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

Final Report, Volume II—Detailed Results

MASTER

November 1977
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Work Performed Under Contract No. EY-76-C-03-1234

Energy Resources Center
Honeywell, Incorporated
Minneapolis, Minnesota

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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 II - DETAILED RESULTS

Date Published–June 1977

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

PREPARED FOR THE
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Office of the Assistant Administrator for Conservation
Division of Buildings and Conservation Services

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SECTION I

INTRODUCTION

Homeowners and building owners and operators have become acutely aware of the need to use energy more efficiently. In response, both government and private industry are examining a broad spectrum of energy conservation measures and alternative energy sources (e.g., solar).

The potential payoff to the nation is enormous with more efficient energy use in buildings. The buildings sector accounts for approximately one third of the nation's energy (about 12 million barrels of oil a day) in 70 million dwelling units and 24 billion square feet of commercial space. Of this, nearly 75 percent is used for space heating and cooling and water heating.

For the past several years, both the Federal Government and private industry have been keenly aware of high energy utilization in the nation's buildings. Guidelines for energy conservation and the use of alternative energy sources and lengthy lists of potential energy conservation measures have been published. In addition, a large number of hardware demonstrations have occurred or are currently underway covering a broad spectrum of measures and techniques. Most of these studies and demonstrations have been aimed, however, at a single technique or strategy and have not addressed the issues of energy conservation and energy utilization simultaneously. Considering that only limited resources are available to solve the nation's energy problem, it is imperative that solutions be developed that are cost-effective while providing the desired energy savings.

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 homeowners and building owners select mixed strategies of energy conservation and use of 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) and Bather, Ringrose, and Wolsfeld Inc., a Minneapolis consulting engineering firm.

The overall objective of this project was to identify the technical and economic benefits of implementing mixes of energy conservation and sources in buildings. Fully developed conservation products in conjunction with conventional on-site solar heating and cooling were emphasized in the project. In addition, the project focussed on energy utilization by the end user at the commercial and residential level. Energy conservation and solar energy effects external to this user group were assumed to be represented by energy rate structures.

Energy conservation measures applicable to space conditioning (heating and cooling), lighting, and domestic water heating were emphasized. Options that require major life style changes were not considered. The annual cycle energy system (ACES) concepts were considered to be outside the project scope.

The overall study approach relied heavily on the use of building models and simulation. Five building classifications representing a majority of the nation's new and existing building types and the major energy users were selected as models for the computer analysis. Results were developed for four U. S. cities representing different weather and building construction situations.

Economic assumptions obviously have a large impact on any results of the type presented in the report. Federal Energy Administration projections were assumed as the basic future price scenario for oil, gas, and electricity. Hardware costs were based on current estimates. However, wherever possible in this report, results are presented in a manner which permits the reader to interpret the results with his or her own economic assumptions.

The following sections of the report describe:

- The general approach used in the study including a presentation of assumptions and basic data
- The detailed results with discussion by building type for each city studied

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SECTION II
APPROACH AND ASSUMPTIONS

2.1 INTRODUCTION

The mixed strategy analysis was a tradeoff analysis between energy conservation methods and an alternative energy source (solar) considering technical and economic benefits. The objective of the analysis was to develop guidelines for:

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

The analysis was done with a solar system in place. This makes the study unique in that it is determining the interaction of energy conservation with a solar system. The study, therefore established guidelines as to how to minimize capital investment while reducing the 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 2-1. Ideally, 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

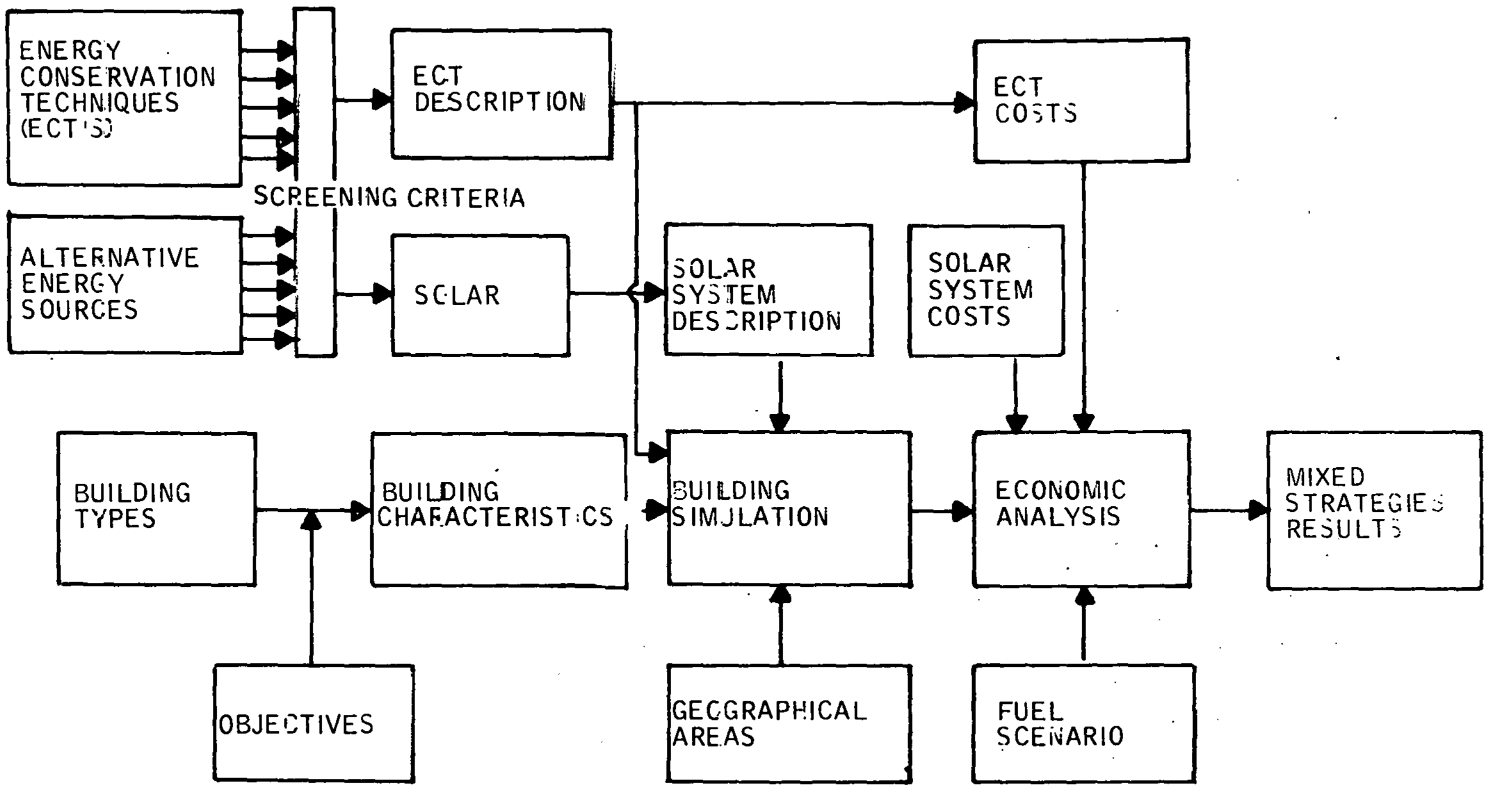


Figure 2-1. Mixed Strategies Study Approach

conservation techniques were described in detail and installed costs determined. The alternative energy source reduced to solar. 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 was analyzed using computer simulation to determine the interaction between energy conservation and the solar system. Finally, using FEA fuel price scenarios and installed costs for the solar system and energy conservation techniques, an economic analysis was performed to determine the cost effectiveness of the combination. The following paragraphs detail the approach employed in the study.

2.2 PROGRAM SCOPE

This study addresses energy use by the consumer. Honeywell evaluated mixed strategy options implemented at the commercial and residential level. Energy conservation and alternative energy source effects external to this user group are represented by end-user energy rate structures. By this technique, the impact of external effects on the user were evaluated without requiring modeling of specific external mechanisms. Categories of energy conservation methods and alternative energy sources to form the candidate mixed strategies are:

a) Energy conservation measures applicable to
   - Space conditioning (heating and cooling)
   - Lighting
   - Hot water generation

   (These comprise nearly 80 percent of the energy utilization in commercial/residential buildings)

b) Heat reclamation methods.

c) Packaged and central HVAC systems, and their associated controls for techniques such as enthalpy economizers, load feedback, and optimum start-up.

d) Solar assisted heating, heating and cooling, and water heating systems found in buildings.

e) Building insulation and structural (architectural) considerations that affect energy utilization and conservation.

Technically feasible energy savings/alternate energy source options that do not appear acceptable for wide-spread application were not pursued. Further, options requiring major development before being integrated into the energy needs of buildings were also eliminated. These considerations left only one viable alternate source, solar energy. Options that require major life style changes are also eliminated from the scope of this study.

2.3 SELECTION OF BUILDING TYPE

Selection of building type was based on a literature survey. Tables 2-1, 2-2 and 2-3 are summaries of energy consumption and building inventories By selecting the single-family residence, low rise multi-family dwellings, office buildings, retail stores and schools, the majority of buildings and the largest energy users are represented.

The task to define the typical construction for each of the five building types revolved around literature surveys and consultation with the National Association of Home Builders Research Foundation and Bather, Ringrose, Wolsfeld Incorporated, a Minneapolis architectural engineering firm. Table 2.4 summarizes the various descriptions of typical buildings as defined by the references. The last column is the selection made for this study. The energy conservation and alternate energy tradeoff analysis was based on these five basic building types. The details of constructions and occupancy patterns are in Appendix A.

Table 2.1. National Energy End Use By Building Type

Building Type	% Energy Use
1. Residential Single-Family	15.00
2. Residential Multi-Family	4.38
3. Schools	3.28
4. Retail Stores and Supermarkets	2.78
5. Office Buildings	2.51
6. Hospitals	1.59
7. Hotels/Motels	1.00
8. Restaurants	.96
9. Theatres	.01
10. Research Facilities	–
11. Library/Museums	-

Source: FEA Project Independence - Residential and Commercial Energy Use

Table 2.2. U. S. Residential Inventory

	1970 Thousands of Year Round Units	% of Total	1974 Thousands of Year Round Units	% of Total
Single Family	44,801	66	48,235	63
Low Density	10,997	16	12,495	16
Low Rise	6,533	10	7,605	10
High Rise	3,295	5	3,836	6
Mobile Home	2,073	3	3,714	5

Sources: U. S. Department of Commerce, 1970 Census of Housing and A. D. Little Annual Housing Survey, 1974, U. S. and Regions, Part A, General Housing Characteristics

Table 2.3. Commercial Building Inventory

	1970	% of Nations Total	1980 Ext.	% of Nations Total
Offices	3,380	16	5,681	17
Retail	4,210	19	7,575	23
Schools	5,040	23	6,804	21
Hospitals	1,500	7	2,218	7
Other	7,480	35	10,458	32
Total	21,650	100	32,645	100

Source: Arthur D. Little, Ref 50

Table 2-4. Building Size (ft^2) Summary

BUILDING TYPE	REPORTS						CURRENT SELECTION	
	A.D. Little	G. E.	TRW	Westing-house	NAHB New	NAHB Existing	New	Existing
Single Family	1,660 (1)*	1,800+B (2)	1,400 (1)	1,550 (1)	1,570 (1)	1,213 (1)	1,512	1,204
Apartment Building	18,000 (2)	21,600 (3)	3,200 (2)	14,600 (2.3)	14,400 (2.3)		14,400	14,400
Office Building	40,000 (3)	20,000 (2)	10,000 (2)	33,400 (3.34)			30,000	30,000
Store Building	32,400 (1)	5,200 (1)	15,000 (1)	1,400 (1)			5,000	5,000
School Building	40,000 (1)	52,000 (1)	9,600 (1)				10,000	40,000

* Numbers in parenthesis are the average number of floors in the building.

A.D. Little: Ref 50
G.E.: Ref 119
TRW: Ref 120
Westinghouse: Ref 121
NAHB: Appendix H

2.4 SELECTION OF GEOGRAPHICAL AREAS

To determine the influence of weather on the tradeoff study, four cities were selected. The Arthur D. Little, Inc. study of the impact of ASHRAE Standard 90-75 on the nations energy industry selected these four cities to represent the four census regions in Figure 2-2. The next paragraphs and Table 2-5 are excerpts from that report.

"Geographical location will have a major effect on building energy demands for space heating and cooling. From previous studies, it has been shown that space heating is the overriding factor in energy demand within the construction sector. As such, the variation in space heating requirements (as measured in degree days) became the prime criteria in selecting geographical locations for the impact study. In order to evaluate ASHRAE 90's effect on energy consumption using computer simulation techniques, specific geographical locations had to be selected which were representative of the nation's climatic variations."

To best describe the heating requirements within each of the four Census regions, a weighted average number of annual heating degree days was derived which represented the "center of gravity" for heating within each region. Using data compiled by the U. S. Weather Bureau, and weighing it by metropolitan population centers, ADL derived the average number of annual degree days within each state. Once these weighted averages were determined, they were multiplied by the number of housing units in the state, and the products totaled by region. The total of the products were then divided by the number of units within each region to get a weighted average of the heating degree days within the region.

Once the weighted average degree day was calculated, five to ten candidate cities were selected within each region whose annual heating degree day load was close to the regional average. For each candidate location, the ASHRAE recommended design dry bulb and wet bulb outdoor design temperatures were compared to determine which single location was most "representative" of the cooling requirements of that region. This criterion was admittedly subjective and although the methodology is somewhat unsophisticated, the energy usage estimates are believed to be reasonably representative for each region as a whole.

A second exercise in the application of ASHRAE 90 was a brief investigation into how effective a nondepletable energy system (in this case, solar energy) would be in reducing the conventional building's demand for utilities. The solar energy system analysis was based upon ADL's rather sophisticated in-house computer model which utilizes actual hourly insolation data. In as much as hourly data is available from a relatively few number of U. S. Weather Bureau locations, some consideration in the selection of the representative cities in each of the regions was given to the availability of solar weather data.

Table 2-5 lists the weighted average annual heating degree days for each region along with the city selected for use in the analysis. Also, Figure 2-2 is a map showing the locations of the selected cities representing their regions; New York for the Northeast Region, Omaha for the North Central Region, Atlanta for the South, and Albuquerque for the West.

TABLE 2-5

REPRESENTATIVE LOCATIONS SELECTED FOR COMPUTER ANALYSIS OF PROTOTYPICAL BUILDINGS

	Weighted Average Annual Heating Degree Days	Location Selected				Data Used for Solar Energy Analysis
		City	Degree Days	Summer Design Conditions db	Summer Design Conditions wb	
Northeast	5,470	New York (Airport)	5,219	87°	76°	New York (City)
North Central	6,345	Omaha	6,612	94°	78°	Omaha
South	2,795	Atlanta	2,961	92°	77°	Nashville
West	3,515	Albuquerque	4,348	94°	65°	Albuquerque

SOURCE: Arthur D. Little, Inc.

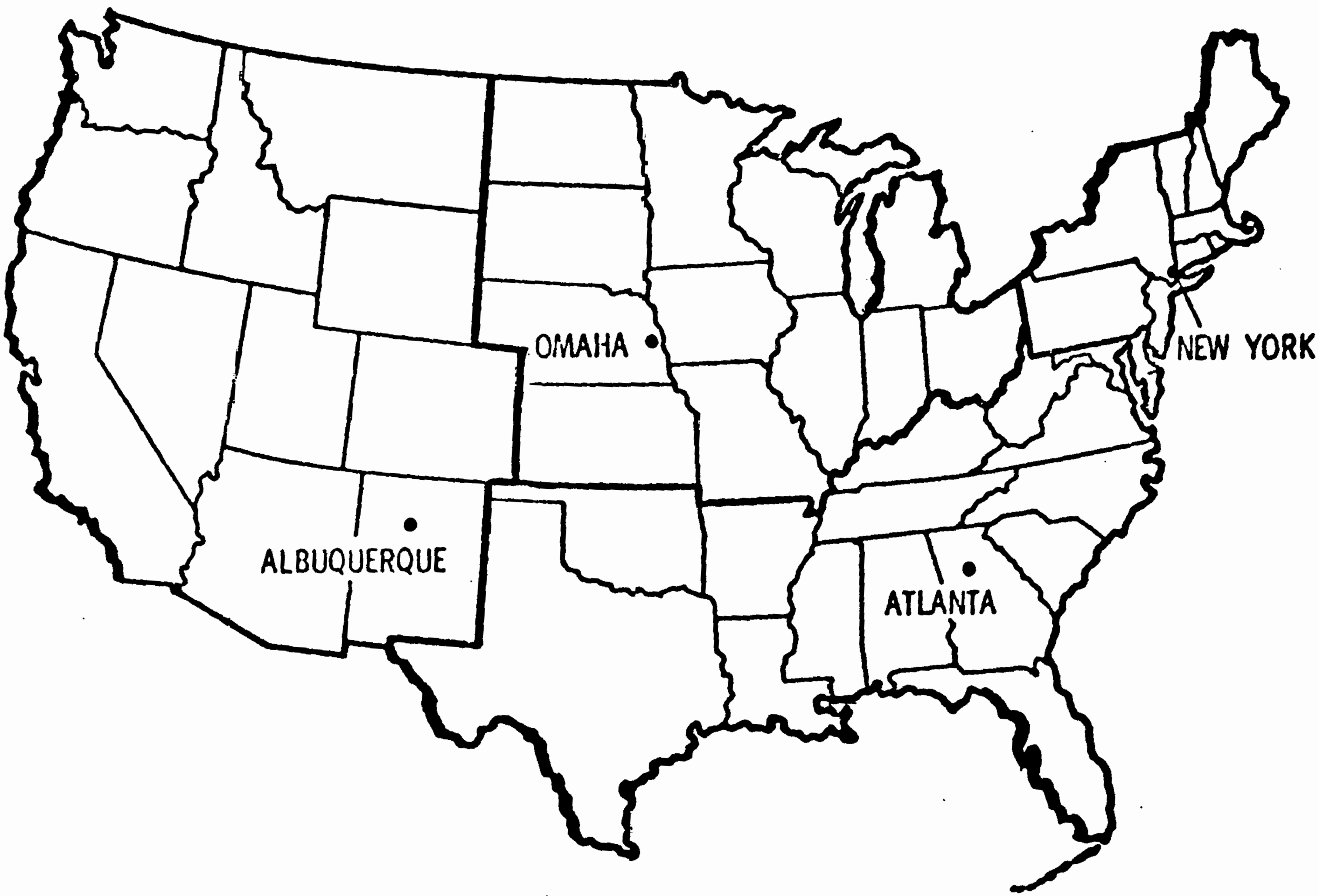


Figure 2-2. Regions and Representative Locations

2.5 SELECTION OF ALTERNATIVE ENERGY SOURCES, PRELIMINARY AND FINAL SCREENING

A comprehensive list of energy sources was compiled as shown in Appendix B. The fuel or energy sources to be studied were selected from this list. By considering the criteria that the energy source must be suitable for use at the building site and should be commercially available, non-polluting and suitable for wide spread application, the condidate energy sources reduce quickly to one, solar energy. The other non-conventional energy sources are not easily used at the building location. Most of them, in fact, will either be turned into gas, oil or electricity and transported through conventional means. For example, geothermal energy can be used to generate electricity and then put on the power grid that is also supplied by conventional power plants. The price projections of the three fuels; gas oil and electricity, for the next 20 years (the defined period of the analysis) reflects these types of developments.

2.6 Selection of Energy Conservation Techniques

In determining the possible methods of energy conservation, the building was looked at in a functional manner, Figure 2-3. A building consists of three functional elements, the structure, the building systems and the control systems. Each one of these functions has a significant impact on energy consumption. In this model, the inputs weather, occupants, appliances and equipment are given. That is, these parameters exist and cause stochastic energy demands on the building, but the only control that exists for reducing energy consumption is through the properties of the three functional components. Therfore, a basis for developing energy conservation techniques can be established by using methods that reduce energy consumption of each function. Table 2 in Appendix B is a comprehensive list of energy conservation techniques. These techniques can be condensed to a smaller appearing list (Table 2-6) by grouping the various techniques into broad classes. In order for a class of energy conserving techniques to be a candidate for a mixed strategy tradeoff analysis with solar energy, it must satisfy the following criteria.

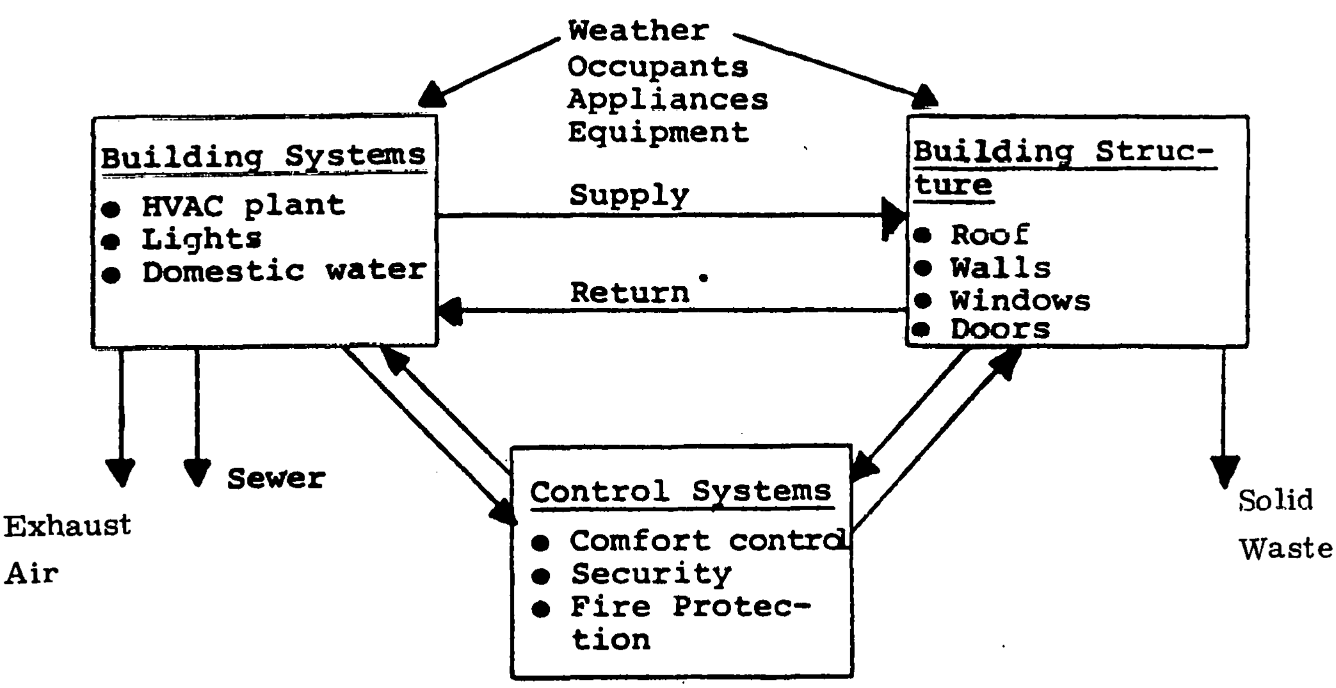


Figure 2-3.
Building Components Functional Relationships

Table 2-6. Energy Conservation Technique Categories

1.0 Building Structure

- Heat loss reduction
- Natural storage
- Solar Load Control
- Natural ventilation

2.0 Building Systems

2.1 HVAC

- Solar heating and cooling systems
- Heat pump
- Air economizers
- Higher efficiency furnaces
- Zoning
- Heat recovery
- Storage tanks

2.2 Lighting

- Natural lighting
- Task lighting
- Higher efficiency lights

2.3 Water

- Use waste heat from systems and equipment
- Decrease storage heat loss
- Increase efficiency of hot water generating equipment
- Reduce consumption of water

3.0 Control System

- Reduce ΔT, ΔRH
- Load management
- Optimize equipment efficiency through sequencing and utilization of inherent component efficiency tradeoffs.

- Potential for Synergism
- No major change in lifestyle
- No major development, i. e., in demonstration today, or a logical extension of today's techniques.
- Acceptable for widespread application
- Significant impact in terms of saving energy and fuel
- No or minimal pollution
- Cost effective - life cycle basis
- Accessible to quantitative analysis
- Inside - including building envelope

The items that met the criteria were then selected from the master list and evaluated in terms of their technical attributes. Each item was rated as good, fair or poor, in relation to the attributes listed in Table 2-7.

Table 2-8 shows the ratings for residential construction and Table 2-9 for commercial applications. Using a weighting of 3 = good, 2 = fair, 1 = poor and a neutral weight for the blanks, the energy conservation techniques were prioritized for mixed strategies tradeoff analysis.

The energy conservation techniques surviving the screening process are listed below in order of priority.

- Single Family Home (New and Existing), Energy Saving Techniques
  - Night Setback
  - Increased Insulation and Storm Windows and Doors
  - Insulate the Hot Water Tank and Decrease its Temperature
  - Air Economizer System, "Free Cooling"
  - Use High Efficiency Furnace

High Efficiency Lights
Solar Shading of Windows

- Multi - Family Residence(New and Existing), Energy Saving Techniques
  - Night Setback
  - Increased Insulation with Storm Windows and Doors
  - Insulate the Hot Water Tank and Decrease its Temperature
  - Air Economizer System, "Free Cooling"
  - Solar Shading of Windows
  - High Efficiency Lights
  - High Efficiency Furnace

- Office Building(New), Energy Savings Techniques (Variable Air Volume, HVAC System)
  - Heat Recovery from Exhaust Air
  - Reflective Film on Windows
  - Shading with Drapes
  - Triple Glazing
  - Task Lighting
  - Reset Hydronic Loop from Zone Thermostats
  - Increased Building Insulation
  - Reduce Hot Water Tank Temperature

- Office Building (Existing), Energy Savings Techniques (Reheat HVAC System)
  - Adjust Minimum Ventilation Rate
  - Close Outdoor Air Dampers at Night
  - Air Economizer System
  - Heat Recovery
  - Reflective Film on Windows
  - Solar Shading of Windows
  - Double Glazing
  - Delamping

Reheat Optimization
Convert to Variable Air Volume System
Night Setback and Cooling Shutdown
Increased Building Insulation
Reduce Hot Water Tank Temperature

- Retail Store (New and Existing)
  - Adjust Minimum Ventilation Level
  - Close Outdoor Air Dampers at Night
  - Air Economizer
  - Heat Recovery of Exhaust Air
  - Reflective Film on Windows
  - Awnings
  - Double Glazing, Triple Glazing
  - Change Lighting Schedule
  - Night Setback
  - Increase Building Insulation
  - Insulate Hot Water Tank and Decrease its Temperature
  - High Efficiency Furnace

- School Building (New and Existing), Energy Savings Techniques
  - Adjust Minimum Ventilation Air
  - Air Economizer System
  - Reflective Film on Windows
  - Solar Shading of Windows
  - Double Glazing, Triple Glazing
  - Delamping, Task Lighting
  - Night Setback, Cooling Night Shutdown
  - Increased Building Insulation
  - Insulate Hot Water Tank and Reduce its Temperature

Table 2-7. Technical Attributes to be Considered.

- Modularity - Subsystems components that are of standard design and size that could be put together to achieve the desired capability. An example that meets this constraint is the flat-plate collector panel, a component of standard size that can be combined to create any desired collector area.

- Scalability - A subsystem component of standard design that can provide a progressive increase in capability by changing some of the components of that subsystem. An example of this type of subsystem component is the standard home furnace, the output capability of which can be increased by scaling burners and blower motors.

- Architectural Aspects - Includes interface of solar-heating/cooling system on building (especially collectors), impact on construction, and aesthetic qualities.

- Fuel-Type Availability - Assurance that local utilities will provide the type and amounts of fuel required.

- Economic Aspects - Costs of procurement, installation, maintenance and operation.

- Development Risks - Availability of components within required time frame. Subsystem design maturity.

- Maintainability - Skill, knowledge, and training required to maintain system.

- Reliability - Confidence in assuring continued system operation over life cycle.

- Safety - Safety of operation and use of system.

- Control Philosophy - Control of solar-heating/cooling system to use needed energy directly from collector or storage. Store excess energy and use auxiliary energy when required.

Table 2-8. Rating of Attributes of Energy Conservation Technique for Residences (Single and Multi-family)

Constraint	Insulation Ceiling	Insulation Wall	Insulation Floor	Storm Windows	Weather Stripping	Nite Set Back	Air Econ.	Solar Shading	High Effic. Furna(
Modularity	G	G	G	G	G	-	-	G	-
Scalability	G	G	G	G	G	G	G	G	G
Architectural	G	G	G	G	G	-	F	F	-
Fuel Type Availability	-	-	-	-	-	-	-	-	F
Economics	G	G	G	G	G	G	F	F	G
Development	G	G	G	G	G	G	G	F	F
Maintainability	G	G	G	G	G	G	G	G	G
Reliability	G	G	G	G	G	G	G	G	G
Safety	-	-	-	-	-	-	-	-	-
Control	-	-	-	-	-	G	G	F	G
Operational Efficiency	-	-	-	-	-	G	G	G	G
Potential Energy Savings	G	G	G	G	G	G	G	G	G

G = Good
F = Fair
P = Poor

Table 2-8. Rating of Attributes of Energy Conservation Technique for Residences (Single and Multi-family (Concluded)

CONSTRAINT	WASTE HEAT RECOVERY	HIGH EFFICIENCY LIGHTS	INSULATE WATER TANK & DECREASE TEMP.
Modularity	F	F	-
Scalability	G	F	G
Architectural	F	G	G
Fuel Type Availability	G	G	G
Economics	P	F	P
Development	F	F	G
Maintainability	F	G	G
Reliability	G	G	G
Safety	G	G	G
Control	F	G	G
Operational Efficiency	G	G	G
Potential Energy Savings	F	G	G

Table 2-9. Rating of Attributes of Energy Conservation Techniques For Buildings (Office, School & Store)

Constraint	Ventilation	Window Transmission Loss/ Gain	Lighting	HVAC System Control	HVAC System Efficiency	Conduction Heat Loss/ Gain	Domestic Water
Modularity	G	G	G	G	G	G	G
Scalability	G	G	G	G	G	G	G
Architectural	G	G	G	G	-	G	G
Fuel Type Availability	G	-	G	G	-	-	-
Economics	G	G	G	G	G	G	G
Hardware Operational	G	G	G	G	G	G	G
Development	G	G	G	G	G	G	G
Maintainability	G	G	G	G	G	G	G
Reliability	G	G	G	G	G	G	G
Safety	G	G	G	G	G	G	G
Control	G	G	G	G	G	-	G
Operational Efficiency	G	G	G	G	G	G	G
Potential Energy Savings	G	G	G	G	G	G	G

2.7 Cost Model

To assess the economics of energy conservation and the size of the solar system, a common basis has to be established. One suggested method is to use heat energy savings. For example, an energy conservation technique, such as adding insulation to a building, will save a given amount of energy. A quantity such as BTU savings per inch of insulation could be calculated for the insulation and this could be compared to the BTU collected from a square foot of solar panel (in a system). Then tradeoffs of inches of insulation versus area of the collector to minimize the auxiliary energy use can be done. One problem, a significant one, is that it does not include the practical considerations such as the difficulties associated with adding insulation. For example, it is easy to add 3 1/4" of insulation to an existing 2x4 stud wall compared to adding six inches of insulation to the same wall; Therefore, a common denominator that reflects installation effort for the energy conservation technique was selected, that is cost.

The costs to be considered should include all of the items that have to be paid for in owning a solar system and installing energy conservation techniques. The costs include the following:

- Installed costs (Instl)
- Operating costs (O_p)
- Maintenance costs (Mnt)
- Insurance costs (Ins)
- Salvage value (Salv)
- Auxiliary fuel costs (Oaux F_j)

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. The method of computing costs is based on he suggestion by the National Bureau of Standards (1). The following equation :omputes an annualized life cycle cost.

$$AC = CRF \left\{ Instl - \frac{Salv}{(1+i)^N} + Mnt \sum_{j=1}^{N} \left(\frac{1}{1+i}\right)^j + O_p \sum_{j=1}^{N} \left(\frac{E_j}{1+i}\right)^j + O_{anx} \sum_{j=1}^{N} \left(\frac{F_j}{1+i}\right)^j + Ins \sum_{j=1}^{N} \left(\frac{1}{1+i}\right)^j \right\}$$

The annual cost is equal to the capital recovery factor times the present value of the costs previously mentioned, considered over N years (in this case N = 20). Appendix D contains d etails of the economic model.

How is this annual cost related to the dollars spent each year to supply energy to b uildings being analyzed ? The first term in the equation, i. e. , capital recovery factor times the installed cost is the yearly payment at the given discount rate. To neglect inflation, the discount rate should be the difference between the inflation rate and the market cost of money. In this case, 2% is used. The other terms in the equation are the present value of the costs for the twenty years times the capital recovery factor. These terms equal the yearly cost for items that do not escalate, that is those that do not increase in price faster than inflation. Gas, oil and electricity are projected to escalate and therefore, their annual cost is an average annual cost for the 20 year period.

2. 8 Fuel Prices

Fuel prices are obviously important in a trade-off 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.

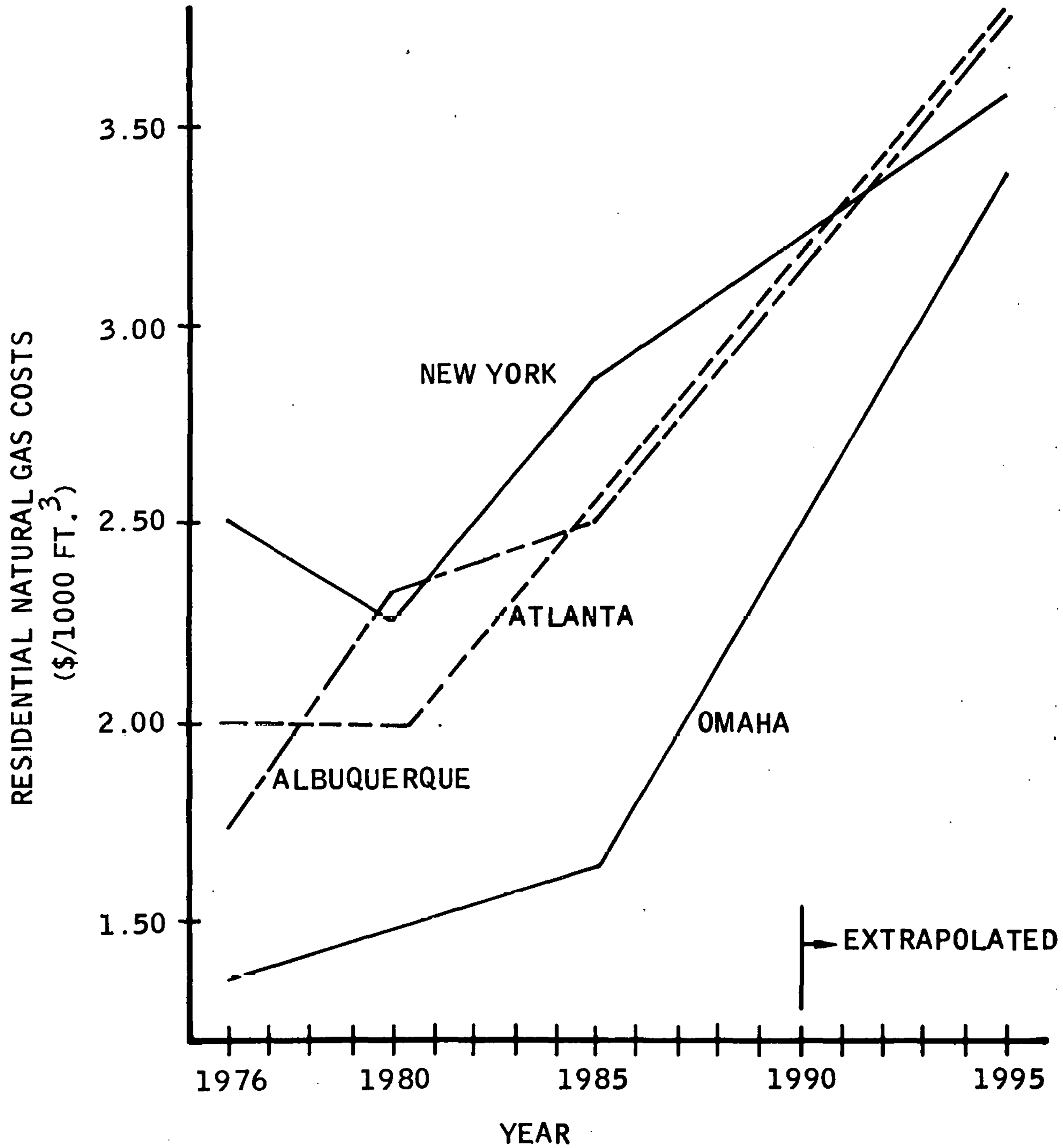
(1) Rosalie Ruegg, Ref. 115

After examining price projections from various sources it appeared that the Dec. 1976 FEA projections were reasonable, in agreement with most other projections, and were the most complete set of information. Figures 2-4 through 2-9 are plots of these prices for the four different geographic areas. The prices are in terms of 1975 dollars. To convert them to 1976 dollars they were increased by 6% the 1975 inflation. These prices are tabulated in Appendix C.

The FEA's approach in projecting fuel prices is to obtain current prices from the State, Local Database (published by FEA), then get the 1980, 1985 and 1990 prices from the current reference case of the National Energy Outlook and finally, obtain the remaining years by linear extrapolation.

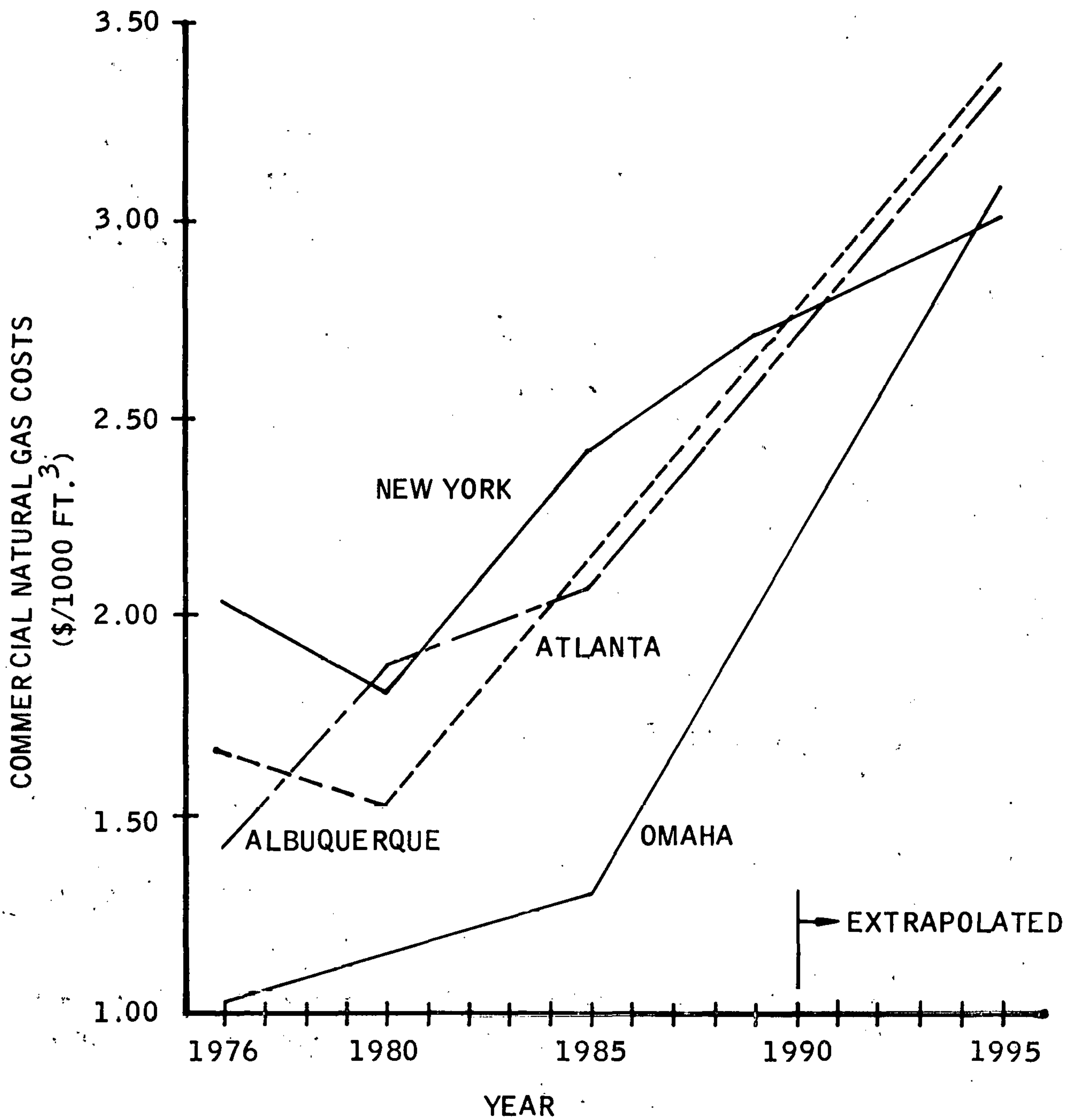
The fuel prices are in constant dollars, therefore the data shows the escalation above inflation. In the cost formula used in this study the annual fuel costs are computed by determining their present value and then multiplying by the capital recovery factor. This cost is then the average cost for the 20 year period. The averages corrected for 1975 to 1976 inflation are presented in Table 2-10. The actual costs as seen by the consumer in any year will vary according to inflation, but his average cost in 1976 dollars will be the prices of Table 2-10, assuming the escalation projections are correct.

The equivalent escalation rate to obtain the same 20 year average costs was calculated, Table 2-11. Gas has the highest escalation rate of all the fuels. The equivalent escalation rate is calculated by determining what cor. escalation is needed to yield the same average fuel prices given in Table 2-10.



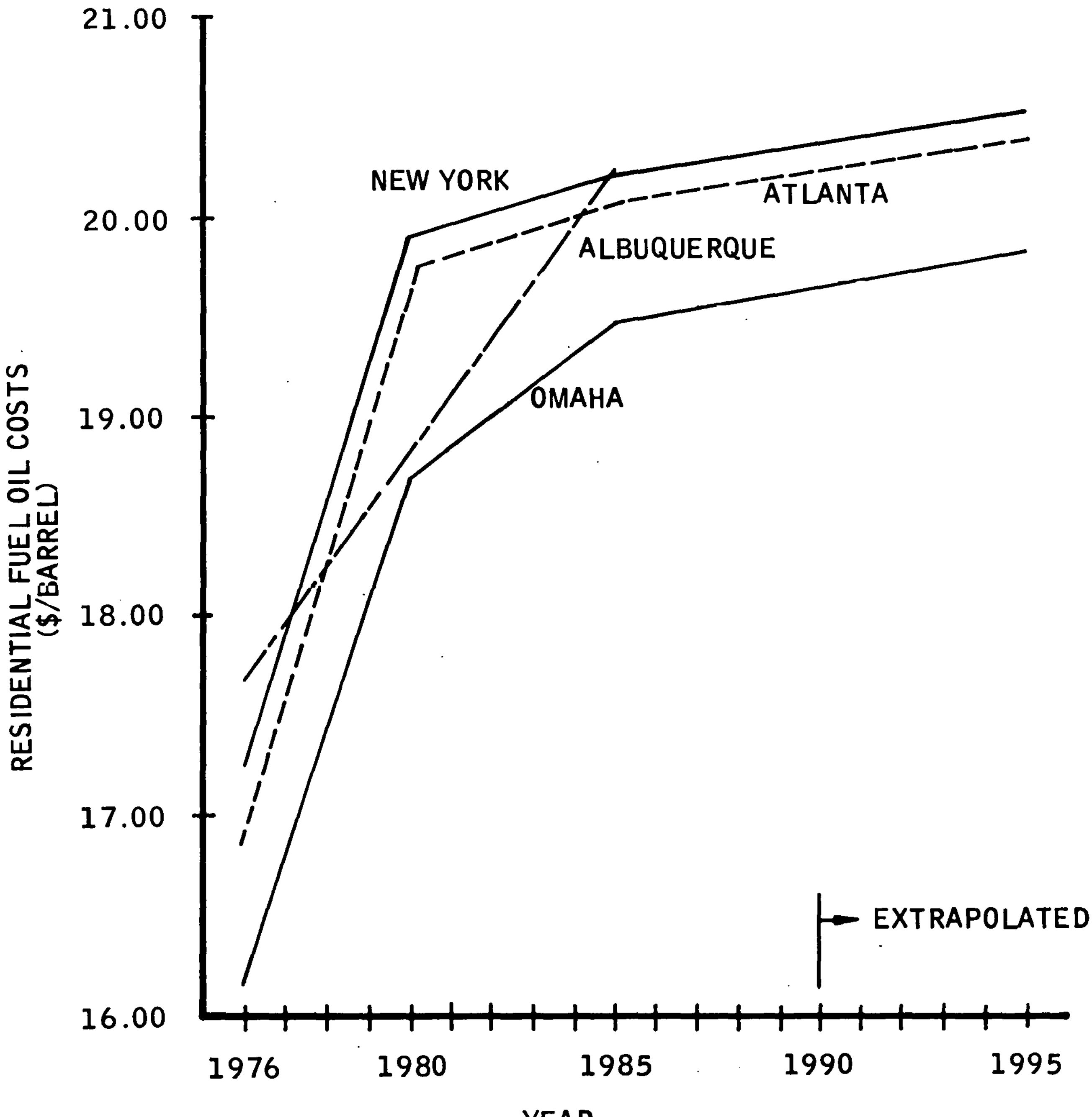
SOURCE: FEA 12/30/76; 1975 DOLLARS

FIGURE 2-4



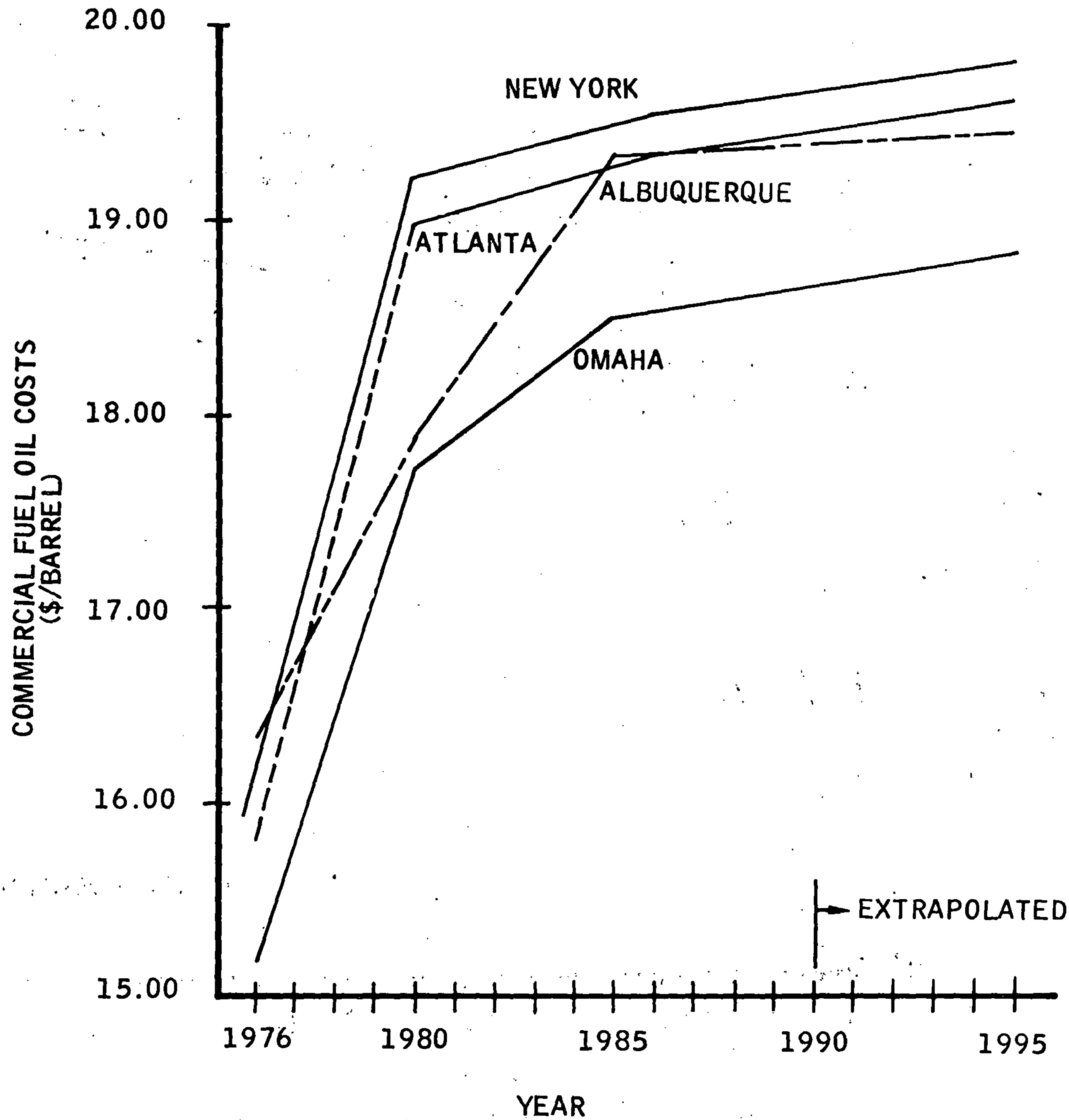
SOURCE: FEA, 12/30/76; 1975 DOLLARS

FIGURE 2-5



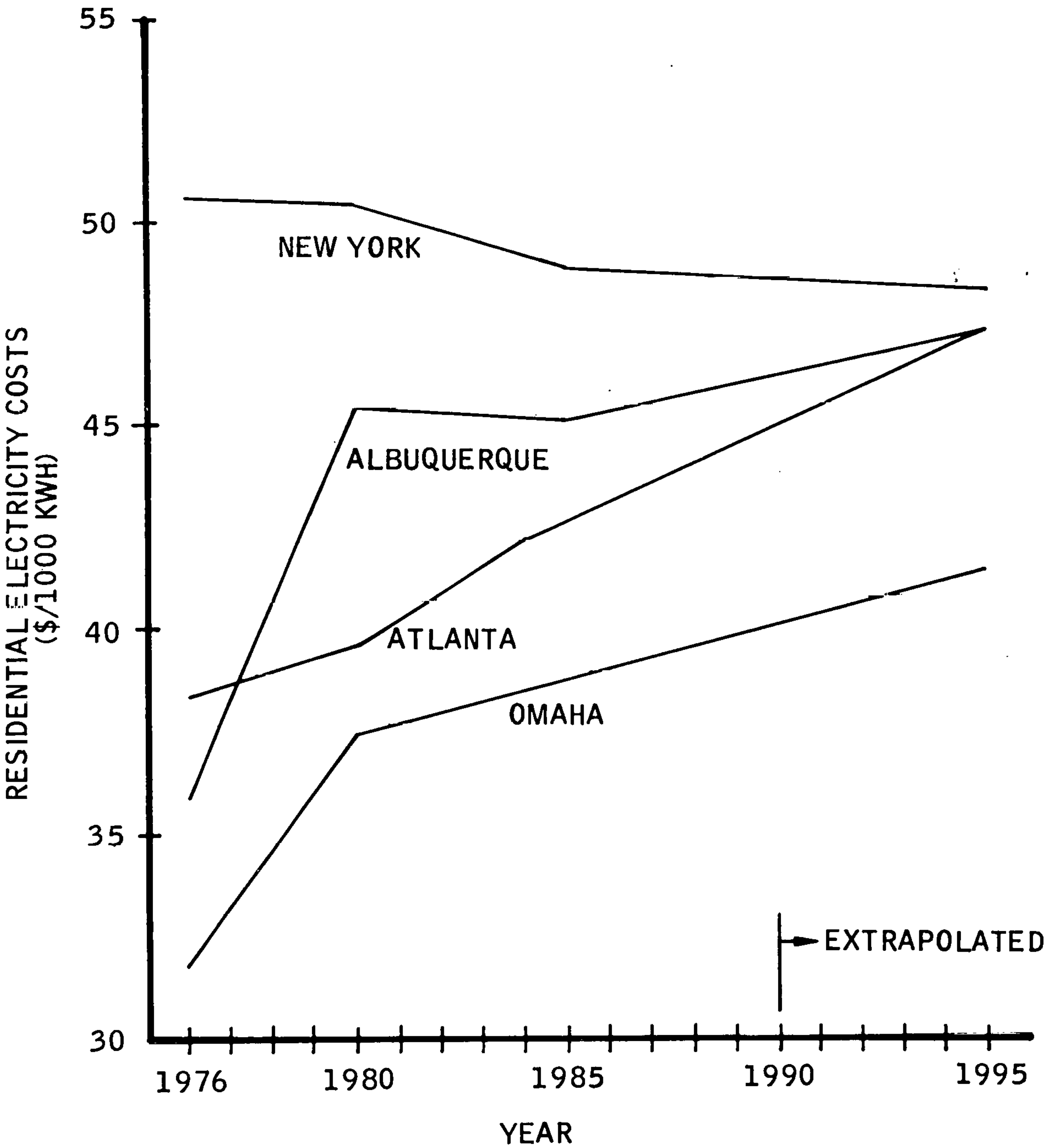
SOURCE: FEA, 12/30/76; 1975 DOLLARS

FIGURE 2-6



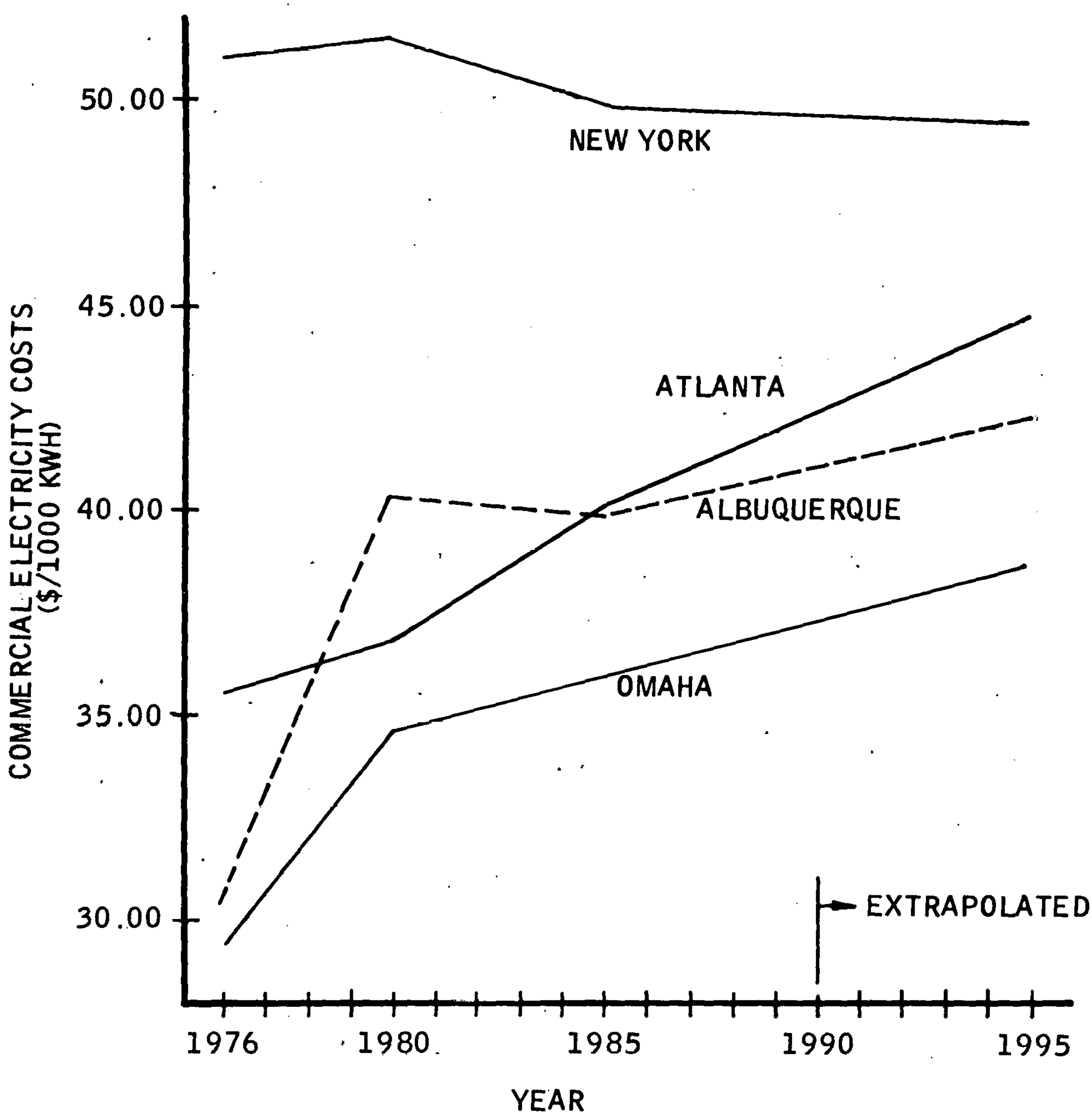
SOURCE: FEA, 12/30/76; 1975 DOLLARS

FIGURE 2-7



SOURCE: FEA, 12/30/76; 1975 DOLLARS

FIGURE 2-8



SOURCE: FEA, 12/30/76; 1975 DOLLARS

FIGURE 2-9

TABLE 2-10

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
Alburquerque	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 2-11

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	-.4	1.5	1.8	0
Alburquerque	4	1	2.1	4.4	1.3	2.4
Atlanta	2.7	1.5	1	2.8	1.7	1.1

TARGET SOLAR SYSTEM COSTS

Based on these average fuel prices, escalation rates and an estimate of BTU's obtainable from a solar system, a sensitivity analysis was performed to determine:

- Target costs for installed solar system
- Fuel escalation rates required to make solar systems cost effective

Target costs for installed solar systems were predicted for each region of the country. Tabulated in Table 2-12, target costs are illustrated for both residential and commercial buildings for three auxiliary fuel types and two seasonal furnace efficiencies.

In Omaha for example, the average cost of gas fuel for the next 20 years is $2.10 per million BTU (residential rates). For a solar system to be competitive, the cost of the system has to be equal to or less than the price of the fuel it's displaying. Therefore, in this case, assuming a 20 year analysis period, the solar system cost has to be less than $5.80 per ft^2 of collectors, for residential (55 percent efficiency) systems. Since fuel prices for commercial users are slightly lower than the residential rates, the installed costs have to be slightly less also. This is contrary to current installation charges. Usually commercial tradesmen receive higher wages than residential, making the cost of commercial field erected systems higher priced than residential. Target prices for solar systems are based on the assumption that the system was installed now and can collect and use 120,000 BTU/year/ft^2 of solar energy for the next 20 years.

Table 2-12. Target Costs for Total Installed System in Dollars Per Square Foot of Net Collector Area*

REGION	To Be Competitve With Gas				To Be Competitive With Oil				To Be Competitive With Electricity	
	Residential		Commercial		Residential		Commercial		Residential	Commercial
	55% Seasonal Eff.	80% Seasonal Eff.	55% Seasonal Eff.	80% Seasonal Eff.	55% Seasonal Eff.	80% Seasonal Eff.	55% Seasonal Eff.	80% Seasonal Eff.	100% Seasonal Eff.	100% 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.

Fuel Escalation Rates

Given the uncertainty of future fuel prices, another viewpoint consists of determining fuel escalation rates required to make solar systems cost effective. These results are illustrated in Table 2-13 for installed solar system costs of $40, $20 and $10 per square foot. Usually low cost solar systems are not as efficient as the higher cost systems, but this table is based on systems that collect and use 120,000 BTU/ft^2/ year for all prices.

2.9 Selection of Solar System

The best alternative energy for use on site is solar energy. To precisely define the system to be studied, the same procedure used to select energy conservation techniques was followed. The major components of solar systems were rated by technical attributes, Tables 2-14, 2-15 and 2-16. From this analysis, several systems were selected, then analyzed the same way, Table 2-17. It is apparent that the system that most consistently is the best is a liquid flat plate collector array using water/glycol heat transfer medium with water storage, and a Rankine cycle for cooling. The baseline solar system used in this analysis is depicted in Figure 2-10. Collector efficiency was given by:

$$\text{Efficiency } (\eta) = .74 - .6 \frac{T_{inlet} - T_{ambient}}{Q_{inc}}$$

2.10 Computer Programs

The computer programs selected for the analysis of the mixed strategies are DYNSIM and SUNSIM and ECON 1. DYNSIM is a software package that simulates the building and solar system dynamically, whereas SUNSIM excludes most of the dynamics. See Appendix E for a detailed description. ECON 1 is the economic program based on the cost model discussed in Appendix D.

Table 2-13. Fuel Escalation Rates (%) Required to Make Solar Systems Cost Effective

Total System Installed Cost - $40/ft^2

REGION	RESIDENTIAL			COMMERCIAL		
	GAS	OIL	ELECT.	GAS	OIL	ELECT.
North Central	19	15	8	20	16	9
North East	16	15	5	17	16	4
South	17	15	6	18	16	7
West	18	15	7	19	16	8

Total System Installed Cost - $20/ft^2

REGION	RESIDENTIAL			COMMERCIAL		
	GAS	OIL	ELECT.	GAS	OIL	ELECT.
North Central	15	12	3	17	12	3
North East	12	11	*	13	12	*
South	13	11	1	14	12	2
West	14	11	1	15	12	3

Total System Installed Cost - $10/ft^2

REGION	RESIDENTIAL			COMMERCIAL		
	GAS	OIL	ELECT.	GAS	OIL	ELECT.
North Central	11	7	*	13	7	*
North East	7	7	*	9	7	*
South	9	7	*	10	7	*
West	10	6	*	11	7	*

* No price escalation required to be cost effective.

TABLE 2-14

RANKING OF SOLAR HARDWARE

COLLECTOR TYPES

ATTRIBUTES	LIQUID FLAT PLATE	CONCENTRATOR	AIR
Modularity	G	G	G
Scalability	G	G	G
Architectural	G	P	G
Fuel Type Availability	-	-	-
Economics	F	P	F
Development	G	F	G
Maintainability	G	F	G
Reliability	G	G	G
Safety	G	F	G
Control	-	-	-
Operational Efficiency	F	G	P
Potential Energy Savings	-	-	-

TABLE 2-15

RANKING OF SOLAR HARDWARE
SPACE COOLING

CONSTRAINT	RANKINE	ABSORPTION	HEAT PUMP/ DX
Modularity	G	G	G
Scalability	G	G	G
Architectural	F	F	G
Fuel Type Availability	G	F	G
Economics	P	F	F
Development	F	G	G
Maintainability	F	G	G
Reliability	F	F	G
Safety	G	G	G
Control	F	P	G
Operational Efficiency	G	F	G

TABLE 2-16

RANKING OF SOLAR HARDWARE

STORAGE

CONSTRAINT	WATER/GLYCOL	ROCK	HEAT OF FUSION (SALT)
Modularity	G	G	G
Scalability	G	G	G
Architectural	F	F	G
Fuel Type Availability	-	-	-
Economics	G	G	P
Development	G	G	P
Maintainability	G	G	P
Reliability	G	G	F
Safety	G	G	P
Control	-	-	-
Operational Efficiency	G	G	F

Table 2-17. Ranking of Solar Systems

Constraint	Flat Plate Rankine	Liq Flat Plate Absorption	Liq Flat Plate Heat Pump	Concentrator Rankine
Modularity	G	G	G	G
Scalability	G	G	G	G
Architectural	G	G	G	F
Fuel Type Availability	G	G	G	G
Economics				
(Hardware)	F	F	F	P
(Operating)	G	F	F	G
Development	F	G	G	F
Maintainability	F	G	G	F
Reliability	F	F	G	F
Safety	G	G	G	G
Control	G	P	G	F
Operation Efficiency	G	F	F	G
Potential Energy Savings	G	F	F	G

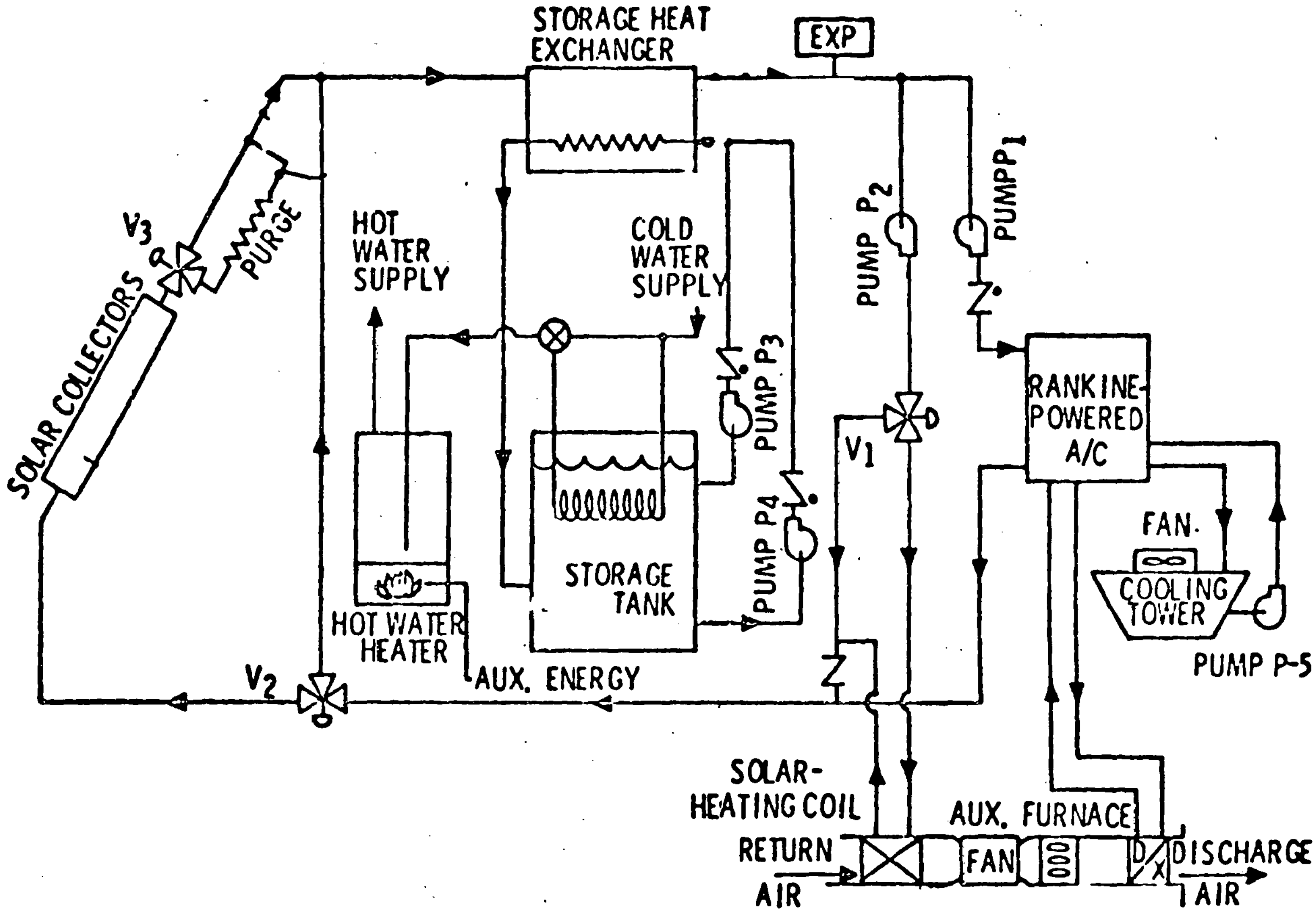


Figure 2-10. Solar Heating/Cooling System

DYNSIM is a full dynamic simulation, Figure 2-11, which includes the transients such as heat conduction through the building walls heat flow through pipes and temperature excursions in the room or system.

SUNSIM uses a static building load calculation and the only dynamics of the solar system is in the storage tank, Figure 2-12. These simplified calculations run 18 times faster than DYNSIM, which is an advantage for doing extensive analyses.

The approach was to simulate one building with DYNSIM to establish the suitability of SUNSIM. Then use SUNSIM because of its lower computer cost.

A single family residence was selected for this correlation test because it has a relatively low ventilation rate (infiltration) and therefore, the building dynamics will have a more significant impact on the loads than the other types of buildings. SUNSIM contains the dynamics of the storage tank, which is the most significant factor in the solar system transient performance, and therefore, it was expected that it would predict performance reasonably well.

DYNSIM and SUNSIM correlated and predicted the same economic tradeoffs (see Appendix E). SUNSIM was used to do the mixed strategies tradeoff analysis with confidence that it would predict the same tradeoffs as a more complicated method.

DYNSIM & ECON 1

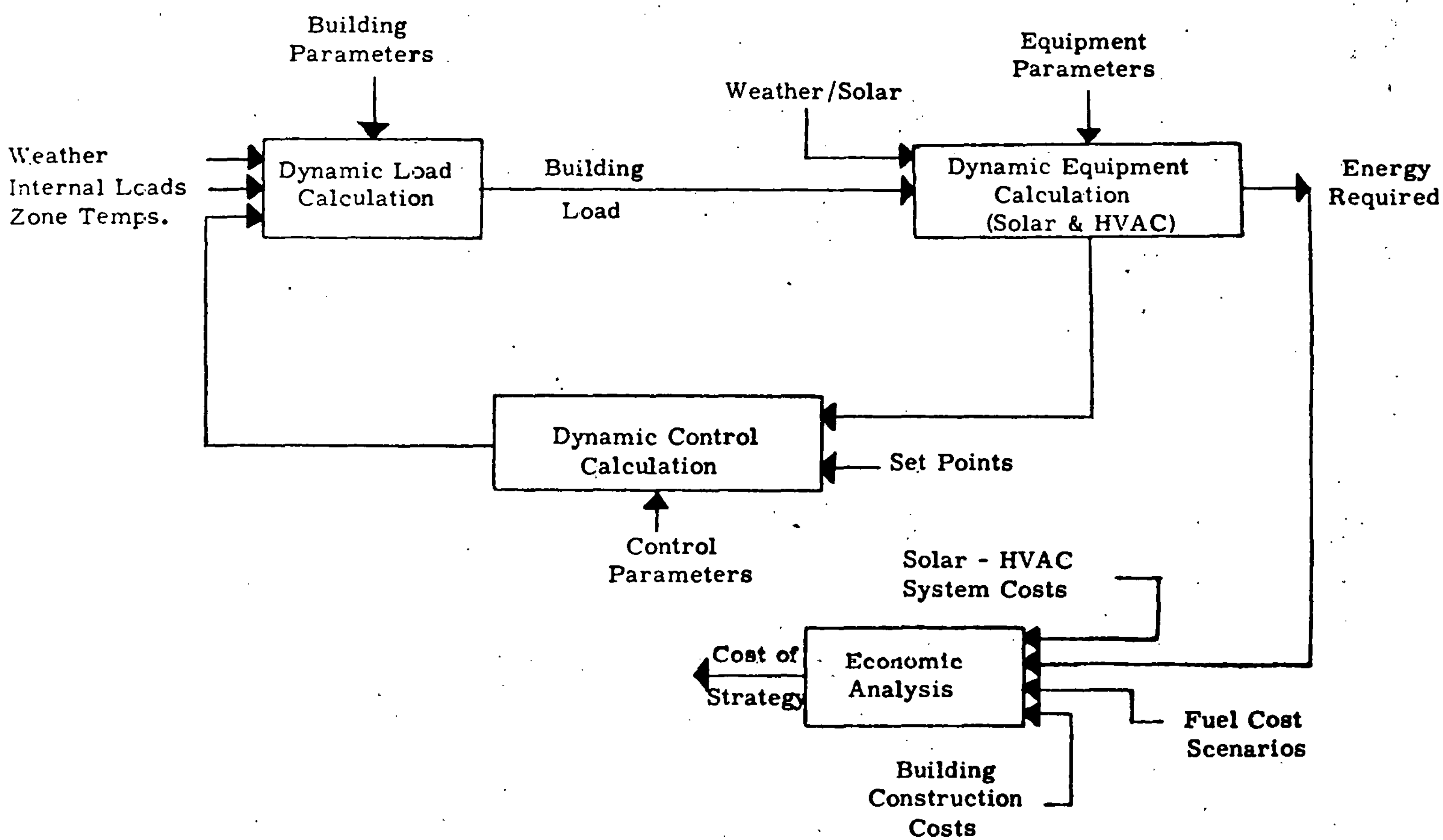


Figure 2-11. Block Diagram of the Dynamic Simulation Program

SUNSIM & ECON 1

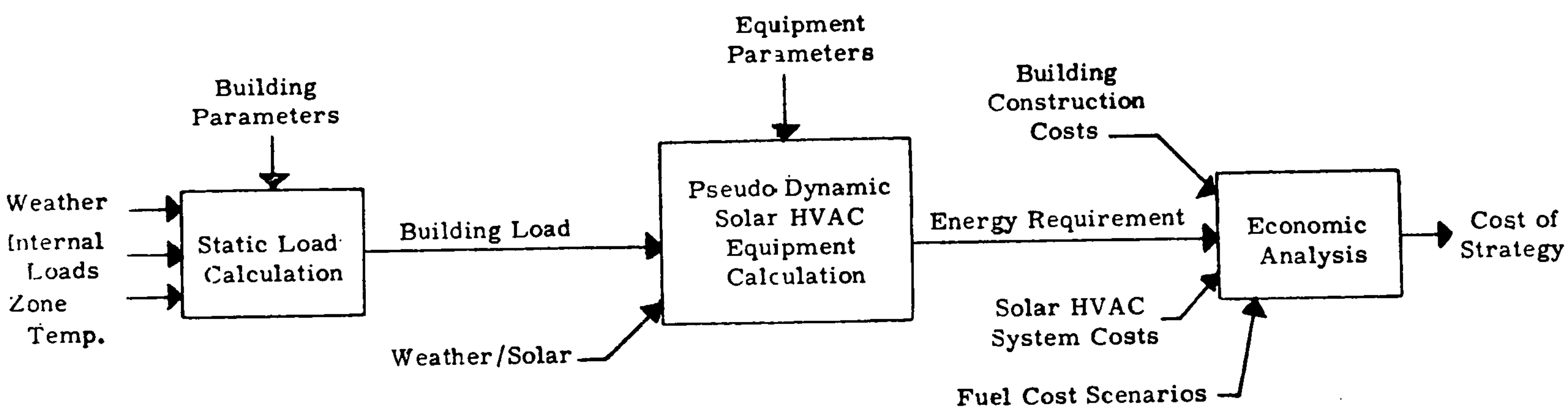


Figure 2-12. Block Diagram of Simulation Program

To make SUNSIM run even faster the number of days on the weather input was reduced. The original version used all 365 days of the year and did a hour-by-hour computation. The idea is to use only three days per month to represent the entire month. In order to reduce run costs, TRANE Co. uses a similar technique. They reduced the weather used in the TRACE program to 12 average days, one for each month and got good results. Since SUNSIM has fewer dynamics than TRACE, it seemed reasonable for SUNSIM to use fewer than 365 days. A statistical analysis of each hour of each day was done, and 3 days for each month were computed. These three are the average or mean day, a warm day (a standard deviation above mean) and a cold day (a standard deviation below mean). Also, weighting factors were calculated to make the days match the dry bulb temperature frequency of occurence histogram (binned dry bulb temperature). These weighting factors can be interpreted to be the number of each type of day that would typically occur in a month. This analysis reduced the energy year to 3 days/month or 36 days/year, a reduction by a factor of 10. Therefore, this version of SUNSIM uses 10 times less computer time.

The procedure used is to calculate the energy consumed each day and multiply it by the weighting factor, then sum these 36 answers for the year. This procedure calculates energy usage quite close to the 365 day weather calculation. See Appendix G for weather tape calculation procedure and comparison of the 36 day and 365 day calculation.

The calculation procedure was reduced to a small set of calculations making execution very fast on the computer.

SECTION III
RESULTS

INTRODUCTION

The following pages discuss the detailed analysis for each of the five building types; single and multi-family residence, retail store, office building, and school. The building characteristics are described first, followed by assumptions, the application of the solar system to the typical building, and finally, the impact of energy conservation. A comparison is also made between the expensive dynamic simulation, DYNSIM, and the faster simulation, SUNSIM.

The mixed strategy analysis shows the effect of an energy conservation technique on the percent of building energy requirement supplied by the solar system costs, and annual savings. Figure 3-1 illustrates the general trends of these three factors as a function of collector area. Note as the size of the solar system increases the effect of energy conservation decreases.

Because of the volume of data generated during this study, tables are generally used instead of curves to illustrate the effects of energy conservation on system costs and savings. Usually one collector size is selected for the table and data for each conservation technique are itemized.

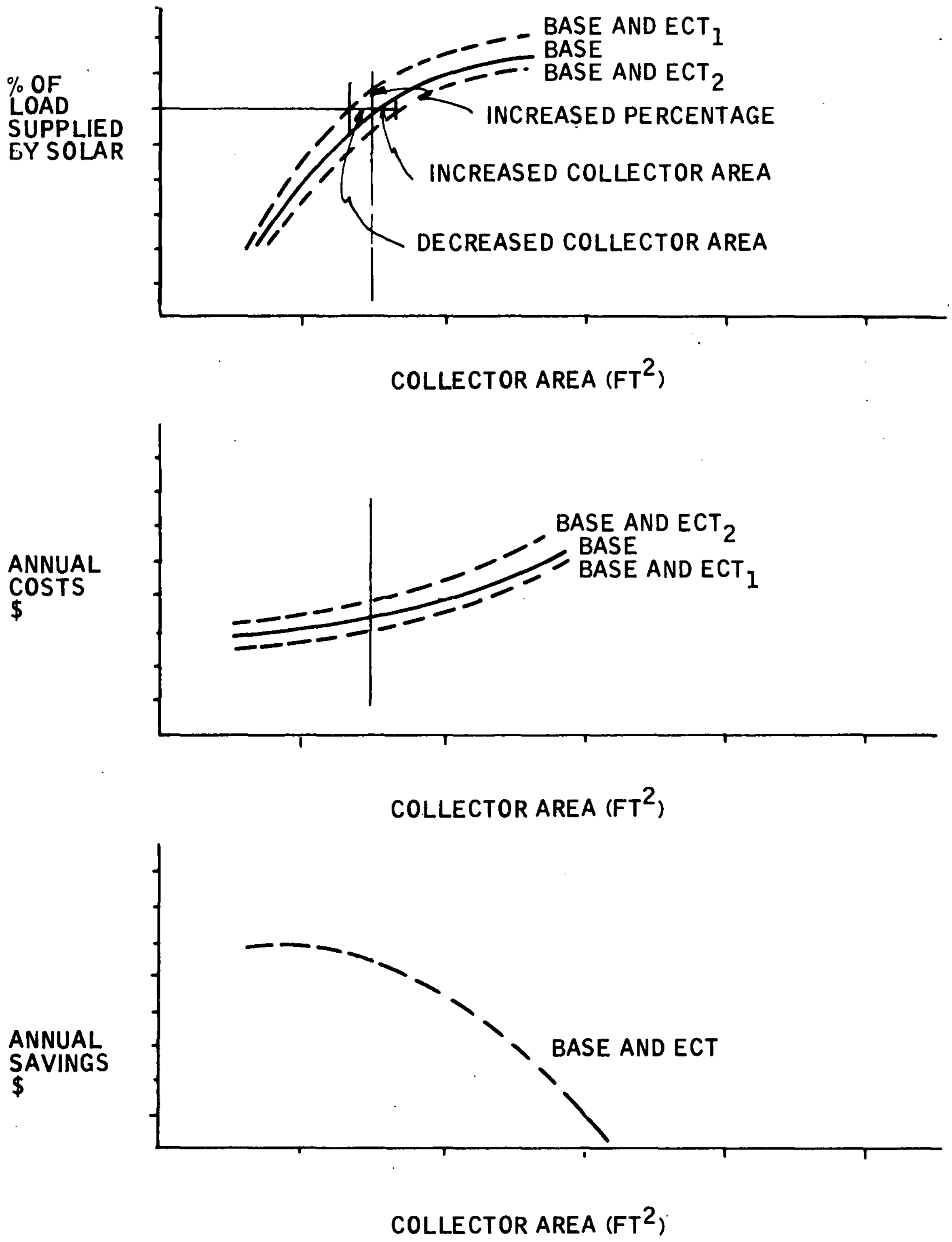


Figure 3-1. Mixed Strategy Results

3.0 DYNSIM VS SUNSIM COMPARISON

3.0.1 Building Description

The new, single-family dwelling in the North Central region was used to check the correlation of SUNSIM with DYNSIM. This building is a 1500 square foot structure with lapped wood exterior walls and a basement. The basement, house walls and ceiling are insulated and the windows are single pane with storms and there is an insulated glass sliding door. A more detailed description of the structure's construction can be found in Appendix A.

The end result of the construction is a structure with an overall transmission heat loss of 329 BTU/HR/°F. The infiltration rate of .75 air changes per hour adds another heat loss equivalent to 170 BTU/HR/°F.

3.0.2 Modeling Assumptions -- Dynamic Model Comparison

The DYNSIM model, described in detail in Appendix E, is a simulation of the dynamic response of the house temperatures, the controls, the heating system, the solar collectors and the energy storage system to the time varying stimuli of ambient temperature, internal loads and solar radiation. The internal loads accounted for are: sensible heat produced by the occupants, heat rejected from the use of lights and appliances and the heat lost from the solar storage tank into the house.

The greatest difference between DYNSIM and SUMSIM is that DYNSIM accounts for the thermal capacities of all the masses in the various systems. The effect of the inclusion of thermal capacities is to introduce lags in the system's response to a change in stimulus. For example, SUNSIM assumes that a BTU of sunshine coming through the windows instantly displaces the need for a BTU of auxiliary heat. This sort of instant trade does not occur in DYNSIM.

For example, when a furnace switches on, it does not immediately deliver its full rated output to the interior air. Rather, a large part of the heat in the combustion gases is initially lost to raising the temperature of the furnace. The length of time required to heat up the mass of the furnace depends on the thermal capacitance of the material composing it. This characteristic is modeled as a time constant; a delay in response. In this case, the furnace must consume fuel at its normal input rate for 4 minutes before it is delivering even 63 percent of its rated output to the job of raising the spaces interior temperature to the desired level.

Once warm air is being delivered to the space to be heated, the inclusion of thermal capacitances again has an effect. In SUNSIM, the walls are merely barriers to heat flow. However, in actuality, the walls absorb heat and DYNSIM takes this into account. Therefore, in DYNSIM, it is necessary to heat up both the walls and the air in order to maintain a desired interior temperature. These differences will, of course, lead DYNSIM to predict greater heating loads than SUNSIM.

The other difference between SUNSIM and DYNSIM deals with how the physical orientation of the collector was modeled. Because of differences in physical placement assumed, the collector used in DYNSIM has a greater effective area per gross square foot of collector than does the collector placement used in SUNSIM. However, both SUNSIM and DYNSIM predict that the solar system will collect around 93,000 BTU per square foot of effective area per year.

3.0.3 Results

Because of the differences between the two models, it was felt that DYNSIM, by more accurately modeling the actual operations of the systems, would yield significantly different results concerning dollar and energy savings

Table 3-1. Summary Loads, Costs and Savings DYNSIM Comparison to SUNSIM Heating and Hot Water 600 Ft^2 Collector

Comparison Cases	Total Load (BTU) x10^6	Percent Supplied By Solar %	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual BTU Saving Gas/Oil x10^6	Electric x10^6	% Savings %
DYNSIM											
Base Building	89.8	62	$1450	$1530	$1720						
High Eff. Furnace	89.8	62	$1410	$1470	$1720	$40	$60	$ 0	17 *		31 *
Night Setback	82.6	65	$1440	$1500	$1670	$10	$30	$50	7	7	8
Well Insulated	49.4	78	$1390	$1420	$1480	$60	$110	$240	40	40	45
SUNSIM											
Base Building	74.9	63	$1360	$1420	$1580						
High Eff. Furn.	74.9	63	$1330	$1370	$1580	$30	$50	$ 0	11 *		31 *
Night Setback	69.1	66	$1340	$1400	$1530	$20	$20	$50	6	6	8
Well Insulated	49.2	73	$1330	$1360	$1440	$30	$60	$140	26	26	34

*These numbers refer to savings on fuel input to furnaces (gas & oil) available from various courses of action. However, data displayed in Table 3-1 demonstrates that, with one exception, this was not the case. Notice, in particular, the dollar and BTU savings predicted by the two models. Both predict savings which are, essentially, the same.

The one exception to this close correlation between DYNSIM and SUNSIM is for the case of the well insulated house. For this house, the walls are made with 2x6's rather than 2x4's and there is 6 inches of insulation in the walls and one inch of styrofoam insulation between the siding and framing. In addition, there are 16 inches of insulation in the ceiling. Under these circumstances, the building thermal mass had a significant effect on its operating characteristics. The implication of this finding is that when assessing the effects of significant alterations to a building's thermal mass, a dynamic simulation gives a better reading on the size of the effects. SUNSIM, however, is well within engineering accuracy to be used for assessing economic tradeoffs.

Since SUNSIM was on the conservative side when it does differ from DYNSIM (i.e., predicts less of an impact than there is), and only one ECT significantly affects the structure's thermal mass and since SUNSIM is 18 times cheaper to run than DYNSIM (about $6/run compared with $110/run) the decision was made to complete the Mixed Strategies analysis using the SUNSIM model.

3.1 SINGLE FAMILY BUILDING

3.1.1 Introduction

Results for the single family residence, both new and existing, are outlined by region in the following paragraphs. The interaction of the solar system with each energy conservation technique is described. Annual costs, cost savings, and annual load savings are illustrated. Results for a specific collector area (600 $FT.^2$); the approximate design area required by the single family residence with a heating, hot water and air conditioning system are also shown.

The analysis revealed that the interaction of the solar system with the single family residences, energy conservation techniques and heating, and hot water and cooling loads followed identical trends for each city. That is, those energy conservation techniques, such as insulation, always tend to decrease heating loads and increase cooling loads. This trend is the same for all regions with the amount of change depending on the amount of insulation added. Those variables that do change with respect to regions are loads, installed costs, and fuel prices. These variables determine whether a particular energy conservation technique is cost effective.

Since resultant trends are identical for all regions, a detailed explanation of the interaction of the solar system, building loads, and energy conservation technique is provided only for the new single family residence for Omaha. Results for the existing building in Omaha and buildings in other cities are tabulated in tables illustrating loads, percent of loads supplied by solar, annual costs, annual savings, and load savings. Plots are also provided for the base single family residences in all regions to illustrate the percentage of the load supplied by a given collector area. Since building loads are known for each city, these curves also provide a relative comparison of the amount of solar radiation available in the representative cities.

3.1.2 Building Description

The single family residence chosen for the study is a one story wood frame structure with a non-conditioned attic. The representative new house has a gross first-floor area of 1,512 ft^2, while the existing house has a floor area of 1,204 ft^2. Depending upon the geographic location and whether the house is of new or existing construction, the house may have either a basement, a concrete slab-on-grade floor, or simply a crawlspace between the wood floor and the ground. These two factors also determine the level of insulation in the house. In general, new houses have better insulation than existing houses, and houses located in the North Central and Northeast regions of the country have better insulation than those in the South and West regions. A detailed description of the representative new and existing houses for each region is given in Appendix A.

The thermal performance of the building envelope is determined by the following factors: 1) the thickness and quality of the insulation in the walls, ceiling, and crawlspace (if there is one), 2) whether or not the house has storm windows and storm doors, 3) the quality and style of the window and door frames, 4) whether or not the house is adequately caulked and weatherstripped, and 5) the use of solar shading devices such as awnings.

3.1.3 Modeling Assumptions

The single family residence was modeled as a single zone conditioned space employing on-off control for both the heating and cooling functions. During the cooling mode of operation the furnace fan cycles on and off with the air conditioner. When heating either directly from the solar collectors or from the storage tank, the furnace fan and the heating coil cycle on and off together. For a gas or oil furnace there is a lag between the time the burner starts and the furnace fan starts. Also, the furnace fan continues to run after the burner has stopped. For the simulation these lags were neglected, therefore, the furnace fan and the burner run for the same length of time in this mode.

The thermostat set point was 68 °F during the heating season and 78 °F during the cooling season. It was assumed that the indoor dry-bulb temperature is equal to the thermostat set point whenever either heating or cooling are required. At all other times the indoor temperature was allowed to float within the thermostat deadband (i.e., between the heating and cooling set points). The humidity level inside the house was allowed to float at all times, thus increasing the accuracy of the cooling load calculations. The heating and cooling loads as well as the indoor moist air state, were determined by considering the heat and moisture transfers through the building envelope including solar radiation transmission through windows, and the internal loads due to occupants, lights, appliances, domestic hot water tank heat loss, and solar storage tank heat loss. The internal loads resulting from occupants, lights, and appliances were varied throughout the day according to the schedules given in Appendix B. The house infiltration was condidered to be constant at all times, except for cases of added insulation.

3.1.4 Results for Single Family Residence

Omaha-North Central Region

New Construction-Base Building--

Percent of Load Supplied by Solar vs Collector Area--The percentages of the loads supplied by the solar heating/cooling systems (Figure 3-2)are found by dividing the solar contribution to the load by the load itself. Both the heating and hot water (H and HW) curve and the heating, hot water and air conditioning (H,HW, and AC) curve increase as the collector area increases. This is because as the collector becomes larger, it is able to supply an ever increasing portion of the total load. The total load remains nearly constant as the collector area changes.

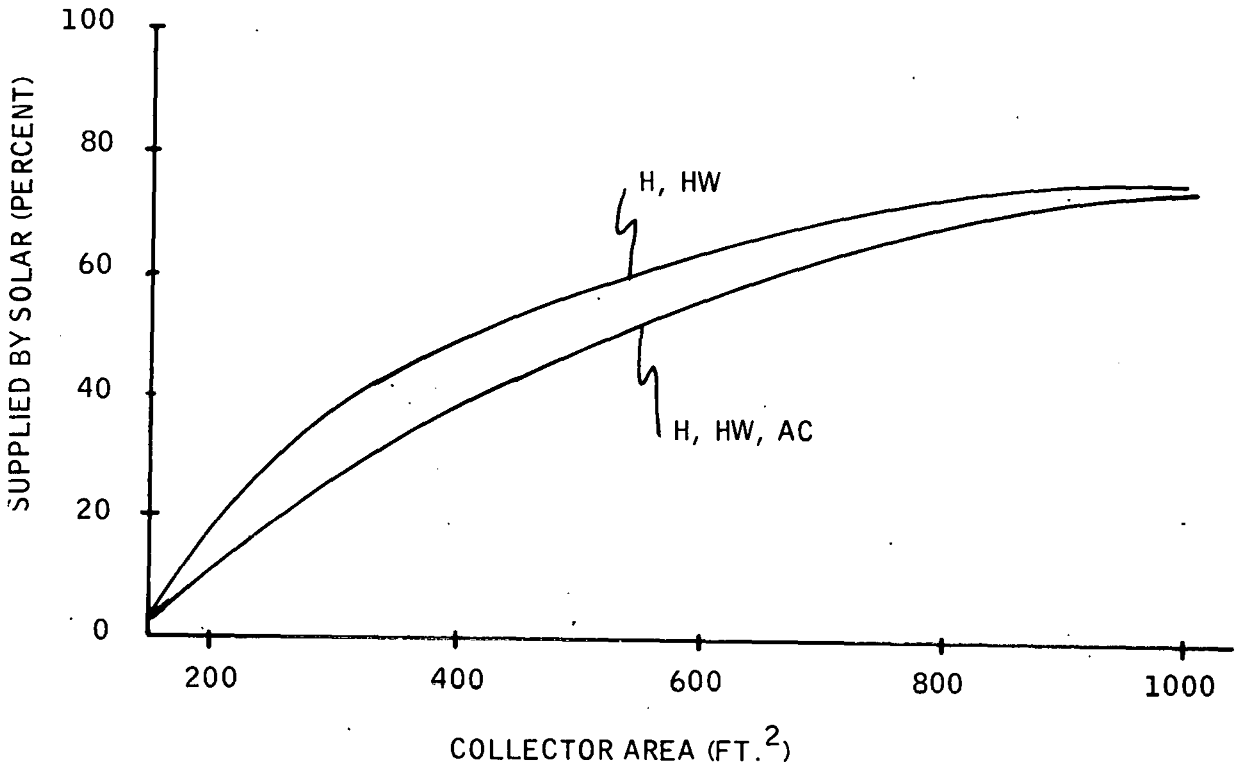


Figure 3-2. Percent of Load Supplied by Solar versus Collector Area for (New) Omaha Single-Family Base Building

The solar system can supply heating more efficiently than it can supply cooling; thus, the heating and hot water curve lies above the heating, hot water and air conditioning curve. The curves level off at high collector areas because the solar system' s storage system is unable to provide enough energy to satisfy the house' s heating requirements throughout the year especially when depleted by several days of cold weather.

Auxiliary Energy Demands vs Collector Area-- The Auxiliary energy demand (Figure 3-3) is the sum of the heating, hot water and cooling loads that cannot be met by the solar system. Both curves decrease as the collector size increases, since the solar system can supply increasingly larger portions of the load. The H, HW, and AC curve lies above the H and HW curve because the solar system can supply space heating and hot water more easily than it can supply cooling.

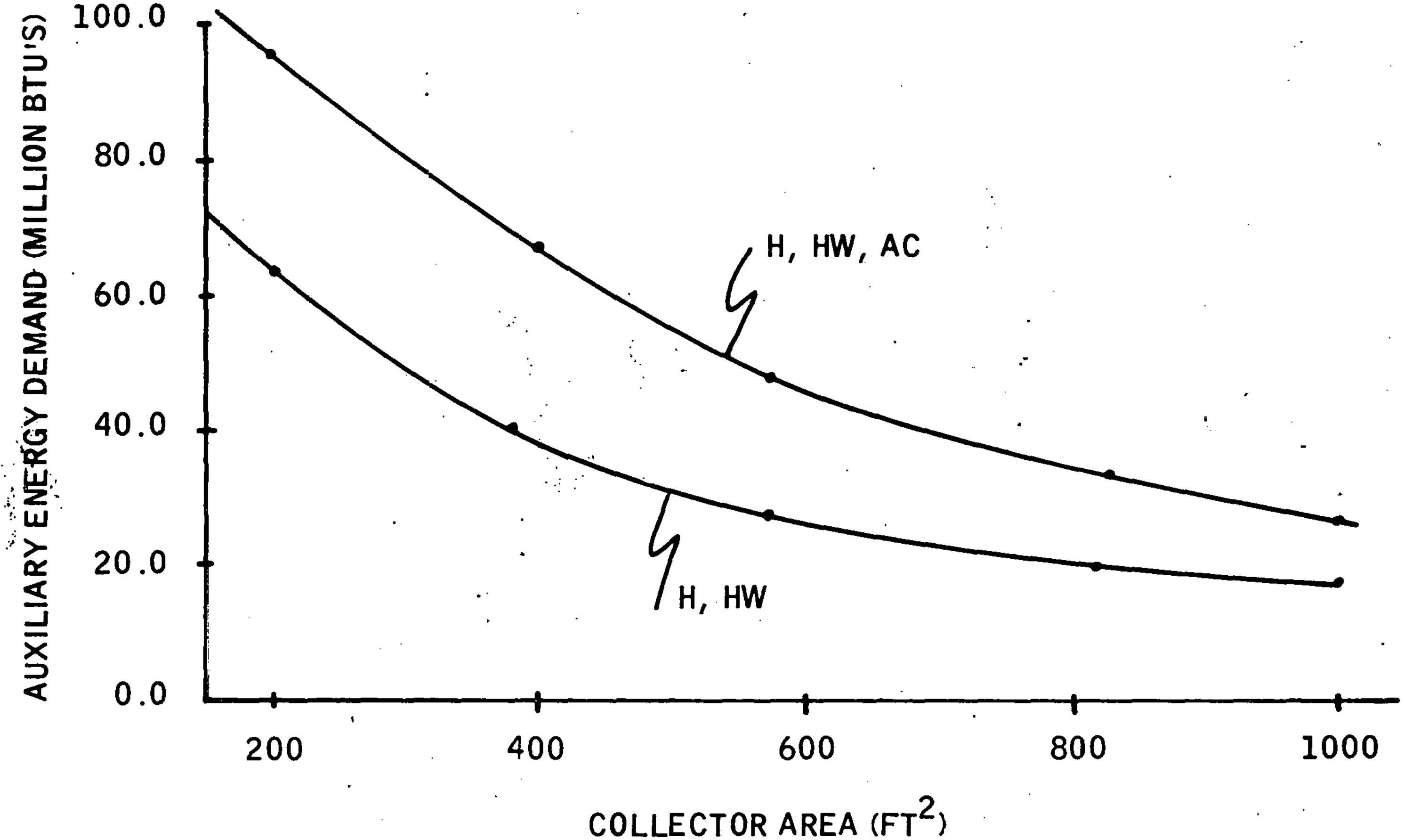


Figure 3-3. Auxiliary Energy Demand versus Collector Area for (New) Omaha Single Family Base Building

Annual Cost versus Collector Area -- Two of the graphs (Figures 3-4 and 3-5) exhibit the same trends. The H, HW, and AC curve lies above the H and HW curve simple because a system that can supply air conditioning is more expensive than one that cannot. Both curves increase as the collector area increases because collectors are fairly expensive. A minimum cost collector area exists when electricity is used as an auxiliary fuel (Figure 3-6).

Impact of Individual Energy Conservation Techniques on New Construction -- Tables 3-2 through 3-4 present results which demonstrate the energy cost impact of individual conservation techniques. Variations in annualized costs, savings, and total load are shown in Table 3-2 for solar systems supplying space and hot water heating, and in Table 3-3 for heating plus air conditioning. An in-place solar system with 600 square feet of collectors was assumed as a base case supplying about 60 percent of the load for the heating system and 50 percent of the load for the heating and air conditioning system. Any technique with a positive annual savings is cost effective and should be implemented, although the overall solar system size is not necessarily most cost effective.

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 3-4. The homeowner can choose the better investment by comparing the cost of the conservation technique with the cost of additional collector area.

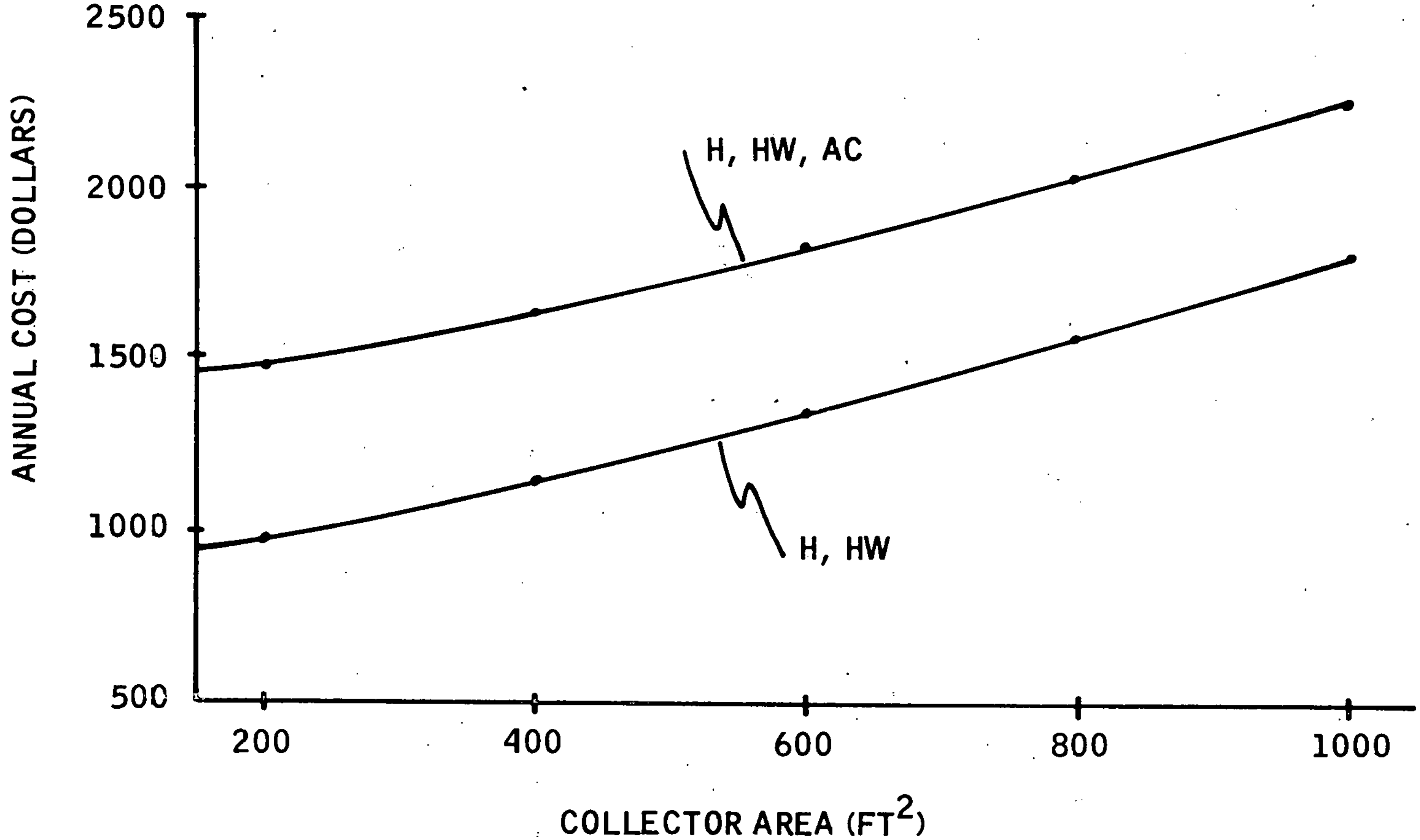


Figure 3-4. Annual Cost versus Collector Area for (New) Omaha Single Family Base Building, Gas Auxiliary Fuel

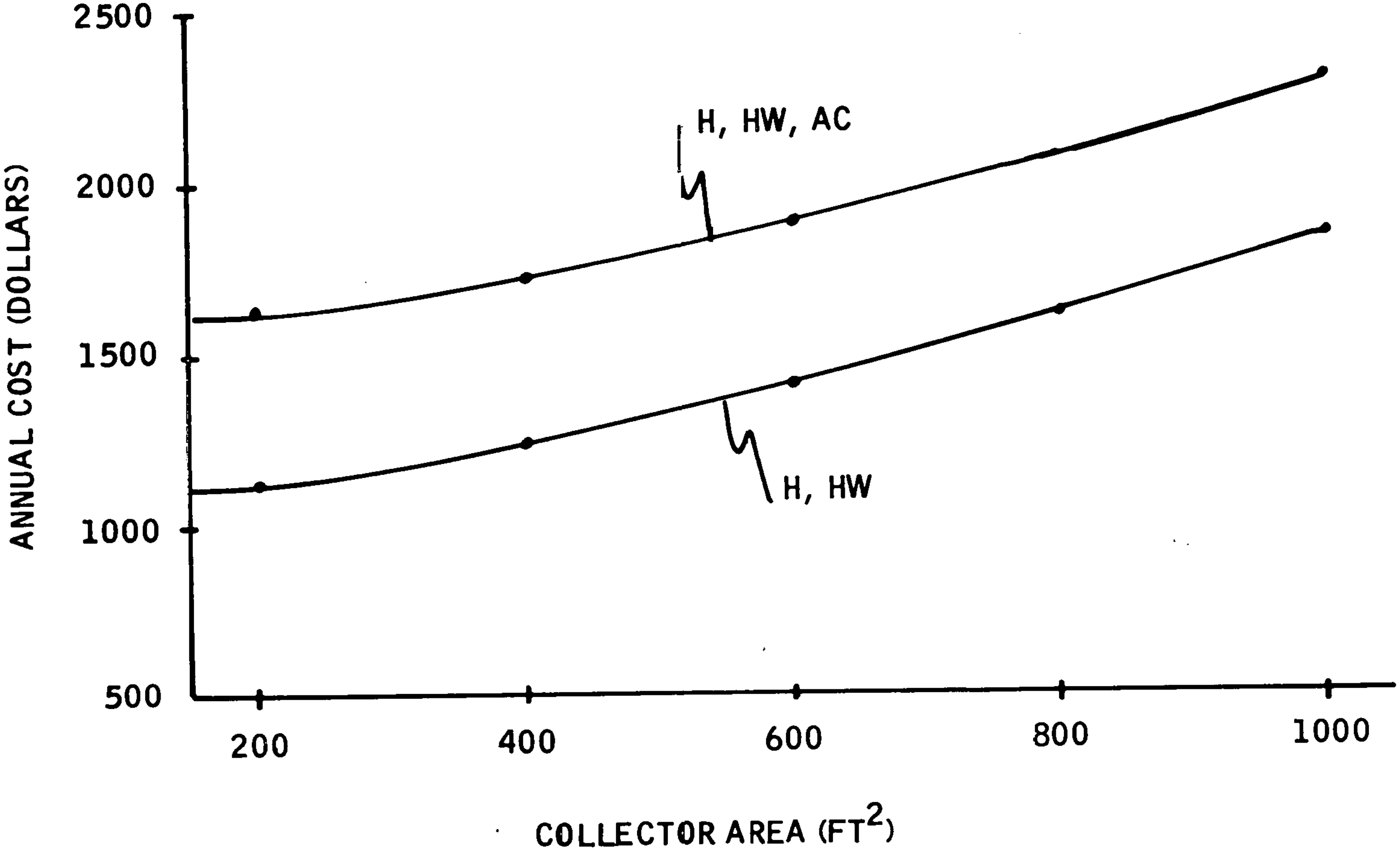


Figure 3-5. Annual Cost versus Collector Area for (New) Omaha Single Family Base Building, Oil Auxiliary Fuel

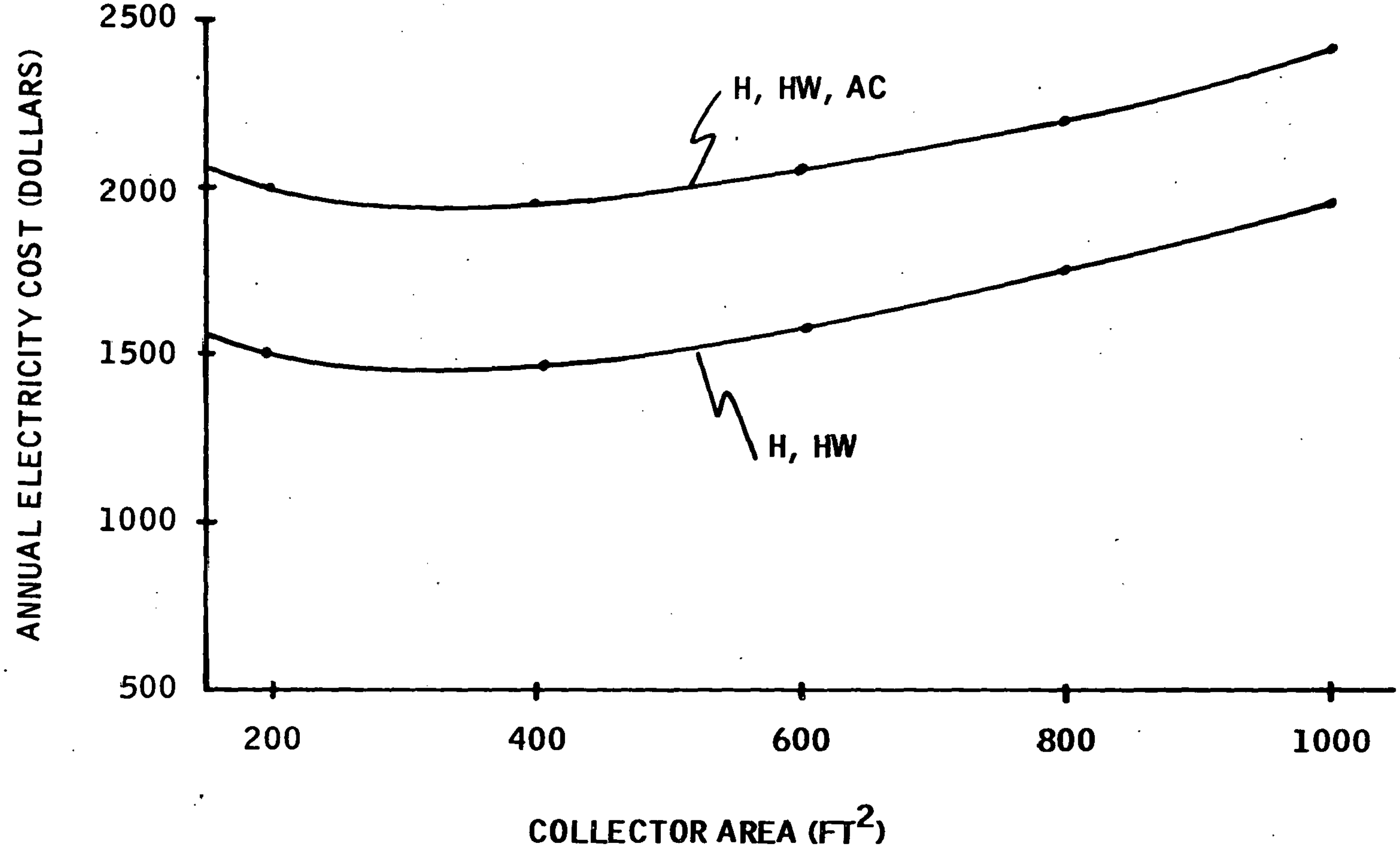


Figure 3-6. Annual Cost versus Collector Area for (New) Omaha Single Family Base Building, Electric Auxiliary Fuel

Table 3-2. Summary Loads, Costs and Savings
Omaha - New - Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft^2

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	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	2095	18	14	8	4.5	4
Awnings	102.5	59	1872	1937	2093	8	8	8	6.4	6

Table 3-3. Summary Loads, Costs and Savings
Omaha - New - Single Family
Heating and Hot Water
Collector Area - 600 Ft^2

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 3-4. Impact of Energy Conservation on Solar System Sized for 50% of Load New Single-Family Residence

ENERGY CONSERVATION TECHNIQUE	EQUIVALENT COLLECTOR AREA REDUCTION FT^2 SPACE AND HOT WATER HEATING	SPACE AND HOT WATER HEATING AND SPACE AIR CONDITIONING
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.

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 employed, namely electricity. Of course, the lowest annual cost is achieved when night setback is used in conjunction with gas, the cheapest auxiliary energy source. Night setback is equally cost effective whether cooling is employed or not. 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. Several different configurations were studied, Table 3-5. 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 3-5) is equivalent to a collector area of approximately 250 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

Table 3-5. Insulation Configurations Omaha New Single-Family Residence

Case	Exterior Walls	R	Roof and Ceiling	R	Windows	R	Doors	Infiltration	Basement	R	Costs
Base	Wood Siding	0.81	6" Loose Fill Ins.	13.00	Single Pane and Storm		Solid Wood with Storm	.74 ACH	12" Block	2.27	Base
	.5" Ply. Sheating	0.62	2x6 Joists	6.86			U = 0.19		.75" styrofoam	3.00	Case
	3.5" Batt Insul.	11.00	.75" Plaster	0.47			Sliding Glass Patio Door		.5" Gypsumbd.	.45	
	2x4 Studs						U = .65				
	.5" Gypsumbd.	0.45									
1	Wood Siding	0.81	12" Batts Insul.	38.00	Insulated Glass		Same	.45	Same		855
	2" Styrofoam	10.82	2x6 Joists	6.85	Double (1/4")						
	3.5" Batt Insul.	11.00	.75" Plaster	0.47	and Storm U = 0.36						
	2x4 Studs	4.35									
	.5" Gypsumbd.	0.45									
2	Wood Siding	0.81	Same		Same		Same	.50	Same		944
	.5" Plywood Sheating	0.62									
	6" Batt Insul.	19.00									
	2x6 Studs	6.75									
	5" Gypsumbd.	0.45									
3	Wood Siding	0.81	Same		Same		Same	.45	Same		958
	1" Styrofoam	5.41									
	6" Batt Insul.	19.00									
	2x6 Studs	6.85									
	.5" Gypsumbd.	0.45									
4	Wood Siding	0.81	Same		Same		Same	.375	Same		1180
	2" Styrofoam	10.82									
	6" Batt Insul.	19.00									
	2x6 Studs	6.85									
	5" Gypsumbd.	0.45									

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 very 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.

High Efficiency Lights -- The same lighting level as for the base case was maintained but the energy requirement and heat output were reduced. Since the lights normally supply a substantial portion of the heating load, the heating load goes up for this case. However, the solar system is able to supply most of this increased load. Since the internal load has decreased, the air-conditioning load goes down. The large savings on the electric bill combined with the low installed cost of this ECT make it cost effective.

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 aheating 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 three sides of the house, east, south and west. They were assumed to be down in summer and up in winter. Awnings have the same effect on the total load as that described for reflective film. However, due to their relatively high installed cost, they are not cost effective.

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 most attractive combination of solar and conservation techniques, Figures 3-7 and 3-8 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:

- Improved thermal envelope (Case 5 from Table 3-5)
- Night setback

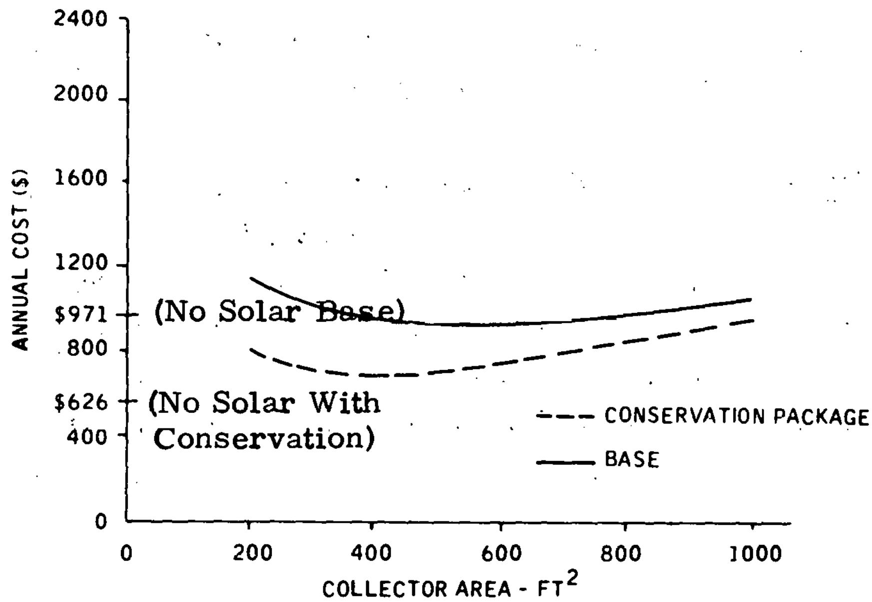


Figure 3-7. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel, for Space and Hot Water Heating System, 1/2-Price Solar System

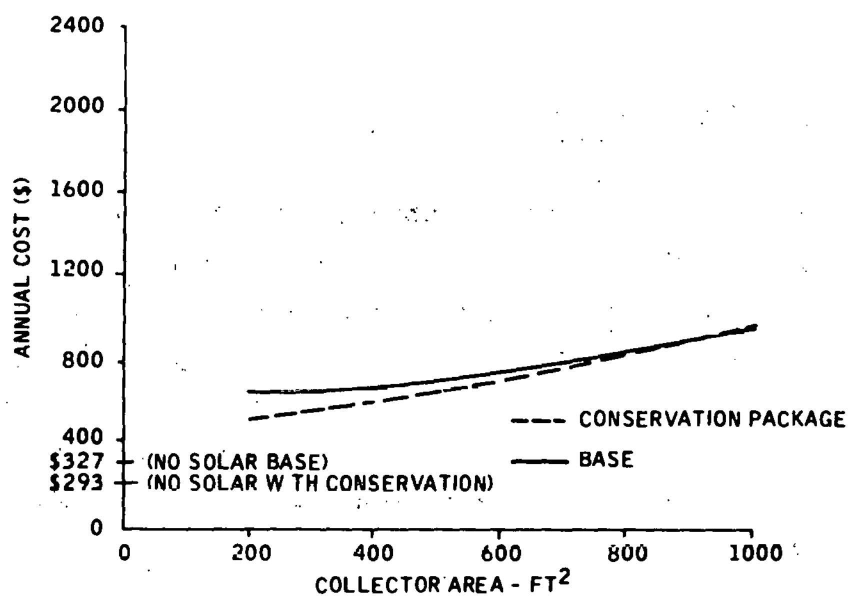


Figure 3-8. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, for Space and Hot Water Heating System, 1/2-Price Solar System

- High efficiency gas furnace
- Improved hot water system

Figure 3-7 illustrates that for the electric auxiliary system, the base case has a minimum annual cost at about a 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 feet square). Notice that conservation techniques have a greater impact as the collector area is reduced.

Natural gas system performance is shown in Figure 3-8. 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.

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 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. As could happen through government incentives or a technological breakthrough.

Figures 3-9 and 3-10 present data directly comparable to the orginal scenario except that fuel prices escalate at 10 percent per year. Here, it is seen that properly sized solar systems are 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.

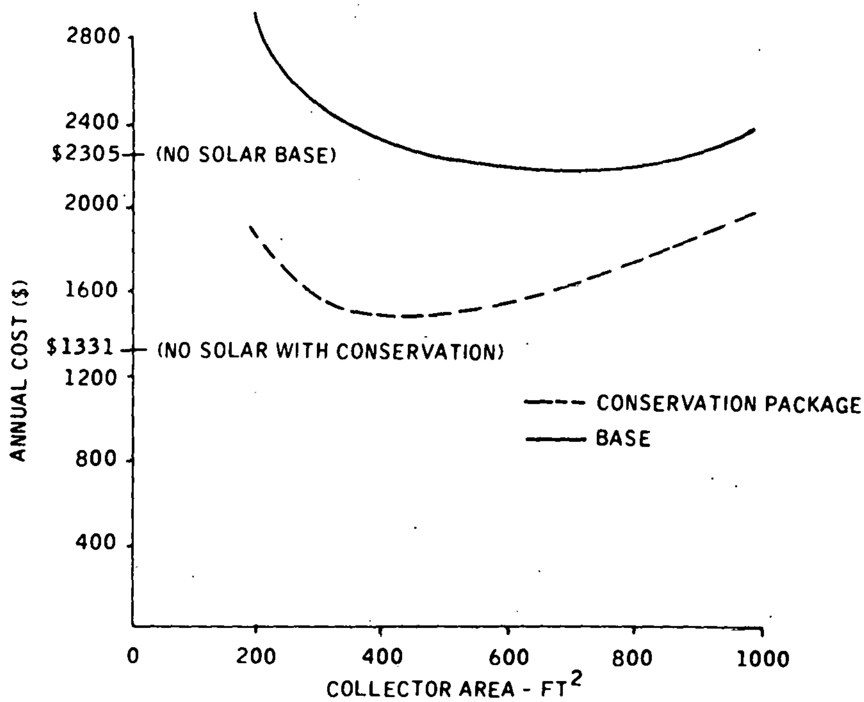


Figure 3-9. Annual Cost vs. Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel, for Space and Hot Water Heating System, Escalated Fuel Costs

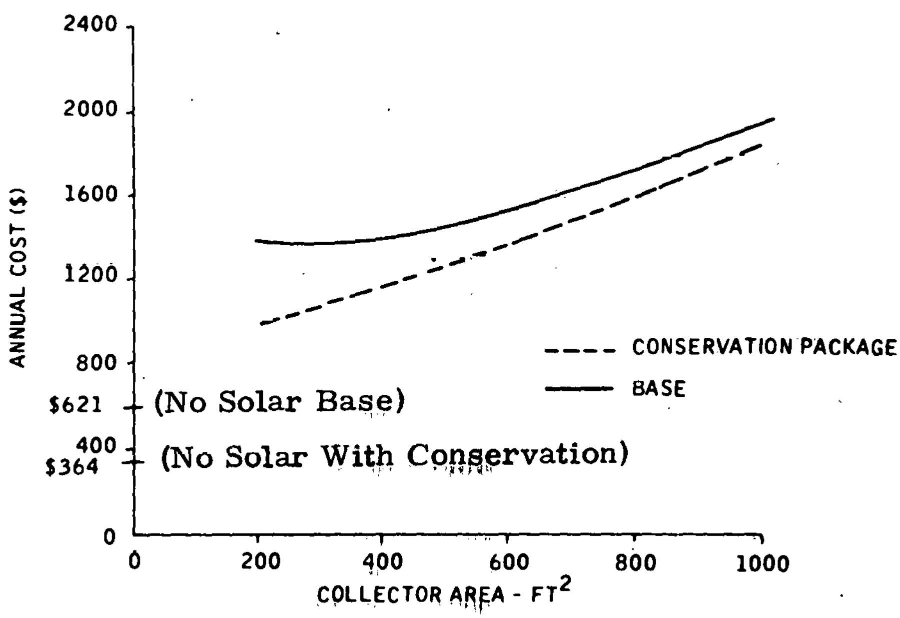


Figure 3-10. Annual Cost vs. Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, for Space and Hot Water Heating System, Escalated Fuel Costs

The effects of reduced initial system costs are shown in Figures 3-11 and 3-12. With this assumption, a natural gas auxiliary solar system is still not justified although the annual cost difference between a solar and nonsolar system is significantly less than that which occurs under the base scenario.

Omaha-North Central Region

Existing Construction -- Summary-results for the existing single family residence in Omaha are illustrated in Figure 3-13 and Tables 3-7 and 3-8. Four cases of insulation were analyzed (Table 3-6). All were found to be cost effective; even though considerable expense was involved in retrofitting the existing single family residence.

Air economizers were not cost effective for existing buildings because the cooling load is less for the existing building; there being less insulation. In addition, the retrofit and operating costs for the air economizer do not offset the reduced operating costs for the solar/rankine air conditioning system.

New York-North East Region

New Construction -- Results for the new single family residence in New York are summarized in Figure 3-14 and Tables 3-9 and 3-10.

Four levels of insulation were analyzed. These are summarized in Appendix A, Vol. III. All were cost effective for heating and hot water systems. Where cooling was considered, all cases were cost effective for oil and auxiliary fuels. None were cost effective where gas was used.

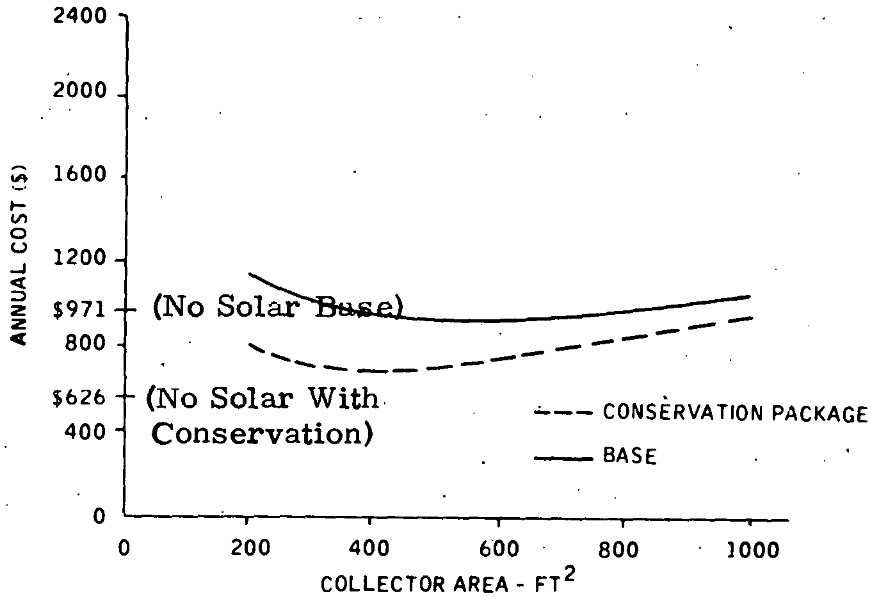


Figure 3-11. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Electric Auxiliary Fuel, 1/2-Price Solar System

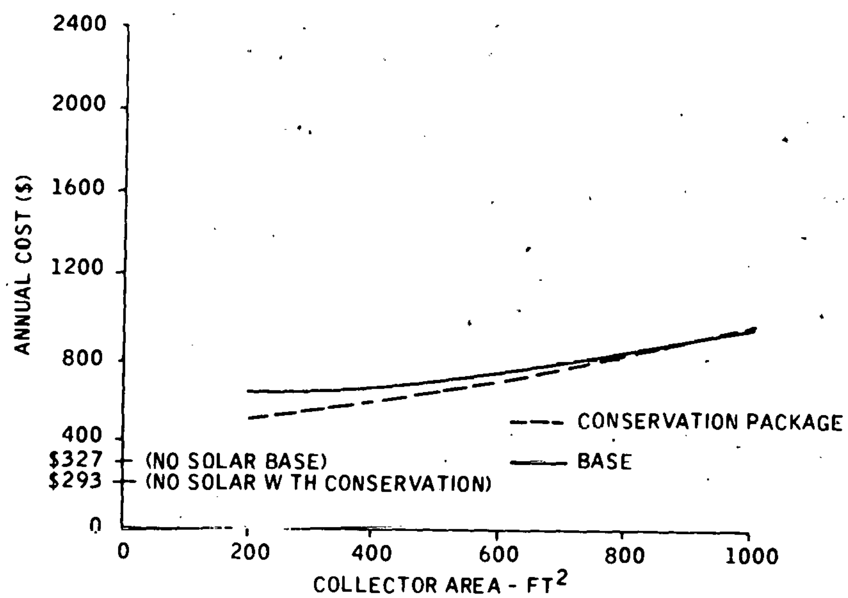


Figure 3-12. Annual Cost versus Collector Area Omaha Single-Family Residence (New) Gas Auxiliary Fuel, 1/2-Price Solar System

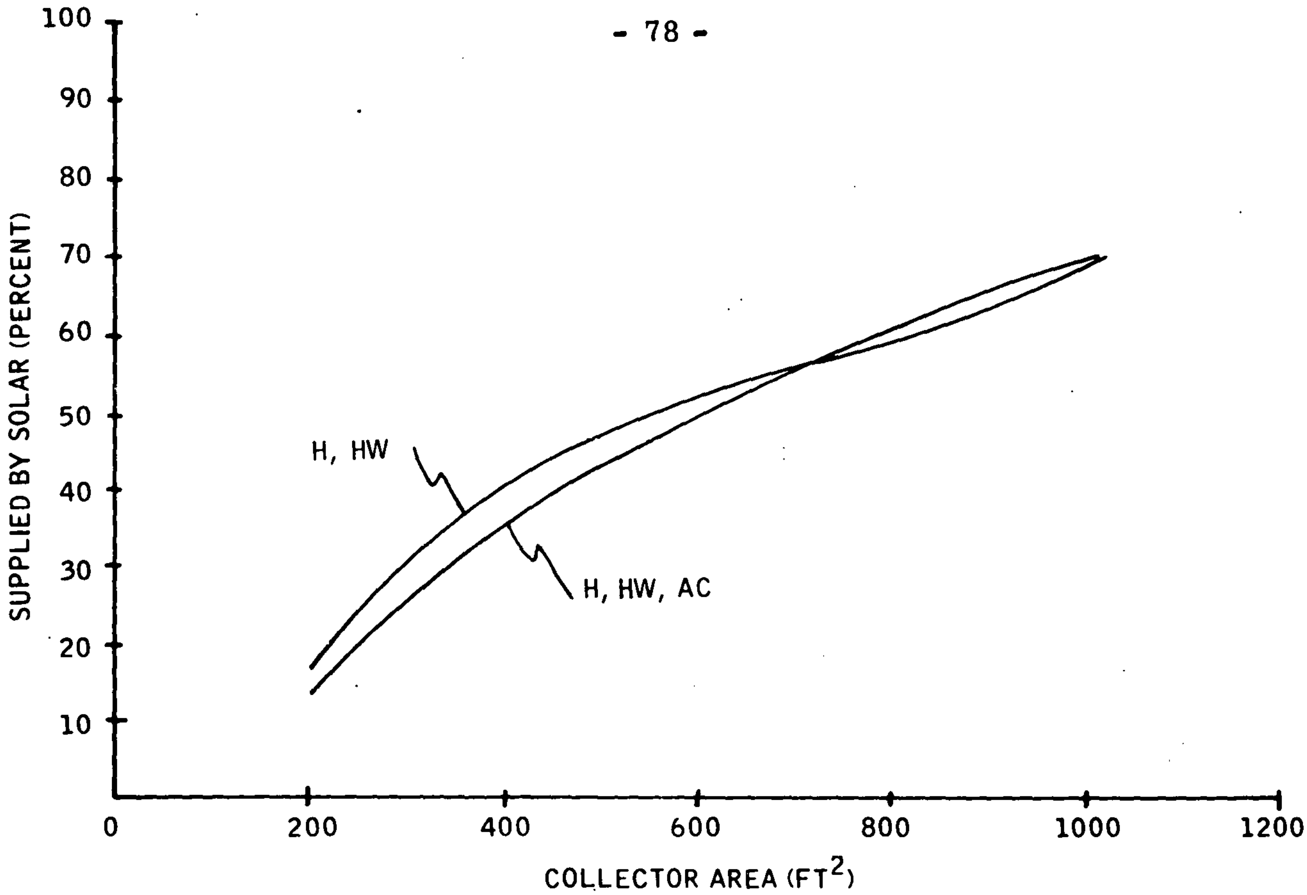


Figure 3-13. Percent of Load Supplied by Solar versus Collector Area for (Existing) Omaha Single Family Base Building

Table 3-6. Insulation Package Costs for Existing Single-Family Residences

Case No.	Additions/Alterations	Infiltration (Air Change/Hr)	Cost For Omaha (1976)
1	12" Loose Fill in Ceiling Storm Windows		$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 3-7. Summary Loads, Costs and Savings
Omaha Single Family - Existing
Heating, Hot Water, Air Conditioning
Collector Area - 600 Ft^2

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	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	2037	2168	2477	3	-4	-19	.3	0
Awnings	132.2	52.4	2037	2161	2455	3	3	3	5.2	4

Table 3-8. Summary Loads, Costs and Savings
Omaha - Single Family - Existing
Heating and Hot Water

COLLECTOR AREA = 600 FT^2

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	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

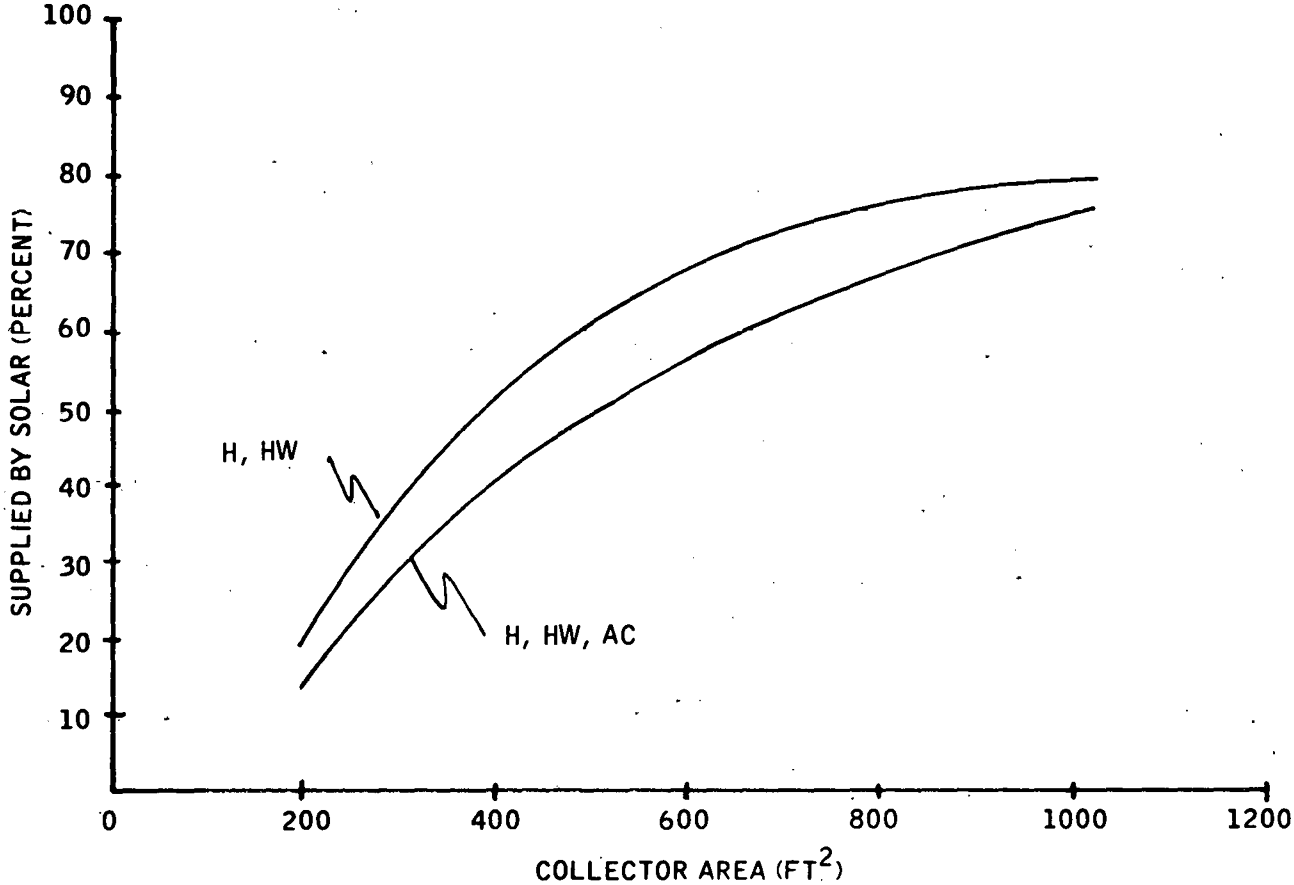


Figure 3-14. Percent of Load Supplied by Solar versus Collector Area for (New) New York Single Family Base Building

Table 3-9. Summary Loads, Costs and Savings
New York - New - Single Family
Heating, Hot Water, Air Conditioning
Collector Area - 600 Ft^2

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	84.8	56	1886	1907	2087					
Night Setback	79.3	57	1869	1887	2039	17	20	48	5.5	6
Increased House Insulation Case 1	71.0	57	1890	1901	2001	-4	6	86	13.8	16
Increased Insul. Case 2	71.2	57	1895	1907	2010	-9	0	77	13.6	16
Increased Insul. Case 3	70.8	57	1892	1904	2002	-6	3	85	14.0	16
Increased Insul. Case 4	69.5	56	1906	1916	2007	-20	-9	80	15.3	18
Insulate Hot Water & Decrease Temp.	78.9	59	1855	1872	2016	31	35	71	5.8	7
Air Economizer	76.1	63	1874	1893	2062	12	14	25	8.7	10
High Eff. Furn.	84.8	56	1875	1893	2087	9	14	N/A	0	0
High Eff. Lights	83.8	58	1739	1752	1951	157	155	136	1.0	1
Reflective Film	82.4	62	1875	1898	2088	11	9	-1	2.4	3
Awnings	80.6	59	1881	1902	2086	5	5	1	1.2	2

Table 3-10. Summary Loads, Costs and Savings
New York - New - Single Family
Heating and Hot Water
Collector Area - 600 Ft^2

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	61.6	67	1352	1373	1554					
Night Setback	56.0	69	1332	1350	1502	20	23	52	5.6	9
Increased Insul. Case 1	45.0	75.0	1330	1342	1441	22	31	113	16.6	27
Increased Insul. Case 2	45.3	75.2	1340	1352	1455	12	21	99	16.3	26
Increased Insul. Case 3	44.6	75.1	1341	1353	1455	11	20	99	15.3	25
Increased Insul. Case 4	42.4	75.6	1338	1349	1440	14	24	114	19.2	31
Insulate Hot Water & Decrease Temp	57.4	71.5	1334	1351	1495	18	22	59	4.1	7
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NA
High Eff. Furn.	61.6	67	1343	1359	1554	9	14	N:A	0	0
High Eff. Lights	65.4	65	1233	1256	1456	119	117	98	-3.8	6
Reflective Film	66.4	68	1396	1418	1609	-44	-35	-55	-4.9	-9
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

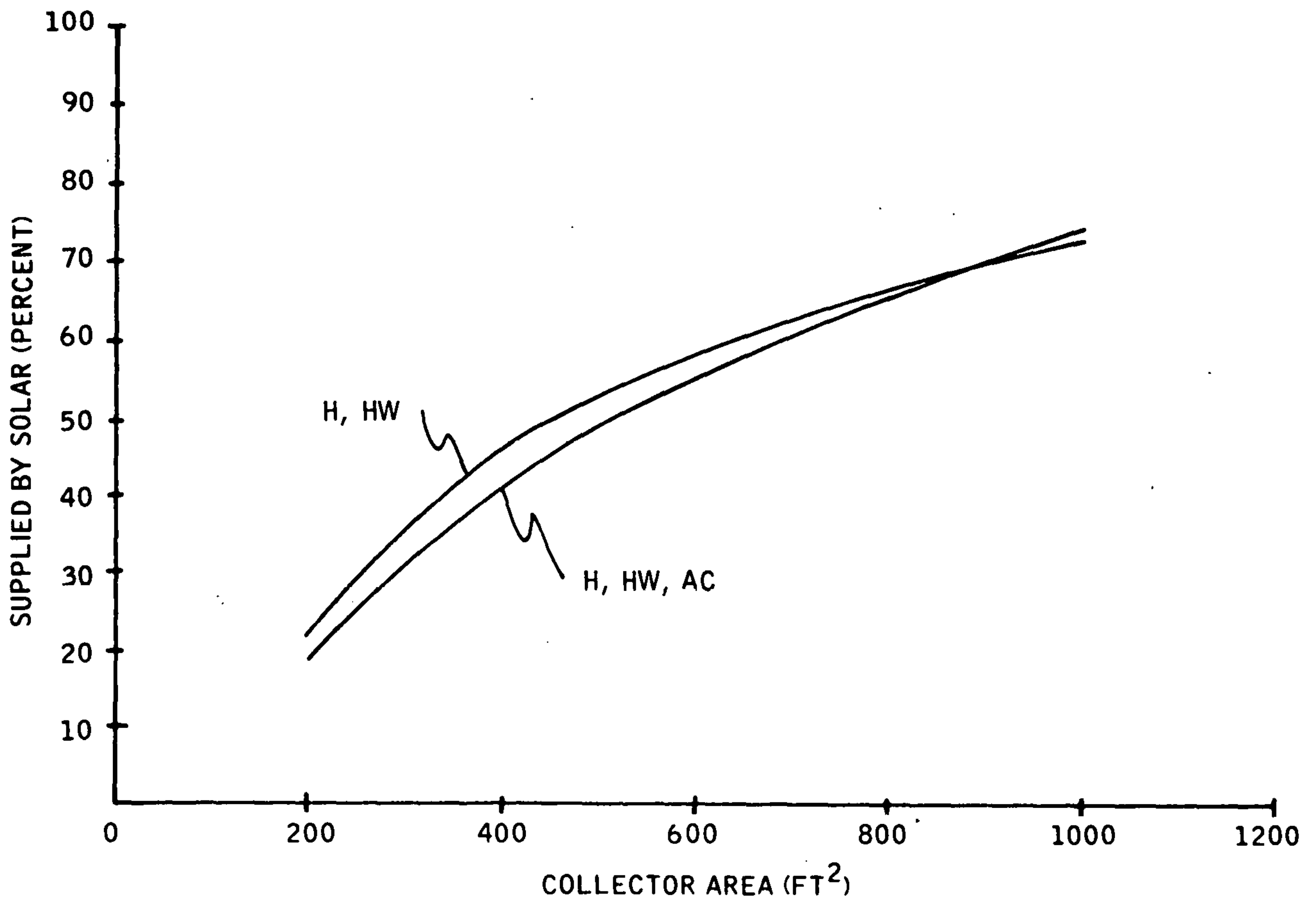


Figure 3-15. Percent of Load Supplied by Solar versus Collector Area for (Existing) New York Single Family Base Building

New York-North East Region

Existing Construction -- Results for the Existing single family residence in New York are summarized in Figure 3-15 and Tables 3-11 and 3-12. The four cases of insulation (tabulated in Appendix A, Vol III) were cost effective for all auxiliary fuel types. The air economizer was not cost effective. Savings resulting from using the air economizer for cooling were not sufficient to offset installed and operating costs. Reflective window films were not cost effective. The reduction in the cooling load and the costs savings that resulted from reduced utilization of the solar cooling system did not offset the cost of the reflective film. Awnings also were not cost effective: the reasons being similar to those for reflective film.

Table 3-11. Summary Loads, Costs and Savings
New York - Single Family - Existing
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft^2

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	104.8	54.9	2024	2063	2398					
Night Setback	96.9	56.3	2000	2035	2330	24	28	68	7.9	8
Increase Insul. Case 1	92.3	58.7	1995	2025	2283	29	38	115	12.5	12
Increase Insul. Case 2	86.1	60.2	1990	2017	2240	34	46	158	18.7	18
Increase Insul. Case 3	66.4	66.6	1969	1981	2089	55	82	309	38.4	37
Increase Insul. Case 4	62.8	66.3	1977	1988	2083	47	75	315	42.0	40
Increase Hot Water Tank & Decrease Temp.	99.5	58.0	1997	2031	2328	27	32	70	5.3	5
Air Economizer	101.5	56.4	2047	2085	2416	-23	-22	-18	3.3	3
High Eff. Furn.	104.8	54.9	2007	2033	2445	17	29	-47		0
High Eff. Lights	105.6	55.7	1939	1980	2332	85	83	66	-0.8	1
Reflective Film	106.5	57.2	2033	2074	2427	-9	-11	-29	-1.7	-2
Awnings	101.5	56.9	2025	2064	2398	-1	-1	0	3.3	3

Table 3-12. Summary Loads, Costs and Savings
New York - Single Family - Existing
Heating and Hot Water
Collector Area - 600 Ft^2

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	90.3	58.1	1565	1604	1939					
Night Setback	82.4	59.4	1538	1572	1868	27	32	71	7.9	9
Increase Insul. Case 1	78.0	62.5	1533	1563	1821	32	41	118	12.4	14
Increase Insul. Case 2	71.2	64.6	1522	1548	1771	43	36	168	19.0	21
Increase Insul. Case 3	49.7	75.4	1471	1483	1591	94	121	348	40.6	45
Increase Insul. Case 4	45.2	76.3	1479	1490	1585	86	113	354	45.1	50
Increase Hot Water Tank & Decrease Temp.	86.0	61.0	1546	1580	1877	19	24	62	4.3	5
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	90.3	58.1	1548	1574	1986	17	30	-47	.01	-
High Eff. Lights	93.8	57.5	1503	1544	1896	62	60	43	-3.5	4
Reflective Film	96.1	58.5	1608	1649	2002	-43	-45	-63	-5.8	-6
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Atlanta-South East Region

New Construction -- Results for the new single family residence in Atlanta are summarized in Figure 3-16 and Tables 3-13 and 3-14. In addition, four cases of insulation were analyzed, tabulated in Appendix A, Vol. III. None were cost effective where air conditioning was considered. For heating and hot water systems, additional insulation was cost effective only where electricity was used as the auxiliary fuel.

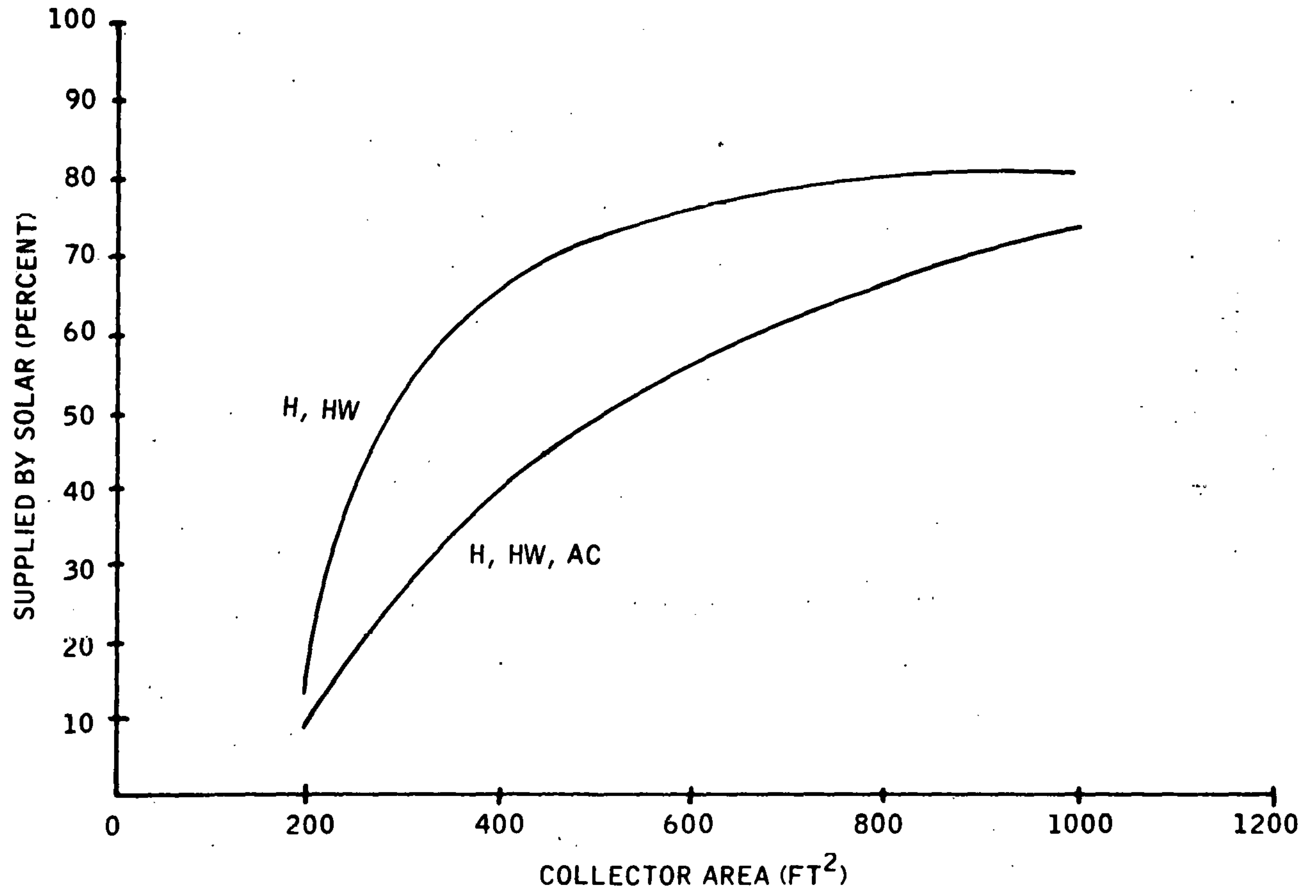


Figure 3-16. Percent of Load Supplied by Solar versus Collector Area for (New) Atlanta Single Family Base Building

Table 3-13. Summary Loads, Costs and Savings
Atlanta - New - Single Family
Heating, Hot Water, Air Conditioning

COLLECTOR AREA = 600 FT.^{2}

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	100.5	55.3	1937	1955	2041					
Night Setback	93.4	54.8	1933	1949	2026	4	6	15	7.2	7
Insul. Case 1	85.5	52.5	1970	1982	2039	-33	-27	2	15.0	15
Insul. Case 2	86.1	52.8	1975	1986	2044	-38	-31	-3	14.4	14
Insul. Case 3	85.5	52.4	1976	1988	2045	-39	-33	-4	15.1	15
Insul. Case 4	81.6	51.9	1998	2009	2061	-61	-54	-20	18.9	19
Insul. Hot Wat. Tank Decrease Water Temp.	93.4	59.2	1903	1915	1969	34	40	72	7.2	7
Awnings	94.9	59.0	1931	1948	2034	6	7	7	5.6	6
Air Economizer	90.3	61.4	1921	1936	2012	16	19	29	10.2	10
High Eff. Furn	100.5	55.3	1928	1954	2041	9	1	0	0	0
High Eff. Lights	96.4	59.2	1787	1805	1894	151	150	147	4.1	4
Reflective Film	91.1	64.1	1886	1902	1981	51	53	60	9.5	9

Table 3-14. Summary Loads, Costs and Savings
Atlanta - New - Single Family
Heating and Hot Water
Collector Area - 600 Ft^2

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	53.9	76.4	1281	1299	1385					
Night Setback	48.7	76.5	1274	1290	1367	7	9	18	5.2	10
Insul. Case 1	37.4	77.4	1298	1310	1367	-17	-11	18	16.5	31
Insul. Case 2	38.2	77.5	1304	1316	1374	-23	-17	11	15.7	29
Insul. Case 3	37.2	77.3	1303	1315	1372	-22	-16	13	16.7	31
Insul. Case 4	33.7	76.8	1325	1335	1388	-44	-36	-3	20.2	37
Insul. Hot Wat. Tank & Decre. Water Temp.	48.8	83.4	1261	1272	1327	20	27	58	5.1	9
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	53.9	76.4	1272	1298	1385	9	1	0	0	0
High Eff. Lights	56.0	76.6	1170	1189	1277	111	110	107	-2.1	-4
Reflective Film	57.1	79.6	1306	1322	1401	-25	-23	-16	-3.2	-6
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

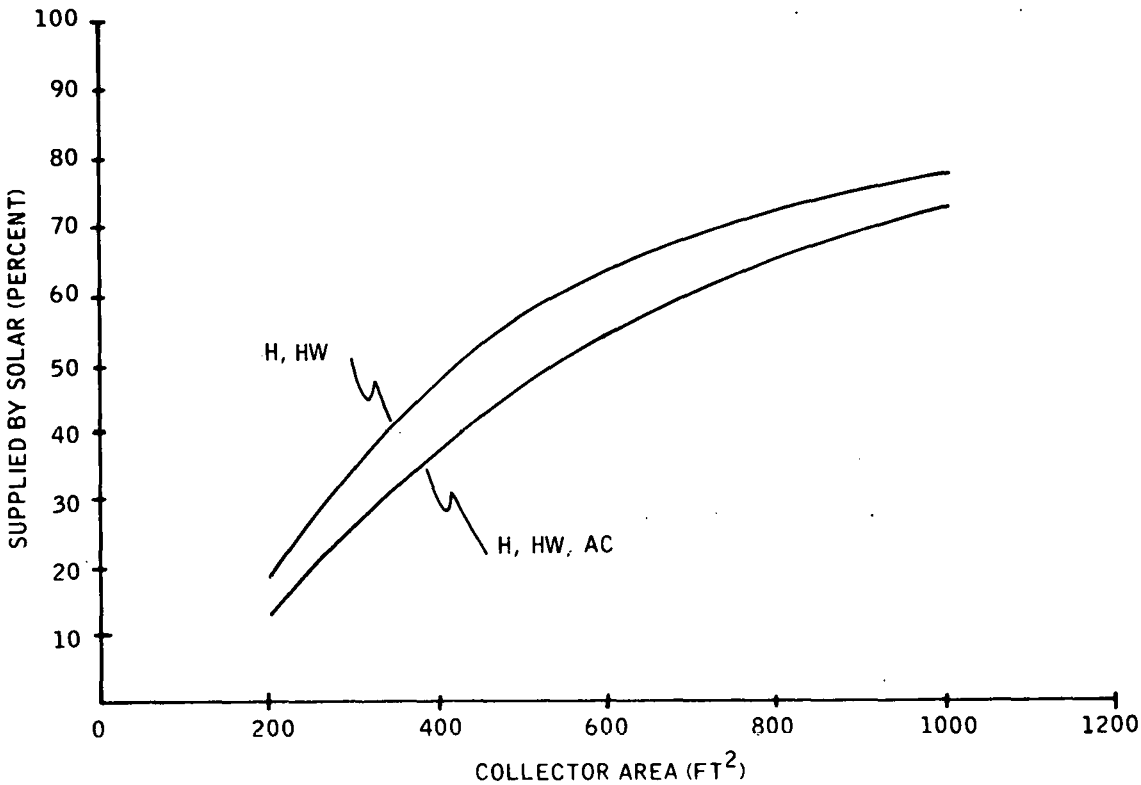


Figure 3-17. Percent of Load Supplied by Solar versus Collector Area for (Existing) Atlanta Single Family Base Building

Atlanta-South East Region

Existing Construction -- Results for the existing single family residences in Atlanta are summarized in Figure 3-17 and Tables 3-15 and 3-16 (tabulated in Appendix A, Volume III). In addition, four cases of insulation were found to be cost effective for all auxiliary fuel types. In contrast to the new building, the existing building was poorly insulated. The air economizer was not cost effective for the existing single family residence. Installed and operating costs were greater than savings that resulted from reduced usage of the solar/rankine cooling system. Awnings and reflective films (for oil and electric auxiliary fuels) were not cost effective. In both cases, installed costs were greater than savings.

Table 3-15. Summary Loads, Costs and Savings Atlanta - Existing - Single Family Heating, Hot Water, Air Conditioning Collector Area - 600 Ft^2

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	147.7	54.8	2142	2195	2456					
Night Setback	136.2	57.2	2102	2145	2356	40	50	100	11.5	8
Insul. Case 1	137.9	57.5	2119	2164	2384	23	31	72	9.8	7
Insul. Case 2	90.55	62.6	2029	2046	2127	113	149	329	57.14	39
Insul. Case 3	76.1	61.4	2054	2066	2126	88	129	330	71.62	48
Insul. Case 4	73.5	61.3	2003	2075	2131	139	120	325	74.2	50
Insul. Hot Water Tank Decrease Water Temp.	141.7	56.8	2116	2164	2397	26	30	59	6.0	4
Air Economizer	145.6	56.2	2161	2213	2465 1	-19	-18	-9	2.10	1
High Eff. Furn	147.7	54.8	2105	2145	2456	37	50	0	0	0
High Eff. Lights	147.	55.7	2065	2121	2393	77	74	63	.6	0
Reflective Film	147.2	56.8	2140	2196	2468	2	-1	-12	.5	0
Awnings	144.0	56.2	2147	2201	2462	-5	-6	-6	3.7	2

Table 3-16. Summary Loads, Costs and Savings
Atlanta - Existing - Single Family
Heating and Hot Water
Collector Area - 600 Ft^2

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	108.5	64.4	1553	1606	1867					
Night Setback	97.0	67.8	1510	1553	1764	43	53	103	11.5	11
Insulation Case 1	100.7	67.6	1539	1584	1804	14	22	63	7.8	7
Insulation Case 2	54.8	77.9	1439	1456	1538	114	150	329	53.7	50
Insulation Case 3	40.1	77.9	1459	1471	1530	94	135	337	68.4	63
Insulation Case 4	37.4	77.6	1466	1478	1534	87	128	333	71.1	66
Insul. HW Tank Decr. Water Temp.	10[illegible].9	66.7	1535	1583	1816	18	23	51	4.5	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. Furnace	108.5	64.4	1516	1556	1867	37	50	0	0	0
High Eff. Lights	111.5	63.8	1500	1555	1827	53	51	40	-3.0	-3
Reflective Film	113.9	64.5	1586	1642	1914	-33	-36	-47	-5.4	-5
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

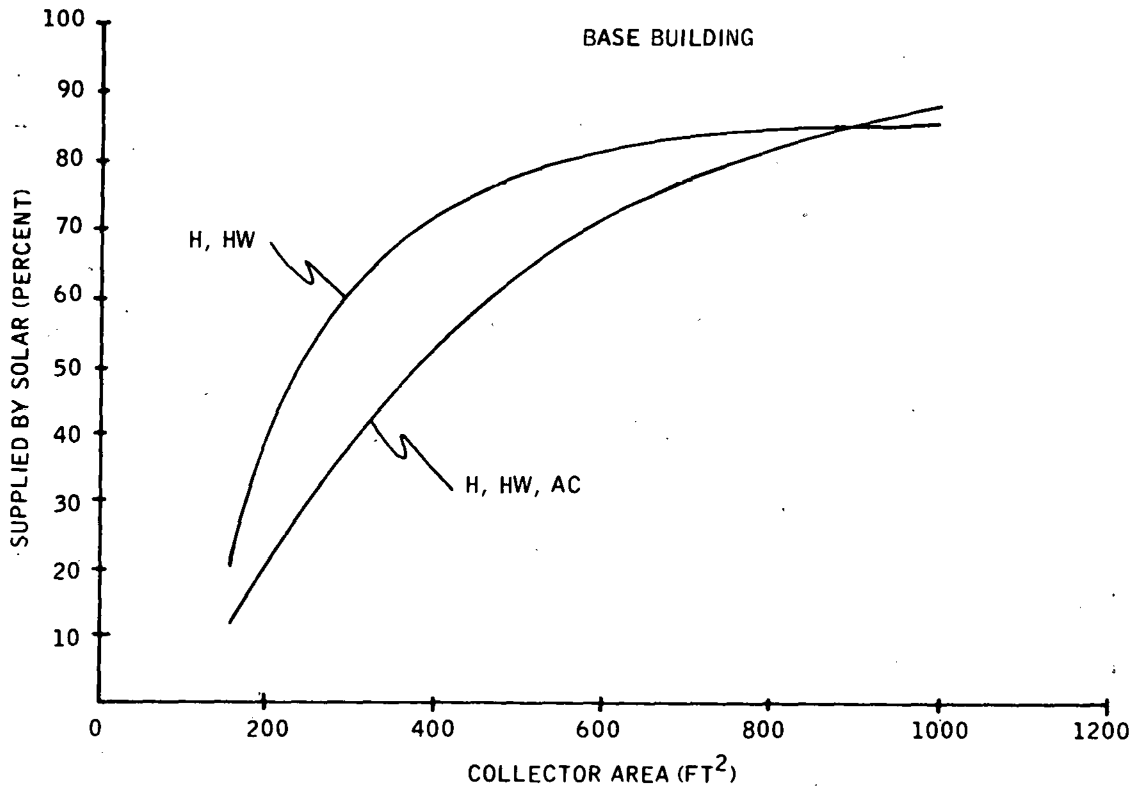


Figure 3-18. Percent of Load Supplied by Solar versus Collector Area (New) Albuquerque Single Family Base Building

Albuquerque-South West Region

New Construction -- Results for the new single family residence in Albuquerque are summarized in Figure 3-18 and Tables 3-17 and 3-18. Four levels of insulation were analyzed. These levels are described in Appendix A, Volume III. All were non-cost effective where air conditioning was considered. For heating and hot water systems, most were cost effective where electricity was the auxiliary fuel.

Table 3-17. Summary Loads, Costs and Savings
Albuquerque - New - Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	102.8	72.	1888	1904	1995					
Night Setback	96.6	72	1881	1896	1978	7	8	17	6.2	6
Insulation Case 1	83.9	69.	1955	1965	2023	-67	-61	-28	18.9	18
Insulation Case 2	84.5	70.	1936	1946	2005	-48	-42	-10	18.3	18
Insulation Case 3	83.7	69.	1940	1950	2007	-52	-46	-12	19	19
Insulation Case 4	79.1	69	1995	2005	2058	-107	-101	-63	23.7	23
Insul. HW Tank & Decr. Temp.	96.3	77	1857	1867	1924	31	37	71	6.5	6
Air Economizer	92.8	77	1878	1893	1978	10	11	17	10.0	10
High Eff. Furnace	102.8	72	1887	1902	1995	1	2	0	0	0
High Eff. Lights	100.1	75	1736	1753	1848	152	151	147	2.7	3
Reflective Film	98.0	80	1844	1861	1956	44	43	39	4.8	[illegible]
Awnings	96.2	77	1872	1888	1979	16	16	16	6.6	6

Table 3-18. Summary Loads, Costs and Savings
Albuquerque - New - Single Family
Heating and Hot Water
Collector Area - 600 Ft^2

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	67.4	81.6	1291	1307	1398					
Night Setback	61.3	81.8	1283	1297	1379	8	10	19	6.2	
Insulation Case 1	43.5	82.1	1319	1329	1386	-28	-22	12	23.9	35
Insulation Case 2	44.8	82.2	1305	1315	1374	-14	-8	24	22.7	34
Insulation Case 3	43.2	82.1	1302	1312	1369	-11	-5	29	24.3	36
Insulation Case 4	38.2	81.2	1354	1363	1416	-63	-56	-18	29.2	43
Insul. HW Tank & Decr. Water Temp.	62.6	87.5	1271	1281	1339	20	26	59	4.8	7
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.	67.4	81.6	1290	1305	1398	1	2	0	0	0
High Eff. Lights	70.2	81.5	1175	1193	1288	115	114	110	-2.8	-4
Reflective Film	75.1	82.7	1330	1347	1442	-39	-40	-44	-7.7	-11
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

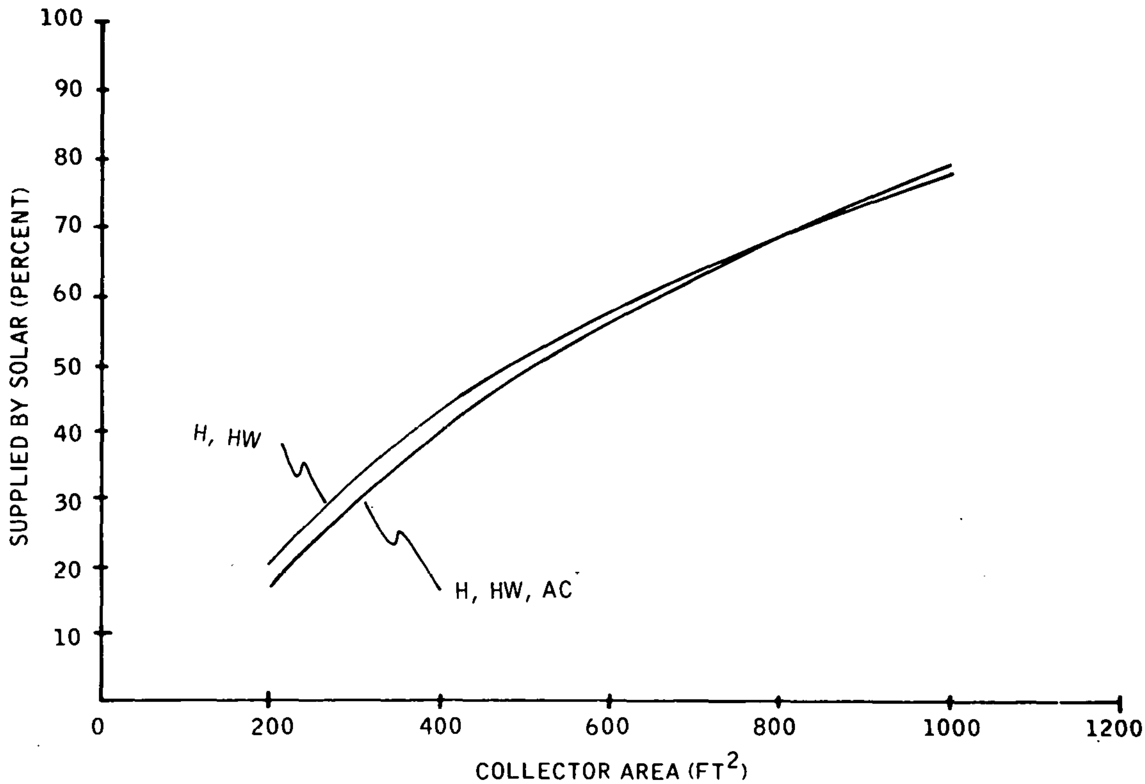


Figure 3-19. Percent of Load Supplied by Solar versus Collector Area for (Existing) Albuquerque Single Family Base Building

Albuquerque-South West Region

Existing Construction -- Results for the existing single family residence in Albuquerque are summarized in Figure 3-19 and Tables 3-19 and 3-20 (tabulated in Appendix A, Volume III). All four cases of additional insulation were cost effective for all auxiliary fuel types. The air economizer was not cost effective. Awnings were cost effective. Savings resulting from reduced operation of the solar/rankine system were sufficient to offset the cost of awnings.

Table 3-19. Summary Loads, Costs and Savings
Albuquerque - Existing - Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	181.8	56.2	2244	2328	2808					
Night Setback	167.9	58.4	2195	2268	2680	49	60	128	13.9	8
Insulation Case 1	168.7	59.6	2021	2272	2680	223	56	128	13.1	7
Insulation Case 2	110.58	76.11	2018	2040	2167	226	288	641	71.3	39
Insulation Case 3	76.78	78.3	2010	2021	2084	234	307	724	105.1	58
Insulation Case 4	73.9	77.7	2032	2042	2100	212	286	708	108.0	59
Insul HW Tank & Decr. Water Temp.	176.6	57.9	2219	2298	2747	25	30	61	5.2	3
Air Economizer	180.4	56.6	2272	2356	2834	-28	-28	-26	1.5	1
High Eff. Furnace	181.8	56.2	2198	2260	2808	46	69	0	0	0
High Eff. Lights	182.5	56.2	2170	2257	2747	75	71	62	-.7	0
Reflective Film	187.9	55.8	2276	2370	2907	-32	-42	-99	-6.1	-3
Awnings	177.8	57.5	2243	2327	2807	1	1	1	4.0	2

Table 3-20. Summary Loads, Costs and Savings
Albuquerque - Existing - Single Family
Heating and Hot Water
Collector Area - 600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	154.3	57.5	1718	1802	2232					
Night Setback	140.4	59.7	1665	1737	2149	53	65	133	13.9	9
Insulation Case 1	142.7	61.0	1683	1754	2152	35	48	120	11.6	7
Insulation Case 2	85.2	79.8	1493	1515	1642	225	287	640	69.1	45
Insulation Case 3	49.0	82.7	1459	1470	1533	259	332	749	105.3	68
Insulation Case 4	44.9	82.5	1471	1481	1539	247	321	743	109.4	71
Insul. HW Tank & Dec. Water Temp.	150.1	59.0	1700	1778	2228	18	24	54	4.20	3
Air Econoomizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furnace	154.3	57.5	1672	1733	2232	46	69	0	0	0
High Eff. Lights	157.8	56.7	1663	1750	2250	55	52	32	-3.5	-2
Reflective Film	165.7	55.6	1784	1878	2415	-66	-76	-133	-11.5	-7
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Conclusions

Results for the economic analysis are summarized in Tables 3-21 through 3-26 which illustrate annual savings (dollars) and payback periods (years) for each energy conservation technique for each of the four regions. Results are summarized for each of the three auxiliary fuel types and for both heating, hot water, and air conditioning and heating and hot water systems. The magnitude of annual savings provide a means to rank energy conservation techniques;providing an indication of which are most preferable. Payback periods indicate the length of time required for savings to offset initial investment costs. Paybacks of greater than 20 years are tabulated and should be used as a means or relative ranking. Some instances of negative annual saving with positive payback years occur because the annual savings are calculated from annual costs which include the cost of the energy conservation technique.

Results shown in the summary are based on an analysis which considered implementing each energy conservation technique separately. Greater energy savings and dollar savings can be achieved by combining the more promising energy conservation techniques. The combined effect would not be completely additive because of the interaction of the solar system and energy conservation techniques.

Savings and payback periods for any single energy conservation technique vary greatly between regions because of differences in climate, the amount of solar radiation available, fuel costs, auxiliary fuel types used, and retrofitting costs. Night setback devices, for example, have payback periods which vary from one year (electric auxiliary fuel, Albuquerque) to 11 years (gas, auxiliary fuel, Atlanta). When retrofit costs differ markedly from costs for new buildings, energy conservation techniques become non-cost effective and/or payback periods are greatly extended (e.g. high efficiency lights).

A summary of conclusions for each energy conservation technique includes:

- High Efficiency Furnace-Increasing the efficiency of the gas and oil furnaces from a seasonal average of 0.55 to 0.80 reduces the amount of gas and oil auxiliary fuel required. High efficiency furnaces are cost effective for both new and existing residences in all four regions.

- Night Setback-Night setback involves reducing the thermostat setpoint from 68°F during the hours of 10:00 p.m. to 6:00 a.m. This technique reduces the house heating load because the average indoor temperature is lower. Night setback is cost effective for both new and existing buildings in all regions.
  The greatest dollar savings are realized where the most expensive auxiliary fuel is employed. Incorporating night setback devices also reduced the amount of collector area required to supply a fixed percentage of the load. This resulted in lower initial investment costs for the solar system and lower annual costs.

- Air Economizer-The air economizer reduces the cooling load by introducing outdoor air into the conditioned space to provide natural cooling when outdoor air temperature and relative humidity are less than 75°F and 50 %, respectively. Air economizers are marginally cost effective, only in new single family residences with savings being marginal and payback periods always greater than 10 years. In these buildings, the cooling load is higher because the buildings are better insulated. Operating and installed costs are lower. Including an air economizer into the building reduced the amount of collector area required resulting in lower initial investment costs and annual costs.

- Increased Hot Water Tank Insulation/Decreased Temperature-
  When the amount of insulation on the domestic hot water tank is increased (R-6) and the water temperature is decreased (140°F to 130°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 was found to be cost effective in all four regions for both new and existing construction. Collector areas can be reduced resulting in both lower initial investment and annual costs.

- Reflective Films-Reflective films reduce the amount of radiation that enters the building and heat loss through glass surfaces. Reductions in the cooling load result while the heating load is slightly increased. Reflective films are cost effective only when air conditioning is considered. Even then, its cost effectiveness depends on the type of auxiliary fuel used. Reflective films also allow the amount of collector area to be reduced; further reducing the amount of initial investment in solar system costs.

- Awnings-Awnings shade a portion of the window keeping radiation from entering the building; reducing the cooling load. Awnings are cost effective in all regions for new buildings. For existing buildings, awnings were not cost effective for the Northeast and Southwest regions. In those two instances, the amount of reduction in the cooling operational costs did not offset the installed costs of the awnings. In those instances where awnings are cost effective, collector area requirements can be reduced.

- High Efficiency Lights-High efficiency lights consist of using 80 percent fluorescent lights in lieu of incandescent lights. This technique results in an increased heating requirement that must be satisfied by the solar system and auxiliary furnace and a decreased cooling load on the building. This technique is cost effective in most regions where air conditioning is considered and for new buildings for heating and hot water systems. Savings result primarily from the reduced electrical usage for lighting. Collector area can be reduced for heating, hot water and air conditioning systems resulting in lower annual costs and initial investment costs. For heating and hot water, where the collector must be increased to satisfy a fixed percentage of the load, a constant collector area minimizes annual costs.

Table 3-21. Energy Conservation Techniques, Cost Effectiveness
Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft^2
Gas Auxiliary

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Night Setback	13/[illegible]	19/5	17/5	24/4	4/11	40/3	7/8	49/2
Insul. Case 1	19/15	41/7	-4/22	29/10	-33/49	23/10	-67/177	223/2
Insul. Case 2	11/17	50/9	-9/24	34/12	-38/55	113/8	-48/107	226/5
Insul. Case 3	14/16	90/10	-6/22	55/13	-39/55	88/12	-52/153	234/7
Insul Case 4	3/19	73/13	-20/28	47/14	-61/64	139/10	-107/209	212/8
Insul. Hot Water Tank & Decrease Water Temp.	22/2	20/2	31/1	27/1	34/*	26/1	31/1	25/1
Air Economizer	1/19	-21/71	12/14	-23/65	16/12	-19/60	10/14	-28/1293
High Eff. Furnace	12/9	12/16	10/10	17/15	45/4	37/10	1/18	47/10
High Eff. Lights	119/2	63/7	157/1	85/6	187/1	77/6	152/1	75/6
Reflective Film	18/12	3/18	11/15	-9/32	51/7	2/18	44/7	-32/-
Awnings	8/15	3/18	5/17	-1/21	6/16	-5/25	16/12	1/19

* - Less than one year

Table 3-22. Energy Conservation Techniques, Cost Effectiveness
Single Family
Heating and Hot Water
Collector Area - 600 Ft^2
Gas Auxiliary

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Night Setback	15/5	20/5	20/4	27/4	7/8	43/2	8/7	53/2
Insul. Case 1	23/14	34/8	22/14	32/9	-17/29	14/12	-28/32	35/8
Insul. Case 2	14/16	43/10	12/17	43/10	-23/32	114/8	-14/26	225/5
Insul. Case 3	18/15	82/11	11/17	94/10	-22/31	94/11	-11/25	259/6
Insul. Case 4	11/17	67/13	14/17	86/12	-44/40	87/12	-63/43	247/7
Insul. Hot Water Tank & Decrease Water Temp	13/2	12/3	18/2	19/2	20/2	18/2	20/2	18/2
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furn.	12/9	41/10	9/10	17/15	9/10	37/10	1/18	47/10
High Eff. Lights	91/2	43/9	119/2	62/8	111/2	53/8	115/2	55/8
Reflective Film	-37/-	-38/-	-44/-	-43/-	-25/414	-33/-	-39/-	-66/-
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A Not Applicable

Table 3-23. Energy Conservation Techniques, Cost Effectiveness
Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 500 Ft^2
Oil Auxiliary

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Night Setback	22/4	31/3	20/4	28/4	6/9	50/2	8/7	60/2
Insul. Case 1	52/8	70/5	6/18	38/8	-27/39	31/8	-61/104	56/6
Insul Case 2	42/12	93/6	0/20	46/10	-31/41	149/7	-42/69	288/4
Insul. Case 3	46/11	176/7	3/19	82/11	-33/43	129/10	-46/87	307/6
Insul. Case 4	38/13	163/9	-9/23	75/12	-54/51	120/11	-101/136	286/7
Insul. Hot Water Tank & Decrease Water Temp.	31/1	30/1	35/1	32/1	40/*	30/1	37/*	30/1
Air Economizer	6/16	-18/52	14/14	-22/59	19/12	-18/54	11/14	-28/1293
High Eff. Furnace	26/5	72/7	14/8	29/12	1/18	50/9	2/17	67/8
High Eff. Lights	113/2	58/7	155/1	83/6	150/1	74/6	151/1	71/6
Reflective Film	14/13	-4/25	9/15	-11/38	53/7	-1/21	43/7	-42/-
Awnings	8/15	3/18	5/17	-1/21	7/16	-6/27	16/12	1/19

* Less than once a year

Table 3-24. Energy Conservation Techniques, Cost Effectiveness
Single Family
Heating and Hot Water
Collector Area - 600 Ft^2
Oil Auxiliary

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Night Setback	24/3	33/3	23/4	32/4	9/7	53/2	10/6	65/2
Insul. Case 1	56/10	63/5	31/12	41/8	-11/25	22/10	-22/28	48/6
Insul. Case 2	45/11	86/6	21/15	36/11	-17/28	150/7	-8/23	287/4
Insul. Case 3	51/11	168/7	20/15	121/9	-16/27	135/10	-5/22	332/5
Insul. Case 4	46/12	157/9	24/15	113/10	-36/34	128/10	-56/38	321/6
Insul. Hot Water Tank & Decrease Water Temp	22/2	22/2	22/2	24/2	27/1	23/1	26/1	24/1
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furnace	26/5	72/7	13/9	30/12	1/18	50/9	2/17	67/8
High Eff. Lights	84/2	38/9	117/2	60/8	110/2	51/8	114/2	52/8
Reflective Film	-40/-	-45/-	-35/-	-45/-	-23/161	-36/-	-40/-	-76/-
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A Not Applicable

Table 3-25. Energy Conservation Techniques, Cost Effectiveness
Single Family
Heating, Hot Water and Air Conditioning
Collector Area - 600 Ft^2
Electric Auxiliary

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Night Setback	44/2	60/12	48/2	68/2	15/5	100/1	17/4	128/*
Insul. Case 1	130/6	139/3	86/7	115/4	2/19	72/5	-28/32	128/3
Insul. Case 2	117/7	194/4	77/9	158/5	-3/21	329/4	-10/24	641/2
Insul. Case 3	125/6	379/4	85/8	309/5	-4/21	330/6	-12/25	7[illegible]4/3
Insul. Case 4	122/7	378/5	80/9	315/5	-20/26	325/6	-63/43	708/3
Insul. Hot Water Tank & Decr. Water Temp.	55/*	52/*	71/*	70/*	72/*	59/*	71/*	61/*
Air Economizer	19/12	-13/36	25/11	-18/43	29/10	-9/29	17/12	-26/233
High Eff. Furnace	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	100/2	45/9	136/1	66/7	147/1	63/7	147/1	62/7
Reflective Film	8/15	-19/163	-1/21	-29/-	60/6	-12/52	39/8	-99/-
Awnings	8/15	3/18	1/19	0/20	7/16	-6/27	16/12	1/19

* - Less than once a year

Table 3-26. Energy Conservation Techniques, Cost Effectiveness
Single Family
Heating and Hot Water
Collector Area - 600 Ft^2
Electric Auxiliary

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Night Setback	46/2	63/2	52/2	71/2	18/4	103/1	19/4	133/*
Insul. Case 1	134/6	133/3	113/6	118/4	18/15	63/5	12/17	120/3
Insul. Case 2	120/7	188/4	99/7	168/4	11/17	329/4	24/14	640/2
Insul. Case 3	130/6	372/4	99/7	348/5	13/16	337/5	29/13	749/3
Insul. Case 4	130/7	373/5	114/8	354/5	-3/21	333/6	-18/24	743/3
Insul. Hot Water Tank & Decr. Water Temp.	46/*	44/*	59/*	62/*	58/*	51/*	59/*	54/*
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Furn.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	71/2	25/12	98/2	43/9	107/2	40/9	110/2	32/10
Reflective Film	-47/-	-59/-	-55/-	-63/-	-16/51	-47/-	-44/-	-133/-
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Less than once a year
N/A Not Applicable

- Insulation-Improving the thermal resistance of the building significantly reduced the heating load while increasing the cooling load. Four cases were analyzed for each region. Results indicate that some amount of additional insulation is cost effective in all regions. The amount is dependent on the heating load, auxiliary fuel costs and type of auxiliary fuel used. Since added insulation heavily impacts heating loads, annual savings and additional amounts are greater for heating and hot water systems. In these systems, the amount of collector area required can be reduced significantly and initial investment and annual costs can be greatly reduced. Where air conditioning is considered, savings occur but are not as substantial. In these cases, collector area can be slightly reduced.

3.2 MULTIFAMILY BUILDING

3.2.1 Introduction

Results for the multifamily residence, both new and existing, by region are outlined in the following paragraphs. The interaction of the solar system with each energy conservation technique is described. Annual costs, cost savings and annual load saving are illustrated. Results are illustrated for a specific collector area: the approximate design area required by the multifamily residence with a heating, hot water and air conditioning system. Buildings analyzed were similar in size and internal loads. The buildings differed with respect to construction characteristics and insulation, all of which varied by region.

The analysis revealed that the interaction of the solar system with the multifamily residence's energy conservation techniques, and heating, hot water, and cooling loads followed identical trends for each region. That is, those energy conservation techniques, such as insulation, always tend to decrease heating loads and increase cooling loads. This trend is the same for all regions;the amount of change depends on the amount of insulation added. Those variables that did change with respect to regions are loads, installed costs and fuel prices. These variables determine whether or not a particular energy conservation technique is cost effective. Since resultant trends are identical, a detailed explanation of the interaction of the solar system, building loads and energy conservation technique is provided only for the new multifamily residence for Omaha. Results for the existing building in Omaha and buildings in other cities are shown in tables illustrating loads, percent of loads supplied by solar, annual costs, annual savings and load savings. Plots are also provided for the base multifamily residences to illustrate the percentage of the load supplied by a given collector area. These plots show the percentage of both heating, hot water and air conditioning, and heating and hot water loads supplied by the solar system. Since building loads are known for each city, these curves also provide a relative comparison of the amount of solar radiation available in the representative cities.

The multifamily building is a low rise structure containing 11 occupied apartments. Each of the three floors contains four apartments, one apartment being designated as a storage/laundry room. Each unit was assumed to have its own forced air heating and cooling and domestic hot water facilities. The solar system (Appendix F) was assumed integrated into each facility. Appendix A itemized construction specifics, surface areas, building dimensions, etc.

3.2.2 Building Modeling Assumptions

Building loads are calculated as a function of outdoor temperature and internal loads. The building is considered to be a single zone with a controlled temperature of 68°F during the heating season and 78°F during the cooling season. Heat gain/loss through the ceiling, walls, windows, sliding glass doors and doors are calculated hourly as a function of outdoor dry-bulb temperature and construction characteristics. A model calculates the temperature of the attic as a function of both indoor and outdoor dry-bulb temperature. Heat loss through walls below ground are calculated as a function of ground temperature which varies monthly with location. Heat loss through slab floors is not considered. Infiltration loads are based on 0.75 air changes per hour for new building and 1.0 air changes for an existing building. No ventilation loads are assumed. The various tabulation levels studied are tabulated in Table 3-27.

Internal loads simulated include occupants, lights, appliances, losses from domestic hot water tanks and, for new buildings, losses from the solar storage tank. For existing buildings, the solar storage tank is assumed to be outside the building. Occupancy, lights and appliance loads are calculated using schedules (Appendix A) which describe the percentage of peak loads on an hourly basis. No special provisions are made for weekends and holidays.

3.2.3 Results for Multifamily Building

Omaha-North Central Region--

New Construction-Base Building--The base case represents the interaction of the solar system with the new multifamily building in Omaha for both heating/hot water/air conditioning and heating/hot water. The results are illustrated in Figures 3-20 through 3-23 and are expressed as the percentage of the load supplied by solar and annual costs expressed as a function of collector area. These curves will form the basis of comparison against which each energy conservation technique will be compared to determine if collector areas can be reduced and cost effectiveness of the

Table 3-27. Insulation Case Multi-Family Residence

CASE/SURFACE		CITY							
		OMAHA		NEW YORK		ATLANTA		ALBUQUERQUE	
		NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
1 (BASE CASE)	CEILING WALLS WINDOW	R-13 R-11 DOUBLE GLAZE	R-9 R-0 SINGLE GLAZE	R-13 R-11 DOUBLE GLAZE	R-9 R-0 SINGLE GLAZE	R-13 R-11 SINGLE GLAZE	R-0 R-0 SINGLE GLAZE	R-19 R-11 SINGLE GLAZE	R-0 R-0 SINGLE GLAZE
2	CEILING WALLS WINDOW	N/A	R-30 R-12 DOUBLE GLAZE	N/A	R-30 R-12 DOUBLE GLAZE	R-38 R-15 DOUBLE GLAZE	N/A	N/A	N/A
3	CEILING WALLS WINDOW	N/A	R-38 R-12 DOUBLE GLAZE	R-38 R-19 DOUBLE GLAZE	R-38 R-12 DOUBLE GLAZE	R-38 R-22 DOUBLE GLAZE	R-30 R-12 DOUBLE GLAZE	R-38 R-19 DOUBLE GLAZE	R-30 R-12 DOUBLE GLAZE
4	CEILING WALLS WINDOWS	N/A	N/A	R-38 R-24 DOUBLE GLAZE	N/A	R-38 R-19 DOUBLE GLAZE	R-38 R-12 DOUBLE GLAZE	R-38 R-24 DOUBLE GLAZE	R-38 R-12 DOUBLE GLAZE
5	CEILING WALLS WINDOW	N/A	N/A	R-38 R-24 TRIPLE GLAZE	N/A	R-38 R-24 TRIPLE GLAZE	N/A	R-38 R-24 TRIPLE GLAZE	N/A
6	CEILING WALLS WINDOW	N/A	R-38 R-18 DOUBLE GLAZE	N/A	R-38 R-18 DOUBLE GLAZE	N/A	R-30 R-18 DOUBLE GLAZE	R-38 R-30 TRIPLE GLAZE	R-30 R-18 DOUBLE GLAZE
7	CEILING WALLS WINDOW	N/A	N/A	N/A	N/A	N/A	R-38 R-18 DOUBLE GLAZE	N/A	R-38 R-18 DOUBLE GLAZE
8	CEILING WALLS WINDOW	R-38 R-24 DOUBLE GLAZE	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	CEILING WALLS WINDOW	R-38 R-24 TRIPLE GLAZE	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	CEILING WALLS WINDOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	CEILING WALLS WINDOW	R-38 R-30 TRIPLE GLAZE	N/A	N/A	N/A	N/A	N/A	N/A	N/A

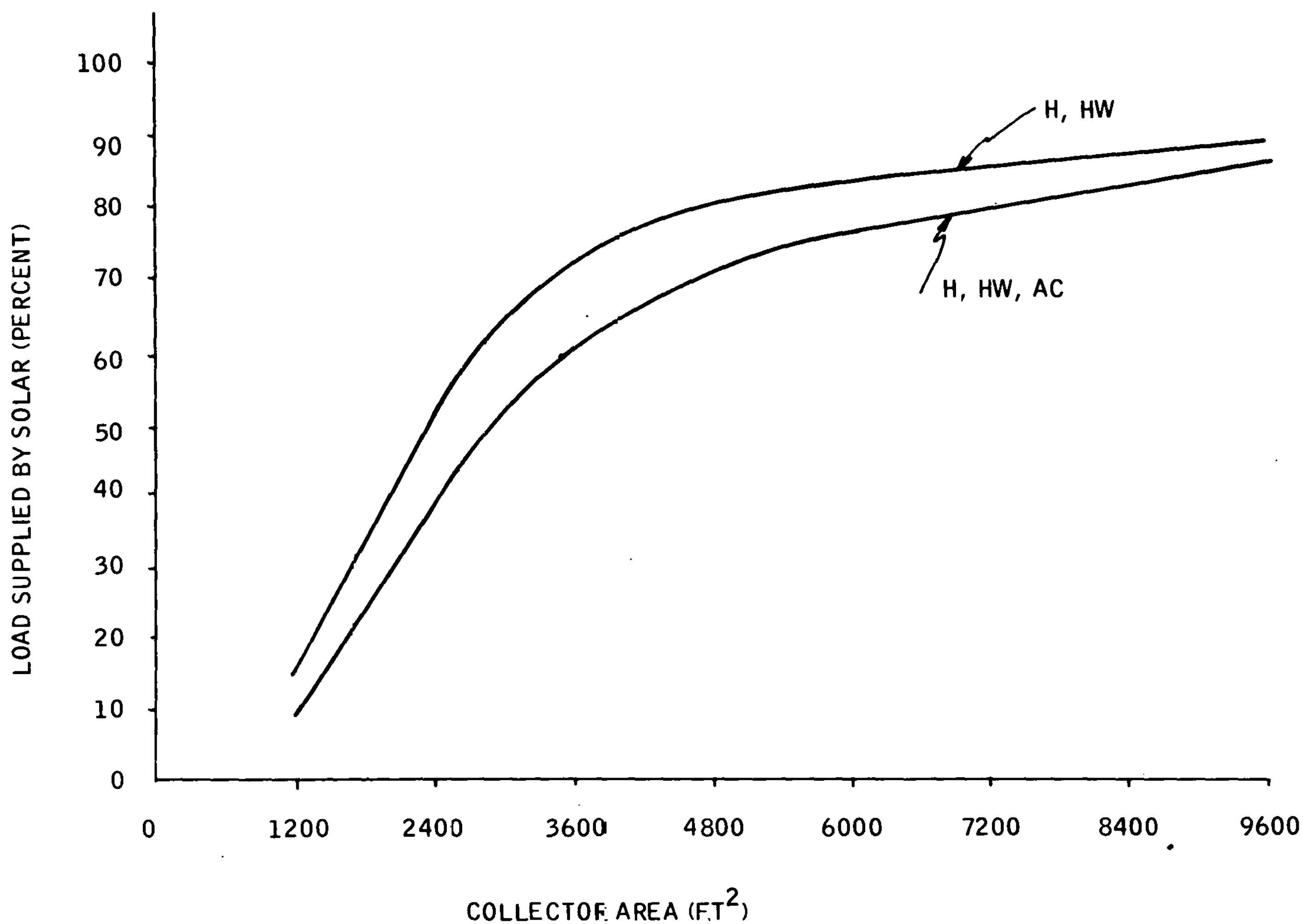


Figure 3-20. Percent of Load Supplied by Solar Versus Collector Area for Multifamily (New) Omaha Base Building

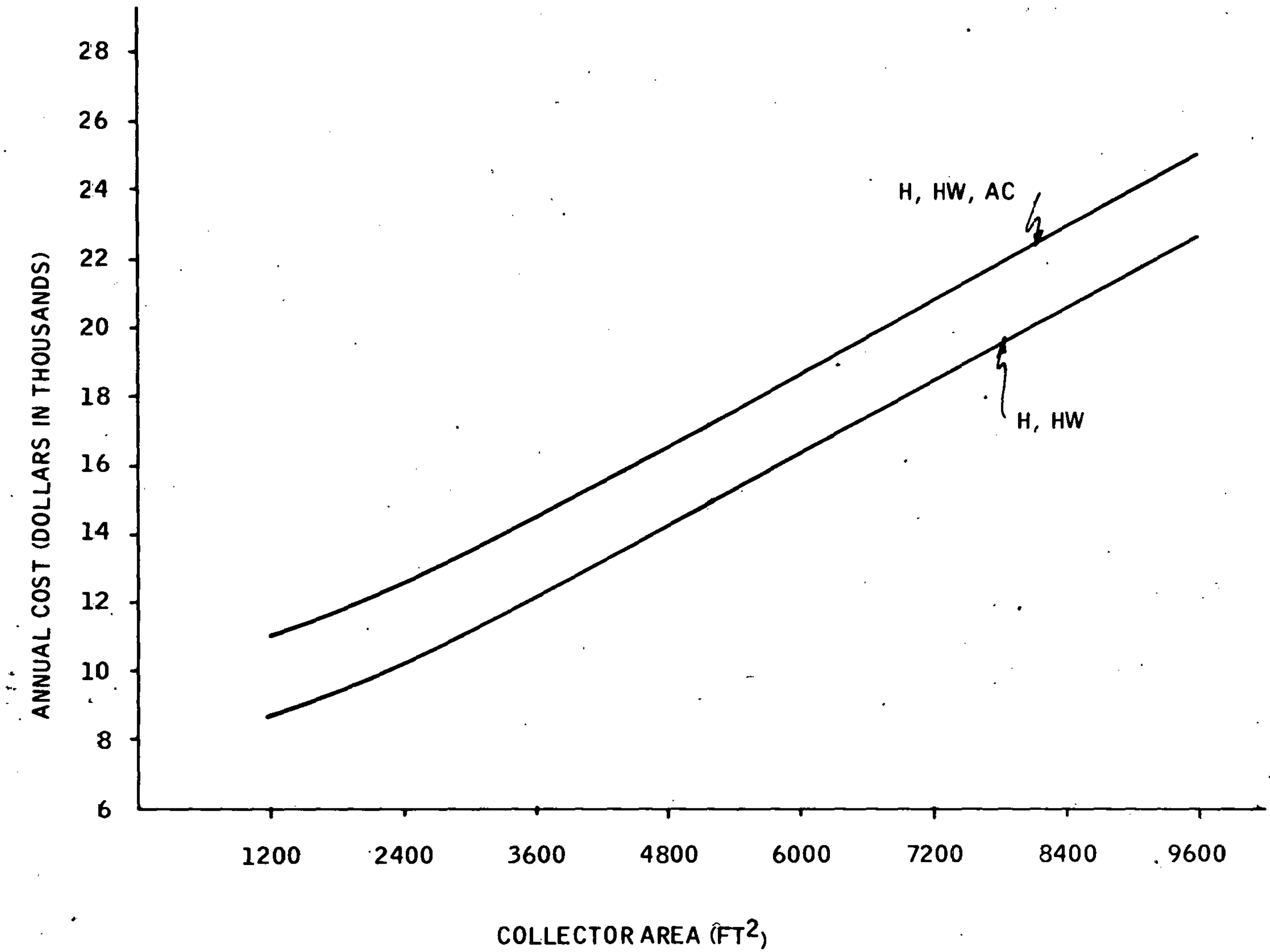


Figure 3-21. Annual Cost Versus Collector Area for Multifamily (New) Omaha Base Building with Gas Auxiliary Fuel

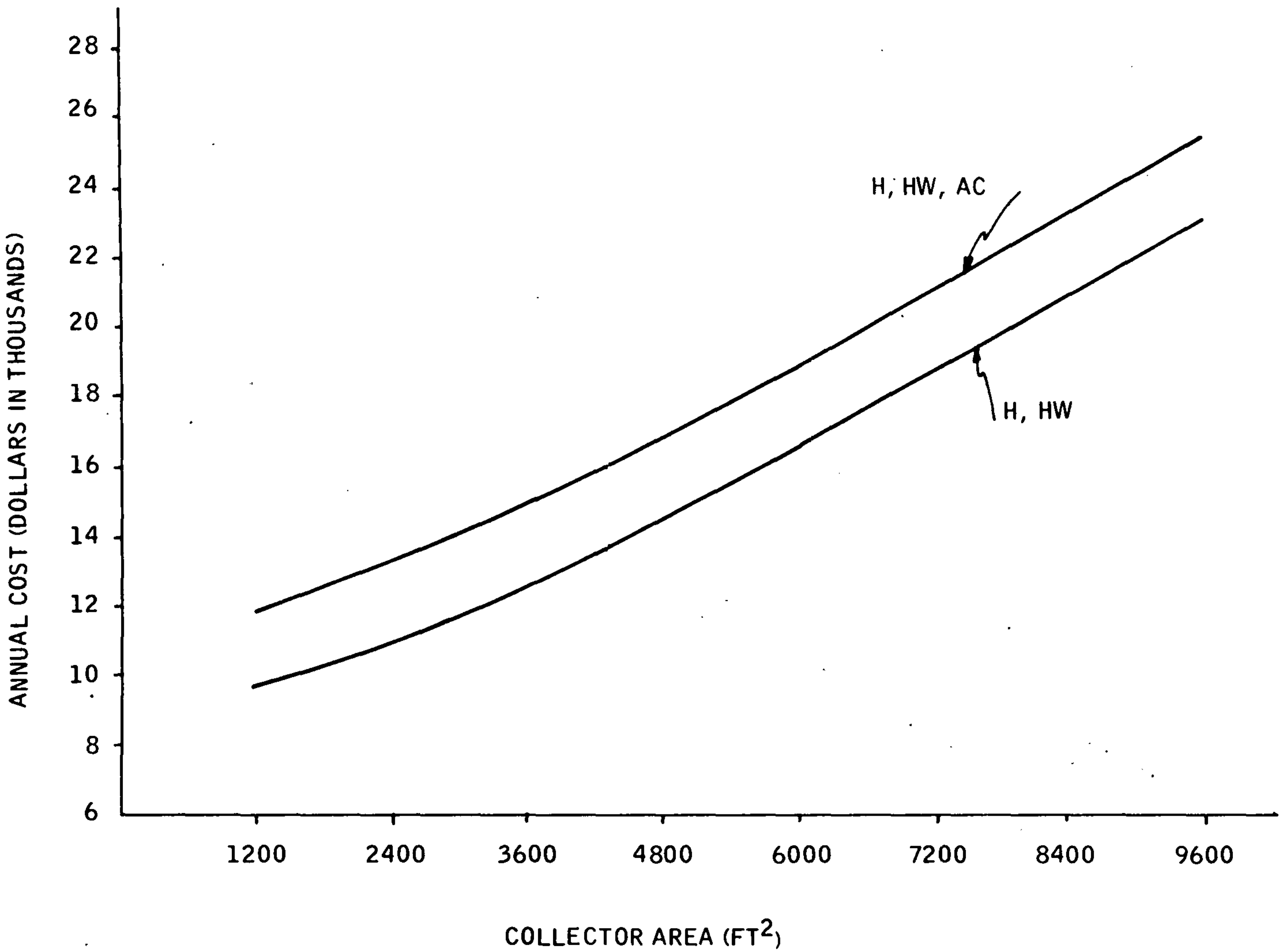


Figure 3-22. Annual Cost Saving Versus Collector Area for Multifamily (New) Omaha Base Building with Oil Auxiliary Fuel

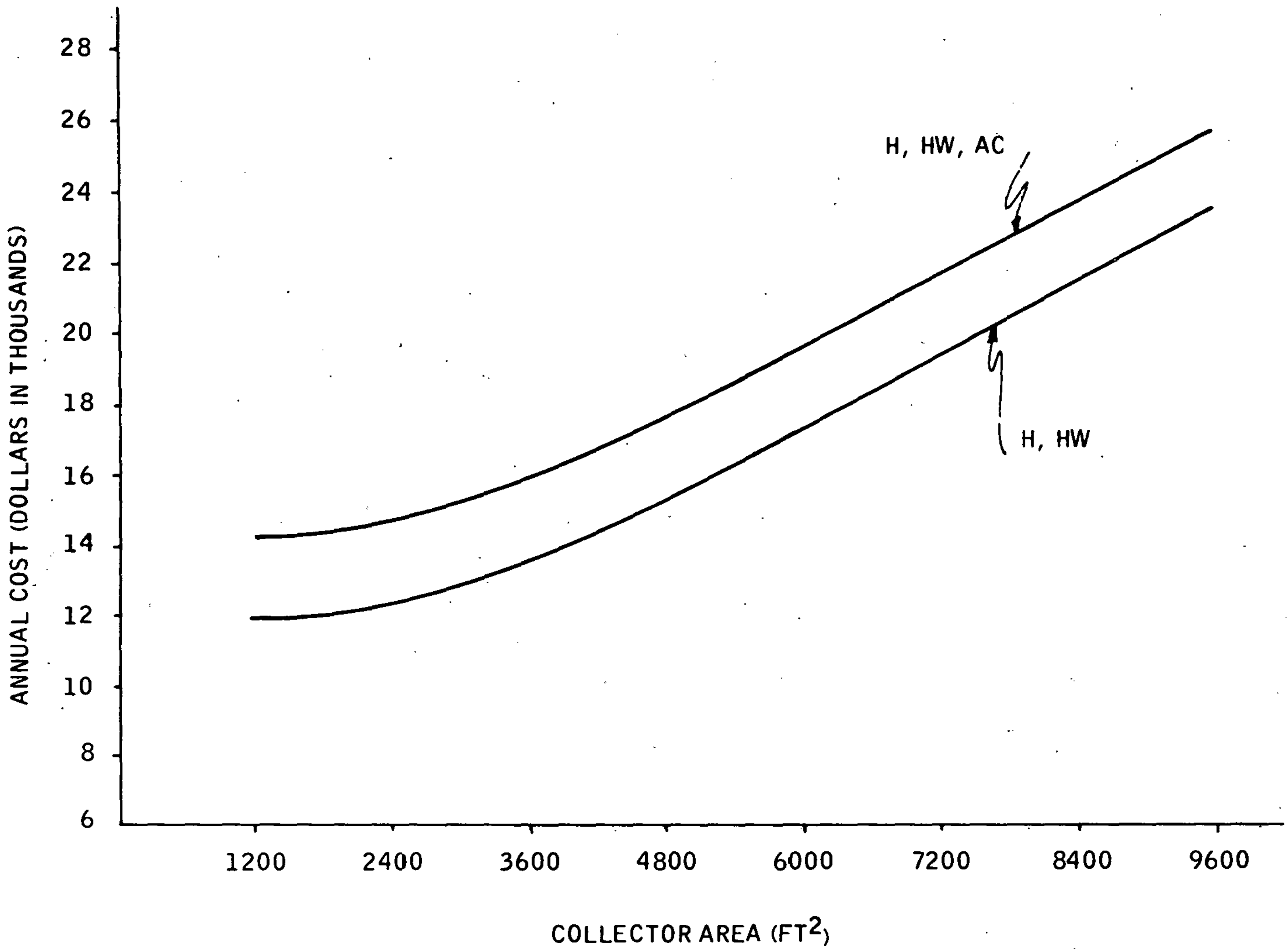


Figure 3-23. Annual Cost Versus Collector Area for Multifamily (New) Omaha Base Building with Electric Auxiliary

energy conservation technique achieved.

Example costs, percentages and cost savings will be cited during the analysis of the energy conservation techniques. Examples will be compared on the basis of 3600 FT^2. This is the approximate design point collector area for cooling for the multifamily building summarized in Tables 3-28 and 3-29.

New Construction-Application of ECT's--Night setback-involves reducing the heating thermostat setpoint from 68°F to 63°F during the hours of 10:00 p.m. and 6:00 a.m. Incorporating night setback devices into each of the eleven apartments of the multifamily building, reduces the heating load, allowing the solar system to supply a greater percentage (Figure 3-24) of the load for a fixed collector area. Annual savings, Figure 3-25, indicates that night setback devices are only cost effective in the lower collector areas; where the solar system is not supplying a high percentage of the load. At higher collector areas, cost savings of auxiliary fuels do not offset the cost of the night setback devices. This later trend exists for all fuel types with cost savings increasing for fuels (e.g., electricity) that are more costly.

By keeping the percentage of the load supplied by solar fixed (e.g., 59.4 percent for heating/hot water/air conditioning and 72.4 percent for heating and hot water), it is possible to achieve the same results by decreasing the collector area approximately 250 and 350 square feet, respectively. These reduced collector areas, shown in Figure 3-24, result in initial solar system investment savings of approximately $ 6450 and $9030 at a collector price of $25.80 per square foot. This decrease can then be compared to the $ 839.96 increased initial investment cost of the night setback devices. Alternately, night setback devices are good investment strategies at any point where collector areas can be reduced by 33 (839.96/25.80) or more

Table 3-28. Summary Loads, Costs and Savings
Omaha - New - Multi-Family
Heating, Hot Water, Air Conditioning
3600 Ft^2

ECT Description	Total Load (BTU) $x\ 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	620.9	59	14494	14895	15844					
Night Setback	593.5	61	14455	14816	15674	39	80	175	27.4	4
Air Economizer	575.2	64	15668	16058	16985	-1173	-1162	-1135	45.7	7
Awnings	591.1	62	14489	14890	15844	5	5	6	29.8	4
Reflective Film	581.0	65	14446	14826	15727	48	70	122	39.9	6
High Eff. Lights	611.0	61	13840	14285	15338	654	610	506	9.9	2
Water Tank Insul. Dec. Temp.	607.5	61	14303	14604	15316	191	292	533	13.4	2
Insulation Case 8	509.4	62	14281	14529	15116	213	367	733	111.5	16
Case 9	485.2	59	14344	14559	15070	150	337	779	135.7	20
Case 11	484.0	59	14410	14621	15122	84	275	727	136.9	20
Furnace Eff.	620.9	59	14269	14546	15827	225	350	0	0	0

Table 3-29. Summary Loads, Costs and Savings
Omaha - New - Multi-Family
Heating and Hot Water
3600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	408.7	72	12159	12561	13514					
Night Setback	380.5	64	12113	12475	13332	46	86	182	28.2	6
Air Economizer	N/A									
Awnings	N/A									
Reflective Films	412.8	75	12279	12659	13560	-120	-98	-45	-4.1	-1
High Eff. Lights	431.7	70	11629	12075	13132	530	486	382	-23.0	-6
Water Tank Insul. Dec. Temp.	413.9	72	12046	12347	13059	112	214	455	-5.2	-1
Insulation Case 8	278.2	84	11850	12098	12686	309	463	829	130.5	27
Case 9	235.6	87	11837	12053	12564	321	508	950	173.1	36
Case 11	231.8	87	11894	12105	12606	265	456	908	176.9	37
High Eff. Furnace	408.7	72	11934	12210	13492	225	351	0	0	0

N/A Not Applicable

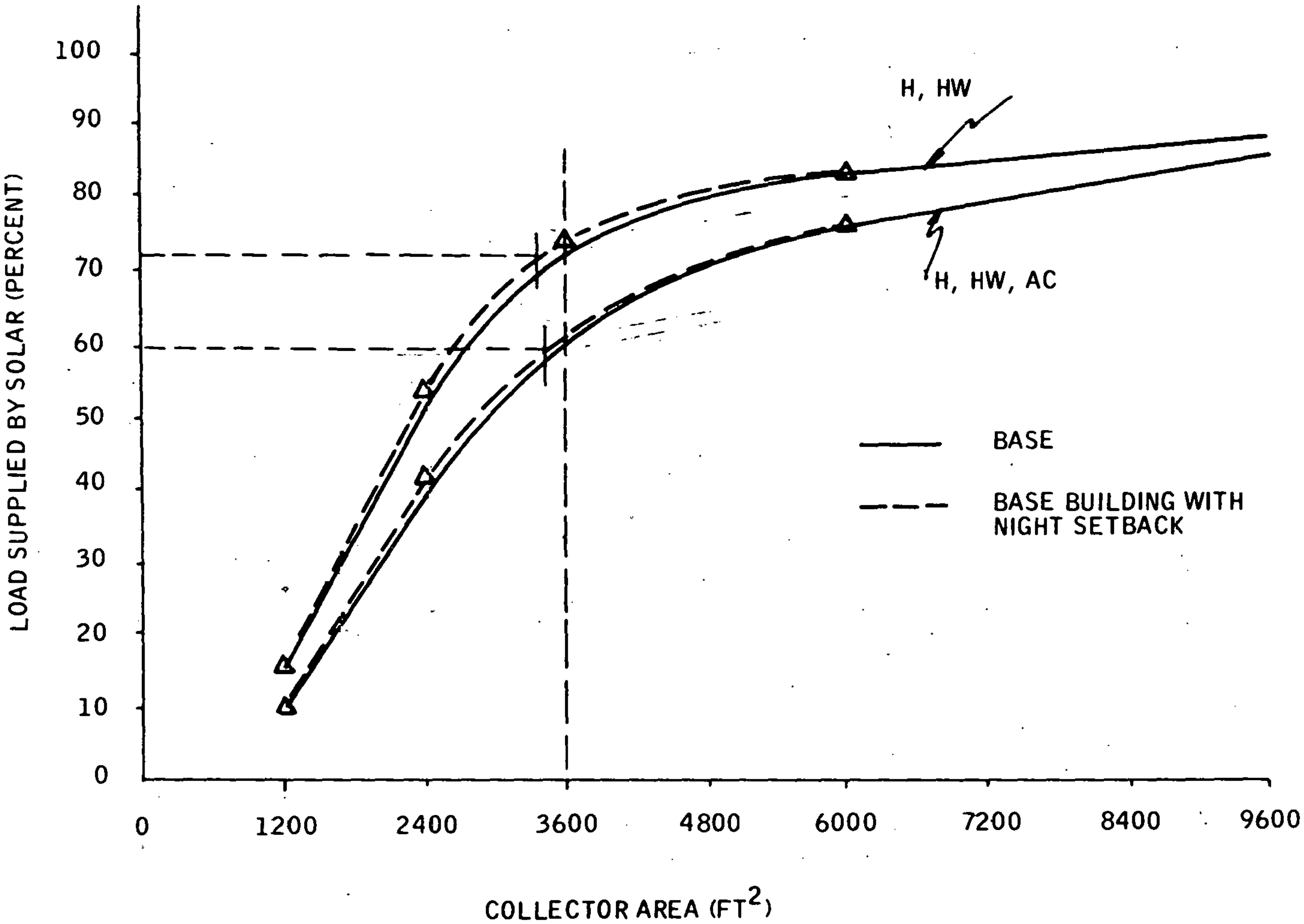


Figure 3-24. Percent of Load Supplied by Solar Versus Collector Area for Multifamily (New) Omaha Base Building with Night Setback

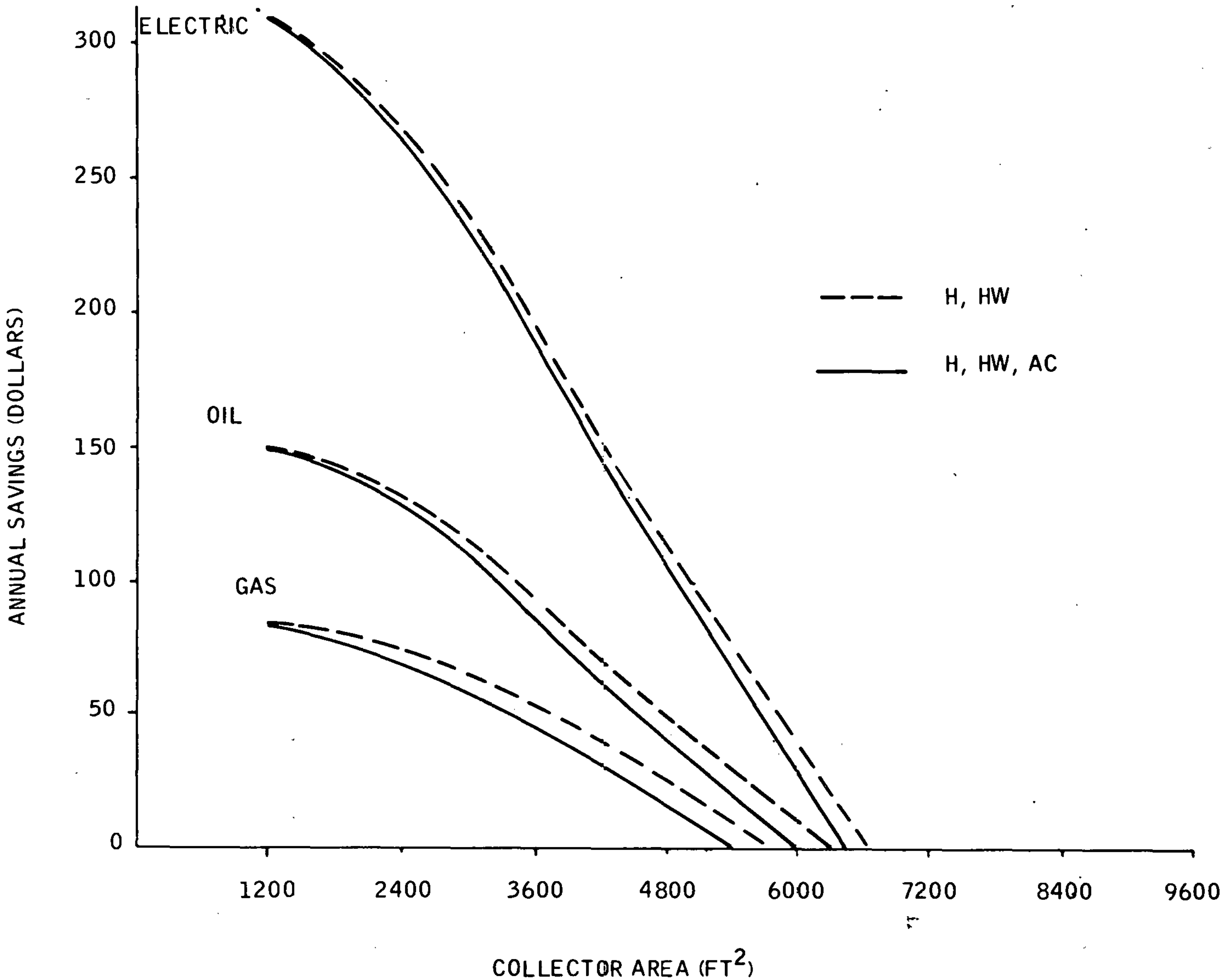


Figure 3-25. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Night Setback

square feet. The strategy of reducing the collector area also reduces annual costs.

The air economizer introduces outdoor air into the conditioned space to provide natural cooling. Installing air economizer systems into each of the 11 apartments reduces the cooling load allowing the cooling system to satisfy a greater percentage of the heating, hot water, and air conditioning load (Figure 3-26). A small increase in the percentage of load supplied to heating/hot water is also realized since the solar system has additional energy to satisfy these loads.

If collector areas are fixed, the increased costs of the air economizer systems do not offset the decreased costs of auxiliary fuels. Negative annual savings occur indicating that air economizers are not cost effective when compared on the basis of fixed collector areas. If the percentage of the load is held constant, the collector area must be reduced by a minimum of 188 (4340/25.8) square feet to offset initial investment costs. This occurs for heating, hot water, and air conditioning. However, yearly operational and maintenance costs further extend the amount of collector area reduction required. Examination of the annual cost curves indicate that the air economizer is not cost effective at any collector area. Thus, the air economizer does not appear to be a cost-effective energy conservation technique at a fixed or reduced collector area.

Awnings act to shade a portion of the window, keeping radiation from entering the building. Awnings considered in this analysis consisted of metal roll up awnings. They were considered to be down during the cooling season and raised during the heating season. The building was oriented south with awnings on three sides.

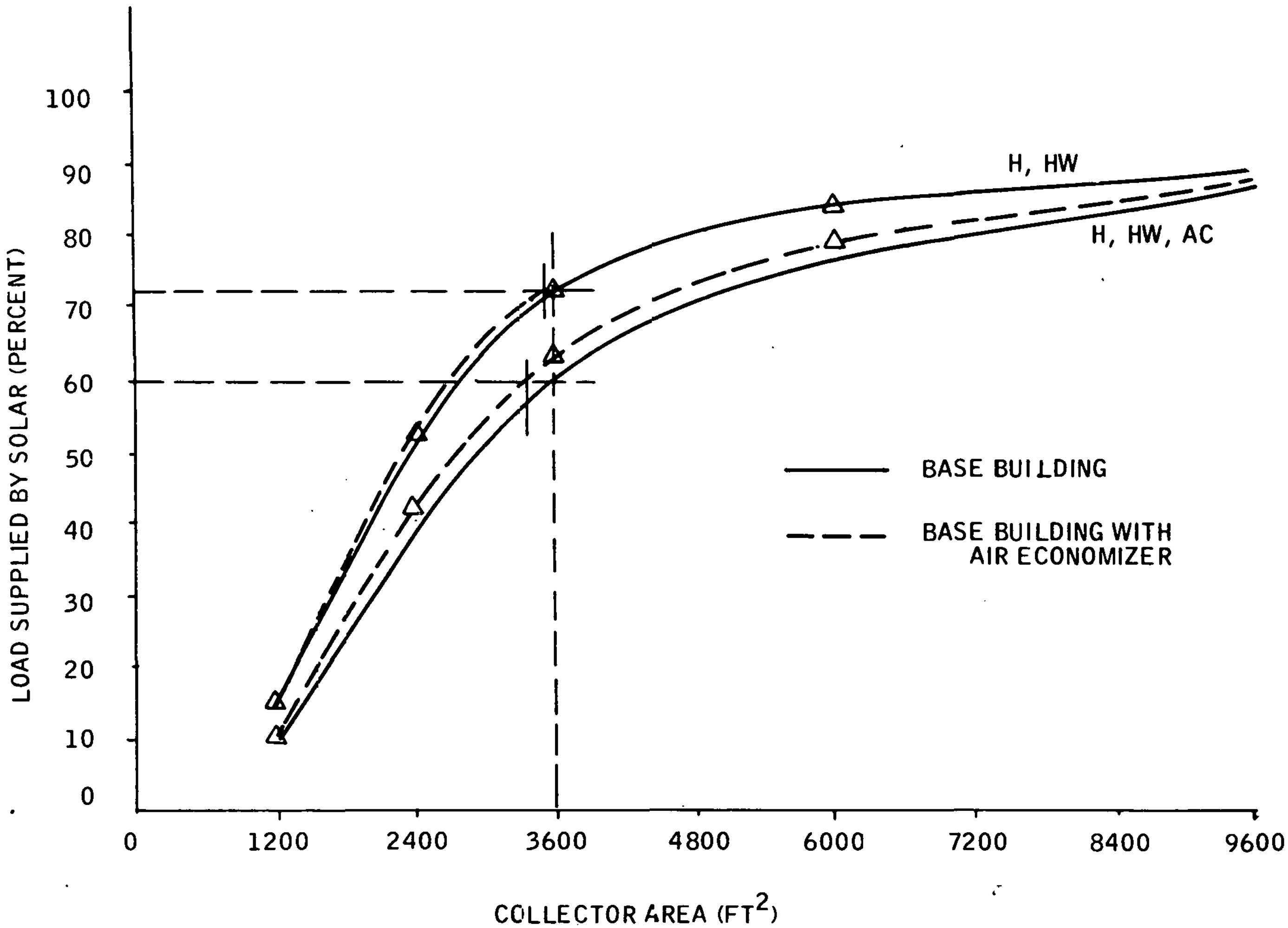


Figure 3-26. Percent of Load Supplied by Solar Versus Collector Area for Multifamily (New) Omaha Base Building with Air Economizer

Awnings reduced the net cooling load allowing the percentage of load supplied by solar, (Figure 3-27) to increase. For fixed collector areas, cost savings, (Figure 3-28) from auxiliary fuels and pump consumption slightly offset initial investment costs of the awnings. This occurs only in the lower collector areas. The amount of savings indicate a long payback period. Awnings are not cost effective at larger collector areas because the solar system supplies such a large percentage of the load.. Awnings do not interact with heating/hot water.

Using the alternate strategy of keeping the percentage of the load supplied by solar constant, the collector area can be reduced approximately 150 $ft.^2$ for heating, hot water and air conditioning. This reduced area represents a cost reduction greater than that required to offset the initial cost of the awnings. Since annual costs are lower, awnings represent a good investment strategy when combined with a solar system using cooling.

Reflective films act to reduce the amount of radiation that enters the building and heat loss through glass surfaces. All windows and sliding glass patio doors were considered to have reflective films.

Results indicate that reflective films significantly reduce the cooling load and slightly increase the heating load. The latter results from reduced radiation through the glass during the heating season. However, the percentage of load supplied by solar (Figure 3-29) increases for both heat/hot water/air conditioning and heat/hot water. The latter occurs since the solar system is able to supply more energy to heating/hot water.

For a fixed collector area, reflective films are cost effective for heating, hot water and air conditioning systems (Figure 3-30). Annual cost savings indicate that the payback period is relatively long; especially for larger

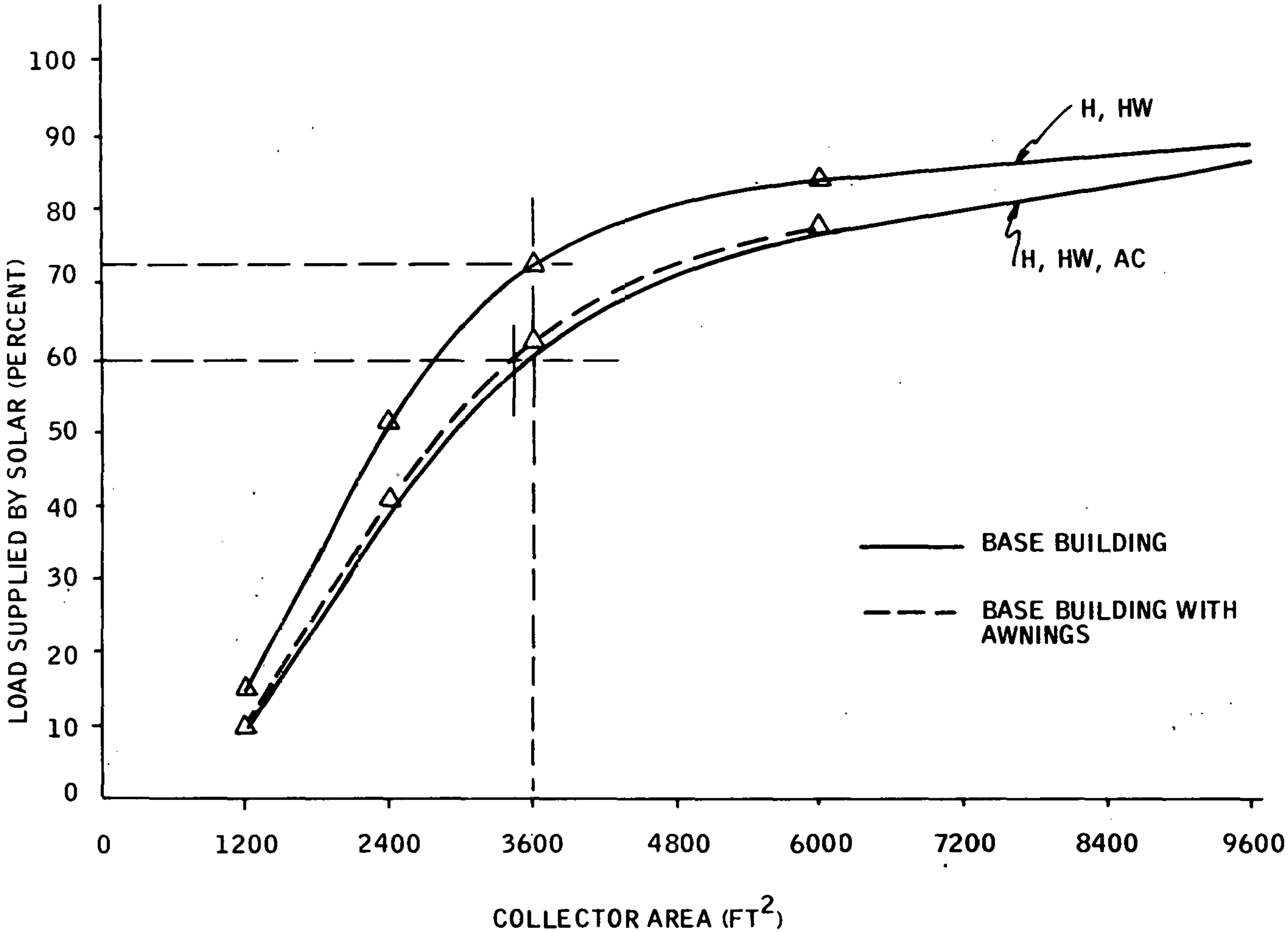


Figure 3-27. Percent of Load Supplied by Solar Versus Collector Area for Multifamily (New) Omaha Base Building with Awnings

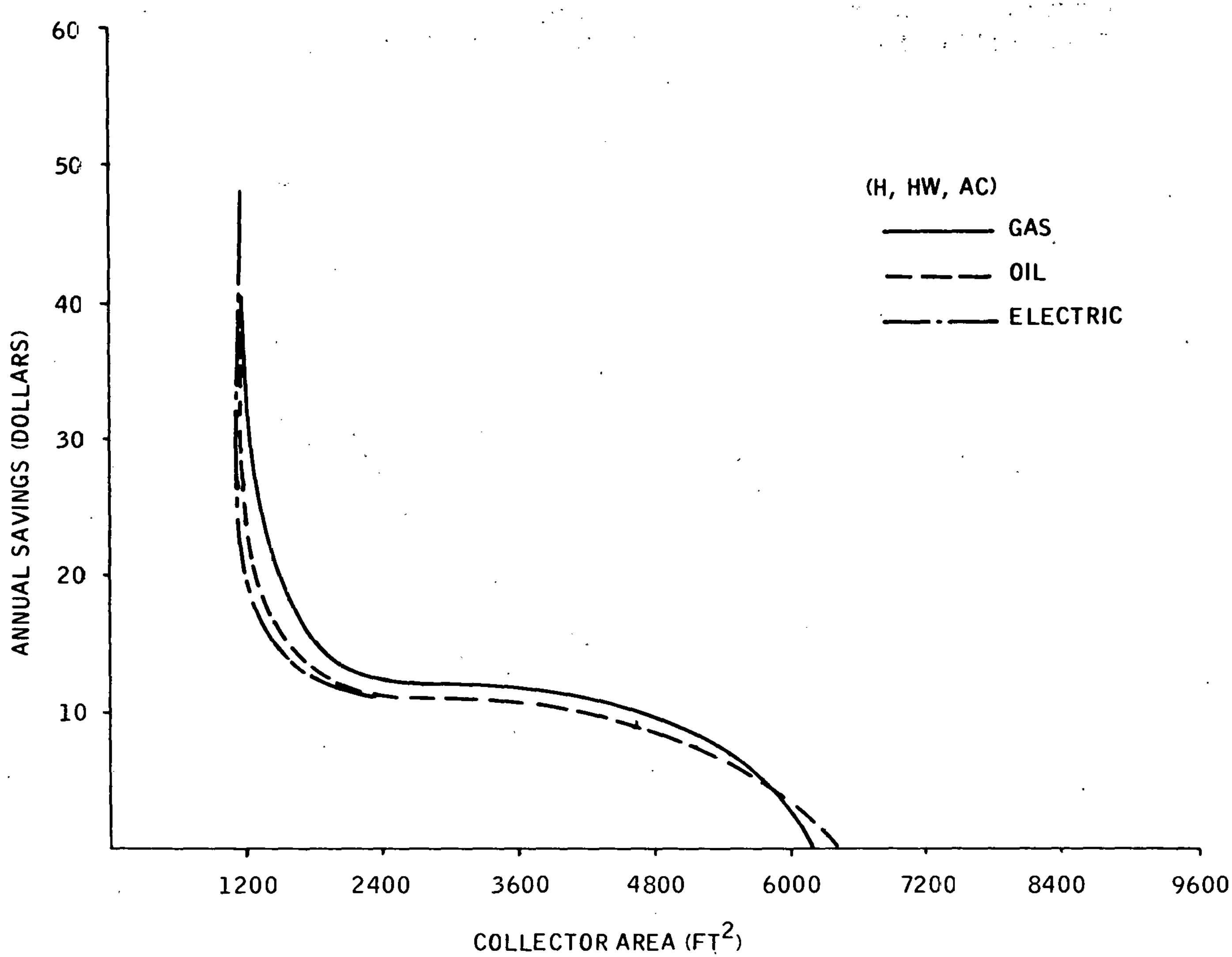


Figure 3-28. Annual Saving Versus Collector Area for Multifamily (New) Omaha Base Building with Awnings

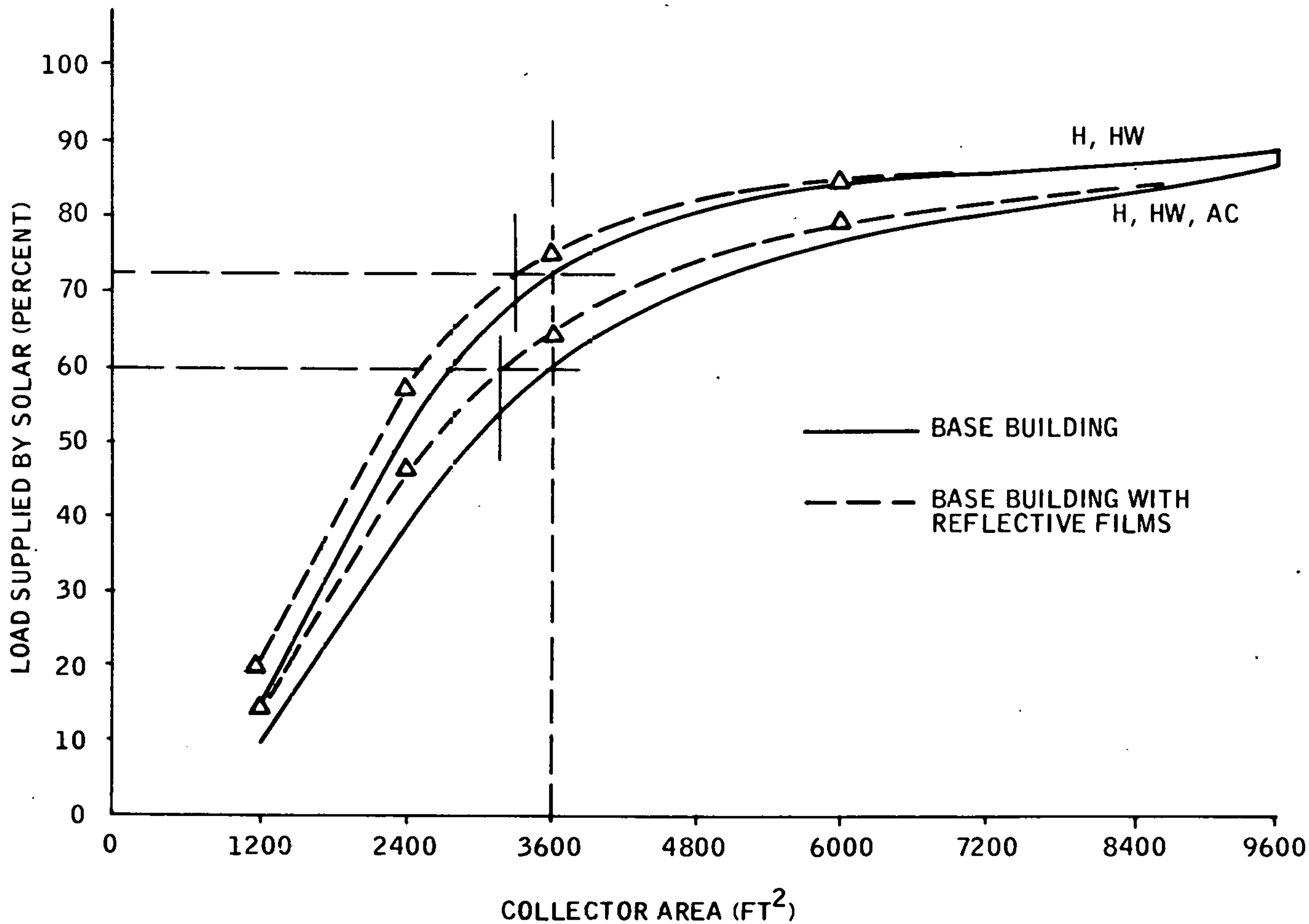


Figure 3-29. Percent of Solar Supplied to Load Collector Area for Multifamily (New) Omaha Base Building with Reflective Films

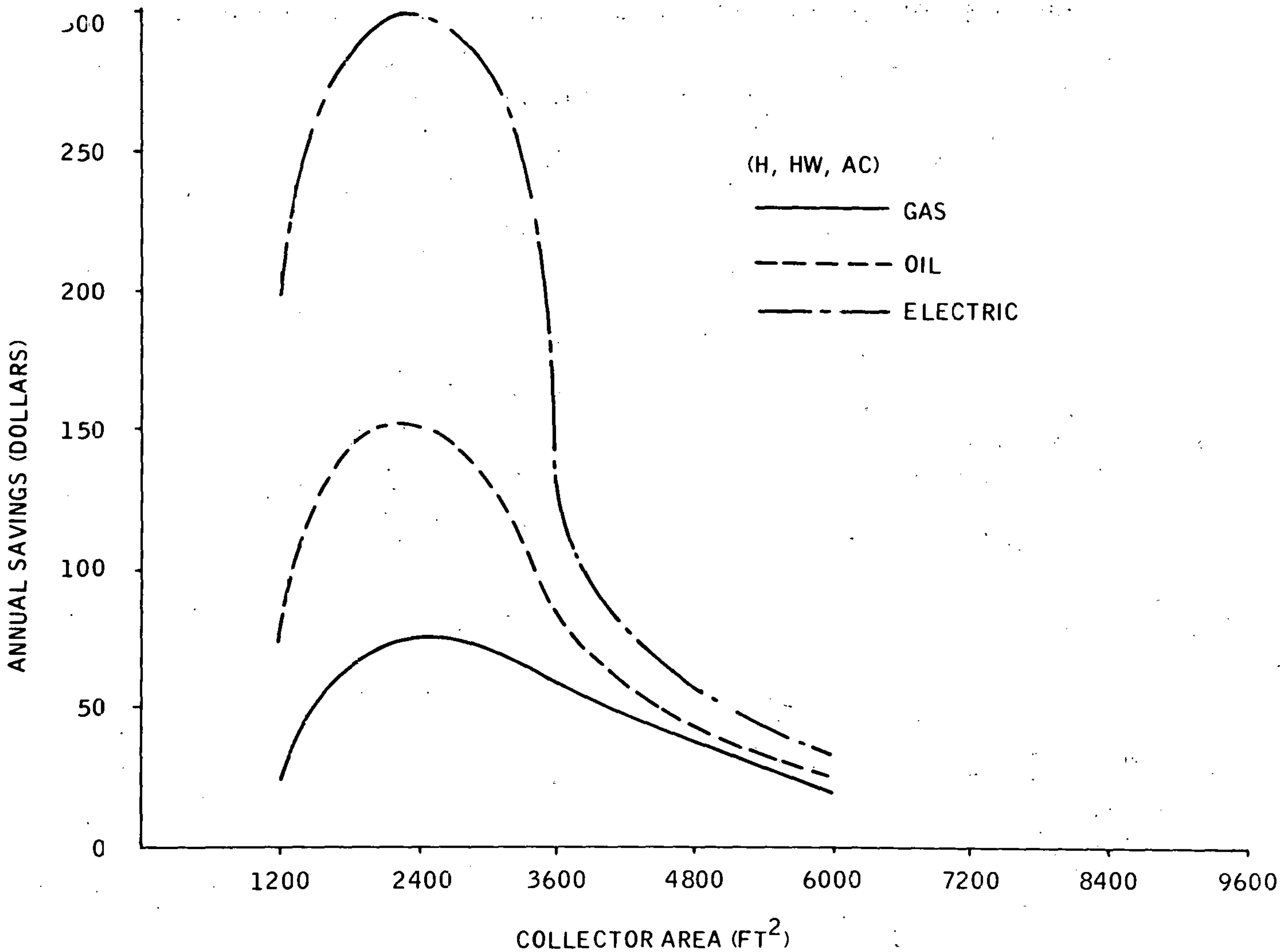


Figure 3-30. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Reflective Film

collector areas and for less expensive auxiliary fuels. Annual savings for heating and hot water are negative since the cost of installing reflective films is greater than the savings from auxiliary fuels.

Figure 3-29 indicates that collector area can be substantially reduced by keeping the percentage of load supplied by solar constant. Since reflective films have no operational costs associated with them, the collector area must be reduced by 2144/25.8 or 84 square feet in order to equal initial investment costs. From the percentage of load supplied by solar versus collector area curve, the collector area can be reduced considerably more than this amount for both heating, hot water and heating, hot water and air conditioning. Since annual costs are lower, reflective films are cost effective and represent a good investment strategy where air conditioning occurs. For heating and hot water systems, reflective films are not cost effective, even at reduced collector area.

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. The net effect is a slight decrease in the total annual load for heating/hot water/air conditioning and an increase for heating/hot water. The percentage of the load satisfied by solar (Figure 3-31) increases where cooling occurs and decreases with respect to heating and hot water.

Annual savings (Figure 3-32) for fixed collector areas 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. Thus, auxiliary fuel costs decrease and net saving increase.

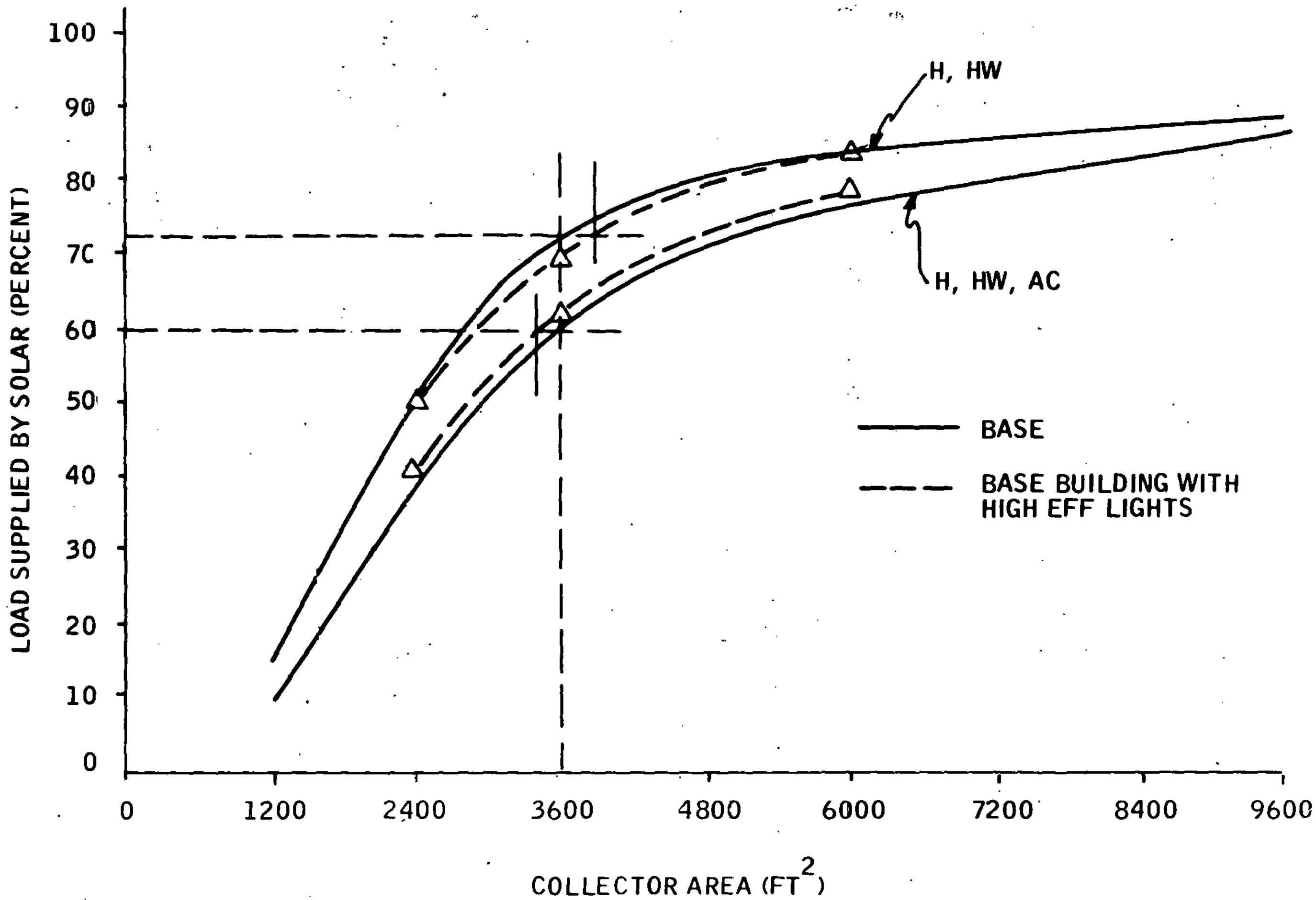


Figure 3-31. Percent of Load Supplied by Solar Versus Collector Area for Multifamily (New) Omaha Base Building with High Efficiency Lights

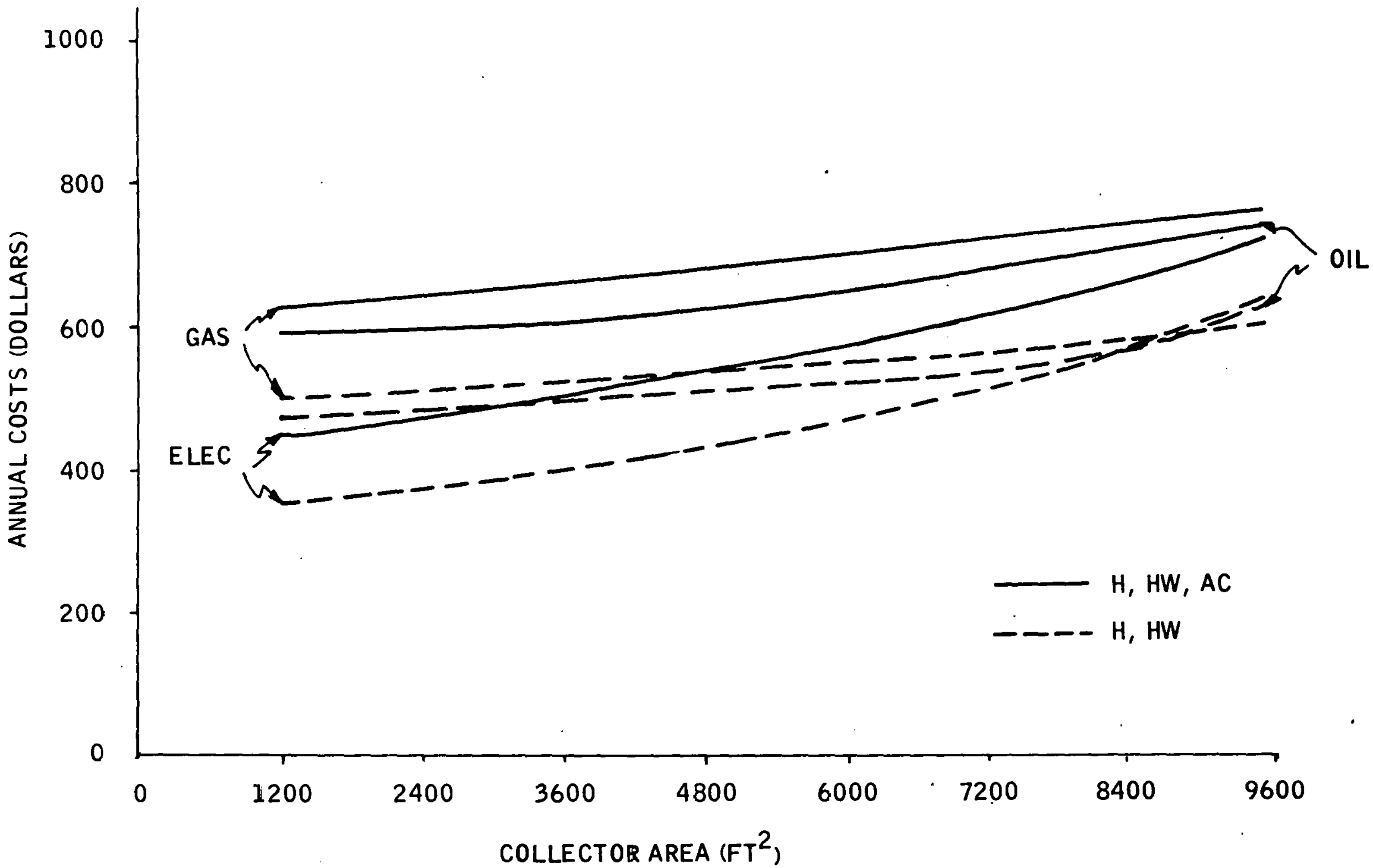


Figure 3-32. Annual Savings for Fixed Collector Areas

If the percentage of the load is held constant, collector area can be reduced approximately 200 $ft.^2$ where air conditioning is considered, but must be increased approximately 300 ft^2 for heating and hot water. At constant and lower collector areas, annual costs are always lower when high efficiency lights are included in the building. For heating and hot water, where the collector area must be increased, annual costs are greater. Thus a strategy of decreased collector area for heating, hot water and air conditioning and constant collector area for heating and hot water minimize annual costs and maximize savings.

Increasing the level of insulation on the domestic hot water tank (R-6) and decreasing the temperature by 10°F resulted in a decreased cooling and hot water load and an increased heating load. Because the domestic hot water tank is now better insulated, losses to the building are decreased. Therefore, less cooling is required to maintain the space temperature and additional heat is required to match previous losses. These shifts are reflected in the percentage of load supplied by the solar system (Figure 3-33).

Annual cost savings (Figure 3-34) result for both heating/hot water and air conditioning and heating/hot water. Savings occur as a result of decreased cooling operational costs and auxiliary fuel usage for both hot water and air conditioning. The magnitude of the annual savings indicates a short payback period for fixed collector areas. Holding the percentage of solar supplied to the load constant, the collector area can be reduced by approximately 150 ft^2 for heating/hot water and air conditioning. This represents an initial investment cost decrease considerably greater than the initial cost of $329.45 for the additional tank insulation. Since annual costs are lower, added tank insulation and decreased temperature represent a cost effective energy conservation technique.

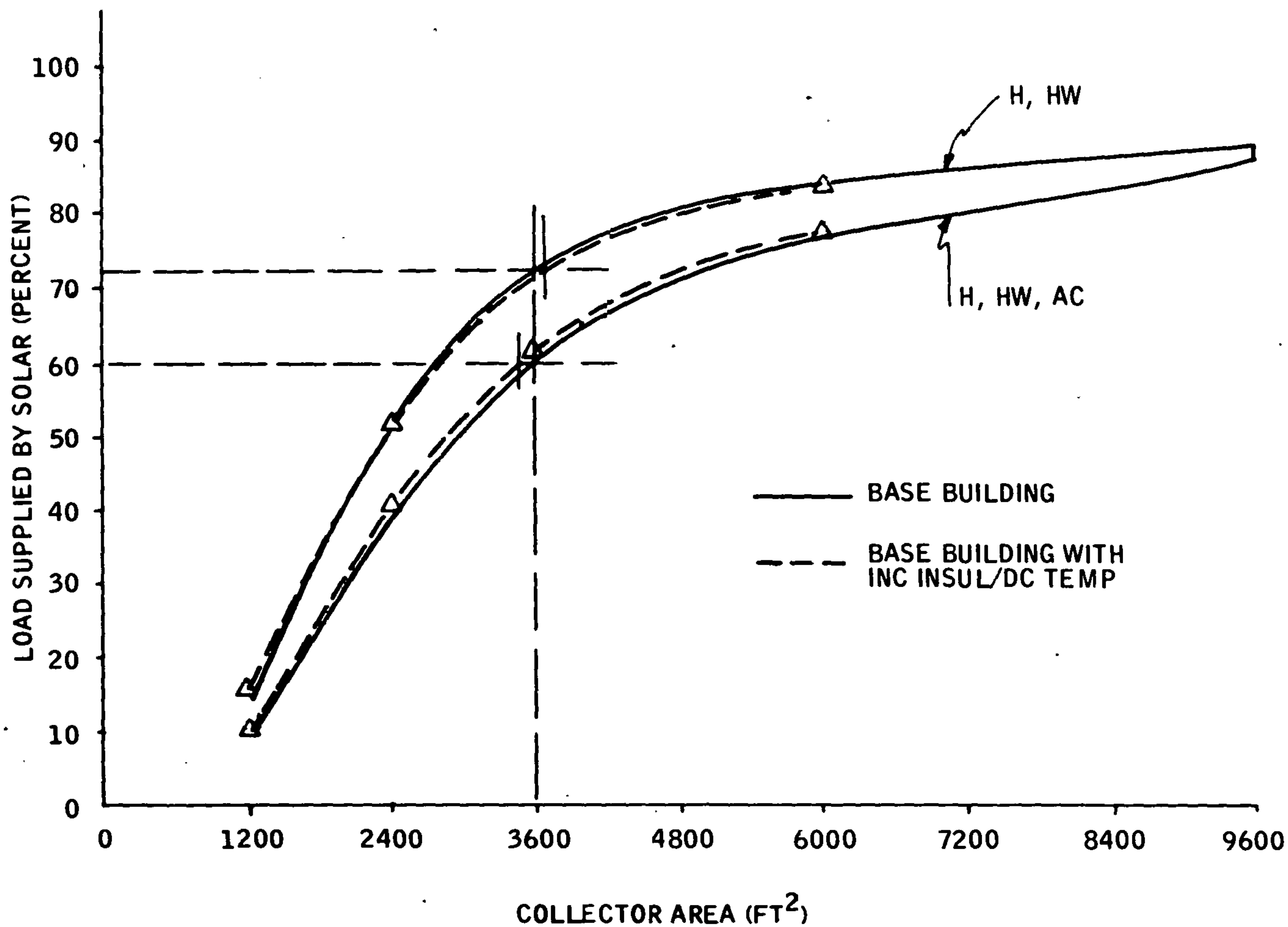


Figure 3-33. Percent of Load Supplied by Solar Versus Collector Area for Multifamily (New) Base Building with Increased Domestic Water Heater Insulation/Decreased Temperature

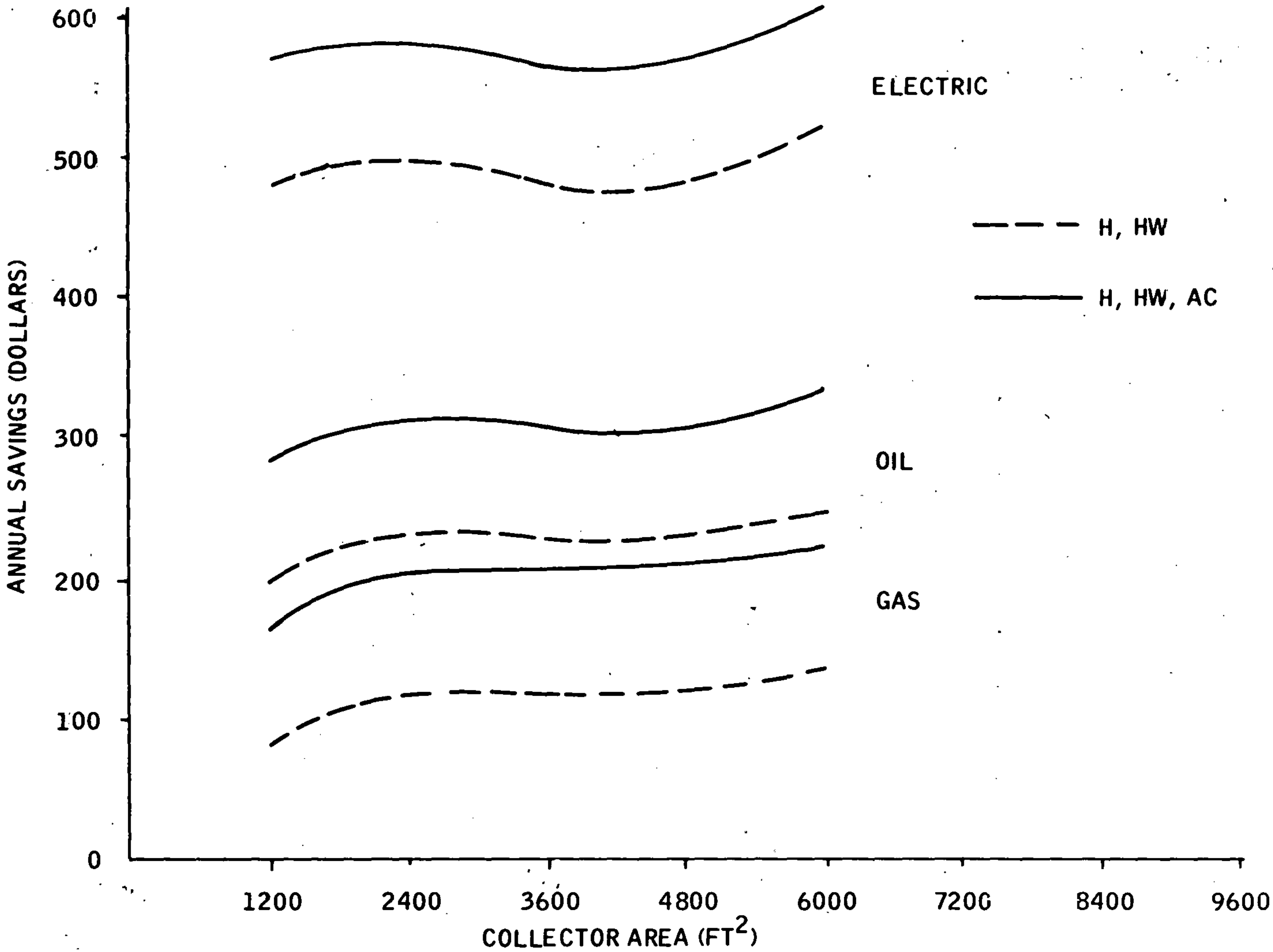


Figure 3-34. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Increased Tank Insulation and Decreased Temperature

For heating and hot water, the collector area must be slightly increased. Examination of the annual cost curves indicate that the increased area still results in lower annual costs as compared to the base case. However, annual costs are minimized at a fixed collector area indicating the preferable strategy.

Improving the thermal resistance (Figure 3-35) of the multifamily building significantly reduced the heating load while increasing the cooling load. The cooling load tends to increase because the added insulation traps the heat within the building. As a net result, a sizeable decrease in the building load is achieved and a significant amount of energy saved.

- Case 8 Ceiling R-38 Total
  2x6 Walls R-19
  1" Styrofoam sheathing
  Double Glazing

- Case 9 Ceiling R-38 Total
  2x6 Walls R-19
  1" Styrofoam
  Triple Glazing

- Case 11 Ceiling R-38 Total
  2x6 Walls R-19
  2" Styrofoam
  Triple Glazing

All three cases of insulation were cost effective with respect to fixed collector area. Annual savings (Figures 3-36 through 3-38) are maximized at different insulation levels with respect to the type of auxiliary fuel.

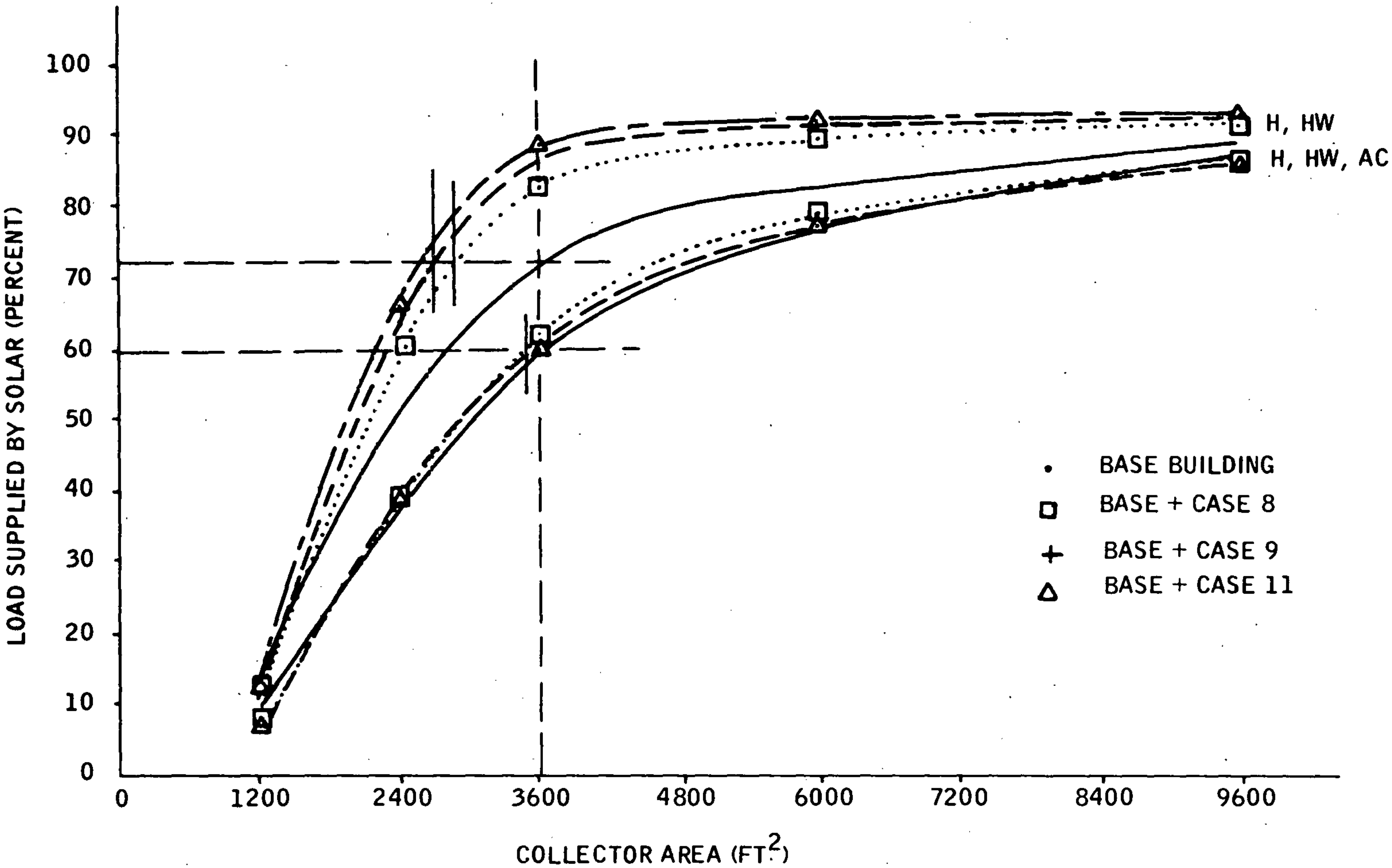


Figure 3-35. Percent Solar Versus Collector Area for Multifamily (New) Omaha Base Building with Increased Insulation

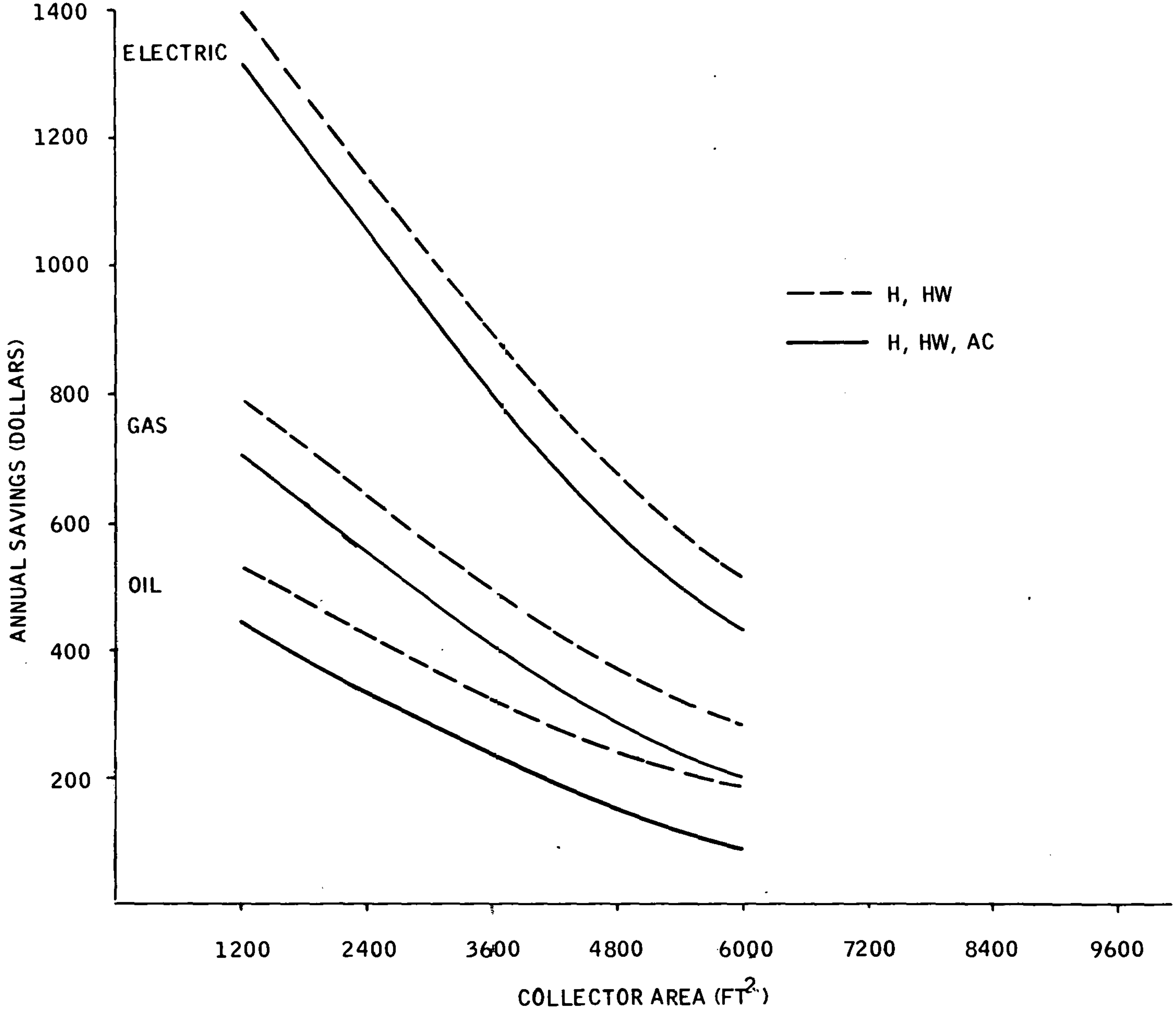


Figure 3-36. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Increased Insulation - 12" Ceiling, 2 x 6 Walls, 1" Styro, Triple Glazing, Case 8

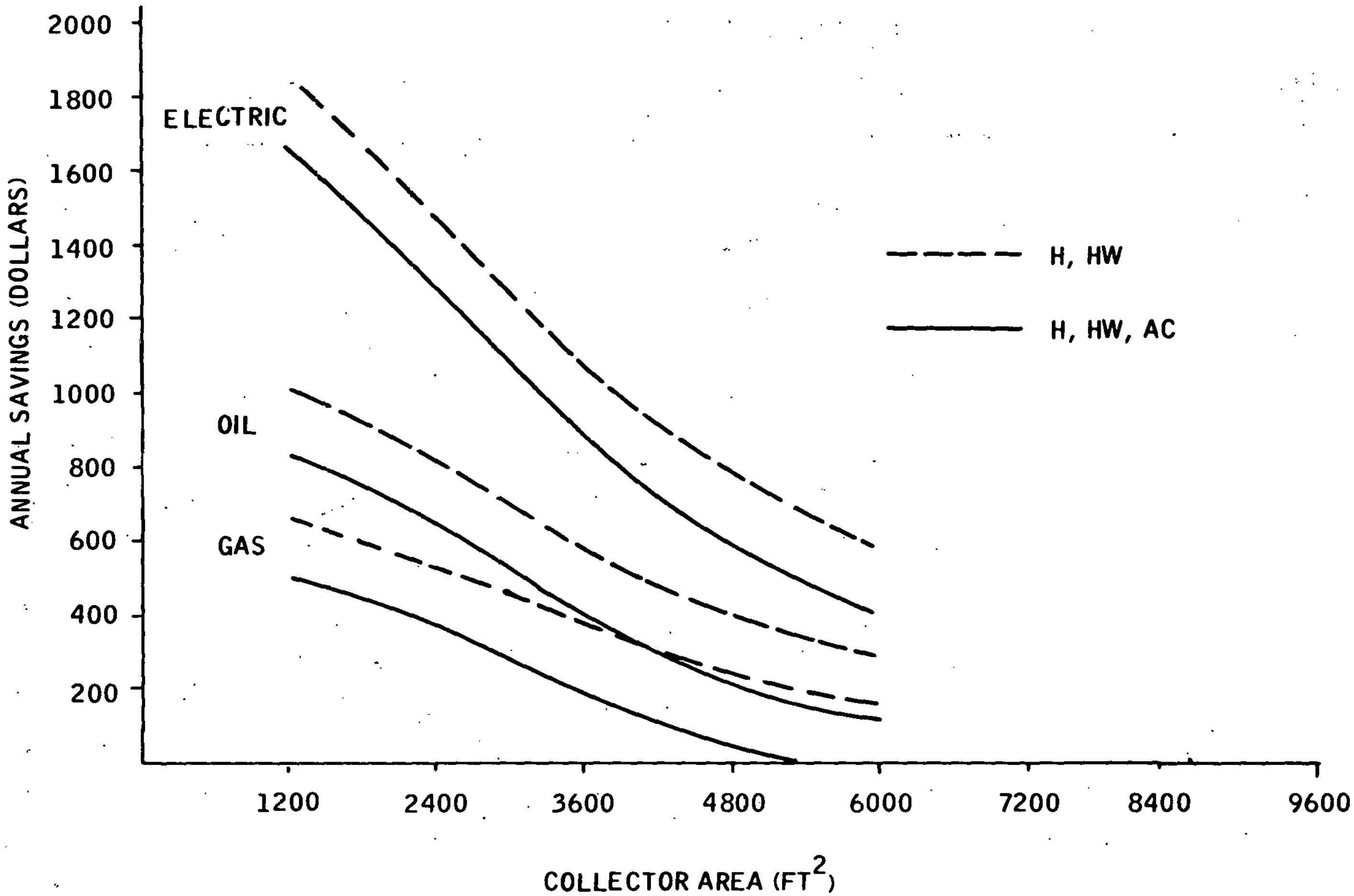


Figure 3-37. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Increased Insulation - 12" Ceiling, 2 x 6 Walls, 1" Styro, Triple Glazing, Case 9

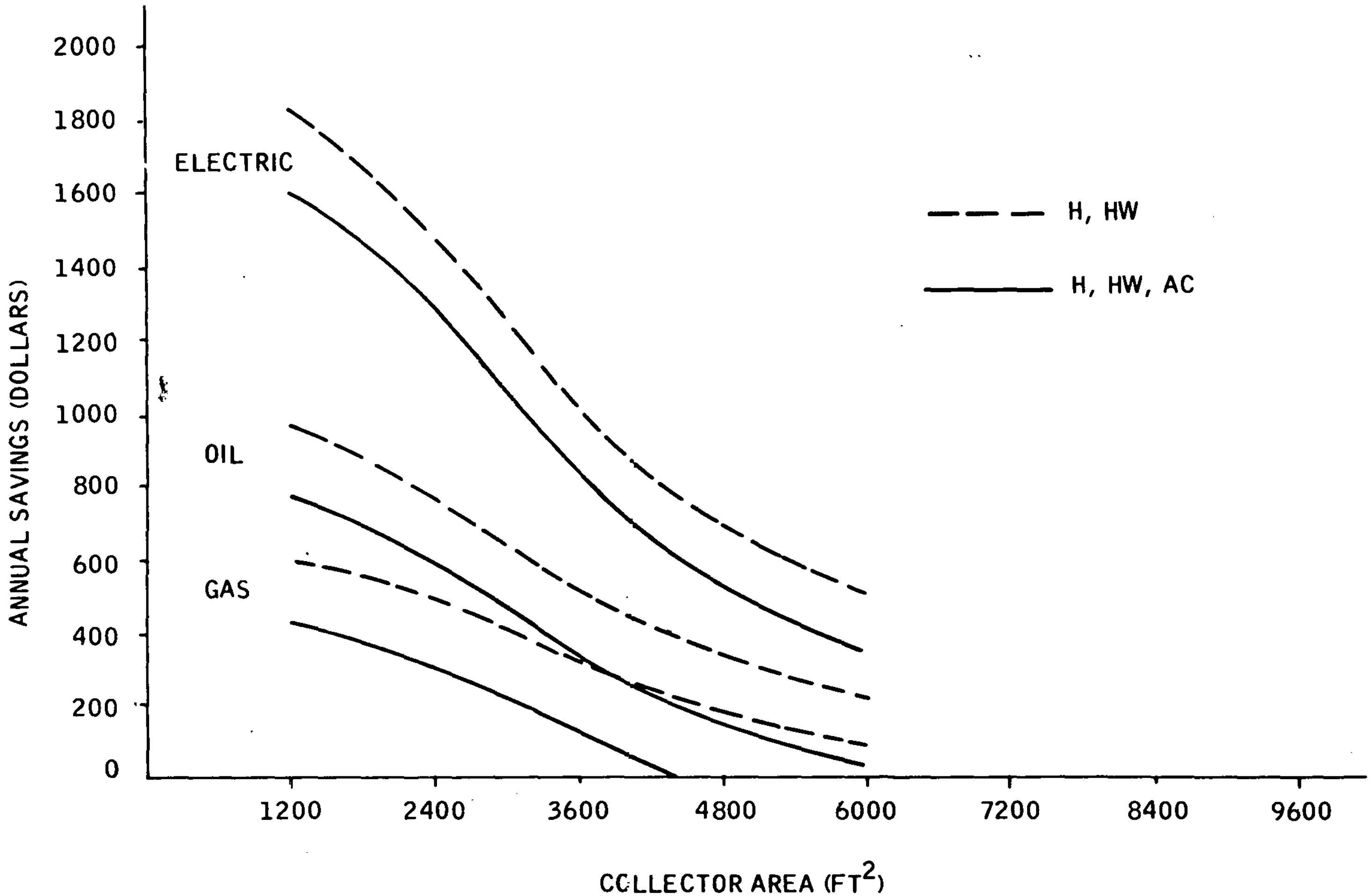


Figure 3-38. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Increased Insulation - 12" Ceiling, 2 x 6 Walls, 2" Styro, Triple Glazing, Case 11

For gas and oil, Case 8 provided maximum savings. For more expensive electric fuel, Case 9 provided maximum savings.

Keeping the percentage of load supplied by solar constant, the collector area can be significantly reduced for heating and hot water (Figure 3-37). The amount of reduction represents initial investment savings far in excess of the initial cost of the added insulation. Where air conditioning is considered, the reduction in collector area about equals the cost of added insulation for Case 8. For Case 9, the amount of reduction does not appear to offset insulation costs. However, since annual costs are lower, additional insulation is cost effective.

Increasing the efficiency of the gas and oil furnaces from 0.55 to 0.80 reduces the amount of auxiliary fuels used and operational times of furnace fans. For analysis purposes, the high efficiency furnace was assumed to be a part of the heating plant within the new multifamily building. Hence, no installed costs are assumed.

Annual cost savings (Figures 3-39) reflect the amount of fuel savings and electric fan consumption for gas and oil auxiliary fuels. At 3600 ft^2 of collector, auxiliary fuel savings amount to 102 x 10^6 BTU/year.

Existing Construction-Omaha, North Central Region--The interaction of the solar system with the existing multifamily building in Omaha is illustrated in Figures 3-40 and tabulated in Tables 3-30 and 3-31. The existing multifamily residence is similar in size and internal loads, but differs considerably in the amount of insulation. As a result, the heating load is noticeably higher and the percentage of the load supplied by solar is lower for comparable collector areas. Comparative results include:

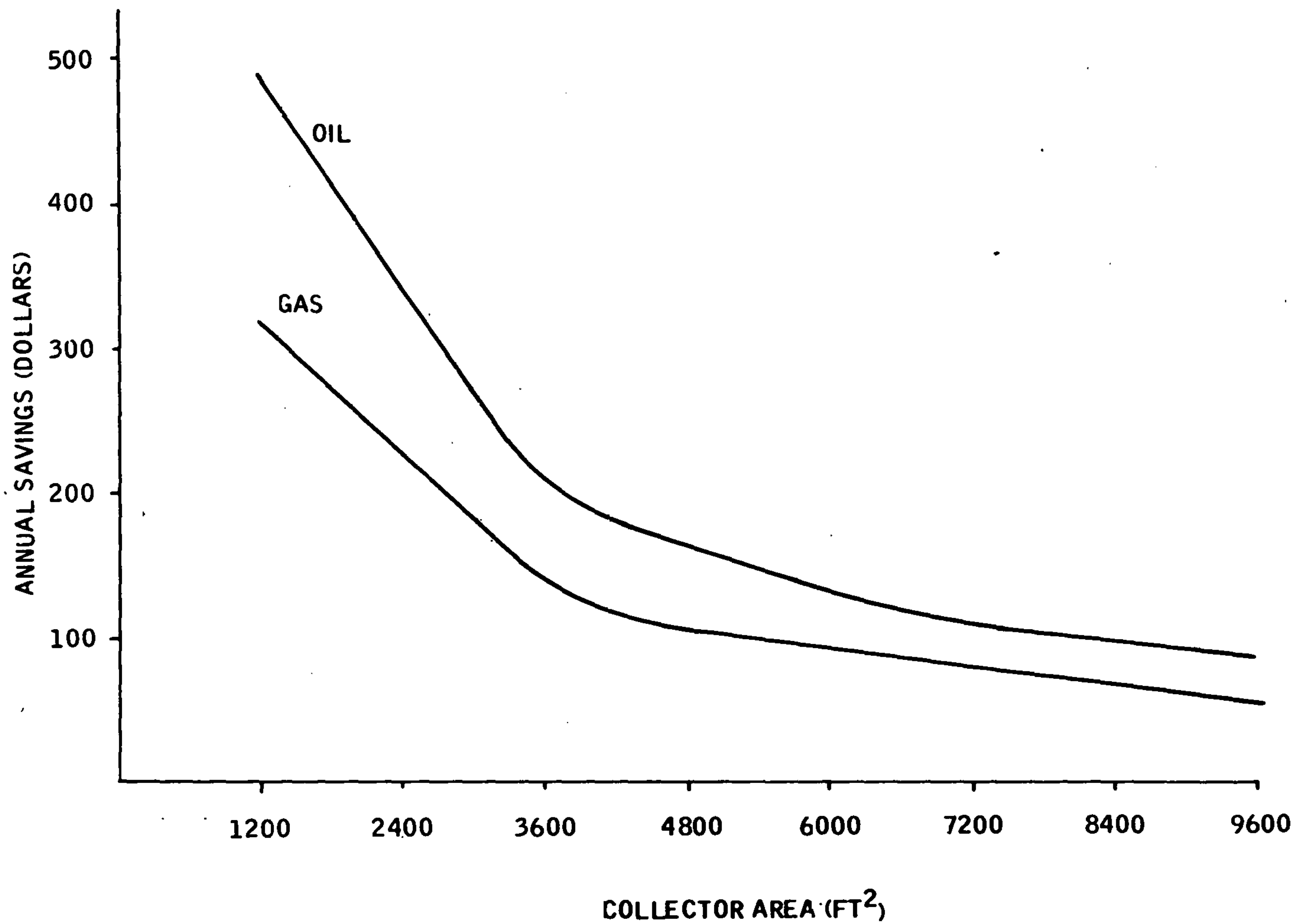


Figure 3-39. Annual Savings Versus Collector Area for Multifamily (New) Omaha Base Building with Furnace Efficiency (H, HW and H, HW, AC)

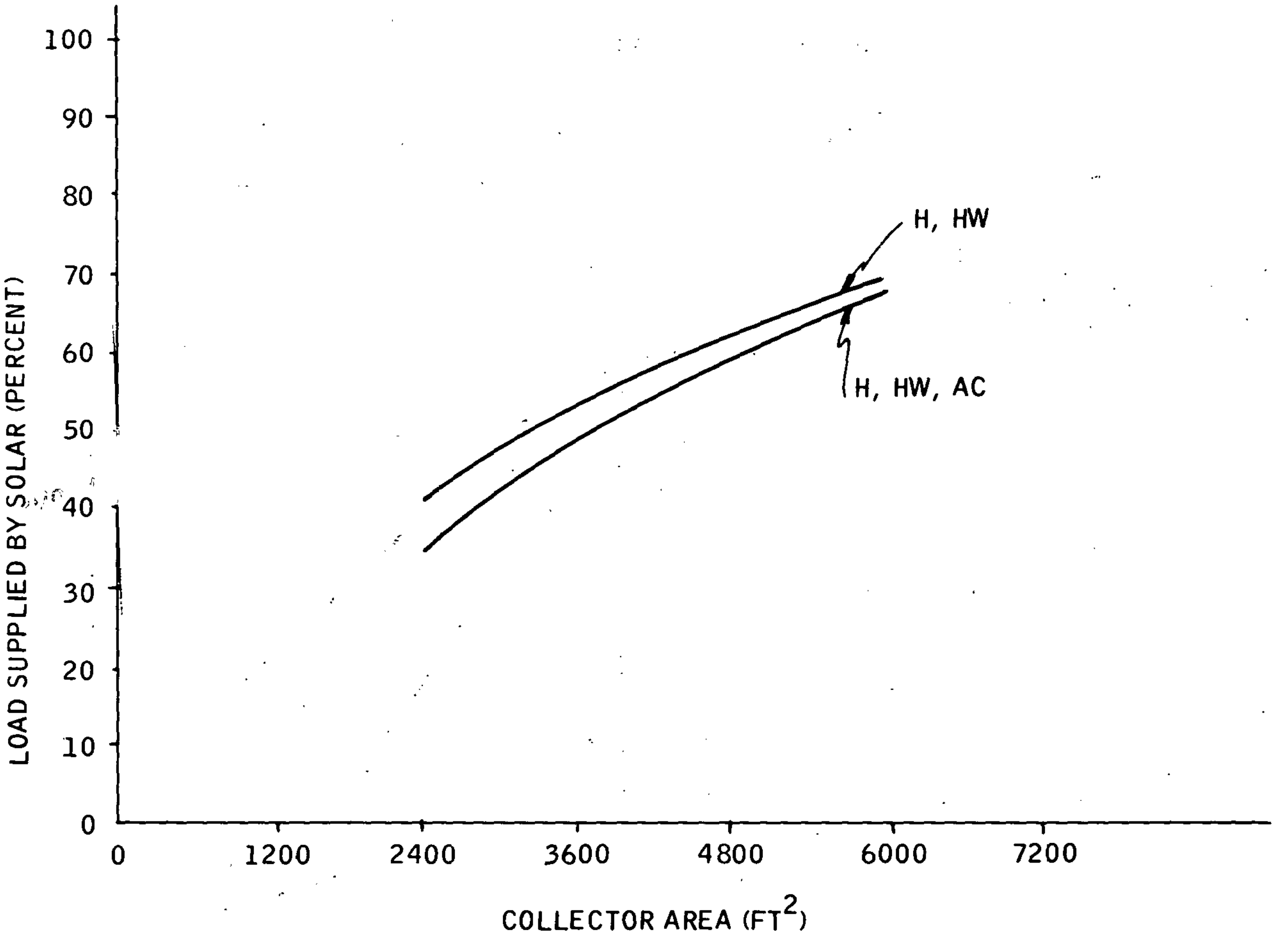


Figure 3-40. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (Existing) Omaha Base Building

Table 3-30. Summary Loads, Costs and Savings
Omaha - Existing - Multi-Family
Heating and Hot Water
3600 Ft^2

ECT Description	Total Load (BTU) $x 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU $x 10^{-6}$	% Savings
Base	717.0	53	13977	14939	17219					
Air Economizer	NA									
High Eff. Lights	755.0	52	13752	14776	17204	225	163	15	-38	-5
Water Tank Insul. & Decrease Temp.	727.1	52	12871	14732	16776	106	207	443	-10.1	-1
Awnings	NA									
Increased Insul. Case 3	361.6	80	13000	13332	14121	977	1607	3098	355.3	
Increased Insul. Case 2	409.8	75	13165	13567	14520	812	1372	2699	307.2	43
Increased Insul. Case 6 1	308.3	83	12915	13197	13866	1062	1742	3353	408.7	57
Night Setback	664.3	55	12859	14733	16804	118	206	415	52.7	7
Reflective Films	730.3	54	14101	15059	17332	-124	-120	-113	-13.3	-2
Improved Furnace Efficiency	717.0	53	14120	14856	17725	-143	83	0	0	0

NA - Not Applicable

Table 3-31. Summary Loads, Costs and Savings
Omaha - Existing - Multi-Family
Heating, Hot Water, Air Conditioning
3600 Ft^2

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	925.7	48	16370	17331	19611					
Air Economizer	901.3	50	17637	18590	20849	-1267	-1259	-1238	24.4	3
High Eff. Lights	932.3	49	15995	17019	19448	375	312	163	-6.6	-1
Water Tank Insul.	921.0	49	16192	17054	19098	178	277	513	4.7	1
Awnings	890.3	50	16318	17276	19549	52	55	62	35.4	4
Increased Insul. Case 3	567.9	65	15414	15747	16535	956	1584	3076	357.8	39
Increased Insul. Case 2	611.9	63	15556	15958	16911	814	1373	2700	313.8	34
Increased Insul. Case 6	521.5	65	15372	15654	16323	998	1677	3288	404.2	44
Night Setback	873.0	50	16258	17131	19202	112	200	409	52.7	6
Reflective Films	895.6	51	16313	17271	19544	57	60	67	30.1	3
Improved Furnace Efficiency	925.7	48	16512	17248	19611	-142	83	0	0	0

- To realize the same load contribution by the solar system as that obtained on the new multifamily residence in Omaha, the collector would have to be increased by approximately 1200 square feet for heating, hot water and air conditioning and 3300 square feet for heating/hot water. This considerable increase in collector area represents a substantial increase in initial system costs and is a further indication of the cost effectiveness of energy conservation.

- The high-efficiency furnace is not cost effective where gas auxiliary fuel is used. Retrofit costs for high-efficiency furnaces exceed fuel cost savings.

- Three cases of insulation were analyzed. All included filling cavities within the stud walls with insulation. Even though this involves considerable expense, the added insulation is cost effective.

New Construction-New York, Northeast Region--Figure 3-41 illustrates the interaction of the solar system with the multifamily residence for New York (Northeast Region). Tables 3-32 and 3-33 are tabulated results for the new residence with each energy conservation technique. Annual costs, annual savings and load savings are tabulated for a collector

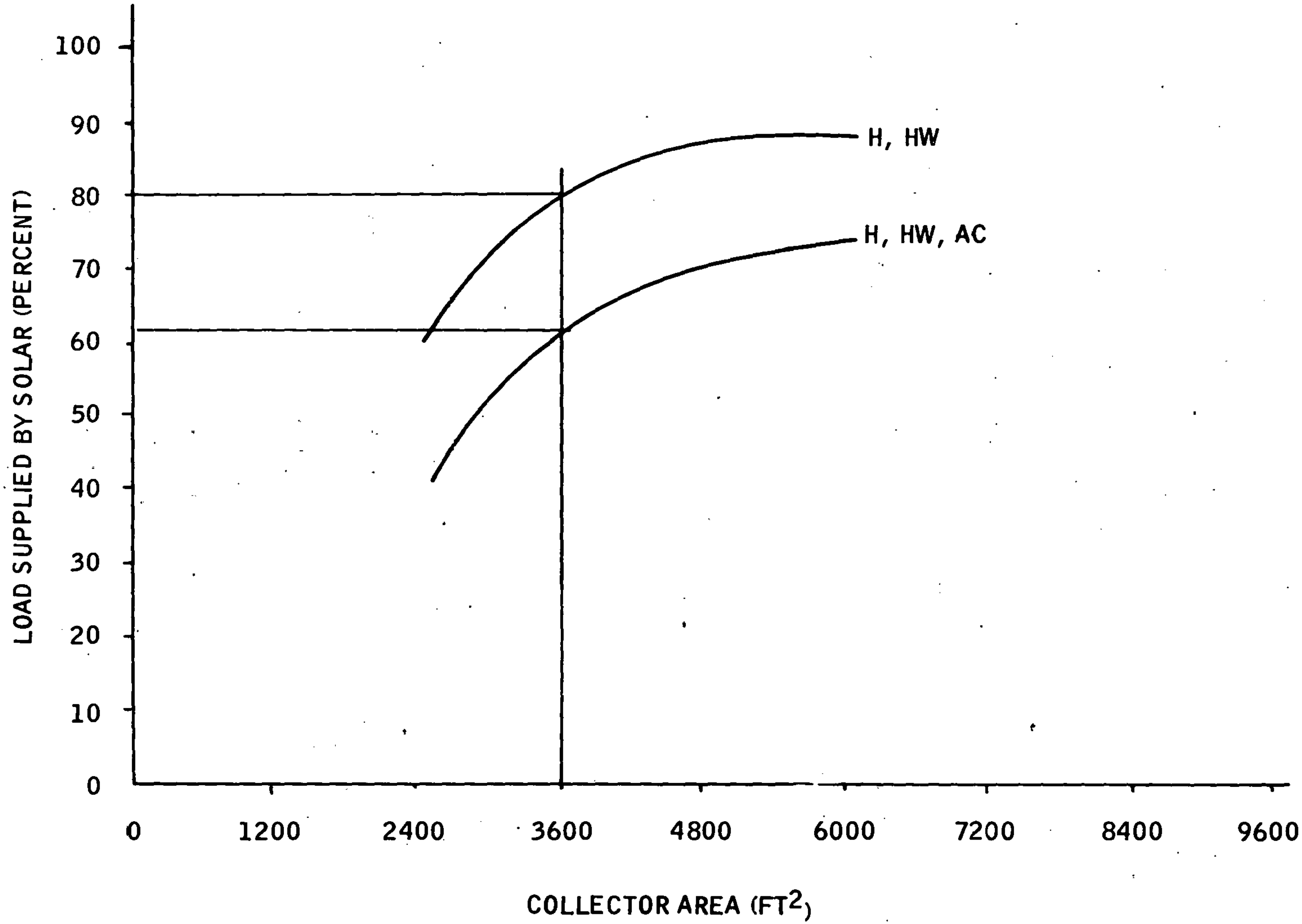


Figure 3-41. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (New) New York Base Building

Table 3-32. Summary Loads, Costs and Savings New York - New - Multi-Family Heating and Hot Water 3600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	325.9	80	12245	12381	13552					
Night Setback	300.4	82	12188	12311	13373	57	70	179	25.5	6.5
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Reflective Films	333.3	82	12392	12520	13630	-145	-139	-78	-8.4	-2
High Eff. Lights	383.2	74	11677	11845	13296	568	536	256	[illegible]	[illegible]
Water Tank Insul & Decreased Tem	328	79	12060	12150	12920	186	232	632	-2.1	-1
Increased Insul Case 4	232.8	90	11911	12000	12768	334	381	784	93.1	23
Increased Insul. Case 5	207.8	90	11947	12034	12783	298	347	769	118.1	30
Increased Insul Case 3	244.4	90	12017	12112	12925	229	270	627	81.5	21
Increased Fur. Efficiency	325.9	80	12155	12249	13552	90	132	0	0	0

N/A Not Applicable

Table 3-33. Summary Loads, Costs and Savings
New York - New - Multi-Family
Heating, Hot Water, Air Conditioning
3600 Ft^2

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	487.2	61	14706	14841	16013					
Night Setback	461.9	62	14657	14780	15842	49	61	171	25.3	5
Air Economizer	404.8	73	15651	15786	16865	-955	-945	-852	82.4	15
Awnings	465.1	63	14695	14831	16001	11	11	12	21.3	4
Reflective Films	462.1	68	14680	14809	15918	27	32	95	25.1	5
Water Tank Insul. & Decreased Temp	467.9	64	14399	14488	15259	308	353	754	19.3	3
Increased Insul. Case 4	442.2	57	14668	14757	15524	39	85	489	45.0	8
Increased Insul. Case 5	450.3	51	14886	14972	15721	-179	-131	292	32.0	6
Increased Insul Case 3	444.0	59	14717	14811	15625	-10	30	383	43.2	8
Increased Furnace Efficiency	487.2	61	14616	14709	16013	90	132	0	0	0
High Eff. Lights	475.7	67	13733	13901	15352	973	940	661	11.5	

area of 3600 square feet.

Three cases of added insulation, corresponding to descriptions provided in Appendix B, were analyzed. All cases were cost effective for heating and hot water systems, while only Case 4 was cost effective for heating, hot water and air conditioning. Case 4 was the most cost effective as indicated by the annual savings.

Existing Construction-New York, Northeast Region--Summary results for an existing multifamily residence in New York are illustrated in Figures 3-42 and Tables 3-34 and 3-35.

Three cases of added insulation were analyzed. All cases involved adding insulation to the wall cavities and ceiling. All were cost effective as indicated by the positive annual savings.

High efficiency furnaces were not cost effective because the high cost of replacing furnaces did not offset the additional fuel savings.

Reflective films were not cost effective for existing residences because savings resulting from a low air conditioning load were not sufficient to offset the cost of installing reflective films.

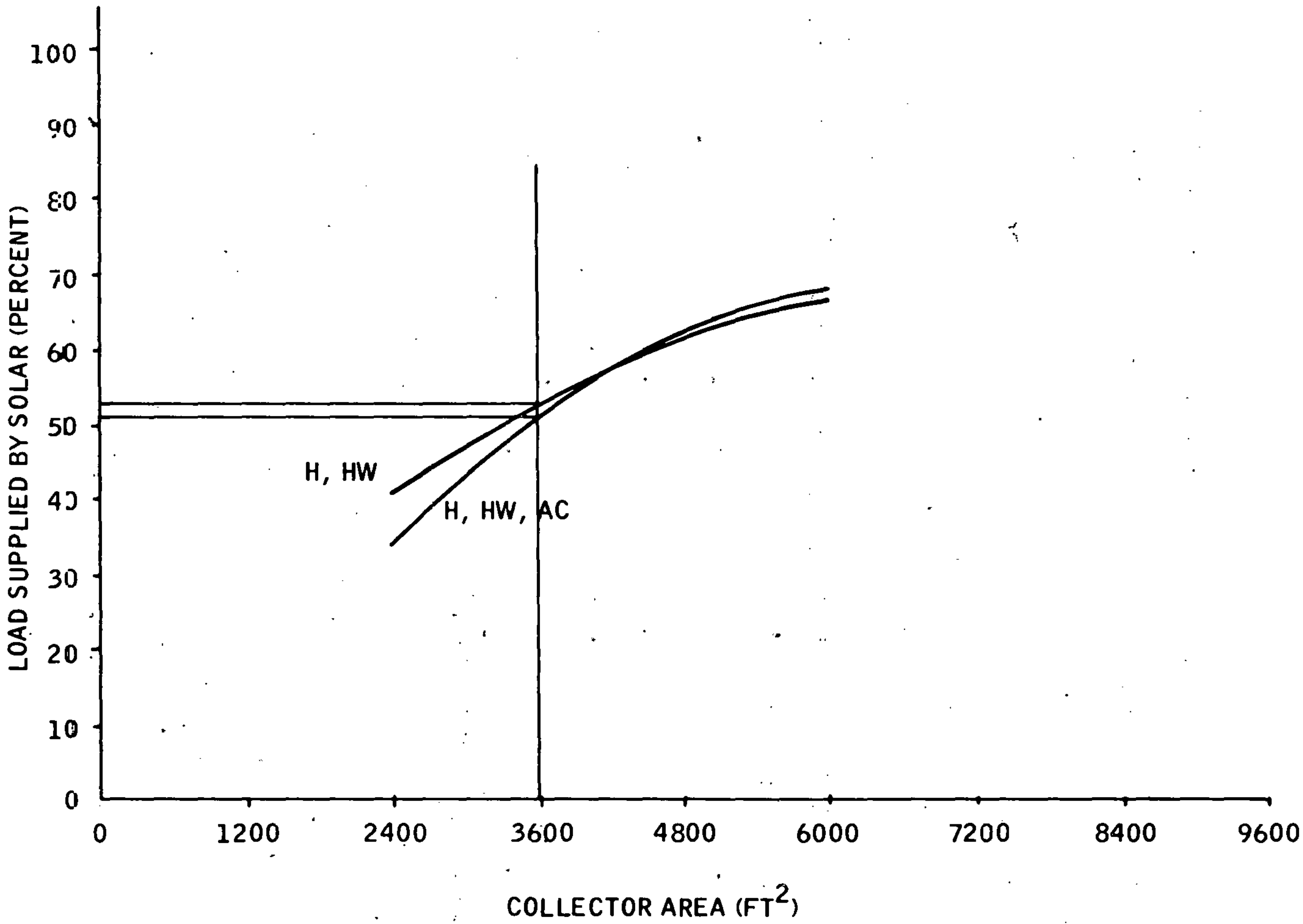


Figure 3-42. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (Existing) New York Base Building

Table 3-34. Summary Loads, Costs and Savings New York - Existing - Multi- Family Heating and Hot Water, Air Conditioning 3600 Ft^2

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	692	54	16, 387	16695	19553					
Night Setback	642.2	56	16225	16501	18877	161	179	445	16.8	2
Air Economizer	656.7	56	16555	16860	19485	-169	-178	-146	2.6	0
Awnings	670.3	56	16369	16676	19329	18	12	17	-11.3	-2
Reflective Films	678.4	57	16388	16697	19355	-2	-7	-6	-19.4	-3
High Eff. Lights	719.8	54	15950	16307	19375	437	388	178	-27.2	-4
Water Tank Insul. & Decreased Temp	687.1	54	16129	16404	18683	247	274	631	-28.1	-4
Increased Insul. Case 2	441.5	63	15707	15814	16740	680	806	2441	217.5	30
Increased Insul. Case 3	452.8	63	15610	15727	16736	776	888	2444	206.2	28
Increased Insul. Case 6	439.8	63	15652	15759	16683	735	853	2489	219.2	30
Improved Furnace Efficiency	692.0	54	16557	16797	553	-170	-102	0	0	0

Table 3-35. Summary Loads, Costs and Savings
New York - Existing - Multi-Family
Heating, Hot Water
3600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	575	59	14189	14498	17156					
Night Setback	525.3	62	14015	14290	16666	160	191	458	49.7	8
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Reflective Films	587.4	60.3	14330	14639	17297	-139	-139	-138	-12.4	-2
High Eff. Lights	643	57	13998	14354	17423	191	144	-267	-68	-12
Water Tank Insul & Decreased Temp.	583.3	59	14016	14280	16560	162	204	561	-8.3	-1
Increased Insul. Case 2	274.4	86	13170	13277	14202	937	1127	2762	300.6	47
Increased Insul. Case 3	293.8	84	13127	13244	14253	977	1158	2714	281.2	44
Increased Insul. Case 6	274.1	86	13121	13229	14153	997	1269	2467	300.9	47
Improved Furnace Efficiency	575	59	14359	14600	17156	-170	-102	0	0	0

New Construction-Atlanta, Southeast Region--Summary results for a new multifamily residence in Atlanta are illustrated in Figures 3-43 and tabulated in Tables 3-36 and 3-37.

Four cases of insulation were analyzed. None were cost effective where air conditioning was considered. For heating and hot water systems, only Case 2 was cost effective.

Reflective films became cost effective for heating and hot water systems where electric auxiliary fuel was used.

Existing Construction-Atlanta, Southeast Region--Summary results for the existing multifamily residence in Atlanta are illustrated in Figure 3-44 and tabulated in Tables 3-38 and 3-39.

Four cases of insulation were analyzed for existing multifamily residences. All were cost effective; Case 2 being the most cost effective.

High efficiency furnaces were not cost effective because of the high cost of retrofitting.

New Construction-Albuquerque, Southwest Region--Summary results for the new multifamily residence in Albuquerque are illustrated in Figures 3-45 and tabulated in Tables 3-40 and 3-41.

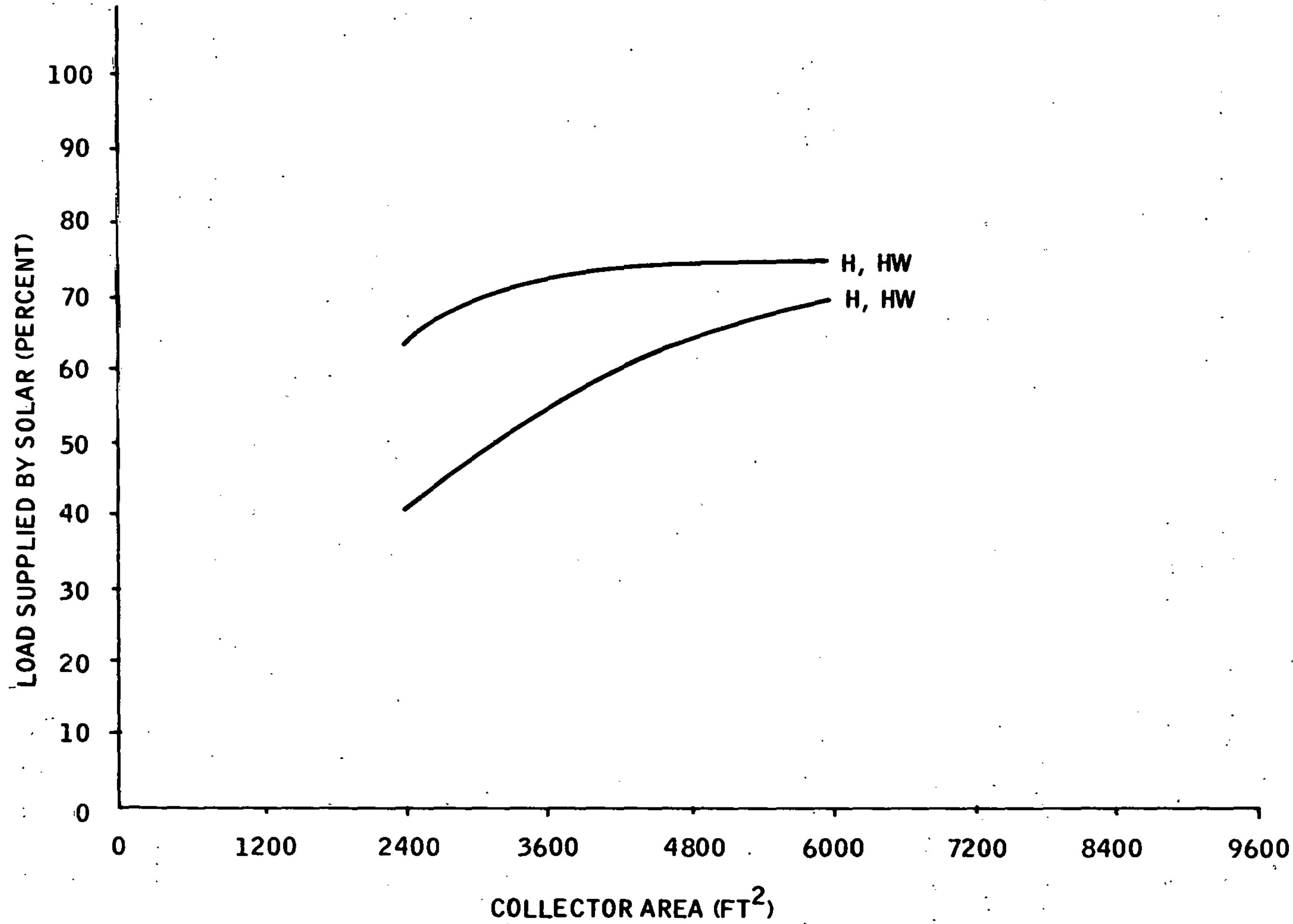


Figure 3-43. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (New) Atlanta Base Building

Table 3-36. Summary Loads, Costs and Savings
Atlanta - New - Multi-Family
Heating, Hot Water, Air Conditioning
3600 Ft^2

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	642	55	14716	14852	15517					
Reflective Film	564	59	14563	14683	15270	154	169	247	78	12
Increase Water Tank Insulation	565	62	14384	14451	14779	332	401	738	77	12
Night Setback	615.9	54	14716	14842	15461	1	10	56	26	4
Air Economizer	561.9	60	16014	16143	16787	-1298	-1290	-1270	80	12
High Eff. Lights	600.4	63	13682	13883	14571	1034	1019	946	41.6	6
Awnings	602.9	58	14632	14767	15429	84	85	88	39	6
Improved Furnace Efficiency	642.0	55	14680	14806	15517	36	5	0	0	0
Increased Insul. Case 2	599.5	50	14874	14985	15529	-158	-133	-12	39	6
Increased Insul. Case 3	600.8	50	14954	15065	15607	-238	-213	-90	41	6
Increased Insul. Case 4	600.3	50	14946	15058	15605	-230	-206	-87	42	6
Increased Insul. Case 5	600.7	49	14980	15090	15629	-264	-238	-112	41	6

Table 3-37. Summary Loads, Costs and Savings
Atlanta - New - Multi-Family
Heating and Hot Water
3600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	358.2	72	11808	11944	12609					
Reflective Film	330.5	74	11872	11993	12580	-64	-48	29	28	8
Increase Water Tank Insulation	307.2	84	11599	11666	11994	209	278	615	51	14
Night Setback	331.9	72	11804	11931	12550	4	13	59	26	7
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	405.6	73	11209	11361	12099	599	583	510	– 47.4	– 13
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Improved Furnace Efficiency	358.2	72	11772	11898	12609	36	46	0	0	0
Increased Insul. Case 2	276.1	71	11764	11876	12419	44	69	190	83	23
Increased Insul. Case 3	277.2	71	11843	11954	12497	-35	-10	113	81	23
Increased Insul. Case 4	280.7	71	11854	11966	12512	-45	-21	97	77	22
Increased Insul. Case 5	271.6	71	11843	11953	12492	-34	-9	117	87	24

N/A Not Applicable

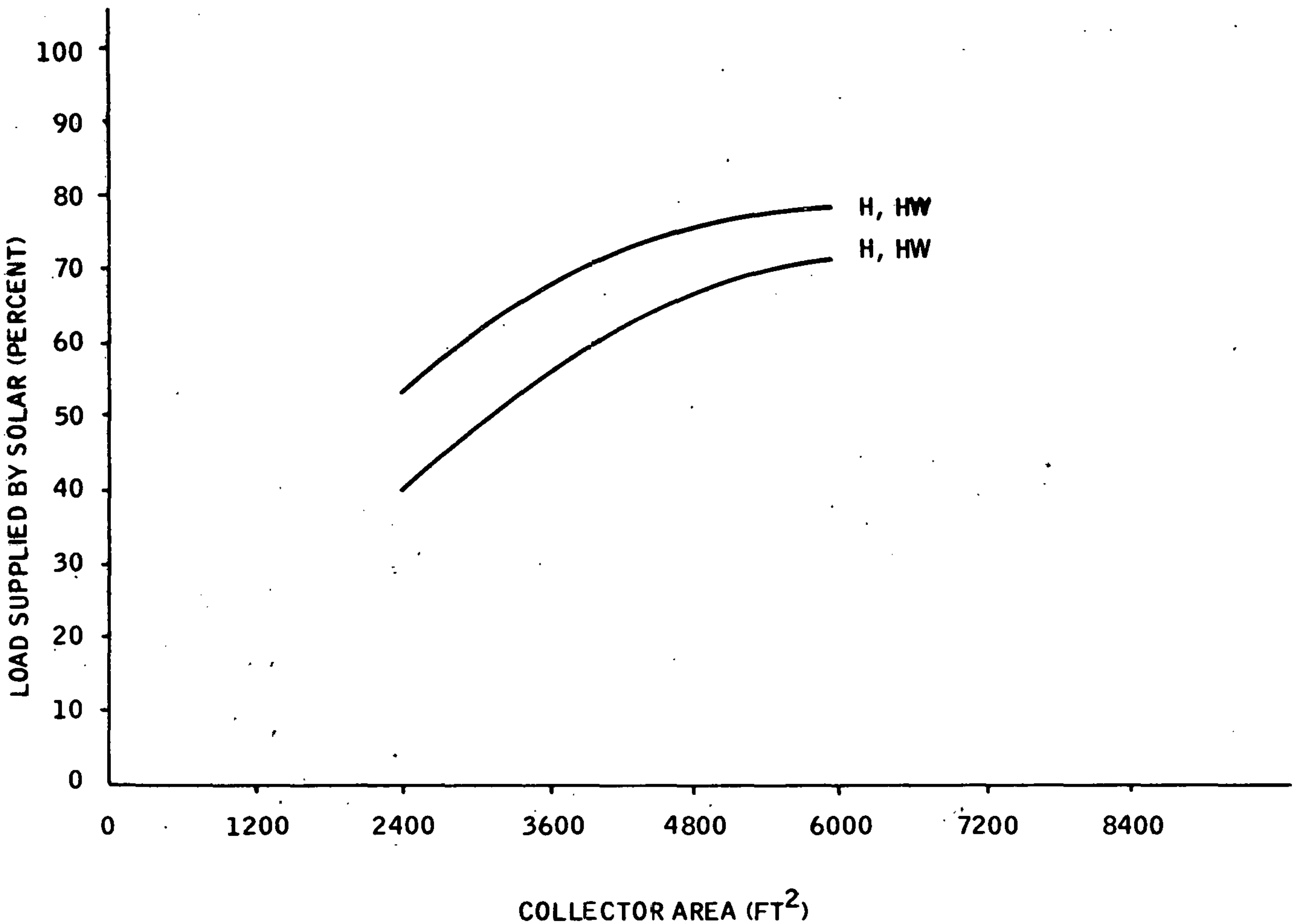


Figure 3-44. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (Existing) Atlanta Base Building

Table 3-38. Summary Loads, Costs and Savings
Atlanta - Existing - Multi-Family
Heating, Hot Water, Air Conditioning
3600 Ft^2

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	856.8	56	16028	16292	17582					
Improved Furnace Efficiency	856.8	56	16273	16491	582	-245	-199	0	0	0
Night Setback	802.6	56	15925	16155	17282	104	137	301	54.2	6
Ins. Water Tank	793.4	61	15745	15944	16914	283	349	669	63.4	7
Reflective Films	820.4	59	15962	16218	17469	67	75	114	36.4	4
Awnings	831.1	58	15987	16250	17538	42	42	44	25.7	3
Air Economizer	828.3	57	17501	17759	19023	-1472	-1467	-1440	28.5	3
High Eff. Lights	853.2	58	15351	15656	17143	677	636	439	3.2	0
Increased Insul. Case 3	607.1	54	15667	15788	16381	362	504	1202	249.7	29
Increased Insul. Case 4	603.9	54	15697	15817	16405	332	476	1177	252.9	30
Increased Insul. Case 6	599.9	52	15749	15865	16428	279	428	1154	256.9	30
Increased Insul Case 7	592.7	52	15783	15898	16455	245	395	1128	264.1	31

Table 3-39. Summary Loads, Costs and Savings
Atlanta - Existing - Multi-Family
Heating and Hot Water
3600 Ft^2

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	593.3	68	13210	13475	14765					
Improved Furnace Efficiency	593.3	68	13455	13673	14765	-245	-198	0	0	0
Night Setback	539.1	69	13099	13329	14456	112	146	309	54.2	9
Insulated Water Tank	548.4	74	13022	13221	14191	189	255	275	44.9	8
Reflective Films	600.1	69	13345	13602	14853	-135	-127	-88	-6.8	-1
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	549.4	66	12835	13140	14627	375	335	138	-51.5	-9
Increased Insul. Case 3	318.9	72	12697	12819	13412	504	656	1353	274.4	46
Increased Insul. Case 4	313.5	72	12715	12835	13423	496	640	1342	279.8	47
Increased Insul. Case 6	292.9	72	12724	12840	13404	486	635	1361	300.4	51
Increased Insul. Case 7	290.0	73	17436	17544	18071	99	175	544	303.3	51

N/A Not Applicable

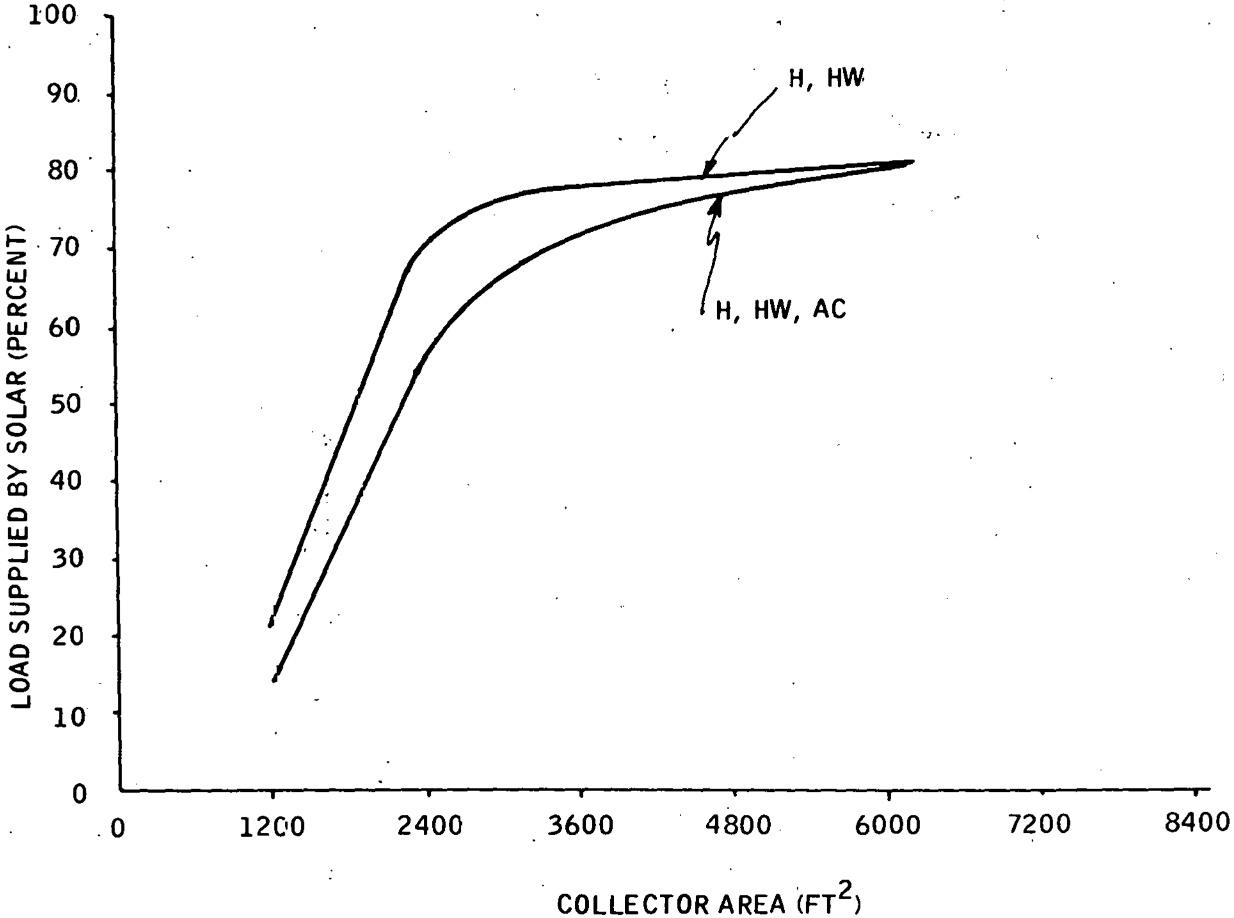


Figure 3-45. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (New) Albuquerque Base Building

Table 3-40. Summary Loads, Costs and Savings
Albuquerque - New - Multi-Family
Heating, Hot Water, Air Conditioning
2400 Ft^2

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	646.3	56	12558	12730	13715					
Improved Furnace Efficiency	646.3	56	12476	12629	13715	82	101	0	0	0
Air Economizer	577.0	64	14015	14177	15104	-1457	-1447	-1389	69.3	11
Night Setback	612.6	57	12500	12653	13525	58	77	190	33.7	5
High Eff. Lights	628.3	58	11437	11638	12792	1121	1092	923	18.0	3
Awnings	607.6	61	12460	12631	13608	98	99	107	38.7	6
Reflective Films	598.3	64	12448	12608	13525	110	122	190	48.0	7
Increase Water Tank Insulation	579.9	63	12274	12388	13040	284	342	675	66.4	10
Increased Insul. Case 3	559.9	53	12550	12667	13332	8	63	383	86.4	13
Increased Insul. Case 4	556.7	51	12648	12762	13411	-90	-32	304	89.6	14
Increased Insul. Case 5	546.3	49	12752	12857	13461	-194	-127	254	100.0	15
Increased Insul. Case 6	547.5	48	12845	12949	13544	-287	-219	171	98.8	15

Table 3-41. Summary Loads, Costs and Savings
Albuquerque - New - Multi-Family
Heating and Hot Water
2400 Ft^2

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	442.6	70	9967	10139	11124					
Improved Furnace Efficiency	442.6	70	9886	10038	11124	81	101	0	0	0
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	408.7	71	9885	10038	10910	82	101	214	33.9	8
High Eff. Lights	473.2	67	9519	9721	10875	448	418	249	-30.6	-7
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Reflective Films	447.7	72	10108	10269	11186	-141	-130	-62	-5.1	-1
Increase Water Tank Insulation	396.6	78	9790	9904	10556	177	235	568	46.0	10
Increased Insul. Case 3	323.4	72	9791	9907	10572	176	232	552	119.2	27
Increased Insul. Case 4	307.6	71	9830	9944	10593	137	195	531	135.0	31
Increased Insul. Case 5	280.1	71	9846	9951	10555	121	188	569	162.5	37
Increased Insul. Case 6	276.6	71	9915	10019	10614	52	120	510	166.0	38

N/A Not Applicable

Four cases of insulation were examined. All were cost effective where only heating and hot water were analyzed. Only Case 3 was cost effective where air conditioning was considered.

Existing Construction-Albuquerque, Southwest Region--Summary results for the new multifamily residence in Albuquerque are illustrated in Figures 3-46 and tabulated in Tables 3-42 and 3-43.

Four cases of insulation were analyzed. All were cost effective, even when air conditioning was considered.

High efficiency furnaces were cost effective for existing buildings because the saving resulting from the reduced fuel auxiliary usage was sufficient to offset the cost of retrofitting the building with high efficiency furnaces.

Reflective films were not cost effective where air conditioning was considered because of the same cooling load.

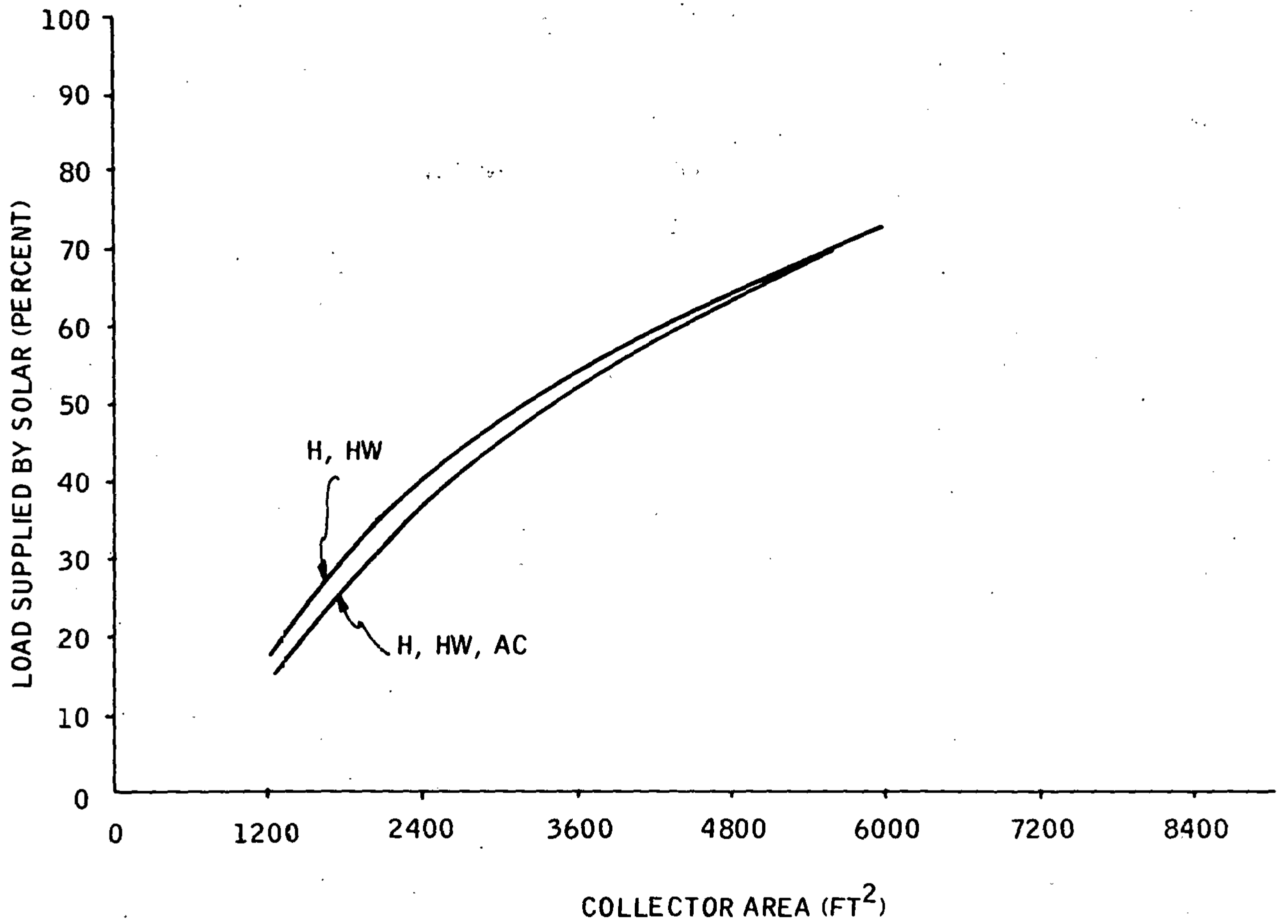


Figure 3-46. Percent of Load Supplied by Solar Versus Collector Area for Multifamily Residence (Existing) Albuquerque Base Building

Table 3-42. Summary Loads, Costs and Savings
Albuquerque - Existing - Multi-Family
Heating, Hot Water, Air Conditioning
3600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	1239.0	53	17590	18221	21826					
Improved Furnace Efficiency	1239.0	53	17430	17902	21816	160	319	0	0	0
Night Setback	1149.0	55	17263	17812	20946	327	409	880	90.0	7
Air Economizer	1216.0	54	19170	19798	23386	-1580	-1577	-1560	23.0	2
Awnings	1217.0	54	17561	18192	21800	29	29	26	22.0	2
High Eff. Lights	1247.0	52	17153	17828	21691	437	395	135	-8.0	-1
Reflective Film	1228.0	54	17640	18282	21952	-50	-61	-126	11.0	1
Increase Tank Insulation	1186.0	55	17355	17934	21243	235	287	583	53.0	4
Increased Insul. Case 3	591.5	71	15337	15453	16115	2253	2768	5711	647.5	52
Increased Insul Case 4	577.0	64	15425	15587	16514	2165	2634	5312	662.0	53
Increased Insul. Case 6	565.7	70	15400	15507	16119	2190	2714	5707	673.3	54
Increased Insul. Case 7	561.6	69	15428	15533	16132	2162	2688	5694	677.4	54

Table 3-43. Summary Loads, Costs and Savings
Albuquerque - Existing - Multi-Family
Heating and Hot Water
3600 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	1063.0	54	15200	15831	19436					
Improved Furnace Efficiency	1063.0	54	15040	15512	19436	160	319	0		
Night Setback	972.7	56	14869	15418	18552	331	413	884	90.3	8
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	1101	52	14922	15598	19460	278	233	-24	-62	-6
Reflective Film	1087.0	54	15431	16073	19743	-231	-242	-307	-24.0	-2
Increased Tank Insulation	1023.0	56	15036	15615	18923	164	216	513	40.0	4
Increased Insul. Case 3	391.0	77	12768	12884	13546	2432	2947	5890	672.0	63
Increased Insul. Case 4	441.8	72	13120	13282	14209	2080	2549	5227	621.2	58
Increased Insul. Case 6	350.3	76	12757	12864	13477	2443	2967	5959	712.7	67
Increased Insul. Case 7	342.0	76	12766	12871	13470	2434	2960	5966	721.0	68

N/A Not Applicable

Conclusions-- Results for the economic analysis are summarized in Tables 3-44 through 3-51 which illustrate annual saving (dollars) and payback periods (years) for each energy conservation technique for each of the four regions. Results are summarized for each of the three auxiliary fuel types and for both heating, hot water, and air conditioning and heating and hot water systems. The magnitude of annual savings provide a means to rank energy conservation techniques; providing an indication of which are most preferable. Payback periods indicate the length of time required for savings to offset initial investment costs. Paybacks of greater than 20 years are tabulated and should be used as a means of relative ranking. Some instances of negative annual saving with positive payback years occur because the annual saving are calculated from annual costs which include the cost of the energy conservation technique.

Results shown are based on an analysis which considered implementing each energy conservation technique separately. No computerized analysis of combinations of energy conservation techniques was performed for the multifamily residence. Greater energy and dollar savings can be achieved by combining the more promising energy conservation techniques. The combined effect would not be completely additive because of the interaction of the solar system and energy conservation techniques.

Savings and payback periods for any single energy conservation technique vary greatly between regions because of differences in climate, in amount

Table 3-44. Energy Conservation Techniques, Cost Effectiveness Multi-Family Residence Heating, Hot Water, Air Conditioning Gas Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
High Eff. Furnace	225/*	-142/28	90/*	-170/31	36/-	245/13	82/-	629/9
Night Setback	38/11	112/7	49/11	161/6	1/20	104/8	58/9	327/3
Air Economizer	-1173/-	-1267/-	-955/-	-169/37	-1298/-	-1472/-	-1457/-	-1580/-
High Eff Lights	654/3	375/10	973/2	437/10	1034/2	677/5	1121/2	437/9
Reflective Films	48/15	57/12	27/17	-2/20	154/9	67/13	110/11	-50/32
Awnings	5/19	52/14	11/18	18/17	84/11	42/14	98/11	29/16
Water Tank Insulation Decreased Temp.	191/2	178/2	308/1	247/2	332/1	283/1	284/1	235/1
Increased Insulation	213/8	998/7	39/16	776/7	-158/-	362/10	8/19	2253/3

Table 3-45. Energy Conservation Techniques, Cost Effectiveness
Multi-Family Residence
Heating, Hot Water
Gas Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
High Eff Furnace	225/*	-143/28	90/*	-170/31	36/-	245/13	81/-	629/9
Night Setback	46/11	118/7	57/10	160/6	4/19	112/7	82/7	331/3
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	530/3	225/12	568/3	191/14	599/3	375/7	448/4	278/11
Reflective Films	-120/236	-124/-	-145/-	-139/-	-64/37	-135/-	-411/-	-231/-
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water Tank Insulation Decreased Temp.	112/3	106/3	186/2	162/2	209/2	189/2	177/2	164/2
Increased Insulation	321/9	1062/6	334/6	997/6	44/17	504/9	176/12	2443/3

N/A Not Applicable

Table 3-46. Energy Conservation Techniques, Cost Effectiveness
Multi-Family Residence
Heating, Hot Water, Air Conditioning
Oil Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
High Eff. Furnace	350/5	83/17	132/9	- 102/25	5/19	199/13	101/10	788/7
Night Setback	80/8	200/5	61/10	179/6	10/17	137/6	77/8	409/3
Air Economizer	-1162/-	-1259/-	-945/-	-178/39	-1290/-	-1467/-	-1447/-	-1577/-
High Eff. Lights	610/3	312/11	940/2	388/10	1019/2	636/5	1092/2	393/10
Reflective Films	70/13	60/11	32/16	-7/22	169/9	75/13	122/10	-61/37
Awnings	5/19	55/13	11/18	12/18	85/11	42/14	99/17	29/16
Water Tank Insulation Decreased Temp.	292/1	277/1	353/1	274/1	401/*	349/1	342/1	287/1
Increased Insulation	367/6	1677/5	85/12	888/7	-133/46	50[illegible]/9	63/16	2768/2

N/A Not Applicable

* Less than 1 year

\- Negative

Paybacks greater than 20 years for relative ranking only

Table 3-47. Energy Conservation Techniques, Cost Effectiveness
Multi-Family Residence
Heating, Hot Water
Oil Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
High Eff. Furnace	351/5	83/17	132/9	-102/2	46/14	198/14	101/10	788/7
Night Setback	86/7	206/5	70/9	191/6	13/16	146/6	101/7	413/3
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	486/4	163/14	536/3	144/1	583/3	335/8	418/4	233/12
Reflective Films	-98/79	-120/-	-139/492	-139/-	-48/31	-127/1012	-130/100	-242/-
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water Tank Insulation Decreased Temp	214/2	207/2	232/2	204/2	278/1	255/1	235/1	216/2
Increased Insulation	508/7	1742/4	381/5	2467/4	69/15	656/7	232/10	2967/3

N/A Not Applicable

* Less than 1 year

\- Negative

Paybacks greater than 20 years for relative ranking only

Table 3-48. Energy Conservation Techniques, Cost Effectiveness
Multi-Family Residence
Heating, Hot Water, Air Conditioning
Electric Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
High Eff. Furnace	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
Night Setback	175/5	409/3	171/5	445/3	56/10	301/4	190/4	880/1
Air Economizer	-1135/-	-1238/-	-852/-	-146/33	-1270/-	-1440/-	-1389/-	-1560/-
High Eff. Lights	506/4	163/14	661/3	178/14	946/2	439/6	923/2	135/15
Reflective Films	122/10	67/11	95/12	-6/21	247/7	114/11	190/8	-126/399
Awnings	6/19	62/13	12/18	17/17	88/11	44/14	107/10	26/16
Water Tank Insulation Decreased Temp.	533/*	513/*	754/*	631/*	738/*	669/*	675/*	583/*
Increased Insulation	779/5	3288/3	489/4	2489/4	-12/21	1202/5	383/8	5711/1

* Less than 1 year

\- Negative

Paybacks greater 20 years for relative ranking only

Table 3-49. Energy Conservation Techniques, Cost Effectiveness
Multi-Family Residence
Heating, Hot Water
Electric Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
High Eff. Furnace	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
Night Setback	182/4	415/3	179/5	458/3	59/9	309/3	214/4	884/1
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Eff. Lights	382/4	14/19	256/6	-267/57	510/4	138/12	249/6	-24/21
Reflective Films	-45/30	-113/-	-78/43	-138/-	29/17	-88/62	-62/38	-307/-
Awnings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water Tank Insulation Decreased Temp.	455/1	443/*	632/*	561/*	615/*	275/1	-62/-	513/*
Increased Insulation	950/4	3353/3	784/3	2762/3	190/11	1361/5	569/9	5966/1

N/A Not Applicable

* Less than 1 year

- Negative

Paybacks greater than 20 for relative ranking only

Table 3-50. Energy Conservation Techniques, Cost Effectiveness Multi-Family Residence 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	Y	Y	Y	Y	Y	Y	Y
Air Economizer	N	N	N	N	N	N	N	N
High Eff. Lights	Y	Y[2]	Y	Y	Y	Y	Y	Y[2]
Reflective Films	Y	Y	Y	N	Y	Y	Y	N
Awnings	Y	Y	Y	Y	Y	Y	Y	Y
Water Tank Insulation Decreased Temp.	Y	Y	Y	Y	Y	Y	Y	Y
Increased Insulation	Y[1]	Y[1]	Y[3]	Y[1]	N[1]	Y[1]	Y[1]	Y[1]

Y- Cost Effective

N- Not Cost Effective

1 All Cases Examined
2 Depends on Aux fuel type
3 Depends on amounts added

Table 3-51. Energy Conservation Techniques, Cost Effectiveness
Multi-Family Residence
Heating, Hot 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	Y	Y	Y	Y	Y	Y	Y
Air Economizer	N	N	N	N	N	N	N	N
High Eff Lights	Y	Y	Y	Y	Y	Y	Y	Y
Reflective Films	N	N	N	N	Y[2]	N	N	N
Awnings	N	N	N	N	N	N	N	N
Water Tank Insulation Decreased Temp	Y	Y	Y	Y	Y	Y	Y	Y
Increased Insulation	Y[1]	Y[1]	Y[1]	Y[1]	Y[3]	Y[1]	Y[1]	Y[1]

Y - Cost Effective
N - Not Cost Effective
1 All Cases Examined
2 Depends on Aux fuel type
3 Depends on amounts added

of solar radiation available, fuel costs, auxiliary fuel types used, and retrofitting costs. Night setback devices, for example, have payback periods which vary from one year (electric auxiliary fuel, Albuquerque) to 17 years (oil, auxiliary fuel, Atlanta). When retrofit costs differ markedly from costs for new buildings, energy conservation techniques become non-cost effective and/or payback periods are greatly extended (e.g. improved furnace efficiency and high efficiency lights).

A summary of conclusions for each energy conservation technique analyzed include:

- <u>High Efficiency Furnace</u>-Increasing the efficiency of the gas and oil furnaces from a seasonal average of 0.55 to 0.80 reduces the amount of auxiliary fuel required. For new buildings, the small additional cost for a high efficiency furnace is offset by auxiliary fuel savings making this a cost effective technique for all regions. For existing buildings, the high cost of retrofitting is greater than fuel savings except in regions that have a considerable heating load. High efficiency furnaces were cost effective for existing buildings in Omaha (oil only) and Albuquerque.

- <u>Night Setback</u>-Night setback involves reducing the thermostat setpoint from 68°F to 63°F during the hours of 10:00 pm to 6:00 am. Night setback is cost effective for both new and existing buildings in all regions. Fuel savings resulting from the reduced heating load were sufficient to offset the installed costs of night setback devices even when each of the 11 apartments was assumed to have its own device. Incorporating night setback devices also reduced the amount of collector area required to supply a fixed percentage of the load resulting in lower initial investment costs for a solar system and lower annual costs.

- Air Economizer-The air economizer reduces the cooling load by introducing outdoor air into the conditioned space to provide natural cooling when outdoor air temperature and relative humidity are less than 75°F and 50 percent RH. Negative annual savings resulted in all regions for both new and existing buildings indicating that the costs of installing and operating the air economizer (one for each apartment) were far greater than the fuel saved. Incorporating air economizers into the buildings did result in reduced collector requirements where air conditioning was considered. Even though this resulted in lower initial investment and annual costs, the air economizer still is not cost effective.

- High Efficiency Lights-High efficiency lights consist of using 80 percent fluorescent lights in lieu of incandescent lights. This technique results in an increased heating requirement that must be satisfied by the solar system and auxiliary furnace and a decreased cooling load on the building. This technique is cost effective in all regions for new buildings. For existing buildings, the cost effectiveness depends on auxiliary fuel types in the Northeast and Southwest regions. Savings result primarily from the reduced electrical usage for lighting. Collector area can be reduced for heating, hot water and air conditioning to supply a fixed percentage of the load,resulting in lower annual costs. For heating and hot water, where the collector must be increased to satisfy a fixed percentage of the load, a constant collector area minimized annual costs.

- Reflective Films-Reflective films reduce the amount of radiation that enters the building and heat loss through glass surfaces reducing the cooling load while increasing the heating load slightly. Reflective films are cost effective where air conditioning is considered in all regions except the existing residence in the southwest (as represented by Albuquerque). In this single incidence, the reduction in the cooling load did not offset installed costs. For heating and hot water systems, reflective films are only cost effective for new buildings in the south region, and then only where electricity is the auxiliary fuel. The analysis indicated collector areas can be substantially reduced, while maintaining a constant percentage of load supplied by solar, in both systems. Reducing collector area further reduces initial investments and annual costs.

- Awnings-Awnings shade a portion of the window keeping radiation from entering the building and reduce the cooling load. Awnings are cost effective in all regions where air conditioning is considered. There is no interaction with heating and hot water systems. Collector areas can be reduced while supplying a constant percentage of the load. At reduced collector areas, initial investment and annual costs are lower.

- Increased Domestic Hot Water Tank Insulation/Decreased Temperature-Increasing the level of insulation on the domestic hot water tank(R-6) and decreasing the temperature from 140° to 130° reduced the hot water and cooling loads and increase the heating loads. This energy conservation technique was found to be cost effective in all four regions; for both new and existing construction. Where air conditioning is considered, collector areas can be reduced resulting in both lower initial investment and annual costs. The collector area must be slightly increased for heating and hot water systems. Even at increased areas, annual costs are still lower as compared to the base case.

- Insulation-Improving the thermal resistance of the building significantly reduced the heating load while increasing the cooling load. A number of cases were analyzed for each region. Results indicate that some amount of additional insulation is cost effective in all regions. The amount is dependent on the heating load, auxiliary fuel costs and type of auxiliary fuel used. Since added insulation heavily impacts heating loads, annual savings and additional amounts are greater for heating and hot water systems. In these systems, the amount of collector area required can be reduced significantly and initial investment and annual costs can be greatly reduced. Where air conditioning is considered, savings occur but not as substantial. In these cases, collector area can be slightly reduced.

3.3 RETAIL STORE

3.3.1 Building Description

The retail store which has been chosen for study is a fairly small (5035 ft^2) one-story building. It has one window and one glass door. It is built on a 4-inch concrete slab. The entire floor area is open with the exception of one restroom and one small office.

Depending on location, the walls are either curtain wall or masonry construction. In either case, new retail stores have wall insulation, while existing stores do not. Similarly, new stores have roof insulation, while existing stores do not. In all cases, roof construction is a 3/8 inch built-up roof with a metal deck.

The glass in the windows and doors is single pane for existing buildings and air-insulated double pane for new buildings, for all locations.

3.3.2 Modeling Assumptions

The model of the retail store is fairly uncomplicated. Since the floor area is almost entirely open, the store was modeled as a single zone with a uniform indoor temperature. Heat loss through the floor was neglected. Thus, the only surfaces which had heat transfer were the walls, roof, window, and door. Heat transfer effects associated with the introduction of outdoor air due to ventilation and infiltration were modeled. The heat given off by the ventilation fan motors was not modeled since it is very small in comparison with the just-mentioned effects.

Heating and cooling effects associated with the presence of people, lights, and hot water usage as well as fresh air ventilation were included. These effects were varied during the day according to the schedules provided in the Appendix. Additionally, heat gain due to solar insolation through the window and the glass door was modeled. All glass surfaces are on the same side of the building. It was assumed that these surfaces face southeast.

3.3.3 Results for Retail Store

Results for the retail store, both new and existing, for all four regions are outlined in the following paragraphs. Each energy conservation technique is discussed individually. Annual costs, cost savings and annual load savings are presented. The results that are presented for the energy conservation techniques are for a specific collector area: namely, the approximate design area required by the retail store.

The retail stores that were analyzed (new and existing construction in four different regions) were similar in size and internal loads. The buildings differed with respect to construction characteristics and insulation, which varied by region.

The analysis revealed that the interaction of the solar system with any particular energy conservation technique followed the same trend regardless of building type or region. That is, certain energy conservation techniques, such as increased insulation, always tend to decrease heating loads and increase cooling loads. This trend is the same for all regions, the amount of change being dependent on the amount of insulation added.

Those variables that do change with respect to regions are loads, installed costs and fuel prices. These variables determine whether or not a particular energy conservation technique is cost effective.

Since resultant trends are identical and costs vary, a detailed explanation of the interaction of the solar system, building loads and energy conservation techniques is provided only for the new retail store in Omaha. Results for the existing building and other cities are presented in tables and graphs illustrating loads, percent of loads supplied by solar, annual costs, annual savings and load savings (Tables 3-52 through 3-67 and Figures 3-47 through 3-58). Also tabulated are regional comparisons of cost effectiveness and payback periods (Tables 3-68 through 3-73).

Omaha - North Central Region

- New Construction - Base Building --

Percent of Load Supplied by Solar vs Collector Area (Figure 3-47) -- The percentages of the loads supplied by the solar heating/cooling systems are found by dividing the solar contribution to the load by the load itself. Both the heating and hot water (H and HW) curve and the heating, hot water and air conditioning (H, HW and AC) curve increase as the collector area increases. This is because, as the collector becomes larger and larger, it is able to supply an ever increasing portion of the total load. The total load remains nearly constant as the collector area changes.

The solar system can supply heating more efficiently than it can supply cooling; thus, the heating and hot water curve lies above the heating, hot water and air conditioning curve. The H and HW curve levels off at high collector areas because the solar system's storage system is unable to provide enough energy to simultaneously satisfy the store's heating requirements and charge a large storage tank which has been depleted by several days of cold weather. The H, HW and AC curve would level off at a higher level and at even higher collector areas because effective solar powered air conditioning requires a large collector area, relative to heating and hot water collector area requirements.

Auxiliary Energy Demands vs Collector Area (Figure 3-48) -- The auxiliary energy demand is the sum of the heating, hot water and cooling loads

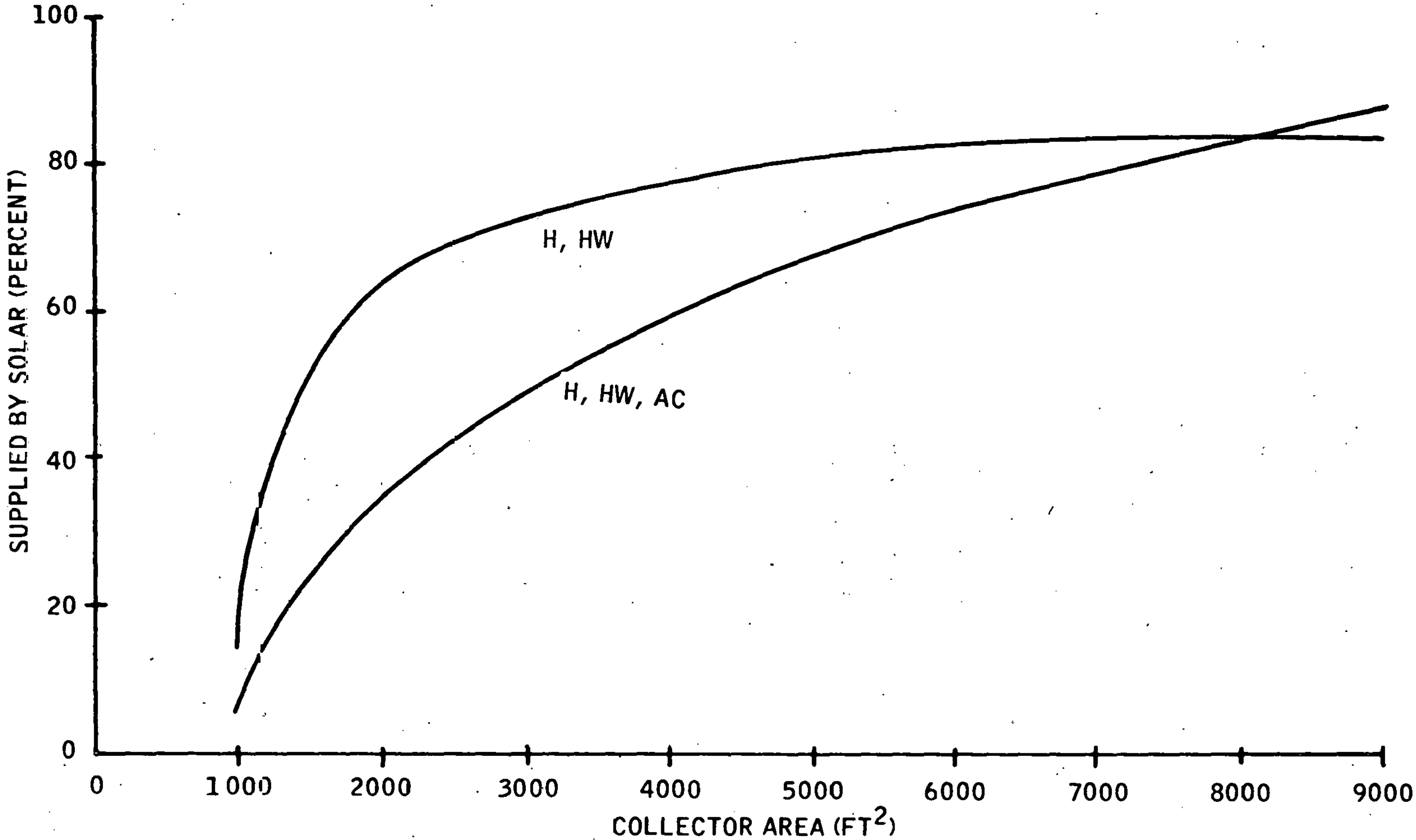


Figure 3-47. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (New) Omaha Base Building

that cannot be met by the solar system. Both curves decrease as the collector size increases, since the solar system can supply increasingly larger portions of the load. The H, HW and AC curve lies above the H and HW curve because the solar system can supply space heating and hot water more easily than it can supply cooling. The H and HW curve levels out much sooner than the H, HW and AC curve does because the solar system can supply nearly all of the store's heating and hot water requirements with a minimal amount of collector area.

Annual Cost vs Collector Area (Figures 3-49 - 3-51) -- All three graphs (oil, gas and electric) exhibit the same trends. The H, HW, and AC curve lies above the H and HW curve simply because a system that can supply air conditioning is more expensive than one that cannot. Both curves increase as the collector area increases because collectors are fairly expensive. The noticeable lack of a minimum in the curves suggests that solar collectors are not cost effective, given present fuel price projections and analyses time period.

- New Construction -- Application of Energy Conservation Techniques (ECT's) -- Tables 3-52 and 3-53 summarize the loads, costs, and savings for the base case and each ECT. Table 3-52 presents the data for a heating and hot water system, while Table 3-53 presents the data for a heating, hot water, and air conditioning system. Since the solar-powered air conditioning system is quite expensive, the annual costs in Table 3-53 are higher than those in Table 3-52. Both tables are for a collector area of 4000 ft^2.

Each of the ECTs listed in the tables will be briefly discussed in the following paragraphs. In general, a brief description of the ECT is given, followed by a discussion of the energy and annual cost data in the appropriate lines of the tables.

Adjust Minimum Ventilation Level and Close Dampers at Night -- It was

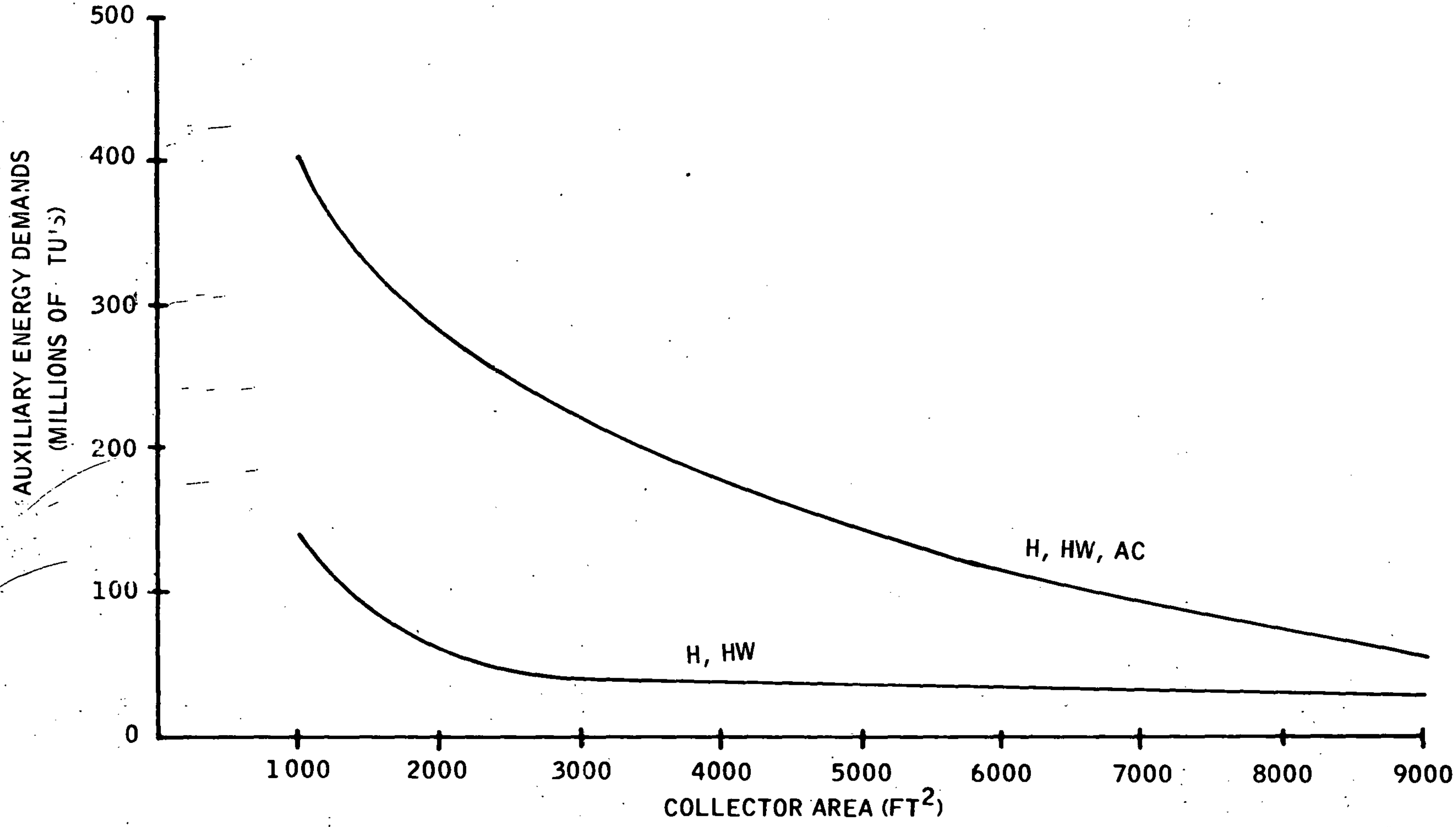


Figure 3-48. Auxiliary Energy Demands Versus Collector Area for Retail Store (New) Omaha Base Building

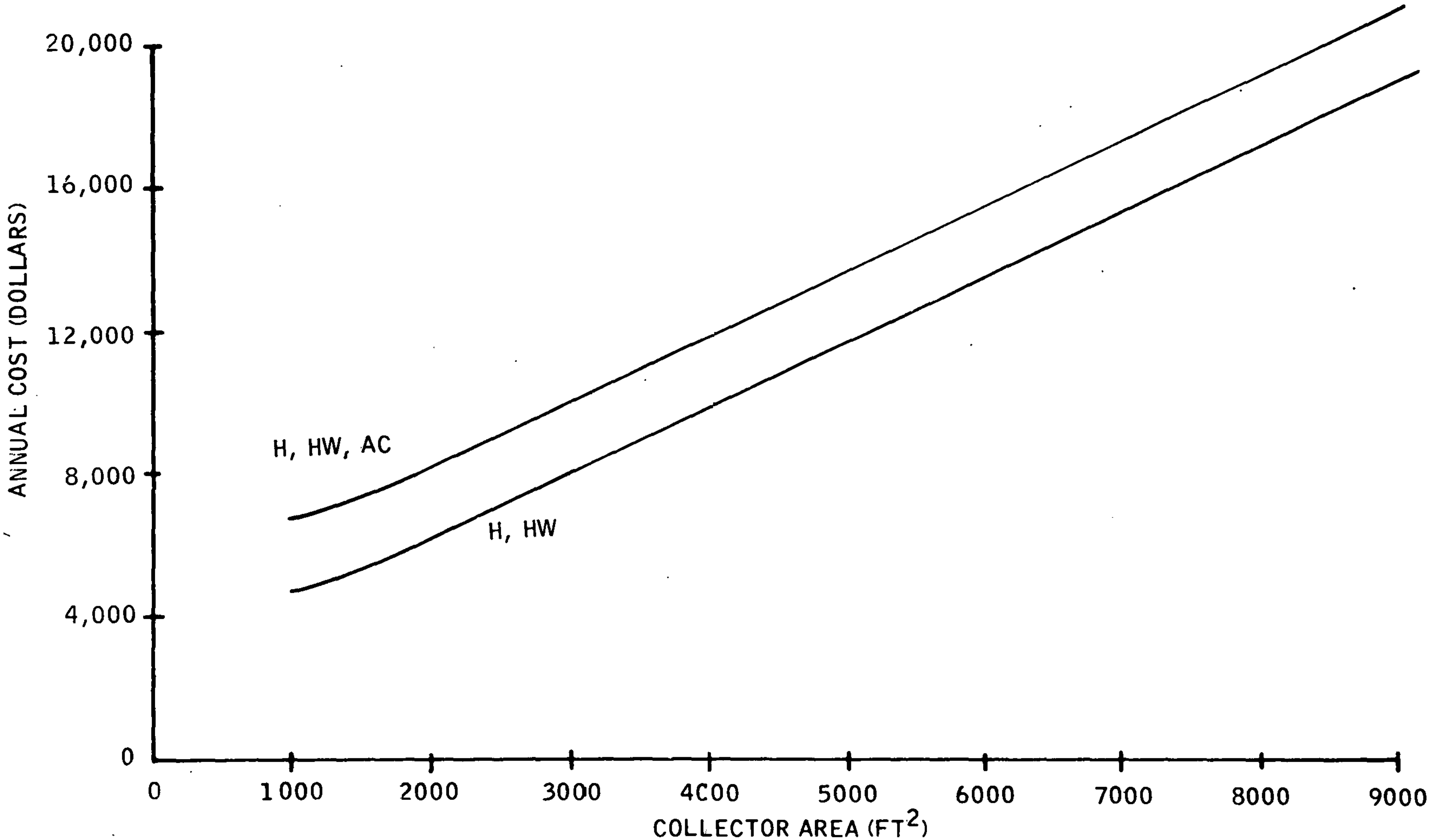


Figure 3-49. Annual Cost Versus Collector Area for Retail Store (New) Omaha Base Building, Oil Auxiliary Fuel

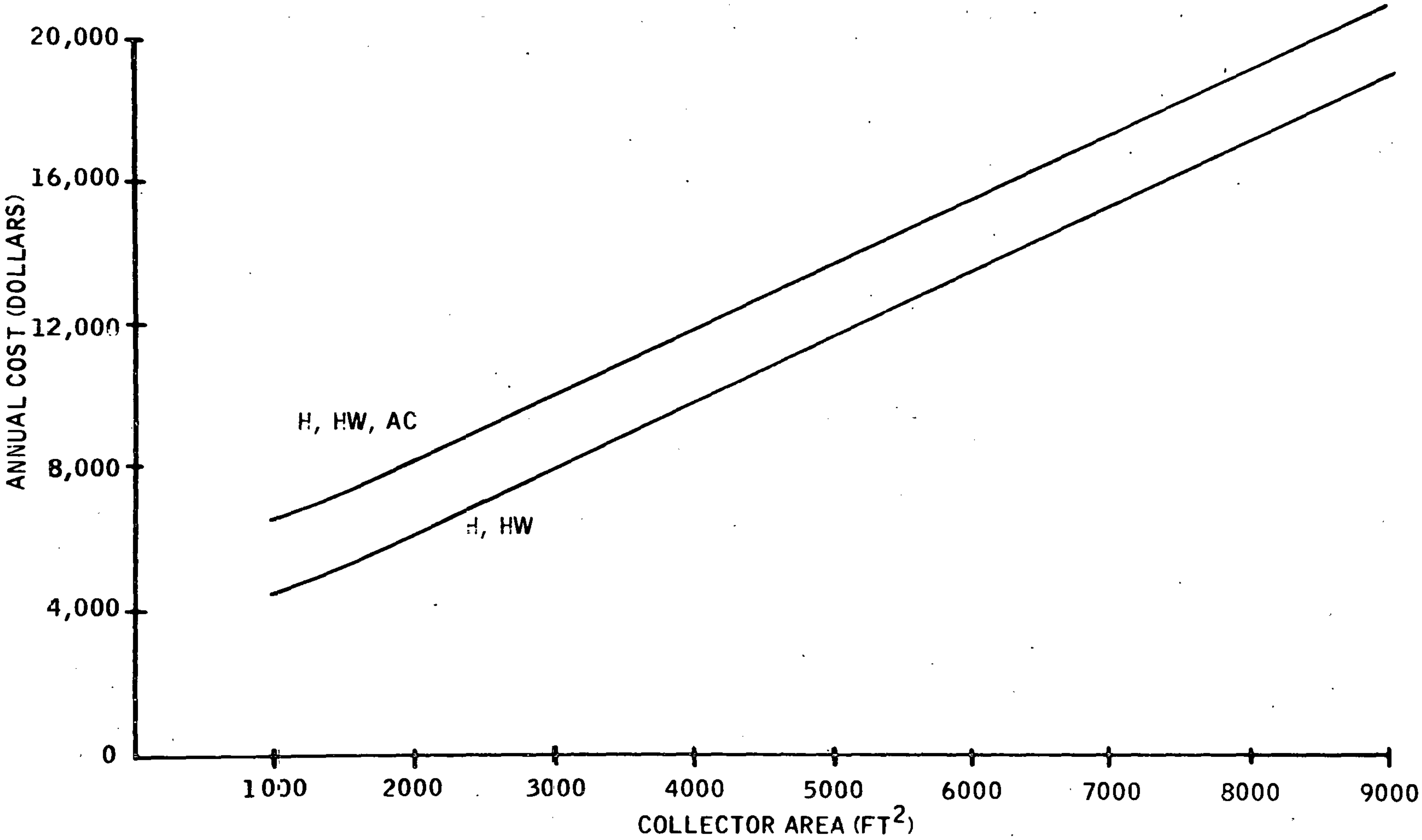


Figure 3-50. Annual Cost Versus Collector Area for Retail Store (New) Omaha Base Building, Gas Auxiliary Fuel

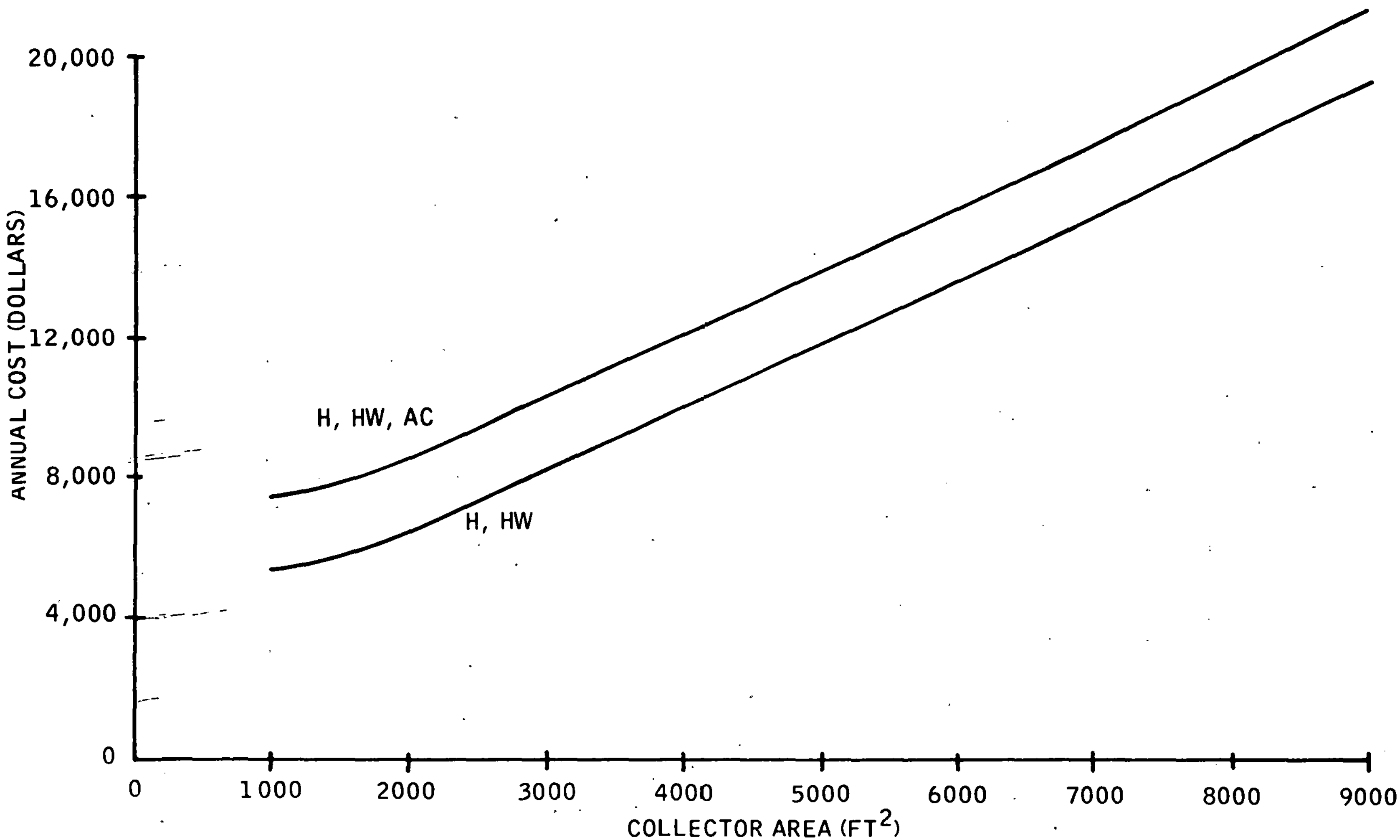


Figure 3-51. Annual Cost Versus Collector Area for Retail Store (New) Omaha Base Building, Electricity Auxiliary Fuel

Table 3-52. Summary Loads, Costs and Savings, Omaha - New Retail Store, Heating and Hot Water (Collector Area = 4000)

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar %	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base Case	151.8	77	9731	9840	10046					
Lowered Ventilation	96.7	81	9660	9725	9849	71	115	197	55.1	36
Air Economizer	N/A									
Vent. Heat Recov.	114.2	82	9808	9880	10016	-78	-41	30	37.6	25
Reflective Film	154.4	77	9777	9886	10093	-46	-46	-47	-2.6	-2
Awnings	N/A									
Triple Glazing	148.8	77	9752	9859	10061	-21	-19	-15	3.0	2
Reduced Lighting Schedule	183.3	78	9169	9295	9534	561	545	512	-31.5	-21
Night Setback	135.5	77	9718	9817	10005	13	22	41	16.3	11
Wall Insulation	128.6	79	9745	9833	10010	-15	6	36	23.2	15
Wall & Roof Insul.	87.7	81	9880	9941	10058	-150	-102	-12	64.1	42
Water Tank Insul. & lower water temp.	148.7	79	9720	9818	10004	11	22	42	3.1	2
High Eff. Furnace	151.8	77	9716	9797	10046	14	43	0	0	0

Table 3-53. Summary Loads, Costs and Savings, Omaha- New Retail Store, Heating, Hot Water, Air Conditioning (Collector Area = 4000)

ECT Description	Total Load (BTU) $x 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU $x 10^{-6}$	Annual Load Savings % Savings
Base Case	424.0	59	11838	11947	12154					
Lowered Ventilation	379.7	58	11835	11901	12025	3	46	129	44.3	10
Air Economizer	371.7	64	11661	11770	11977	177	177	177	52.3	12
Ventilation Heat Recov.	387.3	59	11921	11993	12129	-83	-46	25	36.7	9
Reflective Film	407.5	61	11834	11943	12150	4	4	4	16.5	4
Awnings	411.1	61	11813	11922	12128	25	25	25	12.9	3
Triple Glazing	417.8	60	11853	11960	12162	-15	-13	-7	6.2	1
Reduced Lighting Sch.	435.8	62	11209	11335	11574	629	612	580	-11.8	-3
Night Setback	408.4	59	11829	11928	12116	9	19	37	15.6	4
Wall Insulation	404.8	59	11873	11961	12132	-35	-14	21	19.2	4
Wall & Roof Insulation	374.3	57	12056	12117	12234	-218	-170	-80	49.7	12
Water Tank Insulation & Lower Water Temp.	423.3	60	11821	11919	12106	16	27	48	0.7	0.2
High Eff. Furnace	424.0	59	11824	11904	12154	14	43	0	0	0

assumed that the ventilation was maladjusted, as is typically found in the field, and was at twice the recommended level of the base case. The fresh air ventilation level was decreased from 14 cfm per person to 7 cfm per person, and the fresh air vent dampers were closed from 9:00 pm to 6:00 am. This greatly decreases the heating load and slightly increases the cooling load. This can be seen by comparing the percentage of total annual BTU savings for H and HW to those for H, HW and AC. Note that this ECT saves large amounts of energy, and is also quite cost effective. Additionally, it does not involve the purchase and installation of new equipment. It simply requires resetting the controls of existing equipment. Therefore, it is a recommended ECT.

Air Economizer -- If the retail store requires cooling and if the outdoor air temperature is low enough to provide natural cooling, an air economizer will provide cool outside air to the store, thus reducing the air conditioning load. Since the air economizer is air conditioning related, this explains why the H and HW load is essentially constant while the H, HW and AC load drops markedly. In fact, the air economizer reduces the H, HW and AC load more than any other ECT that was examined. When air conditioning is required, the air economizer saves large amounts of energy and is very cost-effective.

Heat Recovery of Exhaust Air -- Heat is recovered from the exhaust air by passing the incoming outdoor air and the outgoing exhaust air through an air-to-air heat exchanger. In this way, cold incoming air can accept some of the heat from the exhaust air that would otherwise be lost to the surroundings. The tables show that the total load has been lowered by the use of this technique. This overall reduction is primarily due to the reduction in the space heating load. However, due to its fairly high cost, this ECT is only cost-effective for electricity. It is not cost-effective for other fuels.

Reflective Film -- Reflective film cuts down solar insolation as well as heat transmission through the coated surfaces. Both the glass window and the door were coated. As the tables show, this ECT 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, but due to its moderate cost, it is marginally cost-effective for a system which must provide air conditioning.

Awnings -- An awning was placed over the retail store's single window, which faces southeast.. Like reflective film, this reduces solar insolation, but it does not reduce heat transmission through the window. Consequently, the heating load increased only by a very small amount, much smaller than it did with reflective films. The cooling load was decreased, but not as much as reflective film reduced it. However, because the awnings cost less than reflective film, it was more cost effective than the film.

Triple Glazing -- Triple glazing involves adding a third pane of glass to the standard double-pane window. This has the effect of decreasing both the solar insolation and the heat transmission through the window. The door was not triple glazed. In this case, both the heating and cooling loads decreased slightly, but not enough to offset the cost of the ECT for any fuel type. Due to its moderate cost and modest fuel savings, it is not cost-effective.

Reduced Lighting Schedule -- For this ECT, the maximum lighting level of 3 watts/ft^2 was maintained, but the schedule was reduced. That is, from the 9:00 pm to 6:00 am, the schedule was reduced from 50 percent or 60 percent of this maximum level to only 25 percent of maximum. Also, the schedule was reduced from 100 percent to 75 percent from noon to 2:00 pm. Since the lights normally supply a substantial portion of the heating load, the heating load goes up for this ECT; however, the solar system is able to supply most of this increased load. Since the internal cooling load has decreased due to the reduced lighting schedule, the air conditioning load goes down markedly. The net result is that, even though the total load has increased, the auxiliary load has not increased. The large savings on the electric bill combined with the negligible cost of manually turning on fewer lights combi.. to made this ECT by far the most cost-effective technique that was examined. It is highly recommended.

Night Setback -- Night setback involves setting the thermostat down from 68 °F to 63 °F from 10:00 pm to 6:00 am. This type of technique has a major effect only on the heating load; the cooling and hot water loads for a retail store are nearly unchanged. These trends can be seen in the tables. Consequently, night setback is proportionately more cost-effective for a heating and hot water system than for a system which must also provide air conditioning, although it still is cost-effective for such a system.

Wall Insulation -- For this ECT, the wall insulation was increased from one inch of rigid insulation to two inches. This has the effect of significantly decreasing the heating load and slightly increasing the cooling load. The net auxiliary load decreases. However, due to the moderate cost of the insulation, this ECT is not always cost-effective.

Wall and Roof Insulation -- For this ECT, the roof insulation was increased from two inches to four inches, in addition to the wall insulation just discussed. The effects that were discussed in the preceding paragraph were again evidenced with this ECT, but the magnitude of the changes was larger. That is, the heating load showed a very large drop while the cooling load increased moderately. Even though the total load was reduced substantially, this combination of wall and roof insulation is not cost-effective. This is due primarily to the substantial cost of the additional roof insulation.

Insulate Hot Water Tank and Decrease the Temperature -- Extra insulation was added to the hot water tank and its temperature was decreased from 140°F to 130°F. Since the retail store's hot water usage is so minimal, the energy effects associated with this ECT are very small. Since the already small tank losses to the house are reduced, the heating load increases very slightly. The solar system is able to supply most of this increased load, however, so the load for heating and hot water decreases slightly. The cooling load also decreases. In the case of H, HW, AC, this decrease is enough to decrease the total load slightly. The tables show that the reduced cooling requirements are enough to make this inexpensive ECT more attractive for a H, HW and AC system than for a H and HW only system. Even though its energy effects are slight, this ECT's low cost makes for moderate savings.

High-Efficiency Furnace -- The assumed furnace efficiency was increased from 0.55 to 0.80. (This efficiency applies only to a gas or oil-fired furnace. Electric furnace efficiency is always assumed to be unity.) This efficiency increase does not affect the total load for either H & HW or H, HW and AC. It does affect the amount of fuel which must be consumed by the furnace in order to meet the heating load in either case. Since the loads remain unchanged while the fuel requirement decreases, one would naturally expect this ECT to be cost-effective. It is quite cost-effective; particularly for an oil-fired furnace.

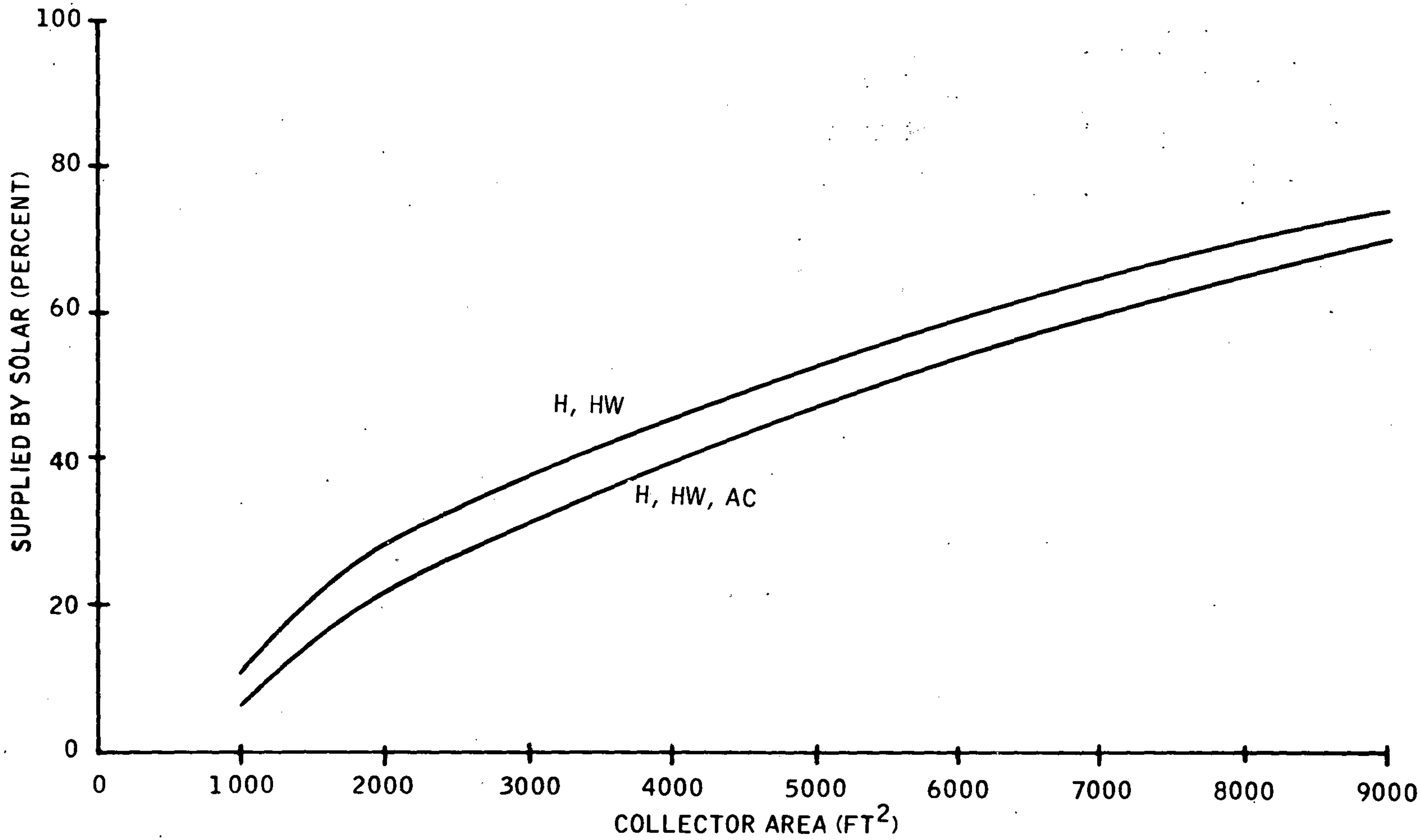


Figure 3-52. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (Existing) Omaha Base Building

Table 3-54. Summary Loads, Costs and Savings, Omaha Retail (Existing), Heating and Hot Water, A = 4000 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	629	44.5	11193	12137	13927					
Min. Ventilation	562	47.0	11034	11843	13375	159	294	552	66.8	11
Air Economizer	N/A									
Vent Heat Recovery	583	46.4	11211	12059	13666	-18	78	261	45.6	7
Reflective Film	633	45.0	11257	12199	13986	-64	-62	-59	-4.7	-1
Awnings	N/A									
Double Glaze	619	45.0	11198	12120	13869	-5	17	58	9.2	1
Reduce Light Level	821	42.0	7677	8956	11381	3516	3181	2546	-191.9	-31
Reduce Light Sch.	702	43.6	10106	11177	13208	1087	960	719	-73.6	-12
Night Setback	569	46.6	11041	11865	13428	152	272	499	59.3	9
Wall Insulation	500	50.6	11069	11742	13017	124	395	910	129.0	21
Wall & Roof Insul.	29	71.9	10504	10542	10612	689	1595	3315	600.0	95
Hot Water Tank	626	44.9	11184	12118	13890	9	19	37	2.7	0
High Eff. Furnace	629	44.5	10872	11526	13927	321	611	N/A	0	0

Table 3-55. Summary Loads, Costs and Savings, Omaha Retail (Existing), Heating, Hot Water, Air Conditioning, A = 4000 Ft^2

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	1019	39.8	13562	14506	16296					
Min. Ventilation	944	41.5	13423	14231	15764	139	275	532	75.1	7
Air Economizer	983	41.2	13429	14358	16119	133	148	177	35.7	4
Vent Heat Recovery	973	40.7	13581	14428	16036	-19	78	260	45.8	4
Reflective Film	1007	40.6	13600	14543	16330	-38	-37	-34	12.0	1
Awnings	1006	40.3	13548	14492	16281	14	14	15	13.0	1
Double Glazed	1007	40.1	13565	14487	16236	-3	19	60	12.0	1
Reduce Light Level	1076	42.3	9750	11029	13454	3812	3477	2842	-57.0	-6
Reduce Light Schedule	1067	40.0	12393	13464	15495	1169	1042	801	-48.0	-5
Night Setback	960	40.9	13412	14236	15799	150	270	497	59.5	6
Wall Insulation	894	42.7	13484	14157	15432	78	349	864	124.8	12
Wall & Roof Insul.	549	33.4	13554	13591	13662	8	915	2634	470.0	46
Hot Water Tank	1019	39.9	13549	14483	16255	13	23	41	0	0
High Eff. Furnace	1019	39.8	13241	13895	16296	321	611	0	0	0

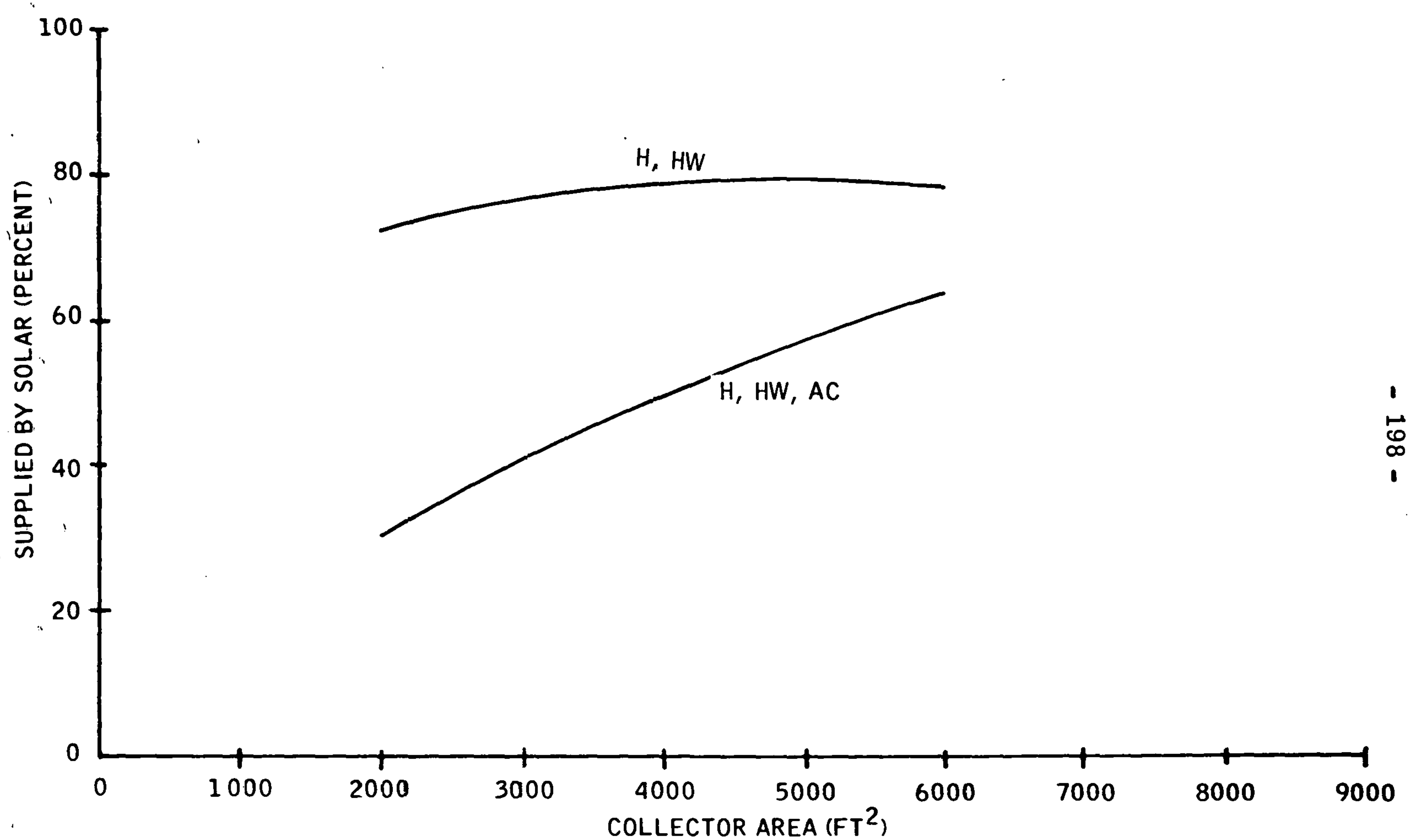


Figure 3-53. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (New) New York Base Building

Table 3-56. Summary Loads, Costs and Savings, Retail Store, New York, Heating and Hot Water (Collector = 4000 Ft^2)

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	87.52	78.5	9,673	9,704	9,881					
Min. Ventilation	51.87	72.9	9,631	9,655	9,787	42	49	94	35.7	41%
Air Economizer	N/A									
Vent Heat Recovery	63.05	75.0	9,820	9,846	9,994	-147	-142	-113	24.5	28%
Reflective Film	88.27	78.9	9,728	9,759	9,934	- 55	- 55	- 53	- .75	- 1%
Awnings	N/A									
Triple Glaze	85.19	78.3	9,703	9,733	9,907	- 30	- 29	- 26	2.33	3%
Reduce Lt. Sched	115.9	81.7	8,808	8,843	9,043	865	861	838	-28.38	-32%
Night Setback	75.54	78.0	9,667	9,696	9,860	6	8	21	11.98	14%
Wall Insulation	74.16	77.0	9,841	9,870	10,030	-168	-166	-149	13.36	15%
Wall & Roof Ins.	47.66	72.2	10,041	10,063	10,187	-368	-359	-306	39.86	46%
Hot Water Tank	83.99	82.8	9,657	9,681	9,816	16	23	65	3.53	4%
High Eff. Furnace	87.52	78.5	9,675	9,699	9,881	2	5	0	0	0

Table 3-57. Summary Loads, Costs and Savings, Retail Store New York, Heating, Hot Water, Air Conditioning (Collector = 4000 Ft^2)

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	313.5	49.3	12,092	12,124	12,300					
Min Ventilation	309.3	42.6	12,226	12,249	12,381	-134	-125	- 81	4.2	1%
Air Economizer	229.2	57.6	11,668	11,699	11,876	424	425	424	84.2	27%
Vent Heat Recovery	289.1	46.2	12,241	12,267	12,415	-149	-143	-115	24.4	8%
Reflective Film	297.7	50.6	12,075	12,106	12,280	17	18	20	15.8	5%
Awnings	303.8	50.6	12,061	12,092	12,268	31	32	32	9.7	3%
Triple Glaze	309.4	49.2	12,114	12,145	12,318	- 53	- 21	- 18	4.1	1%
Reduce Lt. Schedule	320.1	55.1	11,115	11,150	11,350	977	974	950	- 6.6	- 2%
Night Setback	301.5	47.8	12,087	12,115	12,279	5	9	21	12.0	4%
Wall Insulation	307.6	47.3	12,303	12,331	12,491	-211	-207	-191	5.9	2%
Wall & Roof Insul.	300.8	42.3	12,612	12,634	12,758	-520	-510	-458	12.7	4%
Hot Water Tank	307.5	50.6	12,063	12,087	12,223	29	37	77	6.0	2%
High Eff. Furnace	313.5	49.3	12,094	12,119	12,300	- 2	5	0	0	0

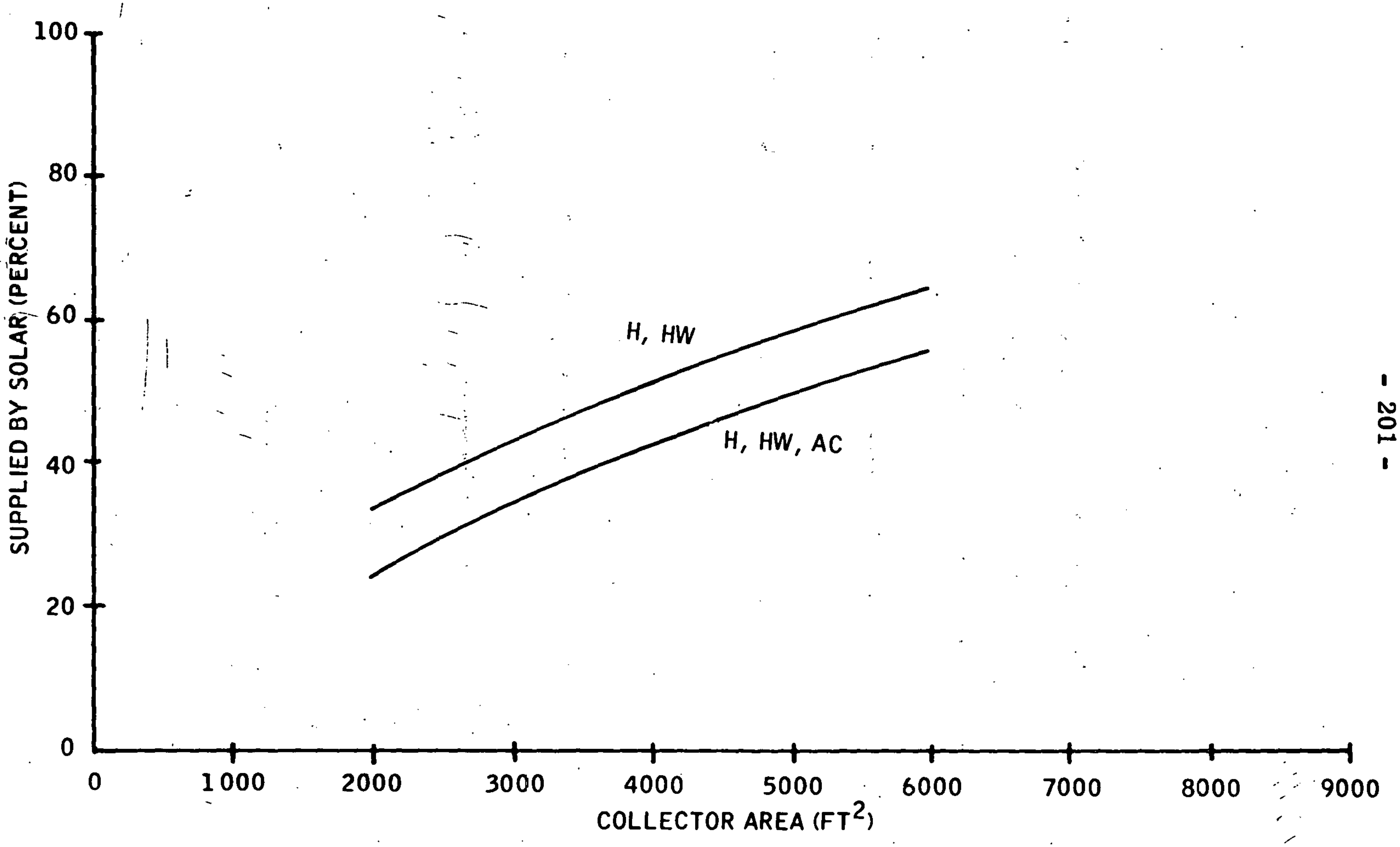


Figure 3-54. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (Existing) New York Bas⌢ Building

Table 3-58. Summary Loads, Costs and Savings, Retail Store (Existing) New York, Heating and Hot Water, A = 4000 Ft^2

ECT Description	Total Load (BTU) $x\ 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU $x\ 10^{-6}$	% Savings
Base	481.6	51.1	11,201	11,588	13,778					
Min Ventilation	427.3	53.9	11,021	11,345	13,178	180	243	600	54.3	11
Air Economizer	N/A									
Vent Heat Recovery	444.5	53.1	11,254	11,596	13,535	-53	-8	243	37.1	8
Reflective Film	484.7	51.4	11,291	11,678	13,867	-90	-90	-89	-3.1	-1
Awnings	N/A									
Double Glaze	474.1	51.5	11,214	11,592	13,730	-13	-4	48	7.5	2
Reduce Lt. Level	658.9	47.3	6,165	6,736	9,963	5036	4852	3815	-177.3	-37
Reduce Light Schedule	551.4	49.7	9,641	10,098	12,680	1560	1490	1098	-69.8	-14
Night Setback	420.1	53.0	10,996	11,319	13,150	205	269	628	61.5	13
Wall Insulation	340.3	59.1	11,033	11,262	12,556	168	326	1222	141.3	29
Wall & Roof Insul.	157.9	56.1	10,695	10,706	10,771	506	882	3007	323.7	67
Hot Water Tank	478.8	51.4	11,188	11,570	13,731	13	18	47	2.8	1
High Eff. Furnace	481.6	51.1	10,898	11,167	13,778	303	421	0	0	0

Table 3-59. Summary Loads, Costs and Savings, Retail Store (Existing)
New York, Heating, Hot Water, Air Conditioning, A = 4000 Ft^2

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	748.2	42.2	13,799	14,187	16,377					
Min. Ventilation	698.2	43.4	13,675	13,999	15,832	124	188	545	86.0	11
Air Economizer	711.7	44.5	13,615	14,000	16,176	184	187	201	72.5	9
Vent Heat Recov.	711.1	43.1	13,856	14,196	16,137	-57	-11	240	73.1	9
Reflective Film	740.1	43.0	13,858	14,246	16,435	-59	-59	-58	44.1	6
Awnings	738.7	42.8	13,780	14,167	16,357	19	20	20	45.5	6
Double Glaze	739.8	42.5	13,814	14,192	16,330	-15	-5	47	44.4	6
Reduce Lt. Level	803.3	45.9	8,256	8,826	12,053	5543	5361	4324	-19.1	- 2
Reduce Lt. Sched	795.9	42.5	12,122	12,578	15,161	1677	1609	1216	-11.7	- 1
Night Setback	686.8	43.2	13,611	13,935	15,766	188	252	611	97.4	12
Wall Insulation	630.0	44.1	13,786	14,015	15,309	13	172	1068	154.2	20
Wall & Roof Insul.	535.2	21.4	14,734	14,745	14,810	-935	-558	1567	249.0	32
Hot Water Tank	743.9	42.6	13,782	14,164	16,325	17	23	52	40.3	5
High Eff. Furn.	748.2	42.2	13,496	13,766	16,377	303	421	0	0	0

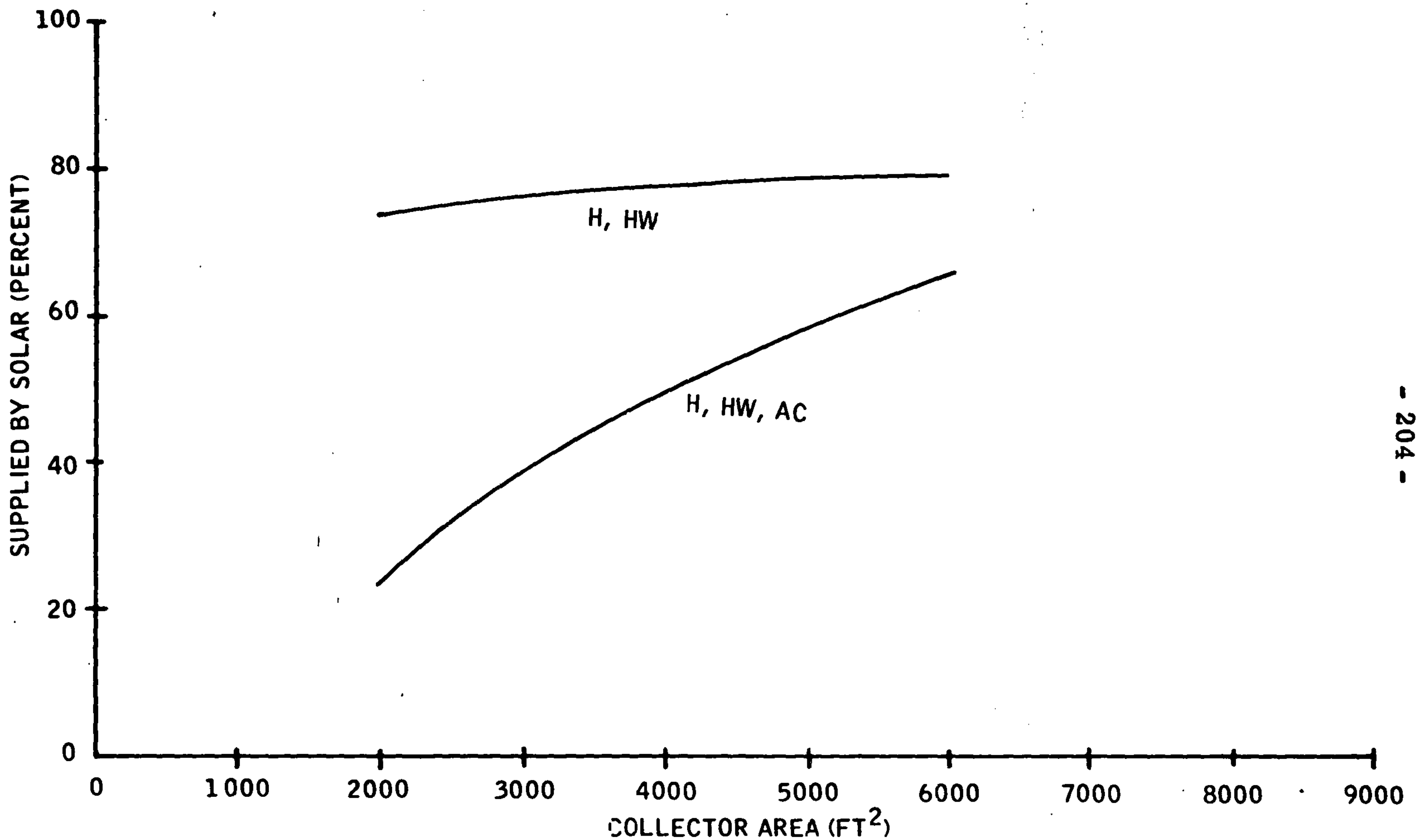


Figure 3-55. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (New) Atlanta Base Building

Table 3-60. Summary Loads, Costs and Savings, Retail Store (New) Atlanta, Heating and Hot Water (Collector = 4000 Ft^2)

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	43.74	77.8	9,539	9,607	9,667					
Min. Ventilation	28.19	71.2	9,579	9,595	9,645	10	12	22	15.55	36
Air Economizer	N/A									
Vent Heat Recovery	34.27	75.0	9,709	9,725	9,778	- 120	- 118	- 111	9.47	22
Reflective Film	43.18	77.8	9,632	9,650	9,709	- 43	- 43	- 42	.50	1
Awnings	N/A									
Triple Glaze	42.38	77.7	9,612	9,630	9,689	- 23	- 23	- 22	1.36	3
Reduce Lt Sched.	64.27	80.6	8,900	8,923	9,000	689	684	667	- 20.53	- 47
Night Setback	33.97	73.9	9,588	9,604	9,659	1	3	8	9.77	22
Wall Insulation	36.59	76.0	9,719	9,736	9,790	- 130	- 129	- 123	7.15	16
Wall & Roof Insul.	22.66	66.2	9,879	9,894	9,941	- 290	- 287	- 274	21.08	48
Hot Water Tank	39.68	86.0	9,573	9,584	9,618	16	23	49	4.06	9
High Eff. Furnace	43.74	77.8	9,604	9,620	9,667	- 15	- 13	0	0	0

Table 3-61. Summary Loads, Costs and Savings, Retail Store (New)
Atlanta, Heating, Hot Water, Air Conditioner (Collector = 4000 Ft^2)

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	397.0	49.4	12,156	12,174	12,234					
Min Ventilation	401.2	48.7	12,258	12,273	12,323	- 102	- 99	- 89	- 4.2	- 1
Air Economizer	307.8	52.2	11,830	11,848	11,908	326	326	326	89.2	22
Vent Heat Recovery	387.6	48.6	12,277	12,293	12,346	- 121	- 119	- 112	9.4	2
Reflective Film	373.4	49.8	12,130	12,148	12,207	26	26	27	23.6	6
Awnings	386.4	50.6	12,135	12,153	12,213	21	21	21	10.6	3
Triple Glaze	392.4	49.4	12,172	12,190	12,249	- 16	- 16	- 15	4.6	1
Reduce Light Sched.	388.2	53.7	11,356	11,379	11,456	800	795	778	8.8	2
Night Setback	387.3	48.5	12,154	12,171	12,226	2	3	8	9.7	2
Wall Insulation	396.0	48.9	12,317	12,334	12,389	- 161	- 160	- 155	1.0	0
Wall & Roof Insul.	399.0	46.8	12,554	12,569	12,616	- 398	- 395	- 382	- 2.0	- 1
Hot Water Tank	389.9	50.2	12,130	12,141	12,175	26	33	59	7.1	2
High Eff. Furnace	397.0	49.4	12,171	12,187	12,234	- 15	- 13	0	0	0

Table 3-62. Summary Loads, Costs and Savings, Retail Store (Existing) Atlanta, Heating and Hot Water, A = 4000 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	270.5	77.3	10,254	10,369	10,745					
Min. Ventilation	239.6	78.1	10,212	10,310	10,634	42	59	111	30.9	11
Air Economizer	N/A									
Vent Heat Recovery	250.1	78.4	10,347	10,448	10,780	- 93	- 79	- 35	20.4	8
Reflective Film-	273.2	78.8	10,298	10,406	10,763	- 44	- 37	- 18	- 2.7	- 1
Awnings	N:A									
Double Glaze	265.9	77.5	10,277	10,389	10,757	- 23	- 20	- 12	4.6	2
Reduced Lt. Lev.	403.2	75.8	6,032	6,212	6,803	4222	4157	3942	- 132.7	- 49
Reduced Lt. Sch.	372.2	76.9	8,935	9,076	9,540	1319	1293	1205	- 101.7	- 38
Night Setback	223.1	78.4	10,175	10,265	10,561	79	104	184	47.4	18
Wall Insulation	184.1	81.4	10,393	10,457	10,668	- 139	- 88	77	184.1	68
Wall & Roof Ins.	11.51	48.6	10,529	10,540	10,576	- 275	- 171	169	259.0	96
Hot Water Tank	267.1	78.4	10,240	10,349	10,704	14	20	41	3.4	1
High Eff. Furnace	270.5	77.3	10,200	10,284	10745	54	85	0		

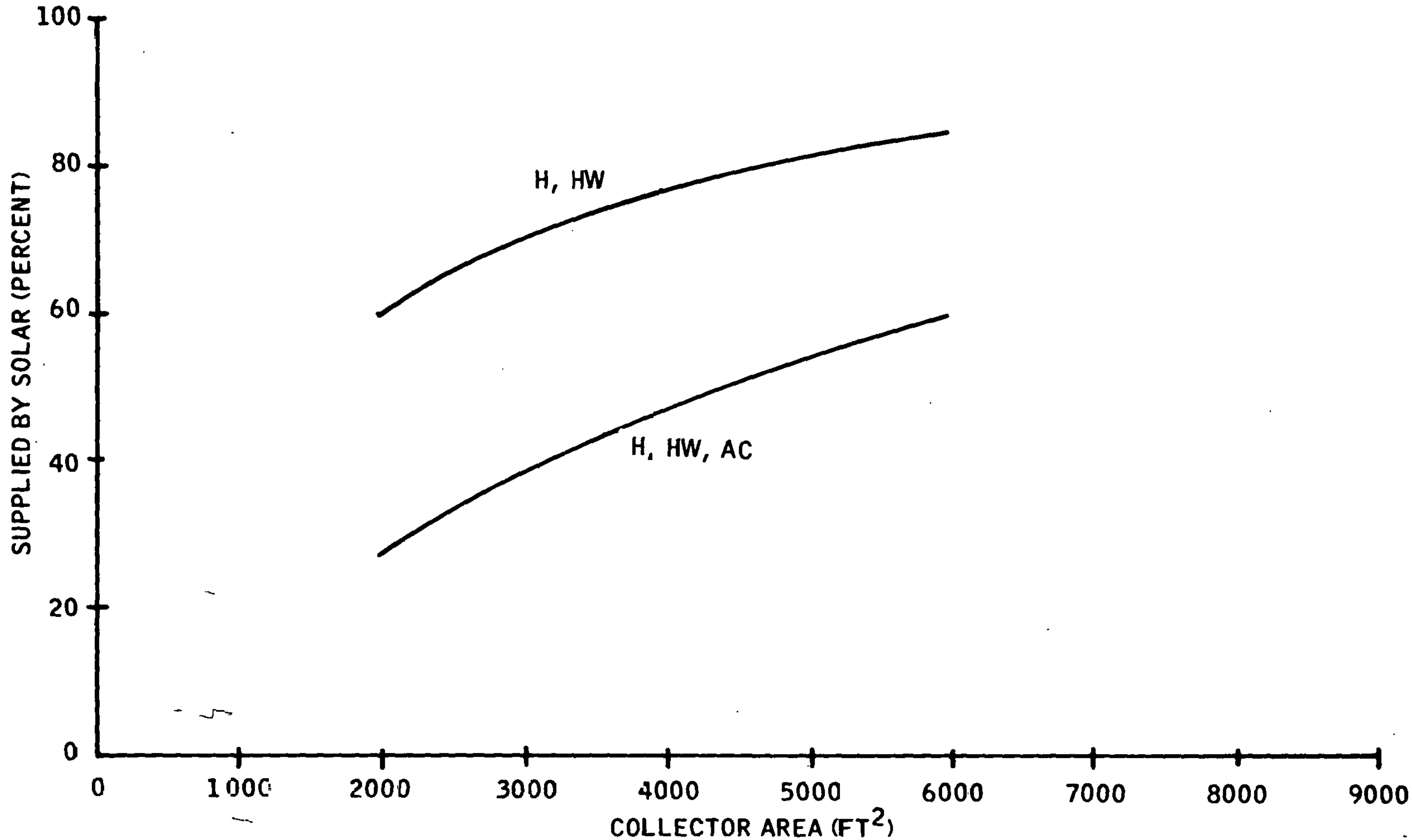


Figure 3-56. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (Existing) Atlanta Base Building

Table 3-63. Summary Loads, Costs and Savings, Retail Store (Existing), Atlanta, Heating, Hot Water, Air Conditioning, A = 4000 Ft^2

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	761.0	47.3	13,154	13,268	13,645					
Min Ventilation	719.3	47.4	13,136	13,235	13,558	18	33	87	41.7	5
Air Economizer	711.1	49.6	12,938	13,040	13,373	216	228	275	49.9	7
Vent Heat Recovery	740.6	46.8	13,249	13,350	13,683	- 95	- 82	- 38	20.4	3
Reflective Film	744.4	48.5	13,160	13,268	13,625	- 6	0	20	16.6	2
Awnings	749.9	47.9	13,144	13,258	13,635	10	10	10	11.1	1
Double Glaze	753.5	47.2	13,174	13,286	13,654	- 20	- 18	- 9	7.5	1
Reduced Light Lev.	712.8	60.4	8,450	8,630	9,221	4704	4638	4424	48.2	6
Reduced Lt. Schedu	780.6	50.5	11,696	11,838	12,301	1458	1430	1344	- 19.6	3
Night Setback	713.7	46.1	13,084	13,174	13,470	70	94	175	47.3	6
Wall Insulation	684.6	45.1	13,389	13,453	13,664	- 235	- 185	- 19	76.4	10
Wall & Roof Insul.	697.0	28.0	14,444	14,455	14,491	- 1290	- 1187	- 846	64.0	8
Hot Water Tank	755.6	47.6	13,134	13,243	13,598	20	25	47	5.4	1
High Eff. Furnace	761.0	47.3	13,100	13,183	13,645	54	85	0	0	0

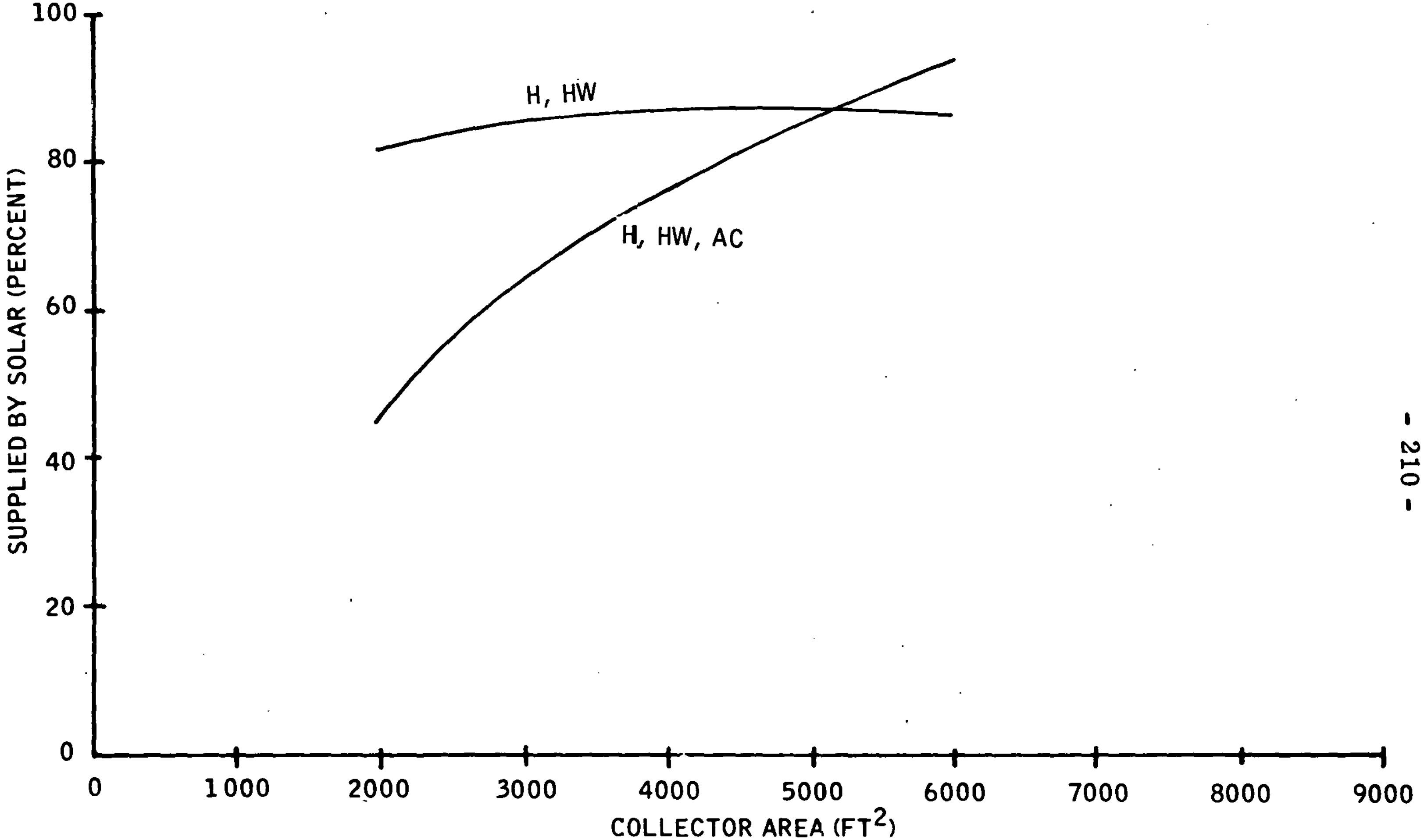


Figure 3-57. Percent of Load Supplied by Solar Versus Collector Area Retail Store (New) Albuquerque Base Building

Table 3-64. Summary Loads, Costs and Savings, Retail Store (New) Albuquerque, Heating and Hot Water, A = 4000 Ft^2

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	94.20	87.1	9,620	9,641	9,715					
Min Ventilation	61.81	82.6	9,604	9,623	9,688	16	18	27	27	34
Air Economizer	N:A									
Vent Heat Recovery	73.42	85.5	9,728	9,749	9,818	- 108	- 108	- 103	20.78	22
Reflective Film	98.93	87.7	9,660	9,682	9,756	- 40	- 41	- 41	- 4.73	- 5
Awnings	N/A									
Triple Glaze	92.38	86.9	9,640	9,662	9,735	- 20	- 21	- 20	1.82	2
Reduced Lt.Sch.	122.8	89.2	8,936	8,959	9,040	684	682	675	- 28.6	- 30
Night Setback	78.79	85.2	9,617	9,638	9,709	3	3	6	15.41	16
Wall Insulation	78.24	85.4	9,699	9,719	9,788	- 79	- 78	- 73	15.96	17
Wall & Roof Insu.	51.24	80.7	9,846	9,863	9,924	- 226	- 222	- 209	42.96	46
Hot Water Tank	90.73	91.4	9,603	9,617	9,664	17	24	51	3.47	4
High Eff. Furna.	94.20	87.1	9,631	9,649	9,715	- 11	- 8	0	0	0

Table 3-65. Summary Loads, Costs and Savings, Retail Store (New)
Albuquerque, Heating, Hot Water, Air Conditioning, $A = 4000\ Ft^2$

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	326.0	76.1	11,724	11,745	11,820					
Min Ventilation	320.0	73.8	11,805	11,824	11,889	- 81	- 79	- 69	6.0	2
Air Economizer	260.4	81.4	11,496	11,518	11,592	228	227	228	65.6	20
Vent Heat Recovery	305.3	75.1	11,833	11,853	11,922	- 109	- 108	- 102	20.7	6
Reflective Film	309.4	78.3	11,697	11,718	11,793	27	27	27	16.6	5
Awnings	313.4	78.5	11,687	11,709	11,783	37	36	37	12.6	4
Triple Glaze	320.9	76.4	11,735	11,757	11,830	- 11	- 12	- 10	5.1	2
Reduced Light. S.	336.2	80.5	10,966	10,990	11,070	758	755	750	- 10.2	- 3
Night Setback	310.7	75.4	11,720	11,740	11,811	4	5	9	15.3	5
Wall Insulation	316.5	75.1	11,826	11,846	11,916	- 102	- 101	- 96	9.5	3
Wall & Roof Insul.	304.8	72.7	12,030	12,048	12,108	- 306	- 303	- 288	21.2	7
Hot Water Tank	320.4	77.7	11,699	11,713	11,760	25	32	60	5.6	2
High Eff. Furnace	326.0	76.1	11,735	11,753	11,820	- 11	- 8	0	0	0

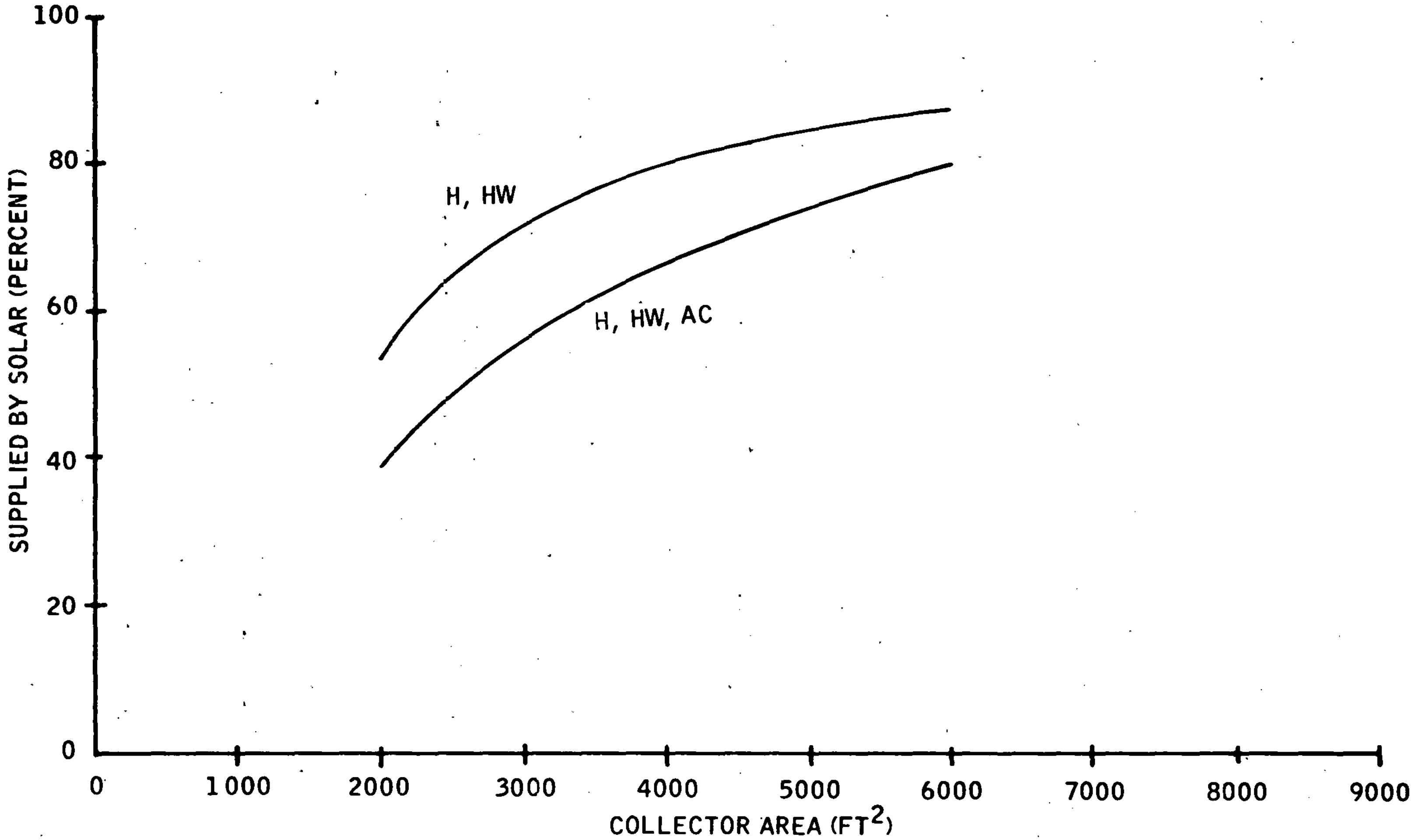


Figure 3-58. Percent of Load Supplied by Solar Versus Collector Area for Retail Store (Existing) Albuquerque Base Building

Table 3-66. Summary Loads, Costs and Savings, Retail Store (Existing) Albuquerque, Heating and Hot Water, A = 4000 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	446.4	79.7	10,438	10,597	11,141					
Min. Ventilation	397.3	82.1	10,343	10,468	10,896	95	129	245	49.1	11
Air Economizer	N/A									
Vent Heat Recovery	413.7	81.3	10,490	10,627	11,092	- 52	- 30	49	32.7	7
Reflective Film	457.9	79.7	10,504	10,667	11,225	- 66	- 70	- 84	- 11.5	- 3
Awnings	N/A									
Double Glaze	440.5	80.0	10,450	10,605	11,133	- 12	- 8	8	5.9	1
Reduce Lt. Level	615.6	71.3	6,498	6,810	7,874	3940	3787	3267	- 169.2	- 38
Reduce Lt. Sched.	515.9	77.9	9,175	9,375	10,061	1263	1222	1080	- 69.5	- 16
Night Setback	389.8	81.0	10,343	10,473	10,918	95	124	223	47.6	11
Wall Insualation	346.2	84.7	10,430	10,523	10,843	8	74	298	100.2	22
Wall & Roof Insul.	18.46	57.5	10,422	10,436	10,484	16	161	657	427.94	96
Hot Water Tank	443.5	80.6	10,421	10,573	11,090	17	24	51	2.9	1
High Eff. Furnace	446.4	79.7	10,346	10,459	11,141	92	138	0	0	0

Table 3-67. Summary Loads, Costs and Savings, Retail Store (Existing) Albuquerque, Heating, Hot Water, Air Conditioning, A = 4000 Ft^2

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	774.4	66.5	12,897	13,056	13,600					
Min. Ventilation	732.7	66.9	12,844	12,969	13,397	53	87	203	41.7	5
Air Economizer	734.5	68.4	12,755	12,914	13,458	142	142	142	39.9	5
Vent Heat Recovery	741.7	67.0	12,952	13,089	13,554	- 55	- 33	46	32.7	4
Reflective Film	770.4	67.6	12,927	13,090	13,647	- 30	- 34	- 47	4.0	[illegible]
Awnings	762.3	67.5	12,374	13,033	13,577	23	23	23	12.1	2
Double Glaze	766.2	66.8	12,907	13,062	13,590	- 10	- 6	10	8.2	1
Reduce Lt. Level	812.8	70.1	8,589	8,900	9,964	4308	4156	3636	- 38.4	- 5
Reduce Lt. Sched.	821.6	67.2	11,555	11,756	12,442	1342	1300	1158	- 47.2	- 6
Night Setback	717.8	66.8	12,802	12,932	13,377	95	124	223	56.6	7
Wall Insulation	681.7	67.5	12,950	13,043	13,363	- 53	13	237	92.7	12
Wall & Roof Insul.	526.3	48.4	13,739	13,753	13,801	- 842	- 697	- 201	248.10	32
Hot Water Tank	769.9	67.1	12,876	13,027	13,544	21	29	56	4.5	1
High Eff. Furnace	774.4	66.5	12,805	12,918	13,600	92	138	0	0	0

Regional Savings/Payback Periods -- Regional comparison tables were constructed to illustrate the cost effectiveness and payback period for each energy conservation technique. Tables were tabulated for each building type and for the three auxiliary fuels. Tables 3-68 and 3-69 summarize the results for the retail store using gas auxiliary fuel for heating only and heating and cooling systems.

The magnitude of the annual savings provides a means to rank each energy conservation technique, providing an indication of which are most preferable and should be implemented first. Payback periods indicate the length of time required for savings to offset initial investment costs. Paybacks greater than 20 years are tabulated and are illustrated only for relative ranking. Some instances of negative savings with positive payback periods occur. This occurs because annual savings are calculated from annual costs which include the cost of the energy conservation technique.

Table 3-68. Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating and Hot Water, Collector Area = 4000 Ft^2

Auxiliary Fuel: Gas

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Minimum Ventilation	71/2	159/*	42/4	180/1	10/8	42/3	16/6	95/1
Air Economizer	N/A							
Vent Heat Recovery	-78/42	-18/23	-147/79	-53/27	-120/136	-93/59	-108/110	-52/33
Reflective Film	-46/1940	-64/177	-55/1099	-90/292	-43/-	-44/65	-40/-	-66/-
Awnings	N/A							
Double/Triple Glazing	-21/99	-5/24	-30/218	-13/29	-23/242	-23/72	-20/218	-12/35
Reduced Light Level	NA/NA	3516/*	NA/NA	5036/*	NA/NA	4222/*	NA/NA	3940/*
Reduced Light Schedule	561/*	1087/*	865/*	1560/*	689/*	1319/*	684/*	1263/*
Night Setback	13/7	152/*	6/12	205/*	1/17	79/1	3/13	95/1
Additional Wall Insulation	-15/29	124/13	-168/196	168/13	-130/337	-139/38	-79/165	8/19
Additional Wall and Roof Insulation	-150/55	689/9	-368/150	506/12	-290/301	-275/35	-226/169	16/19
Water Tank Insulation/ Decreased Temperature	11/3	9/3	16/3	13/3	16/2	14/2	17/2	17/2
High Efficiency Furnace	14/12	321/1	-2/22	303/1	-15/86	54/5	-11/46	92/4

*Payback less than 1 year

Table 3-69. Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating, Hot Water, Air Conditioning, Collector Area = 4000 Ft^2

Auxiliary Fuel: Gas

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Minimum Ventilation	3/14	139/1	-134/-	124/2	-102/-	18/6	-81/-	53/2
Air Economizer	177/1	133/2	424/*	184/2	326/*	216/*	228/*	142/1
Vent Heat Recovery	-83/46	-19/23	-149/82	-57/28	-121/143	-95/62	-109/114	-55/34
Reflective Film	4/18	-38/42	17/15	-59/51	26/12	-6/22	27/12	-30/41
Awnings	25/5	14/8	31/5	19/7	21/5	10/9	37/3	23/5
Double/Triple Glazing	-15/47	-3/22	-53/-	-15/31	-16/55	-20/54	-11/40	-10/31
Reduced Light Level	NA/NA	3812/*	NA/NA	5543/*	NA/NA	4704/*	NA/NA	4308/*
Reduced Light Schedule	629/*	1169/*	977/*	1677/*	800/*	1458/*	758/*	1342/*
Night Setback	9/9	150/*	5/13	188/*	2/15	70/2	4/12	95/1
Additional Wall Insulation	-35/70	78/15	-211/-	13/19	-161/-	-235/99	-102/-	-53/28
Additional Wall and Roof Insulation	-218/253	8/20	-520/-	-935/-	-398/-	-1290/-	-306/-	-842/-
Water Tank Insulation/ Decreased Temperature	16/2	13/2	29/1	17/2	26/1	20/2	25/1	21/1
High Efficiency Furnace	14/12	321/1	-2/22	303/1	-15/86	54/5	-11/46	92/4

*Payback less than 1 year

Table 3-70. Energy Conservation, Techniques, Cost Effectiveness
Retail Store, Heating and Hot Water, Collector Area = 4000 Ft^2
Oil Auxiliary Fuel

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Minimum Ventilation	115/1	294/*	49/4	243/*	12/7	59/2	18/5	129/*
Air Economizer	N/A							
Vent Heat Recovery	-41/28	78/13	-142/72	-8/21	-118/124	-79/46	-108/110	-30/26
Reflective Film	-46/1940	-62/142	-55/1099	-90/292	-43/-	-37/48	-41/-	-70/-
Awnings	N/A							
Double/Triple Glazing	-19/72	17/13	-29/164	-4/22	-23/242	-20/54	-21/433	-8/28
Reduced Light Level	NA/NA	3181/*	NA/NA	4852/*	NA/NA	4157/*	NA/NA	3787/*
Reduced Light Schedule	545/*	960/*	861/*	1490/*	684/*	1293/*	682/*	1222/*
Night Setback	22/5	272/*	8/10	269/*	3/13	104/1	3/13	124/*
Additional Wall Insulation	6/18	395/7	-166/177	326/10	-129/300	-88/29	-78/151	74/14
Additional Wall andRoof Insulation	-102/35	1595/5	-359/130	882/10	-287/262	-171/27	-222/150	161/15
Water Tank Insulation/ Decreased Temperature	22/2	19/2	23/2	18/2	23/1	20/2	24/1	24/1
High Efficiency Furnace	43/6	611/*	5/16	421/*	-13/60	85/4	-8/34	138/2

*Payback less than 1 year

Table 3-71. Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating, Hot Water and Air Conditioning, Collector Area = 4000 Ft^2

Auxiliary Fuel: Oil

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Minimum Ventilation	46/3	275/*	-125/-	188/1	-99/-	33/4	-79/-	87/1
Air Economizer	177/1	148/2	425/*	187/2	326/*	228/*	227/*	142/1
Vent Heat Recovery	-46/29	78/13	-143/73	-11/21	-119/130	-82/48	-108/110	-33/27
Reflective Film	4/18	-37/41	18/15	-59/51	26/12	0/20	27/12	-34/48
Awnings	25/5	14/8	32/5	20/7	21/5	10/9	36/3	23/5
Double/Triple Glazing	-13/40	19/13	-21/55	-5/23	-16/55	-18/46	-12/44	-6/26
Reduced Light Level	NA/NA	3477/*	NA/NA	5361/*	NA/NA	4638/*	NA/NA	4156/*
Reduced Light Schedule	612/*	1042/*	974/*	1609/*	795/*	1430/*	755/*	1300/*
Night Setback	19/5	270/*	9/10	252/*	3/13	94/1	5/10	124/*
Additional Wall Insulation	-14/28	349/8	-207/-	172/13	-160/-	-185/54	-101/-	13/19
Additional Wall and Roof Insulation	-170/71	915/8	-510/-	-558/66	-395/-	-1187/-	-303/-	-697/-
Water Tank Insulation/ Decreased Temperature	27/1	23/1	37/1	23/2	33/*	25/1	32/*	29/1
High Efficiency Furnace	43/6	611/*	5/16	421/*	-13/60	85/4	-8/34	138/2

*Payback less than 1 year

Table 3-72. Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating and Hot Water, Collector Area = 4000 Ft^2

Auxiliary Fuel: Electric

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Minimum Ventilation	197/*	552/*	94/2	600/*	22/5	111/1	27/4	245/*
Air Economizer	N/A							
Vent Heat Recovery	30/17	261/7	-113/47	243/9	-111/95	-35/27	-103/91	49/15
Reflective Film	-47/-	-59/110	-53/371	-89/253	-42/1057	-18/28	-41/-	-84/-
Awnings	N/A							
Double/Triple Glazing	-15/47	58/7	-26/94	48/9	-22/163	-12/32	-20/218	8/15
Reduced Light Level	NA/NA	2546/*	NA/NA	3815/*	NA/NA	3942/*	NA/NA	3267/*
Reduced Light Schedule	512/*	719/*	838/*	1098/*	667/*	1205/*	675/*	1080/*
Night Setback	41/3	499/*	21/6	628/*	8/9	184/*	6/10	223/*
Additional Wall Insulation	36/12	910/4	-149/98	1222/4	-123/182	77/16	-73/106	298/8
Additional Wall and Roof Insulation	-12/21	3315/3	-306/72	3007/4	-274/169	169/16	-209/108	657/9
Water Tank Insulation/ Decreased Temperature	42/	37/*	65/*	47/*	49/*	41/*	51/*	51/*

*Payback less than 1 year

Table 3-73. Energy Conservation Techniques, Cost Effectiveness Retail Store, Heating, Hot Water, Air Conditioning Collector Area = 4000 Ft^2

AUXILIARY FUEL: ELECTRICITY

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Minimum Ventilation	129/1	532/*	-81/-	545/*	-89/-	87/1	-69/-	203/*
Air Economizer	177/1	177/1	424/*	201/1	326/*	275/*	228/*	142/1
Vent Heat Recovery	25/17	260/7	-115/48	240/9	-112/98	-38/27	-102/88	46/15
Reflective Film	4/18	-34/36	20/15	-58/50	27/12	20/15	27/12	-47/105
Awnings	25/5	15/7	32/5	20/7	21/5	10/9	37/3	23/5
Double/Triple Glazing	-7/27	60/7	-18/44	47/9	-15/50	-9/28	-10/37	10/15
Reduced Light Level	NA/NA	2842/*	NA/NA	4324/*	NA/NA	4424/*	NA/NA	3636/*
Reduced Light Schedule	580/*	801/*	950/*	1216/*	778/*	1344/*	750/*	1158/*
Night Setback	37/3	497/*	21/6	611/*	8/9	175/*	9/8	223/*
Additional Wall Insulation	21/14	864/4	-191/-	1068/5	-155/-	-19/21	-96/-	237/9
Additional Wall and Roof Insulation	-80/30	2634/4	-458/-	1567/7	-382/-	-846/-	-288/-	-201/32
Water Tank Insulation/ Decreased Temperature	48/*	41/*	77/*	52/*	59/*	47/*	60/*	56/*

*Payback less than 1 year

-Negative Payback

Note· Payback greater than 20 should be used only for relative ranking

3.4 OFFICE BUILDINGS

Results for the Office Building, both new and existing, are outlined in the following paragraphs. First, the building description as well as its interaction with the solar system is presented, then a description of the various techniques for energy conservation and their interaction with the building is given. Tables for both building types in each city for heating and hot water systems and heating, hot water and air conditioning systems are listed. These tables show the various energy conservation techniques with the amount of energy saved or lost by the techniques, as well as the dollar savings or loss for the various auxiliary fuels.

Since the description of the conservation techniques is a general one which describes the cause and effect relationship of conservation techniques and amount of energy saved or lost; it has only been described once (for the new and existing building in Omaha). The effects of the techniques remain the same for the various locations, although the load and energy savings may change greatly. This variation is due to the different climatic conditions, as well as the various construction types of the different locations. The savings will also vacillate greatly from location to location due to the varying loads, different costs of implementation and fuels.

At the end of the section, a brief discussion is given on the overall results of the conservation techniques. Also, a set of comprehensive tables are given showing the payback times for these techniques.

3.4.1 Building Description

Several office buildings were studied for this report and the typical existing as well as improved building types were chosen as documented in Appendix A. The typical office building consists of three stories, with a floor area of 10,000 square feet. It has 15 zones, 5 on each floor; one large central zone and 4 exterior zones. Each zone has one air flow terminal controlled from a zone thermostat. The existing building utilizes a constant volume terminal reheat (CVTR) system, while the new building incorporates a variable air volume (VAV) system. Minimum outdoor air ventilation is 0.3 CFM/ft^2 (30 CFM/person), unless the zone is incapable of maintaining the desired temperatures, in which case the CFM would be reduced. This meets ASHRAE Standard 62-73. Occupants consume 0.5 gallons of hot water per day per person.

Control of the central air handling unit (shown in Figure 3-59) for the VAV and CVTR systems is sequenced as illustrated in Figure 3-60. The HVAC system modeled has a 15°F throttling range and a discharge air set point of 55°F. It is capable of preheat, if necessary, and the heating and cooling coils are operable year round depending on ambient conditions. The relative humidity of the office space is maintained at a minimum of 25 percent (15 percent for Albuquerque). System design is based on summer and winter room temperatures of 75°F with twice the minimum requirement of outdoor air. Convective radiation units are assumed to be located in any zone where heat would be required to maintain the desired temperature.

Design of a solar heating and cooling system for a multi-storied building is different than the system design for a residential dwelling. The reason for this difference is the complexity of the building systems as well as the enormous energy requirements of the building. To maintain comfortable conditions year round, the building design requires that the HVAC system be capable of simultaneous heating and cooling. Figure 3-61 shows a schematic diagram of the solar heating and cooling system. Pump 2 will be activated if the solar panels supply enough energy for direct heating, pump 4 will be activated if stored energy is to be utilized. If there is no energy available from either of these sources, auxiliary energy will be used. If cooling is necessary and the solar panels collect enough energy to run the Rankine cycle,

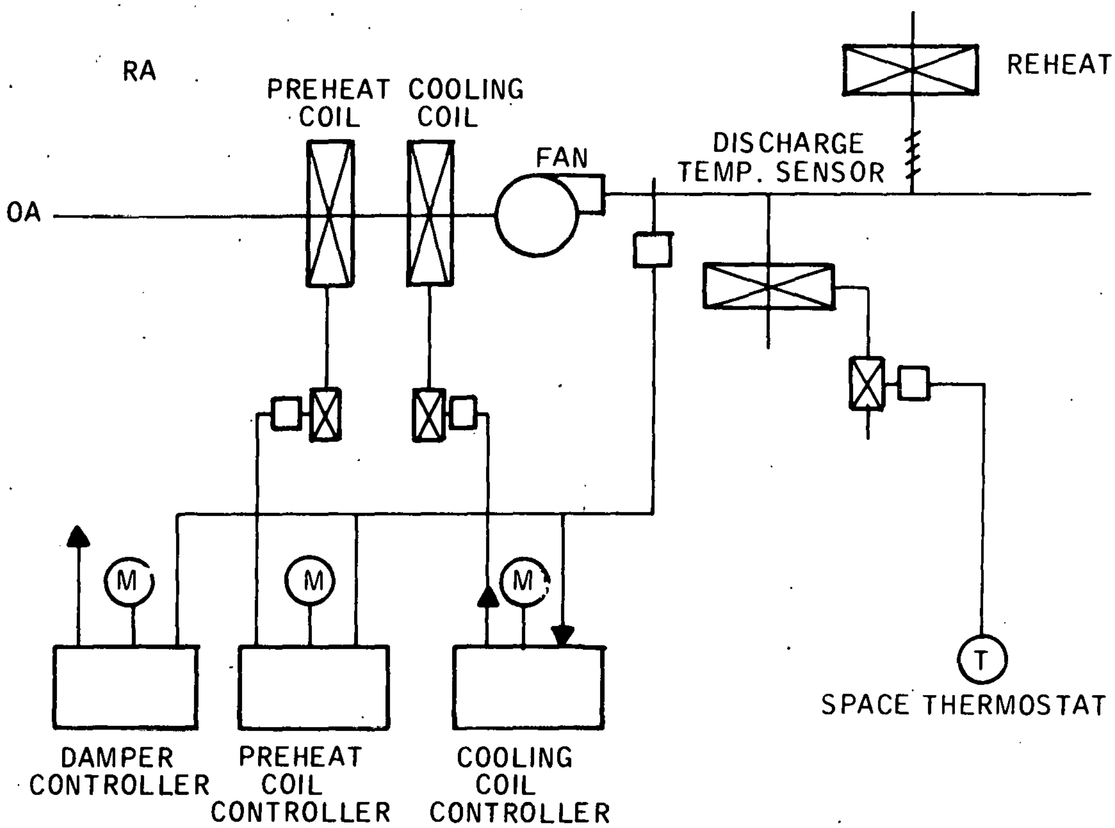


Figure 3-59. Schematic of Central Air Handling Unit

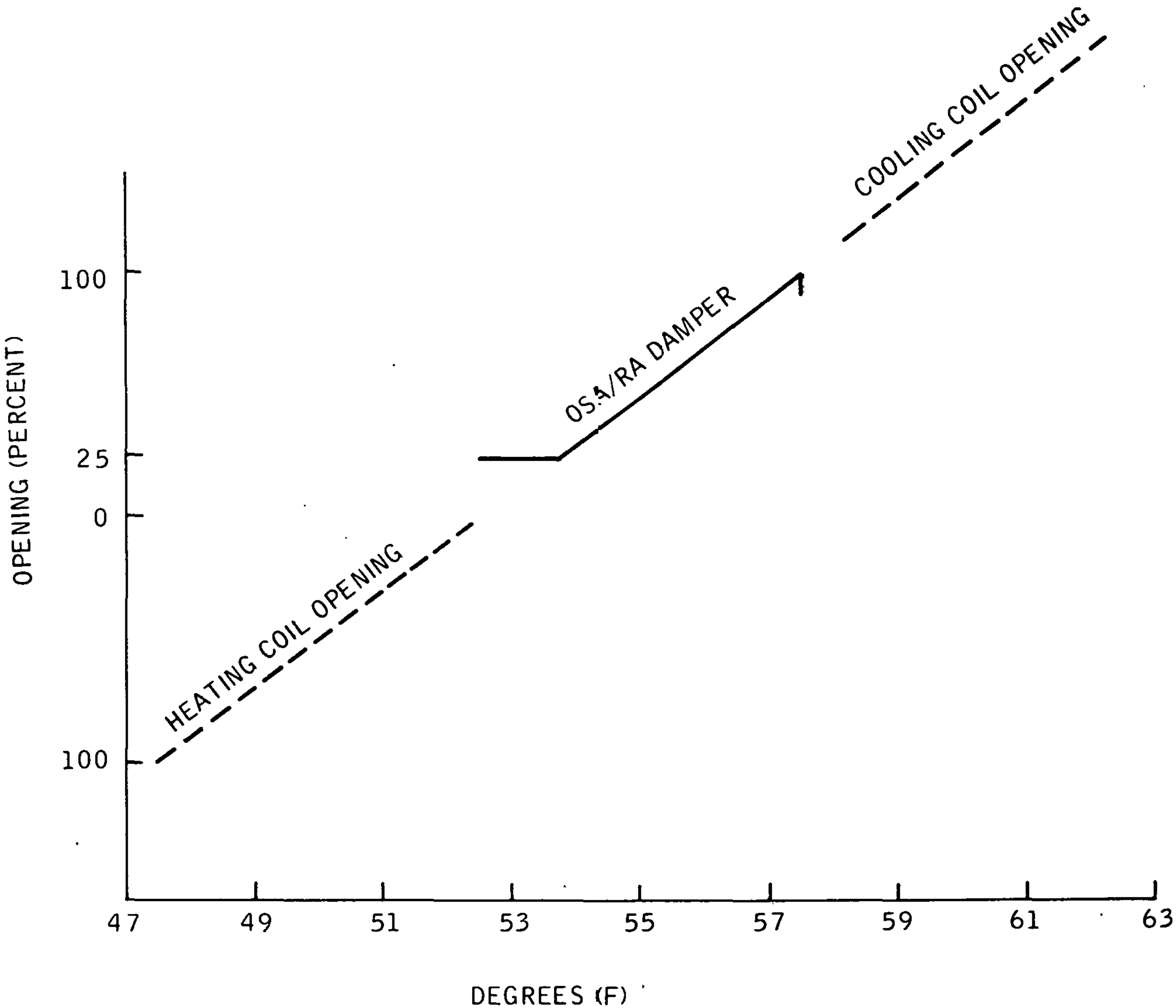


Figure 3-60. Supply Unit Discharge Temperature Versus Percent Opening

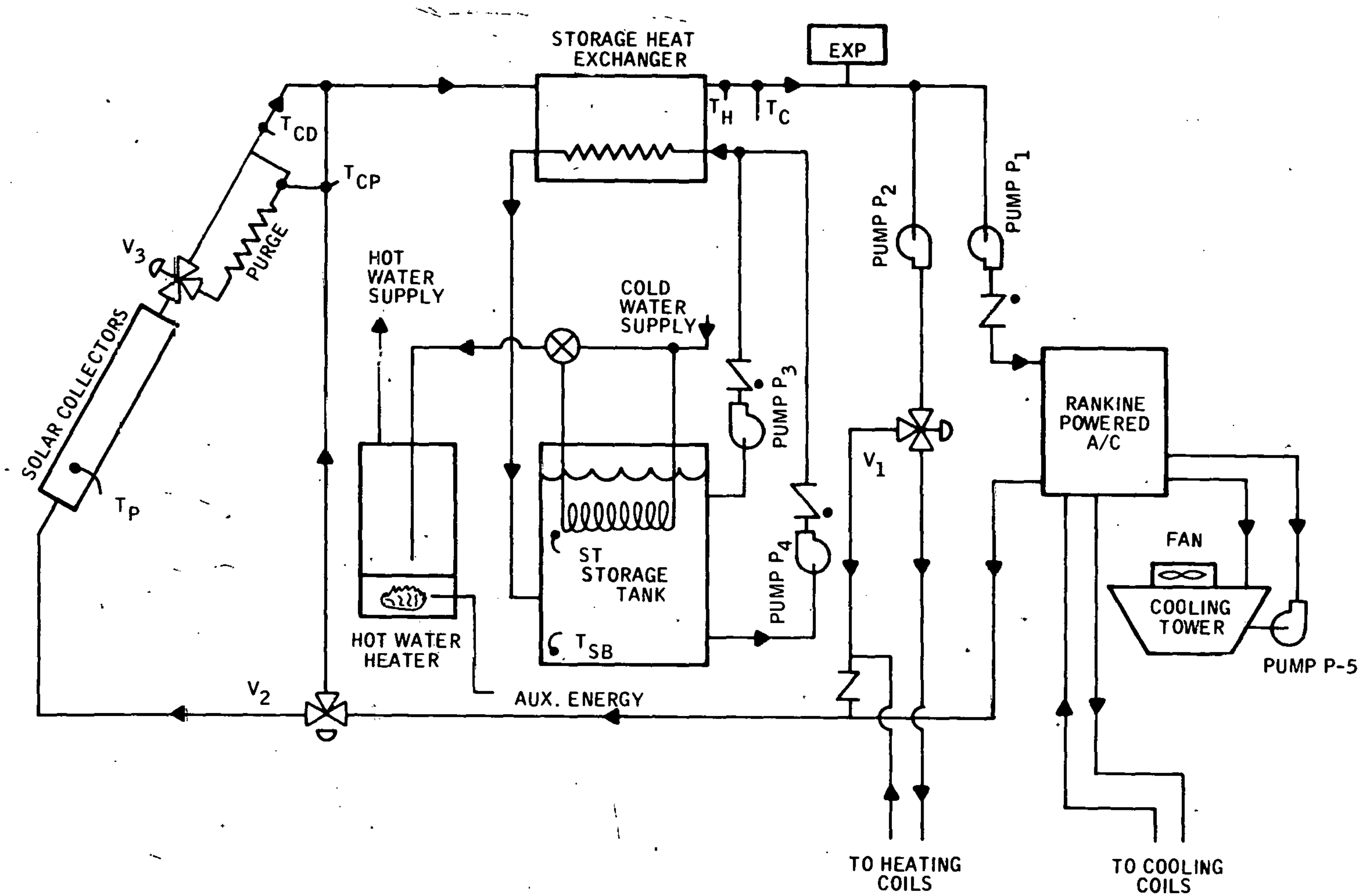


Figure 3-61. Baseline Solar System

pump 1 will run. Pump 4 will run in conjunction with pump 1 if the stored energy plus energy collected by the solar panels is enough to run the Rankine cycle. Otherwise electrical energy will be input to the motor generator which will run the vapor compression cycle, thus supplying the necessary cooling by auxiliary energy. The entire system is monitored by measuring temperature at the desired points shown in the figure. Since no present control scheme exists (software as well as hardware), for the optimization in diverting simultaneous heating and cooling loads between the Rankine system and the heating system, the system will simply use the total collected and stored energy for heating purposes from January to May and from October to December, and use auxiliary energy to meet the cooling load if one exists during this period. From May to October, all the collected energy is used for cooling, while any heating requirements are met by auxiliary fuels.

3.4.2 Modeling Assumptions

Simulation of the office building makes the following assumptions:

- There is no heat transfer between zones.
- All loads go into the zones and not the return air plenum (i.e., return air temperature is equal to the room temperature).
- Air handling unit losses are not building gains since the central unit is in an unconditioned space.
- Seventy-five percent of the fan heat is rejected into the air stream while the remainder is lost to the unconditioned space.

- The storage tank (which is optimized for minimum surface area per required volume) is located outside the building since its size prohibits burying beneath the building, thus tank losses are not assumed to be building gains.
- 1.5 gallons of storage per square foot of collector.

3.4.3 Results for Office Building

Omaha - North Central Region

New Construction - Base Building -- The base case (system before Energy Conservation Techniques (ECTs) have been implemented) is a VAV system using an air economizer. Hours of operation are from 6:00 am to 10:00 pm and the various operating schedules can be seen in Appendix A. Heat is supplied from baseboard radiators operated on an outdoor air reset schedule which is based on satisfying the entire transmission load at design and humidification only (dehumidification occurs if the right coil condition exists). The thermostat is set at 75°F year round.

Although the base case was run with a setpoint of 75°F, a simulation was run with the thermostat lowered to 72°F during the winter (October-March). Figure 3-62 shows the energy profiles of this run compared to the base case. The cooling loads are coincident during the period when the temperatures are both at 75°F and increases slightly when the temperature is set down to 72°F. Almost no decrease in heating load is realized by reducing the thermostat setpoint during the winter since the heat delivered by the radiators is controlled by outdoor air reset. There is, however, a very slight reduction in humidification necessary at the reduced temperature. The interesting result is that the fan power consumption increases significantly when the thermostat is set down. If there were no mechanical cooling possible during the months of temperature setback even more power would be consumed by

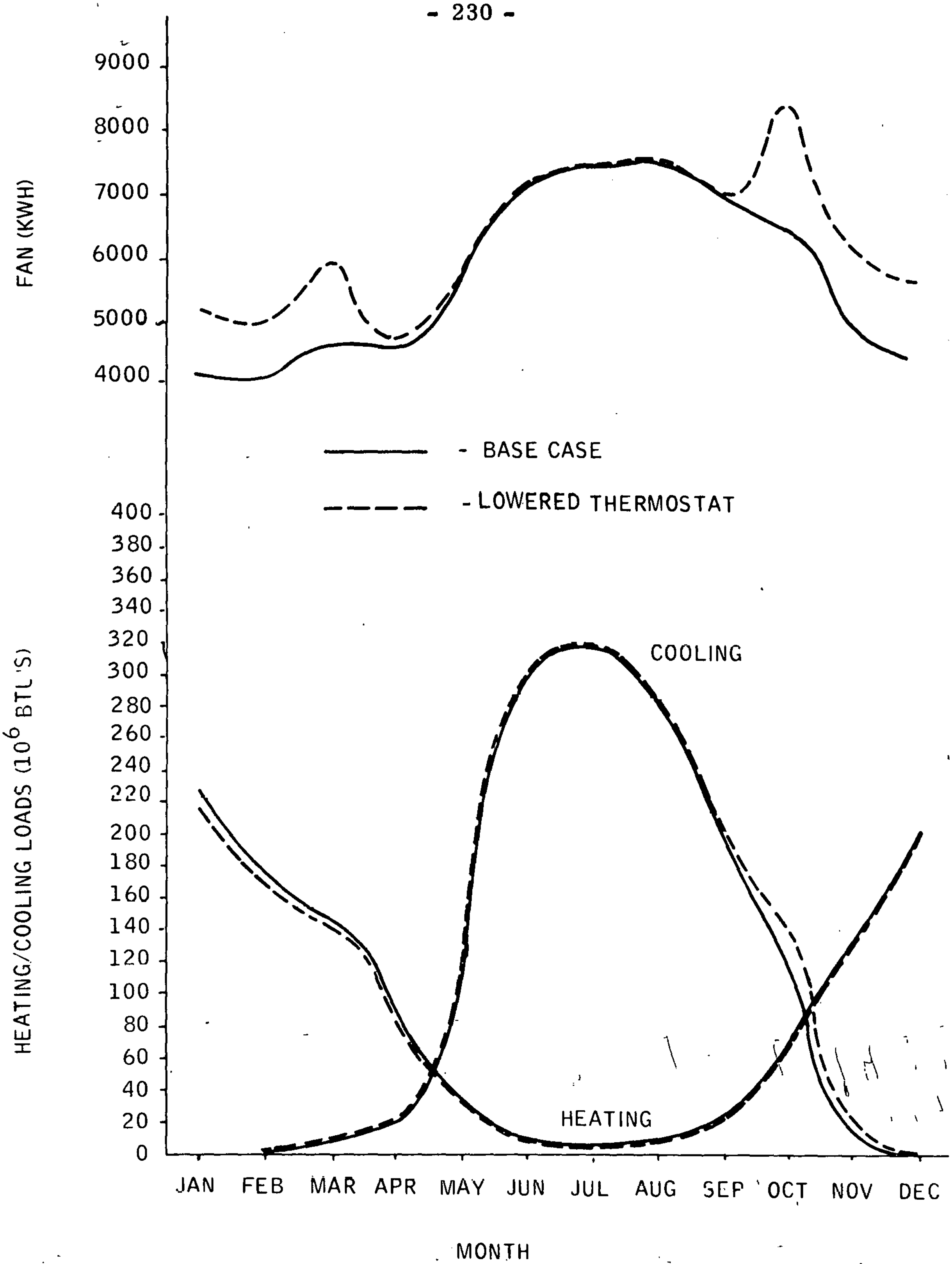


Figure 3-62. Load Profile, Base Case -- Reduced Setpoint, VAV, Omaha

the fans. Increasing the setpoint during the winter will result in a reduction in power consumption. Decreasing the thermostat during the summer will result in an increase in power consumption (cooling load as well as increase electrical demand by the fan), while an increase in temperature during the summer will result in a reduction in power consumption.

The heating,cooling and fanpower consumption profiles of the base case (VAV) system can be seen in Figure 3-63. The trends depicted on this graph are general for a VAV system. Their particular energy profiles are for the city of Omaha. It can be seen that the heating energy (baseboard heat plus preheat and latent heat of vaporization for humidification if necessary) decreases through the summer and increases through the winter while cooling and fan energy peak during the summer. Figure 3-64 shows the auxiliary energy demand of the solar heating and cooling system as a function of collector area for the load profile shown in Figure 3-63.

The general trend is for a decrease in auxiliary energy demand as the size of the solar collectors (and storage tank) increase. This happens since the building load is fixed and the amount of collected solar energy increases, thus the auxiliary energy demand decreases. At low collector areas, the system is incapable of supplying any cooling (the Rankine cooling cycle is inefficient compared to the solar heating cycle) which requires that all of the cooling load be met by auxiliary fuel, therefore, the heating, hot water and air conditioning curve (H, HW, AC) lies above the heating and hot water curve (H, HW). As the collector area increases, more and more of the cooling load is supplied by the solar energy. Thus, the curves approach one another. This approach is not asymptotic since there is a demand for cooling before the Rankine system is operable and this cooling is always supplied by auxiliary energy. Figure 3-65 shows how much of the load is supplied by the solar heating and cooling system for various collector areas (and storage tank size) for the base system. The most striking result depicted in this figure is that the system is incapable of meeting the entire load with solar

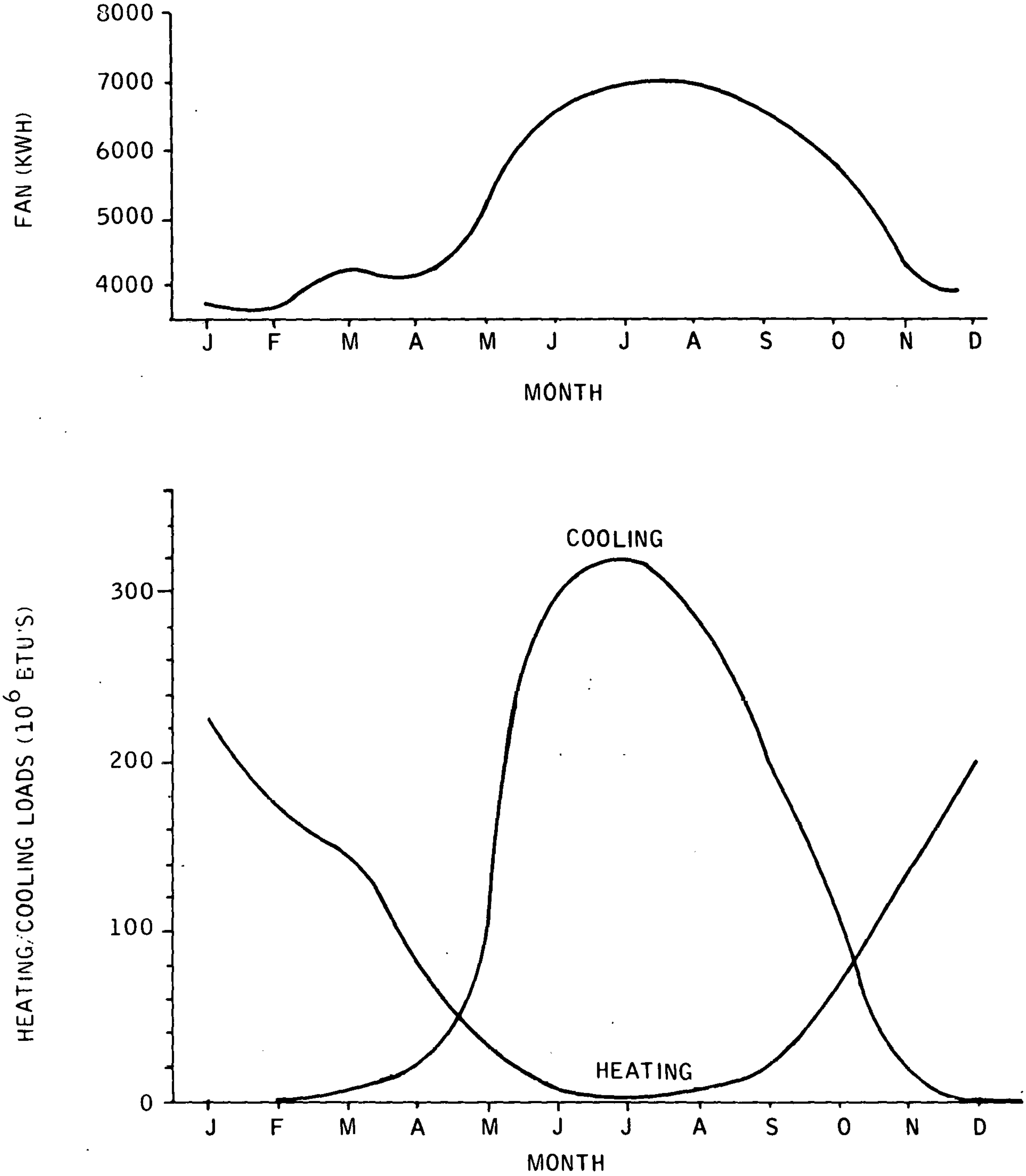


Figure 3-63. Load Profile Base Case, UAU, Omaha

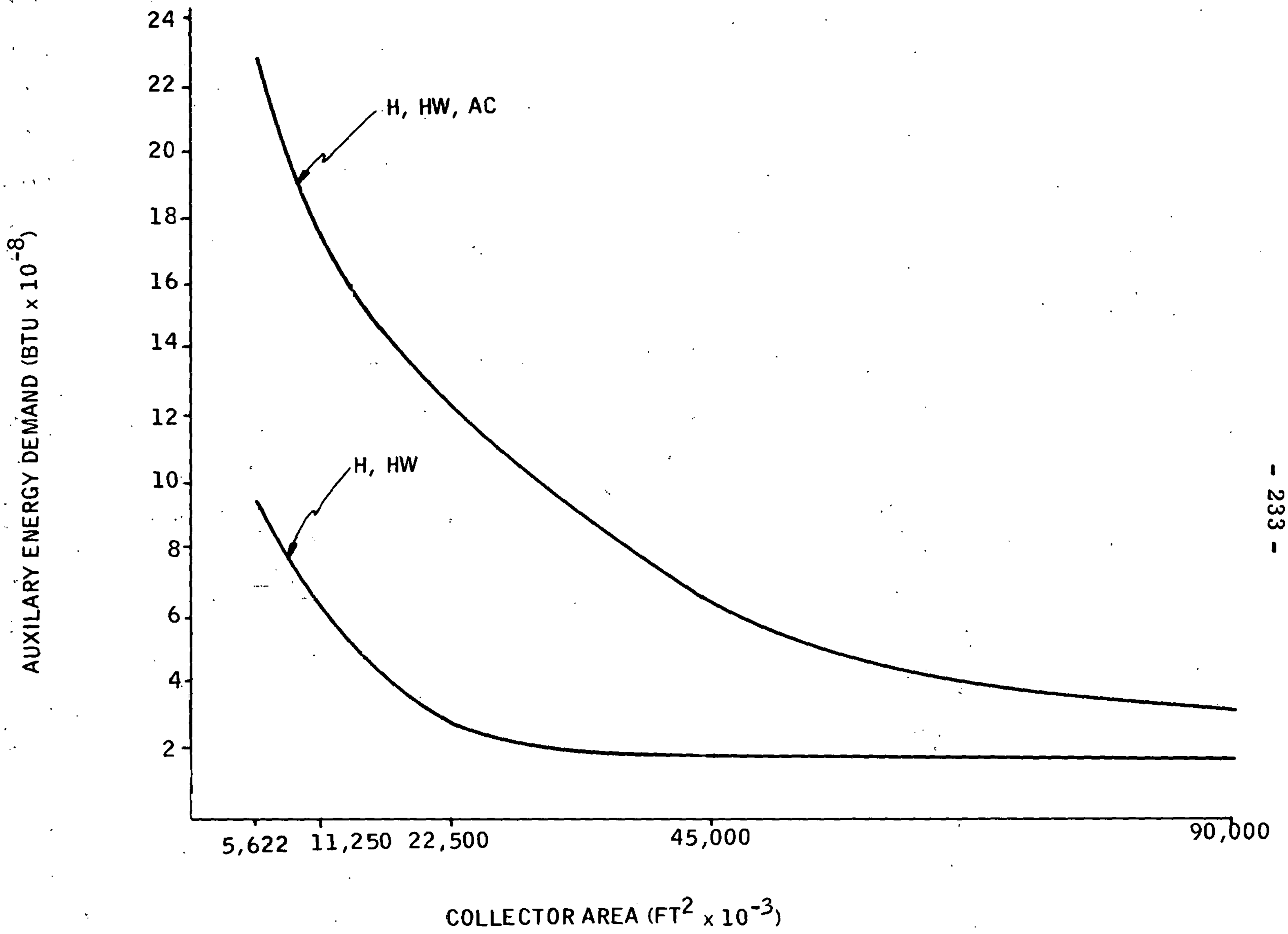


Figure 3-64. Auxiliary Energy Demand Versus Collector Area

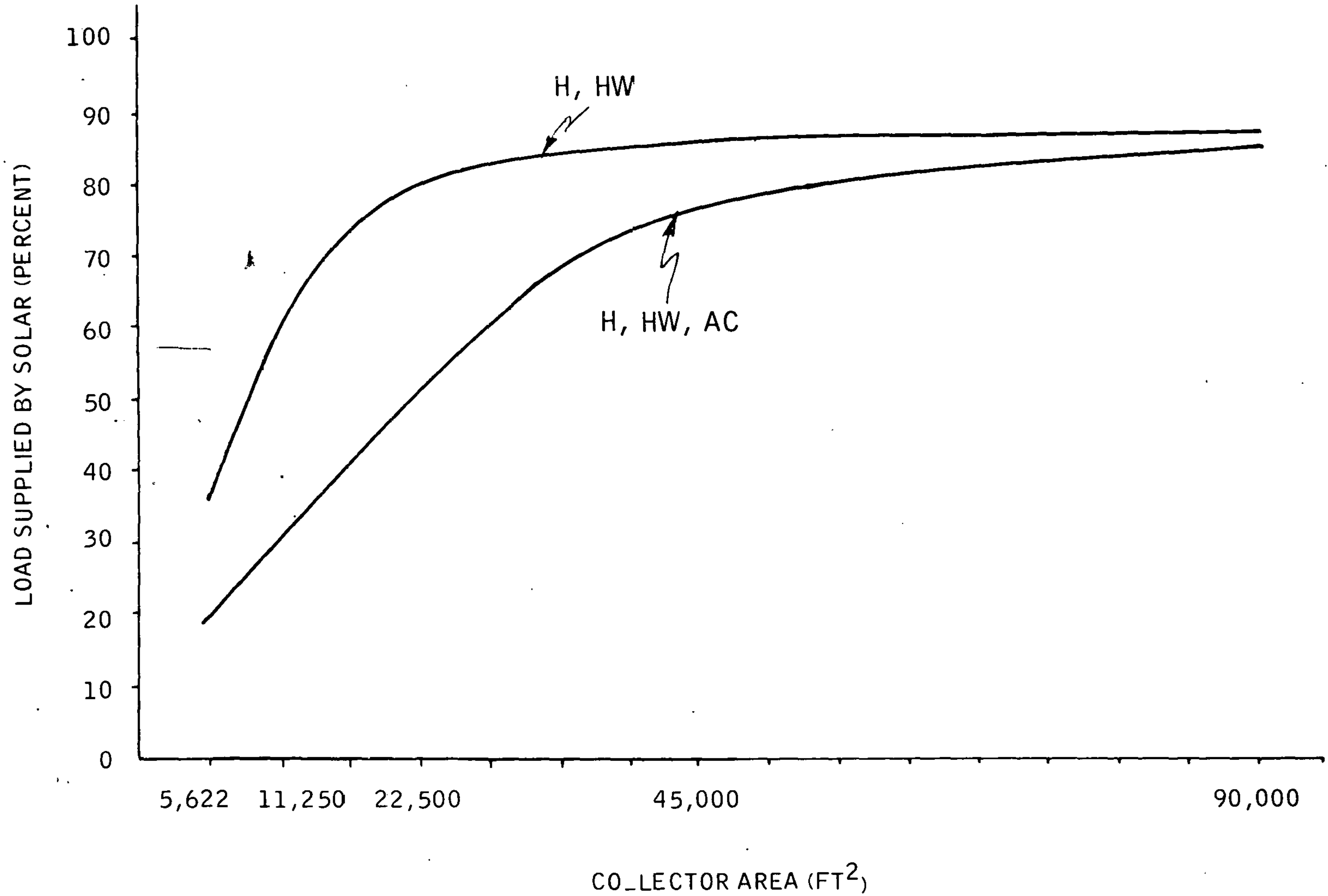


Figure 3-65. Omaha New Office Building Base Case

energy regardless of the collector area. Again, this anomoly is due to the fact that heating energy during the summer and cooling energy during the winter, is supplied by auxiliary fuel. For smaller collector areas, there lies above the H, HW, and AC curve. As the collector area increases, more cooling energy is supplied by the solar collector.

Figures 3-66, 3-67 and 3-68 show the annual cost of the base system as a function of collector area for oil, gas and electric. The most obvious trend in the three figures is the continual increasing cost for systems with increasing collector areas. This trend points out that for the given period (20 years) and economic inputs (see Appendix E) there is no optimum solar heating and cooling system. As one would expect, the curves shift upward for the more expensive fuels, gas being the cheapest, and electric being the most expensive. The H, HW, and AC curve is always greater than the H, HW curve. This is because of the added expense of the Rankine cooling cycle.

New Construction - Application of Energy Conservation Techniques (ECTs) -- Tables 3-74 and 3-75 show the loads and savings for the base case and each ECT. Table 3-74 is for the heating, hot water and air conditioning system, while Table 3-75 is for the heating and hot water system. This set of tables is for a collector area of 22,500 square feet.

Annual costs represent the cost of solar heating and/or cooling systems, auxiliary fuel and ECT cost with associated fuel cost, if they exist, ammortized over the 20 year period. Annual savings are the differences between base case and ECT annual cost. BTU savings are the differences between the total load for the base case and the ECT.

Reflective Film -- In order to understand how the VAV system responds to various ECTs, one must realize how the VAV system works. As mentioned earlier, the central air handling unit supplies the cooling and humidification

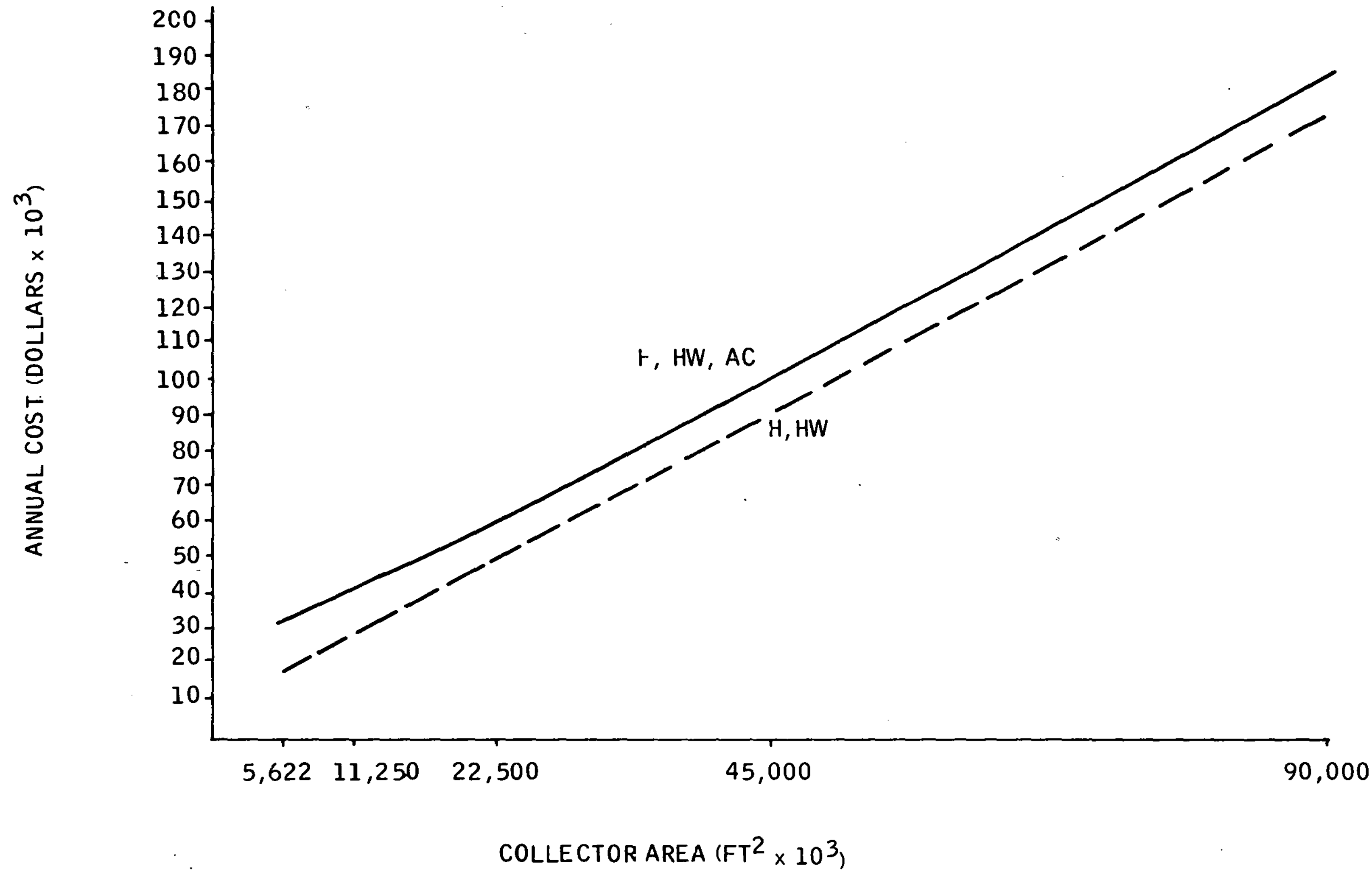


Figure 3-66. Annual Cost Versus Collector Area,
Base Case -- Omaha
Gas Auxiliary Fuel

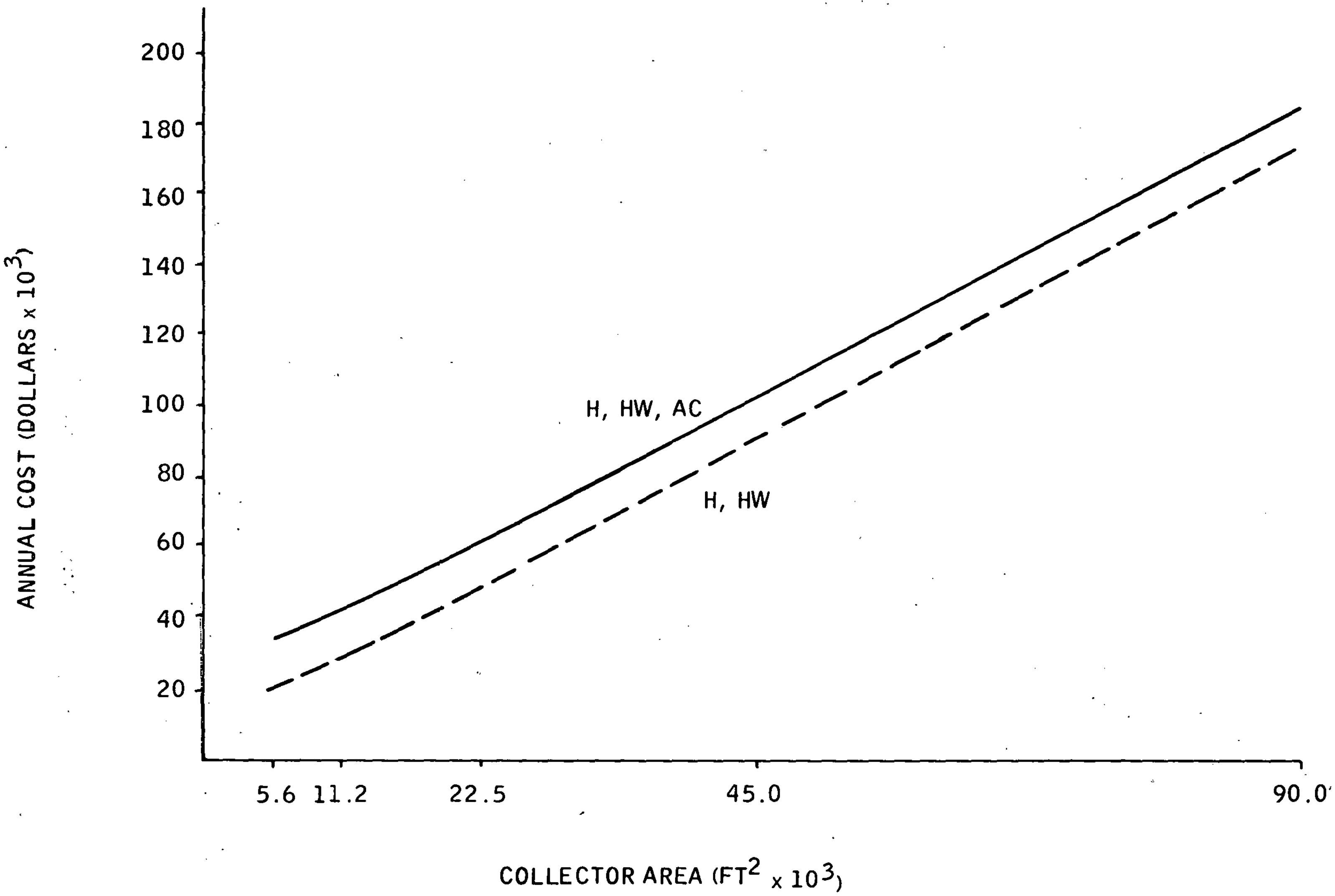


Figure 3-67. Annual Cost versus Collector Area, Base Case - Omaha (Oil Auxiliary Fuel)

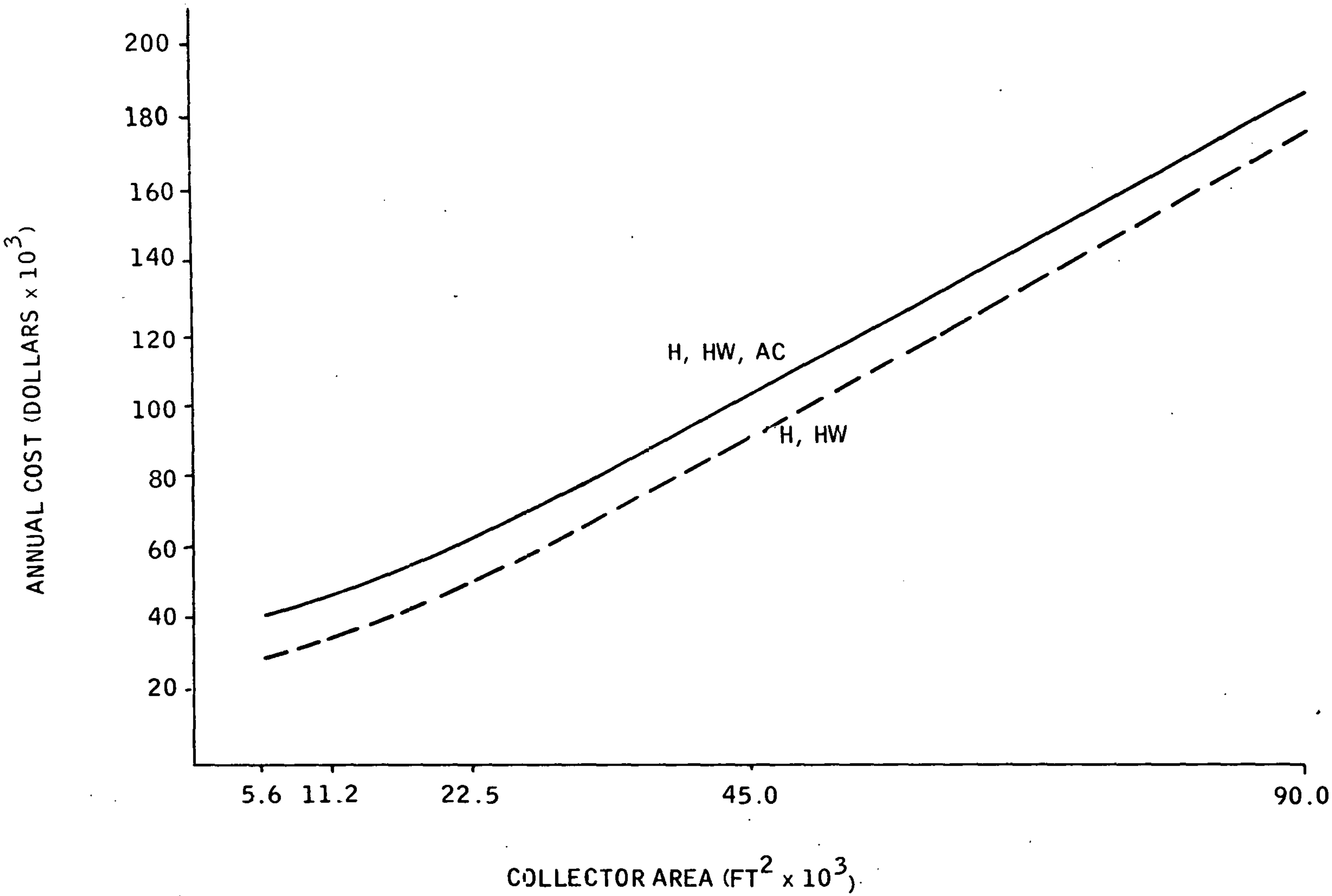


Figure 3-68. Annual Cost versus Collector Area, Base Case - Omaha (Electric)

Table 3-74. Summary Loads, Costs and Savings, Omaha - Heating, Hot Water and Air Conditioning (Collector area 22,500 ft^2)

OFFICE BLDG.
OMAHA
VAV

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	2,897	56.30	61,447	62,005	63,982					
Reflective Film	2,647	61.33	61,162	61,723	63,618	285	282	274	250	9
Shading	2,679	60.44	60,469	61,020	62,878	977	986	1,014	218	8
Triple Glazing	2,856	57.48	62,154	62,724	64,650	- 707	- 719	- 759	41	1
Reduced Lighting	2,617	61.44	54,487	55,027	56,850	6,960	6,978	7,041	280	10
Night Setback	2,897	56.30	61,459	62,017	63,904	- 12	- 12	- 12	0	0
Increased Wall Insulation	2,899	56.57	61,616	62,179	64,082	- 169	- 174	- 190	- 2	0
Increased Wall & Roof Insulation	2,902	56.77	62,048	62,624	64,571	- 601	- 619	- 679	- 5	0
Reduced Hot Water Temperature	2,848	56.34	61,440	61,972	63,770	7	33	122	49	2
Hydronic Control From Zone Thermo. With Night Setback	2,652	54.48	61,539	61,976	63,452	- 92	29	440	245	9
Energy Reclamation from Exhaust Air	2,856	57.06	61,576	62,135	64,022	- 130	- 130	- 131	41	1

Table 3-75. Summary Loads, Costs and Savings, Omaha - Heating and Hot Water

Office Bldg.
Omaha
VAV

collector area 22, 500 FT^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	1, 524	81. 43	49, 016	49, 574	51, 461					
Reflective Film	1, 519	81. 34	49, 466	50, 027	51, 922	- 450	- 453	- 461	5	0
Shading	1, 509	81. 55	48, 619	49, 169	51, 027	397	405	434	15	1
Triple Glazing	1, 541	81. 24	49, 885	50, 455	52, 381	- 869	- 881	- 920	- 17	- 1
Reduced Lighting	1, 493	81. 73	42, 790	43, 330	45, 154	6, 226	6, 244	6, 307	31	2
Night Setback	1, 524	81. 43	49, 028	49, 586	51, 473	- 12	- 12	- 12	0	0
Increased Wall Insulation	1, 533	81. 39	49, 193	49, 757	51, 660	- 178	- 183	- 199	- 9	- 1
Increased Wall & Roof Insulation	1, 547	81. 12	49, 662	50, 238	52, 185	- 646	- 664	- 724	- 23	- 2
Reduced Hot Water Temperature	1, 476	81. 72	48, 983	49, 515	51, 313	32	59	147	48	3
Hydronic Control From Zone Thermo. With Night Setback	1, 274	82. 63	49, 029	49, 466	50, 943	- 14	108	518	250	16
Energy Reclamation From Exhaust Air	1, 524	81. 43	49, 262	49, 821	51, 707	- 247	- 247	- 247	0	0

or dehumidification (the energy for vaporization is accounted for by adding it to the energy needed for heating and the latent heat involved in dehumidification is part of the cooling load); while heat is supplied by the convective radiators which are controlled based on outdoor air reset. This means that the amount of heat put into the space is independent of the space conditions (unless control of the hydronic loop is altered), while the amount of supply air delivered to the space is a direct function of the space conditions.

Therefore, if the load in the space decreases, the amount of air delivered by the discharge unit will decrease. This decrease will mean a reduction in the amount of humidification (if any is necessary), a reduction in the amount of mechanical cooling (if any is necessary), and a reduction in electrical power required by the supply fan. The converse is true if the load in the space increases. For both situations, the amount of heat delivered by the radiators remains constant.

By incorporating reflection film into the building structure, which is done by using specially treated windows instead of the standard double paned windows, the transmissivity (amount of sunlight passing through the window) is reduced by 80 percent while the transmission coefficient is also slightly reduced. Putting these windows on a building reduces the solar heat gain year round, as well as slightly reducing the heat loss in winter and the heat gain in summer. In effect, the average load on the space is decreased which results in a substantial decrease in the cooling load and a slight decrease in the heating load for the reason described above.

<u>Shading</u> -- Little information exists on the cost of shading an office building since this is not generally done. Therefore, this ECT cost was assigned zero dollars for the economic simulation. To evaluate this measure, the owner would find the amount of dollars saved per year by this technique and see if the implementation cost is less than this value. The positive difference between the savings per year and the implementation cost per year s the actual savings realized by the owner per year.

For the VAV system, the effect of shading is basically the same as it was for reflective film. The difference is that for shading, only the solar load is reduced, while for reflective film, the solar load as well as heat transfer through the window is reduced. As is the case for this and most of the ECTs, most of the savings are realized through the reduction in fan power consumption, since the humidification load is only a small portion of the total load.

Triple Glazing -- This ECT causes a decrease in the window U valve (less heat transfer) and a slight decrease in the window transmissivity. The overall effect is to reduce the transmission heat loss in the winter and to reduce the heat gain in the summer.

Anything done to reduce the heat loss through the windows (or walls or roof) will result in a larger load in the conditioned space and thus, increase the building's energy consumption. Anything done to reduce the heat gain through the windows (or wall or roof) will result in a smaller load on the conditioned space and thus decrease the building's energy consumption, provided that the perimeter heat reset schedule is not changed. As shown in Tables 3-74 and 3-75, implementation of this ECT in Omaha results in an overall Energy savings with a heating, hot water, and air conditioning system, but a loss with a heating and hot water only system.

Reduced Lighting -- Reduced lighting is implemented by uniformly de-lamping the building, decreasing the overall lighting level from 3 watts per square foot to 2 watts per square foot. The effect is a large reduction in the internal load, thus a decrease in the required air supply CFM. The heating load is reduced due to a lower humidification load during the winter which results from a reduction in outdoor air intake (reduced fan, CFM). The cooling load is also reduced since less supply air CFM during the summer is needed. The third benefit of reduced lighting is a reduction in electrical power consumption, not only due to the reduced fan consumption, but also due to the decreased power needed by the lights. Since there is no cost associated with de-lamping this measure is very cost effective as shown in the figures.

Night Setback -- This is implemented by setting the thermostat down to 55°F from 10 pm to 6 am (when the HVAC system is off). Night setback has no effect on the VAV system with perimeter heat on an outdoor air reset schedule since the zone thermostat has no control over the heating system and the central air handling unit is off.

Increased Wall Insulation -- This ECT consists of using an extra inch of insulation in the walls at the time of construction. The effect is to decrease the heat loss during the winter and decrease the heat gain during the summer. The net load savings depends on whether the savings in the summer are larger than the losses in the winter and this depends upon local climatological inputs. Three important factors include: the base building is fairly well insulated so that the increase in insulation is not as significant as it would be in a poorly insulated building; the major cooling load is due to ventilation; the heat delivered by the radiators is designed for the heat losses of the base system. Cooling loads can increase with increased insulation as would be the case when the outside temperature is less than 75°F and greater than 55°F (in this situation, there is less heat loss with the increased insulation, thus more required CFM, since the outdoor air is greater than 55°F, the mechanical cooling system is on; hence, the cooling loads increase).

Increased Wall and Roof Insulation -- This ECT consists of an additional one inch of wall insulation and two inches of roof insulation and has the effect of reducing the heat loss in the winter and the heat gain in the summer. The loads are affected in the same way as with the increased wall insulation only to a greater extent.

Reduced Hot Water Temperature -- The hot water temperature is reduced from a nominal temperature of 140°F to 130°F. This reduction in temperature has no effect on building loads since the hot water tank is in an unconditioned pace. The results of this measure can be seen in Tables 3-74 and 3-75.

Hydronic Control From Space Thermostat with Night Setback -- This technique entails controlling the heating in each zone, as well as the cooling by zone thermostats. The effect is to reduce the fighting between heating and cooling systems, and to make night setback effective by enabling the heating system to respond to a thermostat setback. The wintertime heating load is reduced significantly (23 percent in Omaha) since the heat is linked more closely to the actual zone requirements. The heating load is also reduced during the setback periods. This measure has no effect on the cooling load when the heating system is inoperable, but it can lead to increases in the cooling load compared to the base case when the heating system is on. This anomaly is possible since the base case CFM was allowed to drop below minimum required CFM when the internal loads were small (in order to maintain the desired temperature) whereas this method will supply the necessary heat to maintain the required minimum CFM. Thus, with an increase in CFM, the cooling load will increase if the outdoor air temperature is greater than 55°F.

Energy Reclamation From Exhaust Air -- This ECT is implemented by using an air-to-air heat exchanger with an effectiveness of 0.4 which is capable of transferring heat between the exhaust and intake air streams. Heat recovery is not possible in the winter since the outside air dampers do not close to their minimum positions, allowing the discharge air to be maintained at the required temperature without using mechanical cooling. Thus, Table 3-75 shows no annual BFU savings for heating and hot water with energy reclaim. During the cooling season, energy reclaim does save energy as shown by the reduced annual load in Table 3-74. Energy reclaim may only be used to supplement cooling when the intake air temperature is greater than the exhaust temperature (75°F). Under that condition, the economizer will normally have the outside air damper shut down to the minimum position (11 percent).

Existing Construction - Base Building -- The base case (system before Energy Conservation Techniques (ECT) have been implemented), is a CVTR system using an air economizer. Hours of operation are from 6:00 am to 10:00 pm and the various operating schedules can be seen in Appendix A. The thermostat is set at 75°F year round.

Although the base case was run with a setpoint of 75°F, two simulations were made with other setpoints, one at 78°F and another with the setpoint at 72°F. A very interesting result, depicted in Figure 3-69, is that with the setpoint at 72°F, the monthly energy consumption is decreased. This would be expected when most of the load comes in the winter and reduction in temperature would mean less heating required, but at this reduced setpoint, there is also less cooling required in the summer. One of the two reasons for this is that with the CVTR system, the return air temperature plays a significant role in determining the amount of conditioning required by the supply unit. Therefore, by reducing the room setpoint and thus the return air temperature, the load on the cooling coil is reduced. Hence, the cooling load decreases as the setpoint decreases. The other reason is that less reheat is needed to maintain cool space temperatures.

Conversely, when the setpoint is raised to 78°F, there is an increase in the monthly energy consumption. During winter operation, more steam is required to maintain the elevated setpoint as would be expected, but during the summer, there is also more steam required to maintain the higher setpoint. Again, this anomaly is caused by the role the return air plays in the cooling mode of the supply unit and the need for more reheat to maintain high space temperatures.

Figure 3-70 shows that the general rule of thumb of decreasing the setpoint in the winter and increasing it the summer consumes much more energy than setting the thermostat down year round. It is important to note that although this trend is not geographically dependent, the result can only be realized with CVTR system.

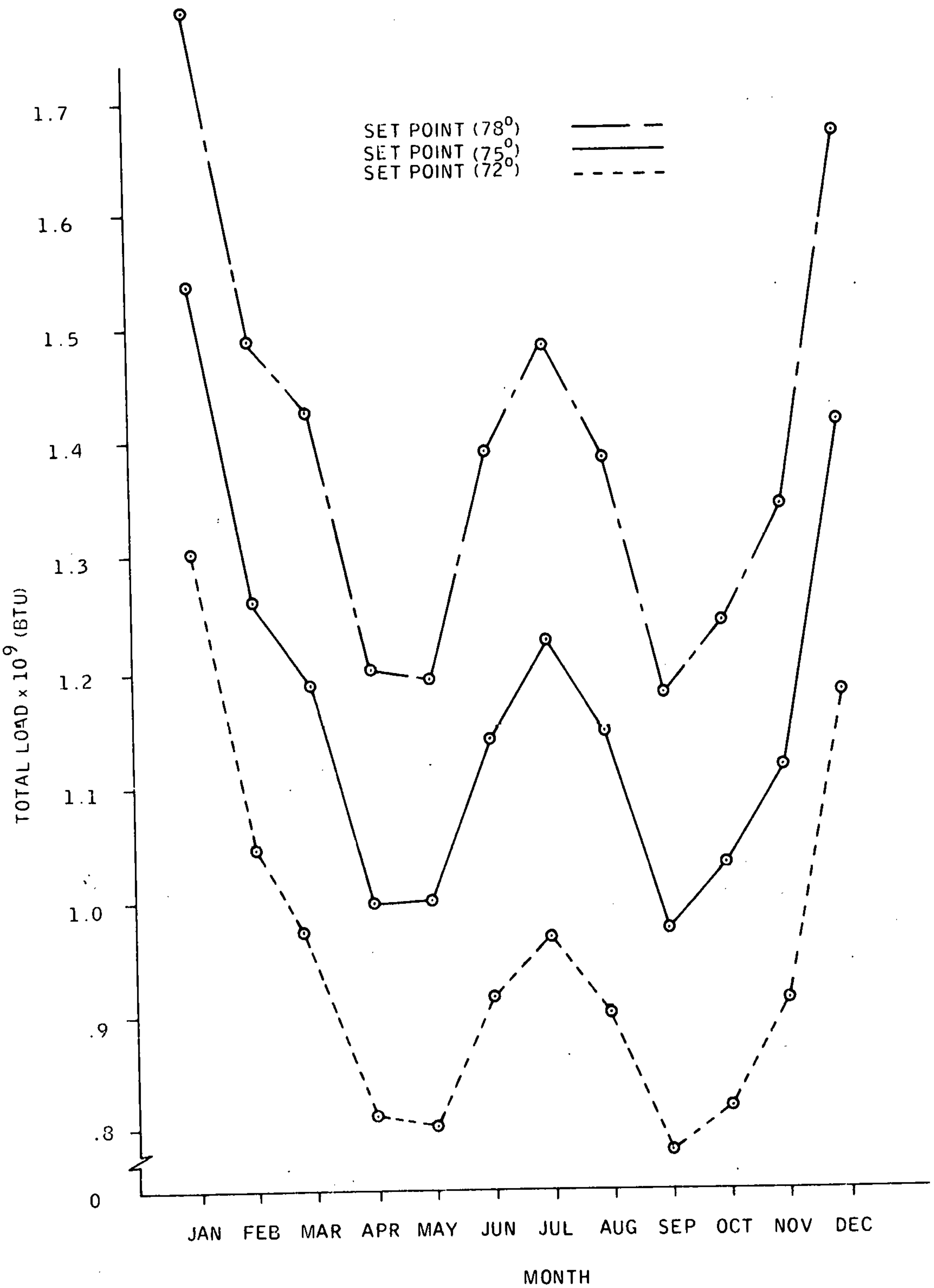


Figure 3-69. Set Point Changes Load Profile for CVTR, Omaha

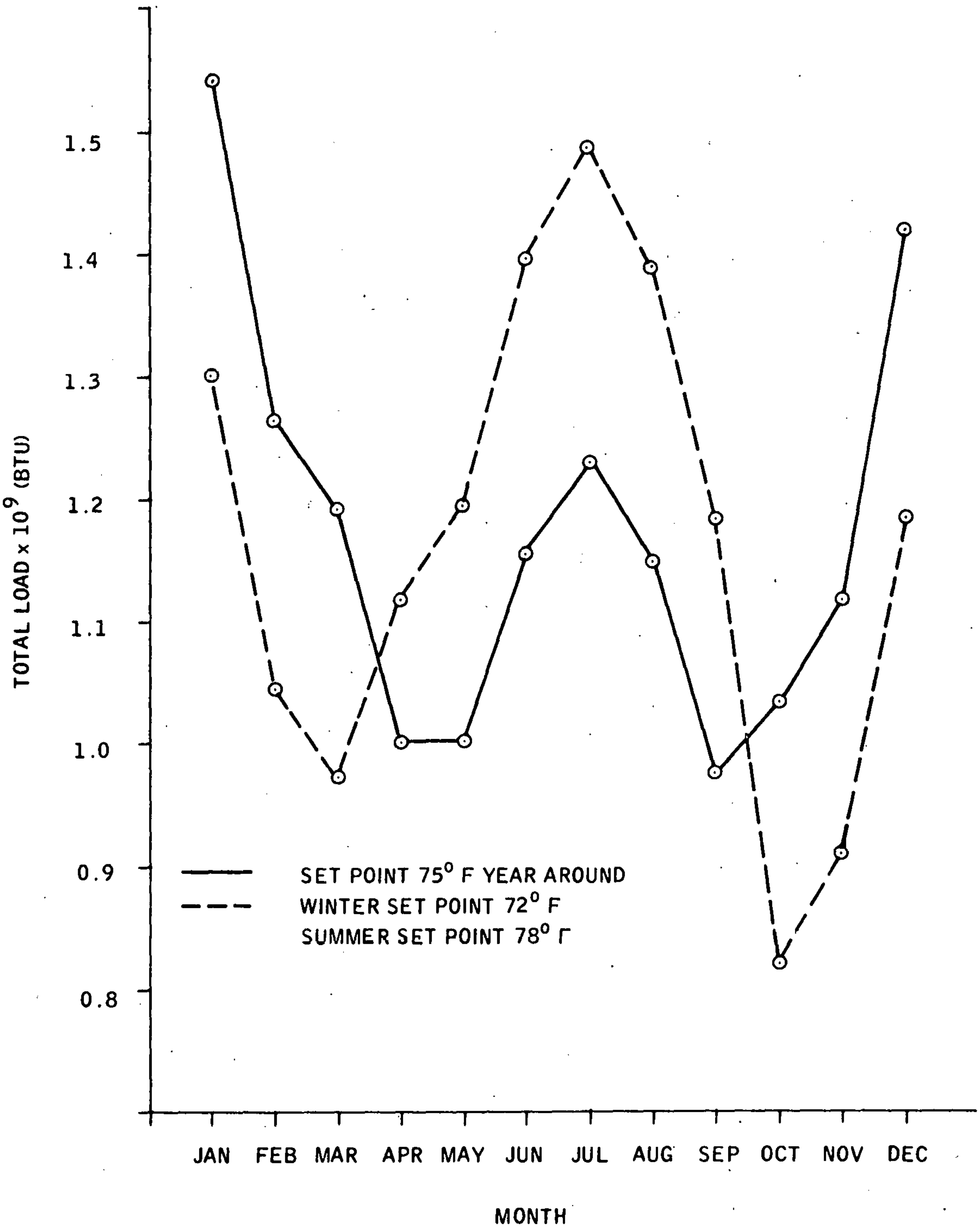


Figure 3-70. Seasonal Set-Point-Changes Load Profile for CVTR, Omaha

The base system chosen for this study is representative of the current constant volume terminal reheat system in a typical building; however, there are many existing buildings that are run in a less efficient energy mode. Below are a few such cases.

- HVAC system with no economizer, run 24 hours a day with twice the minimum required CFM, otherwise same as base case (Case 1).
- HVAC system with no economizer, shut down during the hours of 10:00 pm - 5:00 am with twice the minimum required CFM, otherwise same as base case (Case 2).
- HVAC system with no economizer, otherwise same as base case (Case 3).

Table 3-76. Comparison of Three Systems and the Base Case

Case	Hot Water Load (BTU x 10^{-9})	Cooling Load (BTU x 10^{-9})	Heating load (BTU x 10^{-9})	Total load (BTU x 10^{-9})	Percent Over Base
Base	.4229	3.59	10.50	14.52	---
1	.4229	9.815	12.32	22.56	55.4
2	.4229	7.204	8.715	16.34	12.5
3	.4229	8.062	8.346	16.83	15.9

Table 3-76 shows a comparison of these three systems and the base case. Although the energy consumption is for Omaha, the trends represented are independent of geographic location. Case 1 shows that the system that runs continuously with twice the necessary amount of outdoor air uses almost twice the energy of this base case. After reducing the hours of operation, there is a dramatic decrease in energy consumption. Comparing Cases 2 and 3 shows that with reduced CFM (Case 3) the cooling load increases significantly. This is caused by the lack of enough outdoor air to cool the return air stream to the desired discharge temperature. Thus, mechanical cooling must be done to obtain the desired discharge temperature.

The heating and cooling energy profile of the base case (CVTR) system can be seen in Figure 3-71. The trends depicted on this graph are general for a CVTR system. This particular energy profile is for the city of Omaha. It can be seen that the heating energy (reheat plus preheat and latent heat of vaporization for humidification, if necessary) decreases through the summer and increases through the winter, and cooling energy peaks during the summer as would be expected. What may not be expected, is that approximately 50 percent of the energy load in the summer is due to reheating (this percentage can vary greatly depending on design and location). Figure 3-72 shows auxiliary energy demand of the solar heating and cooling system, as a function of collector area, for the load profile illustrated in Figure 3-71. The general trend is for a decrease in auxiliary energy demand as the size of the solar collectors (and storage tank) increase. This happens since the building load is fixed and the amount of collected solar energy increases, thus the auxiliary energy demand decreases. At low collector area, the system is incapable of supplying any cooling (the Rankine cooling cycle is inefficient compared to the solar heating cycle) which requires that all of the cooling load be met by auxiliary fuel, therefore, the heating, hot water and air conditioning curve (H, HW, AC) lies above the heating and hot water curve (H, HW).

As the collector area increases, more and more of the cooling load is supplied by the solar energy, thus the curves approach one another. This approach is not asymptotic since there is a demand for cooling before the Rankine system is operable and this cooling is always supplied by auxiliary energy. Figure 3-73 shows how much of the load is supplied by the solar heating and cooling system for various collector areas (and storage tank size) for the base system. The most striking result depicted in this figure, is that the system is incapable of meeting the entire load with solar energy regardless of the collector area. Again, this anomaly is due to the fact that, reheat energy in the summer and cooling energy during the winter, is supplied by auxiliary fuel. For smaller collector areas, there is no solar contribution to cooling. Therefore, the H, HW curve lies above the H, HW, and AC curve, but as described previously,

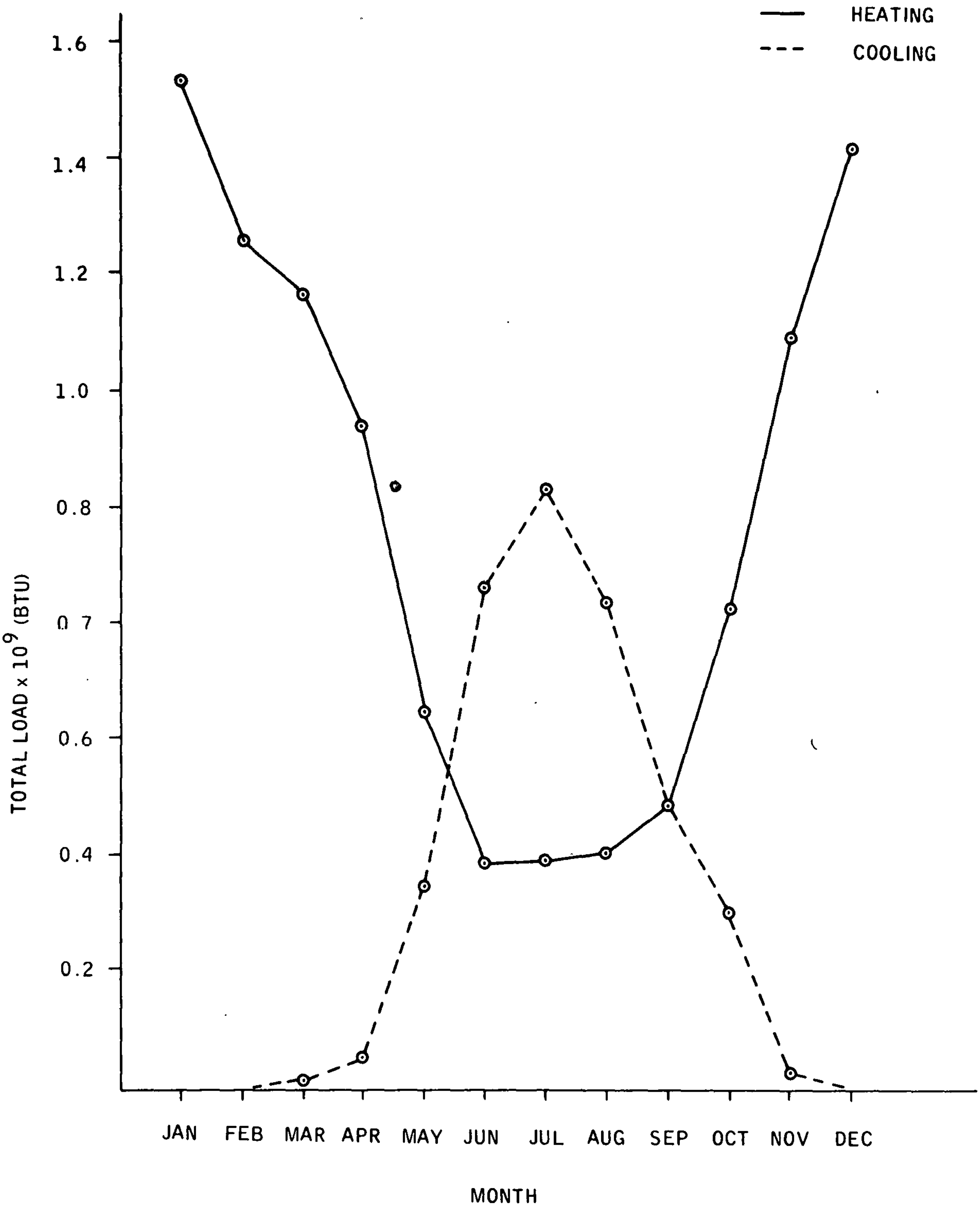


Figure 3-71. Load Profile Base Case CVTR, Omaha

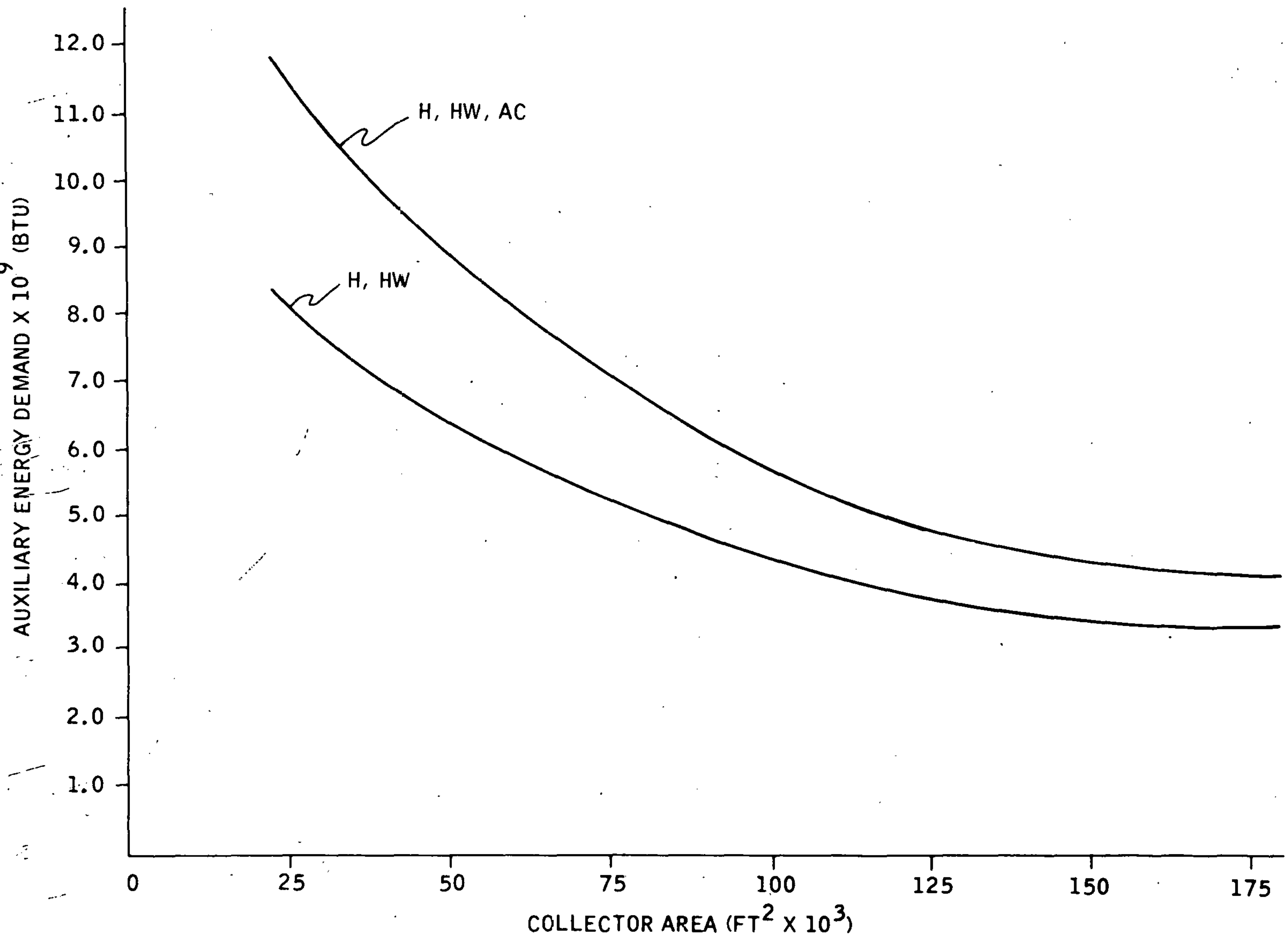


Figure 3-72. Auxiliary Energy Demand versus Collector Area

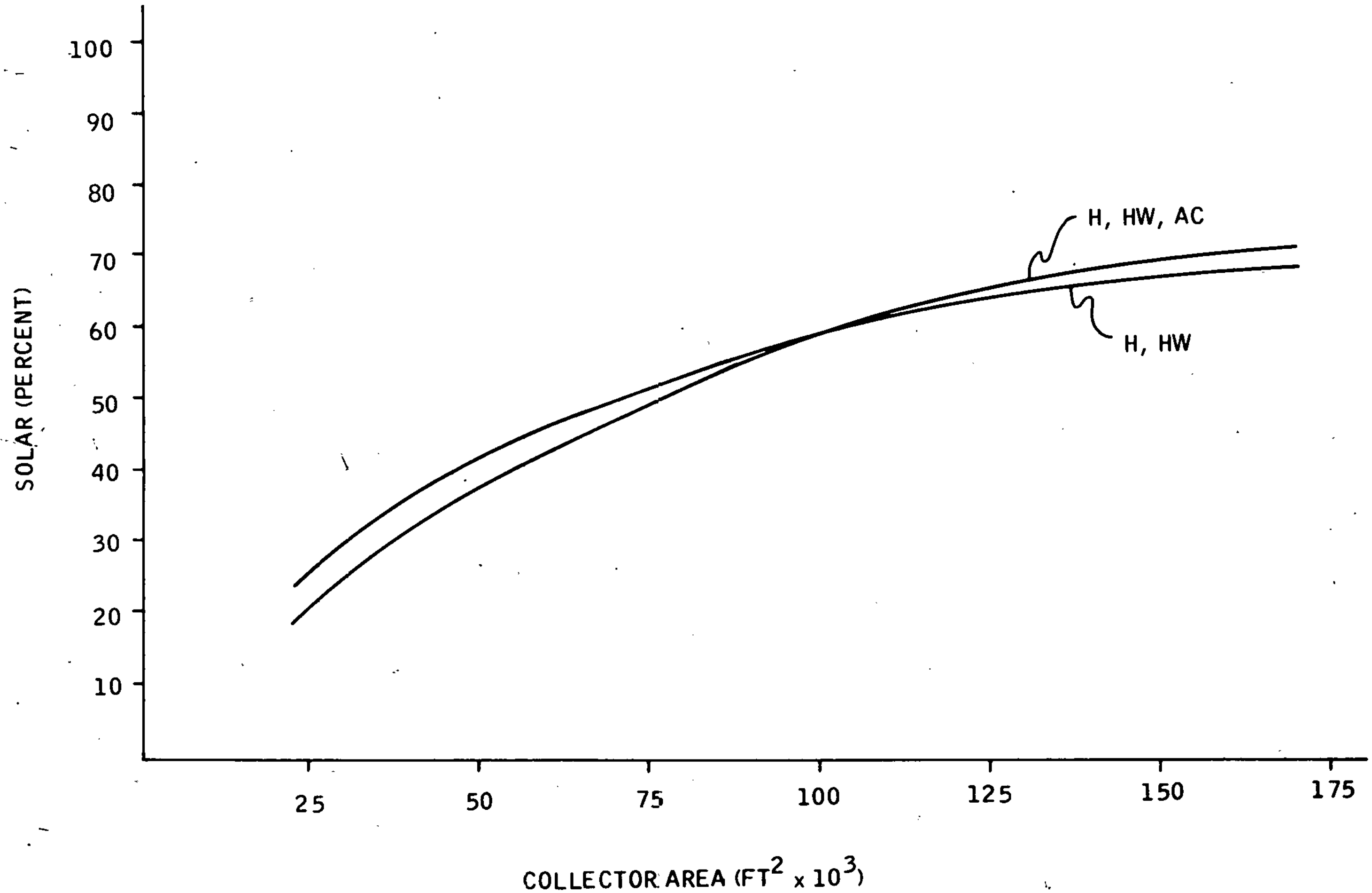


Figure 3-73. Percent of Load Supplied by Solar versus Collector Area (Base Case), CVTR Omaha

as the collector area increases, more and more cooling energy is supplied by the solar collector. Energy supplied to the Heat and Hot Water system, levels off faster than the energy supplied to the H, HW, AC system since there is less of an energy demand by the H, HW system. Therefore, at larger collector areas, the H, HW, AC curve is above the H, HW curve. Figures 3-74, 3-75 and 3-76 show the annual cost of the base system as a function of collector area for oil, gas and electric.

The most obvious trend in the three figures is the continually increasing cost for systems with increasing collector areas. This trend points out that for the given period (20 years), and economic inputs (see Appendix E), there is no optimum solar heating and cooling system. As one would expect, the curves shift upward for the more expensive fuels, gas being the cheapest and electric being the most expensive. The H, HW, and AC curve is always greater than the H, HW curve because of the added expense of the Rankine cooling cycle.

Existing Construction - Application of Energy Conservation Techniques (ECT) -- Tables 3-77 and 3-78 show the loads and savings for this base case and each ECT. Table 3-77 is for the heating hot water and air conditioning system, while Table 3-78 is for the heating and hot water system. Due to the large cost of the Rankine cycle, the annual costs in Table 3-77 are larger than those in Table 3-78. This set of tables is for a collector area of 45,000 ft^2.

Annual costs, represent the cost of solar heating and/or cooling system, auxiliary fuel and ECT cost with associated fuel cost, if they exist, amortized over the 20 year period. Annual savings, are the differences between base case and ECT annual cost. BTU savings, is the difference between the total load for the base case and the ECT.

Reflective Film -- This measure entails replacing the existing windows with windows that are specially treated. The effect is to reduce the transmissivity (amount of sunlight passing through the window) by eighty percent

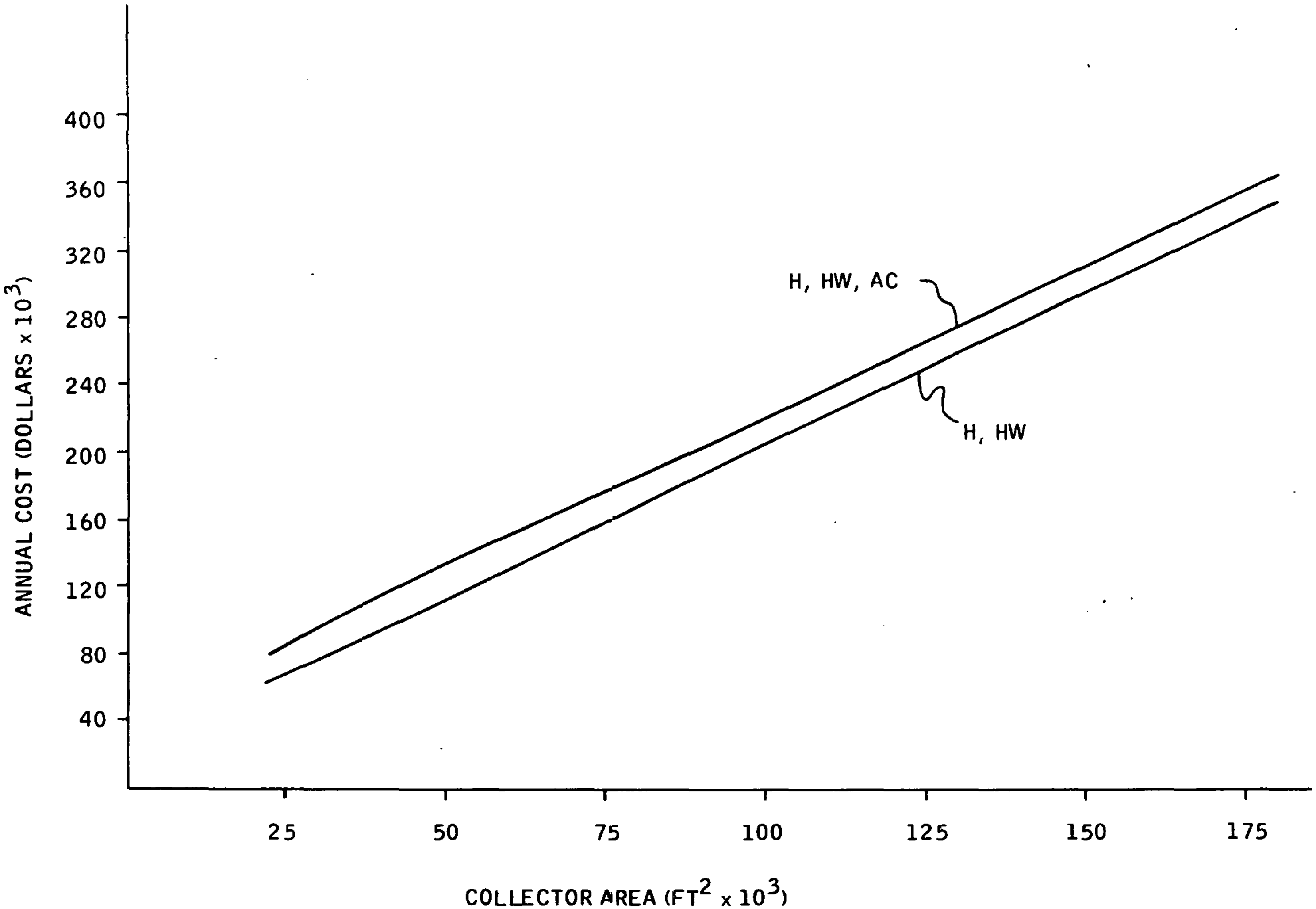


Figure 3-74. Annual Cost versus Collector Area (Base Case - Gas), CVTR Omaha

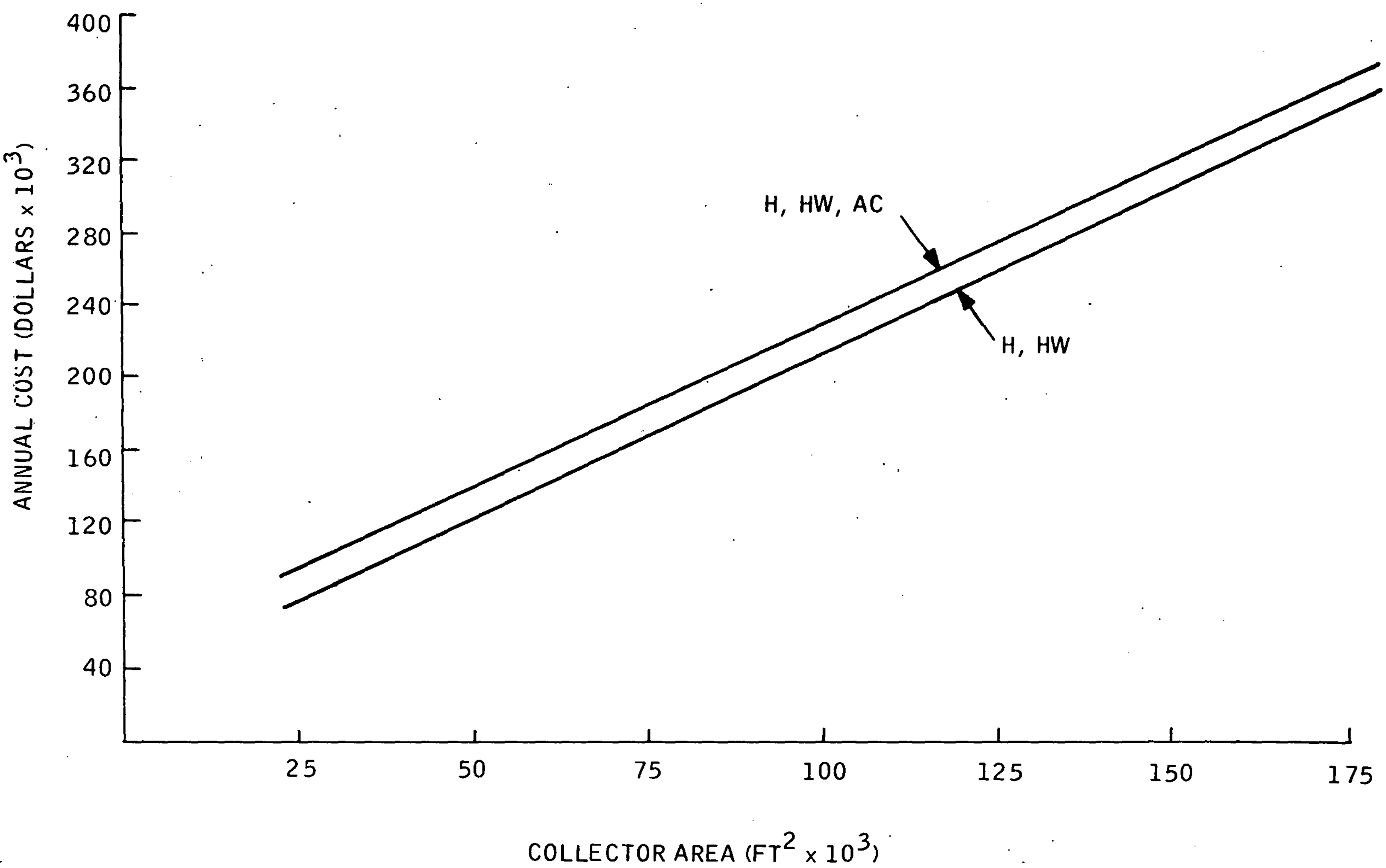


Figure 3-75. Annual Cost versus Collector Area (Base Case - Oil), CVTR Omaha

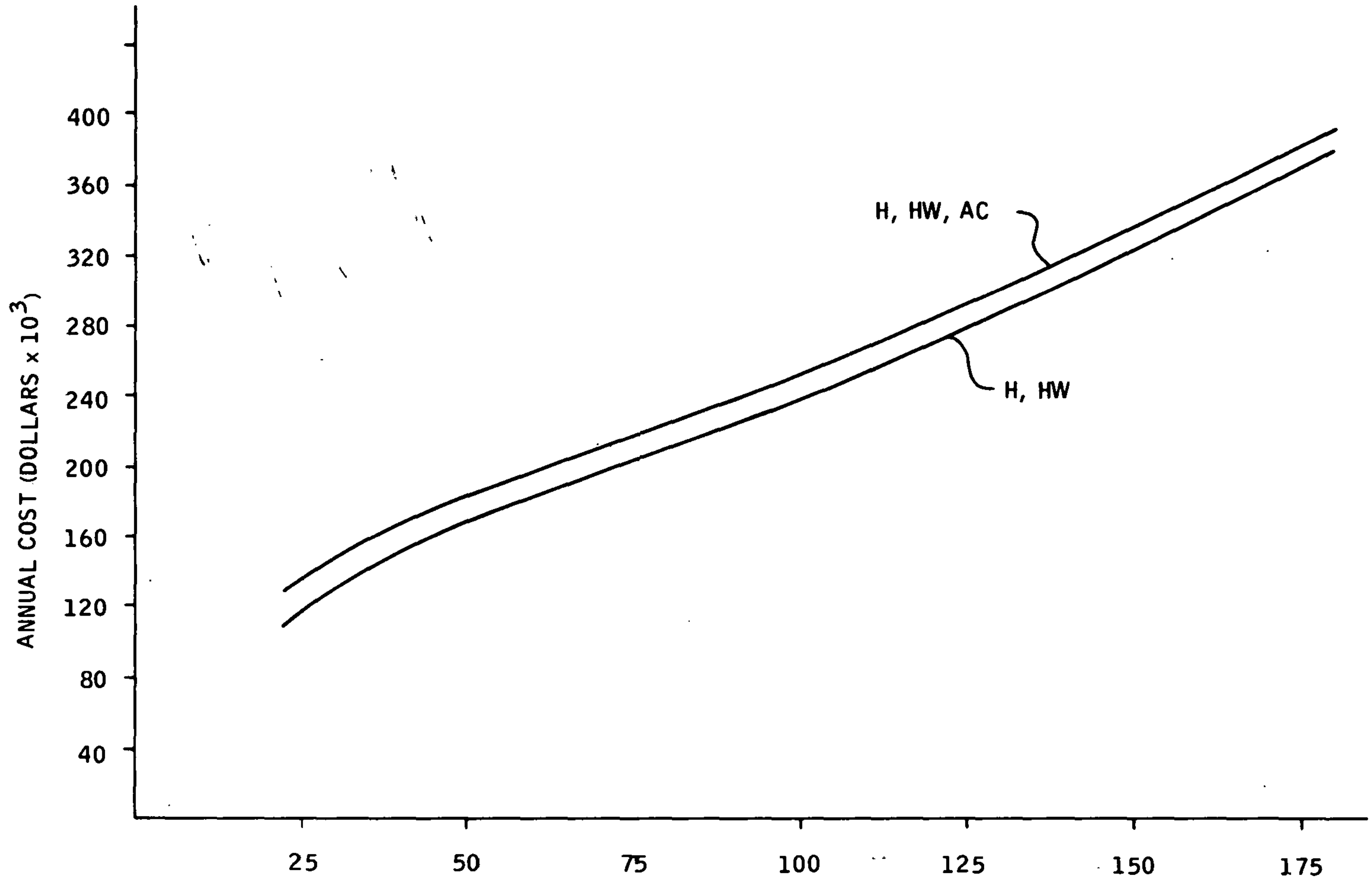


Figure 3-76. Annual Cost versus Collector Area (Base Case - Electric), CVTR Omaha

and also slightly decrease the transmission coefficient. Putting these windows on a building reduces the solar gain through the windows year round, as well as slightly reducing the heat loss in winter and the heat gain in summer. This technique proves to expend more energy than it saves for a reheat system. The reason for this occurrence is that the central air handling unit has a constant discharge temperature irrespective of the loads that are seen by the occupied space. In order for the space to maintain the desired temperature, the relatively cool air from the central unit must be heated up. The air can be heated up by four energy sources; reheat energy, internal loads (people, lights, etc.) , solar and transmission loads. Effectively, the reflective film has removed most of the solar load, so this energy must be furnished in return by the reheat system. Thus, there is a net increase in total load and decrease in savings. For reflective film, the highest dollar loss would be with the electric backup system. Installation prices for various ECTs can be seen in Appendix B.

Shading -- Little information exists on the cost of shading of an office building since this is not generally done. Therefore, the ECT cost was assigned zero dollars for the economic simulation. To evaluate this measure, the owner would find the amount of dollars saved by this measure per year and see if the implementation cost is less than this value.

The positive difference between the savings per year and the installation cost per year is the actual saving realized by the owner per year. For the reheat system, the effect of shading is basically the same as it was for reflective film, only worse. For shading, the only effect is the reduction in solar load (increase in reheat). In the case of reflective films, there was a decrease in the heat loss during the winter and heat gain in summer. Since there is a larger heating load than cooling load, the reduction in heat loss tends to offset the reduction in solar load.

Double Glazing -- This ECT causes a large decrease in the window U value (less heat transfer) and a slight decrease with window transmissivity. The overall effect is to reduce the total heat loss from the building, thus a reduction in reheat energy is realized. This is borne out in Tables 3-77 and 3-78. The larger difference in annual saving for the three different fuels for this ECT do not reflect the difference in dollar value/BTU for these fuels, but rather a combination of interrelated factors. The most significant factor is that installed cost is extremely high compared to the BTU saving. For example, if the installed cost were reduced to zero, the saving would be $825, $1410, $3526 for gas, oil, and electricity respectively, which is much more in line with expected cost differential of the various fuels.

Reduced Lighting -- By reducing the lighting, the internal load on the space decreases and the reheat system must supply the lost energy. Therefore, the total load increases as witnessed by Figures 3-72 and 3-73. There is no cost for this ECT as it can be implemented by a delamping procedure. The increase in the load is supplied by an auxiliary fuel source and by the energy collected by the solar panels. Therefore, there is a net saving since the cost of running the extracted lights has been reduced. It can be seen that the gas backup system saves the most and the electric backup saves the least. This is to be expected since you are replacing the expensive electric energy by less expensive fuels (i. e., instead of heating with lights, you can heat with collected solar energy and gas backup which saves $4387; collect solar energy and oil backup which saves $3562; collect solar energy and electric backup which saves $774).

Night Setback -- Implementation of night setback is accomplished by setting the thermostat down to 55°F in evening hours (when the HVAC system is off). Generally, adjusting the thermostat on a reheat system will cause significant changes in energy consumption, but when the HVAC system is off, the only energy used is for the skin radiation system which is a very small amount of energy in comparison to the energy used for ventilation. Therefore, even though the reduction of energy used by the skin radiation system is significant, the reduction in total load is fairly small. The interesting result in this ECT is the dollar saving. This substantial savings is caused by the relatively inexpensive cost of the timeclock set down system.

Table 3-77. Summary Loads, Costs and Savings; Heating, Hot Water, Air Conditioning; Collector Area = 45,000 ft²

office bldg.
Omaha
CVTR

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	14520	35	123931	137061	181435					
Reflective Film	14730	35	125665	139109	184545	- 1734	- 2048	- 3111	- 210	- 1
Shading	14890	35	124605	138318	184663	- 674	- 1257	- 3229	- 370	- 3
Double Glazing	14160	36	124149	136652	178894	- 218	409	2541	360	2
Reduced Lighting	15010	35	119544	133449	180659	4387	3562	774	- 490	- 3
Night Setback	14100	36	123035	135405	177211	896	1656	4224	420	3
Reheat Optimization	9447	47	113493	119619	140322	10439	17442	41113	5070	35
Increase Wall Insul	14150	36	123652	136147	178376	280	914	3058	370	3
Increase Wall & Roof Insulation	12870	38	121721	131998	163547	2210	5063	17888	1650	11
Hot Water Temp. Reduced	14470	35	123851	136935	181154	80	126	280	50	0
Convert To VAV HVAC	5271	68	100951	102922	109583	22980	34139	71851	9250	64
Energy Reclaim. From Exhaust Air	14490	35	124063	137211	181644	- 132	- 150	- 209	30	0

Table 3-78. Summary Loads, Costs and Savings; Heating and Hot Water Collector Area = 45,000 ft^2

office bldg.
CVTR
Omaha

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	10920	39	107199	120328	164702					
Reflective Film	11130	39	108969	122413	167849	- 1770	- 2084	- 3147	- 210	- 2
Shading	11290	38	107110	121623	167968	- 711	- 1294	- 3266	- 370	- 3
Double Glazing	10560	40	107416	119720	162162	- 217	408	2540	470	3
Reduced Lighting	11410	38	102849	116803	163964	4350	3525	738	- 490	- 4
Night Setback	10500	40	106302	118672	160478	897	1656	4224	420	4
Reheat Optimiza.	6743	54	99147	105273	125976	8052	15056	38726	4180	38
Increase Wall In.	10550	40	106920	119415	161644	279	913	3058	370	3
Increase Wall & Roof Insulation	9268	44	104956	115232	146781	2243	5096	17921	1650	15
Hot Water Temp. Reduced	10870	39	107144	120228	164447	55	101	255	50	0
Convert to VAV HVAC	3675	73	88765	90736	97397	18434	29593	67305	7240	69
Energy Reclaim. From Exhaust Air	10930	39	107474	120620	165054	- 275	- 292	- 352	- 10	0

Reheat Optimization -- This ECT is very cost effective as shown in Tables 3-77 and 3-78. Figure 3-77 is a schematic of a control system with a load demand reset capability. Figure 3-78 shows the current thermostat control sequence before system modification. It can be seen from this figure that only the reheat coil is controlled from the zone thermostat, the supply unit acts independently. Hence, a large amount of reheat (as well as cooling in the summer must be done since the room set point is higher than the discharge air set point. Figure 3-79 illustrates the load reset modification in the existing equipment. Here, the zone thermostat controls both the reheat system and also the supply unit. The reheat coil operates over only a portion of the thermostat band; the other portion controls the setpoint of the supply unit as a function of the space demand. Only the zone with the largest cooling requirement controls the supply air temperature. Therefore, higher discharge temperatures are maintained over a major portion of the year, resulting in substantial energy savings as can be seen in the comparison of the load profiles shown in Figure 3-80. The dollar saving for this technique shows that the $6000 is an extremely worthwhile investment.

Increase Wall Insulation -- Increasing the wall insulation decreases the heat flow reducing heat loss in the winter and heat gain in the summer. Reduction in the heat loss represents less energy that must be supplied by the reheat system during the winter and the reduction in heat gain represents more reheat energy needed during the summer.

Increase Wall and Roof Insulation -- This ECT increases the insulation to the amount shown in Appendix E and the trends are the same as those mentioned in the previous ECT. Figure 3-81 shows the load profile for the base case and the load profile for the case with increased insulation for Omaha. It can be seen from Figure 3-81 that the reduced heat load in the winter by far offsets the decreased heat gain (this heat must be supplied by the reheat system) in the summer.

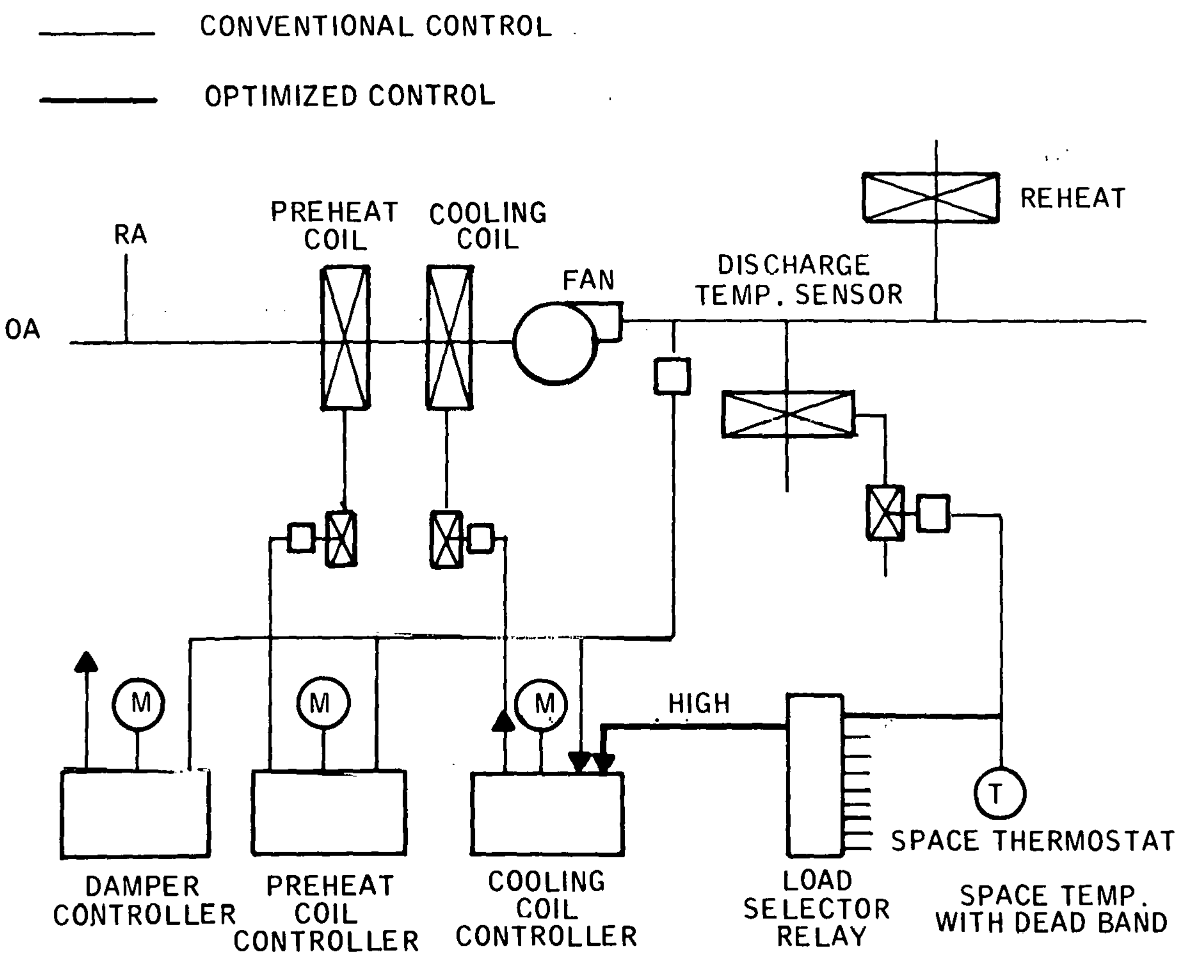


Figure 3-77. Schematic Reheat System

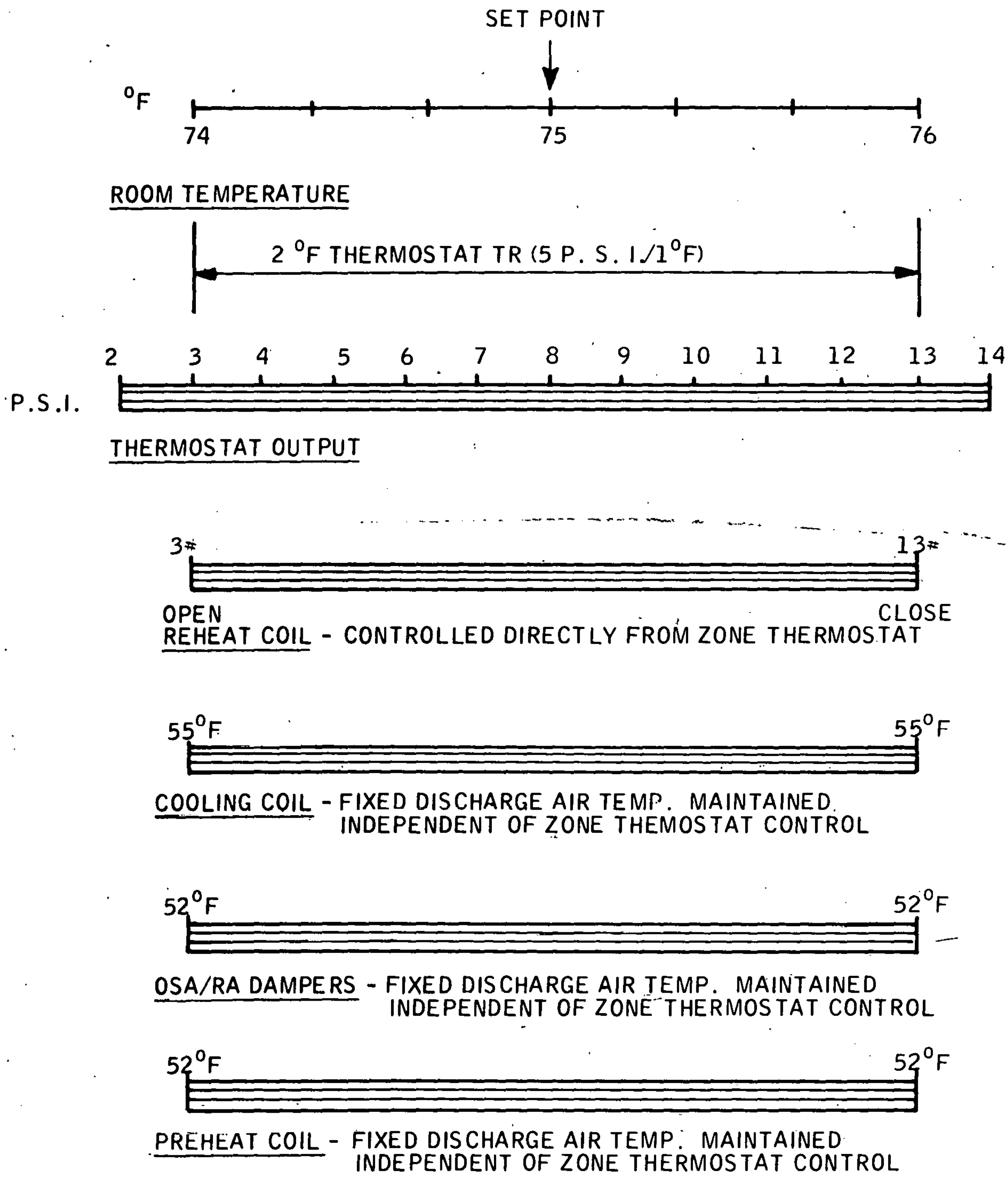


Figure 3-78. Control Sequence Before Retrofit Reheat System

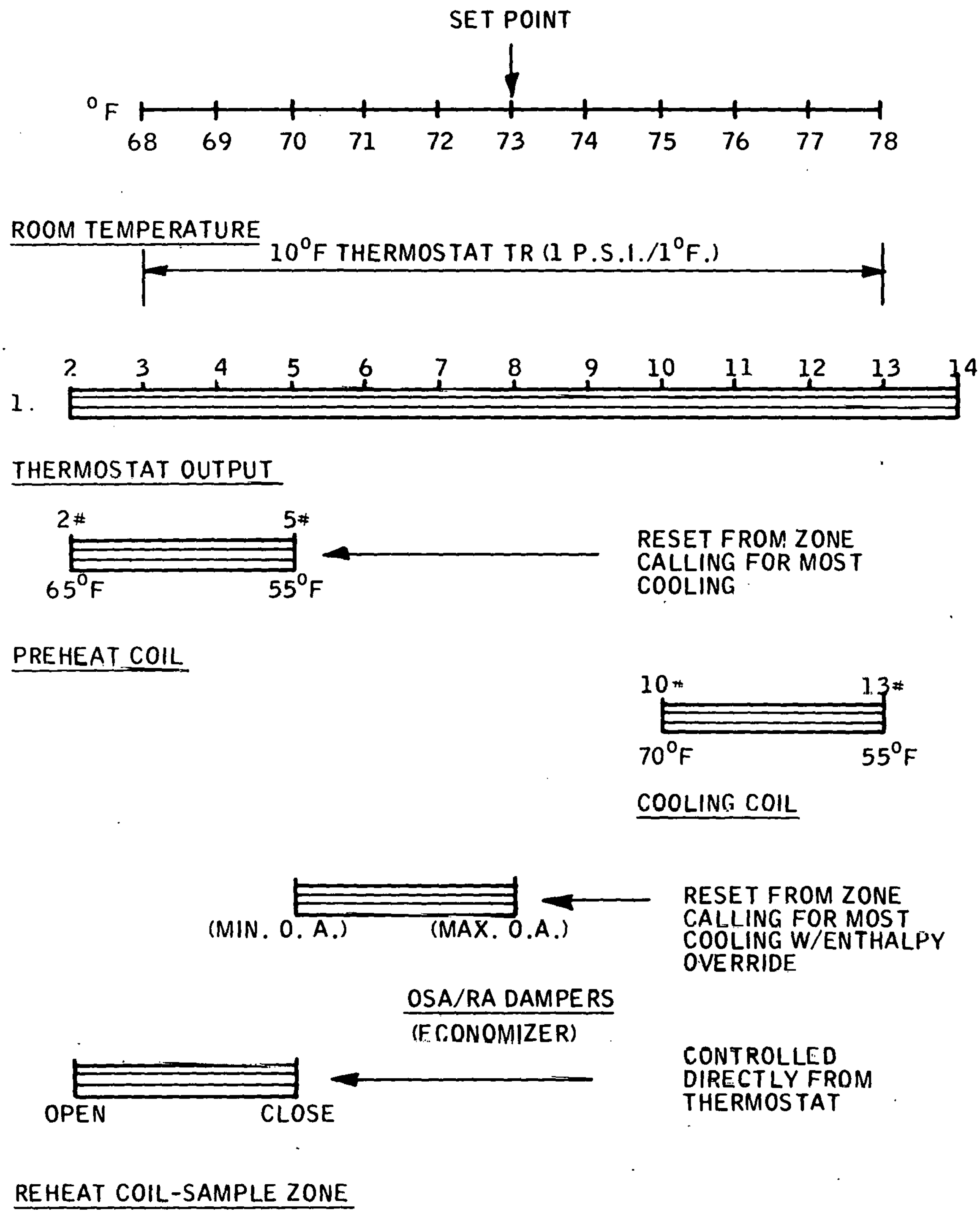


Figure 3-79. Retrofit Control Sequence Reheat System

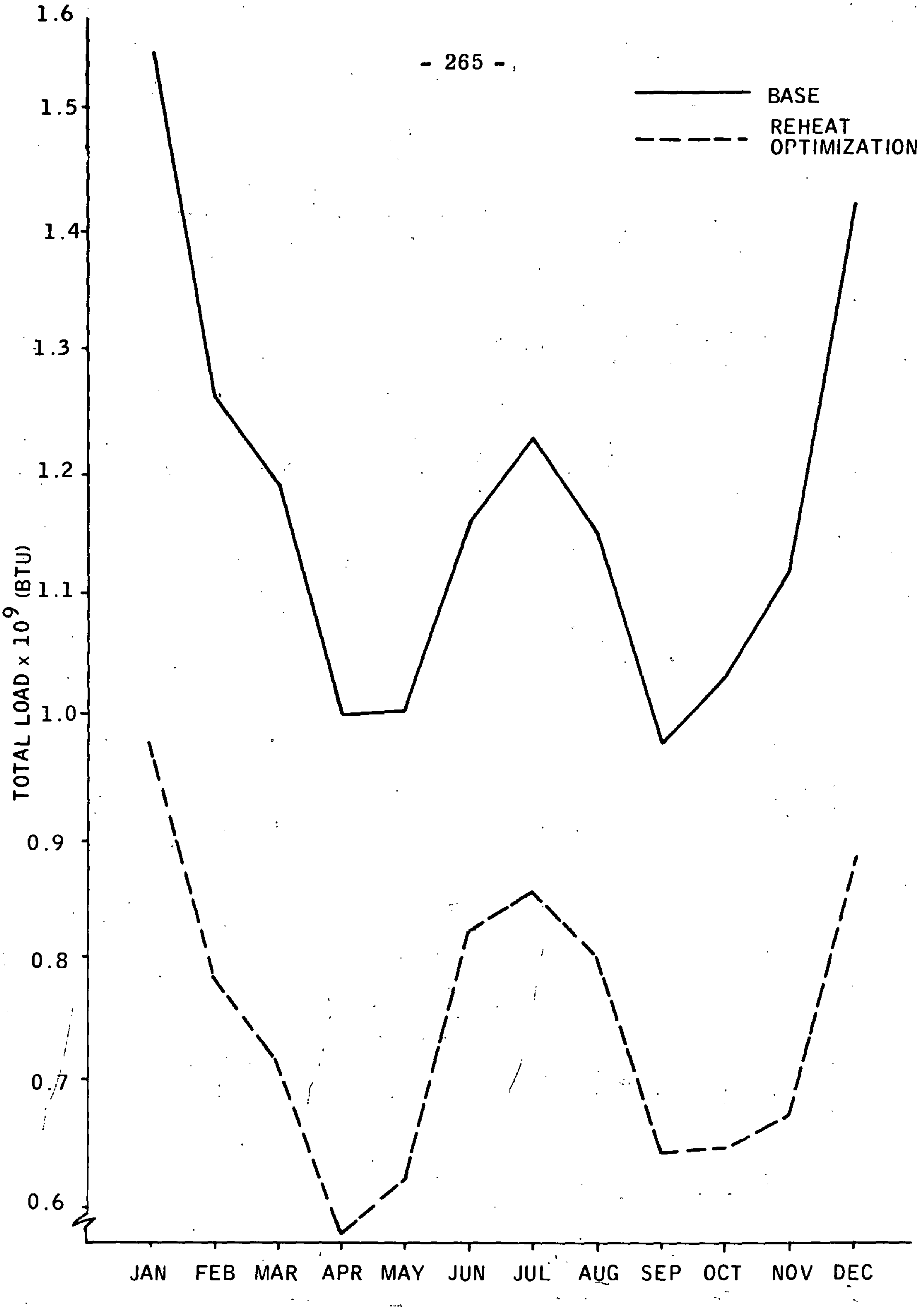


Figure 3-80. Load Profile Reheat Optimization versus (Base) CVTR Omaha

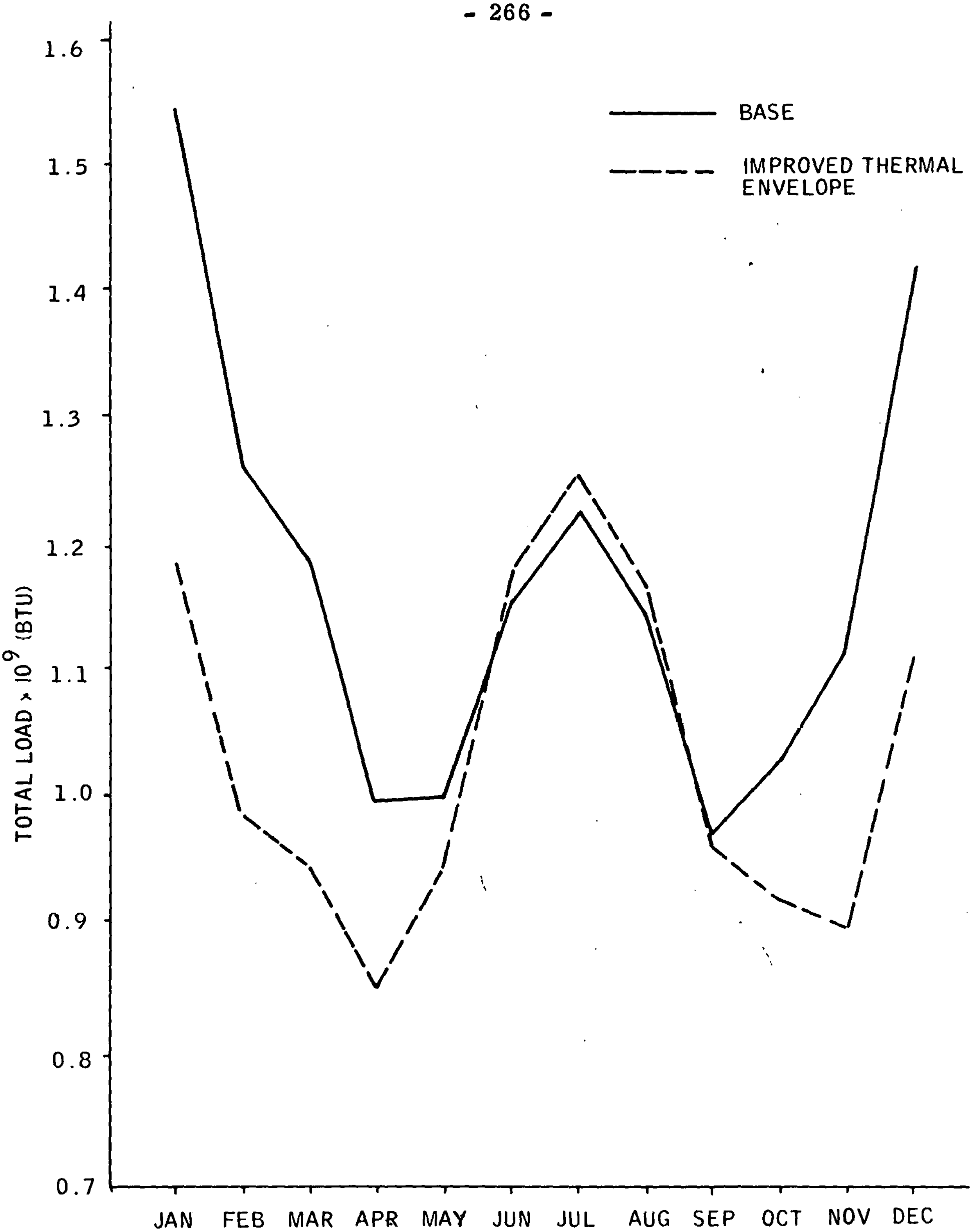


Figure 3-81. Load Profile Increased Insulation versus (Base), CVTR Omaha

Hot Water Temperature Reduction -- The hot water temperature is reduced from a nominal temperature of 140°F to 130°F which has no effect on building loads since the hot water tank is in an unconditioned space. The results of this measure can be seen in Tables 3-77 and 3-78.

Conversion to a Variable Air Volume (VAV) System -- In essence, this measure consists of removing the CVTR system and replacing it with a VAV system. This eliminates reheat as well as reducing the system CFM. Figure 3-82 shows the system CFM reduction possible with a VAV system. The reason for this tremendous reduction is that the CVTR system CFM is based on the worst possible condition occurring in each zone simultaneously and designing the system CFM for this condition. Whereas the VAV system delivers only as much CFM as is necessary to cool the space. Besides eliminating the reheat that is necessary with a CVTR system, the VAV load is further decreased since there is less air to condition (less CFM) (see Figure 3-83).

Energy Reclamation from Exhaust Air -- This ECT is accomplished by using an air-to-air heat exchanger with an effectiveness of 0.4 which is capable of transferring heat between the exhaust and intake air streams.

Generally, heat is transferred from the exhaust air stream to the intake air stream during the winter when the dampers are at their minimum position. In the summer, heat is transferred from the intake air stream to the exhaust air stream. This results in an increase in inlet temperature in winter and a decrease in inlet temperature in the summer. For the small amounts of required outdoor air and the desired discharge temperature setpoint, the dampers never reach the minimum position in the winter and therefore, winter heat recovery is not possible. When the heat recovery system is used in the summer, a decrease in inlet air temperature is realized; thus the amount of cooling required decreases. At the same time, the discharge air temperature decreases. Since the loads in the conditioned space remain the same, the reheat system must add more heat to the discharge air stream to keep the occupied space at

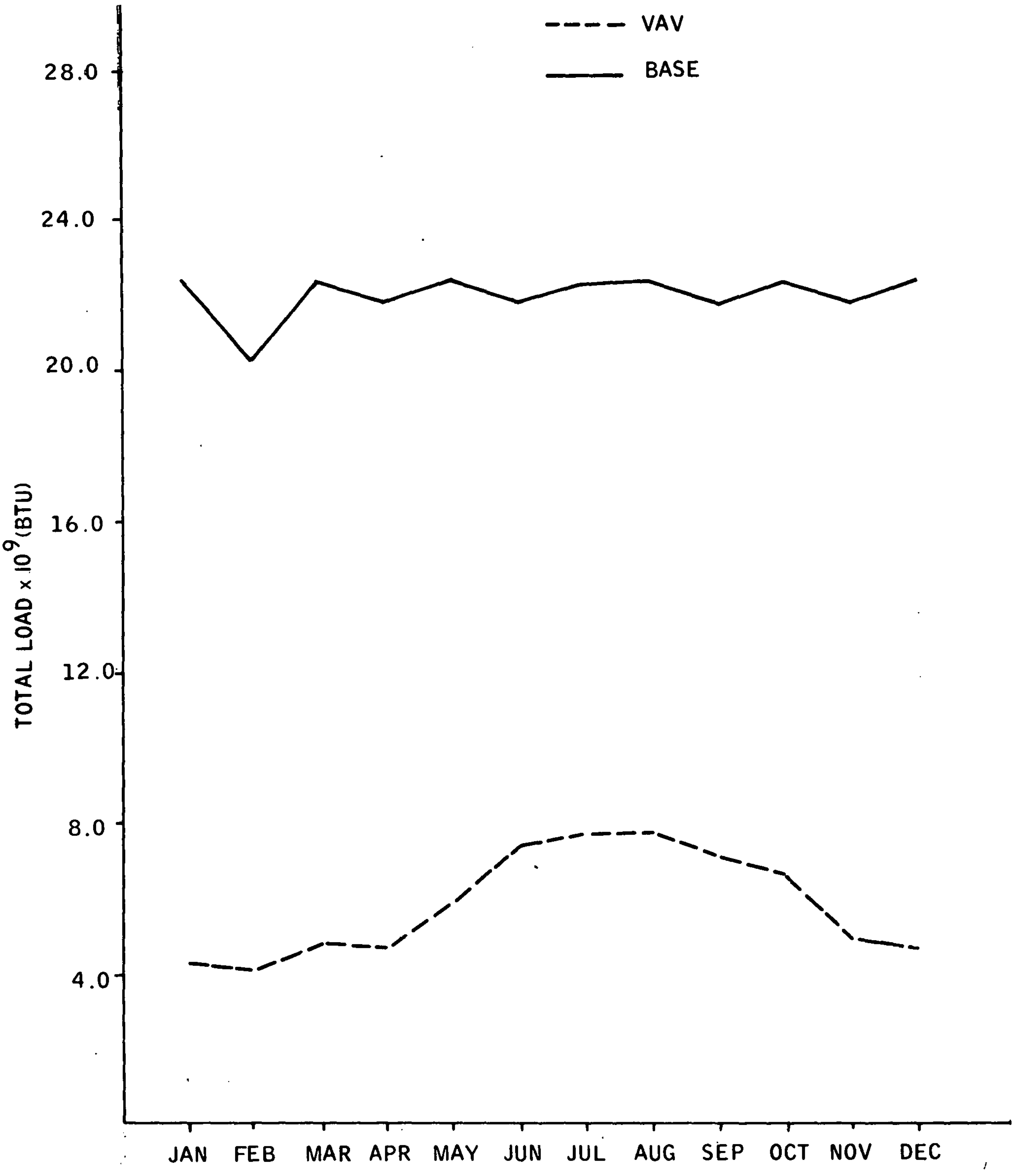


Figure 3-82. Fan Power Consumption VAV versus Base, CVTR Omaha

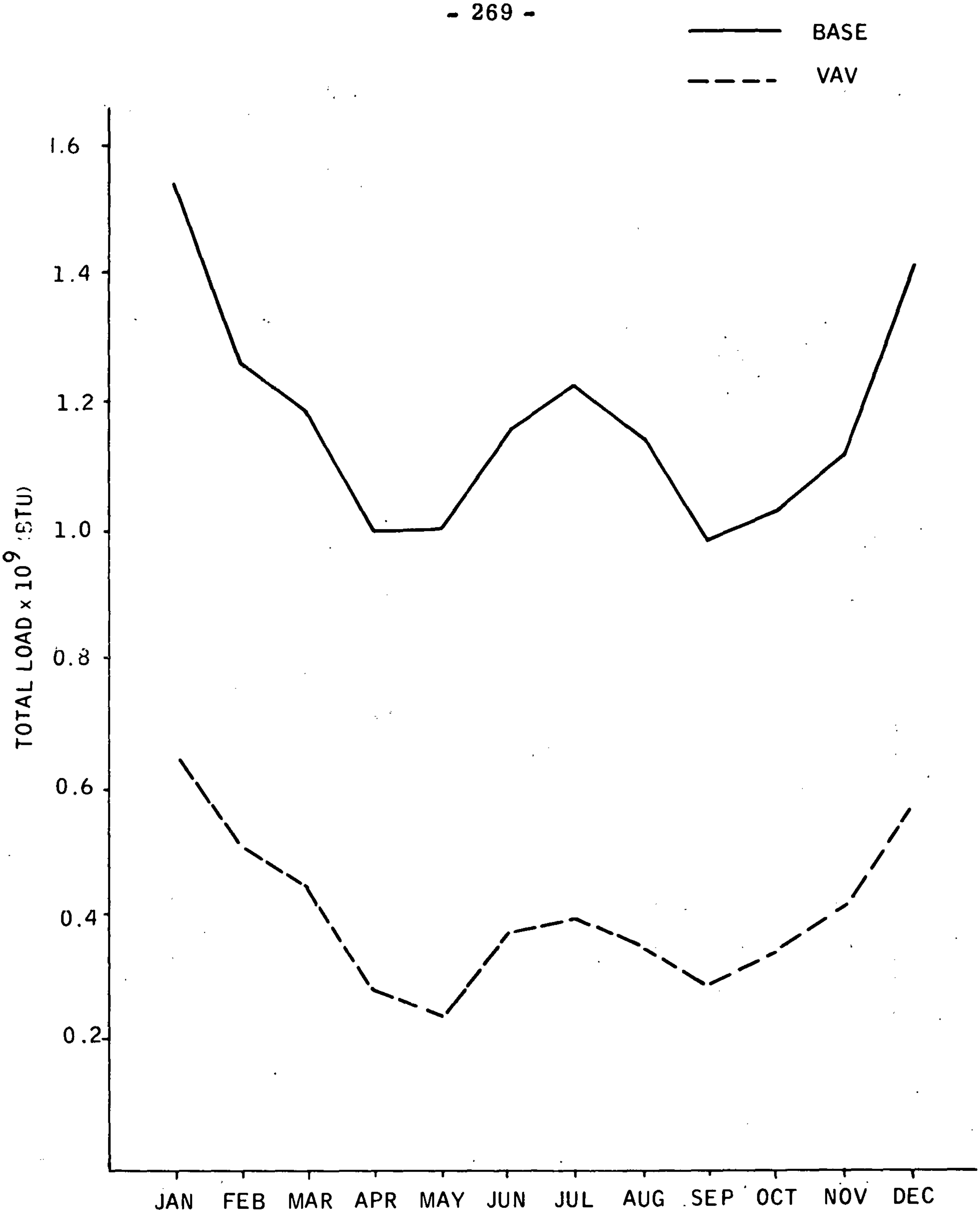


Figure 3-83. Load Profile VAV versus Base, CVTR Omaha

the desired temperature. This additional reheat energy is less than the savings by the cooling system, and therefore, represents an overall decrease in required BTUs.

Albuquerque - Southwest Region

New Construction -- Summary results for the new office building in Albuquerque can be seen in Figure 3-84 and Tables 3-79 and 3-80.

The most dramatic change is the increase in the amount of available solar energy, as witnessed by the sharp increase in percent load supplied by solar, for a fixed collector area, over that delivered in Omaha.

As can be seen in comparing Tables 3-79 and 3-80 with Tables 3-74 and 3-75, the percent savings are fairly close for the ECTs, although the loads do vary somewhat. The dollar figures can change significantly as seen in the different savings for the reduced hot water ECTs, as well as the different savings with hydronic control with night setback.

Existing Construction -- Summary results for the existing office building in Albuquerque can be seen in Figure 3-85 and Tables 3-81 and 3-82.

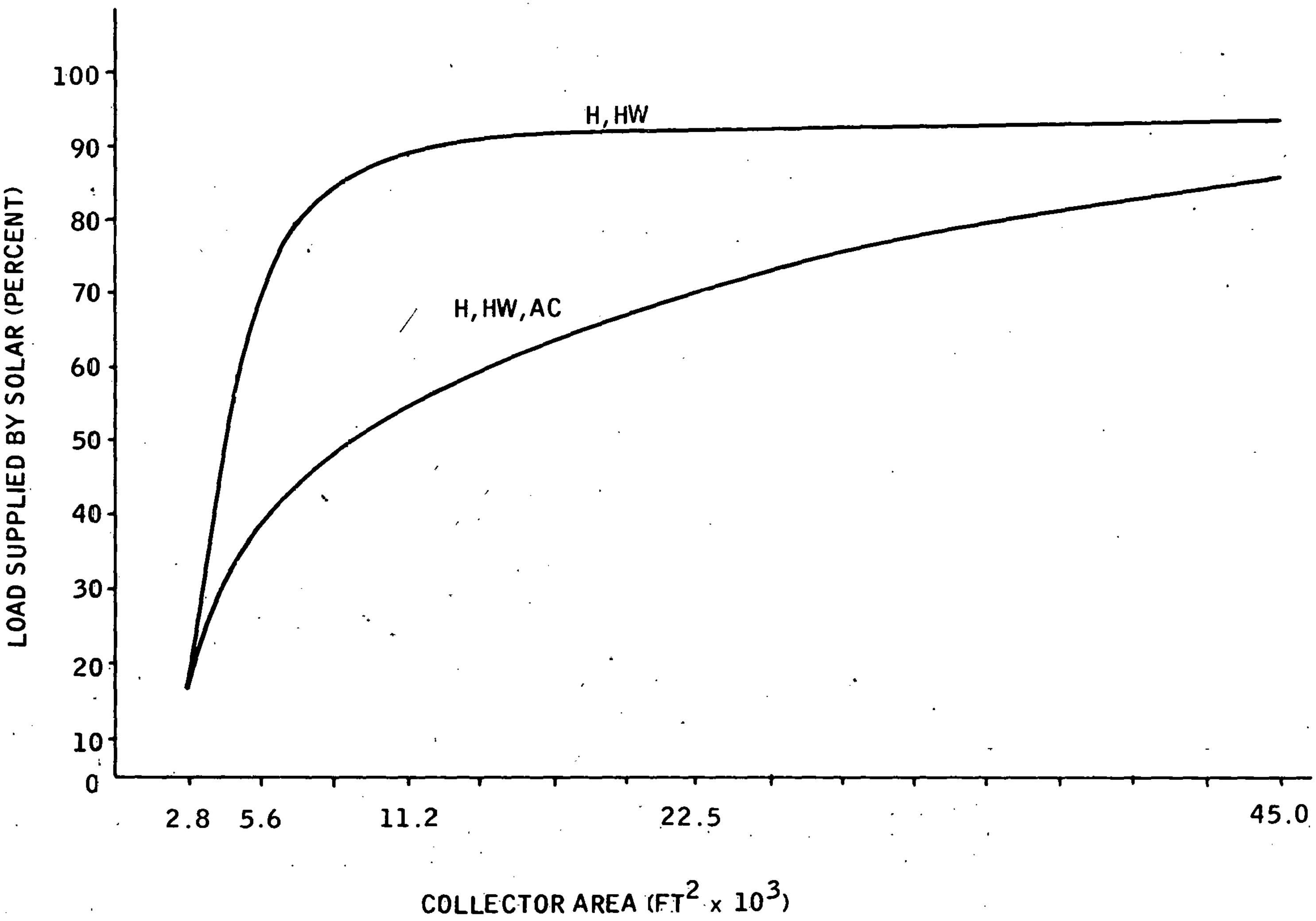


Figure 3-84. New Office Building Base Case, VAV Albuquerque

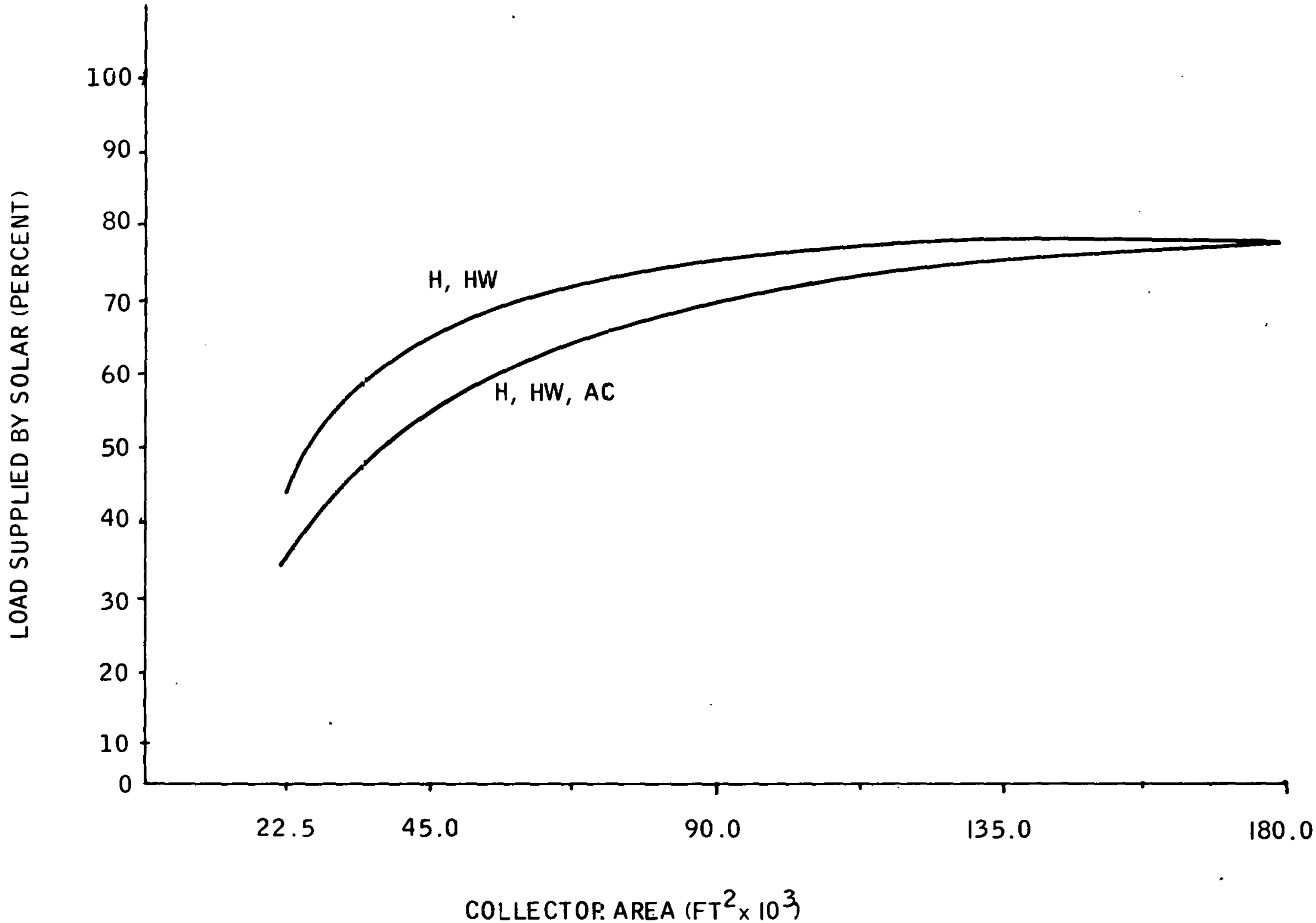


Figure 3-85. Existing Office Building Base Case, CVTR Albuquerque

office bldg.
CVTR
ALBUQUERQUE

Table 3-79. Summary Loads, Costs and Savings Heating and Hot Water Collector Area 45,000 Ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	9, 545	63	102855	107450	134569					
Reflective Film	9, 875	62	103966	108849	137667	- 1111	- 1399	- 3098	- 330	- 4
Shading	9, 975	62	103777	108739	138022	- 922	- 1289	- 3453	- 430	- 5
Double Glazing	9, 255	65	102898	107176	132428	- 43	274	2141	290	3
Reduced Lighting	10, 040	61	97728	102788	132648	5127	4662	1921	- 490	- 5
Night Setback	9, 105	65	101653	105761	130007	1202	1689	4562	440	5
Reheat Optimization	5, 864	75	95707	97633	108997	7148	9817	25572	3680	39
Increase Wall In.	9, 225	64	102526	106809	132089	329	641	2480	320	4
Increase Wall & Roof Insulation	8, 125	67	101103	104609	125139	1752	2841	9430	1420	15
Hot Water Temp. Reduced	9, 495	63	102801	107375	134372	54	75	197	50	0
Convert to VAV & HVAC	3, 157	90	85585	85990	88384	17270	21460	46185	6390	67
Energy Reclaim. From Exhaust Air	9, 551	63	103095	107695	134839	- 240	- 245	- 270	- 10	0

Table 3-80. Summary Loads, Costs and Savings; Heating, Hot Water, Air Conditioning Collector area 45,000 ft^2

office bldg.
CVTR

ALBUQUERQUE

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	13,060	56	119628	124223	151342					
Reflective Film	13,390	56	120753	125636	154453	- 1125	- 1413	- 3110	- 330	- 2
Shading	13,490	55	120558	125519	154802	- 930	- 1296	- 1458	- 436	- 3
Double Glazing	12,770	57	119693	123972	149223	65	251	2119	290	2
Reduced Lighting	13,550	55	114495	119554	149414	5133	4669	1928	- 490	- 4
Night Setback	12,620	58	118455	122563	146809	1173	1660	4533	440	3
Reheat Optim	8,476	68	110114	112039	123403	9514	121844	27939	4580	35
Increase Wall Ins.	12,740	57	119323	123607	148886	305	616	2456	320	3
Increase Wall & Roof Insulation	11,640	59	117909	121387	141917	1719	2836	9425	1420	11
Hot Water Temp. Reduced	13,010	56	119573	124147	151143	55	76	199	50	0
Convert to VAV & HVAC	4,633	85	98536	98942	101335	21097	25281	50007	8430	65
Energy Reclaim. from Exhaust Air.	13,050	56	119815	124414	151559	- 187	- 191	- 217	10	0

Table 3-31. Summary Loads, Costs and Savings Heating and Hot Water Collector area 22, 500 ft^2

office bldg.
Albuquerque
VAV

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	1, 304	93	48, 567	48, 686	49, 390					
Reflective Film	1, 293	93	48, 761	48, 880	49, 577	194	- 194	- 187	11	1
Shading	1, 292	93	48, 089	48, 207	48, 905	478	479	485	13	1
Triple Glazing	1, 307	93	49, 255	49, 374	50, 079	- 688	- 688	- 689	- 2	0
Reduced Lighting	1, 291	93	41, 689	41, 806	42, 499	6878	6880	6891	13	1
Night Setback	1, 304	93	48, 579	48, 699	49, 402	- 12	- 12	- 12	0	0
Increased Wall Insulation	1, 307	94	48, 884	48, 954	49, 658	- 267	- 268	- 268	- 2	0
Increased Wall & Roof Insulation	1, 311	93	49, 338	49, 458	50, 164	- 771	- 772	- 774	- 6	0
Reduced Hot Water Temperature	1, 256	93	48, 563	48, 679	49, 364	4	7	26	48	4
Hydronic Control From Zone Thermo & Night Setback	1, 095	91	48, 761	48, 885	49, 618	- 194	- 199	- 228	209	16
Energy Reclaim. From Exhaust Air.	1, 304	93	48, 792	48, 911	49, 614	- 225	- 225	- 224	0	0

Table 3-82. Summary Loads, Costs and Savings; Heating, Hot Water, Air Conditioning
Collector area 22,500 ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	2,582	71	61,794	61,914	62,617					
Reflective	2,361	76	61,415	61,533	62,230	379	381	387	221	8
Shading	2,397	75	60,854	60,972	61,670	940	942	947	185	7
Triple Glazing	2,538	72	62,373	62,492	63,197	- 579	- 578	- 580	44	2
Reduced Lighting	2,323	77	54,184	54,302	54,995	7610	7612	7622	259	10
Night Setback	2,582	71	61,807	61,926	62,630	- 13	- 13	- 13	0	0
Increased Wall Insulation	2,579	71	62,073	62,192	62,897	- 279	- 278	- 280	3	0
Increased Wall & Roof Insulation	2,576	71	62,562	62,682	63,388	- 768	- 768	- 771	6	0
Reduced Hot Water Temperature	2,533	71	61,926	62,042	62,728	- 132	- 128	- 111	49	2
Hydronic Control From Zone Thermo. & Night Setback	2,378	68	62,210	62,834	63,067	- 416	- 420	- 450	204	8
Energy Reclaim. From Exhaust Air	2,560	73	61,943	62,062	62,765	- 149	- 148	- 148	22	1

New York - Northeast Region

New Construction -- Summary results for the new office building in New York can be seen in Figures 3-86 and Tables 3-83 and 3-84.

New York is characterized by relatively mild winters and fairly cool summers in comparison to the other cities of this study, as can be seen by the total load of the base case which is the lowest of all the cities investigated. Again, comparison of the percent savings for the various ECTs of this city with others shows a fairly close energy savings or loss while the dollar savings is representative of the effect that the external input, (cost, solar insolation, ECT) and characteristics of the city, has on the energy savings.

Existing Construction -- Summary results for the existing office building in New York can be seen in Figure 3-87 and Tables 3-85 and 3-86.

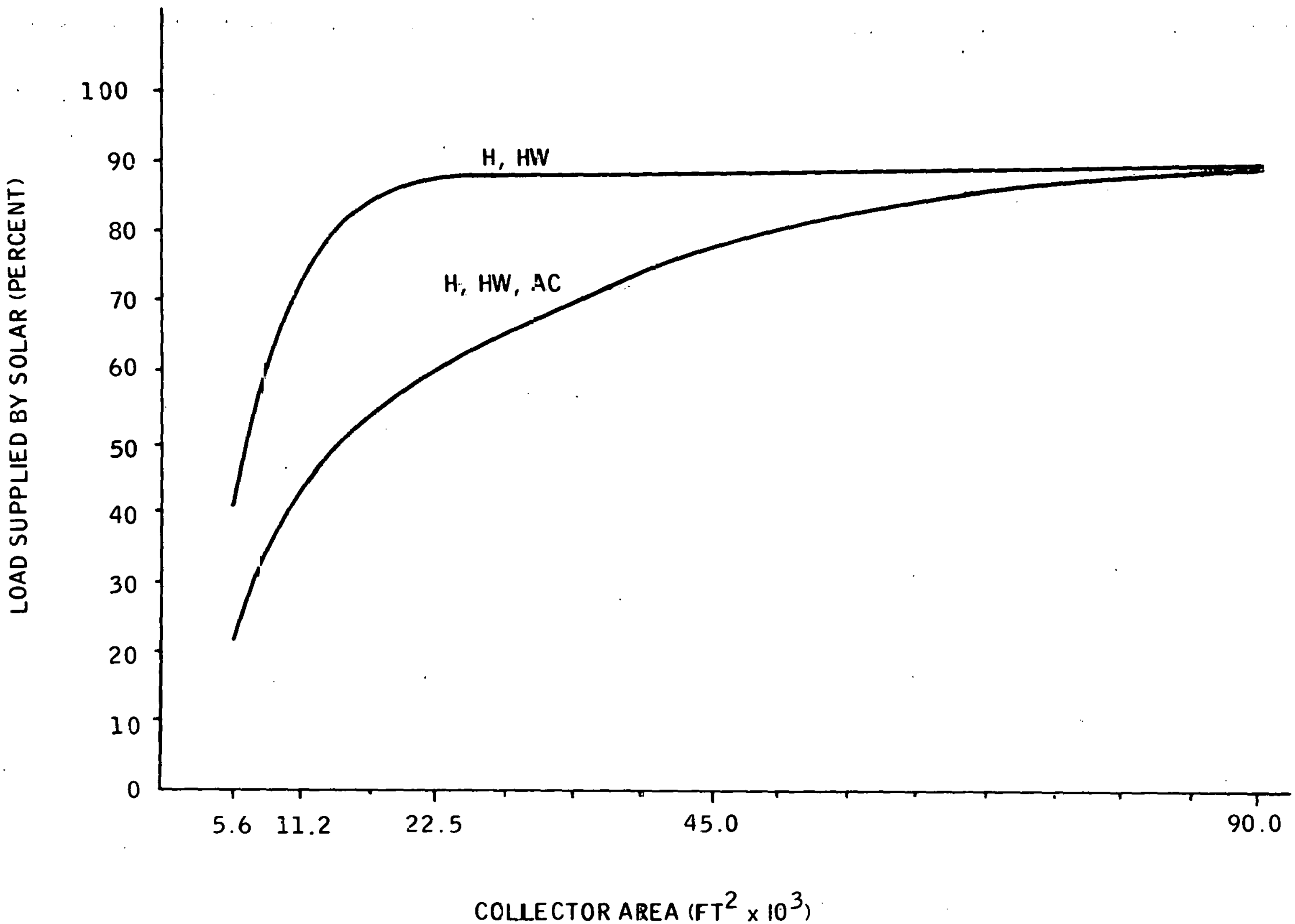


Figure 3-86. New Office Building Base Case, VAV New York

Table 3-83. Summary Loads, Costs and Savings
Heating, Hot Water, Air Conditioning
Collection Area 22,500 ft^2

OFFICE BLDG.
NEW YORK
VAV

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	2384	60.0	62533	62724	64459					
Reflective Film	2236	64.1	62463	62655	64398	70	69	61	148	6
Shading	2250	63.4	61575	61765	63493	958	959	966	134	6
Triple Glazing	2372	60.8	63511	63706	65469	- 978	- 982	- 1010	12	1
Reduced Lighting	2139	66.3	52737	52924	54621	9796	9800	9838	245	10
Night Setback	2384	60.0	62551	62742	64478	- 18	- 18	- 19	0	0
Increase Wall. In.	2391	60.0	63058	63250	64998	- 525	- 526	- 539	- 7	0
Increase Wall & Roof Insulation	2402	60.2	63663	63858	65627	- 1130	- 1134	- 1168	- 18	- 1
Reduce Hot Water Temperature	2336	59.6	62549	62731	64379	- 16	- 7	80	48	2
Hydronic Control From Zone Thermo.	2179	56.5	62819	62995	64593	- 286	- 271	- 134	205	9
Energy Reclaim. From Exhaust Air	2370	60.4	62811	63002	64739	- 278	- 278	- 280	14	1

Table 3-84. Summary Loads, Costs and Savings Heating and Hot Water Collector Area = 22,500 ft^2

OFFICE BLDG.
NEW YORK
VAV

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	1315	88.1	49045	49236	50972					
Reflective Film	1315	88.0	49649	49841	51584	- 604	- 605	- 612	0	0
Shading	1307	88.0	48616	48807	50534	429	429	438	8	1
Triple Glazing	1329	88.0	50151	50345	52108	- 1106	- 1109	- 1136	- 14	- 1
Reduced Lighting	1290	88.1	40210	40397	42095	8835	8839	8877	25	2
Night Setback	1316	88.0	49064	49255	50990	- 19	- 19	- 18	- 1	0
Increase Wall Ins.	1322	88.0	49570	49763	51511	- 525	- 527	- 539	- 7	1
Increase Wall & Roof Insulation	1333	88.0	50167	50362	52131	- 1122	- 1126	- 1159	- 18	1
Reduced Hot Water Temperature	1267	88.2	49019	49201	50849	26	35	123	48	4
Hydronic Control From Zone Thermo	1102	86.9	49184	49360	50958	- 139	- 124	14	213	16
Energy Reclaim. From Exhaust Air.	1315	88.1	49385	49576	51310	- 340	- 340	- 338	0	0

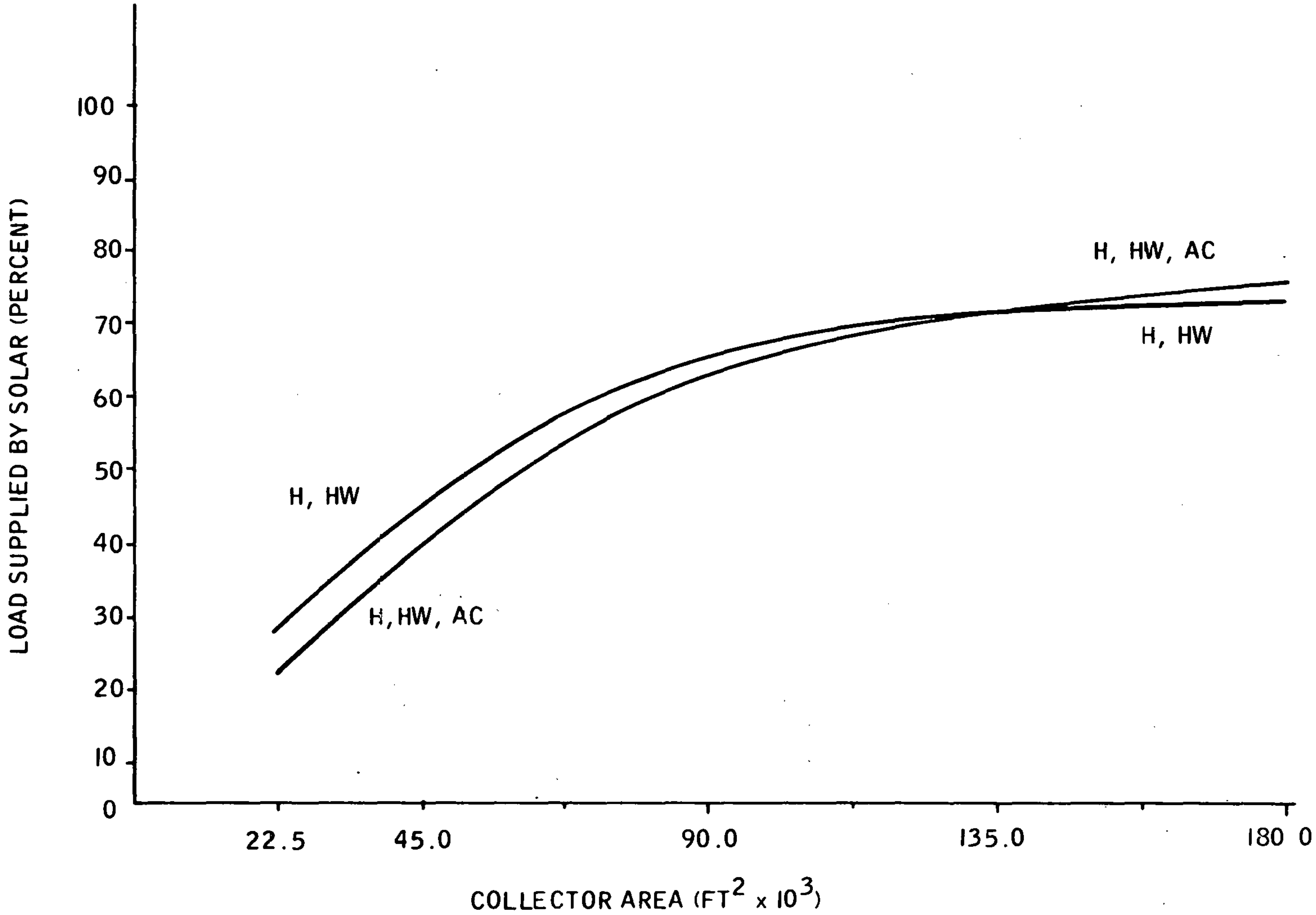


Figure 3-87. Existing Office Building Base Case, CVTR New York

Table 3-85. Summary Loads, Costs and Savings
Heating, Hot Water, Air Conditioning
Collector Area = 45,000 ft^2

OFFICE BLDG.
CVTR
NEW YORK

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	11790	39.8	126985	132952	187113					
Reflective Film	11960	39.6	128041	134153	189629	- 1056	- 1201	- 2516	- 170	- 1
Shading	12090	39.4	127721	133948	190472	- 736	- 996	- 3359	- 300	- 3
Double Glazing	11460	40.5	127294	132911	183899	- 309	41	3214	330	3
Reduced Lighting	12290	38.9	120280	126732	185294	6705	6220	1819	- 500	- 4
Night Setback	11360	41.0	125645	121119	180805	1340	1833	6308	430	4
Reheat Optimization	7638	52.9	114920	117623	142166	12065	15329	44947	4152	35
Increase Wall Insu.	11310	40.9	126326	131776	181243	659	1176	5870	480	4
Increase Roof & Wall Insulation	10000	43.5	123757	127977	166286	3228	4975	20827	1790	15
Hot Water Temp. Reduced	11750	39.8	126855	132789	186649	130	163	464	40	3
Convert to VAV HVAC	4530	74.4	100945	101766	109224	26040	31186	77889	7260	62
Energy Reclaim. From Exhaust Air	11780	39.8	127268	133239	187436	- 283	- 287	- 323	10	1

Table 3-86. Summary Loads, Costs and Savings
Heating and Hot Water
Collector Area = 45, 000 ft^2

CVTR
NEW YORK
OFFICE BLDG.

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	9047	45.6	108596	114483	160643					
Reflective Film	9217	45.3	109580	115691	171168	- 984	- 1208	-2525	- 170	- 2
Shading	9347	44.9	109262	115489	172013	- 666	- 1006	- 3370	- 300	- 3
Double Glazing	8717	46.7	108830	114447	165434	- 234	36	3209	330	4
Reduced Lighting	9547	44.1	101831	108282	166844	6765	6201	1799	- 500	- 6
Night Setback	8617	47.5	107154	112628	162314	1442	1855	6329	430	5
Reheat Optimiza.	5669	60.6	99696	102400	126943	8900	12083	41700	3378	37
Increase Wall Ins.	8567	47.4	107844	113293	162761	752	1190	5882	480	5
Increase Roof & Wall Insulation	7257	52.1	105261	109482	147790	3335	5001	20853	1790	20
Hot Water Temp. Reduced	9007	45.5	108423	114356	168216	173	127	427	40	0
Convert to VAV HVAC	3378	78.9	87998	88820	96277	20593	25663	72366	5669	63
Energy Reclaim. From Exhaust Air	9055	45.6	108870	114841	169038	- 274	- 358	- 395	- 8	0

Atlanta - Southeast Region

New Construction -- Summary results for the new office building in Atlanta can be seen in Figure 3-88 and Tables 3-87 and 3-88.

As shown in Figure 3-88, the H, HW curve rises quickly as the collector area increases, while the H, HW, and AC curve rises significantly slower. This happens since the heating load in Atlanta is fairly small, while the cooling load is relatively large. The same comments can be made for the load, cost, and savings table for Atlanta as was made for similar tables in other regions.

Existing Construction -- Summary results for the existing office building in Atlanta can be seen in Figures 3-89 and Tables 3-89 and 3-90.

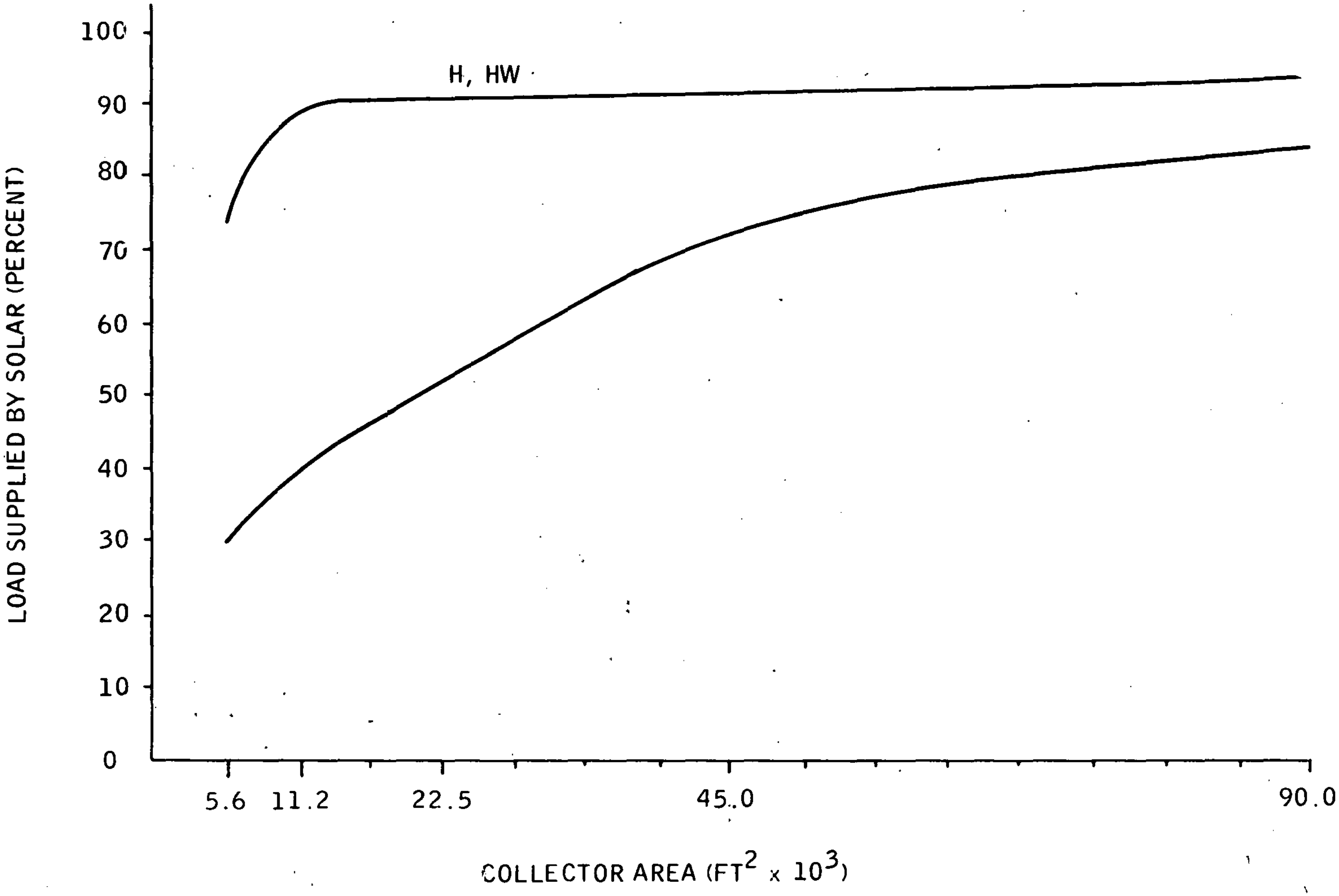


Figure 3-88. New Office Building Base Case, VAV Atlanta

Table 3-87. Summary Loads, Costs and Savings
Heating, Hot Water, Air Conditioning
Collector Area = 22, 500 ft2

Office Bldg.
Atlanta
VAV

ECT Description	Total Load (BTU) x 10^-6	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^-6	% Savings
Base	2, 715	51.2	63, 345	63, 465	64, 146					
Reflective Film	2, 459	57.0	62, 827	62, 948	63, 632	518	517	514	256	9
Shading	2, 506	55.9	62, 263	62, 323	63, 063	1082	1082	1083	209	8
Triple Glazing	2, 659	52.7	63, 851	63, 973	64, 661	- 506	- 508	- 515	56	2
Reduced Lighting	2, 377	58.6	55, 199	55, 316	55, 980	8146	8149	8166	338	12
Night Setback	2, 715	51.2	63, 359	63, 479	64, 160	- 14	- 14	- 14	0	0
Increased Wall Insulation	2, 710	51.5	63, 665	63, 786	64, 470	- 320	- 321	- 324	5	0
Increased Wall & Roof Insulation	2, 703	51.8	63, 938	64, 110	64, 799	- 643	- 645	- 653	12	0
Reduced Hot Water Temp.	2, 666	50.9	63, 289	63, 404	64, 056	56	61	90	49	2
Hydronic Control from Zone Thermo	2, 570	48.4	63, 627	63, 736	64, 351	- 282	- 271	- 205	145	5
Energy Reclaim. From Exhaust Air.	2, 665	53.4	63, 382	63, 502	64, 183	- 37	- 37	- 37	46	2

Table 3-88. Summary Loads, Costs and Savings Heating and Hot Water Collector Area = 22,500 ft²

Office Building
Atlanta
VAV

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	1019	91.5	48,517	48,637	49,318					
Reflective Film	1019	91.4	48,852	48,972	49,656	-335	-335	-338	0	0
Shading	1017	91.4	48,113	48,233	48,913	404	404	405	2	0
Triple Glazing	1023	91.4	49,282	49,403	50,091	-765	-766	-85	-4	0
Reduced Lighting	1011	91.6	41,515	41,632	42,296	7002	7005	7022	8	1
Night Setback	1019	91.5	48,531	48,651	49,332	-14	-14	-14	0	0
Increased Wall Insulation	1021	91.4	48,880	49,001	49,685	-363	-364	-367	-2	0
Increase Wall & Roof Insulation	1025	91.3	49,277	49,398	50,088	-760	-761	-770	-6	1
Reduced Hot Water Temperature	970.3	91.4	48,503	48,618	49,269	14	19	49	49	5
Hydronic Control From Zone Thermo.	864.3	90.9	48,705	48,814	49,429	-188	-177	-111	155	15
Energy Reclaim. From Exhaust Air.	1019	93.2	48,750	48,870	49,551	-233	-233	-233	0	0

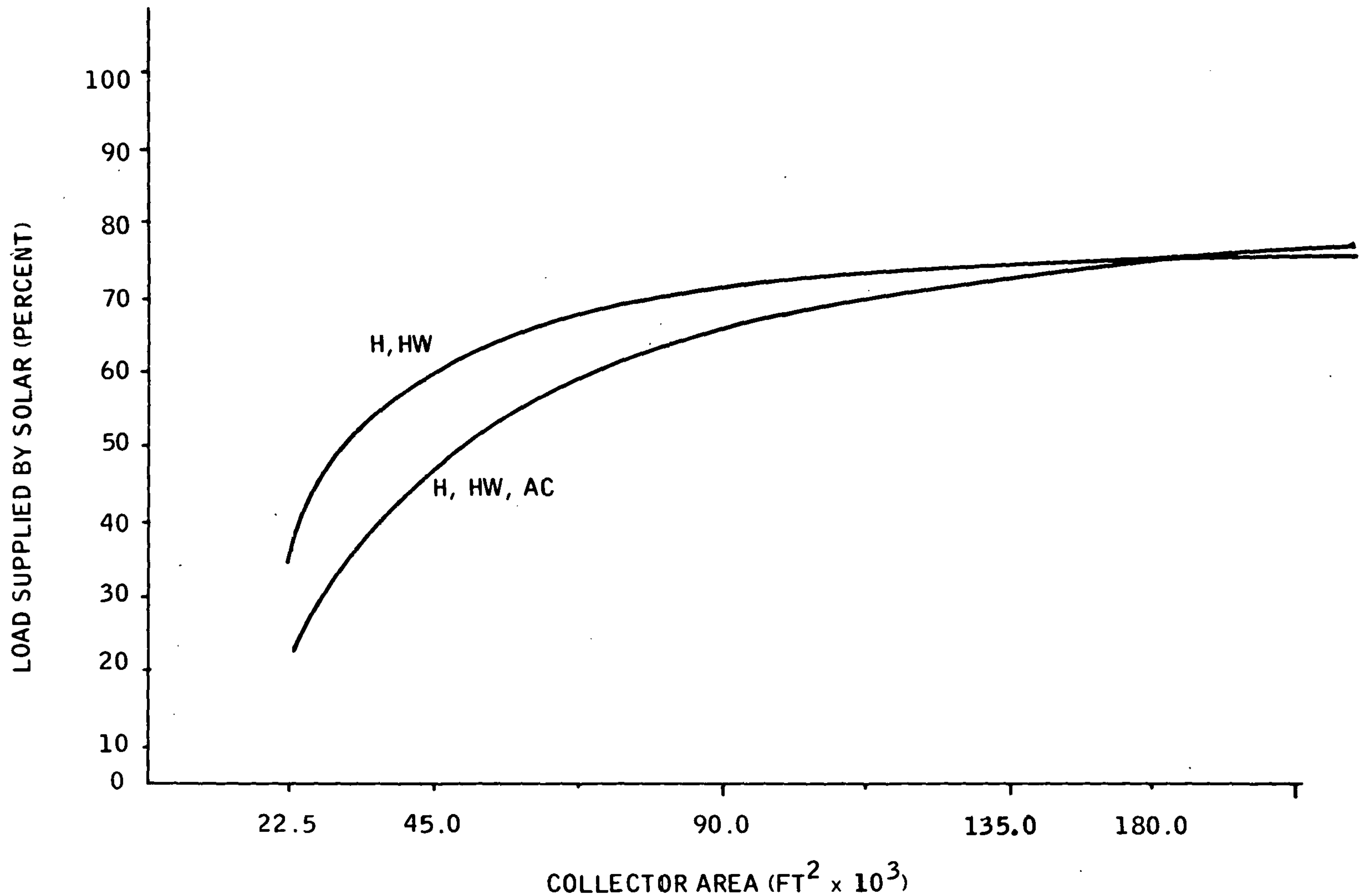


Figure 3-89. Existing Office Building Base Case, CVTR Atlanta

Table 3-89. Summary Loads, Costs and Savings
Heating and Hot Water
Collector Area = 45,000 ft²

OFFICE BLDG.
ATLANTA
CVTR

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base	8868	60.0	102,776	107,622	135,070					
Reflective Film	9138	59.4	103,755	108,832	137,586	- 979	- 1210	- 2516	- 270	- 3
Shading	9198	59.0	103,517	108,677	137,904	- 741	- 1055	- 2834	- 330	- 4
Double Glazing	8668	60.8	103,218	107,842	134,030	- 442	- 220	- 1040	200	2
Reduced Lighting	9358	58.1	97,624	102,989	133,378	5152	4633	1692	- 490	- 6
Night Setback	8438	61.3	101,904	106,376	131,709	872	1246	3361	430	5
Reheat Optimiza.	5406	71.3	96,656	98,780	110,815	6120	8842	24255	3862	39
Increase Wall Ins.	8538	60.9	102,799	107,360	133,196	- 23	262	1874	330	4
Increase Wall & Roof Insulation	7678	61.5	102,215	106,259	129,166	561	1363	5904	1190	13
Reduce Hot Water Temperature	8818	60.0	102,718	107,540	134,854	58	82	216	50	1
Convert to VAV HVAC	2532	89.1	85,851	86,232	88,390	16925	21390	46680	6336	71
Energy Reclaim From Exhaust Air	8873	59.4	103,048	107,904	135,414	- 272	- 282	- 344	- 50	0

Table 3-90. Summary Loads, Costs and Savings Heating, Hot Water, Air Conditioning Collector Area = 4, 500 ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base	13, 600	46.0	123, 800	128, 647	156, 095					
Reflective Film	13, 870	45.6	124, 783	129, 859	158, 613	- 982	- 1212	- 2518	- 270	- 2
Shading	13, 930	45.5	124, 456	129, 706	158, 934	- 655	- 1059	- 2839	- 330	- 2
Double Glazing	13, 400	46.3	124, 246	128, 889	155, 057	- 445	- 222	1038	200	1
Reduced Lighting	14, 090	45.1	118, 653	124, 018	154, 407	5148	4629	1688	- 490	- 4
Night Set Back	13, 170	46.3	122, 945	127, 945	152, 751	856	1229	3340	430	3
Reheat Cptimization	8, 890	54.3	114, 119	116, 243	128, 278	9682	12404	27817	4710	35
Increase Wall Ins.	13, 270	46.1	123, 847	128, 409	154, 245	- 46	238	1850	330	2
Increase Wall & Roof Insulation	12, 410	45.6	123, 336	127, 380	150, 287	465	1267	5808	1190	9
Hot Water Temp. Reduced	13, 550	45.9	123, 754	128, 754	155, 889	47	71	206	50	0
Convert to VAV HVAC	4, 471	73.7	100, 070	100, 451	102, 610	23731	28196	35485	9129	67
Energy Reclaim From Exhaust Air	13, 560	46.0	123, 957	128, 814	156, 223	- 156	- 167	- 228	40	0

3.4.4 Conclusions

Results for the economic analysis are summarized in Tables 3-91 through 3-96, which illustrate annual savings (dollars) and payback time (years), for each energy conservation technique for the four regions studied. The results are summarized for the auxiliary fuels, gas, oil, and electricity and for both systems; heating and hot water, and heating, hot water, and air conditioning. The payback times allow one to determine the effectiveness of the various ECTs, where the payback time is the amount of time it takes for the dollar savings of the ECT to pay for the amortized initial capital cost as well as the operating cost of the ECT. Payback times of greater than 20 years are not strictly correct from a theoretical viewpoint, (since the costs are only distributed over the 20 year period). However, they are listed since they give a relative ranking for the various conservation techniques. Summarized below are the conclusions for the energy conservation techniques:

Reflective film -- This measure is cost effective,(payback less than 20 years) although only marginally,for all regions of the country for the new building construction with a heating, hot water, and air conditioning system. However, it is not effective if the building were only to have a heating and hot water system. It is never cost effective for a building that uses a terminal reheat system.

Shading -- Since no implementation costs were available for this ECT, the payback period was not calculated. However, no matter what the cost, it would never be effective on a CVTR system (existing building type).

Double glazing -- This is only done on the existing building (on the new building, triple glazing is used), and its cost effectiveness varies widely from location to location as well as varying for the different auxiliary fuels.

Reduced lighting -- This is always one of the most favorable measures and has a payback time of less than one year in all cases. The return on investment

Table 3-91. Energy Conservation Techniques, Cost Effectiveness
Office Building Fuel-Electricity
Heating, Hot Water and Air Conditioning
Collector Area = 22,500 ft^2-UAU 45,000 ft^2 CVTR

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Reflective Film	274/15	-3113/-	61/19	-2516/-	514/12	2518/-	387/13	-3110/-
Shading	1014/N/A	-3229/N/A	966/N/A	-3359/NA	1083/N/A	-2839/N/A	947/N/A	-1458/NA
Double Glazing	N/A/N/A	2541/6	N/A/N/A	3214/6	N/A/N/A	1038/10	N/A/N/A	2119/6
Reduced Lighting	7041/*	774/*	9838/*	1819/*	8166/*	1688/*	7622/*	1928/*
Night setback		4224/*		6308/*		3340/*		4533/*
Reheat Optimization	N/A/N/A	41113/*	N/A/N/A	44947/*	N/A/N/A	27817/*	N/A/N/A	27939/*
Increased Wall Insu.	-190/-	3058/3	-539/-	5870/3	-324/765	1850/6	-280/-	2456/3
Increase wall & Roof	-679/-	17888/1	-1168/-	20827/2	-653/609	5808/4	-771/-	9428/2
Reduced Hot Water	121/*	280/*	80/*	464/*	90/*	206/*	-111/_	199/*
Convert to VAV	N/A/N/A	71851/*	N/A/N/A	77889/1	N/A/N/A	35485/1	N/A/N/A	50007/*
Energy reclaim from exhaust air	-131/38	-209/83	-280/83	-323/161	-37/23	-228/146	-148/50	-217/161
Triple Glazing	-758/279	N/A/N/A	-1010/2021	N/A/N/A	-515/60	N/A/N/A	-580/-	N/A/N/A
Hydronic control from zone thermostat with night setback	439/8	N/A/N/A	-134/32	N/A/N/A	-205/85	N/A/N/A	-450/-	N/A/NA/

Table 3-92. Energy Conservation Techniques, Cost Effectiveness
Office Building Fuel-Oil
Heating, Hot Water and Air Conditioning
Collector Area = 22,500 ft^2 22,500 ft^2 UVU 45,000 ft^2 CVTR

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Reflective Film	282/15	-2048/-	69/19	-1201/-	517/12	-1212/-	381/13	-1413/-
Shading	985/N/A	-1257/N/A	959/N/A	-996/N/A	1082/N/A	-1059/N/A	942/N/A	-1296/N/A
Double Glazing	N/A/N/A	409/14	N/A/N/A	41/19	N/A/N/A	-222/26	N/A/N/A	251/15
Reduced Lighting	6778/*	3562/*	9800/*	6220/*	8149/*	4529/*	7612/*	4669/*
Night Setback		1656/*		1833/*		1229/*		1660/*
Reheat Optimization	N/A/N/A	17442/*	N/A/N/A	15329/*	N/A/N/A	12404/*	N/A/N/A	12194/*
Increased Wall Insul.	-173/-	914/7	-526/-	1176/8	-321/569	238/15	-278/-	616/9
Increased Wall & Roof	-618/-	5063/4	-1134/-	4975/5	-645/448	1267/11	-768/-	2836/6
Reduced Hot Water	33/*	126/*	-7/*	163/*	61/*	71/*	-128/-	76/*
Convert to VAV	N/A/N/A	34139/1	N/A/N/A	31186/1	N/A/N/A	28196/1	N/A/N/A	25281/1
Energy reclaim from Exhaust air	-130/38	-150/44	-278/81	-287/90	-37/23	-167/54	-148/50	-191/87
Triple glazing	-719/167	N/A/N/A	-982/536	N/A/N/A	-508/58	N/A/N/A	578/-	N/A/N/A
Hydronic Control from zone thermostat with night setback	29/18	N/A/N/A	-271/81	N/A/N/A	-271/-	N/A/N/A	-420/-	N/A/N/A

Table 3-93. Energy Conservation Techniques, Cost Effectiveness
Office Building Fuel-Gas
Heating, Hot Water and Air Conditioning
Collector Area = 22,500 ft^2 VAV 45,000 ft^2 CVTR

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Reflective Film	284/15	-1734/-	70/19	-1056/-	518/12	-982/-	379/13	-1125/-
Shading	977/N/A	-675/NA	958/N/A	-736/N/A	1083/NA	-655/N/A	940/N/A	-930/N/
Double Glazing	N/A/N/A	-218/26	N/A/N/A	-309/2[illegible]	N/A/N/A	-445:36	N/A/N/A	65/19
Reduced lighting	6959/*	4387/*	9796/*	6705/*	8146/*	5148/*	7610/*	5133/*
Night setback		896/*		1340/*		856/*		1173/*
Reheat Optimization	N//N/A	10439/*	N/A/NA	12069/*	N/A/NA	9682/*	N/AN/A	9514/*
Increased Wall Ins.	-168/-	280/113	-525/-	659/11	-320/524	-46/21	-279/-	305/12
Increased Wall & Rf	-600/-	2210/7	-1130/-	3228/7	-643/420	465/15	-768/-	1719/8
Reduced Hot Water	7/*	80/*	-16/*	130/*	56/*	47/*	-132/-	55/*
Convert to VAV	N/A/N/A	22480/1	N/A/NA	26040/2	N/A/NA	23721/1	N/A/N/A	21091/1
Energy Reclaim from Exhaust Air	-130/38	-132/38	38/-278	-283/86	-37/23	-156/48	-149/50	-187/82
Triple Glazing	-707/149	N/A/N/A	-978/485	N/A/N/A	-506/58	N/A/N/A	-579/-	N/A/N/A
Hydronic Control	-92/28	N/A/N/A	-286/98	N/A/N/A	-282/-	N/AN/A	-416/-	N/A/N/A

Table 3-94. Energy Conservation Techniques, Cost Effectiveness
Office Building Fuel-Electricity
Heating and Hot Water
Collector Area = 22,500 ft^2 12,500 ft^2 VAV 45,000 ft^2 CVTR

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Reflective Film	-461/46	-3147/-	-612/53	-2525/-	-338/36	-2516/-	-187/28	-3098/-
Shading	434/N/A	-3266/NA	438/N:A	-3370/NA	405/N/A	-2834/NA	485/N/A	-3453/NA
Double Glazing	N/A/N/A	2540/6	N/A/N/A	3209/6	N/A/N/A	1040/10	N/A/N/A	2141/6
Reduced Lighting	6307/*	738/*	8877/*	1799/*	7022/*	1692/*	6891/*	1921/*
Night Setback		4224/*		6329/*		3361/*		4562/*
Reheat Optimization	N/A/N/A	38726/*	N/A/N/A	41700/*	N/A/N/A	24255/*	N/A/N/A	25572/*
Increased Wall Ins.	-199/-	3058/3	-539/-	5882/2	-367/41	1874/5	-268/48	2480/3
Increased Wall (Roof	-724/-	17921/-	-1159/-	20853/2	-770/44	5904/4	-774/64	9430/2
Reduced hot water	147/*	255/*	123/*	427/*	49/*	216/*	26/*	197/*
Convert to VAV	N/A/N/A	67305/*	N/A/N/A	72366/*	N/A/N/A	46680/*	N/A/N/A	46185/*
Energy reclaim from exhaust air	-247/195	- 352/-	-338/239	- 395/ -	-233/169	- 344/-	-224/209	-270/-
Triple Glazing	-920/-	N/A/N/A	-1136/-	N/A/N/A	-85/22	N/A/N/A	-689/-	N/A/N/A
Hydronic Control	518/7	N/A/N/A	14/19	N/A/N/A	-111/34	N/A/N/A	-228/126	N/A/N/A

Table 3-95. Energy Conservation Techniques, Cost Effectiveness Office Building Fuel-Oil Heating and Hot Water Collector Area = 22,500 ft^2 22,500 ft^2 VAV 45,000 ft^2 CVTR

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Reflective Film	-453/45	-2084/-	-605/52	-1208/-	-335/36	-1210/-	-194/28	-1399/-
Shading	405/N/A	-1294/N/A	429/N/A	-1006/N/A	404/N/A	-1055/N/A	479/N/A	-1289/N/A
Double Glazing	N/A/N/A	408/14	N/A/N/A	36/19	N/A/N/A	-220/26	N/A/N/A	274/15
Reduced Lighting	6244/*	3525/*	8839/*	6201/*	7005/*	4633/*	6880/*	4652/*
Night Setback		1656/*		1855/*		1246/*		1689/*
Reheat Optimization	N/A/N/A	15056/*	N/A/N/A	12083/*	N/A/N/A	8842/*	N/A/N/A	9817/*
Increase Wall Ins.	-183/-	913/7	-527/-	1190/8	-364/41	262/15	-268/48	641/8
Wall & Roof Ins.	-664/-	5096/4	-1126/-	5001/5	-761/44	1363/10	-772/63	2841/6
Reduced Hot Water	59/*	101/*	35/*	127/*	19/*	82/*	7/*	75/*
Convert to VAV	N/A/N/A	29593/1	N/A/N/A	25663/2	N/A/N/A	21390/1	N/A/N/A	21460/1
Energy Reclaim from Exhaust Air	-247/195	-297/-	-340/25[illegible]	-358/684	-233/169	-282/-	-225/218	-245/1845
Triple Glazing	-881/-	N/A/N/A	-1109/-	N/A/N/A	-766/1878	N/A/N/A	-688/-	N/A/N/A
Hydronic Control	108/15	N/A/N/A	-124/31	N/A/N/A	-177/59	N/A/N/A	-199/75	N/A/N/A

Table 3-96. Energy Conservation Techniques, Cost Effectiveness
Office Building Fuel-Gas
Heating and Hot Water
Collector Area = 22,500 ft^2 22,500 ft^2 VAV 45,000 ft^2 CVTR

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Reflective Film	-451/45[1]	-1770/--	-604/51	-984/ --	-335/36	-979/ --	-194/28	-1111/--
Shading	397/N/A	- 711/N/A	429/N/A	-666/N/A	404/N/A	-741/N/A	478/N/A	- 922/N/A
Double Glazing	N/A/N/A	-217/26	N/A/N/A	-234/24	N:A/N/A	-442/36	N/A/N/A	- 43/21
Reduced Lighting	6226/*	4350/*	8835/*	6765/*	7002/*	5152/*	6878/*	5127/*
Night Setback [2]		897/*		1442/*		872/*		1202/*
Reheat Optimization	N/A/N/A	8052/*	N/A/N/A	8900/*	N/A/N/A	6120/*	N/A/N/A	7148/*
Increase Wall Insul.	-178/-	279/13	-525/-	752/10	-363/41	- 23/21	-267/47	329/12
Wall & Roof Insul.	-646/-	2243/7	-1122/-	3335/7	-760/44	561/14	-771/63	1752/8
Reduced Hot Water	32/*	55/*	26/*	173/*	14/*	58/*	4/*	54/*
Convert to VAV	N/A/N/A	18434/2	N/A/N/A	20598/2	N/A/N/A	16925/2	N/A/N/A	17270/2
Energy Reclaim From Exhaust Air	-247/195	-275/26788	-340/256	-274/78	-233/169	-272/-	-225/218	-240/644
Triple Glazing	-869/-	N/A/N/A	-1106/-	N/A/NA	-765/1675	N/A/N/A	-688/-	N/A/N/A
Hydronic Control	-14/21	N/A/N/A	-139/33	N/A/N/A	-188/66	N/A/N/A	-194/70	N/A/N/A

* Payback less than 1 year

\- No payback

1 Payback over twenty year only give a relative ranking

2 Night set back for VAV is included in Hydronic control

is the best of any ECT since it costs nothing to implement and saves at least $4000 per year (a distributed saving over 20 years).

Night setback -- This is always cost effective for the existing building with a payback time less than one year. It is not listed for the new building since it was combined with another energy conservation technique.

Reheat optimization -- This technique applies only to a CVTR system, and again, pays back in less than one year. This measure also has a very good return on investment which realizes a large dollar savings per year for only a moderate investment.

Increase wall insulation -- This procedure is never cost effective for the new building (due to the large initial cost and relatively poor savings). Cost effectiveness varies widely from location to location and also varies for the different auxiliary fuels in the existing building (it is not cost effective in New York due to the high implementation costs).

Increase wall and roof insulation -- The same discussion holds for this procedure except that this is even more cost effective than the previous technique.

Reduced hot water temperature -- This is generally cost effective since there are no implementation costs associated with it. However, in some sections of the country, reducing the hot water temperature causes a shifting of the modes of the solar system which can result in excess energy usage by the pumps. For example, if the modes shift such that more energy is called for from storage, the heat transfer fluid must be pumped twice rather than once, thus using more electrical energy and causing a reduction in system efficiency.

Convert to VAV -- This only applies to the CVTR system, and is always cost effective, with payback time less than three years. This is the largest dollar saver, but does not pay back in less than one year due to the high implementation cost.

Energy reclamation from exhaust air -- This procedure is never cost effective due to the small energy saving as well as relatively high implementation costs.

Triple glazing -- This ECT only applies to the VAV system (new construction) and is never cost effective due to the small energy saving and high implementation costs.

Hydronic control from zone thermostat with night setback -- The effectiveness of this method varies from location to location. It also varies for the different auxiliary fuels.

3.5 SCHOOLS

3.5.1 Building Description

A detailed description of the construction details for both new and existing schools in the four cities being studied is given in Appendix A.

There are two basic types of construction: masonry (Omaha, Albuquerque); and curtainwall (New York, Atlanta). The school building has 40,000 square feet of roof area and 1,700 square feet of glass, including doors and windows. In all four cities, the existing school buildings have no ceiling or wall insulation, and have single pane windows. The existing buildings have a 3/8 inch built-up roof with a metal deck. The new school buildings in all four cities have wall and ceiling insulation and double pane glass windows and doors. The new building roofs are 3/8 inch built-up with metal deck and 2 inches of roof insulation. The new masonry building walls have 1 inch of rigid insulation and 1/2 inch of gypsum board. The new curtainwall building walls have 2 inches of rigid insulation and 1/2 inch of gypsum board.

The new building's heating, ventilation and cooling system is a roof top packaged multizone unit with forced air direct expansion cooling. The heating capacity of the unit is 4 million BTU/HR. The conventional cooling capacity is 0.9 million BTU/HR. The solar system described in Appendix F was sized for these loads. It supplies hot and/or chilled water to the roof-top air handler.

The existing building's heating, ventilation and cooling system consists of four pipe unit ventilators with a central system. The solar system would then provide hot or chilled water for the unit ventilators. The total capacity of these units is 4 million BTU/HR for heating, and 0.9 million BTU/HR for cooling The solar system is the same as the one for new schools, except that it supplies hot and/or chilled water to the control plant. (See Appendix F for a description of the solar system.)

3.5.2 Modeling Assumptions

The school building is modeled as a single zone. The internal heating losses are computed as a summation of the following:

- Heat losses through envelope (walls and roof)
- Infiltration heat loss based on an infiltration rate of 1000 CFM
- Ventilation heat loss based on 7950 CFM peak ventilation

It is assumed that there is no heat loss through the floor. The internal heating gains are computed as a summation of:

- People load
- Lighting load
- Glass load (solar insolation)
- Hot water tank loss
- Applicance load

The people, lighting, ventilation, hot water and appliance loads are computed based on the schedules and maximum values in Appendix A. The hot water usage for schools was based on the assumption of 3.65 gallons per person per day.

The gas or oil furnace was assumed to be 75 percent efficient The electric furnace was assumed to be 100 percent efficient.

3.5.3 Results for the School

Omaha - North Central Region

New Construction - Base Case -- The analysis of a typical new building without any energy conservation improvements is called the base case. The base case results for the new school in Omaha are presented Figures 3-90 through 3-94. Figure 3-90 shows the percent of the heating and hot water load supplied and the percent of the total heating, cooling, and hot water load supplied by solar energy as a function of solar collector area. As is typical of the new school with a Rankine air conditioner, the percent solar contribution is less for a given collector area than for heating only systems.

Figures 3-91 and 3-92 show the annual cost of the heating, hot water, and cooling system and the heating and hot water system as a function of solar collector area. The generally increasing costs indicate that the cost of solar system is greater than the cost savings of the fuel it displaces.

Figure 3-93 shows the auxiliary heating load and Figure 3-94 shows the auxiliary cooling load for the base case as a function of solar collector area. This is energy supplied by the conventional furnace, hot water heater and electric compressor motor. As the collector area increases more solar energy is supplied by the system, reducing the auxiliary energy requirement.

The collector area of 20,000 square feet, which supplies 78 percent of all heating, hot water and cooling load with solar energy, was chosen as the collector area which will be used on all the energy conservation technique models.

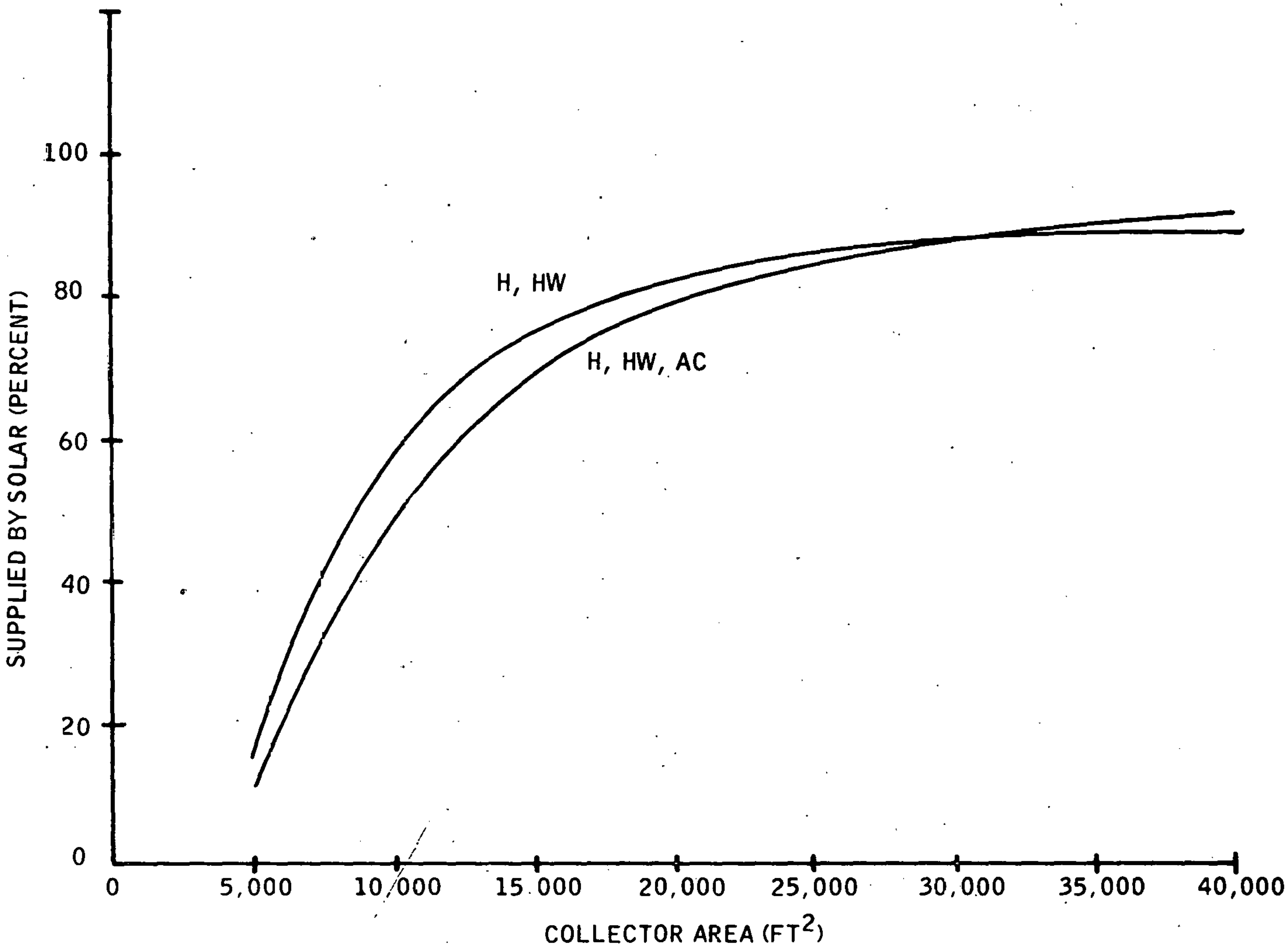


Figure 3-90
Percent Of Load Supplied By Solar Versus Collector Area For (New) School Omaha Base Building

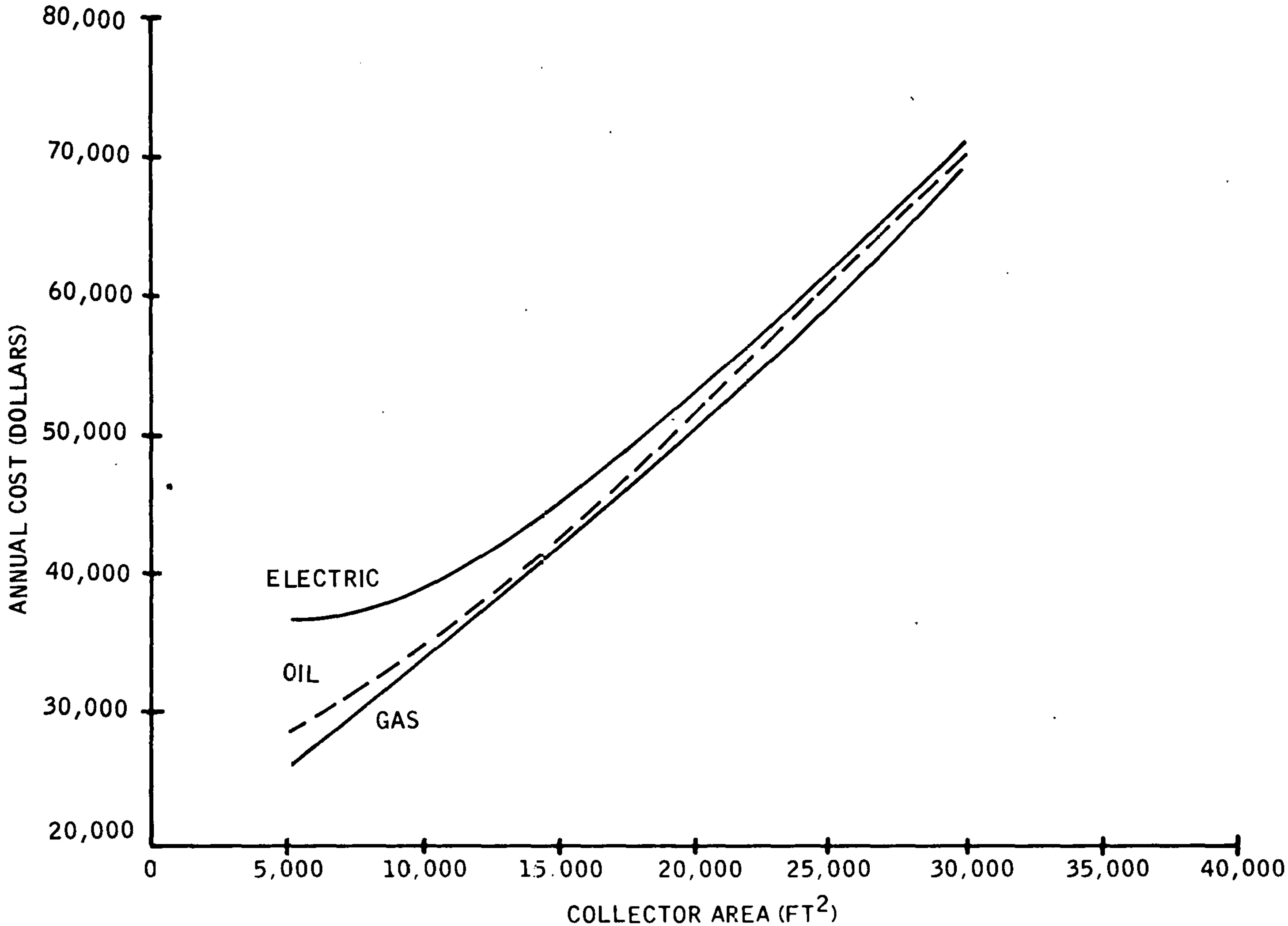


Figure 3-91
Annual Cost Versus Collector Area For
(New) School Omaha Base Building
Heating, Hot Water, And Air Conditioning

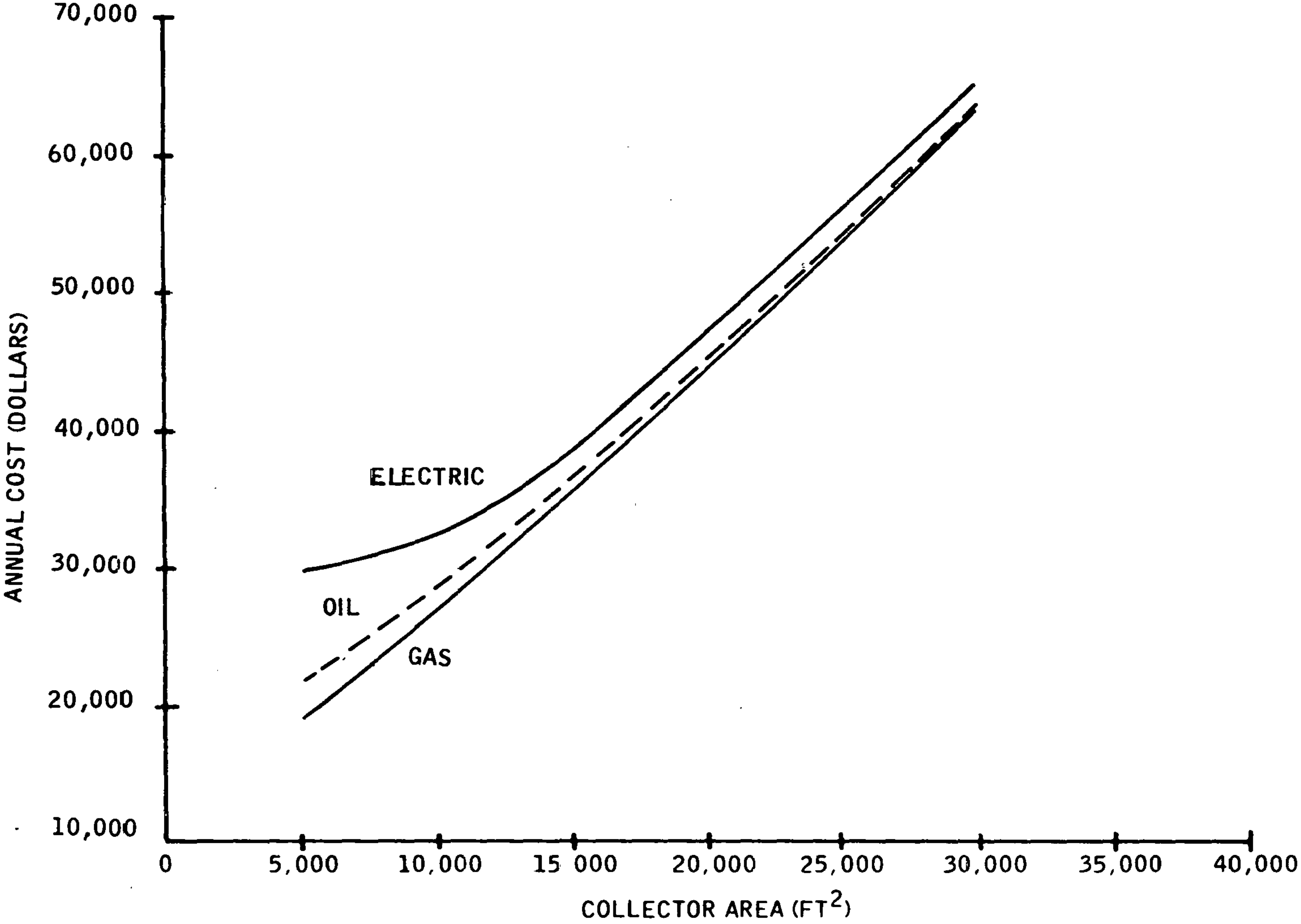


Figure 3-92

Annual Cost Versus Collector Area For (New) School Omaha Base Building

Heating, Hot Water, And Air Conditioning

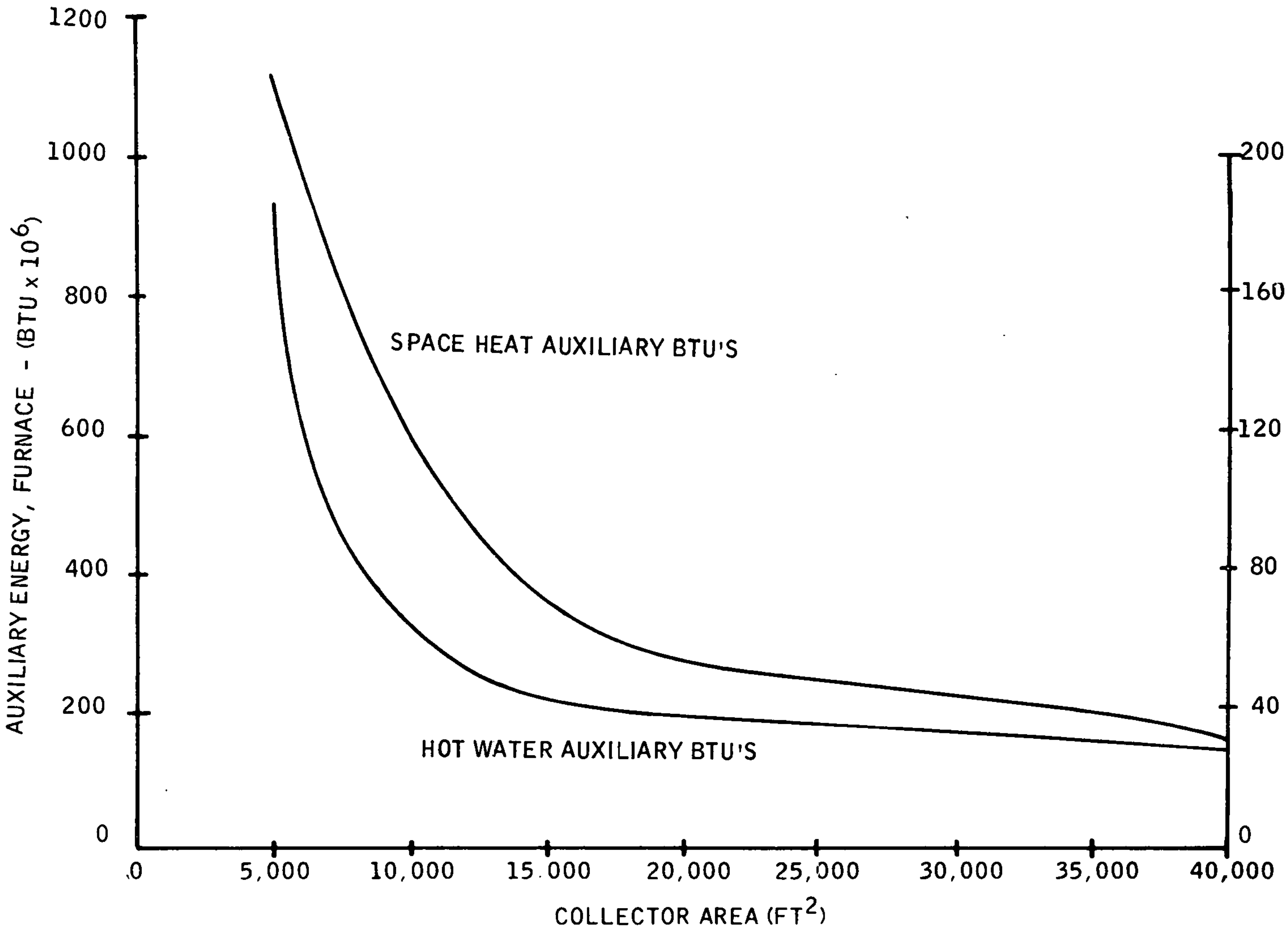


Figure 3-93

Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area For (New) School Omaha Base Building

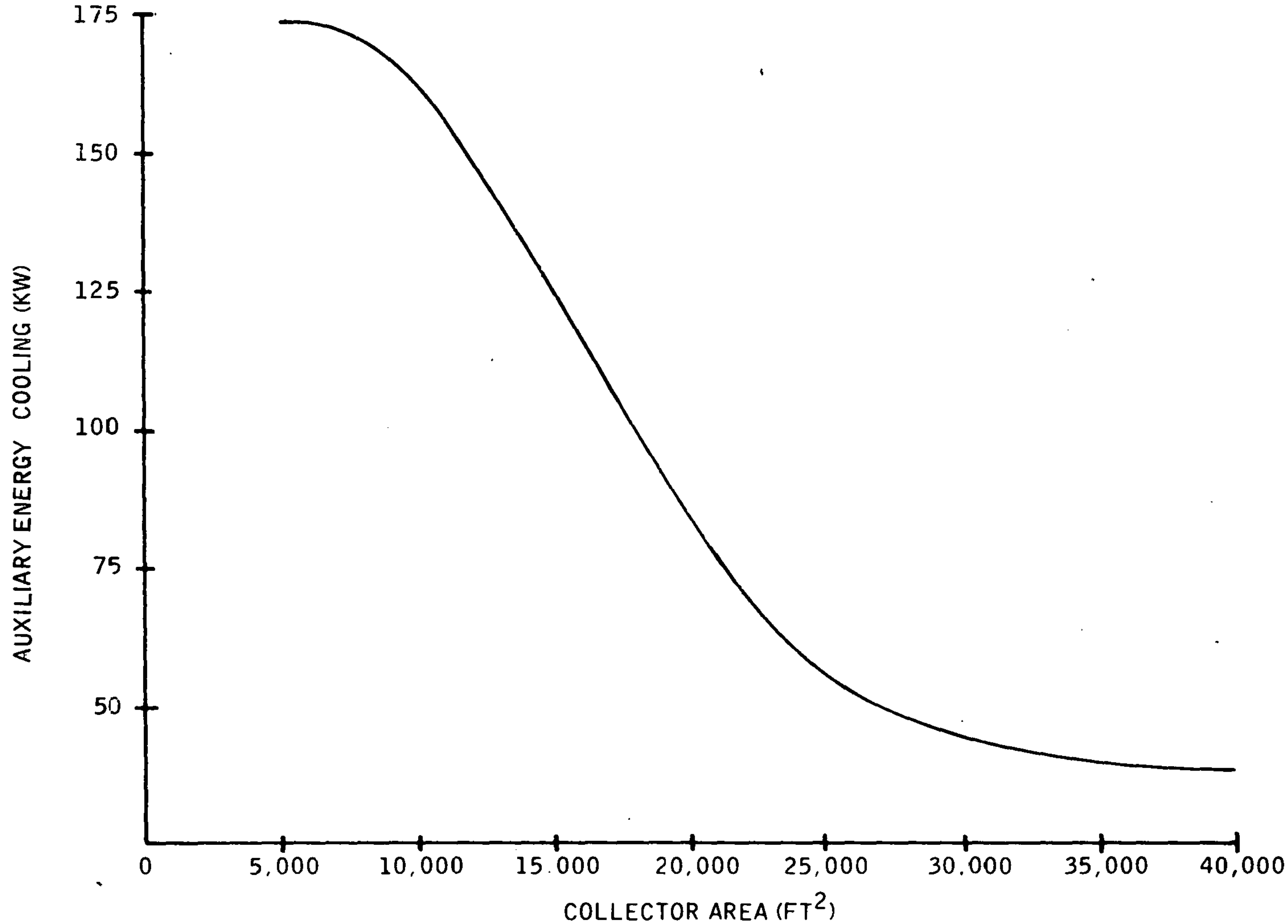


Figure 3-94
Auxiliary Cooling Energy Load Versus Collector Area For
(New) School Omaha Base Building

Omaha - School (New)
Table 3-97 Summary Loads, Costs And Savings

HEATING, HOT WATER, AIR CONDITIONING
COLLECTOR AREA = 20,000 ft^2

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base Case	2199	78	51085	51686	53718					
Add Wall Ins.	2110	78	51082	51630	53492	3	56	226	89	4
Wall & Ceiling Ins.	1704	81	52068	52387	53467	-983	-299	251	49	22
Reflective Coating	2139	79	51208	51801	53808	-123	-115	-90	60	23
Triple Glazing	2137	79	51274	51868	53784	-189	-182	-66	62	23
Insulate Hot Water Tank, Reduce Hot Water to 130° Max	2174	78	51036	51601	53511	49	85	207	25	11
Air Economizer	2108	80	50823	51428	52463	262	258	1255	91	44
Night Setback	2018	79	50910	51446	53258	175	240	460	181	88
*Shading	2175	79	50953	51581	53640	132	105	78	24	1
Reduced Ventilation	2092	79	50850	51364	53103	235	322	615	15	7

*Shading was assumed to cost nothing, so the savings shown must be balanced against actual cost

Omaha School (New)
Table 3-98 Summary Loads, Costs and Savings

HEATING AND HOT WATER
COLLECTOR AREA = 20,000 ft^2

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 Case	1504	80	44922	45523	47555					
Add Wall Ins.	1415	81	44903	45441	47302	19	82	253	89	6
Wall & Ceiling Insul	1005	85	45821	46141	47170	-899	-618	385	499	33
Reflective Coating	1506	80	45270	45863	47871	-348	-340	-316	-2	0
Triple Glazing	1453	81	45171	45738	47655	-249	-215	-100	51	3
Ins. HW Tank, Reduce HWT to 130°M	1482	80	44885	45450	47360	37	73	195	21	1
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	1328	80	44746	45281	47092	176	242	463	176	12
*Shading	1534	80	44986	45598	47673	-64	-75	-118	-30	-2
Reduced Ventilation	1353	81	44680	45194	46976	242	329	579	151	10

New Construction - Application of Energy Conservation Techniques (ECT's) -- The various energy conservation techniques used in the school analysis are described below. The cost for each ECT is shown in Appendix B. Tables 3-97 and 3-98 show the results of applying each ECT to the new construction base case for Omaha.

All ECT's are studied with the above defined base building model at 20,000 ft^2 of solar collectors. Each ECT will be briefly described. The results are tabulated in Tables 3-97 and 3-98. The values for loads, BTU savings, and percent solar were results of SUNSIM simulation runs. The annual costs are from the computer cost analysis program (see Appendix E for descriptions of these programs). (All ECT discussion below refers to the new Omaha school.)

Adding Wall Insulation -- To implement this, one inch of rigid insulation is added to the walls. This results in both dollar and BTU savings for heating.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding one inch of rigid wall insulation plus an additional 2 inches of roof insulation. This results in dollar and BTU savings for the heating, hot water, and cooling case and the heating only case, for electric auxiliary fuel.

Reflective Window Coating -- This is implemented by installing windows and doors which are coated with a reflective coating which reduces the glass transmittance by 80 percent and decreases the thermal conductivity of the glass by 20 percent. This ECT loses rather than saves dollars. It saves a small amount of energy during cooling, but increases energy consumption during heating.

Triple Glazing -- This ECT is accomplished by installing triple pane insulated glass, thereby reducing both the glass transmittance and thermal conductivity. This ECT saves energy, but costs more than the cost of energy savings.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130°F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water. This technique saves a little energy and saves dollars for all fuel types for both heating and heating/cooling systems.

Air Economizer -- An air economizer was added, which is used to supply some of the cooling load when the outside temperature is less than 75°F. The air economizer saves dollars and energy for the heating/cooling system.

Night Setback; Cooling Off at Night -- This ECT involves installing a time clock thermostat which can set the temperature back to 60°F (during the heating season) between the hours of 10 p. m. and 6 a. m., and shut off the cooling between these hours (during the cooling season). This ECT is a cooling conservation technique and saves both dollars and energy.

Shading -- Shading was accomplished in the simulation by reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced. Therefore, savings must be weighed against the actual costs. Both dollars and energy are lost by shading in the heating-only case.

Reduced Ventilation -- The present system in the new schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position of the dampers. This ECT produces significant dollar and energy savings for heating, cooling, and heating only systems for all the auxiliary fuels considered.

Existing Construction - Base Case -- The base case results (that is, for a building/system without energy conservation techniques) for the existing school in Omaha are presented in Figures 3-95 through 3-97. Figure 3-95

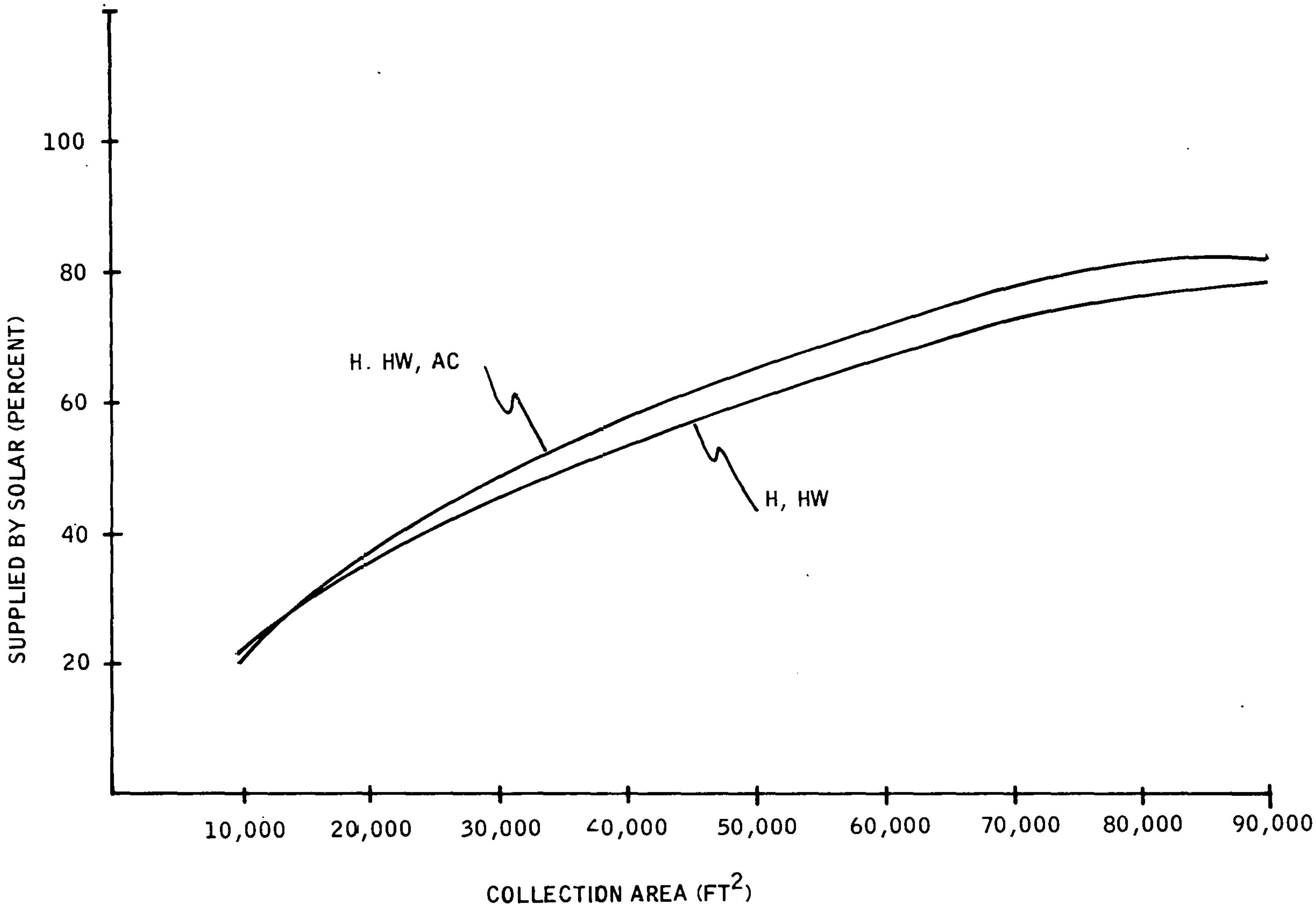


Figure 3-95
Percent Of Load Supplied By Solar Versus Collector Area For (Existing) School Omaha Base Building

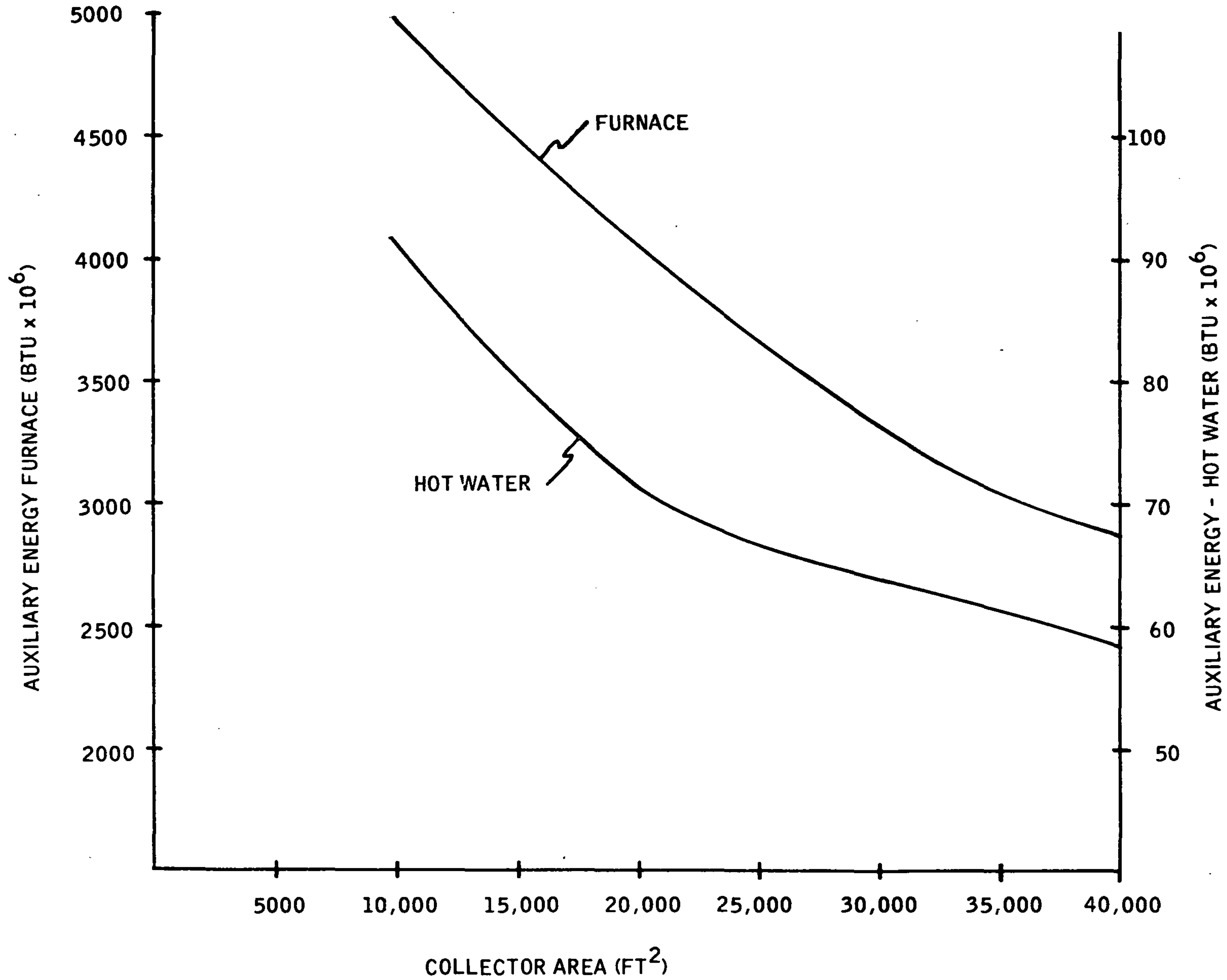


Figure 3-96
Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area For (Existing) School Omaha Base Building

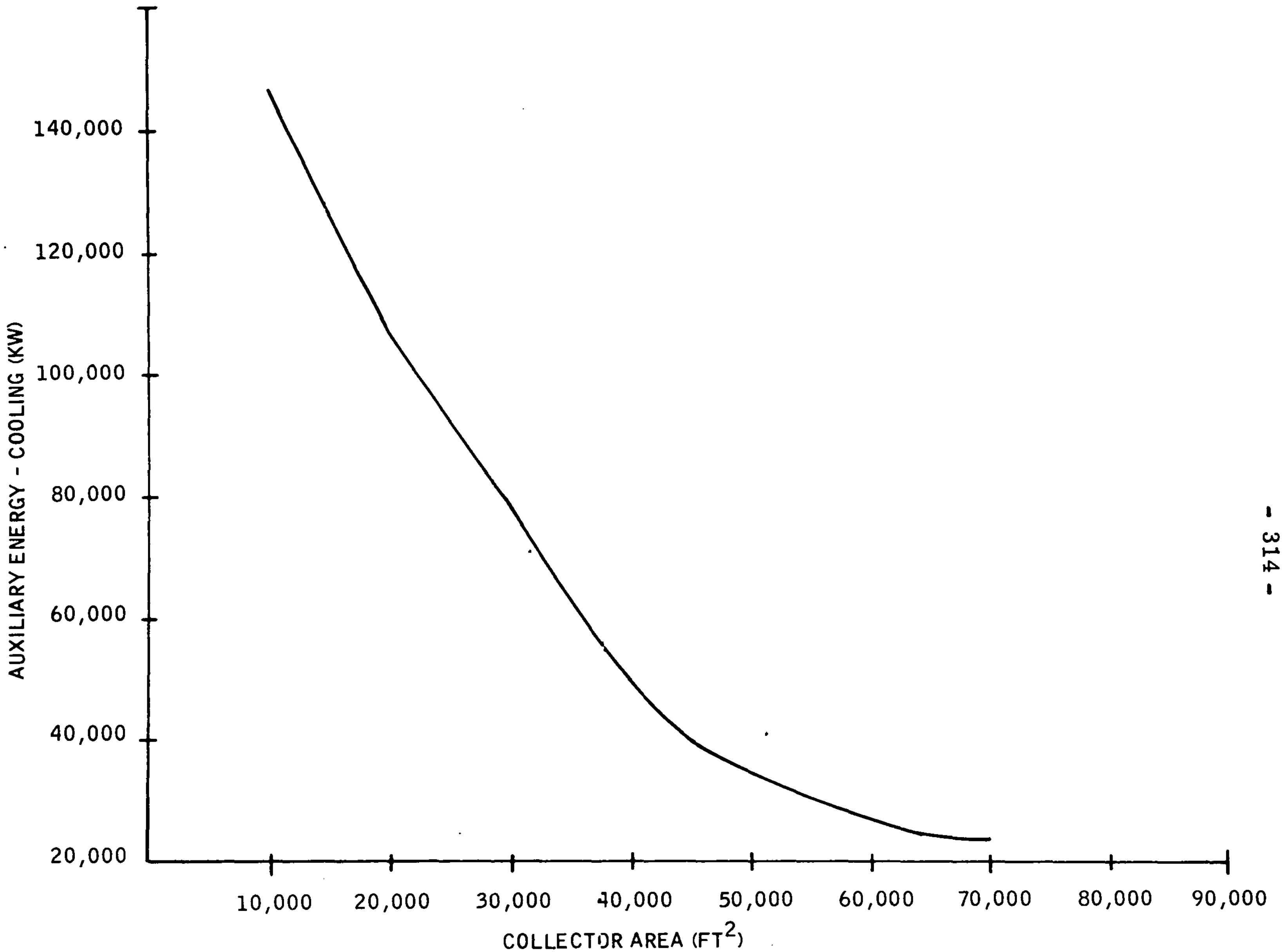


Figure 3-97
Energy Supplied For Auxiliary Cooling Versus Collector Area For (Existing) School Omaha Base Building

shows the percent of the load supplied by solar energy as a function of solar collector area. Both heating and hot water, and heating, hot water and cooling systems are shown. The percent solar contribution (for a given collector area) is less for heating and hot water only than for heating, hot water and cooling.

Figures 3-96 and 3-97 show the heating, hot water and cooling auxiliary loads as a function of solar collector area. The collector area of 30,000 ft^2 was chosen for the analysis of energy conservation techniques for the existing school in Omaha.

Existing Construction -- Application of Energy Conservation Techniques (ECTs)-- The various energy conservation techniques used in the existing school analysis are described below. The costs are shown in Appendix B. Tables 3-99 through 3-102 show the results of applying the various ECTs to the existing base case for Omaha.

Adding Wall Insulation -- To implement this, 2 inches of rigid insulation are added to the walls. This causes both fuel and dollar savings for both heating and hot water, and heating, hot water and cooling.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus 4 inches of roof insulation. This results in large dollar and fuel savings for all types of fuels for heating and hot water, and heating, hot water and cooling.

Reflective Window Coating -- This is implemented by installing a reflective film over the inside of the window panes which reduces the glass transmittance by 80 percent. This also results in a reduced thermal conductivity of the glass (20 percent less). While this ECT saves a slight amount of fuel, it costs more to implement for all auxiliary fuels considered, both for heating and hot water, and heating, hot water and cooling.

Table 3-99 Summary Loads, Costs and Savings

HEATING, HOT WATER, AIR CONDITIONING

OMAHA - EXISTING - SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base Case	7296	49.33	79790	86486	109108					
Add Wall Insul.	6935	50.9	79539	85712	106566	251	774	2542	361	5
Add Wall & Ceil Insulation	1851	90.9	73217	73492	74423	6573	12994	34685	5400	75
Reflective Film	7239	49.5	79980	86658	109160	-190	-172	-52	60	.8
Add Pane Glass	7142	50.1	79915	86373	108191	-125	113	917	154	2
Insul. H. W. Tank Reduce Max T. to 130 $^\circ$F	7273	49.3	79736	86388	108858	54	98	250	23	.3
Air Economizer	7285	49.3	79834	86536	109177	-44	-50	-69	11	1.5
Night Setback	6498	51.8	78215	83897	103090	1575	2589	6018	798	11
Shading *	7306	49.3	79777	86533	109356	13	-47	-248	10	-.1
Reduced Vent.	7062	50.4	79419	85844	107549	371	642	1559	234	3.2

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Table 3-100

SUMMARY LOADS, COSTS AND SAVINGS

HEATING AND HOT WATER

OMAHA - EXISTING - SCHOOL

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 Case	6372	45.8	73349	80044	102666					
Add Wall Insul.	6030	47.35	73133	79307	100161	216	737	2505	342	5.4
Add Wall & Ceil Insulation	1127	89	67071	67347	68277	6278	12697	34389	5250	82
Reflective Film	6367	46	73515	80175	102677	-166	-131	-11	- 5	-.1
Add Pane Glass	6234	46.6	73417	79875	101692	-68	237	1211	38	.6
Insul. H. W. Tank Reduce Max. T. to 130°F.	6351	45.8	73302	79953	102422	47	91	242	22	.4
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	5599	47.6	71864	77545	96739	1485	2499	5927	773	12
Shading *	6424	45.8	73450	80206	103029	-101	-162	-363	-52	3
Reduced Vent.	6173	46.7	73037	79461	101107	312	583	1499	189	-.8

* Shading was assumed to cost nothing, so the savings must be balanced against actual cost.

Existing Omaha School
Table 3-101 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
A COMPARISON OF 3 WATTS/FT.^{2} AND 2 WATTS/FT.^{2}

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base (3 Watts/ft.^{2})	7229	49.67	84444	91258	114277					
Base (2 Watts/ft.^{2})	7296	49.33	79790	86486	109108	4654	4772	5169		

Table 3-102 Summary Loads, Costs And Savings

HEATING AND HOT WATER

OMAHA - EXISTING - SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base (3 Watts/ft.^{2})	6162	46.37	77697	84511	107530					
Base (2 Watts/ft.^{2})	6372	45.8	73349	80044	102666	4348	4467	4864		

Double Glazing -- This ECT is accomplished by installing an interior glass storm window, thereby reducing both the glass transmittance and thermal conductivity. This method saves a small amount of energy and saves dollars for both oil and electric auxiliary fuels in heating and hot water, and heating, hot water and cooling modes.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130° F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water. This ECT saves auxiliary fuel as well as dollars for all types of auxiliary fuels considered for both heating and hot water, and heating, hot water and cooling.

Air Economizer--An air economizer was added to supply some of the cooling load when the outside temperature is less than 75°F. This ECT is only operative during the cooling season and is shown to save a small amount of energy, but it costs more to operate than it saves.

Night Setback; Cooling Off at Night -- This ECT involves installing a Chronotherm which can set the temperature back to 60°F (during the heating season) between the hours of 10 p.m. and 6 a.m. The cooling is assumed to be shut off between these hours (during the cooling season) by maintenance personnel. This ECT saves both dollars and energy for all fuel types and for both heating and hot water, and heating, hot water and cooling operations.

Shading -- Shading was accomplished in the simulation be reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced. Therefore, savings must be weighed against the actual cost. It is shown to save a small amount of dollars for heating, hot water, and cooling for gas auxiliary fuel. As is expected, shading increases operating costs during the heating season.

Reduced Ventilation -- The HVAC system in existing schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air, it is necessary to mechanically adjust the minimum position of the dampers. This ECT saves both energy and dollars for all auxiliary fuels considered and for both heating and hot water, and heating, hot water and cooling systems.

Lighting--All ECT simulations were run using two watts/square foot as the maximum lighting level, so as to be comparable to the new construction case. To examine the effect of increased lighting levels, the base case was evaluated with a maximum lighting level of three watts/square foot. The effect of increased lighting levels is shown in Tables 3-101 and 3-102. To compare costs, the cost of an extra watt/square foot was included in the three watt case, using the average predicted electric rates for Omaha. It is seen that a substantial savings is realized by lower lighting levels.

New York - Northeast Region

New Construction - Base Case -- The base case results for the new school in New York are presented in Figures 3-98 through 3-100. Figure 3-98 shows the percent of energy supplied by solar vs. collector area. Figures 3-99 and 3-100 show auxiliary heating and cooling loads as a function of solar collector area. A collector area of 20,000 square feet was chosen as the base case for the various energy conservation techniques.

New Construction - Application of Energy Conservation Techniques (ECTs) -- The various ECTs used in the new school for New York are described below. The costs are shown in Appendix B. Tables 3-103 and 3-104 show the results of applying the various ECTs to the new school base case for New York.

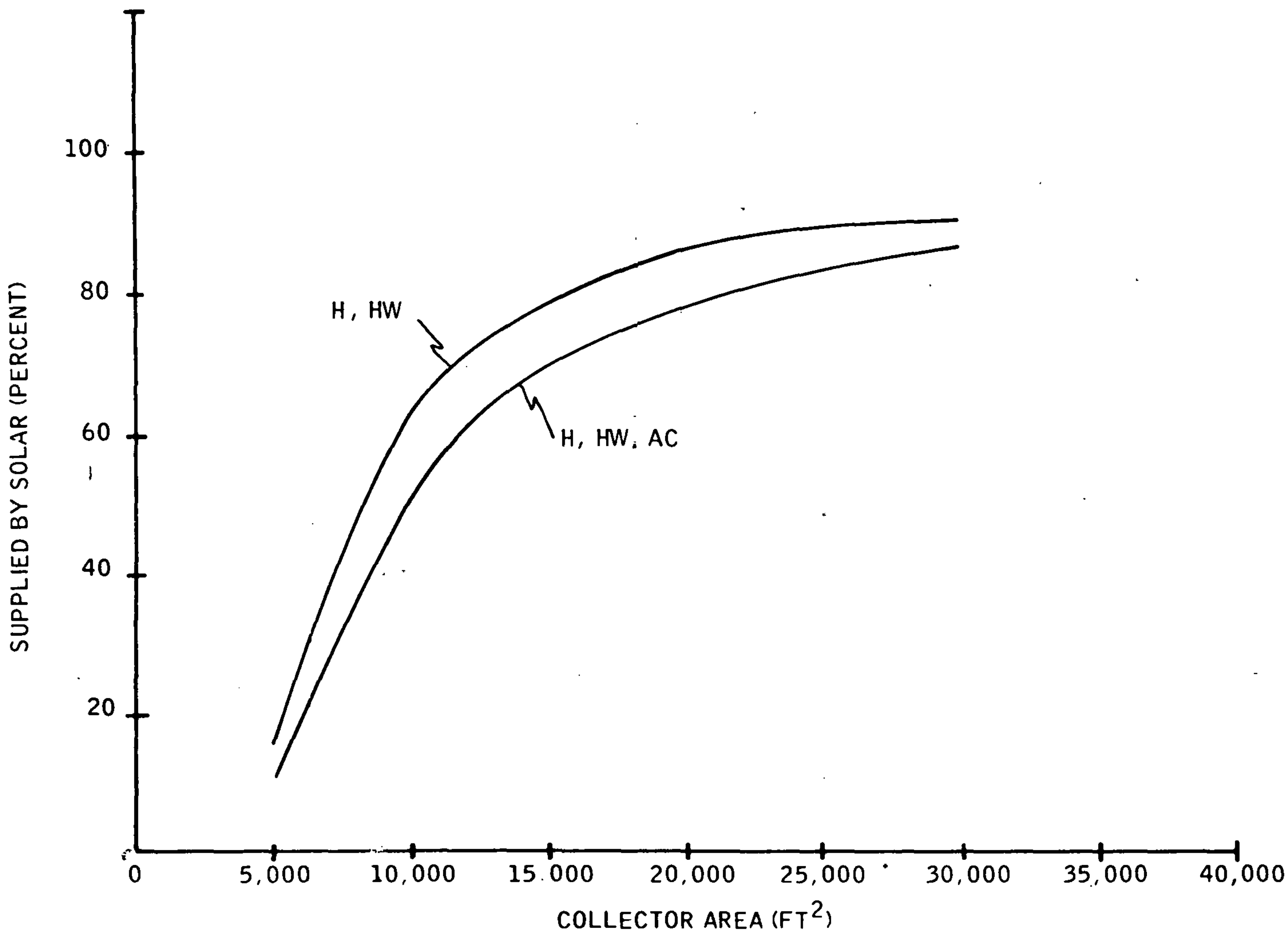


Figure 3-98
Percent Of Load Supplied By Solar Versus Collector Area For (New) School New York Base Case Building

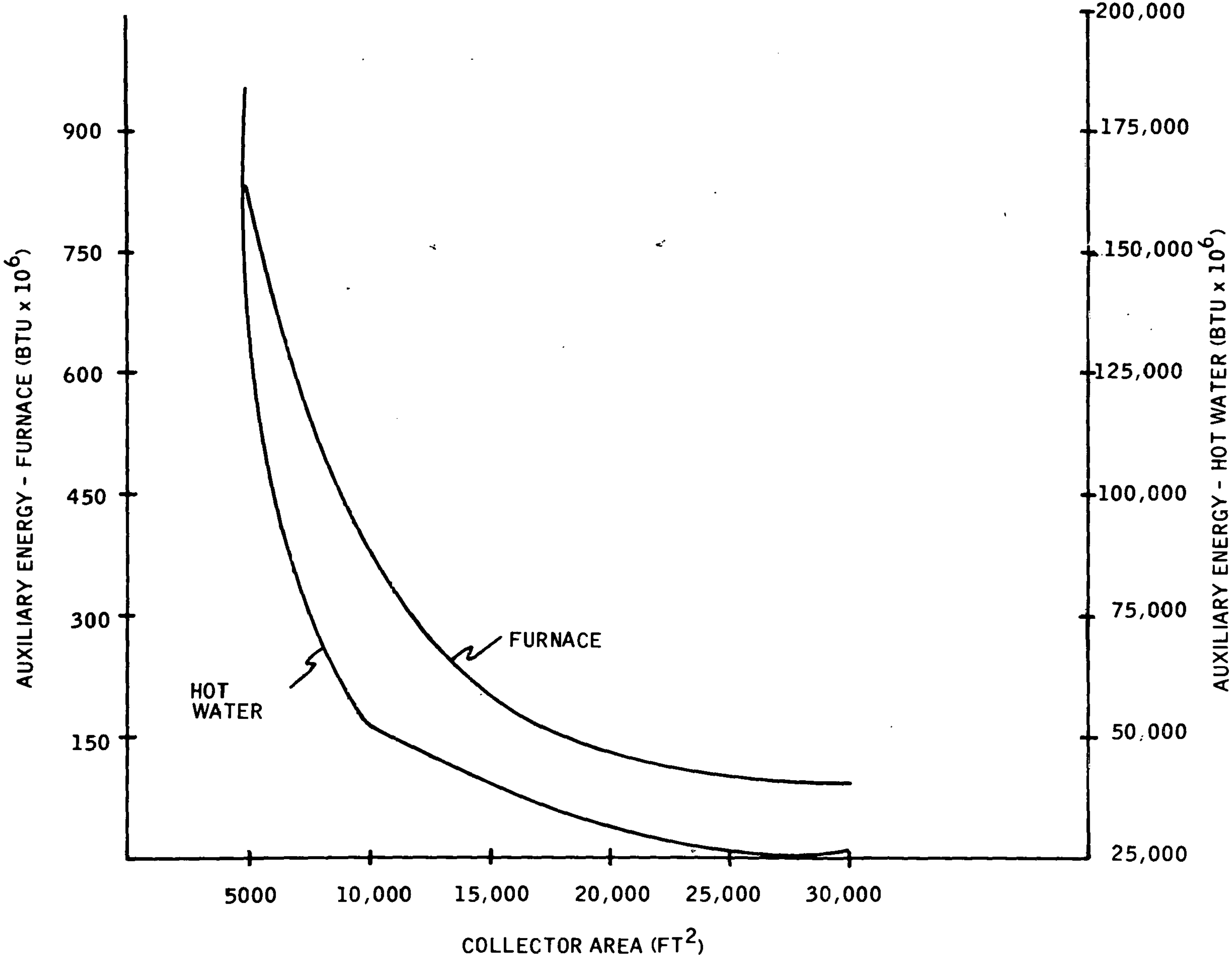


Figure 3-99
Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area For (New) School New York Base Building

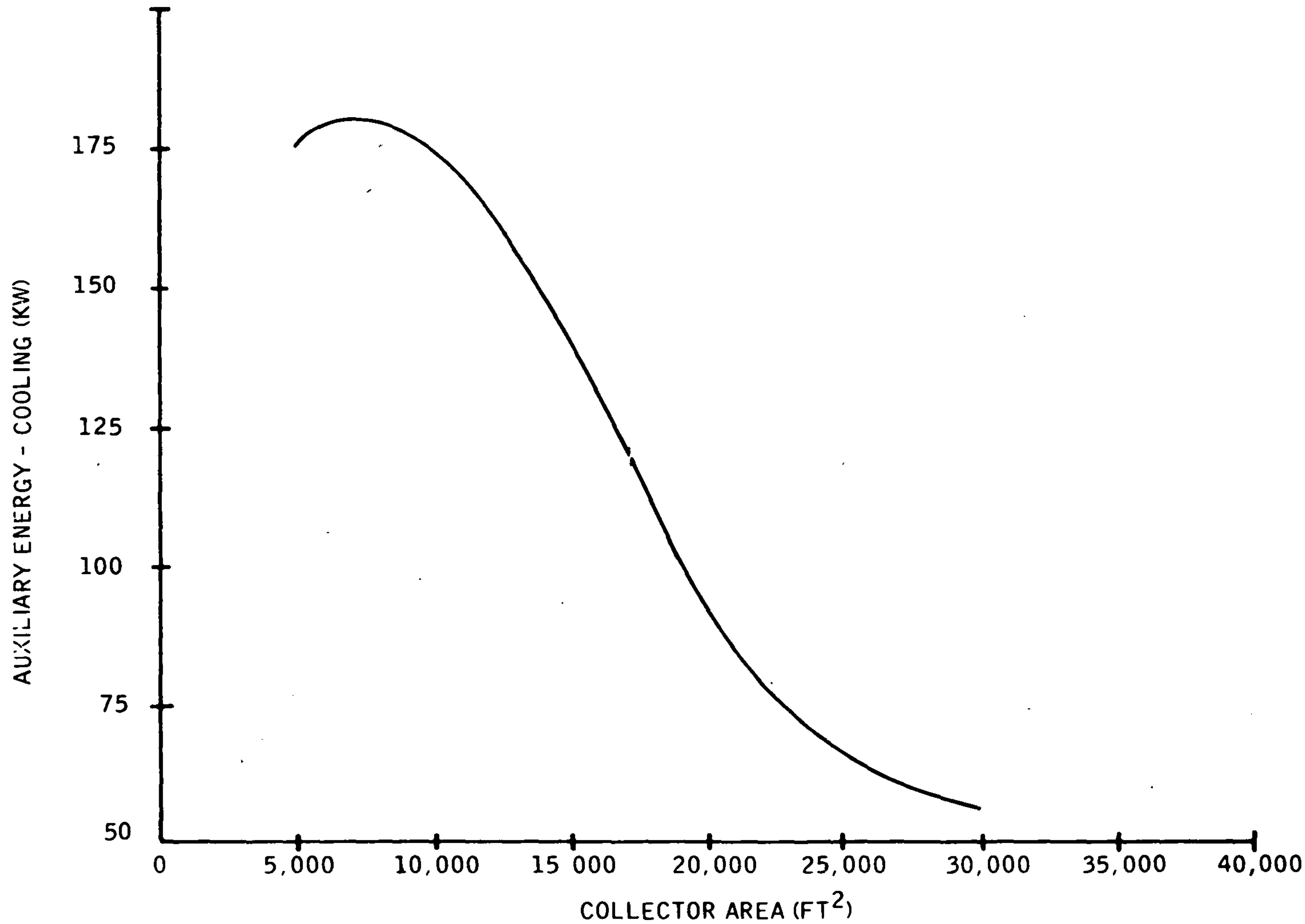


Figure 3-100
Auxiliary Cooling Energy Load Versus Collector Area For (New) School New York Base Building

Table 3-103 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
NEW YORK - SCHOOL (NEW)

ECT Description	Total Load (BTU) x 10^-6	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^-6	% Savings
Base Case	1658	78.8	51401	51599	53402					
Add Wall Insul.	1616	78.9	51794	51977	53641	-393	-378	-239	42	2.5
Add Wall & Ceil. Insulation	1335	78.2	53355	53459	54404	-1954	-1860	-1002	23	19.5
Reflective Film	1615	80	51562	51755	53512	-161	-156	-110	43	2.6
Add Pane Glass	1614	7[illegible]	51718	51905	53594	-317	-306	-192	44	2.66
Insul. HW Tank Reduce Max. T to 130°F.	1633	79.1	51330	51507	53117	71	92	285	25	1.5
Air Economizer	1535	81.5	50809	51008	52814	592	591	588	123	7.7
Night Setback	1498	79	51219	51378	52822	1[illegible]2	221	580	160	9.7
Shading*	1641	79.8	51235	51436	53261	166	163	141	17	1
Reduced Vent.	1590	78	51417	51588	53142	-16	11	260	68	4.1

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Table 3-104 Summary Loads, Costs And Savings

HEATING AND HOT WATER
NEW YORK - NEW SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base Case	1151	87.1	44849	45048	46850					
Add Wall Insul.	1104	87.7	45203	45386	47049	-354	-338	-199	47	4.1
Add Wall & Ceil. Insulation	779	91	46471	46575	47521	-1622	-1527	-671	372	32.3
Reflective Film	1152	87.5	45257	45451	47208	-408	-403	-358	1	.1
Add Pane Glass	1110	87.6	45178	45364	47054	-329	-316	-204	41	3.6
Insul. HW Tank Reduce Max. T. to 130°F.	1129	87.4	44797	44974	46584	52	74	266	2	
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	987.7	88.3	44623	44787	46230	221	261	720	163	14.2
Shading*	1174	87.2	44905	45107	46932	-57	-59	-82	-23	-2
Reduced Vent.	1041	88	44609	44780	46334	240	268	516	11	9.6

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Adding Wall Insulation -- To implement this ECT, two inches of rigid insulation are added to the walls, saving energy but increasing costs. The additional costs are less for the more expensive fuels.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus an additional two inches of roof insulation. This technique reduces energy consumption by 20 percent for heating and cooling and 32 precent for heating only. However, it results in greater annual costs, the smallest increased cost being for electric auxiliary fuel.

Reflective Window Coating -- This is implemented by installing windows and doors which are coated with a reflective coating which reduces the glass transmittance by 80 percent and the thermal conductivity of the glass by 20 percent. This ECT increases annual costs without saving energy.

Triple Glazing -- This ECT is accomplished by installing triple pane insulated glass, thereby reducing both the glass transmittance and thermal conductivity. This ECT saves a small amount of energy, but it increases annual costs.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130 °F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water. This ECT saves both energy and dollars.

Air Economizer -- An air economizer was added, which is used to supply some of the cooling load when the outside temperature is less than 75 °F. This ECT saves energy and dollars during the cooling season. The savings are about the same for gas, oil, and electric auxiliary fuels. This is to be expected, since savings occurs only for cooling which is handled by electricity in all cases.

Night Setback; Cooling Off at Night -- This ECT involves installing a time clock thermostat which can set the temperature back to 60°F (during the heating season) between the hours of 10:00 p.m. and 6:00 a.m., and shut off the cooling between these hours (during the cooling season). This ECT is a cooling conservation technique and saves both dollars and energy for heating only, as well as heating and cooling. The dollar savings are greatest for electric auxiliary fuel, as would be expected, and least for gas auxiliary fuel.

Shading -- Shading was accomplished in the simulation by reducing the energy tranmitted through the east and west windows by 60 percent and the south windows by 90 percent. The technique (awnings, drapes, etc.) was not priced; therefore, savings must be weighed against the actual cost. Shading could save money during the cooling season if the installation is not very costly. (See Table 3-103).

Reduced Ventilation -- The present system in the new schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position that the dampers can close down to. Reduced ventilation saves energy and dollars for all fuels in the heating only system, Again, the savings are greater for electric auxiliary fuel.

Existing Construction - Base Case -- The base case results for the existing school building in New York are presented in Figures 3-101 through 3-103. Figure 3-94 shows the percent of energy that is supplied by solar as a function of collector area for both heating and cooling modes. Figures 3-102 and 3-103 show auxiliary heating and cooling loads vs. collector area. A collector area of 30,000 square feet was used as the base case against which the various energy conservation techniques will be compared.

Existing Construction - Application of Energy Conservation Techniques (ECTs)

The various ECTs used in the existing school analysis are described below. The costs for the various ECTs are shown in Appendix B.

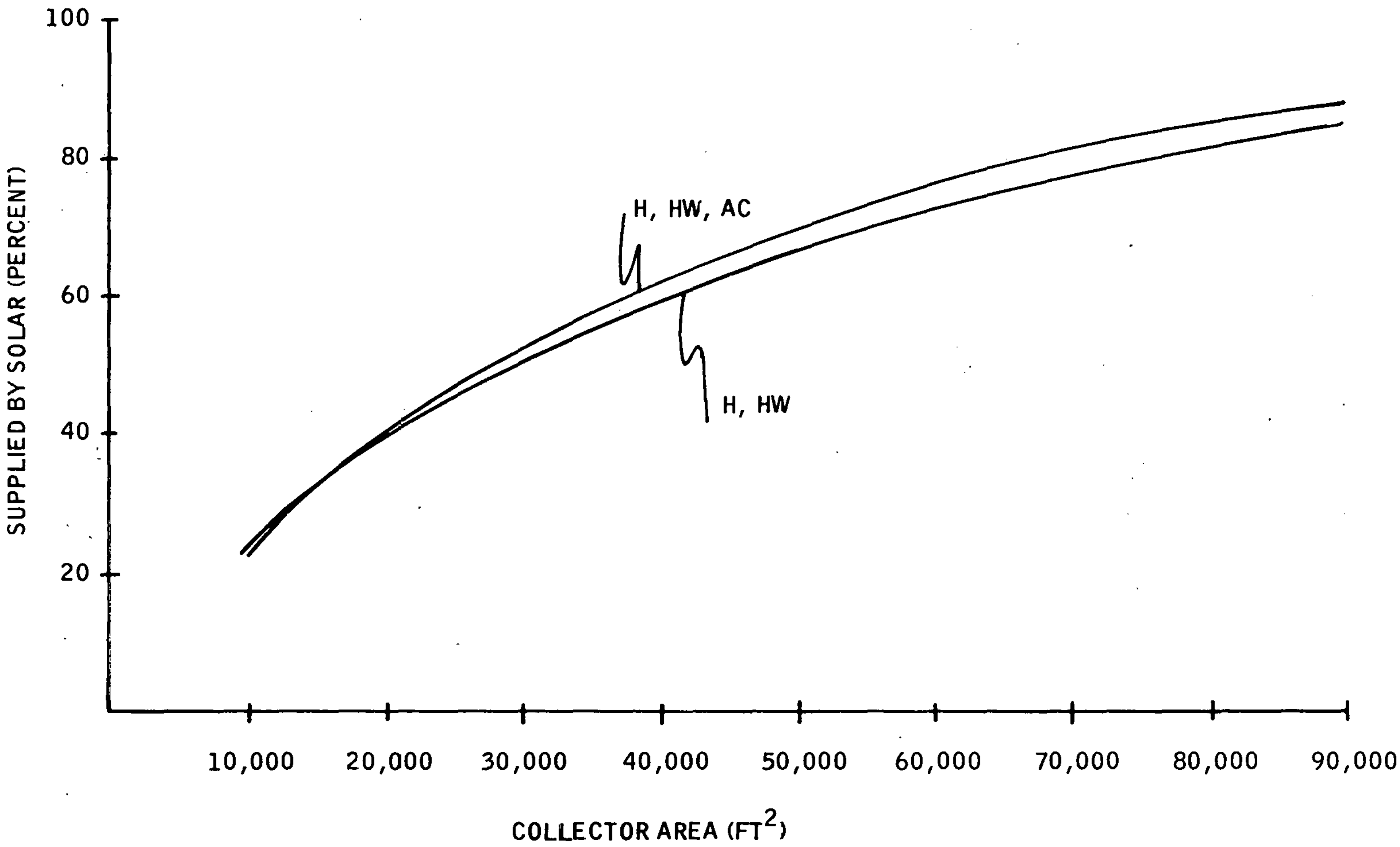


Figure 3-101
Percent Of Load Supplied By Solar Versus Collector Area For (Existing) School New York Base Building

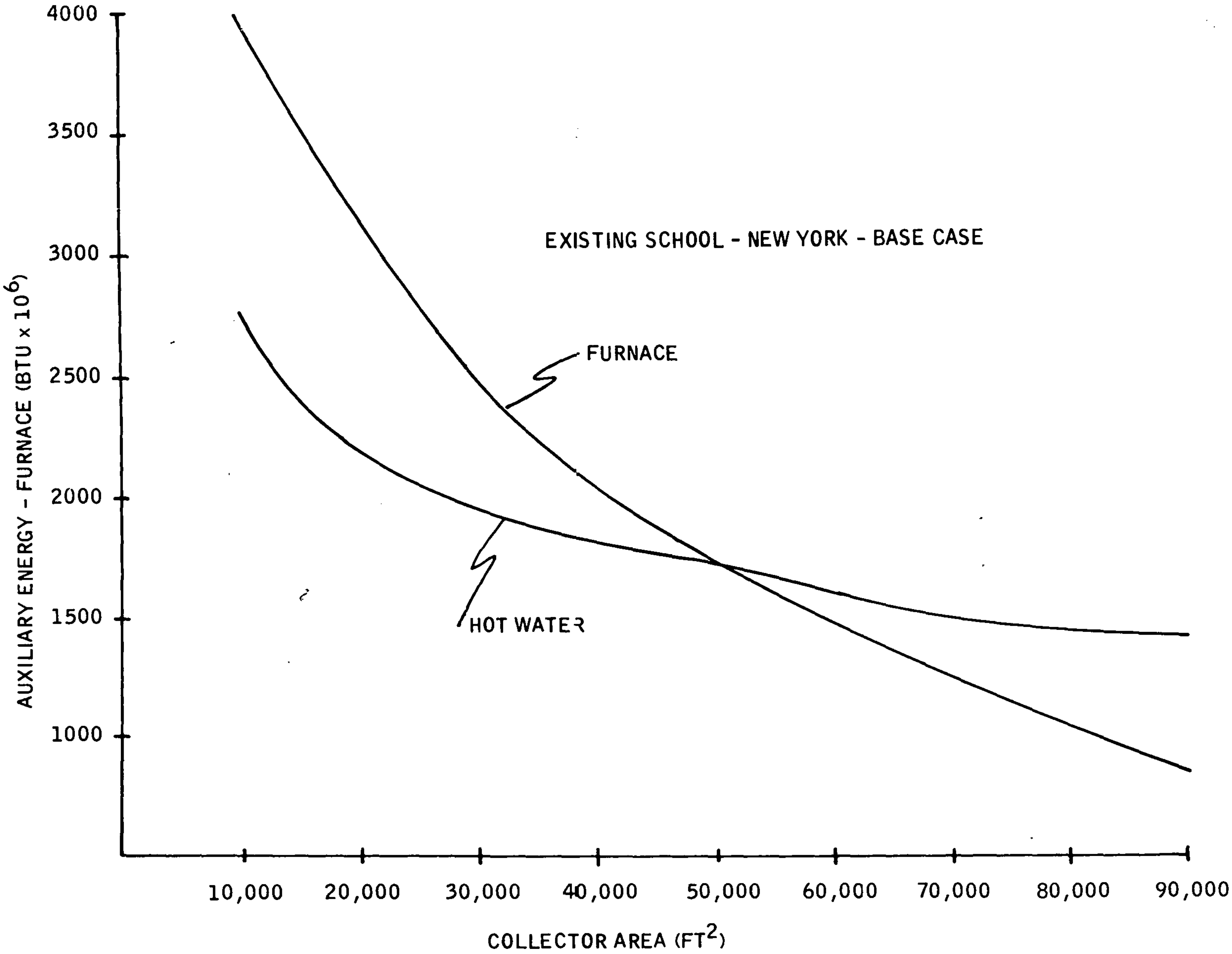


Figure 3-102
Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area
Existing School New York Base Case

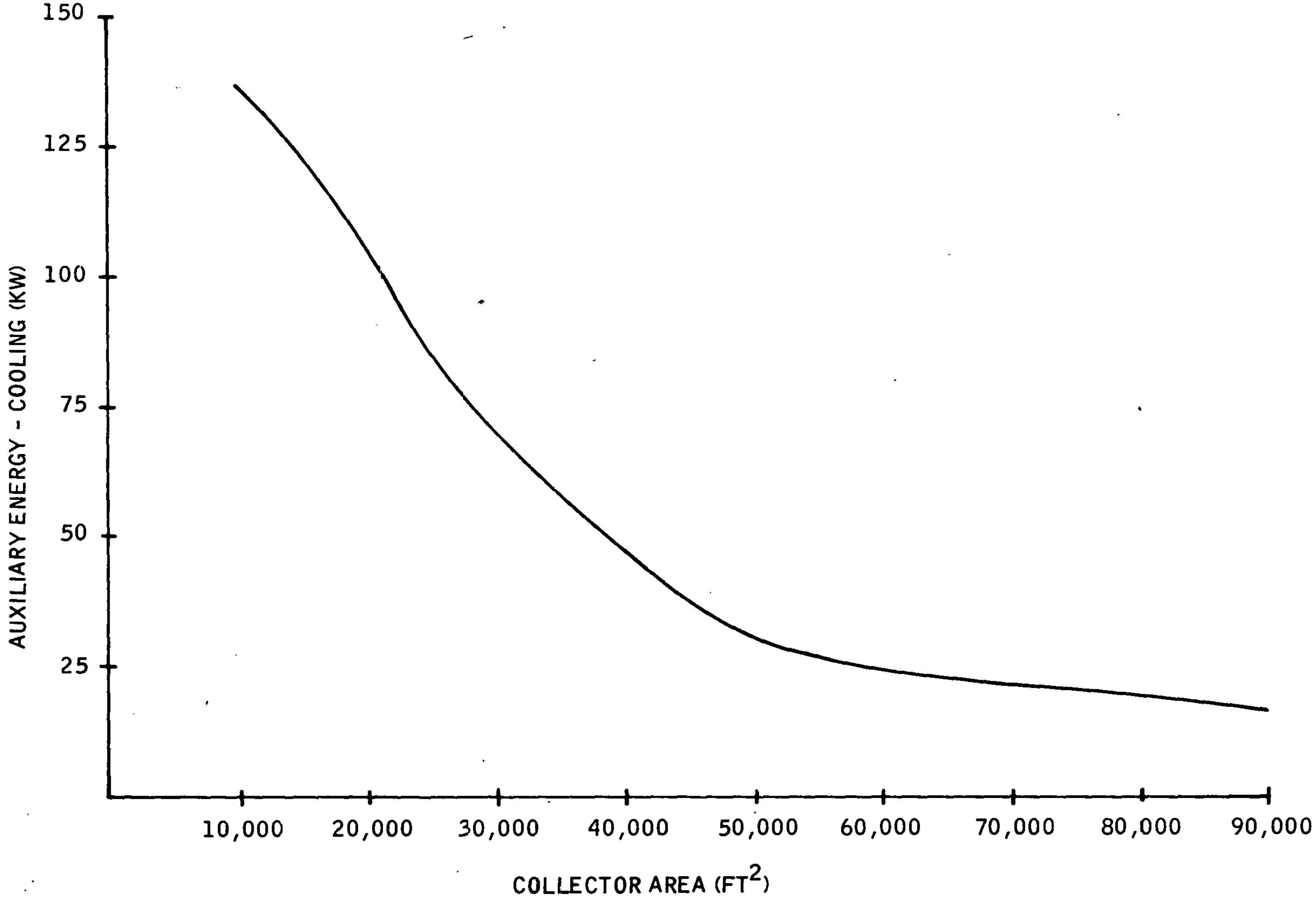


Figure 3-103
Auxiliary Cooling Energy Load Versus Collector Area For

(Existing) School New York Base Building

Tables 3-105 through 3-108 show the results of applying the various ECTs to the above described base case.

Adding Wall Insulation --To implement this, four inches of rigid insulation are added to the walls resulting in energy and money savings in all cases considered.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus four inches of roof insulation. This ECT results in the greatest energy and dollar savings for heating and cooling, and heating only systems for all auxiliary fuels. It can be seen that the total load is about the same as that of the new building with the same insulation. (The difference can be accounted for by additional panes of glass in the new building.)

Reflective Window Coating -- This is implemented by installing a reflective film over the inside of the window panes reducing the glass transmittance by 80 percent and the thermal conductivity of the glass by 20 percent. As is expected, this decreases the cooling load, but the annual cost is still greater than the base case. The cost increase is least for the most expensive auxiliary fuel. Of course, for heating only, this ECT costs even more.

Double Glazing -- This ECT is accomplished by installing an interior glass "storm" window thereby reducing both the glass transmittance and thermal conductivity. This ECT saves a little energy and saves dollars for both oil and electric auxiliary fuel, most of the savings occur during heating only.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130°F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water. Although the energy savings are not very large (less then 1 percent), there are dollar savings for all auxiliary fuels for both heating only, and heating and cooling systems.

Table 3-105 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
NEW YORK - EXISTING - SCHOOL

ECT Description	Total Load (BTU) x 10^-6	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^-6	Annual Load Savings % Savings
Base Case	5708	52.6	80775	83893	11202					
Add Wall Insulation	5301	55.3	79922	82512	106014	853	1381	6188	407	7.1
Add Wall & Ceiling Insulation	1406	86.7	74792	74888	75755	5983	9005	36447	4302	75.4
Reflective Film	5680	53.0	81240	84335	112430	-465	-442	-228	28	.5
Add Pane Of Glass	5567	53.4	80823	83802	110847	-48	91	1355	141	2.5
Insul. H W Tank Reduce Max. T. to 130° F.	5685	52.6	80700	83792	111857	75	101	345	23	.4
Air Econc.	5678	52.6	80703	83822	112134	72	71	68	30	.5
Night Setb.	4938	56.1	78541	81125	103677	2134	2768	8525	770	13.5
Shading	5730	52.5	80561	83815	112445	114	78	-243	-22	-.4
Reduced Vent.	5540	53.7	80330	83298	110239	445	595	1963	168	2.9

* Shading was assumed to cost nothing so the savings must be balanced against the actual cost.

Table 3-106 Summary Loads, Costs And Savings

HEATING AND HOT WATER

NEW YORK - EXISTING - SCHOOL

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 Case	5268	50.7	75011	78130	106439					
Add Wall Insul.	4857	53.4	74142	76731	100233	869	1399	6206	411	7.8
Add Wall & Ceil. Insulation	846	91.2	68137	68233	69100	6874	9897	37339	4422	84
Reflective Film	5265	51.2	75634	78729	106824	-623	-599	-385	3	.1
Add Pane of Glass	5129	51.5	75083	78062	105107	-72	68	1332	139	2.6
Insul. HW Tank Reduce Max. T. to 130°F.	5242	50.78	74939	78031	106096	72	99	343	26	.5
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	4488	53.9	72840	75324	97876	2171	2806	8563	780	14.8
Shading *	5311	50.7	75017	78170	106801	-6	-40	-362	-43	-.8
Reduced Vent.	5107	51.9	74590	77558	104599	421	572	1840	161	3.1

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Table 3-107 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
NEW YORK - EXISTING SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base (3 Watts)	5644	53	86927	89898	116865					
Base (2 Watts)	5708	52.6	80775	83893	112202	6152	6005	4663		

Table 3-108 Summary Loads, Costs And Savings

HEATING AND HOT WATER
NEW YORK - EXISTING SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base (3 Watts/ft.^{2})	5065	51.37	80599	83570	110538					
Base (2 Watts/ft.^{2})	5263	50.7	75011	78130	106439	5588	5440	4099		

Air Economizer -- An air economizer was added which is used to supply some of the cooling load when the outside temperature is less than 75°F. This ECT which is only applicable during the cooling season, saves minimal dollars and energy.

Night Setback; Cooling Off at Night -- This ECT involves installing a chronotherm which can set the temperature back to 60°F (during the heating season) between the hours of 10 p.m. and 6 a.m. The cooling is assumed to be shut off between these hours (during the cooling season) by maintenance personnel. This technique results in a sizable energy and dollar savings for all types of auxiliary fuels considered.

Shading -- Shading was accomplished in the simulation by reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced. Therefore, savings must be weighed against the actual cost. As expected, shading costs more money for heating only. During the cooling season, it can be seen from Tables 3-105 and 3-106 that shading reduces the cooling load.

Reduced Ventilation -- The HVAC system in existing schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position. Reduced ventilation saves dollars both for heating and cooling, the savings being greater for the higher priced auxiliary fuel.

Lighting -- All ECTs were examined on the base building using two watts/ft^2 maximum illumination. To examine the effect of reducing the lighting maximum level from three watts/ft^2, the base case was run at the three watts/ft^2 level for comparison. Tables 3-107, 3-108 show the effect of reducing the maximum lighting level by 1 watt/ft^2. It is seen that fairly large savings are involved for all auxiliary fuels. The savings are less for electric auxiliary fuel, since the heating load which was supplied by the lights now must be supplied by the auxiliary fuel. The cost of the extra watt/ft^2 is included in the three watt case, based on the average predicted cost of electricity in New York over the twenty year period considered.

Atlanta - Southeast Region

New Construction - Base Case -- The base case results for the new school in Atlanta are presented in Figures 3-104 through 3-106. Figure 3-104 shows the percent of load that is supplied by solar energy as a function of solar collector area for heating, hot water and heating, hot water and cooling. It is seen that the heating, hot water curve is considerably above the heating and cooling curve for most collector areas. Figures 3-105 and 3-106 show the auxiliary heating and cooling loads as a function of collector area. A collector area of 20, 000 ft^2 was chosen as the base case.

New Construction - Application of Energy Conservation Techniques (ECTs) -- The various ECTs used in the new school analysis for Atlanta are described below. The costs for the various ECTs are shown in Appendix B. Tables 3-109, 3-110 show the results of applying the various ECTs to the above described base case.

Adding Wall Insulation -- To implement this ECT, two inches of rigid insulation are added to the walls, saving energy but adding to annual cost. The additional cost is less for the more expensive auxiliary fuels.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus an additional two inches of roof insulation. Again, energy is saved by this technique, but total annual costs are increased.

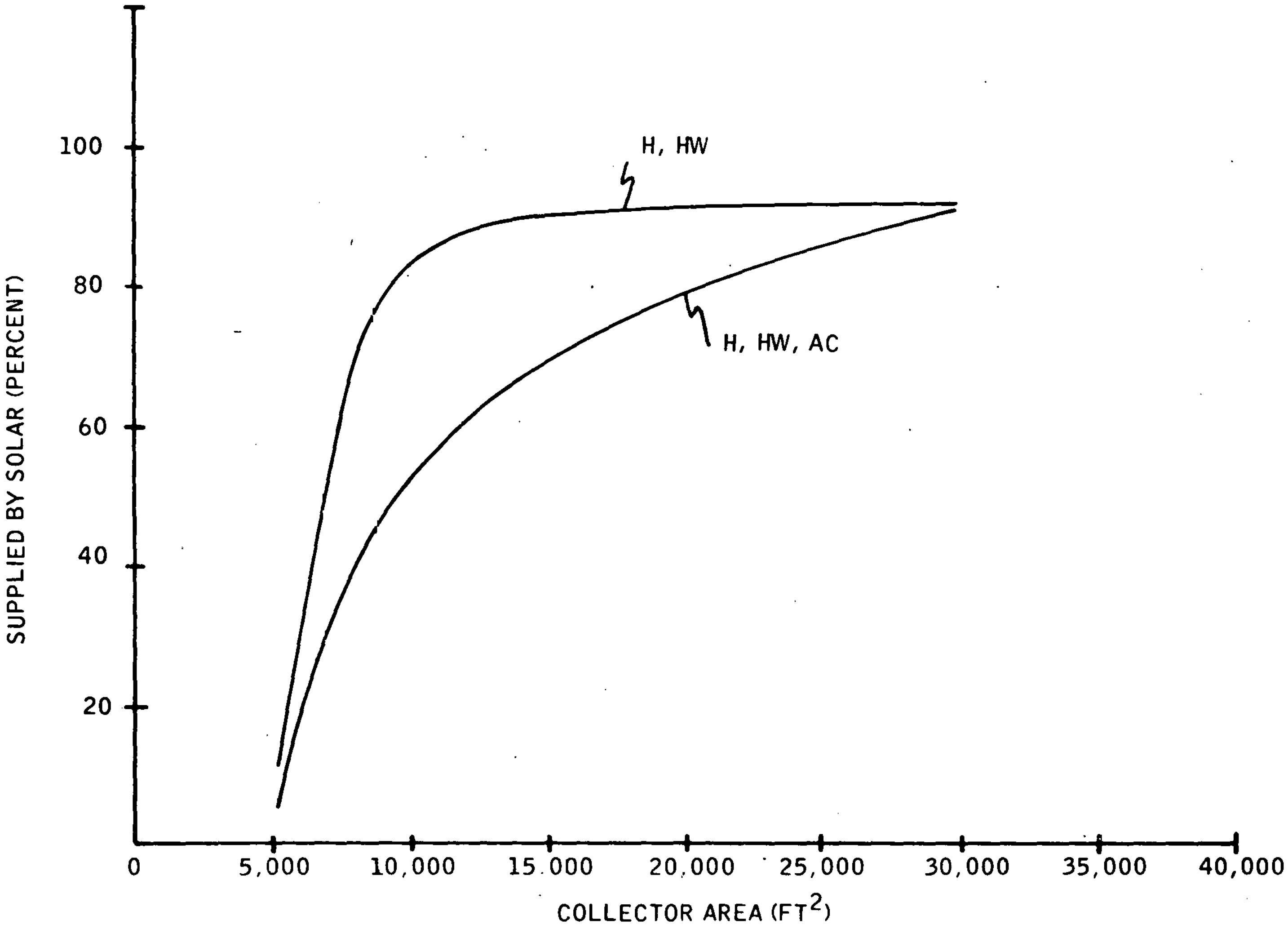


Figure 3-104
Percent Of Load Supplied By Solar Versus Collector Area For
(New) School Atlanta Base Building

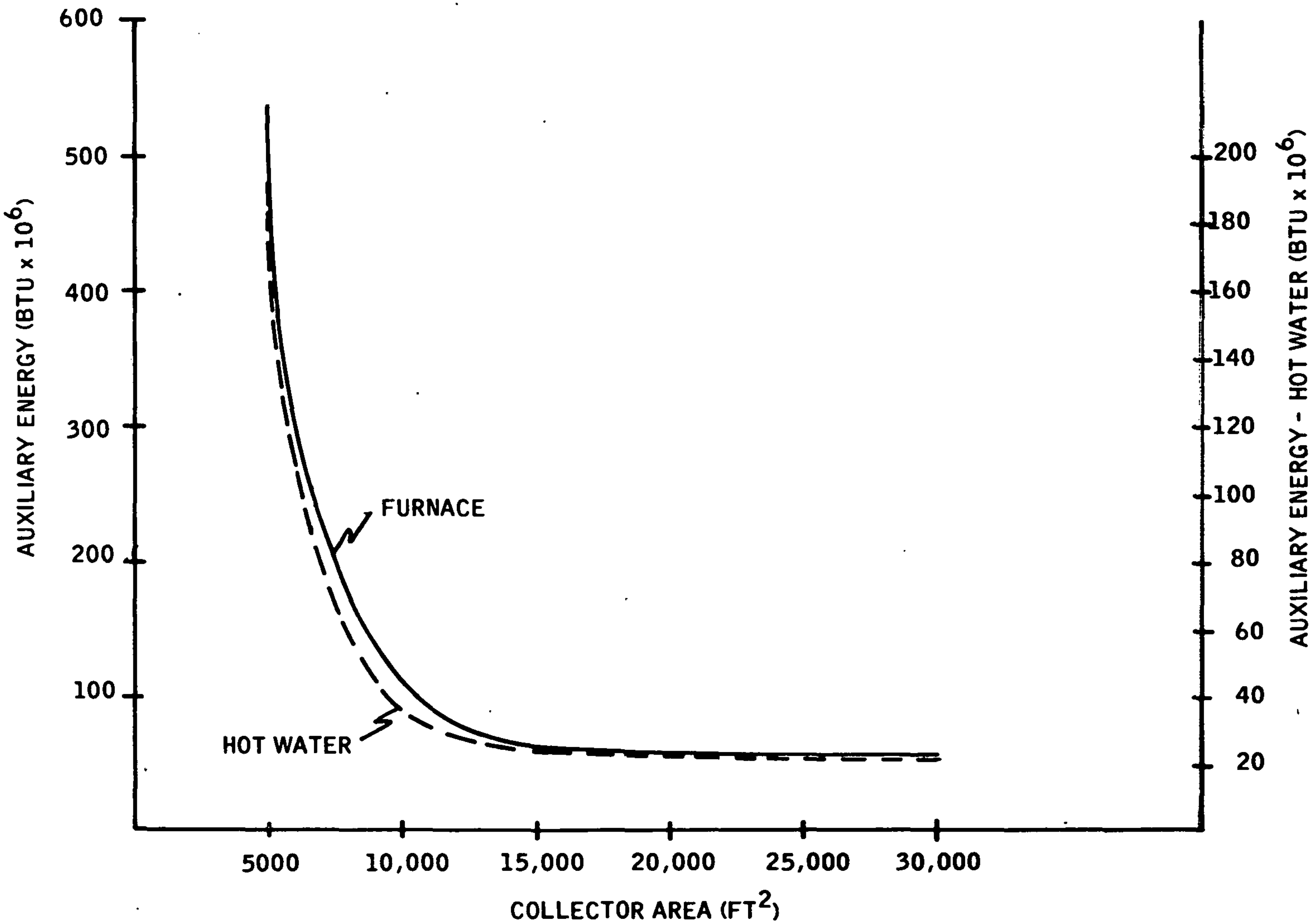


Figure 3-105
Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area For (New) School Atlanta Base Building

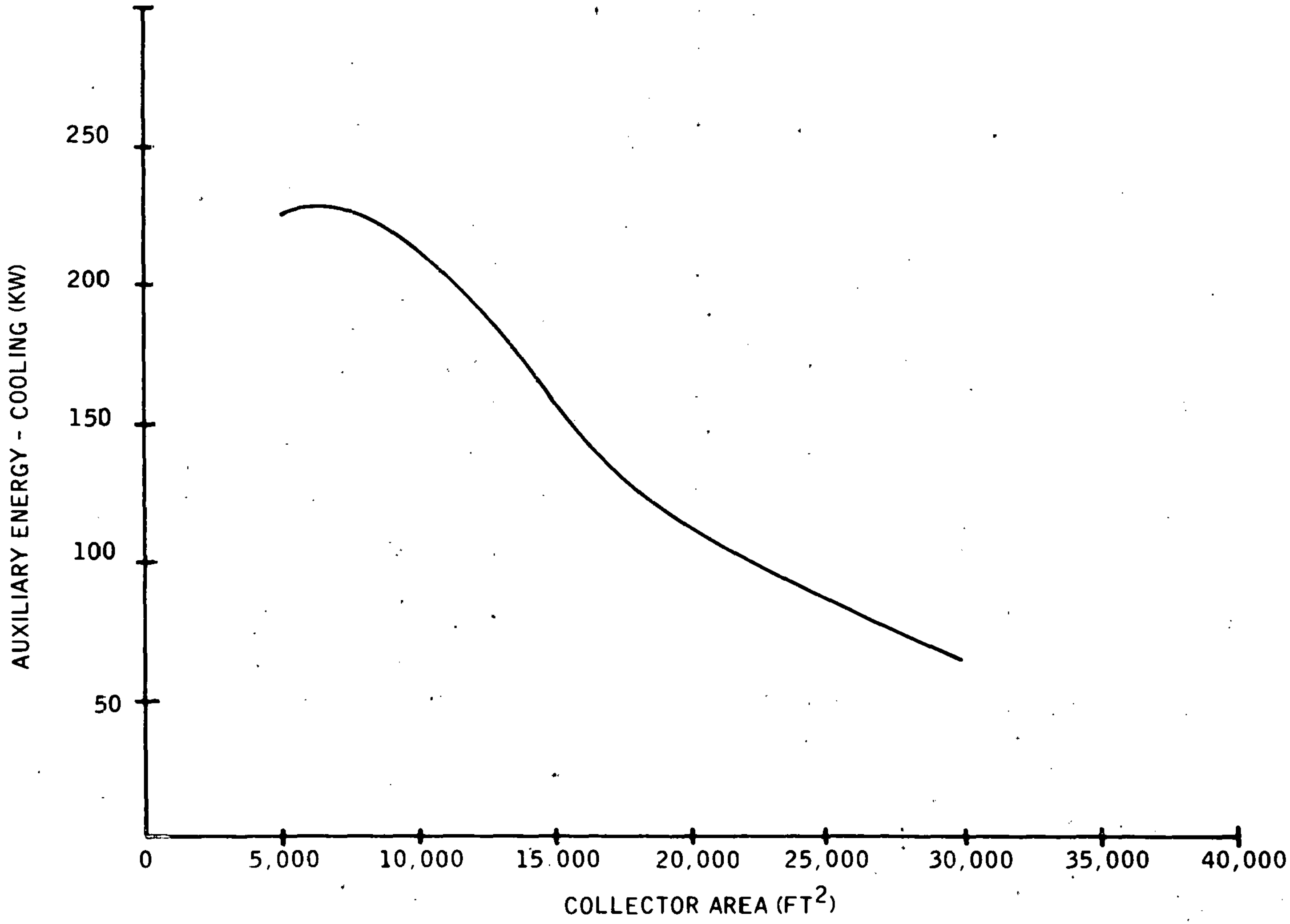


Figure 3-106
Auxiliary Cooling Energy Load Versus Collector Area For
(New) School Atlanta Base Building

Table 3-109 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
ATLANTA - NEW - SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base Case	1645	79.5	51305	51420	52075					
Add Wall Insul.	1616	79.6	51598	51708	52330	-293	-288	-255	29	1.8
Add Wall & Ceil. Insulation	1431	79.1	52798	52875	53308	-1493	-1455	-1233	214	13
Reflective Film	1571	81.1	51341	51455	52096	-36	-35	-21	74	4.5
Add Pane Glass	1608	79.8	51542	51652	52276	-237	-232	-201	37	2.2
Insul. HW Tank Reduce Max. T. to 130 °F.	1617	79.8	51244	51340	51883	61	80	192	28	1.7
Air Economizer	1513	81.1	50910	51024	51671	395	386	404	132	8
Night Setback	1501	79.2	51210	51311	51881	95	109	194	144	8.8
Shading*	1595	80.8	51111	51226	51880	194	194	195	50	3
Reduced Vent.	1598	80.5	51185	51291	51889	120	129	186	47	3

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Table 3-110 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
ATLANTA - NEW - SCHOOL

ECT Description	Total Load (BTU) x 10^-6	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^-6	Annual Load Savings % Savings
Base Case	777	91.2	43902	44018	44673					
Add Wall Insul.	747	91.4	44194	44304	44926	-292	-286	-253	30	3.9
Add Wall & Ceil. Insulation	547	92.6	45324	45401	45834	-1422	-1383	-1161	230	29.6
Reflective Film	774	91.4	44218	44331	44973	-316	-313	-300	3	.4
Add Pane Glass	751	91.4	44178	44288	44912	-276	-270	-239	26	3.3
Insul. H. W. Tank Reduce Max. T. to 130°F.	753	91.3	43861	43956	44499	41	62	174	24	3.1
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	639	91.1	43814	43915	44486	88	103	187	138	17.8
Shading	789	91.3	43933	44049	44703	-31	-31	-30	-12	-1.5
Reduced Vent.	728	91.6	43812	43917	44515	90	101	158	49	6.3

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Reflective Window Coating -- This is implemented by installing windows and doors which are coated with a reflective coating which reduces the glass transmittance by 80 percent and the thermal conductivity of the glass by 20 percent. This technique saves energy and dollars during the cooling season. However, for heating and cooling, and heating only, it costs more than the base case.

Triple Glazing -- This ECT is accomplished by installing triple pane insulated glass, thereby reducing both the glass transmittance and thermal conductivity. This technique costs more than the base case and reduces the heating and cooling loads somewhat.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130°F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water, saving both dollars and energy for all auxiliary fuels during both heating and cooling.

Air Economizer -- An air economizer is used to supply some of the cooling load when the outside temperature is less than 75°F. This technique, operative only during the cooling season, is seen to save both dollars and energy for the heating and cooling system.

Night Setback; Cooling Off at Night -- This ECT involves installing a time clock thermostat which can set the temperature back to 60°F (during the heating season) between the hours of 10:00 p.m. and 6:00 a.m., and shut off the cooling between these hours (during the cooling season). This ECT is a cooling conservation technique and saves both dollars and energy. The savings are higher for the higher priced fuels.

Shading -- Shading was accomplished in the simulation be reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced, therefore, savings must be weighed against the actual cost. Shading could save dollars during the cooling season as evidenced by Tables 3-105 and 3-106.

Reduced Ventilation -- The present system in the new schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position. Reducing the ventiliation results in energy and dollar savings both for cooling and heating.

Existing Construction - Base Case -- The base case results for the existing school in Atlanta are presented in Figures 3-107 through 3-109. Figure 3-107 shows the percentage of load supplied by solar energy vs. collector area, both for heating only and heating and cooling systems. Figures 3-108 and 3-109 show the auxiliary energy load as a function of collector area for furnace, hot water heater and auxiliary air conditioning. A collector area of 30,000 ft^2 was chosen as the base case against which the various energy conservation techniques will be evaluated.

Existing Construction - Application of Energy Conservation Techniques (ECTs) -- The various ECTs used in the existing school analysis are described below. The costs are shown in Appendix B. Tables 3-111 through 3-114 show the results of applying the various ECTs.

Adding Wall Insulation -- To implement this, four inches of rigid insulation are added to the walls. This ECT saves energy and, in the case of electric auxiliary fuel, dollars.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus four inches of roof insulation. This technique saves significant energy (67 percent - heating and cooling; 83 percent heating only) and dollars for all auxiliary fuel types.

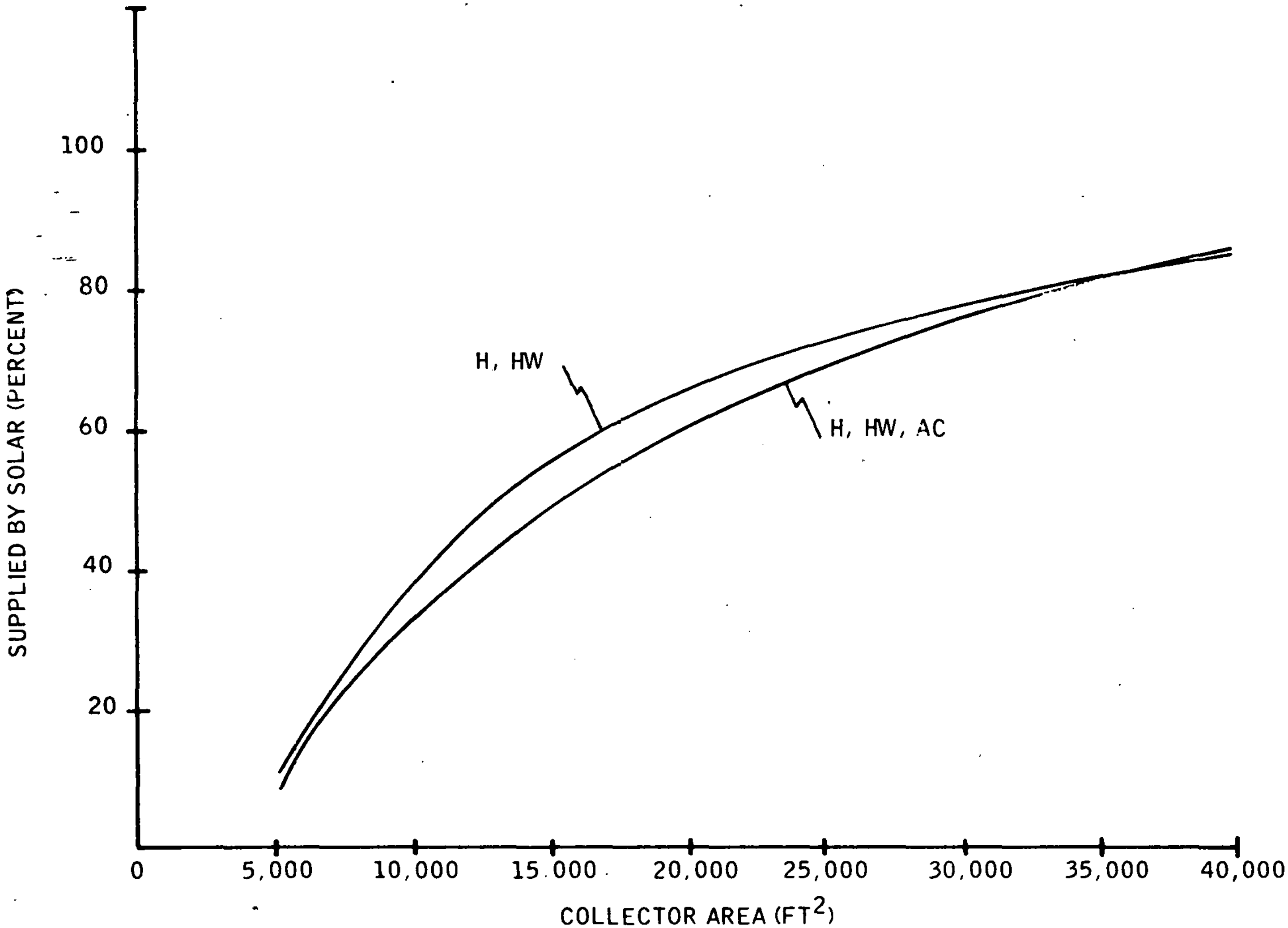


Figure 3-107
Percent Of Load Supplied By Solar Versus Collector Area For (Existing) School Atlanta Base Building

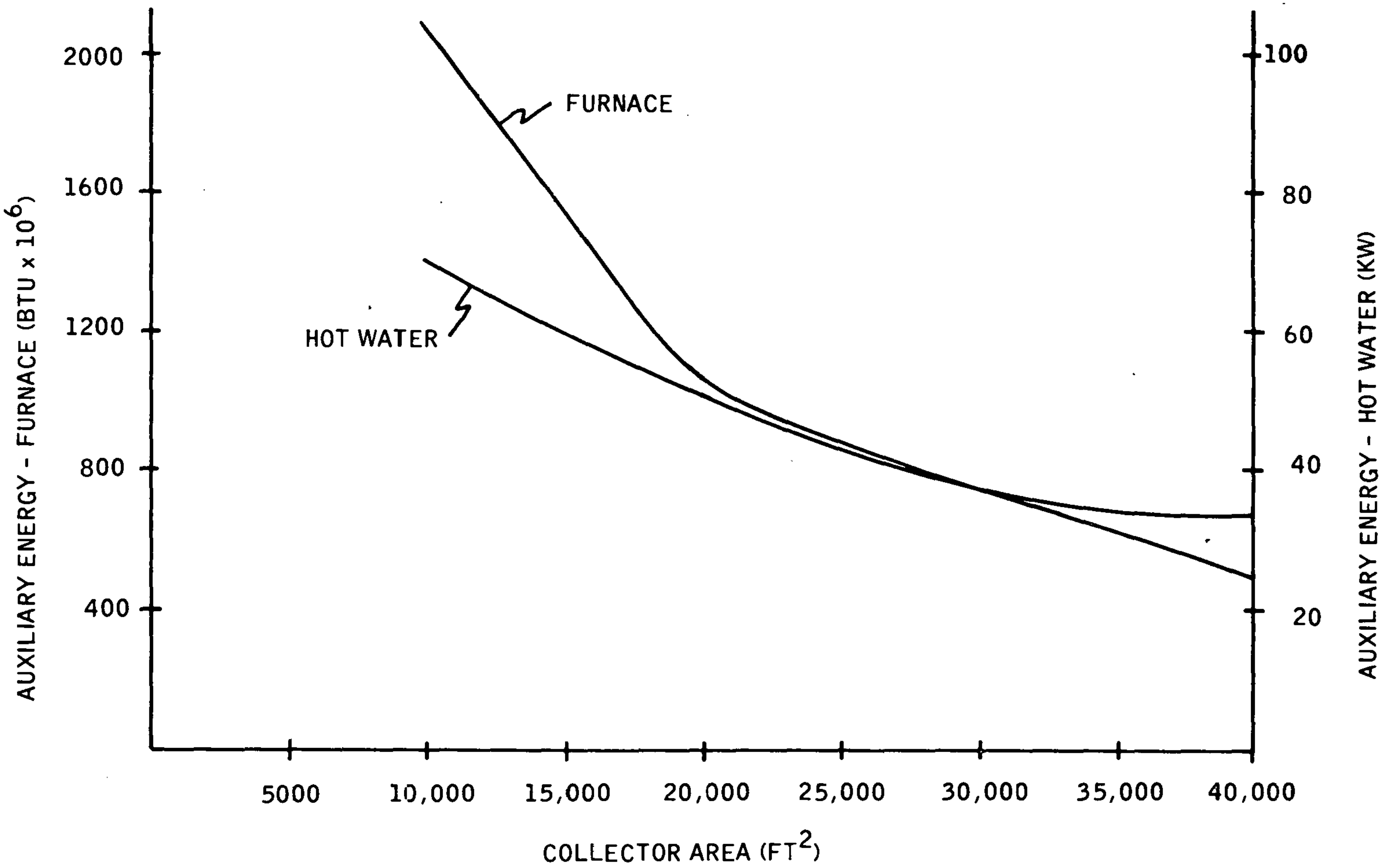


Figure 3-108
Auxiliary Energy Supplied By Furnace And Hot Water Heaters Versus Collector Area For (Existing) School Atlanta Base Building

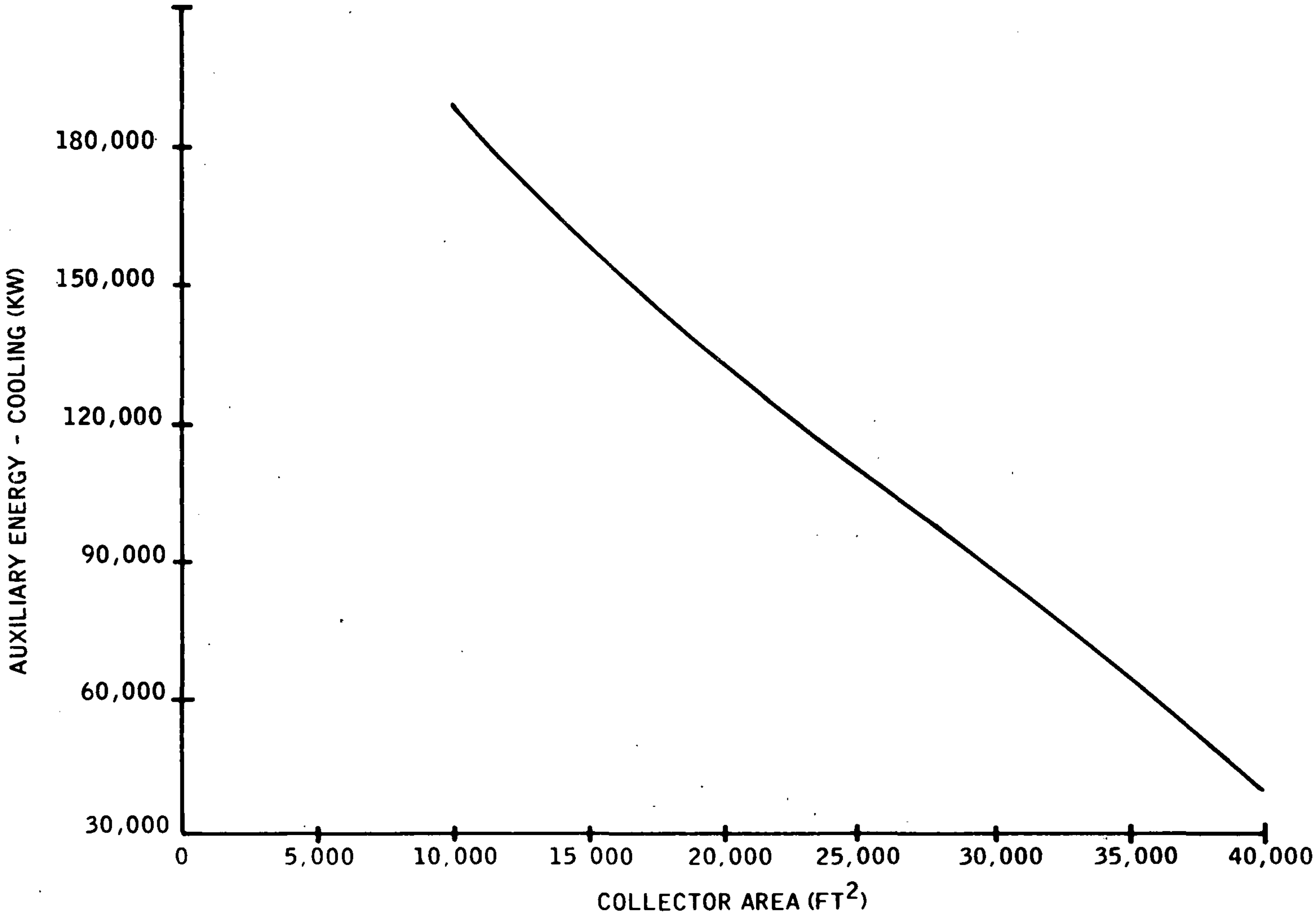


Figure 3-109
Auxiliary Cooling Energy Load Versus Collector Area For (Existing) School Atlanta Base Building

Table 3-111 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING

ATLANTA - EXISTING - SCHOOL

ECT Description	Total Load (BTU) x 10^-6	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^-6	% Savings
Base Case	4587	76.3	74506	75575	81626					
Add Wall Insul.	4301	78.4	74641	75550	80699	-135	25	927	286	6.2
Add Wall & Ceil Insulation	1511	91.1	73987	74066	74509	519	1509	7117	3076	67
Reflective Film	4508	77.1	74703	75749	81675	-197	-174	-49	79	1.7
Add Pane Glass	4495	76.9	74696	75718	81507	-180	-143	119	92	2
Insul. H. W. Tank Reduce Max. T. to 130°F.	4562	76.5	74432	75474	81381	74	101	245	25	.5
Air Economizer	4571	76.43	74505	75573	81622	1	2	4	16	.3
Night Setback	3887	80.6	73223	73926	77909	1283	1649	3717	700	15.3
Shading*	4585	76.6	74421	75499	81605	65	76	21	2	0
Reduced Vent.	4432	77.6	74300	75323	81118	206	252	508	155	3.4

Table 3-112 Summary Loads, Costs And Savings

ATLANTA - EXISTING - SCHOOL

HEATING AND HOT WATER

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base Case	3495	77.81	66994	68062	74113					
Add Wall Insul.	3236	79.8	67197	68106	73256	-203	-44	857	259	7.4
Add Wall & Ceil In	601	93.1	6[illegible]86	66664	67107	408	1398	706	2894	
Reflective Film	3470	78.12	67380	68426	74352	-386	-364	-239	25	.7
Add Pane Glass	3420	78.3	67234	68256	74046	-240	-194	67	75	2.1
Insul. HW Tank Reduce Max. T. to 130°F.	3472	77.9	66934	67977	73883	60	85	230	23	.7
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	2830	82.1	65868	66571	70555	1126	1491	3558	665	19
Shading*	3531	77.8	67044	68122	74228	-50	-62	-115	-36	-1
Reduced Vent.	3398	78.4	66871	67894	736[illegible]9	123	168	424	97	2.8

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Table 3-113 Summary, Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
ATLANTA - EXISTING - SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base (3 Watts/ft.^{2})	4616	74.8	79615	80632	86393					
Base (2 Watts/ft.^{2})	4587	76.3	74506	75575	81626	5109	5057	4767		

Table 3-114 Summary Loads, Costs And Savings

HEATING AND HOT WATER

ATLANTA - EXISTING - SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base (3 Watts/ft.^{2})	3339	78.1	71589	72605	88367					
Base (2 Watts/ft.^{2})	3495	77.81	66994	68062	74113	4595	4544	4254		

Reflective Window Coating -- This is implemented by installing a reflective film over the inside of the window panes which reduces the glass transmittance by 80 percent and the thermal conductivity of the glass by 20 percent. This technique, although it saves a small amount of energy, adds to the base cost.

Double Glazing -- This ECT is accomplished by installing an interior glass "storm" window, reducing both the glass transmittance and thermal conductivity. This ECT saves dollars only for electric auxiliary fuel.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130°F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water. Both energy and dollars are saved as a result of this ECT.

Air Economizer -- An air economizer was added, which is used to supply some of the cooling load when the outside temperature is less than 75 °F. This ECT saves energy and dollars during cooling.

Night Setback; Cooling Off at Night -- This ECT involves installing a chronotherm which can set the temperature back to 60°F (during the heating season) between the hours of 10 p.m. and 6 a.m. The cooling is assumed to be shut off between these hours (during the cooling season) by maintenance personnel. Both dollars and energy are saved.

Shading -- Shading was accomplished in the simulation be reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced. Therefore, savings must be weighed against the actual cost. This ECT could save dollars if it could be used only during the cooling season.

Reduced Ventilation -- The HVAC system in the existing schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position, saving both energy and dollars for heating and heating and cooling systems.

Lighting -- Tables 3-113 and 3-114 show the dollar savings which result from using 2 watts/ft^2 maximum illumination rather than 3 watts/ft^2. All of the above ECTs and the base case used 2 watts/ft^2. The cost of the additional watt was computed based on the average predicted cost of electricity for Atlanta during the 20 year period considered.

Albuquerque - Southwest Region

New Construction - Base Case -- The base case results for the new school in Albuquerque are presented in Figures 3-110 through 3-112. Figure 3-110 shows the percent of energy supplied by solar vs. collector area. Figures 3-111 and 3-112 show auxiliary energy usage versus collector area. A solar collector area of 10,000 ft^2 was chosen as the base case for new schools in Albuquerque.

New Construction - Application of Energy Conservation Techniques (ECTs) -- The various ECTs used are described below. Costs of ECTs are shown in Appendix B. Tables 3-115 and 3-116 show the results.

Adding Wall Insulation - To implement this, one inch of rigid insulation is added to the walls. This causes slight savings for electric auxiliary fuel.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus an additional two inches of roof insulation. This costs more than the base case, except for the case of electric auxiliary fuel.

Reflective Window Coating -- This is implemented by installing windows and doors which are coated with a reflective coating which reduces the glass transmittance by 80 percent and the thermal conductivity of the glass by 20 percent. This ECT costs more than the base case. It lowers the cooling load, but not

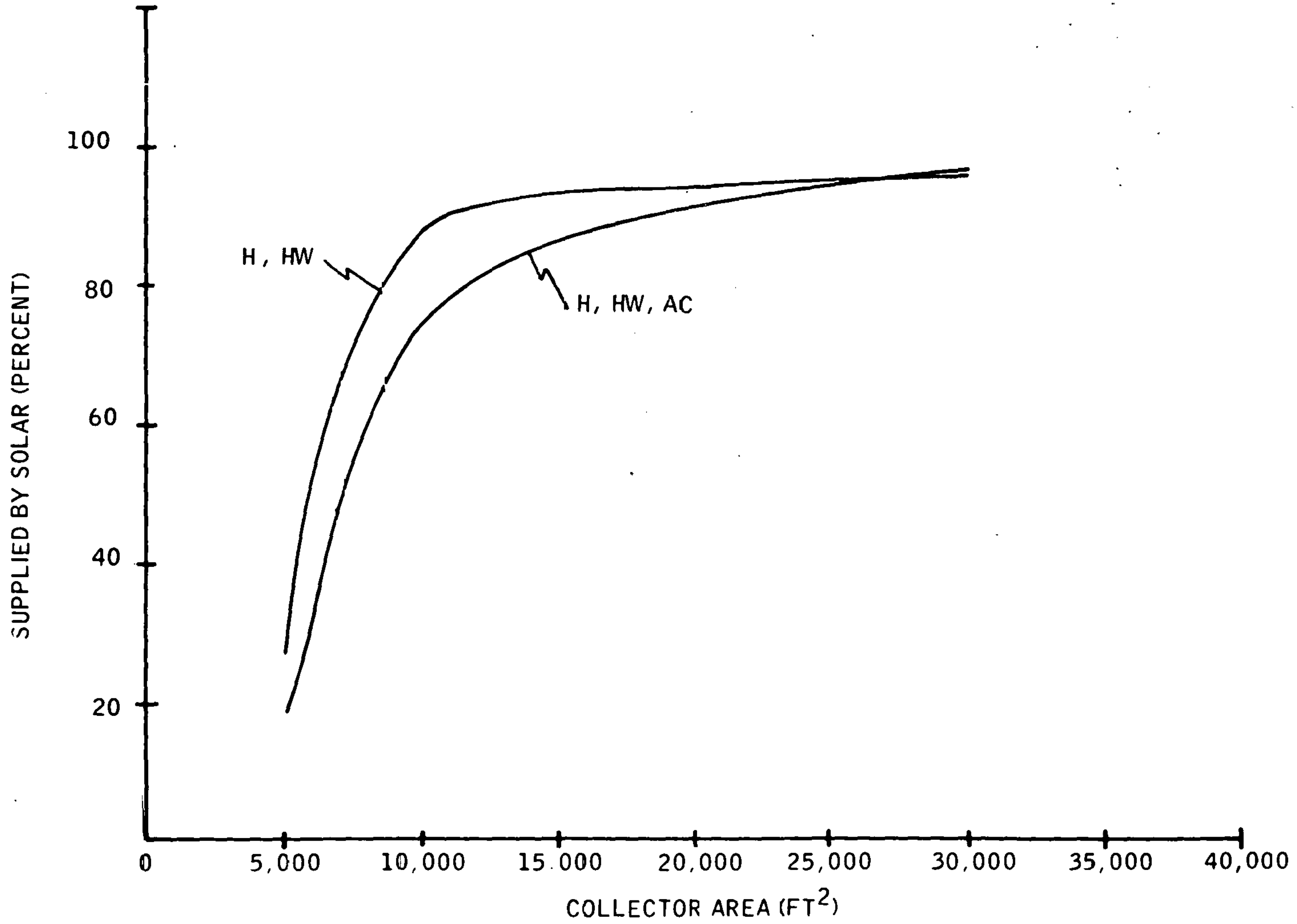


Figure 3-110
Percent Of Load Supplied By Solar Versus Collector Area For
(New) School Albuquerque Base Building

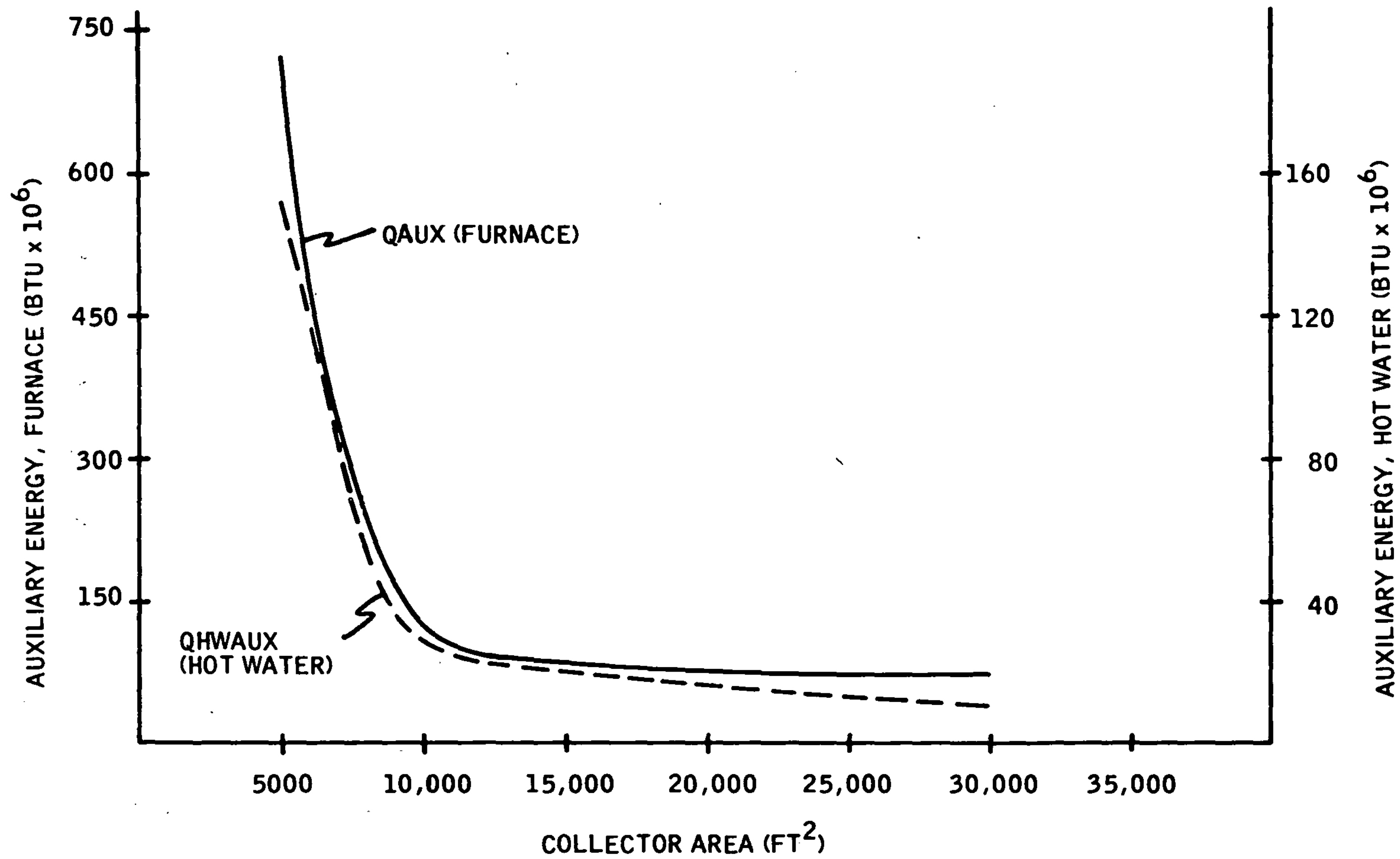


Figure 3-111
Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area For (New) School Alburquerque Base Building

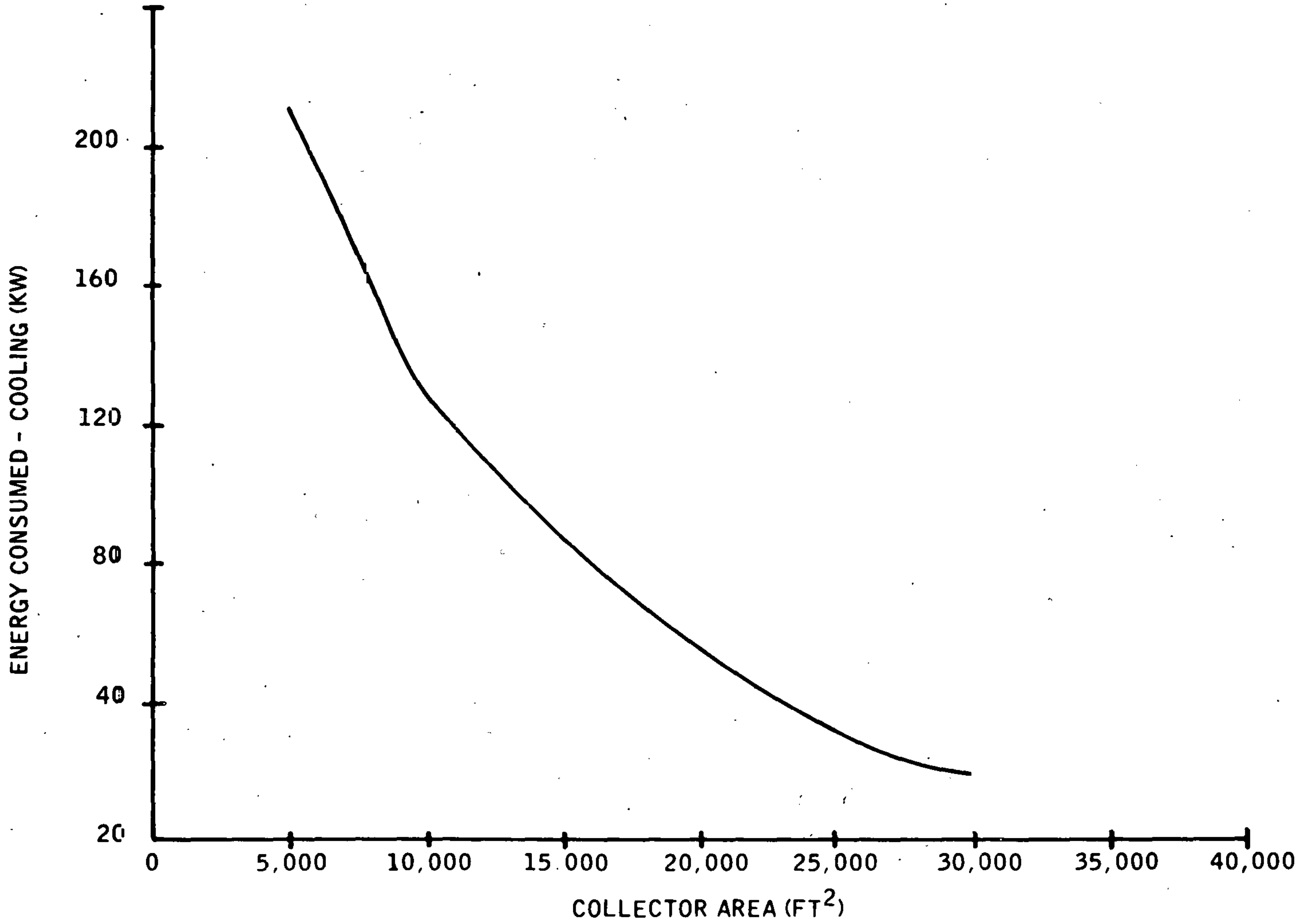


Figure 3-112
Energy Required For Auxiliary Cooling Versus Collector Area For (New) School Albuquerque Base Building

Table 3-115 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
ALBUQUERQUE - NEW SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU x 10^{-6}	Annual Load Savings % Savings
Base Case	1723	75	32170	32368	33532					
Add Wall Insul.	1655	75.5	32297	32464	33449	-127	-96	83	68	4
Add Wall & Ceil. Insulation	1358	74.9	32861	32952	33487	-691	-584	45	365	21.2
Reflective Film	1684	74.8	32322	32558	33949	-152	-190	-417	39	2.3
Add Pane of Gla.	1676	75.6	32342	32522	33584	-172	-154	-52	47	2.7
Insul. HW Tank Reduce MAX T. to 130°F.	1698	75.3	32116	32292	33328	54	76	204	25	1.5
Air Economizer	1624	78.3	31800	31997	33155	370	371	377	99	5.7
Night Setback	1550	75.9	31982	32129	32993	188	239	539	175	10
Shading *	1711	76.6	32060	32268	33496	110	100	36	12	.7
Reduced Vent.	1653	74.6	32082	32243	33192	88	125	340	70	4.1

* Shading was assumed to cost nothing, so the savings must be balanced against the actual cost.

Table 3-116 Summary Loads, Costs And Savings

HEATING AND HOT WATER

ALBUQUERQUE - NEW - SCHOOL

ECT Description	Total Load (BTU) x 10^{-6}	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Oil	Electric	Annual Savings (Dollars) Gas	Oil	Electric	Annual Load Savings BTU x 10^{-6}	% Savings
Base Case	1165	88.2	25837	26034	27199					
Add Wall Insul.	1095	89.6	25941	26107	27093	-104	-73	106	70	6
Add Wall & Ceiling Insulation	778	93	26371	26462	26997	-534	-428	202	386	33.2
Reflective Film	1183	85.9	26261	26496	27887	-424	-462	-688	-18	-1.5
Add Pane of Glass	1126	89	26034	26214	27276	-197	-180	-77	39	3.3
Insul. H. W. Tank Decr. Max T. to 130°F.	1142	88.4	25784	25960	26996	53	74	203	23	2
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	991	90.1	25626	25772	26636	211	262	563	174	14.9
Shading	1202	87.9	25929	26137	27365	-92	-103	-166	-37	-3.2
Reduced Ventilation	1062	89.8	25611	25772	26722	226	262	477	103	8.8

enough to compensate for the cost of the ECT.

Triple Glazing -- This ECT is accomplished by installing triple pane insulated glass; thereby reducing both the glass transmittance and thermal conductivity. Again, this ECT does not result in dollar savings.

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130°F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water. This ECT saves both dollars and energy for all auxiliary fuel types.

Air Economizer -- An air economizer was added, which is used to supply some of the cooling load when the outside temperature is less than 75°F. This ECT is operative only during the cooling season. For cooling and heating systems, it saves both dollars and energy.

Night Setback; Cooling Off at Night -- This ECT involves installing a time clock thermostat which can set the temperature back to 60°F (during the heating season) between the hours of 10:00 pm and 6:00 am, and shut off the cooling between these hours (during the cooling season). This ECT is a cooling conservation technique and saves both dollars and energy. More savings occur in the case of electric auxiliary fuel.

Shading -- Shading was accomplished in the simulation by reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced. Therefore, savings must be weighed against the actual cost. This can benefit during the cooling season.

Reduced Ventilation -- The present system in the new schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position. Both dollars and energy are saved by this ECT, especially in the heating only system.

Existing Construction - Base Case -- The base case results for the existing school in Albuquerque are presented in Figures 3-113 through 3-115. Figure 3-113 shows percent solar versus collector area. Figures 3-114 and 3-115 show auxiliary furnace, hot water and cooling requirements versus solar collector area. A solar collector area of 30,000 ft^2 was chosen for the base case.

Existing Construction - Application of Energy Conservation Techniques (ECTs) -- The various ECTs used are discussed below. Costs of ECTs are shown in Appendix B. Tables 3-117 through 3-120 show the results of applications of the various ECTs to the base case.

Adding Wall Insulation -- To implement this, two inches of rigid insulation are added to the walls saving both dollars and energy.

Adding Wall and Ceiling Insulation -- This ECT is implemented by adding the above wall insulation plus 4 inches of roof insulation. This ECT saves significant energy (75 percent for heating and cooling; 83 percent for heating alone) and money.

Reflective Window Coating -- This is implemented by installing a reflective film over the inside of the window panes, which reduces the glass transmittance by 80 percent and the thermal conductivity of the glass by 20 percent. Reflective coatings increase annual costs.

Double Glazing -- This ECT is accomplished by adding an interior "storm" window; thereby reducing both the glass transmittance and thermal conductivity. This saves dollars for oil and electric auxiliary fuel systems.

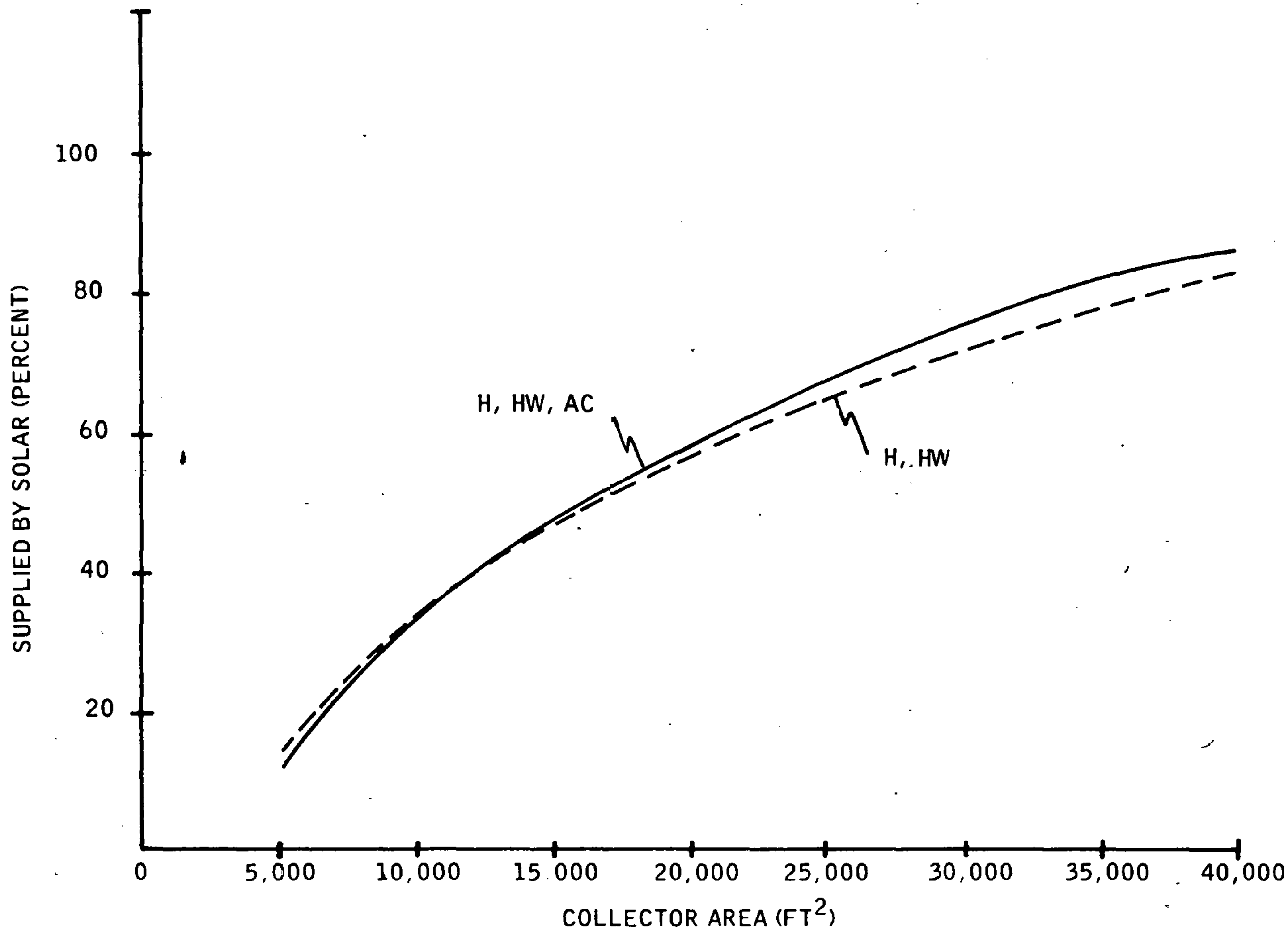


Figure 3-113
Percent Of Load Supplied By Solar Versus Collector Area For (Existing) School Albuquerque Base Building

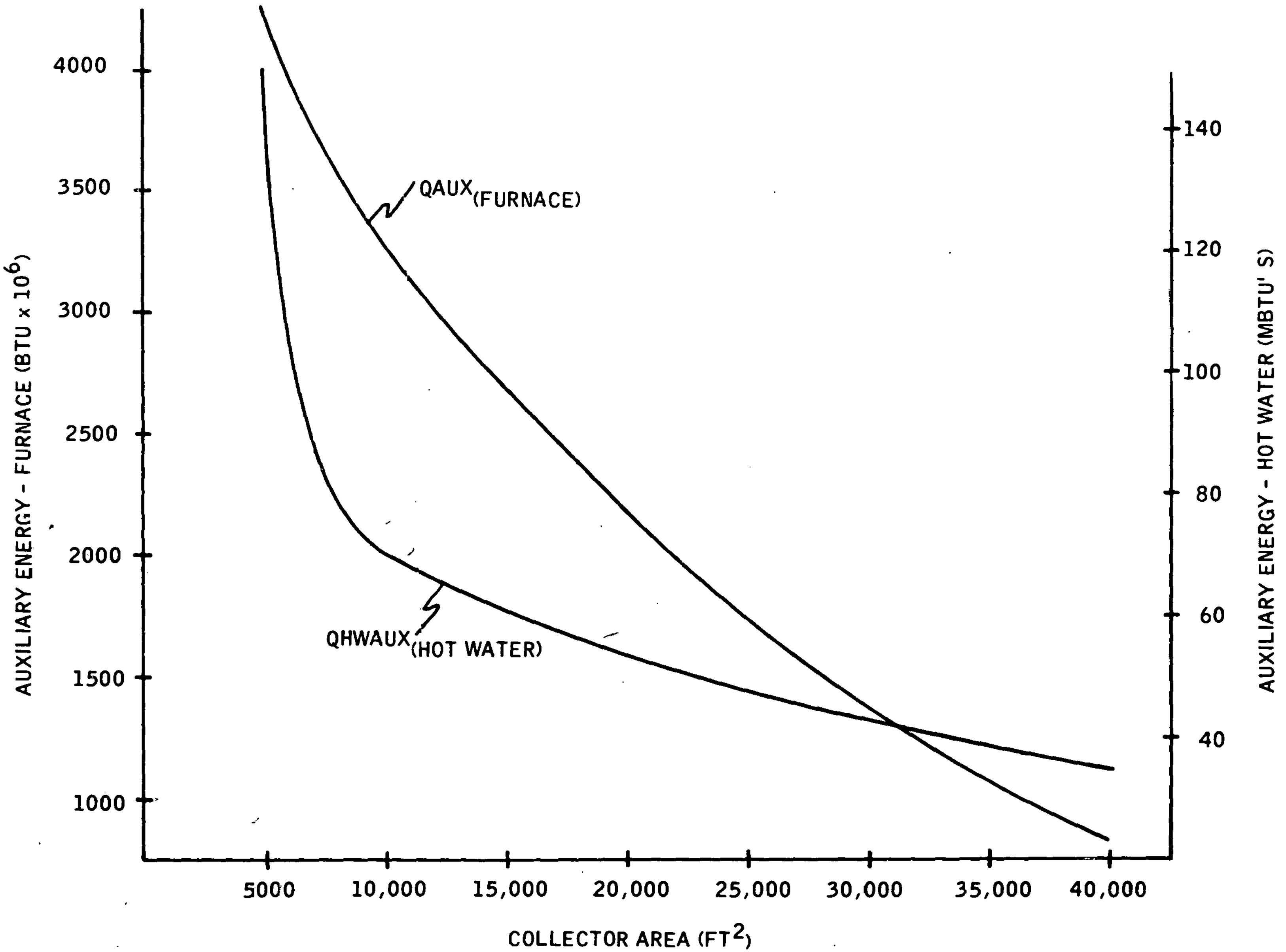


Figure 3-114
Energy Supplied By Auxiliary Furnace And Hot Water Heaters Versus Collector Area For (Existing) School Albuquerque Base Building

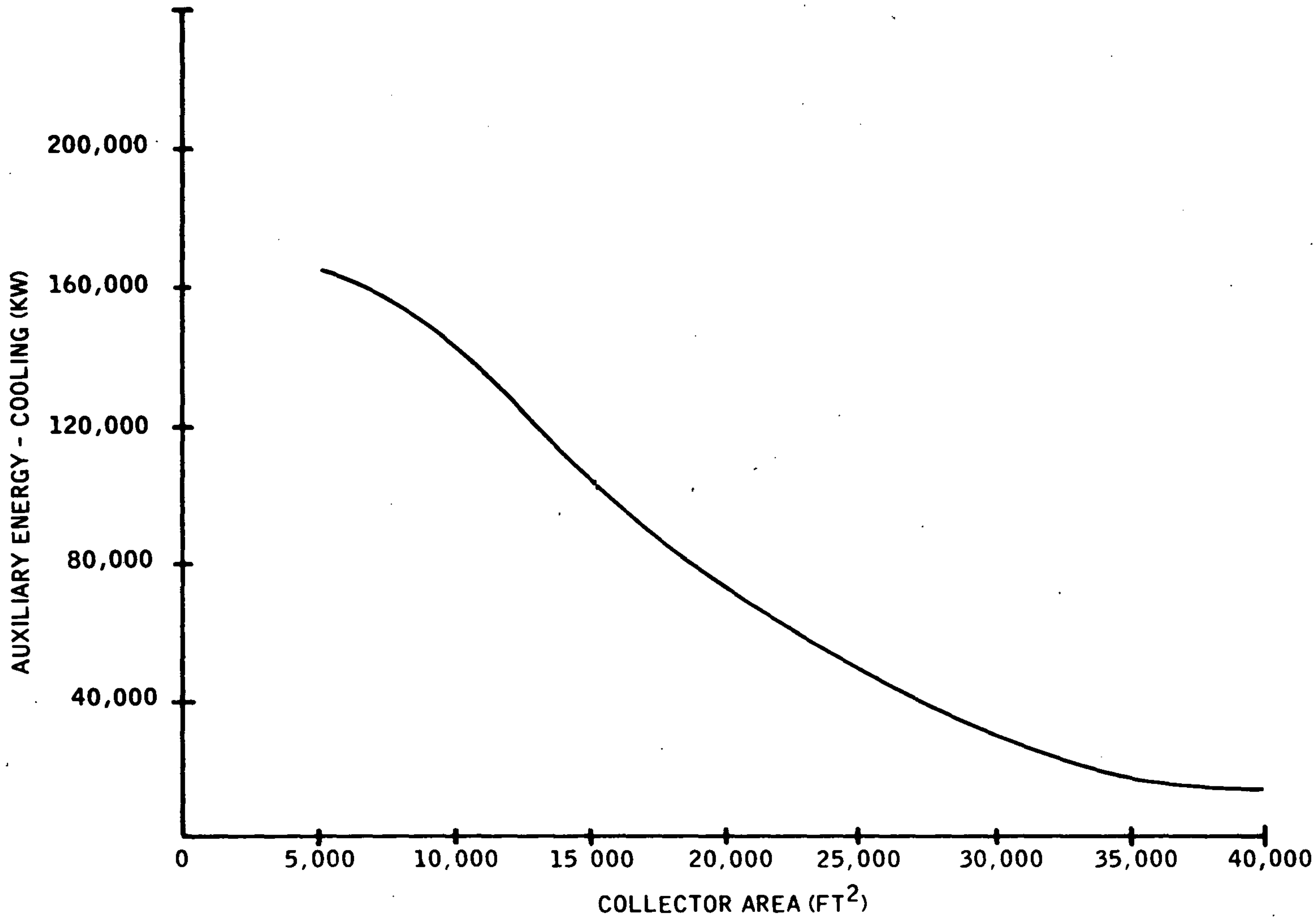


Figure 3-115
Energy Consumed By Auxiliary Cooling Versus Collector Area For (Existing) School Albuquerque Base Building

Table 3-117 Summary Loads, Costs And Savings

HEATING, HOT WATER, AIR CONDITIONING

ALBUQUERQUE - EXISTING - SCHOOL

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 Case	5771	75.1	75888	77739	88663					
Add Wall Insul.	5480	77.3	75630	77233	86693	258	506	1970	291	5
Wall & Ceil. Insul.	1464	97.5	72385	72947	73310	3003	4592	15353	4307	74.6
Reflective Film	5707	75.3	76101	77927	88701	-213	-188	-38	64	1.1
Double Glazing	5652	75.9	75924	77678	88029	-36	61	634	119	2.1
Insul. H. W. Heat	5748	75.1	75835	77661	88439	53	78	224	23	.4
Air Economizer	5752	75	75889	77740	88633	-1	-1	0	19	.3
Night Setback	5008	79.9	74357	75647	83263	1531	2052	5400	763	13.2
Shading	5807	74.5	75956	77866	89133	-68	-127	-470	-36	-.6
Reduced Vent.	5613	76.2	75571	77296	87476	317	443	1187	158	2.7

Table 3-118 Summary Loads, Costs And Savings

HEATING AND HOT WATER
ALBUQUERQUE - EXISTING SCHOOL

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 Case	5053	72	69801	71652	82577					
Add Wall Insul.	4776	74.3	69574	71177	80638	227	475	1939	277	5.5
Wall & Ceil. Insul.	0847	96.2	66496	66557	66920	3305	5095	15657	4206	83.2
Reflective Film	5037	72.2	70171	71997	82771	-370	-345	-194	16	.3
Double Glazing	4947	72.9	69872	71626	81977	-71	26	600	106	2.1
Insul. H. W. Tank	5032	72	69755	71581	82359	46	71	218	21	.4
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	4293	77	68221	69512	77128	1580	2140	5449	760	15
Shading*	5126	71.5	69988	71898	83166	-187	-246	-589	-73	-1.4
Reduced Vent.	4905	73.2	69496	71221	81400	305	431	1177	148	2.9

Table 3-119 Summary Loads, Costs And Savings

HEATING, HOT WATER AND AIR CONDITIONING
ALBUQUERQUE - EXISTING SCHOOL

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 Case (3 Watt)	5718	76.3	80560	82272	92378					
Base Case (2 Watt)	5771	75.1	75888	77739	88663	4672	4533	3715		

Table 3-120 Summary Loads, Costs And Savings

HEATING AND HOT WATER

ALBUQUERQUE - EXISTING SCHOOL

ECT Description	Total Load (BTU) $x 10^{-6}$	Percent Supplied By Solar	Annual Costs (Dollars) Gas	Annual Costs (Dollars) Oil	Annual Costs (Dollars) Electric	Annual Savings (Dollars) Gas	Annual Savings (Dollars) Oil	Annual Savings (Dollars) Electric	Annual Load Savings BTU $x 10^{-6}$	Annual Load Savings % Savings
Base Case (3 Watt)	4860	73.1	74063	75775	85881					
Base Case (2 Watt)	5053	71.2	69801	71652	82577	4262	4123	3304		

Insulate Hot Water Tank, Reduce Hot Water Temperature from 140°F to 130°F -- This ECT reduces the heat loss from the water tank as well as the energy required to heat the water resulting in dollar savings for all cases.

Air Economizer -- An air economizer was added, which is used to supply some of the cooling load when the outside temperature is less than 75°F. This ECT does not result in dollar savings.

Night Setback; Cooling Off at Night -- This ECT involves installing a chronotherm which can set the temperature back to 60°F (during the heating season) between the hours of 10 pm and 6 am. The cooling is assumed to be shut off between these hours (during the cooling season) by maintenance personnel. The results are substantial dollar and energy savings for all cases.

Shading -- Shading was accomplished in the simulation by reducing the energy transmitted through the east and west windows by 60 percent and the south window by 90 percent. The technique (awnings, drapes, etc.) was not priced. Therefore, savings must be weighed against the actual cost.

Reduced Ventilation -- The HVAC system in the existing schools can be controlled so as to minimize the amount of outdoor air introduced into the conditioned space. However, the dampers in the outdoor air inlets will only close down to their minimum setting. Thus, to decrease the intake of unconditioned air further, it is necessary to mechanically adjust the minimum position. This resulted in dollar and energy savings.

Lighting -- Tables 3-119 and 3-120 show the dollar savings resulting from using 2 watts/ft^2 max. illumination rather than 3 watts. All the above base and ECT results were computed with the 2 watt level. The cost of the additional watt was computed using average predicted electric rates for Albuquerque.

Summary of Results for Schools

Tables 3-121 through 3-128 summarize annual savings and payback periods for various Energy Conservation Techniques used in the school analysis for electric gas and oil auxiliary fuels, for both heating only and heating, cooling operations. An ECT is considered to be cost effective if the payback is less than 20 years.

It is readily seen that insulating the hot water tank and reducing the maximum hot water temperature from 140°F to 130°F pays for itself quickly in all cases. Reduced ventilation and night setback with cooling off at night are two techniques which yield savings in all cases (except for the new building in New York during the cooling season, for gas auxiliary fuels, a slight increase in cost occurs for reduced ventilation). For existing buildings in all regions except the southeast, adding insulation to walls and to walls and ceilings is reasonably cost effective. For Atlanta, adding wall insulation is cost effective in the case of electric auxiliary fuel. For new buildings, adding insulation is cost effective only in Omaha and Albuquerque, and then for the case of auxiliary electric fuel, but not for gas.

Air economizers are seen to be cost effective in all regions in the case of new construction buildings. (Only the heating and cooling mode is pertinent for this ECT, since it is only operative during the cooling season.)

In existing buildings, it is seen that double glazing is cost effective for auxiliary electric fuel in all regions both for heating and cooling. Reflective coating on windows is not a cost effective ECT in any of the cases studied.

As has been mentioned previously, shading was incorporated into the building model with no regard to cost. From Tables 3-121 through 3-128, it can be seen that shading, which is used during the cooling season only may be cost effective, especially for gas auxiliary fuel in new buildings.

Summaries of the auxiliary energy savings of the various techniques are shown in Table 3-129 for new construction and existing construction. Numbers are entered in these tables only for those ECTs which are cost effective with gas auxiliary fuel for heating and cooling operations, i.e., those which show a payback of less than 20 years in Table 3-123.

Table 3-121 Energy Conservation Techniques, Cost Effectiveness

HEATING, HOT WATER, AIR CONDITIONING - SCHOOLS

ELECTRIC AUXILIARY FUEL

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Add Wall Insulation	226/7	2542/3	-239/43	6188/2	-255/90	927/9	83/13	1970/4
Add Wall and Ceiling Insulation	251/17	34685/2	-1002/35	36447/2	-1233/74	7117/7	45/19	15353/3
Reflective Coating	-90/28	-52/27	-110/28	-228/30	-21/22	-49/25	-417/343	-38/23
Add Pane of Glass	-66/25	917/6	-192/38	1355/5	-201/59	119/15	-52/26	634/6
Insulate Hot Water Tank· Reduce Hot Water Max. Temperature to 130°	207/*	250/*	285/*	345/*	192/*	245/*	204/*	224/*
Air Economizer	1255/*	-69/(156)	688/2	68/10	404/2	4/18	377/2	0/20
Night Setback: Cooling Off at Night	460/*	6018/*	580/*	8525/*	194/*	3717/*	539/*	5400/*
Shading[1]	78/-	-248/-	141/-	-243/-	195/-	21/-	36/-	-470/-
Reduced Ventilation	615/*	1559/*	260/1	1963/*	186/1	508/1	340/*	1187/*
	$20000\ ft^2$	$30000\ ft^2$	$20000\ ft^2$	$30000\ ft^2$	$20000\ ft^2$	$3000\ ft^2$	$10000\ ft^2$	30000 ft

*Payback less than 1

[1] Payback is not computed for shading, since the method and cost of shading techniques were not considered for this analysis.

Table 3-122

ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
HEATING, HOT WATER - SCHOOLS

ELECTRIC - AUXILIARY FUEL

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Add Wall Insulation	253/6	2505/3	-199/(36)	6206/2	-253/87	857/9	106/12	1934/4
Add Wall & Ceiling Insulation	385/16	34389/2	-671/28	37339/2	-1161/64	7006/7	202/15	15657/3
Reflective Film	-316/(886)	-11/21	-358/250	-385/47	-300/(1750)	-239/43	-688/(12)	-194/39
Add Pane of Glass	-100/29	1211/5	-204/41	1332/6	-239/93	67/17	-77/28	600/7
Insul. HW Tank Reduce Hot Water Max T. to 130°F.	195/*	242/*	266/*	343/*	174/*	230/*	203/*	218/*
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	463/*	5927/*	720/*	8563/*	187/1	3558/*	563/*	5449/*
Shading[1]	-118/-	-363/-	-82/-	-362/-	-30/-	-115/-	-166/-	-589/-
Reduced Ventilation	579/*	1499/*	516/*	1840/*	158/1	424/1	477/*	1177/*

* Payback is less than 1 year

1 Payback is not computed for shading, since the method and cost of shading techniques were not considered in this analysis

Table 3-123

ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS

HEATING, HOT WATER AND AIR CONDITIONING - SCHOOLS
OIL AUXILIARY FUEL

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Add Wall Insulation	56/13	774/8	-378/21	1381/7	-288/165	25/19	-96/21	506/9
Add Wall Insul & Ceiling Insulation	-299/24	12994/4	-1860/102	9005/7	-1455/144	1509/14	-584/31	4592/8
Reflective Film	-115/31	-172/197	-156/33	-442/58	-35/23	-174/33	-190/71	-188/38
Add Pane of Glass	-182/30	113/15	-306/84	91/17	-232/84	-143/32	-154/47	61/17
Insul. Hot Water Tank & Decr. Water Temp.	85/*	98/*	92/*	101/*	80/*	101/*	76/*	78/*
Air Economizer	258/4	-50/110	591/2	71/10	386/3	2/19	371/2	-1/20
Night Setback	240/*	2589/*	221/2	2768/*	109/2	1649/*	239/*	2072/*
Shading	105/-	-47/-	163/-	78/-	194/-	76/-	100/-	-127/-
Reduced Ventilation	322/*	642/1	11/12	595/1	129/2	252/2	125/2	443/1

* Payback is less than 1 year

1 Payback is not computed for shading, since the method and cost of shading techniques were not considered in this analysis.

Table 3-124

ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS

HEATING AND HOT WATER - SCHOOLS
OIL AUXILIARY FUEL

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Add Wall Insulation	81/12	737/8	-338/21	1399/7	-286/157	-44/21	-73/26	475/10
Add Wall & Ceiling Insulation	-618/32	12697/4	-1527/59	9847/6	-1383/110	1398/14	-428/27	5095/8
Reflective	-340/(38[illegible])	-131/63	-403/(55	-599/18	-313/361	-364/112	-462/(27	-345/141
Add Pane of Glass	-215/33	237/12	-316/94	68/18	-270/176	-194/40	-180/62	26/19
Insul. Hot Water Tank Decr. Hot Water Temp	73/*	91/*	74/*	99/*	62/*	85/*	74/*	71/*
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	242/*	2499/*	261/1	2806/*	103/2	1491/*	262/*	2140/*
Shading	-75/-	583/-	-59/-	-40/-	-31/-	-62/-	-103/-	-246/-
Reduced Ventilation	329/*	583/1	268/1	572/1	101/2	168/3	262/*	431/1

* Payback is less than 1 year

1 Payback is not computed for shading, since the method and cost of shading techniques were not considered in this analysis

Table 3-125

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

GAS - AUXILIARY FUEL

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Add Wall Insulation	3/19	251/13	-393/(178)	853/9	-293/188	-135/25	-127/74	258/13
Add Wall & Ceiling Insulation	-983/52	6573/7	-1954/(128)	5983/9	-1493/172	519/17	-691/302	3003/10
Reflective Film	-123/32	-190/1581	-161/34	-465/65	-36/23	-197/36	-152/47	-213/43
Add Pane of Glass	-189/48	-125/30	-317/95	-48/22	-237/90	-190/39	-172/56	-36/22
Insul. HW tank Reduce Hot Water to Max. T. 130°F.	49/*	54/*	71/*	75*	61/*	74/*	54/*	53/*
Air Economizer	262/4	-44/71	592/2	72/10	395/2	1/30	370/3	-1/20
Night Setback	175/1	1575/*	182/2	2134/*	95/3	1283/*	188/1	1531/*
Shading[1]	132/-	13/-	166/-	114/-	194/-	85/-	110/-	-68/-
Reduced Ventilation	235/*	371/3	-16/660	445/1.7	129/2	206/3	88/2	317/2

* Payback is less than 1 year

1 Payback is not computed for shading, since the method and cost of shading techniques were not considered in this analysis.

Table 3-126

ENERGY CONSERVATION TECHNIQUES, COST EFFECTIVENESS
HEATING, HOT WATER - SCHOOLS

GAS - AUXILIARY FUEL

ENERGY CONSERVATION TECHNIQUE	NORTH CENTRAL		NORTH EAST		SOUTH EAST		SOUTH WEST	
	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING	NEW	EXISTING
	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback	Savings/ Payback
Add Wall Insulation	19/17	216/14	-354/100	869/9	-292/183	-203/28	-104/49	227/15
Add Wall & Ceiling Insulation	-899/46	6278/7	-1622/67	6874/8	-1422/126	408/18	-534/86	3305/10
Reflective Film	-348/(261)	-166/150	-408/(409)	-623/285	-316/306	-386/155	-424/(33)	-370/252
Add Pane of Glass	-249/89	-68/24	-329/(111)	-72/23	-276/213	-240/53	-197/77	-71/25
Insul. HW Tank Reduce Hot Water Max. T. to 130°F.	37/*	47/*	52/*	72/*	41/*	60/*	53/*	46/*
Air Economizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night Setback	176/1	1485/*	221/2	2171/*	88/3	1126/*	211/*	1580/*
Shading[1]	-64/-	-101/-	-57/-	-6/-	-31/-	-50/-	-92/-	-187/-
Reduced Ventilation	242/*	312/3	240/1	421/2	90/2	123/4	226/*	305/2

* Payback is less than 1 year.

1 Payback is not computed for shading, since the method and cost of shading techniques were not considered in this analysis.

Table 3-127 Energy Conservation Techniques, Cost Effectiveness

AUXILIARY ENERGY SAVINGS
FOR NEW CONSTRUCTION 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
	HEATING HW	COOLING	HEATING HW	COOLING	HEATING HW	COOLING	HEATING HW	COOLING
Add Wall Insulation	26	1	-	-	-	-	-	-
Add Wall & Ceil. Insul.	-	-	-	-	-	-	-	-
Reflective Film	-	-	-	-	-	-	-	-
Triple Glazing	-	-	-	-	-	-	-	-
Insul. Hot Water Tank Reduce Max. T. To 130°F	18	3	17	2	14	3	16	4
Air Economizer	0	9	0	15	1	6	1	17
Night Setback	33	1	32	-5	11	-10	39	-
Reduced Ventilation	40	2	-	-	7	2	28	-12

*Depends on fuel type
-Not applicable

Table 3-128

AUXILIARY ENERGY SAVINGS
FOR EXISTING CONSTRUCTION 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
	HEATING HW	COOLING	HEATING HW	COOLING	HEATING HW	COOLING	HEATING HW	COOLING
Add Wall Insulation	255	2	335	5	-	-	191	1
Add Wall & Ceil. Insul.	3251	34	2484	17	718	18	1371	-4
Reflective Film	-	-	-	-	-	-	-	-
Triple Glazing	-	-	-	-	-	-	-	-
Insul. Hot Water Tank Reduce Max. T.	23	1	22	1	18	1	15	1
Air Economizer	-	-	-1	5	-	-	-	-
Night Setback	514	5	521	7	264	2	430	-
Reduced Ventilation	138	2	124	3	33	3	98	0

*Depends on fuel type
-Not applicable

Table 3-129

DIVISION OF ANNUAL HEATING AND HOT WATER LOADS FOR SOLAR ASSISTED HEAT PUMP, S.F., OMAHA 400 FT^2 COLLECTOR AREA

Case	Energy Collected (MMBTU)	Space Heat Load (MMBTU)	Direct Solar Energy (MMBTU)	Heat From Heat Pump (MMBTU)	Auxiliary Space Heat (MMBTU)	Total Hot Water Load (MMBTU)	Hot Water From Solar (MMBTU)	Total Energy From Solar (MMBTU)	Percent Solar
Base (No Heat Pump)	71.85	51.99	27.30	0	24.58	28.10	22.06	49.36	60%
Heat Pump	79.14	51.99	18.56	19.61	13.82	28.10	18.60	56.77	71%
Reduced Hot Water	68.56	51.99	31.50	0	20.41	7.02	5.77	37.27	63%
Heat Pump with Reduced Hot Water	75.33	51.99	22.10	17.16	12.73	7.02	4.92	44.18	75%
Heat Pump with Night Setback	76.52	43.31	16.29	16.40	10.62	28.10	19.45	52.14	73%
Heat Pump with Increased Insulation	75.49	38.62	18.06	13.91	6.65	28.10	20.01	51.98	78%

3.6 SOLAR ASSISTED HEAT PUMP/LIQUID FLAT PLATE

The addition of a water-to-air heat pump to a solar heating system, with the storage tank as a source, allows the collectors to operate at a higher seasonal efficiency and effectively increases the storage capacity. The heat pump can extract heat for space conditioning from the storage water down to 40°F or less. This adds usable stored heat in the 40°F to 90°F range, or approximately 410 BTU/gallon. Also, the average temperature of the storage water is lowered, reducing transmission losses and increasing the efficiency of the collectors when charging storage. For example, when the outdoor temperature is 32°F and the radiation incident on the collectors is 200 BTU/ft^2, the efficiency of the collector may vary from 0.72 for an inlet temperature of 40°F (typical of a heat pump system) to 0.21 for an inlet temperature of 210°F (typical of conventional systems).

3.6.1 Building and System Description

The new construction, single family residence for the north central region was used for this analysis. It is described in Section 4.1.1 and Appendix A.

The solar system modeled was basically the system described in Appendix F without the cooling equipment and with the addition of the 3 ton water to air heat pump shunting the storage tank/space heat loop (Figure 3-116). The system was used for space heating and hot water heating only. No cooling was provided. The heat pump was operated to provide space heat with the storage water as a source when the storage temperature was between 40°F and 90°F. At storage temperatures above 90°F, the heat pump was by-passed and space heat was provided direct from the storage tank. At storage temperatures below 40°F, space heat was provided by auxiliary electric resistance strips installed in the air-side of the heat pump. Domestic hot water preheat was provided by a heat exchanger in the storage tank, and additional heat was supplied by an auxiliary electric unit, if necessary, to bring the water up to 140°F. The heat pump supplied no preheat for domestic hot water.

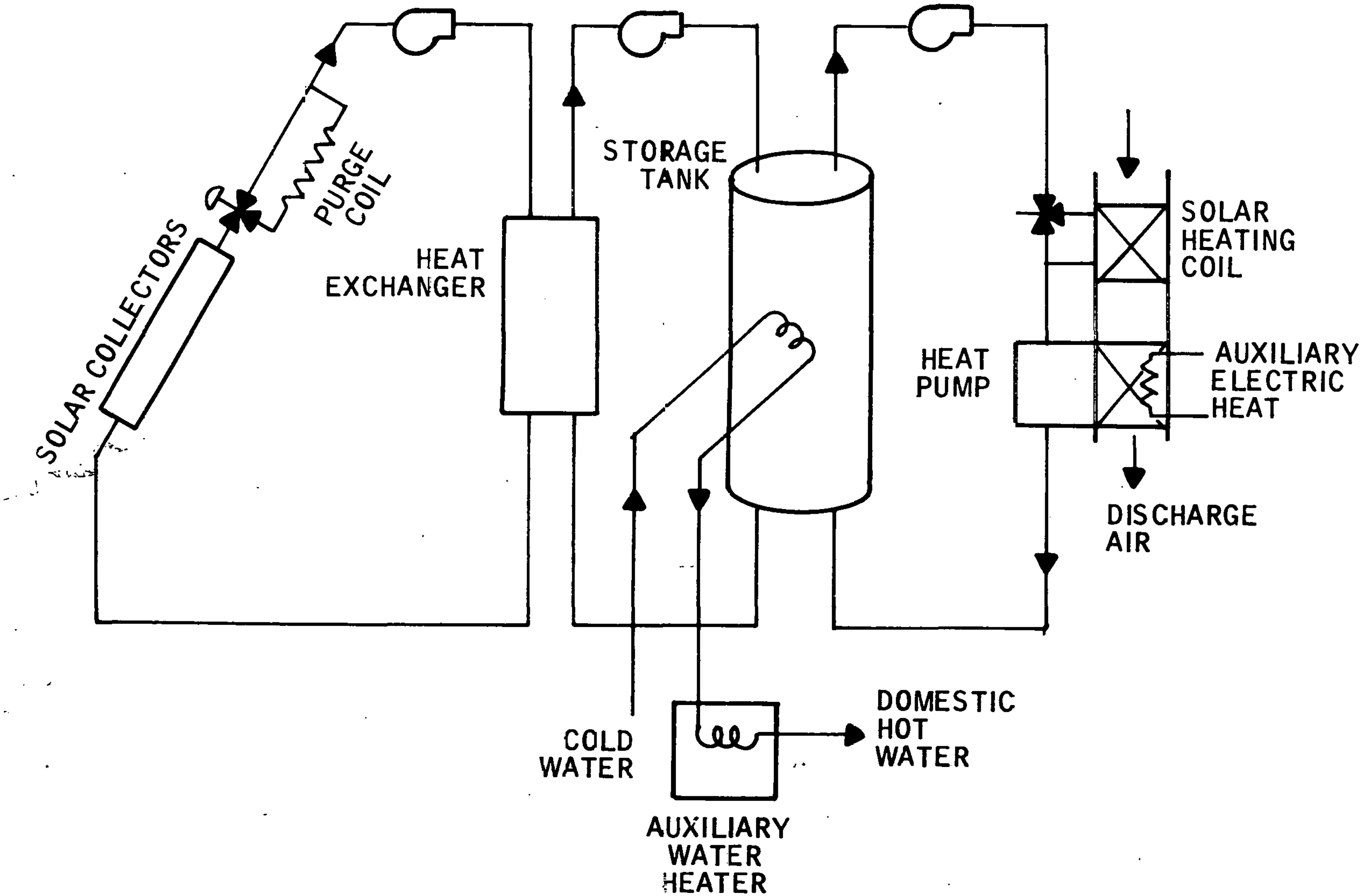


Figure 3-116. Solar Assisted Heat Pump System

3.6.2 Modeling Assumptions

The following assumptions were made for the building and system:

- The house was modeled as a single thermal zone.
- Wall, window, floor and ceiling loads were modeled from the U values and areas for the single family residence, new construction, north central region given in Appendix A.
- The basement temperature was held at 60°F.
- Infiltration load was 0.75 air exchanges per hour.
- Internal loads were based on the schedules for the single family residence in Appendix A.
- Solar heat gain was based on incident radiation on each of the window exposures and was assumed to be instantaneous.
- Storage tank and hot water tank losses were added to the internal load.
- No cooling was done for this analysis.
- The heat pump performance was modeled by a linear equation:

  Heat out (BTUs) = Energy in (KWH) x (5532 + 126.4T_s) where T_s is the water side source temperature (°F).

3.6.3 Results

Percent of Load Supplied by Solar -- The energy supplied by solar has two components in the solar-assisted heat pump system, the heat supplied direct from solar at 90°F and above and the heat supplied indirectly by the heat pump from 40°F to 90°F storage water. These two components, as well as their sum, are shown in Figure 3-117 as functions of collector area. They are expressed as percentages of the sum of the annual space heating and hot water loads for the building.

The portion supplied by both direct and heat pump contributions increases monotonically from 50 percent for 200 ft^2 to 89 percent for 800 ft^2. The direct component increases from 31 percent for 200 ft^2 to 74 percent at 800 ft^2. The heat pump contribution peaks at 25 percent for 400 ft^2, then decreases to 15 percent for 800 ft^2. The decreasing contribution by the heat pump at collector areas greater than 400 ft^2 is due to the ability of the collectors to keep the storage water above the heat pump set point of 90°F most of the time. The 400 ft^2 collector size was chosen for further analysis of the heat pump system because it maximizes the heat pump contribution.

Interaction of Hot Water Heating and Heat Pump Operations -- The heat pump, operating with the 400 ft^2 solar system supplied 25 percent of the total heating and hot water load. The direct solar contribution added another 36 percent for a total of 71 percent of the load supplied by solar. The large hot water load effectively limits the heat pump contribution since the heat pump cannot supply any of the hot water load and the hot water draws preheat energy from storage when it is below 90°F, competing directly with the heat pump for stored energy. Table 3-130 shows the results of reducing the hot water load from 28.1 MMBTU or 35 percent of the total load to 7.02 MMBTU or 12 percent of the load. The contribution of the heat pump, while smaller in magnitude, was 33 percent of the combined heating and hot water load.

Auxiliary Energy -- Auxiliary energy consumption, including the input energy requirement of the heat pump is shown in Figure 3-117. As expected, auxiliary requirements decrease as a function of collector area from the full load, 80 MMBTU with no collectors to 11.5 MMBTU for 800 ft^2. For 400 ft^2, the requirement is 28.3 MMBTU.

Annual Cost -- Cost figures for the heat pump analysis were all based on an installed cost of \$2750 for the heat pump including integral electric resistance strips for auxiliary heat. The cost of the solar system auxiliary furnace was assumed to be \$500, and that amount was deducted from the installed cost of the solar system. Operating costs were based on the assumption that all

Table 3-130. Division of Annual Heating and Hot Water Loads for Solar Assisted Heat Pump, S. F., Omaha, 400 Ft^2 Collector Area

CASE	Energy Collected (MMBTU)	Space Heat Load (MMBTU)	Direct Solar Energy (MMBTU)	Heat From Heat Pump (MMBTU)	Auxiliary Space Heat (MMBTU)	Total Hot Water Load (MMBTU)	Hot Water From Solar (MMBTU)	Total Energy From Solar (MMBTU)	Percent Solar
Case (No heat pump)	71.85	51.99	27.30	0	24.58	28.10	22.06	49.36	61%
Heat Pump	79.14	51.99	18.56	19.61	13.82	28.10	18.60	56.77	71%
Reduced Hot Water	68.56	51.99	31.50	0	20.41	7.02	5.77	37.27	63%
Heat Pump With Reduced Hot Water	75.33	51.99	22.10	17.16	12.73	7.02	4.92	44.18	75%
Heat Pump With Night Setback	76.52	43.31	16.29	16.40	10.62	28.10	19.45	52.14	73%
Heat Pump With Increased Insulation	75.49	38.62	18.06	13.91	6.65	28.10	20.01	51.98	78%

auxiliary heating, including hot water, was done with electricity.

The annual cost as a function of collector area is shown in Figure 3-112. Cost increases monotonically from \$1480 for 200 ft^2 to \$1883 for 800 ft^2. Operating costs are shown on the lower curve in Figure 3-118. These costs reflect the annual electric energy cost for pumps, fans and auxiliary heat. Operating costs decrease as a function of collector area from \$649 for 200 ft^2 of collectors to \$291 for 800 ft^2. This decrease was mainly due to the reduction in electricity for auxiliary heat as the solar system picked up more of the load.

Comparison of Heat Pump System with Base Solar System -- The base solar system was the system of Figure 3-116 without the heat pump. It was different from the single-family residence system described in Appendix F in that no cooling equipment was included and all solar energy is transferred through the storage tank. System differences are significant enough that results for this base system and the base system of Section 4. 1 cannot be compared directly.

Annual Energy Savings -- The addition of a heat pump to the base solar system did not change the annual heating load. However, it did reduce the auxiliary energy consumption slightly. Figure 3-118 shows the difference. At the 400 ft^2 collector size, the annual auxiliary requirement for the system without the heat pump was 30. 6 MMBTU while for the same solar system with the heat pump, it was 28. 3 MMBTU or a savings of 2. 3 MMBTU. This represents a 7. 5 precent savings in auxiliary energy.

Annual Cost Savings -- The total annual cost for the solar assisted heat pump with 400 ft^2 of collector was greater than the cost for the same system without the heat pump. Costs for both systems are shown on Table 3-131. The solar assisted heat pump system costs \$1566 per year or \$129 greater than the same system without the heat pump. Again, costs are based on electricity as auxiliary energy. Operating costs are slightly lower with the heat pump which reflects the lower auxiliary energy consumption.

Table 3-131. Summary Loads, Costs and Wavings, Heating and Hot Water

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	80.1	60	NA	NA	1437					
Heat Pump	80.1	71	NA	NA	1566	NA	NA	-129	0	0
Heat pump and 5°F Night Setback	71.4	73	NA	NA	1511	NA	NA	-74	8.7	11
Heat Pump and Increased Insulation	66.7	78	NA	NA	1488	NA	NA	-51	13.4	17

Collector Efficiency -- Table 3-130 shows that the annual energy collected by the 400 ft^2 of collector was increased by 7.29 MMBTU. This represents a 10 percent increase in the seasonal collector efficiency which was due to the ability of the heat pump system to draw energy from the system at temperatures below 90°F. That allowed the collector loop to operate at a lower average temperature, increasing the collector efficiency. The storage tank temperature was drawn down lower at night also, which increased the capacity of storage for charging during the day. From Table 3-131, the total energy from solar increased from 49.4 MMBTU for the base system to 56.8 MMBTU with the heat pump. The difference, 7.4 MMBTU, was nearly equal to the increase in collected energy. The heat pump was able to take full advantage of the increase in collected solar energy.

Interaction of Hot Water Heating and Heat Pump -- The portion of the hot water load supplied by solar dropped with the addition of the heat pump to the base system. Table 3-131 shows the solar contribution to hot water was 22.06 MMBTU for the base system, or 79 percent of the hot water load. With the heat pump, the solar contribution was 18.60 MMBTU, or 66 percent of the hot water load.

Solar Assisted Heat Pump System with Night Setback -- Night setback is setting the space heat thermostat down 5°F to 63°F between the hours of 10:00 p.m. and 6:00 a.m. It is intended to reduce the heating load during that period.

Annual Energy Savings -- Table 3-131 shows that the total heating and hot water load was reduced by 8.7 MMBTU to 71.4 MMBTU, a reduction of 11 percent. The total auxiliary energy was reduced by 4.9 MMBTU to 23.4 MMBTU.

Annual Cost Savings -- The cost was reduced from $1566 to $1511 for a savings of $55 over the heat pump system with no night setback.

Solar Assisted Heat Pump System with Increased Insulation -- The insulation of the walls was increased from R-11 to R-19 and the insulation of the ceiling was increased from R-19 to R-38. This ECT was intended to decrease the heating load.

Annual Energy Savings -- Table 3-131 shows that the total heating and hot water load was reduced by 13.4 MMBTU to 66.7 MMBTU, a reduction of 17 percent. Auxiliary Energy was reduced by 10.1 MMBTU to 18.2 MMBTU.

Annual Cost Savings -- The cost comparison included the effect of an additional $730 installed cost for the increased insulation.

The cost was reduced from $1566 to $1488 for a savings of $78 over the heat pump with the base insulation level.

3.6.4 Summary Analysis

The heat pump/flat plate system for the new single family residence supplied 71 percent of the annual heating and hot water loads from solar with 400 ft^2 of collector area. The contribution of the heat pump was a maximum of about 25 percent for 400 ft^2 collector area. For that reason, the 400 ft^2 size was chosen as the basis of comparisons in this section.

When compared to the base solar system with 400 ft^2 of collector, the heat pump system supplied 10 percent more of the total load with solar energy. The addition of the heat pump reduced the auxiliary energy requirement by 7.5 percent. The heat pump was not cost effective, however, with a $129 higher annual cost than the base system. The heat pump increased the seasonal collector efficiency by 10 percent. The addition of the heat pump diverted 3.46 MMBTU of solar energy from the hot water to space heating; changing the percent of the hot water load supplied by solar from 79 percent to 66 percent.

The incorporation of 5°F night setback with the heat pump solar system resulted in a load reduction of 8.7 MMBTU or 11 percent. The auxiliary energy was reduced by 4.9 MMBTU. Night setback reduced the annual cost by $55.

Increasing the wall insulation from R-11 to R-19 and the ceiling insulation from R-19 to R-38 reduced the annual load by 13.4 MMBTU or 17 percent. Auxiliary energy was reduced by 10.1 MMBTU. The improved insulation saved $78 in actual cost.

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