World Business Council for Sustainable Development

Case Study 2008

TEPCO
High-efficiency heat pumps

The business case

As the energy efficiency of heat pumps improves dramatically, higher oil prices make heat pumps even more cost effective where major electricity sources consist of non-fossil fuels. While the initial equipment cost of heat pumps is still relatively higher than that of a less-efficient combustion system, these costs are compensated for by decreasing heating and cooling bills over the long term. TEPCO has developed a heat-pump technology-based heating and cooling system that uses waste heat from treated sewage water from a nearby public sewage treatment plant to power the heat pumps in Sony City. This reduces CO_2 emissions by about 3,500 tons, almost 70% less than a conventional gas absorption chiller, and reduces water use to 117,800 m^3, or 92% less than a common office building.

Situation

Humanity must overcome problems associated with global warming and securing energy supply. The key to resolving these problems lies in realizing dramatic improvements in energy utilization efficiency and decarbonizing energies. A technology that can accomplish both these tasks simultaneously is the heat pump.

Heat pumps

Heat pumps are based on a simple heat transport engine that applies basic principles of thermodynamics. They convert unused “ambient heat” into heat of utilizable temperatures; using small amounts of electric power instead of using the resistant heat or the heat of combustion of fossil fuels (see Figure 1).

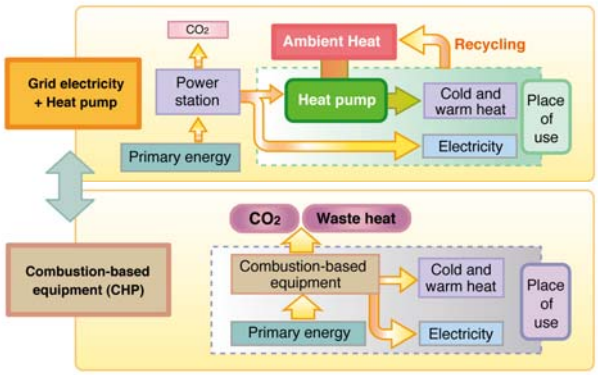

Figure 1: How a heat pump works
Source: Heat Pump & Thermal Storage Technology Center of Japan. "Heat pumps: Long Awaited Way out of Global Warming".

A heat pump’s energy consumption efficiency is much higher than that of a combustion-based system. The amount of thermal energy that heat pumps transport is much larger than the input energy (normally electric power). As a result, collecting ambient heat by a heat pump after converting fossil fuels into electricity is a more efficient means of obtaining “heat” than burning fossil fuels directly.

With combustion-based equipment (upper diagram of Figure 2), it is impossible to use the excess heat from the energy inputted. With a high-efficiency heat pump that uses heat in the air (lower diagram); it is possible to use more than twice as much heat as the amount of energy inputted, even though the inputted energy goes back to the primary energy source.

In commercial Japanese residential and business buildings, heating and hot water supply account for nearly half of the energy consumed. About 90% of hot water supply, heating and other heat-based demand are met with heat generated by burning CO_2-emitting fossil fuels.

A comparison of energy prices in the Tokyo metropolitan area as of November 2006 shows that the energy price of high-efficient heat pump air conditioners (with 6.6 coefficient of performance) is 0.9 yen per megajoule (MJ), that of 100% thermal efficient kerosene stoves is 2.1 yen per MJ, and that of 100% thermal efficient gas stoves is 2.5 yen per MJ.

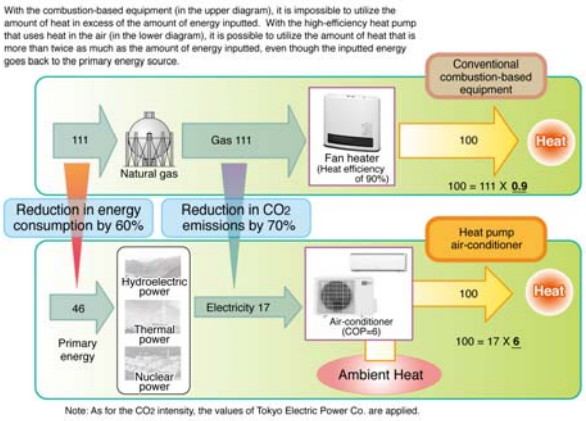

Figure 2: Use of ambient heat by heat pumps is the key to energy conservation and CO_2 emissions reductions
Source: Heat Pump & Thermal Storage Technology Center of Japan. "Heat pumps: Long Awaited Way out of Global Warming".

The Coefficient of Performance (COP) is a measure of the efficiency of energy conversion of a system. It is the ratio of cooling or heating output divided by the energy inputted. For example, a COP of 5 means that input of 1 is required to produce heat of 5.

Based on current energy demand projections for Japan, it has been estimated that by replacing fossil fuel-based direct combustion systems with heat pump equipment to meet the demand for cooling and heating and hot water supply, the decrease in primary energy consumption could lead to CO_2 emissions reductions of up to 130 million tons per year, equivalent to about 10% of Japan's total emissions at present, without changing the amount of thermal energy available to users.

According to a simulation by the IEA Heat Pump Center, more widespread use of heat pumps globally (about 30% of ownership of heat pumps) could cut global CO_2 emissions by approx. 6% or 1.2 billion tons worldwide.

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.

TEPCO

TEPCO, the largest electricity supplier and one of the most eminent energy service companies (ESCO) in Japan, has been active in promoting energy efficiency in residential and commercial buildings and factories. The main technologies TEPCO proposes are heat pumps and thermal storage systems that play a major role in reducing buildings' CO_2 emissions.

Sony City

Completed in October 2006, Sony City is Sony Corporation's new headquarters in Tokyo. The building uses a high-efficiency heating and cooling system proposed by TEPCO. The system makes efficient use of waste heat from sewage water. Sony City is the first single private building to introduce heat pumps using unused heat from a public sewage treatment plant in Japan. The energy conversion coefficient of performance of this building exceeds top class district heating and cooling systems in Japan.

Targets

Under its new mid-term group environmental targets, Green Management 2010, Sony set a goal to reduce CO_2 emissions of 7% or more by 2010 (from fiscal year 2000 levels). The aim of the heating and cooling system was to increase energy conversion efficiency to much higher levels than those seen in conventional heating systems (e.g., gas absorption chillers). Sony and TEPCO set the target to achieve a 5.8 energy conversion coefficient of performance (see Annex for details of this target).

The Sony City heat pump system

The heat-pump technology-based heating and cooling systems use waste heat from treated sewage water from a nearby public sewage treatment plant to power the heat pumps (see Figure 3). Using large thermal storage for heating and cooling can lower energy costs by using special utility tariffs for the user of thermal storage tank. A combination of a high efficiency centrifugal chiller and an inverter type chiller reduces energy use dramatically compared to conventional absorption type chillers, resulting in one of the most efficient cooling and heating system in Japan. This helps Sony reduce energy use and ensures more efficient resource use at its business facilities.

Nearby Sewage Plant

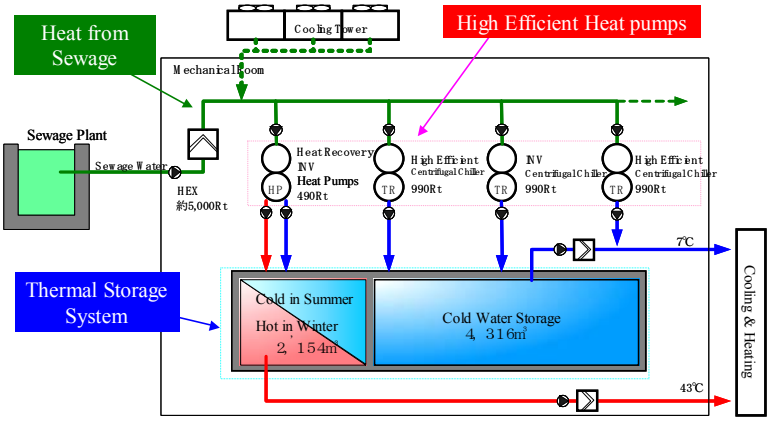

Figure 3: Heat source system using untapped energy

Furthermore, Sony introduced a natrium and sulfur (NAS) battery service on its site and managed to shift the peak load caused by the new heat pumps from day to night. The NAS battery (with an output capacity of 2.5MW) stores electricity at night and discharges the stored electricity during day time to reduce electricity peak demand.

Problems and difficulties

Developing a procedure to use public facilities for private use took up much of the project's time, as this building was the first to start using unused heat from public sewer treatment. The plan needed to be submitted to the Tokyo Metropolitan Government for approval, which proved to be a big challenge. But finally, the project turned out to be a win-win situation as it meant energy savings for Sony and new business for the government's bureau of sewage.

Results

The average coefficient of performance for this heating and cooling system in the year after commissioning was 5.19 (January 2007 – April 2008), exceeding the initial target of 5.18.

The environmental benefits of the Sony City project estimated by TEPCO are as follows: Reduction of approximately 3,500 tons of CO_2 per year, which is almost 70% less than a conventional gas absorption chiller and 117,800 m^3 water used, or 92% less than a common office building (see Table 1).

	Conventional	Unutilized heat source Heat pumps	Comparison
Cooling Source	Absorption Chiller	Centrifugal Chiller	
Heating Source	Boiler	Water heat source heat pumps	
CO_2 ($tonCO_2$/YR)	5,000 ＜baseline＞	1,500	▲3,500 (▲70%)
Clean Water usage (m^3/YR)	117,100 ＜baseline＞	9,300	▲107,800 (▲92%)

※TEPCO Estimation

Table 1: Estimation of environmental merits of this project

Figure 4 shows the COP of *primary energy conversion* of the Sony City heat pump system compared to other systems. (The COP of primary energy conversion is calculated as the system COP of 5.18 multiplied by the thermal power generation efficiency in Japan of 37%). The COP of primary energy conversion of 1.9 of Sony City is much higher than the most efficient District Heating and Cooling (DHC) systems in Japan and one of the highest among Japanese office buildings.

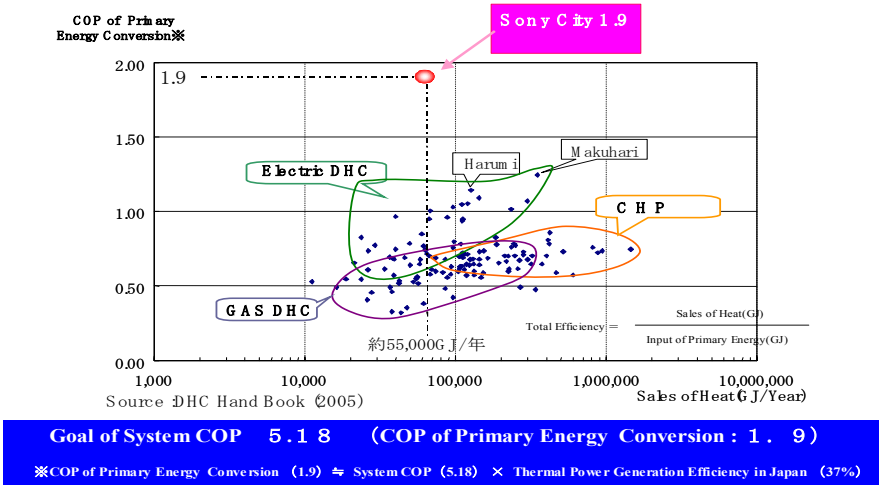

Figure 4: Coefficient of Performance of Sony City's heating system

Lessons learned

The project revealed that the high construction cost of a facility to use sewage water is a hurdle for potential users. Any replication will require strong support from the local authorities. Furthermore, financial incentives from government such as subsidies to overcome the barrier of higher initial cost and tax exemption are needed to make this kind of project economically feasible.

A further challenge will be to use heat from sewage water for other buildings of this area and to optimize the area energy management. To realize this, there will be a need to promote new sewage infrastructure and bring out the new position and purpose of the use of the sewage plant.

Further information

Heat Pump & Thermal Storage Technology Center of Japan (2007), Heat Pumps – Long-awaited Way out of the Global Warming http://www.hptcj.or.jp/

About the WBCSD

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Our **mission** is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

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