Heat Pumps the Trump Card in Fight against Global Warming

Yatabe Takashi of the Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ) describes the promising new environmental technology that is the heat pump.

Global warming is getting worse. If the volume of carbon dioxide (CO_2) emissions continues to increase as it has been, rising sea levels and extreme weather threatens to impact on ecosystems. Meanwhile, prices for fossil fuels, which produce CO_2 when burned, have skyrocketed, hitting both household budgets and corporate bottom lines hard. The key to resolving these two problems is to cut back on our consumption of fossil fuels.

In February 2005, the Kyoto Protocol came into effect as the international community's only framework prescribing limits for greenhouse gas emissions. As the host of COP3, in which the Kyoto Protocol was adopted, Japan must demonstrate to the world the measures it is introducing to cut CO_2 emissions and to provide for energy security not reliant on fossil fuels.

On a global scale, the development of natural energy such as solar power and wind power is progressing, as are moves to conserve energy. Amidst this, an effective environmental tool has come to the fore in Japan that can be implemented by households and companies without the need for any major changes to their current way of life. This technology is heat pump technology, which transfers ambient heat to industrial or domestic applications.

In Europe, heat pumps are used for heating applications that make use of geothermal heat, and are defined as a form of natural energy. In Japan, too, we are now beginning to see the introduction of home appliances that adopt heat-pump systems, such as hot water heaters, washer-dryers, refrigerators, and air conditioners.

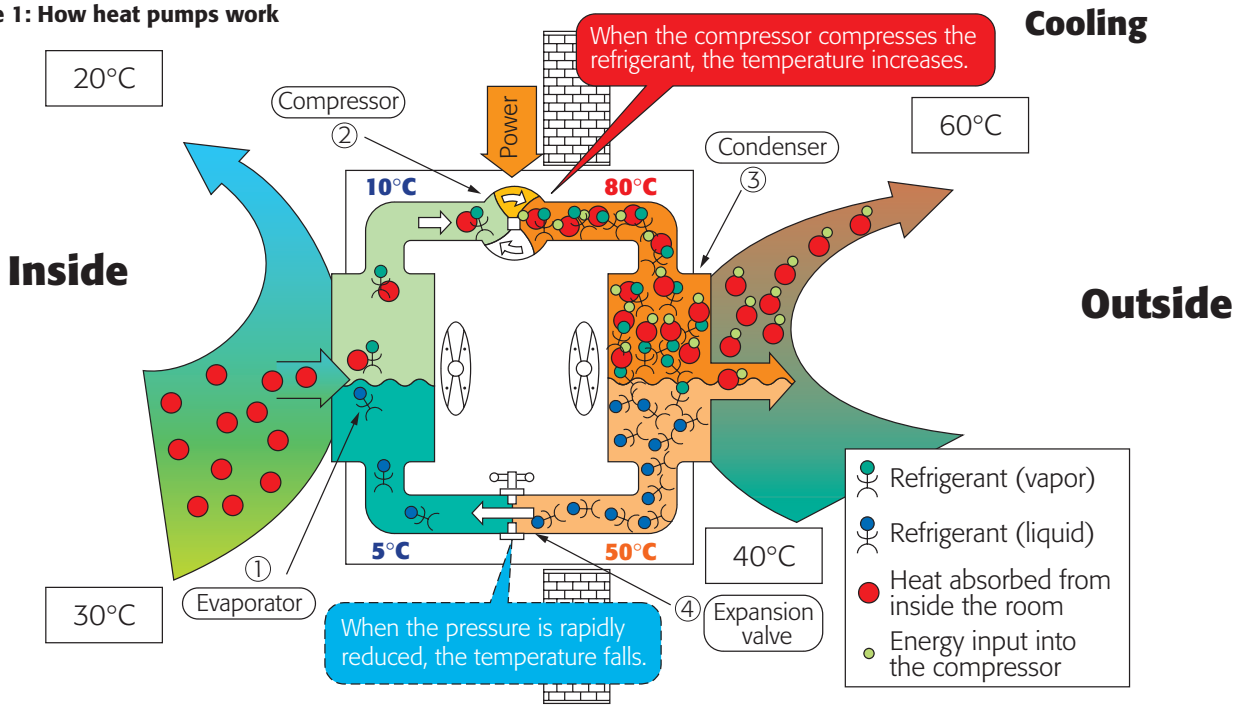
Heat pumps use thermal energy in the ground or in the atmosphere for heating and cooling applications, converting the energy from the state in which it naturally occurs into a usable state.

Heat pumps adopt a motor-driven compressor that compresses the refrigerant (a heat conductive material) and warms it in the same way that a bicycle pump gets warm when pumping air into tires. Heat pumps thus use ground or ambient heat energy to heat a refrigerant that is then pressurized using a motor to create a high-temperature state, and this heat is then used to heat up the air in rooms, or to produce hot water. In the same way that a pump pushes water up to a high level, heat pumps are so named because they are systems that pump up and transfer ambient heat (**figure 1**).

Applications

In the household sector of Japan, around 58% of energy demand is for air-conditioning needs and hot water supplies. Kitchen use accounts for around 7% and demand for other domestic appliance

Figure 1: How heat pumps work



products accounts for some 35%. Similarly in the commercial sector, heating and cooling applications and hot water supply account for more than 50% of total demand. For the most part, this demand is still being met through the use of the heat generated through the burning of fossil fuels. It is such consumption of fossil fuels that is the main contributor to rising levels of CO_2 emissions.

However, environmental awareness is growing in Japan, as is evident from the increase in the number of households that have adopted photovoltaic solar or wind power generation systems for the home. Making use of energy that exists in the natural world in this way is thus now coming to be seen as a standard measure we can take to protect the environment. These types of inexhaustible energy sources that exist in the natural world are referred to as renewable energy sources.

Generally, renewable energy is most often associated with power generation. However if we can extract the necessary efficacy from these renewable energy sources for everyday applications through some minor modification to the state in which they are naturally found, then these renewable energy sources no longer need to be limited to the realms of power generation. Using sunlight to reduce the intensity of lighting illumination or installing an air vent on the roof for natural, wind-powered ventilation are examples of how naturally occurring energy can be used in its natural form. Heat pumps will enable the thermal energy found in the natural world to be utilized to great effect instead of burning fossil fuels.

Heat pumps exchange thermal energy between the inside and the outside of a room, for example. Heat pumps are highly energy efficient because they take naturally occurring ambient heat and turn it into usable energy, thereby reducing the use of fossil fuels.

To date, Europe has led the way in using geothermal heat for heat pumps. However, with recent technological developments, practical applications are starting to be developed for new heat sources as well, such as air. Despite regional temperature differences, air is a ubiquitous energy that is not affected by space limitations or time zones as other environmental technologies are, thus providing a stable energy source.

EcoCute

More and more household appliances that utilize heat-pump systems are coming onto the market. Demand for household supply of hot water in Japan accounts for around 30% of the final household energy consumption, and to date this demand has been met with the hot water supply units that adopt combustion systems. Heat pumps that offer outstanding efficiency have been developed for the hot water sector, which has higher temperature needs than air conditioning applications. An example of this is EcoCute, a heat-pump hot water heater that uses CO_2 as the refrigerant, released in 2001 (**photo**). With a COP (coefficient of performance) of over 3.0 and given that it collects ambient heat and uses this to generate and supply hot water, the EcoCute provides more than 100% efficiency—something that is inconceivable with combustion-based systems—based on the average power generation efficiency in Japan of 36.9% (3.0×36.9%≒110%).

Just five years on from its debut on the market, a new model has been released this year that offers a COP of over 4.9. In terms of its effectiveness in mitigating CO_2 emissions, the EcoCute produces around 800 kg less CO_2 annually per unit than its conventional counterparts. In reality, this equates to around a 60% cut in the volume of CO_2 emissions produced through the supply of hot water. Therefore, the EcoCute is now expected to become increasingly popular, as it is currently the most effective household device in the Japanese market for curbing CO_2 emissions.

Behind EcoCute's groundbreaking success is the fact that it is capable of heating water to 90°C using only the heat pump, even in subzero external temperature conditions.

Conventional heat pumps suffered from a dramatic loss in efficiency (refrigerant efficiency) when external temperatures fell below the zero-degree barrier. To compensate for this, geothermal heat that does not fall below 0°C even in winter was used in very cold areas. However, EcoCute can operate in temperatures as low as -20°C. What this means is that heat pumps can now be run on ambient heat energy alone even in those cold climates where such devices could not be used previously.

Both in the household and commercial sectors, what is very important is to reduce energy consumption associated with hot water supply, so expectations for EcoCute are high. While conventional hot water units cost around 45 dollars on average a month to run, EcoCute, with its excellent energy efficiency and use of off-peak electricity, costs less than 9 dollars a month to run, making it an extremely affordable option for household use. Heat pumps use ambient heat energy instead of fuel, and so it follows that heat-pump air conditioners and heat-pump washers and dryers will also be cheaper to run as well.

COURTESY OF THE AUTHOR

Heat pump unit (right) and hot water storage unit

Urban Use

Heat pumps are also being put to use in the area of urban development. In order to reduce the daytime electrical power load and make use of off-peak electricity, large buildings are now storing power in the form of cold water, ice, or hot water in underground tanks for use during the day. In this way, heat pumps are now often being used in conjunction with thermal storage air conditioning systems.

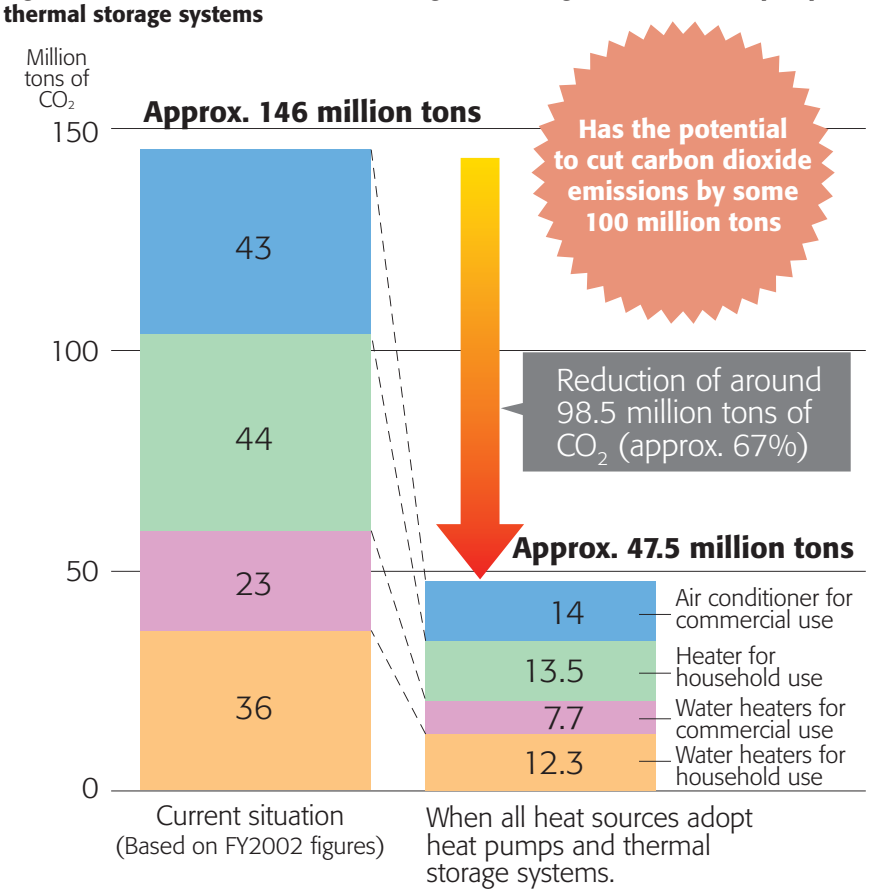
Harumi Island Triton Square, which opened in Tokyo in 2001, is a district heating and cooling (DHC) facility that uses heat pumps in conjunction with a thermal storage system. It boasts the highest energy efficiency of the 150 similar facilities dotted around Japan, generating 61% less CO_2 emissions than average DHC facilities in Japan. What's more, no CO_2 is produced at the site.

So what would happen if heat pumps were introduced into all household and commercial air-conditioning and hot-water systems? Currently the household and commercial sectors combined are responsible for some 150 million tons of CO_2 emissions annually in Japan. If heat pumps were introduced across the board, then this could reduce CO_2 emissions by households by 54.2 million tons and by the commercial sector by 44.3 tons, reducing CO_2 emissions overall by a total of 98.5 million tons (**figure 2**).

Under the Kyoto Protocol, which is aimed at mitigating global warming, the target for Japan is to reduce CO_2 emissions to 6% below 1990 levels by 2010. Within this, the target for the energy sec-

Coefficient of Performance: Thermal energy output Q divided by energy input L. The higher this value is, the more heat (for heating and cooling applications) can be obtained using less energy (greater energy efficiency).

Figure 2: Potential for CO_2 emission mitigation through the use of heat pumps and thermal storage systems



tor is to cut emissions by 118 million tons. Thus heat pumps alone have massive potential in terms of being able to bring Japan close to achieving this target.

Blowing Hot and Cold

More and more air conditioners are being installed in Europe with the soaring summer temperatures in recent years, whereas in Japan, where the climatic conditions call for both coolers and heaters, in the past separate devices were commonly used to provide heating and cooling. However, with the emergence of heat pumps that enable a single device to be used for both heating and cooling, dual heating and cooling heat pumps have become the mainstay for air-conditioning units. Not only has this enabled room conditions to be maintained at comfortable levels, but it has also enabled a drastic reduction in the amount of fossil fuel burned for heating.

This effect is also expected to flow on to Europe and the BRICs, where air-conditioner installations are predicted to increase dramatically with future economic development, as well as other cold-weather climates. We applied the simulations we used to measure the potential for CO_2 emission reductions through the use of heat pumps in Japan to energy demand in France and China as well. The results of this show that, assuming energy demand remains the same in France, then the use of heat pumps in France will bring CO_2 emissions down from 91 million tons to 16 million tons, while CO_2 emissions in China will come down from 500 million tons to 300 million tons. There is a pressing need for energy conservation measures to be introduced particularly in those countries experiencing remarkable economic growth given that economic growth is strongly tied to energy supply-and-demand problems. Conceivably, what Japan needs to do is to contribute to the global community by promoting the installation of highly efficient heat pumps when office buildings and homes are being built in these countries. Once heat pump equipment is installed it will have a service life of at least ten years, and we do not envisage that there will be any improvements in energy efficiency at least within this time frame. EcoCute was used for the first time outside of Japan in 2005 when it was adopted for use in heating equipment in Swedish homes, although only 3,000 units have been used at this stage.

Spreading the Word

In this, the "Century of the Environment," it will be of paramount importance for Japan to contribute to the international community by continually developing cutting-edge technologies for fuel cells and the like. However, as the Kyoto Protocol's first commitment period approaches, we can no longer afford to pin all our hopes on future technologies. In the case of Japan, for example, while EcoCute is just as effective in cutting down on fossil fuel use as fuel cells are, it will be more effective in cutting CO_2 emissions than fuel cells, given that non-CO_2-producing power generation, such as hydro, wind, and nuclear power generation, is also involved. What is most important, however, is that heat pumps are already commercially available in air conditioner, hot water heater, washer-dryer, and refrigerator products, and that they are able to make an immediate contribution to mitigating the environmental impact of these devices.

EcoCute and heat-pump washer-dryers have only just come onto the market in Japan, and as such, they have not really taken off as yet. As of the end of March 2006, 480,000 EcoCute units had been installed, and with 45 million households in Japan, this equates to a penetration rate of only 1%.

However, the Japanese Government has set some ambitious goals and is aiming to have 5.2 million units installed by 2010. They are also subsidizing installation to promote the more widespread use of this technology in order first to cut CO_2 emissions through energy conservation, and second to have power generation plants operate off-peak to improve power-generation efficiency as well.

Applications for these subsidies are handled by the Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ). Obviously this is not the HPTCJ's only role. As the national center promoting the popularization of heat pump technology, we are also responsible for providing information on heat pumps within Japan and overseas as well.

Today, as we enter a new phase in the wake of the soaring crude-oil prices, surely many of the problems we are facing now as a result can be resolved through the use of energy conservation technology. We believe that the heat pump—a technology developed in Europe and refined through technical innovation in Japan—holds the key to this.

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