National Energy Savings Potential in HUD-Code Housing from Thermal Envelope and HVAC Equipment Improvements

KEYWORDS

Energy efficiency, air infiltration, duct leakage, HUD-code manufactured housing

National Energy Savings Potential in HUD-Code Housing from Thermal Envelope and HVAC Equipment Improvements

ABSTRACT

More than 200,000 homes are factory built in the United States each year to the federally preemptive Manufactured Housing Construction and Safety Standards, mandated by the U.S. Department of Housing and Urban Development (HUD-code). This paper analyzes national energy use and savings potential from improvements to thermal distribution system efficiency, thermal envelopes and heating, ventilation and air conditioning (HVAC) equipment over what is currently required by HUD-code. Estimated energy savings over current HUD-code are provided for four cases: National Fire Protection Association Standard 501-2005 (NFPA 2005); the 2006 International Energy Conservation Code (IECC 2006); the U.S. Environmental Protection Agency's Energy Star® manufactured housing guidelines (EPA 2004); and Best Practice, based on the U.S. Department of Energy's Building America Industrialized Housing Partnership program home built in the Pacific Northwest (BAIHP 2005, NEEM 2004). Savings estimates are also provided from improved HVAC system efficiencies such as using Energy Star heat pumps in lieu of electric furnaces, and Energy Star air conditioners. Energy use and associated savings are provided in terms of both energy cost and source energy.

INTRODUCTION

Manufactured homes are built and installed to the U.S. Department of Housing and Urban Development's (HUD) Manufactured Home Construction and Safety Standards (MHCSS). The standards address structural, fire safety, and energy efficiency issues, and require adequate ventilation. The MHCSS supersedes local and state building codes. The MHCSS (HUD 1994) is the current minimum standard that all HUD-code homes are required to meet. The National Fire Protection Association (NFPA) periodically updates the NFPA 501 Standard on Manufactured Housing. NFPA 501 2005 is the standard currently approved by industry and other stakeholders, but is yet to be adopted by HUD. The NFPA does not have authority over the MHCSS but rather provides recommendations to HUD. Research conducted in 2004 by the authors for the U.S. Department of Energy (DOE) has contributed to NFPA 501 2005 improved stringency of thermal efficiency U_o [overall building thermal transmittance, Btu/hr·ft^2·°F) factors. (Conner et al. 2004). NFPA 501 has incorporated improvements over the current HUD-code based on the experiences of energy efficient manufactured home programs, such as Energy Star® and the DOE Building America Industrialized Housing Project, which can significantly improve energy and indoor air quality performance of manufactured homes. These NFPA 501 improvements include: (1) ductwork air leakage testing guidelines; (2) increase in crossover duct insulation from R-4 to R-8; (3) requirements for mastic systems to seal ductwork; (4) quality assurance protocols and materials that systematically address air leakage of the building envelope and ductwork; (5) de-pressurizing limits to reduce fireplace back-drafting and potential problems from moisture condensation; (6) quiet, durable and energy efficient whole house ventilation fans; (7) lower thermal transmittance heat loss; (8) window, roof color and overhang/shading approaches that lower solar heat gain in hot climates; and (9) use of T-8 lighting when linear fluorescent light fixtures are used (NFPA 2005).

The International Energy Conservation Code (IECC 2006) and its predecessors are the predominant codes used for site-built housing in more than half of the states in the United States. Although the IECC does not apply to manufactured housing, it is interesting to compare this code to the MHCSS because these two codes are by far the most important national residential energy efficiency codes. The IECC has a different structure and climate zones compared to the MHCSS, but these codes can readily be compared for any given home design.

The Energy Star Manufactured Home Program is the voluntary program with guidelines that seek to substantially improve energy efficiency over minimum HUD-code, by focusing on improved insulation and HVAC systems and requiring quality assurance performance testing protocols for factories and field installations. Energy Star manufactured homes built in 2006-2007 may qualify for a $1000 federal energy tax credit (IRS 2006). There are four climate zone regions for Energy Star manufactured homes, and the building options vary with fuel type, climate zone, use of set-back thermostats, domestic hot water energy factors, duct leakage rates, etc. For analysis simplification, and because some manufacturers do not offer Energy Star with heat pumps or electric heat in certain climate zones, the Energy Star requirements for natural gas heating with an 80% annual fuel utilization efficiency (AFUE) were selected to represent the Energy Star program thermal efficiency package in all cases. This has the effect of underestimating per house and national "fuel and production weighted" energy savings associated with Energy Star because the heat pump and electric heat packages have lower building envelope thermal transmittance (U_o) values than the gas package.

The Best Practice case represents insulation levels, duct and envelope leakage rates typical of over a hundred thousand Energy Star/ Building America HUD-code homes built in the Pacific Northwest over the past 15 years. The Best Practice uses the current Energy Star guidelines as developed by the Environmental Protection Agency (EPA) and a stakeholder consortium of utilities, manufacturers and state energy offices in the Pacific Northwest. The Best Practice package is fuel blind, and is believed to represent the tightest duct and envelope leakage rates of HUD-code homes currently built. The Best Practice analysis assumes practices are adopted nationally and may be overkill in some milder climate zones.

ANALYSIS APPROACH

The analysis approach evaluates a matrix of climates, efficiency levels and HVAC system fuel types and efficiencies. There are five levels of envelope and HVAC distribution system thermal efficiency: (1) HUD-Code 1994, (2) NFPA 2005, (3) IECC, (4) Energy Star, and, (5) Best Practice. Three climates (Houston TX, Raleigh NC and Chicago IL) were selected to cover the three zones in the MHCSS and to represent hot, mixed, and cold climates. Six HVAC equipment packages are evaluated for electric and gas furnaces, heat pumps and air-conditioning that include minimum National Appliance Energy Conservation Act (NAECA) and Energy Star efficiency levels. This analysis matrix includes a total of 90 cases. The analysis assumes that the MHCSS-required whole house ventilation systems are operated continuously by the occupants. This assumption represents significant energy use, which may not represent the real world, and results in significant periods where the homes (especially the HUD 1994 homes) are over-ventilated. Previous research suggests that significant energy savings potential exists in HUD-code manufactured homes from improved ventilation controls that reduce periods of over-ventilation (Lubliner et al. 2005, Persily 2000, Stevens et al. 1997). Future sensitivity analysis is needed to evaluate energy impacts related to occupant ventilation and control issues over a range of climate types, and duct and envelope leakage rates.

The analysis was conducted using a DOE-2 (LBNL 1981) hourly simulation residential energy analysis software program called EnergyGauge® USA version 2.5 (FSEC 2006). The EnergyGauge analysis assumptions are provided in Table 1. Duct insulation values are all R-8 except for HUD (R-4) and Energy Star (R-6).

TABLE 1
EGUSA Analysis—Thermal Input Assumptions

City and Thermal Efficiency Level	U_o analyzed (Btu/hr·ft^2·°F)	Floor /Ceiling /Wall R-Value	Fenes-tration U-factor	Glazing SHGC[1]	Air Exchange Rate (ACH[2] at 50 PA)	Duct Leakage Rate (25 PA/ft^2)
Houston						
HUD 1994	0.116	11/30/11	1.10	0.70	9.0	Qn=12%
NFPA 2005	0.098	11/28/11	0.52	0.60	7.0	Qn=7%
IECC	0.097	13/30/13	0.75	0.40	7.0	Qn=9%
EStar 2004	0.087	11/30/11	0.38	0.40	7.0	Qn=5%
Best Practice	0.056	33/38/21	0.34	0.40	4.0	Qn=3%
Raleigh						
HUD 1994	0.096	11/30/11	0.52	0.60	9.0	Qn=12%
NFPA 2005	0.089	14/28/11	0.52	0.60	7.0	Qn=7%
IECC	0.067	19/38/13	0.40	0.40	7.0	Qn=9%
ESTAR 2004	0.084	11/33/13	0.38	0.40	7.0	Qn=5%
Best Practice	0.056	33/38/21	0.34	0.40	4.0	Qn=3%
Chicago						
HUD 1994	0.079	22/30/11	0.52	0.60	9.0	Qn=12%
NFPA 2005	0.073	22/33/13	0.52	0.60	7.0	Qn=7%
IECC	0.062	25/38/19	0.35	0.55	7.0	Qn=9%
ESTAR 2004	0.059	33/36/19	0.38	0.40	7.0	Qn=5%
Best Practice	0.056	33/38/21	0.34	0.40	4.0	Qn=3%

1. Conversations, e-mail correspondence with R. Garcia, Fleetwood Housing Division, Riverside, CA, 2006.
2. ACH: air changes per hour

PROTOTYPE DESCRIPTION

A typical 56-foot double-section three-bedroom manufactured home prototype with 12% glass-to-floor area was used in this study. Previous HUD-code related research efforts have used this same prototype, which is generally accepted as representative of the majority of HUD-code homes (Conner et al. 1992, Conner et al. 2004). In 2005, double-section homes represented roughly 80% of the market share[1]. The vented roof has typical dark asphalt shingles and is built using flat 2-by-2 ft roof trusses, 24 inches-on-center. Insulation is assumed to be blown and tapered at baffled eave vents. The 2-by-6 framed, 24 inches-on-center floor is located over a vented crawlspace with blanket/batt floor insulation located in the "belly" and compressed at the I-beams. The walls are assumed to be 16 inches-on-center and 2-by-4 for the R-13 and R-11 batt insulation cases, and 2-by-6 for the R-19 and R-21 batt insulation cases. The doors and windows are industry representative and available models, with the exception of the IECC case, which assumes the prescriptive U-factor requirement of 0.75, 0.4 and 0.35 Btu/hr·ft^2·°F for the three cities examined. Electric domestic water heating with 50-gallon tanks located in the conditioned space with energy factor of 0.90 are assumed for all cases. Table 1 provides the prototype assumptions used in the analysis.

Overall Thermal Transmission

[1] Conversations, e-mail correspondence with R. Garcia, Fleetwood Housing Division, Riverside, CA, 2006.

The analysis approach defined insulation R-values and associated U_o overall heat loss transmission (MHCSS), for the HUD 1994, NFPA 501 and Energy Star cases. For the IECC and Best Practice case, U_o is determined based on the prescriptive R-values. The U-values used were taken from previous HUD-code research, and U_o calculated as follows:

$$U_o = (U_{ceiling} \text{ x } A_{ceiling} + U_{wall} \text{ x } A_{wall} + U_{floor} \text{ x } A_{floor})/\underline{(A_{ceiling} + A_{wall} + A_{floor})}$$

where:
U = thermal transmittance of the envelope component, $Btu/h{\cdot}ft^2{\cdot}{}^oF$
A = area of the envelope component, ft^2.

In the development of these cases, it is assumed that the manufacturer first improves windows from single pane aluminum to double pane vinyl, then additional insulation is added to ceiling, floors and walls, then upgrades to windows are again made. All assumptions used for each of these cases are provided in Table 1 including the U_o analyzed based on the insulation and windows.

HVAC Equipment

Six HVAC system packages evaluate fuel type and minimum efficiency and Energy Star level efficiency heat pumps, air-conditioning systems and gas furnaces, as well as electric furnaces. Table 2 provides a description of the fuel type and assumed seasonal energy efficiency ratio (SEER), heating seasonal performance factor (HSPF) and/or annual fuel utilization efficiency (AFUE) equipment efficiency levels. The HVAC system options provide a way to evaluate the energy usage and saving impacts from interactions between equipment efficiency and home thermal efficiency cases. The thermostat setting was assumed to be 68°F for heating and 78°F for cooling. It should be noted that the Best Practice and Energy Star cases typically require a set-back thermostat, which means that the energy use for these cases may be higher than presented in this analysis.

TABLE 2
Heating and Cooling System Assumptions

	Heating Efficiency		Cooling Efficiency (SEER)	
	Standard Level	**Improved Level**	**Standard Level**	**Improved Level**
Electric Furnace	1.00	1.00	13	14
Gas Furnace	78% AFUE	90% AFUE	13	14
Heat Pump	7.7 HSPF	8.5 HSPF	13	14

Thermal Distribution System

A portion of supply duct system outside the conditioned space is in the crawlspace for all climate zones. A minority of homes in Climate Zone 1 have supply ductwork located in the attic. These homes are believed to have lower thermal distribution system efficiencies, and if analyzed, would result in greater energy savings because the energy efficiency of the buildings is improved compared to what is presented in this paper. This ductwork is assumed to be flexible duct with R-values of R-4, R-6 and R-8, as shown in Table 1, and a surface area of 64 square feet. The return ductwork and air handler location is within the home. The duct leakage rates (cfm per ft^2 of floor area leakage to outside at a test pressure of 25 Pascals) are assumed to be 3%, 5%, 7%, 9% and 12%; and are believed to be representative of typical practices associated with program guidelines and standards (BAIHP 2005, NEEM 2004, EPA 2004, Davis 2003, Lubliner et al. 2003). Duct leakage tests and EnergyGauge analysis were conducted in accordance with procedures provided in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 152 (ASHRAE 2004).

Infiltration and Ventilation

Air infiltration rates used in the analysis are: four air changes per hour (ACH) at 50 Pascals pressure, 7 ACH at 50 PA and 9 ACH at 50 PA, and are again believed to be representative of typical practices based on blower door testing from published research and guidelines (Lubliner et al. 2003, Persily et al. 2003, Stevens et al. 1997, Palmiter 1992). HUD MHCSS requires whole house ventilation systems be installed. For this analysis, the ventilation system is assumed to be a continuously operated 55 cubic feet per minute

(CFM) whole house exhaust fan system to comply with the MHCSS requirements of 0.035 CFM/ft^2 of floor area (HUD 1994). All whole house fans are assumed to be 50 watts, except for the Best Practice case, where the fan energy is 25 watts. The assumption of continuous whole house ventilation system operation has a significant impact on energy use and savings from this analysis. It should be noted that occupants, not engineers, generally decide to how much to operate the whole house mechanical ventilation system.

Climate Zones

HUD Climate Zones 1, 2 and 3 are evaluated using representative cities selected to approximate the heating degree days (HDD) of the three HUD-code zones, as determinted by an average weighted placements of new manufactured homes in 2004:

Houston: 1599 HDD vs. Zone 1 average 1678 HDD
Raleigh: 3457 HDD vs. Zone 2 average 3267 HDD
Chicago: 6176 HDD vs. Zone 3 average 5974 HDD

Each of the three cities are close to the zone averages and therefore, are appropriate representatives for the HUD climate zones.

Fuel Prices

The national residential average electricity price of 9.80 cents per kilowatt-hour for July/August 2005 and 9.25 cents for December 2005 (DOE 2006a) was assumed for cooling and heating costs costs, respectively. Because natural gas prices have varied greatly over the past few heating seasons, the DOE projection of average future residential prices over the next 5 years of $11 per million Btu (DOE 2006b) was assumed. Fuel prices will vary by location and future prices cannot be known with any accuracy. Therefore, these national average prices are only intended to represent typical estimated prices.

ANALYSIS RESULTS

The heating, cooling and HVAC system fan energy annual energy costs per home are provided by city in Figures 1 through 4 for Houston, Raleigh, Chicago, and the national average, respectively. These figures are for the low heating and cooling efficiency levels. The figures contain the results by climate zone for the five energy efficiency levels and three heating system types. The bars show heating and cooling energy use, with fan energy broken out, while the clusters represent the three heating system types. Aggregation to national averages is based on manufactured housing placements by state using 2004 data. HUD Zones 1, 2 and 3 have 31%, 35%, and 34% of the national total of 128,840 placements, respectively (MHI 2004).

We were not able to obtain detailed data on heating system types by climate, but it is likely that electric resistance and heat pumps are common in southern locations while natural gas (or propane) is more common in colder locations. As expected, the highest energy cost, almost $1500 per year (mostly heating), shown in Figure 3 is the current HUD-code home in Chicago (HUD Climate Zone 3) with electric resistance heating. The lowest energy cost of about $350 per year (slightly more heating than cooling), shown in Figure 2 is the Best Practice home in Raleigh (HUD Climate Zone 2), with a heat pump. With the fuel prices and system efficiencies assumed in this analysis, heat pumps have a lower energy cost than natural gas furnaces.

Figure 1. Annual Energy Costs for the Five Energy Efficiency Scenarios in Houston

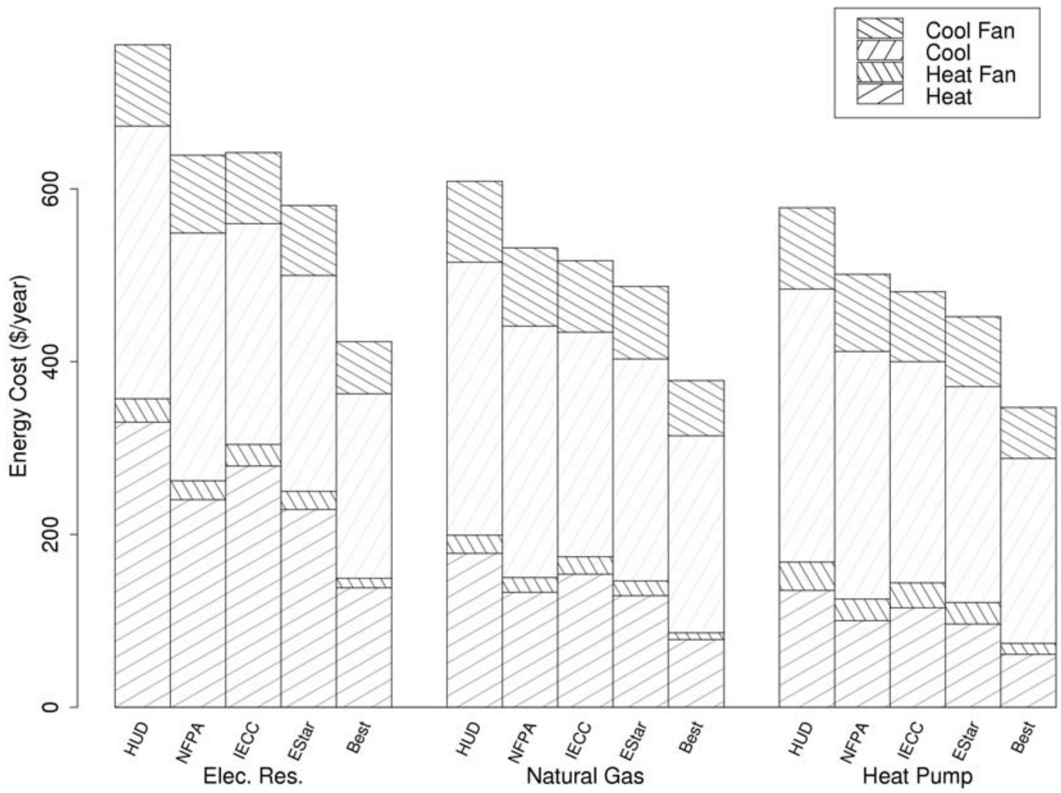


Figure 2. Annual Energy Costs for the Five Energy Efficiency Scenarios in Raleigh

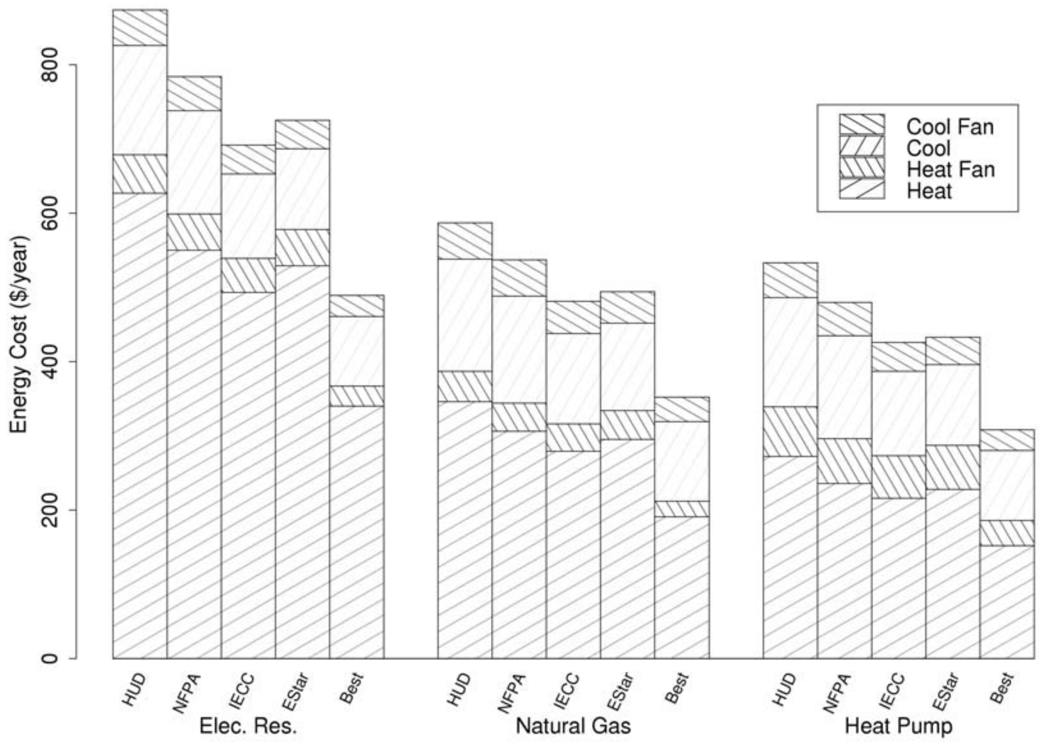


Figure 3. Annual Energy Costs for the Five Energy Efficiency Scenarios in Chicago

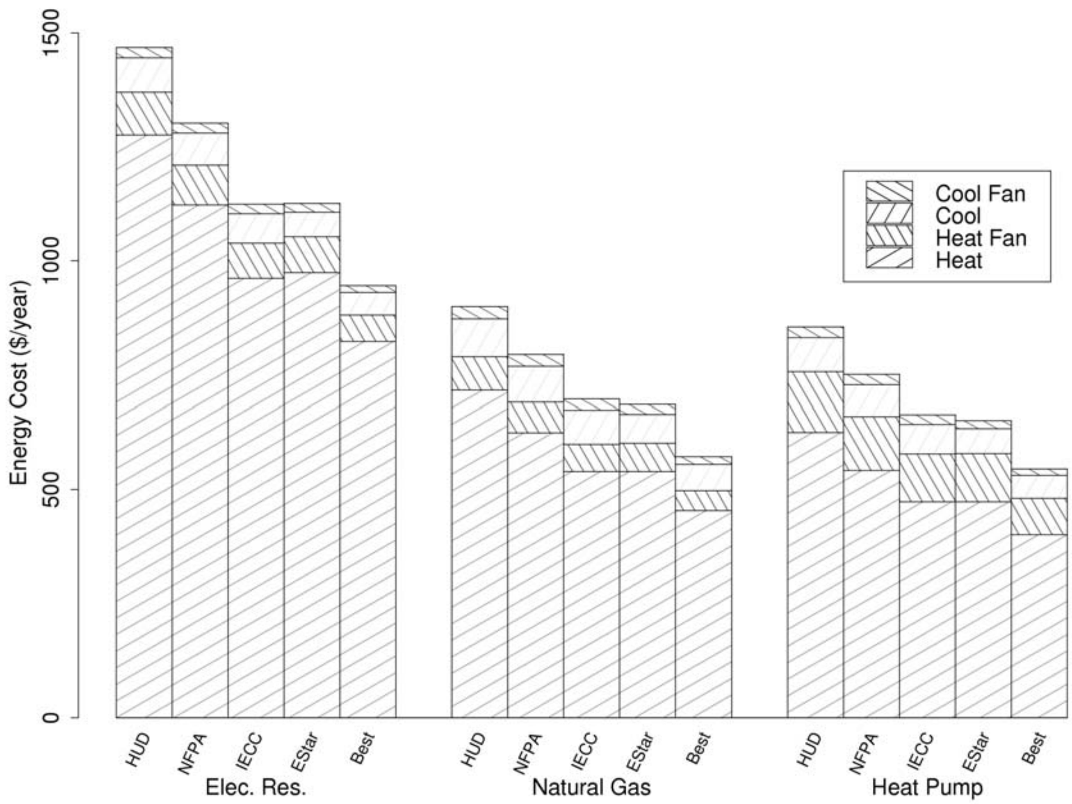


Figure 4. Annual Energy Costs for the Five Energy Efficiency Scenarios as a National Average

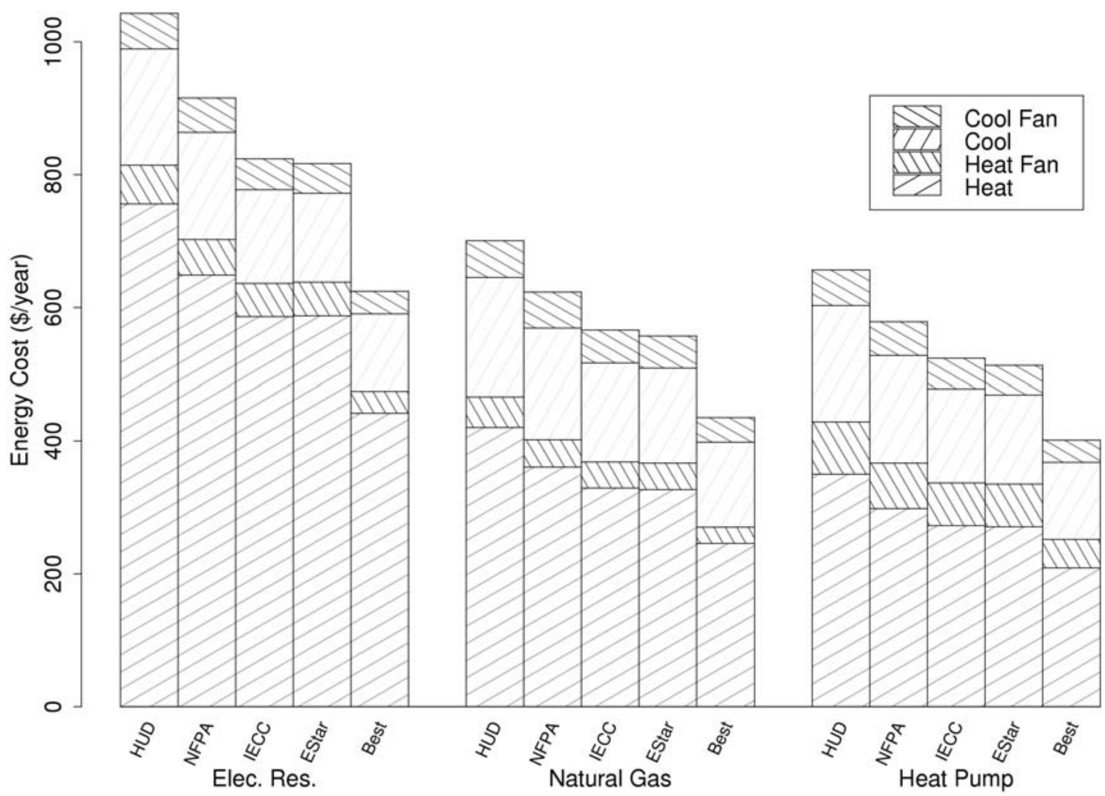


Table 3 reproduces the national average results shown in Figure 4. This table provides the energy cost savings over the worst case, the current HUD-code. The savings are shown both with and without the improved heating and cooling equipment efficiencies. The first three columns of results are at the standard, or low, efficiency level from Table 2. The final column accounts for both the improved codes/programs and additionally the improvement in the HVAC efficiency.

TABLE 3

National Average Energy Costs by Heating System Type

					Savings Over HUD ($)	
		Heating ($)	**Cooling ($)**	**Total ($)**	**Without Improved HVAC**	**With Improved HVAC**
Electric Resistance	HUD	814	229	1043	--	25
	NFPA	702	213	915	128	152
	IECC	636	187	823	220	241
	Energy Star	638	179	817	226	246
	Best Practice	474	150	624	419	435
Natural Gas	HUD	466	234	700	--	75
	NFPA	402	221	623	77	143
	IECC	368	198	566	134	194
	Energy Star	366	191	557	143	203
	Best Practice	270	165	435	265	312
Heat Pump	HUD	428	228	656	--	61
	NFPA	366	212	578	78	132
	IECC	337	187	524	132	181
	Energy Star	335	178	513	143	190
	Best Practice	252	149	401	255	293

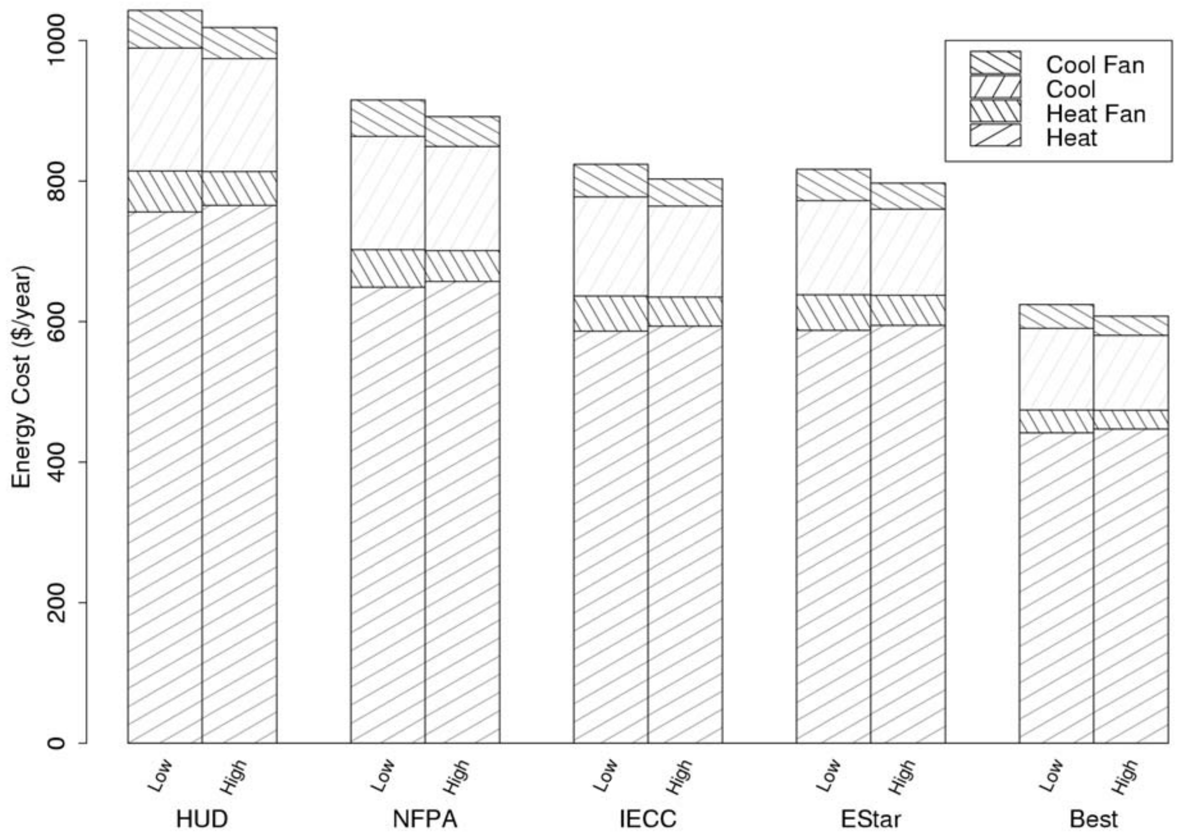
Table 4 shows the same results but using source energy, not energy cost. Source energy takes into account the impact of power plant and distribution system efficiency by multiplying the energy used by 3.2 for electric and 1.02 for gas (DOE 2006c, DOE 1995).

TABLE 4
National Average Source Energy Use by Heating System Type

		Heating (MBtu)	Cooling (MBtu)	Total (MBtu)	Savings Over HUD (MBtu) Without Improved HVAC	Savings Over HUD (MBtu) With Improved HVAC
Electric Resistance	HUD	96	25	121	--	2
	NFPA	83	24	107	14	17
	IECC	75	21	96	25	27
	Energy Star	75	20	95	26	28
	Best Practice	56	17	73	48	50
Natural Gas	HUD	44	26	70	--	8
	NFPA	38	25	63	7	14
	IECC	35	22	57	13	19
	Energy Star	34	21	55	15	20
	Best Practice	25	18	43	27	32
Heat Pump						
	HUD	51	25	76	--	7
	NFPA	43	24	67	9	15
	IECC	40	21	61	15	21
	Energy Star	40	20	60	16	22
	Best Practice	30	17	47	29	34

Figures 5 through 7 show the savings from improving heating and cooling system efficiencies, as described in Table 2. Electric resistance furnaces are 100% efficient and therefore cannot be improved (other than by the use of a heat pump).

1 *Figure 5. Impacts of Improved Heating and Cooling Equipment Efficiency – Electric Resistance*
2 *Heating*
3



4

Figure 6. Impacts of Improved Heating and Cooling Equipment Efficiency – Natural Gas Furnace Heating

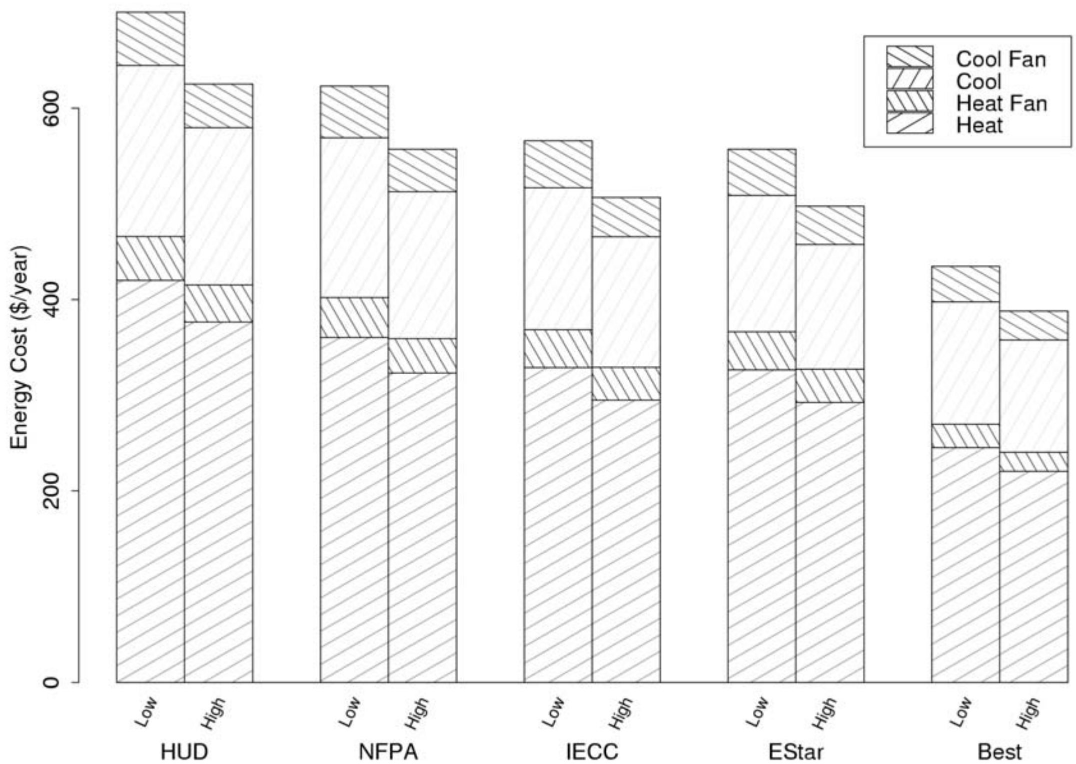
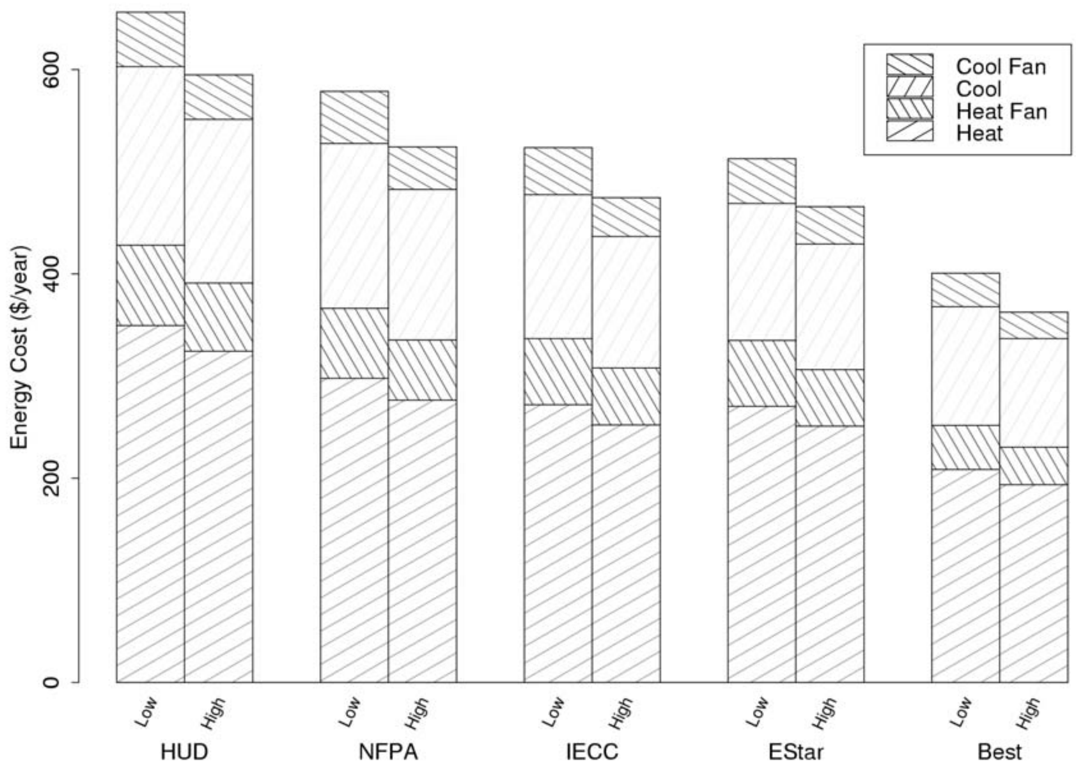


Figure 7. Impacts of Improved Heating and Cooling Equipment Efficiency – Heat Pump Heating



CONCLUSIONS

Comparisons of energy efficient and minimum HUD-code homes suggest significant improvements in energy efficiency and HVAC performance are achievable. Adoption of any of these improvement scenarios would result in hundreds of millions of dollars of on-going utility savings to new HUD-code homebuyers, reduce national residential energy consumption, and reduce power plant greenhouse gas emissions, while improving occupant comfort and control of the indoor environment.

Energy Star manufactured homes with high efficiency equipment save from $190 to $246 a year in average energy costs over the minimum HUD-code, or 24% to 29% of total heating and cooling costs. This improvement in energy efficiency adds up to $25 million to $32 million of energy savings for each year of new construction (assuming the 2004 number of new home placements), or $750 million to $960 million over 30 years (undiscounted). There would also be $128 million of income tax credits available per year.

The HUD-code lags well behind its counterpart code for site-built housing, the IECC. Even if the HUD is updated to the specifications in NFPA Standard 501, it will still fall short of the IECC, particularly in colder climates—HUD Zones 2 and 3. Even the Energy Star levels for manufactured homes barely exceed the IECC code requirements.

The savings presented do not consider the fact that many HUD-code homes are built to more efficient thermal standards than minimum code assumptions used in this analysis. The current HUD-code is sufficiently lenient so that a market evaluation of HUD-code minimum versus actual practice is required to quantify these savings.

The impact of the continuously operated 55 CFM whole house exhaust fan system on the annual energy cost was assessed. The presence of mechanical ventilation doesn't have a clear effect on savings from improving the code. The ventilation typically increases the total heating and cooling cost by 10% to 15% depending on the efficiency level and city. Again, this is assuming the ventilation is operated 24 hours a day. Further evaluation and research related to occupant ventilation as well as other occupant behavioral issues such as thermostat set-point is suggested.

Large potential national savings suggest the need for HUD and DOE to conduct further cost-benefit analyses that evaluates life-cycle costs, increased mortgage “purchase power,” increased re-sale value, federal energy tax credits, and evaluation of environmental benefits.

ACKNOWLEDGEMENTS

Funding for this work was provided by the Department of Energy’s (DOE) Building Technology Division. The authors would also like to acknowledge the contributions from the Manufactured Housing Research Alliance, DOE Building America Industrialized Housing Program, EPA Energy Star Home Program, Ecotope Inc., and Lee Link of the Washington State University Extension Energy Program.

REFERENCES

ASHRAE. (2004). Standard 152, MOT for Determining Seasonal and Steady State Efficiency of Residential Thermal Distribution Systems. American Society of Heating, Refrigerating and Air-Conditioning Engineers. Atlanta, GA.

BAIHP. (2005). Building America Industrialized Housing Partnership Annual Report. FSEC-CR-1534-05. Florida Solar Energy Center, Cocoa, FL.

Conner, C., R. Lucas, and Z. Taylor. (1992). Revisions of the Energy Conservation Requirements in the Manufactured Home Construction and Safety Standards. PNL-7109. 1992. Pacific Northwest National Laboratory, Richland, WA.

Conner, C.C., H.E. Dillon, R.G. Lucas, and M. Lubliner. (2004). Update of Energy Efficiency Requirements for Manufactured Homes. 2004 Summer Study on Energy Efficiency in Buildings. PNNL-SA-41119, Pacific Northwest National Laboratory, Richland, WA.

Davis, B. (2003). Summary of SGC Manufactured Home Field Data 1997-98: Sitings in Idaho and Washington. Ecotope, Inc., Seattle, WA.

EPA. (2004). Energy Star® Labeled Manufactured Homes; Design, Manufacturing, Installation and Certification Procedures. U.S. Environmental Protection Agency. Washington, DC.

FSEC. (2006). EnergyGauge USA Version 2.42. Florida Solar Energy Center. Cocoa, FL.

HUD. (1994). Manufactured Home Construction and Safety Standards, Part 3280. U.S. Department of Housing and Urban Development. Washington, DC.

IECC. (2006). International Energy Conservation Code. 2006. International Code Council. Country Club Hills, Illinois.

IRS. (2006). U.S. Department of the Treasury. Internal Revenue Service. Part III – Administrative, Procedural, and Miscellaneous Energy Efficient Home Credit; Manufactured Homes. Notice 2006-28. http://www.irs.gov/pub/irs-drop/n-06-28.pdf US Internal Revenue Service. Washington, DC.

LBNL. (1981). DOE-2 Engineering Manual, Version 2.1A. Lawrence Berkeley National Laboratory and Los Alamos National Laboratory. LBL-11353. DOE-2 User Coordination Office, LBL, Berkeley, CA.

Lubliner, M., A. Gordon, A. Hadley, and D. Parker. (2005). Heat and Non-Heat Recovery Ventilation Performance in Energy-Efficient HUD-Code Manufactured Housing. 26th AIVC Conference, Brussels, 21–23 September 2005.

Lubliner, M., A. Gordon, N. Moyer, W. Richins, and J. E. Blakeley. (2003) Building Envelope, Duct Leakage and HVAC System Performance in HUD-code Manufactured Homes. 24th AIVC Conference Proceedings. September 2003. Brussels, Belgium.

MHI. (2004). Manufactured Home Shipments by State 2004. http://www.manufacturedhousing.org/media_center/quick_facts2006/econ_impacts.htm. Manufactured Housing Institute. Arlington Virginia.

NEEM. (2004). Northwest Energy-Efficient Manufactured Home Program In-plant Inspection Manual. Oregon Office of Energy. Salem, OR.

NFPA. (2005). Standard on Manufactured Housing. NFPA 501 2005. National Fire Protection Agency. Quincy, MA.

Palmiter, L., I. Brown, T. Bond, and D. Baylon. 1992. Residential Construction Demonstration Project, Cycle II: Measured Infiltration and Ventilation in Manufactured Homes. Ecotope. Seattle, Washington.

Persily, A.K. (2000). A Modeling Study of Ventilation in Manufactured Homes. NISTIR 6455. National Institute Standards and Technology. Gaithersburg, MD.

Persily, A.K., J. Crum, S. Nabinger, and M. Lubliner. (2003). Ventilation Characterization of a New Manufactured Home. 24th AIVC Conference Proceedings. Air Infiltration and Ventilation Centre, Brussels, Belgium.

Stevens, D.T, M. Lubliner and B. Davis. (1997). Mechanical Ventilation in HUD-code Manufactured Housing in the Pacific Northwest. ASHRAE Transactions, 103 (1), pp. 693-705.

U.S. Department of Energy, Energy Information Administration. (1995). Measuring Energy Efficiency In The United States' Economy: A Beginning. http://www.eia.doe.gov/emeu/efficiency/ee_ch7.htm

U.S. Department of Energy, Energy Information Administration. (2006b). Annual Energy Outlook. http://www.eia.doe.gov/oiaf/aeo/pdf/aeotab_3.pdf

U.S. Department of Energy, Energy Information Administration. (2006a). Electric Power Monthly. http://tonto.eia.doe.gov/ftproot/electricity/epm/02260603.pdf

U.S. Department of Energy. (2006c). Core Databook. http://btscoredatabook.eren.doe.gov/docs/6.2.4.pdf

Figure Caption Sheet

Figure 1. Annual Energy Costs for the Five Energy Efficiency Scenarios in Houston
Figure 2. Annual Energy Costs for the Five Energy Efficiency Scenarios in Raleigh
Figure 3. Annual Energy Costs for the Five Energy Efficiency Scenarios in Chicago
Figure 4. Annual Energy Costs for the Five Energy Efficiency Scenarios as a National Average
Figure 5. Impacts of Improved Heating and Cooling Equipment Efficiency – Electric Resistance Heating
Figure 6. Impacts of Improved Heating and Cooling Equipment Efficiency – Natural Gas Furnace Heating
Figure 7. Impacts of Improved Heating and Cooling Equipment Efficiency – Heat Pump Heating