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Energy Metrics for Unitary HVAC Equipment

Among the many issues competing for attention across the HVAC industry, keeping up with energy efficiency metrics continues to rise to the top of the list for engineers, contractors, building owners and manufacturers alike. As regulatory frameworks change and performance expectations continue to shift, understanding both current and emerging energy metrics is becoming increasingly important in commercial HVAC design and application.

This EN will take a closer look at the energy metrics used for commercial unitary air conditioners and heat pumps, which are commonly referred to as rooftop units and split systems. These systems are widely used as HVAC solutions because they are relatively straightforward to apply.

The widespread use of rooftop units and split systems makes the energy metrics used to evaluate their performance especially important. Engineers depend on these metrics for equipment selection and code compliance, manufacturers use them to design and position products in a competitive and regulated market, and building owners and operators rely on them to better understand energy use and long-term value.

Energy Metric Evolution

Efficiency ratings for commercial unitary equipment developed over time in response to changes in technology, testing requirements, and market expectations. Early metrics focused largely on full-load performance, or how an HVAC equipment operates when it is operating at design (peak) conditions at or near maximum capacity under standard test conditions. This offered a starting point but did not always reflect how equipment operates in the field. As the industry gained a better understanding of part-load performance—how equipment operates during the more common condition of reduced building demand, when equipment cycles, unloads, stages, or modulates to match the actual load—rating methods began to shift to better reflect actual operation.

That evolution took the industry from simple single point (or full-load) efficiency metrics to energy metrics intended to depict seasonal and part-load performance. While this improved the industry's ability to compare products on a more realistic basis, it also introduced a new layer of complexity. As a result, even seasoned engineers can struggle to keep the acronyms, formulas, and codes straight.

ASHRAE Standard 90.1

HVAC engineers often refer to ASHRAE Standard 90.1 for the minimum energy performance requirements for commercial equipment. Table 6.8.1-1 and Table 6.8.1-2 in this standard establish the minimum efficiency thresholds for a broad range of cooling equipment and heat pumps used in commercial buildings.

Table 6.8.1-1 covers unitary air conditioners, condensing units, and packaged terminal air conditioners, organizing them by equipment type, application, and capacity range. This table uses the applicable energy metric, such as SEER, SEER2, EER, EER2, IEER, or IVEC. For engineers specifying packaged rooftop units, split systems, or other common cooling products, this is typically the first stop for determining whether the equipment meets the efficiency requirements of the standard. Table 6.8.1-2 serves as the companion table for commercial unitary heat pumps.

Together, Tables 6.8.1-1 and 6.8.1-2 form the backbone of ASHRAE Standard 90.1 for this equipment, helping engineers map equipment type to the correct minimum performance requirement during design, specification, and compliance review. But these tables are not just isolated references. They are part of a broader framework that connects AHRI standards, U.S. Department of Energy (DOE) test procedures, and code compliance requirements. They define which efficiency metric applies to each equipment class, under which rating standard, and in which capacity range. A unit can appear efficient in a submittal, but if it is being judged against the wrong table, wrong energy metric, or wrong capacity range, the compliance conclusion can get off track quickly.

Figure 1 illustrates how the industry moved from legacy full-load efficiency metrics to more comprehensive part-load and seasonal performance energy metrics, reflecting a broader shift in the way equipment energy performance is evaluated. By mapping these milestones across time, the figure provides context for understanding not only when specific energy metrics were introduced, revised, or phased out, but also how those changes aligned with the code development process and corresponding industry adoption.

Figure 1. U.S. Department of Energy Regulatory Timeline for Commercial Unitary Products

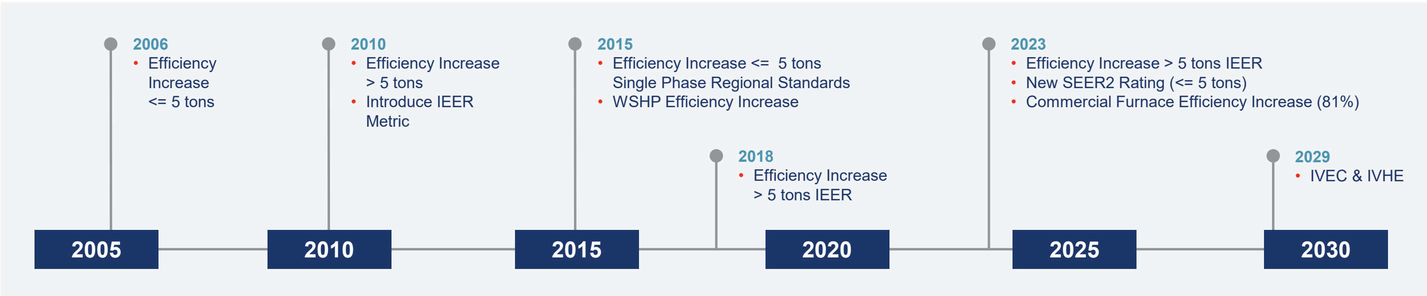


Table 1 complements Figure 1 by providing a more detailed reference of the energy metrics included in ASHRAE Standard 90.1, and the AHRI test standards associated with them, from 2007 through 2025. Rather than serving as a simple timeline, the table functions as a cross reference, showing which energy metrics applied during each code cycle and which test procedures govern their verification. Together, the figure and table offer both a high level and detailed view of how ASHRAE Standard 90.1 efficiency requirements have evolved over time, helping connect changes in regulatory language with the underlying rating methodologies used by manufacturers.

Table 1. ASHRAE Standard 90.1 Commercial Unitary Equipment Energy Metrics List

Unitary Air Conditioning & Heat Pump (Unitary) Equipment Energy Metrics					ASHRAE Standard 90.1						
Acronym (Alphabetical)	Name	Definition	Description	AHRII Rating Standard	2007	2010	2013	2016	2019	2022	2025
COP	Coefficient of Performance	A ratio of useful heating or cooling provided to the energy input required to produce it.	COP is a dimensionless efficiency metric commonly used for heat pumps, chillers, and refrigeration systems. Higher values indicate more efficient equipment performance.	AHRI 210/240 (Residential Unitary) AHRI 340/360 (Commercial Unitary)							
COP-H	Coefficient of Performance - Heating	A heating-specific form of COP that measures the ratio of useful heating output to the energy input required to produce it.	COP-H is used to express heating-mode efficiency for equipment such as heat pump. Higher values indicate more efficient heating performance.	AHRI 210/240 (Residential Unitary) AHRI 340/360 (Commercial Unitary)							
COP2-47	Coefficient of Performance 2 at 47°F	An updated heating efficiency metric measured at an outdoor test condition of 47°F under revised test procedures.	COP2-47 is used to indicate heating performance at milder outdoor conditions under newer test procedures and helps describe part of the heat pump heating profile.	AHRI 1340							
COP2-17	Coefficient of Performance 2 at 17°F	An updated heating efficiency metric measured at an outdoor test condition of 17°F under revised test procedures.	COP2-17 is used to indicate heating performance at 17°F using newer rating methods and is useful for evaluating heat pump efficiency in moderate winter conditions.	AHRI 1340							
COP2-5	Coefficient of Performance 2 at 5°F	An updated heating efficiency metric measured at an outdoor test condition of 5°F under revised test procedures.	COP2-5 is used to indicate heating performance under low outdoor temperature conditions using newer rating methods. It helps characterize cold-weather heat pump efficiency.	AHRI 1340							
EER	Energy Efficiency Ratio	A measure of cooling capacity divided by the electrical power input at a specific set of rating conditions.	EER reflects equipment efficiency at a single operating point, typically under peak load conditions. It is commonly used to evaluate steady-state cooling performance.	AHRI 210/240 (Residential Unitary) AHRI 340/360 (Commercial Unitary)							
EER2	Energy Efficiency Ratio 2	An updated version of EER based on revised rating conditions and test procedures intended to better reflect actual operating conditions.	EER2 provides a more current measure of full-load cooling efficiency under the newer testing framework. Like SEER2, EER2 values are generally not directly interchangeable with older EER values.	AHRI 1340							

Table 1. **ASHRAE Standard 90.1 Commercial Unitary Equipment Energy Metrics List Continued**

Unitary Air Conditioning & Heat Pump (Unitary) Equipment Energy Metrics					ASHRAE Standard 90.1						
Acronym (Alphabetical)	Name	Definition	Description	AHRII Rating Standard	2007	2010	2013	2016	2019	2022	2025
HSPF	Heating Seasonal Performance Factor	A measure of the total heating output of a heat pump over a typical heating season divided by the total electric energy input during the same period.	HSPF represents seasonal heating efficiency for heat pumps. Higher values indicate better heating-season energy performance.	AHRI 210/240 (Residential Unitary)							
HSPF2	Heating Seasonal Performance Factor 2	An updated version of HSPF based on revised test procedures intended to better reflect real-world operating conditions.	HSPF2 provides a more representative measure of seasonal heating efficiency under newer testing standards. Because the test procedure is more stringent, HSPF2 values are generally lower than equivalent HSPF values for the same equipment.	AHRI 210/240 (Residential Unitary)							
IEER	Integrated Energy Efficiency Ratio	A measure of cooling efficiency that accounts for performance at multiple load points, weighted to reflect typical operating conditions.	IEER is commonly used for unitary air-conditioning and heat pump equipment to better represent part-load performance in real-world operation. Higher values indicate better overall seasonal and part-load efficiency.	AHRI 340/360 (Commercial Unitary)							
IPLV	Integrated Part-Load Value	A single-number efficiency metric that represents cooling performance at multiple load points, weighted to reflect typical operating conditions.	Used to indicate expected real-world part-load efficiency, since rooftop and unitary equipment often operates below full load for much of the year.	AHRI 340/360 (Commercial Unitary)							
IVEC	Integrated Ventilation Efficiency for Cooling	A metric intended to represent cooling-related ventilation efficiency under integrated or varying operating conditions.	IVEC is used to characterize how effectively a system provides cooling performance in conjunction with ventilation requirements, particularly under part-load or integrated operating scenarios.	AHRI 1340							
IVHE	Integrated Ventilation Heating Efficiency	A metric intended to represent heating-related ventilation efficiency under integrated or varying operating conditions.	IVHE is used to characterize how efficiently a system delivers heating performance while also meeting ventilation requirements under integrated operating conditions.	AHRI 1340							
IVHE-C	Integrated Ventilation Heating Efficiency - Combined	A metric intended to represent combined heating efficiency performance for systems providing ventilation and heating under integrated operating conditions.	IVHE-C is used to characterize how efficiently a system delivers heating in conjunction with ventilation functions when evaluated as an integrated system.	AHRI 1340							
SEER	Seasonal Energy Efficiency Ratio	A measure of the cooling output of an air conditioner or heat pump over a typical cooling season divided by the total electric energy input during that same period.	SEER represents seasonal cooling efficiency across a range of outdoor temperatures and operating conditions. Higher values indicate greater cooling-season energy efficiency.	AHRI 210/240							
SEER2	Seasonal Energy Efficiency Ratio 2	An updated version of SEER based on revised test procedures intended to better reflect real-world external static pressure conditions.	SEER2 provides a more representative measure of seasonal cooling efficiency under newer testing standards. Because the test method is more stringent, SEER2 values are generally lower than equivalent SEER values for the same equipment.	AHRI 210/240							

EER

Now, let's dive in and start at the beginning with EER (Energy Efficiency Ratio). EER is a full-load cooling efficiency metric used to express how efficiently an air conditioning unit produces cooling at a single set of operating conditions. In simple terms, it tells you how many Btu/h of cooling a unit delivers for each watt of electrical input it consumes.

$$EER = \frac{\textit{Net Total Cooling Capacity (Btu/h)}}{\textit{Effective Power Input (W)}}$$

That may look simple and mathematically it is, but as every engineer knows the real fun begins when someone asks, "at what conditions?" For air-cooled commercial unitary equipment, the EER rating point is based on:

- Outdoor Air Temperature: 95°F dry bulb
- Evaporator Entering Air Conditions: 80°F dry bulb / 67°F wet bulb

EER is associated with full-load performance and has historically been used as a key energy metric for evaluating commercial unitary equipment. EER has been used for products rated by AHRI Standard 340/360, which covers commercial unitary air-conditioning equipment with a cooling capacity of 65,000 Btu/h or greater.

SEER

Products with cooling capacities below 65,000 Btu/h are rated under AHRI Standard 210/240 using SEER (Seasonal Energy Efficiency Ratio).

$$SEER = \frac{\Sigma \text{Cooling output over the season (Btu)}}{\Sigma \text{Electrical energy consumed over the season (W-h)}}$$

SEER describes how efficiently an air-conditioning system or heat pump delivers cooling over an entire cooling season rather than at a single operating point. Because it reflects performance across a range of outdoor temperatures and part-load conditions, SEER provides a more realistic indication of expected seasonal efficiency than a single point efficiency test like EER.

EER2

EER2 (Energy Efficiency Ratio 2) is an updated full-load cooling efficiency metric defined by AHRI Standard 1340, the newer rating standard for unitary air conditioners and heat pumps. Like EER, it expresses the ratio of net cooling capacity to electrical power input at a single rating condition: 95°F outdoor air dry-bulb temperature and 80°F dry bulb / 67°F wet bulb entering the evaporator. The key difference is that EER2 is based on a more stringent test method, including increased external static pressure assumptions, so its values are generally lower than legacy EER ratings for similar equipment.

Why does EER or EER2 matter? Because it provides a clean, direct snapshot of full-load cooling efficiency. It does not attempt to represent every operating hour throughout the year. Instead, it gives engineers a defined reference point for verifying compliance and understanding how a unit behaves when the load is high.

IEER

IEER (Integrated Energy Efficiency Ratio) was introduced in 2010 and adopted as an integrated energy metric that weighs efficiency across several load points, providing a more realistic indication of expected field performance. By evaluating equipment efficiency at 100%, 75%, 50%, and 25% load, and applying weighting factors that represent these various operating conditions, IEER provides a more representative measure of part-load cooling performance. This is because most unitary cooling equipment and heat pumps rarely operate at full load for extended periods of time. For years, EER was the only metric available to compare the efficiencies of various products. Although EER provided a standardized measure of full-load cooling efficiency, it did not adequately represent the part-load behavior that dominates the operating profile of most commercial unitary equipment. In short, if EER tells engineers how a unit performs on a hot design afternoon, IEER provides a clearer picture of how that same unit performs over a range of operating conditions.

A simplified summary of IEER rating conditions is that air conditions entering the evaporator are maintained at standard cooling rating conditions (80°F dry bulb / 67°F wet bulb), while the outdoor ambient temperature is reduced as the load point decreases. Unit efficiency is measured at four operating points:

A = 100% load at 95°F outdoor dry bulb

B = 75% load at 81.5°F outdoor dry bulb

C = 50% load at 68°F outdoor dry bulb

D = 25% load at 65°F outdoor dry bulb

The four results are subsequently weighted into a single integrated efficiency value (see formula below). As the outdoor temperature decreases, the unit is evaluated at correspondingly lower load fractions, allowing the IEER rating to capture the benefits or shortcomings of part-load operation. For equipment with good compressor staging, efficient fan turndown, intelligent unloading, and well-tuned refrigeration circuits, these test points can reveal meaningful performance advantages that an EER value would not fully show.

$$IEER = (0.020 \times A_{100}) + (0.617 \times B_{75}) + (0.238 \times C_{50}) + (0.125 \times D_{25})$$

Where:

A = efficiency at 100% load / 95°F outdoor dry bulb

B = efficiency at 75% load / 81.5°F outdoor dry bulb

C = efficiency at 50% load / 68°F outdoor dry bulb

D = efficiency at 25% load / 65°F outdoor dry bulb

One of the first things that stands out in this formula is that the 75% load point carries the heaviest weighting factor, which is 61.7%. This formula is the industry's way of representing that most rooftop units spend more time in the middle of the operating envelope versus 100% capacity. Each of these values is determined under specified test conditions defined by the applicable rating standard.

For engineers, this weighting matters because it rewards equipment that performs efficiently under the conditions where it is most likely to operate. A unit with only modest full-load EER can still achieve a high IEER if it provides good unloading capability and efficient fan turndown at part-load conditions. Conversely, a product with a higher EER but weaker part-load performance may appear less favorable when evaluated using IEER.

IPLV

This emphasis on part-load operation was first reflected in IPLV (Integrated Part-Load Value), a precursor to IEER that was used in ASHRAE Standard 90.1-2007. Although IPLV was replaced by IEER in 2010, it was the first metric to highlight the importance of capturing part-load performance.

$$IPLV = 1 / ((0.1 \times A_{100}) + (0.42 \times B_{75}) + (0.45 \times C_{50}) + (0.12 \times D_{25}))$$

Where:

A = efficiency at 100% load / 95°F outdoor dry bulb

B = efficiency at 75% load / 81.5°F outdoor dry bulb

C = efficiency at 50% load / 68°F outdoor dry bulb

D = efficiency at 25% load / 65°F outdoor dry bulb

Newest Metrics

IVEC (Integrated Ventilation, Economizer, and Cooling Efficiency) and **IVHE (Integrated Ventilation and Heating Efficiency)** are new metrics designed to capture system performance more holistically. Rather than looking only at cooling or heating performance, these energy metrics account for how ventilation and economizer operation affect overall efficiency. These energy metrics reflect the fact that modern HVAC systems do more than heat or cool a space. They also bring in outdoor air for ventilation and, when conditions allow, use economizer controls to reduce mechanical cooling demand. As a result, IVEC and IVHE provide a more complete picture of actual performance by recognizing how these functions interact within the system.

The formula shown in Figure 2 from AHRI Standard 1340 defines IVEC as a weighted efficiency metric (IVHE is discussed further on page 7.

Figure 2. AHRI Standard 1340 - IVEC Formula

6.2.9 Cooling Annualized Efficiency Metric Calculation (IVEC)

Calculate *IVEC* in units of Btu/(W·h) using Equation 21.

$$IVEC = \frac{977.658 \times q_{t,A} + 185 \times q_{t,adj,B} + 862 \times q_{t,adj,C} + 1293 \times q_{t,adj,D}}{E_B + E_C + E_D + E_V + E_S}$$

Where:

$q_{t,A}$	=	The *cooling capacity* measured for the full-load cooling test in Section 6.2.5, Btu/h
$q_t,adj,_B$	=	Capacity adjustment for cooling bin B, determined in Section 6.2.6.2.2, Section 6.2.6.3.2, or Section 6.2.6.4.2, as applicable, Btu/h
$qAt,adj,_C$	=	Capacity adjustment for cooling bin C, determined in Section 6.2.6.2.2, Section 6.2.6.3.2, or Section 6.2.6.4.2, as applicable, Btu/h
$qt,A,adj,_D$	=	Capacity adjustment for cooling bin D, determined in Section 6.2.6.2.2, Section 6.2.6.3.2, or Section 6.2.6.4.2, as applicable, Btu/h
E_B	=	Energy consumption for cooling bin B calculated in Section 6.2.6.5, W·h
E_C	=	Energy consumption for cooling bin C calculated in Section 6.2.6.5, W·h
E_D	=	Energy consumption for cooling bin D calculated in Section 6.2.6.5, W·h
E_V	=	Ventilation energy consumption calculated in Section 6.2.7, W·h
E_S	=	Standby energy consumption calculated in Section 6.2.8, W·h

IVEC measures the performance of a unit at multiple operating points, applies weighting factors to each point, and combines them into a single value, with a higher value being better. AHRI Standard 1340 was developed through a collaborative process by the U.S. Department of Energy and industry stakeholders. The Appliance Standards Rulemaking Advisory Committee, specifically the Commercial Unitary Air Conditioners and Heat Pumps Working Group, oversaw the development process.

IVEC compares the total cooling delivered over multiple operating conditions to the total electrical energy used over those same conditions.

$$IVEC = \frac{\textit{Total Annual Cooling Capacity (Btu)}}{\textit{Total Annual Cooling Energy (Mechanical Cooling + Economizer + Ventilation Fan Energy + Controls + Crankcase Heat) (W-h)}}$$

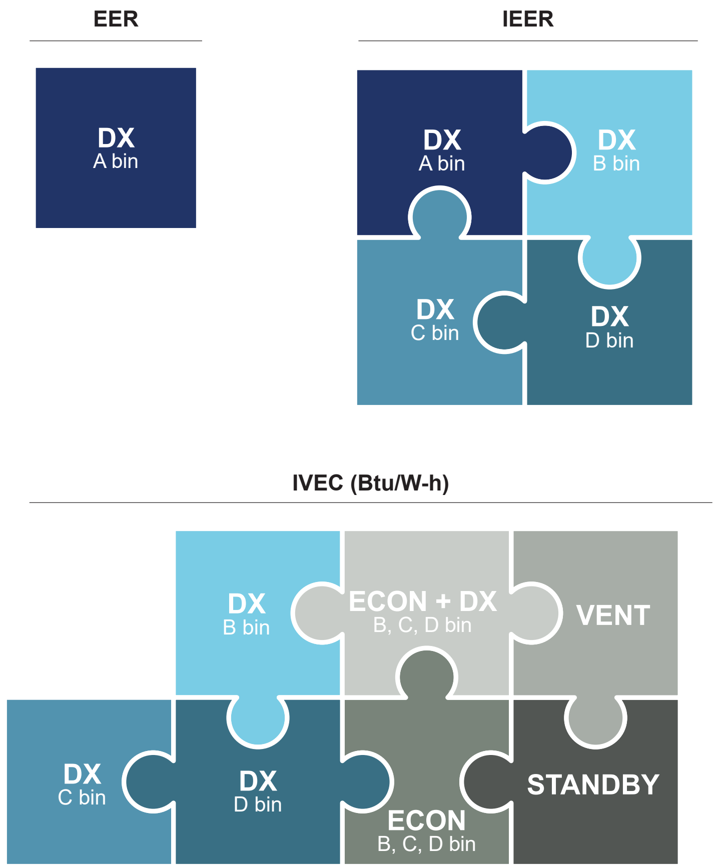
The various components of IVEC can be viewed individually as illustrated in Figure 3 where each term in the formula represents part of the equipment's overall performance, and each operating point adds another component to the result. The individual components may not mean much on their own, but once they are assembled correctly, they reveal a complete picture of expected performance across real operating conditions.

A commonly asked question is, "Is there a direct correlation between IEER and IVEC?" The short answer is no, and there is no direct one-to-one relationship between the two metrics. A unit can have a high IEER and a lower IVEC, or vice versa. While both metrics are intended to reflect part-load performance, IVEC expands the evaluation beyond what IEER captures. In addition to part-load cooling efficiency, IVEC accounts for factors such as ventilation, economizer operation, standby operation, and a greater contribution from fan energy. As a result, IVEC provides a better assessment of real-world unit performance, which is why its relationship with IEER is not strictly linear.

It can be difficult to keep EER, IEER, and IVEC straight. One way to think about these metrics is as pieces of an efficiency puzzle as shown in Figure 3.

EER represents full-load energy efficiency and provides the foundational piece. With the transition to IEER, additional pieces were added to better represent part-load energy efficiency. IVEC adds still more pieces, further expanding the picture of real-world performance.

Figure 3. Commercial Unitary Cooling Energy Metric Components



Heat Pumps

Heat pumps deserve special attention because they operate differently from conventional cooling-only equipment and are becoming more popular. As engineers design more systems with heat pumps, COP (Coefficient of Performance) becomes an important metric for understanding efficiency.

COP

COP depicts how much heating or cooling a heat pump delivers compared with the energy it consumes (see formula below). For example, a COP of 3.0 means the system provides three units of thermal energy for every one unit of electrical energy used. This helps show why heat pumps are often more efficient than electric resistance heating (which has a COP of 1.0).

COP = Heat Delivered (W) or Btu/h / Electrical Energy Consumed (W or Btu/h, Same)

COP_{47} = Heat Delivered (W) or Btu/h / Electrical Energy Consumed (W or Btu/h, Same) at 47°F Ambient

COP_{17} = Heat Delivered (W) or Btu/h / Electrical Energy Consumed (W or Btu/h, Same) at 17°F Ambient

COP_{5} = Heat Delivered (W) or Btu/h / Electrical Energy Consumed (W or Btu/h, Same) at 5°F Ambient

As the outdoor air temperature drops, the COP of a heat pump decreases because there is less available heat in the outdoor air to capture and transfer indoors. In other words, the colder it gets outdoors, the harder the heat pump must work to deliver the same amount of heating capacity. To account for this, heat pumps are rated at multiple outdoor test conditions rather than at just one point. Standard ratings are typically based on outdoor temperatures of 47°F and 17°F (low ambient heat pumps may also be rated at 5°F) and expressed as COP_{47}, COP_{17} and COP_{5}. These rating points help engineers better understand how heat pump performance changes as conditions become more demanding. Instead of viewing COP as a fixed value, it is more accurate to see it as an energy metric that varies with outdoor temperature and operating conditions.

HSPF

Next, let's consider HSPF (Heating Seasonal Performance Factor) for heat pumps. Whereas COP describes performance at a single operating condition, HSPF is intended to represent heating efficiency over an entire season. HSPF is defined as the ratio of the total seasonal heating output provided by the heat pump to the total electrical energy consumed over that same period.

HSPF = Total seasonal heating output (Btu) / Total seasonal electrical energy input (W-h)

HSPF indicates how much seasonal heating the unit delivers for each watt-hour of electrical energy consumed. As with other efficiency metrics, a higher HSPF indicates better seasonal heating performance.

IVHE

Finally, IVEC's companion metric for heat pumps is IVHE (Integrated Ventilation and Heating Efficiency). IVHE is a new annualized heating season efficiency metric developed for commercial unitary heat pumps with a cooling capacity of 65,000 Btu/h and above. Unlike traditional full-load COP ratings, IVHE is designed to reflect real-world annual performance by accounting for the heat delivered by the DX (direct expansion) heat pump plus any supplemental/auxiliary electric heat needed to meet the building load across a full heating season.

IVHE is calculated by dividing total heating capacity by the total annual energy consumed in heating mode (see formula below). This includes compressor power, defrost energy impacts, indoor and outdoor fan power, controls power, crankcase heater power, and auxiliary/supplemental electric heat. Importantly, IVHE also incorporates the energy used by the supply fan for continuous (or scheduled) ventilation during all hours with a heating load, regardless of whether the heat itself is operating.

$$IVHE = \frac{\textit{Total Annual Heating Capacity (DX Heat Pump + Auxiliary / Supplemental Heat) (Btu)}}{\textit{Total Annual Heating Energy (Mechanical Heating + Auxiliary Heat + Defrost + Ventilation Fan Energy + Controls + Crankcase Heat) (W-h)}}$$

Both IVHE and IVEC are defined, tested, and rated under AHRI Standard 1340. This standard specifies the outdoor air temperature, bin hours, building load profiles, test conditions, and calculation procedures required to determine the energy metric. Because IVHE captures part-load operation, defrost impacts, auxiliary/supplemental heat contribution, and ventilation fan energy, it represents the whole picture of seasonal energy use. Unlike COP, which is an energy metric at a specific operating temperature, IVHE is a seasonal, integrated metric based on weighted building load bins that represent typical commercial building heating loads and U.S. climate conditions that represent the national average. A colder climate variant, $IVHE_C$ uses a load profile weighted toward Climate Zones 5 through 8. IVHE and $IVHE_C$ are expressed in Btu/W-h with a higher value indicating better performance.

Summary

Energy metrics are far more than acronym heavy shorthand; they are the framework engineers use to compare products, verify compliance, and better predict real-world performance. From familiar full-load measures like EER and COP, to more comprehensive seasonal and integrated metrics, such as IEER, IVEC, and IVHE, the industry continues to move toward ratings that better reflect how equipment truly operates in the field. For design engineers, understanding what each energy metric represents is essential to making sound design decisions in an increasingly regulated and performance-driven market.

By Greg DuChane, applications engineer, Trane. You can find this and previous issues of the *Engineers Newsletter* at www.trane.com/EN. To comment, send e-mail to ENL@trane.com.

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