MEMORANDUM

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Re: Initial Review of Impacts of NFRC Board Committee Proposed Changes for Residential modeling assumptions

This memo represents an initial review and comments on the proposed changes suggested by the NFRC Board Committee as posted on the NFRC web site prior to the January NFRC Technical Committee meetings. As this work is still in progress and additional modeling comparisons are underway, some of these comments may change in the future. But they provide additional data for the AEP Task Group to consider in Ft. Worth.

The NFRC Board Committee that reviewed the modeling assumptions used in RESFEN has recently proposed six changes : (1) change the prototypical building size and type from a 2000 ft^2 one-story to a 2400 ft^2 two-story building, (2) change the envelope insulation levels from 1993 MEC to 2003 IECC, (3) change the shading effect of window drapes from 0.80 in the summer and 0.90 in the winter to an annual constant of (0.9 – 0.25 * SHGC), (4) lower the cooling thermostat from 78 F to 75 F, (5) increase the house internal load from roughly 60 kBtu to 92 kBtu per day, and (6) eliminate the modeling of natural ventilation.

The rationale for each of the original assumptions has been given in prior RESFEN documentation, some of which is included at the end of this document. Since the RESFEN assumptions were developed over a multiyear period some of the prior data may be in need of updating. The assumptions were largely based on extensive discussions with members of the AEP Task Group, on data from published sources whenever possible and on discussions with a group of national energy modelers, engineers and simulators whose major professional activities are computer simulations of building energy performance. As with many computer modeling studies there is frequently room for disagreements over inputs and modeling assumptions. We explain below our thinking on each of these issues and provide references to the available data that may assist in making a final decision on these issues.

How do we know if we have the "correct" answers?
Even when specific modeling assumptions taken separately appear to be "reasonable" it is important to check to see that the interactive sum of all assumptions give results that "make sense". Also results are likely to be highly climate dependent in terms of heating and cooling impacts. We believe that when all the discussions are concluded on the details of each modeling assumption and the final decisions are made the overall modeling results must approximate the measured energy use of the nations residential stock, which is reported in some detail in the Residential Energy Consumption Survey (RECS), most recently updated in 2001 and available at (http://www.eia.doe.gov/emeu/recs/recs2001/detail_tables.html)

Discussions of Proposed Changes

Initial Conclusions: We are not convinced that collectively all of the proposed changes will result in better modeling of typical conditions. All six and particularly the last three will tend to decrease heating use and increase the calculated cooling energy use. Together, the changes will likely push the calculated cooling energy use substantially above typical utility bills as reported in RECS today. This generalization covers a wide range of situations, a few of which are discussed below and can be seen in the accompanying tables.

To analyze the impact of these proposed modeling changes, we have done sensitivity studies for five of the six proposed measures on a new prototypical house in six different US climates, and have tabulated the results in Table 1. We have not yet studied the second proposed change in the envelope insulation levels because we did not have the new insulation levels required by 2003 IECC. But we do show data on the states, which have adopted various IECC and MEC codes in TABLE 11 in this document. For the other five proposed changes, the sensitivity study shows the following:

1) **House type/Size**: Table 1 combines building type and size into a single parameter, i.e., from a 2000 ft^2 1-story house to a 2400 ft^2 2-story house. According to the NFRC review task force, the larger floor area and two-story configuration are slightly more prevalent than the size and configuration used in the NFRC900 simulations done using RESFEN. (It should be pointed out that RESFEN itself does not have an assumed base case house size or configuration, but rather allows users to choose from two house configurations, two vintages, two wall types, and any floor area between 1000 and 4000 ft^2). The proposed building type and size will produce a 10-15% reduction in heating energy, virtually no change in cooling energy use in the hot climates (Miami and Phoenix), but from 20-40% increase in cooling energy in the other climates (please keep in mind that all the percentages have been normalized per ft^2 of floor area, so that the total changes are actually larger).

2) **Internal Shading**: Using the annual constant instead of the seasonally varying shading schedule has virtually no effect on heating energy use, and from 4-14% increase in cooling energy use, depending on location, with the smaller percentage in the hotter locations.

3) **Internal Gain**: When the internal gain is increased by 50% as proposed, heating energy use is naturally reduced by 10-15% in the cold climates and 30-44% in the hot climates, while cooling energy use is increased from 14-24% in the hot climates and 45-52% in the cold climates. (in almost all the parametrics, the larger percentage sensitivity occurs in those locations with the smaller heating or cooling energy use). The RESFEN internal load assumptions of 43 kBtu + 8.42 Btu/ft^2 per day for lighting are based on work done at LBNL in the early 1980s that estimated the annual or daily heat output from occupants, human activity, and appliances, their saturation level at that time, and the amount of heat that was likely to remain in the building space. The methodology and assumptions are documented in Appendix D of an LBL technical support document that I have attached at the end of this memo. Although this work was done more than 20 years ago, the overall framework remains valid and could be easily updated incorporating, e.g., current average electricity consumptions for refrigerators and televisions. It is unclear but unlikely that such a revision would result in the proposed 50% increase in internal gains, as increases in the amount of heat-generating appliances and equipment (computers, leaking electricity, etc.) will be offset by decreases in occupant density and improved efficiency of most major appliances. For example refrigerators now use only half the energy they consumed at the time of the earlier studies.

4) **Thermostat Setpoints**: When the cooling setpoint is reduced from 78 F to 75 F, cooling energy use goes up by 23-37% in the hot locations and 54-80% in the cold locations. The cooling setpoint of 78 F used in RESFEN is corroborated by a study of occupant behavior and indoor conditions done for the California Energy Commission in 1990 (CEC 1997). Although 75 F is used as the temperature for sizing calculations, it does not necessarily correspond to actual operating temperatures in typical residential buildings. 78 F was the cooling setpoint used in the simulations done for the ASHRAE 90.2 standard for residential buildings, as well as in state residential energy standards such as California, Washington, Minnesota, New York, Massachusetts, and Florida. It should also be kept in mind that 78 F is an average cooling setpoint that balances those houses with lower cooling setpoints against those houses whose occupants are away during the day and set up or turn off their cooling thermostat.

5) **Natural Ventilation:** The current ventilation controls assume that windows will be opened only at times when they are likely to produce beneficial impacts. When natural ventilation is eliminated, cooling energy use changes very little in the hot climates (2-4% in Miami and Phoenix), increases slightly in the eastern locations with humid summers (4% in Washington to 12% in Minneapolis), but substantially more in western locations with dry summers (22% in Denver, 14% in Pasadena, and 120% in Los Angeles). The bottom line is that the natural ventilation controls as modeled in RESFEN considers enough factors such as not opening the windows from 11pm to 7 am, when outside air is more humid, etc., that it has a major impact only in climates where it is clearly beneficial and commonly used.

Combined Impact of Multiple Changes:

The combined impact from all six of the proposed modifications is a 16-24% decrease in heating energy use, and increases in cooling energy use ranging from 50-60% in the hot climates to 150-220% in the other climates (ignoring for the moment the 1300% increase in Los Angeles). The major drivers for these substantial increases in cooling energy use are the increase in internal gains and the lowering of the cooling setpoint.

As noted in the beginning we believe it is also very important to see if the net impact from all or a collection of them produces results that correspond to heating and cooling energy budgets typically found in new or existing homes. When we worked on RESFEN, we did a bit of this by canvassing researchers about the typical residential heating and cooling bills in their parts of the country. Since a key purpose of the modeling exercise was to predict the likely energy savings from going to more energy-efficient windows, if the base numbers are skewed, the predictions would also be misleading. So for these proposed changes we must ask if the resultant predicted energy use correlate to RECS or other measured data. For example, the sum of all the proposed modeling changes would result in cooling electricity budgets 2750 kWh in Washington DC, 3150kWh in Pasadena, 10200kWh in Miami, and 9300kWh in Phoenix. Do these match typical consumptions?

We have begun to explore these issues by reviewing RECS data on cooling and heating loads (and associated equipment penetration characteristics) and comparing these data to existing and modified RESFEN assumptions. The RECS data reminds us that we are using a very small number of “prototypical” conditions and designs to approximate a large and diverse building population, an intrinsically difficult task if we are trying to get agreement between the two. (see Tables 2 and 5-8 for example)

Tables 3 and 4 below compare some RECS measured consumption data with RESFEN runs using variations on windows using existing RESFEN operating data. Note here we are comparing calculated data for one city in a state to the statewide measured data, which likely explains some of the discrepancies in California for example.

Given the importance of understanding these cooling impacts we include Table 9 that provides RECS data on the characteristics of houses with cooling systems and indirectly addresses some of the size and operations issues. Table 10 addresses the one-story vs. two-story issue.

Tables and appendices referenced above follow:

Table 1. Sensitivity analyses of impact of proposed modeling changes on calculated heating and cooling energy uses.

	Annual_Energy		Pct_Change/ft2	
Parametric and	Heat	Cool	Heat	Cool
Location	(MBtu)	(kWh)	(%)	(%)
RESFEN Base Case Assumption				
Denver	56.72	435		
Washington	54.75	929		
Los_Angeles	8.85	120		
CTZ09C	11.57	837		
Minneapolis	97.98	514		
Miami	0.50	5313		
Phoenix	6.80	5218		
House Type and Size				
Denver	58.29	693	-14.4	32.9
Washington	57.41	1392	-12.6	24.8
Los_Angeles	8.04	241	-24.4	67.2
CTZ09C	11.19	1247	-19.4	24.2
Minneapolis	105.17	855	-10.6	38.6
Miami	0.69	6375	16.0	-0.0
Phoenix	7.96	6323	-2.4	1.0
Weighted Average			-12.6	6.8
Internal Shading				
Denver	56.65	499	-0.1	14.8
Washington	54.75	1012	-0.0	9.0
Los_Angeles	8.84	126	-0.2	5.2
CTZ09C	11.56	904	0.0	8.0
Minneapolis	97.94	580	-0.0	12.8
Miami	0.48	5565	-4.0	4.7
Phoenix	6.79	5434	-0.3	4.1
Weighted Average			-0.1	5.6

Internal Gains				
Denver	48.07	658	-15.3	51.2
Washington	46.86	1351	-14.4	45.4
Los_Angeles	4.97	206	-44.0	71.3
CTZ09C	7.31	1136	-36.7	35.7
Minneapolis	88.69	771	-9.5	49.9
Miami	0.27	6559	-44.0	23.5
Phoenix	4.63	5967	-31.8	14.4
Weighted Average			-15.3	24.5
Cooling Setpoint				
Denver	57.42	778	1.2	78.8
Washington	55.21	1433	0.8	54.2
Los_Angeles	9.35	445	5.4	270.8
CTZ09C	12.57	1424	8.7	70.2
Minneapolis	98.39	886	0.4	72.3
Miami	0.69	7258	36.0	36.6
Phoenix	7.47	6409	9.7	22.8
Weighted Average		1.6	39.4	
Natural Ventilation				
Denver	56.64	529	-0.1	21.7
Washington	54.73	972	-0.0	4.6
Los_Angeles	8.82	262	-0.5	118.5
CTZ09C	11.46	953	-0.9	13.9
Minneapolis	97.95	574	-0.0	11.6
Miami	0.46	5409	-8.0	1.8
Phoenix	6.71	5400	-1.2	3.5
Weighted Average			-0.2	5.5
Combination of all above				
Denver	51.55	1907	-24.3	265.5
Washington	51.04	2765	-22.3	148.0
Los_Angeles	5.39	2004	-49.2	1291.5
CTZ09C	8.54	3146	-38.4	213.4
Minneapolis	97.46	2000	-17.1	224.2
Miami	0.52	10212	-16.0	60.2
Phoenix	6.49	9266	-20.6	48.0
Weighted Average			-22.4	95.2

From 2001 Residential Energy Consumption Survey (RECS) (All construction years and types)
(http://www.eia.doe.gov/emeu/recs/recs2001/detail_tables.html)

TABLE 2

Electric Air Conditioning, Basic Data (Table CE3-1c):

Total Households in US: **107.0 million**
Households using air conditioning in US: **80.8 million**

Electric Air Conditioning Energy Consumption in US Households by Climate Zone (Table CE3-1c):

Air conditioning Type	Households (millions)	% of total households	KWh per household
Central	57.5	71%	2,802
Room/Wall	23.3	29%	943

Million Households					
Air conditioning Type	< 2,000 CDD				≥ 2,000 CDD < 4,000 HDD
	> 7,000 HDD	5,500 – 7,000 HDD	4,000 – 5,499 HDD	< 4,000 HDD	
Electric AC	5.3	20.5	19.9	13.4	21.8
Central	3.1	12.9	12.7	105.	18.2
Room/Wall	2.2	7.6	7.2	2.9	3.6

Cooled Square Footage						
Air conditioning Type	Total	< 2,000 CDD				≥ 2,000 CDD < 4,000 HDD
		> 7,000 HDD	5,500 – 7,000 HDD	4,000 – 5,499 HDD	< 4,000 HDD	
Electric AC	1724	1867	1863	1697	1732	1579
Central	2032	2405	2336	2101	1989	1729
Room/Wall	967	1090	1058	981	790	811

KWh per Household						
Air conditioning Type	Total	< 2,000 CDD				≥ 2,000 CDD < 4,000 HDD
		> 7,000 HDD	5,500 – 7,000 HDD	4,000 – 5,499 HDD	< 4,000 HDD	
Electric AC	2,265	1,074	1,220	1,683	2,355	4,014
Central	2,802	1,429	1,589	2,159	2,687	4,412
Room/Wall	943	562	590	837	1,135	1,982

TABLE 3

Electric Air Conditioning Energy Consumption in US Households by Four Most Populated States (Table CE3-7c):

Million Households					
AC Type	**Total**	**New York**	**California**	**Texas**	**Florida**
Electric AC	80.8	4.7 (6%)	5.2 (6%)	7.4 (9%)	6.1 (7%)
Central	57.5	1.3	3.9	6.2	5.7
Room/Wall	23.3	3.4	1.2	1.2	.3

Cooled Square Footage					
AC Type	**Total**	**New York**	**California**	**Texas**	**Florida**
Electric AC	1724	1149	1374	1697	1682
Central	2032	1852	1640	1856	1732
Room/Wall	967	886	512	889	unknown

KWh Per Household					
AC Type	**Total**	**New York**	**California**	**Texas**	**Florida**
Electric AC	2,265	693	959	4368	4613
Central	2,802	961	1151	4765	4767
Room/Wall	943	593	337	2343	2098

RESFEN Runs (one representative city) compared to RECS data by state				
	Window U	SHGC	New / Existing	Cooling kWh
New York (RESFEN = New York City)				
RECS Electric AC				693
1 Story, 2000 sf, current assumptions	0.40	0.40	New	728
1 Story, 2000 sf, current assumptions	0.49	0.56	New	950
1 Story, 2000 sf, current assumptions	0.49	0.56	Existing	1072
California (RESFEN = Red Bluff)				
RECS Electric AC				959
1 Story, 2000 sf, current assumptions	0.40	0.40	New	2015
1 Story, 2000 sf, current assumptions	0.84	0.63	New	2612
1 Story, 2000 sf, current assumptions	0.84	0.63	Existing	3618
Texas (RESFEN = Ft Worth)				
RECS Electric AC				4368
1 Story, 2000 sf, current assumptions	0.40	0.40	New	2703
1 Story, 2000 sf, current assumptions	0.84	0.63	New	3353
1 Story, 2000 sf, current assumptions	0.84	0.63	Existing	4189
Florida (RESFEN = Miami)				
RECS Electric AC				4613
1 Story, 2000 sf, current assumptions	0.40	0.40	New	5315
1 Story, 2000 sf, current assumptions	0.84	0.63	New	6233
1 Story, 2000 sf, current assumptions	0.84	0.63	Existing	7309

TABLE 4

Natural Gas Heating Energy Consumption in US Households by Four Most Populated States (Table CE2-7c):

Million Households					
Heating Type	**Total (U.S.)**	**New York**	**California**	**Texas**	**Florida**
Space Heating	106	7.1	12	7.7	6.2
Natural Gas	59.1	4.2	8.9	4	1

Million Btu Per Household					
Heating Type	**Total (U.S.)**	**New York**	**California**	**Texas**	**Florida**
Natural Gas	55.4	65.1	25.6	37.6	12.2

Heated Square Footage					
Heating Type	**Total (U.S.)**	**New York**	**California**	**Texas**	**Florida**
Natural Gas	1836	1788	1394	1716	1958

RESFEN Runs (one representative city) compared to RECS data by state				
	Window U	SHGC	New / Existing	MBtu
New York (RESFEN = New York City)				
RECS Electric AC				65.1
1 Story, 2000 sf, current assumptions	0.40	0.40	New	61.85
1 Story, 2000 sf, current assumptions	0.49	0.56	New	61.17
1 Story, 2000 sf, current assumptions	0.49	0.56	Existing	120.02
California (RESFEN = Red Bluff)				
RECS Electric AC				25.6
1 Story, 2000 sf, current assumptions	0.40	0.40	New	27.13
1 Story, 2000 sf, current assumptions	0.84	0.63	New	32.74
1 Story, 2000 sf, current assumptions	0.84	0.63	Existing	60.64
Texas (RESFEN = Ft Worth)				
RECS Electric AC				37.6
1 Story, 2000 sf, current assumptions	0.40	0.40	New	20.81
1 Story, 2000 sf, current assumptions	0.84	0.63	New	24.58
1 Story, 2000 sf, current assumptions	0.84	0.63	Existing	37.84
Florida (RESFEN = Miami)				
RECS Electric AC				12.2
1 Story, 2000 sf, current assumptions	0.40	0.40	New	0.50
1 Story, 2000 sf, current assumptions	0.84	0.63	New	0.76
1 Story, 2000 sf, current assumptions	0.84	0.63	Existing	1.32

TABLE 5

Electric Air Conditioning Energy Consumption in US Households by Northeast Census Region (Table CE3-9c):

Million Households				
AC Type	US Total	Northeast Census Region		
		Total	Census Division	
			Mid Atlantic	New England
Electric AC	80.8	14.2 (18%)	11.1 (14%)	3.2 (4%)
Central	57.5	5.7	4.9	0.8
Room/Wall	23.3	8.5	6.1	2.4

Cooled Square Footage				
AC Type	US Total	Northeast Census Region		
		Total	Census Division	
			Mid Atlantic	New England
Electric AC	1724	2021	2031	2003
Central	2032	2378	2438	2261
Room/Wall	967	1146	1045	1354

KWh Per Household				
AC Type	US Total	Northeast Census Region		
		Total	Census Division	
			Mid Atlantic	New England
Electric AC	2,265	941	987	779
Central	2,802	1457	1424	1674
Room/Wall	943	596	637	492

TABLE 6

Electric Air Conditioning Energy Consumption in US Households by Midwest Census Region (Table CE3-10c):

Million Households				
		Midwest Census Region		
			Census Division	
AC Type	US Total	Total	East North Central	West North Central
Electric AC	80.8	20.2 (25%)	13.4(17%)	6.7 (8%)
Central	57.5	14.3	9.5	4.8
Room/Wall	23.3	5.8	3.9	1.9

Cooled Square Footage				
		Midwest Census Region		
			Census Division	
AC Type	US Total	Total	East North Central	West North Central
Electric AC	1724		1368	1809
Central	2032		1658	2153
Room/Wall	967		665	944

KWh Per Household				
		Midwest Census Region		
			Census Division	
AC Type	US Total	Total	East North Central	West North Central
Electric AC	2,265	1515	1368	1809
Central	2,802	1825	1658	2153
Room/Wall	943	756	665	944

TABLE 7

Electric Air Conditioning Energy Consumption in US Households by South Census Region (Table CE3-9c):

Million Households					
AC Type	US Total	South Census Region			
		Total	Census Division		
			South Atlantic	East South Central	West South Central
Electric AC	80.8	36.9(46%)	19.0(24%)	6.4 (8%)	11.5 (14%)
Central	57.5	30.4	16.1	5.0	9.2
Room/Wall	23.3	6.4	2.9	1.3	2.2

Cooled Square Footage					
AC Type	US Total	South Census Region			
		Total	Census Division		
			South Atlantic	East South Central	West South Central
Electric AC	1724	1732	1737	1891	1636
Central	2032	1904	1896	2086	1819
Room/Wall	967	923	852	1162	872

KWh Per Household					
AC Type	US Total	South Census Region			
		Total	Census Division		
			South Atlantic	East South Central	West South Central
Electric AC	2,265	3366	3098	2972	4031
Central	2,802	3714	3413	3259	4487
Room/Wall	943	1725	1338	1900	2125

TABLE 8

Electric Air Conditioning Energy Consumption in US Households by West Census Region (Table CE3-9c):

Million Households				
		West Census Region		
			Census Division	
AC Type	US Total	Total	Mountain	Pacific
Electric AC	80.8	9.6 (12%)	3.2 (4%)	6.3 (8%)
Central	57.5	7.1	2.6	4.5
Room/Wall	23.3	2.5	0.6	1.9

Cooled Square Footage				
		West Census Region		
			Census Division	
AC Type	US Total	Total	Mountain	Pacific
Electric AC	1724	1394	1383	1399
Central	2032	1660	1568	1713
Room/Wall	967	643	640	644

KWh Per Household				
		West Census Region		
			Census Division	
AC Type	US Total	Total	Mountain	Pacific
Electric AC	2,265	1572	2810	946
Central	2,802	1935	3327	1137
Room/Wall	943	548	729	487

TABLE 9

Air Conditioning Consumption for all households using air conditioning by Square Footage and Usage Indicators (Table CE3-6.2u):

Total value Per household: **7.7 million Btu, for 1,724 cooled square feet**

By Cooled Floorspace

Square feet cooled	Households (millions)	% of total households	Consumption per household (million Btu)	Consumption per square foot (million Btu)
< 500	9.2	11%	2.5	7.3
500 – 999	17.4	22%	5.1	6.7
1,000 – 1,499	17.2	21%	7.5	6.1
1,500-1,999	12.0	15%	8.5	4.9
2,000 – 2,499	8.5	11%	9.4	4.2
2,500 – 2,999	5.6	7%	9.7	3.5
3,000 – 3,499	3.7	5%	11.5	3.5
3,500 – 3,999	2.2	3%	14.2	3.8
4,000 or more	5.0	6%	14.7	2.8

Square Footage:

Cooled Floorspace (from table above):

< 500 – 1,499: 43.8 million households, 44% of total cooled households
1,500 – 2,499: 20.5 million households, 25% of total cooled households
2,500 – 4,000 or more: 16.5 million households, 20% of total cooled households

Comment: this data argues for a typical house closer to 2,000 square feet rather than 2,500 square feet as the default

By Year of Construction

Square feet cooled	Households (millions)	% of total households	Consumption per household (million Btu)	Consumption per square foot (million Btu)
1939 or before	11.9	15%	4.6	3.2
1940 - 1949	5.2	6%	6.1	4.2
1950 – 1959	10.2	13%	6.3	3.8
1960 – 1969	10.1	13%	6.7	4.2
1970 – 1979	14.2	18%	8.7	5.6
1980 – 1989	15.8	20%	9.0	5.1

1990 – 1999	12.6	16%	10.4	4.6
2000 - 2001	.8	1%	10.5	3.4

Comment: we know the existing building stock is large; since about half of all windows are sold for use in existing houses the size, AC equipment and thermal properties of existing houses should probably be addressed, in addition to new construction.

Occupancy Patterns:

Someone home all day (Table CE3-6.2u):

- Yes: 49% (39.9 million households / 80.8 million total households)
- No/Don't Know: 51% (40.8 million households / 80.8 million total households)

Comment: These data were used to support the original natural ventilation strategy and the interior moveable shade strategy, since at least half the time someone is home to operate these things.

Table 10

Number of Stories in New One-Family Houses Completed: Built For Sale1

http://www.census.gov/const/C25Ann/sfforsalestories.pdf

(Components may not add to totals because of rounding. Percents computed from unrounded figures.)

1 2 stories Split 1 2 stories Split

2 Total story or more 2 level

	Number of houses (in thousands)				Percent distribution			
Year	Total	1 story	2 stories or more	Split level	Total	1 story	2 stories or more	Split level
1973	731	461	190	80	100	63	26	11
1974	542	320	159	63	100	59	29	12
1975	498	299	130	68	100	60	26	14
1976	615	368	166	81	100	60	27	13
1977	756	443	221	92	100	59	29	12
1978	839	484	254	101	100	58	30	12
1979	799	452	258	89	100	57	32	11
1980	583	336	191	56	100	58	33	10
1981	484	275	168	42	100	57	35	9
1982	366	209	133	24	100	57	36	7
1983	603	328	234	41	100	54	39	7
1984	669	334	293	41	100	50	44	6
1985	698	332	326	41	100	48	47	6
1986	724	335	348	41	100	46	48	6
1987	706	315	354	38	100	45	50	5
1988	688	285	373	30	100	42	54	4
1989	661	274	359	28	100	42	54	4
1990	594	245	323	27	100	41	54	4
1991	481	206	247	29	100	43	51	6
1992	577	251	294	32	100	44	51	6
1993	642	282	329	30	100	44	51	5
1994	740	333	377	30	100	45	51	4
1995	682	310	347	25	100	45	51	4
1996	746	339	379	28	100	46	51	4
1997	757	350	385	21	100	46	51	3
1998	815	368	432	15	100	45	53	2
1999	885	395	478	11	100	45	54	1
2000	883	385	482	16	100	44	55	2
2001	906	390	506	10	100	43	56	1
2002	967	420	536	10	100	43	55	

Comment: the stock is relatively evenly split between 1 and 2 story construction, with construction since the mid-80s shifting to 2 story. Total existing stock is likely to be more one story although the balance will change with time. A single model is unlikely to accurately represent the stock although the impact of this alone on relative energy use is not large.

TABLE 11

Status of Energy Code Adoption by State

This summary is from the Status of State Energy Codes, "BUILDING CODES ASSISTANCE PROJECT NEWSLETTER**",** September/October 2003, which can be found on their website at:
http://www.bcap-energy.org/newsletter_51.htm

48% (24 states) have or are going to have 2000 IECC
52% (26 states) have earlier codes or no codes

MEC Version or Equivalent State Code	**States Adopted or Adopting**
2000 IECC, IRC or equivalent state code adopted or under review or in rulemaking for statewide adoption/equivalence	24 States (AL, KS, CA, DC, OR, WA, ID, NE, FL, KY, MD, NC, SC, NH, NY, PA, LA[2], TX, UT, GA, WI, WV, RI, VA) **20 States have adopted 2000 IECC with the following 4 States with 2000 IECC under review: AL, FL, MD, PA**
1998 IECC	1 State (OK)
95 MEC, Mandatory statewide adoption/equivalence	7 States (AK[1],,CT, MA, MN, NJ, OH, VT, HI)
95 MEC, Partial adoption/equivalence	
93 MEC, Mandatory statewide adoption/equivalence	3 States (DE, ND, MT,)
92 MEC, Mandatory statewide adoption/equivalence	5 States (AR, IA, IN, TN, NM)
No statewide residential code or residential code is not EPAct compliant	10 States (AZ[1, 3], CO[3], IL[3], ME, MI, MO[1], MS[3], NV, SD, WY[3])

1 State code is required for state-owned and -funded buildings only.
2 LA has adopted 95 MEC for multi-family residential only.
3 Code implementation depends upon the voluntary adoption of the code by local jurisdictions.

APPENDIX D: INTERNAL LOADS

Introduction

All hourly building energy use simulation models require input for internal loads. These loads consist of heat energy added to the indoor environment by occupants, lighting, and appliances. Internal loads increase total cooling loads and decrease total heating loads. In order to calculate a schedule of internal loads it is necessary to know the annual energy use of lighting and appliances, their saturations, and their use schedules. Additionally, an activity schedule for the building occupants is required. There is a significant uncertainty in the internal loads schedules used in most modeling efforts. This uncertainty is due to the lack of information on average appliance and lighting energy use in new or existing housing stock and also on the schedule of use for these appliances. The loads calculated in this appendix are for new (1982) appliances in new buildings. They were computed using estimates of lighting and appliance energy use for new 1982 equipment. These internal load schedules served as input to a large series of DOE-2 simulations from which data was gathered to construct the slide rules.

Calculation of Internal Loads from Occupants

Even while asleep, people generate metabolic heat. Metabolic heat energy is both sensible and latent in form. The latent portion is due to moisture exhaled from the lungs and to evaporation through the skin. As one's activity level increases, so does the generation of sensible and latent heat. In the case of internal loads used in the slide rule analyses, it was assumed that there were 3.2 occupants who spent 30% of their time asleep, 30% at rest or performing light work, and 40% of their time away from the house. While asleep, it was assumed that the sensible and latent heat generation rates averaged (for this family of 3.2) 147 Btu/hr and 98 Btu/hr, respectively.[1] During the other 30% of indoor activities, it was assumed that the occupants averaged 230 Btu/hr and 200 Btu/hr, respectively of sensible and latent heat generation.[2] On an annual basis, the total amount of sensible and latent heat generated is 3.17 MBtu and 2.50 MBtu, respectively.

Calculation of Internal Loads from Lighting

Most of the electrical energy input to incandescent bulbs and fluorescent lamps is converted to heat energy. The small percentage that is converted to light energy, will end up mostly as internal heat energy also. Some lighting is outdoors and some indoor lighting will escape through the windows. It is assumed that 90% of the electrical energy input to lights results in a sensible heat gain

1. American Society of Heating and Air-conditioning Engineers, *Handbook of Fundamentals*, 1977 Chapter 8, ASHRAE, Atlanta GA 30329.
2. 2. American Society of Heating and Air-conditioning Engineers, *Handbook of Fundamentals*, 1977 Chapter 26, ASHRAE, Atlanta GA 30329.

indoors. Assuming an annual electric energy input of 1 kWh/ft^2 and 1540 ft^2 of floor area, the annual sensible heat gain for the base case ranch house is 1386 kWh (4.73 MBtu). Since we have assumed that lighting energy use is proportional to floor area, we can obtain the internal load from lighting for the other prototypes by scaling the load to the floor area of each of the other four prototypes.

Calculation of Internal Loads from Appliances

There are several major appliances that contribute to internal loads in residential buildings. These are refrigerators, freezers, ranges, dryers, and hot water heaters. In our analysis, we also include the contribution to internal loads from televisions and miscellaneous electrical equipment.

Refrigerators and Freezers

Our analysis assumed that on average the saturation level for refrigerators was 100% and 15% per household for new and old models respectively. The new refrigerators use 1125 kWh/yr and the old ones 1600 kWh/yr. The sales weighted efficiency of new refrigerators is increasing rapidly compared to other appliances. Internal load estimates for refrigerators should be updated often to obtain more accurate values for their contribution to total loads. We assumed that most (85%) of the old refrigerators were located in non-conditioned areas and that all of the new refrigerators were located in space conditioned areas. Therefore, the total annual contribution from refrigerators is 1160 kWh. The annual energy consumption for freezers is assumed to be equal to 950 kWh. The saturation level for new houses is approximately 45% but, half of these are assumed to be in unconditioned locations. Therefore, the contribution of freezers to the total internal load is 214 kWh/yr.

Cooking

The internal load from cooking is strongly dependent on whether a vented or unvented stove is used in a residence. According to ASHRAE standards, for a vented commercial gas range, 20% of the input energy is sensible load, and for electrical ranges, 32% is sensible load.[3] For an unvented range, approximately 33% of the input energy results in a latent load and 67% results in sensible heat.

The gas stove contribution was calculated as follows. It was assumed that 33% of the cooking is vented (primarily baking) and therefore the sensible load from this activity is 20% of the gas ?? tent heat from the combustion process and the other 36 therms/yr result in a 67% sensible heat (24 therms/yr) and 33% latent heat (12 therms/yr) load. Therefore, total sensible and latent loads from cooking with natural gas are 28 and 16 therms/yr, respectively.

3. American Society of Heating and Air-conditioning Engineers, *Handbook of Fundamentals*, 1977 Chapter 26, ASHRAE, Atlanta GA 30329.

For electric ranges, it is assumed that the energy input is 1200 kWh/yr. If the electric range is unvented, it is assumed that 67% of the input energy (800 kWh/yr) results in sensible heat and 33% of the input energy (400 kWh/yr) results in latent heat. The saturations of electric and gas ranges in new U.S. residences are approximately 78% and 19% respectively. Therefore, the average internal loads from a range are about 805 kWh/yr sensible and 415 kWh/yr latent heat.

Dryers

Clothes dryers can be electric or gas powered. In either case, most of the heat energy generated is vented to the outside. Additionally, in many houses, dryers are located in unconditioned spaces and do not contribute to the internal loads at all. For the DOE-2 internal load schedules, it was assumed that electric dryers used 900 kWh/yr. It was also assumed that only 10% of this energy input appears as sensible heat indoors. If the saturation of dryers in new U.S. households is 70%, the sensible internal loads from electric dryers is 63 kWh/yr. The saturation of new gas dryers in new residences is very small (about 8%) and their annual energy consumption is lower (500 kWh) than for electric dryers. Therefore, gas dryers contribute only 4 kWh/yr of sensible load.

Hot Water Heaters

Hot water heaters require energy input for both standby losses and heating of incoming cold water. The assumed annual energy use for gas and electric hot water heaters was 275 therms and 4000 kWh (136.5 therms) respectively. It was also assumed that half of gas water heaters are located in conditioned areas and that all electric water heaters are located in conditioned areas. Therefore, electric water heaters will produce the same internal loads as gas water heaters. For the DOE-2 analysis, it was assumed that standby losses amounted to 90 therms/yr for gas water heaters and that half of the standby losses are conductive. Since half of the gas hot water heaters are located in conditioned spaces, 22.5 therms/yr is the sensible load from standby losses.

The energy used to heat hot water is calculated from the product of water use, specific heat of water and water temperature change. We assumed 39 gallons per day per household for water consumption and a delta temperature of 80°F. Since the specific heat of water is 8.3 Btu/gal/ºF, the heat energy needed to raise the temperature of 39 gallons of water per day by 80ºF is 95 therms/yr. If 10% of this heat energy appears as sensible heat, then 9.5 therms/yr will appear as sensible heat energy. Most of the sensible heat energy resulting from this heat energy added to incoming cold water is lost to the outside when this water is sent down the drain. Therefore, the total sensible heat energy input is 32 therms/yr.

The latent heat load from water use is more difficult to estimate. Hot water is used for showers, baths, and hand, dish, and clothes washing. The greatest contribution to latent heat production will probably be from shower usage. Much of this latent load is likely to be vented through natural or mechanical ventilation. It was assumed that 5% of the hot water energy is converted to latent heat. Therefore, .05 x 95 therms/yr = 4.75 therms/yr is the latent load from hot water use.

Television and Miscellaneous

Televisions require about 10OW of electrical power input. Assuming that they operate for 2000 hours per year per set, the annual energy consumption is 200 kWh. If we also assume that only one set is in operation per household for these 2000 hours, then 200 kWh/yr is the energy use per household. Miscellaneous appliances are assumed to use 300 kWh/yr.

Table D.a summarizes the sensible and latent loads from people, lighting, and appliances. These loads are applicable to the ranch house prototype. As noted earlier, for other prototypes, the lighting energy use most be scaled up or down for the appropriate floor areas. The following formula can be used to calculate the sensible internal load as a function of floor space area (Area) expressed in square feet:

$$\text{Sensible internal load (kWh)} = 4614 + 1386\ (\text{Area})/1540$$

Table D.a Estimated Average Annual Internal Loads For Residences

Use	Saturation	Annual Energy Use	% Indoors	Sensible Load	Latent Load
New Refrigerator	1.0	1125 kWh	100	1125 kWh	0
Old Refrigerator	0.15	1600 kWh	15	35 kWh	0
Freezer	0.45	950 kWh	50	214 kWh	0
Range gas	0.19	60 therms	100	805 kWh	415 kWh
electric	0.78	1200 kWh			
Hot Water gas	0.37	275 therms	50	940 kWh	140 kWh
electric	0.59	1285 kWh	100		
Dryer electric	0.70	900 kWh	10	63 kWh	0
gas	0.08	500 kWh	10	4 kWh	
Television	1.0	100 W	100	200 kWh	0
Miscellaneous	1.0	-	100	300 kWh	0
Lighting	1.0	1 kWh/ft^2	90	1386 kWh	0
People	3.2	-	-	930 kWh	735 kWh
Totals	-	-	-	6000 kWh/yr	1290 kWh/yr