MIDWEST
COLLABORATIVE

Heat Pump Glossary of Terms

Part 1. Technical Information

Part 2. Equipment

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.

Bolded terms indicate the definition for that term is available in either Part 1 or Part 2 of the glossary.

Contents

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.

Reliable sources for verified performance data include the AHRI Directory of Certified Product Performance, which lists independently tested and certified equipment, and the NEEP Cold Climate Air Source Heat Pump (ccASHP) Product List, which highlights models meeting specific efficiency and low-temperature performance requirements for the Northeast and Midwest regions. These directories help contractors, utilities, and consumers identify products that meet both federal and regional performance standards.

Weather data, including temperature, humidity, and climate design conditions for locations worldwide, can be accessed through the ASHRAE Climate Data Center at https://ashrae-meteo.info/v2.0, a resource commonly used for building and HVAC system design.

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 and rated 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 (in a specific testing environment). 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 or 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 or HSPF2 ratings are calculated by dividing the total heating output (measured in BTUs) during the heating season (in a specific testing environment) by the total energy consumed during the same period (measured in watt-hours). The higher the unit's HSPF or HSPF2 rating, the more energy efficient it is in heating mode. The rated/nameplate HSPF or HSPF2 are based on the temperatures typical in IECC climate zone IV.

Seasonal Energy Efficiency Ratio (SEER & SEER2)

The Seasonal Energy Efficiency Ratio (SEER or 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 (**BTU**s) 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 or SEER2 rating, the more energy efficient it is in cooling mode. The rated/nameplate SEER or SEER2 are based on the temperatures typical in IECC climate zone IV.

Energy Efficiency Ratio (EER & EER2)

The Energy Efficiency Ratio (EER or EER2) 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 (in a specific testing environment). 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 the unit's EER or EER2 rating, the more energy efficient it is at peak cooling conditions.

Note: HSPF2, SEER2, and EER2 became the new efficiency metrics standards for product regulation in 2023 (and all have moved to the "2" metric). The DOE periodically evaluates energy efficiency levels, available technology, and the economic impact of changing standards. 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 ratings is the use of testing conditions that better reflect real-world operating conditions. 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 maximum **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, the tonnage rating is crucial. Proper sizing ensures that the heat pump has sufficient **cooling capacity** to maintain comfort levels without unnecessary energy consumption or strain on the system from rapid starts and stops.

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, 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 maximum **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 maximum 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 estimating the amount of space conditioning needed to keep a building comfortable in specific conditions. Properly calculating heating and cooling loads is necessary to choose the right heat pump. Calculating heating and cooling loads typically involves using a method like Manual J, which accounts for different factors to estimate the heat loss and gain from the building. Load calculations are crucial for selecting a heat pump system appropriately (using Manual S). Oversizing can lead to excessive cycling, low efficiency, shortened equipment life, and ineffective summer dehumidification. Undersizing can result in overreliance on **auxiliary heat**, or inadequate summer cooling and increase energy costs.

Note: Manual J and Manual S - Both published by the Air Conditioning Contractors of America (ACCA), these manuals are complementary tools for HVAC system design. Manual J provides the methodology for calculating a building's heating and cooling loads, determining how much capacity is needed to maintain comfortable indoor temperatures under varying outdoor conditions. Manual S uses those load calculations to guide the *selection and sizing of HVAC equipment, ensuring the system meets the building's needs without being over- or under-sized. In short, Manual J tells you "How much" heating or cooling is required, and Manual S tells you "What to install".*

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

Heating load is the amount of heat energy that needs to be added to maintain a building's desired indoor temperature setpoint in cold weather. It is determined by factors such as outdoor temperature, building size, insulation levels, and internal heat gains. Heating load is different from **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. By accurately calculating 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

Cooling load refers to the total amount of heat energy that must be removed 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, humidity levels, and internal heat sources. Cooling load is different from **cooling capacity**, which measures the amount of heat energy that a heat pump system can transfer from a building's interior to provide cooling. By accurately calculating 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.

Switchover Temperature

Also known as compressor or heat pump lockout temperature – a common control setting corresponding to the outdoor temperature at which a hybrid heat pump system turns the heat pump off and switches to its auxiliary heat source(s) for heating. The switchover temperature represents the coldest outdoor temperature the system controller allows the heat pump to operate in. The best switchover temperature for a heat pump depends on many factors including economics, auxiliary fuel type, home characteristics, heat pump specifications, other available control features.

Note: Systems with staged heating controls, independently controlled **auxiliary heat**, or **all-electric systems** may not need or have a **switchover temperature** setting at all

Thermal Balance Point

Thermal balance points occur when the heat leaving a space is equal to the heat entering. The outdoor temperature at which the **heating load** of a building matches the heat pump's maximum output **heating capacity** is called the heat pump's 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 **auxiliary or 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 **auxiliary** or **supplementary heat**. A system's **switchover temperature** can be set by the installer or customer based on its economic balance point or the thermal balance point.

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. The temperature where a home's heat loss is equal to its heat gains is also called a thermal balance point.

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 **back-up system**. Calculation of the economic balance point requires the cost of electricity, cost of **back-up system** fuel, **heat pump COP**, **back-up 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 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.

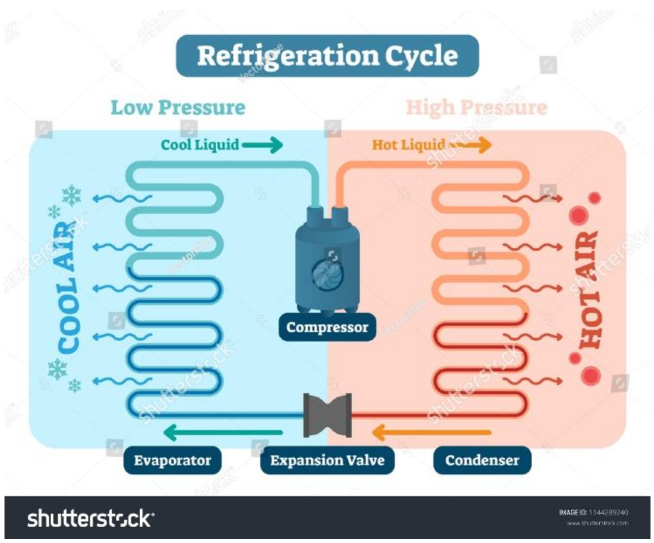
Cooling degree days (CDDs) are a measure of how hot the temperature was on a given day or during a period of days. A day with a mean temperature of 80°F has 15 CDDs. If the next day has a mean temperature of 83°F, it has 18 CDDs. The total CDDs for the two days is 33 CDDs.

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. 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. Proper charge is determined by factors like length of lineset, system size, system specifications, and the type of **refrigerant**.

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 (CO_2). **Refrigerants** today are often thousands of times more polluting than carbon dioxide. High-global warming potential (high-GWP) **refrigerants** include all ozone-depleting substances and any **refrigerant** with a GWP of 150 or higher.

*Note: **Refrigerants** are also classified based on toxicity and flammability. Regulation around the world is trending towards lower GWP **refrigerants***.

Class A1 Refrigerants

A1 **refrigerants**, classified by ASHRAE as having low 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 and natural **refrigerants** (like CO_2 and hydrocarbons), which offer comparable or improved performance with significantly lower environmental impact.

Class A2L Refrigerants

A2L **refrigerants** are classified by ASHRAE as having low toxicity and low flammability compared to all other classes except A1. 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 as low in toxicity and high in flammabilitys. These **refrigerants**, such as R-290 (propane), offer a balance between safety and environmental impact, 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 high demand or 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 modify 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 connectivity with utility systems. Some ***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.* ***Grid-interactive*** *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.

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Part 2. Equipment

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Contents

Table of Contents

Heat Pump Types

A heat pump is a heating and cooling system that moves heat from one place to another (similar to an air conditioner or refrigerator) instead of generating heat directly. During cold weather, it pulls heat from the outdoor air, ground, or nearby water sources such as lakes or ponds, and pumps it inside to warm a building. During hot weather, it reverses the process - it takes heat from inside a building and pumps it outside to provide cooling.

There are several different kinds of heat pump systems used in residential settings. The main differences are where they source their heat from, and how they distribute the heated or cooled air throughout a building. In this section, we will explore the terms used to describe the most frequently encountered types of residential heat pump systems.

Heat Exchange Medium

Air-source Heat Pump (ASHP)

An air-source heat pump is the most common type of heat pump. The heat pump absorbs heat from the outside air and transfers the heat to the space to be heated in the heating mode. In the cooling mode, the heat pump absorbs heat from the space to be cooled and rejects the heat to the outside air. The term "air-source heat pump" is a broad term used to describe a variety of heat pump system configurations that utilize air as the primary medium for heat transfer. These systems include both air-to-air and air-to-water heat pumps (see definitions below). Additionally, distinct distribution methods are employed, such as **hydronic systems** for **air-to-water heat pumps**, ductwork for **ducted** air source heat pumps, and individual blower heads (wall, ceiling, or floor mounted) for **ductless air-source heat pumps**.

- **Air-to-air Heat Pump**

An air-to-air heat pump is a type of air source heat pump system that uses forced air distribution. It operates by transferring heat between the indoor air and outdoor air directly using refrigerant.

- **Air-to-water Heat Pump**

  Air-to-water heat pumps exchange heat with the outdoor air but distribute the heat indoors through a **hydronic system**. All air-to-water heat pumps provide heating, and some can also provide cooling. To provide heating, air-to-water heat pumps extract heat from the outdoor air, transfer the heat to water, and circulate the water through radiators, fan coils, and/or in-floor loops. Air-to-water heat pumps have the potential of also heating domestic hot water, unlike typical **air-source heat pumps**. They can provide cooling if they are connected to a cooling system that can use chilled water, like a **hydronic** fan **coil**.

- **Cold-climate Air-source Heat Pump (ccASHPs)**

  Cold climate air source heat pumps are an iteration of traditional heat pump technology, engineered to efficiently heat homes in extremely cold conditions, typically at or below 5°F, while also providing cooling during warmer seasons. These heat pumps utilize advanced technology and enhanced components, such as variable-speed, inverter-driven **compressors** to maintain comfort and energy efficiency in challenging climates. They offer a sustainable alternative to traditional heating systems by leveraging electric power and renewable energy sources, reducing reliance on fossil-fuels and lowering greenhouse gas emissions.

  Note: To promote the adoption of cold climate heat pump technologies and address the challenges of heating in colder climates, the U.S. Department of Energy launched the Cold Climate Heat Pump Technology Challenge*. This initiative aims to accelerate the development and deployment of high-performance* cold climate heat pump systems*. Additionally, NEEP maintains a list of cold climate air source heat pumps that meet specific performance criteria. The list includes heat pump models that are well-suited for efficient heating in IECC climate zone 4 and higher, which encompasses regions with extended periods of cold temperatures*.

  - **Geothermal Heat Pump (also referred to as “Ground source, Water-source, Water-to-water, Water-to-air, GeoExchange, and Earth-coupled heat pumps”)**

Geothermal heat pumps are similar to **air-source heat pumps**, but instead of using heat found in outside air, they rely on the relatively constant heat of the earth (thermal energy) to provide space heating, air conditioning and, in many cases, domestic hot water. In winter, geothermal heat pump systems collect the Earth’s natural heat through a series of pipes made of copper or plastic, called a loop, installed below the surface of the ground or submersed in a body of water. Fluid circulating in the loop carries this heat to the home.

There, an electric **compressor** and a **heat exchanger** concentrate the Earth's energy and release it inside the home at a higher temperature. In summer, the process is reversed in order to cool the home. Excess heat is drawn from the home, expelled to the loop, and absorbed by the Earth.

Note: There are four basic types of geothermal heat pump ground loop systems. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type of system is the open-loop option. Several factors such as climate, soil conditions, available land, and local installation costs determine which is best for the site.

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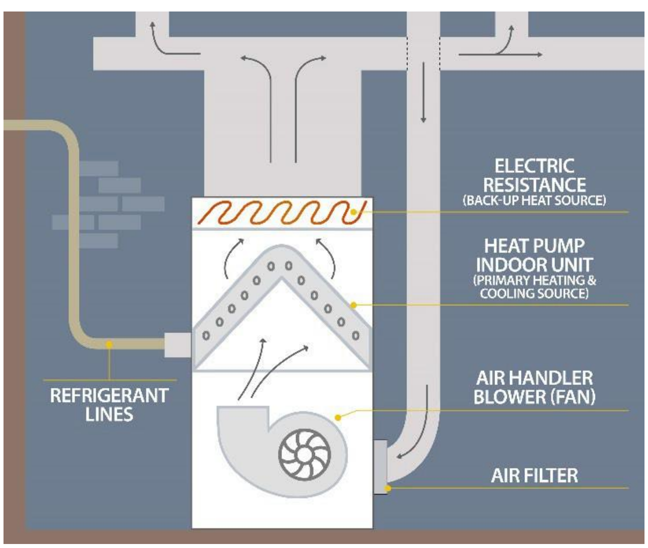
System Fuel Type

All-electric Centrally Ducted Heat Pump System

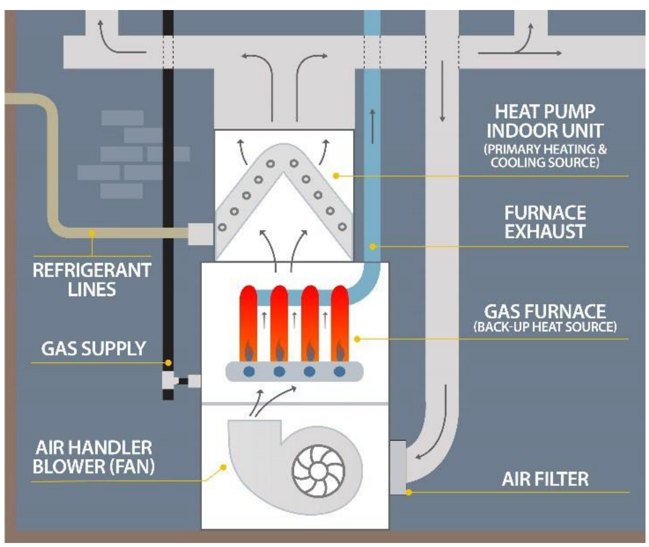
An all-electric centrally **ducted** heat pump system can either rely solely on the heat pump for heating or can merge the capabilities of an electric **air-source heat pump** with **auxiliary electric heat**. No **gas-powered heating system** is involved in either scenario. If the heat pump has **auxiliary electric heat**, when outdoor temperatures reach a certain low point, the **auxiliary electric heat** turns on to supplement the heating from the heat pump. All-electric heat pumps offer the most potential for lowering greenhouse gas emissions over time, depending on how quickly the local electric grid is decarbonizing.



*Note: **Ductless** heat pumps may be integrated with a variety of other heating systems. All-electric **ductless** heat pump systems may be integrated with electric baseboard heating or boilers as a "multi-system" application.*

Hybrid Heat Pump System (also referred to as "Dual-fuel heat pump system")

A hybrid heat pump system merges the capabilities of a centrally **ducted** electric air-source heat pump with a secondary fossil-fuel-fired furnace. As outdoor temperatures change, the system alternates between the two fuel sources, maximizing comfort, economics, and efficiency – offering the homeowner the key benefits of both fuel sources. In moderate winter weather, the heat pump efficiently draws warmth from the outdoor air to heat the home, while in summer, it reverses its operation to provide cooling. There are different methods used to control when the hybrid system switches from the electric air-source heat pump to the fossil-fuel-fired **secondary heating source**. The most common method is based on outdoor air temperature. When outdoor temperatures dip below a pre-set **switchover point** defined by the homeowner, the system seamlessly shifts to the **secondary heating source**, like a gas furnace, ensuring consistent comfort levels. This adaptability empowers homeowners to tailor energy usage and operational expenses to their preferences.



*Note: In addition to the commonly used outdoor air temperature control method, other control methods for hybrid heat pump **switchover** include indoor air temperature "droop" and more sophisticated algorithm-based controls. In the indoor air "droop" control method, the system continuously monitors the indoor air temperature for variations. If the indoor temperature begins to "droop" or fall below the desired setpoint, the system recognizes that the heat pump alone is not sufficient to maintain the desired comfort level. As the temperature continues to drop, the system engages the fossil-fuel-fired secondary heating source to provide the necessary warmth. There are also more advanced algorithm-based* *control methods, which use a combination of data inputs and predictive models to optimize **hybrid heat pump system** performance, such as minimizing operational costs.*

Absorption Heat Pump System (also referred to as "Gas-fired heat pump system")

Absorption heat pumps are essentially **air-source heat pumps** driven not by electricity, but by a heat source such as natural gas, propane, solar-heated water, or geothermal-heated water. Because natural gas is the most common heat source for absorption heat pumps, they are also referred to as gas-fired heat pumps. There are also absorption (or gas-fired) coolers available that work on the same principle. Residential absorption heat pumps use an ammonia-water absorption cycle to provide heating and cooling. As in a standard heat pump, the **refrigerant** (in this case, ammonia) is condensed in one **coil** to release its heat; its pressure is then reduced, and the **refrigerant** is evaporated to absorb heat. If the system absorbs heat from the interior of your home, it provides cooling; if it releases heat to the interior of your home, it provides heating.

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Heat Pump System Configurations

Residential heat pumps are available in a wide array of configurations that offer versatility to accommodate individual preferences, building designs, and spatial constraints. There are multiple indoor/outdoor unit types, sizes, mounting styles, and design options available. In this section, we will explore the definitions of terms used to describe the various configurations of residential heat pump systems.

Location of Heat Pump Components: Split system vs. Packaged system

Split-system Heat Pump

Most heat pumps are split-systems—that is, they have one **refrigerant coil** inside and one outside. Supply and return ducts connect to the indoor blower fan in **ducted**, central systems. In **ductless** heat pumps, air is distributed via one or more indoor units mounted to the wall, ceiling, or floor.

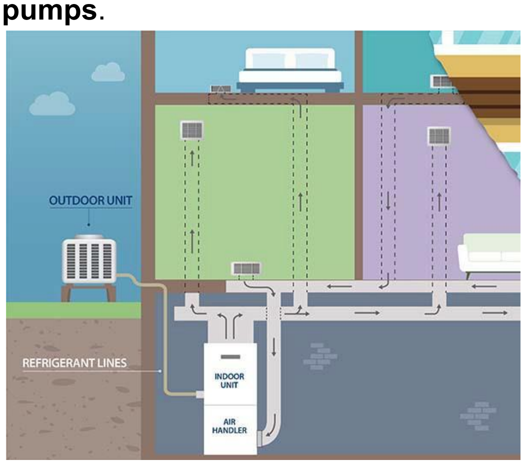
Packaged Heat Pump

Packaged systems usually have both **coils** and the **blower fan** located outdoors. Heated or cooled air is delivered to the interior from ductwork that is connected to the packaged heat pump and passes through a wall or roof.

Type of Distribution System: Ducted vs. Ductless vs. Short-run Ducted vs. Hydronic

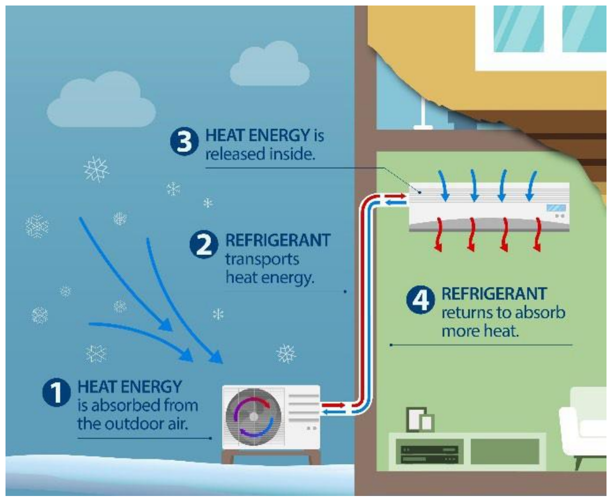
Ducted Systems (also referred to as “Central systems”)

Ducted systems, also known as central heat pumps, use a network of ducts to distribute heated or cooled air throughout the home. They can integrate with existing ductwork or be installed with planned ductwork as part of new construction. Several types of heat pumps can have ducted configurations, including **air-source heat pumps**, **geothermal heat pumps**, and **hybrid heat pumps**.



Ductless Systems

Whereas traditional heat pumps and central air conditioning systems force cooled and heated air through ducts, ductless heat pumps deliver air directly into different zones. The term “ductless” refers to a type of distribution system where air is delivered through individual indoor units, or “heads,” that are mounted to the wall, ceiling, or floor of the room that they condition. A head or several heads (see single-zone vs. multi-zone definitions below) can be connected to a single outdoor unit to create zones. Several types of heat pumps can have ductless configurations, including **air-source heat pumps** and **geothermal heat pumps**.



*Note: Ductless systems are a cost-effective way to replace inefficient window air conditioning units and replace or displace space heaters and electric baseboard heaters. They can be installed in home additions, new construction, condominiums, and apartments, or to improve temperature control in specific rooms. Ductless systems can even be fit for buildings that currently use **ducted** forced-air systems.*

Short-run Ducted Systems (also referred to as Compact-ducted systems”)

Short-run ducted heat pumps have an indoor unit located above the ceiling or below the floor that is connected by short runs of ductwork to one or more registers. One advantage is that the indoor unit is out of sight and the registers are inconspicuous. Because one indoor unit can be ducted to multiple registers, they can also be well suited to heating several small rooms like bathrooms and bedrooms. A common configuration is an indoor unit installed in an insulated attic connected to a grill in a hallway ceiling below. Hallway air is returned to the unit, heated or cooled, then supplied to multiple adjacent rooms via ceiling vents. Alternatively, they can be installed beneath the floor (typically in the basement ceiling below). Super-insulated homes with very small heating demands may be good candidates for a small **mini-duct** indoor unit with ducts throughout the house.

Hydronic Systems

Hydronic distribution systems for heat pumps use water as a medium to transfer heat to and from a home through a closed-loop system of pipes. For both heating and cooling, the water circulates through various types of indoor emitters, such as radiators, radiant panels, baseboards, or fan coil units. These emitters release heat from the water into the living spaces for warmth or absorb heat from the living spaces into the water for cooling. Radiators and radiant flooring provide radiant space conditioning, while fan coil units use forced air circulation. The hydronic system efficiently moves heat by taking advantage of water's high thermal capacity.

Zoning: Single-zone vs. Multi-zone

Single-zone Heat Pump

A single-zone heat pump is a **ductless** heat pump that consists of one indoor air-handler unit (or 'head') and one outdoor compressor unit. This type of system is designed to provide air conditioning in one specific area or 'zone' within a space, providing individualized control over temperature settings in that area. Single-zone systems are often used in scenarios where there is only a need for additional heating or cooling in a specific room, or to bring air conditioning to a section of a home that doesn't receive heating and cooling through its original HVAC system, like a garage, a newly finished basement, or a home addition.

Multi-zone Heat Pump (also referred to as "Multi-split heat pump")

A multi-zone heat pump is designed to provide air conditioning to multiple rooms or areas in a space. The system features a single outdoor unit (or sometimes more depending on the size of the home) that connects to multiple indoor units. Unlike **single-zone** systems, multi-zone systems allow for individualized temperature control in different zones. While the entire system must be in heating or cooling mode, each zone in a multi-zone system can be controlled independently for optimal individual comfort. Multi-zone heat pumps often utilize **ductless** distribution systems, though some models combine both **ductless** and **ducted** distribution.

Heat Pump Components

Heat pump systems are composed of various components that work together to provide heating and cooling. Each component plays a crucial role in the system's functionality and efficiency. In this section, we will explore the definitions of key terms used to describe the components of residential heat pump systems.

Air Handling Unit (AHU)

The air handling unit (AHU) plays a vital role in the heat pump system by conditioning and circulating air within the building or space. Tailored for heat pump operations, the AHU incorporates essential components like a **blower** or fan for air circulation, air filters to eliminate particulates, and a **coil** serving as a **heat exchanger**. During operation, the air handler directs air across the **coil**, where heat is added or removed, depending on the heating or cooling requirements, ensuring optimal indoor comfort.

*Note: For **ducted** central heat pump systems, the AHU houses the coil, blower, and filters within its casing. The coil inside the AHU allows heat transfer between the **refrigerant** piped from the outdoor unit and the air being circulated by the blower. The conditioned air is then distributed throughout the building via the **duct** network.*

*For **ductless** heat pump systems, the AHU is an indoor unit, or head, often mounted on the wall, ceiling, or floor. Each individual unit houses a **coil, fan**, and filter to condition the air in that particular zone or room.*

*For packaged heat pump systems, the AHU is located outdoors and consolidates all the necessary air handling components like the **coil, blower**, and filters into a single enclosed casing.*

Compressor

A heat pump compressor is a crucial component that circulates **refrigerant** through the system, enabling the transfer of heat for both heating and cooling. It works by compressing the **refrigerant**, raising its temperature and pressure, which facilitates heat exchange with the surrounding environment. The type of compressor significantly impacts the heat pump's efficiency and performance. The compressor's efficiency directly affects the overall energy consumption and operating costs of the heat pump system, making it a key factor in system selection and performance optimization. Residential heat pump systems use compressors with various designs and speed configurations.

- **Single-stage Compressor**

  Single-stage, or single-speed, compressors are the most basic compressors for heat pumps. They have two settings: on or off, meaning they operate at full capacity or not at all. These systems work at full speed to reach the desired temperature and then shut off completely once the indoor temperature is reached. Because of the frequent switch from on to off, and because they can

only operate at 100% max speed, heat pumps with single-stage compressors are usually the most expensive to operate.

- **Two-stage Compressor**

  Two-stage, or two-speed, compressors take heat pumps with single-stage systems up a notch and control temperature more accurately. While single-stage systems must operate at either 0 percent or 100 percent capacity, two-stage systems add more variety by offering a high and low setting. In most cases, the low stage operates at around 65 percent capacity, while the high stage operates at 100 percent capacity. Compared to single-stage systems, the two-stage system provides improved efficiency and temperature control.

- **Variable-speed Compressor** (also referred to as "Inverter-driven compressor")

  Variable speed compressors use inverter technology to adjust the compressor's speed continuously to match the exact heating or cooling demand, offering the highest efficiency and most precise temperature control. Variable speed systems can operate anywhere from 25 percent capacity to 100 percent capacity to meet temperature needs. Because they can operate at lower speeds, they consume less power, which makes them the least expensive to operate over time. You will often hear efficient heat pumps with variable-speed compressors referred to as variable-speed heat pumps, variable-capacity heat pumps, or inverter-driven heat pumps. Cold climate heat pumps are a subtype of variable-speed heat pumps.

- **Coils (also referred to as "Heat exchangers", "Evaporators", "Condensers" or "A-coils")**

The evaporator and condenser coils inside a heat pump make it possible for these systems to complete the heat exchange process. The coils form a loop and, even though they are continuous, each has a different function. The ability of the condenser and evaporator coils to reverse their roles is a fundamental feature of heat pumps, enabling efficient heating and cooling by reversing the direction of the **refrigerant** flow through a **reversing valve**.

- **Condenser Coil**

  In a heat pump, the condenser coil is responsible for rejecting the heat from the **refrigerant** to the surrounding environment. cooling mode, the outdoor unit's coil serves as the condenser coil. The high-pressure, high-temperature **refrigerant** gas flows into the condenser coil, where it releases heat to the outdoor air, condensing into a high-pressure liquid.

  Heating Mode: In heating mode, the indoor unit's coil serves as the condenser coil. The high-pressure **refrigerant** gas releases heat to the indoor air, warming the space, and condenses into a high-pressure liquid in the process.

Note: Sometimes the outdoor unit is referred to as the condenser unit because air conditioners always use the outdoor unit as the condenser and were popularized earlier than heat pumps that can reverse direction.

- **Evaporator Coil**

  The Evaporator Coil is responsible for absorbing heat and transferring it to the **refrigerant**.

  Cooling Mode: In cooling mode, the indoor unit's coil serves as the evaporator coil. The low-pressure, low-temperature **refrigerant** vapor/liquid enters the evaporator coil, where it absorbs heat from the indoor air and evaporates into a low-pressure gas, cooling the indoor space.

  Heating Mode: In heating mode, the outdoor unit's coil serves as the evaporator coil. The low-pressure **refrigerant** liquid absorbs heat from the outdoor air and evaporates into a low-pressure gas, even in cold temperatures, to provide heating indoors.

  Note: In packaged heat pump systems, both the condenser and evaporator coils are housed in the same outdoor unit. Sometimes the indoor unit is referred to as the evaporator unit because air conditioners always use the outdoor unit as the evaporator and were popularized earlier than heat pumps that can reverse direction.

Reversing Valve

The reversing valve is a crucial component in a heat pump system, allowing it to provide both heating and cooling functions by reversing the flow of **refrigerant**. The reversing valve has four ports that connect to different parts of the system: the **compressor**, the indoor **coil**, the outdoor **coil**, and the **expansion valve**. When the heat pump is in heating mode, the reversing valve directs the flow of **refrigerant** through the outdoor **coil**, absorbing heat from the surroundings. **Refrigerant** then flows to the indoor coil where it releases the absorbed heat, providing warmth. In cooling mode, the reversing valve changes the flow of **refrigerant** through the indoor **coil**, absorbing heat from the indoors. **Refrigerant** then flows to the outdoor coil where it releases the absorbed heat to the outdoors, providing a cooling effect inside the home or building.

Expansion Valve

The expansion valve drops the **refrigerant** pressure and expands the **refrigerant** as it passes from the high-pressure **condenser coil** into the low-pressure **evaporator coil**. The expansion valve's control of **refrigerant** pressure helps the **evaporator coil** to transfer heat most efficiently over its entire surface area while still guaranteeing the **refrigerant** fully evaporates before entering the **compressor**.

Blower Motor

The blower motor is the component of a heat pump that turns the system's fan that circulates the hot or cold air through a home. The exact HVAC blower motor location will vary slightly depending on the system type and model. For **central heat pumps**, it will be located inside the **air handler** (i.e., the indoor unit). For a **ductless system**, each indoor unit will have its own **blower motor** that is typically located behind the air handler casing and between the control panel and the fan blade. The efficiency and performance of a heat pump are heavily influenced by the type of **blower motor** employed. Single-speed motors operate at a fixed speed, while two-speed motors offer high and low settings for better efficiency and comfort. Variable-speed motors adjust their speed precisely to meet heating or cooling demands, maximizing energy efficiency and comfort. The choice of blower motor impacts energy use, noise levels, and overall comfort in the home.

Refrigerant

Refrigerants are the working fluids used in heat pump systems. They are chemical compounds that absorb and release heat as they transition between liquid and gas form at specific temperatures and pressures. It is this property that gives heat pumps their ability to heat and cool. Refrigerants are circulated throughout the heat pump system during the refrigeration cycle to effectively transfer heat between the indoor and outdoor environments (see below definition of refrigeration cycle).

- **Line Set (also referred to as "Refrigerant lines")**

A pair of copper tubes that connect a **condenser** to an **evaporator** so **refrigerant** can move between the two. The smaller tube is called a liquid line and carries the liquid **refrigerant** from the **condenser** to the **evaporator**. The larger tube is called a suction line, and it moves **refrigerant** in its gaseous form from the **evaporator** back to the **condenser**.

- **Heat Strips (also referred to as "Electric resistance heating elements or Plenum heaters")**

Heat strips, also known as electric resistance heating elements, are commonly integrated into the **air handler unit** of a heat pump system. Depending on the specific design of the system, they are ideally placed downstream of the heat pump's **refrigerant coil**. In colder climates or during periods of extreme cold, heat pumps may experience reduced efficiency as they struggle to extract heat from the air. To maintain consistent comfort, heat strips automatically activate to provide additional warmth. This ensures that occupants remain comfortable and the desired temperature is maintained throughout the home or building, regardless of external conditions impacting the heat pump's efficiency.

Note: Heat strip activation can be linked to outdoor air temperature and/or supply air temperature, depending on the controls. Utilizing supply air temperature as the control can help maintain occupant comfort.

Thermostat

A heat pump thermostat is a specialized device that controls the operation of a heat pump system. It regulates indoor temperature by activating the heat pump based on predefined settings, typically triggered by temperature thresholds. Additionally, thermostats may offer programmable scheduling options, allowing users to automate temperature adjustments throughout the day or week. Advanced models, such as smart thermostats, connect to the internet for remote access and may incorporate adaptive learning algorithms to optimize comfort and energy efficiency. Heat pump thermostats can also activate supplementary heating elements when necessary to maintain indoor comfort levels.

Mounting System

The primary goal of a mounting system is to keep the outdoor unit above the snow. There are several options available for mounting outdoor units. Foundation brackets (mounted to the homes foundation) do the best job at minimizing noise and staying out of the way of rakes, shovels, and lawn mowers. Ground stands minimize noise but can be susceptible to frost heaves if installed with inadequate drainage. Wall mounts keep units away from rakes, shovels, and mowers, but can transmit a low hum inside.

System Features and Functions

Heat pumps offer a range of modern features and functions, many of which differ from traditional residential HVAC systems. These capabilities are necessary for efficient heating and cooling, as well as for ensuring comfortable indoor temperatures throughout the year. Familiarity with diverse features and functions is essential for understanding how heat pumps operate in residential settings. In this section, we will explore key terms related to heat pump features and functions.

Auxiliary Heat (also referred to as "Supplemental heat", Secondary or "Back-up heat")

Auxiliary heat is a feature on some heat pump systems that is used when the outside temperature is too cold for the heat pump to efficiently heat the home on its own. Auxiliary heat supplements the heat pump by providing extra heat using a secondary source, such as **electric heat strips**, to ensure that the desired indoor temperature is reached. When the auxiliary heat setting is activated, the heat pump will continue to pull in as much heat as it can from the outside, but it will also use the secondary heat source to maintain the desired indoor temperature. If the outdoor temperature increases and the heat pump is able to efficiently heat the home on its own, the auxiliary heat setting will automatically turn off.

Note: The terms "auxiliary," "supplemental,", "secondary", or "back-up heat" heat is also often used to refer to a fossil fuel-fired system in ***hybrid heat pump systems****. The distinction lies in how the heat pump system operates: instead of augmenting the heat pump's heat with electric heating elements, it switches off the heat pump entirely and transitions to use solely the fossil fuel system.*

Emergency Heat

Emergency heat is a setting on a heat pump system that is used in emergency situations, such as when the heat pump is not functioning properly. This setting is activated manually and bypasses the heat pump, using an alternate heating source, such as a fossil-fuel-fired furnace or **electric resistance (heat strips)**, to heat the home. The emergency heat setting is meant to be used as a temporary solution when there is not enough time to call a technician for repairs or when the heat pump is not working. It serves as the secondary heat source for the system, allowing the home to continue to be heated while the heat pump is being repaired or replaced.

Defrost Cycle (also referred to as "Defrost mode")

In heating mode, a heat pump pulls heat from the outside air and transfers it inside to warm it. Under certain ambient temperature and humidity conditions (more common when outdoor temperatures are around freezing and outdoor humidity is relatively high), the moisture in the air freezes on the outdoor unit's **heat exchanger** as the fan blows the air across it, and frost can form on the outdoor coil. This layer of frost will ultimately make the heat pump operate inefficiently, so it needs to be removed. During the defrost cycle, the heat pump is operated in reverse (switches to cooling mode). A defrost control tells the **reversing valve** when to send hot refrigerant outdoors to thaw the outdoor **coil**.

The time it takes to thaw the outdoor **coil** will vary, but heat pumps will typically be in defrost cycle for only a few minutes. Once the unit is free of frost, the reversing valve will switch back and the unit will resume the heating cycle.

Note: During the defrost cycle of a heat pump, an occupant might hear a noise similar to a tire losing pressure, which is normal for single-stage systems. Additionally, it may appear as though smoke is coming from the outdoor unit, but this is actually steam generated during the defrost process. Both phenomena are typical and indicate that the defrost cycle is operating correctly.

Dehumidification

Dehumidification is the process of reducing moisture or humidity levels in the indoor air, typically by condensing water vapor into liquid form. Heat pumps in cooling mode can dehumidify like air conditioners. During the cooling mode, warm, humid air from the home is drawn into the system by the indoor fan. Inside the unit, this air passes over the evaporator coil, which is maintained at a colder temperature. The temperature difference between the warm indoor air and the cold evaporator coil causes moisture (water vapor) in the air to condense. This condensed moisture collects on the surface of the **evaporator coil** and drips down into a drain pan or drainage system.

*Note: Some heat pump models include a specialized "dry mode" setting. In dry mode, the unit operates at a lower fan speed, allowing the **evaporator coil** to stay colder for longer periods. This extended exposure helps the **coil** remove more moisture from the air without over cooling the room temperature. Additionally, **variable-speed** heat pumps tend to be more proficient at dehumidification than other types of systems.*

Grid-interactive Heat Pumps

A grid interactive heat pump has built-in communication capabilities allowing it to receive signals and commands from the utility company over the electrical grid. This communication link allows the utility to remotely control or curtail the heat pump's operation during periods of peak energy demand as part of **demand response** programs. In exchange for this control, utilities often provide incentives like rebates or lower electricity rates to customers with connected heat pumps enrolled in **demand response** programs. However, many **variable-speed** heat pump units are currently incompatible with utility **demand response** programs.

Note: Grid interactivity can occur through various communication methods, such as Wi-Fi or hard-wired connections. Common standards that define or enable these *communications include AHRI 1380, CTA-2045, and OpenADR 2.0, which support interoperability between heat pumps, utilities, and **demand response** systems*.

Zoning

Zoning is a feature of some heat pump systems that allow them to divide a home into different areas, or zones, to provide separate heating and cooling. Instead of having one **thermostat** or controller for the entire building's air conditioning, each zone has its own **thermostat** or controller to adjust the temperature according to occupant preferences, making it possible to meet different temperature requirements in different zones.

*Note: Zoning can be done using both **ducted** and **ductless** heat pump systems. In the case of **ducted** systems it requires dampers, which are movable vents that channel the air that circulates through the ducts by fully or partially opening and closing them. Modern systems have automatic dampers that move according to the comfort required in each **zone** and are controlled by the thermostat or controller. **Ductless** heat pump systems can be **zoned** using **multi-split** systems. Depending on the system, each interior unit can have its own remote control to adjust temperature to different **zones'** requirements. There is also the option of having a centralized controller that gives the operator full visibility of a **zoned** heat pump system's operation.*