IIR Informatory Note on *Air source heat pump for space heating and cooling*

Summary for policymakers

Currently, energy consumption in the building sector accounts about 30% of total energy consumption worldwide, of which almost half is consumed by heating, ventilation and air-conditioning (HVAC) systems. Traditionally, both a chiller and a boiler are used in a building for cooling and heating respectively, and electricity is even used directly for heating in some areas, while these technologies are neither environmentally friendly nor energy efficient. Among the promising technologies that can provide both heating and cooling with a single device, air-source heat pump (ASHP) has been widely developed and used all over the world and is playing an increasingly important role in reducing greenhouse gas emissions.

The IIR Informatory Note "Air source heat pump for space heating and cooling" [**a**] aims to raise awareness that ASHP is an energy-efficient technology which could be used for both cooling and heating, notably more energy-efficient than direct electric heating. At the same time, the state of the art of ASHP technologies on how to improve the heating performance at low ambient temperatures, how to effectively prevent frost or defrost, and alternative refrigerants are presented to further emphasise that ASHP can be used for different functions in different climate. The main facts and recommendations are summarised as follows:

- By the year 2018, buildings accounted for 30% of global energy consumption and 28% of global greenhouse gas emissions [**b**]. About 40% of the energy consumed by buildings was used for space heating and cooling [**c**].
- ASHP is an energy-efficient technology for heating at different ambient temperatures. The normal heating efficiency of ASHP is three to four times higher than that of direct electric heating. ASHP can be used in different climates, from −25°C to +50°C, by developing technologies such as variable frequency compressor, cascade ASHP, two-stage compression and quasi-two-stage compression.
- The significant improvement in defrosting for ASHPs has been achieved over the last two decades. Anti-frosting technologies, different types of defrosting technologies, and smart control defrosting strategies have been developed to ensure that ASHPs operate efficiently and reliably in a humid environment.

Global warming is motivating researchers, manufacturers etc. to consider alternative refrigerants for ASHPs. Low GWP refrigerants have been applied in different types of ASHPs.

Of course, there are still many challenges for the development and application of ASHPs, such as reducing initial costs, developing more energy-efficient and environmentally friendly products, etc. Considering that many cooling and heating technologies have much lower efficiency and the quick growth of air conditioners worldwide, more favourable policies for manufacturers and customers should be applied all over the world.

This Informatory Note, see an extract of this note below, provides detailed information on the principles of ASHP, the state of the art of ASHP technologies and their application all over the world.

The International Institute of Refrigeration (IIR) is at the disposal of its members and governments, companies, public and private actors, to help them achieve the United Nations' Sustainable Development Goals.

The International Institute of Refrigeration (IIR) is an independent intergovernmental organisation.
It is the only one in the world to gather scientific and technical knowledge in every sector of refrigeration.

Founded in 1908, it has developed a worldwide network of leading experts.

The IIR is committed to disseminating knowledge of refrigeration to improve the quality of life for all, while respecting the environment and taking into account economic imperatives.

The IIR has resolutely stepped up its efforts to become a major global player taking action to implement sustainable refrigeration in all its uses. This is evidenced by the report on the IIR's 2020 actions according to the UN Sustainable Development Goals available below.

a) The IIR Informatory Note "Air source heat pump for space heating and cooling" is accessible following this link: https://iifiir.org/en/iir-informatory-notes (free for IIR members after logging-in on the website)

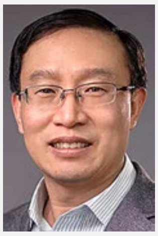
b) International Energy Agency, 2019 Global status report for buildings and construction.

c) http://energy.mit.edu/news/cooling-buildings-worldwide/.

41st IIR Informatory Note on Refrigeration Technologies

Extract of the Informatory Note;
the full text of this Informatory Note is available here:
https://iifiir.org/en/fridoc/air-source-heat-pumps-for-space-heating-and-cooling-41-lt-sup-gt-st-lt-sup-gt-143232

Air source heat pumps for space heating and cooling



XIANTING LI
President of IIR Section E

BAOLONG WANG
Secretary of IIR Section E

Introduction

Since the energy crisis in the 1970s, energy conservation has always been a hot topic for policymakers and practitioners worldwide. Currently, energy consumption in buildings accounts for about 30% of total energy consumption [**1**]. Owing to the increasing demand for improved thermal comfort in the building environment, the energy use of heating, ventilation and air conditioning (HVAC) systems accounts for almost half of the energy consumption of buildings. Therefore, it is important to increase the energy efficiency of HVAC systems in order to meet energy saving and low carbon emission targets.

Traditionally, both a chiller and a boiler are used in a building for cooling and heating, respectively. However, boilers, such as coal-fired and gas-fired boilers, are not environmentally friendly because of the emissions of greenhouse gases and particles during combustion. The electric boiler, or direct electric heating, is not energy-efficient due to low primary energy efficiency. Thus, as one of the promising technologies for efficient heating and cooling with a single device, the heat pump has been widely developed and used all over the world. Depending on the type of heat source/sink, the heat pump can generally be classified as an air-source heat pump (ASHP), ground-source heat pump (GSHP), water-source heat pump (WSHP), etc.

Contrary to WSHP and GSHP, ASHP takes/rejects heat from/into the ambient air, which is cheap and can be implemented anywhere. Therefore, ASHP plays an increasingly important role in cases where both heating and cooling are required. In recent years, many efforts have been devoted to extending the application of reversible ASHP in the heating and cooling of buildings.

This Informatory Note provides detailed information about the principles of ASHP, the state of the art of ASHP technologies and their applications all over the world. Since the research on ASHP cooling has been well developed in recent years, the current challenge comes from heating. Therefore, this Informatory Note focuses mainly on new developments in the field of heating, and some technologies are also applicable to cooling.

Applications

As a promising technology for space cooling and heating, ASHP has been applied in various commercial and residential buildings worldwide. Over the past decades, the radiator has been used as the main terminal for space heating, resulting in high supply water temperatures. However, in recent years, the increasing use of fan coil and floor heating has led to a decrease in the temperature of supply water. This has contributed to an increase in ASHP applications in recent years. Besides, another reason for the increase in ASHP applications is the growing demand for both cooling and heating equipment.

According to statistics by International Energy Agency [**2**], the global stock of air conditioning (including room air conditioner, VRF system, packaged window units, etc.) reached about 1.5 billion units in 2016 (**Figure 1**). Among all types of air-conditioning systems, room air conditioners and VRF systems account for the majority, as shown in **Figure 2(a)**. In addition, the stock in China and the United States accounts for more than half of total sales (**Figure 2(b)**). Other countries with more than 20 million units include Japan, Korea, Brazil and India.

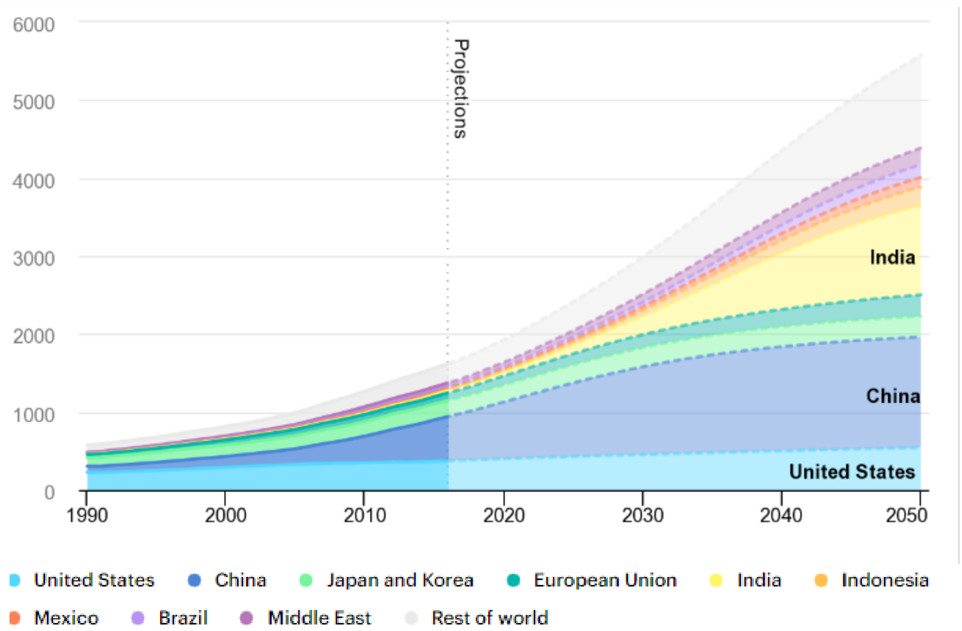
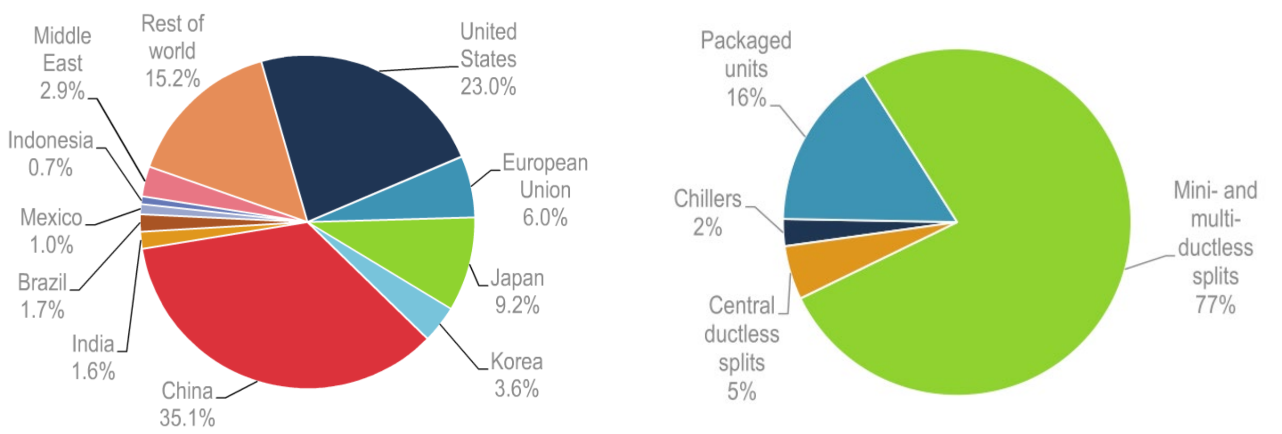


Figure 1. Global air conditioner stock, 1990-2050 (million units).[2]



(a) Stock of ACs by type, end 2016

(b) Stock of ACs by country/region, end 2016

Figure 2. Global air conditioner stock, 1990-2050.[2]

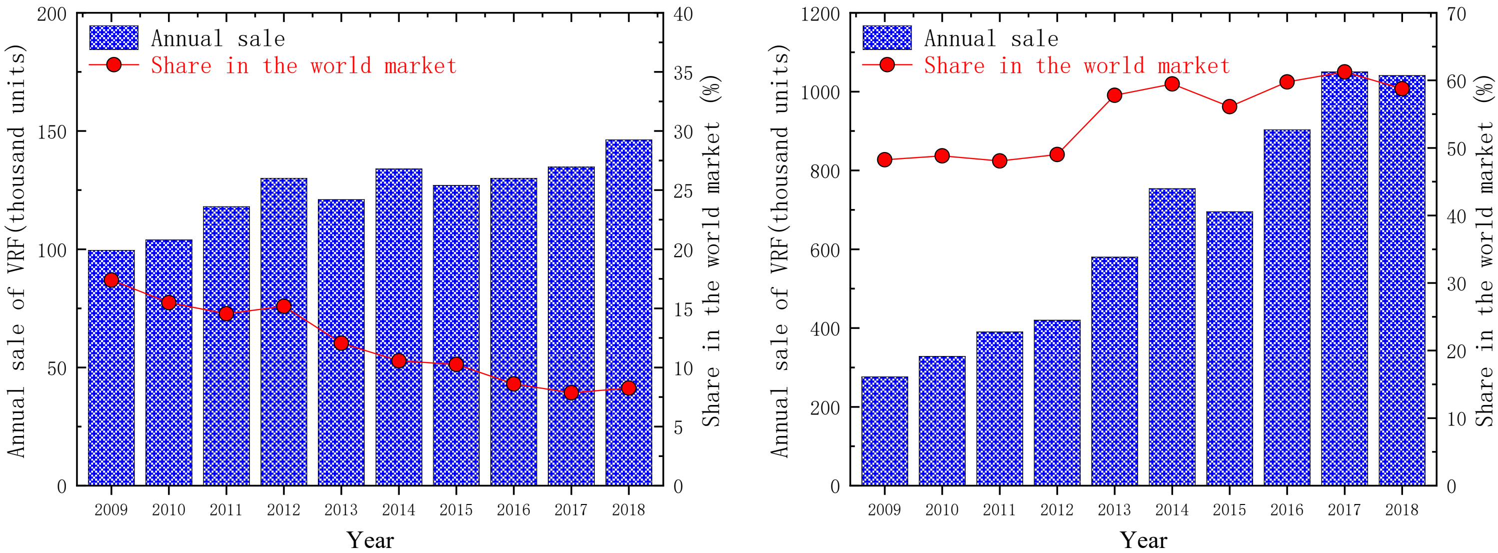
The application of multi-split VRF system has developed rapidly all over the world since its creation in 1982 in Japan. The multi-split VRF system reached the European market in 1987, the Chinese market at the end of the 1990s, and the American market after 2000, successively [**3**]. In 2018, the annual sale volume of multi-split VRF systems in Japan reached 146,000 units (**Figure 3(a)**) [**4**]. In China, VRF systems have for many years maintained the highest share and growth rate among the central air-conditioning market, which is used in about half of medium-sized commercial buildings and one third of large commercial buildings [**5**]. According to statistics, VRF sales volume in China in 2018 reached about 1 million units, which accounts for 58.8% of the world market (**Figure 3(b)**). Moreover, such a huge sales volume in the Chinese market has promoted the development of VRFs in European and American markets.

In order to combat air pollution from traditional boilers, low-temperature ASHPs have been widely used in cold regions around the world, including northern Europe, northern China and Canada. In recent years, northern Chinese provincial administrations have launched programmes to accelerate the phase-out of coal in rural domestic heating [**6**], which has led to the booming development of low-temperature ASHP. Among the main alternative options, direct expansion heat pumps designed for heating in very cold regions have experienced rapid growth in recent years. In addition, novel heating equipment such as ASHP air heaters [**7**] are widely applied in northern China. In 2017, the output value of ASHP used for space heating in China reached RMB 5.6 billion (USD 850 million) [**8**]. Low-temperature ASHPs with quasi two-stage or two-stage compression have been widely applied in northern China, even in areas with ambient temperatures as low as −35°C.

IIR recommendations

Heat pump can play an important role in decreasing the energy consumption of buildings and in meeting global targets for energy savings and low carbon emissions. Because it extracts heat directly from the ambient air or rejects it into the air, the convenient air source heat pump is the most widely used type of heat pump, and is expected to become an essential part of the green heating objective.

Although ASHPs have been investigated and implemented for decades, their total installed capacity worldwide is still much lower than that of direct burning of fossil fuels and direct heating with electricity. Many measures still need to be taken to



(a) Japan

(b) China

Figure 3. Market sales of the multi-split VRF system in Japan and China.[2]

accelerate the use of ASHPs in buildings. The main conclusions and recommendations are as follows:

- Over a year (2018), buildings account for 30% of global energy consumption and 28% of global greenhouse gas emissions. About 40% of the energy consumed by buildings is used for space heating and cooling. ASHPs can play an important role in reducing greenhouse gas emissions.
- ASHP is an energy-efficient technology that allows heating at different ambient temperatures. The normal heating efficiency of ASHP is 3 to 4 times higher than that of direct electric heating. ASHPs can be used in different climates, from −25°C to +50°C, by developing technologies such as variable frequency compressor, cascade ASHP, two-stage compression and quasi two-stage compression.
- ASHPs with higher energy efficiency should be continuously developed, adapted to local ambient conditions and the economic situation. International communication and cooperation should be encouraged.
- The actual performance in the field is the most important factor to consider in order to reduce real energy consumption, as it is generally lower than the performance under nominal conditions. Developing field-adaptive intelligent controls is necessary.
- Further efforts should be made to raise awareness among decision-makers and the public about the benefits of air-source heat pumps. ■

References

[1] International Energy Agency, 2019 Global status report for buildings and construction.

[2] International Energy Agency. The future of cooling: Opportunities for energy- efficient air conditioning (2019).

[3] Shi W., Cheng J., Zhao W., Guidelines for Implementation of Multi-connected Air Conditioning Technology and Related Standards. Standards Press of China. 2011. (in Chinese)

[4] Japan Air Conditioning, Heating & Refrigeration News. VRF Special Issue (2019).

[5] Central Air Conditioning Market. China Central Air Conditioning Market Summary Report, (2018). (in Chinese)

[6] Ministry of Environmental Protection. Technical Guide for Comprehensive Control of Pollution Caused by Civil Coal Combustion (Trial) (2016). (in Chinese)

[7] Chinese Standard JB/T13573-2018. Low ambient temperature air source heat pump air heaters. MIIT, Beijing, China: Standards Press of China (2018). (in Chinese)

[8] Air Source Heat Pump Market Development Report in China (2017). (in Chinese)