A Low-Carbon Office Building using Innovative Methods and Technologies

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Summary

This paper introduces our new office building (Tecno-Station, Obayashi Technical Research Institute), which will achieve a 55% of CO2 emission reduction compared to conventional office buildings in Tokyo. In order to achieve this reduction, we adopted not only the passive methods but also the innovative active technologies. Renewable energy such as solar power and natural ventilation are used as passive methods to strengthen the building's thermal performance. An innovative HVAC system has been applied as an active method. High-performance air-cooled heat pumps and ground-coupled heat pumps are applied as a heat source system. The two kinds of heat storage systems are applied for normal chilled water (6 ºC) and latent heat storage for middle range chilled water (13-19ºC). The sensible heat and latent heat load of the main office space are separately treated using a desiccant OHU and a task panel, which were newly developed for this project.
In addition, BEMS is applied for the energy management and control. The building's energy performance is visualized to the occupants to facilitate user participation in CO2 management action.
These systems reduce CO2 emissions by 55 % during operation, the highest level in Japan. Furthermore, the building achieved a CASBEE® S rank and 7.6 BEE because of its overall reduction in environmental burdens. The building was completed in September 2010 and was then put into operation.
We are planning to accumulate and analyze the data, which is fundamental to achieving ZEB (Net Zero Energy Building) in the future.

Keywords: Low-carbon office building, Passive methods, Active method, Thermal storage, Desiccant OHU, Net Zero Energy Building

1. Introduction

Obayashi Corporation established its Technical Research Institute in 1965. The research office was constructed in 1982 and it adopted 98 technologies achieving 410MJ/ (m^2•year), 1/4 of the energy consumption of conventional offices as the most energy efficient building in the world around that time. This building was quite famous as a super energy conservation building and was awarded by ASHRAE or AIJ. [1]
Previously, researchers were working at various buildings of their specialities and packaged at their laboratories. In order to improve the research productivity of researchers, communication between

the researchers is important. Those researchers and managers are now concentrated in the main building: Techno-Station located in the middle of the site, connecting all the laboratories with covered passages called “Spine”. It was built to establish a new R&D base that would create new technologies through integrated research functions and intellectual exchange, apply and demonstrate its own technologies, and disseminates them to our clients and society.
The Techno-Station is the core facility of the Technical Research Institute and has three main concepts; the most advanced research environment, the most advanced environment-friendliness and the most advanced safety and security. [2] Fig. 1 shows the appearance of the building and Fig. 2 shows an internal view of main workspace.
We have adopted a lot of technologies in order to identify a goal for a Net Zero Energy Building. New technologies such as “Task Panel” or “Latent Heat Storage System” have been developed for this project. Others apply optimal design integration such as “Ecological Roof” or “Ground-Coupled Heat Pump”. This project has obtained CASBEE® S rank and BEE 7.6.

Fig. 1 Building Appearance

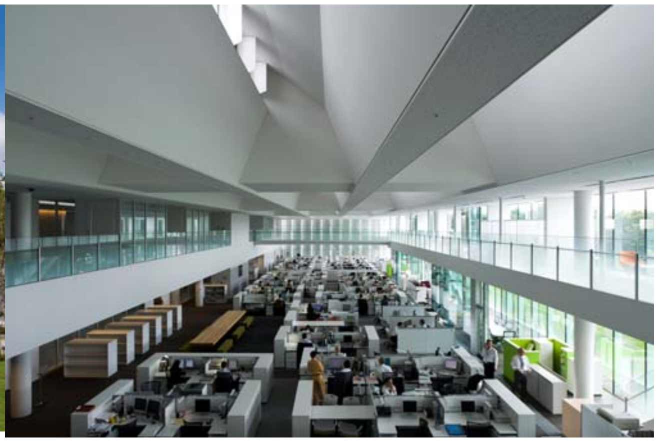

Fig. 2 Internal View of Workspace

2. Building Outline

2.1 Architectural design outline

Location	: 4-640 Shimo-kiyoto Kiyose-city, Tokyo
Client	: Obayashi Corporation
Designer's supervision	: Obayashi Corporation architect’s office
Site District	: Semi-industrial, Semi-fire proof area,
Site area	: 69,401.30 m^2
Building area	: 3,370.51 m^2
Total floor area	: 5,535.38 m^2
Structure	: Steel frame (Super-active base isolation system)
Number of stories	: +3, +1 penthouse
Principal use	: Laboratory (Office)
General constructor	: Obayashi Corporation
Construction period	: November 2009 − September 2010

2.2 Facility design outline

【Electric System】

Incoming	: 1 line, Indoor Cabinet, 1Φ300 kVA, 3Φ750 kVA
Generator	: Generator 1 of 50 kVA , CGS 2 of 25 kW, Solar Cell 150 kW, Wind Power 2 of 1 kW
Battery	: Lithium - ion Battery 10 kWh
BAS	: BEMS using BACnet®, LONworks®
Access Control	: RFID tag and Card, Sensing System using active RFID tag

【M&E outline】

Heat Source	: Air-cool Heat pump Chilling Unit（9 of 30HP incl. Heat Machine 1）, Well water combined Ground Coupled Heat Pump Chilling Unit (2 of 30 HP) Water thermal Storage tank 430 m^3（6°C）, Latent Heat Thermal Storage Tank 96 m^3（15°C)
HVAC System	: Latent and sensible heat separated air-conditioning system, Task Ambient HVAC, Return air Desiccant OHU, Personal Floor Diffusing、Task-Panel (Personal Radiant and Natural Convectional Panel)

【Sanitary System】

Water Source	: City Water for potable, Well Water for irrigation and Rain Water for flushing

2.3 Environmental Performance

We have aimed to achieve a substantial reduction in environmental load without reducing workplace productivity. Three systems are integrated to achieve the highest reduction rate of 55 % of the average kg-CO2/m^2 emission in Tokyo.

(1) A passive system; integrated passive natural energy use
(2) An active system; active mechanical/ electrical system
(3) A management system; new management system to reduce CO2 and energy consumption in the operation phase

These three systems enable a 55 % reduction in CO2 emissions during operation, which is the highest level in Japan. Furthermore, we expect that the Techno-Station will be the Japan's first achievement of carbon neutral as a research facility, through purchase of carbon credits equivalent to 45%.

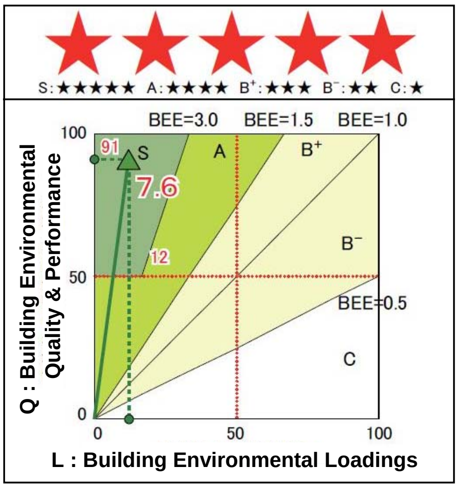

Fig. 3 Certification of CASBEE® 2008 v3.3

The building was rated as CASBEE® S rank and achieved BEE 7.6 scores because of its overall reduction in environmental burdens. Fig. 3 shows the certification result of CASBEE® 2008 v.3.3. Other performance parameters of energy saving are a 36 % reduction in PAL value and a 42 % reduction in ERR value, an integration of CEC values

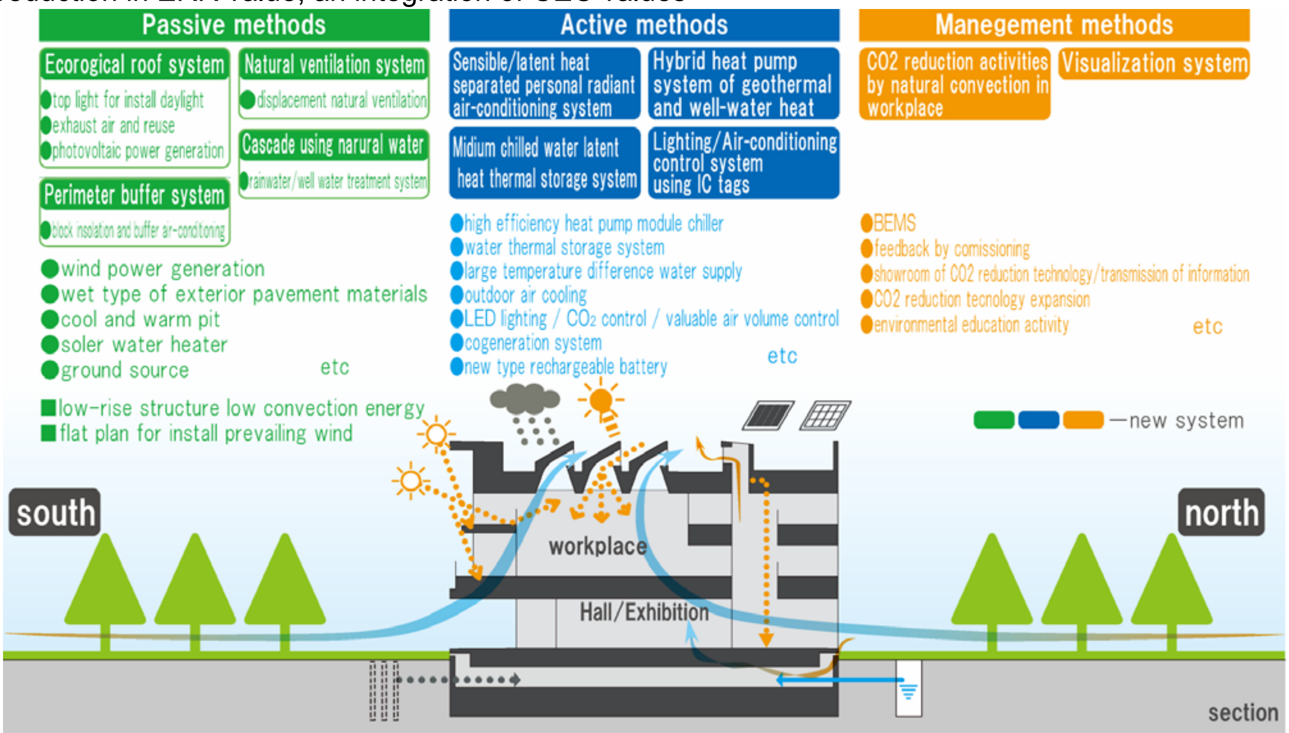

Fig. 4 Map of Technologies of CO2 Reduction

3. Technologies for CO2 saving

Fig. 4 shows the representative technologies mapping which are applied in this project. All methods are categorized in the above three categories. The green category indicates passive methods that utilize the natural renewable energy and architectural design considerations that reduce the heat load. The blue category indicates active methods that apply the highest performance mechanical and electrical system. The orange category indicates the management system. The building operation is very important in accomplishing the best environmental performance.

3.1 Passive Methods

3.1.1 Ecological Roof System

Techno-Station is a low-rise building with top lights installed on a wide upper portion of the room to make full use of the building's characteristics. Fig. 5 shows the Ecological Roof System. The system utilizes a skylight for day-lighting but, eliminates direct sun-shine using a reflecting wall in order to accomplish stable day-lighting during daytime to promote energy saving in the office. The 150kW solar panels are installed all over the slanted roof to generate power with high efficiently. The top lights are opened/closed remotely for the displacement natural ventilation and flesh air is taken from the floor, exhausted from top light ventilator.

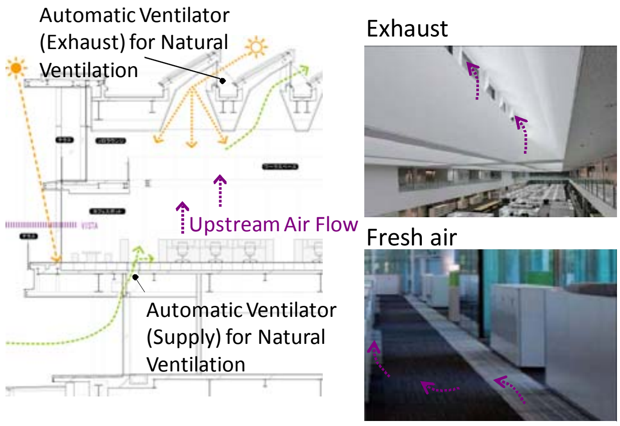

Fig. 5 Ecological Roof System

3.1.2 Perimeter Buffer System

Large eaves, vertical glass fins with ceramic print and low-e glasses are installed to reduce air-conditioning load while allowing for an open space structure. Fig. 6 shows the Perimeter Buffer System.
In addition to using the exterior to reduce the energy demand of the air-conditioning, this perimeter buffer zone is intended to control the impact of air-conditioning loads on the inside working zone, and consists of aisles, meeting space and lounges located around the working area and adjacent to an outdoor deck. A floor-mounted fan-coil unit is erected as a barrier between interior and perimeter, thereby minimizing the thermal effect of the perimeter zone.
This system decreases glare light in the workspace. Automatically controlled blinds and an inner light shelf provide the brightness.

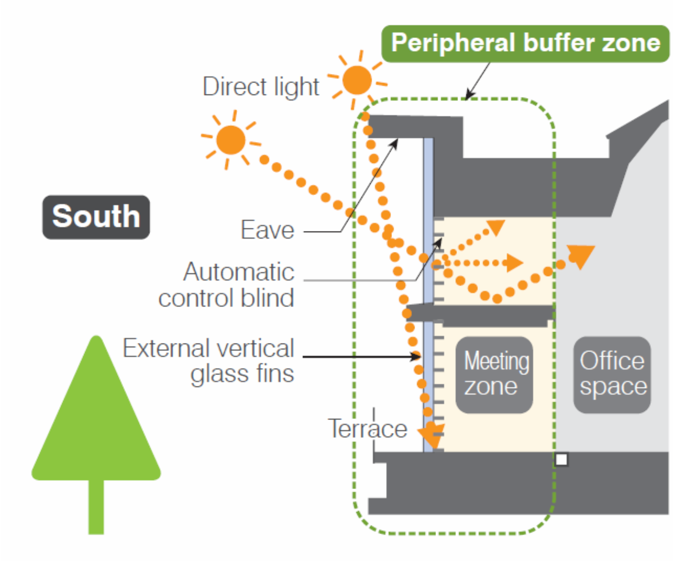

Fig. 6 Perimeter Buffer System

3.2 Active Methods

3.2.1 Heat Source System

Fig. 7 shows a schematic of the heat source system of this building. Heat sources combine an air-cooling heat pump chilling unit and a well water combined ground-coupled heat pump chilling unit. Water thermal storage and latent heat thermal storage are adopted, and the electric load is thus

levelled by using midnight power.
Waste heat from a micro-cogeneration system is used for regeneration of the desiccant rotor in summer, and heating water in winter.
The heat source system is composed of 5 temperature zones; cold water (6ºC), medium chilled water (approximately 13ºC to 19ºC), warm water (46ºC), medium heated warm water (approximately 40ºC to 44ºC), hot water for regeneration (85ºC).
The CO2 reduction system of heat source focused on following considerations. Partial load operation efficiency of air-cooling heat pump, a water-cooled heat pump system using natural energy such as geothermal heat and well water, an HVAC system with medium chilled water for improvement of the COP, water thermal storage and latent heat thermal storage as a transition to lower CO2 emissions and midnight power, and sensible/latent heat separated air-conditioning system.

3.2.2 Hybrid Heat Pump System of Geothermal and Well-Water Heat

The annual temperatures of the soil and outdoor atmospheres are almost the same, for example around 17 ºC in Tokyo. Compared to the outdoor temperature, the soil temperature is cool in summer and warm in winter. This ground thermal potential is used by ground source heat pump system using boreholes (10 of 100 m) with a double U-tube.
In addition, there's a well in the site, and we can use the water from it of under 20 m^3/day. Well water is used as heat source for the heat pump to improve the efficiency of heat source operation. The well water that is used for the heat exchanger is reused for flushing toilets and watering around the building (cascading).

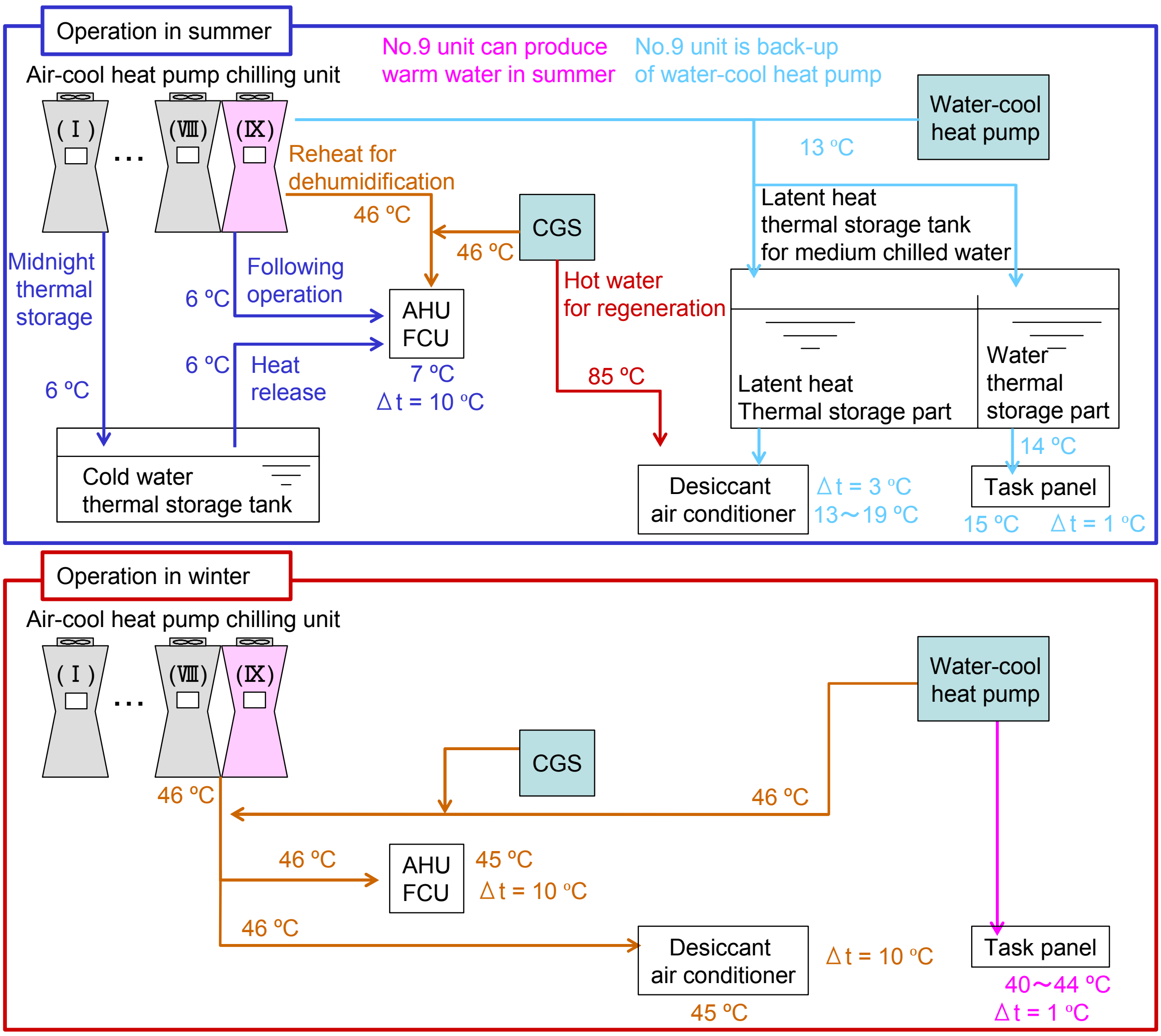

Fig. 7 Heat Source System

3.2.3 HVAC System aim to Improved COP by using Medium Range Chilled Water

The air-conditioning system in the workspace adopts task-ambient and sensible/latent heat separation the air-conditioning system. Fig. 8 shows a schematic diagram of the main HVAC system of this building.
For the air-conditioning of the ambient area, a return-air desiccant air-conditioner treats latent heat of the outside air properly. The system employs chemical dehumidification.
For the air-conditioning of the task area, a personal radiation and natural convectional panel, which is called "Task Panel" is installed for sensible heat removal. [3] Fig. 9 outlines the outline of Task-ambient air-conditioning system. Target room temperature will be 28ºC, but the relative humidity is 45%, which is lower than that of ordinal HVAC system. Fig. 10 shows the task panel with is installed at a personal desk.
Medium chilled water supply temperature to the desiccant air-conditioning system is 13 to 19ºC, and the medium chilled water supply temperature to the task-panel is also about 15ºC. Therefore, the temperature of the chilled water can be higher than normal temperature by about 6 to 7ºC.
This can be expected to improve the COP of heat pump.

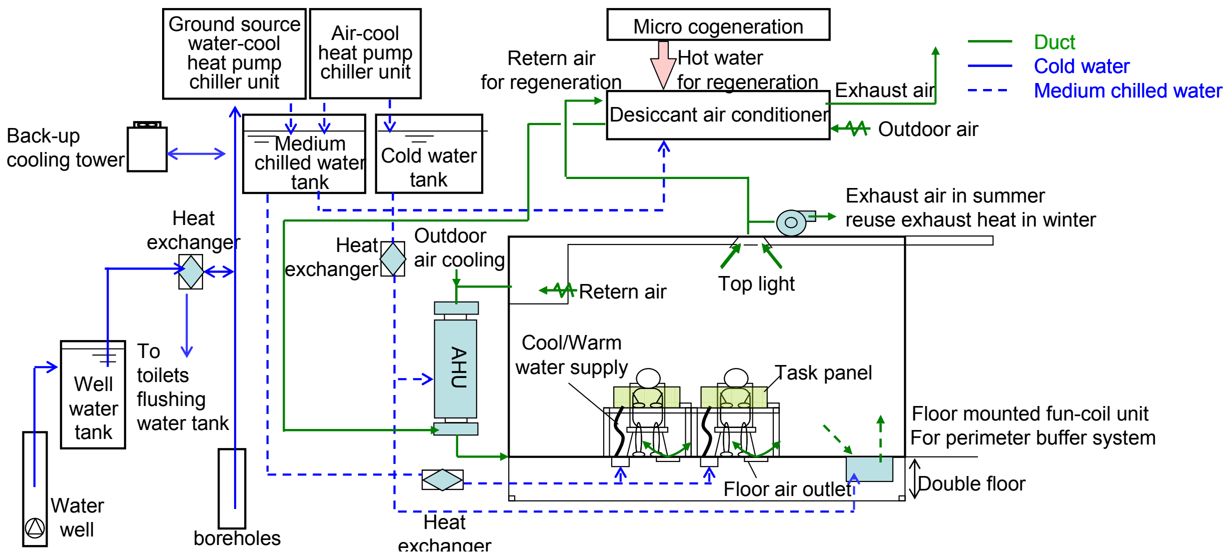

Fig. 8 Outline of integrated medium chilled water air-conditioning system

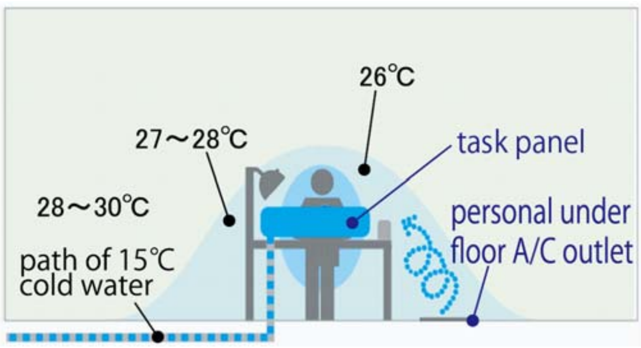

Fig. 9 Outline of Task-ambient air-conditioning system in summer

Fig. 10 Example of installation of "Task Panel"

3.2.4 Medium Range Chilled Water Latent Heat Storage System

In order to achieve a CO_2 reduction system by using midnight power, latent heat storage material is necessary, which has non-traditional temperature zone.
One such material is a paraffin-based latent heat storage material. The latent heat storage material that melts/freezes at a temperature of 15ºC to 16ºC is used for the HVAC system. [4] Fig. 11 shows a schematic chart and photo of the latent heat storage system. The storage tank is designed smaller than the water thermal storage using the latent heat of paraffin. Therefore, the tank is installed on the roof of building. This tank is separated between water thermal storage and latent heat storage. If a stable water temperature is required for static control of the Task Panel, the water storage tank is used. If not, the latent heat storage is used for desiccant OHU cooling. One of the weaknesses of latent heat storage is the unstable of discharge water temperature, so we applied the design of tank separation.

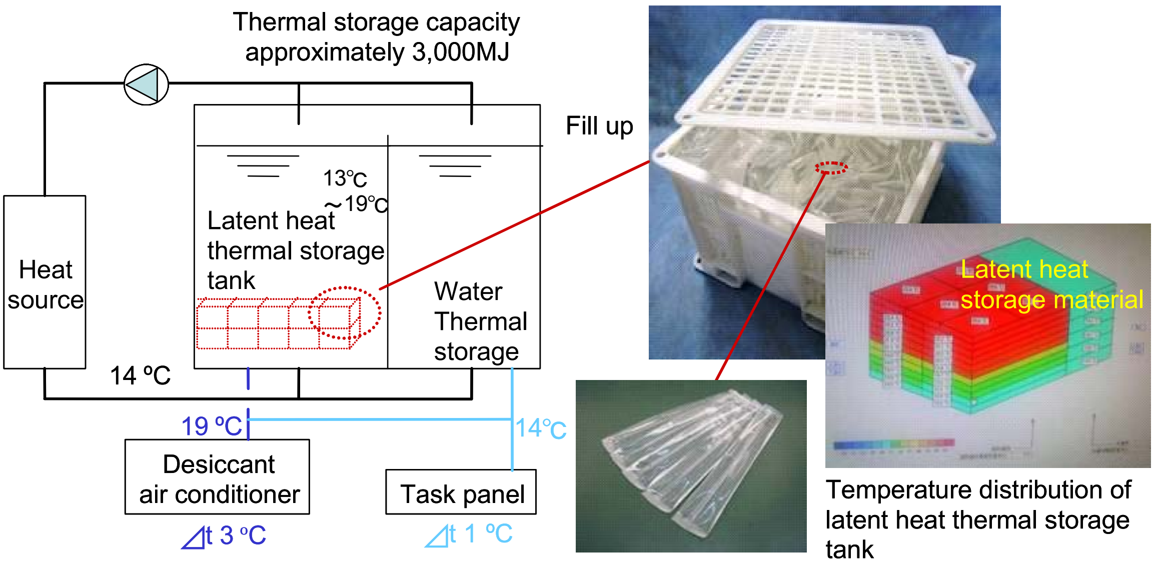

Fig. 11 Outline of integrated medium chilled water air-conditioning system

3.2.5 Power Grid System

To emphasize the efficient power management, we adopted the micro-grid power network in this facility. Main power is supplied by the public power company and several electric power systems are connected to the network. This building has 150kW of solar cells, 2 sets of 25kW co-generation system and 2 sets of power windmills. All electricity which is generated by these systems is coordinated with commercial power. A lithium ion battery system 10kWh is also applied for the peak shift of demand. The surplus electricity can be supplied to other facilities in our institute and helps the reduction of CO_2 emission by other facilities in the site.

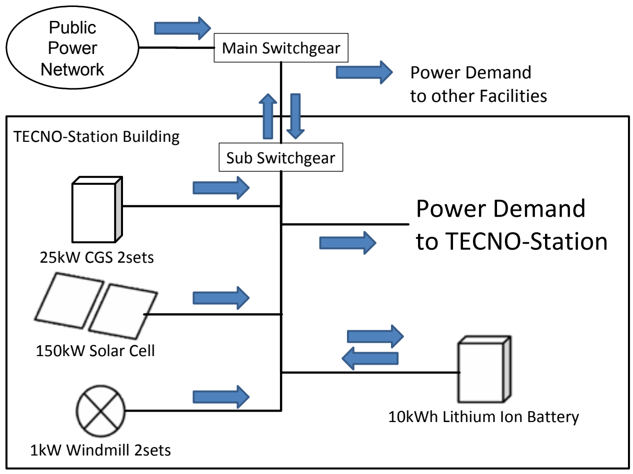

Fig. 12 Power Grid Network

4. Conclusions

We verified by simulation that our challenging office building (laboratory) project that we have been developing for CO_2 emission saving, achieves 55% CO_2 emission reduction compared to conventional office buildings in Japan. Fig. 13 compares the comparison between our simulation

result and that of a conventional office building, which has an average value in Tokyo. In order to achieve such a drastic reduction, we have adopted passive, active, and management methods of utilizing natural energy. Almost 45% of CO2 emissions are saved by our energy saving technologies, 10% of emissions are reduced by generating energy using renewable energy. We adopted new technologies such as an active system like the hybrid heat pump system using geothermal and well-water heat and an air-cooling heat pump system. The COP rises by producing medium chilled water of about 13 to 19 °C. We developed a new task-ambient air-conditioning system and sensible/latent heat separated air-conditioning system as suitable for medium chilled water air-conditioning system.
These systems allowed for 55 % reduction in CO2 emissions during operation, the highest level in Japan. Furthermore, the building was rated as S rank of CASBEE® and achieved BEE 7.6 scores because of the overall reduction in environmental load. This building was completed in September 2010 and then began operation. We are planning to accumulate and analyze more data.

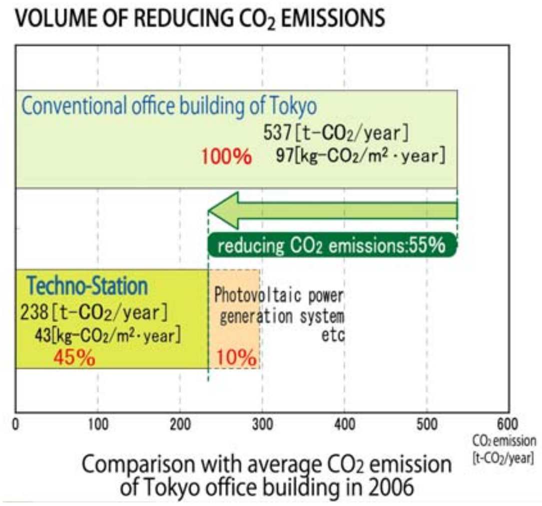

Fig. 13 Estimation of CO2 reduction effect

The authors have realized CO2 reduction building design from collaborative research, and would like to acknowledge the follow peoples.

- Experimental evaluation of task ambient air-conditioning system with radiation and convection
  Prof. Dr. Tatsuo NOBE, Kogakuin University
- Development of "task-panel" with radiation and convection
  Yoshihisa Hirayama, PS Company Ltd.
- Experimental evaluation of Latent heat storage tank system
  Prof. Dr. Motoi Yamaha, Chubu University
- Development of latent heat storage material and storage containers
  Tadafumi Yokota, JX Nippon Oil & Energy Corp.

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