Heat Pump Glossary of Terms

Technical Information

This glossary of terms is a valuable resource tailored for professionals working with residential heat pumps, aiming to clarify the complex terminology often encountered within the industry.

Whether you are a program administrator navigating the intricacies of heat pump systems, or an experienced contractor looking to expand your knowledge, this resource will equip you with the foundational knowledge needed to understand the terminology you may encounter.

Each entry is carefully selected to offer clarity and understanding, ensuring that you are thoroughly prepared to grasp the terminology encountered in your work.

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Performance and Efficiency Metrics

Performance and efficiency metrics are essential indicators utilized to quantify the operational performance and energy efficiency of heat pump systems under different conditions and applications. These metrics encompass a range of key terms that quantify how efficiently a heat pump transfers heat and manages energy consumption under different scenarios, such as heating and cooling modes, varying outdoor temperatures, and part-load conditions. These metrics are typically prominently displayed on labels, such as Energy Guide labels in the United States, to provide consumers with clear information about the system's energy performance and efficiency standards. In this section, we explore terminology related to heat pump performance and efficiency.

Coefficient of Performance (COP)

The coefficient of performance (COP) is a metric that captures how efficiently a heat pump uses electricity to move heat from one place to another. Specifically, the COP is the ratio of the useful energy output of the system (i.e., heating or cooling) to the electrical energy needed for the system to operate. A higher COP means that less energy is required for the same output. For air-source heat pumps, the COP is higher at higher outdoor temperatures during heating mode and at cooler outdoor temperatures during cooling mode, as a smaller temperature difference between the indoor and outdoor environments (delta-T) results in higher efficiency. COP is measured under specific standardized conditions to ensure consistency and comparability between different systems.

Seasonal Coefficient of Performance (SCOP)

The seasonal coefficient of performance (SCOP) is a metric that captures the overall efficiency of a heat pump over an entire heating or cooling season. Unlike the coefficient of performance (COP), which measures efficiency at a specific operating point, the SCOP accounts for variations in temperature and operating conditions throughout the year. Specifically, the SCOP is the ratio of the total useful energy output of the system (i.e., heating or cooling) to the total energy needed for the system to operate over a season. A higher SCOP means that less energy is required for the same output over the course of a year. This metric provides a more comprehensive view of a heat pump’s real-world performance and energy efficiency, considering local climate conditions and seasonal variations. For air-source heat pumps, the SCOP reflects how the system performs across a range of temperatures, providing a more accurate measure of its efficiency and potential energy savings in varying seasonal conditions.

Heating Seasonal Performance Factor (HSPF & HSPF2)

The Heating Seasonal Performance Factor (HSPF & HSPF2) is a metric that quantifies heat pump heating operation efficiency. It is the measure of a heat pump’s efficiency during the heating season. HSPF & HSPF2 ratings are calculated by dividing the total heating output during the heating season (measured in BTUs) by the total watt-hours of energy consumed during these months (measured in kWh). The higher the unit’s HSPF & HSPF2 rating, the more energy efficient it is. The rated/nameplate HSPF & HSPF2 are based on the temperature in IECC climate zone IV.

Seasonal Energy Efficiency Ratio (SEER & SEER2)

The Seasonal Energy Efficiency Ratio (SEER & SEER2) is a metric that quantifies the efficiency of heat pump cooling operation over the course of one year. More specifically, it is the cooling output (measured in (BTUs) during a typical cooling season (in a specific testing environment) divided by the total electric energy consumed (measured in watt-hours) during the same period. The higher a unit's SEER & SEER2 rating, the more energy efficient it is. The rated/nameplate SEER & SEER2 are based on the temperature in IECC climate zone IV.

Energy Efficiency Ratio (EER & EER2)

The Energy Efficiency Ratio (EER) of a heat pump is the ratio of output cooling energy (in BTU) to input electrical energy (measured in watt-hours) at a given operating point. EER is normally calculated with a 95°F outside temperature and an inside (return air) temperature of 80°F and 50% relative humidity. The higher a unit's EER & EER2 rating, the more energy efficient it is at peak cooling conditions.

Note: EER2 became the new efficiency metric standard for product regulation in 2023. The DOE periodically evaluates energy efficiency levels, available technology and the economic impact of changing standards. In the case of EER2, they determined that changes to the test procedure to better represent the average use cycle were warranted. They also determined that higher efficiency levels were technologically feasible and economically justified. The main difference between the EER2 and EER ratings is the testing conditions for each rating system. The new testing conditions produced different data values and warranted a new rating system.

Heat Pump Performance and Sizing

Understanding the key performance metrics and measurement units related to heat pump capacity is crucial for properly sizing and selecting the right system to meet a building's heating and cooling needs. Capacity ratings quantify how much heating or cooling a heat pump can provide, while heating and cooling loads determine the amount of heating or cooling actually required for a given space. Properly calculating these loads and matching them to the heat pump's rated capacities is essential for ensuring optimal comfort, efficiency, and energy savings. This section explores terms related to fundamental concepts and units used to evaluate heat pump performance and sizing.

BTU (British Thermal Unit)

BTU stands for British Thermal Unit, and it is a unit of measurement used to quantify heat energy. Specifically, a BTU is defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. When it comes to heat pumps, BTUs are important because they measure the heating or cooling capacity of the system. For heating, the BTU rating indicates how much heat the heat pump can transfer into a space during a certain period, usually an hour (BTU/hr). For cooling, it indicates how much heat the heat pump can remove from a space. The BTU rating of a heat pump is a key factor in determining its efficiency and effectiveness in heating or cooling a given area. Higher BTU ratings generally mean the heat pump can manage larger spaces or provide more heating/cooling power, though efficiency and proper sizing for the specific application are also critical considerations.

Ton of Refrigeration

A ton of refrigeration is a unit used to measure the cooling capacity of a heat pump system. It represents the amount of heat energy that the system can remove from a space in one hour. One ton is equal to 12,000 British Thermal Units (BTUs) of cooling capacity per hour. When choosing a heat pump for a space, the tonnage rating is crucial. It indicates how effectively the system can cool a space, with higher tonnage numbers implying greater cooling capacity. Proper sizing ensures that the heat pump can efficiently maintain comfort levels without unnecessary energy consumption or strain on the system.

Heating Capacity

The heating capacity of a heat pump refers to the amount of heat energy that the system can transfer from the outdoor environment into a building's interior to provide heating. Heating capacity is measured in BTU/hr or kW, providing a standardized way to compare different heat pump models and understand their heating capabilities under various conditions. When the "size" of a heat pump is referenced, it is often in reference to the heat pump's heating and/or cooling capacity.

Note: Manufacturers specify heating capacity ratings based on standardized conditions to provide a benchmark for comparison. Heating capacity is not constant and typically varies *with outdoor temperatures. In general, the heating capacity of a heat pump decreases as the outdoor temperature drops. This is because the efficiency of heat transfer decreases at lower temperatures, requiring the system to work harder to extract heat from the outdoor air. Heat pumps are designed to operate effectively across a range of temperatures, but their ability to provide sufficient heating capacity may diminish in extremely cold climates or during temperature extremes.*

Cooling Capacity

The cooling capacity of a heat pump refers to the rate at which the system can remove heat from a space and transfer it outdoors, effectively providing cooling. It is typically measured in British Thermal Units per hour (BTU/hr) or tons of refrigeration (12,000 BTU = 1 ton). The cooling capacity of a heat pump depends on factors such as outdoor temperature, indoor temperature set points, airflow rate, and the efficiency of the refrigerant cycle. When the “size” of a heat pump is referenced, it is often in reference to the heat pump's cooling and/or heating capacity.

Note: Manufacturers specify cooling capacity ratings based on standardized conditions to provide a benchmark for comparison. Understanding the cooling capacity of a heat pump is essential for selecting the right system size to match the cooling load of a building. Proper sizing ensures efficient operation, optimal comfort levels, and energy savings during the cooling season.

Capacity Maintenance

Capacity maintenance is a ratio that often refers to what percentage of heating capacity an air source heat pump provides at colder temperatures compared to its rated capacity at 47°F. This ratio is often communicated for outdoor air conditions at 17°F, 5°F, and lower.

Load Calculation

A load calculation is a method of determining the heat gain and loss of a home or building so that heat pump equipment is properly sized. A building’s heating or cooling design load is based on how well-insulated the building is and in what climate it is located. It represents the amount of heating or cooling capacity that is needed during the coldest or hottest day of an average year to keep the interior of the space comfortable. Properly calculating heating and cooling loads is necessary to choose the right heat pump. Calculating heating and cooling loads typically involves using methods like Manual J calculations, which account for different factors to estimate the heat loss and gain from the building. This calculation is crucial for sizing a heat pump system appropriately—undersized systems may struggle to keep up with heating and cooling demands, while oversized systems can be inefficient and costly to operate.

Note: Oversizing can lead to excessive cycling, low efficiency, shortened equipment life, and ineffective summer dehumidification. Under sizing can result in overreliance on backup heat, or inadequate summer cooling and increase energy costs.

Design Condition (also referred to as "Design temperature")

The design condition or design temperature for a heat pump is used during the design and sizing stage to ensure the system can maintain indoor comfort under typical extreme weather conditions specific to a location. It involves calculating the heating and cooling loads based on the lowest and highest outdoor temperatures the heat pump will encounter. This information guides the selection of the appropriate heat pump size and capacity, preventing it from being oversized or undersized. Additionally, it influences the overall system design, including ductwork, insulation, and controls, ensuring that the system performs efficiently and reliably while meeting the building's heating and cooling demands effectively.

Heating Load

In contrast to heating capacity, which refers to the amount of heat energy that a heat pump system can transfer from the outdoor environment into a building's interior to provide heating, heating load is the amount of heat energy that needs to be added to maintain a building's desired temperature setpoint in cold weather. It is determined by factors such as outdoor temperature, building size, insulation levels, and internal heat gains. By accurately assessing heating load, homeowners and HVAC professionals can ensure that the heat pump installed is capable of efficiently meeting the heating needs of the building.

Cooling Load

In contrast to cooling capacity, which measures the amount of heat energy that a heat pump system can transfer from a building's interior to provide cooling, cooling load refers to the total amount of heat energy that must be extracted to maintain a desired indoor temperature setpoint in warm weather. It is determined by factors such as outdoor temperature, building size, insulation levels, solar heat gain, and internal heat sources. By accurately assessing the cooling load, homeowners and HVAC professionals can select a heat pump system that efficiently meets the cooling requirements of the building, ensuring optimal comfort and energy efficiency.

Thermal Balance Point

The outdoor temperature at which the heating load of a building matches the heat pump's output heating capacity is called the thermal balance point. Above the thermal balance point, the heat pump is capable of meeting the building's heating requirements. Below the thermal balance point, the heat pump may not be capable of meeting the building's heating requirements and supplementary heating will be required (such as a fossil-fuel fired furnace). Many modern heat pump controls can automate a safeguard to ensure occupant comfort is always met in heat pump configurations that utilize supplementary heat.

Note: Setting the switchover point for propane applications at the thermal balance point can result in missed savings. This is because the heating load is often overestimated by Manual J calculations or rules of thumb.

Economic Balance Point

The balance point of a heat pump system can also be determined based on economic considerations. The economic balance point is the outdoor temperature at which it is economically desirable to switch from the heat pump system to a back-up heating source (such as a fossil-fuel fired furnace). It is determined based on the estimated costs of heat delivery by the heat pump versus the backup system. Calculation of the economic balance point requires the cost of electricity, cost of backup system fuel, heat pump COP, backup system efficiency, and outdoor temperature.

Heating and Cooling Degree Days (HDD & CDD)

Degree days are measures of how cold or warm a location is. A degree day compares the mean (the average of the high and low) outdoor temperatures recorded for a location to a standard temperature, usually 65° Fahrenheit (F) in the United States. The more extreme the outside temperature, the higher the number of degree days. A high number of degree days generally results in higher energy use for space heating or cooling. HDD and CDD help HVAC professionals and homeowners determine the annual energy use of heat pumps for specific climates. This ensures the heat pump can manage the peak heating and cooling loads efficiently.

Note: Heating degree days (HDDs) are a measure of how cold the temperature was on a given day or during a period of days. For example, a day with a mean temperature of 40°F has 25 HDDs. Two such cold days in a row have 50 HDDs for the two-day period.

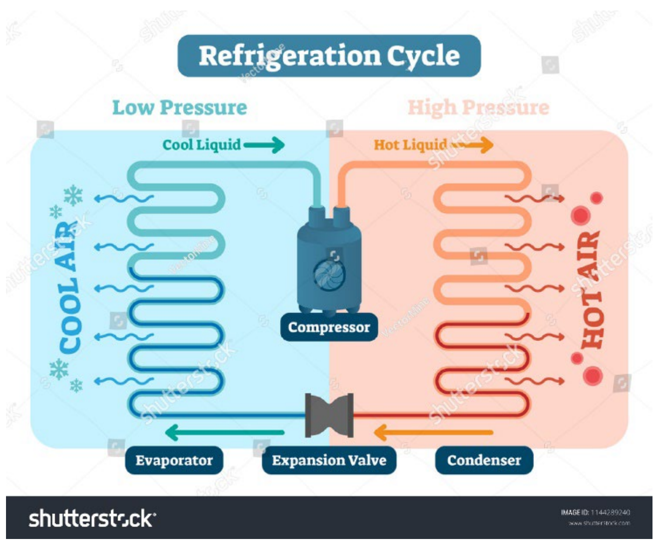
Cooling degree days (CDDs) are a measure of how hot the temperature was on a given day or during a period of days. A day with a mean temperature of 80°F has 15 CDDs. If the next day has a mean temperature of 83°F, it has 18 CDDs. The total CDDs for the two days is 33 CDDs.

Refrigerants

Heat pumps utilize refrigerants as a crucial component in their operation, playing a key role in transferring heat efficiently. Refrigerants enable the heat pump to move heat from one place to another, making them essential for the system's performance. Understanding refrigerants and their function within the heat pump system is vital for grasping how these systems achieve effective heating and cooling. There are different classes of refrigerants used in heat pumps, categorized based on their safety, environmental impact, and efficiency. Regulation of refrigerants is overseen globally by agreements such as the Montreal Protocol and regional regulations that aim to phase out ozone-depleting substances and reduce high Global Warming Potential refrigerants. These regulations drive the adoption of safer, more environmentally friendly alternatives in heat pump technology, ensuring compliance with stringent safety and sustainability standards. In this section, we will explore important terms related to refrigerants.

Refrigeration Cycle

The heat pump refrigeration cycle is the core process by which heat pumps transfer heat between indoor and outdoor environments. This cycle comprises four key components: the evaporator coil, compressor, condenser coil, and expansion valve. These components work together to facilitate the transfer of heat using a refrigerant.



Note: In cooling mode, the heat pump functions by absorbing heat from indoors. The indoor coil acts as the evaporator where the refrigerant, initially a low-pressure, low-temperature gas, absorbs warmth from the indoor air or surroundings, causing it to evaporate. This vapor then moves through the compressor, where it undergoes compression into a high-pressure, high-temperature state. As the refrigerant enters the condenser, it releases heat to the outdoor environment or a heat sink, transforming into a liquid. The expansion valve then regulates the refrigerant's pressure drop, allowing it to return to the evaporator as a low-pressure, low-temperature gas, thereby completing the cycle of cooling. Conversely, in *heating mode, the heat pump reverses the cycle to warm the indoor space. The outdoor coil now acts as the evaporator, where the refrigerant extracts heat from the outdoor air, causing it to evaporate as a low-pressure, low-temperature gas. The compressor then increases the pressure and temperature of the gas, transforming it into a high-pressure, high-temperature state. Upon entering the indoor coil, which now serves as the condenser, the refrigerant releases heat into the indoor environment, turning it into a liquid. Finally, the expansion valve lowers the refrigerant's pressure, returning it to the outdoor coil as a low-pressure, low-temperature gas, ready to repeat the heating cycle.*

Refrigerant Charge

The heat pump refrigerant charge refers to the amount of refrigerant fluid that is present in a heat pump system. This charge is crucial for the system's efficiency and performance. If the refrigerant charge is too low or too high, it can lead to issues such as reduced heating or cooling capacity, increased energy consumption, and potential damage to or failure of the system. Properly maintaining the correct refrigerant charge ensures optimal operation and longevity of the heat pump.

Global Warming Potential (GWP)

Global Warming Potential, or GWP, is a measure of the impact of a substance on global warming relative to carbon dioxide. Refrigerants today are often thousands of times more polluting than carbon dioxide (CO_2). The GWP of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, CO_2, which is assigned a value of 1. GWPs can also be used to define the impact greenhouse gases will have on global warming over different time periods or time horizons. These are usually 20 years, 100 years, and 500 years. High-global warming potential (high-GWP) refrigerants include all ozone-depleting substances and any refrigerant with a GWP of 150 or higher.

Class A1 Refrigerants

A1 refrigerants, classified by ASHRAE as having lower toxicity and no flame propagation, are commonly used in modern heat pump systems. These refrigerants, such as R-410A, are favored for their safety and efficiency in residential heating and cooling applications. Their low toxicity ensures minimal health risks to users and service personnel, while their non-flammable nature enhances overall safety. A1 refrigerants, such as R-410A, are currently under scrutiny due to their relatively high Global Warming Potential (GWP). Manufacturers and policymakers are increasingly focusing on alternative refrigerants, such as A2L (lower flammability) and natural refrigerants (like CO2 and hydrocarbons), which offer comparable or improved performance with significantly lower environmental impact.

Class A2L Refrigerants

A2L refrigerants are classified by ASHRAE as having lower toxicity and lower flammability compared to other classes. These refrigerants, such as R-32 and R-454B, offer a balance between safety and environmental impact. They are increasingly favored for their significantly lower Global Warming Potential (GWP) compared to traditional A1 refrigerants like R-410A. Regulation of A2L refrigerants is stringent, with standards ensuring their safe use and handling in various applications. Their adoption is driven by global agreements and regulations aiming to reduce greenhouse gas emissions, making them a pivotal choice for sustainable heat pump technology.

Class A3 Refrigerants

A3 refrigerants are classified by ASHRAE lower toxicity and higher flammability compared to other classes. These refrigerants, such as R-290 (propane), offer a balance between safety and environmental impact, despite their higher flammability. Despite their higher flammability, these refrigerants are chosen for their excellent thermodynamic properties and exceptionally low Global Warming Potential (GWP). The use of A3 refrigerants in residential heat pumps is more common in regions where regulations and safety standards support their safe handling and application. Manufacturers design these systems to minimize the risks associated with flammability through careful engineering and safety features. Their adoption is driven by global agreements and regulations aiming to reduce greenhouse gas emissions, making them a pivotal choice for sustainable heat pump technology.

Program Administration

The successful implementation and management of heat pump programs requires strong administration practices. Program administrators, typically utilities or state/regional energy efficiency organizations, oversee a range of critical functions to ensure these initiatives achieve their energy-saving goals in a cost-effective manner. Effective program administration encompasses several key elements that are vital for maximizing the impact of heat pump adoption efforts while providing appropriate oversight and quality assurance. These core administrative aspects include program design and planning, customer outreach and marketing, contractor engagement, application processing, quality control inspections, data tracking, regulatory compliance, cost-effectiveness evaluations, and performance measurement and verification. Properly executing these administrative responsibilities is essential for delivering well-run heat pump programs that overcome market barriers, transform markets, and deliver sustained energy and greenhouse gas emissions reductions over time. In this section, we will explore terminology related to program administration.

TRM – Technical Reference Manual

A Technical Reference Manual (TRM) is a comprehensive document that provides standardized methods for calculating energy savings and cost-effectiveness of energy efficiency measures. In heat pump programs, the TRM standardizes assumptions and calculations to ensure consistent and reliable energy savings estimates. It includes detailed algorithms and baseline conditions to assess the impact of heat pump installations. The TRM also aids in evaluating the cost-effectiveness of these programs, ensuring compliance with regulatory standards. Additionally, it supports the design and assessment of incentives and rebates, promoting the adoption of efficient and sustainable heating and cooling solutions.

Note: A statewide TRM contains approved savings values for all energy efficiency measures that could be included in programs in the state. The value of a TRM comes from having all parties working with the same playbook, with values from the TRM being considered non-controversial in most regulatory situations. TRMs should be created with a process for regular and ongoing updates to account for new technologies and changes to federal appliance standards that may change baseline assumptions. In the absence of a statewide TRM, utility-specific measure lists serve the same purpose but may vary between utilities, making the regulatory role more complicated. Utility measure lists often draw on out-of-state TRMs or vendor-supplied values and may lack the specificity of a regularly updated statewide TRM.

Demand Response

Demand response provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives. Integrating heat pumps into demand response programs can be highly beneficial. These programs strategically automate electric usage to reduce consumption during peak demand periods. This not only helps manage grid constraints but also keeps peaking power plants offline, reducing carbon output.

Note: A demand response-enabled heat pump can automatically adjust its operation to reduce energy consumption without compromising occupant comfort. For instance, homes can be pre-heated slightly before the peak period begins, allowing the heat pump to maintain a constant temperature without drawing excessive power during peak hours. The key to effective demand response lies in smart thermostats and connectivity. Modern thermostats can be programmed to communicate with utility systems, receiving signals to adjust temperature settings during peak demand periods. This seamless integration ensures that the demand response process is automated and minimally intrusive for occupants. Not only can thermostats receive signals from grid operators or utility companies to adjust their operation during DR events, but grid connected heat pump equipment also has this capability.

Measurement and Verification (M&V)

Energy and demand savings cannot be directly measured as they represent energy that was not consumed and demand that did not occur. Therefore, energy and demand savings must be calculated. Measurement and Verification (M&V) is the process for determining energy and demand savings using a combination of measured data and calculations. M&V involves planning, measuring, collecting and analyzing data to verify and report energy savings within a facility by implementing energy efficiency measures (such as heat pump installations). In the context of a heat pump retrofit, M&V involves comparing the measured energy usage of the baseline (e.g., existing) heating system with the heat pump's energy usage while adjusting for weather and any other key differences between the baseline and reporting periods.

Cost-Effectiveness Analysis (CEA)

Cost-effectiveness analysis is a fundamental step in the design and evaluation of energy efficiency programs. In its simplest form, energy efficiency cost-effectiveness is measured by comparing the benefits of an investment with the costs. Five key cost-effectiveness tests have, with minor updates, been used for over 20 years as the principal approaches for energy efficiency program evaluation. These five cost-effectiveness tests are the participant cost test (PCT), the utility/program administrator cost test (PACT), the ratepayer impact measure test (RIM), the total resource cost test (TRC), and the societal cost test (SCT). Regulated utilities must demonstrate cost-effectiveness to obtain program approval from the state public utility commission.

Baseline Energy Consumption

Energy savings are the difference between energy consumption with an energy efficiency activity in place and the consumption that otherwise would have occurred during the same period. The consumption that otherwise would have occurred is called the baseline. Establishing baselines for savings is a key challenge of Measurement & Verification because determining the baseline requires identifying the counterfactual, or what would have happened absent the energy efficient activity.

Return on Investment (ROI)

The return on investment (ROI) of heat pump systems is influenced by various factors, including initial investment, energy savings, maintenance costs, and potential government incentives or rebates. By calculating the projected ROI based on estimated energy savings and operational efficiency, users can determine the payback period for their heat pump investment and evaluate the overall financial feasibility of integrating heat pump technology into their heating and cooling systems. A positive ROI signifies the economic advantages and cost savings associated with heat pump installations, making them a practical and lucrative investment for both residential and commercial properties.