Study on reducing the environmental burden of a government building with an energy saving system

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Abstract. This study aims to grasp the energy consumption of the government buildings currently being planned. The target building is the new government building in U City Japan, which is planned as a zero energy building for ZEB ready. In addition, considering the latest equipment to be introduced to the government building, energy simulation was performed using the Building Energy Simulation Tool (BEST) program. Simulation results revealed that the annual primary energy consumption was reduced by 30% below the reference value. In the future, the energy consumption will be further reduced by examining the methods for operation and control of the heat source equipment.

1. Introduction
In Japan, energy consumption in the consumer sector is significantly increasing. The energy consumption of the business sector is 2.9 times that of the household sector. Therefore, there is an urgent need for energy saving in government buildings in the business sector. Several government buildings that were constructed in the 1950s and 1960s have recently been found to have many problems, including a lack of seismic performance and convenience, and an increase in maintenance costs due to deterioration. It is essential to solve such problems and to plan government buildings that can be used in the future.

2. Summary of new government building
2.1. Overview of the building
Table 1 shows the outline of the new government building in U city. The total building area is 5,708.18 m² with a total floor area of 18,690.17 m². The first phase RC construction of a public viewing gallery on the sixth floor, and the second phase involves the S construction of a lobby and multipurpose hall on the third floor.

| Building area       | 5,708.18 m²  |
|---------------------|--------------|
| Total floor area    | 18,690.17 m² |
| Building height     | The first phase government building : 30.0 m |
|                     | the second phase government building : 16.2 m |
| Construction        | The first phase government building : RC construction |
|                     | the second phase government building : S construction |
| Floor               | The first phase government building : 6th floors above ground |
|                     | the second phase government building : 3rd floors above ground |
2.2. Overview of the equipment

Table 2 presents an overview of the equipment. The heat source equipment will be operated by combining a thermal storage tank, an air-cooled heat pump chiller, an absorption refrigerating machine, a micro cogeneration system, and a solar heat collector. The ventilation system provides both air supply and exhaust in the main rooms, and exhaust alone in the restrooms. LED will be used for lighting equipment and there are plans to install four elevators.

| Table 2. Overview of the equipment |
|-----------------------------------|
| **Heat source equipment**         |
| Thermal storage tank: Water capacity 600 m$^3$  
  (cold water: 19→13°C)  
  Air-cooled heat pump chiller  
  Absorption refrigerating machine  
  Cogeneration system, Solar heat collector |
| **Air conditioning**              |
| Desiccant air conditioner (4 units), FCU (48 units), PAC (27 units) |
| **Ventilation**                   |
| Office: Mechanical ventilation for both air supply and exhaust  
  Restroom: Mechanical ventilation Exhaust only |
| **Lighting**                      |
| LED lighting                      |
| **Other**                         |
| Automatic fire alarm system, Emergency lighting |
| **Elevator**                      |
| 4 groups                          |

| Table 3. Overview of the heat source equipment |
|-----------------------------------------------|
| **Thermal storage tank**                      |
| Type: Thermal stratification type  
  Thermal storage tank (10 tanks)  
  Total Water capacity: 600 m$^3$  
  Water temperature difference: 6°C (Cold water 19→13°C) |
| **HP-1**                                       |
| Cooling capacity: 354 kW, Heating capacity: 354 kW  
  Amount of cold water: 1089 L/min (Normal time) 14.5~20.5°C  
  1075 L/min (During heat storage) 12.0~18.0°C  
  Amount of hot water: 671 L/min (Normal time) 39.0~45.0°C  
  628 L/min (During heat storage) 47.5~41.5°C |
| **HP-2**                                       |
| Cooling capacity: 91.8 kW, Heating capacity: 97.2 kW  
  Amount of cold water: 192 L/min (During cooling and heating) 14.5~20.5°C  
  Amount of hot water: 362 L/min (During cooling and heating) 65.0~70.0°C  
  204 L/min (During heating) 45.0~39.0°C |
| **Absorption refrigerating machine**           |
| Cooling capacity: 528.0 kW, Heating capacity: 352.0 kW  
  Amount of cold water: 1512 L/min (14.5~20.5°C)  
  Amount of hot water: 1512 L/min (39.0~45.0°C)  
  Cooling water volume: 2500 L/min (37.5~32.0°C)  
  Waste water volume: 395 L/min (83.0~88.0°C)  
  Waste heat recovery amount: 167 kW |
| **Cogeneration system**                        |
| Rated output: 35 kW, Amount of hot water: 167 L/min  
  Waste heat recovery amount: 55.8 kW |
| **Solar heat collector**                       |
| Rated output: 270 kW, Area: 430.92 m$^2$       |
2.3. Environmental plan

Figure 1 provides an overview of the environmental plan. There are six basic policies regarding the city hall related to environmental planning:
1. Remove one load from the original;
2. Make the most of the blessings of nature;
3. Utilize renewable energy;
4. Build a highly efficient facility system;
5. Operate buildings efficiently;
6. Review work style.

![Environmental planning chart](image)

1. Highly efficient equipment: Use motion-controlled LED lighting throughout the government building.
2. Eco void (Atrium Space): Install an eco void and ventilation windows to maintain thermal, air and light environments.
3. Ventilation windows: Install windows on all floors to promote natural ventilation.
4. High heat insulation: In consideration of the heat insulation performance for the parts in contact with the outside such as walls, glass, and roof.
5. Task-ambient lighting: Ambient lighting ensures minimum brightness of the entire room and saves power by using task lighting only where necessary.
6. Control system using ICT: Using ICT, such as control of lighting and air conditioning by infrared sensor.
7. Use of hydrogen: Move the machine using hydrogen.
8. Photovoltaic power generation/solar heat collector: Reduce environmental impact by utilizing natural energy.
9. Balcony and louvers: Block solar light and control heat load with balcony and horizontal louvers.
10. Rainwater storage tank: Effective use of rainwater for toilet flush water and sprinkler system using existing underground housing to save water.
11. Residential area air conditioning: With the floor-level air conditioning system, air conditioning can be efficiently performed without waste.
12. Visualization of energy use: Using building energy management system (BEMS) for centralized management of energy information.
2.4. Heat source system

Figure 2 shows the heat source flow of the new government building. There are five pieces of heat source equipment so that the operation method can be fine-tuned according to the outdoor air conditions and indoor heat load.

![Heat source flow diagram](image)

Figure 2. Heat source flow

3. Summary of current government building

3.1. Overview of the building

Table 4 presents an overview of the government building. The building area is 4867.97 m², the height of the building is 16.66 m, and the total floor area is 13448.36 m². The structure is an RC construction (partial S construction) on the fourth floor and the lower ground floor.

| Building area        | 4867.97 m² |
|----------------------|------------|
| Total floor area     | 13448.36 m²|
| Building height      | 16.66m     |
| Construction         | RC construction (Partial S construction) |
| Floor                | 4 floors above ground, 1 floor underground |

3.2. Overview of the equipment

Table 5 presents an overview of the equipment in the current government building. The heat source equipment is an absorption chiller-heater. The air conditioners include 76 fan coil units, 10 air handling units, nine packaged air conditioners, and five gas heat pump air conditioners.

| HVAC                  | Absorption refrigerating machine |
|-----------------------|----------------------------------|
|                       | Cooling capacity : 843kW, Heating capacity : 725kW |
| Pump                  | Cooling water pump:30kW, Hot and cold water pump:15kW |
| Air conditioner       | FCU 76 units, AHU 10 units, PAC 9 units |
|                       | gas heat pump air conditioner 5 units |
| ventilation           | Restroom: Mechanical ventilation Exhaust only |
| Lighting              | Fluorescent light 2072 units, Downlight 116 units, Incandescent bulb 24 units |
| Elevator              | 1 groups |
4. Simulation by the BEST program

4.1. About simulation tools
For the energy simulation, we used the BEST program (design tool), which is one of the tools with the highest credit rating in Japan, and is characterized by detailed settings. In addition, the BEST program conducts coupled calculations such as for construction and heat, ventilation, and air conditioning (HVAC), as well as lighting. Therefore, even if multiple energy saving methods that affect each other are adopted, it is possible to calculate the combined effect with high accuracy.

4.2. Overview of simulation
Table 6 shows the calculation reference conditions of the simulation. We simulated conditions using standard year EA weather data (2010 version).

| Table 6. Overview of calculation conditions |
|---------------------------------------------|
| Weather | Standard year EA weather data (2010 version) |
| Window glass | Windows: Double-glazed windows (Transparent glass 6 mm + Transparent glass 6 mm) |
| | Heat conduction rate: 3.16(W/m² · K) |
| Outer wall | Heat conduction rate: 0.84(W/m² · K) |
| Inner wall | Heat conduction rate: 1.96(W/m² · K) |
| Internal heat | Personnel:0.1(人/m²), Lighting:8.0(W/m²), Equipment: 10(W/m²) |

4.3. Monthly Simulation results
We compared the monthly simulation results with the reference values calculated by the BEST program. Figure 3 is a graph of monthly simulation results. As a result of simulation, the annual primary energy consumption amounted to 755.9 (MJ/m² · year), a reduction of 24.2% compared to the standard value of 996.9 (MJ/m² · year). The main reason for the decrease in annual energy consumption was the reduction in energy consumption in July, the hottest spot in Japan. Energy consumption related to air conditioning went from 651.9 (MJ/m² · year) to 381.5 (MJ/m² · year), a reduction of 41.5%. Energy consumption of lighting decreased from 133.1 (MJ/m² · year) to 98.9 (MJ/m² · year), a reduction of 25.7%.

4.4. Annual simulation results
Figure 4 shows a graph comparing the design value with the current government building. The use of
LED lighting in all buildings reduced the power consumed by the lighting. Furthermore, the internal heating value of the lighting can be suppressed to 8.0 W/m², and the air conditioning load is reduced. The annual primary energy consumption was reduced by 30.0% from that of the old government building.

![Energy consumption comparison](image)

Fig. 4. Annual Simulation results

5. Discussion
Energy consumption of heat source equipment increased in August, which may be because it is the hottest month in Japan and there are many external heat loads. However, since energy use for air conditioning is significant in June, total energy consumption will be greatest in June. In the simulation, since desiccant air conditioners could not be considered, energy consumption increases in June, when humidity is high. Therefore, energy consumption can be further reduced when the building is actually operated. The internal calorific value from lighting can be suppressed to 8.0 W/m² by using LED lighting for all buildings, and the air conditioning load is also thus reduced. As task-ambient lighting is introduced to the new government building, the energy consumption from lighting can be further suppressed.

6. Conclusion
We conducted an energy simulation for a newly built government building in U city. The results revealed that the annual primary energy consumption was reduced by 30% compared to the current government office building. This is because the heat source equipment was changed to a more efficient product, a 25mm heat insulator was installed in the outer wall, and double-glazed windows were used. Energy consumption can be further reduced by actively utilizing natural ventilation during high and low temperatures. Furthermore, since hydrogen can be used to store energy, the heat to be discarded can be reduced, thus achieving energy savings. Even after the building becomes operational, it can become a zero-energy building by changing the heat source operating method to a more efficient one.

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