

THE EFFECT OF INTRODUCING OF HEAT PUMP FOR HEAT SOURCE SYSTEM AT THE UNIVERSITY -A CASE AT CHUO UNIVERSITY TAMA CAMPUS-

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Abstract: As reducing the environmental load becomes more important, we have been tracking energy consumption data and implementing improvements at Chuo University Tama Campus. Measures such as increasing lighting efficiency and improving operations have yielded steady results in reducing CO₂ emissions. However, to further reduce the environmental load, the main heat source system was renovated in fiscal 2008 to improve heat generation efficiency.

The university eliminated the centralized system that high-temperature water generated from an oil boiler was transferred to two substations and supplied hot and cold water generated from the heat exchangers and absorption refrigerators in the substations to each building. And several ice thermal storage air conditioning systems and electric heat pumps were distributed. The measures eliminated existing problems such as energy loss during transfer and too much auxiliary equipment power, and improved heat generation efficiency. At the same time, the university also changed the main energy source from oil to electricity.

Compared to before renovating the heat source system, heat generation efficiency increased by about 50%, and CO₂ emissions reduced about 3,200 tons.

**Key Words: University, heat pump, ice thermal storage, air conditioning,
Environmental load-reduction methods**

1 Introduction

The Tokyo Metropolitan Government introduced duties to reduce total greenhouse gas (GHG) emissions and an emissions trading scheme, mandating GHG reduction at businesses in Tokyo. The scheme entered the first compliance period, from fiscal 2010 through 2014, this fiscal year. During the same period, it is obligatory to reduce the 8% of guideline value for CO₂ emissions on the average annually.

As reducing the environmental load becomes more important, we have been tracking energy consumption data and taking remedial measures based on the data at Chuo University Tama Campus. Measures such as increasing lighting efficiency and improving operations have steadily yielded CO₂ emissions reductions. To further reduce the environmental load, the main heat source system was renovated in fiscal 2008 for lower heat generation efficiency.

This report provides an overview of the renovation plan for the heat source system and the results.

2 Facility Overview

2.1 Building Overview

Chuo University Tama Campus, located in the western part of Tokyo, is a verdant suburban campus with buildings including administrative offices, lecture rooms, a large spatial hall, library, and gymnasium spread over approximately 520,000 m².

Figure 1 shows a map of Chuo University Tama Campus and the buildings the Energy Center supplies energy to. The heat source machines were set up in the Energy Center, Substation I, and Substation II. High-temperature water was generated from an oil boiler in the Energy Center and transferred to the two substations. The water was converted into hot and cold water by a heat exchanger and an absorption refrigerator at each substation. Substation I supplies hot and cold water to Buildings No. 1 through 3 and the library building; Substation II supplies the water to Buildings No. 5 through 9, 11 and Hilltop.

Chuo University
 742-1 Higashi-Nakano, Hachioji, Tokyo
 Site Area: 518,401 m²
 Total Floor Area: 206,476 m²
 Construction Completed in June 1977

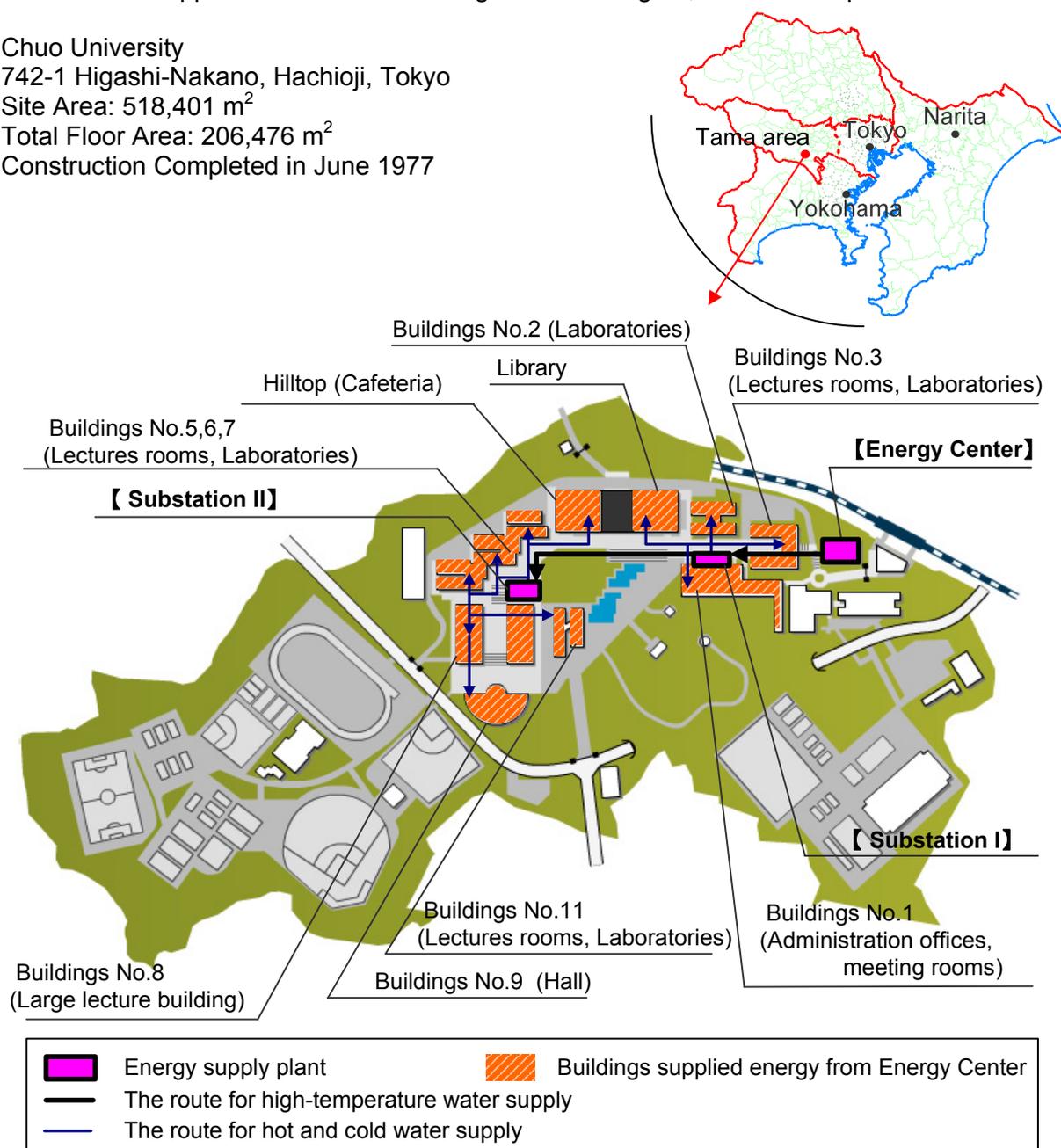


Figure 1 Map of Chuo University Tama Campus

2.2 Heat source system before renovation

Figure 2 shows the heat source system before renovation. The heat source system adopted the Energy Center scheme to supply heat. High-temperature water was generated from an oil boiler in the Energy Center and transferred to the two substations. The water was converted into hot and cold water by a heat exchanger and an absorption refrigerator at each substation. Then the generated hot and cold water were supplied to each building. The total floor area of the buildings supplied from the Substation I is 69,864m², and from the Substation II is 70,414m².

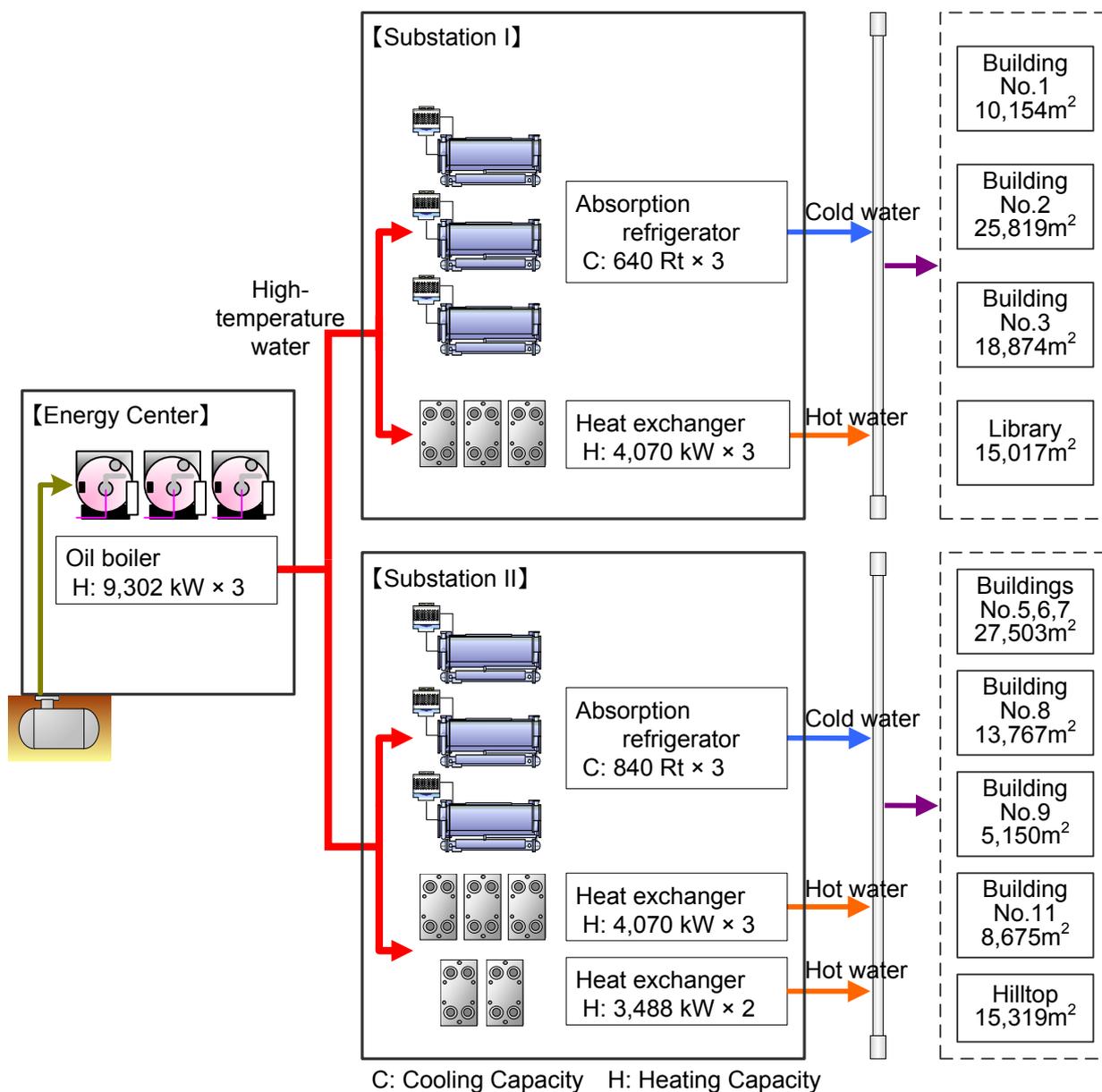


Figure 2 Heat source system before renovation

2.3 Energy loss analysis before renovation

To clarify the heat supply problems before renovation, energy loss was analyzed from heat generation to supply based on the fiscal 2005 operation records. Figure 3 shows the transition of primary energy consumption in the heat source system and auxiliary equipment power. The thermal energy input is considered as the base for the energy loss during each process. The loss was 20% while generating high-temperature water, and 14% during the

heat transfer. The power consumption of the auxiliary equipment was 14,929 GJ per year. Approximately 41% of the total was consumed for the heat sources and 59% during the heat transfer. The heat generation efficiency [heat amount supplied to the buildings / (the amount of thermal energy input + auxiliary equipment power)] of the heat source system was 0.53.

The heat supplying issues discovered in the Energy Center scheme were low heat generation efficiency, energy loss during transfer, and too much power consumption for auxiliary equipment and transfer. We determined the renovated heat source system that solved these problems, and achieved the reduction of CO2 and the lower life-cycle cost.

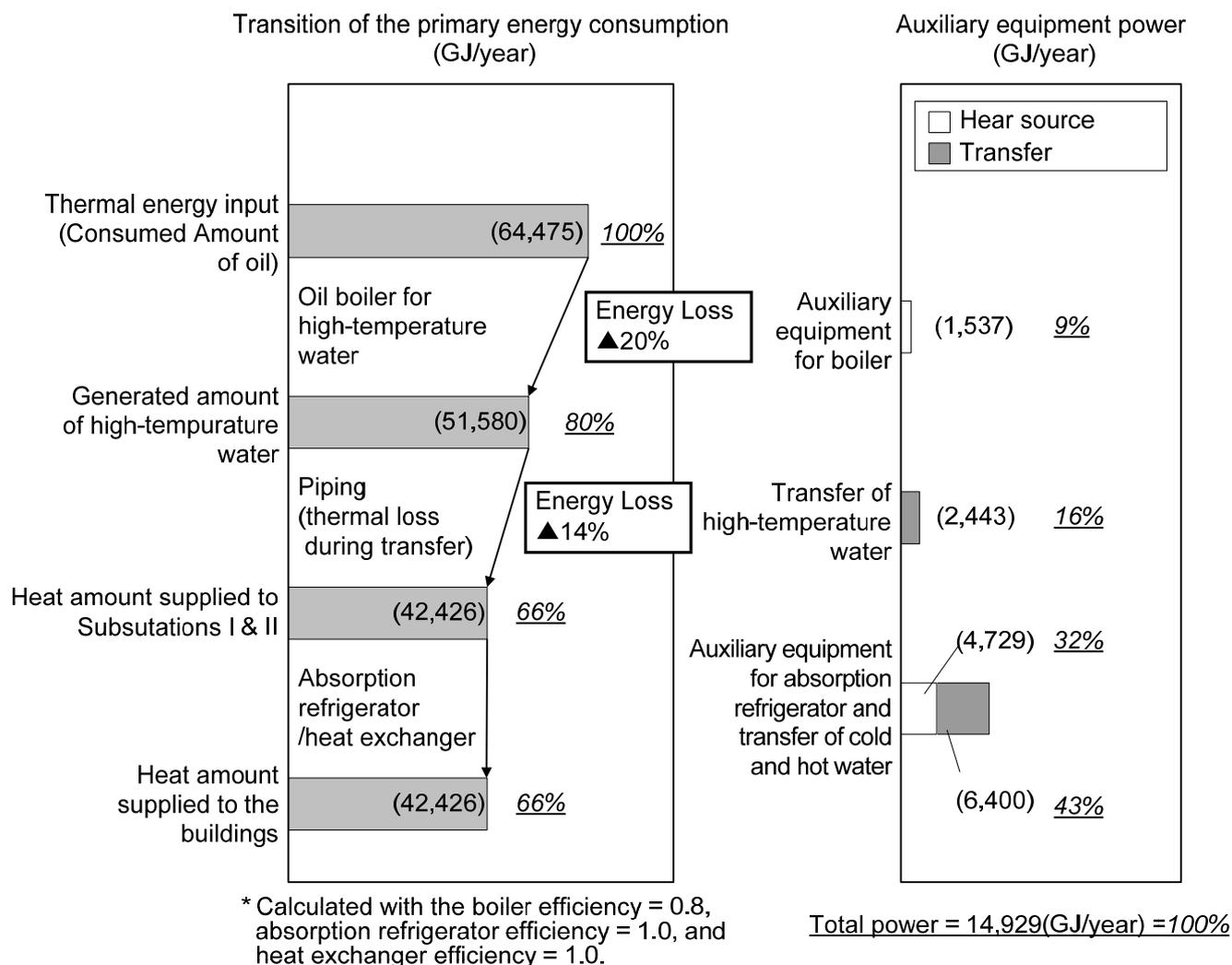


Figure 3 Transition of primary energy consumption and auxiliary equipment power

3 Renovation

3.1 Renovated heat source system

Figure 4 shows the renovated heat source system. Instead of supplying high-temperature water from the oil boiler, highly efficient electric heat pumps were distributed in Substations I and II. This resolved the existing issue of energy loss during transfer and consequently enhanced the heat generation efficiency. At the same time, to reduce further environmental load, the main energy source was changed from oil to electricity.

An ice thermal storage system was adopted to compress the capacity of the heat source units. The space no longer needed for water in frame tanks was utilized to install the ice thermal storage tanks.

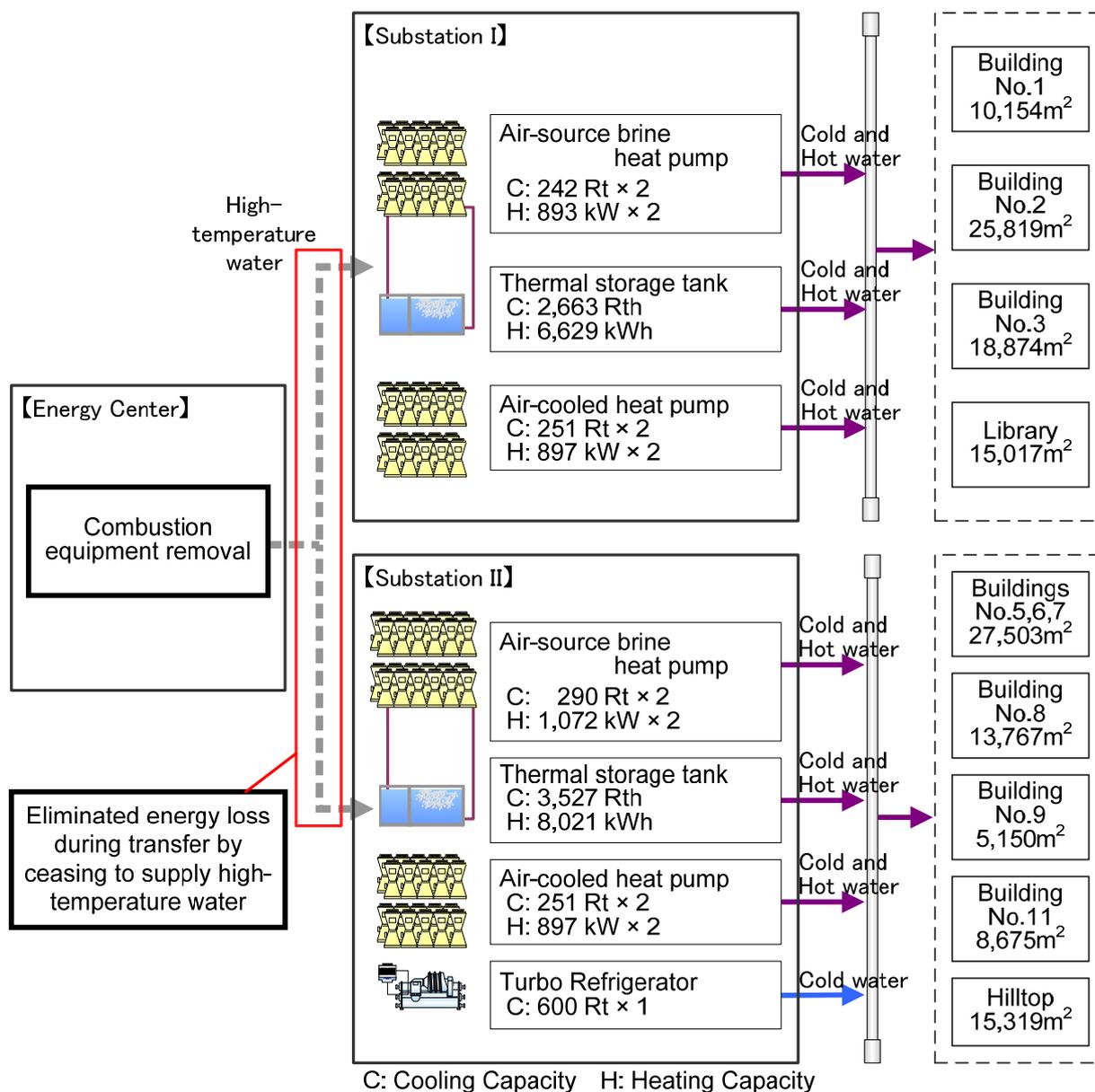


Figure 4 Heat source system after renovation

3.2 Renovation work overview

3.2.1 Heat source system components

Air-cooled heat pumps are the main unit of the heat source system due to their highly efficient operation in both cooling and heating. The pumps were installed on the rooftops of Buildings No.2 and No.7 where cooling towers were placed before the renovation. The renovated units fit in the space, effectively utilizing the existing equipment foundations. The weight is within the allowable load-carrying capacity of the buildings. The brine type was selected to meet the requirements for the ice thermal storage system.

Highly efficient turbo refrigerator was installed in Substation II where the cooling load is higher. The system is able to control the heat balance between the substations depending on the cooling load.

3.2.2 Transfer power reduction rate

In the supply of the hot and cold water from each substation to the buildings, the transfer power is reduced by introducing the inverters into the pumps. This is an efficient energy-conserving method for university where the air conditioning load fluctuates greatly due to differences including between academic terms and breaks and between day and night.

3.2.3 Ice thermal storage system

Thermal storage is an economical system that utilizes lower-rate nighttime electricity, stores cold water or ice for cooling and hot water for heating in the storage tanks, and consumes the stored thermal energy during daytime.

The thermal storage that we adopted required the following:

- a. The system should be able to deice intensively during peak hours in summer.
- b. The configuration for the thermal storage tanks including size, depth and positioning should be flexible to utilize the existing underground frame tank.
- c. The system should be able to double as a hot water thermal storage system.

To meet these conditions, the system was configured to produce sherbet ice from super-cooled water, and store the ice.

3.2.4 Effective use of underground frame tank

The underground frame tank, previously used for receiving and fire water tanks before renovation, was used for the thermal storage tanks. Calculating the necessary tank capacity for the clean water used showed that the required capacity was less than the existing capacity. The receiving tanks were thus reconfigured as ground panel tanks and located in a machine room.

3.2.5 Renovation work schedule

Table 1 shows the renovation work schedule. The renovation work had to start after August 2008 and be completed within that fiscal year. In addition to this demanding schedule, the work had to be undertaken without closing any services on campus. Therefore, taking advantage of the transitional season, starting the renovation work for Substations I and II was staggered so they could complement each other for supplying hot and cold water.

Table 1 Renovation work schedule

	2008										2009			
	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	
University schedule	First semester		Summer break			Second semester			Graduation ceremony		Entrance ceremony			
Air conditioning schedule	Ventilation	Cooling				Ventilation	Heating		Heating		Ventilation			
Renovation work schedule														
Substation I (SSI)							Unit installation, piping work		Field Test					
Operated system	The existing system										From SSII		New system	
Substation II (SSII)					Unit installation, piping work		Field Test							
Operated system	The existing system				From SSI				New system					

4 Renovation effects

4.1 Annual amount of heat generated

Figure 5 shows the transition of the annual heat-generating load. The heat release operation of the thermal storage system accounts for 40%, the air-cooled heat pumps and Turbo refrigerator for 44% and the follow-up operation by air-source brine heat pumps for 16% of the generated heat per heat source unit. The released heat per day during the cooling period was approximately 78 GJ/day, mostly as designed. The heat release operation of the thermal storage system accounts for 34%, the air-cooled heat pumps for 52% and the follow-up operation by air-source brine heat pumps for 14% of the generated heat per heat source unit. The released heat per day during the heating period was approximately 53 GJ/day, mostly as designed as well.

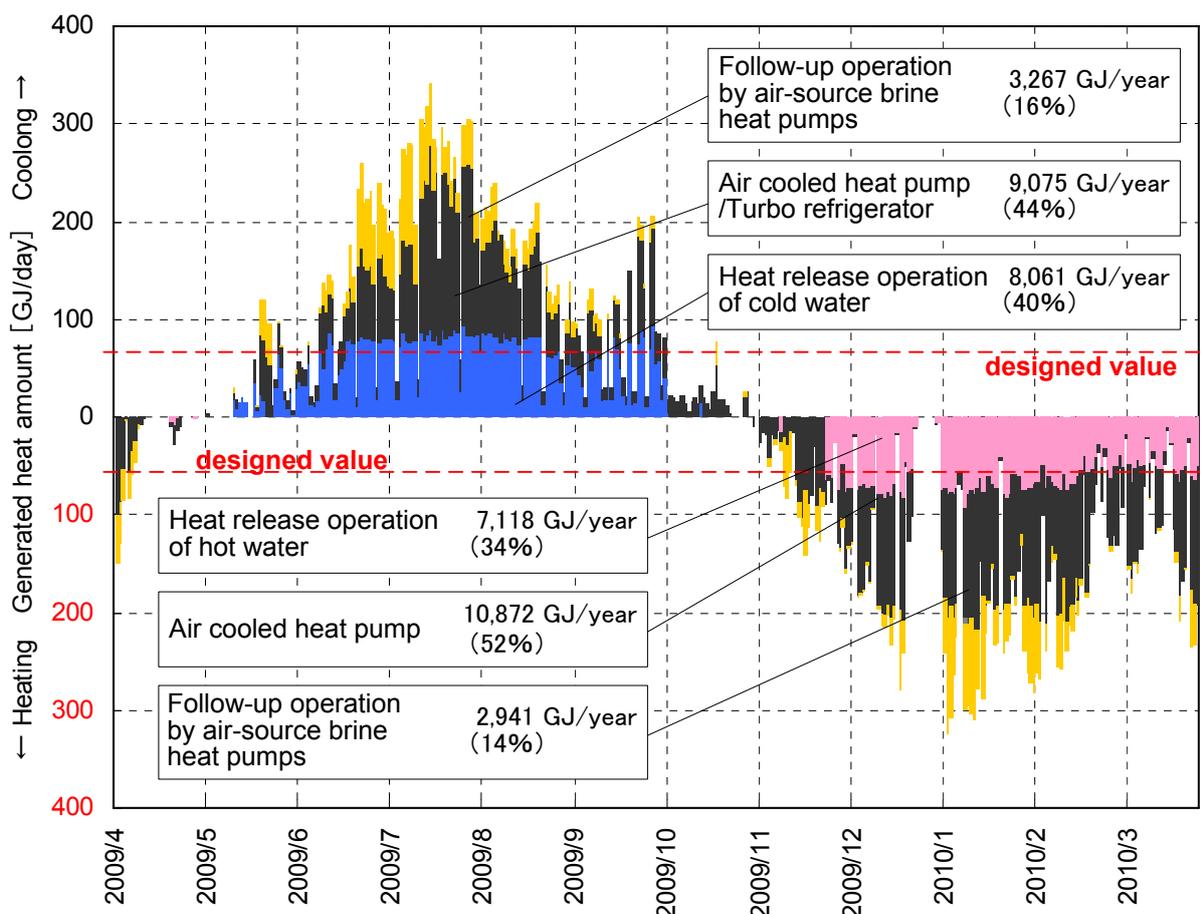


Figure 5 Transition of annual heat-generating load

4.2 Energy consumption analysis after renovation

Figure 6 shows the transition of the primary energy consumption of the heat source system and auxiliary equipment power after renovation. Compared with before renovation, although the heat supplied to the buildings decreased due to environmental load reduction, the thermal energy input was about 33% reduced.

The auxiliary equipment power of the heat source system is also approximately 20% (2,899 GJ/y) of the system before renovation.

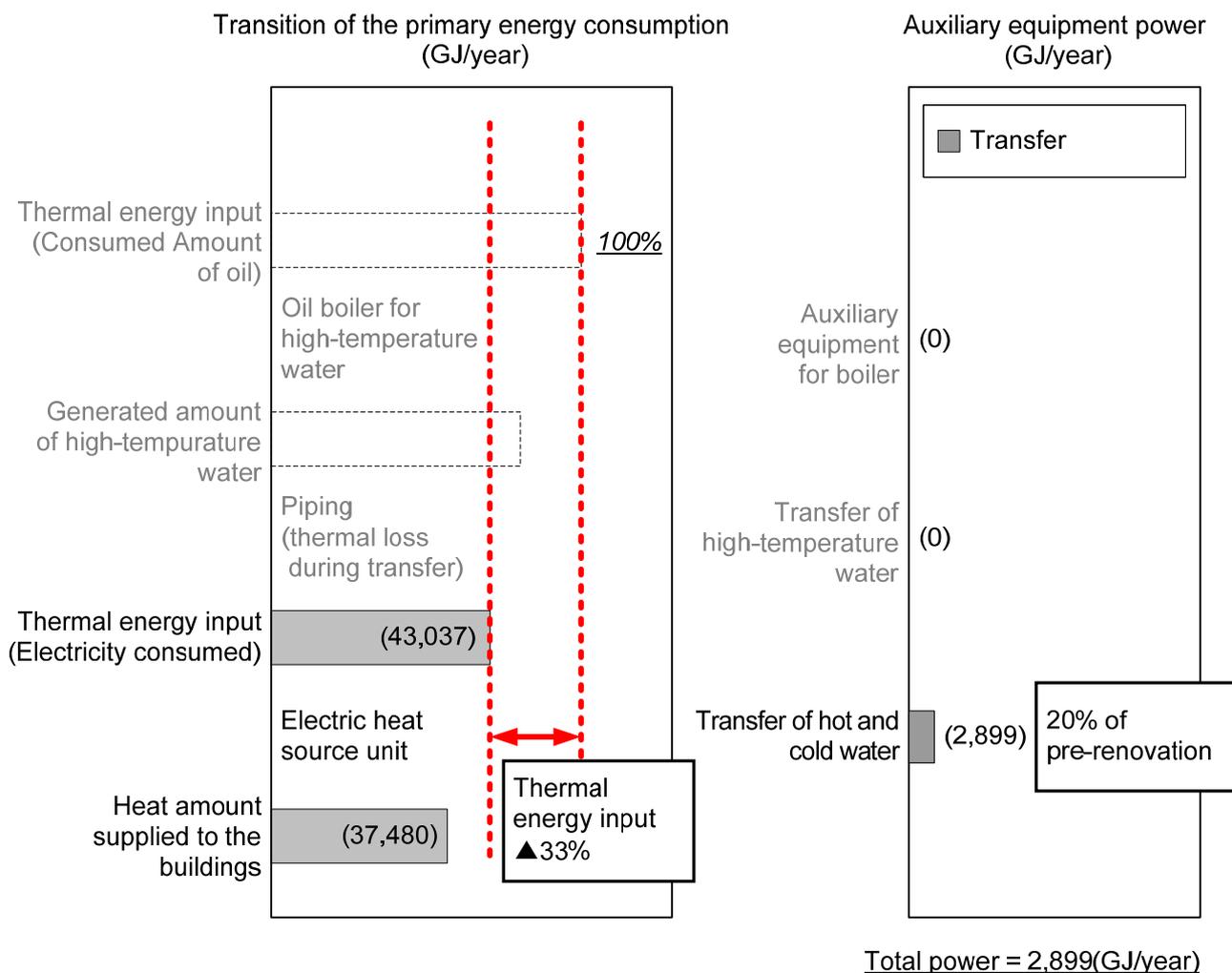


Figure 6 Transition of primary energy consumption and auxiliary equipment power

4.3 Effects on environmental load reduction

Table 2 shows the energy consumption of the air conditioning and heating before and after renovation (2005 and 2009). Figure 7 shows the CO₂ emissions and intensity of CO₂ emissions (the CO₂ emissions / the heat supplied to the buildings) for both cooling and heating periods before and after renovation (2005 and 2009).

Although the heat supplied to the buildings decreased due to environmental load reduction, the total energy efficiency of the air conditioning and heating increased from 0.53 to 0.82 due to the renovation. Approximately 42% of the primary energy consumption and 64% of the CO₂ emissions were reduced.

CO₂ emissions were reduced by 1,371 and 1,786 tons during the cooling and heating periods. The intensity of CO₂ emissions for supplying cooling and heating was also reduced approximately 65% and 53% during the cooling and heating periods.

Table 2 Energy consumption of heat source system

		Before Renovation (2005)	After Renovation (2009)	Reduced Amount	Reduced Rate
Heat supplied to the buildings		42,426 GJ	37,480 GJ	—	—
Energy consumption	Oil	1,752 kL	— kL	—	—
	Gas	3,820 m ³	— m ³	—	—
	Electricity	1,530 MWh	4,707 MWh	—	—
Primary energy consumption (Total)		79,404 GJ	45,936 GJ	-33,468 GJ	-42%
Cooling period		35,857 GJ	20,209 GJ	-15,648 GJ	-44%
Heating period		43,547 GJ	25,727 GJ	-17,820 GJ	-41%
Total energy efficiency		0.53	0.82	—	—
CO ₂ emissions amount (Total)		4,955 t-CO ₂	1,798 t-CO ₂	-3,157 t-CO ₂	-64%
Cooling period		2,162 t-CO ₂	791 t-CO ₂	-1,371 t-CO ₂	-63%
Heating period		2,793 t-CO ₂	1,007 t-CO ₂	-1,786 t-CO ₂	-64%
CO ₂ emissions intensity (Total)		117 g/MJ	48 g/MJ	-69 g/MJ	-59%
Cooling period		122 g/MJ	43 g/MJ	-79 g/MJ	-65%
Heating period		113 g/MJ	53 g/MJ	-60 g/MJ	-53%

CO₂ emissions intensity: Electricity 0.382kg-CO₂/kWh, Gas 2.277kg-CO₂/Nm³, Oil 2.492kg-CO₂/L
 Primary energy conversion factor: Electricity 9.76 MJ/kWh, Gas 45 MJ/Nm³, Oil 36.7 MJ/L

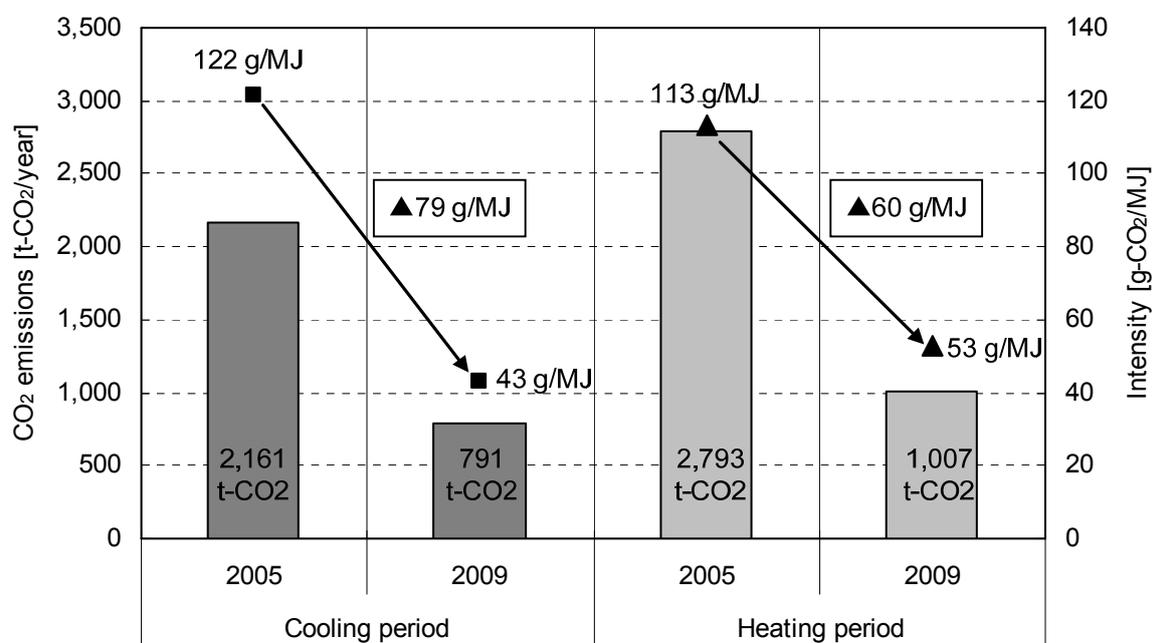


Figure 7 Transition of the CO₂ emissions and intensity of heat source system

5 Conclusions

This report explained the overview and effect of the renovated heat source system at Chuo University Tama campus. The centralized system using oil boiler was eliminated, and several ice thermal storage air conditioning systems and electric heat pumps were distributed. At the same time, the university also changed the main energy source from oil to electricity. As a result, CO₂ emissions were reduced significantly.

Figure 8 shows the CO₂ emissions on the entire campus. The CO₂ emissions reduction rate on Tama campus as a whole is approximately 23% of the 3-year averaged CO₂ emissions from 2002 to 2004. This surpasses by far the averaged mandatory reduction rate of 8% for the first compliance period (2010 to 2014) in the environmental regulations of the Tokyo Metropolitan Government.

We will operate the heat source system appropriately by tracking the operations in detail and analyzing the data, continuing to further reduce the environmental load.

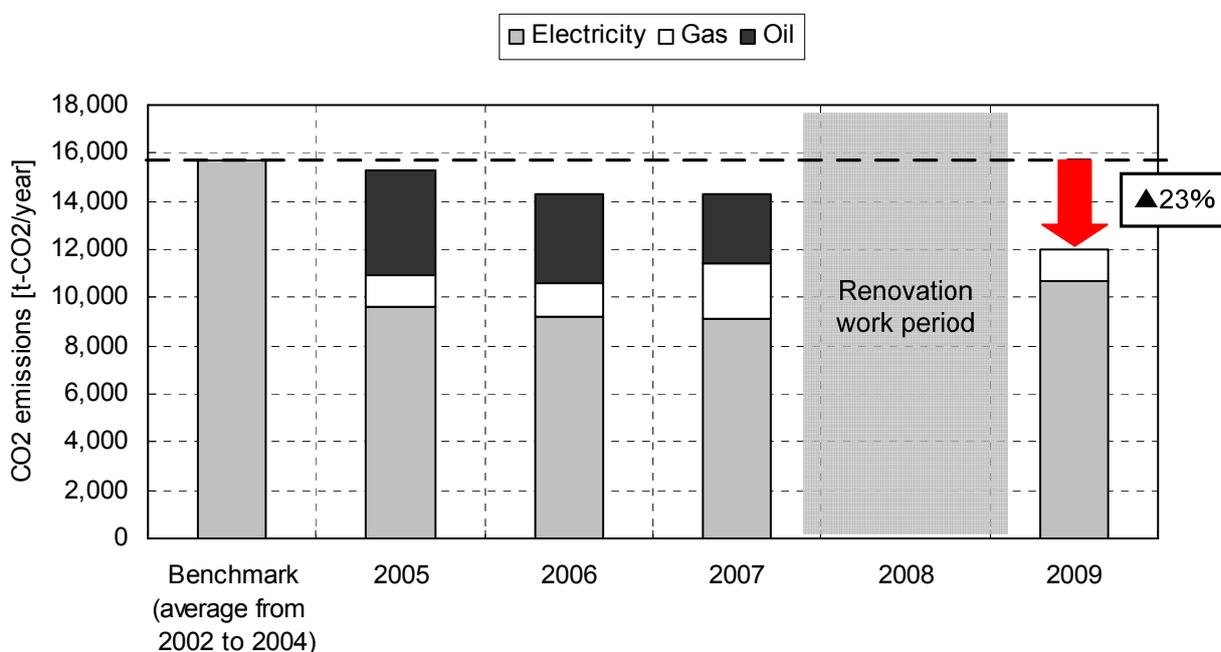


Figure 8 CO₂ emissions on the entire campus