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Discussion of PJM Forecasting Model – Efficiency Index

Prepared for the PJM Load Forecasting Group

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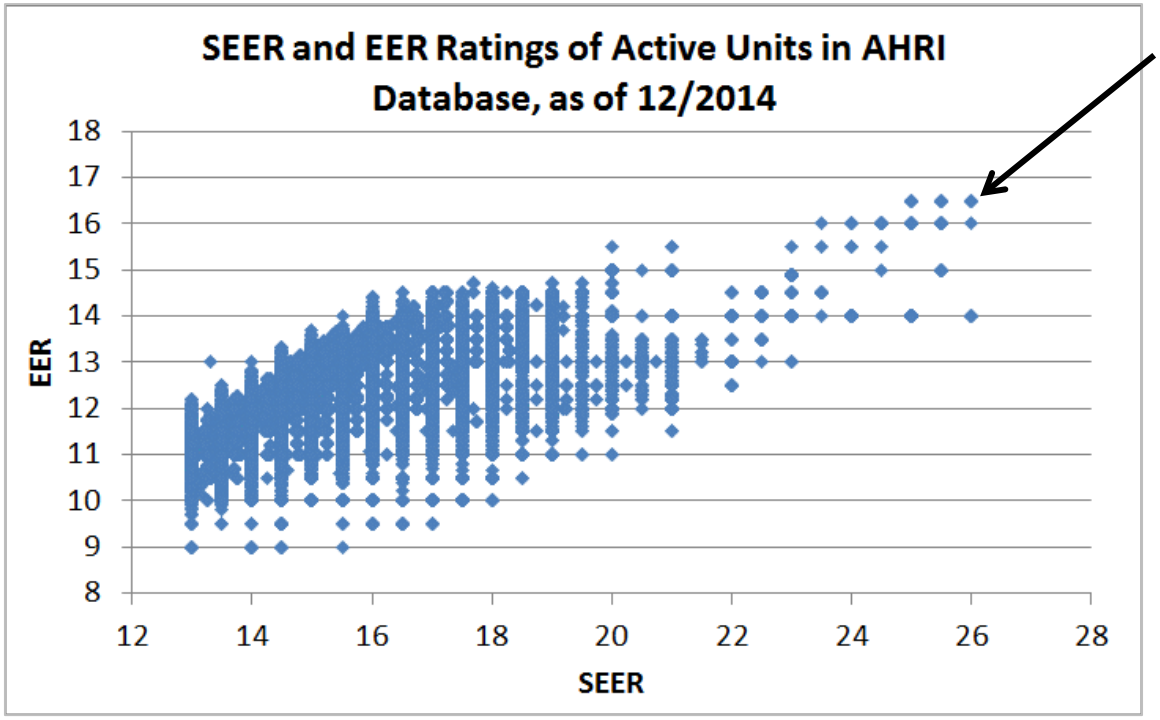
Issue: SEER Forecasts Underestimate Peak Demand

- PJM bases its cooling demand forecast on projected efficiency improvements for different equipment classes.
- For residential AC and heat pumps (HP), PJM uses efficiency indexes based on seasonal energy efficiency ratio (SEER).
- SEER is not the ideal metric for forecasting capacity needs, since it is calculated using full-load and part-load test conditions.
- Forecasts based on SEER may overestimate the impact that efficiency improvements have on peak demand.
- The energy efficiency ratio (EER) is more appropriate for capacity forecasts, since it measures equipment running at full load.
- Correlations show that large improvements in SEER correlate with only moderate improvements in EER.

Illustration of SEER-EER Relationship



Points represent the SEER and EER ratings of individual AC systems in the AHRI database of certified products.

Note each metric's range:
SEER: 13.0 to 26.0,
100% above lowest
EER: 9.0 to 16.5,
83% above lowest

- There is no direct relationship between SEER and EER.
- AC and HP manufacturers can increase SEER in ways that do not increase EER, such as advanced motors, compressors, and controls.

Source: Plot shows all residential split system AC records listed in the 2014 AHRI Database of Certified Product Performance, at https://www.ahridirectory.org/ahridirectory/pages/ac/defaultSearch.aspx

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Conversion of Projections from SEER to EER

- The average EER of a set of equipment can be estimated from the average SEER using past correlations of equipment databases.
  - A combination of old and new data sets is appropriate since DOE promulgated standards in 2006 that raised the mandatory minimum standard.
  - At 10-13 SEER, we used Median EER ratings reported in the 2002 DOE rule for residential central ACs.*
    At 13.0 SEER and higher, we observed an EER-SEER correlation from AHRI database circa 12/2014.**
- Navigant estimated how average EER changes over time at the regional level using Itron forecasts.

* Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (2002). Technical Support Document to Energy Conservation Standards for Central Air Conditioners and Heat Pumps (Docket No. EERE-2006-STD-0089). Chapter 4 Engineering Analysis, Table 4.27. Available online at: http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0089-0371

** Source: Independent export and analysis of publicly-available residential central AC records listed in the AHRI Database of Certified Product Performance as of January, 2014, at: https://www.ahridirectory.org/ahridirectory/pages/ac/defaultSearch.aspx

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Application of EER-based Indices to Residential CAC

- PJM calculates the residential cooling index and the total cooling index relative to a 1998 base year.
- Increases in saturation make the index go up and increases in average stock efficiency make the index go down.
- At the national and regional levels, Itron forecasts that saturation and efficiency will go up over time for residential ACs and HPs.
- Example Residential Cooling Index from East North Central region:

Basis	1998	2000	2005	2010	2015	2020	2025
SEER	1.00	0.99	0.97	0.93	0.93	0.92	0.93
EER	1.00	1.00	0.98	0.96	0.97	0.97	0.98

- The EER-based capacity index forecasts a lesser impact from efficiency gains compared to the SEER-based efficiency index.

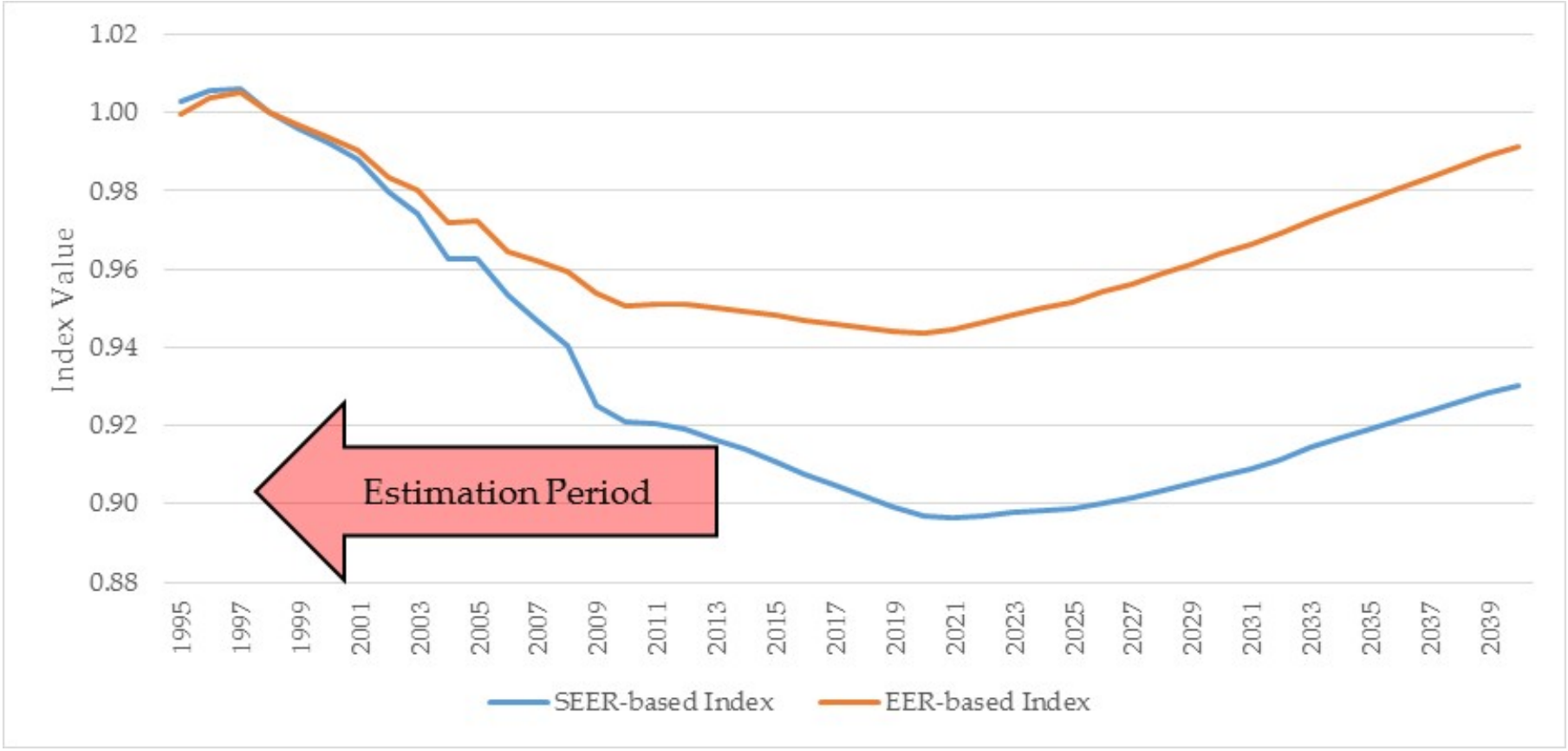
The Effect on PJM's Total Cooling Index

- The SEER vs. EER discussion pertains only to residential indices. PJM calculates commercial indices based on EER.
- PJM uses weighted average to combine residential and commercial into a "Total Cooling Index."
- The SEER vs. EER effect is dampened somewhat at the Total Cooling Index level.
- For Total Cooling Index, relative to 1.0 in the base year of 1998:

Year	East South Central		East North Central		Middle Atlantic		South Atlantic		National	
Basis:	**SEER**	**EER**	**SEER**	**EER**	**SEER**	**EER**	**SEER**	**EER**	**SEER**	**EER**
2010	0.91	0.95	0.93	0.96	0.95	0.97	0.88	0.91	0.92	0.95
2015	0.92	0.96	0.93	0.97	0.94	0.98	0.85	0.89	0.93	0.97
2020	0.91	0.97	0.92	0.97	0.94	0.98	0.81	0.87	0.92	0.97

The Effect on PJM's Total Cooling Index (Continued)

» Graphical comparison of load-weighted average Total Cooling Index (SEER-based vs. EER-based).



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Conclusions & Recommendations

- Previously, PJM has demonstrated that the forecast is highly sensitive to the efficiency index (PJM forecast changes update of 2015-05-27) – small changes to this index can have a material impact on forecast accuracy.
- Using an EER-based efficiency index more accurately reflects equipment performance under weather conditions coincident with system peaks.
- Converting the residential cooling efficiency index to an EER-based index will bring it in line with the commercial efficiency index that is already EER-based.
- All the data required to calculate an EER-based index are publically available .
- We believe that conversion to an EER-based residential efficiency index will more accurately capture the underlying drivers of demand, and recommend that PJM explore replacing the current SEER-based index.


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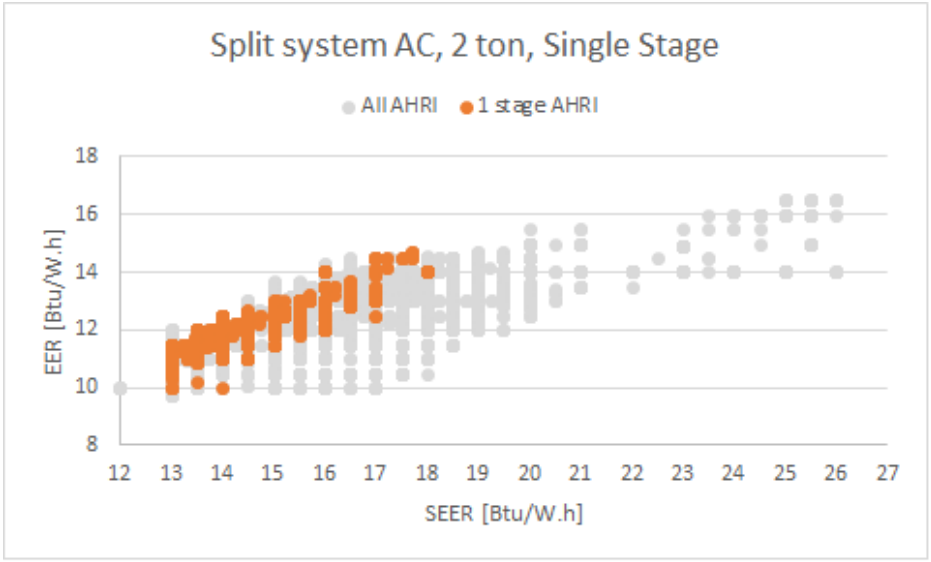
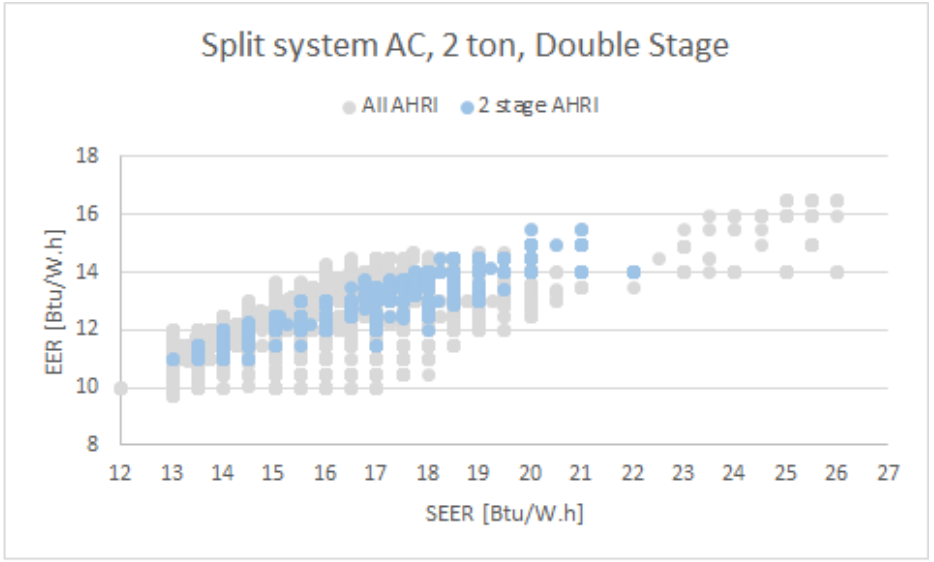
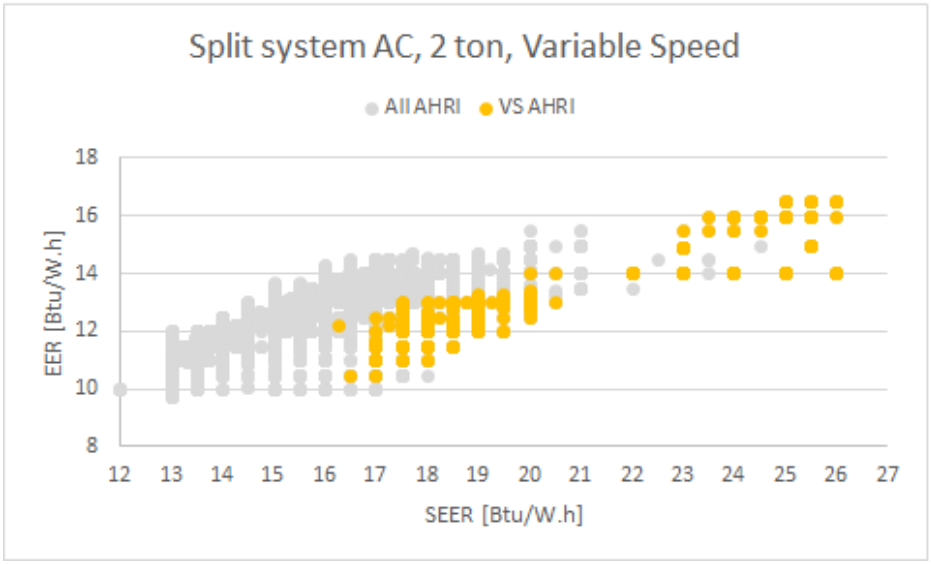
Implications for PJM's Total Heating Index

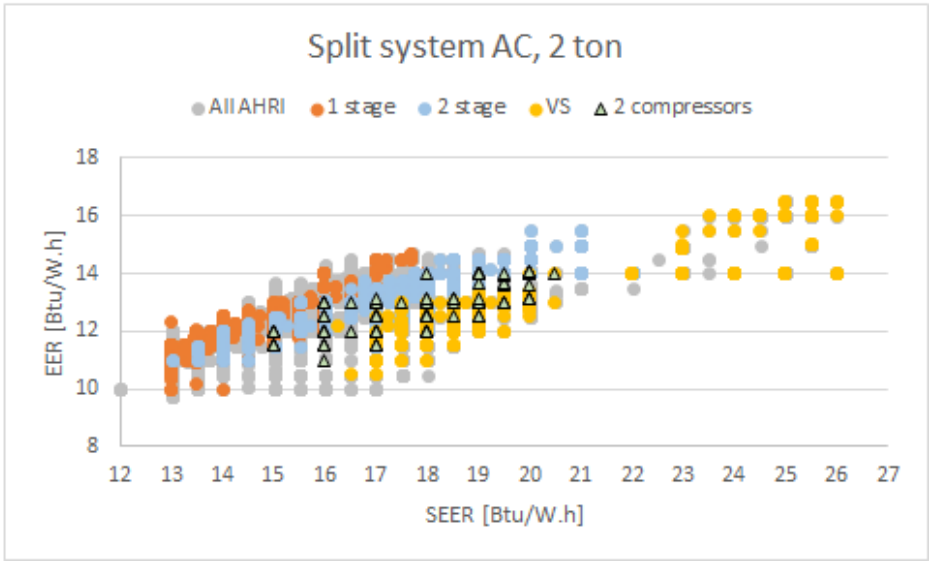
- Similar effects could exist in the Total Heating Index, since the residential heating efficiency metric is the heating seasonal performance factor (HSPF).
- Like SEER, the HSPF metric accounts for part-load operation and does not accurately represent efficiencies at peak demand.
- This could be treated similar to the SEER-EER issue, with a correlation of HSPF to the coefficient of performance (COP) at full-load, and a recalculation of key indices.
- We expect this to have little effect on summer peak loads, since heating equipment is infrequently used at summer peaks.
- We expect the effects on Total Heating Index to be less than the effects on Total Cooling Index, since a smaller proportion of heating equipment is electric powered (compared to cooling equipment).

Backup Slide: AC Models by Compressor Technology

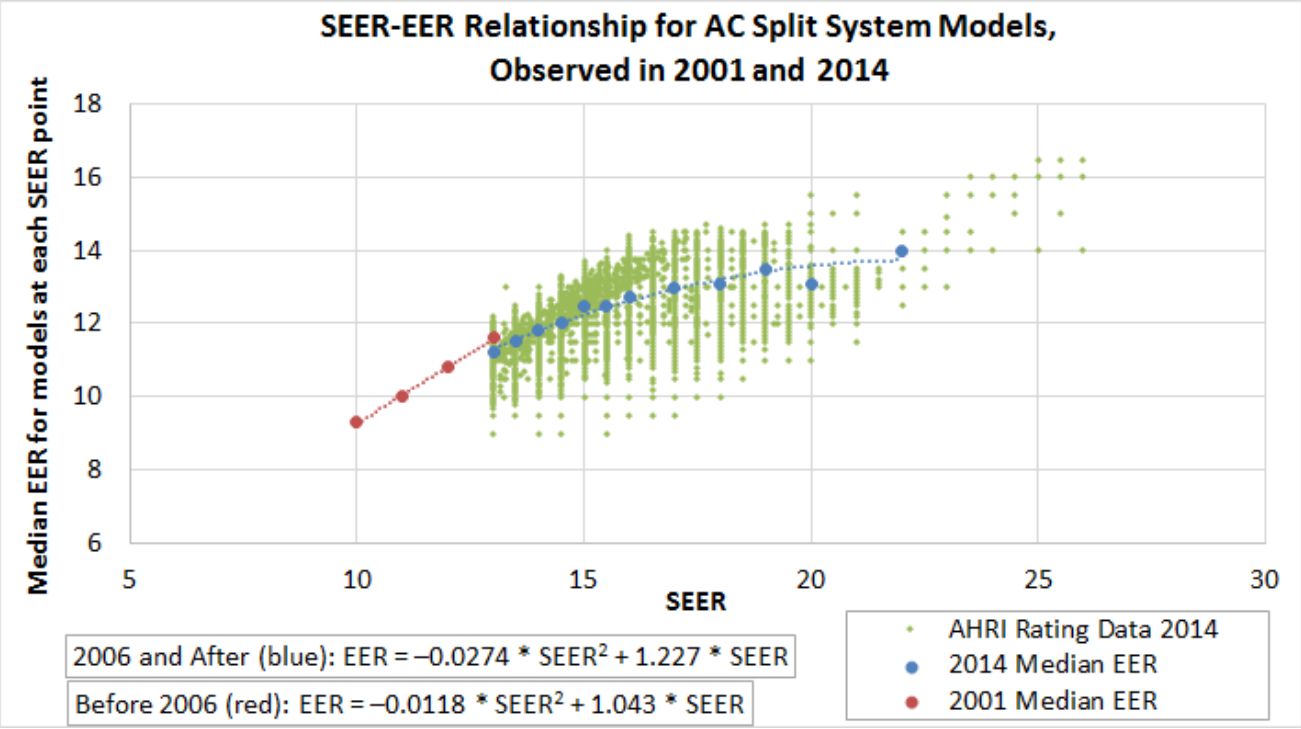








Correlation of SEER and EER



In 2006, the federally mandated minimum efficiency increased to 13 SEER. This rule prompted major equipment re-designs.

Two correlations are used here, based on data snapshots before and after January 2006.

- Median EER ratings at levels of 10.0 – 13.0 SEER (red series above) are reported in the 2001 DOE rule for residential central ACs.
- Median EER ratings at 13.0 SEER and higher (blue series above) are observed from AHRI database circa 12/2014.

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Backup: SEER and EER Calculation

$$SEER = \frac{\sum_{j=1}^{8} q_c(T_j)}{\sum_{j=1}^{8} e_c(T_j)} \qquad EER = \frac{q_c(95)}{e_c(95)}$$

- $Q_c(T_j)$ = the total space cooling provided during periods of the space cooling season when the outdoor temperature fell within the range represented by bin temperature T_j.
- $E_c(T_j)$ = electrical energy consumed by the test unit during periods of the space cooling season when the outdoor temperature fell within the range represented by bin temperature T_j.
- T_j = the outdoor bin temperature, °F. Outdoor temperatures are grouped or "binned." Use bins of 5 °F with the 8 cooling season bin temperatures being 67, 72, 77, 82, 87, 92, 97, and 102 °F.

Source: 10 CFR 430, appendix M, section 4.1