Volume 7, Issue 2

CARRIER® eDESIGN SUITE NEWS

EXchange

turn to the experts

Best Practices for Modeling Equipment Efficiency in HAP

One of the most common measures of unit efficiency is the **EER – Energy Efficiency Ratio**. The EER is the ratio of the Net Cooling Capacity in Btu/h to the Total Unit Power Input in Watts at a given set of rating conditions, in units of Btu/W·h., often expressed by the equation:

EER = Net Cooling Capacity (Btu/h) / Total Unit Input Power (Watts) [Eq 1]

The term "Net" refers to the fact the indoor (ID) supply fan heat is not included in the capacity or efficiency rating, which is explained in more detail in the next section.

To understand how to interpret and apply EER ratings for equipment it is important to differentiate between a "system" EER and a "component" EER value. Split systems such as direct-expansion (DX) splits or Variable Refrigerant Flow (VRF) systems or even a hydronic chiller system consist of an outdoor (OD) unit interconnected to one or multiple indoor (ID) unit(s). Typically, OD units are rated for capacity and EER based on their stand-alone properties, that is without any matched ID units. These OD units are then matched with one or more ID units, along with the associated refrigerant (or water) piping, and rated such that a combined "system," EER can be derived. The system EER includes all energy required for both OD and ID system components.

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eDesign Suite

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On Packaged RTUs and other self-contained equipment (e.g. Unit Ventilators, Room Air Conditioners, PTACs), all of the system components are located inside the unit's cabinet, which includes the ID fan, the compressor(s) and the outdoor condenser fan(s), therefore their EER ratings are already "system" EERs. So Eq 1 can then be expressed as:

RTU EER = (Net Cooling Capacity) / (ID Fan kW + Compressor kW + OD Fan kW) [Eq 2]

EERs may be readily compared for the same type of HVAC equipment, such as comparing two different brands of Packaged Rooftop Units (RTUs), for instance. Figure 1 below shows a typical manufacturer's catalog AHRI rating for a Packaged RTU. The AHRI certified ratings include Nominal Capacity in Tons, Net Cooling Capacity in MBH as well as Total Unit Power (kW), EER and IEER.

AHRI COOLING RATINGS

UNIT	COOLING STAGES	NOM. CAPACITY (TONS)	NET COOLING CAPACITY (MBH)	TOTAL POWER (kW)	EER	IEER WITH SINGLE SPEED INDOOR FAN MOTOR	IEER WITH 2-SPEED INDOOR FAN MOTOR
17	2	15.0	202.0	18.7	10.8	12.0	12.7
20	2	17.5	208.0	19.3	10.8	11.7	12.7
24	2	20.0	242.0	24.7	9.8	10.6	11.7
28	2	25.0	280.0	28.6	9.8	10.4	11.5
30	2	27.5	330.0	32.4	10.2	10.4	11.5

Figure 1. AHRI Certified Rating (15-27.5 Ton) Pkg RTU

Contrast this to the AHRI ratings for an air-cooled chiller, as shown below in Figure 2.

A/C CHILLER RATINGS

UNIT SIZE	CAPACITY		COMP	FAN	TOTAL POWER	FULL LOAD		IPLV		COOLER FLOW RATE		COOLER PD	
	Tons	kW	kW	kW	kW	EER†	COP	EER†	COP	GPM	L/s	ft wg	kPa
060	57.1	200.6	60.3	10.3	70.6	9.7	2.8	13.1	3.8	136.9	8.6	8.9	26.6
070	66.2	232.8	70.1	10.3	80.4	9.9	2.9	13.4	3.9	158.9	10.0	11.7	34.8
080	76.0	267.3	83.1	10.3	93.4	9.8	2.9	14.3	4.2	182.4	11.5	7.0	21.0
090	86.6	304.6	85.2	15.5	100.7	10.3	3.0	13.7	4.0	207.8	13.1	9.0	26.7
100	92.8	326.5	94.1	15.5	109.6	10.2	3.0	13.5	4.0	222.8	14.1	10.2	30.4
110	106.0	372.8	110.2	15.5	125.7	10.1	3.0	13.9	4.1	254.4	16.1	9.0	26.7

Figure 2. AHRI Certified Rating (60-110 Ton) Air-Cooled Chillers

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Consider the highlighted fields in Figures 1 and 2 above. At first glance you might think you can readily compare EER ratings between air-cooled chillers and packaged RTUs. Comparing the full load EERs between Tables 1 and 2 above might lead you to the conclusion that chillers and RTUs both have similar efficiencies (~10 EER). However, a direct comparison of the EER of a Packaged RTU to the EER of an Air-cooled chiller, or even a VRF system, is not possible because the chiller and VRF system EERs are "component" EERs while the Packaged RTU EER is a "system" EER.

As an example, we can compare the full load energy efficiency of a 20-Ton Packaged RTU to a 90-Ton air-cooled chiller. Which one is more efficient?

Equipment Type	Full Load Energy Efficiency Ratio (EER)
90-Ton Air-cooled Chiller	10.3 (1.17 kW/Ton)
20-Ton Packaged RTU	9.8

Table 1. Full Load EERs of Pkg RTU and A/C Chiller

Is the chiller more efficient than the RTU because its EER is larger? Not necessarily because all EERs are <u>not</u> created equal. An EER for a Packaged RTU means something different than an EER for an air-cooled chiller, so you can't directly compare the two unless you put them on the same footing. This is because a chiller does not have an evaporator fan, it only has condenser fan(s) and compressor(s) while a Packaged RTU has all three: evaporator fan, compressor(s) and condenser fan(s). **The EER represents the Total energy consumed, so the EER for an air-cooled chiller will tend to be greater than a Packaged RTU because the chiller EER does not include the indoor (ID) evaporator fan.**

Here are the EER equations for both types of equipment:

RTU EER = (Net Cooling Capacity) / (ID Fan kW + Compressor kW + OD Fan kW) [Eq 2]

Chiller EER = (Gross Cooling Capacity) / (Compressor kW + OD Fan kW) [Eq 3]

<u>Gross</u> capacity ratings include the effects of ID fan motor heat while <u>Net</u> capacity ratings have the ID fan motor heat subtracted.

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To ensure that we are comparing apples-to-apples we need to look at an equivalent Gross RTU EER that has the ID fan power (kW) and fan heat deducted from the rating.

$$\text{RTU EER}_{\text{gross}} = \text{(Gross Cooling Capacity) / (Compressor kW + OD Fan kW)} \qquad \text{[Eq 4]}$$

To compute the ID Fan Heat we can use the following equation:

$$\text{ID Fan Heat (MBH)} = \text{ID Fan kW} \times 3.412 \text{ MBH/kW} \qquad \text{[Eq 5]}$$

The only missing data is the ID Fan power (kW), which may be determined from the manufacturer's product data or electronic equipment selection software at the supply fan's design external static pressure (ESP).

For this example, let's assume the ID fan kW is 4.1 kW. We can now compute the fan heat using Eq 5:

$$\text{ID Fan Heat (MBH)} = \text{ID Fan kW} \times 3.412 \text{ MBH/kW} = 4.1 \times 3.412 = 14.0 \text{ MBH}$$

Now that we have the ID fan heat MBH this is added to the Net Cooling Capacity to get Gross Cooling Capacity. Referring back to Fig 1 for our RTU Net Capacity:

$$\text{Gross Cooling Capacity} = \text{Net Cooling Capacity} + \text{ID Fan Heat} = 242.0 + 14.0 = 256.0 \text{ MBH}$$

Also, from Fig 1 we know the Total Unit kW is 24.7 kW so we can subtract the ID fan kW and solve Eq 4 for the equivalent Gross EER for the RTU:

$$\text{RTU EER}_{\text{gross}} = \text{(Gross Cooling Capacity) / (Compressor kW + OD Fan kW)} = 256.0 / (24.7 - 4.1) = 12.4$$

To conclude, our actual RTU EER when ID fan heat and power is deducted is 12.4 rather than the AHRI value of 9.8, therefore the RTU has a higher EER than the air-cooled chiller, which was 10.3.

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To summarize, the following suggestions should be considered when entering equipment performance data in HAP:

- As a preliminary (quick) analysis it is fine to estimate a "typical" or "ballpark" equipment EER and ID fan static pressure, however once you finalize the design you should go back and use actual kW values for both OD and ID units in the HAP inputs.

- Whenever possible use actual AHRI certified product data from the manufacturer. This can come from a product catalog or electronic product selection software tool such as Carrier's E-CAT.

- If entering an EER value enter the total "system" EER for the cooling system under the Equipment tab, which includes all system components (compressor, OD fans and ID fans). Also make sure you accurately enter the ID fan kW under the fan input. HAP will then back-calculate the compressor and OD fan kW from the total system EER.

- The most accurate way to model the cooling equipment in HAP is to enter the compressor and OD fan kW value directly rather than EER. That way no conversions or back-calculations are required as the power input is already in kW terms. Again, the use of a manufacturer's electronic product selection software is recommended, that way you get the precise total and sensible capacities and kW values based on your specific set of design conditions (entering air temperatures, airflow, fan static pressure, etc).

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Why Use Industry Efficiency Ratings?

HVAC manufacturers test and rate their equipment to meet industry Standards as developed by the Air-Conditioning, Heating & Refrigeration Institute (AHRI)[1]. AHRI develops specific test Standards for HVAC manufacturers to use for predicting the performance and energy efficiency of their equipment. Much like fuel MPG ratings for automobiles, an AHRI certified rating allows the designer or customer to readily compare cooling and heating capacities, energy use and efficiency values of one or more manufacturer's HVAC equipment side-by-side and be assured they are comparing apples-to-apples. If not for these standardized test procedures each manufacturer could use whatever set of test conditions they deemed appropriate, which would lead to lots of confusion in the field when selecting a particular HVAC unit.

[1] AHRI Certified™ is a Registered Trademark of the Air Conditioning, Heating & Refrigeration Institute

Each type or "class" of HVAC equipment has a different AHRI test Standard, along with a distinct Standard number, which is specifically applicable only to that class of equipment. For example, Small Unitary cooling equipment (< 65 Btu/h capacity) is tested to AHRI Standard 210/240, as indicated on the blue seal here. AHRI establishes the evaporator and condenser entering air temperatures as well as airflow and supply external fan static pressure conditions at which the equipment is tested under. Separate tests exist for single-speed, multi-speed and variable-speed equipment in both cooling and heat pump heating modes of operation. When selecting any type of HVAC equipment, you should make sure its performance ratings are AHRI certified.

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Frequently Asked Questions

Q: How does HAP size zone airflow rates and zone heating equipment on a VAV system?

A: A "typical" VAV system schematic is shown in Figure 3 below.

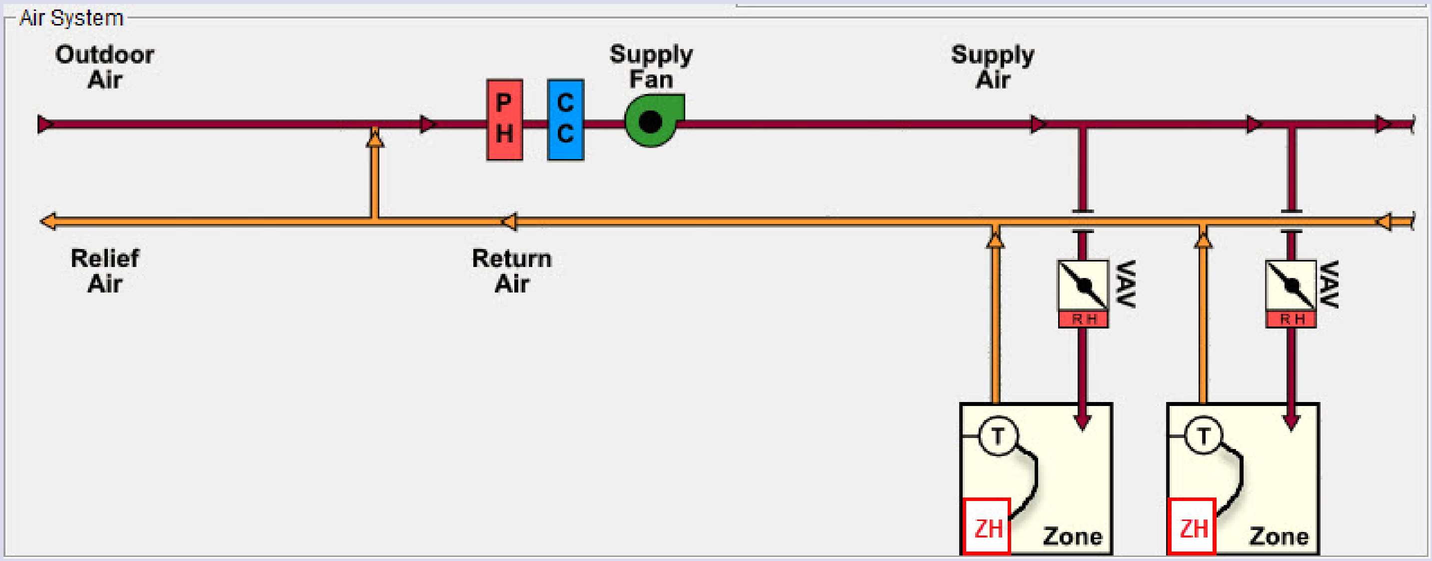

Figure 3. VAV Reheat System with Optional Zone Heating Unit

This system includes a zone terminal reheat (RH) coil and an optional zone heating (ZH) unit, in this case a baseboard heater, which is normally controlled by the same zone thermostat that controls the VAV box. To explain the sizing logic let's consider two possible scenarios, one without the ZH unit and one with it.

Scenario 1: VAV reheat-only with no zone heating unit. When a zone contains only a VAV/RH terminal controlled by zone thermostat, and no ZH unit, the terminal RH coil is sized to handle the reheat of the primary air off the central cooling coil plus the heat necessary to heat the zone. As a result, the airflow sizing for the terminal RH coil is determined by the largest of four criteria:

a. the zone cooling load requirement
b. the zone heating load requirement
c. the outdoor ventilation air requirement
d. any special minimum airflow requirements, such as a zone air change (ACH) requirement or zone direct exhaust rate.

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Scenario 2: VAV reheat plus a zone heating unit. When a zone contains both a VAV/RH terminal and a ZH unit controlled by zone thermostat, the terminal RH coil is sized to handle the reheat of the primary air off the central cooling coil and the ZH unit is sized to handle the zone heating load. As a result, the airflow sizing for the terminal RH coil is determined by the largest of three criteria:

a. the zone cooling load requirement
b. the outdoor ventilation air requirement
c. any special minimum airflow requirements, such as a zone air change (ACH) requirement or zone direct exhaust rate.

User inputs exist in HAP for both cooling coil supply air temperature (SAT) and heating SAT off the reheat coil, as indicated in Figure 4.

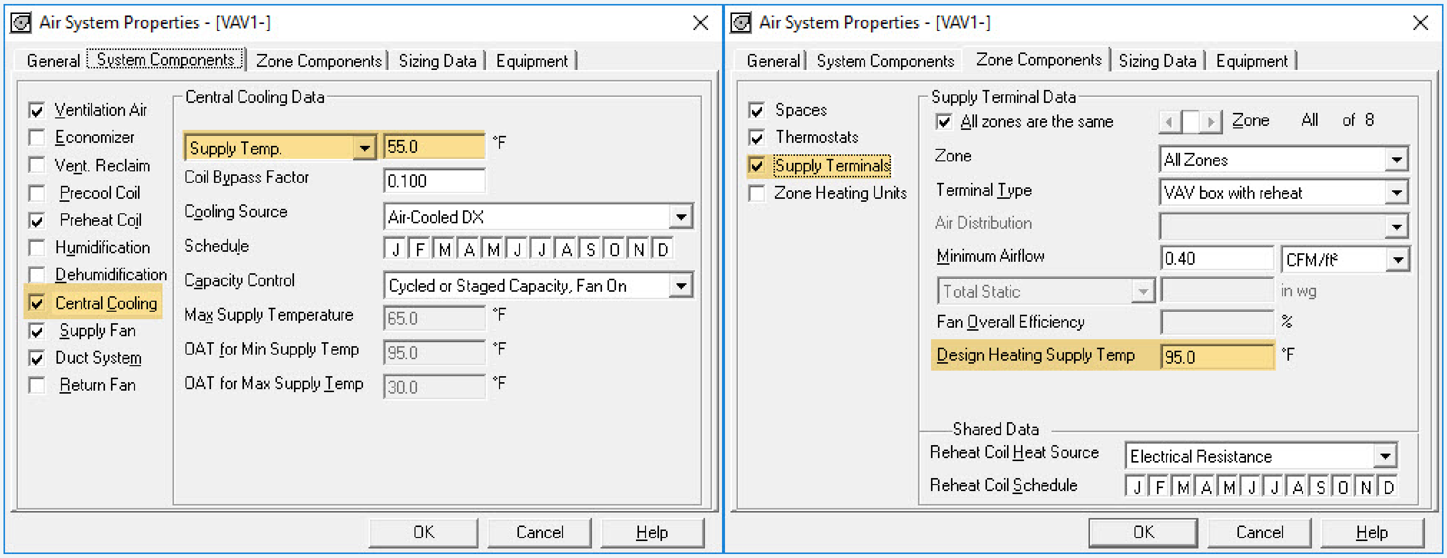

Figure 4. VAV Reheat System – Central Cooling Coil & Reheat Coil Design SATs

HAP uses these design SATs, along with the reheat load and zone cooling and heating loads, to compute the airflow quantities for the VAV terminals. Generally, these airflow quantities will establish the largest or "design" airflows, however as explained in the two scenarios above in rare circumstances ventilation airflow, required ACH or direct exhaust airflow settings supersede the values computed from the loads.

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Q: I am modeling a Variable Refrigerant Flow (VRF) system in HAP and see that the inputs for cooling equipment efficiency are either EER or SEER, however I would like to enter the IEER to properly account for the part-load efficiency advantages of the particular equipment that I am using. How do I do this?

A: In order to accurately simulate performance of the VRF outdoor units (ODUs), input power at the design rating condition is needed. Once you have input power at design, the HAP model will correct that input power for each hour's operating conditions throughout the year. HAP offers two input options for VRF equipment, as shown in Figure 5, and as described below:

1. Input of an AHRI cooling EER or heating COP at design conditions. HAP will then back-calculate from the EER or COP rating to estimate the input kW at design. During the energy simulation, HAP will automatically derive the compressor and outdoor fan kW from the rating, subtracting the indoor fan power and adjusting for any difference between the AHRI rating condition and the design OAT you specified for this equipment. This can be done relatively accurately, but it is not quite as accurate as directly entering the ODU kW.

2. Direct input of the design input kW for the ODUs. This is the most accurate approach since it directly specifies the kW so no back-calculations are necessary. This kW value represents only the compressor and outdoor fan input power, which should be available in the manufacturer's product literature or using their electronic equipment selection software. The indoor fan power is entered separately under the terminal unit's fan input screen.

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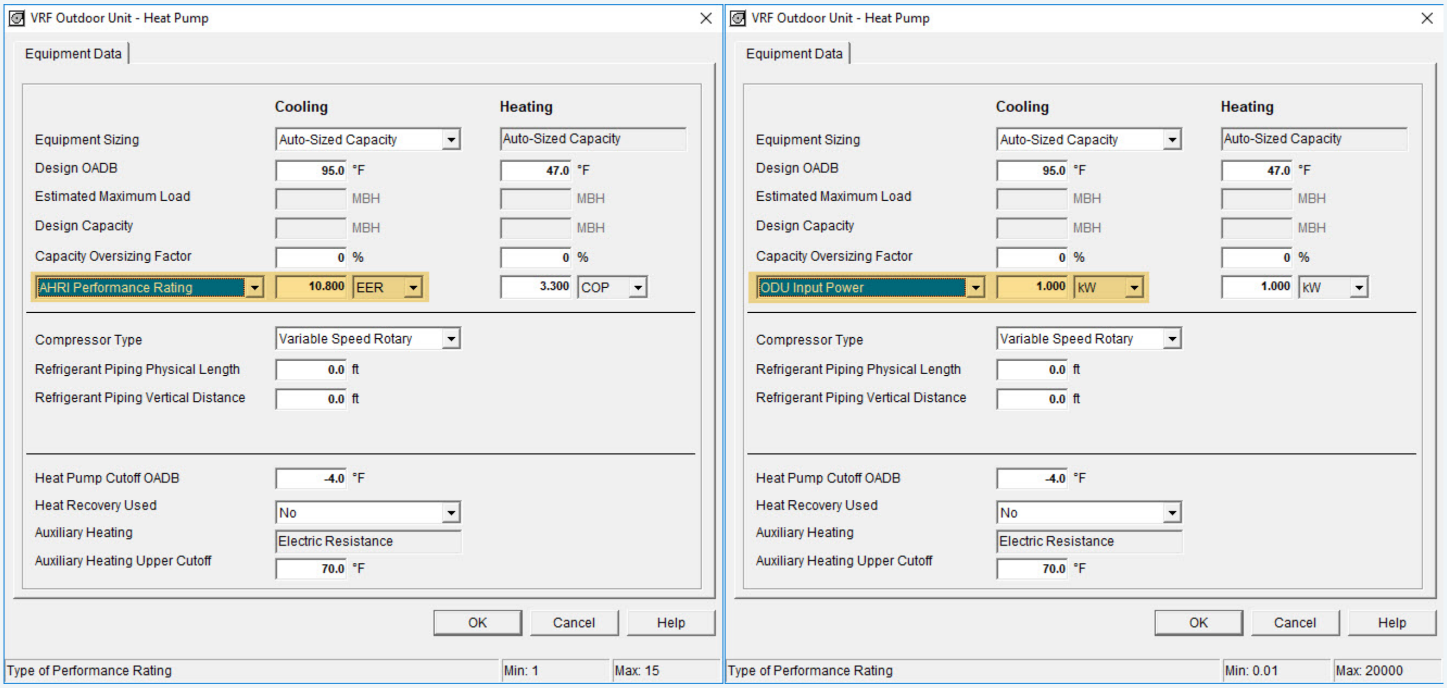

Figure 5. VRF System Cooling Equipment Efficiency & Power Inputs

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The reason for not allowing an IEER input is due to the way the IEER rating is derived. Let's explain further. As previously discussed in the first article in this newsletter, an EER is a ratio of the capacity to the power input at a particular set of test conditions. An IEER (or ICOP for heating efficiency) is a weighted-average of EERs at four part-load operating points (100, 75, 50 and 25%). At each of these part-load points the outdoor ambient condensing temperature is adjusted downward from 95F (at 100%) to 65F at the 25% capacity point. In the IEER equation, most (86%) of the weighting is applied in the 50-75% operating range because most systems spend the majority of their operating hours between these two capacity points and very few hours at peak design or at the minimum operating condition.

So, given a single IEER value there is no way to determine the four individual EERs that are involved in its calculation. Therefore, we cannot back-calculate from IEER to get the design EER to then subsequently back-calculate from design EER to get the input kW at design. That is why HAP requires an input of EER at the design condition only.

HAP takes your design EER input and modifies the equipment efficiency for each hour's operating conditions, so we need to start with the design (certified) rating as a credible anchor point such as the AHRI EER. The VRF system model in HAP then uses performance curves that consider how equipment efficiency varies with operating conditions. For cooling duty those conditions are part-load ratio, outdoor air dry-bulb, indoor unit entering wet-bulb temperature, refrigerant line length and heat recovery. For heating duty those conditions are part-load ratio, outdoor air dry-bulb, outdoor air humidity (for defrost cycles), indoor unit entering dry-bulb temperature, refrigerant line length and heat recovery. This means the equipment efficiency HAP calculates each hour of the year changes as operating conditions and loads change.

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Upcoming eDesign Suite Training Classes

Location	**Load Calculation for Commercial Buildings** *System Design Load HAP*	**Energy Simulation for Commercial Buildings** *HAP*	**Energy Modeling for LEED® Energy & Atmosphere Credit 1** *HAP*	**Advanced Modeling Techniques for HVAC Systems** *HAP*	**Engineering Economic Analysis** *EEA*	**Block Load Basic** *Block Load*
Chicago, IL	Oct 9	Oct 10	—	Oct 11	—	—
Lenexa, KS	Oct 29	Oct 30	—	Oct 31	—	—
Syracuse, NY	Nov 11	Nov 12	—	—	—	—

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eDesign Suite Software Current Versions (North America)

Program Name		Current Version	Functionality
HAP	Hourly Analysis Program (HAP)	v5.11	Peak load calculation, system design, whole building energy modeling, LEED® analysis
BSO	Building System Optimizer	v1.60	Rapid building energy modeling for schematic design
BLK	Block Load	v4.16	Peak load calculation, system design
EEA	Engineering Economic Analysis	v3.06	Lifecycle cost analysis
RPD	Refrigerant Piping Design	v5.00	Refrigerant line sizing
SDL	System Design Load	v5.11	Peak load calculation, system design

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