

MEASURING EFFECTIVENESS OF INSTALLING A TURBO CHILLER ON UNIVERSITY HOSPITAL BUILDINGS —TODAI SUSTAINABLE CAMPUS PROJECT—

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Abstract: Universities are responsible for proposing a new social model based on environmentally friendly economic activities that puts into practice sustainable education and research activities in harmony with the environment. To fulfill this responsibility through specific actions, the University of Tokyo has launched a university-wide project known as the Todai Sustainable Campus Project (TSCP). As its top priority, the university set the target of reducing total CO₂ emissions and has already launched a wide range of initiatives. As a part of the project, the CO₂ emissions from the hospital facilities, which consume an especially large amount of energy within the campuses, were estimated based on measurement data in order to improve the efficiency of the heat source equipment for the air conditioners. Also, after the equipment had been introduced and put into proper operation, it became possible to realize a significant CO₂ reduction that contributes to the target for TSCP-2012.

Keywords: Sustainable Campus, University Facilities, Hospital, CO₂ Emissions Reduction, Heat-recovery Turbo Chiller

1 Introduction

University campuses include a wide range of facilities for various purposes for both the humanities and science faculties and for medical facilities such as the university hospital and housing. On the campus, energy is consumed in a variety of ways to meet the needs of the diverse activities of faculty members and students. As an educational and research institute, a university with these characteristics that intends to formulate and execute a plan to reduce greenhouse gas emissions and verify the effects of the plan must implement distinct measures. In this context, the University of Tokyo has launched a university-wide project called the Todai Sustainable Campus Project (TSCP) under the strong leadership of the President with the aim of clearing a path towards building a sustainable society, and has established an office, TSCP Office, responsible for carrying out the project under the direct control of the President. While TSCP should address a wide range of environmental issues, short-term priority is given to creating a low-carbon campus by reducing energy-derived greenhouse gas emissions. The project has set targets to reduce total CO₂ emissions with the keyword “co-evolution” as the main concept (Figure 1). TSCP-2012 and TSCP-2030 have been put forward as two action plans. TSCP-2012 aims to reduce CO₂ emissions from non-research activities by 15% over the fiscal 2006 level by the end of fiscal 2012 by employing energy-saving equipment with a short investment recovery period. In TSCP-2030, the goal is to reduce CO₂ emissions from both research and non-research activities by 50% by introducing new technologies and energy generation equipment on a campus-wide scale in addition to the installation of high-efficiency devices. A specific plan for TSCP-2030 will be formulated by the end of fiscal 2012.

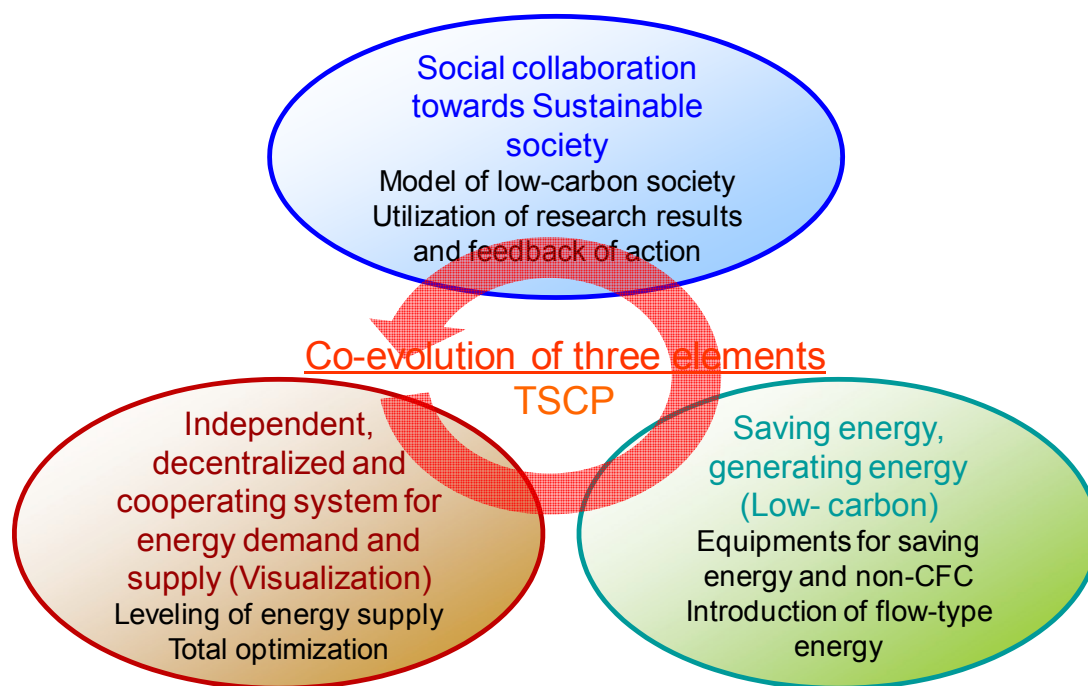


Figure 1: Creating a low carbon campus

2 Overview

2.1 Current status of energy consumption

The University of Tokyo has five main campuses (Hongo, Komaba I, Komaba II, Shirokane, Kashiwa), which account for the vast majority of the energy consumed by the entire university. While the annual primary energy consumption by campus had increased every year in line with the expansion of university activities, it showed a year-on-year decline in fiscal 2009 (line graph in Figure 2) as the effects of the TSCP initiatives on reducing the energy consumption outweighed the increase in energy. Total CO₂ emissions, which are calculated taking into account changes in the CO₂ emission factor (kg-CO₂/kWh) announced by the power utilities every year, also decreased by 4% over the fiscal 2006 level in fiscal 2009, the reference year for TSCP (bar graph in Figure 2). Thus, progress is being made towards achieving the targets for TSCP-2012. These CO₂ emissions were calculated in detail for each building and broken down by use for the buildings shown in Figure 3. The figure indicates that while the science and engineering faculty buildings emit the largest amount of CO₂, emissions per gross floor area are largest from the medical faculties and the hospital (more than three times the emissions from the humanities and social sciences faculty buildings).

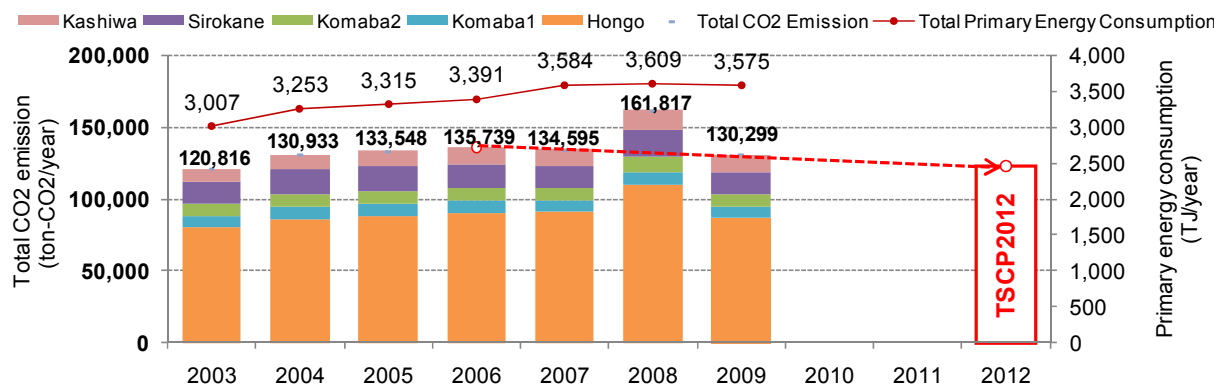


Figure 2: Primary energy consumption and total CO₂ emissions by year

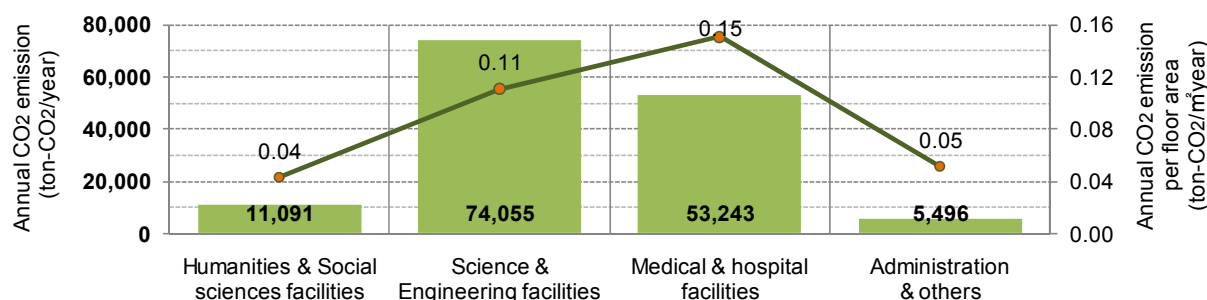


Figure3: Calculation of total CO₂ emissions and CO₂ emissions per floor area (Fiscal 2008)

2.2 The organization that promotes the project

The TSCP Office was set up in July 2008 under the direct control of the President to promote the university-wide project (TSCP) and to make prompt decisions on implementation. With the TSCP Office playing the core role, an organization to promote the project was also established, including a working group composed of experts from the University and department directors, a faculty liaison committee composed of the faculty members appointed as TSCP Officers, and an academic-industrial collaborative research group with private companies. This organization has enabled effective measures to be planned. In addition to the Office, a university-wide financial mechanism has also been established to secure the funds necessary to implement the measures. Specifically, a certain percentage of the utility costs paid by each faculty is collected across the board and pooled for use as funds for the TSCP. The funds will be allocated to measures whose investment recovery period exceeds four years. As a result, investment in older faculties is prioritized in the short term, but funds will also be allocated to faculties that are relatively new at this point in the long term. This mechanism ensures the sustainability of the project and fairness throughout the University.

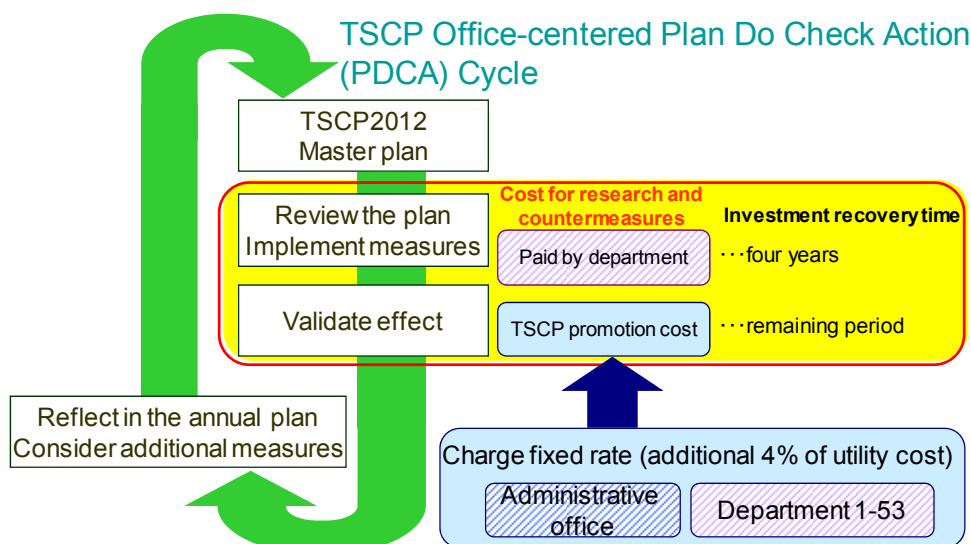


Figure 5: Scheme of TSCP promotion

3 TSCP Initiatives at the University of Tokyo Hospital

3.1 Outline of the buildings

As shown in Figure 3 above, the medical faculty buildings and the hospital emit large amounts of CO₂ per floor area. Therefore, priority is given to measures in the University of Tokyo Hospital area at the Hongo Campus. The area can be divided into two sections: the hospital facility area where an inpatients' ward and clinical building are located (yellow painted area in Figure 5), and the research and administrative facility area consisting of research facilities for the Faculty of Medicine and administrative facilities for the hospital (blue painted area in Figure 5). The hospital facility area, which consumes an especially large amount of energy, was selected as the target for examining the TSCP initiatives.

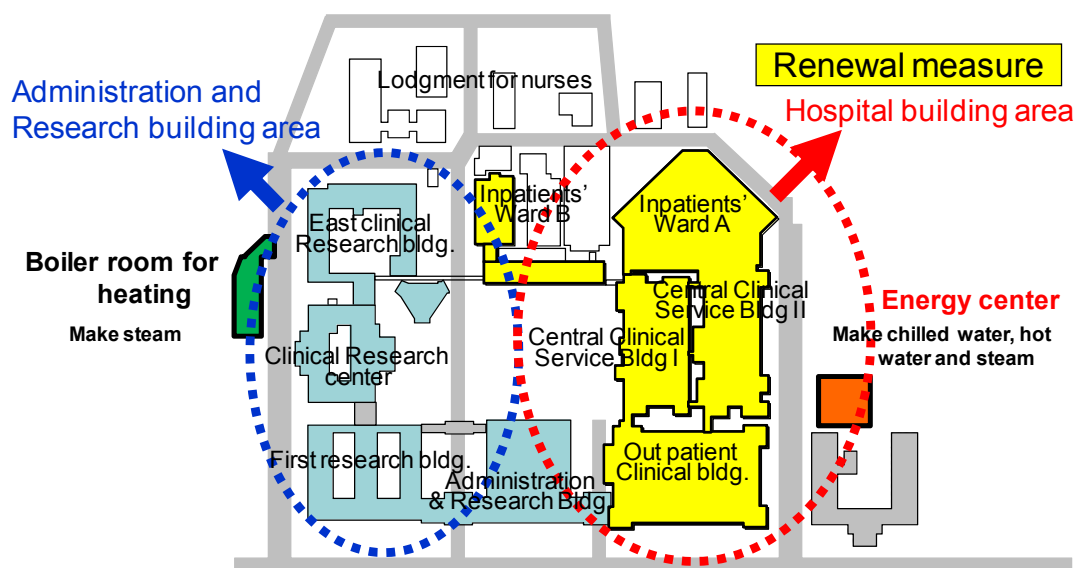


Figure 5: The University of Tokyo Hospital area (Hongo Campus)

3.2 Outline of the equipment

In the hospital facility area, all of the cool and hot water production devices for air conditioning and the boiler facilities that generate steam for the hot water supply and

sterilization are concentrated in the Energy Center and the heating boiler room, and a centralized system is adopted to supply utilities to the buildings. (Only the inpatients' ward has an independent heat source for combined use.) The heat source system is installed in the basement of the Energy Center, and is composed of large-scale heat source equipment and thermally stratified water heat storage tanks (393 m³ and 2,526 m³ tanks dedicated to cool water, a 2,230 m³ tank for both cool and hot water, and a 391 m³ tank dedicated to hot water; 4 tanks with a total volume of 5,540 m³)(Figure 6). Based on the results of the examination described later, the air cooling screw style chiller (SCR-1) was selected as the device to be replaced.

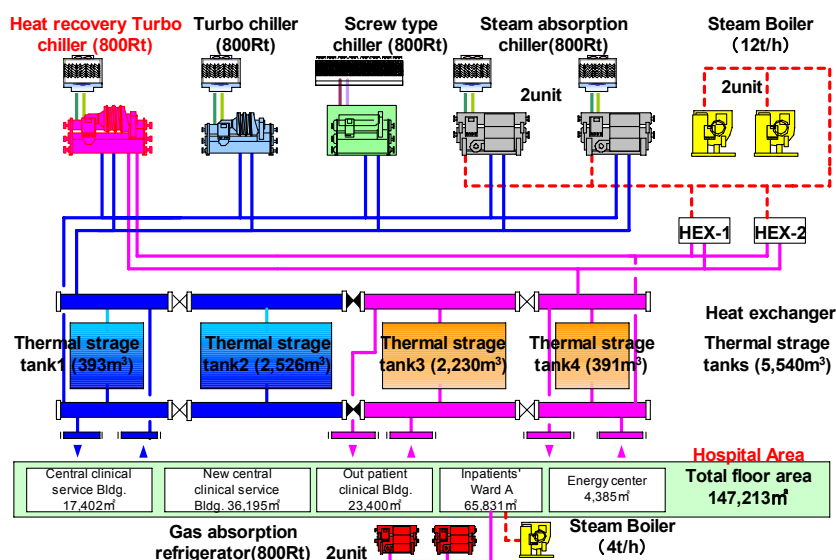


Figure 6: Heat source system diagram (Energy Center)

3.3 Examining the replacement measures

3.3.1 Planning stage

Before examination, the BEMS data and short-term measurement data adopted in the Energy Center in the hospital facility area were used to identify the current status of the heat load and the operation and heat production efficiency of the heat source equipment. The data shows that the cooling loads reach a peak of approximately 800 GJ/day in July and the heating loads reach a peak of approximately 400 GJ/day in January. There are both cooling and heating loads throughout the year and a cooling load of approximately 100 GJ/day even during the winter season. Therefore, a turbo chiller with a function to recover waste heat while producing cool water with heat pumps was selected to cope with the balance between the cooling and heating loads in winter. Moreover, an efficient combination of the existing heat storage tanks (especially the hot water tanks that had not been fully utilized) as thermal buffers was adopted for the simultaneous production of cool and hot water in order to expand the heat recovery operating range.

3.3.2 Design and construction stage

Since the main body of the heat-recovery turbo chiller does not control the temperature at the hot water outlet during heat recovery operation, the design was modified to control the variable flow in the primary hot water pump, in addition to the cooling water pump, in order to stabilize the temperature at the hot water outlet. This has mitigated the fluctuations in the temperature of the water returned from the hot water tanks so that the temperature of the hot water at the outlet can be maintained at the design temperature of approximately 43°C while

producing cool water at the design temperature of 5°C even during heat recovery, as shown in Figure 7.

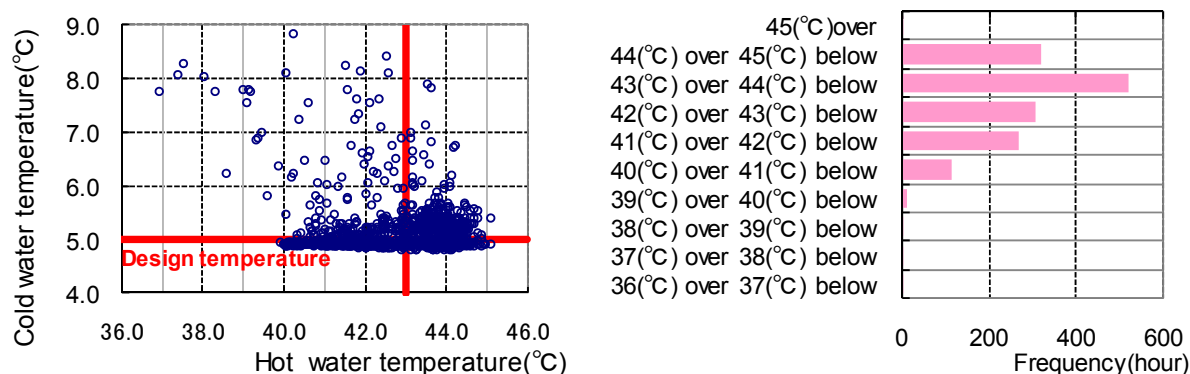


Figure 7: Temperature of the cold water and hot water at the outlet during the heat recovery operation (left) and a frequency histogram of the hot water temperature at the outlet (right)

3.3.4 Proper operation and maintenance stage

To maximize the time for the heat recovery operation, the most effective way is to use up the heat stored in both the cool water and hot water tanks. Therefore, the cold water thermal storage was preferentially reduced in line with the loads in the daytime. For the hot water tanks, the existing heat source equipment in the inpatients' ward was used to produce additional hot water on an as-needed basis based on the temperature of the water supplied from the hot water tanks.

As a result, as shown in Figure 8, the storage of the hot water produced by the heat recovery operation as well as the production of cold water during the heat storage operation at night maximized the efficiency of the heat recovery operation and the operation to release cold and hot heat during the daytime. Figure 9 compares the quantity of heat in the annual cold and hot water production by the heat source equipment before and after replacing the air cooling screw style chiller, showing that the heat-recovery turbo chiller produced approximately 36% of the total cold water, including that from the operation dedicated to cold water production during the summer, and 45% of the total heat. (The operation was dedicated to cold water production during the summer and intermediate seasons.)

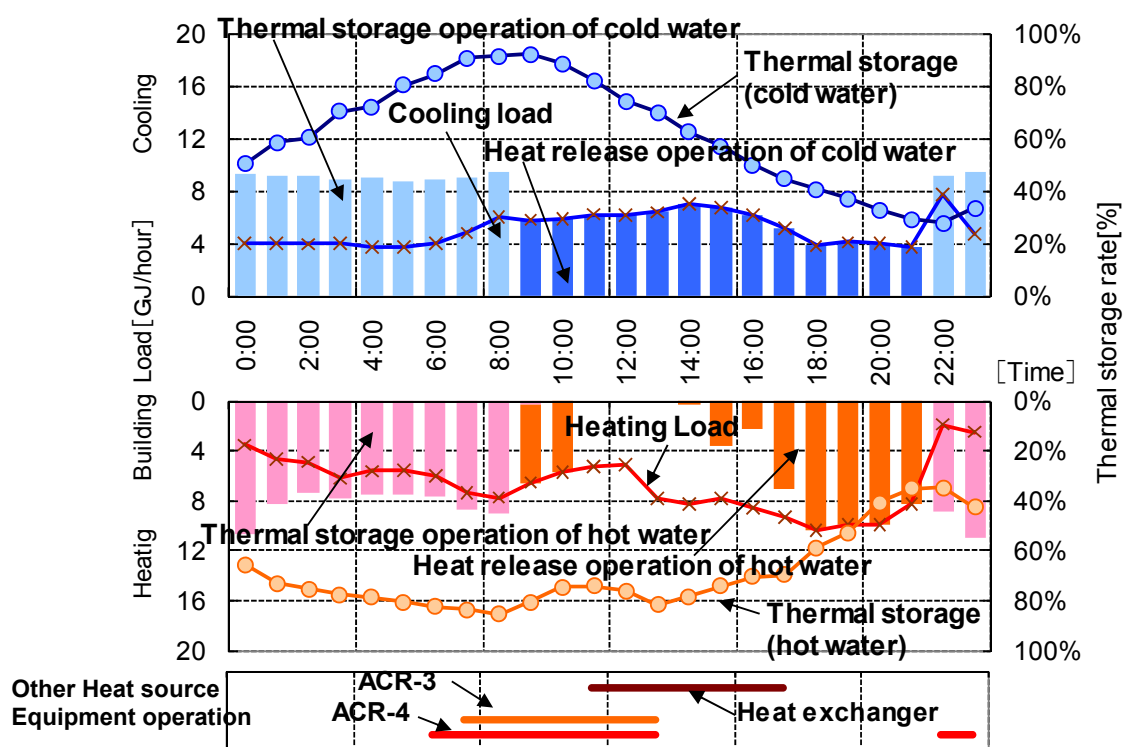


Figure 8: Fluctuations in loads on a representative day (March 12, 2009)

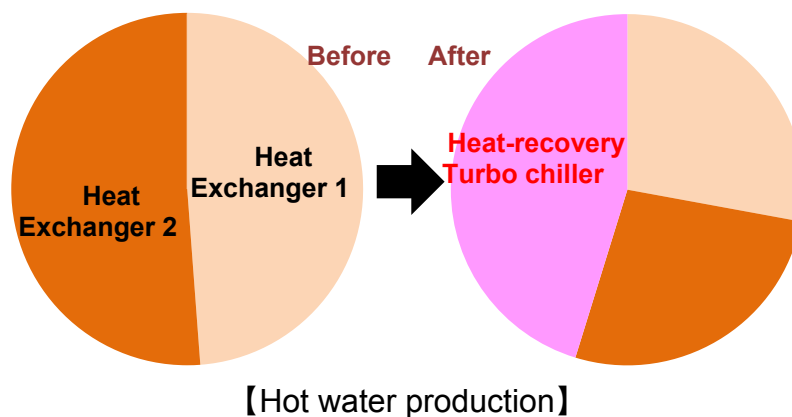
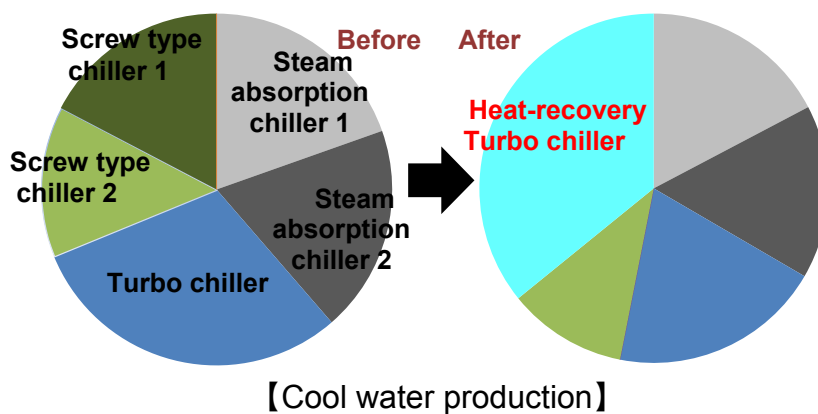


Figure 9: Comparison of the ratio of cold water and hot water production by the heat source equipment before and after replacing the chiller

4 Effect of replacing the chiller

Table 1 shows the effects of replacing the chiller by comparing the annual figures before and after replacing the chiller. The primary energy consumption was reduced by approximately 55,200 GJ/year and CO₂ emissions by approximately 2,550 tons-CO₂/year, which exceeded the initially estimated effect. The annual efficiency of the heat source system on the whole (the quantity of heat in the annual cold water and hot water production divided by the annual primary energy consumption) also increased by about 31% from 0.81 to 1.06 after the repair.

Table 1: Reduction effects

Item	Annual CO ₂ emission (ton-CO ₂ /year)	Primary energy consumption(GJ/year)
Before renewal	17,511	373,605
After renewal	14,958	318,448
Reduction effects	▲ 2,553	▲ 55,157

Primary energy converted into electricity at 9.76 MJ/kWh and into city gas at 45 MJ/m³.

CO₂ emissions converted into electricity at 0.368 kg-CO₂/kWh and into city gas at 2.309 kg-CO₂/m³.

5 Conclusions

To create a low-carbon campus, a TSCP initiative was implemented in the University of Tokyo Hospital area, where the energy consumption per floor area is the highest within the University. The current status of building load based on identified data was used as the basis for the review of the equipment design. After communicating and coordinating with the equipment operators and contractors and checking the effect of replacing the chiller during operation and maintenance of the equipment, the maximum annual reduction effect was produced, including the effect of heat recovery. In implementing the TSCP initiative, while improvements to the heat production efficiency through the technical development of heat pumps will make the largest contribution to a low-carbon environment, it is also important to maximize the effect by appropriately operating the equipment continuously after its introduction. As an educational and research institute, the University of Tokyo will continue to contribute to and play a leading role in creating a low-carbon campus.

6 References

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