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Energy and Cost Analysis of Residential Heating Systems

Dennis L. O'Neal

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OAK RIDGE NATIONAL LABORATORY
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ENERGY AND COST ANALYSIS OF RESIDENTIAL HEATING SYSTEMS

Dennis L. O'Neal

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

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ABSTRACT

Several energy-saving design changes in residential space heating systems were examined to determine their energy conservation potential and cost effectiveness. Changes in conventional and advanced systems (such as the gas heat pump) were considered. The energy and cost estimates were developed from current literature, conversations with heating and equipment manufacturers and dealers, and discussions with individuals doing research and testing on residential space heating equipment.

Energy savings as large as 26, 20, and 57% were estimated for design changes in conventional gas, oil, and electric space heating systems, respectively. These changes increased capital cost of the three systems by 27, 16, and 26%, respectively. For advanced gas and electric systems, energy savings up to 45 and 67%, respectively, were calculated. The design changes needed to produce these energy savings increased capital costs 80 and 35%.

The energy use and cost relationships developed for the space heating systems were used as input to the ORNL residential energy use simulation model to evaluate the effect of space heating improvements on national energy use to the year 2000. Results indicated a large reduction in national energy use if improved conventional and advanced systems were made available to consumers and if consumers minimized lifecycle costs when purchasing these systems.

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ENERGY AND COST ANALYSIS OF RESIDENTIAL SPACE HEATING SYSTEMS

Dennis L. O'Neal

1. Introduction

This report provides preliminary estimates of the energy and cost (both purchasing and operating) impacts of several energy conserving options for residential gas, oil, and electric space heating systems. The options include not only design changes in current technology, but also new technologies that might be introduced in the market within the next five years (such as the gas heat pump). The energy and cost impacts were developed to help evaluate the energy conservation potential and cost-effectiveness of design changes implemented by the manufacturer or installer of new heating equipment. Retrofit impacts were not considered.

Sources of the information included current literature, heating equipment manufacturers and dealers, and individuals involved in research and testing of residential space heating equipment.

Outputs from these analyses were used as inputs to the ORNL engineering-economic model of residential energy use.^{1,2} The energy use simulation model estimates the distribution of new residential equipment each year from 1970 to 2000 as functions of fuel prices, consumer demand functions, and technological characteristics of each type of equipment. This study provides estimates of the relationships between operating energy requirements and initial costs for space heating systems needed by the simulation model.

From 1960 to 1975, the annual energy use for residential space heating grew from 4.8×10^{15} Btu to 8.6×10^{15} Btu.^{3,4} The energy used for space heating accounted for over half the total energy used in the residential sector during this time period. Because space heating accounts for such a large share of residential energy use, improvements in new space heating systems could have significant long-term energy conservation effects.

Tables 1 and 2 summarize the energy and cost impacts of the design changes in gas, oil, and electric space heating systems evaluated in

Table 1. Gas and oil heating systems energy savings with various design changes

Option	Gas systems		Nominal ^a payback period (years)	Oil systems		Nominal ^a payback period (years)
	% Energy savings	% Cost increase		% Energy savings	% Cost increase	
1. Properly sized furnace	5	-12	0	4	-13	0
2. Bonnet thermostat set 5°F above room temperature	6	0	0	6	0	0
3. Automatic flue damper	11	5	5	8	5	4
4. Duct insulation increased to 2"	2	1	5	2	1	4
5. Sealed combustion	13	14	8	11	8	6
6. Increase steady state efficiency to 84%	16	9	5	18	8	4
7. Electric ignition	5	7	13	-	-	-
8. Gas organic fluid absorption heat pump	45	80	16	-	-	-
9. 3, 7	17	13	7	-	-	-
10. 3, 6, 7	24	22	8	-	-	-
11. 2, 5, 6, 7	26	27	9	-	-	-
12. 3, 6	-	-	-	18	12	5
13. 2, 5, 6	-	-	-	20	16	7
Baseline	84.9 × 10 ⁶ Btu/yr	\$1310		78.5 × 10 ⁶ Btu/yr	\$1815	

^a1975 gas and oil prices assumed. Gas is \$1.69 per 10⁶ Btu and oil is \$2.80 per 10⁶ Btu.

Table 2. Electrical heating system energy savings with various design changes for two cities

Option	Cleveland		Nominal ^a payback period (years)	Atlanta		Nominal ^a payback period (years)
	% Energy savings	% Cost increase (1975 \$)		% Energy savings	% Cost increase (1975 \$)	
1. 1975 model heat pump	35	11	1	50	13	2
2. High efficiency I	48	25	2	57	26	4
3. High efficiency II	47	41	3	53	35	6
4. High efficiency III	44	15	1	52	18	3
5. Compressor indoors (optimized at 28°F)	48	13	1	56	15	3
6. Two equally sized compressors (optimized at 32°F)	53	16	1	60	19	3
7. Two speed compressor (optimized at 32°F)	53	21	1	61	24	4
8. Compressor indoors (optimized at 19°F)	55	27	2	62	31	5
9. Two equally sized compressors (optimized at 24°F)	61	31	2	67	35	5
10. Compressor indoors (optimized at 16°F)	59	62	4	65	70	10
11. Duct insulation increased to 2"	3	1	1	3	1	2
Baseline ^b	77.0 × 10 ⁶ Btu/yr	\$2802		28.2 × 10 ⁶ Btu/yr	\$2488	

^aBased on an end use price of \$0.032 per kWhr (\$9.38 per 10⁶ Btu).

^bBaseline is electric furnace plus central air conditioning.

this report. These energy use and cost figures represent those expected on "average" heating systems.*

For the gas heating system, the largest reduction in annual energy use was due to the organic fluid absorption heat pump. This reduced energy use 45% relative to the conventional central gas furnace, and increased installed cost \$1060.[†] The payback period for the gas heat pump was 16 years.^{††} For a gas heating system modified to include sealed combustion, electric ignition, increased steady state efficiency, and lower bonnet thermostat setting, energy use decreased 26% and capital cost increased \$350. The payback period for this option was 9 years. Calculated energy use and installed cost of the energy conserving options for the gas furnace are shown in Fig. 1.

For the oil heating system, increasing the steady state efficiency to 84%, reducing the bonnet thermostat setting, and switching to a sealed combustion unit produced the largest decrease in energy use of all options considered (see Fig. 2): 20%. The increased installed cost was \$290.

The conservation options considered for electric systems were heat pumps. These included both conventional and advanced heat pumps. To provide a realistic estimate of improvement in energy use with heat pumps, both a Northern climate (Cleveland) and Southern climate (Atlanta) were used in the evaluation. The large opportunities for reducing energy use

*The uncertainty in the energy and cost figures used for the "average" system is reflected in the wide variation in the figures reported from the sources used in this report. For example, option 5 for a gas furnace considers a switch to a sealed combustion furnace. The value used for the energy saving is 13%. Values from 4 to 26% can be found in published literature. Appendix B gives the range of energy savings and capital cost increases for each option where information was available.

[†]All costs were 1975-\$.

^{††}The payback period (also called "nominal payback period") was based on 1975 fuel prices. For a particular option, it was defined as

$$\text{payback period} = \frac{\text{Increase in Capital Cost}}{\text{Yearly Savings in Fuel Costs}}$$

This definition does not include the time value of money or increase in fuel prices.

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Fig. 1. Annual space heating energy use vs installed cost for design changes in a gas heating system in Philadelphia. The price of a central air conditioner was subtracted from the price of the organic fluid absorption heat pump.

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Fig. 2. Annual space heating energy use vs installed cost for design changes in an oil heating system in Philadelphia.

with heat pumps (as compared to a central electric furnace) are illustrated in Figs. 3 and 4. For Cleveland, a 48% decrease in energy use was calculated for the best conventional heat pump. The same system in Atlanta provided a 57% reduction in energy use. For the best advanced heat pump system, energy reductions of 61% and 67% were calculated for Cleveland and Atlanta, respectively.

Section 2 discusses historical trends in residential heating systems sales and installations. These data are used to define representative gas, oil, and electric systems. The energy and cost impacts of various energy conserving design options for gas, oil, and electric heating systems are discussed in Sections 3, 4, and 5, respectively. The national energy and economic effects of adopting these design changes are discussed in Section 6. Section 7 presents conclusions from this study and recommendations for further study based on the results of this investigation.

2. Market Trends

This section reviews data on residential space heating installations. These data are used to define representative gas, oil, and electric heating systems analyzed in Sections 3-5.

Table 3 shows the number of space heating systems in use for the years 1950 to 1975.^{5,6} During this period, the percentage of homes heated by gas grew from 26% to 56%. In 1975, oil and electric heating systems accounted for 23% and 13%, respectively, of all residential heating systems. However, in the five years from 1970 to 1975, the number of homes heated by electricity increased 86%. A large portion of this growth is attributable to the large percentage of new single family homes with electric heating. Forty nine percent of single family homes built in 1976 had electric heating.¹¹ This was up from 31% in 1971.¹⁰ If electric heating continues its rapid growth, it could surpass oil as the second leading heating fuel in the residential sector by 1980.

Fig. 3. Annual space heating energy use vs installed cost for design changes in an electric heating system in Cleveland. The base system included central electric furnace and air conditioner.

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Fig. 4. Annual space heating energy use vs installed cost for design changes in an electric heating system in Atlanta. The base system included central electric furnace and air conditioner.

Table 3. Household space heating systems ownership: 1955-1975
(10⁶ systems)^a

Year	Electricity	Gas	Oil	Other	None	Total
1950	0.3	11.1	9.5	20.6	0.6	42.1
1960	1.0	22.9	17.2	11.6	0.5	53.0
1970	4.9	35.0	16.5	6.7	0.4	63.4
1973	7.2	38.5	17.3	6.0	0.5	69.3
1974	8.4	39.4	16.9	5.6	0.5	70.8
1975	9.1	40.9	16.3	5.7	0.4	72.5

^aDeveloped from refs 5 and 6.

Table 4 shows the distribution of residential space heating equipment in use in the ten federal regions for 1975 (See Fig. 5 for a map of the ten regions.)⁶ Gas was used in over 70% of the homes in five of the ten regions (5, 6, 7, 8, and 9).⁷ These regions included the midwestern, plains, mountain, and southwestern states. The convenience of installing and burning gas, its lower price, and availability could help explain its popularity in these states. The price of gas averaged \$1.37 per 10⁶ Btu in these five regions in 1975 compared to \$2.76 per 10⁶ Btu and \$8.92 per 10⁶ Btu for oil and electricity,^{*} respectively.^{7,8} Over half the homes in the Northeast (regions 1 and 2) used oil for space heating.⁷ Availability and lower price (compared to either gas or electricity) were probably the factors most influencing its popularity in these two regions.⁸ Electricity was popular in regions 4 and 10. In both these regions, electricity has been a traditionally inexpensive and available fuel for residential space heating because of the presence of the Tennessee Valley Authority (region 4) and the Bonneville Power Administration (region 10).

^{*}Based on end use, not primary energy

Table 4. Residential space heating equipment distribution in the ten Federal regions in 1975
(percent)

Fuel	Federal Region ^a									
	1	2	3	4	5	6	7	8	9	10
Gas	24.9	39.8	48.3	33.8	70.0	77.2	73.5	74.2	80.1	24.6
Oil	67.8	55.7	34.9	18.1	17.1	5.0	8.5	11.3	7.0	30.7
Electricity	5.7	3.1	8.9	30.8	6.0	10.8	5.1	4.0	13.3	37.3
Other	2.0	1.4	7.9	17.3	6.8	11.5	13.0	10.5	5.9	7.3

^aDue to rounding, the totals for a region may not add up exactly to 100%.

Fig. 5. Map of the United States showing Federal regions.

Residential heating systems were divided into three general categories: central, built in, and other.⁹ Central systems included forced-air furnaces (with ducts), heat pumps, gravity furnaces, and hot water* systems. Built-in heating systems included electric baseboard, panel and radiant heat, space heaters, floor furnaces, and wall furnaces. The classification, "other", included solar systems, no heating systems, wood stoves, fireplaces, and unknown systems. Figure 6 shows the breakdown of the installation of these three classes of heating systems in new single-family residences from 1950 to 1976.^{9,10,11} During the past twenty years, central systems were the most widely installed systems of the three with a market share of approximately 80% in new single-family residences.

Figure 7 shows the distribution of central heating systems installed in new, single-family residences from 1950 to 1976.^{9,10,11,12} Forced-air systems, which include warm air furnaces and heat pumps, were the most popular, accounting for over 90% of the central systems installed since 1970.^{9,10,11} Perhaps one reason why forced-air systems account for such a large share of the central systems market is their compatibility with central air conditioning systems. Central air conditioning and central forced-air furnaces use the same thermostat and air distribution system. From 1974 to 1976, central air conditioning systems (including heat pumps) were installed in approximately two thirds of new single-family residences.^{12,13} During that same period, central and forced-air heating systems comprised 73% of the installations in new single-family residences (see Figs. 6 and 7).

The percentage of central, forced-air gas furnaces to the total number of gas heating systems in single-family residences increased from 58% in 1970 to 64% in 1975 (see Appendix A for a breakdown of heating systems in use by equipment and fuel type). During that same period, the percentage of central, forced-air oil furnaces grew from 44% to 51% of the total oil systems in existing single-family residences.⁶ For

*"Hot water" systems include heating systems that use steam or hot water.

Fig. 6. Heating systems installed in new single family residences: 1950-1976. NOTE: The Bureau of the Census did not distinguish between "built-in" and "other". (Based on 1973 data from the NAHB Research Foundation, it was assumed that "other" accounted for 1% of the total in 1974, 1975, and 1976.)

Fig. 7. Central heating systems installed in new single family residences: 1950-1976.

both oil and gas heating systems, the forced-air central furnace was chosen as the "typical" or representative heating system for this analysis.

Table 5 shows a breakdown of the eight most important heating systems in existing single-family residences for the years 1970, 1973, 1974, and 1975.⁶ The gas central, forced-air systems was the most common heating system for each of the four years. Of particular note is the dramatic percentage increase in the market share for electric central, forced-air systems: a jump from 0.9% to 3.2%, a 255% increase.

Table 5. Breakdown (by percent) of eight popular heating systems in existing single-family homes^a

System	Year				% Change from 1970 to 1975
	1970	1973	1974	1975	
Gas central forced-air	33.0	36.5	32.2	32.8	-1
Oil central forced-air	10.8	10.9	12.0	11.8	9
Oil boiler	7.7	7.9	7.5	7.4	-4
Gas floor or wall furnace	7.9	8.7	7.2	7.0	-11
Built-in electric	4.4	4.9	6.4	6.6	50
Electric central forced- air furnace ^b	0.9	2.0	2.6	3.2	255
Electric heat pump ^b	0.8	1.1	1.2	1.3	63
Gas boiler	5.0	4.6	4.2	4.0	-20
Other	29.5	23.4	26.7	25.9	-12

^aDeveloped from ref. 6.

^bDeveloped from estimates given by Edison Electric Institute and ref. 6.

Figure 8 shows the number of electric space heating systems in residences from 1956 to 1975.¹¹ Electric furnaces and baseboard systems comprise the largest percentage of units in use (27% for each type in 1975). However, in 1975, electric furnaces were installed in 52% of new electrically heated residences, while baseboard heaters were installed

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Fig. 8. Electric space heating systems in residences: 1956-1975.

in only 22%. Heat pump installations were third with 17% that year. However, heat pump installations in new residences increased by 113% in 1976 over installations in 1975.¹⁴ Because installations of central forced-air electric furnaces have grown rapidly in recent years, a central forced-air furnace was chosen as the base electric system for the analysis in section 5. Electric heat pumps were used as conservation options to the furnace.

3. Gas Systems

The annual energy requirements and capital costs of several advanced gas heating systems and various energy conserving design options for a representative gas furnace are examined in this section. The energy usage data were developed from recent literature,^{14,15,16,17,18,19,20} while cost data were obtained from manufacturers and dealers of gas heating equipment and available literature.^{14,21,22,23}

The reported energy saving (and capital cost) of each of the energy conserving design options varied widely in the above references. Appendix B gives the range of energy savings and capital cost increases reported in these references. In each of the studies cited, authors made different assumptions about the characteristics of the structure, distribution system, and furnace. These assumptions lead to the variations in energy and capital cost figures.

The characteristics of the base house used in this analysis were developed from ref. 14. These are listed in Table 6. The house exceeds the ASHRAE 90-75 standards for residential energy conservation construction (see refs. 14 and 24).

Table 6. Characteristics of the base house

Location:	Philadelphia
Living area:	1850 ft ²
Design heating load:	41×10^3 Btu/hr
Annual heating load:	48.6×10^6 Btu

The atmospheric combustion furnace has been the most commonly installed central gas forced-air heating system in single-family detached housing.¹⁵ If the atmospheric combustion furnace was placed in the conditioned space, then it would draw its combustion and draft hood air from the conditioned space. However, if the furnace was located in an attic, basement (assuming the basement is not heated), crawl space, or outside the house, it would draw little or no air from the conditioned space.

For this analysis the base furnace was assumed to be an atmospheric unit, located within the conditioned space and double oversized.* Reference 15 suggests that double oversizing of residential gas furnaces is "typical" practice. Field investigations on hundreds of oil-fired systems in homes in the Minneapolis and Boston areas found that, on the average, furnaces were oversized by approximately 91 and 147% in those two cities.^{26,27} Because sizing practices are similar for oil and gas furnaces, oversizing of gas heating systems should be comparable to that of oil heating systems.

Seasonal performance factors (SPF) from available literature were averaged to determine the SPF and annual energy consumption for particular energy conservation options examined in this report (See Appendix B for SPFs and details on calculations). The SPF is defined as:

$$\text{SPF} = \frac{\text{Total annual heat energy provided by the heating system}}{\text{Total annual fuel energy used by the heating system}}$$

The total energy used by the system for heating the house includes the fuel used for heating, and the auxiliary energy used by the system (such as electricity used for air distribution).

* A heating system is properly sized when its output matches the design heating load of the house. A double oversized system has a rated output twice the design heating load of the house.

The SPF of the base furnace was 0.61. SPF values calculated in this section were averaged from SPF values calculated in refs. 15, 16, 17, and 20 (see Appendix B). The climate and degree of oversizing of the base gas heating system in these references are shown in Table 7.

Table 7. Climate and degree of oversizing of reference gas furnaces in refs. 15-17 and 20

Reference	Climate		Percent oversizing
	City	Annual heating ^{a,b} degree days	
15	Philadelphia, PA	4815	100
16	Washington, D.C.	4224	85
17	Baltimore, MD	4383	100
20	Canton, OH	6037	61 ^c

^aAlso abbreviated HDD

^bAssumes a base of 65°F

^cEstimated from data given in ref. 20

Details of the characteristics of the reference gas heating system chosen for this study are listed in Table 8.

Energy saving and installed cost increases were evaluated for several energy saving design modifications in the base furnace (See Table 1). These included:

1. Properly sizing the unit
2. Adjusting the bonnet thermostat to 5°F above room temperature
3. Installing an automatic flue damper
4. Installing 2" of fiberglass duct insulation instead of 1"
5. Switching to a sealed combustion furnace
6. Increasing steady state efficiency to 84%
7. Installing electric ignition.

Properly Sizing the Unit — As stated previously, it has been common practice to oversize heating systems. With the reference furnace properly sized, the calculated annual energy saving is 4.0×10^6 Btu.^{15,17} For a

Table 8. Characteristics of the reference gas heating system

Furnace system	Ductwork
Location: within living area	Insulation: 1" fiberglass
Size: input - 110,000 Btu/hr output - 84,700 Btu/hr	Heat loss: 3.2×10^6 Btu/yr
Type: Atmospheric combustion with standing pilot	Costs (1975-\$)
Efficiency: steady state - 77% seasonal - 61%	Furnace: 500
Annual fuel consumption: 84.9×10^6 Btu	Ductwork: 573
	Chimney 80
	Duct
	Insulation: 157
	Total 1310
	Gas price: 1.69 per 10^6 Btu

natural gas price of \$1.69 per 10^6 Btu, the annual saving is \$6.70.*²⁵ The initial saving in capital cost with the properly sized unit is \$150. The SPF increases from 0.61 in the base case to 0.64 for the properly sized unit.

Adjusting the Bonnet Thermostat to 5°F above Room Temperature — Gas furnaces have a thermostat that senses bonnet air temperatures and controls the temperature that the circulating air fan comes on and off. Typically, the fan is set to come on between 125 and 140°F and turn off at 100°F.¹⁵ Most of the heat stored in the heat exchanger after the blower stops is not distributed to the heated space and is thus lost.

Adjusting the thermostat so the fan comes on and off at 5°F above room temperature reduces annual energy use by 5.2×10^6 Btu, decreases fuel cost by \$9, and incurs no increase in capital cost.^{15,17,20}

Installing an Automatic Flue Damper — During the off cycle, heat can escape up the flue of the standard atmospheric combustion furnace. An automatic flue damper closes the flue during the off cycle to prevent heat from escaping. Adding a flue damper to a furnace increases the installed cost \$85. The calculated annual energy reduction is 9.8×10^6 Btu; this yields an annual saving in fuel cost of \$17 and a payback period of 5 years.^{16,17,18,20} The automatic flue damper is sold as an option on gas furnaces by some manufacturers.

Installing 2" of Fiberglass Duct Insulation Instead of 1" — In the base case, only 1" of insulation was used to cover the ducts. Increasing the insulation to 2" adds \$20 to the capital cost, decreases annual energy use 2.1×10^6 Btu, and saves \$3.50 in fuel costs. The payback period is 5 years.

Switching to a Sealed Combustion Unit — A sealed combustion furnace has its combustion chamber separated from the conditioned air in the house. Its combustion air is drawn directly from the outside, and, in many cases, is preheated by the hot combustion products in the flue. A sealed combustion unit costs about \$140 more than a comparable atmospheric combustion unit. There are only a few sealed combustion units on the

*The gas price is the national average for residential customers in 1975.

market designed for use in single-family residences. Most are designed for application in mobile homes because mobile home codes specify that the combustion air for furnaces not be drawn from the living area.²⁸

An average SPF of 0.70 was calculated for a switch to a sealed combustion furnace.^{15,16,17,20} The annual fuel and cost savings are 10.9×10^6 Btu and \$18, respectively. The payback period is 8 years.

Increasing the Steady State Efficiency to 84% — The theoretical upper limit of the steady state efficiency before water starts to condense on the heat exchanger or flue is between 82 and 86%. A source from one manufacturer stated that the "real world" limit was about 82%. A recent report stated that the theoretical upper limit was about 86% for a gas furnace.¹⁷ For this study, 84% was used as the upper limit for the steady state efficiency.

To approach this limit, several furnace modifications must be made. These included: redesigning the heat exchanger, constructing the heat exchanger from rust resistant materials (such as aluminized steel), and adding an induced draft fan.^{17,20} The estimated installed cost of the unit increases \$115. The calculated annual energy and cost savings are 13.9×10^6 Btu and \$24, respectively. The payback period is 5 years.

Installing Electric Ignition — The pilot light in the base furnace operates continuously. Thus, the pilot heat is not delivered to the living area when the circulating fan (blower) is not in operation. The calculated energy loss for the standing pilot is 4.0×10^6 Btu/yr.^{15,16,17,20} With the installation of electric ignition, this loss is eliminated. This adds \$90 to the cost of the furnace and reduces annual fuel costs \$6.70. The payback period is 13 years. This option is available on new furnaces from some manufacturers.

Advanced Gas Heating Systems — There are several types of advanced gas heating systems being developed for residential applications. These include the organic fluid absorption heat pump, the Stirling/Rankine heat pump, and the pulse combustion furnace. References 14 and 29 give detailed descriptions of these systems.

The organic fluid absorption heat pump is expected to be marketed by 1981, and the Stirling/Rankine heat pump by 1985.*¹⁴ No timetable was available at the writing of this report on when the pulse combustion furnace would be marketed.³¹

The projected heating seasonal performance factors for the three advanced systems are given in Table 9.¹⁴

Table 9. Estimates of the SPF for three advanced gas heating systems

System	SPF
Organic fluid absorption heat pump	1.10
Stirling/Rankine heat pump	1.41
Pulse combustion furnace	0.93

Only price estimates for the organic fluid absorption heat pump were available.^{14,29} Most of the cost information has not been released by the companies developing the advanced systems.^{14,29}

The organic fluid absorption heat pump used with the base house has a cooling capacity of 36,000 Btu/hr at 95°F and heating capacities of 76,000 and 87,000 Btu/hr at 17°F and 47°F, respectively.¹⁴ This unit has an estimated installed cost of \$3540.¹⁴ Because the gas heat pump provides both cooling and heating, while gas furnaces provided only heating, the price of the heat pump was adjusted to account for its cooling capabilities. The price of a central air conditioning system (\$1200) was subtracted from the price of the organic fluid absorption heat pump. This yielded a price of \$2340 for the heat pump for comparison with the furnace.

The annual energy and cost savings with the gas absorption heat pump are 38×10^6 Btu and \$64, respectively. The added cost of the heat pump is \$1040, which gives a payback period of 16 years.[†]

* One goal of the American Gas Association's heat pump research program is "to have gas-fired heat pumps available for the residential market by 1981."³⁰

[†] The payback period for the gas heat pump does not include the expected increased maintenance cost of the heat pump.

4. Oil Systems

The annual energy requirements and capital costs of several energy conserving design options for a representative oil furnace are examined in this section. The energy use estimates were developed from refs. 14, 17, 20, 26, and 32. Cost data were obtained from manufacturers and dealers of oil heating equipment. The same house and weather conditions used in Section 3 were also used for the oil furnace analysis. The furnace is assumed to be located within the conditioned space and oversized by a factor of two. The SPF of the base furnace is 0.66. The SPF values used in this section to determine annual energy use were calculated by averaging the SPF values found in refs. 14, 17, 20, and 26. (See Appendix B for details.) The climate and degree of oversizing of the base oil furnaces in these references are shown in Table 10.

Table 10. Climate and degree of oversizing of the base oil furnaces in refs. 14, 17, 20, and 26

Reference	Climate		Percent oversizing
	City	Annual heating degree days ^a	
14	Philadelphia, PA	4815	122
17	Baltimore, MD	4383	100
20	Canton, OH	6037	61
26	Boston, MA	6870	147

^a Assumes a base of 65°F

^b Estimated from data given in ref. 20.

The characteristics of the base oil heating systems used are listed in Table 11.

Energy savings and installed cost increases were evaluated for several energy conserving design modifications in the base furnace. These included:

1. Properly sizing the unit
2. Adjusting the bonnet thermostat to 5°F above room temperature

3. Installing an automatic flue damper
4. Installing 2" of fiberglass duct insulation instead of 1"
5. Switching to a sealed combustion furnace
6. Increasing the steady state efficiency to 84%.

Table 11. Characteristics of the base oil heating system

Furnace system	Ductwork
Location: within living area	Insulation: 1" fiberglass
Size: input - 110,000 Btu/hr output - 84,700 Btu/hr	Heat loss: 3.2×10^6 Btu/yr
Type: flame-retention head burner	Costs (1975-\$)
Efficiency: steady state - 77% seasonal - 66%	Furnace: 649
Annual fuel consumption: 78.5×10^6 Btu	Ductwork: 573
	Chimney: 194
	Duct insulation: 157
	Oil tank: 266
	Total 1839
	Fuel oil price: \$2.80 per 10^6 Btu

Because oil and gas furnaces are both fossil fuel furnaces, most of the energy conserving design options are the same for the two. For this reason, only a brief discussion of the options is given in this section to avoid repetition of what was stated in Section 3. Table 1 presents a summary of the energy use and cost information of the energy conserving design options for the base oil heating system; see also Fig. 2.

Electric ignition is not included as an energy conserving design option for oil furnaces because oil furnaces already come equipped with electric ignitors. Because of this, the energy saving potential for an oil furnace is smaller than a gas furnace which normally has a standing pilot.

As with the gas furnace, the options that provide the fastest return on initial investment are properly sizing the furnace, and lowering the bonnet thermostat setting. By properly sizing the unit, not only is the

annual energy cost reduced by \$10, but the capital cost is \$250 less than the base furnace. Reducing the setting on the bonnet thermostat reduces the annual fuel costs by \$13 but does not increase the installed cost of the system.

The option with the longest payback period is the sealed combustion furnace. Even though the savings in annual fuel bills is \$24, the increased capital cost of the unit makes the payback period longer than the other options.

Brookhaven National Laboratory (BNL) is currently testing three "new" technology oil burner designs. These include: the blue flame burner, the air atomizing burner, and the ultrasonic atomizing burner.^{34,35} Descriptions of these burners can be found in ref. 35, and a description of the atomizing burner in ref. 36. The blue flame burner is currently available on warm air furnaces. From initial tests on blue flame furnaces (a warm air furnace with a blue flame burner), steady state efficiencies up to 84.5% were measured. The added capital cost of a blue flame furnace is about \$90.³⁴ No seasonal performance data is available on any of the three burners. As more testing is completed at BNL, the apparent benefits and drawbacks of these burners should become known.

5. Electrical Systems

The annual energy requirements and capital costs of a central electric furnace and several current and advanced heat pumps are examined here. Energy use and cost data were developed from refs. 14 and 37.

The base house used in Section 3 was also used to evaluate the effects of conservation options for electrical heating systems. However, the house was placed in two climates — a northern and southern climate. For the northern climate, the house was assumed to be in Cleveland, Ohio, which averages 6350 heating degree days (HDD) annually.³⁸ For the southern climate, the house was assumed to be in Atlanta, Georgia, which averages 2960 HDD annually.³⁸ The two different climates were needed to provide a realistic evaluation of the annual heat pump performance, which is very climate dependent. The characteristics of the

base house for the two climates are listed in Table 12.¹⁴ Because central, forced-air electric furnaces comprise the largest percentage of any single type of new electric heating systems (see Section 2), it was used as the reference heating system in this section. The base furnace in the Cleveland house is rated at 15.4 kW (52,400 Btu/hr), while the one in the Atlanta house is rated at 10.6 kW (36,000 Btu/hr).^{14*}

Table 12. Characteristics of the base house

Item	Climate	
	Northern	Southern
Location	Cleveland	Atlanta
Living area (ft ²)	1850	1850
Design heating load (Btu/hr)	42.9×10^3	33.3×10^3
Annual heating load (Btu)	70.7×10^6	25.4×10^6

The installed costs of the central electric furnaces are \$1700 and \$1440 for Cleveland and Atlanta, respectively.¹⁴ The ductwork and duct insulation, and their associated prices are the same as those in Section 3. The heat loss in the duct system is 4.8×10^6 Btu/yr in Cleveland and 2.2×10^6 Btu/yr in Atlanta. Electricity is assumed to cost \$0.032 per kWhr.[†]

Because only heat pumps are considered as energy conserving options to the electric furnaces, some adjustment has to be made to account for the cooling capabilities of the heat pump. For comparison purposes, it is assumed that the household buying the furnace would also buy a central air conditioner. This increases the price of the base system to \$2800 and \$2490 in Cleveland and Atlanta, respectively.¹⁴

The conventional heat pumps save significant amounts of energy compared to the base heating system. Even a representative 1975 heat

* All electrical energy figures are end use energy.

† The average residential electrical rate was \$0.034 and \$0.028 per kWhr in Cleveland and Atlanta, respectively in 1975. \$0.032 was the national average residential electrical rate in 1975.

pump model with a coefficient of performance (COP)^{*} of 1.6 at 17°F and 2.6 at 47°F ambient temperature has a seasonal performance factor of 1.68 and 1.97 in Cleveland and Atlanta, respectively.¹⁴ For Cleveland, this yields an annual reduction of \$250 in fuel bills over the central electric furnace. For Atlanta, a \$130 reduction was calculated. The payback period is one year in Cleveland and two years in Atlanta.

The energy conserving options considered in this analysis came from refs. 14 and 37. The options from ref. 14 were primarily heat pump designs already on the market (labeled as "high efficiency" heat pumps).[†] Some advanced designs were discussed in that reference, but no cost estimates were given for them.

Various optimized heat pump designs were considered in ref. 37 using a heat pump computer simulation program. The primary changes in component design dealt with the compressor: placing the compressor indoors, using a two speed compressor motor to drive the compressor and using two equally sized compressors. The heat pump systems were optimized for these three design changes at different design (or balance) temperatures.[‡] Other design changes in the optimization included: indoor and outdoor coil effective size and air flow rates, fin spacing, number of rows of tubes, fraction of indoor coil devoted to liquid subcooling, and indoor duct system effective size.

By placing a heat pump compressor indoors, the heat loss from the compressor shell is utilized inside the house. This modification can provide a "gain of up to 20 percent in cold day capacity and COPH[§]".³⁷ Using either a two speed compressor motor or two equally sized compressors

^{*} Coefficient of performance is defined as:³⁷

$$\text{COP} = \frac{\text{Heat delivered by the heat pump}}{\text{Electric energy used by the heat pump}}$$

[†] Very little information was given in ref. 14 on the physical characteristics of the "high efficiency", I, II and III heat pumps.

[‡] Balance temperature is the temperature that resistance heating is first needed to augment the heat pump.

[§] COPH as used in ref. 37 is the same as COP used in this report.

allows the heat pump to better match the heating load on the house, thus reducing the on and off cycling at lower heating loads and saving energy.*

Heat pump performance was evaluated in three Northern cities in ref. 37: Albany, Denver, and Boston. The heat pump performance data from Albany were used for the analysis of advanced heat pump systems in this section. The seasonal performance factors from ref. 37 were modified to account for the effect of dynamic operation on the heat pump performance.^{40,41} To make the findings from ref. 37 consistent with those in ref. 14 (which accounted for the lower dynamic performance of heat pumps) the SPF's were reduced by 8%.[†] This is the same reduction used in ref. 14 for Cleveland. It was assumed that the same reduction can be used because the climate of Albany with 6580 heating degree days is similar to Cleveland with 6380 heating degree days.

To begin with the same price heat pump in refs. 14 and 37, the price of the 1975 unit in ref. 37 was set equal to the price of the standard unit in ref. 14. Sources of the prices in ref. 14 included manufacturers, contractors, and the *Means Building Construction Cost Data Book*.²² In ref. 37, the source of prices was the Westinghouse Corporation. How the prices on the advanced systems were determined was "Westinghouse proprietary data and ... not available to general distribution" p. 2.2-13.

The energy use, capital costs, fuel cost savings, and payback periods of the energy conservation design options for electric heating systems

* Even though these advanced technology design changes save more energy than conventional changes, some of them might not make it to the market place for other reasons. In particular, placing the compressor indoors may save energy in the heating mode but it will also increase the cooling load on the house in the summer. An indoor compressor could also be very disturbing to the occupants if the compressor were not made quieter by redesign or acoustic isolation.

[†] No seasonal performance information for the advanced systems in the Southern climate (Atlanta) was available since ref. 37 considered only the heat pump performance in Northern climates. To estimate the seasonal performance of the advanced systems in Atlanta, SPF improvement information was adapted from ref. 14. The average improvement in seasonal performance for the conventional heat pumps in moving from Cleveland to Atlanta was first calculated. This improvement was 18%. Each of the seasonal performance factors of the advanced heat pumps were then increased by this same amount to obtain an estimate of their SPF values in Atlanta.

are listed in Table 2 for Cleveland and Atlanta. Even though the percentage energy saved for a particular option is larger in Atlanta than Cleveland, the amount of energy saved is larger in Cleveland because of the larger heating load and the longer heating season. The payback period for a particular design option is also shorter in Cleveland than in Atlanta.

6. National Effects of Reducing Space Heating Energy Use

The ORNL residential energy use simulation model^{1,2} was used to evaluate the effects on national energy use and household economics of adopting combinations of the space heating design options discussed in the previous section. This simulation model was also used to estimate the average SPF of new equipment and to provide projections of the total number of homes heated by either electricity, gas or oil in 1978, 1980, 1985, 1990 and 2000.

Four cases were run with the simulation model. In the first, the baseline, it was assumed that the market for purchasing new heating systems was allowed to operate under free market conditions and that improvements in conventional systems were available during the projection period (1977-2000). The input data for this case were developed from the energy use versus capital cost curves for improvements in conventional heating systems given in Sections 3-5. For the baseline, space heating energy use grew from 8.4 QBtu^{*} per year in 1977 to 11.8 QBtu per year in 2000, an average growth of 1.5%/year (see Figure 9).

The second case assumed that advanced heating systems became available to consumers in 1980. These advanced systems included the gas heat pumps discussed in Section 3 and the advanced electric heat pumps in Section 5. Space heating energy use grew at an average annual rate of 1.6%. The cumulative energy use was 3.7 QBtu below the baseline (see Table 13). This resulted in a saving in fuel expenditures of \$3.8 billion

^{*} 1 QBtu = 10^{15} Btu.

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Fig. 9. Alternative projections of residential space heating energy use to the year 2000.

Table 13. Cumulative (1977-1980) effects of reducing residential space heating energy use

Case	Description	Space heating energy savings (10 ¹⁵ Btu) 1977-2000	Present worth at 8% real interest			Benefit/cost
			Increased equipment expenditures (cost)	Fuel expenditures savings (benefit)	Net economic benefit	
1	Baseline (Free market)					
2	Baseline plus introduce advanced systems in 1981	3.7	0.4	3.8	3.4	9.5
3	Baseline plus advanced systems plus consumer minimizes life cycle costs	14.2	7.2	10.9	3.7	1.5
4	No space heating Equipment improvement	-15.3	-2.4	-16.0	-13.6	0.2 ^a

^aFor case 4, the negative cost becomes the benefit and the negative benefit the cost.

and an increase in equipment expenditure of \$0.4 billion. The net economic benefit was therefore \$3.4 billion.*

The third case was the same as the second case except that it assumed that consumers would minimize life cycle costs beginning in 1980.[†] The previous cases assumed that consumers would respond to fuel and capital cost increases as they had in the past under free market conditions. The average annual space heating energy growth rate was cut to 0.9%. Even though cumulative equipment expenditures were \$7.2 billion more than the baseline, the saving in fuel expenditures was \$10.9 billion. The resulting economic benefit to consumers from purchasing equipment on a life cycle cost basis was \$3.7 billion for the simulation period.

The ratio of the economic benefits (reduced fuel bills) to economic costs (higher equipment costs) for cases 2 and 3 were greater than 1.0. For case 2, the benefit to cost ratio was 9.5; for case 3, the ratio was 1.5. These results indicate that improvements in space heating performance can yield large energy and economic benefits to the nation.

If no improvements were made in space heating equipment through the year 2000, how would this affect energy use and fuel bills in the residential sector? This option was explored in the fourth case. Space heating energy use grew at an average annual rate of 2.1%. This was a 40% higher growth rate than the baseline case and over 100% higher than the third case. The cumulative energy use was 15.3 QBTU greater than the baseline forecast. Even though equipment expenditures were less than in the baseline (\$2.4 billion), there was a net economic loss of \$13.6 billion because of larger fuel expenditures. Though this was not a realistic case, it does provide an estimate of the upper limit of residential space heating energy use through the end of this century.

Table 14 shows the estimates from the ORNL simulation model of the percentage of homes heated by electricity, gas, or oil for the baseline. These estimates consider the number of homes in use for a particular year

* Present worth at 8% real interest rate.

[†] Life cycle cost is defined as the sum of the capital cost of the heating system plus the present worth of yearly operating costs discounted at 8%.

Table 14. Estimate of heating fuels used in existing homes
(percent)

Case	Description	Year				
		1978	1980	1985	1990	2000
1	Baseline (Free Market) ^a					
	Electricity	16	18	23	28	37
	Gas	56	55	54	51	43
	Oil	21	20	18	17	18
Total Stock of Homes (10 ⁶ units)		76.3	79.9	87.8	95.1	106.5

^aPercentages will not add to 100 because there are "other" systems such as coal, wood, etc. in use.

and are not estimates for the new housing market. Electricity is projected to increase its share of the market in home heating. In 1978, the model projected its use in 16% of all homes. This increased to 37% in 2000. In contrast, the model projected gas and oil declining from 56% and 21%, respectively, in 1978, to 43% and 18% in 2000. Projected percentages in cases 2, 3, and 4 deviated little from the baseline.

The average SPF's for new space heating equipment bought in 1978, 1980, 1985, 1990, and 2000 is shown in Table 15. The average SPF's increase with time because consumers are willing to pay for more efficient equipment as fuel prices rise. The largest increase in average SPF came when advanced systems were introduced in 1981 and consumers minimized life cycle (case 3). The smallest increase came when consumers responded to price increases as they had in the past and no advanced systems became available (case 1).^{*} These two cases provided a range in average SPF values expected of new space heating equipment bought in a particular year.

7. Conclusions and Recommendations

This report presents a "first cut" at defining the relationships between energy and capital cost for energy conserving design options

^{*}If case 4 were included, it would have the smallest increase in average SPF since no increase in SPF's were allowed for that case.

Table 15. Projected average SPF's of all new space heating equipment installed in homes

Case	Description	Year				
		1978	1980	1985	1990	2000
1	Baseline (Free Market)					
	Electricity	1.09	1.14	1.23	1.30	1.40
	Gas	0.65	0.67	0.70	0.73	0.76
	Oil	0.73	0.74	0.77	0.78	0.80
2	Baseline plus introduce advanced systems in 1981					
	Electricity	1.09	1.14	1.31	1.40	1.49
	Gas	0.65	0.67	0.73	0.76	0.80
	Oil	0.73	0.74	0.77	0.78	0.80
3	Baseline plus introduce advanced systems in 1981 plus consumers minimize life cycle costs starting in 1980					
	Electricity	1.09	1.26	1.95	2.22	2.28
	Gas	0.65	0.69	0.79	0.83	0.85
	Oil	0.73	0.76	0.82	0.83	0.84

on gas, oil, and electric space heating systems. These relationships were determined by surveying the current literature and consulting with personnel in the manufacturing, installation, research, and development of heating equipment.

Reductions in space heating energy use up to 26, 20 and 57% were calculated for design options in conventional gas, oil, and electric space heating systems, respectively. With advanced gas and electric systems, reductions of 45 and 67%, respectively, were calculated. These numbers indicate the large heating energy reductions possible on representative space heating systems. These reductions in energy use were generally accompanied by higher installed costs.

Most of the conservation options for gas, oil and electric space heating systems are cost effective at current energy prices. Payback periods range from 0 to 16 years for gas and oil systems, and from 1 to 10 years for electric systems.

For both gas and oil systems, proper sizing of the units provides the most attractive investment because it reduces the installed cost and uses less energy than a typical unit. Although the recent ASHRAE 90-75 standards provided design conditions to reduce oversizing the heating equipment,²⁴ it will be interesting to see if this has affected contractors and heating equipment installers.

The sealed combustion furnace has one of the longest payback periods for both gas and oil heating systems. One reason for this is the higher cost of the unit compared to the base furnace. The cost of the sealed combustion furnace was adopted from cost estimates of similar sized sealed combustion furnaces designed specifically for mobile home application. As companies "tool up" for sealed combustion furnaces for single-family residences, the price difference may drop and not be as great as given in this report. A smaller price difference would make the sealed combustion furnace a more attractive option.

If advanced gas heating systems continue to be developed and gas remains available, their impact on the market could be significant. With the possibility of using 45% less energy than a conventional gas furnace, these advanced systems could provide an attractive option in gas heated homes.

For electric heating systems, conventional heat pumps are cost effective alternatives to the electric furnace in both Atlanta and Cleveland. Even though conventional heat pumps have higher COP's in Atlanta, the savings in heating energy is greater in Cleveland because of the larger heating loads and longer heating season. The payback period for a particular heat pump is generally shorter in Cleveland than in Atlanta.

Due to limitations in this analysis, several recommendations for further study can be made:

1. Future analysis should be expanded to include representative systems in multi-family units and mobile homes. Only a single-family residence was considered when developing the energy use versus capital cost curves. A more detailed approach is needed. For example, as mentioned previously, most mobile homes have a

sealed combustion furnace rather than an atmospheric furnace. This would change the energy use and capital cost of the base furnace for analysis in mobile homes.

2. Future analyses should be expanded to provide estimates of the effects of heating systems improvements on a regional basis. The relationships between energy use and capital costs for the oil and gas systems were developed for only one city, and for electric systems, two cities. Because these relationships vary from region to region (because of variations in weather conditions and installation costs), using only one (or two) region(s) to provide estimates of the impact of space heating systems improvements on a national or regional basis is limited. Because gas accounts for such a large share of heating systems and electric heating is growing rapidly, it is recommended that a regional analysis (for at least 3 of the 10 Federal regions) be done for both of these heating systems. For oil systems, it is recommended that an analysis be done in those regions included in the Northeast areas of the country where oil systems are common. Because of the large number of oil hot water space heating systems, hot water systems should also be included in the oil analysis.
3. Future analyses should address the relationship between the residential structure and the heating system. The analysis in this report only considered changes in heating systems. It was assumed that the structural characteristics were constant. This is unrealistic. For instance, increases in insulation would lower the total annual energy used for heating and would thereby increase the payback period for improvement to the heating system. Or, improvements in the heating system would lower the total energy use for heating and would increase the payback period for added insulation. A better approach would be to examine the heating system and the structure as a complete system to determine the best conservation options.

4. Future analysis should include life cycle cost comparisons of all competing heating systems. For example, given the choice between an advanced gas heat pump, oil furnace, and an electric heat pump, which provides the most attractive option (in terms of minimum life cycle cost) to the consumer? Such a study (if sufficient in detail) could provide consumers with useful information to make intelligent decisions about home space heating equipment.

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Appendix A

HEATING SYSTEMS IN USE BY EQUIPMENT AND FUEL TYPE
(1970, 1973, 1974, and 1975)

The following is an explanation of the terms used to describe heating systems in the tables A.1 thru A.12.

1. Steam — Refers to a central heating system in which heat from steam or hot water is delivered through radiators or other outlets.
2. Central — Refers to a central system which provides warm air through ducts leading to various rooms. Heat pumps are included in this category.
3. Electric — Built-in electric units that are permanently installed in floors, walls, ceilings, or baseboards.
4. Pipeless — A floor, wall or pipeless furnace delivers warm air to the room right above the furnace to the room(s) on one or both sides of the wall in which the furnace is installed.
5. Flue — Room heaters with a flue which includes circulating heaters, convectors, radiant gas heaters, and other nonportable heaters that burn gas, oil, kerosene, or other liquid fuels, and which are connected to a flue, vent, or chimney to remove smoke or fumes.
6. W/O Flue — Room heater without a flue which includes any room heater (not portable) that burns gas, oil, or kerosene which is not connected to a flue, vent, or chimney.
7. Room — Portable heaters, fireplaces, or stoves that are used for heating purposes.
8. No Heat — The house is not equipped with any heating system.

Three classes of housing types are listed in tables A.1 thru A.12: single-family, multi-family, and mobile homes. Single-family includes "one-family detached and attached" units specified in the Department of Commerce, Bureau of Census, *Census of Housing* (ref. 5). Mobile homes include the category "mobile homes or trailers" in that same reference. Multi-family includes all other residential housing not included in those definitions.

The numbers in these tables come directly from the Bureau of Census, *Census of Housing and Annual Housing Survey*, tapes (ref. 6). Heating systems are classified by equipment and fuel type. There are four numbers for each classification. The following example shows how to interpret the numbers. Assume you are interested in gas hot water heating systems in existing single-family homes in 1970. Turn to Table A.1, and find gas hot water systems in the row labelled "STEAM" under the column labelled "GAS". There are four numbers. The top number, 2209, gives the total number of gas hot water heating systems in the survey. The second number, 5.0, gives the percentage of all space heating systems in existing single family residences that were gas hot water heating systems. The third number, 37.4, gives the percentage of all hot water heating systems that used gas as a fuel. The fourth number, 8.9, gives the percentage of gas heating systems that were hot water systems.

Table A.1 — Heating systems in existing single-family residences: 1970

TABLE VALUES FOR 1970 FUEL VERSUS EQUIPMENT TYPE ARE:

COUNT
TOTAL PERCENTAGE
ROW PERCENTAGE
COLUMN PERCENTAGE

EQUIPMENT	FUEL-TYPES				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0	2209.0 5.0 37.4 8.0	3396.0 7.7 57.4 31.5	309.0 0.7 5.2 5.7	5914.0
CENTRAL	730.0 1.7 3.4 25.2	14544.0 33.0 47.8 58.4	4768.0 10.8 22.2 44.2	1394.0 3.2 6.5 25.6	21436.0
ELECTRIC	1921.0 4.4 100.0 66.2	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	1921.0
PIPELESS	0.0 0.0 0.0 0.0	3485.0 7.9 81.2 14.0	441.0 1.0 10.3 4.1	365.0 0.8 8.5 6.7	4291.0
FLUE	0.0 0.0 0.0 0.0	2575.0 5.8 50.2 10.3	1756.0 4.0 34.2 16.3	803.0 1.8 15.6 14.8	5134.0
W/O FLUE	0.0 0.0 0.0 0.0	1659.0 3.8 59.8 6.7	281.0 0.6 10.1 2.6	836.0 1.9 30.1 15.4	2776.0
ROOM	251.0 0.6 10.6 8.6	453.0 1.0 19.2 1.8	147.0 0.3 6.2 1.4	1507.0 3.4 63.9 27.7	2358.0
NO-HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	230.0 0.5 100.0 4.2	230.0
TOTAL	2902.0	24925.0	10789.0	5444.0	44060.0

Table A.2 — Heating systems in existing single-family residences: 1973

TABLE VALUES FOR 1973 FUEL VERSUS EQUIPMENT TYPE ARE:

COUNT
TOTAL PERCENTAGE
ROW PERCENTAGE
COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE			TOTAL
	ELEC	GAS	OTHER	
STEAM	0.0 0.0 0.0	1521.0 4.6 35.6 8.0	2605.0 7.9 61.0 34.5	4269.0
CENTRAL	1013.0 3.1 5.8 36.2	12003.0 36.5 68.5 63.0	3581.0 10.9 20.4 47.4	17529.0
ELECTRIC	1609.0 4.9 100.0 57.6	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	1609.0
PIPELESS	0.0 0.0 0.0 0.0	2858.0 8.7 80.4 15.0	324.0 1.0 9.1 4.3	3555.0
FLUE	0.0 0.0 0.0 0.0	1170.0 3.6 45.4 6.1	904.0 2.7 35.1 12.0	2578.0
W/O FLUE	0.0 0.0 0.0 0.0	1416.0 4.3 63.9 7.4	86.0 0.3 3.9 1.1	2215.0
ROOM	173.0 0.5 17.7 6.2	95.0 0.3 9.7 0.5	50.0 0.2 5.1 0.7	975.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	175.0 0.5 100.0 5.0	175.0
TOTAL	2795.0	19063.0	7550.0	32905.0

Table A.3 — Heating systems in existing single-family residences: 1974

TABLE VALUES FOR 1974 FUEL VERSUS EQUIPMENT TYPE ARE:

COUNT

TOTAL PERCENTAGE

ROW PERCENTAGE

COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	1835.0 4.2 34.1 8.1	3323.0 7.5 61.8 31.3	218.0 0.5 4.1 3.6	5376.0
CENTRAL	1666.0 3.8 7.3 35.1	14211.0 32.2 62.5 62.4	5300.0 12.0 23.3 49.9	1571.0 3.6 6.9 26.2	22746.0
ELECTRIC	2816.0 6.4 100.0 59.2	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	2816.0
PIPELESS	0.0 0.0 0.0 0.0	3180.0 7.2 76.1 14.0	426.0 1.0 10.2 4.0	574.0 1.3 13.7 9.6	4180.0
FLUE	0.0 0.0 0.0 0.0	1683.0 3.8 42.9 7.4	1398.0 3.2 35.6 13.2	846.0 1.9 21.5 14.1	3927.0
W/D FLUE	0.0 0.0 0.0 0.0	1719.0 3.9 57.0 7.5	96.0 0.2 3.2 0.9	1198.0 2.7 39.8 20.0	3012.0
ROOM	271.0 0.6 14.8 5.7	142.0 0.3 7.8 0.6	83.0 0.2 4.8 0.8	1331.0 3.0 72.9 22.2	1827.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	249.0 0.6 100.0 4.2	249.0
TOTAL	4753.0	22769.0	10626.0	5987.0	44135.0

Table A.4 — Heating systems in existing single-family residences: 1975

TABLE VALUES FOR 1975 FUEL VERSUS EQUIPMENT TYPE ARE:

COUNT

TOTAL PERCENTAGE

ROW PERCENTAGE

COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	1765.0 4.0 33.7 7.7	3282.0 7.4 62.7 31.7	191.0 0.4 3.6 3.2	5238.0
CENTRAL	1999.0 4.5 8.5 38.1	14600.0 32.8 62.1 63.7	5262.0 11.8 22.4 50.0	1653.0 3.7 7.0 27.4	23514.0
ELECTRIC	2934.0 6.6 100.0 56.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	2934.0
PIPELESS	0.0 0.0 0.0 0.0	3108.0 7.0 77.3 13.6	352.0 0.8 8.8 3.4	561.0 1.3 14.0 9.3	4021.0
FLUE	0.0 0.0 0.0 0.0	1572.0 3.5 42.3 6.9	1311.0 2.9 35.3 12.7	836.0 1.9 22.5 13.9	3719.0
W/D FLUE	0.0 0.0 0.0 0.0	1708.0 3.8 59.3 7.5	65.0 0.1 2.3 0.6	1105.0 2.5 38.4 18.3	2878.0
ROOM	309.0 0.7 15.3 5.9	156.0 0.4 7.7 0.7	89.0 0.2 4.4 0.9	1471.0 3.3 72.6 24.4	2025.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	205.0 0.5 100.0 3.4	205.0
TOTAL	5242.0	22909.0	10361.0	6022.0	44534.0

Table A.5 — Heating systems in existing multi-family residences: 1970

TABLE VALUES FOR 1970 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPES				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	2872.0 16.5 39.4 30.4	3759.0 21.6 51.6 74.2	654.0 3.8 9.0 55.8	7285.0
CENTRAL	465.0 2.7 6.8 26.9	3301.0 19.0 69.2 35.0	833.0 4.8 17.5 16.4	170.0 1.0 3.6 14.5	4769.0
ELECTRIC	1201.0 6.9 100.0 69.6	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	1201.0
PIPELESS	0.0 0.0 0.0 0.0	979.0 5.6 91.2 19.4	64.0 0.4 6.0 1.3	30.0 0.2 2.8 2.6	1073.0
FLUE	0.0 0.0 0.0 0.0	1517.0 8.7 91.0 16.1	291.0 1.7 15.5 5.7	65.0 0.4 3.5 5.5	1873.0
W/O FLUE	0.0 0.0 0.0 0.0	563.0 3.2 82.4 6.0	77.0 0.4 11.3 1.5	43.0 0.2 6.3 3.7	683.0
ROOM	60.0 0.3 16.4 3.5	200.0 1.1 54.6 2.1	41.0 0.2 11.2 0.8	65.0 0.4 17.8 5.5	366.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	146.0 0.8 100.0 12.4	146.0
TOTAL	1726.0	9432.0	5065.0	1173.0	17396.0

Table A.6 — Heating systems in existing multi-family residences: 1973

TABLE VALUES FOR 1973 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	1857.0 15.4 37.1 29.2	2999.0 24.9 59.8 82.3	155.0 1.3 3.1 38.8	5011.0
CENTRAL	663.0 5.5 17.5 40.1	2547.0 21.1 67.3 40.1	528.0 4.4 13.9 14.5	49.0 0.4 1.3 12.3	3787.0
ELECTRIC	958.0 7.9 100.0 57.9	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	958.0
PIPELESS	0.0 0.0 0.0 0.0	992.0 8.2 96.6 15.6	21.0 0.2 2.0 0.6	14.0 0.1 1.4 3.5	1027.0
FLUE	0.0 0.0 0.0 0.0	680.0 5.6 86.5 10.7	70.0 0.6 8.9 1.9	36.0 0.3 4.6 9.0	786.0
W/O FLUE	0.0 0.0 0.0 0.0	219.0 1.8 89.4 3.8	16.0 0.1 6.5 0.4	10.0 0.1 4.1 2.5	245.0
ROOM	33.0 0.3 29.7 2.0	59.0 0.5 53.2 0.9	11.0 0.1 9.9 0.3	8.0 0.1 7.2 2.0	111.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	127.0 1.1 100.0 31.8	127.0
TOTAL	1654.0	6354.0	3645.0	399.0	12052.0

Table A.7 — Heating systems in existing multi-family residences: 1974

TABLE VALUES FOR 1974 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	1908.0 14.7 37.8 28.7	3033.0 23.3 60.1 79.3	107.0 0.8 2.1 29.2	5048.0
CENTRAL	924.0 7.1 21.6 42.8	2641.0 20.3 61.9 39.7	657.0 5.1 15.4 17.2	48.0 0.4 1.1 13.1	4270.0
ELECTRIC	1197.0 9.2 100.0 55.4	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	1197.0
PIPELESS	0.0 0.0 0.0 0.0	1015.0 7.8 95.6 15.2	23.0 0.2 2.2 0.6	24.0 0.2 2.3 6.5	1062.0
FLUE	0.0 0.0 0.0 0.0	809.0 6.2 86.8 12.2	93.0 0.7 10.0 2.4	30.0 0.2 3.2 8.2	932.0
W/O FLUE	0.0 0.0 0.0 0.0	239.0 1.8 87.9 3.6	14.0 0.1 5.1 0.4	19.0 0.1 7.0 5.2	272.0
ROOM	39.0 0.3 37.1 1.8	46.0 0.4 43.8 0.7	4.0 0.0 3.8 0.1	16.0 0.1 15.2 4.4	105.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	123.0 0.9 100.0 33.5	123.0
TOTAL	2160.0	6658.0	3824.0	367.0	13009.0

Table A.8 — Heating systems in existing multi-family residences: 1975

TABLE VALUES FOR 1975 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	2200.0 16.5 43.2 30.9	2812.0 21.1 55.2 81.0	63.0 0.6 1.6 22.2	5095.0
CENTRAL	1086.0 8.1 24.4 45.3	2782.0 20.0 62.5 39.1	533.0 4.0 12.0 15.4	50.0 0.4 1.1 13.4	4451.0
ELECTRIC	1235.0 9.2 100.0 51.5	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	1235.0
PIPELESS	0.0 0.0 0.0 0.0	1067.0 8.0 95.2 15.0	27.0 0.2 2.4 0.8	27.0 0.2 2.4 7.2	1121.0
FLUE	0.0 0.0 0.0 0.0	750.0 5.6 86.6 10.5	84.0 0.6 9.7 2.4	32.0 0.2 3.7 8.6	866.0
W/O FLUE	0.0 0.0 0.0 0.0	259.0 1.9 91.5 3.6	7.0 0.1 2.5 0.2	17.0 0.1 6.0 4.5	283.0
ROOM	77.0 0.6 45.8 3.2	53.0 0.4 31.5 0.7	8.0 0.1 4.8 0.2	30.0 0.2 17.9 8.0	168.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	135.0 1.0 100.0 36.1	135.0
TOTAL	2398.0	7111.0	3471.0	374.0	13354.0

Table A.9 — Heating systems in existing mobile homes: 1970

TABLE VALUES FOR 1970 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPES				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	3.0 0.1 17.6 0.5	10.0 0.5 54.9 1.3	4.0 0.2 23.5 0.8	17.0
CENTRAL	53.0 2.6 3.9 31.9	485.0 23.8 36.0 75.5	518.0 25.4 38.4 68.3	292.0 14.3 21.7 62.0	1348.0
ELECTRIC	95.0 4.7 100.0 57.2	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	95.0
PIPELESS	0.0 0.0 0.0 0.0	49.0 2.4 35.5 7.6	47.0 2.3 34.1 4.2	42.0 2.1 30.4 8.9	138.0
FLUE	0.0 0.0 0.0 0.0	58.0 3.3 23.6 10.6	159.0 3.4 52.1 19.8	70.0 3.4 24.3 14.9	288.0
W/O FLUE	0.0 0.0 0.0 0.0	28.0 1.4 31.8 4.4	24.0 1.2 27.3 3.2	36.0 1.8 40.9 7.6	88.0
ROOM	18.0 0.9 31.6 10.8	9.0 0.4 15.8 1.4	9.0 0.4 15.8 1.2	21.0 1.0 36.8 4.5	57.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	6.0 0.3 100.0 1.3	6.0
TOTAL	166.0	642.0	758.0	471.0	2037.0

Table A.10 — Heating systems in existing mobile homes: 1973

TABLE VALUES FOR 1973 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	2.0 0.1 28.6 0.3	5.0 0.3 71.4 0.9	0.0 0.0 0.0 0.0	7.0
CENTRAL	133.0 7.2 8.7 68.2	494.0 26.6 32.5 85.2	505.0 27.2 33.2 86.3	390.0 21.0 24.6 78.5	1522.0
ELECTRIC	45.0 2.4 100.0 23.1	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	45.0
PIPELESS	0.0 0.0 0.0 0.0	60.0 3.2 35.7 10.3	45.0 2.4 26.8 7.7	63.0 3.4 37.5 12.7	168.0
FLUE	0.0 0.0 0.0 0.0	16.0 0.9 27.6 8.8	20.0 1.1 34.5 3.4	22.0 1.2 37.5 4.4	58.0
W/O FLUE	0.0 0.0 0.0 0.0	7.0 0.4 28.0 1.2	5.0 0.3 20.0 0.9	13.0 0.7 52.0 2.6	25.0
ROOM	17.0 0.9 68.0 8.7	1.0 0.1 4.0 0.2	5.0 0.3 20.0 0.9	2.0 0.1 8.0 0.4	25.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	7.0 0.4 100.0 1.4	7.0
TOTAL	195.0	580.0	585.0	497.0	1857.0

Table A.11 — Heating systems in existing mobile homes: 1974

TABLE VALUES FOR 1974 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	2.0 0.1 16.7 0.2	10.0 0.3 83.3 0.9	0.0 0.0 0.0 0.0	12.0
CENTRAL	355.0 9.5 11.2 70.2	868.0 23.2 27.5 85.3	1009.0 27.0 32.0 91.2	926.0 24.8 29.3 83.4	3158.0
ELECTRIC	103.0 2.8 100.0 20.4	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	103.0
PIPELESS	0.0 0.0 0.0 0.0	101.0 2.7 44.7 9.9	43.0 1.2 19.0 3.9	62.0 2.2 36.3 7.4	226.0
FLUE	0.0 0.0 0.0 0.0	25.0 0.7 24.3 2.5	40.0 1.1 38.8 3.6	38.0 1.0 36.9 3.4	103.0
W/O FLUE	0.0 0.0 0.0 0.0	19.0 0.5 36.5 1.9	3.0 0.1 5.8 0.3	30.0 0.8 57.7 2.7	52.0
ROOM	48.0 1.3 67.6 9.5	2.0 0.1 2.8 0.2	1.0 0.0 1.4 0.1	20.0 0.5 28.2 1.8	71.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	14.0 0.4 100.0 1.3	14.0
TOTAL	506.0	1017.0	1106.0	1110.0	3739.0

Table A.12 — Heating systems in existing mobile homes: 1975

TABLE VALUES FOR 1975 FUEL VERSUS EQUIPMENT TYPE ARE:
 COUNT
 TOTAL PERCENTAGE
 ROW PERCENTAGE
 COLUMN PERCENTAGE

EQUIPMENT	FUEL TYPE				TOTAL
	ELEC	GAS	OIL	OTHER	
STEAM	0.0 0.0 0.0 0.0	1.0 0.0 6.7 0.1	12.0 0.3 80.0 1.3	2.0 0.1 13.3 0.2	15.0
CENTRAL	368.0 10.6 12.5 71.3	901.0 25.9 29.6 87.3	855.0 24.6 29.0 90.7	826.0 23.8 28.0 84.0	2950.0
ELECTRIC	105.0 3.9 100.0 20.3	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	105.0
PIPELESS	0.0 0.0 0.0 0.0	80.0 2.3 39.6 7.8	51.0 1.5 25.2 5.4	71.0 2.0 35.1 7.2	202.0
FLUE	0.0 0.0 0.0 0.0	22.0 0.6 33.3 2.1	20.0 0.6 30.3 2.1	24.0 0.7 36.4 2.4	66.0
W/O FLUE	0.0 0.0 0.0 0.0	26.0 0.7 43.3 2.5	4.0 0.1 6.7 0.4	30.0 0.9 50.0 3.1	60.0
ROOM	43.0 1.2 70.5 8.3	2.0 0.1 3.3 0.2	1.0 0.0 1.6 0.1	15.0 0.4 24.6 1.5	61.0
NO HEAT	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	15.0 0.4 100.0 1.5	15.0
TOTAL	516.0	1032.0	943.0	983.0	3474.0

Appendix B

COST AND SPF INFORMATION FOR SPACE HEATING SYSTEMS CALCULATIONS

This appendix provides details on the variation in energy use and capital cost values for oil and gas heating systems. Estimates on the variation of values for electrical systems were not available. However, the SPF values for design option of electrical heating systems are listed in table B.1.

Tables B.2 and B.3 summarize the performance and cost information for gas and oil systems, respectively. The reported ranges in values for the percent reduction in seasonal fuel use and increase in capital cost (in 1975 \$) for conservation options are given in these tables. The source for these values are footnoted in the tables.

The SPF for each option is calculated by averaging the SPF from available references. For the base gas furnace, SPFs of 0.517, 0.64, 0.639, and 0.627 were reported from refs. 15, 16, 17 and 20, respectively. The value used in this report is 0.61. The reported range in SPF is 0.517 to 0.64. For an example of calculating the reduction in energy use for an option, consider the switch to sealed combustion for the gas furnace. The reported SPFs are 0.696, 0.677, 0.668, and 0.759 from refs. 15, 16, 17, and 20, respectively. The average SPF is 0.70 which provides a reduction in fuel use of 14%. The reported reduction in these references ranged from 4% (ref. 17) to 26% (ref. 15).

The SPF for the oil furnace is 0.66. This was calculated from values of 0.674, 0.703, 0.64, and 0.615 in refs. 17, 20, 26, and 32, respectively.

The range in capital costs increases was developed from values given in the literature and phone conversations with manufacturers and dealers. Figures B.1 and B.2 show the correlation between furnace cost (installation not included) and rated output (in 10^3 Btu/hr) developed from the survey. The cost of the base and properly sized furnace are estimated from these correlations. Installation costs ranged from \$115 to \$216 for a furnace. Ductwork estimates ranged from \$630 to \$710.

Table B.1. Average SPF values for designs options
on electric heating systems in Cleveland and Atlanta

Option	Average SPF	
	Cleveland	Atlanta
Base	0.98 ^a	0.98 ^a
1) 1975 model heat pump	1.68 ^a	1.97 ^a
2) High efficiency I	1.87 ^a	2.31 ^a
3) High efficiency II	1.86 ^a	2.10 ^a
4) High efficiency III	1.74 ^a	2.07 ^a
5) Compressor indoors (optimized at 28°F)	1.90 ^b	2.24 ^b
6) Two equally sized compressors (optimized at 32°F)	2.08 ^b	2.46 ^b
7) Two speed compressor (optimized at 32°F)	2.10 ^b	2.48 ^b
8) Compressor indoors (optimized at 19°F)	2.17 ^b	2.56 ^b
9) Two equally sized compressors (optimized at 24°F)	2.54 ^b	3.00 ^b
10) Compressor indoors (optimized at 16°F)	2.39 ^b	2.82 ^b

^aDeveloped from ref. 14.

^bDeveloped from ref. 37.

Table B.2. Seasonal performance and capital cost information
for gas heating systems

Option	SPF ^a used	Percent reduction in seasonal fuel use		Capital cost increase for option (1975 \$)	
		This report	Reported range in values	This report	Reported range in values
Base	0.61 ^{b,c,d,e}	--	--	--	--
1) Properly sized furnace	0.64 ^{b,d}	5	4 to 14 ^{b,d}	-150	60 to 240 ^f
2) Bonnet thermostat set 5°F above room temp.	0.65 ^{b,d,e}	6	2 to 21 ^{b,d,e}	0	0
3) Automatic flue damper	0.69 ^{c,d,e}	11	4 to 17 ^{c,d,e,g}	85 ^f	70 to 110 ^{c,f}
4) Duct insulation increased to 2"	0.61 ^{b,d}	2	0 to 3 ^{b,d,i}	20 ^f	0 to 90 ^f
5) Sealed combustion	0.70 ^{b,c,d,e}	13	4 to 26 ^{b,c,d,e}	140 ^{e,h}	65 to 218 ^{e,h}
6) Increase steady state efficiency to 84%	0.73	16	6 to 25 ^{c,d,e}	115 ^{e,f}	100 to 130 ^{e,f}
7) Electric ignition	0.64 ^{b,c,d,e}	5	2 to 10 ^{b,c,d,e}	90 ^f	52 to 123 ^{e,f}
8) Organic fluid absorption heat pump	1.10 ⁱ	45	N.A. ^k	1040 ⁱ	N.A. ^k
9) 3,7	0.74 ^{c,e}	17	14 to 20 ^{c,e,f}	180 ^f	134 to 233 ^{e,f}
10) 6,7	0.78 ^{c,d,e}	22	11 to 28 ^{c,d,e}	210 ^{e,f}	152 to 253 ^{e,f}
11) 2,6	0.75 ^d	19	N.A. ^k	115 ^f	100 to 130 ^{e,f}
12) 3,6,7	0.80 ^{c,d,l}	24	20 to 24 ^{c,d,l}	295 ^{e,f}	222 to 363 ^{e,f}
13) 5,6,7	0.82 ^{d,e}	26	17 to 28 ^{d,e}	350 ^{e,f,h}	217 to 471 ^{e,f,h}
14) 2,5,6,7	0.82 ^d	26	N.A. ^k	350 ^{e,f,h}	217 to 471 ^{e,f,h}

^aSPF values used in this report were developed by averaging SPF values from each reference for a particular option.

^bReference 15.

^cReference 16.

^dReference 17.

^eReference 20.

^fSurvey of dealers and manufacturers.

^gReference 42.

^hEstimated from sealed combustion units on the market.

ⁱReference 14.

^jReference 29.

^kNo range available, only one value.

^lReference 19.

Table B.3. Seasonal performance and capital cost information for oil furnaces

Option	SPF ^a used	Percent reduction in seasonal fuel use		Capital cost increase for option (1975 \$)	
		This report	Reported range in values	This report	Reported range in values
Base	0.66 ^{b,c,d,e}	--	--	--	--
1) Properly sized furnace	0.69 ^{b,d}	4	1 to 9 ^{b,d}	250 ⁱ	140 to 360 ⁱ
2) Bonnet thermostat set 5°F above room temp.	0.70 ^{b,c}	6	1 to 3 ^{b,c}	0	0
3) Automatic flue damper	0.72 ^{b,c,d}	8	5 to 15 ^{b,c,d,f}	85 ^{c,i}	70 to 110 ^{c,i}
4) Duct insulation increased to 2"	0.66	2	0 to 3 ^{b,k}	20 ⁱ	0 to 90 ⁱ
5) Sealed combustion	0.74 ^{b,c,d,g}	11	4 to 18 ^{b,c,d,g}	150 ^{c,j}	93 to 222 ^{c,j}
6) Increase steady state efficiency to 84%	0.80 ^{b,c}	18	12 to 17 ^{b,c}	140 ^{c,i}	100 to 206 ^{c,i}
7) 5,6	0.79 ^b	16	N.A. ^h	290 ^{c,i,j}	193 to 428 ^{c,i,j}
8) 2,5	0.71 ^b	7	N.A. ^h	150 ^{c,j}	93 to 222 ^{c,j}
9) 2,6	0.79 ^b	16	N.A. ^h	140 ^{c,i}	100 to 206 ^{c,i}
10) 3,6	0.80 ^b	18	N.A. ^h	225 ^{c,i,j}	170 to 316 ^{c,i,j}
11) 2,5,6	0.82 ^b	20	N.A. ^h	290 ^{c,i,j}	193 to 428 ^{c,i,j}

^aSPF values used in this report were developed by averaging SPF values from each reference for a particular option.

^bReference 17.

^cReference 20.

^dReference 26.

^eReference 32.

^fReference 43.

^gReference 44.

^hNo reporting range available.

ⁱSurvey of dealers and manufacturers.

^jEstimated from sealed combustion units on the market.

^kReference 15.

Fig. B.1 — Retail cost of residential gas furnaces as a function of rated output.

Fig. B.2. Retail cost of residential oil furnace as a function of rated output.

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