# A DEVELOPMENT OF A HEAT PUMP FOR A THERMAL RECOVERY SYSTEM USING $CO_2$ AS A REFRIGERANT

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**Abstract:** This paper discusses the capacities of $CO_2$ as a refrigerant that recovers geothermal heat and waste heat from storage tanks. The $CO_2$ allows heat exchange through latent heat. Thus, it increases the exchanger duty per unit length of a heat collection pipe, which drastically reduces the heat pump installation cost and running cost. In this study, authors created pilot versions of an air conditioning system using geothermal heat and a cold and hot water production system using waste heat from a storage tank with $CO_2$. Authors evaluated their performance and electricity consumption. As a result, the air conditioning system showed about the same air conditioning abilities as a system with propylene glycol, which was installed for comparison when the installed length of the heat recovery pipe was one-third to one-half, and the electricity consumption was one-half with the $CO_2$. Meanwhile, the cold and hot water production system that used waste heat from a storage tank recovered as much as one to nine kilowatts of heat capacity per meter of a heat collection pipe when the $CO_2$ was used.

**Key Words: Heat Pumps, Geothermal Recovery, $CO_2$, Latent Heat, Cost Reduction**

## 1 INTRODUCTION

The heat pump technology has been attracting attention in recent years for its lower running cost and $CO_2$ emissions in comparison to systems that use fossil fuels. The demand for heat pumps for air conditioning, both heating and cooling, has been increasing in the field of protected horticulture because the inside of greenhouses needs to be kept at a constant temperature throughout the year depending on the crops produced. However, common heat pump systems use the air as a heat source; thus, they need to work under extremely large loads when they recover and release heat in cold regions where the temperature drops below zero and in extremely hot summer, like the summer in Japan in 2010, when the temperature rose above 40 °C. Thus, the load on the systems can be reduced if the heat is recovered underground where the temperature is relatively constant. In addition, the system releases the heat underground rather than into the air during cooling, which becomes an effective way of mitigating the heat island phenomenon. To recover geothermal heat, the system now exchanges heat through sensible heat by circulating the water refrigerant to which anti-freezing agent was added through pipe laid underground. Yet, the high initial cost for laying the pipe has been considered as one of the obstacles in promoting the system. When a system uses $CO_2$ refrigerant to recover geothermal heat, it means latent heat exchange, which increases the exchanger duty per unit space of laid pipes. This decreases