“How to” Manual

Leonardo ENERGY

Heat Pumps

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ECON International
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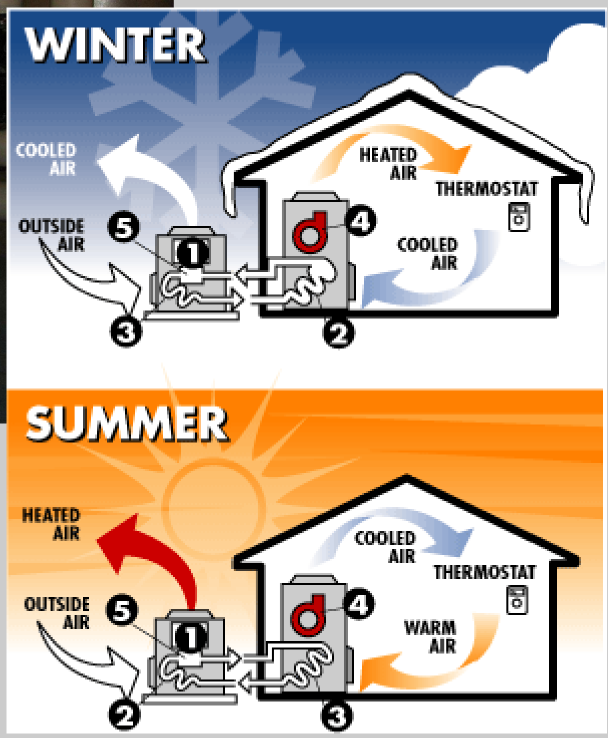

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Introduction

If you are exploring the heating and cooling options for your home, or looking for ways to reduce your energy bills, you may be considering an air-source heat pump. Although heating and cooling may appear to be complete opposites, an air-source heat pump can provide you with both. By using the dependable, efficient electric power that many people have come to trust, you can choose an air-source heat pump with confidence. During the summer, air-source heat pumps operate much like air conditioners. During winter, air-source heat pumps find heat from the air outdoors and pump it into your home (see Figure 1).

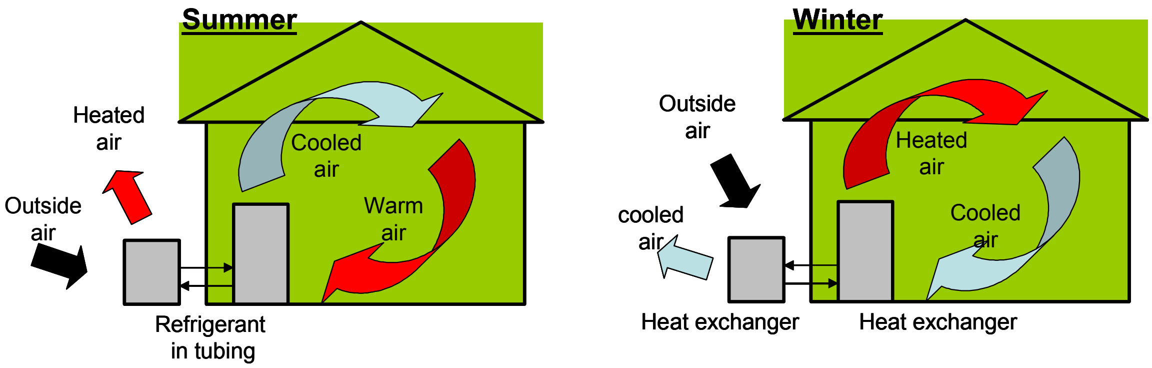

Figure 1 Principle of air-source heat pump during summer and winter [1]

The advantage of the heat pump, is that it takes less energy to pump heat than it does to convert electrical energy into heat. Furthermore, heat pumps do not produce any harmful gases such as carbon monoxide and, therefore, do not need to be vented.

Millions of heat pumps have been installed across Europe and, due to increased awareness of the system's obvious benefits, the market is growing rapidly [2]. In this guide we will focus mainly on the air-source heat pump system.

How to use this guide

The purpose of this guide is to provide you with basic information about air-source heat pump systems for the home. A heat pump will provide you with safe, clean and efficient warmed or cooled air. In addition to this, a correctly sized and installed heat pump can reduce your heating costs. Three times as much heat can be obtained from each watt of electricity than can be obtained from an electric heating system.

Whatever your reason for looking into heat pump systems, this guide will help you decide whether an air-source heat pump is a viable option for you. To this end, this guide will:

- give you some very basic theory on how heat pumps work;
- introduce you to some of the main components within an air heat pump system;
- give you some pointers to determine how to design and place a heat pump system;
- outline how to determine whether a heat pump system makes sense for you.

Overview of available heat pumps used in Europe

Although this guide focuses on air-source heat pumps, we will also provide an overview of other types of heat pump. The most important aspects to consider when evaluating the different heat sources are [3]:

- availability;
- temperature levels;
- annual temperature fluctuations; and
- investment costs.

In reality, the choice is limited according to prevailing local conditions. The overview in this guide is restricted to the heat sources commonly used for domestic heat pumps.

Air-source heat pump systems:

Ambient air is by far the most common heat source for heat pump applications worldwide. The reason for this is the unlimited availability of air, which enables simple and quick installation. In most European climates the ambient air temperature changes significantly, depending on the time of year. Since a heat pump's performance is reduced in correspondence with a fall in the heat source temperature, this leads to unfavourable characteristics. The performance of an ambient air-source heat pump will decrease as the heating demand increases.

At a certain point the temperature difference between the heat source and heat sink will be too high for the heat pump to operate at all, and the pump will have to be stopped. For most ambient air-source heat pumps this will occur at temperatures in the range of -20 °C to -15 °C. In cold climates this increases the necessity for a supplementary heating system that will ensure that the home's maximum heating requirements are adequately covered. Another disadvantage related to ambient air as a heat source, is that cold moist air in mild and humid climates, will cause frost formation on the heat exchanger that is exposed to ambient air. This frost will eventually induce such a large thermal resistance that the heat exchanger will need to be defrosted. During defrosting, the heat pump will not be able to provide heat to the inside of the house.

Ground soil:
The use of ground soil as a heat source for heat pumps enables the use of energy stored in the ground. Ground soil serves as a seasonal storage of solar energy. At a depth of 0,9 – 1,5 m the amplitude of temperature change due to changes in outdoor temperature is suppressed and delayed. This results in very favourable working conditions for a heat pump that extracts energy from the ground. Ground soil may additionally serve as a heat sink for cooling applications.

Ground rock:
In the last decade, there has been a growing interest in using ground rock as a heat source for heat pumps. A lot of research and development has been performed in order to improve the knowledge base for the design of such systems. Most of the benefits associated with ground soil systems are also valid for ground rock systems. However, ground rock systems, require much less surface area and have consequently become the preferred choice in densely populated areas in which space is limited.

Ground water:
In areas in which ground water is abundant and easily accessible, then ground water can also be used as a heat source. In these systems, ground water is extracted from a well and circulated through the cold side of the heat pump. Ground water can be used either directly via circulation through the evaporator, or indirectly via the use of an intermediate heat exchanger. An intermediate heat exchanger is the preferred choice in most cases, as ground water may cause corrosion or clogging of the evaporator. After leaving the heat exchanger, the cold ground water is directed back into the ground via an injection well.

Surface water:
Lakes are excellent heat storages for solar energy. Heat absorbed by the surface during the summer may be used for heat extraction during the winter. However, installations in lakes are relatively few and such installations are mostly restricted to larger applications. The most common sea or lake heat collector, is of a similar basic design to the surface soil heat collector. The collector is lowered to the bottom of the lake and is secured by anchors. The anchors counteract the lifting power of the ice that is produced around the collector pipe. In order for lake heating to be considered, a number of conditions need to be fulfilled:

- the house should be close to the sea or lake, with rights to access the water;
- the site for the collector must be free of activities, i.e. no fishing, anchoring etc;
- the water should not be rapid flowing and must be deep enough so that it does not freeze to the bottom.

Choice of technology:
All the different types of heat pumps described above, have been developed for different applications and have been adapted to cater for the predominant local conditions. As a consequence, the choice of heat pump technology is quite different in the northern part of Europe to that in the southern part. In Northern Europe, the need for heating dominates, and cooling of domestic households is only required for a few weeks during summer. Whereas cooling is a necessity in Southern Europe and heating is required only for a few months of the year. In addition to climatic differences, geological variations will also influence the choice of technology. For example, ground rock heat pumps are not viable in areas in which the bedrock has low thermal conductivity or in areas in which the bedrock is covered by a deep layer of soil. Table 1 gives a generalised overview of the use of different types of heat pumps in Europe.

Type of heat pump	Common capacity range	Application	Dominant region
Air- Air	3 – 5 kW	Heating + cooling	Southern Europe
Ground soil	5 – 25 kW	Heating	Northern + Central Europe
Ground rock	5 – 40 kW	Heating + cooling	Northern + Central Europe
Lake water	15 – 40 kW	Heating	

Table 1 Generalised overview of the use of different types of heat pumps in Europe.

Figure 2 Example of a heat pump at Zuidpoort (the Netherlands) [4]

Air-source heat pump technology

A heat pump is an electrical device that extracts heat from one place and transfers it to another. The heat pump is not a new technology; it has been used around the world for decades. Refrigerators and air conditioners are both common examples of this technology.

Almost all heat pumps currently in operation are based on either a vapour compression, or on an absorption cycle. These two principles will be briefly discussed in the following two sections.

How a heat pump works (vapour)

Heat pumps transfer heat by circulating a substance called a refrigerant through a cycle of evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed en route to the second coil, where it condenses at high pressure. At this point, it releases the heat it absorbed earlier in the cycle.

Refrigerators and air conditioners are both examples of heat pumps, but such systems operate only in the cooling mode. A refrigerator is essentially an insulated box with a heat pump system connected to it. The evaporator coil is located inside the box, usually in the freezer compartment. Heat is absorbed from this location and is transferred outside, usually behind or underneath the unit where the condenser coil is located. Similarly, an air conditioner transfers heat from the inside to the outside of a house .

The heat pump cycle is fully reversible, and heat pumps can provide year-round climate control for your home (heating in winter and cooling and dehumidifying in summer). Since the ground and air outside always contain some heat, a heat pump can supply heat to a house even on cold winter days.

How a heat pump works (absorption)

Absorption heat pumps are thermally driven, which means that heat, rather than mechanical energy, is supplied to drive the cycle. Absorption heat pumps for space-conditioning are often gas-fired, while industrial installations are usually driven by high-pressure steam or waste heat.
Absorption systems utilise the ability of liquids or salts to absorb the vapour of the working fluid. The most common working pairs for absorption systems are:

- water (working fluid) and lithium bromide (absorbent); and
- ammonia (working fluid) and water (absorbent).

In absorption systems, compression of the working fluid is achieved thermally in a solution circuit which consists of an absorber, a solution pump, a generator and an expansion valve. Low-pressure vapour from the evaporator is absorbed in the absorbent. This process generates heat. The solution is pumped to high pressure and then enters the generator, where the working fluid is boiled off at a high temperature, using an external heat supply. The working fluid (vapour) is condensed in the condenser while the absorbent is returned to the absorber via the expansion valve.
Heat is extracted from the heat source in the evaporator. Heat that is utilised for the heating system is given off at medium temperature in the condenser and in the absorber. In the generator, high-temperature heat is supplied to run the process. A small amount of electricity may be needed to operate the solution pump.

Parts of the system

The primary components of a heat pump system are basically the same as those found in air conditioning and refrigeration systems. However, a heat pump uses a special reversing valve that (automatically) changes the direction of the refrigerant flow, allowing the systems to remove heat from outdoors in winter and from indoors in summer.

The heat pump components are [5]:

Refrigerant:
This is the liquid/gaseous substance that circulates through the heat pump, alternately absorbing, transporting and releasing heat.

Reversing valve:
The reversing valve controls the flow direction of the refrigerant in the heat pump and changes the heat pump from heating to cooling mode or vice versa.

Coil:
A coil is a loop, or loops, of tubing where heat transfer takes place. The tubing may be fitted with fins to increase the surface area available for heat exchange.

Evaporator:
The evaporator is a coil in which the refrigerant absorbs heat from its surroundings and then boils to become a low temperature vapour. As the refrigerant passes from the reversing valve to the compressor, an accumulator collects any excess liquid that did not vaporize into a gas. However, not all heat pumps, ,have an accumulator.

Compressor:
The compressor squeezes the molecules of the refrigerant gas together, increasing the temperature of the refrigerant.

Condenser:
The condenser is a coil within which the refrigerant gives off heat to its surroundings and becomes a liquid.

Expansion device:
The expansion device lowers the pressure created by the compressor. This causes a temperature drop, and the refrigerant becomes a low-temperature vapour/liquid mixture.

Plenum:
The plenum is an air compartment that forms part of the system for distributing heated or cooled air throughout the house. It is generally a large compartment immediately above or around the heat exchanger.

Efficiency (Coefficient of performance)

Heat pumps are very energy-efficient heating systems. Since, unlike conventional fuel burning systems, they do not generate heat but only transfer it from one location to another, they require much less energy to produce the same amount of room heating as other heating systems.

An air-source heat pump extracts low temperature energy from the environment and increases this temperature for heating purposes. The efficiency of a heat pump is usually quoted as the system's coefficient of performance (COP). The coefficient of performance is determined by dividing the energy output of the heat pump by the electrical energy needed to run the heat pump at a specific temperature. The higher the COP, the more efficient the heat pump. This number is comparable to the efficiency of oil and gas fired heating systems. The COP decreases when the temperature is lower, because it is more difficult to extract heat from cooler air. The higher the air-source temperature, the higher the efficiency will be.

Typical COP values are in the range of 3 to 5. In other words, extracting heat from renewable sources requires 1 kWh of electrical input in order to generate 3 to 5 kWh of heating output (see figure 3). Heat pump systems are, therefore, more efficient than fossil fuel boilers.

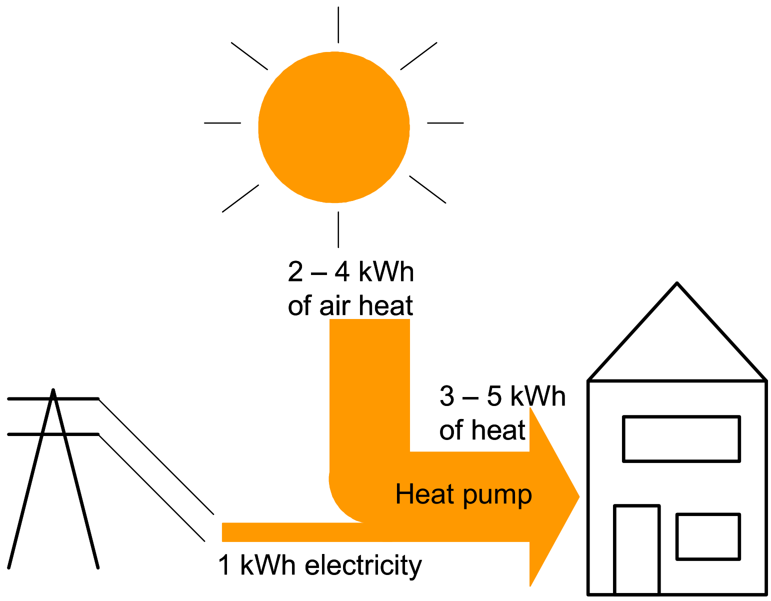

Figure 3 Example of a heat pump's coefficient of performance.

Installation of air heat pumps

Compared to other types of heat pumps, air-source heat pumps are relatively easy to install and represent an economic investment for existing buildings. Incorrect installation of heat pumps leads to high electricity bills, poor indoor comfort and maintenance problems. Incorrect airflow across the indoor coil is a common problem in air-source heat pump installations. Low airflow affects the cooling and heating capacity and, ultimately, the efficiency of the unit. Excess airflow is a less common problem, but can cause poor dehumidification during cooling, duct noise and drafts [6].

Design

To ensure that your heat pump is the correct size for your home and for your heating and cooling requirements, the heat pumped should be purchased from an experienced heat pump contractor. An too high-capacity heat pump will cycle on and off more often, resulting in higher energy use, poor humidity control in the summer and a shorter operational lifespan. Heat pumps are designed to be unobtrusive in size and are neutral in colour to fit within the décor of your home . They run at a low noise levels.

The design and installation of a heat pump system must also address the following elements before or during equipment installation:

- the duct system must be correctly designed to work with the heat pump equipment and to distribute conditioned air sufficiently throughout the house;
- the duct system must be properly installed and sealed to ensure its performance.

Newly built or well-insulated buildings can be heated easily with a heat pump. However, old and badly insulated buildings can be problematic in cold weather, with heat pumps struggling to heat them adequately. In these buildings, the temperature setting of the radiators or underfloor heating may have to exceed the heat pump’s efficient working temperature levels. Supplementary fires or boilers are often required to ensure adequate heating in the winter. Even in very well-insulated houses, it is not uncommon to retain a fire or stove for extra comfort in cold weather.

Heat pumps are driven by fairly large electric motors. Such motors work best with a 3-phase electrical supply. Unfortunately this supply is not common in European homes. Having said that, small heat pumps (with up to say 8 kW output) work just as efficiently with a single phase supply. Multiple compressor systems are also available. The 3-phase unit is considered to be more durable, and may be somewhat more reliable than a single phase unit, so we favour this type. It may be worthwhile asking your electricity supplier for the costs involved in installing a 3-phase electrical supply.

Installation

Heat pumps should be installed by knowledgeable technicians according to both the manufacturer’s installation instructions and all national and local code requirements. General installation guidelines are applicable to most units and should be followed insofar as they do not conflict with other requirements. In general, correct heat pump installation can be achieved by addressing four critical areas:

- the indoor air handler, especially the airflow over the fan-coil unit and through the forced air duct system;

- the refrigerant system, especially the refrigerant charge;
- the outdoor unit, especially its air supply; and
- the control system, especially the thermostat that turns the equipment on and off.

Heat pumps are very efficient heating and cooling systems and can significantly reduce energy costs. However, there is little point in investing in an efficient heating system if your home is losing heat through poorly insulated walls, ceilings, windows and doors, and by air leakage through cracks and holes. In many cases, it makes good sense to reduce air leakage and upgrade thermal insulations levels before buying or upgrading your heating system.

Operation and maintenance

Correct maintenance is critical to ensure that your heat pump operates efficiently and has a long service life. You can do some simple maintenance yourself, but you may also wish to ask a competent service contractor to conduct an annual inspection of your unit. The best time to service your unit is at the end of the cooling season, prior to the start of the next heating season.

Filter and coil maintenance has a dramatic impact on system performance and service life. Dirty filters, coils and fans reduce airflow through the system. This reduces system performance, and can lead to compressor damage if it continues for extended periods of time.

As a general rule, filters should be inspected monthly and cleaned or replaced as required by the manufacturer’s instructions. The coil should be vacuumed or brushed clean at regular intervals as indicated in the manufacturer’s instruction booklet. The outdoor coil may be cleaned using a garden hose. While cleaning filters and coils, check for signs that may indicate other potential problems.

The fan should be cleaned, but the fan motor should only be lubricated if the manufacturer’s instructions specify this. This should be done annually to ensure that the fan provides the airflow required for correct operation. The fan speed should be checked at the same time. Incorrect pulley setting, loose fan belts, or incorrect motor speeds, in the case of direct drive fans, can all contribute to poor performance.

Ductwork should be inspected and cleaned as required to ensure that airflow is not obstructed by loose insulation, abnormal build-up of dust, or any other obstructions that occasionally find their way through the grilles.

Be sure that vents and registers are not blocked by furniture, carpets or other items that can block airflow. Extended periods of inadequate airflow can lead to compressor damage

Additionally, heat pump manufacturers recommend that homeowners consider the following operational and maintenance issues:

- a heat pump works most efficiently when it maintains a constant room temperature; avoid large temperature changes overnight or during the day;
- while it may seem as though cold air is coming from the supply outlets during the heating season, this is a factor of heat pump design; comfort heating should still be attainable with a correctly designed and used system;
- the system will periodically go into defrost mode to remove any ice build up on the outdoor coil in the winter;
- the outdoor unit should be positioned above the prevailing snow-line, with suitable clearance around the unit maintained all year round;
- expect the unit to run continuously in periods with low outdoor temperatures, or switch over to the supplementary heating system.

Costs and benefits

It is important to consider all the benefits and costs before purchasing a heat pump. While heat pumps may have lower energy costs than conventional heating and cooling systems, they are more expensive to buy. It is important to carefully weigh up your anticipated energy savings against this initial cost. It is also important to realise that heat pumps are most economical when used year-round. Thus, investing in a heat pump will make more sense if you are interested in both summer cooling and winter heating.

Investment costs

When buying a heat pump system, you should be alert regarding the price. The best buy is not always the cheapest quotation. For instance, if the output of a cheap heat pump is insufficient to heat your house, then the savings made in the purchase price can be swallowed up by higher heating bills.

Air-source heat pumps are the most common type of heat pumps for households. Most heat pumps of this type are of 4 to 7 kW, they cost between 1.200 to 3.000 Euros, and they can deliver up to 50 kWh of heating effect [7]. But these are obviously just guidelines and you should be cautious in this matter. Prices may also depend strongly on the quality of the pump.

Operational costs

The energy costs of a heat pump may be lower than those of other heating systems, particularly electric or oil-fired heating. However the relative savings will

depend on whether you are currently using electricity, oil, propane or natural gas, and on the relative costs of these different energy sources in your area. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area in which electricity is expensive, your operational costs may be higher. Depending on these factors, the payback period on the initial investment in an air-source heat pump rather than in a central air conditioner could be anywhere from two to seven years.

Life expectancy

Air-source heat pumps have a service life of between 15 and 20 years. The compressor is the critical component of the system. Most heat pumps are covered by a one-year warranty on parts and labour, but warranties do vary between manufacturers

Benefits of air-source heat pumps

Air-source heat pumps are emerging as a popular choice because of their simple ‘plug and play’ installation, competitive pricing and energy savings. Nevertheless, it is important to consider all the benefits and costs before purchasing a heat pump. While heat pumps may have lower costs than conventional heating and cooling systems, they are more expensive to buy.

In addition to looking at the costs, you should also consider other factors. How much space will the equipment require? Will you need changes or improvements to your ducting system? How much servicing will the system need, and what will it cost? You may also have questions about noise levels. Modern heat pumps models are very silent, but it is advisable to view and listen to an installed heat pump yourself, if possible.

For colder climates, you should also select a heat pump with a demand-defrost control. Most modern models include this essential option: it minimizes the defrost cycles, and thus reduces supplementary energy use.

The advantages of heat pumps systems are that it takes less energy to pump heat than it does to convert electrical energy into heat, and heat pumps do not produce any harmful gases such as carbon monoxide.

Notes

[1] Air-source heat programs; East Central Energy
[2] Altherma by Daikin; Home heating and cooling solution
[3] Heat pumps technology and environmental impact; European Heat pump association, July 2005
[4] www.eneco.nl
[5] Heating and cooling with a heat pump; Natural resources Canada, Dec 2004
[6] Central heat pump and air conditioner installation. US Department of Energy; Feb 2003.
[7] http://www.renewableenergy.no

The European Heat Pump Association represents the European Heat Pump industry and has developed a number of case studies and other guidelines.