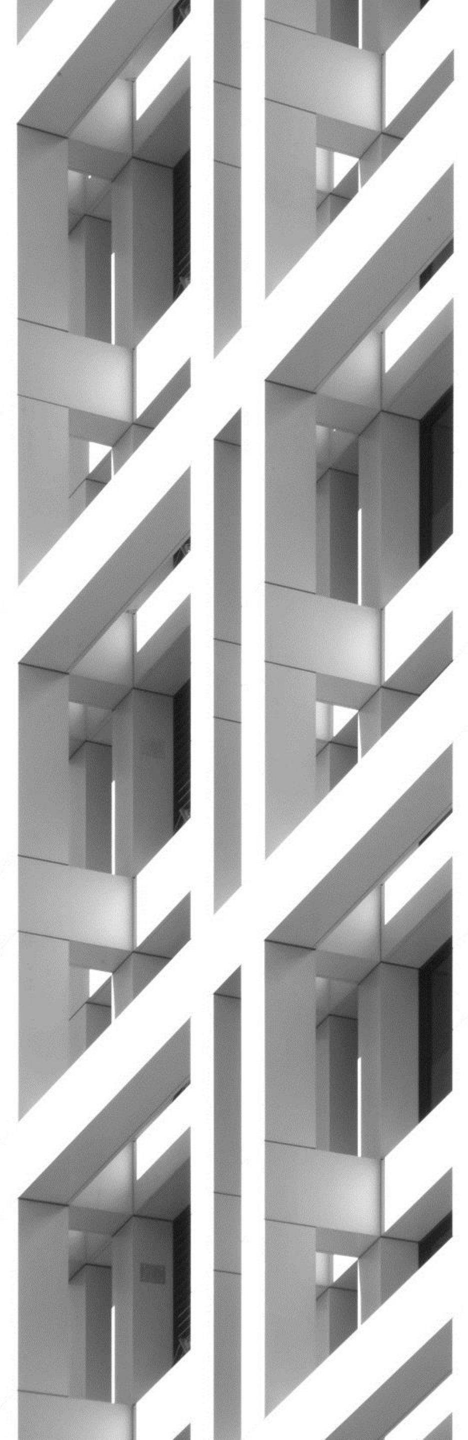

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HVAC System Design and Operation Performance of a Low-Carbon High-Rise Tenant Office Building Located in Tokyo

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1 Introduction

- Redevelopment projects that arrange densely buildings with large floor area are moving ahead in Tokyo, Japan.

- Tenant office business requires not only high-standard office space but also resilient and environmentally-friendly design.
- For HVAC system design of tenant office buildings, redundancy is required because it is designed when tenants are not determined and human behavior of users is uncertain.

- K Building is a 30-story complex building composed of tenant office, rented housing and retail.
- We aimed for realization of safety, functionality and environmental performance that are required of next-generation high-rise buildings.

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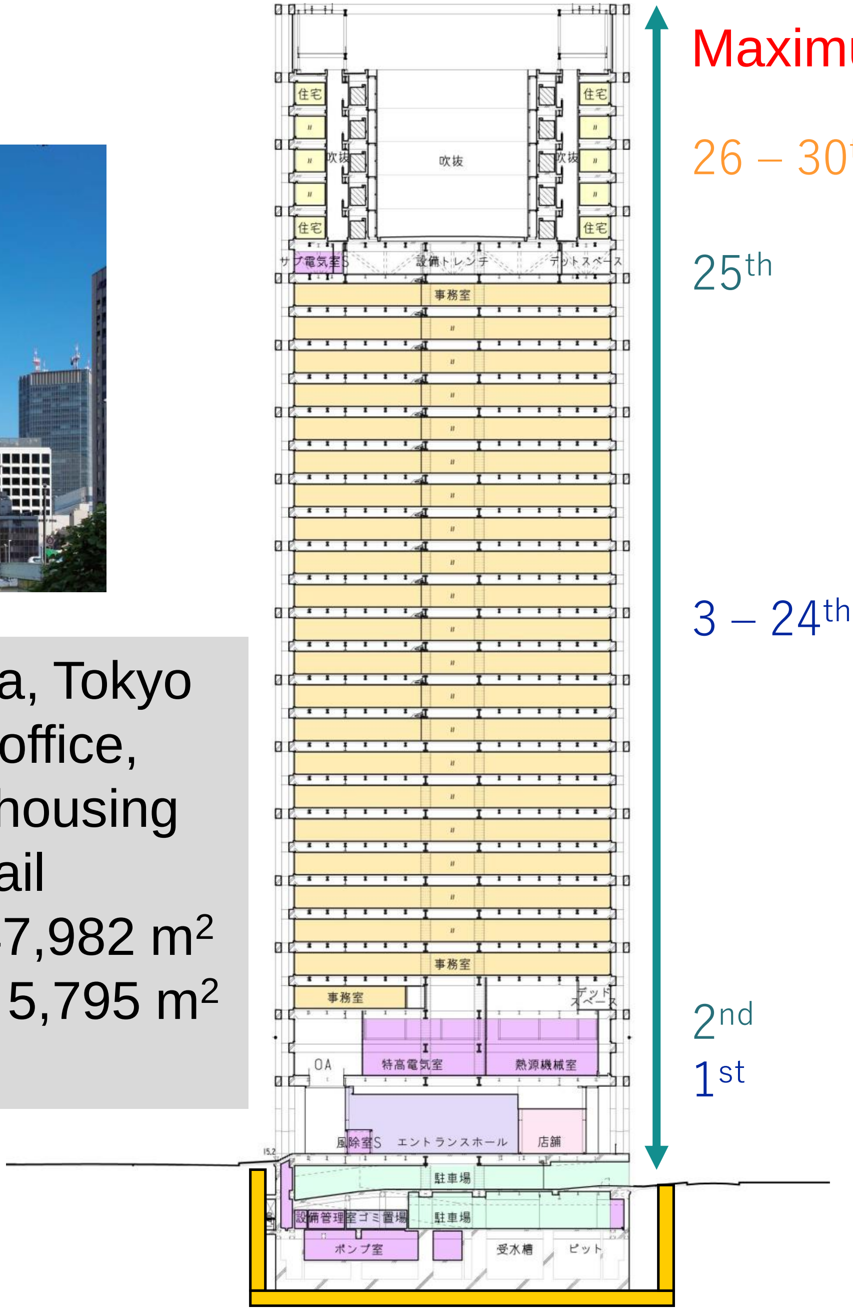
K Building

Location : Akasaka, Tokyo
Building use : Tenant office, rented housing and retail
Floor area : Office 47,982 m^2
Housing 5,795 m^2
Stories : 30



Maximum height：158.0m

26 – 30th : Housing

25th : Machine room

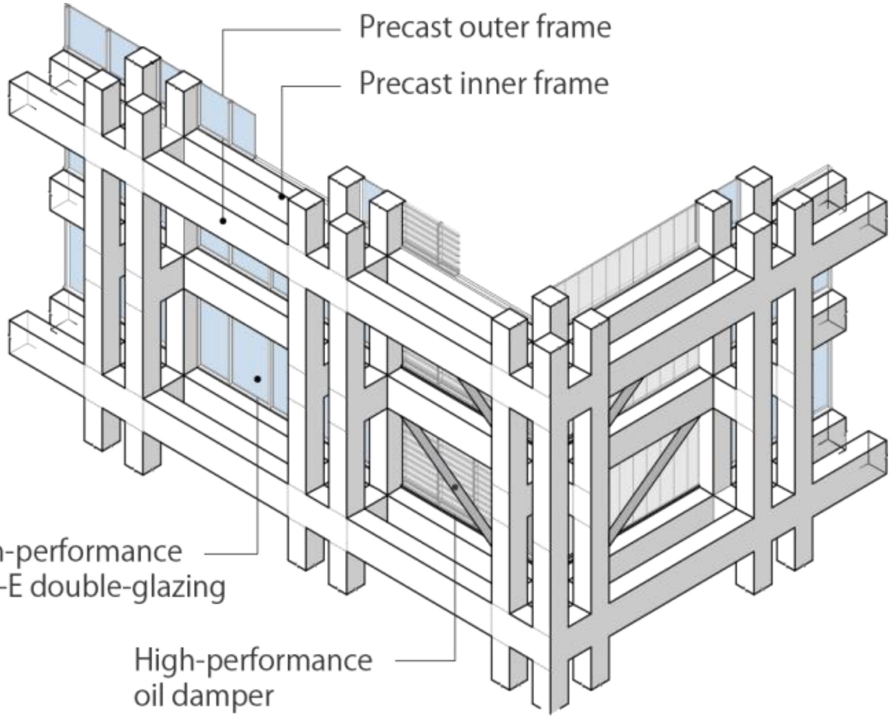
3 – 24th : Office

2nd : Machine room

1st : Entrance and retail

Facade design

- Integrates the building and equipment functions.
- Simple exterior that offers high heat insulating performance.
- Precast outer frame structure to cut annual direct solar radiation by 75%.
- High performance low-e double glazing.

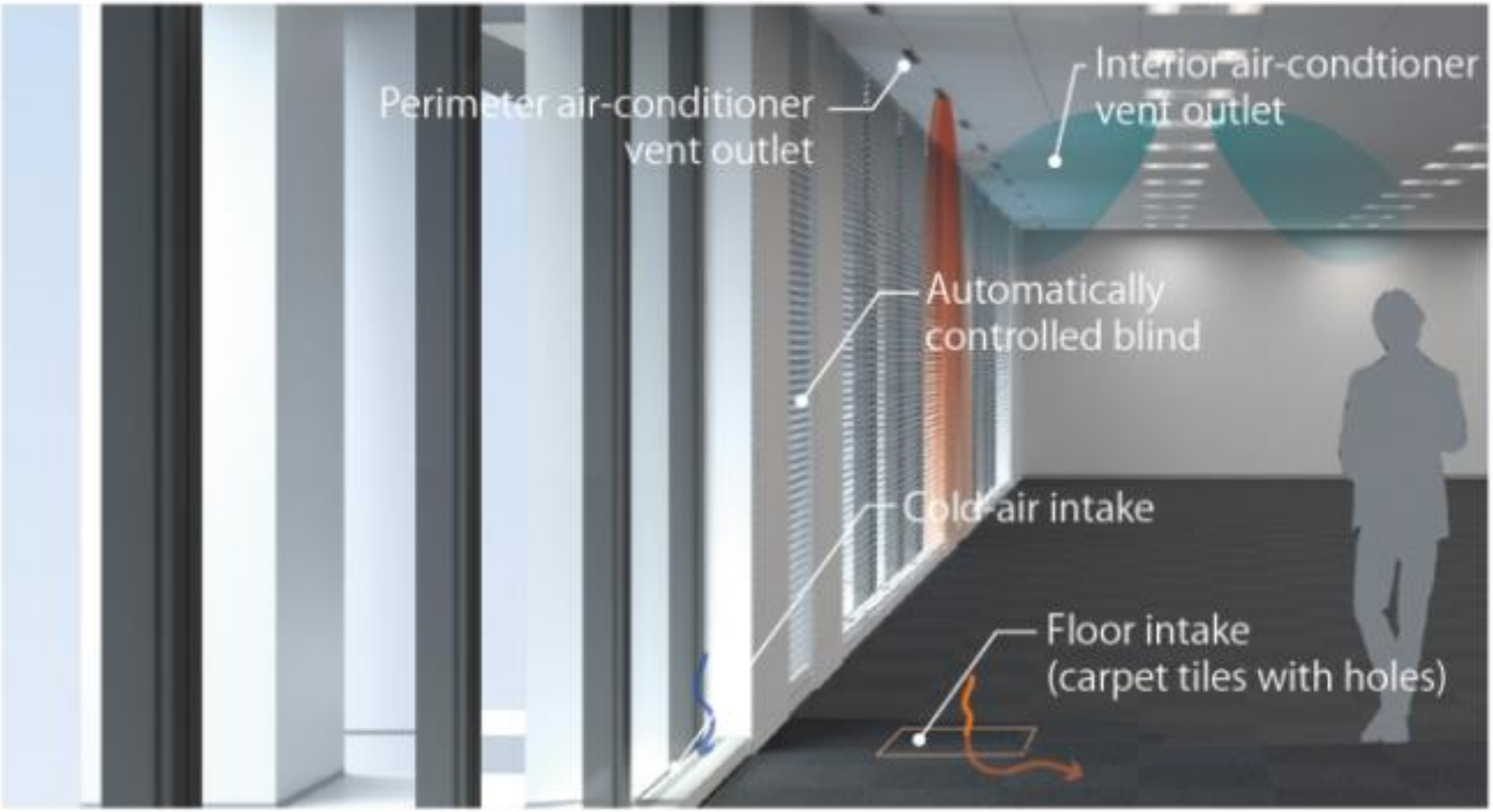


Perimeter design

- Outer skin load is reduced by 35%.

⇒ The performance equal to or better than airflow windows.

- Cold draft intake ports are installed to improve the vertical temperature distribution in winter.



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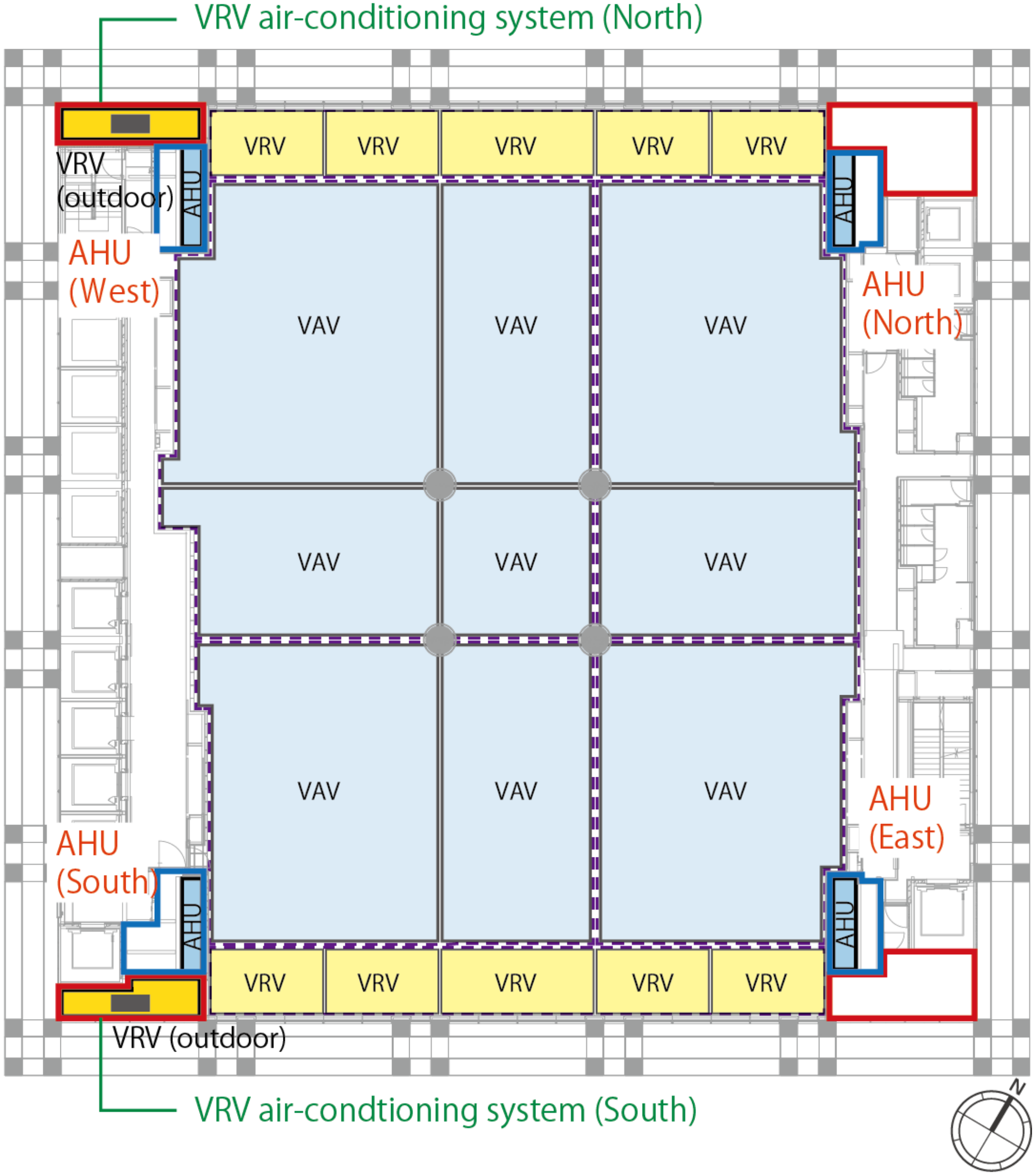
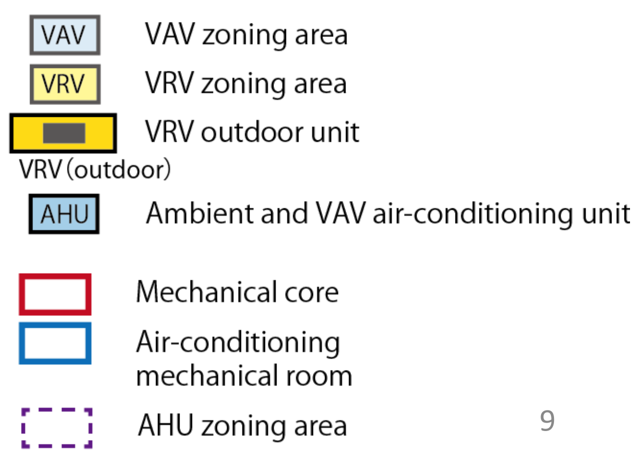
Air-conditioning system design

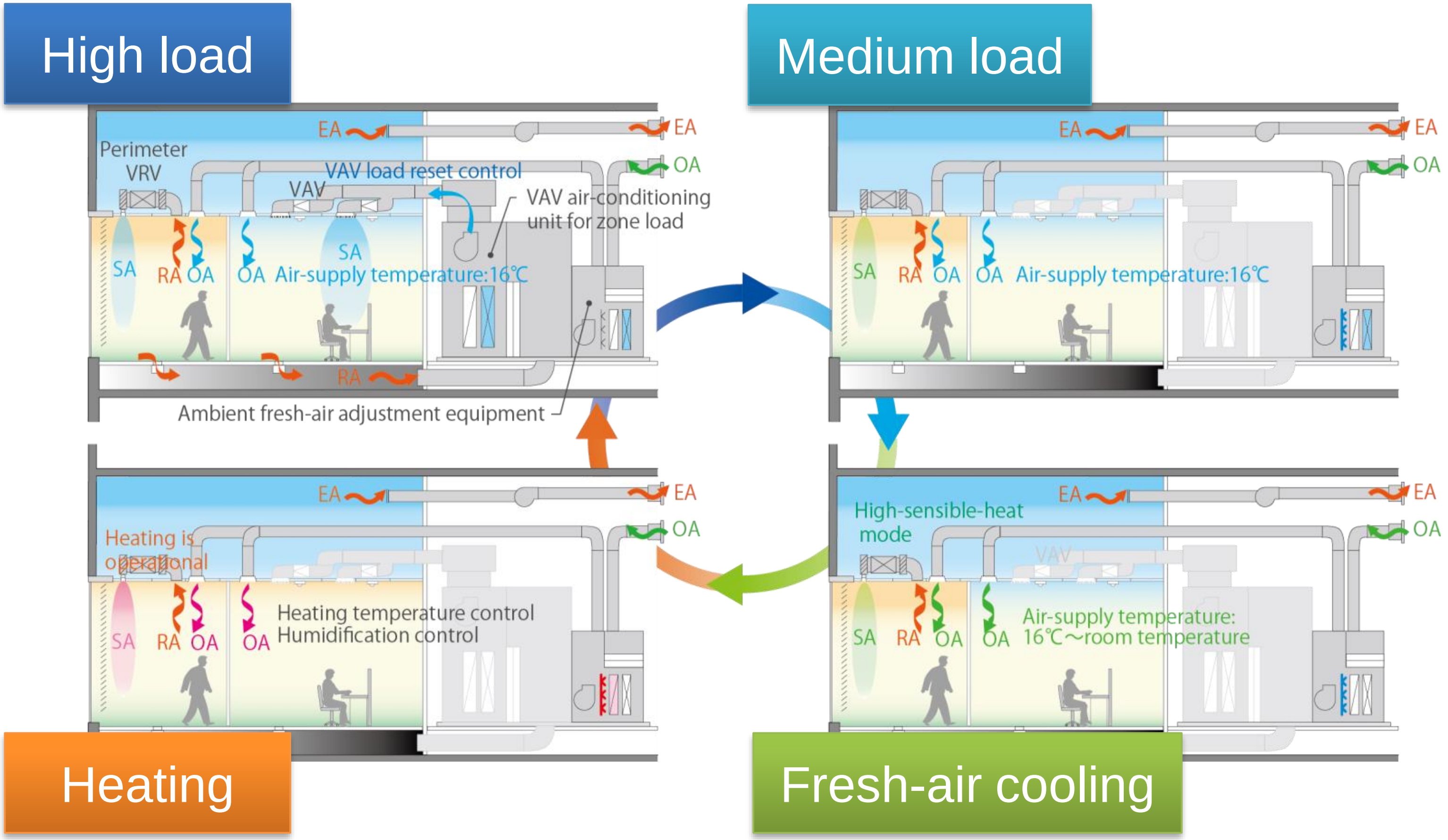


- Ambient outdoor AHU (4 zones), VAV AHU and VRV systems
- 4 tenants per floor
- VAV (9 zones)
- Perimeter VRV units (10 zones)



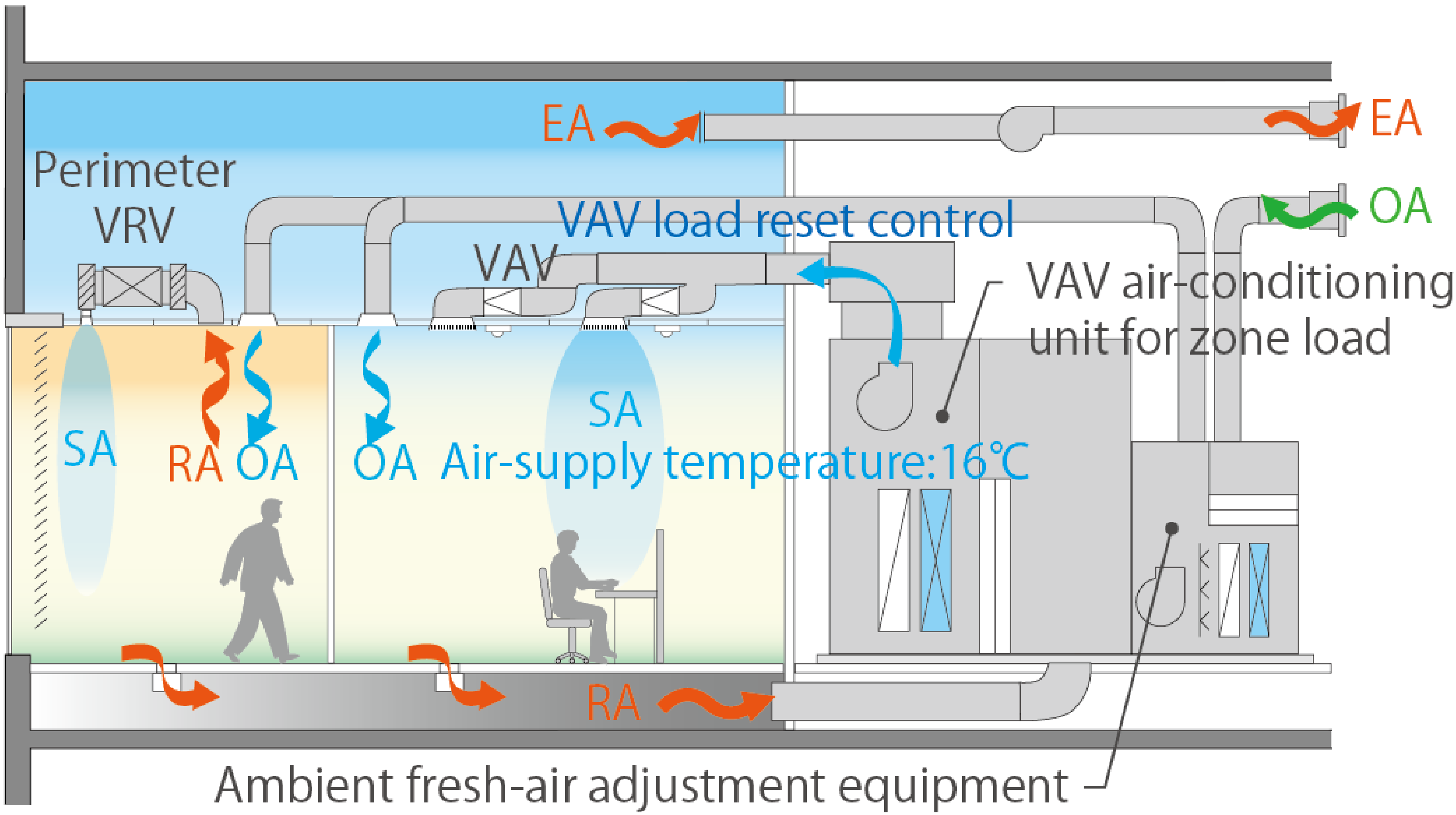
Operation of air-conditioning system

This air-conditioning system is designed to enable high-efficiency operation under a variety of conditions.
This is accomplished by switching the 3 air-conditioning systems to the following 4 modes in accordance with the load status and outside air conditions.



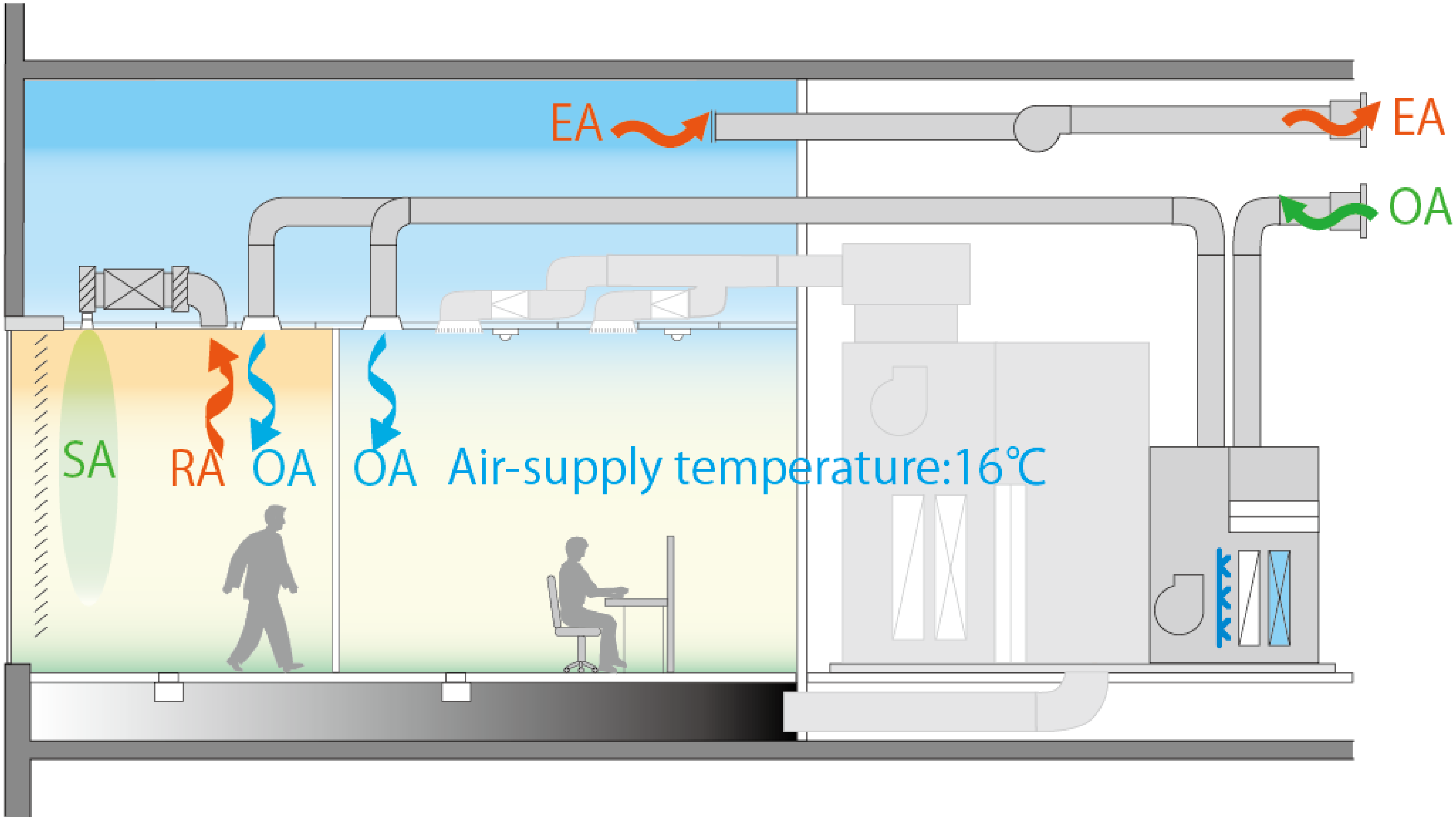
High load

Ambient fresh-air adjustment equipment, VAV air-conditioning unit and perimeter VRV system operate simultaneously.



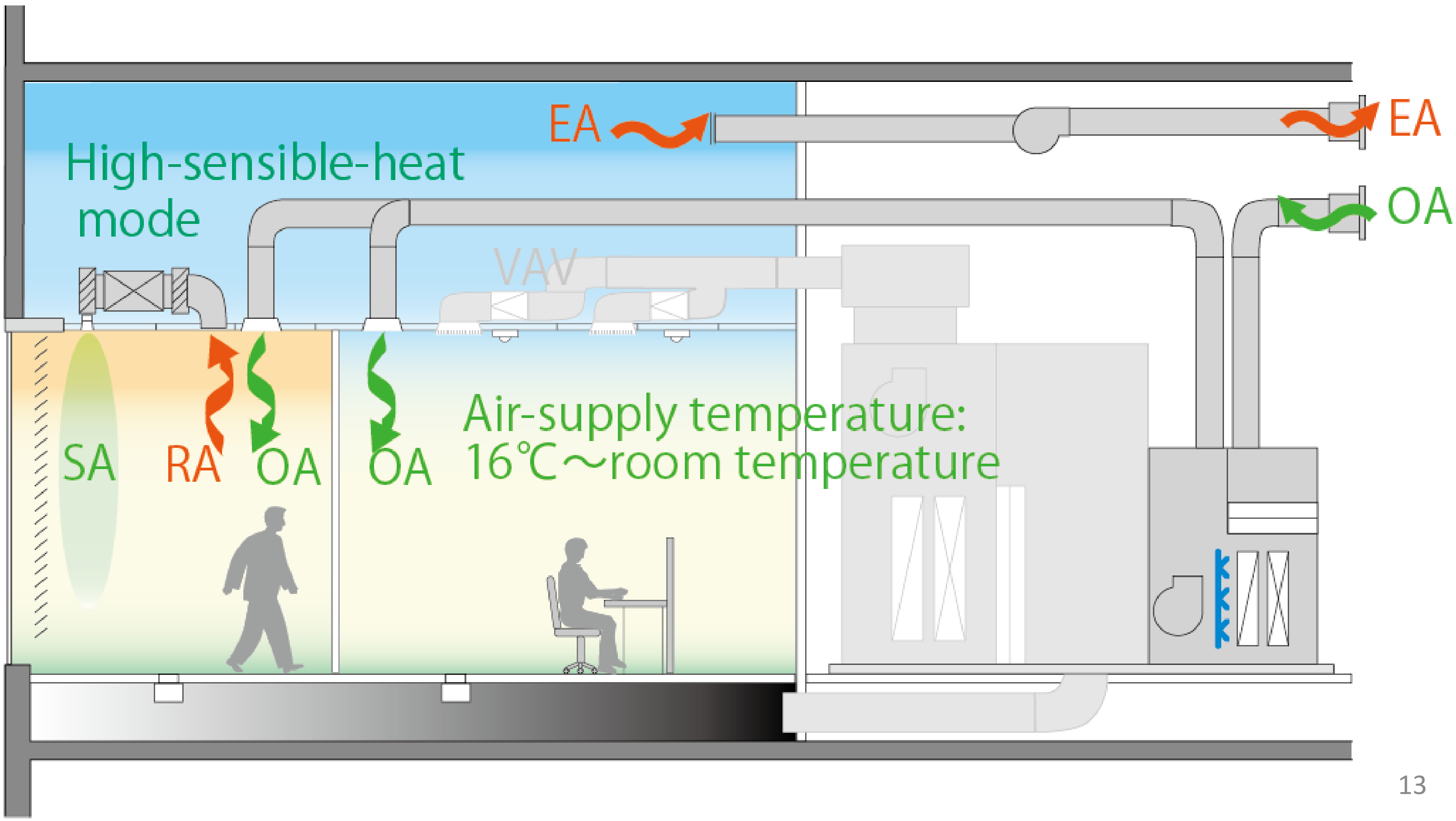
Medium load

As load becomes smaller, VAV air-conditioning unit stops.
The VAV AHUs are switched to start-stop control status.



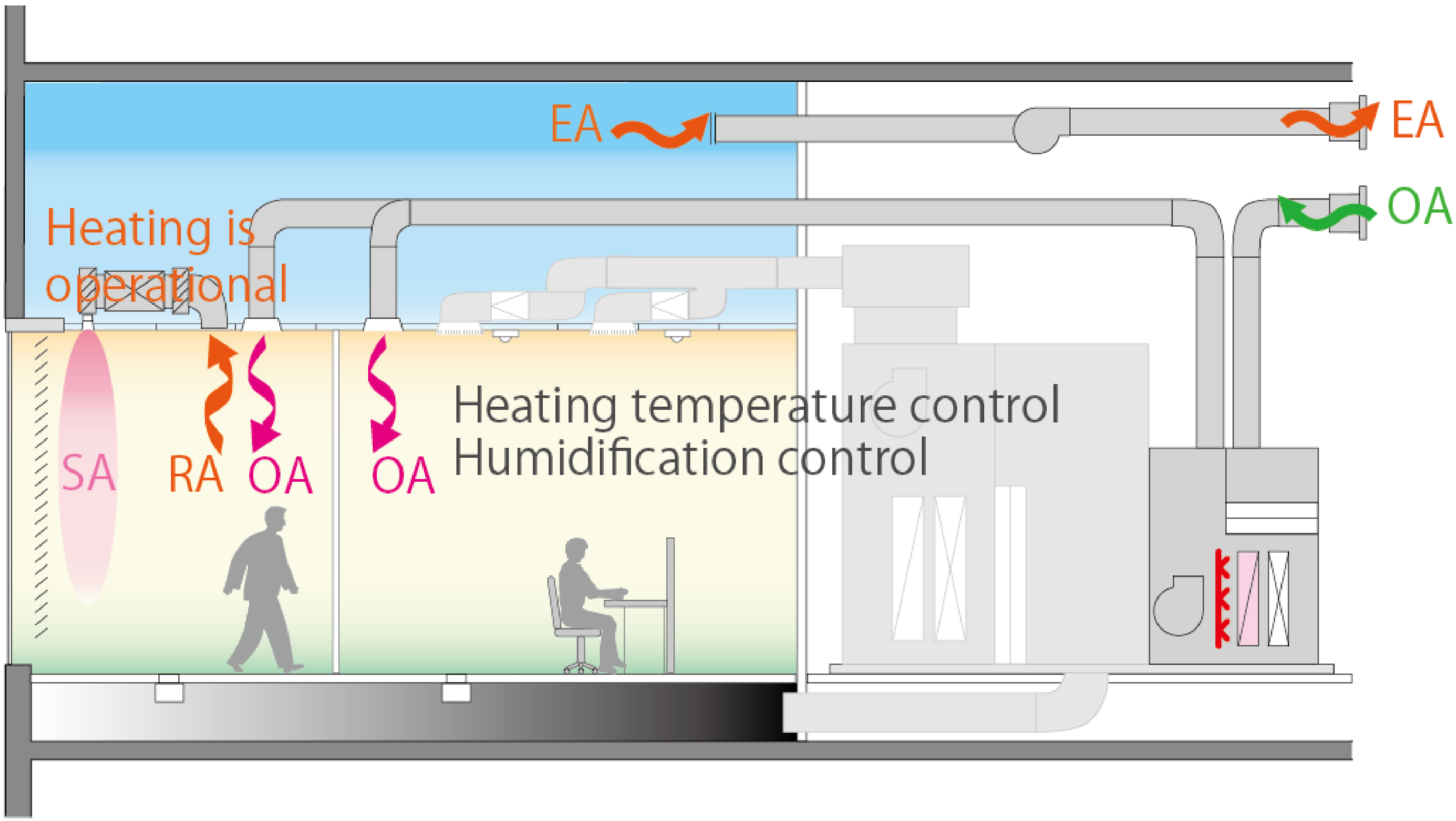
Fresh-air cooling

As load continues to become smaller, perimeter VRV system switches over to energy-saving mode and ambient fresh-air adjustment equipment enters fresh-air cooling mode.

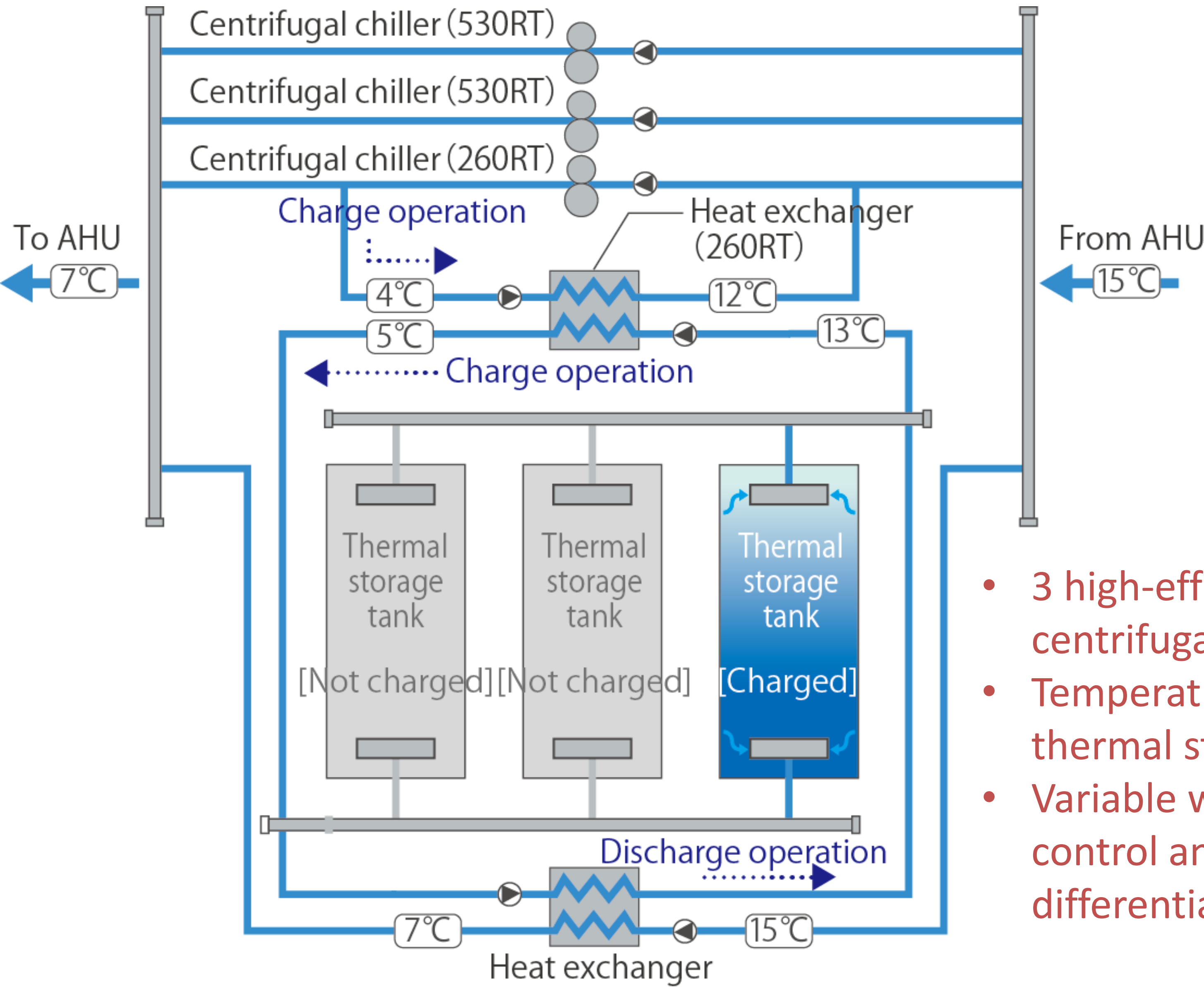


Heating

In winter, heating is carried out using fresh-air adjustment equipment and perimeter VRV system.



Heat source system design



- 3 high-efficiency inverter centrifugal chillers
- Temperature-stratified-type thermal storage tanks
- Variable water flow rate control and large temperature differential of chilled water

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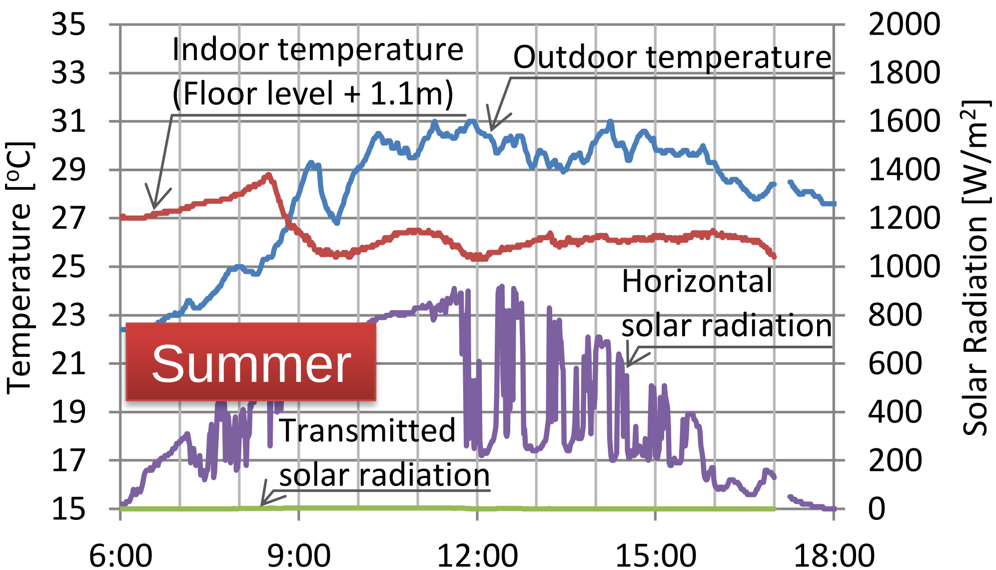
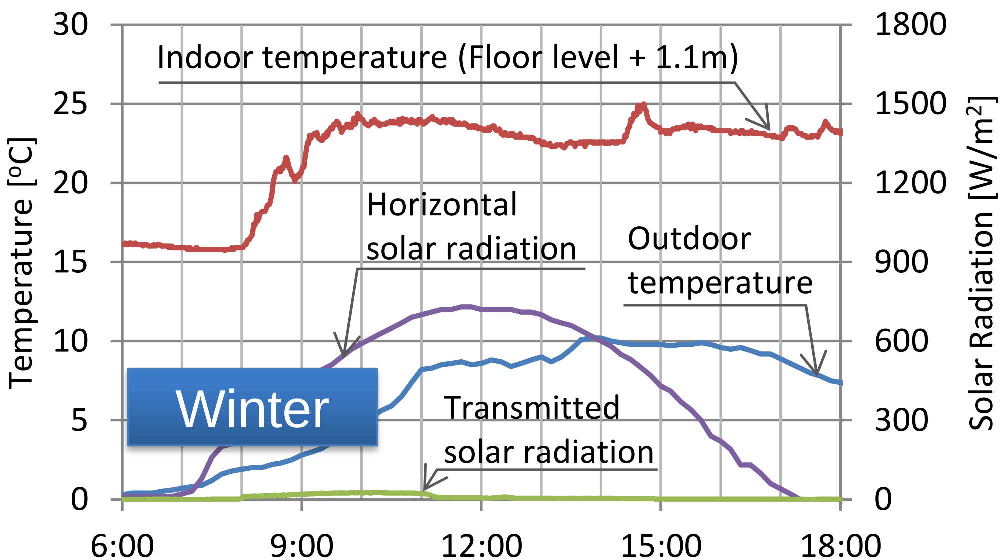
Evaluation of thermal environment near the window



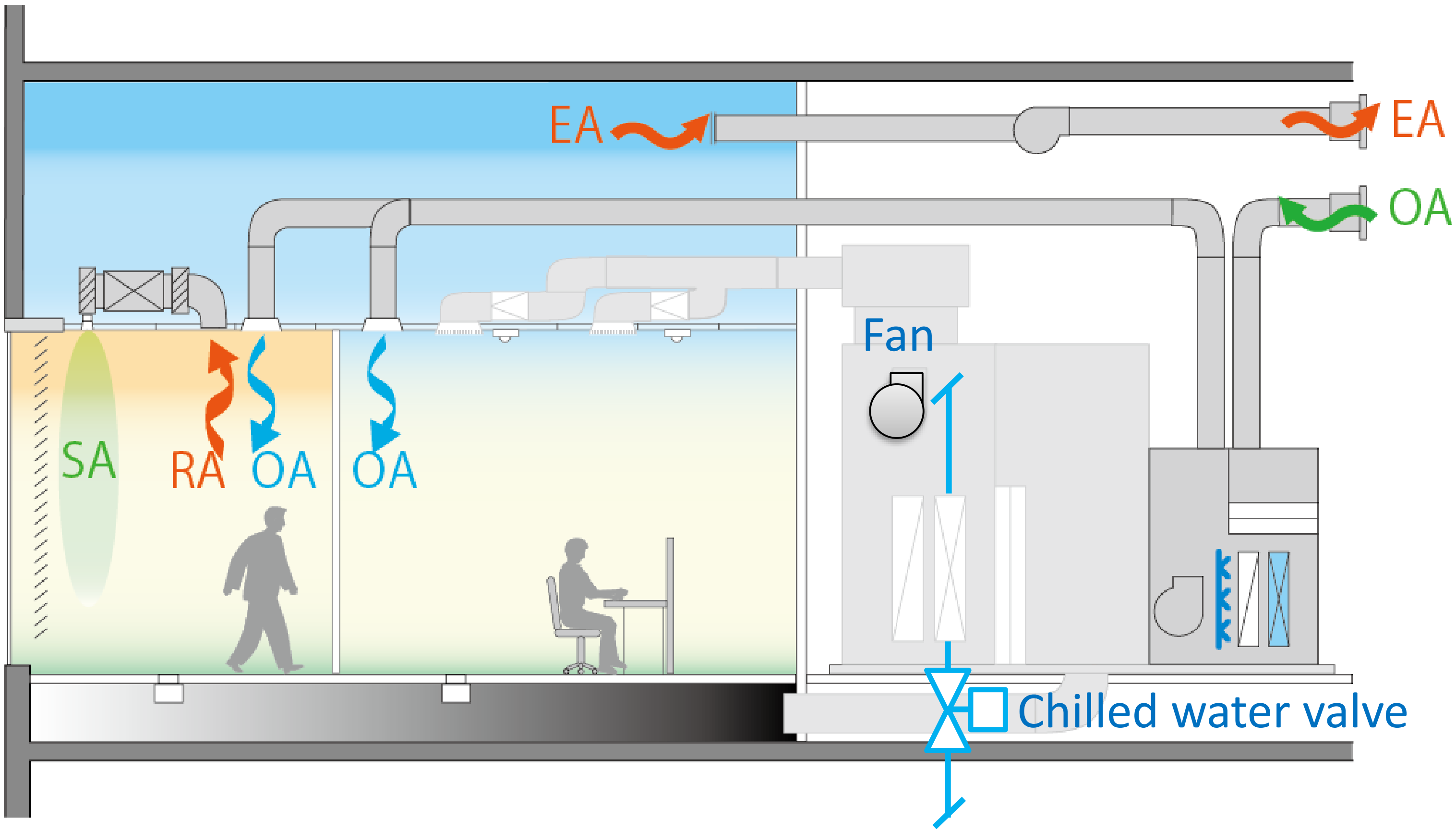
- Measurement of the thermal environment in the 3rd floor, oriented toward the southeast
- In summer, the room temperature is controlled to around 26ºC. PMV is held to around 0.4 – 0.6.
- Even the maximum globe temperature was around 27ºC.



- In winter, the room temperature is controlled to around 22ºC. PMV is held to around -0.5 – 0.3.

Evaluation of VAV start-stop control

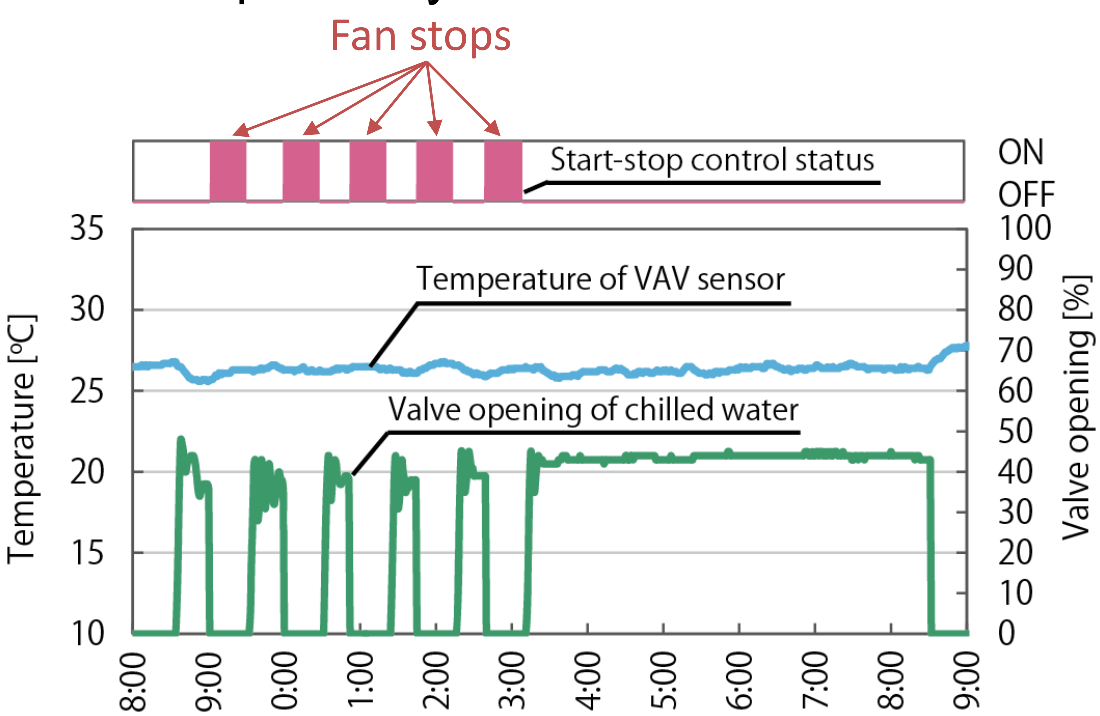
Aiming at improvement of low load operation efficiency, the fan of VAV AHU stops when opening of chilled water valve is smaller than 40%.



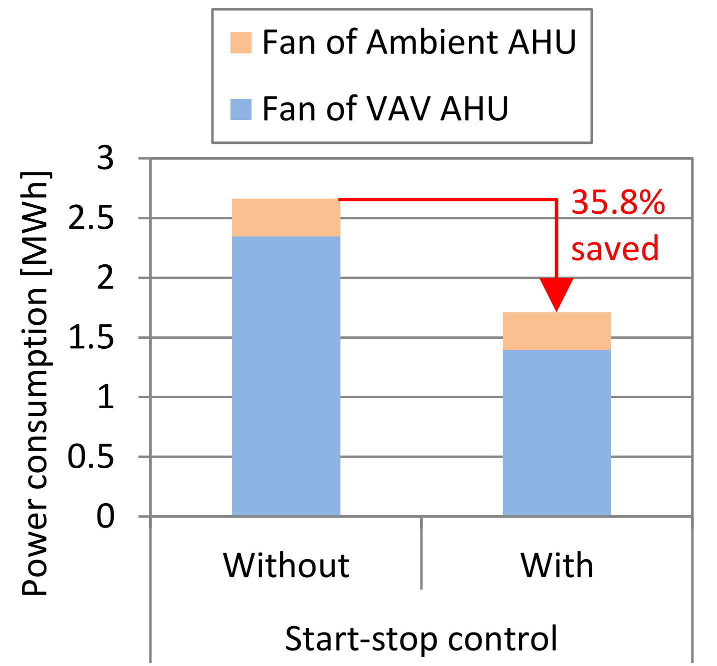
The fan is restarted when the differential between the set temperature and the measured temperature is 2°C or more.

Measurement and simulation of start-stop control

- The AHU was in start-stop control status up until 1:00 p.m., and subsequently the chilled water valve opening was controlled to 40% or greater. There was no change in room temperature regardless of whether start-stop control was conducted.
- There was a total reduction of 35.8% in annual energy consumption for fan power by our simulation tool “ENe-ST”



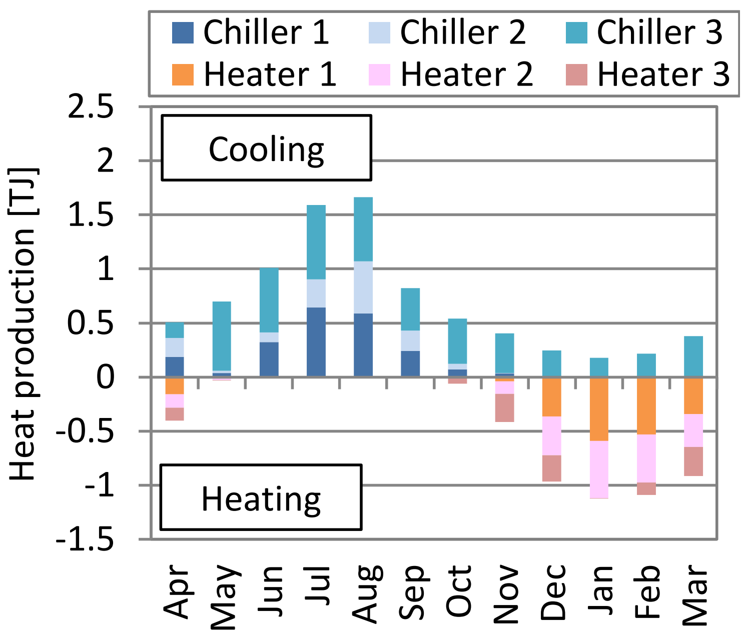
Measurement data on a typical day



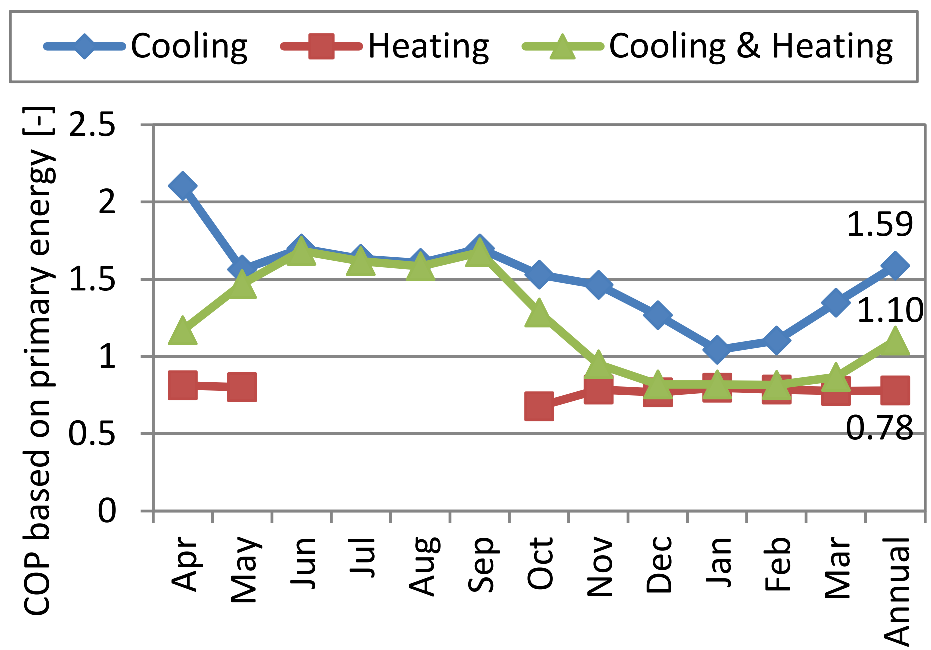
Annual energy saving effect for fan by simulation, ENe-ST

Heat source system performance in FY 2014

- The annual quantity of cooling produced was 8.3 TJ/year, and the annual quantity of heating produced was 5.0 TJ/year.
- The annual system COP for the cooling is 1.6, while in summer the value is high at 1.6 - 1.7.
- This is excellent efficiency compared to the performance of other buildings in Japan.



Heat production by heat sources



System COP based on primary energy

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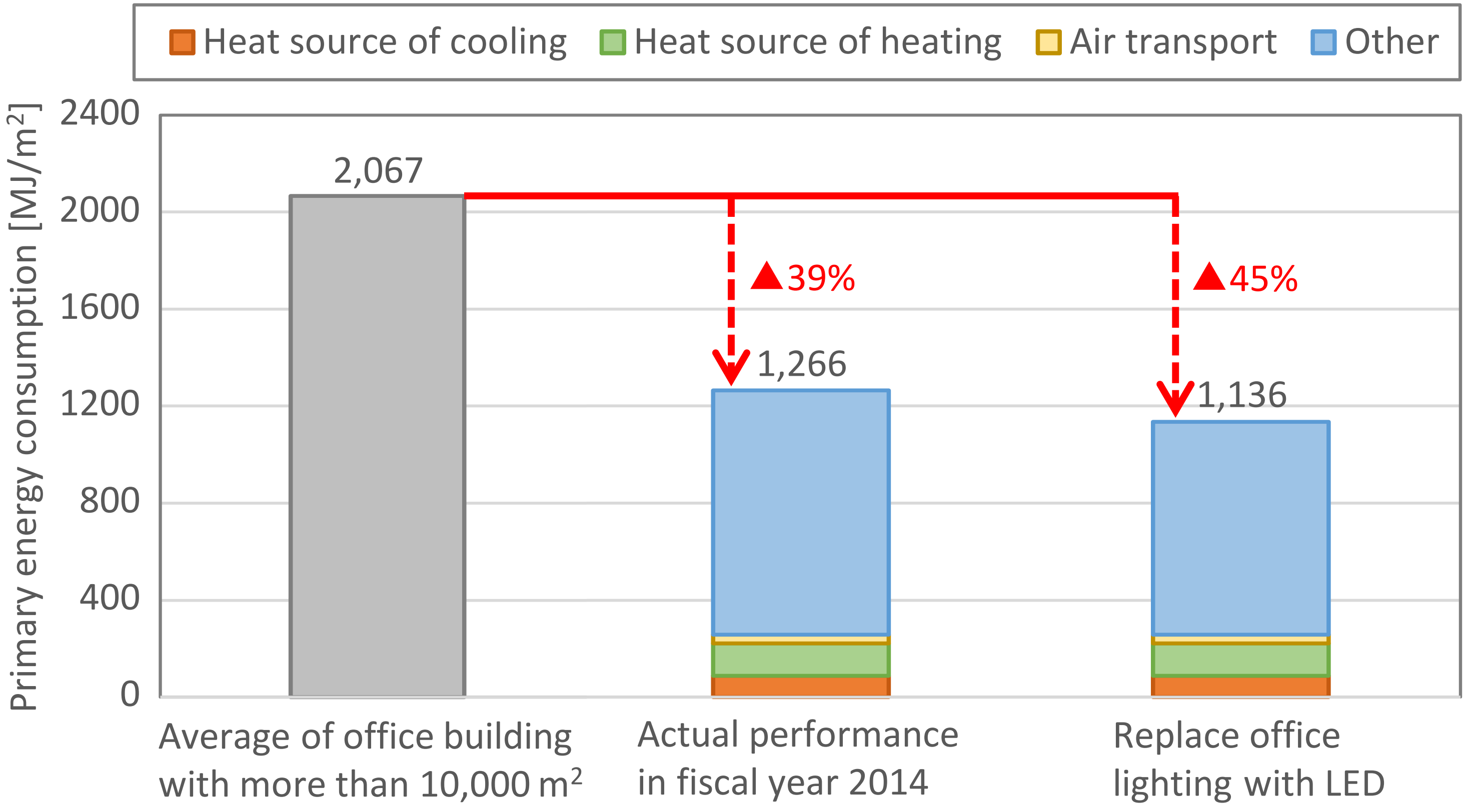
Evaluation of overall building performance in FY 2014

- The primary energy consumption of the building was 1,266 MJ/m^2, demonstrating that a high level of overall energy-saving performance had been achieved despite a high-rise tenant office building.
- If the ceiling lights are changed from Hf fluorescent to LED, the value will become 1,136 MJ/m^2.



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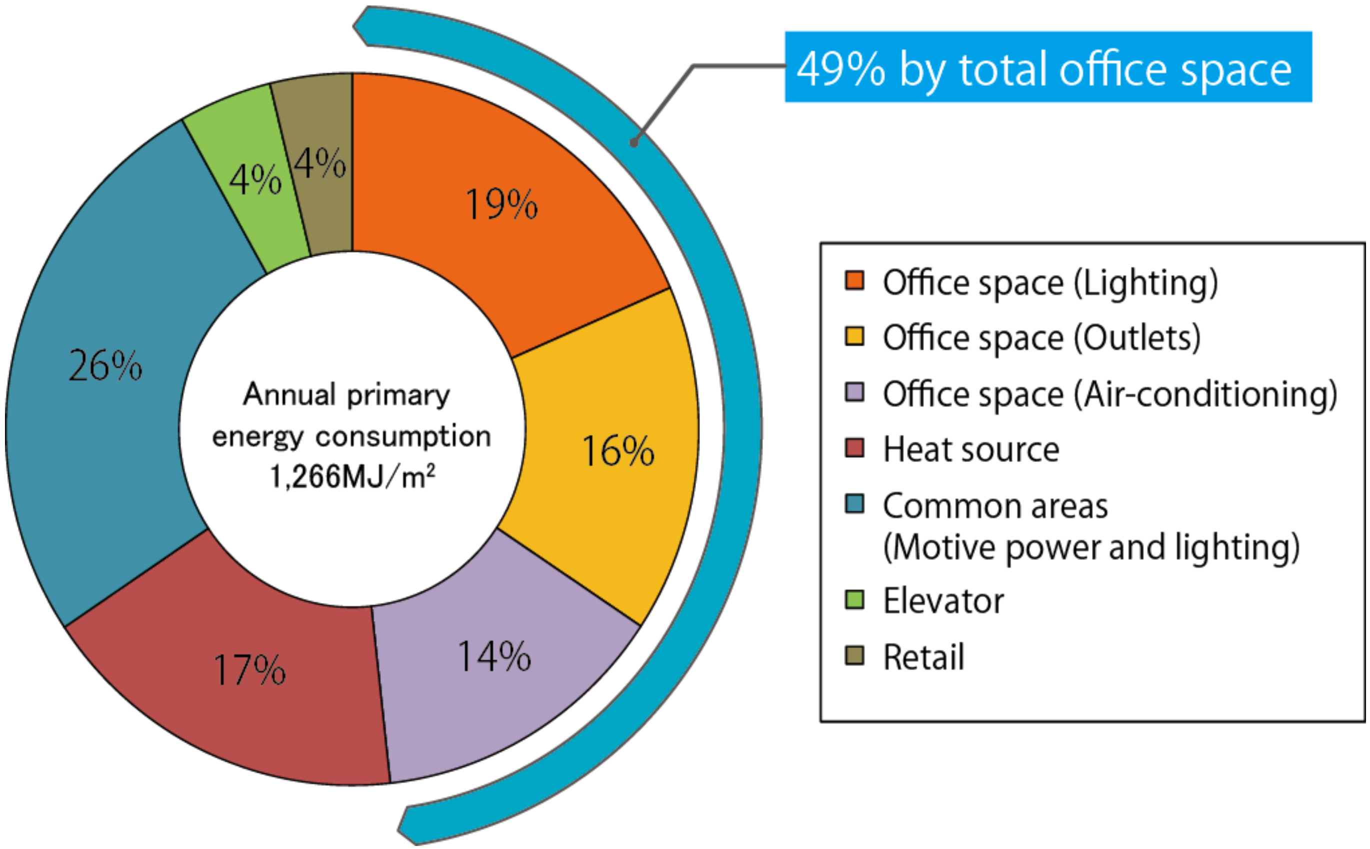
Conclusions

- An example of HVAC system design in high-rise tenant office buildings can be produced for actual practice of low-carbon when high functionality and redundancy are required in condition of uncertain users.
- In facade design, building envelope heat load was reduced by 35% compared to office baseline using precast outer frame structure with high-performance glazing.
- In heat source system design, inverter centrifugal chillers and thermal energy storage (TES) with variable capacity were introduced and the high efficiency was verified in actual operation. Air-conditioning system with unique control, which stops VAV air-handling unit automatically in low load operation, was implemented.
- By these energy-saving technologies, annual primary energy consumption for the whole building was 1,266 MJ/m^2 and reduced by 40% compared to the averaged actual performance value for office buildings in Tokyo.

Thank you for your attention.

Primary energy consumption in FY 2014

- The total percentage of energy consumption for lighting, electrical outlets and air conditioning for standard office floors was 49%.



Percentage for each type of use