Heat Pump Systems

An Online Continuing Education Course for Engineers

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Lee Layton, P.E.

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Introduction

For climates with moderate heating and cooling needs, heat pumps offer an energy-efficient alternative to furnaces and air conditioners. Like a refrigerator, heat pumps use electricity to move heat from a cool space into a warm space, making the cool space cooler and the warm space warmer. During the heating season, heat pumps move heat from the cool outdoors into a warm house; during the cooling season, heat pumps move heat from a cool house into the warm outdoors. Because they move heat rather than generate heat, heat pumps can provide up to four times the amount of energy they consume.

Heat Pumps can provide up to four times the amount of energy they consume.

A heat pump is a device that moves heat from one location to another location using mechanical work. Most heat pump technology moves heat from a low-temperature heat *'source'* to a higher temperature heat *'sink.'* A heat pump for heating and cooling a building is known as a reversible cycle heat pump. Other examples of heat pumps are food refrigerators, freezers, and air conditioners. These systems can also operate in reverse, producing heat.

Heat pumps can be thought of as a heat engine which is operating in reverse. Heat flows naturally from a higher to a lower temperature. Heat pumps, however, can force the heat flow in the other direction, using a relatively small amount of drive energy such as electricity. Thus, heat pumps can transfer heat from natural heat sources in the surroundings, such as the air, ground or water, or from man-made heat sources such as industrial or domestic waste, to a building or an industrial application. Heat pumps can also be used for cooling. Heat is then transferred in the opposite direction, from the application that is cooled, to surroundings at a higher temperature. Sometimes the excess heat from cooling is used to meet simultaneous heat demand.

In order to transport heat from a heat source to a heat sink, external energy is needed to drive the heat pump. Theoretically, the total heat delivered by the heat pump is equal to the heat extracted from the heat source, plus the amount of drive energy supplied.

The most common type of heat pump is the air-source heat pump, which transfers heat between the house and the outside air. It works by exploiting the physical properties of an evaporating and condensing fluid known as a refrigerant. In heating, ventilation, and cooling (HVAC) applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed. When heating with electricity, a heat pump can reduce the amount of electricity used for heating by as much as 30%–40%. High-efficiency heat pumps also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months. However, the efficiency of most air-source heat pumps as a heat source drops dramatically at low temperatures, generally making them unsuitable for cold climates, although there are systems that can overcome that problem.

Higher efficiencies are achieved with geothermal (ground-source or water-source) heat pumps, which transfer heat between the residence and the ground or a nearby water source. Although they cost more to install, geothermal heat pumps have low operating costs because they take advantage of relatively constant ground or water temperatures. Ground-source or water-source heat pumps can be used in more extreme climatic conditions than air-source heat pumps, and customer satisfaction with the systems is very high.

Another type of heat pump for residential systems is the absorption heat pump, also called a gas-fired heat pump. Absorption heat pumps use heat as their energy source and can be driven with a wide variety of heat sources.

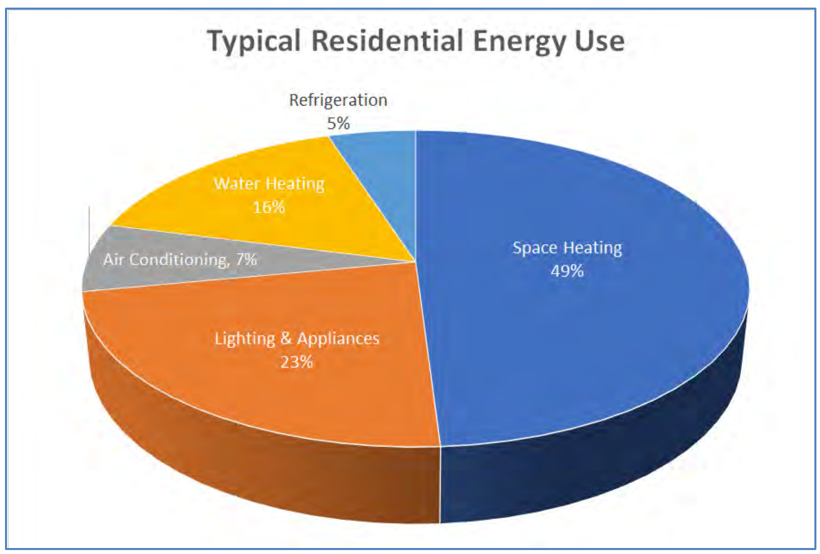


Figure 1

Heating and cooling are the major energy consumers in a residential dwelling. The adjacent chart, Figure 1, shows the typical energy use for a residential building. As you can see, space heating is the largest consumer of energy at 49% of the total usage in a home, followed by lighting and appliances, which is 23% of the total. Water heating is the third-largest consumer of energy at 16% of the total. These values vary based on the area of the country with air conditioning making up a larger percentage in the South and Southwest parts of the United States. Small commercial buildings will have similar usage patterns except that the water heating will be less, and the air conditioning and lighting will be a larger percentage.

As previously mentioned well over half the energy consumption in residential and small commercial buildings is for the heating, ventilation, and air-conditioning system. The next two pie charts show the types of heating and cooling systems in use today. Looking at Figure 2. For cooling needs, packaged systems make up 54% of the systems in use. Chillers are the next largest segment, with a total of 31% of the market spread among the different types of chillers. The remaining systems are divided between individual units such as window units and through-the-wall systems. Of the chiller systems, centrifugal units are the predominate system, and only 2% of the systems are absorption systems. Unfortunately, packaged systems, which represent the largest share of the market, generally have efficiencies that are much lower than chiller type systems.

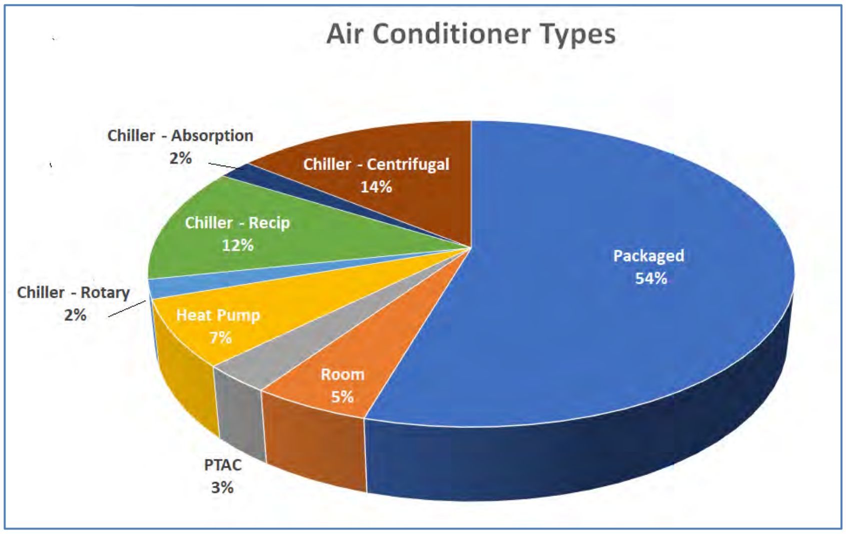


Figure 2

For heating systems, the types of systems are more evenly divided among the different types of systems.

Like the cooling systems, packaged heating systems have the largest percentage share of the market, but the share is only 25% of the total. Next, are boiler systems at 21%, followed closely by furnaces and unit systems.

In the commercial markets, retail space is the major heating consumer with public buildings and office space being the next largest users. This type of floor space tends to have packaged and boiler systems.

Figure 3 shows the energy consumption impact of various heating systems. Because heat pumps consume less primary energy than conventional heating systems, they are an important technology for reducing gas emissions that harm the environment, such as carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NOx). However, the overall environmental impact of electric heat pumps depends very much on how the electricity is produced. Heat pumps are driven by electricity from, for instance, hydropower or renewable energy reduces emissions more significantly than if the electricity is generated by coal, oil or gas-fired power plants.

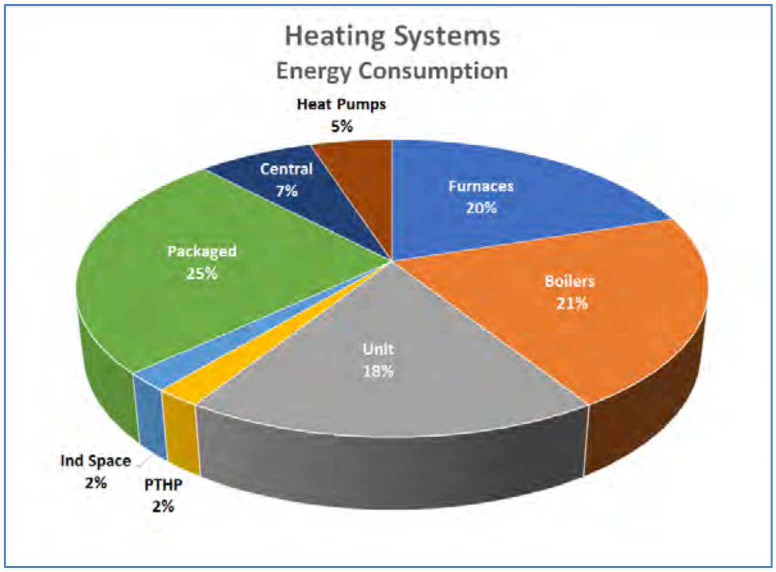


Figure 3

In this course, we will review the basic operation of a heat pump, the components that make up a heat pump, operating cycles, and discuss a few of the advantages and disadvantages of the most common types of heat pumps in use today.

Chapter 1 - Heat Pump Components

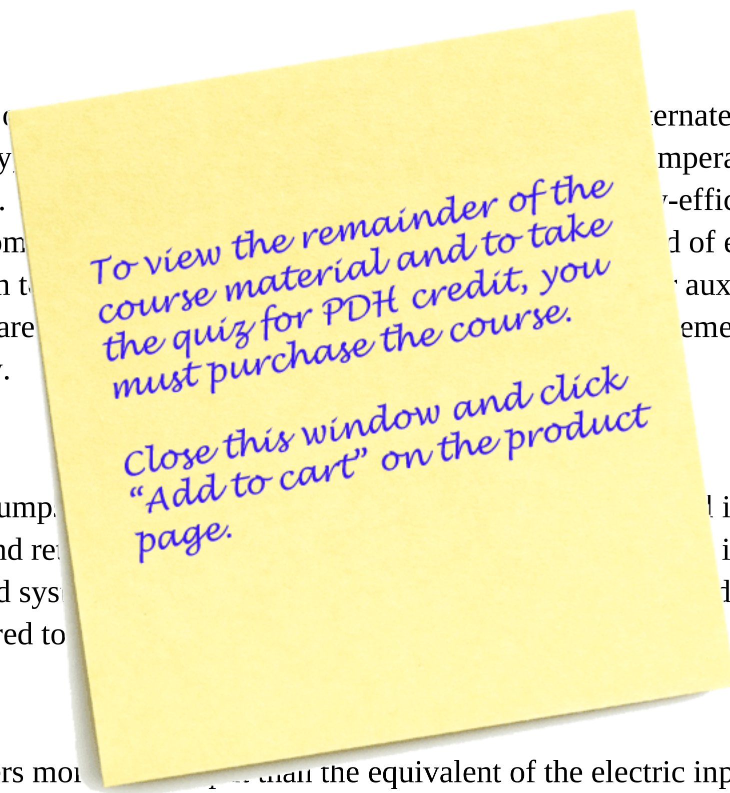
To move heat from a colder location to a warmer area requires thermodynamic work. Heat pumps differ in how they apply this work to move heat, but they can essentially be thought of as heat engines operating in reverse. A heat engine allows energy to flow from a hot *source* to a cold heat *sink*, extracting a fraction of it as work in the process. Conversely, a heat pump requires work to move thermal energy from a cold source to a warmer heat sink.

Since the heat pump uses a certain amount of work to move the heat, the amount of energy deposited at the hot side is greater than the energy taken from the cold side by an amount equal to the work required. Conversely, for a heat engine, the amount of energy taken from the hot side is greater than the amount of energy deposited in the cold heat sink since some of the heat has been converted to work.

A typical heat pump's refrigeration system consists of a compressor and two coils made of copper tubing - one indoors and one outside - which are surrounded by aluminum fins to aid heat transfer. In the heating mode, liquid refrigerant in the outside coils extracts heat from the air and evaporates into a gas. The indoor coils release heat from the refrigerant as it condenses back into a liquid. A reversing valve, near the compressor, can change the direction of the refrigerant flow for cooling as well as for defrosting the outdoor coils in winter.

In HVAC applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed. The reversing valve switches the direction of refrigerant through the cycle, and therefore the heat pump may deliver either heating or cooling to a building. In the cooler climates, the default setting of the reversing valve is heating. The default setting in warmer climates is cooling. Because the two heat exchangers, the condenser and evaporator, must swap functions, they are optimized to perform adequately in both modes. As such, the efficiency of a reversible heat pump is typically slightly less than two separately optimized machines.

Traditionally when ... ernate source of heating was required. Today ... mperatures – some even down to minus 15F. ... -efficient, electric resistance coils. Som... d of electric resistance coils, allowing them t... auxiliary heat, air-source heat pumps are ... emely cold weather areas of the country.



Most central heat pump... indoors and one outdoors. Supply and re... indoors. Some heat pumps are packaged sys... doors. Heated or cooled air is delivered to ... wall or roof.

A heat pump delivers mo... than the equivalent of the electric input it uses. It is not uncommon for a heat pump to deliver 250% to 400% more heat than you would obtain from an equivalent electric resistance heating system.