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DRAFT

METHODOLOGY FOR CALCULATING COOLING AND HEATING ENERGY-INPUT-RATIO (EIR) FROM THE RATED SEASONAL PERFORMANCE EFFICIENCY (SEER OR HSPF)

A Project for
Texas' Senate Bill 5 Legislation
For Reducing Pollution in
Nonattainment and Affected Areas

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EXECUTIVE SUMMARY

This report provides the recommendations to calculate cooling and heating energy-input-ratio (EIR) for DOE-2 simulations excluding indoor fan energy, from the rated cooling and heating seasonal performance efficiency (i.e., SEER or HSPF) that does include indoor fan energy[1] to resolve the following two issues.

Issue 1: SEER/HSPF to COP Conversion

- For units less than 65,000 Btu/hr, the system efficiency is rated using the seasonal performance ratings such as Seasonal Energy Efficiency Ratio (SEER) for cooling and Heating Seasonal Performance Factor (HSPF) for heat pump heating, which cannot be directly used in the simulations. For a simulation input, a SEER or a HSPF rating needs to be converted to COP_{95} (i.e., Energy Efficiency Ratio (EER)/3.412) or COP_{47}, respectively, which is the steady-state efficiency at certain test conditions specified in the ANSI/AHRI Standard 210/240-2008 (AHRI 2008).

Issue 2: Fan Energy Removal

- The system efficiency ratings currently available (i.e., SEER, EER, or HSPF) are based on net cooling or heating capacity (i.e., total cooling capacity less supply fan heat for cooling; and total heating capacity plus supply fan heat for heating) and total electric input (i.e., compressor plus outdoor and indoor fans). However, for a simulation input, supply fan energy should be excluded from the ratings to separately model indoor fan in the simulations.

To resolve the two issues identified, this report reviewed the existing methodologies proposed by the Florida Solar Energy Center (FSEC) (Fairey et al. 2004) as well as by the ASHRAE RP-1197 (Brandemuehl and Wassmer 2009). A comparison was made against the two datasets recently downloaded from the California Energy Commission (CEC) database (CEC 2012) and the 2012 Air-Conditioning, Heating, and Refrigeration Institute (AHRI, formally known as ARI) directory (AHRI 2012). The major findings and recommendations on each issue are as follows:

Issue 1: SEER/HSPF to COP Conversion

- It was found that the two methods agree with each other in low SEER (i.e., < SEER 14) and low HSPF (i.e., < 7.7 HSPF) ranges. Unfortunately, they do not agree anymore in high SEER/HSPF ranges. This is because the datasets used in both methods mainly consist of the units lower than SEER 13 for cooling or HSPF 7.7 for heat pump heating, which does not adequately reflect the units currently available in the market[2]. Therefore, the two new regression models that correlate the rated EER and COP_{47} against the rated SEER and HSPF, respectively, were developed using the selected dataset downloaded from the 2012 AHRI directory (N=18,664) for cooling and the dataset downloaded from the 2012 CEC database (N=11,842) for heating. Based on a quartile range analysis on binned data into 1.0 SEER and 0.3 HSPF, it was found that a second-order polynomial fit

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[1] The EIR is defined in DOE-2 to be the ratio of the electric energy input (Btu/hr) to the rated capacity (Btu/hr) of the unit (i.e., reciprocal of COP) at the Air-Conditioning, Heating, and Refrigeration Institute (AHRI, formally known as ARI) rated condition. In DOE-2, the indoor fan energy should be excluded to determine the EIR, to separately model indoor fan in the simulations.

[2] Most of the units have SEER ratings lower than 13 or HSPF ratings lower than 7.7. Those units are not available in the market anymore since the National Appliance Energy Conservation Act (NAECA) provision on SEER 13/HSPF 7.7 became effective on January 23, 2006.

(i.e., a quadratic equation) with the Y intercept forced to be zero represents the data well, and generally, the data are condensed in a quartile range.

Issue 2: Fan Energy Removal

- A review of the existing methods revealed that both FSEC and ASHRAE RP-1197 methods have limitations such that the FSEC's 0.365 Watt per CFM assumption[3] may not be appropriate for the units currently available on the market (i.e., ≥ SEER 13); and that a linear extrapolation error was expected with the ASHRAE RP-1197 approach[4]. Therefore, a new regression model that correlates supply fan power at the AHRI rating conditions against the rated SEER was calculated using the surveyed fan performance dataset consisting of 339 data points. It was found that a 3-parameter (3-P) change-point model best fits the surveyed dataset based on a quartile analysis.

Finally, new models, which directly convert the rated cooling and heating seasonal efficiency to the steady-state efficiency that does not include supply fan energy, were developed using the dataset downloaded from the 2012 AHRI directory and the 2012 CEC database after excluding supply fan energy using the 3-P model developed in this study. The proposed models fit the data well based on the results of a quartile analysis. However, the use of a second-order polynomial fit (i.e., a quadratic equation) yields a decreasing COP_{95_nf} when the SEER is higher than 25 and a decreasing COP_{47_nf} when the HSPF is higher than 11.8. Thus, corrections were made on the final model fits by forcing the calculated COP_{95_nf} for high SEER over 25 to be a constant value of 4.74, which is the peak COP_{95_nf} at SEER 25; and by forcing the calculated COP_{47_nf} for high HSPF over 11.8 to be a constant value of 4.30, which is the peak COP_{47_nf} at HSPF 11.8, as shown in Equations (1) and (2) for cooling and heating, respectively[5].

$$\begin{array}{ll} \text{If SEER} \leq 25.0, & COP_{95\_nf} = -0.0076 \times SEER^2 + 0.3796 \times SEER;\ \text{and} \\ \text{if SEER} > 25.0, & COP_{95\_nf} = 4.74 \end{array} \quad (1)$$

$$\begin{array}{ll} \text{If HSPF} \leq 11.8, & COP_{47\_nf} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF;\ \text{and} \\ \text{if HSPF} > 11.8, & COP_{47\_nf} = 4.30 \end{array} \quad (2)$$

In an analysis that examined the impact of the new models on energy simulation results using a 2009 IECC code-compliant, 2,500 square foot house with air conditioners of five different SEER ratings (i.e., SEER 13, 15, 17, 19, and 21) and heat pump units of five different HSPF ratings (i.e., HSPF 7.7, 8.3, 8.9, 9.5, and 10.1), it was found that the use of different EIR calculation models affects the cooling and heating energy use of a house. The percent difference in the cooling energy use against the proposed model varied between -29.2% and -9.6% (Houston) and between-29.9% and -10.0% (Dallas) with the FSEC method; and between -5.4% and 0.0% (Houston) and between -5.3% and 0.0% (Dallas) with the ASHRAE RP-1197 method. The percent difference in the heating energy use against the proposed model varied between -13.7% and -2.5% (Houston) and between -13.7% and -2.7% (Dallas) with the FSEC method; and between 3.8% and 5.5% (Houston) and between 4.5% and 5.9% (Dallas) with the ASHRAE RP-1197 method.

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[3] The FSEC assumes 0.365 W/CFM in the calculations, which is the AHRI default value for the units tested without indoor fans (AHRI 2008).

[4] The ASHRAE RP-1197 proposed a formula by correlating indoor fan power against the rated SEER using one manufacturer's set of rating data: Fan Power (Watt/1,000 CFM) = -30.4 × SEER + 686.1. The estimated fan power approaches zero as the SEER approaches 22.5 SEER.

[5] Future modifications would be desirable to a constant COP_{95_nf} and COP_{47_nf} assumptions with a reasonably large number of data points for high efficiency units.

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1 INTRODUCTION

The energy-input-ratio (EIR) is defined in DOE-2 to be the ratio of the electric energy input (Btu/hr) to the rated capacity (Btu/hr) of the unit (i.e., reciprocal of COP) at the Air-Conditioning, Heating, and Refrigeration Institute (AHRI, formally known as ARI) rated condition. In DOE-2, the indoor fan energy should be excluded to determine the EIR, to separately model indoor fan in the simulations. Unfortunately, the following two issues were identified to calculate the EIR for DOE-2 simulations that does not include indoor fan energy.

Issue 1: SEER/HSPF to COP Conversion

- For units less than 65,000 Btu/hr, the system efficiency is rated using the seasonal performance ratings such as Seasonal Energy Efficiency Ratio (SEER) for cooling and Heating Seasonal Performance Factor (HSPF) for heat pump heating, which cannot be directly used in the simulations. For a simulation input, a SEER or a HSPF rating needs to be converted to COP_{95} (i.e., Energy Efficiency Ratio (EER)/3.412) or COP_{47}, respectively, which is the steady-state efficiency at certain test conditions specified in the ANSI/AHRI Standard 210/240-2008 (AHRI 2008).

Issue 2: Fan Energy Removal

- The system efficiency ratings currently available (i.e., SEER, EER, or HSPF) are based on net cooling or heating capacity (i.e., total cooling capacity less supply fan heat for cooling; and total heating capacity plus supply fan heat for heating) and total electric input (i.e., compressor plus outdoor and indoor fans). However, for a simulation input, supply fan energy should be excluded from the ratings to separately model indoor fan in the simulations. Unfortunately, the current rating procedure does not require quantifying or specifying the actual amounts of indoor fan energy during the rating conditions. Thus, a reliable method of how to exclude supply fan energy at the rating conditions from the currently available system efficiency ratings is necessary.

To resolve the two issues identified, this report reviewed the existing methodologies proposed by the Florida Solar Energy Center (FSEC) (Fairey et al. 2004) as well as by the ASHRAE RP-1197 (Brandemuehl and Wassmer 2009). An additional comparison was also performed against the two datasets recently downloaded from the California Energy Commission (CEC) database (CEC 2012) and the AHRI directory (AHRI 2012) as well as the fan performance data collected from several manufacturers. Finally, new models were developed to directly convert the rated cooling and heating seasonal efficiency to the steady-state efficiency that does not include supply fan energy to be used in the simulations.

1.1 Organization of the Report

The report is organized in the following order:

- Section 1 presents the introduction and purpose of the report.
- Section 2 reviews the two existing methods proposed by the FSEC and the ASHRAE RP-1197.
- Section 3 gives recommendations to resolve the issues identified from a comparison of the two existing methods against the CEC database and the AHRI directory.
- Section 4 provides the final model developed to calculate the EIR for DOE-2 simulations with excluding indoor fan energy, directly from the rated SEER and HSPF ratings.
- Section 5 examines the impact of the new models on energy simulation results.
- Section 6 is a summary which is followed by references.

2 REVIEW OF THE EXISTING METHODS

This Section provides a review of the two existing methods proposed by the Florida Solar Energy Center (FSEC) (Fairey et al. 2004) in Section 2.1 and the ASHRAE RP-1197 (Brandemuehl and Wassmer 2009) in Section 2.2.

2.1 Method Proposed by the FSEC

The FSEC proposed SEER to COP_{95_nf} (i.e., $COP_{95\_no\ fan}$, which excludes supply fan energy) and HSPF to COP_{47_nf} (i.e., $COP_{47\_no\ fan}$, which excludes supply fan energy) conversion formulas with the AHRI default fan power (0.365 Watt per CFM) removed based on an assumed airflow of 400 CFM/ton. These formulas are currently referenced in the Residential Energy Services Network (RESNET) verification procedures - RESNET Publication No. 07-003 (RESNET 2007). The software programs should use these formulas to be RESNET-accredited International Energy Conservation Code (IECC) performance verification software such as the FSEC's EnergyGauge USA v.2.8 (FSEC 2012) and the Energy Systems Laboratory's (ESL) International Code Compliance Calculator (IC3) v.3.10.3 (ESL 2012).

The formulas were developed using the CEC database for over 9,600 air conditioners for cooling and over 5,500 heat pumps for heating that were manufactured between 1991 and 2002. Using a simple linear regression model with the Y intercept forced to be zero, the conversion formulas were calculated as Equations (3) and (4) for cooling and heating, respectively (Figures 1 and 2[6]).

$$COP_{95\_nf} = 1.063 \times SEER/3.413 \quad (3)$$

$$COP_{47\_nf} = 1.718 \times HSPF/3.413 \quad (4)$$

Where:

COP_{95_nf} = Air conditioner cooling performance efficiency in Coefficient of Performance (COP) at 95°F outdoor dry-bulb temperature which excludes supply fan energy at the AHRI rating conditions

COP_{47_nf} = Heat pump heating performance efficiency in Coefficient of Performance (COP) at 47°F outdoor dry-bulb temperature which excludes supply fan energy at the AHRI rating conditions

However, about 87% of the dataset for air conditioners and about 73% of the dataset for heat pumps consist of the units of which system efficiency are less than SEER 13 and HSPF 7.7, respectively. Those units are not available in the market anymore since the National Appliance Energy Conservation Act (NAECA) of 2006 provision became effective on January 23, 2006. High efficiency units occupy a very small portion of the dataset: less than 1% for units over SEER 15 and less than 5% for units over 8.7. Therefore, caution should be taken in the use of these models with a linear extrapolation for high efficiency units.

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[6] Figure 2 presents two different models. The FSEC model is the formula proposed in the paper (Fairey et al. 2004), and the linear model is the formula that we calculated using the data provided by the FSEC.

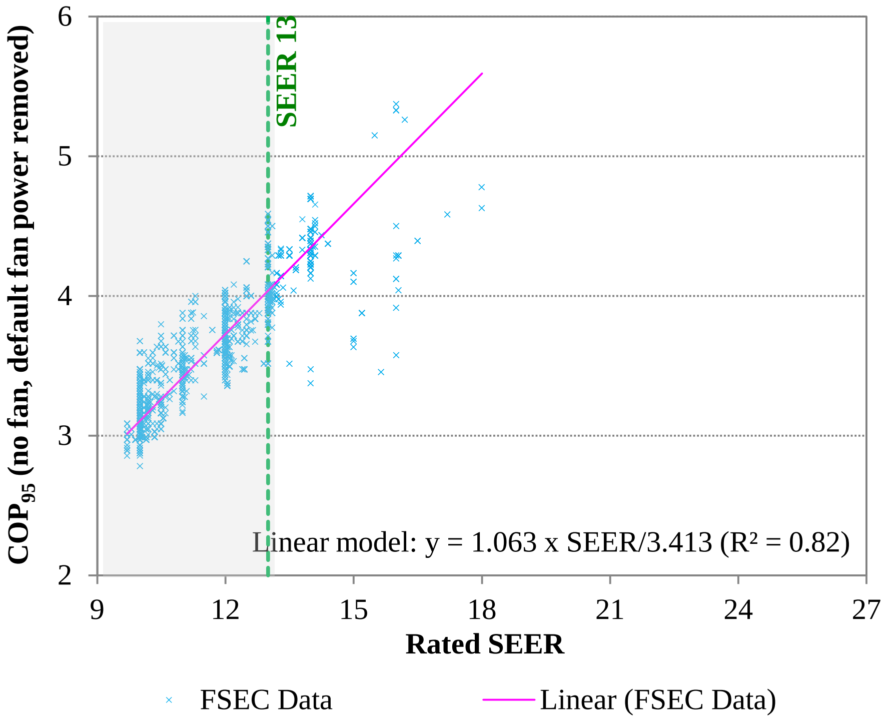

Figure 1: Plot of COP_{95} with Default Fan Power Removed versus Rated SEER

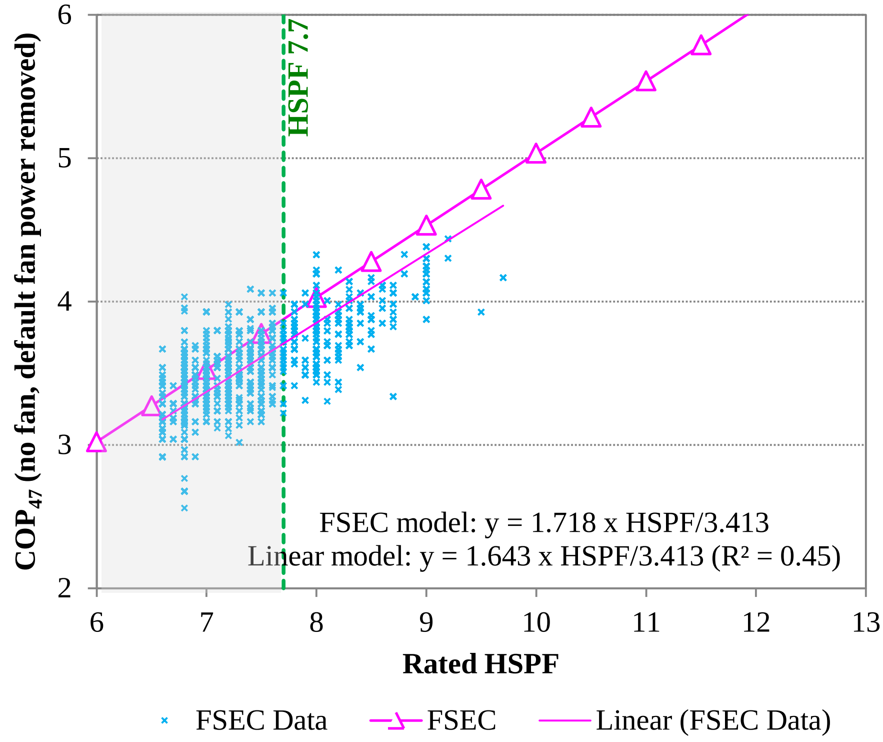

Figure 2: Plot of COP_{47} with Default Fan Power Removed versus Rated HSPF

2.2 ASHRAE RP-1197 Method

The ASHRAE RP-1197 developed SEER to EER (i.e., 3.412/Cooling EIR) and HSPF to COP_{47} conversion formulas with including supply fan energy, and then separately proposed a method to exclude supply fan energy from the calculated EER or COP_{47}. The SEER to EER conversion formula is currently referenced in the U.S. Department of Energy (DOE) Building America House Simulation Protocols (Henderson and Engebrecht 2010).

The formulas were developed using the 2002 AHRI directory of certified equipment. The conversion formulas were calculated as Equations (5) and (6) for cooling and heating, respectively (Figures 3 and 4).

$$EER = -0.0182 \times SEER^2 + 1.1088 \times SEER \qquad (5)$$
$$COP_{47} = -0.0255 \times HSPF^2 + 0.6239 \times HSPF \qquad (6)$$

Unfortunately, the same issue was found such that the dataset used in the analysis does not adequately reflect the units currently available in the market. In the figures, most of the dataset consists of the low efficiency units (≤ SEER 13 or ≤ HSPF 7.7). As mentioned above, those units are not available in the market anymore since the NAECA provision on SEER 13/HSPF 7.7 became effective on January 23, 2006. The highest SEER found in the Figure 3 was less than SEER 15. Thus, caution should be taken in the use of this formula with an extrapolation for high efficiency units.

It should be noted that the conversion formula proposed by the ASHRAE RP-1197 includes supply fan energy for both EER and COP_{47}. To exclude supply fan energy at the AHRI rating conditions from the calculated EER or COP_{47}, another formula was proposed by correlating supply fan power at the AHRI rating conditions against the SEER using a small amount of data from one manufacturer, as shown in Equation (7)[7] and Figure 5. For airflow, an actual airflow at the rating conditions was suggested to be used if the data is available; or an assumed airflow of 400 CFM/ton for air conditioners and 450 CFM/ton for heat pumps was expected to be used if the actual data is unavailable. The proposed fan power equation accounts for lower supply fan power consumption of high SEER units with an ECM motor. However, an extrapolation error was expected in the proposed linear model such that the estimated fan power approaches zero as the SEER approaches 22.5 SEER.

$$\text{Fan Power (Watt/1,000 CFM)} = -30.43 \times SEER + 686.06 \qquad (7)$$

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[7] The authors emphasized that the conversions could not be made directly from net values (i.e., rated capacity/power with fan energy) to gross values (i.e., capacity/power with excluding fan energy).

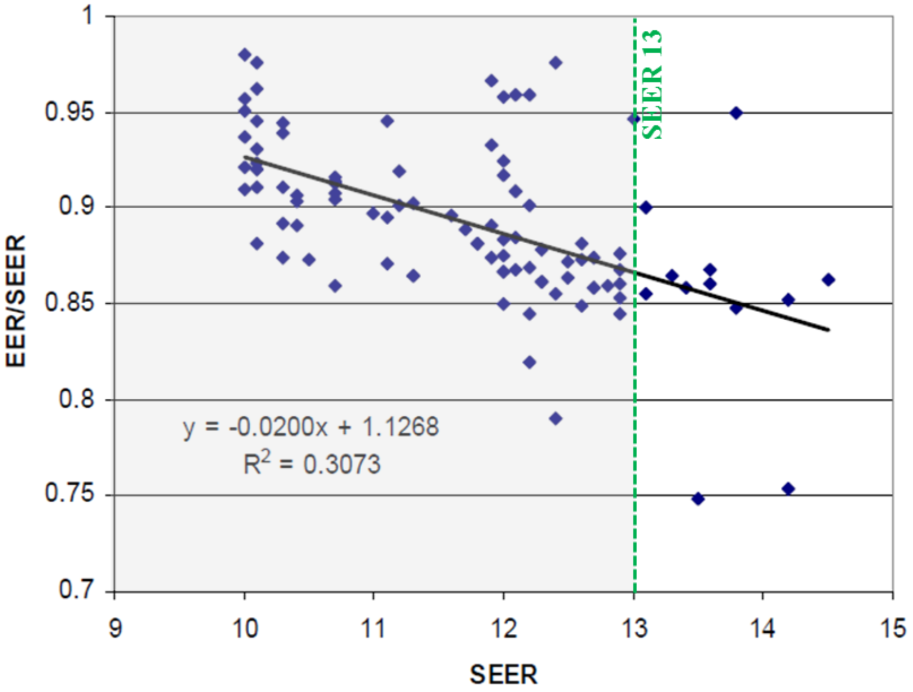

Figure 3: Plot of EER/SEER versus Rated SEER (Figure 3-3 in Brandemuehl and Wassmer 2009)

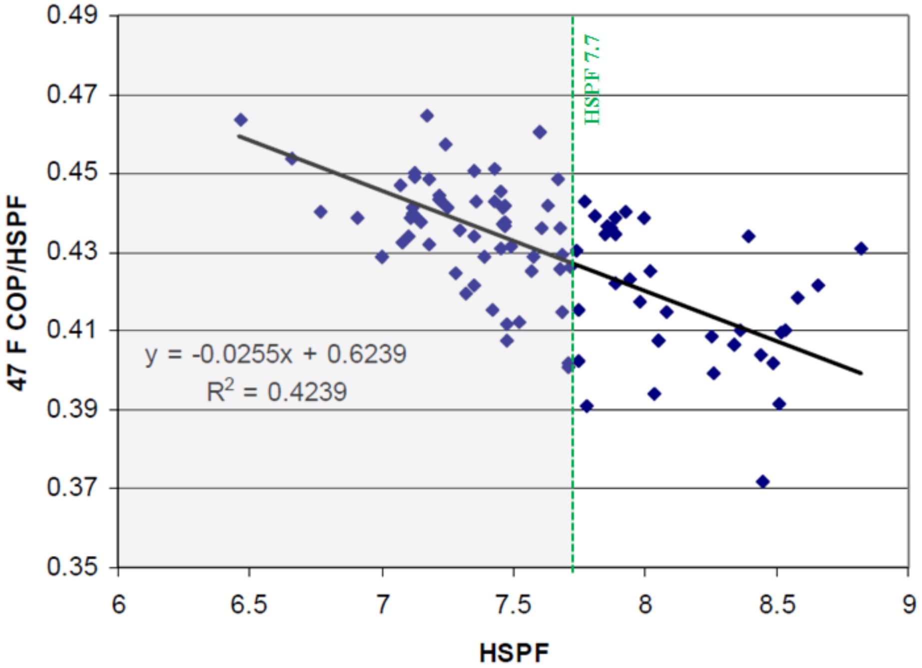

Figure 4: Plot of COP_{47}/HSPF versus Rated HSPF (Figure 3-4 in Brandemuehl and Wassmer 2009)

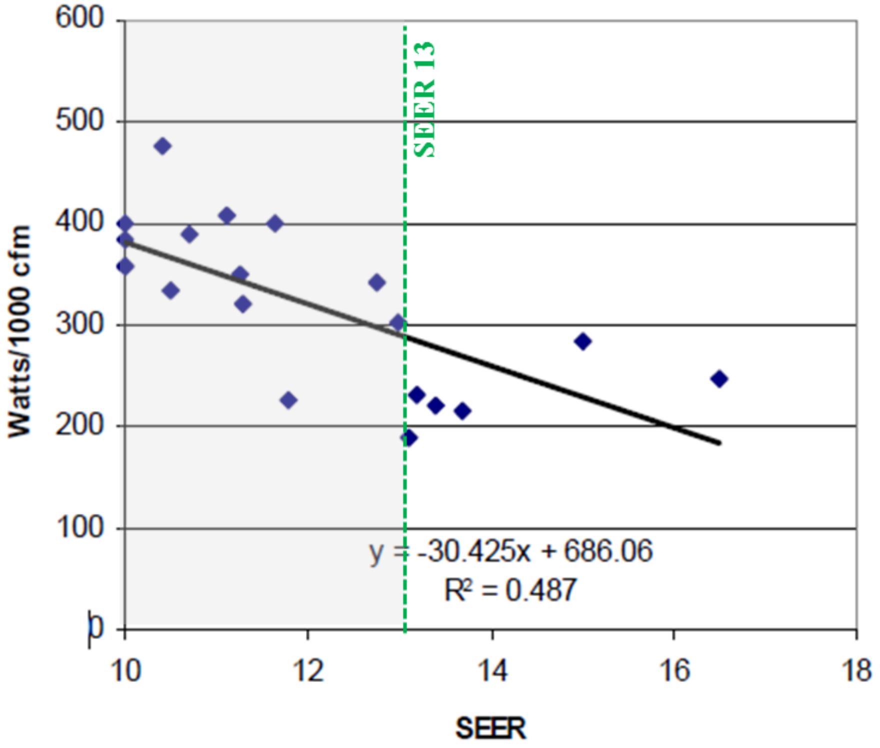

Figure 5: Plot of Fan Power (Watt per 1,000 CFM) versus Rated SEER (Figure 3-6 in Brandemuehl and Wassmer 2009)

3 RECOMMENDATIONS TO RESOLVE THE ISSUES IDENTIFIED FROM THE EXISTING METHODS

This Section provides recommendations to resolve the issues identified from a comparison of the two existing methods (i.e., FSEC and the ASHRAE RP-1197 methods) against the CEC database (CEC 2012) and the AHRI directory (AHRI 2012): *Issue 1 SEER/HSPF to COP Conversion* in Section 3.1 and *Issue 2 Fan Energy Removal* in Section 3.2. Section 3.1 presents a comparison of the two existing methods proposed by the FSEC and the ASHRAE RP-1197 against a large amount of data recently downloaded from the CEC as well as the AHRI directory to validate the extrapolation of the models. The two new regression models that correlate the rated EER and COP_{47} against the rated SEER and HSPF, respectively, were developed using the selected dataset downloaded from the 2012 AHRI directory (N=18,664) for cooling and the dataset downloaded from the 2012 CEC database (N=11,842) for heating. Section 3.2 examines the FSEC's 0.365 Watt per CFM assumption and the linear model proposed by the ASHRAE RP-1197 by comparing them against the fan performance data collected from several manufacturers (N=339). A new regression model that correlates supply fan power at the AHRI rating conditions against the rated SEER was also calculated using the surveyed fan performance dataset.

3.1 Issue 1: SEER/HSPF to COP Conversion

Figure 6 presents a plot of rated EER (i.e., including supply fan energy) versus rated SEER, which were surveyed from the two datasets (i.e., an entire dataset of the CEC database for small air-cooled air conditioners (N=14,298) and a large amount of selected data from the 2012 AHRI directory[8] (N=18,664)), with the two extrapolated models derived from the two previous studies. In this analysis, only the units of which SEER are higher than or equal to SEER 13 were considered. For the FSEC model, the AHRI default fan power (0.365 Watt per CFM) was added with an assumed airflow of 400 CFM/ton, since the FSEC model directly converts the SEER rating to COP_{95_nf}.

As a result, it was observed that the two models agree with each other in a low SEER range (<SEER 14). Unfortunately, they do not agree anymore in a high SEER range (≥SEER 14), and the discrepancy increases as the SEER increases. In a comparison against the two datasets, it was found that the use of both models would overestimate the EER, which is the rating for the unit's high temperature cooling performance at 95°F outdoor dry-bulb temperature. Therefore, a new regression model that correlates the rated EER against the rated SEER was calculated using the selected dataset downloaded from the 2012 AHRI directory, which covered a wider range of SEER ratings (i.e., higher SEER units) compared to the CEC database[9], as shown in Figure 7 and Equation (8).

$$EER = -0.0228 \times SEER^2 + 1.1522 \times SEER \qquad (8)$$

To determine the most appropriate functional form of a model, a quartile analysis was also performed on binned data into 1.0 SEER since a further inspection of data revealed that many data points significantly overlapped each other. The analysis results showed that a second-order polynomial fit (i.e., a quadratic equation) with the Y intercept forced to be zero represents the data well, and generally, the data are condensed in a quartile range. However, some exceptions were found for high SEER range over SEER 21.

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[8] As of May 2012, there is information available for 1,018,509 certified equipment (≥ SEER 13) for residential air conditioners in the AHRI directory. In this study, for the units that have higher than or equal to SEER 19, the full dataset (N=6219) was downloaded. For the units that have lower than SEER 19, approximately 1,000 units were randomly downloaded for each 0.5 SEER range.

[9] About 88% of a total of 14,298 CEC dataset for small air-cooled air conditioners consist of the units of which system efficiency is less than SEER 15.

Thus, caution should be taken in the use of this proposed model with an extrapolation for the high efficiency units (≥ SEER 21).

Figure 8 presents a plot of rated COP_{47} (i.e., including supply fan energy) versus rated HSPF, which were surveyed from an entire dataset of the CEC database for small air-source heat pump (N=11,842), with the two extrapolated models derived from the two previous studies. In this analysis, only the units of which HSPF are higher than or equal to HSPF 7.7 were considered. For the FSEC model, the AHRI default fan power (0.365 Watt per CFM) was added with an assumed airflow of 400 CFM/ton, since the FSEC model directly converts the HSPF rating to COP_{47_nf}.

As a result, it was observed that the two models agree with each other in a low HSPF range (<HSPF 7.7). Unfortunately, they do not agree anymore in a high HSPF range (≥HSPF 7.7), and the discrepancy increases as the HSPF increases. In a comparison against the CEC dataset, it was found that the use of FSEC model would overestimate the COP_{47}, while the ASHRAE RP-1197 model would underestimate the COP_{47}, which is the rating for the unit's high temperature heating performance at 47°F outdoor dry-bulb temperature. Therefore, a new regression model that correlates the rated COP_{47} against the rated HSPF was calculated using the dataset downloaded from the CEC database, as shown in Figure 9 and Equation (9).

$$COP_{47} = -0.0235 \times HSPF^2 + 0.6293 \times HSPF \tag{9}$$

To determine the most appropriate functional form of a model, a quartile analysis was also performed on binned data into 0.3 HSPF since a further inspection of data revealed that many data points significantly overlapped each other. The analysis results showed that a second-order polynomial fit (i.e., a quadratic equation) with the Y intercept forced to be zero represents the data well, and generally, the data are condensed in a quartile range. However, some exceptions were found for high HSPF range over HSPF 10. Thus, caution should be taken in the use of this proposed model with an extrapolation for the high efficiency units (≥ HSPF 10).

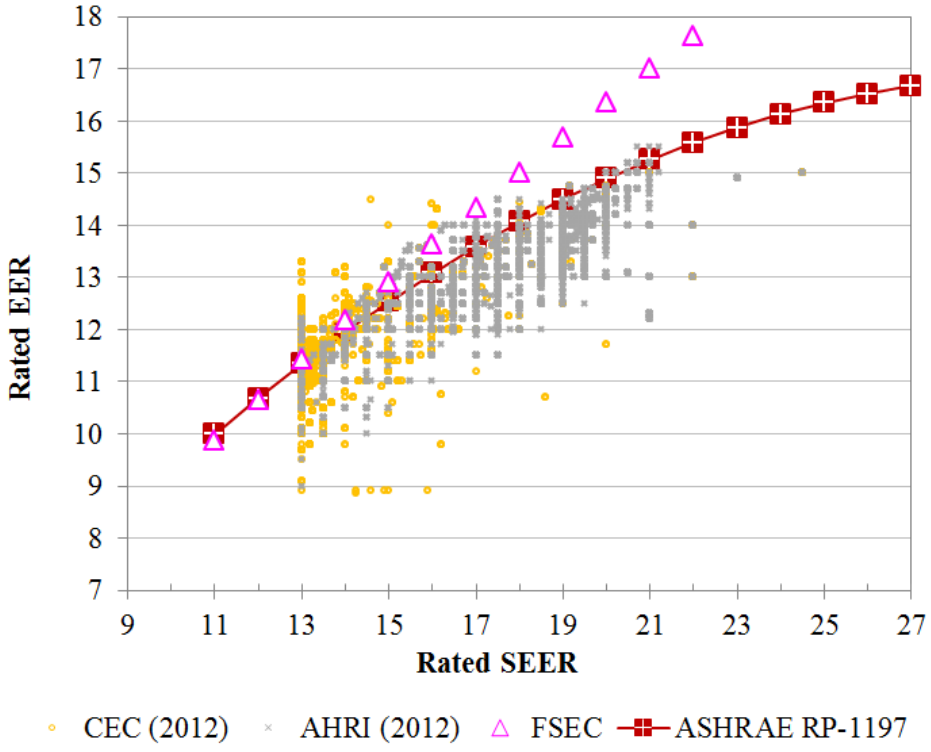


Figure 6: Plot of rated EER versus rated SEER surveyed from the CEC database and the 2012 AHRI directory with the regression models proposed by the FSEC and the ASHRAE RP-1197

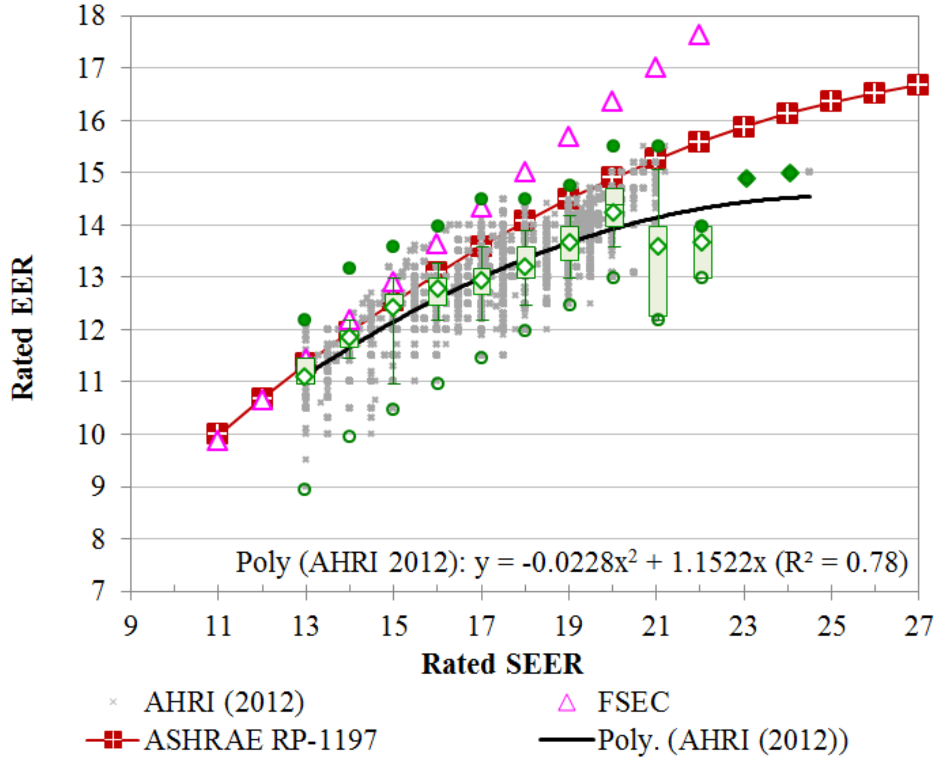


Figure 7: Proposed quadratic polynomial regression model (SEER to EER) with a quartile analysis of the 2012 AHRI dataset binned into 1.0 SEER

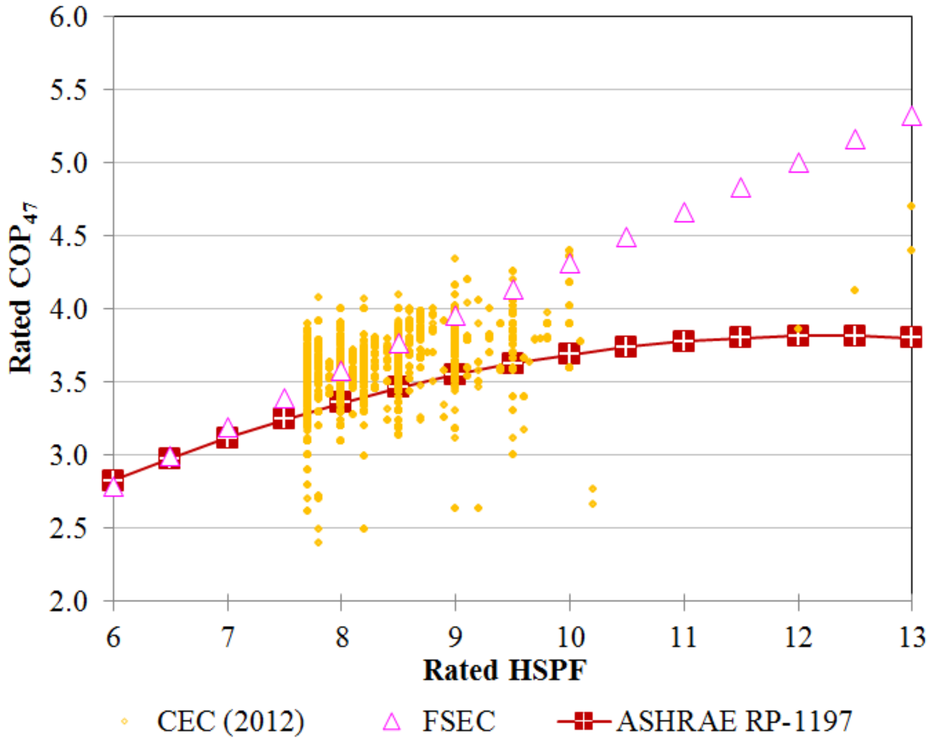


Figure 8: Plot of rated COP_{47} versus rated HSPF surveyed from the CEC database with the regression models proposed by the FSEC and the ASHRAE RP-1197

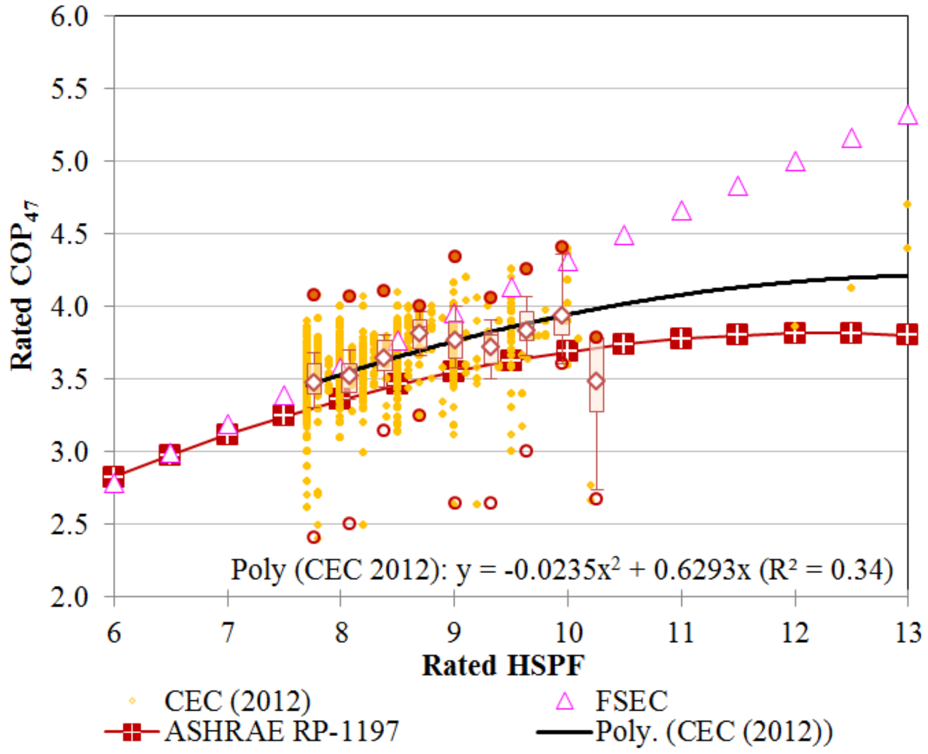


Figure 9: Proposed quadratic polynomial regression model (HSPF to COP_{47}) with a quartile analysis of the CEC dataset binned into 0.3 HSPF

3.2 Issue 2: Fan Energy Removal

A review of the existing methods revealed that both FSEC and ASHRAE RP-1197 methods have limitations such that the FSEC's 0.365 Watt per CFM assumption may not be appropriate for the units currently available on the market (i.e., ≥ SEER 13); and that a linear extrapolation error was expected with the ASHRAE RP-1197 approach. Therefore, to confirm the observed potential limitations of the existing methods, fan performance data at the AHRI rating conditions were surveyed from several manufacturers, including Trane, Rheem, Goodman Manufacturing, and Sanyo: supply fan power at the AHRI rating conditions versus rated SEER, as shown in Figure 10 (N=339).

A direct survey method was applied when the manufacturers provided actual supply fan power at the rating conditions with an actual airflow rate used. In this method, the surveyed fan power was simply divided by the surveyed airflow rate. However, this information was available only for a few units (10% of a total of 339 units surveyed). Thus for the units without information, an indirect survey method was used.

An indirect survey method was applied when the manufacturers provided supply fan power data to provide a certain amount of airflow for a given range of external static pressure for various fan speed settings if the unit had. From a large amount of data provided, to find out the actual amounts of supply fan power during the AHRI rating conditions, the ANSI/AHRI Standard 210/240-2008 (AHRI 2008) was referenced.

The ANSI/AHRI Standard 210/240-2008 presents the conditions for standard rating tests, including the minimum external static pressure for ducted systems tested with an indoor fan installed in Table 11 of the Standard 210/240-2008 as well as the maximum airflow rate allowed for rating (37.5 sCFM per 1,000 Btu/h of rated capacity) in Section 6.1.3.3 of the standard. Thus this study first calculated the maximum airflow rate and the minimum external static pressure to meet the testing requirements for each surveyed unit. An appropriate fan power value that meets the flow and pressure requirements (i.e., the value required to provide airflow that does not exceed the calculated, maximum airflow rate for an external static pressure that is equal to or greater than calculated, minimum external static pressure) was then selected.

In the figure, the use of the AHRI default fan power for the units tested without indoor fans (i.e., 0.365 Watt per CFM) was found to be inappropriate for the units currently available on the market. The use of 0.365 Watt per CFM fan power would result in higher COP_{95_nf} than the actual COP_{95_nf} calculated using the actual fan power. It was also found that a linear regression model does not well represent the dataset with a linear extrapolation error expected for very high SEER units. Therefore, a new regression model that correlates supply fan power at the AHRI rating conditions against the rated SEER was calculated using the surveyed fan performance dataset, as shown in Figure 11 and Equation (10).

$$\begin{aligned}&\text{If } 13.0 \leq \text{SEER} \leq 14.4,\ \text{Fan power (Watt/CFM)} = -0.071 \times \text{SEER} + 1.210;\\&\text{if SEER} > 14.4,\ \text{Fan power (Watt/CFM)} = 0.187\end{aligned} \tag{10}$$

Since the data points were widely spread and overlapped each other, a quartile analysis was performed on binned data into 1.0 SEER and presented together. The analysis results showed that a three-parameter (3-P) change-point model best fits the surveyed dataset. The ASHRAE Inverse Modeling Toolkit (IMT) (Kissock et al. 2004) was used to calculate the proposed model. However, caution should be taken in the use of this proposed formula with an extrapolation.

Figure 12 presents the surveyed supply fan airflow rate at the AHRI rating conditions versus rated SEER with two reference lines of 450 CFM/ton and 400 CFM/ton. A 450 CFM/ton is the maximum airflow rate allowed for rating (i.e., 37.5 sCFM/per 1,000 Btu/hr of rated capacity), and a 400 CFM/ton is the assumption used in previous studies. Based on the results of a direct survey, an assumed airflow of 400 CFM/ton was found reasonable within an acceptable degree of accuracy.

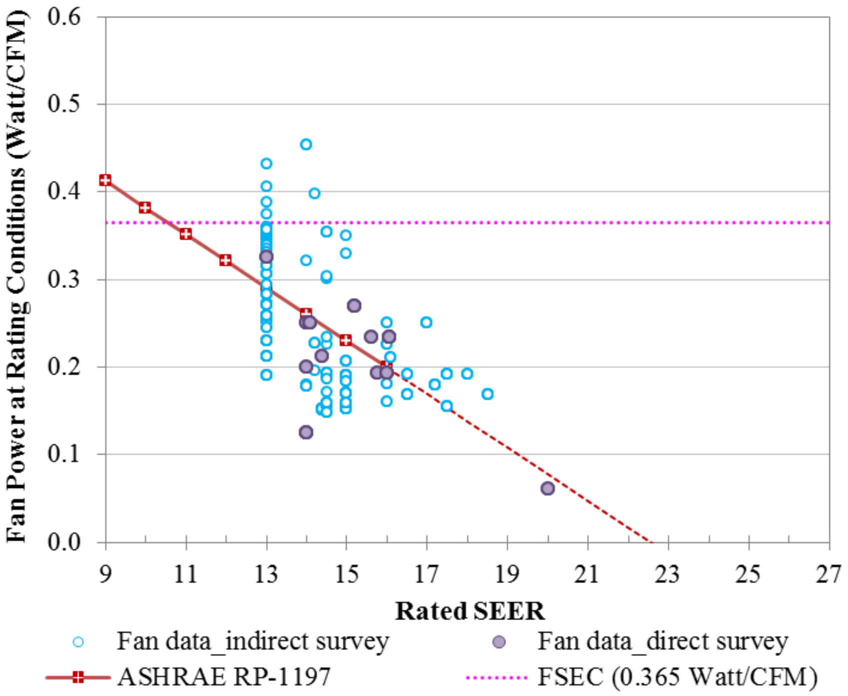


Figure 10: Plot of surveyed AHRI fan power versus rated SEER with the models proposed by the FSEC and the ASHRAE RP-1197

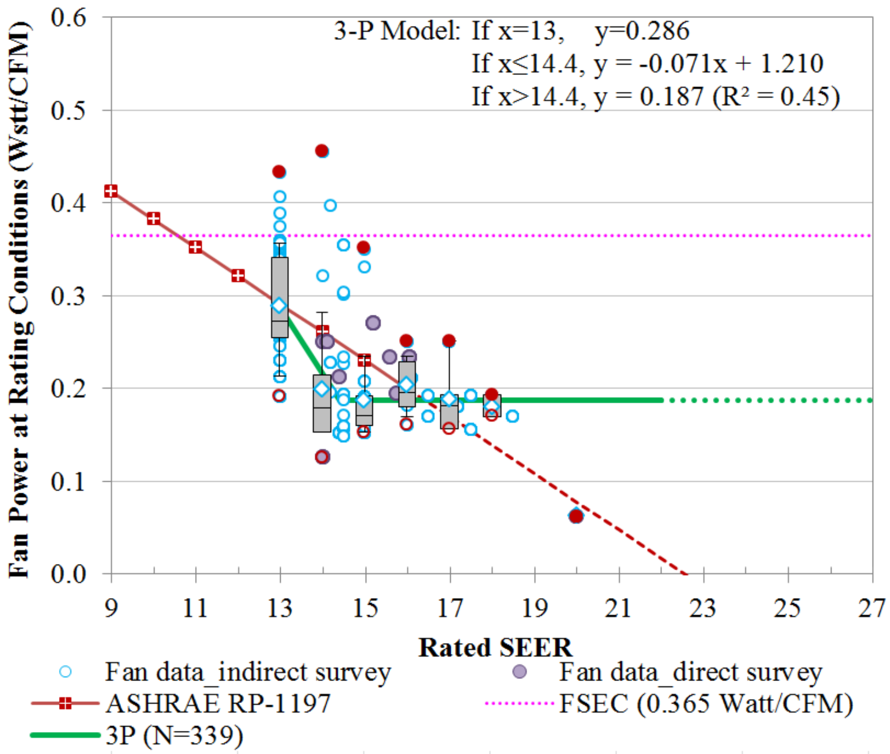


Figure 11: Proposed three-parameter change-point regression model (SEER to AHRI fan power) with a quartile analysis of the surveyed dataset binned into 1.0 SEER

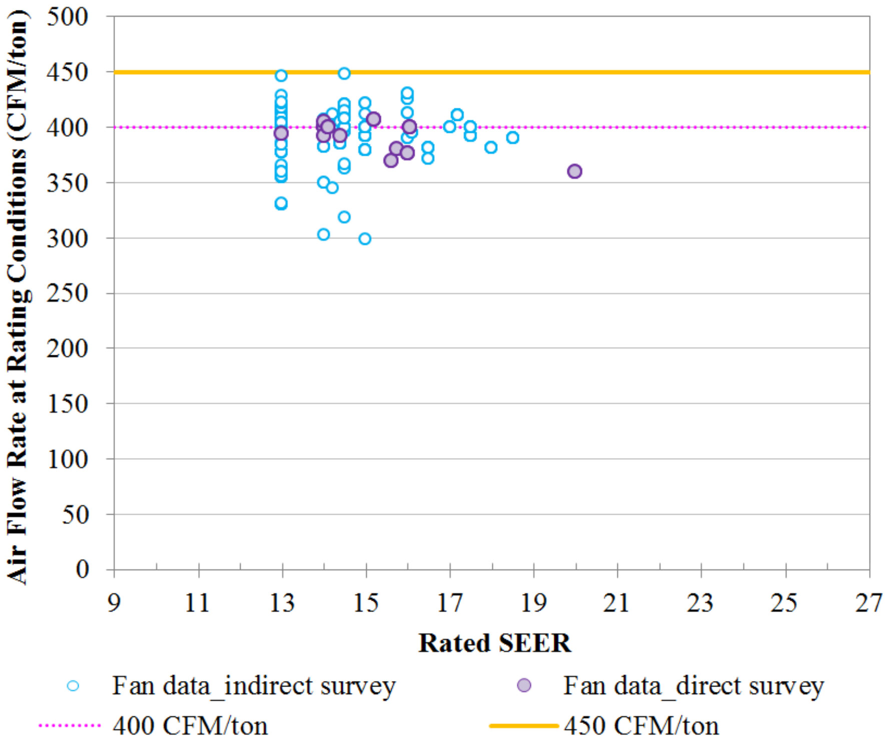


Figure 12: Plot of surveyed AHRI fan airflow rate versus rated SEER with two reference lines of 450 CFM/ton and 400 CFM/ton

4 FINAL MODELS TO CONVERT SEASONAL PERFORMANCE RATINGS TO STEADY-STATE EFFICIENCY WITH THE AHRI FAN POWER REMOVED

This Section provides the final models that directly convert the rated cooling and heating seasonal efficiency to the steady-state efficiency ratings that do not include supply fan energy. The models were calculated using the dataset downloaded from the 2012 AHRI directory (N=18,664) and the 2012 CEC database (N=11,842) after excluding supply fan energy using the 3-P model developed in this study.

4.1 Final Model

Figure 13 presents the proposed cooling model (i.e., SEER to COP_{95_nf}), which was derived using the selected dataset downloaded from the 2012 AHRI directory (N=18,664) after excluding supply fan energy using the 3-P model proposed in Figure 11. Figure 14 presents the proposed heating model (i.e., HSPF to COP_{47_nf}) using the dataset downloaded from the 2012 CEC database (N=11,842) after excluding supply fan energy using the same 3-P model. For both cooling and heating models, the calculations were made with an assumed airflow of 400 CFM/ton.

The proposed models fit the data well based on the results of a quartile analysis. However, the use of a second-order polynomial fit (i.e., a quadratic equation) yields a decreasing COP_{95_nf} when the SEER is higher than 25 and a decreasing COP_{47_nf} when the HSPF is higher than 11.8, which are labeled as final model w/o correction in the figures. Thus, corrections were made on the final model fits by forcing the calculated COP_{95_nf} for high SEER over 25 to be a constant value of 4.74, which is the peak COP_{95_nf} at SEER 25; and by forcing the calculated COP_{47_nf} for high HSPF over 11.8 to be a constant value of 4.30, which is the peak COP_{47_nf} at HSPF 11.8, as shown in Equations (11) and (12) for cooling and heating, respectively. Future modifications would be desirable to a constant COP_{95_nf} and COP_{47_nf} assumptions with a reasonably large number of data points for high efficiency units.

If $SEER \leq 25.0$, $COP_{95\_nf} = -0.0076 \times SEER^2 + 0.3796 \times SEER$; and
if $SEER > 25.0$, $COP_{95\_nf} = 4.74$ (11)
If $HSPF \leq 11.8$, $COP_{47\_nf} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$; and
if $HSPF > 11.8$, $COP_{47\_nf} = 4.30$ (12)

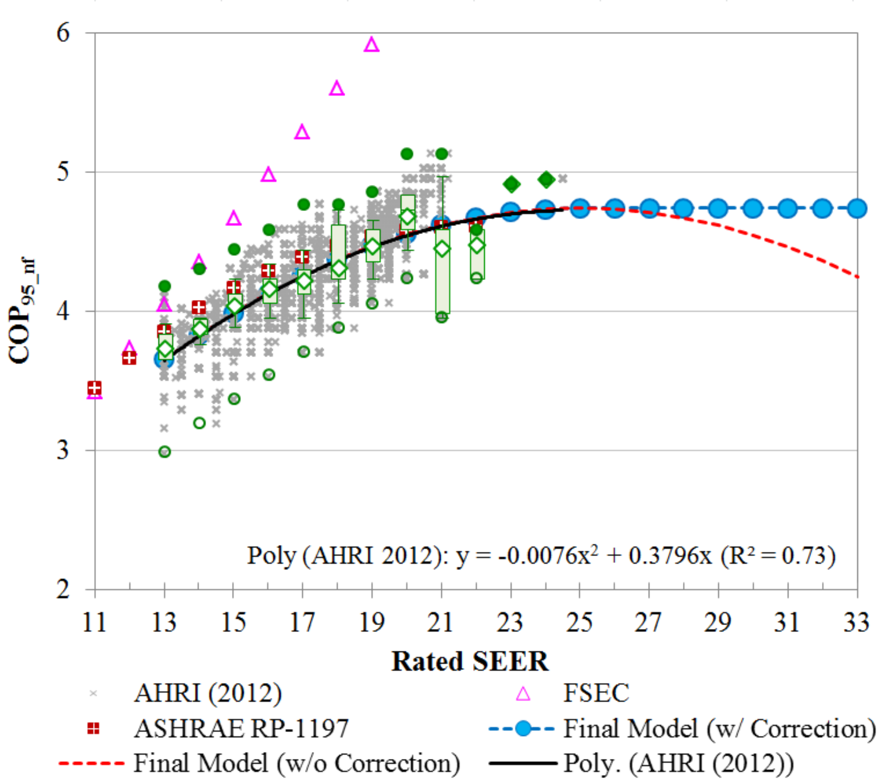


Figure 13: Proposed quadratic polynomial regression model (SEER to COP_{95_nf}) with a quartile analysis of the 2012 AHRI dataset after excluding supply fan energy binned into 1.0 SEER

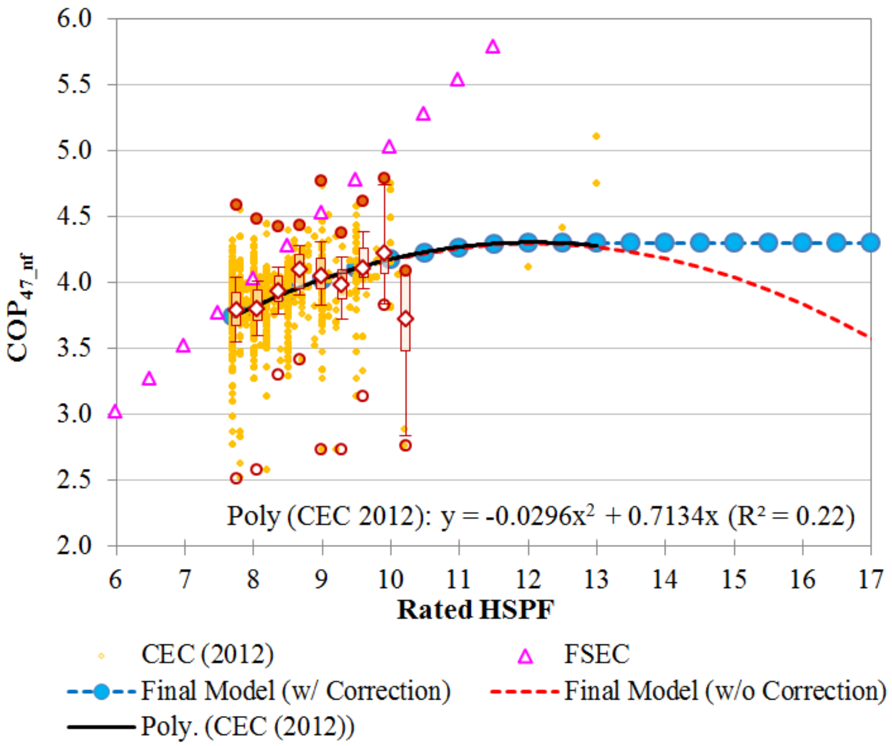


Figure 14: Proposed quadratic polynomial regression model (HSPF to COP_{47_nf}) with a quartile analysis of the CEC dataset after excluding supply fan energy binned into 0.3 HSPF

5 IMPACT OF THE NEW MODELS ON ENERGY SIMULATION RESULTS

This Section examines the impact of the new model proposed to calculate cooling and heating EIR for DOE-2 simulations (with excluding indoor fan energy) from the rated SEER and HSPF, on energy simulation results. The analysis was performed using the 2009 IECC code-compliant houses with air conditioners of five different SEER ratings (i.e., SEER 13, 15, 17, 19, and 21) and heat pump units of five different HSPF ratings (i.e., HSPF 7.7, 8.3, 8.9, 9.5, and 10.1) for two locations in Texas: Houston and Dallas. The three different methods were simulated, including the FSEC method, the ASHRAE RP-1197 method, and the new method proposed in this study, and then the differences in the calculated annual cooling, heating, and total site energy use were compared. Section 5.1 describes the base-case building characteristics. Section 5.2 provides the simulation results.

5.1 Base-Case House Description

The base-case house used in this analysis is based on the *standard* design as defined in Chapter 4 of the 2009 IECC and certain assumptions (ICC 2009). The base-case house is a 2,500 sq. ft., square-shape, one story, single-family, detached house oriented N, S, E, W, with a floor-to-ceiling height of 8 feet. The house has an attic with a roof pitched at 23 degrees. The wall construction is light-weight wood frame with 2x4 studs at 16” on center with a slab-on-grade-floor, which is typical construction according to the National Association of Home Builders - survey (NAHB 2003). The systems were assumed to be located in conditioned spaces. The five different SEER and HSPF ratings were simulated, including: 1) Test Set No. 1 Cooling: SEER 13, 15, 17, 19, and 21 with a 0.78 AFUE furnace for cooling models; and 2) Test Set No. 2 Heating: HSPF 7.7 (SEER 13.1), 8.3 (SEER 14.1), 8.9 (SEER 15.1), 9.5 (SEER 16.1), and 10.1(SEER 17.1) for heating models. The other envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as specified in the 2009 IECC performance path analysis per Section 405 of the 2009 IECC. Table 1 summarizes the base-case house characteristics used in the simulation model for Houston and Dallas, TX.

5.2 Results

Tables 2 and 3 present the results of simulation (i.e., annual site energy use (MMBtu/year) by total and end use; and annual source energy use (MMBtu/year) by total and fuel type) and the calculated percent of difference against the new model proposed for Test Set No.1 Cooling and Test Set No.2 Heating, respectively. The results are also graphically represented in Figures 15 and 16.

Apparently, the use of different EIR calculation models affects the cooling and heating energy use of a house. Of the three methods, the proposed model resulted in the largest cooling energy use, as shown in Figure 15. The percent difference in the cooling energy use against the proposed model varied between -29.2% and -9.6% (Houston) and between-29.9% and -10.0% (Dallas) with the FSEC method; and between -5.4% and 0.0% (Houston) and between -5.3% and 0.0% (Dallas) with the ASHRAE RP-1197 method. The impact of the proposed model on the total site energy use was lower: between -4.0% and -1.7% (Houston) and between-3.3% and -1.4% (Dallas) with the FSEC method; and between -0.9% and 0.0% (Houston) and between -0.7% and 0.0% (Dallas) with the ASHRAE RP-1197 method.

For heating, the proposed model resulted in the larger heating energy use compared to the FSEC method, but smaller heating energy use compared to the ASHRAE RP-1197 method. The percent difference in the heating energy use against the proposed model varied between -13.7% and -2.5% (Houston) and between -13.7% and -2.7% (Dallas) with the FSEC method; and between 3.8% and 5.5% (Houston) and between 4.5% and 5.9% (Dallas) with the ASHRAE RP-1197 method. The impact of the proposed model on the total site energy use was lower: between -5.5% and -2.5% (Houston) and between -5.5% and -2.3%

(Dallas) with the FSEC method; and between -0.8% and 0.0% (Houston) and between -0.4% and 0.3% (Dallas) with the ASHRAE RP-1197 method. With the ASHRAE RP-1197 method, a decrease in cooling energy use canceled out an increase in heating energy use, which yielded smaller percent difference in the total site or source energy use against the proposed model.

Table 1: Base-Case House Description: Houston, TX and Dallas, TX

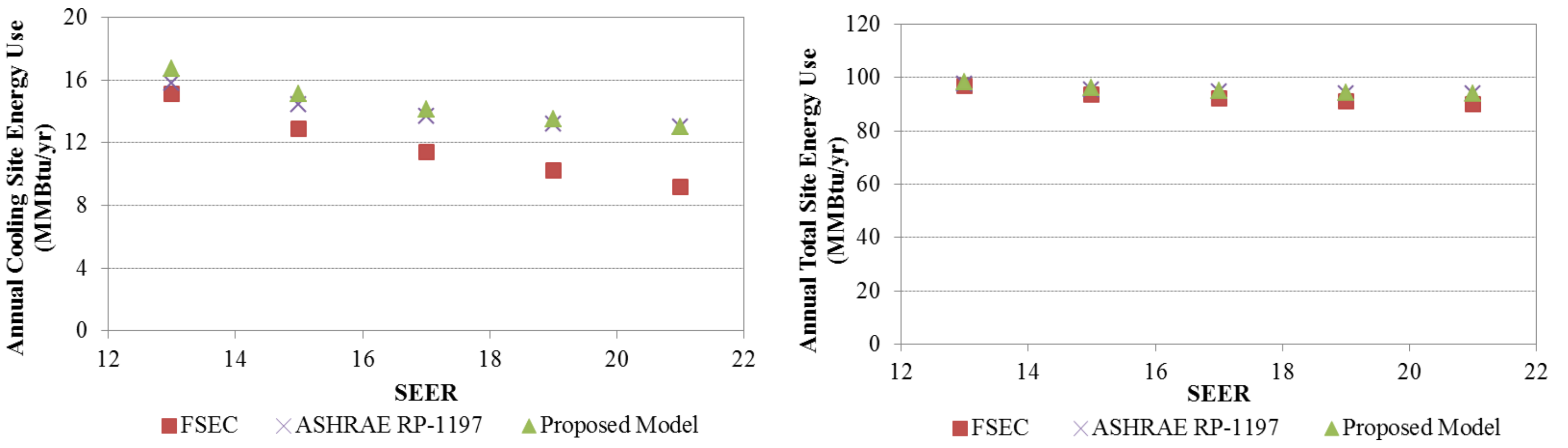
Characteristics	Houston, TX (Climate Zone 2)	Dallas, TX (Climate Zone 3)
Building		
Building Type	Single family, detached house	
Gross Area	2,500 sq. ft. (50 ft. x 50 ft.)	
Number of Floors	1	
Floor to Floor Height (ft.)	8	
Orientation	South facing	
Construction		
Construction	Light-weight wood frame with 2x4 studs spaced at 16” on center	
Floor	Slab-on-grade floor	
Roof Configuration	Unconditioned, vented attic	
Roof Absorptance	0.75	
Ceiling Insulation (hr-sq.ft.-°F/Btu)	R-27.8	
Wall Absorptance	0.75 (Assuming brick facia exterior)	
Wall Insulation (hr-sq.ft.-°F/Btu)	R-11.8	
Slab Perimeter Insulation	None	
Ground Reflectance	0.24 (Assuming grass)	
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	0.65	0.50
Solar Heat Gain Coefficient (SHGC)	0.30	
Window Area	15% of conditioned floor area	
Interior Shading	Summer 0.7, Winter 0.85	
Exterior Shading	None	
Roof Radiant Barrier	No	
Slope of Roof	5:12 (= 23 degrees)	
Space Conditions		
Space Temperature Set point	72°F Heating, 75°F Cooling	
Internal Heat Gains	1.146 kW (0.573 kW for lighting and 0.573 kW for equipment)	
Number of Occupants	None (Assuming internal gains include heat gain from occupants)	
Air Leakage (SG)	SLA= 0.00036	
Mechanical Systems		
HVAC System Type	Set No.1 Cooling: Electric cooling and natural gas heating (gas fired furnace) Set No.2 Heating: Electric cooling and heat pump heating	
HVAC System Efficiency	Set No.1 Cooling: SEER 13, 15, 17, 19, and 21 AC (0.78 AFUE furnace) Set No.2 Heating: HSPF 7.7 (SEER 13.1), 8.3 (SEER 14.1), 8.9 (SEER 15.1), 9.5 (SEER 16.1), and 10.1(SEER 17.1)	
Cooling Capacity (Btu/hr)	60,000 (= 500 sq. ft./ton)	
Heating Capacity (Btu/hr)	60,000 (= 1.0 x cooling capacity)	
DHW System Type	Set No. 1 Cooling: 40-gallon tank type gas water heater Set No. 2 Heating: 50-gallon tank type electric water heater	
DHW Heater Energy Factor	Set No. 1 Cooling: 0.594 Set No.2 Heating: 0.904	
Duct Distribution System Efficiency	0.88	
Supply Air Flow (CFM/ton)	360	

Table 2: Simulation Results: Test Set No.1 Cooling

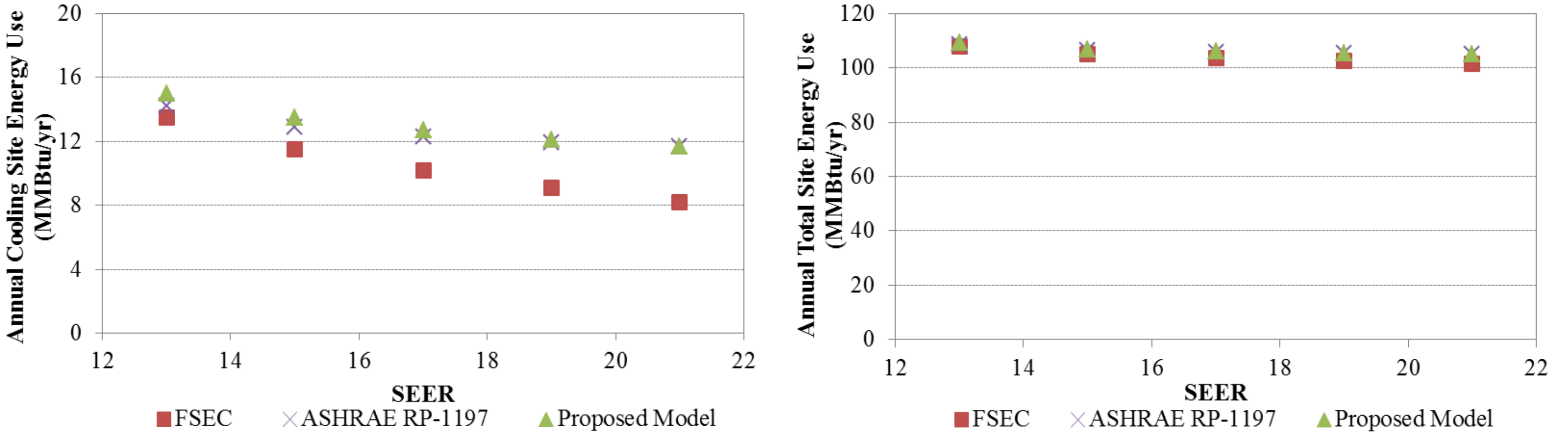
Test Cases		Cooling EIR for DOE-2 Simulations	Annual Site Energy Consumption (MMBtu/year)						Annual Source Energy Consumption (MMBtu/year)			% Difference against the New Model Proposed			
			Total	Cooling	Heating	Lgt & Appl	Fans & Pumps	DHW	Total	Total Elec.	Total NG	Site Cooling	Site Total	Source Elec.	Source Total
(a) Houston, TX															
FSEC	**SEER 13**	**0.247**	96.8	15.1	25.9	34.2	5.0	16.6	218.3	171.6	46.8	-9.6%	-1.7%	-3.0%	-2.4%
	SEER 15	**0.214**	93.7	12.9	26.2	34.2	3.8	16.6	207.9	160.8	47.1	-14.6%	-2.4%	-4.3%	-3.4%
	SEER 17	**0.189**	92.2	11.4	26.2	34.2	3.8	16.6	203.2	156.1	47.1	-19.1%	-2.9%	-5.4%	-4.2%
	SEER 19	**0.169**	91.0	10.2	26.2	34.2	3.8	16.6	199.4	152.3	47.1	-24.4%	-3.5%	-6.4%	-5.0%
	SEER 21	**0.153**	90.1	9.2	26.2	34.2	3.8	16.6	196.5	149.5	47.1	-29.2%	-4.0%	-7.4%	-5.8%
ASHRAE RP-1197	**SEER 13**	**0.259**	97.6	15.8	25.9	34.2	5.0	16.6	220.9	174.1	46.8	-5.4%	-0.9%	-1.6%	-1.3%
	SEER 15	**0.240**	95.3	14.4	26.2	34.2	3.8	16.6	213.0	165.9	47.1	-4.6%	-0.7%	-1.3%	-1.0%
	SEER 17	**0.227**	94.6	13.7	26.2	34.2	3.8	16.6	210.8	163.7	47.1	-2.8%	-0.4%	-0.8%	-0.6%
	SEER 19	**0.220**	94.1	13.2	26.2	34.2	3.8	16.6	209.2	162.1	47.1	-2.2%	-0.2%	-0.4%	-0.3%
	SEER 21	**0.217**	93.9	13.0	26.2	34.2	3.8	16.6	208.6	161.5	47.1	0.0%	0.0%	0.0%	0.0%
Proposed Model	**SEER 13**	**0.274**	98.5	16.7	25.9	34.2	5.0	16.6	223.7	177.0	46.8				
	SEER 15	**0.251**	96.0	15.1	26.2	34.2	3.8	16.6	215.2	168.1	47.1				
	SEER 17	**0.235**	95.0	14.1	26.2	34.2	3.8	16.6	212.0	165.0	47.1				
	SEER 19	**0.224**	94.3	13.5	26.2	34.2	3.8	16.6	209.8	162.7	47.1				
	SEER 21	**0.216**	93.9	13.0	26.2	34.2	3.8	16.6	208.6	161.5	47.1				
(b) Dallas, TX															
FSEC	**SEER 13**	**0.247**	107.8	13.5	37.5	34.2	5.1	17.4	227.6	167.2	60.4	-10.0%	-1.4%	-2.8%	-2.0%
	SEER 15	**0.214**	105.0	11.5	37.9	34.2	3.9	17.4	217.9	157.1	60.8	-14.8%	-1.9%	-3.9%	-2.8%
	SEER 17	**0.189**	103.7	10.2	37.9	34.2	3.9	17.4	213.8	152.9	60.8	-19.7%	-2.4%	-4.9%	-3.6%
	SEER 19	**0.169**	102.6	9.1	37.9	34.2	3.9	17.4	210.3	149.5	60.8	-24.8%	-2.8%	-6.0%	-4.3%
	SEER 21	**0.153**	101.7	8.2	37.9	34.2	3.9	17.4	207.5	146.6	60.8	-29.9%	-3.3%	-7.0%	-5.1%
ASHRAE RP-1197	**SEER 13**	**0.259**	108.5	14.2	37.5	34.2	5.1	17.4	229.8	169.4	60.4	-5.3%	-0.7%	-1.5%	-1.1%
	SEER 15	**0.240**	106.4	12.9	37.9	34.2	3.9	17.4	222.3	161.5	60.8	-4.4%	-0.6%	-1.2%	-0.8%
	SEER 17	**0.227**	105.8	12.3	37.9	34.2	3.9	17.4	220.4	159.6	60.8	-3.1%	-0.4%	-0.8%	-0.6%
	SEER 19	**0.220**	105.4	11.9	37.9	34.2	3.9	17.4	219.1	158.3	60.8	-1.7%	-0.2%	-0.4%	-0.3%
	SEER 21	**0.217**	105.2	11.7	37.9	34.2	3.9	17.4	218.5	157.7	60.8	0.0%	0.0%	0.0%	0.0%
Proposed Model	**SEER 13**	**0.274**	109.3	15.0	37.5	34.2	5.1	17.4	232.3	171.9	60.4				
	SEER 15	**0.251**	107.0	13.5	37.9	34.2	3.9	17.4	224.2	163.4	60.8				
	SEER 17	**0.235**	106.2	12.7	37.9	34.2	3.9	17.4	221.7	160.8	60.8				
	SEER 19	**0.224**	105.6	12.1	37.9	34.2	3.9	17.4	219.8	158.9	60.8				
	SEER 21	**0.216**	105.2	11.7	37.9	34.2	3.9	17.4	218.5	157.7	60.8				

Table 3: Simulation Results: Test Set No.2 Heating

Test Cases		Heating EIR for DOE-2 Simulations	Annual Site Energy Consumption (MMBtu/year)						Annual Source Energy Consumption (MMBtu/year)			% Difference against the New Model Proposed		
			Total	Cooling	Heating	Lgt & Appl	Fans & Pumps	DHW	Total	Total Elec.	Total NG	Site Cooling	Site Heating	Site/Source Total
(a) Harris County														
FSEC	**HSPF 7.7/SEER 13.1**	**0.258**	72.7	14.9	7.7	34.2	5.0	10.8	229.7	229.7	0.0	-10.2%	-2.5%	-2.5%
	HSPF 8.3/SEER 14.1	**0.239**	69.9	13.7	7.3	34.2	3.8	10.8	220.9	220.9	0.0	-12.2%	-6.4%	-3.3%
	HSPF 8.9/SEER 15.1	**0.223**	68.6	12.8	6.9	34.2	3.8	10.8	216.8	216.8	0.0	-14.7%	-9.2%	-4.1%
	HSPF 9.5/SEER 16.1	**0.209**	67.4	12.0	6.6	34.2	3.8	10.8	213.0	213.0	0.0	-17.2%	-10.8%	-4.8%
	HSPF 10.1/SEER 17.1	**0.196**	66.4	11.3	6.3	34.2	3.8	10.8	209.8	209.8	0.0	-19.9%	-13.7%	-5.5%
ASHRAE RP-1197	**HSPF 7.7/SEER 13.1**	**0.280**	74.0	15.7	8.2	34.2	5.0	10.8	233.8	233.8	0.0	-5.4%	3.8%	-0.8%
	HSPF 8.3/SEER 14.1	**0.271**	71.8	14.9	8.1	34.2	3.8	10.8	226.9	226.9	0.0	-4.5%	3.8%	-0.7%
	HSPF 8.9/SEER 15.1	**0.264**	71.2	14.4	7.9	34.2	3.8	10.8	225.0	225.0	0.0	-4.0%	3.9%	-0.4%
	HSPF 9.5/SEER 16.1	**0.259**	70.6	14.0	7.8	34.2	3.8	10.8	223.1	223.1	0.0	-3.4%	5.4%	-0.3%
	HSPF 10.1/SEER 17.1	**0.256**	70.3	13.6	7.7	34.2	3.8	10.8	222.1	222.1	0.0	-3.5%	5.5%	0.0%
Proposed Model	**HSPF 7.7/SEER 13.1**	**0.268**	74.6	16.6	7.9	34.2	5.0	10.8	235.7	235.7	0.0			
	HSPF 8.3/SEER 14.1	**0.258**	72.3	15.6	7.8	34.2	3.8	10.8	228.5	228.5	0.0			
	HSPF 8.9/SEER 15.1	**0.250**	71.5	15.0	7.6	34.2	3.8	10.8	225.9	225.9	0.0			
	HSPF 9.5/SEER 16.1	**0.244**	70.8	14.5	7.4	34.2	3.8	10.8	223.7	223.7	0.0			
	HSPF 10.1/SEER 17.1	**0.239**	70.3	14.1	7.3	34.2	3.8	10.8	222.1	222.1	0.0			
(b) Dallas County														
FSEC	**HSPF 7.7/SEER 13.1**	**0.258**	75.0	13.4	10.8	34.2	5.0	11.5	237.0	237.0	0.0	-10.1%	-2.7%	-2.3%
	HSPF 8.3/SEER 14.1	**0.239**	72.1	12.3	10.2	34.2	3.8	11.5	227.8	227.8	0.0	-12.1%	-6.4%	-3.2%
	HSPF 8.9/SEER 15.1	**0.223**	70.7	11.5	9.7	34.2	3.8	11.5	223.4	223.4	0.0	-14.8%	-8.5%	-4.1%
	HSPF 9.5/SEER 16.1	**0.209**	69.5	10.7	9.2	34.2	3.8	11.5	219.6	219.6	0.0	-17.7%	-11.5%	-4.8%
	HSPF 10.1/SEER 17.1	**0.196**	68.5	10.1	8.8	34.2	3.8	11.5	216.5	216.5	0.0	-19.8%	-13.7%	-5.5%
ASHRAE RP-1197	**HSPF 7.7/SEER 13.1**	**0.280**	76.5	14.1	11.6	34.2	5.0	11.5	241.7	241.7	0.0	-5.4%	4.5%	-0.4%
	HSPF 8.3/SEER 14.1	**0.271**	74.3	13.3	11.4	34.2	3.8	11.5	234.8	234.8	0.0	-5.0%	4.6%	-0.3%
	HSPF 8.9/SEER 15.1	**0.264**	73.6	12.9	11.1	34.2	3.8	11.5	232.6	232.6	0.0	-4.4%	4.7%	-0.1%
	HSPF 9.5/SEER 16.1	**0.259**	73.1	12.5	10.9	34.2	3.8	11.5	231.0	231.0	0.0	-3.8%	4.8%	0.1%
	HSPF 10.1/SEER 17.1	**0.256**	72.7	12.2	10.8	34.2	3.8	11.5	229.7	229.7	0.0	-3.2%	5.9%	0.3%
Proposed Model	**HSPF 7.7/SEER 13.1**	**0.268**	76.8	14.9	11.1	34.2	5.0	11.5	242.7	242.7	0.0			
	HSPF 8.3/SEER 14.1	**0.258**	74.5	14.0	10.9	34.2	3.8	11.5	235.4	235.4	0.0			
	HSPF 8.9/SEER 15.1	**0.250**	73.7	13.5	10.6	34.2	3.8	11.5	232.9	232.9	0.0			
	HSPF 9.5/SEER 16.1	**0.244**	73.0	13.0	10.4	34.2	3.8	11.5	230.7	230.7	0.0			
	HSPF 10.1/SEER 17.1	**0.239**	72.5	12.6	10.2	34.2	3.8	11.5	229.1	229.1	0.0			

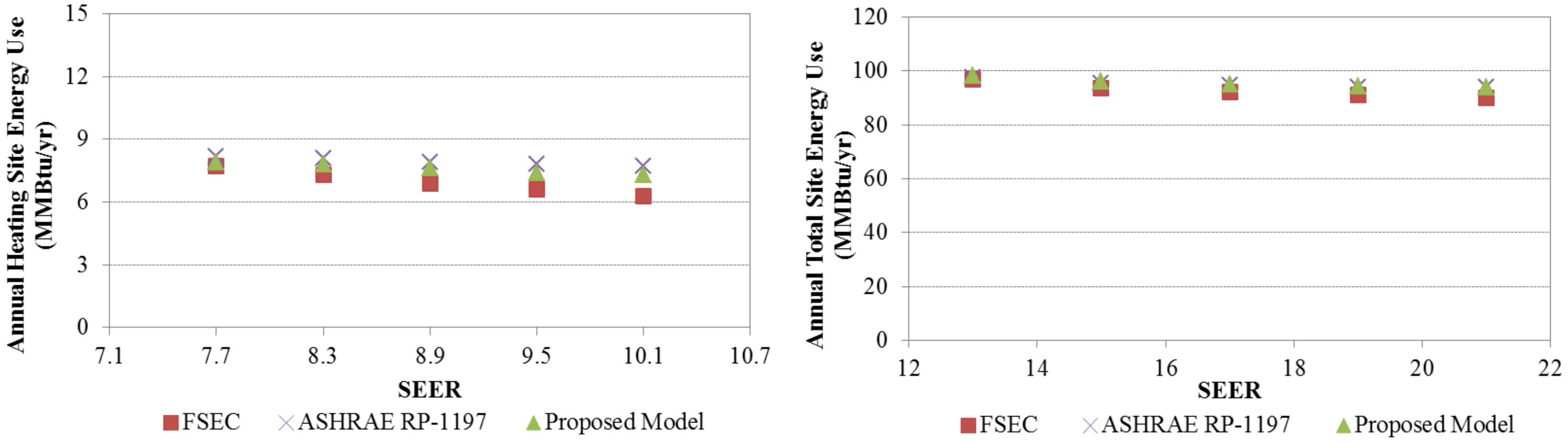


(a) Houston, TX

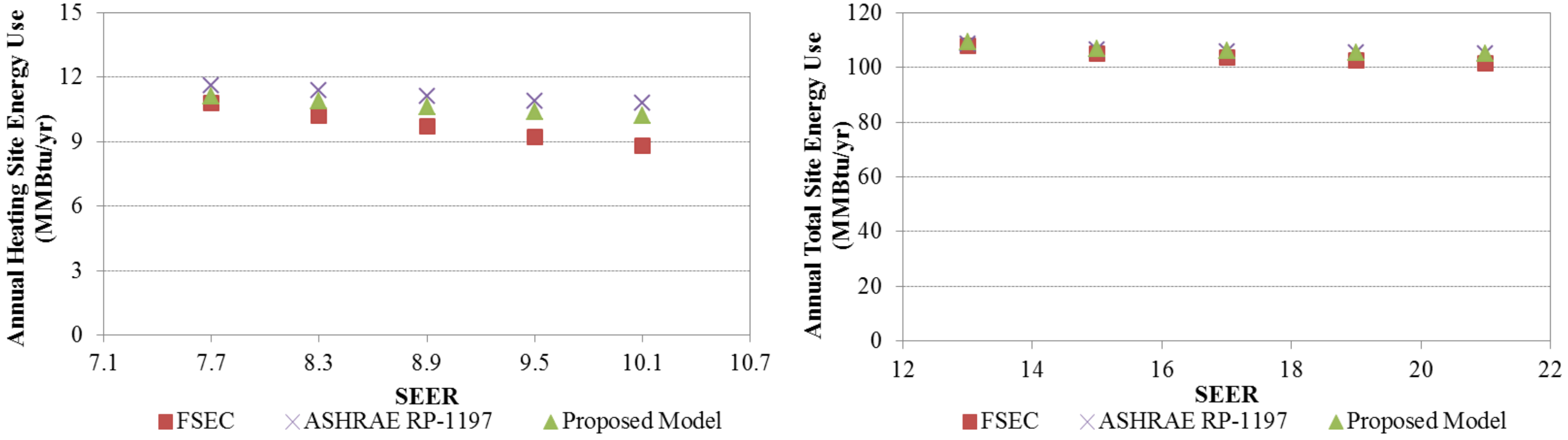


(b) Dallas, TX

Figure 15: Annual Cooling and Total Site Energy Use by Three Different Methods, Including FSEC, ASHRAE RP-1197, and Proposed Model: Test Set No.1 Cooling



(a) Houston, TX



(b) Dallas, TX

Figure 16: Annual Heating and Total Site Energy Use by Three Different Methods, Including FSEC, ASHRAE RP-1197, and Proposed Model: Test Set No.2 Heating

6 SUMMARY

To provide the recommendations to calculate cooling and heating EIR for DOE-2 simulations with excluding indoor fan energy, from the rated cooling and heating seasonal performance efficiency (i.e., SEER or HSPF) that does include indoor fan energy, this report reviewed the existing methodologies proposed by the FSEC (Fairey et al. 2004) as well as by the ASHRAE RP-1197 (Brandemuehl and Wassmer 2009). Additional comparison was also performed against the two datasets recently downloaded from the CEC database and the AHRI directory as well as the fan performance data collected from several manufacturers.

Finally, new models, which directly convert the rated cooling and heating seasonal efficiency to the steady-state efficiency that does not include supply fan energy, were developed using the dataset downloaded from the 2012 AHRI directory and the 2012 CEC database after excluding supply fan energy using the 3-P model developed in this study. The proposed models fit the data well based on the results of a quartile analysis. However, the use of a second-order polynomial fit (i.e., a quadratic equation) yields a decreasing COP_{95_nf} when the SEER is higher than 25 and a decreasing COP_{47_nf} when the HSPF is higher than 11.8. Thus, corrections were made on the final model fits by forcing the calculated COP_{95_nf} for high SEER over 25 to be a constant value of 4.74, which is the peak COP_{95_nf} at SEER 25; and by forcing the calculated COP_{47_nf} for high HSPF over 11.8 to be a constant value of 4.30, which is the peak COP_{47_nf} at HSPF 11.8 (Equations (11) and (12))[10].

In an analysis that examined the impact of the new models on energy simulation results using a 2009 IECC code-compliant, 2,500 square foot house with air conditioners of five different SEER ratings (i.e., SEER 13, 15, 17, 19, and 21) and heat pump units of five different HSPF ratings (i.e., HSPF 7.7, 8.3, 8.9, 9.5, and 10.1), it was found that the use of different EIR calculation models affects the cooling and heating energy use of a house. The percent difference in the cooling energy use against the proposed model varied between -29.2% and -9.6% (Houston) and between-29.9% and -10.0% (Dallas) with the FSEC method; and between -5.4% and 0.0% (Houston) and between -5.3% and 0.0% (Dallas) with the ASHRAE RP-1197 method. The percent difference in the heating energy use against the proposed model varied between -13.7% and -2.5% (Houston) and between -13.7% and -2.7% (Dallas) with the FSEC method; and between 3.8% and 5.5% (Houston) and between 4.5% and 5.9% (Dallas) with the ASHRAE RP-1197 method.

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[10] Future modifications would be desirable to a constant COP_{95_nf} and COP_{47_nf} assumptions with a reasonably large number of data points for high efficiency units.

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