What to Expect from New Residential Efficiency Standards: Whole-Building Analysis of the Model Energy Code, ASHRAE 90.2P, and NAECA

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Within the 50 states some form of federal code or standard for energy efficiency in new building construction is incorporated into state and local codes. For residential buildings two of these codes, the Model Energy Code (MEC) and the ASHRAE 90 standard, are of special importance because they are widely used and have either been recently updated (MEC) or are soon to be revised (ASHRAE).

The overall focus of this work is to demonstrate what changes can be expected in new single-family buildings with regard to end use annual and peak energy use. We use DOE-2.1D to evaluate the impacts of these two codes on building energy performance for 16 U.S. locations. The baseline is a prototypical 1990 vintage building with thermal integrity and appliance and equipment efficiency levels based on current (1980) construction practices. Energy savings are evaluated for the thermal envelope provisions of the 1989 MEC and the proposed ASHRAE 90.2P standard. We also address the end use impacts of efficiency improvements in appliances and HVAC equipment using target levels likely to be implemented by the mid-1990s under the National Appliance Energy Conservation Act (NAECA).

Not surprisingly, the ASHRAE and MEC thermal envelope standards give significant heating savings but yield small changes in cooling energy consumption. The HVAC equipment standards from NAECA are more effective than the envelope standards for reducing cooling energy use. NAECA appliance standards reduce appliance electricity consumption by 10 to 15 percent while slightly increasing heating and decreasing cooling loads due to reduced internal gains.

Introduction

The analysis summarized in this paper is an extension of earlier work aimed at developing a database of typical heating, cooling, water heating and other building loads for single family and multifamily buildings (Ritschard, Hanford, and Sezgen 1992a; Ritschard and Huang 1989). It was surmised that building energy requirements and consumption may be significantly modified in the future after adoption of updated building codes. Two of these codes are of special importance because they are national standards; that is, they serve as programmatic bases for energy codes throughout the U.S.

One of these buildings codes is ASHRAE 90 (Energy Efficient Design of New Low-rise Residential Buildings), which covers residential buildings of three stories or less and manufactured housing. An updated version of the ASHRAE 90 Standard, ASHRAE 90.2P, is currently being reviewed and may be adopted in 1992 (ASHRAE 1990). The ASHRAE 90.2P Standard considers, for the first time, both heating and cooling requirements (only space and water heating, and lighting are covered in other building energy codes), and is based on energy costs as well as climate variations. It allows for two methods of compliance: a prescriptive approach and a systems analysis approach.

The Model Energy Code (MEC), developed by the Council of American Building Officials (CABO) with assistance from a variety of building organizations, was updated in 1989 to provide simplified nomographs for making thermal envelope "tradeoffs" between wall and roof/ceiling requirements for new residential buildings (CABO 1989). The technical requirements of the MEC were also updated from the previous 1983 version. The intent and scope of the 1989 Model Energy Code are similar to that of ASHRAE 90.2P. It covers the same building types, components, and systems and it also allows for multiple methods of compliance.

In this study the impacts of the 1989 MEC and ASHRAE 90.2P on the energy performance of new single-family buildings are evaluated. Base case current construction and modified code buildings are simulated with the DOE-2.1D building energy simulation program. In addition, the effects of appliance and heating and cooling equipment efficiencies are calculated by using the requirements of the National Appliance Energy Conservation Act (NAECA) of 1987 (P.L. 100-12) and the NAECA Amendments of 1988 (P.L. 100-357). These provisions mandate energy-efficiency standards for most major household appliances. NAECA allows for periodic updates, which will likely continue into the next century (Turiel et al. 1990).

The impacts of the NAECA standards are evaluated separately (i.e., improved appliance efficiency and improved efficiency of space conditioning equipment) and also in combination with either the 1989 MEC or the ASHRAE 90.2P Standard. The appliance standards will not only decrease base load energy use in the building but will also affect heating and cooling energy consumption through changes in internal gains. In addition, potential future savings from improvements in space conditioning equipment efficiency will be affected by improvements in building envelopes. In this analysis, we consider the ASHRAE and MEC codes as thermal codes; we only consider the code provisions which regulate building envelope heat loss and gain. While these codes contain standards for space heating, cooling, and water heating equipment, these provisions will likely be superseded in the coming decade by updated standards developed under NAECA, and in this project are presented as NAECA impacts.

The overall focus of this work is to demonstrate which changes can be expected in single-family buildings with regard to end use and total building energy consumption and peak energy use. In analyzing the effects of the ASHRAE standard, 16 cities are studied while only a subset (7) of these cities are used for the study of the Model Energy Code. A more detailed summary of the methodology and results can be found in Ritschard, Hanford and Sezgen (1992b).

Standard Modeling Methodology

The heating and cooling, appliance and hot water modeling methodologies are based on those used in developing the building loads databases (Ritschard and Huang 1989; Ritschard, Hanford, and Sezgen 1992a). The base cities for the analysis are also taken from that project. The cities were originally chosen based on uniqueness of climate and significance of the population represented by that climate. The cities and climate parameters are listed in Table 1.

Structural Assumptions

The building prototype used in the analysis is the 1990s vintage prototype developed for the building loads database. This prototype was assumed to be similar to the 1980s vintage building but larger, based on recent trends towards larger buildings size found in published data. Building dimensions and other specifications were derived from a variety of sources, including the 1987 National Association of Home Builders Builder's Survey (NAHB 1989), U.S. Census Bureau Reports (U.S. Dept. of Commerce 1980 to 1989), the 1984 RECS data tape (EIA 1986), and a previous single family building study (Bluestein and DeLima 1985). One building in each of the 16 base cities, which was representative of typical construction types in that location and climate zone, was defined from this analysis. The basic building descriptions are given in Table 1.

In this study, we model average, rather than typical, building conditions. The average building orientation is modeled by apportioning the amounts of walls, windows, and doors equally in the four cardinal directions. Similarly, shading from two adjacent buildings is simulated. We accounted for average window shade operations by using a window shading coefficient of 0.80 during the winter and 0.60 during the summer. Since the existing DOE-2 program does not adequately model the building-to-ground interface, heat fluxes are calculated by a two-dimensional finite difference program and incorporated into the DOE-2 model. We simulate HVAC energy use with standard gas furnace and central electric air conditioning systems in all cities.

Operating Assumptions

The prototype building is modeled with a heating set point of 70°F during the day, with an 8-hour setback to 64°F between 11 p.m. and 7 a.m. To account for natural ventilation, window venting (i.e., opening windows) is assumed when indoor temperatures rise above 78°F, while during the cooling season venting is assumed down to a level of 72°F. Since occupants typically do not adjust windows after going to bed, window conditions are fixed between 11 p.m. and 7 a.m. unless indoor temperatures drop below the heating set point. We combine assumptions of occupancy levels, schedules, and typical occupancy heat gains for a three person household with regional data on appliance saturations and the appliance heat load to calculate hourly internal heat gains for input to the DOE-2 model.

Table 1. Base Cities and Prototype Building Specifications

			Prototype Specifications					Appliances	
City	Heating Degree Days† (65F°)	Cooling Degree Hours/24† (75F°)	No. Stories	Floor Area (ft²)	Window Area (ft²)	Wall Type	Fndn Type	DHW Fuel	Cook Fuel
Boston	5627	186	2	2280	285	Wood	Bsmt	Elec	Elec
New York	4882	256	2	2280	265	Wood	Bsmt	Elec	Elec
Chicago	6120	318	2	2420	300	Alum	Bsmt	Gas	Elec
Minneapolis	8004	238	2	2420	264	Wood	Bsmt	Gas	Elec
Kansas City	4799	632	2	2420	307	Wood	Bsmt	Gas	Elec
Washington	4180	403	2	2390	316	Alum	Bsmt	Elec	Elec
Atlanta	2965	405	2	2390	289	Wood	Bsmt	Elec	Elec
Miami	222	1193	1	1830	242	Stucco	Slab	Elec	Elec
Fort Worth	2329	1044	1	1830	242	Wood	Slab	Elec	Gas
New Orleans	1374	789	1	1830	242	Brick	Slab	Elec	Gas
Denver	5879	329	2	2290	291	Wood	Bsmt	Gas	Elec
Phoenix	1320	2144	1	1880	203	Stucco	Slab	Gas	Elec
Albuquerque	4186	540	1	1880	203	Stucco	Slab	Gas	Elec
Seattle	5136	39	2	2290	424	Wood	Crawl	Elec	Elec
San Francisco	3172	28	2	2290	360	Stucco	Slab	Gas	Elec
Los Angeles	1636	54	2	2290	360	Stucco	Slab	Gas	Elec

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† From WYEC weather tapes used in the simulations.
TMY weather tapes used for Chicago, New Orleans, and San Francisco.

Non-HVAC Energy Calculation

We calculate average annual non-HVAC electricity and gas consumption for each prototype using the same method for calculating internal gains, by combining typical appliance and lighting energy usage with appliance saturations for each census division derived from 1984 RECS data (EIA 1986). Water heating energy is calculated separately. Based on the fuel type data found in RECS, electricity is assumed for all appliances except for cooking fuel in the West South Central division where gas was predominant. The non-HVAC electric value includes all electricity used by the household, including that which does not contribute to internal heat gains in the conditioned space.

Domestic Hot Water Methodology

Energy use for heating water is a function of several variables such as water storage temperature, inlet and outlet temperatures, air temperatures, and the rate of usage of hot water. To calculate the annual hot water load, we use the following equation taken from DOE calculations (USDOE 1985).

$$\text{Load} = W \times C_P \times (T_T - T_M) \times 365 \text{ days}$$

where:

W = average daily hot water usage (62.4 gallons, 3 occupants)
C_P = energy required per gallon heated (8.25 Btu/gal/°F)
T_T = tank set temperature (140°F)
T_M = city water main temperature (estimated by well temperatures)

Average hot water usage is assumed to be the ASHRAE standard value of 62.4 gal/household-day (ASHRAE 1987), which agrees well with a recent survey of available data (Thrasher, DeWerth and Becker 1990). A climatic variation in consumption levels as a function of outdoor temperatures is included based on methods described in a previous study for multifamily buildings (Ritschard and Huang 1989). Since the average well temperature in most cities corresponds to the average air temperature, we use data from the weather tapes to estimate city water main temperature.

To determine annual water heating energy, the energy factor (EF) from the DOE water heater test procedure is combined with annual hot water loads calculated as shown. Water heating fuel for each census division is taken from an analysis of recently constructed building data in the 1987 RECS (EIA 1989).

Code Requirements and Modeling

The base case buildings - the 1990 building prototype with current (1980s) envelope components, heating and cooling equipment efficiencies, hot water heater efficiencies, and appliance energy consumption - are modified to model the effects of the various code components. Savings in energy use for the NAECA appliance measures are calculated outside of DOE-2, but the reductions in internal heat gains serve as a DOE-2 input. The thermal codes and HVAC equipment measures are modeled in DOE-2. The results from each calculation are summed to compare the impacts on end uses and the relative impacts on total building energy use for each of the codes.

Envelope Codes

For the base case thermal integrity, we use thermal characteristics typical of 1980s vintage buildings taken from the single family data base. For the code buildings, we "upgrade" the base case building to meet the ASHRAE or MEC prescriptive standards on a component-by-component basis. In cases where the base case meets or exceeds the standard, the component thermal integrity is left unchanged. Insulation levels for the base case prototype, and the ASHRAE and MEC standards, are given in Table 2. For prototypes with basement foundations, the base case is modeled with the predominant insulation location (if any), and "codes" buildings are modeled with floor insulation rather than basement wall insulation for simplicity.

For the ASHRAE 90.2P measures, the component R-values and U-values are taken from the nomographs which give the maximum allowable component U-value based on the heating degree days and cooling degree hours of the climate. The R-values in Table 2 reflect a variety of assumptions in reducing the ASHRAE requirements to DOE-2 inputs. For example, for each building component two nomographs are given; one for buildings with ducts in the conditioned space, and one for ducts outside of the conditioned space. For this analysis we choose the latter since it is the more typical construction practice. The ASHRAE code also gives requirements for air leakage. However, these are based on test values for building components such as windows and doors and not on whole-building performance estimates in real-life conditions. We rely on the guidelines in ASHRAE Standard 119 (ASHRAE 1988) to model infiltration in the code houses.

Table 2 also contains the parameters used to model the impacts of the 1989 Model Energy Code. These requirements are also taken from nomographs. However, the MEC requirements are based only on the climate heating degree days. In addition, the MEC specifies an overall wall performance parameter, or the average area-weighted U-value for walls and windows. For this analysis, the U-values of the window and wall component are changed to meet the standard without changing the relative area of window or wall. Note that in Atlanta, the base case building meets all of the requirements in the MEC, and in Phoenix and Albuquerque the changes required are minimal.

NAECA Standards

For the purposes of this study, the standards expected to be in effect in the mid-1990s are applied to the appliances and equipment in the prototype houses. The actual effect of staggered implementation of standards under NAECA is not measured. The energy savings from the appliance standards calculated here does not replace the more detailed assessments carried out as technical support for the standards themselves (see for example Turiel et al. 1990). They are calculated here only to maintain consistency with the change in internal gains calculated for the DOE-2 model and to generate values comparable to the savings in the space-conditioning end uses.

Typically, the standards set for these appliances will be a function of capacity or appliance size. For simplicity, we use average energy use values for average 1980 stock and new 1995 appliances derived from the LBL Residential Energy Model (McMahon 1987). Unit energy consumption values used in this study are provided in Table 3. This table also gives the estimated contribution of each appliance to internal loads in the conditioned versus unconditioned spaces and to sensible versus latent loads. The effect of the change in appliance energy efficiency is a decrease in internal gains from appliances (not including lighting) of 17%, with total internal gains in the conditioned space (from lights, appliances, and occupants) decreasing by about 9%.

For the heating and cooling equipment, we simulate a natural gas furnace and central electric air-conditioner in each location. The assumed base case and code efficiencies are also given in Table 3. Base case equipment efficiencies are weighted averages for 1981-89 shipments taken from the LBL-REM data base. NAECA

Table 2. Building Envelope Parameters for Base Case and Code Compliance Buildings

	Base Case					ASHRAE 90.2P					1989 MEC				
Base City	Wall (R)	Ceil (R)	Floor (R)	Glz Lay	Fndn Insl	Wall (R)	Ceil (R)	Floor (R)	Glz Lay	Fndn Insl	Wall (R)	Ceil (R)	Floor (R)	Glz Lay	Fndn Insl
Boston	13	27	0	2	none	16	28	19	3	none	16	37	19	2	none
New York	13	27	19	2	none	16	28	19	3	none					
Chicago	13	32	0	2	none	16	32	19	3	none					
Minneapolis	19	32	0	2	R-5 4ft	24	48	19	3	none	19	40	19	2	none
Kansas City	11	29	0	2	none	16	29	19	3	none					
Washington	13	30	19	2	none	16	30	19	3	none					
Atlanta	11	27	19	2	none	16	28	19	2	none	11	27	19	2	none
Miami	11	25	0	1	none	16	28	0	1	R-5 2ft					
Fort Worth	11	27	0	1	R-5 2ft	16	28	0	1	R-5 2ft	11	27	0	2	R-5 2ft
New Orleans	11	19	0	1	none	16	28	0	1	R-5 2ft					
Denver	13	31	11	2	none	16	31	19	3	none	13	40	19	2	none
Albuquerque	13	29	0	2	R-5 2ft	16	29	0	3	R-5 2ft	13	30	0	2	R-5 2ft
Phoenix	13	27	0	2	none	16	28	0	2	R-5 2ft	13	27	0	2	R-5 2ft
Seattle	11	32	19	2	none	16	32	19	3	none					
San Francisco	11	25	0	2	none	16	28	0	2	R-5 2ft					
Los Angeles	11	25	0	2	none	16	25	0	2	none					

Note: Building components are upgraded independently to meet ASHRAE and MEC code provisions.

requirements are those listed in the code. The NAECA furnace standard of AFUE=78% was increased to 80% following the assumption that 2% of the jacket loss would be input to the heated space (the new AFUE test calculation assumes the jacket loss goes to the unheated space).

Results and Discussion

Because we made discrete choices about the fuels and systems for space heating and cooling, water heating, and other end uses, the results of this analysis can not be directly extrapolated to sector-wide estimates of potential fuel energy savings. However, the results suggest the relative importance of each code on potential future reductions in residential energy usage.

Space Conditioning End Uses

Figures 1 and 2 show the potential reductions in heating and cooling energy use with a variety of code combinations. For heating, the eight climates with the greatest space heating loads are shown, while for cooling we present the seven most extreme cooling climates.

In space heating, the greatest potential for energy savings is with the combination of ASHRAE envelope and NAECA standards. Most of this savings is from the envelope standards. Savings from ASHRAE range from a high of 35% (38 MMBtu/yr) in Minneapolis to 15% in the New York climate, with typical savings of 25-30% in Boston, Chicago, Kansas City, Denver, and Seattle. MEC envelope savings are approximately half of the ASHRAE savings in these locations where we model the MEC. We found that in all cities the ASHRAE 90.2P standards are more effective in reducing heating energy use than the MEC standards except for the Fort Worth location, where the MEC requirement leads to greater thermal integrity for windows. The savings from the NAECA furnace standards are approximately 9% in all locations, which directly reflects the assumed increase in furnace AFUE. These savings are reduced to 4 to 7% when including the impact of reduced internal gains from NAECA appliance standards. Total savings from the best code combinations range from 27 to 40% in the most extreme climates to 10% in the lesser heating climates (not shown in Figure 1). The percentage savings in heating energy, as well as the absolute heating energy reductions, are greatest in the colder climates.

The relative impact of the codes on cooling energy use is very different than for heating. Figure 2 shows that potential future savings in cooling energy usage will come almost totally from improvements in appliance and

Table 3. Appliance Annual Energy Use and Equipment Efficiency Base Case (mid-1980 stock) and post-NAECA (mid-1995 new)

Appliance or Equipment	Units	Base Case	Post-NAECA	Typical Saturation‡	Internal Gains Percent to		
					Cond.	Uncond.	Latent
Electric Appliances							
Refrigerators							
New	kWh	1125	705	1.0	100	0	0
Old	kWh	1600	1600	0.2	15	85	0
Range/Oven	kWh	1200	1010	1.0	100	0	35
Dishwasher*	kWh	200	160	0.5	0	0	0
Clothes Washer*	kWh	110	95	1.0	0	0	0
Clothes Dryer	kWh	900	750	0.7	10	0	0
Freezer	kWh	950	475	0.3	50	50	0
B/W Television	kWh	100	100	0.6	100	0	0
Color Television	kWh	320	320	1.4	100	0	0
Small Appliances	kWh	300	300	1.0	100	0	0
Lighting	kWh/Sqft	1	1	1.0	90	0	0
Water Heat†							
Standby	kWh	1320	1320	1.0	50	50	0
Use	kWh	2800	2800	1.0	10	0	33
Gas Appliances							
Gas Cooking	MMBtu	8.99	4.89	1.0	100	0	35
Gas Dryer	MMBtu	4.07	3.21	0.2	10	0	0
Thermal Equipment							
Gas Water Heater	EF	51.2	56.1				
Electric Water Heater	EF	82.9	88.0				
Gas Furnace	AFUE	73.0	78.0				
Air Conditioning	SEER	8.5	10.0				

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* Does not include water heat energy.

† These values used only to calculate internal loads inputs to DOE-2.

‡ The appliance saturation varies by location. Typical values are given here.

equipment efficiencies found in the NAECA standards. These savings are partially due to cooling load reduction with decreased internal gains but primarily a result of increased cooling equipment efficiency. The effect of combined appliance and equipment improvements is a 15 to 18% reduction in annual electricity use for cooling, which for the climates shown ranges from over 900 kWh in Phoenix and Miami to 480 kWh in Kansas City.

As shown in Figure 2, the envelope provisions in the ASHRAE standard and the MEC only minimally impact cooling energy use, yet there are some interesting results. In the southern and western portions of the U.S., envelope improvements yield up to 6% reductions in annual cooling energy, but actually increase the cooling load in Boston, Chicago, Kansas City, and Minneapolis. These cooling penalties occur in climates with colder winters but with some cooling energy demand during the summer.

Internal Gains Interactions

By simulating the reduced internal gains from appliances under the NAECA standards, we are able to quantify the effects of improved appliance efficiency on heating and cooling loads in new buildings. The results are presented for a range of climate types in Table 4. The impact of reduced gains on the heating load is related to the length of the heating season. In Minneapolis about 60% of the reduction in heat gain appears as increased heating load,

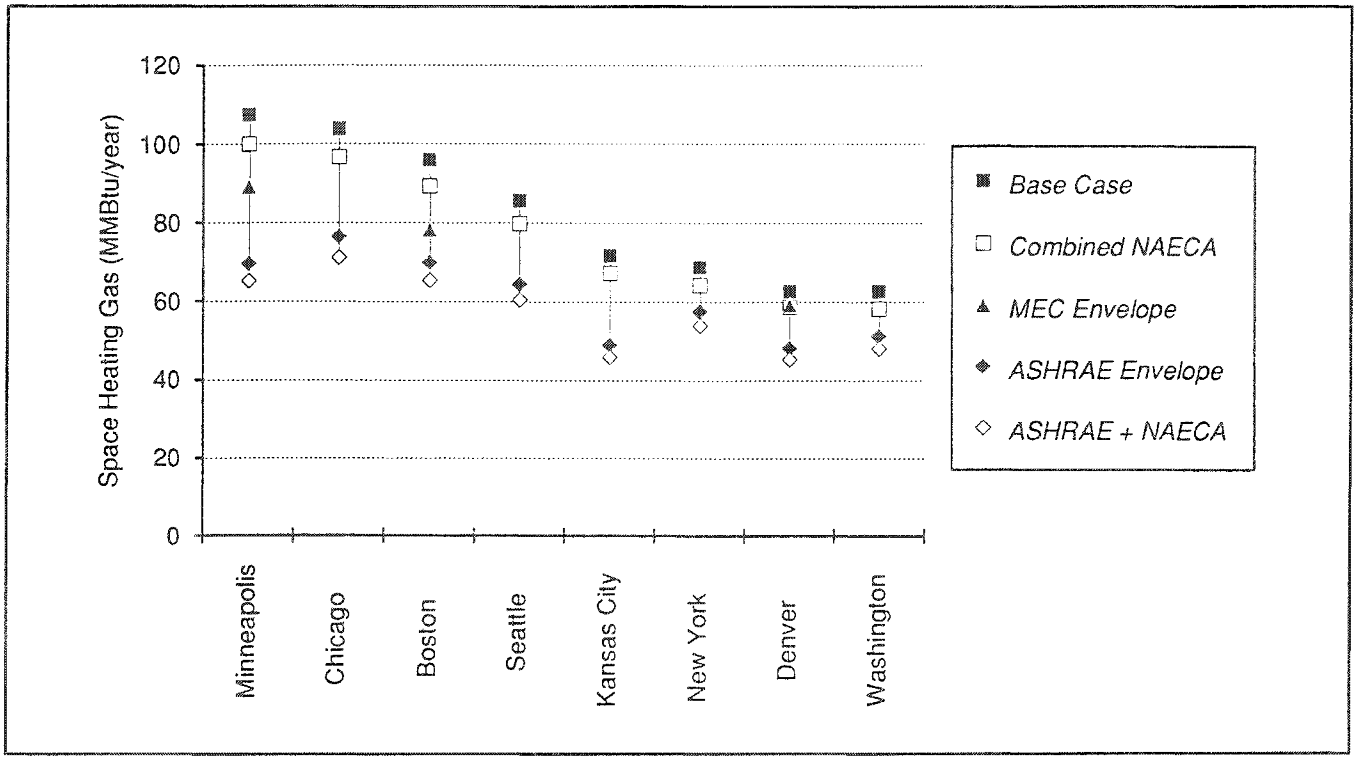

Figure 1. Annual Space Heating Gas Used in Selected Cities Under Base Case Conditions and Various Code Combinations. ASHRAE 90.2P envelope provisions reduced heating consumption by 15 to 35%.

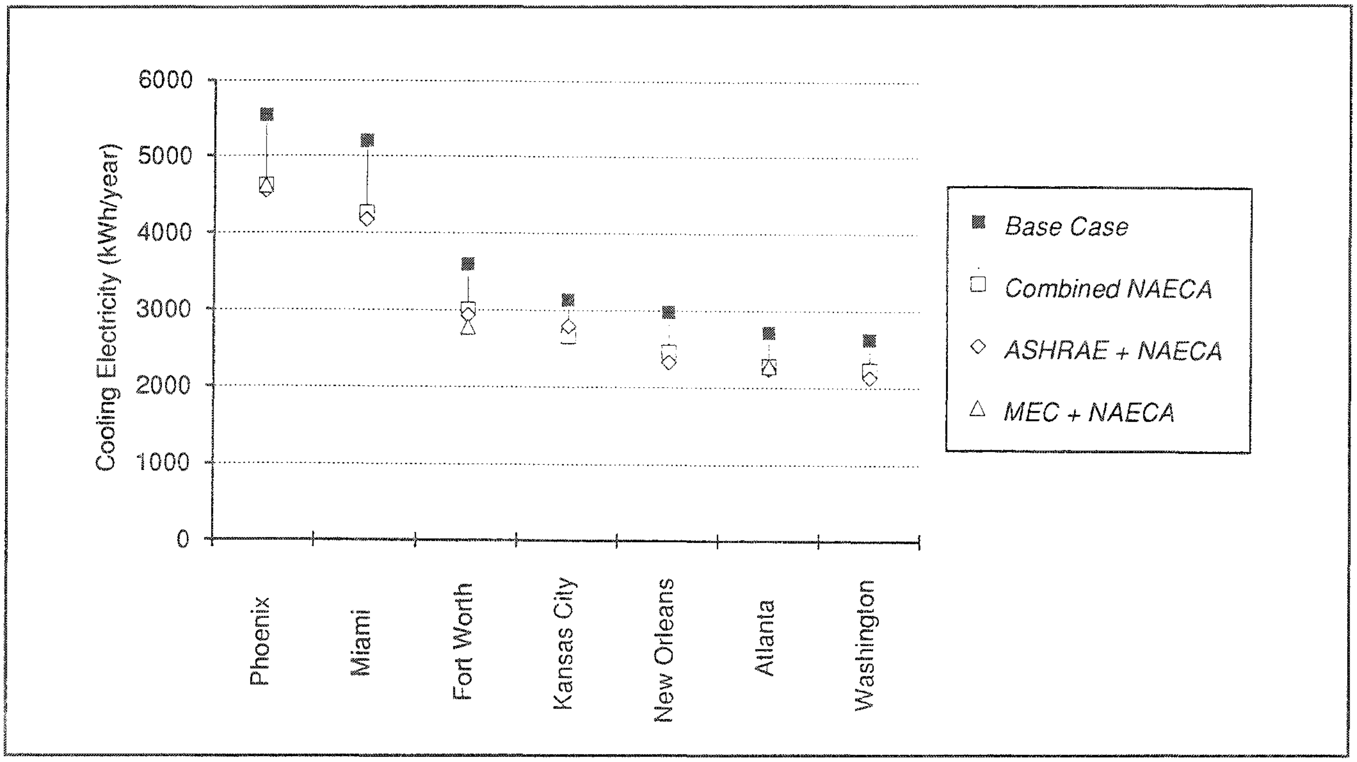

Figure 2. Annual Cooling Electricity Used in Selected Cities Under Base Case Conditions and Various Code Combinations. Virtually all savings are from the NAECA appliance and equipment standards.

Table 4. NAECA Appliance Standard Impacts on Space Conditioning Energy Use

City	ΔInternal Gains (MMBtu)	ΔHeating Load (MMBtu)	ΔHeating Energy (MMBtu)	ΔCooling Load (MMBtu)	ΔCooling Energy (kWh)
Minneapolis	-2.6	+1.5	+2.1	-0.4	-50
Washington	-2.5	+1.1	+1.4	-0.7	-80
San Francisco	-2.5	+1.0	+1.3	-	-
Phoenix	-2.5	+0.4	+0.7	-1.1	-150
Miami	-2.5	+0.1	+0.1	-1.8	-230

while only 4% does so in Miami. Alternatively, 70% of the reduction in internal gains appears as reduced cooling load in Miami. The appliance standards thus have an obvious double benefit in cooling-dominated climates but the net energy savings are less than 100% of appliance savings in areas where heating is more important.

Total House Energy Savings

By looking at the potential energy savings across all end uses we can understand the relative impacts the various standards may have on future energy use in the single family sector. The total potential savings for a variety of code combinations are presented in Table 5. Because the effects of the codes on household energy use are dominated by the type of domestic hot water system (natural gas or electric), appliance saturations, and the type of cooking fuel, the table is sorted by fuel type for those appliances.

Table 5 shows that in the best case, with the ASHRAE envelope measures and full provisions of NAECA, electricity savings assuming gas heating are 1000 to 2000 kWh/year in the cities with gas water heat and 1400 to 2200 kWh/year in the cities with electric water heat, depending on the climate. The reductions in electricity consumption are dominated by the various appliance standards resulting from NAECA except in the extreme cooling climates where cooling electricity consumption becomes a significant portion of the overall electricity bill. Electricity savings can be approximated across locations as 1100 kWh/year from household appliances, 200 kWh/year from water heating where applicable, and between 0 and 700 kWh/year from cooling.

Overall, the potential savings in natural gas are dominated by space heating energy reductions (in gas heated buildings) from building envelope measures in the colder climates. Combined equipment and appliance savings from NAECA are about 7% with and without gas water heating, whereas the combined NAECA and ASHRAE envelope measures give 20-30% savings. Savings from MEC standards, while less than for ASHRAE, are also significant in those cities where the MEC requires increased thermal integrity from current construction practices.

Peak Energy Demand

Potential reductions in peak energy demand for space conditioning end uses are presented in Table 6. The source of peak demand savings for gas heating is basically split between improvements in the building envelope and improvements in equipment efficiency. For cooling, the equipment standards in NAECA provide the majority of the peak demand reduction, between 0.4 and 0.6 kW. The effects of the thermal codes on peak cooling with electricity are quite small. In the best case, these codes shave an additional 0.3 kW from the peak but more typical values are 0.1 to 0.2 kW. These savings may be significant for utilities and could reduce initial homeowner investment in heating and cooling equipment.

Conclusions

The analysis shows some obvious results - that more codes generally mean greater reductions in energy use and demand - yet it also reveals some more subtle effects. For example, the greatest reduction in electricity usage (neglecting the potential in electric space heating) come from the NAECA efficiency standards for typical household appliances. Even in the most extreme cooling climates, electricity savings from cooling equipment efficiency and envelope measures are only one-third of the electricity savings from the total code packages.

Table 5. Base Case Energy Use and Total House Energy Savings from Code Measures

	Base Case Energy Use		Total House Energy Savings							
			NAECA Appliance		NAECA Combined		ASHRAE+ NAECA		MEC+ NAECA	
City	Gas (MMBtu)	Electric (kWh)	Gas (MMBtu)	Electric (kWh)	Gas (MMBtu)	Electric (kWh)	Gas (MMBtu)	Electric (kWh)	Gas (MMBtu)	Electric (kWh)
Gas DHW/Electric Cooking										
Minneapolis	144.9	8800	1.2	1100	10.8	1200	45.6	1100	27.6	1000
Chicago	137.6	9300	1.0	1100	10.2	1300	35.5	1200		
Kansas City	103.2	10500	1.2	1200	7.6	1500	28.7	1400		
Denver	98.0	8700	1.5	1100	7.1	1200	20.3	1300	10.2	1200
San Francisco	71.7	7700	1.3	1000	5.1	1000	13.1	1000		
Albuquerque	68.0	8000	1.1	1100	4.7	1200	10.4	1300	5.0	1200
Los Angeles	46.9	7900	1.6	1000	3.4	1100	7.5	1100		
Phoenix	35.2	12200	1.4	1200	2.5	1900	3.2	2000	2.5	1900
Electric DHW/Electric Cooking										
Boston	95.9	14900	-1.9	1300	6.7	1500	30.6	1400	23.1	1400
Seattle	85.6	14200	-1.8	1300	5.8	1400	25.2	1500		
New York	68.8	15000	-1.7	1400	4.5	1600	14.9	1700		
Washington	62.6	15200	-1.4	1400	4.2	1700	14.5	1800		
Atlanta	38.2	14500	-1.1	1300	2.4	1700	6.8	1700	2.4	1700
Miami	2.9	15100	-0.1	1400	0.1	2100	0.6	2200		
Electric DHW/Gas Cooking										
Fort Worth	47.5	13400	2.9	1200	6.4	1700	8.7	1800	17.5	1900
New Orleans	30.5	12600	3.2	1200	5.2	1600	7.7	1700		

Note: Gas space heating and electric air conditioning assumed in all locations.

In fact, the envelope measures in ASHRAE 90.2P and the MEC are minimally effective in reducing cooling energy usage. This suggests that future efforts to reduce residential cooling energy consumption in new construction should not focus on conductive heat gains through the building envelope. The primary impact of the envelope measures is in reducing heating energy consumption in the colder U.S. climates. The magnitude of heating energy savings from the envelope and furnace measures suggest there are still significant improvements that can be achieved in the residential space heating end use.

Table 6. Peak Heating and Cooling Energy Use in Selected Cities

	Peak Heating (kBtu/hr)					Peak Cooling (kW)			
City	Base Case	ASHRAE Envelope	ASHRAE+ NAECA	MEC+ NAECA	City	Base Case	NAECA	ASHRAE+ NAECA	MEC+ NAECA
Minneapolis	56.4	47.6	42.8	49.5	Phoenix	4.1	3.5	3.5	3.5
Chicago	67.2	59.1	53.9		Miami	2.4	2.0	1.9	
Boston	61.6	55.7	50.1	53.5	Fort Worth	3.2	2.7	2.7	2.4
Seattle	63.1	55.6	50.8		New Orleans	2.5	2.1	2.0	
Kansas City	57.3	53.6	47.6		Atlanta	2.7	2.3	2.2	2.3
New York	49.8	46.2	40.8		Albuquerque	1.9	1.5	1.5	1.5
Denver	57.8	54.1	48.0	51.4	San Francisco	3.0	2.5	2.4	
Washington	60.8	56.4	50.8		Los Angeles	4.1	3.5	3.3	

Overall, there remains significant potential for reducing energy consumption in new single family buildings with the combination of these building, appliance, and equipment codes. The savings from ASHRAE 90.2P, the 1989 MEC, and the standards set under NAECA, if realized, will help make the residential sector much more energy-efficient.

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