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A REGIONAL ANALYSIS OF RESIDENTIAL ENERGY CONSERVATION PROGRAMS*

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ABSTRACT

This paper evaluates the energy and direct economic effects of implementing various residential energy conservation programs in each of the ten Federal regions. The programs considered are those proposed in the *National Energy Plan:* appliance efficiency targets, thermal standards for construction of new residences, and weatherization of existing housing units. Implementation of these programs might cut cumulative (1977-2000) national residential energy use by 41 QBtu. Relative energy savings are highest in regions 7 and 8 (11 and 10% respectively, of their baselines) and smallest in region 9 (7%). The net economic benefit to the nation's households of these three federal programs is $21 billion. Benefits exceed costs in each region; the benefit/cost ratio ranges from a low of 1.4 in region 10 to a high of 2.0 in region 6.

INTRODUCTION

The purpose of this paper is to evaluate the energy and economic effects in each of the ten Federal regions of implementing the residential energy conservation programs of the *National Energy Plan* (NEP). This work follows from our recent analysis of the *national* effects of these conservation programs [1]. Five of the same residential energy "futures" are evaluated here. The first (our baseline) involves increases in real fuel prices to the year 2000, as estimated by the Federal Energy Administration (now part of the Department of Energy).

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However, no government conservation programs are implemented. Changes in energy use are voluntary and come about because of normal market forces only.

The second, third, and fourth cases consider the residential conservation programs authorized by the 94th Congress and expanded upon in the April 1977 energy message: appliance efficiency targets, thermal performance standards for new construction, and a retrofit program to affect 90 per cent of the nation's housing stock. The final case is the combination of these three programs.

Each program is evaluated for its effects on regional residential energy use (by fuel, end use, and in aggregate) and on household economics (fuel bills, capital costs for equipment and structures) between 1977 and 2000. Tables 1 and 2 summarize the estimated energy and economic effects of each of the five cases for each of the regions.[1] Figure 1 is a map of the United States showing the ten Federal regions.

Table 1 shows 1976 energy use for the ten regions. The table also shows cumulative (1977-2000) energy use for the five simulations. Differences in energy use between the baseline and any other simulation show energy savings due to that program. Although the combined program reduces national annual growth by 0.5 per cent (from 1.7% to 1.2%), the reduction in annual growth rate among regions ranges from 0.3 per cent (regions 9 and 10) to 0.6 per cent (regions 5, 7, and 8).

Table 2 shows cumulative (1977-2000) household energy-related expenditures for each region and simulation. These expenditures are in terms of

Figure 1. Map of the United States showing Federal regions.

[1] Quantities are given in British units. 1 QBtu = 1 Quad = 10^{15} Btu. 1 Btu = 1055 joules. Electricity use figures are in terms of primary energy (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 1. Alternative Regional Residential Energy Use Projections: Energy Use (QBtu)

Federal Region	Baseline			Appliance Efficiency Program		New Construction Standards		Retrofit Program		Combined Federal Program	
	1976 Fuel Use	Cumulative Energy Use[a]	Annual Growth Rate[b]	Cumulative Energy Use[a]	Annual Growth Rate[b]	Cumulative Energy Use[a]	Annual Growth Rate[b]	Cumulative Energy Use[a]	Annual Growth Rate[b]	Cumulative Energy Use[a]	Annual Growth Rate[b]
1	0.9	26.8	1.8	26.4	1.7	26.1	1.7	25.5	1.6	24.4	1.3
2	1.7	49.6	1.6	48.7	1.5	48.6	1.5	47.5	1.4	45.6	1.2
3	1.7	51.6	1.8	50.6	1.7	50.7	1.7	49.1	1.6	47.1	1.4
4	2.4	78.3	2.1	77.1	2.0	76.9	2.0	74.3	1.9	71.8	1.7
5	3.9	115.1	1.5	112.3	1.3	112.5	1.3	110.1	1.2	104.8	1.0
6	1.6	46.4	1.5	45.1	1.3	45.8	1.4	43.7	1.2	41.9	1.0
7	1.0	30.3	1.5	29.3	1.3	29.7	1.3	28.7	1.2	27.1	0.9
8	0.5	14.3	1.4	14.0	1.2	13.8	1.2	13.6	1.1	12.8	0.8
9	1.5	45.6	1.9	45.0	1.8	44.9	1.8	43.8	1.7	42.4	1.6
10	0.6	18.6	1.4	18.4	1.3	18.3	1.3	17.9	1.2	17.2	1.0
U.S.	15.8	476.6	1.7	466.9	1.6	467.2	1.5	454.2	1.5	435.1	1.2

[a] Refers to 1977-2000 period.
[b] 1976-2000 average annual growth rate (%/year).

Table 2. Alternative Regional Residential Energy Use Projections
Direct Economic Effects
Present Worth of Cumulative (1977-2000) Expenditures at 8 Per Cent
Real Interest Rate (1975 Dollars, in Billions)

Federal Region	Baseline		Appliance Efficiency Program		New Construction Standards		Retrofit Program		Combined Federal Program	
	Fuels	Total[a]	Fuels	Total[a]	Fuels	Total[a]	Fuels	Total[a]	Fuels	Total[a]
1	44.2	54.0	43.7	53.8	43.3	53.4	42.3	53.2	40.9	52.4
2	81.3	102.6	80.1	102.2	80.0	101.8	78.1	101.3	75.7	100.1
3	73.8	97.4	72.6	97.1	72.7	96.7	70.4	96.0	68.0	94.9
4	95.9	134.5	94.6	134.7	94.5	133.7	91.1	132.4	88.5	131.8
5	147.7	191.1	144.4	190.0	144.9	189.4	141.6	188.5	135.6	185.8
6	63.3	86.1	61.5	85.0	62.6	85.6	59.7	84.5	57.3	83.1
7	34.5	45.7	33.5	45.2	33.9	45.3	32.9	45.0	31.2	44.1
8	14.5	19.4	14.2	19.4	14.1	19.3	13.8	19.1	13.2	19.0
9	63.7	86.8	62.9	86.8	62.9	86.4	61.3	85.8	59.6	85.4
10	16.8	22.0	16.6	22.1	16.6	21.9	16.1	21.8	15.6	21.7
U.S.	635.8	839.7	624.1	836.2	625.4	833.4	607.3	827.6	585.6	818.3

[a] Total expenditures includes both fuel expenditures and capital expenditures for improved equipment and structures.

their present worth (in 1977) at a real interest rate of 8 per cent. The regional variation in economic benefits is larger than is the variation in energy benefits.

The two U.S. maps of Figure 2 show the regional variation in energy and economic benefits for the combined Federal program. These maps show the energy (or economic) benefit per household in each region relative to the national per household benefit.

These analyses were conducted with a detailed engineering-economic model of residential energy use developed at ORNL [2]. Development of the input data required to run these models for regions (rather than for the nation as a whole) is discussed in reference [3].

BASELINE

Inputs to the ORNL energy use model required to develop a projection include: population, fuel prices, per capita income, and specifications for government conservation programs. Each of these inputs must be provided for the 1970-2000 period.

We assume that national population grows according to the Bureau of the Census Series II projection [4]. National per capita income is derived from a

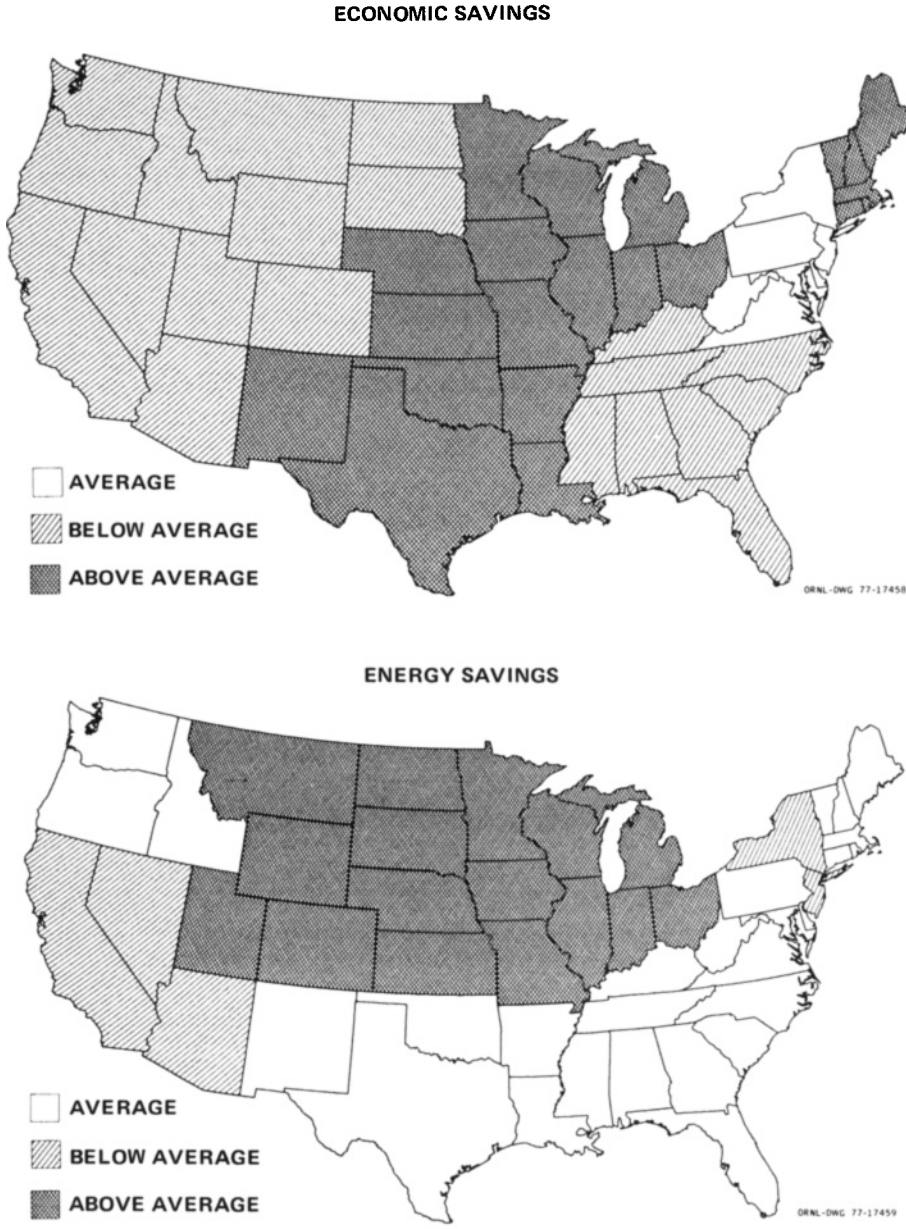

Figure 2. Regional variation in per household energy and economic benefits of the combined Federal program.
("Average" is defined as regional per household benefit in the range of 90 per cent to 110 per cent of national per household benefit.)

recent GNP projection prepared for FEA [5] and the Series II population projection. These projections show population growing at an average rate of 0.8 per cent/year and real per capita income growing at 2.4 per cent/year between 1976 and 2000.

Projections of household formation, stocks of occupied housing units, and new construction are obtained from our housing model [2] using the per capita income and population projections noted above. The nation's households are distributed among regions on the basis of the most recent federal government projection of population distribution (from the Water Resources Council) [6]. Distribution of households among housing types is based on assumed national trends and regional variations in 1970 [7]. We assume that trends in housing choices (among single-family, multi-family, and mobile homes) between 1960 and 1970 will continue through the end of the century [2, 7] : increases in multi-family and mobile home occupancy and declines in single-family unit occupancy.

The regional variation in per capita income is derived from the national projection using the Water Resources Council projections of income growth [6].

National fuel price trajectories for electricity, gas, and oil are from the Federal Energy Administration [5] and the Brookhaven National Laboratory [8] energy models. These national projections were regionalized using FEA projections for each region [9].

Tables A1-A10 in reference [10] show the values used for population, households, housing distribution, per capita income, and fuel prices for each region from 1970 through 2000. These inputs remain constant for each of the five cases discussed.

Based on information from Owens-Corning Fiberglas and the Bureau of the Census, we assume that 14.3 million single-family units and 2.0 million multi-family units will be retrofit during the 1974-1980 period. (See Section 3 of reference [1] for a discussion of this.) These retrofit units are shared among Federal regions on the basis of the regional variation in 1975 [11] (fraction of occupied single-family detached homes in each region that had some retrofit action taken in 1975, compared with the national fraction).

Finally, we assume that there are *no* Federal or state conservation programs in the baseline. That is, we ignore the programs mandated by the Energy Policy and Conservation Act (EPCA) [12] and the Energy Conservation and Production Act (ECPA) [13], in particular the state energy conservation plans required by these Acts. These programs are considered explicitly in the following sections.

These inputs are provided to the ORNL residential energy use model [1–3]. This model simulates household energy use at the regional level for four fuels, eight end uses, and three housing types. Each of these ninety-six 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

Table 3. Regional Baseline Projections: Energy Use by Fuel (QBtu/Year)

Federal Region	Electricity		Gas		Oil		Total[a]	
	1975	2000	1975	2000	1975	2000	1975	2000
1	0.32	0.77	0.16	0.28	0.37	0.28	0.86	1.33
2	0.52	1.26	0.56	0.75	0.56	0.43	1.67	2.45
3	0.69	1.66	0.59	0.70	0.30	0.18	1.66	2.56
4	1.59	3.25	0.47	0.61	0.19	0.07	2.40	3.98
5	1.36	3.32	1.94	1.99	0.47	0.19	3.91	5.55
6	0.83	1.61	0.57	0.59	0.05	0.01	1.57	2.25
7	0.39	0.90	0.48	0.51	0.05	0.02	1.01	1.45
8	0.17	0.42	0.25	0.23	0.03	0.01	0.48	0.68
9	0.67	1.63	0.77	0.72	0.01	0.00	1.48	2.36
10	0.46	0.72	0.09	0.15	0.06	0.02	0.63	0.90
U.S.	7.00	15.54	5.88	6.53	2.09	1.21	15.67	23.51

[a] Includes electricity, gas, oil, and "other" fuels (coal, coke, and LNG).

for each type of 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.

Table 3 shows the model's estimates of baseline energy use by fuel for each region; see also Table 1. National household energy use grows at 1.7 per cent/year, from 15.8 QBtu in 1976 to 23.5 QBtu in 2000. Region 4 has the highest growth (2.1%/year); regions 8 and 10 have the lowest growth (1.4%/year). Most of this variation is explained by differences in household growth among regions.

Energy use *per household* declines in all but one region. In region 7, energy use per household remains constant between 1976 and 2000, while in region 5 the decline is greatest at 0.4 per cent/year. Fuel prices increase more rapidly in region 5 than in region 7. Growth in per capita income is the same in both regions so this is unlikely to cause differences in energy use. The fraction of homes retrofit in region 5 is slightly higher than the fraction in region 7.

Energy use per household varies considerably across regions. For example, in 1976 per household fuel use in regions 7 and 10 was more than 50 per cent greater than in region 9. To some extent, higher fuel use in regions 7 and 10 is due to much colder winters (5800 heating degree days (HDD) in region 7 and 5600 HDD in region 10, compared with 2600 HDD in region 9). Also, fuel prices were lower in region 7 than in region 9 during the early 1970's. Electricity prices were lower in region 10 than in any other region during the early 1970's. Finally, the fraction of households in single-family units was higher in regions 7 and 10 than in region 9 (75% versus 65%); single-family units require more fuel

for heating and air conditioning than do either multi-family or mobile home units. These differences in per household energy use across regions persist to the end of the century.

The average fuel bill also varies considerably among regions. In 1976, region 1 had the highest average fuel bill ($690/household), while region 9 had the lowest ($440). In the year 2000, fuel bills are still highest in region 1 ($850) but the lowest fuel bill is now in region 10 ($580 compared with $610 in region 9). Fuel bills are high in region 1 because of cold winters and high fuel prices. Fuel bills are low in region 9 because mild winters lead to low energy use per household. Fuel bills are low in region 10 because of their very low electricity prices.

The distribution of household energy use by fuel changes over time. Shares of total fuel use accounted for by electricity increase and shares accounted for by oil decrease in every region. The shares accounted for by gas decrease in all regions except 1 and 10; in these regions the gas share increases only slightly. Electricity's share increases in all regions primarily because increases in electricity prices are less than increases in gas and oil prices.

The following sections evaluate the regional effects of government conservation programs. We evaluate the programs in four elements [12–14]:

1. appliance efficiency targets;
2. thermal performance standards for new construction;
3. weatherization (retrofit) of existing housing units; and
4. all of the above.

The time between Congressional authorization and full program implementation can involve several years. The programs discussed here were all authorized by the 94th Congress; the President has proposed stronger programs in each area. However, none of the programs is yet implemented. Each of these programs is compared to the baseline in terms of energy use and household costs in each region.

APPLIANCE EFFICIENCY TARGETS

The Federal Energy Administration administers a program to develop and implement a set of appliance efficiency targets. These targets must ensure that the average efficiency of new appliances sold in 1980 is at least 20 per cent higher than the 1972 average [12, 13]. The president proposed that the existing voluntary program be made mandatory [14]. The FEA targets used in this analysis are shown in Table 4 [5]. The numbers in Table 4 show the maximum allowable annual energy use for new equipment relative to annual energy use averages for 1970.

Inputs to the model require that the appliance targets of Table 4 be met for each year, 1980-2000. The model chooses either the given appliance efficiency

Table 4. Assumed Improvements in 1980 Energy Requirements for New Equipment from FEA Appliance Efficiency Targets (1970 = 1.0)

Space Heating	
Electric	1.0
Gas	0.81
Oil	0.93
Water Heating	
Electric	0.85
Gas	0.80
Oil	0.81
Refrigerators	0.68
Freezers	0.77
Air Conditioners	
Room	0.65
Central	0.80
Other Appliances	0.90

Source: Reference [1].

target or the voluntary response to fuel price changes, whichever yields more efficient equipment. Thus the standards affect equipment choices only when the assumed price response in the energy model does not.

Table 5 summarizes the energy and economic effects of adopting these appliance efficiency targets in each region. (The "normalized" savings refer to the per household benefit in the region compared to the national per household benefit. Thus, households in regions with normalized savings greater than 1.0 enjoy larger than average benefits.) The cumulative (1977-2000) energy saving for the nation is 9.7 QBtu, equal to 2.0 per cent of the baseline. The percentage savings range from a low of 1.4 per cent in regions 1, 4, 9, and 10 to a high of 3.4 per cent in region 7.

The relatively low prices for natural gas throughout the forecast period and the slow growth in electricity prices in region 7 account for the relative strength of the appliance program. Low fuel prices lead to only slight voluntary improvements in appliance efficiency; hence the standards have a large effect.

Fuel prices increase rapidly in the four regions where the appliance standards have little effect on energy use. For example, electricity prices increase by almost 50 per cent between 1975 and 2000 in regions 9 and 10. In these regions, the voluntary response to fuel price increases robs the targets of their potency.

The variation in economic benefits among regions is larger (and more difficult to explain) than the variation in energy savings; see Table 5. Nationally,

Table 5. Cumulative (1977-2000) Energy and Economic Effects of Appliance Efficiency Program[a]

Federal Region	Energy Savings				Economic Benefits[b]			
	QBtu	Per Cent of Baseline	Per Cent of National Savings[c]	Normalized Savings	1975 Dollars (in billions)	Benefit[d] / Cost	Per Cent of National Savings	Normalized Savings
1	0.37	1.4	3.8	0.7	0.13	1.3	3.8	0.7
2	0.87	1.8	8.9	0.7	0.45	1.6	13.0	1.1
3	1.01	2.0	10.4	0.9	0.35	1.4	10.1	0.9
4	1.13	1.4	11.6	0.7	-0.17	0.9	-4.9	-0.3
5	2.81	2.4	28.9	1.4	1.10	1.5	31.9	1.5
6	1.30	2.8	13.3	1.4	1.13	2.7	32.8	3.4
7	1.03	3.4	10.6	2.1	0.55	2.0	15.9	3.2
8	0.32	2.2	3.3	1.3	-0.02	0.9	-0.6	-0.2
9	0.64	1.4	6.6	0.6	0.03	1.0	0.9	0.1
10	0.26	1.4	2.7	0.9	-0.10	0.7	-2.9	-1.0
U.S.	9.74	2.0	100.0	1.0	3.45	1.4	100.0	1.0

[a] The energy and economic changes are calculated relative to the baseline.
[b] Present worth of economic benefits at 8 per cent real interest rate.
[c] Per Cent of national energy or economic savings divided by per cent of 1990 households.
[d] Fuel expenditures savings divided by incremental capital costs.

the economic benefits (reduced fuel bills) exceed the economic costs (higher capital costs for more efficient equipment) by $3.5 billion. However, in some regions the costs exceed the benefits (regions 4, 8, and 10).

Economic costs exceed benefits in regions 4 and 10 because of their very low electricity prices throughout the projection period. Electricity prices have historically been low because of the presence of large federal power agencies (Tennessee Valley Authority in region 4 and Bonneville Power Administration in region 10). Thus, even though electricity prices increase faster in these regions than in the nation as a whole, prices start from such a low level that they are generally lower in regions 4 and 10 than anywhere else. Because of low electricity prices, electricity is the dominant fuel in these regions, accounting for about 75 per cent of cumulative household fuel use.

In region 8, on the other hand, gas is the dominant household fuel. Gas prices in region 8 are always lower than in any other region. Also, electricity prices remain roughly constant in region 8 between 1970 and 2000. Thus, the price of electricity in region 8 is lower during the projection period than is the price of electricity in region 4.

It appears that low prices for the dominant household fuels in regions 4, 8, and 10 account for the economic cost of appliance program in these regions. The dollar value of the fuel saved does not exceed the extra cost of efficient equipment because fuel prices are so low.

The relative economic benefits are highest in regions 6 and 7. The energy savings due to the appliance program are also largest in these regions. Natural gas prices remain low in both regions throughout the projection period. Thus, it appears that the large energy and economic benefits are due to the lack of voluntary improvement in gas appliance efficiency and the large changes in efficiency required by the standards.

NEW CONSTRUCTION STANDARDS

The ECPA requires the Department of Housing and Urban Development (HUD) to develop thermal standards for construction of new buildings within three years (by 1979) [13]. These standards must then be implemented by the states, but only if Congress first approves them. The President proposed to "advance by one year, from 1981 to 1980, the effective date of the mandatory standards required for new residential and commercial buildings." [14] Table 6 summarizes the likely improvements in space heating and air conditioning loads because of these standards [15]. These standards provide larger percentage savings in multi-family units than in single-family units. This is consistent with the changes likely from implementing the ASHRAE 90-75 standards or the June 1974 HUD standards [16]. We also assume that all mobile homes constructed between 1976 and 2000 meet the recent HUD standards [17].

We assume that there is no regional variation in the standards for multi-family

Table 6. Assumed Improvements in Thermal Integrities for Space Heating of Residential Structures (1970 = 1.0)

	1980 New Construction Standards	*Retrofit Actions*[a]	
		Voluntary	*Federal*
Single-Family Units	0.70 (0.48 0.68[b])	0.80	0.65
Multi-Family Units	0.48	0.80	0.72
Mobile Homes	0.80		

[a] Voluntary retrofits are assumed to apply to 14.3 million single-family and 2.0 million multi-family units between 1974 and 1980. The federal program is assumed to apply to 42.3 million single-family and 7.3 million multi-family units between 1974 and 1984; this includes the voluntary retrofits. See Table 8 for regional allocations of these totals.

[b] The first number applies to electrically heated homes; the range of the second and third numbers applies to homes heated with gas and oil. For the regional value within this range see Figure 3 and Table A11 of reference [10].

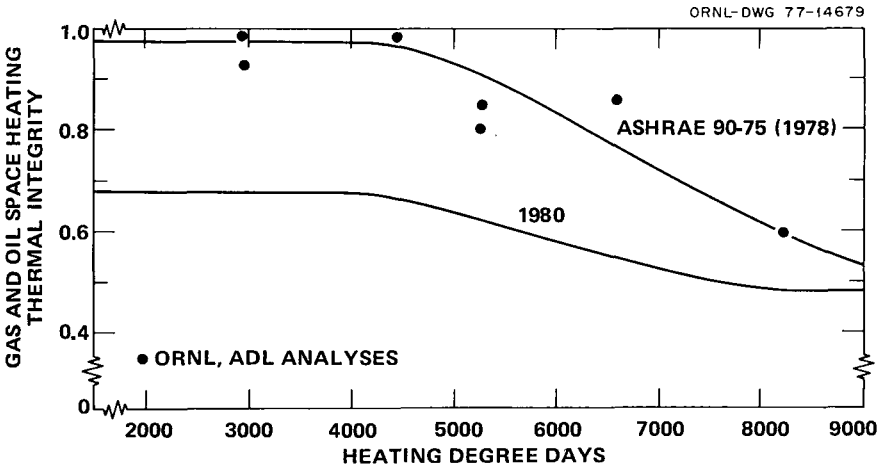

Figure 3. Effects of thermal performance standards on annual space heating thermal loads relative to 1970 thermal loads for new single-family units.

units and for mobile homes [16, 18]. This implies that the standards will require approximately the same *percentage* reduction in annual space heating load (relative to construction practices of the early 1970's) in each region.

Figure 3 shows the assumed regional variation in construction standards for gas- and oil-heated single-family homes [16, 18, 19]. These standards require greater percentage improvements in cold climates (high HDD) than in mild climates. This regional variation is based on variations in the ASHRAE 90-75 standards and the 1974-FHA standards.

As Figure 3 shows, we assume that the ASHRAE standards are adopted in all regions in 1978 and that tougher standards are adopted in 1980. (This type of two-part standard is also assumed for multi-family units, but not for mobile homes.)

Table 7 summarizes the regional effects of adopting these assumed HUD standards in 1980. The cumulative national savings amount to 9.4 QBtu, 2.0 per cent of the baseline. This is almost as much as the savings due to the appliance program.

The regional variation in relative energy savings is much smaller than for the appliance standards. The saving in region 8 is 3.2 per cent of its baseline while that in region 6 is 1.4 per cent. This variation can be explained primarily by differences in climate between the two regions. Region 8 is the coldest in the nation; thus the standards offer the largest savings here in both absolute and relative terms. Region 6, on the other hand, has the mildest winters (2600 HDD compared with 7800 HDD in region 8). The other regions with larger than average energy savings due to the standards (regions 1, 2, 5, 7, and 10) all have colder than average winters.

In contrast with the appliance standards, the benefits exceed costs in each region for the new construction standards. Nationally, benefits exceed costs by $6.2 billion. The relative economic benefits are highest in region 1, probably because of the high fuel prices in this region. The benefits are relatively small in region 10 because of the region's very low fuel prices. In region 9, the relative benefits are low because of the mild climate.

FEDERAL RETROFIT PROGRAM

A number of provisions in EPCA [12] and ECPA [13] 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. The April 1977 energy message [14] proposes a number of measures to meet the goal of "insulating 90 per cent of all residences." These measures include tax credits for retrofits, requirements that electric and gas utilities assist their customers in weatherizing structures, increased funding for the low-income weatherization program, and implementation of a rural home weatherization program.

Based on conversations with FEA staff [15], we assume the parameters for the national retrofit program shown in Table 6. The national average retrofit costs per housing unit are $580 for single-family and $240 for multi-family units. These reductions in heating and cooling demands are assumed to be implemented in 42 million single-family homes and 7 million multi-family homes by 1985.

Table 8 shows the number of homes retrofit in each region. In allocating the

Table 7. Cumulative (1977-2000) Energy and Economic Effects of New Construction Program[a]

Federal Region	Energy Savings				Economic Benefits[b]			
	QBtu	Per Cent of Baseline	Per Cent of National Savings[c]	Normalized Savings	1975 Dollars (in billions)	Benefit[d] / Cost	Per Cent of National Savings	Normalized Savings
1	0.67	2.5	7.1	1.2	0.58	2.9	9.3	1.6
2	1.00	2.0	10.6	0.9	0.82	2.6	13.2	1.1
3	0.98	1.9	10.4	0.9	0.73	2.7	11.7	1.0
4	1.35	1.7	14.3	0.8	0.82	2.6	13.2	0.8
5	2.61	2.3	27.6	1.3	1.68	2.5	27.0	1.3
6	0.64	1.4	6.8	0.7	0.50	2.8	8.0	0.8
7	0.65	2.1	6.9	1.4	0.41	3.0	6.6	1.3
8	0.46	3.2	4.9	1.9	0.16	1.7	2.6	1.0
9	0.74	1.6	7.8	0.7	0.41	1.9	6.6	0.6
10	0.34	1.8	3.6	1.2	0.11	1.9	1.8	0.6
U.S.	9.44	2.0	100.0	1.0	6.22	2.5	100.0	1.0

[a] The energy and economic changes are calculated relative to the baseline.
[b] Present worth of economic benefits at 8 per cent real interest rate.
[c] Per cent of national energy or economic savings divided by per cent of 1990 households.
[d] Fuel expenditures savings divided by incremental capital costs.

Table 8. Regional Distribution of Retrofit Housing Stocks (10^6)

Federal Region	Retrofit Intensity Relative to U.S.[a]	Voluntary Retrofit Program (1974-1980)		Federal Retrofit Program (1974-1984)	
		Single-Family	Multi-Family	Single-Family	Multi-Family
1	1.31	0.87	0.21	1.96	0.78
2	1.26	1.44	0.55	3.44	2.02
3	0.96	1.65	0.19	5.08	0.68
4	0.76	1.98	0.14	7.59	0.49
5	1.32	4.11	0.52	9.37	1.91
6	0.76	1.28	0.08	4.93	0.29
7	1.27	1.11	0.09	2.63	0.32
8	1.16	0.49	0.04	1.26	0.17
9	0.65	1.03	0.15	4.60	0.53
10	0.66	0.33	0.03	1.44	0.10
U.S.[b]	1.00	14.29	2.00	42.30	7.29

[a] Ratios calculated from unpublished data in *Annual Housing Survey: 1975.*
[b] U.S. totals are from reference [1].

national totals among regions for the voluntary program (baseline), we assume that the regional variation in retrofit intensity (i.e., the fraction of housing units retrofit in each region) will follow that observed in 1975 [11].

FEA assumes that 90 per cent of the 1974 stock of occupied single-family units will be retrofit under the *National Energy Plan* [14, 15]. We assume that this percentage applies to each region. Thus, a larger fraction of homes are retrofit because of NEP in regions that have low retrofit intensities (first column of Table 8): regions 3, 4, 6, 9, and 10. However, for multi-family units (of which about one-third are retrofit because of NEP), we use the regional variation observed during 1975 [11].

Finally, we assume that the federal retrofit program will encourage households to adopt weatherization practices that are cost-effective in each region. In other words, we assume that the program will recognize regional differences in climate, fuel prices, and historical construction practices (as is roughly true for the new construction standards). This was implemented in our analysis by retrofiting homes in each region to the same benefit/cost ratio.

Table 9 summarizes the regional energy and economic benefits of implementing the federal retrofit program described above. The cumulative national energy saving of 22.5 QBtu is more than double the energy savings estimated for either the appliance efficiency or new construction standards. The retrofit energy savings are large both because so many housing units are affected by the program and because of the large improvement in thermal integrity assumed for those units retrofit.

Table 9. Cumulative (1977-2000) Energy and Economic Effects of Federal Retrofit Program[a]

	Energy Savings				Economic Benefits[b]			
Federal Region	QBtu	Per Cent of Baseline	Per Cent of National Savings[c]	Normalized Savings	1975 Dollars (in billions)	Benefit[d] / Cost	Per Cent of National Savings	Normalized Savings
1	1.25	4.7	5.6	1.0	0.77	1.7	6.3	1.1
2	2.08	4.2	9.3	0.8	1.31	1.7	10.8	0.9
3	2.56	4.9	11.4	1.0	1.47	1.8	12.1	1.1
4	3.98	5.1	17.7	1.0	2.10	1.8	17.3	1.0
5	5.00	4.3	22.2	1.1	2.59	1.8	21.4	1.0
6	2.69	5.8	12.0	1.2	1.58	1.8	13.0	1.3
7	1.56	5.2	6.9	1.4	0.72	1.8	5.9	1.2
8	0.70	4.9	3.1	1.2	0.28	1.8	2.3	0.9
9	1.85	4.1	8.2	0.7	1.03	1.8	8.5	0.7
10	0.78	4.2	3.5	1.2	0.28	1.8	2.3	0.8
U.S.	22.45	4.7	100.0	1.0	12.13	1.8	100.0	1.0

[a] The energy and economic changes are calculated relative to the baseline.
[b] Present worth of economic benefits at 8 per cent real interest rate.
[c] Per cent of national energy or economic savings divided by per cent of 1990 households.
[d] Fuel expenditures savings divided by incremental capital costs.

As a per cent of baseline energy use, retrofit savings are greatest in region 6 (5.8% of the baseline) and lowest in region 9 (4.1%). Energy savings *per household* are highest in region 7 and lowest in region 9. The regional variation seems to be due to the interaction of climatic variation (HDD) and the number of *additional* homes retrofit because of the program. The regional variation in energy savings, however, is much smaller than for either the appliance standards or the new construction standards.

The net economic benefit of the federal retrofit program amounts to $12 billion for the nation. The benefit/cost ratio is roughly the same for each region (1.8), by assumption. The economic benefit per household is highest in regions 6 and 7 and lowest in region 9. Here again, the regional variation is much smaller than for either the appliance standards or the new construction standards.

COMBINED FEDERAL PROGRAM

Table 10 and Figure 2 summarizes the regional effects of implementing all three of the programs. National cumulative energy savings total 41 QBtu. The relative savings are largest in regions 7 and 8 (11 and 10% of their baselines) and smallest in region 9 (7%). Because the retrofit program accounts for more than half the energy savings, the regional variation for the combined federal program is similar to that for the retrofit program.

The net economic benefit of the combined federal program is $21 billion. Benefits exceed costs in each region. Once again, the regional variation in economic benefits closely follows that for the retrofit program.

Implementing the residential conservation programs of NEP reduces regional energy use growth by 0.3 to 0.6 per cent/year. The benefit/cost ratio for the combined program ranges from a low of 1.4 (region 10) to a high of 2.0 (region 6).

As Table 10 and Figure 2 show, regions 1, 5, 6, and 7 enjoy larger than average economic benefits due to implementation of these conservation programs. Regions 4, 8, 9, and 10 enjoy smaller than average benefits. Fortunately, benefits exceed costs in every region. Benefits are particularly low in regions 9 and 10 because of mild winters (region 9) and low fuel prices (region 10).

The regional variation in energy savings is greatest for the appliance efficiency targets and least for the retrofit program; the same is true for the economic benefits. Benefits of the appliance targets show such large regional variations because the appliance efficiency targets are the same across regions and do not account for regional variation in fuel prices and climate. The new construction standards and retrofit program, on the other hand, do account for regional differences.

Figure 4 shows the cumulative (1977-2000) energy savings by fuel for the combined program in each region. Of the total savings (41 QBtu), 66 per cent is

Table 10. Cumulative (1977-2000) Energy and Economic Effects of Combined Federal Program[a]

Federal Region	Energy Savings				Economic Benefits[b]			
	QBtu	Per Cent of Baseline	Per Cent of National Savings[c]	Normalized Savings	1975 Dollars (in billions)	Benefit[d] / Cost	Per Cent of National Savings	Normalized Savings
1	2.33	8.7	5.6	1.0	1.52	1.8	7.2	1.3
2	3.93	7.9	9.5	0.8	2.53	1.8	11.9	1.0
3	4.50	8.7	10.9	1.0	2.49	1.7	11.7	1.0
4	6.45	8.2	15.6	0.9	2.69	1.6	12.7	0.7
5	10.34	9.0	25.0	1.2	5.23	1.8	24.6	1.2
6	4.50	9.7	10.9	1.1	2.97	2.0	14.0	1.4
7	3.21	10.6	7.8	1.6	1.61	1.9	7.6	1.5
8	1.48	10.3	3.6	1.4	0.41	1.5	1.9	0.7
9	3.18	7.0	7.7	0.6	1.43	1.5	6.7	0.6
10	1.40	7.5	3.4	1.1	0.35	1.4	1.6	0.5
U.S.	41.32	8.7	100.0	1.0	21.23	1.7	100.0	1.0

[a] The energy and economic changes are calculated relative to the baseline.
[b] Present worth of economic benefits at 8 per cent real interest rate.
[c] Per cent of national energy or economic savings divided by per cent of 1990 households.
[d] Fuel expenditures savings divided by incremental capital costs.

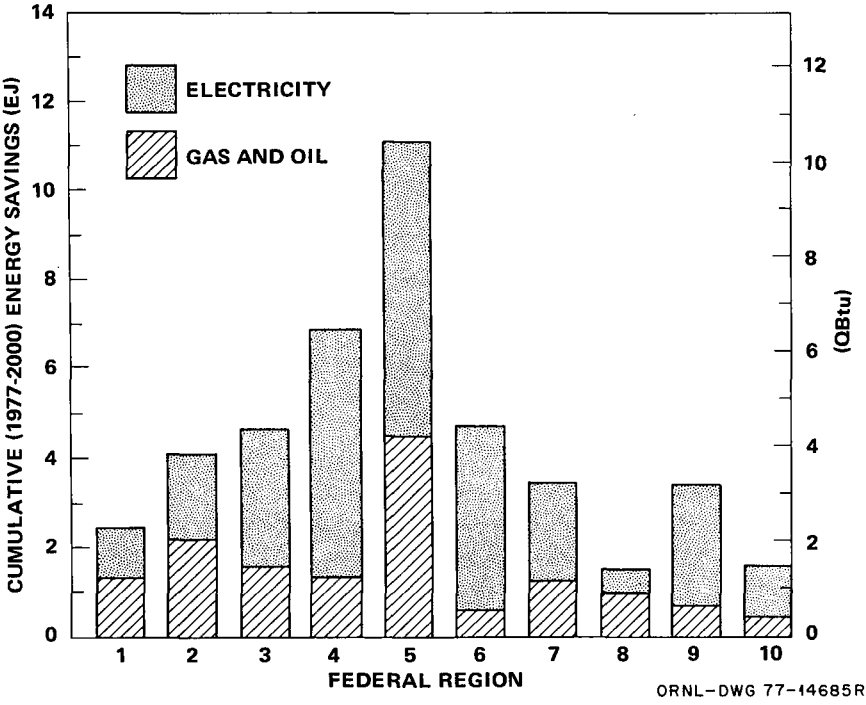

Figure 4. Regional energy savings by fuel for combined Federal program.

electricity and 34 per cent is gas and oil. Electricity savings as a fraction of the total are lowest in regions 1, 2, and 8 (0.46) and highest in regions 4, 6, and 9 (0.81, 0.85, 0.79). These fractions correspond closely to the contribution of electricity to the baseline energy totals in 2000 for the regions (Table 3). Electricity accounts for large fractions of total energy savings primarily because baseline growth in electricity is so much higher than for other residential fuels. This is because of the assumed slower growth in electricity prices and because air conditioning and freezers (the only "growth" markets in the residential sector) are served only by electricity.

SUMMARY

We used a detailed engineering-economic model of residential energy use to evaluate the effects of five residential energy futures for each of the ten Federal regions. The five futures include a baseline, applicance efficiency program, thermal standards for new residential construction, a retrofit program, and the

combination of these three programs.[2] Each of these futures is described in terms of annual and cumulative (1977-2000) energy use by fuel, end use, and in aggregate. Outputs from the model also include economic information on the costs to households in each region of fuels, equipment, and thermal improvements to new and existing structures. The major outputs from these runs are shown in Tables 1 and 2; detailed outputs are in Appendix B of reference [10].

Each of the residential conservation programs in the *National Energy Plan* is likely to reduce energy growth in each of the Federal regions. However, the energy benefits vary substantially across regions. Cumulative energy savings in regions 7 and 8 are 11 and 10 per cent, respectively, of their baseline energy figures. Savings in regions 9 and 10, on the other hand, are less than 8 per cent of the baseline. Average annual growth rates are reduced by 0.3 and 0.6 per cent cent/year.

The combined federal program saves money for households in each of the federal regions. However, the appliance program is likely to cost more than it saves in regions 4, 8, and 10. Regions 1, 5, 6, and 7 enjoy larger than average economic benefits. Regions 4, 8, 9, and 10, on the other hand, receive smaller economic benefits than the average.

It is difficult to pinpoint and quantify those factors that account for differences among regions in the energy and economic benefits of these conservation programs. It appears that fuel prices and climate play particularly important roles. However, levels and growth in income, household formation, new housing construction, housing choices, and other variables not explicitly included in the analysis surely influence the results.

In closing, we note again that these programs are likely to provide large *national* energy and economic benefits [1]. However, the regional distribution of these benefits varies significantly. Implementation of these conservation programs requires careful attention to issues of equity to ensure that some regions do not suffer economically.

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