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Commissioning of Energy Consumption and performance of Heat Source of Eco-Campus in Urban Area

Maho Hasegawa[#1], Masaya Okumiya[*2],

[#]Nagoya University
Furo-cho,Chikusa-ku,Nagoya 464-8601,Japan

[1]hasegawa.maho1109@outlook.jp

[2]okumiya@davinci.nuac.nagoya-u.ac.jp

Abstract

New Campus of University introduces various advanced technologies to offer comfortable learning field and achieve a low carbon campus. This campus consists of the Lecture hall wing, the High-rise building wing, Library wing, and the Restaurant and Cafe wing.

All wings have cool and heat pits to reduce outside air load. Central heat source system supply chilled / hot water to the Lecture hall and the High-rise building. The others have individual air conditioning system. The central heat source system introduces cogeneration and consists of two waste heat input type absorption water cooling and heating machines and three air source heat pumps, making efficient use of waste heat and purposing the best mix between gas and electricity according to the heat load.

As a result of first year operation, 1,200tCO_2 of CO_2 emission of whole campus is lower than design requirement of 1,449tCO_2 which is 69% of reference facilities. So it can be said that low carbon campus is realized. Aiming to further improvement, the plan to improve the operation of heat source is proposed according to the analysis of performance of heat source in summer. Then the validity of the plan is evaluated by using system simulation.

Keywords –commissioning; heat source system; system simulation

1. The outline of a campus

A campus consists of 4wings, the Lecture hall wing, the High-rise building wing, Library wing, and the Restaurant and Café wing. The outline of the sites is indicated in Table 1. Outline of the campus is shown in Figure 1. All wings have cool and heat pits to reduce outside air load. Central heat source system supply chilled / hot water to the Lecture hall and the High-rise building. The others have individual air conditioning system. And the others have individual air conditioning system.

Table 1 Outline of the sites

Area		Height		Structure
Site erea	23,000㎡	Stories	10F	Reinfoorced concrete structure
Total floor area	33,132㎡	Building heighit	44m	Concrete structure
Bulding area	9164㎡			

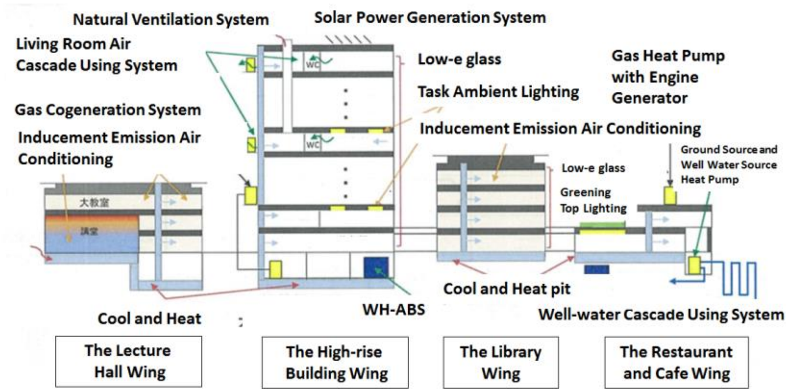


Fig 1 Outline of the campus

2. Energy consumption of the whole campus and CO_2 emission

2.1 Energy consumption of the whole campus

Figure 2 shows the monthly electric power consumption of this campus. As Figure 2 shows, the electric power consumption of July, December and January is much larger than that of other month. It is caused by the amount of electric power consumption for air conditioning of the High-rise building wing in particular. In contrast, the power consumption for lighting and plug are mostly stable during a year

Figure 3 shows the monthly gas consumption of this campus. As Figure 3 shows, the gas consumption of June, July, December January and February is much larger than other month. It is caused by the amount of gas consumption of absorption water cooling and heating machine (RH1-1, RH1-2), gas engine heat pump (GHP) and cogeneration system. Figure 4 shows the ratio of electric consumption of each use from April, 2014 to March, 2015. Figure 5 shows the ratio of gas consumption of each use during the same period. Most part of the power consumption consists of air conditioning (40%) and lighting, plug (34%). Most part of the gas consumption consists of GHP (45%), absorption water cooling and heating machine (26%) and cogeneration system (17%).

2.2 CO_2 emission of the whole campus

Figure 6 shows the monthly CO_2 emission of the campus. As a result of first year operation, 1,201t-CO_2 of CO_2 emission of whole campus is lower than design requirement of 1,449t-CO_2 which is 69% of reference facilities (2,092t-CO_2). In the figure, solid line shows the monthly accumulated CO_2 emission. It can be said that low carbon campus is realized.

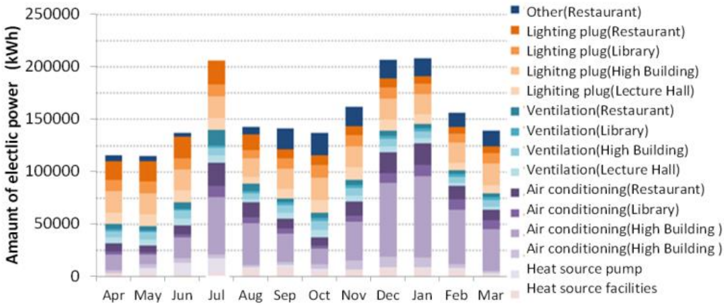


Fig 2 Monthly electric power consumption

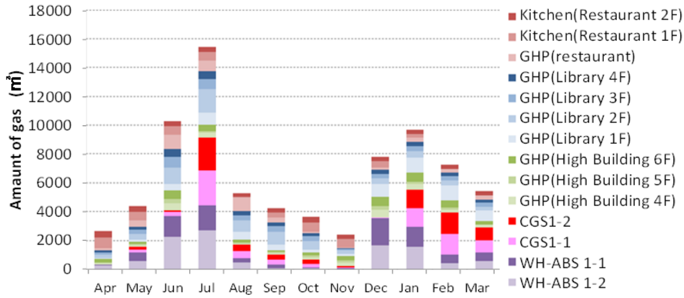
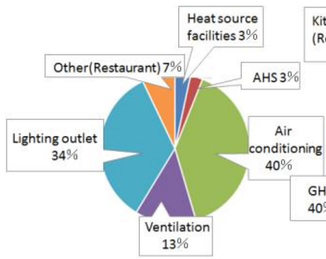


Fig 3 Monthly gas consumption



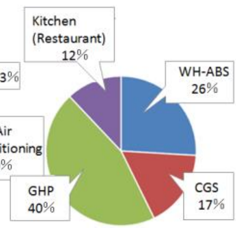


Fig 4 Raito of each use of power

Fig 5 Raito of each use of gas

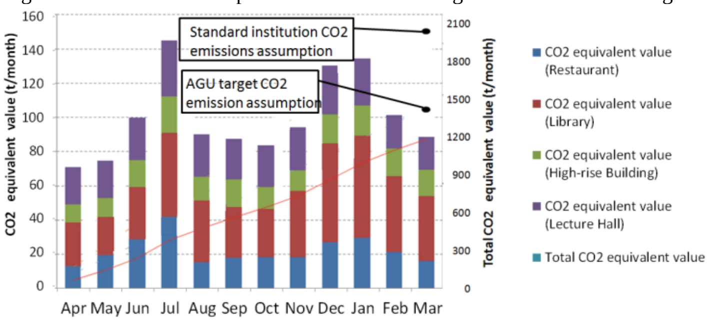


Fig 6 Monthly CO_2 emission

3. Cool and heat pit

The outdoor air load reduction effect of the cool/heat pit of the Lecture hall wing, the High-rise building wing, the Library wing and the Restaurant wing is shown in figure 6 to 9. Cooling effect in summer is evaluated using measurement data in July-September. In addition heating effect in winter season is evaluated using measurement data in November- December.

Temperature of outside air and outlet of cool/heat pit is shown in figures. The value of the vertical axis is equal to a transverse on the diagonal line. When plotted points are below the diagonal, the air is cooled. When plotted points are above the diagonal, the air is heated.

In addition the comparison between absolute humidity of the outside air and that of the air after passing through the pit is also carried out in the summer. Such a comparison is performed to inspect whether condensation does not occur in the pit. When there are points below a diagonal, absolute humidity of the air after passing the cool/heat pit is lower than that of outside air, and it means that condensation occurs in a pit.

In particular, at the beginning of the summer season, high-humidity air is introduced to the pit cooled in winter, so condensation occurs easily. But condensation does not occur because this system worked properly.

3.1 Outdoor air load reduction effect in summer (cooling effect)

While the temperature of outside air introduced into a pit of the Lecture hall wing, the High-rise building wing and the Library wing is within 22 ℃- 35 ℃, the air temperature after passage is within 23 ℃- 27 ℃. So, considerable cooling effect is proved. It's cooled at least to around 27 ℃ in spite of the condition of the outside air. It is said that almost all sensible heat load of outside air is processed. Enough cooling effect is also seen in the Restaurant and Café wing, but its effect is slightly less than three wings.

3.2 Outdoor air load reduction effect in winter (heating effect)

Pit also achieves a considerable effect in the winter season. Even if the outside temperature is around 0 ℃ in particular, the air temperature after passage is within 12 ℃- 15 ℃. So the reduction effect is obvious.

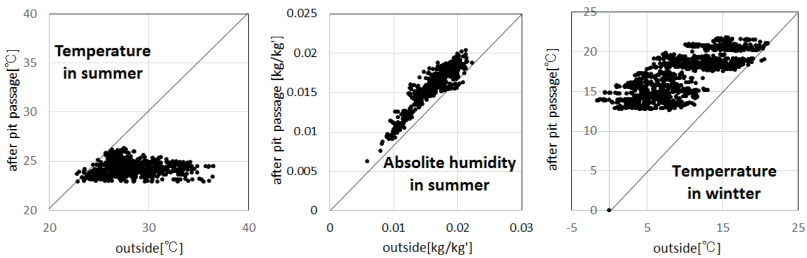


Fig 6 the High-rise Building wing (temperature/absolute humidity)

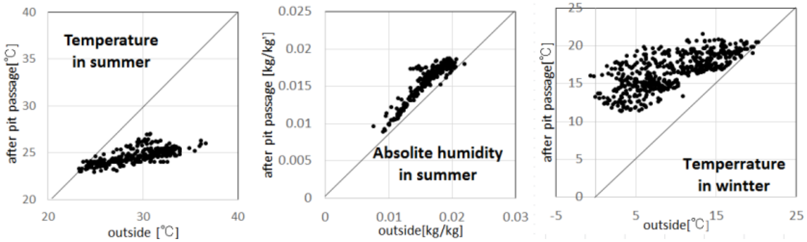


Fig 7 the Lecture Hall wing (temperature/absolute humidity)

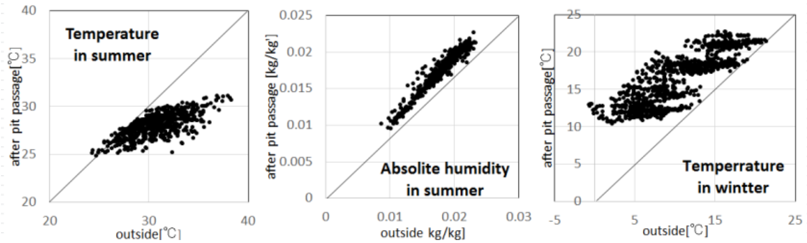


Fig 8 the Restaurant wing (temperature/absolute humidity)

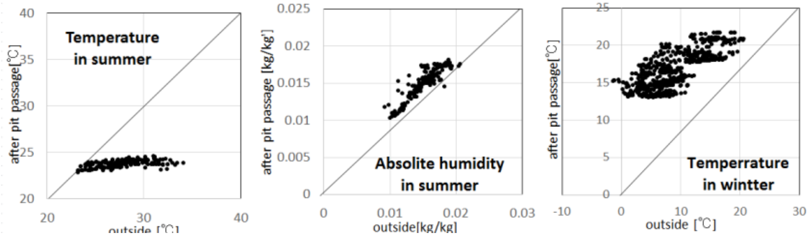


Fig 9 the Library wing (temperature/absolute humidity)

4. Performance analyis of heat source system in summer

4.1 Outline of the central heat source system

This system consists of two waste heat input type absorption water cooling and heating machines(WH-ABS, hereafter) and three air source heat pumps（ASH, hereafter), making efficient use of waste heat and purposing the best mix between gas and electricity according to the heat load. Table 2 shows specification of equipment drawings and Figure 10 shows diagram of the heat source system.

Table 2 Equipment specification

	absorption cooling and heating machine	air heat source heat pump	cogeneration generator
cooling capacity	528kW(20℃→10℃)	164kW(20℃→10℃)	
heating capacity	350kW(38℃→45℃)	150kW(38℃→45℃)	
fuel consumption	25.9N㎥/h		8.96N㎥/h
voltage source capacity	8.6kVA	47.1kW	0.98kW
overall efficiency			85%
power output			35kW
exhaust heat recovery amount			51.5kW

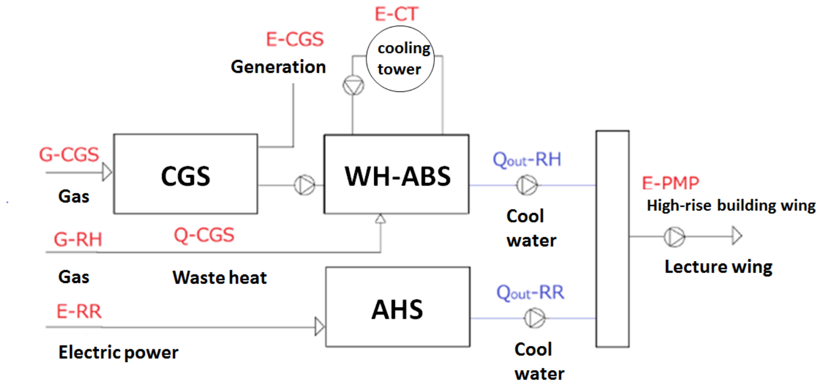


Fig 10 Heat source system diagram

4.2 Operation in summer

The performance in summer operation is analyzed using measurement data from July 1 to October 31, 2014. There are WH-ABS priority operation mode (ABS mode) and AHS priority operation mode (AHS mode). Number of machine operated is determined according to the heat load and the temperature of return/supply water as shown in figure11.

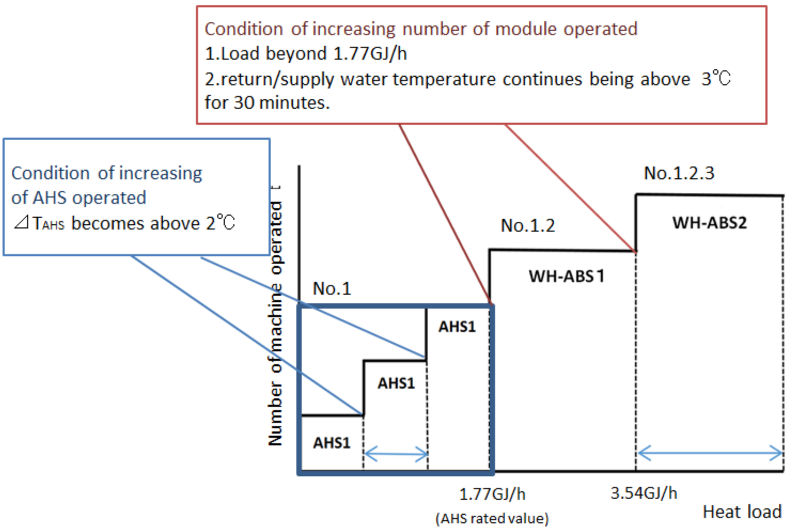


Fig 11 Condition of increasing number of machine operated

4.3 Analysis of the results

4.3.1 Performance analysis of AHS

Figure 12 shows the correlation of the COP and the load factor of the AHS. Points in figure are classified by color according to four temperature range of cooling water. Above 25℃ of cooling water, it showed good agreement with the part load performance submitted by the manufacturer in which COP reaches the highest value at the load factor of 0.5 to 0.7 and considerably decrease at load factor below 0.3. According to the analysis of measurement data it was found that the frequency of AHS operate at load factor below 0.3 is approximately 50%. It is necessary that operation of AHS is shifted to high load factor.

4.3.2 Performance analysis of WH-ABS

In the summer operation of WH-ABS, COP is stable with around rated value of 1.76 as far as load factor is more than 0.2. On the other hand, ON-OFF of WH-ABS becomes frequent in the extremely small load to be often seen in October and the COP considerably decreases. Figure 13 shows the correlation of the COP and the load factor of WH-ABS.

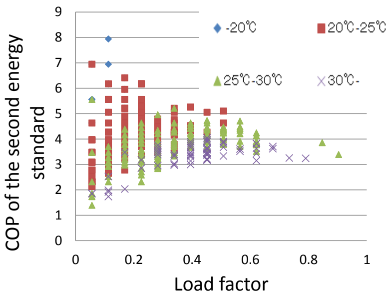


Fig 12
The correlation of the COP and the load factor of the AHS

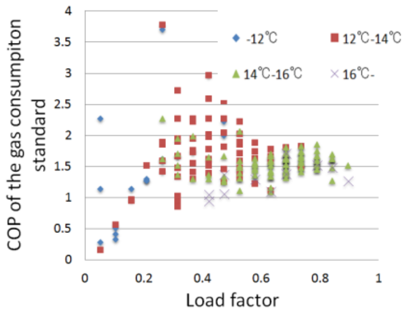


Fig 13
The correlation of the COP and the load factor of WH-ABS

4.3.3 Performance analysis of the whole heat source system

Figure14 shows the correlation of COP and load factor of the heat source system. In spite of the load factor, COP of AHS mode is bigger than that of ABS mode. COP changes in ABS mode in 0.2-1.0, and COP increases in proportion to the load factor. In AHS mode COP is 1.0 to 2.0 at the time of operation of high load factor. However for the low load operation COP decreased. A calculation method of COP of heat source system is indicated in (1) (2).

$$\mathrm{COP}=\frac{(Q_{outRH1-1}+Q_{outRH1-2}+Q_{outRR})\times 1000}{\sum E} \tag{1}$$

$$\sum E = G_{CGS.E} + E_{CGS.E} + E_{ex.E} + G_{RH.E} + E_{RH.E} + E_{CT.E} + E_{CP.E} + E_{RR.E} + E_{HP.E} \tag{2}$$

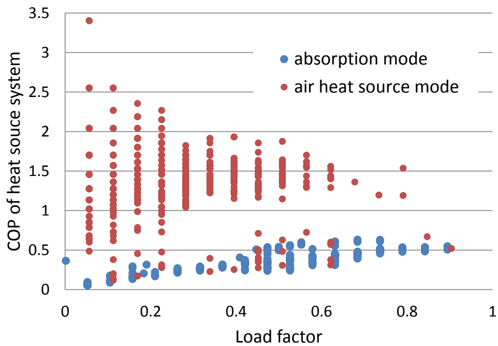


Fig 14 The correlation of COP and load factor of the heat source system

Nomenclature

$E_{CGS.E}$	CGS power consumption primary energy equivalent value	(MJ)
$E_{CT.E}$	Cooling tower power consumption primary equivalent value	(MJ)
$E_{CP.E}$	Cooling water pump power consumption primary equivalent value	(MJ)
$E_{ex.E}$	Exhaust heat recovery system power consumption primary equivalent value	(MJ)
$E_{HP.E}$	AHS power consumption primary equivalent value	(MJ)
$G_{RH.E}$	WH-ABS power consumption primary equivalent value	(MJ)
$G_{CGS.E}$	CGS gas consumption primary equivalent value	(MJ)
$Q_{outRH1-1}$	RH1-1 heat quantity integration	(GJ)
$Q_{outRH1-2}$	RH1-2 heat quantity integration	(GJ)
Q_{outRR}	AHS power consumption primary equivalent value	(GJ)

Primary energy equivalent value: 1kW=9.8MJ Lower heating value 41.65MJ/N m^3
Higher heating value 46.05MJ/N m^3

5. Operation improvement plan

As described in 4.3.1 the frequency of AHS operate at load factor below 0.3 is approximately 50%. A number of AHS in operation is controlled by temperature difference between supply and return water of AHS($\triangle T_{AHS}$). $\triangle T_{AHS}$ was set at 2℃ and it is much smaller than design temperature difference of AHS. Small $\triangle T_{AHS}$ results in operation at low load factor. This is to avoid stop of AHS as soon as WH-ABS started operation because of sudden increase of flowrate in heat source side. Following three measures to improve operation of heat source equipment based on the point mentioned above are proposed.

(1) Select the preferred machine according to the load

It is expected that WH-ABS is set as priority machine when load beyond 1.77GJ/h which is total capacity of AHS. Also it is expected that AHS is set as priority machine when load below 1.77GJ/h. In the latter case WH-ABS does not operate then $\triangle T_{AHS}$ can be set at wider value. In addition, this plan can solve the problem that WH-ABS repeats ON-OFF and cool/warm water temperature is not stable in the case of extremely small heat load.

(2)Reduce the flowrate of WH-ABS

Flowrate of WH-ABS is reduced to maintain temperature difference of heat source side when it starts operation. If flow is adjusted to obtain proper temperature difference, the pump power can also be reduced.

(3)Unity parameters for control of the number of operated heat source in heat load

Increase step is also complicated because the conditions of the increase step control are 2 elements of the heat load and the temperature difference. Unity of parameters results in avoiding conflict between parameters.

6. Examination of measures to improve the operation of heat source equipment

By simulation, a utility of the operational improvement measure is examined. In this paper firstly the plan (1) is examined because it costs least. The life cycle management tool (LCEM tool) that developed under super vision of Ministry of Land, Infrastructure and Transport and Tourism is used for simulation. The LCEM tool is software reproducing energy performance properties of the air conditioning facility.

7. Simulation conditions

Cooling load was below 1.77GJ/h for a month in September 2014. Then simulation was conducted for this month. $\triangle T_{AHS}$ to control number of heat source in operation is set to 2 ℃ and 10 ℃. $\triangle T_{AHS}$ of 10 ℃ is improvement measure.

8. Simulation result

Figure 15 shows output of each AHS and figure 16 shows correlation of COP and load factor. Measured value and calculation results for ⊿T_{AHS} of 2℃ and 10℃ are shown from the left to right in each figure. Each simulation value and actual measured value is compared. Figure14 shows state of increase or decrease control of number of AHS in operation for standard daily load. By comparison between measured value and result for ⊿T_{AHS} of 2℃ it can be said that good reproducibility was obtained. By making ⊿T_{AHS} large, number of AHS in operation decrease and output of each AHS increase as shown in figure 15. Therefore load factor of each AHS also increase and it results in improvement of COP as shown in figure 15.

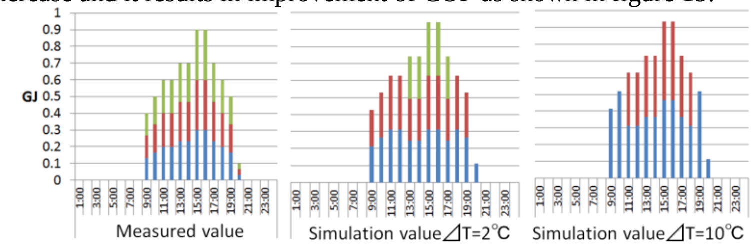


Fig15 number of AHS in operation decrease and output of each AHS increase (left: actual value middle: the current state simulation right: the improvement simulation)

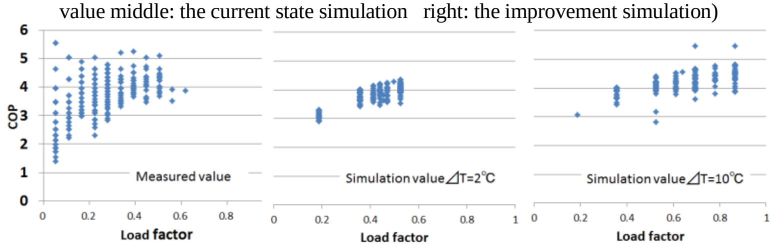


Fig16 correlation of COP and load factor of AHS
(left: actual value middle: the current state simulation right: the improvement simulation)

9. Summary and future's schedule

In this paper, new Campus of University which brings in various advanced technologies to offer comfortable learning field and achieve a low carbon campus was introduced. Energy consumption and CO_2 emission of whole campus and performance of central heat source system for one year after beginning of operation were presented. CO_2 emission is much lower than the requirement in design phase. Also several kinds of measure for improving performance were offered and one of them was examined by using system simulation. The rest of them will be examined also by using simulation. The measure of which effectiveness is improved will be applied to real operation in near future and confirmed.