AN ANALYSIS OF THE ECONOMICS OF REPLACING EXISTING RESIDENTIAL FURNACES AND BOILERS WITH HIGH EFFICIENCY UNITS

Revised
October 1980

Submitted to the
Office of Planning and Evaluation
U.S. Environmental Protection Agency

Contract No. 68-01-5845

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November 4, 1980

Office of Planning and Evaluation
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Gentlemen:

ICF Incorporated is pleased to provide this revised and updated report, "Analysis of the Economics of Replacing Existing Residential Furnaces and Boilers with High Efficiency Units."

The analysis performed in this report indicates that early replacement of existing low efficiency oil and gas heating equipment with new high efficiency units would reduce oil imports, have environmental benefits, and be a good investment for both the homeowner and the nation.

We hope that this report will be helpful to you in your efforts to develop policies which will improve the environment while reducing the nation's dependence on foreign oil in a cost-effective manner.

Sincerely,

Theodore R. Breton

Theodore R. Breton
Principal

TRB/bb

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The assumptions, findings, conclusions, judgments, and views expressed herein are those of ICF Incorporated and should not be interpreted as necessarily representing the official policies of the U.S. government.

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EXECUTIVE SUMMARY

Now is a very good time for homeowners to change their traditional patterns and make some investments in home energy conservation:

- Government policy regulating oil and gas prices appears to have finally stabilized. Significant policy changes are unlikely for at least four years.
- Heating oil prices are high and will be going higher. Residential gas prices have increased substantially and over the next 10-15 years will get closer to the price of heating oil.
- Tax credits and both subsidized and unsubsidized loans are available from a variety of sources for investments in conservation.
- Energy audit services are now available from electric and gas utilities and other heating fuel suppliers that can provide homeowners with good information about home weatherization and heating system replacement options.
- Very high efficiency oil and gas heating equipment is now being produced by a rapidly growing number of manufacturers. Little additional improvement in efficiencies will be made for at least five years.
- The new DOE equipment efficiency labeling program now makes it possible for the homeowner to identify those furnaces and boilers which truly are high in efficiency.
- Investments in conservation no longer are lost to the homeowner when the house is sold. When the house is offered for sale, potential purchasers now inquire about annual heating bills.

This report was prepared to analyze the economics of replacing existing residential oil and gas heating equipment with new high efficiency units in houses which are at least partially weatherized. Homeowners in houses which do not have caulking, weatherstripping, or insulation should invest in building weatherization before they consider heating equipment investments.

Potential investment decisions were grouped into the following three categories for analysis purposes:

- Investment in high efficiency equipment instead of a "standard" unit at normal replacement time.
- Early replacement of existing oil or gas heating equipment with new high efficiency equipment.
- Switching from heating oil to natural gas.

All of the potential investments were examined from both the homeowner's and the national perspective. For the national perspective, natural gas was valued based on its best alternative use in the industrial and electric utility sectors.

The results of the analysis performed in this report are relevant for the entire northern region of the United States, which contain 64% of all gas-heated housing units and 83% of all oil-heated housing units in the nation. The most important conclusions which can be drawn from this analysis are as follows:

- Whenever an existing gas furnace or boiler wears out, the homeowner should definitely purchase a new high efficiency gas unit. The incremental investment is very low relative to the standard gas unit, the payback period is 1-2 years, and the total savings for the homeowner and the nation are very large over the life of the investment.
- Early replacement of existing gas heating equipment is economically desirable under the assumptions used in the analysis, but the return on investment is not nearly as high as most homeowners require for conservation investments. However, for high income homeowners who have a variety of investment alternatives, early replacement of existing gas equipment with a high efficiency unit offers a much higher after-tax return than alternative investments whose return is subject to income tax.

- Whenever an existing oil furnace or boiler wears out, any homeowner who already uses gas for non-heating purposes or who has ready access to a gas main should install gas heating equipment. The best gas heating equipment is equal to or better than the best oil heating equipment from an efficiency and cost standpoint, and even after price decontrol, gas will continue to be cheaper than heating oil where it is available.1/ As noted above, the new unit installed should be a high efficiency unit.

- Any existing oil heating equipment which is over ten years old and has never been upgraded should be upgraded or replaced as soon as possible.

  -- Homeowners should replace the existing oil unit with a new high efficiency gas unit if they already use gas for non-heating purposes or have ready access to a gas main. The best gas heating equipment is equal to or better than the best oil equipment from an efficiency and cost standpoint, and gas will continue to cost less than heating oil where it is available.1/

  -- Homeowners who do not have ready access to a gas main should upgrade their existing oil heating equipment if it has twenty years of remaining useful life. If the remaining useful life is much shorter than twenty years, the old unit should be replaced with a new oil unit.

The immediate opportunities for increased energy conservation are clearly in the houses with oil heating systems. Many of these homeowners are switching to gas. They should be encouraged to install high efficiency units.

Over the near term as high efficiency gas equipment is produced in greater volume, programs should be developed which will provide an incentive for homeowners to replace existing gas heating equipment with high efficiency units. Information should be provided to high income homeowners about the considerable benefit to them of investing in high efficiency equipment. Programs to assist moderate and low income homeowners to replace existing gas

1/ See the discussion on Fuel Prices and Fuel Value in the Methodology section.

equipment should be developed prior to natural gas price decontrol to help cushion the impact of higher residential gas prices.

The end result of these programs could improve the average seasonal efficiency of the heating equipment in the nation's residential housing stock from about 60% today to about 80% by 1990. This change would reduce oil and gas space heating fuel consumption in the existing housing stock by 25%, which is equal to a saving of 725,000 barrels/day of oil.

I. INTRODUCTION

Since 1973, the way we use energy has become an important national and individual concern. Our extensive use of imported oil has made us highly vulnerable to oil supply disruptions. In addition, the increasing cost of acquiring oil is siphoning off many of the economic resources we formerly used for other things. As a result, our continued extensive reliance on oil has adverse implications for our economic well-being as a nation.

The major use of energy in the home is for space heating and cooling. As shown in Table 1, natural gas and petroleum-based fuels (heating oil, LPG, and kerosene) are used as the primary heating fuel in over 80% of all housing units. Rising heating oil and gas prices have greatly increased homeowner energy bills. In the colder regions of the U.S., heating costs now account for a sizeable portion of a homeowner's budget.

Table 2 presents data on the price of heating oil and natural gas during the 1974-1980 period in constant 1980 dollars (i.e., what would have been paid in this year's dollars to buy fuel in each year). The natural gas cost data is calculated in cents per gallon to present it as if it were heating oil from the consumer's standpoint. The data show that both heating oil and natural gas prices have risen significantly in real terms since 1974, but that average gas prices are still below average 1974 heating oil prices. Natural gas prices vary considerably between different parts of the country, but where natural gas is available, it is cheaper than heating oil at the present time.

Greater use of coal, synthetic fuels made from coal, oil from shale, and nuclear power have all been cited as potential solutions to our oil import dependence problem. Unfortunately, these solutions are not cheap, they pose environmental problems, and they will take time to implement.

TABLE 1
PRIMARY HEATING FUEL BY TYPE OF HOUSING STRUCTURE
(Percentage of Housing Units)

	Total Housing Units	Single Family Detached	Single Family Attached	Building With 2-4 Units	Building With 5 Or More Units	Mobile Home	Other
Natural Gas	55	55	72	63	48	27	85
Fuel Oil, Kerosene	22	23	11	20	22	26	-
Electricity	16	13	14	15	27	23	6
LPG	4	4	1	2	-	19	-
Wood	2	3	1	-	-	4	-
Other	1	1	1	-	-	-	9
Not Applicable	-	-	1	-	2	-	-
Total	100	100	100	100	100	100	100

Note: Data may not sum to totals due to rounding.

Source: U.S. Department of Energy, Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households, February 1980, p. 45.

TABLE 2

NATIONAL AVERAGE DELIVERED PRICE OF HEATING FUELS
IN THE RESIDENTIAL SECTOR IN 1980 DOLLARS
(Cents/Gallon)

Year	Heating Oil	Natural Gas*
1974	56.7	28.1
1975	56.4	31.8
1976	57.4	36.1
1977	61.1	41.6
1978	61.0	45.0
1979	89.7	50.9
1980	97.8**	52.9**

* Converted to cents/gallon from dollars/thousand cubic feet (MCF) using the relative heat content of an MCF of gas and a gallon of heating oil.

** July 1980

Source: ICF Incorporated adjustment of nominal price data taken from DOE, Monthly Energy Report, various issues.

Conservation Can Help the Nation and the Homeowner

ICF performed an analysis of energy conservation as an alternative solution to the oil import dependence problem for the U.S. Senate Budget Committee.[1/] The analysis indicated that oil and gas conservation is a real bargain for the nation. Conservation of oil and gas can:

- reduce oil imports,
- reduce environmental contamination, and
- save money

1/ ICF Inc., Oil Import Reduction: An Analysis of Production and Conservation Alternatives, August 30, 1979

We found that some of the best opportunities for conservation at low cost are in the residential sector.

These savings are possible because the existing housing stock is not very energy-efficient. A very large proportion of the heat produced in most residential furnaces and boilers currently goes up the flue or chimney and never reaches the heated portion of the house. The heat which does reach the heated portion of many houses quickly leaks out through poorly insulated doors, windows, walls, and ceilings and through cracks and other openings to the outside.

Oil and gas with an energy content equal to about 3.7 million barrels/day of oil was used in the residential sector in 1978. We have estimated that if every conservation investment were made in the existing housing stock which could reduce oil and gas use at a cost of less than $34/barrel (the current average cost of imported oil today), the use of oil and gas in the existing 1978 housing stock could be reduced by almost 50% by 1990.[1/]

Investments to improve the efficiency of existing residential oil and gas heating equipment and to weatherize houses reduce oil and gas consumption. Reduced oil use through conservation leads directly to reduced oil imports. Reduced gas use through conservation makes additional gas available to the industrial and electric utility sectors. The additional gas enables these sectors to reduce their consumption of oil which reduces oil imports.

Switching from oil to gas in the residential sector also leads to reduced oil imports if heating unit efficiencies are concurrently improved. Increased

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1/ Ibid., P. B-10

use of gas in the residential sector reduces the gas available for the industrial and electric utility sectors. However, if the efficiency of the new gas heating equipment is higher than the efficiency of the old oil unit replaced, switching reduces the total amount of oil and gas used in the nation. Since gas is generally used instead of oil when it is available, a reduction in total oil and gas consumption reduces oil imports.

Investments which improve oil and gas heating equipment efficiency also have environmental benefits. Since less fuel is consumed to heat the residence, all other things being equal, there is less pollution of the air.[1/] Also, since oil imports are reduced, the danger of oil spills is also reduced. Consequently, unless the efficiency improvements increase pollution emissions per unit of fuel burned, efficiency improvements are good for the environment.

Studies have shown that investments in more efficient oil and gas equipment and in weatherizing the housing stock will save homeowners and the nation money over the life of the investment. Unfortunately, homeowners often do not make energy conservation investments unless they pay for themselves very quickly. In a survey performed by ICF and Westat, Inc., many homeowners indicated they were seeking a payback period of four years for their conservation investments.[2/] A four year pay-back on a twenty year

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1/ Recently there has been concern that energy conservation obtained by reducing air infiltration in residential units may increase indoor pollution levels. It should be noted that improving furnace or boiler efficiencies conserves energy without affecting air infiltration rates.

2/ U.S. Department of Energy, Energy Extension Service Pilot Program Report. The First Year, Vol. 1, pg. 116-117 investment is equivalent to a very high return on investment (much higher than makes sense from a national perspective).

Many Obstacles Have Restrained Conservation in the Past

Much can be done to reduce the use of energy in the existing housing stock, but homeowners have done relatively little to date for many reasons:

- Until recently oil prices were much lower than they are now.
- Price controls have kept natural gas prices at a low level, so there is less incentive for gas users to invest in conservation.
- Because fuel prices have been low for so many years, homeowners are not accustomed to making energy conservation investments. Houses have been weatherized primarily when the house is built, and new furnaces and boilers have been installed only when the old ones cease to function.
- Homeowners know that additional weatherization and the installation of higher efficiency heating equipment will save fuel, and a wide variety of heating equipment and home weatherization services are available, but the information on the potential savings in fuel costs has been inconsistent, sometimes misleading, and not widely available.
- High efficiency heating equipment has been produced but, especially in the case of gas equipment, has only recently become commercially available.
- Some homeowners are unsure whether they should delay their investment in new heating equipment until even more efficient units become available.
- The high installation cost of a new furnace or boiler and the low or non-existent salvage value of an old unit can create a financing problem for the homeowner.
- Homeowners have been uncertain whether the investments they make to conserve energy will be fully capitalized into the price of the house if they decide to sell soon after making the investment.

The net result is that while homeowners have made some investments in conservation, the total effort has been rather disappointing. Homeowners appear to have focused mostly on minimizing the initial investment cost and the pay-back period, instead of the total costs over the life of the investment; this orientation usually results in the purchase of less sophisticated equipment which uses more fuel.

The large price differential between heating oil and natural gas has encouraged a large number of homeowners who heat with oil to reduce their fuel bills by switching to natural gas. The American Gas Association has estimated that about 365,000 house heating units converted from oil to gas heat in 1979, and utility company forecasts indicate that 383,000 conversions will occur in 1980.[1/] Since only a small fraction of the gas heating equipment sold in the recent past has been high in efficiency, it is quite likely that homeowners heating with oil who otherwise would have invested in conservation decided to take advantage of controlled gas prices and invested in a low efficiency gas furnace or boiler instead.

Controlled gas prices can be a liability to the nation's conservation program. Because gas prices have been kept low, homeowners with gas heating equipment have less incentive to weatherize their homes and invest in high efficiency gas equipment. Also, homeowners with oil heat may convert to gas and install low efficiency units.

However, controlled gas prices also offer the nation an opportunity. High efficiency gas furnaces and boilers are now available, and the most efficient gas units are more efficient than the most efficient oil units. Homeowners with oil heating systems, who probably would not replace those systems if gas

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1/ AGA, "An Analysis of Oil-to-Gas Conversion Trends in the Residential Gas Space Heating Market," September 18, 1980, p. 2

prices were high, are currently buying new gas units. If these homeowners can be persuaded to install high efficiency gas units when they convert to gas, both they and the nation will benefit.

Now is a Good Time to Make Conservation Investments

Now is a very good time for homeowners to change their traditional patterns and make some investments in home energy conservation:

- Government policy regulating oil and gas prices appears to have finally stabilized. Significant policy changes are unlikely fcr at least four years.
- Heating oil prices are high and will be going higher. Residential gas prices have increased substantially and over the next 10-15 years will get closer to the price of heating oil.
- Tax credits and both subsidized and unsubsidized loans are available from a variety of sources for investments in conservation.
- Energy audit services are now available from electric and gas utilities and other heating fuel suppliers that can provide homeowners with good information about home weatherization and heating system replacement options.
- Very high efficiency oil and gas heating equipment is now being produced by a rapidly growing number of manufacturers. Little additional improvement in efficiencies will be made for at least five years.
- The new DOE equipment efficiency labeling program now makes it possible for the homeowner to identify those furnaces and boilers which truly are high in efficiency.
- Investments in conservation no longer are lost to the homeowner when the house is sold. When the house is offered for sale, potential purchasers now inquire about annual heating bills.

Remaining Problems Affecting Investment Decisions

Despite these recent events which make it much easier for the homeowners to make good conservation investment decisions, there is still some confusion and potential for incorrect decision-making. Homeowners have a variety of conservation options to choose from including:

- Weatherizing the housing shell,
- Upgrading existing heating equipment,
- Replacing existing oil and gas equipment with a higher efficiency unit, and
- Switching from heating oil to natural gas.

These options are not independent of each other. If one conservation investment is made, it reduces the potential energy saving which can be obtained from subsequent investments. For example, if an uninsulated house has a furnace with 50% efficiency and it consumes 100 units of heat, increasing the efficiency to 75% will save 33 units of heat. If the house is first weatherized until only 80 units of heat are consumed, then the improvement in furnace efficiency from 50 to 75% will only save 27 units of heat.

Consequently, fuel saving investments should not be considered in isolation. Homeowners in houses which do not have caulking, weatherstripping, or insulation should invest in building weatherization before they consider heating equipment investments. However, most houses in the colder regions of the United States are at least partially weatherized.[1/] Homeowners in these structures should consider heating equipment investments to reduce fuel consumption.

1/ The Department of Energy has collected data which indicate that only 16% of all housing units in the colder regions of the country (greater than 4000 heating degree days), have no attic insulation at all. DOE/EIA, Residential Energy Consumption Survey: Conservation, February 1980, p. 13

As mentioned previously, controlled gas prices are another potential obstacle to conservation investments. The current price differential between home heating oil and natural gas, which results primarily from Federal and state regulation of gas prices, is now causing homeowners who heat with oil to consider investments in gas heating equipment which they probably would not make if gas prices were not controlled. If homeowners replace the burner in their existing oil heating equipment with a gas burner, no oil or gas will be saved, and the nation will lose an opportunity to reduce oil imports and improve the environment at very low cost.

If the efficiency of the heating equipment is not improved during the switch, the only significant effect of homeowner switching from oil to gas is to reallocate gas supplies within the nation. The savings homeowners obtain by switching are largely matched by increased costs somewhere else in the nation. However, if homeowners replace low efficiency oil furnaces and boilers which are still in good working condition with high efficiency gas units, oil imports will be reduced, the environment will be improved, and both the consumer and the nation as a whole may save money.

Purpose and Scope of This Report

This report was prepared to provide both homeowners and government policy makers with information about the economics of residential heating equipment replacement. Potential investment decisions were grouped into the following three categories for analysis purposes:

- Investment in high efficiency equipment instead of a "standard" unit at normal replacement time. This analysis examines the desirability of spending additional money for a higher efficiency unit once a decision has been made to install a new oil or gas unit.

- Early replacement of existing oil or gas heating equipment with new high efficiency equipment. This analysis examines whether the higher fuel efficiencies of new equipment warrant early retirement of old equipment which is still in good working condition.

- Switching from heating oil to natural gas. This analysis examines the desirability of replacing existing oil-fired equipment with new gas-fired equipment both at and before normal replacement time.

All of the potential investments were examined from both the homeowner's and the national perspective. For the national perspective, natural gas was valued based on its best alternative use in the industrial and electric utility sectors.

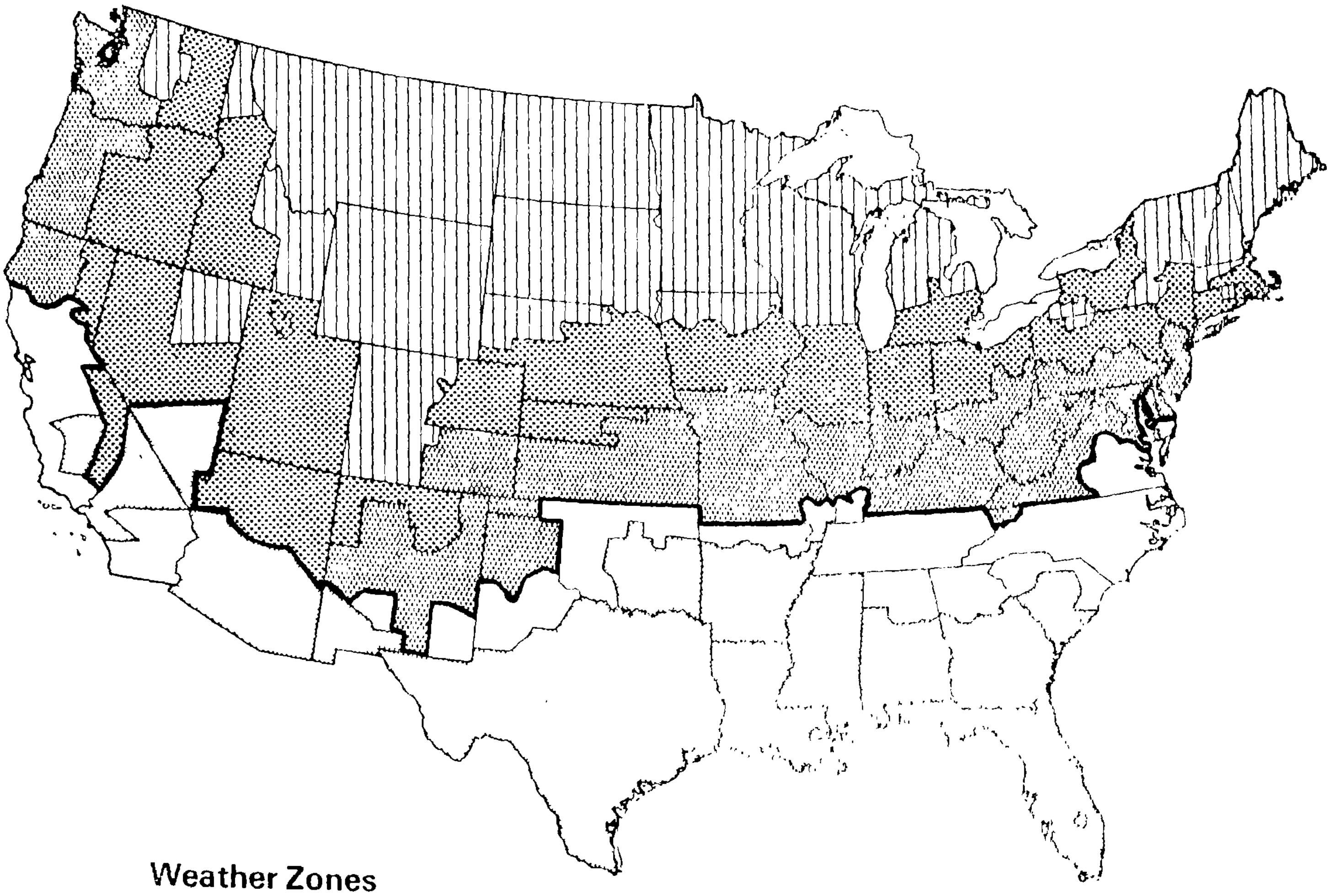
The report is designed to provide information on the economics of residential heating system investments in the colder parts of the nation where annual heating degree days exceed 4000. Figure 1 contains a map which indicates the location of this region. About 64% of gas-heated housing units and 83% of oil-heated housing units are located in this region.[1/]

The approach used in the report was to examine a small detached, moderately weatherized house with an average heating system efficiency of 60% consuming 94.5 million BTU's/year. Such a house is representative of houses in Baltimore or Kansas City. Their owners would have heating bills of about \$820 in 1980 if they had old 50% efficiency oil heating systems and about \$410 if they had old 60% efficiency gas units.

1/ Calculated from data in U.S. Department of Energy, Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households, February 1980, p. 42

FIGURE 1

UNITED STATES WEATHER ZONE MAP OF HEATING DEGREE DAYS (HDD) AND COOLING DEGREE DAYS (CDD)



Weather Zones

- Zone 1 is less than 2,000 CDD and greater than 7,000 HDD.
- Zone 2 is less than 2,000 CDD and 5,500 - 7,000 HDD.
- Zone 3 is less than 2,000 CDD and 4,000 - 5,499 HDD.
- Zone 4 is less than 2,000 CDD and less than 4,000 HDD.
- Zone 5 is greater than 2,000 CDD and less than 4,000 HDD.

Source: U.S. Department of Energy, Residential Energy Consumption Survey: Conservation, February 1980, p. 133.

The annual fuel consumption for space heating used as the basis for the analysis in this report is lower than average for the northern region of the country. As a result, the estimates of the return on investment in heating equipment are conservative for the majority of homeowners in the region.

No comparison was made between heating equipment investments and weatherization investments in this report. However, as mentioned previously, houses which are not weatherized at all (e.g. no insulation) should be weatherized first. Homeowners should obtain an energy audit to determine exactly what should be done in their home. For a house which is well insulated and caulked, heating equipment investments definitely should be considered if fuel bills are still high.

Organization of the Report

The remainder of the report is organized as follows: Section II explains the methodology used in the report, including the critical assumptions in the analyses, such as the cost and seasonal efficiencies of new heating equipment and fuel prices. Section III presents the results of the analyses. Section IV contains a discussion of the implications of the results for both the homeowner and for national policy.

II. METHODOLOGY

The analysis was organized to correspond to the kinds of decisions the homeowner has to make when considering heating equipment replacement or modification. The following investment alternatives were analyzed:

- Normal replacement of worn out gas heating equipment. When gas heating equipment reaches the end of its useful life, a homeowner must select a unit to replace it. Switching to oil is not economically attractive, so the homeowner's choices are between units with different costs and fuel efficiencies. This analysis compared the economic desirability of several investment alternatives.

- Early replacement of existing gas heating equipment with a new high efficiency unit. Although controlled gas prices limit the incentive to replace low efficiency existing gas heating equipment, early replacement with a high efficiency unit may be in the national interest. This analysis examined the economic desirability of installing high efficiency gas furnaces and boilers in 1981 and heat pumps in 1986.

- Normal replacement of worn out oil heating equipment. When oil heating equipment reaches the end of its useful life, a homeowner may replace it with a new oil unit, a "standard" gas unit, or a high efficiency gas unit. This analysis compared the economic desirability of these investment alternatives.

- Early replacement of existing oil heating equipment. The existing stock of oil heating equipment that is over ten years old and has not been upgraded is very inefficient. Homeowners have a wide variety of investment alternatives which can reduce their home heating costs, including upgrading the existing unit, purchasing a new oil unit, and switching to gas. They may switch to gas by installing a conversion burner or by purchasing a new standard or high efficiency unit. This analysis examined the economic desirability of these alternatives.

In this report furnaces refer to forced air heating systems and boilers refer to hot water heating systems. Steam systems were not examined.

The analysis was performed to determine the economic desirability of these investments from both the homeowner's and the nation's perspective. The approach used for the homeowner's perspective was to estimate 1) the number of years required for payback and 2) the present discounted value of the investment, maintenance costs, and fuel savings over the assumed life of the equipment. The number of years required for payback was calculated because homeowners often make investment choices based on this calculation. The payback period is not a good indicator of the desirability of an investment because it provides no information about the return on the investment during the period after payback. The present discounted value of the investment was calculated because this is a good way to determine the desirability of investments in different kinds of equipment over the equipment's useful life.[1/] Only the present discounted value was used to assess the desirability of the investment from the nation's perspective.

In the calculations for the homeowner, the fuel costs were based on an estimate of the fuel prices the homeowner would actually pay over the life of the equipment. For a variety of reasons, the price charged the homeowner for natural gas is not equal to its value to the nation. In the analysis from the national perspective, the price of gas was set equal to its estimated value to the nation. All other assumptions used in the analysis were the same for the homeowner and the nation.

Specific Assumptions Used in the Analysis

The following assumptions were required to perform the analysis:

- The annual heating requirements for the residential unit where the equipment was installed,
- The remaining useful life of the equipment which was replaced or modified,
- The date the heating equipment was installed,

1/ See pg. 35 for a discussion of present discounted value.

- The characteristics of the new and existing heating equipment being compared, including the installation cost, the annual maintenance cost, the seasonal fuel use efficiency, and the expected life,
- Oil to gas conversion costs other than heating equipment costs,
- The fuel prices and the fuel value to the nation,
- The discount rate.

When in doubt about what assumptions to use, we made an effort to specify conditions which would avoid biasing the results in favor of making early replacement or oil-to-gas switching investments. The assumptions we made and our rationale for them is explained below.

Annual Heating Requirements

The amount of fuel and fuel costs which can be saved are directly related to the amount of heat required to maintain the house at its desired temperature. The amount of heat required depends on the characteristics of the house, including its size and degree of weatherization, the climate where it is located, and the behavior of the occupants.

We selected a small single-family house in Baltimore, Maryland as the prototype for estimating the annual heating requirements used in the analysis. We reasoned that if the investments looked desirable for the owner of a house in Baltimore, they would look even better for the owner of a house in a colder climate. The house used to specify the heating requirements was a twelve hundred square foot wood frame house typical of the type built in 1973. This house has some insulation in the walls and ceiling, but it is not as weatherized as houses being built today. In Baltimore, Maryland this house requires 56.7 million Btu's of delivered heat from a boiler or furnace each year.[1/] The amount of fuel required to provide this amount of heat depends on the seasonal efficiency of the heating unit. If the unit has a 60% seasonal efficiency, which is typical for existing, installed units, the unit would consume 94.5 million Btu's per year to provide 56.7 million Btu's of heat.[2/]

The results of the analysis are generally valid for any house which has this annual heating requirement, whether it is a larger, better insulated house in Baltimore, or a similar-sized townhouse located farther north. The return on investment in new heating equipment is determined primarily by the amount of heat required to heat a house, not the characteristics of the house in question.

Remaining Useful Life in Units Replaced or Modified

In order to assess the desirability of replacement or modification, an assumption must be made about the remaining useful life in the heating unit to be replaced or modified. When equipment is replaced before it is worn out, a capital cost is incurred before it is necessary. The newer the equipment being replaced, the greater the total capital costs incurred over the life of the house on an undiscounted or a discounted basis.

To avoid biasing the results in favor of early replacement, the equipment being replaced was assumed to have twenty years of remaining useful

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1/ Office of Technology Assessment, Residential Energy Conservation, Volume I, Washington, D.C., pg. 56-61.

2/ If the unit is gas-fired and has a 60% seasonal efficiency, and gas costs \$4.50/MCF, the annual fuel bill for this house would be \$410. If the unit is oil-fired and has a 50% seasonal efficiency, and heating oil costs \$1.00/gallon, the annual fuel bill for this house would be \$815. If the unit is oil-fired and has a 60% seasonal efficiency, the annual fuel bill would be \$680.

life.[1/] Since the new equipment was also assumed to have twenty years of useful life, none of the capital cost of the new unit was discounted based on an assumption that the old unit would have to be replaced anyway. For the analysis of oil heating equipment modifications the existing equipment was also assumed to have twenty years of remaining useful life. Since most homeowners considering early replacement have units with fewer years of remaining useful life, the economics of early replacement should generally be better from their perspective and from a national perspective than what is shown in the analysis.

Date the Equipment Was Installed

A variety of investment possibilities were analyzed, including some occurring at normal replacement time when the old furnace or boiler was worn out and some occurring before normal replacement time to take advantage of the fuel cost savings associated with new units and old unit modifications. Except for gas heat pump investments, all the investments analyzed were assumed to occur on January 1, 1981. Gas heat pumps are not commercially available at the present time. For the purpose of the analysis, investments in gas heat pumps were assumed to occur on January 1, 1986, five years after the other investments were made.

Characteristics of Heating Equipment Used in the Analysis

ICF conducted a literature search in an attempt to identify the most efficient oil and gas furnaces and boilers and the most cost-effective

1/ Except for the gas heat pump analysis where the remaining useful life in the old unit was assumed to be fifteen years, the same as the assumed useful life of the new heat pump.

equipment modifications. We subsequently augmented that effort through conversations with various manufacturers, installers, and industry associations. We found that the most efficient gas boilers which are commercially available are the "low volume" boilers, such as those manufactured by Teledyne-Lears and NEGEA Energy Products, and the pulse combustion boiler, manufactured by Hydrotherm. The most efficient furnaces presently available are condensing flue-gas furnaces incorporating copper heat exchangers, automatic flue dampers, and spark ignitions. These furnaces are available from a large number of well-known furnace manufacturers, such as Janitrol, Carrier, Tappan and Bryant Air Conditioning, but the Janitrol furnace appears to be somewhat more efficient than the others.

Most new oil furnaces and boilers have seasonal efficiencies between 70% and 80%, but the Blueray furnace appears to be somewhat more efficient. Efforts are underway to produce a pulse combustion oil boiler, but these units are not yet commercial.

In a residential boiler the firebox, the heat exchanger, and the water must be heated. In conventional boilers, these items constitute a large thermal mass that is slow and difficult to heat, resulting in the consumption of large amounts of fuel in the process. Conventional boilers are not only slow to heat, they are also slow to cool down. But, in most cases, the heat remaining in the system after the burner goes out is wasted because the water pump also stops circulating the water through the system. Much of the remaining heat is simply lost up the chimney or is dissipated through the walls of the boiler.[1/] Low volume boilers counteract these sources of

1/ If the boiler is located in an unheated space, the heat dissipated through the insulation is wasted. Any heat vented through the chimney is is also wasted.

inefficiency by incorporating materials with less thermal mass and by heating only a small quantity of water in the boiler.

Pulse combustion is not a new technology; it was first employed in World War II. In the pulse combustion process, a mixture of air and fuel is ignited in the combustion chamber, producing rapid, efficient burning and a pressure pulse. The pulse forces the combustion products from the chamber across the heat-exchange surfaces where the increased pressure and turbulance increase the efficiency of heat transfer. This raises the overall efficiency of the unit.

When flue gases condense, a corrosive residue forms which can damage parts of the heating system. When home heating fuels were low in cost, an easy solution to this problem was to keep the gases hot to prevent them from condensing and vent them through a chimney. Now that home heating fuels are no longer inexpensive, heating systems are being designed to reduce the amount of heat lost up the chimney by cooling the gases before they are vented to the outside. In some condensing flue gas systems, so much heat is extracted from the gases that no chimney is needed. The cool flue gases which result are vented through plastic tubing to the outside through a small hole in the wall.

Old furnaces and boilers may be upgraded to some degree by modifying their design to incorporate some of the features included in new equipment. Since these modifications cannot change the basic design of the old equipment, the resulting efficiency improvement can vary considerably.

We examined only one oil unit retrofit package in this analysis, a combination of a new high-speed flame-retention-head burner and a vent damper. The flame-retention-head burner improves the firing efficiency of the boiler, and the vent damper prevents the loss of the heat up the chimney when the boiler is not in operation. Other unit modifications are possible, but these two seemed to be the most cost-effective. To estimate the efficiency of the retrofit package, we assumed that the existing unit had a 50% efficiency and that the installation of the flame-retention-head burner and the vent damper would increase the unit's efficiency to 67.6%.1/

Most existing oil furnaces and boilers can be converted to gas by changing the burner. The alteration does not significantly affect the efficiency of the unit. In the absence of any empirical information, we assumed that a heating unit with a conversion burner had a 55% efficiency.

Tables 3 and 4 show the characteristics of the specific heating equipment used in the analysis.2/ Installed costs include both the capital cost of the furnace or boiler and the labor charged by the dealer. Labor costs are in the range of $30 to $35 per hour. Most dealers quote an installed price to a homeowner after an on-site inspection rather than work on a time and materials basis, but their installed prices are based on these labor rates. Installed costs and estimated operating and maintenance costs for new equipment were obtained from dealers and distributors, while seasonal efficiencies were

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1/ The estimate of the increase in efficiency was based on the fuel consumption test results for these devices presented in Popular Science, "High Efficiency Heating," October, 1979, p. 101 and Consumer Reports, "Flue Dampers for Oil Furnaces," January 1980, p. 19.

2/ In selecting the size of the units for the installed cost comparisons, no effort was made to reduce the size (input capacity) of the higher efficiency units to account for their higher efficiency. As a result, the assumed installed cost of the high efficiency units may be too high. However, if homeowners and heating equipment installers do not correctly downsize the units to account for their higher efficiencies, the costs shown in Table 3 are representative of what will be paid.

TABLE 3

CHARACTERISTICS OF THE GAS HEATING EQUIPMENT USED IN THE ANALYSIS
(1980 dollars)

Type	Manufacturer	Installed Cost	O & M Cost ($/Yr)	BTU/Hr. Input	Seasonal Efficiency	Life Span (Yrs)	Commercially Available	Source of Cost Data
Low Volume Boiler	NEGEA Energy Products	$1,500	$40	89,000	.842	20	1980	Michael Belanger, Marketing Manager for NEGEA Energy Products
Pulse Combustion Boiler	Hydrotherm	$1,950	$50	100,000	.925	20	1980	Apex Plumbing, Washington, D.C.
High Efficiency Gas Furnace	Janitrol	$1,250	$50	100,000	.855	20	1980	E.E. Donaldson & Son, Baltimore, MD.
Gas Heat Pump	Allied Chemical/ Philips Engineering	$2,650 *	$50	90,000	1.300	15	1986	Philips Engineering
Standard Gas Boiler	Dunkirk	$1,450	$50	85,000	.711	20	1980	Sears
Standard Gas Furnace	Heil-Quaker	$1,050	$50	105,000	.652	20	1980	Sears
Oil to Gas Conversion Burner	Wayne	$800 **	$50	100,000	.550	20	1980	Alma Heating and Air Conditioning, Washington, D.C.

* Reduced from projected Allied Chemical and Phillips Engineering cost of $4,100 to adjust for the cost savings associated with not having to purchase a separate air conditioning system.

** Includes the $200 which was added to the other installed cost estimates for oil-to-gas conversion.

Source: ICF survey of manufacturers and Washington, D.C. area installers of heating equipment.

TABLE 4

CHARACTERISTICS OF THE OIL HEATING EQUIPMENT USED IN THE ANALYSIS
(1980 dollars)

Type	Manufacturer	Installed Cost	O & M Cost ($/Yr)	BTU/Hr. Input	Seasonal Efficiency	Life Span (Yrs)	Commercially Available	Source of Cost Data
High Efficiency Oil Furnace	Blueray	$1,700	$80	100,000	.841	20	1980	Rowan Heating and Air Conditioning, Washington, D.C.
Standard Oil Furnace	Heil-Quaker	$1,150	$80	105,000	.795	20	1980	Sears
Oil Boiler	Dunkirk	$1,700	$80	115,000	.795	20	1980	Sears
Flame-Retention-Head Burner/Vent Damper Modification	Beckett*	$625**	--	--	.676***	20	1980	R.E. Michael Co., Washington, D.C. and ICF estimate.

* Flame-Retention-Head Burner Only

** Does not account for the value of the 15% conservation tax credit available to homeowners.

*** After modification.

Source: ICF survey of manufacturers and Washington, D.C. area installers of heating equipment.

obtained directly from the manufacturers. The efficiency estimates are the Annual Fuel Utilization Efficiency (AFUE) ratings which are based on a standardized Department of Energy test method.

Installed cost estimates varied widely even for the same equipment, but we did notice that gas equipment prices have risen considerably since our spring survey while oil equipment prices have fallen. While the installed costs of the high efficiency systems in Table 3 and 4 are typical of those which a homeowner would pay, the installed costs provided by Sears of the standard furnace and the standard boiler lie at the low end of the estimated cost range obtained in the survey of Washington, D.C. area installers of heating equipment. Use of the relatively inexpensive installed cost of standard efficiency heating equipment rather than a more representative cost lying near the middle or the upper end of the estimated cost range avoids biasing the analysis in favor of investment in high efficiency equipment.

The Office of Technology Assessment carried out a field survey of existing heating equipment efficiencies and determined that the average seasonal efficiency of installed oil-fired units was 50% and the average seasonal efficiency of installed gas-fired units was 61.4%.[1/] The average efficiency of oil heating equipment sold in recent years is much higher.[2/] In the analysis of oil unit modification, the existing unit was assumed to have a 50% seasonal efficiency. Since newer oil heating equipment is more efficient, the

1/ Office of Technology Assessment, Residential Energy Conservation, Vol. 1, Washington, D.C., p. 39.

2/ DOE has estimated that the average efficiency of indoor gas heating equipment sold in 1978 was 65% and that the average efficiency of oil indoor equipment sold in that year was 76%. Federal Register, Volume 45. No. 127, June 30, 1980 p. 44003 analysis of early replacement of oil units was performed for units with both 50% and 60% seasonal efficiency. In the analysis of early replacement of existing gas units, the existing unit was assumed to have a 61.4% efficiency.

Oil-to-Gas Conversion Costs

The installation costs shown in Tables 3 and 4 are for replacement of heating equipment with new equipment using the same fuel (except for the conversion burner in Table 3). There are additional costs associated with switching from oil-to-gas. They include hook-up costs paid to the utility, additional costs paid to the installer to run a new gas line within the house and the loss of any oil which may remain within the oil tank.

Hook-up costs can vary widely depending primarily on the distance from the house to a gas main. Of course, some houses converting to gas heat may already have gas service for cooking or water heating. In such cases, the existing gas line to the house and the meter will usually have sufficient capacity to service a furnace or boiler. If a new line must be installed, many utilities do not charge the homeowner anything unless the house is a long distance (more than 50-100 feet) from the main.1/ If the house is far from the main, the homeowner usually must pay a substantial hook-up fee.

The cost of a new gas line within the house is included in the installer's estimate. For most installations, our survey indicated that the cost of switching from oil to gas was about $100 more than the cost of simple gas unit replacement.

1/ Although utilities incur an initial hook-up cost when they provide gas service to houses for the first time, if these houses are located along an existing main, they recoup these costs through the economics associated with higher gas main utilization and the low administrative cost of reading extra meters in areas where there already are other customers.

Homeowners may incur other costs in the switch. Frequently, the oil tank contains some oil. The homeowner is unlikely to recoup any of the cost of this oil and may even have to pay to have it removed. In the analysis, we assumed that oil-to-gas conversion costs $200 more than simple gas unit replacement.

Most of the homeowners who will switch to gas have ready access to gas distribution lines, and many already use gas for cooking or water heating. Accordingly, the conversion costs used in the analysis should be appropriate for most homeowners who contemplate switching.

Fuel Prices and Fuel Value

The most controversial assumptions in any analysis of this type are the heating oil and natural gas price projections and the value of natural gas to be used when evaluating the investments from a national perspective. The results of the analysis are sensitive to both the assumed level of crude oil prices and the assumptions about heating oil and natural gas price differentials.

The fuel prices used in the analysis were selected to avoid biasing the results in favor of the early replacement and oil-to-gas switching investments. The average price of imported crude oil in the U.S. Gulf used in the analysis was $34/barrel (1980 dollars) in 1980 rising 2% annually in real terms (i.e., in addition to inflation) to $50.50/barrel (1980 dollars) in the year 2000. This crude price is equal to the actual average imported crude price in 1980 and is consistent with Saudi Arabia's plan for future crude oil price increases. It underestimates the level of prices which could prevail if political disruptions continue to occur in the Middle East. A low estimate of crude oil prices biases the results against investments in higher efficiency units because the value of the fuel savings is lower.

Average home heating oil prices for the northern part of the U.S. were generated based on the cost of producing distillate in large U.S. Gulf refineries plus the average of the transportation cost to Chicago and Baltimore plus a distributor's cost. The assumed distributor margin was 16.7¢/gallon (1980 dollars) which was the actual margin for the first five months of 1980.[1/] The effect of the crude oil entitlements program was taken into account by reducing the average price of crude oil paid by U.S. refiners by $1.00/barrel in 1981 (the entitlements program ends on September 30, 1981). The 1981 delivered price of heating oil used in the analysis was $1.01/gallon (1980 dollars).

Natural gas prices will be determined by the supply of gas available and the demand for natural gas, which will be significantly affected by government price control and boiler fuel use policy during the 1981-2000 time period. During the next ten years, the most important factor will be the timing of wellhead price decontrol. Under the current law (the Natural Gas Policy Act), over half the gas produced domestically is scheduled for wellhead price decontrol on January 1, 1985 or in the case of reimposition of controls, in late 1987 or early 1988.

When (and if) decontrol occurs, the price of this gas could increase considerably at the wellhead. However, since a large amount of domestic gas production is not slated for price decontrol and since most of this gas is under contract to the interstate market, the average price of gas in the

1/ DOE, Monthly Energy Report, September, 1980, p. 81

interstate market will initially remain below the price in the intrastate markets (primarily New Mexico, Texas, Oklahoma, Louisiana, and Arkansas) after price decontrol. If natural gas supplies are reasonably plentiful and if state regulatory commissions continue to require average cost or rolled-in pricing, the old gas contracts will enable residential consumers in the north to continue to obtain gas at prices below the price of heating oil on a Btu basis. Of course, if natural gas prices are not decontrolled, residential consumers in the north who can obtain gas will also continue to obtain gas at prices below the price of heating oil on a Btu-basis.

The Powerplant and Industrial Fuel Use Act (PIFUA) also affects natural gas prices. The Act prohibits that the installation of any new oil and gas boilers with capacities in excess of 100 million BTU's/hour unless exemptions are granted. The Act also prohibits electric utilities from using more natural gas than they used during the 1974-1976 time period and prohibits their use of natural gas except for peak load after 1990. Because PIFUA limits gas demand, it helps keep down the market price when wellhead decontrol occurs.

Natural gas prices from 1981 to 1995 were generated using the Natural Gas Market Simulator, a computer-based representation of the intrastate and interstate natural gas markets developed by ICF for the Department of Energy's Office of Gas Policy. The model was developed specifically to assess the effect of price controls and their removal on gas prices in these markets. Since all the northern parts of the country are in the interstate gas market, the average interstate residential sector gas price estimated by the model was used to assess the desirability of investments from the homeowner's perspective.

A detailed discussion of all the assumptions used to generate the gas prices is beyond the scope of this study, but some of the most important are as follows:

- Industrial and electric utility coal conversion proceeds at a modest pace with respect to both reconversion of existing coal capable units and accelerated replacement of existing oil and gas-fired units.

- The 1974-76 base period PIFUA limits on gas use are assumed to remain in place, but the 1990 prohibition on electric utility use of gas is eliminated.

- The conventional U.S. gas resource base is consistent with the "median" estimate contained in U.S. Geological Survey Circular 725, adjusted for subsequent increases in Overthrust Belt resource potential and decreases in Permian Basin potential.

- No liquified natural gas imports are used in the U.S. during the period.

- Consistent with current policy, wellhead price decontrol is achieved permanently on January 1, 1985.

Using these assumptions the model estimated U.S. supply, intrastate and interstate demand, and intrastate and interstate prices for different classes of customers. Table 5 shows U.S. gas consumption by sector, Table 6 shows U.S. gas supply, and Table 7 shows the fuel prices generated by the model.

The data in Table 7 show that prices fly up in the intrastate gas market in 1985 when decontrol occurs. Prices also rise in the interstate market, but more gradually due to the existence of old gas contracts. The market clearing price for gas is set by the value of gas to industrial customers who choose between gas and petroleum boiler fuels, depending on which cheaper. After decontrol under the conditions specified, the model indicates that the natural gas market clearing price will be the price of low-sulfur residual fuel in the intrastate market. Since residual fuel is priced below distillate (heating

TABLE 5

U.S. GAS CONSUMPTION
(Tcf/year)

	1980	1982	1985	1988	1990	1995
U.S. Total						
Residential/Commercial	7.3	7.8	7.8	7.7	7.5	7.8
Industrial	7.1	7.1	7.2	8.0	8.3	8.6
Electric Utility	3.0	2.8	2.1	2.4	2.4	1.3
LPTD Uses*	2.4	2.4	2.4	2.5	2.5	2.5
	19.8	20.1	19.5	20.6	20.7	20.2

Source: ICF Incorporated estimates made using the Natural Gas Market Simulator developed for the U.S. Department of Energy's Office of Gas Policy.

* Lease, gas processing plant, and fuel use and losses in transmission and distribution.

TABLE 6

U.S. GAS SUPPLY
(Tcf/year)

	1980	1982	1985	1988	1990	1995
Lower-48 Conventional	18.4	17.8	16.8	16.5	16.3	15.3
Unconventional	0.1	0.3	0.6	0.8	1.1	1.9
ANGTS*	--	--	--	0.8	0.8	0.8
Coal Synthetic	--	--	0.1	0.1	0.1	0.1
SNG**	0.2	0.5	--	--	--	--
Imports						
Canada	1.0	1.4	1.6	1.7	1.7	1.5
Mexico	0.1	0.1	0.4	0.7	0.7	0.6
Total	19.8	20.1	19.5	20.6	20.7	20.2

* Alaska Natural Gas Transportation System
** Synthetic Natural Gas

Source: ICF Incorporated.

TABLE 7

FUEL PRICES ESTIMATED BY
THE NATURAL GAS MARKET SIMULATOR
(1980 Dollars/Million BTU)

	1980	1982	1985	1988	1990	1995
Interstate Natural Gas						
Residential	4.24	4.82	6.85	7.47	7.87	8.65
Commercial	3.96	4.53	6.56	7.18	7.59	8.36
Exempt Industrial	3.41	3.98	6.01	6.63	7.03	7.81
Non-Exempt Industrial	3.41	4.16	6.01	6.63	7.03	7.81
Electric Utility	3.41	3.98	6.01	6.63	7.03	7.81
Intrastate Natural Gas						
Residential	3.21	3.54	7.03	7.22	7.63	8.22
Commercial	2.92	3.24	6.73	6.92	7.33	7.92
Exempt Industrial	2.55	2.87	6.37	6.55	6.96	7.55
Electric Utility	2.55	2.87	6.37	6.55	6.96	7.55
U.S. Gulf Refinery Gate						
Distillate	5.61	6.11	6.84	7.23	7.51	8.25
Low-Sulfur Residual	4.67	5.57	6.29	6.66	6.92	7.63
High-Sulfur Residual	3.44	4.51	5.47	5.81	6.07	6.72
Interstate Heating Oil	7.01	7.51	8.24	8.63	8.91	9.65

Source: ICF Incorporated estimates made using the Natural Gas Market Simulator developed for the U.S. Department of Energy's Office of Gas Policy.

oil), the price of natural gas delivered to interstate residential customers remains below the price of heating oil throughout the 1980-95 period even though the price differential narrows as old gas contracts expire.

The model currently only generates gas prices through 1995. Gas prices for 1996 to 2000 were generated by keeping the 1995 price differential between heating oil and natural gas constant, under the assumption that the clearing price for natural gas continues to be set by the price of low sulfur residual fuel.

These prices can be compared to official Department of Energy forecasts. The Energy Information Administration (EIA) develops annual forecasts of energy prices. In their most recent published medium price forecast, natural gas prices are between the price of high-sulfur residual fuel and coal. The EIA gas prices are very low because they assume that rapid conversion of industrial boilers to coal and electric utilities to coal and nuclear power will greatly reduce gas demand.[1/] As a result, in EIA's projection, the residential price of natural gas remains far below heating oil prices even after gas wellhead price decontrol. ICF's gas price projections are higher because we assume slower conversion to coal in the industrial and electric utility sectors, which we believe is a more realistic assumption.[2/] The effect of ICF's higher gas price assumption in the analyses is to reduce the estimated homeowner savings associated with oil-to-gas switching.

1/ EIA, Annual Report to Congress 1979, Volume Three, p. 93

2/ For example, in ICF's projection the residential gas price is $1.04/million BTU less than the heating oil price in 1990. In EIA's projection the residential gas price is $3.11/million BTU (1980 dollars) less than the heating oil price in 1990. Ibid., pg. 103.

The fuel costs used in the investment analyses from the consumer's perspective (the actual prices for heating oil and natural gas, in dollars/million Btu) and the national perspective are shown in Table 8.

As mentioned previously, the value of natural gas from a national perspective is not the same as the price the homeowner pays. The value to the nation is the cost incurred by the nation when homeowners use additional gas or the costs saved when homeowners reduce gas consumption. If homeowners are already hooked up to gas distribution lines, the costs or savings are the same. For the homeowners who require a new gas line from the main to use additional gas, the additional capital cost must be added to the estimate of the nation's costs when a new gas heating unit is installed.

In the forecasts for natural gas supply and demand over the time period, gas use remains below 1972 levels. As a result, little new infrastructure is required, and changes in gas consumption by residential customers only reallocate gas use within the existing pipeline system. Since this system would have to be maintained anyway, little or no additional cost to the nation beyond hook-up costs is involved in conversions to gas.

ICF's Natural Gas Market Simulator was used to estimate the value of gas to the nation within this framework. All customers were allowed to bid for available natural gas without any price controls in place. Fixed costs (e.g., pipeline depreciation) were allocated annually to all customers using natural gas. The resulting estimate of the value of natural gas to the nation is shown in Table 8. A hook-up capital cost must be added, if relevant. To be conservative in the analysis from a national perspective, we assumed that <u>all</u> oil-to-gas conversions involved a new hook-up. We assumed that all oil-to-gas

TABLE 8

COST OF RESIDENTIAL HEATING FUELS
USED IN THE ANALYSIS
(1980 dollars/million Btu)

Year	Heating Oil	Natural Gas Homeowner	Natural Gas Nation*
1981	7.25	4.52	5.56
1982	7.51	4.82	5.87
1983	7.80	5.12	6.19
1984	8.11	5.50	6.50
1985	8.24	6.85	6.63
1986	8.36	6.99	6.65
1987	8.50	7.29	6.77
1988	8.63	7.47	6.90
1989	8.77	7.64	7.01
1990	8.91	7.87	7.14
1991	9.06	8.01	7.25
1992	9.20	8.24	7.46
1993	9.35	8.30	7.54
1994	9.50	8.47	7.70
1995	9.65	8.65	7.86
1996	9.81	8.80	8.13
1997	9.97	8.96	8.29
1998	10.14	9.13	8.46
1999	10.31	9.30	8.63
2000	10.48	9.47	8.80

* Does not include any capital costs incurred to hook up new customers or to increase existing gas service capacity to existing customers.

Source: ICF Incorporated estimates made using the Natural Gas Market Simulator developed for the U.S. Department of Energy's Office of Gas Policy.

conversions cost the nation $356 (1980 dollars) for a new hook-up.[1/] This estimate included installation of 50-75 feet of gas line and new metering equipment. In fact, many homeowners already use gas and can install gas heating equipment without causing the gas utility to incur any additional costs.

For comparability, the cost to the nation of supplying heating oil to the homeowner should be used in the analysis from the national perspective. However, since the fixed costs of supplying heating oil are not very large, we decided to use the market price as an estimate of the real cost to the nation of using heating oil.

Discount Rate

Money saved in the future through reduced fuel consumption is not worth as much to a homeowner as money which must be invested today. As a result, when two competing investment options with different cash flow patterns must be compared, the value of the future savings is discounted, and the present discounted value of the two income streams is calculated. This method makes it possible to compare all of the costs and benefits of the two options on a life cycle basis.

The choice of the discount rate is an important determinant of the outcome of the analysis. An investment in efficiency which has a large initial cost will not look very attractive if a very high discount rate is used because the present value of future savings will be very small.

1/ Department of Energy, Natural Gas Hook-Ups: Real Resource Cost Analysis, January 23, 1979, p. 19 (hook-up cost was multiplied by 1.19 to change 1978 to 1980 dollars).

The discount rate used in investment analysis has two components, the risk-free rate of return expected by investors and the additional return they expect if asked to take on some risk. Clearly, investing in heating unit efficiency has some risk because the future savings will depend on the actual efficiencies of the unit in practice and the future price of fuels. Additionally, if the homeowner sells his house, he may not receive a price for the house which completely compensates him for the increased investment in the heating unit.

In order to bound the rate which is appropriate for the analysis, the cost to the homeowner of investing money in a residential heating unit must be calculated. This cost varies considerably depending on 1) whether the homeowner must borrow money or only give up an alternative investment and 2) the marginal income tax bracket of the homeowner.

The highest cost of funds is incurred by a low income homeowner who must borrow money and who pays no income tax; he/she will pay a high interest rate which cannot be deducted from taxable income. If the interest rate paid is 18% in nominal terms and the inflation rate is 9%, the real cost of the loan to the low income homeowner is 8.2%[1/]

The lowest cost of funds is incurred by a high income homeowner who gives up an alternative investment which provides a return which is subject to a high income tax. If the (risk-free) investment returns 12% in nominal terms, the inflation rate is 9%, and his/her marginal tax rate is 50%, then the real cost of giving up the investment is -2.8%,[2/] i.e., after tax the high income homeowner is losing money on his alternative investment.

1/ 1.18 ÷ 1.09 = 1.082 or 8.2%.

2/ 1.06 ÷ 1.09 = 0.972 or -2.8%.

A 10% real discount rate was used to assess the desirability of the investments examined on a life cycle basis. A 10% real rate is equal to a nominal after tax interest rate of 19.9% for the homeowner if inflation is 9% (no tax is paid when the homeowner increases disposable income by reducing total heating costs). This rate provides a substantial amount of risk premium for the average homeowner and for the nation. Clearly, this assumption poses a severe test for the desirability of the investments considered. Obviously this test is far too strict for a high income homeowner.

III. RESULTS OF THE ANALYSIS

Homeowners considering replacement or modification of existing residential heating equipment fall into the following four categories:

- Homeowners who must replace worn out gas heating equipment,
- Homeowners considering early replacement of gas heating equipment which is in good working order,
- Homeowners who must replace worn out oil heating equipment, and
- Homeowners considering early replacement or modification of existing oil heating equipment which is in good working order.

The presentation of the results of the analysis is organized so that the investment options available to homeowners in each of these categories can be readily compared. The results are based on the projected average interstate residential oil and gas prices used in the analysis. Since there is considerable variation in residential gas prices in the interstate market, the sensitivity of the results to higher gas prices is discussed after the presentation of the results.

Replacement of Gas Heating Equipment at Normal Replacement Time

When an existing gas furnace or boiler wears out, a homeowner must purchase a new unit. The cheapest unit available is a low efficiency "standard" unit. In the first set of investment options examined, we calculated the return on the incremental investment which is required to buy a high efficiency unit instead of a standard unit. The results of the analysis are shown in Table 9.

In every case the homeowner and the nation are best served when the homeowner buys a high efficiency boiler or furnace rather than a standard

TABLE 9

PAYBACK PERIOD AND PRESENT DISCOUNTED VALUE OF INVESTING IN MORE EFFICIENT GAS HEATING SYSTEMS AT NORMAL REPLACEMENT TIME

High Efficiency Gas Unit Compared to Standard Unit	Seasonal Efficiency	Homewoner's Perspective: Payback Period (Years)	Homewoner's Perspective: Present Discounted Value (1980 $)	National Perspective: Present Discounted Value (1980 $)
Low Volume Boiler	.842	1	792	781
Pulse Combustion Boiler	.925	5	619	609
High Efficiency Gas Furnace	.855	2	1,052	1,041

unit. Despite low gas prices, the payback on the incremental investment cost of the low volume gas boiler relative to the standard boiler is only one year, and the payback on the high efficiency gas furnace is only two years. The pulse combustion boiler is somewhat more efficient than the low volume boiler, but it is considerably more expensive. For the annual heating requirement used in the study, the low volume boiler is the preferred investment, and it is used to represent the high efficiency gas boiler in the other analyses. The higher efficiency of the pulse combustion boiler makes it more appropriate for houses with higher heating requirements than the one used in the study because there is a greater opportunity to save fuel when more heat is required.

Early Replacement of Gas Heating Equipment

Early replacement of gas heating equipment is desirable only if the much higher efficiencies of new equipment can provide substantial fuel savings. The economics of early replacement of gas heating equipment with high efficiency units is shown in Table 10. The results of the analysis indicate that over the life of the investment homeowners can save a modest amount of money by replacing their existing unit in 1981 with a high efficiency unit, but the payback period is 8-10 years. With a payback period this long, few homeowners are likely to make this investment without government encouragement. For homeowners with higher heating requirements or with heating equipment which has less than twenty years of remaining useful life, the investment would be better than shown in Table 10.

The analysis also indicates that the economic desirability of early replacement of an existing unit with a gas heat pump in 1986 is not much better than early replacement with a high efficiency furnace in 1981. Once the high efficiency furnace is installed, it clearly is not economically desirable to replace it when the gas heat pump becomes available in 1986.

Replacement of Oil Heating Equipment at Normal Replacement Time

When the existing oil unit wears out, homeowners with access to natural gas can choose either a new oil unit or a new gas unit. Table 11 contains the results of a comparison ot the economics of 1) conversion to gas or 2) installation of a high efficiency oil unit to installation of a standard oil unit. Unlike the situation with gas equipment, however, there is not much difference in efficiency between standard and high efficiency oil equipment.

The results of the analysis are that the slightly higher efficiency of the high efficiency oil furnace does not overcome its higher installed cost. For the heating requirement used in the analysis, the homeowner does not save money with the higher efficiency unit. The most interesting results are that for homeowners near a gas main, conversion to gas is far superior to investment in a new oil unit. Also, as already shown in Table 9, installation of a high

TABLE 10

PAYBACK PERIOD AND PRESENT DISCOUNTED VALUE FOR EARLY REPLACEMENT OF GAS FURNACES AND BOILERS WITH MORE EFFICIENT UNITS

Gas Unit Used to Replace Existing Gas Unit	Unit Replaced	Year of Replacement	Homeowner's Perspective: Payback Period (Years)	Homeowner's Perspective: Present Discounted Value (1980 $)	National Perspective: Present Discounted Value (1980 $)
High Efficiency Low Volume Boiler	Existing Boiler*	1981	9	105	109
High Efficiency Furnace	Existing Furnace*	1981	8	328	332
Gas Heat Pump	Existing Furnace*	1986	8	465	217
Gas Heat Pump	High Efficiency Furnace**	1986	15	-1,199	-1,314

* .614 seasonal efficiency.

** .855 seasonal efficiency.

TABLE 11

PAYBACK PERIOD AND PRESENT DISCOUNTED VALUE
OF CONVERSION TO GAS UNITS AS COMPARED TO INVESTMENT
IN A HIGH EFFICIENCY OIL UNIT AT NORMAL REPLACEMENT TIME

Unit Used Instead of Standard Oil Unit	Seasonal Efficiency	Homeowner's Perspective: Payback Period (Years)	Homeowner's Perspective: Present Discounted Value (1980 $)	National Perspective: Present Discounted Value (1980 $)
Blueray Oil Furnace	.841	11	(56)	(56)
Standard Gas Furnace	.652	1	507	137*
High Efficiency Gas Furnace	.855	2	1,559	1,192*
Low Volume Boiler	.842	Immediate	1,559	1,232*
Standard Gas Boiler	.711	Immediate	897	528*

* Assumes a new hook-up is required. If a new hook-up or an increase in gas service capacity is not required, the value from a national perspective is $356 higher.

efficiency gas unit is a much better investment for the homeowner than investment in a standard unit.

The results also indicate that conversion from oil to gas is economically desirable to the nation. Little is saved when the homeowner installs a standard gas unit instead of a standard oil unit if a new hook-up is required. However, if the homeowner is already hooked up and the existing gas line capacity is sufficient to service a furnace or boiler, then the savings to the nation from switching are substantial even if only a standard gas unit is installed. The savings when a high efficiency gas unit is installed are considerable.

The results of this analysis are not valid for houses which are located a long distance from an existing gas main. The results are sensitive to the assumptions about the price of natural gas relative to home heating oil. The effect of higher gas prices on these results is discussed below.

Early Replacement of Oil Heating Equipment

Tables 12 and 13 present the results of the analysis of the modification and early replacement alternatives for existing oil boilers and existing oil furnaces. The results indicate that every alternative considered is better than continuing with the existing equipment in its present state. For the homeowner with access to natural gas, the best alternative is to replace the existing oil unit with a new high efficiency gas unit. If a new hook-up is required, the low efficiency gas conversion burner modification is about equal to the oil unit upgrading package from the homeowner's perspective after the value of the 15% conservation tax credit for the upgrading devices is taken into account.

TABLE 12

PAYBACK PERIOD (IN YEARS) AND PRESENT DISCOUNTED VALUE FOR EARLY REPLACEMENT OF OIL BOILERS WHICH HAVE 50% AND 60% SEASONAL EFFICIENCIES

Unit Used to Replace or Modify Existing Oil Boiler	Homeowner's Perspective: Payback Period (Years)		Homeowner's Perspective: Present Discounted Value (1980 $)		National Perspective: Present Discounted Value* (1980 $)	
	50%**	60%**	50%**	60%**	50%**	60%**
Flame-Retention-Head Burner/Vent Damper***	3	N/A	1,710****	N/A	1,616	N/A
New Oil Boiler	6	9	1,494	60	1,494	68
Gas Conversion Burner	3	4	1,826	391	1,453	19
Standard Gas Boiler	4	5	2,391	956	2,022	588
Low Volume Gas Boiler	3	4	3,183	1,748	2,816	1,381

* Assumes a new hook-up is required. If a new hook-up or an increase in gas service capacity is not required, the value from a national perspective is $356 higher.

** Existing boiler seasonal efficiency.

*** The flame retention burner/vent damper option does not replace the oil boiler. These units improve the seasonal efficiency of the existing boiler.

**** Assumes the 15% tax credit increases the return on this investment by $94 from the homeowner's perspective.

TABLE 13

PAYBACK PERIOD IN YEARS AND PRESENT DISCOUNTED VALUE FOR EARLY REPLACEMENT OF OIL FURNACES WHICH HAVE 50% AND 60% SEASONAL EFFICIENCIES

Unit Used to Replace or Modify Existing Oil Boiler	Homeowner's Perspective: Payback Period (Years)		Homeowner's Perspective: Present Discounted Value (1980 $)		National Perspective: Present Discounted Value* (1980 $)*	
	50%**	60%**	50%**	60%**	50%**	60%**
Flame-Retention-Head Burner/Vent Damper***	3	N/A	1,710****	N/A	1,616	N/A
New Oil Furnace	4	7	1,847	412	1,847	412
Gas Conversion Burner	3	4	1,826	391	1,453	19
Standard Gas Furnace	3	4	2,354	919	1,984	549
High Efficiency Gas Furnace	3	4	3,405	1,971	3,039	1,604

* Assumes a new hook-up is required. If a new hook-up or an increase in gas service capacity is not required, the value from a national perspective is $356 higher.

** Existing boiler seasonal efficiency.

*** The flame retention burner/vent Damper option does not replace the oil boiler. These units improve the seasonal efficiency of the existing boiler.

**** Assumes the 15% tax credit increases the return on this investment by $94 from the homeowner's perspective.

If the existing oil heating equipment has a 60% efficiency, the equipment upgrading package is not applicable, and the conversion burner will not save the nation much money over the life of the investment. Investing in a high efficiency gas unit is optimal, but all the other investments are economically desirable, including replacing the existing oil equipment with high efficiency oil equipment. If the homeowner is already hooked up to a gas line which has enough capacity to service gas heating equipment, a reconversion burner is superior to upgrading the existing oil unit, but far inferior to replacing the old unit with a new high efficiency gas unit.

For a homeowner without access to natural gas from a nearby main, modifying the existing oil heating equipment is superior to early replacement with a new oil unit if the existing equipment has twenty years of remaining useful life. If the existing oil unit does not have many years of remaining useful life, early replacement is better than modifying the old unit.

Sensitivity of the Results to Higher Gas Prices

If the same heating oil prices and higher residential gas prices are used in the analysis, the results do change somewhat. Higher gas prices make early replacement of gas equipment with high efficiency units more desirable. Higher gas prices also make incremental investment in higher efficiency more desirable when gas units are replaced at normal replacement time.

Higher gas prices also reduce the desirability of switching from oil to gas at or prior to normal replacement time. After 1984 residential natural gas prices are projected to be \$1.00-\$1.50/million BTU (1980 dollars) below the price of home heating oil. If the assumed price of natural gas is increased by \$1.00/million BTU (1980 dollars) over the entire period, the results would change in the following ways:

- The present discounted value of switching to a high efficiency low volume gas boiler instead of buying a new oil burner at normal replacement time falls from $1,559 to $986, but it is still a highly desirable investment.

- The present discounted value of switching to the standard gas furnace instead of buying a new oil furnace falls from $507 to -$232.

- The present discounted value of the gas conversion burner falls $877, which makes it much less desirable than simply upgrading the existing oil unit.

This sensitivity analysis indicates that investments in high efficiency gas equipment will be highly desirable to the homeowner even if natural gas prices rise substantially above ICF's forecast.

IV. CONCLUSIONS

This report was prepared to analyze the economics of replacing existing residential oil and gas heating equipment with new high efficiency units in houses which are at least partially weatherized. Homeowners in houses which do not have caulking, weatherstripping, or insulation should invest in building weatherization before they consider heating equipment investments.

The analysis was based on annual heating requirements of 56.7 million BTU's/year. An existing heating system with 60% seasonal efficiency would consume 94.5 million BTU's/year to provide this amount of heat. An average homeowner with this efficiency unit and this heating requirement would have paid about $410 for natural gas and $680 for heating oil in 1980. As discussed in the introduction, this heating requirement is typical for homeowners in Baltimore or Kansas City with moderately weatherized homes wnere heating degree days exceed 4,000 per year. Homeowners farther north typically have significantly higher heating requirements.

The results of the analysis performed in this report are relevant for the entire northern region of the United States, which contain 64% of all gas-heated housing units and 83% of all oil-heated housing units in the nation.[1/] Figure 1 contains a map which indicates the location of this region. The most important conclusions which can be drawn from this analysis are as follows:

- Whenever an existing gas furnace or boiler wears out, the homeowner should definitely purchase a new high efficiency gas unit. The incremental investment is very low relative to the standard gas unit, the payback period is 1-2 years, and the total

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1/ Calculated from data in U.S. Department of Energy, Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households, February 1980, p. 42.

savings for the homeowner and the nation are very large over the life of the investment.

- Early replacement of existing gas heating equipment is economically desirable under the assumptions used in the analysis, but the return on investment is not nearly as high as most homeowners require for conservation investments. However, for high income homeowners who have a variety of investment alternatives, early replacement of existing gas equipment with a high efficiency unit offers a much higher after-tax return than alternative investments whose return is subject to income tax.

- Whenever an existing oil furnace or boiler wears out, any homeowner who already uses gas for non-heating purposes or who has ready access to a gas main should install gas heating equipment. The best gas heating equipment is equal to or better than the best oil heating equipment from an efficiency and cost standpoint, and gas will continue to be cheaper than heating oil where it is available. As noted above, the new unit installed should be a high efficiency unit.

- Any existing oil heating equipment which is over ten years old and has never been upgraded should be upgraded or replaced as soon as possible.

  -- Homeowners should replace the existing oil unit with a new high efficiency gas unit if they already use gas for non-heating purposes or have ready access to a gas main. The best gas heating equipment is equal to or better than the best oil equipment from an efficiency and cost standpoint, and gas will continue to cost less than heating oil where it is available.

  -- Homeowners who do not have ready access to a gas main should upgrade their existing oil heating equipment if it has twenty years of remaining useful life. If the remaining useful life is much shorter than twenty years, the old unit should be replaced with a new oil unit.

These conclusions are sensitive to changes in the assumptions used in the study. However, the assumptions were selected to avoid biasing the conclusions in favor of new investment, so changes in the conclusions are unlikely. The benefits of replacing worn out gas heating equipment and old oil heating equipment with high efficiency gas units are so large from both the homeowner's and the national perspective that major changes in the assumptions would not affect these conclusions.

Government Policy Implications

A review of the data on the use of heating fuel by type of housing structure indicates that 11.4 million single-family homes and 2.2 million units in buildings with 2-4 units were heated with fuel oil or kerosene in 1978.[1/] These data suggest that there are about 12 million residential-type oil furnaces and boilers installed in the U.S. Data on manufacturers shipments of oil furnaces and boilers indicate that about four million new oil units have been installed since 1970.[2/]

These data suggest that there are about 8 million residential oil heating units in the U.S. which are over ten years old. Some of these units have been upgraded, but the majority probably have not. Data collected by the Department of Energy suggest that most homeowners have not made heating equipment modifications.[3/] Since 83% of all oil heating units in the U.S. are located in the region covered by this analysis, over 6 million oil units may be in need of modification or replacement.

The AGA Gas Househeating Survey indicates that there are almost 4 million residential gas customers (44% of all customers) in the Middle Atlantic and

1/ Department of Energy, Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households, 1978, February 1980, p. 44.

2/ Oak Ridge National Laboratory, Buildings Energy Use Data Book, Edition 2, December 1979, pp. 2-70 and 2-71.

3/ Department of Energy, Residential Energy Consumption Survey: Conservation, February 1980, p. 55.

New England regions which currently do not use gas for heating.[1/] Some of these customers are undoubtedly apartment dwellers who do not have their own heating unit, but clearly there are a vast number of homeowners in this group with old oil heating equipment who are already hooked up to a gas main. Many other homeowners may have ready access to an existing gas main, although they are not hooked up. These homeowners should be encouraged to replace their existing oil heating equipment with high efficiency gas units.

The immediate opportunities for increased energy conservation are clearly in the houses with oil heating systems. Many of these homeowners are switching to gas. They should be encouraged to install high efficiency units. The required Federal role in this process is minimal. The economic incentives are clear; the homeowner can save a great deal of money if he/she is just given the correct information.

Over the near term as high efficiency gas equipment is produced in greater volume, programs should be developed which will provide an incentive for homeowners to replace existing gas heating equipment with high efficiency units. Information should be provided to high income homeowners about the considerable benefit to them of investing in high efficiency equipment. Programs to assist moderate and low income homeowners to replace existing gas equipment in their homes should be developed prior to natural gas price decontrol to help cushion the impact of higher residential gas prices.

The end result of these programs could improve the average seasonal efficiency of the heating equipment in the nation's residential housing stock

1/ American Gas Association, Gas Facts 1978, 1979, p. 76.

from about 60% today to about 80% by 1990. This change would reduce oil and gas space heating fuel consumption in the existing housing stock by 25%, which is equal to a saving of 725,000 barrels/day of oil.[1/]

1/ (X ÷ .8) − (X ÷ .6) = −.25X, where X is fuel consumption. Oil and gas consumption for space heating was 6.0 quadrillion Btu's in 1977. See ICF, Oil Import Reduction: An Analysis of Production and Conservation Alternatives, August 30, 1979, p. B-1.