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MIXED STRATEGIES FOR ENERGY CONSERVATION
AND ALTERNATIVE ENERGY UTILIZATION (SOLAR)
IN BUILDINGS

Final Report, Volume I—Executive Summary

November 1977
(TIC Issuance Date)

Work Performed Under Contract No. EY-76-C-03-1234

Energy Resources Center
Honeywell, Incorporated
Minneapolis, Minnesota

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

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**MIXED STRATEGIES FOR ENERGY
CONSERVATION AND ALTERNATIVE ENERGY
UTILIZATION (SOLAR) IN BUILDINGS**

FINAL REPORT

VOLUME I - EXECUTIVE SUMMARY

Date Published-June 1977

Work Performed Under Contract No. E(04-3)-1234

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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
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TABLE OF CONTENTS
Volume I: Executive Summary

	Page
SECTION 1.0 ACKNOWLEDGEMENTS	1
SECTION 2.0 PREFACE	3
SECTION 3.0 INTRODUCTION	5
3.1 Statement of the Problem	5
3.2 Program Objectives	5
3.3 Program Overview	6
3.3.1 Selection of Building Types	8
3.3.2 Selection of Geographical Areas	8
3.3.3 Selection of Alternative Energy Sources, Preliminary, and Final Screening	8
3.3.4 Selection of Solar System	10
3.3.5 Selection of Energy Conservation Techniques	10
3.3.6 Fuel Prices	11
3.3.7 Building Simulation	11
3.3.8 Economic Analysis	13
SECTION 4.0 RESULTS AND CONCLUSIONS	15
4.1 General Results and Conclusions	15
4.2 Specific Results and Conclusions by Building Type	18
4.2.1 Sample Results - Single Family Residence	18
4.3 Specific Results and Conclusions for all Building Types	34
SECTION 5.0 APPENDIX - CONTRACT STATEMENT OF WORK	51

LIST OF FIGURES

Figure		Page
3-1	Mixed Strategies Study Approach	7
3-2	Regions and Representative Locations	9
4-1	Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel for Space and Hot Water Heating System	31
4-2	Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel for Space and Hot Water Heating System	31
4-3	Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel, for Space and Hot Water Heating System, Escalated Fuel Costs	33
4-4	Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, for Space and Hot Water Heating System, Escalated Fuel Costs	33
4-5	Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, for Space and Hot Water Heating System, 1/2-Price-Solar System	35

LIST OF TABLES

Table		Page
3-1	Average Fuel Prices for the Next 20 Years Dollars Per Million BTU ⁺	12
3-2	Escalation Factor (%) for Fuel Prices	12
4-1	Target Costs for Total Installed System in Dollars per Square Foot of Net Collector Area	17
4-2	Construction Characteristics Omaha Single-Family Residence	19
4-3	Installed Costs (1976\$) for Single-Family Residences	21
4-4	Insulation Package Costs for New Single-Family Residences	22
4-5	Insulation Package Costs for Existing Single-Family Residences	22
4-6	Summary Loads, Costs and Savings; Omaha (New) Single-Family Heating and Hot Water Collector Area - 600 ft ²	23
4-7	Summary Loads, Costs and Savings; Omaha (New) Single-Family Heating, Hot Water and Air Conditioning Collector Area - 600 ft ²	24
4-8	Summary Loads, Costs and Savings; Omaha Single-Family Existing Heating and Hot Water	25
4-9	Summary Loads, Costs and Savings; Omaha Single-Family Existing Heating, Hot Water, Air Conditioning Collector Area - 600 ft ²	26
4-10	Impact of Energy Conservation on Solar System Sized for 50 Percent of Load, New Single Family Residence.	27
4-11	Energy Conservation Techniques, Cost Effectiveness; Single Family Heating, Hot Water and Air Conditioning Collector Area - 600 ft ²	36
4-12	Energy Conservation Techniques, Cost Effectiveness Single Family Heating and Hot Water Collector Area 600 ft ²	37

LIST OF TABLES (CONTINUED)

Table		Page
4-13	Energy Conservation Techniques, Cost Effectiveness Multi Family Residence, 3600 ft ² Heating, Hot Water Air Conditioning	38
4-14	Energy Conservation Techniques, Cost Effectiveness Multi Family Residence, 3600 ft ² Heating, Hot water	39
4-15	Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating, Hot Water and Air Conditioning Collector Area = 4,000 ft ²	40
4-16	Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating and Hot Water Collector Area = 4000	41
4-17	Energy Conservation Techniques, Cost Effectiveness Office Building Heating, Hot Water, Air Conditioning	42
4-18	Energy Conservation Techniques, Cost Effectiveness Office Building Heating, Hot Water	43
4-19	Energy Conservation Techniques, Cost Effectiveness Schools Heating, Hot Water and Air Conditioning	44
4-20	Energy Conservation Techniques, Cost Effectiveness Schools Heating and Hot Water	45
4-21	ECT Description - Single Family Residence	46
4-22	ECT Description - Multi Family Residence	47
4-23	ECT Description - Office Building	48
4-24	ECT Description - Retail Store	49
4-25	ECT Description - Schools	50

TABLE OF CONTENTS
Volume II: Detailed Results

	Page
SECTION I INTRODUCTION	1
SECTION II APPROACH AND ASSUMPTIONS	5
2.1 Introduction	5
2.2 Program Scope	7
2.3 Selection of Building Type	9
2.4 Selection of Geographical Areas	13
2.5 Selection of Alternative Energy Sources, Preliminary and Final Screening	17
2.6 Selection of Energy Conservation Techniques	17
2.7 Cost Model	27
2.8 Fuel Prices	28
Target Solar System Costs	37
Fuel Escalation Rates	39
2.9 Selection of Solar System	39
2.10 Computer Programs	39
SECTION III RESULTS	51
Introduction	51
3.0 DYN-SIM versus SUNSIM Comparison	53
3.0.1 Building Description	53
3.0.2 Modeling Assumptions -- Dynamic Model Comparison	53
3.0.3 Results	54
3.1 Single Family Building	56
3.1.1 Introduction	56
3.1.2 Building Description	57
3.1.3 Modeling Assumptions	58
3.1.4 Results for Single Family Residence	59
Omaha-North Central Region	59
Combined Conservation Techniques	72
Alternative Scenarios	74
Omaha-North Central Region	76
New York-North East Region	76
Atlanta-South East Region	87
Atlanta-South East Region	90
Albuquerque-South West Region	93
Conclusions	99
3.2 Multifamily Building	108
3.2.1 Introduction	108

3.2.2	Building Modeling Assumptions	109
3.2.3	Results for Multifamily Building	110
3.3	Retail Store	180
3.3.1	Building Description	180
3.3.2	Modeling Assumptions	180
3.3.3	Results for Retail Store	181
	Omaha - North Central Region	184
3.4	Office Buildings	223
3.4.1	Building Description	223
3.4.2	Modeling Assumptions	228
3.4.3	Results for Office Building	229
	Omaha - North Central Region	229
	Albuquerque - Southwest Region	270
	New York - Northeast Region	277
	Atlanta - Southeast Region	284
3.4.4	Conclusions	291
3.5	Schools	300
3.5.1	Building Description	300
3.5.2	Modeling Assumptions	301
3.5.3	Results for the School	302
	Omaha - North Central Region	3-2
	New York - Northeast Region	321
	Atlanta - Southeast Region	338
	Albuquerque - Southwest Region	354
	Summary of Results for Schools	370
3.6	Solar Assisted Heat Pump/Liquid Flat Plate	381
3.6.1	Building and System Description	381
3.6.2	Modeling Assumptions	383
3.6.3	Results	383
3.6.4	Summary Analysis	389

TABLE OF CONTENTS
Volume III: List of Appendices

APPENDIX A	BUILDING CHARACTERISTICS
APPENDIX B	ALTERNATE ENERGY SOURCES AND ENERGY CONSERVATION TECHNIQUES DESCRIPTION, COSTS
APPENDIX C	FUEL PRICE SCENARIOS
APPENDIX D	LIFE CYCLE COST MODEL
APPENDIX E	SIMULATION MODELS
APPENDIX F	SOLAR HEATING/COOLING SYSTEM
APPENDIX G	CONDENSED WEATHER
APPENDIX H	SINGLE-AND MULTI-FAMILY DWELLING CHARACTERISTICS AND ENERGY CONSERVATION TECHNIQUES
APPENDIX I	MIXED STRATEGIES FOR ENERGY CONSERVATION AND ALTERNATIVE ENERGY UTILIZATION IN BUILDINGS
APPENDIX J	REFERENCES

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Battelle Energy Information Center, for its work in providing a computerized literature search.

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2.0 PREFACE

One of the roles of the U. S. Energy Research and Development Administration is to disseminate information concerning the more efficient use of both existing and new energy sources in buildings. As part of this effort, ERDA sponsored a project to provide information to assist home-owners and building owners select mixed strategies of energy conservation and energy sources other than gas, oil or electricity. The results of this project, which was performed by the Honeywell Energy Resources Center over a ten month period, are summarized in this report. Honeywell was assisted in this study by the National Association of Home Builders (NAHB), Bather, Ringrose, and Wolsfeld Inc. (BRW), a Minneapolis consulting architecture and engineering firm and Battelle Energy Information Center.

The results are published in three volumes:

- Volume I - Executive Summary
- Volume II - Detailed Results
- Volume III - Appendices

Volume I is a brief synopsis of the project and its results and contains the contract statement of work. Volume II outlines the assumptions that were used, a description of approach and detailed results. Volume III, the Appendices, contains the background information including technical descriptions and costs of components.

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3.0 INTRODUCTION

3.1 STATEMENT OF THE PROBLEM

Information is not available to residential and commercial builders and owners concerning which energy conservation techniques and alternate energy sources are technically feasible and cost effective. This project is an analysis of mixed strategies; i. e., combination of energy conservation techniques and the only viable alternate energy source; solar energy. The results provide an important step in arriving at the most effective way of supplying the energy needs of residential and commercial buildings.

3.2 PROGRAM OBJECTIVES

The overall objectives as stated in the Request for Proposal are the following:

- Provide ERDA with "information that will allow for selection of technical options that are optimally cost beneficial and energy saving involving both energy conservation and alternative energy approaches in buildings."
- This information will assist ERDA "in planning and setting priorities for research, development, and demonstration activities for energy conservation in buildings."

3.3 PROGRAM OVERVIEW

The mixed strategy analysis was a tradeoff analysis between energy conservation methods and an alternative energy source (solar) considering technical and economic benefits. To meet the project objectives, the analysis developed guidelines for:

- Reducing Energy Requirements
- Reducing Conventional Fuel Use
- Identifying Economic Alternatives for Building Owners

Fully developed conservation products in conjunction with conventional on-site solar heating and cooling were emphasized in the project. The analysis was done with a solar system in place, therefore determining the interaction of energy conservation. The study established guidelines as how to minimize capital investment while reducing conventional fuel consumption through either a larger solar system or an energy conserving technique.

The overall study methodology employed on the Mixed Strategies study is illustrated in Figure 3-1. Initially, all energy sources that have been studied and described in literature were identified and listed. To focus the scope of energy conservation techniques and alternative energy sources considered, five building types were selected and some initial program objectives were defined. Finally, the lists of energy conservation techniques and alternative energy sources were reduced to lists of manageable size by using technical attributes to select the best candidates for further study. The resultant energy conservation techniques were described in detail and installed costs determined. Solar was the alternative energy source chosen and building construction characteristics were defined for each building for each of four geographic regions of the country. A mixed strategy consisting of an energy conservation technique and solar heating/hot water/cooling system were analyzed using computer simulation to determine the interaction between energy conservation and the

Figure 3-1. Mixed Strategies Study Approach

solar system. Finally, using FEA fuel price scenarios and installed costs for the solar system and energy conservation techniques, and economic analysis was performed to determine the cost effectiveness of the combination. The following paragraphs describe the highlights of the approach employed in the study. A detailed description of the approach and assumptions employed is contained in Volume II, Detailed Results.

3.3.1 Selection of Building Types

Based on a literature survey and discussion with consultants, five building classifications, representing a majority of the nation's new and existing building types and the major portion of energy use, were selected as models for the computer analysis. The five types are (1) single family residence, (2) multi-family residence, (3) office building, (4) retail store and (5) school.

3.3.2 Selection of Geographical Areas

One U. S. city was selected to represent different weather and building construction characteristics in each of the four geographic regions. The four cities are Omaha, Atlanta, New York, and Albuquerque, Figure 3-2.

3.3.3 Selection of Alternative Energy Sources, Preliminary, and Final Screening

A comprehensive list of alternative energy sources was compiled and is described in Volume III, Appendix B. By considering the criteria that the energy source must be appropriate for use at the building site and should be commercially available, non-polluting, and suitable for widespread application, the candidate energy sources reduce quickly to one, solar energy. The other

Figure 3-2. Regions and Representative Locations

non-conventional energy sources are not easily used at the building location and most of them will be changed into either gas, oil or electricity and transported through conventional means.

3.3.4 Selection of Solar System

The best alternative energy for use on-site is solar energy. A review of current solar system activities indicated that selecting a liquid flatplate collector system for the analysis would point out salient and important interactions of energy conservation and solar energy utilization. The base system included collectors, a storage tank, domestic hot water heating, forced air heating, and solar-assisted cooling (Rankine cycle). The usual system used gas, oil, or electric resistance heaters for auxiliary heating, but an analysis of a solar-assisted heat pump was also included.

3.3.5 Selection of Energy Conservation Techniques

First, a comprehensive list of energy conservation techniques was compiled. These techniques were then condensed to a smaller list by grouping the various techniques into broad classes. Then the final selection was made through a screening procedure considering evaluation attributes and criteria. The items that met the criteria were then selected from the master list and evaluated in terms of their technical attributes.

● Modularity	● Development Risks
● Scalability	● Maintainability
● Architectural Aspects	● Reliability
● Fuel-Type Availability	● Safety
● Economic Aspects	● Control Philosophy

3.3.6 Fuel Prices

Fuel prices are obviously important in a tradeoff study of alternative energy sources. In this case, the study period selected was 20 years (a probable solar system life); therefore, the fuel prices for the next 20 years had to be estimated. After examining price projections from various sources, it appeared that the FEA (December 1976, see Appendix C, Volume III) projections were reasonable, in agreement with most other projections, and were the most complete set of information.

To easily depict the 20 year fuel prices for this summary, two tables (3-1 and 3-2) were constructed. Table 3-1 is the average price for each fuel type and Table 3-2 shows the average escalation rate of the fuel prices in the next 20 years.

3.3.7 Building Simulation

Computer simulation programs were used to examine the interaction of the solar system, building, and energy conservation techniques. Heating, hot water, and cooling loads for the base buildings were determined as a function of ambient conditions. The interaction of these loads and the solar system were examined to determine what portion could be supplied by the solar system and what portion must be supplied by auxiliary sources. To establish a means of comparison, each energy conservation technique was incorporated into the building, one at a time, and new heating, hot water, and cooling loads determined. The resultant auxiliary building loads and solar operational times were then used to determine the cost effectiveness of the energy conservation technique. Two computer simulation programs, DYN-SIM and SUN-SIM, were used to determine building loads and simulate the interaction of the solar system.

Table 3-1. Average Fuel Prices for the Next 20 Years
Dollars Per Million BTU⁺

City	Residential			Commercial		
	Gas	Oil	Elec.	Gas	Oil	Elec.
Omaha	2.10	3.31	11.82	1.75	3.14	10.98
New York	3.01	3.47	15.34	2.51	3.33	15.61
Albuquerque	2.81	3.42	13.78	2.36	3.25	12.17
Atlanta	2.78	3.43	13.18	2.35	3.29	12.34

⁺1976 Dollars Source: FEA

Table 3-2. Escalation Factor (%) for Fuel Prices

City	Residential			Commercial		
	Gas	Oil	Elec.	Gas	Oil	Elec.
Omaha	3.5	1.5	1.8	4.4	1.6	1.8
New York	1.2	1.4	-0.4	1.5	1.8	0
Albuquerque	4.0	1.0	2.1	4.4	1.3	2.4
Atlanta	2.7	1.5	1.0	2.8	1.7	1.1

DYNSIM is a full dynamic simulation, which includes the transients such as heat conduction through the building walls heat flow through pipes and temperature excursions in the room or system. The approach was to simulate one building with DYNSIM to verify the results of SUNSIM, a simpler and lower cost program.

SUNSIM uses a static building load calculation and the only dynamics of the solar system is in the storage tank. These simplified calculations run 18 times faster than DYNSIM, which was an advantage for doing extensive analyses. DYNSIM and SUNSIM correlated and predicted the same economic results (see Appendix E, Volume III). SUNSIM was used to do the mixed strategies tradeoff analysis.

3.3.8 Economic Analysis

To determine the cost effectiveness of an energy conservation technique with the solar system, a common basis had to be established. The common denominator which reflects installation effort and material costs for the energy conservation technique is life cycle costs. Life cycle costs of each energy conservation technique were compared to life cycle costs of the base building to establish the cost effectiveness of the combination.

The costs that were considered included all of the items that have to be paid for in owning a solar system and installing energy conservation techniques such as:

- Installed costs
- Operating costs
- Maintenance costs

- Insurance costs
- Salvage value
- Auxiliary costs for gas, oil and electricity

A solar system requires a large capital investment and returns energy for many years, therefore, any analysis has to be done over a period of years. A twenty-year period was selected and a present value cost model (Volume III, Appendix D) patterned after the one developed by the National Bureau of Standards¹ was used.

¹Rosalie Ruegg, Ref. 115, Appendix J

4.0 RESULTS AND CONCLUSIONS

Results and conclusions are grouped into two sections. The first group includes general conclusions that cover all the buildings (new and existing) and geographic areas. The second group presents results and conclusions for each individual building type.

4.1 GENERAL RESULTS AND CONCLUSIONS

The results and conclusions listed below are based on the technical and economic assumptions employed in the mixed strategies analysis. These are general statements. The specific actions needed to obtain these results are presented in Section 4.2.

- Energy conservation is the most cost effective way to save energy in all buildings and geographic regions.
- For solar systems sized to provide 50 to 70 percent of the total heating and cooling load, the well known energy conservation techniques considered in this study reduce required collector size, therefore, reducing solar system initial costs. In many cases, the solar system size can be reduced by 30 to 50 percent while maintaining 50 to 70 percent solar contribution. Since energy conservation is cost effective with or without a solar system, an extensive conservation package should be implemented before solar is considered. This approach minimizes costs and offers less risk to the building owner in terms of uncertainties in future fuel and solar system costs.
- With or without energy conservation, solar systems are currently not cost effective. This conclusion applies to each of the five building types in all four regions. Higher future fuel prices and/or lower installed

costs may result in cost effective solar systems. Table 4-1 illustrates the installed costs required for solar systems to be cost effective, based on the annual fuel prices. Now, installed costs are in the area of \$30 to \$40 per square foot.

- Solar energy is the most viable alternate energy source.
- Solar assisted heat pump systems saved more energy than conventional solar systems, but like solar, are not currently cost effective.
- In determining the cost effectiveness of an energy conservation technique, the installed cost of the technique and the resulting system fuel costs are the dominant factors.
- For space heating and cooling systems, conservation techniques save energy and dollars inversely to solar system size. The larger solar system requires less conventional fuel, therefore, the fuel cost savings resulting for energy conservation are smaller. This means that techniques are less cost effective when installed with a solar system than without a solar system.
- Energy conservation techniques should be applied on the building during initial construction. High retrofit costs associated with some good energy conservation techniques often cause the technique to become non-cost effective, result in marginal savings, or extended payback periods.
- Energy conservation techniques that are cost effective in one region tend to be cost effective in other regions. However, differences in fuel prices, solar radiation, and installed costs of the energy conservation technique result in savings and payback periods that vary from region to region.
- In general, energy conservation techniques can be divided into three classes; ones that reduce heating energy, ones that reduce hot water energy, and the others that reduce cooling energy. Usually, those

Table 4-1. Target Costs for Total Installed System in Dollars per Square Foot of Net Collector Area*

R E G I O N	To Be Competitive With Gas				To Be Competitive With Oil				To Be Competitive With Electricity	
	Residential		Commercial		Residential		Commercial		Resi- dential	Com- mercial
	55%	80%	55%	80%	55%	80%	55%	80%	100%	100%
	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.	Seasonal Eff.
North Central	5.80	4.00	4.80	3.30	9.10	6.30	8.64	5.90	17.90	16.60
North East	8.30	5.70	6.90	4.80	9.55	6.60	9.20	6.30	23.20	23.60
South	7.70	6.30	6.50	4.50	9.40	6.50	8.95	6.20	20.85	18.40
West	7.65	6.20	6.50	4.40	9.50	6.50	9.10	6.20	19.95	18.70

*Based on a high efficiency flat plate collector system, one that collects and contributes 120,000 BTU per year for each square foot of collector area.

that help one have a negative effect on the other. For example, increasing a building's insulation helps reduce heat loss in winter and captures heat from the internal loads greatly reducing the heating energy requirement. During the cooling season, insulation will reduce the cooling load when the outdoor temperature is above the inside temperature (78°F). However, the bottling up of the internal heat has the opposite effect of increasing the cooling load. If there is a lot of time in the cooling season when the outdoor temperature is less than the indoor temperature, increased building insulation will increase energy consumption.

4.2 SPECIFIC RESULTS AND CONCLUSIONS BY BUILDING TYPE

To illustrate the analysis procedure and to indicate some of the elements of the other volumes, sample detailed results for the single family residence and the sensitivity analysis performed on fuel prices and solar system costs are presented here. These results are based on a residence located in Omaha, Nebraska; the North Central region.

After the single family residence is discussed thoroughly, summary tables of all the regions and building types are presented. These tables indicate cost effectiveness of each energy conservation technique.

4.2.1 Sample Results - Single Family Residence

The information provided by the National Association of Home Builders Research Foundation, Inc. described the construction details for new and existing homes, Table 4-2. New construction characteristics met ASHRAE 90-75 standards.

Table 4-2. Construction Characteristics Omaha
Single Family Residence

CHARACTERISTIC	EXISTING	NEW
Size - FT ² /fl	1204	1512
Dimensions	28'x43'	28'x54'
No. of Floors	2(1+B)	2(1+B)
Height of Story	8'	8'
Foundation Type	Basement	Basement
Roof Type	Gable	Gable
Ext. Glass - Windows (ft ²)	177 w/out storms	198 - single w/storm
Sliding Door (ft ²)	---	26
Ext. (Wood) Door - ft ²	63 w/out storms	76 w/storms
Ext. Wall Construction	Wood Frame	Wood Frame
Ext. Finish	Wood Siding	Wood Siding
Sheathing	Wood	$\frac{1}{2}$ " fiberboard
Int. Finish	Plaster	$\frac{1}{2}$ " gypsumboard
Insulation	None	$3\frac{1}{2}$ " Batt, R-11
Ext. Wall Below Grade	12" Concrete Block	12" Concrete Block
Ceiling Insulation	4" Loose Fill, R-9	6" Loose Fill, R-13
Floor Construction	Wood Frame	Wood Frame
Sheathing	Wood	$\frac{3}{4}$ " Plywood
Underlayment	---	None
Finish	Hardwood	Carpet
Insulation	None	None
Bottom/Basement Floor	4" Concrete Slab	4" Concrete Slab

Using the liquid flat plate collector solar system and the FEA December, 1976 fuel projections, the mixed strategies analysis was performed. This analysis examined the cost effectiveness of many energy conservation techniques using the life cycle cost considerations.

Key parameters used in the economic analysis were:

- Salvage Value - 10 percent of installed value of solar system
- Maintenance Rate/Year - 1 percent of installed value of solar system
- Insurance Rate/Year - 0.4 percent of installed value of solar system
- Real Discount Rate - 2 percent
- Analysis Period - 20 years

The installed costs assumed for the solar system and the various energy conservation techniques are presented in Tables 4-3 through 4-5. Installation costs for the conservation items were developed both through discussion with contractors and consulting the 1976 Dodge Manual for Building Construction of Pricing and Scheduling.

4.2.1.1 Impact of Individual Energy Conservation Techniques on New Single Family Residence -- Tables 4-6 through 4-9 present results which demonstrate the energy cost impact of individual conservation techniques. An in-place solar system with 600 square feet of collectors was assumed as a base case supplying about 63 percent of the load for the heating system or 55 percent of the load for the heating and air conditioning system. Any technique with a positive annual savings is cost effective and should be considered for implementation, although the overall solar system size is not necessarily the most cost effective. Variations in annual costs, savings, and total load are shown in Tables 4-6 and 4-8 for solar systems supplying space and hot water heating, and in Tables 4-7 and 4-9 for heating plus air conditioning. The dramatic impact of individual conservation techniques becomes apparent when viewed in terms of a

reduction in collector area (energy saved with conservation compared to energy delivered by a certain collector size). These data are shown in Table 4-10. The homeowner can choose the better investment by comparing the cost of the conservation technique with the cost of additional collector area.

Table 4-3. Installed Costs (1976\$) for Single-Family Residences

<u>SYSTEM</u>	<u>NEW</u>	<u>EXISTING</u>
Automatic Night Setback	\$76	\$98
Improved Hot Water System	\$30	\$30
Air Economizer	\$440	\$480
High Efficiency Furnace	\$160	\$160
Awnings	\$555	\$555
Reflective Film	\$2/FT ²	\$2/FT ²
Solar System*(Space and Hot Water)	\$6035+\$17.85/FT ²	\$6535+\$19.85/FT ²
Solar System (Heating plus Air Conditioning)	\$10166+\$17.85/FT ²	\$10666+\$19.85/FT ²
High Efficiency Lights	162	\$561

*Includes conventional furnace and hot water heater

Each conservation technique is discussed in the following paragraphs.

Night Setback -- Night setback involves automatically setting the thermostat down from 68 degrees F to 63 degrees F during the time period from 10:00 pm to 6:00 am in the heating season. This technique significantly reduces the house heating load because the average indoor air temperature is lower. Night setback has very little effect on the cooling and domestic hot water loads. Night setback was found to be cost effective for each of the three auxiliary energy sources -- gas, oil, and electricity. The greatest dollar savings are realized when the most expensive energy source is (electricity) employed. Of course, the lowest annual cost is achieved when night setback is used in conjunction

Table 4-4. Insulation Package Costs for New Single Family Residences

<u>Case No.</u>	<u>Additions/Alternatives</u>	<u>Infiltration (Air Change/hr)</u>	<u>Additional Cost for Omaha (1976)</u>
1	6" batts added in ceiling 2" styrofoam sheathing triple glazing	0.45	855
2	6" batts added in ceiling 6" studs walls insulated triple glazing	0.50	944
3	6" batts added in ceiling 6" stud walls insulated with 1" styrofoam sheathing triple glazing	0.45	958
4	6" batts added in ceiling 6" stud walls insulated with 2" styrofoam sheathing triple glazing	0.375	1180

Table 4-5. Insulation Package Costs for Existing Single-Family Residences

<u>Case No.</u>	<u>Additions/Alterations</u>	<u>Infiltration (Air Change/Hr)</u>	<u>Cost For Omaha (1976)</u>
1	12" Loose Fill In Ceiling Storm Windows	0.90	\$675
2	12" Loose Fill In Ceiling 3.5" Foam In Walls Insulated Glass and Storms	0.75	\$1532
3	12" Loose Fill In Ceiling 3.5" Foam In Walls Insulated Glass and Storms Caulk and Weatherstrip	0.5	\$2025
4	14" Loose Fill In Ceiling 3.5" Foam In Walls Insulated Glass and Storms	0.72	\$1593

Table 4-6. Summary Loads, Costs and Savings
Omaha - New - Single Family
Heating and Hot Water
Collector Area - 600 Ft²

ECT Description	Total Load (BTU) $\times 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars)			Annual Savings (Dollars)			Annual Load Savings	
			Gas	Oil	Electric	Gas	Oil	Electric	BTU $\times 10^{-6}$	% Savings
Base	74.9	63	1341	1406	1562					
Night Setback	69.1	65	1326	1382	1516	15	24	46	5.8	8
Insulation Case 1	51.0	73	1318	1350	1428	23	56	134	23.9	32
Insulation Case 2	52.8	73	1327	1361	1442	14	45	120	22.1	30
Insulation Case 3	50.6	73	1323	1355	1432	18	51	130	24.3	32
Insulation Case 4	47.6	73	1330	1360	1432	11	46	130	27.3	36
Insul. HW Tank Decr. Water Tmp.	70.4	67	1328	1384	1516	13	22	46	4.5	6
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furnace	74.9	63	1329	1380	1562	12	26	0	0	0
High Eff. Lights	78.5	62	1250	1322	1491	91	84	71	-3.6	-5
Reflective Film	80.1	64	1378	1446	1608	-37	-40	-46	-5.2	-7
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A - Not Applicable										

Table 4-7. Summary Loads, Costs and Savings
Omaha - New - Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft²

ECT Description	Total Load (BTU) x 10 ⁻⁶	Percent Supplied By Solar	Annual Costs (Dollars)			Annual Savings (Dollars)			Annual Load Savings	
			Gas	Oil	Electric	Gas	Oil	Electric	BTU x 10 ⁻⁶	% Savings
Base	108.9	55	1880	1945	2101					
Night Setback	103.1	57	1867	1923	2057	13	22	44	5.8	5
Insulation Case 1	85.0	60	1861	1893	1971	19	52	130	23.9	22
Insulation Case 2	86.5	60	1869	1903	1984	11	42	117	22.4	21
Insulation Case 3	84.6	60	1866	1899	1976	14	46	125	24.3	22
Insulation Case 4	82.2	59	1877	1907	1979	3	38	122	26.7	25
Insu. HW Tank Decr. Water Temp.	102.8	58	1858	1914	2046	22	31	55	6.1	6
Air Economizer	101.8	60	1879	1939	2082	1	6	19	7.1	7
High Eff. Furnace	108.9	55	1868	1919	2101	12	26	0	0	0
High Eff. Lights	107.6	57	1761	1832	2001	119	113	100	1.3	1
Reflective Film	104.3	60	1862	1931	2093	18	14	8	4.5	4
Awnings	102.5	59	1872	1937	2093	8	8	8	6.4	6

Table 4-8. Summary Loads, Costs and Savings
Omaha - Single Family - Existing
Heating and Hot Water

ECT Description	COLLECTOR AREA=600 FT ²									
	Total Load (BTU) x 10 ⁻⁶	Percent Supplied By Solar	Annual Costs (Dollars)			Annual Savings (Dollars)			Annual Load Savings	
			Gas	Oil	Electric	Gas	Oil	Electric	BTU x 10 ⁻⁶	% Savings
Base	110.0	52.4	1545	1669	1964					
Night Setback	101.9	53.8	1525	1636	1901	20	33	63	8.1	7
Insulation Case 1	94.5	57.7	1511	1606	1831	34	63	133	15.5	14
Insulation Case 2	86.2	60.3	1502	1583	1776	43	86	188	23.8	22
Insulation Case 3	59.2	72.8	1463	1501	1592	82	168	372	50.8	46
Insulation Case 4	53.4	73.7	1478	1512	1591	67	157	373	56.6	51
Insul. Hot Water Tank & Decrease Water Temp.	105.8	54.4	1533	1647	1920	12	22	44	4.2	4
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furn.	110.0	52.4	1504	1497	1964	41	72	0	0	0
High Eff. Lights	113.7	52.0	1502	1631	1939	43	38	25	-3.7	-3
Reflective Film	116.9	53.0	1583	1714	2023	-38	-45	-59	-6.9	-6
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A - Not Applicable

Table 4-9. Summary Loads, Costs and Savings
Omaha Single Family - Existing
Heating, Hot Water, Air Conditioning
Collector Area - 600 Ft²

ECT Description	Total Load (BTU) $\times 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars)			Annual Savings (Dollars)			Annual Load Savings	
			Gas	Oil	Electric	Gas	Oil	Electric	BTU $\times 10^{-6}$	% Savings
Base	137.4	50.4	2040	2164	2458					
Night Setback	129.3	51.7	2021	2133	2398	19	31	60	8.1	6
Insulation Case 1	120.1	55.1	1999	2094	2319	41	70	139	17.3	13
Insulation Case 2	111.6	57.3	1990	2071	2264	50	93	194	25.8	19
Insulation Case 3	83.6	67.0	1950	1988	2079	90	176	379	53.8	39
Insulation Case 4	77.8	67.7	1967	2001	2080	73	163	378	59.6	43
Insul. Hot Water Tank & Decrease Water Temp.	131.9	52.4	2020	2134	2406	20	30	52	5.5	4
Air Economizer	134.6	51.8	2061	2182	2471	-21	-18	-13	2.8	1
High Eff. Furnace	137.4	50.4	1999	2092	2458	41	72	0	0	0
High Eff. Lights	137.9	0	1977	2106	2414	63	58	45	-0.5	0
Reflective Film	137.1	52.5	2057	2168	2477	3	-4	-19	.3	0
Awnings	132.2	52.4	2037	2161	2455	3	3	3	5.2	4

Table 4-10. Impact of Energy Conservation on Solar System
Sized for 50 Percent of Load, New Single Family
Residence.

<u>ENERGY CONSERVATION TECHNIQUE</u>	<u>EQUIVALENT COLLECTOR AREA REDUCTION FT²</u>	
	<u>SPACE AND HOT WATER HEATING</u>	<u>SPACE AND HOT WATER HEATING AND SPACE AIR CONDITIONING</u>
5F Night Setback	55	55
Improved Thermal Envelope*	150	150
Increased Hot Water Tank Insulation and Reduced Temperature	45	60
Air Economizer	NA	70
High Efficiency Furnace	100	100
Reflective Film on Windows	50	45
Awnings	NA	45
High Efficiency Lights	30	15

*Case 4 Table 4-4.

with gas, the cheapest auxiliary energy source. The energy saved by night setback is equivalent to about 55 additional square feet of high efficiency collectors.

Improved Thermal Envelope -- Improving the building envelope reduces heat transfer due to conduction and air infiltration. This energy conservation technique was found to be cost effective for all three auxiliary energy sources and is very effective, even though the initial cost is relatively high. The annual dollar savings are somewhat lower when the house is equipped with a cooling system because the improved insulation makes it more difficult to transfer the internal loads to the outside whenever the outdoor air temperature is lower than the thermostat setpoint for cooling. Under these conditions, the cooling load actually increases. Of all the energy conservation techniques which were studied, improved house insulation resulted in the greatest annual energy savings. The improved thermal envelope (Case 4 from Table 4.4) is equivalent to a collector area of approximately 150 square feet, a reduction of 42 percent in solar system size.

Increased Insulation of the Hot Water Tank and Reduced Temperature -- When the amount of insulation on the domestic hot water tank is increased (one inch in this case) and the water temperature is decreased by 10 degrees F, the amount of energy required to heat the water and maintain it at the given temperature in the tank is significantly reduced. Since the tank heat loss is reduced, the space heating load increases somewhat, even though there is no net change in the total heating load (i. e., space heating plus hot water) during the heating season. However, during the cooling season, the cooling load is reduced due to the lower internal load. This energy conservation technique is cost effective for all three types of auxiliary energy, whether the house is equipped with a cooling system or not, although the annual dollar savings are slightly greater when the house has a cooling system. This technique is equivalent to a collector area of 45 square feet.

Air Economizer -- The air economizer is an automatic device which brings outdoor air into the house whenever the thermostat calls for cooling and the outdoor air has a low enough temperature to provide at least part of that cooling. The air economizer is connected to the forced air ductwork and operates in conjunction with the furnace fan. For this study, the air economizer was permitted to operate whenever the outdoor drybulb temperature was 75 degrees F or less. If the economizer can meet the cooling load by itself, it cycles on and off to try to maintain the house temperature at the thermostat setpoint. If the economizer cannot handle the cooling load by itself, it runs continuously, along with the furnace fan, while the direct expansion cooling coil cycles on and off.

The air economizer significantly reduces the cooling load and has only a slight effect on the space heating and domestic hot water loads, as would be expected. When the house has a solar cooling system, the air economizer is marginally cost effective in Omaha and saves energy that could be supplied by about 70 square feet of collectors.

High Efficiency Furnace -- The high efficiency furnace (e. g., assuming a stack damper, proper sizing, and intermittent ignition) has a seasonal efficiency of about 80 percent, compared to the standard furnace seasonal efficiency of an estimated 55 percent when used with a solar system. Of course, the use of a high efficiency furnace does not change the house heating load, but it significantly reduces the amount of oil or natural gas required for auxiliary heating. The annual dollar savings obtained by using a high efficiency oil furnace are greater than the savings for a gas furnace because oil is more expensive than gas. However, this energy conservation technique is cost effective in both instances. The high efficiency furnace obviously produces no annual savings for the solar-electric home since electric resistance heating has an efficiency of unity. A high efficiency furnace is equivalent to a collector size of about 100 square feet.

Reflective Film -- Reflective film cuts down solar insolation as well as heat transmission through the coated surfaces. As the tables show, this technique slightly increases the space heating load, but it decreases the cooling load. For this reason, reflective film is naturally not cost effective for a heating and hot water system unless active control is possible, but due to its moderate cost, it is marginally cost effective for a system which must provide air conditioning. For air conditioning systems, collector area is reduced by 45 square feet.

Awnings -- Awnings were placed over the windows on the east, south, and west sides of the house. The awnings have approximately the same effect on the total load as reflective film.

High Efficiency Lights -- High efficiency lights consist of using 80 percent fluorescent lights in lieu of incandescent lights while holding the level of light (lumens) at a constant level. The resultant heating load on the building increases while the cooling load decreases.

Annual savings occur primarily from reduced electrical usage for lighting. Annual savings increase with increased area because the solar system is contributing additional heat, etc. and less auxiliary fuels are required. This, costs for auxiliary fuels are decreased and savings increased. For air conditioning systems, collector area can be reduced by 75 square feet.

4.2.1.2 Combined Conservation Techniques -- Although the previous results demonstrate the benefits of conservation techniques, they do not indicate the most attractive economic solution. To develop insight into the combination of conservation techniques, Figures 4-1 and 4-2 were developed. These figures illustrate the variation between annual cost and collector area for heating only systems with electricity and natural gas as auxiliary energy sources. Each graph shows a comparison between the base system and a system employing the following conservation techniques:

Figure 4-1. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel for Space and Hot Water Heating System

Figure 4-2. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel for Space and Hot Water Heating System

- Improved thermal envelope (Case 4 from Table 4-4)
- Night setback
- High efficiency gas furnace
- Improved hot water system

Figure 4-1 illustrates that for the electric auxiliary system, the base case has a minimum annual cost at about 350 square foot collector size. However, the annual cost without solar is only \$971, indicating that a solar system is not cost effective under the assumptions employed. When conservation techniques are added, the minimum annual cost is \$300 less, at a smaller collector area (250 square feet). Notice that conservation techniques have a greater impact as the collector area is reduced.

Natural gas system performance is shown in Figure 4-2. Here, a system without solar is definitely the preferred solution. Significantly reduced annual costs occur when compared with any solar system. Conservation techniques do not impact the solar system performance as strongly here because the purchased energy is relatively inexpensive.

4.2.1.3 Alternative Scenarios -- To test the benefits of conservation under conditions most favorable to the widespread implementation of solar systems, two alternative future scenarios were examined. In one case, future energy prices were assumed to be escalate at 10 percent per year in constant dollars. A second case was tested where current installed solar system costs are assumed to be reduced by 50 percent. This could happen through government incentive programs or a major manufacturing technology breakthrough.

Figures 4-3 and 4-4 present data directly comparable to the original scenario except that fuel prices escalate at 10 percent per year. Here, it is seen that properly sized solar systems are nearly justified for electric systems, but that conservation techniques still should be implemented to minimize overall annual costs. Conservation techniques reduce the most effective solar system collector area by about 45 percent.

Figure 4-3. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel, for Space and Hot Water Heating System, Escalated Fuel Costs

Figure 4-4. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, for Space and Hot Water Heating System, Escalated Fuel Costs

The effects of reduced initial system costs are shown in Figures 4-5 and 4-6. With this assumption, the annual cost difference between a solar and non-solar system is significantly less than that which occurs under the base scenario. Conservation is still cost effective but the combination of a solar system with energy conservation saves the most energy.

4.3 SPECIFIC RESULTS AND CONCLUSIONS FOR ALL BUILDING TYPES

Conclusions and recommendations for each of the five building types and each energy conservation technique analyzed are summarized in Tables 4-11 through 4-20. These regional comparison tables indicate the cost effectiveness of each energy conservation technique and denote those with short payback periods. Conclusions are summarized for both heating/cooling and heating systems for both new and existing buildings. Cost effectiveness (Y=yes, N=no) is based on positive yearly savings assuming a 20 year life cycle cost analysis. That is, the annual life cycle cost of the building with the solar system and energy conservation technique is less than the annual cost of the building with only the solar system. Those energy conservation techniques with short payback periods (3 years or less for residential and 5 years or less for commercial) are denoted by an "Y". A brief description of each energy conservation technique are in Tables 4-21 through 4-25 and a detailed description in Appendix B, Volume III. Conservation techniques listed in these tables resulted from the screening process.

Figure 4-5. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel, for Space and Hot Water Heating System, 1/2-Price Solar System

Figure 4-6. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, for Space and Hot Water Heating System, 1/2-Price Solar System

TABLE 4-11
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
SINGLE FAMILY
HEATING, HCT WATER AND AIR CONDITIONING
COLLECTOR AREA = 600 FT.²

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Night Setback	Y	<u>Y*</u>	<u>Y*</u>	<u>Y*</u>	Y	<u>Y</u>	Y	<u>Y</u>
Insul. Case 1	Y	<u>Y*</u>	Y*	Y	Y*	Y	N	<u>Y*</u>
Insul. Case 2	Y	Y	Y*	Y	N	Y	N	<u>Y*</u>
Insul. Case 3	Y	Y	Y*	Y	N	Y	N	<u>Y</u>
Insul. Case 4	Y	Y	Y*	Y	N	Y	N	<u>Y*</u>
Insu. Hot Water Tank & Decr. Temp.	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Air Economizer	Y	N	Y	N	Y	N	Y	N
High Eff. Furnace	Y	Y	Y	Y	Y	Y	Y	Y
High Eff. Lights	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y
Reflective Window Film	Y	Y*	Y*	N	Y	Y*	Y	N
Awnings	Y	Y	Y	N	Y	N	Y	Y

Y = cost effective
N = not cost effective
Y = less than 3 year payback

*Depends on fuel type
-Not applicable

TABLE 4-12
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
SINGLE FAMILY
HEATING AND HOT WATER,
COLLECTOR AREA = 600 FT.²

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Night Setback	<u>Y*</u>	<u>Y*</u>	<u>Y*</u>	<u>Y*</u>	Y	<u>Y</u>	Y	<u>Y</u>
Insul. Case 1	Y	<u>Y*</u>	Y	Y	Y*	Y	Y*	<u>Y*</u>
Insul. Case 2	Y	Y	Y	Y	Y*	Y	Y*	<u>Y*</u>
Insul. Case 3	Y	Y	Y	Y	Y*	Y	Y*	<u>Y*</u>
Insul. Case 4	Y	Y	Y	Y	N	Y	N	<u>Y*</u>
Insul. Hot Water Tank & Decr. Temp.	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furnace	Y	Y	Y	Y	Y	Y	Y	Y
High Eff. Lights	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y
Reflective Window Film	N	N	N	N	N	N	N	N
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Y = Cost effective
N = not cost effective
Y - less than 3 year payback
N/A - Not Applicable

*Depends on fuel type

TABLE 4-13
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
MULTI FAMILY RESIDENCE, 3600 FT²
HEATING, HOT WATER, AIR CONDITIONING

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
High Eff Furnace	Y ²	Y ²	Y ²	N	Y	N	Y ²	Y
Night Setback	Y	<u>Y²</u>	Y	<u>Y²</u>	Y	Y	Y	<u>Y</u>
Air Economizer	N	N	N	N	N	N	N	N
High Eff. Lights	<u>Y²</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y
Reflective Films	Y	Y	Y	N	Y	Y	Y	N
Awnings	Y	Y	Y	Y	Y	Y	Y	Y
Water Tank Insulation								
Decreased Temp.	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Increased Insulation	Y ²	<u>Y²</u>	Y ³	Y ¹	N ¹	Y ¹	Y ¹	<u>Y¹</u>
Y - Cost Effective N - Not Cost Effective <u>Y</u> - less than 3 year payback 1 All Cases examined 2 Depends on Aux fuel type 3 Depends on amounts added								

TABLE 4-14
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
MULTI FAMILY RESIDENCE, 3600 FT²
HEATING, HCT WATER

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
High Eff Furnace	Y	Y ²	Y	N	Y	N	Y	Y
Night Setback	Y	<u>Y²</u>	Y	<u>Y²</u>	Y	<u>Y²</u>	Y	<u>Y</u>
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff Lights	<u>Y²</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	Y	Y
Reflective Films	N	N	N	N	<u>Y²</u>	N	N	N
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water Tank Insulation								
Decreased Temp	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Increased Insulation	Y ¹	<u>Y²</u>	<u>Y²</u>	<u>Y²</u>	<u>Y³</u>	<u>Y¹</u>	<u>Y¹</u>	<u>Y¹</u>
Y - Cost Effective N - Not Cost Effective <u>Y</u> - less than 3 year payback								
1. All Cases Examined								
2. Depends on Aux Fuel Type								
3. Depends on Amount Applied								
N/A - not applicable								

TABLE 4-15
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
RETAIL STORE, HEATING, HOT WATER AND AIR CONDITIONING
COLLECTOR AREA = 4,000 FT²

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Minimum Ventilation	<u>Y*</u>	<u>Y</u>	N	<u>Y</u>	N	<u>Y*</u>	N	<u>Y</u>
Air Economizer	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Vent Heat Recovery	Y*	Y*	N	Y*	N	N	N	Y*
Reflective Film	Y	N	Y	N	Y	Y*	Y	N
Awnings	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	<u>Y</u>
Double/Triple Glazing	N	Y*	N	Y*	N	N	N	Y*
Reduced Light Level	-	<u>Y</u>	-	<u>Y</u>	-	<u>Y</u>	-	<u>Y</u>
Reduced Light Schedule	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Night Setback	<u>Y*</u>	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>
Additional Wall Insulation	Y*	<u>Y*</u>	N	<u>Y*</u>	N	N	N	Y*
Additional Wall and Roof Insulation	N	<u>Y*</u>	N	<u>Y*</u>	N	N	N	N
Water Tank Insulation Decreased Temp.	<u>Y</u>	<u>Y*</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
High Efficiency Furnace	Y	<u>Y</u>	Y*	<u>Y</u>	N	<u>Y</u>	N	<u>Y</u>

Y = cost effective
N = not cost effective
Y = less than 5 year payback

* Depends on fuel type
- Not applicable

TABLE 4-16
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
RETAIL STORE, HEATING AND HOT WATER
COLLECTOR AREA = 4000

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Minimum Ventilation	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y*</u>	<u>Y</u>	<u>Y*</u>	<u>Y</u>
Air Economizer	-	-	-	-	-	-	-	-
Vent Heat Recovery	Y*	Y*	N	Y*	N	N	N	Y*
Reflective Film	N	N	N	N	N	N	N	N
Awnings	-	-	-	-	-	-	-	-
Double/Triple Glazing	N	Y*	N	Y*	N	N	N	Y*
Reduced Light Level	-	<u>Y</u>	-	<u>Y</u>	-	<u>Y</u>	-	<u>Y</u>
Reduced Light Schedule	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Night Setback	<u>Y*</u>	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>
Additional Wall Insulation	Y*	<u>Y*</u>	N	<u>Y*</u>	N	Y*	N	Y
Additional Wall and Roof Insulation	N	<u>Y*</u>	N	<u>Y*</u>	N	Y*	N	Y
Water Tank Insulation/ Decreased Temperature	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
High Efficiency Furnace	Y	<u>Y</u>	Y*	<u>Y</u>	N	<u>Y</u>	N	<u>Y</u>
Y = cost effective N = not cost effective <u>Y</u> = payback less than 5 years								
*Depends on fuel type - Not applicable								

TABLE 4-17
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
OFFICE BUILDING HEATING
HOT WATER, AIR CONDITIONING

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Reflective Film	Y	N	Y	N	Y	N	Y	N
Shading	-	-	-	-	-	-	-	-
Double Glazing*		Y***		Y***		Y***		Y
Triple Glazing**	N		N		N		N	
Reduced Lighting	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Night Setback*		<u>Y</u>		<u>Y</u>		<u>Y</u>		<u>Y</u>
Reheat Optimization *		<u>Y</u>		<u>Y</u>		<u>Y</u>		<u>Y</u>
Increased Wall Insulation	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***
Increased Wall & Roof Insulation	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***
Reduced Hot Water Temp	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	Y	<u>Y</u>
Convert to VAV HVAC*		<u>Y</u>		<u>Y</u>		<u>Y</u>		<u>Y</u>
Hydronic Control from zone Thermostat with NSB**	Y***		N		N		N	
Energy Reclaim From Exhaust Air	N	N	N	N	N	N	N	N

- Not applicable

* Existing Construction Only

** New Construction Only

*** Depends on Aux. fuel source

Y = cost effective

N = not cost effective

Y = less than 5 year payback

TABLE 4-18
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
OFFICE BUILDING
HEATING, HOT WATER

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Reflective Film	N	N	N	N	N	N	Y***	N
Shading	-	-	-	-	-	-	-	-
Double Glazing*		Y***		Y***		Y***		Y***
Triple Glazing**	N		N		N		N	
Reduced Lighting	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Night Setback*		<u>Y</u>		<u>Y</u>		<u>Y</u>		<u>Y</u>
Reheat Optimization*		<u>Y</u>		<u>Y</u>		<u>Y</u>		<u>Y</u>
Increased Wall Insul.	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***
Increased Wall & Roof Insulation	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***	N	<u>Y</u> ***
Reduced Hot Water Temp	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Convert to VAV HVAC*		<u>Y</u>		<u>Y</u>		<u>Y</u>		<u>Y</u>
Hydronic Control from Zone T-stat with NSB**	Y***		Y***		N		Y	
Energy Reclaim From Exhaust Air	N	N	N	N	N	N	N	N

- Not applicable

* Existing Construction Only

** New Construction Only

*** Depends on Aux. fuel source

Y = cost effective

N = not cost effective

Y = less than 5 year payback

TABLE 4-19
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
SCHOOLS
HEATING, HOT WATER AND AIR CONDITIONING

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Add Wall Insulation	Y	<u>Y*</u>	N	<u>Y*</u>	N	Y	Y*	<u>Y*</u>
Add Wall & Ceiling Insulation	<u>Y*</u>	<u>Y*</u>	N	<u>Y*</u>	N	Y	Y*	<u>Y*</u>
Reflective Film	N	N	N	N	N	N	N	N
Add Pane of Glass	N	Y*	N	<u>Y*</u>	N	Y*	N	Y*
Insul. Hot Water Tank								
Reduce Max Water Temp	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Air Economizer	<u>Y</u>	N	<u>Y</u>	Y	<u>Y</u>	Y	<u>Y</u>	N
Night Setback	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Shading	-	-	-	-	-	-	-	-
Reduced Ventilation	<u>Y</u>	<u>Y</u>	<u>Y*</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
<p>Y = cost effective N = not cost effective <u>Y</u> = less than 5 year payback</p>								
<p>-Depends on fuel type -Not applicable</p>								

TABLE 4-20
ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
SCHOOLS
HEATING AND HOT WATER

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
Add Wall Insulation	Y	<u>Y</u> *	N	<u>Y</u> *	N	Y	Y*	<u>Y</u> *
Add Wall & Ceiling Insulation	Y*	<u>Y</u> *	N	<u>Y</u> *	N	Y	Y	<u>Y</u> *
Reflective Film	N	N	N	N	N	N	N	N
Add Pane of Glass	N	<u>Y</u> *	N	Y*	N	Y*	N	Y*
Insul. Hot Water Tank								
Decr. Water Temp.	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Air Economizer	-	-	-	-	-	-	-	-
Night Setback	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
Shading	-	-	-	-	-	-	-	-
Reduced Ventilation	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>

Y = cost effective
 N = not cost effective
Y = less than 5 year payback

-Depends on fuel type
 -Not applicable

Table 4-21. ECT Description - Single Family Residence

- Night Set Back
 - 68°F to 63°F - 10.00 PM to 6:00 AM
- Increased Insulation (see Tables 4-4 and 4-5)
 - Decreased Infiltration
 - Increased Ceiling - 12 inches
 - Increased Walls
 - Styrofoam Sheathing
 - 2 x 6 Walls with 6 inch batts
 - Double, Triple Glazing
- Water Tank Insulation/Increased Temperature
 - Add R-6, Decrease temperature from 140°F to 130°F
- Air Economizer
 - Introduce outdoor air if less than 75°F and 50% RH
- Improved Furnace Efficiency
 - Seasonal efficiency 0.55 to 0.80
- High Efficiency Lights
 - Replace 80% incandescent with fluorescent
- Reflective Films
 - 80% reduction transmittance, 20% reduction transmission
- Awning
 - 3 sides, down in summer, up in winter

Table 4-22. ECT Description - Multi Family Residence

- Night Set Back
 - 68°F to 63°F - 10:00 PM to 6:00 AM
- Increased Insulation
 - Decreased Infiltration
 - Increased Ceiling - 12 inches
 - Increased Walls
 - Styrofoam Sheathing
 - 2 x 6 Walls with 6 inch batts
 - Double, Triple Glazing
- Water Tank Insulation/Increased Temperature
 - Add R-6, Decrease temperature from 140°F to 130°F
- Air Economizer
 - Introduce outdoor air if less than 75° and 50% RH
- Reflective Films
 - 80% reduction transmittance, 20% reduction transmission
- Awning
 - 3-sides, down in summer, up in winter
- High Efficiency Lights
 - Replace 80% incandescent with fluorescent
- Improved Furnace Efficiency
 - Seasonal efficiency 0.55 to 0.80

Table 4-23. ECT Description - Office Building

- Reflective Film - 80% reduction in transmittance, 20% reduction in transmission.
- Shading - 60% reduction in transmittance on the east and west side and 90% reduction in transmittance on the south side, 0% reduction in transmission.
- Double Glazing - 13% reduction in transmittance, 14% reduction transmission.
- Triple Glazing - reduce lighting level from 3 watts/ft² to 2 watts/ft².
- Night Setback - 75°F to 55°F from 10:00 PM to 6:00 AM.
- Reheat Optimization - Minimize the amount of reheat and cooling energy necessary by controlling the discharge air from the zone with the largest cooling load.
- Increased Insulation - Add up to 4" wall insulation, add up to 4" roof insulation.
- Reduced Hot Water Temperature - Decrease hot water temperature from 140°F to 130°F.
- Convert to VAV - Convert the existing constant Volume Terminal reheat (CVTR) system to a variable air volume system (VAV)
- Hydronic Control From Zone Thermostat with Night Setback - Control radiation system from room temperature rather than from outdoor air temperature and set down to 55° at night.
- Energy Reclamation From Exhaust Air - Allow heat transfer to or from intake or exhaust air stream (effectiveness of 0.4).

Table 4-24. ECT Description - Retail Store

- Minimum Ventilation - Reduce outdoor air from 14 cfm to 7 cfm
- Air Economizer - Introduce outdoor air if less than 75°F and 50% RH
- Vent Heat Recovery - Recover heat from exhaust ventilation air
- Reflective Film - 80% reduction transmittance, 20% reduction transmission
- Awnings - Front window down in summer, up in winter
- Double/Triple Glazing - Add glass panes to door and window
- Reduced Lighting - Reduce lighting schedule, reduced lighting level, (6 watts/ft² to 3 watts/ft²)
- Night setback - 68°F, 10:00 PM to 6:00 AM
- Additional Insulation - Add up to 4" wall insulation, add up to 4" roof insulation
- Water Tank Insulation/Decreased Temperature - Add R-6, decrease temperature from 140°F to 130°F
- High Efficiency Furnace - Seasonal efficiency 0.55 to 0.80

Table 4-25. ECT Description - Schools

- Reduced Ventilation
 - Reducing ventilation by 50%
- Air Economizer
 - Introduce outdoor air if less than 75° and 50% RH
- Reflective Films on Windows
 - 80% reduction in transmittance, 20% reduction transmission
- Shading
 - Reduce transmittance on east west windows by 60% and south window by 90%
- Double/ Triple Glazing
 - Add glass panes to windows
- Reduce Lighting
 - Reduce amount of lights on 50% - 9:00 PM to 6:00 AM
25% - 12:00 AM to 2:00 PM
- Night Setback
 - Heating - 68°F to 60°F - 10:00 PM to 6:00 AM
 - Cooling - shut off system 10:00 PM to 6:00 AM
- Increased Insulation
 - Add 1 inch to walls, 2 inches to ceiling
- Increased Water Tank Insulation/Decreased Temperature
 - Add R-6, Decrease temperature from 140°F to 130°F

5.0 APPENDIX - CONTRACT STATEMENT OF WORK

The following paragraphs are the statement of work from Contract No. E(04-3)-1234, Mixed Strategies for Energy Conservation and Alternative Energy Utilization in Buildings.

The objective of this program is to supply ERDA with information that will allow for selection of technical options that are optionally cost beneficial and energy saving, involving both energy conservation and alternative energy approaches in buildings. Three tasks, as defined in the request for proposal, were outlined.

Task 1 -- Submit, within 15 days of execution of a contract, a detailed program plan which indicates more completely than the proposal does, final allocation of financial and personnel resources, timing of principal events that are to occur during the execution of the project, decision points and major milestones, program management plan, and other items of direct relevance to timely and successful accomplishment of the program objectives. The Contractor shall not proceed with Task II or beyond, until this plan is approved by the ERDA program manager. No change to the plan shall be made without approval of the program manager.

Task 2 -- Conduct a comprehensive review of literature and other data sources sufficient to provide the background information for the project. Such background information shall include but not be limited to the ERDA Phase Zero Reports on Solar Heating and Cooling of Buildings (General Electric, TRW Systems, Westinghouse), and follow-on information developed as a result of Phase I of this ERDA program; the Project Independence Report (Federal Energy Administration) together

with attendant companion studies in building energy conservation. Establish contacts in government, industry, and educational institutions to provide information useful to the project. "(The reference "Phase I of this ERDA program" relates to the ERDA Phase Zero Reports mentioned in the same paragraph.)"

Assemble detailed information on both energy conservation features, and on alternative energy utilization methods that might be incorporated into buildings of the following kinds, at a minimum:

- Single-family residential
- Multi-family residential
- Small commercial/industrial
- Large commercial/industrial

Additional breakdown to more detailed building types and uses may be desirable to adequately address the goals of this project.

Such assembled information shall include, but not be limited to, the following data:

- A listing of all important conservation/alternative energy components, systems and methods included.
- Technical attributes.
- Present and projected market availability of materials, components and labor.
- Costs, broken down into materials, equipment, labor operating, and maintenance components.
- Energy consumption characteristics and impacts of all items listed.

- The influence of geographical location.
- Information on probable development of all of the above parameters with time.

To the greatest extent possible the Contractor shall make best use of existing information on techniques for conserving energy in buildings and for using alternative energy forms; major development of new information in these areas is not the primary thrust of this project, although some work of this kind may be necessary.

Task 3 -- Perform an analysis for each of the identified building types and building classes, new and existing, using the information assembled during the accomplishment of Task 2. Identify and evaluate the effectiveness of the most promising mixed conservation/alternative energy strategies and configurations, as a function of time. It is anticipated that techniques of building energy simulation and life cycle costing will have to be employed to accomplish this task effectively, using existing analytical and computational tools to the maximum extent possible. The results of the analysis should clearly show, for the building types and building classes selected, the balance that must be struck by the strategy for mixed conservation/alternative energy implementation to give maximum energy savings and cost effectiveness in the life cycle, with acceptable short run first-cost, labor, financial, etc., requirements.