APPENDIX 7-F. DETERMINATION OF CENTRAL AIR CONDITIONER ENERGY USE IN THE LCC ANALYSIS

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7-F.1 INTRODUCTION

DOE accounted for the fact that more efficient furnace fans will tend to contribute less heat and thereby require less cooling operation by the central air conditioner. Since the cooling load of each sample housing unit is known, it is possible to estimate what the air conditioner energy consumption would be if more efficient fan equipment, rather than the baseline equipment, were used in each housing unit.

7-F.2 DETERMINATION OF NON-FURNACE FAN COOLING ENERGY USE

DOE calculated the non-furnace fan cooling energy using the following formula:

$$CoolingEnergyUse_{non-furnace\_fan} = COH \times Power_{non-furnace\_fan}$$

Where:

COH = as defined in section 7-F.2.1,

$Power_{non\text{-}furnace\_fan}$ = power consumption of all non-furnace fan components of the central air conditioner (kW).

7-F.2.1 Determination Cooling Operating Hours

The cooling operating hours are calculated using the following formula:

$$COH = \frac{HCL}{CoolingCapacity} \times Adj\_Factor_{motor}$$

Where:

COH = cooling operating hours, hour/year,

HCL = house cooling load, MMBtu/year,

CoolingCapacity = cooling capacity of air conditioner, Btu/h (see section 7-F.2.2.1), and

Adj_Factor_{motor} = adjustment factor to account for impact of motor heat on cooling operating hours.

The house cooling load (HCL) assumes that the household has a default furnace fan motor power output of 365 watts per 1000 CFM (used in the CAC test procedure). To properly account for increased or decreased cooling operating hours due to the higher or lower motor power output for different furnace fan efficiencies, DOE used the following equation to determine the adjustment factor:

$$Adj\_Factor_{motor} = \frac{1}{\left(1 + 3.412 \times \frac{\frac{365}{1000} * CFM - FFPcooling}{CoolingCapacity}\right)}$$

Where:

$\frac{365}{1000} * CFM$ = default central air conditioner blower output used for calculating SEER, watts,

CFM = nominal cooling load CFM measured at 400 CFM per AC ton, cu. ft. per min,

$FFP_{cooling}$ = furnace fan power during the cooling operation, kW, and

CoolingCapacity = cooling capacity of air conditioner, Btu/h.

The house cooling load is derived using the EIA's RECS 2005[1] cooling energy use data for the sample households as follows:

$$HCL = \frac{CoolingEnergyUseRECS \times SEER_{ex}}{CoolingCapacity_{ex}} \times Adj\_Factor$$

$CoolingEnergyUseRECS$ = annual electricity consumption for cooling based on RECS 2005 (kBtu/yr),

$SEER_{ex}$ = SEER of the existing central air conditioner (See Table 7-F.2.3),

Adj_Factor = adjustment factors (discussed below).

DOE made adjustments to the house cooling load to reflect the expectation that newly built housing units in 2018 will have a somewhat different house cooling load than the housing units in the RECS 2005 sub-sample. Similar to furnace fan energy use calculation above, the building shell efficiency index sets the cooling load value at 1.00 for an average home in 2005 (by type) in each census division. DOE developed adjustment factors to represent the change in cooling load based on the difference in physical size and shell attributes for homes in the future (which takes into account physical size difference and efficiency gains from better insulation and windows). This factor differs for new construction and replacement households. The value for households in 2018 is 0.94 for replacements and 1.01 for new construction. To add variability, the factor is varied by plus or minus 15 percent.

DOE also made adjustments to the HCL calculated using RECS 2005 data to reflect historical average climate conditions. Table 7-F.2.1 shows the 2002-2011 average heating degree days (HDD) as well as the 2005 average CDD for the 29 geographical areas. The adjustment factors are calculated using the equation below.

$$Adj\_Factor_{average\_climate} = \frac{CDD_{10\_yr\_avg}}{CDD_{res\_stock\_2005}}$$

Where:

$CDD_{res\_stock\_2005}$ = CDD in 2005 for the specific region where the housing unit is located, and

$CDD_{10\_yr\_avg}$ = 10-year average CDD (2002–2011) based on NOAA data[2] for the specific region where the housing unit is located.

Table 7-F.2.1 Cooling Degree Day Adjustment Factors

Geographical Areas		Average CDD		Adjustment Factor
		2002-2011	2005	
1	CT, ME, NH, RI, VT	485	562	0.86
2	MA	522	576	0.91
3	NY	737	943	0.78
4	NJ	932	1121	0.83
5	PA	765	901	0.85
6	IL	924	1151	0.80
7	IN, OH	879	1027	0.86
8	MI	622	828	0.75
9	WI	552	747	0.74
10	IA, MN, ND, SD	637	792	0.81
11	KS, NE	1327	1491	0.89
12	MO	1325	1534	0.86
13	VA	1206	1250	0.97
14	DE, DC, MD, WV	1004	1034	0.97
15	GA	1832	1804	1.02
16	NC, SC	1654	1644	1.01
17	FL	3558	3436	1.04
18	AL, KY, MS	1813	1832	0.99
19	TN	1517	1576	0.96
20	AR, LA, OK	2266	2392	0.95
21	TX	2841	2908	0.98
22	CO	352	345	1.02
23	ID, MT, UT, WY	575	533	1.08
24	AZ	3171	3130	1.01
25	NV, NM	1753	1740	1.01
26	CA	923	837	1.10
27	OR, WA	235	227	1.04
28	AK	NA	NA	1.04
29	HI	NA	NA	1.10

Note: Data for Alaska and Hawaii was not available. The region 27 adjustment factor was used for Alaska, while region 26 adjustment factor was used for Hawaii.

DOE is calculating multi-stage cooling the same way as single-stage equipment (i.e., at the highest cooling mode only) and therefore used the same number of operating hours, since:

1) Multi-stage heating is not necessarily associated with multi-stage cooling equipment (e.g. multi-stage cooling is much less common than multi-stage furnace equipment); and
2) SEER already captures cases when multi-stage heating and cooling equipment are matched.

For households in which it is clear that the electricity use for cooling is associated solely with the use of central air conditioning equipment, DOE used the annual electricity consumption for cooling the household from RECS 2005. DOE adjusted the house cooling load for households that used both a central air conditioner and a room air conditioner. RECS 2005 reports the percentage of cooling energy consumption attributable to room air conditioners. DOE derived the house cooling load applicable to the central air conditioner by subtracting the estimated amount of cooling provided by the other cooling system.

7-F.2.1.2 Existing Space-Cooling Efficiency ($SEER_{ex}$)

To estimate annual space-cooling energy consumption data at the baseline and higher efficiency levels, DOE relies on the cooling and heating energy calculated for the stock households and the historic space-cooling efficiency levels of the stock equipment, $SEER_{res\_stock}$. The space-cooling efficiency of stock equipment is related to the vintage of the equipment. In the 2005 RECS database, the age of the equipment is reported in terms of age groups and not the specific vintage year. The five age groups are “less than 2 years old,” “2 to 4 years old,” “5 to 9 years old,” “10 to 19 years old,” and “20 years or older.” The data also include one additional age category: “as old as the home.” In RECS the years of construction of each residence for older homes are also reported in age bands, though the specific year of construction is indicated for the newer homes. DOE assumed that the age of the central air conditioner system, within a given age group in the general population, would be approximately uniformly distributed throughout the range of the age band. For example, for the central air conditioner systems in the “less than 2 years old” age group, it was assumed that 50 percent of heat pumps were 1 year old and the other 50 percent were 2 years old. A similar technique was used in ascertaining the probable vintage year of the home and the equipment when the equipment was reported to be the age of the home. The resulting age distribution of the central air conditioners and central heat pumps in the RECS households identified for analysis is listed in the table below

Table 7-F.2.2 Number of Observations for Each Age Group

Equipment Type	Less than 2 Years Old	2 to 4 Years Old	5 to 9 Years Old	10 to 19 Years Old	20 Years or Older	Total
Central Air Conditioners	243	321	472	502	316	1854
	13.1%	17.3%	25.5%	27.1%	17.0%	100%
Cooling-Performance Heat Pump	57	61	104	89	28	339
	16.8%	18.0%	30.7%	26.3%	8.3%	100%

Once the age group into which the household equipment falls was established, DOE estimated the vintage of the equipment for each household in each age group by random assignment using the uniform age distribution assumption for each age group and the known 2005 survey year. For the 20-year and older age group, all equipment was assumed to be between 20 and 29 years old with the actual vintage assigned using a uniform distribution. The resulting vintage distribution of the residential air conditioners and heat pumps in the overall sample is shown in the table below.

DOE estimated the stock cooling SEER for each household using equipment vintage and average shipped efficiency for each vintage year. The latter was developed from AHRI data[3] and is shown in the table below.

Table 7-F.2.3 Average Annual Shipped Space-Cooling Efficiency

Year	Central A/C *SEER*
1976	7.15
1977	7.18
1978	7.41
1979	7.45
1980	7.51
1981	7.73
1982	8.30
1983	8.44
1984	8.70
1985	8.84
1986	8.87
1987	8.95
1988	9.11
1989	9.23
1990	9.25
1991	9.44
1992	10.43
1993	10.52
1994	10.58
1995	10.64
1996	10.63
1997	10.62
1998	10.23
1999	10.86
2000	10.95
2001	11.07
2002	11.07
2003	11.22
2004	11.32
2005	11.33

7-F.2.2 Determination of Power Consumption of non-Furnace Fan Components of the Central Air Conditioner

DOE determined the power consumption of all non-furnace fan components of the central air conditioner as follows.

$$Powerofnon_{FanComponents} = (\frac{CoolingCapacity}{SEER} - \frac{365}{1000} * CFM)$$

Where:

$\frac{365}{1000} * CFM$ = default central air conditioner blower output, watts,

CFM = nominal cooling load CFM measured at 400 CFM per AC ton, cfm (see Table 7-F.2.4 labeled airflow rating),

SEER = SEER of central air conditioner in 2018, Btu/h/W, and

CoolingCapacity = cooling capacity of air conditioner, Btu/h (see Table 7-F.2.4).

7-F.2.2.1 Cooling CFM and Cooling Capacity of 0the Central Air Conditioner in 2018

As described in appendix 7-E (section 7-E.6.2), DOE determined the distribution of airflow for furnaces based on shipments of central air conditioner equipment by cooling capacity. Table 7-F.2.4 shows the distribution of cooling capacity bins that match to cooling airflow based on 12,000 Btu/h for every 400 CFM.

Table 7-F.2.4 Distribution of Airflow for Furnaces

Airflow Rating *cfm*	Cooling Capacity *btu/h*	2007-2011 AHRI Shipments %	Cumulative Fraction %
600	18,000	9.5	9.5
800	24,000	19.6	29.1
1000	30,000	16.5	45.6
1200	36,000	22.5	68.0
1400	42,000	8.7	76.8
1600	48,000	12.5	89.2
2000	60,000	10.8	100.0

7-F.2.2.2 Central Air Conditioner SEER in 2018

DOE used the SEER efficiency distributions developed in the 2011 Central Air Conditioning, Heat Pump, and Furnace Final Rule,[4] as well as central air conditioner standards that will take effect before 2018. Table 7-F.2.5shows the distribution of SEER used in the analysis. DOE assumed that all central air conditioners with SEER levels above 15 SEER are associated with ECM furnace fan design option only.

Table 7-F.2.5 Distribution of SEER in 2018 by CAC Region and CAC Type

North				South			
Coil Only		Blower Coil		Coil Only		Blower Coil	
SEER	***Frac.***	***SEER***	***Frac.***	***SEER***	***Frac.***	***SEER***	***Frac.***
13	24.6%	13	18.5%	14	76.9%	14	57.7%
13.5	48.2%	13.5	36.2%	14.5	7.4%	14.5	5.6%
14	4.1%	14	3.1%	15	5.9%	15	4.4%
14.5	7.4%	14.5	5.6%	15.5	2.1%	15.5	1.5%
15	5.9%	15	4.4%	16	7.2%	16	5.4%
15.5	2.1%	15.5	1.5%	16.5	0.5%	16.5	0.4%
16	7.2%	16	5.4%			17	10.0%
16.5	0.5%	16.5	0.4%			18	7.0%
		17	10.0%			19	3.0%
		18	7.0%			20	2.0%
		19	3.0%			21	2.0%
		20	2.0%			22	1.0%
		21	2.0%				
		22	1.0%				

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