# Appendix C-1:  Technology data

This appendix contains information on the technology costs, efficiencies, lifetimes, energy savings, and costs of conserved energy (CCEs) for the various technologies and policies considered in the analysis.

Residential HVAC is treated separately, because of its complexity. The tables for Residential HVAC are first, followed by residential non-HVAC, followed by the commercial sector. Assumptions behind the technology data vary between the residential HVAC, residential non-HVAC, and commercial end-uses. A general description of the assumptions underlying the data for residential HVAC end-uses can found in the pages preceding Table C-1.1.mod. Specific assumptions for residential non-HVAC and commercial end-uses are described in the introductions to Table C-1.6 and Table C-1.7, respectively. Those assumptions which are common to all end-uses are described below.

*Economic Calculations*

All costs are presented in 1997 dollars. Costs of conserved energy (CCE) are presented in 1997 dollars per million site Btu (site MBtu). Costs from the original sources were adjusted to 1997 dollars, if necessary, using the implicit GDP deflator (Bureau of Economic Analysis 1998). The cost of conserved energy is calculated using a 7% real discount rate.

*Energy Calculations*

All energy data (annual household energy consumptions and energy savings) are in million Btu (MBtu) of site energy. Unit energy savings or percent savings are calculated relative to the new units in the year 2000 (frozen efficiency).[1] Mandatory programs such as equipment standards and building codes are assumed to be implemented before the non-mandatory programs, in order to avoid double counting the energy savings. Thus, the energy saved by non-mandatory programs (e.g., ENERGY STAR) are calculated relative to an adjusted baseline consumption, which reflects the implementation of all applicable mandatory programs. The costs of non-mandatory programs are also adjusted to account for the mandatory programs. Further details can be found in the tables in this appendix.

[1] See Appendix D for a detailed explanation of the frozen efficiency baseline and how it is used in the analysis.

# Index to the Tables in Appendix C-1

**Introduction to the Residential HVAC Technology Tables (Tables C-1.1.mod – C-1.5)**

*Economic Calculations*

All costs are presented in 1997 dollars. Costs of conserved energy (CCE) are presented in 1997 dollars per million site Btu (site MMBtu). Costs from the original sources were adjusted to 1997 dollars, if necessary, using the implicit GDP deflator (Bureau of Economic Analysis 1998). The cost of conserved energy is calculated using a 7% real discount rate.

*Energy Calculations*

All energy data (annual household energy consumptions and energy savings) are in million Btu (MMBtu) of site energy. Energy savings are calculated relative to the a typical new unit in 2000 (frozen efficiency baseline). Appendix D details the role of the frozen efficiency baseline in the analysis.

*Residential Building Stocks and Starts*

Residential buildings were divided into "new" and "existing" categories for purposes of this analysis. "New" homes are defined as all homes built during the forecast period (2000-2020), including homes that were built to replace existing homes that decayed during that period. "Existing" homes are defined as all homes that were built prior to the year 2000. The stock of existing homes decreases over time, due to natural decay[1]. For this analysis, we used the CEF-NEMS reference case forecast of housing starts and stocks, by house type and HVAC equipment type, from 2000-2020. All house types (single-family, multifamily, and manufactured homes) are addressed in the analysis, although some policies are only applied to a segment of the existing home market (see the Market Segmentation discussion below).

*Equipment Retirement (Replacement)*

We calculated annual retirements (replacements) of HVAC equipment using several equations derived by LBNL for this analysis. We analyzed the retirement of the stock of equipment existing in 2000 separately from the retirement of equipment that was added or replaced in 2000 or later. This is because we do not know the age distribution of the existing stock, whereas we are able to keep track of the age of equipment that was replaced or added during the forecast period. In each case, we base the retirement calculations on the minimum, maximum, and average life expectancies of the equipment. The average life expectancy of residential HVAC equipment was estimated to be the simple average of the minimum and maximum life expectancies (from a NEMS input file). Appendix C-1 documents the average equipment lifetimes used in this analysis. We estimated that the maximum and minimum lifetimes of each HVAC equipment type would be 4/3 and 2/3, respectively, of the average lifetime. The formulas we used in the case of existing equipment in 2000 and in the case of equipment that was replaced or added in 2000 or later can be found in Appendix D.

[1] We used a 0.4% per annum decay rate for residential buildings, which is a stock-weighted average of residential building decay rates for the three house types (Single-family, Multifamily, and Manufactured Housing) from the NEMS model.

*Market Segmentation*

In some cases, a particular measure was not cost-effective in the "average" home. For example, ENERGY STAR condensing gas furnaces have a high incremental cost and may require modifications when installed in existing homes that make them cost-effective only in colder climates, and/or in homes with higher than average energy consumption. We applied such technologies only to the market segments that were cost effective, which invariably had a higher consumption than the average consumption for the entire market. The baseline and measure energy use for these technologies reflect the high energy consumption of the market segment. In each case where we segmented the market, we estimated the market share for that segment and restricted the program penetration to be less than the market share. Where technologies already have a substantial market saturation (e.g., condensing gas furnaces, which are estimated to have about a 25% market saturation in 1999), we subtracted the current saturation from the maximum program penetration. That is, the energy saved by each program only includes the penetration of technologies that is over and above the penetration in 1999. Note that we only segmented the market in the existing homes analysis, not in the new homes analysis. Tables C-1.2.mod and C-1.2.adv describe the market segments assumed for each policy in the existing homes analysis.

*Guide to the Information in Tables C-1.1.mod through C-1.5*

<u>Existing Homes</u>
The technology data for the existing home policy measures, including efficiencies, energy savings, measure lifetimes, costs, and costs of conserved energy (CCEs) can be found in Tables C-1.1.mod and C-1.1.adv. Additional details of the policies, including market segmentation and average energy consumptions for the base case and policy case, are documented in Tables C-1.2.mod and C-1.2.adv.

<u>New Homes</u>
Average costs, energy savings, lifetimes, and CCEs for the new home policies are in Tables C-1.3.mod and C-1.3.adv. The values in Tables C-1.3 are aggregated in some cases over several different efficiency levels or equipment types. A more disaggregated presentation of the costs and energy savings of each policy can be found in Tables C-1.4.mod and C-1.4.adv. An additional table, Table C-1.5, documents the procedure we used to calculate the average lifetime of policies that affect the whole house and that implement a variety of measures, all of which have different lifetimes. The average lifetimes documented in Table C-1.5 were used for the ENERGY STAR new homes, tax credit for new homes, and Building America programs.

**Table C-1.1.mod: Technology Data for Existing Residential Building HVAC End-Uses, Moderate Case**

| Fuel | End Use | Equipment Type[g] | Policy | Policy Period[h] | Baseline Efficiency[a] | Measure Efficiency | Efficiency Notes | Energy Savings[b] (MMBtu/yr) | Equipment Lifetime[c] (years) | Incremental Cost[d] (1997$) | Cost Notes | Cost of Conserved Energy[e] 2010 ($/MMBtu) | 2020 ($/MMBtu) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elec | Space Heating | ASHP | NAECA standard 2006 | 2006-2020 | 7.17 HSPF | 7.4 HSPF | 1 | 0.45 | 12 | $53 | 15 | $14.80 | $14.80 |
| | | | ENERGY STAR HVAC | 2000-2005 | 7.17 HSPF | 7.4 HSPF | 2 | 0.95 | 12 | $156 | 16 | $20.72 | NA |
| | | | ENERGY STAR HVAC | 2006-2020 | 7.4 HSPF | 8.5 HSPF | 3 | 1.93 | 12 | $195 | 16 | $12.71 | $12.71 |
| | | | Tax credit ASHP (10%) | 2000-2001 | 7.17 HSPF | 9.0 HSPF | 4 | 3.12 | 12 | $354 | 17 | $14.28 | NA |
| | | | Tax credit ASHP (20%) | 2000-2003 | 7.17 HSPF | 9.0 HSPF | 4 | 3.12 | 12 | $457 | 18 | $18.42 | NA |
| | | | average, all programs | | | | | | | | | $15.96 | $14.12 |
| | | Resistance | no policies for moderate | - | COP = 1 | - | 5 | - | - | - | 5 | - | - |
| | | | **Elec Heating avg** | | | | | | | | | **$15.96** | **$14.12** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $21.15 | $20.45 |
| Elec | Space Cooling | ASHP | NAECA standard 2006 | 2006-2020 | 10.89 SEER | 12 SEER | 1 | 0.76 | 12 | $89 | 15 | $14.80 | $14.80 |
| | | | ENERGY STAR HVAC | 2000-2005 | 10.89 SEER | 12 SEER | 2 | 2.34 | 12 | $128 | 16 | $20.72 | NA |
| | | | ENERGY STAR HVAC | 2006-2020 | 12 SEER | 14 SEER | 3 | 1.64 | 12 | $150 | 16 | $12.71 | $12.71 |
| | | | Tax credit, level 1 | 2000-2001 | 10.89 SEER | 13.5 SEER | 4 | 2.45 | 12 | $189 | 17 | $9.71 | NA |
| | | | Tax credit, level 2 | 2000-2003 | 10.89 SEER | 15 SEER | 4 | 3.47 | 12 | $345 | 18 | $12.52 | NA |
| | | | average, all programs | | | | | | | | | $14.19 | $14.14 |
| | | CAC | NAECA standard 2006 | 2006-2020 | 10.42 SEER | 12 SEER | 6 | 1.00 | 12 | $132 | 19 | $16.49 | $16.49 |
| | | | ENERGY STAR HVAC | 2000-2005 | 10.42 SEER | 12 SEER | 7 | 1.86 | 12 | $263 | 20 | $17.78 | NA |
| | | | ENERGY STAR HVAC | 2006-2020 | 12 SEER | 14 SEER | 7 | 1.76 | 12 | $258 | 21 | $18.49 | $18.49 |
| | | | Tax credit, level 1 | 2000-2001 | 10.42 SEER | 13.5 SEER | 8 | 3.23 | 12 | $444 | 22 | $17.32 | NA |
| | | | Tax credit, level 2 | 2000-2003 | 10.42 SEER | 15 SEER | 8 | 4.32 | 12 | $657 | 23 | $19.15 | NA |
| | | | average, all programs | | | | | | | | | $16.86 | $16.83 |
| | | RAC | NAECA standard 2001 | 2001-2009 | 9.1 EER | 9.7 EER | 9 | 0.17 | 15.5 | $17 | 24 | $10.39 | NA |
| | | | NAECA standard 2010 | 2010-2020 | 9.1 EER | 10.5 EER | 9 | 0.39 | 15.5 | $65 | 24 | NA | $18.25 |
| | | | ENERGY STAR HVAC I | 2000 only | 9.1 EER | 10.0 EER | 10 | 0.56 | 15.5 | $39 | 25 | $7.40 | NA |
| | | | ENERGY STAR HVAC II | 2001-2009 | 9.7 EER | 11.3 EER | 11 | 0.88 | 15.5 | $166 | 25 | $20.32 | NA |
| | | | ENERGY STAR HVAC III | 2010-2020 | 10.5 EER | 12.2 EER | 11 | 0.81 | 15.5 | $135 | 25 | NA | $17.96 |
| | | | average, all programs | | | | | | | | | $13.35 | $17.46 |
| | | | **Elec Cooling avg** | | | | | | | | | **$16.10** | **$16.59** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $21.15 | $20.45 |
| Gas | Space Heating | Furnace | NAECA standard | - | 81.7 AFUE | - | 12 | - | 23.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2009 | 81.7 AFUE | 90 AFUE | 13 | 11.36 | 23.5 | $769 | 26 | $5.95 | NA |
| | | | ENERGY STAR HVAC | 2010-2020 | 81.7 AFUE | 90 AFUE | 13 | 11.36 | 23.5 | $577 | 27 | $4.47 | $4.47 |
| | | Boiler | NAECA standard | - | 80.0 AFUE | - | 12 | - | 22.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2009 | 80.0 AFUE | 86 AFUE | 14 | 7.13 | 22.5 | $457 | 28 | $5.73 | NA |
| | | | ENERGY STAR HVAC | 2010-2020 | 80.0 AFUE | 86 AFUE | 14 | 7.13 | 22.5 | $342 | 29 | $4.30 | $4.30 |
| | | | **Gas Heating avg** | | | | | | | | | **$5.73** | **$4.84** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $5.82 | $5.35 |

**Table C-1.1.mod, continued**

| Fuel | End Use | Equipment Type[g] | Policy | Applicable Time Period | Baseline Efficiency[a] | Measure Efficiency | Efficiency Notes | Energy Savings[b] (MMBtu/yr) | Equipment Lifetime[c] (years) | Incremental Cost[d] (1997$) | Cost Notes | Cost of Conserved Energy[e] 2010 ($/MMBtu) | 2020 ($/MMBtu) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil | Space Heating | Furnace | NAECA standard | - | 81.9 AFUE | - | 12 | - | 23.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 81.9 AFUE | 90 AFUE | 13 | 13.05 | 23.5 | $769 | 30 | $5.18 | $5.18 |
| | | Boiler | NAECA standard | - | 80.4 AFUE | - | 12 | - | 22.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 80.4 AFUE | 86 AFUE | 14 | 8.32 | 22.5 | $522 | 31 | $5.61 | $5.61 |
| | | | **Oil Heating avg** | | | | | | | | | **$5.41** | **$5.36** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $7.65 | $7.77 |
| LPG | Space Heating | Furnace | NAECA standard | - | 82.2 AFUE | - | 12 | - | 23.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 82.2 AFUE | 90 AFUE | 13 | 8.33 | 23.5 | $769 | 32 | $8.12 | $8.12 |
| | | | **LPG Heating avg** | | | | | | | | | **$8.12** | **$8.12** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $12.15 | $12.46 |

a The baseline efficiency is the efficiency of the equipment that is replaced by the program in the stated time period. Most of the time, the base case efficiency is the average efficiency of replacement equipment purchased in 2000 (from an output file of the CEF-NEMS reference case). However, for programs that get implemented after a future NAECA standard takes effect, the baseline efficiency is assumed to be equal to the new NAECA standard for purposes of calculating the energy savings due to the program. This is done to avoid double-counting the savings due to the standards.

b Annual energy savings (site MMBtu/house-yr) is simply the difference between the annual energy consumptions for the baseline and the measure, from Table C-1.2.mod.

c Equipment lifetimes are averages of the minimum and maximum life expectancies from an input file to the CEF-NEMS model.

d Average incremental measure cost to the consumer, per house. The measure cost is relative to the cost of a baseline efficiency unit, described in Note a. Costs are in 1997 dollars and were inflated to 1997 dollars where necessary by using the GDP deflator (BEA 1998). The incremental cost of a heat pump measure, which saves both heating and cooling energy, is split up between the heating and cooling end-uses according to the amount of energy saved by the measure for each end-use.

e Cost of conserved energy (CCE) is presented for two time periods. The "2010" CCE is the average CCE for all equipment replacements due to the program(s) that occurred during the 2000-2010 time period. The "2020" CCE is the average CCE for all equipment replacements due to each program that occurred during the 2000-2020 period. If the policy ends before 2010, no 2020 CCE is reported. For equipment types with more than one program, the "average, all programs" CCE is presented; it is the average of the individual program CCEs, weighted by the sum of the energy savings due to each program during the time period. The CCE for NAECA standards is calculated relative to the average efficiency of a replaced unit in 2000, from an output file of the CEF-NEMS reference case. The CCEs for the tax credit and ENERGY STAR programs are relative to the average efficiency of a replaced unit in 2000, if the program replacement occurs between 2000 and the year before a future standard takes effect. If the program replacement occurs in the same year that a future standard takes effect, or in subsequent years, the CCE for that replacement is relative to a unit of efficiency equal to the standard in effect in that year. The discount rate is 7% real.
In addition, the CCE is presented as an average for all programs affecting a given equipment type. It is an energy savings weighted average; that is, the program CCEs are weighted by the total energy saved by the policy during the 2000-2010 or 2000-2020 time periods.

f Average residential fuel cost is the average price of fuel in the residential sector in 2010 and 2020, from a preliminary integrated NEMS run of our Moderate case.
These prices were used to compare to the measure CCEs in order to check that the CCEs were lower than the price of fuel in each time period, thus could be included in the scenario.

g Key to the Equipment type codes: ASHP - air source heat pump; Resistance - electric resistance heaters (e.g., baseboard, furnace, etc.); CAC - central air conditioner; RAC - room air conditioner.

h The years during which the policy is assumed to be in effect; see Table B-1.1.mod for details on policy periods.

**Notes**

1 The baseline efficiency is the average efficiency of replacement equipment purchased in 2000 (from an output file of the CEF-NEMS reference case). We assume the new NAECA standard for heat pumps will take effect on January 1, 2006 and the minimum efficiencies for cooling and heating will be 12 SEER and 7.4 HSPF, respectively.

**Table C-1.1.mod Notes, continued**

2 We assume the average efficiency of an ENERGY STAR heat pump from 2000-2005 is 12 SEER (the minimum SEER currently required by the program). We assume the average heating efficiency of an ENERGY STAR heat pump from 2000-2005 is 7.4 HSPF, which is the same efficiency as the future heat pump standard - some ENERGY STAR heat pumps have lower HSPFs, and some have higher HSPFs than this. The base case efficiency prior to the 2006 standard is the average efficiency of a new unit in 2000 from an output file of the CEF-NEMS reference case.

3 When the new heat pump standard takes effect on January 1, 2006, we assume that EPA will increase the ENERGY STAR efficiency level for heat pumps to 14 SEER, based on discussion with Steve Offutt of the U.S. EPA (Offutt 1999). We estimated the average heating efficiency of 14 SEER heat pumps to be around 8.5 HSPF. The base case efficiency from 2006-2020 is the efficiency of the 2006 NAECA standard. That is, the energy saved by going from the current frozen efficiency base case to 12 SEER is attributed in the analysis to the NAECA standard, and the energy saved by going from 12 SEER to 14 SEER is attributed to the ENERGY STAR program.

4 Tax credit program efficiencies (13.5 SEER/9.0 HSPF and 15 SEER/9.0 HSPF) are those proposed by the Treasury Department (US DOT 1999). The Moderate case applicable time period is the same as proposed by the Treasury Department (US DOT 1999) - see Table B-1.1.mod for more details.)

5 There are no policies affecting electric resistance heating equipment in the Moderate case.

6 The baseline efficiency is the average efficiency of replacement equipment purchased in 2000 (from an output file of the CEF-NEMS reference case). We assume the new NAECA standard for CACs will take effect on January 1, 2006 and the minimum efficiencies will be 12 SEER.

7 We assume the average efficiency of an ENERGY STAR CAC from 2000-2005 is 12 SEER (the minimum SEER currently required by the program). Starting in 2006, when the new NAECA standard for CACs takes effect, we assume that EPA will increase the ENERGY STAR efficiency level for CACs to 14 SEER, based on discussion with Steve Offutt of the U.S. EPA (Offutt 1999). The base case efficiency from 2006-2020 is the efficiency of the 2006 NAECA standard.

8 Tax credit program efficiencies (13.5 SEER and 15 SEER) are those proposed by the Treasury Department (US DOT 1999). The Moderate case applicable time period is the same as proposed by the Treasury Department (US DOT 1999) - see Table B-1.1.mod for more details.)

9 A new room A/C standard will come into effect on October 1, 2000. The CEF-NEMS reference case includes this standard, but delays the start date to Jan 1, 2001. To be consistent with the reference case, we also began the standard on Jan 1, 2001 in the Moderate and Advanced cases. Federal standards for room A/C vary by equipment capacity. We used an estimated average efficiency weighted by product class shipments of 9.7 EER for the October 2000 standard. In addition, we estimated that a future standard for RAC would take effect in 2010 at 10.5 EER (on average over the most common capacities).

10 The efficiency of room air conditioners varies by the capacity of the unit. We assumed the average efficiency of a current ENERGY STAR room air conditioner is 9.98 EER. This is a simple average of the EERs of the least-efficient room air conditioners currently listed on the U.S. EPA ENERGY STAR website directory of ENERGY STAR room A/C products (US EPA 1999b). We included only units with the most common capacities ( <6000 Btu/hr up to 19,999 Btu/hr). The average efficiency is a conservative estimate, since most of the ENERGY STAR products listed are more efficient than the least-efficient products in the directory. The baseline efficiency is the average efficiency of a unit bought to replace an existing RAC unit in 2000 (9.1 EER, from an output file of the CEF-NEMS reference case). This measure applies only in the year 2000, because we assume that when the new RAC standard enters into force in 2001, the ENERGY STAR level will be increased. See Note 11.

11 When the new room A/C standard takes effect on January 1, 2001, we assume DOE will increase the ENERGY STAR level by the same percentage above the 2001 standard as the current ENERGY STAR level is above the current standard. On average, the efficiency of the least-efficient ENERGY STAR RACs currently listed on the ENERGY STAR website (US EPA 1999b) is 14.1% higher than the current NAECA standard. (We estimated this by taking a simple average of the percent improvement in EER over the NAECA standard (listed on the web site for each product) for the least-efficient products listed that had a capacity between <6000 Btu/hr and 19,999 Btu/hr). So, the energy savings is 14.1% from 2001 until 2010, when a new NAECA standard is assumed to take effect. From 2010-2020, we assume the ENERGY STAR level will also be set at 14.1% higher than the standard in effect during that time. The baseline efficiency for these measures is the standard in effect during the applicable time period.

12 There are assumed to be no new NAECA standards for furnaces or boilers during the forecast time period.

13 The ENERGY STAR efficiency for gas, oil, and LPG furnaces is assumed to remain at the current level (90 AFUE) throughout the forecast period. The baseline efficiency is the average efficiency of units bought in 2000 to replace retired units (81.7 AFUE for gas, 82.2 AFUE for LPG, and 81.9 AFUE for oil furnaces), from an output file of the CEF-NEMS reference case.

14 The ENERGY STAR efficiency for gas and oil boilers is assumed to remain at the current level (86 AFUE) throughout the forecast period. The baseline efficiency is the average efficiency of units bought in 2000 to replace retired units (80.0 AFUE for gas and 80.4 AFUE for oil boilers), from an output file of the CEF-NEMS reference case.

15 LBNL estimate of mature market costs for a 12 SEER/7.4 HSPF standard. We assume the incremental cost of a 12 SEER/7.4 HSPF unit compared to the baseline efficiency will be half of current market costs. Current market costs of heat pumps are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). The total incremental cost of the heat pump was divided up between the heating and cooling end-uses according to the relative energy saved in heating and cooling. Costs assume one 3 ton unit per house.

**Table C-1.1.mod Notes, continued**

16 Costs based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990 dollars using the GDP inflator. Cost is a shipment weighted average over the most common product classes (from under 6 Btuh to 20 Btuh capacity), using 1989 shipments by product class from US DOE 1993b. Cost assumes a U.S. average of 1.51 room AC units per house (i.e., the average cost per unit was multiplied by 1.51 to get the cost per house of the standards measure). The average number of units in the U.S. is from a query of the 1990 RECS electronic database (US DOE 1993a); 1.51 units is the average (weighted using the RECS household weighting factor "nweight") number of room AC units in all house types in the U.S. that claim room A/C units as their primary cooling equipment.

17 Average current market cost of a 13.5 SEER heat pump relative to the cost of the average replaced unit in 2000. Source: same as note 15. The full incremental cost was used (i.e., the tax credit was not subtracted), and it was apportioned between heating and cooling according to the relative energy saved in each end-use.

18 Average current market cost of a 15 SEER heat pump relative to the cost of the average replaced unit in 2000. Source: same as note 15. The full incremental cost was used (i.e., the tax credit was not subtracted), and it was apportioned between heating and cooling according to the relative energy saved in each end-use.

19 LBNL estimate of mature market costs for a 12 SEER standard. We assume the incremental cost of a 12 SEER unit compared to the frozen efficiency in 2000 (10.42 SEER from an output file of the CEF-NEMS reference case) will be half of current market costs. Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume one 3 ton unit per house.

20 Average current market costs for a 12 SEER unit relative to the average efficiency of a new unit bought in 2000 (10.42 SEER from an output file of the CEF-NEMS reference case). Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume a 3 ton unit.

21 LBNL estimate of incremental cost to go from the future standard of 12 SEER to the predicted future ENERGY STAR efficiency of 14 SEER. Costs are current market costs from a variety of data sources (see Note 20), for a 3 ton unit.

22 Average current market cost of a 13.5 SEER CAC relative to the cost of the average replaced unit in 2000. Source: same as note 3. This is the full incremental cost (i.e., the tax credit was not subtracted).

23 Average current market cost of a 15 SEER CAC relative to the cost of the average replaced unit in 2000. Source: same as note 20. This is the full incremental cost (i.e., the tax credit was not subtracted).

24 Costs based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990 dollars using the GDP inflator. Cost is a shipment weighted average over the most common product classes (from under 6 Btuh to 20 Btuh capacity), using 1989 shipments by product class from US DOE 1993b. Cost assumes a U.S. average of 1.51 room AC units per house (i.e., the average cost per unit was multiplied by 1.51 to get the cost per house of the standards measure). The average number of units in the U.S. is from a query of the 1990 RECS electronic database (US DOE 1993a); 1.51 units is the average (weighted using the RECS household weighting factor "nweight") number of room AC units in all house types in the U.S. that claim room A/C units as their primary cooling equipment.

25 Costs based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990 dollars using the GDP inflator. Cost assumes an average of 1.67 room AC units per house (i.e., the average cost per unit was multiplied by 1.67 to get the cost per house of the ENERGY STAR measures). 1.67 units represents the average number of room A/C units per house in Single-family and Manufactured Homes located in the South and that claim room AC as their primary cooling equipment. We selected only SF and MH houses in the South because we asssumed that the ENERGY STAR RAC program would only be marketed to owners of these types of homes in the South (see Table C-1.2.mod). The average number of units is from a query of the 1990 RECS electronic database (US DOE 1993a). The costs are incremental to the cost of the NAECA standard valid during the program time period. That is, the incremental cost of an ENERGY STAR room AC in 2000 is relative to the cost of a room AC that just meets the standard valid in the year 2000; the incremental cost of an ENERGY STAR room AC from 2001-2009 is relative to the cost of a room AC that just meets the October, 2000 standard (assumed to take effect in January of 2001), and so on.
Note: the incremental cost of ENERGY STAR RAC in 2010-2020 is based on the US DOE 1993b, but was reduced by 60% to account for technological innovations that will happen by 2010 to reduce the cost of high-efficiency RACs. These technologies may include microchannel heat exchangers already developed by Modine, or other technologies.

**Table C-1.1.mod Notes, continued**

26 This is the incremental cost to go from an 81.7 AFUE gas furnace to a 90 AFUE gas furnace. This cost assumes an input capacity of 75 MBtuh, includes installation, and is from Jakob 1994, p. G-24, G-27. The Jakob costs are actually for units with AFUE range of 80-82 or 89-92 AFUE, so they may slightly overestimate the cost to go from 81.7 to 90 AFUE. The Jakob incremental cost is composed of $230 for installation and $477 for equipment, in 1993 dollars. The Jakob costs were inflated to 1997 dollars using the GDP inflator. The installation cost is higher for a 90 AFUE furnace to account for the installation of a sidewall vent. This cost is used for the 2000-2009 period only.

27 Starting in 2010, the incremental cost was assumed to be 25% lower than the cost prior to 2010, because increased supply and demand of condensing furnaces will bring down the prices.

28 Incremental cost to go from an 80 AFUE to an 86 AFUE gas boiler of output capacity 80 Mbtuh. Costs include installation and are from Johnson (1994), p.67. 80 AFUE is the average efficiency of a unit bought in 2000 to replace a retired unit, from an output file of the CEF-NEMS reference case. Costs were inflated to 1997 dollars using the GDP inflator. This cost is used during the 2000-2009 period only.

29 Starting in 2010, the incremental cost was assumed to be 25% lower than the cost prior to 2010, because increased supply and demand of ENERGY STAR boilers will bring down the prices.

30 Incremental installed cost to go from an 81.9 AFUE to a 90 AFUE oil furnace was assumed to be the same as the incremental cost of the 90 AFUE gas furnace. No other cost data were available. The cost in the table applies to the entire 2000-2020 period; the cost of ENERGY STAR oil furnaces was not assumed to decrease significantly after 2010.

31 Incremental cost to go from an 80.4 AFUE to an 86 AFUE oil boiler of output capacity 80 Mbtuh. Costs include installation and are from Johnson (1994), p.67. 80.4 AFUE is the average efficiency of a unit bought in 2000 to replace a retired unit, from an output file of the CEF-NEMS reference case. Costs were inflated to 1997 dollars using the GDP inflator. The cost in the table applies to the entire 2000-2020 period; the cost of ENERGY STAR oil boilers was not assumed to decrease significantly after 2010.

32 The incremental cost for LPG furnaces was assumed to be the same as for natural gas furnaces. However, the cost of LPG furnaces remains the same during the 2000-2020 period. We assumed the cost of condensing LPG furnaces would not decrease significantly during the forecast period.

**Table C-1.1.adv: Technology Data for Existing Residential Building HVAC End-Uses, Advanced Case**

| Fuel | End Use | Equipment Type[g] | Policy | Policy Period[h] | Baseline Efficiency[a] | Measure Efficiency | Efficiency Notes | Energy Savings[b] (MMBtu/yr) | Equipment Lifetime[c] (years) | Incremental Cost[d] (1997$) | Cost Notes | Cost of Conserved Energy[e] 2010 ($/MMBtu) | 2020 ($/MMBtu) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elec | Space Heating | ASHP | NAECA standard 2006 | 2006-2020 | 7.17 HSPF | 7.4 HSPF | 1 | 0.45 | 12 | $53 | 15 | $14.80 | $14.80 |
| | | | ENERGY STAR HVAC | 2000-2005 | 7.17 HSPF | 7.4 HSPF | 2 | 0.95 | 12 | $156 | 16 | $20.72 | NA |
| | | | ENERGY STAR HVAC | 2006-2020 | 7.4 HSPF | 8.5 HSPF | 3 | 1.59 | 12 | $147 | 17 | $11.61 | $11.61 |
| | | | Tax credit ASHP (10%) | 2000-2003 | 7.17 HSPF | 9.0 HSPF | 4 | 2.58 | 12 | $307 | 18 | $14.95 | NA |
| | | | Tax credit ASHP (20%) | 2000-2005 | 7.17 HSPF | 9.0 HSPF | 4 | 3.12 | 12 | $380 | 19 | $15.31 | NA |
| | | | Tax credit ASHP (20%) | 2006-2007 | 7.4 HSPF | 9.0 HSPF | 4 | 2.50 | 12 | $265 | 20 | $15.24 | NA |
| | | | average, all programs | | | | | | | | | $15.12 | $13.40 |
| | | Resistance | Switch to frozen effic. ASHP | 2000-2005 | COP = 1 | 7.17 HSPF | 5 | 7.80 | 12 | $600 | 21 | $9.69 | NA |
| | | | Switch to 2006 standard ASHP | 2006-2020 | COP = 1 | 7.4 HSPF | 5 | 8.02 | 12 | $600 | 22 | $9.42 | $9.42 |
| | | | **Elec Heating avg** | | | | | | | | | **$12.90** | **$11.84** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $23.41 | $22.05 |
| Elec | Space Cooling | ASHP | NAECA standard 2006 | 2006-2020 | 10.89 SEER | 12 SEER | 1 | 0.76 | 12 | $89 | 15 | $14.80 | $14.80 |
| | | | ENERGY STAR HVAC | 2000-2005 | 10.89 SEER | 12 SEER | 2 | 2.34 | 12 | $128 | 16 | $20.72 | NA |
| | | | ENERGY STAR HVAC | 2006-2020 | 12 SEER | 14 SEER | 3 | 1.33 | 12 | $112 | 17 | $11.61 | $11.61 |
| | | | Tax credit ASHP (10%) | 2000-2003 | 10.89 SEER | 13.5 SEER | 4 | 1.99 | 12 | $236 | 18 | $14.95 | NA |
| | | | Tax credit ASHP (20%) | 2000-2005 | 10.89 SEER | 15 SEER | 4 | 3.47 | 12 | $422 | 19 | $15.31 | NA |
| | | | Tax credit ASHP (20%) | 2006-2007 | 12 SEER | 15 SEER | 4 | 2.56 | 12 | $226 | 20 | $15.24 | NA |
| | | | average, all programs | | | | | | | | | $13.55 | $13.55 |
| | | CAC | NAECA standard 2006 | 2006-2020 | 10.42 SEER | 12 SEER | 6 | 1.00 | 12 | $132 | 23 | $16.49 | $16.49 |
| | | | ENERGY STAR HVAC | 2000-2005 | 10.42 SEER | 12 SEER | 7 | 1.86 | 12 | $263 | 24 | $17.78 | NA |
| | | | ENERGY STAR HVAC | 2006-2020 | 12 SEER | 14 SEER | 7 | 1.42 | 12 | $193 | 25 | $18.49 | $18.49 |
| | | | Tax credit CAC (10%) | 2000-2003 | 10.42 SEER | 13.5 SEER | 8 | 3.23 | 12 | $444 | 26 | $17.32 | NA |
| | | | Tax credit CAC (20%) | 2000-2005 | 10.42 SEER | 15 SEER | 8 | 4.32 | 12 | $657 | 27 | $19.15 | NA |
| | | | Tax credit CAC (20%) | 2006-2007 | 12 SEER | 15 SEER | 8 | 3.75 | 12 | $374 | 28 | $19.18 | NA |
| | | | average, all programs | | | | | | | | | $17.32 | $16.68 |
| | | RAC | NAECA standard 2001 | 2001-2009 | 9.1 EER | 9.7 EER | 9 | 0.17 | 15.5 | $17 | 29 | $10.39 | NA |
| | | | NAECA standard 2010 | 2010-2020 | 9.1 EER | 10.5 EER | 9 | 0.39 | 15.5 | $65 | 29 | NA | $18.25 |
| | | | ENERGY STAR HVAC | 2000 only | 9.1 EER | 10.0 EER | 10 | 0.54 | 15.5 | $38 | 30 | $7.48 | NA |
| | | | ENERGY STAR HVAC | 2001-2009 | 9.7 EER | 11.3 EER | 11 | 0.85 | 15.5 | $162 | 30 | $20.52 | NA |
| | | | ENERGY STAR HVAC | 2010-2020 | 10.5 EER | 12.2 EER | 11 | 0.79 | 15.5 | $132 | 30 | NA | $18.14 |
| | | | average, all programs | | | | | | | | | $14.27 | $17.63 |
| | | | **Elec Cooling avg** | | | | | | | | | **$16.53** | **$16.43** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $23.41 | $22.05 |
| Gas | Space Heating | Furnace | NAECA standard | - | 81.7 AFUE | - | 12 | - | 23.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 81.7 AFUE | 90 AFUE | 13 | 7.27 | 23.5 | $464 | 31 | $5.61 | $5.61 |
| | | Boiler | NAECA standard | - | 80.0 AFUE | - | 12 | - | 22.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 80.0 AFUE | 86 AFUE | 14 | 4.23 | 22.5 | $274 | 32 | $5.79 | $5.79 |
| | | | **Gas Heating avg** | | | | | | | | | **$5.65** | **$5.65** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $6.73 | $6.26 |

**Table C-1.1.adv, continued**

| Fuel | End Use | Equipment Type[g] | Policy | Applicable Time Period | Baseline Efficiency[a] | Measure Efficiency | Efficiency Notes | Energy Savings[b] (MMBtu/yr) | Equipment Lifetime[c] (years) | Incremental Cost[d] (1997$) | Cost Notes | Cost of Conserved Energy[e] 2010 ($/MMBtu) | 2020 ($/MMBtu) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil | Space Heating | Furnace | NAECA standard | - | 81.9 AFUE | - | 12 | - | 23.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 81.9 AFUE | 90 AFUE | 13 | 9.13 | 23.5 | $464 | 33 | $4.47 | $4.47 |
| | | Boiler | NAECA standard | - | 80.4 AFUE | - | 12 | - | 22.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 80.4 AFUE | 86 AFUE | 14 | 4.90 | 22.5 | $313 | 34 | $5.73 | $5.73 |
| | | | **Oil Heating avg** | | | | | | | | | **$5.15** | **$5.00** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $8.62 | $8.80 |
| LPG | Space Heating | Furnace | NAECA standard | - | 82.2 AFUE | - | 12 | - | 23.5 | - | 12 | - | - |
| | | | ENERGY STAR HVAC | 2000-2020 | 82.2 AFUE | 90 AFUE | 13 | 5.15 | 23.5 | $464 | 35 | $7.92 | $7.92 |
| | | | **LPG Heating avg** | | | | | | | | | **$7.92** | **$7.92** |
| | | | Avg Res'l Fuel Cost[f] | | | | | | | | | $12.90 | $12.58 |

a The baseline efficiency is the efficiency of the equipment that is replaced by the program in the stated time period. Most of the time, the base case efficiency is the average efficiency of replacement equipment purchased in 2000 (from an output file of the CEF-NEMS reference case). However, for programs that get implemented after a future NAECA standard takes effect, the baseline efficiency is assumed to be equal to the new NAECA standard for purposes of calculating the energy savings due to the program. This is done to avoid double-counting the savings due to the standards.

b Annual energy savings (site MMBtu/house-yr) is simply the difference between the annual energy consumptions for the baseline and the measure, from Table C-1.2.adv.

c Equipment lifetimes are averages of the minimum and maximum life expectancies from an input file to the CEF-NEMS model.

d Average incremental measure cost to the consumer, per house. The measure cost is relative to the cost of a baseline efficiency unit, described in Note a. Costs are in 1997 dollars and were inflated to 1997 dollars where necessary by using the GDP deflator (BEA 1998). The incremental cost of a heat pump measure, which saves both heating and cooling energy, is split up between the heating and cooling end-uses according to the amount of energy saved by the measure for each end-use.

e Cost of conserved energy (CCE) is presented for two time periods. The "2010" CCE is the average CCE for all equipment replacements due to the program(s) that occurred during the 2000-2010 time period. The "2020" CCE is the average CCE for all equipment replacements due to each program that occurred during the 2000-2020 period. If the policy ends before 2010, no 2020 CCE is reported. For equipment types with more than one program, the "average, all programs" CCE is presented; it is the average of the individual program CCEs, weighted by the sum of the energy savings due to each program during the time period. The CCE for NAECA standards is calculated relative to the average efficiency of a replaced unit in 2000, from an output file of the CEF-NEMS reference case. The CCEs for the tax credit and ENERGY STAR programs are relative to the average efficiency of a replaced unit in 2000, if the program replacement occurs between 2000 and the year before a future standard takes effect. If the program replacement occurs in the same year that a future standard takes effect, or in subsequent years, the CCE for that replacement is relative to a unit of efficiency equal to the standard in effect in that year. We use a real discount rate of 7% in the CCE calculations.
In addition, the CCE is presented as an average for all programs affecting a given equipment type. It is an energy savings weighted average; that is, the program CCEs are weighted by the total energy saved by the policy during the 2000-2010 or 2000-2020 time periods.

f Average residential fuel cost is the average price of fuel in the residential sector in 2010 and 2020, from a preliminary integrated NEMS run of our Advanced case. These prices were used to compare to the measure CCEs in order to check that the CCEs were lower than the price of fuel in each time period, thus could be included in the scenario.

g Key to the Equipment type codes: ASHP - air source heat pump; Resistance - electric resistance heaters (e.g., baseboard, furnace, etc.); CAC - central air conditioner; RAC - room air conditioner.

h The years during which the policy is assumed to be in effect; see Table B-1.1.adv for details on policy periods.

**Notes**

1 The baseline efficiency is the average efficiency of replacement equipment purchased in 2000 (from an output file of the CEF-NEMS reference case). We assume the new NAECA standard for heat pumps will take effect on January 1, 2006 and the minimum efficiencies for cooling and heating will be 12 SEER and 7.4 HSPF, respectively.

**Table C-1.1.adv Notes, continued**

2 We assume the average efficiency of an ENERGY STAR heat pump from 2000-2005 is 12 SEER (the minimum SEER currently required by the program). We assume the average heating efficiency of an ENERGY STAR heat pump from 2000-2005 is 7.4 HSPF, which is the same efficiency as the future heat pump standard - some ENERGY STAR heat pumps have lower HSPFs, and some have higher HSPFs than this. The base case efficiency prior to the 2006 standard is the average efficiency of a new unit in 2000 from an output file of the CEF-NEMS reference case.

3 When the new heat pump standard takes effect on January 1, 2006, we assume that EPA will increase the ENERGY STAR efficiency level for heat pumps to 14 SEER, based on discussion with Steve Offutt of the U.S. EPA (Offutt 1999). We estimated the average heating efficiency of 14 SEER heat pumps to be around 8.5 HSPF. The base case efficiency from 2006-2020 is the efficiency of the 2006 NAECA standard. That is, the energy saved by going from the current frozen efficiency base case to 12 SEER is attributed in the analysis to the NAECA standard, and the energy saved by going from 12 SEER to 14 SEER is attributed to the ENERGY STAR program.

4 Tax credit program efficiencies (13.5 SEER/9.0 HSPF and 15 SEER/9.0 HSPF) are those proposed by the Treasury Department (US DOT 1999).
The Advanced case policy period is assumed to be twice as long as was proposed by the Treasury Department (US DOT 1999) - see Table B-1.1.adv for more details.
The base case efficiency changes to the new NAECA standard efficiency (7.4 HSPF) when the standard takes effect in 2006.

5 In the Advanced case only, we include a policy assumed to be funded by lines charges that encourages replacing electric resistance heating equipment with electric heat pumps (see Table B-1.1.adv for more details on the policy). We assume that the replacement heat pump efficiency is equal to the frozen efficiency in 2000 until 2006, when the new NAECA standard takes effect. Beginning in 2006, we assume that the replacement efficiency is equal to the 2006 NAECA standard minimum efficiency. The baseline efficiency of electric resistance heaters is 100%, or a COP of 1, from an output file of the CEF-NEMS reference case. The measure efficiency (HSPF) can be converted to COP using the formula (COP = HSPF/3.412).

6 The baseline efficiency is the average efficiency of replacement equipment purchased in 2000 (from an output file of the CEF-NEMS reference case). We assume the new NAECA standard for CACs will take effect on January 1, 2006 and the minimum efficiency will be 12 SEER.

7 We assume the average efficiency of an ENERGY STAR CAC from 2000-2005 is 12 SEER (the minimum SEER currently required by the program). Starting in 2006, when the new NAECA standard for CACs takes effect, we assume that EPA will increase the ENERGY STAR efficiency level for CACs to 14 SEER, based on discussion with Steve Offutt of the U.S. EPA (Offutt 1999). The base case efficiency from 2006-2020 is the efficiency of the 2006 NAECA standard.

8 Tax credit program efficiencies (13.5 SEER and 15 SEER) are those proposed by the Treasury Department (US DOT 1999).
The Advanced case policy period is assumed to be twice as long as was proposed by the Treasury Department (US DOT 1999) - see Table B-1.1.adv for more details.
The base case efficiency changes to the new NAECA standard efficiency (12 SEER) when the standard takes effect in 2006.

9 A new room A/C standard will come into effect on October 1, 2000. The CEF-NEMS reference case includes this standard, but delays the start date to Jan 1, 2001.
To be consistent with the reference case, we also began the standard on Jan 1, 2001 in the Moderate and Advanced cases. Federal standards for room A/C vary by equipment capacity. We used an estimated average efficiency weighted by product class shipments of 9.7 EER for the October 2000 standard.
In addition, we estimated that a future standard for RAC would take effect in 2010 at 10.5 EER (on average over the most common capacities).

10 The efficiency of room air conditioners varies by the capacity of the unit. We assumed the average efficiency of a current ENERGY STAR room air conditioner is 9.98 EER. This is a simple average of the EERs of the least-efficient room air conditioners currently listed on the ENERGY STAR website directory of ENERGY STAR room A/C products (US EPA 1999b). We included only units with the most common capacities ( <6000 Btu/hr up to 19,999 Btu/hr). The average efficiency is a conservative estimate, since most of the ENERGY STAR products listed are more efficient than the least-efficient products in the directory. The baseline efficiency is the average efficiency of a unit bought to replace an existing RAC unit in 2000 (9.1 EER, from an output file of the CEF-NEMS reference case). This measure applies only in the year 2000, because we assume that when the new RAC standard enters into force in 2001, the ENERGY STAR level will be increased. See Note 11.

11 When the new room A/C standard takes effect on January 1, 2001, we assume DOE will increase the ENERGY STAR level by the same percentage above the 2001 standard as the current ENERGY STAR level is above the current standard. On average, the efficiency of the least-efficient ENERGY STAR RACs currently listed on the ENERGY STAR website (US EPA 1999b) is 14.1% higher than the current NAECA standard. (We estimated this by taking a simple average of the percent improvement in EER over the NAECA standard (listed on the web site for each product) for the least-efficient products listed that had a capacity between <6000 Btu/hr and 19,999 Btu/hr). So, the energy savings is 14.1% from 2001 until 2010, when a new NAECA standard is assumed to take effect. From 2010-2020, we assume the ENERGY STAR level will also be set at 14.1% higher than the standard in effect during that time. The baseline efficiency for these measures is the standard in effect during the applicable time period.

12 There are assumed to be no new NAECA standards for furnaces or boilers during the forecast time period.

13 The ENERGY STAR efficiency for gas, oil, and LPG furnaces is assumed to remain at the current level (90 AFUE) throughout the forecast period. The baseline efficiency is the average efficiency of units bought in 2000 to replace retired units (81.7 AFUE for gas, 82.2 AFUE for LPG, and 81.9 AFUE for oil furnaces), from an output file of the CEF-NEMS reference case.

14 The ENERGY STAR efficiency for gas and oil boilers is assumed to remain at the current level (86 AFUE) throughout the forecast period. The baseline efficiency is the average efficiency of units bought in 2000 to replace retired units (80.0 AFUE for gas and 80.4 AFUE for oil boilers), from an output file of the CEF-NEMS reference case.

**Table C-1.1.adv Notes, continued**

15 LBNL estimate of mature market costs for a 12 SEER/7.4 HSPF standard. We assume the incremental cost of a 12 SEER/7.4 HSPF unit compared to the baseline efficiency will be half of current incremental market costs. Current market costs of heat pumps are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). The total incremental cost of the heat pump was divided up between the heating and cooling end-uses according to the relative energy saved in heating and cooling. Costs assume one 3 ton unit per house.

16 Average current market costs for a 12 SEER/7.4 HSPF heat pump relative to the average efficiency of a new unit bought in 2000 (10.42 SEER/7.17 HSPF, from an output file of the CEF-NEMS reference case). Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume a 3 ton unit.

17 LBNL estimate of incremental cost to go from the future standard of 12 SEER to the predicted future ENERGY STAR efficiency of 14 SEER. Costs are current market costs from a variety of data sources (see Note 15), for one 3 ton heat pump unit, but were reduced by 25% in the Advanced case to account for an expected decrease in prices of higher-efficiency units after the 12 SEER standard takes effect in 2006. That is, we assume that the average incremental cost during the 2006-2020 period will be 25% lower than the current incremental cost.

18 Average current market cost of a 13.5 SEER heat pump relative to the cost of the average replaced unit in 2000. Source: same as note 16. The full incremental cost was used (i.e., the tax credit was not subtracted), and it was apportioned between heating and cooling according to the relative energy saved in each end-use.

19 Average current market cost of a 15 SEER heat pump relative to the cost of the average replaced unit in 2000. Source: same as note 16. The full incremental cost was used (i.e., the tax credit was not subtracted), and it was apportioned between heating and cooling according to the relative energy saved in each end-use.

20 LBNL estimate of the incremental cost of a 15 SEER electric heat pump relative to the cost of the 12 SEER standard unit after the standard takes effect in 2006. We used current market costs of 12 and 15 SEER units of 3-ton capacity (source: same as Note 16), but reduced the current incremental cost by 5% to account for a slight decrease in prices of higher efficiency units once the standard takes effect and higher efficiency technologies becomes more widespread. Incremental cost is the full incremental cost of the measure (i.e., the tax credit was not subtracted).

21 There is virtually no difference in cost between a standard heat pump and a system having standard CAC plus electric resistance heating (EPRI 1987).
The cost of changing controls and ductwork to accommodate the heat pump was assumed to be $600, based on LBNL estimates.
The total cost of this measure is ascribed to heating, since we assume that the cooling savings for this measure is zero (see Table C-1.2.adv, Note 5).
We assume that the central air conditioner will retire naturally at the same time as the electric heating unit. This assumes that the CAC and the heater were originally installed at the same time, and since the average lifetime of an electric heater is almost exactly twice that of a CAC (23.5 years and 12 years, respectively, from an output file of the CEF-NEMS reference case), when the heater retires, the CAC will retire also (or be very close to retirement). Thus we assume that we incur no additional cost due to an early retirement of the CAC unit.

22 The incremental cost to switch from a frozen efficiency electric resistance heating system with CAC to a 12 SEER heat pump is still assumed to be $600 (for changes in ductwork and controls). There is no additional cost due to the higher efficiency because the 2006 standard cooling efficiency for CAC and HPs is the same --12 SEER. We assume, based on EPRI (1987), that an electric resistance heater with CAC costs the same as an air source heat pump, no matter what the efficiency of the CAC and HP is, as long as they have the same efficiency. The total cost of this measure is allocated to heating, since we assume that the cooling savings for this measure is zero, as described in Table C-1.2.adv, Note 5. We assume that we incur no additional cost due to early retirement of the CAC unit (see Note 21 for more details).

23 LBNL estimate of mature market costs for a 12 SEER standard. We assume the incremental cost of a 12 SEER unit compared to the frozen efficiency in 2000 (10.42 SEER from an output file of the CEF-NEMS reference case) will be half of current market costs. Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume one 3 ton unit per house.

24 Average current market costs for a 12 SEER unit relative to the average efficiency of a new unit bought in 2000 (10.42 SEER from an output file of the CEF-NEMS reference case). Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume a 3 ton unit.

25 LBNL estimate of incremental cost to go from the future standard of 12 SEER to the predicted future ENERGY STAR efficiency of 14 SEER. Costs are current market costs from a variety of data sources (see Note 23), for one 3 ton unit, but were reduced by 25% in the Advanced case to account for an expected decrease in prices of higher-efficiency units after the 12 SEER standard takes effect in 2006. That is, we assume that the average incremental cost during the 2006-2020 period will be 25% lower than the current incremental cost.

26 Average current market cost of a 13.5 SEER CAC relative to the cost of the average replaced unit in 2000. Source: same as note 23. This is the full incremental cost (i.e., the tax credit was not subtracted).

27 Average current market cost of a 15 SEER CAC relative to the cost of the average replaced unit in 2000. Source: same as note 23. This is the full incremental cost (i.e., the tax credit was not subtracted).

**Table C-1.1.adv Notes, continued**

28 LBNL estimate of the incremental cost of a 15 SEER CAC relative to the cost of the 12 SEER standard unit after the standard takes effect in 2006. We used current market costs of 12 and 15 SEER units of 3-ton capacity (source: same as Note 23), but reduced the current incremental cost by 5% to account for a slight decrease in prices of higher efficiency units once the standard takes effect and higher efficiency technologies becomes more widespread. Incremental cost is the full incremental cost of the measure (i.e., the tax credit was not subtracted).

29 Costs based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990 dollars using GDP inflator. Cost is a weighted average over the most common product classes (from under 6 Btuh to 20 Btuh capacity), using 1989 shipments by product class from US DOE 1993b. Cost assumes a U.S. average of 1.51 room AC units per house (i.e., the average cost per unit was multiplied by 1.51 to get the cost per house of the standards measure). The average number of units in the U.S. is from a query of the 1990 RECS electronic database (US DOE 1993a); 1.51 units is the average (weighted using the RECS household weighting factor "nweight") number of room AC units in all house types in the U.S. that claim room A/C units as their primary cooling equipment.

30 Costs based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990 dollars using the GDP inflator. Cost assumes an average of 1.67 room AC units per house (i.e., the average cost per unit was multiplied by 1.67 to get the cost per house of the ENERGY STAR measures). 1.67 units represents the average number of room A/C units per house in Single-family and Manufactured Homes located in the South and that claim room AC as their primary cooling equipment. We selected only SF and MH houses in the South because we asssumed that the ENERGY STAR RAC program would only be marketed to owners of these types of homes in the South (see Table C-1.2.adv). The average number of units is from a query of the 1990 RECS electronic database (US DOE 1993a). The costs are incremental to the cost of the NAECA standard valid during the program time period. That is, the incremental cost of an ENERGY STAR room AC in 2000 is relative to the cost of a room AC that just meets the standard valid in the year 2000; the incremental cost of an ENERGY STAR room AC from 2001-2009 is relative to the cost of a room AC that just meets the October, 2000 standard (assumed to take effect in January of 2001), and so on.

Note: the incremental cost of ENERGY STAR RAC in 2010-2020 is based on US DOE 1993b, but was reduced by 60% to account for technological innovations that will happen by 2010 to reduce the cost of high-efficiency RACs. These technologies may include microchannel heat exchangers already developed by Modine, or other technologies.

31 The average incremental cost of an ENERGY STAR gas furnace over the 2000-2020 forecast period in the Advanced case is assumed to be the same as the current incremental cost of a condensing gas furnace in a mature market. Currently, the state of Wisconsin is a mature market for condensing gas furnaces. The incremental cost of $464 in the table is to go from an 80 AFUE gas furnace to a 90 AFUE gas furnace and is from Suozzo 1998, page 51. The Suozzo cost is from 1997 Wisconsin survey data. It will take a number of years, even in the Advanced case, to achieve a mature market in most of the Northern U.S., but we use this cost as an estimate for three reasons: (1) it's the only available data on mature market furnace costs; (2) our baseline efficiency is higher than Suozzo's (81.7 AFUE compared to 80 AFUE) thus the Suozzo cost overestimates our incremental cost; and (3) costs in earlier years of the program will be higher, but costs in the later years of the program will be lower due to increased production experience.

32 Incremental cost to go from an 80 AFUE to an 86 AFUE gas boiler of output capacity 80 Mbtuh. Costs include installation and are from Johnson (1994), page 67. For the Advanced case, we assume mature market costs, so we reduced Johnson's incremental cost by 40% to estimate the lower prices of a mature market. The cost is assumed to be the average over the entire forecast period. Costs from Johnson were inflated to 1997 dollars using the GDP inflator.

33 Incremental installed cost of an ENERGY STAR oil furnace in a mature market was assumed to be the same as the incremental cost of the ENERGY STAR gas furnace in a mature market. No mature market cost data for oil furnaces were available. The cost in the table is assumed to be the average over the 2000-2020 period.

34 Incremental cost to go from an 80.4 AFUE to an 86 AFUE oil boiler of output capacity 80 Mbtuh. Costs include installation and are from Johnson (1994), page 67. For the Advanced case, we assume mature market costs, so we reduced Johnson's incremental cost by 40% to reflect lower prices in a mature market. Johnson's costs were inflated to 1997 dollars using the GDP inflator.

35 The incremental cost of LPG furnaces in a mature market was assumed to be the same as for natural gas furnaces.

**Table C-1.2.mod: Average Household Energy Consumption and Market Segments for Existing Residential Building HVAC Policies**
**Case: Moderate**

| Fuel | End-Use | Equipment Type | Policy | Policy Period[d] | Average Household Energy Consumption for Subset of Homes to which Policy applies[a] Base Case (site MMBtu/yr) | Policy (site MMBtu/yr) | Market Segment the policy applies to[b] description | (% of homes) | Maximum annual penetration achieved in policy case[c] (% of homes) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Elec | Space Heating | Heat Pump | NAECA standard 2006 | 2006-2020 | 14.64 | 14.19 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000-2005 | 30.75 | 29.80 | South (SF, highest consumption) | 12.4% | 7.6% | 6 |
| | | | ENERGY STAR HVAC | 2006-2020 | 14.90 | 12.97 | South (SF only) | 57.8% | 20.0% | 3 |
| | | | Tax credit ASHP (10%) | 2000-2001 | 15.37 | 12.25 | South (SF only) | 57.8% | 8.0% | 3 |
| | | | Tax credit ASHP (20%) | 2000-2003 | 15.37 | 12.25 | South (SF only) | 57.8% | 3.1% | 3 |
| | | | | | | | | Max, all Programs: | 20.0% | |
| | | Resistance | no policies for moderate | - | | | | | | 5 |
| Elec | Space Cooling | Heat Pump | NAECA standard 2006 | 2006-2020 | 8.20 | 7.44 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000-2005 | 25.31 | 22.97 | South (SF, highest consumption) | 12.4% | 7.6% | 6 |
| | | | ENERGY STAR HVAC | 2006-2020 | 11.49 | 9.85 | South (SF only) | 57.8% | 20.0% | 3 |
| | | | Tax credit ASHP (10%) | 2000-2001 | 12.66 | 10.21 | South (SF only) | 57.8% | 8.0% | 3 |
| | | | Tax credit ASHP (20%) | 2000-2003 | 12.66 | 9.19 | South (SF only) | 57.8% | 3.1% | 3 |
| | | | | | | | | Max, all Programs: | 20.0% | |
| | | Central A/C | NAECA standard 2006 | 2006-2020 | 7.63 | 6.63 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000-2005 | 14.15 | 12.29 | South (SF only) | 37.7% | 7.6% | 3 |
| | | | ENERGY STAR HVAC | 2006-2020 | 12.29 | 10.53 | South (SF only) | 37.7% | 20.0% | 3 |
| | | | Tax credit CAC (10%) | 2000-2001 | 14.15 | 10.92 | South (SF only) | 37.7% | 8.0% | 3 |
| | | | Tax credit CAC (20%) | 2000-2003 | 14.15 | 9.83 | South (SF only) | 37.7% | 3.1% | 3 |
| | | | | | | | | Max, all Programs: | 20.0% | |
| | | Room A/C | NAECA standard 2001 | 2001-2009 | 2.95 | 2.78 | all | 100.0% | 100.0% | 1 |
| | | | NAECA standard 2010 | 2010-2020 | 2.95 | 2.57 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000 only | 6.63 | 6.07 | South (SF only) | 25.8% | 1.0% | 3 |
| | | | ENERGY STAR HVAC | 2001-2009 | 6.24 | 5.36 | South (SF only) | 25.8% | 9.0% | 3 |
| | | | ENERGY STAR HVAC | 2010-2020 | 5.76 | 4.95 | South (SF only) | 25.8% | 10.0% | 3 |
| Gas | Space Heating | Furnace | NAECA standard | - | 60.49 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 123.31 | 111.95 | North (SF, high consumption) | 11.7% | 10.9% | 4 |
| | | Boiler | NAECA standard | - | 53.97 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 102.42 | 95.29 | North (SF, high consumption) | 17.1% | 12.1% | 4 |

**Table C-1.2.mod: Average Household Energy Consumption and Market Segments for Existing Residential Building HVAC Policies**
**Case: Moderate**

| Fuel | End-Use | Equipment Type | Policy | Policy Period[d] | Average Household Energy Consumption for Subset of Homes to which Policy applies[a] Base Case (site MMBtu/yr) | Policy (site MMBtu/yr) | Market Segment the policy applies to[b] description | (% of homes) | Maximum annual penetration achieved in policy case[c] (% of homes) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil | Space Heating | Furnace | NAECA standard | - | 73.51 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 144.91 | 131.85 | North (SF, high consumption) | 26.8% | 18.4% | 4 |
| | | Boiler | NAECA standard | - | 75.01 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 128.23 | 119.90 | North (SF, high consumption) | 23.3% | 10.0% | 4 |
| LPG | Space Heating | Furnace | NAECA standard | - | 50.33 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 95.81 | 87.48 | North (SF, high consumption) | 17.8% | 10.9% | 4 |

[a] This is the average household site energy consumption in MMBtu/year for space heating or cooling during the specified policy period. It is the average consumption for market segment to which the policy is assumed to apply (see Note b). The energy consumption is presented for two situations: Base Case and Policy Case. The annual energy saved by the policy is simply the difference between the base case and policy case consumptions. The heating and cooling consumptions for both cases are derived from the end-use consumptions provided by an output file of the CEF-NEMS reference case. The CEF-NEMS consumptions we started with are the average consumption of all existing homes in 2000, adjusted by the ratio of average replacement equipment efficiency in 2000 to average existing equipment efficiency in 2000. The average replacement and existing equipment efficiencies are also from an output file of the CEF-NEMS reference case. This consumption is used as the base case for NAECA standards and for non-mandatory policies in years prior to when a new NAECA standard takes effect. Once a new NAECA standard takes effect, the base case consumption used for non-mandatory policies will decrease to reflect the new minimum equipment efficiency level. The base case consumption has also been adjusted to reflect the market segment to which the policy applies - see Notes below for details of the calculations for specific policies. The policy case consumption is always calculated by applying the ratio (policy efficiency / base case efficiency) to the base case consumption. Base case and policy case equipment efficiencies are documented in Table C-1.1.mod.

[b] In some cases, a policy was not cost-effective in the "average" home. In these cases, we segmented the market and applied the policy only to a subset of homes in which the measure would be cost-effective. The NAECA standards are a mandatory program and therefore are always applied to the "average" (i.e., all) homes. The household consumptions shown in this table only apply to the market segment listed. In general, most policies affecting heating are more cost-effective in the North, and most policies affecting cooling are more cost-effective in the South, because of higher than average loads for heating and cooling, respectively, in those regions. Often, we further segmented the market to include only single-family (SF) homes, because of their higher heating and cooling loads. In some cases, we had to further segment to include only the highest energy consumers. See the Notes below for details on what was done for specific policies. In this table, we show the market segment as a percent of all existing homes with the specified equipment type. For example, in the Moderate case, the ENERGY STAR HVAC program for room A/C was assumed to apply only to single-family homes in the Southern U.S.; these homes account for 25.8% of all existing U.S. homes with room A/C as primary cooling equipment. (In other words, 25.8% of all existing U.S. homes with room A/C as primary cooling equipment are single-family homes in the South). Percent of existing homes by region (south and north), fuel type, equipment type, and house type are from Hanford 1994, Tables 3.20-3.21, except for the fuel end-uses. For gas, LPG, and oil heating, the percent of existing homes by energy consumption, equipment type, house type, and region are from a query of the 1990 RECS database (US DOE 1993a). We provide the market segment as a % of all homes so that we can compare it to the maximum policy penetration achieved (which is defined as % of all homes). The maximum policy penetration must never exceed the market segment percentage. See note c for more details about the maximum policy penetrations.

[c] The maximum annual penetration rate achieved by the program during the policy period shown in this table. The penetration rate is defined as the percent of equipment retiring in each year that would be replaced with new equipment due to the policy. For example, the maximum penetration rate achieved by the ENERGY STAR HVAC program for gas furnaces is 10.9% in the Moderate case; i.e., 10.9% of all existing homes with gas furnaces that retired in that year were replaced with ENERGY STAR gas furnaces

**Table C-1.2.mod, continued**

as a result of the ENERGY STAR program. See Table B-1.1.mod for more details about policy penetrations.
Note that the maximum annual penetrations for the various policies are not necessarily additive, because the maximum may occur in different years for different policies. For example, the maximum penetration for ENERGY STAR central A/C occurs in 2020, but the maximum annual penetration for the central A/C tax credit of 10% occurs in 2001. For equipment types with multiple policies, we show the maximum annual penetration of all programs combined, with the exception of standards, in the "Max, all Programs" row.

[d] The years during which the policy is assumed to be in effect; see Table B-1.1.mod for details on policy periods.

## Notes

1 The NAECA standard measures are mandatory and therefore apply to the entire market. The base case consumption is the U.S. average site energy consumption in the year 2000 for an existing home (i.e., a home built before 2000) with new equipment of efficiency equal to the average efficiency of a unit bought in the year 2000 to replace a retiring unit. This consumption is the average annual consumption for all house types in all regions of the country, from an output file of the CEF-NEMS reference case. See Table C-1.1.mod for the base case and policy case efficiencies.

2 We assume that the NAECA standards for gas, LPG and oil heating equipment will not be updated during the forecast period.

3 In most cases, we applied policies which affected cooling equipment to one of three market segments: (1) all house types in the South, (2) single-family and manufactured homes in the South, or (3) single-family homes in the South. The base case consumptions for these market segments are estimates based on the U.S. average base case consumption described in note a. We estimated the regional and house type consumptions using regional and house type scaling factors from data in Hanford (1994). We used Hanford's database UEC from Tables 3.20-3.21, which provided annual heating and cooling consumptions of existing homes by region (North and South), house type (single-family, multifamily and manfuctured housing), and by equipment and fuel type. We used the existing home populations from the same tables to weight the consumptions for each house type and equipment type. We used the Hanford data to scale the U.S. average consumption described in Note a.
Note: The base case consumptions for ENERGY STAR heat pumps and central A/Cs decrease after 2005 because of the NAECA standard which takes effect in 2006. Similarly, the base case consumptions for ENERGY STAR room A/Cs decrease after 2000 and again after 2009 because of the NAECA standards which take effect in 2001 and 2010.

4 We found that the ENERGY STAR furnaces and boilers are in most cases not cost-effective for the average single-family house in the North, so we restricted the market even further to SF homes in the North with high heating consumption. We estimated the consumption of this subset of homes using the 1990 RECS individual household data (electronic database, US DOE 1993a). We calculated the population weighted average heating consumption for RECS single-family homes in the north, using the RECS population weighting factor "nweight", for each heating equipment type. From this set of homes, we selected the highest consumers of heating energy, and calculated the average consumption for those homes. We calculated a consumption ratio - average single-family north high consumption homes to the average north, single-family homes (both from 1990 RECS) - and used it to scale the "North, SF" consumption (derived from Hanford 1994 data, as described in note 3). The resulting consumptions are shown in the base case column of this table.

5 We do not have any policies to improve the energy consumption of homes with electric resistance heaters in the Moderate case.

6 We found that ENERGY STAR heat pumps are not cost-effective in the average single-family home in the south prior to the 2006 NAECA standard. They are cost-effective, however, in homes that use at least twice as much energy (for heating and cooling combined) as the average single-family home in the south with a heat pump. Based on a query of the 1990 RECS electronic database (US DOE 1993a), we estimated that 12.4% of all single-family homes in the South with an electric heat pump use twice as much energy for heating and cooling than the average single-family home in the south with an electric heat pump. The base case heating and cooling consumptions in this table are simply twice the "South, SF only" consumptions described in Note 3.

**Table C-1.2.adv: Average Household Energy Consumption and Market Segments for Existing Residential Building HVAC Policies**
**Case: Advanced**

| Fuel | End-Use | Equipment Type | Policy | Policy Period[d] | Average Household Energy Consumption for Subset of Homes to which Policy applies[a]: Base Case (site MMBtu/yr) | Policy (site MMBtu/yr) | Market Segment the policy applies to[b]: description | (% of homes) | Maximum annual penetration achieved in policy case[c] (% of homes) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Elec | Space Heating | Heat Pump | NAECA standard 2006 | 2006-2020 | 14.64 | 14.19 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000-2005 | 30.75 | 29.80 | South (SF, highest consumption) | 12.4% | 12.4% | 6 |
| | | | ENERGY STAR HVAC | 2006-2020 | 12.32 | 10.73 | South (all house types) | 81.9% | 40.0% | 3 |
| | | | Tax credit ASHP (10%) | 2000-2003 | 12.71 | 10.13 | South (all house types) | 81.9% | 16.0% | 3 |
| | | | Tax credit ASHP (20%) | 2000-2005 | 15.37 | 12.25 | South (SF only) | 57.8% | 10.0% | 3 |
| | | | Tax credit ASHP (20%) | 2006-2007 | 12.32 | 9.82 | South (all house types) | 81.9% | 11.2% | 3 |
| | | | | | | | | Max, all Programs: | 40.0% | |
| | | Resistance | Replace with Heat Pump | 2000-2005 | 14.87 | 7.08 | homes with CAC & cost-effective | 26.1% | 4.1% | 5 |
| | | | Replace with Heat Pump | 2006-2020 | 14.87 | 6.86 | homes with CAC & cost-effective | 26.1% | 6.5% | 5 |
| Elec | Space Cooling | Heat Pump | NAECA standard 2006 | 2006-2020 | 8.20 | 7.44 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000-2005 | 25.31 | 22.97 | South (SF, highest consumption) | 12.4% | 12.4% | 6 |
| | | | ENERGY STAR HVAC | 2006-2020 | 9.34 | 8.01 | South (all house types) | 81.9% | 40.0% | 3 |
| | | | Tax credit ASHP (10%) | 2000-2003 | 10.30 | 8.31 | South (all house types) | 81.9% | 16.0% | 3 |
| | | | Tax credit ASHP (20%) | 2000-2005 | 12.66 | 9.19 | South (SF only) | 57.8% | 10.0% | 3 |
| | | | Tax credit ASHP (20%) | 2006-2007 | 9.34 | 6.78 | South (all house types) | 81.9% | 11.2% | 3 |
| | | | | | | | | Max, all Programs: | 40.0% | |
| | | Central A/C | NAECA standard 2006 | 2006-2020 | 7.63 | 6.63 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000-2005 | 14.15 | 12.29 | South (SF only) | 37.7% | 15.3% | 3 |
| | | | ENERGY STAR HVAC | 2006-2020 | 9.95 | 8.53 | South (all house types) | 55.7% | 40.0% | 3 |
| | | | Tax credit CAC (10%) | 2000-2003 | 14.15 | 10.92 | South (SF only) | 37.7% | 16.0% | 3 |
| | | | Tax credit CAC (20%) | 2000-2005 | 14.15 | 9.83 | South (SF only) | 37.7% | 10.0% | 3 |
| | | | Tax credit CAC (20%) | 2006-2007 | 12.29 | 8.54 | South (SF only) | 37.7% | 11.2% | 3 |
| | | | | | | | | Max, all Programs: | 40.0% | |
| | | Room A/C | NAECA standard 2001 | 2001-2009 | 2.95 | 2.78 | all | 100.0% | 100.0% | 1 |
| | | | NAECA standard 2010 | 2010-2020 | 2.95 | 2.57 | all | 100.0% | 100.0% | 1 |
| | | | ENERGY STAR HVAC | 2000 only | 6.41 | 5.87 | South (SF and MH only) | 29.6% | 2.4% | 3 |
| | | | ENERGY STAR HVAC | 2001-2009 | 6.04 | 5.18 | South (SF and MH only) | 29.6% | 19.0% | 3 |
| | | | ENERGY STAR HVAC | 2010-2020 | 5.58 | 4.79 | South (SF and MH only) | 29.6% | 23.1% | 3 |
| Gas | Space Heating | Furnace | NAECA standard | - | 60.49 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 78.88 | 71.61 | North (SF only) | 45.7% | 21.7% | 4 |
| | | Boiler | NAECA standard | - | 53.97 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 60.81 | 56.58 | 2/3 SF + 1/3 MF in >4000 HDD regions | 39.1% | 24.1% | 4 |

**Table C-1.2.adv: Average Household Energy Consumption and Market Segments for Existing Residential Building HVAC Policies**
**Case: Advanced**

| Fuel | End-Use | Equipment Type | Policy | Policy Period[d] | Average Household Energy Consumption for Subset of Homes to which Policy applies[a] Base Case (site MMBtu/yr) | Policy (site MMBtu/yr) | Market Segment the policy applies to[b] description | (% of homes) | Maximum annual penetration achieved in policy case[c] (% of homes) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil | Space Heating | Furnace | NAECA standard | - | 73.51 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 101.37 | 92.23 | North (SF only) | 61.2% | 36.7% | 4 |
| | | Boiler | NAECA standard | - | 75.01 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 75.42 | 70.52 | North (all house types) | 96.6% | 11.2% | 4 |
| LPG | Space Heating | Furnace | NAECA standard | - | 50.33 | - | all | 100.0% | 100.0% | 1,2 |
| | | | ENERGY STAR HVAC | 2000-2020 | 59.22 | 54.06 | North (all house types) | 53.8% | 21.7% | 4 |

[a] This is the average household site energy consumption in MMBtu/year for space heating or cooling during the specified policy period. It is the average consumption for market segment to which the policy is assumed to apply (see Note b). The energy consumption is presented for two situations: Base Case and Policy Case. The annual energy saved by the policy is simply the difference between the base case and policy case consumptions. The heating and cooling consumptions for both cases are derived from the end-use consumptions provided by an output file of the CEF-NEMS reference case. The CEF-NEMS consumptions we started with are the average consumption of all existing homes in 2000, adjusted by the ratio of average replacement equipment efficiency in 2000 to average existing equipment efficiency in 2000. The average replacement and existing equipment efficiencies are also from an output file of the CEF-NEMS reference case. This consumption is used as the base case for NAECA standards and for non-mandatory policies in years prior to when a new NAECA standard takes effect. Once a new NAECA standard takes effect, the base case consumption used for non-mandatory policies will decrease to reflect the new minimum equipment efficiency level. The base case consumption has also been adjusted to reflect the market segment to which the policy applies - see Notes below for details of the calculations for specific policies. The policy case consumption is always calculated by applying the ratio (policy efficiency / base case efficiency) to the base case consumption. Base case and policy case equipment efficiencies are documented in Table C-1.1.adv.

[b] In some cases, a policy was not cost-effective in the "average" home. In these cases, we segmented the market and applied the policy only to a subset of homes in which the measure would be cost-effective. The NAECA standards are a mandatory program and therefore are always applied to the "average" (i.e., all) homes. The household consumptions shown in this table only apply to the market segment listed. In general, most policies affecting heating are more cost-effective in the North, and most policies affecting cooling are more cost-effective in the South, because of higher than average loads for heating and cooling, respectively, in those regions. Often, we further segmented the market to include only single-family (SF) homes, because of their higher heating and cooling loads. In some cases, we had to further segment to include only the highest energy consumers. See the Notes below for details on what was done for specific policies. In this table, we show the market segment as a percent of all existing homes with the specified equipment type. For example, in the Advanced case, the ENERGY STAR HVAC program for room A/C was assumed to apply only to single-family and manufactured homes in the Southern U.S.; these homes account for 29.6% of all existing U.S. homes with room A/C as primary cooling equipment. (In other words, 29.6% of all existing U.S. homes with room A/C as primary cooling equipment are single-family or manufactured homes located in the south). Percent of existing homes by region (south and north), fuel type, equipment type, and house type are from Hanford 1994, Tables 3.20-3.21, except for the fuel end-uses. For gas, LPG, and oil heating, the percent of existing homes by energy consumption, equipment type, house type, and region are from a query of the 1990 RECS database (US DOE 1993a).
We provide the market segment as a % of all homes so that we can compare it to the maximum policy penetration achieved (which is defined as % of all homes). The maximum policy penetration must never exceed the market segment percentage. See note c for more details about the maximum policy penetrations.

[c] The maximum annual penetration rate achieved by the program during the policy period shown in this table. The penetration rate is defined as the percent of equipment retiring in each year that would be replaced with new equipment due to the policy. For example, the maximum penetration rate achieved by the ENERGY STAR HVAC program for gas

**Table C-1.2.adv, continued**

furnaces is 21.7% in the Advanced case; i.e., 21.7% of all existing homes with gas furnaces that retired in that year were replaced with ENERGY STAR gas furnaces as a result of the ENERGY STAR program. See Table B-1.1.adv for more details about policy penetrations.

Note that the maximum annual penetrations for the various policies are not necessarily additive, because the maximum may occur in different years for different policies. For example, the maximum penetration for ENERGY STAR central A/C occurs in 2020, but the maximum annual penetration for the central A/C tax credit of 10% occurs in 2003. For equipment types with multiple policies, we show the maximum annual penetration of all programs combined, with the exception of standards, in the "Max, all Programs" row.

[d] The years during which the policy is assumed to be in effect; see Table B-1.1.adv for details on policy periods.

## Notes

1 The NAECA standard measures are mandatory and therefore apply to the entire market. The base case consumption is the U.S. average site energy consumption in the year 2000 for an existing home (i.e., a home built before 2000) with new equipment of efficiency equal to the average efficiency of a unit bought in the year 2000 to replace a retiring unit. This consumption is the average annual consumption for all house types in all regions of the country, from an output file of the CEF-NEMS reference case. See Table C-1.1.mod for the base case and policy case efficiencies.

2 We assume that the NAECA standards for gas, LPG and oil heating equipment will not be updated during the forecast period.

3 In most cases, we applied policies which affected cooling equipment to the single-family, Southern U.S. market segment. The base case consumptions for this market segment are estimates based on the U.S. average base case consumption described in note a. We estimated the regional and house type consumptions using regional and house type scaling factors from data in Hanford (1994). We used Hanford's "database UEC" from Tables 3.20-3.21, which provided annual heating and cooling consumptions of existing homes by region (North and South), house type (single-family, multifamily and manfuctured housing), and by equipment and fuel type. We used the existing home populations from the same tables to weight the consumptions for each house type and equipment type. We used the Hanford data to scale the U.S. average consumption described in Note a. Note: The base case consumptions for ENERGY STAR heat pumps and central A/Cs decrease after 2005 because of the NAECA standard which takes effect in 2006. Similarly, the base case consumptions for ENERGY STAR room A/Cs decrease after 2000 and again after 2009 because of the NAECA standards which take effect in 2001 and 2010.

4 We found that the ENERGY STAR furnaces and boilers are in most cases not cost-effective for the average single-family house in the North, so we restricted the market even further to SF homes in the North with high heating consumption. We estimated the consumption of this subset of homes using the 1990 RECS individual household data (electronic database, US DOE 1993a). We calculated the population weighted average heating consumption for RECS single-family homes in the north, using the RECS population weighting factor "nweight", for each heating equipment type. From this set of homes, we selected the highest consumers of heating energy, and calculated the average consumption for those homes. We calculated a consumption ratio - average single-family north high consumption homes to the average north, single-family homes (both from 1990 RECS) - and used it to scale the "North, SF" consumption (derived from Hanford 1994 data, as described in note 3). The resulting consumptions are shown in the base case column of this table.

5 Note that this policy (replace electric resistance heating and CAC with electric heat pump) is only listed in this table under the Electric Space heating end-use, not under the Electric Cooling end-use, because this policy saves no energy for cooling. This is because we have assumed that this policy only applies to homes that are replacing their CAC at the same time as their heating equipment (see Table B-1.1.adv for more details). During the policy time period 2000-2005, we assume that the efficiency of the replacement heat pump is the frozen efficiency (average new unit efficiency of a heat pump in 1999). This is approximately the same efficiency as the frozen efficiency of a CAC, thus the cooling savings due to the replacement will be zero. During the policy period 2006-2020, we assume that the heat pump has the 2006 NAECA standard efficiency, which is assumed to be the same for heat pumps and central air conditioners in this analysis, 14 SEER. Therefore, the energy saved for cooling during the 2006-2020 time period is also zero.

6 We found that ENERGY STAR heat pumps are not cost-effective in the average single-family home in the south prior to the 2006 NAECA standard. They are cost-effective, however, in homes that use at least twice as much energy (for heating and cooling combined) as the average single-family home in the south with a heat pump. Based on a query of the 1990 RECS electronic database (US DOE 1993a), we estimated that 12.4% of all single-family homes in the South with an electric heat pump use twice as much energy for heating and cooling than the average single-family home in the south with an electric heat pump. The base case heating and cooling consumptions in this table are simply twice the "South, SF only" consumptions described in Note 3.

| Table C-1.3.mod: Average Technology Data[a] for New Residential Building HVAC End-Uses, Moderate Case | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Average Incremental Cost per House[b] | | Average Annual Energy Savings per House[c] | | Measure Lifetime | Measure Lifetime | Average Cost of Conserved Energy[d] | |
| End-Use | Program | 2000-2010 | 2000-2020 | 2000-2010 | 2000-2020 | | Notes | 2000-2010 | 2000-2020 |
| | | (1997 dollars/house) | | (site MMBtu/house/yr) | | (years) | | (1997$/site MMBtu) | |
| **Electric Heating** | | | | | | | | | |
| | Heat Pump standard | $52 | $52 | 0.51 | 0.51 | 12.0 | 1 | $12.79 | $12.95 |
| | Building Codes | $135 | $125 | 3.94 | 3.92 | 30.0 | 2 | $2.77 | $2.57 |
| | ENERGY STAR Homes | $942 | $707 | 6.46 | 6.61 | 24.4 | 3 | $12.61 | $9.26 |
| | New Home Tax credit (30% level) | $947 | $947 | 6.56 | 6.46 | 24.4 | 3 | $12.50 | $12.69 |
| | New Home Tax credit (40% level) | $1,267 | $1,267 | 7.81 | 7.68 | 24.4 | 3 | $14.04 | $14.28 |
| | New Home Tax credit (50% level) | $1,587 | $1,587 | 9.06 | 8.97 | 24.4 | 3 | $15.16 | $15.31 |
| | Building America | $338 | $298 | 6.15 | 6.80 | 24.4 | 3 | $4.76 | $3.79 |
| | R&D (ENERGY STAR Homes level) | $835 | $606 | 5.82 | 5.56 | 24.4 | 3 | $12.42 | $9.44 |
| | R&D (Building America level) | $330 | $284 | 6.26 | 7.01 | 24.4 | 3 | $4.56 | $3.50 |
| | **Average, all programs** | | | | | | | **$10.08** | **$7.37** |
| **Electric Cooling** | | | | | | | | | |
| | CAC, heat pump, and RAC standards | $106 | $114 | 1.09 | 1.06 | 12.3 | 4 | $11.99 | $13.39 |
| | Building Codes | $136 | $126 | 2.33 | 2.31 | 30.0 | 2 | $5.13 | $4.80 |
| | ENERGY STAR Homes | $367 | $279 | 3.78 | 3.43 | 23.5 | 3 | $8.54 | $7.16 |
| | New Home Tax credit (30% level) | $267 | $267 | 3.72 | 3.54 | 23.5 | 3 | $6.32 | $6.64 |
| | New Home Tax credit (40% level) | $354 | $354 | 4.37 | 4.14 | 23.5 | 3 | $7.13 | $7.53 |
| | New Home Tax credit (50% level) | $440 | $440 | 5.06 | 4.90 | 23.5 | 3 | $7.65 | $7.91 |
| | Building America | $145 | $163 | 1.88 | 2.12 | 23.5 | 3 | $6.75 | $6.77 |
| | R&D (ENERGY STAR Homes level) | $326 | $240 | 3.39 | 3.25 | 23.5 | 3 | $8.46 | $6.51 |
| | R&D (Building America level) | $141 | $122 | 1.79 | 2.19 | 23.5 | 3 | $6.96 | $4.89 |
| | **Average, all programs** | | | | | | | **$10.41** | **$10.42** |
| **Gas or LPG Heating** | | | | | | | | | |
| | NAECA Standards | - | - | - | - | - | 5 | - | - |
| | Building Codes | $136 | $126 | 14.87 | 14.81 | 30.0 | 2 | $0.74 | $0.69 |
| | ENERGY STAR Homes | $1,308 | $997 | 20.96 | 20.31 | 24.3 | 3 | $5.42 | $4.26 |
| | New Home Tax credit (30% level) | $1,299 | $1,299 | 24.81 | 24.56 | 24.3 | 3 | $4.55 | $4.59 |
| | New Home Tax credit (40% level) | $1,734 | $1,734 | 29.55 | 29.23 | 24.3 | 3 | $5.09 | $5.15 |
| | New Home Tax credit (50% level) | $2,169 | $2,169 | 34.26 | 34.05 | 24.3 | 3 | $5.49 | $5.53 |

**Table C-1.3.mod: Average Technology Data[a] for New Residential Building HVAC End-Uses, Moderate Case**

| End-Use | Program | Average Incremental Cost per House[b] (1997 dollars/house) | | Average Annual Energy Savings per House[c] (site MMBtu/house/yr) | | Measure Lifetime (years) | Measure Lifetime Notes | Average Cost of Conserved Energy[d] (1997$/site MMBtu) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2000-2010 | 2000-2020 | 2000-2010 | 2000-2020 | | | 2000-2010 | 2000-2020 |
| **Gas or LPG Heating, continued** | | | | | | | | | |
| | Building America | $338 | $301 | 23.83 | 26.21 | 24.3 | 3 | $1.23 | $1.00 |
| | R&D (ENERGY STAR Homes level) | $1,161 | $852 | 20.96 | 20.04 | 24.3 | 3 | $4.81 | $3.69 |
| | R&D (Building America level) | $330 | $285 | 24.38 | 27.15 | 24.3 | 3 | $1.17 | $0.91 |
| | **Average, all programs** | | | | | | | **$3.60** | **$2.45** |
| **Oil Heating** | | | | | | | | | |
| | NAECA Standards | - | - | - | - | - | 5 | - | - |
| | Building Codes | $133 | $126 | 24.19 | 24.11 | 30.0 | 2 | $0.44 | $0.42 |
| | ENERGY STAR Homes | $1,429 | $1,112 | 34.71 | 33.48 | 25.4 | 3 | $3.51 | $2.83 |
| | New Home Tax credit (30% level) | $1,370 | $1,370 | 40.46 | 40.22 | 25.4 | 3 | $2.89 | $2.90 |
| | New Home Tax credit (40% level) | $1,828 | $1,828 | 48.20 | 47.86 | 25.4 | 3 | $3.23 | $3.26 |
| | New Home Tax credit (50% level) | $2,286 | $2,286 | 55.84 | 55.60 | 25.4 | 3 | $3.49 | $3.50 |
| | Building America | $339 | $303 | 38.83 | 42.61 | 25.4 | 3 | $0.74 | $0.61 |
| | R&D (ENERGY STAR Homes level) | $1,257 | $921 | 34.27 | 32.77 | 25.4 | 3 | $3.13 | $2.40 |
| | R&D (Building America level) | $330 | $285 | 39.81 | 44.38 | 25.4 | 3 | $0.71 | $0.55 |
| | **Average, all programs** | | | | | | | **$2.44** | **$1.66** |

[a] This table presents average costs, energy savings, and costs of conserved energy (CCEs) for each policy in the Moderate scenario. In some cases, the costs, savings and CCEs are averaged over different efficiency levels of the policy. This is the case for building codes, where the values shown are averaged over the 1993 MEC, 1998 IECC and future IECC codes. This is also the case for Building America, which is assumed to have greater energy savings during the 2010-2020 period than prior to 2010. The costs, savings, and CCEs of the NAECA standards for the electric cooling end-use in this table are averages over three standards: heat pump, central A/C, and room A/C. The values for ENERGY STAR homes are averaged over two different cost levels (the cost of an ENERGY STAR home is assumed to decrease in 2010). Additionally, since we assumed that the energy saved by the ENERGY STAR homes and new home tax credit programs for the cooling end-use vary by the type of heating fuel present (see Table C-1.4.mod for further explanation), the cooling values for these two programs are averaged over different heating fuel types.
One of the differences between the data in this table and the more disaggregated data in Table C-1.4.mod is that the energy savings in this table account for the interactions between policies (for example, the savings of non-mandatory programs has been reduced by the savings of the mandatory policies (standards and building codes) to avoid double-counting of energy savings. See Note c for more details.

[b] Average incremental cost per house is an average over all homes affected by the program during the stated time period (2000-2010 inclusive or 2000-2020 inclusive). Note that for the electric cooling end-use, the cost and energy savings of ENERGY STAR homes and New home tax credits vary by heating fuel (see Table C-1.4.mod). The costs and energy savings by heating fuel (shown in Table C-1.4.mod) were weighted by

**Table C-1.3.mod, continued**

the number of new homes built of each fuel type (from output of the CEF-NEMS reference case) during the stated time period to obtain the average costs shown in this table.

[c] Average annual site energy savings per house, for only those homes affected by the program during the stated time period (2000-2010 inclusive or 2000-2020 inclusive). The energy savings of the non-mandatory programs (i.e., all programs except NAECA standards and building codes) are reduced by the mandatory programs, which are assumed to be implemented first, thereby reducing the energy savings potential of the non-mandatory programs - see Table C-1.4.mod for more information). This was done to avoid double-counting the energy savings; we arbitrarily chose to implement building codes first, followed by the NAECA standards. The average household energy savings for the non-mandatory programs is lower in the Advanced case than in the Moderate case because the Advanced case has more stringent building codes and a higher penetration of building codes. For the same reason, the NAECA standards also have a lower per-house energy savings in the Advanced case than in the Moderate case. See Table C-1.4.mod for the disaggregated energy savings for each policy.

[d] Cost of Conserved Energy (CCE), in 1997 dollars per million site Btu, is presented for each program and also as an average over all programs affecting each end-use. In both cases, the CCE is an average over all homes affected by the policy during the stated time period (either 2000-2010, inclusive or 2000-2020, inclusive). All CCEs were calculated using a real discount rate of 7%. The average CCE for each end-use was calculated by weighting the individual program CCEs by the energy savings for each program.

**Notes**

1 Estimated average lifetime of an electric heat pump, calculated by averaging electric heat pump minimum and maximum life expectancies from an input file to the CEF-NEMS model.

2 Compliance with building codes usually involves primarily the use of building shell measures (rather than HVAC equipment measures). We assumed a 30 year lifetime for building shell measures (Brown et. al. 1998).

3 Whole-house improvement programs such as ENERGY STAR New Homes, New Home Tax Credit, and Building America are assumed to utilize three different types of measures, which have quite different lifetimes: building shell improvements, duct improvements, and HVAC equipment upgrades. We assumed the average lifetime is 30 years for building shell measures and 15 years for duct measures (Brown et. al. 1998). HVAC equipment lifetimes are from the same source described in Note 1. We calculated an average lifetime for each end-use and used it for each of the whole-house policies. Table C-1.5 provides details of the calculations.

4 Lifetime of electric cooling equipment measures is a weighted average over the three main cooling equipment types (CAC, HP, and RAC). We calculated the average lifetime of each of the cooling equipment types, using their minimum and maximum lifetime expectancies (from an input file to the CEF-NEMS model). These average lifetimes were then weighted by the saturation of each equipment type in homes built in the year 2000 (from an output file of the CEF-NEMS reference case) in order to obtain the average lifetime of 12.3 years shown in this table.

5 No new NAECA standards for gas-, oil-, or LPG-fired HVAC equipment were assumed to be implemented during the forecast time period.

**Table C-1.3.adv: Average Technology Data[a] for New Residential Building HVAC End-Uses, Advanced Case**

| End-Use | Program | Average Incremental Cost per House[b] 2000-2010 (1997 dollars/house) | Average Incremental Cost per House[b] 2000-2020 (1997 dollars/house) | Average Annual Energy Savings per House[c] 2000-2010 (site MMBtu/house/yr) | Average Annual Energy Savings per House[c] 2000-2020 (site MMBtu/house/yr) | Measure Lifetime (years) | Measure Lifetime Notes | Average Cost of Conserved Energy[d] 2000-2010 (1997$/site MMBtu) | Average Cost of Conserved Energy[d] 2000-2020 (1997$/site MMBtu) |
|---|---|---|---|---|---|---|---|---|---|
| **Electric Heating** | | | | | | | | | |
| | Heat Pump standard | $52 | $52 | 0.51 | 0.50 | 12.0 | 1 | $12.89 | $13.18 |
| | Building Codes | $68 | $106 | 3.99 | 4.08 | 30.0 | 2 | $1.38 | $2.10 |
| | ENERGY STAR Homes | $808 | $440 | 6.14 | 6.10 | 24.4 | 3 | $11.39 | $6.25 |
| | New Home Tax credit (30% level) | $947 | $947 | 6.51 | 6.38 | 24.4 | 3 | $12.60 | $12.86 |
| | New Home Tax credit (40% level) | $1,267 | $1,267 | 7.70 | 7.55 | 24.4 | 3 | $14.23 | $14.53 |
| | New Home Tax credit (50% level) | $1,587 | $1,587 | 8.68 | 8.61 | 24.4 | 3 | $15.83 | $15.95 |
| | Building America | $322 | $212 | 6.04 | 6.57 | 24.4 | 3 | $4.61 | $2.79 |
| | R&D (ENERGY STAR Homes level) | $612 | $322 | 5.68 | 5.21 | 24.4 | 3 | $9.33 | $5.35 |
| | R&D (Building America level) | $297 | $184 | 6.16 | 6.67 | 24.4 | 3 | $4.17 | $2.39 |
| | **Average, all programs** | | | | | | | **$10.46** | **$5.96** |
| **Electric Cooling** | | | | | | | | | |
| | CAC, heat pump, and RAC standards | $106 | $114 | 1.08 | 1.03 | 12.3 | 4 | $12.09 | $13.67 |
| | Building Codes | $69 | $105 | 2.38 | 2.60 | 30.0 | 2 | $2.33 | $3.25 |
| | ENERGY STAR Homes | $287 | $158 | 3.63 | 3.18 | 23.5 | 3 | $6.95 | $4.36 |
| | New Home Tax credit (30% level) | $267 | $267 | 3.69 | 3.50 | 23.5 | 3 | $6.37 | $6.72 |
| | New Home Tax credit (40% level) | $354 | $354 | 4.32 | 4.09 | 23.5 | 3 | $7.21 | $7.61 |
| | New Home Tax credit (50% level) | $440 | $440 | 4.17 | 4.12 | 23.5 | 3 | $9.30 | $9.40 |
| | Building America | $137 | $93 | 1.82 | 1.97 | 23.5 | 3 | $6.64 | $4.16 |
| | R&D (ENERGY STAR Homes level) | $218 | $117 | 3.31 | 3.02 | 23.5 | 3 | $5.81 | $3.40 |
| | R&D (Building America level) | $127 | $80 | 1.73 | 1.98 | 23.5 | 3 | $6.47 | $3.56 |
| | **Average, all programs** | | | | | | | **$8.95** | **$7.68** |
| **Gas or LPG Heating** | | | | | | | | | |
| | NAECA Standards | - | - | - | - | - | 5 | - | - |
| | Building Codes | $69 | $104 | 15.05 | 15.43 | 30.0 | 2 | $0.37 | $0.55 |
| | ENERGY STAR Homes | $1,089 | $599 | 20.74 | 19.21 | 24.3 | 3 | $4.56 | $2.71 |
| | New Home Tax credit (30% level) | $1,299 | $1,299 | 24.60 | 24.22 | 24.3 | 3 | $4.58 | $4.65 |
| | New Home Tax credit (40% level) | $1,734 | $1,734 | 29.14 | 28.74 | 24.3 | 3 | $5.16 | $5.24 |
| | New Home Tax credit (50% level) | $2,169 | $2,169 | 33.57 | 33.36 | 24.3 | 3 | $5.61 | $5.64 |

**Table C-1.3.adv: Average Technology Data[a] for New Residential Building HVAC End-Uses, Advanced Case**

| End-Use | Program | Average Incremental Cost per House[b] 2000-2010 (1997 dollars/house) | Average Incremental Cost per House[b] 2000-2020 (1997 dollars/house) | Average Annual Energy Savings per House[c] 2000-2010 (site MMBtu/house/yr) | Average Annual Energy Savings per House[c] 2000-2020 (site MMBtu/house/yr) | Measure Lifetime (years) | Measure Lifetime Notes | Average Cost of Conserved Energy[d] 2000-2010 (1997$/site MMBtu) | Average Cost of Conserved Energy[d] 2000-2020 (1997$/site MMBtu) |
|---|---|---|---|---|---|---|---|---|---|
| **Gas or LPG Heating, continued** | | | | | | | | | |
| | Building America | $320 | $219 | 23.40 | 25.41 | 24.3 | 3 | $1.19 | $0.75 |
| | R&D (ENERGY STAR Homes level) | $830 | $444 | 20.42 | 18.74 | 24.3 | 3 | $3.53 | $2.05 |
| | R&D (Building America level) | $297 | $188 | 23.99 | 25.92 | 24.3 | 3 | $1.07 | $0.63 |
| | **Average, all programs** | | | | | | | **$3.72** | **$2.05** |
| **Oil Heating** | | | | | | | | | |
| | NAECA Standards | - | - | - | - | - | 5 | - | - |
| | Building Codes | $70 | $209 | 25.43 | 52.01 | 30.0 | 2 | $0.22 | $0.32 |
| | ENERGY STAR Homes | $1,187 | $669 | 34.04 | 31.55 | 25.4 | 3 | $2.97 | $1.81 |
| | New Home Tax credit (30% level) | $1,370 | $1,370 | 40.14 | 39.77 | 25.4 | 3 | $2.91 | $2.94 |
| | New Home Tax credit (40% level) | $1,828 | $1,828 | 47.54 | 47.02 | 25.4 | 3 | $3.28 | $3.31 |
| | New Home Tax credit (50% level) | $2,286 | $2,286 | 54.70 | 54.36 | 25.4 | 3 | $3.56 | $3.58 |
| | Building America | $324 | $224 | 38.17 | 41.40 | 25.4 | 3 | $0.72 | $0.46 |
| | R&D (ENERGY STAR Homes level) | $896 | $477 | 33.41 | 30.64 | 25.4 | 3 | $2.29 | $1.33 |
| | R&D (Building America level) | $298 | $188 | 39.19 | 42.36 | 25.4 | 3 | $0.65 | $0.38 |
| | **Average, all programs** | | | | | | | **$2.41** | **$1.35** |

[a] This table presents average costs, energy savings, and costs of conserved energy (CCEs) for each policy in the Advanced scenario. In some cases, the costs, savings and CCEs are averaged over different efficiency levels of the policy. This is the case for building codes, where the values shown are averaged over the 1993 MEC, 1998 IECC and future IECC codes. This is also the case for Building America, which is assumed to have greater energy savings during the 2010-2020 period than prior to 2010. The costs, savings, and CCEs of the NAECA standards for the electric cooling end-use in this table are averages over three standards: heat pump, central A/C, and room A/C. The values for ENERGY STAR homes are averaged over two different cost levels (the cost of an ENERGY STAR home is assumed to decrease in 2010). Additionally, since we assumed that the energy saved by the ENERGY STAR homes and new home tax credit programs for the cooling end-use vary by the type of heating fuel present (see Table C-1.4.adv for further explanation), the cooling values for these two programs are averaged over different heating fuel types.
One of the differences between the data in this table and the more disaggregated data in Table C-1.4.adv is that the energy savings in this table account for the interactions between policies (for example, the savings of non-mandatory programs has been reduced by the savings of the mandatory policies (standards and building codes) to avoid double-counting of energy savings. See Note c for more details.

[b] Average incremental cost per house is an average over all homes affected by the program during the stated time period (2000-2010 inclusive or 2000-2020 inclusive). Note that for the electric cooling end-use, the cost and energy savings of ENERGY STAR homes and New home tax credits vary by heating fuel (see Table C-1.4.adv). The costs and energy savings by heating fuel (shown in Table C-1.4.adv) were weighted by

**Table C-1.3.adv, continued**

the number of new homes built of each fuel type (from output of the CEF-NEMS reference case) during the stated time period to obtain the average costs shown in this table.

[c] Average annual site energy savings per house, for only those homes affected by the program during the stated time period (2000-2010 inclusive or 2000-2020 inclusive). The energy savings of the non-mandatory programs (i.e., all programs except NAECA standards and building codes) are reduced by the mandatory programs, which are assumed to be implemented first, thereby reducing the energy savings potential of the non-mandatory programs - see Table C-1.4.adv for more information). This was done to avoid double-counting the energy savings; we arbitrarily chose to implement building codes first, followed by the NAECA standards. The average household energy savings for the non-mandatory programs is lower in the Advanced case than in the Moderate case because the Advanced case has more stringent building codes and a higher penetration of building codes. For the same reason, the NAECA standards also have a lower per-house energy savings in the Advanced case than in the Moderate case. See Table C-1.4.adv for the disaggregated energy savings for each policy.

[d] Cost of Conserved Energy (CCE), in 1997 dollars per million site Btu, is presented for each program and also as an average over all programs affecting each end-use. In both cases, the CCE is an average over all homes affected by the policy during the stated time period (either 2000-2010, inclusive or 2000-2020, inclusive). All CCEs were calculated using a real discount rate of 7%. The average CCE for each end-use was calculated by weighting the individual program CCEs by the energy savings for each program.

**Notes**

1 Estimated average lifetime of an electric heat pump, calculated by averaging electric heat pump minimum and maximum life expectancies from an input file to the CEF-NEMS model.

2 Compliance with building codes usually involves primarily the use of building shell measures (rather than HVAC equipment measures). We assumed a 30 year lifetime for building shell measures (Brown et. al. 1998).

3 Whole-house improvement programs such as ENERGY STAR New Homes, New Home Tax Credit, and Building America are assumed to utilize three different types of measures, which have quite different lifetimes: building shell improvements, duct improvements, and HVAC equipment upgrades. We assumed the average lifetime is 30 years for building shell measures and 15 years for duct measures (Brown et. al. 1998). HVAC equipment lifetimes are from the same source described in Note 1. We calculated an average lifetime for each end-use and used it for each of the whole-house policies. Table C-1.5 provides details of the calculations.

4 Lifetime of electric cooling equipment measures is a weighted average over the three main cooling equipment types (CAC, HP, and RAC). We calculated the average lifetime of each of the cooling equipment types, using their minimum and maximum lifetime expectancies (from an input file to the CEF-NEMS model). These average lifetimes were then weighted by the saturation of each equipment type in homes built in the year 2000 (from an output file of the CEF-NEMS reference case) in order to obtain the average lifetime of 12.3 years shown in this table.

5 No new NAECA standards for gas-, oil-, or LPG-fired HVAC equipment were assumed to be implemented during the forecast time period.

| Table C-1.4.mod: Supplemental Technology Data for New Residential Building HVAC End-Uses, Moderate Case | | | | | | | |
|---|---|---|---|---|---|---|---|
| **End-Use** | **Policy** | **Time Period** | **Average Incremental Cost per House[a] (1997 dollars)** | **Cost Notes** | **Base Case Household Energy Consumption[b] (site MMBtu/yr)** | **Measure Energy Savings as % of base case consumption[c] (%)** | **Measure Energy Savings Notes** |
| **Electric Heating** | | | | | 15.58 | | |
| | NAECA standard heat pump (2006) | 2006-2020 | $52 | 1 | | 3.3% | 16 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $128 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $308 | 2 | | 17.7% | 14 |
| | Building Code: future IECC | 2009-2020 | $414 | 2 | | 23.0% | 15 |
| | ENERGY STAR New Homes | 2000-2009 | $995 | 3 | | 40.1% | 18 |
| | ENERGY STAR New Homes | 2010-2020 | $585 | 4 | | 40.1% | 18 |
| | New Home Tax Credit (30% above 1998 IECC) | 2000-2001 | $947 | 7 | | 42.4% | 21 |
| | New Home Tax Credit (40% above 1998 IECC) | 2000-2002 | $1,267 | 7 | | 50.6% | 21 |
| | New Home Tax Credit (50% above 1998 IECC) | 2000-2004 | $1,587 | 7 | | 58.9% | 21 |
| | DOE's Building America | 2000-2009 | $350 | 5 | | 40.0% | 19 |
| | DOE's Building America | 2010-2020 | $280 | 6 | | 50.0% | 20 |
| | R&D (ENERGY STAR New Home level) | 2005-2009 | $995 | 8a | | 40.1% | 22 |
| | R&D (ENERGY STAR New Home level) | 2010-2020 | $585 | 8b | | 40.1% | 22 |
| | R&D (Building America level) | 2005-2009 | $350 | 9a | | 40.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $280 | 9b | | 50.0% | 22 |
| **Electric Cooling** | | | | | 8.83 | | |
| | NAECA standard heat pump (2006) | 2006-2020 | $90 | 1 | | 9.2% | 16 |
| | NAECA standard CAC (2006) | 2006-2020 | $132 | 10 | | 13.2% | 16 |
| | NAECA standard Room A/C (2001) | 2001-2009 | $17 | 11 | | 5.9% | 17 |
| | NAECA standard Room A/C (2010) | 2010-2020 | $65 | 11 | | 13.0% | 17 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $72 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $192 | 2 | | 19.5% | 14 |
| | Building Code: future IECC | 2009-2020 | $286 | 2 | | 28.0% | 15 |
| | ENERGY STAR New Homes, electrically heated | 2000-2009 | $705 | 3 | | 45.6% | 18 |
| | ENERGY STAR New Homes, electrically heated | 2010-2020 | $415 | 4 | | 45.6% | 18 |
| | ENERGY STAR New Homes, gas or LPG heated | 2000-2009 | $315 | 3 | | 52.7% | 18 |
| | ENERGY STAR New Homes, gas or LPG heated | 2010-2020 | $186 | 4 | | 52.7% | 18 |
| | ENERGY STAR New Homes, oil heated | 2000-2009 | $206 | 3 | | 52.7% | 18 |
| | ENERGY STAR New Homes, oil heated | 2010-2020 | $121 | 4 | | 52.7% | 18 |
| | New Home Tax Credit (30% above 1998 IECC), electrically heated | 2000-2001 | $553 | 7 | | 43.7% | 21 |

| Table C-1.4.mod: Supplemental Technology Data for New Residential Building HVAC End-Uses, Moderate Case | | | | | | | |
|---|---|---|---|---|---|---|---|
| **End-Use** | **Policy** | **Time Period** | **Average Incremental Cost per House[a] (1997 dollars)** | **Cost Notes** | **Base Case Household Energy Consumption[b] (site MMBtu/yr)** | **Measure Energy Savings as % of base case consumption[c] (%)** | **Measure Energy Savings Notes** |
| **Electric Cooling, continued** | | | | | | | |
| | New Home Tax Credit (40% above 1998 IECC), electrically heated | 2000-2002 | $733 | 7 | | 51.7% | 21 |
| | New Home Tax Credit (50% above 1998 IECC), electrically heated | 2000-2004 | $913 | 7 | | 59.8% | 21 |
| | New Home Tax Credit (30% above 1998 IECC), gas or LPG heated | 2000-2001 | $201 | 7 | | 43.7% | 21 |
| | New Home Tax Credit (40% above 1998 IECC), gas or LPG heated | 2000-2002 | $266 | 7 | | 51.7% | 21 |
| | New Home Tax Credit (50% above 1998 IECC), gas or LPG heated | 2000-2004 | $331 | 7 | | 59.8% | 21 |
| | New Home Tax Credit (30% above 1998 IECC), oil heated | 2000-2001 | $130 | 7 | | 43.7% | 21 |
| | New Home Tax Credit (40% above 1998 IECC), oil heated | 2000-2002 | $172 | 7 | | 51.7% | 21 |
| | New Home Tax Credit (50% above 1998 IECC), oil heated | 2000-2004 | $214 | 7 | | 59.8% | 21 |
| | DOE's Building America | 2000-2009 | $150 | 5 | | 30.0% | 19 |
| | DOE's Building America | 2010-2020 | $120 | 6 | | 40.0% | 20 |
| | R&D (ENERGY STAR New Home level), electrically heated | 2005-2009 | $705 | 8a | | 45.6% | 22 |
| | R&D (ENERGY STAR New Home level), electrically heated | 2010-2020 | $415 | 8b | | 45.6% | 22 |
| | R&D (ENERGY STAR New Home level), gas or LPG heated | 2005-2009 | $315 | 8a | | 52.7% | 22 |
| | R&D (ENERGY STAR New Home level), gas or LPG heated | 2010-2020 | $186 | 8b | | 52.7% | 22 |
| | R&D (ENERGY STAR New Home level), oil heated | 2005-2009 | $206 | 8a | | 52.7% | 22 |
| | R&D (ENERGY STAR New Home level), oil heated | 2010-2020 | $121 | 8b | | 52.7% | 22 |
| | R&D (Building America level) | 2005-2009 | $150 | 9a | | 30.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $120 | 9b | | 40.0% | 22 |

| Table C-1.4.mod: Supplemental Technology Data for New Residential Building HVAC End-Uses, Moderate Case | | | | | | | |
|---|---|---|---|---|---|---|---|
| End-Use | Policy | Time Period | Average Incremental Cost per House[a] (1997 dollars) | Cost Notes | Base Case Household Energy Consumption[b] (site MMBtu/yr) | Measure Energy Savings as % of base case consumption[c] (%) | Measure Energy Savings Notes |
| **Gas or LPG Heating** | | | | | 58.80 | | |
| | NAECA standard | - | - | 12 | | - | 7 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $128 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $308 | 2 | | 17.7% | 14 |
| | Building Code: future IECC | 2009-2020 | $414 | 2 | | 23.0% | 15 |
| | ENERGY STAR New Homes | 2000-2009 | $1,385 | 3 | | 37.1% | 18 |
| | ENERGY STAR New Homes | 2010-2020 | $814 | 4 | | 37.1% | 18 |
| | New Home Tax Credit (30% above 1998 IECC) | 2000-2001 | $1,299 | 7 | | 42.4% | 21 |
| | New Home Tax Credit (40% above 1998 IECC) | 2000-2002 | $1,734 | 7 | | 50.6% | 21 |
| | New Home Tax Credit (50% above 1998 IECC) | 2000-2004 | $2,169 | 7 | | 58.9% | 21 |
| | DOE's Building America | 2000-2009 | $350 | 5 | | 40.0% | 19 |
| | DOE's Building America | 2010-2020 | $280 | 6 | | 50.0% | 20 |
| | R&D (ENERGY STAR New Home level) | 2005-2009 | $1,385 | 8a | | 37.1% | 22 |
| | R&D (ENERGY STAR New Home level) | 2010-2020 | $814 | 8b | | 37.1% | 22 |
| | R&D (Building America level) | 2005-2009 | $350 | 9a | | 40.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $280 | 9b | | 50.0% | 22 |
| **Oil Heating** | | | | | 95.76 | | |
| | NAECA standard | - | - | 12 | | - | 7 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $128 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $308 | 2 | | 17.7% | 14 |
| | Building Code: future IECC | 2009-2020 | $414 | 2 | | 23.0% | 15 |
| | ENERGY STAR New Homes | 2000-2009 | $1,494 | 3 | | 37.1% | 18 |
| | ENERGY STAR New Homes | 2010-2020 | $879 | 4 | | 37.1% | 18 |
| | New Home Tax Credit (30% above 1998 IECC) | 2000-2001 | $1,370 | 7 | | 42.4% | 21 |
| | New Home Tax Credit (40% above 1998 IECC) | 2000-2002 | $1,828 | 7 | | 50.6% | 21 |
| | New Home Tax Credit (50% above 1998 IECC) | 2000-2004 | $2,286 | 7 | | 58.9% | 21 |
| | DOE's Building America | 2000-2009 | $350 | 5 | | 40.0% | 19 |
| | DOE's Building America | 2010-2020 | $280 | 6 | | 50.0% | 20 |
| | R&D (ENERGY STAR New Home level) | 2005-2009 | $1,494 | 8a | | 37.1% | 22 |
| | R&D (ENERGY STAR New Home level) | 2010-2020 | $879 | 8b | | 37.1% | 22 |
| | R&D (Building America level) | 2005-2009 | $350 | 9a | | 40.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $280 | 9b | | 50.0% | 22 |

**Table C-1.4.mod, continued**

[a] Costs are average per-house costs to the consumer, and are relative to the cost of average purchased equipment in 2000 or of average new home construction in 2000. Costs for whole-house programs such as new home tax credit, ENERGY STAR Homes, and Building America, reflect just the cost of measures that affect heating and/or cooling. If a policy saves both heating and cooling energy, we apportion the measure cost to heating and cooling according to the amount of site energy saved in each end-use. See the Notes below for further details on costs.

[b] The frozen efficiency (base case) household energy consumption (site million Btu per household per annum in 2000) is from an output file of the CEF-NEMS reference case. It is an average over all equipment types in that end-use, weighted by the saturation of each equipment type in all homes built in 2000. This initial consumption was only used to calculate the energy saved by building codes. We assumed that, of the two mandatory policies, building codes are implemented first, then the NAECA standards, then the non-mandatory policies. Energy savings for all policies other than building codes were calculated from a changing baseline consumption, not the frozen efficiency consumption in this table. We did this to avoid double counting the energy saved by mandatory programs. The changing baseline is a result of the implementation of the mandatory policies. (Equipment standards cause a one-time decrease, but the penetration of building codes is constantly increasing, which causes a continual decrease in the baseline consumption). We applied the percent energy savings shown in the table for each policy (other than building codes) to the changing baseline consumption in each year.

[c] The measure energy savings is the energy saved by the policy per house as a percent of the baseline consumption. For building codes only, the baseline consumption is the frozen efficiency (base case) household energy consumption shown in this table. For all other policies, the baseline consumption is calculated each year as described in note b, and the percent energy savings gets applied to this changing baseline consumption. The NAECA standard percent savings in this table are given as a percent of the energy consumed by the equipment subject to the standard. The percent energy savings of a NAECA standard gets applied to a baseline consumption for that equipment only, not the overall end-use consumption. See the Notes below for detailed assumptions about the energy saved by the individual policies. The percent energy savings is assumed to be the same for the Moderate and Advanced cases.

## Notes

1 LBNL estimate of mature market costs for a 12 SEER standard. We assume the incremental cost of a 12 SEER unit compared to the frozen efficiency in 2000 (10.89 SEER from an output file for the CEF-NEMS reference case) will be half of current market costs. Current market costs of heat pumps are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume one 3 ton unit per house.

2 LBNL's estimate of the incremental cost of a home built to 1993 CABO Model Energy Code requirements, or 1998 International Code Council's International Energy Conservation Code (IECC), or to a future IECC code level, relative to the cost of an average new home in 2000, is $200, $500 and $700, respectively. These costs include measures which affect both heating and cooling, and were apportioned to the heating and cooling end-uses in the manner described in Note 3. We assume that the 50% increase in R&D funding in the Moderate case will have no effect on the cost of building codes because the codes are nowhere near as stringent as the voluntary programs.

3 The incremental cost to the homebuyer of an ENERGY STAR home during the 2000-2009 period is assumed to be $1700, which includes only those measures which affect the heating and cooling end-uses. This is an average cost over the time period, which takes into account the effect of the 50% increase in R&D funding for whole house measures starting in 2005, which will begin to lower costs toward the end of the 2000-2009 period. We assume that most of the cost decrease due to increased R&D spending will happen after 2009 (see Note 4 for more details). ENERGY STAR homes may include improved water heaters, but the cost of water heating measures was accounted for in the water heating end-use (see Residential non-HVAC technology data tables) and therefore was not included here. We assume that all ENERGY STAR homes have both heating and cooling equipment, and apportioned the total measure cost among the heating and cooling end-uses according to the site energy savings for each end-use. We applied the energy savings percentages to the base case household energy consumptions, both shown in this table, in order to determine the respective energy savings for the heating and cooling end-uses. (Building codes and NAECA standards will lower the base case energy consumption, thereby reducing the energy savings for both heating and cooling, but this effect was ignored for the purpose of apportioning the cost). Note that the percent energy savings for cooling depends on whether the house is heated by electricity or fuel (see Measure Energy savings notes for more details). The cost apportioned to cooling also differs by the type of fuel heat (gas/LPG or oil) because, even though the percent energy savings percentage is the same for gas/LPG and oil, the base case energy consumption is higher for oil heating than gas/LPG heating, thus the total cost will be apportioned more to oil heat than to gas/LPG because the oil savings is greater. Electric cooling costs by heating fuel type are shown in this table.

4 In the Moderate case, we assume there will be a 50% increase in R&D funding starting in 2005. We assume that the incremental cost of efficient homes will decrease gradually between 2005 and 2020 due to the increased R&D funding. We assume that the average incremental cost of an ENERGY STAR New Home after 2010 will be reduced from an

**Table C-1.4.mod Notes, continued**

estimated cost of $1300 (in the absence of increased R&D funding) to $1000 (with a 50% increase in R&D funding). This cost is only for heating and cooling measures (water heating measure costs were accounted for in the water heating end-use). The total cost of the heating and cooling measures was apportioned between heating and cooling end-uses as described in Note 3.

5 DOE's program goal is to keep the incremental cost of Building America homes under $500 per house. Costs for homes already built as part of this program have been in many cases $0 or negative, but we assumed an average cost per house of $500 until 2010. This cost includes the cost of measures which affect heating and cooling, and it was apportioned to the heating and cooling end-uses as follows. Because the cost is so low, we did not calculate heating and cooling costs separately for each heating fuel, as we did for ENERGY STAR homes and the new home tax credits. In the case of ENERGY STAR and tax credits, the costs are higher, so the heating fuel becomes an important determinant in the cost-effectiveness of the measure because of differences in fuel prices and base case energy consumptions. However, because the cost of Building America homes is so low, the heating fuel type would not affect the cost-effectiveness enough to rule out the measure as being not cost-effective. In other words, the Building America homes are cost-effective for all the heating equipment types evaluated in this analysis. The $500 cost was estimated to be apportioned 70% to heating and 30% to cooling. Although we assume that increased funding for R&D affecting whole-house efficiency starts in 2005, and affects the penetration starting in 2005, we assume that the incremental cost of Building America homes will not decrease significantly until after 2009 (see Note 6). This is because the incremental cost is so low to begin with.

6 After 2009, we assume that the Building America homes will be built to higher efficiency levels (see Measure Energy Savings notes in this table for details). At current R&D funding levels, we assume that the average cost per house could remain at $500 after 2010, even though the houses are built to a higher standard, due to economies of scale and improvements in building construction techniques and in equipment technology. However, in the Moderate case, we assume there will be a 50% increase in R&D funding that will reduce the cost of whole-house measures in new homes. We assume that we will begin to see the effect of the funding increase on prices in 2010. We assume that the average incremental cost of a Building America home after 2010 will be reduced from the estimated cost of $500 (in the absence of increased R&D funding) to $400 (with a 50% increase in R&D funding). The cost is assumed to be apportioned 70% to heating and 30% to cooling, as described in Note 5.

7 LBNL's estimate of the full incremental cost per house (i.e., the tax credit is not subtracted). The total incremental costs are assumed to be $1500 for level 1 (30% more efficient than the 1998 IECC code), $2000 for level 2 (40% more efficient than the 1998 IECC code) and $2500 for level 3 (50% more efficient than the 1998 IECC code). These costs are the total costs of all measures that affect heating and cooling end-uses. The cost of measures that affect the water heating end-use are accounted for in the water heating end-use calculations (see Residential non-HVAC tables in this Appendix for more details). The cost of heating and cooling measures was apportioned to the heating and cooling end-uses according to the relative energy savings in each end-use, in the manner described in Note 3. We did not reduce the cost of the new home tax credit programs to account for the Moderate Case increase in funding for whole-house R&D, because the tax credit program officially ends prior to 2005 in the Moderate Case. We do assume that there will be a very small residual penetration of homes built to the tax credit levels after the program ends and continue to be built through 2020 (see Table B-1.2.mod for more details), but the decrease in prices due to R&D funding would have only a small effect due to the small penetration levels, which we ignored.

8a This is the average incremental cost of the additional homes built to the ENERGY STAR new home level due solely to a 50% increase in R&D funding for whole-house efficiency measures during the 2005-2009 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the ENERGY STAR program during the same time period (see Note 3 for more details).

8b This is the average incremental cost of the additional homes built to the ENERGY STAR new home level due solely to a 50% increase in R&D funding for whole-house efficiency measures during the 2010-2020 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the ENERGY STAR program during the same time period (see Note 4 for more details).

9a This is the average incremental cost of the additional homes built to the Building America level due solely to a 50% increase in R&D funding for whole-house efficiency measures during the 2005-2009 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the Building America program from 2000-2009 (see Note 5 for more details).

9b This is the average incremental cost of the additional homes built to the Building America level due solely to a 50% increase in R&D funding for whole-house efficiency measures during the 2010-2020 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the Building America program from 2010-2020 (see Note 6 for more details).

10 LBNL estimate of mature market costs for a 12 SEER standard. We assume the incremental cost of a 12 SEER unit compared to the frozen efficiency in 2000 (10.42 SEER from an input file used by the NEMS model) will be half of current market costs. Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume one 3 ton unit.

11 Incremental cost to go from a unit of frozen efficiency in 2000 (9.13 EER, from an output file for the CEF-NEMS reference case) to either the average efficiency required by the new standard taking effect in October, 2000 (9.7 EER on average), or to the future estimated standard level of 10.5 EER. Based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990$ using the GDP deflator. Cost is a shipment weighted average over the most common product classes (from under 6 Btuh to 20 Btuh capacity), using 1989 shipments by product class from US DOE 1993b. Cost assumes an average of 1.5 room A/C units per house.

12 We assume that NAECA standards for gas, LPG and oil heating equipment will not be updated during the forecast period.

**Table C-1.4.mod Notes, continued**

13 LBNL modeling of typical new home builder practice in 14 U.S. cities (Brown et. al. 1998) estimates a typical new home HERS rating of 76.7. Each point away from 80 HERS is equivalent to 5% energy difference (aggregated over space heating, cooling, and water heating enduses). The 1993 MEC requirement is 80 HERS, which is 16.5% more energy efficient than a house with a 76.7 HERS rating. For simplicity, we assumed that each of the 3 end-uses (water heating, cooling, and space heating) would get the same (16.5%) improvement. The 1995 Model Energy Code differs only slightly from the 1993 MEC and is assumed to have about the same energy savings as the 1993 MEC.

14 The main difference between 1993 MEC and 1998 IECC codes is in the added solar heat gain coefficient requirement in southern climates. There are also some small improvements affecting heating. To estimate the cooling savings to go from (typically) double or single pane clear windows to double pane low-e windows in the south, we used results of previous LBNL research (Arasteh 1999). We averaged Arasteh's cooling savings for 5 cities (Phoenix, Memphis, Las Vegas, Jacksonville, and Atlanta). Typical (base case) windows varied among these cities but were either a double or single pane window with clear glazing. The cooling savings estimate in the table above represents an average of the southern savings and the northern cooling savings (northern cooling savings were assumed to be the same as the 1993 MEC savings because the solar heat gain coefficient requirement in 1998 IECC only applies to southern climates). The heating savings in the south are an average of the heating savings from the Arasteh DOE-2 runs for the 5 cities. For heating in the north, to account for the small improvements affecting heating, we assumed that the 1998 code savings would be 5% greater than the 1993 code. The heating and cooling percent savings in this table are a simple average of our percent savings estimates for the south and north climates.

15 LBNL estimate of future IECC building code efficiency level. We assume that a new IECC code is created sometime before 2009, but it only begins to be adopted by states and local jurisdictions in 2009. See Table B-1.2.mod for more details about the program.

16 A new heat pump and CAC standard analysis has been completed but is pending approval. We assume that it will be finalized sometime next year and the new standards will take effect on January 1, 2006. We assume the standard for heat pumps will be 7.4 HSPF/12 SEER and the standard for CAC will be 12 SEER. The percent energy savings in the table were estimated using a simple ratio of efficiencies (future standard efficiency to the average new unit efficiency in 2000). The average new unit efficiency in 2000 for heat pumps is 7.15 HSPF/10.89 SEER and 10.42 SEER for CAC, from an output file for the CEF-NEMS reference case.

17 A new room A/C standard will come into effect on October 1, 2000. The CEF-NEMS reference case includes this standard, but starts it on Jan 1, 2001. To be consistent with the reference case, we also began the standard on Jan 1, 2001 in the Moderate and Advanced cases. Federal standards for room A/C vary by equipment capacity. We calculated an average efficiency of 9.7 EER for the October 2000 standard by weighting the standard efficiency for each product class by the 1989 shipments of each product class. In addition, we estimated that a future standard for room A/C would take effect in 2010 at 10.5 EER (on average over the most common capacities). The percent energy savings in the table was estimated using a simple ratio of efficiencies (future standard efficiency to the average new unit efficiency in 2000 (9.13 EER, from an output file for the CEF-NEMS reference case).

18 LBNL estimate based on work for the U.S. EPA to determine typical cost-effective packages of measures that builders in 14 U.S. cities could use in order to meet the ENERGY STAR certification requirements (Brown et. al. 1998). We calculated average heating and cooling savings for homes with the recommended ENERGY STAR package of measures, compared to current building practice of large production home builders in each city. On average over Southern and Northern cities, ENERGY STAR homes with electric heat pumps saved 40.1% of the annual heating and 45.6% of the annual cooling consumptions, compared to current construction in those cities. Homes with gas furnaces and central air conditioners saved 37.1% in heating and 52.7% in cooling on average over Southern and Northern cities, compared to current building practices in those cities. We assume that all ENERGY STAR homes have both heating and cooling equipment. We assume that the ENERGY STAR efficiency level will remain at the current level during the entire forecast period, although the cost is assumed to decrease due to increased R&D funding (see Notes 3 and 4). Brown et. al. (1998) did not provide any savings estimates for oil-heated homes, so we assumed that oil-heated homes would have the same percentage savings as gas-heated homes.

19 Energy savings reflect typical, low-side, savings from current program participants (Pettit, 1999 and James, 1999). We assume that up until 2010, the average energy savings among program participants will tend toward the lower end of the current range of savings.

20 Energy savings reflect upper bound of estimates from current program participants (Pettit, 1999 and James, 1999). We assume that from 2010 through 2020, the average energy savings among program participants will tend toward the higher end of the current range of savings, due to a variety of factors which might include smarter building design, increased availability of technologies, and decreased prices.

21 Energy savings are based on Treasury Department efficiency proposals for the three levels of tax credits, from US DOT 1999. The proposed levels are 30%, 40%, or 50% better than the 1998 IECC code. The energy savings in this table for the tax credits are simply 30%, 40% and 50% more than our estimated savings for the 1998 IECC code. For example, the estimated electric heating energy savings for level 1 of the tax credit is (100% - (1-17.7%)*(1 - 30%)), or 42.4%. The terms in this formula represent the baseline electric heating consumption of a 1998 IECC code house (1-17.7%), and the (1-17.7%)*(1-30%) term represents the consumption of a house that is 30% better than the 1998 IECC code. Cooling energy savings was calculated in the same way. The percent energy savings is assumed to be the same for all heating fuels.

22 We assume that increased R&D funding for whole-house programs affects the cost of building homes to efficiency levels that meet or exceed the efficiency of ENERGY STAR new homes. We assume that R&D funding increases begin to have an impact on the market in 2005 (see Table B-1.2.mod for more details). While we recognize that increased R&D funding would also affect homes built to the new home tax credit efficiency levels, we did not include this explicitly in our analysis. Thus, we attributed the entire effect of

**Table C-1.4.mod Notes, continued**

increased R&D funding for whole-house measures to ENERGY STAR new homes and Building America, in the form of lower prices and increased penetration for these programs. We assume that the percentage energy saved by the programs will not change due to increased R&D funding. Thus, the percent energy savings for R&D during each time period analyzed (2005-2009 and 2010-2020) are assumed to be the same as the percent energy savings for the ENERGY STAR and Building America programs during the same time period.

| Table C-1.4.adv: Supplemental Technology Data for New Residential Building HVAC End-Uses, Advanced Case | | | | | | | |
|---|---|---|---|---|---|---|---|
| End-Use | Policy | Time Period | Average Incremental Cost per House[a] (1997 dollars) | Cost Notes | Frozen Efficiency Household Energy Consumption[b] (site MMBtu/yr) | Measure Energy Savings as % of baseline consumption[c] (%) | Measure Energy Savings Notes |
| **Electric Heating** | | | | | 15.58 | | |
| | NAECA standard heat pump (2006) | 2006-2020 | $52 | 1 | | 3.3% | 16 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $167 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $411 | 2 | | 17.7% | 14 |
| | Building Code: future IECC | 2009-2020 | $564 | 2 | | 23.0% | 15 |
| | ENERGY STAR New Homes | 2000-2009 | $912 | 3 | | 40.1% | 18 |
| | ENERGY STAR New Homes | 2010-2020 | $304 | 4 | | 40.1% | 18 |
| | New Home Tax Credit (30% above 1998 IECC) | 2000-2003 | $947 | 7 | | 42.4% | 21 |
| | New Home Tax Credit (40% above 1998 IECC) | 2000-2005 | $1,267 | 7 | | 50.6% | 21 |
| | New Home Tax Credit (50% above 1998 IECC) | 2000-2009 | $1,587 | 7 | | 58.9% | 21 |
| | DOE's Building America | 2000-2009 | $350 | 5 | | 40.0% | 19 |
| | DOE's Building America | 2010-2020 | $175 | 6 | | 50.0% | 20 |
| | R&D (ENERGY STAR New Home level) | 2005-2009 | $912 | 8a | | 40.1% | 22 |
| | R&D (ENERGY STAR New Home level) | 2010-2020 | $304 | 8b | | 40.1% | 22 |
| | R&D (Building America level) | 2005-2009 | $350 | 9a | | 40.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $175 | 9b | | 50.0% | 22 |
| **Electric Cooling** | | | | | 8.83 | | |
| | NAECA standard heat pump (2006) | 2006-2020 | $90 | 1 | | 9.2% | 16 |
| | NAECA standard CAC (2006) | 2006-2020 | $132 | 10 | | 13.2% | 16 |
| | NAECA standard Room A/C (2001) | 2001-2009 | $17 | 11 | | 5.9% | 17 |
| | NAECA standard Room A/C (2010) | 2010-2020 | $65 | 11 | | 13.0% | 17 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $33 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $89 | 2 | | 19.5% | 14 |
| | Building Code: future IECC | 2009-2020 | $136 | 2 | | 28.0% | 15 |
| | ENERGY STAR New Homes, electrically heated | 2000-2009 | $588 | 3 | | 45.6% | 18 |
| | ENERGY STAR New Homes, electrically heated | 2010-2020 | $196 | 4 | | 45.6% | 18 |
| | ENERGY STAR New Homes, gas or LPG heated | 2000-2009 | $264 | 3 | | 52.7% | 18 |
| | ENERGY STAR New Homes, gas or LPG heated | 2010-2020 | $88 | 4 | | 52.7% | 18 |
| | ENERGY STAR New Homes, oil heated | 2000-2009 | $174 | 3 | | 52.7% | 18 |
| | ENERGY STAR New Homes, oil heated | 2010-2020 | $58 | 4 | | 52.7% | 18 |
| | New Home Tax Credit (30% above 1998 IECC), electrically heated | 2000-2003 | $553 | 7 | | 43.7% | 21 |

Table C-1.4.adv: Supplemental Technology Data for New Residential Building HVAC End-Uses, Advanced Case

| End-Use | Policy | Time Period | Average Incremental Cost per House[a] (1997 dollars) | Cost Notes | Frozen Efficiency Household Energy Consumption[b] (site MMBtu/yr) | Measure Energy Savings as % of baseline consumption[c] (%) | Measure Energy Savings Notes |
|---|---|---|---|---|---|---|---|
| **Electric Cooling, continued** | | | | | | | |
| | New Home Tax Credit (40% above 1998 IECC), electrically heated | 2000-2005 | $733 | 7 | | 51.7% | 21 |
| | New Home Tax Credit (50% above 1998 IECC), electrically heated | 2000-2009 | $913 | 7 | | 59.8% | 21 |
| | New Home Tax Credit (30% above 1998 IECC), gas or LPG heated | 2000-2003 | $201 | 7 | | 43.7% | 21 |
| | New Home Tax Credit (40% above 1998 IECC), gas or LPG heated | 2000-2005 | $266 | 7 | | 51.7% | 21 |
| | New Home Tax Credit (50% above 1998 IECC), gas or LPG heated | 2000-2009 | $331 | 7 | | 59.8% | 21 |
| | New Home Tax Credit (30% above 1998 IECC), oil heated | 2000-2003 | $130 | 7 | | 43.7% | 21 |
| | New Home Tax Credit (40% above 1998 IECC), oil heated | 2000-2005 | $172 | 7 | | 51.7% | 21 |
| | New Home Tax Credit (50% above 1998 IECC), oil heated | 2000-2009 | $214 | 7 | | 59.8% | 21 |
| | DOE's Building America | 2000-2009 | $150 | 5 | | 30.0% | 19 |
| | DOE's Building America | 2010-2020 | $75 | 6 | | 40.0% | 20 |
| | R&D (ENERGY STAR New Home level), electrically heated | 2005-2009 | $588 | 8a | | 45.6% | 22 |
| | R&D (ENERGY STAR New Home level), electrically heated | 2010-2020 | $196 | 8b | | 45.6% | 22 |
| | R&D (ENERGY STAR New Home level), gas or LPG heated | 2005-2009 | $264 | 8a | | 52.7% | 22 |
| | R&D (ENERGY STAR New Home level), gas or LPG heated | 2010-2020 | $88 | 8b | | 52.7% | 22 |
| | R&D (ENERGY STAR New Home level), oil heated | 2005-2009 | $174 | 8a | | 52.7% | 22 |
| | R&D (ENERGY STAR New Home level), oil heated | 2010-2020 | $58 | 8b | | 52.7% | 22 |
| | R&D (Building America level) | 2005-2009 | $150 | 9a | | 30.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $75 | 9b | | 40.0% | 22 |

| Table C-1.4.adv: Supplemental Technology Data for New Residential Building HVAC End-Uses, Advanced Case | | | | | | | |
|---|---|---|---|---|---|---|---|
| End-Use | Policy | Time Period | Average Incremental Cost per House[a] (1997 dollars) | Cost Notes | Frozen Efficiency Household Energy Consumption[b] (site MMBtu/yr) | Measure Energy Savings as % of baseline consumption[c] (%) | Measure Energy Savings Notes |
| **Gas or LPG Heating** | | | | | 58.80 | | |
| | NAECA standard | - | - | 12 | | - | 7 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $167 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $411 | 2 | | 17.7% | 14 |
| | Building Code: future IECC | 2009-2020 | $564 | 2 | | 23.0% | 15 |
| | ENERGY STAR New Homes | 2000-2009 | $1,236 | 3 | | 37.1% | 18 |
| | ENERGY STAR New Homes | 2010-2020 | $412 | 4 | | 37.1% | 18 |
| | New Home Tax Credit (30% above 1998 IECC) | 2000-2003 | $1,299 | 7 | | 42.4% | 21 |
| | New Home Tax Credit (40% above 1998 IECC) | 2000-2005 | $1,734 | 7 | | 50.6% | 21 |
| | New Home Tax Credit (50% above 1998 IECC) | 2000-2009 | $2,169 | 7 | | 58.9% | 21 |
| | DOE's Building America | 2000-2009 | $350 | 5 | | 40.0% | 19 |
| | DOE's Building America | 2010-2020 | $175 | 6 | | 50.0% | 20 |
| | R&D (ENERGY STAR New Home level) | 2005-2009 | $1,236 | 8a | | 37.1% | 22 |
| | R&D (ENERGY STAR New Home level) | 2010-2020 | $412 | 8b | | 37.1% | 22 |
| | R&D (Building America level) | 2005-2009 | $350 | 9a | | 40.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $175 | 9b | | 50.0% | 22 |
| **Oil Heating** | | | | | 95.76 | | |
| | NAECA standard | - | - | 12 | | - | 7 |
| | Building Code: 1993 or 1995 MEC | 2000-2020 | $167 | 2 | | 16.5% | 13 |
| | Building Code: 1998 IECC | 2000-2020 | $411 | 2 | | 17.7% | 14 |
| | Building Code: future IECC | 2009-2020 | $564 | 2 | | 23.0% | 15 |
| | ENERGY STAR New Homes | 2000-2009 | $1,326 | 3 | | 37.1% | 18 |
| | ENERGY STAR New Homes | 2010-2020 | $442 | 4 | | 37.1% | 18 |
| | New Home Tax Credit (30% above 1998 IECC) | 2000-2003 | $1,370 | 7 | | 42.4% | 21 |
| | New Home Tax Credit (40% above 1998 IECC) | 2000-2005 | $1,828 | 7 | | 50.6% | 21 |
| | New Home Tax Credit (50% above 1998 IECC) | 2000-2009 | $2,286 | 7 | | 58.9% | 21 |
| | DOE's Building America | 2000-2009 | $350 | 5 | | 40.0% | 19 |
| | DOE's Building America | 2010-2020 | $175 | 6 | | 50.0% | 20 |
| | R&D (ENERGY STAR New Home level) | 2005-2009 | $1,326 | 8a | | 37.1% | 22 |
| | R&D (ENERGY STAR New Home level) | 2010-2020 | $442 | 8b | | 37.1% | 22 |
| | R&D (Building America level) | 2005-2009 | $350 | 9a | | 40.0% | 22 |
| | R&D (Building America level) | 2010-2020 | $175 | 9b | | 50.0% | 22 |

**Table C-1.4.adv, continued**

[a] Costs are average per-house costs to the consumer, and are relative to the cost of average purchased equipment in 2000 or of average new home construction in 2000. Costs for whole-house programs such as new home tax credit, ENERGY STAR Homes, and Building America, reflect just the cost of measures that affect heating and/or cooling. If a policy saves both heating and cooling energy, we apportion the measure cost to heating and cooling according to the amount of site energy saved in each end-use. See the Notes below for further details on costs.

[b] The frozen efficiency (base case) household energy consumption (site million Btu per household per annum in 2000) is from an output file of the CEF-NEMS reference case. It is an average over all equipment types in that end-use, weighted by the saturation of each equipment type in all homes built in 2000. This initial consumption was only used to calculate the energy saved by building codes. We assumed that, of the two mandatory policies, building codes are implemented first, then the NAECA standards, then the non-mandatory policies. Energy savings for all policies other than building codes were calculated from a changing baseline consumption, not the frozen efficiency consumption in this table. We did this to avoid double counting the energy saved by mandatory programs. The changing baseline is a result of the implementation of the mandatory policies. (Equipment standards cause a one-time decrease, but the penetration of building codes is constantly increasing, which causes a continual decrease in the baseline consumption). We applied the percent energy savings shown in the table for each policy (other than building codes) to the changing baseline consumption in each year.

[c] The measure energy savings is the energy saved by the policy per house as a percent of the baseline consumption. For building codes only, the baseline consumption is the frozen efficiency (base case) household energy consumption shown in this table. For all other policies, the baseline consumption is calculated each year as described in note b. The NAECA standard percent savings are expressed as a percent of the energy consumed by the equipment subject to the standard. See the Notes below for detailed assumptions about the energy saved by the individual policies. The percent energy savings is assumed to be the same for the Moderate and Advanced cases.

## Notes

1 LBNL estimate of mature market costs for a 12 SEER standard. We assume the incremental cost of a 12 SEER unit compared to the frozen efficiency in 2000 (10.89 SEER from an output file for the CEF-NEMS reference case) will be half of current market costs. Current market costs of heat pumps are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume one 3 ton unit per house.

2 LBNL's estimate of the incremental cost of a home built to 1993 CABO Model Energy Code requirements, or 1998 International Code Council's International Energy Conservation Code (IECC), or to a future IECC code level, relative to the cost of an average new home in 2000, is $200, $500 and $700, respectively. These costs include measures which affect both heating and cooling, and were apportioned to the heating and cooling end-uses in the manner described in Note 3. We assume that the 100% increase in R&D funding in the Advanced case will have no effect on the cost of building codes because the codes are nowhere near as stringent as the voluntary programs.

3 The incremental cost to the homebuyer of an ENERGY STAR home during the 2000-2009 period is assumed to be $1500, which includes only those measures that affect the heating and cooling end-uses. This is an average cost over the time period, that takes into account the effect of a 100% increase in R&D funding for whole-house efficiency measures starting in 2005. We assume that the increased R&D funding will begin to lower the cost of ENERGY STAR homes toward the end of the 2000-2009 period. However, we assume that most of the cost decrease due to increased R&D funding will happen after 2009 (see Note 4 for more details). ENERGY STAR homes may include improved water heaters, but the cost of any water heating measures is accounted for in the water heating end-use (see Residential non-HVAC technology data tables) and therefore was not included here. We assumed that all ENERGY STAR homes have both heating and cooling equipment, and apportioned the total measure cost among the heating and cooling end-uses according to the site energy savings for each end-use. We applied the energy savings percentages to the base case household energy consumptions, both shown in this table, in order to determine the respective energy savings for the heating and cooling end-uses. (Building codes and NAECA standards will lower the base case energy consumption, thereby reducing the energy savings for both heating and cooling, but this effect was ignored for the purpose of apportioning the cost). Note that the percent energy savings for cooling depends on whether the house is heated by electricity or fuel (see Measure Energy savings notes for more details). The cost apportioned to cooling also varies by the type of fuel heat (gas/LPG or oil) because, even though the percent energy savings percentage is the same for gas/LPG and oil, the base case energy consumption is higher for oil heating than gas/LPG heating, thus the total cost will be apportioned more to oil heat than to gas/LPG because the oil savings is greater. Electric cooling costs by heating fuel type are shown in this table. Note that the average cost of ENERGY STAR homes during the 2000-2009 period is assumed to be $200 less in the Advanced case than in the Moderate case. The difference is due to lower prices and increased availability of measures in the more aggressive scenario, due in part to a doubled expenditure for R&D in the Advanced case.

**Table C-1.4.adv Notes, continued**

4 In the Advanced case, we assume there will be a 100% increase in R&D funding starting in 2005. We assume that the incremental cost of efficient homes will decrease gradually between 2005 and 2020 due to the increased R&D funding. We assume that the average incremental cost of an ENERGY STAR New Home after 2010 will be reduced from an estimated cost of $1000 (for the Advanced case penetration levels, in the absence of increased R&D funding) to $500 (with a 100% increase in R&D funding). This cost is only for heating and cooling measures (water heating measure costs were accounted for in the water heating end-use). The total cost of the heating and cooling measures was apportioned between heating and cooling end-uses as described in note 3.

5 DOE's program goal is to keep the incremental cost of Building America homes under $500 per house. Costs for homes already built as part of this program have been in many cases $0 or negative, but we assumed an average per-house cost of $500 until 2010. This cost includes the cost of measures which affect heating and cooling, and it was apportioned to the heating and cooling end-uses as follows. Because the cost is so low, we did not calculate heating and cooling costs separately for each heating fuel, as we did for ENERGY STAR homes and the new home tax credits. In the case of ENERGY STAR and tax credits, the costs are higher, so the heating fuel becomes an important determinant in the cost-effectiveness of the measure because of differences in fuel prices and base case energy consumptions. However, because the cost of Building America homes is so low, the heating fuel type would not affect the cost-effectiveness enough to rule out the measure as being not cost-effective. In other words, the Building America homes are cost-effective for all the heating equipment types evaluated in this analysis. The $500 cost was estimated to be apportioned 70% to heating and 30% to cooling.

6 After 2009, we assume that the Building America homes will be built to higher efficiency levels (see Measure Energy Savings notes in this table for details). At current R&D funding levels, we assume that the average per-cost house could remain at $500 after 2010, even though the houses are built to a higher standard, due to economies of scale and improvements in building construction techniques and in equipment technology. However, in the Advanced case, we assume there will be a 100% increase in R&D funding that will reduce the cost of whole-house measures in new homes. We assume that we will begin to see the effect of the funding increase on prices starting in 2010. We assume that the average incremental cost of a Building America home over the 2010-2020 period will be reduced from the estimated cost of $500 (in the absence of increased R&D funding) to $250 (with a 100% increase in R&D funding). The cost is assumed to be apportioned 70% to heating and 30% to cooling, as described in Note 5.

7 LBNL's estimate of the full incremental cost per house (i.e., the tax credit is not subtracted). The total incremental costs are assumed to be $1500 for level 1 (30% more efficient than the 1998 IECC code), $2000 for level 2 (40% more efficient than the 1998 IECC code) and $2500 for level 3 (50% more efficient than the 1998 IECC code). These costs are the total costs of all measures that affect heating and cooling end-uses. The cost of measures that affect the water heating end-use are accounted for in the water heating end-use calculations (see Residential non-HVAC tables in this Appendix for more details). The cost of heating and cooling measures was apportioned to the heating and cooling end-uses according to the relative energy savings in each end-use, in the manner described in Note 3. Although the 100% increase in R&D funding for whole-house efficiency measures would likely affect the incremental cost and penetration of homes qualifying for the DOE tax credit program after 2005, we did not account for this effect in our analysis.

8a This is the average incremental cost of the additional homes built to the ENERGY STAR new home level due solely to a 100% increase in R&D funding for whole-house efficiency measures during the 2005-2009 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the ENERGY STAR program during the same time period (see Note 3 for more details).

8b This is the average incremental cost of the additional homes built to the ENERGY STAR new home level due solely to a 100% increase in R&D funding for whole-house efficiency measures during the 2010-2020 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the ENERGY STAR program during the same time period (see Note 4 for more details).

9a This is the average incremental cost of the additional homes built to the Building America level due solely to a 100% increase in R&D funding for whole-house efficiency measures during the 2005-2009 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the Building America program from 2000-2009 (see Note 5 for more details).

9b This is the average incremental cost of the additional homes built to the Building America level due solely to a 100% increase in R&D funding for whole-house efficiency measures during the 2010-2020 period. The incremental cost of the R&D measure is assumed to be the same as the cost of the Building America program from 2010-2020 (see Note 6 for more details).

10 LBNL estimate of mature market costs for a 12 SEER standard. We assume the incremental cost of a 12 SEER unit compared to the frozen efficiency in 2000 (10.42 SEER from an input file used by the NEMS model) will be half of current market costs. Current market costs of CACs are from a variety of survey data including XENERGY (1996), Energy Center of Wisconsin (1997), and "Mr. Cool" (1998). Costs assume one 3 ton unit.

11 Incremental cost to go from a unit of frozen efficiency in 2000 (9.13 EER, from an output file for the CEF-NEMS reference case) to either the average efficiency required by the new standard taking effect in October, 2000 (9.7 EER on average), or to the future estimated standard level of 10.5 EER. Based on 1993 standards analysis (US DOE 1993b) for the most common product classes and type (i.e., louvered sides and no reverse valve) of room A/C, inflated to 1997 dollars from 1990$ using the GDP deflator. Cost is a shipment weighted average over the most common product classes (from under 6 Btuh to 20 Btuh capacity), using 1989 shipments by product class from US DOE 1993b. Cost assumes an average of 1.5 room A/C units per house.

12 We assume that NAECA standards for gas, LPG and oil heating equipment will not be updated during the forecast period.

**Table C-1.4.adv Notes, continued**

13 LBNL modeling of typical new home builder practice in 14 U.S. cities (Brown et. al. 1998) estimates a typical new home HERS rating of 76.7. Each point away from 80 HERS is equivalent to 5% energy difference (aggregated over space heating, cooling, and water heating enduses). The 1993 MEC requirement is 80 HERS, which is 16.5% more energy efficient than a house with a 76.7 HERS rating. For simplicity, we assumed that each of the 3 enduses (water heating, cooling, and space heating) would get the same (16.5%) improvement. The 1995 Model Energy Code differs only slightly from the 1993 MEC and is assumed to have about the same energy savings as the 1993 MEC.

14 The main difference between 1993 MEC and 1998 IECC codes is in the added solar heat gain coefficient requirement in southern climates. There are also some small improvements affecting heating. To estimate the cooling savings to go from (typically) double or single pane clear windows to double pane low-e windows in the south, we used LBNL researcher Dariush Arasteh's DOE-2 runs for the "NFRC 900" project. We averaged the cooling savings for 5 cities (Phoenix, Memphis, Las Vegas, Jacksonville, and Atlanta). Typical (base case) windows varied among these cities but were either a double or single pane window with clear glazing. The cooling savings estimate in the table above represents an average of the southern savings and the northern cooling savings (northern cooling savings were assumed to be the same as the 1993 MEC savings because the solar heat gain coefficient requirement in 1998 IECC only applies to southern climates).
The heating savings in the south are an average of the heating savings from the Arasteh DOE-2 runs for the 5 cities. For heating in the north, to account for the small improvements affecting heating, we assumed that the 1998 code savings would be 5% greater than the 1993 code. The heating and cooling percent savings in this table are a simple average of our percent savings estimates for the south and north climates.

15 LBNL estimate of future IECC building code efficiency level. We assume that a new IECC code is created sometime before 2009, but it only begins to be adopted by states and local jurisdictions in 2009. See Table B-1.2.adv for more details about the program.

16 A new heat pump and CAC standard analysis has been completed but is pending approval. We assume that it will be finalized sometime in the year 2000 and the new standards will tal effect on January 1, 2006. We assume the standard for heat pumps will be 7.4 HSPF/12 SEER and the standard for CAC will be 12 SEER. The percent energy savings in the table were estimated using a simple ratio of efficiencies (future standard efficiency to the average new unit efficiency in 2000). The average new unit efficiency in 2000 for heat pumps is 7.15 HSPF/10.89 SEER and 10.42 SEER for CAC, from an output file for the CEF-NEMS reference case.

17 A new room A/C standard will come into effect on October 1, 2000. The CEF-NEMS reference case includes this standard, but starts it on Jan 1, 2001. To be consistent with the reference case, we also began the standard on Jan 1, 2001 in the Moderate and Advanced cases. Federal standards for room A/C vary by equipment capacity. We calculated an average efficiency of 9.7 EER for the October 2000 standard by weighting the standard efficiency for each product class by the 1989 shipments of each product class. In addition, we estimated that a future standard for room A/C would take effect in 2010 at 10.5 EER (on average over the most common capacities). The percent energy savings in the table was estimated using a simple ratio of efficiencies (future standard efficiency to the average new unit efficiency in 2000 (9.13 EER, from an output file for the CEF-NEMS reference case).

18 LBNL estimate based on work for the U.S. EPA to determine typical cost-effective packages of measures that builders in 14 U.S. cities could use in order to meet the ENERGY STAR certification requirements (Brown et. al. 1998). We calculated average heating and cooling savings for homes with the recommended ENERGY STAR package of measures, compared to current building practice of large production home builders in each city. On average over Southern and Northern cities, ENERGY STAR homes with electric heat pumps saved 40.1% of the annual heating and 45.6% of the annual cooling consumptions, compared to current construction in those cities. Homes with gas furnaces and central air conditioners saved 37.1% in heating and 52.7% in cooling on average over Southern and Northern cities, compared to current building practices in those cities. We assume that all ENERGY STAR homes have both heating and cooling equipment. We assume that the ENERGY STAR efficiency level will remain at the current level during the entire forecast period, although the cost is assumed to decrease due to increased funding for R&D (see Notes 3 & 4). Brown et. al. (1998) did not provide any savings estimates for oil-heated homes, so we assumed that oil-heated homes would have the same percentage savings as gas-heated homes.

19 Energy savings reflect typical, low-side, savings from current program participants (Pettit, 1999 and James, 1999). We assume that up until 2010, the average energy savings among program participants will tend toward the lower end of the current range of savings.

20 Energy savings reflect upper bound of estimates from current program participants (Pettit, 1999 and James, 1999). We assume that from 2010 through 2020, the average energy savings among program participants will tend toward the higher end of the current range of savings, due to a variety of factors which might include smarter building design, increased availability of technologies, and decreased prices.

21 Energy savings are based on Treasury Department efficiency proposals for the three levels of tax credits, from US DOT 1999. The proposed levels are 30%, 40%, or 50% better than the 1998 IECC code. The energy savings in this table for the tax credits are simply 30%, 40% and 50% more than our estimated savings for the 1998 IECC code. For example, the estimated electric heating energy savings for level 1 of the tax credit is (100% - (1-17.7%)*(1 - 30%)), or 42.4%. The terms in this formula represent the baseline electric heating consumption of a 1998 IECC code house (1-17.7%), and the (1-17.7%)*(1-30%) term represents the consumption of a house that is 30% better than the 1998 IECC code. Cooling energy savings was calculated in the same way. The percent energy savings is assumed to be the same for all heating fuels.

22 We assume that increased R&D funding for whole-house programs affects the cost of building homes to efficiency levels that meet or exceed the efficiency of ENERGY STAR new homes. We assume that R&D funding increases begin to have an impact on the market in 2005 (see Table B-1.2.adv for more details). While we recognize that increased R&D funding would also affect homes built to the new home tax credit efficiency levels, we did not include this explicitly in our analysis. Thus, we attributed the entire effect of

**Table C-1.4.adv Notes, continued**

increased R&D funding for whole-house measures to ENERGY STAR new homes and Building America, in the form of lower prices and increased penetration for these programs. We assume that the percentage energy saved by the programs will not change due to increased R&D funding. Thus, the percent energy savings for R&D during each time period analyzed (2005-2009 and 2010-2020) are assumed to be the same as the percent energy savings for the ENERGY STAR and Building America programs during the same time period.

| Table C-1.5: Measure Lifetime Estimates for New Residential Whole-House Policies affecting HVAC End-Uses | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Percent of total Heating (or Cooling) Energy Savings, by measure type[1]: | | | Estimated measure lifetime (years), by measure type[2]: | | | % of New Homes[3] | Average lifetime of Whole-House Policy[4] (years) |
| End-Use | Equipment type | shell | HVAC equip. | ducts | shell | HVAC equip. | ducts | | |
| **Electric heating** | resistance | 50.0% | 50.0% | 0% | 30 | 23.5 | 0 | 51.6% | 26.8 |
| | heat pump | 50.0% | 17.4% | 32.6% | 30 | 12.0 | 15 | 48.4% | 22.0 |
| | **all (average)** | | | | | | | 100.0% | **24.4** |
| **Electric cooling** | heat pump or central A/C | 58.9% | 13.3% | 27.8% | 30 | 12.0 | 15 | 91.6% | 23.4 |
| | RAC | 58.9% | 41.1% | 0.0% | 30 | 15.5 | 0 | 8.4% | 24.0 |
| | **all (average)** | | | | | | | 100.0% | **23.5** |
| **Gas heating** | furnace or HP | 51.8% | 17.1% | 31.1% | 30 | 23.5 | 15 | 97.4% | 24.2 |
| | boiler | 51.8% | 48.2% | 0.0% | 30 | 22.5 | 0 | 2.6% | 26.4 |
| | **all (average)** | | | | | | | 100.0% | **24.3** |
| **Oil heating** | furnace | 51.8% | 17.1% | 31.1% | 30 | 23.5 | 15 | 43.9% | 24.2 |
| | boiler | 51.8% | 48.2% | 0.0% | 30 | 22.5 | 15 | 56.1% | 26.4 |
| | **all (average)** | | | | | | | 100.0% | **25.4** |

**Lifetimes in bold type are averages over all equipment types for that end-use and are used to calculate the Cost of Conserved Energy.**

1 Percent of total site heating (or cooling) energy savings for an ENERGY STAR new home compared to a house of average construction, by type of measure. Energy savings by measure type were derived from LBNL's analysis of ENERGY STAR New Homes (Brown et. al. 1998). We chose one house in Chicago to represent the northern climate, and one house in Dallas to represent the southern climate. We took a simple average of the north and south results to get the numbers in the table. Results for oil furnaces were unavailable, so we used the same percent savings distribution as for gas furnaces. Results for boilers were also unavailable, so we used the gas furnace percent savings due to the shell for the boiler shells, and attributed the remainder of the savings to HVAC equipment measures, since boilers do not have ducts. Results for homes with electric resistance heating were also unavailable; we assumed the percent savings due to shell measures was the same as homes with heat pumps, and attributed the remainder of the savings to equipment measures (since electric resistance heaters do not have ducts). Percent savings for homes with RAC were estimated in the same way, using results for the HP/CAC shell savings for cooling.

2 HVAC equipment lifetimes are averages of the minimum and maximum life expectancies of each equipment type, from an input file to the CEF-NEMS model. The lifetimes for duct and shell measures are from LBNL's ENERGY STAR New Homes analysis (Brown et. al. 1998).

3 Percent of new homes built in the year 2000 with the given heating or cooling equipment, from output of the CEF-NEMS reference case.

4 The average lifetime used to calculate the CCE for the whole-house new home HVAC measures are in bold type. Lifetimes not in bold type represent the average lifetime for each equipment type; these were calculated by taking a weighted average of the measure lifetimes by measure type and the percent energy savings by measure type shown in this table. The average lifetime used in the CCE calculations (shown in bold type) is an average of the lifetime for each equipment type, weighted by the percent of new homes in 2000 that have each equipment type (see Note 3). The average end-use lifetime was used to calculate the CCE for all policies that involved a whole-house approach to energy conservation (i.e., shell, HVAC equipment, and/or duct measures). These policies are ENERGY STAR New Homes, Building America, and new home tax credits. Even though the proportion of energy savings due to each type of measure was derived for ENERGY STAR new homes, we assumed that the proportion would be the same for the Building America and new home tax credit programs.

**Introduction to Residential non-HVAC Technology Table (Table C-1.6)**

Table C-1.6 presents technology assumptions for policies affecting residential non-HVAC end uses. Included are unit energy savings (UECs) in kilowatt-hours for electricity end uses and million Btus for gas end uses, product lifetime (necessary for stock accounting and cost-effectiveness calculations), incremental cost ( in 1997 dollars), and the cost of conserved energy (CCE). The CCE can be compared to the applicable fuel or electricity price to guage the cost effectiveness of a policy.

*Financial Calculations*

All costs are presented in 1997 dollars. Costs from the original sources were adjusted to 1997 dollars, if necessary, using the implicit GDP deflator (Bureau of Economic Analysis 1998). The cost of conserved energy, expressed as $/kWh or $/MMBtu, is the annualized incremental cost of the technology divided by the unit energy savings. The annualized cost is calculated over the lifetime of the product using a seven percent real discount rate.

*Market Segmentation*

In some cases a particular measure was not cost effective in “the average” home or application. For example, very high efficiency gas water heaters (0.80 EF) have such a high incremental cost that they are only cost effective in homes with extremely high hot water use (3-4 times average household use). We applied such technologies only to the market segments that were cost effective, which invariably had a higher consumption than the average consumption for the entire market. The baseline and measure energy use for these technologies reflect the high energy consumption of the market segment. We calculated the share of gas water heating energy used by this market segment and estimated a market penetration for the technology as a subset of the segment.

As noted above, at current prices CFLs are cost effective in high-use fixtures only (those used 3 or more hours per day). Unit energy savings for the ENERGY STAR fixtures program are average savings for this segment of the market only. The penetrations used (expressed as a percent of energy because of the disproportionate share of energy consumed by high-use fixtures) reflect the replacement of a subset of this market segment. About 62% of lighting energy (24% of fixtures) belongs to this market segment (Wenzel et al, 1997). In the moderate case we assume that by 2020 ENERGY STAR fixtures will replace 2/3 of fixture sales for this market segment. This is equivalent to about 18% of total fixtures sales or about 40% of the baseline energy for new fixtures.

We also consider a CFL R&D program for residential lighting, which has the effect of reducing costs of CFLs and therefore making both CFL lamps and CFL fixtures more cost effective (we assume that CFL fixtures are sold with a ballast, so fixture cost is reduced by the amount of ballast cost savings). We assume that lower costs will increase the effectiveness of the ENERGY STAR fixtures program. Rather than increasing the penetration of CFLs in the above market segment (fixtures used 3 or more hours per day), we assume that lower costs will extend the market into lower use fixtures—those used 2 to 3 hours per day in the moderate case and 1 to 3 hours per day in the advanced case (the cost reduction due to R&D is greater in the advanced case). The calculations were similar to those described above. The unit energy savings were calculated for fixtures in these market segments, we calculated the share of total energy for each market segment and finally we estimated penetrations as a subset of energy for the segment.

*Avoiding Double-Counting*

In many cases multiple policies affect the same end use. To avoid double counting, we had to establish rules for how savings would be divided between policies. Mandatory programs, such as equipment standards, were given primacy. Standards are assumed to affect 100% of a certain type of equipment and are credited with the full savings of moving from a baseline unit to a unit just meeting the standard. Any non-mandatory policy is considered to be on top of standards (if any). Savings are calculated relative to the standard in place. If a non-mandatory policy affects 40% of an equipment type and saves 15% of the energy of a baseline unit, but standards are in place that affect 100% of equipment and save 10% over a baseline unit, the non-mandatory program is credited with saving 5% of baseline energy on 40% of the equipment. A single non-mandatory policy may therefore have multiple baselines if standards are updated once or more while the policy is in place. Because the energy savings change when the baseline changes, we treat each policy/baseline combination separately in our analysis. The penetrations for each policy/baseline combination are listed separately in these tables.

**Table C-1.6. Technology Data for Residential Buildings--Non-HVAC**

| Fuel | End-Use | Policy | Baseline[1] | Case[2] | Unit Energy Savings | *UES Notes* | Life-time | *Life-time Notes* | Incre-mental Cost[3] | *Incre-mental Cost Notes* | CCE[4] 2000-09 | CCE[4] 2010-20 | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric | | | | | kWh | | Years | | 1997$ | | $/kWh | $/kWh | |
| | Water heating | | | | | | | | | | | | |
| | | ENERGY STAR CW | 2004 EWH std/2000 new CW | M, A | 361 | *5* | 14 | *6* | 277 | *7* | 0.038 | 0.038 | *8* |
| | | ENERGY STAR CW | 2004 EWH std/CW interim std | M | 242 | *5* | 14 | *6* | 252 | *7* | 0.052 | 0.052 | *8* |
| | | ENERGY STAR DW | 2000 new EWH/2000 new DW | M, A | 44 | *9* | 13 | *6* | 7 | *10* | 0.019 | 0.019 | |
| | | ENERGY STAR HPWH | 2004 standard EWH | M | 2,137 | *11* | 10 | *6* | 471 | *12* | 0.031 | 0.016 | *13* |
| | | ENERGY STAR HPWH | 2004 standard EWH | A | 2,137 | *11* | 10 | *6* | 471 | *12* | NA | 0.016 | *13* |
| | | ENERGY STAR Homes | 2000 new EWH | M, A | 585 | *14* | 10 | *15* | 85 | *16* | 0.021 | NA | |
| | | ENERGY STAR Homes | 2004 standard EWH | M, A | 299 | *14* | 10 | *15* | 85 | *16* | 0.040 | 0.038 | *17* |
| | | Building America | 2000 new EWH | M, A | 585 | *14* | 10 | *15* | 85 | *16* | 0.021 | NA | |
| | | Building America | 2004 std EWH | M, A | 299 | *14* | 10 | *15* | 85 | *16* | 0.040 | 0.038 | *17* |
| | | Whole House Tax Credit I | 2000 new EWH | M, A | 585 | *14* | 10 | *15* | 85 | *16* | 0.021 | NA | |
| | | Whole House Tax Credit I | 2004 std EWH | M, A | 299 | *14* | 10 | *15* | 85 | *16* | 0.040 | 0.038 | *17* |
| | | Whole House Tax Credit II | 2000 new EWH | M, A | 585 | *14* | 10 | *15* | 85 | *16* | 0.021 | NA | |
| | | Whole House Tax Credit II | 2004 std EWH | M, A | 299 | *14* | 10 | *15* | 85 | *16* | 0.040 | 0.038 | *17* |
| | | Whole House Tax Credit III | 2000 new EWH | M, A | 585 | *14* | 10 | *15* | 85 | *16* | 0.021 | NA | |
| | | Whole House Tax Credit III | 2004 std EWH | M, A | 299 | *14* | 10 | *15* | 85 | *16* | 0.040 | 0.038 | *17* |
| | | ENERGY STAR Homes R&D | 2004 std EWH | M, A | 299 | *14* | 10 | *15* | 81 | *18* | NA | 0.038 | |
| | | Building America R&D | 2004 std EWH | M, A | 299 | *14* | 10 | *15* | 76 | *18* | NA | 0.036 | |
| | | 2004 EWH Std | 2000 new EWH | M, A | 286 | *19* | 10 | *6* | 51 | *20* | 0.026 | 0.026 | |
| | | CW interim standard | 2004 EWH std/1994 CW Std | M | 119 | *21* | 14 | *6* | 8 | *22* | 0.002 | 0.002 | *23* |
| | | CW Horizontal Axis Std | 2004 EWH std/2000 new CW | M,A | 361 | *24* | 14 | *6* | 202 | *22* | 0.015 | 0.015 | *8* |
| | | DW Std | 2000 new EWH/2000 new DW | A | 44 | *25* | 13 | *6* | 7 | *10* | 0.019 | 0.019 | |
| | | Utility HPWH | 2000 new EWH | M, A | 2,423 | *26* | 10 | *6* | 522 | *12* | 0.031 | NA | |
| | | Utility HPWH | 2004 standard EWH | M | 2,137 | *26* | 10 | *6* | 471 | *12* | 0.031 | 0.016 | *13* |
| | | Utility HPWH | 2004 standard EWH | A | 2,137 | *26* | 10 | *6* | 471 | *12* | 0.031 | 0.016 | *13* |
| | | Tax Credit HPWH | 2000 new EWH | M, A | 2,423 | *27* | 10 | *6* | 522 | *12* | 0.031 | NA | |
| | | Tax Credit HPWH | 2004 standard EWH | M | 2,137 | *27* | 10 | *6* | 471 | *12* | 0.031 | 0.016 | *13* |
| | | Tax Credit HPWH | 2004 standard EWH | A | 2,137 | *27* | 10 | *6* | 471 | *12* | 0.031 | 0.016 | *13* |
| | | HPWH R&D | 2004 standard EWH | M | 2,137 | *12* | 10 | *6* | 235 | *28* | NA | 0.016 | |
| | | HPWH R&D | 2004 standard EWH | A | 2,137 | *12* | 10 | *6* | 235 | *28* | NA | 0.016 | |
| | | Utility Fuel Switching Prog. | | A | NA | | 10 | *6* | NA | | NA | NA | |

**Table C-1.6 (continued). Technology Data for Residential Buildings--Non-HVAC**

| Fuel | End-Use | Policy | Baseline[1] | Case[2] | Unit Energy Savings | *UES Notes* | Life-time | *Life-time Notes* | Incre-mental Cost[3] | *Incre-mental Cost Notes* | CCE[4] 2000-09 | CCE[4] 2010-20 | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric | | | | | kWh | | Years | | 1997$ | | $/kWh | $/kWh | |
| | Refrigeration | | | | | | | | | | | | |
| | | 2001 Refrigerator Std | 2000 new Refrigerator | M, A | 170 | *29* | 19 | *30* | 60 | *30* | 0.034 | 0.034 | |
| | | NAECA Std 2010 | 2000 new Refrigerator | A | 244 | *31* | 19 | *30* | 98 | *30* | 0.039 | 0.039 | |
| | | Utility Rebate | 2000 new Refrigerator | M, A | 106 | *32* | 19 | *30* | 27 | *33* | 0.025 | 0.025 | |
| | | Utility Rebate | 2001 standard Refrigerator | M, A | 79 | *32* | 19 | *30* | 51 | *33* | 0.062 | 0.062 | |
| | | ENERGY STAR Refrigerator | 2000 new Refrigerator | M, A | 106 | *34* | 19 | *30* | 27 | *33* | 0.025 | 0.025 | |
| | | ENERGY STAR Refrigerator | 2001 standard Refrigerator | M, A | 79 | *34* | 19 | *30* | 51 | *33* | 0.062 | 0.062 | |
| | | ENERGY STAR Refrigerator | 2010 standard Refrigerator | A | 67 | *34* | 19 | *30* | 91 | *33* | NA | 0.130 | *35* |
| | Cooking | | | | | | | | | | | | |
| | | Utility Fuel Switching Prog. | | A | NA | | 18 | *36* | NA | | NA | NA | |
| | Clothes Dryers | | | | | | | | | | | | |
| | | Utility Fuel Switching Prog. | | A | NA | | 17 | *36* | NA | | NA | NA | |
| | Freezers | | | | | | | | | | | | |
| | | 2001 Std | 2000 new freezer | M, A | 64 | *37* | 19 | *30* | 39 | *30* | 0.059 | 0.059 | |
| | | 2010 Std | 2000 new freezer | A | 101 | *38* | 19 | *30* | 60 | *30* | 0.035 | 0.035 | |
| | Lighting | | | | | | | | | | | | |
| | torchieres | | | | | | | | | | | | |
| | | R&D--CFL Torchiere | 300 W Halogen torchiere | M, A | 136 | *39* | 5 | *40* | 50 | *41* | 0.061 | 0.053 | *42* |
| | | E STAR Res Ltg Fixture Prog | 300 W Halogen torchiere | M, A | 136 | *43* | 5 | *40* | 50 | *41* | 0.061 | 0.053 | *42* |
| | | CFL R&D--Fixtures Effect | 300 W Halogen torchiere | M, A | 136 | *44* | 5 | *40* | 43 | *45* | NA | 0.053 | |
| | other | | | | | | | | | | | | |
| | | E STAR Res Ltg Fixture Prog | Fixtures uses >3 hrs/day | M | 149 | *46* | 11 | *47* | 12 | *48* | 0.011 | 0.008 | *49* |
| | | E STAR Res Ltg Fixture Prog | Fixtures uses >3 hrs/day | A | 149 | *46* | 11 | *47* | 12 | *48* | 0.011 | 0.006 | *49* |
| | | CFL R&D--Fixtures Effect | Fixtures used 1-3 hrs/day | M | 52 | *50* | 46 | *51* | 12 | *52* | NA | 0.028 | |
| | | CFL R&D--Fixtures Effect | Fixtures used 1-3 hrs/day | A | 52 | *50* | 46 | *51* | 10 | *52* | NA | 0.022 | |
| | | Mini-HID lamps R&D | 100 W inc. lamp used 1500 hrs/yr | M | 58 | *53* | 13 | *54* | 3 | *55* | NA | 0.006 | |
| | | Mini-HID lamps R&D | 100 W inc. lamp used 1500 hrs/yr | A | 58 | *53* | 13 | *54* | 3 | *55* | NA | 0.006 | |

**Table C-1.6 (continued). Technology Data for Residential Buildings--Non-HVAC**

| Fuel | End-Use | Policy | Baseline[1] | Case[2] | Unit Energy Savings | *UES Notes* | Life-time | *Life-time Notes* | Incre-mental Cost[3] | *Incre-mental Cost Notes* | CCE[4] 2000-09 | CCE[4] 2010-20 | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric | | | | | kWh | | Years | | 1997$ | | $/kWh | $/kWh | |
| | Clothes Washers | | | | | | | | | | | | |
| | | ENERGY STAR CW | 2000 new CW | M, A | 30 | *56* | 14 | *6* | 23 | *7* | 0.038 | 0.038 | *8* |
| | | ENERGY STAR CW | CW interim stds | M | 30 | *56* | 14 | *6* | 31 | *7* | 0.052 | 0.052 | *8* |
| | | CW interim standard | 2000 new CW | M | 0 | *57* | 14 | *6* | 0 | *22* | NA | NA | |
| | | CW Horizontal Axis Std | 2000 new CW | M,A | 30 | *58* | 14 | *6* | 17 | *22* | 0.015 | 0.015 | *8* |
| | Dishwashers | | | | NA | | 13 | *6* | NA | | NA | NA | |
| | Color Televisions | | | | | | | | | | | | |
| | | ENERGY STAR TVs | 2000 new TV | M,A | 38 | *59* | 11 | *60* | 2 | *61* | 0.007 | 0.007 | |
| | | TV Standards | 2000 new TV | A | 38 | *62* | 11 | *60* | 2 | *61* | 0.007 | 0.007 | |
| | | Global 1 Watt | 2010 TV stds | A | 5 | *63* | 11 | *60* | 0 | *64* | 0.000 | 0.000 | |
| | Personal Computers | | | | NA | | NA | | NA | | NA | NA | |
| | Furnace Fans | | | | NA | | NA | | NA | | NA | NA | |
| | Other Uses | | | | | | | | | | | | |
| | coils | | | | NA | | NA | | NA | | NA | NA | |
| | motors | Global 1 W | | A | 9.7 | *63* | 5 | *65* | 2 | *66* | 0.049 | 0.049 | |
| | | Ceiling Fans | | M,A | 37 | *67* | 15 | *68* | 10 | *69* | 0.030 | 0.030 | |
| | | Pool Pumps | | M,A | 750 | *70* | 10 | *40* | 100 | *71* | 0.013 | 0.013 | |
| | electronics | | | | | | | | | | | | |
| | | ENERGY STAR VCR | | M,A | 16 | *72* | 11 | *60* | 2 | *60* | 0.017 | 0.017 | |
| | | ENERGY STAR Audio | | M,A | 24 | *73* | 7 | *74* | 2 | *60* | 0.015 | 0.015 | |
| | | ENERGY STAR Settop | | M,A | 88 | *75* | 10 | *40* | 2 | *60* | 0.003 | 0.003 | |
| | | ENERGY STAR Telephony | | M,A | 18 | *76* | 8 | *77* | 2 | *60* | 0.019 | 0.019 | |
| | | ENERGY STAR MWave | | M,A | 18 | *78* | 12 | *67* | 2 | *60* | 0.014 | 0.014 | |
| | | Global 1 W | | A | 27 | *63* | 7 | *79* | 2 | *60* | 0.014 | 0.014 | |

**Table C-1.6 (continued). Technology Data for Residential Buildings--Non-HVAC**

| Fuel | End-Use | Policy | Baseline[1] | Case[2] | Unit Energy Savings | *UES Notes* | Life-time | *Life-time Notes* | Incre-mental Cost[3] | *Incre-mental Cost Notes* | CCE[4] 2000-09 | CCE[4] 2010-20 | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas | | | | | MBtu | | Years | | 1995$ | | $/MBtu | | |
| | Water heating | | | | | | | | | | | | |
| | | ENERGY STAR CW | 2000 new GWH/2000 new CW | M,A | 1.06 | *80* | 14 | *6* | 142 | *7* | 6.67 | 6.67 | *8, 81* |
| | | ENERGY STAR CW | 2000 new GWH/CW stage 1 std | M | 0.71 | *80* | 14 | *6* | 112 | *7* | 7.91 | 7.91 | *8, 81* |
| | | ENERGY STAR DW | 2000 new GWH/2000 new DW | M,A | 0.19 | *82* | 13 | *6* | 7 | *6* | 4.66 | 4.66 | |
| | | ENERGY STAR Homes | 2000 new GWH | M,A | 3.30 | *83* | 14 | *15* | 136 | *84* | 4.71 | NA | |
| | | ENERGY STAR Homes | 2004 GWH Std | M,A | 0.43 | *83* | 14 | *15* | 95 | *85* | NA | 23.02 | *85* |
| | | Building America | 2000 new GWH | M,A | 2.87 | *87* | 14 | *15* | 41 | *84* | 1.62 | NA | |
| | | Building America | 2004 GWH Std | M,A | 0.00 | *87* | 14 | *15* | 0 | *84* | NA | NA | |
| | | Whole House Tax Credit I | 2000 new GWH | M,A | 2.87 | *87* | 14 | *15* | 41 | *84* | 1.62 | NA | |
| | | Whole House Tax Credit I | 2004 GWH Std | M,A | 0.00 | *87* | 14 | *15* | 0 | *84* | NA | NA | |
| | | Whole House Tax Credit II | 2000 new GWH | M,A | 2.87 | *87* | 14 | *15* | 41 | *84* | 1.62 | NA | |
| | | Whole House Tax Credit II | 2004 GWH Std | M,A | 0.00 | *87* | 14 | *15* | 0 | *84* | NA | NA | |
| | | Whole House Tax Credit III | 2000 new GWH | M,A | 2.87 | *87* | 14 | *15* | 41 | *84* | 1.62 | NA | |
| | | Whole House Tax Credit III | 2004 GWH Std | M,A | 0.00 | *87* | 14 | *15* | 0 | *84* | NA | NA | |
| | | ENERGY STAR Homes R&D | 2004 GWH Std | M,A | 0.43 | *83* | 14 | *15* | 86 | *88* | NA | 23.02 | *86* |
| | | Building America R&D | 2004 GWH Std | M,A | 0.00 | *87* | 14 | *15* | 0 | *84* | NA | NA | |
| | | GWH Std | 2000 new GWH | M,A | 2.87 | *89* | 14 | *6* | 41 | *84* | 1.62 | 1.62 | |
| | | CW interim standard | 2004 GWH Std/2000 new CW | M | 0.35 | *21* | 14 | *6* | 2 | *22* | 0.22 | 0.22 | *23* |
| | | CW Horizontal Axis Std | 2004 GWH Std/2000 new CW | M,A | 1.06 | *24* | 14 | *6* | 104 | *22* | 2.54 | 2.54 | *8* |
| | | DW Std | 2004 GWH Std | A | 0.19 | *25* | 13 | *6* | 7 | *7* | 4.66 | 4.66 | |
| | | Tax Cr for 0.65 EF NGWH | 2000 new GWH | M,A | 6 | *90* | 14 | *6* | 256 | *91* | 4.85 | 4.85 | |
| | | Tax Cr for 0.65 EF NGWH | 2004 GWH Std | M,A | 4.95 | *90* | 14 | *6* | 215 | *91* | 4.97 | 4.97 | |
| | | Tax Cr for 0.80 EF NGWH | 2000 new GWH | M,A | 30 | *92* | 14 | *6* | 1295 | *91* | 4.95 | 4.95 | |
| | | Tax Cr for 0.80 EF NGWH | 2004 GWH Std | M,A | 29 | *92* | 14 | *6* | 1254 | *91* | 4.98 | 4.98 | |
| | Cooking | | | | NA | | NA | | NA | | NA | NA | |
| | Clothes Dryers | | | | NA | | NA | | NA | | NA | NA | |
| | Other Uses | | | | NA | | NA | | NA | | NA | NA | |

**Notes to Table C-1.6**
**Technology Data for Residential Buildings--Non-HVAC**

1 Because different policies affect the same market segment, it was often necessary to adjust penetrations or savings in order to avoid double counting. In particular, we had to address the effect on existing programs, such as ENERGY STAR, when new equipment standards come into effect. We adopted the practice of attributing savings to mandatory programs, such as standards, before calculating savings for other policies. When the savings for a policy are affected by a standard, we essentially analyze the policy as several different policies according to the baseline that applies (year 2000 new equipment, 2004 standard, 2010 standard). For example, the ENERGY STAR Homes program appears twice under electric water heating. The first appearance lists "2000 new EWH" as the baseline, indicating that the baseline water heating UEC is for a typical new electric water heater in year 2000. The second entry lists "2004 standard EWH" as the baseline indicating that the savings corresponding to these penetrations were calculated relative to the new electric water heating standard in 2004.

2 We specify the applicable case for each policy as A for advanced or M for moderate. Some policies apply to only one case (e.g. 2010 dishwasher standards), some may be effective for different dates, and others may have different costs due to different R&D effects in the moderate and advanced case.

3 Unless otherwise stated, the incremental cost is a mature market cost; that is, it is the cost of equipment after the market has adjusted to the presence of the policy, e.g. by increasing production, because increasing cumulative production experience reduces costs per unit.

4 The cost of conserved energy is a measure of cost effectiveness. An energy conservation measure is cost effective if the cost of conserved energy is less than the cost of the relevant fuel. The cost of conserved energy is calculated using a 7% real discount rate. For some technologies, the CCE is assumed to drop over time due to the effect of R&D programs. We model this effect by using different CCEs for 2000-2009 and 2010-2020. If there is no R&D, the CCE is the same for both periods. If the program ends before 2010, the CCE for 2010 to 2020 is reported as "NA". Similarly, if the program begins in 2010 or later, the CCE for 2000-2010 is reported as "NA."

5 ENERGY STAR clothes washers are assumed to be horizontal axis or equivalent efficiency. Water heating savings are from Koomey et al. (1999b) (savings assume that water heater standby losses have already been reduced compared to a water heater just meeting 1994 NAECA standards). Baseline electric water heating UEC is also from Koomey et al. (1999b). When interim standards for clothes washers come into effect in the moderate case (2004-2006), the energy savings and incremental costs are recalculated using the new standard as the baseline.

6 Geller et al (1998).

7 The cost shown here is an LBNL estimate of the current incremental cost for a horizontal axis washer, based on a current incremental cost of $350. The cost of a baseline unit is $421 (US DOE 1998b) and we estimate that a typical horizontal axis washer retails for $700-$800 (with so few models currently on the market and recent the recent introduction of a high-end model, it is not possible to estimate a robust shipment weighted average price). Costs were allocated to water heating, motor energy and dryer energy according to the estimated amount of site energy saved (also from US DOE 1998b). Because these costs are prorated based on the share of energy savings, comparisons between costs may be misleading (for example, the costs allocated to motors for different policies may differ even though the energy savings are the same, due to changes in water heating and drying energy). When interim standards for clothes washers come into effect in the moderate case, the energy savings and incremental costs are recalculated using the new standard as the baseline.

8 The cost of conserved energy for horizontal axis clothes washers takes into account $22 in annual water bill savings due to decreased water use (based on water usage and water price estimates from US DOE, 1998b). Annualized incremental cost net of annual water bill savings are used to calculate the CCE.

9 ENERGY STAR dishwashers are 13% more efficient than contemporary standards. Total dishwasher savings are from an unpublished analysis of ENERGY STAR dishwashers by Barbour (1998). Dishwasher savings from reduced water heating savings were broken out based on data from US DOE (1990). In the advanced case, we assume that the ENERGY STAR dishwasher program is discontinued when new standards for dishwashers come into effect in 2010

10 A $10 incremental cost from Geller et al (1998) was divided between motor and water heating according to the share of energy savings.

11 Although no program currently exists, we hypothesize that DOE will introduce an ENERGY STAR water heater program to promote heat pump water heaters. Baseline unit energy consumption and unit energy savings due to heat pump water heaters are from Koomey et al. (1999b).

**Notes to Table C-1.6 (continued)**

12 Koomey et al (1999b).

13 CCEs for heat pump water heater programs are reduced for 2010 to 2020 due to the cost reductions attributable to R&D (see the heat pump water R&D program for details, note 28). The cost reduction is greater in the advanced case than in the moderate case.

14 Whole-house programs (ENERGY STAR, Building America, and whole-house tax credits) are assumed to save 15% of water heating energy. Savings are based on DOE-2 runs assuming the addition of an R-12 wrap to the water heater. The baseline energy factor is 0.86; the wrap increases the energy factor to 0.93. When new electric water heater standards become effective, energy savings are recalculated with respect to the new baseline.

15 The lifetime for whole house programs is the life of the water heating equipment (see note 6) for the purposes of calculating the CCE.

16 The incremental costs for water heating for all the whole-house programs (ENERGY STAR, Building America, and whole-house tax credits) are assumed to be the same. The costs are based on the cost of materials and labor for an R-12 wrap (Means 1996, p 454).

17 CCEs for whole house programs are reduced for 2010 to 2020 due to the effects of R&D (see the technology data for "ENERGY STAR Homes R&D" and "Building America R&D" for details, note 18).

18 Research and development reduces the cost of whole house programs by 10% from year 2010 onward. See note 16 for costs for the 2000-2009 period.

19 Electric water heater standard tightened to reduce standby losses. Baseline unit energy consumption and unit energy savings are from Koomey et al. (1999b).

20 US DOE (1993b).

21 Clothes washer standards are expected to be tightened starting in 2004. A horizontal axis standard remains controversial, however, so for the moderate case we consider an interim clothes washer standard that saves 15% over the baseline. This interim standard is assumed to come into effect in 2004 and be replaced by a horizontal axis standard in 2007. In the advanced case the horizontal axis standard goes into effect in 2004 and there is no interim standard. Savings were taken from US DOE (1998b) and Koomey et al. (1999b).

22 The incremental costs are from US DOE (1998b). Costs were allocated to water heating, motor energy and dryer energy according to the estimated amount of site energy saved (also from US DOE, 1998b).

23 The cost of conserved energy for the moderate case interim clothes washer standard takes into account 70 cents in annual water bill savings due to decreased water use. The CCE is calculated using the annualized incremental cost net of water bill savings. In this case, the present value of lifetime water bill savings is almost as large as the incremental investment cost, so the CCE is close to zero.

24 We expect that DOE will eventually succeed in finalizing a horizontal axis clothes washer standard. This standard is assumed to go into effect in 2007 in the moderate case and 2004 in the advanced case. Savings are compared to the interim standard in the moderate case and a year 2000 average new washer in the advanced case. Savings were taken from Koomey et al. (1999b).

25 We assume that new dishwasher standards will go into effect in 2010 for a 13 percent efficiency improvement over 1994 standards. Savings are assumed to be the same as for ENERGY STAR units (see note 9).

26 Utilities promote the use of heat pump water heaters through the use of rebates and informational campaigns. Energy savings due to heat pump water heaters are from Koomey et al. (1999b). After electric water heater standards come into effect the energy savings attributed to utility heat pump water heater programs is reduced.

27 Tax credits for heat pump water heaters in the moderate case are assumed to be for 20 percent of the purchase price and last from December 31, 1999 until January 1, 2004 (US DOT, 1999). Tax credits for heat pump water heaters in the advanced case are assumed to be for 10 percent of the purchase price and last for 10 years (the longer duration more than offsets the lower tax credit). Baseline unit energy consumption and unit energy savings due to heat pump water heaters are from Koomey et al. (1999b). After electric water heater standards come into effect savings attributed to tax credits are reduced.

28 R&D reduces the cost of heat pump water heaters by 10% in the moderate case and 20% in the advanced case, effective from 2010 onward. Cost reductions are applied to costs from Koomey et al (1999b).

29 New refrigerator standards are scheduled to come into effect in 2001. These standards are already incorporated in the AEO99 forecast. However, since we calculate achievable potential energy use from the frozen efficiency baseline we had to include them in our savings. Baseline unit energy consumption

**Notes to Table C-1.6 (continued)**

and savings are from US DOE (1995b).

30 US DOE (1995b)

31 We assume that NAECA standards for refrigerators will be tightened again in 2010 in the advanced case. Data were obtained from US DOE (1995b).

32 Utility rebates for refrigerators are assumed to be based on the same efficiency levels as ENERGY STAR refrigerators (16% over existing NAECA standards) and have the same savings (see note 34).

33 US DOE (1995b). Costs for 2000-2001 are incremental to the cost of a baseline unit, costs for 2001-2009 are incremental to the cost of a unit meeting 2001 standards. In 2010, new standards become effective in the advanced case. For the 2010-2020 period, advanced case costs are incremental to the cost of a unit meeting 2010 standards while in the moderate case, costs continue to be calculated relative to the 2001 standard.

34 ENERGY STAR refrigerators are assumed to be 16% more efficient than existing NAECA standards. Baseline year 2000 refrigerator efficiency is taken from US DOE (1995b). The 16% savings were applied to baseline 2000 efficiency to obtain year 2000 savings; to 2001 NAECA standards efficiency to obtain savings for 2001 to 2009 (to 2020 in the moderate case); and to 2010 NAECA standards efficiency to obtain savings for 2010 to 2020 (advanced case only).

35 Note that after the 2010 standard goes into effect, the ENERGY STAR efficiency level (as specified relative to standards) is not cost effective. We therefore assume zero penetration for ENERGY STAR refrigerators from 2010 onward.

36 Koomey et al (1999b).

37 New freezer standards are scheduled to come into effect in 2001. These standards are already incorporated in the AEO99 forecast. However, since we calculate achievable potential energy use from the frozen efficiency baseline we had to include them in our savings. Baseline unit energy consumption and savings are from US DOE (1995b).

38 We assume that NAECA standards for freezers will be tightened again in 2010 in the advanced case. Data were obtained from US DOE (1995b).

39 Compact fluorescent torchieres were developed with DOE funding as replacement for low-efficiency halogen torchieres (typically 300W, Calwell (1999)). Since then, CFL torchieres have become widely available at retailers and costs have fallen significantly. CFL torchieres are assumed to use 1/3 the energy of a halogen torchiere. Usage is assumed to be 1.87 hours per day (average usage for floor lamps from the latest EPA ENERGY STAR program savings forecasts, LBNL spreadsheets dated June, 1999, US EPA (1999c)).

40 Sanchez et al (1998).

41 The $50 incremental cost for ENERGY STAR torchieres came from an EPA ENERGY STAR savings calculator (US EPA 1999a).

42 R&D is expected to reduce the cost of compact fluorescent life and correspondingly reduce the cost of ballasts sold with CFL fixtures. The CCE for the 2010 to 2020 period takes into account a 25% reduction in the ballast cost in the moderate case and a 40% reduction in the advanced case. The ballast cost is assumed to account for only $15 of the total incremental cost.

43 Because CFL torchieres qualify under the ENERGY STAR Lighting program, we expect there to be continued efforts to promote the technology. Energy savings are the same as for the CFL Torchiere R&D program (see note 39).

44 Research and development is expected to reduce the costs of compact fluorescent lamps and therefore increase sales of CFL torchieres by reducing both their first cost (we assume that a ballast is sold with the fixture) and the lamp replacement cost. Energy savings are the same as for the CFL Torchiere R&D program (see note 39).

45 CFL R&D is assumed to reduce the cost of a CFL torchiere by the same amount that it reduces the cost of other ENERGY STAR fixtures (see notes 41 and 49).

46 The ENERGY STAR Fixtures Program is assumed to target high-use fixtures. Energy savings data are taken from the latest EPA ENERGY STAR program savings forecasts (LBNL spreadsheets dated June, 1999, US EPA (1999c)). Baseline fixture energy is the average energy of high-use fixtures (>3 hrs per day) from the same source. ENERGY STAR replacements of incandescent fixtures are assumed to reduce energy use by 67%; ENERGY STAR replacements of magnetic ballast fluorescent fixtures are assumed to save 10%.

47 ENERGY STAR lighting fixture lifetime is from the latest EPA ENERGY STAR program savings forecasts (LBNL spreadsheets dated June, 1999, US EPA (1999c)), and assumes (conservatively) that fixture lifetime is equal to a single ballast lifetime, i.e. consumers replace the fixture rather than replace the ballast.

**Notes to Table C-1.6 (continued)**

48 Incremental cost data are taken from the latest EPA ENERGY STAR program savings forecasts (LBNL spreadsheets dated June, 1999, US EPA (1999c)).

49 We assume that due to CFL R&D the cost of manufacturing CFL fixtures is reduced (we assume the fixture is sold with a ballast). We assume that the incremental cost of a CFL fixture is reduced by 25% in the moderate case and 40% in the advanced case for the 2010 to 2020 period. This reduces the CCE.

50 Baseline unit energy consumption for fixtures used 1-3 hours per day is from the latest EPA ENERGY STAR program savings forecasts (LBNL spreadsheets dated June, 1999, US EPA (1999c)), and excludes fluorescent fixtures. Fixtures in this usage range were not assumed to be replaced at baseline CFL prices; the price reduction allows CFLs to capture more of the market but at a lower savings per unit. Savings are assumed to be 67%.

51 Lifetime is the estimated ballast lifetime for fixtures used 1-3 hours per day (assuming a 30,000 hour ballast life), and is taken from the latest EPA ENERGY STAR program savings forecasts (LBNL spreadsheets dated June, 1999, US EPA (1999c)).

52 Incremental cost data are taken from the latest EPA ENERGY STAR program savings forecasts (LBNL spreadsheets dated June, 1999, US EPA (1999c)) and represent CFL fixtures only (the cost is different from the cost used for the ENERGY STAR fixture program because that cost is assumed to also include switching from magnetic ballast to electronic ballast tube fluorescent fixtures as well as lighting controls for outdoor fixtures). R&D is assumed to reduce the cost of CFLs, and by association the incremental cost of CFL fixtures, by 10% in the moderate case and 20% in the advanced case.

53 Small metal halide (mini-HID) lamps provide similar brightness to incandescent lamps at a much lower wattage. Research and development has the potential to reduce costs and speed the commercialization of the technology. The baseline lamp is a 100 W incandescent; the replacement is a 20 W mini-HID with an electronic ballast (Nadel et al 1998). Usage is assumed to be 730 hours/year.

54 Lifetime for mini-HIDs is from Nadel et al (1998), adjusted for our modified usage assumption (we assume 730 hrs/yr. while the report assumes 1500 hrs/yr.).

55 The baseline costs for an incandescent A-lamp are taken from Vorsatz et al (1999). The incremental cost for a mini-HID is from Nadel et al (1998). The incremental cost compares the initial cost of the mini-HID to the present value of the cost of incandescent lamp replacements over the same period.

56 ENERGY STAR clothes washers are assumed to be horizontal axis or equivalent efficiency. Baseline motor energy and motor savings are from US DOE (1998b). When interim standards for clothes washers come into effect in the moderate case, the energy savings and incremental costs are recalculated using the new standard as the baseline. The ENERGY STAR program is assumed to be discontinued when a horizontal axis standard goes into effect.

57 Clothes washer standards are expected to be tightened starting in 2004. A horizontal axis standard remains controversial, however, so for the moderate case we consider an interim clothes washer standard that saves 15% over the baseline. This interim standard is assumed to come into effect in 2004 and be replaced by a horizontal axis standard in 2007 (in the advanced case the horizontal axis standard goes into effect in 2004). Motor savings were taken from US DOE (1998b).

58 We expect that DOE will eventually succeed in finalizing a horizontal axis clothes washer standard. This standard is assumed to go into effect in 2007 in the moderate case and 2004 in the advanced case. Motor savings were taken from US DOE (1998b).

59 ENERGY STAR TVs consume less than 3 watts in standby compared to almost 6 watts for standard units. Analysis performed by LBNL for EPA indicates an energy savings of 21% (based on plausible usage assumptions). The program is assumed to continue with no changes in the efficiency level through 2020 in the moderate case and 2009 in the advanced case. In the advanced case, the ENERGY STAR program is assumed to end in 2010 with the arrival of the global one watt initiative.

60 *Appliance* , 1996.

61 $2 incremental cost assumes most savings come from circuit redesign during the normal design phase (at negligible cost) plus an improved power supply.

62 For the advanced case, we assume that DOE will issue television standards in 2010. The efficiency level under standards is assumed to be the same as that promoted under the ENERGY STAR program (see note 58).

63 The "global one-watt" initiative is an idea for reducing leaking electricity that has garnered international interest. Although the structure of such a plan is a matter for speculation, we can nonetheless calculate the effect of such a program. Many products would be affected including televisions, most miscellaneous electronics and some miscellaneous motors. Calculations for miscellaneous electronics and motors are based on Sanchez et al. (1998). Calculations for TVs were based the same usage assumptions that underlie the ENERGY STAR calculation (see note 58). The global one-watt initiative is considered only in the advanced case.

**Notes to Table C-1.6 (continued)**

64 Using currently available technology, it costs no more for a manufacturer to reduce standby losses to 1 watt than to 3 watts. Since the global 1 watt initiative coincides with the advent of TV standards, the entire cost is attributed to standards and the incremental cost for TVs under the global one-watt initiative is zero.

65 Average of lifetimes from Sanchez et al (1998) for miscellaneous motor end-uses that also leak electricity when turned off.

66 Motor savings for the Global 1 Watt plan are attributable primarily to electronics associated with those end-uses--battery chargers, etc. The $2 incremental cost for motors assumes most savings come from circuit redesign and an improved power supply.

67 The Florida Solar Energy Center with AeroVironment developed an innovative ceiling fan blade design promising to save 50% of ceiling fan energy (Parker, et al. 1999). The technology has been licensed to a manufacturer and a modified design is expected to be on the market sometime in 2000 (FSEC 1999). Based on comments by representatives from AeroVironment about the modifications to the design, we reduced the savings to 30% (Su and Zambrano, 1999).

68 *Appliance* , 1998.

69 LBNL estimate.

70 Pool pumps were targeted because they make up a fairly large share of miscellaneous motor energy. For analytical purposes, the program was conceived of as an ENERGY STAR-type voluntary program. The savings potential was taken from Sanchez et al (1998).

71 Davis Energy Group (1994). Cost is for a two-speed motor.

72 ENERGY STAR VCRs consume less than 4 watts in standby compared to about 5 watts for standard units. Analysis performed by LBNL for EPA indicates an energy savings of 26% (based on plausible usage assumptions). In the advanced case, the ENERGY STAR program is assumed to end in 2010 with the arrival of the global one-watt initiative.

73 ENERGY STAR audio equipment consumes less than 1 watts in standby compared to about 3.6 watts for standard units. Analysis performed by LBNL for EPA indicates an energy saving of 64% (based on plausible usage assumptions). In the advanced case, the ENERGY STAR program is assumed to end in 2010 with the arrival of the global one-watt initiative.

74 Average audio equipment lifetime is a weighted average over several different products, taken from LBNL ENERGY STAR audio equipment spreadsheets dated June, 1999, US EPA (1999c).

75 We assume that EPA will launch a settop box program (for cable boxes and satellite receivers) in 2000. Baseline energy was obtained from LBNL metering work. An ENERGY STAR power level of 4.0 watts was assumed. In the advanced case, the ENERGY STAR program is assumed to end in 2010 with the arrival of the global one-watt initiative.

76 We assume that EPA will launch a telephony program (for cordless phones, answering machines, etc.) in 2000. Baseline energy was obtained from LBNL metering work. An ENERGY STAR power level of one watt was assumed. In the advanced case, the ENERGY STAR program is assumed to end in 2010 with the arrival of the global one-watt initiative.

77 Median of answering machine and cordless phone lifetimes from *Appliance* (1998).

78 We assume that EPA will launch a microwave oven program in 2001. Baseline energy was obtained from LBNL metering work. An ENERGY STAR power level of one watt was assumed. In the advanced case, the ENERGY STAR program is assumed to end in 2010 with the arrival of the global one-watt initiative.

79 Average of lifetimes from Sanchez et al (1998) for miscellaneous electronics end-uses that leak electricity when turned off.

80 ENERGY STAR clothes washers are assumed to be horizontal axis or equivalent efficiency. Water heating savings are from Koomey et al. (1999b) (savings assume that water heater standby losses have already been reduced compared to a water heater just meeting 1994 NAECA standards). Baseline gas water heating UEC is also from Koomey et al. (1999b). Whenever clothes washer standards improve, savings attributed to the ENERGY STAR program are reduced. The ENERGY STAR program is assumed to be discontinued when a horizontal axis standard goes into effect.

81 Note that at current market prices ENERGY STAR clothes washers are not cost effective in gas water heating homes. We therefore assume zero penetration for this program in gas water heating homes.

**Notes to Table C-1.6 (continued)**

82 ENERGY STAR dishwashers are 13% more efficient than contemporary standards. Total dishwasher savings are from an A.D. Little analysis of ENERGY STAR dishwashers (Barbour 1998). Dishwasher savings from reduced water heating savings were broken out based on data from US DOE (1990). Whenever dishwasher standards improve, ENERGY STAR dishwasher savings are recalculated based on the standard.

83 The ENERGY STAR Homes program is assumed to save 10 percent of water heating energy. When new gas water heater standards become effective, savings attributed to the Homes program will be reduced.

84 Atkinson (1996).

85 Incremental cost for an 0.63 water heater is from Atkinson (1996) after subtracting the cost for the 2004 standard (the new baseline). At this cost it is not cost-effective to make the additional investment to purchase an 0.63 EF gas water heater over the standard (0.60 EF). We therefore zero penetration for water heating measures in ENERGY STAR homes after the standard goes into effect.

86 Note that once standards go into effect in 2004, it is no longer cost effective to make the additional investment required to reach the savings we assume for ENERGY STAR homes (the standard gets almost all the savings at a much lower cost). We therefore assume zero penetration for water heating measures in ENERGY STAR homes in 2004 and beyond.

87 Building America and whole-house tax credits are assumed to improve water heater efficiency to 0.62 EF. This is the same energy factor we assume for 2004 water heater standards. Since standards take precedence over voluntary programs in our analysis, once water heater standards are tightened savings for Building America and whole-house tax credits are reduced to zero.

88 R&D effects due to the ENERGY STAR Homes program are expected to reduce incremental costs by 10%. This is not sufficient to make this level of savings cost effective in the presence of the 2004 gas water heater standard.

89 The 2004 gas water heater standard is assumed to increase the minimum energy factor from 0.54 to 0.62 (our baseline, 0.56 EF, is slightly more efficient than the minimum standard, 0.54 EF).

90 Tax credits for 0.65 EF gas water heaters are assumed to be for 10 percent of the purchase price for the period December 31, 1999 to January 1, 2002 (US DOT, 1999). Because 0.65 EF gas water heaters are cost effective only in homes with high hot water use, the baseline unit energy consumption and savings shown reflect only cost-effective applications. Energy savings are recalculated for 2004 and beyond using the new gas water heater standard as the baseline.

91 Incremental costs for 2000-2003 are from Atkinson (1996). Because tax credits are expected to have a market transformation effect, we assume that by the time new standards become effective in 2004, production experience will have reduced the price of high-efficiency gas water heaters by 10%. Therefore incremental costs for 2004 and beyond are calculated using the lower prices and are calculated using the 2004 standards as a baseline.

92 Tax credits for 0.80 EF gas water heaters in the moderate case are assumed to be for 20 percent of the purchase price and last from December 31, 1999 through January 1, 2004. Tax credits for 0.80 EF gas water heaters in the advanced case are assumed to be for 10 percent of the purchase price and last for 10 years. Because 0.80 EF gas water heaters are cost effective only in extremely high hot-water-use homes, the baseline unit energy consumption and savings shown reflect only cost-effective applications. Energy savings are recalculated for 2004 and beyond using the new gas water heater standard as the baseline.

## Introduction to Commercial Technology Table (Table C-1.7)

Table C-1.7 presents technology assumptions for policies affecting commercial end uses. Included are percent energy savings with respect to the frozen efficiency energy use (i.e. with respect to energy use for typical new equipment in the year 2000), product lifetime (necessary for stock accounting and cost-effectiveness calculations), incremental cost ( in 1997 dollars), and the cost of conserved energy (CCE, a measure of cost effectiveness).

*Financial Calculations*

All costs are presented in 1997 dollars. Costs from the original sources were adjusted to 1997 dollars, if necessary, using the implicit GDP deflator (Bureau of Economic Analysis 1998). The cost of conserved energy, expressed as $/kWh or $/MMBtu, is the annualized incremental cost of the technology divided by the unit energy savings. The annualized cost is calculated over the lifetime of the product using a seven percent real discount rate.

*Market Segmentation*

In some cases a particular measure was not cost effective in "the average" application. Commercial heat pump water heaters, for example, are cost effective in buildings with large hot water loads, such restaurants and laundries. Suozzo and Nadel (1998) report energy use and potential savings for feasible applications and what percent of electric water heating load those applications represent. Energy savings and costs are reported for those applications only.

*Avoiding Double-Counting*

In many cases multiple policies affect the same end use. To avoid double counting, we had to establish rules for how savings would be divided between policies. Mandatory programs, such as equipment standards, were given primacy. Standards are assumed to affect 100% of a certain type of equipment and are credited with the full savings of moving from a baseline unit to a unit just meeting the standard. Any non-mandatory policy is considered to be on top of standards (if any). Savings are calculated relative to the standard in place. If a non-mandatory policy affects 40% of an equipment type and saves 15% of the energy of a baseline unit, but standards are in place that effect 100% of equipment and save 10% over a baseline unit, the non-mandatory program is credited with saving 5% of baseline energy on 40% of the equipment. A single non-mandatory policy may therefore have multiple baselines if standards are updated once or more while the policy is in place. Because the energy savings change when the baseline changes, we treat each policy/baseline combination separately in our analysis. The penetrations for each policy/baseline combination are listed separately in these tables.

**Table C-1.7. Technology Data for Commercial Buildings**

| Policy by Fuel and End-Use | Case[1] | Baseline[2] | % Saving with Respect to Baseline[3] | *Savings Notes* | Life-time years | *Life-time Notes* | Incr. Cost[4] 1997$ | *Incr. Cost Notes* | CCE[5] 2000-09 $/MBtu | *CCE Notes* | CCE[5] 2010-20 $/MBtu | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric | | | | | | | | | | | | |
| Space heating | | | | | | | | | | | | |
| Energy Star Bldgs/Rebuild America | M | Typ. extg bldg in 2000 | 45% | *6* | 50 | *7* | N/A | | $3.95 | *8* | $3.56 | *9* |
| Energy Star Bldgs/Rebuild America | A | Typ. extg bldg in 2000 | 45% | *6* | 50 | *7* | N/A | | $3.95 | *8* | $3.16 | *9* |
| Whole Bldg R&D-existing bldgs | M | Typ. extg bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $4.27 | *11* | $3.56 | *12* |
| Whole Bldg R&D-existing bldgs | A | Typ. extg bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $4.27 | *11* | $3.16 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $4.27 | *11* | $3.56 | *12* |
| Whole Bldg R&D-new bldgs | A | Typ. new bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $4.27 | *11* | $3.16 | *12* |
| Commercial Bldg Codes | M | Typ. new bldg in 2000 | 10% | *13* | 50 | *7* | N/A | | $0.30 | *14* | $0.27 | *9* |
| Commercial Bldg Codes | A | Typ. new bldg in 2000 | 15% | *13* | 50 | *7* | N/A | | $0.45 | *14* | $0.36 | *9* |
| Space cooling | | | | | | | | | | | | |
| E* Bldgs/Rebuild America pre 2005 AC std | M,A | Typ. extg bldg in 2000 | 50% | *6* | 50 | *7* | N/A | | $3.95 | *8* | NA | |
| E* Bldgs/Rebuild America w/ 2005 AC std | M | Typ. extg bldg in 2000 w/ 2005 AC std | 46% | *6,15* | 50 | *7* | N/A | | $3.95 | *8* | $3.56 | *9* |
| E* Bldgs/Rebuild America w/ 2005 AC std | A | Typ. extg bldg in 2000 w/ 2005 AC std | 46% | *6,15* | 50 | *7* | N/A | | $3.95 | *8* | NA | |
| E* Bldgs/Rebuild America w/ 2010 AC std | A | Typ. extg bldg in 2000 w/ 2010 AC std | 43% | *6,16* | 50 | *7* | N/A | | NA | | $3.16 | *9* |
| 2005 Com'l Pkg AC Stds 2005-2020 | M | Typ. new equip in 2000 | 10% | *17* | 15 | *18* | $490 | *18* | $9.21 | | $9.21 | |
| 2005 Com'l Pkg AC Stds 2005-2009 | A | Typ. new equip in 2000 | 10% | *17* | 15 | *18* | $490 | *18* | $9.21 | | NA | |
| 2010 Com'l Pkg AC Stds 2010-2020 | A | Typ. new equip in 2000 | 17% | *17* | 15 | *18* | $1,103 | *18* | NA | | $12.91 | *18* |
| Whole Bldg R&D-existg bldgs w/ 2005 AC std | M | Typ. extg bldg in 2000 w/ 2005 AC std | 46% | *10,14* | 50 | *7* | N/A | | $3.95 | *11* | $3.56 | *12* |
| Whole Bldg R&D-existg bldgs w/ 2005 AC std | A | Typ. extg bldg in 2000 w/ 2005 AC std | 46% | *10,14* | 50 | *7* | N/A | | $3.95 | *11* | $3.16 | *12* |
| Whole Bldg R&D-existg bldgs w/ 2010 AC std | A | Typ. extg bldg in 2000 w/ 2010 AC std | 43% | *10,15* | 50 | *7* | N/A | | $3.95 | *11* | $3.16 | *12* |
| Whole Bldg R&D-new bldgs w/ 2005 AC std | M | Typ. new bldg in 2000 w/ 2005 AC std | 46% | *10,14* | 50 | *7* | N/A | | $3.95 | *11* | $3.56 | *12* |
| Whole Bldg R&D-new bldgs w/ 2005 AC std | A | Typ. new bldg in 2000 w/ 2005 AC std | 46% | *10,14* | 50 | *7* | N/A | | $3.95 | *11* | $3.16 | *12* |
| Whole Bldg R&D-new bldgs w/ 2010 AC std | A | Typ. new bldg in 2000 w/ 2010 AC std | 43% | *10,15* | 50 | *7* | N/A | | $3.95 | *11* | $3.16 | *12* |
| Commercial Bldg Codes w/ 2005 AC std | M | Typ. new bldg in 2000 w/ 2005 AC std | 10% | *13* | 50 | *7* | N/A | | $0.79 | *14* | $0.71 | *9* |
| Commercial Bldg Codes w/ 2005 AC std | A | Typ. new bldg in 2000 w/ 2005 AC std | 15% | *13* | 50 | *7* | N/A | | $1.19 | *14* | $0.95 | *9* |
| Commercial Bldg Codes w/ 2010 AC std | A | Typ. new bldg in 2000 w/ 2010 AC std | 8% | *13* | 50 | *7* | N/A | | $1.19 | *14* | $0.95 | *9* |
| Water heating | | | | | | | | | | | | |
| Utility HPWH | M,A | Typ. new equip in 2000 | 58% | *18* | 15 | *18* | $3,627 | *18* | $6.87 | | $6.87 | |
| E* Bldgs/Rebuild America | M | Typ. comm bldg in 2000 | 32% | *6* | 50 | *7* | $0.09 | *19* | $2.19 | *20* | $1.98 | *9* |
| E* Bldgs/Rebuild America | A | Typ. comm bldg in 2000 | 32% | *6* | 50 | *7* | $0.09 | *19* | $2.19 | *20* | $1.76 | *9* |
| Whole Bldg R&D-existing bldgs | M | Typ. extg com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.98 | *12* |
| Whole Bldg R&D-existing bldgs | A | Typ. extg com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.76 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.98 | *12* |
| Whole Bldg R&D-new bldgs | A | Typ. new com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.76 | *12* |
| Commercial Bldg Codes | M | Typ. new com bldg in 2000 | 10% | *13* | 50 | *7* | N/A | | $0.69 | *14* | $0.63 | *9* |

**Table C-1.7 (continued). Technology Data for Commercial Buildings**

| Policy by Fuel and End-Use | Case[1] | Baseline[2] | % Saving wrt Frozen Efficiency[3] | *Savings Notes* | Life-time years | *Life-time Notes* | Incr. Cost[4] 1997$ | *Incr. Cost Notes* | CCE[5] 2000-09 $/MBtu | *CCE Notes* | CCE[5] 2010-20 $/MBtu | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric | | | | | | | | | | | | |
| Water Heating | | | | | | | | | | | | |
| Commercial Bldg Codes | A | Typ. new com bldg in 2000 | 15% | *13* | 50 | *7* | N/A | | $1.04 | *14* | $0.83 | *9* |
| Ventilation | | | | | | | | | | | | |
| E* Bldgs/Rebuild America | M | Typ. comm bldg in 2000 | 57% | *6* | 50 | *7* | N/A | | $1.35 | *7* | $1.21 | *9* |
| E* Bldgs/Rebuild America | A | Typ. comm bldg in 2000 | 57% | *6* | 50 | *7* | N/A | | $1.35 | *7* | $1.08 | *9* |
| Whole Bldg R&D-existing bldgs | M | Typ. extg com bldg in 2000 | 57% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.21 | *12* |
| Whole Bldg R&D-existing bldgs | A | Typ. extg com bldg in 2000 | 57% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.08 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new com bldg in 2000 | 57% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.21 | *12* |
| Whole Bldg R&D-new bldgs | A | Typ. new com bldg in 2000 | 57% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.08 | *12* |
| Commercial Bldg Codes | M | Typ. new com bldg in 2000 | 10% | *13* | 50 | *7* | N/A | | $0.24 | *14* | $0.21 | *9* |
| Commercial Bldg Codes | A | Typ. new com bldg in 2000 | 15% | *13* | 50 | *7* | N/A | | $0.35 | *14* | $0.28 | *9* |
| Cooking | | | NA | | NA | | NA | | NA | | NA | |
| Lighting | | | | | | | | | | | | |
| E* Bldgs/Rebuild America | M,A | Typ. extg com bldg in 2000 | 28% | *21* | 50 | *7* | N/A | | $7.31 | *22* | NA | |
| E* Bldgs/Rebuild America | M | 2004 Ballast Standards | 24% | *23* | 50 | *7* | N/A | | $9.39 | *22* | $6.58 | *9* |
| E* Bldgs/Rebuild America | A | 2004 Ballast Standards | 24% | *23* | 50 | *7* | N/A | | $9.39 | *22* | $5.84 | *9* |
| 2004 Ballast Standards | M,A | Typ. new equip in 2000 | 9% | *24* | 12.5 | *25* | N/A | | $16.99 | *24* | $16.99 | *24* |
| Whole Bldg R&D-existing bldgs | M | Typ. extg bldg in 2000 w/ 2004 ballast std | 24% | *10* | 50 | *7* | N/A | | $7.31 | *11* | $6.58 | *12* |
| Whole Bldg R&D-existing bldgs | A | Typ. extg bldg in 2000 w/ 2004 ballast std | 24% | *10* | 50 | *7* | N/A | | $7.31 | *11* | $5.84 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new bldg in 2000 w/ 2004 ballast std | 24% | *10* | 50 | *7* | N/A | | $7.31 | *11* | $6.58 | *12* |
| Whole Bldg R&D-new bldgs | A | Typ. new bldg in 2000 w/ 2004 ballast std | 24% | *10* | 50 | *7* | N/A | | $7.31 | *11* | $5.84 | *12* |
| Commercial Bldg Codes | M | Typ. new bldg in 2000 w/ 2004 ballast std | 10% | *13* | 50 | *7* | N/A | | $3.86 | *14* | $3.47 | *9* |
| Commercial Bldg Codes | A | Typ. new bldg in 2000 w/ 2004 ballast std | 15% | *13* | 50 | *7* | N/A | | $5.79 | *14* | $4.63 | *9* |
| Refrigeration | | | | | | | | | | | | |
| Energy Star Bevge Merchandisers | M,A | Typ. new equip in 2000 | 55% | *27* | 20 | *26* | $390 | *26* | $3.28 | | $3.28 | |
| Energy Star Vending Machines | M,A | Typ. new equip in 2000 | 32% | *18* | 20 | *26* | $100 | *18* | $2.87 | | $2.87 | |
| Energy Star Ice Machines | M,A | Typ. new equip in 2000 | 18% | *26* | 20 | *26* | $152 | *26* | $2.98 | | $2.98 | |
| Office equip.-PCs | | | NA | | NA | | NA | | NA | | NA | |
| Office equip.-non-PCs | | | NA | | NA | | NA | | NA | | NA | |
| Other Uses | | | | | | | | | | | | |
| Miscellaneous | | | | | | | | | | | | |
| Energy Star Exit Signs | M,A | Typ. new equip in 2000 | 93% | *18* | 10 | *27* | $44 | *18* | $5.68 | | $5.68 | |
| Energy Star Transformers | M,A | Typ. new equip in 2000 | 41% | *28* | 30 | *18* | $121 | *29* | $1.88 | | $1.88 | |
| Energy Star Traffic Lights | M,A | Typ. new equip in 2000 | 89% | *30* | 10 | *18* | $2,824 | *18* | $9.39 | | $9.39 | |
| Transformer Standards | A | Typ. new equip in 2000 | 41% | *31* | 30 | *18* | $202 | *32* | $4.45 | | $4.45 | |

**Table C-1.7 (continued). Technology Data for Commercial Buildings**

| Policy by Fuel and End-Use | Case[1] | Baseline[2] | % Saving wrt Frozen Efficiency[3] | *Savings Notes* | Life-time years | *Life-time Notes* | Incr. Cost[4] 1997$ | *Incr. Cost Notes* | CCE[5] 2000-09 $/MBtu | *CCE Notes* | CCE[5] 2010-20 $/MBtu | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric | | | | | | | | | | | | |
| Other Uses | | | | | | | | | | | | |
| District Services | | | NA | | NA | | NA | | NA | | NA | |
| Adjust to SEDs | | | NA | | NA | | NA | | NA | | NA | |
| Gas | | | | | | | | | | | | |
| Space heating | | | | | | | | | | | | |
| E* Bldgs/Rebuild America 2000-2020 | M | Typ. extg com bldg in 2000 | 45% | *6* | 50 | *7* | N/A | | $1.35 | *8* | $1.21 | *9* |
| E* Bldgs/Rebuild America pre 2010 std | A | Typ. extg com bldg in 2000 | 45% | *6* | 50 | *7* | N/A | | $1.35 | *8* | NA | |
| E* Bldgs/Rebuild America w/ 2010 furn std | A | Typ. extg bldg in 2000 w/ 2010 furn std | 38% | *33* | 50 | *7* | N/A | | NA | | $1.08 | *9* |
| 2010 Gas Furnace and Boiler Stds | A | Typ. new equip in 2000 | 7% | *34* | 15 | *18* | $507 | *18* | NA | | $2.93 | |
| Whole Bldg R&D-existing bldgs | M | Typ. extg com bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.21 | *12* |
| Whole Bldg R&D-extg bldgs pre 2010 furn std | A | Typ. extg com bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.08 | *12* |
| Whole Bldg R&D-extg bldgs w/ 2010 furn std | A | Typ. extg bldg in 2000 w/ 2010 furn std | 38% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.08 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new com bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.21 | *12* |
| Whole Bldg R&D-new bldgs pre 2010 furn std | A | Typ. new com bldg in 2000 | 45% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.08 | *12* |
| Whole Bldg R&D-new bldgs w/2010 furn std | A | Typ. new bldg in 2000 w/ 2010 furn std | 38% | *10* | 50 | *7* | N/A | | $1.35 | *11* | $1.08 | *12* |
| Commercial Bldg Codes | M | Typ. new com bldg in 2000 | 10% | *13* | 50 | *7* | N/A | | $0.30 | *14* | $0.27 | *9* |
| Commercial Bldg Codes pre 2010 furn std | A | Typ. new com bldg in 2000 | 15% | *13* | 50 | *7* | N/A | | $0.45 | *14* | $0.36 | *9* |
| Commercial Bldg Codes w/ 2010 furn std | A | Typ. new bldg in 2000 w/ 2010 furn std | 8% | *13* | 50 | *7* | N/A | | $0.45 | *14* | $0.36 | *9* |
| Space cooling | | | | | | | | | | | | |
| E* Bldgs/Rebuild America | M | Typ. extg com bldg in 2000 | 50% | *6* | 50 | *7* | N/A | | $3.95 | *8* | $3.56 | *9* |
| E* Bldgs/Rebuild America | A | Typ. extg com bldg in 2000 | 50% | *6* | 50 | *7* | N/A | | $3.95 | *8* | $3.16 | *9* |
| Whole Bldg R&D-existing bldgs | M | Typ. extg com bldg in 2000 | 50% | *10* | 50 | *7* | N/A | | $3.95 | *11* | $3.56 | *12* |
| Whole Bldg R&D-existing bldgs | A | Typ. extg com bldg in 2000 | 50% | *10* | 50 | *7* | N/A | | $3.95 | *11* | $3.16 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new com bldg in 2000 | 50% | *10* | 50 | *7* | N/A | | $3.95 | *11* | $3.56 | *12* |
| Whole Bldg R&D-new bldgs | A | Typ. new com bldg in 2000 | 50% | *10* | 50 | *7* | N/A | | $3.95 | *11* | $3.16 | *12* |
| Commercial Bldg Codes | M | Typ. new com bldg in 2000 | 10% | *13* | 50 | *7* | N/A | | $0.79 | *14* | $0.71 | *9* |
| Commercial Bldg Codes | A | Typ. new com bldg in 2000 | 15% | *13* | 50 | *7* | N/A | | $1.19 | *14* | $0.95 | *9* |
| Water heating | | | | | | | | | | | | |
| E* Bldgs/Rebuild America | M | Typ. extg com bldg in 2000 | 32% | *6* | 50 | *7* | $0.09 | *19* | $2.19 | *20* | $1.98 | *9* |
| E* Bldgs/Rebuild America | A | Typ. extg com bldg in 2000 | 32% | *6* | 50 | *7* | $0.09 | *19* | $2.19 | *20* | $1.76 | *9* |
| Whole Bldg R&D-existing bldgs | M | Typ. extg com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.98 | *12* |
| Whole Bldg R&D-existing bldgs | A | Typ. extg com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.76 | *12* |
| Whole Bldg R&D-new bldgs | M | Typ. new com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.98 | *12* |
| Whole Bldg R&D-new bldgs | A | Typ. new com bldg in 2000 | 32% | *10* | 50 | *7* | N/A | | $2.19 | *11* | $1.76 | *12* |
| Commercial Bldg Codes | M | Typ. new com bldg in 2000 | 10% | *13* | 50 | *7* | N/A | | $0.69 | *14* | $0.63 | *9* |

**Table C-1.7 (continued). Technology Data for Commercial Buildings**

| Policy by Fuel and End-Use | Case[1] | Baseline[2] | % Saving wrt Frozen Efficiency[3] | *Savings Notes* | Life-time years | *Life-time Notes* | Incr. Cost[4] 1997$ | *Incr. Cost Notes* | CCE[5] 2000-09 $/MBtu | *CCE Notes* | CCE[5] 2010-20 $/MBtu | *CCE Notes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas | | | | | | | | | | | | |
| Water heating | | | | | | | | | | | | |
| Commercial Bldg Codes | A | Typ. new com bldg in 2000 | 15% | *13* | 50 | *7* | N/A | | $1.04 | *14* | $0.83 | *9* |
| Cooking | | | NA | | | | | | | | | |
| Other Uses | | | | | | | | | | | | |
| Misc | | | NA | | NA | | NA | | NA | | NA | |
| District Services | | | NA | | NA | | NA | | NA | | NA | |
| Cogen | | | NA | | NA | | NA | | NA | | NA | |
| Adjust to SEDS | | | NA | | NA | | NA | | NA | | NA | |

**Notes to Table C-1.7**
**Technology Data for Commercial Buildings**

1 We specify the applicable case for each policy as A for advanced or M for moderate. Some policies apply to only one case (e.g. 2010 commercial packaged AC standards), some may be effective for different dates, and others may have different costs due to different R&D effects in the moderate and advanced cases.

2 Because different policies affect the same market segment, it was often necessary to adjust penetrations or savings in order to avoid double counting. In particular, we had to address the effect on existing programs, such as ENERGY STAR Buildings/Rebuild America, when new equipment standards come into effect. We adopted the practice of attributing savings to mandatory programs, such as standards, before calculating savings for other policies. When the savings for a policy are affected by a standard, we essentially analyze the policy as several different policies according to the baseline that applies (year 2000 new equipment, 2004 standard, 2010 standard). For example, ENERGY STAR Buildings/Rebuild America appears four times under electric cooling. Three baselines apply: the year 2000 baseline applies for the period 2000-2004 for both the moderate and advanced case. In 2005, commercial packaged AC standards go into effect in both the moderate and advanced cases. This becomes the baseline for the moderate case for the remainder of the analysis period. For the advanced case, the 2005 standard is the baseline until the standard is tightened in 2010. The 2010 standard applies in the advanced case for the remainder of the period.

3 Because most of the commercial policies apply to broadly defined end-uses rather than specific technologies (e.g. ENERGY STAR Buildings and Rebuild America take an integrated approach toward heating, cooling, ventilation, lighting, and water heating), in many cases we did not have a unit energy consumption or savings to present. We therefore present here only the percent savings with respect to the baseline unit, as given in the table. For defined equipment, such as commercial packaged a/c, this translates directly into a percent reduction in unit energy consumption compared to the baseline unit. For whole building programs, it should be interpreted as a reduction in energy intensity (kWh/sq. foot or MBtu/sq. foot) compared to the baseline.

4 The incremental cost is the cost of equipment after the market has adjusted to the presence of the policy, e.g. by increasing production experience.

5 The cost of conserved energy is a measure of cost effectiveness, expressed here in 1997 dollars per MBtu. An energy conservation measure is cost effective if the cost of conserved energy is less than the cost of the relevant fuel. The cost of conserved energy is calculated using a 7% real discount rate. For some technologies, the CCE is assumed to drop over time due to the effect of R&D programs. We model this effect by using different CCEs for 2000-2009 and 2010-2020. If there is no R&D, the CCE is the same for both periods. If the program ends before 2010, the CCE for 2010 to 2020 is reported as "NA". Similarly, if the program begins in 2010 or later, the CCE for 2000-2010 is reported as "NA."

6 EPA ENERGY STAR Building estimates.

7 We assume a 50 year lifetime for commercial buildings. By using the commercial building lifetime for whole-building measures, we assume that once buildings join a program, they do not drop out and that they replace high-efficiency equipment with new high-efficiency equipment as it retires. This lifetime is applicable to energy savings calculations, since program participation insures the persistence of savings measure taken. This lifetime is not used in any financial calculations, including the CCEs shown in this table. See the CCE notes for further clarification.

8 Weighted average CCE based on cost and savings for a variety of HVAC systems from Sezgen et al (1995). To convert from CCE in terms of primary energy to CCEs for site energy, we assumed that the CCE for electric HVAC was the same as for gas and oil HVAC in primary terms. We then converted the CCE for electric HVAC to site energy using a conversion of 10,000 primary Btu to 3,412 site Btu.

9 Whole building R&D programs are expected to reduce the costs for ENERGY STAR Buildings/Rebuild America and commercial building codes by 10% in the moderate case and 20% in the advanced case.

**Notes to Table C-1.7 (continued)**

10 Whole building R&D programs are assumed to make other whole building policies less expensive and therefore increase their penetrations. In our analysis we model R&D programs as increasing the penetration of ENERGY STAR Buildings/Rebuild America. We therefore assume that percent energy savings is the same as ENERGY STAR Buildings for each end-use. Percent savings are assumed to be the same for new and existing buildings (since energy use is assumed to be lower in new buildings, the absolute savings will be smaller).

11 Whole building R&D is not expected to affect the market until 2010. For 2000-2009 we therefore assume the same CCE as ENERGY STAR Buildings/ Rebuild America.

12 Whole building R&D programs are expected to reduce building costs by 10% in the moderate case and 20% in the advanced case.

13 Commercial building codes are assumed to reduce whole-building energy use by 10% in the moderate case and 15% in the advanced case. End-uses affected are heating, cooling, ventilation, lighting and water heating.

14 CCEs for commercial building codes were scaled down from ENERGY STAR Buildings CCEs proportionally to energy savings.

15 Savings are reduced to take into account the effect of commercial packaged AC standards that go into effect in 2005.

16 Savings are reduced to take into account the effect of commercial packaged AC standards that go into effect in 2010.

17 Energy savings assumptions for commercial packaged a/c standards were taken from Suozzo and Nadel (1998). Our 2005 standards correspond to their tier 1 efficiency (10.3 EER), while our 2010 standards (advanced case only) correspond to their tier 2 efficiency (11 EER). Although a higher efficiency could be justified in the advanced case (12 SEER has been proposed in past policy discussions), we did not have sufficient data to analyze such a policy.

18 Suozzo and Nadel (1998).

19 The cost of water heating measures is per square foot and is derived from EPA estimates of program costs (the EPA forecasts participation by phase of program, so some aggregation was performed to obtain savings by end-use).

20 To calculate a CCE, we needed to estimate energy savings per square foot to go with our estimate of incremental cost per square foot (see note 18). Total water heater savings (gas and electric) attributable to ENERGY STAR Buildings/Rebuild America (outputs of this analysis) were divided by an estimate of square feet affected by water heating measures (also from the EPA ENERGY STAR Buildings analysis).

21 Because the EPA lighting savings estimates were high (55%), we believed the savings represented a comparison to a less efficient baseline than appropriate for this analysis. To estimate savings, we used data from Suozzo and Nadel (1998) for a variety of lighting programs (including the use of T8 lamps with electronic ballasts, occupancy controls, daylight dimming controls, improved lighting design). Savings were weighted by the applicable lighting stock.

22 Weighted average of lighting measure CCEs from Suozzo and Nadel (1998).

23 Because ballast standards are assumed to be revised in 2003, it was necessary to calculate a new ENERGY STAR Buildings/Rebuild America energy saving estimate. We used data from Suozzo and Nadel (1998) for a variety of lighting programs (including the use of occupancy controls, daylight dimming controls, improved lighting design). Savings were weighted by the applicable lighting stock.

24 Ballast standards savings and cost estimates were obtained from the commercial electricity supply curve (Vorsatz and Koomey, 1999).

25 LBNL (1997)

26 Westphalen et al. (1996).

27 ENERGY STAR exit sign life is from the latest EPA ENERGY STAR program savings forecasts, LBNL spreadsheets dated June, 1999, US EPA (1999c).

**Notes to Table C-1.7 (continued)**

28 The ENERGY STAR commercial and industrial transformer program aims to reduce transformer losses in commercial buildings. Because transformer data is reported by transformer type (low or medium voltage and dry type or liquid immersed) rather than by sector, we had to make some assumptions in order to to determine commercial transformer energy use and shipments data. Electric League of the Pacific Northwest et al. (1998) report that low voltage equipment dominates the commercial sector, medium voltage equipment dominates the industrial sector, and almost all low voltage transformers are dry-type. We therefore used total low-voltage sales (from EPA's transformer program) as a proxy for commercial sales in estimating the stock of commercial transformers. EPA's estimates of energy savings assume an increase in efficiency from 95% to 98%. Suozzo and Nadel (1998), however, estimate that baseline transformer efficiency is 97.3%. In personal communication, Margaret Suozzo indicated that she felt EPA's 95% efficiency baseline was too low. We therefore used the efficiency estimates in Suozzo and Nadel with the average capacity, average load factor and hours per year from EPA's transformer analysis (45 kVA, 35% and 8760 hours per year, respectively) to estimate baseline and ENERGY STAR transformer energy losses.

29 Suozzo and Nadel (1998) report a single incremental cost ($1770) for transformers ranging in capacity from 75 kVA to 1500 kVA. We estimated the average capacity for transformers in their analysis to be 645 kVa (we determined that a weighting of 60% 75 kVA and 40% 1500 kVA yielded the average unit energy savings given in the report). ENERGY STAR transformers assume a 45 kVA capacity. Working from the assumption that $1770 accurately reflected the incremental cost for a 645 kVA transformer, we scaled the cost based on transformer capacity to estimate the incremental cost for a 45 kVA transformer.

30 The ENERGY STAR traffic lights program is proposed to promote the replacement of incandescent traffic lights with LED traffic lights. This is currently highly cost effective for red traffic lights, but less so for green and yellow lights because they have shorter duty cycles and green and yellow LEDs are more expensive than red. We therefore assume only red traffic lights are replaced in the program. Baseline and ENERGY STAR unit energy consumption were taken from Suozzo and Nadel (1998).

31 Dry-type transformer standards are assumed to go into effect in 2004. Baseline energy and energy savings estimates are from Suozzo and Nadel (1998).

32 Suozzo and Nadel (1998) report a single incremental cost ($1770) for transformers ranging in capacity from 75 kVA to 1500 kVA. We estimated the average capacity for transformers in their analysis to be 645 kVa (we determined that a weighting of 60% 75 kVA and 40% 1500 kVA yielded the average unit energy savings given in the report). Since our savings estimates for transformer standards are based on a 75 kVA capacity, we scaled down the $1770 cost based on capacity and assuming that $1770 accurately reflected the incremental cost for a 645 kVA transformer.

33 Savings are reduced to take into account the effect of commercial furnace and boiler standards that go into effect in 2010 in the advanced case.

34 It appears unlikely that gas furnace and boiler standards will be tightened in the near term (Suozzo and Nadel, 1998). We therefore consider such standards only in the advanced case, and even then only in 2010. Energy savings are from Suozzo and Nadel (1998) assuming 82% combustion efficiency and 2.5% casing losses under the standard.

***APPENDIX C-1 REFERENCES***

Appliance. 1996. "A Portrait of the US Appliance Industry 1996." In *Appliance Magazine*. September. pp 85-91.

Appliance. 1998. "A Portrait of the US Appliance Industry 1998." In *Appliance Magazine*. September. pp 67-73.

Arasteh, Dariush 1999. *Personal Communication*: "Unpublished window modeling results performed by Dariush Arasteh of Lawrence Berkeley National Laboratory using the DOE-2 modeling program as part of the "NFRC 900" project."

Atkinson, Celina. March, 1996. *Personal Communication:* "Unpublished telephone survey of 4 WH dealers/stores in CA, IL, and MI."

Barbour, Edward. January, 1998. *Personal Communication:* "Unpublished analysis of ENERGY STAR products provided to Carrie Webber at Lawrence Berkeley National Laboratory in support of ENERGY STAR program savings forecasts."

BEA. *Bureau of Economic Analysis web site; from the Survey of Current Business* [website]. http://www.bea.doc.gov/bea/dn/0898nip3/table3.htm, 1998 [cited August 1998].

Brown, Richard E., Celina S. Atkinson, Jeffrey L. Warner, Judy A. Roberson, Marla C. Sanchez, Donald L. Mauritz, Sarah E. Bretz, and Jonathan G. Koomey. 1998. *Methodology and Inputs Used to Develop Regional Builder Option Packages for Energy Star New Homes*. Berkeley, CA: Lawrence Berkeley National Laboratory. Draft LBNL-41690. April.

Calwell, Chris. 1999. "Customers Turn Out for Torchiere Trade-In." In *Home Energy*. March/April. pp. 32-35.

Davis Energy Group. 1994. *Two-Speed Pool Pump Project: Final Report*. Davis, CA: Prepared for Fred Rohe of Southern California Edison. December.

ELPN, CEE, ACEEE, and PEA. 1998. *Draft Proposal to NW Energy Efficiency Alliance for Promotion of Energy Efficient Transformers*. Electric League of the Pacific Northwest, Consortium for Energy Efficiency, Inc., American Council for an Energy-Efficient Economy, and Pacific Energy Associates, Inc. May.

Energy Center of Wisconsin. 1997. *Forced-Air Furnace and Central Air Conditioner Markets - Tracking Sales Through Wisconsin HVAC Contractors*. August.

EPRI, Electric Power Research Institute. 1987. *TAG-Technical Assessment Guide: Vol. 2: Electricity End Use. Part 1: Residential Electricity Use--1987*. EPRI. EPRI P-4463-SR, vol.2, Part 1. September.

FSEC. 1999. "The Gossamer Wind: What is so special about this fan?" Florida Solar Energy Center, http://www.fsec.ucf.edu/~bdac/PROTOTYPE/CFAN.htm.

Geller, Howard, Steven Nadel, R. Neal Elliott, Martin Thomas, and John DeCicco. 1998. *Approaching the Kyoto Targets: Five Key Strategies for the United States*. Washington, DC: American Council for an Energy-Efficient Economy. August.

Hanford, J.W., J.G. Koomey, L.E. Stewart, M.E. Lecar, R.E. Brown, F.X. Johnson, R.J. Hwang, and L.K. Price. 1994. *Baseline Data for the Residential Sector and Development of a Residential Forecasting Database*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBL-33717. May.

Jakob, F. E., J. J. Crisafulli, J.R. Menkedick, R.D. Fischer, D.B. Philips, R.L. Osborne, J.C. Cross, G.R. Whitacre, J.G. Murray, W.J. Sheppard, D. W. DeWerth, and W. H. Thrasher. 1994. *Assessment of Technology for Improving the Efficiency of Residential Gas Furnaces and Boilers, Volume II: Appendices*. Gas Research Institute. GRI-94/0175.2. September.

James, George. 1999. *Personal Communication*: "Unpublished energy savings range (as a percentage of typical new home energy use) for Building America homes provided to Celina Atkinson of Lawrence Berkeley National Laboratory by George James of the United States Department of Energy."

Johnson, Francis X., James W. Hanford, Richard E. Brown, Alan H. Sanstad, and Jonathan G. Koomey. 1994. *Residential HVAC Data, Assumptions and Methodology for End-Use Forecasting with EPRI-REEPS 2.1*. Lawrence Berkeley Laboratory. LBL-34045. June.

Koomey, Jonathan G., Marla C. Sanchez, Diana Vorsatz, Richard E. Brown, and Celina S. Atkinson. 1999a. *Working Paper: The Potential for Natural Gas Efficiency Improvements in the U.S. Residential Sector*. Lawrence Berkeley Laboratory. DRAFT LBNL-38893. To be posted on the web in Fall 1999.

Koomey, Jonathan G., Diana Vorsatz, Richard E. Brown, Celina S. Atkinson, and Marla C. Sanchez. 1999b. *Working Paper: Updated Potential for Electricity Efficiency Improvements in the U.S. Residential Sector*. Lawrence Berkeley Laboratory. DRAFT LBNL-38894. To be posted on the web in Fall 1999.

LBNL. 1997. *Draft Report on Potential Impact of Possible Energy Efficiency Levels for Fluorescent Lamp Ballasts*. Berkeley, CA: Prepared for the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Codes and Standards, by Lawrence Berkeley National Laboratory. July.

Means. 1996. *Residential Cost Data*. Kingston, MA: R.S. Means Company, Inc. 15th Annual Edition.

Mr. Cool. *"Jim Ginther's Wholesale A/C & Heat" website* http://mrcoolu.com/, 1998 [cited 1998].

Nadel, Steven, Leo Rainer, Michael Shepard, Margaret Suozzo, and Jennifer Thorne. 1998. *Emerging Energy-Saving Technologies and Practices for the Buildings Sector*. Washington, DC: American Council for an Energy-Efficient Economy. December.

Offutt, Steven. 1999. *Personal Communication*: "Unpublished estimate of year and efficiency level of future ENERGY STAR central air conditioners and heat pumps provided to Celina Atkinson of Lawrence Berkeley National Laboratory."

Parker, Danny S., Michael P. Callahan, Jeffrey K. Sonne, and Guan H. Su. 1999. *Development of a High Efficiency Ceiling Fan: The Gossamer Wind*. Florida Solar Energy Center, Online Publications. FSEC-CR-1059-99. http://www.fsec.ucf.edu/~bdac/pubs/CR1059/CR1059.html.

Pettit, Betsy. 1999. *Personal Communication*: "Unpublished energy savings range (as a percentage of typical new home energy use) for Building America homes provided to Celina

Atkinson of Lawrence Berkeley National Laboratory by Betsy Pettit of Building Science Consortium."

Sanchez, Marla C., Jonathan G. Koomey, Mithra M. Moezzi, Alan K. Meier, and Wolfgang Huber. 1998. *Miscellaneous Electricity Use in the U.S. Residential Sector*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-40295. April.

Sezgen, A. Osman, Ellen M. Franconi, Jonathan G. Koomey, Steve E. Greenberg, and Asim Afzal. 1995. *Technology data characterizing space conditioning in commercial buildings: Application to end-use forecasting with COMMEND 4.0*. Lawrence Berkeley Laboratory. LBL-37065. December.

Su, Guan H., and Tom Zambrano. January 14th, 1999. *Personal Communication:* "Information on the Gossamer Wind Ceiling Fan, Provided at a Building Energy Seminar at Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division."

Suozzo, Margaret, and Steven Nadel. 1998. *Selecting Targets for Market Transformation Programs: A National Analysis*. Washington, DC: American Council for an Energy-Efficient Economy. August.

US DOE. 1990. *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers*. U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Building Equipment Division. DOE/CE-0299P. December.

US DOE. 1993a. *1990 Residential Energy Consumption Survey (RECS): Data Tapes*. Energy Information Administration. April.

US DOE. 1993b. *Technical Support Document: Energy Conservation Standards for Consumer Products: Room Air Conditioners, Water Heaters, Direct Heating Equipment, Mobile Home Furnaces, Kitchen Ranges and Ovens, Pool Heaters, Fluorescent Lamp Ballasts, and Television Sets*. U.S. Department of Energy, Assistant Secretary, Energy Efficiency and Renewable Energy, Building Equipment Division. Volume 3: Water Heaters, Pool Heaters, Direct Heating Equipment, Mobile Home Furnaces; DOE/EE-0009. November.

US DOE. 1995b. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, & Freezers*. U.S. Department of Energy, Assistant Secretary, Energy Efficiency and Renewable Energy, Office of Codes and Standards. DOE/EE-0064. July.

US DOE. 1998b. *Preliminary Technical Support Document: Energy Efficiency Standards for Consumer Products: Clothes Washers (TSD)*. U.S. Department of Energy, Assistant Secretary, Energy Efficiency and Renewable Energy, Office of Codes and Standards. October.

US DOT. 1999. *General Explanations of the Administration's Revenue Proposals*. Washington, DC: U.S. Department of the Treasury. February.

US EPA. *ENERGY STAR Purchasing Toolkit Simple Savings Calculator (Excel Spreadsheet)* Available for download from the EPA's ENERGY STAR web site, 1999a [cited August 1999]. Available from www.energystar.gov.

US EPA. *ENERGY STAR-labeled heating and cooling equipment online product directory* United States Environmental Protection Agency, 1999b [cited June 1999]. Available from http://www.epa.gov/appdstar/hvac/.

US EPA. June, 1999c. *Personal Communication:* "Spreadsheets developed by LBNL for the U.S. Environmental Protection Agency's ENERGY STAR programs. Contact Marla Sanchez at the United States EPA office in Washington D.C., telephone (202) 564-1248."

Vorsatz, Diana, and Jonathan G. Koomey. 1999. *Working Paper: The Potential for Efficiency Improvements in the U.S. Commercial Lighting Sector*. Lawrence Berkeley Laboratory. DRAFT LBNL-38895. To be posted on the web in Fall 1999.

Wenzel, Tom P., Jonathan G. Koomey, Gregory J. Rosenquist, Marla C. Sanchez, and James W. Hanford. 1997. *Energy Data Sourcebook for the U.S. Residential Sector*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-40297. September.

XENERGY. 1996. *1996 Measure Cost Study: Final Report*. Oakland, CA: California Demand-Side Management Measurement Advisory Committee (CADMAC). December.