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SPACE HEATING SYSTEMS IN THE NORTHWEST — ENERGY USAGE AND COST ANALYSIS

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SPACE HEATING SYSTEMS IN THE NORTHWEST - ENERGY USAGE AND COST ANALYSIS

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ABSTRACT

This study addresses the question of energy usage and cost of providing space heat in the Northwest. Though space heating needs represents only 18% of the U.S.'s total energy consumption, it nevertheless appears to offer the greatest potential for conservation and near term applications of alternate energy sources.

Efficiency and economic feasibility factors are considered in providing for space heating demands. These criteria are presented to establish energy usage,cost effectiveness and beneficial conservation practices for space heating of residential, commercial, and industrial buildings.

Four Northwestern cities have been chosen whose wide range of climate conditions are used to formulate the seasonal fuel and capital cost and hence the annual heating cost covering a broad spectrum of heating applications, both the traditional methods, the newer alternate forms of energy, and various methods to achieve more efficient utilization of all types.

Reviewed and Approved By

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1.0 INTRODUCTION

Space heating requirements for 1975 are approximately at 14 x 10^{15} Btu/year, or 18% of the total U.S. energy demand for 1975[1]. With such large requirements for energy, some discretion should be used in choosing space heating systems to provide the maximum utilization of available resources. Efficiency and economic feasibility factors should be conisdered in this choice.

The Northwestern U.S. region, comprising Utah, Wyoming, Montana, Idaho, Oregon, and Washington, represents extremes of heating requirements--from the relatively moderate climate of the Pacific coast to the extreme winter conditions experienced in the high mountain plateau regions. Aside from these extremes, the Northwestern U.S. has specific uniquenesses making its energy situation different from the other regions of the contiguous 48 states. Much of the area (all except the extreme eastern part) has very meager indigenous resources of the conventional fuels of coal, oil, and gas. Yet the area has an abundance of developed hydroelectric facilities. Consequently, the area is a highly electric economy, as shown in Figures 1, 2, and 3, compared to the U.S. in general. Presently, the Northwest is 60% more "electrified" than the rest of the U.S. This trend will continue though the gap will narrow. The rest of the United States will be building more and more electric generating plants (the majority nuclear), thus decreasing its fractional dependence on gas and oil.

The future projections of the Northwest area are perhaps of more significance than the current situation. The population of these six states is 8.5 million (4% of the U.S. total), with half of it concentrated along the narrow coastal band west of the Cascades, in Washington and Oregon. Yet the total area of these six states is 19% of the total area of the contiguous 48 states.

Population projections indicate a much faster growth rate in the area than will be typical of the nation. In addition, the area already is young for its population pyramid. If we build a population pyramid that shows the present Northwest population by 5-year age groups, the bottom of the pyramid will have those between 0 and 19 years of age, who will be in the prime working year by 1990. (Figure 4) Near the middle of the pyramid are those between 45 and 64 who will be retired at that time. The difference between those leaving and those entering the working years is about 1,100,000. We must provide jobs for more than 800,000 young people--the children who are already here. This is one-third greater than the present Northwest labor force and is going to take a lot of additional energy to provide those jobs.

Table I lists comparative energy statistics for today (1975). It may appear surprising that the Northwest presently has a lower per capita total energy consumption than the rest of the U.S. This is attributed largely to the extensive use of hydroelectric power, a much more efficient means of using energy. Unfortunately, future realistic expansion of the hydroelectric capacity cannot possibly meet the expansion needs of the area, and nuclear and coal thermal electric plants will represent the major additions, as will be true for the rest of the U.S.

This document concentrates on space heating because it represents what is perhaps the energy usage that has the most potential for savings via conservation or alternate approaches. There is even more potential for improvement in the Northwest because of two factors:

1. The very large space heating needs of the mountain plateau areas, where much of the growth in population is likely to occur. Table II shows the typical residential energy usage in such an area, while Tables III and IV show climatic data for two of the typical cities.

2. The very common use of electric resistant heat in new buildings and in retrofits since approximately 1950. The inexpensive hydroelectric power plus the utility minimum demand at night when space heating needs were greatest cause utilities to provide rate reduction incentives for all electric homes. Unfortunately, if the electricity is produced by fossil-fueled thermal plants (as much of it will in the Norhtwest in the future), electric resistance heating is a wasteful form of supplying space heat. And with nuclear plants, where fuel costs and future fuel supplies are not critical, the cost of electric resistance heating is costly, compared to the other alternatives. This heavy emphasis on recent electrical growth on space heating applications is shown in Figure 5. It should be noted that the chart applies only to the "West group" of Bonneville Power Association utilities, the area where the climate is mildest.

Space heating needs can be satisfied by various energy resources. For each of these, conversion to useful heat energy is accompanied by an efficiency loss. This study presents an energy and cost analysis of various space heating concepts whose ultimate criteria are: 1) the conversion or direct use of energy to maintain acceptable human comfort levels and 2) the maximum utilization of each source for cost effectiveness and beneficial conservation purposes. If all of the U.S. space heating needs could be provided by a single resource, the cost and quantity required for that source would be as shown on Table V.

This cost analysis for space heating systems was based on the heat transfer medium (i.e., hot water, steam, hot air, electricity) which would be available by a district heating plant, individual complex heating plant, or an individual residence heating unit. Heating unit terminal devices are analyzed for their annual costs in relation to the energy source used and the size of the heating system (district heat, complex heating systems, or individual residence).

Table VI lists the space heating systems discussed in this report. Four types of buildings were selected for comparing these heating systems and for calculation of heating load and fuel requirements for each case.

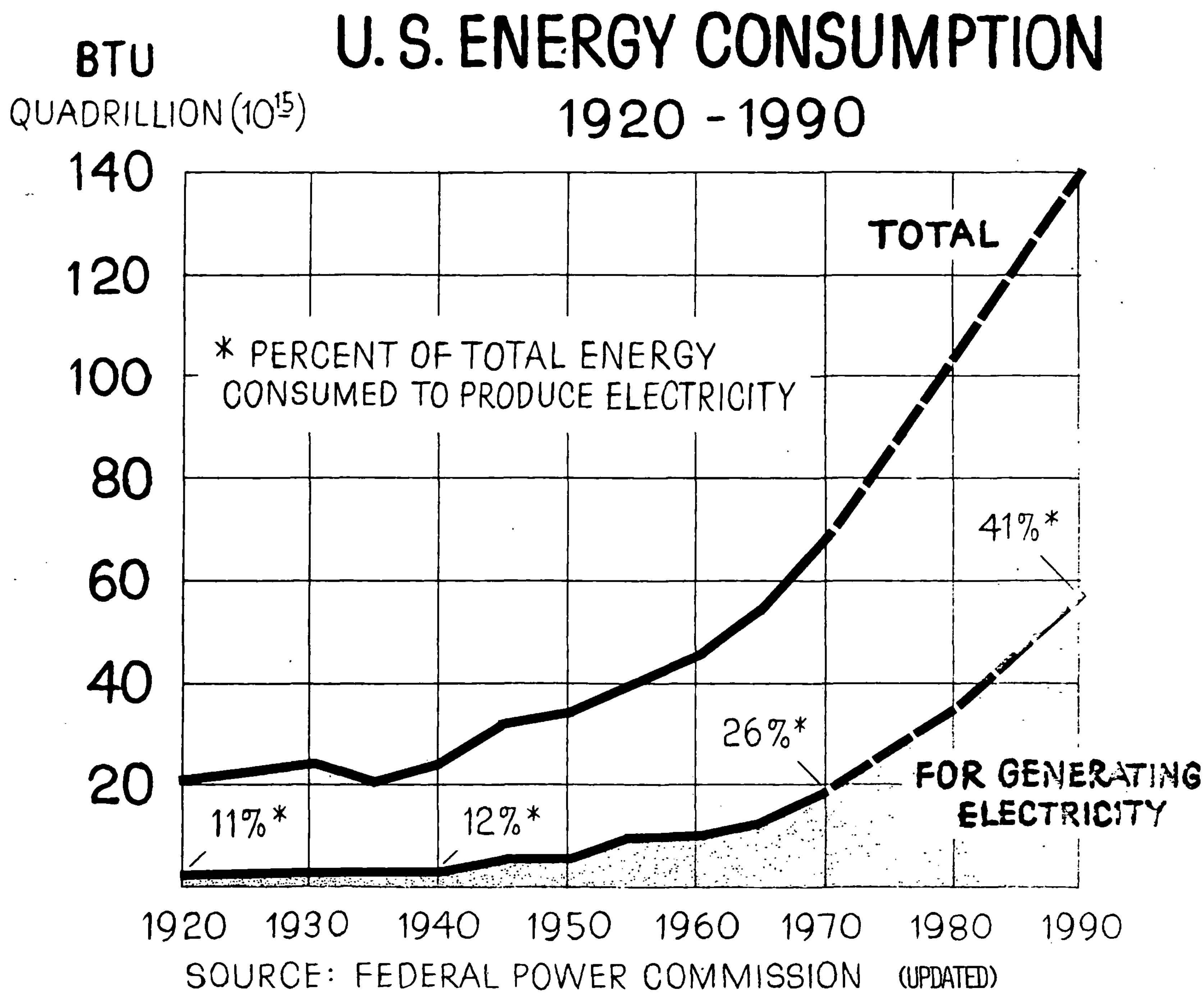

U. S. ENERGY CONSUMPTION
1920 - 1990
BTU
QUADRILLION (10^{15})
140
120
100
80
60
40
20
TOTAL
* PERCENT OF TOTAL ENERGY CONSUMED TO PRODUCE ELECTRICITY
41%*
26%*
11%*
12%*
FOR GENERATING ELECTRICITY
1920
1930
1940
1950
1960
1970
1980
1990
SOURCE: FEDERAL POWER COMMISSION (UPDATED)

Fig. 1

PACIFIC NORTHWEST ENERGY CONSUMPTION
BY ENERGY SOURCE 1950-1990

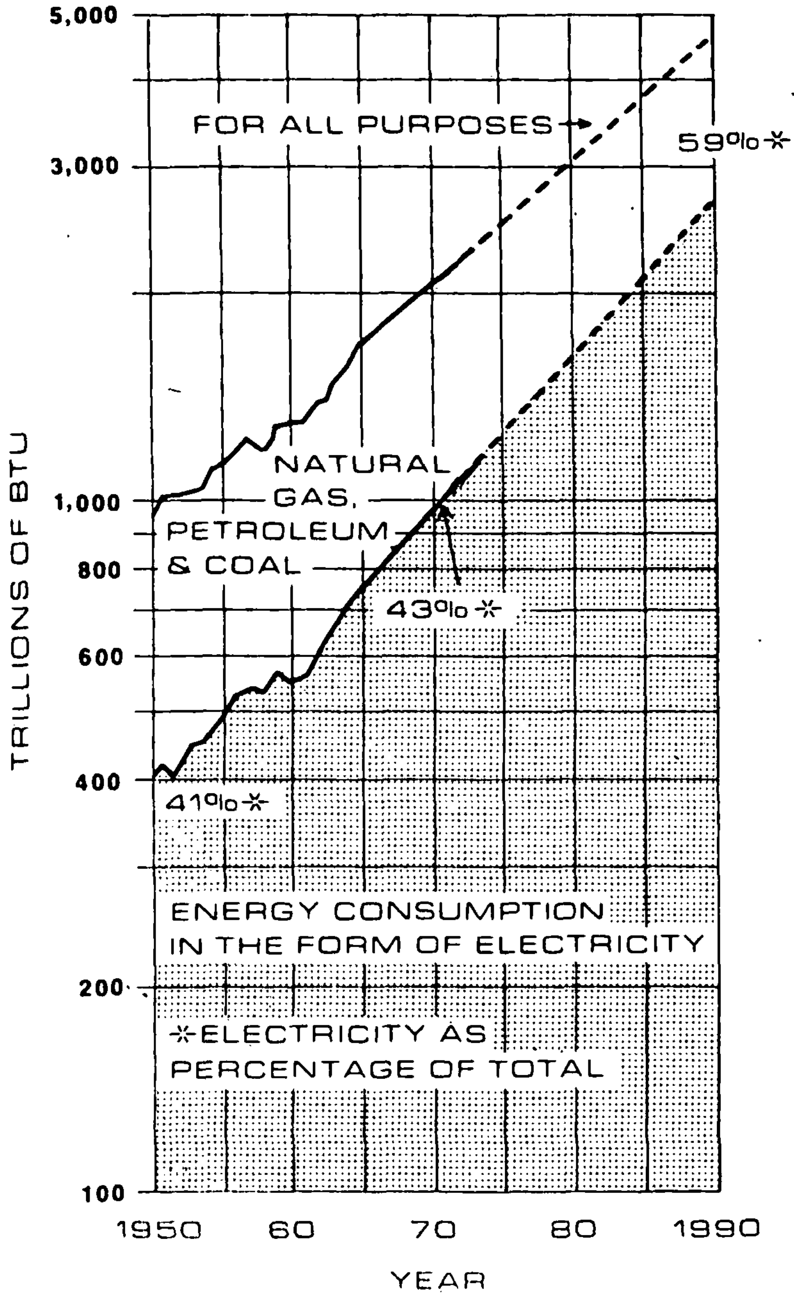


Fig. 2 (Source: Bonneville Power Administration)
(U.S. Department of Interior Energy Fact Sheets)

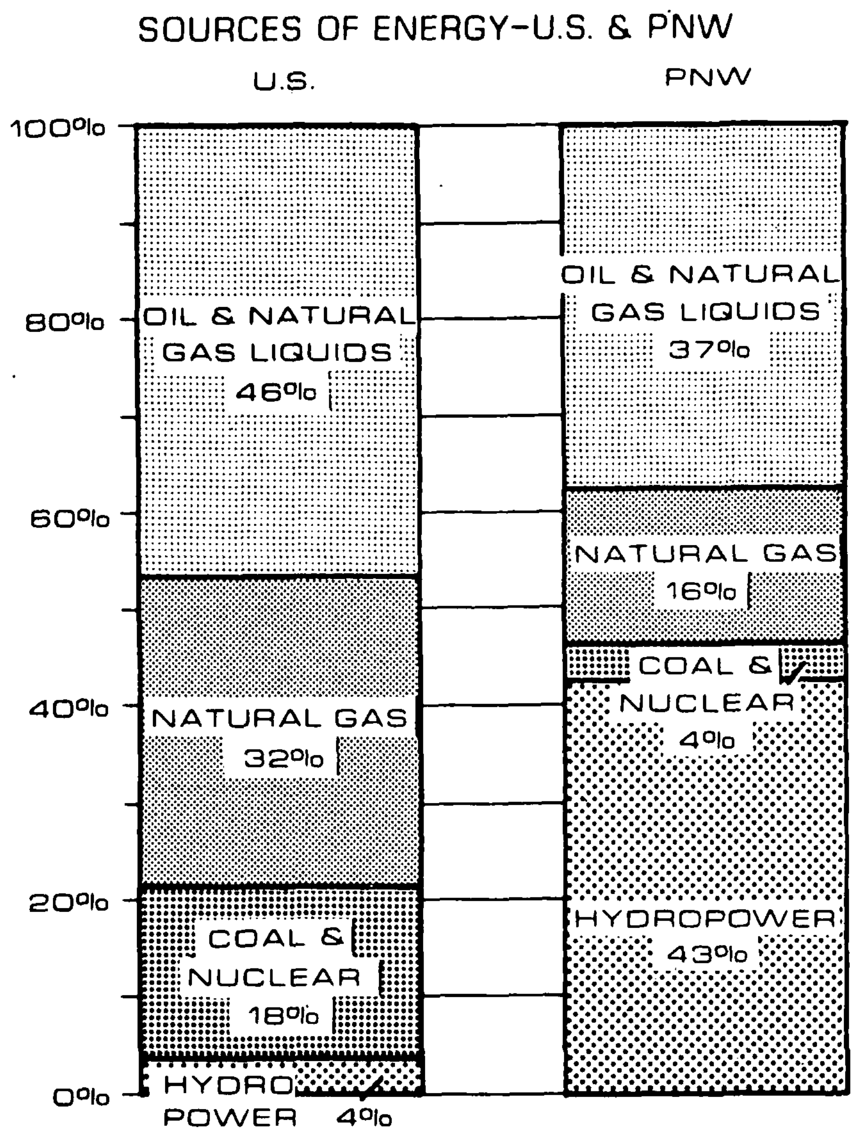


Fig. 3 (Source: Bonneville Power Administration)

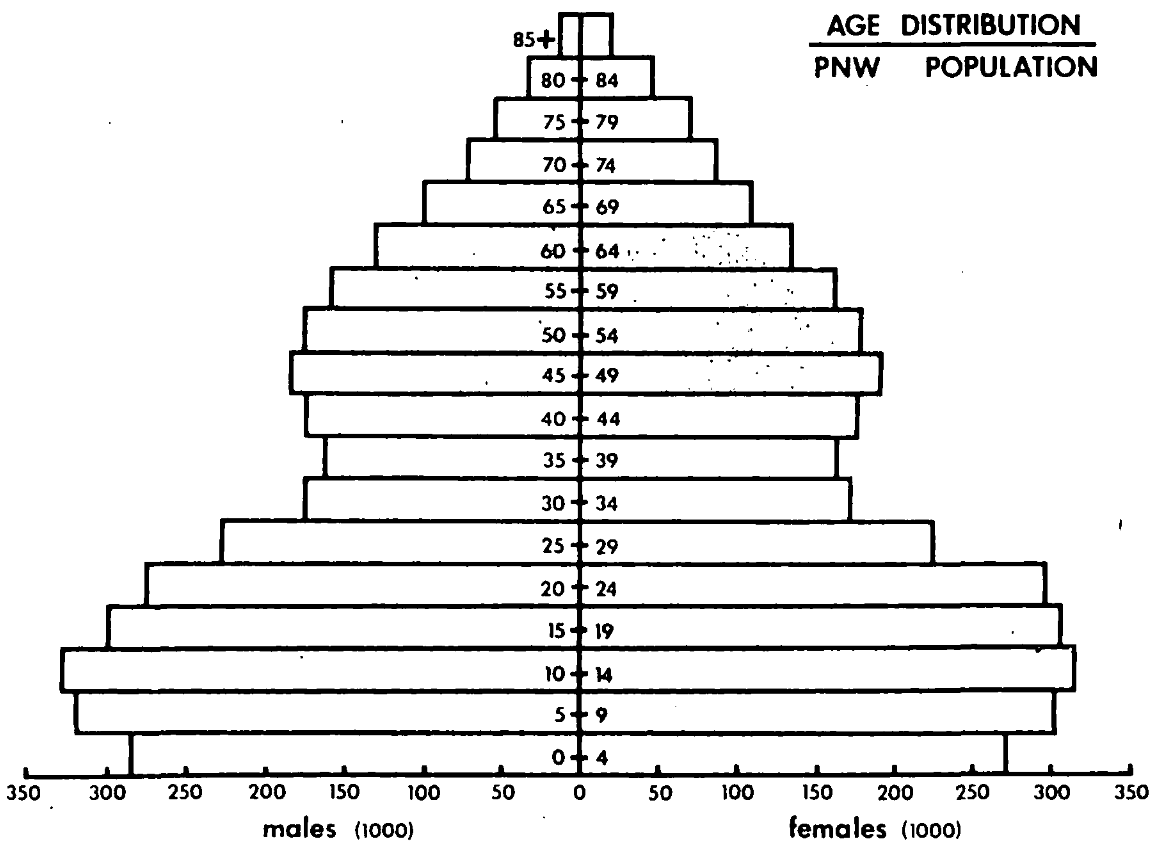


Fig. 4 (Source: Bonneville Power Administration)

FACTORS CAUSING INCREASE IN ENERGY SALES TO DOMESTIC CONSUMERS IN WEST GROUP OF PNW

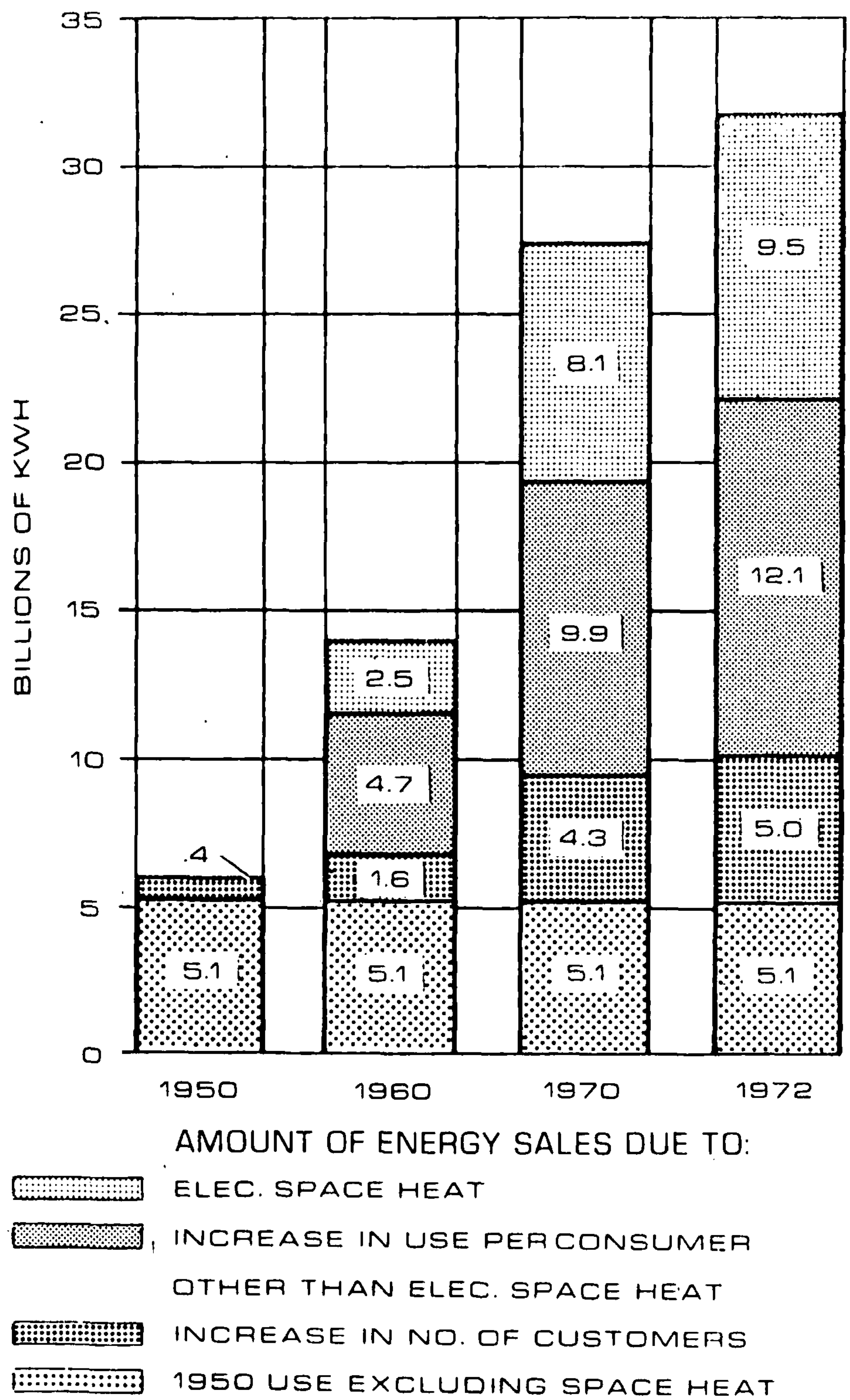


Fig. 5 (Source: Bonneville Power Administration)

TABLE I

1975 Per Capita Annual Energy Consumption

	U.S. in General	Pacific Northwest
Total Energy	4.1×10^8 Btu	3.8×10^8 Btu
Electrical Energy (all uses)	8000 kW hrs	19,000 kW hrs
Electrical Energy (residential)	1500 kW hrs	5,000 kW hrs

TABLE II

AVERAGE ANNUAL HOME ENERGY CONSUMPTION

UPPER SNAKE RIVER VALLEY (1975)
(Idaho Falls and Typical SE Idaho Residence)

		Typical Costs/M Btu	
Space Heating	120×10^6 Btu	Oil	$4.40
		Gas	2.20
Hot Water Heating	40	Electricity	4.00
Electricity	60		5.00 (1.7¢/kW hr)
Gasoline for Cars (1000 gallons)	140		3.50

Table III

Summary of Pertinent Climatological and Meteorological Data at the Idaho National Engineering Laboratory

Based on Weather Bureau Records from 1950 to Present

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Temperatures												
a. Ranges												
Average Maximum	27.6	32.9	41.9	56.0	67.1	75.5	88.1	85.7	73.4	60.5	42.9	31.1
Average Minimum	3.8	8.2	18.0	29.0	38.0	42.6	50.3	48.1	38.6	27.3	17.0	9.1
b. Annual Average Temperature: 41±2°F												
2. Nominal Degree Days of Heating - 8800 (average). Extremes: 9600 in 1964; 7800 in 1958												
Nominal Degree Days of Cooling - 250 (average). Extremes: 500 in 1961; 130 in 1965												
3. Solar Radiation Received (average integrated daily total) June - 620 cal/cm^2 December - 180 cal/cm^2 on horizontal surface												
4. Wind Velocity												
a. Nominal monthly average (mph) (average 7.8)	6.9	7.5	9.5	9.1	8.8	9.4	8.2	7.5	7.0	6.9	6.5	6.0
b. Maximum hourly average	39	36	51	39	37	35	35	31	38	44	40	41
5. Average growing season - 115 days, May 20 to September 15												

Table IV

Summary of Pertinent Climatological and Meteorological Data at Salt Lake City, Utah

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Temperatures												
a. Ranges												
Average Maximum	36.8	42.0	52.0	63.4	74.0	83.7	94.1	90.8	80.3	65.2	47.5	39.0
Average Minimum	17.5	22.9	28.8	36.4	43.8	51.0	59.6	58.2	48.5	38.2	25.9	21.2
b. Annual Average Temperature: 50.9°F												
2. Nominal Degree Days of Heating - 6052 (Average)												
Nominal Degree Days of Cooling - 926 (1971)												
3. Solar Radiation Received (Average integrated daily total) June - 702 cal/cm^2 December - 160 cal/cm^2 on horizontal surface												
4. Wind Velocity												
a. Nominal monthly average (mph)	7.6	8.2	9.1	9.4	9.3	9.2	9.3	9.5	9.0	8.4	7.7	7.4
b. Maximum hourly average	52	56	71	57	57	63	49	58	61	67	63	54
5. Average growing season - 140 days, May 5 to September 25												

NOTE: The climate of Boise, Idaho, one of the cities selected for further detailed analysis, approximates the climate of Salt Lake City.

TABLE V

Space Heating Fuel Cost Provided by a Single Source 1975
For Total U.S.

	Energy Source	Heat Content (a)	Quantity Needed For 1975 (b)	Average Cost/Unit (c)	Thermal Efficiency (d)	Heat Conversion Cost For 1975
I	Oil	145,000 Btu / gallon	236.6 Billion gallons	246 mills / Therm	70%	$ 84.4 Billion
II	Coal	11,700 Btu / lb	1.47 Billion Tons	136 mills / Therm	70%	46.8 Billion
III	Gas (Natural)	873 Btu / cu ft	34.1×10^{12} cu ft	173 mills / Therm	75%	57.0 Billion
IV	Electric A. (fossil fuel) Electric Plant	3412 Btu / Kwhr	7,737 Billion Kwhr	436 mills / Therm	100%	115.0 Billion
	B. Nuclear Electric Plant	3412 Btu / Kwhr	7,737 Billion Kwhr	(e) 221 mills / Therm	100%	58.5 Billion
	C. Geotherm. Electric Plant	3412 Btu / Kwhr	7,737 Billion Kwhr	(f) 175.8 mills / Therm	100%	46.2 Billion
V	Geothermal (Steam/Hot Water Direct)	1 Btu / lb°F	(h) 26.4×10^{15} Btu	(g) 220 mills / Therm	100%	58.6 Billion
VI	Solar	2 cal/mm/cm^2	(h) 26.4×10^{15} Btu	10 mills / Therm	50%	52.8 Billion

(a) Perry's Chemical Engineers Handbook, Fourth Edition, 1963.

(b) Quantity needed - reflects the thermal efficiency of systems used in individual home heater units.

(c) Fuel costs: Oil, Gas, and Electric rates from Lawrence Livermore Laboratory Klamath Falls Report, UCRL-13614, September 1974. Personal communication, Idaho Falls, March 1975.

(d) Thermal Efficiencies - Taken from ASHRAE Guide & Data Book, 1972, p.p. 285, 334, 275. Solar efficiencies from ASHRAE - Applications Book 59.14, 1974.

(e) Geothermics 1970, Kaufman, p. 967, Volume II, Part I.

(f) Economics of Electric Power Generation Utilizing Geothermal Energy, W.H. Comtois, May 1973.

(g) Lawrence Livermore Lab - Klamath Falls Hot Water Well Study. UCRL-13614. Cost per unit was derived from total cost of geothermal compared to total cost of alternative source. Average cost of domestic hot water usage in Boise, Idaho.
NOTE - 1f Thermal Efficiency is 50% unit costs are 110 mills/Therm.

(h) The quantity needed for Geothermal and Solar are dependent upon the flow rates and temperature (Geothermal) of the Source. Quantities, therefore, reflect heat content.

TABLE VI

Space Heating Systems by Transfer Medium

1. District Heating Plants

   A. Steam
      1. Nuclear - with heat exchanger
      2. Boiler - coal, gas, oil or geothermal preheat
      3. Geothermal - direct or with heat exchanger
         (types of final delivery listed under individual units.)
      4. Solar

   B. Hot Water
      1. Nuclear - with heat exchanger and pump assisted
      2. Boiler - coal, gas, oil or electric
      3. Geothermal - direct or with heat exchanger
      4. Use of heat pumps to assist the above
         types of final delivery listed under individual units.
      5. Solar conversion

   C. Electric
      1. Power Plants as a District Heating System -Oil,Coal,Gas,Nuclear, Geothermal

2. Individual complex heating systems (apartments, schools, etc.)

   A. Steam
      1. Central boiler - coal, gas, oil, or geothermal preheat
      2. Geothermal - direct or with heat exchanger
      3. Heat pumps
      4. Types of terminal devices listed under individual units

   B. Hot Water
      1. Boiler - coal, gas, oil, electric
      2. Geothermal - direct or with heat exchanger
      3. Heat pump assisted
      4. Electrically heated
      5. types to be listed under individual units
      6. Solar conversion

   C. Hot air
      1. Furnace - gas, coal, or oil
      2. Water/air or steam/air heat exchangers
         The water or steam provided by boiler or geothermal source
      3. Types of terminal devices listed under individual units
      4. Solar Conversion

3. Individual heating systems

   A. Steam
      1. Boiler - gas, coal, oil, or geothermal preheat
      2. Geothermal - direct or with heat exchanger
      3. Heat pumps
      4. Types of steam systems:
         - Two pipe system - (gravity or mechanical return)
           - Vapor systems
           - Vacuum systems
           - Subatmospheric systems
           - Mechanical system
         - Two pipe orifice system

TABLE VI (Cont'd)

5. Types of terminal devices
   Radiators and conductors, baseboard and finned tube radiation unit ventilators, unit heaters, fan-coil units, central air handling units.

B. Hot water systems
1. Boiler - coal, gas, oil, electric
2. Geothermal - direct or with heat exchanger
3. Heat pumps
4. Solar
5. Types of hot water systems
   Low temperature (160 psig, 250°F)
      Series loop system
      one pipe (diverting fitting) system
      two pipe system
      combination systems
   Medium and High Temperature Systems
      saturated steam cushion systems
      gas or pump pressurized systems
6. Types of terminal devices
   Natural convection units - cast iron radiators, cabinet convectors, baseboard and finned tube radiation
   Forced convection units - unit heaters, unit ventilators, fan-coil units, induction units, air handling units
   Radiation - panel systems, unit radiant panels.

C. Hot Air Systems
1. Types of systems
   Single Zone System
   Variable volume air systems (VAV)
      VAV reheat or VAV dual duct
      VAV with independent air or hydronic perimeter system
      VAV with constant zone volume
      pulsating zone VAV with constant system volume
   Reheat system
      primary air constant volume reheat system
      induction type reheat
      low temperature reheat induction
      variable volume reheat
   Dual duct systems
   Multizone systems
   Ceiling induction systems
   perimeter loop heating system
   perimeter radial systems
2. Solar Systems
3. Geothermal heat conversion

D. Electric Systems
   Decentralized systems
      Natural convection units, forced air units, radiant units, radiant panel type units
   Centralized systems
      heated water systems, steam system, heated air systems

E. Total energy systems

F. Heat recovery systems

G. Remote units

H. Space heaters

2.0 SPACE HEATING REQUIREMENTS

Factors which affect the space heating requirements of buildings and which are considered in this report are climate, population density and system type.

Climatic factors constitute the majority of design requirements for any space heating equipment. Four locations, each with different climatic conditions, were chosen for calculation of heating loads and design factors. The cost analysis of space heating systems was based upon these heating requirements and thus the selection of locations was chosen to cover a wide range of climatic conditions.

The four locations selected were: 1) Boise, Idaho, where a current ERDA-State of Idaho Demonstration Geothermal Project is being investigated and conducted; 2) Pendelton, Oregon[2] with semi-arid climate and hot sunny summers; 3) San Francisco, California, with a cool coastal climate, and 4) Idaho Falls, Idaho, with a dry climate, severe winter conditions, and cool summers.

Ten-year average values for degree-days were taken from American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) with a 65°F base[3]. Attempts were made to show the effects of solar radiation, relative humidity and wind speed for each of the locations selected.

The heating requirements of the following types of buildings were investigated.

1. Apartments

2. Residential houses

3. Shopping - Office buildings

4. Industrial buildings

Apartments

The apartments considered are of 8400 sq ft per story and 3 stores high. Total enclosed area therefore, is 25,200 sq ft, or 201,600 cubic ft for 8 ft ceilings.

Residential Houses

The residential area is made up of individual houses each of 1800 sq ft or 14,400 cubic ft per building.

Shopping - Office

An office building or local shopping building is considered to be of 25,300 sq ft or 202,400 cubic ft.

Industrial Buildings

The industrial buildings are of large area, 200,000 sq ft or 2,000,000 cubic ft with 10 ft ceilings.

The heat losses of these buildings were estimated by the degree day method[4] with 65°F as the base temperature. The hourly heat loss was estimated using the methods described in the Handbook of Air Conditioning, Heating and Venting[3].

The seasonal heat loss was estimated from the equation:

$$H = \frac{24\, hd\, (t_1 - t_a)}{t_1 - t_o} \qquad \text{(Eq. 1)}$$

H = Seasonal Heat Loss

h = Hourly Heat Loss

d = Number of Heating Days

t_1 = Design Temperature Inside (65°F)

t_o = Design Temperature Outside

t_a = Average Outside Temperature

$K = \frac{H}{hD} \cdot 1000$, D = degree days/yr

The following data taken from ASHRAE - Fundamentals were used to calculate the seasonal heat loss[4].

	Idaho Falls,	Pendelton, Oregon	S.F.,Calif.	Boise,ID
Normal Degree Days	8900	5204	3421	5890
Winter Design Temperature	-15°F	+15°F	+30°F	-10°F
Heating Days Per Season	320	260	365	277
Average Winter Temperature[4]	34.9°F	45.0°F	55.6°F	43.7°F
K	350	352.7	1053.1	370.5

The last line, K, is a measure of the relative effectiveness of building design and construction in reducing heat loss. It represents average heat transfer for the building exterior.

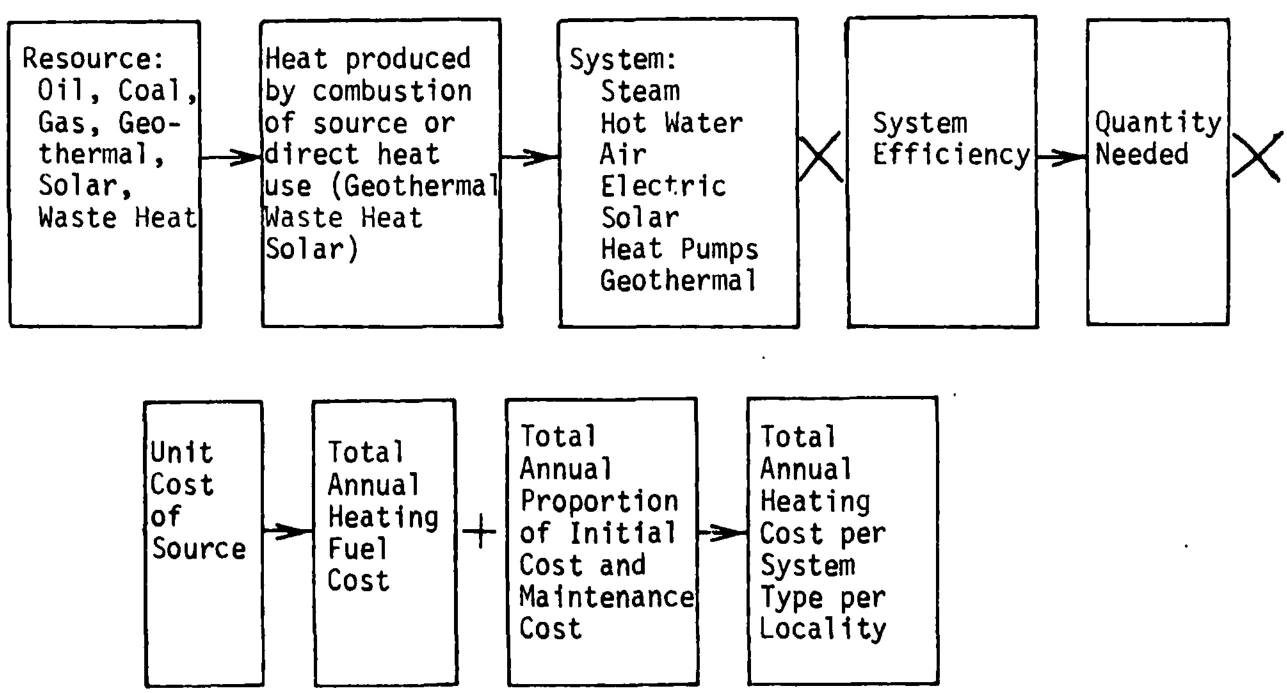
Hourly heat loss per building type for the four locations chosen is given below in Btu/hr:

	Idaho Falls,	Pendelton	San Francisco	Boise
Apartments	1,330,560	860,000	630,000	1,270,000
Residential	95,760	61,920	44,640	88,200
Shopping	1,275,120	820,000	610,000	1,190,000
Industrial	13,000,000	8,200,000	5,800,000	12,200,000

Substituting the hourly heat loss into Equation 1, the following seasonal heat losses were calculated (Btu/yr).

	Idaho Falls	Pendelton	San Francisco	Boise
Apartments	$4,144 \times 10^6$	$1,578 \times 10^6$	$2,269 \times 10^6$	$2,771.5 \times 10^6$
Residential	298.3×10^6	113.6×10^6	160.8×10^6	192.5×10^6
Shopping	$3,971.9 \times 10^6$	$1,505 \times 10^6$	$2,197.6 \times 10^6$	$2,596.8 \times 10^6$
Industrial	$40,495 \times 10^6$	$15,050 \times 10^6$	$20,895 \times 10^6$	$26,623 \times 10^6$

The following block diagram has been used in calculation of the annual cost of a particular system to supply the heating demand.



3.0 HEATING SYSTEMS

3.1 Total Air Systems

An Air System includes various distribution networks to supply heat by a hot air medium[5].

Air systems may be classified into the categories of: 1) single path systems and 2) dual path systems. The single path system utilizes a common duct system in series to provide heat to all terminal devices. The dual path system consists of the variable air volume (VAV) and multizone systems. Air systems have the advantage of being centrally located thus easing maintenance and providing a flexible system.

The American Gas Association certifies forced air gas furnaces at a rating based on 80% efficiency. Oil fired furnaces equipped with pressure-atomizing or rotary burners require a minimum efficiency of 80% for forced air furnaces. Furnaces equipped with pot-type oil burners require a minimum efficiency of 70%.[6]

3.2 Steam and Water Systems

Radiators, convectors, baseboard, and finned tube terminal devices are used in both steam and hot water systems. Small and large tube cast iron radiators emit 240 Btu per hour per square foot of exposed area[6].

240 Btuh = 1 sq ft EDR (equivalent direct radiation) with 1 psig steam

Tables are available for converting steam ratings to hot water ratings at various temperatures. Water systems will be analyzed here for a temperature of 180^{o}F at which a factor of 169 is used to determine water ratings from steam ratings. The Packaged Firetube Branch of the American Boiler Manufacturers Association conducted tests used by its member companies resulting in efficiency ratings of not less than 80% when burning oil and not less than 75% when burning gas to fire boilers[7] ASHRAE Guide and Data Book[6] produces the following efficiencies:

Anthracite, hand fired	60-70%
Bituminous coal, hand fired	50-65%
Stoker fired	60-75%
Oil and Gas Fired	70-80%
Electric	90-99%

The above are those used in steady state operation and are thus higher than those obtained in actual service. The steam or hot water once distributed through the terminal devices is returned to the boiler. The heat extracted from the heat medium will be assumed equal to that gained by the air.

3.3 Heat Pump Use

Commercial heat pumps generally resemble commercial air conditioning systems. The thermodynamic cycle is the same, except that for heating, the outside coil becomes the evaporator, the inside coil the condenser. Most heat pumps have a four way valve to switch the roles of the inside and outside coils and hence provide either heating or cooling as the need exists.

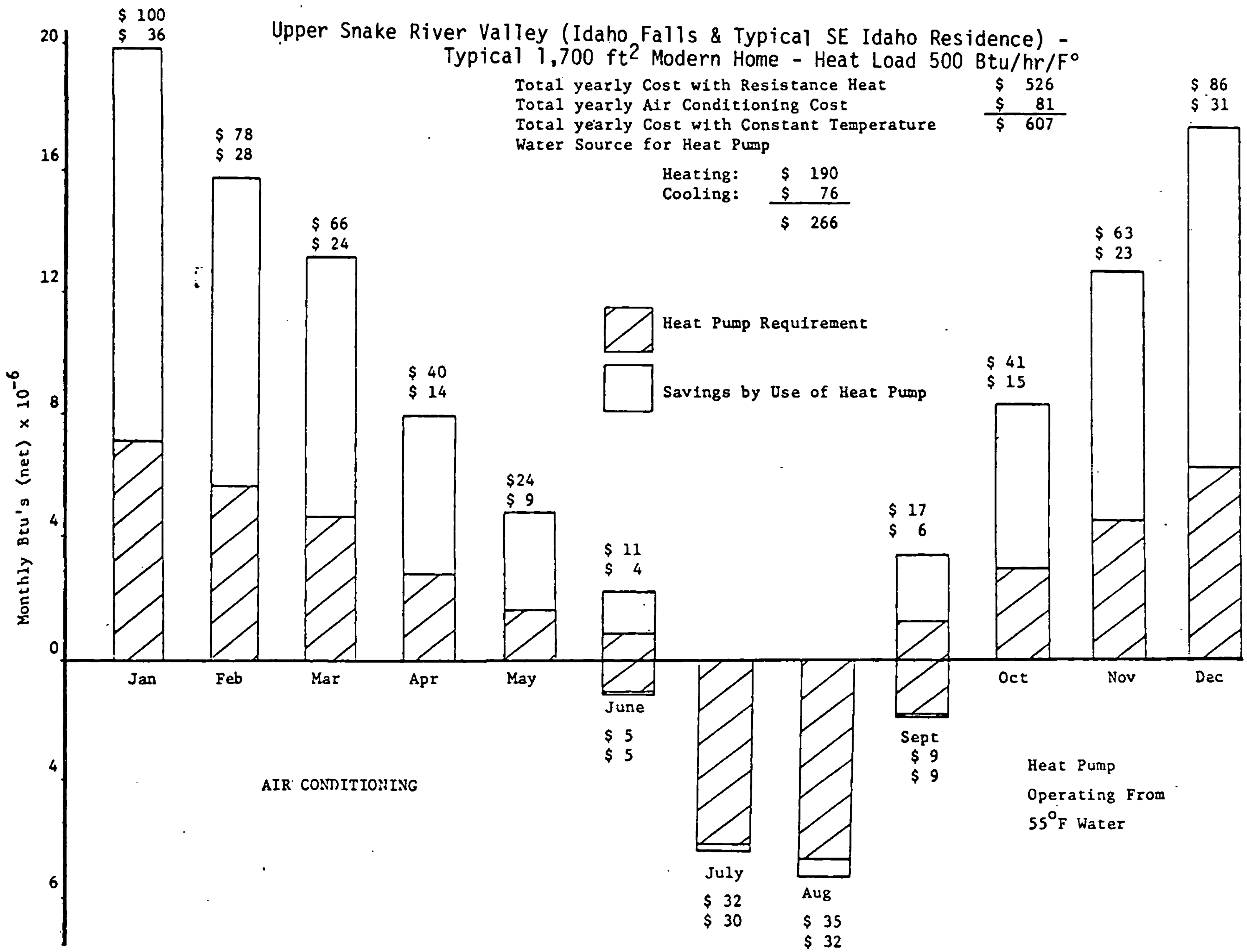
Heat output in Btu's is generally 2-3 times larger than the heat input when using a heat pump (typical 2 at 32°F, 3 at 50°F). However, at about 0°F most current commercial heat pumps reach a coefficient of performance (COP) of unity. For the Northwest's "average" climate, a coefficient of performance of 2.06 has assigned to the utilization of heat pumps. Because of the drop in efficiency with temperature drop, heat pump installation is not designed to provide the full heat load on the coldest of days. For this reason, supplementary heat is usually supplied in areas where temperature entraces are large. Heat pumps, although in commercial and residential operation for well over 20 years, have remained generally localized in application. Only recently has emphasis on consumer marketing been revived by the principal manufacturers, particularly in the colder northern climates where they had seen little previous use.

Several sources are available as a heat source for heat pumps during the heating season and include the following: air, city water, well water, surface water, waste water, earth and solar sources. The heat source is used to supply heat to the conditioned space, the heat sink. Principal mass produced commercial units for single residents (20,000 to 50,000 Btu/hr) use air as the source, and thus are adversely affected by extremely cold (approximately 0°F or below) winter temperatures. Many large commercial systems have been built to utilize water as the heat source, and hence show virtually constant coefficient performance (COP) throughout the year of about 3 or larger. Despite earlier poor reports on reliability, recent analysis by electric utilities on heat pump usage in their service areas show typical failure rates of 3 to 4% annually, nearly constant throughout the first 20 years of service.

The use of water "cooled" heat pumps (with typical source temperatures of 50° to 60°F) seems to offer considerable attraction where adequate water supplies are available. Extracting heat equivalent to a 10°F drop in temperature of the water gives a requirement of 5 gallons/minute for a typical residence on a -20°F day. Thus the water usage is not unrealistic, and it can be non-consumptive by returning the water to its source. Figure 6 shows a typical example of the advantage to be gained by a heat pump compared to electric resistance heating, for instance.

Heat pump applications have two other intrinsic advantages.

1. Compared to oil and gas furnaces operating at 70% efficiency, a heat pump supplied by a fossil-fueled electric generating plant will usually consume less fossil fuel than an oil or gas furnace. The latter typically have 70% efficiency, and new fossil-fueled electric generating plants have 40% efficiency. Thus, any heat pump exceeding a COP of 1.75 is more conserving of fuel than the direct burning of the fuel.


Upper Snake River Valley (Idaho Falls & Typical SE Idaho Residence) -
Typical 1,700 ft² Modern Home - Heat Load 500 Btu/hr/F°
Total yearly Cost with Resistance Heat $ 526
Total yearly Air Conditioning Cost $ 81
Total yearly Cost with Constant Temperature Water Source for Heat Pump $ 607
Heating: $ 190
Cooling: $ 76
$ 266
Heat Pump Requirement
Savings by Use of Heat Pump
Monthly Btu's (net) x 10⁻⁶
20
16
12
8
4
0
4
6
$ 100
$ 36
Jan
$ 78
$ 28
Feb
$ 66
$ 24
Mar
$ 40
$ 14
Apr
$24
$ 9
May
$ 11
$ 4
June
$ 5
$ 5
July
$ 32
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Aug
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Sept
$ 9
$ 9
$ 41
$ 15
Oct
$ 63
$ 23
Nov
$ 86
$ 31
Dec
AIR CONDITIONING
Heat Pump
Operating From
55°F Water

Fig. 6

2. Heat pumps will require the greatest use during the cold night-time hours when utility demands are at the minimum. Thus, electric utilities highly favor the use of heat pumps for space heating.

3.4 Electric Systems

Electric systems are generally suitable for a number of space heating applications owing to their ease of distribution, control, simplicity, and cleanliness. Compared to fossil fuel types, an electric system is more efficient and effective. An electric heating unit consists of a frame or casing to support one or more heating elements. The principal types of electric heating systems are either centralized or decentralized systems, with the former utilizing electricity to heat water or air as described under air and steam systems. The coefficient of performance of electric heating systems is 1.00 or 100%.

3.5 Geothermal Space Heating Systems

Geothermal systems vary according to the salinity, chemical analysis, temperature and flow rate of the water used. Two cases have been considered here:

1. The geothermal water is low enough in salinity that a direct water distribution system may be used.

2. The geothermal water is hot enough to allow the use of a heat exchanger.

The distribution network in either case approximates that of a steam or hot water heating system. Geothermal prices are dependent upon proximity to local sources .

3.6 Solar Heating Systems

Solar energy is received in sufficient quantities to make a major contribution to U.S. heat and power needs[8]. The following inherent characteristics of solar radiation limits its use at present.

1. Solar radiation is low in intensity

2. Solar radiation is intermittent due to variations of the solar angle

3. Solar radiation received at earth is variable, owing to clouds, rain, snow, and various other climatic conditions.

The solar constant is 2 calories/min/cm^2 for direct incident sunlight. However, this value is substantially reduced by the above listed three conditions. Solar radiation for space heating can be used by two processes: 1) helio-electrical and 2) heliothermal. The former through convectors,changes the radiation into electrical energy. This method is extremely expensive and impractical for consideration of space heating. The latter method is a conversion process from solar to heat energy. This method is direct, workable, and technically quite practical. (It's current high cost is discussed below.)

The flat-plate collector is simply a back-insulated, radiation-absorbing surface warmed by the sun's rays and, if the desired temperature justifies it, protected against too rapid loss of energy due to back-radiation and connection by being covered with one or more solar-transparent but long wave-opaque layers of glass or plastic(9). Improvements on solar transmittance have greatly increased the efficiency of solar collectors.

The efficiency of a well-constructed and properly-designed thermo-syphon water heater will range from 45 - 65%(10). The efficiencies of forced-circulation air heaters will vary hourly due to changes in incident angles.

The monthly degree days for each of the cities considered in this report provide a method for calculation of the annual heating load. A suitable percentage of this load handled by a solar heating system will optimize its utilization leaving days of low solar radiation and/or high heat loss days to be handled by a supplemental heating system. The following are average solar radiation amounts received on a horizontal surface during the heating season:

San Francisco	1343 Btu/sq ft/day
Pendelton	1317 Btu/sq ft/day
Boise and Idaho Falls	1376 Btu/sq ft/day

Assuming that sufficient surface area is present, the solar system analyzed for economical consideration in this report will provide 30%, 50%, or 70% of the total heating load. All of these systems will require some type of storage to provide the needed energy overnight. The 70% system will need more than overnight storages. Supplemental heat must be supplied to fulfill the additional requirements, and must be designed to carry 100% of full load during low solar radiation periods and/or high heat loss days.

Many solar houses have been built, demonstrating an average 80% efficiency rate (11, 12, & 9). Thus for the time that the solar system is on-line, 80% will be used in this report for the efficiency of a solar heating system. (This is in addition to the 30, 50, or 70% values for "on-line" time.)

The above values are considered average for a moderate climate. However, for the extreme winter conditions of the high mountain plateaus of the Northwest, solar heating systems of typical design (single or double pane) are essentially out-of-service (or useless) during much of December and virtually all of January. Though for a few hours on a bright sunny day (sunny days are usually the coldest days at that time of year) the system may reach sufficient temperature to be operable, it will be supplying a virtually infinitesimal fraction of the energy needs during those two months. Figure 7 shows a typical analysis for the Idaho Falls area, which is the most severe of the four example cities considered. For this reason, neither the 50% or 70% solar systems are considered as reasonable or practical for Idaho Falls. Similarly, the 70% system is considered impractical for Boise or Pendelton.

SOLAR HEAT SYSTEM

- 1000 ft² INSTALLATION
- UPPER SNAKE RIVER VALLEY
- TYPICAL 1700 ft² MODERN HOME
- HEAT LOAD 500 Btu/hr/°F

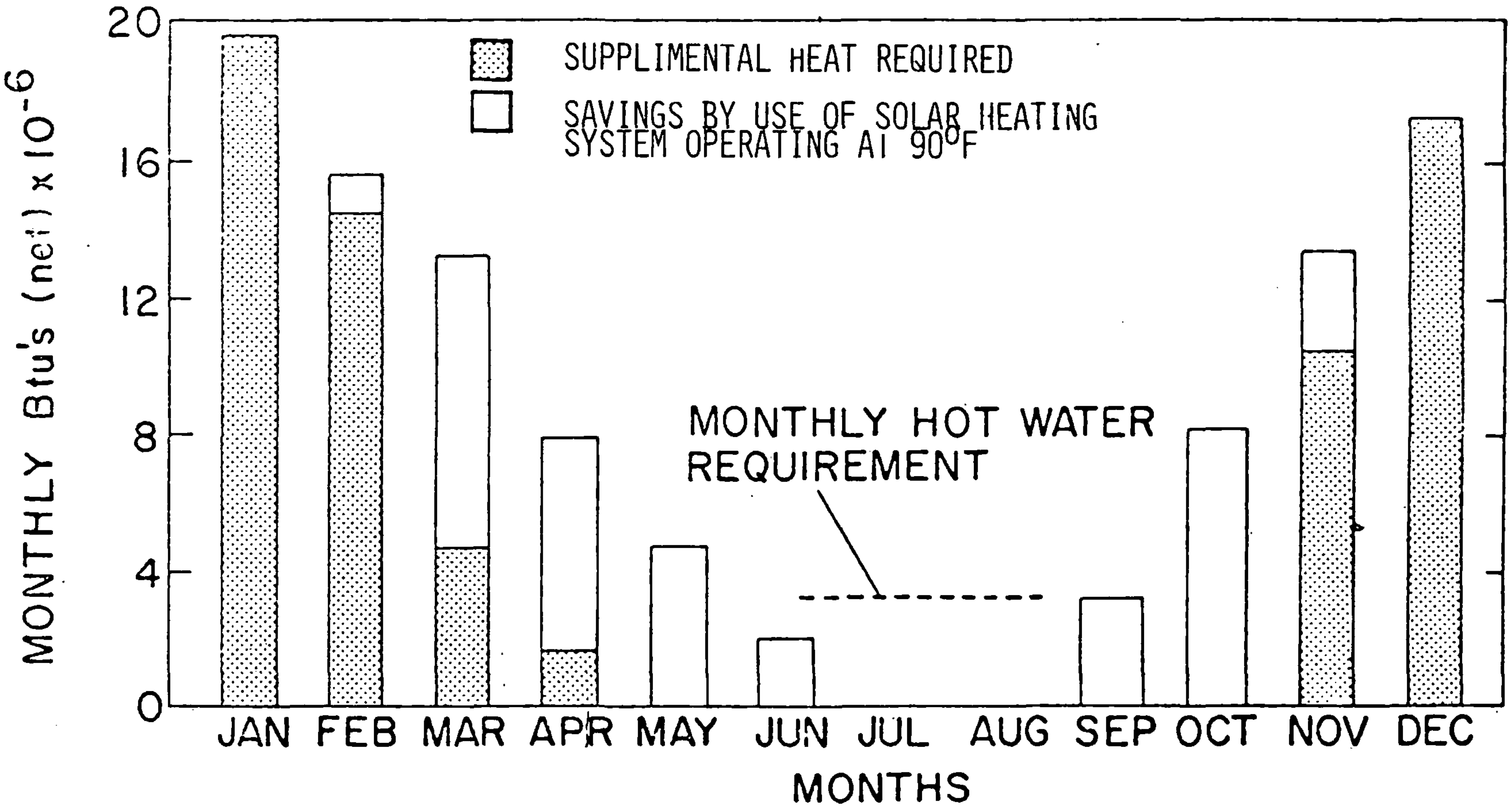

Fig. 7

Capital costs are roughly calculated for these systems. $4/ft^2 for single pane and $7/ft^2 for double pane systems are considered typical. Overnight storage systems, either air or water, are likely to cost $1,000 to $3,000, depending on the location and type of system (rock or water). The interior heat distribution systems will generally cost more than for the conventional fossil-fueled heating systems, because the solar device should be able to work at lower effective temperatures in order to increase its on-line time capability.

3.7 Waste Heat Systems

Waste Heat Systems are those in which waste power plant heat is utilized to provide heating through a normal steam space heating distribution network. The first costs of the distribution network have been estimated as equivalent to those accrued by a steam heating system.

It will be assumed that power plant waste heat is available through a district piping system.

3.8 Hybrid Solar - Heat Pump System

In cold climates where the air exchange heat pump suffers from poor coefficient of performance and conventional solar heating systems are ineffective in winter, a hybrid system may have potential. The performance of the heat pump can be enhanced by raising its source temperature moderately i.e., such as from -10^{o}F to 30^{o}F, thus doubling its COP. A solar collector system would thus need to work only in the range of 30^{o}F instead of approximately 100^{o}F, required for direct solar heating. The difference could be quite significant in terms of the on-line time of the solar heating system, since it can enhance the heat pump regardless of the temperature outside. The largest gains will be affected on the coldest days, with present commercial heat pump systems. During days of moderate temperature (30^{o} to 50^{o}F), enhancement is likely to occur to temperatures above 80^{o}F, beyond which point gains in COP are minimal, and often turn negative. Figure 8 shows the type of improvement that might be expected with the use of a relatively small solar collection system. Use of different working fluids and perhaps multistaging of the compressor units would better adapt heat pumps to these extremes of temperature.

The types of hybrid systems that could be used are several, and detailed analysis of each is needed before definitive answers can be given. For this reason, the hybrid solar-heat pump system is not dealt with in the tables that follow.

3.9 Wind Energy

Windmills for producing electricity have received considerable attention of late. Their problem is one of cost, partly in the cost of switch gear, frequency control and/or battery storage. However, the direct input of the electrical energy into heating coils (in an electric furnace, for instance) would require no switchgear control mechanisms, and would enable one to utilize all the available windmill energy at those times of the year when furnace heat or hot water heat is needed. The advantage is greatest for the coldest climates.

HEAT PUMP SYSTEM

400 ft² INSTALLATION
UPPER SNAKE RIVER VALLEY

TYPICAL 1700 ft² MODERN HOME
HEAT LOAD 500 Btu/hr/°F

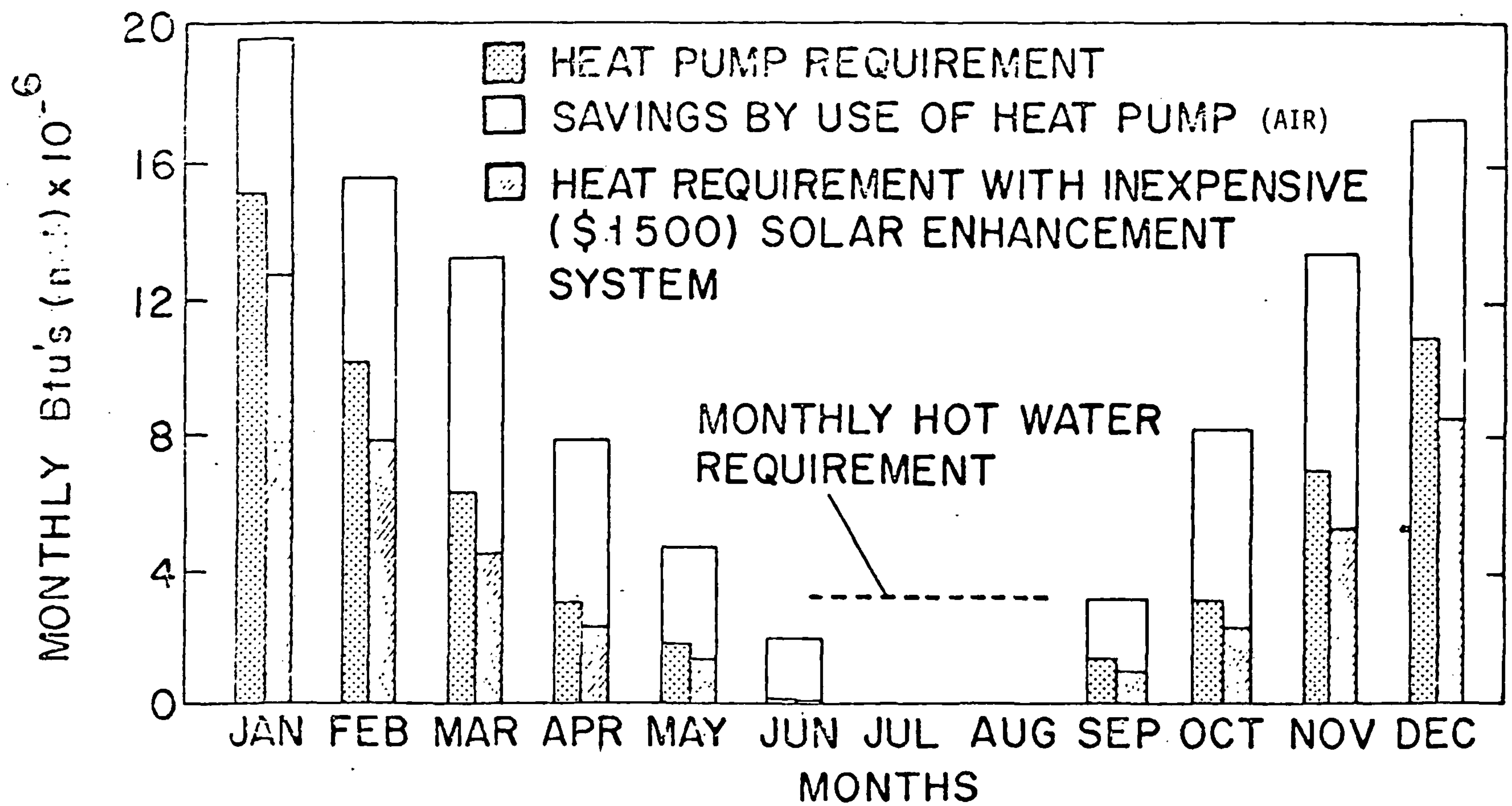

Fig. 8

This concept has not been analyzed in detail for costs, and hence is not included in the subsequent tables. However, current capital costs of commercially produced windmills make these systems even more expensive than solar installations, and hence the need for including them at this state-of-development does not appear important.

4.0 FUEL COSTS

Fuel costs used to estimate the annual heating costs are, for the 1975 listing, those actually being charged in the Idaho Falls area for 1975. These are considered typical for the entire Northwest. The projections into future years were derived from the 1970 National Power Survey Part I[13]. The Federal Power Commission estimated that fuel oil and coal will increase 2.27 percent per year during the 1968-1990 period (uninflated). Natural gas rates are estimated by the Federal Power Commission to increase 4.55 percent per year (uninflated) between the 1968 to 1990 period. The commission also estimated an increase of 1.22 percent per year (uninflated) for electricity during the same period.* Present fuel costs were estimated by conversations and rate schedules of local companies (Idaho) and projected to 1985 using the yearly percentage increases as given by the Federal Power Commission. Table VII lists residential fuel rates unless specified otherwise.

The annual consumption rate of fuels for heating is a function of both the heating system type used and the fuel type used. Fuel oil, for example, could be utilized to heat water and thereby produce hot water/steam for use in a hot water/steam heating system or be used in a total air heating system. In each case a different quantity of fuel oil would be consumed owing to various heating systems efficiency rates. Table VIII presents the quantity of fuel consumed (per hr °F) as a function of resource and heating system type used. Selection of the resource and heating system type to be utilized gives the fuel consumptive rate for the size of buildings under consideration. Table VIII also lists the life expectancy of the various space heating systems.

Those systems which are hot air circulation also have an annual electrical cost due to expenditures of energy in running fans and circulation pumps. To this end, additional quantities are needed, although relatively small, and have been estimated at 703 kWh/1000 sq ft floor area annually[2]. Referring back to the caluclations of annual heating requirements, Table VIII can be utilized to formulate the annual fuel consumption. This number, when multiplied by fuel cost presented in Table VII provides the yearly fuel cost associated with heating systems. Tables IX, X, XI, and XII list the yearly fuel costs of Pendelton, San Francisco, Boise, and Idaho Falls, respectively.

* Needless to say, the referenced report did not anticipate the dramatic step function that occurred in 1974 in oil costs, with many other forms of energy following competitively. It is impossible to anticipate future political situations which may severely perturb the Federal Power Commission estimates of orderly fuel cost escalation.

TABLE VII

Present and Predicted Residential Fuel Costs

	1975	1980	1985
Electricity			
(Residential)a	$4.78/MBtu	$5.54/MBtu	$6.42/MBtu
(Industrial)b	2.69	2.97	3.28
Natural Gas(a	2.91	4.19	6.03
Fuel Oil(ab	2.48	3.20	4.13
Coal(a	1.62	2.08	2.66
Waste Heat(c	2.87	3.71	4.80
Geothermal Water(d	1.75	1.93	2.12

a Federal Power Commission, National Power Survey, 1970 updated to 1975 $4.78/MBtu

b Idaho electric companies, Idaho oil companies, personal communications

c A System Analysis of the Economic Utilization of Warm Water Discharge from Power Generating Stations, Oregon State University Report, 1974. Heat Available from Power Plants (Coal, Nuclear).

d Boise, Warm Springs Avenue, $1.75, July 1975

TABLE VIII

RESOURCE QUANTITIES NEEDED PER HR°F AS A FUNCTION OF HEATING SYSTEM TYPE AND RESOURCE USED

Resource	System	Efficiencies	Quantity Needed/hr°F				Life Expectancy (yrs)
			Apartments	Residential	Shopping	Industrial	
Oil 145,000 Btu gall	Air System	80% oil & gas forced air	.144 gal oil	.01 gal oil	.137 gal oil	1.34 gal oil	19
			23.9 cu ft gas	1.69 cf ft gas	22.76 cu ft g.	222.9 cu ft gas	19
		100% electric	3.9 Kwhr	.28 Kwhr	3.78 Kwhr	37.1 Kwhr	13
Coal 11,700 Btu/lb	Steam & Hot Water System	60-75% cool	1.85 lb coal	.131 lb coal	1.76 lb coal	17.32 lb coal	19
		70-80% oil & gas	.144 gal oil	.01 gal oil	.137 gal oil	1.34 gal oil	19
		90-99% Electric	23.9 cu ft gas	1.69 cu ft gas	22.76 cu ft g.	222.9 cu ft gas	19
		100% Waste Heat (B)	17,400 Btu	1230 Btu	16,565 Btu	162,222 Btu	25
			3.9 Kwhr	.28 Kwhr	3.78 Kwhr	37.1 Kwhr	13
Gas 873 Btu cu ft	Electric System	100% electric	5.35 Kwhr	.378 Kwhr	5.34 Kwhr	49.9 Kwhr	13
Electric 3412 Btu Kwhr	Heat Pump System Utilization +1kw/12,000 Btu Pump	202% + 100% elect. 20% Utilization	4.87 Kwhr	.344 Kwhr	4.63 Kwhr	45.44 Kwhr	D 10 (25)
		30% Utilization	4.76 Kwhr	.335 Kwhr	4.53 Kwhr	44.39 Kwhr	10 (25)
		40% Utilization	4.65 Kwhr	.322 Kwhr	3.42 Kwhr	43.34 Kwhr	10 (25)
Waste Heat							
Solar 429.2 Btu sq ft	Solar System 30%,50%,70% Utilization (C)	30% Utilization	3.57 Kwhr	.252 Kwhr	3.39 Kwhr	33.28 Kwhr	19
		50% Utilization	2.55 Kwhr	.18 Kwhr	2.43 Kwhr	23.77 Kwhr	19
		70% Utilization	1.53 Kwhr	.108 Kwhr	1.45 Kwhr	14.26 Kwhr	19
Geothermal 1Btu/lb°F	Geothermal System	100% (A)	17,400 Btu	1230 Btu	16,565 Btu	162,222 Btu	25

(A) Varying percentage efficiency depending on final use of waste water.

(B) Steam from a Power Plant supplied to a residence
Waste steam is cycled in a closed system.

(C) Solar System supplemented by an electric system 30, 50 or 70% or annual requirements.

(D) 10 years is considered the average life of the heat pump compressor and outside coil unit, which represents about 40% of the cost of the entire system. The rest of the system should have a life of 25 years.

TABLE IX

Annual Fuel Cost - Pendelton, Oregon (Dollars/Year)

Type-System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air		4763	330	4532	44,330
Gas-Forced Air		5571	394	5305	51,598
Electric Furnace		5945	424	5722	56,042
Coal Fired Steam		3211	227	3050	30,010
Oil Fired Steam		4763	330	4532	44,330
Gas Fired Steam		5571	394	5305	51,958
Electric Fired Steam		6311	445	6300	61,704
Waste Heat a		6909	478	6575	64,319
All-Electric		5945	424	5722	56,042
Heat Pump (COP 2.06)		2886	205	2778	27,205
Solar System (plus electric)	30%	5399	380	5127	22,652
	50%	3856	333	3675	16,180
	70%	2315	164	2192	9,706
Geothermal System b		2762	190	2628	25,705

a Waste Heat available from power generating plants - Nuclear and Coal.

b Fuel costs dependent upon availability.

TABLE X

Annual Fuel Cost - San Francisco, California (Dollars/Year)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air		6544	453	6226	60,842
Gas-Forced Air		7654	541	7288	71,385
Electric Furnace		8265	583	7860	34,680
Coal Fired Steam		4402	312	4190	41,112
Oil Fired Steam		6544	453	6226	60,842
Gas Fired Steam		7654	541	7288	71,182
Electric Fired Steam		8672	612	8655	36,295
Waste Heat		9493	656	7437	88,115
All-Electric		8265	583	7860	34,680
Heat Pump (COP 2.5)		3306	233	3144	13,872
Solar System (plus electric)	30%	9418	522	7044	31,035
	50%	5298	375	5050	22,165
	70%	3179	225	3013	13,297
Geothermal System		3795	262	2970	35,210

TABLE XI

Annual Fuel Cost - Boise, Idaho (Dollars/Years)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air		8494	588	8082	79,058
Gas-Forced Air		9935	702	9460	92,661
Electric Furnace		10,729	757	10,205	45,011
Coal Fired Steam		5715	405	5440	53,520
Oil Fired Steam		8494	588	8082	79,058
Gas Fired Steam		9935	702	9460	92,661
Electric Fired Steam		11,255	795	11,234	47,248
Waste Heat		12,324	852	11,727	114,706
All-Electric		10,729	757	10,205	45,011
Heat Pump (COP 2.06)		5,208	367	4,953	21,850
Solar System (plus electric)	30%	9630	678	9144	40,398
	50%	6877	487	6555	28,854
	70%	4127	291	3910	17,310
Geothermal System		4934	340	4682	45,925

TABLE XII

Annual Fuel Cost - Idaho Falls, Idaho (Dollars/Year)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air		12,702	882	12,123	118,587
Gas-Forced Air		14,902	1053	14,190	138,991
Electric Furnace		16,093	1135	15,307	67,516
Coal Fired Steam		8,572	607	8,160	80,280
Oil Fired Steam		12,741	882	12,123	118,587
Gas Fired Steam		14,902	1053	14,190	144,991
Electric Fired Steam		16,882	1192	16,851	70,872
Waste Heat		18,486	1278	17,590	172,059
All-Electric		16,093	1135	15,307	67,516
Heat Pump (COP 2.8)*		8,940	630	5,467**	24,113**
Solar System (plus electric)	30%	14,445	1017	13,716	60,597
	50%	10,315	730	9,832	43,281
	70%	6,190	436	5,865	25,965
Geothermal System		7,401	510	7,023	68,887

* For Idaho Falls, the water "cooled" heat pump is the preferred choice, giving a COP of approximately 2.8, and decreasing the quoted fuel costs by 36%. However, commercial units for residential and apartment use are not generally available as of this date.

** Water "cooled" units.

5.0 CAPITAL COSTS

The cost of heating systems and their installation charges are estimated per building type per location and are listed in Tables XIII, XIV, XV, and XVI for Pendelton, San Francisco, Boise, and Idaho Falls, respectively. Estimates were based on averages of vendor catalogs, brochures and conversations with local Idaho heating companies. Steam systems were all estimated on a two-pipe distribution network and with all components of construction approximately similar, thus reflecting variations of systems per energy source used. Oil fired systems naturally reflect a higher initial investment because of greater controlling practices for oil utilization.

Large buildings (Industrial and Shopping Centers) require first cost whose material costs were estimated at 25% total construction cost.

TABLE XIII

First Costs - Pendelton, Oregon (Dollars)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		28,616	1915	69,800	462,815
Gas-Forced Air Furnace		27,397	1836	67,262	445,820
Electric-Forced Air Fur.		26,227	1760	64,579	427,640
Coal Fired Steam		56,110	3606	104,266	740,313
Oil Fired Steam		37,210	2470	89,586	597,080
Gas Fired Steam		35,830	2381	86,348	575,141
Electric Fired Steam		34,326	2284	82,925	551,948
Waste Heat		25,200	1027	59,033	400,000
Geothermal		25,200	1027	59,033	400,000
Total Electric		33,673	2100	73,792	483,750
Heat Pump		48,229	3171	106,465	888,027
Solar System (A)	30%	80,214	4943	153,638	1,041,880
	50%	87,775	5488	160,847	1,113,970
	70%	95,335	6032	168,055	1,186,058

(A) Solar Systems are estimated at supplying 30, 50 or 70% of the annual heating load in Northwestern cities. Supplemental heat is supplied by an electric system by 70, 50, and 30%. ($8-10/sq ft for 350 Btu/hr solar collector plus storage tank and piping.)

TABLE XIV

First Costs - San Francisco, California (Dollars)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		27,616	1816	69,120	449,454
Gas-Forced Air Furnace		26,498	1742	66,410	432,259
Electric-Forced Air Fur.		25,438	1672	63,835	414,081
Coal Fired Steam		46,845	3340	97,147	678,827
Oil Fired Steam		35,406	2329	88,190	574,550
Gas Fired Steam		34,026	2240	84,952	561,580
Electric Fired Steam		32,522	2143	81,529	538,387
Waste Heat		21,420	872	50,178	387,000
Geothermal		21,420	872	50,178	387,000
All Electric		28,622	1785	62,723	483,750
Heat Pump (1)		37,350	2450	89,895	687,715
Solar System	30%	66,350	4200	130,592	885,600
	50%	71,898	4665	136,720	946,875
	70%	77,426	5128	142,846	1,008,150

(1) Every 10 years a new compressor @ $400 is needed for a 63 MBH heat pump. Thus its life expectency is 25 years with installation of a new compressor each 10 years.

TABLE XV

First Costs - Boise, Idaho (Dollars)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		30,466	1965	71,716	485,935
Gas-Forced Air Furnace		29,247	1886	69,178	468,740
Electric-Forced Air Fur.		28,077	1810	66,495	450,562
Coal Fired Steam (3)		63,310	4206	112,226	844,233
Oil Fired Steam		39,060	2520	91,502	620,000
Gas Fired Steam		37,680	2431	88,264	598,061
Electric Fired Steam		36,176	2334	84,841	574,868
Waste Heat (1)		25,200	1027	59,033	400,000
Geothermal (2)		25,200	1027	59,033	400,000
All Electric		33,673	2100	73,792	500,000
Heat Pump		75,293	3234	166,208	1,386,348
Solar Systems	30%	144,758	9163	284,918	1,932,152
	50%	156,841	10,177	298,288	2,065,838
	70%	168,925	11,188	311,655	2,199525

(1) The first cost of a Waste Heat System includes only distribution network, terminal units, and installation charges.

(2) Geothermal Systems follow from the above footnote.

(3) Coal fired boilers cost 450% more than gas fired boilers. (personal communications)

TABLE XVI

First Costs - Idaho Falls, Idaho (Dollars)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		31,685	2043	74,585	505,372
Gas-Forced Air Furnace		30,416	1961	71,945	487,489
Electric-Forced Air Fur.		29,200	1882	69,155	468,584
Coal Fired Steam		65,842	4374	116,715	878,002
Oil Fired Steam		40,622	2620	95,162	644,800
Gas Fired Steam		39,187	2528	91,795	621,983
Electric Fired Steam		37,623	2427	88,234	597,862
Waste Heat		26,208	1068	61,395	416,000
Geothermal		26,208	1068	61,395	416,000
Total Electric		35,019	2184	76,744	520,000
Heat Pump		78,304	3363	172,856	1,441,801
Solar System	30%	151,660	9599	298,504	2,024,300
	50%	164,320	10,662	312,512	2,164,350
	70%	176,980	11,721	326,516	2,304,410

6.0 TOTAL COSTS OF HEATING SYSTEMS

The preceding tables list annual fuel cost and first costs. Each of the system's life expectency is listed in Table VIII. Using straight-line depreciation of the first cost assuming cost of capital for the installation is 10% over its expected life period and adding annual fuel cost and maintenance to the annual capital cost thus figured, the total annual heating cost is thereby calculated. It is assumed that the system experiences no loss of efficiency with continued use and therefore annual fuel cost remains constant. Tables XVII, XVIII, XIX, and XX for Pendelton, San Francisco, Boise, and Idaho Falls, respectively, list the annual heating costs of the various systems described in this report.

Maintenance costs have not been included for the shopping centers, apartments, and industrial installation columns, since these units will require a full time maintenance staff. Hence, it is believed that total maintenance charges will not differ much for each of the systems considered.

However, for residential units, the bulk of the maintenance is anticipated to be for equipment repair. The annual costs for maintenance are as estimated below:

Type	Estimated Annual Residential Maintenance
Oil, gas, coal furnaces	$30
Electric furnaces	$20
Total Electric (baseboard)	$10
Geothermal	$40
Solar	$80
Heat Pump	$60
Oil, Gas & Coal Steam Systems	$40

TABLE XVII

ANNUAL HEATING COSTS - PENDELTON, OREGON (DOLLARS)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		13,974	976	27,000	193,307
Gas-Forced Air Furnace		14,390	1015	26,956	195,105
Electric-Forced Air		12,909	911	22,870	169,596
Coal Fired Steam		21,272	1427	36,612	268,312
Oil Fired Steam		16,740	1165	33,369	236,526
Gas Fired Steam		17,105	1200	33,099	237,092
Electric Fired Steam		17,360	1220	32,993	239,373
Waste Heat		17,830	963	32,159	237,679
Geothermal		13,683	675	28,212	199,065
Total Electric		14,886	991	25,316	184,496
Heat Pump		23,788	1639	48,919	412,075
Solar Systems (A)	30%	31,219	2051	54,582	358,027
	50%	32,110	2179	55,450	374,761
	70%	33,002	2185	56,288	391,491

(A) Life expectancy of Solar Systems we estimated to be 19 years (an average of piping and supplemental electric system life expectency).

TABLE XVIII

ANNUAL HEATING COST - SAN FRANCISCO, CALIFORNIA (DOLLARS)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		15,433	1067	28,475	205,518
Gas-Forced Air Furnace		16,183	1131	28,665	210,526
Electric-Forced Air		15,019	1056	24,810	144,634
Coal Fired Steam		19,481	1417	35,461	259,623
Oil Fired Steam		17,941	1242	34,613	245,786
Gas Fired Steam		18,607	1302	34,633	251,952
Electric Fired Steam		19,140	1342	34,899	209,599
Waste Heat		18,776	1073	29,184	255,840
Geothermal		13,078	680	24,717	202,935
Total Electric		15,865	1067	24,515	163,134
Heat Pump		19,494	1355	42,105	311,927
Solar System	30%	30,775	1954	49,080	316,105
	50%	28,438	1956	49,059	326,959
	70%	28,102	1957	48,994	337,815

TABLE XIX

ANNUAL HEATING COST - BOISE, IDAHO (DOLLARS)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		18,300	1250	31,167	235,478
Gas-Forced Air Furnace		19,349	1339	31,728	243,546
Electric-Forced Air		18,184	1257	27,862	164,652
Coal Fired Steam		26,094	1798	41,565	325,274
Oil Fired Steam		21,067	1439	37,536	278,633
Gas Fired Steam		22,064	1524	37,871	285,174
Electric Fired Steam		22,899	1566	38,544	232,295
Waste Heat		23,245	1337	37,312	288,066
Geothermal		15,855	825	30,266	219,285
Total Electric		19,670	1325	29,799	177,780
Heat Pump		37,839	1828	76,987	622,693
Solar System	30%	56,226	3707	100,857	662,347
	50%	57,363	3843	102,572	693,836
	70%	58,503	3972	104,230	725,325

TABLE XX

ANNUAL HEATING COST - IDAHO FALLS, IDAHO (DOLLARS)

Type of System		Apartment	Residential	Shopping	Industrial
Oil-Forced Air Furnace		22,901	1569	36,131	281,264
Gas-Forced Air Furnace		24,693	1714	37,348	295,911
Electric-Forced Air		23,846	1655	33,670	191,943
Coal Fired Steam		29,766	2055	45,730	362,904
Oil Fired Steam		25,817	1765	42,755	326,145
Gas Fired Steam		27,516	1907	43,738	345,204
Electric Fired Steam		28,992	1993	45,253	263,320
Waste Heat		29,844	1780	44,198	352,353
Geothermal		18,759	1013	33,631	249,181
Total Electric		25,391	1725	35,685	205,596
Heat Pump		42,877	2147	80,383	648,990
Solar System	30%	63,263	4187	109,807	712,208
	50%	63,208	4242	110,428	739,974
	70%	63,159	4289	110,968	767,742

7.0 CONCLUSIONS

Approximately 18%, or 14 x 10^{15} Btu/year of the total U.S. energy demand (1975) is utilized in the space heating of U.S. buildings. This space heating requirement will continue to increase, thus necessitating the use of conservation methods applied to heating systems using depleting resources or the introduction of alternative resources, heretofore, unused. Conservation, by its nature, can effect substantial benefits, but only on a short term basis. The initiation of alternate resources not only transfers up to 18% of U.S. energy demands on existing sources over for uses of non-heat energy but allows conservation of fossil fuels to have an extended term.

Prior to the current energy crisis, the capital costs of heating systems provided a major deciding factor as to the type of system installed in new building constructions or replacement of older heating systems. As has been presented, other factors may have large influences and should be weighted accordingly in selections of space heating systems. These factors include: capital costs, expected life of the heating system, fuel cost, projected fuel cost and resource availability, efficiency and locality.

These factors must be discussed independently to arrive at weighting to be attached to each. Only after all weighting factors have been averaged in is it possible to provide a basis for selection.

The last of these factors, locality, is useful in determining the weight factor attached to fuel costs. Larger heat losses associated with colder climates increase the relative importance of proper resource selection and tend to decrease the importance of capital cost. To this end, the cost analysis was based on four localities, each of varying climatic conditions. For example, analysis of apartment utilizing oil furnaces:

	Annual Fuel Costs	Capital Costs	Total Annual Costs
Idaho Falls, Idaho	$12,702	$31,685	$22,901
San Francisco, California	6,544	27,616	15,433
Variance	194%	115%	148%

Capital costs are only 115% greater for Idaho Falls, Idaho for apartments operating oil furnaces. This ratio is generally true for each system used representative of the fact that heating system size is based on expected temperature extremes. The duration of the heating season and the hours/day a heating system is utilized effects primarily the fuel consumption ration. Thus, Idaho Falls, Idaho experiences 194% greater annual fuel cost that San Francisco (apartments using oil furnaces). The total annual heating costs, up 148% in Idaho Falls, Idaho, reflects primarily the fuel cost weighting factor.

The fuel cost weighting factor is directly proportionate to anticipated resource availability. Future depletion of fossil fuels and therefore increased costs will substantially increase the importance of heating system selection based on fuel costs rather than capital costs.

The life expectancy, likewise a primary factor in calculations of the total annual heating cost, is independent, for the most part, of locality. For example:

	Life Expectancy	Boise Apartment Capital Cost	Yearly Capital Cost
Total Electric Heating System	13 years	$33,673	$2,590
Gas Fired Steam System	19 years	37,680	1,983
Geothermal/Waste Heat System	25 years	25,200	1,008

Favoritism might be placed on a total electric heating system over a gas-fired steam system at first glance. Inspection of these costs averaged over the life expectancy of the systems reveals that a lower annual cost is accrued to the gas-fired steam system - 77%. Varying amounts of annual cost would conceivably be accrued at different climates pending actual duration of heating season, therefore, actual life expectancy.

Efficiency of a heating system governs the quantity of heat retrievable from the intrinsic heat of the resource. Inefficiencies arise from energy conversion of fuels used indirectly and/or from the heating systems capability to transmit the available direct heating. The efficiencies listed in Table VIII represent the heating system's ability to transmit the available heat. The heat content of the various resources are indicative of any conversion losses from one energy source to another and are also listed in Table VIII.

These efficiency percentages govern to a large extent the quantity of fuel/resource consumed. Suggested efficiency rates are normally certified under steady state conditions and do not necessarily remain constant with extended use. Heat losses arising from inefficiency, are for the most part, irretrievable, in air handling heating systems. Hot water/steam systems are closer to operating efficiently, owing to recirculation within a closed system or alternative uses in the case of waste heat from generating plants.

Of the above factors considered for analysis, each tends to be individually weighted such that percentage importance is exhibited in the total annual heating costs. Colder climates would represent the maximum utilization of each heating resource and would give the appropriate weighting of selection factors (exclusive of capital costs). Table XX, for example, lists the annual heating costs in Idaho Falls, Idaho. Analysis of least cost systems is fair only to the extent that it is exclusive of future availability and cost. For apartment utilization, the 10 least cost systems in order of costs are:

1. Geothermal Heating System (where resource is available)
2. Oil Fired Furnace
3. Electric Forced Air Furnace
4. Gas Forced Air Furnace
5. Total Electric

6. Oil Fired Steam
7. Gas Fired Steam
8. Electric Fired Steam
9. Coal Fired Steam
10. Waste Heat

The above reflect 1975 costs of space heating systems.

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