

## Executive Summary

## Introduction

Would you believe it? That such realities are already within our reach. That “the use of CO<sub>2</sub>-emitting ‘fire’ has become a thing of the past.” And that “here comes a new era that we can use the clean, renewable and inexhaustible energy source we haven’t ever been aware.” This is not at all fantasy: in fact, the dream technology that meets all these challenges is in our hands already.

Problems associated with global warming and energy supply and demand are the issues that humankind in the 21st century must overcome. The key to resolving these problems lies in realizing “dramatic improvements in energy utilization efficiency” and “decarbonization of energies.” A technology that can accomplish both these tasks simultaneously is the heat pump.

As a resource-scarce nation, Japan has waged a government-orchestrated campaign to promote energy efficiency, drawing lessons from the Oil Crisis in the 1970s that triggered the unrest of resource imports. These efforts helped the nation to achieve the highest energy conservation standards in the world. And it was the heat pump technology that made this feat possible as a major pillar of energy-saving technology in the residential and business sectors.

Most households in Japan are equipped with heat pump-based heating and cooling equipment. Under the government’s Top Runner Regulations, a unique program even by global standards, home appliance retailers dispense at reasonable prices air-conditioners that vie for the world’s highest level performance. Highly efficient heat pumps are also employed in large-scale district heating and cooling (DHC) services. Moreover, Japan developed, for the first time in the world, a CO<sub>2</sub> refrigerant heat pump water heater, an equipment that takes advantage of “heat in the air” to supply hot water. As such, Japan is one of the most advanced countries in heat pump technologies.

It is our earnest hope that more and more people in the world would learn the truth – by obtaining correct information and knowledge – about the “heat pump technology” that has an enormous impact on energy conservation and CO<sub>2</sub> reduction, so that each one of us would be motivated to do what he or she can to tackle global warming. We look forward to the aggregate achievement of such endeavors bearing fruit. And we wish to make a contribution globally through the dissemination of this innovative technology to save our planet earth that is on the verge of crisis.

## Current Situation

Today, as problems associated with global warming increasingly threaten our environment, the time has come for heat pumps, with their rapid technological innovation, to show its true ability on the international scene as the Trump Card in the Measures Against Global Warming.

Based on a concept devised by Sadi Carnot and developed by Lord Kelvin and others in the 1800s Europe, this thermal utilization technology has a long history for use in refrigerators and for cooling.

In contrast to cutting-edge technologies under development that tend to attract public attention with loud fanfare and drum up expectations, however, the public has shown little interest in the fundamental mechanism of heat pump, which is a mature conventional technology. For all these reasons, the truth about heat pumps – that widespread dissemination of the heat pump technology holds a huge and realistic potential for resolving both energy and environment issues confronting humans – has not been fully understood in spite of its monumental significance.

## Need for Combustion-free Systems: A Conversion from Fossil Fuel-dependent Culture

In the commercial sector that includes residences and office buildings, the bulk of the energy has been consumed for heating, hot water supply and other purposes to sustain living. This energy comes primarily from “combustion” systems that utilize thermal energy generated by burning fossil fuels.

The 4th Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming, which today calls for urgent response, is “very likely” to have been caused by an increase in the atmospheric concentration of carbon dioxide (CO<sub>2</sub>) that accompanies mass consumption of fossil fuels as a result of human activity.

In order to resolve global warming issues, break away from the constraints posed by fossil energy resources and realize environmental preservation along with sustainable development of our economy and society, we will need to build a “low-carbon society” that accomplishes a substantial reduction of CO<sub>2</sub> and other GHG emissions and stabilization of the atmospheric concentration of GHGs at levels that would not adversely impact the climate.

In this regard, heat pump is the key technology that would enable energy suppliers and consumers to make an active choice to join the movement to halt global warming towards this goal.

## Outstanding Features of Heat Pump: A Highly Efficient Heat Transport Engine

Heat pumps have two outstanding features.

First, a heat pump moves thermal energy between out-of-doors and indoors instead of “generating” thermal energy from scratch by combustion. The heat pump, based on a simple heat transport engine that applies basic principles of thermodynamics, is already widely used in refrigerators and for cooling and other purposes.

Second, theoretically speaking, the energy consumption efficiency of a heat pump system is much higher than that of a combustion-based system by several times to more than tenfold. The amount of thermal energy transported is much larger than the inputted energy (normally electric power) consumed to power thermal transport. This means that collecting ambient heat by a heat pump after converting fossil fuels into electricity is a more efficient – resource-saving and CO<sub>2</sub> reducing – means of obtaining “heat” than burning fossil fuels directly.

In the past, attention on the heat pump, being an essential technology for cooling purposes, has been focused primarily on the first feature as a heat transport engine. Although its theoretically high efficiency had been known, little attention has been paid to the energy-saving properties, the second feature, of this technology partly because the technology was in the developing stage and also because fossil fuels for competing combustion equipment could be obtained at low cost.

However, amid major transformations in energy, environment and other social conditions in the past decade or so, the appearance of many kinds of heat pump equipment with higher energy consumption efficiency on the market has reinvigorated interest in the energy-saving properties of heat pumps.



## Rapid Technological Progress

Rapid technological innovation in the heat pump technology has been fueled by two major factors: continuous improvement or “kaizen” at the production site toward even greater leaps in energy conservation and expectations for a “combustion-free technology” that would help combat global warming.

A monumental breakthrough was achieved with Eco Cute, a CO<sub>2</sub> refrigerant heat pump water heater, which was developed in 2001 in Japan as the first such product in the world. Eco Cute opened up new possibilities for the application of heat pump in hot water supply systems, an accomplishment that had been difficult with CFC-based refrigerants, while its high efficiency led to substantial improvements in both energy conservation and CO<sub>2</sub> reductions.

The Japanese government has introduced a scheme named the Top Runner Regulations in an effort to encourage continuous improvement in the energy-saving performance of various home electric appliances. This one-of-a-kind program in the world has served to double the energy consumption efficiency of air-conditioners for residential use in just ten years and consolidated the status of heat pumps as being far superior to combustion-type heaters in terms of energy-saving and CO<sub>2</sub>-reducing performance.

Globally, high-efficiency centrifugal chillers, developed in the U.S. with the application of heat pump technology, are widely used for cooling office buildings and district cooling. Also, in recent years, further advances in the energy conservation performance have been achieved with the commercialization of centrifugal chillers that allow variable speed operation with inverter control.

In Europe, systems that employ heat pumps to utilize heat in the ground for heating have been increasing. Ground source heating can only be realized with the application of heat pump technology.

Furthermore, in Japan, heat pumps are now being used in clothes dryers, signifying a new stage in their applications.

## Potential of CO<sub>2</sub> Reduction

Controlling CO<sub>2</sub> emissions has been a major motivating force behind the recent surge in the development of numerous heat pump systems in Japan. In the commercial sector for residential and business uses of Japan, energy consumption has been constantly expanding for these years. In this sector, heating and hot water supply account for nearly half of the energy consumed, which is one of the main contributors to the CO<sub>2</sub> increase. Moreover, about 90% of hot water supply, heating and other heat-based demands are met by the heat generated by burning CO<sub>2</sub>-emitting fossil fuels. It is against this background that heat pumps are drawing huge attention as an alternative, CO<sub>2</sub>-reducing technology for fulfilling heat-related demands.

Also, expectations for the dissemination of heat pump air-conditioners run high in replacement of absorption type refrigerators that burn fossil fuels now, commonly used in business sector of Japan for cooling, primarily in large-scale facilities, in an effort for reducing the enormous volume of CO<sub>2</sub> emissions.

By replacing fossil fuel-based direct combustion systems prevalent today with heat pump equipments, which drastically improve energy utilization efficiency with the use of “ambient heat” to meet such demands for cooling and heating, primary energy consumption and CO<sub>2</sub> emissions can be reduced substantially without changing the amount of thermal energy available to users. The estimation was made on the basis of current energy demand figures in Japan to gauge the impact of the maximum possible introduction of heat pumps on CO<sub>2</sub> emission reductions. Thanks to extraordinary progress in the heat pump technology that led to drastic improvements in energy utilization efficiency in recent years and an expansion in the scope of application, the projected CO<sub>2</sub> emission reductions totaled 130 million tons per year, equivalent to about 10% of Japan’s total emissions at present.

A simulation by the IEA Heat Pump Center estimates that more widespread use of heat pumps would cut CO<sub>2</sub> emissions by about 6% or 1.2 billion tons.

Furthermore, this advantage of CO<sub>2</sub> reduction can be quite easily realized by heat pump equipment that are already available on the commercial market, instead of having to place expectations on the development of unreliable future technology or equipment. In other words, we should draw much attention to this highly effective and realistic measure because the advantage of significant CO<sub>2</sub> reductions can be obtained immediately by anyone, anywhere, anytime who would care to purchase and install a heat pump-based unit.

## Significance of Dissemination that Extends beyond CO<sub>2</sub> Reduction

As we have seen, the replacement of fossil fuel consumption with the “ambient heat” amassed by heat pumps carries great significance in various ways. Its CO<sub>2</sub> reduction performance would not only have a huge impact on controlling global warming, but also significantly cut back on the amount of resource imports and contribute to energy security, and promote the utilization of renewable energy that takes advantage of heat in the air that relies on a clean and - inexhaustible supply that exists in abundance in the natural world.

Japan, a nation scarce in natural resources, is not the only country that carries out measures to disseminate heat pumps. In an effort for doing without oil and without global warming, steps to promote the use of heat pumps are actively pursued in Europe and the U.S. with a view to promoting the thermal utilization of renewable energy and also mitigating the energy supply-demand situation that has tightened further in response to the growth in global energy demand that is expected to continue into the future.

## Japan's Position

With the intensification of measures to tackle global warming in recent years, the reputation of the heat pump technology has come to be established as a realistic and highly effective means for energy conservation and CO<sub>2</sub> reduction. This, in turn, further raised expectations on heat pumps as a tool for resolving both energy and environmental problems at the same time.

Also, the successful development of various types of heat pumps in Japan may be attributed to its climatic conditions – warmer and more humid than in Europe or the U.S. – that are fit for heat pumps. By installing a heat pump air-conditioner, heating and cooling needs can be met without having to install separate units, which means small energy consumption and less energy costs. The same applies to heat pump hot water supply.

However, due to their high initial costs in comparison to simple combustion-based systems, the dissemination of heat pump systems has been far from adequate.

At present, the Japanese government is launching campaign to promote the use of heat pump units, rating them highly in the Kyoto Protocol Target Achievement Plan, New National Energy Strategy, reports by environment and energy-related government councils and other programs. Also, the government hopes to make a positive contribution by disseminating Japan's energy conservation technology, which ranks among the top in the world, toward building a “low-carbon society” for a better global environment.

## Conclusion

Heat pumps – using the power of technology to recycle the “heat” found in the “air” and “ground” – a recyclable, clean and inexhaustible supply with the blessing of the sun. A solar energy recycling society, which recycles the blessing of the sun – the heat in the air, heat in the ground, heat in the lake water and heat in the river water – is the ultimate sustainable society. The time has come for people in the world to join hands, with each individual citizen and business utilizing the technology and putting the achievements together toward building a sustainable society.

This text introduces the heat pump technology and its evolution up to its advanced stage in its entirety. It also reveals that the action toward building a sustainable “low-carbon society,” in a departure from dependence on the use of fossil fuels, while sustaining comfortable and convenient way of life and highly efficient economic activities, has already begun through greater utilization of natural energy including ambient heat generated by heat pumps.

Furthermore, it is our earnest hope that this text, which explains in detail the current condition of such technologies, impact of their dissemination, policy trends in Japan and elsewhere, among others, would be of help in the policy planning of governments that care sincerely for our planet and humankind.

