ECONOMIC ANALYSIS OF WIND-POWERED FARMHOUSE AND FARM BUILDING HEATING SYSTEMS

Final Report
January 1981

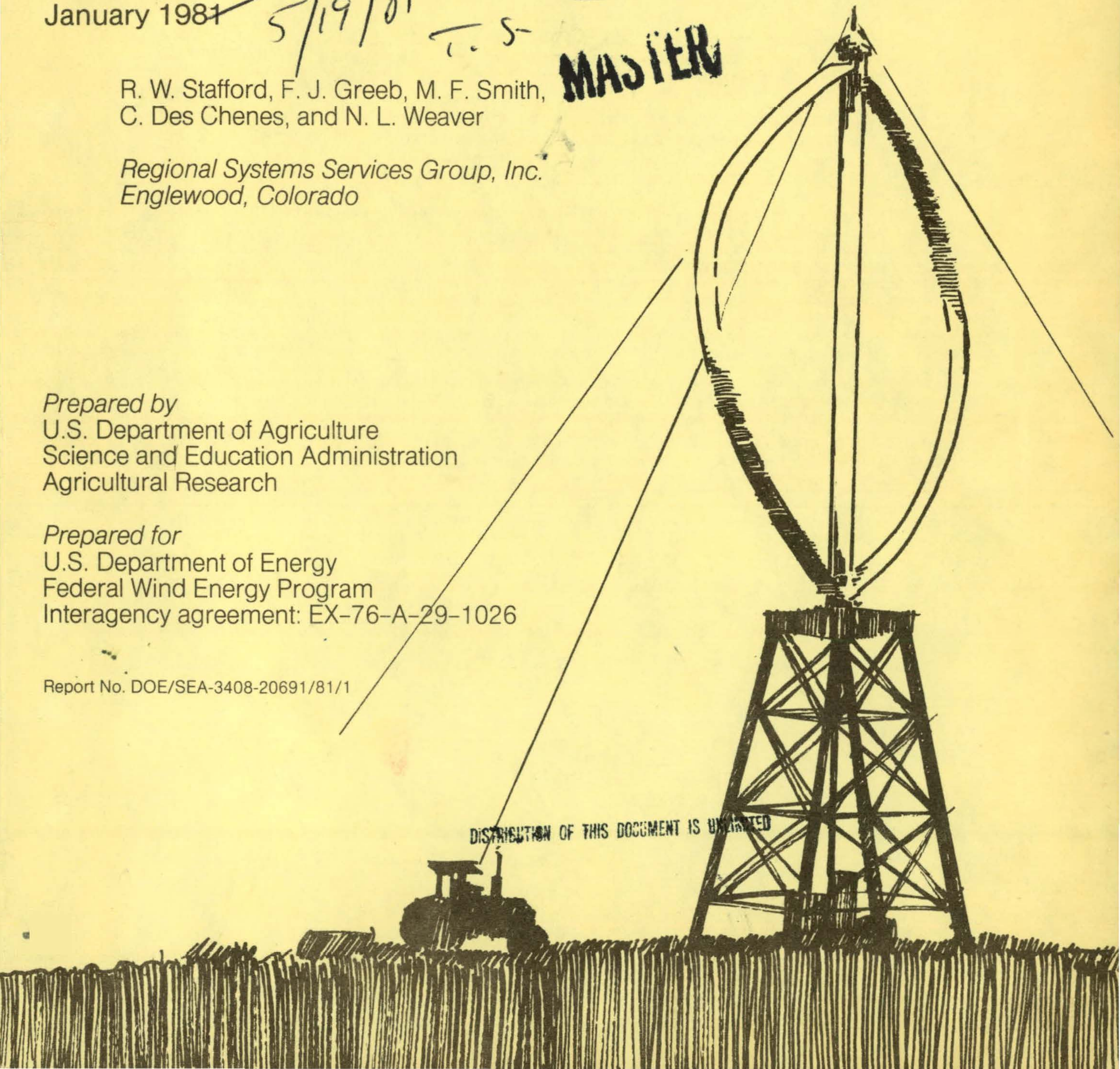
R. W. Stafford, F. J. Greeb, M. F. Smith, C. Des Chenes, and N. L. Weaver

Regional Systems Services Group, Inc.
Englewood, Colorado

Prepared by
U.S. Department of Agriculture
Science and Education Administration
Agricultural Research

Prepared for
U.S. Department of Energy
Federal Wind Energy Program
Interagency agreement: EX-76-A-29-1026

Report No. DOE/SEA-3408-20691/81/1



DISCLAIMER

Report No. DOE/SEA-3408-20691/81/1, printed May 1981.

Report No. DOE/SEA-3408-20691/81/1

ECONOMIC ANALYSIS OF WIND-POWERED FARMHOUSE AND FARM BUILDING HEATING SYSTEMS

FINAL REPORT

R. Wayne Stafford, Principal Investigator
Fredrick J. Greeb
Monica F. Smith
Craig Des Chenes
Norman L. Weaver

Regional Systems Services Group, Inc.
5680 South Syracuse Circle Suite 514
Englewood, Colorado 80111

January, 1981

Prepared For:

United States Department of Agriculture
Science and Education Administration
Agricultural Research
North Central Region
Iowa State University
Ames, Iowa 50111

Research Agreement Number 53-519B-9-15
Interagency agreement: EX-76-A-29-1026

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

Abstract

This report presents the results of the study entitled "Economic Analysis of Wind-Powered Farmhouse and Farm Building Heating Systems", sponsored by the United States Department of Agriculture, Science and Education Administration, Agricultural Research, by Research Agreement No. 53-519B-9-15. Dr. Leo H. Soderholm, USDA, SEA, AR, NCR, was the ADODR for USDA. The study was performed by Regional Systems Services Group, Inc., Englewood, Colorado, R. Wayne Stafford, Program Manager.

The study evaluated the break-even values of wind energy for selected farmhouses and farm buildings focusing on the effects of thermal storage on the use of WECS production and value. Farmhouse structural models include three types derived from a national survey - an older, a more modern, and a passive solar structure. The eight farm building applications that were analyzed include: poultry-layers, poultry-brooding/layers, poultry-broilers, poultry-turkeys, swine-farrowing, swine-growing/finishing, dairy, and lambing. These farm buildings represent the spectrum of animal types, heating energy use, and major contributions to national agricultural economic values. All energy analyses were based on hour-by-hour computations which allowed for growth of animals, sensible and latent heat production, and ventilation requirements. Hourly or three-hourly weather data obtained from the National Climatic Center was used for the nine chosen analysis sites, located throughout the United States and corresponding to regional agricultural production centers.

Use of thermal storage was found to significantly enhance wind energy uses and its value for all applications. Thermal storage increased the break-even value of WECS energy for farmhouses by more than 50% - to over 4 cents/kwh for electric resistance and LP heating, to over 3 cents/kwh for fuel oil heating, and to over 2 cents/kwh for natural gas fuels. Use of thermal storage for farm building heating applications showed break-even values of energy falling between .8 and 6.3 cents/kwh for electricity, .8 and 4.6 cents/kwh for natural gas, .9 and 4.9 cents/kwh for LP gas, and .8 and 4.1 cents/kwh for fuel oil heating.

The study also evaluated the added value to the WECS production if the WECS output was also used for thermal storage for space heating and water heating, appliances and machinery, and sell-back to the local utility. State-by-state average wholesale electric rates for rural electric cooperatives were used as a basis for the value of WECS production sold to the local utility.

It is noted that for this study farmhouses were defined as any rural home reported by the 1970 Census of Housing, rather than assuming that one farmhouse would be associated with each farm operation reported by the Census of Agriculture. This definition of the farmhouses is believed to more completely represent the number of farmhouses located in rural areas which could accomodate the type of wind energy conversion systems (WECS) considered with this study.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Table of Contents

Economic Analysis of Wind-Powered Farmhouse and Farm Building Heating Systems

Table of Contents
(Continued)

Table of Contents
(Continued)

List of Tables

Economic Analysis of Wind-Powered Farmhouse and Farm Building Heating Systems

List of Tables

(Continued)

List of Tables

(Continued)

List of Tables

(Continued)

List of Tables

(Continued)

List of Figures

Economic Analysis of Wind-Powered
Farmhouse and Farm Building
Heating Systems

List of Figures
(Continued)

List of Figures

(Continued)

List of Figures

(Continued)

List of Figures
(Continued)

List of Figures

(Continued)

1.0 EXECUTIVE SUMMARY

This section presents a brief introduction and summary of the results of the investigations conducted under the Research Agreement Number 53-519B-9-15 entitled "Economic Analysis of Wind-Powered Farmhouse and Farm Building Heating Systems", sponsored by the United States Department of Agriculture, Science and Education Administration, Agricultural Research.

The ensuing paragraphs summarize the principal findings of this research and present an overview of the major study tasks and the approach defined for their investigation.

1.1 BACKGROUND

This study was initiated in August, 1979 by Regional Systems Services Group, Inc. of Englewood, Colorado to provide information about the economic break-even value of wind energy as it is applied to farmhouse and farm building heating systems, and in so doing, to define the analytical methodologies generally applicable.

Principal areas of research in this study have included:

- A survey of farmhouses and farm buildings to identify and quantify principal space heating requirements in agriculture using three characteristic farmhouse and eight farm building structures, located at nine geographically separate regions correlated to agricultural production centers.

- An analytical determination of the annual energy flows for the selected farmhouse and farm building structures.

- An examination of wind energy applications to the farmhouse and farm buildings to evaluate the needs that wind energy could satisfy considering:
  - The effects of wind variability on farmhouse and farm building energy requirements.
  - An evaluation of wind energy to serve in a self-sufficient or supplemental mode.
  - The effects of non-uniformity in electric rates and other fuel costs on practicality and economic value.

- An evaluation of life cycle wind energy break-even value goals considering present heating systems and energy sources used in agriculture.

- A survey of present agricultural heating systems and heating costs.

- An evaluation of the number of potential wind energy uses correlated to agricultural energy sources and life cycle break-even cost goals for wind energy applications.

The analysis has proceeded with the recognition that building heating consumes approximately 10% of the energy used in agriculture, and more than 90% of the heating energy is used in the farmhouse. Subsequent sections summarize the principal conclusions and the results of the research.

1.2 PRIMARY CONCLUSIONS

The principal conclusions suggested by this research are presented in the following paragraphs:

o Thermal storage, even in small amounts, significantly improves the ability to utilize WECS production for space heating.

This conclusion is illustrated in Figures E-1 and E-2 which show the percentage of WECS production usable with and without the inclusion of thermal storage for farmhouses and farm buildings, respectively. The results are separated by warmer and colder climates for the farmhouses, and are specific for the sites used for the farm buildings. A WECS with a 20 foot diameter rotor and a 10 KW generator is used for the illustration. The thermal storage used for the farmhouses was 600 gallons for a preheat tank and a normal 100 gallon hot water heater. Thermal storage for the farm buildings was sized for the specific application and is discussed in the main body of the report.

The increased use of the WECS production is most dramatic in the warmer climates where the space heating requirements are lower. Even in colder climates the use of thermal storage nearly doubled the use of WECS energy. All of the analyses were based on hour by hour evaluation of the time coincidence of the production from the WECS and the farmhouse and farm building energy needs.

o Wind-powered heating systems, over long periods, can displace significant proportions of primary heating fuels.

With thermal storage, the heating fuel displacement increases greatly, nearly doubling in most cases. This result is further illustrated in Figures E-3 and E-4 which show the percentage of heating energy which was displaced in the farmhouse and farm building applications, respectively. The results shown also use a WECS of 20 foot rotor diameter with a 10 KW generator. For the older and modern farmhouse models used with the study, thermal storage with the WECS allowed the displacement of nearly 2/3 of the heating energy in a warmer climate and approximately 1/3 of the heating energy in the colder climates. Using a WECS in combination with a passive solar farmhouse allowed the displacement of nearly 90% of the heating energy needs in cooler climates, and nearly all of the heating energy in a warmer climate.

For farm buildings with thermal storage, nearly 1/3 of heating needs were provided by the 20 foot diameter WECS for the dairy and turkey applications. 13% to 16% of heating was provided for brooding/layers, swine-farrowing, and swine growing and finishing. Less than 10% of the farm building heating needs were met elsewhere due to the warm climate

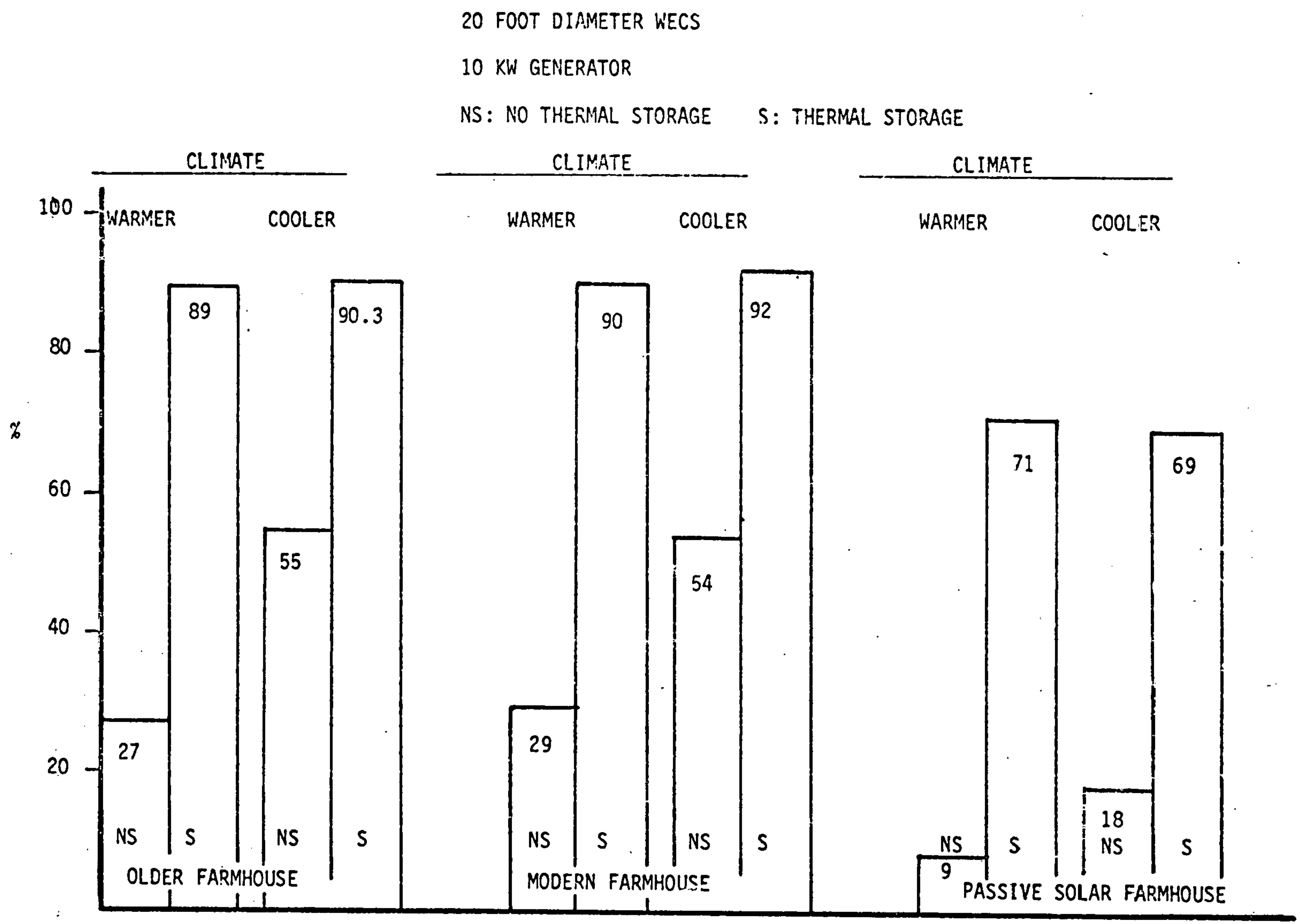


Figure E-1 Effect Of Thermal Storage On The Percentage Of WECS Production Usable For Heating In Farmhouses

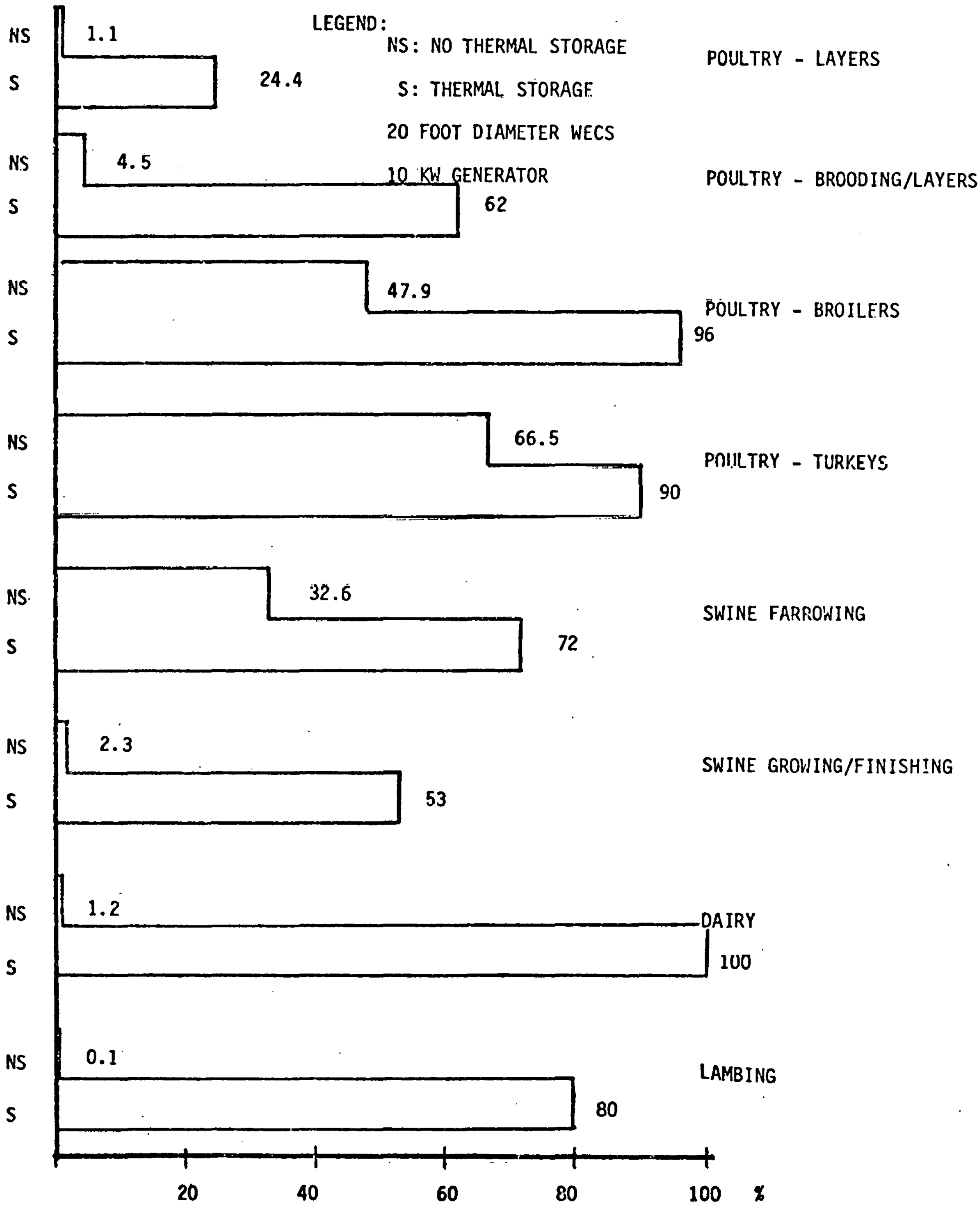


Figure E-2 Effect Of Thermal Storage On The Percentage Of WECS Production Usable For Heating In Farm Buildings

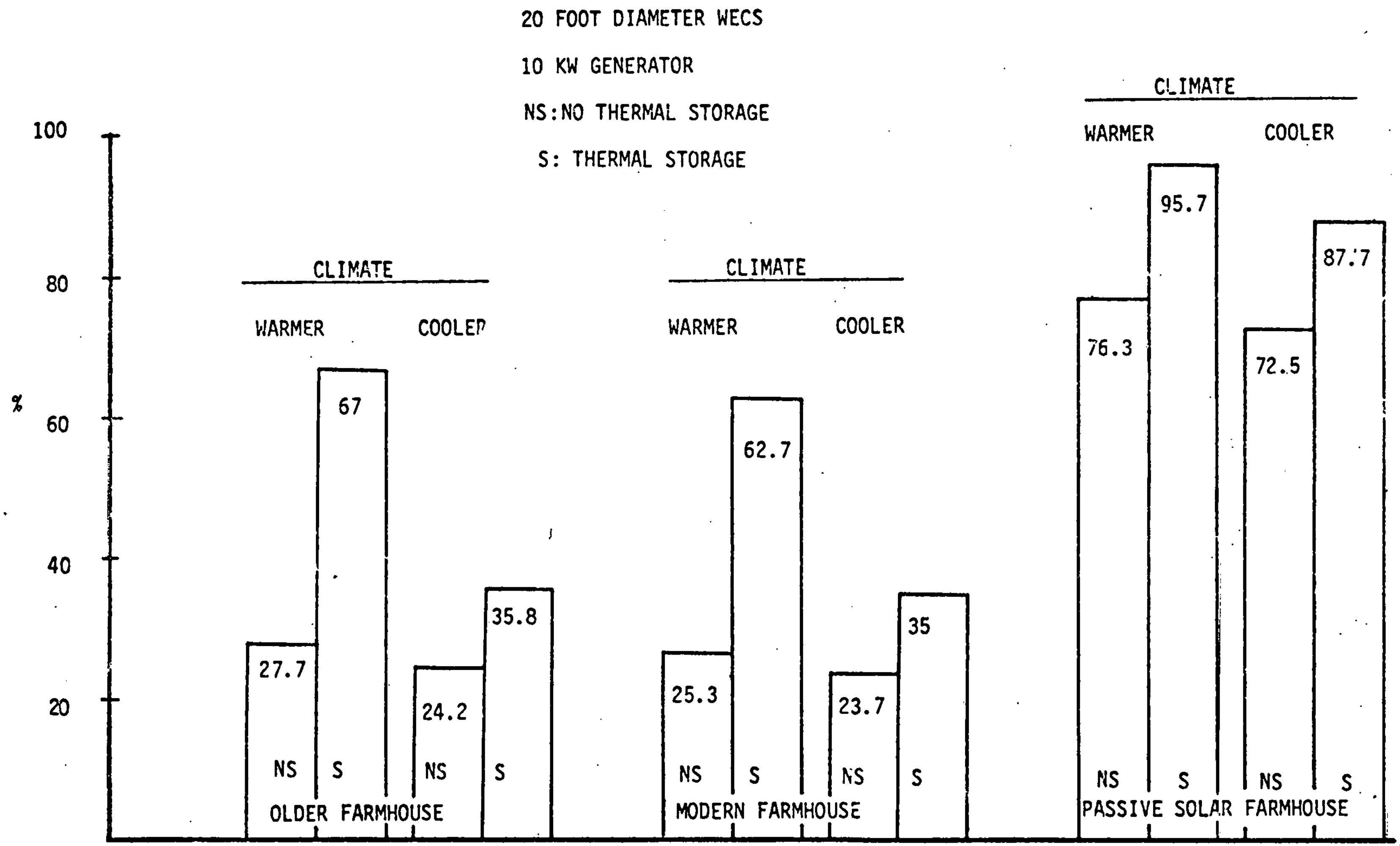


Figure E-3 Effect Of Thermal Storage On Heating Energy Displacement By WECS In Farmhouses - %

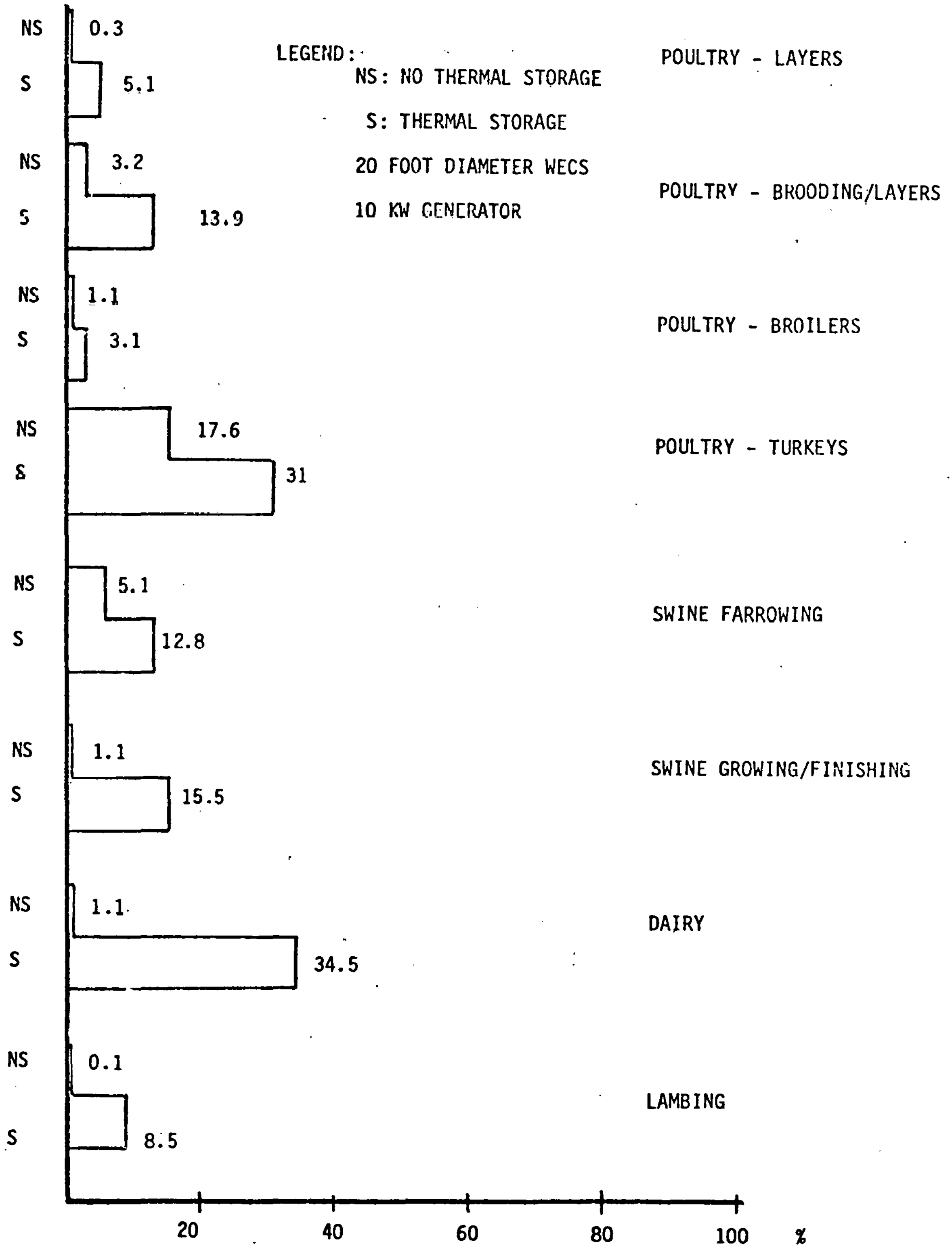


Figure E-4 Effect Of Thermal Storage On Heating Energy Displacement By WECS In Farm Buildings - %

or small need for space heating energy.

Simply increasing the size of the WECS does not necessarily displace more of the heating energy needs, since as this study showed, the time coincidence of the wind energy and the heating needs are the determining factors in using the WECS production.

o Thermal storage allows for significantly increased value of the WECS energy, and thus allows higher break-even costs for the WECS.

If the economic break-even results were averaged for each farmhouse type studied at each of the nine geographic locations dispersed throughout the United States, a comparative summary of the effects of thermal storage can be presented. The summary below further illustrates the significant ability of thermal storage to make better use of the WECS production and accrue further value by displacing more primary heating energy.

Levelized Break-even Value of WECS Energy--Cents/Kwh

	No Thermal Storage				Thermal Storage			
Farmhouse Type*	Electric	Nat Gas	LP Gas	Fuel Oil	Electric	Nat Gas	LP Gas	Fuel Oil
Older	2.9	1.4	2.6	2.0	4.1	2.2	4.0	3.2
Modern	3.0	1.5	2.6	2.0	4.5	2.5	4.1	3.1
Passive	1.0	.9	.9	.7	2.2	1.3	2.0	1.7
Farm Building Type**								
Poultry-Layers	.2	.1	.1	.1	4.6	3.9	4.2	4.1
Poultry-Brooding/Layers	.3	.1	.2	.2	3.8	3.1	3.3	3.2
Poultry-Broilers	3.3	2.2	2.1	2.5	6.3	4.4	4.9	4.1
Poultry-Turkeys	3.0	1.6	2.5	2.1	4.6	2.7	3.8	3.2
Swine-Farrowing	2.1	.9	1.5	1.3	3.4	1.8	2.7	2.3
Swine-Growing/Finishing	.3	.1	.1	.1	2.2	1.2	1.8	1.6
Dairy	.1	.1	.1	.1	5.1	4.6	4.9	4.7
Lambing	0	0	0	0	.8	.8	.9	.8

*Average for 6 locations in colder climates
**Specific to analysis locations

o Many farmhouses are located in relatively windy areas where heating energy needs are large.

Nearly 2,200,000 farmhouses are located in areas where annual average wind speeds exceed 12 miles per hour (65.62 foot reference height) and where there are more than 6000 heating degree days. Further, more than 4,100,000 farmhouses are located where the annual average wind speeds exceed 10 miles per hour and where there are more than 6000 heating degree days. Less than 2,200,000 farmhouses are located where annual average wind speeds are less than 10 miles per hour and where there are less than 2000 heating degree days.

o <u>The design ratings of farmhouse heating systems are closely correlated to the annual average wind speeds.</u>

The required peak ratings for the heating systems, defined using methods recommended by ASHRAE, were found to be directly related to the annual average wind speeds in the area of the farmhouse. For example, the peak ratings in areas where the annual average wind speeds exceeded 12 miles per hour were nearly double the heating system peak ratings where the annual average wind speeds were less than 10 miles per hour (65.62 foot reference height). The brief summary below further illustrates this conclusion.

Average Annual Wind Speed, miles per hour (65.62 foot reference) Equivalent	Farmhouse Heating System Peak Rating BTU/hour	Kwh/hour
< 10	55,000 - 62,000	15 - 18
10 - 12	62,500 - 91,000	18 - 26
> 12	67,500 - 112,000	19 - 33

With the wide range of heating system peak ratings in the higher wind regimes, greater flexibility of matching the WECS output power to the present energy needs will exist. Both the minimum and maximum ratings shown in the above summary are seen to increase with annual average wind speed.

o <u>Heating system peak sizes also increase directly with the heating degree days.</u>

Although some variations in local solar insolation, wind and temperature conditions were noted, the peak heating system sizes were closely correlated with the heating degree days. Based on the thermal envelopes for the farmhouses selected for this study, the older farmhouse, in spite of its smaller size (1067 square feet of living area), would require about the same peak furnace rating as a more modern farmhouse (1650 square feet of living area) if the rating is based on both conduction and infiltration loads. The levelized annual heating cost of the two houses is nearly equal. This result clearly shows the use of improved insulation, double pane windows throughout, and the use of improved building materials for the more modern type farmhouse.

o <u>The levelized annual heating cost increases with the annual average wind speed.</u>

Combining the state by state energy costs (reported by the Department of Energy) with wind speeds and heating energy found in this study, the range of levelized annual heating costs for the older and modern farmhouses is compared below.

	Levelized Annual Heating Costs in Dollars *								
	Wind Regime **								
	Low Less Than 10 MPH			Medium 10 to 12 MPH			High Greater Than 12 MPH		
Heating Fuel	Low Dollar Amount	Median Dollar Amount	High Dollar Amount	Low Dollar Amount	Median Dollar Amount	High Dollar Amount	Low Dollar Amount	Median Dollar Amount	High Dollar Amount
Electric-Resistance	500	1000	1500	1400	2200	3200	900	1400	3600
Electric-Heat Pump	250	500	750	700	1100	1600	500	700	1800
Natural Gas	400	600	1100	700	1200	2500	620	1100	2900
LP Gas	400	930	1735	1100	1800	2400	750	1300	3600
Fuel Oil	270	420	1400	1200	1600	1900	1400	1700	2600
All Fuels	230	930	1700	700	1530	3550	600	1700	3600

* Levelized with a 25 year life and 10 % discount rate

** Wind speeds referenced to 65.62 feet (20 meters)

Considering the aggregate of all fuels and all winds, the median levelized annual heating costs fall between $930 and $1700. The median cost for LP is generally greater than for electric resistance heating. The electric heat pump showed potential for lower median heating costs than all other fuels, and was competitive with natural gas and fuel oil even in low wind regimes.

o <u>The combined use of WECS production for more than just space heating significantly increases the value of the WECS energy and greatly increases the potential numbers of economically viable applications.</u>

If, in addition to its use for spaceheating and thermal storage for spaceheating, the WECS output was applied to hot water, appliances, and machinery before selling the surplus back to the local utility, the break-even value of the WECS energy more than doubles for electric heating, and nearly triples for petroleum based heating fuels. This result is further illustrated in Figure E-5 which shows the potential number of farmhouses which had levelized heating energy costs equal to or greater than the break-even value of the WECS production found with this study. The break-even values of the WECS production are shown for five different strategies for the use of WECS production, beginning with space heating only.

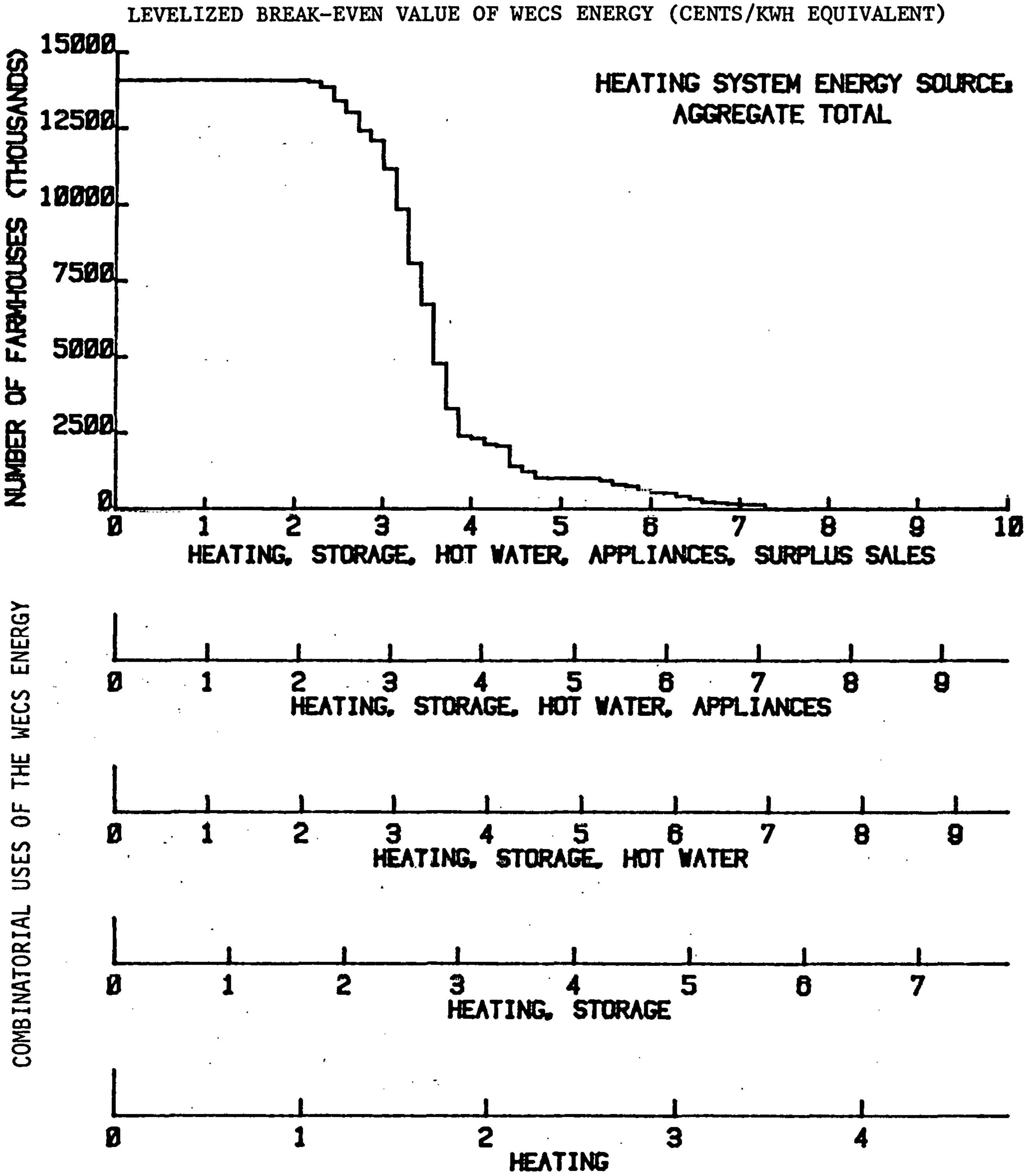


Figure E-5 Effect Of Combinatorial Uses Of WECS Production On Break-even Value And Number Of Economically Viable Applications For Farmhouses Using All Types Of Fuel Examined For Heating

The result shows that the combinatorial use of the WECS production greatly increases its value and allows the economically viable applications to increase greatly. For example, if a WECS were available costing 3 cents/kwh and used only for heating, fewer than 500,000 farmhouse applications would be economically viable. However, if a WECS were available at 3 cents/kwh and it was used for space heating, thermal storage for space heating, and hot water needs, more than 10,000,000 farmhouse applications would be economically viable.

The number of potential farmhouse applications versus the WECS levelized break-even value of energy is further summarized below using specific results from Figure E-5.

Number of Potential Farmhouse Applications With Thermal Storage Included

(1000's)

Heating Fuel Type	WECS Levelized Break-even Value of Energy - Cents/Kwh 3¢	4¢	5¢	6¢	7¢	8¢	9¢
Electricity	1364	1079	1005	608	176	63	42
Natural Gas	2595	289	0	0	0	0	0
LP Gas	2863	132	5	0	0	0	0
Fuel Oil	5285	899					
Totals	12107	2399	1010	608	176	63	42

The study has shown that thermal storage, using only a water storage medium and less than 1000 gallons of storage capacity, can be an effective approach to matching the variable WECS production with heating loads. Since projected costs for this type of thermal storge (Reference 51) are modest, this technique has been shown to increase the value of the WECS production using practical and reasonable approaches.

The study has also demonstrated that with storage, more than 90% of the WECS value is dependent on local use rather than on rates established by the utilities for purchase of any surplus WECS production. Thus, it is suggested that further research to examine the matching of loads among farmhouses, farm buildings, and other farm uses be conducted to further measure the value and combinatorial use of the WECS production.

1.3 STUDY APPROACH

The objective of this study was to determine the economic potential for the use of wind energy conversion systems (WECS) in the heating of farmhouses and farm buildings. An overview of the research is presented in Figure E-6.

The study was organized into separate and distinct tasks to address the following principal topics:

1. An investigation of agricultural farmhouse and farm building heating requirements for diverse regions throughout the United States

2. A determination of baseline farmhouse and farm building heating needs and energy use patterns

3. An analysis of wind energy applications considering the utilization of thermal storge

4. An analysis of break-even economic values required for wind energy applications

5. A survey of present agricultural use of heating systems and heating costs

6. A correlation of wind energy market potential at various break-even cost levels

The following paragraphs present brief summaries of the analytical approaches applied to the major study tasks.

Agricultural Farmhouse and Farm Building Heating Requirements

The objective of this task was to survey U. S. agriculture and determine the principal building heating requirements for the representative farmhouses and farm buildings most prevalent in agricultural operations.

Three typical farmhouse structural envelopes were defined following a survey of farmhouses indicated by the U. S. Census of Agriculture and other standard references. Farmhouse structures were developed separately for older farmhouses constructed before 1960, more modern farmhouses constructed after 1960, and a hybrid farmhouse design for complementary use of passive solar and wind energy applications.

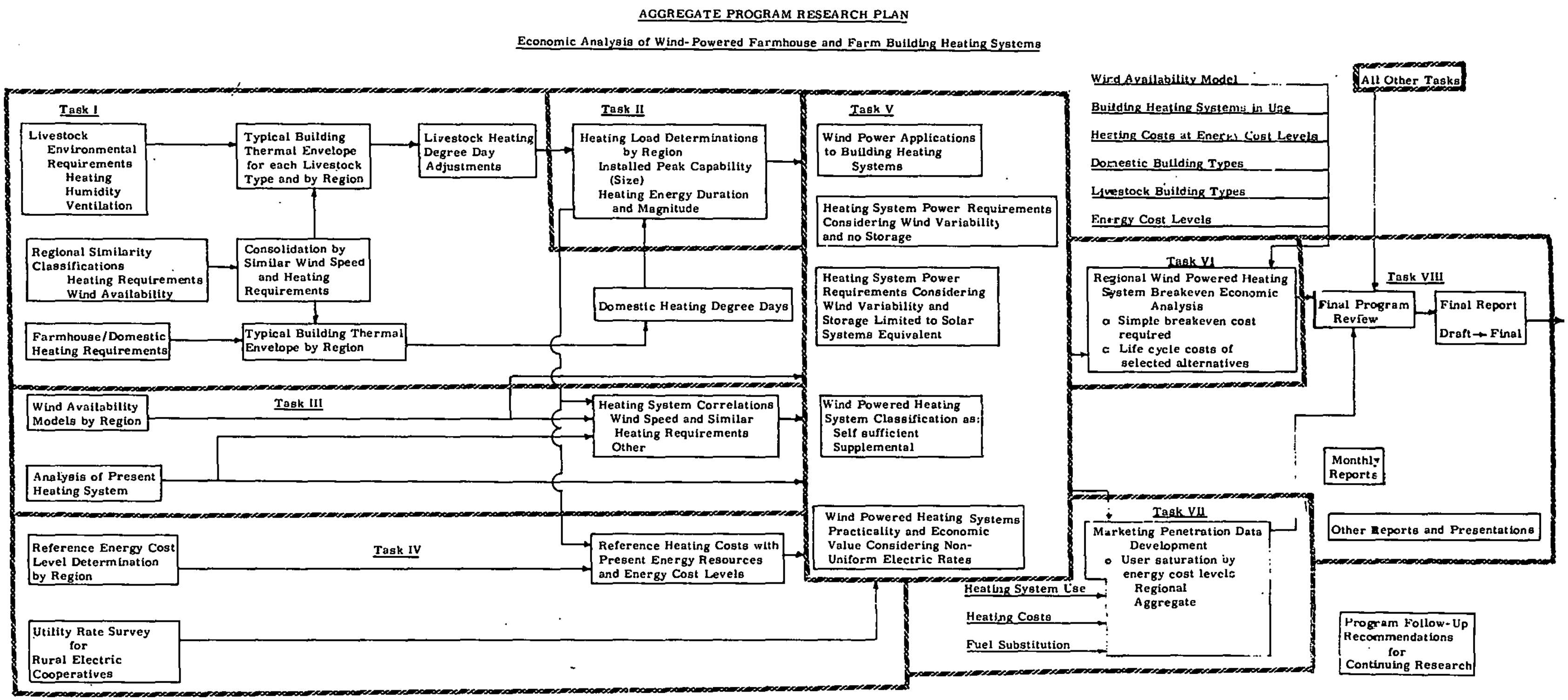


Figure E-6 Study Approach For An " Economic Analysis Of Wind-Powered Farmhouse and Farm Building Heating Systems "

A survey of reported livestock operations throughout the United States utilizing confinement structures was completed. Following a screening process, eight farm building types were correlated to eight agricultural production centers for analysis. The distinct farm building structural envelopes were developed using references from the Midwest Plan Service and other standard agricultural references for the farm buildings. The selected farm buildings were located in the nine geographical centers representing the most prevalent agricultural production regions, diversity of wind energy, climatic conditions, and cost of competing energy. The sites included:

Farm Building Applications	Geographic Production Centers
Poultry-Broilers	Baltimore, Maryland
Poultry-Layer/Brooding	Sacramento, California
Poultry-Layers	Sacramento, California
Poultry-Turkeys	Minneapolis, Minnesota
Swine-Farrowing	Des Moines, Iowa
Swine-Growing and Finishing	Des Moines, Iowa
Dairy	Madison, Wisconsin
Lambing	Casper, Wyoming

The specific city references mentioned above were utilized because of the availability of hourly wind resource data from the National Weather Service and the National Climatic Center.

Also included in this task was a determination of farmhouse and farm building environmental requirements to provide for the needs of the inhabitants. The required internal environmental conditions were then utilized as the basis for determining the energy flows and balances corresponding to the local climatic conditions, farmhouse and farm building structural envelopes, heating, ventilating and environmental control.

The heating requirements and wind availability for the nine geographic locations were utilized to examine the agricultural applications throughout the nation.

Baseline Farmhouse and Farm Building Heating Loads

The objective of this task was to determine the duration and size of the heating loads and energy needs for the three farmhouses and the eight farm building types operating in the geographically diverse areas selected for the confinement structure applications. This data was then to be used as a baseline against which wind energy applications could be examined.

Due to the study requirement to evaluate the interaction of wind energy applications with and without thermal storage systems, the analyses were predicated on sequential hour by hour determinations of the energy flows considering hourly weather and climatic data, internal appliance loads, internal machinery loads, inputs from animals or humans, and a determination of required ventilation (all considering sensible and latent heat losses and gains).

The sequential hour by hour energy needs analysis was completed for all three farmhouse types and eight farm building types for an annual period at all eight locations. An additional geographic location of Chicago, Illinois was utilized for farmhouse applications to provide a comparison with previous USDA studies of wind energy applications utilizing data available from the upper midwest (Ohio) region. The hour by hour energy flow analyses were calibrated using data from the houses located near Canton, Ohio and from actual billing data for a farmhouse in the Denver, Colorado area.

Wind Energy Applications Analysis

The objective of this task was to examine the applications of wind energy to a number of farmhouse and farm building heating energy use patterns. Wind energy was analyzed with and without storage of thermal energy to examine the sensitivity of directly usable (i. e. coincident) wind energy to the use of thermal storage and other thermal and electric applications in the farmhouses and farm buildings.

Since the climatic data were evaluated at hourly intervals, and the energy balances made at subhourly intervals, the effects of wind variability and the time coincidence of heating needs and the wind resource were fully analyzed. This detailed approach provided for assessments of wind energy as a self-sufficient or supplemental resource subject to the constraint that desired internal environmental conditions be maintained. The sizing of the thermal storage systems was based on guidelines developed for passive and active solar system applications by the Los Alamos Scientific Laboratories, DOE Division of Buildings and Community Systems, The Solar Energy Research Institute, and other available references.

Economic Break-Even Value Analysis For Wind Energy Applications

The objective of this task was to determine the range of break-even costs of energy required by wind energy systems to compete with the energy now used in the farmhouses and farm buildings in U. S. agriculture. The required life cycle levelized break-even costs of energy were also utilized to describe the relative number of potential wind energy applications for heating and energy use in farmhouses and farm buildings, considering alternative break-even cost goals for WECS equipment. Life cycle break-even values were determined for heating alone and for heating in combination with thermal storage, domestic hot water, appliance loads, and sell-back of any surplus wind energy to the local utility, considered to be a rural electric cooperative. Competing fuels considered were electricity, natural gas, bottle gas, and fuel oil or distillate fuels. The value added to wind energy, due to all of the above uses of energy plus livestock feed and incremental productivity, was also included in the evaluation. Energy costs, electric rates, feed costs, and wind resource availability were correlated to the nine geographical areas representative of the wind regimes and agricultural operations throughout the United States.

Agricultural Heating Systems and Heating Cost Survey

The objectives of this task were to survey farmhouse and farm building applications, to evaluate the correlation of heating systems used in agriculture with heating fuel types, to examine regional similarities, to make correlations with the wind resource, and to evaluate the relative cost of heating fuels with present energy sources.

Wind Energy Market Potential At Selected Break-even Cost Goals

The objective of this task was to aggregate potential wind energy system uses according to each cost level for present energy sources. Based on this data, potential applications were correlated to the break-even value of energy goals determined from the economic analyses.

This task included a survey of all rural occupied farmhouses based on the most recent Census of Agriculture and Department of Commerce surveys, together with fuel costs reported by the Department of Energy in its regional surveys. Analyses of these results yielded an understanding of the relative number of applications and their dependency on available break-even cost goals for wind energy conversion systems.

The subsequent chapters present detailed results and expanded discussions of the research topics addressed with this study. Chapter 2 discusses farmhouse and farm building structural and environmental requirements. Chapter 3 develops the baseline annual farmhouse and farm building heating loads for comparison with wind-powered heating system applications. Chapter 4 presents the quantitative aspects of the wind energy analysis. Chapter 5 discusses the economic break-even value analysis for wind energy applications. Chapter 6 presents the results of the agricultural heating systems and heating costs survey, and finally, Chapter 7 evaluates wind system market potential based on a wide range of break-even values of wind energy with thermal storage and other complementary uses.

2.0 FARMHOUSE AND FARM BUILDING STRUCTURAL AND ENVIRONMENTAL REQUIREMENTS

2.1 INTRODUCTION

This section presents a summary of the farmhouses and farm buildings most prevalent in U.S. agriculture selected for wind energy applications analysis.

Three representative farmhouses and farm buildings were established; these were derived from a survey of farmhouses completed using the 1970 U.S. Census of Housing and the 1974 Annual Housing Survey. The three typical farmhouse structures are categorized below:

1. An older farmhouse constructed prior to 1960
2. A more modern farmhouse constructed after 1960
3. A hybrid farmhouse design utilizing passive solar principles

The representative farm buildings were selected from a survey of livestock operations throughout the United States. Twenty two farm building types, which could employ space heating systems, were pinpointed. A screening process, considering five separate factors, allowed a narrowing to 8 farm buildings from the 22 for further analysis. Regional locations, where detailed use of wind-powered heating systems was examined, were henceforth cited as farm building operations production centers.

The farm building types selected, along with their representative production centers, were:

Selected Farm Building Operation	Representative Production Center
Poultry-Broilers	Baltimore, Maryland
Poultry-Brooding	Sacramento, California
Poultry-Layer	Sacramento, California
Poultry-Turkey	Minneapolis, Minnesota
Swine-Farrowing	Des Moines, Iowa
Swine-Growing/Finishing	Des Moines, Iowa
Dairy	Madison, Wisconsin
Lambing	Casper, Wyoming

Farmhouses were also analyzed in detail at additional locations to provide a comparison and a cross-check of this analysis with previously conducted studies. These locations were utilized because of available hourly wind resource and climatic data from the National Climatic Center, Ashville, North Carolina, and included:

Casper, Wyoming
Denver, Colorado
Chicago, Illinois

Using the prevalent farmhouse characteristics and farm building operations from the analysis, structural and thermal envelopes were developed using recommendations of ASHRAE, the Midwest Plan Service, and other standard agricultural references. Annual heating energy balances were determined using sequential hour by hour analysis considering local factors, climatic histories, and the indoor environmental requirements of humans and animals. Heat and moisture production of the animals was computed dynamically, allowing for growth and indoor temperature to moderate sensible heat and moisture production.

Subsequent paragraphs summarize the farmhouse and farm building surveys, the environmental requirements involved, and the structural models utilized in this study.

2.2 FARMHOUSE CHARACTERISTICS

This section will illustrate how the farmhouse structural characteristics were developed from a survey of farmhouses presently found in agriculture. It will also show the environmental requirements selected from standard designs recommended by ASHRAE, and examine in detail the farmhouse reference structures.

2.2.1 FARMHOUSE STRUCTURAL SURVEY

Data from the 1970 Census and the 1974 Census of Housing was consolidated to define the three models which comprise a reasonable sample of rural housing. The overall structure size was based primarily on the selected factors listed below, although other criteria were also considered:

- o Size
- o Equipment
- o House heating fuel
- o Water heating fuel
- o Cooking fuel
- o Structure age (year constructed)
- o Structure type (detached single, duplex, mobile home, etc.)
- o Air conditioning used
- o Cooling system fuels

Table 1 summarizes the above characteristics in a more concise manner. This summary indicates that more than 90% of all farmhouses were constructed prior to 1960, with less than 3% between 1968 and 1970; 44% contained one detached structure, and approximately 5% were mobile homes or trailers.

To compare the above heating fuel data, the 1974 Annual Housing Survey was consulted. Although no specific farm data was available, information was available on both a national and a regional basis. The check revealed that fuel use had not changed appreciably over the four year period for existing structures, but new construction, on the other hand, showed increased utilization of electricity as a space heating fuel. Corresponding decreases in natural gas and fuel oil use were also found.

Size - %	0-1 Bdrm	2 Bdrm	3 Bdrm	4 Bdrm	5 Bdrm-up
	4.3	26	42.7	19.3	6.9

Heating Equipment - %	Steam/ Hot Water	Warm Air Furnance	Built-In Electricity	Floor, Wall or Pipeline Furnace	Room Heater w/floor-wo/floor	Fireplace Stove/ Portable Heating	None
	7.9	40.6	6.7	5.8	18.2/8.9	11.7	0.2

	Utility Gas	Fuel, Oil Kerosene, Etc.	Coal Coke	Wood	Electricity	Bottled, Tank LP Gas	Other	None
House Heating Fuel	12.1	36.3	7.8	6.5	8.4	28.4	0.2	0.3
Water Heating Fuel	8.6	3.5	0.4	0.4	54.1	20.4	0.1	12.4
Cooking Fuel	8.8	56.0	0.6	0.7	30.7	2.9	0.1	0.1

Year Structure Built - %	1969-May 1970	1965-68	1960-64	1950-59	1940-49	1939 or Earlier
	2.6	7.8	8.4	13.8	10.4	56.9

Housing Units w/Single Structure	1 detached	1 attached	2 attached	3 or 4 attached	5 or more attached	Mobile Home or Trailer
	93.7	0.2	1.1	0.1		4.8

Air Conditioning-%	1 Room Unit	2 or More Room Units	Central System	None
	14	4.1	5.1	76.8

Table 1 Frequency Distribution Of Farmhouse Characteristics

Three farmhouse structures were defined for detailed evaluation, each with distinctly different thermal characteristics:

1. An older house (constructed prior to 1960)
2. A modern house (constructed after 1960)
3. A passive solar designed house

The third structure selected incorporated a passive solar design. This structure completes the triad of past and present construction by adding a possible future construction practice. These three structures encompass a wide spectrum of housing options. Major construction differences are included, providing a comprehensive analysis of the single major use of agricultural space heating energy. A comparative summary of the thermal and structural features of the three farmhouse types is shown in Table 2.

The selected farmhouse types were used consistently for annual energy flow analyses at nine locations throughout the United States, corresponding to agricultural production centers.

2.2.2 FARMHOUSE ENVIRONMENTAL REQUIREMENTS

The farmhouse environmental requirements were assumed to be similar to urban structures; environmental guidelines recommended by ASHRAE were therefore incorporated. A summary of the optimum environmental conditions to be maintained inside the farmhouses is shown in Table 3.

It should be recognized that actual environmental conditions maintained in a farmhouse will be subject to owner preference and individual practices. However, for purposes of this study, optimum conditions were employed in order to provide a consistent baseline for the measurement of energy flows to be analyzed for wind system applications.

2.2.3 FARMHOUSE REFERENCE STRUCTURES

The three farmhouse structures defined - the older, more modern, and hybrid solar-wind houses - are next scanned in light of their overall layouts. The older farmhouse is depicted in Figures 1, 2, and 3. This house, a two bedroom structure, includes an attached garage, a kitchen, a dining room and a living room. The main floor living space totals 1067 square feet. A concrete basement covers most of the space below the structure. Exterior walls of the house (as well as the wall adjacent to the garage) consist of a standard frame covered with plaster, with air space for insulation. The ceiling is also standard plaster-covered coupled with 5.5 inches of fill insulation. Concrete comprised the basement wall and floor, of 8 and 4 inches thickness, respectively. All doors were made of wood; windows of single pane glass. The garage was a single car design of wood frame and plaster construction. An average air infiltration rate of one air exchange per hour, based upon ASHRAE recommendations, was assumed in the older farmhouse.

	Older House	Modern House	Passive House
Heated floor area (ft.^{2})	1067	1650	1650
Bedrooms	2	3	3
Exterior Walls:			
Type 1:			
Materials	Frame, plaster, air space, siding	Wood siding, frame (2x4), batt insulation	Wood siding, frame (2x6), batt insulation
Resistance *	4.48	15.91	22.27
Area (Ft^2)	848	712	15.59
Type 2:			
Materials		Brick veneer, frame (2x4), batt insulation	Concrete, air space, thermal pane glass
Resistance *		14.91	3.78
Area (Ft^2)		209	400 ft.^{2}
Ceiling:			
Materials	Frame, 5.5" fill insulation	Frame, batt insulation	Frame, batt insulation, plywood, shingling
Resistance *	22.2	34	34.79
Area (Ft^2)	1067	1650	1680
Crawl Space	No	No	Yes
Basement	Yes	Yes	No
Glass:			
Materials	Single pane glass	Double pane glass	Double pane glass
Resistance*	0.95	1.54	1.54]
Area (Ft^2)	190	177	82 Ft.^{2}
Design Heat Loss:			
Conductive	809.3	545.9	545.9
Vent'n, Infilt'n*	384.1	594.0	594.0
* $\frac{Hr\text{-}Ft^2\text{-}F}{Btu}$	Attic, single car garage, 1 air exchange per hour	Gypsum walls, attached 2-car garage, attic, 1 air exchange per hour	Vaulted ceiling, 1 air exchange per hour

Table 2 Farmhouse Characteristics Selected For Wind-powered Heating System Analysis

	Older House	Modern House	Passive House
Minimum Environmental Design Temperature			
Day (°F)	65	65	65
Night (°F)	60	60	60
Maximum Relative Humidity	85	85	85
Electric			
Lighting Appliances (Btu/day)	56840	45406	45406
Hot Water (Btu/day)	56901	46060	46060
Air Exchange (per hour)	1	1	1

Table 3 - Farmhouse Indoor Environmental Requirements

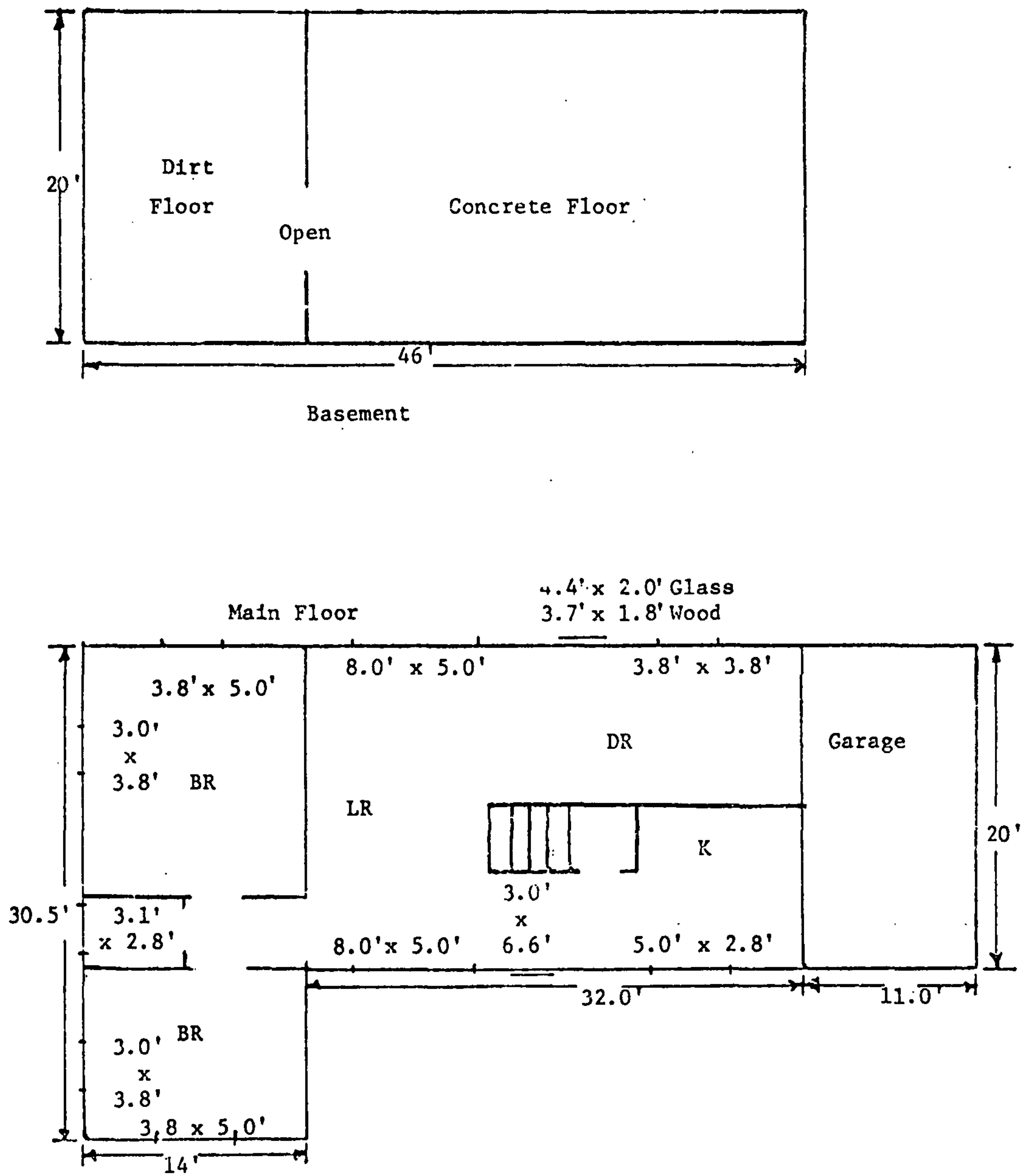
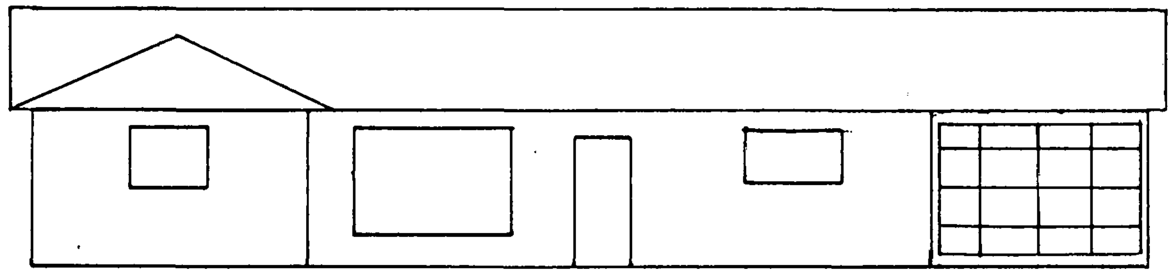
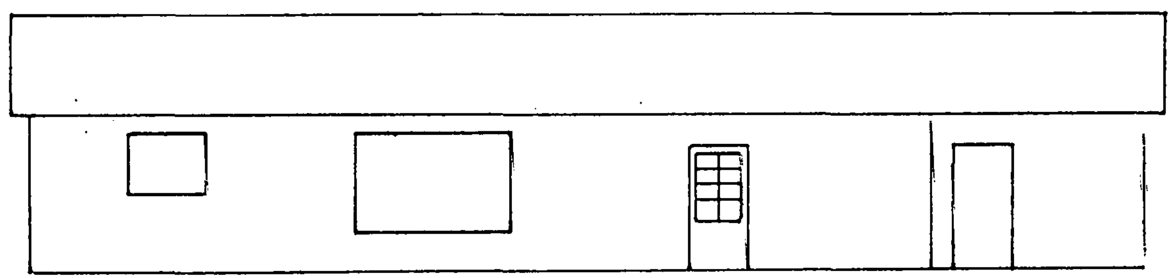


Figure 1 Older Farmhouse Floor Plan and Window Dimensions

Front View

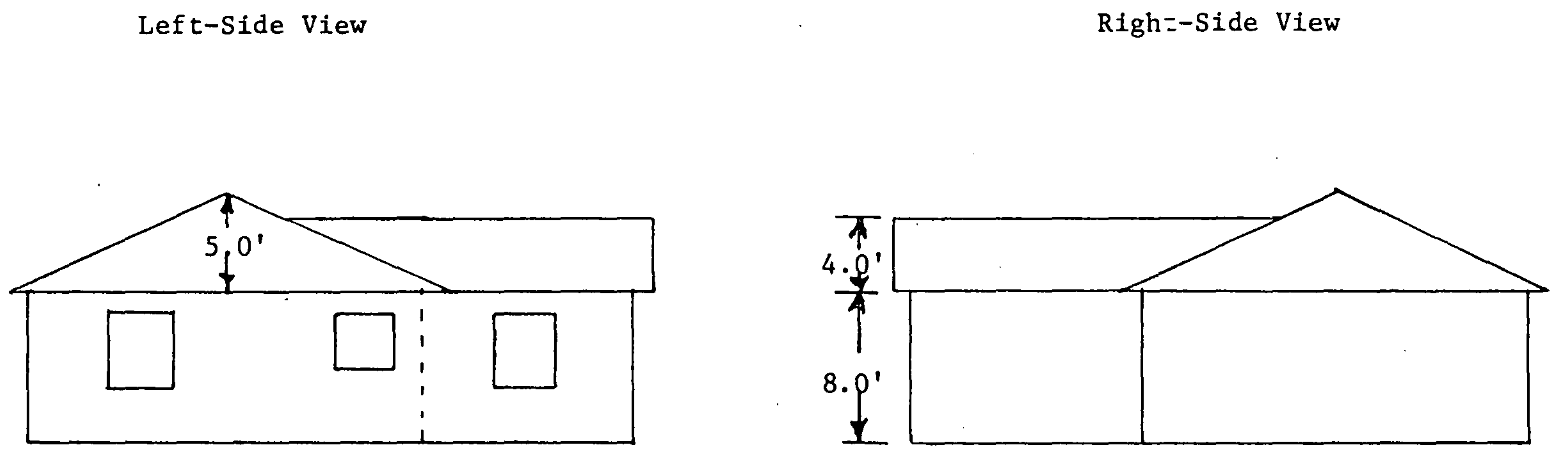


Rear View



Older Farmhouse

Figure 2 Older Farmhouse Front and Rear Views



Older Farmhouse

Figure 3 Older Farmhouse Side Views

Scale: 10' per inch

The more modern house layout is presented in Figures 4, 5, and 6. It has three bedrooms, a kitchen and dining area, a living room, an attached garage and a full basement; total floor area is approximately 1650 square feet. The exterior walls were composed of two types of exterior surfaces. Most of the wall area (75%), including the wall adjacent to the garage, consisted of a 2 in. by 4 in. frame with wood exterior siding, gypsum interior and an R-11 batt insulation. The remainder of the walls substituted a brick veneer for the exterior wood siding. The wood from the ceiling areas was insulated with R-30 batt insulation and had a gypsum interior surface. Basement walls were 8 inch concrete, and the floor was of 4 inch concrete. Exterior doors were made of steel, insulated with polyurethane and the windows were of thermal pane design. Again, the assumed infiltration rate was one air exchange per hour.

The final home, a hybrid passive solar-wind structure, is illustrated in Figures 7, 8, and 9. The passive solar design incorporated the use of a "Trombe wall". This wall is simply a massive vertical wall of concrete oriented south with an exterior surface covered with thermal pane glass, which forms a dead air space. The wall stores and transmits solar energy for use in space heating. The house includes 1650 square feet of living area and is a ranch style incorporating three bedrooms, a kitchen, dining and family rooms, and a sloping vaulted ceiling. Exterior wall construction consists of external siding, vapor barrier, framing, R-11 batt insulation and interior wood paneling.

The ceiling is comprised of R-34 batt insulation, with wood frame having shingle-covered plywood on the exterior surface, and wood paneling covering the interior surface. A hardwood floor situated over a crawl space, of dirt, is insulated wth an R-19 batt. All windows are thermal pane and use an air infiltration rate of one air exchange per hour.

Environmental requirements within each of the three structures were held constant; internal temperatures of 65 degrees F (winter) and 85 degrees F (summer) were maintained, and an evening internal temperature setback (60 degrees F) was modeled during late night periods. The variety of design allowed a broad spectrum of general residential structures to be evaluated.

2.3 FARM BUILDING CHARACTERISTICS

This section summarizes the rationale involved in selecting the eight farm buildings which represent a wide range of potential heating energy uses. It also encompasses the environmental requirements and the reference structures of the farm buildings themselves. A review of the Midwest Plan Service- Structures and Environment Handbook- revealed more than 20 distinct farm building types. The 1974 Census of Agriculture was also surveyed for additional farm building production applications (which included goats, mink, fish, etc.). Each was then investigated for its economic significance, yet due to limited impact, were not included in subsequent screenings.

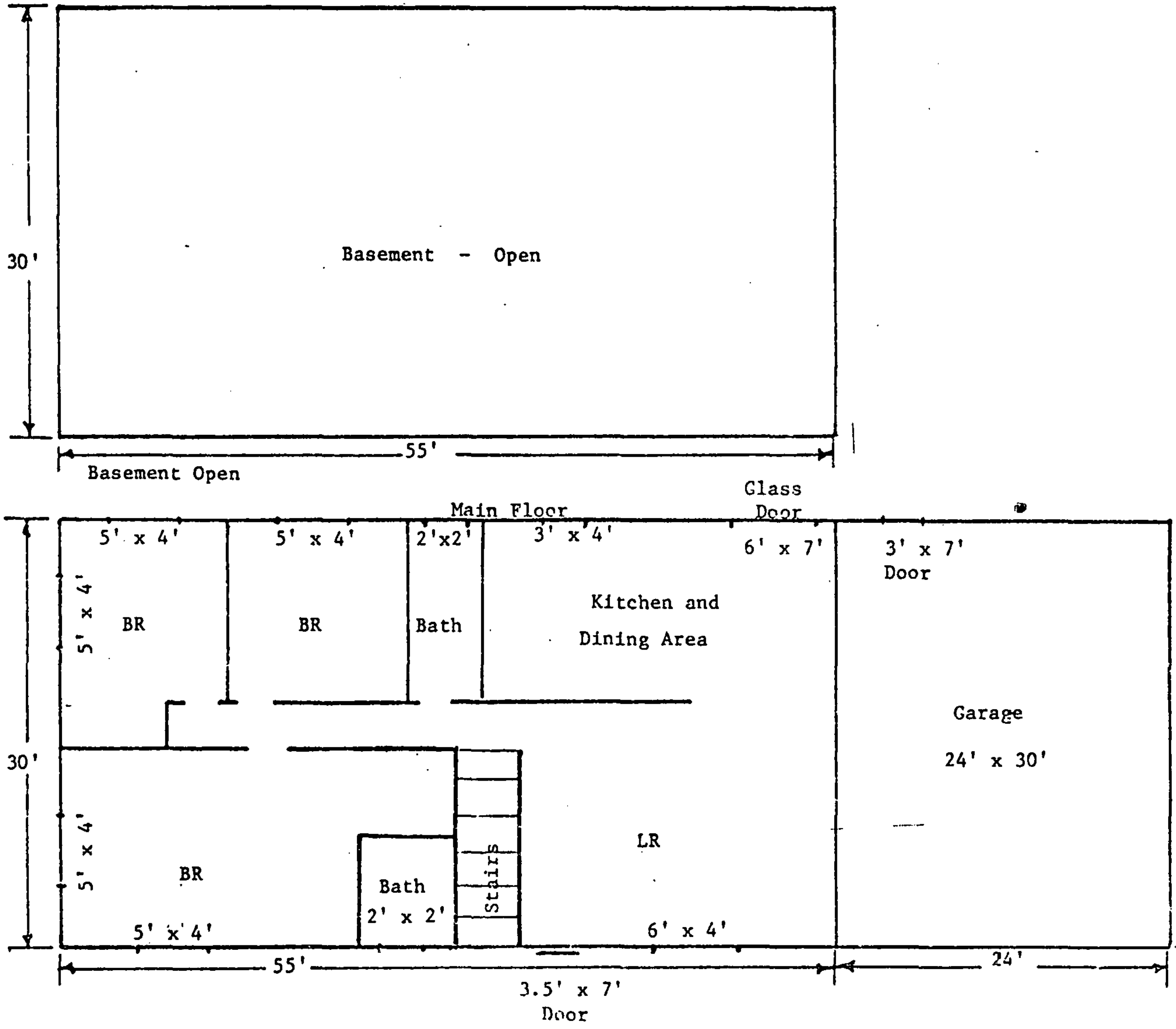


Figure 4 Modern Farmhouse Floor Plan and Window Dimensions

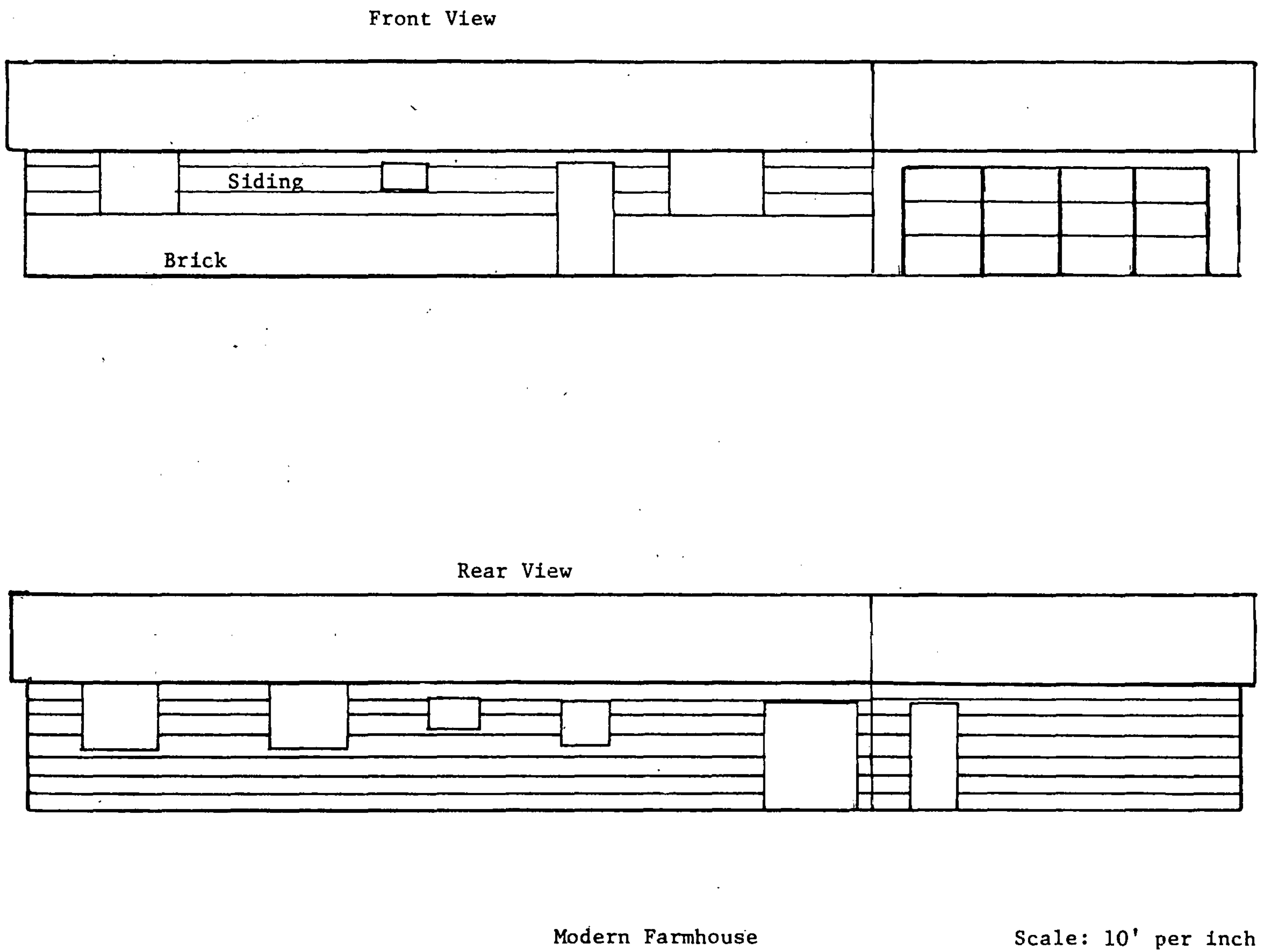
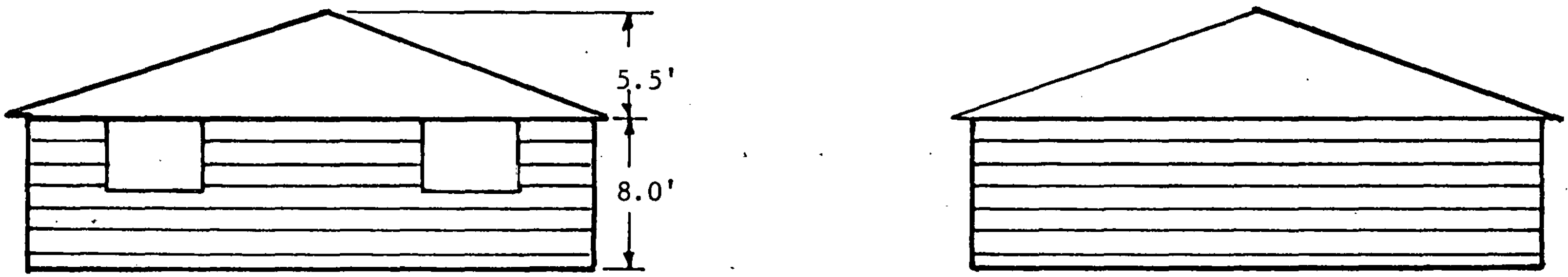


Figure 5 Modern Farmhouse Front and Rear Views

Left-Side View

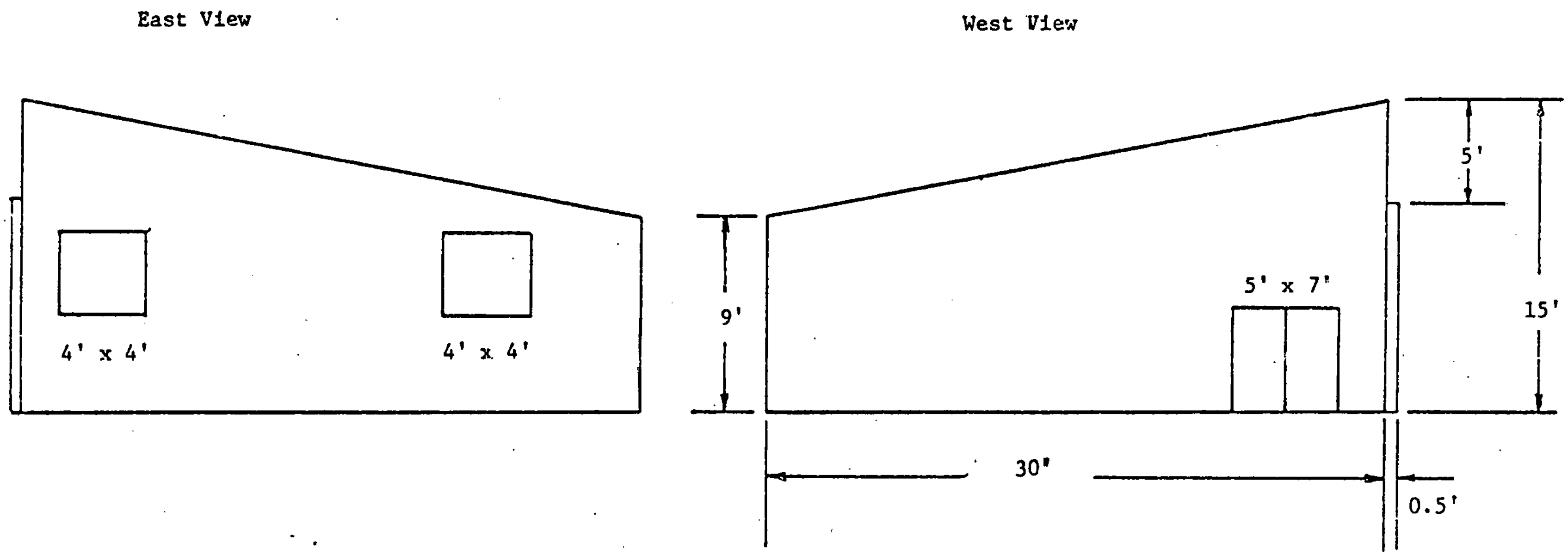
Right-Side View



Modern Farmhouse

Scale: 10' per inch

Figure 6 Modern Farmhouse Side Views



(400 Ft. Trombe Wall)

Figure 7 Passive Solar Farmhouse Side Views

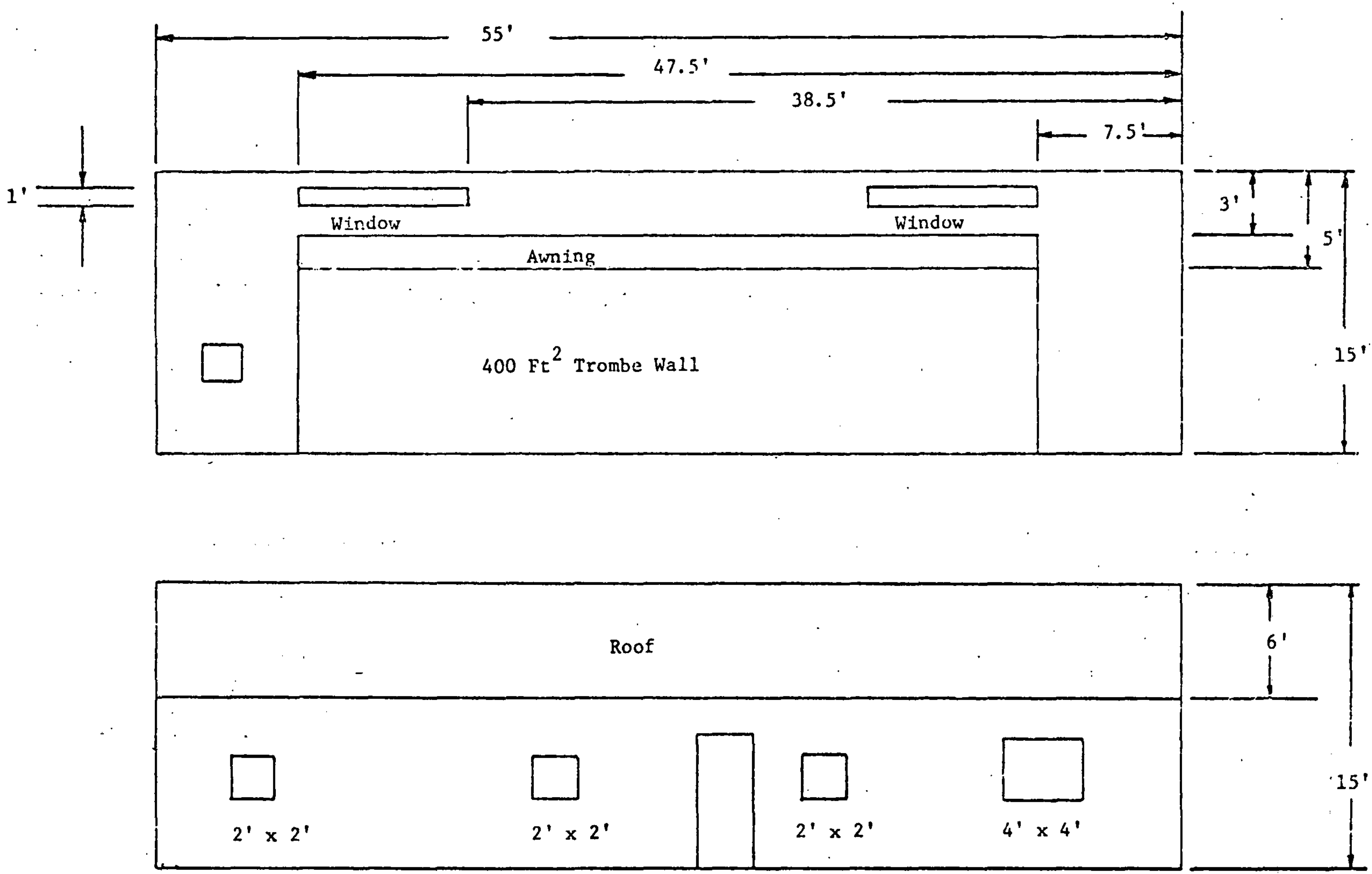
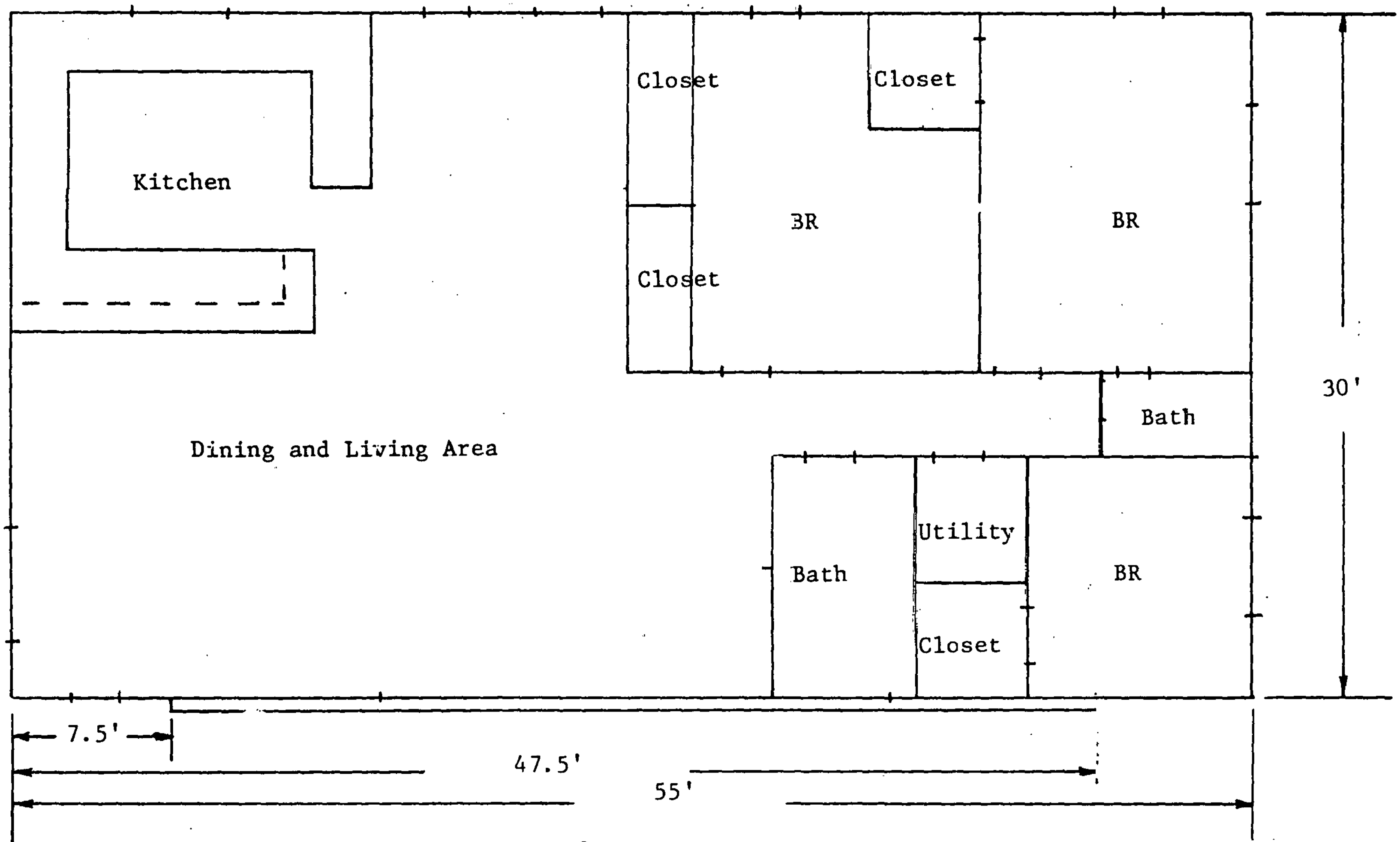


Figure 8 Passive Solar Farmhouse South and North Views



(400 Ft.^{2} Trombe Wall)

Figure 9 Passive Solar Farmhouse Floor Plan

Livestock and poultry applications were classified by major group, as well as subgroups. The subgroups were defined considering various production methods, growth cycles or environmental variations. Twenty two various livestock and poultry applications comprised the subgroup list and are shown in Table 4.

From the above list, a maximum of eight applications were selected for subsequent energy flow analysis. As an initial screening factor, the need for a controlled environment was used. Rabbit, pidgeon, and horse farm buildings were screened out using only this criteria. In order to further limit the applications for this study, the five criteria utilized included:

- o Structural requirements
- o Energy use index
- o Desirability of warm confinement
- o Annual structure usage
- o Extent of the operation

Each criteria was allowed individual ranking between 1 and 10, but criteria 5 was assigned a relative weight of three to emphasize the applications of greater national economic value. Other criteria were weighted at unity. The analysis also revealed that in typical farm operations related functions might be found in the same building. For example, for a dairy operation, the same structure might provide for a lactating cow area, water heating area, milking parlor, milk room, and hospital area.

Based on applications of the screening criteria shown in Table 5, the eight buildings selected for further analysis included:

1. Poultry-Broilers
2. Poultry-Brooding
3. Poultry-Layers
4. Poultry-Turkeys
5. Swine-Farrowing
6. Swine-Finishing
7. Dairy
8. Lambing

2.3.1 FARM BUILDING REFERENCE LOCATIONS

Regional production centers for the selected farm building applications were ranked from production data reported by the Department of Commerce 1974 Census of Agriculture and are shown in Table 6. States from the regions of highest production were then identified as locations for detailed analyses of wind energy applications. The production by state for each livestock type is summarized in Table 7.

Based on their contribution to national livestock production, the states selected to represent the farm building applications for this

Major Grouping	Sub-Groups
Swine	Farrowing House Growing House Finishing House Gestating Sow Facility
Poultry	Laying House Broiler House Turkey House Brooding House Pidgeon Housing
Dairy	Lactating Cow Housing Non-Milking Animal Housing (Calves and Young Stock) Dry Cow-Heifer Housing Milking Parlor Milk Room Hospital
Beef	Cow-Calf Housing Beef Cattle Housing
Sheep	Ewe Lambing Area Feeder
Horse	Horse Housing
Rabbit and Small Animals	

Table 4 - Potential Agricultural Facilities

Source: Midwest Plan Service, 1974 Census of Agriculture

	Structural Requirements	Energy Use Index	Desirability of Warm Confinement	Extent of Operation (Weight by 3)	Annual Structure Usage	Overall (Σ1-5) Score
Swine Operation						
Farrowing	10	8	10	24	9	61
Growing	8	7	8	24	9	56
Finishing	8	7	8	24	9	56
Gestating	5	5	5	18	9	42
Poultry						
Layer Brooding	10	8	10	18	9	55
Layer	10	5	9	24	9.5	57.5
Broiler	10	10	10	27	9	66
Turkey Brooding	9	8	7	18	9	51
Turkey Growing	2	1	2	18	2	25
Dairy						
Dry Cow, Heifer	6	1	2	15	8	32
Lactating Cow Barn (Water Heating) (Milk Room) (Milking Parlor) (Hospital)	9	9	8	27	10	63
Beef						
Cow-Calf	4	6	4	27	2	43
Steer	1	1	1	27	1	31
Sheep						
Ewe Housing	1	1	1	18	9	30
Lambing Area	7	5	8	18	6	44
Feeder Housing	5	2	6	21	9	43

Table 5 - Evaluation of Energy Use Potential

Source: 1974 Census of Agriculture, Midwest Plan Service

Region	Layers	Brooding Layers	Broilers	Turkey Brooding	Swine	Lamb	Dairy Cows
New England	5.3	8.4	2.4	0.1	0.1	0.1	4.3
Middle Atlantic	7.8	7.9	2.3	2.1	1.3	0.8	16.6
E.N. Central	14.1	14.1	1.1	9.8	27.3	6.7	26.7
W.N. Central	11.4	9.7	1.1	28.4	52.6	19.3	15.9
S. Atlantic	20.5	22.5	39.4	27.5	8.4	1.9	9.3
E.S. Central	10.3	9.2	23.2	0.1	4.9	0.4	5
W.S. Central	11.3	13.3	25.9	15.8	2.7	20.0	5.4
Mountain	2.5	1.9	0.04	4.5	1.7	34.0	4.0
Pacific	16.7	13.0	4.4	11.5	0.7	16.0	12.6

Table 6 - Regional Production of Selected Livestock Types - %

Source: 1974 Census of Agriculture

	Production						
	Layers	Brooding/ Layers	Broilers	Turkeys	Swine	Lambs	Dairy
Maine	2.6	5.4	2.4	0.1	0.1	0.1	0.6
New Hampshire	0.4	0.1	0.1	0.1	0.1	0.1	0.3
Vermont	0.3	0.1	0.1	0.1	0.1	0.1	1.9
Massachusetts	0.6	0.1	0.1	0.1	0.1	0.1	0.6
Rhode Island	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Connecticut	1.4	1.9	0.1	0.1	0.1	0.1	0.6
New York	2.7	3.9	0.1	0.1	0.2	0.3	9.2
New Jersey	0.7	0.3	0.1	0.1	0.1	0.1	0.5
Pennsylvania	4.4	3.6	2.2	1.9	1.0	0.4	6.8
Ohio	3.4	2.1	0.3	2.8	4.0	2.9	3.6
Indiana	4.7	5.7	0.3	3.7	7.5	0.8	1.8
Illinois	2.5	2.6	0.1	0.3	11.8	1.3	2.0
Michigan	2.1	2.9	0.1	1.1	1.3	1.1	3.8
Wisconsin	1.4	0.7	0.3	1.8	2.7	0.5	15.5
Minnesota	3.0	2.7	0.3	19.1	6.6	2.5	6.9
Iowa	3.0	2.0	0.1	3.1	25.8	3.6	3.0
Missouri	2.2	3.1	0.6	4.6	6.3	1.1	1.9
North Dakota	0.2	0.1	0.1	0.6	0.7	2.2	0.7
South Dakota	0.9	0.8	0.1	0.7	3.5	5.7	1.2
Nebraska	1.2	0.6	0.1	0.1	6.1	2.0	1.0
Kansas	0.8	0.5	0.1	0.2	3.4	2.0	1.2
Delaware	0.1	0.4	5.0	0.1	0.1	0.1	0.1
Maryland	0.5	0.5	6.1	0.1	0.3	0.1	1.5
Virginia	1.4	2.0	2.5	7.9	1.0	1.2	1.7
West Virginia	0.2	0.1	0.6	2.1	0.1	0.5	0.3
North Carolina	4.4	5.5	8.8	13.2	3.0	0.1	1.4
South Carolina	1.8	2.0	0.8	3.0	0.7	0.1	0.5
Georgia	7.6	8.0	13.7	1.1	2.7	0.1	1.2
Florida	4.4	3.8	1.8	0.1	0.4	0.1	2.5
Kentucky	0.7	1.0	0.2	0.1	1.9	0.2	1.7
Tennessee	1.5	0.8	1.4	0.1	1.4	0.1	1.7
Alabama	4.6	3.9	13.6	0.1	1.1	0.1	0.7
Mississippi	3.5	3.5	8.1	0.1	0.4	0.1	0.8
Arkansas	5.6	6.0	17.5	8.4	0.5	0.1	0.6
Louisiana	1.0	1.4	1.6	0.1	0.1	0.1	1.0
Oklahoma	0.6	0.7	1.0	0.1	0.4	0.9	0.9
Texas	4.0	5.1	5.8	6.4	1.7	19.0	2.9
Montana	0.3	0.2	0.1	0.1	0.5	3.5	0.2
Idaho	0.3	0.4	0.1	0.1	0.2	4.3	1.1
Wyoming	0.1	0.1	0.1	0.1	0.1	7.1	0.1
Colorado	0.7	0.3	0.1	2.0	0.6	9.7	0.7
New Mexico	0.3	0.2	0.1	0.1	0.1	2.2	0.3
Arizona	0.3	0.1	0.1	0.1	0.2	2.6	0.7
Utah	0.6	0.7	0.1	2.4	0.1	3.8	0.7
Nevada	0.1	0.1	0.1	0.1	0.1	0.8	0.1
Washington	1.5	0.9	0.4	0.1	0.1	0.5	2.0
Oregon	0.8	0.6	0.4	0.6	0.2	2.9	0.9
California	14.0	10.8	3.5	10.8	0.2	13.0	9.5
Alaska	0.1	0.0	0.0	0.1	0.0	0.1	0.1
Hawaii	0.4	0.5	0.1	0.1	0.1	0.1	0.1

Table 7 - Livestock Production by State - %

Source: 1974 Census of Agriculture

study are shown below. Also included are the cities for which hourly wind speed and climatic data could be obtained from the National Climatic Center.

Farm Building Applications	Representative State	Reference City For Climatic Data
Poultry-Broilers	Maryland	Baltimore
Poultry-Layers	California	Sacramento
Poultry-Brooding	California	Sacramento
Poultry-Turkeys	Minnesota	Minneapolis
Swine-Farrowing	Iowa	Des Moines
Swine-Finishing	Iowa	Des Moines
Dairy	Wisconsin	Madison
Lambing	Wyoming	Casper

A correlation of the selected production centers to wind energy density is shown in Figure 10. Note that the wind power shown is referenced to a 50 meter height. This study has adjusted the wind data reported by the National Climatic Center to a 65.62 foot (20 meter) reference height as directed by USDA.

2.3.2 FARM BUILDING ENVIRONMENTAL REQUIREMENTS

Environmental requirements in this section were based on the indoor conditions recommended for optimum production in each of the selected farm building operations. The conditions established a reference for determining required feed, energy and ventilation necessary to attain optimum production, and provided a measure of the essential quantity of heating energy. These results are presented in Table 8.

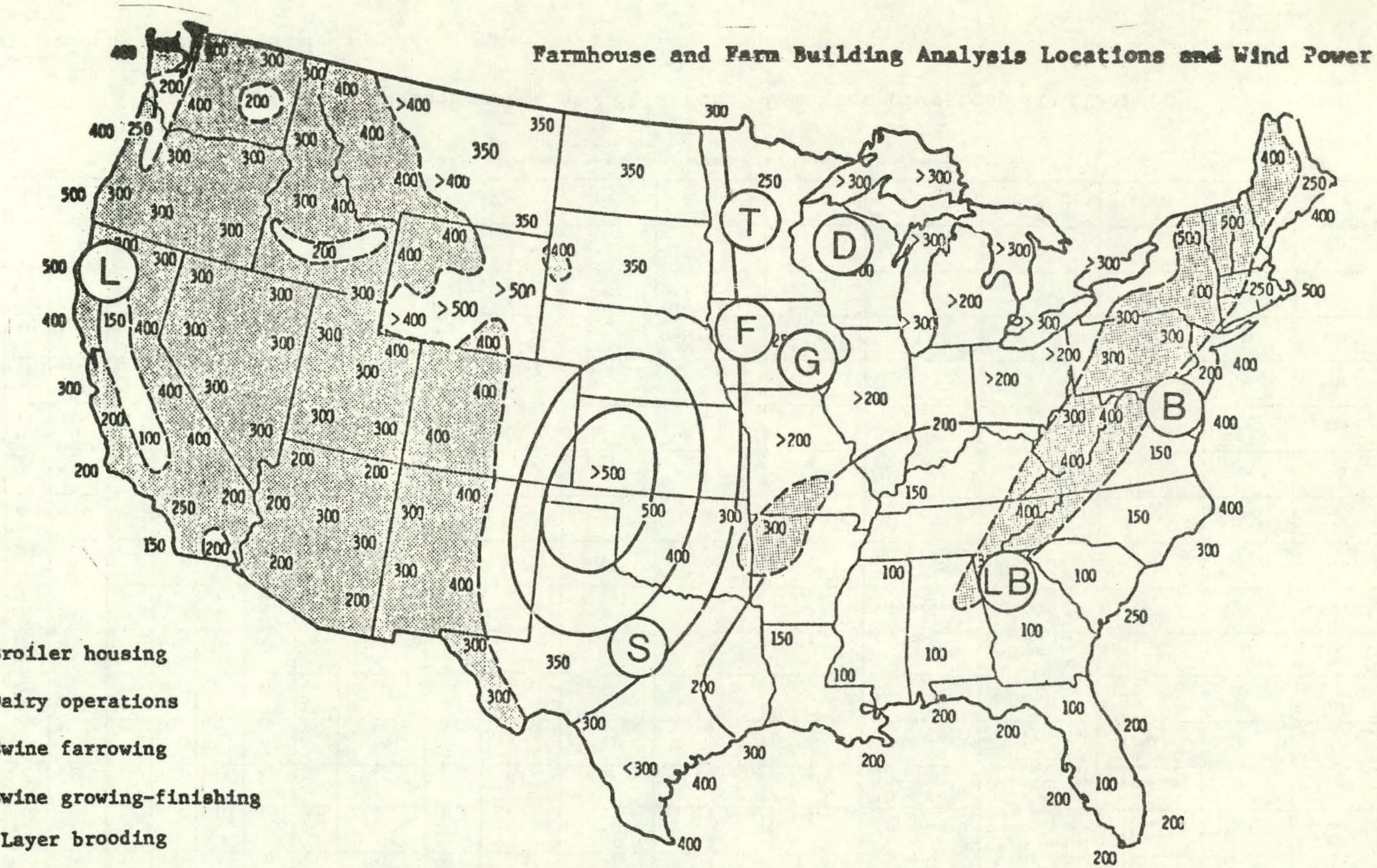
The following paragraphs present summaries of the design conditions, as well as the environmental requirements, formulated for each of the farm buildings.

2.3.3 FARM BUILDING REFERENCE STRUCTURES

It is recognized that there is significant diversity in farm building structure size throughout U. S. agriculture due to the varying herd sizes. However, for purposes of this analysis, herd sizes were selected to represent those most prevalent in agriculture. The characteristics of these operations were then held constant throughout the study so that energy flows and economic breakeven requirements will be correlated to the local wind resource, the cost of competing energy and farm commodity prices. The energy and feed requirements were determined by applying animal growth rates moderated by the internal environments of the buildings throughout the growth cycles.

Animal growth and productivity were allowed to vary dynamically with the indoor temperature of the structures. Animal growth rates were developed from recommended efficiencies of feed conversion.

The eight previously defined applications, which will now be reviewed, include:



B - Broiler housing
D - Dairy operations
F - Swine farrowing
G - Swine growing-finishing
LB - Layer brooding
T - Turkey brooding
L - Layer house
S - Lambing house

Mean Annual Wind Power (W/m^2) Estimated at 50 m Above Exposed Areas. Over mountainous regions (shaded areas), the estimates are lower limits expected for exposed mountain tops and ridges.
Source: "Synthesis of National Wind Energy Assessments", Dennis Elliott, Battelle-PNL, BNWL-2220

Figure 10 Correlation of Analysis Locations to Wind Power Referenced to 50 Meters

Proc. Code Word	Max Temp °F	Min Temp °F	Max Rh %	Min Vent CFM/Lb.	Max Vent CFM/Lb.	1st Day Opt. Temp °F	Opt. Rh %	Ref. Temp °F	Area Req. Ft^2/Anim	Length-Width Ratio X 1.0	Window-Wall Area Ratio X:1.0	Temperature Charge Cycle (Days)	Cycle Temperature Change (°F)	Maximum Production	Production Cycle and Animal Use Distribution	Number of Animals	Critical Maximum Temp. (°F)	Critical Minimum Temp. (°F)
Lambing	Opt. +10	Opt. -10	85	0.025	0.25	77	55	50	16.67	[illegible].7	0.05	1.0	-2.0	Will maintain Opt.	0.666 ewes/lamb (6 wk cycle)	300 lambs	100	30
Cow-Calf	70	40	85	0.015	0.2	70	55	70	110	[illegible].0	0.05	0	0	Will maintain Opt.	1 calf/cow 1 mnth cycle	100 calves	100	0
Farrowin	Opt. +10	Opt. -5	85	0.042	0.441	90	70	60	0.56	2.25	0.05	[illegible]	-2.0	Will maintain Opt.	(0.125 sows/pig) (remove sows 4 wks - 8 wk cycle)	128 pigs	100	Opt. -40
Swine	65	55	85	0.057	0.577	60	70	60	9	1.17	0.05	0	0	Diff in daily weight from weight formula	(50% 8 wk hogs) (50% 16 wk hogs) (8 week cycle)	256 hogs	95	0
Layers	75	50	85	0.5	1.0	60	60	60	0.75	7.25	0.0	0	0	0.75 eggs/daily	Uniform (1 year cycle)	15,000	95	0
Brocdlay	Opt. +5	Opt. -5	85	0.5	1.0	92	60	60	1.0	7.25	0.0	7	-5	Will maintain Opt.	Uniform (3 mth cycle)	40,000	100	Opt. -30
Broodtur	Opt. +5	Opt. -5	85	0.5	1.0	95	60	60	2.0	6 0	0.0	7	-5	Will maintain Opt.	Uniform (5 wk cycle)	1,000	103	Opt. -30
Broiler	Opt. +5	Opt. -5	85	0.5	1.0	90	60	75	0.8	8 5	0.0	7	-5	Will maintain Opt.	Uniform (2.5mth cycle)	20,000	100	Opt. -30
Dairy Co	80	35	85	025	0.4	50	55	50	70	2.5	0.0	0	0	0.032 # milk/ lb. of animal	Average weight 1200# (continuous cycle)	100	100	-20
Hospital	80	35	85	0.025	0.4	50	55	50	2.8	1.6	0.0	0	0	NA	NA	4	100	-20
Mlk Room	80	40	85	700 cfm press	700 cfm press	65	55	65	6	2.25	0.15	0	0	NA	NA	NA	100	32
Water Ht	165	112	NA	NA	NA	165	NA	NA	5 Sq. Ft. Total	NA	NA	0	0	NA	NA	NA	212	110
Mlk Prlr	80	40	85	100 per stall	400 per stall	60	55	60	14	1.14	0.15	0	0	NA	NA	8	95	32
Human	78	65	85	7 cfm /Hse	10 cfm /Hse	72	50	65	375 ft^2 per person	1.67	0.15	Ht. Production Btu/Hr/Person Day 434 Night 253	0	NA	NA	4	100	32

Table 8 - Design Environmental and Structural Data For Livestock Confinement
Source: Midwest Plan Service

Table 8 Design Environmental and Structural Data for Livestock Confinement

Source: Midwest Plan Service

1. Broiler house
2. Layer/brooding facility
3. Layer house
4. Turkey brooding facility
5. Swine farrowing house
6. Swine growing/finishing house
7. Dairy operation
8. Lambing house

2.3.3.1 POULTRY - BROILER PRODUCTION

The broiler building (Figure 11), rectangular in shape with a concrete floor and 8 ft. ceiling, represents a typical large broiler production operation. It has a capacity for 20,000 birds living over a floor area of 13,904 square feet, divided into pens. A narrow design is used to ensure adequate cross flow ventilation. The structural characteristics can be seen in Table 9.

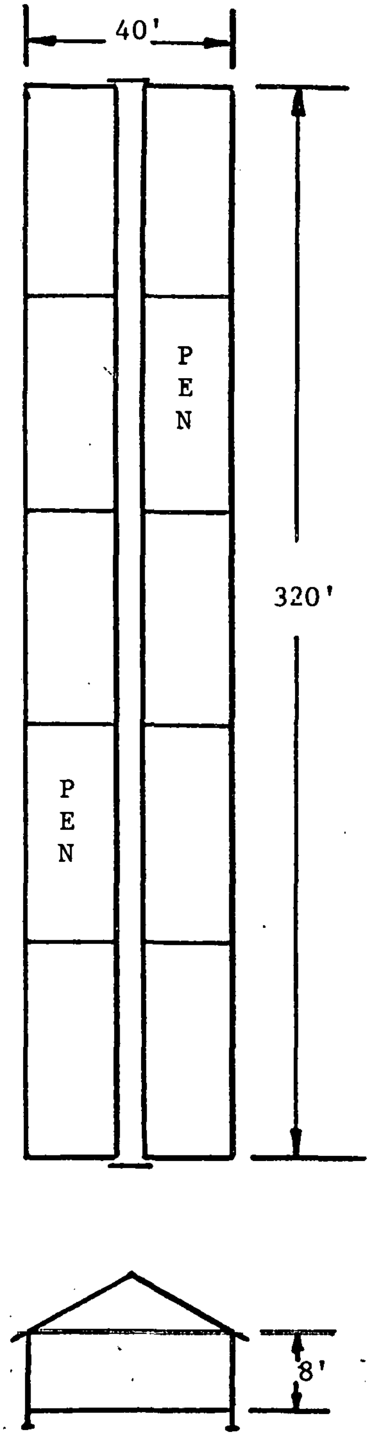
Environmental constraints were previously listed for all of the applications in Table 8. From this table, it is evident that the broiler production cycle is approximately 75 days. The first day optimum temperature is 90 degrees F, subsequently dropping by 5 degrees F every week to a minimum of 75 degrees F. Also included in the table are space, critical temperture, and ventilation design criteria. Further information is found in Table 9.

The Baltimore, Maryland area was chosen as the test site for broiler production. In light of the fact that this study focuses upon space heating, it seemed advantageous to locate applications in significantly cooler production centers whenever possible. Though Arkansas (of the W.S. Central region) is the largest single producer, Maryland's region (S. Atlantic) accounts for the greatest portion of regional production. Georgia is the major producer in the region (13.7% of total national production) but is located in the deep south. Maryland's 6.1% production is nationally significant and is located in a somewhat cooler climate; this is desirable in a space heating study.

2.3.3.2 POULTRY LAYER/BROODING

Figure 12 shows the brooding building plan, very similar to the broiler structure. The floor space is divided into pens comprising an area of about 24,000 square feet, and no windows were utilized. This building is designed to accommodate roughly 40,000 birds. It is a large production facility since little layer production is done with smaller scale operations. Table 10 lists much of the pertinent design criteria used in the structure. Environmental conditions were constrained to a nearly optimum level over a three month production cycle, an interior temperature of 92 degrees F was lowered 5 degrees F per week to 60 degrees F.

Indiana would have been the clear choice if the same rationale that was applied to broiler site selection were utilized here; it has a cooler climate as well as significant production. The production center



Scale: 40' per inch

Figure 11-Broiler House Building Plan

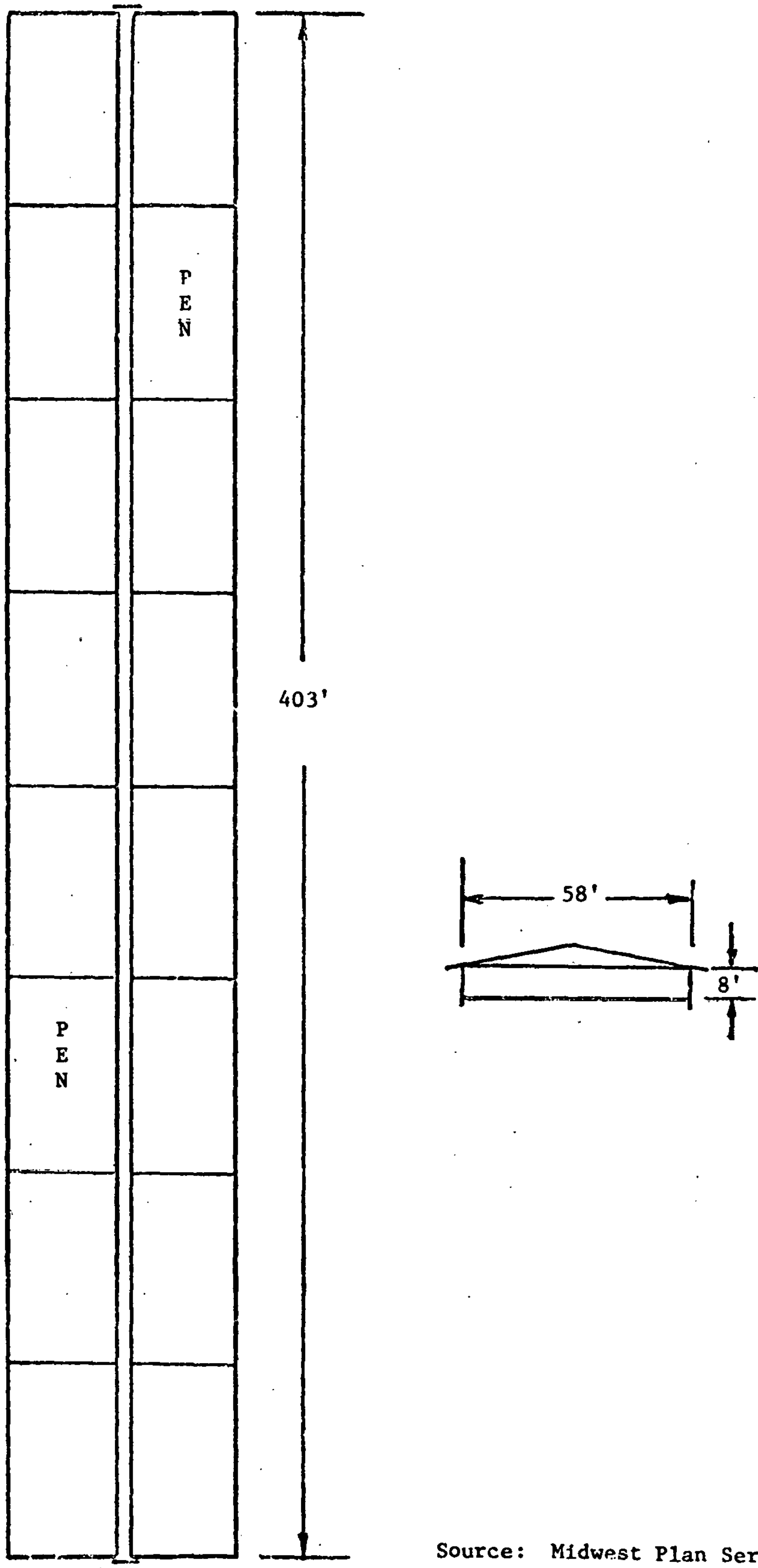
Source: Midwest Plan Service

	Materials	Combined Resistance ($Hr - Ft^2 - °F/Btu$)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier, R-11 batt insulation, siding	13.62	5,760
Ceiling	Plywood, vapor barrier R-19 batt	21.69	13,904
Floor	Concrete	0.83*	13,904
Window	NA	NA	NA

*Ground effects are not included

Table 9 - Broiler Building Thermal Characteristics

Source: Midwest Plan Service



Source: Midwest Plan Service

Figure 12 Layer/Brooding Building Plan

	Materials	Combined Resistance ($Hr - Ft^2 - °F/Btu$)	Area (Ft^2)
Exterior wall	Plywood, vapor barrier, R-11 batt insulation, siding	13.62	9,760
Ceiling	Plywood, vapor barrier, R-19 batt	21.69	40,125
Floor	Concrete	0.83*	40,125
Window	NA	NA	NA

*Ground effects are not included

Table 10 - Layer Brooding House Thermal Characteristics

Source: Midwest Plan Service

chosen, however, for brooding layers was Sacramento, California. While the South Atlantic region leads in layer production, the state of California is the single largest producer. Based on this, and on the fact that the far west was not a major production center for any other production group, California was chosen over other production regions even though it has a milder climate.

2.3.3.3 POULTRY LAYERS

A layer building layout is presented in Figure 13. The structure is very similar to those previously discussed. A one year production cycle was used in the study, and egg production was modeled versus environmental condition. Other pertinent structural design data was obtained from Table 11.

Layer buildings were also located in the Sacramento, California area, the rationale being the same used in the preceding section. Again, California is the leading state in egg production. Cooler climates having significant production are available, but studying layer brooding and egg production in separate locations would not yield insight into climatic effects on environmental control for layer applications. This is due to the fact that the two applications are distinctly unique in their environmental requirements. Layer buildings (as opposed to brooding) are occupied by the same birds for a year or more and require an optimal internal temperature of about 60 degrees F. Although the applications are very different, they may be studied at the same location.

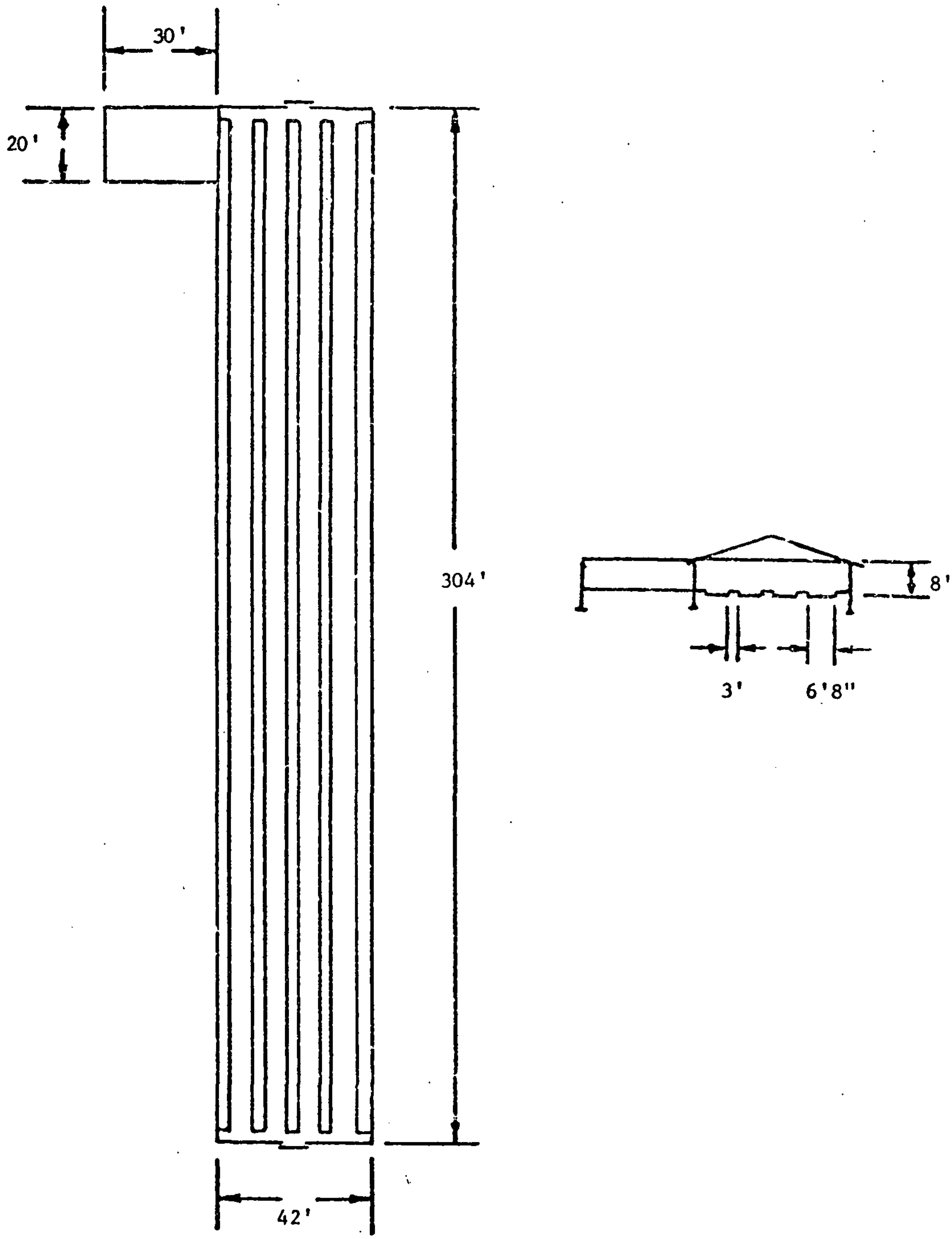
2.3.3.4 POULTRY - TURKEY BROODING

The turkey brooding building seen in Figure 14 is similar to the other poultry structures. It has the capacity to handle approximately 1000 birds over its 2300 square feet of floor area. This application is of less significance nationally both in actual production and in space heating since typical operations tend to be smaller than in the other poultry areas and brooding cycles are shorter. A five week production cycle was studied with the environmental temperature beginning at 95 degrees F and dropping 5 degrees F per week to a minimum of 60 degrees F. The turkey brooding house characteristics are found Table 12.

Site selection was relatively simple in this case since Minnesota, a northern, cool climate state, is the nation's leading producer of turkeys. As turkey production increases in importance, and environmentally controlled confinement techniques are employed, a shift in the production center, from the W. N. Central to warmer weather regions, is likely. Such shifts have been seen most dramatically in the broiler production center as demand for broilers increased.

2.3.3.5 SWINE FARROWING, GROWING, AND FINISHING

Swine production consists of several stages. The operations studied here include swine farrowing, growing and finishing. Two structures were designed to accommodate these three functions. The swine farrowing building (Figure 15) is designed to house 112 pigs. The



Source: Midwest Plan Service

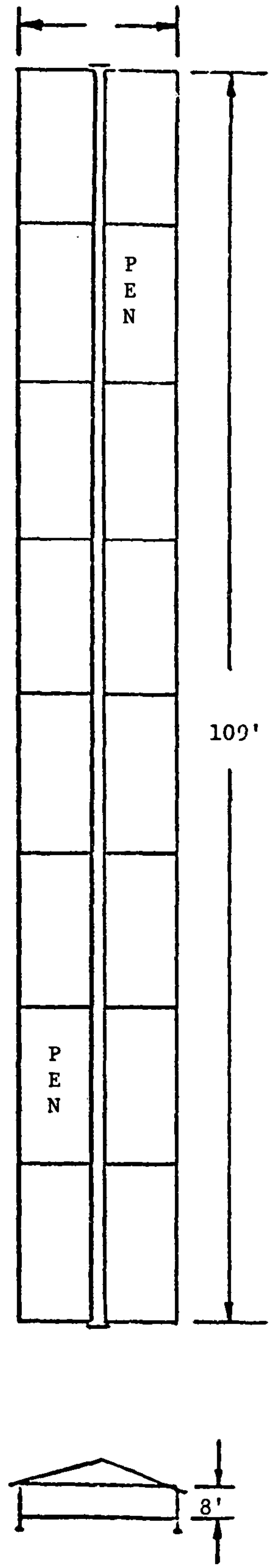
Figure 13 Layer House Building Plan

	Materials	Combined Resistance ($Hr - Ft^2 - °F/Btu$)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier R-11 batt insulating siding	13.62	6,228
Ceiling	Plywood, vapor barrier R-19 batt insulation	21.69	12,768
Floor	Concrete	0.83*	12,768
Window	NA	NA	NA

*Ground effects not included

Table 11-Layer Building Thermal Characteristics

Source: Midwest Plan Service



Source: Midwest Plan Service

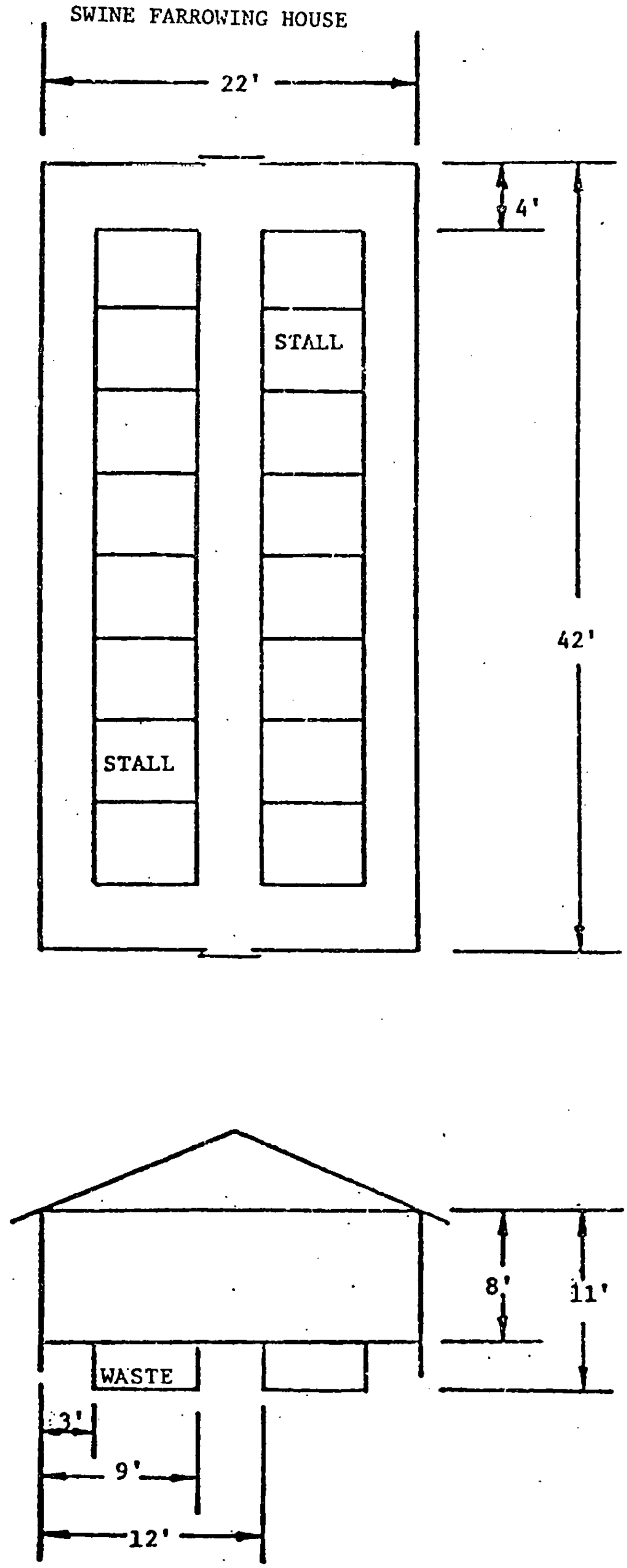
Figure 14 Turkey Brooding Building Plan

	Materials	Combined Resistance (Hr - Ft^2 - °F/Btu)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier, R-11 batt insulation, siding	13.62	2,080
Ceiling	Plywood, vapor barrier, R-19 batt	21.69	2,289
Floor	Concrete	0.83*	2,289
Window	NA	NA	NA

*Ground effects not included

Table 12 - Turkey Brooding House Thermal Characteristics

Source: Midwest Plan Service



Source: Midwest Plan
Service

Figure 15 Swine Farrowing House Building Plan system employed here is one utilizing a waste pit beneath a slotted floor. The animals are situated in pens surrounded by aisleways to accommodate workers. Environmental conditions for the 1000 square foot structure were maintained at warm temperatures for the small pigs. Air temperature began at 90 degrees F and was lowered 2 F degrees per day to a minimum of 60 degrees F. Sows were left in the building until the pigs were weaned, and the models compensated for both sow presence as well as absence. Other pertinent design data is presented in Table 13.

Swine growing and finishing operations were accomplished in the same structure. Pigs from the farrowing operation are used to replace swine marketed so that the growing/finishing building is always stocked with about 112 animals, 56 growing and 56 finishing. The structure layout (Figure 16) consists of several pens over a 2000 square foot floor surface. Again, a slotted floor waste pit arrangement was utilized as shown. Optimum environmental conditions for the structure demand a constant 60 degrees F internal temperature and proper ventilation for odor and noxious gas control. Other data is listed in Table 14.

The swine production system was designed with complementing facilities. The two houses, farrowing and growing/finishing, could be located very near one another. Geographic site selection for these applications was very simple; Iowa is by far the major producer in the nation. Iowa and its neighboring states of Nebraska, Minnesota and Illinois account for fully 50% of the nation's total production and was thus the natural selection.

2.3.3.6 DAIRY

Dairy operations comprise another application studied. The structural layout is shown in Figure 17. This operation differs from the others since water heating is of major importance both for washing of the cows and for milkroom cleanup, requiring substantial quantities of hot water in the actual milking process. Several distinct partitioned areas make up the dairying facility and each area was modeled as a component of the total operation. Included are a cow barn, a hospital area, milking parlor, milk store room, utility room and an office.

A 100 cow facility included Holsteins of 1200 pound average weight. Optimum design temperatures were 50 degrees F for the barn, parlor and hospital, and 65 degrees F for the remaining areas. Milk production was modeled as a function of internal environmental temperature, and a production cycle of one year was used. Other structural and environmental parameters are continued in Table 15.

Dairy production siting was based upon criteria similar to that used in all the selections. Milk production centers are generally located in cooler areas because of significant losses in milk production at higher temperatures. The E. N. Central region accounts for the greatest amount of milk production. Wisconsin is by far the single largest milk producing state in the Union (Wisconsin and Minnesota, states with similar climatic conditions, account for above 25% of U. S.

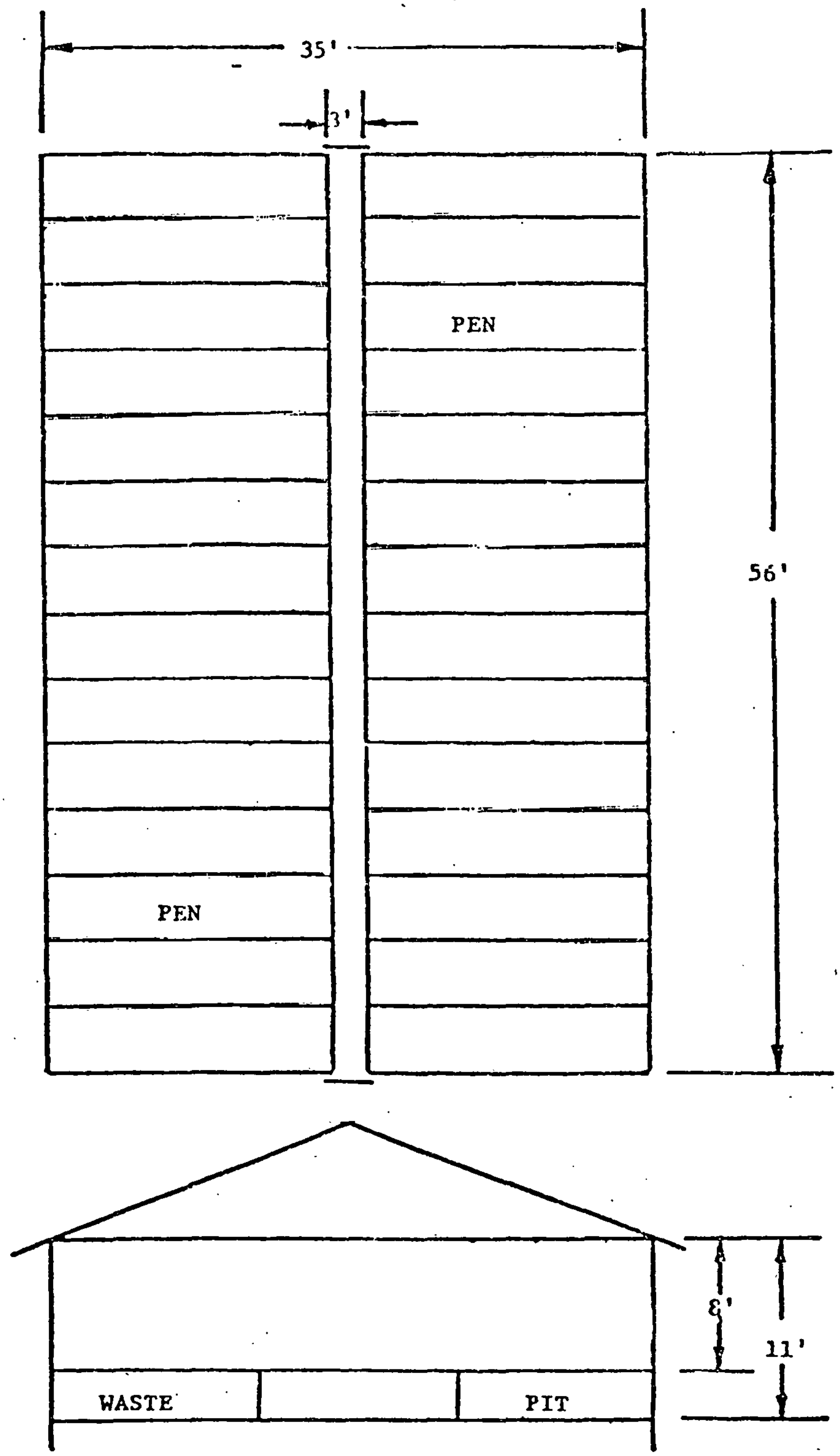
	Materials	Combined Resistance ($Hr - Ft^2 - °F/Btu$)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier, R-11 batt insulating, siding	13.62	972
Ceiling	Plywood, vapor barrier, R-19 batt	21.69	924
Floor	Concrete	0.83*	462
Below grade space			
floor	Concrete	0.83*	462
wall	Concrete	0.83*	318
Window	Single pane glass	0.95	51

*Ground effects not included

Table 13 - Swine Farrowing House Thermal Characteristics

Source: Midwest Plan Service

SWINE GROWING - FINISHING HOUSE



Source: Midwest Plan Service

Figure 16 Swine Growing and Finishing Building Plan

	Materials	Combined Resistance ($Hr - Ft^2 - °F/Btu$)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier, R-11 batt insulation, siding	13.62	1,382
Ceiling	Plywood, vapor barrier, R-19 batt insulation	21.69	
Floor	Concrete	0.83*	980
Below grade			
Floor	Concrete	0.83*	980
Wall	Concrete	0.83*	
Window	Single pane glass	0.95	73.25

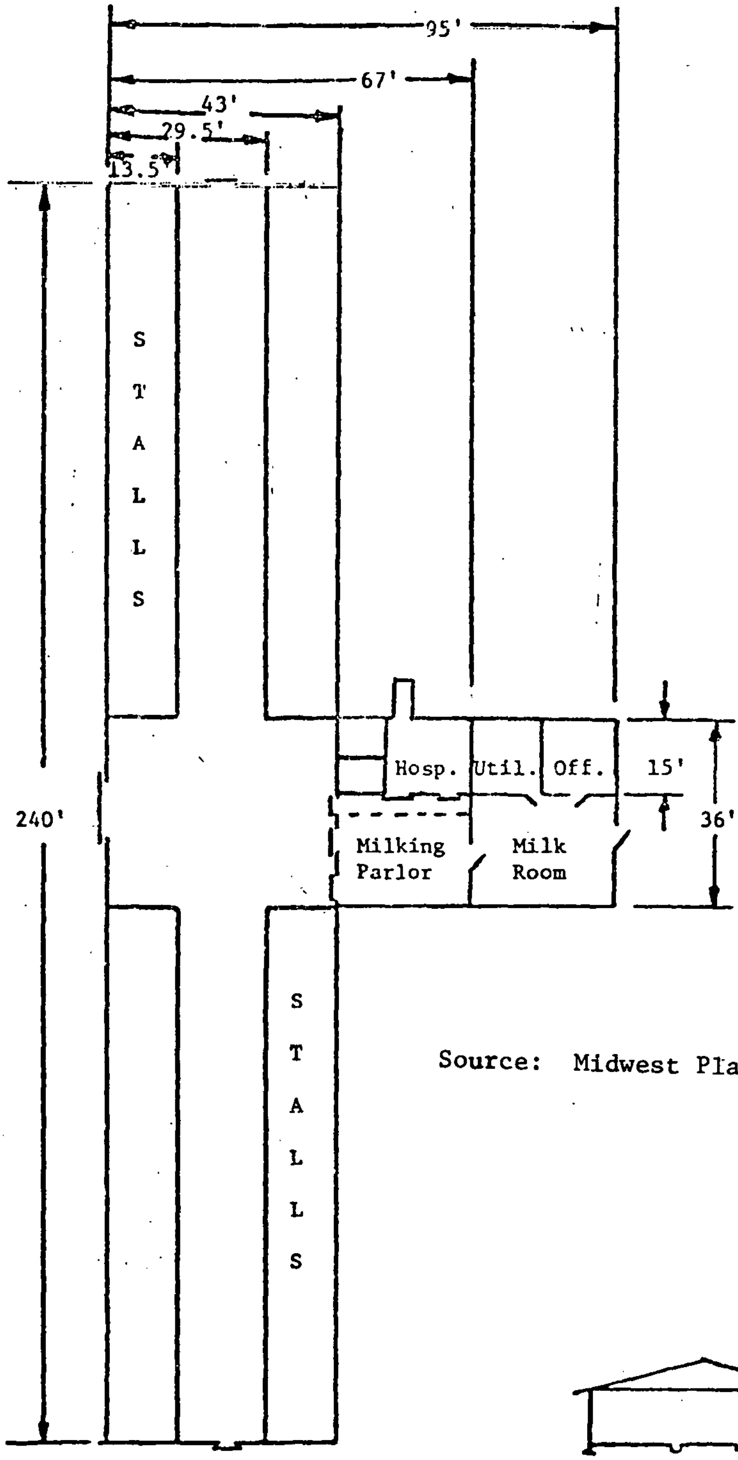
*Growing effect not included

Table 14 - Swine Growing/Finishing Building Thermal Characteristics

Source: Midwest Plan Service

DAIRY HOUSE

(100 lactating cows)



Source: Midwest Plan Service

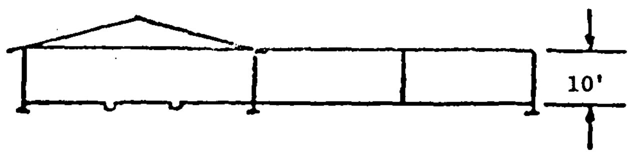


Figure 17 Dairy House Building Plan

	Materials	Combined Resistance ($Hr - Ft^2 - °F/Btu$)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier R-11 batt insulation, siding	13.62	7,060
Ceiling	Plywood, vapor barrier, R-19 batt insulation	21.69	11,328
Floor	Concrete	0.83*	11,328
Window	NA	NA	NA

*Ground effects not included

Table 15 - Dairy House Thermal Characteristics

Source: Midwest Plan Service

milk production). The decision was made for Wisconsin based on these facts.

2.3.3.7 LAMBING

The lambing operation, like turkey brooding, is an application limited in scope and space heating demand. A 1300 square foot structure (Figure 18) was modeled which could accommodate approximately 300 lambs. A required environmental temperature of 77 degrees F was maintained initially, dropping 2 degrees F per day to a 50 degree F minimum. The production cycle was relatively short (6 weeks), and several six week cycles were therefore studied throughout the year. Table 16 provides pertinent design data.

Site selection for lambing was somewhat difficult. Two regions together comprised over 50% of national production - the mountain region (34%) and the W. S. central region (20%). Colorado was the major producer (9.7%) in the mountain region followed by Wyoming with 7.1%, while Texas (19%) accounted for most of the W. S. Central region's wind resource availability, yet these results may be readily extended to the other mountain states, accounting for the majority of lamb production. Texas was also modeled for this application, but due to the warm climate, did not prove to be a valuable site for space heating. This decision lent credibility to the earlier choice of Maryland as the broiler production model site. It can be seen here again, as in the turkey brooding case, that as lamb production and warm confinement application increase, a southward shift in production centers may follow.

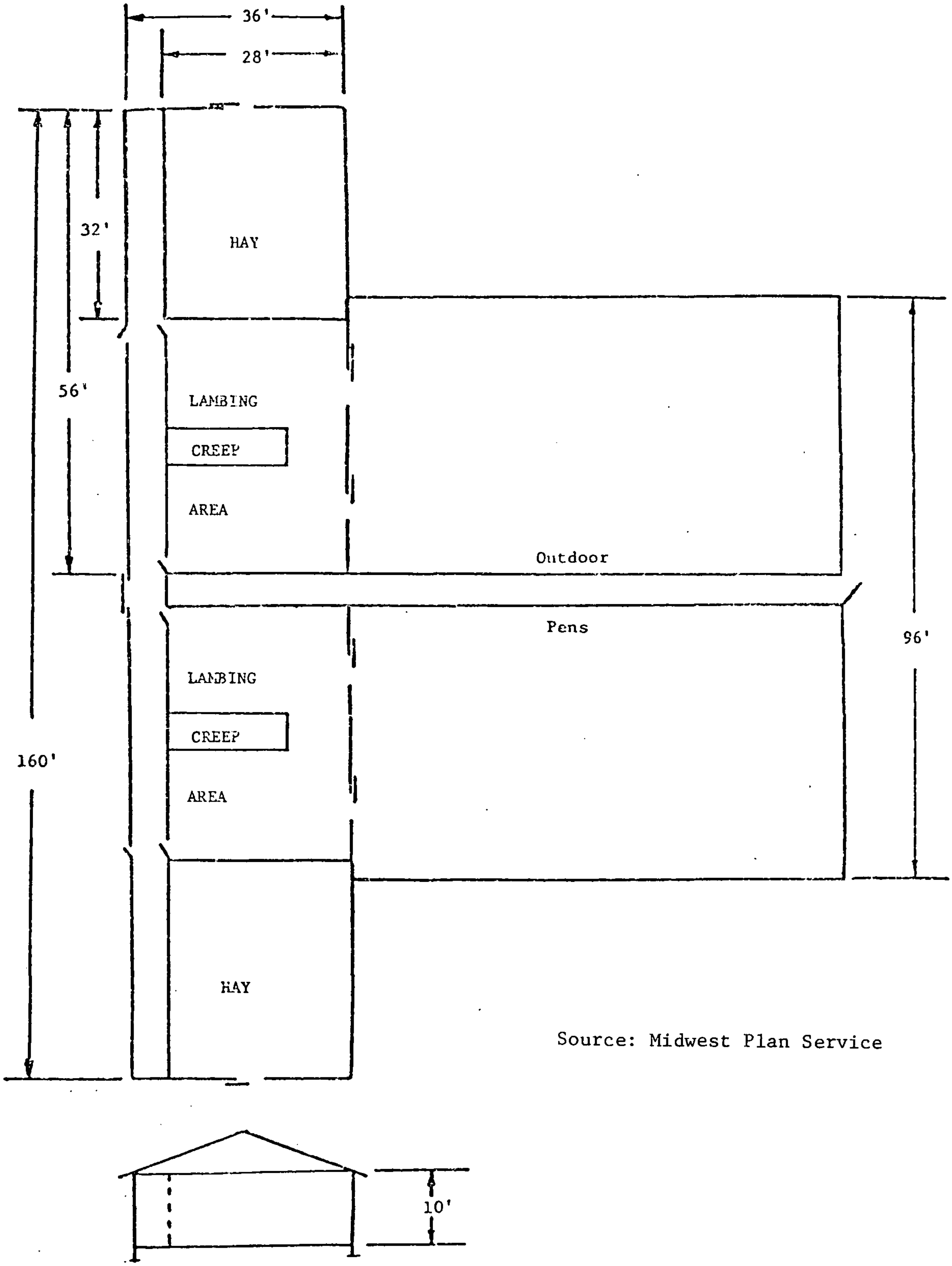
2.4 SYNOPSIS

This chapter has described the procedures employed to survey the farmhouses and farm buildings located in rural areas, and to define consistent criteria for the selection of three model farmhouses and eight model farm buildings to be used for further analysis considering the application of wind energy to the space heating requirements.

The model farmhouses included three: an older, modern and passive solar structure. The older farmhouse model included 1067 square feet of living space with less insulation and the modern and passive solar farmhouses included 1650 square feet of living space and improved insulation.

The farm buildings finally selected for further analysis represent the livestock operations found to be most prevalent in U. S. agriculture and which encompass a diversity of space heating and climatic requirements. The farm buildings were located at regional production centers defined from a survey of the most recent data available from USDA and the Census of Agriculture.

The farmhouses and farm buildings selected were used consistently throughout the study to uniformly evaluate the potential applications of wind-powered heating systems.



Source: Midwest Plan Service

Figure 18 Lambing House Building Plan

	Materials	Combined Resistance (Hr - Ft^2 - °F/Btu)	Area (Ft^2)
Exterior Wall	Plywood, vapor barrier, R-11 batt insulation, siding	13.62	2,350
Ceiling	Plywood, vapor barrier, R-19 Batt	21.69	2,688
Floor	Concrete	0.83*	2,688
Window	Single pane glass	0.95	130

*Ground effects are not included

Table 16 - Lambing House Thermal Characteristics

Source: Midwest Plan Service

3.0 BASELINE FARMHOUSE AND FARM BUILDING HEATING LOADS

3.1 INTRODUCTION

The focus of this analysis is to determine the duration and magnitude of heating loads for the principal heating requirements in agriculture. For this study, heating requirements were analyzed for three representative farmhouses and eight selected farm buildings. Farm buildings were located at seven locations, representing regional production centers, and although farmhouses were also analyzed at each of these locations, two additional locations were used to provide comparative results with other studies of USDA-SEA.

The baseline building energy requirements are used as a reference to evaluate the effects of a number of wind-powered heating system applications. The baseline energy requirements were developed from an hour by hour analysis of the buildings which considered climatic data compiled by the National Climatic Center. The program also utilized hourly inputs of heat and moisture from animals, humans, and internal building uses of hot water (a form of storage), machinery and appliances. Animal growth was modeled dynamically using rates moderated by indoor temperature and humidity ratios, as recommended by the Midwest Plan Service and other agricultural references.

In subsequent chapters, the expected hourly energy production of WECS of three sizes was used to offset heating and ancillary energy requirements. The analysis also considered the effects of thermal storage on the ability to utilize the production of the WECS systems.

The following section discusses the development of baseline energy requirements for the three farmhouse models and the eight farm buildings.

3.2 ANALYSIS METHODOLOGY

The analysis methodology used to establish the heating requirements in the farmhouses and farm buildings is based on an hour by hour calculation of sensible and latent heat flows. Hourly solar, climatic and wind data is combined with hourly environmental requirements for animals based on indoor temperature, ventilation and humidity requirements. The heat transfer calculations are based on consideration of energy balance principles and utilize techniques recommended by ASHRAE for all building thermal gain and loss calculations. Climatic data for 1978 for the nine cities representing the analysis areas was translated from magnetic tape summaries obtained from the National Climatic Center.

The general relationship of the energy flows and their interrelationships is shown in Figure 19. An expanded listing of the digital computer simulation used to evalute the energy flows is found in Appendix A of this report.

The results of the analyses in this study were compared to an actual farmhouse located in the Denver, Colorado area, and to results of

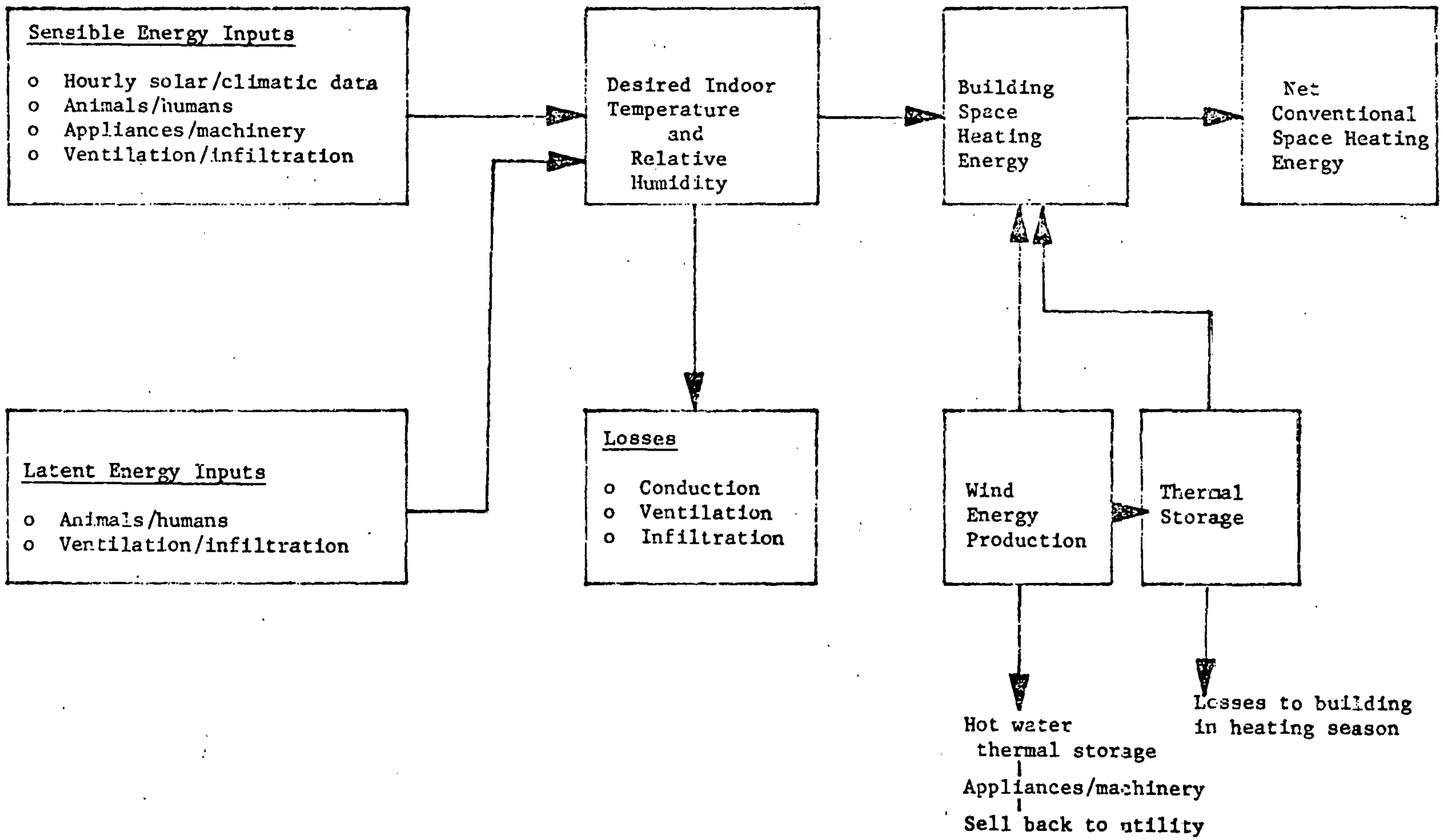


Figure 19 Energy Flows For Hourly Building Thermal Analysis

other USDA research (Reference 20). The results of this study were found to correlate closely with these test cases. The results of the comparative analysis are presented in Tables 17 and 18. Applying correction factors recommended by ASHRAE, the results of this study correlated closely to the results from the Canton, Ohio research study when allowance for hourly rather than monthly heating needs are considered. The hourly analysis produces lower predicted energy requirements than monthly procedures.

A comparative summary of the heating and climatic conditions associated with each of the geographic areas is presented in Table 19. The geographic locations selected are seen to represent a wide range of climatic and heating conditions.

3.3 FARMHOUSE BASELINE ENERGY USE

Farmhouse baseline energy use is summarized in this section. Heating requirements were moderated by typical inputs from building occupants, machinery, appliances, and hot water requirements. Hourly energy profiles established for appliances and used consistently are shown in Table 20.

Annual energy requirements attributable to these inputs are given below:

Annual Building Input From Appliances and Hot Water

	Hot Water		Appliances/Machinery	
	Annual Load 10^6 Btu	Space Heat Offset 10^6 Btu	Annual Load 10^6 Btu	Space Heat Offset 10^6 Btu
Farmhouses:				
Older	20.77	3.12	26.32	21.69
Modern	16.81	2.52	26.32	21.69
Passive	16.81	2.52	26.32	21.69
Farm Buildings:				
Poultry-Layer	0	0	59.4	48.95
Poultry-Layer/Brooding	0	0	164	135.15
Poultry-Broilers	0	0	54.6	45.0
Poultry-Turkey Brooding	0	0	10.5	8.65
Swine Farrowing	0	0	1.6	1.32
Swine-Growing/Finishing	0	0	15.3	12.6
Dairy	114.7	17.2	28.2	23.2
Lambing	0	0	6.4	5.3

An overall summary of the baseline annual heating energy use for the older, modern, and passive farmhouses is shown in Table 21.

		Thermal Load x 10^6 BTUs					
		Denver Test House (1			Older Test Farmhouse		
Month	1978 Degree Days (1	Degree Day Method	Actual (2	Model (2	Degree Day Method	Actual (3	Model
1	1206	10.85	NA	5.66	21.59	10.12	11.13
2	936	8.42	NA	4.75	16.75	7.86	8.87
3	665	5.98	NA	2.65	11.90	5.58	5.55
Subtotal	2807	25.25	NA	13.06	50.24	23.56	25.55
4	435	3.91	NA	1.53	7.79	3.65	3.27
5	335	3.04	NA	1.24	6.00	2.81	2.68
6	87	0.78	0.48	.42	1.56	0.71	.99
Subtotal	857	7.73	NA	3.19	15.35	7.17	6.94
7	0	0.00	0.00	.04	0.00	0.00	.12
8	20	0.18	0.00	.18	0.36	0.17	.41
9	96	0.86	0.00	.38	1.72	0.81	.94
Subtotal	116	1.04	0.00	.60	2.08	0.98	1.47
10	366	3.29	1.45	1.20	6.55	3.07	2.98
11	811	7.29	3.57	3.33	14.52	6.81	6.59
12	1245	11.20	5.65	6.31	22.29	10.45	10.56
Subtotal	2422	21.78	10.67	10.38	43.36	20.33	20.13
Annual	6202	55.8	NA	NA	111.00	52.04	54.17

NA - Not Available

1) Degree Days from Public Service Company of Colorado

2) Frequency of meter readings varied model monthly cycles adjusted accordingly.

3) Estimated from three month billing data

Table 17 - Model Calibration - Denver Area 1978

Canton, Ohio House Model at Chicago Location

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly (1 Degree Day	4960	4284	3651	1969	864	196	0	0	331	1336	3088	4865	25544
Modified Degree Day (2	3174	2742	2337	1260	553	125	0	0	212	855	1976	3114	16348
RSSG (3	3103	2796	1702	535	228	21	5	4	16	146	826	2198	11580

1) Results from "Wind Power Hydrogen Electric Systems For Farm and Rural Use, NSF/RA-760184

2) ASHRAE 1976 System Handbook, Chapter 43

3) RSSG Hour by Hour Computer Model, ASHRAE 1976 System Handbook, 1978 Weather Data

Table 18 - Comparison of Study Model With The Institute of Gas Technology at the Chicago Location

Analysis Location	Annual Heating Degree Days	Design Temp 99% Dry Bulb °F	Annual Wind Speed MPH @ 65.62 Feet	% Possible Sunshine	Mean Annual Insolation Langleys	Energy Cost $/10^6 Btu Elect	Nat Gas	LP	Fuel Oil
Minnesota	8382	-16	5.2	58	490	10.84	2.07	3.25	2.50
Wisconsin	7863	-11	5.1	56	450	10.82	2.42	3.31	2.63
Wyoming	7410	-11	5.7	64	650	7.50	1.54	3.67	2.24
Illinois	6639	-8	5.1	56	450	12.07	2.14	3.31	2.63
Iowa	6588	-10	5.5	59	550	11.75	1.87	3.22	2.37
Colorado	6283	-5	4.8	70	600	10.08	1.57	3.67	2.24
California	2502	30	3.2	79	750	11.63	1.83	3.24	2.49
Texas	1711	24	4.5	56	650	10.41	2.32	3.10	2.01
	1)	2)	3)	4)	5)	6)	6)	6)	6)

Table 19 - Comparative Heating and Climatic Conditions For Analysis Locations

1), 2) Reference 54

3) Reference 49

4) Reference 52

5) Reference 52

6) Reference 36

	Hourly Load Factor												
Hour	Coffee Maker	Dish Washer	Dryer	Freezer	Hi Fi Stereo	Lights	Micro wave Range Oven*	Refrigerator	TV	Washing Machine	Misc	Electric Load Watt Hrs	Space Heat Input Watt. Hrs
1	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
2	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
3	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
4	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
5	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
6	.25	0	0	.40	0	.10	.12	.40	0	0	.20	1368	1368
7	.10	0	0	.40	0	.115	0	.40	0	0	.20	500	500
8	.25	0	0	.40	1.0	0	0	.40	0	0	.38	630	630
9	0	0	0	.40	1.0	0	0	.40	0	1.0	1.22	1002	1002
10	0	0	.75	.40	1.0	0	0	.40	0	0	1.75	4305	1305
11	0	0	0	.40	1.0	0	0	.40	0	0	1.20	260	260
12	0	0	0	.40	1.0	0	.10	.40	0	0	1.20	1130	1130
13	0	0	0	.40	1.0	0	0	.40	0	0	1.10	499	499
14	0	0	0	.40	1.0	0	0	.40	0	0	1.10	499	499
15	0	0	0	.40	1.0	0	0	.40	0	0	1.10	499	499
16	0	0	0	.40	1.0	0	0	.40	0	0	1.10	499	499
17	0	0	0	.40	1.0	.10	.27	.40	1.0	0	.90	2471	2471
18	.25	0	0	.40	0.0	.40	0	.40	1.0	0	.45	1138	1138
19	0	.75	0	.40	0	.20	0	.40	1.0	0	.20	1780	1060
20	0	0	0	.40	0	.20	0	.40	1.0	0	.20	700	700
21	0	0	0	.40	0	.20	0	.40	1.0	0	.20	700	700
22	0	0	0	.40	0	.20	0	.40	1.0	0	.20	700	700
23	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
24	0	0	0	.40	0	.05	0	.40	0	0	.20	350	350
Totals												21130	17410

*Total of three units = 6300 watts

Table 20 - Hourly Appliance Loads

Location	Modern House		Older House		Passive House w/wall		Passive House w/o Wall	
	Heat Req*	Heat/Ft^2**	Heat Req*	Heat/Ft^2**	Heat Req*	Heat/Ft^2**	Heat Req*	Heat/Ft^2**
Illinois	81.932	0.050	74.413	0.045	16.225	0.0098	31.972	0.019
Minnesota	101.489	0.061	91.297	0.085	23.314	0.014	41.743	0.025
Wisconsin	91.166	0.055	90.408	0.084	21.172	0.012	39.838	0.024
Iowa	80.821	0.048	76.501	0.071	21.091	0.012	35.488	0.021
Wyoming	78.551	0.047	83.91	0.078	15.011	0.009	32.909	0.019
Colorado	57.648	0.034	57.095	0.053	7.317	0.004	22.83	0.013
Maryland	50.321	0.03	44.13	0.041	3.742	0.002	16.729	0.01
California	20.334	0.012	18.455	0.017	0.905	0.0005	6.367	0.0038
Texas	18.198	0.011	15.379	0.014	2.513	0.001	7.297	0.0044

* 10^6 BTU

** 10^6 BTU/ Ft.^{2}

Table 21 Overall Comparison of Baseline Annual Energy Use For Farmhouses

3.3.1 OLDER FARMHOUSE BASELINE ANNUAL HEATING ENERGY

A survey of the 1970 Census of Housing and the most recent Census of Agriculture indicated that 94% of farmhouses were constructed prior to 1960. During this time period, less attention was given to insulation levels and other energy conserving features in many areas since the cost of energy was relatively low. Accordingly, based on the general characteristics of the older farmhouses, a reference structure was selected and analyzed with the climatic conditions reported in 1978 by the National Weather Service for each selected geographic location.

A comparative summary of the monthly and annual energy use of the older farmhouse model is presented in Table 22 for each analysis location. The energy values are the actual energy delivered to the living area of the house. Economic analyses (Section 6.3) used conversion efficiencies typical of the five major fuel and furnace types used in agriculture. WECS were applied with and without storage against the set of internal energy requirements to assess their use as self-sufficient, supplemental or stand alone heating systems.

3.3.2 MODERN FARMHOUSE BASELINE ANNUAL HEATING ENERGY

Based on the Department of Commerce Census of Housing, less than 6% of farmhouses were constructed after 1960. Baseline annual heating energy was determined for the modern farmhouses at all analysis locations using the structure selected in Chapter 2. A comparative summary of the net heating energy required inside the modern farmhouse is presented in Table 23. The same appliance, occupant, and hot water loads were used for all farmhouses.

3.3.3 PASSIVE SOLAR FARMHOUSE

A passive solar farmhouse design was included to represent possible future construction practices in agriculture. The passive solar house included thermal storage in all cases, and was examined with and without a Trombe wall (See Section 2.2). The hot water thermal storage needs were augmented by a Trombe wall to further examine the potential for wind-powered heating systems to complement even a modern energy conserving farmhouse design.

Results of the energy use with storage and wind-powered heating systems are presented in Chapters 4 and 5. The energy use without the Trombe wall is comparable to the modern farmhouse which includes increased insulation, double pane windows and other energy conserving features. Though few passive solar homes now exist, increased interest makes it a likely representative of future construction.

Annual energy use with and without the Trombe wall is shown in Tables 24 and 25.

3.4 FARM BUILDING BASELINE ENERGY USE

This section presents baseline energy use determined for each farm _uilding type. The baseline annual energy needs for the eight farm

Location	10^6 BTUs Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Denver, Colorado	12.065	9.526	5.839	3.313	2.693	.904	.073	.316	.878	2.991	6.940	11.558	57.095
Des Moines, Iowa	19.201	16.970	10.174	3.831	1.512	.114	.073	.087	.331	3.278	6.974	13.956	76.501
Madison, Wisconsin	19.491	17.491	11.741	5.202	2.667	.892	.277	.547	1.163	5.344	9.132	15.461	90.408
Casper, Wyoming	15.914	12.975	8.489	5.603	4.597	1.529	.633	.888	2.153	4.797	10.785	15.547	83.910
Minneapolis, Minnesota	21.685	18.015	11.403	5.937	1.541	.519	.108	.184	.772	4.433	9.053	17.647	91.297
Austin, Texas	5.904	4.396	1.268	.057	.048	.002	.000	.019	.013	.071	.676	2.925	15.379
Sacramento, California	3.007	2.390	1.182	1.548	.399	.154	.063	.046	.146	.503	3.056	5.961	18.455
Chicago, Illinois	16.995	15.691	10.645	4.810	2.399	.480	.092	.123	.387	3.294	6.385	13.112	74.413
Baltimore, Maryland	11.323	10.979	6.426	2.162	.901	.080	.055	.078	.107	2.001	3.343	6.677	44.131

Table 22 Older Farmhouse Space Heating Requirements Not Considering Furnace Efficiency (1978)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	10^6 BTUs												
Denver, Colorado	11.677	9.581	5.672	3.321	2.763	.901	.678	.310	.888	3.056	7.213	11.588	57.648
Des Moines, Iowa	20.417	17.985	10.575	3.861	1.495	.136	.370	.266	.400	3.320	7.269	14.727	80.821
Madison, Wisconsin	20.259	17.996	11.745	6.001	2.442	.724	.416	.678	.931	5.038	9.104	15.833	91.167
Casper, Wyoming	15.452	12.394	7.959	4.977	4.037	1.200	.423	.616	1.809	4.270	10.285	15.129	78.552
Minneapolis, Minnesota	23.838	19.680	12.404	6.663	1.828	.816	.319	.463	1.008	5.042	10.044	19.379	101.484
Austin, Texas	6.298	4.703	1.296	.085	.526	.346	.101	.171	.471	.178	.777	3.141	18.198
Sacramento, California	3.359	2.662	1.340	1.705	.397	.077	.025	.045	.178	.614	3.375	6.558	20.335
Chicago, Illinois	17.673	17.074	10.983	5.424	2.746	0.505	0.062	0.151	0.492	3.651	7.125	13.662	81.932
Baltimore, Maryland	11.64	11.913	6.671	2.469	1.047	0.228	0.197	1.1	0.378	2.157	3.786	8.715	50.301

Table 23 Modern Farmhouse Space Heating Requirements Not Considering Furnace Efficiency (1978)

10^6 BTU

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Denver, Colorado	5.14	4.216	2.007	0.852	0.743	0.112	0.0	0.0	0.149	0.749	0.749	2.382	22.83
Des Moines, Iowa	9.803	8.992	4.278	0.902	0.238	0.0	0.0	0.0	0.017	0.626	2.768	6.403	35.488
Madison, Wisconsin	9.665	8.907	4,848	1.985	0.632	0.052	0.001	0.018	0.108	1.285	3.763	7.204	39.838
Casper, Wyoming	3.589	3.403	2.777	1.519	1.204	0.176	0.004	0.033	0.389	1.166	4.673	6.452	32.909
Minneapolis, Minnesota	10.971	9.263	4.493	1.765	0.193	0.011	0.0	0.0	0.035	0.868	3.782	8.54	41.743
Austin, Texas	2.889	2.285	0.479	0.005	0.003	0.0	0.0	0.0	0.0	0.009	0.2	1.179	7.297
Sacramento, California	0.761	0.702	0.216	0.409	0.041	0.0	0.0	0.0	0.011	0.093	1.16	2.364	6.367
Chicago, Illinois	8.413	7.981	4.327	1.26	0.468	0.013	0.0	0.0	0.008	0.552	2.157	5.719	31.972
Baltimore, Maryland	5.037	5.042	2.324	0.35	0.108	0.0	0.0	0.0	0.001	0.286	0.78	2.166	16.729

Table 24 Passive Solar Farmhouse Space Heating Requirements Not Considering Furnace Efficiency (1978)

10^6 BTU

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Denver, Colorado	1.857	1.521	0.674	0.126	0.447	0.026	0.0	0.0	0.011	0.068	0.633	1.4	7.317
Des Moines, Iowa	6.841	5.851	1.78	0.186	0.016	0.0	0.0	0.0	0.0	0.012	1.312	3.86	21.091
Madison, Wisconsin	6.166	4.871	1.76	0.375	0.066	0.0	0.0	0.0	0.005	0.144	1.945	4.945	21.172
Casper, Wyoming	4.002	2.49	0.682	0.101	0.637	0.001	0.0	0.0	0.027	0.03	2.195	3.412	15.011
Minneapolis, Minnesota	6.85	5.068	1.385	0.387	0.001	0.0	0.0	0.0	0.0	0.059	2.19	5.826	23.314
Austin, Texas	0.819	1.34	0.093	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.018	0.145	2.513
Sacramento, California	0.064	0.048	0.001	0.015	0.0	0.0	0.0	0.0	0.0	0.0	0.051	0.226	0.905
Chicago, Illinois	5.714	4.083	1.784	0.136	0.005	0.0	0.0	0.0	0.0	0.022	0.827	3.197	16.225
Baltimore, Maryland	2.083	0.955	0.444	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.257	3.742

Table 25 Passive Solar Farmhouse Spaceheating Energy Use With A Trombe Wall

building applications were determined in the same manner as described in Section 3.3. The livestock structures were, however, each evaluated only at the location corresponding to their respective production center. Although two of the eight applications (layer and layer brooding) were evaluated at the same location, one was analyzed at two different locations so that eight separate geographic locations were studied.

Detailed modeling of the sensible and latent heat and moisture production of the animals during their growth cycles was simulated as a function of indoor temperature and input feed rates. The animals, in the process of feed conversion and growth, produce both heat and moisture, which offsets the heating system requirements except for ventilation needs. This study has considered farm building operations to maintain optimum production using recommended environmental conditions. Sensitivity studies allowed for both narrow (1 degree F) and wider (10 degree F) indoor temperature bands to examine improved use of wind energy systems production. An aggregate comparison of annual energy use for the farm building applications is presented in Table 26.

Each of the eight livestock applications were evaluated at a specific location. Variations in baseline energy demand resulted from animal and production differences as well as geographical climatic conditions. Below, the applications are listed by energy demand from highest to lowest, location, application, and space heating energy requirement. Hot water needs are greatest in the dairy applications and allowed greater use of WECS production than in most other applications.

3.4.1 POULTRY-BROILERS

Broiler operations were found to be energy intensive. The example operation required more than 1000 million Btu's. Thus, although the production from WECS used with this study represented a small percentage (0.0% to 4.2%) of total needs, this case provided a good basis to examine the maximum utilization without storage and is discussed further in Chapter 4. The baseline annual energy use for broilers is summarized in Table 27.

3.4.2 POULTRY-LAYER/BROODING

Layer/brooding energy use was evaluated in the Sacramento, California area, and the energy required was found to be relatively low (26 million BTU's annually). The application of a 10 and 40 foot diameter WECS resulted in the displacement of 0.8% and 10.7% of the space heat requirement, respectively, and 4.5% and 3.7% of WECS energy output was utilized.

Though the energy demand was relatively low, WECS energy output could provide only minimal benefit without thermal storage. Space heat demands and WECS energy production were not coincident events, thus rendering large portions of WECS energy of no value without other uses. A summary of the monthly and annual energy use of the layer/brooding application is shown in Table 28.

Farm Building Applications	Reference Location	Indoor Heat Energy Required 10^6 Btu	Building Area Ft^2	Annual Energy Use Per Ft^2 10^6 Btu	Heating Degree Day 65°F Base
Poultry-Turkey Brooding	Minnesota	146.24	2290	0.063	8382
Poultry-Layers	California	62.812	12768	0.005	2502
Poultry-Layer/Brooding	California	26.65	40125	0.0007	2502
Poultry-Broilers	Maryland	116.05	12800	0.009	4654
Swine-Farrowing	Iowa	243.05	924	0.262	6588
Swine-Growing/Finishing	Iowa	79.53	1960	0.04	6588
Dairy	Wisconsin	35.83	11184	0.003	7863
Lambing	Wyoming	33.02	2700	0.012	7410

Table 26 - Aggregate Comparison of Annual Heating Energy Use In Farm Buildings

Days of Year	Net Space Heating Load 10^6 Btu	Feed Lbs	Production (Lbs)
1-75	736.24	273,285	90,132
76-150	19.767	273,285	93,085
151-225	0.733	273,285	90,322
226-300	72.591	273,285	92,704
301-365	286.72	207,337	85,749
Annual Total	1116.05	1,300,477	451,999

Broiler Operations Summary:

Number of Birds: 20,000
Building Area: 13,904
Production Cycle: 75 days

Table 27 - Broiler Baseline Annual Heating Energy Use-Baltimore, Maryland

Days of Year	Net Space Heating Load 10^6 Btu	Feed Lbs	Production (Birds)
1-92	12.143	741,870	40,000
93-184	10.853	741,870	40,000
185-276	0.737	741,870	40,000
277-365	2.92	715,611	40,000
Annual Total	26.653	2,941,221	

Layer/Brooding Characteristics:

Number of Birds	15,000
Building Area, Ft^2	40,125
Production Cycle, Days	92

Table 28 - Layer/Brooding Baseline Annual Heating Energy- Sacramento, California

3.4.3 POULTRY-LAYERS

The layer structure was also evaluated in the Sacramento, California area. It houses older birds (starting at about three months) for the purpose of egg production. This application demands over twice the energy required in brooding, but can make only little use of wind energy. The 10 and 40 foot diameter WECS displaced only 0.08% and 1.3% of the required heat energy, respectively. WECS use in both cases amounted to only 1.1% of the total produced.

Annual energy demand was substantial, yet with most of the heat energy demand occurring during the winter months, direct WECS application without thermal storage facilities was not significant. A summary of the annual baseline energy use is shown in Table 29.

3.4.4 TURKEY BROODING

Turkey brooding operations could require relatively substantial amounts of heating energy if the growth cycles were initiated during the winter season. Since larger birds are often housed in open shelters during most of the year, the need for heating is highly concentrated during a few of the winter months and is greatly subject to the time that the growth cycles are initiated. A summary of baseline annual energy use is shown in Table 30.

3.4.5 SWINE FARROWING

Swine farrowing operations are dispersed widely throughout the Midwest, and other areas of the U. S. , where colder climates and availability of common feeds exists. Thus, the use of heating energy is relatively significant for this application - 243 million Btu's annually - second only to the concentrated broiler operations examined. The baseline energy analysis allowed for the growth of the young pigs until the time they would be transferred to the growing/finishing house. Baseline annual energy use is summarized in Table 31.

3.4.6 SWINE GROWING AND FINISHING

This application required relatively less heating energy because of the larger animal sizes involved. However, a significant amount of energy use occurs due to ventilation requirements to maintain productivity and health of the herd, and a comparatively large amount of hot water use. Due to the very limited need for space heating, WECS can be used directly only for the coldest months of the year. A summary of the baseline annual energy use is given in Table 32.

3.4.7 DAIRY

Dairy operations tend to be concentrated in cooler climates since milk production is greatly reduced with increased temperatures. The Wisconsin-Minnesota area was analyzed for this application. Dairy operations feature both a large amount of hot water and year-round operations. The baseline energy analysis for heating assumed that the dairy herd would be confined in an integrated facility for optimum

Days of Year	Net Space Heating Load 10^6 Btu	Feed Lbs	Production (Eggs)
1-30	0.0	102,914	332,965
31-60	0.0	106,834	332,385
61-90	0.0	108,353	327,412
91-120	0.0	110,197	329,178
121-150	0.0	112,073	320,040
151-180	0.0	113,981	317,380
181-210	0.0	115,922	314,160
211-240	0.0	117,896	314,100
241-270	0.0	119,903	316,650
271-300	7.643	121,944	321,450
331-360	42.596	126,131	335,840
361-365	12.573	21,231	55,973
Annual Totals	62.812	1,277,379	3,617,533

Table 29 - Layer Baseline Annual Heating Energy Use-Sacramento, California

Days of Year	Net Space Heating Load 10^6 Btu	Feed Lbs	Production (Birds)
1-35	36.296	11310	1000
36-70	28.692	11310	1000
71-105	14.682	11310	1000
106-140	6.743	11310	1000
141-175	2.938	11310	1000
176-210	1.721	11310	1000
211-245	1.79	11310	1000
246-280	5.38	11310	1000
281-315	10.898	11310	1000
316-350	28.995	11310	1000
351-365	8.092	1745	1000
Annual Total	146.244	114845	

Table 30-Turkey Brooding Baseline Annual Heating Energy Use- Minneapolis, Minn.

Days of Year	Net Space Heating Energy 10^6 Btu	Feed -lbs			Production (Animals)
		Oats	Corn	Concentrate	
1-56	114.99	800	9950	3102	128
57-112	46.864	800	9950	3102	128
113-168	8.322	800	9950	3102	128
169-224	1.479	800	9950	3102	128
225-280	0.578	800	9950	3102	128
281-336	12.284	800	9950	3102	128
337-365	58.533	127	5911	1082	128
Annual Totals	243.05	4927	65611	19694	

Table 31 - Swine Farrowing Baseline Annual Heating Energy Use- Des Moines, Iowa

Days of Year	Net Space Heating Energy 10^6 Btu	Feed-Lbs Corn	Feed-Lbs Concentrate	Production Lbs
1-56	55.473	68764	11063	42620
57-112	6.121	68832	11074	42732
113-168	0.0	68761	11063	42567
169-224	0.0	68585	11033	42392
225-280	0.0	68608	11037	42479
281-336	0.0	68823	11073	42728
337-365	17.946	32091	5137	22540
Annual Totals	79.536	444464	71480	278058

Table 32 - Swine Growing/Finishing Baseline Annual Heating Energy Use- Des Moines, Iowa

production. A summary of the baseline annual energy use is given in Table 33.

3.4.8 LAMBING

Lambing is analyzed to complete the spectrum of representative farm building applications. It is recognized that the use of confined structures with space heating for lambing is rare. Furthermore, in many of the Great Plains states, lambing operations tend to occur in the open with little concentration of heated structures dedicated to this purpose. The baseline energy use for the farm building employed for this function in the Casper, Wyoming area is given in Table 34.

3.5 SYNOPSIS

This chapter has investigated the duration and the size of the heating loads required for the three representative farmhouses and the eight selected farm buildings. Also studied were the energy flows for these facilities, on an hourly basis, at all previously cited geographic locations, as well as at the additional location of Chicago, Illinois.

The above analyses are subsequently used as references for evaluating possible wind-powered heating system applications, and clearly indicate the value of including thermal storage. The following section examines WECS applications in greater detail.

Days of Year	Net Space Heating Load 10^6 Btu	Feed Lbs	Production Milk - Lbs
1-30	10.651	141,900	113,859
31-60	4.243	141,900	114,548
61-90	0.0	141,900	115,129
91-120	0.0	141,900	114,818
121-150	0.0	141,900	113,487
151-180	0.0	141,900	112,720
181-210	0.0	141,900	112,349
211-240	0.0	141,900	112,498
241-270	0.0	141,900	112,742
271-300	0.0	141,900	114,340
301-330	0.0	141,900	114,990
331-360	1.322	141,900	115,000
361-365	.001	23,650	19,166
Annual Totals	16.217	1,726,450	1,385,646

Table 33 - Dairy Baseline Annual Heating Energy Use- Madison, Wisconsin

Days of Year	Net Space Heating Energy 10^6 Btu	Feed - Lbs Oats	Corn	Supplement	Hay
1-42	7.693	896	15110	2039	11632
43-84	23.04	896	15110	2039	11632
85-126	0.122	896	15110	2039	11632
127-168	1.1	896	15110	2039	11632
169-210	0.0	896	15110	2039	11632
211-252	0.0	896	15110	2039	11632
253-294	0.0	896	15110	2039	11632
295-336	1.067	896	15110	2039	11632
337-365	0.0	896	15110	2039	11632
Annual Totals	33.02	8064	135990	18351	104688

Table 34 - Lambing Baseline Annual Heating Energy Use- Casper, Wyoming

4.0 WIND ENERGY APPLICATIONS ANALYSIS

4.1 INTRODUCTION

The objective of this task is to examine the specific farmhouse and farm building heating applications that wind energy could satisfy. Guiding considerations for this analysis included:

- The effect of wind energy variability on conventional heating systems integration
- Interaction of wind energy use and suitability of a specified finite thermal energy storage system correlated to storage periods typical for solar heating applications
- An assessment of the wind energy system to serve as a self-sufficient or supplemental source of heat
- The effect of electric rates and their non-uniformity or practicality on economic value

Investigation of these factors was based on hour by hour matching of the wind resource to farmhouse and farm building energy needs. This procedure provided information about the coincidence of the wind system with heating needs both with and without thermal storage. The energy needs with conventional heating systems were consistently utilized as a reference to compare the relative performance of wind energy systems. Baseline energy needs for farmhouses and farm buildings using local hour by hour climatic conditions were defined for all structures at the nine geographic test locations.

A total of 151 separate wind energy applications comprised the basis for this analysis - 108 for farmhouses and 43 for farm buildings. This places emphasis on the farmhouse applications by a ratio of more than 2 to 1 for the overall analysis, and corresponds to the generally higher proportion of energy use in the farmhouse, the sizes of the WECS studied and the presence or absence of thermal storage.

Without thermal storage, WECS having the following general characteristics were applied to all farmhouses and farm buildings:

- A WECS of 10 foot rotor diameter (2 KW generator)
- A WECS of 20 foot rotor diameter (10 KW generator)
- A WECS of 40 foot rotor diameter (40 KW generator)

The generator ratings were assigned to the rotor diameters using the relationship below which defines the rated velocity associated with the generator rating:

$$P = 0.5 \times p \times A \times V_r^3 \times C_p \times C_g \times C_u$$

where:

P = Power in kilowatts corresponding to rated velocity

p = Air Density

A = Area swept by the rotor of the WECS

V_r = The rated velocity of the WECS

C_p = The coefficient of performance for the rotor

C_g = The efficiency fraction of the generator and power conditioning equipment

C_u = Constants of conversion for consistent units

Based on the results of sizing sensitivity studies discussed later in this section, applications with thermal storage for space heating and water heating consistently utilized a WECS of 20 foot rotor diameter with a 10 KW generator.

All WECS were assigned a cut-in velocity (Vi) of 6 miles per hour (mph), a cut-out velocity (Vo) of 40 mph, and a rated velocity (Vr) corresponding to the rotor-generator combination from the equation shown above. The resulting rated velocities are given in the following summary:

WECS Size	WECS Rated Velocities (mph) At Hub Height of 65.62 Feet
10 foot diameter	24
20 foot diameter	26
40 foot diameter	26

A summary of the thermal storage for space heating and hot water use is given in Table 35. Also shown is the annual space heating and hot water energy associated with each application. Separate analyses were made for each storage combination using the 20 foot diameter WECS system, mounted at a 65.62 foot hub height.

Analysis without thermal storage allocated the WECS production to only two uses:

- o Space heating
- o Sell-back to the utility for surplus energy

This procedure provides a conservative determination of WECS use, yet still furnishes a use for all the wind energy provided.

Analysis with thermal storage fully allocated the hour by hour production from the WECS to building needs in the following sequence of priorities:

1. Direct space heating
2. Thermal storage for space heating

Farmhouse & Farm Buildings	Thermal Storage Size - Gallons		Annual Thermal Requirements 10^6 Btu	
	Space Heating	Water Heating	Space Heating	Water Heating
Older House	600	100	see Table 49	20.768
Modern House	600	100	see Table 49	16.812
Passive Solar House	600	100	see Table 49	16.812
Poultry-Layer	600	0	62.752	0.0
	2000	0	62.692	0.0
Poultry-Layer/Brooding	1000	0	26.6	0.0
	2000	0	26.58	0.0
Poultry-Broiler	850	0	1115.5	0.0
	2000	0	1115.25	0.0
Poultry-Turkey Brooding	500	0	153.118	0.0
	2000	0	152.205	0.0
Swine-Farrowing	300	0	234.88	0.0
	2000	0	233.7	0.0
Swine-Growing/Finishing	100	0	73.556	0.0
	2000	0	72.296	0.0
Dairy	300	800	27.645	114.706
	2000	800	21.938	114.706
	250	0	30.02	0.0
Lambing	2000	0	29.591	0.0

Table 35 - Thermal Storage For Space Heating and Water Heating Examined

3. Direct hot water
4. Thermal storage for hot water
5. Appliances and machinery
6. Sell-back to the local utility

For this study, the local utility was assumed to be a rural electric cooperative (REC), and the state by state average wholesale rates for power and energy purchased by the REC's was used to value the energy sold back to the local utility. Further, since the focus of this study is an economic analysis of wind-powered farmhouse and farm building heating systems, the first priority for WECS production is the space heating requirement. It is recognized that, except for electric resistance heating, this priority results in the WECS displacing lower valued fuels first, at an overall reduced value. Further research is recommended so that the effects on WECS value from higher valued fuel displacement may be considered.

The following sections present the quantitative effects of WECS use with and without thermal storage for space heating. In all cases, significantly greater amounts of the WECS energy could be utilized with only nominal amounts of thermal storage, commensurate with that recommended for other solar heating systems.

4.2 WIND ENERGY UTILIZATION WITHOUT THERMAL STORAGE

Wind energy use without thermal storage depends directly on the time coincidence of hourly heating needs and the availability of production from the WECS. As a result, the utilization is significantly reduced compared to WECS use with thermal storage. In this study, the direct use of WECS without storage considered only two possibilities - space heating or sell-back to the utility. Additional value could be obtained in the case of WECS surplus if space heating were allocated to hot water heating, machinery and appliances and the local use prior to sell-back to the local utility.

The following paragraphs discuss in more detail the use of WECS without thermal storage in both the farmhouses and farm buildings.

4.2.1 FARMHOUSE WECS USE WITHOUT THERMAL STORAGE

Three representative farmhouse models were evaluated at nine locations for use of WECS energy without thermal storage. A summary of the proportion of WECS production directly usable and surplus is given in Tables 36, 37, and 38, respectively, for the older, modern, and passive solar farmhouse structures.

An overall comparison of the direct utilization of WECS production according to warm and cold climates is given in Table 39. Based on these results, a 20 foot diameter WECS was selected for additional analyses considering thermal storage. The analyses also suggest that for direct space heating, the average utilization factors for WECS production considering locations, climate factors, wind availability and a 20 foot diameter are:

Heating Energy and WECS Use Without Storage - 10^6 Btu/Year

	Total Heat Requirement	Coincident WECS			Surplus WECS			Net Heat Requirement		
		10 *	20	40	10	20	40	10	20	40
Minnesota	91.297	5.86	19.934	44.217	3.447	18.11	107.959	85.43	71.36	47.08
Wisconsin	90.408	5.353	19.107	40.759	2.136	11.651	82.239	85.05	71.31	49.64
Illinois	74.413	7.143	23.89	46.615	3.091	18.501	123.951	67.27	50.52	27.79
California	18.455	1.321	3.257	5.925	3.307	15.701	69.906	17.13	15.19	12.53
Wyoming	83.91	8.738	27.071	48.068	3.8	26.591	166.581	75.17	56.83	35.85
Colorado	57.095	1.993	6.535	16.615	2.421	11.628	56.037	55.1	50.56	40.48
Maryland	44.13	3.513	11.295	22.065	2.754	14.404	80.732	40,61	32.83	22.06
Texas	15.379	2.156	6.041	9.937	4.753	22.047	102.413	13.22	9.33	5.44
Iowa	76.501	5.974	20.841	42.75	3.439	18.346	114.001	70.52	55.66	33.75

* Diameter of WECS Examined

Table 36 Older Farmhouse--WECS Energy Used For Spaceheating Without Thermal Storage

Heating Energy and WECS Use Without Thermal Storage - 10^6 Btu/Year

	Total Heat Requirement	Coincident WECS Production by Diameter			WECS Production Surplus to Space Heating			Net Space Heating Energy		
		10' *	20'	40'	10'	20'	40'	10'	20'	40'
Minnesota	101.489	6.037	20.865	47.52	3.27	17.178	104.655	95.45	80.62	53.96
Wisconsin	91.166	5.187	18.628	40.252	2.302	12.13	82.781	85.97	72.53	50.91
Illinois	81.932	7.174	24.886	49.6	3.06	17.525	120.97	74.759	57.066	33.333
California	20.334	1.377	3.402	6.302	3.251	15.555	69.529	18.95	16.93	14.03
Wyoming	78.551	8.266	25.329	44.909	4.272	28.333	169.739	70.28	53.22	33.64
Colorado	57.648	1.896	6.302	16.288	2.518	11.861	56.364	55.75	51.34	41.36
Maryland	50.301	4.583	11.801	23.96	2.684	13.898	78.837	46.73	38.52	26.36
Texas	18.198	2.245	6.589	11.241	4.663	21.498	101.109	15.95	11.6	6.95
Iowa	80.821	5.933	20.928	40.083	3.479	18.259	112.667	74.88	59.87	40.73

* Diameter of WECS Examined

Table 37 Modern Farmhouse--WECS Energy Used For Spaceheating Without Thermal Storage

Heating Energy and WECS Use Without Thermal Storage - 10^6 Btu/Year

20' WECS Rotor Diameter

		Total Heating Requirement	Coincident WECS Production	WECS Production Surplus to Heating	Net Heating Requirement
Without Trombe Wall and Thermal Storage	Minnesota	41.743	12.155	25.889	29.588
	Wisconsin	39.838	11.736	19.022	28.102
	Illinois	31.972	13.558	28.734	18.31
	California	6.367	0.931	18.027	5.436
	Wyoming	32.909	12.563	41.0	20.246
	Colorado	22.83	3.056	15.107	19.774
	Maryland	16.729	5.661	20.09	11.068
	Texas	7.297	3.322	24.766	3.975
	Iowa	35.488	13.078	26.11	22.41
With Trombe Wall and Thermal Storage	Minnesota	23.314	8.403	29.641	14.911
	Wisconsin	21.172	7.621	23.137	13.551
	Illinois	16.225	8.426	33.966	7.799
	California	0.905	0.098	18.86	0.807
	Wyoming	15.011	5.566	48.097	9.445
	Colorado	7.317	1.027	17.136	6.29
	Maryland	3.742	2.065	23.686	1.677
	Texas	2.513	1.373	26.715	1.14
	Iowa	21.091	9.402	29.786	11.689

Table 38 Passive Solar Farmhouse--WECS Energy Used For Space Heating Without Thermal Storage

	Farmhouse Type							
					Passive Solar			
	Older		Modern		No Trombe Wall		Trombe Wall	
WECS Rotor Diameter - Feet	WECS Use %	Heating Energy Displaced %	WECS Use %	Heating Energy Displaced %	WECS Use %	Heating Energy Displaced %	WECS Use %	Heating Energy Displaced %
10								
Colder Climate	67	8	67	7.8				
Warmer Climate	38	9.7	39	8.7				
20								
Colder Climate	55	26.9	54	26	29	33	18	39
Warmer Climate	27	27.5	29	26	10	31	9	49
40								
Colder Climate	27	53.8	27	50.9				
Warmer Climate	12	48.9	14	46				

Table 39 - Overall Comparison of WECS Production and Use By Climate Without Thermal Storage

Percentage of WECS Production Used Without Storage

Farmhouse Type	Climate type Warm *	Moderate to Cold **
Older	27	55
Modern	29	54
Passive Solar	10	29

* Heating degree days less than 4000
** Heating degree days more than 4000

These overall utilization factors were considered for the generalized economic break-even analysis discussed in Chapters 5 and 7.

4.2.2 FARM BUILDING WECS USE WITHOUT THERMAL STORAGE

Farm buildings exhibit a wider diversity of heating requirements. This is due to the great variation in environmental needs for optimum production, the animal types, and the production of heat and moisture by the animals. Each selected farm building was analyzed at its representative production center considering WECS of 10, 20, and 40 foot diameters. These correspond to ratings of approximately 2, 10, and 40 KW of output power at rated velocity.

The WECS production directy usable and the surplus to space heating without thermal storage is presented in Table 40 for the farm buildings.

4.2.2.1 BROILER BUILDING

This application had the greatest annual baseline energy use of over 1000 million Btus. Because of the large demand, even high percentage use of WECS energy results in limited heat energy displacement. The 10, 20, and 40 foot WECS offset, respectively, 0.2%, 1.1%, and 4.2% of the total heat energy need. Use of produced WECS energy was nearly identical for all three systems (45%), and a fairly high degree of coincidence between energy demand and production existed, as shown in Table 41.

This building appears to have good potential for WECS application. Baseline energy demands are high and distributed about the year, and thermal storage may be expected to greatly enhance the percentage of usable WECS energy.

4.2.2.2 LAYER BROODING

Layer brooding energy use was evaluated in the Sacramento, California area. The annual energy required was found to be relatively low at 26 million Btus. The application of the 10, 20, and 40 foot diameter WECS (without storage) resulted in the displacement of 0.8%, 3.2%, and 10.7% of the space heating requirement, respectively. This corresponds to 4.5%, 4.5%, and 3.7% of the 10, 20, and 40 foot diameter WECS energy output, respectively.

Though the energy demand was relatively low, WECS energy output

Farm Building	Annual Heating Energy 10^6 Btu	WECS Direct Use - %			Heat Supplied By WECS - %		
		10'*	20'	40'	10'	20'	40'
Brooding	26.653	4.5	4.5	3.7	0.8	3.24	10.71
Layer	62.812	1.1	1.1	1.1	0.08	0.3	1.3
Broiler	1116.05	47.8	47.9	45.8	0.2	1.1	4.2
Turkey	146.244	76.7	66.5	40.0	4.9	17.6	42.4
Swine Growing	79.53	3.1	2.3	1.8	0.3	1.1	3.4
Swine Farrowing	243.05	40.56	32.6	29.1	1.2	5.1	18.3
Lambing	33.02	0.1	0.1	0.9	0.0	0.1	5.2
Dairy*	35.825	1.3	1.2	1.0	0.2	1.1	3.5

* Diameter of WECS Examined

Table 40 - WECS Use and Heating Energy Displaced For Farm Buildings Without Storage

*1°F temperature band controlled

Broilers

WECS Space Heating Summary - 1978

No Storage

Cycle Days of Year	Net Thermal Load (1 10^6 Btu	10 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	20 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	40 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-75	736.24	1.908	1.789	0.119	734.45	8.05	7.484	0.566	728.76	32.2	29.064	3.136	707.18
+ 4 days	796.26	2.037	1.869	0.168	794.39	8.572	7.806	0.766	788.45	34.291	30.354	3.937	765.91
75-150	19.767	1.68	0.31	1.37	19.457	6.786	1.162	5.624	18.606	27.144	3.864	23.28	15.903
+ 1 day	19.767	1.682	0.311	1.371	19.457	6.791	1.161	5.63	18.606	27.167	3.864	23.303	15.903
151-225	0.733	0.7	0.004	0.696	0.73	2.807	0.014	2.793	0.719	11.228	0.053	11.175	0.631
+ 4 days	0.733	0.723	0.003	0.72	0.73	2.901	0.014	2.887	0.719	11.607	0.053	11.554	0.681
226-300	72.591	0.76	0.084	0.676	72.567	3.041	0.334	2.707	72.257	12.161	1.316	10.845	71.269
+ 1 day	80.946	0.764	0.086	0.678	80.86	3.058	0.34	2.718	80.606	12.232	1.342	10.89	79.603
301-365	286.72	1.23	0.814	0.416	285.91	5.065	3.34	1.725	283.38	20.264	12.885	7.379	273.84
Cycle	1116.05	6.278	3.001	3.277	1113.05	25.749	12.334	13.415	1103.72	102.99	47.152	55.215	1068.87
Cycle +	1184.42	6.436	3.083	3.353	1181.34	26.387	12.661	13.726	1171.76	105.561	48.498	57.063	1135.93

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 41 - Broiler Building - WECS Space Heating Summary Without Thermal Storage

could provide only minimal benefit without storage. Space heat demands and WECS energy production were not coincident events, rendering large portions of the WECS energy of no value. Results are shown in Table 42.

4.2.2.3 LAYER BUILDING

The layer structure was also evaluated in the Sacramento, California area. It houses older birds, starting at about three months of age, for the purpose of egg production. This application demands over twice the energy required in brooding, but can only make little use of wind energy. The 10, 20, and 40 foot diameter WECS displaced only 0.08%, 0.3%, and 1.3% of the required heat energy, respectively. The proportion of WECS direct use to WECS produced energy was about 1.1% in each of these cases.

Annual energy demand was substantial but direct WECS application, without a storage facility, did not reap significant benefits. Most of the heat energy need occurred in heavy concentrations during the winter months. Results are presented in Table 43.

4.2.2.4 TURKEY BUILDING

The turkey brooding operation demanded a substantial amount of heat energy, 146 million Btus. Over 75% of the energy produced by a 10 foot diameter WECS was directly usable in this operation. This percentage dropped to 66% and 40%, however, with the use of the 20 and 40 foot systems. Similar results occurred in the amounts of energy displaced - 4.9%, 17.6%, and 42.4% for the 10, 20, and 40 foot systems. While the percentage of WECS energy use decreased with increases in system size, significant increases in displaced heat energy occurred as shown in Table 44.

Heat energy demand was dispersed throughout the year, making it appear to be a viable WECS application. Thermal storage capabilities should greatly enhance WECS application to this building.

4.2.2.5 SWINE GROWING AND FINISHING

While this application demands a significant amount of heat energy annually (79 million Btus), the demands are concentrated in only the coldest months. This causes the WECS to fall far short of peak demand over short periods and have extremely large excesses the remainder of the year. Only 0.3%, 1.1%, and 3.4% of the total required heat energy could be displaced by the 10, 20, and 40 foot WECS, respectively. The percentages of WECS energy used were equally low - 3.1%, 2.3%, and 1.8% for the 10, 20, and 40 foot systems, as shown in Table 45.

Though the baseline energy is relatively high, the concentrated nature of the demand acts as an obstacle to WECS application. Storage may allow WECS energy production to more closely match demand, but the extent is dependent upon demand distribution; a better match exists with wide distribution, worse with concentrated distribution.

Layer/Brooding

WECS Space Heating Summary - 1978

No Storage

Cycle Day of the Year	Net Thermal Load (1 10^6 Btu	10 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	20 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	40 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-92	12.143	1.516	0.143	1.373	12.0	6.328	0.594	5.734	11.549	25.313	1.821	23.492	10.323
93-184	10.853	1.429	0.043	1.386	10.81	5.82	0.172	5.646	10.081	23.283	0.575	22.608	10.178
185-276	0.737	0.988	0.008	0.98	0.728	3.976	0.035	3.941	0.702	15.946	0.109	15.797	0.628
277-365	2.92	0.693	0.017	0.676	2.904	2.832	0.065	2.767	2.855	11.329	0.251	11.078	2.669
Annual	26.653	4.626	0.211	4.415	26.442	18.956	0.866	18.09	25.787	75.821	2.856	72.925	23.798

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 42 - Layer/Brooding - WECS Space Heating Summary Without Thermal Storage

Layer (10^{o}F Band)

WECS Space Heating Summary - 1978

No Storage

Cycle Day of the Year	Net Thermal Load (1 10^6 Btu	10 Foot Diameter WECS				20 Foot Diameter WECS				40 Foot Diameter WECS			
		WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-30	0.0	0.623	0.0	0.623	0.0	2.655	0.0	2.655	0.0	10.62	0.0	10.62	0.0
21-60	0.0	0.449	0.0	0.449	0.0	1.885	0.0	1.885	0.0	7.54	0.0	7.54	0.0
61-90	0.0	0.417	0.0	0.417	0.0	1.679	0.0	1.679	0.0	6.717	0.0	6.717	0.0
91-120	0.0	0.332	0.0	0.332	0.0	1.359	0.0	1.359	0.0	5.437	0.0	5.437	0.0
121-150	0.0	0.579	0.0	0.579	0.0	2.393	0.0	2.393	0.0	9.572	0.0	9.572	0.0
151-180	0.0	0.463	0.0	0.463	0.0	1.854	0.0	1.854	0.0	7.418	0.0	7.418	0.0
181-210	0.0	0.319	0.0	0.319	0.0	1.276	0.0	1.276	0.0	5.106	0.0	5.106	0.0
211-240	0.0	0.377	0.0	0.377	0.0	1.509	0.0	1.509	0.0	6.035	0.0	6.035	0.0
241-270	0.0	0.353	0.0	0.353	0.0	1.435	0.0	1.435	0.0	5.739	0.0	5.739	0.0
271-300	0.0	0.103	0.0	0.103	0.0	0.412	0.0	0.412	0.0	1.65	0.0	1.65	0.0
301-330	7.643	0.298	0.006	0.292	7.637	1.201	0.026	1.175	7.618	4.804	0.102	4.702	7.542
331-360	42.596	0.285	0.043	0.242	42.553	1.194	0.171	1.023	42.425	4.778	0.673	4.105	41.922
361-365	12.573	0.02	0.005	0.015	12.569	0.063	0.017	0.046	12.556	0.247	0.068	0.179	12.508
Annual	62.812	4.618	0.054	4.564	62.759	18.915	0.214	18.701	62.599	75.66	0.84	74.82	61.972

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 43 Layer Building - WECS Space Heating Summary Without Thermal Storage

Turkeys

WECS Space Heating Summary - 1978

No Storage

10 Foot Diameter WECS

Cycle Day of the Year	Net Thermal Load (1 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-35	36.296	0.976	0.976	0.0	35.42
36-70	28.692	0.572	0.572	0.0	28.119
71-105	14.682	1.213	1.1905	0.0225	13.492
106-140	6.743	1.187	0.894	0.293	5.848
141-175	2.938	0.851	0.352	0.499	2.587
176-210	1.721	0.678	0.227	0.451	1.494
211-245	1.79	0.665	0.147	0.518	1.644
246-280	5.38	0.845	0.553	0.292	4.828
281-315	10.898	1.015	0.892	0.123	10.0
316-350	28.995	0.941	0.941	0.0	28.053
351-365	8.092	0.527	0.527	0.0	7.564
Annual	146.244	9.47	7.271	2.198	139.

20 Foot Diameter WECS

Cycle Day of the Year	Net Thermal Load (1 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-35	36.296	4.084	4.05	0.034	32.346
36-70	28.692	2.338	2.328	0.00916	26.362
71-105	14.682	5.01	4.398	0.612	10.284
106-140	6.743	4.907	2.786	2.121	3.957
141-175	2.938	3.5	0.946	2.554	1.992
176-210	1.721	2.714	0.606	2.108	1.115
211-245	1.79	2.693	0.414	2.279	1.377
246-280	5.38	3.387	1.641	1.746	3.739
281-315	10.898	4.14	2.871	1.269	8.027
316-350	28.995	3.822	3.717	0.105	25.278
351-365	8.092	2.182	2.040	0.142	6.051
Annual	146.244	38.777	25.797	12.979	120.52

40 Foot Diameter WECS

Cycle Day of the Year	Net Thermal Load (1 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-35	36.296	16.338	11.603	4.735	24.794
36-70	28.692	9.353	7.372	1.981	21.319
71-105	14.682	20.04	9.596	10.444	5.084
106-140	6.743	19.63	4.74	14.89	2.002
141-175	2.938	14.0	1.8	12.2	1.144
176-210	1.721	10.856	1.078	9.778	0.643
211-245	1.79	10.773	0.832	9.941	0.959
246-280	5.38	13.551	3.089	10.462	2.291
281-315	10.898	16.562	5.943	10.619	4.954
316-350	28.995	15.289	11.376	3.913	17.619
351-365	8.092	8.73	4.625	4.105	3.466
Annual	146.244	155.122	62.05	93.06	84.27

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 44 - Turkey Building - WECS Space Heating Summary Without Thermal Storage

Swine Growing/Finishing

WECS Space Heating Summary - 1978

No Storage

Cycle Day of the Year	Net Thermal Load[1] 10^6 Btu	10 Foot Diameter WECS: WECS[2] Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	20 Foot Diameter WECS: WECS[2] Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	40 Foot Diameter WECS: WECS[2] Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-56	55.473	1.714	0.255	1.459	55.218	7.451	0.788	6.663	54.684	29.807	2.348	27.459	53.125
+ 2 days	55.486	1.796	0.257	1.539	55.23	7.789	0.794	6.995	54.692	31.156	2.358	28.798	53.128
57-112	6.121	2.024	0.009	2.015	6.112	8.444	0.033	8.411	6.087	33.78	0.114	33.666	6.007
+ 2 days	6.121	2.14	0.009	2.131	6.112	8.967	0.034	8.933	6.087	35.868	0.114	35.754	6.007
113-168	0.0	1.617	0.0	1.617	0.0	6.811	0.0	6.811	0.0	27.247	0.0	27.247	0.0
+ 3 days	0.0	1.728	0.0	1.728	0.0	7.263	0.0	7.263	0.0	29.054	0.0	29.054	0.0
169-224	0.0	0.718	0.0	0.718	0.0	2.88	0.0	2.88	0.0	11.522	0.0	11.522	0.0
+ 3 days	0.0	0.767	0.0	0.767	0.0	3.074	0.0	3.074	0.0	12.298	0.0	12.298	0.0
225-280	0.0	0.882	0.0	0.882	0.0	3.538	0.0	3.538	0.0	14.555	0.0	14.555	0.0
+ 3 days	0.0	0.916	0.0	0.916	0.0	3.672	0.0	3.672	0.0	14.69	0.0	14.69	0.0
281-336	0.0	1.212	0.0	1.212	0.0	4.913	0.0	4.913	0.0	19.654	0.0	19.654	0.0
+ 2 days	0.0	1.339	0.0	1.339	0.0	5.445	0.0	5.445	0.0	21.781	0.0	21.781	0.0
+ 29 days	17.942	0.978	0.022	0.956	17.92	4.048	0.08	3.968	17.862	16.194	0.289	15.905	17.653
Cycle	79.536	9.145	0.286	8.859	79.25	38.085	0.901	37.184	78.633	11.663	2.751	150.008	76.785
Cycle + days	79.549	9.664	0.288	9.376	79.262	40.258	0.908	39.35	78.641	161.041	2.761	158.28	76.788

1.) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 45 - Swine Growing/Finishing - WECS Space Heating Summary Without Thermal Storage

4.2.2.6 SWINE FARROWING

Baseline energy demand (243 million Btus) is second only to the broiler application. Distribution of energy demand is fairly wide, as evidenced by higher percentages of WECS energy utilization - over 40% of the 10 foot system, 32% of the 20 foot, and nearly 30% of the 40 foot WECS total production. The percentage of total heat demand displaced was 1.2%, 5.1%, and 18.3%, respectively, for the 10, 20, and 40 foot WECS as shown in Table 46.

Storage should add substantially to the total usable WECS energy output. The smaller WECS is limited by its size in the degree of its effect on displacing energy. The 10 foot WECS could displace only about 4% of the required energy as opposed to a potential of over 50% for the 40 foot system.

4.2.2.7 DAIRY

Dairy is the one livestock application which requires large quantities of hot water year round. This will tend to add WECS value with storage even if space heating annual demand is low, which in fact it is, at 35 million Btus. Small percentages (from 0.2% to 3.5%) of heat energy were displaced by the WECS energy. The space heat demand appears to be concentrated within the year, limiting expected favorable impacts due to storage utilization as seen in Table 47.

Results show that thermal storage should positively affect this application considering hot water heating needs. Some space heating improvements should be realized to a limited extent. Unlike applications discussed earlier, storage should favorably affect WECS use in the dairy application even with its space heating need concentrated in the winter.

4.2.2.8 LAMBING

Lambing required a small amount of annual space heat energy, only 33 million Btus. This demand appears very concentrated with energy displacements of near zero, 0.1%, and 5% for the 10, 20 and 40 foot WECS systems. The percentage of total produced energy utilized was equally poor, delivering less than 1% of the produced energy as seen in Table 48.

Baseline energy level is low and little storage benefit can be projected. There is a possibility that distribution is wide and some disparities result from a lack of daily coincidence. This is determined in subsequent storage facility applications.

4.3 WIND ENERGY UTILIZATION WITH THERMAL STORAGE

Thermal storage for space heating, commensurate with other solar space heating systems, as well as for hot water, was examined to determine the effects on the utilization of WECS production. In all

Farrowing - 10°F Band

WECS Space Heating Summary - 1978

No Storage

Cycle Days of Year	Net Thermal Load (1 10^6 Btu	10 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-56	114.99	1.719	1.483	0.236	113.51
57-112	46.864	2.024	0.414	1.61	46.451
113-168	8.322	1.621	0.216	1.405	8.11
169-224	1.479	0.718	0.04	0.678	1.439
225-280	0.578	0.882	0.029	0.853	0.549
281-336	12.284	1.215	0.21	1.065	12.078
337-365	58.533	0.978	0.734	0.244	57.779
Annual	243.05	9.157	3.126	4.582	239.916

Cycle Days of Year	20 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-56	7.479	6.09	1.389	108.93
57-112	8.446	1.624	6.822	45.241
113-168	6.826	0.818	6.008	7.519
169-224	2.88	0.15	2.73	1.329
225-280	3.539	0.09	3.449	0.489
281-336	4.924	0.712	4.212	11.583
337-365	4.048	2.956	1.092	55.577
Annual	38.142	12.44	25.702	230.668

Cycle Days of Year	40 Foot Diameter WECS: WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-56	29.916	23.017	6.899	92.081
57-112	33.785	6.225	27.56	40.645
113-168	27.305	2.279	25.026	6.101
169-224	11.522	0.409	11.113	1.09
225-280	14.157	0.206	13.951	0.373
281-336	19.698	1.947	17.751	10.381
337-365	16.194	10.469	5.725	48.064
Annual	152.577	44.556	108.025	198.735

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 46 - Swine Farrowing - WECS Space Heating Summary Without Storage

Dairy (10^{o}F Band)

WECS Space Heating Summary - 1978

No Storage

Cycle Day of the Year	Net Thermal Load 10^6 Btu (1	10 Foot diameter WECS				20 foot Diameter WECS				40 Foot Diameter WECS			
		WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu	WECS (2 Production 10^6 Btu	Usable WECS 10^6 Btu	Excess WECS 10^6 Btu	Net Furnace 10^6 Btu
1-30	10.651	0.996	0.027	0.969	10.625	4.363	0.118	4.245	10.533	17.452	0.472	16.93	10.179
31-60	4.243	0.477	0.0	0.477	4.243	1.939	0.0	1.939	4.245	7.756	0.0	7.756	4.243
61-90	0.0	0.658	0.0	0.658	0.0	2.727	0.0	2.727	0.0	10.911	0.0	10.911	0.0
91-120	0.0	0.812	0.0	0.812	0.0	3.336	0.0	3.336	0.0	13.348	0.0	13.348	0.0
121-150	0.0	0.652	0.0	0.652	0.0	2.688	0.0	2.688	0.0	10.755	0.0	10.755	0.0
151-180	0.0	0.547	0.0	0.547	0.0	2.211	0.0	2.211	0.0	8.844	0.0	8.844	0.0
181-210	0.0	0.387	0.0	0.387	0.0	1.556	0.0	1.556	0.0	6.224	0.0	6.224	0.0
211-240	0.0	0.364	0.0	0.364	0.0	1.465	0.0	1.465	0.0	5.861	0.0	5.861	0.0
241-270	0.0	0.362	0.0	0.362	0.0	1.448	0.0	1.448	0.0	5.795	0.0	5.795	0.0
271-300	0.0	0.548	0.0	0.548	0.0	2.202	0.0	2.202	0.0	8.809	0.0	8.809	0.0
301-330	0.0	0.558	0.0	0.558	0.0	2.238	0.0	2.238	0.0	8.953	0.0	8.953	0.0
331-360	1.322	0.9108	0.0008	0.91	1.321	3.704	0.003	3.701	1.318	14.817	0.013	14.804	1.309
361-365	0.001	0.217	0.001	0.218	0.0	0.881	0.0	0.881	0.001	3.50	0.00	3.50	0.001
Annual	16.217	7.489	0.027	7.462	16.189	30.758	0.121	30.637	16.095	123.03	0.48	122.55	15.732

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 47 Dairy Building-- WECS Space Heating Summary Without Thermal Storage

Lambing (Wyoming) - 10°F Band

WECS Space Heating Summary - 1978

No Storage

Cycle Day of the Year	Net Thermal Load (1 10^6 Btu	10 Foot Diameter WECS: WECS (2 Production 10^6 Btu	10 Foot: Usable WECS 10^6 Btu	10 Foot: Excess WECS 10^6 Btu	10 Foot: Net Furnace 10^6 Btu	20 Foot Diameter WECS: WECS (2 Production 10^6 Btu	20 Foot: Usable WECS 10^6 Btu	20 Foot: Excess WECS 10^6 Btu	20 Foot: Net Furnace 10^6 Btu	40 Foot Diameter WECS: WECS (2 Production 10^6 Btu	40 Foot: Usable WECS 10^6 Btu	40 Foot: Excess WECS 10^6 Btu	40 Foot: Net Furnace 10^6 Btu
1-42	7.693	1.618	0.085	1.533	7.609	6.967	0.337	6.63	7.358	27.871	1.084	26.787	6.62
43-84	23.04	1.607	0.019	1.588	23.02	6.765	0.077	6.688	22.967	27.062	0.287	26.775	22.759
85-126	0.122	1.517	0.005	1.512	0.121	6.57	0.021	6.549	0.115	26.283	0.083	26.2	0.0936
127-168	1.1	1.236	0.014	1.22	1.085	5.206	0.056	5.15	1.046	20.827	0.140	20.687	0.7727
169-210	0.0	0.805	0.0	0.805	0.0	3.307	0.0	3.307	0.0	13.231	0.0	13.231	0.0
211-252	0.0	0.928	0.0	0.928	0.0	3.759	0.0	3.759	0.0	15.037	0.0	15.037	0.0
253-294	0.0	0.99	0.0	0.99	0.0	4.165	0.0	4.165	0.0	16.662	0.0	16.562	0.0
295-336	1.067	1.651	0.008	1.643	1.06	7.06	0.032	7.028	1.041	28.243	0.129	28.114	0.967
337-365	0.0	0.744	0.0	0.744	0.0	2.99	0.0	2.99	0.0	11.961	0.0	11.961	0.0
Annual	33.02	11.096	0.0131	10.963	32.895	46.789	0.0523	46.266	32.527	187.177	1.723	185.45	31.412

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Table 48 Lambing Building--WECS Space Heating Summary Without Thermal Storage cases, this utilization was greatly increased with only minimal amounts of thermal storage. The thermal storage medium employed was water since this mode was found to be the most economical and effective type of low quality thermal storage (Reference 24). Operating temperatures were held between 100 and 200 degrees F. A conceptual diagram of the use of thermal storage with the WECS is shown in Figure 20.

The thermal storage system was conceptually sized to operate through a 15 degree F temperature drop, utilizing a water-to-air heat exchanger inserted into forced air ducts, or operating with heat exchangers and circulating fans, a common installation practice. Circulating pumps would pump water from the preheat tank to the heat exchanger in a continuous mode. WECS production was used to heat the preheat tank, provided that the available energy would not raise the temperature beyond its upper limit. Storage was not utilized if its temperature was below a minimum of 100 degrees F. A maximum heat exchange of 15000 BTUs per hour was assumed to be controllable through adjustment of the rate of pumping from the tank. WECS production was assumed to be inserted into the storage medium using resistance heating elements, controlled by a switching network that matches the WECS production to the end use.

The heat transfer from the preheat and hot water tank was dynamically analyzed using the current temperatures of the inside heated space and the temperature of the storage medium. During summer months, the heat input to the controlled space was vented to the outside; this was done to ensure practical operations and to avoid extra burdens on a cooling system.

The following sections present results of the use of WECS energy wth thermal storage for the farmhouses and farm buildings defined in this study.

4.3.1 FARMHOUSE WECS USE WITH THERMAL STORAGE

Based on sizing studies, a WECS of 20 foot rotor diameter was consistently used for the thermal storage effects analysis. The farmhouses were evaluated at all nine geographic locations.

Analysis wth thermal storage considered use of WECS production from space heating, water heating, machinery and appliances prior to defining the amount of surplus available for sell-back to the local utility. This procedure recognizes that, for most farm operations, greater flexibility of energy use and larger numbers of potential loads may exist, compared to other applications. Thus, this phase of the analysis examines the maximum use of WECS production in conjunction with applications to space heating and thermal storage needs.

A summary of the direct and surplus WECS production is shown for all farmhouses and analysis locations in Table 49. The direct and surplus use of WECS energy is summarized by warm, moderate and colder climates in Table 50. These results indicate that with thermal storage, a significant improvement in the use of WECS energy is possible. Overall average use factors for the 20 foot diameter WECS production with thermal storage and other uses is given by:

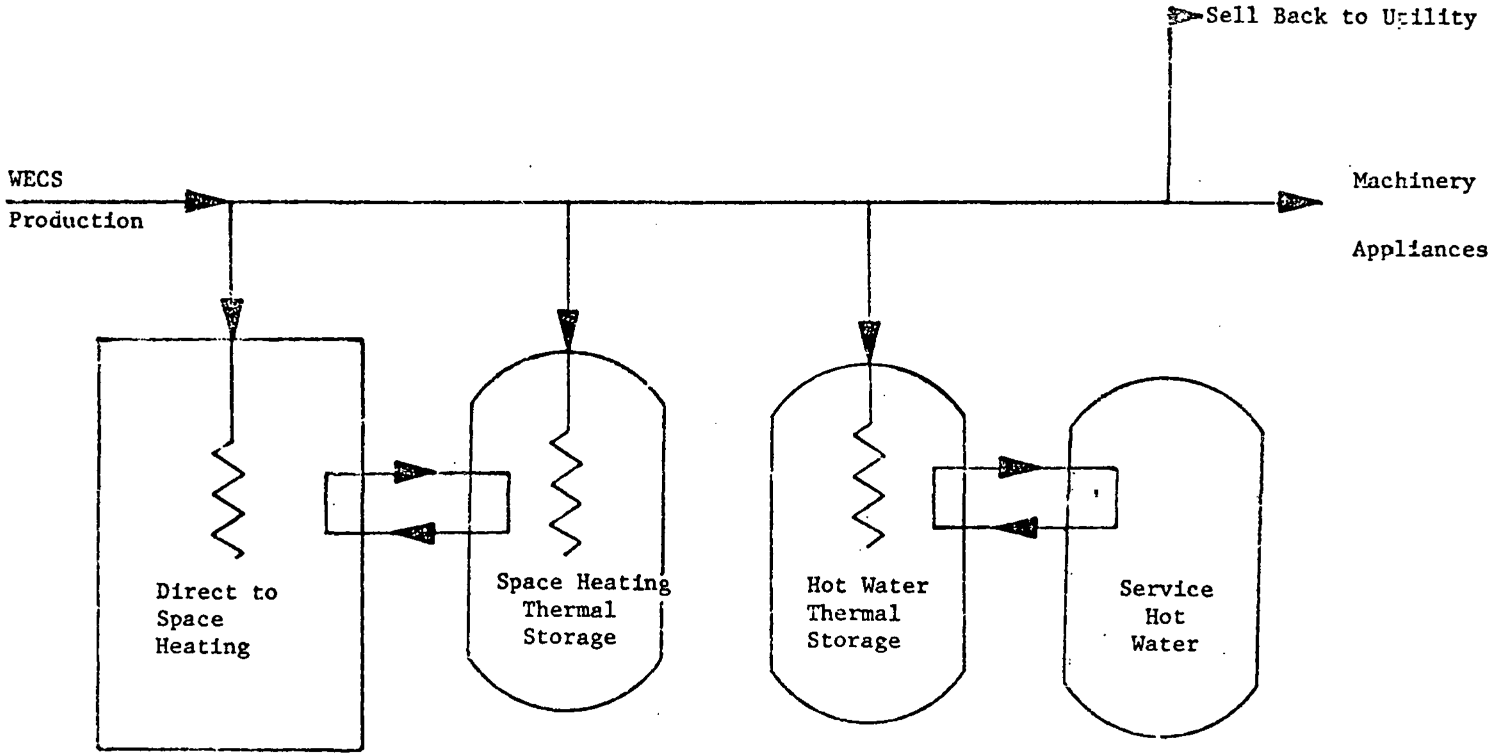


Figure 20 Schematic of The Use of WECS Production With Thermal Storage

Annual Heating Energy and Summary of WECS Production With Thermal Storage - 10^6 BTU

Farmhouse Type	Location	Total Heating Energy	Heating Energy With WECS	Summary of WECS Total Production: Total WECS Production	Direct Heating	Thermal Storage Space Heating	Hot Water Use	Appliances	Excess
Older	Minnesota	89.05	61.42	38.05	19.43	8.21	6.77	1.0	2.64
	Wisconsin	88.15	61.66	30.82	18.77	7.72	3.36	0.28	.69
	Wyoming	80.92	37.91	53.67	26.27	16.74	5.88	1.05	3.73
	Illinois	71.77	39.63	42.40	23.18	8.97	6.87	.84	2.54
	Iowa	75.06	47.22	39.19	20.45	7.38	6.57	1.08	3.71
	Colorado	55.46	44.90	18.16	6.33	4.22	3.73	0.17	3.71
	Maryland	41.97	21.88	25.71	10.86	9.23	4.83	0.29	0.50
	California	16.44	6.37	18.95	2.80	7.27	6.18	0.79	1.91
	Texas	14.21	1.12	28.09	5.66	7.43	10.27	1.37	3.36
Modern	Minnesota	99.19	70.55	38.05	18.96	9.68	6.19	0.69	2.53
	Wisconsin	92.23	65.63	30.77	18.74	7.87	3.22	0.21	0.73
	Wyoming	79.25	36.79	53.67	25.47	16.99	6.10	0.91	4.20
	Illinois	79.99	48.06	42.40	24.38	9.11	6.06	0.56	2.29
	Iowa	81.79	53.22	39.19	20.98	7.59	6.21	0.77	3.64
	Colorado	59.29	45.38	18.19	6.44	7.47	3.47	0.11	0.68
	Maryland	46.98	26.15	25.71	11.34	9.49	4.34	0.17	0.374
	California	18.65	8.05	18.94	3.00	7.60	5.86	0.59	1.89
	Texas	15.90	2.10	28.09	6.02	7.78	9.88	0.99	3.42
Passive *	Minnesota	23.31	8.56	38.06	8.41	6.35	12.48	2.08	8.74
	Wisconsin	21.17	6.03	30.77	7.62	7.53	10.20	1.07	4.34
	Wyoming	15.01	1.81	53.67	5.57	7.64	15.74	3.603	21.123
	Illinois	16.23	2.95	42.40	8.43	7.86	13.34	2.20	10.57
	Iowa	21.09	4.55	38.90	9.40	7.14	11.58	1.83	8.95
	Colorado	7.32	0.56	18.17	1.03	5.73	7.99	0.62	2.80
	Maryland	3.74	.31	25.71	2.07	4.71	11.32	1.43	5.68
	California	0.905	0.295	18.95	.098	3.45	9.325	1.105	4.474
	Texas	2.51	.27	28.152	1.373	4.40	13.333	1.706	6.84

*With Trombe Wall

Table 49 - Summary of WECS Use With Thermal Storage for All Farmhouses

Farmhouse Type	Heating Energy 10^6 Btu	WECS Production Use - % *				
		Direct to Heating	Space Heating Storage	Hot Water Storage	Appliances	Excess
Older						
Colder Climate	76.73	51.5	24	14.8	2	7.7
Warmer Climate	24.2	26.6	32.8	29.3	3.4	7.9
Modern						
Colder Climate	81.96	52	26	14	2.0	6.0
Warmer Climate	27.2	28	34	28	2.0	8.0
Passive Solar						
Colder Climate	17.35	18	19	32	5.0	26.0
Warmer Climate	2.4	5.0	17	49	6.0	23.0

Table 50 - Comparative Farmhouse Use of WECS Production By Climate With Storage

* 20 Foot Diameter WECS With 10 KW Generator

Utilization Of WECS Production for Heating With Storage-%

Farmhouse Type	Warm Climate *	Moderate to Cold Climate **
Older	89	90.3
Modern	90	92
Passive Solar	71	69

* Degree days less than 4000
** Degree days more than 4000

Detailed monthly and annual comparisons of the use of energy produced by the 20 foot diameter WECS are shown in Tables 51, 52, and 53 for the older, modern, and passive solar farmhouse designs. An additional passive solar farmhouse incorporating a Trombe wall is shown in Table 54.

The passive solar farmhouse, with thermal storage and the Trombe wall, does not detract from the overall use of wind energy. Rather, the passive solar and wind-powered heating systems are seen to complement each other in a constructive way.

4.3.2 FARM BUILDING WECS USE WITH THERMAL STORAGE

Thermal storage for space and hot water heating was analyzed for the effects on WECS energy use by applying the same fuel displacement priorities previously adopted for farmhouses. Moreover, as found in the farmhouses, significantly improved direct use of the WECS production resulted with small amounts of thermal storage. A WECS size of 20 feet in diameter was also used in this analysis to maintain consistency of results. Alternate sizes of thermal storage were used for the farm buildings, as discussed in this section.

The storage analysis also applied the WECS production to hot water, machinery, and appliance uses before determining any surplus available for sell-back to the local utility. A comparison of direct and surplus WECS energy (using the 20 foot diameter system) is shown in Table 55. An expanded tabulation of the use of WECS energy with thermal storage and other functions for farm buildings is presented in Table 56. For all applications, the effect of thermal storage was to substantially increase the utilization of WECS energy production, and to reduce the amount of excess available for sell-back to the local utility.

4.3.2.1 BROILERS

Broiler production constitutes the largest space heat energy application. Very effective use of the WECS energy was possible with this case - 86% and 88%, respectively, for the 850 and 2000 gallon storage facilities. However, small percentages of the total energy demand were displaced because the WECS total production was small relative to the large space heat demand. Tables 57 and 58 present WECS performance data.

Older Farmhouse

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With Thermal Storage

		Space Heating Energy Summary - 10^6 BTUs				20 Foot Diameter WECS Energy Use - 10^6 BTUs				
Location	20 Ft. Dia. WECS (2 Production 10^6 Btu	Total Thermal Load (1	WECS or Storage	Backup	Storage Draw	Direct	Storage	Hot Water Preheat	Appliances	Excess
Denver, Colorado	18.163	55.457	12.332	43.125	6.003	6.329	7.231	3.733	.166	.705
Des Moines, Iowa	39.188	75.060	26.167	48.893	5.715	20.452	7.382	6.566	1.077	3.711
Madison, Wisconsin	30.758	88.153	25.289	62.863	6.517	18.772	7.665	3.355	.280	.685
Casper, Wyoming	53.663	80.918	41.961	38.957	15.688	26.273	16.736	5.881	1.048	3.725
Minneapolis, Minnesota	38.044	89.053	26.170	62.884	6.743	19.427	8.206	6.770	1.000	2.642
Austin, Texas	28.088	14.211	10.238	3.973	4.577	5.661	7.426	10.271	1.366	3.363
Sacramento, California	18.958	16.440	8.040	8.399	5.238	2.802	7.266	6.184	0.793	1.913
Chicago, Illinois	42.392	71.772	30.654	41.118	7.479	23.175	9.165	6.871	0.842	2.538
Baltimore, Maryland	25.699	41.969	18.483	23.480	7.632	10.856	9.225	4.832	0.289	0.495

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
600	100.0	200.0

Table 51 Older Farmhouse-- WECS Use With Thermal Storage

Modern Farmhouse

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With Thermal Storage

Location	20 Ft. Dia WECS (2) Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Total Thermal Load (1)	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
Denver, Colorado	18.163	59.293	12.729	46.564	6.285	6.444	7.466	3.471	0.107	.675
Des Moines, Iowa	39.188	81.794	26.979	54.816	5.996	20.983	7.593	6.205	0.773	3.635
Madison, Wisconsin	30.758	92.233	25.477	66 756	6.742	18.735	7.869	3.216	3.211	0.729
Casper, Wyoming	53.663	79.253	41.349	37.903	15.876	25.473	16.991	6.095	0.908	4.196
Minneapolis, Minnesota	38.044	99.191	27.281	71.910	6.955	18.964	8.317	6.185	0.685	2.530
Austin, Texas	28.088	15.898	11.112	4.787	5.096	6.016	7.780	9.884	0.985	3.422
Sacramento, California	18.958	18.651	8.693	9.358	5.687	3.006	7.621	5.864	0.590	1.898
Chicago, Illinois	60.349	79.985	31.93	48.055	7.548	24.382	9.105	6.055	0.558	2.285
Baltimore, Maryland	25.699	46.977	19.342	27.835	8.007	11.335	9.490	4.335	0.165	0.374

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
600	100.0	200.0

Preheat Parameters:

Gallons	Max Temp °F
100	165.0

Table 52 Modern Farmhouse-- WECS Use With Thermal Storage

Passive House w/o Trombe Wall

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With Thermal Storage

Location	20 Ft. Dia WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
Denver, Colorado	18.163	22.831	8.006	14.825	4.95	3.056	6.763	5.797	0.453	2.093
Des Moines, Iowa	39.188	35.488	18.947	16.541	5.849	13.078	7.97	9.865	1.433	6.841
Madison, Wisconsin	30.758	39.838	18.971	20.868	7.235	11.736	9.149	7.116	0.569	2.187
Casper, Wyoming	53.663	32.909	22.044	10.866	9.381	12.663	11.656	12.767	2.597	13.98
Minneapolis Minnesota	38.044	41.743	17.048	24.695	4.893	12.155	7.003	10.693	1.604	6.587
Austin, Texas	28.088	7.297	6.391	0.906	3.069	3.322	6.268	12.148	1.326	5.022
Sacramento, California	18.958	6.367	4.008	2.358	3.077	0.931	5.568	8.229	0.864	3.365
Chicago, Illinois	42.392	31.972	20.319	11.653	6.661	13.658	9.001	10.77	1.62	7.342
Baltimore, Maryland	25.751	16.729	11.37	5.358	5.709	5.661	8.066	8.497	0.789	2.737

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
600	100.0	200.0

Preheat Parameters:

Gallons	Max Temp °F
100	165.0

Table 53 Passive Solar Farmhouse-- WECS Use With Thermal Storage And No Trombe Wall

Passive House

With 400 Square Foot Trombe Wall

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With Thermal Storage

Location	20 Ft. Dia. WECS (2) Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1)	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
Denver, Colorado	18.163	7.317	4.241	3.075	3.214	1.027	5.728	7.986	0.619	2.801
Des Moines, Iowa	39.188	21.091	13.824	7.267	4.422	9.401	7.14	11.858	1.834	8.954
Madison, Wisconsin	30.758	21.172	12.727	6.445	5.106	7.621	7.525	10.2	1.07	4.342
Casper, Wyoming	53.663	15.011	10.436	4.575	4.87	5.566	7.633	15.737	3.603	21.123
Minneapolis, Minnesota	38.044	23.314	12.412	10.901	4.009	8.403	6.348	12.476	2.077	8.74
Austin, Texas	28.088	2.513	2.248	0.264	0.875	1.373	4.334	13.833	1.706	6.84
Sacramento, California	18.958	0.905	0.61	0.294	0.512	0.098	3.455	9.825	1.105	4.474
Chicago, Illinois	42.392	16.225	13.274	2.951	4.848	8.426	7.465	13.342	2.197	10.561
Baltimore, Maryland	25.751	3.742	3.432	0.309	1.367	2.065	4.26	11.818	1.427	5.68

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
600	100.0	200.0

Preheat Parameters:

Gallons	Max Temp °F
100	165.0

Table 54 Passive Solar Farmhouse--WECS Use With Thermal Storage and Trombe Wall

Farm Building Type	Annual Heating Energy 10^6 Btu	Summary of WECS Production and Use - %					
		Direct to Heating	Space Heating From Storage	Storage Reserve	Service Hot Water	Machinery/ Appliances	Excess
Brooding/Layers							
1000 gallons storage	26.6	4.5	9.0	29.7	0.0	26.5	30.3
2000 gallons storage	26.6	4.5	10.5	46.7	0.0	17.65	20.5
Layers							
600 gallons storage	62.75	1.1	10.2	13.07	0.0	45.8	29.83
2000 gallons storage	62.69	1.1	14.82	26.2	0.0	35.44	22.40
Broilers							
850 gallon storage	1115.5	47.8	32.6	7.0	0.0	5.8	6.8
2000 gallon storage	1115.3	47.9	38.1	10.2	0.0	1.9	1.9
Turkeys							
500 gallon storage	153.1	50.83	18.2	5.5	0.0	4.7	20.8
2000 gallon storage	152.21	50.70	20.7	18.2	0.0	2.2	8.2
Swine-Growing/Finishing							
100 gallon storage	73.56	2.1	5.5	3.6	0.0	3.3	85.5
2000 gallon storage	72.30	2.0	25.6	27.4	0.0	1.5	43.5
Swine-Farrowing							
300 gallon storage	234.9	31.71	13.8	5.6	0.0	0.5	48.4
2000 gallon storage	234.0	31.5	15.5	24.8	0.0	0.5	27.7
Dairy							
300 gallon storage	27.65	0.4	7.4	6.7	85.5	0.0	0.0
2000 gallon storage	21.94	0.4	23.7	20.4	55.5	0.0	0.0
Lambing							
250 gallon storage	30.02	1.1	1.9	8.0	0.0	5.5	91.5
2000 gallon storage	29.6	1.6	2.7	71.5	0.0	4.3	62.9

Table 55 Farm Building WECS Production and Use With Thermal Storage -%

Application	Total Space Heat Required	Net Heating Energy With WECS	Added Value By Storage: Direct WECS Space Heat	Thermal Storage Space Heat	WECS Energy To Hot Water	WECS to Appliance	Excess
Broiler							
850 gallon	1115.5	1094.78	12.329	8.389	0.0	1.507	1.768
2000 gallon	1115.25	1093.1	12.336	9.813	0.0	0.484	0.48
Brooding Layers							
1000 gallon	26.6	24.04	0.858	1.701	0.0	5.03	5.75
2000 gallon	26.58	23.72	0.864	1.992	0.0	3.346	3.9
Layers							
600 gallon	62.752	60.6	0.213	1.932	0.0	8.668	5.643
2000 gallon	62.692	59.67	0.212	2.804	0.0	6.705	4.246
Turkey Brooding							
500 gallon	153.118	126.33	19.71	7.075	0.0	1.849	8.083
2000 gallon	152.205	124.54	19.641	8.016	0.0	0.857	3.191
Farrowing							
300 gallon	234.88	217.51	12.017	5.264	0.0	0.181	18.48
2000 gallon	233.7	215.77	12.005	5.921	0.0	0.21	10.59
Swine Growing/Finishing							
100 gallon	73.556	70.66	0.796	2.093	0.0	1.268	32.582
2000 gallon	72.296	61.78	0.753	9.755	0.0	0.567	16.566
Lambing							
250 gallon	30.02	28.729	0.486	0.809	0.0	2.75	40.28
2000 gallon	29.591	27.75	0.674	1.165	0.0	1.832	26.61
Dairy							
300 gallon	27.645	25.23	0.12	2.286	26.317	0.0	0.0
2000 gallon	21.938	14.51	0.124	7.297	17.067	0.0	0.0

Table 56 – WECS Energy Production and Use For Farm Buildings – 10^6 Btu Per Year

Broilers

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 850 Gallon Thermal Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1	Space Heating Energy Summary - 10^6 BTUs: WECS or Storage	Space Heating Energy Summary - 10^6 BTUs: Backup	Space Heating Energy Summary - 10^6 BTUs: Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Storage	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Hot Water Preheat	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Appliances	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Excess
1-75	8.05	735.92	8.039	727.88	0.556	7.483	0.566	0.0	0.0	0.0
+ 4 days	8.572	795.93	8.587	787.34	0.781	7.806	0.766	0.0	0.0	0.0
76-150	6.786	19.692	4.87	14.822	3.711	1.159	4.377	0.0	0.601	0.648
+ 1 day	6.791	19.692	4.87	14.822	3.711	1.159	4.383	0.0	0.601	0.648
151-225	2.8	0.73	0.1	0.63	0.086	0.014	1.212	0.0	0.727	0.852
+ 4 days	2.901	0.73	0.1	0.63	0.086	0.014	1.249	0.0	0.741	0.896
225-300	3.041	72.548	2.52	70.02	2.186	0.334	2.259	0.0	0.179	0.268
+ 1 day	2.058	80.9	2.536	78.364	2.197	0.339	2.27	0.0	0.179	0.263
301-365	5.065	286.61	5.189	281.42	1.85	3.339	1.727	0.0	0.0	0.0
Cycle	25.742	1115.5	20.718	1094.772	8.389	12.329	10.141	0.0	1.507	1.768
Cycle +	26.387	1183.862	21.282	1162.576	8.625	12.657	10.395	0.0	1.521	1.812

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
850.	100.0	200.0

Table 57 - Broilers - WECS Space Heating Summary With 850 Gallon Thermal Storage

Broilers

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Thermal Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-75	8.05	735.8	8.014	727.75	0.531	7.483	0.566	0.0	0.0	0.0
+ 4 days	8.572	795.8	8.541	787.26	0.735	7.806	0.767	0.0	0.0	0.0
76-150	6.786	19.658	5.722	13.935	4.565	1.157	5.297	0.0	0.194	0.135
+ 1 day	6.791	19.658	5.722	13.935	4.565	1.157	5.303	0.0	0.194	0.135
151-225	2.807	0.728	0.178	0.55	0.164	0.014	2.157	0.0	0.29	0.345
+ 4 days	2.901	0.728	0.178	0.55	0.164	0.014	2.222	0.0	0.3	0.365
226-300	3.041	72.524	3.018	69.505	2.684	0.334	2.707	0.0	0.0	0.0
+1 day	3.058	80.875	3.033	77.841	2.694	0.339	2.719	0.0	0.0	0.0
301-365	5.065	286.55	5.217	281.33	1.879	3.338	1.727	0.0	0.0	0.0
Cycle	25.749	1115.25	22.149	1093.10	9.813	12.336	12.454	0.0	0.484	0.48
Cycle +	26.337	1183.61	22.691	1160.91	10.037	12.654	12.738	0.0	0.494	0.5

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 58- Broilers - WECS Space Heating Summary With 2000 Gallon Thermal Storage

4.3.2.2 LAYER BROODING

Layer brooding was evaluated with both a 1000 and 2000 gallon thermal storage facility. Effects of storage use are presented in Tables 59 and 60. A 20 foot diameter WECS was used; 40% and 33% of the WECS energy produced was utilized in the 1000 and 2000 gallon storage studies, respectively. This energy displaced nearly 14% of the required space heat in both cases - an increase of nearly 10% due to the thermal storage facilities.

4.3.2.3 LAYERS

Thermal storage facilities of 600 and 2000 gallon capacity were applied to the layer house. The 20 foot WECS was able to deliver 57% and 50% of the energy it produced for direct use with the 600 and 2000 gallon facilities, respectively. Displaced space heat energy (62 million BTUs) amounted to only 3.7% and 5.2% for the small and large storage capacities. High concentrations of energy demand over short periods minimized the storage effectiveness. Tables 61 and 62 present percentage breakdowns of WECS use and the energy displaced.

4.3.2.4 TURKEYS

WECS use amounted to aproximately 73% of that produced with both the 500 and 2000 gallon thermal storage systems. The WECS displaced heat energy amounting to about 30% of that required for both uses. Fairly high WECS usage and energy displacement occurred in this application. Storage improved WECS use by only about 7% because of the high energy demand and low WECS production correlation. The larger storage tank (2000 gallons) was not justified and a tank smaller than 500 gallons, or even no storage, would be better for this application. Tables 63 and 64 present the results for this application.

4.3.2.5 SWINE GROWING AND FINISHING

Only small amounts of WECS energy could be used with the 100 gallon storage tank. WECS use with this storage capability was 10%. Equally low energy displacement is found - 2.9%. Substantial improvement was realized by increasing the storage capacity to 2000 gallons - 29% WECS use and 15% space heat displacement. While increased storage capacity increased the system performance, utilization and displacement percentages are still low. High demand concentration over a short time period causes this result. Tables 65 and 66 present energy use and energy displacement results.

4.3.2.6 SWINE FARROWING

300 and 2000 gallon storage systems were applied to the swine farrowing application. WECS use changed from 46% to 47% between the large and small storage systems; larger storage facilities are unjustified based on this analysis. The demand met by WECS was only 12.5%. This amounts to only a 7% displacement increase over using no storage at all. Tables 67 and 68 present annual energy use.

Layer/Brooding

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 1000 Gallon Space Heating Storage and No Hot Water Storage

		Space Heating Energy Summary - 10^6 BTUs				20 Foot Diameter WECS Energy Use - 10^6 BTUs				
Cycle Days of Year	20 Ft. Dia WECS (2 Production 10^6 Btu	Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	Direct	Storage	Hot Water Preheat	Appliances	Excess
1-92	6.328	12.125	1.03	11.094	0.437	0.593	1.9337	0.0	1.626	2.173
93-184	5.82	10.835	1.05	9.736	0.8767	0.1733	2.279	0.0	1.731	1.635
185-276	3.976	0.7383	0.24	0.4348	0.2112	0.0288	1.684	0.0	1.117	1.141
277-368	2.832	2.912	0.24	2.67	0.1766	0.0534	1.413	0.0	0.5548	0.7986
Annual	18.96	26.6	2.57	24.03	1.701	0.8585	7.309	0.0	5.03	5.75

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
1000	100.0	200.0

Table 59 Layer/Brooding-- WECS Space Heating Summary With 1000 Gallons Of Thermal Storage

Layer/Brooding

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net (1 Thermal Load	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-92	6.328	12.116	1.111	11.006	0.517	0.594	2.955	0.0	1.145	1.632
93-184	5.82	10.831	1.119	9.712	0.946	0.173	0.001	0.0	1.32	1.104
185-276	3.976	0.7275	0.316	0.4111	0.284	0.032	2.497	0.0	0.561	0.784
277-365	2.832	2.909	0.31	2.599	0.245	0.065	2.166	0.0	0.22	0.38
Annual	18.956	26.583	2.856	23.728	1.992	0.864	7.619	0.0	3.346	[illegible]

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 60 Layer/Brooding-- WECS Space Heating Summary With 2000 Gallons Of Thermal Storage

Layers
(10°F Band)

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 600 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net (1 Thermal Load	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-30	2.655	0.0	0.0	0.0	0.0	0.0	0.572	0.0	0.973	1.109
31-60	1.885	0.0	0.0	0.0	0.0	0.0	0.275	0.0	0.87	0.738
61-90	1.679	0.0	0.0	0.0	0.0	0.0	0.252	0.0	0.892	0.523
91-120	1.359	0.0	0.0	0.0	0.0	0.0	0.255	0.0	0.711	0.391
121-150	2.393	0.0	0.0	0.0	0.0	0.0	0.251	0.0	1.367	0.773
151-180	1.854	0.0	0.0	0.0	0.0	0.0	0.257	0.0	1.025	0.571
181-210	1.276	0.0	0.0	0.0	0.0	0.0	0.249	0.0	0.699	0.327
211-240	1.509	0.0	0.0	0.0	0.0	0.0	0.25	0.0	0.823	0.434
241-270	1.435	0.0	0.0	0.0	0.0	0.0	0.243	0.0	0.82	0.37
271-300	0.412	0.0	0.0	0.0	0.0	0.0	0.21[illegible]	0.0	0.124	0.0777
301-330	1.201	7.634	0.847	6.786	0.822	0.0[illegible]5	0.501	0.0	0.358	0.3[illegible]
331-360	1.194	42.55	1.256	41.298	1.085	0.171	1.023	0.0	0.0	0.0
361-365	0.063	12.568	0.042	12.523	0.025	0.017	0.046	0.0	0.006	0.0043
Annual	18.915	62.752	2.145	60.607	1.932	0.213	4.384	0.0	8.663	5.643

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
600	100.0	200.0

Table 61 Layers--WECS Space Heating Summary With 600 Gallons Of Space-heating Thermal Storage

Layers

(10°F Band)

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallons Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2) Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1)	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-30	2.655	0.0	0.0	0.0	0.0	0.0	1.539	0.0	0.528	0.586
31-60	1.885	0.0	0.0	0.0	0.0	0.0	0.5589	0.0	0.704	0.621
61-90	1.679	0.0	0.0	0.0	0.0	0.0	0.515	0.0	0.702	0.46
91-120	1.359	0.0	0.0	0.0	0.0	0.0	0.508	0.0	0.568	0.282
121-150	2.393	0.0	0.0	0.0	0.0	0.0	0.51	0.0	1.211	0.669
151-180	1.854	0.0	0.0	0.0	0.0	0.0	0.522	0.0	0.851	0.48
181-210	1.276	0.0	0.0	0.0	0.0	0.0	0.493	0.0	0.534	0.247
211-240	1.599	0.0	0.0	0.0	0.0	0.0	0.495	0.0	0.657	0.343
241-270	1.435	0.0	0.0	0.0	0.0	0.0	0.462	0.0	0.681	0.29
271-300	0.412	0.0	0.0	0.0	0.0	0.0	0.412	0.0	0.0	0.0
301-330	1.201	7.624	1.807	5.816	1.782	0.025	0.658	0.0	0.254	0.262
331-360	1.194	42.513	1.192	41.32	1.022	0.17	1.024	0.0	0.0	0.0
361-365	0.053	12.555	0.017	12.539	0.0	0.017	0.0491	0.0	0.005	0.004
Annual	18.915	62.692	3.016	59.675	2.804	0.212	7.746	0.0	6.705	4.24[illegible]

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 62 Layers--WECS Space Heating Summary With 2000 Gallons Of Space-heating Thermal Storage

Turkey

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 500 Gallon Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-35	4.084	54.57	4.119	50.45	0.057	4.062	0.022	0.0	0.0	0.0
36-70	2.338	33.671	2.362	31.309	0.093	2.269	0.069	0.0	0.0	0.0
71-105	5.01	8.746	5.088	3.658	1.732	3.356	1.655	0.0	0.0	0.0
106-140	4.907	3.193	2.614	0.578	0.989	1.725	1.381	0.0	0.267	1.632
141-175	3.5	1.076	0.874	0.201	0.474	0.4	0.539	0.0	0.358	1.801
176-210	2.714	0.468	0.387	0.081	0.197	0.19	0.689	0.0	0.443	1.39
211-245	2.693	0.683	0.499	0.183	0.383	0.116	0.837	0.0	0.392	1.346
246-280	3.387	1.336	1.172	0.163	0.746	0.426	1.304	0.0	0.329	1.527
281-315	4.14	5.599	3.592	2.006	1.911	1.681	2.011	0.0	0.06	0.387
316-350	3.822	34.777	3.847	30.929	0.212	3.635	0.286	0.0	0.0	0.0
351-365	2.182	8.999	2.231	6.767	0.281	1.95	0.332	0.0	0.0	0.0
Annual	38.777	153.118	26.785	126.325	7.075	19.71	9.225	0.0	1.849	8.083

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
500	100.0	200.0

Table 63 - Turkey - WECS Space Heating Summary With 500 Gallon Space Heating Thermal Storage

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Space Heat Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-35	4.084	54.348	4.216	50.131	0.155	4.061	0.0238	0.0	0.0	0.0
36-70	2.338	33.446	2.444	31.021	0.177	2.267	0.07	0.0	0.0	0.0
71-105	5.01	8.695	5.152	3.543	1.804	3.348	1.662	0.0	0.0	0.0
106-140	4.907	3.16	2.75	0.409	1.138	1.612	2.525	0.0	0.142	0.627
141-175	3.5	1.066	0.949	0.116	0.552	0.397	2.044	0.0	0.209	0.839
176-210	2.714	0.457	0.38	0.076	0.192	0.187	1.729	0.0	0.205	0.591
211-245	2.693	0.674	0.581	0.0926	0.467	0.114	1.949	0.0	0.149	0.479
246-280	3.387	1.256	1.168	0.0881	0.768	0.4	2.19	0.0	0.152	0.645
281-315	4.14	5.548	3.759	1.788	2.088	1.671	2.469	0.0	0.0	0.0
316-350	3.822	34.608	3.938	30.669	0.303	3.635	0.187	0.0	0.0	0.0
351-365	2.182	8.947	2.321	6.626	0.372	1.949	0.254	0.0	0.0	0.0
Annual	38.777	152.205	27.658	124.559	8.016	19.641	15.082	0.0	0.857	3.191

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 64 Turkey--WECS Space Heating Summary With 2000 Gallons of Space-heating Thermal Storage

Swine Growing/ Finishing

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 100 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2) Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1)	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-56	7.451	50.809	2.196	48.612	1.493	0.703	1.504	0.0	0.135	5.108
+ 2 days	7.789	50.822	2.209	48.612	1.501	0.708	1.519	0.0	0.142	5.417
57-112	8.444	5.326	0.159	5.166	0.128	0.031	0.376	0.0	0.241	7.793
+ 2 days	8.967	5.326	0.159	5.166	0.128	0.031	0.384	0.0	0.252	8.797
113-168	6.811	0.0	0.0	0.0	0.0	0.0	0.271	0.0	0.253	6.303
+ 3 days	7.263	0.0	0.0	0.0	0.0	0.0	0.282	0.0	0.247	6.732
169-224	2.88	0.0	0.0	0.0	0.0	0.0	0.255	0.0	0.164	2.458
+ 3 days	3.074	0.0	0.0	0.0	0.0	0.0	0.267	0.0	0.177	2.628
225-280	3.538	0.0	0.0	0.0	0.0	0.0	0.263	0.0	0.18	3.093
+ 3 days	3.672	0.0	0.0	0.0	0.0	0.0	0.275	0.0	0.191	3.204
281-336	4.913	0.0	0.0	0.0	0.0	0.0	0.273	0.0	0.194	4.443
+ 2 days	5.445	0.0	0.0	0.0	0.0	0.0	0.281	0.0	0.205	4.956
337-365	4.048	17.421	0.534	16.887	0.472	0.062	0.499	0.0	0.101	3.384
Cycle	38.085	73.556	2.889	70.665	2.093	0.796	3.441	0.0	1.268	32.582
Cycle + Days	40.258	73.569	2.902	70.665	2.101	0.801	3.507	0.0	1.315	34.613

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
100	100.0	200.0

Table 65 Swine Growing/Finishing--WECS Space Heating Summary With 100 Gallons Of Thermal Storage

Swine Growing/Finishing

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia WECS (2) Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1)	WECS or Storage	Backup	Storage Draw	20 Ft. Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-56	7.451	49.156	7.023	42.133	6.35	0.663	6.77	0.0	0.0	0.0
+ 2 days	7.789	49.169	7.036	42.133	6.358	0.678	7.111	0.0	0.0	0.0
57-112	8.444	5.951	0.975	4.976	0.944	0.031	2.783	0.0	0.142	5.487
+ 2 days	8.967	5.951	0.975	4.976	0.944	0.031	2.822	0.0	0.153	5.959
113-168	6.811	0.0	0.0	0.0	0.0	0.0	2.089	0.0	0.152	4.568
+ 3 days	7.263	0.0	0.0	0.0	0.0	0.0	2.141	0.0	0.161	4.958
169-224	2.88	0.0	0.0	0.0	0.0	0.0	1.933	0.0	0.046	0.839
+ 3 days	3.074	0.0	0.0	0.0	0.0	0.0	1.986	0.0	0.054	1.032
225-280	3.538	0.0	0.0	0.0	0.0	0.0	2.024	0.0	0.076	1.437
+ 3 days	3.672	0.0	0.0	0.0	0.0	0.0	2.078	0.0	0.084	1.508
281-336	4.913	0.0	0.0	0.0	0.0	0.0	2.06	0.0	0.114	2.737
+ 2 days	5.445	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.125	3.219
337-365	4.048	17.187	2.52	14.668	2.461	0.059	2.512	0.0	0.037	1.438
Cycle	38.085	72.296	10.518	61.777	9.755	0.753	20.171	0.0	0.567	16.566
Cycle + Days	40.258	72.309	10.531	61.777	9.763	0.768	20.75	0.0	0.614	18.114

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 66 Swine Growing/Finishing-- WECS Space Heating Summary With 2000 Gallons Of Thermal Storage

Swine - Farrowing (1) F Band)

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 300 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net (1 Thermal Load	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-56	7.45	113.57	6.7	106.87	0.715	5.785	0.9153	0.0	0.0032	0.548
57-112	8.444	45.472	2.389	43.08	0.807	1.582	1.13	0.0	0.0336	5.698
113-168	6.811	8.069	1.285	6.783	0.494	0.791	0.898	0.0	0.0435	5.078
169-224	2.88	1.461	0.44	1.021	0.2919	0.148	0.724	0.0	0.0334	1.973
225-280	3.538	0.488	0.312	0.1759	0.2258	0.086	0.704	0.0	0.04135	2.705
281-336	4.913	10.175	2.084	8.091	1.397	0.687	1.745	0.0	0.0261	2.554
337-365	4.048	55.65	4.152	51.497	1.334	2.818	1.205	0.0	0.00034	0.24
Annual	38.08	234.88	17.362	217.51	5.264	12.097	7.321	0.0	0.181	18

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal ener[illegible]

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
300	100.0	200.0

Table 67 Swine Farrowing-- WECS Space Heating Summary With 300 Gallons Of Space-heating Thermal Storage

Swine - Farrowing

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-56	7.451	112.96	6.861	106.1	0.894	5.967	1.483	0.0	0.0	0.0
57-112	8.444	45.344	2.538	42.806	0.9579	1.5801	2.702	0.0	0.0219	4.139
113-168	6.811	7.99	1.373	6.617	0.5878	0.7852	2.475	0.0	0.0327	3.517
169-224	2.88	1.453	0.554	0.898	0.407	0.147	2.174	0.0	0.00758	0.55
225-280	3.538	0.514	0.34	0.173	0.255	0.085	2.173	0.0	0.1397	1.266
281-336	4.913	10.064	2.048	8.016	1.388	0.66	3.121	0.0	0.0103	1.121
337-365	4.048	55.371	4.213	51.158	1.432	2.781	1.2681	0.0	0.0	0.0
Annual	38.09	233.7	17.927	215.77	5.921	12.005	15.396	0.0	0.21	10.59

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 68 Swine Farrowing-- WECS Space Heating Summary With 2000 Gallons Of Thermal Storage

4.3.2.7 DAIRY

Dairying was the only livestock application to use a hot water heat storage facility. Hot water storage size was held constant at 800 gallons. Thermal storage, for space heating, was varied from 300 to 2000 gallons. WECS use found was between 80% and 93%, respectively, for the small and large thermal storage alternatives, showing that WECS use increased with increased thermal storage size. Water heating constitutes the major energy demand in dairying. Tables 69 and 70 present use and displacement values for the alternatives examined.

4.3.2.8 LAMBING

Only about 9% of the WECS energy was usable for either the 250 or 2000 gallon storage systems. Equally poor energy displacement of 5.9% and 8.5% resulted for the respective small and large storage systems. Lambing also had low annual energy requirements of 30 million BTUs. Tables 71 and 72 show the contribution by the WECS to the lambing energy needs.

4.4 WIND ENERGY AS A SELF SUFFICIENT OR SUPPLEMENTAL ENERGY SOURCE

The wind resource, although intermittent and capricious, can provide significant quantities of energy over a long period of time. Based on the procedures of this study which selected WECS sizes appearing to balance the direct use of energy and to minimize excess production, farmhouse WECS applications did not approach self-sufficiency unless the wind-powered heating system was combined with a passive solar design including a Trombe wall. In this case the wind-passive solar combination penetrated between 85% and 97% of the space heating energy needs. In the colder climates, the WECS passive solar combination accounted for 85% to 93% of space heating energy needs. This result suggests that further research may be warranted to more closely examine such combinatorial designs.

Using WECS of 20 foot rotor diameter and 600 gallons of thermal storage, heating energy penetration fell between 23% and 87% of heating needs for all climates, and between 23% and 54% for colder climates.

Using WECS without thermal storage allowed farmhouse heating energy displacement to fall between 3% and 14%, 11% and 39%, and 29% and 65% for the 10, 20, and 40 foot diameter rotors, respectively.

The contribution of wind systems of various sizes to the total farmhouse heating needs is summarized in Table 73. The proportionate contributions for smaller WECS is somewhat higher than that of the larger WECS. Again, the results of this analysis indicate that the WECS with thermal storage can provide a substantial amount of supplemental energy for farmhouse applications. In fact, in some of the applications studied, the wind energy nearly displaced all required heat energy. Many of the passive homes came close to self-sufficiency, as did the older and the modern houses located in Texas and California. With additional conservation practices, some of these applications may prove self-sufficient. None of the farm building applications were very close to self-sufficiency, however.

Dairy (10°F Band)

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 300 Gallon *Storage and 800 Gallon Hot Water Storage

		Space Heating Energy Summary - 10^6 BTUs				20 Foot Diameter WECS Energy Use - 10^6 BTUs				
Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Net Thermal Load (1	WECS or Storage	Backup	Storage Draw	Direct	Storage	Hot Water Preheat	Appliances	Excess
1-30	4.363	17.769	1.308	16.461	1.197	0.111	1.146	3.105	0.0	0.0
31-60	1.939	3.766	0.39	3.376	0.389	0.001	0.652	1.386	0.0	0.0
61-90	2.727	0.0	0.0	0.0	0.0	0.0	0.203	2.523	0.0	0.0
91-120	3.336	0.0	0.0	0.0	0.0	0.0	0.199	3.137	0.0	0.0
121-150	2.688	0.0	0.0	0.0	0.0	0.0	0.192	2.496	0.0	0.0
151-180	2.211	0.0	0.0	0.0	0.0	0.0	0.184	2.026	0.0	0.0
181-210	1.556	0.0	0.0	0.0	0.0	0.0	0.193	1.362	0.0	0.0
211-240	1.465	0.0	0.0	0.0	0.0	0.0	0.187	1.277	0.0	0.0
241-270	1.448	0.0	0.0	0.0	0.0	0.0	0.183	1.265	0.0	0.0
271-300	2.202	0.0	0.0	0.0	0.0	0.0	0.196	2.006	0.0	0.0
301-330	2.238	0.109	0.109	0.0	0.109	0.0	0.286	1.951	0.0	0.0
331-360	3.704	5.999	0.598	5.4	0.59	0.008	0.661	3.034	0.0	0.0
361-365	0.881	0.002	0.001	0.002	0.001	0.0	0.04	0.849	0.0	0.0
Annual	30.758	27.645	2.406	25.239	2.286	0.12	4.322	26.317	0.0	0.0

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

*space heating storage

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
300	100.0	200.0

Table 69 - Dairy - WECS Space Heating Summary With 300 Gallon Thermal Heating Storage and 800 Gallon Hot Water Storage

Dairy (10°F Band)

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Thermal Heating Storage and 800 Gallon Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net (1 Thermal Load	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-30	4.363	13.33	3.608	9.721	3.5	0.108	3.88	0.375	0.0	0.0
31-60	1.939	3.79	1.618	2.172	1.617	0.001	1.938	0.0	0.0	0.0
61-90	2.727	0.0	0.0	0.0	0.0	0.0	0.948	1.779	0.0	0.0
91-120	3.336	0.0	0.0	0.0	0.0	0.0	0.572	2.764	0.0	0.0
121-150	2.688	0.0	0.0	0.0	0.0	0.0	0.544	2.144	0.0	0.0
151-180	2.211	0.0	0.0	0.0	0.0	0.0	0.514	1.697	0.0	0.0
181-210	1.556	0.0	0.0	0.0	0.0	0.0	0.557	0.998	0.0	0.0
211-240	1.465	0.0	0.0	0.0	0.0	0.0	0.527	0.937	0.0	0.0
241-270	1.448	0.0	0.0	0.0	0.0	0.0	0.521	0.927	0.0	0.0
271-300	2.202	0.0	0.0	0.0	0.0	0.0	0.555	1.647	0.0	0.0
301-330	2.238	0.0	0.0	0.0	0.0	0.0	0.562	1.676	0.0	0.0
331-360	3.704	4.817	2.195	2.622	2.178	0.017	2.343	1.343	0.0	0.0
361-365	0.881	0.001	0.0	0.001	0.000	0.000	0.105	0.78	0.0	0.0
Annual	30.758	21.938	7.421	14.516	7.297	0.124	13.566	17.067	0.0	0.0

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 70 Dairy--WECS Space Heating Summary With 2000 Gallons Of Space-heating Thermal Storage

Lambing (Wyoming) - 10°F Band

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 250 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net (1 Thermal Load	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-42	6.965	6.856	0.748	6.108	0.421	0.327	0.769	0.0	0.312	5.536
43-84	6.764	20.984	0.2288	20.756	0.1599	0.0689	0.513	0.0	0.218	5.86
85-126	6.557	0.0914	0.03	0.0614	0.0226	0.0074	0.41	0.0	0.32	5.817
127-168	5.203	0.9416	0.101	0.8402	0.05	0.051	0.43	0.0	0.335	4.385
169-210	3.307	0.0	0.0	0.0	0.0	0.0	0.382	0.0	0.286	2.637
211-252	4.158	0.0	0.0	0.0	0.0	0.0	0.391	0.0	0.308	3.457
253-294	4.158	0.0	0.0	0.0	0.0	0.0	0.391	0.0	0.308	3.457
295-336	7.023	0.812	0.0845	0.728	0.0629	0.0216	0.447	0.0	0.336	6.246
337-365	3.526	0.338	0.1	0.237	0.093	0.007	0.44	0.0	0.224	2.96
Annual	47.7	30.02	1.192	28.73	0.809	0.4829	4.175	0.0	2.75	40.28

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
250	100.0	200.0

Table 71 - Lambing - WECS Space Heating Summary With 250 Gallon Space Heating Thermal Storage

Lambing (Wyoming) - 10°F Band

WECS Space Heating Summary - 1978

20 Foot Diameter WECS With 2000 Gallon Space Heating Storage and No Hot Water Storage

Cycle Days of Year	20 Ft. Dia. WECS (2 Production 10^6 Btu	Space Heating Energy Summary - 10^6 BTUs: Net (1 Thermal Load	WECS or Storage	Backup	Storage Draw	20 Foot Diameter WECS Energy Use - 10^6 BTUs: Direct	Storage	Hot Water Preheat	Appliances	Excess
1-42	6.965	6.985	0.831	6.153	0.503	0.328	2.379	0.0	0.249	4.006
43-84	6.764	21.013	0.364	20.649	0.296	0.068	2.109	0.0	0.235	4.35
85-126	6.557	0.085	0.0513	0.0337	0.044	0.0073	1.937	0.0	0.233	4.378
127-168	5.203	0.877	0.245	0.632	0.194	0.051	2.053	0.0	0.237	2.86
169-210	3.307	0.0	0.0	0.0	0.0	0.0	1.82	0.0	0.145	1.338
211-252	3.758	0.0	0.0	0.0	0.0	0.0	1.794	0.0	0.181	1.781
252-294	4.158	0.0	0.0	0.0	0.0	0.0	1.888	0.0	0.196	2.072
295-336	7.053	0.631	0.15	0.48	0.128	0.22	2.055	0.0	0.25	4.725
337-365	2.984	0.0	0.0	0.0	0.0	0.0	1.767	0.0	0.106	1.109
Annual	46.749	29.591	1.641	27.947	1.165	0.6743	17.802	0.0	1.832	26.619

1) BTUs for space heating does not include furnace efficiency

2) WECS production after conversion from electrical to thermal energy

Storage Parameters:

Gallons	Min. Temp °F	Max Temp °F
2000	100.0	200.0

Table 72 - Lambing - WECS Space Heating Summary With 2000 Gallon Space Heating Thermal Sto

Percentage of SpaceHeating from WECS

Analysis Location	Older Farmhouse: No Storage 10*	Older Farmhouse: No Storage 20*	Older Farmhouse: No Storage 40*	Older Farmhouse: Storage 20*	Modern Farmhouse: No Storage 10*	Modern Farmhouse: No Storage 20*	Modern Farmhouse: No Storage 40*	Modern Farmhouse: Storage 20*	Passive Solar Farmhouse: WECS and Storage 10*	Passive Solar Farmhouse: WECS and Storage 20*	Passive Solar Farmhouse: WECS and Storage 40*	Passive Solar Farmhouse: WECS Trombe Wall and Storage 20*
Minnesota	6	22	48	31	6	21	47	29		71		85
Wisconsin	6	21	45	30	6	20	44	29		69		85
Wyoming	10	32	57	53	11	32	57	54		74		88
Illinois	10	32	63	45	10	32	57	40		83		93
Iowa	8	27	56	37	7	26	50	35		72		86
Colorado	3	11	29	19	3	11	28	23		66		89
Maryland	8	26	50	48	7	23	48	44		78		97
California	7	18	32	61	7	17	31	57		73		96
Texas	14	39	65	92	12	36	62	87	—	78		94

* WECS Diameter (Feet)

Table 73 Contribution of WECS to Total Space Heating Requirements of Typical Farmhouses

Farm building WECS applications without thermal storage showed heating energy displacements and proportion of usable WECS energy falling between .01% and 4.9%, .01% and 17.6%, and 1.3% and 42.4% for the 10, 20, and 40 foot WECS rotor diameters, respectively. With the exception of the dairy operation which included large hot water needs, most of the WECS production was surplus to farm building needs. Adding thermal storage to the farm building greatly improved the use of WECS production. With hot water thermal storage for space heating, heating energy displacement fell between 25% and 56% of total needs for brooding and layer operations, and was 8% for the broiler application, an energy intensive application. WECS applications to swine operation met 38% and 20% for growing and farrowing operations, respectively. The dairy operation was a very good application due to high hot water needs, even though space heating requirements were small. With hot water for dairy applications included, storage allowed total use of the expected production of the 20 foot diameter WECS.

A tabulation of the contributions of WECS to farm building space heating requirements is shown in Table 74. Without storage, it is clear that the WECS is a supplemental resource displacing significant quantities of heating energy. Use of a larger WECS without storage does not necessarily improve overall use because WECS applicability is still limited by the coincidence of the heating needs and the wind energy production. The addition of storage, particularly with dairy and broiler operations, greatly improves the utilization of WECS production. Since the cost of heating fuels has alreay been cited as a significant factor in the location of livestock operations (e.g. shifts of broiler production to warmer climates), the life cycle costs of fuels will become an even greater factor in livestock operations.

This study has shown that for common farmhouse designs incorporating thermal storage, WECS can displace significant amounts of heating energy, but are a supplemental energy source. The study also indicates that WECS combined wih thermal storage in the passive solar farmhouse can approach self-sufficiency for heating energy needs. These results suggest that the WECS and passive solar design are highly complementary and should be examined further. In all cases, the use of thermal storage with farmouse heating systems significantly increased the ability to utilize the WECS production.

4.5 SYNOPSIS

This analysis has studied applications of wind energy in the previously outlined farmhouse and farm building structures. WECS of three sizes (10, 20 and 40 foot diameters) were examined together with the alternate thermal storage systems. The analysis showed significant use of wind energy for both the farmhouses and farm buildings, and that the addition of thermal storage greatly increased the utilization of the WECS output. In fact, the wind energy was able to displace nearly all of the heating energy required by farmhouses at several locations. The passive-solar home came close to self-sufficiency.

Thus, wind energy systems, though supplemental, can provide

Percentage of Spaceheating from WECS

Farm Building Type	No Storage: WECS Diameter - Feet 10	20	40	Storage and 20 Ft. WECS System: Storage Size Gallons	Heating Displacement
Brooding/Layers	0.80	3.24	10.71	1000	12.8
				2000	13.9
Layers	0.08	0.30	1.3	600	3.7
				2000	5.1
Broilers	0.20	1.10	4.20	850	2.9
				2000	3.1
Turkeys	4.9	17.6	42.4	500	30.4
				2000	31.0
Swine-Growing/Finishing	0.3	1.1	3.4	100	4.9
				2000	15.5
Swine-Farrowing	1.2	5.1	18.3	300	12.5
				2000	12.8
Dairy	0.2	1.1	3.5	300	9.1
				2000	34.3
Lambing	.01	.1	5.2	250	5.9
				2000	8.5

Table 74 -Contribution of WECS to Farm Building Space Heating Energy - %

significant quantities of energy for farm applications. As fuel costs rise, the operator must tradeoff the relative costs of feed, fuel, and productivity to maximize the net value of the operation. It should be recognized that the farm operator may have no choice but to rely on conventional energy sources, perhaps complemented by wind energy, to ensure the survival, safety, and optimum productivity of his animals. The results of this study, however, suggest that wind energy can displace significant quantities of conventional energy, especially if thermal storage is included with the wind-powered heating system.

5.0 ECONOMIC BREAK-EVEN ANALYSIS FOR WIND ENERGY APPLICATIONS

5.1 INTRODUCTION

The objective of this task is to estimate the break-even costs required for wind-powered heating systems considering present agricultural heating practices and energy costs.

Since the study guidelines also required an evaluation of the effects of thermal storage on the value of WECS production, the WECS value and use was first computed at the hourly interval using the following thermal storage applications:

- o Thermal storage for space heating
- o Thermal storage for hot water needs

An analysis of additional value for the WECS production from other electric needs of the farmhouses and farm buildings considered:

- o Typical hourly appliance loads
- o Typical hourly machinery loads
- o Sell-back of any remaining surplus to the local utility

The primary focus of the study is the use of wind energy for space heating both with and without thermal storage. Such uses would not necessarily require interconnection with the utility supplier. In order to derive additional value for appliance and machinery applications, and sell-back of surplus electric energy, an interconnection with the utility would be required unless the local electric needs were met independently from the utility supply.

Heating fuels considered in this analysis included:

- o Electricity
- o Natural gas
- o LP or bottle gas
- o Fuel oil

These fuels comprise more than 99% of the total heating fuel used in agriculture.

The break-even cost of wind-powered heating systems depends on both the value of energy displaced and the ability to use production from the wind energy conversion system (WECS). This analysis has recognized the effects of climatic variability, local heating needs, and typical farm house and farm building internal thermal and electric hourly energy profiles. A sequential hour by hour examination of WECS use was necessary to examine the effects of thermal storage. The studies were generalized using nine geographic locations, selected from both agricultural production surveys and previous USDA research, located throughout the United States. The hour by hour analysis at the nine geographic locations (found in Table 75) used climatic data from the National Weather Service and the National Climatic Center, Ashville, North Carolina. Since the locations represent wide diversity in climatic conditions, heating requirements, competing energy costs, and wind availability, the analysis brackets a wide range of wind-powered heating systems applications which might be found in U. S. agriculture. Figures 21 through 24 present comparative distributions of all farmhouses according to annual wind speed, electricity, natural gas, fuel oil, and bottle gas (LP) costs.

At the break-even point, the cost of the wind-powered heating systems must be equal to or lower than the life cycle value of the savings produced by using the WECS. This study has determined break-even value using two measures:

o Levelized value of annual savings (LVAS)

o Levelized cost of energy (COE)

The LVAS is computed from the cost of heating before and after use of a WECS. The COE is derived from the ratio of LVAS to the total annual WECS production. The life cycle economic analysis has consistently employed a 25 year life cycle, a 10% discount rate, and typical uniform future price increases (including inflation) for the fuels displaced as reported by DOE.

5.2 ECONOMIC ANALYSIS METHODOLOGY

The economic analysis utilizes life cycle principles which recognize the time equivalence of money over a uniform life cycle of 25 years. The value of the savings possible with a WECS application then acknowledges uncertainties about future competing energy costs, a discount rate, and the life cycle period an individual WECS owner may accept.

While the value of the savings may change from year to year due to increasing utility rates, the cost of the WECS may be relatively consistent if mortgage payments are involved. Variable WECS costs would include periodic maintenance, taxes, and insurance. Thus, for break-even computation, it is necessary to determine an equivalent levelized value of savings from the WECS to compare with the levelized costs.

Farmhouse Types				
Older	Modern	Passive Solar	Farm Building Operation	Geographic Analysis Location
X	X	X	Poultry-Turkeys	Minneapolis, Minnesota
X	X	X	Dairy	Madison, Wisconsin
X	X	X	Lambing	Casper, Wyoming
X	X	X		Chicago, Illinois
X	X	X	Swine-Farrowing Swine-Growing	Des Moines, Iowa
X	X	X		Denver, Colorado
X	X	X	Poultry-Broiler	Baltimore, Maryland
X	X	X	Poultry-Layer Poultry-Broilers	Sacramento, California
X	X	X	Lambing	Austin, Texas

X City locations used for availability of hourly weather data from NCC for 1978 test year

Table 75 -Geographic Locations for Detailed Farmhouse and Farm Building Energy Analysis

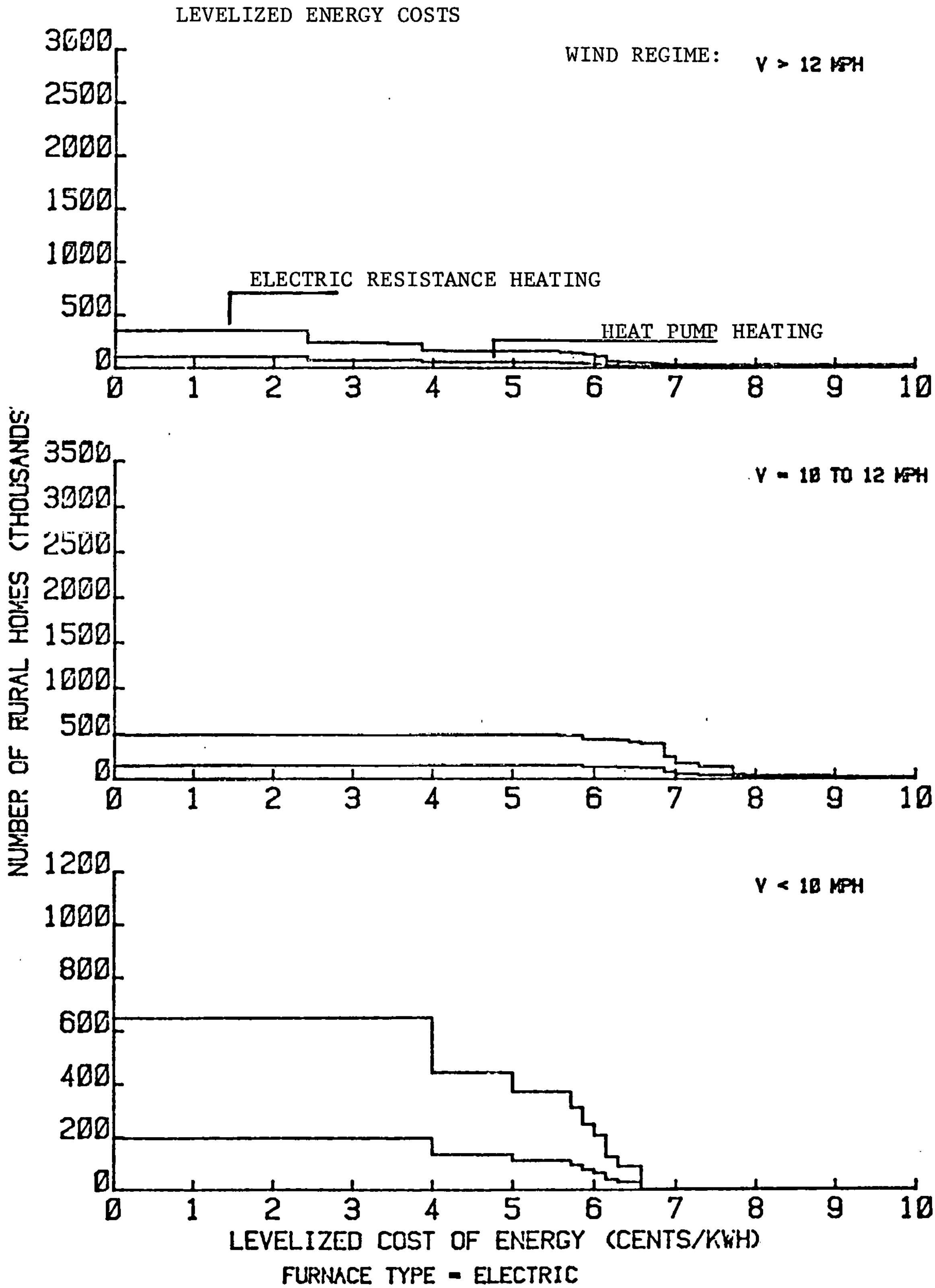


Figure 21 Levelized Electricity Cost for Farmhouses

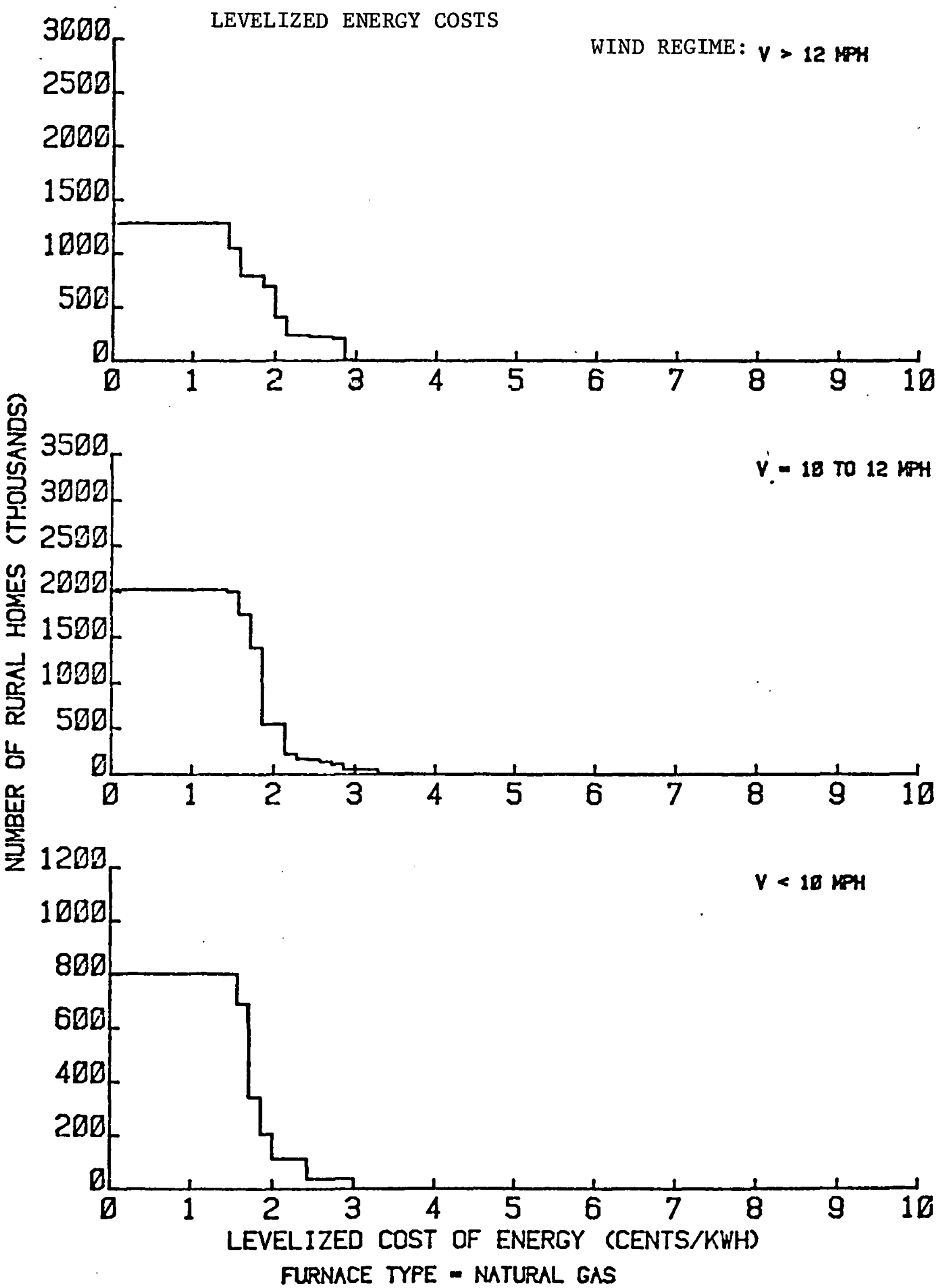


Figure 22 Levelized Natural Gas Cost for Farmhouses

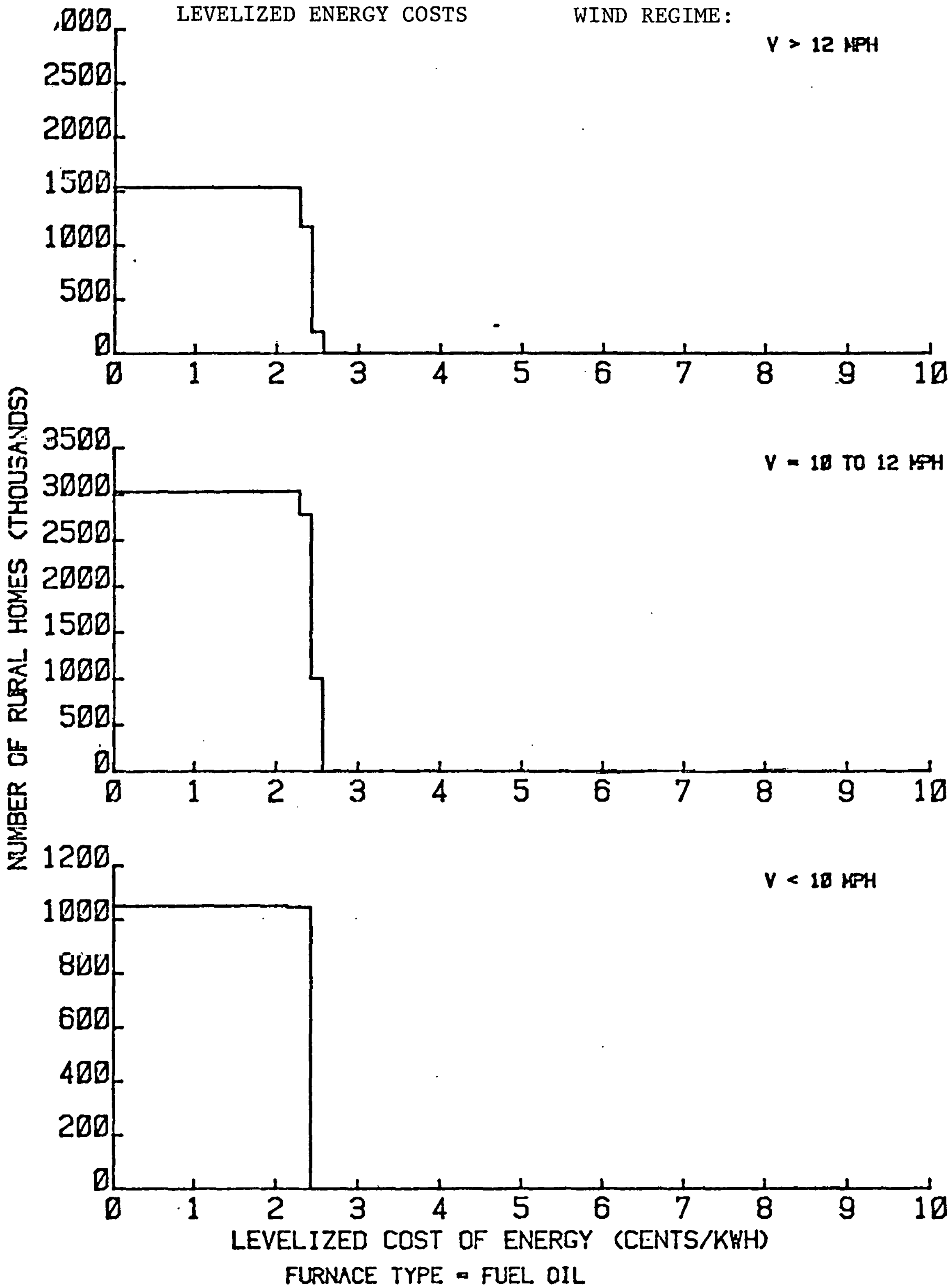


Figure 23 Levelized Fuel Oil Cost for Farmhouses

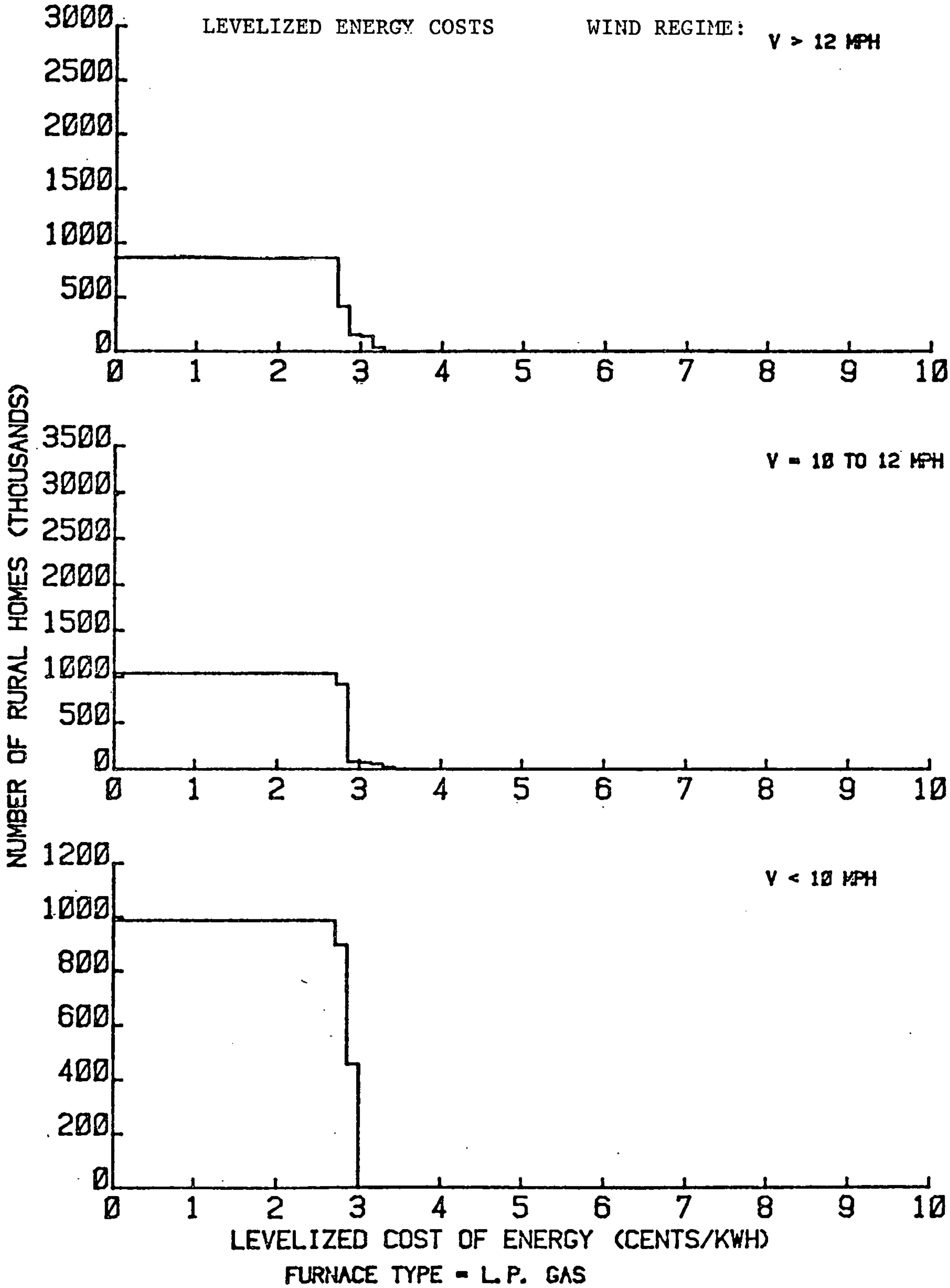


Figure 24 Levelized LP Gas Cost for Farmhouses

The levelized value of annual savings (LVAS) is given by:

LVAS = (value of test year savings) x LF

The levelized annual value of energy (VOE) is given by:

$$VOE = \frac{(\text{ value of test year savings }) \times LF}{AEWEC}$$

where:

LVAS = The levelized value of annual savings resulting from WECS use, $ value of annual savings is the measured value of energy displaced by WECS production, dollars

LF = A life cycle levelizing multiplier such that the present worth of the levelized values is equivalent to the present worth of the increasing values of the test year savings over the life cycle using the same discount rate

VOE = The levelized energy value per unit, $/kwh or $ per MM Btu, for example

AEWEC = The annual WECS energy production in kilowatt hours, or MM Btu

The cost of a WECS is often described using a levelized cost of energy (COE) and a levelized annual cost (LAC), such that:

$$COE = \frac{(IC)\ (FCR)}{AKWH} + \frac{(AOM)\ (LFA)}{AKWH}$$

$$LAC = COE \times AKWH = (IC)(FCR) + (AOM)\ (LFA)$$

where:

COE = Levelized energy cost in $/kwh
IC = Initial installed (turn-key) system cost in first year dollars
FCR = Annual fixed charge rate
AOM = Annual operation and maintenance cost in first year dollars
LFA = A levelizing constant to adjust the operations and maintenance costs for inflation over the system lifetime
AKWH = Total annual kilowatt hours produced by the WECS system
LAC = Levelized annual costs for the WECS

For break-even, the levelized annual value of savings must equal or exceed the levelized costs for the wind system. This equivalence is given by:

$$LVAS \geqq LAC$$
$$VOE \geqq COE$$

This study, due to the required analysis of the effects of thermal storage, has evaluated the LVAS and VOE by estimating the hour by hour use of wind energy production. It has considered the time coincidence of the wind resource with building losses, inputs from the sun and building inhabitants, thermal storage use for space heating and hot water, appliances and machinery, and nominal rates for sell-back of any surplus energy to the local rural electric cooperative utility.

The statistically expected value of the WECS production depends on numerous factors including interactions with the intermittent solar and wind resources, heating requirements, building inhabitants, sizes of the WECS, thermal and hot water storage systems, costs of conventional energy sources, and ancillary WECS uses (machines, appliances, and sell-back of surplus energy). These interactions were examined at nine widely dispersed locations, and the break-even analysis results are presented in the following sections for the set of farmhouse and farm building structures previously discussed. Chapters 6 and 7 aggregate the results and correlate the potential numbers of WECS applications if the cost of WECS matched the value of energy used by agriculture for heating.

5.3 ECONOMIC BREAK-EVEN ANALYSIS

Economic break-even analysis for farmhouses and farm buildings considered the value possible from the following applications of wind energy:

- o Space heating only (no thermal storage)
- o Space heating with thermal storage
- o Space heating with thermal storage plus the following additional uses:
- o Hot water needs
- o Machinery and appliance electric needs
- o Sell-back of surplus WECS energy to the utility

Based on preliminary sizing evaluations, WECS of 10, 20, and 40 foot rotor diameters were analyzed with and without thermal storage. Thermal storage used a water medium of 100 and 600 gallons in size for hot water, and in the case of farm buildings, was adjusted for the herd sizes selected and held constant throughout the analyses.

The following paragraphs present results of the economic break-even value analyses for farmhouses and farm buildings in detail.

5.3.1 FARMHOUSE WIND ENERGY APPLICATIONS

The three farmhouse structures, defined from a national survey, were used consistently for the analysis at all geographic locations and include:

- o Pre-1960 construction
- o Post 1960 construction
- o Passive solar (potential new construction)

A summary of the structure thermal characteristics was presented in Chapter 2. Wind energy was applied to the thermal and electric needs of the farmhouses considering the following priorities:

1. Space heating
2. Thermal storage for space heating
3. Hot water heating (a form of storage)
4. Appliances
5. Sell-back to the utility

Site specific break-even value analyses utilized local heating fuel costs reported by DOE (Reference 36), and the range of actual and levelized values are summarized in Tables 76 and 77. The costs are expressed as levelized annual values using price increases reported by DOE (Reference 43). The analysis considers multiple levels of fuel costs and life cycle levelizing factors. Moreover, distinct costs were derived for agricultural usage of electricity (resistance and heat pumps), natural gas, fuel oil, and LP gas.

Localized hour by hour analysis was necessary to determine the proportionate use of wind energy; that is, the break-even value of WECS depends on more than simply the cost of displaced heating fuels. For example, if heating fuel costs were 6 cents/kwh, and WECS energy output was only 50% coincident with demand, the required WECS COE would be 3 cents/kwh (without thermal storage). Since WECS output was used first for space heating, the subject of this study, higher values may be possible by displacing higher cost fuels first.

The levelized break-even values of annual savings, in cents per kilowatt hour, were found at each of the nine geographic centers and are presented in Figures 25 through 39. The effect of thermal storage for space heating and hot water is very pronounced - it nearly doubles the value of WECS production at all locations. Furthermore, analysis of incremental storage costs, not a subject of this study, is not expected to significantly detract from the added value since a small (less than 1000 gallons) water storage medium is considered. Further research could examine the incremental cost of storage for the system concepts analyzed.

The analyses show consistency in the break-even values among all locations except Austin, Texas, and Sacramento, California where solar loads are considerably higher and wind speeds somewhat lower than at other locations. Increased WECS value due to thermal storage for space heating and hot water is pronounced at all locations. This result suggests that local thermal storage should be examined further as an effective way to match WECS production with local space heating needs.

A summary of the average of the break-even values for WECS production according to warm and colder climates including the thermal storage option is shown in Table 78.

5.3.2 FARM BUILDING WIND ENERGY APPLICATIONS

Annual energy balances, based on hourly analysis for the eight

Heating Fuel	Minneapolis, Minnesota	Madison, Wisconsin	Casper, Wyoming	Chicago, Illinois	Des Moines, Iowa	Denver, Colorado	Baltimore, Maryland	Sacramento, California	Austin, Texas
	Analysis Location								
Electric-Resistance									
Current	10.84	10.82	7.50	12.07	11.75	10.08	12.51	11.63	10.41
6% increase *	18.03	17.99	12.47	20.07	19.54	16.76	20.80	19.34	17.31
8% increase *	21.97	21.93	15.20	24.47	23.82	20.43	25.36	23.57	21.10
10% increase *	27.14	27.09	18.78	30.22	29.42	25.24	31.33	29.12	26.07
Electric - Heat Pump									
Current	5.42	5.41	3.75	6.04	5.89	5.04	6.23	5.82	5.21
6% increase *	9.02	8.90	6.24	10.04	9.77	8.38	10.40	9.67	8.66
8% increase *	10.99	10.97	7.6	12.24	11.91	10.22	12.68	11.79	10.55
10% increase *	13.57	13.55	9.39	15.11	14.71	12.62	15.67	14.56	13.04
Natural Gas									
Current	2.07	2.42	1.54	2.14	1.87	1.57	3.08	1.83	2.32
6% increase *	3.44	4.02	2.56	3.56	3.11	2.61	5.12	3.04	3.86
8% increase *	4.20	4.91	3.12	4.34	3.79	3.18	6.24	3.71	4.70
10% increase *	5.18	6.06	3.86	5.36	4.68	3.93	7.71	4.58	5.81
LP/Bottle Gas									
Current	3.25	3.31	3.67	3.31	3.22	3.67	3.41	3.24	3.10
6% increase *	5.40	5.50	6.10	5.50	5.35	6.10	5.67	5.39	5.16
8% increase *	6.59	6.71	7.44	6.71	6.53	7.44	6.91	6.57	6.28
10% increase *	8.14	8.29	9.19	8.29	8.06	9.19	8.54	8.11	7.76
Fuel Oil									
Current	3.30	3.36	3.33	3.36	3.28	3.33	3.49	3.52	3.08
6% increase *	5.49	5.59	5.54	5.59	5.45	5.54	5.80	5.85	5.12
8% increase *	6.69	6.81	6.75	6.81	6.65	6.75	7.07	7.14	6.24
10% increase *	8.26	8.41	8.34	8.41	8.21	8.34	8.74	8.81	7.71

*** Levelized with 25 year life cycle and 10% discount rate**

Table 76 Comparison Of Heating Fuel Costs--$/ 10^6 BTU

Heating Fuel	Minneapolis, Minnesota	Madison, Wisconsin	Casper, Wyoming	Chicago, Illinois	Des Moines, Iowa	Denver, Colorado	Baltimore, Maryland	Sacramento, California	Austin, Texas
	Analysis Locations								
Electric -Resistance									
Current	3.7	3.7	2.6	4.1	4.0	3.4	4.3	4.0	3.6
6% Increase *	6.2	6.1	4.3	6.8	6.7	5.7	7.1	6.6	5.9
8% Increase *	7.5	7.5	5.2	8.4	8.1	7.0	8.7	8.0	7.2
10% Increase *	9.3	9.2	6.4	10.3	10.0	8.6	10.7	9.9	8.9
Electric-Heat Pump									
Current	1.9	1.9	1.3	2.1	2.0	1.7	2.2	2.0	1.8
6% increase *	3.1	3.1	2.2	3.4	3.4	2.9	3.6	3.3	3.0
8% increase *	3.8	3.8	2.6	4.2	4.2	3.5	4.4	4.0	3.6
10% increase *	4.7	4.6	3.2	5.2	5.0	4.3	5.4	5.0	4.5
Natural Gas									
Current	0.7	0.8	0.5	0.7	0.6	0.5	1.1	0.6	0.8
6% Increase *	1.2	1.4	0.9	1.2	1.1	0.9	1.7	1.0	1.3
8% Increase *	1.4	1.7	1.1	1.5	1.3	1.1	2.1	1.3	1.6
10% Increase *	1.8	2.1	1.3	1.8	1.6	1.3	2.6	1.6	2.0
LP/Bottle Gas									
Current	1.1	1.1	1.3	1.1	1.1	1.3	1.2	1.1	1.1
6% Increase *	1.8	1.9	2.1	1.9	1.8	2.1	1.9	1.8	1.8
8% Increase *	2.2	2.3	2.5	2.3	2.2	2.5	2.4	2.2	2.1
10% Increase *	2.8	2.8	3.1	2.8	2.8	3.1	2.9	2.8	2.6
Fuel Oil									
Current	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.1
6% Increase *	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.0	1.7
8% Increase *	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.1
10% Increase *	2.8	2.9	2.8	2.9	2.8	2.8	3.0	3.0	2.6

* Levelized with a 25 year life and 10% discount rate

Table 77 Comparison Of Heating Fuel Costs--Cents/Kwh Equivalent

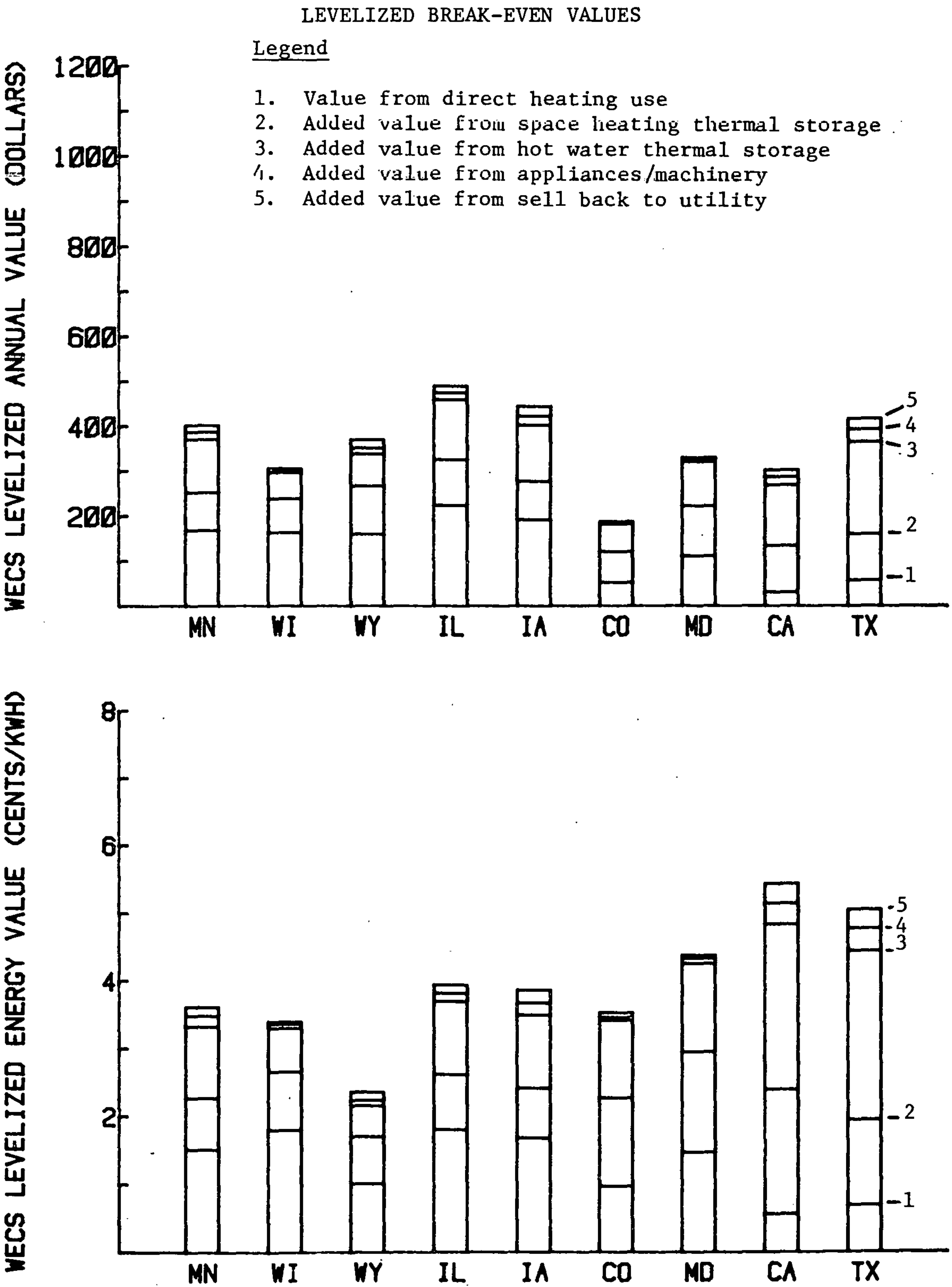


Figure 25 Older Farmhouse With Thermal Storage and Heat Pump Heating

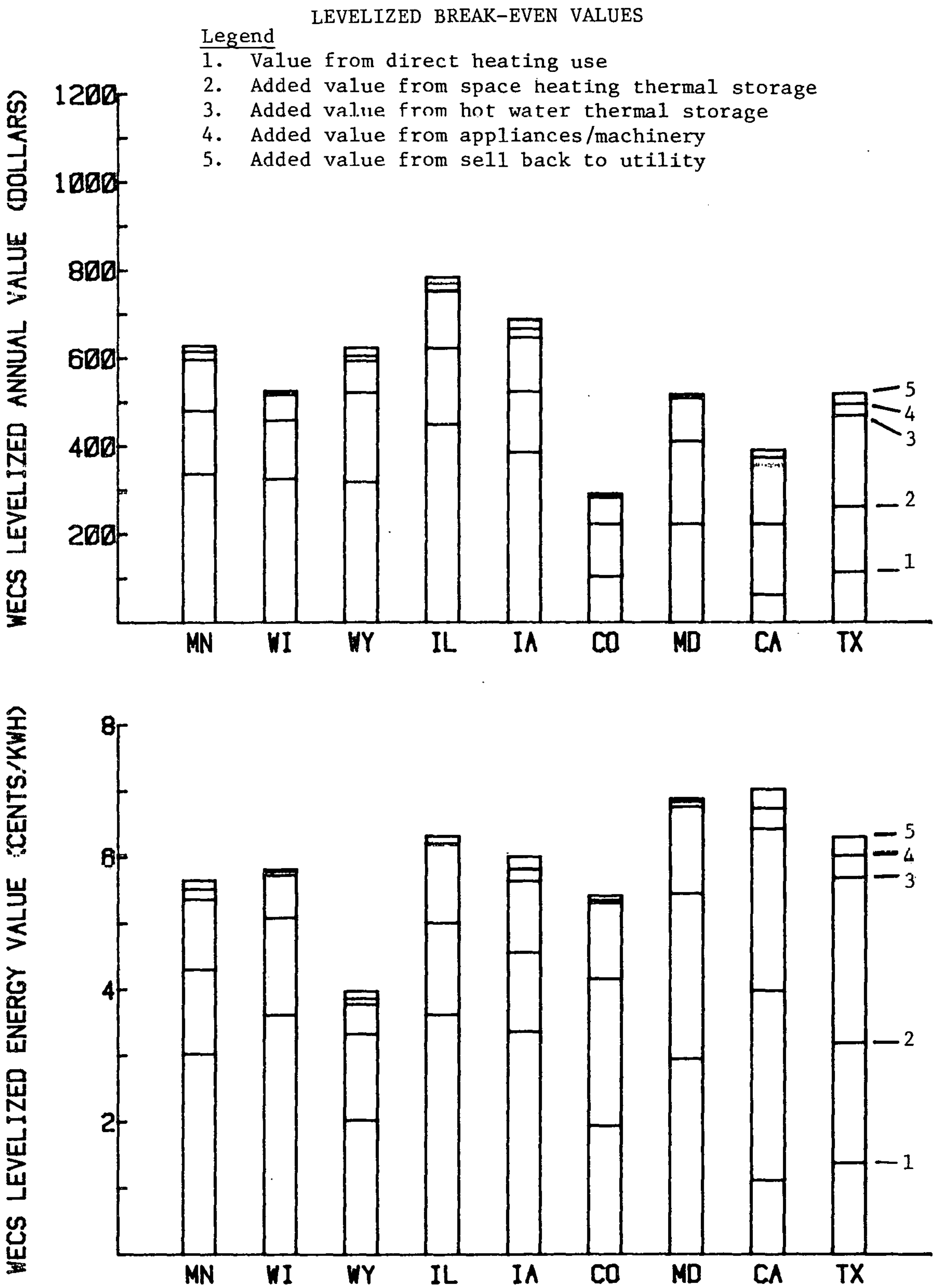
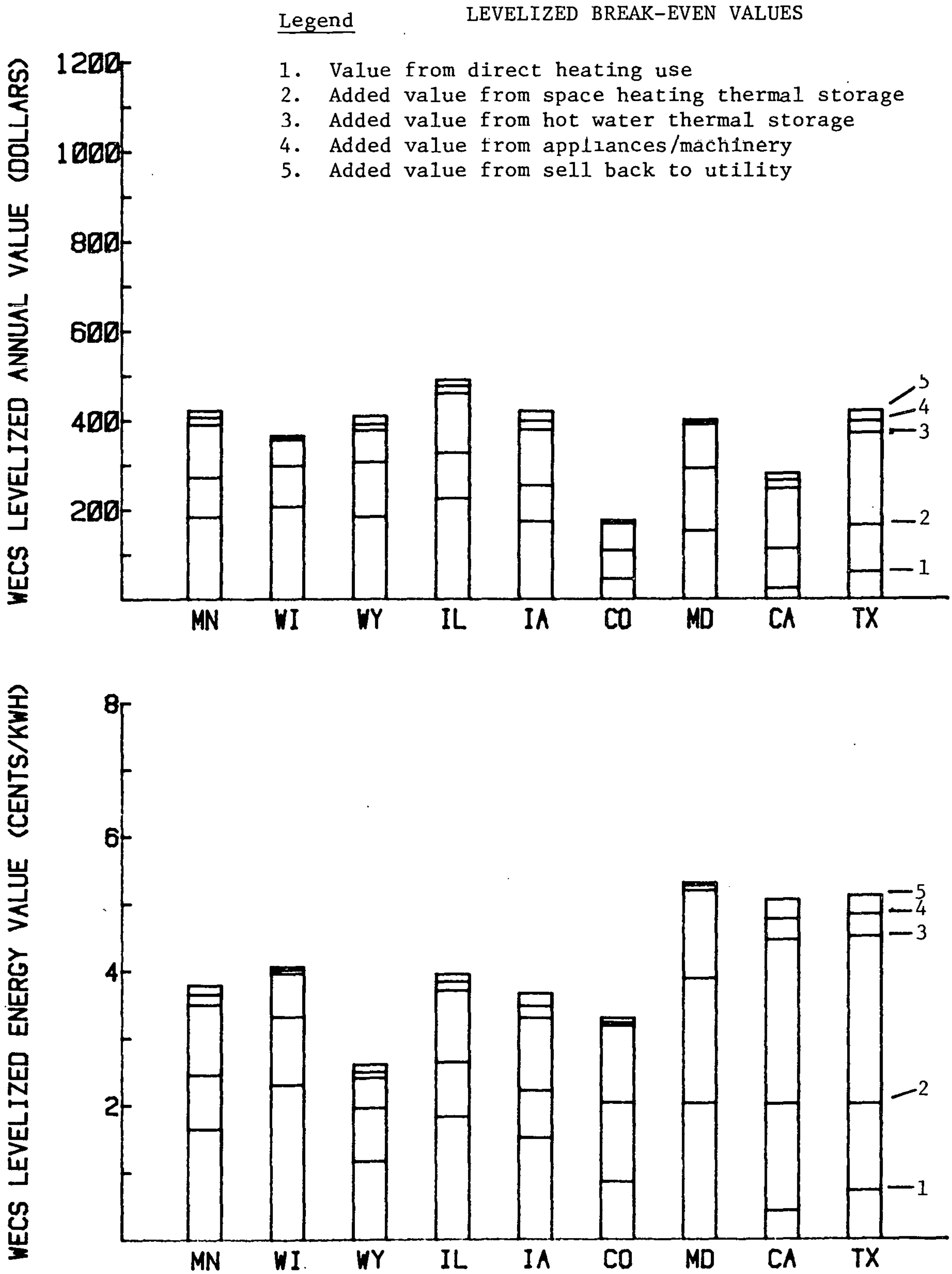


Figure 26 Older Farmhouse With Thermal Storage and Electric Resistance Heat



gure 27 Older Farmhouse With Thermal Storage and Natural Gas Heating

LEVELIZED BREAK-EVEN VALUES

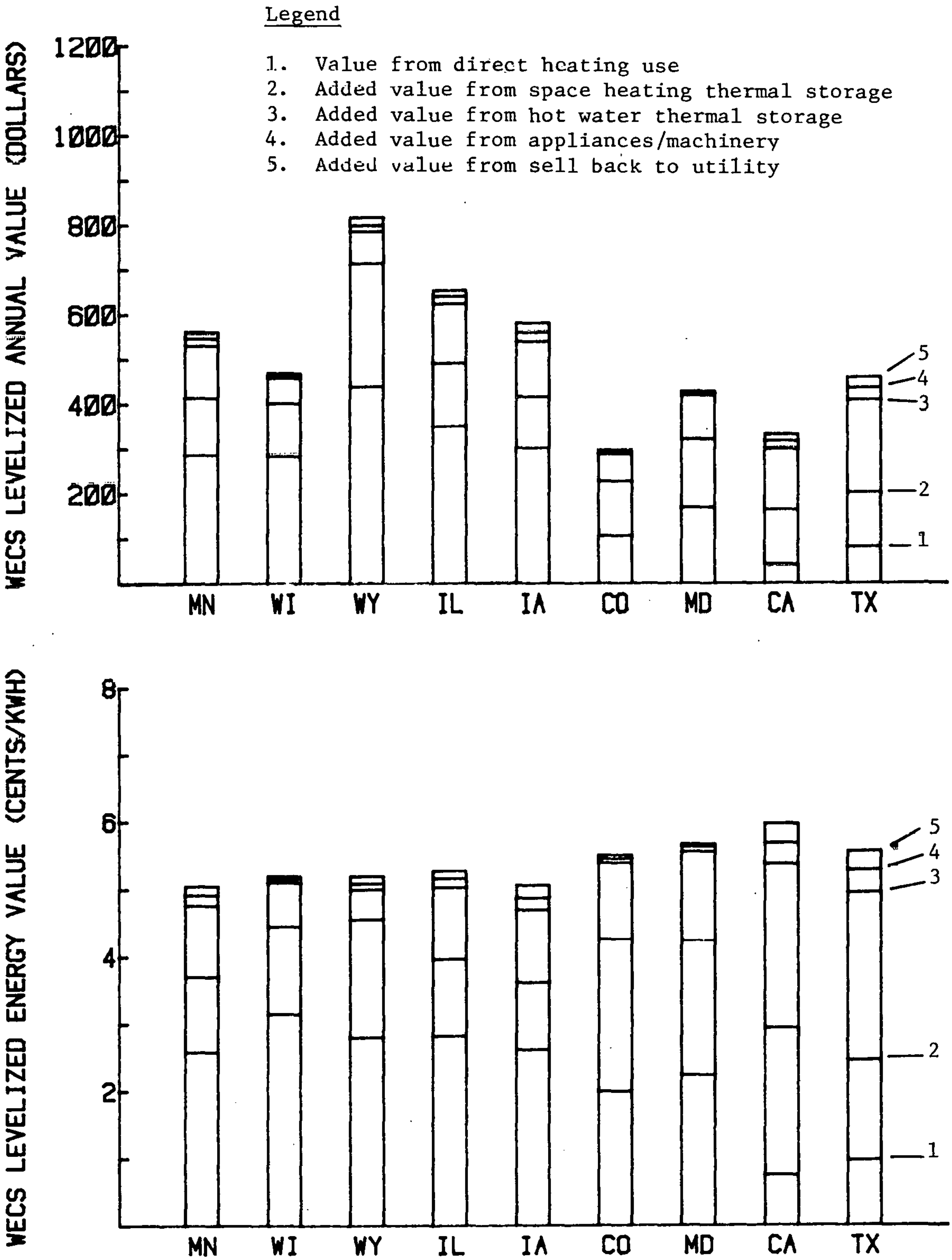


Figure 28 Older Farmhouse With Thermal Storage and LP Gas Heating

LEVELIZED BREAK-EVEN VALUES

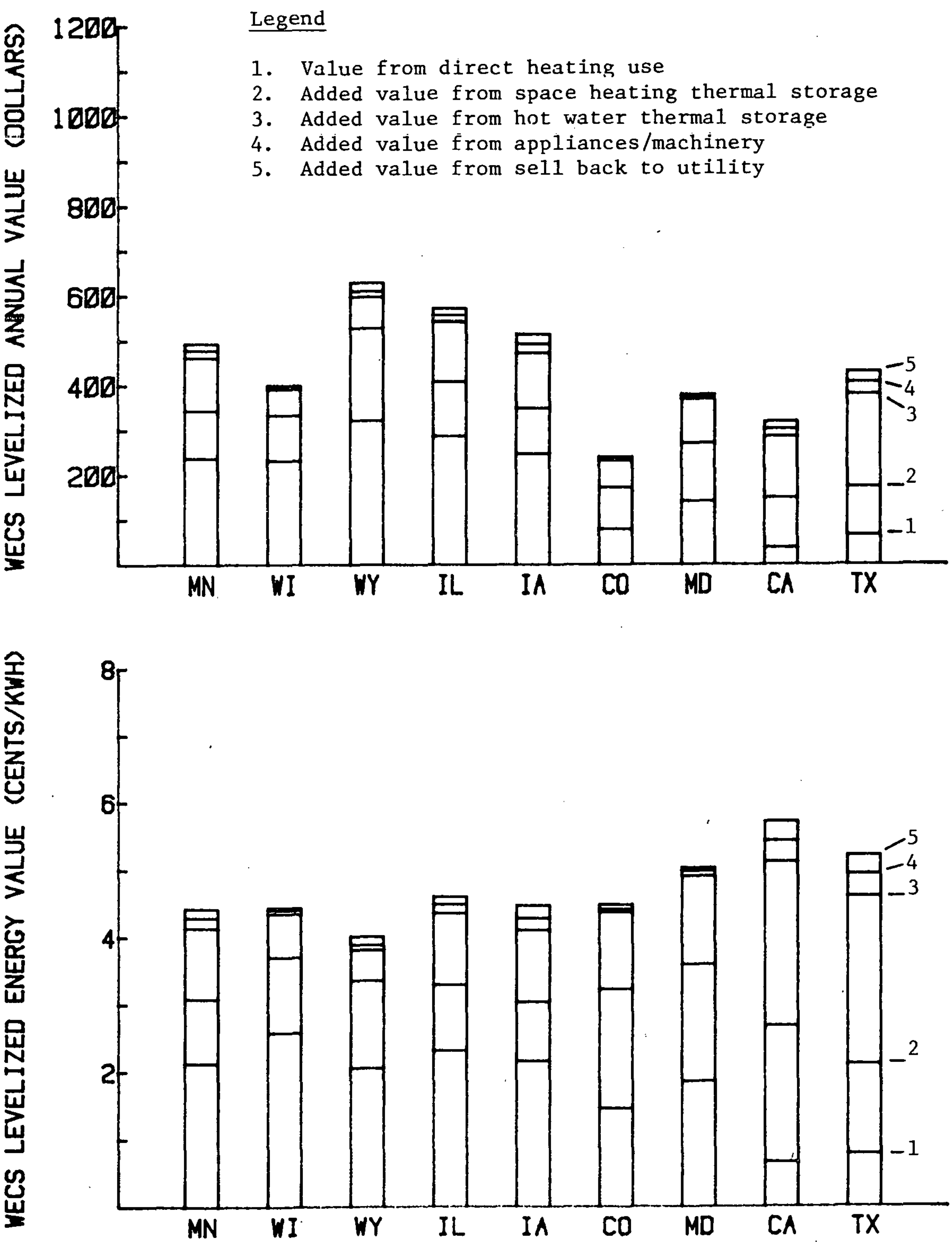


Figure 29 Older Farmhouse With Thermal Storage and Fuel Oil Heating

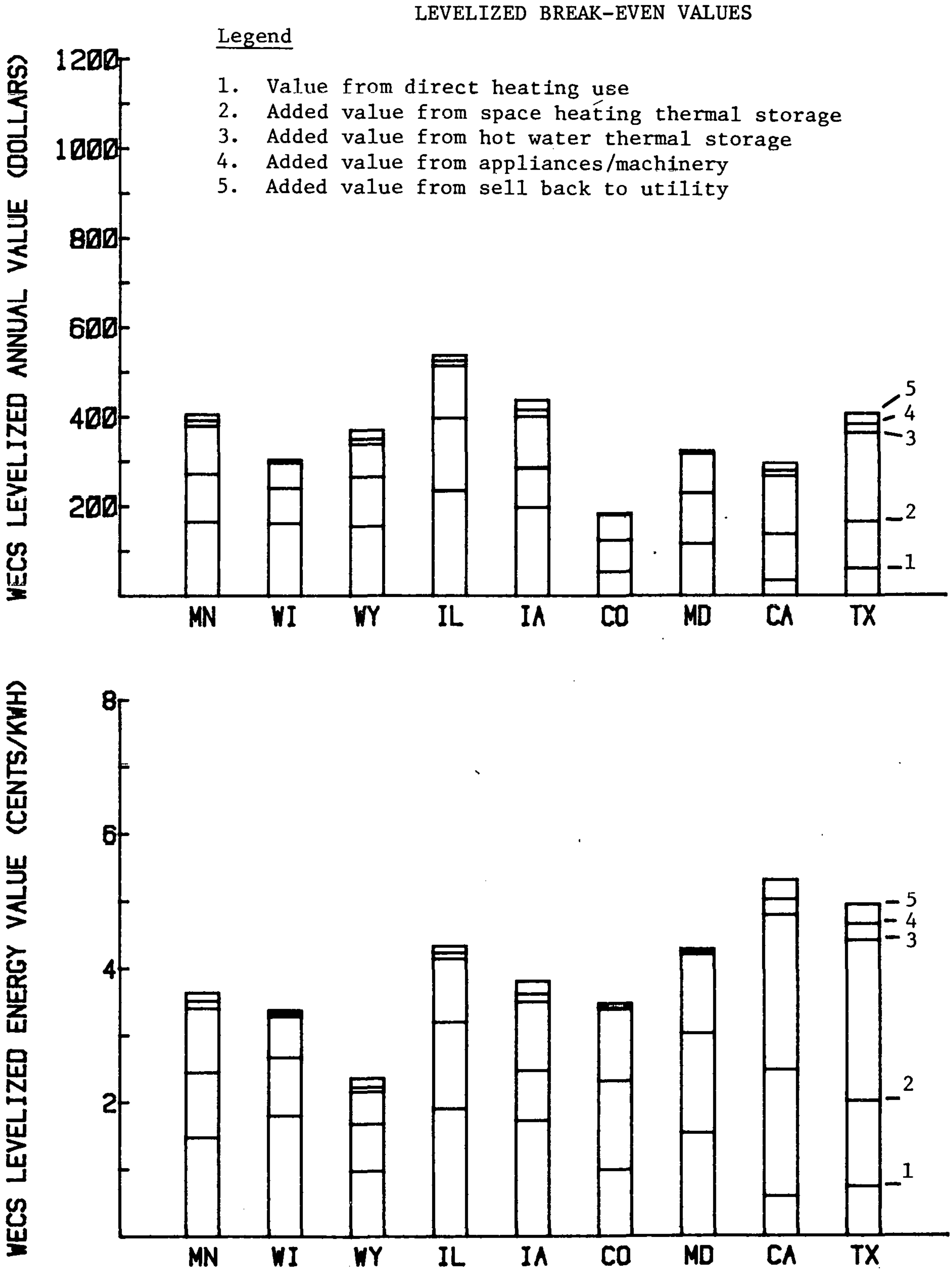
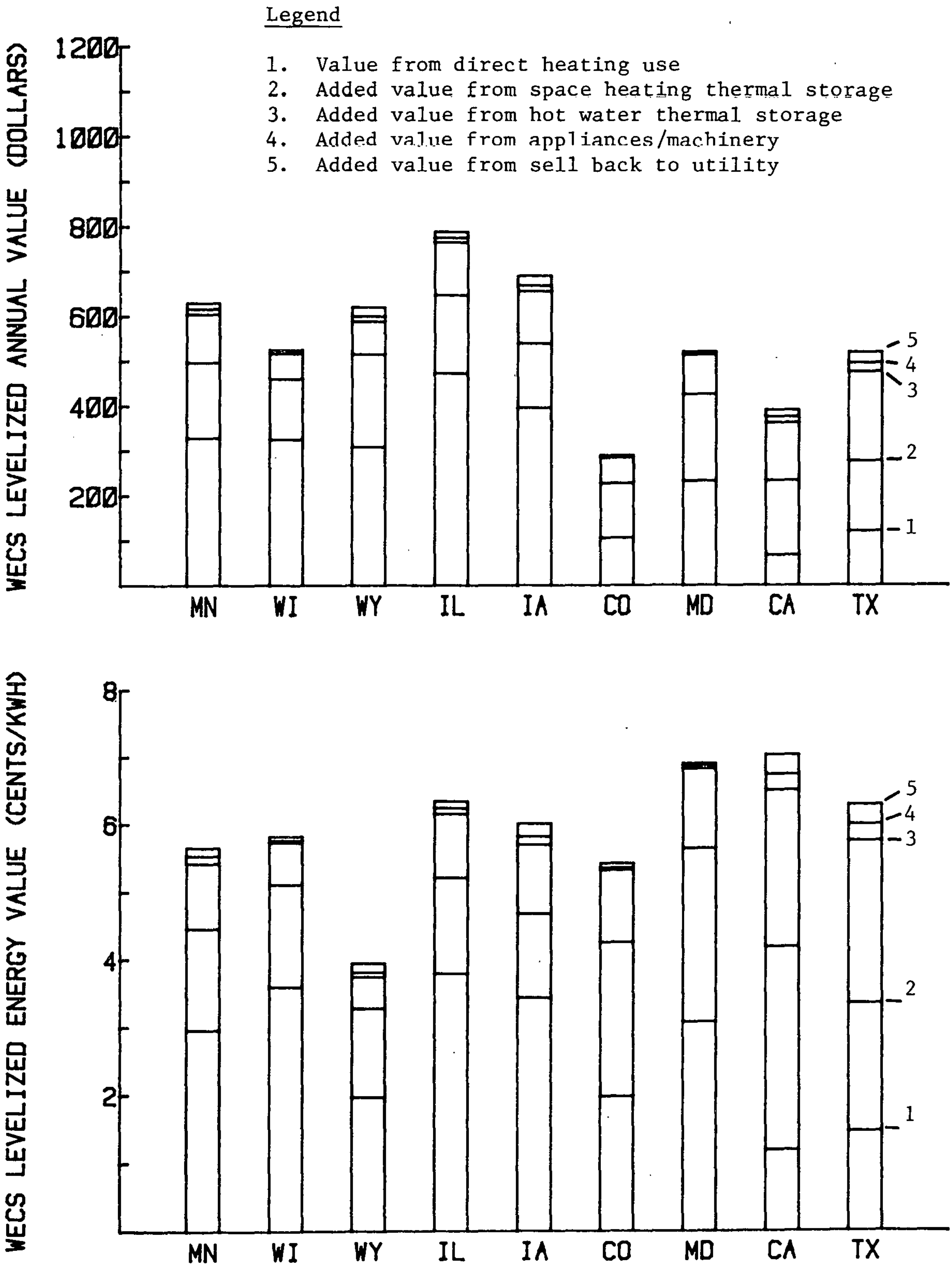


Figure 30 Modern Farmhouse With Thermal Storage and Heat Pump Heating

LEVELIZED BREAK-EVEN VALUES



igure 3.1 Modern Farmhouse With Thermal Storage and Electric Resistance Heating

LEVELIZED BREAK-EVEN VALUES

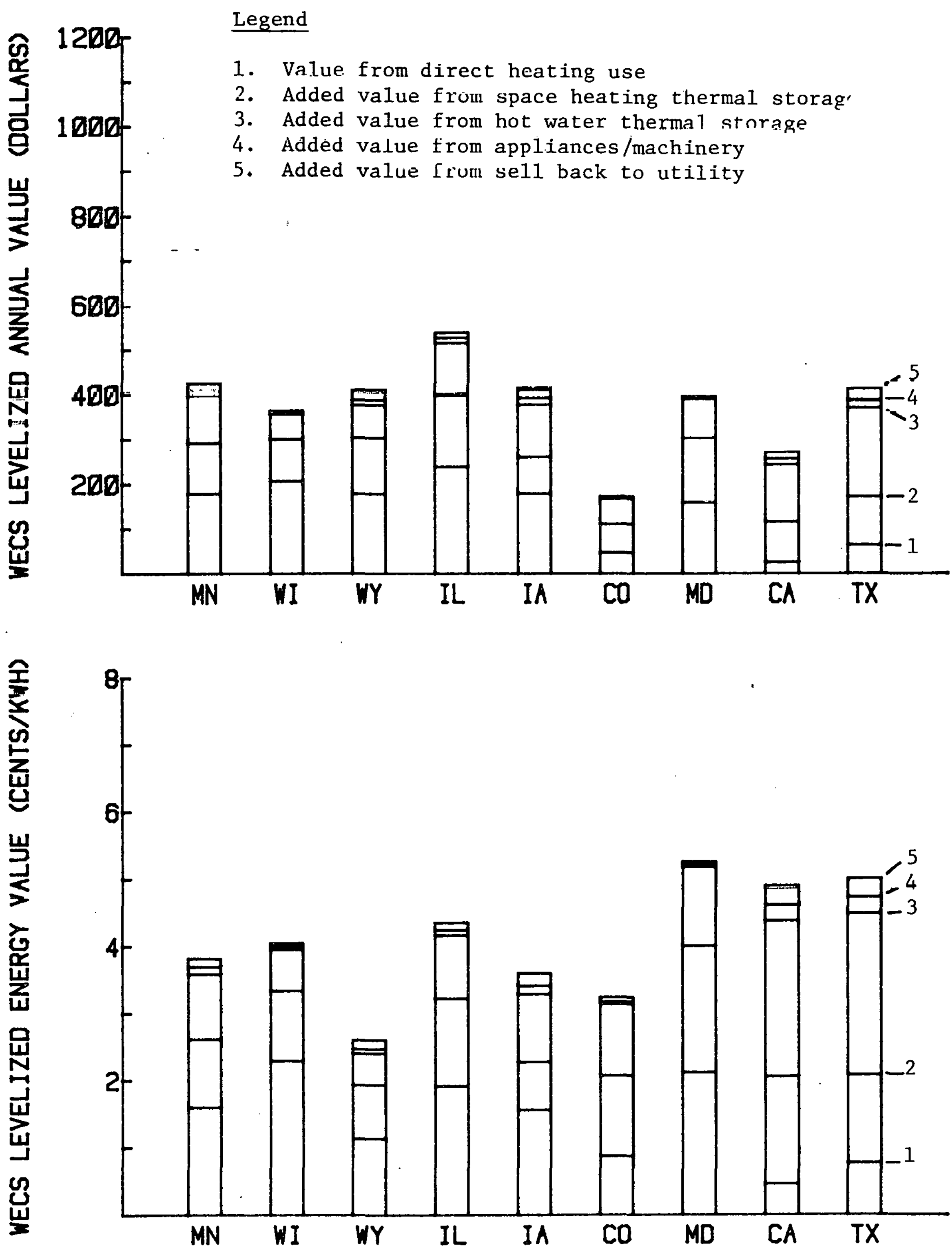


Figure 32 Modern Farmhouse With Thermal Storage and Natural Gas Heating

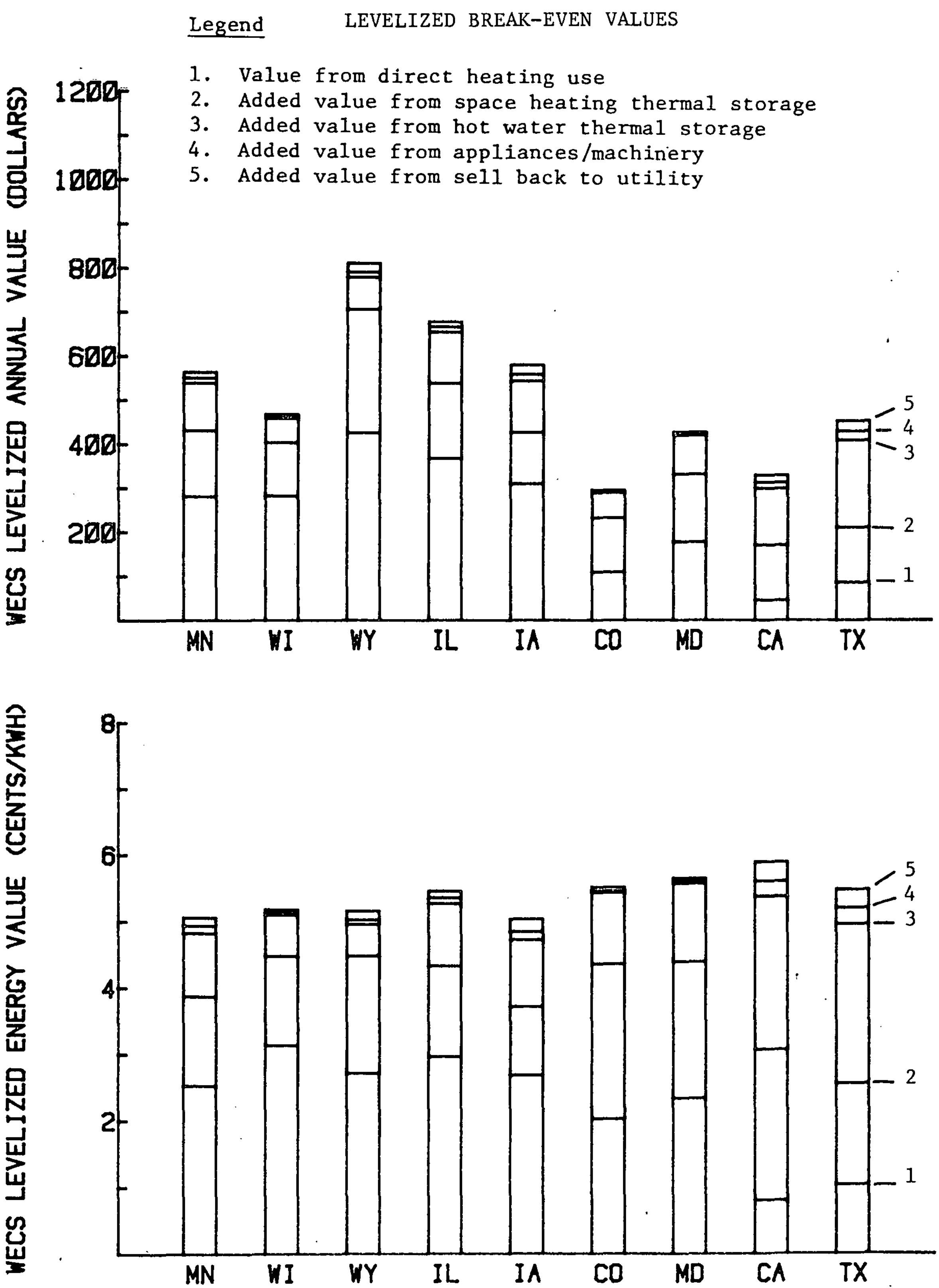


Figure 33 Modern Farmhouse With Thermal Storage and LP Gas Heating

LEVELIZED BREAK-EVEN VALUES

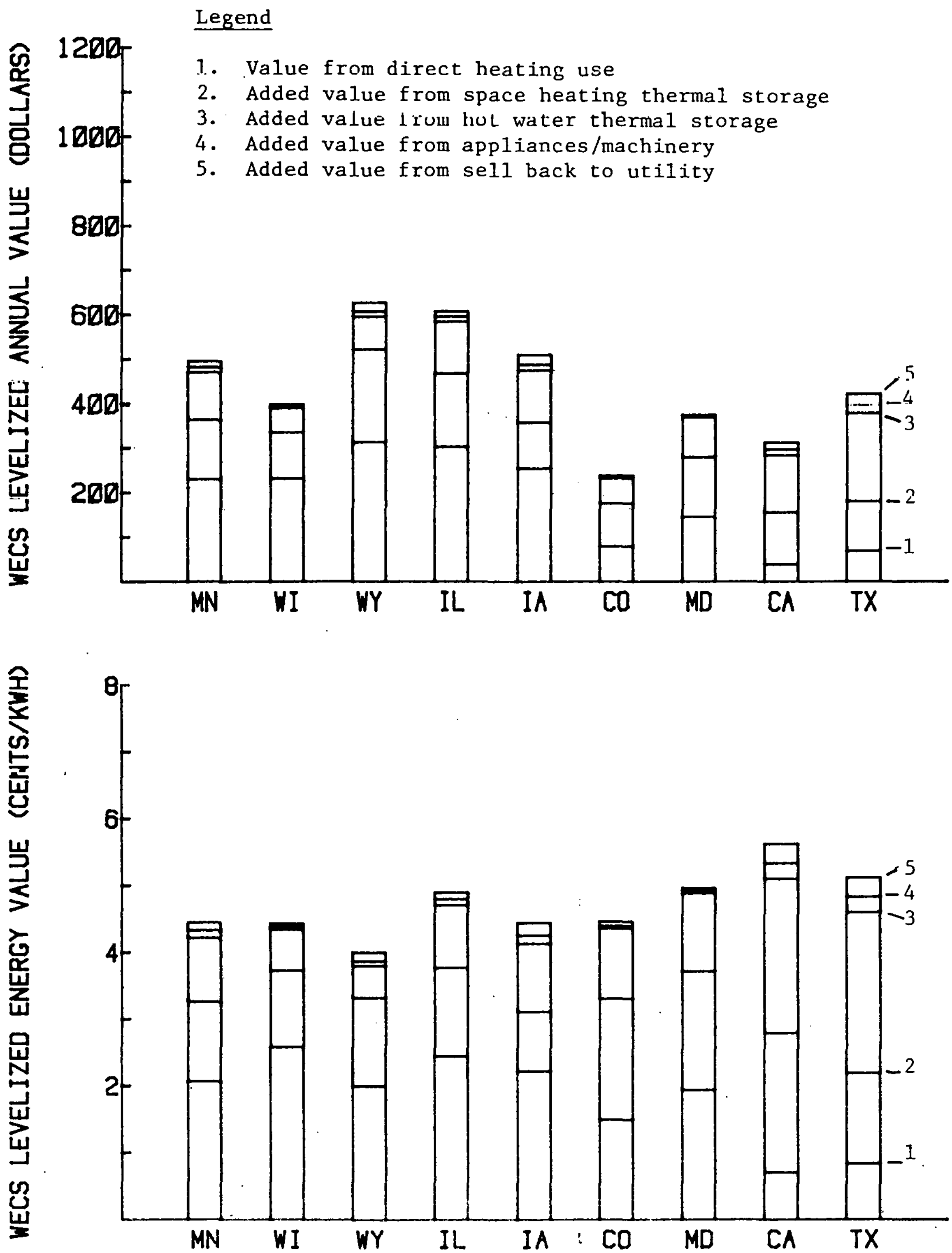


Figure 34 Modern Farmhouse With Thermal Storage and Fuel Oil Heating

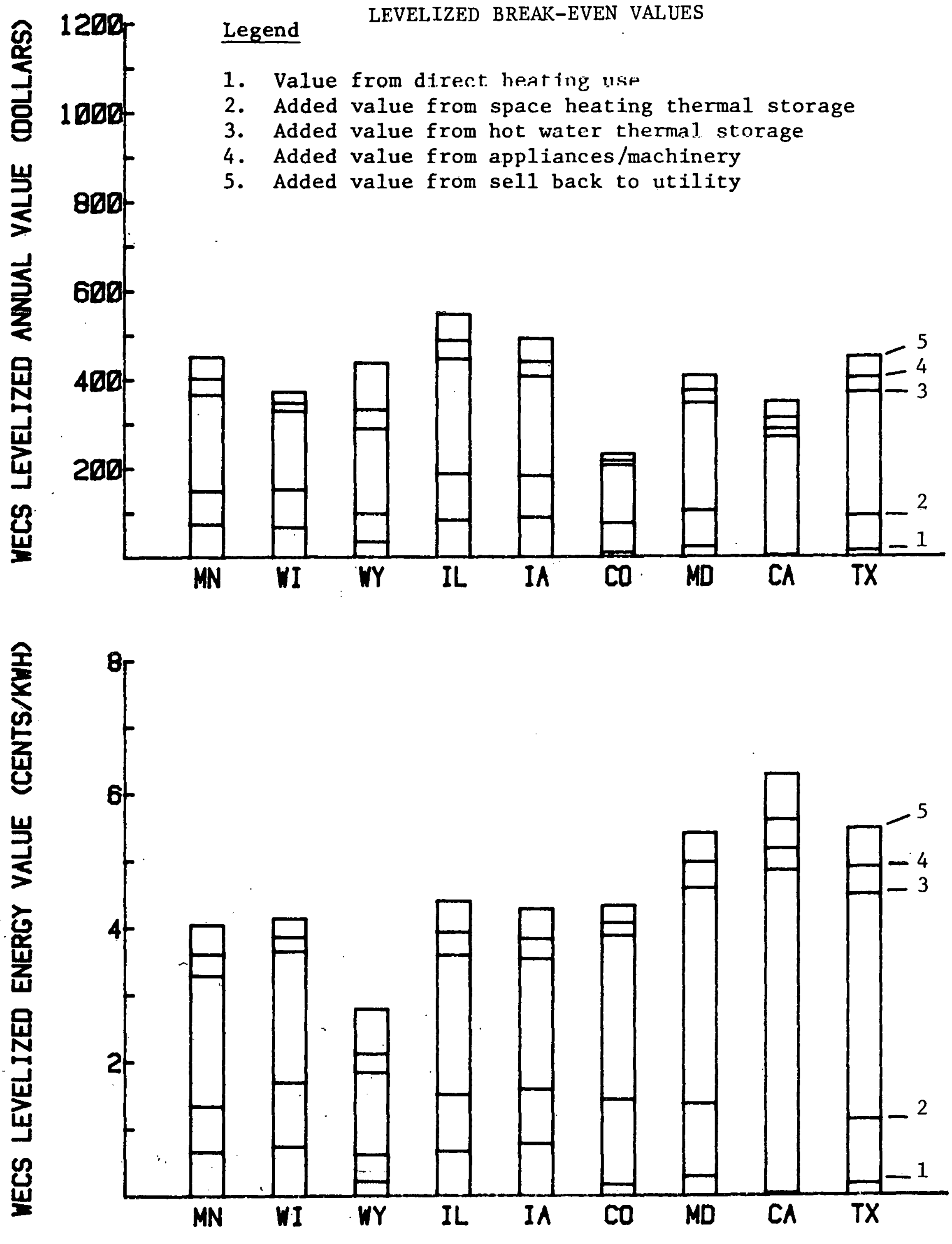


Figure 35 Passive Solar Farmhouse With Thermal Storage and Heat Pump Heating

LEVELIZED BREAK-EVEN VALUES

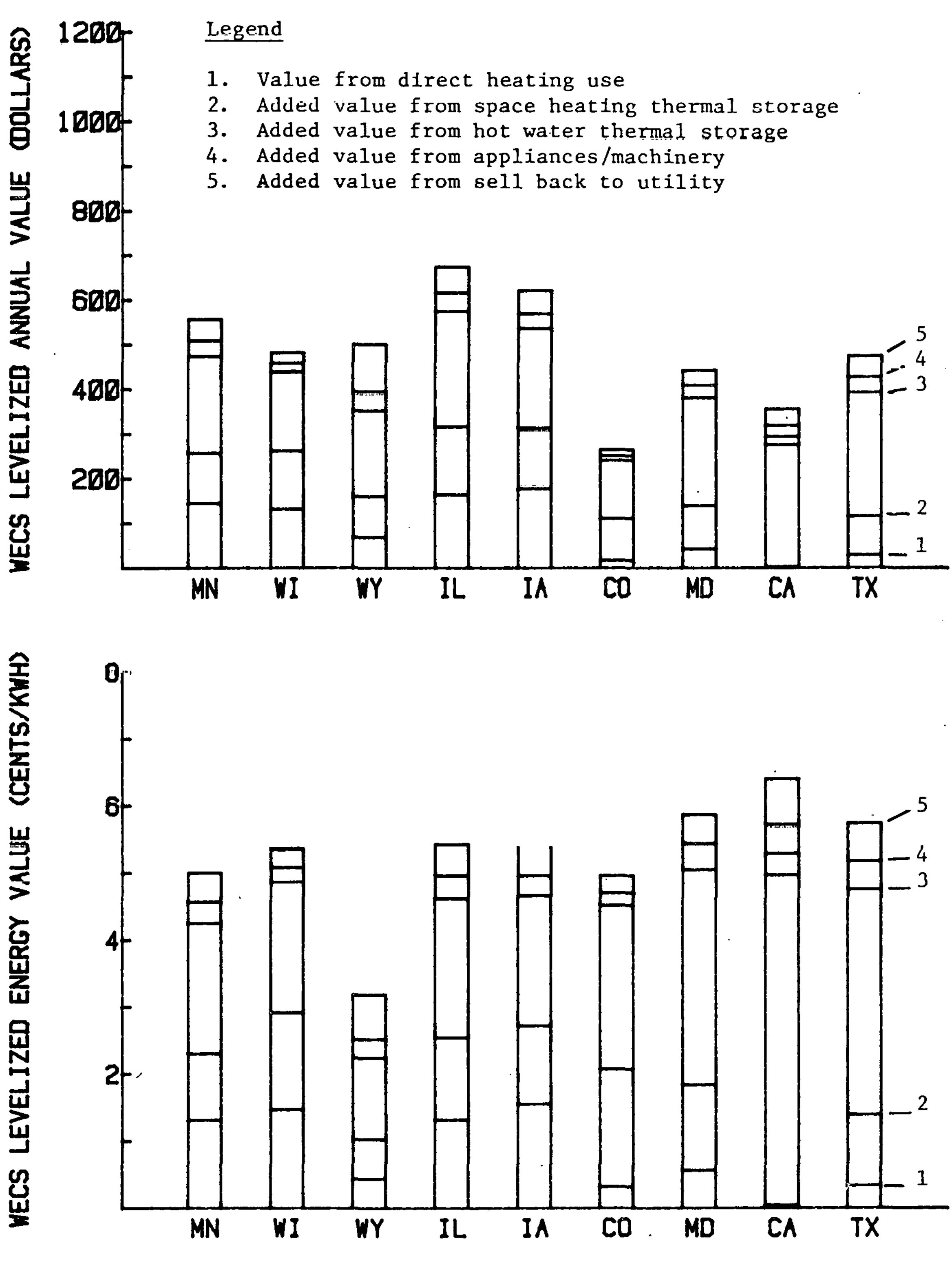


Figure 36 Passive Solar Farmhouse With Storage and Electric Resistance Heating

LEVELIZED BREAK-EVEN VALUES

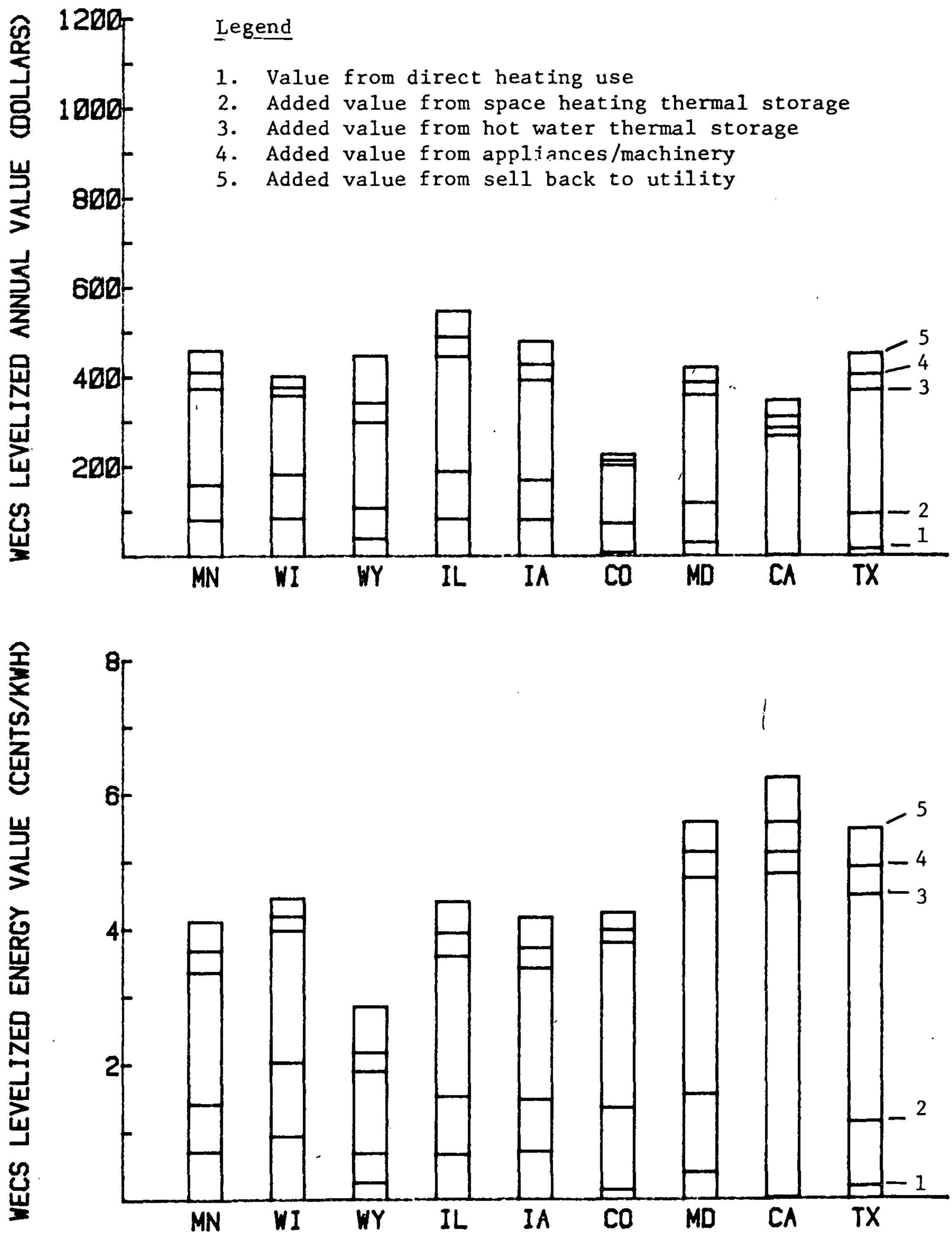


Figure 37 Passive Solar Farmhouse With Thermal Storage and Natural Gas Heating

LEVELIZED BREAK-EVEN VALUES

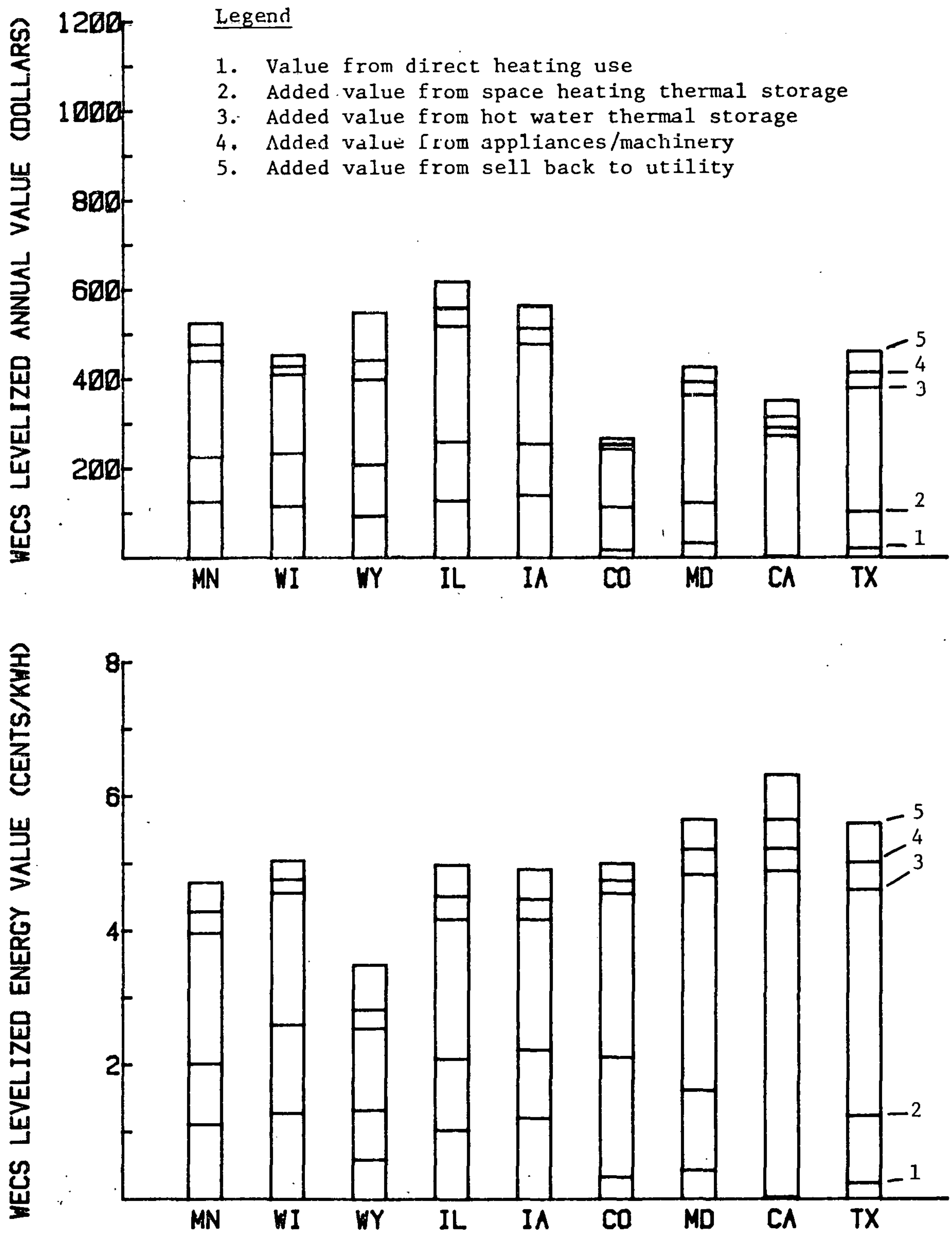


Figure 38 Passive Solar Farmhouse With Thermal Storage and LP Gas Heating

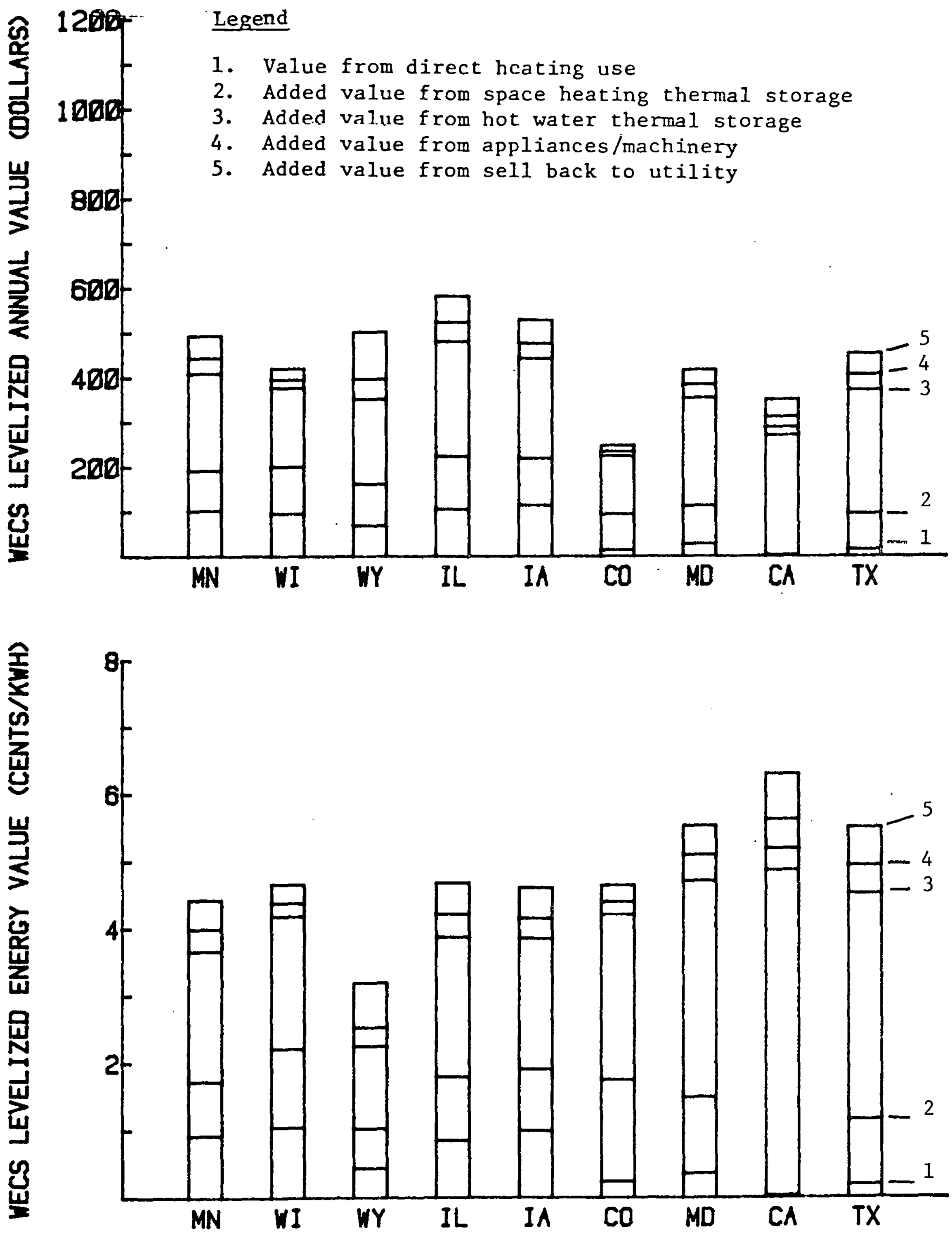


Figure 39 Passive Solar Farmhouse With Thermal Storage and Fuel Oil Heating

	Older Farmhouse			Modern Farmhouse			Passive Solar Farmhouse		
	No Thermal Storage	Storage For Heating	Storage For All Uses	No Thermal Storage	Storage For Heating	Storage For All Uses	No Thermal Storage	Storage For Heating	Storage For All Uses
Electric Heating-Resistance									
Degree day more than 4000	2.9	4.1	5.5	3.0	4.5	5.5	1.0	2.2	4.8
Degree day less than 4000	1.7	4.3	6.7	1.9	4.4	6.7	.25	2.6	6.0
Electric Heating-Heat Pump									
Degree day more than 4000	1.5	2.3	3.4	1.5	2.4	3.5	.50	1.3	3.9
Degree day less than 4000	.8	2.4	4.8	.9	2.5	4.7	.20	3.3	5.6
Natural Gas Heating									
Degree day more than 4000	1.4	2.2	3.6	1.5	2.5	3.6	.90	1.3	4.0
Degree day less than 4000	1.0	2.6	5.1	1.0	2.7	5.0	.20	2.3	5.7
LP Gas Heating									
Degree day more than 4000	2.6	4.0	5.2	2.6	4.1	5.2	.90	2.0	4.6
Degree day less than 4000	1.3	3.1	5.8	1.3	3.2	5.7	.20	2.5	5.8
Fuel Oil Heating									
Degree day more than 4000	2.0	3.2	4.3	2.0	3.1	4.4	.70	1.74	4.25
Degree day less than 4000	1.1	2.6	5.3	1.0	2.9	5.1	.15	2.3	5.6

Table 78 Farmhouse Average Levelized Break-even Value Of WECS Energy-- Cents/KWH

buildings selected from the survey (presented in their geographic locations in Table 75), were analyzed to determine the break-even value of wind energy and total annual heating costs using the same economic procedures applied to the farmhouses. Local climatic data and hourly evaluations considered the heat and moisture production of the growing animal herds inhabiting the farm buildings. The economic value measured for the WECS also considered the incremental use of feed and productivity resulting from indoor temperature variations with WECS.

Fuel costs used were the same for both farmhouse and farm building applications. Results are summarized in the following sections for electricity and fuel oil, the prevalent fuels in the farm building applications. A survey showed that costs for LP and fuel oil were nearly equivalent in most locations. Natural gas was not found to be a prevalent fuel in farm building applications.

Results are then presented graphically for each farm building application to show the break-even value of WECS energy and annual costs for electricity and fuel oil energy.

5.3.2.1 POULTRY - BROILERS

The broiler operation encompasses both the brooding and growing functions. Production is completed on an approximate 2.5 month cycle. A model broiler operation of 20,000 birds was adopted for this analysis; corresponding structural considerations were taken from the Midwest Plan Service (structural designs were presented in Chapter 2). Broiler production, analyzed in the Baltimore, Maryland area, required significant supplemental space heating energy; in fact, it required more than any other application studied. Wind energy use was studied for both 850 and 2000 gallon thermal storage facilities.

Break-even value of WECS energy and annual savings without storage are shown in Figure 40. Break-even results including thermal storage are shown in Figures 41 and 42. The effect of storage is to double the value of the WECS production, and also to render this value much less dependent on sell-back to the local utilities.

5.3.2.2 POULTRY - BROODING LAYERS

This section discusses the application of wind energy to layer/brooding operations, which have an energy intensive, 3 month production cycle. Layers are brooded for 3 months prior to their sale as pullets used in egg production. The layer brooding operation considered a flock size of 40,000 birds, located in the Sacramento, California area. While supplemental space heating energy was required, it was in limited quantities due to the high animal density and mild California climate. The brooding structure design was adopted from the Midwest Plan Service and was presented earlier in Chapter 2. Wind energy usage is evaluated hourly for two storage sizes - 1000 and 2000 gallons.

WECS break-even value of energy and annual savings are shown in Figure 43. Break-even values with 1000 and 2000 gallon thermal storage

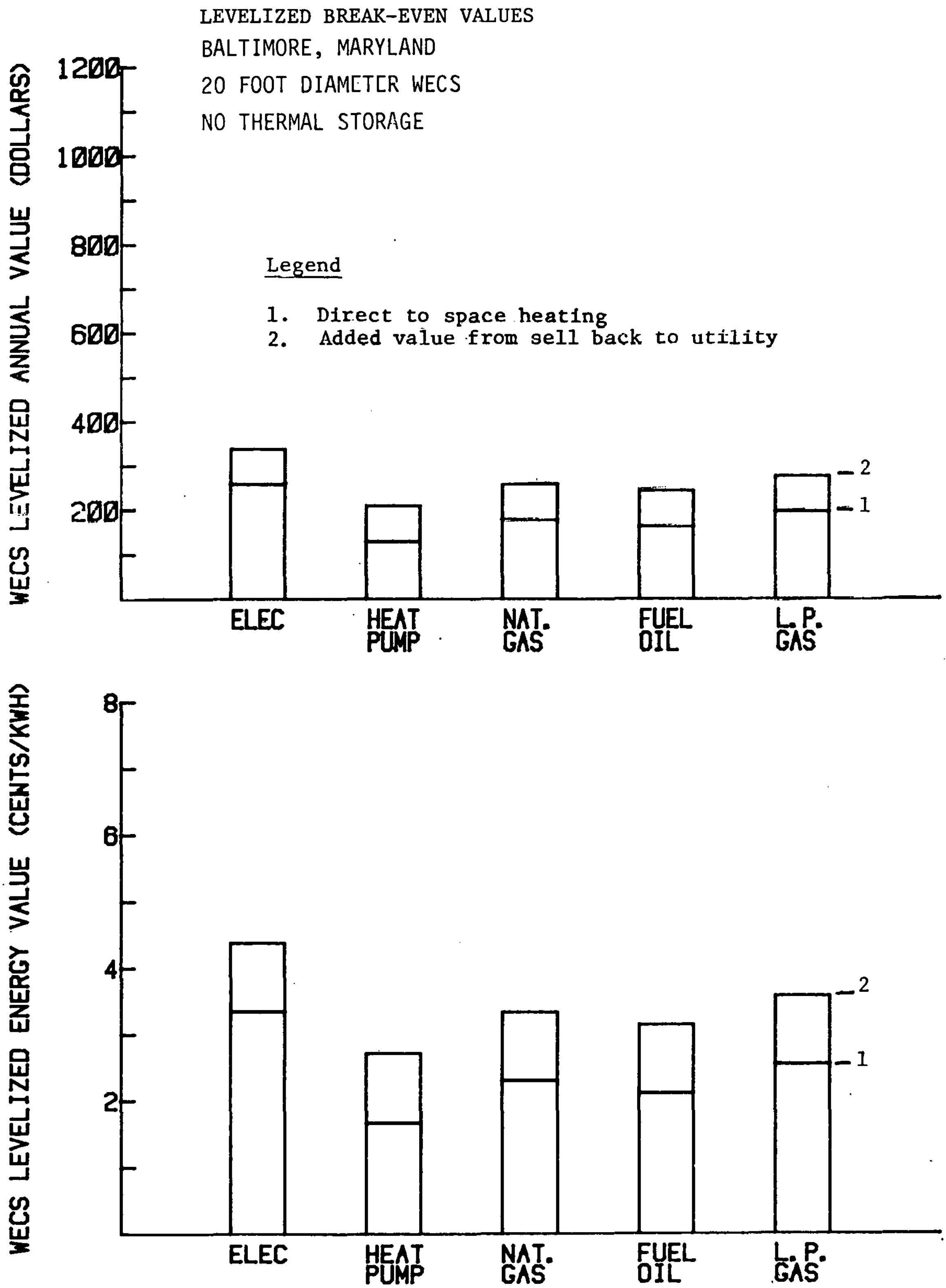
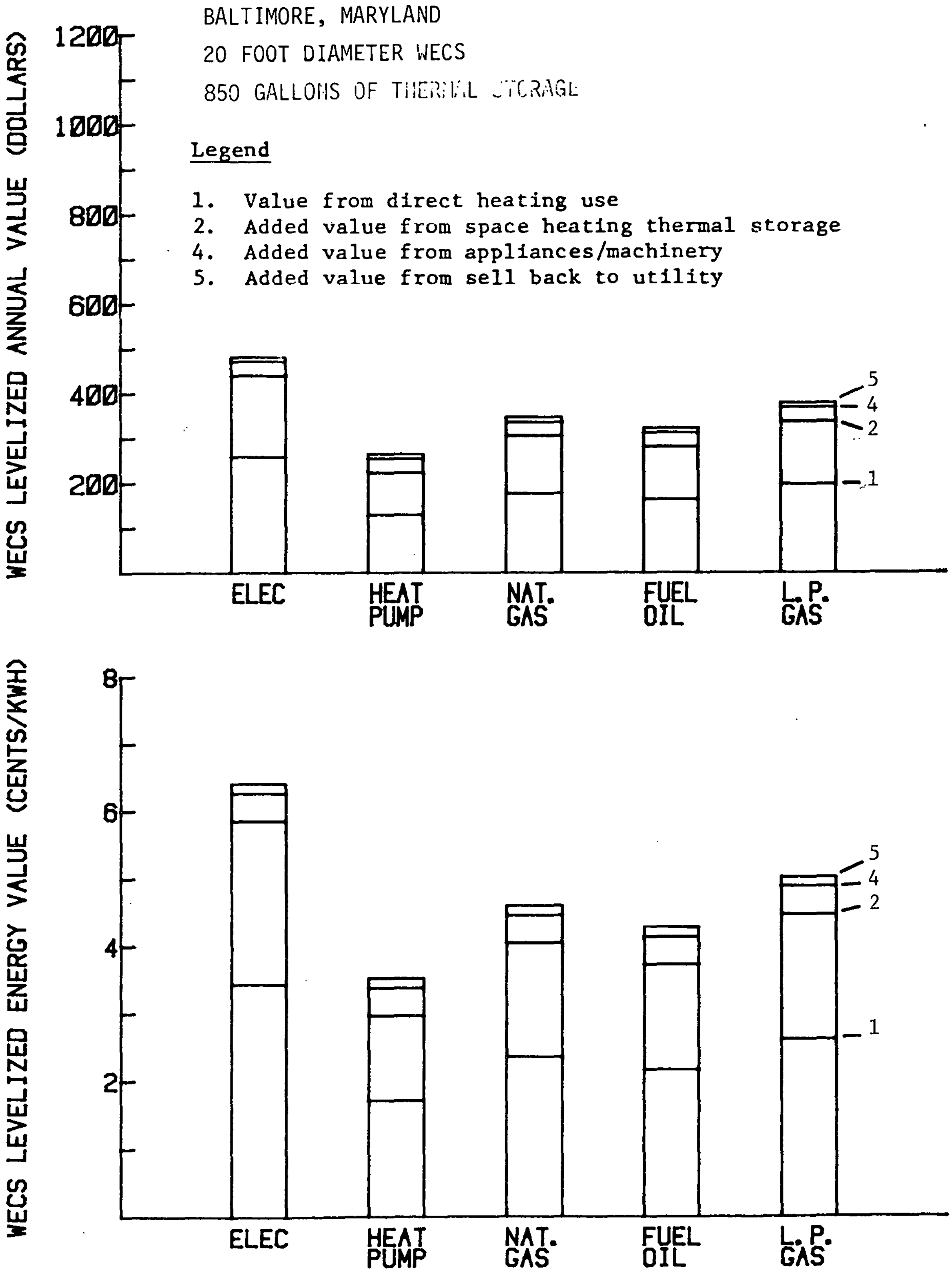


Figure 40 Poultry-Broilers Without Thermal Storage



igure 41 Poultry-Broilers With 850 Gallons Of Thermal Storage

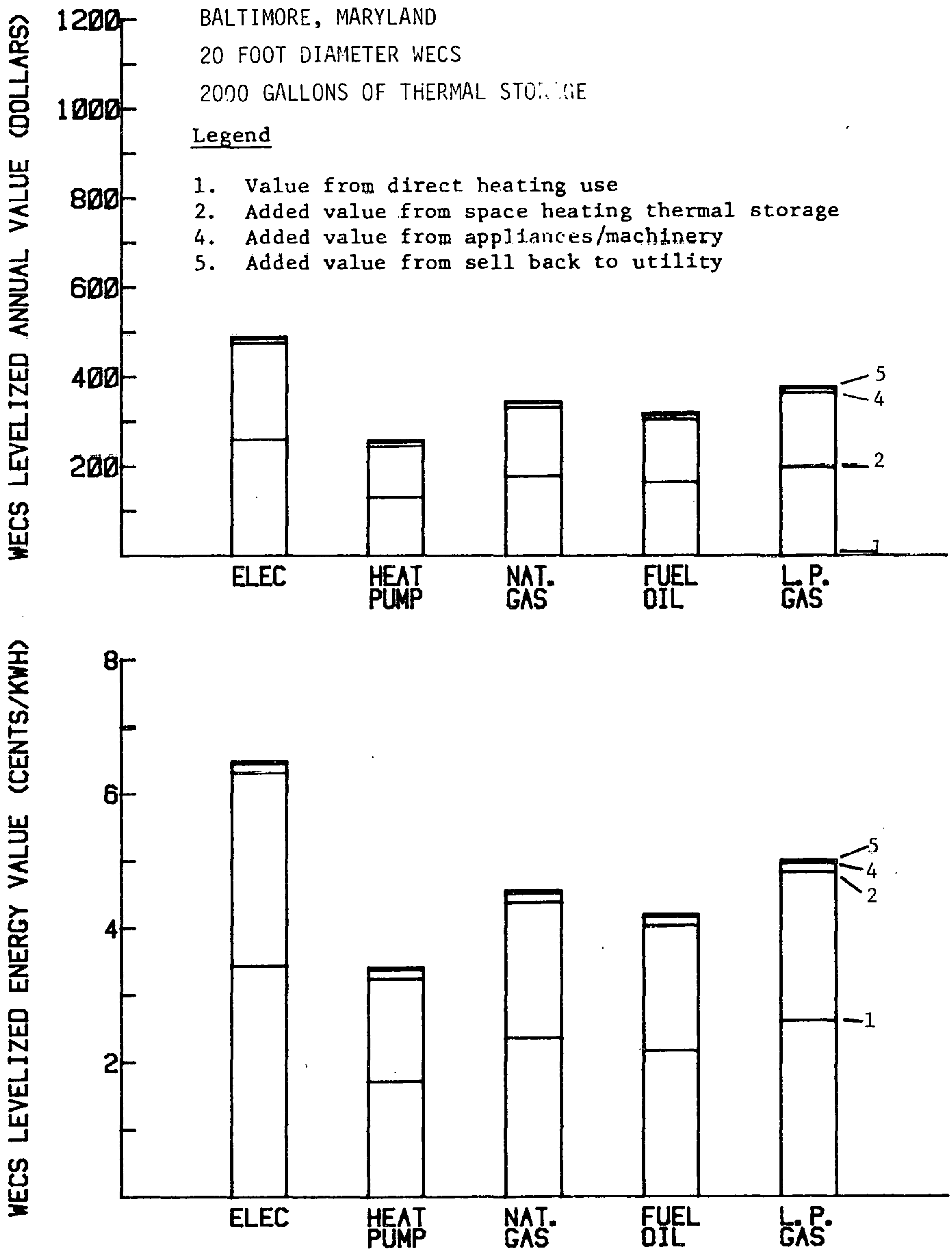


Figure 42 Poultry-Broilers With 2000 Gallons Of Thermal Storage

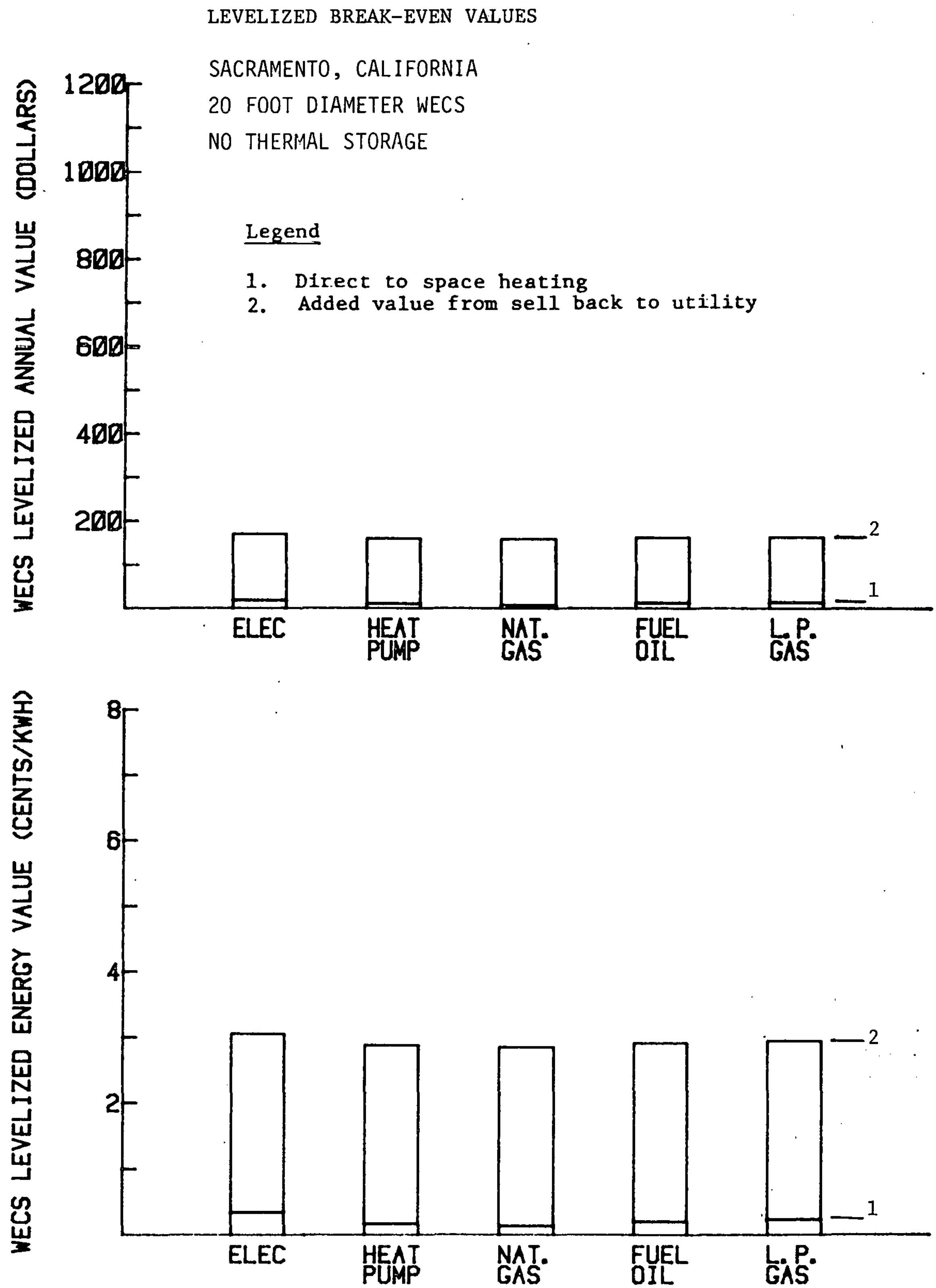


Figure 43 Poultry-Layer/Brooding Without Thermal Storage

are shown in Figures 44 and 45. The added storage increased the break-even value of WECS energy, yet it lowered the annual value of savings. This was due to the fact that storage was being supplied, rather than displacing higher value fuels. Without storage, 85% to 90% of WECS value is dependent on the sell-back of surplus to the local utility in this application.

5.3.2.3 POULTRY - LAYERS

Pullets (birds less than one year of age) are introduced to the layer building at an age of 100 days, where they remain for a period of one year. Environmental conditions, energy demands, and egg production levels were analyzed on an hourly basis. 15,000 layers occupied the structure (adopted from Midwest Plan Service recommendations and previously presented in Chapter 2), and Sacramento, California served as the study site for layers, as it did in the case of the brooded layers. More supplemental heat was required for the layers than brooders. The reason for this, in spite of higher brooding temperature requirements, is because of the higher ventilation rates required in the layer operations for control of interior moisture levels. Consequently, larger quantities of internal heat energy were lost, thereby necessitating replacement by a supplemental energy source. Wind energy usage is studied hourly for two thermal storage sizes - 600 and 2000 gallons.

Break-even WECS annual values and levelized energy values in cents/kwh are shown in Figure 46. Since little space heating is required in California for this application, nearly all of the WECS value is derived from the thermal storage application. Results are shown in Figures 47 and 48 for the 600 and 2000 gallon storage sizes, respectively. The effect of the larger storage size is to increase the break-even value of energy somewhat, but to decrease the levelized annual value of the savings. The overall effect of storage is, however, to greatly enhance the value of WECS production - a fourfold increase for electric and a twofold value addition for petroleum fuels occurs.

5.3.2.4 POULTRY - TURKEYS

Wind energy could be applied to turkey operations for the initial brooding phase of production until the time that larger birds are moved to growing facilities, generally out of doors or to open shelters for safety and confinement. The turkey operations considered a flock size of 1000 birds, a brooding cycle of 25 days, and a northern location represented by the Minneapolis, Minnesota weather data. Heating energy could be used even if the cycle was initiated during the winter season, or in the application of heat to the brooders themselves. The structural design adopted from the Midwest Plan Service for this application was presented in Chapter 2. Wind energy usage is studied hourly for the two storage sizes of 500 and 2000 gallons.

The break-even values without storage are shown in Figure 49. Break-even values with 500 and 2000 gallons of storage are shown in Figures 50 and 51. Thermal storage led to an increase in the break-even value of energy by 10% to 15%, and the levelized annual value of savings

LEVELIZED BREAK-EVEN VALUES

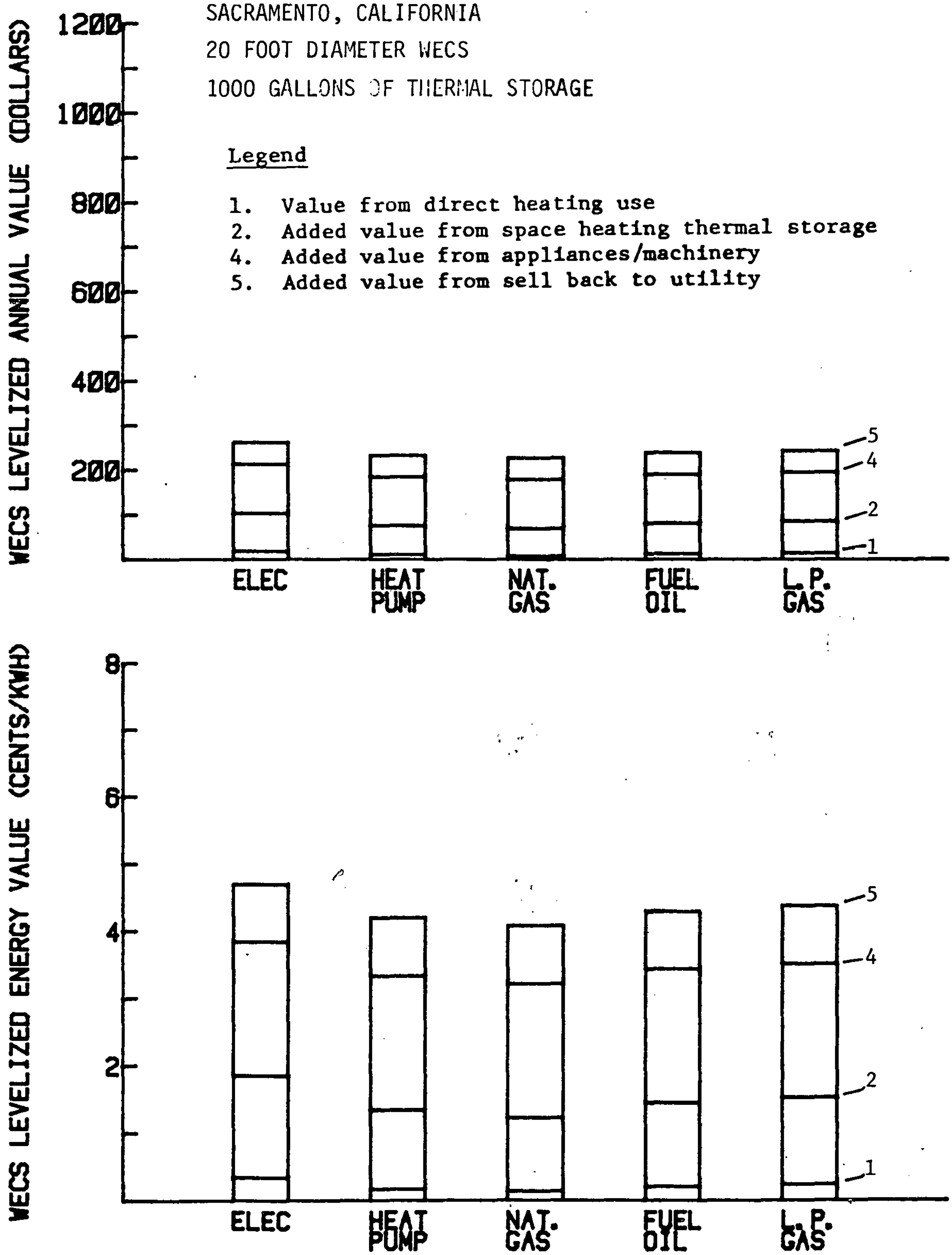
SACRAMENTO, CALIFORNIA

20 FOOT DIAMETER WECS

1000 GALLONS OF THERMAL STORAGE

Legend

1. Value from direct heating use
2. Added value from space heating thermal storage
4. Added value from appliances/machinery
5. Added value from sell back to utility



'igure 44 Poultry-Layer/Brooding With 1000 Gallons Of Thermal Storage

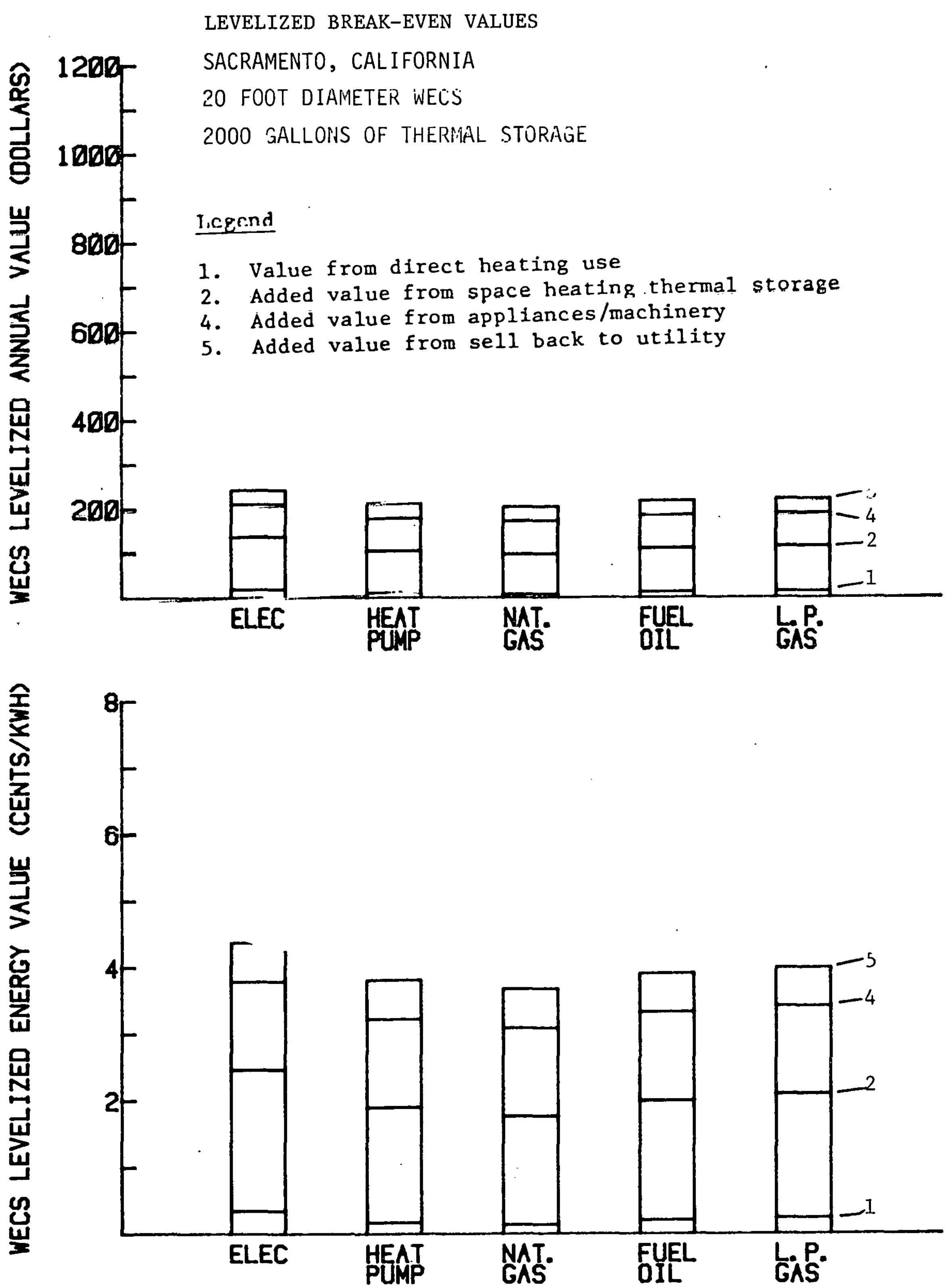


Figure 45 Poultry-Layer/Brooding With 2000 Gallons Of Thermal Storage

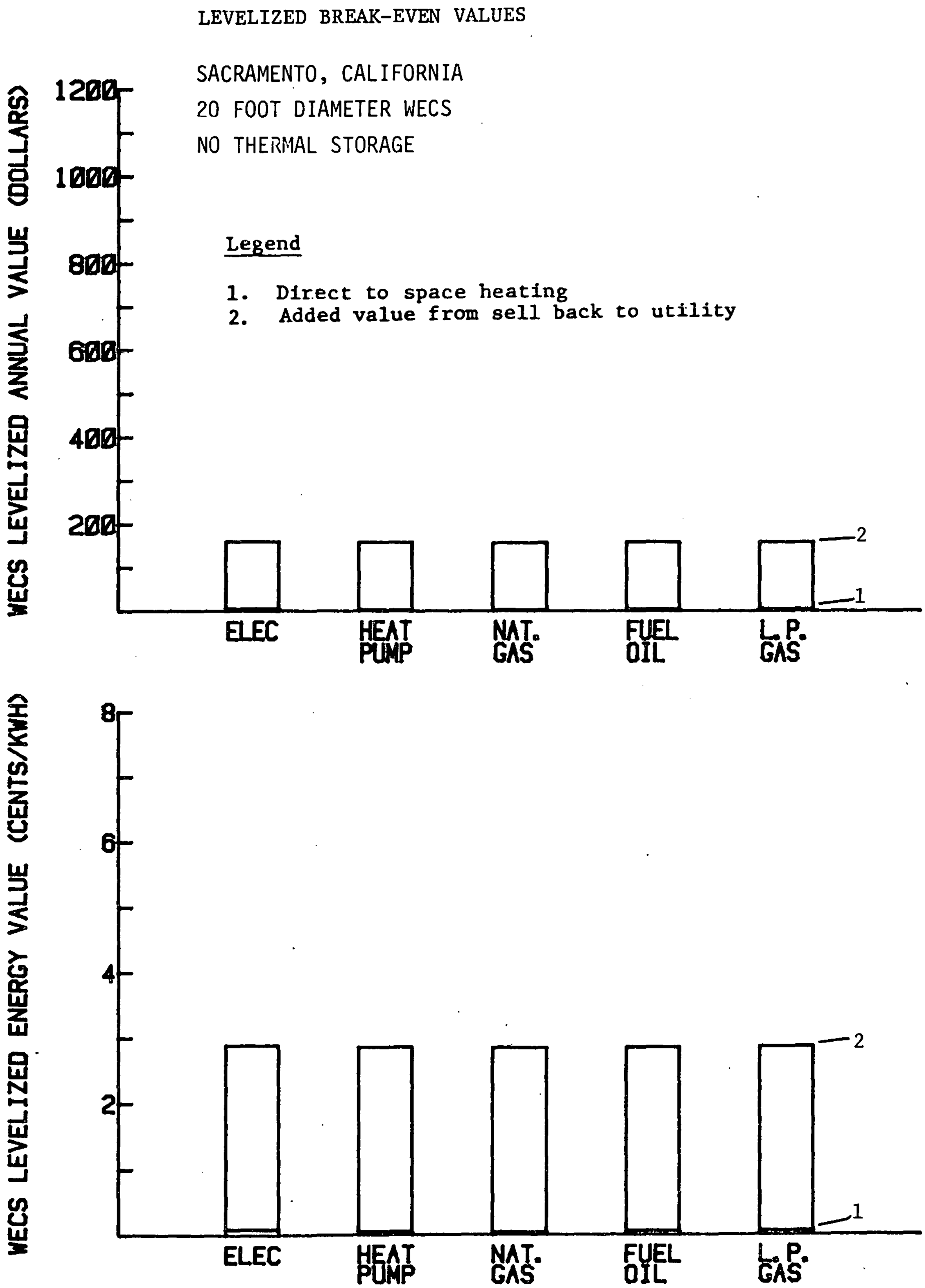


Figure 46 Poultry-Layers Without Thermal Storage

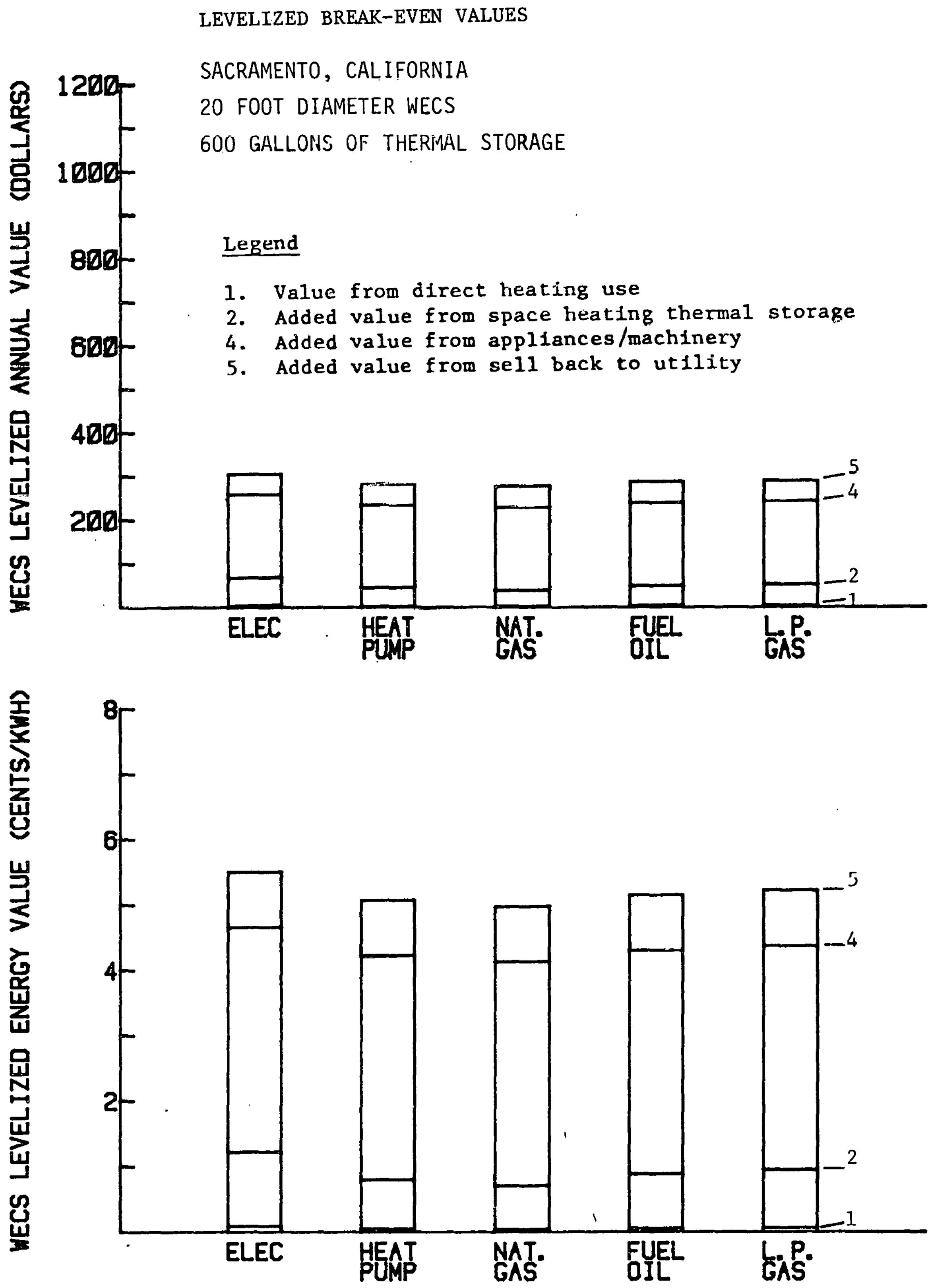


Figure 47 Poultry-Layers With 600 Gallons Of Thermal Storage

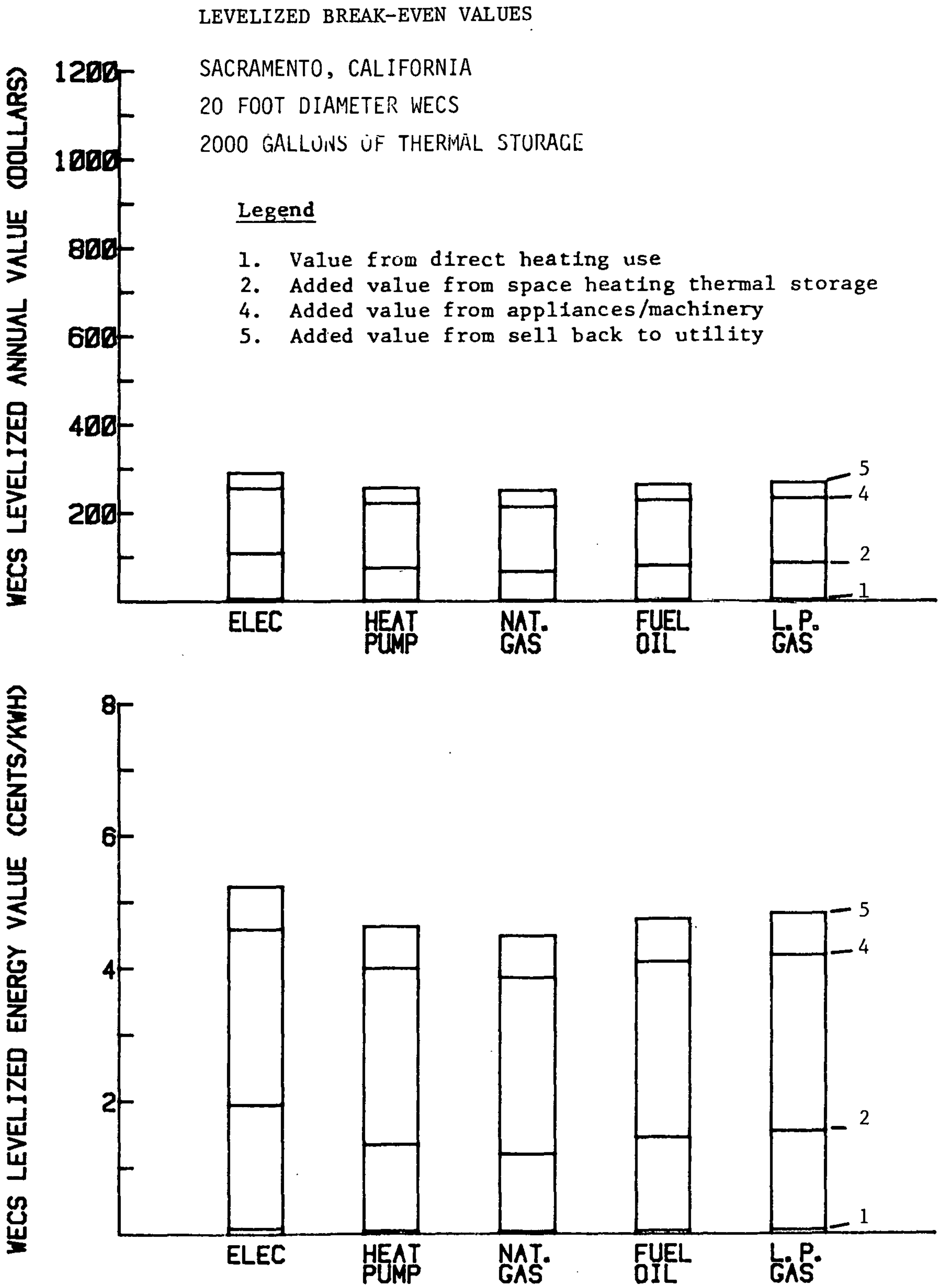


Figure 48 Poultry-Layers With 2000 Gallons Of Thermal Storage

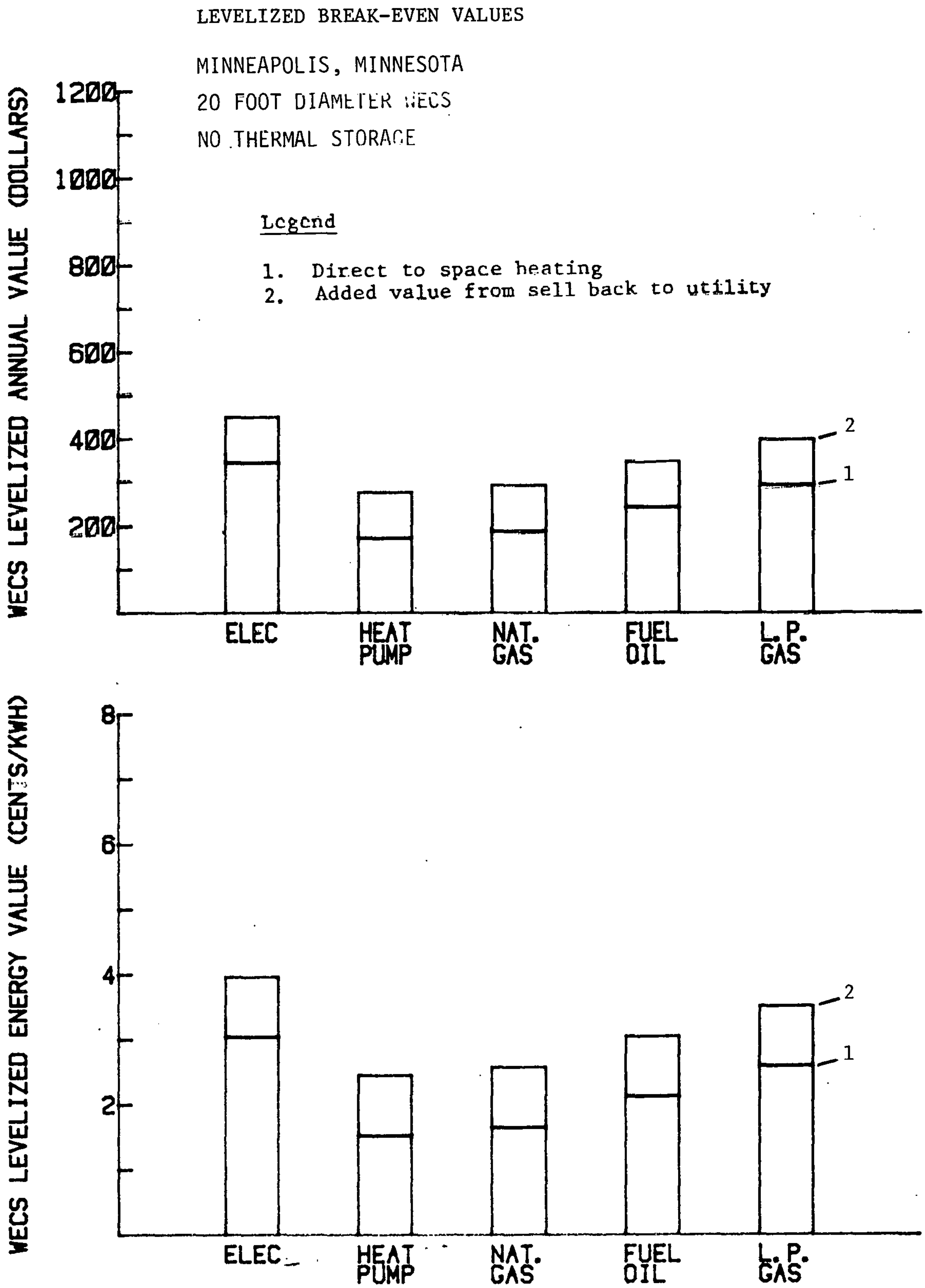
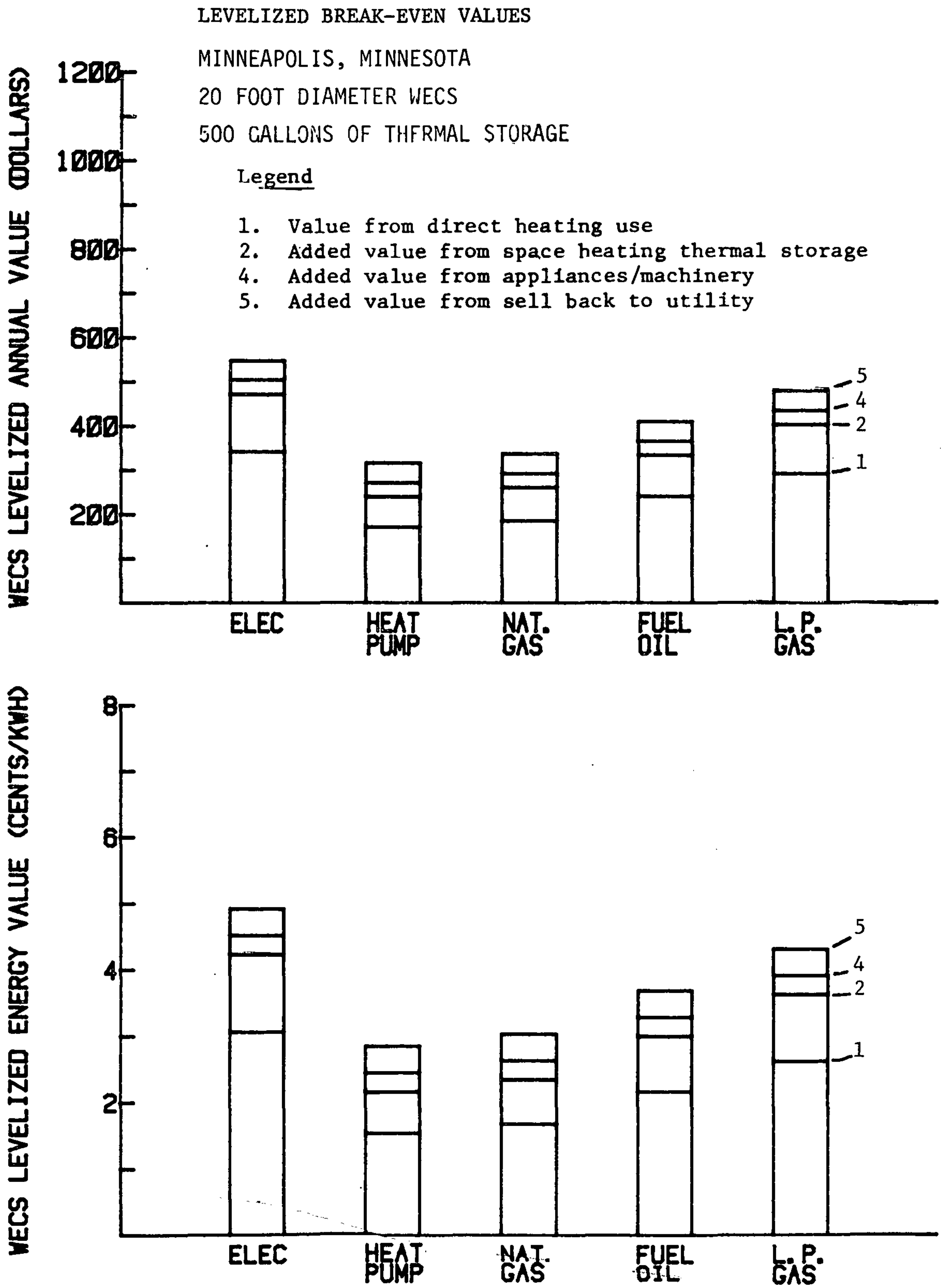


Figure 49 Poultry-Turkeys Without Thermal Storage



igure 50 Poultry-Turkeys With 500 Gallons Of Thermal Storage

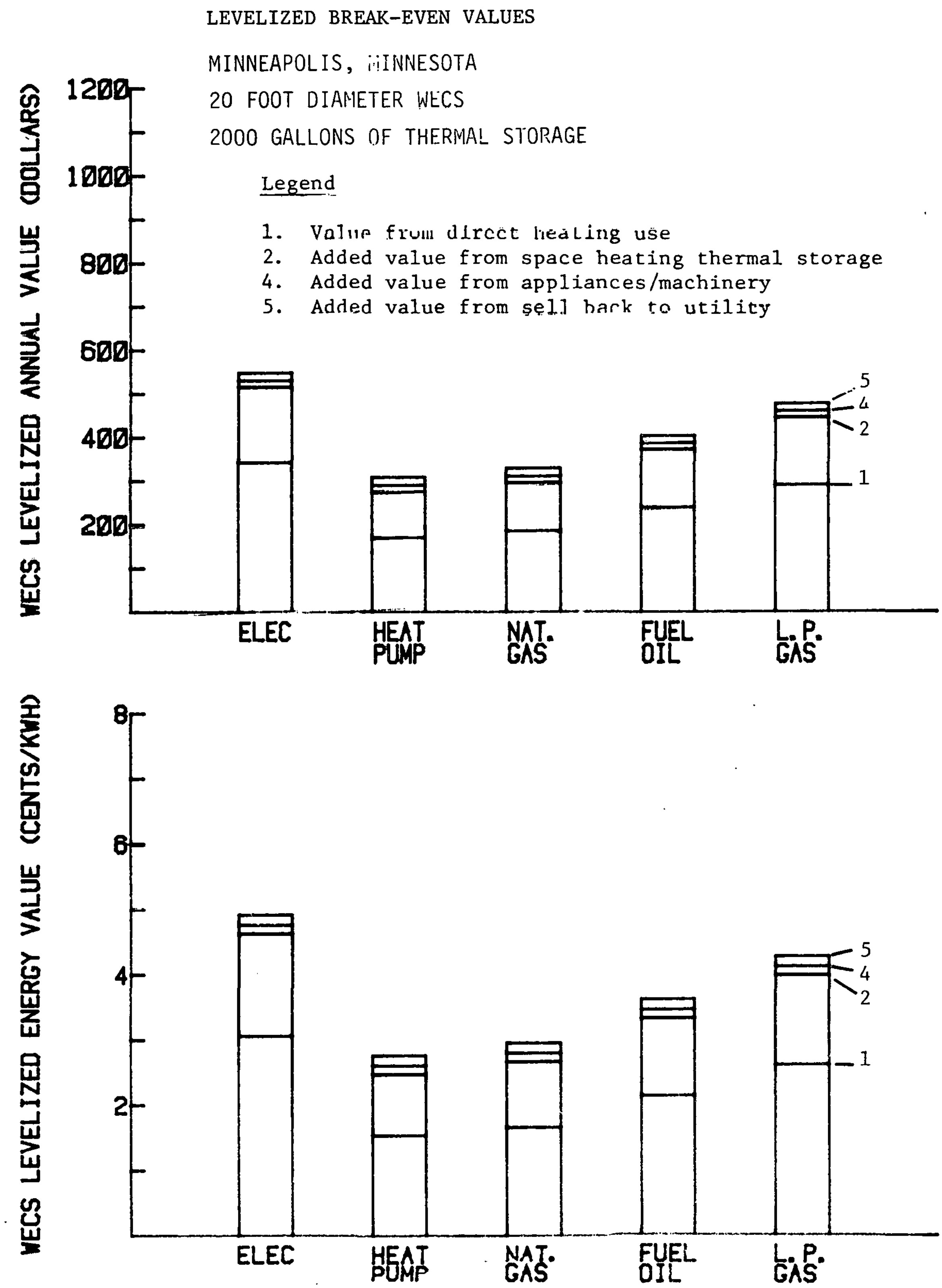


Figure 51 Poultry-Turkeys With 2000 Gallons Of Thermal Storage

by less than 10%. Storage contributed more than 50% additional value to WECS production than the value without storage.

5.3.2.5 SWINE FARROWING

Swine farrowing is an extensive operation, predominantly located in the Midwest; Iowa was thus chosen as the study location. Significant quantities of energy are required in this application. A 56 day production cycle is utilized in this function, after which the animals are transferred to growing and finishing facilities. The model structure housed nearly 130 animals and was based on the Midwest Plan Service design criteria (a design diagram is found in Chapter 2). Wind energy is analyzed on an hourly basis for thermal storage systems of 300 and 2000 gallons.

Break-even values for WECS without storage are shown in Figure 52. Without storage, approximately 50% of WECS value depends on the sell-back of surplus to the utilities. Break-even values for 300 and 2000 gallon thermal storage are shown in Figures 53 and 54. Storage causes an increase in the WECS value by 30% to 40% and a reduction in the value from sell-back to the utility to less than 33%.

5.3.2.6 SWINE GROWING AND FINISHING

The growing/finishing structure was also located in Iowa and contained nearly 130 animals. Farrowed swine replace half the house every 56 days, with the finishing half marketed. Energy demand, though substantial, is less than that required by farrowing applications. Wind energy utilization potential was analyzed on an hourly basis to determine actual wind usage with thermal storage facilities of 100 and 2000 gallons.

WECS break-even values without storage are shown in Figure 55. Due to the larger animal sizes and small space heating requirements, little value is available from WECS production used to displace space heating needs alone. Break-even values for 100 and 2000 gallon thermal storage are shown in Figures 56 and 57. This application did not show effective use of wind energy, and more than 50% to 75% of the WECS value depended on sell-back to the local utility. The 2000 gallon storage showed a relative improvement in break-even values.

5.3.2.7 DAIRY

Dairying facilities afford an energy option not present in the other applications - hot water heating. Large volumes of heated water are required daily; however, space heating demands are relatively minimal. Without the hot water heating option (no storage), little available wind energy was utilized. Including the hot water use, this case became an excellent application of wind energy for the 100 cow herd evaluated. The operation size and structure were adopted from the Midwest Plan Service. Wind energy use was analyzed for two thermal storage sizes (300 and 2000 gallons), and one hot water preheat storage tank of 600 gallons was included.

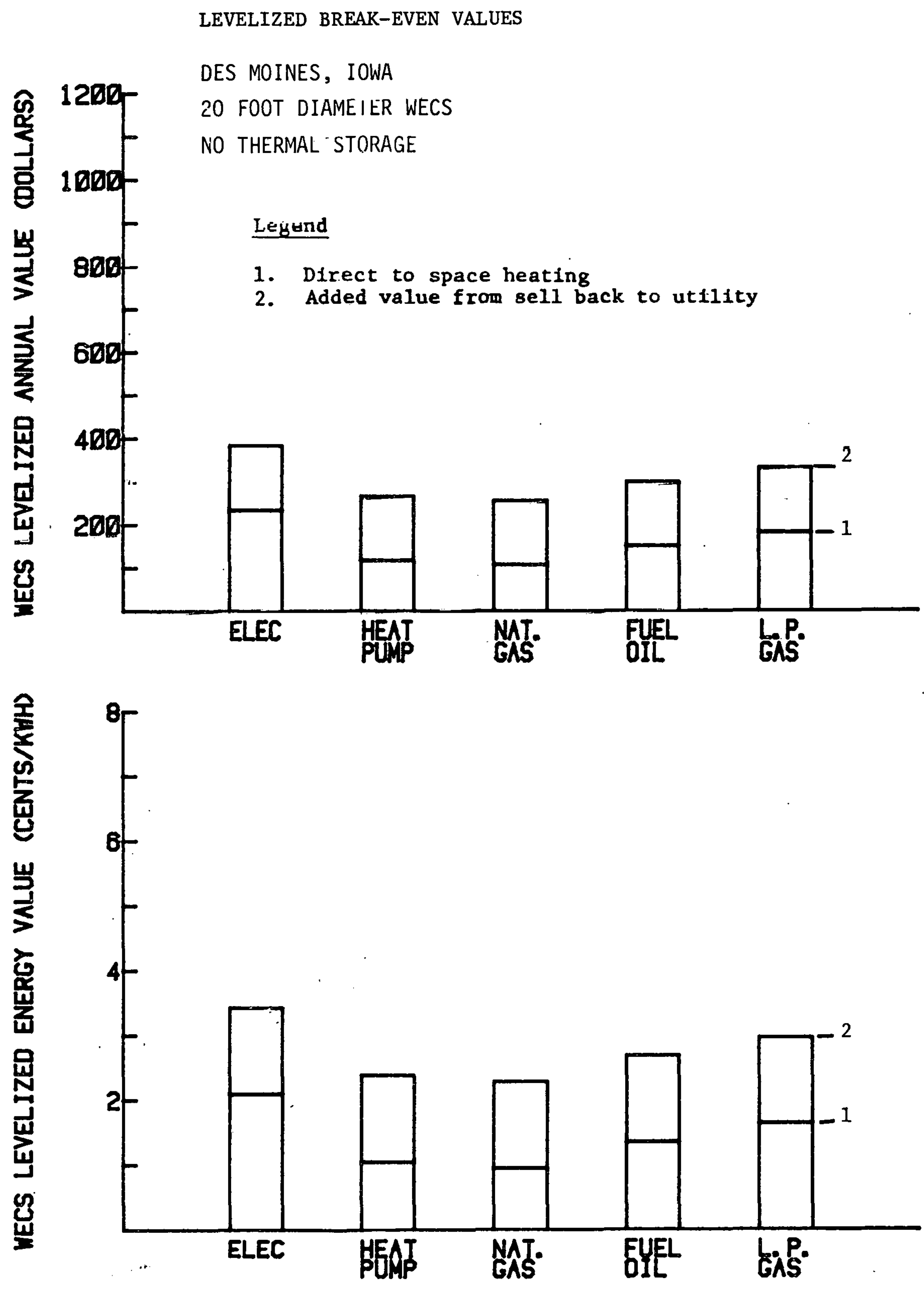


Figure 52 Swine Farrowing Without Thermal Storage

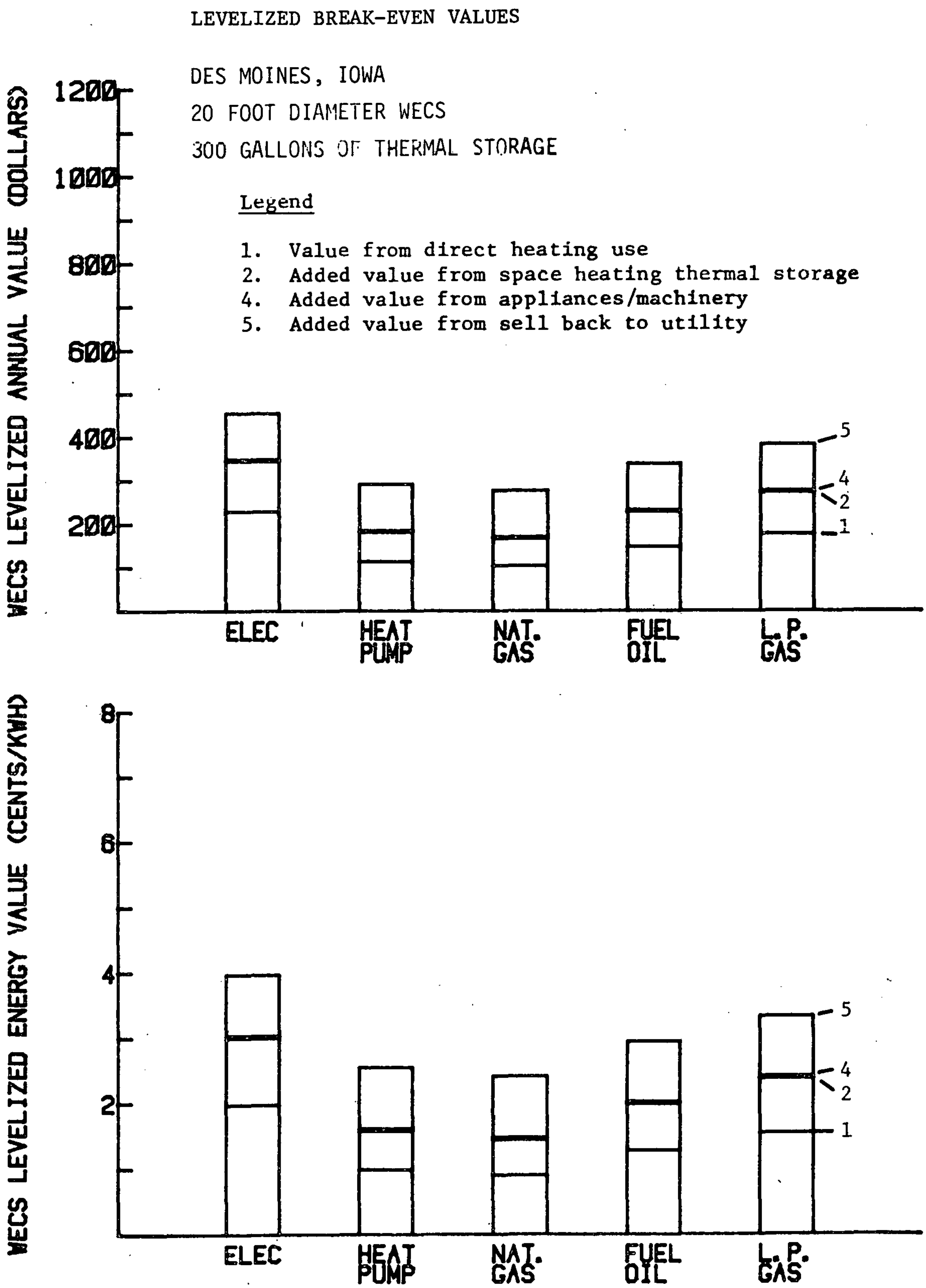


Figure 53 Swine Farrowing With 300 Gallons Of Thermal Storage

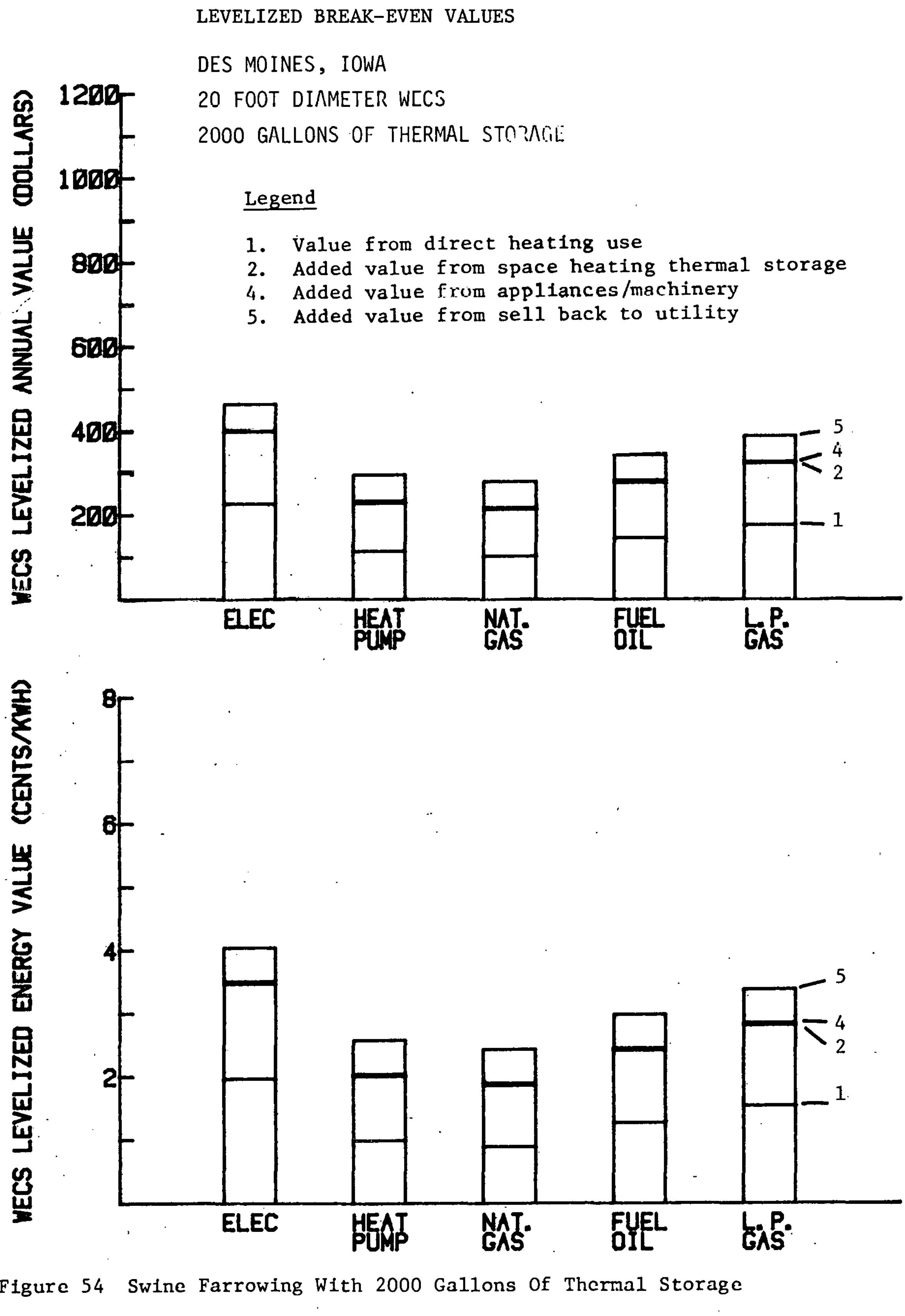


Figure 54 Swine Farrowing With 2000 Gallons Of Thermal Storage

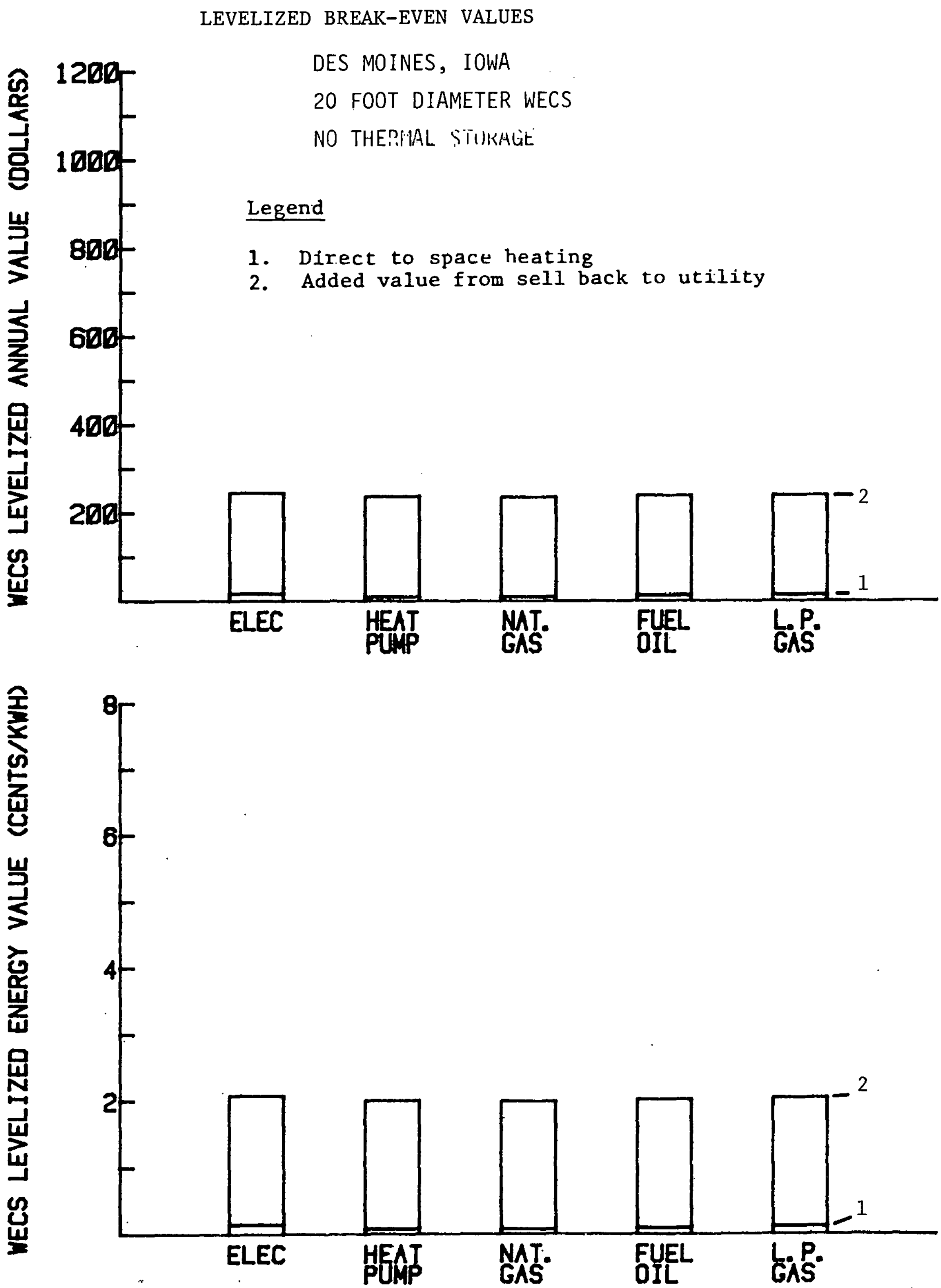


Figure 55 Swine Growing/Finishing Without Thermal Storage

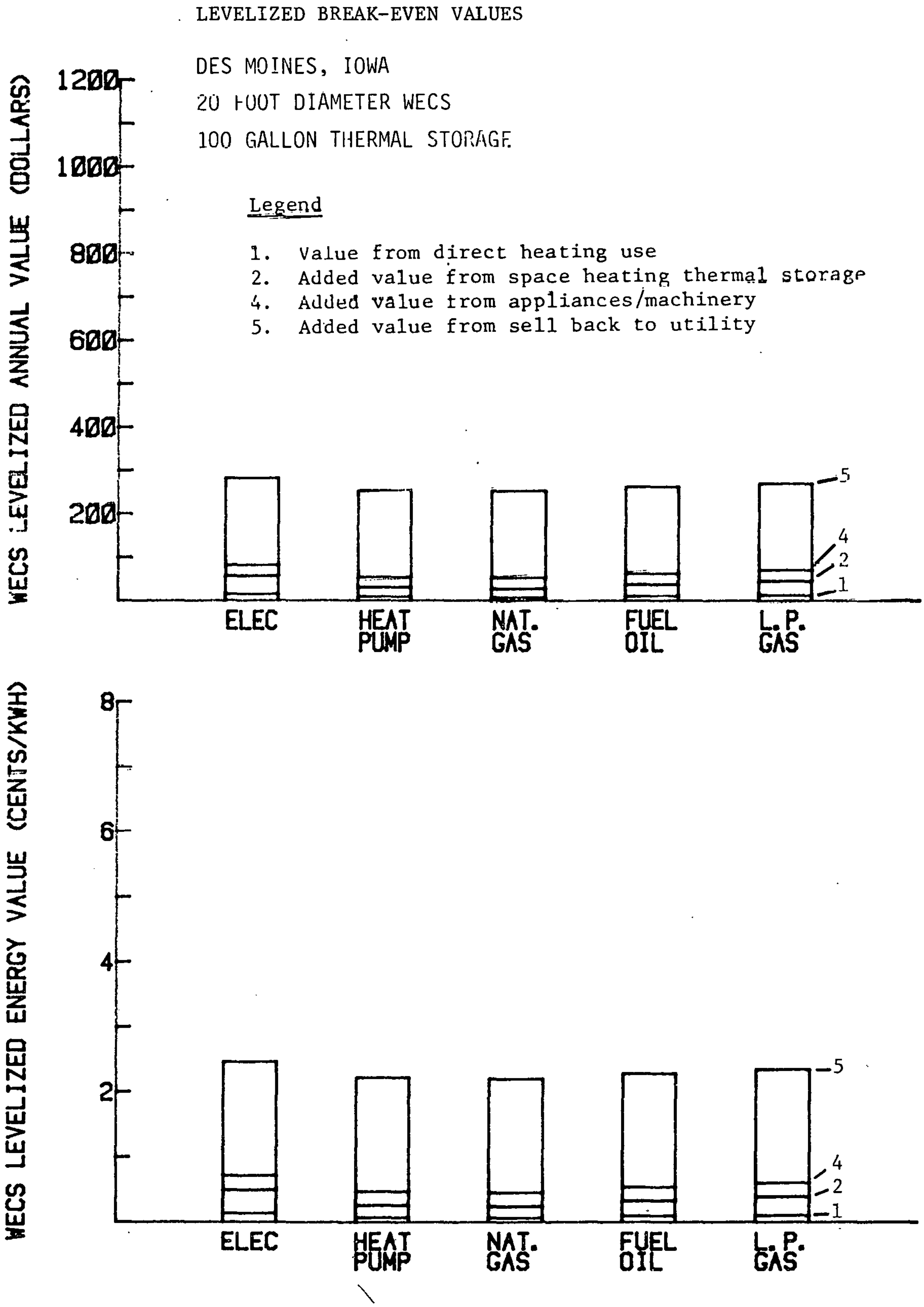


Figure 56 Swine Growing/Finishing With 100 Gallons of Thermal Storage

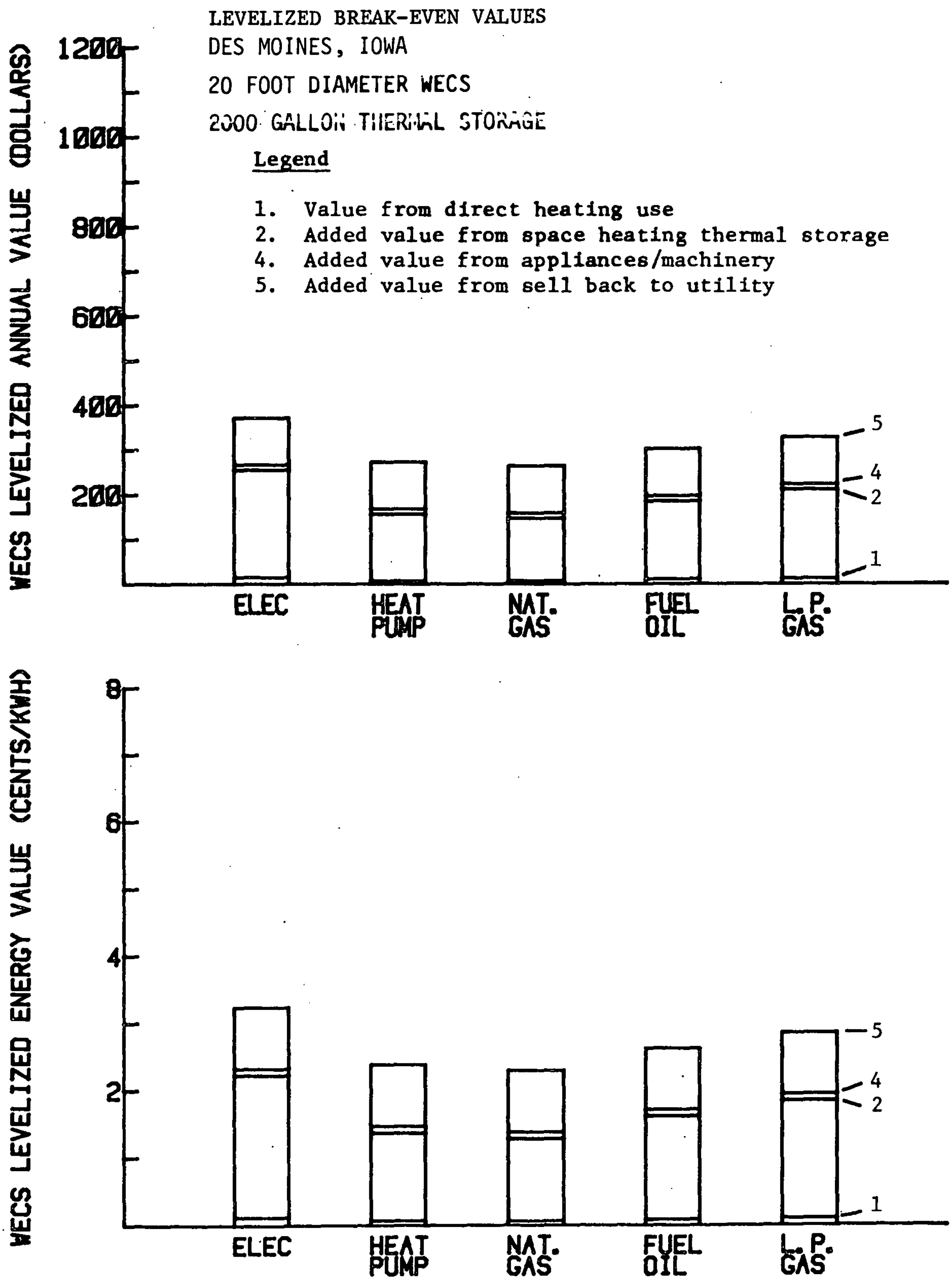


Figure 57 Swine Growing and Finishing With 2000 Gallons Of Thermal Storage

Figure 58 shows that, without storage and multiple use of WECS production, nearly all WECS energy would depend on sell-back to the utility for value. Break-even values with 300 and 2000 gallons of space heating thermal storage and 600 gallons of water preheat are shown in Figures 59 and 60. The effect of storage is to triple the levelized break-even values of WECS production, showing all WECS production was used for hot water and space heating for the 20 foot diameter WECS system.

5.3.2.8 LAMBING

Warm confinement lambing is one of the least extensive of the operations surveyed and also uses little space heating energy. The operation model consisted of a 300 lamb facility and a forty day lambing cycle. The operation was modeled because of its relative economic contribution to overall agricultural value.

The lambing operation results are shown in Figures 61 through 63. Unless the lambing structure can be considered together with other farm buildings, nearly all of the WECS production would be surplus, dependent on value from sell-back to the utility.

5.4 SYNOPSIS

This task has estimated the break-even costs of wind-powered heating systems with heating systems in farmhouses and farm buildings currently found in U. S. agriculture. Economic analysis included the value added to the WECS from other electric uses (i.e. appliances and machinery, sell-back of surplus), and more importantly, the value added with thermal storage for space heating and hot water needs. The competing fuels considered for break-even determination were electricity, natural gas, bottle gas and fuel oil, and the costs of these fuels were based on localized data. For the selected farmhouses and farm buildings, represented at all the chosen geographic locations, it was shown that the WECS break-even value is substantially increased with thermal storage and thus makes the WECS a more economically feasible energy alternative.

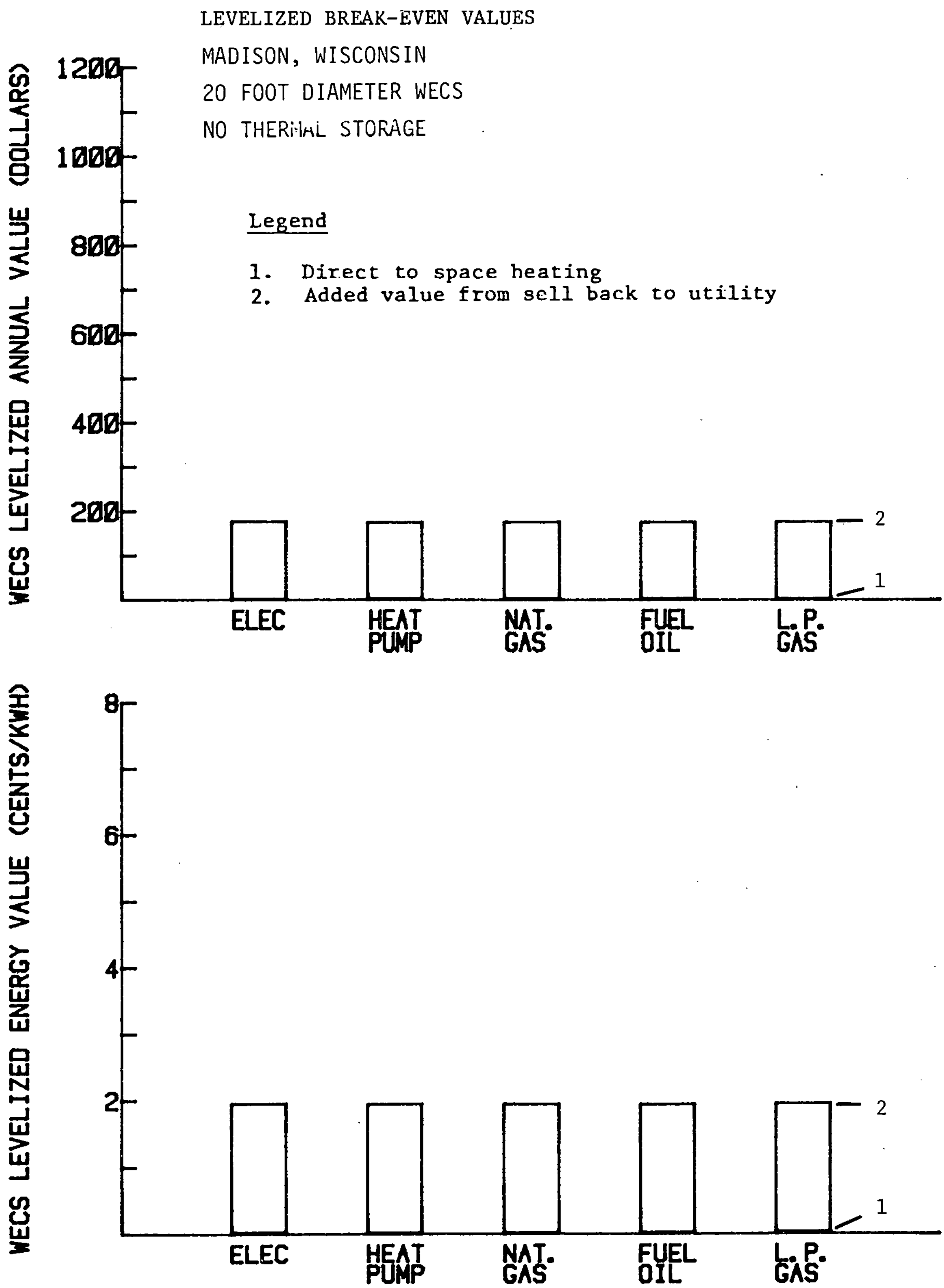


Figure 58 Dairy Without Thermal Storage

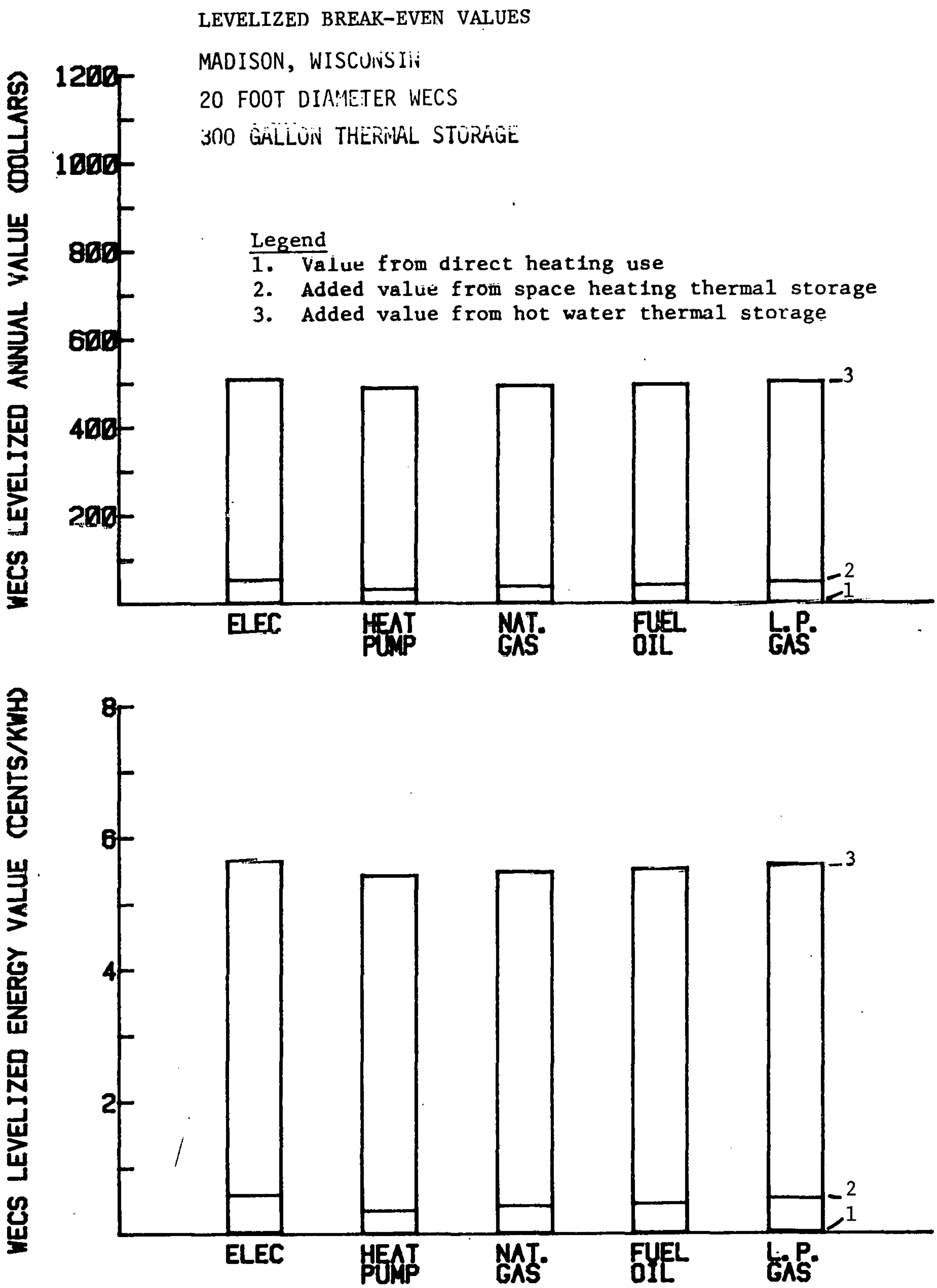
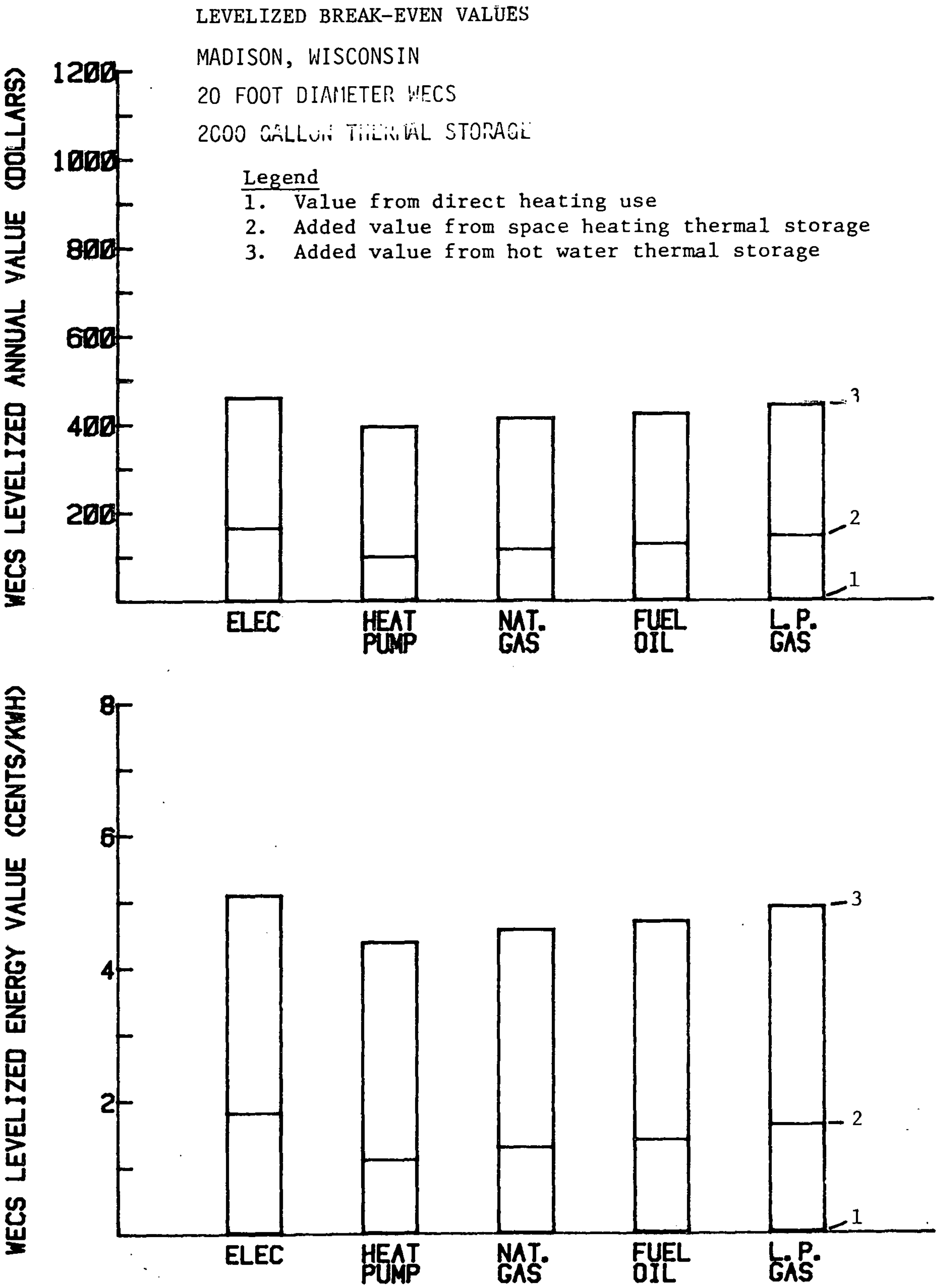


Figure 59 Dairy With 300 Gallons Of Thermal Storage



gure 60 Dairy With 2000 Gallons Of Thermal Storage

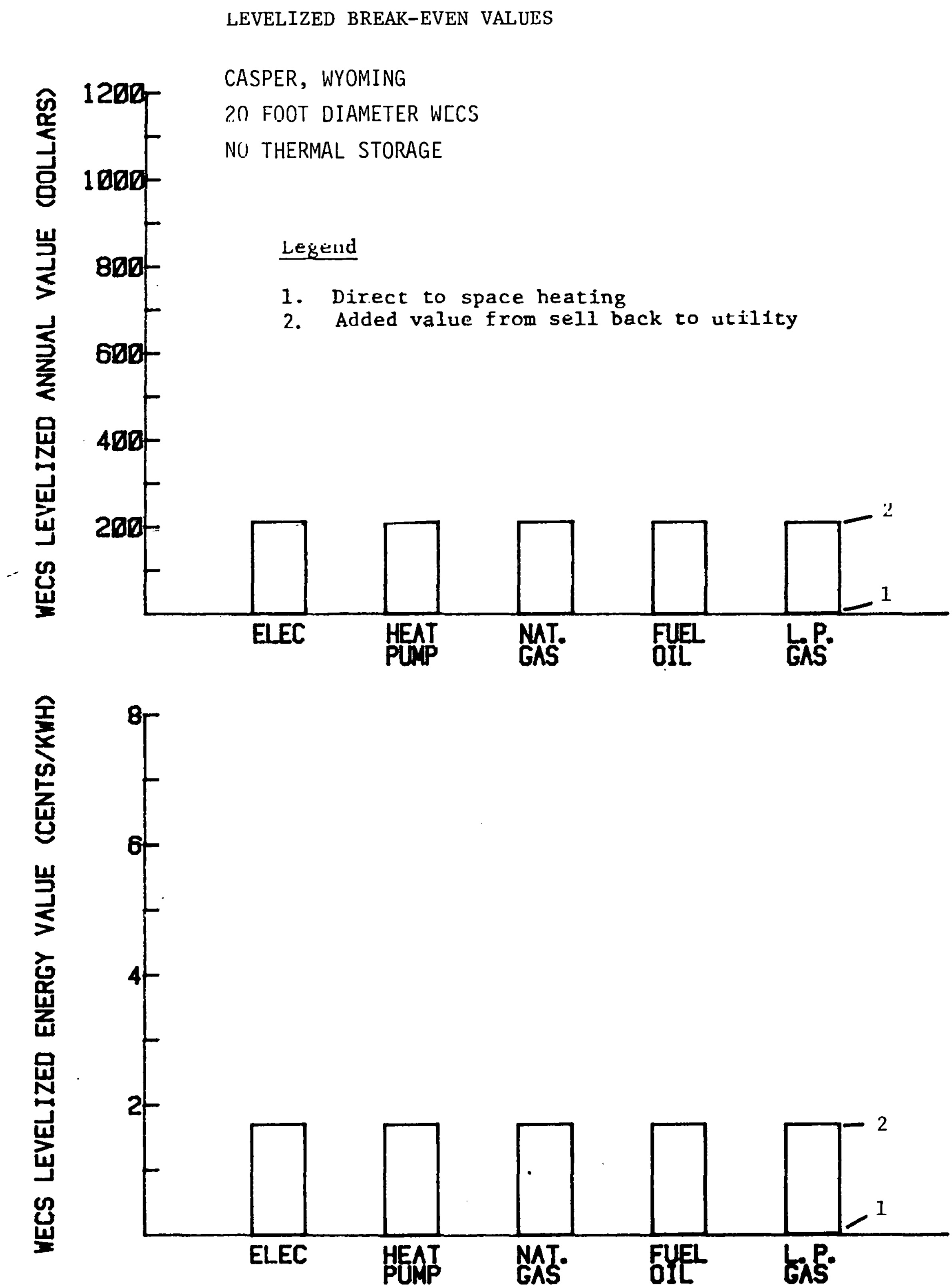


Figure 61 Lambing Without Thermal Storage

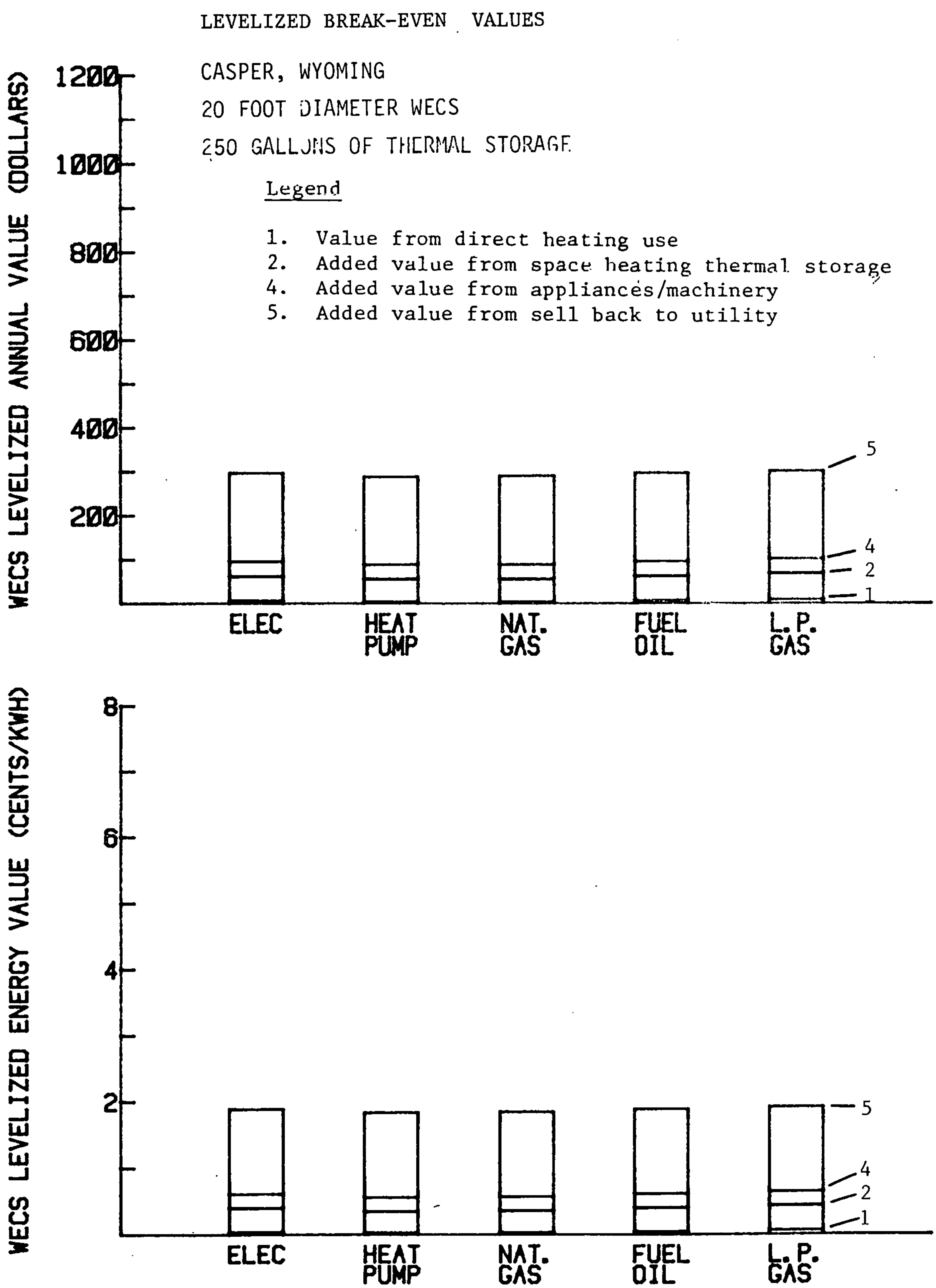


Figure 62 Lambing With 250 Gallons of Thermal Storage

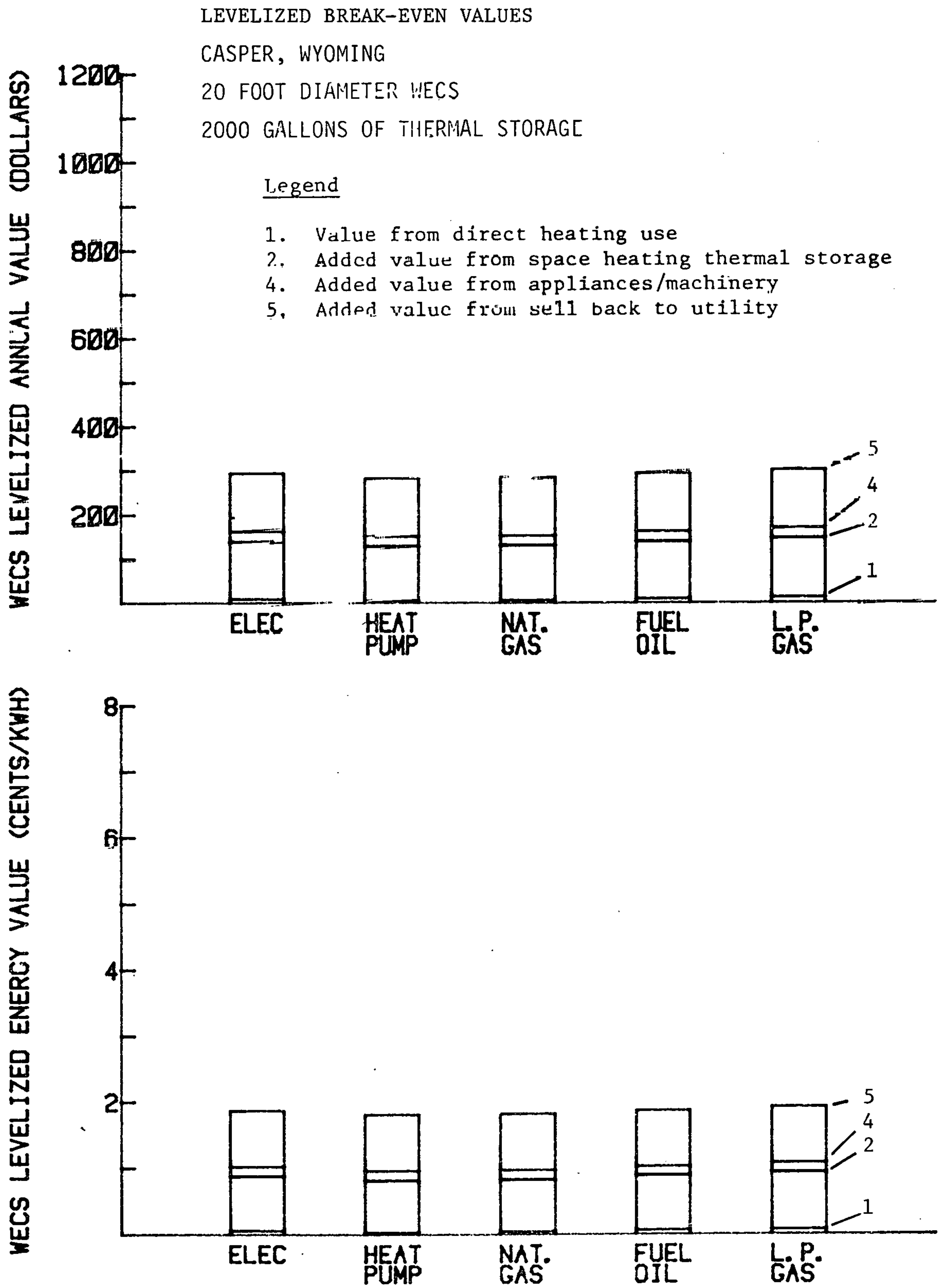


Figure 63 Lambing With 2000 Gallons Of Thermal Storage

6.0 AGRICULTURAL HEATING SYSTEMS AND HEATING COSTS SURVEY

6.1 INTRODUCTION

The objective of this survey is twofold: to estimate the size distribution of the heating units presently used in agriculture, and to determine the levelized annual cost of heating with present energy sources.

Since more than 90% of agricultural heating energy is used in the farmhouse, a detailed national survey was concentrated on farmhouse heating systems. Typical farm building heating energy costs were developed from the hour by hour analyses of the eight selected farm buildings located at the agricultural production centers throughout the United States.

Heating fuels used in occupied rural buildings, including farmhouses, were surveyed in 1970 and 1974 by the Departments of Commerce and Agriculture. From the numbers of rural units using each heating fuel type, the distribution of farmhouse heating system sizes was defined on a state by state basis. Fuels considered included electricity, fuel oil, natural gas, and LP (bottle gas).

Annual heating costs were estimated on a state by state basis using design temperatures and degree days recommended by ASHRAE, farmhouse models developed from the survey of rural housing, and DOE summaries of regional fuel costs. The heating costs were levelized using a 25 year life cycle, a 10% discount rate, and future energy price increases reported by DOE. Furnace efficiencies were employed to describe electric resistance, electric heat pump, natural gas, fuel oil, and LP furnace types.

The following paragraphs present the distribution of heating system sizes, estimated annual heating costs, and subsequent correlations to regions of similar heating requirements and wind energy densities. Multiple levels of energy costs were examined by using the different heating fuels, local fuel costs, and alternative future price values.

6.2 AGRICULTURAL HEATING SYSTEM SIZE SURVEY

Heating system sizes were estimated using the farmhouse thermal and structural models developed from the Department of Commerce Housing data, local design temperatures, state by state distribution of farmhouses reported by the national housing data, and sizing procedures recommended by ASHRAE and presented below.

It is noted that for this study a farmhouse was defined as any rural home reported by the national references, rather than assuming that one farmhouse would be associated with each farm operation as defined by USDA economic statistics. This approach was believed to better represent the total potential for wind energy applications in rural areas. It resulted in nearly 15,000,000 rural homes, compared to the approximately 2,500,000 farms reported from the USDA economic statistics.

ASHRAE recommends that heating systems can be sized, considering both conduction and infiltration losses by:

(ASHRAE, Fundamentals-1977), Chapter 24)

$$q_t = q + q_s$$

$$q_t = AU(t_i - t_o) + .018\ \dot{V}(t_i - t_o)F$$

where:

q_t = total heat loss due to conduction in Btu per hour

q = heat transfer through surfaces, Btu per hour

q_s = heat loss due to infiltration, Btu per hour

A = area of exposed surface, square feet

U = air to air heat transfer coefficient, Btu per hour per square foot per degree Fahrenheit

t_i = indoor air temperature near surface involved, Fahrenheit

t_o = outdoor air temperature, or temperature of adjacent unheated air space, Fahrenheit

$\dot{V}$ = volume of outdoor air entering per hour, ft^3

F = an oversizing factor, taken as 1.2 for this study

The above sizing procedure was used consistently for all evaluations of this section using the three farmhouse models and the state by state housing density, degree days and design temperatures.

6.2.1 HEATING SYSTEM SIZE DISTRIBUTION BY WIND REGIME

An aggregate distribution of farmhouse heating system sizes for all wind regimes reported for the United States is shown in Figure 64. The wind speed for each site is referenced to 65.62 feet (20 meters) as directed by USDA for this study. The figures show the number of rural homes versus the rated furnace size. The furnace ratings are presented both in units of thousands of BTU per hour and the equivalent kwh/h electrical value. The analysis shows that furnace peak rating generally increases with annual average wind speed.

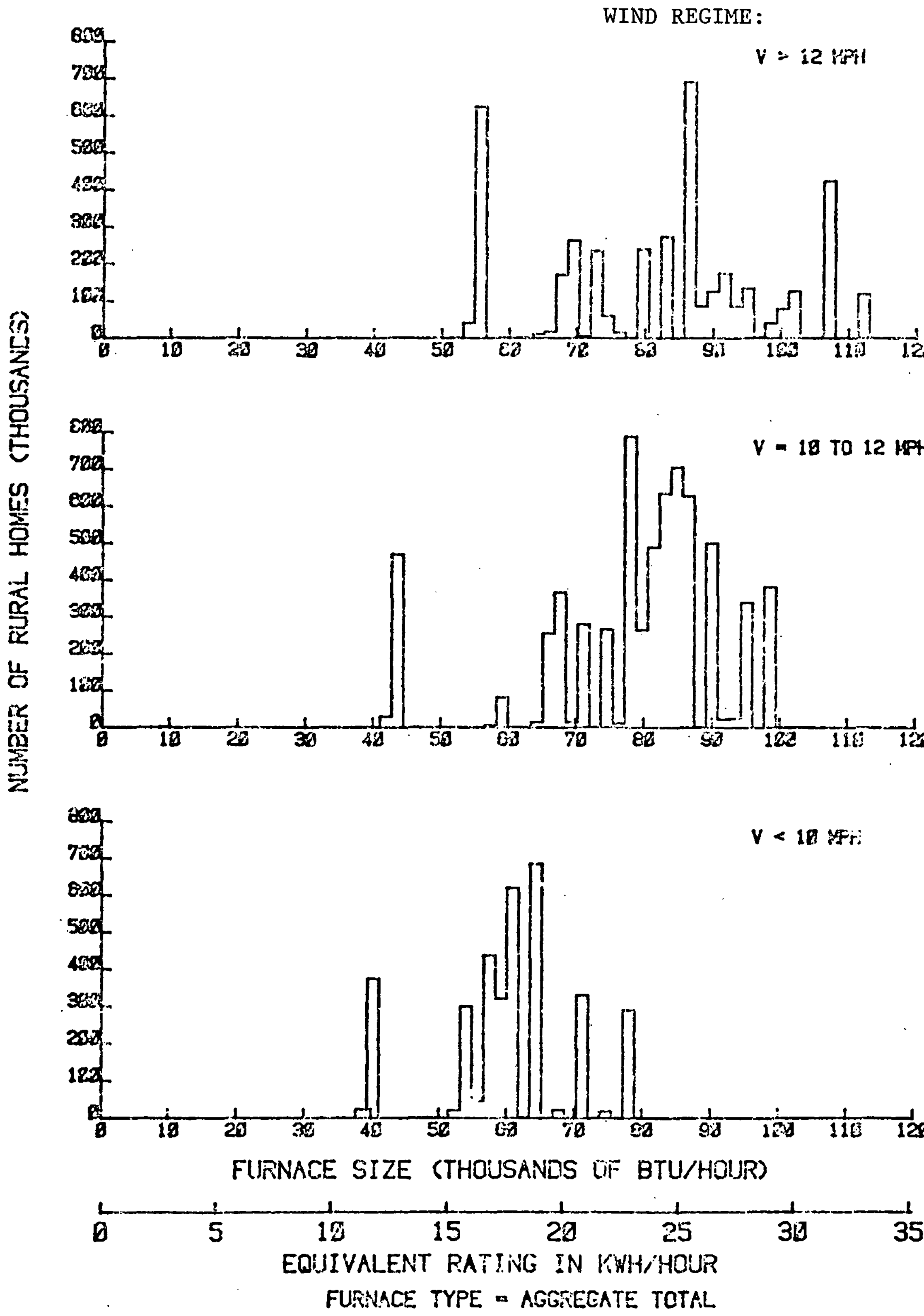


Figure 64 Distribution Of The Sizes Of All Farmhouse Heating Systems

Excluding the lowest 10% of the distribution of the furnace sizes found, a summary of the aggregate sizing analysis is given by:

Mean Annual Wind Speed at 65.62 Foot Height	Farmhouse Heating System Size-Peak Rating BTU/hour	Kwh/hour Equivalent
< 10	55,000 - 78,000	16 - 23
10 - 12	62,500 - 99,000	18 - 29
> 12	67,500 - 112,000	20 - 33

Distribution of heating system sizes for individual furnace types, including electric resistance, heat pump, natural gas, LP gas and fuel oil, are presented in Figures 65 through 69, according to selected wind regimes. These analyses also demonstrate the general increase in heating system peak rating with annual mean wind speed.

An overall comparison of furnace sizes for each fuel type is presented in Table 79, together with the median for each furnace type. A review of the 1970 and 1974 Department of Commerce data bases did not indicate significant changes in the relative proportion of furnace types during the 4 year period.

6.2.2 HEATING SYSTEM SIZES AND HEATING DEGREE DAY REQUIREMENTS

Additional surveys compared the distribution of estimated heating system peak size with state by state average heating degree days. Heating degree days recommended by ASHRAE for each state are summarized in Table 80.

Using both thermal envelopes selected to represent older and modern farmhouses, and estimated infiltration losses (derived from ASHRAE sizing procedures and average design temperatures), an array of peak heating system sizes with heating degree days is presented in Figure 70. This figure displays the overall relationship of heating system size and heating degree days and illustrates a general increase of heating size with degree days. Moreover, the older farmhouse exhibited a slightly higher peak heating system size due to its lower insulation and greater infiltration.

Although data is scattered, an increase in heating degree days with annual average wind speed is also shown in Figure 71. Thus, it can be expected that greater availability of energy production from a WECS will be correlated with greater heating energy requirements.

6.2.3 HEATING SYSTEM TYPES AND HEATING DEGREE DAYS

An analysis of the numbers of farmhouses using selected furnace types in regions of similar heating requirements and wind resource availability indicated the types of furnaces most likely to be involved with potential wind-powered heating systems. An aggregate summary of the distribution of heating system types among farmhouses is given below, based on the 1970 and 1974 Departments of Commerce and Agriculture Census of Housing:

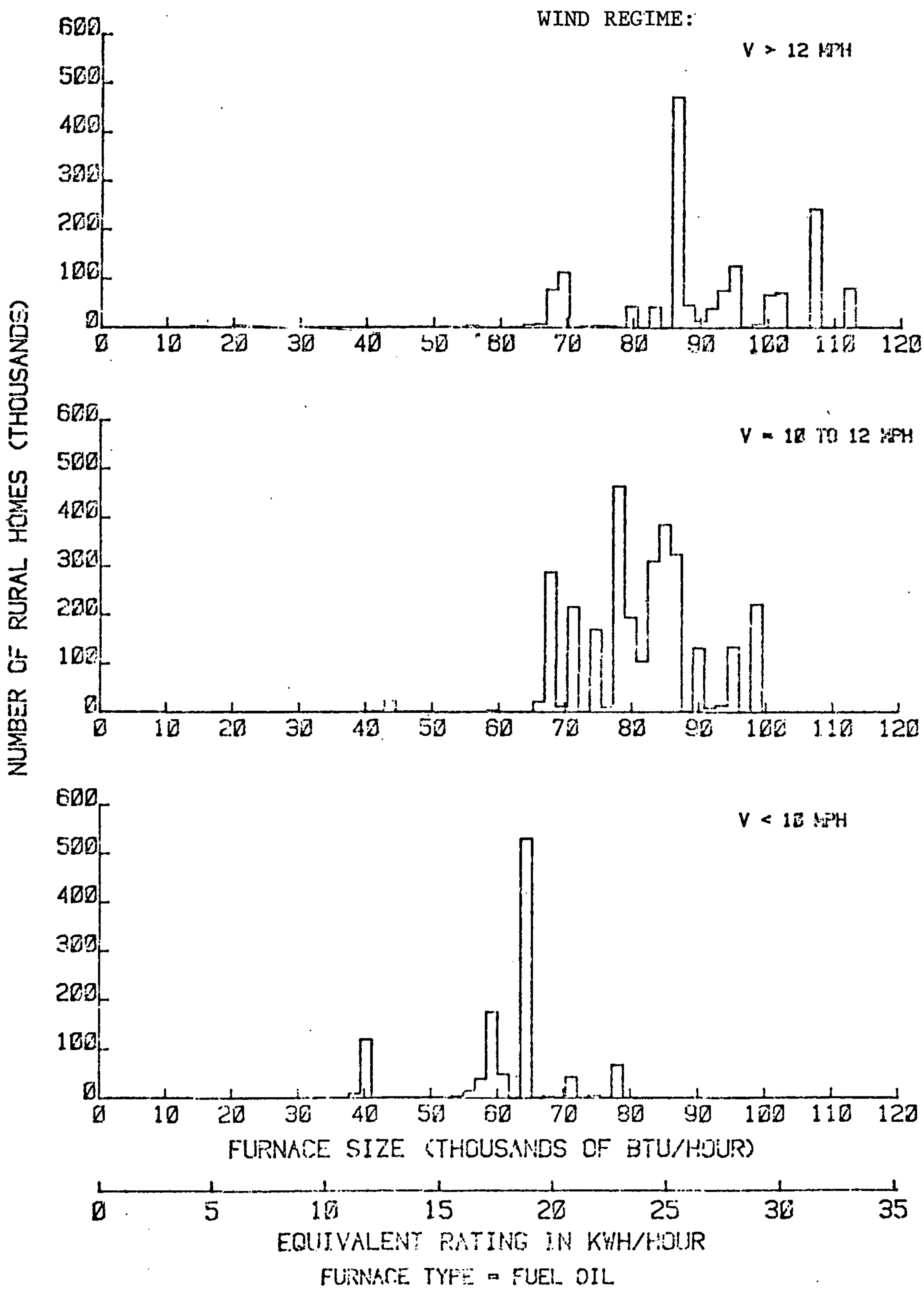


Figure 65 Distribution of Fuel Oil Heating System Sizes For Farmhouses

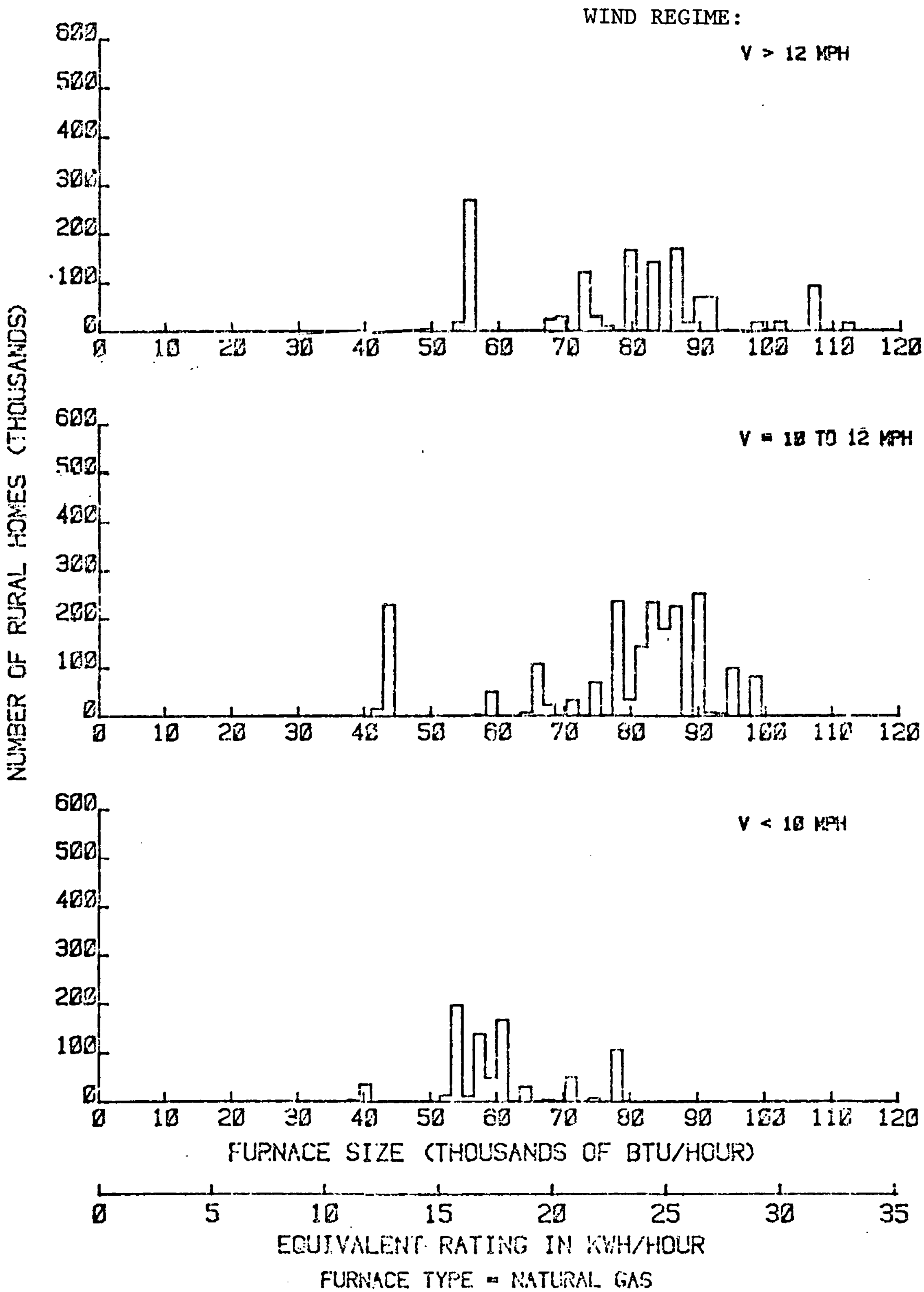


Figure 66 Distribution of Natural Gas Heating System Sizes For Farmhous

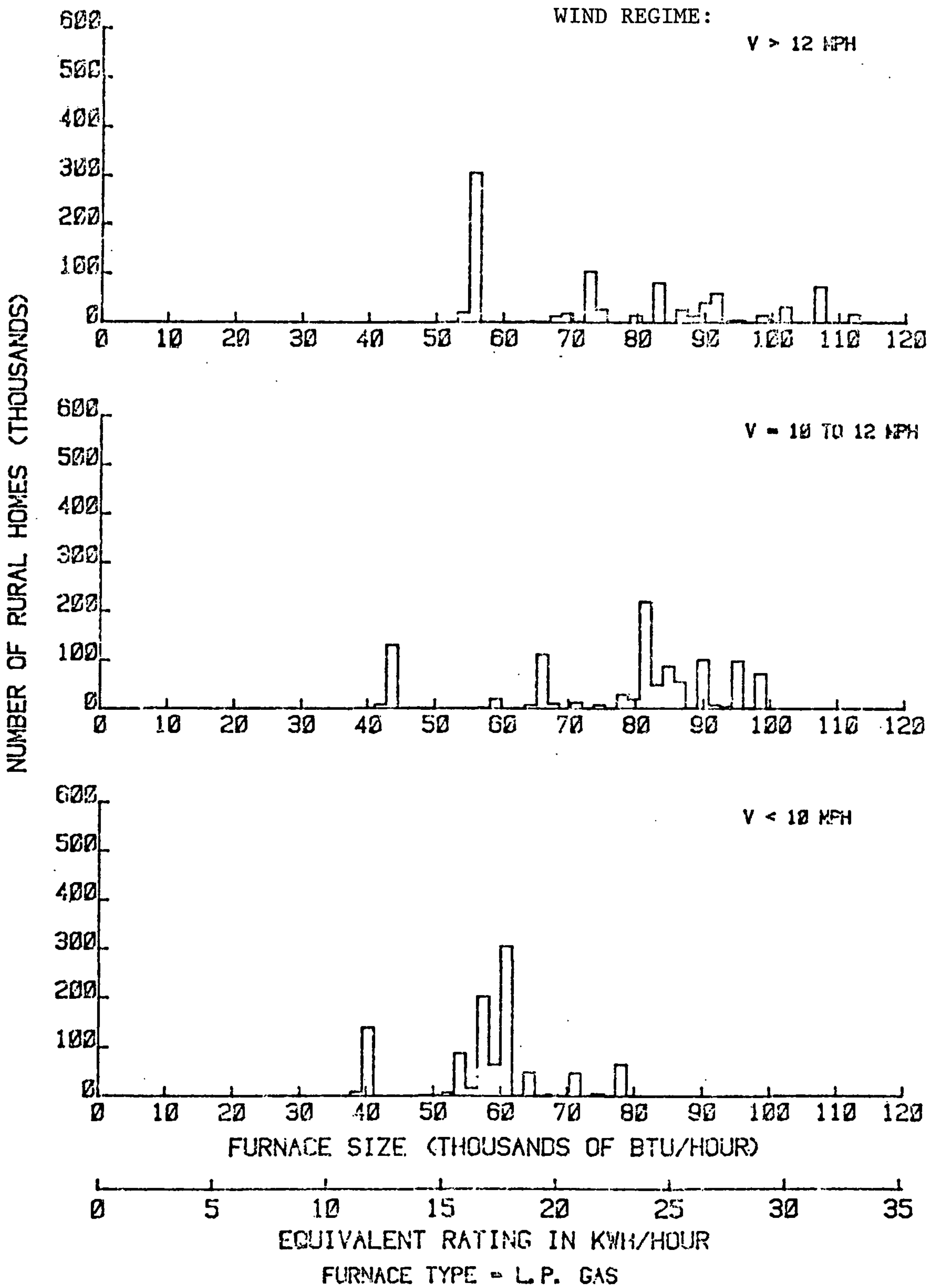


Figure 67 Distribution of LP Gas Heating System Sizes For Farmhouses

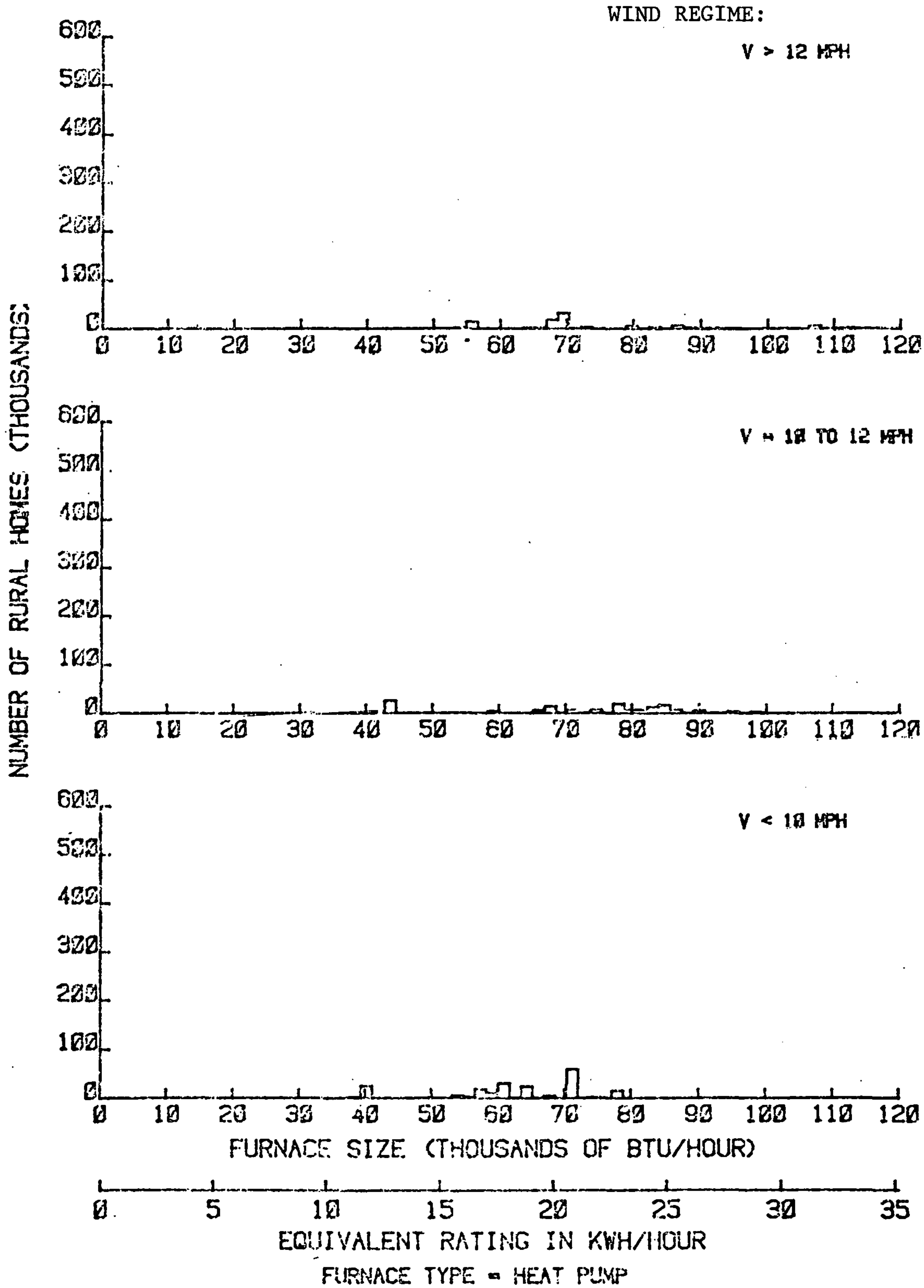


Figure 68 Distribution of Heat Pump Heating System Sizes For Farmhous

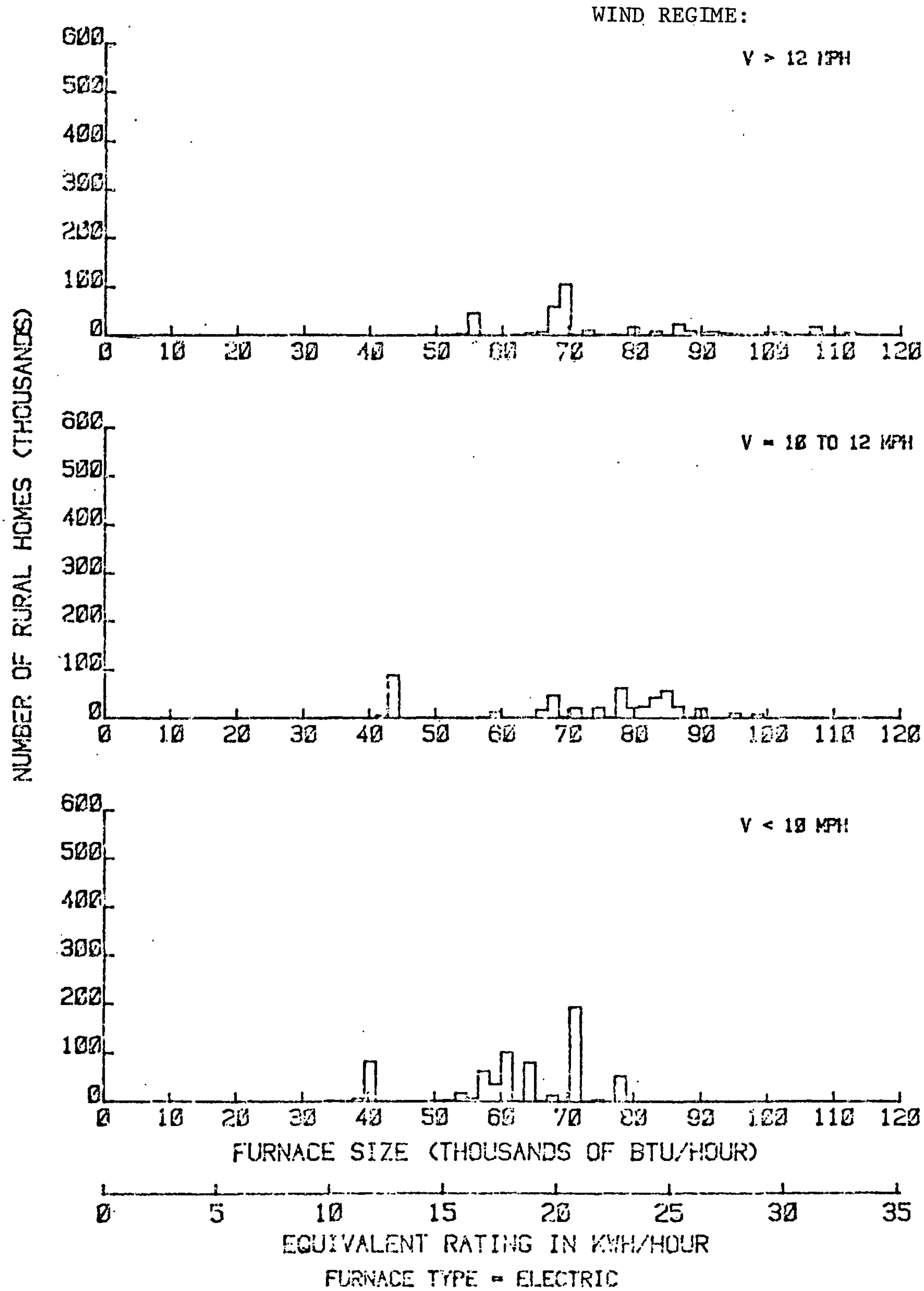


Figure 69 Distribution of Electric Resistance Heating System Sizes For Farmhouses

Fuel Type	Peak Heating Requirement BTU/Hour								
	Low Wind Regime			Medium Wind Regime			High Wind Regime		
	Minimum Rating	Median Rating	Maximum Rating	Minimum Rating	Median Rating	Maximum Rating	Minimum Rating	Median Rating	Maximum Rating
Electric-Resistance	40,000	60,000	78,000	42,000	70,000	99,000	55,000	70,000	108,000
Electric-Heat Pump	40,000	60,000	78,000	42,000	70,000	99,000	55,000	70,000	108,000
Natural Gas	40,000	60,000	78,000	42,000	84,000	99,000	52,000	85,000	112,000
LP Gas	38,000	60,000	78,000	42,000	82,000	99,000	55,000	82,000	112,000
Fuel Oil	38,000	62,000	78,000	68,000	85,000	99,000	68,000	92,000	112,000

Table 79 Comparative Summary of Typical Farmhouse Heating Requirements Not Considering Furnace Efficiency By Wind Regime

	Wind Speed mph @ 65.62 Feet	Heating Degree Days	Design Temp °F	Number of Farmhouses by Fuel Type (1000's) Fuel Oil	LP Gas	Electric	Nat Gas
US	11.7	5384.	5.	5610.9	2887.4	1474.8	4104.8
AL	8.6	2368.	19.	12.3	163.8	60.6	92.0
AK	14.7	12097.	-24.	26.9	0.6	2.1	4.5
AZ	11.7	3295.	20.	2.2	19.9	12.8	52.7
AR	11.3	3015.	14.	2.9	117.4	14.3	111.5
CA	10.6	2989.	33.	23.2	138.3	94.1	243.0
CO	13.8	6310.	-6.	7.3	42.3	4.8	73.7
CT	11.5	5916.	3.	165.7	5.5	14.3	9.0
DE	10.8	4930.	11.	37.7	2.3	2.7	3.1
FL	8.7	730.	36.	126.0	147.5	87.7	37.4
GA	8.7	2435.	21.	41.1	204.5	62.4	140.7
HI	11.7	0.	62.	0.3	0.2	1.3	0.1
ID	12.3	6128.	-4.	46.3	8.8	10.4	13.8
IL	10.8	5899.	-6.	139.2	105.3	19.6	266.7
IN	10.8	5695.	-2.	224.4	83.1	43.6	151.3
IA	11.3	6870.	-10.	141.7	103.4	10.3	105.1
KS	13.6	5282.	0.	9.6	84.0	6.9	138.8
KY	9.4	4869.	4.	70.7	68.9	55.4	112.4
LA	9.4	1627.	24.	2.7	90.8	16.9	208.7
ME	12.7	8693.	-10.	129.8	2.9	3.0	0.7
MD	10.4	4617.	10.	182.5	10.2	18.4	26.2
MA	11.7	6518.	-0.	184.2	8.0	15.6	39.1
MI	10.8	7372.	-2.	334.2	51.2	23.0	222.2
MN	12.1	8892.	-20.	226.2	59.2	9.8	59.3
MS	8.7	2190.	20.	2.9	156.9	41.2	83.1
MO	10.8	4921.	2.	65.9	217.5	18.3	103.3
MT	13.5	8094.	-20.	26.8	17.0	6.8	37.3
NE	12.7	6681.	-7.	33.5	62.0	7.5	74.0
NV	11.7	6194.	4.	6.1	8.9	4.1	6.8
NH	14.8	10600.	-9.	80.7	4.0	4.9	2.0
NJ	10.8	4794.	8.	148.5	5.2	18.0	57.4
NM	12.7	4646.	8.	2.3	27.6	1.8	31.6
NY	13.2	6266.	-2.	502.1	24.2	23.8	174.7
NC	9.9	3284.	17.	563.6	50.1	83.5	31.8
ND	13.0	9305.	-24.	58.8	17.3	4.3	11.5
OH	10.8	5840.	0.	329.0	50.9	44.6	248.1
OK	13.2	3793.	9.	1.2	110.2	11.7	127.2
OR	12.1	5283.	13.	82.6	13.0	61.7	25.4
PA	11.7	5532.	4.	461.7	14.4	62.4	239.5
RI	11.7	5879.	5.	26.3	1.3	1.7	1.9
SC	8.7	2336.	21.	184.6	55.9	34.1	44.4
SD	13.0	7802.	-16.	59.3	28.9	5.2	12.6
TN	9.9	3531.	10.	45.0	48.8	205.6	52.6
TX	12.8	1940.	23.	4.9	323.9	48.2	286.5
UT	11.7	6109.	1.	9.3	6.6	2.2	23.4
VT	14.8	8269.	-14.	71.0	5.8	5.4	1.4
VA	11.0	3776.	13.	303.7	10.5	49.1	22.4
WA	12.3	5368.	12.	119.9	11.4	111.3	21.9
WV	12.7	4838.	3.	44.6	9.4	17.4	167.8
WI	10.8	7779.	-12.	234.5	75.3	8.2	85.6
WY	14.2	7586.	-13.	3.0	12.3	1.8	18.6

Table 80 Comparison Of State By State Wind Speeds Referenced To 65.52 Feet And Numbers Of Farmhouse Heating Systems

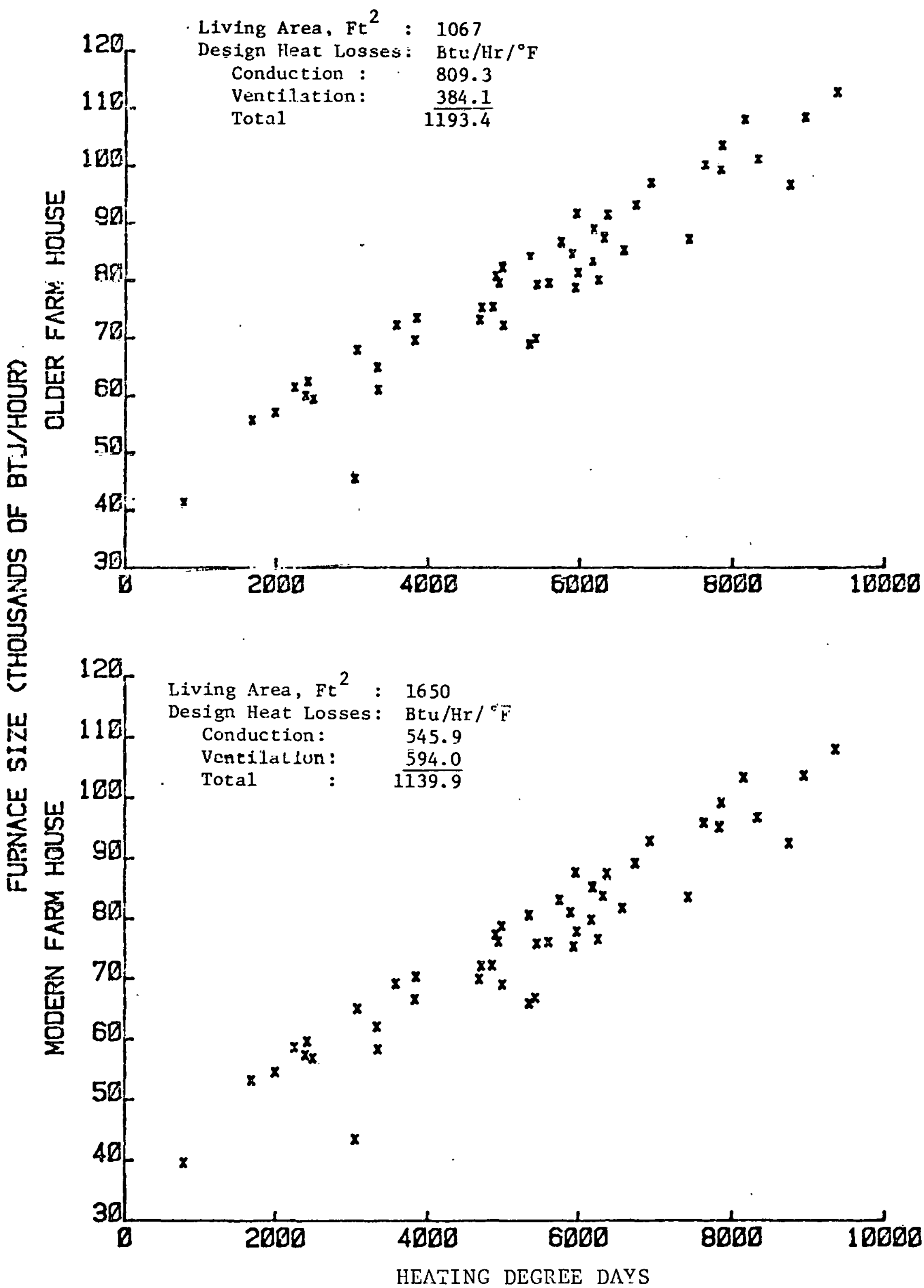


Figure 70 Peak Heating System Sizes and Heating Degree Days

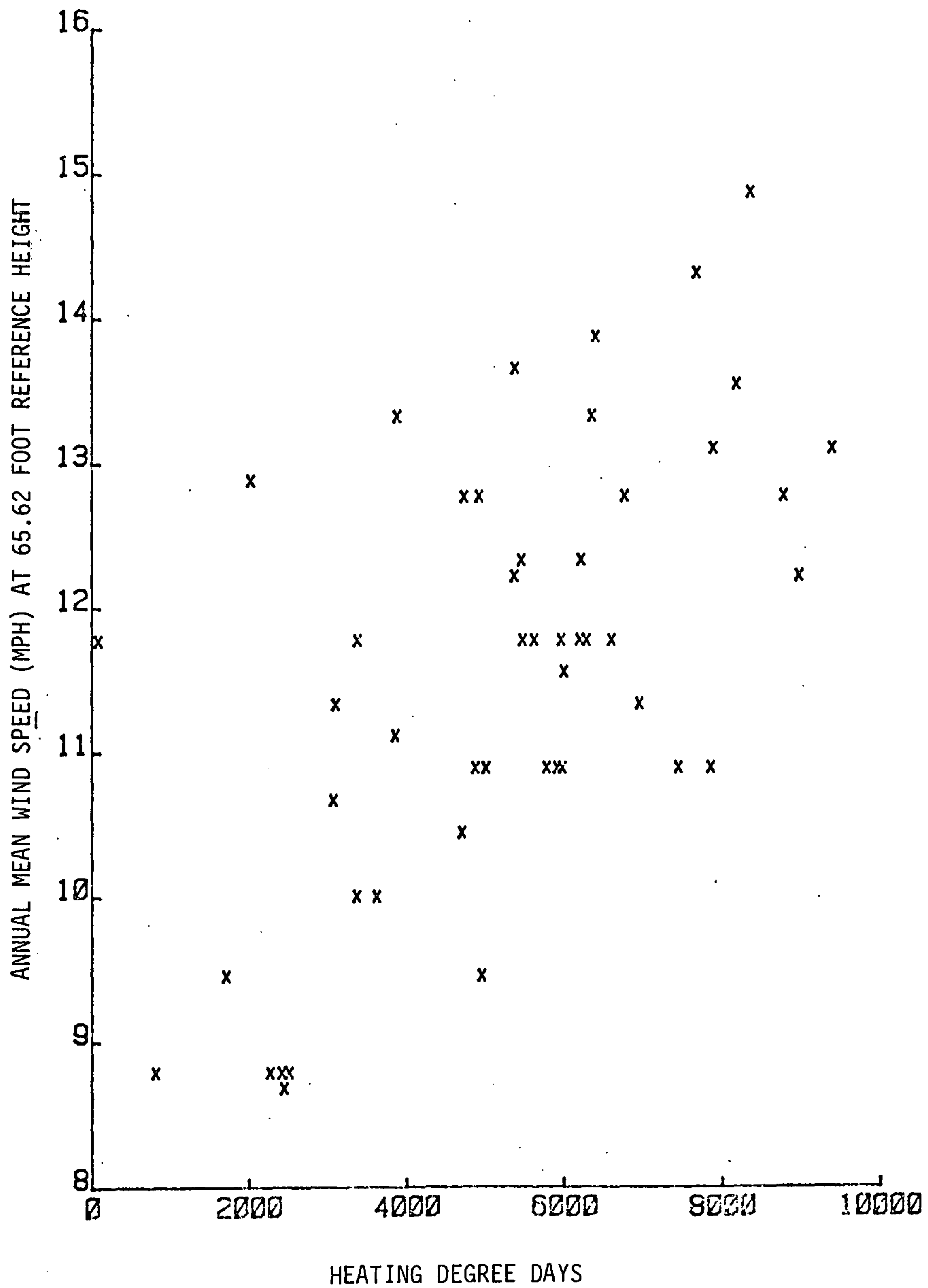


Figure 71 Annual Average Wind Speed At 65.62 Feet and Heating Degree Days

Heating System Type	Number of Farmhouses	Percentage of Total
Electric resistance	1,600,000	10.3
Electric heat pump	(500,000) *	--
Natural gas	4,100,000	26.5
LP gas	2,900,000	18.7
Fuel oil	5,800,000	37.5
Other	1,100,000	7.0
Total	15,500,000	100.0

* Heat pump applications were taken as replacements for electric resistance units and are not additive with the totals reported above

WECS were analyzed in this study with all furnace types except the "other" category reported above. Therefore, subsequent charts show an aggregate total for all furnaces of 14,400,000 units rather than the total of 15,500,000.

Fuel oil, natural gas and LP gas heating systems were utilized by approximately 80% of farmhouses on a national basis. However, many regions of the country such as the Tennessee Valley, Missouri Basin, and Columbia River Basin use electric heat intensively.

Comparisons of the numbers of farmhouses using selected heating systems in regions of similar wind speed and heating degree day requirements are given in Figures 72 through 76. The figures presented are cumulative distributions in which the numbers of farmhouses using selected heating systems at least equal to the degree days are shown on the horizontal axis.

The overall analysis shows that fuel oil heating systems were most widely used. Electric heating systems were used where heating degree days were less than 5500, and natural gas heating systems were widely used where degree days were less than 7500.

6.3 AGRICULTURAL HEATING FUEL COSTS

Heating fuel costs in agriculture were determined for electricity, natural gas, LP gas, and fuel oil in order to estimate the most prevalent experience. Results have been presented in levelized cents per kilowatt hour equivalents for a more ready comparison among different fuel types using a consistent 25 year life cycle, 10% discount rate, and future price increases reported by DOE.

Levelized energy cost is a uniform cost considering both inflation and a discount rate; it yields the same present worth as a uniformly increasing annual fuel cost at the same discount rate.

The levelized fuel cost can be computed from actual fuel costs using the formula:

$$LCOE = ACOE \times LF$$

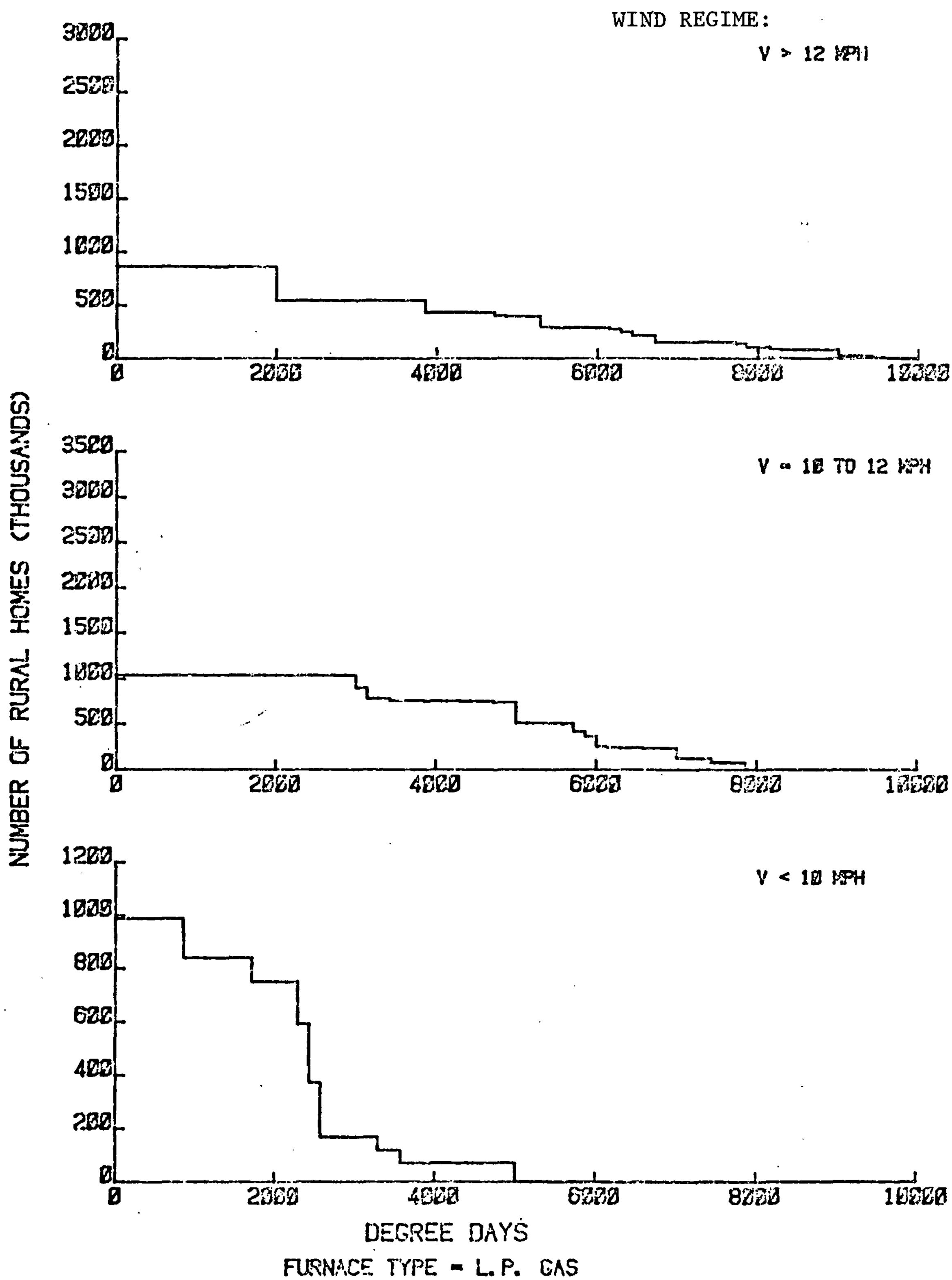


Figure 72 Cumulative Distribution of Farmhouses Using LP Gas Heating Systems By Degree Days

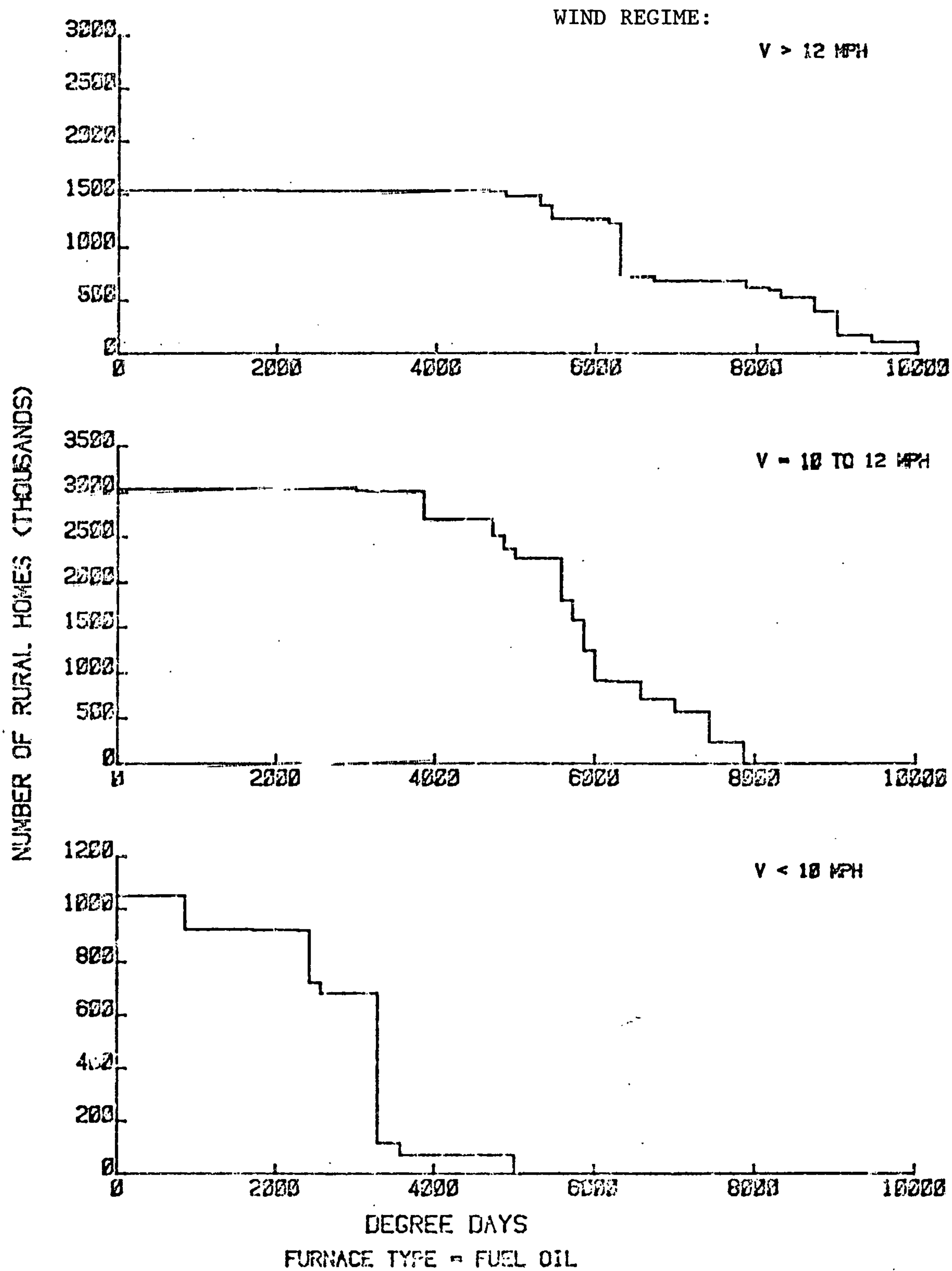


Figure 73 Cumulative Distribution of Farmhouses Using Fuel Oil Heati
Systems By Degree Days

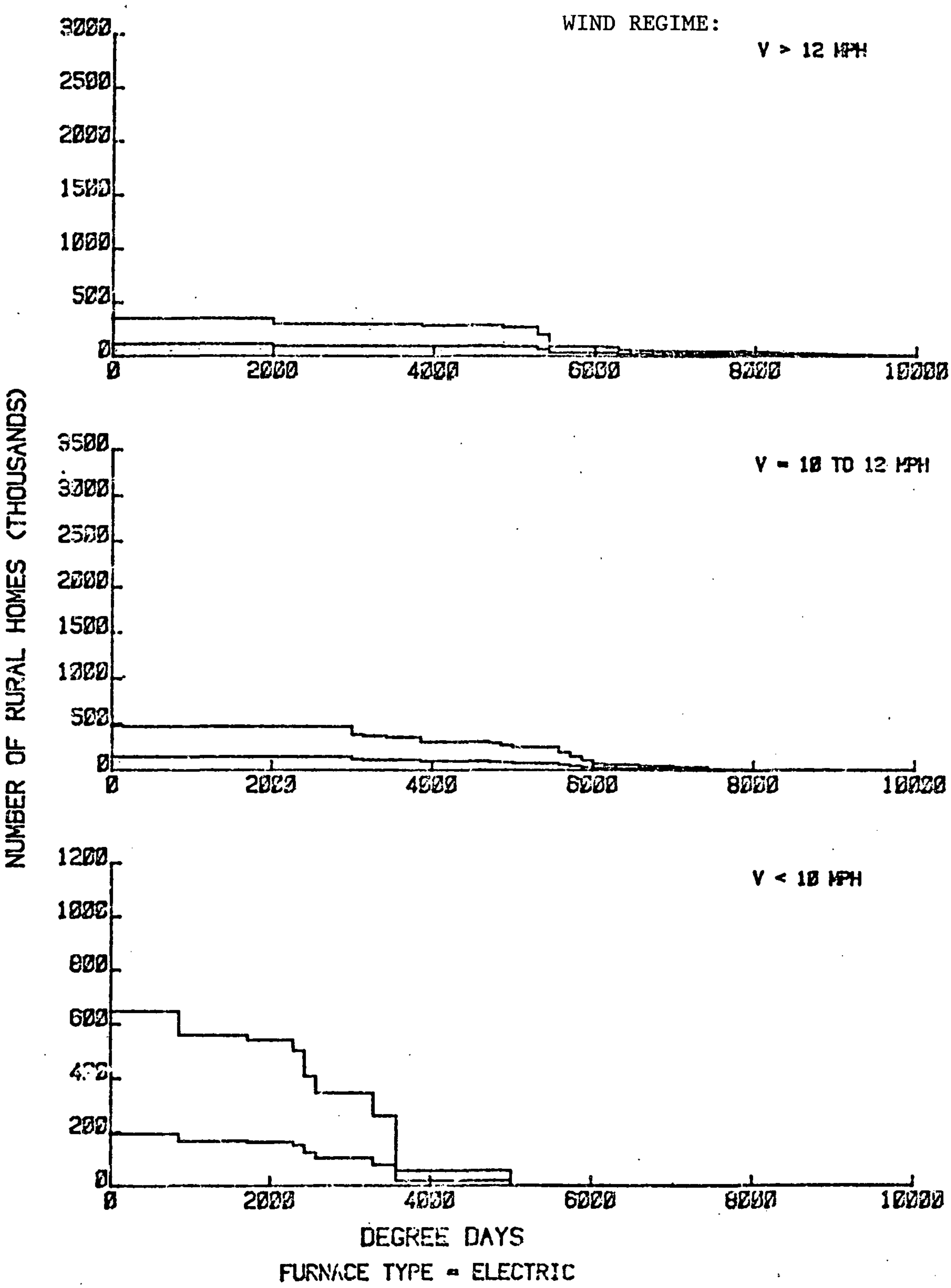


Figure 74 Cumulative Distribution of Farmhouses Using Electric Resistance Heating Systems By Degree Days

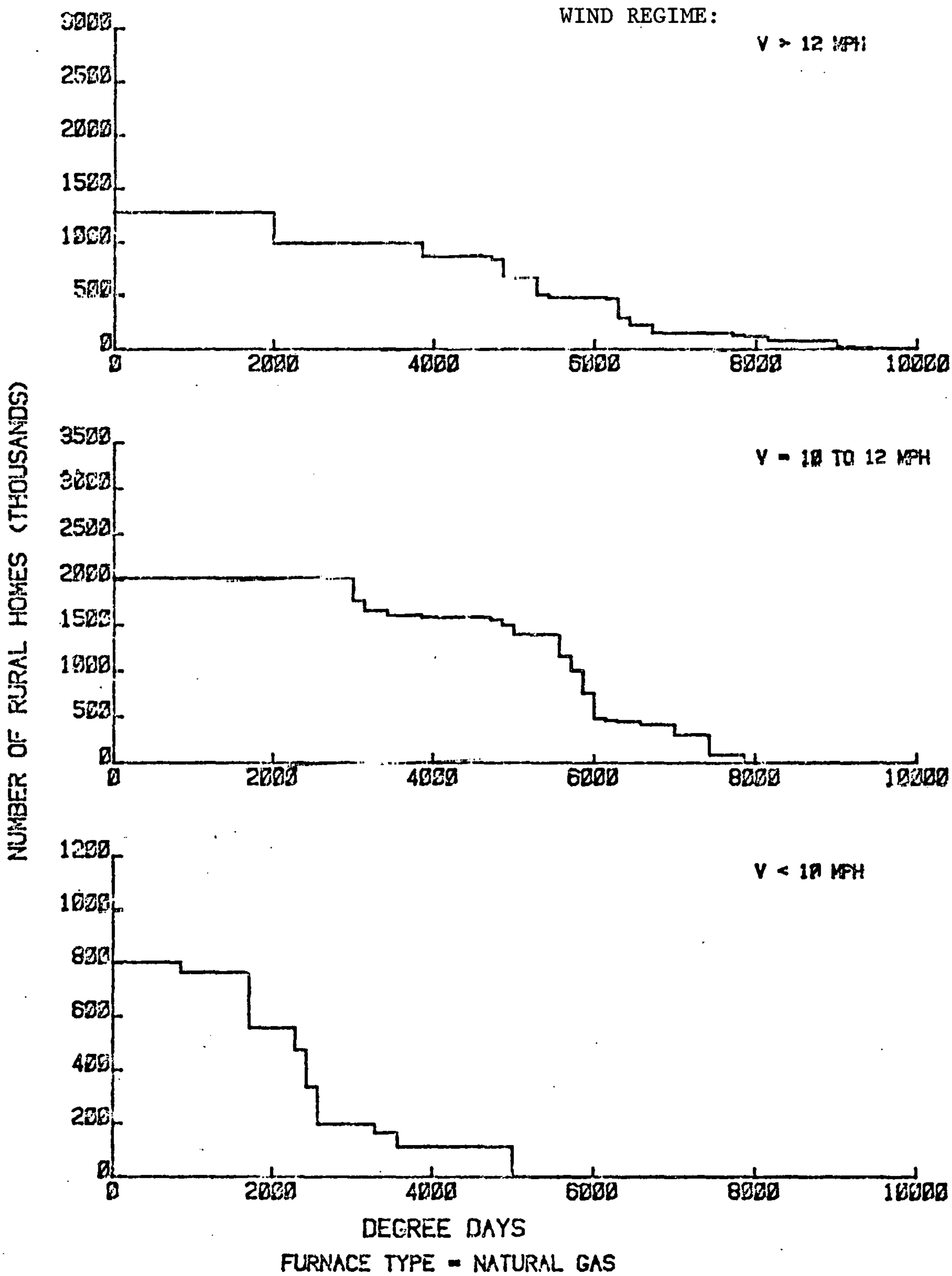


Figure 75 Cumulative Distribution of Farmhouses Using Natural Gas Heating Systems By Degree Days

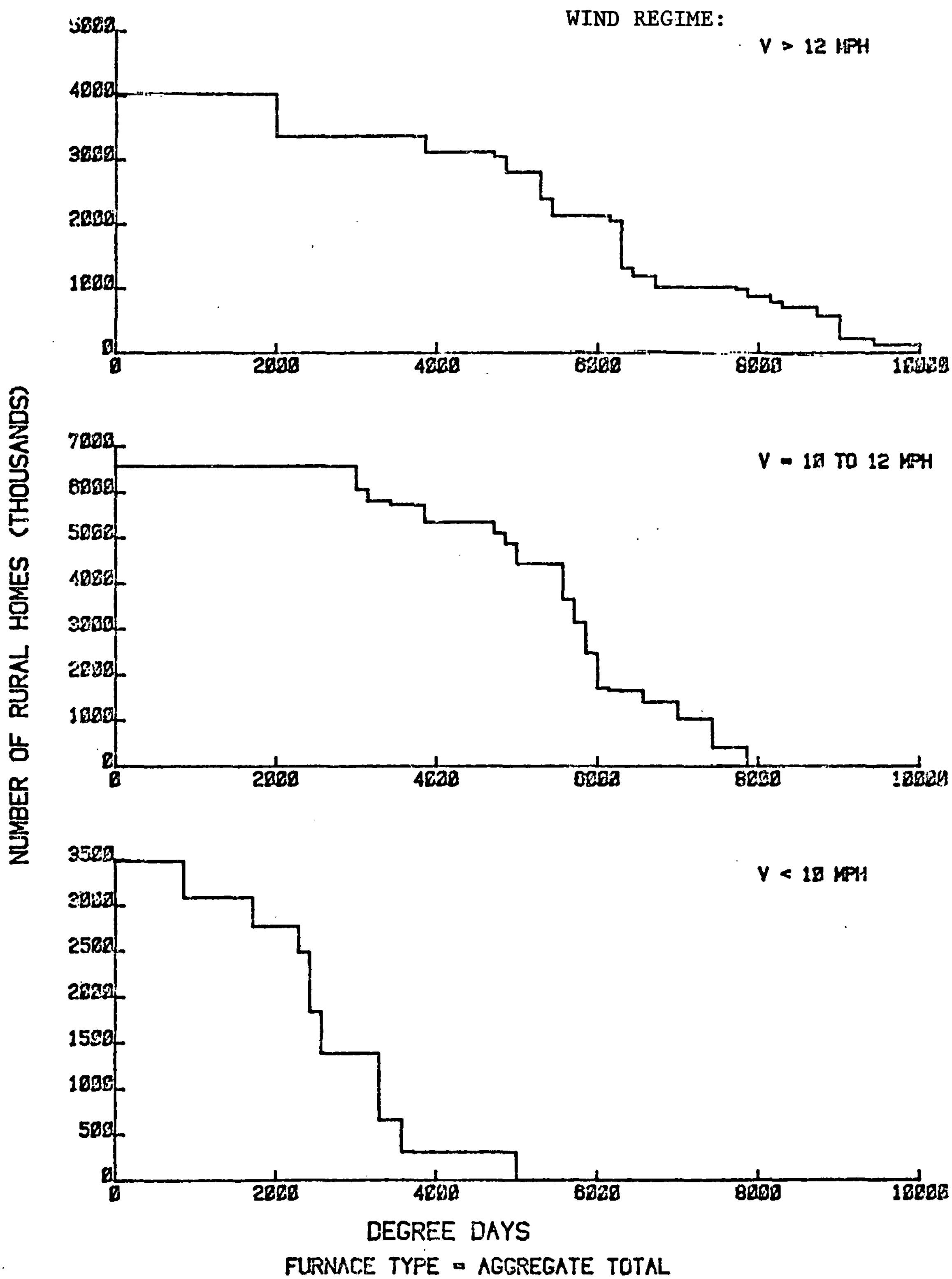


Figure 76 Cumulative Distribution of Farmhouses Using All Types of Heating Systems Examined

where: LCOE = Levelized cost of energy
ACOE = Actual cost of energy in the base year
LF = Life cycle levelizing factor to equate the present worth of energy value

For this study, the uniform annual price increases assumed for fuels, including inflation, were;

- o Electricity 8%
- o Natural gas 10%
- o LP gas 10%
- o Fuel oil 10%

The cumulative distributions of farmhouse heating energy costs are provided in Figures 77 through 81. Electric costs, shown in Figure 77, indicate that levelized costs fall between 4.5 and 6.2 cents/kwh in low wind regimes and between 4 and 7 cents/kwh in higher wind regimes. In Figure 78,natural gas costs show a uniform distribution between 1.5 and 3 cents/kwh (equivalent) in nearly all regimes. The LP gas fuel costs are shown in Figure 79 and consistently fall between 2.5 and 3 cents/kwh (equivalent), regardless of wind regime. Fuel oil costs, diagrammed in Figure 80, presently fall between 2 and 2.3 cents/kwh for all farmhouses. Figure 81 shows similar results considering all fuels.

A summary of the range of levelized heating fuel costs for all farmhouses is given by:

Range of Levelized Heating Fuel Costs
By Wind Regime--Cents/kwh

Heating Fuel	Low Winds	High Winds
Electricity	4.5 - 6	2.2 - 7.2
Natural gas	1.5 - 2.8	1.5 - 3.1
LP gas	2.5 - 2.8	2.4 - 3.0
Fuel oil	2.1 - 2.2	2.1 - 2.3
All fuels-average	1.5 - 6.1	1.5 - 7.2

6.4 ANNUAL HEATING COSTS IN AGRICULTURE

Estimated annual heating costs comprise one measure of comparison for break-even cost goals for wind-powered heating systems. The actual break-even annual cost is not the total annual heating cost, but only a portion depending on the ability to utilize the WECS production. This study has examined the use of WECS production with and without thermal storage to determine effects on WECS break-even cost goals.

Annual heating costs for farmhouses were determined on a state by state basis using two farmhouse models, the ASHRAE modified degree day method, state level energy costs, a uniform 25 year life cycle, and economic variables shown in paragraph 6.3.

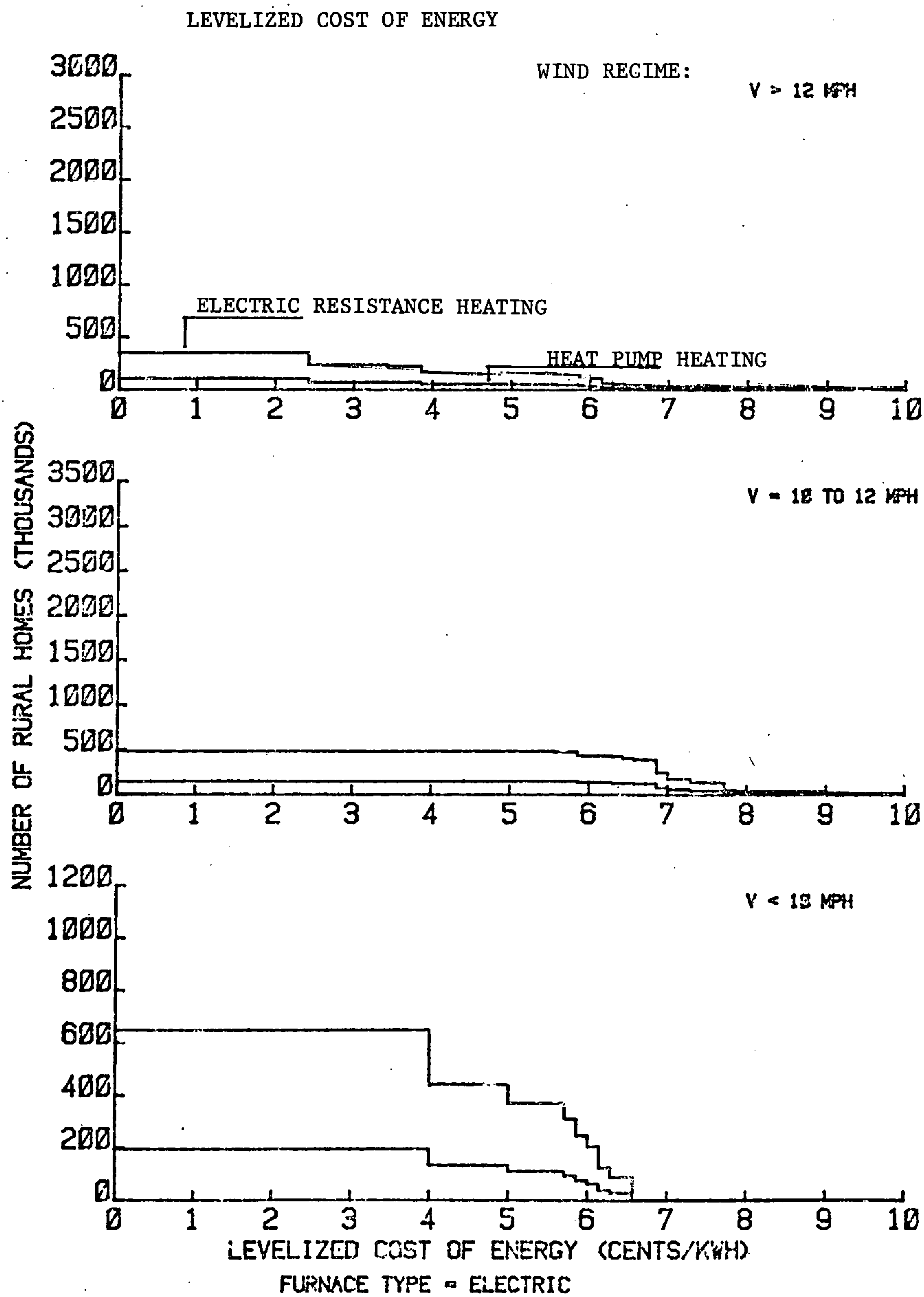


Figure 77 Cumulative Distribution Of Farmhouses and Electric Energy Cost

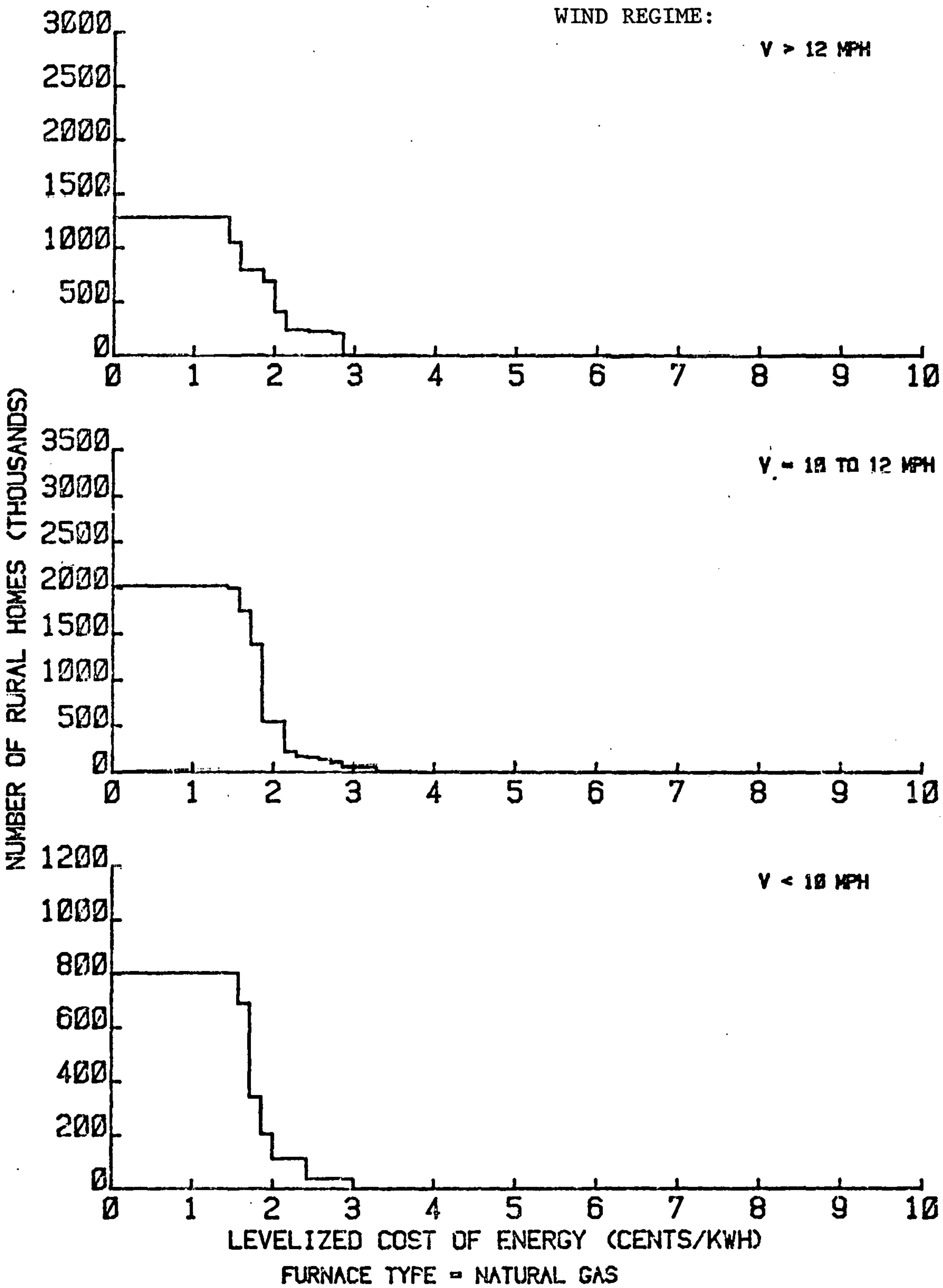


Figure 78 Cumulative Distribution Of Farmhouses And Natural Gas Cost

LEVELIZED COST OF ENERGY

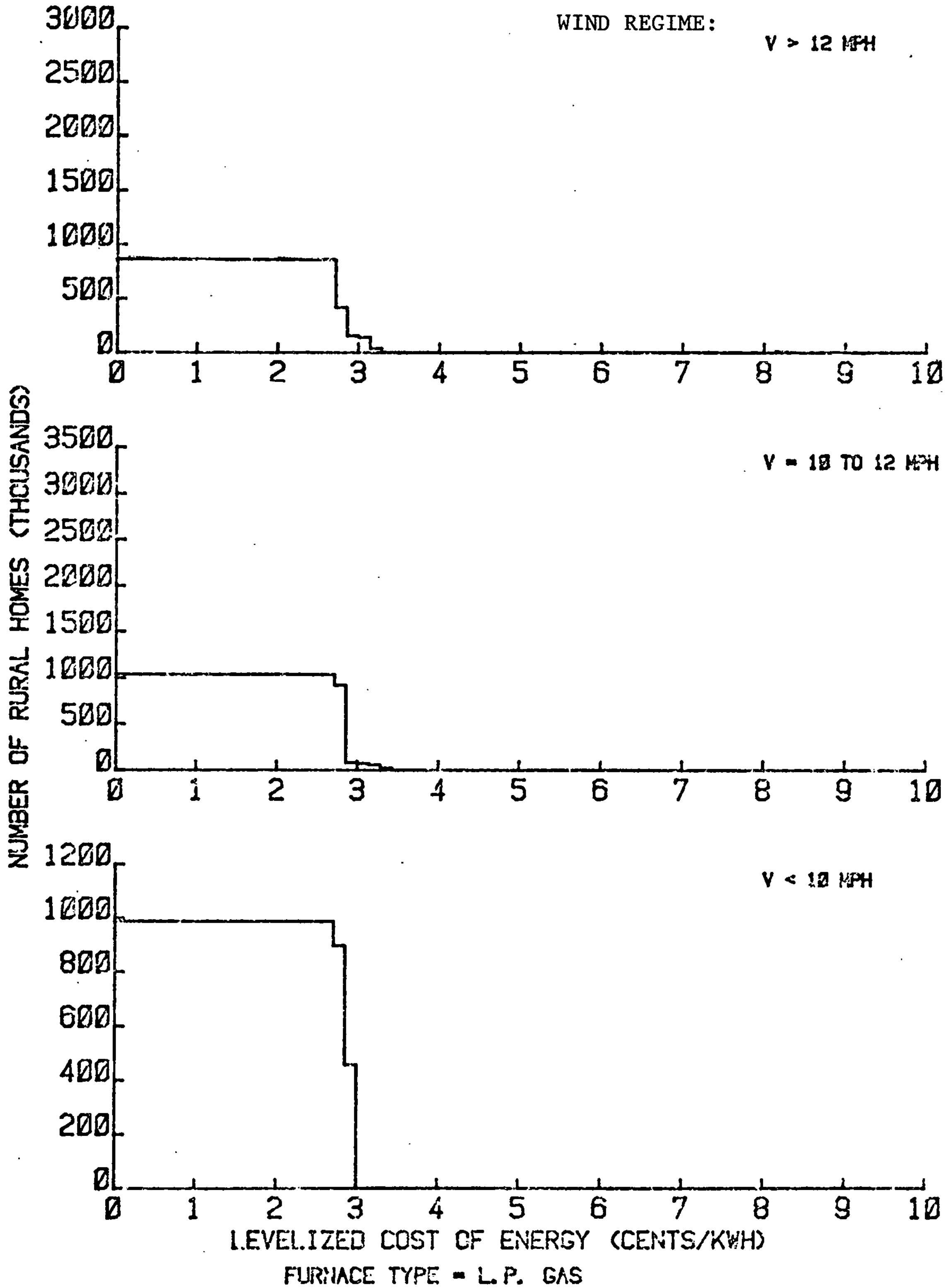


Figure 79 Cumulative Distribution Of Farmhouses and LP Gas Cost

LEVELIZED COST OF ENERGY

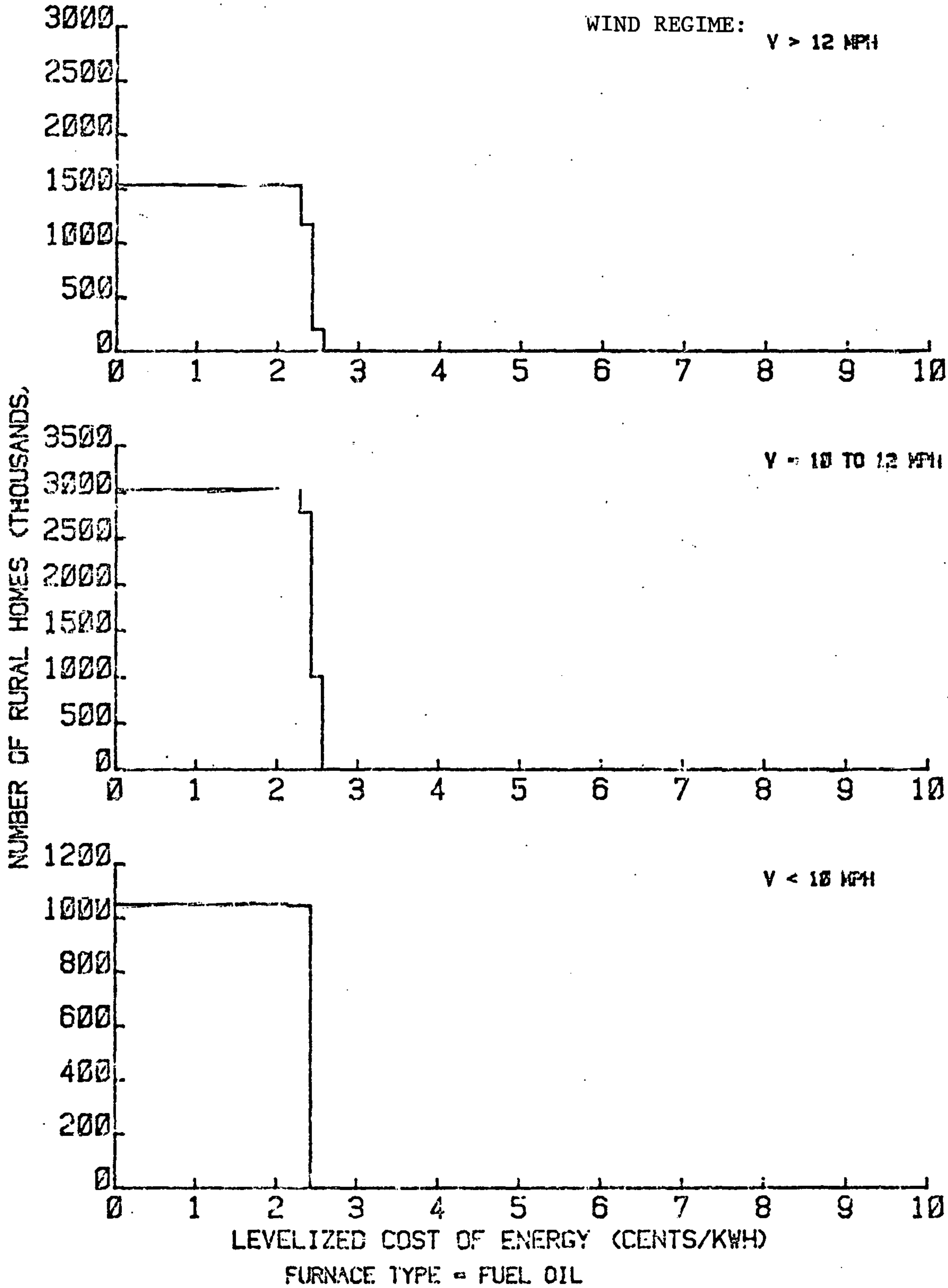


Figure 80 Cumulative Distribution of Farmhouses And Fuel Oil Cost

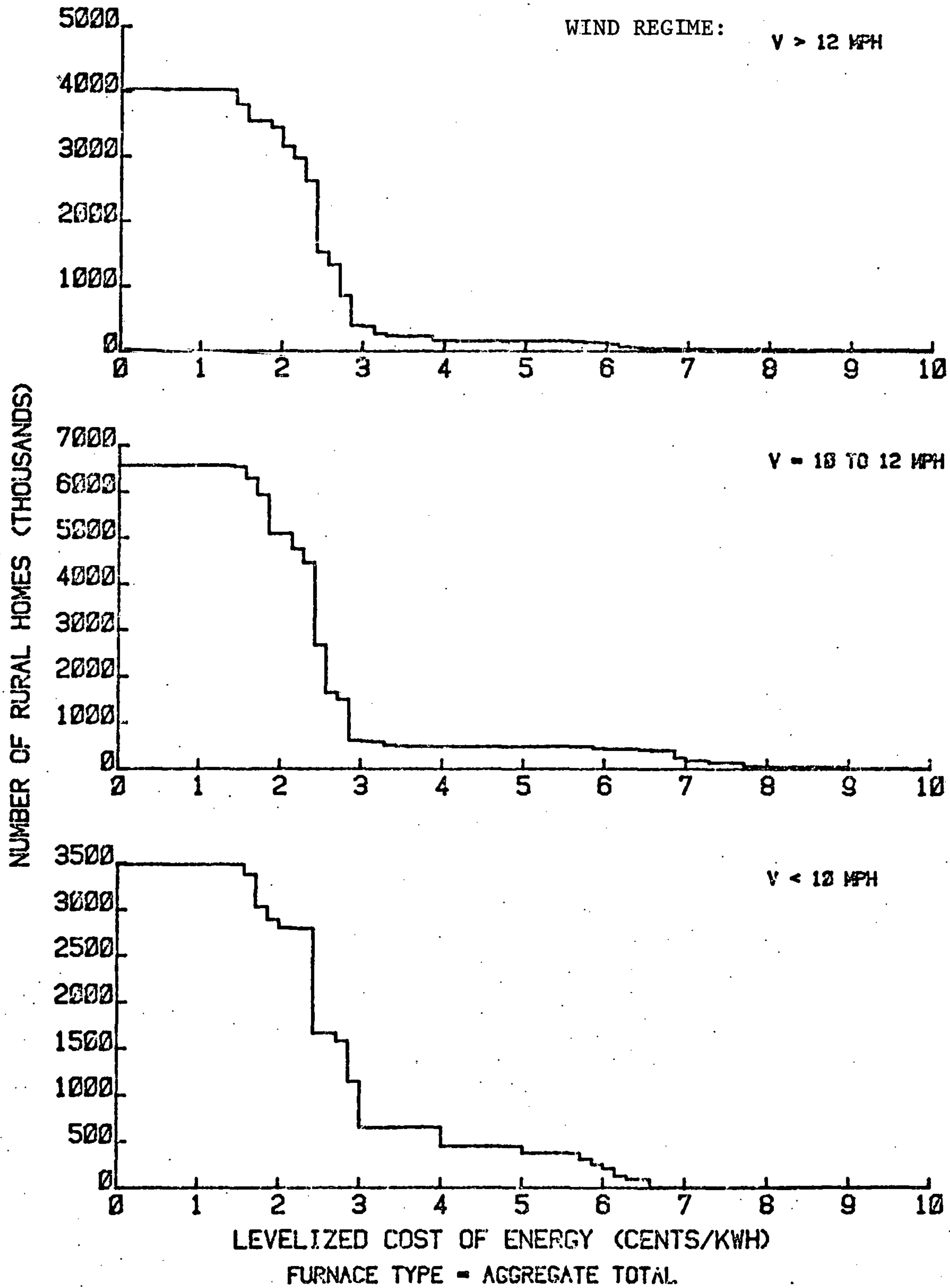


Figure 81 Cumulative Distribution of Farmhouses With All Energy Costs Combined

ASHRAE suggests that a modified degree day method can be used to estimate annual heating energy required for selected furnace types according to the equation: (Reference 53 and 54)

$$E = \frac{(H_L \times D \times 24)}{D_t \times n \times V} \times C_D \times C_F \times 1/10^6$$

where: E = fuel or energy consumption for the estimated period, Btu

H_L = design heat loss, including infiltration, Btu per hour

D = number of 65°F degree days for the estimate period

D_t = design temperature difference, Fahrenheit

n = rated full load efficiency, decimal

V = heating value of fuel, consistent with H_L and E

C_D = interim correction factor for heating effect vs. degree days

C_F = interim part-load correction factor for fueled systems only; equals 1.0 for electric resistance heating

Value of Hl was determined to include both conduction and infiltration losses for the model farmhouse structures as presented in 6.3.

Values for C_D and C_F are given by ASHRAE as:

	Heat Loss vs. Degree Days Interim Factor, C_D				
Outdoor design temperature, F	-20	-10	0	+10	+20
Factor, D_D	0.57	0.64	0.71	0.79	0.89

	Part Load Correction Factor For Fuel-Fired Equipment				
Percent oversizing	0	20	40	60	80
Factor, C_F	1.36	1.56	1.79	2.04	2.32

The levelized annual heating costs can be developed from the annual heating energy by:

$$LAHC = \frac{H_L \times D \times 24}{D_t \times n} \times C_D \times C_F \times F_C \times L_F \times 1/10^6$$

$$= \frac{(AU(D_t) + 0.18\ \dot{V}(D_t)) \times D \times 24 \times F \times C_D \times C_F \times F_C \times L_F \times 1/10^6}{D_t \times n}$$

$$= \frac{(AU + .018\dot{V}) \times D \times 24 \times F \times C_D \times C_F \times F_C \times L_F \times 1/10^6}{n}$$

where:

- LAHC = levelized annual heating cost
- H_L = design heat loss including infiltration, Btu per hour
- D = annual heating degree days
- 24 = hours per day
- C_D = heat loss vs. degree day interim factor
- C_F = part load correction factor
- F_C = fuel cost, $\$/10^6$ Btu
- L_F = life cycle levelizing factor
- $1/10^6$ = $Btu/10^6$ Btu
- D_t = inside design temperatures less outside design temperature, Fahrenheit
- F = Sizing margin, 1.25
- n = design efficiency of furnace, (1.0 for electric resistance heating)

The ASHRAE modified degree method shows that annual heating energy and thus annual heating costs are directly related to heating degree days. Based on the thermal characteristics of the older and modern farmhouse models, levelized annual heating costs have been estimated according to heating fuel type, cost and heating degree days in Figures 82 through 86. A wide range of levelized heating fuel costs have been included for each heating fuel. The range of heating fuel costs considered includes:

Heating Fuel	Range of Costs	Units	Furnace Efficiencies
Electricity-Resistance	2 - 16	Cents/kwh	1.0
Electricity-Heat Pump	2 - 16	"	2.0
Natural gas	.2 - 1.60	$/CCF	.55
LP gas	.6 - 2.0	$/gallon	.55
Fuel oil	.6 - 2.0	$/gallon	.55

Thus, a typical levelized annual heating cost can be identified for selected fuel type and heating degree day requirement directly from the appropriate figure for the farmhouse structure of interest.

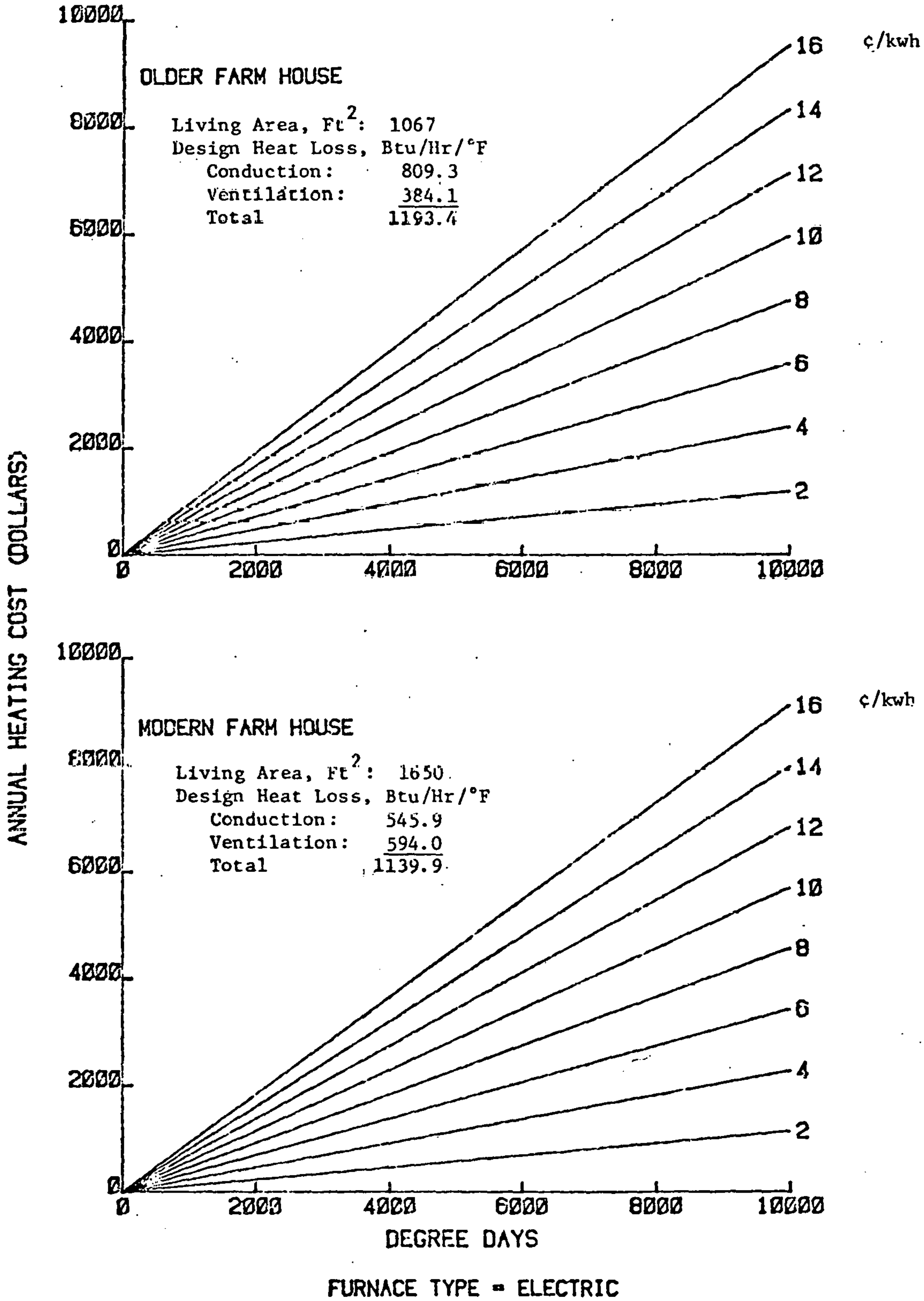


Figure 82 Older and Modern Farmhouse Annual Heating Costs With Electric Resistance Heating

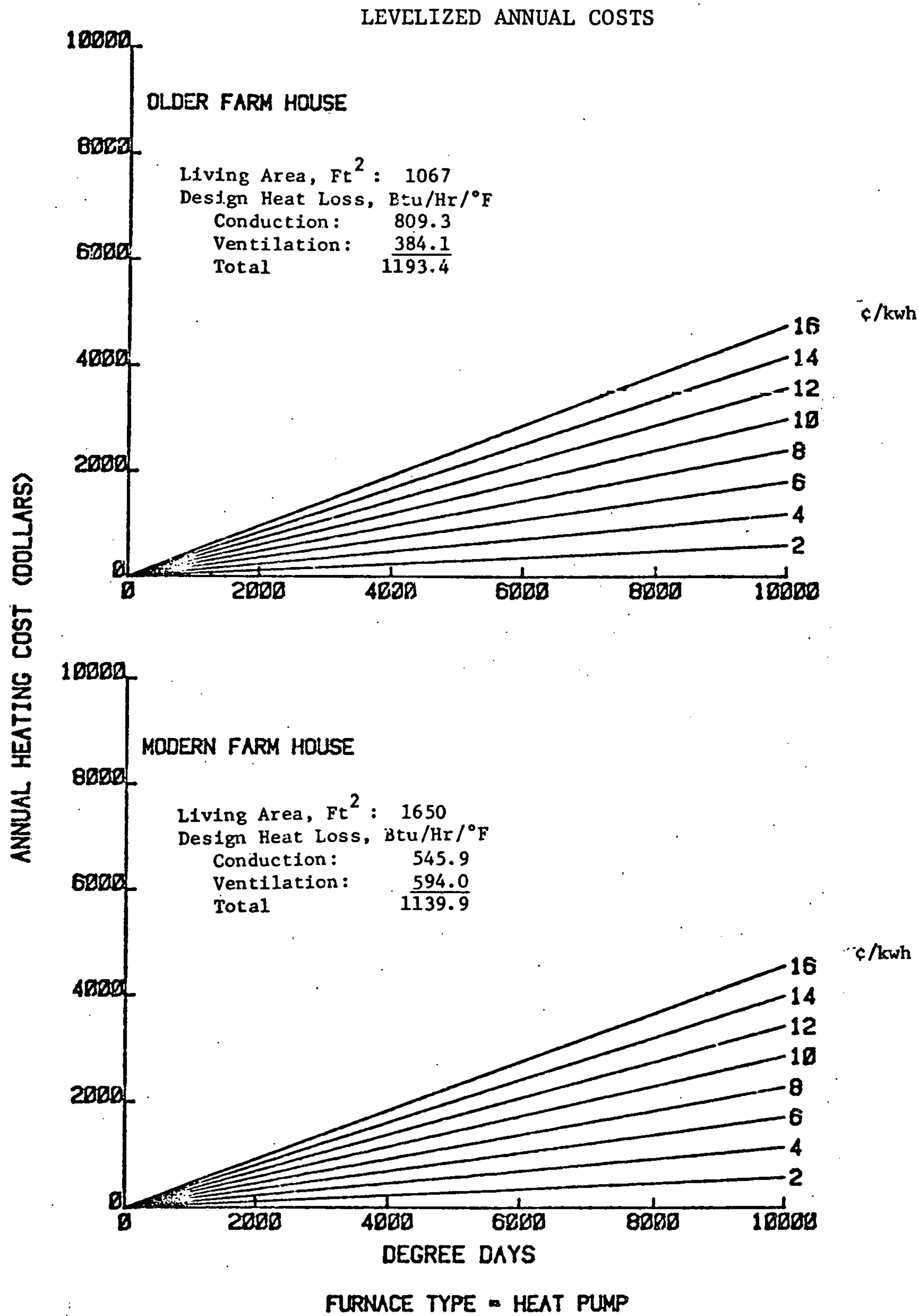


Figure 83 Older and Modern Farmhouse Annual Heating Costs Using A Heat Pump

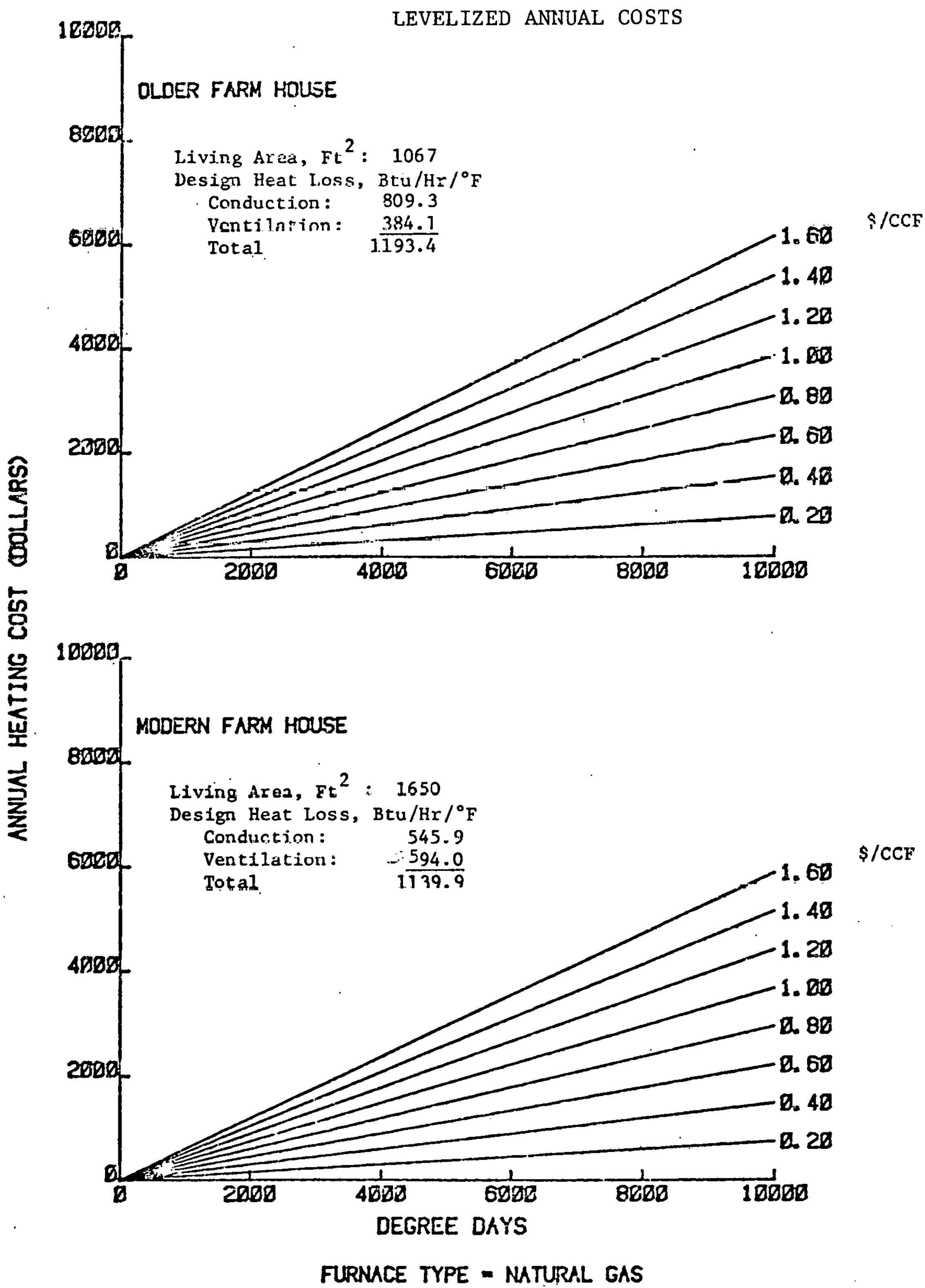


Figure 84 Older and Modern Farmhouse Annual Heating Costs Using Natural Gas

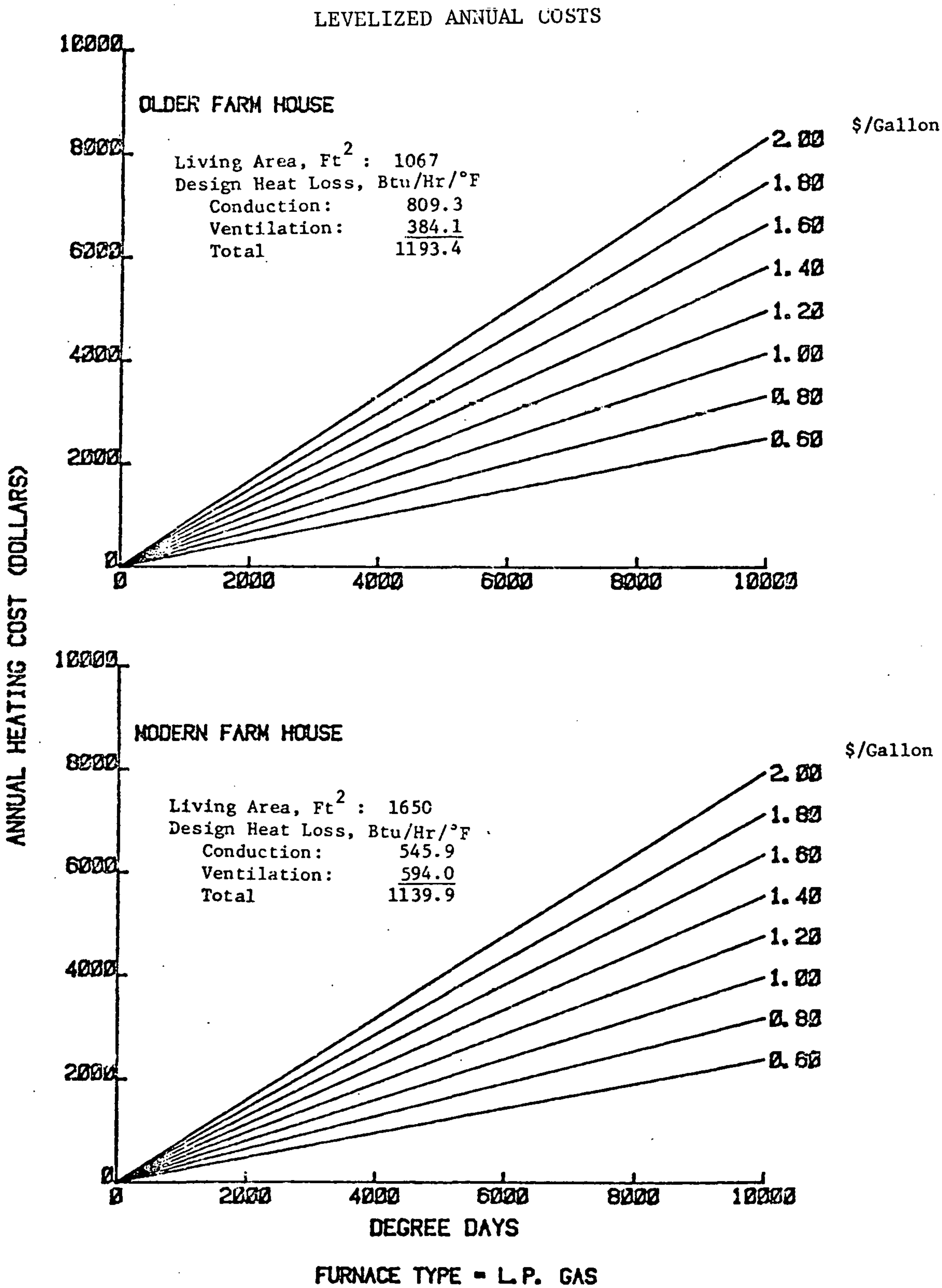


Figure 85 Older and Modern Farmhouse Annual Heating Costs Using LP Gas

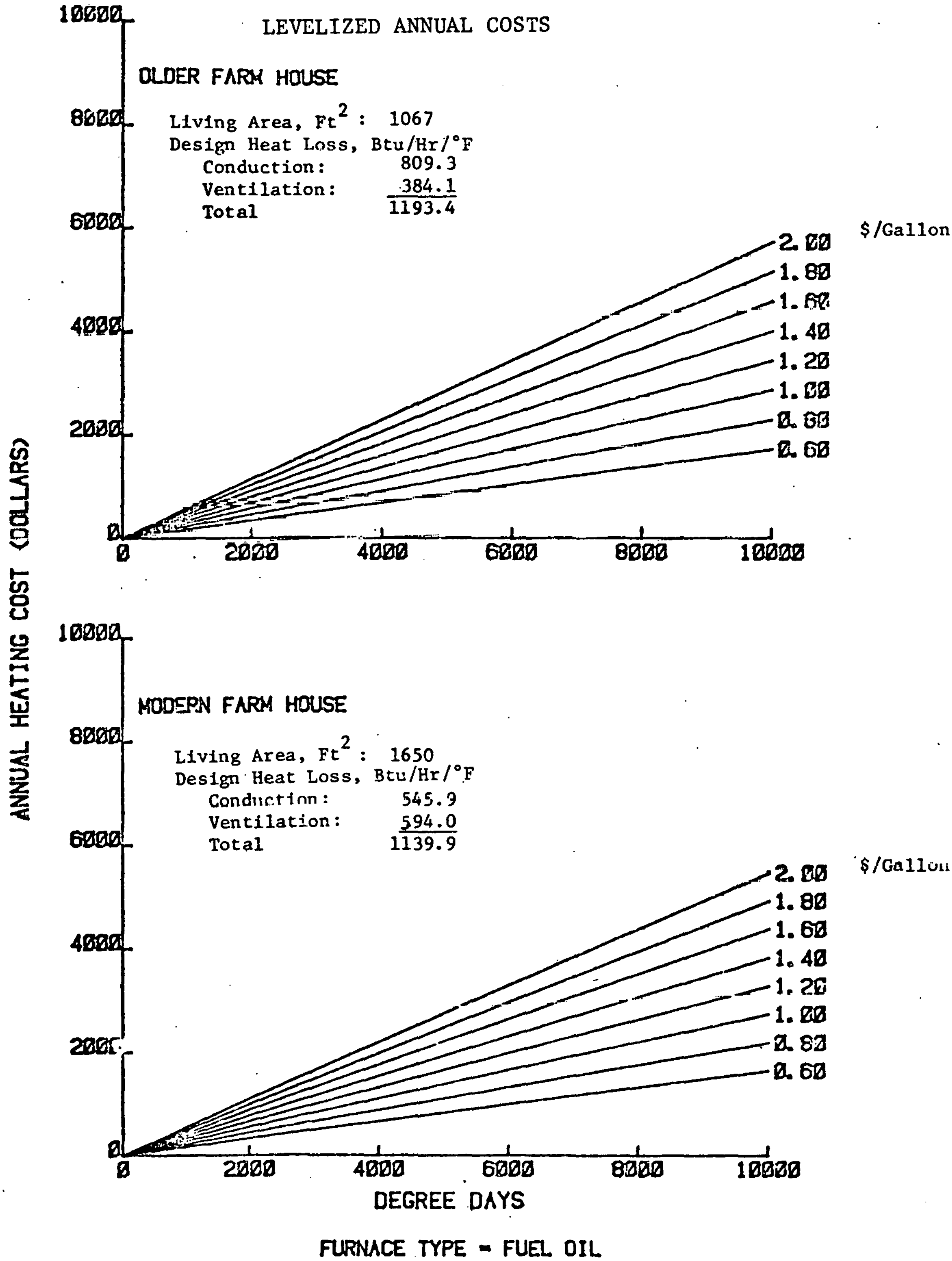


Figure 86 Older and Modern Farmhouse Annual Heating Costs Using Fuel Oil

Estimated levelized annual heating costs in agriculture have been combined with heating degree day requirements, wind regimes, heating fuel and life cycle analysis on a state by state basis, to correlate annual heating costs to regions of similar heating requirements, and wind regimes, in Figures 87 through 91. The national data base of rural housing, fuel costs, and mix of older and newer farmhouses defined previously have been used consistently throughout.

The low, median and high levelized annual heating costs for the farmhouses and each fuel type analyzed is summarized in Table 81. The table shows that the median levelized annual heating costs fall between $930, $1530, and $1700 for the low, medium, and high wind regimes, respectively.

6.5 SYNOPSIS

This survey has accomplished two tasks - an estimate of the distribution of the sizes of heating systems currently used in agriculture, and a correlation of these systems to levelized annual heating fuel costs with present energy sources. Farmhouse and farm building analyses were based on detailed national surveys of structures and entailed the use of an hour by hour analysis yielding the respective energy use for WECS with and without thermal storage.

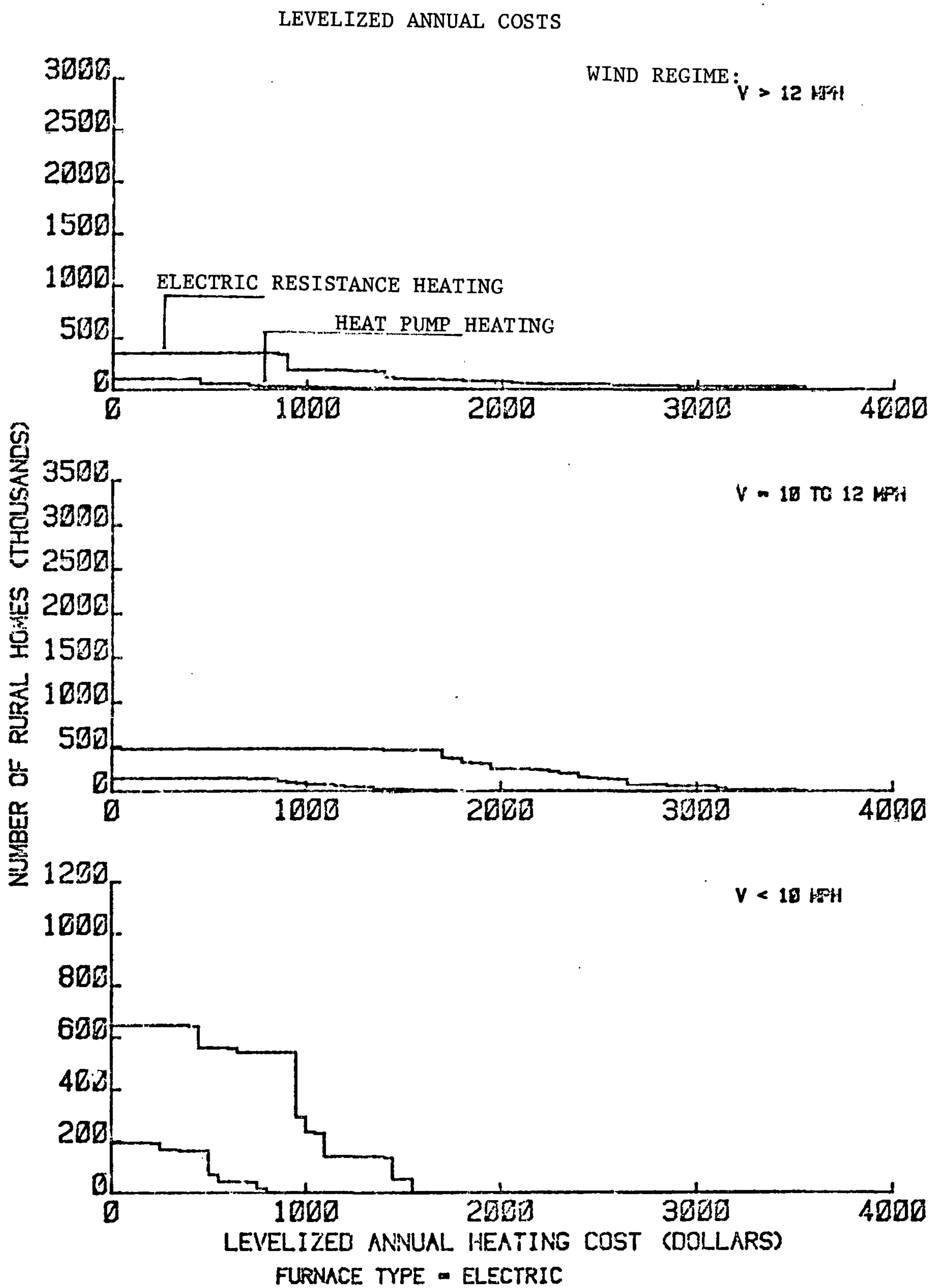


Figure 87 Cumulative Distribution of Farmhouses Using Electric Resistance Heating By Annual Heating Cost

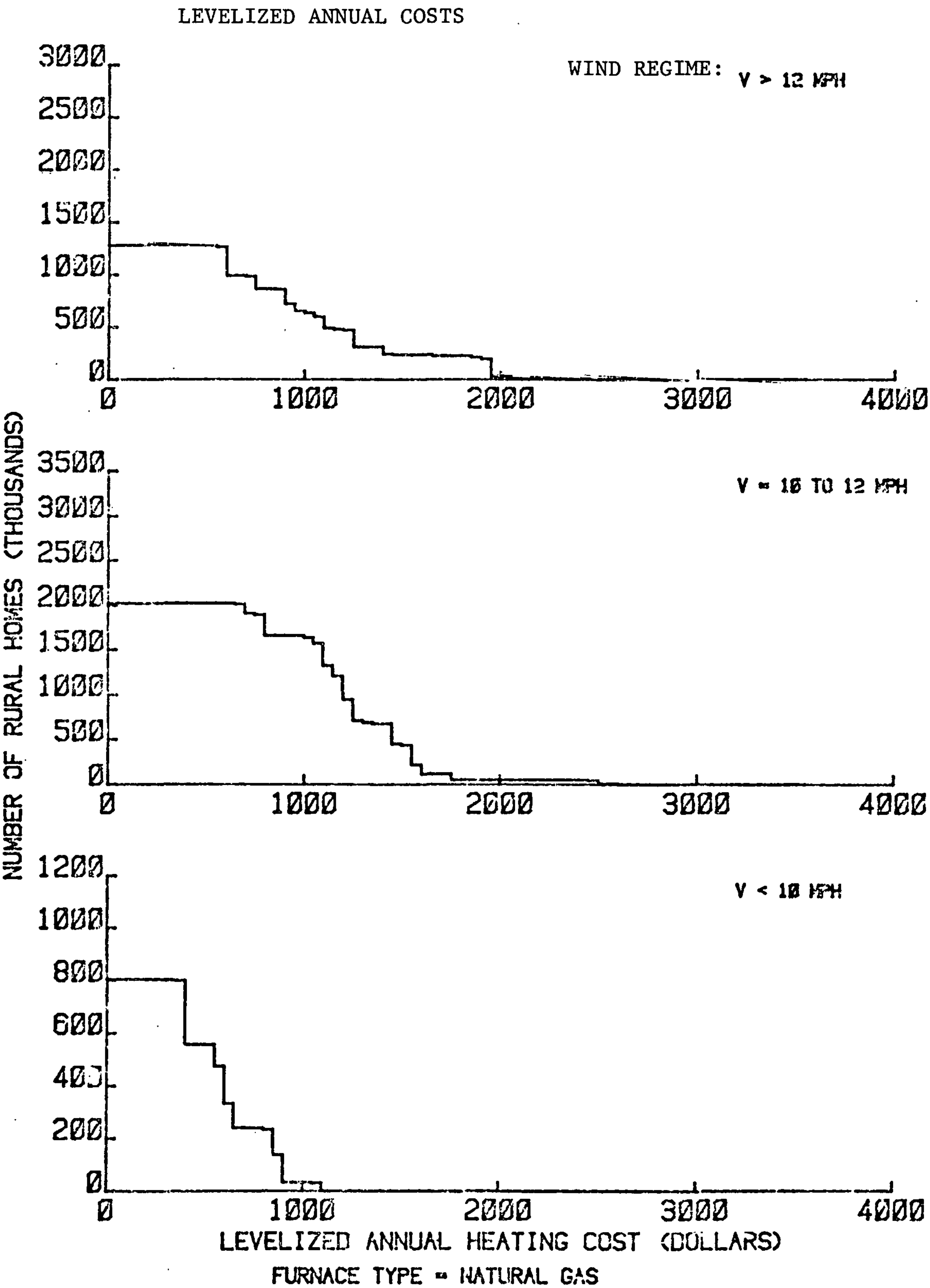


Figure 88 Cumulative Distribution of Farmhouses Using Natural Gas Heating By Annual Heating Cost

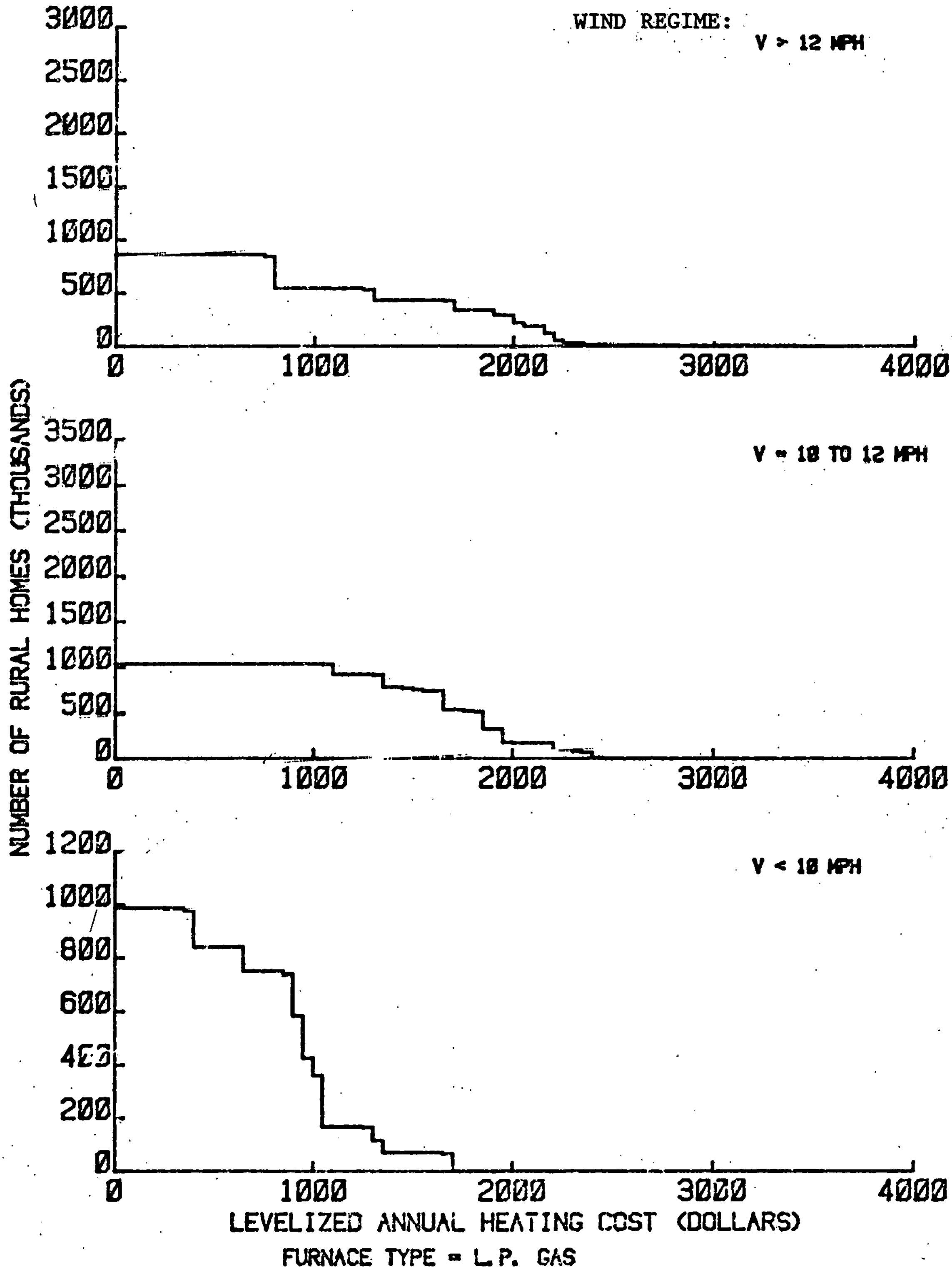


Figure 89 Cumulative Distribution of Farmhouses Using LP Gas Heatin~ By Annual Heating Cost

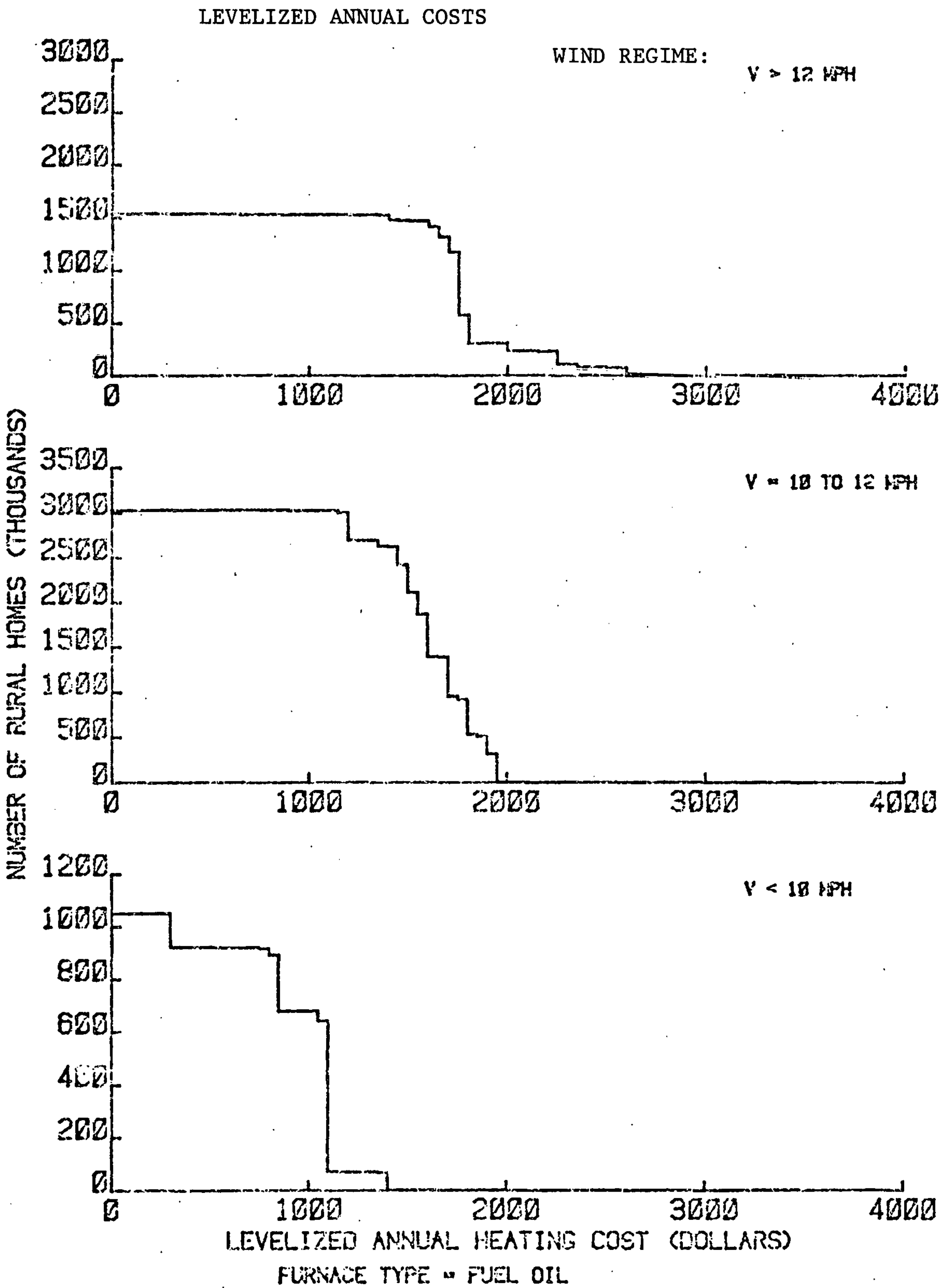


Figure 90 Cumulative Distribution Of Farmhouses Using Fuel Oil Heating By Annual Heating Cost

LEVELIZED ANNUAL COSTS

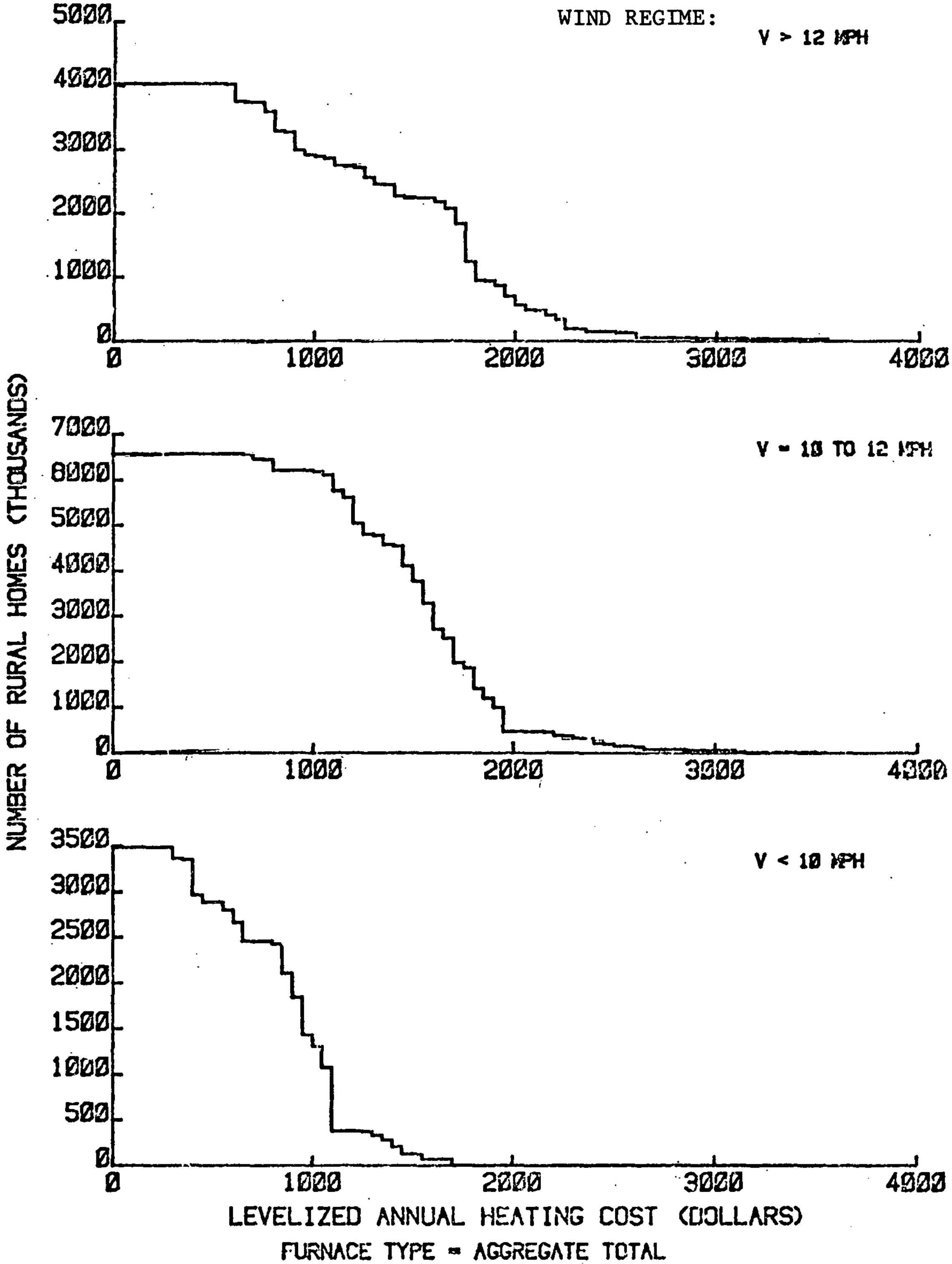


Figure 91 Cumulative Distribution Of Farmhouses For All Types Of Heating Examined By Annual Heating Cost

	Levelized Annual Heating Costs in Dollars *								
	Wind Regime **								
	Low Less Than 10 MPH			Medium 10 to 12 MPH			High Greater Than 12 MPH		
Heating Fuel	Low Dollar Amount	Median Dollar Amount	High Dollar Amount	Low Dollar Amount	Median Dollar Amount	High Dollar Amount	Low Dollar Amount	Median Dollar Amount	High Dollar Amount
Electric-Resistance	500	1000	1500	1400	2200	3200	900	1400	3600
Electric-Heat Pump	250	500	750	700	1100	1600	500	700	1800
Natural Gas	400	600	1100	700	1200	2500	620	1100	2900
LP Gas	400	930	1735	1100	1300	2400	750	1300	3600
Fuel Oil	270	420	1400	1200	1600	1900	1400	1700	2600
All Fuels	330	930	1700	700	1530	3550	600	1700	3600

* Levelized with a 25 year life and 10 % discount rate

** Wind speeds referenced to 65.62 feet (20 meters)

Table 81 Summarized Levelized Annual Heating Costs For Rural Homes By Fuel Type and Wind Regime

7.0 WIND-POWERED HEATING SYSTEM MARKET POTENTIAL

This analysis aggregates the number of potential wind system users according to the breakeven values of WECS production. The results are presented as cumulative distributions of potential users for the range of heating costs found in the national survey. They are shown for the levelized breakeven values for wind energy; these values were developed considering the following uses of wind energy:

- o Space heating only
- o Space heating with thermal storage
- o Hot water heating with thermal storage
- o Above uses plus appliances
- o Above uses plus machinery
- o Sell-back of remaining surplus to the local utility

Instead of selecting only a few discrete cost levels to correlate with the number of potential uses, continuous cumulative distribution functions using the total numbers of farmhouses reported by the 1970 Census and 1974 Census of Agriculture were developed for the following heating system energy sources:

- o Electricity (Resistance and heat pump applications)
- o Natural gas
- o LP gas
- o Fuel oil

The Census utilized here reported the total number of farmhouses using each fuel. Current retail fuel costs and life cycle levelizing factors, provided by the DOE Energy Information Administration, the Office of Management and Budget, and other recognized sources, have been applied in this analysis to define life cycle levelized costs of energy.

Results are presented separately for each fuel type and used the overall heating system efficiency ratios given by the following:

o Electricity-resistance	1.0
o Electric-heat pump	2.0
o Natural gas	0.55
o Fuel oil	0.55
o LP gas	0.55

The efficiencies for the electric resistance, natural gas, LP gas, and fuel oil systems are those derived from ASHRAE (Reference 53). The electric heat pump efficiency is used as an overall value, even though the coefficient of performance (COP) for heat pumps is related to the specific system type and the actual outdoor temperatures. Since this study addressed only heating, the added value to WECS production possible from cooling has not been examined.

Results are given for the following levelized break-even indicators:

- o Levelized annual break-even values of wind energy, dollars o Levelized break-even value of wind energy, cents/kwh

A consistent 25 year life cycle and 10% uniform discount rate have been employed for all presentations.

The levelized break-even annual value of wind energy is shown to be significantly greater with the incorporation of thermal storage for either space heating or hot water needs. It also depends on the ability to directly use the WECS production, e.g., the time coincidence of heating needs and availability of wind production. The average direct utilization of wind production was notably consistent for the 9 geographic locations analyzed in detail for farmhouse applications. The composite WECS average utilization factors for moderate to colder climates have been incorporated into the break-even market penetration study and are shown in Table 82 for the 20 foot diameter WECS. Since all wind energy cannot be directly used, even with storage, the utilization factor defines the break-even value of wind energy required to compete with present heating energy sources. For example, if 80% of the WECS production could be used with thermal storage, and the present levelized value of heating energy was 6 cents/kwh, the required levelized break-even value of wind energy would be .8 x 6 = 4.8 cents/kwh.

The following distributions present the numbers of potential space heating applications for farm buildings, provided that the wind energy was used in the various applications shown. The significant contribution of thermal storage is evident in the higher break-even values of wind energy which are possible when storage is utilized.

The cumulative distributions of potential applications were developed using the average utilization of wind energy at each of the nine analysis locations. The development of the WECS break-even energy value can be derived from the levelized annual value of savings from WECS use as presented below:

$$LVAS = WDH \times VH \times LFH + WSH \times VH \times LFH + WHW \times VHW \times LFHW + WMA \times VMA \times LFMA + WSUR \times VSUR \times LFS$$

$$VOE = LVAS/AKWH$$

where:

LVAS = Levelized value of annual savings
WDH = WECS production directly displacing heating energy
VH = Value of heating energy, per unit
LFH = Life cycle levelizing factor for heating energy
WSH = WECS additional use from space heating thermal storage
WHW = WECS additional production from hot water thermal storage
VHW = Value of hot water fuel, per unit
LFHW = Life cycle levelizing factor for hot water fuel
WMA = WECS additional use with machinery or appliances
VMA = Value of energy source for machinery and appliances
LFMA = Life cycle levelizing constant for electricity
WSUR = WECS additional use for sell back to the utility
VSUR = Value of surplus energy, per unit
LFS = Life cycle levelizing constant for sell-back energy
AKWH = Annual kwh WECS production
VOE = Levelized breakeven value of WECS energy

Analysis Location	Direct Space Heating %	Thermal Storage for Space Heating-%	Thermal Storage For Hot Water-%	Machinery and Appliances-%	Sell-back to Utility-%
	Summary of WECS Production and Use --%				
Minnesota	41.	21.5	22.2	3.2	12.1
Wisconsin	48.9	25.2	18.1	1.6	6.2
Wyoming	35.6	25.7	17.2	3.45	18.
Illinois	44.0	20.52	20.6	2.8	12.1
Iowa	43.2	19.0	20.9	3.1	13.8
Colorado	25.3	32.2	27.8	1.6	13.1
Maryland	31.4	30.7	27.1	2.4	8.4
California	10.3	32.4	38.45	4.3	14.5
Texas	15.4	23.4	40.3	4.8	16.1
Average	32.8	28.6	24.4	3.0	11.5

Table 82 - Average Wind Energy Utilization For Typical Farmhouses --%

If the levelized value of annual savings is not available, the ›ak-even WECS energy value can be developed from:

$$VOE = P1 \times VH \times LFH + P2 \times VH \times LFH + P3 \times VHW \times LFHW + P4 \times VMA \times LFMA + P5 \times VSUR \times LFS$$

where:

VOE	=	Levelized breakeven value of WECS energy
P1	=	Fraction of WECS production used directly for space heating
VH	=	Unit value of space heating energy
LFH	=	Life cycle levelizing constant for space heating energy
P2	=	Additional fraction of WECS production usable with thermal storage
P3	=	Additional fraction of WECS production usable with hot water storage
VHW	=	Unit value of hot water energy source
LFHW	=	Life cycle levelizing constant for hot water energy
P4	=	Additional fraction of WECS production usable for appliances
VMA	=	Unit value of energy for machinery and appliances
LFMA	=	Life cycle levelizing constant for machinery/appliance energy
P5	=	Additional fraction of WECS surplus energy
VSUR	=	Unit value of energy for surplus energy
LFS	=	Life cycle levelizing constant for surplus energy

This study used the state by state fuel costs, life cycle levelizing constants, and number of farmhouses to develop the break-even values of WECS production, provided that various uses of WECS energy are presented for electric (Figure 92), natural gas (Figure 93), LP gas (Figure 94), and fuel oil (Figure 95) space heating fuels in this section.

The aggregate distribution of the number of potential farmhouse applications for WECS break-even energy value is shown in Figure 96.

In farm building applications, the dairy, broiler, and brooding/layer operations showed good potential use of WECS energy. Other applications showed relatively small needs for space heating energy, due to the size of the animals involved or to the relatively minor space heating demands. The value of WECS energy with thermal storage increased significantly in all cases, and should thus be examined further. With most farm building heating applications, much of the value of WECS production is dependent on the value given to the surplus by the local utility. Since much of the WECS production in the farm building applications is surplus, coordination of farm building and farmhouse needs should be examined to make greater use of WECS production directly on the farm.

The analyses indicate that with electric space heating, nearly 1,000,000 applications are possible if WECS were available at less than

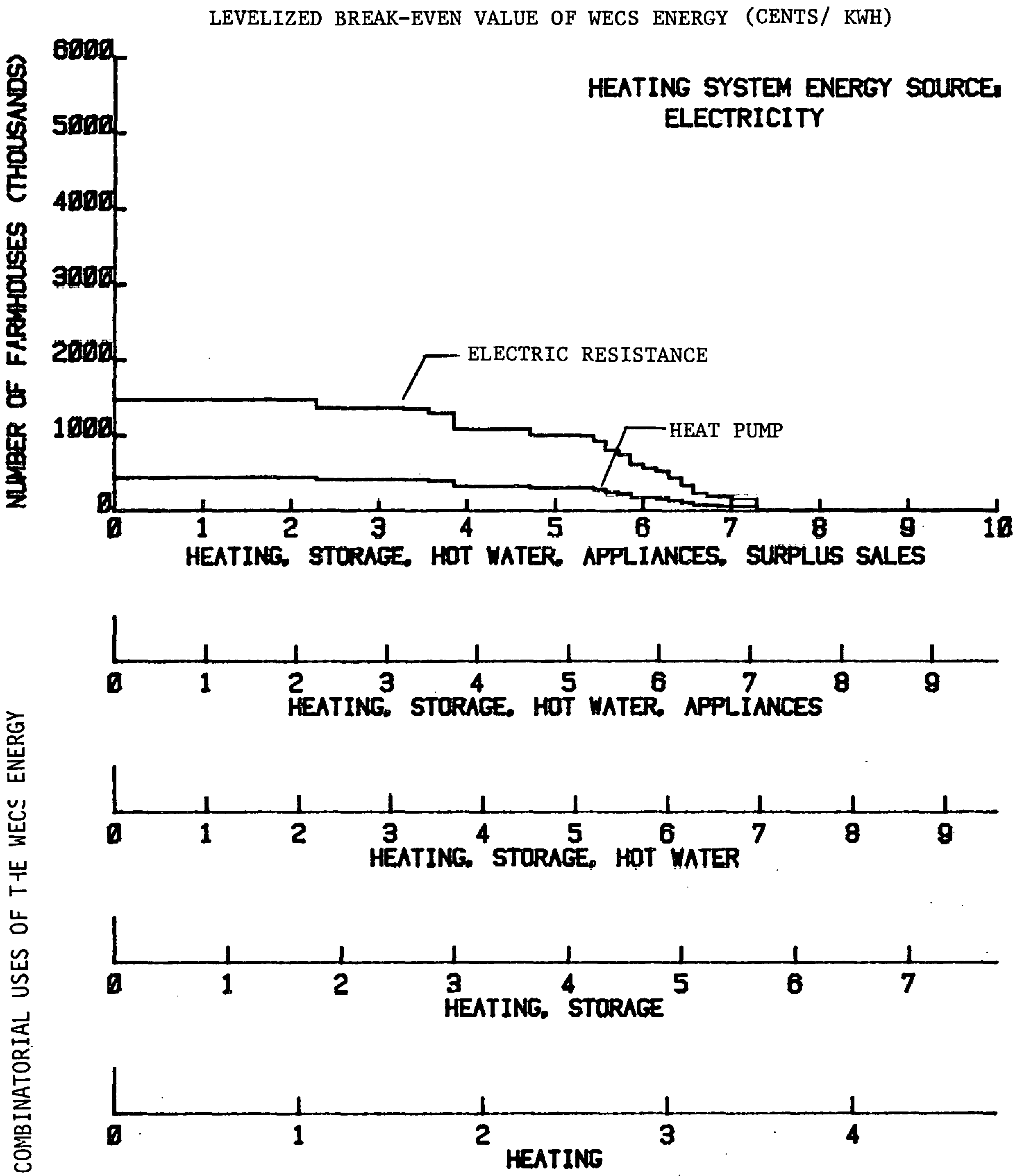


Figure 92 Effect of Combinatorial Uses Of WECS Production On Break-even Value And Number Of Economically Viable Applications For Farmhouses Using Electricity For Heating

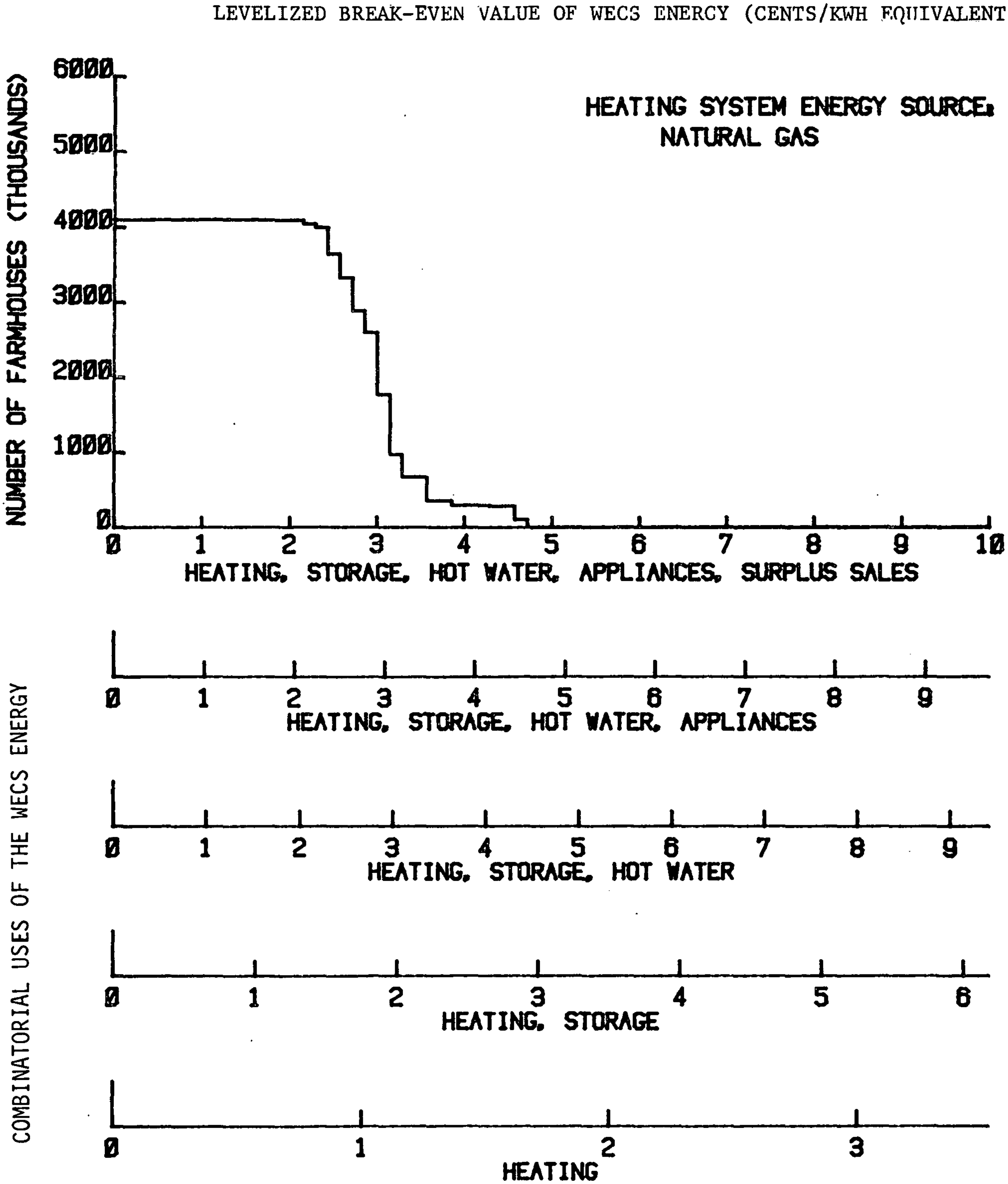


Figure 93 Effect of Combinatorial Uses Of WECS Production On Break-even Value And Number Of Economically Viable Applications For Farmhouses Using Natural Gas For Heating

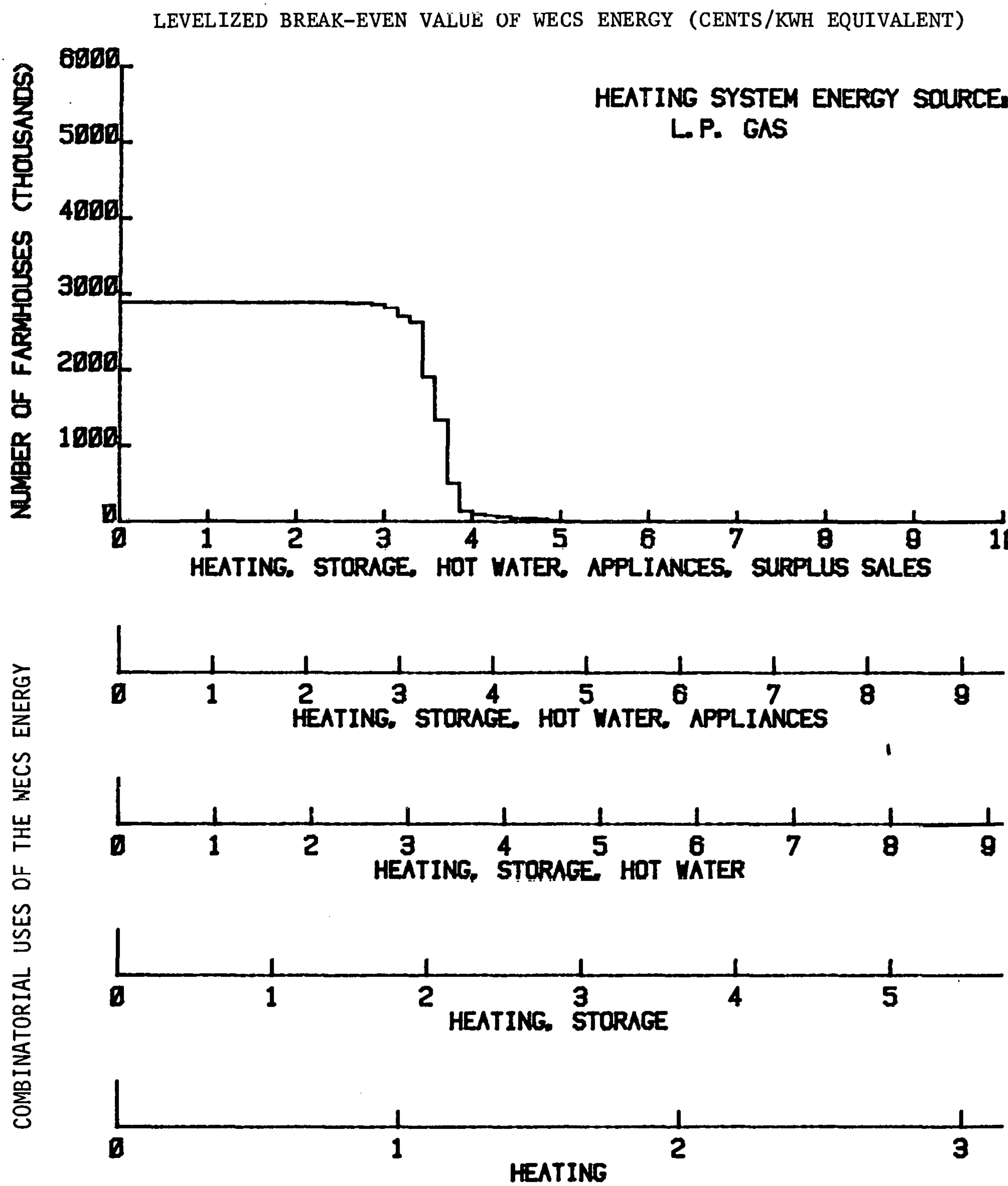


Figure 94 Effect Of Combinatorial Uses Of WECS Production On Break-even Value And Number Of Economically Viable Applications For Farmhouses Using LP Gas For Heating

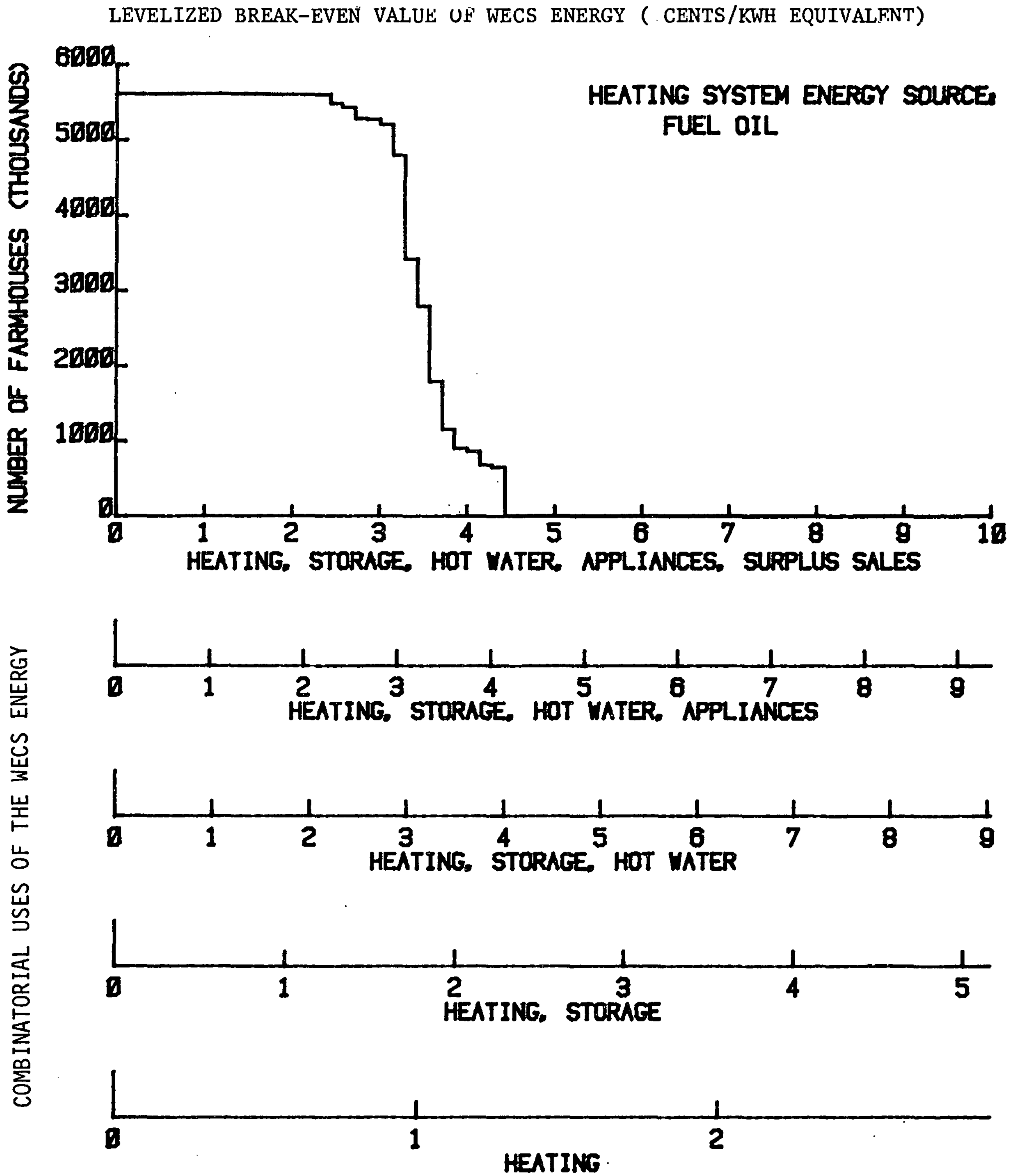


Figure 95 Effect Of Combinatorial Uses Of WECS Production On Break-even Value And Number Of Economically Viable Applications For Farmhouses Using Fuel Oil For Heating

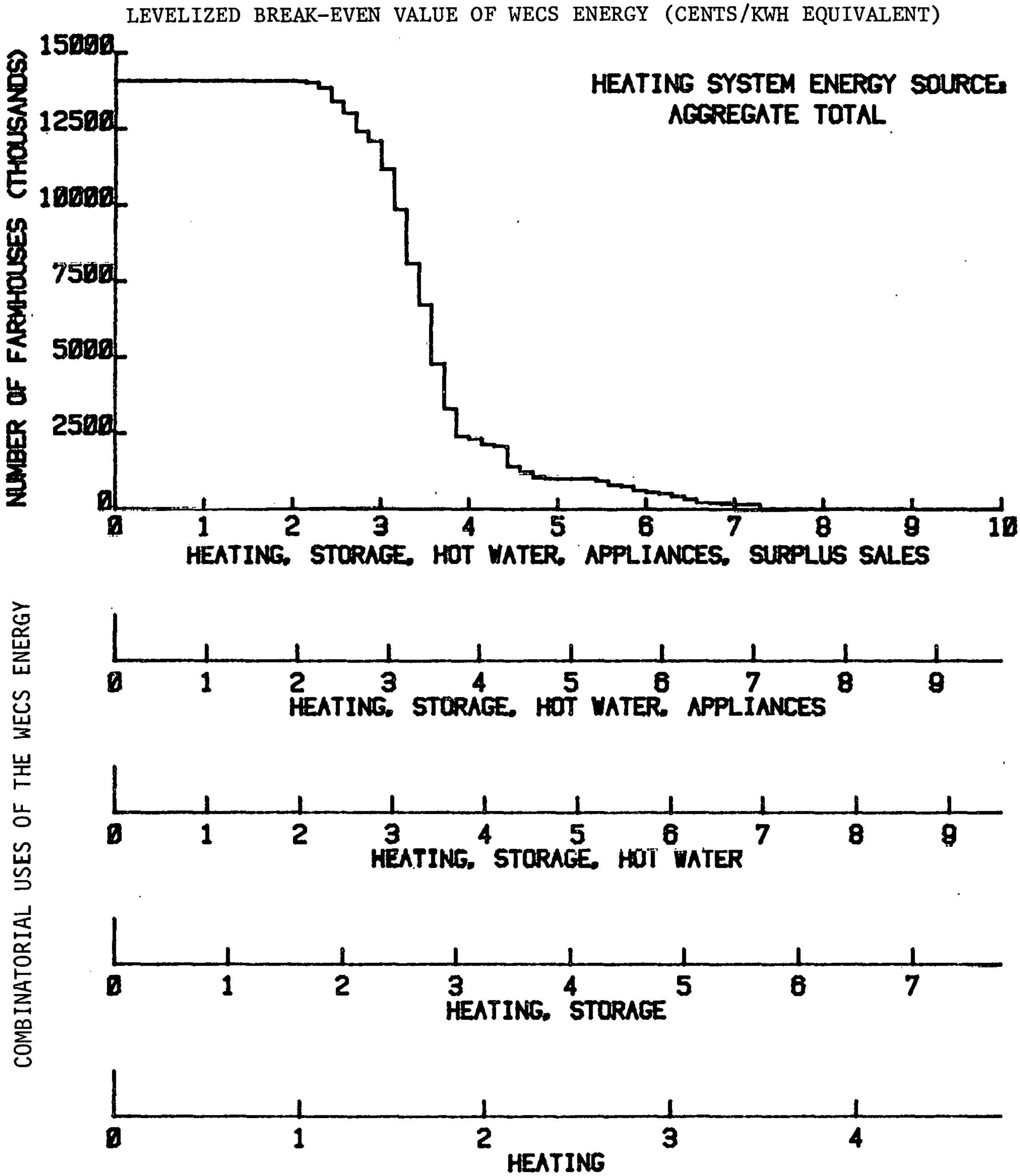


Figure 96 Effect Of Combinatorial Uses Of WECS Production On Break-even Value And Number Of Economically Viable Applications For Farmhouses Using All Types Of Energy Examined

2.75 cents/kwh. With storage for space heating, the WECS break-even value increases to 4.2 cents/kwh. If thermal storage for hot water is also included, the WECS break-even cost increases to 5.3 cents/kwh for 1,000,000 applications. Incorporating all uses of WECS, a break-even cost of 5.5 cents/kwh is realized for 1,000,000 applications.

Since fuel oil, LP gas, and natural gas costs found in the national survey were much less than electric costs, the break-even cost of WECS energy is correspondingly lower to compete with these fuels. Without thermal storage, the WECS break-even costs must be less than 1.25, 1.30, and 1.2 cents/kwh to compete with fuel oil, LP gas, and natural gas, respectively, and reach 1,000,000 applications. However, with thermal storage for space heating and service hot water, the break-even costs of WECS energy can increase to 3.3, 2.8, and 3.2 cents/kwh for fuel oil, natural gas, and LP gas, respectively, for 1,000,000 potential applications. The number of potential applications for other break-even cost levels for WECS can be determined directly from the cumulative distribution diagrams.

7.1 SYNOPSIS

The value of thermal storage for space heating and water is significant for all WECS applications. With thermal storage, the heating value of WECS energy doubles for all heating fuels, allowing a higher break-even cost for WECS. Even though the costs of heating with petroleum fuels is about 1/3 the cost of heating with electricity, using WECS for other local uses increased the allowable WECS break-even costs to more than 3 cents/kwh. In the case of electric space heating with thermal storage, the allowable break-even costs for WECS increases from less than 3 cents/kwh to more than 6.2 cents/kwh. When all the local uses for WECS production were considered, the allowable break-even costs reached 6.5 cents/kwh and provided at least 500,000 potential farmhouse applications. Recent deregulation of petroleum based and hydrocarbon heating fuels may cause the economic results for these fuels to be conservative.

REFERENCES AND BIBLIOGRAPHY

1. Foley, Richard C. :
   1972, Dairy Cattle-Principles, Practices, Problems, Profiles
2. Ensminger, M. Eugene :
   1976, Beef Cattle Science, 5th Edition
3. Ensminger, M. Eugene :
   1970, Sheep and Wool Science, 4th Edition
4. Lockeretz, William :
   1977, Agriculture and Energy
5. U. S. Department of Commerce :
   1974, 1974 Census of Agriculture
6. Midwest Plan Service:
   1977, Structures and Environment Handbook
7. Ensminger, M. Eugene:
   1971, Poultry Science 1st Edition
8. U. S. Department of Commerce :
   1974, 1974 Census of Agriculture, Vol IV, Pt. 1. Graphic Summary
9. U. S. Department of Agriculture:
   1974, Economic Research Service, The U. S. Food and Fiber Sector : Energy Use and Outlooks
10. Denham, H. H. :
    1975, Cow-Calf Performance in Total Confinement, Semi-Confinement and on Native Range, PR-75-52
11. Knox, P., and Hobson, B. :
    1975, Modeling of Energy and Resource Use in Colorado Beef Production
12. Chaloupka, G. W. :
    1973, Substation Flock S. 376, Report on Weekly Growth and Feed Consumption
13. Collins, N. E., and Walpole, E. W. :
    1974, Computer Simulation of Fuel Requirements for Growing Broilers, 74-5020
14. Oti, H.:
    1972, The Effect of Heat and Moisture on Growing Broilers, 1972 Broiler Housing Seminar
15. Council For Agricultural Science and Technology:
    1975, Potential for Energy Conservation in Agricultural Production, 40
16. American Society of Agricultural Engineers:
    1975, Energy-A Vital Resource For the U. S. Food System: Cost and Policy Impacts on Agriculture and the Consumer
17. U. S. Department of Agriculture:
    1977, Energy and U. S. Agriculture: 1974 Data Base Volume 2: Commodity Series of Energy Tables
18. U. S. Department of Agriculture:
    1979, Agricultural Prices, Annual Summary 1978, PR 1-3 (79)

19. U. S. Department of Energy;
1979, Wind Energy Applications in Agriculture, DOE/SEA-11109-20401/79/2
20. Institute of Gas Technology:
1976, Wind-Powered Hydrogen Electric Systems For Farm and Rural Use, NSF/RA-760184
21. Holman, J. P. :
1972, Heat Transfer
22. Esmay, Merle L.:
1978, Principles of Animal Environment
23. U. S. Department of Agriculture, Rural Electrification Administration:
1978, Annual Statistical Report, Rural Electric Borrowers
24. U. S. Department of Energy:
1978, Fundamentals of Solar Heating, EG-77-C-01-238
25. Kreith, Frank:
1972, Principles of Heat Transfer, 3rd Edition
26. Hudson, Ralph G.:
1917, The Engineers' Manual, 2nd Edition
27. Myers, Glen E.:
1971, Analytical Methods in Conduction of Heat Transfer
28. Brooker, Donald B., Bakker-Arkema, Fred W. et. al.:
1974, Drying Cereal Grains
29. U. S. Department of Agriculture:
1978, Agricultural Statistics
30. Miller,Irwin and Freund, John E.:
1977, Probability and Statistics For Engineers 2nd Edition
31. Hicks, Tyler G.:
1972, Standard Handbook of Engineering Calculations
32. DeWinkel, Carel C.:
1979, An Assessment of Wind Characteristics and Wind Energy Conversion Systems For Electric Utilities, IES Report 104
33. U. S. Department of Energy:
1979, Statistical Models For Wind Characteristics At Potential Wind Energy Conversion Sites, DOE/ET/20283-1
34. U. S. Department of Energy:
1978, A Wind Powered Heat Pump in a Dairy Farm Application, DOE/HC/10227
35. U. S. Department of Energy;
1979, Application of Wind Energy to Great Plains Irrigation, DOE/SEA-707020741/80/1
36. U. S. Department of Energy:
1979, State Energy Fuel Prices By Major Economic Sector from 1960 through 1977, DOE/EIA-0190

37. Information Please Almanac:
1978, Information Please, Inc. 0-449-7-6681-0
38. American Gas Association:
1975, Gas Facts: A Statistical Record of the Gas Utility Industry, 1974 Data Base
39. U. S. Department of Commerce, Bureau of the Census:
1974, Statistical Abstract of the United States, 95th Edition
40. U. S. Department of Energy:
1977, Design Study of Wind Turbines, 50 KW to 3000 KW for Electric Utility Applications, ERDA/NASA-1904-76
41. U. S. Department of Commerce, Bureau of the Census:
1978, Annual Survey of Manufacturers 1976, Fuels and Electric Energy Consumed, M76(AS)-4.2
42. U. S. Department of Energy, Federal Energy Management Program:
1980, Architects and Engineers Guide to Energy Conservation in Existing building, DOE/DC-0132
43. Energy Research and Development Administration, Division of Const.:
1976, Life cycle Costing Emphasizing Energy Conservation-Guidelines for Investment Analysis,E(49-1)-3850
44. Elliot, Dennis L.:
1977, Synthesis of National Wind Energy Assessments, BNWL-2220 WIND-5
45. Cliff, William C. :
1977, The Effect of Generalized Wind Characteristics on Annual Power Estimates from Wind Turbine Generators, PWL-2436
46. U. S. Department of Energy, Office of Conservation and Solar Energy:
1980, Federal Register, Part IX
47. U. S. Department of Agriculture, Rural Electrification Administration:
1977,Annual Statistical Report, Rural Electric Borrowers
48. ERDA, Division of Solar Energy:
1975, United States Wind Speed and Wind Power Duration Tables By Months(Cumulative Distributions), SAN/1075-2
49. U. S. Department of Commerce, National Technical Information Service:
1075, Wind Power Climatology of the United States, SAND-74-0348
50. U. S. Department of Energy:
1978, National Wind Data Index,HCOC/T1041-01
51. U. S. Department of Commerce, Economic Development Administration:
1977, Solar Heating and Cooling of Residential Building-Sizing, Installation and Operation Systems

52. U. S. Department of Commerce, Economic Development Administration:

1977, Solar Heating and Cooling of Residential Buildings-Design of Systems

53. American Society of Heating, Refrigerating and Air-Conditioning Engineers:

1977, Handbook and Product Directory, 1977 Fundamentals

54. ibid,:

1976, Handbook and Product Directory, 1976 Systems

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

APPENDIX

This appendix presents the digital computer program used for the study analyses. The program is designed to be interactive and self-prompting. Input variables required are requested by displays at the computer terminal. The program is not configured for a batch processing environment. The program is written in ANSI Fortran IV and was developed under the Digital Equipment Corporation PDP 11 operating system.

All energy balances were made at an hourly interval to allow for dynamic modeling of sensible and latent heat gains from the animals and humans, the time coincidence of the wind resource and the building energy needs, and for the effects of the thermal storage.

Particular attention was focused on the effects of ventilation on building energy needs. In most cases, the energy inputs and losses were integrated from calculations made at 1/10th and 1/20th hourly intervals. Input data files were prepared from hourly climatic data obtained obtained from the National Climatic Center.

A flow chart listing the program and its subroutines is presented in Figure 1. The program listing is presented on the following pages.

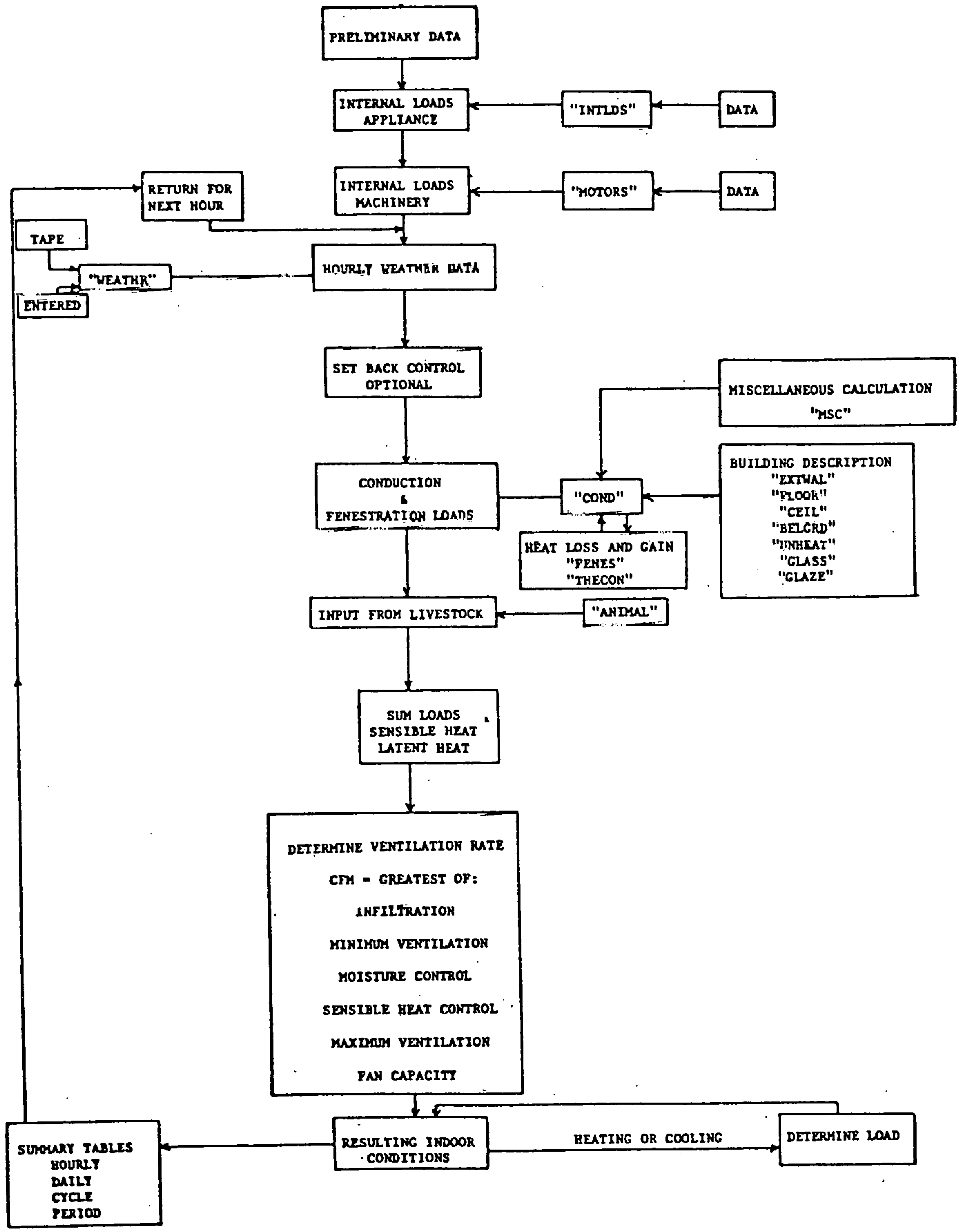


Figure A-1.--Flow Chart of Energy Balance Calculations

```
C         THIS PROGRAM CALCULATES THE PHYSICAL PLANT REQUIREMENTS
C         TO MAINTAIN INSIDE TEMPERATURE AND HUMIDITY OR THE
C         PROGRAM CAN BE USED WITH PLANT CAPACITIES TO FIND
C         RESULTING CONDITIONS.
C
C         LOADS INCLUDED IN THE CALCULATIONS, CONDUCTION, FENESTRATION,
C         INTERNAL EQUIPMENT, ANIMAL, AND VENTILATION AND INFILTRATION
C
C
C
          DIMENSION SUMFED(12),SUCYFD(12),CCY(5)
          DIMENSION FEED(12),QAPPL(24),WAPPL(24),QMOTOR(24)
C
C
          INTEGER DATE1,PROG,DATE2,SETBAC,PRINT
C
C
C
          BYTE YES, NO, RESP, FLNAM(15), FINA(12)
C
C
          REAL LAT,MSTCFM,LONG,MINCFM,MAXCFM,LWRTO,MAXPRO
          1    ,MNCFM,MXCFM
C
CC
          DOUBLE PRECISION CITY, STATE   , RZONE(5), ZONE
C
C
C
          COMMON/DAYS/WTT1(9)
          COMMON/PASS/PST(9)
          COMMON/PROP/PST2(12)
          COMMON/STO/ STORI(10)
          COMMON/PRE/ PREI(13)
          COMMON/WECS/BTUWEC,PNET,QNET1,QNET2,QTOPRE,QTOAPP,WECEXE,
          1   WECDAY,PLNT1,DAILYD,DAILYS,DAILYH,DAILYA,DAILYE,
          2   WECCYC,PCYC,DRCYC,STCYC,PRCYC,APCYC,EXCYC,
          3   WECSUM,SUMPLN,SUMDRA,SUMSTR,SUMPRE,SUMAPP,SUMEXE
C
C
          COMMON/KEEP56/ BULARE, CPMASS
C
          COMMON/KEEP33/IBIRD, IPASSV
C
          COMMON/SAAA/ BEAR(7,24)
          COMMON/DAYSUM/DAILYF, DAILYC, DAILYQ, DAILYP, DAILYW, DAILYR
          COMMON/CYCSUM/ CCY, SUMCOM, SUMPR2, SUCYFD,TOTR
C
C
          COMMON/SUMPER/ SUMFUR, SUMCOL, SUMCFM, SUMWTR, SUMP
          1   ,SUMFED, SUMPAS
```

```
      COMMON/FURN/ FURNC1, QFURN
C
C
      COMMON/PLANT/ JAP, AIRMIN, TMIN1, AIRDNO, TOUT, AIRMAX, TMAX1,
      1  QSUM, QPLANT, WSUM, CFM, VMASS, QLAT, WPLANT
C
C
C
C
      COMMON/COOL/ CHILL1, QCHILL, RHMAX1, PATS, WOT, EXMOST,
      1    CFMINF, CFMN1
C
C
      COMMON/PNTCOM/IDUMMY(26)
C
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,
     1 CLOUD,WIND,WINDIR,RHO,MINCFM,MAXCFM,IYEAR,
      2  WEIGHT,TL1,TL2,QS
      COMMON/PRO/SUMPRO,SCOMM,DIFF
C
      COMMON/KEEP5/QANIM,WANIM,PROC,IDAY,QWATER,FEED,LEAF
      1  ,PPROD,TEMPA,SUM,SUM1,AVTEMP,OPR,ICAN,JACK,TE
C
      COMMON/WTHCOM/STN
C
      COMMON/ INTL / ELEV, PRINT, FURNC, CHILL, CFMFAN,
      1  AP1, AP2, AP3, AP4, AP5, SETBAC, STMIN,
      2   STMAX, IBTIME, IPTIME,DATE1,DATE2, INTERV
C
      COMMON/KEEP3/QAPPL,WAPPL,QMOTOR
C
      COMMON/KEEP6/ RZONE,NTS, ALST, ALSTT(5), ZONE
C
      COMMON/KEEP35/WATER(24), GALLON(24)
C
C     COMMON/KEEP10/ TEMPG,TEMPC
C
      COMMON/REQIR/ANIML,IMAX,TMIN,RHMAX,MNCFM,MXCFM,OPTT,OPTRIY,
     1 DDREFT,SPAREQ,LWRTO,WWARO,TEMPCY,DELTEM,MAXPRO,ANDIST,PROCYC,
     2 COUNT
C
      DATA IBALL/0/ , IBOAT/0/
      DATA QSTORG, STRLSS/ 0.0, 0.0/
      DATA FLNAM/'D','L','1',':','S',' ',' ',' ',' ',
      1  ' ','.','D','A','T',0/
      DATA PR1,PR2,PR3/'HOUR','DAIL','CYCL'/
      DATA SUMFED,SUCYFD,CCY/29*0.0/
      DATA IPETE,TOTR,SUMPAS/0,0.0,0.0/
      DATA YES/'Y'/,NO/'N'/
      DATA HELP/'HELP'/
      DATA FEED/ 12*0.0/
      DATA WATER/24*0.0/,IPASSV/0/
C
C     INITIALIZE DATA
      DATA IHOUR,NDAY,IDAY,JAP,ICOUNT,SUMP,INTER/1,1,1,0,0,0.0,1/
```

```
C
      OPEN(UNIT=1,NAME='THRMDA.DAT',TYPE='OLD',ACCESS='DIRECT',
     1FORM='UNFORMATTED',DISPOSE='SAVE',RECORDSIZE=16,
     2MAXREC=349,ASSOCIATEVARIABLE=NREC)
C
C     OPEN FILE FOR DATA INPUT
      CALL TIME(ZONE)
      WRITE(6,39482) ZONE
C     WRITE(7,1220)
C     READ(5,510) RESP
C     IF(RESP .NE. YES) GO TO 12345
      WRITE(7,2020)
      READ(5,2030) N, (FINA(J),  J=1,N)
      CALL CLOSE(5)
      CALL ASSIGN(5,FINA,0,'RDO')
C
C     SET INTIAL DATA
C
12345 CALL INTL
C
C
C
C      INTITIALIZE ANIMAL DATA
C
C
      CALL ANIML1
      IF(LEAP.LT.5.OR.LEAP.GT.8) CALL ANIML3
      IF(LEAP.GT.4.AND.LEAP.LT.9) CALL ANIML1
      OPTRIY=OPTRIY/100.
      RHMAX=RHMAX/100.
      RHMAX1 = RHMAX
C
C
C
C
C     INITIALIZE DATA
C
      IDATE=DATE1
      AP1 = TMIN
      AP2 = TMAX
      TMASS = TEMPI
C
C
C
C     ************* THIS IS THE RETURN POINT ***
C
C
25    CONTINUE
      QROOM = 0.0
      QLAT=0.0
      QCHILL=0.0
      QFURN=0.0
      QPLANT=0.0
      EXMOST=0.0
```

```
      WECENE = 0.0
      BTUWEC = 0.0
      PNET = 0.0
      OPT = OPTT +5.0
      QNET1 = 0.0
      QNET2 = 0.0
C
C
C
C     SET WEATHER DATA FOR DAY AND HOUR
      CALL WEATHR
      TOUT = TEMPO
C
C
C     WRITE(6,9990) TEMPO, RHO, WIND, WINDIR, CLOUD
C9990 FORMAT(1HO, 'TEMPO, RHO, WIND, WINDIR, CLOUD, ',/,
C     1       5(5X,F10.3))
C
C
C     SETBACK CONTROLS
      WRITE(7,2040) IHOUR, IDAY
C
C
      IF (SETBAC.EQ.0) GO TO 440
      IF(IBTIME.EQ.IHOUR)FROG=1
      IF(IPTIME.EQ.IHOUR)FROG=0
C     SET SETBACK VALUES, TMIN, TMAX
C     IF FROG = 1 OPERATE IN SETBACK MODE
      IF (FROG.EQ.0) GO TO 441
      TMIN=STMIN
      TMAX=STMAX
      GO TO 442
441   CONTINUE
      TMIN= AP1
      TMAX=AP2
442   CONTINUE
440   CONTINUE
C
C
C
C     DETERMINE LOCAL ATS, PRESSURE
      PATS=PREATS (ELEV,TEMPO)
C     DETERMINING PLANT LOADS
C
C     AIR DENSITIES AT START OF HOUR
      AIRDNI = AIRDEN(PATS,TEMPI)
      AIRDNO=AIRDEN(PATS,TEMPO)
      AIRMAX=AIRDEN(PATS,TMAX)
      AIRMIN=AIRDEN(PATS,TMIN)
C
C     OUTSIDE HUMIDITY RATIO
      WIN=HUMRTO(TEMPI,OPTRIY,PATS)
      WOT=HUMRTO(TEMPO,RHO,PATS)
      CALL WECPR2 (BTUWEC, AIRDNO, WIND)
      CALL PREHET (QTOPRE, QPREL, QHLS, TEMPI, IHOUR)
```

```
      CALL STORE1 (QNET, QSAVB, QSTL, QSLOSS, TEMPI, IHOUR)
C
C     PRINT ALTERNATIVE SYSTEM PARAMETERS
C
      IF(KAT .EQ. 0 ) CALL SYSPRN
      IF(IPASSV .NE. 0 ) GO TO 1
      WRITE(7,2050)
      READ(5,510) RESP
      IPASSV = 5
      IF(RESP .EQ. YES) IPASSV = 10
1     IF(IPASSV .EQ.10)
      1  CALL PASSIV(TEMPI, IBOAT, AIRDNI,TEMPO, QROOM
      2  ,TMIN,TMAX)
C
C     WRITE(6,9119) QHLS, QPREL, QNET, QSAVB, QSTL, QSLOSS
C9119 FORMAT(2X,' QHLS, QPREL, QNET, QSAVB, QSTL, QSLOSS = ' 6F10.1)
C     ANIMAL PRODUCTION - SENSIBLE AND LATENT
C
C
      IF(LEAF.LT.5.OR.LEAF.GT.8) CALL ANIML3
      IF(LEAF.GT.4.AND.LEAF.LT.9) CALL ANIML1
      IF(KAT.EQ.0 ) RHMAX = RHMAX/100.0
      IF(KAT.EQ.0 ) OPTRIY = OPTRIY/100.0
      IF ( IHOUR .NE. 24 ) GO TO 666
      DO 665 JR=1,12
      SUMFED(JR)=SUMFED(JR)+FEED(JR)
      SUCYFD(JR)=SUCYFD(JR)+FEED(JR)
665   CONTINUE
666   CONTINUE
C
C     RESET TEMPI = TMIN OR TMAX IF LIMITS CHANGED
      IF ( TEMPI .LT. TMIN .AND. FURN .NE. 0.0 ) TEMPI = TMIN
      IF ( TEMPI .GT. TMAX .AND. CHILL .NE. 0.0 ) TEMPI = TMAX
C
C     CALL STRUCTURAL DESCRIPTION AND EVALUATION ROUTINES
C
C
      CALL CONDIT(QCOND,CFMINF,ADJFAC,VOLUME,SQFT)
C
C
C
C
C
C     DETERMINE VENTILATION RATE
      QSUM=( QROOM + QCOND + QAPPL(IHOUR) + QMOTOR(IHOUR) +
      1   QANIM + QSLOSS + QHLS)*ADJFAC
      WSUM=(WANIM+WAPPL(IHOUR))*ADJFAC
      BTUWTR = WATER(IHOUR)
C
C
D     WRITE(6,9994) QSUM, QCOND, QAPPL(IHOUR), QMOTOR(IHOUR), QANIM
D9994 FORMAT(1H0,' QSUM, QCOND, QAPPL, QMOTOR ', 4(3X,F10.3))
D     WRITE(6,9993) WSUM, WANIM, WAPPL(IHOUR), ADJFAC, BTUWTR,
D     1       WATER(IHOUR)
D9993 FORMAT(1H0, ' WSUM, WANIM, WAPPL, ADJFAC, BTUWTR, QWATER,',/,
```

```
D        1       6(5X,F10.3))
C
C        HOURLY BALANCE
C
         TMSAVE = TMASS
         WSAVE = WIN
         SAVE = TEMPI
180      CONTINUE
         CFMSUM = 0.0
         TEMPI = SAVE
         WIN = WSAVE
         TMASS = TMSAVE
C
C
C        SENSIBLE HEAT BALANCE
C
         ITERX=30
         TERX=FLOAT(ITERX)
         DO 2014 I15=1,ITERX
         IF(JAP .EQ. 5 ) GO TO 155
         CFM=CFMINF
C
C
C
C        MOISTURE BALANCE CHECK
C        ROOM AIR MASS * CP
         RMASS = VOLUME * (.240 + .444 * WIN)
         WMAXI=HUMRTO(TEMPI,RHMAX,PATS)
C        MINIMUM VENTILATION FOR MOISTURE CONTROL
C
         DELW = WMAXI-WOT
         IF(DELW .NE. 0.0)
         1  MSTCFM=WSUM/((DELW)*AIRDNO*60.)
         IF(DELW .EQ. 0.0) MSTCFM = MAXCFM
C
C
C        SENSIBLE HEAT CONTROL
         TVENT = OPTT
         IF((TEMPO + 5.0) .GT. OPTT) TVENT = TEMPO + 5.0
         AIRVET = AIRDEN( PATS,TVENT)
         QMASS1 = 1.80 * BULARE * (TMASS - OPTT)
         QVENT = QSUM + QMASS1
C        CALCULATE CFM FOR SENSIBLE HEAT CONTROL
         SHTCFM=QVENT/((AIRVET*60.*(.240 + .444 * WIN))*TVENT-TEMPO*
         2  (AIRDNO*60.*(.24 + .444 * WOT)))
C
C
C        MINCFM IS THE MINIMUM VENTILATION RATE
         IF(CFM.LT.MINCFM)CFM = MINCFM
C
C        MOISTURE CONTROL
         IF(CFM.LT.MSTCFM)CFM = MSTCFM
C
C        SENSIBLE HEAT CONTROL
         IF (CFM.LT.SHTCFM) CFM=SHTCFM
```

```
C
C        CHECK IF FANS CAN HANDLE VENT RATE
         IF(CFMFAN.EQ.1.0) GO TO 153
         IF(CFM.GT.CFMFAN)CFM = CFMFAN
153      CONTINUE
C
C        CHECK IF VENT RATE IS GREATER THAN MAX
         IF(CFM.GT.MAXCFM) CFM = MAXCFM
C
C        CHECK IF VENT RATE IS LESS THAN INFCFM
         IF(CFMINF.GT.CFM) CFM=CFMINF
C
D        WRITE(6,8700) CFMINF, MINCFM, MSTCFM,
D        1    SHTCFM, CFMFAN, MAXCFM, CFM
D8700    FORMAT(1H0,' CFMINF, MINCFM, MSTCFM,
D        1     SHCFM, CFMFAN, MAXCFM, CFM,'/,    7F8.0)
C
155      CONTINUE
         VMASS=CFM*60. * (.240 + .444 * WOT)
C        DELTA TEMP BETWEEN MASS AND AIR
         QMASS = 1.80 * BULARE *(TMASS - TEMPI)
C
C        NET PLANT LOAD
         QPNET = (QPLANT/(QPLANT + .01)) * (QPLANT - QMASS)/TERX
         IF(QPLANT .LT. 0.0 .AND. QPNET .GT. 0.0 ) QPNET = 0.0
         IF(QPLANT .GT. 0.0 .AND. QPNET .LT. 0.0 ) QPNET = 0.0
C
C        INDOOR AIR DENSITY
         AIRDNI=AIRDEN(PATS,TEMPI)
C
C        THERMAL BALANCE
         BALANI=VMASS*(AIRDNO*TEMPO-AIRDNI*TEMPI)/TERX
         1  + RMASS * TEMPI * AIRDNI
         2  + QMASS/TERX + QSUM/TERX + QPNET
C
C        ACTUAL PLANT LOADS
         IF(QPNET .GT. 0.0 ) QFURN = QFURN + QPNET
         IF(QPNET .LT. 0.0 ) QCHILL = QCHILL - QPNET
         TEMPI=BALANI/(RMASS*AIRDNI)
         TMASS = TMASS - QMASS/(TERX * CPMASS)
         IF(TEMPI .LT. TEMPO .AND. QPNET .GT. 0.0) TEMPI = TEMPO
C         SUM VENTILATION
         CFMSUM = CFMSUM + CFM
D        WRITE(7,5052) TEMPI, TMASS, QMASS, CPMASS, BULARE
D5052    FORMAT(1H0,' TEMPI, TMASS, QMASS, CPMASS, BULARE,
D        1  ,5(2X,F10.3))
C        WRITE(7,5050) BALANI, VMASS, AIRDNO, AIRDNI, RMASS, TEMPI
C5050    FORMAT(1H0,F10.0,2X,F10.0,2X,F10.8,2X,F10.8,2X,2F10.5)
C
C        DETERMINE HUMIDITY RATIO WITH EXHAUST
         ORANGE=WIN+(CFM*60.0*AIRDNO*(WOT-WIN)
         1    +WSUM+WPLANT)/(AIRDNI*VOLUME*TERX)
         WIN=ORANGE
C
2014     CONTINUE
```

```
      RESTEM=TEMPI
      RESW=WIN
      TIDE = TEMPI
      IF(TEMPI.LT.TMIN) TIDE = TMIN
      WMAXI=HUMRTO(TIDE,(RHMAX + 0.01),PATS)
      TMIN1 = TMIN
      TMAX1 = TMAX
      FURNC1 = FURNC
      CHILL1 = CHILL
      CFMN1 = MINCFM
C
C     IF FURNACE OR CHILLER HAVE RUN FOR THE HOUR GO AROUND
      IF ( JAP .NE. 0 ) GO TO 5070
C
C     IF(RESTEM .LT. TMIN .OR. RESTEM .GT. TMAX) CFM = MINCFM
C     IF(MINCFM .LT. CFMINF) CFM = CFMINF
C      CHECK FOR FURNACE OR CHILLER LOAD
C
C     FURNACE
      IF( RESTEM .LT. TMIN ) CALL FURNAC
C
C
C     CHILLER SENS. HEAT
      IF( RESTEM .GT. TMAX ) CALL CHILLR
C     CHILLER MOISTURE CONTROL CHECK
      IF( RESW .GT. WMAXI .AND. RESTEM .GT. TMIN ) CALL CHILLR
C
C
C
      IF(JAP .EQ. 5) GO TO 180
5070  CONTINUE
      QCHILL = QCHILL + QLAT
      QPLANT = QFURN + QCHILL
      TMSAVE = TMASS
      CFM = CFMSUM/TERX
      IF(QFURN .GT. BTUWEC) PNET = QFURN - BTUWEC
      WECENE - BTUWEC - (QFURN - PNET)
      CALL DISPCH (QNET, QSTL, QSAVB, QTOPRE, QPREL,
      1  QTOAPP, QAPPL(IHOUR), PNET, WECEXE, WECENE)
C     WRITE RESULTS
C
C
      IF(QNET .LT. 0.0) QNET1 = QNET
      IF(QNET .GE. 0.0) QNET2 = QNET
C     DAILY TOTALS
C
C
      DAILYR = DAILYR + QROOM
      DAILYF=DAILYF+QFURN
      DAILYC=DAILYC+QCHILL
      BURP=CFM*60.0
      DAILYQ=DAILYQ+BURP
      DAILYP=DAILYP+QFURN+QCHILL
      DAILYW=DAILYW+BTUWTR
      PLNT1 = PLNT1 + PNET
```

```
      WECDAY = WECDAY + BTUWEC
      DAILYD = DAILYD + QNET1
      DAILYS = DAILYS + QNET2
      DAILYH = DAILYH + QTOPRE
      DAILYA = DAILYA + QTOAPP
      DAILYE = DAILYE + WECEXE
      SUMP = SUMP + TEMPI/24.
      CCY(4) = CCY(4) + TEMPI/24.
C
C
C
      IF(IHOUR .NE. 24 ) GO TO 865
C     PERIOD SUMMATION
C
      SUMPAS=SUMPAS + DAILYR
      SUMFUR=SUMFUR + DAILYF
      SUMCOL=SUMCOL + DAILYC
      SUMCFM=SUMCFM + DAILYQ
      SUMWTR=SUMWTR + DAILYW
      SUMPLN = SUMPLN + PLNT1
      WECSUM = WECSUM + WECDAY
      SUMDRA = SUMDRA + DAILYD
      SUMSTR = SUMSTR + DAILYS
      SUMPRE = SUMPRE + DAILYH
      SUMAPP = SUMAPP + DAILYA
      SUMEXE = SUMEXE + DAILYE
      SUMCOM = SCOMM
      SUMPR2 = SUMPRO
C
C
C     CYCLE TOTALS
C
      CCY(1)=CCY(1)+DAILYF
      CCY(2)=CCY(2)+DAILYC
      CCY(3)=CCY(3)+DAILYQ
      CCY(5)=CCY(5)+DAILYW
      PCYC = PCYC + PLNT1
      WECCYC = WECCYC + WECDAY
      DRCYC = DRCYC + DAILYD
      STCYC = STCYC + DAILYS
      PRCYC = PRCYC + DAILYH
      APCYC = APCYC + DAILYA
      EXCYC = EXCYC + DAILYE
      TOTR=TOTR + DAILYR
C
865   CONTINUE
C
      IF(KAT.EQ.0) IPETE=5
C
C
C     PERIODIC HOURLY PRINT OPTION
C
      IPERF = PRINT
      IF ( INTERV .EQ. INTER ) PRINT = 1
      IF(PRINT.NE.1) GO TO 1501
```

```
C
C
      CALL PEAR(KAT,IBEEP,IHOUR, WIND,IDATE,IDAY,
      1  RESTEM, TEMPO, CFM, QPLANT, EXMOST,
      1  QFURN, QCHILL, SAVE, IPERF)
      IBEEP = 0
1501  CONTINUE
      PRINT = IPERF
C     IF A DAY IS COMPLETED WRITE TOTAL CONSUMPTION
      IBEEP = 0
      IF( IHOUR .NE. 24 ) GO TO 85
      IF(PRINT.LE.2 .OR. INTERV .EQ. INTER )
      1 CALL DAYPRN(IDATE, IDAY, PRINT, IPETE, INTERV, INTER, PPROD,
      1  AVTEMP, TEMPA)
      IF( INTERV .EQ. INTER .AND. IHOUR .EQ. 24) INTER = 0
      IF( IHOUR .EQ. 24 )INTER = INTER + 1
      IPETE = 5
      IBEEP = 5
      DAILYF=0.0
      DAILYC=0.0
      DAILYQ=0.0
      DAILYP=0.0
      DAILYW=0.0
      BTUWTR=0.0
      DAILYR = 0.0
      WECDAY = 0.0
      PLNT1 = 0.0
      DAILYD = 0.0
      DAILYS = 0.0
      DAILYH = 0.0
      DAILYA = 0.0
      DAILYE = 0.0
82    CONTINUE
      IF(PRINT.GT.3) GO TO 85
      IF(FLOAT(NDAY).NE.PROCYC) GO TO 85
      IF(IBALL.EQ.1) GO TO 850
      WRITE(7,1040)
      READ(5,510) RESP
      IF(RESP .EQ. YES) IBALL  = 1
C     CYCLE SUMMARY TABLE
850   CONTINUE
      SUMPR2 = SUMPR2 / FLOAT(NDAY)
      CCY(4)=CCY(4)/FLOAT(NDAY)
      CALL CYCPRN
      DO 88 JB = 1,5
88    CCY(JB) = 0.0
      PCYC = 0.0
      WECCYC = 0.0
      DRCYC = 0.0
      STCYC = 0.0
      PRCYC = 0.0
      APCYC = 0.0
      EXCYC = 0.0
      TOTR = 0.0
      SUMPRO = 0.0
```

```
      DO 89 JB = 1,12
8     SUCYFD(JB) = 0.0
      IF(KAT .EQ. -1 .OR. IBALL .EQ. 0) GO TO 75
      NDAY = 0
      IPETE = 1
85    CONTINUE
      IF(KAT .EQ. -1 ) GO TO 75
      IF(IDATE .EQ. DATE2 .AND. IHOUR .EQ. 24) GO TO 75
      JAP = 0
      IHOUR = IHOUR + 1
      IF(IDATE.EQ.366) IYEAR=IYEAR + 1
      IF(IDATE.EQ.366) IDATE = 1
      IF(IHOUR.NE.25) GO TO 251
      IDATE=IDATE+1
      IHOUR=1
      IDAY=IDAY+1
      NDAY=NDAY+1
251   CONTINUE
      KAT=5
      GO TO 25
C
C
C
C     END RUN AT 75
75    CONTINUE
      SUMP=SUMP/FLOAT(IDAY)
C     WRITE FINAL SUMS
      CALL SUMPRN (IDAY)
510   FORMAT(A1)
1040  FORMAT(1H0,'THE PROCESS CYCLE IS COMPLETE DO YOU WISH TO',
      1 $,/,  ' COMPLETE THE EVALUATION PERIOD ? ')
1220  FORMAT(1H0,$,'DO YOU WANT TO READ FROM DISK ? ')
2020  FORMAT(1X,$,'ENTER FILE NAME ----> ')
2030  FORMAT( Q,12A1)
2040  FORMAT(10(/), 1H0,10X,
      1' NOW EVALUATING HOUR ',I2,' , OF DAY ',
      1  I3,' OF THE PROCESS CYCLE',10(/))
2050  FORMAT(1H0,$,'IS THERE A PASSIVE WALL ? ')
      CALL TIME(ZONE)
      WRITE(6,39482) ZONE
39482 FORMAT(12X,'THE TIME IS ',A8)
      STOP
      END
```

```
      SUBROUTINE CONDIT(QCOND,CFMINF,ADJFAC,VOLUME,SQFT)
C
C
      DIMENSION SUAZAN(8),AWALL(8),AU(8),RADT(8),GAU(8,5),
     1GCODE(8,5),AREA(8,5),
     2 SLOPE(8),SUN(8),ADJ(6),QEXTWL(8),TEMPS(8),
     3 ICON(9),AUFLR(9),QFLR(9),JFN(8),GLAR(8,5),GPROP(8,5,20),
      4 AFEN(8),FLAREA(4)
C
C
C
      REAL MINCFM,MAXCFM,LWRTO,MAXPRO
      REAL LAT,LONG,LST,LSTT
C
C
      DOUBLE PRECISION CITY,STATE,RZONE(5),ZONE
C
C
      BYTE YES,NO,RESP
C
C
      COMMON/KEEP56/ BULARE, CPMASS
C
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,
      1CLOUD,WIND,WINDIR,RHO
C
      COMMON/KEEP6/ RZONE,NTS, LST, LSTT(5), ZONE
C
      COMMON/KEEP10/ TEMPG
C
      COMMON/KEEP15/APPLE(995)
C
      COMMON/KEEP16/BAPPLE(155)
C
      COMMON/SCRTCH/RADT,GAU, FFACT(8,5)
C
      COMMON/REQIR/ANIML,TMAX,TMIN,RHMAX,MINCFM,
      1MAXCFM,OPTT,OPTRIY,DDREFT,SPAREQ,LWRTO,WWARO,
      2TEMPCY,DELTEM,MAXPRO,ANDIST,PROCYC,COUNT
C
C
      DATA YES,NO/'Y','N'/
C
C
C     THIS SUBPROGRAM DETERMINES THE BUILDING THERMAL
C     ENVELOPE.
C
C
C
      QFENE=0.0
      IF(KAT .NE. 0) GO TO 16
      WRITE(6,1602)
C     MISC CALCULATIONS
      CALL MSC(CFMINF, VOLUME, SQFT, PERIM, CPMASS, BULARE)
C
```

```
C        CALCULATE THE MASS AND THE AREA FOR DAMPINING

         IF(BULARE.GT.0.0.AND.CPMASS.GT.0.0) GO TO 2
         BULARE = 0.0000001
         CPMASS = 0.0000001
2        CONTINUE
C        THIS PORTION OF THE PROGRAM CONTROLS THE SOLAR-GAIN
C        THROUGH FENESTRATION AREAS AND EXTERNAL WALLS.  CLOUD
C        IS THE FACTOR USED TO DISCOUNT SOLAR INPUT.
C        EXTERNAL VERTICAL WALLS
         WRITE(7,1100)
         WRITE(6,1101)
         CALL EXTWAL( AWALL, NW, AU, SUAZAN, SLOPE, SUN, ADJ)
C        DETERMINE SOLAR INTENSITY-VERTICAL WALLS
         WRITE (7,1200)
         WRITE (6,1201)
         WRITE (6,1203)
16       CONTINUE
         AURUM=0.0
         DO 15 I = 1,NW
         AURUM=AURUM+AU(I)
         CALL FENES(SUAZAN(I), SLOPE(I), TOTIN)
         RADT(I) = TOTIN*CLOUD
         TEMPS(I)=0.0
C        FENESTRATION GAIN
         IF(KAT.NE.0) GO TO 18
11       WRITE(7,700)I
         READ(5,704)JFN(I)
18       CONTINUE
         NGLAZE=JFN(I)
         IF ( NGLAZE .EQ. 0) GO TO 8
         DO 7 J = 1,NGLAZE
         IF(KAT.NE.0) GO TO 17
         WRITE(7,701)I,J
         READ(5,802)GW
         WRITE(7,803)
         READ(5,802)GH
         WRITE(7,804)
         READ(5,805)GCODE(I,J)
         AREA(I,J) = GW * GH
         WRITE(7,806)GW,GH,GCODE(I,J)
         READ(5,809)RESP
         IF(RESP.NE.YES) GO TO 11
17       CONTINUE
C
C
C
C
C
         II=I
         JJ=J
         CALL GLAZE (QFENES, RADT(I),GAU(I,J),II,JJ,
         1GCODE(I,J),AREA(I,J),FFACT(I,J))
         QFENE = QFENE + QFENES
         AURUM = AURUM + GAU(I,J)
```

```
      IF ( NGLAZE .NE. 0 .AND. KAT .EQ. 0 )
      1WRITE(6,900) I,J,AREA(I,J),GCODE(I,J)
      IF ( NGLAZE .EQ. 0 .AND. KAT .EQ. 0 )
      1   WRITE ( 6,1205 )  I
7     CONTINUE
8     CONTINUE
15    CONTINUE
C     EXTERNAL WALLS THERMAL EXCHANGE
C
C
      CALL THECON(NW,AU,AWALL,QEXTWL,
    1 TEMPO,TEMPI,RADT,QTOT,SUN,ADJ)
21    CONTINUE
      ADJFAC=1.0-0.02/(PERIM*AURUM)
C     THIS PORTION OF THE PROGRAM EVALUATES THE HEAT EXCHANGE
C     THROUGH THE STRUCTURE CEILING.
C     IF(KAT.NE.0) GO TO 20
C     WRITE(7,1300)
C     WRITE(6,1301)
C20   CONTINUE
      QCEIL=0.
C     IF(KAT.EQ.0) CALL INCEIL (IBALL)
C     IF(IBALL.NE.5) CALL CEIL(QCEIL,IBALL)
C     THIS PORTION OF THE PROGRAM EVALUATES THE HEAT EXCHANGE
C     THROUGH THE STRUCTURE FLOOR.
      QFLOOR=0.0
      IF(KAT.NE.0) GO TO 2000
      WRITE(7,1400)
      WRITE(6,1401)
      CALL FLOOR(ICON,FLAREA,AUFLR,IFLOOR,TEMPC)
2000  CONTINUE
      IF (IFLOOR.EQ.0) GO TO 2010
      DO 2001 KAP = 1, IFLOOR
      IF(ICON(KAP).EQ.1)QFLR(KAP) = AUFLR(KAP) * (TEMPG - TEMPI)
      IF(ICON(KAP).EQ.2)QFLR(KAP) = AUFLR(KAP) * (TEMPC - TEMPI)
      IF(ICON(KAP).EQ.3)QFLR(KAP) = AUFLR(KAP) * (TEMPI - TEMPI)
2001  QFLOOR = QFLOOR + QFLR(KAP)
C
C
C
C
2010  CONTINUE
C     HEAT EXCHANGE WITH UNHEATED OR SEPARATELY CONTROLLED
C     SPACES
      IF(KAT.NE.0) GO TO 23
      WRITE(7,1500)
      WRITE(6,1501)
23    CONTINUE
      QUNHET=0.
C
CC
      IF(KAT .EQ. 0) CALL INUNHT(IUNSPS)
      IF(IUNSPS .NE. 0) CALL UNHEAT (QUNHET)
C     HEAT EXCHANGE THROUGH BELOW GRADE WALLS
      IF(KAT.NE.0) GO TO 70
```

```
      WRITE(7,1600)
      WRITE(6,1601)
      CALL BELGRD(  BGAU)
70    CONTINUE
      QBELGR = BGAU * ( TEMPG - TEMPI)
D     WRITE(6,905)QCOND, QTOT, QFENES, QCEIL, QFLOOR, QUNHET, QBELGR
      QCOND=QTOT+QFENES+QFLOOR+QUNHET+QBELGR+QCEIL
1100  FORMAT(' EVALUATE THE STRUCTURES ABOVE GRADE EXTERIOR WALLS.')
1101  FORMAT(////,15X,'STRUCTURE EXTERIOR WALL SUMMARY TABLE',//)
1200  FORMAT(//////////,
      1' EVALUATE THE STRUCTURES EXTERIOR GLAZED WALL AREAS')
1201  FORMAT(1H1,15X,'EXTERIOR GLAZED AREA SUMMARY ',
      1' TABLE')
1203  FORMAT (1H0, //, ' WALL NUMBER',5X, ' AREA NUMBER ', 5X,
      1  ' AREA SQFT', 5X, 'GLASS CODE')
1205  FORMAT( 1H0, 'AREA', 2X, I, ' HAS NO GLAZED AREAS')
1300  FORMAT(' EVALUATE THE STRUCTURES CEILING AREAS')
1301  FORMAT(////,15X,'STRUCTURE CEILING AREA SUMMARY TABLE')
1400  FORMAT(' EVALUATE THE STRUCTURES FLOOR AREAS')
1401  FORMAT(////,15X,'STRUCTURE FLOOR AREA SUMMARY TABLE')
1500  FORMAT(' EVALUATE THE STRUCTURES ADJACENT UNHEATED AREAS')
1501  FORMAT(////,10X,'STRUCTURE ADJACENT UNHEAT SPACE SUMMARY',
     1 ' TABLE')
1600  FORMAT(' EVALUATE THE STRUCTURES BELOW GRADE AREAS')
1601  FORMAT(////,15X,'STRUCTURE BELOW GRADE SUMMARY TABLE')
1602  FORMAT(////,6X,'GENERAL STRUCTURE CHARACTERISTICS')
700   FORMAT(/,$,' ENTER NUMBER OF GLAZED AREAS ON',
     1 ' THE NUMBER ',I1,' WALL')
701   FORMAT(' FOR GLAZED AREA NUMBER ',I1,',',I1,' ENTER THE',
     1 /,$,' WIDTH-FEET:')
704   FORMAT(I1)
800   FORMAT(' FENESTRATION GAIN = ',F10.1,'BTU/HR    THERMAL',
     1 ' CONDUCTANCE = ',F10.5,'BTU/SQ.FT.-F',/,' FFACT = ',F5.3,
     2 3X,' RADIATION I = ',F4.1,' BTUH/SQ.FT.',5X,/,' WALL AREA = ',
     3 F10.1,' SQ.FT.')
801   FORMAT(' TOTAL FENESTRATION GAIN = ',F10.2,'BTU/HR')
802   FORMAT(F10.3)
803   FORMAT($,' HEIGHT-FEET:')
804   FORMAT($,' DESCRIPTION CODE:')
805   FORMAT(A4)
806   FORMAT(' GLASS WIDTH = ',F10.3,/,
     1 ' GLASS HEIGHT = ',F10.3,/,
     2 ' DESCRIPTION CODE = ',A4,/,/,
     3 $,' IS THE DATA CORRECT?')
809   FORMAT(A1)
900   FORMAT(1H0,I,15X,I,3X,F10.1,7X,A4)
901   FORMAT(1H0,14X,' EXTERIOR WALL NUMBER',3X,' GLAZED AREA',
      1  'NUMBER ',2X,/,' AREA SQFT ',' CODE ')
D905  FORMAT(1H0,4X,'  QCOND   QTOT     QFENES    QCEIL     QFLOOR
D     1 QUNHET     QBELGRD',//,4X,7F10.1)
      RETURN
      END
```

```
      FUNCTION AIRDEN (PATS, TEMP)
C     DENSITY=ATMOSPHERIC PRESSURE PSIA*/(RAIN + OR)
      AIRDEN=(PATS * 144)/(53.34*(460 + TEMP))
      RETURN
      END
      FUNCTION PREATS (ELEV, TEMP)
      PREATS = 14.7 * 2.7183**(-ELEV/(53.34*(460+TEMP)))
      RETURN
      END
      FUNCTION HUMRTO (TEMP, RH, PRESS)
      DIMENSION C(8)
      CELS=(TEMP-32.0)*5/9
      BOTCH=0.0
      DEGKEL=CELS+273.15
      DATA C/-741.9242,-29.72100,-11.55286,-0.8685635,0.1094098,
     1 0.439993,0.2520658,0.05218684/
      RAN=(0.65-0.01*CELS)
      DO 10 I=1,8
      BOTCH=BOTCH+C(I)*(RAN**(I-1))
10    CONTINUE
      BAT=(0.01/DEGKEL)*(374.136-CELS)*BOTCH
      PWS=217.99*(2.7183**BAT)
      PWS=PWS*14.7
      PW=RH*PWS
      HUMRTO=0.62190*PW/(PRESS-PW)
      RETURN
      END
```

```
      SUBROUTINE INTL
C
C
C
C     THIS PROGRAM CALCULATES THE PHYSICAL PLANT REQUIREMENTS
C     TO MAINTAIN INSIDE TEMPERATURE AND HUMIDITY OR THE
C     PROGRAM CAN BE USED WITH PLANT CAPACITIES TO FIND
C     RESULTING CONDITIONS.
C
C     LOADS INCLUDED IN THE CALCULATIONS, CONDUCTION, FENESTRATION,
C     INTERNAL EQUIPMENT, ANIMAL, AND VENTILATION AND INFILTRATION
C
C
C
      DIMENSION SUMFED(12),SUCYFD(12),CCY(5)
      DIMENSION FEED(12),QAPPL(24),WAPPL(24),QMOTOR(24)
      DIMENSION CHI(5,24),CFQ(5,24),PLN(5,24),WTR(5,24)
C
C
C
      INTEGER DATE1,PROG,DATE2,SETBAC,PRINT
C
C
C
      BYTE YES,NO,RESP,FLNAM(15)
C
C
C
      REAL LAT,MSTCFM,LONG,MINCFM,MAXCFM,LWRTO,MAXPRO
     1    ,MNCFM,MXCFM
C
C
C
      DOUBLE PRECISION CITY, STATE, RZONE(5), ZONE
C
C
C
      COMMON/PNTCOM/IDUMMY(26)
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,
     1 CLOUD,WIND,WINDIR,RHO,MINCFM,MAXCFM,IYEAR,
     2 WEIGHT,TL1,TL2,QS
C
C
      COMMON/KEEP5/QANIM,WANIM,PROC,IDAY,QWATER,FEED,LEAP
     1   ,PPROD,TEMPA,SUM,SUM1,AVTEMP,OPR,ICAN,JACK,TE
C
C
      COMMON/WTHCOM/STN
      COMMON/ INTL / ELEV, PRINT, FURNC, CHILL, CFMFAN,
     1  AP1, AP2, AP3, AP4, AP5, SETBAC, STMIN,
     2   STMAX, IBTIME, IPTIME,DATE1,DATE2, INTERV
C
C
      COMMON/KEEP3/QAPPL,WAPPL,QMOTOR
      COMMON/KEEP6/ RZONE,NTS, ALST, ALSTT(5), ZONE
```

```
      COMMON/KEEP10/ TEMPG,TEMPC
      COMMON/REQIR/ANIML,TMAX,TMIN,RHMAX,MNCFM,MXCFM,OPTT,OPTRIY,
     1 DDREFT,SPAREQ,LWRTO,WWARO,TEMPCY,DELTEM,MAXPRO,ANDIST,PROCYC,
     2 COUNT
C
C
C
      DATA FLNAM/'D','L','1',':','S',' ',' ',' ',' ',
     1 ' ','.','D','A','T',0/
      DATA PR1,PR2,PR3/'HOUR','DAIL','CYCL'/
      DATA SUMFED,SUCYFD,CCY/29*0.0/
      DATA IPETE/0/
      DATA YES/'Y'/,NO/'N'/
      DATA DAYW/365*0.0/
      DATA DAYF,DAYC,DAYQ,DAYP/1460*0.0/
      DATA HELP/'HELP'/
      DATA FEED/ 12*0.0/
      KAT=0
      WRITE(7,6000)
6000  FORMAT($,' WHAT IS THE 5 DIGIT FILE NUMBER?')
      READ(5,6001) (FLNAM(J),J=6,10)
6001  FORMAT(5A1)
      DECODE(5,6002,FLNAM(6))STN
6002  FORMAT(F5.0)
      CALL WOPEN(FLNAM,IFLAG)
92    CONTINUE
      WRITE (7,700)
      READ (5,701) PROC
      IF(PROC.NE.HELP) GO TO 100
      WRITE (7,500)
      READ (5,701) PROC
100   CONTINUE
C
C
C
C     SITE DESCRIPTION
C
      WRITE (7,502)
      READ (5,503) CITY
      WRITE (7,527)
      READ (5,503) STATE
      WRITE (7,520)
      READ (5,504) LAT
      WRITE (7,521)
      READ (5,504) LONG
      WRITE (7,522)
      READ (5,504) ELEV
      WRITE (7,506)
      READ (5,507) DATE1
      WRITE (7,508)
      READ (5,507) DATE2
      WRITE (7,509)
      READ (5,507) IYEAR
      WRITE(7,1235)
      READ(5,503) ZONE
```

```
      WRITE(7,1220)
      WRITE (7,703) CITY,STATE,LAT,LONG,ELEV,DATE1,DATE2,IYEAR,
      1 ZONE
      WRITE (7,711)
      READ (5,510) RESP
      IF (RESP.NE.YES) GO TO 92
      WRITE (6,703) CITY,STATE,LAT,LONG,ELEV,DATE1,DATE2,IYEAR
     1 ,ZONE
C
C
C
C
C     PRINT OPTIONS
C
1080  CONTINUE
      WRITE(7,1050)
      READ(5,1051)PRNT
      PRINT=0
      IF(PRNT.EQ.PR1) PRINT=1
      IF(PRNT.EQ.PR2) PRINT=2
      IF(PRNT.EQ.PR3) PRINT=3
      IF(PRINT.EQ.0) GO TO 1080
      WRITE(7,1060)
      READ(5,510) RESP
      IF(RESP.EQ.YES) WRITE(7,1065)
      IF(RESP.EQ.YES) READ(5,1025) INTERV
C
C
C
C     PHYCICAL PLANT LIMITS
C
C
      WRITE (7,732)
      READ (5,729) FURNC
      WRITE (7,733)
      READ (5,729) CHILL
      WRITE(7,1230)
      READ(5,729) CFMFAN
C
C
C
C
C
C
C     INITIAL OPERATING CONDITIONS
C     TEMPI=OPTT
C     OPTIMUM HUMIDITY RATIO
C
C
C
C     SET APPLIANCE,MOTORS,HOT WATER LOADS
C
C
      CALL INTLDS
      CALL MOTORS
```

```
      CALL HTWATR
C
C
C
C     TEMPERATURE SETBAC OPTION
C
C
95    CONTINUE
      WRITE(7,704)
      READ(5,510)RESP
      SETBAC=0
      IF(RESP.EQ.NO) GO TO 16
      IF(RESP.EQ.YES) SETBAC=1
      IF(RESP.NE.YES.AND.RESP.NE.NO) GO TO 95
      WRITE (7,1005)
      READ (5,1010) STMIN
      WRITE (7,1015)
      READ (5,1010) STMAX
      WRITE (7,1020)
      READ (5,1025) IBTIME
      WRITE (7,1030)
      READ (5,1025) IPTIME
      WRITE (7,717) STMIN,STMAX,IBTIME,IPTIME
      WRITE (7,711)
      READ (5,510) RESP
      IF (RESP.NE.YES) GO TO 95
      IF (RESP.EQ.YES) WRITE (6,717) STMIN,STMAX,IBTIME,IPTIME
16    CONTINUE
C
C
C
C
C     RETURN TO MAIN
C
501   FORMAT(A8)
500   FORMAT(1H0,'HERE ARE THE PROCESS YOU HAVE TO CHOOSE FROM',//,
     1 ' LAMBING-LAMB',5X,'COW CALF-COW-',5X,'FARROWING-FARR',/,
     2 ' SWINE-SWIN',5X,'LAYERS-LAYE',5X,'BROODING LAYERS-BLAY',/,
     3 ' BROODING TURKEYS-BTUR',5X,'BROILERS-BROI',5X,'DAIRY-DAIR',/,
     4 ' HUMAN-HUMA',/,$,' SELECT ONE----------> ')
502   FORMAT(1H0,$,'FROM WHICH CITY WILL THE WEATHER DATA',
     1 ' BE PROVIDED? ',2X)
503   FORMAT(A8)
504   FORMAT(F10.3)
505   FORMAT(3F10.3)
506   FORMAT(1H0,$,'WHAT IS THE STARTING JULIAN DAY?')
507   FORMAT(I3)
508   FORMAT($,' WHAT IS THE ENDING JULIAN DAY? ')
509   FORMAT(1H0,$,'IN WHICH YEAR WILL THE PROCESS BEGIN? 19')
510   FORMAT(A1)
520   FORMAT(1H0,'WHAT IS THE SITE: ',/,
     1 $,' LATITUDE - DECIMAL DEGREES? ')
521   FORMAT($,' LONGITUDE - DECIMAL DEGREES? ')
522   FORMAT($,' ELEVATION - FEET? ')
527   FORMAT($,' AND THE STATE? ')
```

```
700   FORMAT(1H0, 'WHAT PROCESS HAVE YOU SELECTED TO EVALUATE?',/,
     1 $,' IF YOU CANNOT DECIDE ASK FOR HELP.------> ')
 1    FORMAT(A4)
703   FORMAT(1H0,'LOCATION: ',A8,' , ',A8,/,
     1 ' LATITUDE:   ',F10.2,' DEGREES',/,
     2 ' LONGITUDE:  ',F10.2,' DEGREES',/,
     3 ' ELEVATION:      ',F10.0,' FEET',/,
     4 ' STARTING DAY:  ',I3,/,
     5 ' ENDING DAY:    ',I3,/,
     6 ' YEAR:          19',I2,/,
     7 ' TIME ZONE: ',3X,A8)
704   FORMAT(1H0,$,'DO YOU WANT TO EXERCISE THE SETBACK CONTROL? ')
705   FORMAT(I1,2F10.3,2I2)
708   FORMAT(/,6X,I2,6X,F7.2,5X,F6.2,5X,F7.3,5X,F10.2,5X,F8.0,4X,
      1  F8.0,5X,F8.1)
710   FORMAT(1H0,3X,F9.0,3X,F12.0,8X,F10.1,5X,F9.1,6X,F9.1,7X,F9.2,7X,
      1  F7.2)
711   FORMAT(1H0,$,' IS THE DATA CORRECT? ',2X)
717   FORMAT(1H0,3X,'*** SEBACK CONTROL OPTION SELECTED WITH',
     1 ' THE FOLLOWING LIMITS SET ***',/,
     2 ' MINIMUM TEMPERATURE: ',F4.0,' F',5X,'MAXIMUM TEMPERATURE:  ',
     3 F4.0,' F',/,' SETBACK OPERATES BETWEEN ',I2,' AND ',I2,' HOURS')
729   FORMAT(F10.3)
732   FORMAT(1H0,'FURNANCE CONTROL:  ',//,
     1 ' 0.0 FOR NONE',/,
     2 ' 1.0 FOR ALL',/,
     3 ' FURNANCE CAPACITY - BTU/HR',/,
     4 $,' WHICH OPTION ---> ')
733   FORMAT(1H0,'CHILLER CONTROL: ',//,
     1 ' 0.0 FOR NONE',/,
     2 ' 1.0 FOR ALL',/,
     3 ' CHILLER CAPACITY IN TONS/HR',/,
     4 $,' WHICH OPTION ---> ')
1005  FORMAT(1H0,$,'WHAT IS THE MINIMUM TEMPERATURE, F,',
     1 ' DURING SETBACK? ')
1010  FORMAT(F10.3)
1015  FORMAT(1H0,$,'WHAT IS THE MAXIMUM TEMPERATURE, F,',
     1 ' DURING SETBACK? ')
1020  FORMAT(1H0,$,'AT WHICH HOUR IS SETBACK EXECUTED? ')
1025  FORMAT(I2)
1030  FORMAT(1H0,$,'AT WHICH HOUR IS SETBACK TERMINATED? ')
1050  FORMAT(1H0,'WHAT IS THE MINIMUM TIME PERIOD FOR WHICH A',/,
     1 ' PRINTED COPY IS DESIRED ?',/,
      1 $,' HOURLY, DAILY OR PROCESS CYCLE ---> ')
1051  FORMAT(A4)
1060  FORMAT(1H0,$,'WOULD YOU LIKE A PERIODIC HOURLY PRINT OUT ? ')
1065  FORMAT(1H0,$,'FOR WHAT DAILY INTERVAL WOULD YOU LIKE AN',
      1   ' HOURLY PRINT OUT ? ')
1220  FORMAT(1H0,/////,' SITE DATA')
1230  FORMAT(1H0,'FAN CAPACITY: ',//,
      1 ' 1.0 FOR UNLIMITED',/,
      2 ' ACTUAL CAPACITY-CFM'
      3 $,' WHICH OPTION ---> ')
1235  FORMAT( 1H0, $, 'LOCAL TIME ZONE ? ')
      RETURN
```

```
      SUBROUTINE ANIML1
      DIMENSION A(18,15),FEED(12),QS(9),WT(9),TOT(9),W(9)
      REAL HTWTR(24),REQUIR(18),COMPR(15)
      BYTE RESP,LEGHOR,PLYROC,SMALL,LARGE,YES,NO
      REAL MINCFM,MAXCFM,LWRTO,MAXPRO,TL1,TL2,MNCFM,MXCFM
      COMMON/DAYS/DAY1,DAY2,DAY3,SOWWT,EEIGHT,DAIWT,WAIT1
      COMMON/KEEP33/IBIRD
      COMMON/REQIR/ ANIML,TMAX,TMIN,RHMAX,MNCFM,MXCFM,OPTT,OPTRIY,
     1 DDREFT,SPAREQ,LWRTO,WWARO,TEMPCY,DELTEM,MAXPRO,ANDIST,PROCYC
     2 ,COUNT
      COMMON/KEEP2/TEMPO,TEMPI,AT,ONG,IDATE,IHOUR,
      1   KAT,CLOUD,WIND,WINDIR,RHO,MINCFM,MAXCFM,IYEAR,WEIGHT,TL1,
      2  TL2,QS
      COMMON/PRO/SUMPRO,SCOMM,DIFF
      COMMON/KEEP5/QANIM,WANIM,PROC,IDAY,QWATER,FEED,LEAP
      1  ,PPROD,TEMPA,SUM,SUM1,AVTEMP,OPR,ICAN,JACK,TE
      COMMON/A1S/ A1(18),A2(18),A3(18),A4(18),A5(18),A6(18),
     1 A7(18),A8(18),A9(18),A10(18),A11(18),A12(18),A13(18),A14(18),
     2 A15(18)
      EQUIVALENCE(ANIML,REQUIR(1)),(A(1,1),A1(1))
      EQUIVALENCE (A(1,2),A2(1))
      DATA IBIRD/2/
      DATA WT(1),WT(2),WT(3),WT(4),WT(5),WT(6),WT(7),WT(8),WT(9)/
      1  0.0,0.08,0.2,0.57,1.3,2.26,3.54,4.31,5.35/
      DATA DAY1,DAY2,DAY3,SOWWT,EEIGHT,DAIWT/56.0,112.0,1.0,
      1400.0,150.0,1200./,WAIT1/0.01706/
      DATA YES,NO/'Y','N'/
      DATA IFLAG/1/,NDAY/0/,LEGHOR,PLYROC/'L','P'/
     1 ,SMALL,LARGE/'S','L'/,WEIT1,WEIT2/44.34,117.0/
      DATA COMPR/'LAMB','COW-','FARR','SWIN',
     1 'LAYE','BLAY','BTUR','BROI','DAIR',
     2 'HOSP','MLKR','XTRA','MLKP','HUMA','BLAN'/
      DATA FEED/12*0.0/,PPROD/100./,SCOMM,SUMPRO/0.0,0.0/
C     SELECT ANIMAL TYPE
      IF(KAT.NE.0) GO TO 300
      ICAN=1
      SUM1=0.0
      SUM=0.0
36    CONTINUE
      DO 35 I = 1,15
      LEAP = I
      IF(PROC.EQ.COMPR(I)) GO TO 30
35    CONTINUE
      WRITE(7,700)
      READ(5,701)PROC
      GO TO 36
30    CONTINUE
      IFLAG=1
      DO 38 I=1,18
      REQUIR(I)=A(I,LEAP)
38    CONTINUE
      TEMPA=OPTT
      TE=OPTT
      TEMPI=OPTT
      OPR=OPTT
```

```
D         WRITE(6,123) TE,SUM1,ICAN
D123      FORMAT(/,2X,'TE=',F10.3,2X,'SUM1=',F10.3,2X,'ICAN=',I3)
          WRITE(7,1000) TEMPI,OPTT
_ _00     FORMAT(1H0,'TEMPI = ',F10.4,10X,'OPTT = ',F10.4)
300       CONTINUE
          SUM1=SUM1+TEMPO
          SUM=SUM+TEMPI
          IF(IHOUR.NE.24) GO TO 1313
          TEMPA=SUM/24.
          AVTEMP=SUM1/24.
          SUM=0.0
          SUM1=0.0
1313      CONTINUE
          GO TO (1,1,1,1,5,6,7,8,1,1,1,1,1,1,1,1) LEAP
5         CONTINUE
6         CONTINUE
C
C
C
C         LAYERS ********************************************
          IF(IFLAG.NE.1) GO TO 143
          IF(KAT.NE.0) GO TO 143
          IF(LEAP.EQ.5) IDAY=100
712       WRITE(7,710)
          READ(5,711)RESP
          IF(RESP.EQ.LEGHOR)JACK=1
          IF(RESP.EQ.PLYROC)JACK=2
143       IF(JACK.NE.1.AND.JACK.NE.2) GO TO 712
          IF(JACK.EQ.2) GO TO 160
          WEIGHT=2.1948E-2*FLOAT(IDAY)+0.1
          IF(IDAY.GE.140) WEIGHT=2.0667+0.0066*FLOAT(IDAY)
          GO TO 161
160       WEIGHT=1.279E-2*(FLOAT(IDAY)**1.2458)
          IF(IDAY.GE.140) WEIGHT=3.76+0.0102*FLOAT(IDAY)
161       CONTINUE
          IF(IHOUR.NE.24) GO TO 1420
          IF( LEAP .EQ. 6 ) GO TO 990
          IF(10.0.LT.TEMPA.AND.TEMPA.LE.55.0) PPROD=SIN(
          1     0.0343*TEMPA-0.3193)
          IF(55.0.LT.TEMPA.AND.TEMPA.LT.110.0) PPROD=SIN(
          1    -0.0272*TEMPA+3.0645)
          EGGS=MAXPRO*COUNT*PPROD
          PPROD = PPROD*100.
C         SCOMM=SCOMM+EGGS
          IF(LEAP.NE.5) GO TO 990
          FEED(7)=(0.183*EXP(0.08526*WEIGHT))*COUNT
          GO TO 989
990       FEED(8)=(0.183*EXP(0.08526*WEIGHT))*COUNT
989       CONTINUE
1420      CONTINUE
          TWT=WEIGHT*COUNT
          TL1=105.0
          TL2=0.0
          TMIN=OPTT-DIFF
          TMAX=OPTT+DIFF
```

```
        GO TO 1111
C
7       CONTINUE
C       POULTS ******************************************C
C
C


        IF(IFLAG.NE.1) GO TO 165
        IF(KAT.NE.0) GO TO 165
180     WRITE(7,715)
        READ(5,716)RESP
        IF(RESP.EQ.SMALL)JACK=1
        IF(RESP.EQ.LARGE)JACK=2
        IF(JACK.NE.1.AND.JACK.NE.2) GO TO 180
165     CONTINUE
        IF(JACK.EQ.2) GO TO 181
        WEIGHT=7.836E-3*FLOAT(IDAY)**1.5677+0.1
        FEED(9)=.001203*FLOAT(IDAY)**1.4255*COUNT
        GO TO 182
181     WEIGHT=5.9975E-3*FLOAT(IDAY)**1.6929+0.1
        FEED(10)=.00815*FLOAT(IDAY)**1.2548*COUNT
182     CONTINUE
        TWT=WEIGHT*COUNT
        GO TO 1111
C
C
C
8       CONTINUE
C       BROILER ****************************************
        PPROD=100.
        IF(IHOUR.NE.24) GO TO 1520
        IF(IDAY.LT.35) GO TO 1519
        IF(-75..LT.TEMPA.AND.TEMPA.LT.75.) PPROD=25.+TEMPA
        IF(75..LE.TEMPA.AND.TEMPA.LT.145.) PPROD=208.-1.44*TEMPA
1519    WGT=1.706E-2*FLOAT(DAY3+1)**1.30448
        WAIT1=WAIT1+(WGT-WAIT1)*PPROD/100.
        ENDWT=1.706E-2*PROCYC**1.30448
        IF(WAIT1.GE.ENDWT) KAT=-1
        DAY3=(WAIT1/(1.706E-2))**0.7666
        FEED(10)=(.00967+.00454*IDAY)*COUNT
1520    CONTINUE
C       TEMPERATURE CHANGE
        TWT=WAIT1*COUNT
        SCOMM = TWT
        WEIGHT = WAIT1
        GO TO 1111
190     CONTINUE
        IF(ICAN.EQ.169)TE=TE-5.0
        IF(TE.LT.DDREFT) TE=DDREFT
        TMAX=TE+DIFF
        TMIN=TE-DIFF
        TL1=110.00
        TL2=TE-40.0
        OPTT=TE
        ICAN=ICAN+1
```

```
      IF(ICAN.EQ.170)ICAN=1
      IF(IHOUR.EQ.24.AND.FLOAT(IDAY).EQ.PROCYC.AND.LEAF.NE.8) KAT=-1
      GO TO 150
1111  CONTINUE
      PERLAT=5.063*2.7183**(TEMPI*0.027)/100.
      IF(0.0.LT.WEIGHT.AND.WEIGHT.LT.0.08) GO TO 15
      IF(0.08.LE.WEIGHT.AND.WEIGHT.LT.0.2) GO TO 25
      IF(0.2.LE.WEIGHT.AND.WEIGHT.LT.0.57) GO TO 37
      IF(0.57.LE.WEIGHT.AND.WEIGHT.LT.1.3) GO TO 45
      IF(1.3.LE.WEIGHT.AND.WEIGHT.LT.2.26) GO TO 55
      IF(2.26.LE.WEIGHT.AND.WEIGHT.LT.3.54) GO TO 65
      IF(3.54.LE.WEIGHT.AND.WEIGHT.LT.4.31) GO TO 75
      IF(4.31.LE.WEIGHT.AND.WEIGHT.LE.5.35) GO TO 85
      IF(WEIGHT.GT.5.35) GO TO 85
15    I=1
      J=2
      IF(70.0.GT.TEMPI.OR.100.0.LT.TEMPI) GO TO 9999
      QS(I)=0.0
      QS(J)=62.135-0.5463*TEMPI
      GO TO 100
25    I=2
      J=3
      IF(70.0.GT.TEMPI.OR.100.0.LT.TEMPI) GO TO 9999
      QS(I)=62.135-0.5463*TEMPI
      QS(J)=43.6038-0.343*TEMPI
      GO TO 100
37    I=3
      J=4
      IF(TEMPI.LT.70.0.OR.TEMPI.GT.100.0) GO TO 1550
      IF(TEMPI.LT.45.0.OR.TEMPI.GT.100.0) GO TO 9999
1552  QS(I)=43.6038-0.343*TEMPI
      QS(J)=30.269-0.219*TEMPI
      GO TO 100
1550  IF(WEIGHT.LE.0.385) GO TO 9999
      GO TO 1552
45    I=4
      J=5
      IF(TEMPI.LT.45.0.OR.TEMPI.GT.100.0) GO TO 1553
      IF(TEMPI.LT.40.0.OR.TEMPI.GT.100.0) GO TO 9999
1555  QS(I)=30.269-0.219*TEMPI
      QS(J)=365.89*(TEMPI**(-0.83))
      GO TO 100
1553  IF(WEIGHT.LE.0.935) GO TO 9999
      GO TO 1555
55    I=5
      J=6
      IF(40.0.GT.TEMPI.OR.95.0.LT.TEMPI) GO TO 9999
      QS(I)=365.89*(TEMPI**(-0.83))
      QS(J)=123.0*TEMPI**(-0.645)
      GO TO 100
65    I=6
      J=7
      IF(40.0.GT.TEMPI.OR.95.0.LT.TEMPI) GO TO 9999
      QS(I)=123.0*TEMPI**(-0.645)
      IF(75..LE.TEMPI.AND.TEMPI.LE.95.) GO TO 101
```

```
        QS(J)=66.887*TEMPI**(-0.583)
        GO TO 100
101     QS(J)=1.987*TEMPI**(0.241)
        GO TO 100
75      I=7
        J=8
        IF(40.0.GT.TEMPI.OR.95.0.LT.TEMPI) GO TO 9999
        IF(75..LE.TEMPI.AND.TEMPI.LE.95.) GO TO 102
        QS(I)=66.887*TEMPI**(-0.583)
        QS(J)=8.606*2.7183**(TEMPI*(-0.0069))
        GO TO 100
102     QS(I)=1.987*TEMPI**(0.241)
        QS(J)=1.777*TEMPI**(0.2546)
        GO TO 100
85      I=8
        J=9
        IF(40.0.GT.TEMPI.OR.95.0.LT.TEMPI) GO TO 9999
        IF(75..LE.TEMPI.AND.TEMPI.LE.95.) GO TO 103
        QS(I)=8.606*2.7183**(TEMPI*(-0.0069))
        QS(J)=15.703*TEMPI**(-0.272)
        GO TO 100
103     QS(I)=1.777*TEMPI**(0.2546)
        QS(J)=1.224*TEMPI**(0.3255)
100     QSD=QS(J)-QS(I)
        WID=WT(J)-WT(I)
        RWTD=WEIGHT-WT(I)
        PRC=RWTD/WTD
        HDIF=PRC*QSD
        QANIM=(QS(I)+HDIF)*WEIGHT*COUNT
        TOT(I)=QS(I)/(1.-PERLAT)
        TOT(J)=QS(J)/(1.-PERLAT)
        W(I)=TOT(I)-QS(I)
        W(J)=TOT(J)-QS(J)
        WD=W(J)-W(I)
        WDIF=PRC*WD
        WANIM=(W(I)+WDIF)*WEIGHT*COUNT/1044.
        IF(LEAP.NE.5) GO TO 190
C       IF(PROCYC.EQ.FLOAT(IDAY).AND.IHOUR.EQ.24) KAT=-1
150     CONTINUE
        IF(KAT.NE.0) GO TO 195
        IF(IBIRD.EQ.2)WRITE(6,720) (REQUIR(I),I=1,18)
        IBIRD = 6
        IF(LEAP.EQ.14.OR.LEAP.EQ.15.OR.LEAP.EQ.2) GO TO 151
195     IFLAG=IFLAG+1
        IF(IHOUR.NE.24) GO TO 196
        SUMPRO=SUMPRO+PPROD
196     CONTINUE
        MINCFM=MNCFM*TWT
        MAXCFM=MXCFM*TWT
151     IF(TEMPI.LT.TL1.AND.TEMPI.GT.TL2) GO TO 3000
9999    I=7
        WRITE(7,750) I,I
1       CONTINUE
3000    CONTINUE
700     FORMAT($,' PROCESS NOT FOUND ENTER AGAIN')
```

```
701     FORMAT(2A4)
---     FORMAT(1H0)
        FORMAT($,' ARE THEY LEGHORN OR PLYMOUTH ROCK CHICKENS?')
711     FORMAT(A1)
715     FORMAT($,' ARE THEY LARGE OR SMALL TURKEYS?')
731     FORMAT(F10.3)
716     FORMAT(A1)
717     FORMAT(' THE PROCESS IS COMPLETED. HOWEVER',/,
        1  ' THE PROCESS PRODUCTION IS NOT 100% .',/,
        2$,' DO YOU WISH TO CONTINUE ?')
720     FORMAT(1H0,'PROCESS CODE WORD: ',A4,12X,' UPPER TEMP: '
        1,F4.1,' F',20X,' MIN. TEMP: ',F4.1,/,' MAXIMUM RELATIVE
        2HUMIDITY: ',F4.1,' %',2X,' MINIMUM VENTILATION: ',F7.5
        3,' CFM/LB ',2X,' MAXIMUM VENTILATION: ',F7.5,' CFM/LB ',/,
        4' OPT. TEMP DAY 1: ',F4.1,' F ',11X,' OPT. RELATIVE
        5HUMIDITY: ',F4.1,' %',8X,' REFERENCE TEMP: ',F4.1,' F ',/,
        6' AREA/ANIMAL:',F6.1,' SQ.FT. ',9X,' LENGTH TO WIDTH
        7RATIO: ',F4.2,11X,' WINDOW TO WALL RATIO: ',F4.2,/,
        8' TEMP CHANGE CYCLE ',F3.0,' DAYS ',8X,' CYCLE TEMP
        9CHANGE: ',F4.0,' F',13X,' MAXIMUM PRODUCTION: ',A4,/,
        1' ANIMAL DISTRIBUTION: ',F7.3,7X,' PRODUCTION CYCLE ',F4.0,
        2' DAYS ',11X,' NUMBER OF ANIMALS: ',F10.0)
750     FORMAT(1H0,2A2,3(5X,' WARNING',/),/,
        1 ' MAXIMUM TEMPERATURE EXCEEDED',/,
        26(' ANIMALS DYING!!! ',/))
        RETURN
        END
```

```
      SUBROUTINE ANIML3
      DIMENSION A(18,15),FEED(12),QS(9),WT(9),TOT(9),W(9)
      REAL HTWTR(24),REQUIR(18),COMPR(15)
      BYTE RESP,LEGHOR,PLYROC,SMALL,LARGE,YES,NO
      REAL MINCFM,MAXCFM,LWRTO,MAXPRO,TL1,TL2,MNCFM,MXCFM
      COMMON/DAYS/DAY1,DAY2,DAY3,SOWWT,EEIGHT,DAIWT,WAIT1,WEIT1,WEIT2
      COMMON/KEEP33/IBIRD
      COMMON/REQIR/ ANIML,TMAX,TMIN,RHMAX,MNCFM,MXCFM,OPTT,OPTRIY,
     1 DDREFT,SPAREQ,LWRTO,WWARU,TEMPCY,DELTEM,MAXPRO,ANDIST,PROCYC
     2 ,COUNT
      COMMON/KEEP2/TEMPO,TEMPI,AT,ONG,IDATE,IHOUR,
      1   KAT,CLOUD,WIND,WINDIR,RHO,MINCFM,MAXCFM,IYEAR,WEIGHT,TL1,
      2  TL2,QS
      COMMON/PRO/SUMPRO,SCOMM,DIFF
      COMMON/KEEP5/QANIM,WANIM,PROC,IDAY,QWATER,FEED,LEAP
      1  ,PPROD,TEMPA,SUM,SUM1,AVTEMP,OPR,ICAN,JACK,TE
      COMMON/A1S/ A1(18),A2(18),A3(18),A4(18),A5(18),A6(18),
     1 A7(18),A8(18),A9(18),A10(18),A11(18),A12(18),A13(18),A14(18),
     2 A15(18)
      EQUIVALENCE(ANIML,REQUIR(1)),(A(1,1),A1(1))
      EQUIVALENCE (A(1,2),A2(1))
      DATA IBIRD/2/
      DATA WT(1),WT(2),WT(3),WT(4),WT(5),WT(6),WT(7),WT(8),WT(9)/
      1  0.0,0.08,0.2,0.57,1.3,2.26,3.54,4.31,5.35/
      DATA DAY1,DAY2,DAY3,SOWWT,EEIGHT,DAIWT/57.0,113.0,1.0,
      1400.0,150.0,1200./,WAIT1/0.01706/
      DATA YES,NO/'Y','N'/
      DATA IFLAG/1/,NDAY/0/,LEGHOR,PLYROC/'L','P'/
     1 ,SMALL,LARGE/'S','L'/,WEIT1,WEIT2/45.44,118.57/
      DATA COMPR/'LAMB','COW-','FARR','SWIN',
     1 'LAYE','BLAY','BTUR','BROI','DAIR',
     2 'HOSP','MLKR','XTRA','MLKP','HUMA','BLAN'/
      DATA A1/'LAMB',87.0,45.0,85.0,0.025,0.25,77.0,55.0,50.0,
     1 16.67,2.7,0.05,1.0,-2.0,'OPT.',0.666,42.0,300.0/
      DATA A2/'COW-',85.0,40.0,85.0,0.015,0.2,70.0,55.0,70.0,
     1 110.0,2.0,0.05,0.0,0.0,'OPT.',1.0,30.0,100.0/
      DATA A3/'FARR',100.0,75.0,85.0,0.042,0.441,90.0,70.0,60.0,
     1 0.56,2.25,0.05,1.0,-2.0,'OPT.',0.125,56.0,128.0/
      DATA A4/'SWIN',85.0,55.0,85.0,0.057,1.0,60.0,70.0,60.0,
     1 9.0,1.17,0.05,0.0,0.0,'OPT',0.0,55.0,256.0/
      DATA A5/'LAYE',85.0,55.0,85.0,0.5,1.0,60.0,60.0,60.0,
     1 0.75,7.25,0.0,0.0,0.0,.75,0.0,30.0,15000.0/
      DATA A6/'BLAY',85.0,55.0,85.0,0.5,1.0,92.0,60.0,60.0,1.0,
     1 7.25,0.0,7.0,-5.0,'OPT.',0.0,89.0,40000.0/
      DATA A7/'BTUR',85.0,55.0,85.0,0.5,1.0,95.0,60.0,60.0,2.0,
     1 6.0,0.0,7.0,-5.0,'OPT.',0.0,35.,1000.0/
      DATA A8/'BROI',85.0,55.0,85.0,0.5,1.0,90.0,60.0,75.0,
     1 0.8,8.5,0.0,7.0,-5.0,'OPT.',0.0,75.0,20000.0/
      DATA A9/'DAIR',85.0,45.0,85.0,0.025,0.4,50.0,55.0,50.0,
     1 70.0,2.5,0.0,0.0,0.0,0.032,0.0,30.0,100.0/
      DATA A10/'HOSP',80.0,45.0,85.0,0.025,0.4,50.0,55.0,50.0,
     1 2.5,1.6,0.0,0.0,0.0,0.0,0.0,365.0,4.0/
      DATA A11/'MLKR',85.0,60.0,85.0,700.0,700.0,65.0,55.0,65.0,
     1 6.0,2.25,0.15,0.0,0.0,0.0,0.0,365.0,0.0/
      DATA A12/'XTRA',165.0,112.0,0.0,0.0,0.0,165.0,0.0,0.0,
```

```
     1  5.0,0.0,0.0,0.0,0.0,0.0,0.0,365.0,0.0/
        DATA A13/'MLKP',80.0,55.0,85.0,100.0,400.0,60.0,55.0,60.0,
     1  14.0,1.14,0.15,0.0,0.0,0.0,0.0,365.0,8.0/
        DATA A14/'HUMA',78.0,65.0,85.0,7.0,10.0,72.0,50.0,65.0,
     1  375.0,1.67,0.15,0.0,0.0,0.0,0.0,30.0,4.0/
        DATA A15/'BLAN',17*0.0/,DIFF/10.0/
        DATA FEED/12*0.0/,PPROD/100./,SUMPRO,SCOMM/0.0,0.0/
C       SELECT ANIMAL TYPE
        IF(KAT.NE.0) GO TO 300
        ICAN=1
        TE=OPTT
        SUM1=0.0
        SUM=0.0
36      CONTINUE
        DO 35 I = 1,15
        LEAP = I
        IF(PROC.EQ.COMPR(I)) GO TO 30
35      CONTINUE
        WRITE(7,700)
        READ(5,701)PROC
        GO TO 36
30      CONTINUE
        IFLAG=1
        DO 38 I=1,18
        REQUIR(I)=A(I,LEAP)
38      CONTINUE
        TEMPA=OPTT
        TEMPI=OPTT
        OPR=OPTT
        WRITE(7,1000) TEMPI,OPTT
1000    FORMAT(1H0,'TEMPI = ',F10.4,10X,'OPTT = ',F10.4)
300     CONTINUE
        SUM1=SUM1+TEMPO
        SUM=SUM+TEMPI
        IF(IHOUR.NE.24) GO TO 1313
        TEMPA=SUM/24.
        AVTEMP=SUM1/24.
        SUM=0.0
        SUM1=0.0
1313    CONTINUE
        GO TO (1,2,3,4,4,4,4,4,9,10,11,12,13,14,150)LEAP
1       CONTINUE
C
C       LAMBS ***************************************************
        WEIGHT=8.0+0.48*(IDAY+.50)
        HEAT=(37.345-(.3544)*TEMPI)*WEIGHT**0.67*COUNT
        IF(TEMPI.GE.75.0)H20=(1.553E-4*(WEIGHT**.67))*(2.7183**
     1  (.04228*TEMPI))*COUNT
        IF(TEMPI.LT.75.0)H20=(3.83E-3*(WEIGHT**.67))*COUNT
C       EWES
        EHEAT=(17.08-0.16454*TEMPI)*EEIGHT**.67*.666*COUNT
        IF(TEMPI.GE.34.0)EH20=(-.00618+0.000184*TEMPI)*EEIGHT**0.67*
        1.666*COUNT
        IF(TEMPI.LT.34.0) EH20=0.0
        QANIM=HEAT+EHEAT
```

```
      IF(QANIM.LT.0.0) QANIM=10.0
      WANIM=H2O+EH2O
      IF(IDAY.GT.0.AND.IDAY.LT.11) JUMP=1
      IF(IHOUR.NE.24) GO TO 355
      IF(IDAY.GE.11.AND.IDAY.LE.22)JUMP=2
      IF(IDAY.GT.22) JUMP=3
      GO TO (351,352,353) JUMP
351   CONTINUE
      FED=(2.44+.00355*IDAY)*COUNT
      FEED(1)=FED*.085
      FEED(2)=FED*.055
      FEED(3)=FED*.080
      FEED(4)=FED*.81
      GO TO 355
352   CONTINUE
      FED=(1.891*EXP(.02296*IDAY))*COUNT
      FEED(1)=FED*.027
      FEED(2)=FED*.346
      FEED(3)=FED*.060
      FEED(4)=FED*.567
      GO TO 355
353   CONTINUE
      FED=3.1337*COUNT
      FEED(1)=FED*0.0
      FEED(2)=1.9743*COUNT
      FEED(3)=.1880*COUNT
      FEED(4)=.9715*COUNT
355   CONTINUE
      FEED(5)=0.0
C     NEW MIN AND MAX TEMP
      IF(WEIGHT.GE.28.0) KAT=-1
      TWT=(WEIGHT*COUNT+EEIGHT*.666*COUNT)
      TL1 = 100.0
      TL2 = 30.0
      TE = OPR - 2.0*(IDAY-1)
      IF(TE.LT.DDREFT) TE = DDREFT
      OPTT=TE
      TMIN = TE-DIFF
      TMAX = TE+DIFF
      GO TO 150
C
CC
C
C
2     CONTINUE
C DAIRY COW CALF ****************************************************
      WRITE(7,702)
      QANIM=0.0
      WANIM=0.0
      TL1 = 100.0
      TL2 = 0.0
      GO TO 150
C
C
C
```

```
C
      CONTINUE
-     FARROWING ***********************************
      WEIGHT=0.18315*FLOAT(IDAY)**1.3698
      WANIM=(2.828E-2*2.7183**(0.024*TEMPI))*(2.7183**(.0033*WEIGHT))
    1 *COUNT
      QANIM=(69.4988*WEIGHT**0.51379-0.79866*TEMPI*WEIGHT**0.4877)
      1    *COUNT
      IF(IDAY.GT.28) GO TO 140
      WANIM=WANIM+(2.828E-2*2.7183**(0.024*TEMPI))*(2.7183**(.0033*
    1 SOWWT))*.125*COUNT
      QANIM=QANIM+(69.4988*SOWWT**0.51379 - 0.79866*TEMPI*
      1     SOWWT**0.4877)*0.125*COUNT
C     NEW MIN AND MAX TEMP
140   CONTINUE
      IF(IHOUR.NE.24) GO TO 998
      FED=(-.244+.0722*WEIGHT)*COUNT
      FEEDS=0.0
      IF(IDAY.LE.28)FEEDS=.2039*SOWWT**0.69435*.125*COUNT
      FEED(5)=FED*0.6+FEEDS*0.88
      FEED(6)=FED*0.3+FEEDS*0.12
      FEED(1) = FED * 0.1
998   CONTINUE
      IF(WEIGHT.GE.45.0) KAT=-1
      IF(IDAY.GT.28) TWT=WEIGHT*COUNT
      IF(IDAY.LE.28) TWT=WEIGHT*COUNT+SOWWT*0.125*COUNT
      TL1=110.0
      TE=OPR-2.0*(IDAY-1)
      IF(TE.LT.DDREFT) TE=DDREFT
      TMIN=TE-DIFF
      OPTT=TE
      TMAX=TE+DIFF
      TL2=TE-40.0
      GO TO 150
C
C
C
C
4     CONTINUE
C     SWINE FINISHING AND GROWING ******************
C
      IF(IHOUR.NE.24) GO TO 1200
      IF(TEMPA.GT.10.0.AND.TEMPA.LE.60.0)
      1   PPROD= SIN(0.0255 * TEMPA + 0.0366)
      IF(TEMPA.GT.60.0.AND.TEMPA.LT.110.0)
      1   PPROD = SIN( -0.0178 * TEMPA + 2.639)
      WEIT1=WEIT1 + (0.18315*DAY1**1.3698-WEIT1)*PPROD
      WEIT2=WEIT2+(0.10089*DAY2**1.4982-WEIT2)*PPROD
      PPROD = PPROD*100.
      DAY1=(WEIT1/(.18315))**(0.73)
      DAY2=(WEIT2/(0.10089))**(0.6675)
      FED=0.2039*WEIT1**0.69435*COUNT*0.5
      FEEDS=0.2039*WEIT2**0.69435*COUNT*0.5
      FEED(5)=FED*0.83+FEEDS*.88
      FEED(6)=FED*0.17+FEEDS*0.12
```

```
      WRITE(7,1122) WEIT1,WEIT2,DAY1,DAY2
1122  FORMAT(1H0, ' WEIT1, WEIT2, DAY1, DAY2 ', 4F10.2)
1200  CONTINUE
      H201=(2.828E-2*2.7183**(.024*TEMPI))*(2.7183**(.0033*WEIT1))
     1 *(.5*COUNT)
      H202=(2.828E-2*2.7183**(.024*TEMPI))*(2.7183**(.0033*WEIT2))
     1 *(.5*COUNT)
      WANIM=H201+H202
      Q1=(69.4988*WEIT1**0.51379-0.79866*TEMPI*(WEIT1
      1 **0.4877))*(0.5*COUNT)
      Q2=(69.4988*WEIT2**0.51379-0.79866*TEMPI*(WEIT2
      1 **0.4877))*(0.5*COUNT)
      QANIM=Q1+Q2
      IF(IHOUR.EQ.24) DAY1=DAY1+1
      IF(IHOUR.EQ.24) DAY2=DAY2+1
      IF(WEIT1.GE.117.0.AND.WEIT2.GE.218.0) KAT= -1
      TWT=(WEIT1+WEIT2)*0.5*COUNT
      SCOMM = TWT
      TL1=95.0
      TL2=0.0
      TMIN=OPTT-DIFF
      TMAX=OPTI+DIFF
      GO TO 150
13    CONTINUE
10    CONTINUE
9     CONTINUE
C
C
C
C DAIRY COW,HOSPITAL,MLK PRLR *****************
      IF(IFLAG.NE.1) GO TO 1322
      IF(KAT.NE.0) GO TO 1322
1320  WRITE(7,1321)
      READ(5,711) RESP
      IF(RESP.EQ.'H') JACK=1
1321  FORMAT($,' ARE THEY HOLSTEIN OR JERSEY COWS?')
      IF(RESP.EQ.'J') JACK=2
1322  IF(JACK.NE.1.AND.JACK.NE.2) GO TO 1320
      WANIM=.0004016*2.7183**(TEMPI*.02)*COUNT*DAIWT
      THEAT=4.33*2.7183**(-0.0046*TEMPI)*COUNT*DAIWT
      QANIM=THEAT-WANIM*1044.
      IF(QANIM.LT.0.0) QANIM=10.0
      IF(LEAP.NE.9) GO TO 1325
      IF(IHOUR.NE.24) GO TO 1325
      FEED(11)=47.3*COUNT
      IF(JACK.EQ.1) GO TO 1324
      IF(-20..LT.TEMPA.AND.TEMPA.LE.57.) PPROD=SIN(
      1    0.02 * TEMPA + 0.4308)
      IF(57..LT.TEMPA.AND.TEMPA.LT.120.) PPROD=SIN(
      1    -0.0245 * TEMPA + 2.966)
      GO TO 1401
1324  IF(TEMPA.LT.50.0) PPROD=0.852+0.002*TEMPA
      IF(50..LE.TEMPA.AND.TEMPA.LT.120.) PPROD=SIN(
      1     -0.0225 * TEMPA + 2.696)
1401  SCOMM=SCOMM+MAXPRO*COUNT*DAIWT*PPROD
```

```
      PPROD = PPROD * 100.
~25   CONTINUE
      TWT = DAIWT * COUNT
      TL1=100.0
      TL2 = -20.0
      TMIN=OPTT-DIFF
      TMAX= OPTT+DIFF
C     IF(FLOAT(IDAY).EQ.PROCYC) KAT=-1
      IF(LEAP.EQ.13) TL1=95.0
      IF(LEAP.EQ.13) TL2=32.0
C
C
C
C
C
CC
      GO TO 150
14    CONTINUE
C     HUMAN*********************************
      WANIM=0.0
      IF(IHOUR.GE.7.AND.IHOUR.LT.22)QANIM=434.*COUNT
      IF(IHOUR.LT.7.OR.IHOUR.GE.22)QANIM=235.*COUNT
      MINCFM=7.0*COUNT
      MAXCFM=500.0*COUNT
      TL1=100.0
      TL2=32.0
      GO TO 150
C
C
C
C
C
11    CONTINUE
C     MILK ROOM***********************************************
      QANIM=0.0
      WANIM=0.0
      MAXCFM=700.0
      MINCFM=700.0
      TL1=100.0
      TL2=32.0
      TMIN=OPTT-DIFF
      TMAX=OPTT+DIFF
C
C
12    CONTINUE
C
C
C
C
C XTRA ****************************************
      QWATER=0.0
      LT1=212.0
      LT2=32.0
150   CONTINUE
      IF(KAT.NE.0) GO TO 195
```

```
      IF(IBIRD .EQ. 2) WRITE(6,720) (REQUIR(I),I=1,18)
      IBIRD = 6
195   IFLAG=IFLAG+1
      IF(LEAP.EQ.14.OR.LEAP.EQ.15.OR.LEAP.EQ.2) GO TO 151
      IF(IHOUR.NE.24) GO TO 196
      SUMPRO=SUMPRO+PPROD
196   CONTINUE
      MINCFM=MNCFM*TWT
      MAXCFM=MXCFM*TWT
      IF(LEAP.EQ.13) MINCFM=800.0
      IF(LEAP.EQ.13) MAXCFM=350.0
151   IF(TEMPI.LT.TL1.AND.TEMPI.GT.TL2) GO TO 3000
9999  I=7
      WRITE(7,750) I,I
3000  CONTINUE
700   FORMAT($,' PROCESS NOT FOUND ENTER AGAIN')
701   FORMAT(2A4)
702   FORMAT(1H0)
710   FORMAT($,' ARE THEY LEGHORN OR PLYMOUTH ROCK CHICKENS?')
711   FORMAT(A1)
715   FORMAT($,' ARE THEY LARGE OR SMALL TURKEYS?')
731   FORMAT(F10.3)
716   FORMAT(A1)
717   FORMAT(' THE PROCESS IS COMPLETED. HOWEVER',/,
      1 ' THE PROCESS PRODUCTION IS NOT 100% .',/,
      2$,' DO YOU WISH TO CONTINUE ?')
720   FORMAT(1H0,'PROCESS CODE WORD: ',A4,12X,' UPPER TEMP: '
      1,F4.1,' F',20X,' MIN. TEMP: ',F4.1,/,' MAXIMUM RELATIVE
      2HUMIDITY: ',F4.1,' %',2X,' MINIMUM VENTILATION: ',F7.5
      3,' CFM/LB ',2X,' MAXIMUM VENTILATION: ',F7.5,' CFM/LB ',/,
      4' OPT. TEMP DAY 1: ',F4.1,' F ',11X,' OPT. RELATIVE
      5HUMIDITY: ',F4.1,' %',8X,' REFERENCE TEMP: ',F4.1,' F ',/,
      6' AREA/ANIMAL:',F6.1,' SQ.FT. ',9X,' LENGTH TO WIDTH
      7RATIO: ',F4.2,11X,' WINDOW TO WALL RATIO: ',F4.2,/,
      8' TEMP CHANGE CYCLE ',F3.0,' DAYS ',8X,' CYCLE TEMP
      9CHANGE: ',F4.0,' F',13X,' MAXIMUM PRODUCTION: ',A4,/,
      1' ANIMAL DISTRIBUTION: ',F7.3,7X,' PRODUCTION CYCLE ',F4.0,
      2' DAYS ',11X,' NUMBER OF ANIMALS: ',F10.0)
750   FORMAT(1H0,2A2,3(5X,' WARNING',/),/,
      1 ' MAXIMUM TEMPERATURE EXCEEDED',/,
      26(' ANIMALS DYING!!! ',/))
      RETURN
      END
```

```
      SUBROUTINE WEATHR
      REAL LAT,LONG,MINCFM,MAXCFM
      INTEGER YEAR,DATE,HOUR,SLP,DPT,WD,SP,DBT,WBT,RH,TSC,TOSC
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,
     1 KAT,CLOUD,WIND,WINDIR,RHO,MINCFM,MAXCFM,IYEAR
      COMMON/WTHCOM/STN,YEAR,DATE,HOUR,SLP,DPT,WD,WS,
      1  SP,DBT,WBT,RH,TSC,TOSC
      COMMON/KEEP10/TEMPG, KB ,IFIC
      COMMON/DATI/WM,W,P,T,R,C,WIN,WINDI,PAT,TEMO,CLOD,ICT,DDIV
C     THIS PROGRAM WILL BE UPDATED LATER
      BYTE YES,NO,RESP
      DATA YES/'Y'/,NO/'N'/
      DATA KA/0/,KB/0/,ICNT/0/,STEM/0./,ICT/0/,DIV/2./,DDIV/0./
      YEAR=IYEAR
      DATE=IDATE
      HOUR=IHOUR-1
      INTB=0
      INTF=0
      ICT=ICT+1
      DDIV=DDIV+1.
      WINDIR=0.0
      PATS=0.0
      TEMPO=0.0
      RHO=0.0
      CLOUD=0.0
      IFIC=0
      IF(KB.NE.0) GO TO 20
      KB=5
C     WRITE(7,1010)
C     READ(5,905) RESP
C     IF(RESP.EQ.YES) GO TO 21
      WRITE(7,1011)
      READ(5,1012) TEMPG
C     GO TO 20
C     DATE=1
C     HOUR= 0
C21   DO 15 I = 1,8760
C     CALL STORMY(IFLAG)
C     HOUR=HOUR+1
C     IF(IFLAG.NE.0) GO TO 25
C     ICNT=ICNT+1
C     STEM=STEM+ FLOAT(DBT)
C25   CONTINUE
C     IF(HOUR.NE.24) GO TO 15
C     HOUR=0
C     DATE=DATE+1
C15   CONTINUE
C     HOUR=IHOUR-1
C     DATE=IDATE
C     TEMPG=STEM/FLOAT(ICNT)
D     WRITE(6,1013) TEMPG
D1013 FORMAT(1H0,2X,'GROUND TEMP = ', F10.3)
C     KB=5
2^    CONTINUE
1     CONTINUE
```

```
      IF(KA.EQ.1) GO TO 500
      IF(KAT.NE.0) GO TO 1099
      WRITE (7,950)
      READ(5,905)RESP
      IF(RESP.EQ.YES) GO TO 500
      IF(RESP.EQ.NO) KA=2
      IF(RESP.NE.YES.AND.RESP.NE.NO) GO TO 11
1099  IF(KA.EQ.2) GO TO 10
500   CONTINUE
      KA=1
      IF(DDIV.LE.DIV.AND.ICT.GE.6) GO TO 605
      IF(ICT.GE.6) IFIC=1
      IF(ICT.GE.6) INTF=1
2000  CONTINUE
      CALL STORMY(IFLAG)
      IF(INTF.NE.0.AND.IFLAG.EQ.0) GO TO 710
      IF(IFLAG.EQ.0) GO TO 510
      IF(INTB.NE.0.AND.IFLAG.EQ.3) GO TO 609
      IF(IFLAG.EQ.0.AND.IFIC.EQ.1) GO TO 510
      IF(IFIC.EQ.1) GO TO 610
      IF(IFLAG.EQ.0.AND.INTB.NE.0.AND.INTF.EQ.0) GO TO 510
      IF(IFLAG.EQ.0.AND.INTF.NE.0) GO TO 710
      IF(INTF.NE.0) GO TO 610
      IF(IFLAG.EQ.0) GO TO 510
      IF(INTB.NE.0) GO TO 812
C     WRITE(7,515) IFLAG
C515  FORMAT(/,1X,'IFLAG=',I2)
      IF(IFLAG.NE.5) STOP
C     INTERPOLATION SECTION
812   INTB=INTB+1
      HOUR=HOUR-1
      IF(HOUR.GE.0) GO TO 813
      HOUR=23
      DATE=DATE-1
      IF(DATE.GE.1)GO TO 813
      YEAR=YEAR-1
      DATE=365
813   CONTINUE
      GO TO 2000
C
C
609   IFIC=1
610   IF(INTF.EQ.0) HOUR=HOUR+INTB
      DDIV=1.
      YEAR=IYEAR
      DATE=IDATE
      INTF=INTF+1
      HOUR=HOUR+1
      IF(HOUR.GT.23) HOUR=HOUR-24
      GO TO 2000
C
C
710   DIV=FLOAT(INTB)+FLOAT(INTF)
      WM=WS
      W=FLOAT(WD)*10.
```

```
      P=(FLOAT(SP)/100.)/2.036
      T=FLOAT(DBT)
      R=FLOAT(RH)
      C= 1. - FLOAT(TOSC)/10.
      IF(ICT.GE.6) GO TO 605
      WIND=WIN+(((WM-WIN)/DIV)*FLOAT(INTB))
      WINDIR=WINDI+(((W-WINDI)/DIV)*FLOAT(INTB))
      PATS=PAT+(((P-PAT)/DIV)*FLOAT(INTB))
      TEMPO=TEMO+(((T-TEMO)/DIV)*FLOAT(INTB))
      RHO=RO+(((R-RO)/DIV)*FLOAT(INTB))
      CLOUD=CLOD+(((C-CLOD)/DIV)*FLOAT(INTB))
      GO TO 30
C
605   D=DIV/DDIV
      WIND=WIN+(WM-WIN)/D
      WINDIR=WINDI+(W-WINDI)/D
      PATS=PAT+(P-PAT)/D
      TEMPO=TEMO+(T-TEMO)/D
      RHO=RO+(R-RO)/D
      CLOUD=CLOD+(C-CLOD)/D
      IF(D.NE.1.) GO TO 30
      WIN=WIND
      WINDI=WINDIR
      PAT=PATS
      TEMO=TEMPO
      RO=RHO
      CLOD=CLOUD
      GO TO 30
C
510   CONTINUE
      DDIV=0.
      WIND=WS
      WINDIR=FLOAT(WD)*10.
      PATS=(FLOAT(SP)/100.)/2.036
      TEMPO=FLOAT(DBT)
      RHO=FLOAT(RH)
      CLOUD= 1. - FLOAT(TOSC)/10.
      WIN=WIND
      WINDI=WINDIR
      PAT=PATS
      TEMO=TEMPO
      RO=RHO
      CLOD=CLOUD
      IF(INTB.NE.0.AND.INTF.EQ.0) GO TO 610
      GO TO 30
10    CONTINUE
      WRITE(7,900)IDATE,IHOUR
      READ(5,989)TEMPO
      WRITE(7,901)
      READ(5,989)RHO
      WRITE(7,902)
      READ(5,989)WIND
      WRITE(5,903)
      READ(5,989)WINDIR
      WRITE(5,904)
```

```
      READ(5,989)CLOUD
      WRITE(7,906)IDATE,IHOUR,TEMPO,RHO,WIND,WINDIR,CLOUD
      READ(5,905)RESP
      IF (RESP.NE.YES) GO TO 10
30    CONTINUE
      RHO=RHO/100.
806   FORMAT(5F10.3,2I3)
900   FORMAT(1H0,'FOR DAY ',I3,' AND HOUR ',I2,/,
     1 ' ENTER THE FOLLOWING',/,
     2 $,' OUTSIDE TEMPERATURE F: ')
901   FORMAT($,' OUTSIDE RELATIVE HUMIDITY % ')
902   FORMAT($,' WIND SPEED MPH ')
903   FORMAT($,' WIND DIRECTION, DECIMAL DEGREES,',/,' NORTH = ',
     1$,' 0.0 CLOCKWISE ')
904   FORMAT($,' CLOUD COVER FACTOR ')
905   FORMAT(A1)
906   FORMAT(////,'FOR DAY ',I3,' AND HOUR',I2,/,
     1 ' TEMP = ',F4.1,'F',/,
     2 ' REL HUM = ',F4.1,' %',/,
     3 ' WIND SPEED = ',F4.1,' MPH',/,
     4 ' WIND DIREC = ',F5.0,'DEGREES',/,
     5 ' CLOUD FACTOR = ',F6.2,///,
     6 $,' IS THE DATA CORRECT?')
950   FORMAT(1H0,$,'WILL THE WEATHER DATA BE READ FROM TAPE? ')
989   FORMAT(F10.3)
1010  FORMAT(1H0,2X,'DO YOU WISH TO CALCULATE THE AVERAGE AIR TEMP?')
1011  FORMAT(1H0,2X,'ENTER THE GROUND TEMPERATURE ')
1012  FORMAT(F10.3)
      RETURN
      END
```

```
      SUBROUTINE STORMY(FLAG)
C
C     ROUTINE TO READ DATA FOR A GIVEN YEAR, DAY, AND HOUR
C
C     FLAG = 0 IF DATA FOUND
C          = 1 FOR DISK READ ERROR
C          = 2 FOR STATION MISMATCH
C          = 3 FOR YEAR MISMATCH
C          = 4 FOR DAY ERROR
C          = 5 FOR HOUR MISMATCH
C
      INTEGER FLAG
      INTEGER YEAR(2) ,SAMPLS(2)      ,SHR(8,2)      ,SREC(2)
      REAL    STNM(2)
C
      INTEGER YR      ,DAY    ,HOUR   ,DPT    ,WD     ,SP     ,DBT
      INTEGER WBT     ,RH     ,TSC    ,TOSC   ,SLP    ,IEQ(16)
C
      COMMON /PNTCOM/ STNM    ,YEAR   ,SAMPLS ,SHR    ,SREC
C
      COMMON /WTHCOM/  STN    ,YR     ,DAY    ,HOUR   ,SLP
     1                ,DPT    ,WD     ,WS     ,SP     ,DBT
     2                ,WBT    ,RH     ,TSC    ,TOSC
C
      EQUIVALENCE (IEQ(1),STN)
C
      K = 0
      IF(STN .EQ. STNM(1) .OR. STN .EQ. STNM(2)) GO TO 100
      FLAG = 2
      RETURN
100   IF(YR .EQ. YEAR(1)) K = 1
      IF(YR .EQ. YEAR(2)) K = 2
      IF(K .NE. 0) GO TO 200
      FLAG = 3
      RETURN
200   IF(DAY .GT. 0 .AND. DAY .LT. 366) GO TO 300
      FLAG = 4
      RETURN
300   IF(SAMPLS(K) .EQ. 24) GO TO 350
      DO 310 J=1,8
      KDAY = J - 1
      IF(HOUR .EQ. SHR(J,K)) GO TO 400
310   CONTINUE
320   FLAG = 5
      RETURN
350   KDAY = HOUR
      IF(HOUR .LT. 0 .OR. HOUR .GT. 23) GO TO 320
400   IREC = SREC(K) + (DAY-1)*SAMPLS(K) + KDAY
      READ(2'IREC,ERR=500) IEQ
      FLAG = 0
      RETURN
500   FLAG = 1
      RETURN
      END
```

```
      SUBROUTINE DISPCH (QNET, QSTL, QSAVB, QTOPRE, QPREL,
      1   QTOAPP, APPLLD, PNET, WECEXE, WECENE)
C
C     WECENE = WIND ENERGY AVAILABLE AFTER HEATING
C     IF WECENE = 0 GO TO STORAGE DISPATCH
C
      QTOPRE = 0.0
      QNET = 0.0
      QTOAPP = 0.0
      WECEXE = 0.0
      IF(WECENE .LE. 0.0 ) GO TO 100
C
C
C     WECENE TO THERMAL STORAGE
      A = QSTL - WECENE
      QNET = QSTL
      IF(A .GT. 0.0) QNET = WECENE
      WECENE = WECENE - QNET
C
C
C     WECENE TO HOT WATER PREHEAT
      A = QPREL - WECENE
      QTOPRE = QPREL
      IF(A .GT. 0.0) QTOPRE = WECENE
      WECENE = WECENE - QTOPRE
C
C
C     WECENE TO APPLIANCE LOADS
      A = APPLLD - WECENE
      QTOAPP = APPLLD
      IF(A .GT. 0.0) QTOAPP = WECENE
      WECENE = WECENE - QTOAPP
C
C
C     EXCESS WECENE
      WECEXE = WECENE
C
      GO TO 200
C
100   CONTINUE
C     STORAGE DISPATCH
      A = PNET - QSAVB
      QNET = - PNET
      IF(A .GT. 0.0) QNET = - QSAVB
      PNET = PNET + QNET
200   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WECPR2(ENERGY, DENSIT, WSPEED)
C
C
C
C      THIS SUBROUTINE ESTIMATES THE AMOUNT OF ENERGY
C     THAT A SELECTED WECS WOULD PRODUCE
C
      COMMON/SYSTEM/ VI, VO, VR, DIA, HUB
C
C
      DATA VI, VO, VR, HUB/6.0, 40.0, 26.0, 60.0/,DIA/0.0/
C
      IF(DIA .GT. 0.) GO TO 20
      WRITE(7,10)
10    FORMAT(1H0,' WHAT IS THE WIND BLADE DIAMETER ? ')
      READ(5,15) DIA
15    FORMAT(F10.2)
20    AIRDEN = DENSIT/32.174
C
C     STAR CALCULATIONS
C
      ADJ = (.00237202/AIRDEN) ** .33333333
      VCUTIN = VI * ADJ
      VCTOUT = VO * ADJ
      VRATED = VR * ADJ
      WIND = WSPEED * (HUB/20.0) **.14286
C
C     CHECK FOR ENERGY PRODUCTION
      VEL = 0.0
      IF(WIND .LT. VCTOUT) VEL = VRATED
      IF(WIND .LT. VRATED) VEL = WIND
      IF(WIND .LT. VCUTIN) VEL = 0.0
C
C
C     CALCULATE ENERGY PRODUCTION
C     ENERGY = EFF*CP*CG*.5*ROE*AREA*(VEL*1.467) **3 * .00128 BTU
      ENERGY = 1.6453 * AIRDEN * DIA** 2 * VEL**3
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STORE1 ( QNET , QSAVB , QSTL , QSLOS , TEMPI )
C
C
      COMMON/STORAG/ VOL1, TMIN1, TMAX1
      COMMON/STO/ FTF , TS , WTSTOR , TSMAX , QSTOR , CSTO , DITANK ,
     1    RATIO, HEIT, TSMIN
      DATA  FTF , THINS , TS , TSMAX , TSMIN , CSTO /
     1    0.0 , 1.0 , 110.0 , 200.0 , 100.0 , 0.023 /
      IF(FTF . NE. 0.0) GO TO 10
      WRITE(7,20)
20    FORMAT(1HO,' ENTER THE GALLONS OF STORAGE AND THE STORAGE
     1    TANK HEIGHT ')
      READ(5,30) GALSTO, HEIT
30    FORMAT(F10.2)
      TMIN1 = TSMIN
      VOL1 = GALSTO
      TMAX1 = TSMAX
      FTF = 1
      VSTOR = GALSTO * 0.1337
      WTSTOR = GALSTO * 8.3453
      DITANK = ((4.*VSTOR)/(HEIT*3.1415))**0.5
      QSAVB = WTSTOR * (TS -TSMIN)
      RAD1 = DITANK/2.
      RAD2 = RAD1 + THINS
      RATIO = RAD2/RAD1
C     WRITE(7,700) TS, TEMPI, TSMAX, TSMIN
700   FORMAT(1HO,'TS,  TEMPI, TSMAX, TSMIN = ',4F10.0)
10    CONTINUE
      IF( QNET.GE.0.) GO TO 12
      QFSTO = -QNET / 0.85
      IF(QFSTO .GT. QSAVB) QFSTO = QSAVB
      TS = TS - (QFSTO + QSLOS)/WTSTOR
      GO TO 16
12    QTSTO = QNET/0.8
      IF(QTSTO .GT. QSTL) QTSTO = QSTL
      TS = TS + (QTSTO - QSLOS)/WTSTOR
16    CONTINUE
      QSLOS = 6.283 * (TS - TEMPI) * (HEIT * CSTO/ ALOG(RATIO) +
     1        DITANK**2 * CSTO / 4.)
      QSTL = WTSTOR * (TSMAX - TS)
      QSAVB = WTSTOR * ( TS - TSMIN ) * .85
      IF(QSAVB .LT. 0.0) QSAVB = 0.0
      IF(QSTL .LT. 0.0 ) QSTL = 0.0
C     WRITE(7,700) TS, TEMPI, TSMAX, TSMIN
      RETURN
      END
```

```
      SUBROUTINE PREHET (QTPRE , QPREL , QHLS , TEMPI , IHOUR)
C
C
C
      COMMON/PRETNK/ VOL2, TMAX2
      COMMON/PRE/  WTPRE ,  FTF , TPRHT , TPREMX , TPREMN , HTPRE , HTHT
     1              ,RATIO2,RATIO3,COND2,COND3,DITNK2,DITNK3
      COMMON/KEEP35/ QWATER(24), HTWTR(24) , TEMPHW , TEMPMW
      DATA  FTF , TPREMN , TPREMX , TEMPHW , TPRHT ,
     1      THINS2 , THINS3 , COND2 , COND3/ 0.0,
     2      45.0,165.0,150.0,120.0,0.5,0.5,0.023,0.023/
      IF(FTF.NE.0) GO TO 10
C     GALPRE = GALLONS OF PREHEAT WATER , TPREMN = MIN PREHEAT TEMP,
C     TPREMX = MAX. PRE-HEAT TEMPERATURE, CHOT = HOT TANK CONDUCTANCE
C     THINS2 @ THINS3 = INSULATION THICKNESS , CPRE = PREHEAT
C     CONDUCTIVITY
C
      WRITE(7,20)
20    FORMAT(1HO,' ENTER THE NUMBER OF GALLONS OF PREHEAT AND HOT
     1      WATER TANKS ')
      READ(5,30) GALPRE,GALHT
30    FORMAT(F10.2)
      WRITE(7,40)
40    FORMAT(1HO,' ENTER THE PREHEAT AND HOT WATER TANK HEIGHTS ')
      READ(5,30) HTPRE, HTHT
      VOL2 = GALPRE
      TMAX2 = TPREMX
      FTF = 1
C     VOLUME, WEIGHT AND SURFACE AREA OF PRE-HEAT TANK
      VOLPRE = GALPRE * 0.1337
      WTPRE = GALPRE * 8.3453
      DITNK2 = ((4.*VOLPRE)/(HTPRE * 3.1415)) **0.5
C     VOLUME AND SURFACE AREA OF THE HOT WATER TANK
      VOLHWT = GALHT * 0.1337
      DITNK3 = ((4.*VOLHWT)/(HTHT*3.1415))**0.5
      RIN21 = DITNK2/2.
      RIN22 = RIN21 + THINS2
      RIN31 = DITNK3/2.
      RIN32 = RIN31 +THINS3
      RATIO2 = RIN22/RIN21
      RATIO3 = RIN32/RIN31
C     HOT WATER ENERGY REQUIRED FOR REPLACEMENT WATER
10    QWATER(IHOUR) = HTWTR(IHOUR) * 8.3453 * (TEMPHW - TPRHT)
      IF(QWATER(IHOUR) .LT. 0.0) QWATER(IHOUR) = 0.0
C     HOT WATER TANK HEAT LOSS
      QHTLS = 6.283*(TEMPHW-TEMPI) * (HTHT*COND3/ ALOG(RATIO3)
     1       + DITNK3 ** 2 * COND3/4.)
C     TOTAL HOT WATER TANK ENERGY REQUIRED
      QWATER(IHOUR) = QWATER(IHOUR) + QHTLS
C     PRE-HEAT TANK ENERGY TOTAL
      QPRE = WTPRE * (TPRHT - 32.0)
C     ENERGY LOSS FROM PRE-HEAT TANK
      QPRELS = 6.283*(TPRHT-TEMPI) * (HTPRE*COND2/ ALOG(RATIO2)
     1       + DITNK2 ** 2 * COND2/4.)
C     TOTAL HEAT LOSS TO SPACE FROM WATER TANKS
```

```
      QHLS = QPRELS + QHTLS
C     PREHEAT WATER TANK ENERGY LOSS
      QPRELS = QPRELS + HTWTR(IHOUR) * 8.3453 * (TPRHT - TEMPMW)
C     NEW PREHEAT TANK TOTAL ENERGY
      QPRE = QPRE - QPRELS +QTPRE
C     NEW PRE-HEAT TANK WATER TEMPERATURE
      TPRHT = QPRE/WTPRE + 32.
C     PRE-HEAT TANK STORAGE CAPACITY AVAILABLE
      QPREL = WTPRE * (TPREMX - TPRHT)
      IF(QPREL .LT. 0.0 ) QPREL = 0.0
      RETURN
      END
```

```
      SUBROUTINE FENES (SUAZAN,S,TOTIN,SOLALT)
C     S=SLOPE OF SURFACE
C     IZON=TIME ZONE
      DIMENSION A(13),B(13),C(13),DAY(13),LSTT(5)
      DOUBLE PRECISION ZONE(5),RESP
      INTEGER DAY,A,DAYYR,DAYS
      REAL LST,LAT,LSTT,LONG
      COMMON/KEEP6/ ZONE,NTS, LST, LSTT, RESP
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,DAYYR,IHOUR,
      1KAT,CLOUD,WIND,WINDIR,RHO
      DATA LSTT/120.0,105.0,90.0,75.0,60.0/
      DATA DAY/21,52,80,111,141,172,202,233,264,294,325,355,386/
      DATA A/390,385,376,360,350,345,344,351,365,378,387,391,390/
      DATA B/0.142,0.144,0.156,0.180,0.196,0.205,0.207,0.201,0.177,
     1 0.160,0.149,0.142,0.142/
      DATA C/0.058,0.060,0.071,0.097,0.121,0.134,0.136,0.122,0.092,
     1 0.073,0.063,0.057,.058/
      DATA ZONE/'PACIFIC ','MOUNTAIN','CENTRAL ','EASTERN ',
     1 'ATLANTIC'/
      DATA NTS/0/
      DAYS=DAYYR
D     WRITE(6,1010) RESP
D1010 FORMAT(1H0,'TIME ZONE FROM COMMON = ',A8)
      IF(KAT.NE.0) GO TO 199
      IF(NTS.EQ.1) GO TO 199
      GO TO 999
129   WRITE (7,700)
      READ (5,701) RESP
999   CONTINUE
      DO 201 IABL = 1,5
      IF (RESP.EQ.ZONE(IABL))NUTS=1
      IF (RESP.EQ.ZONE(IABL))LST=LSTT(IABL)
201   CONTINUE
      IF (NUTS.NE.1)WRITE (7,702)
      IF (NUTS.NE.1)GO TO 129
      NTS=1
199   CONTINUE
      RADCON=3.14159/180.0
C     SOLAR INTENSITY CALCULATION
      SUAZAN=SUAZAN*RADCON
      S=S*RADCON
      LAT=LAT*RADCON
      SOLRTI=(IHOUR*60.0 + 4.0 * (LST-LONG))
      HRANG=((720.0-SOLRTI) * 15.0/60.0)*RADCON
      DECL=23.45*SIN(.9863*(284+DAYYR)*RADCON)*RADCON
      SOLALT=COS(LAT)*COS(DECL)*COS(HRANG)+SIN(LAT)*SIN(DECL)
      SOLALT=ASIN(SOLALT)
      ANINCO=SIN(DECL)*SIN(LAT)*COS(S)
     1        -SIN(DECL)*COS(LAT)*SIN(S)*COS(SUAZAN)
     2        +COS(DECL)*COS(LAT)*COS(S)*COS(HRANG)
     3        +COS(DECL)*SIN(LAT)*SIN(S)*COS(SUAZAN)*COS(HRANG)
     4        +COS(DECL)*SIN(S)*SIN(SUAZAN)*SIN(HRANG)
C     ANGINC=ANGLE OF INCIDENCE OF THE BEAM RADIATION
      ANGINC=ACOS(ANINCO)
      DIRECT NORMAL INTENSITY
```

```
      DNI=A(I)
      K=0
      J=0
      IF (DAYS.LE.21)J=1
      IF(DAYS.GT.21.AND.DAYS.LE.52)J=2
      IF(DAYS.GT.52.AND.DAYS.LE.80)J=3
      IF(DAYS.GT.80.AND.DAYS.LE.111)J=4
      IF(DAYS.GT.111.AND.DAYS.LE.141)J=5
      IF(DAYS.GT.141.AND.DAYS.LE.172)J=6
      IF(DAYS.GT.172.AND.DAYS.LE.202)J=7
      IF(DAYS.GT.202.AND.DAYS.LE.233)J=8
      IF(DAYS.GT.233.AND.DAYS.LE.264)J=9
      IF(DAYS.GT.264.AND.DAYS.LE.294)J=10
      IF(DAYS.GT.294.AND.DAYS.LE.325)J=11
      IF(DAYS.GT.325.AND.DAYS.LE.355)J=12
      IF(DAYS.GT.355.AND.DAYS.LE.365)J=13
      K=J-1
      IF(K.EQ.0)K=12
      DARA=FLOAT(DAYS-DAY(J))/FLOAT(DAY(K)-DAY(J))
C     SOLCON=APPARENT SOLAR CONSTANT
      SOLCON=DARA*(A(K)-A(J))+A(J)
C     ATEXCO=ATMOSPHERIC EXTINCTION COEFFICIENT
      ATEXCO=DARA*(B(K)-B(J))+B(J)
C     SDF=SKY DIFFUSE FACTOR
      SDF=DARA*(C(K)-C(J))+C(J)
C     WRITE(6,705) B(K),B(J),C(K),C(J),A(K),A(J)
C     WRITE(6,705) SOLCON,ATEXCO,SDF,DARA,DAYS,DAY(J),DAY(K)
C     DIRECT NORMAL INTENSITY
      IF(SOLALT.LT.0.0) SOLALT=0.0
      IF(SOLALT.EQ.0.0) DNI=0.0
      IF(SOLALT.EQ.0.0) GO TO 2550
      DNI=SOLCON*EXP(-ATEXCO/SIN(SOLALT))
2550  CONTINUE
C     DIRECT INTENSITY
      IF(ANINCO.LT.0)DI=0.0
      IF(ANINCO.GE.0)DI=DNI*ANINCO
C     DIFFUSE RADIATION
      DSI=SDF*DNI*(1.0+COS(S))/2.0
      DGI=DNI*(SDF+SIN(SOLALT))
     1          * .20 * (1.0-COS(S))/2.0
      DIFF=DSI+DGI
C     TOTAL SOLAR INTENSITY
      TOTIN=DI+DIFF
D     WRITE(6,703)
      LAT=LAT/RADCON
      SUAZAN=SUAZAN/RADCON
      S=S/RADCON
D     WRITE(6,704)LAT,LONG,LST,DAYYR,IHOUR,SUAZAN,S,TOTIN,ANGINC,
D     1        DECL,HRANG,SOLALT,DNI,DI,DSI,DGI,DIFF
700   FORMAT(1H0,$,'IN WHICH TIME ZONE IS THE FACILITY?')
701   FORMAT(A8)
702   FORMAT(1H0,'TIME ZONE DOES NOT MATCH ENTER:',/,
     1 ' PACIFIC, MOUNTAIN, CENTRAL, EASTERN OR ATLANTIC')
703   FORMAT(' LAT, LONG, LST  ,DAY, HOUR, SOLAR AZ ANGLE, SLOPE,
     1 ' TOTRAD, ANGLE OF INCIDENCE, DECLINATION, HOUR ANGLE,'
```

```
    2  ' SOLAR ALTITUDE')
105    FORMAT  (4(2X,F10.3),3(2X,I3))
104    FORMAT(2X,F10.3,2X,F10.3,2X,F10.3,2X,I5,
       12X,I5,4(2X,F10.3),/,5(2X,F10.3))
       RETURN
       END
       FUNCTION ASIN(X)
       ASIN = 0.00
       IF(X.EQ.-1.0) GO TO 3
       IF(X.EQ.1.0) GO TO 3
       IF(X.GT.1.0) GO TO 2
       IF(X.LT.-1.0) GO TO 2
       ASIN = ATAN(X/((1.0-X**2)**.5))
       GO TO 3
2      CONTINUE
       WRITE (7,100)
100    FORMAT(' ERROR...ERROR...SINX OR COSX > 1 OR < -1')
3      CONTINUE
       RETURN
       END
       FUNCTION ACOS(X)
       ACOS = 3.141593/2.0 - ASIN(X)
       RETURN
       END
```

```
      SUBROUTINE THECON(NAREAS,AU,AREA,
     1 SUMQCN,TEMPO,TEMPI,RADT,QTOT,SUN,ADJ)
      DIMENSION AU(8),SUMQCN(8),SUN(8),RADT(8),ADJ(8)
      DIMENSION AREA(8)
C     THIS SUBROUTINE EVALUATES THE ENERGY EXCHANGES THROUGH
C     AN ARRAY OF WALLS OR OTHER AREAS
C
C
D     WRITE(6,8005)
C
C
      QTOT=0.0
      DO 10 IA = 1,NAREAS
      U=AU(IA)/AREA(IA)
      SOLAT=TEMPO+.23*RADT(IA)
      IF(ADJ(IA) .EQ. 1.0)TEMP2=TEMPI
      IF(SUN(IA) .EQ. 1.0)TEMP2=(3.0*SOLAT+U*TEMPI)/(U+3.0)
      SUMQCN(IA)=AU(IA)*(TEMP2 TEMPI)
      QIUT=QTOT+SUMQCN(IA)
C
C
D     WRITE(6,8000) AU(IA), SUN(IA), ADJ(IA), SOLAT, U,
D     1       TEMP2, TEMPI, SUMQCN(IA), RADI(IA)
D8000 FORMAT( 9 (1X, F7.1))
D8005 FORMAT(2X, 'AU', 6X, 'SUN', 6X, 'ADJ', 4X, 'SOLAT',
D     1       8X, 'U', 4X, 'TEMP2', 8X, 'TEMPI', 3X, 'SUMQCN'
D     1       ,3X, 'RADT')
10    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GLASS(CODE,GPROP,KAT)
      DIMENSION GPROP(20),GPR(20,15)
      BYTE RESP,YES,NO
      DATA YES,NO/'Y','N'/
C     CODE  PANE  TOWO  ROE1 ROE2 ALPHA1 ALPH2 ETTA1 ETTA2 GR1
C     THICK TOWI ROE3 ROE4 ALPH3 ALPH4
C     SINGLE VERTICAL-.125 IN. CLEAR GLASS
      DATA GPR/'GL01',1.0,0.84,.07,.07,.09,.09,.84,.84,57.1,10*0.0,
C     SINGLE VERTICAL-.25 IN. CLEAR GLASS
     1 'GL02',1.0,0.78,.07,.07,.09,.09,.84,.84,28.6,10*0.0,
C     SINGLE-VERTICAL-3.75 IN CLEAR GLASS
     2 'GL03',1.0,0.72,.07,.07,.09,.09,.84,.84,19.0,10*0.0,
C     SINGLE-VERTICAL-.50 IN. CLEAR GLASS
     3 'GL04',1.0,0.67,.07,.07,.09,.09,.84,.84,14.3,10*0.0,
C     DOUBLE-VERTICAL-.125 IN. CLEAR GLASS-3/16 IN. AIR SPACE
     4 'GL05',2.0,0.84,.07,.07,.09,.09,.84,.84,57.1,.1875,0.84,.07,.07,
     5 .09,.09,0.84,0.84,57.1,4.0,
C     DOUBLE-VERTICAL-0.125 IN. CLEAR GLASS-44 IN. AIR SPACE
     6 'GL06',2.0,0.84,.07,.07,.09,.09,.84,.84,57.1,.250,.84,.07,.07,
     7 .09,.09,0.84,0.84,57.1,4.0,
C     DOUBLE-VERTICAL-0.25 IN. CLEAR GLASS-1/2 IN. AIR SPACE
     8 'GL07',2.0,.78,.07,.07,.09,.09,.84,.84,28.6,.50,.084,.07,.07,
     9 .09,.09,0.84,0.84,28.6,4.0,
C     DOUBLE-VERTICAL-0.25 IN. LOW EMITTANCE COATING, NO 3 SURFACE
C     1/2 IN. AIR SPACE
     1 'GL08',2.0,0.80,.07,.07,.13,.13,.84,.84,28.6,.50,.12,.70,.07,
     2 .18,.81,.10,0.84,28.6,4.0,
     3 'GL09',19*0.0,
     4 'GL10',19*0.0,
     5 'GL11',19*0.0,
     6   'GL12',19*0.0,
     7 'GL13',19*0.0,
     8 'GL14',19*0.0,
     9 'GL15',19*0.0/
      IAT = 0
20    CONTINUE
      DO 30 I=1,15
      NUM=I
      J=1
      CHECK=GPR(J,I)
      IF(CODE.EQ.CHECK) GO TO 40
30    CONTINUE
      WRITE (7,700)CODE
      READ(5,701)CODE
      GO TO 20
40    CONTINUE
      DO 70 I=1,20
      GPROP(I)=GPR(I,NUM)
70    CONTINUE
25    CONTINUE
700   FORMAT(' GLAZING CODE ',A4,' NOT FOUND.',/,$,' ENTER AGAIN')
701   FORMAT(A4)
702   FORMAT(1H0,'CODE ',A4,' SELECTED',/,
     1 $,' IS THIS THE CORRECT CODE? ')
      FORMAT(A1)
```

```
704     FORMAT($,' ENTER THE CORRECT CODE: ')
        RETURN
        END
```

```
      SUBROUTINE GLAZE (QF,RADT,GAU,IA,IB,GCODE,AREA,FFACT)
      DIMENSION JFEN(4),GPROP(20)
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,
      1CLOUD,WIND,WINDIR,RHO
      REAL LAT,LONG
      IAT = 0
      IF(AREA.LE.0.0) GO TO 75
      CALL GLASS(GCODE, GPROP,KAT)
C     WRITE(6,700) (IAT+1),(GPROP(I),I=1,20)
C     NUMBER OF PANES GPROP(1)
C     OUTDOOR TO INDOOR PROPERTIES
      PANE=GPROP(2)
      TOWO=GPROP(3)
      ROE1 =GPROP(4)
      ROE2 =GPROP(5)
      ALPH1 =GPROP(6)
      ALPH2 =GPROP(7)
      ETTA1 =GPROP(8)
      ETTA2 =GPROP(9)
      GR1 =GPROP(10)
      THICK =GPROP(11)
      TOWI =GPROP(12)
      ROE3 =GPROP(13)
      ROE4 =GPROP(14)
      ALPH3 =GPROP(15)
      ALPH4 =GPROP(16)
      ETTA3 =GPROP(17)
      ETTA4 =GPROP(18)
      GR2 =GPROP(19)
      CONVO =GPROP(20)
      ICOUNT = 0
      IF(CONVO.LE.0.0) CONVO=4.0
      IF(PANE   .GT. 1.0) GO TO 10
C     SINGLE GLAZE AREAS
84    CONTINUE
      TEMPG = (TEMPO-TEMPI)/2.0 + TEMPI
      DIFFT = (TEMPG - TEMPI)
      IF(DIFFT .EQ. 0.0) DIFFT = 0.0001
83    CONTINUE
      CONVI = .270*(ABS(DIFFT))**.25
      1 + ETTA2 * .1714E-08 * (DBLE((TEMPG + 460.)**4) -
      2 DBLE((TEMPI + 460.)**4))/DIFFT
      GU = 1.0/(1.0/CONVI  + 1.0/CONVO  + 1.0/GR1 )
      QRCI = GU * ((ALPH1  * RADT/CONVO  + TEMPO-TEMPI))
C     CHECK INDOOR TEMPERATURE
C     TEMPERATURE CHECK
      TEGO=TEMPO+(RADT * ALPHAO + QRCI)*(1.0/CONVO +
     1 1.0/(GR1 * 2.0))
      STAR=ABS(TEMPG-TEGO)
      TEMPG = TEGO
      ICOUNT = ICOUNT +1
      IF(ICOUNT .EQ. 50 ) GO TO 84
      IF(ICOUNT .GE. 51) GO TO 85
      IF(STAR.GT.ABS(.05))GO TO 83
      CONTINUE
```

```
      FFACT = TOWO  + GU * ALPH1 /CONVO
      TOW = TOWO
      GO TO 20
10    CONTINUE
C     DOUBLE GLAZE GLASS
      ALPHAO = ALPH1  + (ALPH2  * TOWO   *
     1         ROE3 )/(1.0-ROE2  * ROE3 )
      ALPHI = ALPH3  * TOWO /(1.0 - ROE2  *
     1         ROE3 )
      ABSO = RADT * ALPHAO
      ABSI = RADT * ALPHI
      E = 1.0/((1.0/ETTA2 ) + (1.0/ETTA3 ) - 1.0)
      DELT = ABS(TEMPO-TEMPI)
      TEMGO = TEMPO + 10.0
      TEMGI = TEMPI + 10.0
C     WRITE (6,501) ALPHAO,ALPHI,ABSO,ABSI,E,TEMGO,TEMGI
C501  FORMAT( 3X, 7(3X,F10.3))
      KAP = 0
16    CONTINUE
      TMEAN =  (TEMGO - TEMGI)/2.0 + TEMGI
      DIFFT = (TEMPG - TEMPI)
      IF(DIFFT .EQ. 0.0) DIFFT = 0.0001
      CONVI = .270*(ABS(TEMGI-TEMPI))**.25
      1 + ETTA4 * .1714E-08 * (DBLE((TEMGI + 460.)**4) -
      2 DBLE((TEMPI + 460.)**4))/(DIFFT)
      IF(CONVI .EQ. 0.0) CONVI = .0001
      CONVS = .51
      GU= 1.0/(1.0/CONVO  + 1.0/GR1  + 1.0/CONVS  +
     1    1.0/GR2  + 1.0/CONVI)
C     TRIAL NO. 1
      QRCI = GU * (ABSO/CONVO  + ABSI * (1.0/CONVO  +
     1        1.0/CONVS ) + (TEMPO-TEMPI))
C     CHECK GLASS TEMP
      T1 = TEMPO + (ABSO + ABSI - QRCI)*(1.0/CONVO  +
     1        1.0/GR1 /2.0)
      T2 = TEMPI + QRCI * (1.0/CONVI  + 1.0/GR2 /2.0)
      TM = (T1-T2)/2.0 + T2
D     WRITE(6,502)CONVI,CONVS,GU, QRCI, TEMGO, TEMGI, TM, STAR,TMEAN
D     1  ,T1,T2
      TRY1 = ABS(TEMGO - T1)
      TRY2 = ABS(TEMGI - T2)
      IF ( TRY .LT. .05 .AND. TRY2.LT. .05) GO TO 17
      TEMGO = T1
      TEMGI = T2
      TMEAN = TM
      ICOUNT = ICOUNT + 1
      IF(ICOUNT .EQ. 50) GO TO 10
      IF(ICOUNT .GE. 51) GO TO 17
      GO TO 16
17    CONTINUE
      TEMGO = T1
      TEMGI = T2
      TMEAN = TM
      TOW = TOWO  * TOWI /(1.0-ROE2 *ROE3 )
      FFACT = TOW + GU* ALPHAO/CONVO +(GU/CONVO+GU/CONVS)*ALPHI
```

```
20      CONTINUE
        QF=(FFACT*RADT+GU*(TEMPO-TEMPI))*AREA
        GAU = GU * AREA
D       WRITE(6,8000) FFACT, RADT, GU, TEMPO, TEMPI, AREA, QF
D8000   FORMAT(3X,'FFACT = ',F7.3,3X,'RADT = ',F7.2,3X,
D       1        'GU = ',F7.3,3X, 'TEMPO = ', F5.1,3X, 'TEMPI = ',/,
D       1        F5.1,3X,'AREA = ',F10.2,3X,'QF = ', F10.2)
75      CONTINUE
700     FORMAT(3X,I3,3X,A4,19(/,F10.5))
502     FORMAT(3X,5(3X,F10.3),/,6(3X,F10.3))
        RETURN
        END
```

```
      SUBROUTINE EXTWAL(AWALL,NW,AU,SUAZAN,SLOPE,SUN,ADJCN)
C     THE SUBROUTINE IS DESIGNED TO CALCULATE THE AREA AND U FACTORS
C     OF A STRUCTURE.
C
C
      COMMON/SCRTCH/AUSW,AUSST,SWR,ASW,AFEN,ASWNET,RSW,
     1ASS,RSS,NSW,NSS,SWW,SWH,SSW,SSH
C
C
      DIMENSION RSS(8,3,5), ASS(8,3,5), ASWNET(8,3),AFEN(8)
      DIMENSION AUSW(8,3), AU(8),AUSST(8,3,5),SWR(10)
      DIMENSION RSW(8,3),ASW(8,3),AWALL(8)
      DIMENSION SSR(10),NSW(8)
      DIMENSION NSS(8,3),DESC(10),PROP(5)
      DIMENSION SUAZAN(8), SLOPE(8), SUN(8),ADJCN(8),U(8)
C
C
      BYTE YES,NO,RESP,DUMMY
      COMMON/FIX/YES,NO,RESP,DUMMY
C
C
      DATA YES/'Y'/,NO/'N'/
CC
C     INITIALIZE VARIABLES TO 0.0
C
      SWW = 0.0
      SWH = 0.0
      SSW = 0.0
      SSH = 0.0
      DO 226 I=1,10
      PROP(I) = 0.0
      SWR(I) = 0.0
      SSR(I) = 0.0
      DESC(I) = 0.0
226   CONTINUE
      DO 225 I = 1,8
      SUN(I) = 0.0
      ADJCN(I) = 0.0
      U(I) = 0.0
      SUAZAN(I) = 0.0
      SLOPE(I) = 0.0
      NSW(I) = 0
      AFEN(I) = 0.0
      AWALL(I)=0.0
      AU(I)=0.0
      DO 224 J = 1,3
      AUSW(I,J) = 0.0
      ASW(I,J) = 0.0
      ASWNET(I,J) = 0.0
      NSS(I,J) = 0.0
      RSW(I,J) = 0.0
      DO 223 K = 1,5
      AUSST(I,J,K) = 0.0
      ASS(I,J,K) = 0.0
      RSS (I,J,K) = 0.0
```

```
223     CONTINUE
224     CONTINUE
225     CONTINUE
D       WRITE (6,714) I,AWALL(I),AFEN(I),SLOPE(I),SUAZAN(I),NSW(I),
D       1  SUN(I), ADJCN(I)
C
C
        WRITE (7,699)
        READ (5,698)NW
        IF(NW.LE.0) GO TO 159
278     CONTINUE
        DO 277 IA=1,NW
C       ENTER WALL CHARATERISTICS
        WRITE (7,700)IA
91      WRITE (7,697)IA
        READ (5,696)SUAZAN(IA)
        WRITE (7,690)IA
        READ (5,696)SLOPE(IA)
        WRITE(7,1014)SUAZAN(IA),SLOPE(IA)
        READ(5,694)RESP
        IF(RESP.NE.YES)GO TO 91
2010    CONTINUE
        WRITE (7,695)
        READ (5,694)RESP
        IF(RESP.EQ.YES)SUN(IA)=1.0
        IF(RESP.EQ.NO)SUN(IA)=0.0
        IF(RESP.EQ.YES) GO TO 188
        WRITE (7,1000)
        READ (5,694) RESP
        IF (RESP.EQ.YES)ADJCN(IA)=1.0
        IF(RESP.EQ.NO)ADJCN(IA)=0.0
        IF(SUN(IA).EQ.0.0.AND.ADJCN(IA).EQ.0.0) GO TO 2010
188     WRITE (7,701)
C       NUMBER OF SUBWALLS
90      READ (5,702) NUMWAL
        IF(NUMWAL.LT.1)WRITE(7,1013) NUMWAL
        IF(NUMWAL.LT.1)GO TO 90
        NSW(IA)=NUMWAL
        DO 276 IB=1,NUMWAL
C       DESCRIBE SUBWALL
82      CONTINUE
        WRITE (7,703)IA,IB
        READ (5,696)SWW
        WRITE (7,689)
        READ (5,696) SWH
        WRITE (7,688)
        READ (5,713) NSS(IA,IB)
        NUMSST=NSS(IA,IB)
86      WRITE (7,687)
        READ (5,713)ICODES
        IF(ICODES .EQ. 0) GO TO 10
C       ENTER RESISTANCE CODES
        WRITE (7,705)
        READ (5,706) (SWR(J), J=1,ICODES)
        WRITE (7,685)SWW,SWH,NUMSST
```

```
      WRITE (7,686)(SWR(J),J=1,ICODES)
      WRITE (7,681)
      READ (5,694)RESP
      IF(RESP.NE.YES) GO TO 82
C     CALCULATE SUBWALL THERMAL RESISTANCE
      RSW(IA,IB) = 0.0
      DO 15 I = 1,ICODES
78    CONTINUE
      RAT = SWR(I)
      CALL FNDREC(RAT, DESC, PROF, IDIOT)
      IF (IDIOT .EQ. 0) GO TO 77
      IF(IDIOT.NE.-1) GO TU 77
      WRITE (7,650)SWR(I)
      READ (5,679) SWR(I)
      GO TO 78
77    CONTINUE
      RSW(IA,IB)=RSW(IA,IB)+PROF(5)
15    CONTINUE
      GO TO 20
10    CONTINUE
      WRITE (7,707)
      READ (5,708) NDI, NPD
      RSW(IA,IB)=RSW(NDI,NPD)
      WRITE (7,685)SWW,SWH,NUMSST
      WRITE (7,1001)RSW(IA,IB)
      WRITE (7,681)
      READ (5,694)RESP
      IF (RESP.NF.YES) GO TU 82
20    CONTINUE
C     CALCULATE SUBWALL GROSS AREAS - SQUR.FT.
      ASW(IA,IB)=SWW*SWH
      ASWNET(IA,IB)=ASW(IA,IB)
C     CALCULATE DIRECTION WALL TOTAL AREA
      AWALL(IA)=AWALL(IA) + ASW(IA,IB)
C     EVALUATE SUBSTRUCTURES
      IF(NSS(IA,IB).EQ.0) GO TO 158
89    CONTINUE
      DO 275 IC=1,NUMSST
      WRITE (7,709)IA, IB, IC
      READ (5,696)SSW
      WRITE (7,683)
      READ (5,696)SSH
      ASS(IA,IB,IC)=SSH*SSW
      WRITE (7,682)
      READ (5,713)ISSCOD
      RSS(IA,IB,IC)=0.0
      IF (ISSCOD.EQ.0) GO TO 26
C     ENTER RESISANCE CODES
      WRITE (7,705)
      READ (5,706)(SSR(J),J=1,ISSCOD)
      WRITE (7,1002)SSW,SSH
      WRITE (7,686)(SSR(J),J=1,ISSCOD)
      WRITE (7,681)
      READ (5,694)RESP
      IF(RESP.NE.YES) GO TO 89
```

```
C       SUBSTRUCTURE AREA
|       CALCULATE SUBSTRUCTURE RESISTANCE - RSS(IA,IB,IC)
        DO 30 I = 1, ISSCOD
C       IS SSR(I)=GLASS PROP(5)=0
43      CONTINUE
        RAT = SSR(I)
        CALL FNDREC (RAT, DESC, PROP,IDIOT)
        IF (IDIOT .EQ. 0) GO TO 44
        IF(IDIOT.NE.-1) GO TO 44
        WRITE (7,650)SSR(I)
        READ (5,679) SSR(I)
        GO TO 43
44      CONTINUE
        RSS (IA,IB,IC)=RSS(IA,IB,IC) + PROP(5)
30      CONTINUE
        IF (RSS(IA,IB,IC) .EQ. 100.0) RAT = 'GLAS'
        GO TO 31
26      CONTINUE
        WRITE (7,710)
        READ (5,711) NDI, NPD, NPR
        RSS(IA,IB,IC)=RSS(NDI,NPD,NPR)
        WRITE (7,1002)SSW,SSH
        WRITE (7,1001)RSS(IA,IB,IC)
        WRITE (7,681)
        READ (5,694)RESP
        IF(RESP.NE.YES) GO TO 89
        IF (RSS(IA,IB,IC) .EQ. 100.0) RAT = 'GLAS'
31      CONTINUE
C       CALCULATE SUBSTRUCTURE AREA
C       CALCULATE NE SUBWALL AREA
        ASWNET(IA,IB)=ASWNET(IA,IB) - ASS(IA,IB,IC)
C       CALCULATE AREA OF FENESTRATION\
        IF(RAT .EQ. 'GLAS')AFEN(IA)=AFEN(IA) + ASS(IA,IB,IC)
103     CONTINUE
C       CHECK FOR RETURN POINT
275     CONTINUE
158     CONTINUE
276     CONTINUE
157     CONTINUE
277     CONTINUE
159     CONTINUE
C       AU PRODUCTS AND SUMMARY TABLE
        WRITE (7,1010)
        IF(NW.EQ.0) GO TO 55
        DO 50 I = 1,NW
        WRITE (6,714) I,AWALL(I),AFEN(I),SLOPE(I),SUAZAN(I),NSW(I),
        1  SUN(I), ADJCN(I)
        JAK=NSW(I)
        IF(JAK.EQ.0) GO TO 54
        DO 51 J = 1,JAK
        AUSW(I,J)=ASWNET(I,J)/RSW(I,J)
        WRITE (6,715)I,J,ASW(I,J),ASWNET(I,J),RSW(I,J),AUSW(I,J),
     1  NSS(I,J)
        AU(I)=AU(I) + AUSW(I,J)
        KAR=NSS(I,J)
```

```
      IF (KAR.EQ.0) GO TO 53
      WRITE(6,1012) I,J
      WRITE(6,716)
      DO 52 K = 1,KAR
      IF(RSS(I,J,K).EQ.100.0)AUSST(I,J,K)=0.0
      IF(RSS(I,J,K).EQ.100.0)GO TO 98
      AUSST(I,J,K)=ASS(I,J,K)/RSS(I,J,K)
98    CONTINUE
      IF(RSS(I,J,K) .NE. 100.0)       WRITE (6,717)I,J,K,
     1  ASS(I,J,K),RSS(I,J,K),AUSST(I,J,K)
      IF(RSS(I,J,K) .EQ. 100.0) WRITE (6,719) I,J,K,ASS(I,J,K)
      AU(I)=AU(I) + AUSST(I,J,K)
52    CONTINUE
53    CONTINUE
51    CONTINUE
54    CONTINUE
      U(I)=AU(I)/(AWALL(I)-AFEN(I))
      WRITE(6,718)I,AU(I),U(I)
50    CONTINUE
55    CONTINUE
679   FORMAT(A4)
681   FORMAT($,1H0,'IS THE DATA CORRECT?')
682   FORMAT(' THE NUMBER OF RESISTANCE CODES:',/,
     1 ' NOTE: IF A SUBSTRUCTURE HAVING THE SAME CHARACTERISTICS'/,
     2 ' HAS BEEN EVALUATED AND YOU CAN RECALL THE NUMBER OF'/,
     3 $,' THE SUBSTRUCTURE ENTER A ZERO.')
683   FORMAT($,' HEIGHT - FEET:')
685   FORMAT(1H0,'SUBWALL WIDTH = ',F10.1,' FEET',/,' SUBWALL',
     1 ' HEIGHT = ',F10.1,' FEET',/,' NUMBER OF SUBSTRUCTURE = ',
     2 I2)
686   FORMAT(6(2X,A10),/,6(2X,A10))
687   FORMAT(1H0,'THE NUMBER OF RESISTANCE CODES:',/,
     1 ' NOTE: IF YOU HAVE PREVIOUSLY DESCRIBED A SUBWALL OF',/,
     2 ' THE SAME CONSTRUCTION AND CAN RECALL THE SUBWALL',/,
     3 $,' NUMBER ENTER A ZERO.')
688   FORMAT($,1H0,'THE NUMBER OF SUBSTRUCTURES:')
689   FORMAT($,' HEIGHT - FEET: ')
699   FORMAT(1H0,$,'HOW MANY WALLS ARE TO BE EVALUATED? ' , I1)
698   FORMAT(I1)
690   FORMAT(1H0,'FOR WALL NUMBER ',I1,' ENTER THE SLOPE FROM',/,
     1 ' THE HORIZONTAL MEASURED FROM THE INSIDE SURFACE - ',
     2 $,' DECIMAL DEGREES ')
697   FORMAT(1H0,'FOR WALL NUMBER ',I1,' ENTER IN DECIMAL DEGREES',/,
     1 $,' THE SURFACE AZIMUTH ANGLE,SOUTH=0.0,EAST=POSITIVE ')
695   FORMAT($,1H0,'IS THE WALL AN EXTERIOR WALL?' )
696   FORMAT(F10.3)
694   FORMAT(A1)
703   FORMAT(1H0,'FOR SUBWALL NUMBER ',I1,',',I1,' ENTER:',/,
     1 $,' WIDTH - FEET:')
700   FORMAT(1H0,'ENTER THE NUMBER ',I1,' WALL CHARACTERISTICS AS',
     1 ' REQUESTED')
701   FORMAT(1H0,//////,' ENTER THE NUMBER OF  SUBWALLS.',/,
     1 ' EACH SUBWALL MUST BE RECTANGULAR IN SHAPE AND',/,
     2 ' BE OF A SINGLE CONSTRUCTION TYPE.',//,
     3 ' WHEN EVALUATING EXTERIOR WALLS CONFINING TEMPERATURE',/,
```

```
     4  ' CONTROLLED SPACES, DO NOT INCLUDE WALL AREAS WHICH ARE',/,
     5  ' PART OF THE ATTIC, GARAGE OR OTHER WALLS NOT CONFINING',/,
     5  ' TEMPERATURE',
     6  ' CONTROLLED SPACES.',//,  ' GLASS AND DOOR AREAS WILL BE',
     6  ' SUBTRACTED',
     7  ' FROM EACH SUBWALL AREA LATER',/, ' SO INCLUDE THESE AREAS',
     8  ' IN THE SUBWALL AREAS.',//,' EACH SUBWALL WILL BE',
     9  ' EVALUATED IN SEQUENCE.',//,
     1  ' NOTE: THAT A WALL IS EVALUATED BY SUBWALLS',/, ' AND A',
     1  ' MINIMUM OF ONE SUBWALL IS REQUIRED.',/,
     1  $,' NUMBER OF SUBWALLS? ')
702     FORMAT(I1)
704     FORMAT(2F10.3,2I2)
705     FORMAT(1H0,'ENTER THE CONSTRUCTION RESISTANCE CODES',
     1  ' BEGINNING',/,
     1  ' WITH INSIDE AIR FILM AND ENDING WITH OUTSIDE AIR FILM. ')
706     FORMAT(A4)
707     FORMAT(1H0,'ENTER FOR THE SUBWALL HAVING THE SAME',/,
     1  ' CONSTRUCTION CHARACTERISTICS AS THE SUBWALL PRESENTLY',/,
     2  ' BEING EVALUATED',
     2  $ ,' THE WALL NUMBER AND THE SUBWALL NUMBER ',2I1)
708     FORMAT(2I1)
709     FORMAT(1H0,'FOR SUBSTRUCTURE NUMBER ' ,I1,',',I1,',',I1,
     1  ' ENTER THE',
     1  ' FOLLOWING:',/,$,' WIDTH - FEET: ')
710     FORMAT(1H0,'ENTER THE WALL NUMBER, THE SUBWALL NUMBER AND',/,
     1  ' THE SUBSTRUCTURE NUMBER OF THE SUBSTRUCTURE HAVING THE',/,
     2  ' SAME CONSTRUCTION FOR WHICH THE RESISTANCE CODES HAVE',/,
        3$,' BEEN DEFINED: ')
711     FORMAT(3I1)
712     FORMAT($,1H0,'IS THE SUBSTRUCTURE ',I1,',',I1,',',I1,
     1  ' A FENESTRATION AREA? ')
713     FORMAT(I1)
714     FORMAT(' WALL NUMBER ',I1,' SUMMARY',//,
     1  ' AREA OF WALL = ',F9.1,' SQ.FT.',4X,
     2  ' AREA OF FENESTRATION = ',F9.1,' SQ.FT.',/,
     3  ' SLOPE OF WALL = ',3X,F5.1,' DEGREES',3X,' SURFACE AZIMUTH ',
     4  F5.1,' DEGREES',/,' NUMBER OF SUBWALLS = ',I2,
        1   13X, 'EXTERIOR/ADJACENT WALL CODE    EXTERIOR WALL = ',
        6   F2.0,  1X,' ADJACENT WALL = ',F2.0)
715     FORMAT(1H0,'SUBWALL NUMBER ',I1,',',I1,' SUMMARY',//,
     1  ' GROSS AREA = ',F9.1,' SQ.FT.',13X,
     2  ' NET AREA = ',F9.1,' SQ.FT.',/,
     3  ' RESISTANCE = ',3XF7.2,' HR.-SQ.FT.-F/BTU',2X,
     4  ' A*U PRODUCT = ',F7.2,' BTU/HR-F',/,
     5  ' NUMBER OF SUBSTRUCTURES = ',I3)
716     FORMAT(/,6X,'SUBSTRUCTURE',10X,'AREA',9X,'RESISTANCE',
     1  11X,'A*U',/,9X,'NUMBER',12X,'SQ.FT.',5X,
     2  'HR.-SQ.FT.-F/BTU',7X,'PRODUCT',/)
717     FORMAT(10X,I1,',',I1,',',I1, 8X,F9.1,9X,F7.2,9X,F9.0)
718     FORMAT(1H0,'WALL NUMBER ',I1,/,' SUMMATIONS OF A*U',
     1  ' PRODUCTS = ',F8.2,2X,'BTU/HR-F',/,' COMBINED THERMAL',
     2  ' TRANSMITTANCE = ',F6.4,' BTU/HR.-SQ.FT.-F',////)
719     FORMAT(10X,I1,',',I1,',',I1,8X, F9.1,
        1,5X,' GLAZED AREA SEE GLASS SUMMARY TABLE')
```

```
650     FORMAT($,' RESISTANCE CODE NUMBER ',A4,' NOT FOUND',
     1  ' ENTER AGAIN ')
1000    FORMAT(1H0,'IS THIS WALL A COMMON WALL BETWEEN',/,
     1  $,' THE HEATED SPACE AND AN UNHEATED SPACE? ')
1001    FORMAT(' RESISTANCE = ',F5.2,' HR, SQFT, F/BTU')
1002    FORMAT(' SUBSTRUCTURE WIDTH ',F5.2,'FEET',/,
     1  ' SUBSTRUCTURE HEIGHT ',F5.2,'FEET')
1010    FORMAT(5X,' SUMMARY TABLE')
1012    FORMAT(1H0,15X,'SUBSTRUCTURE SUMMARY TABLE SUBWALL ',I1,
     1  ',',I1)
1013    FORMAT(/,I2,' SUBWALLS WERE ENTERED A MINIMUM OF',/,
     1  ' ONE IS REQUIRED.',/,
     2  $,' ENTER THE NUMBER OF SUBWALLS: ')
1014    FORMAT(1H0,'SURFACE AZIMUTH ANGLE = ',F5.1,' DEGREES',/,
     1  ' SURFACE SLOPE = ',F5.1,' DEGREES',/,
     2  $,' ARE THE AZIMUTH AND SLOPE CORRECT? ')
        RETURN
        END
```

```
      SUBROUTINE MSC(CFMINF,VOLUME,SQFT,PERIM,CPMASS,BULARE)
      BYTE YES,NO,RESP
      DATA YES/'Y'/,NO/'N'/
1     CONTINUE
      WRITE (7,700)
      READ (5,701) VOLUME
      WRITE (7,705)
      READ (5,701) SQFT
      WRITE (7,707)
      READ (5,701)PERIM
      WRITE (7,708)
      READ (5,701) CFMINF
      WRITF(7,720)
      READ(5,701) CPMASS
      WRITE(7,725)
      READ(5,701) BULARE
      WRITE(7,710)VOLUME,PERIM,SQFT,CFMINF,CPMASS,BULARE
      WRITE(7,711)
      READ(5,703)RESP
      IF (RESP.NE.YES) GO TO 1
      WRITE(6,710)VOLUME,PERIM,SQFT,CFMINF,CPMASS,BULARE
700   FORMAT(/,$,' WHAT IS THE VOLUME OF THE FACILITY-CU.FT.? ')
701   FORMAT (F10.3)
703   FORMAT(A1)
705   FORMAT(/,$,' WHAT IS THE FLOOR SPACE OF THE FACILITY-',
     1 'SQ.FT.? ')
707   FORMAT(/,$,' WHAT IS THE PERIMETER OF THE FACILITY-FT.? ')
708   FORMAT(/,$,' WHAT IS THE AVERAGE INFILTRATION RATE-CFM? ')
710   FORMAT(1H0,4X,' VOLUME        = ',F10.0,' CU.FT. ',/,5X,
      1' PERIMETER     = ',F10.0,' FT.',/,5X,
      2' FLOOR SPACE   = ',F10.0,' SQ.FT.',/,5X,
      3' INFILTRATION  = ',F10.0,' CFM',/,5X,
      4' CP*MASS       = ',F10.0,' BTU/F',/,5X,
      5' MASS AREA     = ',F10.0,' SQ.FT.')
711   FORMAT(1H0,$,' IS THE DATA CORRECT? ')
720   FORMAT(1H0,$,'WHAT IS THE CP AND MASS PRODUCT ? ')
725   FORMAT(1H0,$'WHAT IS THE MASS  AREA FOR THERMAL RESPONSE ? ')
      RETURN
      END
```

```
      SUBROUTINE DAYPRN(IDATE, IDAY, PRINT, IPETE,
      1     INTERV, INTER, PPROD, AVTEMP, TEMPA)
C
C
      COMMON/WECS/ DUMMY(7), BTU(7), BUMMY(14)
      COMMON/DAYSUM/ DAILYF, DAILYC, DAILYQ, DAILYP, DAILYW
C
C
      WRITE(6,300) IDATE, IDAY
      WRITE(6,400)IDAY,DAILYF,DAILYC,DAILYQ,AVTEMP,DAILYW
      1  ,TEMPA,PPROD
      WRITE(6,100)
      WRITE(6,200) IDAY,BTU(1),DAILYF,(DAILYF-BTU(2)),
      1     (BTU(I),I=2,7)
82    CONTINUE
      IPETE=5
100   FORMAT(1H0,//,48X, 'DAILY ENERGY SUMMARY',//,6X,
      1     'DAY',5X,'WECS ENERGY',4X,'SP HT DEM',4X,'WECS DELIV',8X,
      2     'BACKUP',5X,'STOR LOSS',5X,'STOR GAIN',5X,'PREH GAIN',
      3     10X,'APPL',8X,'EXCESS')
200   FORMAT(1H0,4X,I3,3X,9(F11.0,3X))
400   FORMAT(1H0,I3,5X,F12.0,4X,F12.0,4X,F10.0,3X,F9.1,6X,
      1  F9.1,5X,F9.2,12X,  F7.1)
300   FORMAT(1H0,//,3X,'DAILY SUMMARY FOR DAY ',I3,
      1  ' OF THE YEAR AND DAY ', I3, ' OF THE EVALUATION',//,
      2  1X,  '   DAY   ',
      3  6X,'FURNACE',8X,'CHILLER',8X,'AIR EXCH',4X,'AVE OUTDOOR',
      4  2X,'HOT WATER',7X,'AVE INDOOR',8X,'PERCENT MAX',/,14X,
      5  'LOAD-BTU',7X,'LOAD-BTU',9X,'CF',11X,'TEMP F',4X,
      6  'LOAD-BTU',11X,'TEMP F',10X,'PRODUCTION')
      RETURN
      END
```

```
      SUBROUTINE CYCPRN
C
C     THIS SUBROUTINE PRINTS CYCLE RESULTS
C
C
      COMMON/WECS/DUMMY(14), BTU(7), BUMMY(7)
      COMMON/CYCSUM/ CCY(5), SCOMM, SUMPRO, SUCYFD(12),TOTR
      COMMON/KEEP5/QANIM,WANIM,PROC,IDAY
C
C
      SUMPL = CCY(1) + CCY(2)
      WRITE(6,100)
      WRITE(6,200) IDAY,(CCY(L),L=1,5),SCOMM,SUMPRO,TOTR
      WRITE(6,300)
      WRITE(6,400) BTU(1), CCY(1), (CCY(1) - BTU(2)), (BTU(I),I=2,7)
      WRITE(6,500)
      WRITE(6,600) (SUCYFD(L),L=1,12)
C
C
100   FORMAT(1H0,/////,51X,'CYCLE TOTALS',//,2X,
     1  'NUMBER OF',5X,'FURNACE',8X,
     2  'CHILLER',8X,'AIR EXCHANGE',4X,'AVG TEMP',5X,'HOT WATER',5X,
     2  'COMMODITY', 8X,'PERCENT MAX',4X,'CYC PASSIVE',/,
     3  4X,'DAYS',8X,'LOAD-BTU',7X,
     1  'LOAD-BTU',12X,'CF',12X,'F',9X,
     2  'LOAD-BTU',8X,'TOTALS',6X,'
     4   PRODUCTION')
200   FORMAT(1H0,4X,I3,4X,F12.0,3X,F12.0,5X,E12.6,
     1  3X,F9.1,7X,F9.1,4X,E12.6,8X,F7.1,4X,F10.0)
300   FORMAT(1H0,///,47X, 'ENERGY CYCLE RESULTS',//,4X,
     1      'WECS ENERGY',4X, 'SP HT DEM',4X, 'WECS DELIV',
     2      8X, 'BACKUP',5X,'STOR LOSS', 5X, 'STOR GAIN',5X,
     3      'PREH GAIN',10X, 'APPL',8X, 'EXCESS')
400   FORMAT(1H0,4X,9(E12.5,2X))
500   FORMAT(1H0,/////,38X,
     1  ,'TOTAL FEED CONSUMED DURING THE CYCLE',//)
600   FORMAT(12(2X,F8.0))
      RETURN
      END
      SUBROUTINE SUMPRN(IDAY)
C
C
C     THIS SUBROUTINE PRINTS SUMS
C
      COMMON/WECS/ DUMMY(21), BTU(7)
      COMMON/SUMPER/ SUMFUR, SUMCOL, SUMCFM, SUMWTR, SUMP,
     1   SUMFED(12),SUMPAS
C
      SUMPL = SUMFUR + SUMCOL
C     WRITE SUMS
C
      WRITE(6,10) IDAY
      WRITE(6,20)
      WRITE(6,30) SUMFUR, SUMCOL, SUMCFM, SUMP, SUMWTR,SUMPAS
      WRITE(6,100)
```

```
      WRITE(6,200) BTU(1), SUMFUR, (SUMFUR - BTU(2)), (BTU(I),I=2,7)
      WRITE(6,40)
      WRITE(6,45)
      WRITE(6,50) (SUMFED(I), I = 1,11)
C
C
10    FORMAT(1H1,//,35X,'   EVALUATION PERIOD TOTALS FOR ',I3,
      1     ' DAYS',//)
20    FORMAT(1H0,22X,'FURNACE',6X,'CHILLER',6X,'AIR EXCH',7X,
      1  'AVE TEMP',10X,'HOT WATER',10X,'PASSIVE',/,
      2  25X,'BTU',10X,'BTU',8X,'RATE-CFM',9X,'IN-F',14X,'BTU',
      1  14X,'BTU')
30    FORMAT(1H0,19X,3(E12.6,1X),7X,F4.1,11X,F10.0,10X,F12.0)
40    FORMAT(1H0,/////,34X,
      1  'TOTAL FEED CONSUMED DURING EVALUATION PERIOD',//)
45    FORMAT(1H0,3X,'OATS',6X,'CORN',3X,'LAMB SUPPL',
      1     3X,'HAY',5X,'GRND CORN',1X,'SWINE CONC',1X,'LAYER FEED',
      2     1X,'BRDR FEED',1X,'TRKY FEED',1X,'BRLR FEED',1X,
      3     'DAIRY FEED',//)
50    FORMAT(12(2X,F8.0))
100   FORMAT(1H0,///,47X, 'ENERGY CYCLE RESULTS',//,4X,
      1     'WECS ENERGY',4X, 'SP HT DEM',4X, 'WECS DELIV',
      2     8X, 'BACKUP',5X,'STOR LOSS', 5X, 'STOR GAIN',5X,
      3     'PREH GAIN',10X, 'APPL',8X, 'EXCESS')
200   FORMAT(1H0,4X,9(E12.5,2X))
      RETURN
      END
```

```
      SUBROUTINE FLOOR (ICON,FLAREA,AUFLR,IFLOOR,TEMPC)
      DIMENSION FLAREA(9), RFLR(9), ICON(9), RCODE(9),
     1  PROP(5),AUFLR(9),DESC(10)
      COMMON/KEEP10/ TEMPG
      COMMON/SCRTCH/ RCODE,RFLR,PROP,DESC
      REAL LENGTH, L
      BYTE GRD,CRW,UNH,YES,NO,RESP
      DATA GRD,CRW,UNH,YES,NO/'G','C','U','Y','N'/
      DO 83 I = 1,9
      RFLR(I)=0.0
83    CONTINUE
C     EVALUATE HEAT EXCHANGE THROUGH FLOORS
      WRITE (7,700)
      READ (5,705) IFLOOR
      IF(IFLOOR.EQ.0)GO TO 10
      DO 5 I = 1,IFLOOR
50    CONTINUE
      WRITE (7,701) I
      READ (5,702) WIDTH
      WRITE(7,703)
      READ(5,702)LENGTH
      WRITE (7,800)
      READ (5,702) DEPTH
      WRITE(7,706)
      READ(5,707)RESP
      IF(RESP.EQ.GRD)ICON(I)=1
      IF(RESP.EQ.CRW)ICON(I)=2
      IF(RESP.EQ.UNH)ICON(I)=3
      WRITE(7,704)
      READ(5,705)ICODES
      IF (ICODES .EQ. 0) GO TO 20
      WRITE (7,708)I
      READ (5,709) (RCODE(J), J=1, ICODES)
      WRITE(7,710)I,IFLOOR,WIDTH,LENGTH,(RCODE(J), J=1,ICODES)
      WRITE(7,720)
      READ (5,707)RESP
      IF(RESP.NE.YES) GO TO 50
      WRITE(7,2000) IFLOOR
      FLAREA(I)=WIDTH*LENGTH
      WRITE(7,2000) IFLOOR
      DO 7  K=1, ICODES
55    CONTINUE
      RAT=RCODE(K)
      CALL FNDREC (RAT, DESC, PROP,IDOT)
      IF(IDOT.EQ.0)GO TO 56
      IF(IDOT.NE.-1) GO TO 56
      WRITE(7,711)RCODE(K)
      READ(5,709)RCODE(K)
      GO TO 55
56    CONTINUE
      RFLR(I) = RFLR(I) + PROP(5)
7     CONTINUE
      IF(ICON(I).NE.1) GO TO 21
      L=LENGTH
      W=WIDTH
```

```
      IF(WIDTH.LE.LENGTH) GO TO 30
      W=LENGTH
      L=WIDTH
30    HTLOSS=((0.0440562-0.0006913*W) + (0.059333-.0055*DEPTH))/2.
      RFLR(I) = 1./HTLOSS + RFLR(I)
      GO TO 21
20    CONTINUE
      WRITE (7,718)
      READ (5,705) K
      RFLR(I) = RFLR(K)
      WRITE(7,712)I,IFLOOR,WIDTH,LENGTH,K
      READ(5,707)RESP
      IF(RESP.NE.YES)GO TO 50
      FLAREA(I)=WIDTH*LENGTH
21    CONTINUE
5     CONTINUE
      DO 60 I = 1,IFLOOR
      AUFLR(I)=FLAREA(I)/RFLR(I)
      WRITE(6,715)I,FLAREA(I),RFLR(I),AUFLR(I)
60    CONTINUE
10    CONTINUE
700   FORMAT(/,$,'HOW MANY FLOOR AREAS ARE TO BE EVALUATED?')
701   FORMAT(1H0,'FOR FLOOR AREA NUMBER ',I1,' ENTER THE FOLLOWING',
     1 /,$,' WIDTH-FEET = ')
702   FORMAT(F10.3)
703   FORMAT($,' LENGTH-FEET = ')
704   FORMAT(1H0,'ENTER THE NUMBER OF RESISTANCE CODES',/,
     1 ' IF CONSTRUCTION OF THE FLOOR AREA',/,' IS THE SAME AS FOR',/,
     2 ' A PREVIOUSLY DEFINED AREA'/' AND YOU CAN RECALL THE FLOOR',/,
     3 ' AREA NUMBER, ENTER A ZERO.',/,
     4 $,' NUMBER OF RESISTANCE CODES = ')
705   FORMAT(I1)
706   FORMAT(/,'IS THE FLOOR IN CONTACT WITH THE GROUND',/,
     1 $, ' OVER A CRAWL SPACE OR ADJACENT TO AN UNHEATED SPACE ? ')
2000  FORMAT(1H0,'IFLOOR = ',I3)
707   FORMAT(A1)
708   FORMAT(1H0,'ENTER THE RESISTANCE CODES DESCRIBING SUBFLOOR',/,
     1 ' NUMBER ',I1)
709   FORMAT(A4)
710   FORMAT(/,' FLOOR AREA ',I1,' OF ',I1,/,
     1 ' FLOOR WIDTH = ',F9.1,' FEET',/,
     2 ' FLOOR LENGTH = ',F9.1,' FEET',/,
     3 ' RESISTANCE CODES AS FOLLOWS:',/,9(2X,A4),//).
711   FORMAT(1H0,'RESISTANCE CODE ',A4,' NOT FOUND,',/,
     1 $,' ENTER AGAIN: ')
712   FORMAT(/,'FLOOR AREA ',I1,' OF ',I1,/,
     1 ' FLOOR WIDTH = ',F9.1,' FEET',/,
     2 ' FLOOR LENGTH = ',F9.1,' FEET',/,
     3 ' SAME CONSTRUCTION AS FLOOR AREA: ',I1,/,/,
     4 $,' IS THE DATA CORRECT? ')
715   FORMAT(1H0,'FLOOR AREA NUMBER ',I1,' SUMMARY',/,
     1 ' AREA OF FLOOR AREA = ',F9.1,' SQ.FT.',/,
     2 ' FLOOR AREA RESISTANCE = ',F6.1,' HR-SQ.FT.-F/BTU',/,
     3 ' A*U PRODUCT = ',7X,F9.1,' BTU/HR-F')
718   FORMAT($,1H0,'WHAT IS THE NUMBER OF THE LIKE FLOOR AREA? ')
```

```
720     FORMAT(1HO,$,'IS THE DATA CORRECT? ')
  )     FORMAT($,' DEPTH-FEET = ')
        RETURN
        END
```

```
      SUBROUTINE BELGRD(AU)
      DIMENSION RBG(9),RCODE(9),DESC(10),PROF(5),AREA(9)
      COMMON/KEEP2/TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,CLOUD,
     1WIND,WINDIR,RHO
      COMMON/KEEP10/ TEMPG
      COMMON/SCRTCH/DESC,PROF
      REAL LAT,LONG,L

      BYTE YES,NO,RESP
      DATA YES,NO/'Y','N'/
C
C     CALCULATE BELOW GRADE AREAS
C
      JJ=0
      AU=0.0
      HTLOSS=0.0
      DO 60 I = 1,25
60    RBG(I) = 0.0
      WRITE(7,700)
      READ(5,701)IWALLS
      IF(IWALLS.EQ.0) GO TO 42
      DO 20 I = 1,IWALLS
200   WRITE (7,702) I
      READ (5,703)WIDTH
      WRITE(7,720)
      READ(5,703)HEIGHT
      WRITE(7,725)
      READ(5,701)ICODES
      AREA(I) = WIDTH*HEIGHT
      IF(ICODES.EQ.0)GO TO 30
      WRITE (7,704)IWALLS
      READ (5,750)(RCODE(J),J=1,ICODES)
      WRITE(7,730)I,WIDTH,HEIGHT,ICODES,(RCODE(J),J=1,ICODES)
      WRITE (7,731)
      READ(5,769)RESP
      IF(RESP.NE.YES)GO TO 200
      DO 25 J = 1,ICODES
220   CONTINUE
      RAT = RCODE(J)
      CALL FNDREC (RAT, DESC, PROF, IDOT)
      IF (IDOT.EQ.0.0) GO TO 210
      WRITE (7,735)RCODE(J)
      READ (5,740)RCODE (J)
      GO TO 220
210   CONTINUE
      RBG(I) = RBG(I) + PROF(5)
25    CONTINUE
      W=WIDTH
      L=HEIGHT
      IF(W.LE.L) GO TO 51
      W=HEIGHT
      L=WIDTH
51    CONTINUE
      DO 50 KK=1,15
      JJ=JJ+1
```

```
      PLA=FLOAT(KK)
      IF(FLOAT(JJ).GT.W) GO TO 52
      HTLOSS=HTLOSS+ 0.41689*PLA**(-0.917345)
50    CONTINUE
C
52    JJ=JJ-1
C
      HTLOSS=HTLOSS/FLOAT(JJ)
      RBG(I)=RBG(I)+1./HTLOSS
      GO TO 35
30    WRITE (7,705)
      READ (5,706)I4
      RBG(I) = RBG(I4)
      WRITE (7,765)I, WIDTH,HEIGHT,I4
      WRITE (7,731)
      READ (5,769)RESP
      IF(RESP.NE.YES) GO TO 200
35    CONTINUE
20    CONTINUE
      DELT = (TEMPG-TEMPI)
      DO 40 K = 1,IWALLS
      AU1 = AREA(K)/RBG(K)
      AU = AU + AU1
      WRITE (6,767) K, AREA(K), RBG(K), AU1
41    CONTINUE
40    CONTINUE
42    CONTINUE
700   FORMAT(1H0,'ENTER THE NUMBER OF BELOW GRADE WALLS',/,
     1 ' TO BE EVALUATED.  A WALL IS ANY AREA THAT IS',/,
     2 ' OF A UNIFORM CONSTRUCTION TYPE AND CAN BE EXPRESSED',/,
     3 ' AS LENGTH AND HEIGHT. IF ALL OF THE EXTERIOR WALLS',/,
     4 ' OF A BELOW GRADE BASEMENT ARE OF THE SAME CONSTRUCTION,'/,
     5 ' THE BASEMENT WALLS CAN BE REPRESENTED BY A SINGLE',/,
     6 ' WALL.',/,$,' NUMBER OF WALLS = ')
701   FORMAT(I1)
702   FORMAT(1H0,'FOR WALL NUMBER ',I1,' ENTER THE WALL',
     1 ' DIMENSIONS',/,$,' WIDTH - FEET = ')
703   FORMAT(F10.3)
704   FORMAT(1H0,'FOR WALL NUMBER ',I2,' ENTER THE RESISTANCE',/,
     1 ' CODES BEGINNING WITH THE INSIDE SURFACE.')
750   FORMAT(A4)
705   FORMAT(1H0,'ENTER THE NUMBER OF THE WALL HAVING THE SAME',/,
     1 $,' CONSTRUCTION: ')
706   FORMAT(I2)
720   FORMAT($,' HEIGHT - FEET = ')
725   FORMAT(' ENTER THE NUMBER OF RESISTANCE CODES ',/,
     1 ' ENTER A ZERO IF THE CONSTRUCTION CHARACTERISTICS ARE',/,
     2 ' THE SAME AS FOR A PREVIOUSLY DESCRIBED WALL.',/,$,
     3 ' NUMBER OF CODES = ')
730   FORMAT(1H0, ' BELOW GRADE WALL ',I1,/,' WIDTH = ',F6.1,' FEET',/,
     1 ' HEIGHT = ',F6.1,' FEET',/,
     2 ' RESISTANCE CODES AS FOLLOWS: ',I1,/,
     3 5(4X,A4),/,4(4X,A4))
731   FORMAT($,1H0,3X,'IS THE DATA CORRECT? ')
735   FORMAT(1H0,'RESISTANCE CODE ',A4,' NOT FOUND',/,
```

```
     1 $,' ENTER AGAIN: ')
740    FORMAT(A4)
765    FORMAT(1H0,'BELOW GRADE WALL ',I1,/,' WIDTH = ',F6.1,' FEET'
     1 ,/,' HEIGHT = ',F6.1,' FEET',/,
     2   ' WALL NUMBER HAVING LIKE CONSTRUCTION: ',I1)
767    FORMAT(1H0,'BELOW GRADE WALL AREA ',I1,' SUMMARY',/,
     1 ' WALL AREA = ',6X,F9.1,' SQ.FT.',/,
     2 ' THERMAL RESISTANCE = ',F4.2,' HR-SQ.FT.-F/BTU',/,
     3 ' A*U PRODUCT = ',3X,F10.1,' BTU-HR/F')
769    FORMAT(A1)
       RETURN
       END
```

```
      SUBROUTINE PASSIV (TEMPI, IBOAT, AIRDNI, TEMPO, QROOM,
      1                    TMIN, TMAX)
      REAL NU, KON, KONA
      COMMON/KEEP2/DM(4), IM(3), CLOUD
      COMMON/PASS/AREA,SUAZAN, S, HEIGHT,TINWAL,SPTEM,WIDTH,
      1  TWALL, ALPHA, BETA1, T(5), DLEN, DTAU, C,  DTIME, ITIME
C     COMMON/PROP/ REFL,ABSOR,KON,THICK,TRANS,SPACE,PNU,CPA,WDEN,R,
C     1   TAU,CPW, KONA, TG, PKE, GDEN, CPG, TOVER, OVERH,OVERL
      COMMON/PROP/ PNU, TG, PKE, TOVER, OVERH, OVERL
      BYTE YES,NO,RESP
C
C
C     ABSOR = WALL ABSORPTIVITY, REFL = WALL REFLECTIVITY,
C     KON = WALL K VALUE, THICK = WALL THICKNESS
C     TRANS = GLASS TRANSMISSIVITY, SPACE = DISTANCE BETWEEN GLASS
C     AND WALL, CPA = SPECIFIC HEAT OF AIR, R = GLASS WALL RESISTANCE
C     TAU = TIME PERIOD OF INDIV ANALYSIS (USE 1 HOUR),
C     WDEN = WALL DENSITY, CPW = SPECIFIC HEAT OF WALL,
C     PNU = DYNAMIC VISCOSITY.
C
C
C     OVERL = OVERHANG LENGTH, OVERH= OVERHANG HEIGHT ABOVE PASSIVE WALL
      DATA TOVER, OVERH, OVERL/7.0,0.0,0.0/
      DATA REFL,ABSOR,KON,THICK,TRANS,SPACE,CPA,WDEN,
      1   R,TAU,CPW/0.02, 0.98, 0.7, 1.0, 0.88, 3.0, 0.25, 140., 1.613,
      2      1.0, 0.20/
      DATA  KONA, GDEN, CPG/ 0.0148,160., 0.18/
      DATA YES/'Y'/,NO/'N'/
      IF(IBOAT .NE. 0) GO TO 70
      DO 1 II = 1, 5
      T(II) = 80.
1     CONTINUE
      IBOAT = 15
      DLEN = THICK/4.
      DTIME = 10.
      DTAU = 1./ DTIME
      BETA1 = (DTAU * KON)/(WDEN * CPW * (DLEN**2))
      ITIME = 10
      SPTEM = TEMPO + 25.
      TG = SPTEM
      PNU = 1.25E-5 / AIRDNI
      IA = 1
      ALPHA = KON/(WDEN * CPW)
C     ENTER WALL CHARACTERISTICS
65    WRITE (7,25) IA
      READ (5,30) SUAZAN
      WRITE (7,35) IA
      READ (5,30) S
      WRITE (7,40)
      READ (5,30) HEIGHT
      WRITE (7,45)
      READ (5,30) WIDTH
      AREA = HEIGHT * WIDTH
      C = WDEN * CPW * AREA * DLEN
      WRITE (7,50) SUAZAN,S,HEIGHT,WIDTH,AREA
```

```
      WRITE (7,55)
      READ(5,60) RESP
      IF(RESP .NE. YES) GO TO 65
      WRITE (7,10)
      READ (5,60) RESP
70    CONTINUE
      CALL FENES (SUAZAN, S, TOTIN,BATA)
      TM1 = TMAX -3.
      IF( TEMPI .GE. TM1) OVERL = OVERL +1.
      TM2 = TMIN +3.
      IF( TEMPI .LE. TM2) OVERL = OVERL -1.
      IF( OVERL .GT. TOVER) OVERL = TOVER
      IF( OVERL .LT. 0.0) OVERL = 0.0
C     SHADING FACTOR
      PLEN = OVERL * TAN(BATA)
      PASCOV = PLEN - OVERH
      IF( PASCOV .LT. 0.0) PASCOV = 0.0
      SHADF = 1.0 - PASCOV/HEIGHT
      IF( SHADF .LT. 0.0 ) SHADF = 0.0
C     RADIATION LOADS
      QSUM = TOTIN * AREA * CLOUD * SHADF
      WRITE(7,919) CLOUD, SHADF, BATA
919   FORMAT(1H0, 'CLOUD = ',F12.4, ' SHADF = ',F12.5,
     1          ' BATA = ',F12.5)
      RADNET = QSUM - QSUM * ((1 - TRANS) + REFL * TRANS)
C     WALL TEMP ON OUTER SURFACE
C     AIR SPACE ENERGY BALANCE, WINDOW AND WALL LOSSES OR GAINS
      QROOM = 0.0
      DO 2 J = 1, ITIME
      DT = T(1) - SPTEM
      IF(DT .EQ. 0.0) DT = 0.1
      CONVC = 0.19*(ABS(DT)**0.333)
      VOL = AREA * SPACE * AIRDNI * CPA * (SPTEM - TEMPI)
D     WRITE(7,990) CONVC, TG, T(1), SPTEM, HIN, TEMPI,T(5)
D990  FORMAT(1H0,' CONVC, TG, T(1), SPTEM, HIN, TEMPI, T(5) ',
D    1     7F10.2)
C     WALL HEAT TRANSFER
C
C
C
C
C     FREE CONVECTION HEATING BY FLOW AROUND WALL
      DT1 = SPTEM - TEMPI
      SVEL = 0.0
      QVOL = 0.0
      DIS = 0.0
      BETA = 1. / (460. + SPTEM)
      GO TO 90
      IF (DT1 .LE. 0) GO TO 90
      DO 5 JJ = 1,6
      VEL = BETA * SPACE **2 * 8.05 * ABS( T(1) - TG) *
     1      DIS * ( 1. - DIS/SPACE) **2 / ( SPACE * PNU)
      DIS = DIS + 0.1
      SVEL = SVEL + VEL
      CONTINUE
```

```
      VELM = SVEL/6.0
      AIR FLOW TO LIVING SPACE
      DOTA = CPA * AIRDNI * SPACE * WIDTH * VELM * 3600.
      QVOL = DOTA * DT1 / DTIME
D     WRITE(7,991) QVOL,VOL,DOTA,SPTEM,PKE,VELM
D991  FORMAT(1H0,' QVOL, VOL, DOTA, SPTEM, PKE, VELM ', 6F7.2)
      IF(QVOL .LT. VOL) GO TO 90
      QVOL = VOL
      SPTEM = TEMPI
90    GR = 32.2 * BETA *ABS(TG - T(1)) * SPACE **3/PNU **2
      IF(GR .GE. 20000. .AND. GR .LE. 11. E6) GO TO 92
      PKE = KONA * 0.18 * GR ** 0.25 * (HEIGHT/SPACE) ** (-.111)
      GO TO 94
92    PKE = 0.065 * KONA * GR ** 0.333 * (HEIGHT/SPACE)** (-.111)
94    QTR = (PKE/SPACE) * AREA * (T(1) - TG)
      TG = TG + (QTR/(0.01042 * AREA * GDEN * CPG)
     1     + (TEMPO - TG)/ (R * GDEN * CPG * 0.01042))/DTIME
      SPTEM = (T(1) + TG)/2.0
C     TOTAL ENERGY TO LIVING AREA
      DT = T(5) - TEMPI
      IF(DT .EQ. 0.0) DT = 0.1
C     CONVECTIVE COEFFICIENT FOR PASSIVE WALL INNER SURFACE
      HIN = 0.19 * ABS(DT) **0.33
      QROOM = HIN * AREA * DT/DTIME  +QVOL + QROOM
      EPSILO = KON/ (CONVC * DLEN)
      EPSILI = KON/ (HIN * DLEN)
      T1 = 1. - 2. * BETA1 - 2. * BETA1/EPSILO
      T2 =  BETA1
      T2P = 2. * BETA1
      T3 = 2. * BETA1 * SPTEM/EPSILO + 2. * RADNET/( C * DTIME)
      T4 = 2. * BETA1 * TEMPI/EPSILI
      T5 = (1. - 2. * BETA1)
      T6 = 1. - 2. * BETA1 - 2. * BETA1/EPSILI
      T(1) = T2P * T(2) + T1 * T(1) + T3
      T(2) = T2 * T(1) + T5 * T(2) + T2 * T(3)
      T(3) = T2 * T(2) + T5 * T(3) + T2 * T(4)
      T(4) = T2 * T(3) + T5 * T(4) + T2 * T(5)
      T(5) =  T2P * T(4) + T6 * T(5) + T4
2     CONTINUE
      WRITE(7,1010) QROOM,RADNET,TG,SPTEM,T(1),T(3),T(5),PKE
1010  FORMAT(1H0, 'PASSIVE HEAT= ' , F7.0,
     1  ' NET RADIATION ',F7.0, 'TG = ',F6.1,' SPTEM = ',F6.1,
     2  ' T(1) = ',F6.1, ' T(3) = ',F6.1, ' T(5) = ',F6.1,
     3  ' PKE = ',F6.4)
10    FORMAT(1H0,' HAVE YOU INITIALIZED DATA STATEMENT')
15    FORMAT(I1)
25    FORMAT(1H0,' ENTER FOR WALL NUMBER ',I1, ' IN DECIMAL, DEGREES,
     1        '/,$,' THE SURFACE AZIMUTH '
     2        'ANGLE, SOUTH, = 0.0, EAST = POSITIVE')
30    FORMAT(F10.3)
35    FORMAT(1H0,' ENTER FOR WALL NUMBER ',I1, ' THE SURFACE SLOPE'
     1         ' FROM HORIZONTAL, 0.0 TO 90.0 DEGREES')
40    FORMAT(1H0,' WALL HEIGHT = ')
45    FORMAT(1H0,' WALL WIDTH = ')
50    FORMAT(1H0,' SURFACE AZIMUTH ANGLE = ',F10.2,/,
```

```
      1         ' SURFACE SLOPE = ', F10.2,/,' LENGTH = ',F10.2,/,
      1         'WIDTH =',F10.2,/, ' AREA = ',F10.2)
55    FORMAT(1H0, 'IS THE DATA CORRECT?')
60    FORMAT(A1)
      RETURN
      END
      FUNCTION TAN(X)
      Y = COS(X)
      TAN = 1.0E10
      IF(ABS(Y) .GT. 0.00001) TAN = SIN(X)/Y
      RETURN
      END
```

```
      SUBROUTINE INUNHT
      DIMENSION      AWALL(8)
      DIMENSION AU(8),   SUAZAN(8), SLOPE(8),  SUN(8)
      DIMENSION ADJACN(8),           ICON(3),   FLAREA(9)
      DIMENSION AUFLR(9),   ARU(3,17), SUAZ(3,8)
      DIMENSION SLP(3,8),SOL(3,8),  ADJ(3,8),  U(3,8)
      DIMENSION RADT(3,8),           JFN(3,8),  GCODE(3,8,5)
      DIMENSION GAREA(3,8,5),        FFACT(3,8,5)
      DIMENSION GAU(3,8,5),          ISURF(8),  ICN(3,9)
      DIMENSION TEMPU(3),VENT(3)
      DIMENSION TEMSUR(3,17),BEL(6), NUM(3),   QUNHT(5)
      REAL LAT,LONG
      BYTE YES,NO,RESP
C
      COMMON/KEEP10/TEMPG
C
      COMMON/KEEP15/  ARU, SUAZ, SLP, SOL, ADJ, U, JFN, GCODE, GAREA,
      1 ISURF, ICN, VENT, TEMSUR,NUM,ISPACS, GAU, BGAU
C
      COMMON/KEEP2/ TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,
      1  CLOUD,WIND,WINDIR,RHO
C
C
      COMMON/KEEP30/ TMAX(5), TMIN(5)
C
C
      DATA YES,NO/'Y','N'/
      WRITE (7,701)
      READ (5,600) ISPACS
5     CONTINUE
      IF(ISPACS.LE.0) GO TO 26
      DO 25 I = 1,ISPACS
      WRITE (7,702) I
      WRITE (7,703) I
      READ (5,802) VENT(I)
      WRITE(7,820)  I
      READ(5,809) RESP
C
      IF(RESP .NE. YES ) GO TO 2000
C
C     TEMPERATURE CONTROLED SPACES LIMITS TMIN, TMAX
      WRITE( 7,825)
      READ(5,815) TMAX(I)
C
      WRITE(7,830)
      READ(5,815) TMIN(I)
2000  CONTINUE
      WRITE(7,900)
      READ(5,809) RESP
      IF(RESP.NE.YES) GO TO 60
      CALL BELGRD (BGAU)
60    CALL EXTWAL(AWALL,NW,AU,SUAZAN,SLOPE,SUN,ADJACN)
      NUM(I) = NW
      DO 300 J = 1,NW
      ARU(I,J) = AU(J)
```

```
      SUAZ(I,J) = SUAZAN(J)
      SLP(I,J) = SLOPE(J)
      SOL(I,J) = SUN(J)
      ADJ(I,J) = ADJACN(J)
      U(I,J) = AU(J)/AWALL(J)
D     WRITE(6,8045) I, J, SOL(I,J), ADJ(I,J)
D8045 FORMAT(1H0,'I', 3X, I1, 3X, 'J', 3X, I1, 5X,
D     1 'SOL = ', F2.0, 5X,'ADJ = ',F2.0)
300   CONTINUE
6     CONTINUE
      NW=NUM(I)
      DO 30 J = 1,NW
      WRITE (7,799) J,I
      READ (5,794) JFN(I,J)
303   CONTINUE
      NGLAZE = JFN(I,J)
      IF( NGLAZE.EQ. 0) GO TO 308
      DO 301 K = 1, NGLAZE
306   WRITE (7,800) I,J,K
      READ (5,802) GW
      WRITE (7,803)
      READ (5,802) GH
      WRITE (7,804)
      READ (5,805) GCODE (I,J,K)
      GAREA(I,J,K) = GW * GH
      WRITE (7,806) K,J,I,GW,GH,GCODE(I,J,K)
      READ (5,809) RESP
      IF (RESP.NE.YES) GO TO 306
      WRITE (6,806) K,J,I,GW,GH,GCODE(I,J,K)
301   CONTINUE
308   CONTINUE
30    CONTINUE
      CALL FLOOR (ICON, FLAREA,AUFLR,IFLOOR,TEMPC)
      K1 = NUM(I) + 1
      K2 = NUM(I)  + IFLOOR
      ISURF(I) = K2
      IF( IFLOOR .EQ. 0) GO TO 9
      DO 8 J1 = K1, K2
      ARU(I,J1) = AUFLR(J1)
      ICN(I,J1) = ICON(J1)
      ADJ(I,J1) = 0.0
      IF (ICN(I,J1).EQ.3) ADJ(I,J1) = 1.0
      IF (ICON(I).EQ.1)TEMSUR(I,J1) = TEMPG
      IF (ICON(I).EQ.2)TEMSUR(I,J1) = TEMPC
      IF (ICON(I).EQ.3)TEMSUR(I,J1) = TEMPI
8     CONTINUE
9     CONTINUE
C
C
C
25    CONTINUE
26    CONTINUE
600   FORMAT(I1)
601   FORMAT(A1)
701   FORMAT(1H0,$,'HOW MANY ADJACENT AIR SPACES ARE',/,
```

```
     1   $,' BEING EVALUATED? ')
  2      FORMAT(1H0,' THE UNHEATED SPACE NUMBER ',I1,' IS NOW BEING',/,
     1   ' EVALUATED.  CONSIDER EACH SURFACE (OTHER THAN THE FLOORS',/,
     2   ' OVER A CRAWL SPACE OR ON GROUND) TO BE A WALL.  INCLUDE',/,
     3   $,' CEILINGS, WALLS, OPEN ROOFS, ETC.')
703      FORMAT(1H0,'WHAT IS THE ESTIMATED AVERAGE RATE OF',/,
     1   ' INFILTRATION AND/OR VENTILATION INTO THE NUMBER ',I1,/,
     2   $,' UNHEATED SPACE - CFM? ')
705      FORMAT(1H0,'EVALUATE THE FLOOR AREAS OF UNHEATED SPACE',/,
     1   $,' NUMBER ',I1)
706      FORMAT(1H0,'EVALUATE THE CEILING AREAS OF THE UNHEATED',/,
     1   ' SPACE NUMBER. ',I1,' IF THE UNHEATED SPACE HAS AN ATTIC',/,
     2   $,' EVALUATE THE ROOF AREAS AS THE CEILINGS.')
794      FORMAT(I1)
799      FORMAT(1H0,'HOW MANY FENESTRATION AREAS ARE THERE',/,
     1   $,' ON WALL ',I1,' OF UNHEATED STRUCTURE ',I1,' ? ')
800      FORMAT(1H0,'ENTER FOR GLAZED AREA ',I1,',',I1,',',I1,/,
     1   $,' WIDTH - FEET: ')
802      FORMAT(F10.1)
803      FORMAT($,' HEIGHT - FEET: ')
804      FORMAT($,' DESCRIPTION CODE: ')
806      FORMAT(1H0,'FOR GLAZED AREA ',I1,' OF WALL ',I1,' OF',/,
     1   ' SPACE ',I1,' GLASS WIDTH = ',F10.1,' FEET',/,
     2   ' GLASS HEIGHT = ',F10.1,' FEET',/,
     3   ' DESCRIPTION CODE = ',A4,/,/,
     4   $,' IS THE DATA CORRECT? ')
805      FORMAT(A4)
809      FORMAT(A1)
815      FORMAT(F10.3)
820      FORMAT(1H0,$,'IS ADJACENT SPACE NUMBER ', I1,/,
         1  $,   ' TEMPERATURE CONTROL ? ')
825      FORMAT(1H0,'WHAT ARE THE TEMPERATURE LIMITS ? ',
         1 $,' MINIMUM TEMPERATURE = ')
830      FORMAT(1H0,$,'MAXIMUM TEMPERATURE = ')
900      FORMAT(1H0,2X,'IS THE SPACE BELOW GROUND')
         RETURN
         END
```

```
      SUBROUTINE INCEIL(IBALL)
C
C
      DIMENSION QCEI(8),ACEIL(8),AUC(8),
     2 SUAZAN(8),SLOPE(8),SUN(8),ADJCN(8),RADT(8),GAU(8,5),
     3 JFN(8),AREA(8,5),FFACT(8,5),GCODE(8,5),TEMPS(8)
C
C
      BYTE YES,NO,RESP,IBATE
      REAL LAT,LONG
C
C
      COMMON/KEEP2/ TEMPO, TEMPI, LAT, LONG, IDATE, IHOUR,
      1KAT, CLOUD, WIND, WINDIR, RHO
C
C
      COMMON/KEEP6/ RZONE,NTS,ALST,ALSTT,ZONE
C
      COMMON/KEEP16/AUC,ACEIL,SUAZAN,SLOPE,SUN,ADJCN,
      1JFN,AREA,GCODE, NC
C
      COMMON/SCRTCH/ QCEI, RADT, FFACT, TEMPS, GAU
C
C
      DATA YES/'Y'/,NO/'N'/
      DATA TEMPS/8*0.01/
      DATA QFENE/0.0/
C
C
      WRITE (7,660)
      READ (5,901)RESP
      IF(RESP.EQ.NO)IBALL = 5
      IF(RESP.EQ.NO) GO TO 50
      WRITE (7,702)
      CALL EXTWAL(ACEIL, NC, AUC, SUAZAN, SLOPE, SUN, ADJCN)
C     FENESTRATION GAIN
      DO 16 I=1,NC
      WRITE(7,700)I
      READ(5,704)JFN(I)
      IF(JFN(I).EQ.0) GO TO 23
18    CONTINUE
      NGLAZE=JFN(I)
      DO 17 J = 1,NGLAZE
11    WRITE(7,701)I,J
      READ(5,802)GW
      WRITE(7,803)
      READ(5,802)GH
      WRITE(7,804)
      READ(5,805)GCODE(I,J)
      AREA(I,J) = GW * GH
      WRITE(7,806)GW,GH,GCODE(I,J)
      READ(5,809)RESP
      IF(RESP.NE.YES) GO TO 11
17    CONTINUE
23    CONTINUE
```

```
12      CONTINUE
        WRITE(6,810)
        DO 49 I=1,NC
        NGLAZE=JFN(I)
        DO 48J=1,NGLAZE
        WRITE(6,811)I,J,AREA(I,J),GCODE(I,J)
48      CONTINUE
49      CONTINUE
50      CONTINUE
901     FORMAT(A1)
702     FORMAT(1H0,'EVALUATE THE EXTERIOR CEILING THE SAME WAY THAT',
     1  /,' EXTERIOR VERTICAL WALLS WERE EVALUATED.')
660     FORMAT($,' ARE THERE EXTERIOR CEILING AREAS TO BE EVALUATED? ')
700     FORMAT(/,$,' ENTER NUMBER OF GLAZED AREAS ON',
     1  ' THE NUMBER ',I1,' CEILING ')
701     FORMAT(' FOR GLAZED AREA NUMBER ',I1,',',I1,' ENTER THE',
     1  /,$,' WIDTH-FEET:')
704     FORMAT(I1)
800     FORMAT(' FENESTRATION GAIN = ',F10.1,'BTU/HR    THERMAL',
     1  ' CONDUCTANCE = ',F10.5,'BTU/SQ.FT.-F',/,' FFACT = ',F5.3,
     2  3X,' RADIATION I = ',F4.1,' BTUH/SQ.FT.',5X,/,' WALL AREA = ',
     3  F10.1,' SQ.FT.')
801     FORMAT(' TOTAL FENESTRATION GAIN = ',F10.2,'BTU/HR')
802     FORMAT(F10.3)
803     FORMAT($,' HEIGHT-FEET:')
804     FORMAT($,' DESCRIPTION CODE:')
805     FORMAT(A4)
806     FORMAT(1H0,' GLASS WIDTH = ',F10.3,/,
     1  ' GLASS HEIGHT = ',F10.3,/,
     2  ' DESCRIPTION CODE = ',A4,/,/,
     3  $,' IS THE DATA CORRECT?')
809     FORMAT(A1)
810     FORMAT(1H0,' CEILING GLASS SUMMARY ',/,
        15X,' CEILING NUMBER ',2X,' GLAZED AREA NUMBER ',2X
        2,' AREA-SQFT ',4X,' CODE ')
811     FORMAT(6X,1I,19X,I1,11X,F10.3,7X,A4)
        RETURN
        END
```

```
      SUBROUTINE SYSPRN
C
C
C     THIS SUBROUTINE PRINT THE ALTERNATIVE ENERGY SYSTEM PARAMETERS
C
      COMMON/SYSTEM/ VI, VO, VR, DIA, HUB
      COMMON/STORAG/ VOL1, TMIN1, TMAX1
      COMMON/PRETNK/ VOL2, TMAX2
C
C
      WRITE(6,700) VI, VO, VR, DIA, HUB
      WRITE(6,710) VOL1, TMIN1, TMAX1
      WRITE(6,720) VOL2, TMAX2
C
C
700   FORMAT(1H0,'ALTERNATIVE ENERGY SYSTEM PARAMETERS',/,X,
      1  'WECS PARAMETERS : ', /, X,
      1  'CUT IN VELUCITY   = ', 3X, F5.1, ' MPH', /, X,
      2  'CUT OUT VELOCITY  = ', 3X, F5.1, ' MPH', /, X,
      3  'RATED VELOCITY    = ', 3X, F5.1, ' MPH', /, X,
      4  'ROTOR DIAMETER    = ', 3X, F5.1, ' FEET', /, X,
      5  'HUB HEIGHT        = ', 3X, F5.1, ' FEET', /)
710   FORMAT(1H0,//,' THERMAL STORAGE TANK : ',/,X,
      1  'VOLUME              = ',3X,F6.0,' GALLONS',/,X,
      2  'MINIMUM TEMPERATURE = ',3X,F6.0,' F',/,X,
      3  'MAXIMUM TEMPERATURE = ',3X,F6.0,' F',/)
720   FORMAT(1H0,//,' PREHEAT TANK : ',/,X,
      1  'VOLUME              = ',3X,F6.0,' GALLONS',/,X,
      2  'MAXIMUM TEMPERATURE = ',3X,F6.0,' F')
      RETURN
      END
```

```
      SUBROUTINE CHILLR
C
C
      REAL MINCFM
C
      COMMON/COOL/ CHILL, QCHILL, RHMAX, PATS,  WOT,
     1   EXMOST, CFMINF, MINCFM
C
C
      COMMON/PLANT/ JAP, AIRMIN, TMIN, AIRDNO, TEMPO,
     1  AIRMAX, TMAX, QSUM, QPLANT, WSUM, CFM, VMASS, QLAT, WPLANT
C
C
      COMMON/WECS/ BTUWEC(3), WECDAY(3), WECSUM(3), WECCYC(3),
     1     WECSTR(3)
C
C
      QCHILL = 0.0
      IF(CHILL.EQ.0.0) GO TO 156
      CFM=MINCFM
      IF(CFM.LT.CFMINF) CFM=CFMINF
      VMASS = CFM * 60. * ( .240 + .444 * WOT)
C     LOAD AT VENTILATION RATE
      QSENS = QSUM +VMASS * (AIRDNO * TEMPO - AIRMAX *TMAX)
      IF (QSENS .LT. 0.0) QSENS = 0.0
C
      WMAXI=HUMRTO(TMAX,RHMAX,PATS)
C     OPTION NO. 1 CONTROL HUMIDITY RATIO WITH CHILLER
C     CALCULATE HOW MUCH MOISTURE MUST BE REMOVED
      WOT2=WMAXI-(WSUM/(CFM*AIRDNO*60.))
      EXMOST=(WOT-WOT2)*AIRDNO*CFM*60.
      IF(EXMOST.LE.0.) EXMOST=0.0
      QLAT=EXMOST*1044.
230   CONTINUE
      QLAT = 0.0
      QCHILL = QSENS + QLAT
      IF(CHILL .EQ. 1.0 ) GO TO 130
      IF ( QCHILL .GT. CHILL ) QCHILL = CHILL
C
130   CONTINUE
C
C
C     WRITE(6,8715) QCHILL, CHILL, QSENS, QLAT, QPLANT
C8715 FORMAT(1H0,'   QCHILL    CHILL      QLAT       QPLANT',/,
C    1        3X,5F10.3)
C
C
C
156   QPLANT = -QSENS
      WPLANT = EXMOST
      QCHILL = 0.0
      JAP = 5
      RETURN
      END
```

```
      SUBROUTINE HTWATR
      BYTE YES, NO, RESP
      COMMON/KEEP35/ QWATER(24) , HTWTR(24) , TEMPHW , TEMPMW
      DATA YES,NO/'Y','N'/
10    CONTINUE
      WRITE(7,740)
      READ(5,711) RESP
      IF(RESP.EQ.NO) GO TO 197
      WRITE(7,730)
      DO 90, I=1,24
      WRITE(7,718) I
      READ(5,731) HTWTR(I)
90    CONTINUE
      WRITE(7,732)
      READ(5,733)TEMPHW
      WRITE(7,734)
      READ(5,733)TEMPMW
      WRITE(6,722)TEMPHW,TEMPMW
195   CONTTNUE
      DO 196 IHOUR - 1,24
      QWATER(IHOUR)=(TEMPHW-TEMPMW)*8.337*HTWTR(IHOUR)
196   CONTINUE
      WRITE(7,722)TEMPHW,TEMPMW
      WRITE(7,721) (I,HTWIR(I),QWATER(I),I=1,24)
      WRITE(7,720)
      READ(5,711) RESP
      IF(RESP .NE. YES ) GO TO 10
      WRITE(6,721) (I,HTWTR(I),QWATER(I),I=1,24)
197   CONTINUE
711   FORMAT( A1 )
718   FORMAT(1H0,$,'  HOUR  ',I2,5X)
720   FORMAT(1H0,$,'IS THE DATA CORRECT ? ')
721   FORMAT(1H0,/,2(10X,'HOUR',5X,'GALLONS/HOUR',5X,'BTU/HOUR',5X)
      1  ,/,  12(/,2(12X,I2,10X,F5.0.,7X,F7.0,5X)))
722   FORMAT(1H0,39X,' HOT WATER SUMMARY TABLE ',/,
      1  11X, ' HOT WATER TEMPERATURE = ',F5.0,' F',
      2  11X, ' MAKEUP WATER TEMPERATURE = ',F5.0,' F')
730   FORMAT(1H0,'ENTER THE AVERAGE HOURLY WATER DEMAND, GALLONS,',
     1 ' BEGINNING WITH HOUR 1: ')
731   FORMAT(F10.3)
732   FORMAT($,1H0,'WHAT IS THE AVERAGE TEMPERATURE OF THE',
     1 ' WATER CONSUMED, F? ')
733   FORMAT(F10.3)
734   FORMAT($,1H0,'WHAT IS THE AVERAGE TEMPERATURE OF THE',
     1 ' MAKE-UP WATER, F? ')
716   FORMAT(A1)
740   FORMAT(1H0,//,$,' IS HOT WATER REQUIRED FOR THE PROCESS? ')
      RETURN
      END
```

```
      SUBROUTINE INTLDS
      DIMENSION QAPPL(24),WAPPL(24),QMOTOR(24)
      DIMENSION WATT(24), PLAT(24), AHLF(20,24)
      COMMON/KEEP3/ QAPPL,WAPPL,QMOTOR
      COMMON/SCRTCH/ WATT,PLAT,AHLF
      BYTE RESP,YES,NO
      DATA YES,NO/'Y','N'/
      DO 1 I=1,24
      QAPPL(I)=0.0
      WAPPL(I)=0.0
1     CONTINUE
C     THIS SUBROUTINE DETERMINES THE ADDITION A1 LOADS TO INTERNAL
C     LIGHTING AND APPLIANCES
C
C     QAPPL-APPLICANCE SENSIBLE LOADS, WAPPL=APPLIANCE LATENT LOAD
C     WATT=WATT INTO APPL, AHLF APPLIANCE HOURLY USE FACTOR
C     PLATT=APPLICANCE LATENT HEAT PROD
      WRITE(7,700)
      READ(5,900) N
      DO 150 I=1,N
      IF(N.EQ.0) GO TO 150
120   CONTINUE
      WRITE(7,701)I
      READ(5,901) WATT(I)
      WRITE(7,702) I
      READ(5,901) PLAT(I)
      WRITE(7,703)I
      READ(5,902)RESP
      IF(RESP.EQ.YES) GO TO 100
      WRITE(7,704)
      READ (5,901)AL
      DO 90 K2=1,24
90    AHLF(I,K2)=AL
      GO TO 110
100   CONTINUE
      WRITE (7,704)
      DO 95,K2 = 1,24
      WRITE (7,705) K2
      READ(5,901) AHLF(I,K2)
95    CONTINUE
110   CONTINUE
      WRITE(7,710) I,WATT(I),PLAT(I),(J,AHLF(I,J),J=1,24)
      WRITE(7,711)
      READ(5,902) RESP
      IF(RESP.EQ.YES) WRITE(6,710) I,WATT(I),PLAT(I),
     1(J,AHLF(I,J),J=1,24)
      IF(RESP.NE.YES)GO TO 120
      DO 140 J=1,24
      QAPPL(J)=QAPPL(J)+WATT(I)*3.413*AHLF(I,J)
      WAPPL(J)=WAPPL(J)+PLAT(I)*AHLF(I,J)
140   CONTINUE
150   CONTINUE
700   FORMAT(1H0,$, 'HOW MANY APPLIANCES? ')
701   FORMAT(1H0,'WHAT IS THE POWER REQUIREMENT FOR ',/,
     1$,' APPLIANCE ',I2,' WATTS? ')
```

```
702       FORMAT(1H0,'WHAT IS THE MOISTURE PRODUCTION, ',/,
          1$,' LBS WATER/HR, BY APPLIANCE ',I2,' ? ',2X)
703       FORMAT(1H0,'DOES THE USE OF APPLIANCE ',I2,/,
          1$,' VARY DURING THE DAY ? ' )
704       FORMAT(1H0,'WHAT IS THE AVERAGE HOURLY DECIMAL USE FACTOR? ')
705       FORMAT(/,$,' HOUR ',I2,2X)
711       FORMAT(1H0,$,' IS THE DATA CORRECT? ')
710       FORMAT(1H0,' APPLIANCE: ',I2,/,5X,' POWER REQUIREMENTS = ',
     1    F6.1,' WATTS',10X,' MOISTURE PRODUCTION = ',F7.2,' LBS',
     2    ' WATER/HR',/,35X,' AVERAGE HOURLY USE FACTORS',/,12X,
     3    2(10X,' HOUR',3X,' USE FACTOR '),/,
          4  12(/,12X,2(13X,I2,5X,F7.2,3X)),///)
715       FORMAT(1H0,' DOES THE USE OF APPLIANCE NUMBER ',I1,/,
     1    $,' VARY DURING THE DAY? ')
900       FORMAT(I2)
901       FORMAT(F10.3)
902       FORMAT(A1)
          RETURN
          END
          SUBROUTINE MOTORS
C         FILE NAME INTLDS.FOR
          DIMENSION POWER(10),EFF(10),AHLF(10,24),IFLAG(10),QMOTOR(24),
          1 QAPPL(24),WAPPL(24)
          COMMON/KEEP3/ QAPPL,WAPPL,QMOTOR
          COMMON/SCRTCH/POWER,EFF,AHLF,IFLAG
C         THIS PROGRAM DETERMINES THE THERMAL INPUT OF POWER EQUIPMENT
C         IN CASES WHERE THE MOTOR AND THE DRIVEN MACHINE ARE WITHIN
C         THE SPACE, DRIVEN MACHINE IS WITHIN THE SPACE, THE MOTOR
C         WITHIN THE SPACE.
          BYTE YES,NO,RESP
          DATA YES,NO/'Y','N'/
          DO 56 I=1,24
          QMOTOR(I)=0.0
56        CONTINUE
          WRITE (7,803)
          READ (5,804)N
          IF(N.EU.0) GO TO 8
          DO 7 I = 1,N
120       CONTINUE
5         WRITE (7,600)I
          WRITE (7,805)
          READ (5,806) POWER(I)
          WRITE (7,807)
          READ (5,806) EFF(I)
          WRITE (7,809)
          READ (5,810) IFLAG(I)
          WRITE (7,715)I
          READ (5,902) RESP
          IF (RESP.EQ.YES) GO TO 100
          WRITE (7,704)
          READ (5,901)AL
          DO 90, K2 = 1,24
90        AHLF(I,K2)=AL
          GO TO 110
100       CONTINUE
```

```
      WRITE (7,704)
      DO 95, K2 = 1,24
      WRITE (7,705) K2
      READ (5,806) AHLF (I,K2)
95    CONTINUE
110   CONTINUE
      WRITE(7,710) I,POWER(I),EFF(I),IFLAG(I),(J,AHLF(I,J),J=1,24)
      WRITE (7,711)
      READ (5,902) RESP
      IF(RESP.EQ.YES) WRITE(6,710) I,POWER(I),EFF(I),IFLAG(I),
      1(J,AHLF(I,J),J=1,24)
      IF (RESP.EQ.NO) GO TO 120
      DO 10 J = 1,24
      IF (IFLAG(I) .EQ. 1) GOTO 1
      IF (IFLAG(I) .EQ. 2) GOTO 2
      IF (IFLAG(I) .EQ. 3) GOTO 3
1     QMOTOR(J) = POWER(I)/EFF(I) * AHLF(I,J) * 2545.0 + QMOTOR(J)
      GO TO 10
2     QMOTOR(J) = POWER(I) * AHLF(I,J) * 2545.0 + QMOTOR(J)
      GO TO 10
3     QMOTOR(J) = POWER(I) * AHLF(I,J) * 2545.0 *(1-EFF(I))/EFF(I)
     1 + QMOTOR(J)
10    CONTINUE
7     CONTINUE
8     CONTINUE
704   FORMAT(1H0,'WHAT IS THE AVERAGE HOURLY DECIMAL USE FACTOR? ')
705   FORMAT($,' HOUR ',I2,2X)
711   FORMAT(1H0,$,'IS THE DATA CORRECT? ')
715   FORMAT(1H0,'DOES THE USE OF MACHINE NUMBER ',I2,/,
     1 $,' VARY DURING THE DAY? ')
900   FORMAT(I2)
901   FORMAT(F10.3)
902   FORMAT(A1)
600   FORMAT(1H0,'FOR MACHINE NUMBER ',I2,' ENTER THE FOLLOWING:',/)
803   FORMAT(1H0,//,$,' ENTER THE NUMBER OF PIECES OF EQUIPMENT--> ')
804   FORMAT(I2)
805   FORMAT($,' THE MOTOR POWER-HP: ')
806   FORMAT(F10.3)
807   FORMAT($,' MOTOR EFFICIENCY-DECIMAL:')
808   FORMAT($,' THE HOURLY USE FACTOR-DECIMAL:')
809   FORMAT(1H0,'ENTER A 1 IF THE MOTOR IS WITHIN THE SPACE, ',/,
      1' ENTER A 2 IF THE MOTOR IS OUTSIDE AND THE EQUIPMENT WITHIN,'
      2,/,' ENTER A 3 IF THE MOTOR IS INSIDE AND THE MACHINE ',
      3 'IS OUTSIDE',/,$,' YOUR SELECTION----> ')
810   FORMAT(I1)
710   FORMAT(1H0,' MACHINE NUMBER: ',I2,/,5X,' POWER REQUIREMENTS= '
      1,F6.3,' HP ' ,10X,' EFFICIENCY= ',F5.3, /,5X,
      2' INSTALLAION CODE: ',I1,/,10X,' AVERAGE HOURLY USE FACTOR
      3S ',/,2(11X,' HOUR',3X,' USE FACTOR '),/,12(/,2(13X,I2,8X,F7.2
      4)))
812   FORMAT(I1)
      RETURN
      END
```

```
      SUBROUTINE WOPEN(FLNAM,FLAG)
C
C     ROUTINE TO OPEN DIRECT ACCESS DATA FILE AND SET UP POINTERS
C
      INTEGER FLAG
      BYTE FLNAM(16)   ,I1(10)  ,I2(10)
      INTEGER YEAR(2),SAMPLS(2),SHR(8,2),SREC(2)
      REAL    STNM(2)
C
      COMMON /PNTCOM/STNM,YEAR,SAMPLS,SHR,SREC
      OPEN(UNIT=2,NAME=FLNAM,TYPE='OLD',READONLY,ACCESS='DIRECT',
     1        FORM='UNFORMATTED',ASSOCIATEVARIABLE=NREC,
     2        DISP='SAVE',RECORDSIZE=8,MAXREC=18000,ERR=900)
      READ(2'1,ERR=900) STNM(1),I1,SREC(1),STNM(2),I2,SREC(2)
      YEAR(1) = I1(1)
      SAMPLS(1) = I1(2)
      DO 100 J=1,8
100   SHR(J,1) = I1(J+2)
      YEAR(2) = I2(1)
      SAMPLS(2) = I2(2)
      DO 200 J=1,8
200   SHR(J,2) = I2(J+2)
      FLAG = 0
      RETURN
900   FLAG = 1
      RETURN
      END
```

```
      SUBROUTINE UNHEAT(QUN)
      DIMENSION      AWALL(8)
      DIMENSION AU(8),    SUAZAN(8), SLOPE(8),  SUN(8)
      DIMENSION ADJACN(8),            ICON(3),   FLAREA(9)
      DIMENSION AUFLR(9),    ARU(3,17), SUAZ(3,8)
      DIMENSION SLP(3,8),SOL(3,8),  ADJ(3,8),  U(3,8)
      DIMENSION RADT(3,8),            JFN(3,8),  GCODE(3,8,5)
      DIMENSION GAREA(3,8,5),         FFACT(3,8,5)
      DIMENSION GAU(3,8,5),           ISURF(8),  ICN(3,9)
      DIMENSION TEMPU(3),VENT(3)
      DIMENSION TEMSUR(3,17),BEL(6), NUM(3),    QUNHT(5)
      REAL LAT,LONG
      BYTE YES,NO,RESP
C
      COMMON/KEEP10/TEMPG
C
      COMMON/KEEP15/  ARU, SUAZ, SLP, SOL, ADJ, U, JFN, GCODE, GAREA,
      1 ISURF, ICN, VENT, TEMSUR,NUM,ISPACS, GAU, BGAU
C
      COMMON/KEEP2/ TEMPO,TEMPI,LAT,LONG,IDATE,IHOUR,KAT,
      1  CLOUD,WIND,WINDIR,RHO
C
C
      COMMON/KEEP30/ TMAX(5), TMIN(5)
C
      DATA BEL/6*0.0/
C
      COMMON/SCRTCH/RADT,FFACT,AU,AWALL,AUFLR,ICON,
      1   SUAZAN,SLOPE,SUN,ADJACN,FLAREA,TEMPU
      DATA TMIN,TMAX/ 5*-100.0, 5*150.0/
      DATA YES,NO/'Y','N'/
      DO 103 I=1,3
      DO 102 J=1,8
      DO 101 K=1,5
C
      FFACT(I,J,K) = 0.0
      RADT(I,J) = 0.0
101   CONTINUE
102   CONTINUE
103   CONTINUE
C
      IF(ISPACS.LE.0) GO TO 26
      DO 25 I = 1,ISPACS
      NW=NUM(I)
      DO 30 J = 1,NW
      CALL FENES(SUAZ(I,J) , SLP(I,J), TOTIN)
      RADT(I,J) = TOTIN * CLOUD
      SOLAT = TEMPO + .230 * RADT(I,J)
      IF (ADJ(I,J).EQ.1.0)TEMSUR(I,J) = TEMPI
      IF (SOL(I,J).EQ.1.0)TEMSUR(I,J) = (3.0 * SOLAT + U(I,J)
     1 * TEMPI)/(U(I,J) + 3.0)
303   CONTINUE
      NGLAZE = JFN(I,J)
      IF( NGLAZE.EQ. 0) GO TO 308
      DO 301 K = 1, NGLAZE
```

```
302     CONTINUE
        J1 = J
        K1 = K
        CALL GLAZE (QGLASS,RADT(I,J),GAU(I,J,K),
     1  J1,K1,GCODE(I,J,K),GAREA(I,J,K),FFACT(I,J,K))
301     CONTINUE
308     CONTINUE
30      CONTINUE
C
C
C
C       INITIALIZE VALUES
        TOP1 = 0.0
        TOP2 = 0.0
        TOP3 = 0.0
        BOT1 = 0.0
        BOT2 = 0.0
        BOT3 = 0.0
        QUN = 0.0
C
C
C
C
        DO 95 J = 1,NW
        DO 96 K = 1,NGLAZE
        TOP1 = TOP1+(FFACT(I,J,K)*RADT(I,J)+
        1GAU(I,J,K)*TEMPU)*GAREA(I,J,K)
        BOT1 = BOT1 + GAU(I,J,K)
96      CONTINUE
95      CONTINUE
        ICOUNT  = ISURF(I)
        DO 97 J = 1,ICOUNT
        TOP2 = TOP2 + ARU(I,J) * TEMSUR(I,J) + BGAU * TEMPG
        BOT2 = BOT2 + ARU(I,J) + BGAU
97      CONTINUE
        TOP 3 = 2.16 * VENT(I) * TEMPO
        BOT 3 = 2.16 * VENT(I)
D       WRITE(6,808) TOP1, TOP2, TOP3, BOT1, BOT2, BOT3
D808    FORMAT (1H0,' TOP1,TOP2,TOP3,BOT1,BOT2,BOT3',/,6(3X,F10.2))
        TEMPU(I) = (TOP1 + TOP2 + TOP3)/(BOT1 + BOT2 + BOT3)
        ICOUNT  = ISURF(I)
        DO 401 J = 1,ICOUNT
        IF (TEMPU(I) .LE. TMAX(I) .AND. TEMPU(I) .GE. TMIN(I))
        1QUNHT(I) = QUNHT(I) + ARU(I,J) * (TEMPU(I) - TEMPI) *
     1  ADJ(I,J)
        IF( TEMPU(I) .LT. TMIN(I) )
        1QUNHT(I) = QUNHT(I) + ARU(I,J) * (TMIN(I) - TEMPI) *
     1  ADJ(I,J)
C       IF THE RESULTING INDOOR TEMP GT MAX USE MAX
        IF ( TEMPU(I) .GT. TMAX(I))
        1QUNHT(I) = QUNHT(I) + ARU(I,J) * (TMAX(I) - TEMPI) *
     1  ADJ(I,J)
D8099   FORMAT(1H0,' QUNHT(I), TEMPU(I), TEMPI, TEMPO, ADJ(I,J)'
D       1  ,/,5(3X, F10.3), 3X,I1, I2, '<--- I AND J')
D       WRITE(6,8099) QUNHT(I), TEMPU(I), TEMPI, TEMPO, ADJ(I,J),I,J
```

```
401     CONTINUE
        QUN = QUN + QUNHT(I)
D       WRITE(6,1000) QUN, QUNHT(I), TMIN(I), TMAX(I), TEMPU(I)
D1000   FORMAT(1H0,3X, 'QUN',4X,'   QUNHT     TMIN      TMAX    TEMPU'
D       1       5F10.2)
D       WRITE(6,1020)(I,J,ARU(I,J),TEMSUR(I,J), J=1,NW)
D1020   FORMAT(1H0,3X,'I',4X,'J',3X,'ARU',5X,' TEMSUR',/,
D       1       3X, I1 ,3X, I1 ,3X,F10.2,4X,F6.1)
25      CONTINUE
26      CONTINUE
        RETURN
        END
```

```
      SUBROUTINE PEAR(KAT,IBEEP,IHOUR,WIND,IDATE,IDAY,RESTEM,
      1  TEMPO, CFM, QPLANT, EXMOST, QFURN, QCHILL, SAVE, IPERF)
C
C
C     THIS SUBROUTINE S THE WECS PRODUCTION FOR AGCALC
C
C
      COMMON/SAAA/ TEMP1(24), TEMP2(24), OUTTEM(24),
      1  CFM1(24), QFURN1(24), QCHIL1(24), EXMOS1(24)
C
      COMMON/WECS/BTU(7), DUMMY(21)
C
C
C
C
C     PRINT HOURLY PLANT HEADINGS
C
      IF(IHOUR .EQ. 1)  WRITE(6,1500) IDATE, IDAY
C
      WRITE(6,2500) IHOUR,WIND,BTU(1),QFURN,(QFURN-BTU(2)),
      1      (BTU(I),I=2,7)
C
C
C     STORE PLANT DATA IN ARRAYS
C
      TEMP1(IHOUR) = SAVE
      TEMP2(IHOUR) = RESTEM
      OUTTEM(IHOUR) = TEMPO
      CFM1(IHOUR) = CFM
      QFURN1(IHOUR) = QFURN
      QCHIL1(IHOUR) = QCHILL
      EXMOS1(IHOUR) = EXMOST
C
C     IF HOUR IS = 24 PRINT PLANT DATA
C
      IF(IHOUR .NE. 24) GO TO 175
C
C
C     PRINT HOURLY PLANT HEADING
C
      WRITE(6,1000) IDATE, IDAY
C
      WRITE(6,2000)(I,TEMP1(I), TEMP2(I), OUTTEM(I), CFM1(I),
      1  QFURN1(I), QCHIL1(I), EXMOS1(I), I=1,24)
C
      WRITE(6,2010)
C
C
175   CONTINUE
C
C
C
1000  FORMAT(1H1,'HOURLY OPERATION SUMMARY FOR DAY ',I3,
      1  ' OF THE YEAR AND DAY ',I3,' OF THE EVALUATION',//,
      2  5X,'HOUR',5X,'INITIAL',5X,'FINAL',6X,'OUTDOOR',5X,
```

```
      3   'VENTILATION',5X,'FURNACE',5X,'CHILLER',5X,'MOISTURE',/,
      4   14X,'INDOOR',6X,'INDOOR',5X,'TEMP-F',
      1   7X,'RATE-CFM',
      6   7X,'  BTU ',5X,'  BTU ',6X,'REMOVED-LB',/,
      5   14X,'TEMP-F',6X,'TEMP-F')
1500      FORMAT(1H1,' HOURLY SUMMARY FOR DAY ',I3,
      1   ' OF THE YEAR AND DAY ',I3,' OF THE EVALUATION',///,
      2   67X,'ALLOCATION OF PRIMARY ENERGY AFTER SPACE HEATING',/,
      3   67X,'------------------------------------------------',/,
      4      1X,'HOUR',2X,'WIND',2X,'WECS ENERGY',2X,
      5      'SP HT DEM',4X,'SYST ADD.',2X,' BACKUP  '
      6      ,4X,'STOR LOSS',2X,'STOR GAIN',2X,
      7      'PREH GAIN',4X,'APPL',8X,'EXCESS')
2000      FORMAT(1H0,5X,I2,4X,F7.1,5X,F7.1,3X,F7.1,8X,F10.0,
      1   3X,F10.0,3X,F10.0,3X,F10.0)
2010      FORMAT(1H1)
2500      FORMAT(1H0,  I3, 3X, F4.1, 4X, F9.0, 2X, F9.0, 3X, F9.0,
      1   2X, F9.0, 2X, F9.0, 2X, F9.0, 2X, F9.0, 2X,
      2   F9.0, 2X, F9.0)
          RETURN
          END
```

```
      SUBROUTINE FURNAC
C
C
C
      COMMON/FURN/ FURNC, QFURN
C
C
      COMMON/PLANT/JAP, AIRMIN,TMIN,AIRDNO,TEMPO,AIRMAX,TMAX,
     1   QSUM,QPLANT,WSUM,CFM, VMASS
C
C
      COMMON/WECS/BTUWEC(3),WECDAY(3),WECSUM(3),WECCYC(3), WECSTR(3)
C     FURNANCE OUTPUT
C
C
C
C
C
      QFURN=0.0
C     DETERMINE HEATING LOAD
      QFURN=VMASS*(AIRMIN*TMIN-AIRDNO*TEMPO)-QSUM
C     CHECK IF FURNANCE LOAD IS GREATER THAN FURNANCE CAPACITY
C     IF FURNC=1.0 ALL HEATING IS MET
      IF (FURNC.EQ.1.0) GO TO 129
      IF (QFURN.GT.FURNC) QPLANT = FURNC
129   CONTINUE
      IF(QFURN.LT.0.0) QFURN=0.0
C
C
C     WRITE(6,8710) QFURN, FURNC, QPLANT
C8710 FORMAT(1H0,'   QFURN     FURNC     QPLANT',/,3X,3F10.3)
C
      QPLANT=QFURN
      QFURN = 0.0
      JAP = 5
C
C     RETURN FOR HEAT BALANCE WITH FURNACE INPUT
C
C
C
      RETURN
      END
      SUBROUTINE WINDSM(QFURN)
C
      COMMON/PLANT/JAP, AIRMIN,TMIN,AIRDNO,TEMPO,AIRMAX,TMAX,
     1   QSUM,QPLANT,WSUM,CFM, VMASS
C
C
      COMMON/WECS/BTUWEC(3),WECDAY(3),WECSUM(3),WECCYC(3), WECSTR(3)
C       WEC INPUTS
      DO 156 JR = 1,3
      WECDAY(JR) = WECDAY(JR) + BTUWEC(JR)
      WECSUM(JR) = WECSUM(JR) + BTUWEC(JR)
      WECCYC(JR) = WECCYC(JR) + BTUWEC(JR)
      IF(BTUWEC(JR).GT.QFURN)
```

```
      1   WECSTR(JR) = BTUWEC(JR) -(QFURN)
156   CONTINUE
      RETURN
      END
```

AI 01-76ET 20319

★ U.S. GOVERNMENT PRINTING OFFICE: 1981— 771-039/37B