HEAT PUMPS

Heat pumps for heating and cooling were first commercialised in the second half of the 20th century, but applications in cold climates were limited to ground-source heat pumps because of the low temperatures of outdoor air.

Today's air-source heat pumps are able to supply heat even with outside air temperatures of -25°C. The market share of heat pumps for both heating and cooling applications is growing rapidly due to improved performance in terms of energy efficiency and CO_2 emissions in the residential, commercial and industrial sectors.

PROCESS AND TECHNOLOGY STATUS

The physics of heat pumps is well-known. While heat (thermal energy) tends to flow naturally from high-temperature sources to low-temperature heat sinks, heat pumps can move heat from low-temperature to high-temperature heat sinks. The heat pump principle is based on the four phases of the reverse Carnot cycle. Therefore, a heat pump can typically be used to extract heat from a refrigerator or an air-conditioner and provide heat for water or space heating.

The basic configuration of a heat pump consists of the evaporator (i.e. outdoor unit) where the process fluid evaporates, absorbing heat from the heat source (e.g. air), a compressor to compress the fluid and increase its temperature, a condenser (i.e. indoor unit), which releases heat by condensing, and an expansion valve to reduce the pressure and temperature of the process fluid to below the level of outside air temperatures in order to restart the cycle. The energy for the process is provided by the electric energy to run the compressor and circulate the fluid.

Heat pumps are highly efficient devices, as they can move and supply six units of thermal energy for each unit of electrical energy consumed. The ratio of the thermal energy provided for space cooling or heating to the energy consumed is the heat pump's coefficient of performance (COP), one of the heat pump performance indicators. Another performance indicator for heat pumps is the seasonal performance factor. Because definitions of heat pumps' energy performance differ between Asia, North America and Europe, the International Organisation for Standardisation (ISO) is working to define a global standard - the annual performance factor (APF) - which is the ratio of the total amount of heat, the device can remove from, or add to, space concerned during the cooling and heating seasons (respectively) to the total amount of energy consumed for both heating and cooling services. The high efficiency of heat pumps can provide advantages in terms of energy and CO_2 emissions, saving in comparison to other approaches (e.g. combustion) to space/water heating and cooling.

As a primary heat/cold source and sink, heat pumps can use outdoor air, river/lake/sea water or even ground (underground) heat and cold. All these sources can be regarded as renewable heat/cold sources, which can be used for residential, commercial and industrial applications. There may be, for example, air-to-air or air-to-water heat pumps or even water-to-air and ground-to-water/air heat pumps. The efficiency of heat pumps based on water sources is generally high because surface water is usually colder than air when space cooling is needed (e.g. summer) and warmer than air when space heating is needed (e.g. night time, winter). Of course, heat pumps can also use all kinds of waste heat, such as industrial and residential waste heat, or heat from sewage treatment.

In cold climates, their use has been limited to ground-source heat pumps as the outside air temperature is too low for using air-to-air heat pumps. However, more recent air-source heat pumps are able to supply heat even with outside air temperatures of -25°C, using injection circuits which bypass the evaporator and inject fluid into the compressor for cooling during compression or two-stage compression to increase fluid circulation volume. Freezing risks have been prevented by passing hot-leg fluid through the colder part of the heat exchanger in the outdoor units. The time needed for defrosting and from start-up to blow-off of heated air has also been shortened. These component technologies have significantly contributed to improving the space heating performance and efficiency of heat pumps. All these improvements have enabled the use of air-source heat pumps in cold climates for applications to space heating, floor heating, water heating and even road heating for snow melting.

In some cases, thermal storage systems are used to increase the efficiency of heat pumps and reduce peak power demand for buildings. These systems typically consist of a thermal storage tank where the heat produced overnight is stored and used during the day. Various thermal storage media have come into practical use. Chilled and hot water storage is used in thermal storage systems for heat pump air-conditioning systems. More recently, air-conditioning systems with ice-based, latent heat storage (and small-size storage tanks) have been developed. Also, air-conditioning systems with thermal storage based on the building body and no storage tank have come into practical use.

HEAT PUMPS ARE HIGHLY EFFICIENT DEVICES, AS THEY CAN MOVE AND SUPPLY SIX UNITS OF THERMAL ENERGY FOR EACH UNIT OF ELECTRICAL ENERGY CONSUMED.

PERFORMANCE AND COSTS

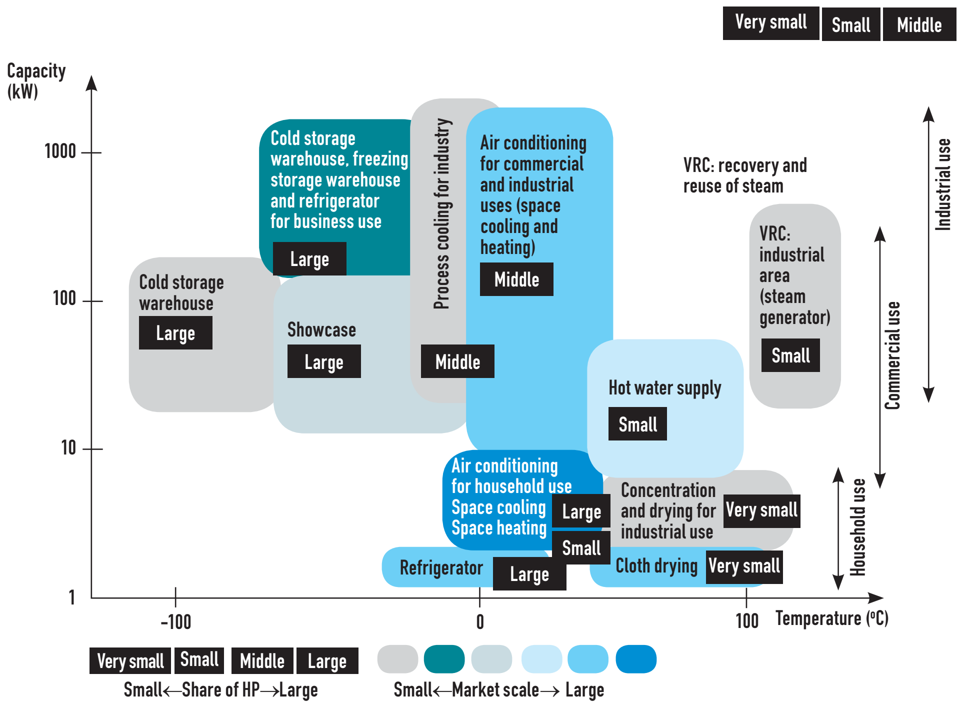
Heat pumps can provide three to six units of useful thermal energy for each unit of energy consumed, whereas traditional combustion-based heating systems only provide less than one unit of thermal energy for each unit of energy consumed. Today's best heat pumps can offer COP values between six and seven and a high reliability under a wide range of operating conditions. The heat pump's efficiency has increased substantially over the past years as a result of technical improvements and the use of inverters and control systems. Recently, the seasonal performance factor (SPF) (i.e. the ratio of heat delivered to the energy consumed over the season) of the most efficient, commercial heat pumps has reached the level of 6-7, although SPF varies considerably with the heat pump technology, heat source and operating conditions.

Ground-source heat pumps (GSHPs) can serve as effective systems for space cooling (summer) and heating (winter), as in most regions the ground temperature remains stable throughout the year (i.e. between 10-15°C). However, air-source heat pumps (ASHPs) are often the technology of choice for air-conditioning. The use of ASHPs is very cost-effective in regions where both space heating and cooling are required throughout the year. Most advanced devices can reach COP of higher than six.

POTENTIAL AND BARRIERS

Currently, space heating and cooling, together with hot-water supply, are estimated to account for roughly half of the global energy consumption in buildings. Most of this energy demand is met by combustion of fossil fuels with their related CO_2 emissions. Air-conditioning and cooling demand is growing, particularly in emerging economies. Heat pumps can reduce energy consumption and CO_2 emissions, as well as improve energy security. If combined with thermal storage, heat pumps can also reduce the

FIG. 1: Heat Pump Application Areas



demand for peak power. It has been estimated that widespread use of heat pumps for space heating/cooling and water heating in the commercial sectors could reduce CO_2 emissions by 1.25 billion tonnes by 2050.

Major barriers to the widespread use of heat pumps include the insufficient recognition of benefits and the high investment costs. Defining international standards for heat pump efficiency, as well as labelling and providing incentives (e.g. subsidies, grants) for heat pump use, could help overcome these barriers. The use of heat pumps would be greatly encouraged if the thermal energy they captured were recognised worldwide as a renewable energy source. As for performance and costs, current R&D activities are expected to increase efficiency by 40-60 per cent for heating services and by 30-50 per cent for cooling services, and to reduce costs by 30-40 per cent and 5-20 per cent, respectively, by 2050.

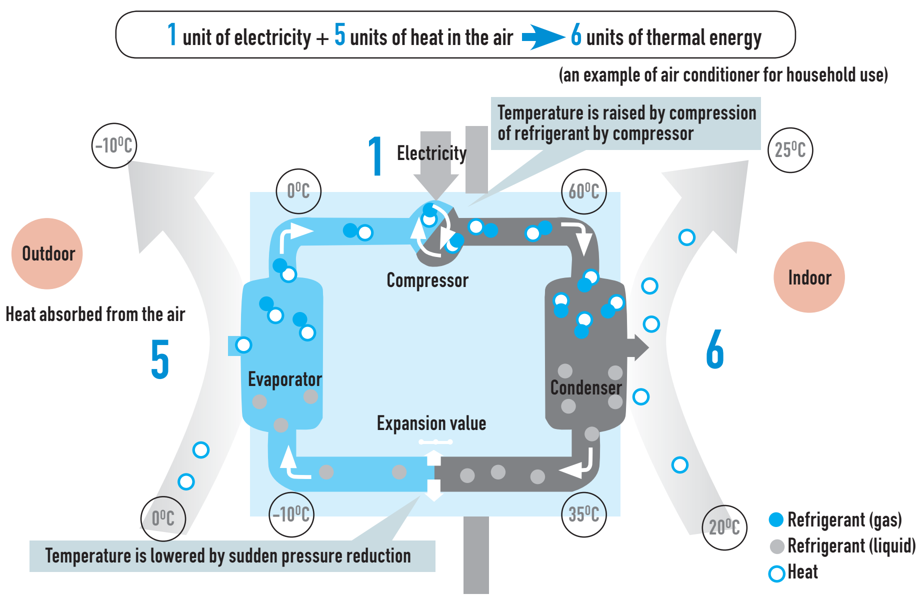
Heat pumps are considered as a renewable energy technology in the European Union (EU), where they are expected to account for between 5 per cent and 20 per cent of the EU's renewable energy target for 2020. Several other countries (e.g. the United States, the United Kingdom, Australia and Japan) grant tax reductions, subsidies or other benefits to facilitate the use of heat pumps. In many other countries however, heat pumps are not considered as renewable technologies and receive no incentives or subsidies. In addition, because significant differences exist in national standards and regulations to measure heat pump performance, their contribution to the penetration of renewable energy is not well captured in today's energy statistics. To support heat pump deployment, national standards should be harmonised, consumers should be fully informed of the efficiency of heat pumps, and the investment costs of heat pumps

SEVERAL COUNTRIES GRANT TAX REDUCTIONS, SUBSIDIES OR OTHER BENEFITS TO FACILITATE THE USE OF HEAT PUMPS. BUT IN MANY OTHERS IT IS NOT CONSIDERED AS RENEWABLE TECHNOLOGIES AND RECEIVE NO INCENTIVES OR SUBSIDIES.

TABLE 1: Typical Cost of Heat Pumps for Residential Space Heating/Cooling and Hot Water Supply

REGIONS		NORTH AMERICA	CHINA AND INDIA	OECD PACIFIC	OECD EUROPE
Typical size (kW)		2-19	1.5-4	2.2-10	2-15
Economic life (year)		15-20	15-20	8-30	7-30
Installed Cost (USD/kW)	A to A	360-625	180-225	400-536	588-1430
	ASHP	475-650	300-400	560-1333	607-3187
	GSHP	500-850	439-600	1000-4000	1170-2267

FIG. 2: Mechanism of Heat Pump



(compared to traditional combustion devices) should be reduced. Therefore, continued support to R&D and policy measures are essential to improve competitiveness and market penetration of heat pumps, thus exploiting their large potential to supply efficient and clean energy services.

APPLICATION

Common applications for heat pumps are air-conditioning, refrigeration and space heating in both residential and commercial buildings. Other applications include hot water supply in commercial buildings, cold storage warehouses and process heat and steam for industrial applications.

With capacities between 1kW and 10 MW, current heat pumps can provide heating and cooling to single houses or to entire districts. In industrial applications, they can be used at temperatures from below -100°C to above 100°C.

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