Impacts of Alternative Residential Energy Standards— Rural Housing Amendments Study, Phase I

Executive Summary

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IMPACTS OF ALTERNATIVE RESIDENTIAL
ENERGY STANDARDS--RURAL HOUSING
AMENDMENTS STUDY, PHASE 1

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Pacific Northwest Laboratory
Richland, Washington 99352

IMPACT OF THE NEW YORK STATE ENERGY DEMAND MANAGEMENT PROGRAM

EXECUTIVE SUMMARY

The New York State Energy Demand Management Program (EDMP) was established in 1990 to encourage energy conservation and demand management among commercial and industrial facilities. The program provides financial incentives for facilities that implement energy conservation measures that result in a reduction in peak demand and total energy consumption.

Over the past several years, the program has been successful in encouraging energy conservation and demand management among commercial and industrial facilities. The program has resulted in a significant reduction in peak demand and total energy consumption.

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FOREWORD

This report summarizes the results of Impacts of Alternative Residential Standards-Rural Housing Amendments Study, Interim Report (PNL-5694). The details of the study are presented in that companion volume.

 
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INTRODUCTION

Congress, numerous administrations, and federal agencies have long recognized the importance of and need for adequate housing for all families. Recent dramatic rises in housing costs have exacerbated an already serious problem for many low income families. A number of government programs and policies have addressed this issue.

This interim report presents the results of a preliminary study conducted by Pacific Northwest Laboratory (PNL) in response to the Rural Housing Amendments of 1983 (Title V of Public Law 98-181, hereafter referred to as the "Act"). The Act requires the Secretary of Energy to deliver a report to Congress on the impacts of several national energy conservation standards that apply to manufactured housing (mobile homes) and conventional site-built housing. This report discusses the housing market and how these standards affect the overall energy economics of these two housing types.

The results presented in this report are preliminary in nature. Though this study uses an approach that tends to minimize potential distortions caused by modeling assumptions, an important consideration must be recognized: the basic data for the different housing types result from separately developed simulations, so comparisons between housing types must be treated with caution.

FEDERAL LEGISLATION AND POLICY BACKGROUND

Historically, the federal government has played a significant role in the national housing market. The U.S. Department of Housing and Urban Development (HUD) administered Federal Housing Administration (FHA) and Veterans' Administration (VA) loan programs with total insurance and loan guarantee funds of \$239 billion in 1982. The Farmer's Home Administration (FmHA) of the Department of Agriculture (DOA) also administers several billion dollars of loan programs, primarily in rural areas. Until recently, however, neither agency has played a major role in funding the purchase of those manufactured homes commonly referred to as mobile homes.

In the Act, Congress permitted the Secretary of Agriculture, through FmHA, to include manufactured homes in the agency's Title V subsidized loan program.

The Act directs FmHA to establish energy conserving requirements for manufactured homes covered under Title V. Those requirements must meet two tests: 1) they must be cost-effective over the home's life or term of mortgage, whichever is less, and 2) they must not increase the owner's annual loan payment more than they decrease annual energy expenditures. In the interim period before FmHA issues the new standards, the Act requires manufactured homes to meet the same energy criteria required of other single-family detached (site-built) homes covered under Title V.

The Act also directs the U.S. Department of Energy (DOE) to compare the impacts of the FmHA energy standards with those of other federal standards and to compare manufactured housing performance to site-built housing performance. This report presents the preliminary results of Phase 1 of the DOE study. The final DOE report, presenting the results of Phase 2, will await the issuance of FmHA's new standard.

STUDY OBJECTIVES AND SCOPE

The Act requires a study that compares the differential construction costs, actual annual energy use, and the projected value of energy saved over the lifetime of manufactured homes built to standards under Title V, with those built to the standards of Titles I and II of the National Housing Act of 1949. (Since Title I applies primarily to home retrofit, it has not been addressed separately.) The Act also requires comparisons with site-built housing built to relevant standards.

The energy impacts of three applicable standards for each housing type have been examined for housing in 13 representative cities. Economic analyses have been conducted for a subset of 6 cities.

Simulated energy consumption data provide the basis for the results presented here. Though no monitored energy consumption data are available for this study, a survey of literature comparing simulated and monitored data suggests that simulations provide an adequate representation of actual energy requirements. Specifically, these results are based on an extensive DOE energy data base, used in conjunction with a DOE data base of cost estimates for a range of energy conservation options.

Cost-effectiveness comparisons are based on discounted (net) life-cycle cost. The economic analysis is conducted from the perspective of the "typical" homebuyer. The impacts of federal loan programs on down payments, interest rates, and mortgage terms are not considered. Though this exclusion deviates somewhat from reality, it provides a common base from which to compare different standards and make comparisons across housing types. The final report will include a more thorough treatment of these variables.

MANUFACTURED HOUSING CHARACTERISTICS AND ROLE IN THE HOUSING MARKET

An understanding of the manufactured housing market and the occupants of manufactured houses is necessary in the assessment of the effects of building standards on those occupants. This section presents relevant background information developed for this assessment.

MANUFACTURED HOME DEFINITION AND DEMOGRAPHICS

The Act and this study focus on manufactured homes covered by the HUD Manufactured Home Construction and Safety Standards (MHCSS) appearing in 24 CFR 3280 ("HUD-code" homes). These homes are "transportable in one or more sections . . . three hundred twenty or more square feet, and . . . built on a permanent chassis." While these homes are commonly called mobile homes, the generic term "manufactured" home also includes modular/sectional houses, panelized houses, and pre-cut houses. Local building codes apply to the last three types, while the HUD standards preemptively cover the mobile homes. Hereafter, the term "manufactured homes" refers only to the HUD-code homes.

Table 1 contains housing stock data for both manufactured and site-built housing. The data suggest that manufactured homes represent a rapidly growing share of the housing stock; they constituted 27% of new housing starts in 1982, but only 6% of the total stock. They are considerably less expensive than site-built homes, both in total cost and in cost per square foot. The distribution of manufactured homes in rural areas and warm climates is higher than that of site-built homes.

Nationally, most (70% to 75%) manufactured homes are single-section units. In the West, however, multi-section units are more prevalent (60% of homes) than single sections. A typical new single-section unit contains 980 sq ft, and a double-section contains 1152 sq ft.

ENERGY CHARACTERISTICS OF MANUFACTURED HOMES

Table 2 compares the thermal and fuel use of manufactured and other single-family homes. It is observed that manufactured homes depend almost

TABLE 1. Capital Stock Housing Data

Parameter	Manufactured Homes	Other Single-Family Homes
Homes completed ^(a)	236,000 (1982) 292,000 (1983)	632,000 (1982)
Median sales price of new home (1983), \$ ^(b)	\$20,400	\$73,200
Average area of existing units, (November 1982), sq ft ^(c)	860 846 (heated area)	2,061 (detached homes) 1,717 (heated area)
Average stock age (1982), years ^(a)	7.7	26.3
Total stock (1982), millions ^(c)	3.7	57.7
Owner occupied stock (1982), % ^(c)	81	83

(a) U.S. Bureau of the Census 1984.

(b) Bus. Trend Analysts 1984.

(c) U.S. EIA 1984a.

TABLE 2. Summary of Thermal Characteristics, 1982 (U.S. EIA 1984a)

Parameter	Manufactured Homes	Other Single-Family Detached Homes
Average total area, sq ft	860	2061
Average heated area, sq ft	846	1717
Main heating fuel, %		
Natural gas	29.3	56.8
Electricity	23.7	12.9
LPG	23.8	5.0
Fuel oil	11.6	12.6
Other	11.5	10.6
Central air conditioning, %	28.5	23.1
Room air conditioning, %	29.4	26.0
Roof insulated, %	66.7	67.2
All walls insulated, %	73.5	51.5

equally on a broader range of fuel types than do site-built homes. Manufactured homes are more likely to have insulated walls, probably because the stock is newer.

Table 3 compares the energy consumption in the two housing types. While manufactured homes compose about 6% of the housing stock, they consume about 4% of the energy due to their smaller size. On a per square foot basis, however, manufactured homes consume 30% more total energy than other single-family homes.

CHARACTERISTICS OF MANUFACTURED HOME OCCUPANTS

Residents of manufactured homes are a diverse group. The ages of about half the occupants are under 30 or over 60. The median age of the household head ranges from 36 in North Dakota to 59 in Florida. Nationally, the median age is 47 years. About one fourth are retired. The median education level of the household head is 12.2 years.

Table 4 presents information on family income. It is noted that manufactured home occupants generally have lower incomes than occupants of site-built homes. However, more recent buyers of manufactured homes appear to have higher incomes than previous buyers.

TABLE 3. Housing Energy Consumption Data, April 1982 - March 1983^(a)

<u>Parameter</u>	<u>Manufactured Homes</u>	<u>Other Single-Family Detached Homes</u>
Total energy consumption (quadrillion Btu)	0.27	6.04
Total energy consumption/ household (million Btu)	72	112
Total energy consumption/ heated area, sq ft (Btu)	85,100	65,200

(a) U.S. EIA 1984b.

TABLE 4. Income Characteristics of Home Occupants

Parameter	Manufactured Homes	All Other Single-Family Homes
Median annual household income, \$(a)	12,000 (1980) 14,424 (1981)	19,800 (1980)
% occupants with 1981 annual family income that was:		
<\$10,000	38	22
<\$20,000	73	47
<\$30,000	92	81
% families earning more than \$20,000 (1983) (b)		
Occupant <3 years	41	--
All occupants	33	--

(a) Bus. Trend Analysts 1984.

(b) U.S. EIA 1984b.

COMPARISON OF MEASURED AND SIMULATED ENERGY CONSUMPTION DATA

To evaluate the energy and economic impacts of the various standards, it would be desirable to monitor a number of homes built to each. However, such a task would necessarily involve a very large number of homes to adequately answer the questions raised in the Act. An alternative method of computer simulation can be used if the model is able to accurately predict actual energy requirements.

Very little information is currently available that compares simulated and actual (monitored) energy consumption in manufactured homes. However, the few papers identified, as well as a wealth of information concerning site-built home energy comparisons, indicate that the popular building models are able to predict annual energy requirements within $\pm 20\%$ for both occupied and unoccupied buildings. This error band tends to be narrower when predicting differential impacts of various constructions than when predicting total annual consumption. Perhaps the area most prone to error is the estimation of air infiltration rates. However, since this study does not address infiltration measures and deals primarily with differential impacts, the accuracy of the simulation data should be sufficient.

The DOE 2.1 building energy analysis model was used to develop the energy data used in this study. The model is quite sophisticated, accounting for many complex phenomena and interactions. Its results generally compare favorably with the 20% error band noted above.

CHARACTERIZATION OF ALTERNATIVE STANDARDS

This section briefly discusses the thermal requirements of each building standard analyzed. For site-built homes, the three standards considered are the HUD Minimum Property Standards (MPS); the FmHA Title V standard; and the American Society of Heating, Refrigerating, and Air Conditioning Engineers' (ASHRAE) Standard 90A-80. The three standards applied to manufactured homes are the HUD Title VI standard (MHCSS), the HUD Title II-E standard (used for HUD's Title II loan program) and the FmHA Title V standard. While the FmHA standard is currently common to both housing types, this may change upon FmHA's issuance of a new manufactured housing standard if it differs from the current Title V standard.

CLIMATE ZONE RELATIONSHIPS BETWEEN STANDARDS

Table 5 lists the 13 cities included in this study, along with the applicable climate zones for each standard. Also listed are annual heating (HDD) and cooling degree days (CDD) (base 65°F). Note that the HUD zones are

TABLE 5. Climate Zone Data

City	HDD (Base 65°F)	CDD (Base 65°F)	HUD Title VI Zone	HUD Title II-E Zone	FmHA Zone	HUD MPS Zone
Phoenix	1765	3334	I	I	2	1
Fort Worth	2405	2500	I	I	2	1
Fresno	2611	1639	I	I	3	1
Atlanta	2961	1469	I	I	3	2
Nashville	3578	1496	I	I	3	2
Washington, D.C.	4224	1491	II	II	3	2
Albuquerque	4348	1345	I	I	3	2
Louisville	4660	1236	II	II	4	5
New York	4871	1027	II	II	4	3
Boston	5634	674	II	II	4	3
Salt Lake City	6052	958	II	II	5	3
Cleveland	6351	613	II	II	5	3
Minneapolis	8382	894	II	III	5	4

geographically based, whereas the other standards use climate (degree days) to define zones. The ASHRAE standard is not included in the table because, rather than defining explicit zones, its requirements are direct functions of climate variables (degree days).

COMPONENT REQUIREMENTS OF SITE-BUILT STANDARDS

Table 6 summarizes the requirements of the site-built home standards. Again, the ASHRAE standard does not appear in the table because its requirements are continuous functions of climate variables. The ASHRAE standard also differs in that it requires consideration of framing members in calculation of component U-values, while the other two standards do not. Therefore, direct comparison of the standards' requirements is not possible. Meaningful comparisons require the specification of prototype designs, as was done in this study.

TABLE 6. Summary of Site-Built Standards' Maximum U-Values^(a)

Component	Standard	Heating Degree Days (HDD)					
		1000 or less	1001-2501	2501-4500	4501-6000	6001-8000	8000 or greater
Ceiling	MPS	0.05	0.05	0.05	0.05	0.05	0.04
	FmHA	0.05	0.05	0.03	0.03	0.026	0.026
Walls	MPS	0.08	0.08	0.08	0.08	0.08	0.08
	FmHA	0.08	0.07	0.05	0.05	0.05	0.05
Windows	MPS	1.13	1.13	1.13	0.69	0.69	0.69
	FmHA	1.13	0.69	0.69	0.47	0.47	0.47
Floors over unheated space	MPS	0.36 0.32 ^(b)	0.32- 0.215 ^(c)	0.215- 0.08 ^(c)	0.08	0.08	0.08
	FmHA	0.08	0.07	0.05	0.05	0.05	0.05

(a) The ASHRAE standard is not shown because it depends directly on HDD rather than climate zone ranges.

(b) U-value is 0.36 for 0 to 500/HDD; between 500 and 1000 HDD, interpolate between figures in table.

(c) Interpolate U-values for heating degree days within range in column heading.

All three standards either require or allow the use of ASHRAE procedures for calculating heat loss and gain.

Only the ASHRAE 90A-80 standard requires air infiltration heat loss calculations or specific heating equipment efficiencies. However, the three standards do not differ significantly in construction requirements that affect air infiltration rates.

COMPONENT REQUIREMENTS OF MANUFACTURED HOME STANDARDS

Table 7 summarizes the requirements of the HUD Title VI and Title II-E standards. The requirements of the FmHA standard are identical to those listed in Table 6 for site-built homes. Only the FmHA standard specifies component requirements. The HUD standards allow more design flexibility by specifying only an overall building U-value (calculated as the weighted average of component U-values). One exception involves windows, which must be, at a minimum, double paned (or single paned with additional storm windows).

All three standards allow ASHRAE procedures for heat loss and gain calculations. The HUD standards require consideration of framing in U-value calculations. Both HUD standards also require air infiltration calculations, while only the Title VI standard specifies heating system efficiencies.

TABLE 7. Summary of Manufactured Housing Standards' Maximum U-Values^(a)

<u>Zone</u>	<u>Title VI</u>	<u>Title II-E</u>
I	0.157	0.145
II ^(b)	0.126	0.099
III ^(b)	0.104	0.087

(a) The FmHA Title V standard requirements used appear in Table 6.

(b) Note that the definition of Zones II and III are different for these two standards.

These standards with respect to allow the use of ASTM procedures for
 calculation of loss and gain.
 Only the ASTM procedures for the calculation of loss and gain
 are applicable to the calculation of loss and gain. However, the
 data do not differ significantly from the data obtained by the
 other methods.

COMPARISON OF RESULTS OF THE TWO METHODS

Table 1 summarizes the results of the two methods for the
 standards. The results of the two methods are identical for the
 standards. Only the first standard is listed in Table 1. The
 results of the two methods are identical for the standards. The
 only difference between the two methods is the calculation of the
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 the standards. The only difference between the two methods is the
 calculation of the loss and gain.

A. The standards allow the use of the two methods for the
 standards. The results of the two methods are identical for the
 standards. The only difference between the two methods is the
 calculation of the loss and gain.

Table 1. Summary of Results of the Two Methods

Standard	Table 1	Table 2
1	0.150	0.150
2	0.150	0.150
3	0.150	0.150

(a) The results of the two methods are identical for the
 standards. The only difference between the two methods is the
 calculation of the loss and gain.

BUILDING PROTOTYPE DESIGNS

To compare the impacts of the various standards, prototype buildings are specified with thermal integrity levels equivalent to those required by each standard. This section discusses the methodology and assumptions used in designing the prototypes.

BUILDING PROTOTYPE DESCRIPTIONS

Two generic prototypes are used in this analysis. The first is a single-story, ranch style, single-family detached house. The other is a single-section manufactured house. Both of these prototypes were used in the development of the energy data base for DOE under the Building Energy Performance Standards Program (BEPS).

The site-built prototype contains 1540 sq ft of conditioned floor area. Glazing is equivalent to 15% of gross floor area. The manufactured prototype contains 902 sq ft of floor area, with windows composing roughly 11% of that amount.

These prototype designs are modified to meet each standard. The modifications are based on two criteria: 1) acceptability of the design as reasonable building practice and 2) lowest first cost where two or more designs would satisfy the standard. Since all the standards are either vague or roughly equivalent in their infiltration control requirements or have no specific requirements, infiltration differences are not considered. The design options available include roof and ceiling insulation, wall insulation, floor insulation, and window type.

MANUFACTURED HOME COMPLIANCE DESIGNS

Table 8 summarizes the manufactured home configurations designed to comply with the applicable standards. Since the HUD standards allow considerable design latitude, the selected designs represent the least first-cost combinations that satisfy the standards, though it is noted that the required overall U-value could be obtained at lower cost if single-pane windows were allowed in Zone II.

TABLE 8. Manufactured Home Compliance Designs

City	Standard	Roof Insul. R-value	Wall Insul. R-value	Windows/ Sash ^(a)	Floor Insul. R-value
Phoenix	FmHA	R22	R19	2,AL	R11
	Title VI	R 7	R 7	1,AL	R 7
	Title IIE	R 7	R11	1,AL	R 7
Fort Worth	FmHA	R22	R19	2,AL	R11
	Title VI	R 7	R 7	1,AL	R 7
	Title IIE	R 7	R11	1,AL	R 7
Fresno	FmHA	R30	R19	2,AL	R19
	Title VI	R 7	R 7	1,AL	R 7
	Title IIE	R 7	R11	1,AL	R 7
Atlanta	FmHA	R30	R19	2,AL	R19
	Title VI	R 7	R 7	1,AL	R 7
	Title IIE	R 7	R11	1,AL	R 7
Nashville	FmHA	R30	R19	2,AL	R19
	Title VI	R 7	R 7	1,AL	R 7
	Title IIE	R 7	R11	1,AL	R 7
Washington, D.C.	FmHA	R30	R19	2,AL	R19
	Title VI	R 7	R11	2,AL	R 7
	Title IIE	R19	R11	2,AL	R19
Albuquerque	FmHA	R30	R19	2,AL	R19
	Title VI	R 7	R 7	1,AL	R 7
	Title IIE	R 7	R11	1,AL	R 7
Louisville	FmHA	R30	R19	3,AL	R19
	Title VI	R 7	R11	2,AL	R 7
	Title IIE	R19	R11	2,AL	R19
New York	FmHA	R30	R19	3,AL	R19
	Title VI	R 7	R11	2,AL	R 7
	Title IIE	R19	R11	2,AL	R19
Boston	FmHA	R30	R19	3,AL	R19
	Title VI	R 7	R11	2,AL	R 7
	Title IIE	R19	R11	2,AL	R19
Salt Lake City	FmHA ^(b)	R33	R24	3,AL	R19
	Title VI	R 7	R11	2,AL	R 7
	Title IIE	R19	R11	2,AL	R19
Cleveland	FmHA ^(b)	R33	R24	3,AL	R19
	Title VI	R11	R11	2,AL	R17
	Title IIE	R19	R11	2,AL	R19
Minneapolis	FmHA ^(b)	R33	R24	3,AL	R19
	Title VI	R11	R11	2,AL	R 7
	Title IIE	R14	R19	2,AL	R11

(a) Number of glazings and sash type (AL = aluminum, and AL/TB = aluminum with thermal break).

(b) Though R33 does not meet the FmHA roof requirements for Region 5, it is the highest R-value available in the data base. To compensate, the wall R-value was increased from the required R-19 to R-24, resulting in a similar overall envelope U-value.

SITE-BUILT HOME COMPLIANCE DESIGNS

Table 9 summarizes the site-built home configurations designed to comply with the relevant standards.

TABLE 9. Site-Built Home Compliance Designs

City	Standard	Roof Insul. R-value	Walls Insul. R-value	Windows/ Sash ^(a)	Floor Insul. R-value
Phoenix	90A	R-19	R-11	1,AL/TB	R-0
	FmHA	R-30	R-19	2,AL	R-11
	MPS	R-19	R-11	1,AL/TB	R-0
Fort Worth	90A	R-19	R-11	2,AL	R-0
	FmHA	R-30	R-19	2,AL	R-11
	MPS	R-19	R-11	1,AL/TB	R-11
Fresno	90A	R-19	R-11	2,AL	R-0
	FmHA	R-30	R-19	2,AL	R-19
	MPS	R-19	R-11	1,AL/TB	R-11
Atlanta	90A	R-19	R-11	2,AL	R-11
	FmHA	R-30	R-19	2,AL	R-19
	MPS	R-19	R-11	1,AL/TB	R-11
Nashville	90A	R-19	R-11	2,AL	R-11
	FmHA	R-30	R-19	2,AL	R-19
	MPS	R-19	R-11	1,AL/TB	R-11
Washington, D.C.	90A	R-19	R-11	2,AL	R-11
	FmHA	R-30	R-19	2,AL	R-19
	MPS	R-19	R-11	1,AL/TB	R-11
Albuquerque	90A	R-19	R-11	2,AL	R-11
	FmHA	R-30	R-19	2,AL	R-19
	MPS	R-19	R-11	1,AL/TB	R-11
Louisville	90A	R-19	R-11	2,AL	R-11
	FmHA	R-30	R-19	3,AL	R-19
	MPS	R-19	R-11	2,AL	R-11
New York	90A	R-19	R-11	2,AL	R-11
	FmHA	R-30	R-19	3,AL	R-19
	MPS	R-19	R-11	2,AL	R-11
Boston	90A	R-30	R-11	2,AL	R-11
	FmHA	R-30	R-19	3,AL	R-19
	MPS	R-19	R-11	2,AL	R-11
Salt Lake City	90A	R-30	R-13	2,AL	R-11
	FmHA	R-30	R-19	3,AL	R-19
	MPS	R-19	R-11	2,AL	R-11
Cleveland	90A	R-30	R-13	2,AL/TB	R-11
	FmHA	R-38	R-19	3,AL	R-19
	MPS	R-19	R-11	2,AL	R-11
Minneapolis	90A	R-30	R-19	2,AL/TB	R-11
	FmHA	R-38	R-19	3,AL	R-19
	MPS	R-19	R-11	2,AL	R-11

(a) Number of glazings and sash type (AL = aluminum, and AL/TB = aluminum with thermal break).

ECONOMIC ANALYSIS METHODOLOGY

The various standards applicable to each prototype are compared in this report for their impacts on the discounted life-cycle cost of the home from the perspective of the homeowner. Also compared are their impacts on first-year incremental cash flows. These economic criteria appear in the Rural Housing Amendments as requirements for the new FmHA manufactured-home standard.

To make comparisons of incremental impacts, a baseline must be assumed that represents common minimum building practices. For site-built homes, the ASHRAE 90A-80 standard is considered the base. For manufactured homes, the HUD Title VI standard (MHCSS) is considered the base.

LIFE-CYCLE COST PARAMETERS

The life-cycle cost calculations are conducted in conformance with the DOE Federal Energy Management Program (FEMP) guidelines of March 1984. Table 10 lists the key economic parameters and their assumed values.

ENERGY COST PARAMETERS

All initial energy costs were obtained by direct query of the suppliers in each city analyzed. The costs include all applicable taxes and adjustments. All heating costs are assumed to occur at the quoted winter rates, and cooling costs at summer rates. Where utilities have block rate structures, the

TABLE 10. Key Economic Parameters

<u>Parameter</u>	<u>Value or Source</u>
Real discount rate, %	10
Nominal mortgage interest rate, %	13
Annual inflation rate, %	5
Length of loan, years	30
Down payment on loan, %	20
Initial energy costs	Utility rates
Real fuel escalation rates	FEMP, March 1984

appropriate rate is selected from the highest block in which a typical residence is likely to operate. These selections are based on average fuel bill data obtained from the U.S. Energy Information Agency (EIA). Table 11 presents the initial energy prices used in the analyses.

Fuel escalation (real) rates are taken from FEMP 1984 estimates for the appropriate regions of interest. These are presented in Table 12.

TABLE 11. Current Utility Rates, \$/MMBtu

City	Electricity		Gas	Fuel Oil
	Summer	Winter		
Phoenix	27.8950	20.0171	5.132	
Atlanta	17.3530	17.2586	5.793	
Nashville	12.9722	12.9722	5.124	
Washington, D.C.	17.8144 ^(a)	17.8144 ^(a)	7.895	
Boston	24.4591	15.6692	6.692	8.2846
Minneapolis	18.2392	15.7534	5.612	

(a) Prices for homes not having electric heating. Homes with electric heating, hot water, and air conditioning pay \$18.5909 summer and winter.

TABLE 12. FEMP Real Fuel Escalation Rates, %/year

City	Fuel	1985-1990	1990-1995	1995-2000
Phoenix	Electric	2.42	2.76	3.60
	Gas	6.27	8.72	1.54
Nashville/Atlanta	Electric	1.47	2.40	3.45
	Gas	5.46	9.56	1.54
Washington, D.C.	Electric	1.38	2.45	3.47
	Gas	4.02	9.36	1.54
Boston	Electric	2.79	2.37	3.44
	Oil	7.49	8.09	1.39
	Gas	4.82	8.98	1.54
Minneapolis	Electric	0.35	2.47	3.48
	Gas	5.41	9.11	1.54

CONSTRUCTION COST ESTIMATES

The estimates used here for conservation option cost differentials are based on data developed for DOE by Steven Winter Associates. The manufactured housing cost data represent costs to the manufacturer, while site-built data represent contractor costs. To estimate final consumer costs, the manufactured home costs are multiplied by a factor of 2.22, provided by HUD officials. Site-built data base costs are multiplied by a factor of 1.22, based on information supplied by the National Association of Home Builders. A national average sales tax of 3.25% is also added to the costs for both housing types. The resulting costs are further adjusted by 1984 Means regional construction cost multipliers.

RESULTS OF THE COMPARISONS

ENERGY REQUIREMENTS

The results of the energy use comparisons are presented in Table 13 for site-built housing and in Table 14 for manufactured housing. The energy use numbers represent overall annual space conditioning loads unadjusted for equipment efficiencies. In this form, the data are of limited use. However, some useful observations are possible. For site-built homes, the FmHA standard is more stringent than the base case (ASHRAE 90A-80). With a few exceptions, the MPS standard is less stringent than the base. For manufactured homes, both the FmHA and HUD Title II-E standards are more strict than the base case HUD Title VI standard.

The reader is cautioned that direct comparisons between manufactured and site-built housing using these tables are not possible. The data originate from two separately conducted simulations, with different assumptions regarding internal heat gains, orientation, glazing area and distribution, etc.

TABLE 13. Building Loads for Site-Built Homes, MMBtu/yr

City	ASHRAE 90A-80		MPS		FmHA	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
Phoenix	26.59	81.04	26.59	81.04	14.72	56.86
Fort Worth	40.95	57.04	31.45	48.63	26.01	44.29
Fresno	47.75	43.92	36.14	32.46	25.83	26.04
Atlanta	35.77	24.56	40.90	25.44	29.55	22.44
Nashville	43.94	26.18	50.07	27.58	36.54	24.04
Washington, D.C.	53.18	25.09	59.45	26.69	44.15	22.76
Albuquerque	45.05	18.40	51.19	19.54	36.59	15.86
Louisville	56.84	21.92	56.84	21.92	44.29	19.36
New York	59.51	14.82	59.51	14.82	45.91	13.07
Boston	72.27	9.52	75.84	9.90	58.63	8.47
Salt Lake City	70.06	14.74	74.73	15.44	56.24	12.57
Cleveland	72.81	8.49	81.01	8.87	61.18	7.30
Minneapolis	98.09	14.21	144.51	15.00	87.07	12.78

TABLE 14. Building Loads for Manufactured Homes, MMBtu/yr

City	Title VI		Title II-E		FmHA	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
Phoenix	17.793	42.583	17.134	41.393	9.292	34.575
Fort Worth	25.906	29.595	24.954	29.017	14.120	25.802
Fresno	30.889	22.773	29.758	22.149	14.259	18.185
Atlanta	28.834	16.313	27.625	15.970	15.860	14.386
Nashville	34.422	17.699	33.033	17.346	19.114	15.662
Washington, D.C.	36.146	14.924	27.029	14.676	22.487	14.628
Albuquerque	38.261	15.018	36.655	14.607	20.173	12.012
Louisville	39.109	13.985	32.399	13.964	23.187	12.914
New York	40.284	9.009	30.195	9.221	23.529	8.668
Boston	51.275	6.324	38.786	6.399	30.443	6.107
Salt Lake City	53.202	12.059	39.994	11.599	31.246	10.524
Cleveland	52.232	5.846	41.751	6.159	33.114	5.584
Minneapolis	73.725	10.010	59.391	9.501	45.067	9.258

ECONOMIC ANALYSES

The results of the energy and economic comparisons for six cities are summarized in Table 15 for site-built homes, and Tables 16 and 17 for manufactured homes with gas and electric heating, respectively. Note that a negative change in life-cycle cost indicates a net benefit to the homebuyer, while a negative change in cash flow represents higher first-year costs to the buyer. The internal rate of return (IRR) is included as an indication of the sensitivity of the results to changes in the discount rate. Large IRRs (about 15% or more) suggest that the conservation investment is not very sensitive to reasonable variations in the discount rate.

The energy values given represent annual building loads adjusted for seasonal equipment efficiencies. Gas and fuel oil heating are assumed to be 69% efficient on a seasonal basis. Electric resistance heating is assumed to be 100% efficient. Seasonal coefficients of performance (COP) for heat pumps are varied according to climate; all air conditioning is assumed to have a seasonal COP of 2.28. Again, the energy results should be viewed with caution, since

TABLE 15. Summary of Energy and Economic Analysis Results for Single-Family Detached Homes for Predominant Fuel Type^(a)

Characteristics	Standard	Washington, D.C.	Phoenix	Minneapolis	Boston	Atlanta	Nashville
Energy use, MMBtu/yr	ASHRAE	41.22	50.21	148.40	108.91	62.62	36.45
	MPS	45.48	50.21	172.54	114.25	70.44	40.54
	FmHA	35.07	33.04	131.80	88.70	52.67	31.31
Energy use, kBtu/sq ft/yr	ASHRAE	26.77	32.60	110.21	70.72	40.66	23.67
	MPS	29.53	32.60	112.04	74.19	45.74	26.33
	FmHA	22.77	21.45	85.58	57.58	34.20	20.33
Change in energy use, MMBtu/yr	MPS vs ASHRAE	4.26	0.00	24.14	5.34	7.82	4.09
	FmHA vs ASHRAE	-6.15	-17.17	-16.60	-20.21	-9.95	-5.14
Change in energy use, kBtu/sq ft/yr	MPS vs ASHRAE	2.77	0	15.68	3.47	5.08	2.66
	FmHA vs ASHRAE	-3.99	-11.15	-10.78	-13.12	-6.46	-3.34
Change in first cost, 1985\$	MPS vs ASHRAE	-464.57	0.00	-1804.34	-1252.97	-464.57	-464.57
	FmHA vs ASHRAE	1849.88	2181.22	1010.49	1259.29	1849.89	1849.89
Change in first cost, 1985\$/ sq ft/yr	MPS vs ASHRAE	-0.30	0.00	-1.17	-0.81	-0.30	-0.30
	FmHA vs ASHRAE	1.20	1.42	0.66	0.82	1.20	1.20
Change in life- cycle cost, 1985\$	MPS vs ASHRAE	536.95	0.00	503.54	-454.08	392.67	282.87
	FmHA vs ASHRAE	247.46	-3414.67	-605.93	-1640.02	472.52	594.10
Change in first-year cash flow, 1985\$	MPS vs ASHRAE	-29.30	0.00	65.62	101.12	-2.46	-8.88
	FmHA vs ASHRAE	-84.61	186.82	-14.01	26.33	-120.00	-109.54

(a) Predominant fuel type is heat pump in Phoenix and Minneapolis, fuel oil in Boston, and gas in Atlanta and Nashville.

they represent total site energy consumption for space conditioning, and there is no distinction between heating and cooling energy use. The economic results, however, incorporate all relevant factors and should be representative of actual impacts in the cities cited.

Some important observations are possible. From Table 15, the MPS, generally a less strict standard than the ASHRAE standard, results in a higher life-cycle cost in all cities except Boston. The FmHA standard, generally more stringent, decreases life-cycle cost in Boston, Minneapolis, and Phoenix, and increases it in the others. Note that these three cities are at the extremes of the climate range. Whether these results indicate a climate inequity cannot be concluded without further examination of sensitivities to other regionally varying parameters.

Table 16. Summary of Results for Manufactured Homes--Gas Heating

Characteristics	Standard	Washington, D.C.	Phoenix	Minneapolis	Boston	Atlanta	Nashville
Change in energy use, MMBtu/yr	FmHA vs Title VI	-19.93	-15.83	-41.86	-30.29	-19.65	-23.08
	Title II-E vs Title VI	-13.32	-1.48	-21.00	-18.07	-1.90	-2.17
Change in energy use, kBtu/sq ft/yr	FmHA vs Title VI	-22.09	-17.55	-46.41	-33.58	-21.78	-25.59
	Title II-E vs Title VI	-14.77	-1.64	-23.28	-20.03	-2.11	-2.40
Change in first cost, 1985\$	FmHA vs Title VI	1455.96	1334.09	2901.91	2076.78	1735.82	1735.82
	Title II-E vs Title VI	575.09	81.64	804.45	575.09	81.64	81.64
Change in first cost, 1985\$/sq ft	FmHA vs Title VI	1.61	1.48	3.22	2.30	1.92	1.92
	Title II-E vs Title VI	0.64	0.09	0.89	0.64	0.09	0.09
Change in life cycle cost, 1985\$	FmHA vs Title VI	-1070.68	-1026.83	-970.68	-1309.15	-468.81	-619.13
	Title II-E vs Title VI	-1073.52	-187.03	-1116.70	-1427.96	-125.40	-126.09
Change in first year cash flow, 1985\$	FmHA vs Title VI	-2.72	9.83	-101.30	-48.41	-58.45	-45.08
	Title II-E vs Title VI	42.54	10.20	26.29	50.32	4.20	4.31
Internal rate of return	FmHA vs Title VI	0.27	0.28	0.17	0.22	0.16	0.19
	Title II-E vs Title VI	>1	>1	0.39	>1	0.36	0.38

Another significant observation is that in Boston, both the MPS and the FmHA standards reduce the life-cycle cost of the site-built home. However, the MPS is less stringent than ASHRAE, while FmHA Title V is more stringent. Clearly, the ASHRAE standard could be adjusted both to save energy and reduce costs to the consumer, according to these analyses.

Referring to Tables 16 and 17, it is evident that the selection of a heating fuel has a significant impact on the economics of the conservation investment due to the variation in costs between fuel types. Electrically heated manufactured homes (Table 17) experience reduced life-cycle cost and positive first-year cash flows in all cities analyzed for both the FmHA and Title II-E standards. In homes heated with gas (Table 16), both standards reduce life-cycle cost in all cities, but the FmHA standard results in negative first-year cash flows in all cities except Phoenix. However, in the worst case, increased monthly expenditures in the first year are less than \$9. In every case, the internal rate of return is greater than 15%, suggesting that the results are relatively insensitive to reasonable changes in the discount rate.

Table 17. Summary of Results for Manufactured Homes--Electric Heating

Characteristics	Standard	Washington, D.C.	Phoenix	Minneapolis	Boston	Atlanta	Nashville
Change in energy use, MMBtu/yr	FmHA vs Title VI	-14.79	-15.01	-28.99	-20.93	-13.82	-16.20
	Title II-E vs Title VI	-9.23	-1.18	-14.56	-12.46	-1.36	-1.54
Change in energy use, kBtu/sq ft/yr	FmHA vs Title VI	-15.29	-13.32	-46.41	-23.20	-15.32	-17.96
	Title II-E vs Title VI	-10.23	-1.31	-16.14	-13.81	-1.51	-1.71
Change in first cost, 1985\$	FmHA vs Title VI	1455.96	1334.09	2901.91	2076.78	1735.82	1735.82
	Title II-E vs Title VI	575.09	81.64	804.45	575.09	81.64	81.64
Change in first cost, 1985\$/ sq ft	FmHA vs Title VI	1.61	1.48	3.22	2.30	1.92	1.92
	Title II-E vs Title VI	0.64	0.09	0.89	0.64	0.09	0.09
Change in life cycle cost, 1985\$	FmHA vs Title VI	-1738.51	-2139.54	-2418.84	-2041.78	-1382.04	-1155.50
	Title II-E vs Title VI	-1519.48	-273.28	-1841.03	-1867.18	-210.51	-174.76
Change in first year cash flow, 1985\$	FmHA vs Title VI	95.03	116.76	117.08	75.98	56.53	39.82
	Title II-E vs Title VI	107.80	18.49	135.52	124.89	14.91	12.01
Internal rate of return	FmHA vs Title VI	>1	>1	0.32	0.33	0.35	0.33
	Title II-E vs Title VI	>1	>1	>1	>1	>1	>1

CONCLUSIONS

This section summarizes the important findings of this initial study. The reader is cautioned that these findings are preliminary and are based on limited analyses.

FINDINGS FOR SITE-BUILT HOUSING

Based on the preliminary analysis, the following results are considered important:

- Site-built homes built to ASHRAE Standard 90A-80 represent typical minimum energy conservation design practices.
- Site energy consumption for space conditioning varies by roughly a factor of 4 across the cities analyzed here.
- The FmHA standard results in the lowest energy use; of the three standards compared, the MPS results in the highest energy consumption. Compared to typical minimum building practice, the FmHA standard reduces consumption between about 11% and 34%, depending on location. The MPS results in consumption increases of 0% to 16%.
- Compared to typical minimum building practice, the FmHA standard decreases life-cycle cost in the hot and cold cities, but increases it in the temperate cities analyzed here. Whether the variation indicates a climate inequity in the standard has not been determined.
- Compared to typical minimum building practice, the FmHA standard produces negative first-year cash flows in all cities except Phoenix and Boston, where the highest life-cycle cost reductions occur. The negative cash flows do not exceed \$10 per month.

FINDINGS FOR MANUFACTURED HOUSING

The following preliminary findings are considered important for manufactured houses. Because the heating type used in the new manufactured homes in the six cities considered here is split fairly evenly between electric

resistance and natural gas, this study presents results for each type separately. The following findings refer to gas heating:

- Manufactured homes built to HUD Title VI requirements represent typical minimum energy conservation design practices.
- Site energy consumption for space conditioning varies by approximately a factor of 2.5 across the cities analyzed here.
- The FmHA standard results in the lowest energy consumption of the three standards analyzed; the Title VI standard results in the highest consumption.
- Compared to typical minimum building practice, the FmHA standard reduces annual energy consumption by 36% to 48%, depending on the location. The Title II-E standard reduces consumption by about 4% to 23%.
- Compared to typical minimum building practice, both the FmHA standard and the Title II-E standard decrease life-cycle cost.
- Compared to typical minimum building practice, the FmHA standard results in negative first-year cash flows in all cities analyzed except Phoenix. The negative cash flows do not exceed \$9 per month.

The following findings refer to manufactured homes heated by electric resistance:

- Site energy consumption for space conditioning varies by a factor of approximately 2.2 across the cities analyzed.
- Compared to typical minimum building practice, the FmHA standard reduces energy consumption by 37% to 46%, depending on location. The Title II-E standard reduces consumption by 4% to 23%.
- Compared to typical minimum building practice, both the FmHA standard and the Title II-E standard reduce life-cycle cost in all cities analyzed.

- Compared to typical minimum building practice, both the FmHA standard and the Title II-E standard effect positive first-year cash flows in all cities analyzed here.

In addition to the previous points, this preliminary analysis also suggests the following:

- The net monthly cash flow impacts of the residential building standards analyzed tend to be small, almost always less than \$10.
- The positive first-year cash flow requirement is a strict test, often causing a homebuyer to forego significant future monetary and energy savings.
- When applied to manufactured housing, the existing site-built FmHA Title V standard does not appear discriminatory. In fact, it produces life-cycle cost reductions more consistently in manufactured homes than in site-built homes in the cities analyzed here.

Again, the reader is cautioned that these findings are preliminary. However, the basic life-cycle cost results appear fairly robust, given that the significant difference in fuel prices between electric resistance and gas heating changes the magnitude, but not the trend, of life-cycle costs for manufactured homes built to different standards. In addition, the internal rate of return on conservation investments in manufactured homes is consistently high for the scenarios considered here, suggesting limited sensitivity to the assumed discount rate.

This interim report will be followed by a final report that analyzes the FmHA manufactured housing standard (yet to be issued) and compares it to the standards analyzed here. That report will expand the sample of locations analyzed and will address the sensitivity of the results to economic and engineering inputs.

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