Life Cycle Cost Analysis of the 2000 International Energy Conservation Code for Nebraska

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Executive Summary

The focus of this report is the cost effectiveness of increasing the state's residential energy code in new home construction. Nebraska last updated its statewide energy code in 1983.

This report compares the first year and life cycle cost impact of:

- upgrading Nebraska's current residential energy code, the 1983 Model Energy Code (MEC), to the 2000 International Energy Conservation Code (IECC), and
- upgrading the average residential energy code currently required by local jurisdictions in the state to the 2000 IECC.

Savings in the Thousands

The findings were clear:
An upgrade to the 2000 IECC from the 1983 MEC would generate dollar savings from reduced energy use in excess of any mortgage payment increases due to higher construction costs. ***The difference would mean a Nebraska homeowner could pocket between $50 and $295 a year in savings, depending on where the homeowner lived.*** Figure A illustrates the savings for four different house sizes in four Nebraska cities.

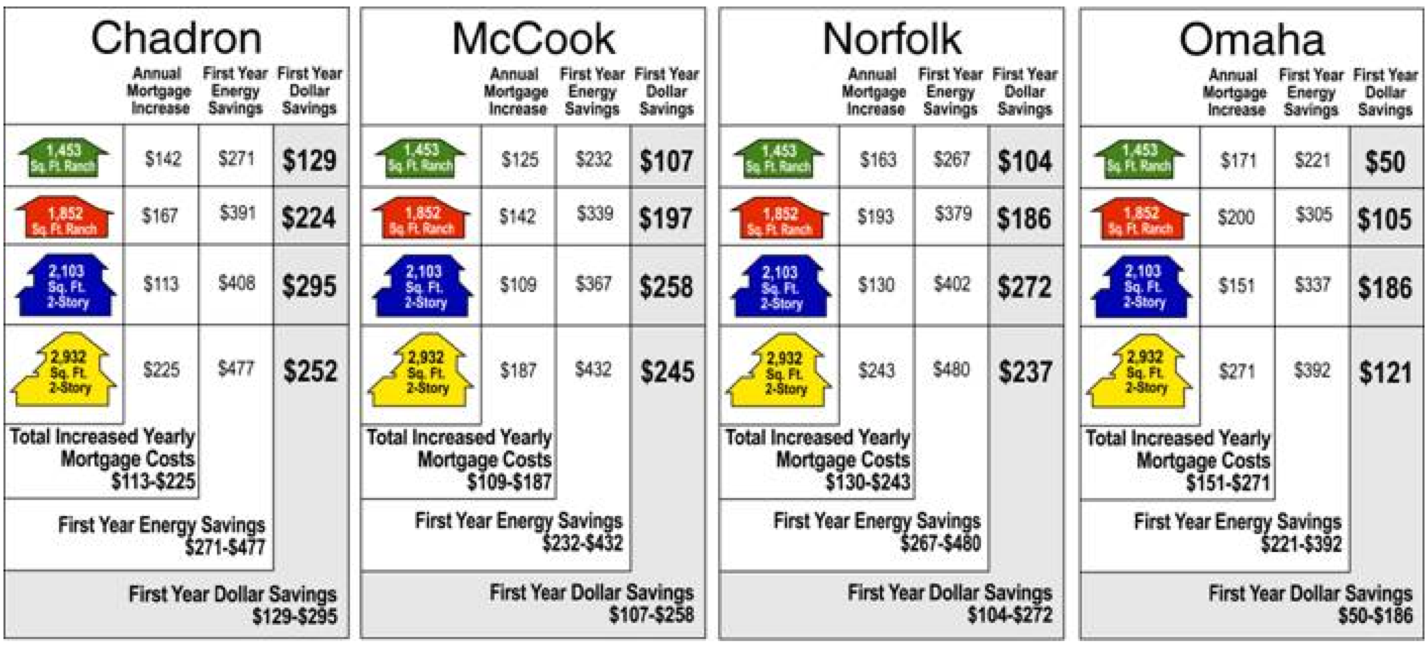

Figure A. Four Cities, Four Houses:
Mortgage Costs and Energy Savings After Upgrade from 1983 Model Energy Code to 2000 International Energy Conservation Code

An upgrade to the 2000 IECC from the current average code used across the state produces first year net savings in every case, as illustrated in Figure B.
While the savings are not as dramatic, they are still compelling: ***The difference would mean a Nebraska homeowner could pocket between $25 and $124 a year in savings, depending on where the homeowner lived.***

Currently, only 13 of 69 jurisdictions accounting for less than 4 percent of the dwellings constructed in the state have codes equivalent to the 2000 IECC.

Chadron

	Annual Mortgage Increase	First Year Energy Savings	First Year Dollar Savings
1,453 Sq. Ft. Ranch	$22	$78	$56
1,852 Sq. Ft. Ranch	$22	$105	$83
2,103 Sq. Ft. 2-Story	$4	$106	$102
2,932 Sq. Ft. 2-Story	$13	$137	$124
Total Increased Yearly Mortgage Costs	$4-$22		
First Year Energy Savings		$78-$137	
First Year Dollar Savings			$56-$124

McCook

	Annual Mortgage Decrease	First Year Energy Savings	First Year Dollar Savings
1,453 Sq. Ft. Ranch	-$8	$41	$49
1,852 Sq. Ft. Ranch	-$12	$59	$71
2,103 Sq. Ft. 2-Story	-$6	$67	$73
2,932 Sq. Ft. 2-Story	-$23	$79	$102
Total Decreased Yearly Mortgage Costs	-$6-$23		
First Year Energy Savings		$41-$79	
First Year Dollar Savings			$49-$102

Norfolk

	Annual Mortgage Increase	First Year Energy Savings	First Year Dollar Savings
1,453 Sq. Ft. Ranch	$22	$70	$48
1,852 Sq. Ft. Ranch	$23	$94	$71
2,103 Sq. Ft. 2-Story	$4	$97	$93
2,932 Sq. Ft. 2-Story	$15	$121	$106
Total Increased Yearly Mortgage Costs	$4-$23		
First Year Energy Savings		$70-$121	
First Year Dollar Savings			$48-$106

Omaha

	Annual Mortgage Increase	First Year Energy Savings	First Yea Dollar Savings
1,453 Sq. Ft. Ranch	$14	$39	$25
1,852 Sq. Ft. Ranch	$17	$53	$36
2,103 Sq. Ft. 2-Story	$12	$60	$48
2,932 Sq. Ft. 2-Story	$19	$67	$48
Total Increased Yearly Mortgage Costs	$12-$19		
First Year Energy Savings		$39-$67	
First Year Dollar Savings			$25-$48

Figure B. Annual Mortgage Increase/Decrease and First Year Energy Savings – Upgrade from the Current Nebraska Average to 2000 International Energy Conservation Code.

Hundreds of Thousands of Dollars Saved Statewide

Based on statewide housing construction figures, an upgrade from the current state average to the 2000 IECC would produce a combined first year cost savings of $254,000 for buyers of new homes this year. And their savings will grow in subsequent years as energy costs rise. ***Over the next thirty years, the houses built during a single year will provide their collective owners with $5.5 million in net savings.*** These savings would be available to the homeowners for additional expenditures, which could bolster the state's economy.

After implementation of the 2000 IECC, savings will continue to grow as more of Nebraska's housing stock is built to the new standard. ***Adoption of the 2000 IECC by the State of Nebraska will result in more than $59.6 million (in 2003 dollars) saved over the life of the houses built before 2015, even if there is no housing growth during this period.*** Because these savings come from reductions in energy use, adoption of the 2000 IECC would also help to shield Nebraska homeowners from future fluctuations in energy prices.

Savings Are Compounded

Other benefits to the state include additional investments in construction cost, which translates to approximately 1.13 million dollars in the first year, benefiting local builders and suppliers while increasing the value of the state's residential infrastructure.

While the new code will require marginally higher construction costs, any increase in mortgage payments is more than offset by the annual energy savings.

The actual first year energy savings are $340,000, and will continue to compound each year as more houses are constructed to the upgraded standard.

With more than 80% of the money Nebraskans spend on energy leaving the state, this savings produces a strong and immediate benefit for the state's economy. Thus, this upgrade benefits builders, suppliers, homeowners, and the state.

About the Study

The study considers the reduction in energy costs associated with energy code upgrades and compares those savings to any increases in costs of construction required to meet the code. Weather conditions, construction costs, and utility rates are considered for four cities selected to represent climate zones in the state: Chadron, McCook, Norfolk, and Omaha.

Four houses were modeled for the study.
These include a small ranch style house with 1,453 square feet (sf), a medium ranch style house with 1,852 sf, a medium two story house with 2,103 sf, and a large two story house at 2,932 sf. Occupancy and usage patterns were based on national data for average use.

Details, including how the building components were constructed to meet the various codes, how the state average requirements were determined, development of the usage patterns, economic data used in the cost calculations, the basis for choosing the four cities mentioned above, and the documented sources are included in the full report.

Introduction

The objective of this research was to investigate the life cycle cost impact of upgrading Nebraska's residential energy code to the 2000 IECC (International Energy Conservation Code). Two other code conditions were used for comparison:
the 1983 MEC (Model Energy Code), the current statewide minimum, and the Nebraska average currently being required by jurisdictions in the state. This average condition was determined by a 2002 survey of Nebraska code officials conducted by the Nebraska Energy Office. The study considered the reduction in energy costs associated with upgrades to the energy code, and compared those savings against any increases in costs of construction required to meet the code. Weather conditions, construction costs and utility rates were considered for four cities: McCook, Omaha, Norfolk and Chadron.

Computational models of four houses were developed for the study. These include a ranch style house at the 20^{th} percentile size being constructed in Nebraska, a ranch style house and a two story house at the median home size, and a two story house at the 80^{th} percentile size. Occupancy and usage patterns were modeled based on national average usage data.
The impact of setback thermostats and an alternate occupancy profile were also investigated.

Selection and specification of houses modeled

House size and type

Based on the survey of Nebraska building code officials, the calculated average Nebraska home built in 2002 was 1,870 square feet (sf) in size. Unfortunately, data on floor area are not recorded in Omaha, and we believe many of the state's larger houses are built in its larger communities. The average new home in Lincoln was approximately 2,200 sf, which supports this assumption. Also, average house sizes have been rising, so a larger area of 2,100-2,200 sf is also relevant as an estimate of the "average" Nebraska home.

These data agree well with published U.S. census data[1]. For 2001, the median new home in the area defined as "Midwest" had 1,965 sf, and the average new "Midwest" home had 2,209 sf (very large homes skew the average higher). The census data also include some information on the distribution of sizes. This was used to estimate the 20^{th} and 80^{th} percentile house sizes for this study. The 20^{th} percentile Nebraska home is larger than 20 percent of new homes built in Nebraska. Likewise, the 80^{th} percentile home is larger than 80 percent of new Nebraska homes. By interpolation of the census data, the 20^{th} percentile home in the "Midwest" is approximately 1,450 sf, and the 80th percentile is about 2,900 sf.

Four houses were modeled using these sizes: a ranch house at the 20^{th} percentile, a ranch house at the mean size determined by the survey of Nebraska
code officials, a two story house between the median and average sizes for Midwest homes according to the U.S. Census data, and a two story house at the 80^{th} percentile. Plans and estimating kits were supplied by Design Basics, an Omaha building plan service that supplies plans for 15,000 houses per year. The actual houses modeled, their square footages, and other characteristics are shown in Table 1.

The decision to model both smaller homes as ranches was based on the survey of code officials, which identified 69% of new homes built in the state as ranch style. The split entry style, which is also likely to be used for smaller homes accounted for only 13% of the total. Two story homes accounted for 18% of the statewide total, and undoubtedly are more common for larger homes. The larger "average" home and the 80^{th}

percentile home were both modeled having two stories.

House	Plan area	Style	Ceiling height (range, ft)	Above grade exterior wall area (sf)	Door area (sf)	Window area (sf)
20^{th} percentile	1,453 sf	ranch	7.5-10.0	1,530	42	160
Surveyed mean	1,852 sf	ranch	7.5-10.0	2,070	70	160
Midwest mean	2,103 sf	2 story	7.5-9.0	2,620	88	229
80^{th} percentile	2,932 sf	2 story	7.5-12.7	2,540	86	477

Table 1. Characteristics of houses modeled.

According to the survey, 92% of Nebraska houses have basements, and 26% of these are finished basements. All four houses were modeled with conditioned basements.

The survey found that when records on the type of heating and cooling systems installed are recorded, 67% of new homes have gas-fired forced air furnaces and central air conditioning systems, 24% reported "electric heat and air conditioning," and only about 4% reported using heat pumps of various types. We suspect that the "electric heat and air conditioning" category may actually contain both electric resistance heating and heat pumps.
Because both were in the minority, all four homes were modeled using forced air heating with gas-fired furnaces and central air conditioning.

An air infiltration rate of 0.5 air change per hour was used in modeling the above ground portions of all four houses under all three code conditions.
Basements located below grade are modeled with 0.2 air change per hour to reflect their reduced tendency toward air exchange with the outdoors.
Air infiltration rates in US houses vary by up to a factor of 10, and have been shown to vary by approximately 15% in identical houses constructed at the same time by the same contractor[2]. The rate of 0.5 air change per hour was selected for the model because it is the median annual infiltration value measured in a study of 312 US houses of "newer, energy efficient construction"[3].

Occupant information

Occupant behavior and heat gains associated with people and their activities influence the energy required for heating and cooling.
This study assumes a family of four living in each house, and two different occupancy conditions were modeled.
In the first, one adult and one child are home during the day while the other adult and child are away from home during the workday.
The second condition assumes that both adults work full-time outside the home and both children are away from home during the workday.
The heat gain from each adult occupant was modeled as 250 Btu/hr sensible and 200 Btu/hr latent[3]. The two children were modeled as having 75% of this heat gain.

Two occupant schedules were used.
In the first, one adult and one child are away from home during the day for work or school and a second adult and child are home during the day. The first two occupants are modeled as being away from home between 8:00 a.m. and 6:00 p.m. on weekdays and between 10:00 a.m. and 5:00 p.m. on weekends. This occupancy schedule was specified to produce the number of "at home" hours as are recommended by the Environmental

Protection Agency's Exposure Factors Handbook[5] for a working American adult. The other two occupants are assumed to have the same weekend activities as the others and to spend two hours each weekday outside the house. Their schedule places them away from home between 2:00 p.m. and 4:00 p.m. on weekdays and between 10:00 a.m. and 5:00 p.m. on weekends.

The second occupant schedule changes in that all four occupants are modeled as being away from home for work or school during the day.
Their activities follow the same schedule as for the first two occupants described above.

Thermostat settings

Occupants' use of setback thermostats also influences heating and cooling energy consumption. This model assumes a thermostat setpoint of 70°F in the winter and 76°F in the summer. These conditions are within the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) comfort ranges for people seasonally dressed. Simulations were conducted with two sets of conditions. The first assumes that thermostat setbacks are not used. The second assumes that the thermostat setting is reduced to 62°F between 10:00 p.m. and 6:00 a.m. in the winter for both occupancy scenarios. For the occupancy condition in which no one is home during the day, this scenario also assumes a setback to 62°F between 8:00 a.m. and 5:00 p.m. in the winter and an increase to 80°F for these same hours during the summer.

Appliance loads

Sensible internal heat gains include the occupants themselves (discussed above), appliances, and lighting. Heat gains for some appliances, such as refrigerators, are generally independent of occupant activities. The usage of other appliances, such as televisions, depends on occupant activity. Sensible loads for appliances were computed primarily based on national residential statistics published by the Energy Information Administration (EIA)[4].
This report shows that the average American home consumes approximately 34.6 million Btu annually for appliances that contribute to internal heat gain. These gains were broken into two categories: those related to occupants and their activities, and those that are nearly constant. The occupancy-related sources account for 18.2 million Btu, and are (in decreasing order of magnitude): hot water, lighting, clothes dryers, color televisions, cooking, dishwashers, microwave ovens, personal computers, VCRs, clothes washers, stereos, and laser printers.
Sources that are independent of occupancy account for 16.4 million Btu and are (in decreasing magnitude): refrigerator, freezer, waterbed heaters, ceiling fans, aquariums, answering machines, battery chargers, cordless phones, fax machines, and residual items. The contribution of each item to energy use is weighted to account for their frequency of occurrence in the nation's housing stock.

Internal heat gains are also related to house size.
The EIA reports median energy expenditures based on number of rooms. These were divided by the median national household energy expenditure to obtain a factor that was used to scale the non-occupancy related heat gains.
The occupancy related heat gains are more likely to be related to the number of occupants than the size of the house, so they were not scaled.

To coincide with occupant activities, the occupancy-related sources were scheduled to occur from 6:00 a.m. to 8:00 a.m. and from 6:00 p.m. to 10:00 p.m. on weekdays, and from 8:00 a.m. to 10:00 a.m. and 5:00 p.m. to 10:00 p.m. on weekends, for a total of 2,288 hours per year. Heat sources that are independent of occupancy were modeled as constant over the entire year. Table 2 summarizes the internal heat gain values used for the analysis.

House size (sf)	# of rooms	% US average	Occupant related	Non-occupant

		energy cost	gains (Btu/hr)	related gains (Btu/hr)
1,453	5	96	7,955	1,790
1,852	6	111	7,955	2,069
2,103	8	143	7,955	2,668
2,932	9	182	7,955	3,413
U.S. Average	N/A	100	7,955	1,872

Table 2. Internal sensible heat gains from equipment.

Latent loads also contribute to a home's cooling energy consumption. For an average family of four, Canada's Institute for Research in Construction[6] recommends the following latent loads: respiration from the occupants themselves, 5,760 Btu/day for occupancy related activities (including showering, bathing, dishwashing, cooking, and cleaning), and 5,760 Btu/day from other sources (including construction moisture, seasonal storage, basements and crawlspaces, rain penetration and unknown sources).

Latent loads from the occupants themselves were modeled according to the occupancy schedules. To achieve the daily rates above, latent loads from occupant activities were modeled using the same schedule as for occupancy-related sensible loads at a rate of 960 Btu/hr. The other latent loads were modeled as constant throughout the day at a rate of 240 Btu/hr.

Codes

Three different energy codes were modeled.

These included the 1983 Model Energy Code (the current Nebraska Building Energy Conservation Standard), the 2000 International Energy Conservation Code, and the Nebraska average being enforced across the state. This average was calculated based on the Nebraska Energy Office's survey of state code officials, concluded in December 2002. Table 3 summarizes the required component values for the three cases.

Component	1983 MEC (note a)	2000 IECC (note b)	Nebraska average
Glazing U-factor	Note a	0.40 - 0.35	0.45
Ceiling R-value	25	38 - 49	33
Wall R-value	5.6	18 - 21	11
Floor R-value	12.5	21	21
Opaque door U-factor	Note a	0.35	0.25
Basement wall R-value	0	10 - 11	8
Glazing SHGC	none	none	none
Forced air furnace	78% AFUE (note c)	80% AFUE	80% AFUE
Central air conditioning	6.8 SEER (note c)	10.0 SEER	10.0 SEER

Table 3. Component requirements by building code.

Note a:
R-values for walls and ceilings using the 1983 MEC are to include the effects of windows, doors, and skylights. Consistent with the published rules of LB755, the statewide average of 6,500 degree days is used to determine the 1983 MEC's requirements for the entire state.

Note b: The ranges shown reflect the fact that Nebraska includes four of the degree day ranges specified in the 2000 IECC, and requirements vary across the state.

Note c:
Although 78% Annual Fuel Utilization Efficiency (AFUE) and 6.8 Seasonal Energy Efficiency Ratio (SEER) are the minimum requirements for the 1983 MEC, 80% AFUE and 10.0 SEER that are locally available and widely installed. These higher values were used for the 1983 MEC case for the energy and cost analysis.

There is no Solar Heat Gain Coefficient (SHGC) requirement for glazing in climates with more than 3,500 degree days. For modeling, a default SHGC of 0.66 was used. This is the default value found in Table 102.5.2(3) of the 2000 IECC for double glazed clear fenestration with operable metal frames or fixed nonmetal frames.

The 1983 MEC wall insulation values are for the composite wall, and include the effects of doors and windows. In our model, we used door and window U-factors equal to those required by the Nebraska average code, and then calculated the required wall insulation R-value, which varied from 7 to 9 depending on the house.
For 2000 IECC and the Nebraska average code condition, the R-values shown for ceilings, walls, and floors apply to insulation only, and the codes specify that other parts of the wall section, including framing, drywall, sheathing, and siding are not to be counted toward this value. From this perspective, these updated codes are actually easier to apply than the 1983 MEC, since less calculation is needed. In the model, resistances of other wall components were specified based on materials indicated in the plans.

In the model, basements were considered conditioned space. The 2000 IECC requirement is for conditioned basement walls to be insulated.
If the basement wall is not a conditioned space, the 2000 IECC allows for the insulation to be placed in the floor cavity between the basement and first floor.

The requirements shown above in Table 3 are associated with the “simplified prescriptive track” of each code, which is the easiest and most often used means of code compliance. The codes also contain “performance tracks” that allow homeowners to trade off upgraded components in one area to allow flexibility in other areas.
Therefore, the actual codes can be more flexible than is implied by the table, but the simplified prescriptive track is used by most builders.

Climates

Four cities were chosen to represent the climate variation in Nebraska. These cities were chosen to represent the heating degree day categories used in the 2000 IECC to specify required thermal performance of envelope components.
The National Oceanic and Atmospheric Administration (NOAA) publishes a list of annual degree days that includes approximately 140 cities and towns in the state of Nebraska. The heating degree days (65°F base) in the state range from 5,552 to 7,862.
This includes four categories specified in the 2000 IECC, and one city from each of these categories was chosen for modeling.
Table 4 summarizes the degree day categories, the selected cities, and their actual numbers of degree days.
Note that the state’s second largest city, Lincoln, has nearly the same climate as Omaha (6,119 vs. 6,153 degree days).
Numbers of degree days for other code jurisdictions not shown can be found in Table A4 in the appendix to this report.
Also shown in Table 4 are the component criteria for thermal performance in each of the four climate zones.

Degree day range	City	Annual degree days	Max. glazing U-factor	Min. ceiling R-value	Min. wall R-value	Min. floor R-value	Min. basement wall R-value
5,500-5,999	McCook	5,967	0.40	38	18	21	10
6,000-6,499	Omaha	6,153	0.35	38	18	21	10
6,500-6,999	Norfolk	6,766	0.35	49	21	21	11
7,000-8,499	Chadron	7,021	0.35	49	21	21	11

Table 4. Cities, their climates, and 2000 IECC component criteria.

Cost analysis

RS Means Residential Cost Data[7]
were used to determine installed cost for the building components considered in the study. This step required that the code-specified U-factors and R-values be translated into defined building components for which costs could be compared.
Only the costs for components that differ between energy codes were included in the construction cost calculation.
In some instances, Means did not provide as much detail as was needed to differentiate the components (for example, window types), so quotes from local vendors were used to supplement the estimates, as described below. The total price for each component includes purchase price, installation, overhead, and profit. This is the total installed cost to the customer.
Local cost adjustment factors from Means were then used to adjust each of the costs to the four locations: Omaha, Norfolk, McCook, and Chadron.

The calculated energy cost for each house includes electricity used by the HVAC system fan year round, electricity needed for cooling, and gas used for heating. Rates were obtained in May 2003 from local utilities serving the four geographical areas (see Tables 9 and 10).

Windows

Base prices for windows were taken from Means values for premium quality vinyl clad windows. A few of the windows listed on the house plans were not exactly the same size as those found in Means, and in these cases the next largest size or a window with the same glass area was used.

The window U-factors required by the different codes vary. U-factor is usually decreased by adding either an insulated air or argon space, adding a low-e coating, or improving frame performance. However, the Means data does not include cost differences for these upgrades. The Means prices are for double glazed insulating glass with ½ inch air space and no coating, a combination that provides U = 0.50. We then obtained costs from local vendors to upgrade to argon fill and low-e coating. An upgrade to low-e glass with e = 0.40 was estimated at $25.00 per window, and an upgrade to low-e glass with e = 0.15 was priced at $30 per window. Argon gas fill requires an additional cost of $15.00 per window. Table 5 below shows the four window U-factor requirements of the various codes and the glass type and coating combinations needed to comply with each. U-factors of various combinations were obtained from a thermal engineering text[8].

U-factor ($Btu/hrft^2 {}^oF$)	Glass type	Coating
0.50	Double glazed, ½" air space	none
0.45	Double glazed, ½" air space	Low-e (0.40)
0.40	Double glazed, ½" air space	Low-e (0.15)
0.35	Double glazed, ½" argon fill	Low-e (0.15)

Table 5. Types of windows used to meet U-factor requirements.

Exterior wall insulation

Wall insulation base prices were also obtained from Means[7] and insulating values not specified by Means taken from a thermal engineering text[8].

All four house plans have 2 by 4 stud walls, but some of the higher wall insulation requirements could not be obtained using only 3 ½ inch batt insulation.

In these cases, the R-value requirement was met by placing 3 ½ inch batt insulation between the studs and a layer of rigid insulation used as sheathing.

The houses with R-11 or lower walls have an outer layer of plywood to which the siding would be nailed. For higher R-value walls, homebuilders may use rigid insulation of up to ½ inch in place of this plywood layer (with plywood for shear bracing at corners).

Since rigid insulation is slightly less expensive than plywood, this allows a more insulated wall to be constructed at approximately the same cost.

R-18 walls can be achieved with a 2 by 4 stud wall if higher density R-15 fiberglass batts are used. To obtain an R-21 wall, 2 by 6 construction is necessary.

Therefore, the costs for the R-21 walls include the incremental cost increase necessary to convert the houses to 2 by 6 construction.

Table 6 shows the wall insulation combinations that were used to meet the code R-value requirements. For easy use, most of the codes specify wall insulation values that apply only to the insulation. However, the 1983

MEC code specifies composite wall insulating values that include the effects of doors and windows. Therefore, the required insulation value for those cases depends on the number of and type of doors and windows in each house.

For our analysis, we modeled the 1983 MEC cases with a glazing U-factor of 0.45 Btu/h.ft^{2}F and an opaque door U-factor of 0.25 Btu/h.ft^{2}F.

With this combination, the insulation requirements for the four houses ranged from 7.0 to 8.9 ºFft^{2}hr/Btu. An R-value of 11 ºFft^{2}hr/Btu was used for all of these cases, since this was the closest reasonable insulation choice.

R-value (ºFft^{2}hr/Btu)	Wall insulation type
7.0	3-½" R-11 fiberglass batts
7.9	3-½" R-11 fiberglass batts
8.1	3-½" R-11 fiberglass batts
8.9	3-½" R-11 fiberglass batts
11	3-½" R-11 fiberglass batts
18	3-½" R-15 fiberglass batts plus ½" isocyanurate rigid insulation
21	5-½" R-19 fiberglass batts plus ½" isocyanurate rigid insulation

Table 6. Wall insulation combinations used to meet code requirements.

Basement wall insulation

The cost analysis was performed with the assumption that the basements are conditioned. Generally, energy codes require insulation between the house and basement if the basement is not conditioned space, and basement wall insulation if the basement is conditioned. In this case, two of the energy codes require basement wall insulation.

Our cost analysis obtains R-8 with polystyrene rigid insulation, which can be placed on the exterior of the basement wall. R-10 and R-11 would more likely be obtained with interior insulation. Here, we have priced 3 ½" R-11 fiberglass batts.

Table 7 shows the basement wall insulation combinations used to meet the code requirements. Depending on the code official, the use of interior insulation may also involve finishing of the interior wall. Such finishing has other benefits and increases value to the homeowner in ways that go beyond energy efficiency. For all of these reasons, the costs of furring and drywalling the interior basement walls was not included in the life cycle cost analysis.

R-value (ºFft²hr/Btu)	Basement wall insulation type
8	2" expanded polystyrene rigid insulation (applied to exterior)
10	3 ½" R-11 fiberglass batts
11	3 ½" R-11 fiberglass batts

Table 7. Basement wall insulation combinations used to meet code requirements.

Ceiling insulation

Most of the ceiling area for the four house plans is beneath attics. Where attics are present, fiberglass batt insulation was used with a layer of blown-in insulation above it if needed to meet the R-value requirement. One floor plan also contains a small amount of cathedral ceiling (about 5% of the overall roof area) directly beneath a sloped roof supported by 2 by 10 inch joists. For these sections, batt insulation was used between the joists. When more insulation is required, foamed in place polyurethane is substituted. Table 8 summarizes the roof/ceiling insulation combinations that were used to meet the codes.

R-value (ºFft²hr/Btu)	Insulation location	Insulation type
25	Cathedral ceiling	9" fiberglass batts
32	Cathedral ceiling	9 ¼" blown in cellulose
33	Cathedral ceiling	9 ¼" blown in cellulose
38	Cathedral ceiling	9 ¼" foamed in place urethane (approx. R-6 per inch)
49	Cathedral ceiling	9 ¼" foamed in place urethane (approx. R-6 per inch)
25	Attic floor	9" fiberglass batts
32	Attic floor	5-½" fiberglass batts plus 6" blown-in fiberglass insulation
33	Attic floor	5-½" fiberglass batts plus 7" blown-in fiberglass insulation
38	Attic floor	5-½" fiberglass batts plus 8-1/2" blown-in fiberglass insulation
49	Attic floor	5-½" fiberglass batts plus 13-½" blown-in fiberglass insulation

Table 8. Roof and ceiling insulation combinations used to meet code requirements.

Exterior doors

Doors meeting the code U-factor requirements for opaque exterior doors were also identified and priced through local suppliers and rated using a thermal engineering text[8]. Installation costs were taken from Means[7]. As mentioned above, the 1983 MEC cases were modeled with U=0.25 Btu/hrft²ºF, which was also the requirement for the Nebraska average case.
This requirement was met with a 1 ¾ inch thick polyurethane core fiberglass door with a thermal break. All

locations for the 2000 IECC code required a door U-factor of 0.35 Btu/hrft^2°F. This was met using a door identical to that above, except that it is constructed of steel. The steel door is slightly less expensive and less insulating.

Mechanical equipment

Price data for gas furnaces and central air conditioning units were also obtained from Means. Because Means only lists a few sizes for each, we consulted with vendors to determine the commonly available size increments and interpolated the Means cost data to these sizes. This allowed us to model a more realistic range of equipment capacities and to specify equipment that more closely meets the design loads for the houses studied.

The 1983 MEC allows gas furnaces with AFUE as low as 78% and air conditioning systems as low as 6.8 SEER.
Upon consultation with local vendors, we learned that these efficiencies are no longer being widely installed. The least efficient systems typically being used are 80% AFUE furnaces and 10.0 SEER air conditioning systems. These are required for the Nebraska average and 2000 IECC codes. Therefore, all of the code conditions were modeled with the same efficiencies, and the only difference in system cost for the codes occurs if increased insulation reduced the design load and equipment could be downsized.

Utility costs

Table 9 shows current rates charged by Nebraska utilities for natural gas. These rates were used to determine heating cost.
Since all of the house and code combinations have gas service and use some gas, the minimum and customer charges were not included in the cost analysis since they will be the same for each house.

City	Gas rate in dollars per therm (100,000 BTU).	Gas supplier
McCook	$0.909	Kinder Morgan Choice Gas
Omaha	$0.6928	Metropolitan Utilities District
Norfolk	$0.81283	Aquila
Chadron	$0.909	Kinder Morgan Choice Gas

Table 9. Nebraska gas rates.

Table 10 shows the rates currently charged in Nebraska for electricity. Both Nebraska utilities charge different rates for winter and summer.
Winter rates are charged between October 1 and May 31 and summer rates are charged June 1 through September 30.
Since the decision to have electrical service is independent of the energy code, the base monthly charge was not included in the analysis.
Furthermore, use of these rates in the cost analysis is more complicated, since electrical rates are tiered. As a customer uses more energy, a lower rate is charged. Since the goal of this analysis is to determine the cost of electricity used for cooling and to operate the fan year-round, it is necessary to estimate the customer's other electricity use so that the correct costs can be applied.

Cities		Electrical power rate	Power supplier

McCook Norfolk Chadron	Base charge (monthly)	$13.00	Nebraska Public Power District
	First 750 kWh (summer)	8.51 Cents/kWh	
	After 750 kWh (summer)	6.98 Cents/kWh	
	First 750 kWh (winter)	6.26 Cents/kWh	
	After 750 kWh (winter)	3.74 Cents/kWh	
Omaha	Base charge (monthly)	$5.15	Omaha Public Power District
	First 1000 kWh (summer)	7.61 Cents/kWh	
	After 1000 kWh (summer)	7.25 Cents/kWh	
	First 100 kWh (winter)	6.88 Cents/kWh	
	100 to 1000 kWh (winter)	5.87 Cents/kWh	
	Above 1000 kWh (winter)	3.65 Cents/kWh	

Table 10. Nebraska electricity rates.

Customers' electrical use for activities other than thermal conditioning were estimated from the same data used to calculate the internal sensible heat gains from equipment. Table 11 shows the hourly internal heat gains from appliances and lighting that were used in the energy analysis of the four houses. The occupancy-related usage occurs during 2,288 hours per year, or 191.7 hours per month. The non-occupancy related gains occur 8,760 hours per year, or 730 hours per month. With these usage frequencies, a total monthly heat gain due to equipment was calculated and converted to electricity use in kWh, since these appliances convert virtually all of their energy input into heat.

Using these values for each house's base electricity usage, all of the space conditioning electricity cost for the NPPD houses (McCook, Norfolk, and Chadron) was calculated at the lower rate for usage above 750 kWh. Likewise, the entire space conditioning electricity cost for the two larger OPPD houses (Omaha) was calculated at the lowest rate for usage above 1000 kWh. For the two smaller OPPD houses, the first 170 or 110 kWh needed each month for space conditioning were calculated at the below 1000 kWh rate, and the remaining usage occurs at the lowest (above 1000 kWh) rate.

House size (sf)	Occupancy related gains (Btu/hr)	Non-occupancy related gains (Btu/hr)	Total monthly equipment heat gain (Btu)	Electricity use (kWh)
1,453	7,955	1,790	2,831,674	830
1,852	7,955	2,069	3,035,344	890
2,103	7,955	2,668	3,472,614	1,018
2,932	7,955	3,413	4,016,464	1,177

Table 11. Internal sensible heat gains from equipment.

Life cycle cost analysis

Life cycle cost analysis was performed over a 30 year period to determine the present value of mortgage payments and energy costs for the different options studied.
A mortgage payment amount for the construction upgrades was estimated using an average rate published by the Federal Housing Finance Board for the previous year[9]. For 2002, this source reports an effective interest rate of 6.43% for 30 year mortgages on new single family housing. This rate was used to convert the construction costs into equal mortgage payments.

The present value of these mortgage payments was then computed using the methodology published by the U.S. Department of Energy (DOE) for Life Cycle Cost (LCC) analysis of energy conservation projects[10]. This methodology forms the basis for the National Institute of Standards and Technology (NIST) Building

Life Cycle Cost (BLCC) program, which is used to calculate life cycle costs for government projects. The BLCC program was not used directly because it does not allow time periods greater than 25 years to be studied.
In this calculation, the April 2003 discount rate of 3.0% for DOE projects related to energy conservation (based on the current rate for T-bills), and a long term average inflation rate of 2.1% were used.

The present value of the annual energy costs was also calculated using the DOE BLCC method, with price indices and discount factors published for April 2003[10]. These are based on the same 3.0% discount rate and projected cost increases for electricity and natural gas in the Midwest census region, which includes Nebraska.

Results

Annual energy simulations and life cycle cost analysis were performed for the four houses under the three code conditions to determine their impact on Nebraska homeowners. This section compares the design heating and cooling loads and construction cost for the three codes in the four climate zones. Annual energy use and life cycle cost for a family of four with two occupants at home during the daytime is then compared in detail for all of the code and climate combinations. The sensitivity of the analysis to several key issues relevant to Nebraska homeowners are also investigated, including: the effects of finished basements, alternate occupancy profiles, and thermostat setbacks. Finally, future economic impacts for Nebraska are discussed.

Design heating and cooling loads

Table 12 shows the heating design loads in MBH (1MBH=1,000 Btu/hr) for each of the house/city/code combinations. The table is arranged to show the codes in decreasing order of stringency for each city. For each house in a specific city, the heating design load increases from the 2000 IECC to the 1983 MEC code, typically by more than 20%.
These differences are large enough to allow smaller equipment to be installed, depending on the actual values in relation to the available equipment sizes.

As would be expected, heating design loads are lowest in McCook, and increase with the number of heating degree days in Omaha, Norfolk, and Chadron. Heating design loads also generally increase with house size. The design loads for the 1,852 sf ranch are usually slightly larger than those for the 2,103 sf two story house. This is due to infiltration effects.
Both houses have full basements, but because the ranch house has a larger footprint, the volume of its basement is larger. Infiltration effects for this much larger basement increase the load for the house. Also, the floor to ceiling height for the ranch house is about 1 foot higher than for the two story house, which also increases its volume and thus its infiltration load slightly.

Combinations		Heating design load (MBH)			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	30	37	36	50
NE average	McCook	32	40	39	55
1983 MEC	McCook	37	48	44	63
2000 IECC	Omaha	31	40	39	54
NE average	Omaha	34	43	43	59
1983 MEC	Omaha	39	51	47	67
2000 IECC	Norfolk	33	40	40	56
NE average	Norfolk	37	46	45	63

1983 MEC	Norfolk	42	55	50	72
2000 IECC	Chadron	32	40	39	55
NE average	Chadron	36	45	44	62
1983 MEC	Chadron	41	54	50	71

Table 12. Heating design load.

Table 13 shows cooling design loads for the house/city/code combinations. The design cooling loads show many of the same general trends, with load increasing for warmer climate and larger houses. Note that Omaha, while its winters are colder than McCook, also has warmer summer weather.

Combinations		Cooling design load (Tons)			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	2.8	3.1	3.5	3.7
NE average	McCook	2.7	3.1	3.5	3.8
1983 MEC	McCook	2.8	3.2	3.6	3.9
2000 IECC	Omaha	2.8	3.2	3.5	3.8
NE average	Omaha	2.9	3.3	3.7	4.0
1983 MEC	Omaha	2.9	3.5	3.7	4.2
2000 IECC	Norfolk	2.7	3.1	3.4	3.6
NE average	Norfolk	2.8	3.2	3.6	3.9
1983 MEC	Norfolk	2.8	3.3	3.6	4.1
2000 IECC	Chadron	2.7	3.1	3.4	3.6
NE average	Chadron	2.8	3.2	3.6	3.9
1983 MEC	Chadron	2.8	3.3	3.6	4.0

Table 13. Cooling design load.

Construction cost

The calculated construction cost includes purchase and installation of all construction items associated with meeting the different code situations.

For walls, this includes cavity wall insulation, either exterior plywood sheathing or rigid insulation as needed to achieve the required R-value, and the incremental cost of upgrading to 2 by 6 stud wall construction if necessary.

Also included are exterior doors, windows, ceiling/roof insulation, gas furnaces, and central air conditioning units.

The more stringent code requirements naturally involve increased costs for most of these components. The HVAC equipment is an exception.

Since availability dictated that the same efficiency equipment be used for all of the code cases, the only difference in cost occurred when more stringent codes allowed the equipment size to be decreased. This provided a small cost reduction in some cases.

Exterior doors, which make up a small portion of the overall cost, are another exception since the 2000 IECC allows a slightly less expensive and less insulating door than is required by the current Nebraska average.

Figure 1 shows a typical distribution of these costs among the construction items. For the 2,103 sf two story house located in Omaha meeting the Nebraska
average code requirements, the construction cost for code-related items is approximately $21,500. Exterior doors contribute 2% of this cost, HVAC equipment 21%, insulation 32%, and windows 45%.

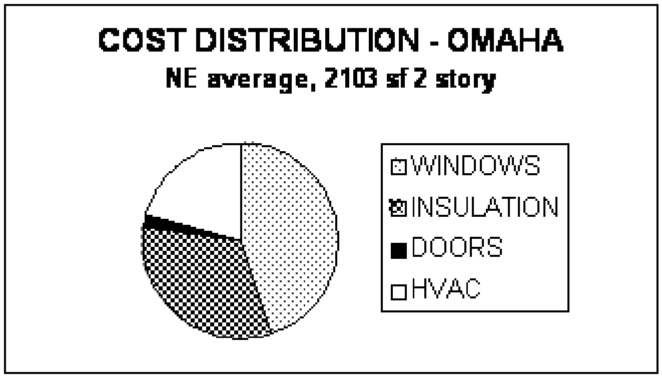

Figure 1. Typical construction cost distribution

Table 14 shows the location-adjusted costs for these construction components for each house for each code.

Location adjustments were made using location factors published in the 2003 Means Residential Cost Data[11] (Means). Means established costs in McCook at 78% of the national average, Omaha at 92%, Norfolk at 84%, and Chadron at 73%.

As would be expected, construction costs usually increase as the code becomes more stringent. However, in a few cases, the upgraded insulation allows the HVAC equipment to be downsized, which reduces the cost impact of the 2000 IECC.

Exterior doors, though a small portion of the total cost, are also slightly less expensive for the 2000 IECC compared to the Nebraska average.

Combinations		Construction cost in 2003 dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	$13,601	$14,726	$18,147	$31,062
NE average	McCook	$13,711	$14,880	$18,226	$31,371
1983 MEC	McCook	$11,942	$12,840	$16,698	$28,577
2000 IECC	Omaha	$16,355	$17,755	$21,735	$37,309
NE average	Omaha	$16,172	$17,536	$21,571	$37,062
1983 MEC	Omaha	$14,086	$15,103	$19,732	$33,706
2000 IECC	Norfolk	$15,097	$16,347	$19,752	$34,014
NE average	Norfolk	$14,803	$16,045	$19,695	$33,810
1983 MEC	Norfolk	$12,928	$13,789	$18,025	$30,787
2000 IECC	Chadron	$13,120	$14,206	$17,166	$29,560
NE average	Chadron	$12,832	$13,914	$17,116	$29,382
1983 MEC	Chadron	$11,235	$11,984	$15,664	$26,566

Table 14. Construction cost for code-related items.

Table 15 translates the construction costs shown in Table 14 into annual mortgage payments for a 30 year fixed mortgage at a rate of 6.43%, based on Federal Housing Finance Board data. This represents the annual cost to the homeowner for the construction of these items. In all cases, any additional cost associated with an upgrade to the 2000 IECC code from the current Nebraska average is less than $25 annually.

Combinations		Annual mortgage payment in dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	$1,024	$1,109	$1,366	$2,339
NE average	McCook	$1,032	$1,120	$1,372	$2,362
1983 MEC	McCook	$899	$967	$1,257	$2,152
2000 IECC	Omaha	$1,232	$1,337	$1,637	$2,809
NE average	Omaha	$1,218	$1,320	$1,624	$2,791
1983 MEC	Omaha	$1,061	$1,137	$1,486	$2,538
2000 IECC	Norfolk	$1,137	$1,231	$1,487	$2,561
NE average	Norfolk	$1,115	$1,208	$1,483	$2,546
1983 MEC	Norfolk	$973	$1,038	$1,357	$2,318
2000 IECC	Chadron	$988	$1,070	$1,293	$2,226
NE average	Chadron	$966	$1,048	$1,289	$2,212
1983 MEC	Chadron	$846	$902	$1,180	$2,000

Table 15. Annual mortgage payment for code-related items.

Energy use

Annual energy consumption for heating and cooling was determined using an annual hourly calculation performed using *Energy Plus*.

Because the orientation of the house impacts the energy consumption, each of the house/city/code conditions was simulated with the house facing due North, South, East, and West, and these four results averaged to obtain one energy consumption value for each condition.

Energy costs for gas, summer electricity, and winter electricity were determined using local utility rates and summed to obtain a single energy cost for each house (See Appendix).

Figure 2 shows the distribution of these costs for the Nebraska average case in McCook and Chadron, the warmest and coldest cities studied. Nebraska homeowners spend a significant amount of money on both heating and cooling. The average homeowner in McCook spends approximately $275 for electricity in the summer used for cooling, and approximately $450 on gas in the winter for heating.
In Chadron, the same house will require approximately $225 in electricity for summer cooling, but $550 in gas for winter heating.

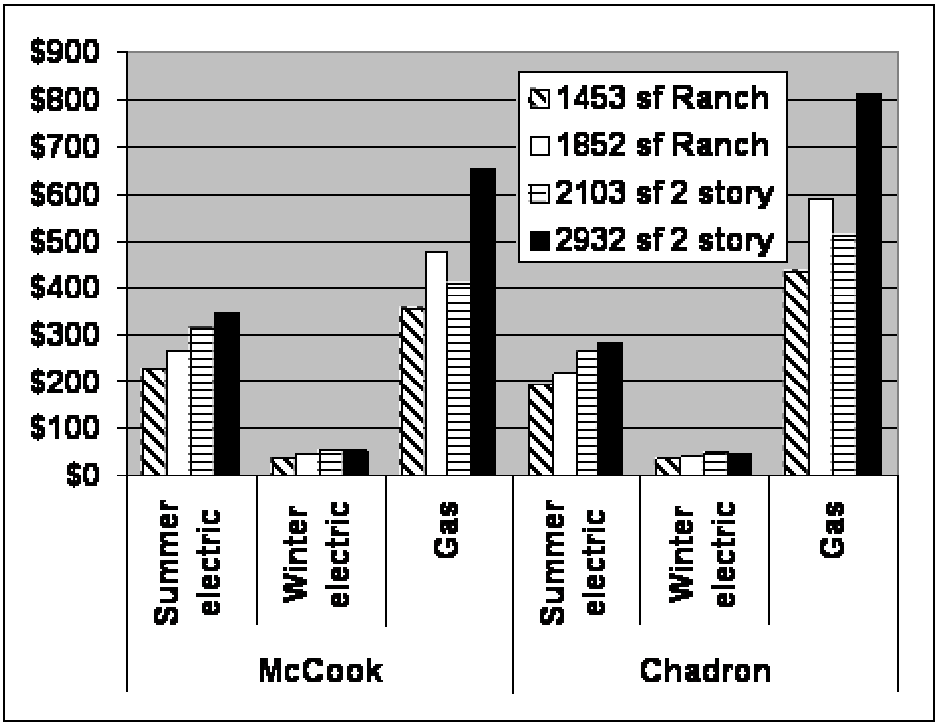

Figure 2. Typical annual heating and cooling cost distribution (NE average code).

Table 16 summarizes the annual energy cost for heating and cooling all of the house/code combinations in 2003 dollars. This is the predicted energy cost for the first year of operation. In every case, energy code upgrades result in decreased energy cost for the homeowner. For a given house and city, the difference in energy cost between the 1983 MEC house and the 2000 IECC house is hundreds of dollars. This illustrates the very real financial effect that timely upgrades to energy codes have on homeowners. The data also show that an upgrade from the current state average to the 2000 IECC will save homeowners between $39 and $137 annually, depending on location and house size.

Combinations		Annual energy cost in 2003 dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	$581	$728	$712	$976
NE average	McCook	$622	$787	$779	$1,055
1983 MEC	McCook	$813	$1,067	$1,079	$1,408
2000 IECC	Omaha	$579	$710	$700	$940
NE average	Omaha	$618	$763	$760	$1,007
1983 MEC	Omaha	$800	$1,015	$1,037	$1,332
2000 IECC	Norfolk	$595	$755	$746	$1,033
NE average	Norfolk	$665	$849	$843	$1,154

1983 MEC	Norfolk	$862	$1,134	$1,148	$1,513
2000 IECC	Chadron	$587	$744	$721	$1,006
NE average	Chadron	$665	$849	$827	$1,143
1983 MEC	Chadron	$858	$1,135	$1,129	$1,483

Table 16. 2003 Annual energy cost.

The accepted economic method for performing cost comparison of alternatives is to complete a life cycle cost analysis. This is shown in the following section.
However, we recognize that home sales are often made on the basis of first year cost. This practice is based on the assumption that the owner's income is likely to rise while the mortgage payment will stay the same. Therefore, a buyer trying to obtain as much house as he/she can afford might be concerned about the trade-off between mortgage increase and energy savings in the first year, rather than whether he/she will save money over the life of the house.

Table 17 shows a comparison of the first year mortgage costs and energy savings that would result from an upgrade from the current Nebraska average code to the 2000 IECC code. This is the change that the average homeowner in Nebraska would experience.
For all sixteen house-city combinations shown, the first year energy savings is greater than the annual mortgage cost increase. This means that these homeowners begin to see cost savings in the first year. Note that for the houses in McCook, the mortgage increases shown are negative, meaning that the 2000 IECC house actually costs less to build.
This happens when downsizing of HVAC equipment and/or the less expensive exterior doors save more money than is required to increase the amount of insulation used.

	1,453 sf ranch		1,852 sf ranch		2,103 sf 2 story		2,932 sf 2 story	
City	Mortgage increase	Energy savings	Mortgage increase	Energy savings	Mortgage increase	Energy savings	Mortgage increase	Energy savings
McCook	-$8	$41	-$12	$59	-$6	$67	-$23	$79
Omaha	$14	$39	$17	$53	$12	$60	$19	$67
Norfolk	$22	$70	$23	$94	$4	$97	$15	$121
Chadron	$22	$78	$22	$105	$4	$106	$13	$137

Table 17. First year mortgage cost-energy savings comparison – upgrade from Nebraska average to 2000 IECC.

Table 18 compares the first year mortgage cost and energy savings associated with an upgrade from the 1983 MEC, the current statewide minimum, to the 2000 IECC. In all sixteen cases, the first year energy savings exceed the annual mortgage increase.
The first year savings to the homeowner ranges from $50 to $295, and is usually more than $100. A code upgrade would therefore provide an even greater benefit to homeowners in jurisdictions where the state minimum code is still being enforced.

	1,453 sf ranch		1,852 sf ranch		2,103 sf 2 story		2,932 sf 2 story	
City	Mortgage increase	Energy savings	Mortgage increase	Energy savings	Mortgage increase	Energy savings	Mortgage increase	Energy savings
McCook	$125	$232	$142	$339	$109	$367	$187	$432
Omaha	$171	$221	$200	$305	$151	$337	$271	$392
Norfolk	$163	$267	$193	$379	$130	$402	$243	$480
Chadron	$142	$271	$167	$391	$113	$408	$225	$477

Table 18. First year mortgage cost-energy savings comparison – upgrade from 1983 MEC to 2000 IECC.

Tables 17 and 18 show clear cost benefits associated with upgrading the state energy code. These benefits can be realized in the first year of home ownership. Over the life of the house, mortgage costs will remain fixed while energy costs continue to rise.
Therefore, owners will experience even greater savings in subsequent years.

Life cycle cost

Life cycle cost analysis is a method of comparing alternatives that have differing first and long-term costs. The method is commonly used to determine if higher initial costs can be justified by reducing long-term operating costs.
The life cycle cost is reported in terms of 2003 dollars, with future payments adjusted to account for these effects.
Therefore, the life cycle cost for each code/city/house combination is the present value (in 2003 dollars) of payments on a 30 year mortgage plus the present value of 30 years of energy costs. These are shown in Table 19 in 2003 dollars, and graphically in Figure 3.

In all sixteen cases, the life cycle cost of the 2000 IECC is the lowest of the three code conditions. This echoes the earlier observation that even in the first year, before any utility rate increases, the 2000 IECC case produces more energy savings than are needed to pay the increased mortgage costs. In subsequent years mortgage costs remain constant while energy prices escalate, bringing even greater savings to the homeowner.

Combinations		Life cycle cost in 2003 dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	*$26,366*	*$30,530*	*$33,911*	*$53,432*
NE average	McCook	$27,322	$31,873	$35,336	$55,358
1983 MEC	McCook	$29,100	$35,123	$39,507	$59,194
2000 IECC	Omaha	*$29,259*	*$33,396*	*$37,538*	*$59,499*
NE average	Omaha	$29,853	$34,210	$38,548	$60,571
1983 MEC	Omaha	$31,068	$36,434	$41,892	$63,166
2000 IECC	Norfolk	*$28,293*	*$32,835*	*$36,346*	*$57,827*
NE average	Norfolk	$29,380	$34,391	$38,213	$60,018
1983 MEC	Norfolk	$31,155	$37,510	$42,345	$63,704
2000 IECC	Chadron	*$26,004*	*$30,335*	*$33,078*	*$52,483*
NE average	Chadron	$27,268	$32,116	$35,132	$55,028
1983 MEC	Chadron	$29,306	$35,648	$39,484	$58,644

Table 19. Life cycle cost.

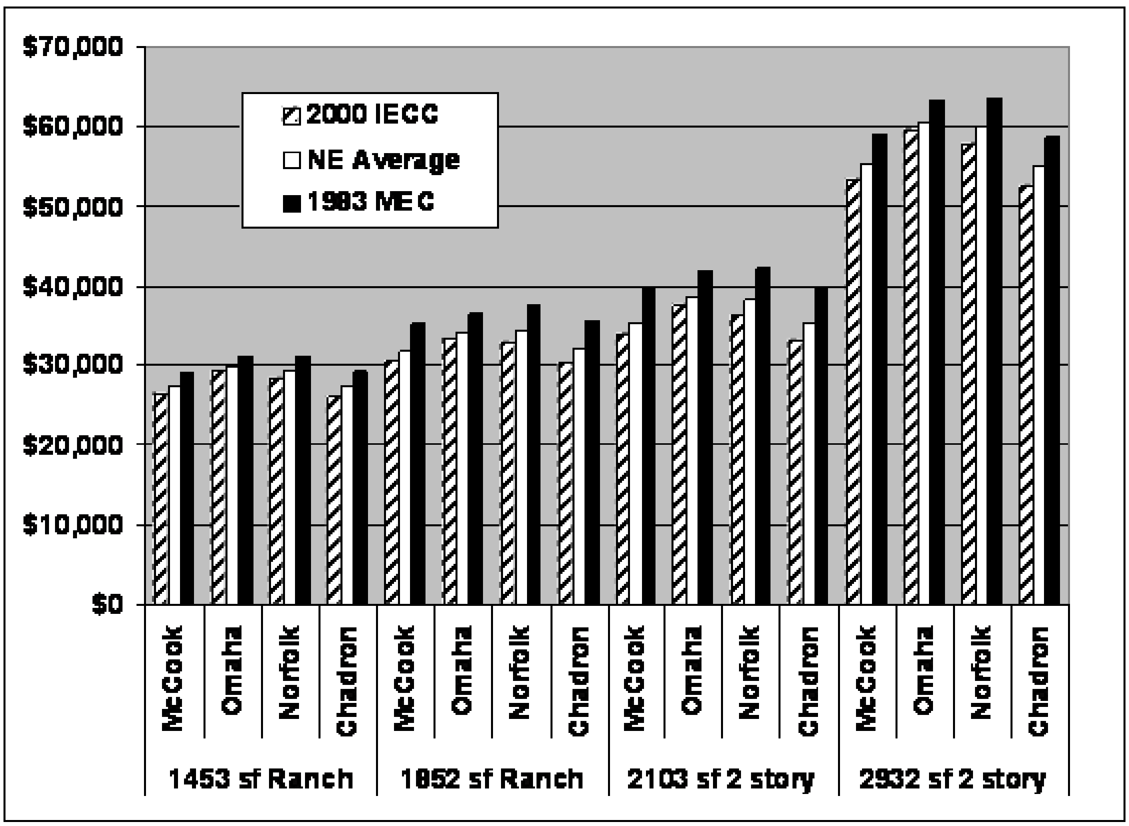

Figure 3. Life Cycle Cost.

Other effects on construction cost and energy use

This study is based on assumptions about how houses will be built and how they will be used by the occupants. Whenever possible, these assumptions are based on statistical information published by U.S. government sources so that they will represent the average citizen as accurately as possible. However, there is value in investigating the study's sensitivity to a few key variations likely to be of interest to Nebraska homeowners.

What impact would finished basements have?

None of the code options studied require basements to be finished, although some require basement wall insulation.

If this insulation is applied to the inside of the wall, some code officials might also require the basement wall to be finished.

Finished basements offer a number of benefits to the homeowner, increasing the livable space in the house and potentially increasing its value.

Therefore, basement wall finishing is unlike the other construction cost items considered because it is not entirely an energy related cost.

Table 20 shows the estimated cost to add furring and drywall to the basement walls of each house. This estimated cost does not include the cost of any finish applied to the drywall, such as paint or wallpaper, since these would be selected for other reasons, and would not be required or specified by a code official. The costs in Table 20 are shown both as total construction cost, and the additional annual mortgage payment on a 30 year mortgage with the same rate as was used for the previous analysis.

Combinations		Costs and payments in 2003 dollars			
Cost	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
Construction cost	McCook	$1,241	$1,385	$1,052	$1,673
	Omaha	$1,464	$1,633	$1,241	$1,974
	Norfolk	$1,337	$1,491	$1,133	$1,802
	Chadron	$1,162	$1,296	$985	$1,566
Annual mortgage payment	McCook	$93	$104	$79	$126
	Omaha	$110	$123	$93	$149
	Norfolk	$101	$112	$85	$136
	Chadron	$87	$98	$74	$118

Table 20. Costs for finished basement walls.

The additional mortgage payment required is approximately $100, depending on the size of the basement. Table 21 shows the impact on life cycle cost if finished basement walls are included in the two cases that require basement wall insulation.

For all of the houses, the life cycle cost for the 2000 IECC with finished basement walls is less than the 1983 MEC case with unfinished basement walls. Both the 2000 IECC and the Nebraska average code condition require basement insulation, so they must be compared with the same wall treatment. The 2000 IECC case has the lowest life cycle cost both with and without the basement insulation included in the life cycle cost calculation.

Combinations		Life cycle cost in 2003 dollars			
Basement walls	Code	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
Unfinished	2000 IECC	$29,259	$33,396	$37,538	$59,499
	NE average	$29,853	$34,210	$38,548	$60,571
	1983 MEC	$31,068	$36,434	$41,892	$63,166

Finished	2000 IECC	$30,872	$35,201	$38,903	$61,685
	NE average	$31,466	$36,014	$39,912	$62,756

Table 21. Life cycle cost including finished basement walls in Omaha.

How sensitive are the results to occupancy profile?

The occupancy profile used to generate the results in this section was based on a family of four, with two members who were away from home for work or school during the day, and two members who were usually at home during the day.

Simulations were also conducted for a family of four in which all four occupants were away from home during the daytime hours.

Occupant related internal gains were again based on national averages and assumed to be the same as for the base case, except that they are shifted to evening and weekend hours. Therefore, the difference in energy consumption is due to changes in the timing of the loads. In the summer, this occupancy pattern would decrease the peak load in the afternoon when outdoor temperatures are highest. In the winter, the shifting of load to evening hours may have little overall effect at times when heating is needed all of the time. However, the lower daytime load during milder weather in the spring and fall may cause the house to require more heating at these times.

Table 22 shows the change in life cycle cost when the different occupancy profile is used in the analysis. A positive change indicates an increase in cost associated with the new occupancy profile, and a negative change indicates a decrease.

Whether the change is positive or negative seems generally to be related to house design, with two of the houses usually showing increases and two usually showing decreases. Variations on the order of several hundred dollars over 30 years can be attributed to a change in occupancy schedule. However, the average for all of these cases is only a reduction in life cycle cost of about $90 over the 30 year period. Therefore, these results should be broadly applicable to Nebraska homeowners, although individual results in a particular house may vary.

Combinations		Change in life cycle cost in 2003 dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	-$129	$31	-$141	$178
NE average	McCook	-$235	$85	-$97	$265
1983 MEC	McCook	-$532	-$101	-$280	-$15
2000 IECC	Omaha	-$425	-$231	-$315	-$91
NE average	Omaha	-$617	-$186	-$290	-$36
1983 MEC	Omaha	-$1,058	-$479	-$585	-$400
2000 IECC	Norfolk	-$11	$122	$4	$237
NE average	Norfolk	-$70	$192	$67	$324
1983 MEC	Norfolk	-$431	-$65	-$190	-$11
2000 IECC	Chadron	$29	$185	$1	$280
NE average	Chadron	$18	$265	$84	$369
1983 MEC	Chadron	-$268	$71	-$124	$169

Table 22. Variations in life cycle cost with occupancy profile.

How would energy use be impacted by thermostat setbacks?
Another issue that may be interesting to many people is the use of setback thermostats. Setback thermostats are not currently required by state energy code, nor are they included in the 2000 IECC. Furthermore, they may not be appropriate for all homeowners.
However, many people set their thermostats back at night and when they are away from home to save energy, and their effects on the cost analysis may be interesting for that reason. Figures 4-7 compare the first year energy cost for occupancy profile #1 (two people at home during the day) and occupancy profile #2 (no one at home during the day) without and with night setback thermostats.

Significant savings are obtained for both occupancy profiles, but the savings are larger for occupancy profile #2.
This is because the setback thermostat for that occupancy profile operates both at night and on weekdays when the occupants are not home.
The setback thermostat for occupancy profile #1 operates only at night, since two of the occupants are home during the day.
Depending on the city, average energy cost savings vary from 20 to 25% for occupancy profile #1 and from 35 to 40% for occupancy profile #2.

The first year energy savings are quite favorable, considering that an automatic programmable setback thermostat costs approximately $30.
For all four houses, the lowest annual savings occur for occupancy profile #1 (night setback only) in Omaha with the 2000 IECC code.
The greatest annual savings occur for occupancy profile #2 (day and night setbacks) in Chadron with the 1983 MEC code. Owners of the 20^{th}
percentile home (1,453 sf ranch) would save a minimum of $120 and a maximum of $384. For the median Nebraska
homeowner, the 1,852 sf ranch home experiences savings between $146 and $485 and the 2,103 sf 2 story home saves between $105 and $387. The 80^{th}
percentile home (2,932 sf 2 story) experiences annual energy savings between $166 and $567.

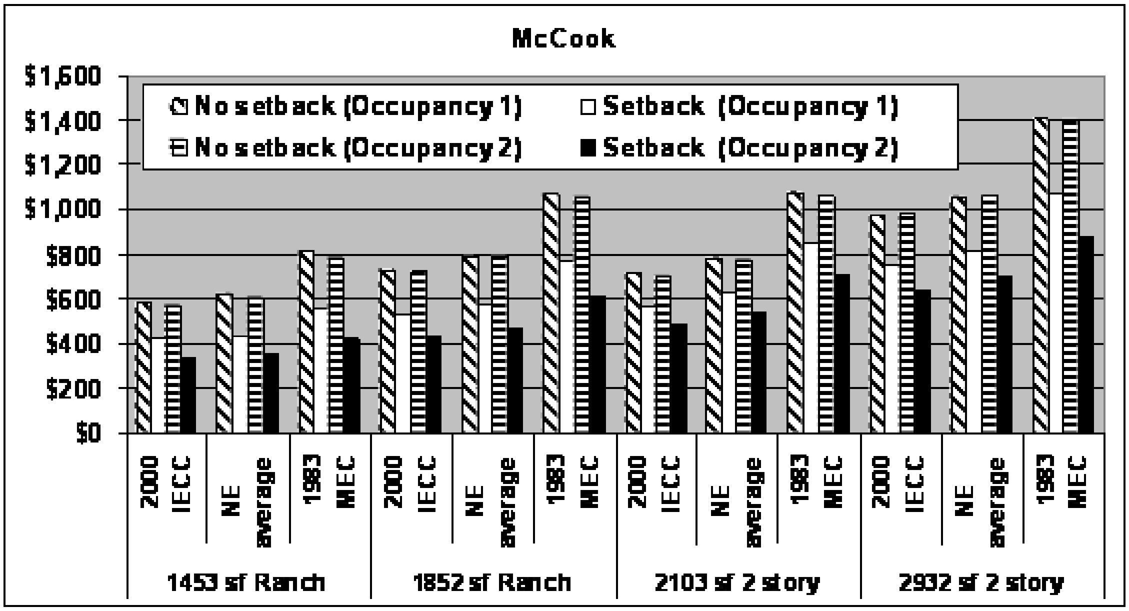

Figure 4. Energy cost impact of thermostat setbacks - McCook.

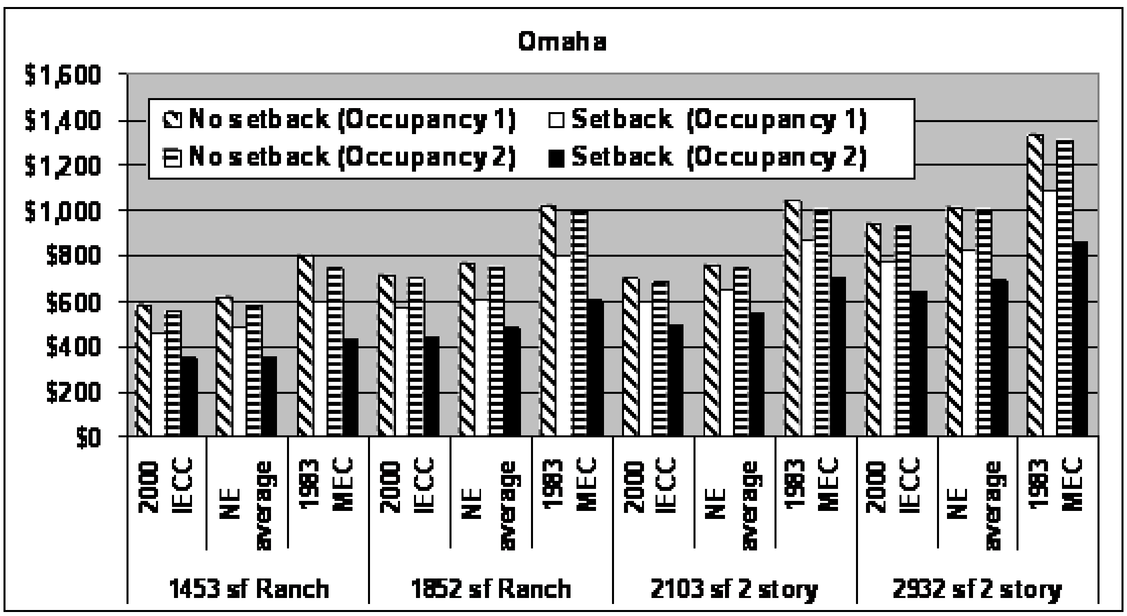

Figure 5. Energy cost impact of thermostat setbacks - Omaha.

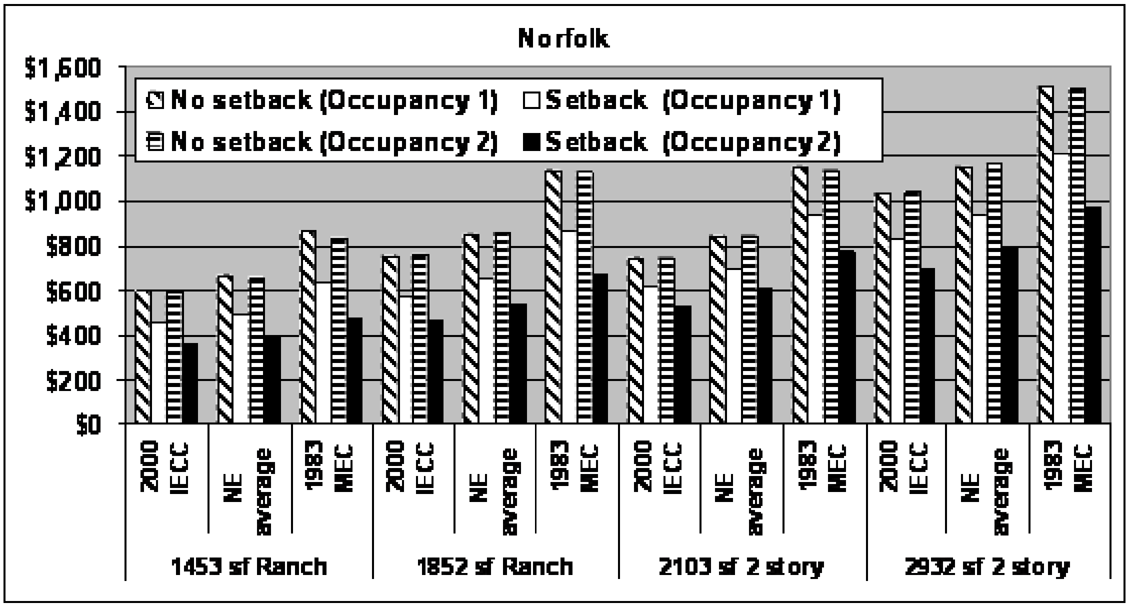

Figure 6. Energy cost impact of thermostat setbacks - Norfolk.

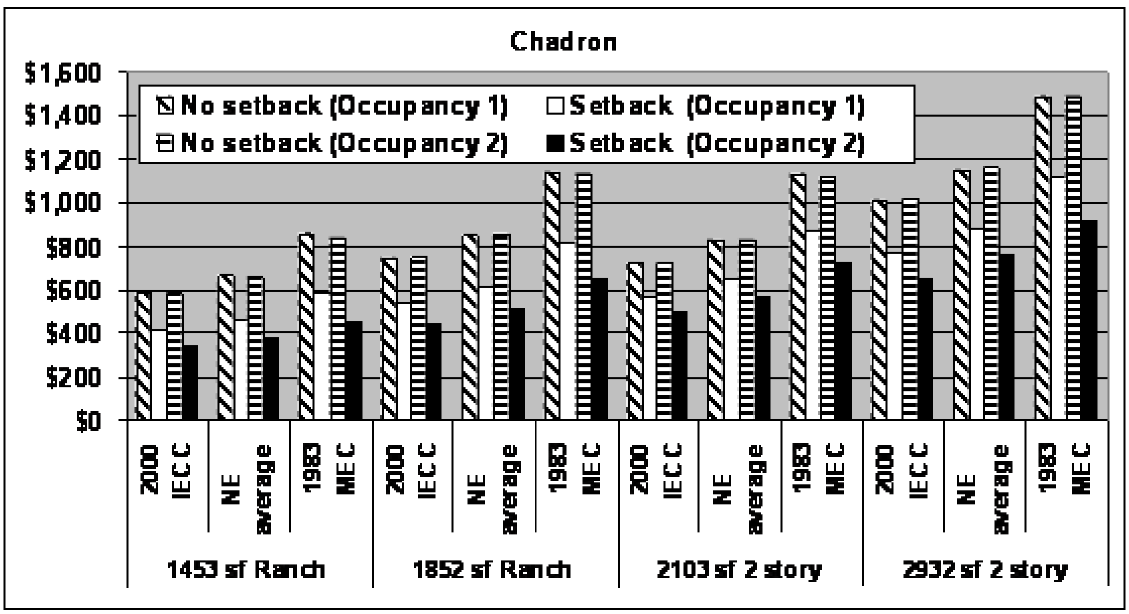

Figure 7. Energy cost impact of thermostat setbacks - Chadron.

Setback thermostats will impact life cycle cost by changing the annual energy use. Tables 23 and 24 show life cycle costs associated with setback thermostats and the two occupancy profiles. Setback thermostats do not change the construction cost, but reduce the energy use. The reduction in energy use gained by setback thermostats, as was seen in Figures 4-7, is largest for the less restrictive codes. Therefore, the use of setbacks acts to reduce the life cycle cost penalty associated with energy use in less restrictive codes.

If a night setback is used with the occupancy profile in which two occupants are at home during the day (Table 23), the IECC 2000 case has the lowest life cycle cost in all sixteen house/city combinations. This means that the code upgrade will also be beneficial to homeowners who choose to use night setback thermostats to conserve energy.

The 2000 IECC case is the lowest cost option in thirteen of the sixteen cases when setback thermostats are used both at night and on weekdays (Table 24).
The 1983 MEC has a slightly lower life cycle cost for the smallest house in McCook, Omaha, and Norfolk.

In McCook and Norfolk the difference is very small, less than $200 over 30 years. The difference is somewhat higher in Omaha due to lower utility rates and higher construction costs there. This is a very conservative thermostat scenario that is unlikely to be followed for an entire 30 year period. Even so, the 2000 IECC provides the lowest costs in most of the houses and all of the “average” sized houses. Furthermore, the 2000 IECC provides a lower life cycle cost than the current state average code in every case except one. In that case, the difference is only $19 over 30 years.

Combinations		Life cycle cost in 2003 dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	*$23,206*	*$26,596*	*$31,090*	*$49,000*
NE average	McCook	$23,649	$27,659	$32,249	$50,634
1983 MEC	McCook	$24,063	$29,214	$34,885	$52,544
2000 IECC	Omaha	*$26,879*	*$30,496*	*$35,444*	*$56,191*
NE average	Omaha	$27,076	$31,089	$36,253	$56,995
1983 MEC	Omaha	$27,117	$32,111	$38,472	$58,184
2000 IECC	Norfolk	*$25,499*	*$29,308*	*$33,831*	*$53,847*
NE average	Norfolk	$26,042	$30,531	$35,373	$55,653
1983 MEC	Norfolk	$26,606	$32,152	$38,145	$57,577
2000 IECC	Chadron	*$22,692*	*$26,184*	*$30,083*	*$47,817*
NE average	Chadron	$23,318	$27,506	$31,704	$49,841
1983 MEC	Chadron	$23,974	$29,281	$34,407	$51,378

Table 23. Life cycle cost with night setback thermostat (Occupancy profile #1).

Combinations		Life cycle cost in 2003 dollars			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	$21,639	*$24,772*	*$29,566*	*$46,852*
NE average	McCook	$22,053	$25,765	$30,659	$48,439
1983 MEC	McCook	*$21,471*	$26,141	$32,265	$48,840
2000 IECC	Omaha	$24,863	*$28,208*	*$33,623*	*$53,644*
NE average	Omaha	$24,844	$28,727	$34,335	$54,347
1983 MEC	Omaha	*$23,882*	$28,460	$35,383	$53,945
2000 IECC	Norfolk	$23,739	*$27,151*	*$32,116*	*$51,263*
NE average	Norfolk	$24,180	$28,237	$33,537	$52,919
1983 MEC	Norfolk	*$23,603*	$28,480	$35,089	$53,136
2000 IECC	Chadron	*$21,143*	*$24,323*	*$28,560*	*$45,570*
NE average	Chadron	$21,721	$25,528	$30,095	$47,468
1983 MEC	Chadron	$21,416	$26,098	$31,697	$47,558

Table 24. Life cycle cost day and night setback thermostat (Occupancy profile #2).

Economic impacts for Nebraska

These results can be generalized for the entire state by considering the number of houses built annually in each of the climate regions.

The four modeled cities were chosen to represent the four heating degree day ranges throughout the state. Table 25 shows these degree day ranges, the city used to represent it, and the number of 2001 permits issued in each region.

The information on number of homes built was taken from the survey of code officials conducted by the Nebraska Energy Office.

As Table 25 shows, the vast majority of houses being constructed in the state, nearly 90%, are in the weather region represented by Omaha.

This region includes the state's seven largest code jurisdictions in terms of 2001 building permits: Omaha, Lincoln, Bellevue, Sarpy County, Gretna, Papillion, and Cass County. The region represented by Norfolk accounts for nearly 8% of the state's total, with Kearney, Norfolk, and North Platte the largest jurisdictions in this area. Seward and Seward County are the largest jurisdictions represented by the McCook region with 1.4% of the state total. Chadron represents the smallest region, with Sidney, Wayne, and Chadron the largest jurisdictions in that area. A full list of all code jurisdictions in the state, their numbers of heating degree days (HDD), and the city used to represent them is included in the appendix (Table A4).

Heating degree days	Modeled city	Number of permits	% of total
5,500-5,999	McCook	78	1.4
6,000-6,499	Omaha	5,142	89.5
6,500-6,999	Norfolk	456	7.9
7,000-8,499	Chadron	67	1.2
Nebraska total		5,743	

Table 25. Number of homes represented by each region.

Using the percentages for each region shown in Table 25 it is possible to calculate a weighted average savings for homeowners across the state.

Table 26 shows the weighted average mortgage increase, first year energy cost, and first year net savings to homeowners if the state energy code is increased from the current average being enforced in the state to the 2000 IECC.

For all four houses, the mortgage increase is smaller than the energy savings, producing a net first year savings to the homeowner. This will be the effect on the average Nebraska homeowner if the 2000 IECC is adopted statewide.

Note that this is most likely a conservative estimate, since nearly 90% of the state is represented by Omaha. As was seen previously, Omaha has higher construction costs and lower gas utility rates than other areas in the state. Some jurisdictions with climates similar to Omaha may have lower construction and higher gas costs, which would produce greater first year energy savings in these areas.

House	Mortgage increase	Energy savings	Net first year savings
1,453 sf ranch	$14	$43	$29
1,852 sf ranch	$17	$57	$40
2,103 sf 2 story	$11	$64	$53
2,932 sf 2 story	$18	$72	$54

Table 26. Weighted average first year savings to Nebraska homeowners – upgrade from Nebraska average to 2000 IECC code.

Table 27 uses the same weighting method to show the mortgage increase, energy savings, and net first year savings associated with an upgrade from the 1983 MEC to the 2000 IECC. Here, the net first year savings to the homeowner are larger.

These are the benefits that would be realized by homeowners in jurisdictions that are enforcing only the state minimum code.

House	Mortgage increase	Energy savings	Net first year savings
1,453 sf ranch	$169	$225	$56
1,852 sf ranch	$198	$312	$114
2,103 sf 2 story	$148	$343	$195
2,932 sf 2 story	$267	$400	$133

Table 27. Weighted average first year savings to Nebraska homeowners – upgrade from 1983 MEC to 2000 IECC code.

The aggregate energy savings for the state can be estimated based on the number of houses built in each size range. For this estimate, it is assumed that the smallest 20% of Nebraska houses can be represented by the 1,453 sf ranch and the largest 20% can be represented by the 2,932 sf 2 story house. The 1,852 sf ranch and 2,103 sf 2 story houses each represent 30% of houses built in the state. If 5,743 houses are built annually in the state, an upgrade from the current state average to the 2000 IECC code provides a $340,000 aggregate energy savings to homeowners of these houses in the first year. The net cash savings to homeowners in the first year is $254,007.

In terms of life cycle cost, the houses built during a single year will provide their owners with a $5.5 million net savings in 2003 dollars over the next 30 years. This means that if the 2000 IECC is adopted by the state of Nebraska, the houses built before 2015 will provide their owners with a net savings of more than 59.6 million 2003 dollars over their lifetimes, even if there is no housing growth during this period.

A more detailed look at where these savings come from shows an even greater benefit for Nebraska's state economy.

Thus far, construction costs have been dealt with primarily in terms of mortgage payment increase, since this is how the vast majority of homeowners finance construction. However, the entire construction cost is paid to builders at the time of construction.

Table 28 shows the construction cost increase associated with an upgrade from the current state average energy code to the 2000 IECC.

Note that the McCook houses, again, show a negative increase, meaning that the 2000 IECC actually costs less to build in that region.

For houses constructed in the first year, the aggregate construction cost increase in the state is 1.13 million dollars. This money enters the state economy during the year of construction, benefiting Nebraska businesses and workers.

City	Construction cost increase in dollars			
	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
McCook	-$110	-$154	-$79	-$309
Omaha	$184	$219	$165	$247
Norfolk	$293	$302	$57	$205
Chadron	$288	$292	$50	$178
Wtd. Average	$189	$221	$151	$235

Table 28. Construction cost increase – upgrade from Nebraska average to 2000 IECC code.

In contrast, a substantial portion – an estimated 80 percent – of energy dollars spent in Nebraska leave the state:

* Virtually all the natural gas used is imported;

*More than 95 percent of fuels used to generate electricity come from outside the state[12].

The aggregate annual energy cost savings for houses built in a single year with an upgrade from the current state average to the 2000 IECC code will be $340,000.

Of this, $43,800 is electricity, for which 95.6% of the purchased fuels are from out of state. The remaining $295,600 is for gas, which is at least 60% out of state. Therefore, less than $120,200 of this expense remains in the state.

Conclusion and recommendations

The findings of this study strongly support adoption of the 2000 IECC as the Nebraska statewide residential energy code.

Four houses ranging from the 20th to 80th

percentile size were studied in four cities that cover the range of climates experienced in the state. For all sixteen house-city combinations, the upgrade to the 2000 IECC from the 1983 MEC, the current state minimum, resulted in first year energy savings greater than the annual mortgage increase. This means that the first year energy savings was greater than the annual mortgage increase required to build houses to the stricter code. The difference was large enough to save most Nebraska homeowners $100 or more during the first year.

For all sixteen house-city combinations, the upgrade to the 2000 IECC from the Nebraska average resulted in first year energy savings greater than the annual mortgage increase. This means that the average Nebraska homeowner would also see savings in the first year of home ownership, and would see even greater savings

with future increases in utility prices.
The aggregate projected savings for all homeowners in the state is $254,000 in the first year. Over the next thirty years, the houses built during a single year will provide their owners with a $5.5 million in net savings. These savings will be compounded in future years as more and more of Nebraska housing stock is built to the upgraded standard.

The study also investigated the effects of setback thermostats and found that Nebraska homeowners can realize substantial savings if they are used.
The change in energy use associated with setback thermostats can begin to close the gap between mortgage cost and energy savings associated with moving to a more restrictive energy code. However, in all of the cases, there is still a lower life cycle cost associated with the 2000 IECC code for houses using night setbacks.
Even with a very conservative and unlikely night and day setback scenario, most of the cases still experienced lower life cycle cost with the 2000 IECC.

Other benefits to the state include additional investments in construction cost, which translates to approximately 1.13 million dollars in the first year and benefits local builders and suppliers. The mortgage payments on this additional construction cost are traded against roughly $340,000 in annual energy savings, less than 35% of which remains in the state.

Finally, every effort has been made to use realistic cost and occupancy assumptions. When future costs are projected, U.S.
government statistics and projections are used to predict items such as inflation and energy cost increases. These projections are often based on past data, and should be regarded as estimates. In particular, the energy cost increases used here are modest.
Larger savings would be obtained if energy costs were to increase suddenly in the future. Adoption of the 2000 IECC would give Nebraska
homeowners peace of mind by helping to insulate them from future fluctuations in energy rates.

REFERENCES

[1] US Census Data http://www.census.gov/const/C25Ann/sftotalsqft.pdf

[2]

Musser, A. and G. Yuill (1999). "Comparison of Residential Air Infiltration Rates Predicted by Single Zone and Multizone Models." ASHRAE Transactions **105**(1).

[3] ASHRAE (2001). ASHRAE Handbook of Fundamentals. Atlanta, GA, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

[4] EIA (1997). A look at residential energy consumption in 1997. Washington, DC, US Department of Energy, Energy Administration**:** 310.

[5] USEPA (1997). Exposure Factors Handbook, National Center for Environmental Assessment, United States Environmental Protection Agency.

[6] Quirouette, R. (1983). Moisture Sources in Houses. Building Science Insight '83, NRC Canada.

[7] RS Means 2003 Residential Cost Data, 22nd Annual Edition. Kingston, MA.

[8] Kuehn, T., J. Ramsey, J. Threlkeld. 1998. Thermal Environmental Engineering. 3rd ed. Prentice-Hall, Inc. New York. 740 pgs.

[9] Federal Housing Finance Board.

[10] Rushing, A. and S. Fuller. 2003.
Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – April 2003. NISTIR 85-3273-18. April, 2003. Building and Fire Research Laboratory, National Institute of Standards and Technology. Gaithersburg, MD.

[11] RS Means 2003 Residential Cost Data, 22nd Annual Edition. Kingston, MA.

[12] Energy Information Administration, U.S. Department of Energy, Washington, DC. And Nebraska Energy Office, Lincoln, NE.

Appendices

Annual summer electricity consumption (kWh)

Combinations		Annual summer electricity consumption kWh			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	3,242	3,678	4,373	4,948
NE average	McCook	3,264	3,766	4,510	4,993
1983 MEC	McCook	4,270	5,083	6,129	6,925
2000 IECC	Omaha	3,763	4,349	5,038	5,877
NE average	Omaha	3,770	4,424	5,166	5,931
1983 MEC	Omaha	5,021	6,015	7,049	8,198
2000 IECC	Norfolk	3,310	3,755	4,475	5,090
NE average	Norfolk	3,338	3,867	4,611	5,160
1983 MEC	Norfolk	4,388	5,220	6,248	7,103
2000 IECC	Chadron	2,754	3,034	3,720	4,026
NE average	Chadron	2,761	3,109	3,807	4,070
1983 MEC	Chadron	3,533	4,113	5,082	5,373

Table A1. Annual summer electricity consumption (kWh).

Annual winter electricity consumption (kWh)

Combinations		Annual winter electricity consumption kWh			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	1,015	1,166	1,413	1,499
NE average	McCook	1,052	1,264	1,499	1,455
1983 MEC	McCook	1,205	1,425	1,821	1,802
2000 IECC	Omaha	1,170	1,349	1,575	1,636
NE average	Omaha	1,210	1,380	1,651	1,723
1983 MEC	Omaha	1,407	1,547	2,059	2,117
2000 IECC	Norfolk	1,223	1,432	1,650	1,746
NE average	Norfolk	1,249	1,468	1,772	1,759
1983 MEC	Norfolk	1,457	1,698	2,192	2,286
2000 IECC	Chadron	949	1,087	1,274	1,247
NE average	Chadron	1,016	1,150	1,372	1,249
1983 MEC	Chadron	1,057	1,193	1,619	1,457

Table A2. Annual winter electricity consumption (kWh).

Annual gas consumption (Therm)

Combinations		Annual gas consumption (Therm)			
Code	City	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2000 IECC	McCook	348	471	390	632
NE average	McCook	391	525	450	717
1983 MEC	McCook	517	725	641	943
2000 IECC	Omaha	339	468	400	656
NE average	Omaha	392	535	469	743
1983 MEC	Omaha	508	723	650	954
2000 IECC	Norfolk	392	540	458	754
NE average	Norfolk	475	645	560	895
1983 MEC	Norfolk	616	869	775	1,146
2000 IECC	Chadron	395	540	455	747
NE average	Chadron	478	647	561	893
1983 MEC	Chadron	629	883	785	1,159

Table A3. Annual gas consumption (Therm).

Number of permits and heating degree days by code jurisdiction

Jurisdiction	Permits	HDD	Modeled City	Jurisdiction	Permits	HDD	Modeled City
Albion	7	7087	Chadron	Louisville	3	6292	Omaha
Alliance	5	6823	Norfolk	McCook	7	5967	McCook
Alma	3	6203	Omaha	Mead	1	6570	Norfolk
Ashland	32	6379	Omaha	Milford	6	5779	McCook
Auburn	6	5765	McCook	Minden	3	6398	Omaha
Beatrice	35	6151	Omaha	Nebraska City	9	6023	Omaha
Bellevue	300	6153	Omaha	Norfolk	65	6766	Norfolk
Blair	56	6455	Omaha	North Platte	53	6766	Norfolk
Bloomfield	1	7057	Chadron	Ogallala	12	6672	Norfolk
Cass County	121	6292	Omaha	Omaha	2136	6153	Omaha
Central City	1	5834	McCook	O'Neill	4	7246	Chadron
Ceresco	1	6613	Norfolk	Palmyra	3	6337	Omaha
Chadron	9	7021	Chadron	Papillion	142	6153	Omaha
Columbus	60	6411	Omaha	Plainview	2	6485	Omaha
Cozad	7	6303	Omaha	Plattsmouth	20	6153	Omaha
Crete	10	5811	McCook	Ralston	2	6153	Omaha
Dakota City	7	6600	Norfolk	Sarpy County	281	6153	Omaha
David City	7	6237	Omaha	Saunders County	47	6613	Norfolk
Douglas County	42	6153	Omaha	Scottsbluff	19	6742	Norfolk
Elkhorn	64	6153	Omaha	Seward	24	5779	McCook
Falls City	1	5795	McCook	Seward County	22	5779	McCook
Fremont	40	6444	Omaha	Sidney	35	7092	Chadron
Gering	32	6742	Norfolk	South Sioux City	23	6600	Norfolk
Grand Island	101	6385	Omaha	Superior	1	5552	McCook
Gretna	166	6379	Omaha	Sutton	2	6347	Omaha
Hall County	24	6385	Omaha	Tekamah	4	6564	Norfolk
Hastings	59	6211	Omaha	Valley	4	6570	Norfolk
Holdrege	8	6482	Omaha	Wahoo	13	6570	Norfolk
Kearney	116	6652	Norfolk	Washington Cty.	79	6455	Omaha
Keith County	50	6672	Norfolk	Waverly	15	6119	Omaha
LaVista	115	6153	Omaha	Wayne	11	7143	Chadron
Lancaster County	34	6119	Omaha	Wymore	5	6151	Omaha
Lexington	7	6303	Omaha	York	19	6338	Omaha
Lincoln	1140	6119	Omaha	Yutan	4	6570	Norfolk

Table A4. 2001 Residential Permits by Nebraska code jurisdiction.

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