Commissioning of Air conditioning System and University Facility Energy Consumption by LCEM Tool

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ABSTRACT

Recently, there has been increased emphasis on designing buildings that fully satisfy the requirements of the owners. In Japan, commissioning is forecast as a means of confirming whether or not required performance (e.g. energy consumption of building, environmental load of building and equipment, and quality of building) is taken full advantage. In the present study, initial commissioning (commissioning during the design phase) of a Japanese university building is carried out for the first time. The target building is located in Aichi Prefecture, Japan, and is an experimental research facility with a total floor area of 7046.9m^2. The heating and cooling system of the target building is both the centralized air conditioning system (the system of student's and teacher's rooms) and the individual air conditioning system (the system of laboratories), and the heat source water is designed to use well water with a stable temperature of about 21°C, regardless of the time of year.

The purpose of this study is to consider the performance value specified in the Owner's Project Requirement (OPR), that is 1.86GJ/ m^2 a, and to make a decision regarding reference value of system assessment during operation phase by evaluating the energy consumption of the target building. Energy consumption calculations were carried out using MicroHASP/TES and the Life Cycle Energy Management (LCEM) tool. MicroHASP/TES is the dynamic thermal load calculation software package, and the LCEM tool is designed to simulate air conditioning equipment in order to carry out life cycle energy management of a building from the design phase to the operation phase. The LCEM tool is used mainly for calculating the energy consumption of the air conditioning equipment.

The results indicate that energy consumption of the entire building is 13667.8 GJ per year (1.94 GJ/(m^2·a)), which includes electrical power for lighting, equipment, the heat source, the cooling tower, pumps, elevators and fans. This is close to the performance value of 1.86 GJ/(m^2·a) specified in the OPR.

The use of such a model-based simulation makes it possible to make appropriate equipment choices during the construction phase and to achieve operation improvement during the operation phase. Thereby, appropriate energy management for the life cycle of the target building can be achieved.

KEYWORDS

LCEM tool, initial commissioning, simulation, energy consumption, university building

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INTRODUCTION

Traditionally, the design and construction of facilities have been based on a relationship among the owner, designer, and builder. But existing system is insufficient to make clear owner's requirement and to achieve. In Japan, commissioning is forecast as a means of confirming, advice, and report whether or not required performance (e.g. energy consumption of building, environmental load of building and equipment, and quality of building) is taken full advantage.

The purposes of commissioning is to summarize the owner's requirements with respect to environment impact, energy consumption, and the usability of the building, to carry out a performance test to determine whether or not the building system is appropriate, to produce documentation for the designer or builder, and to provide advice on the optimum operation method based on operational checks on building equipment or energy usage.

In the present study, initial commissioning (commissioning during the design phase) of a Japanese university building is carried out for the first time, which includes an evaluation of the entire energy consumption of the building. Simulations are carried out using the Life Cycle Energy Management (LCEM) tool that is energy simulation tool for the air conditioning equipment in order to perform life cycle energy management of the building from the design phase to the operation phase. Until now, such simulations have received very little attention because of the cost and additional work involved. However, they are crucial when it comes to making informed decisions about whether or not the required performance of the building is being fully achieved. The purpose of this study is to consider the performance value of 1.86 $GJ/(m^2 \cdot a)$ specified in the Owner's Project Requirement (OPR), and to make a decision regarding reference value of system assessment during operation phase by evaluating the energy consumption of the target building.

BUILDING OUTLINE

In this study, the target building is a university facility located in Aichi Prefecture, Japan, with a total floor area of 7046.9 m^2.

Figure 1 shows the heat source system diagram for the target building. In this system, well water is used as the heat source water and the heat source system of the target building is both the centralized air conditioning system (the system of student's and teacher's rooms) and the individual air conditioning system (the system of laboratories). The heat source water has a maximum flow rate of 500 l/min and is used preferentially for the centralized air conditioning system. If it is not used for this system or the flow rate is less than 500 l/min, it can be used for the individual air conditioning system. The individual air conditioning system has a cooling tower as a backup system. Table 1 shows the major equipment capabilities of both the centralized and individual air conditioning systems.

The target building has an earth tube, and there is also a circuit of the heat source water to cool ambient air in earth tube. Therefore, sensible heat exchange is achieved. Ambient air that is cooled (or heated) is sent mainly to rooms served by the centralized air conditioning system. Consequently, the centralized air conditioning system does not need to be operated in the transitional months of April, May, October, and November.

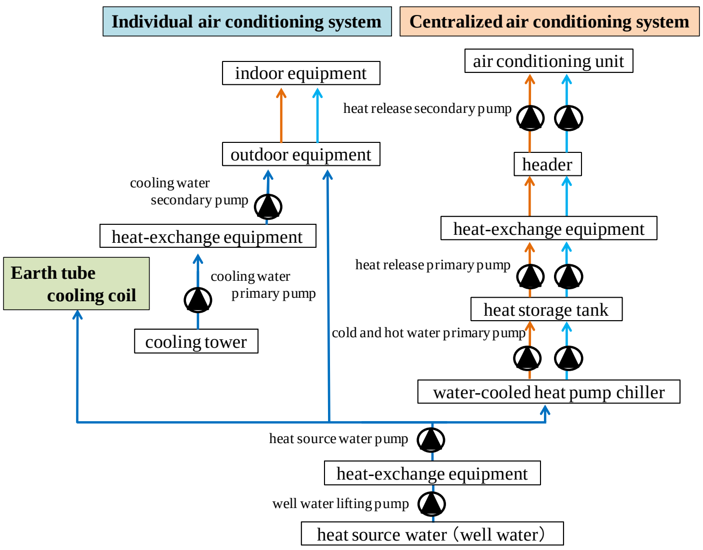

***Table 1**. Major equipment capabilities*

water-cooled heat pump chiller	inverter control cooling capacity : 348.5 kW electric power consumption : 56.4 kW heating capacity : 403.1 kW electric power consumption : 65.4 kW	×1
cold water primary pump	inverter control flow rate : 500 l/min electric power consumption : 2.2 kW	×1
hot water primary pump	inverter control flow rate : 580 l/min electric power consumption : 2.2 kW	×1
heat release primary pump	inverter control flow rate : 640 l/min electric power consumption : 3.7 kW	×2
heat release secondary pump	inverter control flow rate : 140 l/min electric power consumption : 2.2 kW	×6
well water lifting pump	constant flow flow rate : 500 l/min electric power consumption : 18.5 kW	×1
heat source water pump	inverter control flow rate : 250 l/min electric power consumption : 3.7 kW	×2
cooling water primary pump	inverter control flow rate : 1000 l/min electric power consumption : 5.5 kW	×2
cooling water secondary pump	inverter control flow rate : 480 l/min electric power consumption : 3.7 kW	×2
cooling tower	inverter control flow rate : 2000 l/min electric power consumption : 5.5 kW	×1
heat storage tank	volume : 124 m³ storage of heat : 5191 MJ	×2
outdoor equipment	cooling capacity : 916.2 kW heating capacity : 204.8 kW	integrated value

***Figure 1**. Heat source system diagram*

ENERGY CONSUMPTION CALCULATION METHODS

To calculate the energy consumption of the target building, the LCEM tool and MicroHASP/TES input data is used. Figure 2 shows the application range of the LCEM tool and the methods for calculating the energy consumption. Details concerning each calculation method are discussed below.

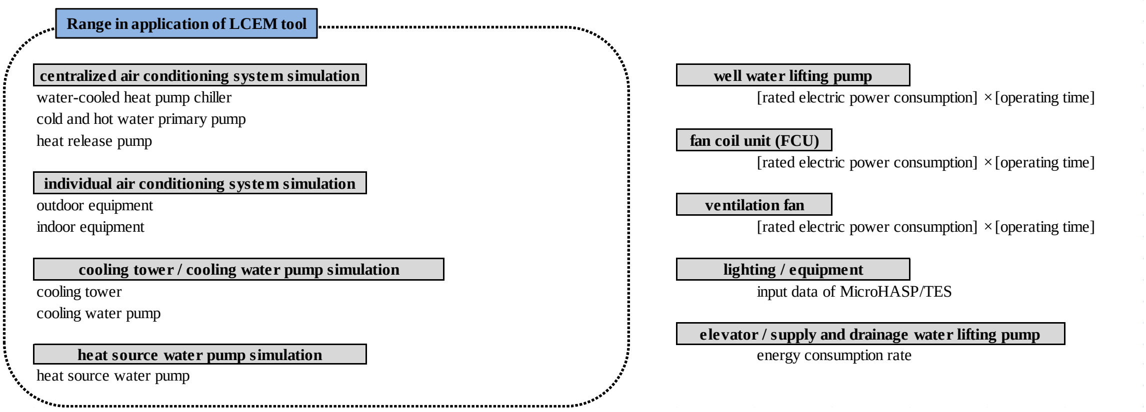

***Figure 2**. Application range of LCEM tool and calculation methods for energy consumption*

THERMAL LOAD CALCULATION BY MICROHASP/TES

The thermal load during a representative day in each month is calculated using MicroHASP/TES. The results are made available to the LCEM tool for use in the energy simulation. Figure 3 shows the thermal load for the centralized and individual air conditioning systems. In the MicroHASP/TES calculations, the fraction of time that the equipment is operating, referred to hereafter as the operation ratio, is taken into account. Figure 4 shows the hourly design values of the operation ratio for lighting and equipment in the office rooms, graduate students' rooms, teachers' rooms (served mainly by the centralized air conditioning system), and laboratories (served mainly by the individual air conditioning system). Figure 5 shows the monthly design values of the operation ratio for each room. The values in figures 4 and 5 are the realistic values verified in the commissioning process. Moreover, on the basis of a survey of actual conditions in the university, for the centralized and individual air conditioning systems, the true monthly operation ratios are 0.5 and 0.35 times the design values, respectively.

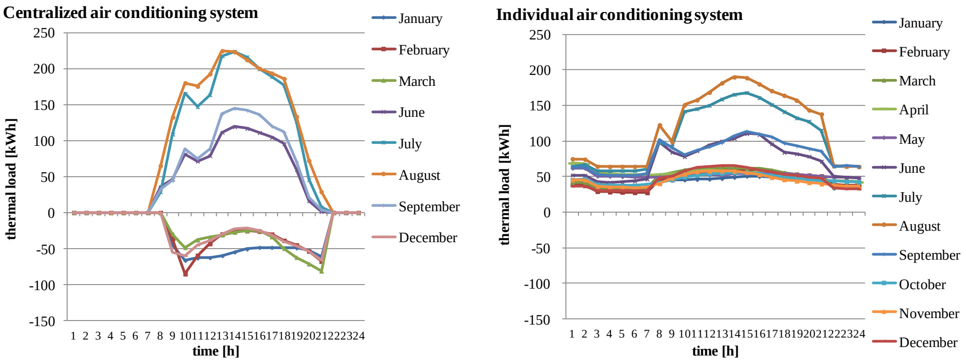

Figure 3. Cooling load (positive values) and heating load (negative values) on a representative day of each month for the centralized air conditioning system (left) and the individual air conditioning system (right)

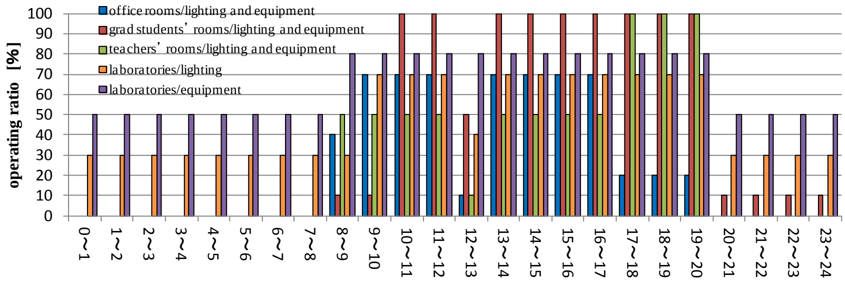

***Figure 4**. Design values of hourly operation ratio*

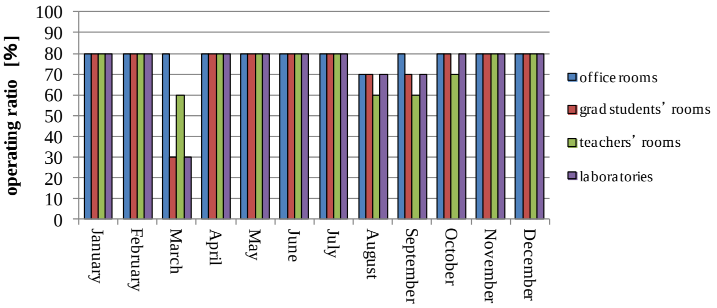

***Figure 5**. Design values of monthly operation ratio*

THE CENTRAL AIR CONDITIONING SYSTEM ENERGY CONSUMPTION

The energy consumption of the water-cooled heat pump chiller, the cold and hot water primary pump, and the heat release pump is calculated in the centralized air conditioning system simulation using the following conditions: the load factor of the heat source (water-cooled heat pump chiller) is 85% during the heat storage period, the heat source water temperature is 21°C, and a single heat storage tank (124 m^3) is used during the winter months of December to March. Figure 6 shows hourly values of the heat storage and the heat release for a day in August and February, and figure 7 shows the corresponding electric power consumption. Figure 8 shows the total primary energy consumption for each month, calculated using a conversion factor of 9.97 MJ/kWh (the same value in the after survey). Because August is the largest thermal load in a year, it can be seen that August is the largest primary energy consumption.

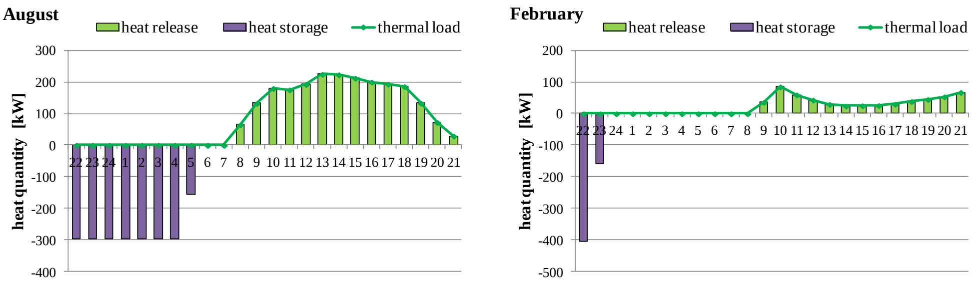

Figure 6*. Hourly values of the heat storage (negative axis) and the heat release (positive axis) for a day in August (left) and February (right)*

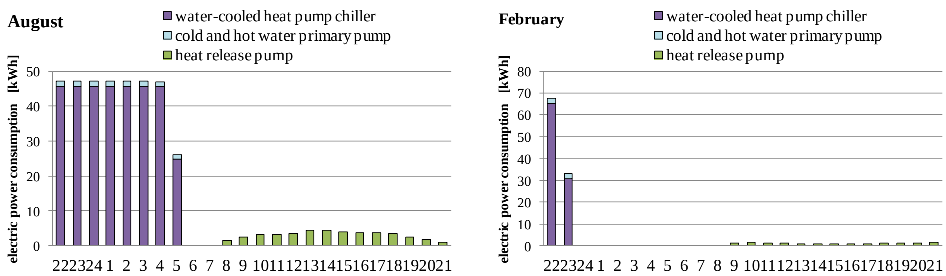

Figure 7*. Electric power consumption in August (left) and February (right)*

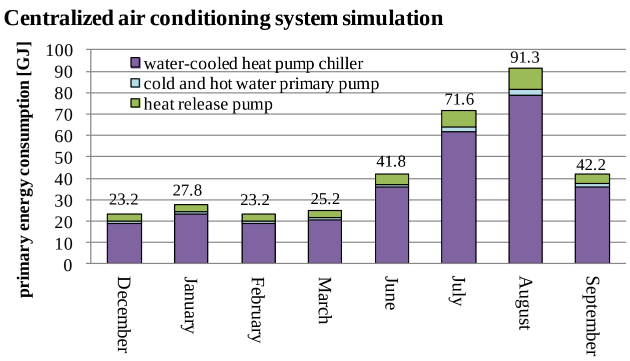

Figure 8*. Total primary energy consumption per month*

INDIVIDUAL AIR CONDITIONING SYSTEM ENERGY CONSUMPTION

The energy consumption of the outdoor equipment and the indoor equipment is calculated in the individual air conditioning system simulation. If the heat source water is not being used by the centralized air conditioning system, it is available for use by the individual air conditioning system. Because the amount of outdoor and indoor equipment exceeds the limitations of the LCEM tool, three separate simulation models are used. Because of the modularity of the LCEM tool, the simulations for the cooling tower and the cooling water pump can be performed separately from that for the individual air conditioning system. The boundary conditions for the cooling tower and the cooling water pump simulations are the total cooling water flow and the wet-bulb temperature. Figure 9 shows the total monthly primary energy consumption of the individual air conditioning system.

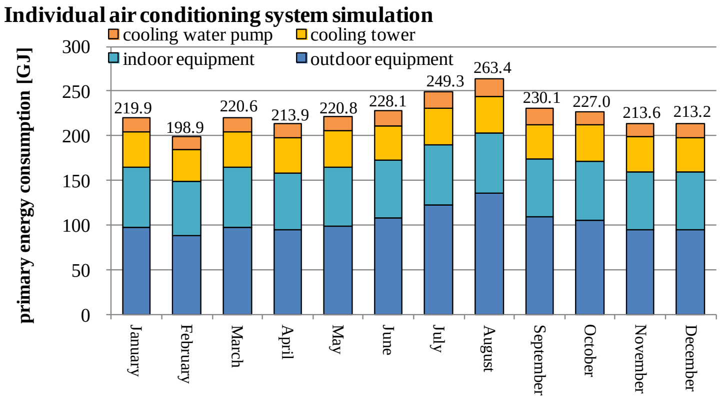

Figure 9. *Total monthly primary energy consumption of individual air conditioning system*

HEAT SOURCE WATER PUMP ENERGY CONSUMPTION

As mentioned above, the modularity of the LCEM tool allows the heat source water pump unit to be simulated separately. The boundary condition used is the heat source water flow. Figure 10 shows the monthly primary energy consumption of the heat source water pump.

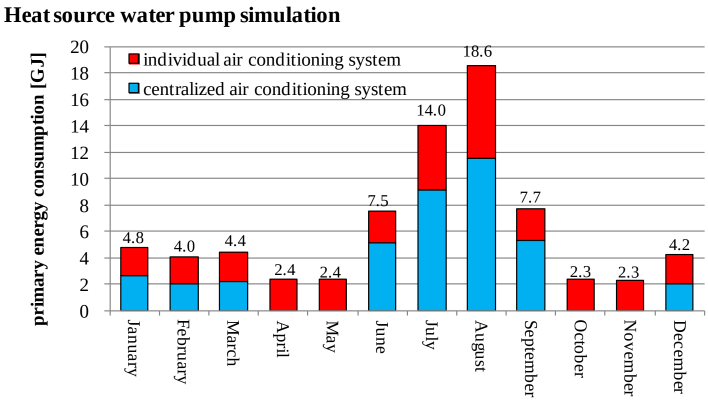

Figure 10. *Monthly primary energy consumption of heat source water pump*

ADDITIONAL ENERGY CONSUMPTION

The energy consumption of the well water lifting pump, the fan coil unit (FCU), and the ventilation fan is calculated by multiplying the operating time by the rated electric power consumption. The energy consumption of the elevator and the supply and drainage lifting pump is calculated from the energy consumption rate (elevator : 0.02 GJ/(m^2·a), supply and drainage lifting pump : 0.01 GJ/(m^2·a)). Figure 11 shows the annual primary energy consumption. Because the individual air conditioning system uses the well water for a longer time, the energy consumption of the well water lifting pump is larger than for the case of the centralized air conditioning system.

The energy consumption of the lighting and equipment is calculated based on the data input to MicroHASP/TES. The design value of the lighting electric power consumption rate is 5.0 Wh/m^2 in each system. The average design value of the equipment electric power consumption rate is 103.7 Wh/m^2 in the centralized air conditioning system, and 309.4 Wh/m^2 in the individual air conditioning system. Because the individual air conditioning system mainly serves the laboratories, the equipment electric power consumption rate is larger than for the centralized air conditioning system. Figure 12 shows the monthly primary energy consumption of the lighting and equipment.

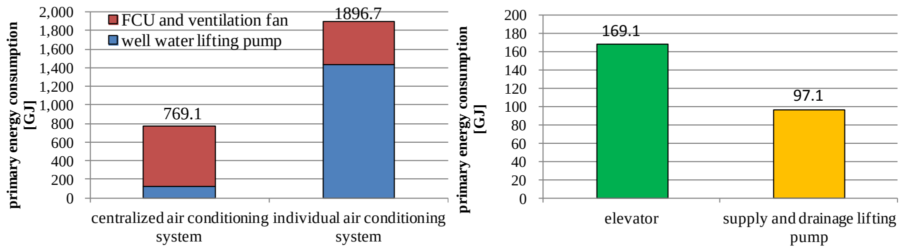

Figure 11*. Primary energy consumption (left : well water lifting pump and fan (FCU and ventilation) / right : elevator and supply and drainage lifting pump)*

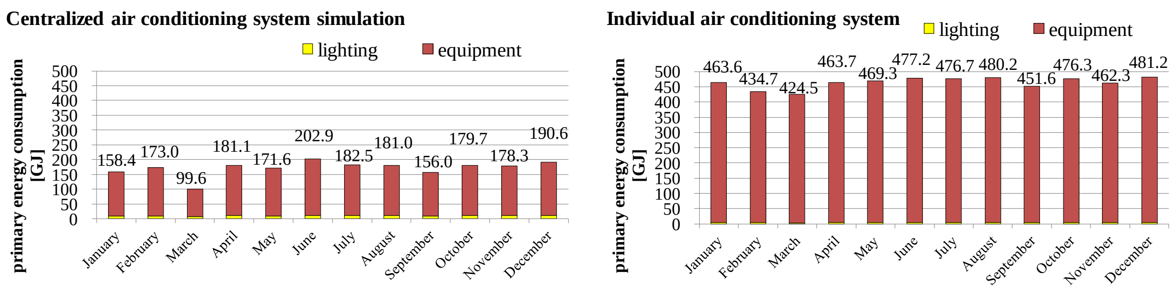

Figure 12*. Monthly primary energy consumption of lighting and equipment in centralized air conditioning system (left) and individual air conditioning system (right)*

ANNUAL ENERGY CONSUMPTION

Table 2 shows a breakdown of the total floor area in the target building and the rentable floor area ratio. The conversion total floor area is a value that is calculated based on the rentable floor area ratio. Figure 13 shows the annual primary energy consumption for each system and the entire building. For the centralized air conditioning system, it is 3210 GJ, which corresponds to a primary energy consumption rate of 729.0 MJ/(m^2·a), considering the conversion total floor area for the centralized air conditioning system. Since the primary energy consumption of other buildings in the university is about 1000 MJ/(m^2·a), this is a lower value. The primary energy consumption of the individual air conditioning system is 10191.5 GJ, which corresponds to a rate of 3855.0 MJ/(m^2·a), taking into account the conversion total floor area of the individual air conditioning system. The primary energy consumption of the entire building is 13667.8 GJ (including the elevator and the supply and drainage lifting pump), corresponding to a rate of 1.94 GJ/(m^2·a) based on the total floor area.

***Table 2**. Floor areas of the target building and rentable floor area ratio*

Centralized air conditioning floor area	Individual air conditioning floor area	Communal floor area	Total floor area	Rentable floor area ratio	Conversion total floor area (centralized air conditioning)	Conversion total floor area (individual air conditioning)
3192.8m^2	1917.0m^2	1937.1m^2	7046.9m^2	0.73	4403.2m^2	2643.7m^2

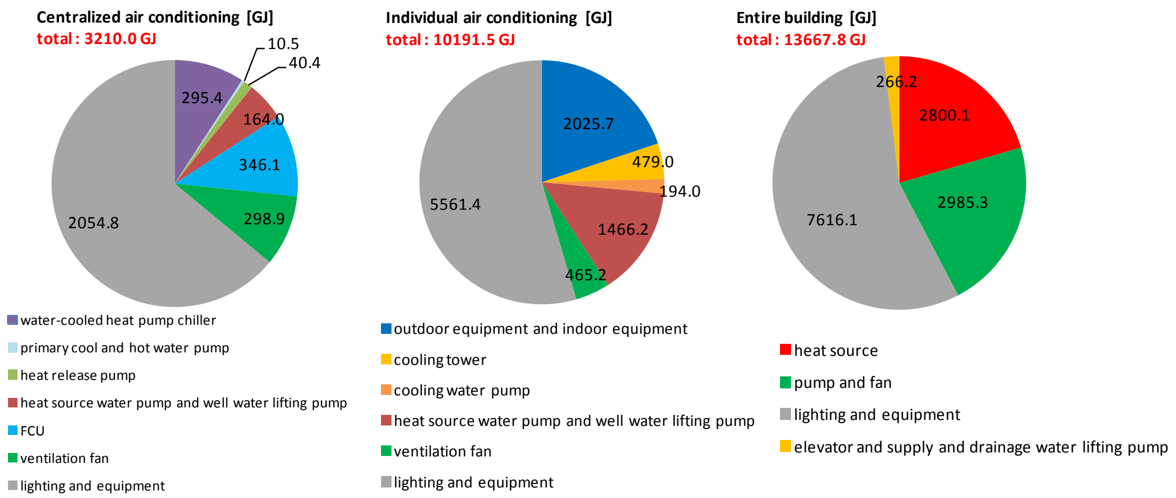

***Figure 13**. Annual primary energy consumption of centralized air conditioning system (left), individual air conditioning system (middle), and entire building (right)*

CONCLUSION

In this study, the energy consumption of the target building is evaluated using the LCEM tool. The primary energy consumption of the entire building is found to be 13667.8 GJ, corresponding to a rate of 1.94 GJ/(m^2·a). This result nearly achieves the required performance value as determined by the OPR, that is 1.86 GJ/(m^2·a). However, further performance improvements are still required aftertime.

Moreover, using the proposed simulation model during design phase that is made in this study, it is possible to make appropriate equipment choices during the construction phase and to achieve operation improvement during the operation phase. Thereby, appropriate energy management for the life cycle of the building can be achieved.

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