ANALYSIS OF FEDERAL RESIDENTIAL ENERGY CONSERVATION PROGRAMS*

Eric Hirst**
Janet Carney

February 1977

INTRODUCTION

This paper reviews several recent residential energy conservation programs under development by the Federal government. Each of these programs is analyzed for its effects on national energy use and on household expenditures between now and the year 2000. The major conclusion of this analysis is that these conservation programs can both save energy for the nation and save money for households.

The basis for these analyses is a detailed engineering-economic model of residential energy use developed at ORNL for the Federal Energy Administration (FEA) and the Energy Research and Development Administration (ERDA).[1] This model simulates household energy use at the national level for four fuels, eight end uses, and three housing types. Each of these 96 fuel use components is calculated for each year of the simulation as functions of: stocks of occupied housing units and new construction, equipment ownership by fuel and end use, thermal integrity of housing units, average unit energy requirements for each type of

*Research sponsored jointly by the Federal Energy Administration and the Energy Research and Development Administration under contract with the Union Carbide Corporation.

**Eric Hirst is a Research Staff Member of the Energy Division and Janet Carney is a member of the Computer Science Division of Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

equipment, and usage factors that reflect household behavior. The model also calculates annual fuel expenditures, equipment costs, and capital costs for improving thermal integrity of new and existing structures at the same level of detail. These cost figures allow us to develop simple benefit/cost measures for each program evaluated.

Table 1 summarizes the key provisions of two recent Federal Acts[2,3] that will affect household energy use in the years to come. The programs evaluated in this paper include:

1. FEA's appliance efficiency targets (two sets).
2. The Department of Housing and Urban Development (HUD) program to develop thermal standards for new construction (two sets).
3. A nationwide program to retrofit single-family units (state conservation plans, HUD and FEA financial assistance and demonstration programs).
4. All of the above programs.
5. A stronger conservation program.

Table 1. Recent federal legislation that affects building energy use

Energy Policy and Conservation Act (PL 94-163, December 22, 1975)

- Residential equipment and appliance labeling (FEA, FTC)
- Residential equipment and appliance efficiency targets (FEA)
- State energy conservation plans (FEA):
  - mandatory lighting standards for public buildings
  - government procurement practices
  - thermal efficiency standards for new and renovated buildings

Energy Conservation and Production Act (PL 94-385, August 14, 1976)

- Thermal standards for new buildings (HUD)
- Financial assistance to weatherize existing buildings (FEA)
- State conservation plans (FEA):
  - public education programs
  - energy audits
- Conservation assistance for existing buildings (HUD):
  - demonstration program
  - financial assistance
- Energy conservation obligation guarantees (FEA)

The time between Congressional authorization and full program implementation can involve several years. The programs discussed here were all authorized by the 94th Congress; none are yet fully implemented.

Each program is evaluated for its effects on residential energy use (by fuel type and in aggregate) and on household economics between 1977 and 2000. The energy and economic benefits are calculated relative to a reference projection of residential energy use developed in the next section.

REFERENCE PROJECTION

Inputs to the ORNL energy use model required to develop a projection include: population, fuel prices, per capita income, new equipment energy efficiencies and initial costs, and thermal integrities and capital costs for both new and existing residential structures. Each of these inputs must be provided for the 1970-2000 period.

We assume that population grows according to the Bureau of the Census series II projection.[4] Residential fuel prices are obtained from the Brookhaven National Laboratory energy system optimization model (BESOM).[5] BESOM yields prices for electricity, gas, and oil for 1985 and 2000; we linearly interpolate between actual 1975 prices and BNL 1985 prices and between 1985 and 2000 BNL prices.

Per capita income is derived from a recent Data Resources Inc. projection of GNP prepared for ERDA[5] and the population projection discussed above. Projections of household formation and stocks of occupied housing units are obtained from our housing model using the DRI per capita income and Census population projections.[1] Table 2 shows

Table 2. Inputs assumed for the reference forecast of residential energy use to 2000

	Population (10^6)	Households (10^6)	Fuel prices (1975-\$/10^9 J)[a] Electricity	Gas	Oil	Per capita income (1975-\$)
1970	204	63.4	2.40	1.39	1.74	5,500
1975	213	70.4	2.64	1.62	2.65	5,940
1980	223	80.4	3.09	2.27	2.86	7,040
1985	234	90.0	3.55	2.93	3.07	7,870
1990	245	99.2	3.50	3.14	3.30	8,860
2000	262	116.7	3.45	3.54	3.75	11,170

[a]To convert fuel prices to 1975-\$/10^6 Btu/ multiply figures in Table 2 by 1.055. Recall that electricity is in terms of primary energy.

the values of population, households, fuel prices, and incomes from 1970 to 2000 used to produce the reference projection with our residential simulation model.

For the reference projection, we assume that technical efficiencies for all residential equipment, appliances, and structures remain constant throughout the projection period. Because fuel prices are assumed to increase (Table 2), efficiencies are likely to improve as manufacturers and consumers respond to these economic forces. Because we do not allow for these voluntary changes in the reference projection, the energy and economic benefits of federal conservation programs are overstated. That is, some of the savings claimed later for these programs would occur naturally because of normal market forces.

Figure 1 shows projections of residential electricity, gas, oil, and total energy use produced with the ORNL simulation model. Overall energy use grows from 15.8 EJ (10^{18} joules*) in 1970 to 17.6 EJ in

*1 Btu = 1055 joules.

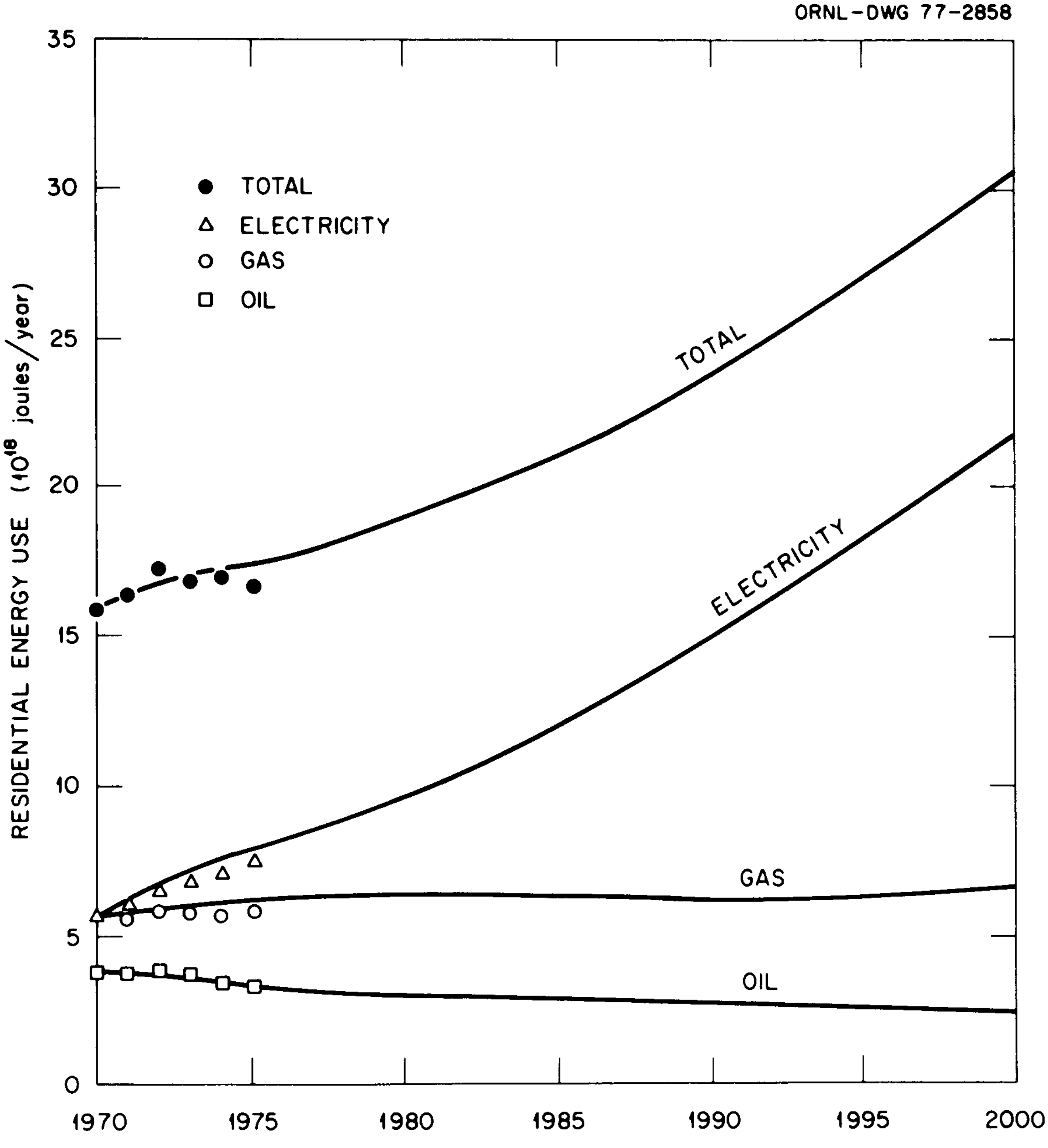

Fig. 1. Reference projection of residential energy use to 2000.

1975, 19.2 EJ in 1980, and 29.9 EJ in 2000.** The average annual growth rate in residential energy use from 1976 to 2000 is 2.2%, compared with 3.4% from 1950-1975.[6] Energy use per household increases very slowly in the reference projection with an average growth rate of 0.2%/year, compared with 1.4%/year from 1950-1975.[6]

As Fig. 1 shows, electricity use grows much more rapidly than do gas or oil use. Average annual growth rates are 4.1% for electricity, 0.2% for gas, and -1.2% for oil. Because of these differences in growth rates, the fraction of residential energy use accounted for by each fuel changes over time. Electricity increases its share of the total from 44% in 1975 to 70% in 2000; the shares accounted for by gas, oil, and other fuels decline from 34%, 18%, and 4% to 22%, 7%, and 1%, respectively.

Residential energy use grows more slowly in the reference projection (1976-2000) than it did during the 1950-1975 period because of higher and rising fuel prices, slower population growth, and approaching saturation for major household energy uses.

APPLIANCE EFFICIENCY STANDARDS

FEA administers the federal appliance efficiency program:[2,3] to develop and implement a set of appliance efficiency targets such that the average efficiency of new appliances sold in 1980 is at least 20% higher than the 1972 average. FEA developed two sets of appliance efficiency targets for 1980,[7] shown in Table 3.

**Electricity use figures are in terms of primary energy (3.37 J/J or 11,500 Btu/kwhr); that is they include losses in generation, transmission, and distribution. Figures for gas and oil do not include losses associated with refining and transportation.

Table 3. Assumed improvements in energy requirements for new equipment from FEA appliance efficiency targets (1970=1.0)[a]

	Low	High
Space heating		
electric	0.91	0.83
gas, oil	0.91	0.83
Water heating		
electric	0.91	0.89
gas, oil	0.75	0.74
Refrigerators	0.70	0.67
Freezers	0.75	0.71
Cooking		
electric	0.93	0.83
gas	0.70	0.67
Air conditioning		
room	0.78	0.71
central	0.83	0.77
Other appliances		
electric	0.80	0.70
gas	0.94	0.91

[a]These efficiency targets are assumed to be fully implemented by 1980 and to affect all new equipment installed between 1980 and 2000.

Before evaluating the national energy and economic impacts of adopting either the high or low targets, we first examine the design changes required for two specific appliances. Figure 2 summarizes the results of our energy and cost analyses of alternative refreigerator designs.[8] FEA's high target (Table 3) requires a reduction in refrigerator energy use of 33%. This goal can be met by increasing the insulation thickness of the refrigerator walls, removing the fan motor from the refrigerated area, adding an anti-sweat heater switch, and increasing the condenser surface area. This combination represents only

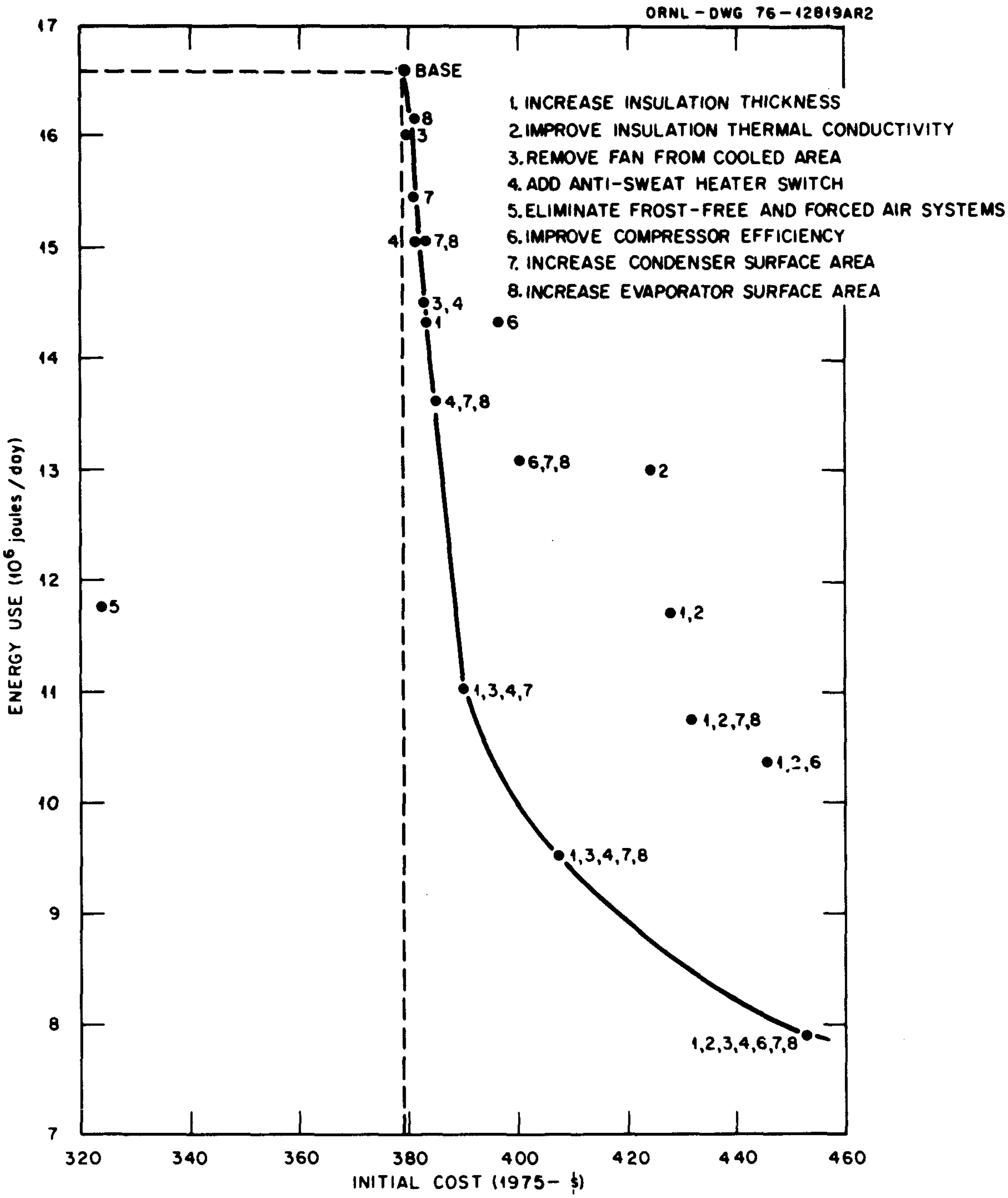

Fig. 2. Electricity use versus retail price for a typical refrigerator.

one possible design for meeting the 1980 target. Such an improvement in refrigerator performance would increase the consumer's purchase price by about $10 (1975-$). The annual savings in electricity bills of $20 (at the assumed 1980 electricity price) is repaid in 6 months, yielding a rate-of-return of 200%.

The FEA high target for gas water heaters (Table 3) requires a reduction in energy use of 26%. Our analysis of water heater designs shows that this target can be met by adding 7.6 cm of urethane foam to the water heater jacket, insulating the distribution pipe, and reducing air flow through the flue. These changes would increase the water heater purchase price by about $30.[1] The annual reduction in gas bills (at the assumed 1980 gas price) is $16. This investment offers a rate-of-return of about 50% and yields a 2 year payback period.

These two examples suggest that the FEA targets provide very good investment opportunities for households.

Table 4 summarizes the national energy savings and economic benefits of adopting either the high or low appliance efficiency targets for 1980. In both cases, the targets are assumed to be fully adopted by 1980 and to remain in force (unchanged) through the year 2000. The energy and economic effects are calculated relative to the reference projection, developed in the preceding section.

The energy savings increase with time as old, inefficient units are replaced with new, efficient ones. For the high targets, the energy savings increase from 0.6 EJ in 1980 to 1.7 EJ in 1990, and 3.1 EJ in 2000. The energy saving in 2000 is 10% of the reference projection energy use for 2000. The cumulative energy saving from 1977 through 2000 is 37 EJ with the high targets and 26 EJ with the low targets.

Table 4. Energy and economic impacts of the FEA appliance efficiency targets

	Low	High
Fuel savings (10^{18} joules/yr)		
1985		
electricity	0.74	1.07
gas	0.07	0.16
oil	-0.02	-0.02
Total	0.78	1.20
2000		
electricity	2.19	3.27
gas	-0.16	-0.12
oil	-0.03	-0.02
Total	2.00	3.13
Present worth of 1977-2000 cost savings @ 10% interest rate (billion 1975-$)		
fuels	24.4	35.5
equipment	-13.4	-19.1
Total	10.9	16.4

The economics of implementing either appliance efficiency target are quite favorable. The present worth of the net economic benefits (in 1977 at a real interest rate of 10%) is $16 billion for the high targets and $11 billion for the low targets. Thus, the dollar value of the fuel savings is much greater than the incremental costs of improved equipment.

The results of Table 4 suggest that the high efficiency targets are better than the low targets, because the high targets save more energy and money. These results also suggest (implicitly at least) that much tougher cost-effective targets could be developed.

THERMAL STANDARDS FOR NEW CONSTRUCTION

The Energy Conservation and Production Act[3] required HUD to develop thermal standards for the construction of new buildings within three years. These standards must then be implemented by the states, but only if Congress takes affirmative action.

Recently, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) developed a standard (ASHRAE 90-75) for the thermal preformance of new buildings.[9] The A.D. Little Company evaluated these standards for their effects on heating and cooling loads in prototypical buildings.[10]

In a similar fashion, A.D. Little analyzed the effects of the HUD Minimum Property Standards (in effect as of June 1976) on heating and cooling loads.[11] We use the ADL evaluations as inputs (Table 5) to our simulation model to analyze the national energy and economic effects of adopting either set of standards. As Table 5 shows, both standards provide larger percentage savings in multi-family units than they do in

Table 5. Assumed improvements in thermal integrities of residential structures (1970=1.0)

	ASHRAE 90-75[a]	1976 HUD[a]	Retrofit program[b]
Single-family units			
space heating	0.89	0.80	0.80
air conditioning	0.91	0.84	0.84
Multi-family units			
space heating	0.54	0.49	1.0
air conditioning	0.63	0.59	1.0
Mobile homes			
space heating	1.0	1.0	1.0
air conditioning	1.0	1.0	1.0

[a]The ASHRAE and HUD standards are assumed to be fully implemented by 1980 and affect all new single- and multi-family construction from 1980 to 2000.

[b]The retrofit program is assumed to run from 1977 through 1990, affecting 20 million single-family units during this period.

single-family units. The June 1976 HUD standards are stricter for both building types than are the ASHRAE standards. The following discussion assumes that the standards now under development by HUD will correspond to either the ASHRAE standards or the existing HUD standards.

The incremental capital cost for constructing a gas-heated single-family home in accordance with the HUD standards is about $200 (compared with construction practices of the early 1970's); see Fig. 3.[1] The 20% reduction in space heating energy use amounts to a savings of $70 in annual gas bills. The 16% reduction in air conditioning requirement

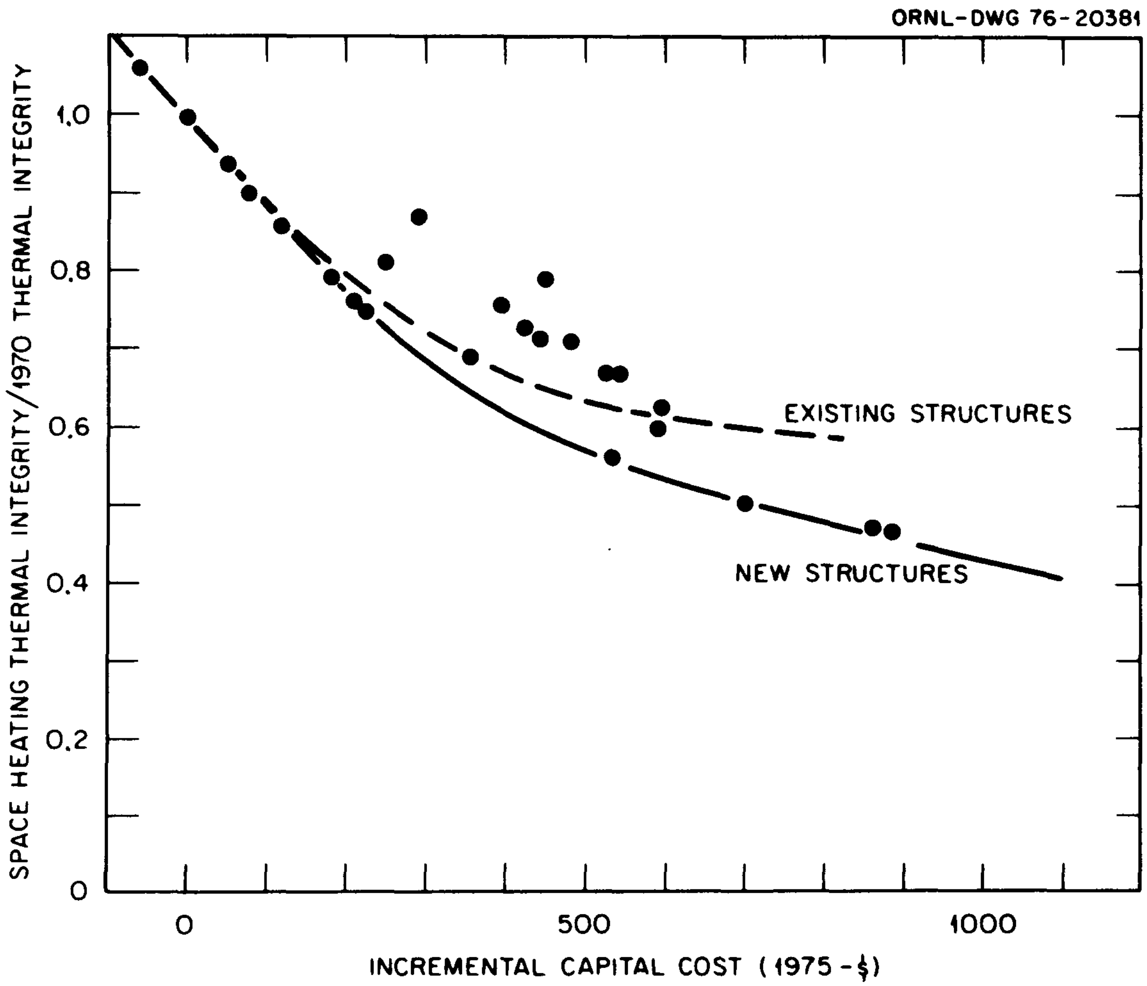

Fig. 3. Space heating thermal integrity for single-family units versus increased capital costs.

amounts to a savings of $19 in annual electricity bills. Thus the payback period for investment in tighter building construction is 2.2 years (=$200/$89); the rate-of-return to the homeowner is 44%. Investing in additional insulation and other weatherization devices is very cost-effective.

Table 6 summarizes the outputs of our analyses of the ASHRAE and HUD standards. In both cases, the standards are assumed to be fully implemented by 1980 and to remain in force (unchanged) to the end of the century. Because the HUD standards are stricter than the ASHRAE standards (Table 5), the energy savings are always greater with the HUD standards.

Table 6. Energy and economic effects of thermal integrity programs

	ASHRAE	HUD	Retrofit
Fuel savings (10^{18} joules/yr)			
1985			
electricity	0.18	0.24	0.15
gas	0.07	0.12	0.11
oil	0.04	0.06	0.05
Total	0.28	0.41	0.30
2000			
electricity	0.64	0.91	0.45
gas	0.08	0.14	-0.03
oil	0.13	0.18	0.02
Total	0.85	1.23	0.44
Present worth of 1977-2000 cost savings @ 10% (10^9 1975-$)			
fuels	8.3	12.0	7.8
equipment	-0.1	- 0.2	-0.2
structures	-3.3	- 5.0	-2.5
Total	4.9	6.9	5.0

Energy savings due to adoption of either set of standards increase over time as new housing units are added to replace old units and to satisfy the demands of new household formation. For example, the HUD savings increase from 0.17 EJ in 1980 to 0.65 EJ in 1990 and 1.23 EJ in 2000. The cumulative energy saving of 13 EJ amounts to 3% of the reference projection. Roughly two-thirds of the energy saving is in electricity; the remainder is split between gas and oil.

For both the ASHRAE and HUD standards, the economic benefits (reduced fuel bills) exceed the economic costs of improving structures. As with the energy savings, the HUD standards offer larger economic benefits to households. The present worth of the net economic benefits is $7 billion with the HUD standards and $5 billion with the ASHRAE standards.

These results suggest that the HUD standards are preferred to the ASHRAE standards. They also implicitly suggest that tougher building construction standards would save even more money and energy.

RETROFIT PROGRAM

A number of provisions in EPCA[2] and ECPA[3] encourage weatherization of existing structures. For example, ECPA authorizes FEA to provide financial assistance to low-income households to weatherize their structures; and authorizes HUD to conduct demonstration programs to provide financial assistance for improving the energy performance of existing buildings.

We assume that these federal programs will serve as catalysts to induce retrofit actions in 20 million single-family units between 1977 and 1990. We assume (Table 5) that the average improvement in thermal integrity will be the same as for new buildings constructed in accordance with the HUD standards. The number of units retrofit each year declines from 2.0 million in 1977 to 0.9 million in 1990.

Table 6 summarizes the energy and economic effects of this retrofit program. The energy savings increase during the period that homes are being retrofit and then declines slowly. Compared with the reference projection, energy use is reduced 1% in 1980, 1.4% in 1985, 1.7% in 1990, and 1.5% in 2000. Cumulative energy savings to the year 2000 amount to 1.4% of the reference projection.

As with the other federal programs, the economics of this retrofit program are favorable. Fuel bill reductions exceed capital costs by $5 billion.

COMBINED FEDERAL PROGRAM

Here we evaluate the effects of adopting all three of the programs discussed earlier. We use the high appliance efficiency targets and the HUD standards because these programs offer larger energy and economic benefits than the low targets and the ASHRAE standards.

Table 7 summarizes the energy savings of the combined federal program. Energy savings increase from 0.9 EJ in 1980 to 4.6 EJ in 2000. The cumulative energy saving of 58 EJ amounts to 10% of the reference projection of cumulative energy use (1977-2000). Electricity accounts for 85% of the cumulative energy saving, while gas and oil account for 10% and 5%, respectively. Figure 4 shows the model's projection of residential energy use with the three federal programs; the reference projection is also shown.

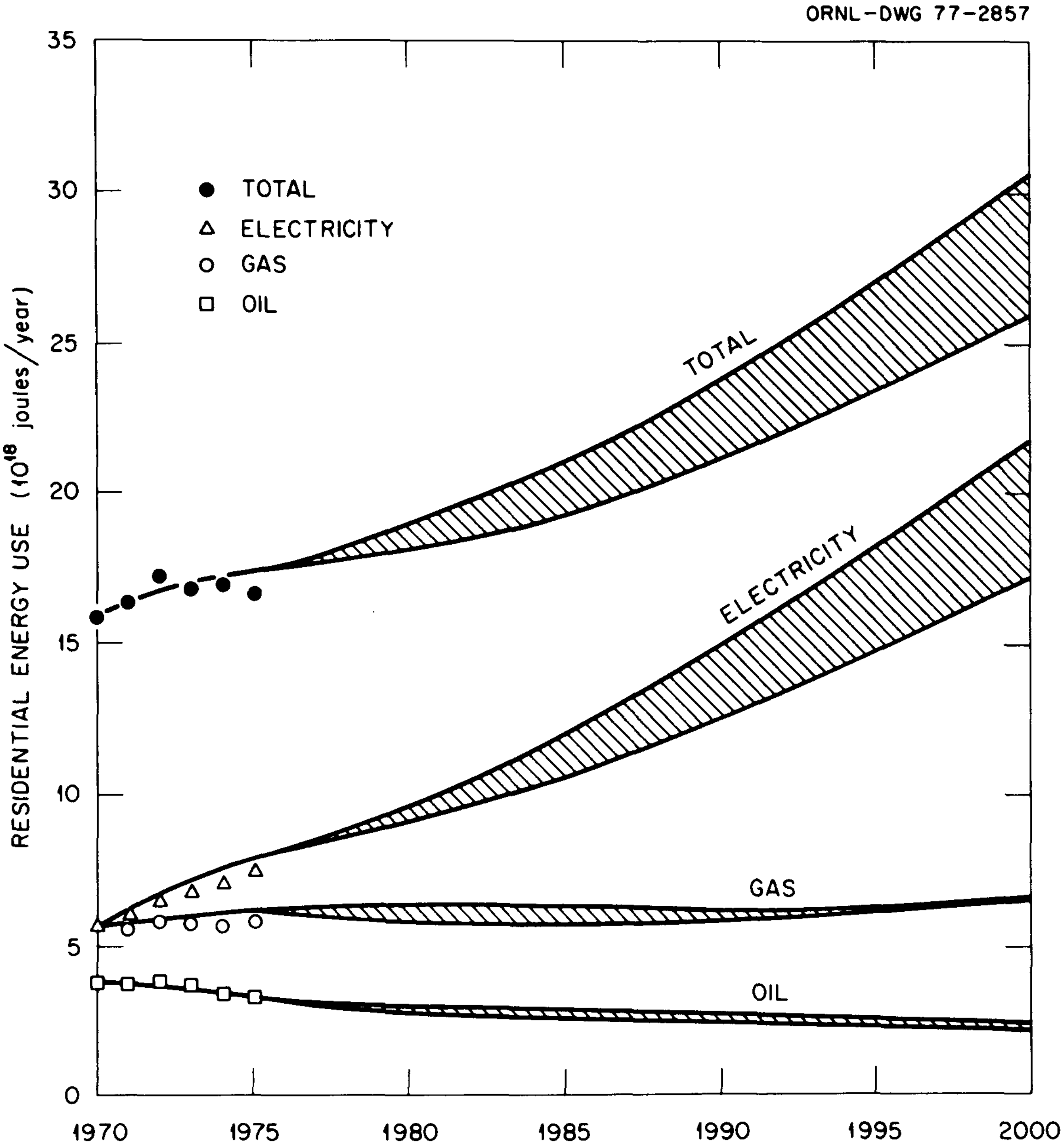

Fig. 4. Projections of residential energy use with and without federal conservation programs.

Table 7. Residential energy use with and without conservation programs[a]

	Run 1	Run 2	% difference
Fuel use (10^{18} J/yr)			
1980	19.2	18.3	- 5
1985	21.0	19.2	- 9
1990	23.6	20.9	-11
2000	29.9	25.3	-15
Present worth of 1977-2000 expenditures @ 10% (10^9 1975-$)			
fuels	635	582	- 8
equipment	164	183	+12
structures	-	8	-
Total	799	772	- 3

[a]Both runs use BNL prices (1985, 2000) for electricity, gas and oil; DRI GNP forecast to 2000; and housing forecast from the ORNL housing model. Run 1 assumes no improvements in energy efficiency for either equipment or structures. Run 2 assumes implementation of the FEA appliance efficiency targets (high) by 1980, adoption of the ASHRAE 90-75 standards for new construction of single-family and multi-family units by 1980, and a mild retrofit program for single-family units constructed before 1974 in force from 1977 through 1990.

The net effect of the combined program is to reduce overall residential energy growth from 2.2%/year (reference projection) to 1.5%/year. On a per household basis, energy growth is reduced from 0.2%/year to -0.5%/year. This decline in per household energy use is due entirely to changes in technical efficiencies of residential structures and equipment; no adverse behavioral changes are implied.

In fact, the reduced operating costs implied by the federal programs increase the intensity with which households are expected to operate their equipment and increase ownership of energy-using equipment. For example, 87% of the households in 2000 own air conditioning systems in the reference projection compared to 89% with the combined federal program. Similarly, ownership of freezers is increased in 2000 from 46% to 49%.

The model results suggest that households will use their space heating systems in the year 2000 15% more intensively with the combined program than in the reference projection. Households respond to fuel bill reductions induced by improved equipment efficiencies and tighter construction by raising winter thermostats and paying less attention to door and window openings. Similarly, water heating systems are used 8% more intensively in 2000 with the federal program than without.

Implementation of these programs saves households a total of $53 billion in reduced fuel bills. This savings is partly offset by an increase in capital costs of $27 billion. Thus the net savings to households is $27 billion (present worth in 1977 of expenditures to the year 2000, discounted at 10%/year).

The appliance program offers the largest energy savings. This is because appliances have much shorter lifetimes than do residential structures; thus more new appliances than new housing units are installed between now and the year 2000. Also, the appliance efficiency targets (Table 3) are stricter than are the new construction standards (Table 5). Finally, improving structural thermal integrity affects space heating and air conditioning, which account for about 60% of total residential energy use. However, the appliance program affects all residential energy uses except lighting.

The new construction standards save 40% as much energy in 2000 as the appliance standards do. The retrofit program offers the smallest savings in 2000. The retrofit program offers smaller savings than new construction standards because fewer single-family units are retrofit than are affected by the new construction standards (20 vs 25 million) and because no multi-family units are assumed to be retrofit.

The year 2000 energy saving of the combined program is slightly less than the sum of the individual savings, because improvements in space heating and cooling equipment interact and partly offset each other.

The benefit/cost ratios for each program and for the combined program are all greater than 1.0. The most attractive program, from the point of view of household economics, is the retrofit program (i.e., the one with the smallest energy savings) with a ratio of 2.9. New construction standards also have a high benefit/cost ratio (2.3).* The appliance standards, which produce the largest energy savings, have the lowest benefit/cost ratio; but its ratio of 1.9 is still far greater than 1.0. The combined program has a benefit/cost ratio of 2.0. These benefit/cost ratios would be even higher had we used a lower interest rate than 10%.

STRONGER PROGRAM

These results (e.g., Table 7) show that each of the federal programs and the combined federal program save energy for the nation and save money for households. However, the energy and economic benefits of these programs are much smaller than could be achieved. The potential

---

*It is less expensive to improve structural thermal performance by a fixed percentage in a new structure than in an existing one (Fig. 3). This would suggest a higher B/C ratio for the new construction standards than for the retrofit program. This is not the case because the new construction standards are much stricter (i.e., less cost-effective) for multi-family units than for single-family units (Table 5).

is large because these programs are implemented by 1980 and do not change between 1980 and 2000. The fuel price projections used here (Table 2) show increases between 1980 and 2000: the real price of electricity increases 12%, gas prices increase 56%, and oil prices increase 31%. These fuel price increases suggest the need for equipment, appliances, and structures with efficiencies better than those required by federal programs for 1980.

In addition, federal (ERDA) and private research is sure to produce more efficient equipment and structures than those available today. For example, the ERDA-sponsored ACES (Annual Cycle Energy System) house (constructed by ORNL in Knoxville, TN) will require only 20% as much electricity for heating, cooling, and water heating as would a conventional house.[12]

To gain a feel for the energy and economic effects of additional efficiency improvements, we ran one more case in which efficiencies for new equipment and structures continue to increase after 1980. We assumed the same retrofit program as before for single-family units and assumed a similar one for multi-family units. Although efficiencies are improved more than with federal programs, these higher efficiencies are attainable with present-day technologies. That is, they are not dependent on emerging technologies such as solar, ACES, and total energy systems

The results of this final computer run show a growth in household fuel use from 1976 to 2000 of 1.0%/year, reaching 22.4 EJ in 2000. This represents a 25% reduction in energy use in 2000 relative to the reference projection and 12% relative to the projection with the federal programs. The cumulative energy saving is 95 EJ relative to the reference projection, 37 EJ relative to the combined federal program.

The economics of this final case are equally favorable. Relative to the reference projection, this case saves $46 billion; relative to the combined federal program, the saving is $20 billion. Thus additional energy and economic savings beyond those implied by the federal programs analyzed here are feasible.

CONCLUSION

This paper analyzed three major federal programs that will substantially affect residential energy use during the remainder of this century. The energy and economic analyses were conducted with a detailed engineering-economic model of residential energy use developed at ORNL.[1]

Our conclusions concerning the computer runs discussed here are (see also ref. 13):

1. Residential energy use will almost surely grow at a much slower rate during the fourth quarter of this century than it did during the third quarter of the century. This reduction in energy growth is due to slower growth in population, changes in fuel price trends (from declines to increases), and approaching saturation of equipment ownership for the major household energy uses. Under the conditions assumed here for the reference projection, residential energy use grows at an average annual rate of 2.2%/year compared with the historical rate (from 1950-1975) of 3.4%/year. Thus energy use in the year 2000 is projected to be 30.7 EJ, 24% less than would obtain if historical trends continued to the year 2000.
2. Implementation of the federal programs now in existence or authorized by the 94th Congress (appliance efficiency standards,

thermal standards for new construction, retrofit program) will save large amounts of energy for the nation and money for households. As shown in Table 9, implementation of these programs would cut energy use in the year 2000 by 4.6 EJ (15% of the reference projection for 2000). In addition, the programs save households a total of $27 billion. This savings is the present worth of fuel bill reductions between now and 2000 minus incremental capital costs associated with new equipment, new structures, and existing structures.

3. These federal programs are designed to match the energy economics of the late 1970's. Thus they represent a cautious set of goals for the 1980's and 1990's. Our final computer run shows that efficiency improvements after 1980 provide additional energy benefits to the nation and economic benefits to households. This suggests the need for additional federal efforts to continually update and revise the energy efficiency standards now under development. The need also exists for research on energy-efficient designs for equipment and structures to ensure that improved technologies will be available as fuel prices rise in the future.

4. The computer runs discussed here assume no lifestyle changes on the part of American households, no changes in government fuel pricing policies (e.g., a Btu tax), and no implementation of advanced technologies for residential applications (e.g., solar heating, ACES, total energy systems). Thus, the potential for saving more energy and money is great. We plan (during the next several months) to develop other cases to explore the maximum

economically-feasible conservation program for the remainder of this century. It is likely that such cases will show even larger energy and economic benefits than the programs discussed here do.

ACKNOWLEDGEMENTS

We thank Roger Carlsmith, John Gibbons, Dan Quigley, René Malès, and James Boyd for their careful reviews of this article in draft form.

REFERENCES

1. E. Hirst, et al., *An Improved Engineering-Economic Model of Residential Energy Use,* Oak Ridge National Laboratory, ORNL/CON-8, March 1977.

2. 94th Congress, *Energy Policy and Conservation Act,* PL 94-163, December 22, 1975.

3. 94th Congress, *Energy Conservation and Production Act,* PL 94-385, August 14, 1976.

4. Bureau of the Census, "Projections of the Population of the United States: 1975-2000," *Current Population Reports,* Series P-25, No. 601, October 1975.

5. S. Carhart, personal communication, Brookhaven National Laboratory, December 1, 1976.

6. E. Hirst and J. Jackson, "Historical Patterns of Residential and Commercial Energy Uses," Oak Ridge National Laboratory, September 1976; to be published in *Energy* 2(2), 1977.

7. Federal Energy Administration, "Proposed FEA Regulations on Energy Efficiency Improvement Targets for Appliances," *Federal Register* 41(95), May 14, 1976; also John Carlin, personal communication, Federal Energy Administration, November 1976.

8. R. Hoskins and E. Hirst, *Energy and Cost Analyses of Residential Refrigerators,* Oak Ridge National Laboratory, ORNL/CON-6, January 1977.

9. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, *Energy Conservation in New Building Design,* ASHRAE 90-75, 1975.

10. A. D. Little, Inc., *An Impact Assessment of ASHRAE 90-75, Energy Conservation in New Building Design,* December 1975.

11. A. D. Little, Inc., *An Energy and Economic Assessment Impact of HUD's Minimum Property Standards,* October 1976.

12. H. C. Fischer, et al., *The Annual Cycle Energy System: Initial Investigations,* Oak Ridge National Laboratory, ORNL/TM-5525, October 1976.

13. E. Hirst, "Residential Energy Use Alternatives: 1976-2000," *Science* 194 December 17, 1976.