becomes an increased part of the expenses that must be offset by a solar total energy system in order to make it attractive to the building owner who must weigh the total cost of an STES against the projected cost of utility energy supply. In the case of a utility-owned and operated STES, however, where the unit is installed on utility property adjacent to the residential structure, such real estate taxes become a cost element in the utility accounting and financing of the project.

Many municipal and county taxing authorities derive a significant portion of their tax revenues from the real estate taxes imposed upon public utility generation, transmission, and distribution facilities. While they may agree in principal to the reduction of real estate taxes on solar total energy systems, they may then be faced with a prospect of losing utility tax revenue since the utility facilities will not expand as rapidly as the general growth of the community. Thus, increased tax levies in other areas may be required to make up for the deficiency in tax revenues. In the case of utility ownership of the STES, of course, this problem does not occur since taxes may be levied on utility generation and distribution in whatever form and at whatever location they may be built, but they will be added cost items in the STES budget.

6.1.2 Earnings

The rate of return allowed a public utility is on the order of 5% or 6% annually in real terms excluding inflation allowances. Real estate investors are accustomed to much higher rates and may seek to obtain 15% to 20% under favorable circumstances. Even though they may not achieve the anticipated rate of return, their planning efforts are usually based upon an expectation much higher than that of the public utility.

In view of this disparity in earning power, the building investor may be dissatisfied at the prospect of earning, perhaps 8% in real terms. He will prefer to provide conventional utility service which requires little or no capital on his part, preserving his funds for real estate investment.

A utility which can foresee making a return comparable to its regulated rate of return may still be interested because it would then be capable of providing utility service at equal or lower cost than conventional utility service.

Unless a rate of return comparable to utility rates can be foreseen, an STES will not be economically attractive to businessmen.

Initially because of low-volume production the cost of an STES will be high, and it may be unattractive compared with the cost of conventional utility service. At present, much attention is being given to ways and means of temporarily offsetting these high initial costs through tax allowances, subsidies, and other devices. However, in the long run, the STES must be competitive with conventional utility service without such subsidies. That is, it must be possible to foresee some point on the production learning curve where subsidies are unnecessary, and the STES can compete on its own merits.

6.2 Material

6.2.1 Reliability of Service

One of the material aspects of solar total energy systems will be the frequency of service interruptions. Homeowners have generally been accustomed to very reliable utility services and usually receive prompt attention simply by calling the local utility when service is interrupted. No further follow-up is usually required and no expenses are involved that are billable to the homeowner except for service that may be required on the components of the system

that are actually owned by the homeowner. This practice has become so ingrained in our normal living patterns, that a homeowner served by a solar total energy system will expect to receive the same reliable service that he has received in the past from his public utility. The ability to provide this degree of reliability in an STES presents a very formidable challenge to the builder and the operator of a system. Past experience with gas-fired total energy systems suggests that this may be the most critical question affecting the acceptance of solar total energy systems by the residential market.

The reliability of service can be greatly enhanced by designing the STES so that it is automatically backed up by gas and electricity services. In this case, many of the malfunctions which may occur result in shifting to the utility services until such time as service personnel can clear the malfunction. Special electronic monitoring systems that will automatically report malfunctions to the servicing organization can permit repairs to be made to malfunctioning systems without the necessity of having the resident report them. This is particularly important where homes may remain unoccupied for extended periods of time.

An additional factor of growing importance is that of obtaining entry to a residential dwelling for the purpose of making service calls or repairs to systems accessible only from within the dwelling. This has become an increasingly serious problem in recent years because of the growing percentage of working wives resulting in an increasing number of unoccupied dwellings during the day. The second problem is the growing tendency among homeowners, particularly in some urban areas, to refuse to allow strangers to enter the home or to allow service personnel to work in a home unless the homeowner is present. This problem has led to the widespread installation of electric and gas utility meters outside of the building and has encouraged the installation of air-conditioning equipment and even heating equipment outside of the dwelling or in enclosures that are accessible from the outside. The problem will be easier in multiple-family dwellings where the solar total energy system is installed separately and only the heating, cooling and electricity generated are delivered to the individual dwellings.

6.2.2 Building Codes

The technological evolution of housing construction has always been hampered by building code restrictions. These codes cannot be set aside for they are needed to maintain building quality standards. Nevertheless, innovations such as solar total energy systems may present many conflicts with existing codes designed without such systems in mind.

There is no easy solution to this conflict. A program is needed similar to that which was used to revise building codes to facilitate energy conservation. The applicable codes must be reviewed by technical committees familiar with STES detail requirements to identify changes, exemptions, additions, etc., that will facilitate STES design and installation without impairing building quality standards. This cannot be done until detailed designs of STES's are available and installation problems have been examined. However, it must be started as early as possible because of the time required to process code changes.

6.2.3 Development Timing

The commercial sale of solar total energy systems is perhaps a decade away. In the interim we can foresee a market developing for the sale of solar heating and perhaps cooling systems. Certainly supplemental water and space heating systems will be available.

The heating, ventilating, and air-conditioning industries and the oil-heating dealers are already offering commercial products for sale. This is a logical outgrowth of these businesses, and we can foresee that these organizations will be in the forefront of the marketing of solar heating and cooling systems long before STES's are offered for sale.

The success of those ventures in marketing solar heating and cooling will provide not only marketing knowledge for the STES but in all probability will provide the marketing organizations as well. The service corporations contracting to maintain and service STES's will be companies already developed in the HVAC industry.

Even where utilities own such systems, service may be contracted to these companies. The experience of the gas-utility industry is significant. The efforts of the utility industry to market gas air-conditioning installations met with effective resistance by local air-conditioning contractors and re-

sulted in arrangements whereby such contractors were employed to install air-conditioners sold by a utility. If it appears that utility ownership may capture a large share of the STES market we can expect reactions from the HVAC industry and the labor unions serving it.

In any case it is important to anticipate the existence of a significant solar equipment industry before the advent of solar total energy systems.

6.3 Technological

6.3.1 Training

The technological development of solar total energy systems is being generously financed by the Federal Government and promises to result in a wide variety of solar systems varying in degree of complexity and sophistication. As in most areas of commercial product development in the United States, there appears to be no lack of interest in developing suitable equipment to fit the various types of applications that can be foreseen. If the development of solar total energy systems parallels that of heating, ventilating, and air-conditioning equipment, we can expect that most of the marketing problems will center around the problems of service and maintenance. It is already apparent that this industry will participate very heavily in the sale, installation, maintenance, and service of solar energy systems of all kinds. By the time solar total energy systems become available commercially, we can expect that the heating, ventilating, and air-conditioning industry will have developed technicians trained and skilled in the maintenance and service of solar heating and cooling systems. However, the service of solar electric generation systems will represent a new area of technology requiring somewhat different skills and experience that will require special training and education programs before reliable maintenance and service is generally available. To provide this support in timely fashion, it may be necessary to provide Federal Government support in education and training programs in anticipation of the need of skilled technicians.

6.3.2 Technical Obsolescence

An additional problem that can be anticipated is the rate of obsolescence of solar total energy systems as improved technology permits the design of more

efficient and lower cost systems. Since there is much new technology involved in the development of solar collectors, energy conversion devices, and energy storage systems, as well as overall system design and controls, we may expect that solar total energy systems may tend to become outdated long before the dwellings in which they are installed become obsolete. It is possible that solar total energy systems may become outmoded and be replaced more than once in the life of a single building. Thus, the type of system and its age may become an important factor in its resale value of the residential property in which it is installed. For this reason a mortgage company may take a keen interest in the quality and operating condition of a solar total energy system installed in a property covered by its mortgage. This problem may not be as severe in the case of a solar total energy system that is owned by a utility or some other service company which contracts for the supply of service to the dwelling. This problem is another reason why prospective manufacturers of solar total energy systems may prefer to enter initially into multi-family dwelling markets in preference to the single-family privately-owned dwelling market.

One particularly critical question which is now apparent is the use of photovoltaic converters versus heat-engine-type electricity converters. The long range outlook suggests possible improvements in photovoltaics that could make heat-engine-type converters less attractive. Yet, there is currently no assurance that this development will actually materialize. If it does, many STE systems using heat engines could become obsolete before their economic life has expired. This could affect the value of the real estate served by such systems.

6.4 Regulatory

6.4.1 Solar Systems/Utility Interface

Perhaps the most important problem pertaining to the regulatory aspects of solar total energy systems is the problem of the interface between the solar total energy system and the utility service connection. Since solar energy is not available continuously, every solar total energy system must be backed up by some form of energy/fuel supply. For the purpose of this discussion we will assume that adequate energy storage systems are not available, either for technical or economic reasons, and that some form of back-up energy supply is neces-

sary. We might note that it is possible to use fuel oil as back-up supply if a heat engine is used to generate electricity. This would avoid the necessity for utility connection.

6.4.2 Gas Utility Interface

Gas utilities are taking an active interest in solar heating and cooling systems and some of them plan to make such installations using solar energy to supplement the gas supply. Such systems currently do not include the generation of electricity, and are intended to fill out energy demands of customers curtailed by gas supply restrictions. Although the straight gas utility can readily provide a utility tie-in and back-up service on a solar heating and cooling system, it can provide backup to a solar total energy system only if the gas supply is to generate electricity onsite for the customer's use without resale to the general public.

Where the solar total energy system uses a heat engine to generate electricity, a gas utility can provide all of the utility backup necessary. If a photovoltaic system is used, an electric utility back-up system is required or a separate electric converter such as a fuel cell would be needed.

6.4.3 Electricity Utility Interface

An alternative arrangement is to tie in the STES with an electric utility system so that shortages of solar energy are made up by electricity generated by the utility. Legally, this situation is somewhat simpler in that there is no encroachment upon the rights of a local gas utility serving the same area even though natural gas service may be provided since the electric utility does not offer to sell natural gas itself. Thus, a solar total energy system could use natural gas utility service to back up its heating demand while using electricity from a separate utility service to back up its electrical demand.

6.4.4 Technical Problems

It has been common practice among electric utilities to prohibit connections between its utility service and any locally installed electrical systems. There are a number of reasons for this restriction. First, such a connection would permit a residential electric generating system to feed electricity back into the utility system. Second, at any time even if that part of the system has been taken out of service, running the utility meter backward would, in

effect, permit the local generating plant to produce and sell electricity to the public utility at its residential rate. In this way a homeowner could conceivably obtain the benefits of utility back-up service including significant quantities of the utility electricity at certain times and yet by generating his own electricity to run the meter backward would pay very little for the benefit of this utility service.

Consequently, the electric utility service connection must be much more complex than a conventional service. Reverse current relays or some similar device must be installed to prevent any flow of current into the utility system when it has been isolated to permit working on the lines. Also, an additional meter must be provided to measure reverse flow separately from inflow because the two flows will be billed at different rates. Time-of-day metering is also needed.

The quality of the electricity fed into the utility system is also of concern to the utility. Solar-generated electricity will usually be d-c power or high-frequency a-c power that must be converted to 60-Hz a-c power and synchronized with the utility power supply. If the power factor of this supply differs greatly from the utility supply, the utility must provide power factor correction equipment to match the power factor of the system. This is not a problem in small systems, but as the number of such installations grows, it may be necessary to add power factor correction.

For this reason utilities are concerned about the specifications of any converter used to produce the 60-Hz a-c power fed back to the utility. Some have considered requiring that this component be part of the utility service connection so that the utility accepts d-c or other types of generated current and converts it to 60-Hz a-c in its own equipment.

Needless to say, these complications will increase the cost of the electric utility service connection in multi-family buildings. These costs must be recovered either in monthly demand charges or increased rates or both.

6.4.5 Utility Viewpoint

Many proponents of STES look upon the electric utility interconnection as an infinite energy sink capable of usefully absorbing all of the electricity

generated from solar energy that cannot be used immediately at the point of generation. The electric utility may have quite a different point of view.

Each electric utility has a system comprised of a variety of electricity-generating units, each with its own incremental cost of generation. These are normally used in approximately the order of their bus bar generation cost. The most economical ones are loaded to their most efficient operating points first, and higher cost units are added in order as the load requires.

A solar electric generating unit, or a group of such units, will contribute to the load in accordance with the intensity of solar radiation irrespective of the utility load requirements. The magnitude and timing of this energy supply is not under the control of the utility. It must accomodate this supply by adjusting other generating units accordingly. The economic value to the utility of the solar energy fed into its system is equal to the generation cost of electricity from the unit that must be shut down to accomodate the solar energy contribution, plus or minus local intrasystem transmission costs. Therefore, the rate that it can afford to pay for solar-generated electricity must be equal to or less than the incremental generation cost of the unit shut down. If it is higher, the overall generation cost is increased and other rate-payers must absorb the difference. If it is lower, the other customers may benefit. The utility itself is regulated at a fixed rate of return, and benefits only as the scale of its operations is increased. This may occur if the utility owns the solar total energy system. It may also result in higher electricity-generation costs if the solar system generation cost is higher than the generation cost of the equipment it would otherwise be using.

The utility is most likely to be interested in STES's if they result in lower overall average bus bar generation costs for its system. Until this can be shown, we expect that electric utilities may resist solar energy system interconnections.

This discussion is addressed to the basic economic issue involved but it is a very much oversimplified treatment of a very complex economic problem. The interactions of fixed costs, operating costs, time-of-day generation costs, responsibility factors for various types of loads, intrasystem transmission and distribution costs, and a host of other factors must be considered.

At present there is considerable public pressure for utilities to offer special rates making it attractive to attach windmills, solar-generating plants and other electricity-generating devices to the local electric-utility grid. If these rates generate less revenue than the use of the alternative generating units would permit, other rate payers must subsidize this practice. This policy is directly contrary to the concept of incremental pricing that is also being advocated publicly. It would therefore be imprudent of anyone planning an STES to depend upon electric utility interchange rates that do not reflect the full cost of service until this inconsistency in policy is resolved.

6.4.6 Alternatives to Utility Interchange Connections

It may be observed that if a utility can obtain solar-powered electricity-generating units capable of reducing its bus bar generation costs, it has an incentive to generate electricity in this manner on its own. By avoiding the more complex utility service connection and lack of control, it should be able to offer solar electricity cheaper than the homeowner can generate it. Thus, it may be possible for the homeowner to use his solar energy for heating and cooling while purchasing his electricity (solar power included) from his utility.

Additional alternatives may also be considered. If the solar electricity-generating unit is a form of heat engine, heat can be provided by burning fuel in the absence of solar radiation. This fuel can be stored oil or LPG or natural gas delivered on demand by a gas utility.

If the solar electricity-generating unit is a photovoltaic system, it may be backed up by a fuel-cell system fed by natural gas or stored LPG and a gas reformer. The evaluation of these alternatives is quite complex because it is necessary to compare service and reliability as well as fixed and operating costs.

A "Study of Solar System — Electric Utility System Interface" by Electric Power Institute, Texas A&M University (Contract No. 05-4563, Sandia Laboratories, Albuquerque, New Mexico) addressed the subject of the interface of solar total energy systems with an electric utility located in Dallas, Texas. The specific STE system studied was a 2-MW generator driven by a Rankine-cycle turbine supplied by a focusing, tracking solar collector together with equipment to utilize turbine exhaust heat to supply air conditioning, space heating, and water heating loads of industrial, commercial, and apartment consumers in the vicinity of the solar unit site. This study was not based on the same STES siting

assumptions as this current study, nor on the same general system sizing; nevertheless, some of the results and conclusions would appear to be pertinent.

This study concluded that the available solar energy and electric utility peak loads would coincide reasonably well for a utility with a large amount of summer air-conditioning load, but peak solar insolation generally occurs 2 to 3 hours before the utility summer daily peak load; furthermore, solar systems make little contribution to reducing peak loads on hot, cloudy days. The incremental value of additional solar units decreases as the number of STES installations increases (the "saturation" effect, primarily because of the inability of the STES to reduce loads on hot, cloudy days; this "saturation" effect becomes less of a consideration as fuel prices increase). High temperature storage permits better management of solar energy and benefits conventional capacity, thus becoming useful in overcoming the "saturation" effect; this becomes less important as fuel prices increase for a given conventional capacity size. Increasing the collector size (for a system that is part of the utility's system) becomes very important when the number of systems is small and can double the breakeven cost of the STES; however, this becomes much less important as the number of STES becomes large because the utility cannot effectively use all of the solar energy collected. STE systems without storage have few load improving features, although some load factor improvement is possible when the number of STE systems is small.

A summary of these effects reflected in the effect on breakeven costs is shown in Table 53, taken from the report on the interface study.

Table 53. BREAKEVEN COSTS OF SOLAR CAPACITY

No. of Units	Case		Annual Capital Charge Saving* M\$	1975		1977		1981		1985	
	Collector	Storage		Annual Fuel Saving M\$	Solar Breakeven \$/kW	Annual Fuel Saving M\$	Solar Breakeven \$/kW	Annual Fuel Savings M\$	Solar Breakeven \$/kW	Annual Fuel Savings M\$	Solar Breakeven \$/kW
100	X1	No	11.25	4.89	448.	8.30	543	14.62	719	19.50	854
200	X1	No	16.65	8.98	356.	15.26	443	26.82	604	35.74	728
400	X1	No	18.00	14.65	227.	24.80	297	43.32	426	57.69	526
100	X1	Yes	13.05	4.75	494.	8.08	587	14.25	758	19.01	891
200	X1	Yes	23.40	9.11	452.	15.49	540	27.30	704	36.39	830
400	X1	Yes	40.05	16.20	391.	27.50	469	48.35	614	64.44	726
100	X2	Yes	21.60	8.61	839.	14.65	1007	25.82	1317	34.42	1556
200	X2	Yes	40.05	16.05	779.	27.26	935	47.92	1222	63.87	1443
400	X2	Yes	51.75	24.45	529.	41.48	647	72.43	862	96.46	1029

* Based on approximately constant reliability. All values are based on a fixed charge of 0.18, and conventional capacity cost of \$500/kW.

Section 7.

IDENTIFICATION OF PERTINENT GOVERNMENT ACTION

Most of the actions being taken or proposed by the Federal Government are addressed to the individual homeowner. They are aimed at relieving the financial burden of costs that cannot be passed on to others as business firms can do with increased business expenses.

Since rental income property is operated as a business, its activities are affected by those government actions taken to aid small business rather than individual homeowners. Even where the dwelling is a condominium, its construction was part of a business venture until the completed dwelling was sold to the homeowner. Therefore, only the retrofitting, add on, and operating expenses are directly influenced by government actions intended to help the individual homeowner. Nevertheless, such actions as corporate income tax credits, low cost business loans, etc., have an indirect benefit in reducing the cost of the STES that he may buy or indirectly pay for in the form of rent.

7.1 Tax Relief

Most of the government actions taken on behalf of homeowners using solar equipment are in the form of income and property tax relief measures designed to reduce or eliminate any penalties incurred in choosing solar energy equipment over conventional energy-consuming equipment. A list of such measures passed by various state legislatures is presented in Appendix A to indicate the type of action being taken at the state level. Similar measures providing relief from Federal income taxes can be taken at the national level.

These actions are capable of reducing the cost of an STES by perhaps 10% to 25% and will be very effective where the cost of an STES is that close to the cost of an alternative such as conventional utility service.

7.2 Support of Research and Development

However, the most effective government action, by far, is the support of technological research and development work aimed at reducing the cost of STES's both directly and indirectly through improvements in efficiency, performance, operating life, and reliability.

The tax relief measures are politically attractive because of their visibility, while R&D support is not only less apparent but may appear to some to be aiding industry rather than the user of an STES.

7.3 Revision of Codes and Laws

Federal Government support of projects to review and revise building codes to facilitate installation of solar equipment is needed and could be carried out along the same pattern that was recently used in revising building codes to improve energy conservation. Utility franchise laws that permit electric utilities to refuse utility backup of nonutility energy supplies can be revised so that back-up service can be provided where it is economically acceptable to the user.

Federal laws clarifying air rights to prevent screening of adjacent property (i.e., "sun rights") in urban areas is also needed. However, these matters affecting solar heating and cooling systems will in all probability be resolved to accomodate heating systems installation problems before solar total energy systems are marketed in any volume.

Section 8.

SYSTEM COSTS *

Projected costs for individual components of the STE designs were developed as part of the Market Penetration effort or derived from other sources, such as the IGT draft report on "Advanced Coal-Using Community Systems" and the prepublication (June 1977) draft report by the Office of Technology Assessment on "Application of Solar Technology to Today's Energy Needs."

8.1 Capital Costs of Conventional Systems

The costs of conventional systems for the three major residential building types (single-family-detached dwellings, townhouses, and low-rise apartments) were obtained from trade literature or contractors and escalated to 1978 wherever possible. For example, construction costs for piping and ductwork have increased approximately 40% during the past year; this means that ductwork costs for heating systems have increased from roughly \$1/sq ft of floor area to \$1.40/sq ft. This increase in ductwork installation results in an overall increase of approximately 30% in the installed cost for a unitary heating system. (Private discussions with contractors.)

Sizes for heating and cooling systems were determined from the design specifications for the different building types, and the heating/cooling requirements determined for the different regions of the country. This was done for electric, gas-fired, and oil-fired systems, taking into consideration the sizes that are currently available.

In general, capital costs of electric systems are lower than those for gas-fired and oil-fired systems in all regions, and overall systems are somewhat more expensive in warmer climates because the greater requirements for air-conditioning are more costly than the difference in heating system requirements.

Central systems are considerably more expensive for apartment buildings than individual (unitary) systems, but could be the system of choice in cities where land costs and construction costs are highest. Since unitary systems

* In 1975 dollars, unless otherwise noted.

require more floor area in each apartment to install individual hot water heaters and heating equipment, the cost of the increased floor area must be added to the cost of the building. Thus, the trade-off between building costs and system costs is a function of land and construction costs. A realistic comparison of costs between STES and conventional systems, therefore, should reflect this factor.

The costs of both central and unitary conventional systems are shown in Table 54 for single-family detached units, townhouses, and low-rise apartments.*

8.2 Capital Cost of ORC-Based STE Systems

The capital costs of solar total energy systems based upon organic Rankine cycle generators and absorption chillers are shown for both the 300°F system (Table 55) and the 600°F system (Table 56). Costs of individual components were taken from the same sources indicated for the conventional system, as well as the team consultants — Honeywell, Sundstrand, and Ormat. Collector costs are shown in Appendix B of this volume as well as in Volume III. ORC costs are shown in Volume III. Storage costs were developed from data in Aerospace Corp. Technical Progress Report on "Solar Thermal Dispersed Power Program, Total Energy Systems Project," (August 1977) DOE Contract No. EY-76-C-03-1101.

The cost of the STE systems is obviously region-dependent. For this reason, the summary cost sheets show collector costs and storage costs as a range of values. Regional collector costs are included in the regional comparison with conventional costs; however, storage cost differences for the various regions have been estimated without benefit of the design evaluations, and will require some modification. This does not constitute a major cost center for the systems, and does not have an appreciable impact on the preliminary market penetration assessment.

Regional cost comparisons of STE systems and conventional systems are shown in Tables 57 and 58 for the single-family detached, townhouse, and low-rise apartment units. Cost comparisons are shown for an aggregate of 36 single-family houses, 36 townhouses, and a 48-unit low-rise apartment building; these values were also converted to a cost per dwelling unit, so that a comparison with unitary systems could be made.

* These costs were taken from several sources: "Advanced Coal-Using Community Systems" draft report by IGT (1977); OTA prepublication report, "Application of Solar Technology to Today's Energy Needs, Volume II;" manufacturers' price catalogs; and personal conversations with contractors.

Table 54. ESTIMATED CAPITAL COSTS, CONVENTIONAL SYSTEM (1975 Dollars)

	UNITARY COSTS		
	<u>Single-Family</u>	<u>Townhouse</u>	<u>Low-Rise Apartment</u>
Number of Units	36	36	48
Hot Water,			
Electricity	\$10,800	\$10,800	\$14,400
Gas/Oil	\$10,800	\$10,800	\$15,840
Space Cooling,			
Electricity	\$30,960 (North)*	\$30,960 (North)	\$29,520 (North)
(Through wall, Low-Rise)	\$46,440 (South)*	\$46,440 (South)	\$39,360 (South)
Space Heating,			
Gas	\$104,400 (North)	\$90,000 (North)	\$100,800 (North)
	\$95,040 (South)	\$90,000 (South)	\$96,000 (South)
Electricity	\$97,560 (North)	\$89,568 (North)	\$91,200 (North)
	\$94,140 (South)	\$87,660 (South)	\$86,400 (South)
Oil	\$106,200 (Both)	\$106,200 (Both)	\$106,200 (Both)
Total	\$146,700 - \$163,440	\$129,420 - \$163,440	\$130,320 - \$161,400

CENTRAL SYSTEM COSTS (Low-Rise Apartment - 48 Units)

Hot Water	\$26,000
Cooling (100-ton absorption chiller)	\$60,000 (including cooling tower)
Heating (160 fan coil units @ \$600 ea.)	\$96,000
Piping	\$10,000
Heater	\$5,400
Total	\$197,400

* North is for northern location (Boston). South is for southern location (Dallas).

Table 55. ESTIMATED CAPITAL COSTS, 300°F ORC STE SYSTEM (1975 Dollars)

<u>Component</u>	<u>Size</u>	<u>Unit Cost</u>	<u>Life</u>	<u>Total Cost</u>
Solar Collector	Region-Dependent	\$20.13 - \$22.13/sq ft	20	\$219,500 - \$386,000 ^a
Storage, High-Temperature	None Required			
Storage, Low-Temperature	4 X 10 ⁶ Btu	\$1500/10 ⁶ Btu	20	\$6,000
Auxiliary Heater	5,000,000 Btu/hr	\$15,000	20	\$15,000
Standby Heater	2,000,000 Btu/hr	\$5,400	20	\$5,400
ORC System, 300°F	100 kW _e	\$700/kW	20	\$70,000
ORC Cooling Tower ^b	310 Tons	\$120/Ton	20	\$37,000
Chiller, Absorption Unit ^b	100 Tons	\$600/Ton	20	\$60,000
Pumps and Controls	--	--	20	\$12,000
Battery and Power Conditioner	50 kWhr; 100 kW	\$50/kWh + \$75/kW	10 (battery) 20 (invert)	\$12,500
Hot Water System	180 gal	\$2000 + \$500/unit	15 - 20	\$26,000
Ducts, Piping, and Heat Terminals	--	--	20	\$106 - \$140,000 ^d
Electric Grid Connection	--	\$7,500	20	\$7,500
Pipefield, SFD, 36 units ^c	--	\$228,000	20	\$228,000
Townhouse, 36 units	--	\$13,500	20	\$13,500
Low-Rise, 48 units	--	\$18,000	20	\$18,000

Total costs are given in Table 57.

^a Plus operation and maintenance costs.

^b Does not include \$12,000 credit from chiller system, as in the 600°F system (Table 56).

^c Including district heat piping costs of \$100,000. Some trench for all underground piping.

^d Breakdown = \$106,000 LR; \$118,000 TH; \$140,000 SFD.

Table 56. ESTIMATED CAPITAL COSTS, 600°F ORC STE SYSTEM (1975 Dollars)

Component	Size	Unit Cost	Life	Total Cost
Solar Collector	Region-Dependent	\$20.13-\$22.13/sq ft.	20	\$219,500-\$386,000 ^a
Storage, high temperature	5-12 X 10 ⁶ Btu	\$5000/10 ⁶ Btu	20	\$25- \$60,000
Storage, low temperature	4 X 10 ⁶ Btu	\$1500/10 ⁶ Btu	20	\$6,000
High Temperature Heater	2,500,000 Btu/hr	\$7800	20	\$7,800
Auxiliary Heater	2,000,000 Btu/hr	\$5400	20	\$5,400
ORC System, 600°F	100 kWe	\$600/kW	20	\$60,000
ORC Cooling Tower	310 ton	\$120/ton	20	\$37,000
Chiller, absorption unit ^b	100 ton	\$600/ton	20	\$48,000
Pumps and Controls	--	--	20	\$12,000
Battery & Power Conditioner	50 kWh; 100 kW	\$50/kWh + \$75/kW	10 (batt.) 20 (invert)	\$12,500
Hot Water System	180 gal	\$2000 + \$500/unit	15-20	\$26,000
Ducts, piping, etc.	--	--	20	\$106-140,000 ^d
Electric Grid Connect	--	\$7,500	20	\$7,500
Pipefield, SFD, 36 units ^c	--	\$241,000	20	\$241,000
Townhouse, 36 units	--	\$13,500	20	\$13,500
Low Rise, 48 units	--	\$18,000	20	\$18,000

Total costs are given in Table 58.

^a Plus operation and maintenance costs.

^b The \$60,000 cost for a 100 ton absorption chiller used in the conventional system included a \$12,000 cost for a cooling tower, which does not apply here since the ORC cooling tower is also used for the chiller.

^c Including district heat piping costs of \$100,000.

^d Breakdown = \$106,000 LR; \$118,000 TH; \$140,000 SFD.

NOTE: High temperature storage costs are a function of location. Storage capacity was determined from the computer output and is related to insulation, electric power generation, and thermal load characteristics. The computer program determined the peak thermal storage needs in each month; the size of the storage system was based on the peak storage needs and the hourly output.

Table 57. ESTIMATED REGIONAL STES COSTS,* 300°F ORC SYSTEM, (1975 Dollars)

Building	Region					
	<u>1, 3, 5, 6</u>	<u>2</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
36-Unit, SFD						
Collector	386,000	320,800	314,200	307,580	267,200	272,760
Pipefield & District Heat	228,000	228,000	228,000	228,000	228,000	228,000
Other	<u>391,400</u>	<u>391,400</u>	<u>391,400</u>	<u>391,400</u>	<u>391,400</u>	<u>391,400</u>
Total	1,005,400	940,200	933,600	926,980	886,600	892,160
Cost/Unit	27,927	26,117	25,933	25,749	24,628	24,782
Incremental Cost/Unit [†]	23,697	21,887	21,703	21,519	20,568	20,722
36-Unit, Townhouse						
Collector	317,200	262,840	257,980	252,680	219,500	223,520
Pipefield	13,500	13,500	13,500	13,500	13,500	13,500
Other	<u>369,400</u>	<u>369,400</u>	<u>369,400</u>	<u>369,400</u>	<u>369,400</u>	<u>369,400</u>
Total	700,100	645,740	640,880	635,580	602,400	606,420
Cost/Unit	19,447	17,937	17,802	17,655	16,733	16,845
Incremental Cost/Unit [†]	15,357	13,847	13,712	13,565	13,343	13,455
48- Unit, Low-Rise						
Collector	382,120	291,280	284,680	304,400	264,380	269,220
Pipefield	18,000	18,000	18,000	18,000	18,000	18,000
Other	<u>357,400</u>	<u>357,400</u>	<u>357,400</u>	<u>357,400</u>	<u>357,400</u>	<u>357,400</u>
Total	757,520	666,680	660,080	679,800	639,780	644,620
Cost/Unit	15,782	13,889	13,752	14,162	13,329	13,430
Incremental Cost/Unit [†]	12,633	10,740	10,603	11,013	10,284	10,385

* Includes 20-year operating and maintenance costs for collector (Volume III).
Collector size for maximum aperture area.

[†] Capital cost of STES less the capital cost of a comparable gas-heated (unitary) per dwelling unit.

Table 58. ESTIMATED REGIONAL STES COSTS,* 600°F ORC SYSTEM (1975 Dollars)

Building	Region					
	<u>1, 3, 5, 6</u>	<u>2</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
36-Unit, SFD						
Collector	386,000	320,800	314,200	307,580	267,200	272,760
Pipefield & District Heat	241,000	241,000	241,000	241,000	241,000	241,000
Other	<u>387,400</u>	<u>372,400</u>	<u>372,400</u>	<u>372,400</u>	<u>372,400</u>	<u>372,400</u>
Total	1,014,400	934,200	927,600	920,980	880,600	886,160
Cost/Unit	28,178	25,950	25,767	25,583	24,461	24,615
Incremental Cost/Unit**	23,948	21,720	21,537	21,353	24,401	20,555
36-Unit, Townhouse						
Collector	317,200	262,840	257,980	252,680	219,500	223,520
Pipefield	13,500	13,500	13,500	13,500	13,500	13,520
Other	<u>380,400</u>	<u>365,400</u>	<u>365,400</u>	<u>365,400</u>	<u>365,400</u>	<u>365,400</u>
Total	711,100	641,740	636,800	631,580	598,400	602,420
Cost/Unit	19,753	17,826	17,689	17,544	16,622	16,734
Incremental Cost/Unit**	15,663	13,736	13,599	13,454	13,232	13,344
48-Unit, Low-Rise						
Collector	382,099	291,245	284,712	304,400	264,380	269,220
Pipefield	18,000	18,000	18,000	18,000	18,000	18,000
Other	<u>368,400</u>	<u>353,400</u>	<u>353,400</u>	<u>353,400</u>	<u>353,400</u>	<u>353,400</u>
Total	768,499	662,645	656,112	675,800	635,780	640,620
Cost/Unit	16,010	13,805	13,669	14,079	13,245	13,346
Incremental Cost/Unit**	12,861	10,656	10,520	10,930	10,200	10,301

* Includes 20-year operating and maintenance costs for collector. Collector is sized for maximum aperture area.

** Incremental cost is the cost of the STES less the cost of a comparable gas-heated conventional* (unitary) system. Roughly speaking, this difference must balance the fuel savings in order for the STES to be competitive, on either a life-cycle or annualized basis.

The collector costs shown in Tables 55 and 56 are based on the maximum aperture areas permitted for the various locations, priced at \$20.13/sq ft for N-S horizontal trough mounting plus 20-year O&M costs of \$3.10/sq ft* and \$22.13/sq ft. for polar mount parabolic troughs plus 20-year O&M costs of \$4.00/sq ft.*

In Table 58, the total capital costs of STE systems in regions 1, 3, and 5 are somewhat different from that for Region 6, although all are shown to be the same. The difference lies in the different high-temperature storage capacities indicated for the different locations. Storage costs for Region 6 (Charleston-Raleigh) are \$40,000; whereas storage costs for the other three regions would be \$30,000 for Region 1 (Miami), \$45,000 for Region 5 (Dallas-Fort Worth) and \$60,000 for Region 3 (Phoenix). High-temperature storage costs for the other regions are estimated at \$25,000. (Differences are due to thermal tracking.)

Pipefield Cost for Thermal STES

Piping is required to transport thermal energy from roof-mounted collectors to storage. Figures 5 and 6 are schematic diagrams of the assumed layout of the SFD dwelling and low-rise piping layouts from which pipefield costs were derived. The single-family-detached collector field is connected to the main 4-inch diameter (3-inch diameter in low-use and townhouse due to shorter pipe runs) distribution piping by 1-inch diameter pipes. The large diameter piping conveys the collected thermal energy to storage using a heat transfer fluid, such as Monsanto Co.'s Therminal 66. All pipes, whether buried (as in the case of the main distribution pipes in the SFD application) or exposed, are provided with insulation to reduce heat loss to tolerable levels.

Total pipefield installed costs in 1975 dollars are summarized in Table 59. The extensive piping required by the 36 unit, SFD application results in piping costs of \$141,000 at a 600°F operating temperature, and \$128,000 at a 300°F operating temperature. With an additional cost of approximately \$100,000 for the required district heating and cooling distribution piping, total pipefield costs of about \$230,000 are comparable with installed collector field costs of around \$300,000. The significantly smaller pipefield for townhouses and low rises results in costs of \$13,500 for the 36-unit townhouse application and \$18,000 for the low-rise application.

* Annual O&M costs X 20. See Appendix B and Volume III.

TOP VIEW

FRONT VIEW

END VIEW

Figure 5. SFD PIPING LAYOUT

Figure 6. LOW-RISE, 2-STORY PIPING LAYOUT

Table 59. INSTALLED COLLECTOR PIPEFIELD COSTS FOR THERMAL STES

<u>Dwelling Type</u>	<u>Operating Temperature, °F</u>	<u>Installed Pipefield Cost (1975 Dollars)</u>
SFD - 36 Units	600	141,000
	300	128,000
Townhouse- 36 Units	600	13,500
	300	13,500
Low Rise- 48 Units	600	18,000
	300	18,000

8.2.2 Future Capital Costs of ORC-Based STES

The capital costs for solar total energy systems should certainly decrease as production levels for individual components rise. This will undoubtedly have to come about as the result of government efforts to promote the use of solar energy through demonstration units. Without knowing what government programs will be implemented and when the implementation will take place, it is difficult to project when certain cost reductions might come about. Nevertheless, some speculations might be used to project some assumed reductions in STES capital costs.

Although our projected collector costs for the parabolic troughs are approximately \$20 and \$22/sq ft for N-S horizontal and polar mount options, respectively, projections to \$13/sq ft by 1980 and \$12/sq ft by 1985 have been made. These projections are based on assumed large-scale production, at the approximate level required to reduce ORC costs in accordance with the ORC cost versus production projections shown in Volume III. Thus, the projected capital cost reductions for an STE system utilizing a 100-kW ORC unit and parabolic trough of about 20% might be indicated for a 48-unit low-rise apartment building in Albuquerque, or a total cost reduction from about \$656,000 to about \$516,252. The reason why a nearly 50% reduction in collector costs and a substantial (20% to 30%) reduction in ORC costs do not provide a larger reduction in overall system costs is the high cost of the more conventional components of the system (cooling tower, chiller, fan coil units, storage, etc.).

Thus, we can assume that considerable reductions in the cost of collectors and ORC units will take place with higher production levels, and this could occur by 1985-1990 with sufficient government inducements. However, the remaining component costs will probably not be reduced accordingly and this will greatly lessen the impact of reduced collector (and ORC) costs on overall system costs; breakeven costs for collectors are shown later in this volume.

8.3 Cost Estimates for Photovoltaic Solar Total Energy Systems

The following components characterize a photovoltaic STES: combined photovoltaic and thermal collector; piping from collector to thermal storage; heat exchangers; batteries; utility interface, inverter, controls; thermal storage; cooling machinery; backup furnace; two-pipe distribution system. In the following sections, we develop the costs for these components.

8.3.1 Photovoltaic Cells

The collector used in the photovoltaic total energy system combines solar cells and a hydronic solar thermal collector. In this section we develop the costs for the unmounted photovoltaic cells. These photovoltaic cell costs must be added to the thermal collector module costs developed in Section 8.3.2.

The costs derived by Westinghouse for single-crystal silicon solar cells were determined in the following manner.³⁶ The projected characteristics of single-crystal silicon solar cells expected to be available in 1985 include a conversion efficiency of 16% at 25°C and air mass one. Using the DOE 1985 cost goal of \$500/kW_{peak} for silicon photovoltaics, and including a cell packing factor of 90%, the cost per unit array area using single-crystal cells becomes \$72/m² (\$6.69/sq ft). Westinghouse developed an 85% learning curve for the 1985 to 2000 period relating cell cost per unit array area and cumulative megawatts of peak installed solar cell power as shown in Figure 7. Using this curve, array costs of approximately \$40/m² (\$3.72/sq ft) in 1990 and \$20/m² (\$1.86/sq ft) in 2000 were projected. (See Table 60.)

8.3.2 Thermal Collector Module

The thermal collector consists of the glazing, glazing gaskets, glazing extrusion, collector module heat removal plate, aluminum flashing, insulation, and hoses, clamps, and piping to connect collectors with storage. The costs of this module, as developed by Westinghouse³⁶ are summarized in Table 61.

Figure 7. LEARNING CURVE FOR CELL COST PER UNIT ARRAY AREA

Table 60. CAPITAL COST SUMMARY — VARIABLE COSTS
(1975 Dollars)

<u>Component</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Thermal Collector, \$/sq ft	11.08	9.04	7.01
Photovoltaics, \$/sq ft*	6.69	3.72	1.86
Collector Rack-Mounted Installation Costs, \$/sq ft	5.45	5.45	4.00
Thermal Storage, \$/sq ft	<u>3.60</u>	<u>3.60</u>	<u>3.60</u>
Total Variable Costs, \$/sq ft	26.82	21.81	16.47

Operating and Maintenance

Combined Photovoltaic/Thermal Collectors, \$/sq ft-yr	0.10	0.10	0.10
Batteries, \$/kWhr-year X 10 ⁻³	0.28	0.28	0.28

* Costs in \$/sq ft (array area), based on 90% packing factor, i.e., cells comprise 90% of array area.

Table 61. UNINSTALLED THERMAL COLLECTOR MODULE COSTS, 1975 DOLLARS
(\$/sq ft)

<u>Year</u>		
<u>1985</u>	<u>1990</u>	<u>2000</u>
11.08	9.04	7.01

Costs to install rack-mounted collectors must be added to these costs. Projected installation costs of \$5.45/sq ft in 1985 and 1990 are the same as used for installation costs of flat plate thermal collectors in the thermal STE system concept. An installation cost of \$4/sq ft projected for the year 2000 represents an anticipated improvement in reducing time and materials involved in collector installation. Collector operations and maintenance (O&M) costs of \$0.10/sq ft-year are projected for the entire combined photovoltaic-thermal collector and correspond to expected O&M costs for flat plate thermal collectors.

8.3.3 Collector System Fixed Cost

The fixed costs of the collector system were scaled linearly from costs developed by Westinghouse for a system applied to an isolated single-family residence. Fixed costs include the storage tank heat exchangers, controls, pump, and cooling tower ("plate fin" coil) to reject excess array thermal energy. The fixed costs per dwelling unit are projected to be \$2,185 in 1985, \$1,630 in 1990, and \$1,179 in 2000.

8.3.4 Pipefield Cost for Photovoltaic STES (See Section 8.2)

Piping is required to transport thermal energy from roof-mounted collectors to storage. The cost of piping collectors mounted on townhouses or low-rise apartments to centrally-located thermal storage is included in the fixed costs of the collectors. However, additional piping is required in the case of single-family detached residences in order to transport the collected energy from the dispersed collector systems to the centrally-located thermal storage. The cost of the additional piping is expected to be close to that for the higher temperature (300°F) piping. This is due to the fact that, although insulation requirements are less for this lower-temperature application, the smaller temperature rise (20°F versus 100°F) requires a greater flow rate and thus larger pipe diameters. The cost of piping for the 300°F system was \$128,000. This cost included the piping required to connect the collector to the large-diameter distribution mains. Since this cost is included in the collector cost, and amounts to about \$28,000 for 15,000 sq ft of collector, a value of \$100,000 was assumed for the cost of the pipefield. (\$128,000 less \$28,000.)

8.3.5 Batteries and Power Conditioning Equipment

Cost estimates for battery storage systems derived from OTA data,¹³ will be given in two categories:

1. An "intermediate term (1985)" estimate based on present estimates of the cost of lead-acid batteries and power conditioning equipment produced in large numbers for distributed storage applications.
2. A "long-term (1990 - 2000)" estimate of future prices which assumes that inexpensive, advanced battery systems (lead-acid or equivalent) are successfully developed.

The cost of a battery storage system will consist of three major components: The cost of the battery; the cost of power conditioning equipment; and

the cost of installation and the space required to house the system. Estimates for battery system costs are summarized in Table 62.

Table 62. BATTERY SYSTEM COST ESTIMATES

	<u>1985</u>	<u>1990 - 2000</u>
Lifetime (deep cycles)	2000	>2000
Depth of Discharge, %	70	70
O&M Cost, mills/kWh	0.28	0.28
Replacement Cost, % of original	100	100
First Costs, Multi-Family Residential Systems		
Battery Cost, * \$/kWh	60	33
Building and Other Costs, ** \$/kWh	13.7 - 1.8 log C	5.7 - 0.7 log C
Power Conditioning Costs, † \$/kWh	200 - 29 log P	80

* Effective battery cost = cost for desired capacity (kWh/depth of discharge).

** C is the capacity of the storage system in kWh.

† P is the rated power of the inverter in kW.

8.3.6 Battery Prices

The current market for batteries capable of multiple deep cycles is very limited and prices are high. Industrial traction batteries with lifetimes near 2000 cycles are available for \$80/kWh. The industrial battery price of \$80/kWh may be used to represent "current" battery prices for residential systems. For the purposes of this analysis, a cost of \$60/kWh is assumed for the intermediate term (1985) price of mass-produced lead-acid batteries for distributed storage applications.

In the long term, development of advanced lead-acid batteries or alternative battery concepts will lower the price of batteries. Estimates gathered by OTA suggest that battery price projections below \$25/kWh may be regarded as very speculative, while prices in the range of \$25 to \$40/kWh are reasonably probable for advanced batteries in the long term if it is assumed that battery development proceeds favorably. A long-term price (1990 - 2000) of \$33/kWh was assumed for this study. Actual battery costs are affected by the permitted depth of discharge. Battery costs are multiplied by the reciprocal of the depth of discharge to obtain the actual cost of batteries.

An O&M cost of \$0.28/kWh-year was used in evaluating battery system costs. Since the photovoltaic system has a 20-year expected lifetime, the limited cycle life of battery systems requires that the batteries be replaced once during the system lifetime. Battery replacement costs are factored into battery system cost estimates.

8.3.7 Power Conditioning Costs

The bulk of the cost of power-conditioning equipment results from the cost of the inverter. Estimates of voltage regulator cost, according to OTA, represent from 1% to 6% of the cost of the inverter. The cost of the utility interface runs from 10% to 20% of the inverter cost for systems up to several hundred kilowatts in size. Many of the inverter units currently available are over-designed for solar applications and many of the systems available operate at input voltages lower than required for solar applications (low-voltage systems are generally more expensive than higher-voltage units with comparable power capabilities).

In the intermediate term (1985), it is assumed that increased production volume will lower prices, although in many current systems, components like inductors and capacitors represent a sizeable fraction of the cost, and this limits the production economies possible. Based on OTA data, a logarithmic dependence of inverter cost on system capacity has been assumed for inverter costs. The 1985 cost of a 100-kW inverter thus becomes \$142/kW.

In the longer-term (1990 - 2000), it was assumed that the power conditioner units can be made for substantially lower prices by mass-producing units designed with power transistors so that use of components such as inductors is minimized. The long-term cost of the power conditioning system is \$80/kW.

8.3.8 Building and Other Costs

In addition to the battery and power conditioner costs, there is a significant cost associated with installation, electrical wiring and instrumentation, the battery cooling system, and the room in which the battery system is housed. On the basis of information from OTA, we have assumed a logarithmic dependence on battery capacity for these costs, with costs decreasing by about 60% from the 1985 costs to the 1990 - 2000 costs. The reduction in balance of plant cost for future battery systems is due to the expected higher energy densities (and

reduced volume) of the batteries, and, particularly for advanced concept batteries, elevated temperature operation results in simpler cooling systems. At 15 kWh of useful battery capacity per dwelling unit, 1985 costs are \$8.78/kWh for single-family detached dwellings and townhouse apartments, \$8.56/kWh for low-rise apartments. The 1990 prices are \$3.79/kWh for houses and townhouses, and \$3.70/kWh for low-rise apartments.

Because the cost of batteries in a photovoltaic solar total energy system is substantial (10% to 20% of overall system capital cost depending upon collector area and time frame), the sizing of battery storage is important in the development of the most economic system configurations. As can be seen by examination of the output reports from system simulations in Appendix D, the battery capacity of 15 kWh per dwelling unit was sufficient to avoid the wasting of electrical power at any time. As a result, it is conceivable that a smaller battery storage capacity might be appropriate in a residential photovoltaic STE system. The impact of this reduction in capacity would be a lowering of system capital cost, perhaps by as much as 10%. Although the evaluation of the potential to reduce battery capacity requirements is beyond the scope of this study, such an effort would entail an examination of the utilization of battery capacity during the yearlong performance of the system, determining the maximum capacity of the batteries. Subsequently, the size of the battery storage system could be adjusted downward, and performance results could be coupled with system economics to determine the point at which a balance is struck between battery capacity and lost electricity due to insufficient battery capacity, thus achieving the best system economics.

8.3.9 Thermal Storage

The requirement for thermal storage is 50 pounds of water per sq ft of collector. Because of the large collector areas involved in photovoltaic STE systems, storage capacities greater than 25,000 gallons are required. In this capacity, storage systems cost \$0.60/gal installed. This translates to a storage cost of \$3.60/sq ft of collector.

8.3.10 Cooling, Heating, and Distribution Equipment

Vapor compression chillers are used with a two-pipe distribution system to provide cooling for the residences. One hundred tons of capacity are required. At \$600/ton, the cost of chillers is \$60,000.

A back-up furnace is required to supplement the heat derived from the thermal collectors. The back-up furnace costs \$5500 installed.

The most expensive components of the heating/cooling systems are the fan coils, piping, and duct work. Fan coils cost \$600 each. The cost of piping and ducting is included in the fan coil cost for the single-family detached units; a cost of \$10,000 is added to the cost of fan coils for piping and ducting for systems applied to townhouses and low-rise apartments.

Two hundred and thirty-four fan coil units are required for the single-family detached dwellings, 180 for the townhouses, and 160 for the low-rise apartments. Resultant costs for fan coils and associated piping/ducting are \$140,000, \$118,000, and \$106,000 for the single-family detached dwellings, townhouses, and low-rise apartments, respectively.

8.3.11 Thermal Energy and Domestic Hot Water Distribution System

A two-pipe system is specified to distribute hot or chilled water to the dwelling units for space heating or cooling. A separate piping system is required to distribute domestic hot water. The costs of the two-pipe distribution system are included in the fan coil, plumbing, and ducting costs for the townhouse and low-rise dwelling units. Hot water plumbing is included in the cost of the dwellings themselves. However, in the case of the single-family detached dwellings, piping is required to distribute hot or cold fluid and hot water from central storage to each dwelling unit. Such a distribution system has many of the attributes of the collector pipefield. In fact, the distribution system shares the trench with the collector pipefield, thus helping to lower installed costs. The main difference is in the temperature of the fluids. The lower temperature of the distribution system when distributing heated water for space heating (160°F for the thermal systems, 130°F for the photovoltaic systems) implies less rigorous insulation requirements to keep losses to a minimum. However, comparable energy throughputs and a smaller temperature swing dictate somewhat larger pipes. Although a detailed estimate of the distribution system costs was not undertaken, an estimate of \$120,000 was made for the thermal and hot water distribution system, based on collector pipefield costs and district heating/cooling costs described in the OTA prepublication report on "Application of Solar Energy to Today's Energy Needs."

8.4 Capital Cost Summary (1975 Dollars)

The cost estimates for photovoltaic STE systems are summarized in Tables 63 and 64.

Table 63. CAPITAL COST SUMMARY OF FIXED COSTS
FOR SINGLE-FAMILY DETACHED DWELLINGS AND TOWNHOUSES
(36 Units)

<u>Component</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Collector System	\$78,660	\$58,680	\$42,444
Fixed Costs	@ \$2,185/D.U.	@ \$1,630/D.U.	@ \$1,179/D.U.
Batteries	\$92,570	\$50,914	\$50,914
Power Conditioning	\$14,200	\$8,000	\$8,000
Building and Other Costs	\$4,741	\$2,047	\$2,047
Fan Coils, Piping, Ducting			
Single-Family Detached	\$140,000	\$140,000	\$140,000
Townhouse	\$118,000	\$118,000	\$118,000
Chiller	\$60,000	\$60,000	\$60,000
Boiler	\$5,500	\$5,500	\$5,500
Pipefield (SFD only)	\$100,000	\$100,000	\$100,000
Thermal Distribution (SFD only)	<u>\$100,000</u>	<u>\$100,000</u>	<u>\$100,000</u>
Total Fixed Costs			
Single-Family Detached	\$595,671	\$525,141	\$508,905
Townhouse	\$373,671	\$303,141	\$286,905

Table 64. CAPITAL COST SUMMARY OF
FIXED COSTS FOR LOW-RISE DWELLING
(48 Units)

<u>Component</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Collector System	\$104,880	\$78,240	\$56,592
Fixed Costs	@ \$2,185/D.U.	@ \$1,630/D.U.	@ \$1,179/D.U.
Batteries	\$123,429	\$67,886	\$67,886
Power Conditioning	\$14,200	\$8,000	\$8,000
Building and Other Costs	\$6,161	\$2,664	\$2,664
Fan Coils, Piping, Ducting	\$106,000	\$106,000	\$106,000
Chiller	\$60,000	\$60,000	\$60,000
Boiler	<u>\$5,500</u>	<u>\$5,500</u>	<u>\$5,500</u>
Total Fixed Costs			
Low-Rise Dwelling	\$420,170	\$328,290	\$306,642

Section 9. MARKET PENETRATION ANALYSIS

9.1 Preliminary Market Penetration Analysis

9.1.1 Methodology

The methodology used in assessing the market penetration of STES in future years involves a preliminary screening of selected options in certain market segments in order to eliminate from detailed consideration those which show no promise of significant market penetration. This is done to reduce the amount of detailed analysis required in the later stages of the study.

Assumptions for the Residential Sector

The market penetration analysis was based on the following assumptions:

1. Conventional fossil fuel supplies will be available throughout the forecast period at the prices cited in Section 3 of this volume.
2. A solar heating/cooling market will be well established by the time an STES is offered. That is, the necessary marketing infra structure will be available.
3. Current conventional energy supply services will be available for back-up energy use. That is, the user may select gas, oil, LPG, and/or electricity as a back-up energy supply for its STES.
4. All costs are in constant dollars and only "real" cost increases are considered in future years, i.e., not including inflation.
5. The STE systems available are as defined in this study.

Basis for Analysis

Under the constraints imposed by the above assumptions, the total cost of an STES, including its back-up energy cost, must be equal to or less than the comparable cost of conventional utility service if the STES is to achieve any significant market acceptance. Stated mathematically:

$$\text{Total STES Cost} \leq (\text{Total Utility Service Cost} - \text{Backup Energy Cost}) \quad (1)$$

This equation does not summarize all of the criteria for assessing market penetration but it does define the major criterion. Other ancillary cost considerations and the non-cost factors can be evaluated more readily when the basic cost comparisons are available.

Each of the terms of the above equation consists of two parts, a fixed cost reflecting the capital and other related costs independent of the usage pattern, and the variable costs such as fuel and operating expenses, which vary with the demand for service.

The variable costs are primarily fuel costs. The annual fuel costs are determined using the energy requirements data on which the STES designs were based and the fuel price data developed in Section 3 of this volume. However, it is necessary to make some assumptions about which fuels may be used for various purposes in the conventional buildings that may be competing with the STES. Representative gas, oil, LPG, and electrically heated dwellings must be compared with the STES to determine market acceptance in regions where these various fuels are used. It is not sufficient to compare an STES with an all-electric residential building, for example, particularly where gas may be the predominant fuel form.

Consequently, total annual conventional energy consumption for each of the four major fuel forms was estimated using the same residential energy load requirements prescribed for the solar total energy system. This is discussed in more detail in a later section. These consumption values are then multiplied by the fuel prices already projected to provide the conventional energy costs against which the STES cost must be measured.

It is necessary, however, to add an allowance for the fixed cost of the conventional energy conversion devices that are displaced by the STES, namely the heating furnace, air conditioning unit, and water heater. Other appliances are assumed to be unchanged by the addition of the STES.

In addition, we must determine the annual cost of the energy needed to meet the demand that cannot be supplied by the solar powered system. This back-up energy cost is determined by pricing out the quantities of purchased energy needed at the same energy prices used to estimate the cost of utility energy service. These back-up energy quantities are obtained from the analysis of the STES performance. (Volume III.)

When the annual back-up energy costs are subtracted from the total annual cost of a conventional energy supply, the difference, as shown in Equation 1, is the allowable fixed annual cost of the STES system that must break even in cost with conventional utility service. Since the prices of utility energy

are projected to increase steadily throughout the forecast period, a chart of the right-hand side of Equation 1 will show a curve increasing with time, as shown in Figure 8, for Curve B.

If we can also estimate the total annual cost of an STES, exclusive of its back-up energy cost (which has already been accounted for), we can plot this quantity versus time on the same chart as Curve C in Figure 8. The two curves cross at the breakeven point, which will indicate the time when an STES can begin to compete with each particular form of utility energy supply. With this knowledge it is possible to begin an assessment of the degree of market penetration that may be achieved beyond that point in time. The shaded area in Figure 8 represents savings from the use of the STES.

However, if the STES cost is too high, as for Curve C, a breakeven point may not be achieved. The preliminary screening is designed to identify those regions and market sectors where no breakeven point is likely to occur and eliminate them from further, more detailed consideration.

Preliminary Evaluation

If a constant percentage of the total capital cost of an STES is assumed for the annual fixed charge rate, the left-hand side of Equation 1 can be readily calculated, using the capital costs presented in Section 8, and an appropriate annual fixed charge ratio.

If the value of the net energy savings as shown in Figure 8 (total utility service cost less back-up fuel cost) is divided by the annual fixed charge rate, an estimated breakeven capital cost can be obtained. If this number is reasonably close to the total capital cost, further more detailed analysis is indicated. If not, that particular market segment can be discarded as an unlikely market for an STES.

This screening has additional value in suggesting shifts in emphasis of the technical evaluations as well as the market assessment. For example, if the high-temperature organic Rankine cycle STES is shown to be marginal in certain market segments, the low-temperature ORC system will be even less attractive. This may suggest some review of the treatment of the low-temperature system. In any case, the screening provides the first indications of the findings of the study.

Figure 8. ANNUAL COST OF STES VS. ENERGY SAVING

9.1.2 Projected Cost of Conventional Utility Service

The yardstick against which the economic performance of the STES is measured is the cost of supplying the equivalent energy demand with conventional utility services. To do this, it is necessary to estimate the cost of utility service in similar dwellings using the following utility service options:

- Utility gas plus utility electricity
- Light heating oil plus utility electricity
- LPG plus utility electricity
- All-electric utility service.

Each of these options is described below.

Gas-Heated Dwellings

The residential energy loads on which the STES designs have been based were aggregated into a gas utility load and an electrical utility load. It was assumed that space heating, water heating, cooking, and clothes drying would be gas loads, while air conditioning, lighting, and other appliances would be supplied electrically. The COP assumed for electric a.c. units was 2.34, based on the EER* of 8 (ratio of Btu output/electrical input in Watts).

No attempt has been made to project step rates for these loads. Obviously, a wide variation in utility energy costs could be estimated by assuming different mixes of appliance loads and various utility rate schedules and demand charges. The utility prices developed earlier are average prices generated by dividing annual revenue by annual sales quantities in pertinent geographical areas and, therefore, reflect the effects of step rates. The appliance mix is chosen to reflect as closely as possible the average makeup of the various residential building loads that is consistent with the energy loads supplied by the STES.

The annual energy costs have been estimated by calculating the annual cost of supplying the prescribed gas and electrical loads per dwelling unit at the pertinent utility energy prices for each of the selected years of the study. These costs have been tabulated in Appendix C, and are referenced where they are referred to in the following text.

$$* \text{EER} = \frac{\text{Cooling Capacity (Btu/hr)}}{\text{Electrical Requirement (watt)}}$$

The annual fixed cost of the energy conversion devices associated with the use of utility energy and the related maintenance and service costs are additional expenses that must be accounted for in making the economic comparisons required by the study. These costs are relatively small on an annual basis, but should be added to the utility service charges to arrive at the full cost of utility service, even though some of these charges may be buried in the mortgage costs of the building itself.

However, in the preliminary analysis, we chose to subtract these costs from the corresponding cost items of the STES in making the comparisons between the two. Thus, we compared a net capital and maintenance cost for the STES (over and above the comparable costs associated with utility service) with the annual utility service charges. This was done to simplify the comparison of the STES with the primary variant, the cost of purchased utility energy.

Oil-Heated Dwellings

For comparable oil-heated residential dwellings, it was assumed that space and water heating would be provided by oil, while all other loads would be served by electricity.

The annual energy costs are estimated in the same manner as the gas-heated dwellings. It should be noted, however, that in all cases the energy costs have been on a per dwelling basis; this was done to preserve flexibility in comparing utility service with an STES sized for different numbers of dwelling units.

Fixed and maintenance costs have been handled as in the case of the gas-heated dwelling, noting that oil equipment costs are generally somewhat higher than comparable gas system capital and maintenance costs.

LPG-Heated Dwellings

The makeup of LPG-heated dwellings is assumed to be the same as the gas-heated units. The only difference is the application of the LPG prices in place of natural gas prices. While LPG requires a relatively expensive storage tank, such tanks are usually leased from the LPG supplier, and their cost is included in the price of the LPG itself.

All-Electric Dwellings

In the all-electric dwelling, heating is assumed to be resistance heating with electrically-driven compressors for air conditioning. It is recognized that a heat pump installation will result in a lower electrical energy consumption and may offer lower overall costs than resistance heating. However, this means that it will fall within the spectrum of annual costs probably represented by all-electric resistance heating at one extreme and gas heating at the other. Since the preliminary analysis, at least, seeks to determine where the cost of an STES falls in relation to this band, we have chosen the more expensive alternative for the all-electric configuration.

As in the other fuel alternatives, annual electricity costs are calculated using the projected electricity prices and tabulated in Appendix C. It is assumed that individual tenants in multi-family dwellings will be metered and billed individually at residential rates. Some utilities provide electric service at commercial rates to multi-family dwellings if only one metered customer is involved. The utility cost is then prorated and included in the rental charge for the dwelling. We believe that the prospective renter will discount "free utility service," when comparing rentals and the pricing practice used will make little difference in the revenue generated by the building.

As in the other alternatives, fixed costs and maintenance charges are subtracted from the projected costs of the STES so that the utility energy costs may stand alone for comparison with the net fixed costs of the STES.

9.1.3 Annual Capital Cost Ratio

In order to simplify the cost comparisons necessary in the preliminary market penetration analysis, capital costs have been converted to annual fixed costs using an annual capital cost ratio.

This ratio generally amounts to some value between 15% and 20%. That is, the total annual fixed charges including depreciation, taxes, insurance, interest, etc., associated with a capital investment, amount to between 15% and 20% of the capital investment annually.

In this analysis an optimistic value is deliberately selected to favor the selection of an STES over conventional fuel supply in order that the preliminary analysis would identify all of the promising market opportunities leaving market penetration estimates to later, more rigorous examination.

A computer program was used to calculate suitable annual capital cost ratios based on various financing arrangements, interest and taxing assumptions, and investment tax credits. This analysis generally yielded annual capital cost ratios between 12% and 16% depending upon the conditions assumed. For example, a 20% investment tax credit was found to reduce the ratio by 3%.

On the basis of this analysis a ratio of 12% annually was selected for STES capital costs while 15% was applied to conventional system capital costs on the premise that a favorable investment tax credit may be made available for solar energy systems. This is done for the preliminary analyses only and provides a simple way to relate capital costs to annual fuel and operating costs. It presumes straight line depreciation since capital charges are spread evenly over the life of the project.

9.1.4. High-Temperature Organic Rankine Cycle System

The high-temperature (600°F) ORC system was examined in two different modes of operation. The technical discussion of these two alternative operating modes is presented in Volume III. One, referred to as the Thermal Tracking System, was designed to use utility electricity to supply electric power when use of the ORC to generate electricity would result in the production of exhaust heat that could not be applied to the thermal load; i.e., when the thermal storage reservoir is full. Thus, in this mode the ORC operates only under operating conditions that permit its exhaust heat to be fully utilized and very little fuel energy is wasted through the generation of electricity by the ORC unit.

The second mode of operation referred to as the independent system does not use utility power as a back-up energy source and all back-up energy needs are met by burning fuel for both electricity and thermal loads.

The market evaluation does not examine the possible variations in component size, seasonal variations in operating modes and other technical refinements that might influence overall performance. The only engineering variable considered other than the types of system configurations mentioned is the amount of solar collector area used. Variations in the thermal storage capacity, electrical storage capacity, energy loads, etc., have not been thoroughly examined although some observations are possible from an examination of the data obtained.

Back-Up Energy Costs

Because the STES does not provide all of the energy required in any of the systems considered, it is necessary to provide some amount of fossil fuel or electricity to make up the shortfall in solar energy supply. The cost of this back-up energy is part of the total cost of the STE system. However, in order to estimate this cost, it is necessary to make some assumptions regarding the manner in which this back-up energy supply is provided.

Conventional Utility Back-Up Energy

We may, for example, assume that the same utility services are available for back-up energy as are available for the supply to a conventional building as described in the preceding section. This implies that a shortfall in electrical energy from the STES is made up by utility electricity, and any shortfall in solar heat and/or waste heat from the STES is provided by gas, oil, or LPG as may be the case for the conventional utility supply being compared.

This pattern of back-up energy supply is consistent with the concept of an STES as a partial or supplemental energy supply system used to reduce the cost of conventional energy supply service.

We have estimated back-up energy costs in this basis, and will refer to them as conventional back-up energy costs. They have been calculated using the quantities of purchased energy needed to meet the energy load in the technical analyses of the STES and the energy prices already discussed.

Independent Back-Up Energy

An alternative to the conventional supply of energy for back-up purposes is the use of the independent system. In this system, no electric utility connection is provided and the required back-up energy is supplied as fossil fuel and burned to provide sufficient heat as needed to make up any deficiency in the output of the solar collector in meeting the electrical load.

The technical analysis reports the quantity of fossil fuel needed on an annual basis for this purpose, and the annual cost has been estimated for gas, oil, and LPG fuels for comparison with a conventional building using these fuels for utility energy service alone.

Net Utility Energy Savings

The difference between the annual cost of conventional utility service and the annual cost of back-up energy supply is the annual net energy cost saving obtained by the use of the STES. This cost saving, represented by the right-hand side of Equation 1, must be equal to or greater than the net annual fixed cost of the STES less the cost of alternative facilities for the use of conventional fuels.

A. Thermal Tracking ORC System

The techniques already described were used to calculate the total annual costs of operating the STES using thermal tracking with several different sizes of solar collectors. This cost was then compared with conventional fuel costs of similar buildings in the various cities selected. The results of this comparison are summarized in Figures 9 through 13 on the following pages.

In making this comparison, the service and maintenance costs were treated as annual operating expenses rather than capitalizing hence as a part of the fixed capital costs as shown in Section 8.2. This refinement, however, had little effect upon the overall cost comparisons.

The curves presented show the influence of unit collector cost on the overall economics of the system as well as the effects of varying the collector area. While these two parameters influence the overall economics, they cannot offset the effects of high capital costs of other parts of the system. Consequently, in all of the geographic regions for all of the building types examined, the total annual cost of the STES exceeds the corresponding cost for conventional heating/cooling with normal utility service. This is true even where the collector costs are assumed to be zero, as shown in the figures.

In Figure 9 the annual savings per dwelling in Los Angeles are shown for selected years during the projected period of study. There is some improvement with time due to the increasing fossil fuel costs projected. These increases are somewhat irregular because fossil fuels and electricity costs were not projected to increase by exactly the same amounts during each period.

Figure 9. OVERALL ANNUAL SAVINGS (By Year) — LOS ANGELES

Figure 10. OVERALL ANNUAL SAVINGS — LOS ANGELES

Figure 11. OVERALL ANNUAL SAVINGS — ALBUQUERQUE

Figure 12. OVERALL ANNUAL SAVINGS — BOSTON

Figure 13. OVERALL ANNUAL SAVINGS — RALEIGH

It is evident from this figure that a relatively small collector area gives better results. However, Figure 10, which shows data for 1990 plotted for various collector areas, shows that lower collector costs favor larger collector areas. In Los Angeles, even a low collector cost of \$10/sq ft requires only 75% of the available roof area for an optimum system. However, the free collector cost curve (\$0/sq ft) continues to rise with increasing area as would be expected.

In Albuquerque (Figure 11), a larger heating load permits more exhaust heat to be absorbed by the heating load, making the ORC unit run longer and use more solar heat before rejecting any to the cooling tower. It thus benefits more from the larger solar collector areas. All of the available space can be used effectively at \$13/sq ft or less.

In Boston (Figure 12) the larger heating load permits the maximum available area to be used at lower collector costs and its performance is economically comparable to Los Angeles.

Raleigh (Figure 13) is less attractive than the others and can make use of only about 75% of the collector area that could be installed, even at the lower collector costs assumed.

While these unfavorable results might not be expected from experience with other studies of STES in the commercial and industrial markets, there are several reasons for this relatively poor performance.

Energy Distribution Costs

In the multi-family residential market, it has become common practice to install unitary heating and cooling systems. That is, each dwelling unit is equipped with its own space heating/electric cooling unit and its own hot water heater. It is only in high-rise apartments that central heating/cooling systems have retained their popularity. In the townhouse and low-rise apartment segments of the residential markets, unitary systems have increased in popularity during the past decade and will predominate during the study period. The basic reason for this is lower costs; the installed cost of unitary systems is reported by heating contractors to be about 2/3 of the installed rates of depreciation are greater because of the shorter depreciation period allowed for the unitary system components.*

*Private conversations with contractors.

Because an STES, which requires a central system, must compete with these unitary systems, we have made our cost comparisons with unitary conventional systems rather than the more analogous central heating and cooling system. These costs are compared for several cities in Table 65. It can be seen that the capital cost of the heat distribution portion of the STES is generally about 50% due to the addition of thermal storage tank, added pipefield, some additional controls, and fan coil units for the central system. Therefore, any saving derived from the use of solar energy is burdened not only with the capital cost of the solar collection facilities, but also with an added increment of cost for central heating and cooling equipment, plus added facilities for storage and control.

Table 65. COMPARISON OF CAPITAL COSTS PER DWELLING UNIT

Item	Region			
	Los Angeles	Albuquerque	Raleigh	Boston
STES High-Temperature ORC				
Total Capital Cost	13,805	13,669	16,010	14,037
Solar System Cost	6,370	6,234	8,418	5,810
Fuel System Cost	373	373	373	373
ORC System Cost	2,308	2,308	2,308	2,308
Heat Distribution Cost	4,754	4,754	4,754	4,754
Conventional System Cost				
Unitary Basis	3,150	3,150	3,150	2,945
Central System	4,112	4,112	4,112	4,112

In commercial and industrial buildings central heating and cooling systems are more common and comparisons of solar heating/cooling may involve only comparisons with central systems. When this is done the thermal distribution portions of both systems are more comparable in cost. In the residential market, however, it is unrealistic to limit comparisons to central systems since the STES must compete with conventional unitary systems.

Other Capital Costs

There are other major capital cost items, which also must be supported by the savings that may be derived from the use of solar energy. The capital cost

of the solar collector installation itself is one such item. The capital cost of the ORC unit is another.

If the electricity generated by the ORC unit was less expensive than the cost of purchased electricity, the savings would contribute to the overall savings of the STES compared to conventional fuels. However, this is not the case in this study, as will be shown in detail later. We have ORC capital costs which are too high and result in generated electricity costs higher than purchased electricity costs. The savings from the use of solar energy must then cover this additional cost as well, in order to show an overall cost advantage.

However, in this case, the overall building operation cost can be reduced by using purchased electricity entirely, allowing the savings from solar energy use to be reflected in lower overall costs. Thus, for a STES to be more attractive than a solar heating/cooling system plus utility power, it is necessary that the generation of electricity be more economical than purchased power on its own merit,* or because the use of solar energy reduces the effective fuel cost sufficiently to make it so.

This criterion is difficult to achieve with ORC system capital costs on the order of \$100,000 for a 48-unit dwelling. This amounts to \$250 per dwelling per year at a 12% annual capital cost ratio. The relatively low cycle efficiency results in the production of a great amount of exhaust heat that must be usefully applied to the thermal load in competition with the solar heat collected. In warmer climates there is insufficient thermal load to absorb all of the solar and waste heat available. Thus, the thermal tracking system cuts out the ORC system more often as priority is given to the storage of solar heat. Then, if purchased electricity is cheaper than generated electricity, this will result in a reduction in overall annual cost. If it is more expensive the cost will be increased. Thus, in order to assess the cost effectiveness of solar energy in STE systems it is necessary to examine more closely the internal economics of the collection of solar energy, the generation of electricity, and the application of heat to the load.

The questions are discussed more thoroughly in a later section under Parametric Analysis.

* Net cost, i.e., including credit for waste heat utilization.

B. Independent (Stand-Alone) ORC System

The cost comparisons for the independent system are even less attractive than for the thermal tracking system. In most cases, the cost of back-up fuel alone exceeds the cost of energy required in the corresponding building using conventional utility service. Some variations in cost were found, depending upon the fuels assumed for the comparisons, but even an all-electric conventional building was clearly more attractive than the independent STES.

This is due to the fact that the ORC system operates to generate electricity whenever there is an electrical demand, regardless of load. To do this it must burn fuel much of the time because of the limited solar energy available. This results in a very large consumption of fuel because of the low efficiency of the ORC turbine. The exhaust heat cannot be fully utilized and is largely wasted. The solar collector becomes largely redundant and its capital cost is employed only to collect energy that is unnecessary because the waste heat from the ORC itself is in excess of the amount useable.

As an example, the data for Boston, where heating loads are high and waste heat can be better utilized, the quantity of back-up fuel purchased annually for the low-rise buildings amounted to 8679 million Btu. The total thermal load amounted to 3111 million Btu and the electric load added 1625 million Btu (at 3412 Btu/kWh) for a total of only 4736 million Btu. Thus, the back-up fuel amounted to 1.8 times the delivered load. This was over and above the 3035 million Btu of solar energy collected. Other cities and buildings gave similar results.

Obviously, the thermal tracking arrangement combined with utility electric back-up supply is a much more attractive configuration. Because of this, further examination of the independent (i.e., stand-alone) system was abandoned. To be attractive this system would require an electric generating system having a much more efficient prime mover than can be attained under the thermal load limitation imposed by the solar energy source.

9.1.5 Stirling Engine System

The Stirling engine STES was not analyzed for its potential market penetration because the technical analysis indicated that it would be less attractive than the ORC unit because of its high cost and relatively low thermal efficiency under the limitations imposed by the solar heat temperature available.

9.1.6 Photovoltaic System

The same technique used for the preliminary analysis of the ORC systems was used to screen the photovoltaic STES. Unfortunately, data were not available in all cases for the same cities so that direct comparisons were not possible in some cities. This is not important, however, as the same general trends prevail and neither system comes close enough to economic feasibility to make direct comparisons critical to the study.

Charts showing projected annual net savings over conventional utility service were prepared for those cities in which a range of solar collector areas was examined. The chart for Dallas (Figure 14) is typical of the results obtained. No optimum collector area is indicated and the curves decline rapidly as collector area is increased. This is obviously due to the fact that electricity is being generated at greater cost than purchased electricity.

Details of the cost factors of the photovoltaic system are discussed further in Section 9.2.2. It is enough to say here that the capital costs of the photovoltaic collectors, even though based on manufacturing costs established as goals for 1985, are still much too high to offer an economically viable STE system for the residential market. This is due in large part to the low load factors and the high related structure and equipment costs. Further, the necessity of collecting reject thermal energy from collectors and transporting the energy to a central location for redistribution through a central heating system results in extremely high capital costs for thermal energy distribution.

However, although the photovoltaic system appears less attractive by comparison with the ORC system it may have more potential for future improvement than does the ORC unit. The photovoltaic system does not have the theoretical thermodynamic heat engine cycle efficiency limitations that are imposed upon the ORC machines. Thus, significant efficiency improvements are possible up to the quantum limitations governing photovoltaic performance. Furthermore, the technology of photovoltaic collectors is in its infancy and stands to benefit from the rapidly developing technology of solid-state devices for various electronic applications.

The future development of solar energy for heating and cooling utilization in small systems for individual dwelling uses could be advantageous. It could eliminate the need to transport the energy collected to a central point for conversion and redistribution to individual dwelling units. Thus, future photo-

Figure 14. OVERALL ANNUAL SAVINGS — DALLAS

voltaic systems, developed for use in individual single-family dwellings, may have more favorable economics than photovoltaic systems designed to serve multiple dwelling units through central systems. This alternative was not a part of this study.

9.2 Parametric Analysis

9.2.1 High-Temperature ORC System

The preliminary market analysis of the ORC system configurations reveals that substantial improvements must be made if they are to become competitive with other alternatives for supplying energy to the residential market.

Since no market penetration is anticipated with ORC systems having the cost and performance projected, it is desirable to examine the improvements that would be required to make the system economically attractive. There are several major cost items affecting the economic performance of the ORC systems. They are common to all of the configurations considered but are discussed here in the context of the high-temperature, thermal tracking configuration only. This is by far the most promising one and should require the least effort to make it competitive. Before discussing these items, however, it is necessary to examine the flow of energy through the system, and the effects of varying solar collector area.

Energy Flow Through STES

Figure 15 shows the flow of energy through the STES for a low-rise apartment building in Boston. In other buildings and regions, the pattern is the same and only the values shown at each point in Figure 15 are changed.

Solar heat energy from the collector is transmitted to the storage tank. The temperature of the working fluid in the storage tank is maintained by adding heat from fuel burned in the boiler so that the working fluid, delivered to the ORC system, is a mixture of solar and fuel energy which varies with the time of day and season of the year. It is important to know whether the heat input to the tank from the solar collector costs more or less than the heat from fuel supply. Obviously, if the heat from the solar collector costs more, the use of a solar collector is not economically justified and fuel should be used exclusively if the lowest cost is desired. This condition would indicate the use of a conventional total energy system rather than a STES.

BOSTON — LOW RISE BUILDING — HIGH TEMPERATURE ORC SYSTEM (100% Area)

Figure 15. ENERGY FLOW CHART — BOSTON

It is also important to know whether the electricity generated is cheaper or more expensive than the electricity purchased. This will determine whether a total energy system (either solar or conventional) is justified. In making this determination, it is necessary to apportion some of the energy between electric generation and the thermal load.

Most of the heat energy in the storage tank is delivered to the ORC system and only a relatively small amount goes directly to the thermal load. The ORC delivers a portion of its heat input to the electrical load in the form of electricity. An additional, rather small quantity is lost through radiation, conduction, I^2R losses, etc. (ORC losses), which are charged to the electric generation cost. Most of the heat delivered to the ORC is passed through the condenser and delivered to the thermal load. This heat is not charged to the generation of electricity. Some heat is diverted to the cooling tower when the thermal load has been satisfied and the thermal storage capacity of the storage tank has been reached. This heat is not charged to electric generation since the thermal tracking system shuts down the ORC unit under these conditions and only surplus solar heat can be delivered to the cooling tower.

Variation of Collector Area

As the area of the solar collector is increased while serving a specific building load, the amount of fuel used is correspondingly reduced. However, the limitation on longer-term heat storage restricts the amount of stored heat that can be accumulated. When that limit is reached, heat must be dissipated in the cooling tower of the system.

The electric generation system is operated to minimize the rejection of exhaust heat to the cooling towers when low temperature storage is filled, condenser temperature is reduced to 110°F (high temperature system) to maximize heat engine cycle efficiency and make best use of solar heat input. Only when high temperature storage is filled is high temperature heat wasted at the cooling tower. Thus, the solar collector may, at times, produce more heat than can be absorbed by the load and stored in the storage tank. If this happens occasionally, it is of no consequence; the collector still operates most of the time to collect and store energy for the system. The more energy it applies to the load during the year, the better will be its utilization and the lower its effective cost per unit of energy delivered.

The quantities of heat put into the system from both solar and fuel sources are shown in Figure 16 for Los Angeles and Figure 17 for Boston. In both cases, as well as other cities examined, the heat discharged through the cooling tower increases as the collector area is increased. In Los Angeles the amount of heat discharged to the tower becomes a significant portion of the total amount of solar heat collected at the larger collector areas. However, there is no point at which it becomes obvious that further increases in collector area are detrimental backup. This must be determined by estimating the effect upon total annual energy cost.

In Los Angeles, the effective fuel cost decreases with increasing collector area at even the highest collector cost (\$22.13/sq ft) due to the large amount of solar energy collected per sq. ft. of area. This is shown in Figure 18. The annual total energy cost is also shown. As the collector area is increased the annual energy cost tends to be reduced as the portion of the lower cost solar energy increases. However, this trend is offset by the increasing amounts of energy discharged to the cooling tower. (Figure 16). This produces a minimum point which varies with the cost of the solar collector. As the collector cost is reduced, the minimum point occurs at larger collector areas. At \$22/sq ft of collector area only about 25% of the available space should be used, while a collector cost of \$13/sq ft would permit 75% of the available space to be used economically.

In Boston, a similar analysis yields slightly different results as shown in Figure 19. At \$22.13/sq ft for the collector, the effective energy cost increases with increasing collector area since the effective cost of collecting solar energy is greater than the effective cost of burning fossil fuel. At \$13/sq ft the solar cost is less and results in a reduction in effective energy cost as the collector area is increased. However, the smaller amount of solar insolation in Boston combined with higher fuel cost results in higher annual energy costs than in Los Angeles, although the shape of the annual energy cost curves are quite similar otherwise.

Unfortunately, the indications obtained from the comparisons made in Figures 6 through 10 may not be very significant since they are based upon capital costs that must be considered unacceptable. It is necessary to have a better

LOS ANGELES — LOW RISE BUILDING-CONSERVATIVE LOAD

Figure 16. HIGH TEMPERATURE ORC SYSTEM — LOS ANGELES

Figure 17. HIGH TEMPERATURE ORC SYSTEM — BOSTON

Figure 18. HIGH TEMPERATURE ORC SYSTEM WITH THERMAL TRACKING
(1990 Costs)
(Los Angeles — Low Rise Building — Conservative Load)

Figure 19. HIGH TEMPERATURE ORC SYSTEM WITH THERMAL TRACKING
(1990 Costs)
(Boston — Low Rise Building — Conservative Load)

understanding of the internal economics of the system, in order to determine what is required to achieve an economically viable STES.

Comparison of Solar and Fuel Energy Costs

To compare the cost of solar energy delivered to the thermal storage tank with the cost of fuel energy delivered to the same tank, both the annual fixed costs and the variable fuel costs must be estimated on a common basis and the cost of the thermal storage tank must be apportioned according to the respective energy quantities.

The cost of delivering solar energy to the high-temperature thermal storage tank is given in Equation 2.

$$ECS = \frac{[(CC)(CA) + \frac{(SR)SH}{TH}(TC)](ACR) + MC(CA)}{(SR)SH} \quad (2)$$

where:

- ECS = effective cost of solar energy (\$/10⁶ Btu)
- CC = unit collector cost (\$/sq ft)
- CA = collector area (sq ft)
- SH = solar heat collected annually (10⁶ Btu)
- TH = total heat delivered to tank annually (10⁶ Btu)
- TC = capital cost of the storage tank (\$)
- ACR = annual capital cost ratio (%/100)
- SR = ratio of solar energy delivered to tank to solar energy collected annually
- MC = annual collector maintenance cost/sq ft (\$)

The cost of delivering fuel energy to the same storage tank can be obtained from a similar equation -

$$ECF = \frac{(FP)(FQ - FT) + [BC + \frac{(e)(FQ - FT)}{TH}(TC)](ACR)}{(e)(FQ - FT)} \quad (3)$$

where:

- ECF = effective cost of fuel energy (\$/10⁶ Btu)
- FP = fuel price (\$/10⁶ Btu)
- FQ = fuel quantity purchased (10⁶ Btu)
- FT = fuel delivered directly to thermal load (10⁶ Btu)
- BC = capital cost of fuel boiler (\$)
- e = boiler efficiency (%/100)

TH = total heat delivered to tank annually (10^6 Btu)
TC = capital cost of storage tank (\$)
ACR = annual capital cost ratio.

These effective energy costs can be calculated for any of the cases examined in the technical analysis. More important, by setting the two effective costs equal, the collector cost equivalent to a given purchased fuel price, can be calculated. This has been done and the results are shown in Figures 20 and 21 for Los Angeles and Boston, respectively.

In Boston, the amount of collector area used has very little effect upon the breakeven cost between fuel and solar energy. This is because the quantities of fuel used are large enough that the fixed costs of the fuel boiler and heat storage tank have little influence upon the effective cost of fuel energy reaching the storage tank. In Los Angeles, the amount of fuel required is much less and the fixed costs per unit of fuel energy are relatively higher, particularly for the larger collector areas. This results in a higher effective fuel energy cost in relation to the fuel price which equates to a higher solar collector cost. In addition, the more solar energy collected per unit of collector area, because of increased solar insolation, the lower the effective unit cost of solar energy delivered into the system.

A collector cost of \$16.00/sq ft is equivalent to a fuel price of \$3.00/million Btu for an STES in Los Angeles using all of the available roof area for collector installation (100%). In Boston, the same design consideration, with the same collector cost would require \$5.85/million Btu to break even. Higher fuel costs than these will produce savings using solar energy. Lower fuel costs do not justify the use of solar energy at all.

Thus, Figures 20 and 21 show that the projected solar collector cost of \$22.13/sq ft would not result in an economically attractive solar system of any kind in Boston, although it could be attractive in Los Angeles after 1990 if other cost factors did not interfere. It would require collector costs of \$15.00/sq ft in Boston after 1985 to justify the collection of solar heat.

While fuel costs above these breakeven curves are necessary for an economically viable solar energy system, these alone may not be sufficient. The savings from the use of solar energy must also offset the added thermal distribution costs discussed above and any net loss in the cost of generating electricity

Figure 20. BREAKEVEN SOLAR COLLECTOR COST — LOS ANGELES

BOSTON — LOW RISE BUILDING—CONSERVATIVE LOAD

Figure 21. BREAKEVEN SOLAR COLLECTOR COST — BOSTON

compared to the cost of purchased electricity. If the electricity can be generated at lower cost than purchased electricity, the saving would, of course, be positive and would help to offset the added thermal distribution costs. It is therefore desirable to know whether the generated electricity is cheaper or more expensive than the electricity purchased.

Electric Generation Costs

Regardless of whether the working fluid is heated by solar energy or fuel energy, the electricity generated absorbs a portion of that energy. The ORC unit must also be charged with those energy losses not recovered and used elsewhere in the system. However, the heat energy delivered to the thermal load from the condenser is chargeable to the thermal loads rather than the ORC system.

Using this basis of allocation, it is possible to estimate the average annual cost of the electricity generated, as shown in Equation 4.

$$GC = \frac{(EQ)(AEC) + (ORCC)(ACR)}{(EG)} \quad (4)$$

where:

- GC = the average generation cost (\$/million Btu)
- EQ = the quantity of energy charged to ORC (million Btu)
(electricity generated + unrecovered energy losses)
- ORCC = capital cost of ORC and related components
- ACR = annual capital cost ratio (%/100)
- EG = electricity generated (million Btu equivalent)
- AEC = the average cost of the solar and fuel energy delivered to the system.

In making the calculation of the cost of electricity generated by the STES, only that portion of the energy flowing through the electric generating unit which contributes to the generation of electricity is charged to the cost of electricity. That is, in Figure 15, the 718×10^6 Btu of energy converted to electricity plus the 153×10^6 Btu of ORC losses are charged to the generated of electricity, but the 3491×10^6 Btu of condenser heat is not charged to electricity costs, and flows through to be charged to the thermal load only.

This differs from conventional practice which would charge the entire 4362×10^6 Btu of energy input to the ORC unit as the fuel cost, and makes it necessary to credit the 3491×10^6 Btu passed to the condenser to the cost

of electricity. By charging only the energy converted to electricity plus those losses attributable to the generation of electricity which cannot be applied to the thermal load, the heat going to the condenser is not involved and no credit is applicable.

This method of handling the energy flow was used in order to make it easier to see the contribution of the ORC unit to the overall energy supply.* Thus, if the ORC unit is eliminated, the capital cost of the unit is saved and the 718×10^6 Btu of electric energy generation plus the 153×10^6 of ORC energy losses, or a total of 871×10^6 Btu, could be applied to the thermal load or eliminated. Since the condenser heat is more than sufficient to provide the thermal load of 3115×10^6 Btu on an annual basis, at least that amount of energy could be saved. Without a detailed analysis, it cannot be determined how much of that saving would be fuel or solar energy. But at the average effective fuel cost of $\$7.80 \times 10^6$ Btu in 1990 for the case shown in Figure 15, a saving of \$141.54 per dwelling unit could be made by a saving of 871×10^6 Btu of energy. (This is for the 48-unit low-rise apartment building in Boston.)

The capital cost of the ORC unit of \$110,800 amounts to \$275/dwelling unit annually at a 12% capital cost factor. This added to the fuel cost saving makes a total saving of \$416.54. This more than offsets the cost of the additional electricity that must be purchased (718×10^6 Btu @ $\$16.51/10^6$ Btu or \$247/dwelling unit) resulting in a net saving of \$170/yr-dwelling unit.

Since the projected capital cost of the ORC system (including its related components) is in excess of \$100,000, the projected electric generation costs range from \$18.00/million Btu equivalent for zero fuel cost and zero collector cost to as much as \$30.00/million Btu equivalent at the higher solar collector costs. Generally speaking, at any realistic collector cost level, the electric generation cost amounts to about twice the cost of purchased electricity. Moreover, the levelized annual fixed cost of the ORC unit alone is greater than the cost of purchased electricity in virtually all cases.

Figure 22 shows the ORC system capital cost required to generate electricity at a given cost with a given average effective cost of energy delivered to

* It must be emphasized that the net result of this method is the same as the more conventional method of crediting the waste heat utilization back to the electric generation step.

Figure 22. . ORC CAPITAL COST TO BREAK EVEN

the ORC unit. This figure is for Los Angeles, using 50% collector area. Operating points are shown for indicated solar collector costs that will permit generation of electricity at the same cost as that projected for purchased electricity in 1990, using the 1990 fuel price for gas.

Comparable charts for other areas, building types, and collector areas do not differ markedly from the chart presented in Figure 22. The sloping lines shift somewhat, but in the area of interest, ORC capital cost of \$25,000 or less are generally required. It is unlikely that the projected cost of \$110,800 for an ORC system and its related equipment can be reduced to this range by further design refinement or quantity production, even though ORC manufacturing costs may be reduced considerably with high production levels. The cost of generating electricity in the ORC unit is in excess of \$20.00/million Btu. For other than 100% collector area, the nearly vertical lines of constant generating cost shift only slightly since the primary cost factor is the capital cost of the ORC unit itself. The effect of fuel cost is relatively minor, as shown by Figure 21, which shows that zero fuel costs would not provide competitive electricity costs.

An increase in projected electric utility costs would, of course, raise the breakeven capital cost. However, Figure 22 shows that it is necessary to approximately double the price of electricity to make this ORC system attractive.

Some minor benefits could be achieved by reducing the size of the ORC unit so that it generates a smaller portion of the electric load and has a better load factor. This causes the overall cost picture to improve since less of the higher cost electricity is generated and more lower cost purchased power is used. To carry this to the extreme would result in the elimination of the electric generation function completely. That is, as long as the onsite generation of electricity is more expensive, on an overall annual basis, than purchased electricity, its use detracts from the economic advantage of a solar heating/cooling system using purchased utility electricity.

This point is important. Cost savings obtained by the use of solar energy for heating and cooling can be used to offset electric generation costs higher than purchased power and may result in lower overall costs than a conventional building. However, using purchased electricity with the same solar heating/cooling system will result in a still lower cost system. The STES must still compete with a solar heating/cooling system using purchased electricity.

It is evident that an economically attractive STES must contain the same elements as an economically attractive fossil fuel total energy system. The addition of solar energy can reduce the effective fuel cost to the system, making it more attractive. However, any solar energy collected which cannot be applied to the generation of electricity, must be used to supply the thermal load only and, in effect, competes with exhaust heat from the electric generation system. When the thermal load is large enough, in relation to the electric load, to absorb all of the exhaust heat as well as the low-temperature solar heat, no energy loss occurs.

When the thermal load is less than that amount, one of these alternatives must be accepted —

- Heat must be rejected to the cooling tower
- The solar collector must be reduced in size
- The generation of electricity must be restricted in some way.

A complete economic analysis of the trade-offs possible among these three alternatives is beyond the scope of this study. However, some observations are possible.

The thermal tracking device described in this study was found to be an effective way to prevent the generation of excessive waste heat. However, its attraction in this study is due largely to the fact that purchased electricity is, in all cases, cheaper than solar-generated electricity. That is, shutting down the generator at any time results in electric energy cost savings directly.

If generated electricity is less expensive than purchased electricity, it may be better to allow the generator to run even when the exhaust heat cannot be fully utilized. This requires a trade-off between the savings from the generation of electricity versus the losses due to rejection of exhaust heat. This is complicated by the role of solar energy in supplying a portion of the heat to both the electric generator and the thermal load.

The simple assumption of a low capital cost for the ORC system to explore resultant relative energy cost savings would be meaningless unless changes in the operating mode of the system are made to take advantage of the altered cost factors. This would result in a very complex technical/economic cost study that cannot be justified in view of the unrealistic capital cost assumptions required.

Time-of-Day Electric Rates

Since increased electricity costs tend to improve the relative position of onsite electricity generation, it is worthwhile to examine the effect that time-of-day pricing in the electric utility business might have upon the attractiveness of a STES.

There are a few special rates applied by certain electric utilities to water heaters and other appliances which are restricted in one way or another to off-peak operation. However, as yet there are no general time-of-day rates which apply to all electricity purchased, using different rates for different hours of the day. Some utilities have discussed the nature of rate revisions they might make to encourage greater use of electricity during nighttime hours. These vary considerably, some are intended to encourage additional electricity use at night with less emphasis on shifting a given load from day to night. Some propose to apply higher demand charges to on-peak or daytime use, as a form of rate increase. Each utility must tailor its rates to its own particular load schedule and future outlook.

Therefore, we have postulated our own daytime/nighttime rate ratios, which would produce the same total revenue from the residential market based on existing residential usage patterns as presented in Volume II of this report. The residential load peak period is from about 4 p.m. to midnight, with the minimum load period running from midnight to 8 a.m., when the normal daytime load comes on.

A rate schedule charging a premium daytime electric rate into the early evening hours would be most favorable to a STES since the solar energy stored during the day could be used to mitigate the evening peak load. However, late evening loads, coming after the normal peak, will usually require purchased electricity, particularly during the winter periods. However, winter peak loads begin to decline after 8 p.m. Thus, a rate schedule that offers a lower nighttime rate between 8 p.m. and 8 a.m. and a premium rate between 8 a.m. and 8 p.m. would be most favorable to the use of a STES.

The system design data for a low-rise building in Albuquerque were used to estimate the effect of such a time-of-day rate schedule. A collector area of 75% of the available space was selected as the most probable system design.

The 24-hour electrical demand schedule indicates that about 50% of the electrical load occurs during the period from 8 a.m. to 8 p.m. so that a premium applied during the day can be offset by an equal discount during the night to provide the same overall annual revenue. However, the STES is required to purchase only 264 million Btu of utility electricity during the day (8 a.m. to 8 p.m.), while purchasing 663 million Btu during the night (8 p.m. to 8 a.m.) for the 48-unit building. This disparity in purchased quantities results in substantial savings in purchased electricity cost, which increase as the difference between daytime and nighttime rates is increased. This relationship is shown in Figure 23 for the projected saving per dwelling in purchased electricity costs in 1990 and 2020. The ratios shown are in relation to the average electricity price.

The STES, of course, generates additional electricity at much higher costs because of the high capital cost of the ORC system. When these costs are added in order to compare total electricity costs of the STES, the savings shown in Figure 23 amount to only a small percentage of the total cost. For the 1.25/0.75 ratios (using the 1990 electricity price for the system considered), the time-of-day rate would result in only a 4% reduction in total electricity cost, although it provides an 11% reduction in purchased electricity cost.

Translating the saving into equivalent capital costs is more useful. For the 1990 price curve shown and ratios of 1.25/0.75, the saving of \$25.00/yr would offset \$10,000 worth of capital costs at an annual capital cost ratio of 12% for the 48-unit low-rise building. At the 1.75/0.25 ratio, it would equate to \$30,250 of capital cost, offsetting 27% of the ORC capital cost. Clearly, time-of-day rates will help to make an STES more competitive, but other measures are needed.

9.2.2 Photovoltaic System

The parameters involved in the photovoltaic STES are quite different from those involved in the ORC STES. Nevertheless, it is desirable to know the internal cost of solar heat collected for comparison with the internal cost of fuel energy. Similarly, the cost of solar-generated electricity should be compared with the cost of purchased utility electricity.

This comparison has been made by dividing the total capital cost projected for the complete photovoltaic system into segments related to the collection of solar heat, the generation of electricity and the distribution of thermal

Figure 23. SAVINGS FROM TIME-OF-DAY RATES

energy within the system. A breakdown of these capital costs and their resulting charges against heat and electricity supplied are presented in Table 66, based on an apportionment of cost data in Section 8.4.

Table 66. PROJECTED COST OF HEAT AND ELECTRICITY
PROVIDED BY PHOTOVOLTAIC STES, IN 1975 DOLLARS
(Dallas, Low-Rise Building, 1990 Costs, 50% Collector Area)

<u>Item</u>	<u>Total System</u>	<u>Solar Heat</u>	<u>Electricity Generated</u>	<u>Thermal Distribution</u>
Fixed Capital Cost, \$	328,290	55,430	98,696	174,164
Collector-Related Capital Cost, \$/sq ft	21.81	13.97	6.45	1.39
Collector Area, sq ft	8,607	8,607	8,607	8,607
Total Collector Capital Cost, \$	187,719	120,240	55,515	11,967
Annual Capital Cost Ratio	.12	.12	.12	.12
Total Annual Capital Cost, \$/yr	61,921	21,080	18,505	22,336
Operating & Maintenance Cost, \$/yr	903	606	338	--
Total Annual Fixed Cost, \$/yr	62,824	21,686	18,843	22,336
Energy Supplied to the Load, 10 ⁶ Btu	3,570	805*	361*	1,313*
Cost of Energy, \$/10 ⁶ Btu	17.60	--	--	--
Cost of Solar Heat, \$/10 ⁶ Btu	--	26.94	--	--
Cost of Photovoltaic Electricity, \$/10 ⁶ Btu	--	--	52.50	--
Fixed Cost of Thermal Distribution, \$/10 ⁶ Btu	--	--	--	17.01
Total Capital Cost, \$	516,009	175,670	154,211	186,127

* Energy supplied is not additive since purchased energy and losses are not shown.

The first column in Table 66 includes data for the entire system and the total annual fixed cost is divided by the total amount of energy demand, including fuel, solar heat, generated and purchased electricity to give an aver-

age cost of energy for the system. The second column includes only costs attributable to the collection of solar heat and is divided by the amount of solar heat collected to give an average annual cost of \$26.94/million Btu, including solar heat not applied to the load. The third column contains costs applicable to the generation of electricity by the photovoltaic system and is divided by the amount of electricity generated to yield an average cost of \$52.50/million Btu. The fourth column collects the remaining capital costs which are charged to the thermal distribution system, which can be charged against the thermal load to give an average cost of \$17.01/million Btu.

The average cost of solar energy to the system of \$26.94 is 2-1/2 times the projected effective fuel cost of \$10.57/million Btu. The effective fuel cost is higher than the purchased fuel price by the fixed costs of the fuel boiler and a share of the thermal storage tank costs. It also includes an allowance for the boiler efficiency of 80%. Obviously, it would be cheaper to eliminate the solar collector and burn fuel entirely. To break even with the effective fuel cost of \$10.57, the solar-related capital costs would have to be reduced to \$65,860 instead of \$175,670, as shown in Table 66 — a reduction of 62%.

The cost of generated electricity, shown in Table 66 as \$52.50/million Btu, is over five times the cost of purchased power projected at \$10.67/million Btu in 1990. Thus, to break even, the cost of the capital equipment related to the generation of electricity would have to be reduced to \$29,282 instead of the \$154,211 shown.

For other locations and collector areas, these figures will change, but no cases were found in which the photovoltaic system appeared to have promise of competing with conventional energy systems because of the high capital cost. It should be noted that this analysis does not involve the capital costs associated with the distribution of thermal energy, but involve only the costs associated with introducing the solar heat and electricity into the system. Therefore, they can be reduced only by reducing the capital costs appearing in Columns 2 and 3 of Table 66.

It should be noted that the capital costs related to the solar collector of \$187,719 amount to only 36% of the total system capital cost. The remaining \$328,290 is composed of items listed in Table 62, p. 110 for 1990. These items alone total more than twice the required capital costs of an equivalent conven-

tional building. Thus it is apparent in this case also that the system would not be competitive even if the collector cost nothing per sq. ft. The problem lies with the cost of equipment necessary to deliver the energy to the load effectively.

No further parametric analysis was carried out because of the wide disparity between projected costs of applied solar energy and purchased fuel and electricity. As in the case of the ORC analysis, time-of-day pricing would help to narrow the gap, but drastic reductions in capital cost must be made before other techniques can make a significant impact on the overall cost problem.

9.3 Hybrid Systems

During the course of this study several alternative systems were considered, although no detailed examinations were made since they do not constitute true solar total energy systems. Some of these were derived from the consideration of using a diesel or gas engine as a back-up unit to the independent ORC system. This was not pursued since the capital cost of the ORC unit plus its high fuel consumption made it unattractive with or without a back-up reciprocating engine.

Conventional total energy systems, using gas or diesel engines could be operated in buildings using supplemental solar energy applied to the building thermal load. However, no such systems were found in which the use of solar energy permitted the onsite generation of electricity to become competitive with purchased power. In all cases, it appeared that the overall savings would be greatest when the solar energy was applied to the thermal load and the electricity was purchased from a utility. Under these conditions, the use of onsite power generation, which becomes attractive only when the exhaust heat can be applied to the thermal load, tends to be less attractive when solar heat is used to supply part of that load.

One hybrid configuration, which may be economically viable in certain situations, is a gas- or diesel-powered onsite generation system operating in conjunction with a solar/heat cooling system. Most, if not all of the exhaust heat from the engines could be utilized, as well as a significant amount of solar heat resulting in a minimum requirement for back-up fuel to serve the thermal load. However, the solar heat contributes nothing technically or economically to the electricity supply and so cannot be regarded as a STES. It

is simply a solar heating/cooling system in which, for certain unrelated reasons, it is economically (or otherwise) attractive to generate electricity on-site rather than using utility electricity. The presence of the solar system can only make the onsite electricity less economical than it would be otherwise. It cannot make it more attractive.

Such systems were not investigated in any detail since they did not appear to offer advantages through the use of solar heat. Their future use and attractions are largely independent of the use of solar energy.

9.4 Potential Market Penetration

The preceding sections reveal that the projected capital costs of components required to install any of the STES examined are so high that they offer little hope of providing annual energy service at costs comparable to conventional energy systems, or solar heating/cooling systems using utility electricity, within the time frame of this study. Nevertheless, all buyers are not similarly motivated and some consideration of the normal distribution of prospective buyers should be made before concluding that a market will not develop.

9.4.1 Market Capture*

The classic statistical classification of potential buyers is based upon the recognition that a small percentage (2.5%) of the population can be classified as "innovators" who will be the first to buy a new product even if the economic incentive is marginal, and a somewhat larger percentage (13.5%) who will be the next to buy even if the economic incentive is small but positive; the latter group is usually termed "early adopters." A historical adoption curve is shown in Figure 24. Based on this recognition and a similar classification for the remaining population, a standard S-shaped diffusion curve can be drawn which shows the form that cumulative market penetration with time will have. (See Figure 25.) Although the general form of the curve will remain S-shaped, the steepness of the curve will depend upon the rate at which the new product is adopted; generally, either a reflection of costs or public acceptance, or both.

* See Appendix E for additional discussion of the methodology.

Figure 24. HISTORICAL ADOPTION CURVE

One statistical approach to determining the number of new adopters, and thereby predicting the market penetration of a new product, makes use of a normal distribution pattern (Figure 25). As applied to the market penetration of STES in the residential sector, this can be used to determine the capital costs that would be required to achieve certain market penetration values for a given saving in fuel costs over conventional energy systems.

Figure 25. HISTORICAL DIFFUSION CURVE

For example, calculations indicated that \$700 in fuel savings could be realized by the year 2010 through the use of STES in single-family residences in Boston, compared with fuel oil. If we assume that half of the innovators (1.25%) would be willing to buy if the annual incremental cost of the system were equal to the fuel savings, i.e., at breakeven costs, and that the early adopters plus the innovators (16%) would be willing to buy if incremental costs were only 75% of the fuel savings (\$525), the methodology shown in Appendix E can be used. From tables on standard normal curve areas, Z values corresponding to 48.75% and 34% (i.e., 50-1.25 and 50-16) are -2.24 and -1.00, respectively. Two equations can thus be written:

$$\frac{525 - \bar{t}}{\sigma_{\bar{t}}} = -1.00 \text{ and } \frac{700 - \bar{t}}{\sigma_{\bar{t}}} = -2.24 \quad (5)$$

Solving for $\sigma_{\bar{t}}$ and $\bar{t}$, $\sigma_{\bar{t}} = -141.12$ and $\bar{t} = 383.88$. If market capture (or the Z value corresponding to it) is equal to annual incremental payment $-\bar{t}/\sigma_{\bar{t}}$, then the expression may be written:

$$\text{Incremental payment} = -141.12Z_{mc} + 383.88 \quad (6)$$

and the incremental payment corresponding to different market capture values may be calculated. Table 67 gives the incremental payments and capital cost differential (at a 12% and a 15% capital cost factor) corresponding to different market capture values.

Table 67. INCREMENTAL PAYMENTS AND CAPITAL COST DIFFERENTIAL

Market Capture	Z_{mc}	Incremental Payment	Capital Cost Differential	
			15%	12%
0.5%	2.57	\$746.56	\$4,977	\$6,221
1.0%	2.33	\$712.69	\$4,747	\$5,939
2.0%	2.05	\$673.18	\$4,488	\$5,610
5.0%	1.645	\$616.02	\$4,107	\$5,134

These values are for an individual dwelling unit, so the capital cost differential for the entire system for 36 units would be 36 times these values, or total capital cost differentials ranging from \$147,852 to \$223,956 for the entire STE system.

A similar calculation for low-rise apartments in Albuquerque is based on a fuel saving of \$385 in the year 2000, compared with natural gas. Using the same assumptions regarding innovator and early adopter actions, incremental payments for each dwelling unit of \$385 and \$290, respectively, are used for the equations. A summary of these results is shown in Table 68.

Table 68. SUMMARY OF INCREMENTAL PAYMENTS AND CAPITAL COST DIFFERENTIAL

Market Capture	Z_{mc}	Incremental Payment	Capital Cost Differential	
			15%	12%
0.5%	2.57	\$410.28	\$2,735	\$3,419
1.0%	2.33	\$391.89	\$2,612	\$3,266
2.0%	2.05	\$370.44	\$2,470	\$3,087
5.0%	1.645	\$339.41	\$2,263	\$2,828

For the system serving an entire 48-unit low-rise, the total capital cost differential corresponding to these values would range from \$108,624 to \$164,112. Thus, the capital cost differential for the STES would have to fall in this range in order for market capture of 0.5% - 5% to take place. As shown in Section 8, capital cost projections are not within the ranges indicated for market capture under the assumptions used; nevertheless, these values suggest the approximate capital cost reductions that must occur in order to achieve market penetration in the residential sector.

Alternatively, the same methodology could be applied to determine how much fuel savings must be realized in order for projected capital costs to achieve market penetration. Unfortunately, zero fuel costs to the electric generation unit still would not result in any indication of market penetration.

9.4.2 Impact on Energy Use

Since no significant market penetration is projected, no significant impact upon the use of energy can be estimated. However, for certain analysis work it may be useful to know what the impact upon energy use would be if a STES were installed in a residential-type building. For this reason some of the energy consumptions estimated in the course of the analysis have been tabulated and are discussed herein.

The energy savings obtainable with an STES using an ORC electric generator are shown in Table 69 for selected cities.

Table 69. ENERGY SAVINGS PER DWELLING UNIT WITH HIGH-TEMPERATURE ORC
(Million Btu/Year)

Location and Building Type	Collector Area, %	Savings With STES						
		Conventional		STES		Total*		
		Fuel	Electricity	Fuel	Electricity	Fuel	Electricity	Energy
Albuquerque								
Low-Rise	100	61.7	24.9	16.8	17.0	44.9	7.90	72.1 (49%)
Low-Rise	75	61.7	24.9	29.7	19.3	32.0	5.54	51.1 (35%)
Low-Rise	50	61.7	24.9	50.2	20.6	11.6	4.25	26.26 (18%)
Boston								
Low-Rise	100	73.7	23.05	40.2	18.9	33.5	4.15	47.8 (32%)
Low-Rise	75	73.7	23.05	51.5	20.1	22.2	2.95	32.4 (22%)
Low-Rise	50	73.7	23.05	54.2	20.2	19.5	2.85	29.3 (20%)
Phoenix								
Low-Rise	100	44.15	33.55	6.34	14.04	37.8	19.51	86.8 (54%)
Townhouse	100	55.25	48.75	23.21	13.83	32.0	34.9	152.4 (68%)
Los Angeles								
Low-Rise	100	39.65	23.50	10.07	18.27	29.6	5.23	47.6 (39%)
Townhouse	100	48.50	31.50	17.74	22.68	30.8	8.82	61.2 (39%)
Single-Family	100	56.55	28.85	10.15	20.3	46.4	8.55	75.9 (49%)

* Total energy includes electric generation at 10,800 Btu/kWh plus 8% transmission loss, (29% efficiency).

The data presented in Table 68 show that the greatest savings in energy consumption are made at the largest collector areas. Since it was pointed out earlier that the optimum (economically) collector area increases as collector cost is reduced, there could be a significant impact upon energy conservation if the cost of solar collectors can be reduced to the levels of \$10 to \$13/sq ft installed. However, energy savings from the use of solar energy for electricity must also depend upon economically attractive onsite generation. Much of the energy saving shown in Table 68 is due to elimination of utility electricity with its conversion efficiency of 29%. These savings cannot be made until an economically competitive solar-powered electric generation system can be developed.

In this respect, the photovoltaic system is currently projected to be less attractive than the ORC unit because it is not only more expensive, but also produces a smaller share of the electrical load.

Nevertheless, a general conclusion can be made that if the cost of capital items can be reduced to the economically viable level, energy savings per dwelling on the order of 50% can be made in the southwest and 30% or more in other parts of the country. The overall regional savings will, of course, depend upon the number of such dwellings that are built. This cannot be predicted until some presently unforeseeable developments permit lower capital costs.

Section 10.

MARKET STRATEGY

The high capital costs of STE systems compared with potential fuel savings have resulted in a rather unpromising outlook for near-term penetration of potential residential markets, even with tax incentives, time-of-day pricing for electricity, and other financial inducements to commercialization. For this reason, it appears premature to consider new demonstration units for the residential sector within the next few years. Rather, we would suggest that the solar total energy program might be better served by first demonstrating the viability of STE systems in more promising non-residential applications. This would establish their suitability as a viable energy option and provide a sounder basis for projecting higher production levels for solar components that would ultimately favor future residential applications.

Meanwhile, research and development efforts to improve the costs and performance of solar components should continue, as should efforts to devise residential systems that could minimize the costs of conventional components. Perhaps some combination of building design and energy system design could reduce the cost differential between unitary systems and central systems. Ultimately, some combination of increasing fuel prices and decreasing STES capital costs will create a more favorable projection for residential market penetration, and a marketing strategy should be developed.

The initial market strategy will undoubtedly involve government-sponsored demonstration units, similar to those scheduled for the industrial sector and probably involving co-funding participation by the private sector, in conjunction with cooperative participation by utilities. This should probably proceed by way of an RFP and utilize site selection criteria as described in Section 10.1.

The type of demonstration unit may very well be a townhouse complex or a low-rise apartment, since the economic analysis indicates that these types of buildings would probably be the first to show favorable economics. As a start, we should consider the possibility of retrofitting an older existing building that already contains a central hydronic heating/cooling system. Since the cost of installing the central hydronic system is a major constraint to STES market penetration, the use of a suitable retrofit might appear more

promising since it would utilize the existing (and depreciated) thermal distribution system of an existing building. If located in a section of the country that permits a smaller collector (aperture) area, sufficient roof area should be available for siting an ORC system and its associated components. Although not specifically addressed as part of this study, a single-family home with an individual photovoltaic-based STES could conceivably be a candidate for a STE residential demonstration unit.

Although the following section has been written with the goal of selecting demonstration sites for a new residential building with a solar total energy system, the selection process could be used for the retrofit situation described above. The major problem would probably be to find a building that meets the retrofit requirements; this could become the overriding site selection criterion.

10.1 Site Selection Criteria

One of the objectives of DOE's Solar Total Energy Program is to develop STES demonstration sites in suitable regions of the country. This objective assumes that a successful solar total energy demonstration system in one region will increase the overall national market penetration of solar systems as well as the penetration of such systems within the specific region of the demonstration site. In support of this objective, we have developed a two-stage site selection procedure which, in its iterations, permits selection of a region and the specific site within the chosen region. The selection procedure has been determined, and an initial set of criteria has been identified for both the regional analysis and the site specific analysis.

The evaluation system contains three elements: the evaluation criteria; the cities within the regions or the specific sites available for development; and the means by which the city or site are linked to the criteria and prioritized. These elements are discussed below.

10.1.1 The Prioritization System

The problem of selecting an appropriate region, or a demonstration site, within a specific region for a residential STES involves a common objective, namely, to produce a list of the options rank ordered in relation to one another and within the constraints of a set of criteria. In some instances, the criteria for selecting a region will be more generalized, or focused differently

than those required for the site selection. Therefore, we have chosen to organize the prioritization system into two iterations: one that focuses on the selection of an appropriate region or regions, and a second that assists in ranking the appropriate demonstration sites. Although the elements being evaluated and the criteria used in the evaluation will differ, the procedure used to produce the ranked list remains constant for both iterations.

In both instances, a matrix is used which has criteria as the row headings and either a city or a site as the column headings. The first step of the analysis is to determine the relative weight of the criteria in relation to one another and in terms of their importance in the overall selection decision. In the second step, a city or site is evaluated in terms of the degree to which it satisfies or corresponds to each criterion. In the final step, the products of Steps 1 and 2 are added to produce a ranking figure for each city or site.

The product of Step 1 is a percentage associated with each criterion. The percentage is representative of the degree of importance of a particular criterion in the overall decision. This importance factor is determined by assigning a scaling number from 1 to 10 to each criterion. The scaling numbers for all criteria are added and the total is divided into the scaling number for each criterion. The quotient is the importance factor, or the percentage of the decision to be attributed to a particular criterion.

Once an importance factor has been assigned to each criterion, we can evaluate the degree to which each city or site satisfies or corresponds to the requirements expressed in the criterion statement. Once again, we use scaling numbers ranging from 1 to 10, which are normalized over 100%. In many instances, however, this number can be derived objectively by using the available data. For example, if one criterion deals with market size, the market within each city can be shown as a percentage of the total market for all cities being evaluated; this percentage is then discounted by the weighting factor for the appropriate criterion by multiplying the two numbers.

In the final step, we add the discounted percentage for each city. Each city total will show the degree to which the city satisfies the set of criteria relative to all the cities or sites.

10.1.2 The Criteria

Our objective in this task was to produce a system which ultimately will enable DOE to select one or more residential demonstration STE sites. The system is designed such that DOE can assign the weights, if necessary, in accordance with internal DOE requirements and values.

We envision the site selection process as having two primary steps: the selection of a region; and the selection of a specific demonstration site within the region chosen. As has been discussed in Volume II, the availability of data has dictated that a region be represented by a typical city in which the demonstration site will be located; it merely serves as a data surrogate for the region as a whole. Once the preferred regions or representative cities are chosen, the available sites within the corresponding regions are evaluated in the second step of the selection process. This second evaluation will probably be performed in-house at DOE with the evaluation being based upon cities and data provided in proposals submitted in response to an RFP similar to EG-77-R-04-0025, "Cooperative Assessment for the Conduct and Evaluation of a Solar Total Energy Large-Scale Experiment," (1-5-77).

Three factors should be included in the site selection; 1) Potential for Market Penetration, 2) Physical Feasibility, and 3) High Visibility. We have chosen to regard these factors as classes of criteria, each of which may have numerous criteria subsumed within it.

In the weighting process, one would first weight the three classes as to their importance in the decision. For example, in the Regional Decision, potential for market penetration could receive a weight of 0.35, physical feasibility could receive a weight of 0.45, and high visibility could receive a weight of 0.20. Several factors that could be included in the weighting decision in regard to these three classes are discussed below. Here, our focus is on the mechanics of the weighting procedure.

Once one has defined a weight for the classes, the process is repeated for the criteria subsumed within each class. In each class the percentages assigned to the criteria will total 100%. The weight for each criterion will then be discounted by the weight assigned the class into which the criterion is subsumed. This eliminates the possibility of the decision being skewed by a criterion which receives a high weight but is in a class which is of minor importance in the overall decision.

Although the three classes of criteria at both the regional and the site level of the selection should be maintained, the criteria within each class at the two levels of analysis will differ in some cases and, of course, have different weights. The criteria shown below constitute a preliminary list which should be refined in accordance with a specific application.

10.1.3 Regional Evaluation

Market Penetration Potential

- Savings on total household energy expenditures (Energy costs displaced by STES)
- Regional housing market potential (Region expected to experience an increase in population)
- Anticipated regional industrial expansion
- Household energy consumption—dependence upon fossil fuels
- Region's susceptibility to fossil fuel curtailments
- Anticipated increase in number of households
- Comparative wage scale between regions
- Comparative regional construction costs
- Regional construction starts.

High Visibility

- Percent urban population in region
- National news services in region.

Physical Feasibility

- Seasonal insolation vs. degree-days during heating season
- Seasonal insolation vs. degree-days during cooling season
- Approximate temperature of water in °F
- Number of hours dry bulb temperature reaches 80°F or over in average year.

10.1.4 Site Evaluation

Market Penetration Potential

- Population growth (SMSA)
- Household growth (SMSA)
- Household income growth (SMSA)
- Employment growth (SMSA)
- Residential energy costs (SMSA), anticipated % savings
- Proximity of site to transportation/employment
- Housing supply — number of units constructed in SMSA
- Vacancy rates in SMSA
- Open space inventory
- Construction costs in SMSA (\$/sq ft)
- Land costs (\$/sq ft)
- Local tax burden
- Site amenities (location, aesthetics, etc.)
- Rental cost per unit in relation to market

High Visibility

- Wire services in site area
- Prestigious location of site
- Aesthetic qualities of proposed development
- Willingness of developer to publicize STES
- Proximity of major news services.

Technical Feasibility

- Ambient water temperature at site
- Willingness of local utilities to cooperate with project
- Willingness of local government to provide tax advantages affecting rental cost of units

- Proximity of solar obstructions to site
- Proposed energy efficient design of development
- Contractor's familiarity with solar systems.

10.1.5 Region and Site Selection

We have made the distinction above between the selection of a region and that of the specific site. This distinction is reflected in the design of the selection procedure which focuses initially on the regions and, once a region is selected, then focuses on the selection of the specific site within that region for a demonstration STES.

Due to data availability, we have chosen to represent the regions by one typical city within each region. The assumption herein is that the city can represent a generalized form of the data for all cities within a particular region and, in fact, the structure of the regions was derived accordingly. Thus, in the first stage of the selection procedure, the city merely represents a data surrogate for the region, and the use of that city is not meant to suggest that the specific site will necessarily be in the city used for this purpose.

Once the most desirable city/region has been chosen, it is our assumption that DOE will then request proposals for construction of a residential STES from any interested developer within that region. Therefore, the second stage of the selection procedure has been designed to select the most appropriate site within the entire region. As the sites will be located throughout the region, in both urban and rural areas, the judgment as to which is most appropriate must deal with the relative market advantages of the various sites as well as the actual technical characteristics. Each area of the region in which sites are located will have differing construction costs, land costs, vacancy rates, etc. It is essential to take these factors into account as they strongly affect the cost per unit of construction and therefore the price or rent that must be charged for each unit. Although these factors can be approached at a very general level in the regional selection, at the site level it is possible to determine the actual rent which must be charged for the developer to break even, and to compare this figure with the rental experience in the vicinity of the site.

10.1.6 Entering the Marketplace

The previous discussions have addressed the subject of market strategy only so far as it relates to the subject of demonstration units and the criteria for selecting demonstration sites. Assuming favorable economics for residential STE systems at some point in time, the strategy for actually capturing a share of the potential residential market will have to go well beyond a demonstration unit. The low-rise apartment appears to be the most likely residential building for STES market penetration, so the apartment builder would be the potential STES buyer and any market strategy would have to include any incentives for him. If the government is to assist in the commercialization of solar total energy, either directly or indirectly, it should be prepared to offer tax incentives to the apartment builder and assist him with any zoning, financial, or regulatory problems. Low interest loans and loan guarantees may be a key part of this early market strategy to provide the buyer with sufficient incentives to consider solar total energy systems in the residential sector in place of conventional systems.

Although the recommendation has already been made (Page 166) that STES demonstration units should first be planned for non-residential applications, primarily because residential applications have the least favorable market potential in the near term, political reasons may dictate that residential STES demonstration units be built. The criteria described in the preceding sections for selecting demonstration sites can be used, even though market penetration prospects are unfavorable. Heretofore, favorable economics have not been a required criterion for building solar demonstration units; otherwise, few, if any, demonstration units would have been built.

Section 11.

GENERAL CONCLUSIONS

1. The formidable capital cost problems associated with the installation of STES in 36- to 48-unit residential complexes makes it very unlikely that such systems will be salable in the foreseeable future in any region of the country where conventional fuel and electricity supplies can be provided.
2. To be economically competitive with other alternates for supplying residential energy needs, a STES must be capable of generating electricity at lower net cost than purchased power, i.e., including credit for reject heat. Unless this condition can be met a solar heating/cooling system using purchased power will be more economical.
3. The capital costs projected for STES-based electrical generating equipment promise generated electricity costs that are two to three times higher than average projected purchased electricity costs.
4. The projected capital costs (for a 36- to 48-unit residential complex) of about \$100,000 for an ORC system and its associated equipment would have to be reduced by a factor of four or five to become attractive. In the photovoltaic system the capital equipment related to the generation of electricity would have to be reduced by similar amounts. Larger residential complexes may show more favorable economics.
5. To justify the use of solar total energy it must be possible to apply solar energy to the system at a lower unit cost than applying fossil fuel energy. Unless this condition can be met it will be more economical to use a fuel fired total energy system, or conventional equipment and normal utility services. The projected cost of solar collectors permits this requirement to be met in the southwest after 1985, but cannot be achieved in cloudier climates unless collector costs can be reduced to \$12-\$15/ft² installed. This alone does not permit solar energy use to become attractive since additional conditions must be met.
6. There are four factors inherent in the nature of the residential market that makes an STES less feasible than similar systems in the commercial and industrial market.

6.1. Availability of Fossil Fuel

The unrestricted availability of fossil fuel to the residential market plus political pressures to increase industrial energy prices relative to residential energy prices combine to make an industrial STES easier to justify than a residential STES.

6.2. Unitary Equipment

The use of unitary systems in conventional residential buildings permits cost savings not attainable with the centralized systems required for an STES. Thus, the addition of a solar collector requires the energy distribution system to be centralized which sharply increases its capital cost. This additional burden must be recovered by the savings from the use of solar energy.

6.3. Central Receiver

Cost advantages for large-scale central receiver/heliostat systems are not applicable to residential applications as to industrial applications.

6.4. Decentralized Load

The advantages of scale in 36- to 48-unit residential buildings are more than offset by high costs for transmission and distribution of heat and cold. The more compact high-rise buildings lack the required roof area for installation of sufficient roof-sited solar collectors.

7. Solar heating/cooling systems using utility electricity will develop more rapidly than solar total energy systems, at least in residential areas. Also, STES developments in commercial and industrial areas may find commercial application before a residential STES. These areas can provide guidance for the future analysis and development of residential STES as costs and performance of components become better defined.
8. Photovoltaic systems potentially offer greater promise in residential structures than heat engines because of their greater adaptability to smaller dispersed installation, permitting greater use of unitary equipment.

Section 12.

RECOMMENDATIONS

1. It is recommended that future development efforts on STES for the residential market be directed toward component R & D that offers prospects of substantial cost reduction and/or efficiency improvement. Systems analysis should be aimed at component elimination, simplification, and reductions in field installed components and plumbing systems.
2. It is suggested that any highly visible demonstration of prototype installations be delayed until other more promising solar systems have been built and operated.
3. Research and development of systems that can be applied to individual dwelling units where unitary systems are installed is desirable. Such systems would avoid the cost complications of central systems and the energy transmission costs between the distributed load and the central system location.
4. Optimization of system designs and building size should be considered and correlated with system economics. This should include larger apartment buildings that permit economies of scale for larger ORC units, as well as optimal building design to minimize thermal distribution costs.
5. A separate heating and cooling study should be made to determine and evaluate optimal arrangements of solar collectors and dwelling units.

REFERENCES CITED

1. Arthur D. Little, Inc., Project Independence Task Force Report: Residential and Commercial Energy Use Patterns, 1970-1990. Prepared for the Federal Energy Administration, Washington, D.C., 1974.
2. Lee, John, Future Residential and Commercial Energy Demand in the Northeast. Report No. BNL 50552, Prepared for the United States Energy Research and Development Administration, Upton, New York: Brookhaven National Laboratory, March 1976.
3. Energy Policy Project of the Ford Foundation, A Time to Choose America's Energy Future. Cambridge, Massachusetts: Ballinger Publishing Co., 1974.
4. Bureau of the Census, Detailed Housing Characteristics, United States Summary, U.S. Census of Housing, 1970. Washington, D.C., 1970.
5. Rand Corporation, Energy Use and Conservation in the Residential Sector: A Regional Analysis. Report No. R-1641 NSF, Prepared for the National Science Foundation, Santa Monica, California, June 1975.
6. Institute of Gas Technology, Seasonal Energy Storage Requirements, ERDA Report No. EY-76-C-02-2906, Chicago, August 1977.
7. Hu, K.S., "Temperature Sensitivity of Utility Gas Consumption in the Residential Sector," Gas Supply Review, May 1977.
8. Mutch, J.J., Residential Water Heating: Fuel Conservation, Economics and Public Policy, Report No. R-1498-NSF, Prepared for the National Science Foundation, Santa Monica, California. May 1974.
9. Strock, C. and Koral, R.L., Eds., Handbook of Air Conditioning, Heating and Ventilating, 2nd Ed. New York: Industrial Press, Inc., 1965.
10. Annual Statistical Review, Appliance Manufacturers 1970 - 75 March issue.
11. Edison Electric Institute, Annual Statistical Yearbook, 1975.
12. United States Bureau of the Census, Population Projections for the United States. Series D-26.
13. Office of Technology Assessment, "Application of Solar Technology to Today's Energy Needs," (Prepublication Draft), Washington, D.C., 1977.
14. Harrigan, Dr. R.W., Sandia Laboratories, private communication, August 11, 1977.
15. Hammond, A.L., Science, 197, 445-7 (1977).
16. Yao, N. and Birk, J.R., "Battery Energy Storage for Utility Load Leveling and Electric Vehicles: A Review of Advanced Secondary Batteries," IECEC Record, 1111, (1975).

17. Spectrolab, Inc., Final Report, Photovoltaic Systems Concept Study, Vol. I of V. Contract No. E(11-1)-2748 (ALO-2748-12), 1977.
18. Future Gas Consumption of the United States, Volume 6. Prepared by the Gas Requirements Committee and published by the Gas Requirements Agency, Denver Research Institute, University of Denver, Denver Colorado, December 1975.
19. Central Intelligence Agency, "The International Energy Situation: Outlook to 1985," Report No. ER 77-10240U, April 1977.
20. "World Oil Shortage May Hit by 1985, Warns IEA," PIW, 3 (1977) March 21.
21. Granville, M.F., "Petroleum's Role From Now to the End of the Century," Oil Gas J. 75, 35(1977) August.
22. Exxon, Annual Energy Forecast, 1977.
23. FEA's LPG Industrial Advisory Committee, June 1977.
24. 1977 - U.S. Energy Outlook.
25. American Gas Association, Gas Facts. 1975 Data, 1976.
26. American Gas Association, 28th Annual Gas Househeating Survey, 1977.
27. Lemon, R., "Analysis of New Gas Supplies and Energy Costs Under the President's National Energy Plan and Three Alternative Regulatory Policies," Published in Energy Topics by The Institute of Gas Technology, (1977) August.
28. Office of Energy Information and Analysis, Federal Energy Administration, Monthly Energy Review. Report No. NTISUB/C/127-007, July 1977.
29. "28th Annual Electrical Industry Forecast," Electrical World, 43-58, (1977) September 15.
30. TRW, "Solar Heating and Cooling of Buildings (Phase Zero)," NSF/RA/N-74-022C, Vol. III, E.2-5 to E.2-9, May 1974.
31. General Electric, "Solar Heating and Cooling of Buildings (Phase Zero)," NSF/RA/N-74-021D, Vol.3, Book 2, 7-77, May 1974.
32. Westinghouse Electric Corp., "Conceptual Design and Systems Analysis of Photovoltaic Power Systems, ALO-2744-13, Vol. IV, 11, July 1977.
33. Brookhaven National Laboratory, "Future Residential and Commercial Energy Demand in the Northeast," BNL 50552, March 1976.
34. Rand Corporation, "Energy Use and Conservation in the Residential Sector: A Regional Analysis," PB-254, 12, June 1975.

35. Acurex Corp., "Solar Total Energy — Large Scale Experiment, Phase II, Conceptual Design Final Report," for U.S. Department of Energy, NTIS Report ALO/3486-1, Sept. 1977.
36. Gruen, D. M., Sheft, I., Lamich, G., and Mendelsohn, M., "HYCSOS: A Chemical Heat Pump and Energy Conversion System Based on Metal Hydrides," ANL-77-39, June 1977.

(Note: Reference is made in Section 5.1 to GATE [Group to Advance Total Energy]. Individual references are far too many to list; however, monthly GATE abstracts were published by IGT, starting in September 1965. These abstracts covered much of the published work on conventional total energy systems at that time.)

APPENDIX A. STATE TAX-RELIEF LEGISLATION

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Increasing public interest in solar energy has prompted many states to pass laws encouraging or facilitating the adoption of solar heating and cooling systems. Legislative support for solar energy utilization is particularly important on the state level. Local tax structures can encourage the choice of solar systems as alternatives to more conventional energy sources. Guaranteeing the future viability of solar systems may require the alternation of zoning and building

ordinances. Accordingly a number of states have taken steps to provide tax incentives for users or vendors of solar systems or equipment and to safeguard the solar energy system user's access to sunlight.

Tax incentive legislation aims at reducing the financial burden of installing solar heating and cooling systems. The addition of a solar unit may increase the market value of a building and therefore some states exempt a building's owner from increased property taxes resulting

STATE	BILL #	DESCRIPTION	CONTACT
Arizona	CH. 129 Laws of 1976	Provides for amortization of the cost of solar energy devices over 36 months in computing net income for state income tax purposes. Applies to all types of buildings.	Neal Trasente, Director, Dept. of Revenue Capitol Building, West Wing Phoenix, AZ 85017 (602) 271-3393
	CH. 165 Laws of 1974	Provides exemption from property tax increases which may result from addition to solar system to new or existing housing.	same as above
Arkansas	CH. 535 Laws of 1977	Allows individual homeowner taxpayer to deduct entire cost of energy saving equipment including solar equipment, from gross income for year of installation.	Dept. of Revenue, Income Tax Section 7th & Wolfe Sts. Little Rock, AR 72201 (501) 371-2193
California	CH. 168 Laws of 1976	Provides for state income tax credit (up to \$1000) of 10% of the cost of installing a solar system.	Franchise Tax Board Sacramento, CA 95814 (916) 355-0370
Colorado	CH. 344 Laws of 1975	Provides that all solar systems be assessed at 5% of their original value for property tax purposes.	Raymond E. Carper Property Tax Administrator Col. Division of Property Taxation 614 Capitol Annex, Denver, CO 80203 (303) 892-2371
	CH. 326 Laws of 1975	Provides procedures for recording voluntary solar easements.	Relevant County Clerk and County Recorder
Connecticut	Public Act 409 (1976)	Authorizes local taxing authorities to exempt property with solar system from increased assessment due to system.	Relevant Local Assessor or Board of Assessors
Georgia	Act No. 1030 (1976)	Provides that purchasers of equipment for solar systems will receive refund of sales and use tax paid on such equipment.	Dept. of Revenue, Sales Tax Unit Room 310, Trinity-Washington Bldg. Atlanta, GA 30334 (404) 656-4671
	Resolution No. 167 (1976)	Enabled constitutional amendment authorizing governing authority of any county or municipality to exempt value of solar system from ad valorem property taxation.	Relevant city council or county board of supervisors
Hawaii	Act 189 (1976)	Provides income tax credit for up to 10% of cost of solar system for year of installation. Also provides exemption from any property tax increase resulting from addition of solar system.	Tax Department Hale Aulalo Building 425 Queen Street, Honolulu, HI 96813 (808) 548-2211
Idaho	CH. 212 Laws of 1976	Provides that cost of residential solar systems may be deducted from taxable income over a period of four years. Deduction shall not exceed \$5,000 in any one taxable year.	Income Tax Division State Tax Commission P.O. Box 36, Boise, ID 83722 (208) 384-3290
Illinois	Public Act 79-943 (1975)	Provides that when a solar system has been installed on real property, owner of property may claim improvement value of a conventional system if that value is less than value of solar system.	Frank A. Kirk, Director Dept. of Local Government Affairs 305 East Monroe St., Springfield, IL 62766 (217) 782-6492
Indiana	Public Law 15 (1974)	Allows owner of real property with solar system an annual deduction from the assessed value of the property equal to the lesser of: (1) the assessed value of the property with solar system minus the assessed value without the system, or (2) \$2,000.	County Assessor
Kansas	CH. 434 Laws of 1976	Allows individuals and businesses to deduct 25% of cost of solar system (up to \$1000 for individuals and \$3000 for businesses) from state income tax.	Kent Kalb, Secretary of Revenue Second Floor, State Office Building Topeka, KS 66612 (913) 296-3041
Maryland	CH. 740 Laws of 1976	Authorizes Baltimore City, any city within a county or any county to provide a credit against local real property taxes for those residential or non-residential buildings using solar heating and cooling units. Amounts and definitions are at the discretion of local jurisdictions.	Relevant city or county Department of Revenue.
	CH. 509 Laws of 1975	Provides that solar system shall not cause property tax assessment of new or existing building to be greater than it would be with conventional system.	Dept. of Assessment and Taxation 301 W. Preston Street Baltimore, MD 21201 (301) 383-2526

from that addition. Other states allow solar system owners to claim a certain percentage of the cost of a solar system as a tax credit against their personal state income tax. Others exempt vendors of solar energy equipment from sales taxes on their receipts.

Three states have passed laws to safeguard a solar system user's access to sunlight either by providing procedures for creating voluntary solar easements or by requiring that solar energy considerations be taken into

account in zoning requirements and land use planning.

Additionally, some states have provided funds for programs to promote research into and development of solar energy. Some states also require that feasibility studies on alternative energy systems be conducted before construction or substantial renovation contracts in public buildings are executed.

The following state legislation concerning solar tax incentives and access to sunlight is currently in effect.

STATE	BILL #	DESCRIPTION	CONTACT (May, 1977)
Massachusetts	CH. 28 Laws of 1977	Authorizes banks and credit unions to make loans with extended payback periods and increased maximum amounts for financing alternative energy systems including solar. Payback period is extended to 10 years. Maximum amount is increased to \$7000 for banks and \$9500 for credit unions.	Local bank or credit union.
	CH. 433 Laws of 1976	Provides that a corporation may deduct cost of a solar system in computing taxable income for year of installation. Also provides that solar system will not be subject to tangible property tax.	Harvey Michaels Asst. to the Director for Solar Energy Energy Policy Office John McCormack State Office Building One Ashburton Place Boston, MA 02108 (617) 727-4732
	CH. 734 Laws of 1975	Provides for real estate tax exemption for solar system.	
Michigan	Public Act 132 (1976)	Provides that receipts from sale of tangible property to be used in solar system shall not be used to compute tax liability for business activities tax.	Edward Kane, Director, Dept. of Treasury State Tax Commission, State Capitol Bldg. Lansing, MI 48922. (517) 373-2910
	Public Act 133 (1976)	Provides that tangible personal property used for solar devices shall be exempt from excise tax on personal property.	same as above
	Public Act 135 (1976)	Provides that solar system shall not be considered in assessing value of real property.	same as above
Montana	CH. 548 Laws of 1975	Allows property tax exemption on capital investments for energy conservation or alternative energy systems. Also allows public utility to lend capital for energy conservation/alternative energy systems at rate not exceeding 7% per year. Provides utilities with license tax credit for difference between 7% and prevailing rate of interest.	William Groff, Director Dept. of Revenue Michell Building Helena, Montana 59601 (406) 449-2460
New Hampshire	CH. 391 Laws of 1975	Allows each city and town to adopt (by local referendum) property tax exemptions for solar systems.	Local or municipal tax assessor
New Mexico	CH. 12 (Special Session of 1975)	Provides income tax credit for 25% of cost of residential solar system. \$1000 credit maximum.	Marshal Morton, Bureau of Revenue Manuel Lujan, SR. Bldg. St. Francis Drive at Alta Vista Santa Fe, NM 87503 (505) 827-3221
North Dakota	H.B. 1000 Passed, 1977	Provides procedures for the creation of voluntary solar easements.	Relevant clerk or recorder
	CH. 588 Laws of 1975	Provides that solar heating and cooling systems utilized in new or existing buildings will be exempt from property taxes for five years following installation.	John Hulteen, Supervisor of Assessments State Tax Department, State Capitol Bismarck, ND 58505 (701) 224-3461
Oregon	CH. 405 Laws of 1975	Provides exemption from ad valorem taxation for any increased value of property resulting from installation and use of a solar system.	Donald M. Fisher, Admin. Assessment and Appraisal Division 506 State Office Bldg. Salem, Oregon 97310 (503) 378-3378
	CH. 153 Laws of 1975	Adds solar energy considerations to comprehensive planning. Allows city and county planning commissioners to recommend ordinances governing building height for solar purposes.	Lon Topaz, Director, Dept. of Energy 528 Cottage Street, N.E. Salem, Oregon 97310 (503) 378-4128
South Dakota	CH. 111 Laws of 1975	Allows owner of residential real property an annual deduction from assessed value for installation of solar device. Deduction may be equal to the lesser of: (1) difference between assessed value with system and value without, or (2) \$2000.	County Auditors/Assessors and Lyle Wendell, Secretary Dept. of Revenue State Capitol Pierre, SD 57501 (605) 224-3311
Texas	CH. 719 Laws of 1975	Provides exemption from sales taxes on receipts from sale, lease and rental of solar devices. Business tax exemption granted to corporations which exclusively manufacture, install and sell solar devices. Corporation may deduct amortized (60 months) cost of solar system from taxable capital.	Bob Bullock, Comptroller Director of Public Accounts LBJ Building 17th & Congress Austin, TX 78711 (512) 475-6001
Vermont	Public Law 226 (1976)	Allows towns to enact real and personal property tax exemptions for solar systems.	State Energy Office, State Office Building Montpelier, VT 05602 (802) 828-2768
Virginia	CH. 782 Laws of 1976	Enabled constitutional amendment authorizing legislature to permit localities to enact tax exemptions on property used for solar systems.	Individual State Senators or Delegates

APPENDIX B. COLLECTOR COSTS

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

For those collectors which have been identified as candidates for the solar total energy residential application we have examined collector costs in terms of

- Factory (F.O.B.) cost
- Shipping cost
- Installation cost
- Operation and Maintenance Cost

The following subsections give our recommended cost values and the range of costs which were found in gathering the collector characteristics data. All reported cost values have been converted to 1975 dollars.

● Factory Costs

Cost estimates for various collectors are shown in Table B-1. The factory costs ($\$/ft^2$) are our evaluation of current and future costs which can be used for comparative collector investigations. In some cases the current costs may reflect the relative stage of development of the collectors.

For example, the parabolic dish costs are from very limited hardware experience, as are the CPC values. We believe that significant errors may be present in these estimates of current cost of collectors in early stages of development. Where collectors are currently closer to a paper design than actual hardware it is easy to estimate a somewhat optimistic current cost. The reason for the optimism is simply a tendency to base estimates on a large production quantity and ignore some design costs.

In fact, the current cost of many available flat plates is higher than pre-production cost estimates. Pre-production cost estimates are much closer to expected future costs of the same designs and thus are rather optimistic.

Table B-1. COLLECTOR COSTS FOR GENERIC CURVES (1975 Dollars)

Collector Type	Factory Costs (\$ / ft ²)	Range (\$/ft ²)	Future Costs (\$ / ft ²)	Range of Future Costs (\$ / ft ²)
Non-Tracking				
Flat Plate 1 (high performance)	15.00	14.60	11.00	5.40-12.00
Flat Plate 2 (middle performance)	9.00	5.75 - 17.00	7.00	4.95-10.00
Flat Plate 3 (lower performance)	5.00	3.12 - 10.00	4.00	3.90-8.00
Evacuated Tube (high performance) 1	20.00/ft ²	20.00	15.00	5.50-14.00
Evacuated Tube (lower performance) 2	12.00/ft ²	11.00 - 13.00	9.00	4.50-11.00
CPC				
CPC 1 - 1.5X	25/ft ²	25/ft ² (estimates only)	14.00	10.00-20.15
CPC 1A - 1.5X	32.5/ft ² @ 50% above state of the art		15.40 @ 10% above state of the art	
CPC 2 - 5X	25/ft ²		14.00	
CPC 2A - 5X	32.5/ft ² @ 50% above state of the art		15.40 @ 10% above state of the art	
One Axis Tracking				
Segmented Mirror T1	20.00/ft ²	\$16 - 28 / ft ²	14.00	9.50 - 14.00
Fixed Mirror Tracking Rcvr.	16.00/ft ²	\$10 - 16 / ft ² worse performance than shown on graph	12.00	6.00 - 14.00
Fresnel Lens T3	19.00/ft ²	\$18 - \$25 / ft ²	11.00	6.00 - 16.00
Parabolic Trough 1 (high performance)	25.00/ft ²	20 - 30 / ft ²	14.00	12.00 - 14.50
Parabolic Trough 2 (middle performance)	\$14 / ft ²	13.70-14.50 / ft ²	12.00	8.00 - 13.00
Parabolic Trough 3 (low)	8.00 / ft ²	7.80 / ft ²	7.00	—
Two Axis Tracking				
Parabolic Dish	\$30 / ft ²	22 - 43 / ft ²	22.00	6.00 - 25.00

Thus, discrepancies in current costs may exist due to different development stages of the collectors.

In the case of the current factory cost estimates, the last section pointed out the references from which they were taken. Future costs are estimated based on our own analysis and the combined projections of several other investigators and manufacturers.

It is difficult to project future reductions (if any) in collector costs. There are forces at work both to lower and raise them. The future solar collector costs may be expected to decrease as more systems are produced. Decreases in collector factory costs should come from mass production which will result in optimal automation. In addition, learning curve effects and lower cost materials could decrease the price of the collector. The learning curve effect indicates a percentage reduction in cost for each doubling of production. This results in part from employing better fabrication techniques and increased efficiency in assembly. On the other hand the diversity of manufacturers of solar components effectively dilutes the effect of the learning curve because each manufacturer follows its own learning curve. This tends to keep costs up. If, as the industry matures, production is concentrated in the hands of only a few manufacturers, perhaps learning curve effects will be pronounced. It is not realistic to think the cost of labor used in collector production will remain stable; it will go up. However, the labor component may be reduced as production volume increases as a result of greater automation. The impact of rising energy costs of manufacture and increased material costs may also keep costs up.

Cost reductions in the 1985-1990 time frame for solar collectors will be dependent on cumulative collector area produced and rate of production (yearly basis). Production quantities and the market for solar collectors are difficult to project. Thus, before trying to determine future costs, we

examined available data from OTA, Metrek and questionnaire responses. These predictions are fairly widespread depending on the source. Assumptions made in determining future predictions are not usually well-defined so it is difficult to analyze whether the predictions are reasonable.

Table B-2 indicates cost estimates as reported in OTA's report (Reference 4). These are manufacturer's estimates of costs in "mass production". No other definition was given. No flat plate manufacturer's are indicated since nearly all of them predicted costs to remain the same.

Table B-3 details Metrek's estimates (Reference 22) of collector costs in mass production. These reductions in cost include decreases due to lower material costs, effects of automation and 80% learning curve effects. For most collectors, a cumulative production of $10^7 - 2.7 \times 10^8 \text{ ft}^2$ was used to determine costs.

It seems highly unlikely that such production will occur by the 1985-1990 time period so these cost projections are optimistic for that time frame. It is also probable that cost reductions above 70% will be very unlikely to occur even at such production levels because of the limiting factor of material cost and labor.

Finally, cost estimates from our own questionnaire show reductions in flat plates from 0 to 50 percent and even a slight cost increase. The increased cost was assumed to be due to a misunderstanding where non-constant dollars were used. Parabolic trough costs are estimated to be 10 to 20 percent less than current day large scale production estimates. This is approximately 60 percent less than actual current costs. Our final cost estimates for the generic collector types previously selected were given in Table B-1. These are based on practical large scale production in the 1985-1990 time frame.

Table B-2. OTA FUTURE FACTORY COST PREDICTIONS (1975 Dollars)

<u>Manufacturer</u>	<u>Collector Type</u>	<u>Current Cost, \$/ft²</u>	<u>Cost in Mass Production</u>	<u>Percent Reduction</u>
Owens Illinois	Evacuated Tube	20.15	10.03 - 12.18	40 - 50
KTA	Evacuated Tube	7.99 - 9.75	5.44 - 7.50	23 - 30
General Electric	Evacuated Tube	20.00	4.50 - 7.59	60 - 75
Steelcraft	CPC	25.21	15.09 - 20.15	20 - 40
General Atomic	Fixed Mirror Tracking Receiver	--	6.09	--
AAI	Tracking Receiver	--	8.06 - 9.09	--
Northrup	Fresnel Lens	12.46 - 16.78	7.97	36 - 53
Sheldahl	Segmented Mirror	20 - 25.30	4.31 - 10.12	50 - 78
Acurex	Parabolic Trough	13 - 19.70	8.06	38 - 60
Sandia Labs	Parabolic Trough	19.00	80% l.c.	--

TABLE B-3. METREK FUTURE FACTORY COST PREDICTIONS

<u>Collector Type</u>	<u>Metrek Estimate</u> (\$ / ft ²)	<u>Percent Reduction</u> (from generic costs)
Flat Plate		
Aluminum (10 yr life)	3.90 - 5.70	0 - 22%
Steel (25 yr life)	5.40 - 7.20	52 - 64
Copper (35 yr life)	4.95 - 6.75	25 - 45
Evacuated Tube	3.74	75 - 80
CPC	3.55	80 - 85
Fixed Mirror Tracking Rcvr.	6.79 - 11.76	26 - 42
Segmented Mirror	6.78 - 7.48	63 - 73
Parabolic Trough	14.40	28
Fresnel Lens	6.40	32 - 40
Parabolic Dish	6.79	77

Significant reduction in cost is indicated for all collector types. Larger decreases are estimated for one axis tracking and CPC collectors. Since pilot production has just begun on these collectors, we would expect larger decreases in cost in the next ten years than for collectors (e. g. flat plates) which have been on the market for a longer time. This will be a result of automation and possibly design improvements which could result in easier assembly, less expensive materials and increased life. Larger cost decreases (in constant dollars) might be expected for

a collector type if production quantities became very large. However, it is impossible to speculate which collector types will be in larger demand by 1985-1990. Therefore, we have tried to estimate costs which will give a reasonable comparison between the collector types. In fact, the estimates may seem optimistic, but we believe they are achievable for any one collector.

Recall that the cost estimates in Table B-1 are for the generic efficiency values in Table A-1. For some collectors, efficiency improvements are possible in terms of increased optical efficiency and reduced heat losses. We have estimated increases in efficiency for the evacuated tube, CPC and one axis trackers (using a parabolic trough as representative for this collector type). We did not examine flat plate efficiencies since improvements are reflected in other collector types (e.g. evacuated tubes).

Evacuated tubes currently have an optical efficiency of .67 - .70. Improvements in this efficiency will result from using etched glass covers (.95 transmissivity) and a possible upgrading of the receiver selective surface which would increase absorptance. High performance evacuated tubes use a silvered reflective surface on the outer tube. This has a high reflectivity and we do not expect much improvement on this material. With these decreases in optical loss, we predict that an optical efficiency of .78 is achievable for evacuated tubes.

The CPC collector optical efficiency could be increased with etched glass covers, improved reflectivity mirrors and a slightly improved selective surface. Currently CPC's have an optical efficiency of .6 - .67. We expect that reflectivity could be increased from 0.84 - 0.88 to .93. Etching the glass cover could improve the transmissivity to .95. This, combined with a slightly improved selective surface could conceivably result in an optical efficiency of .79. An optical efficiency of 0.74 was assumed for the low CR advanced CPC (CPC1A) and 0.67 for the high CR advanced CPC (CPC2A).

For one axis tracking collectors, additional optical losses come from receiver shadowing and spillage due to tracking errors. High performance trough collectors use etched glass and selective surface coatings so we would not expect significant improvements in these areas. The reflectivity is currently .87 - .88. Using better reflective surfaces this could become .93. Blockage and spillage losses could also be reduced. With these improvements, it is feasible for an optical efficiency of .77 to be achieved.

We do not expect any significant decreases in the heat losses. (parameter A in Table A-1) for any of the collector types. Increased concentration ratios could reduce reradiation losses, but this can decrease optical efficiencies. Conduction and convection losses cannot be decreased significantly. Advanced CPC collectors are characterized by the use of etched glass covers, improved mirrors, and improved selective surfaces. Even assuming the use of evacuated tube receivers for CPC collectors and better insulation and glass covers on the receivers of one axis trackers it would be difficult to reduce losses much from current designs. Performance predictions for an advanced design (Ref. 44) indicated increased optical efficiencies but the shape of the performance curve remained essentially the same indicating very little change in heat losses. The characteristics of the generic advanced CPC collectors (CPC 1A and CPC 2A) suggest that improvements are more in the area of optical efficiency than in heat loss characteristics.

Cost increases for these efficiency improvements are difficult to estimate. If cost increases are too large, improved efficiencies would not be feasible. We believe that the improvements indicated here would increase the current cost of the CPC collector by about 30 percent and the future cost by about 10 percent over the state-of-the-art. This pessimistic assessment of cost-effective improvements needs to be tempered by keeping in mind the ex-

tensive experience in industry associated with cost-reductions of other maturing technologies.

● Shipping Costs

Solar collectors are now usually shipped by truck rather than by air or railway. Air shipping can be prohibitively expensive while railway shipping requires quite large loads to be cost effective. For residential solar energy applications, we expect that truck shipping will probably remain the most economic mode to transport solar collectors. We have therefore investigated the parameters which affect the cost of shipping by truck.

Truck shipping rates can vary greatly as a function of the following parameters;

- Distance shipped
- Load Size
- Weight-to-Volume Ratio
- Fragility
- Destination

To obtain an estimate of current shipping cost, it is necessary to determine the collector weight and volume per square foot of collector aperture. The weight and volume should be for a collector ready to ship (packaged). We have very little actual information concerning current collector shipping weights and volume, however, estimates were made for several collectors as shown below;

	<u>Wt.</u>	<u>Vol</u>
Flat Plate	7-10 lb/ft ²	.5 - 1.0 ft ³ /ft ²
Evacuated Tube	4-6 lb/ft ²	.5 - 0.9 ft ³ /ft ²
CPC	5 - 8 lb/ft ²	.8 - 1.4 ft ³ /ft ²
Trough	3 - 6 lb/ft ²	1.0 - 1.6 ft ³ /ft ²

It is our objective to define shipping cost in terms of the expected cost per square foot of collector aperture area. The difficulty with this objective is that there are so many parameters involved in obtaining the costs. To simplify the problem we have assumed that only full truck loads will be shipped. For less than full truck loads the shipping cost can as much as double. A full truck load is nominally 24,000 pounds, which corresponds to shipping between 2000 and 8000 ft² of collector per load. For large scale residential applications this quantity is not significant and should be exceeded in most cases. Furthermore, we assumed that collectors could be packaged for shipment such that the load would not be classed as fragile.

Using these rules, we obtained estimates of shipping rates to various destinations for several weight and volume ratios. For collectors which can be assembled on-site (i. e. troughs) we assumed shipping was accomplished for partially disassembled collectors. This allows the shipping volume to be efficiently used so that we would not be paying to ship air. Figure B-1 shows the range of shipping cost estimates which we obtained. We found that our estimates of collector weight-to-volume values did not significantly effect the costs. Based on figure B-1 and our estimates of collector weight to aperture area ratios the shipping costs for a given collector type and distance shipped can be approximated. Since the present study is directed toward a comparative analysis of system designs with a market penetration study being the final goal, it is recommended that a single nominal value of distance shipped (~ 1000 miles) be used. This avoids the issue of collector selection by close proximity to actual sites, however, the advantage in selecting nearby manufacturers is slight because of the small shipping cost relative to the total collector system cost. For the comparative collector system study, the following values for current shipping cost are recommended:

FIGURE B-1. COLLECTOR SHIPPING COSTS AS A
FUNCTION OF SHIPPING DISTANCE

Flat Plate & Fresnel Lens & Slats	\$0.45/ft ²
CPC	\$0.35/ft ²
Evacuated Tubes, Trough	\$0.25/ft ²
2 Axis Trackers	

Future shipping costs are most likely to be reduced by collector design changes with change reduce collector weight. Metrek estimates of future shipping cost assume future collectors weights of approximately 2-3 lb/ft² for evacuated tubes, 4-5 lb/ft² for CPC's and only 2 lb/ft² for a fresnel lens. Shipping costs based on these weights are estimated at \$0.10 to \$0.20 per square foot, or a reduction of 50% of the current cost estimates.

- Installation Costs

In order to examine installation costs on an equivalent basis for the collector types, several assumptions regarding the elements of installation cost for solar collectors were made. We have addressed piping costs separately so these will not be included. Any other equipment (heat exchangers, pump, etc) is considered to be separate from the collector and installation costs for these components will not be examined. Labor for installing the collector panels, material and labor for the support structure and cost of the control system will be included in the installation costs which follow. We have also included additional costs for supervision of collector installation and any additional costs incurred for roofing due to collector mounting. It should also be noted that installation costs for more advanced collector types are more speculative since less systems have been installed and information in the literature is not readily available.

Information on installation costs for flat plate collector systems has been taken from References 4 and 22 as well as from questionnaire results. A detailed breakdown of costs of 6 solar heating and domestic hot water systems was given in Appendix II of Reference 22 (Volume 2). These costs are summarized in Table B-4.

These appear to be the most realistic costs for installation that were found in the literature since they are taken from actual installed systems. These installations all have the collectors mounted on the roof or wall of a newly constructed house. All costs include additional roof structure required for collector support and collectors are mounted directly on the roof.

Table B-4. Installation Costs for Six Solar Heating and
Hot Water Systems
(All Costs \$/ft²)

<u>House Location</u>	<u>Collector Area</u> (sq. ft)	<u>Total Installation Cost</u> (\$ /ft ²)
419A St. Paul (Denver)	560	9.37
435B St. Paul (Denver)	390	7.59
Mountain Home (W. of Golden Co.)	292	7.68
Gunnison, Co.	468	6.39
Stansberry Park, Utah	585	6.62
Soda Creek, Colorado	312	8.04

Some questionnaire results for the flat plate collectors indicated the following installation costs:

<u>Vendor</u>	<u>Installation Costs (\$/ft²)</u>
C	4.53 - 7.25 (0.91 controls)
U	11.69 (3.25 controls)
S	19.93

The estimate from Vendor U was a guess on their part since they do not install collectors.

Vendor S's estimate is quite high. It is possible that these are installation costs for the whole system rather than as we have them broken down.

This gives a large range of installation costs with most of these costs falling between \$5.50 and \$8.60/ft². We recommend that an installation cost of about \$7.25/ft² would be a reasonable value for a flat plate installation on a new dwelling. The estimate is for what we will call the basic installation which is defined as the option where collectors are mounted directly on the roof. For collectors rack mounted (on frames at an angle relative to the roof structure), some estimate of the increased cost is required. We recommend that a 50% increase over direct roof mounting be applied to the material and labor cost for collector installation. No increase in the control system cost need be applied. Thus, current flat plates installation costs are estimated to be \$7.25/ft² and \$10.90/ft² for direct roof mounting and rack mounting respectively.

For evacuated tube and compound parabolic collectors, the information on installation cost is sketchy. Metreck indicates a future installation cost comparable to copper flat plate collector and less than that of a steel flat plate. IGT experience with Owens-Illinois evacuated tube collectors suggests significantly higher installation costs because of extensive on-site assembly. The figure for current installed cost of evacuated tube collectors as presented here reflects anticipated near term improvements by manufacturers in reducing onsite installation requirements. Control costs should remain about the same for either flat plates, evacuated tubes or CPC's (\$1.00/sq.ft). The compound parabolic collector will cost somewhat more for installation if tilt adjustments will be made since there will have to be additional support structure on the roof. Our own estimates of the cost increase associated with an adjustable frame mounting indicate a 30% increase in material and labor over the non-moving frame.

Using these considerations, in estimating a cost for CPC's with no tilt adjustments and for evacuated tubes, the cost for a flat plate ($\$7.25/\text{ft}^2$) seems reasonable. With tilt adjustments, the installation costs in CPC's will be increased by the percentages already defined. Note that CPC's have no choice but to be mounted at an angle to the south in order to insure that the solar insolation falls inside the collector acceptance angle.

One axis tracking collectors installation costs are not readily available although several manufacturers are installing demonstration systems through ERDA. Vendor M is manufacturing and installing systems in several areas. Vendor N has just begun three installations. Other manufacturers are installing systems but a breakdown of costs is not available. Four estimates of the installation cost of tracking collectors are as follows:

<u>Vendor</u>	<u>Installation Cost ($\\$/\text{ft}^2$)</u>
N	\$6.57 - 9.29 (4.00 control cost)
W	\$5.63 (1.78 controls)
M	\$2.89 (labor only, supports part of collector cost, no controls)
Q	\$4.53 (no controls, field piping site preparation included)

Vendor N states that his trough concentrator costs vary because of the changes in support costs. These are site specific and will change depending on the roof type. In most cases, we feel these numbers are somewhat optimistic estimates. It is expected that current installation of one-axis tracking collectors would be more expensive than flat plates. These systems are more complex and will require more installation time for support structure and collector alignment. In addition, an installation cost differential must be applied for trough collectors in different mounting orientations. Polar mount troughs must be expected to be more expensive to install than E-W or horizontal N-S collectors because of the greater com-

plexity of tracking mechanisms. E-W and N-S trough collectors may be longer than polar mount troughs and as a result they feature less time to set up and adjust the tracking mechanism because a single tracking mechanism can serve a greater collector area.

They also feel that for systems, being built currently, more labor would be required since there is little experience with installing these collectors. Because of this, we recommend an installation cost of \$12.00 - \$16.00/ft² for the one-axis tracking trough concentrators. The \$12/ft² figure refers to trough collectors in an E-W or horizontal N-S orientation. The \$16/ft² figure refers to polar mount troughs which require extensive labor to set up and adjust tracking mechanisms.

Installation costs for the segmented mirror collectors would probably be about the same price as a E-W trough concentrator system with a decrease in time to install the collector. A fair estimate here would be about \$11.00/ft² for installation cost (including a \$1.90/ft² est. control cost).

No information was available on the installation cost of two-axis tracking dishes. Control cost for these systems (based on 10-48 ft. modules) was \$10.90/ft². The installations currently would take place almost completely in the field so labor cost of at least \$16.00/ft² could be expected. A rough estimate for dish systems installation would be \$27.00/ft².

Table B-5 lists our estimate of current installation costs for the collector types examined. Although these prices are estimates, we feel that they fairly represent the installation associated with the various collector types.

	<u>Basic Installation Costs</u> (\$/ft ²)	<u>On Frames</u> (\$/ft ²)	<u>With Tilt Adjustments</u> (\$/ft ²)
Non-Tracking			
Flat Plate	7.25	10.90	
Evacuated Tube	7.25	10.90	
Compound Parabolic Collector	-	10.90	14.00
One-Axis Tracking			
Parabolic Trough Concentrator	-	Polar Mount 16.00 EW & NS Horiz. 12.00	
Segmented Mirror (Slats)	-	11.00	
Fixed Mirror Tracking Receiver	-	11.00	
Fresnel Lens	-	12.00	
Two-Axis Tracking			
Parabolic Dish Concentrator (point focus)	27.00	--	--

Table B-5. Estimated Installation Costs.

These include labor to install collectors, controls cost, support materials, and labor.

- Future Installation Costs

Installation costs for solar collectors should decrease over time as a result of increased field experience and lower control costs. This will be dependent on production quantities and installation of collector systems in the next 10 years. Control costs and labor to install the collector has been estimated for mass-produced collectors in the Metrek reports.

For control costs, it was assumed that prices would level after two doublings of production quantity with a net decrease of 40 percent (assuming 80% learning curve). We assumed that material costs for the CPC with frames (tilt adjustments) would remain the same. The estimate for the parabolic dish assumes that a decrease in field installation because additional factory assembly will occur. These and the fixed mirror distributed focus estimates for installation were not included in the Metrek reports and our approximations are based on the information obtained from current installation costs and the assumptions made to estimate other installation costs.

Table B-6 indicates projected installation costs for the 1985-1990 time frame. Projected total installation costs are uniformly assumed at 50% of current installation costs. It seems reasonable that sufficient quantities of non-tracking collectors will have been installed to achieve this cost reduction. For one-axis trackers, production quantities may not reach the level of non-tracking collectors and so the installation cost decreases may be somewhat less.

Table B-6. Installation Costs - Future Estimates

<u>Collector Type</u>		<u>Future Installation Cost</u> (\$/ft ²)
Non-Tracking ^a		
Flat Plates (on frames)		5.45
Evacuated Tube (on frames)		5.45
CPC (no tilt adj)		5.45
CPC with tilt adj		7.00
One-Axis Tracking ^b		
Parabolic Trough Concentrator	Polar Mount	8.00
Segmented Mirror	EW and N-S	6.00
		5.50
Fixed Mirror Distr. Focus		5.50
Fresnel Lens		6.00
Two-Axis Tracking		
Parabolic Dish		13.50

a. all installation for non-tracking collectors assumes \$.55/ft² for controls

b. this includes 1.14/ft² for controls assumed for all one-axis trackers

Table B-7 summarizes estimates for operation and maintenance of the various collector types.

Table B-7. Operation and Maintenance Costs (\$/ft²-yr)

	<u>Current Cost</u>	<u>Future Estimate</u>
<u>Non -Tracking</u>		
Flat Plates	1.00	.07
Evacuated Tubes	1.25	.10
CPC	1.50 with tilt adjustments	.16
		.20 with tilt adjustments
<u>One-Axis Tracking</u>		
Segmented Mirrors	.75	used .15
Trough Concentrators	PM- 1.00	.20
	EW and N-S - .80	.16
Fixed Mirror Tracking Receiver	.75	.15
Fresnel Lens	.80	.20 - .40
		(shorter life)
<u>Two-Axis Tracking</u>		
Parabolic Dish Concentrator	2.50 - 4.00	1.00

Table B-8 summarizes current capital, installation, and operation and maintenance costs for collectors of interest for STES applications. Table B-9 summarizes future capital, shipping, installation, and operations and maintenance costs for candidate STES collectors.

Table B-8. COLLECTOR INSTALLED COSTS - FUTURE

Collector Type	Future Collector Cost, \$/ft ²	Range, \$/ft ²	Future Shipping Cost, \$/ft ²	Future Installation Cost, \$/ft ²	Future Total Cost, \$/ft ²	Future Operating and Maintenance Cost, \$/ft ² /yr
ET 1	15.00 GF	5.80-14.00	0.10 @ 50% of current	All collectors are rock mounted on roof 5.45 @ 50% of current	20.58 GF	0.10
ET 2	9.00 GF	4.50-11.00	0.13	5.45	14.58 GF	0.10
CPC 1 - 1.5X	14.00 GF	10.00-20.15	0.18 @ 50% of current	5.45 @ 50% of current	19.63 GF	0.16
CPC 2 - 5X (Tilt angle adjusted monthly)	14.00 GF	10.00-20.15	0.18	7.00 with tilt adjustments @ 50% of current	21.18 GF	0.20 @ 25% above O&M for fixed tilt
CPC 1A - 1.5X	15.40 GF @ 10% above state-of-the-art	estimate	0.18	5.45	21.02 GF	0.16
CPC 2A - 5X (Tilt angle adjusted monthly)	15.40 GF @ 10% above state-of-the-art	estimate	0.18	7.00 with tilt adjustments	22.58 GF	0.20
T1 - SLATS	14.00 GF	9.80-14.00	0.23 @ 50% of current	5.50 @ 50% of current	19.73 GF	0.15
PT 1	14.00 GF	12.00-14.50	0.13 @ 50% of current	PM = 8.00 EW & NS = 6.00 All at 50% of current	PM = 22.13 EW & NS = 20.13	PM = 0.20 EW & NS = 0.16
PT 2	12.00 GF	8.00-13.00	0.18	PM = 8.00 EW & NS = 6.00	PM = 20.13 EW & NS = 18.13	PM = 0.20 EW & NS = 0.16
PT 3	7.00 GF	--	0.13	PM = 8.00 EW & NS = 6.00	PM = 15.13 EW & NS = 13.13	PM = 0.20 EW & NS = 0.16

Table B-9. COLLECTOR INSTALLED COSTS - CURRENT

Collector Type	Current Collector Cost, \$/ft ²	Range, \$/ft ²	Current Shipping Cost, \$/ft ²	Current Installation Cost, \$/ft ²	Current Total Cost, \$/ft ²	Current Operation and Maintenance Cost, \$/ft ²
ET 1	20.00 GC	20.00	0.25 GC	10.90 - All collectors are rack mounted on roofs.	31.15 GC	1.00
ET 2	12.00 GC	11 - 18	0.25 GC	10.90	23.15 GC	1.00
CPC 1 - 1.5X	25 GC	25 (estimate, not on production)	0.35 GC	10.90	36.25 GC	1.25
CPC 2A - 5X (Tilt angle adjusted monthly)	25 GC	25 (estimate not on production)	0.35 GC	14.00 with tilt adjustment	39.35 GC	1.50 @ 25% O&M for fixed tilt
CPC 1A - 1.5X	32.5 GC @ 30% above state-of-the-art	Estimate	0.35 GC	10.90	43.75 GC	1.25
CPC 2A - 5X (Tilt angle adjusted monthly)	32.5 @ 30% above state-of-the-art	Estimate	0.35 GC	14.00 with tilt adjustment	46.85 GC	1.50
T1 - SLATS	20.00 GC	16 - 28	0.45	11.00	31.45 GC	0.75
PT 1	2500 GC	20 - 30	0.25	PM - 16.00 EW&NS-12.00	PM - 41.25 EW&NS - 37.25	PM - 1.00 EW&NS - 0.80 PM is more complex
PT 2	14.00 GC	13.70 - 14.50	0.25	PM - 16.00 EW&NS-12.00	PM - 30.25 EW&NS - 26.25	PM - 1.00 EW&NS - 0.80
PT 3	8.00 GC	7.80	0.25	PM - 16.00 EW&NS-12.00	PM - 24 EW&NS - 20	PM - 1.00 EW&NS - 0.80

Note: GC - Generic current.

● Operation and Maintenance Costs

Operation and maintenance costs for solar thermal collectors are quite speculative because of the limited installations and number of years from which to determine maintenance costs. Some limited determination of O & M costs for flat plates has been done. Maintenance on the other collector types has been estimated through questionnaire results and Honeywell experience with collectors. In addition, some attempt has been made to examine operation in the Metrek Division's: Systems Descriptions and Engineering Costs for Solar Related Technologies. This has been used as a reference when other information has not been available. In some cases, the Metrek estimates seem to be quite low. The reason is that cost estimates made on more advanced collectors (segmented mirrors, troughs and parabolic dishes) are for large systems well into commercial production. Therefore, maintenance should be less costly since parts replacement would be less and reliability should be increased.

The operation and maintenance costs that follow are based upon maintenance for the collector and components which are imperative for the solar system as opposed to those common to solar and conventional systems (i. e., collector field pump, controls, receivers, etc.). Operation costs (electricity to run system and controls) are cited where known. In most cases, this cost is so negligible it can be ignored. Any man hours needed to keep the system functioning normally are included in maintenance costs unless specifically mentioned otherwise.

The most definitive operation and maintenance costs available on non-tracking collectors are for flat plate systems. Questionnaire results on

operation and maintenance were as follows:

Vendor

C	.25/ft ² - yr
R	.15/ft ² - yr
U	.50/ft ² - yr
S	negligible

An estimate provided to Metrek for a solar heating and hot water system by Vendor EE for their collector was .67/ft² - yr. This was determined for a 20 year lifetime. Labor (based on \$15.00/hr) was 38 cents of that cost. The most definite maintenance estimate was found in Reference 7. System maintenance was performed to restore the Colorado Solar House in Denver. No maintenance had been done since construction in 1957. After cleaning the system and replacing all parts, the maintenance was \$3,927.00 over the 19 year period (with an average labor cost of \$13.50). This is an average maintenance value of .39/ft² - year. The author claimed that much of the maintenance could have been performed at labor costs of \$4.00/hr which would decrease the cost to .13/ft² - yr. Since this is the most concrete data that has been documented, we recommend that a maintenance cost of .40/sq. ft - yr be used for flat plate collectors.

Operation costs (when broken down from maintenance costs) have been estimated between 3-6 cents/ft² - yr. These are all costs necessary to run a heating and hot water system (fans, pumps, blowers). ¹

- 1 Estimates on Quechee Lake House Heating and Hot Water System (Reference 22).

Our estimate of O & M costs for flat plate systems is $.45/\text{ft}^2$ - yr.

Maintenance estimates for evacuated tube collectors are somewhat higher than those of flat plates. This is probably due to current problems with tube breakage and loss of vacuum. It is expected that these problems will be solved in the future. A survey response from Vendor H suggests an operation and maintenance cost of \$1.00/sq. ft. (8% of their current collector cost). The only other data on O & M for evacuated tubes was again provided in the Mitre Corporation cost reports. These estimates were for the Vendor I Collector. Total maintenance costs for a collector system used for solar heating, cooling and hot water are $.88/\text{ft}^2$ - yr. for materials and labor. An operation cost of .4% of the capital cost of the system was assumed. Collector costs of $\$20/\text{ft}^2$) would indicate that this is about 8 cents/sq. ft. Thus, the total O & M cost is $\$0.96/\text{ft}^2$ - yr. This is very close to the O & M recommended by Vendor H. Current operation and maintenance costs of $\$1.00/\text{ft}^2$ -yr. are recommended for evacuated tube collectors.

Since CPC collectors are not currently being manufactured or demonstrated, it is difficult to estimate operation and maintenance costs. Metrek has predicted that future O & M costs for the collector would be about 1.5 times that of evacuated tubes. This would be expected for CPC's which use the evacuated tube receiver. Certainly, their increased complexity would probably indicate increased labor time for maintenance. Parts replacement costs should not be much higher than those of evacuated tubes since their initial capital cost is in the same range. Based on these assumptions, we estimate a current O&M Cost of about $\$1.25/\text{ft}^2$ -yr. The operating cost to adjust the tilt angle of high concentration ratio CPC's is estimated at 25% above O&M costs for fixed tilt CPC's.

Operation and maintenance for tracking collectors is highly speculative because of limited experience in application. Little data is available on these collectors. We examined Metrek's O&M estimates and manufacturers' data where available. However, we found that these estimates are for larger systems (usually industrial applications) where automated equipment, volume purchasing of replacement parts and less labor per square foot of collector would decrease costs. For smaller systems such as those that would be used in solar total energy systems, O&M costs would most probably be increased.

Estimates for O & M on segmented mirror type collectors were given in Metrek's cost estimates for an agricultural, industrial process heat system. These estimates were for large systems assumed to be in mass production. Cost for operation and maintenance of the Vendor Q collector were \$.06/ft² - yr and \$.16/ft² - yr for the Vendor FF collector. These O & M costs are quite low in comparison to those obtained for non-tracking collectors. This does not seem realistic since the collectors are more complex and have moving parts which require more maintenance. These costs probably indicate future cost when a more reliable product is being built. We believe a more realistic estimate would be somewhat greater than the current O & M cost for flat plate collectors. Metrek estimates were 30-50 percent greater than those for flat plates for the future. In addition, as mentioned earlier for STES applications, we would expect greater labor cost per square foot. We recommend a current O & M cost of \$.75/ft² - yr for this collector.

Data from Vendor M (trough collector) indicates an expected scheduled maintenance cost of \$.48/ft² - yr. This includes monthly reflector washing, parts, and labor for checkout and replacement. Vendor W indicated an estimated cost of \$.27/ft² - yr. This assumes that special equipment is used for washing the collector (a cost of approximately \$.06/ft² - yr).

No replacement of parts except the pylon (once every 10 years) is included in this estimate. One can assume a periodic maintenance check like that estimated by Vendor M which would require an additional \$.19/ft² -yr. This would bring the O & M cost of \$.56/ft² - yr.

Operation costs for trough concentrators were not estimated. Vendor N estimated the operation costs for an Industrial Process trough system to be around \$.03/ft² - yr. This would be the cost of the electricity for the pumps, controls, and motors. This would result in an O & M cost for concentrating collectors of about \$.60/ft² - yr. for an industrial application. Metrek indicates that future O & M is slightly greater for troughs than segmented mirrors. Although not specifically addressed by the questionnaire, it may be expected that trough collectors in a polar mount orientation will require greater maintenance than troughs in other orientations because of the increased complexity of the tracking system. An O&M cost of \$1.00/ft² is used for polar mount troughs and \$0.80/ft² for E-W and N-S troughs.

Estimates for fixed mirror distributed focus collectors and fresnel lens collectors operation and maintenance were not available. We expect that these costs would be comparable to those of other one-axis trackers or about \$.75-.80/ft² - yr.

Two-axis tracking collector O&M estimates are not readily available either. The only collector we have examined in detail in this category was the parabolic dish collector. Metrek has estimated, with the assistance of JPL, that operations and maintenance costs for a steam total energy system were \$1.30/ft² of collector area. This is for commercially available industrial system. Thus, these costs include maintenance for parts other than those directly related to the collector.

In addition, it is probable that these costs assume that the system is fully developed and automated maintenance would occur. For a solar total energy application in the residential sector, we would expect the maintenance and operation to be less extensive but more expensive in the early years of use than that cited above. It was estimated in Ref. 29 maintenance and replacement costs would be about .5 - 1% of the collector system capital cost. This currently would be about 2.50 - 4.00/ft² - yr for the parabolic dish. Other dish systems would be expected to have similar costs for operation and maintenance.

Operation and maintenance costs should decrease significantly as increasing numbers of systems are installed. The largest decrease will be in maintenance which is currently fairly expensive due to frequent replacement of components and fairly high failure. Decreases in maintenance costs should occur because of higher reliability and improved design. As more systems are installed, components which fail frequently should be improved. In addition, regular maintenance procedures should take less time and therefore decrease the labor required on a yearly basis.

The best estimates of future operation and maintenance costs were found in the Metrek reports. These costs were estimated using manufacturer's predictions and experience with conventional energy systems. It should be noted that the costs shown here reflect an average labor cost of about \$15.00/hr. In actual practice, much of this work could be done with less expensive labor or by the owner himself which would decrease the expense somewhat.

APPENDIX C. PROJECTED ANNUAL COSTS OF CONVENTIONAL UTILITY ENERGY SERVICE

The following appendix tabulates the projected annual costs of conventional utility energy service required to serve the same residential dwelling loads as the STES. All quantities are presented on a per dwelling basis.

The following notes apply to each page:

- Type of Dwelling:

1. Single Family Detached
2. Townhouse
3. Low-Rise Apartment

- Region:

1. Florida	7. Kentucky
2. California	8. New England
3. Arizona	9. Illinois
4. Colorado	10. North Dakota
5. Texas	11. Washington
6. Georgia	

- Load Schedule:

1. Generic
2. Conservative

- Type of Heat:

1. Electric Heat (all services electric)
2. Gas Heat (conventional gas heat plus electrical service)
3. Oil Heat (conventional oil heat plus electrical service)
4. LPG Heat (conventional LPG service plus electrical service)

- Pricing Schedule:

Two cost figures are presented for the years from 1990 through 2020. The first column under each year heading is calculated using the "Business-As-Usual" energy prices from Section 2.2.3.2.2, while the second column is based upon "World Oil Shortage" prices from the same section.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TYPE OF DWELLING 1
 REGION 1
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 84.25
 ELE 0.00

GAS HEA DWEL GAS 36.95
 ELE 53.75

OIL HEA DWEL OIL 24.35
 ELE 63.75

LPG HEA DWEL LPG 36.95
 ELE 53.75

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	841.7	1096.1	1124.7	1124.7	1182.0	1182.0	1242.7	1242.7	1305.0	1305.0
2	639.7	903.3	939.6	976.2	1025.0	1026.1	1078.8	1078.8	1133.4	1133.4
3	726.0	945.0	978.4	1021.5	1049.8	1073.6	1128.8	1128.8	1185.7	1185.7
4	760.1	962.7	998.8	1064.2	1077.8	1114.0	1166.7	1166.7	1221.3	1221.3

TYPE OF DWELLING 1
 REGION 1
 GENERIC OR CONSERVATIVE 2 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 80.85
 ELE 0.00

GAS HEA DWEL GAS 35.90
 ELE 51.05

OIL HEA DWEL OIL 23.20
 ELE 61.05

LPG HEA DWEL LPG 35.90
 ELE 51.05

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	807.7	1051.9	1079.3	1079.3	1134.3	1134.3	1192.5	1192.5	1252.4	1252.4
2	609.8	862.3	897.3	932.8	979.4	980.5	1030.9	1030.9	1083.0	1083.0
3	694.8	904.5	936.4	977.4	1004.5	1027.3	1080.1	1080.1	1134.5	1134.5
4	726.8	920.1	954.7	1018.3	1030.7	1065.9	1116.3	1116.3	1168.4	1168.4

TYPE OF DWELLING 1
 REGION 2
 GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL ELE 79.15
 ELE 0.00

GAS HEA DWEL GAS 65.25
 ELE 27.95

OIL HEA DWEL OIL 54.30
 ELE 37.95

LPG HEA DWEL LPG 65.25
 ELE 27.95

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	771.7	1005.2	1031.3	1031.3	1084.4	1084.4	1139.8	1139.8	1197.5	1197.5
2	371.7	570.9	705.4	794.2	799.2	835.1	877.5	877.5	922.0	922.0
3	522.6	700.3	741.6	852.3	821.3	896.2	914.1	941.8	989.6	989.6
4	566.1	727.5	771.3	904.5	855.3	945.4	954.5	987.8	1032.3	1032.3

TYPE OF DWELLING	1
REGION	2
GENERIC OR CONSERVATIVE?	2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	74.40
	ELE	0.00

GAS HEA DWEL	GAS	56.55
	ELE	28.85

OIL HEA DWEL	OIL	44.85
	ELE	38.85

LPG HEA DWEL	LPG	56.55
	ELE	28.85

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	725.4	944.9	969.4	969.4	1019.3	1019.3	1071.4	1071.4	1125.7	1125.7
2	367.2	553.6	671.7	748.6	756.0	787.1	827.1	827.1	869.1	869.1
3	504.8	673.7	710.3	801.8	781.2	843.1	863.1	885.9	930.9	930.9
4	535.8	689.3	728.8	844.1	804.7	882.7	893.9	922.7	964.7	964.7

TYPE OF DWELLING	1
REGION	3
GENERIC1 OR CONSERVATIVE2	1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	110.25
	ELE	0.00

GAS HEA DWEL	GAS	76.25
	ELE	51.90

OIL HEA DWEL	OIL	64.05
	ELE	63.20

LPG HEA DWEL	LPG	76.25
	ELE	51.90

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1175.3	1531.4	1571.1	1571.1	1651.5	1651.5	1735.3	1735.3	1823.5	1823.5
2	692.8	1006.8	1107.9	1226.0	1226.6	1289.1	1354.5	1354.5	1423.4	1423.4
3	840.2	1116.1	1169.6	1309.2	1274.7	1376.5	1394.4	1446.3	1519.9	1519.9
4	981.0	1234.1	1289.3	1455.6	1397.4	1518.6	1522.2	1584.0	1653.0	1653.0

TYPE OF DWELLING	1
REGION	3
GENERIC OR CONSERVATIVE	2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	101.45
	ELE	0.00

GAS HEA DWEL	GAS	65.95
	ELE	49.80

OIL HEA DWEL	OIL	52.85
	ELE	61.10

LPG HEA DWEL	LPG	65.95
	ELE	49.80

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1081.5	1409.1	1445.7	1445.7	1519.7	1519.7	1596.8	1596.8	1678.0	1678.0
2	651.6	939.0	1028.2	1130.4	1134.4	1188.5	1248.8	1248.8	1312.4	1312.4
3	788.7	1045.3	1092.6	1207.9	1185.9	1269.9	1291.5	1334.3	1402.2	1402.2
4	900.8	1135.6	1185.1	1328.9	1282.2	1387.0	1393.9	1447.3	1510.9	1510.9

TYPE OF DWELLING 1

REGION 4

GENERIC OR CONSERVATIVE 2 1

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL ELE 144.20
ELE 0.00

GAS HEA DWEL GAS 155.10
ELE 34.00

OIL HEA DWEL OIL 149.25
ELE 45.30

LPG HEA DWEL LPG 155.10
ELE 34.00

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1309.3	1704.4	1749.1	1749.1	1838.5	1838.5	1932.3	1932.3	2030.3	2030.3
2	488.6	915.3	1144.5	1391.1	1325.3	1461.8	1536.6	1536.6	1615.6	1615.6
3	788.9	1077.2	1161.4	1491.3	1323.8	1567.1	1517.4	1647.3	1731.8	1731.8
4	819.0	1082.8	1166.2	1509.0	1326.9	1579.7	1519.6	1654.5	1733.5	1733.5

TYPE OF DWELLING 1
 REGION 4
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL ELE 121.30
 ELE 0.00

GAS HEA DWEL GAS 119.40
 ELE 34.30

OIL HEA DWEL OIL 104.60
 ELE 45.60

LPG HEA DWEL LPG 119.40
 ELE 34.30

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1101.4	1433.8	1471.4	1471.4	1546.6	1546.6	1625.4	1625.4	1707.9	1707.9
2	449.9	800.6	979.6	1169.5	1123.9	1228.9	1291.8	1291.8	1358.1	1358.1
3	678.7	918.7	982.0	1213.2	1104.4	1274.9	1249.1	1340.1	1408.8	1408.8
4	704.3	929.6	996.3	1260.2	1125.1	1319.7	1278.7	1382.6	1448.9	1448.9

TYPE OF DWELLING	1
REGION	5
GENERIC OR CONSERVATIVE?	1
ENERGY CONSUMPTION(10**6 BTU/YR.)	
ELEC HEATED DWELL	ELE 124.70 ELE 0.00
GAS HEA DWEL	GAS 108.15 ELE 47.50
OIL HEA DWEL	OIL 99.25 ELE 58.80
LPG HEA DWEL	LPG 108.15 ELE 47.50
ANNUAL ENERGY COSTS(\$/YR.)	
TYPE OF FEAT	1975 1985 1990 1990 2000 2000 2010 2010 2020 2020
1	997.6 1296.9 1330.5 1330.5 1523.8 1523.8 1601.1 1601.1 1682.2 1682.2
2	539.0 818.4 1044.3 1204.4 1235.8 1313.7 1381.0 1381.0 1450.8 1450.8
3	735.4 990.7 1056.2 1267.6 1241.6 1391.5 1392.2 1462.6 1536.6 1536.6
4	795.3 1033.7 1100.6 1330.9 1276.9 1440.2 1430.8 1507.5 1577.4 1577.4

TYPE OF DWELLING 1
 REGION 5
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 110.15
 ELE 0.00

GAS HEA DWEL GAS 87.90
 ELE 46.10

OIL HEA DWEL OIL 77.30
 ELE 57.40

LPG HEA DWEL LPG 87.90
 ELE 46.10

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	881.2	1145.6	1175.3	1175.3	1346.0	1346.0	1414.3	1414.3	1485.9	1485.9
2	498.0	743.1	928.7	1058.8	1096.0	1159.3	1218.7	1218.7	1280.3	1280.3
3	665.6	892.2	946.4	1111.0	1108.8	1225.5	1233.3	1288.2	1353.3	1353.3
4	706.3	918.1	974.5	1161.7	1129.4	1262.1	1259.1	1321.5	1383.1	1383.1

TYPE OF DWELLING 1
 REGION 6
 GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 125.70
 ELE 0.00

GAS HEA DWEL GAS 126.70
 ELE 34.85

OIL HEA DWEL OIL 118.75
 ELE 46.15

LPG HEA DWEL LPG 126.70
 ELE 34.85

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1034.5	1345.0	1382.7	1382.7	1453.1	1453.1	1527.3	1527.3	1605.2	1605.2
2	508.5	826.5	1011.8	1199.3	1168.1	1260.6	1325.5	1325.5	1392.8	1392.8
3	695.7	946.2	1019.5	1272.4	1156.9	1337.4	1320.7	1406.2	1477.6	1477.6
4	777.1	1008.9	1082.7	1352.6	1221.3	1413.9	1387.6	1478.8	1546.1	1546.1

TYPE OF DWELLING 1
 REGION 6
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 107.50
 ELE 0.00

GAS HEA DWEL GAS 98.95
 ELE 34.65

OIL HEA DWEL OIL 88.70
 ELE 45.95

LPG HEA DWEL LPG 98.95
 ELE 34.65

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	884.7	1150.2	1182.5	1182.5	1242.7	1242.7	1306.1	1306.1	1372.8	1372.8
2	458.3	725.0	871.9	1018.4	998.2	1070.4	1125.5	1125.5	1182.6	1182.6
3	614.1	829.6	887.7	1076.7	996.9	1131.7	1126.0	1189.8	1250.3	1250.3
4	668.1	867.5	927.4	1138.1	1039.8	1190.2	1174.0	1245.3	1302.4	1302.4

TYPE OF DWELLING 1
 REGION 7
 GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION(10**6 B1U/YR.)

ELEC HEATED DWELL ELE 138.05
 ELE 0.00

GAS HEA DWEL GAS 142.30
 ELE 36.20

OIL HEA DWEL OIL 135.40
 ELE 47.50

LPG HEA DWEL LPG 142.30
 ELE 36.20

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	987.1	1282.5	1321.1	1321.1	1388.8	1388.8	1459.2	1459.2	1533.7	1533.7
2	443.8	770.3	1076.4	1277.1	1253.5	1341.8	1410.0	1410.0	1482.2	1482.2
3	713.3	974.8	1058.5	1340.1	1214.4	1408.0	1399.8	1479.7	1555.4	1555.4
4	850.8	1096.2	1180.3	1476.3	1337.5	1541.0	1525.3	1609.3	1681.5	1681.5

TYPE OF DWELLING	1
REGION	7
GENERIC OR CONSERVATIVE?	2

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL	ELE	118.70
	ELE	0.00

GAS HEA DWEL	GAS	112.80
	ELE	36.00

OIL HEA DWEL	OIL	103.40
	ELE	47.30

LPG HEA DWEL	LPG	112.80
	ELE	36.00

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	848.7	1102.7	1136.0	1136.0	1194.1	1194.1	1254.7	1254.7	1318.8	1318.8
2	404.0	678.5	923.2	1082.2	1067.2	1137.1	1194.9	1194.9	1256.1	1256.1
3	623.6	846.8	913.8	1128.9	1038.3	1186.2	1185.5	1246.5	1310.3	1310.3
4	726.6	936.8	1005.5	1240.2	1133.7	1295.0	1286.3	1352.9	1414.0	1414.0

TYPE OF DWELLING	1
REGION	8
GENERIC1 OR CONSERVATIVE2	1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	172.80
	ELE	0.00

GAS HEA DWEL	GAS	206.75
	ELE	29.35

OIL HEA DWEL	OIL	205.35
	ELE	40.65

LPG HEA DWEL	LPG	206.75
	ELE	29.35

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	2277.5	2199.4	2852.9	2652.9	2998.1	2998.1	3150.1	3150.1	3310.8	3310.8
2	1052.6	1641.5	1772.6	1847.1	1828.3	1942.0	2040.2	2040.2	2144.0	2144.0
3	1112.8	1484.0	1605.5	2024.4	1845.0	2128.4	2131.3	2236.0	2349.8	2349.8
4	1408.2	1747.0	1865.7	2287.4	2097.1	2382.4	2375.1	2480.6	2584.4	2584.4

TYPE OF DWELLING	1
REGION	8
GENERIC OR CONSERVATIVE	2
ENERGY CONSUMPTION (10**6 BTU/YR.)	

ELEC HEATED DWELL	ELE	137.75
	ELE	0.00
GAS HEA DWEL	GAS	152.15
	ELE	29.80
OIL HEA DWEL	OIL	146.15
	ELE	41.10
LPG HEA DWEL	LPG	152.15
	ELE	29.80

ANNUAL ENERGY COSTS (\$/YR.)										
TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1815.5	2231.5	2274.3	2274.3	2390.0	2390.0	2511.2	2511.2	2639.3	2639.3
2	882.7	1340.9	1439.9	1444.7	1487.7	1571.4	1650.9	1650.9	1734.9	1734.9
3	952.4	1253.3	1343.5	1641.7	1524.2	1725.9	1738.7	1813.2	1905.5	1905.5
4	1144.4	1418.5	1508.4	1818.7	1685.5	1895.5	1897.4	1975.0	2059.0	2059.0

TYPE OF DWELLING	1
REGION	9
GENERIC OR CONSERVATIVE?	1

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	191.80
	ELE	0.00

GAS HEA DWEL	GAS	236.25
	ELE	29.20

OIL HEA DWEL	OIL	237.25
	ELE	40.50

LPG HEA DWEL	LPG	236.25
	ELE	29.20

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	2000.5	2606.6	2685.2	2685.2	2823.3	2823.3	2969.1	2969.1	3120.6	3120.6
2	677.8	1163.5	1616.0	1949.1	1899.3	2048.1	2153.0	2153.0	2263.5	2263.5
3	1072.5	1480.4	1620.4	2113.9	1879.7	2221.3	2190.4	2335.1	2454.9	2454.9
4	1353.5	1724.6	1859.4	2350.8	2109.6	2449.8	2410.5	2554.6	2665.1	2665.1

TYPE OF DWELLING 1
 REGION 9
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWEL ELE 148.80
 ELE 0.00

GAS HEA DWEL GAS 169.25
 ELE 29.70

OIL HEA DWEL OIL 164.70
 ELE 41.00

LPG HEA DWEL LPG 169.25
 ELE 29.70

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1552.0	2022.2	2083.2	2083.2	2190.3	2190.3	2303.4	2303.4	2421.0	2421.0
2	577.2	967.2	1280.7	1519.3	1489.9	1596.5	1678.4	1678.4	1764.4	1764.4
3	878.9	1202.8	1305.3	1647.8	1494.5	1731.7	1720.1	1820.5	1913.8	1913.8
4	1061.2	1354.8	1455.0	1807.0	1640.6	1884.3	1862.8	1966.1	2052.2	2052.2

TYPE OF DWELLING 1
 REGION 10
 GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 172.80
 ELE 0.00

GAS HEA DWEL GAS 206.75
 ELE 29.35

OIL HEA DWEL OIL 205.35
 ELE 40.65

LPG HEA DWEL LPG 206.75
 ELE 29.35

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1453.2	1890.4	1938.8	1938.8	2037.3	2037.3	2141.0	2141.0	2249.9	2249.9
2	557.0	974.4	1358.9	1664.9	1601.0	1749.9	1839.8	1839.8	1934.8	1934.8
3	892.2	1231.2	1345.3	1782.7	1563.5	1873.6	1826.1	1969.9	2071.4	2071.4
4	972.5	1284.5	1396.1	1836.5	1609.3	1921.5	1866.7	2011.4	2106.4	2106.4

TYPE OF DWELLING 1
 REGION 10
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 137.75
 ELE 0.00

GAS HEA DWEL GAS 152.15
 ELE 29.80

OIL HEA DWEL OIL 146.15
 ELE 41.10

LPG HEA DWEL LPG 152.15
 ELE 29.80

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1158.5	1507.0	1545.6	1545.6	1624.1	1624.1	1706.7	1706.7	1793.5	1793.5
2	478.8	806.8	1092.1	1317.2	1274.9	1384.4	1455.6	1455.6	1530.6	1530.6
3	737.3	1009.4	1094.0	1405.3	1256.2	1476.9	1450.4	1552.7	1632.7	1632.7
4	784.7	1035.0	1119.4	1443.5	1281.0	1510.7	1475.4	1581.9	1656.9	1656.9

TYPE OF DWELLING	1
REGION	11
GENERIC1 OR CONSERVATIVE2	1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	172.80
	ELE	0.00

GAS HEA DWEL	GAS	206.75
	ELE	29.35

OIL HEA DWEL	OIL	205.35
	ELE	40.65

LPG HEA DWEL	LPG	206.75
	ELE	29.35

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	622.1	1102.9	1368.6	1308.6	1612.2	1612.2	1695.2	1695.2	1781.6	1781.6
2	544.0	1096.9	1297.2	1625.9	1572.2	1737.6	1826.1	1826.1	1919.4	1919.4
3	754.2	1109.3	1241.9	1706.0	1500.5	1833.1	1766.4	1926.6	2024.9	2024.9
4	1340.0	1661.3	1781.0	2248.3	2025.0	2359.9	2287.2	2448.5	2541.7	2541.7

TYPE OF DWELLING 1
 REGION 11
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 137.75
 ELE 0.00

GAS HEA DWEL GAS 152.15
 ELE 29.80

OIL HEA DWEL OIL 146.15
 ELE 41.10

LPG HEA DWEL LPG 152.15
 ELE 29.80

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	495.9	927.1	1091.0	1091.0	1285.2	1285.2	1351.3	1351.3	1420.2	1420.2
2	429.8	862.4	1019.6	1261.5	1233.5	1355.3	1424.3	1424.3	1497.1	1497.1
3	580.6	871.4	980.3	1310.6	1181.4	1418.2	1376.5	1490.5	1566.6	1566.6
4	1015.6	1277.8	1375.6	1719.5	1566.7	1813.2	1763.6	1882.3	1955.0	1955.0

TYPE OF DWELLING	2
REGION	1
GENERIC OR CONSERVATIVE	2 1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	81.45
	ELE	0.00

GAS HEA DWEL	GAS	35.50
	ELE	51.90

OIL HEA DWEL	OIL	22.75
	ELE	61.90

LPG HEA DWEL	LPG	35.50
	ELE	51.90

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	813.7	1059.7	1087.4	1087.4	1142.7	1142.7	1201.4	1201.4	1261.7	1261.7
2	617.2	871.2	906.2	941.4	988.4	989.4	1040.3	1040.3	1092.9	1092.9
3	701.6	913.4	945.3	985.6	1013.6	1035.9	1089.1	1089.1	1144.0	1144.0
4	732.9	928.3	963.0	1025.9	1039.1	1073.9	1124.8	1124.8	1177.4	1177.4

TYPE OF DWELLING 2
 REGION 1
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 79.30
 ELE 0.00

GAS HEA DWEL GAS 34.95
 ELE 50.10

OIL HEA DWEL OIL 22.20
 ELE 60.10

LPG HEA DWEL LPG 34.95
 ELE 50.10

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	792.2	1031.7	1058.7	1058.7	1112.6	1112.6	1169.7	1169.7	1228.4	1228.4
2	597.7	844.7	878.9	913.5	959.1	960.1	1009.5	1009.5	1060.5	1060.5
3	681.7	887.4	918.4	957.7	984.8	1006.6	1058.3	1058.3	1111.7	1111.7
4	711.6	901.0	934.8	996.7	1009.1	1043.3	1092.7	1092.7	1143.7	1143.7

TYPE OF DWELLING	2
REGION	2
GENERIC OR CONSERVATIVE	1

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWEL	ELE	73.45
	ELE	0.00

GAS HEA DWEL	GAS	53.10
	ELE	30.15

OIL HEA DWEL	OIL	41.10
	ELE	40.15

LPG HEA DWEL	LPG	53.10
	ELE	30.15

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	716.1	932.8	957.1	957.1	1006.3	1006.3	1057.7	1057.7	1111.3	1111.3
2	374.7	558.7	670.6	742.8	751.8	781.0	820.7	820.7	862.4	862.4
3	507.0	675.1	710.2	794.0	778.2	834.9	856.4	877.4	921.9	921.9
4	532.9	686.1	724.2	832.5	797.5	870.8	883.4	910.5	952.1	952.1

TYPE OF DWELLING 2
 REGION 2
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 71.85
 ELE 0.00

GAS HEA DWEL GAS 48.50
 ELE 31.50

OIL HEA DWEL OIL 36.15
 ELE 41.50

LPG HEA DWEL LPG 48.50
 ELE 31.50

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	700.5	912.5	936.2	936.2	984.3	984.3	1034.6	1034.6	1087.1	1087.1
2	380.8	560.6	664.1	730.1	741.0	767.7	806.7	806.7	847.6	847.6
3	506.2	672.4	705.2	719.0	769.2	819.1	842.3	860.8	904.4	904.4
4	525.4	677.0	713.1	812.0	782.7	849.6	863.9	888.6	929.6	929.6

TYPE OF DWELLING 2
 REGION 3
 GENERIC1 OR CONSERVATIVE2 1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 98.95
 ELE 0.00

GAS HEA DWEL GAS 62.05
 ELE 49.90

OIL HEA DWEL OIL 48.65
 ELE 61.20

LPG HEA DWEL LPG 62.05
 ELE 49.90

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1054.8	1374.4	1410.0	1410.0	1462.3	1482.3	1557.5	1557.5	1636.6	1636.6
2	645.5	925.8	1010.8	1107.0	1113.0	1163.9	1222.9	1222.9	1285.1	1285.1
3	778.9	1031.0	1076.4	1182.5	1165.9	1243.2	1266.9	1306.3	1372.7	1372.7
4	880.0	1110.7	1158.5	1293.7	1252.0	1350.6	1359.4	1409.6	1471.9	1471.9

TYPE OF DWELLING 2
 REGION 3
 GENERIC OR CONSERVATIVE? 2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 93.40
 ELE 0.00

GAS HEA DWEL GAS 55.25
 ELE 48.75

OIL HEA DWEL OIL 41.30
 ELE 60.05

LPG HEA DWEL LPG 55.25
 ELE 48.75

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	995.6	1297.3	1330.9	1330.9	1399.1	1399.1	1470.1	1470.1	1544.8	1544.8
2	620.8	884.3	961.5	1047.2	1055.7	1101.0	1156.8	1156.8	1215.7	1215.7
3	747.5	987.7	1029.2	1119.2	1111.0	1176.7	1202.9	1236.4	1299.3	1299.3
4	829.6	1049.0	1093.0	1213.5	1179.5	1267.3	1278.4	1323.1	1382.0	1382.0

TYPE OF DWELLING	2
REGION	4
GENERIC OR CONSERVATIVE	1

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	118.95
	ELE	0.00

GAS HEA DWEL	GAS	115.30
	ELE	34.60

OIL HEA DWEL	OIL	106.20
	ELE	45.90

LPG HEA DWEL	LPG	115.30
	ELE	34.60

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1080.1	1406.0	1442.9	1442.9	1516.6	1516.6	1593.9	1593.9	1674.8	1674.8
2	447.9	790.6	963.9	1147.2	1104.1	1205.6	1267.3	1267.3	1332.3	1332.3
3	685.5	928.0	992.2	1226.9	1116.2	1289.3	1262.9	1355.3	1424.7	1424.7
4	693.5	915.1	980.1	1234.9	1105.3	1293.2	1254.6	1354.9	1419.9	1419.9

TYPE OF DWELLING	2
REGION	4
GENERIC1 OR CONSERVATIVE2	2

ENERGY CONSUMPTION(10**6 B1U/YR.)

ELEC HEATED DWELL	ELE	98.55
	ELE	0.00

GAS HEA DWEL	GAS	84.40
	ELE	34.30

OIL HEA DWEL	OIL	72.70
	ELE	45.60

LPG HEA DWEL	LPG	84.40
	ELE	34.30

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	894.8	1164.9	1195.4	1195.4	1256.5	1256.5	1320.6	1320.6	1387.6	1387.6
2	409.3	684.8	814.4	948.6	922.6	996.9	1047.9	1047.9	1101.6	1101.6
3	598.0	802.9	851.2	1011.9	944.9	1063.4	1054.5	1117.8	1174.9	1174.9
4	589.1	775.9	826.2	1012.8	923.5	1061.0	1038.6	1112.0	1165.7	1165.7

TYPE OF DWELLING 2
 REGION 5
 GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL ELE 98.90
 ELE 0.00

GAS HEA DWEL GAS 74.25
 ELE 43.75

OIL HEA DWEL OIL 62.50
 ELE 55.05

LPG HEA DWEL LPG 74.25
 ELE 43.75

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	791.2	1028.6	1055.3	1055.3	1208.6	1208.6	1269.9	1269.9	1334.2	1334.2
2	459.1	677.7	835.8	945.7	984.6	1038.0	1091.2	1091.2	1146.3	1146.3
3	607.3	811.3	857.4	990.5	1002.1	1096.5	1108.1	1152.5	1210.7	1210.7
4	635.1	825.5	874.4	1032.6	1012.8	1124.9	1125.3	1178.0	1233.2	1233.2

TYPE OF DWELLING	2
REGION	5
GENERIC OR CONSERVATIVE	2

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL	ELE	89.25
	ELE	0.00

GAS HEA DWEL	GAS	60.35
	ELE	43.10

OIL HEA DWEL	OIL	47.40
	ELE	54.40

LPG HEA DWEL	LPG	60.35
	ELE	43.10

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	714.0	928.2	952.3	952.3	1090.6	1090.6	1146.0	1146.0	1204.0	1204.0
2	433.5	629.3	759.8	849.1	892.4	935.9	983.7	983.7	1033.4	1033.4
3	561.8	746.6	785.2	886.2	914.6	986.1	1002.8	1036.5	1088.9	1088.9
4	576.5	749.4	791.2	919.7	915.3	1006.5	1011.5	1054.3	1104.0	1104.0

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	875.7	1138.5	1170.4	1170.4	1230.0	1230.0	1292.8	1292.8	1358.7	1358.7
2	458.7	722.1	865.6	1008.2	989.4	1059.8	1114.3	1114.3	1170.8	1170.8
3	611.6	825.4	882.3	1065.2	989.1	1119.7	1115.3	1177.2	1237.0	1237.0
4	663.0	860.9	919.6	1124.8	1029.9	1176.4	1161.5	1230.9	1287.4	1287.4

TYPE OF DWELLING 2
 REGION 6
 GENERIC OR CONSERVATIVE? 2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 88.95
 ELE 0.00

GAS HEA DWEL GAS 70.80
 ELE 34.40

OIL HEA DWEL OIL 58.20
 ELE 45.70

LPG HEA DWEL LPG 70.80
 ELE 34.40

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	732.1	951.6	978.4	978.4	1028.3	1028.3	1080.7	1080.7	1135.9	1135.9
2	407.0	621.5	729.6	834.4	825.3	877.0	922.1	922.1	968.9	968.9
3	530.9	710.7	753.5	877.5	833.8	922.3	927.7	969.6	1018.9	1018.9
4	557.1	723.5	769.2	920.0	855.0	962.6	956.7	1007.7	1054.5	1054.5

TYPE OF DWELLING 2
 REGION 7
 GENERIC1 OR CONSERVATIVE2 1

ENERGY CONSUMPTION(10**6 B1U/YR.)

ELEC HEATED DWELL ELE 116.05
 ELE 0.00

GAS HEA DWEL GAS 108.50
 ELE 36.15

OIL HEA DWEL OIL 98.75
 ELE 47.45

LPG HEA DWEL LPG 108.50
 ELE 36.15

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	829.8	1078.1	1110.6	1110.6	1167.5	1167.5	1226.6	1226.6	1289.3	1289.3
2	399.5	666.8	902.6	1055.5	1041.8	1109.1	1165.5	1165.5	1225.1	1225.1
3	611.8	829.9	894.5	1099.9	1014.5	1155.8	1156.3	1214.5	1276.7	1276.7
4	709.8	915.2	981.8	1207.4	1105.8	1261.0	1253.4	1317.4	1377.0	1377.0

TYPE OF DWELLING 2
 REGION 7
 GENERIC OR CONSERVATIVE? 2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 97.95
 ELE 0.00

GAS HEA DWEL GAS 81.95
 ELE 35.30

OIL HEA DWEL OIL 61.90
 ELE 46.60

LPG HEA DWEL LPG 81.95
 ELE 35.30

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	700.3	910.0	937.4	937.4	985.4	985.4	1035.3	1035.3	1088.2	1088.2
2	358.9	577.9	758.2	873.8	867.3	918.1	964.8	964.8	1014.2	1014.2
3	504.0	676.8	722.0	850.8	805.5	894.0	903.0	939.5	987.5	987.5
4	593.3	765.5	818.0	988.5	915.7	1032.8	1031.2	1079.5	1128.9	1128.9

C-39

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1875.5	2305.3	2349.4	2349.4	2468.9	2468.9	2594.1	2594.1	2726.5	2726.5
2	908.4	1383.2	1486.1	1543.1	1535.2	1622.4	1704.4	1704.4	1791.2	1791.2
3	977.0	1287.6	1381.5	1693.8	1569.5	1780.7	1792.7	1870.7	1966.0	1966.0
4	1181.0	1464.0	1557.4	1880.7	1741.2	1960.0	1961.2	2042.0	2128.8	2128.8

TYPE OF DWELLING	2
REGION	8
GENERIC1 OR CONSERVATIVE2	2

ENERGY CONSUMPTION(10**6 B/D/YR.)

ELEC HEATED DWELL	ELE	107.15
	ELE	0.00

GAS HEA DWEL	GAS	104.20
	ELE	30.35

OIL HEA DWEL	OIL	94.25
	ELE	41.65

LPG HEA DWEL	LPG	104.20
	ELE	30.35

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1412.2	1735.8	1769.0	1769.0	1859.1	1859.1	1953.3	1953.3	2053.0	2053.0
2	735.5	1079.4	1150.2	1187.8	1191.4	1248.7	1311.9	1311.9	1378.6	1378.6
3	813.8	1053.6	1116.5	1308.7	1245.7	1375.8	1397.4	1445.4	1519.0	1519.0
4	914.8	1132.5	1197.1	1409.7	1326.8	1470.6	1480.7	1533.8	1600.6	1600.6

TYPE OF DWELLING 2
 REGION 9
 GENERIC1 OR CONSERVATIVE2 1

ENERGY CONSUMPTION(10**6 Btu/YR.)

ELEC HEATED DWELL ELE 152.70
 ELE 0.00

GAS HEA DWEL GAS 174.60
 ELE 30.15

OIL HEA DWEL OIL 170.45
 ELE 41.45

LPG HEA DWEL LPG 174.60
 ELE 30.15

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1592.7	2075.2	2137.8	2137.8	2247.7	2247.7	2363.8	2363.8	2484.4	2484.4
2	590.3	991.2	1314.3	1560.5	1529.8	1639.8	1723.8	1723.8	1812.3	1812.3
3	899.4	1231.5	1337.1	1691.6	1532.3	1777.7	1764.9	1868.9	1964.7	1964.7
4	1089.7	1391.0	1494.1	1857.3	1685.2	1936.6	1914.2	2020.7	2109.1	2109.1

TYPE OF DWELLING 2
 REGION 9
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 113.35
 ELE 0.00

GAS HEA DWEL GAS 113.75
 ELE 30.35

OIL HEA DWEL OIL 104.55
 ELE 41.65

LPG HEA DWEL LPG 113.75
 ELE 30.35

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1182.2	1540.4	1586.9	1586.9	1668.5	1668.5	1754.7	1754.7	1844.2	1844.2
2	496.3	791.2	1006.2	1106.5	1154.3	1225.9	1288.8	1288.8	1354.9	1354.9
3	720.9	975.9	1047.3	1264.8	1178.7	1329.3	1333.7	1397.5	1469.1	1469.1
4	821.6	1051.7	1123.3	1359.9	1255.5	1419.3	1412.8	1482.2	1548.3	1548.3

TYPE OF DWELLING 2
 REGION 10
 GENERIC OR CONSERVATIVE? 1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELE 142.30
 ELE 0.00

GAS HEA DWEL GAS 158.50
 ELE 30.20

OIL HEA DWEL OIL 153.05
 ELE 41.50

LPG HEA DWEL LPG 158.50
 ELE 30.20

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1196.7	1556.8	1596.6	1596.6	1677.7	1677.7	1763.1	1763.1	1852.7	1852.7
2	491.7	831.2	1128.2	1362.8	1318.2	1432.3	1505.9	1505.9	1583.5	1583.5
3	759.2	1040.2	1128.3	1454.3	1297.4	1528.5	1499.8	1607.0	1689.7	1689.7
4	810.3	1069.0	1156.7	1494.3	1324.5	1563.8	1526.5	1637.4	1715.1	1715.1

TYPE OF DWELLING 2
 REGION 10
 GENERIC OR CONSERVATIVE? 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELEC 107.15
 ELEC 0.00

GAS HEA DWEL GAS 104.20
 ELEC 30.35

OIL HEA DWEL OIL 94.25
 ELEC 41.65

LPG HEA DWEL LPG 104.20
 ELEC 30.35

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	901.1	1172.2	1202.2	1202.2	1263.3	1263.3	1327.6	1327.6	1395.1	1395.1
2	411.5	661.3	859.4	1013.7	990.3	1065.3	1120.0	1120.0	1177.7	1177.7
3	602.9	816.6	875.4	1076.2	988.7	1131.0	1123.0	1189.0	1250.1	1250.1
4	621.0	817.6	878.2	1100.1	994.5	1151.8	1133.6	1206.5	1264.2	1264.2

TYPE OF DWELLING 2
 REGION 11
 GENERIC OR CONSERVATIVE? 1

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 142.30
 ELE 0.00

GAS HEA DWEL GAS 158.50
 ELE 30.20

OIL HEA DWEL OIL 153.05
 ELE 41.50

LPG HEA DWEL LPG 158.50
 ELE 30.20

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	512.3	957.7	1127.0	1127.0	1327.7	1327.7	1396.0	1396.0	1467.1	1467.1
2	444.7	892.7	1055.5	1307.5	1277.1	1403.9	1475.5	1475.5	1550.8	1550.8
3	602.4	902.2	1014.3	1360.2	1222.8	1470.8	1426.4	1545.8	1624.7	1624.7
4	1055.0	1925.4	1426.3	1784.6	1624.3	1881.0	1829.0	1952.6	2027.9	2027.9

TYPE OF DWELLING 2
 REGION 11
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL ELE 107.15
 ELE 0.00

GAS HEA DWEL GAS 104.20
 ELE 30.35

OIL HEA DWEL OIL 94.25
 ELE 41.65

LPG HEA DWEL LPG 104.20
 ELE 30.35

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	385.7	721.1	848.6	848.6	999.7	999.7	1051.1	1051.1	1104.7	1104.7
2	330.2	657.5	777.0	942.7	937.5	1020.9	1073.0	1073.0	1127.8	1127.8
3	428.9	663.9	752.1	965.1	903.2	1055.9	1036.3	1109.8	1166.4	1166.4
4	731.3	942.0	1020.8	1256.3	1165.7	1334.5	1305.3	1386.6	1441.4	1441.4

TYPE OF DWELLING	3
REGION	1
GENERIC OR CONSERVATIVE?	1

ENERGY CONSUMPTION (10*16 BTU/YR.)

ELEC HEATED DWELL	ELE	62.30
	ELE	0.00

GAS HEA DWEL	GAS	32.05
	ELE	35.75

OIL HEA DWEL	OIL	20.65
	ELE	62.30

LPG HEA DWEL	LPG	32.05
	ELE	35.75

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	622.4	810.5	831.7	831.7	874.1	874.1	918.9	918.9	965.0	965.0
2	446.2	642.0	669.9	701.6	736.5	737.5	775.4	775.4	814.7	814.7
3	698.0	908.6	939.7	976.3	1005.8	1026.1	1078.8	1078.8	1133.1	1133.1
4	550.7	693.6	721.2	777.9	782.3	813.7	851.7	851.7	890.9	890.9

TYPE OF DWELLING 3
 REGION 1
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 61.70
 ELE 0.00

GAS HEA DWEL GAS 32.00
 ELE 35.20

OIL HEA DWEL OIL 20.60
 ELE 43.65

LPG HEA DWEL LPG 32.00
 ELE 35.20

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	616.4	802.7	823.7	823.7	865.7	865.7	910.1	910.1	955.7	955.7
2	440.6	634.6	662.2	643.9	728.4	729.4	766.9	766.9	805.7	805.7
3	513.5	668.3	693.1	729.6	746.6	766.8	806.2	806.2	846.9	846.9
4	544.9	686.1	713.4	770.1	774.2	805.5	843.0	843.0	881.9	881.9

TYPE OF DWELLING	3
REGION	2
GENERIC OR CONSERVATIVE	1

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	56.55
	ELE	0.00

GAS HEA DWEL	GAS	40.40
	ELE	23.20

OIL HEA DWEL	OIL	29.25
	ELE	31.85

LPG HEA DWEL	LPG	40.40
	ELE	23.20

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	551.4	718.2	736.8	736.8	774.7	774.7	814.3	814.3	855.6	855.6
2	287.6	428.4	513.6	568.5	575.6	597.8	628.2	628.2	660.1	660.1
3	392.7	522.1	548.1	607.8	598.7	639.0	656.7	671.6	705.7	705.7
4	408.0	525.3	554.4	636.8	610.3	666.1	675.9	696.5	728.4	728.4

TYPE OF DWELLING	3
REGION	2
GENERIC1 OR CONSERVATIVE2	2

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	56.40
	ELE	0.00
GAS HEA DWEL	GAS	39.65
	ELE	23.50
OIL HEA DWEL	OIL	28.45
	ELE	32.15
LPG HEA DWEL	LPG	39.65
	ELE	23.50

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	549.9	716.3	734.9	734.9	772.7	772.7	812.2	812.2	853.3	853.3
2	289.4	429.7	513.6	567.5	574.9	596.7	627.1	627.1	658.9	658.9
3	393.4	522.7	548.4	606.4	598.4	637.6	655.6	670.1	704.1	704.1
4	407.6	524.9	553.6	634.5	609.0	663.7	673.8	694.1	725.9	725.9

TYPE OF DWELLING	3										
REGION	3										
GENERIC OR CONSERVATIVE?	1										
ENERGY CONSUMPTION(10**6 BTU/YR.)											
ELEC HEATED DWELL	ELE	71.00									
	ELE	0.00									
GAS HEA DWEL	GAS	46.05									
	ELE	33.90									
OIL HEA DWEL	OIL	32.95									
	ELE	44.05									
LPG HEA DWEL	LPG	46.05									
	ELE	33.90									
ANNUAL ENERGY COSTS(\$/YR.)											
TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020	
1	756.9	986.2	1011.8	1011.8	1063.6	1063.6	1117.5	1117.5	1174.3	1174.3	
2	445.6	643.6	705.5	776.9	779.1	816.8	858.2	858.2	901.9	901.9	
3	555.2	734.4	766.1	837.9	828.6	881.0	899.0	925.6	972.7	972.7	
4	619.7	780.8	815.1	915.5	882.2	955.4	959.5	996.8	1040.5	1040.5	

TYPE OF DWELLING	3
REGION	3
GENERIC OR CONSERVATIVE?	2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	69.40
	ELE	0.00

GAS HEAT DWELL	GAS	44.15
	ELE	33.55

OIL HEAT DWELL	OIL	30.90
	ELE	43.70

LPG HEAT DWELL	LPG	44.15
	ELE	33.55

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	739.8	964.0	988.9	988.9	1039.6	1039.6	1092.4	1092.4	1147.9	1147.9
2	438.4	631.6	691.3	759.8	762.6	798.8	839.3	839.3	882.1	882.1
3	546.2	721.9	752.5	819.9	812.8	862.0	880.7	905.7	951.8	951.8
4	605.3	763.1	796.4	842.7	861.5	931.7	936.5	972.2	1015.0	1015.0

TYPE OF DWELLING	3										
REGION	4										
GENERIC1 OR CONSERVATIVE2	1										
ENERGY CONSUMPTION(10**6 BTU/YR.)											
ELEC HEATED DWELL	ELE	79.10									
	ELE	0.00									
GAS HEA DWEL	GAS	71.30									
	ELE	25.10									
OIL HEA DWEL	OIL	60.15									
	ELE	35.25									
LPG HEA DWEL	LPG	71.30									
	ELE	25.10									
ANNUAL ENERGY COSTS(\$/YR.)											
TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020	
1	718.2	935.0	959.5	959.5	1008.5	1008.5	1059.9	1059.9	1113.7	1113.7	
2	310.6	532.7	641.0	754.4	730.0	792.7	833.3	833.3	876.0	876.0	
3	472.2	635.0	674.2	807.1	750.2	848.2	839.3	891.6	937.2	937.2	
4	462.5	609.7	651.0	808.6	730.7	846.9	825.5	887.5	930.2	930.2	

TYPE OF DWELLING	3
REGION	4
GENERIC OR CONSERVATIVE	2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	72.65
	ELE	0.00

GAS HEA DWEL	GAS	61.70
	ELE	24.85

OIL HEA DWEL	OIL	49.75
	ELE	35.00

LPG HEA DWEL	LPG	61.70
	ELE	24.85

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	659.7	858.7	881.2	881.2	926.3	926.3	973.5	973.5	1022.9	1022.9
2	297.2	498.0	592.7	620.8	671.6	725.9	763.0	763.0	802.1	802.1
3	443.7	594.3	628.5	738.5	695.0	776.1	772.5	815.8	857.5	857.5
4	428.6	564.6	601.3	737.6	672.2	772.8	756.3	809.9	849.0	849.0

TYPE OF DWELLING	3
REGION	5
GENERIC1 OR CONSERVATIVE2	1
ENERGY CONSUMPTION(10**6 BTU/YR.)	

ELEC HEATED DWELL	ELE	68.25
	ELE	0.00

GAS HEA DWEL	GAS	48.60
	ELE	30.80

OIL HEA DWEL	OIL	30.60
	ELE	40.95

LPG HEA DWEL	LPG	48.60
	ELE	30.80

ANNUAL ENERGY COSTS(\$/YR.)										
TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	546.0	709.8	728.2	728.2	834.0	834.0	876.3	876.3	920.7	920.7
2	317.8	466.1	570.2	642.1	670.9	705.9	742.0	742.0	779.5	779.5
3	409.8	543.5	570.0	635.6	662.7	709.2	723.5	745.4	783.1	783.1
4	433.0	562.8	595.4	699.0	689.4	762.7	764.3	798.9	836.4	836.4

TYPE OF DWELLING 3
 REGION 5
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 Btu/YR.)

ELEC HEATED DWELL ELE 66.15
 ELE 0.00

GAS HEA DWEL GAS 45.40
 ELE 30.80

OIL HEA DWEL OIL 32.70
 ELE 40.95

LPG HEA DWEL LPG 45.40
 ELE 30.80

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	529.2	688.0	705.8	705.8	808.4	808.4	849.4	849.4	892.4	892.4
2	313.1	456.5	554.3	621.5	651.5	684.2	719.2	719.2	755.5	755.5
3	414.9	550.8	578.2	647.9	672.7	722.1	735.7	758.9	797.3	797.3
4	420.7	546.9	577.9	674.6	668.8	737.3	740.1	772.3	808.7	808.7

TYPE OF DWELLING	3										
REGION	6										
GENERIC OR CONSERVATIVE	2	1									
ENERGY CONSUMPTION(10**6 Btu/YR.)											
ELEC HEATED DWELL	ELE	72.00									
	ELE	0.00									
GAS HEA DWEL	GAS	60.10									
	ELE	26.00									
OIL HEA DWEL	OIL	48.20									
	ELE	36.15									
LPG HEA DWEL	LPG	60.10									
	ELE	26.00									
ANNUAL ENERGY COSTS(\$/YR.)											
TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020	
1	592.6	770.4	792.0	792.0	832.3	832.3	874.8	874.8	919.4	919.4	
2	319.2	493.4	584.1	673.0	663.6	707.4	743.8	743.8	781.6	781.6	
3	425.7	570.4	605.4	708.1	670.9	744.2	747.7	782.4	822.2	822.2	
4	446.6	579.9	617.8	745.8	688.8	780.2	773.3	816.5	854.3	854.3	

TYPE OF DWELLING 3
 REGION 6
 GENERIC OR CONSERVATIVE? 2

ENERGY CONSUMPTION(10**6 B10/2YR.)

ELEC HEATED DWELL ELE 66.30
 ELE 0.00

GAS HEA DWEL GAS 51.95
 ELE 25.55

OIL HEA DWEL OIL 39.45
 ELE 35.70

LPG HEA DWEL LPG 51.95
 ELE 25.55

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	545.6	709.4	729.3	729.3	766.4	766.4	805.5	805.5	846.7	846.7
2	301.2	459.4	538.7	615.6	609.1	647.1	680.3	680.3	714.9	714.9
3	398.7	532.3	562.7	646.8	619.8	679.8	686.2	714.6	751.0	751.0
4	411.3	534.2	567.8	678.5	631.0	709.9	705.8	743.2	777.7	777.7

TYPE OF DWELLING 3
 REGION 7
 GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION (10⁹ BTU/YR.)

ELEC HEATED DWELL ELEC 78.55
 ELEC 0.00

GAS HEATED DWELL GAS 68.10
 ELEC 26.60

OIL HEATED DWELL OIL 56.70
 ELEC 36.75

LPG HEATED DWELL LPG 68.10
 ELEC 26.60

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	561.6	729.7	751.7	751.7	790.2	790.2	830.3	830.3	872.7	872.7
2	278.7	454.8	603.9	699.9	693.2	735.4	772.8	772.8	812.4	812.4
3	419.3	564.8	604.6	722.5	678.2	759.2	764.4	797.8	838.6	838.6
4	473.5	610.8	653.6	795.3	733.4	830.8	828.0	868.2	907.7	907.7

TYPE OF DWELLING 3
 REGION 7
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 72.60
 ELE 0.00

GAS HEA DWEL GAS 59.65
 ELE 26.15

OIL HEA DWEL OIL 47.55
 ELE 36.30

LPG HEA DWEL LPG 59.65
 ELE 26.15

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	519.1	674.5	694.8	694.8	730.4	730.4	767.4	767.4	806.6	806.6
2	264.5	424.9	556.3	640.4	635.9	672.9	707.1	707.1	743.3	743.3
3	390.8	524.6	559.5	658.4	623.8	691.8	698.9	727.0	764.2	764.2
4	435.1	561.5	594.8	723.9	671.1	756.4	755.4	790.6	826.8	826.8

TYPE OF DWELLING	3										
REGION	8										
GENERIC1 OR CONSERVATIVE2	1										
ENERGY CONSUMPTION(10**6 Btu/YR.)											
ELEC HEATED DWELL	ELE	87.85									
	ELE	0.00									
GAS HEA DWEL	GAS	87.70									
	ELE	23.20									
OIL HEA DWEL	OIL	77.95									
	ELE	33.35									
LPG HEA DWEL	LPG	87.70									
	ELE	23.20									
ANNUAL ENERGY COSTS(\$/YR.)											
TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020	
1	1157.9	1423.2	1450.4	1450.4	1524.2	1524.2	1601.5	1601.5	1683.2	1683.2	
2	588.2	870.5	929.4	961.0	962.0	1010.3	1061.4	1061.4	1115.4	1115.4	
3	658.6	853.6	905.3	1064.3	1011.2	1118.8	1135.7	1175.4	1235.3	1235.3	
4	739.0	915.2	968.9	1147.8	1076.1	1197.1	1203.5	1248.2	1302.2	1302.2	

TYPE OF DWELLING	3
REGION	8
GENERIC OR CONSERVATIVE	2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL	ELE	78.55
	ELE	0.00

GAS HEA DWEL	GAS	73.70
	ELE	23.05

OIL HEA DWEL	OIL	62.00
	ELE	33.20

LPG HEA DWEL	LPG	73.70
	ELE	23.05

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF FEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1035.3	1272.5	1296.9	1296.9	1362.8	1362.8	1432.0	1432.0	1505.0	1505.0
2	541.1	789.1	839.7	866.2	870.1	910.7	956.7	956.7	1005.4	1005.4
3	614.0	790.3	833.9	962.0	924.6	1011.2	1030.4	1062.4	1116.5	1116.5
4	667.9	826.7	872.9	1023.2	965.9	1067.6	1076.1	1113.7	1162.4	1162.4

TYPE OF DWELLING 3
REGION 9
GENERIC OR CONSERVATIVE 1

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 96.20
ELE 0.00

GAS HEA DWEL GAS 100.90
ELE 23.00

OIL HEA DWEL OIL 92.25
ELE 33.15

LPG HEA DWEL LPG 100.90
ELE 23.00

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	1003.4	1307.4	1346.8	1346.8	1416.1	1416.1	1489.2	1489.2	1565.2	1565.2
2	399.3	648.6	837.6	979.9	966.2	1029.7	1082.5	1082.5	1138.0	1138.0
3	598.5	812.1	873.7	1065.6	987.0	1119.9	1121.1	1177.4	1237.7	1237.7
4	687.9	879.6	941.5	1151.4	1056.0	1201.3	1192.5	1254.0	1309.6	1309.6

TYPE OF DWELLING 3
 REGION 9
 GENERIC OR CONSERVATIVE? 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 83.85
 ELE 0.00

GAS HEA DWEL GAS 81.95
 ELE 22.95

OIL HEA DWEL OIL 71.75
 ELE 33.10

LPG HEA DWEL LPG 81.95
 ELE 22.95

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	874.6	1139.5	1173.9	1173.9	1234.3	1234.3	1298.0	1298.0	1364.2	1364.2
2	368.8	584.8	740.1	855.6	847.6	899.2	945.3	945.3	993.8	993.8
3	541.8	731.1	782.0	931.2	875.4	978.7	985.2	1029.0	1081.7	1081.7
4	603.2	772.4	824.5	994.9	920.5	1038.5	1034.6	1084.6	1133.1	1133.1

TYPE OF DWELLING 3
 REGION 10
 GENERIC OR CONSERVATIVE? 1

ENERGY CONSUMPTION(10**6 BTU/YR.)

ELEC HEATED DWELL ELEC 87.85
 ELE 0.00

GAS HEA DWEL GAS 87.70
 ELE 23.20

OIL HEA DWEL OIL 77.95
 ELE 33.35

LPG HEA DWEL LPG 87.70
 ELE 23.20

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	738.8	961.1	985.7	985.7	1035.8	1035.8	1088.5	1088.5	1143.8	1143.8
2	326.7	530.9	697.0	826.8	805.9	869.0	913.6	913.6	960.7	960.7
3	489.4	663.4	711.7	877.7	804.8	922.5	915.2	969.8	1019.6	1019.6
4	502.9	662.5	712.8	899.6	809.4	941.8	925.0	986.4	1033.5	1033.5

TYPE OF DWELLING 3
 REGION 10
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 78.55
 ELE 0.00

GAS HEA DWEL GAS 73.70
 ELE 23.05

OIL HEA DWEL OIL 62.80
 ELE 33.20

LPG HEA DWEL LPG 73.70
 ELE 23.05

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	660.6	859.3	881.3	881.3	926.1	926.1	973.2	973.2	1022.7	1022.7
2	304.4	485.1	625.6	734.7	719.1	772.2	811.8	811.8	853.6	853.6
3	447.5	603.7	644.4	778.2	723.0	817.8	815.8	859.7	903.9	903.9
4	452.5	595.6	638.9	795.9	722.1	833.4	821.4	873.0	914.8	914.8

TYPE OF DWELLING 3
 REGION 11
 GENERIC1 OR CONSERVATIVE2 1

ENERGY CONSUMPTION(10**6 Btu/YR.)

ELEC HEATED DWEL ELE 87.85
 ELE 0.00

GAS HEA DWEL GAS 87.70
 ELE 23.20

OIL HEA DWEL OIL 77.95
 ELE 33.35

LPG HEA DWEL LPG 87.70
 ELE 23.20

ANNUAL ENERGY COSTS(\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	316.3	591.2	695.8	695.8	819.6	819.6	861.8	861.8	905.7	905.7
2	269.4	537.6	635.4	774.8	767.2	837.4	880.1	880.1	925.0	925.0
3	350.8	541.7	613.3	789.5	736.8	863.0	846.3	907.1	953.4	953.4
4	607.1	777.1	840.6	1038.8	959.3	1101.3	1075.7	1144.1	1189.0	1189.0

TYPE OF DWELLING 3
 REGION 11
 GENERIC OR CONSERVATIVE 2

ENERGY CONSUMPTION (10**6 BTU/YR.)

ELEC HEATED DWELL ELE 78.55
 ELE 0.00

GAS HEA DWEL GAS 73.70
 ELE 23.05

OIL HEA DWEL OIL 62.80
 ELE 33.20

LPG HEA DWEL LPG 73.70
 ELE 23.05

ANNUAL ENERGY COSTS (\$/YR.)

TYPE OF HEAT	1975	1985	1990	1990	2000	2000	2010	2010	2020	2020
1	282.8	528.6	622.1	622.1	732.9	732.9	770.6	770.6	809.9	809.9
2	239.2	475.7	562.1	679.3	677.9	736.9	774.4	774.4	814.0	814.0
3	305.4	479.0	544.3	686.2	652.6	754.4	743.9	792.9	833.4	833.4
4	523.0	676.9	734.6	901.1	839.3	958.7	938.8	996.3	1035.8	1035.8

==> \$EQU

*****JOB EXITED ON 4 JAN 78 14:09:20 *****

*****CPC TIME= 0MINS 19.32SECS *****

*****CONNECT TIME= 0MINS 45SECS *****

APPENDIX D. ESTIMATED NET SAVINGS OVER CONVENTIONAL SYSTEMS

Computer prints are presented for a number of regions and building types to provide some appreciation of the data obtained. The variations due to changing fuel prices and collector areas for the various regions and buildings are shown.

The negative numbers are the differences between the "Conventional Total Annual Cost/Unit" shown in the upper block of data on each page, and the "Net Savings of STES Over Conventional System."

Data are presented only for those regions for which parametric analysis of the collector area was done.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 22.13 REGION LOS AN NO 2 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	290.	430.	568.	597.	627.	659.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	762.	902.	1040.	1069.	1099.	1131.
125.% AREA(13932.5 SQ.FT)						
=====						
STES CAP COST	679726.	679726.	679726.	679726.	679726.	679726.
STES ANNUAL COST/UNIT (# 12%/YR.)	1757.	1757.	1757.	1757.	1757.	1757.
STES BACKUP FUEL COST/UNIT (GAS)	140.	189.	209.	219.	231.	242.
STES TOTAL ANNUAL COST/UNIT	1897.	1946.	1966.	1976.	1988.	1999.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1135.	-1044.	-926.	-907.	-889.	-868.
100.% AREA(11146.0 SQ.FT)						
=====						
STES CAP COST	618061.	618061.	618061.	618061.	618061.	618061.
STES ANNUAL COST/UNIT (# 12%/YR.)	1592.	1592.	1592.	1592.	1592.	1592.
STES BACKUP FUEL COST/UNIT (GAS)	190.	257.	288.	303.	318.	334.
STES TOTAL ANNUAL COST/UNIT	1782.	1849.	1880.	1895.	1910.	1926.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1019.	-946.	-839.	-825.	-810.	-794.
75.% AREA(8359.5 SQ.FT)						
=====						
STES CAP COST	556396.	556396.	556396.	556396.	556396.	556396.
STES ANNUAL COST/UNIT (# 12%/YR.)	1426.	1426.	1426.	1426.	1426.	1426.
STES BACKUP FUEL COST/UNIT (GAS)	213.	296.	349.	367.	385.	405.
STES TOTAL ANNUAL COST/UNIT	1639.	1722.	1775.	1793.	1811.	1831.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-876.	-819.	-734.	-723.	-711.	-699.
50.% AREA(5573.0 SQ.FT)						
=====						
STES CAP COST	494730.	494730.	494730.	494730.	494730.	494730.
STES ANNUAL COST/UNIT (# 12%/YR.)	1260.	1260.	1260.	1260.	1260.	1260.
STES BACKUP FUEL COST/UNIT (GAS)	253.	366.	465.	489.	514.	540.
STES TOTAL ANNUAL COST/UNIT	1513.	1626.	1725.	1749.	1774.	1800.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-751.	-724.	-685.	-680.	-675.	-669.
25.% AREA(2786.5 SQ.FT)						
=====						
STES CAP COST	433065.	433065.	433065.	433065.	433065.	433065.
STES ANNUAL COST/UNIT (# 12%/YR.)	1094.	1094.	1094.	1094.	1094.	1094.
STES BACKUP FUEL COST/UNIT (GAS)	295.	449.	616.	648.	681.	716.
STES TOTAL ANNUAL COST/UNIT	1389.	1543.	1710.	1742.	1775.	1810.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-627.	-641.	-670.	-673.	-676.	-679.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 15.00 REGION LOS AN NO 2 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	290.	430.	568.	597.	627.	659.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	762.	902.	1040.	1069.	1099.	1131.
125.% AREA(13932.5 SQ.FT)						
=====						
STES CAP COST	580388.	580388.	580388.	580388.	580388.	580388.
STES ANNUAL COST/UNIT (# 12%/YR.)	1509.	1509.	1509.	1509.	1509.	1509.
STES BACKUP FUEL COST/UNIT (GAS)	140.	189.	209.	219.	231.	242.
STES TOTAL ANNUAL COST/UNIT	1649.	1698.	1718.	1728.	1740.	1751.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-867.	-796.	-678.	-659.	-641.	-620.
100.% AREA(11146.0 SQ.FT)						
=====						
STES CAP COST	538590.	538590.	538590.	538590.	538590.	538590.
STES ANNUAL COST/UNIT (# 12%/YR.)	1393.	1393.	1393.	1393.	1393.	1393.
STES BACKUP FUEL COST/UNIT (GAS)	190.	257.	288.	303.	318.	334.
STES TOTAL ANNUAL COST/UNIT	1583.	1650.	1681.	1696.	1711.	1727.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-820.	-747.	-640.	-626.	-611.	-595.
75.% AREA(8359.5 SQ.FT)						
=====						
STES CAP COST	496793.	496793.	496793.	496793.	496793.	496793.
STES ANNUAL COST/UNIT (# 12%/YR.)	1277.	1277.	1277.	1277.	1277.	1277.
STES BACKUP FUEL COST/UNIT (GAS)	213.	296.	349.	367.	385.	405.
STES TOTAL ANNUAL COST/UNIT	1490.	1573.	1626.	1644.	1662.	1682.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-727.	-670.	-585.	-574.	-562.	-550.
50.% AREA(5573.0 SQ.FT)						
=====						
STES CAP COST	454995.	454995.	454995.	454995.	454995.	454995.
STES ANNUAL COST/UNIT (# 12%/YR.)	1161.	1161.	1161.	1161.	1161.	1161.
STES BACKUP FUEL COST/UNIT (GAS)	253.	366.	465.	489.	514.	540.
STES TOTAL ANNUAL COST/UNIT	1414.	1527.	1626.	1650.	1675.	1701.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-651.	-624.	-585.	-580.	-575.	-569.
25.% AREA(2786.5 SQ.FT)						
=====						
STES CAP COST	413198.	413198.	413198.	413198.	413198.	413198.
STES ANNUAL COST/UNIT (# 12%/YR.)	1045.	1045.	1045.	1045.	1045.	1045.
STES BACKUP FUEL COST/UNIT (GAS)	295.	449.	616.	648.	681.	716.
STES TOTAL ANNUAL COST/UNIT	1340.	1494.	1661.	1693.	1726.	1761.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-577.	-591.	-620.	-623.	-626.	-629.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 13.00 REGION LOS AN NO 2 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	290.	430.	568.	597.	627.	659.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	762.	902.	1040.	1069.	1099.	1131.
125.% AREA(13932.5 SQ.FT)						
=====						
STES CAP COST	552523.	552523.	552523.	552523.	552523.	552523.
STES ANNUAL COST/UNIT (# 12%/YR.)	1439.	1439.	1439.	1439.	1439.	1439.
STES BACKUP FUEL COST/UNIT (GAS)	140.	189.	209.	219.	231.	242.
STES TOTAL ANNUAL COST/UNIT	1579.	1628.	1648.	1658.	1670.	1681.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-817.	-726.	-608.	-589.	-571.	-550.
100.% AREA(11146.0 SQ.FT)						
=====						
STES CAP COST	516298.	516298.	516298.	516298.	516298.	516298.
STES ANNUAL COST/UNIT (# 12%/YR.)	1337.	1337.	1337.	1337.	1337.	1337.
STES BACKUP FUEL COST/UNIT (GAS)	190.	257.	288.	303.	318.	334.
STES TOTAL ANNUAL COST/UNIT	1527.	1594.	1625.	1640.	1655.	1671.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-765.	-692.	-585.	-571.	-556.	-540.
75.% AREA(8359.5 SQ.FT)						
=====						
STES CAP COST	480074.	480074.	480074.	480074.	480074.	480074.
STES ANNUAL COST/UNIT (# 12%/YR.)	1235.	1235.	1235.	1235.	1235.	1235.
STES BACKUP FUEL COST/UNIT (GAS)	213.	296.	349.	367.	385.	405.
STES TOTAL ANNUAL COST/UNIT	1448.	1531.	1584.	1602.	1620.	1640.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-686.	-629.	-544.	-533.	-521.	-509.
50.% AREA(5573.0 SQ.FT)						
=====						
STES CAP COST	443849.	443849.	443849.	443849.	443849.	443849.
STES ANNUAL COST/UNIT (# 12%/YR.)	1133.	1133.	1133.	1133.	1133.	1133.
STES BACKUP FUEL COST/UNIT (GAS)	253.	366.	465.	489.	514.	540.
STES TOTAL ANNUAL COST/UNIT	1386.	1499.	1598.	1622.	1647.	1673.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-623.	-596.	-557.	-552.	-547.	-541.
25.% AREA(2786.5 SQ.FT)						
=====						
STES CAP COST	407625.	407625.	407625.	407625.	407625.	407625.
STES ANNUAL COST/UNIT (# 12%/YR.)	1031.	1031.	1031.	1031.	1031.	1031.
STES BACKUP FUEL COST/UNIT (GAS)	295.	449.	616.	648.	681.	716.
STES TOTAL ANNUAL COST/UNIT	1326.	1480.	1647.	1679.	1712.	1747.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-563.	-577.	-606.	-609.	-612.	-615.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 10.00 REGION LOS AN NO 2 BUILDING LORISF NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	290.	430.	568.	597.	627.	659.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	762.	902.	1040.	1069.	1099.	1131.
125.% AREA(13932.5 SQ.FT)						
=====						
STES CAP COST	510725.	510725.	510725.	510725.	510725.	510725.
STES ANNUAL COST/UNIT (# 12%/YR.)	1335.	1335.	1335.	1335.	1335.	1335.
STES BACKUP FUEL COST/UNIT (GAS)	140.	189.	209.	219.	231.	242.
STES TOTAL ANNUAL COST/UNIT	1475.	1524.	1544.	1554.	1566.	1577.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-712.	-621.	-503.	-484.	-466.	-445.
100.% AREA(11146.0 SQ.FT)						
=====						
STES CAP COST	482860.	482860.	482860.	482860.	482860.	482860.
STES ANNUAL COST/UNIT (# 12%/YR.)	1254.	1254.	1254.	1254.	1254.	1254.
STES BACKUP FUEL COST/UNIT (GAS)	190.	257.	288.	303.	318.	334.
STES TOTAL ANNUAL COST/UNIT	1444.	1511.	1542.	1557.	1572.	1588.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-681.	-608.	-501.	-487.	-472.	-456.
75.% AREA(8359.5 SQ.FT)						
=====						
STES CAP COST	454995.	454995.	454995.	454995.	454995.	454995.
STES ANNUAL COST/UNIT (# 12%/YR.)	1172.	1172.	1172.	1172.	1172.	1172.
STES BACKUP FUEL COST/UNIT (GAS)	213.	296.	349.	367.	385.	405.
STES TOTAL ANNUAL COST/UNIT	1385.	1468.	1521.	1539.	1557.	1577.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-623.	-566.	-481.	-470.	-458.	-446.
50.% AREA(5573.0 SQ.FT)						
=====						
STES CAP COST	427130.	427130.	427130.	427130.	427130.	427130.
STES ANNUAL COST/UNIT (# 12%/YR.)	1091.	1091.	1091.	1091.	1091.	1091.
STES BACKUP FUEL COST/UNIT (GAS)	253.	366.	465.	489.	514.	540.
STES TOTAL ANNUAL COST/UNIT	1344.	1457.	1556.	1580.	1605.	1631.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-582.	-555.	-516.	-511.	-506.	-500.
25.% AREA(2786.5 SQ.FT)						
=====						
STES CAP COST	399265.	399265.	399265.	399265.	399265.	399265.
STES ANNUAL COST/UNIT (# 12%/YR.)	1010.	1010.	1010.	1010.	1010.	1010.
STES BACKUP FUEL COST/UNIT (GAS)	295.	449.	616.	648.	681.	716.
STES TOTAL ANNUAL COST/UNIT	1305.	1459.	1626.	1658.	1691.	1726.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-542.	-556.	-585.	-588.	-591.	-594.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST(/SQ.FT) 22.13 REGION ALBUQU NO 4 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	297.	498.	691.	726.	763.	802.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	769.	970.	1163.	1198.	1235.	1274.
125.% AREA(13620.0 SQ.FT)						
STES CAP COST	672811.	672811.	672811.	672811.	672811.	672811.
STES ANNUAL COST/UNIT (# 12%/YR.)	1739.	1739.	1739.	1739.	1739.	1739.
STES BACKUP FUEL COST/UNIT (GAS)	142.	204.	240.	252.	265.	279.
STES TOTAL ANNUAL COST/UNIT	1881.	1943.	1979.	1991.	2004.	2018.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1111.	-972.	-815.	-792.	-768.	-743.
100.% AREA(10896.0 SQ.FT)						
STES CAP COST	612528.	612528.	612528.	612528.	612528.	612528.
STES ANNUAL COST/UNIT (# 12%/YR.)	1577.	1577.	1577.	1577.	1577.	1577.
STES BACKUP FUEL COST/UNIT (GAS)	174.	257.	313.	329.	345.	363.
STES TOTAL ANNUAL COST/UNIT	1751.	1834.	1890.	1906.	1922.	1940.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-981.	-863.	-726.	-707.	-686.	-665.
75.% AREA(8172.0 SQ.FT)						
STES CAP COST	552246.	552246.	552246.	552246.	552246.	552246.
STES ANNUAL COST/UNIT (# 12%/YR.)	1415.	1415.	1415.	1415.	1415.	1415.
STES BACKUP FUEL COST/UNIT (GAS)	210.	327.	422.	444.	466.	490.
STES TOTAL ANNUAL COST/UNIT	1625.	1742.	1837.	1859.	1881.	1905.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-855.	-771.	-673.	-660.	-645.	-630.
50.% AREA(5448.0 SQ.FT)						
STES CAP COST	491964.	491964.	491964.	491964.	491964.	491964.
STES ANNUAL COST/UNIT (# 12%/YR.)	1253.	1253.	1253.	1253.	1253.	1253.
STES BACKUP FUEL COST/UNIT (GAS)	245.	409.	566.	595.	626.	657.
STES TOTAL ANNUAL COST/UNIT	1498.	1662.	1819.	1848.	1879.	1910.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-728.	-691.	-655.	-649.	-643.	-635.
25.% AREA(2724.0 SQ.FT)						
STES CAP COST	431682.	431682.	431682.	431682.	431682.	431682.
STES ANNUAL COST/UNIT (# 12%/YR.)	1091.	1091.	1091.	1091.	1091.	1091.
STES BACKUP FUEL COST/UNIT (GAS)	281.	504.	740.	778.	818.	860.
STES TOTAL ANNUAL COST/UNIT	1372.	1595.	1831.	1869.	1909.	1951.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-602.	-624.	-667.	-670.	-673.	-676.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 15.00 REGION ALBUQU NO 4 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990 WOS	2000 WOS	2010 WOS	2020 WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	297.	498.	691.	726.	763.	802.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	769.	970.	1163.	1198.	1235.	1274.
125.% AREA(13620.0 SQ.FT) =====						
STES CAP COST	575700.	575700.	575700.	575700.	575700.	575700.
STES ANNUAL COST/UNIT (# 12%/YR.)	1496.	1496.	1496.	1496.	1496.	1496.
STES BACKUP FUEL COST/UNIT (GAS)	142.	204.	240.	252.	265.	279.
STES TOTAL ANNUAL COST/UNIT	1638.	1700.	1736.	1748.	1761.	1775.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-868.	-729.	-572.	-549.	-525.	-500.
100.% AREA(10896.0 SQ.FT) =====						
STES CAP COST	534840.	534840.	534840.	534840.	534840.	534840.
STES ANNUAL COST/UNIT (# 12%/YR.)	1383.	1383.	1383.	1383.	1383.	1383.
STES BACKUP FUEL COST/UNIT (GAS)	174.	257.	313.	329.	345.	363.
STES TOTAL ANNUAL COST/UNIT	1557.	1640.	1695.	1711.	1728.	1745.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-787.	-669.	-532.	-513.	-492.	-471.
75.% AREA(8172.0 SQ.FT) =====						
STES CAP COST	493980.	493980.	493980.	493980.	493980.	493980.
STES ANNUAL COST/UNIT (# 12%/YR.)	1269.	1269.	1269.	1269.	1269.	1269.
STES BACKUP FUEL COST/UNIT (GAS)	210.	327.	422.	444.	466.	490.
STES TOTAL ANNUAL COST/UNIT	1479.	1596.	1691.	1713.	1735.	1759.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-710.	-626.	-528.	-515.	-500.	-485.
50.% AREA(5448.0 SQ.FT) =====						
STES CAP COST	453120.	453120.	453120.	453120.	453120.	453120.
STES ANNUAL COST/UNIT (# 12%/YR.)	1155.	1155.	1155.	1155.	1155.	1155.
STES BACKUP FUEL COST/UNIT (GAS)	245.	409.	566.	595.	626.	657.
STES TOTAL ANNUAL COST/UNIT	1400.	1564.	1721.	1750.	1781.	1812.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-631.	-594.	-558.	-552.	-546.	-538.
25.% AREA(2724.0 SQ.FT) =====						
STES CAP COST	412260.	412260.	412260.	412260.	412260.	412260.
STES ANNUAL COST/UNIT (# 12%/YR.)	1042.	1042.	1042.	1042.	1042.	1042.
STES BACKUP FUEL COST/UNIT (GAS)	281.	504.	740.	778.	818.	860.
STES TOTAL ANNUAL COST/UNIT	1323.	1546.	1782.	1820.	1860.	1902.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-553.	-575.	-618.	-621.	-624.	-627.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 13.00 REGION ALBUQU NO 4 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	297.	498.	691.	726.	763.	802.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	769.	970.	1163.	1198.	1235.	1274.
125.% AREA(13020.0 SQ.FT)						
=====						
STES CAP COST	548460.	548460.	548460.	548460.	548460.	548460.
STES ANNUAL COST/UNIT (# 12%/YR.)	1428.	1428.	1428.	1428.	1428.	1428.
STES BACKUP FUEL COST/UNIT (GAS)	142.	204.	240.	252.	265.	279.
STES TOTAL ANNUAL COST/UNIT	1570.	1632.	1668.	1680.	1693.	1707.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-800.	-661.	-504.	-481.	-457.	-432.
100.% AREA(10896.0 SQ.FT)						
=====						
STES CAP COST	513048.	513048.	513048.	513048.	513048.	513048.
STES ANNUAL COST/UNIT (# 12%/YR.)	1328.	1328.	1328.	1328.	1328.	1328.
STES BACKUP FUEL COST/UNIT (GAS)	174.	257.	313.	329.	345.	363.
STES TOTAL ANNUAL COST/UNIT	1502.	1585.	1641.	1657.	1673.	1691.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-733.	-615.	-478.	-459.	-438.	-417.
75.% AREA(8172.0 SQ.FT)						
=====						
STES CAP COST	477636.	477636.	477636.	477636.	477636.	477636.
STES ANNUAL COST/UNIT (# 12%/YR.)	1228.	1228.	1228.	1228.	1228.	1228.
STES BACKUP FUEL COST/UNIT (GAS)	210.	327.	422.	444.	466.	490.
STES TOTAL ANNUAL COST/UNIT	1438.	1555.	1650.	1672.	1694.	1718.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-669.	-585.	-487.	-474.	-459.	-444.
50.% AREA(5448.0 SQ.FT)						
=====						
STES CAP COST	442224.	442224.	442224.	442224.	442224.	442224.
STES ANNUAL COST/UNIT (# 12%/YR.)	1128.	1128.	1128.	1128.	1128.	1128.
STES BACKUP FUEL COST/UNIT (GAS)	245.	409.	566.	595.	626.	657.
STES TOTAL ANNUAL COST/UNIT	1373.	1537.	1694.	1723.	1754.	1785.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-604.	-567.	-531.	-525.	-519.	-511.
25.% AREA(2724.0 SQ.FT)						
=====						
STES CAP COST	406812.	406812.	406812.	406812.	406812.	406812.
STES ANNUAL COST/UNIT (# 12%/YR.)	1028.	1028.	1028.	1028.	1028.	1028.
STES BACKUP FUEL COST/UNIT (GAS)	281.	504.	740.	778.	818.	860.
STES TOTAL ANNUAL COST/UNIT	1309.	1532.	1768.	1806.	1846.	1888.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-540.	-562.	-605.	-608.	-611.	-614.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST(/SQ.FT) 10.00 REGION ALBUQU NO 4 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	297.	498.	691.	726.	763.	802.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	769.	970.	1163.	1198.	1235.	1274.
125.% AREA(13620.0 SQ.FT)						
=====						
STES CAP COST	507600.	507600.	507600.	507600.	507600.	507600.
STES ANNUAL COST/UNIT (# 12%/YR.)	1326.	1326.	1326.	1326.	1326.	1326.
STES BACKUP FUEL COST/UNIT (GAS)	142.	204.	240.	252.	265.	279.
STES TOTAL ANNUAL COST/UNIT	1468.	1530.	1566.	1578.	1591.	1605.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-698.	-559.	-402.	-379.	-355.	-330.
100.% AREA(10896.0 SQ.FT)						
=====						
STES CAP COST	480360.	480360.	480360.	480360.	480360.	480360.
STES ANNUAL COST/UNIT (# 12%/YR.)	1246.	1246.	1246.	1246.	1246.	1246.
STES BACKUP FUEL COST/UNIT (GAS)	174.	257.	313.	329.	345.	363.
STES TOTAL ANNUAL COST/UNIT	1420.	1503.	1559.	1575.	1591.	1609.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-651.	-533.	-396.	-377.	-356.	-335.
75.% AREA(8172.0 SQ.FT)						
=====						
STES CAP COST	453120.	453120.	453120.	453120.	453120.	453120.
STES ANNUAL COST/UNIT (# 12%/YR.)	1167.	1167.	1167.	1167.	1167.	1167.
STES BACKUP FUEL COST/UNIT (GAS)	210.	327.	422.	444.	466.	490.
STES TOTAL ANNUAL COST/UNIT	1377.	1494.	1589.	1611.	1633.	1657.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-607.	-523.	-425.	-412.	-397.	-382.
50.% AREA(5448.0 SQ.FT)						
=====						
STES CAP COST	425880.	425880.	425880.	425880.	425880.	425880.
STES ANNUAL COST/UNIT (# 12%/YR.)	1087.	1087.	1087.	1087.	1087.	1087.
STES BACKUP FUEL COST/UNIT (GAS)	245.	409.	566.	595.	626.	657.
STES TOTAL ANNUAL COST/UNIT	1332.	1496.	1653.	1682.	1713.	1744.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-563.	-526.	-490.	-484.	-478.	-470.
25.% AREA(2724.0 SQ.FT)						
=====						
STES CAP COST	398640.	398640.	398640.	398640.	398640.	398640.
STES ANNUAL COST/UNIT (# 12%/YR.)	1008.	1008.	1008.	1008.	1008.	1008.
STES BACKUP FUEL COST/UNIT (GAS)	281.	504.	740.	778.	818.	860.
STES TOTAL ANNUAL COST/UNIT	1289.	1512.	1748.	1786.	1826.	1868.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-519.	-541.	-584.	-587.	-590.	-593.

ESTIMATED ANNUAL NET SAVINGS, STES-600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) .20.13 REGION RALEIG NO 6 BUILDING LORISE NO J. LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
	WOS	WOS	WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	301.	459.	616.	647.	680.	715.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	773.	931.	1088.	1119.	1152.	1187.
125.% AREA(20472.5 SQ.FT)						
=====						
STES CAP COST	798511.	798511.	798511.	798511.	798511.	798511.
STES ANNUAL COST/UNIT (# 12%/YR.)	2065.	2065.	2065.	2065.	2065.	2065.
STES BACKUP FUEL COST/UNIT (GAS)	160.	227.	275.	289.	304.	319.
STES TOTAL ANNUAL COST/UNIT	2225.	2292.	2340.	2354.	2369.	2384.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1451.	-1360.	-1251.	-1234.	-1216.	-1196.
100.% AREA(16378.0 SQ.FT)						
=====						
STES CAP COST	716089.	716089.	716089.	716089.	716089.	716089.
STES ANNUAL COST/UNIT (# 12%/YR.)	1845.	1845.	1845.	1845.	1845.	1845.
STES BACKUP FUEL COST/UNIT (GAS)	187.	269.	333.	350.	368.	387.
STES TOTAL ANNUAL COST/UNIT	2032.	2114.	2178.	2195.	2213.	2232.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1258.	-1182.	-1089.	-1075.	-1060.	-1044.
75.% AREA(12283.5 SQ.FT)						
=====						
STES CAP COST	633667.	633667.	633667.	633667.	633667.	633667.
STES ANNUAL COST/UNIT (# 12%/YR.)	1625.	1625.	1625.	1625.	1625.	1625.
STES BACKUP FUEL COST/UNIT (GAS)	222.	327.	417.	438.	461.	484.
STES TOTAL ANNUAL COST/UNIT	1847.	1952.	2042.	2063.	2086.	2109.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1074.	-1021.	-954.	-944.	-934.	-922.
50.% AREA(8189.0 SQ.FT)						
=====						
STES CAP COST	551245.	551245.	551245.	551245.	551245.	551245.
STES ANNUAL COST/UNIT (# 12%/YR.)	1405.	1405.	1405.	1405.	1405.	1405.
STES BACKUP FUEL COST/UNIT (GAS)	262.	401.	541.	568.	597.	628.
STES TOTAL ANNUAL COST/UNIT	1667.	1806.	1946.	1973.	2002.	2033.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-894.	-875.	-858.	-854.	-850.	-846.
25.% AREA(4094.5 SQ.FT)						
=====						
STES CAP COST	468822.	468822.	468822.	468822.	468822.	468822.
STES ANNUAL COST/UNIT (# 12%/YR.)	1186.	1186.	1186.	1186.	1186.	1186.
STES BACKUP FUEL COST/UNIT (GAS)	307.	488.	691.	727.	764.	803.
STES TOTAL ANNUAL COST/UNIT	1493.	1674.	1877.	1913.	1950.	1989.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-719.	-742.	-788.	-793.	-797.	-801.

ESTIMATED ANNUAL NET SAVINGS, STES-600 F-ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT), 15.00 REGION RALEIG NO 6 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	301.	459.	616.	647.	680.	715.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	773.	931.	1088.	1119.	1152.	1187.
125.% AREA(20472.5 SQ.FT)						
=====						
STES CAP COST	693488.	693488.	693488.	693488.	693488.	693488.
STES ANNUAL COST/UNIT (# 12%/YR.)	1802.	1802.	1802.	1802.	1802.	1802.
STES BACKUP FUEL COST/UNIT (GAS)	160.	227.	275.	289.	304.	319.
STES TOTAL ANNUAL COST/UNIT	1962.	2029.	2077.	2091.	2106.	2121.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1188.	-1097.	-988.	-971.	-953.	-933.
100.% AREA(16378.0 SQ.FT)						
=====						
STES CAP COST	632070.	632070.	632070.	632070.	632070.	632070.
STES ANNUAL COST/UNIT (# 12%/YR.)	1635.	1635.	1635.	1635.	1635.	1635.
STES BACKUP FUEL COST/UNIT (GAS)	187.	269.	333.	350.	368.	387.
STES TOTAL ANNUAL COST/UNIT	1822.	1904.	1968.	1985.	2003.	2022.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1048.	-972.	-879.	-865.	-850.	-834.
75.% AREA(12283.5 SQ.FT)						
=====						
STES CAP COST	570653.	570653.	570653.	570653.	570653.	570653.
STES ANNUAL COST/UNIT (# 12%/YR.)	1468.	1468.	1468.	1468.	1468.	1468.
STES BACKUP FUEL COST/UNIT (GAS)	222.	327.	417.	438.	461.	484.
STES TOTAL ANNUAL COST/UNIT	1690.	1795.	1885.	1906.	1929.	1952.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-916.	-863.	-796.	-786.	-776.	-764.
50.% AREA(8189.0 SQ.FT)						
=====						
STES CAP COST	509235.	509235.	509235.	509235.	509235.	509235.
STES ANNUAL COST/UNIT (# 12%/YR.)	1300.	1300.	1300.	1300.	1300.	1300.
STES BACKUP FUEL COST/UNIT (GAS)	262.	401.	541.	568.	597.	628.
STES TOTAL ANNUAL COST/UNIT	1562.	1701.	1841.	1868.	1897.	1928.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-789.	-770.	-753.	-749.	-745.	-741.
25.% AREA(4094.5 SQ.FT)						
=====						
STES CAP COST	447818.	447818.	447818.	447818.	447818.	447818.
STES ANNUAL COST/UNIT (# 12%/YR.)	1133.	1133.	1133.	1133.	1133.	1133.
STES BACKUP FUEL COST/UNIT (GAS)	307.	488.	691.	727.	764.	803.
STES TOTAL ANNUAL COST/UNIT	1440.	1621.	1824.	1860.	1897.	1936.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-667.	-690.	-736.	-741.	-745.	-749.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 13.00 REGION RALEIG NO 6 BUILDING LOWISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
	WOS					
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	301.	459.	616.	647.	680.	715.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	773.	931.	1088.	1119.	1152.	1187.
125.% AREA(20472.5 SQ.FT)						
=====						
STES CAP COST	652543.	652543.	652543.	652543.	652543.	652543.
STES ANNUAL COST/UNIT (# 12%/YR.)	1700.	1700.	1700.	1700.	1700.	1700.
STES BACKUP FUEL COST/UNIT (GAS)	160.	227.	275.	289.	304.	319.
STES TOTAL ANNUAL COST/UNIT	1860.	1927.	1975.	1989.	2004.	2019.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1086.	-995.	-886.	-869.	-851.	-831.
100.% AREA(16378.0 SQ.FT)						
=====						
STES CAP COST	599314.	599314.	599314.	599314.	599314.	599314.
STES ANNUAL COST/UNIT (# 12%/YR.)	1553.	1553.	1553.	1553.	1553.	1553.
STES BACKUP FUEL COST/UNIT (GAS)	187.	269.	333.	350.	368.	387.
STES TOTAL ANNUAL COST/UNIT	1740.	1822.	1886.	1903.	1921.	1940.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-966.	-890.	-797.	-783.	-768.	-752.
75.% AREA(12283.5 SQ.FT)						
=====						
STES CAP COST	546086.	546086.	546086.	546086.	546086.	546086.
STES ANNUAL COST/UNIT (# 12%/YR.)	1406.	1406.	1406.	1406.	1406.	1406.
STES BACKUP FUEL COST/UNIT (GAS)	222.	327.	417.	438.	461.	484.
STES TOTAL ANNUAL COST/UNIT	1628.	1733.	1823.	1844.	1867.	1890.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-855.	-802.	-735.	-725.	-715.	-703.
50.% AREA(8189.0 SQ.FT)						
=====						
STES CAP COST	492857.	492857.	492857.	492857.	492857.	492857.
STES ANNUAL COST/UNIT (# 12%/YR.)	1259.	1259.	1259.	1259.	1259.	1259.
STES BACKUP FUEL COST/UNIT (GAS)	262.	401.	541.	568.	597.	628.
STES TOTAL ANNUAL COST/UNIT	1521.	1660.	1800.	1827.	1856.	1887.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-748.	-729.	-712.	-708.	-704.	-700.
25.% AREA(4094.5 SQ.FT)						
=====						
STES CAP COST	439629.	439629.	439629.	439629.	439629.	439629.
STES ANNUAL COST/UNIT (# 12%/YR.)	1113.	1113.	1113.	1113.	1113.	1113.
STES BACKUP FUEL COST/UNIT (GAS)	307.	488.	691.	727.	764.	803.
STES TOTAL ANNUAL COST/UNIT	1420.	1601.	1804.	1840.	1877.	1916.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-646.	-669.	-715.	-720.	-724.	-728.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 10.00. REGION RALEIG. NO 6 BUILDING LORISE NO 3. LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	151200.	151200.	151200.	151200.	151200.	151200.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	472.	472.	472.	472.	472.	472.
CONVENTIONAL FUEL COST/UNIT (GAS)	301.	459.	616.	647.	680.	715.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	773.	931.	1088.	1119.	1152.	1187.
125.% AREA(20472.5 SQ.FT)						
=====						
STES CAP COST	591125.	591125.	591125.	591125.	591125.	591125.
STES ANNUAL COST/UNIT (# 12%/YR.)	1546.	1546.	1546.	1546.	1546.	1546.
STES BACKUP FUEL COST/UNIT (GAS)	160.	227.	275.	289.	304.	319.
STES TOTAL ANNUAL COST/UNIT	1706.	1773.	1821.	1835.	1850.	1865.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-933.	-842.	-733.	-716.	-698.	-678.
100.% AREA(16378.0 SQ.FT)						
=====						
STES CAP COST	550180.	550180.	550180.	550180.	550180.	550180.
STES ANNUAL COST/UNIT (# 12%/YR.)	1430.	1430.	1430.	1430.	1430.	1430.
STES BACKUP FUEL COST/UNIT (GAS)	187.	269.	333.	350.	368.	387.
STES TOTAL ANNUAL COST/UNIT	1617.	1699.	1763.	1780.	1798.	1817.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-844.	-768.	-675.	-661.	-646.	-630.
75.% AREA(12283.5 SQ.FT)						
=====						
STES CAP COST	509235.	509235.	509235.	509235.	509235.	509235.
STES ANNUAL COST/UNIT (# 12%/YR.)	1314.	1314.	1314.	1314.	1314.	1314.
STES BACKUP FUEL COST/UNIT (GAS)	222.	327.	417.	438.	461.	484.
STES TOTAL ANNUAL COST/UNIT	1536.	1641.	1731.	1752.	1775.	1798.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-763.	-710.	-643.	-633.	-623.	-611.
50.% AREA(8189.0 SQ.FT)						
=====						
STES CAP COST	468290.	468290.	468290.	468290.	468290.	468290.
STES ANNUAL COST/UNIT (# 12%/YR.)	1198.	1198.	1198.	1198.	1198.	1198.
STES BACKUP FUEL COST/UNIT (GAS)	262.	401.	541.	568.	597.	628.
STES TOTAL ANNUAL COST/UNIT	1460.	1599.	1739.	1766.	1795.	1826.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-687.	-668.	-651.	-647.	-643.	-639.
25.% AREA(4094.5 SQ.FT)						
=====						
STES CAP COST	427345.	427345.	427345.	427345.	427345.	427345.
STES ANNUAL COST/UNIT (# 12%/YR.)	1082.	1082.	1082.	1082.	1082.	1082.
STES BACKUP FUEL COST/UNIT (GAS)	307.	488.	641.	727.	764.	803.
STES TOTAL ANNUAL COST/UNIT	1389.	1570.	1723.	1809.	1846.	1885.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-616.	-634.	-665.	-690.	-694.	-698.

ESTIMATED ANNUAL NET SAVINGS, STES-600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 22.13 REGION BOSTON NO 8 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	141360.	141360.	141360.	141360.	141360.	141360.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	442.	442.	442.	442.	442.	442.
CONVENTIONAL FUEL COST/UNIT (GAS)	541.	789.	866.	911.	957.	1005.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	983.	1231.	1308.	1353.	1399.	1447.
125.% AREA(12647.5 SQ.FT)						
=====						
STES CAP COST	651289.	651289.	651289.	651289.	651289.	651289.
STES ANNUAL COST/UNIT (# 12%/YR.)	1681.	1681.	1681.	1681.	1681.	1681.
STES BACKUP FUEL COST/UNIT (GAS)	333.	462.	498.	523.	550.	578.
STES TOTAL ANNUAL COST/UNIT	2014.	2143.	2179.	2204.	2231.	2259.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-1031.	-912.	-871.	-851.	-832.	-812.
100.% AREA(10118.0 SQ.FT)						
=====						
STES CAP COST	595311.	595311.	595311.	595311.	595311.	595311.
STES ANNUAL COST/UNIT (# 12%/YR.)	1530.	1530.	1530.	1530.	1530.	1530.
STES BACKUP FUEL COST/UNIT (GAS)	385.	541.	585.	615.	646.	679.
STES TOTAL ANNUAL COST/UNIT	1915.	2071.	2115.	2145.	2176.	2209.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-933.	-841.	-808.	-793.	-778.	-763.
75.% AREA(7588.5 SQ.FT)						
=====						
STES CAP COST	539334.	539334.	539334.	539334.	539334.	539334.
STES ANNUAL COST/UNIT (# 12%/YR.)	1380.	1380.	1380.	1380.	1380.	1380.
STES BACKUP FUEL COST/UNIT (GAS)	431.	616.	671.	705.	741.	779.
STES TOTAL ANNUAL COST/UNIT	1811.	1996.	2051.	2085.	2121.	2159.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-828.	-765.	-743.	-732.	-722.	-712.
50.% AREA(5059.0 SQ.FT)						
=====						
STES CAP COST	483356.	483356.	483356.	483356.	483356.	483356.
STES ANNUAL COST/UNIT (# 12%/YR.)	1229.	1229.	1229.	1229.	1229.	1229.
STES BACKUP FUEL COST/UNIT (GAS)	488.	713.	784.	824.	866.	910.
STES TOTAL ANNUAL COST/UNIT	1717.	1942.	2013.	2053.	2095.	2139.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-735.	-712.	-706.	-701.	-697.	-693.
25.% AREA(2529.5 SQ.FT)						
=====						
STES CAP COST	427378.	427378.	427378.	427378.	427378.	427378.
STES ANNUAL COST/UNIT (# 12%/YR.)	1079.	1079.	1079.	1079.	1079.	1079.
STES BACKUP FUEL COST/UNIT (GAS)	551.	821.	909.	956.	1004.	1055.
STES TOTAL ANNUAL COST/UNIT	1630.	1900.	1988.	2035.	2083.	2134.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-647.	-669.	-680.	-682.	-684.	-687.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F, ORC
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST(/SQ.FT) 15.00 REGION BOSTON NO 8 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
	WOS					
CONVENTIONAL CAPITAL COST	141360.	141360.	141360.	141360.	141360.	141360.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	442.	442.	442.	442.	442.	442.
CONVENTIONAL FUEL COST/UNIT (GAS)	541.	789.	866.	911.	957.	1005.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	983.	1231.	1308.	1353.	1399.	1447.
125.% AREA(12647.5 SQ.FT)						
=====						
STES CAP COST	561113.	561113.	561113.	561113.	561113.	561113.
STES ANNUAL COST/UNIT (# 12%/YR.)	1455.	1455.	1455.	1455.	1455.	1455.
STES BACKUP FUEL COST/UNIT (GAS)	333.	462.	498.	523.	550.	578.
STES TOTAL ANNUAL COST/UNIT	1788.	1917.	1953.	1978.	2005.	2033.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-806.	-667.	-646.	-626.	-607.	-587.
100.% AREA(10118.0 SQ.FT)						
=====						
STES CAP COST	523170.	523170.	523170.	523170.	523170.	523170.
STES ANNUAL COST/UNIT (# 12%/YR.)	1350.	1350.	1350.	1350.	1350.	1350.
STES BACKUP FUEL COST/UNIT (GAS)	385.	541.	585.	615.	646.	679.
STES TOTAL ANNUAL COST/UNIT	1735.	1891.	1935.	1965.	1996.	2029.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-752.	-660.	-627.	-612.	-597.	-582.
75.% AREA(7588.5 SQ.FT)						
=====						
STES CAP COST	485228.	485228.	485228.	485228.	485228.	485228.
STES ANNUAL COST/UNIT (# 12%/YR.)	1245.	1245.	1245.	1245.	1245.	1245.
STES BACKUP FUEL COST/UNIT (GAS)	431.	616.	671.	705.	741.	779.
STES TOTAL ANNUAL COST/UNIT	1676.	1861.	1916.	1950.	1986.	2024.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-693.	-630.	-608.	-597.	-587.	-577.
50.% AREA(5059.0 SQ.FT)						
=====						
STES CAP COST	447285.	447285.	447285.	447285.	447285.	447285.
STES ANNUAL COST/UNIT (# 12%/YR.)	1139.	1139.	1139.	1139.	1139.	1139.
STES BACKUP FUEL COST/UNIT (GAS)	488.	713.	784.	824.	866.	910.
STES TOTAL ANNUAL COST/UNIT	1627.	1852.	1923.	1963.	2005.	2049.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-645.	-622.	-616.	-611.	-607.	-603.
25.% AREA(2529.5 SQ.FT)						
=====						
STES CAP COST	409343.	409343.	409343.	409343.	409343.	409343.
STES ANNUAL COST/UNIT (# 12%/YR.)	1034.	1034.	1034.	1034.	1034.	1034.
STES BACKUP FUEL COST/UNIT (GAS)	551.	821.	909.	956.	1004.	1055.
STES TOTAL ANNUAL COST/UNIT	1585.	1855.	1943.	1990.	2038.	2089.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-602.	-624.	-635.	-637.	-639.	-642.

*****JOB EXITED ON 22 AUG 78 1415111 *****

*****CPU TIME= 0MINS 8.85SECS *****

*****CONNECT TIME= 0MINS 24SECS *****

ESTIMATED ANNUAL NET SAVINGS, STES-600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 13.00 REGION BOSTON NO 8 BUILDING LORISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	141360.	141360.	141360.	141360.	141360.	141360.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	442.	442.	442.	442.	442.	442.
CONVENTIONAL FUEL COST/UNIT (GAS)	541.	789.	866.	911.	957.	1005.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	983.	1231.	1308.	1353.	1399.	1447.
125.% AREA(12647.5 SQ.FT)						
=====						
STES CAP COST	535818.	535818.	535818.	535818.	535818.	535818.
STES ANNUAL COST/UNIT (# 12%/YR.)	1392.	1392.	1392.	1392.	1392.	1392.
STES BACKUP FUEL COST/UNIT (GAS)	333.	462.	498.	523.	550.	578.
STES TOTAL ANNUAL COST/UNIT	1725.	1854.	1890.	1915.	1942.	1970.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-742.	-623.	-582.	-562.	-543.	-523.
100.% AREA(10118.0 SQ.FT)						
=====						
STES CAP COST	502934.	502934.	502934.	502934.	502934.	502934.
STES ANNUAL COST/UNIT (# 12%/YR.)	1299.	1299.	1299.	1299.	1299.	1299.
STES BACKUP FUEL COST/UNIT (GAS)	385.	541.	585.	615.	646.	679.
STES TOTAL ANNUAL COST/UNIT	1684.	1840.	1884.	1914.	1945.	1978.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-702.	-610.	-577.	-562.	-547.	-532.
75.% AREA(7588.5 SQ.FT)						
=====						
STES CAP COST	470051.	470051.	470051.	470051.	470051.	470051.
STES ANNUAL COST/UNIT (# 12%/YR.)	1207.	1207.	1207.	1207.	1207.	1207.
STES BACKUP FUEL COST/UNIT (GAS)	431.	616.	671.	705.	741.	779.
STES TOTAL ANNUAL COST/UNIT	1638.	1823.	1878.	1912.	1948.	1986.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-655.	-592.	-570.	-559.	-549.	-539.
50.% AREA(5059.0 SQ.FT)						
=====						
STES CAP COST	437167.	437167.	437167.	437167.	437167.	437167.
STES ANNUAL COST/UNIT (# 12%/YR.)	1114.	1114.	1114.	1114.	1114.	1114.
STES BACKUP FUEL COST/UNIT (GAS)	488.	713.	784.	824.	866.	910.
STES TOTAL ANNUAL COST/UNIT	1602.	1827.	1898.	1938.	1980.	2024.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-619.	-596.	-590.	-585.	-581.	-577.
25.% AREA(2529.5 SQ.FT)						
=====						
STES CAP COST	404284.	404284.	404284.	404284.	404284.	404284.
STES ANNUAL COST/UNIT (# 12%/YR.)	1021.	1021.	1021.	1021.	1021.	1021.
STES BACKUP FUEL COST/UNIT (GAS)	551.	821.	909.	956.	1004.	1055.
STES TOTAL ANNUAL COST/UNIT	1572.	1842.	1930.	1977.	2025.	2076.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-589.	-611.	-622.	-624.	-626.	-629.

ESTIMATED ANNUAL NET SAVINGS, STES, 600 F.O.R.C.
SYSTEM OVER CONVENTIONAL SYSTEM, \$

COLLECTOR COST (/SQ.FT) 10.00 REGION BOSTON NO 8 BUILDING LOWISE NO 3, LOAD CONSERVATIVE NO2

	YEAR					
	1975	1985	1990	2000	2010	2020
			WOS	WOS	WOS	WOS
CONVENTIONAL CAPITAL COST	141360.	141360.	141360.	141360.	141360.	141360.
CONVENTIONAL ANNUAL COST/UNIT (# 15%/YR.)	442.	442.	442.	442.	442.	442.
CONVENTIONAL FUEL COST/UNIT (GAS)	541.	789.	866.	911.	957.	1005.
CONVENTIONAL TOTAL ANNUAL COST/UNIT	983.	1231.	1308.	1353.	1399.	1447.
125.% AREA(12647.5 SQ.FT)						
=====						
STES CAP COST	497875.	497875.	497875.	497875.	497875.	497875.
STES ANNUAL COST/UNIT (# 12%/YR.)	1297.	1297.	1297.	1297.	1297.	1297.
STES BACKUP FUEL COST/UNIT (GAS)	333.	462.	498.	523.	550.	578.
STES TOTAL ANNUAL COST/UNIT	1630.	1759.	1795.	1820.	1847.	1875.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-648.	-529.	-488.	-468.	-449.	-429.
100.% AREA(10118.0 SQ.FT)						
=====						
STES CAP COST	472580.	472580.	472580.	472580.	472580.	472580.
STES ANNUAL COST/UNIT (# 12%/YR.)	1224.	1224.	1224.	1224.	1224.	1224.
STES BACKUP FUEL COST/UNIT (GAS)	385.	541.	585.	615.	646.	679.
STES TOTAL ANNUAL COST/UNIT	1609.	1765.	1809.	1839.	1870.	1903.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-626.	-534.	-501.	-486.	-471.	-456.
75.% AREA(7588.5 SQ.FT)						
=====						
STES CAP COST	447285.	447285.	447285.	447285.	447285.	447285.
STES ANNUAL COST/UNIT (# 12%/YR.)	1150.	1150.	1150.	1150.	1150.	1150.
STES BACKUP FUEL COST/UNIT (GAS)	431.	616.	671.	705.	741.	779.
STES TOTAL ANNUAL COST/UNIT	1581.	1766.	1821.	1855.	1891.	1929.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-598.	-535.	-513.	-502.	-492.	-482.
50.% AREA(5059.0 SQ.FT)						
=====						
STES CAP COST	421990.	421990.	421990.	421990.	421990.	421990.
STES ANNUAL COST/UNIT (# 12%/YR.)	1076.	1076.	1076.	1076.	1076.	1076.
STES BACKUP FUEL COST/UNIT (GAS)	488.	713.	784.	824.	866.	910.
STES TOTAL ANNUAL COST/UNIT	1564.	1789.	1860.	1900.	1942.	1986.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-581.	-558.	-552.	-547.	-543.	-539.
25.% AREA(2529.5 SQ.FT)						
=====						
STES CAP COST	396695.	396695.	396695.	396695.	396695.	396695.
STES ANNUAL COST/UNIT (# 12%/YR.)	1002.	1002.	1002.	1002.	1002.	1002.
STES BACKUP FUEL COST/UNIT (GAS)	551.	821.	909.	956.	1004.	1055.
STES TOTAL ANNUAL COST/UNIT	1553.	1823.	1911.	1958.	2006.	2057.
NET SAVINGS OF STES OVER CONVENTIONAL SYSTEM	-571.	-593.	-604.	-606.	-608.	-611.

==> \$EUJ

*****JUB EXITED ON 22 AUG 78 1415111 *****

*****CPU TIME= 0MINS 8.85SECS *****

*****CONNECT TIME= 0MINS 24SECS *****

APPENDIX E. METHODOLOGY FOR DETERMINING MARKET PENETRATION

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Absence of test-market data makes the task of predicting the market penetration of new products difficult. Fortunately, there has been sufficient analysis of past product introductions to develop a statistical method for making the needed predictions. Past experience has shown that with performance-critical products (as opposed to cosmetic- or prestige-critical products), the number of purchasers will increase when the cost of the product decreases relative to its performance. This is not a very surprising conclusion. However, the number of new purchasers for each unit of cost decrease, relative to performance, will follow a fairly predictable pattern. A graph of the number of new purchasers will approximate a normal (or "bell shaped") curve. When test market or similar data are absent, forecasters will start with a normal curve and adjust it to fit the product and the population of potential buyers.

The area under a standard normal distribution curve represents the total number of potential purchasers of the product — equated to 1.0 (i.e., normalized) or, if converted to percentage, 100%. The fraction (or percentage) of the total assembly that may be expected between two points on the base line is given by the area under the curve that lies above the two points. For example, the historical adoption curve shown in Figure 21 of this report is an adaptation of this normal distribution curve wherein the area under the curve is equal to the total potential buyers of the STE system. This shows that about 34% (34% of the total area under the curve) of the total number of potential buyers (or adopters) falls between the mean, $\bar{t}$, and $\bar{t} + \sigma$, where σ is a statistical term called the standard deviation. Another 13.5% (13.5% of the total area under the curve) of the total buyers falls between $\bar{t} + \sigma$ and $\bar{t} + 2\sigma$, and an additional 2.5% falls between $\bar{t} + 2\sigma$ and the end of the curve. The sum is equal to 50% of the potential buyers, represented by one-half of the total area under the curve; the remaining 50% is represented by the other half of the area under the curve, i.e., on the other side of the mid-point, or mean. By determining the values of $\bar{t}$ and σ , based on certain assumptions, one can establish the criteria that would account for the different categories of potential buyers. The procedure for doing this is given in the following paragraphs.

A random variable, x , can be expressed in terms of the number (z) of standard deviations, σ , away from the mean, $\bar{t}$, by means of the following equation:

$$x = \bar{t} + z\sigma$$

where z , the number of standard deviations, is called the normal deviate, and tables are available for relating areas under the standard normal curve for any value of z . This may be illustrated by the following diagram:

For a given value of z , the area under the curve between $\bar{t}$ and x can be found in standard tables.

In adapting this standard normal curve technique to potential market penetration, we make use of the assumptions made on p. 153, i.e., that half of the innovators (1.25% of all the potential buyers) would be willing to buy an STE system if the annual fuel savings (\$700) were equal to the annualized incremental cost of the system and 16% of the total potential buyers would be willing to buy if the annualized incremental cost of the system were only 75% of the annual fuel savings, or \$525. Graphically, this may be represented by the following curves:

From standard normal curve tables, we can obtain the normal deviate (z) values corresponding to the areas shown in the diagrams. These are:

<u>Area</u>	<u>z</u>
0.4875	± 2.24
0.34	± 1.00

Since the points under consideration lie to the left side of the mean, $\bar{t}$, they are represented by negative values of z . Therefore, the following expressions can be written:

$$\begin{aligned}
 x &= \bar{t} + z\sigma \\
 \$700 &= \bar{t} - 2.24\sigma \\
 \$525 &= \bar{t} - 1.00\sigma
 \end{aligned}$$

Subtracting, $\$175 = -1.24\sigma$, and $\sigma = \$141.12$.

Substituting for σ , $\$525 = \bar{t} + 141.12$, and $\bar{t} = 383.88$.

These values of σ and $\bar{t}$ can now be used to calculate the incremental payment, x , required to achieve a given market capture (the area under the curve corresponding to a given z value). This may be written as:

$$\text{Incremental payment, } x = -141.12z + 383.88$$

$$\text{and } z = \frac{383.88 - x}{141.12}$$

These expressions can now be used to either calculate the annualized capital cost differential required to achieve a given market capture or, conversely, to calculate the market capture to be expected for a given annualized capital

cost differential. For example, assume that an annualized capital cost differential of \$600 per dwelling unit can be achieved for the 36-unit townhouse complex, using a capital cost factor of 12%, and we wish to determine the market capture that might be expected. For the entire 36-unit building, this corresponds to a total cost differential of $\frac{36 \times 600}{0.12}$, or \$180,000 for the STE system. The market capture of this STES would be determined from the expression

$$z = \frac{-(600 - 383.88)}{141.12} = -1.53$$

From standard tables, $z = -1.53$ corresponds to an area of 0.437; market capture is, therefore, $(0.5 - 0.437) \times 100$, or 6.3%.

As illustrated on p. 154, the required capital cost differential required to achieve a given market capture can be determined by first determining the area (from standard tables) corresponding to a given z value. To illustrate, assume a market capture of 2.0%. This is equivalent to an area of $(0.5 - 0.02 = 0.48)$ which, from standard tables, corresponds to a z value of -2.05. Incremental payment required to achieve this market capture would be:

$$\text{Incremental payment} = -141.12z + 383.88$$

$$\text{Incremental payment} = 289.30 + 383.88$$

$$\text{Incremental payment} = \$673.18 \text{ per dwelling unit.}$$

Assuming a 12% capital cost factor, this can be converted to an annualized capital cost differential (ACCD) for a 36-unit system to achieve a 2% market capture;

$$\text{ACCD} = \frac{673.18 \times 36}{0.12} = \$201,954$$