Life Cycle Energy Management of The City Hospital

- Examination of Energy Performance of Heat Source System in First Year of Practical Use and reproducibility of heat source by LCEM-

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ABSTRACT

Nowadays, the energy consumption of commercial/residential sector in Japan tends to increase, so we must consider the countermeasure for energy saving as soon as possible. One of the way reducing the energy consumption of the building is "Energy Management".

Energy consumption of heat source of HVAC and DHW system is large part of the energy consumption of entire building. For energy saving, performance of these system should be examined on each stage throughout the building's life by consistent Energy Management. Hospital consumes a lot of energy as compared to the building of other use. Therefore, it is considered that energy-saving effect by applying an appropriate energy management becomes large.

In this study energy performance of heat source system in city hospital is examined. The hospital examined in this study began operation in May 2015. In this paper, the energy consumption of the entire hospital and the heat source system and the COP (Coefficient of Performance) of the heat source system were examined.

The results of examination mentioned above showed that the heat source was worked properly. However several problems of operation were also extracted. Measure of improvements were proposed for the extracted problems. Then the validity of these improvement were verified by the system simulation and it will be reflected in the operation of the next fiscal year. For system simulation, the reproducibility of the behavior and energy performance was confirmed in this paper.

KEYWORDS

Energy Management, LCEM tool, Hospital ,Commissioning

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INTRODUCTION

In Japan, the energy consumption of commercial/residential sector has been increasing, so it is essential to reduce the energy consumption of this sector. "Life Cycle Energy Management" which is one of the way reducing the energy consumption is able to verify the energy performance on each stage of the building. Also, the hospital facility which is objected building in this paper consumes more energy compared to other buildings and which has is a large hot-water supply demand. So it is very important for a hospital facility to reduce energy by utilizing the advantages of Co-generation System(CGS).

The final purposes of this study are to examine energy performance of heat source system in a city-run hospital by analyzing BEMS data, to consider the best operation of heat source by system simulation, and to validate the energy saving performance. First, this paper shows the primary energy consumption of the whole hospital in first year of practical use and result of performance analysis of each heat source. Then the reproducibility of the behavior and energy performance of the heat source by system simulation is confirmed.

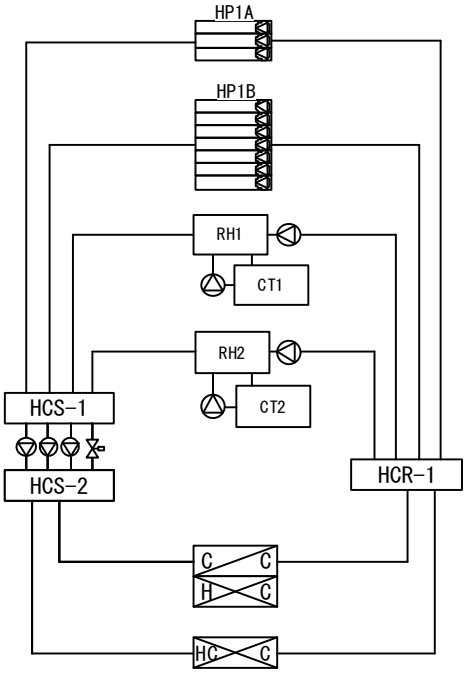


Figure 1. *Heat source system(cooling)*

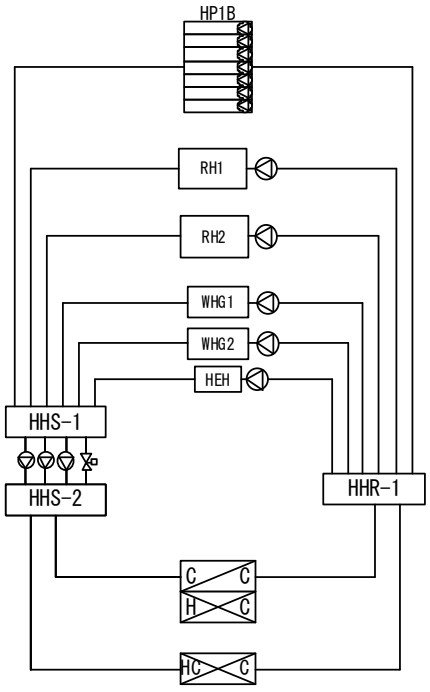


Figure 2. *Heat source system (heating)*

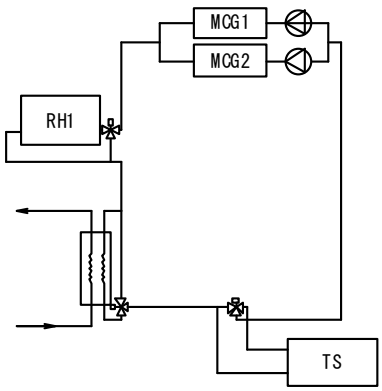


Figure 3. *Exhaust heat system from generator (CGS)*

Table 1. *Operation order of heat source*

		0rder	①	②	③	④	⑤	⑥
summer	chilled water	May~August	RH-1	RH-2	HP-1A	HP-1B		
		September~	RH-1	HP-1A	HP-1B	RH-2		
	hot water	May	HEH	HP-1B	WHG-1	WHG-2		
		June~	HEH	WHG-1	WHG-2			
winter	chilled water		HP-1A					
	hot water	November~	HEH	RH-1	RH-2	WHG-1	WHG-2	
		December~	HEH	HP-1B	RH-1	RH-2	WHG-1	WHG-2

*remarks

RH-1… absorption chiller driven by waste heat-1 RH-2… absorption chiller-2

HP-1A… air source heat pump chiller 1A (only chilled water) HP-1B… air source heat pump chiller 1B

HEH… waste heat exchanger WHG1,2… water heater for heaing

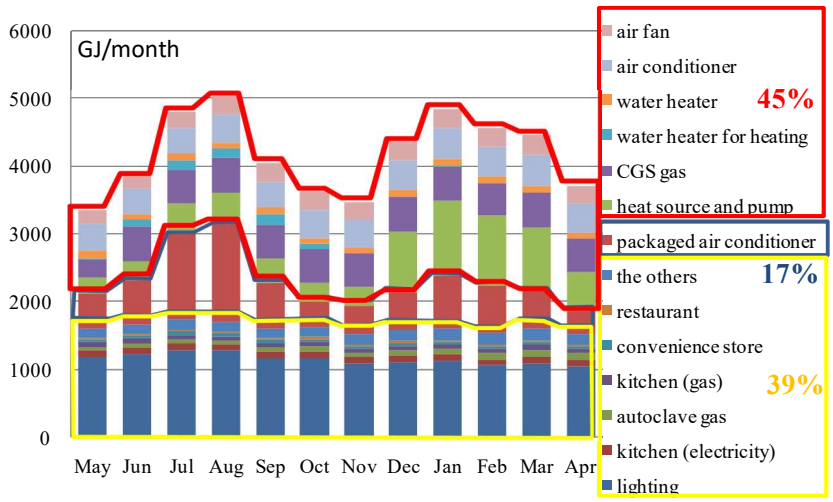
BUILDING AND SYSTEM DESCRIPTION

The study building is located in Aichi Prefecture, Japan, and began to operate in May 2015. And the building has about 20,000m^2 total floor area with 7-story on the ground, the about 250 beds for a hospital room. Figure1,2 shows the heat source system for cooling and heating. In this system, both electrical and gas heat source equipment are introduced for Business Continuity Plan(BCP) of emergency. Figure3 shows the way of the waste heat from generator, and this also plays a role as emergency generator. Additionally hot-water supply system using solar heat is applied for use of natural energy. Air-conditioning(cooling/heating) started the operation in May 2015 and a changeover from cooling to heating was in November. Table1 shows the operation order of heat source. In summer, hot water is consumed as a reheat of cooled air after dehumidification. Hot and chilled water produced by central heat source are consumed mainly by outdoor air handling unit at the secondary side, while indoor loads are treated by the individual air conditioning. In this paper, the annual primary energy consumption of the hospital as object was examined because just a year passed from opening. Also, the performance of each heat source was assessed by coefficient of performance (COP) in August and December as a representative month of summer and winter season. Then annual performance was evaluated by system COP.

RESULT OF ACTUAL ANALYSIS

Primary energy consumption of whole hospital

Figure4 shows the annual primary energy consumption of whole hospital from May, 2015 to April, 2016. It was total 50,089 GJ/year and 2,249 MJ/m^2・year. In figure4, the energy consumption from "lighting" to "the others" is almost constant throughout the year and the share of energy consumption was 39%. While "packaged air conditioner" and items related central heat source from "heat source and pump" to "air-fan" changed each month. The energy consumption of "packaged air conditioner" which was 17% in the whole energy consumption was high in July and August. The energy consumption related central heat source was large in July and August (summer season) and from December to March (winter season). Also it's estimated that energy consumptions of the central heat source were large in winter since outdoor air load is large due to the large temperature difference between indoor and outdoor. The share of energy consumption related central heat source was 45% throughout the year.



※ the surrounded part in red: the energy consumption related central heat source

Figure 4. *Annual primary energy consumption in the whole hospital*

Performance of heat source

Figure5 shows the COP of absorption machine based on the primary energy. The COP of absorption chiller RH1,2 are calculated by energy output divided by energy consumption in the daily total. Rating COP of RH1 which is the first priority heat source for the operation of cooling is 1.64, however measured COP was 1.35-1.5. It was reason why the exhaust heat input to RH1 about 80% of rating quantities and operation hours of generator were 20hours per day. The rating COP of RH2 was 1.21 but actually was around 1.1. This was estimated to contribute to operate in low load factors because RH2 is the second priority heat source.

Figure6 shows the COP of air source heat pump chiller, HP1B. COP1(blue line) is calculated based on the primary energy and COP2(red line) is based on the secondary energy. Figure7 shows the relation of Load Factor with COP about RH1,RH2 and HP1B. The measured COP of HP1B in December was around 2.0 which was higher than 1.4 of the rating COP because it was estimated that operation hours were very enough because of the priority heat source.

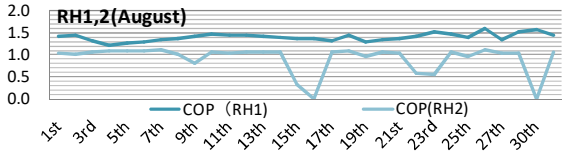


Figure 5. *COP of RH1 and RH2*

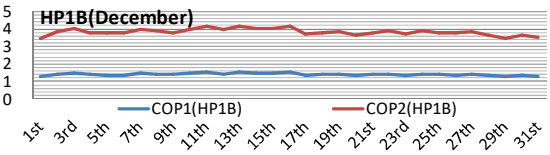


Figure 6. *COP of HP1B*

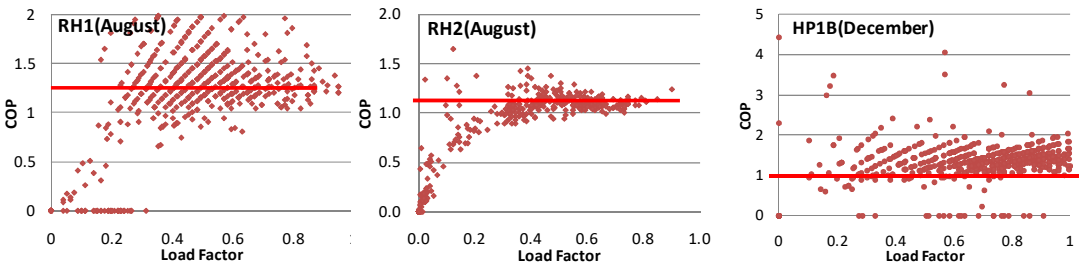


Figure 7. *Load factor-COP (RH1 / RH2 / HP1B)*

System COP

Figure8 shows the annual system COP. It is estimated that system COP will be improved up to about 1.1 if COP of heat source is 1.3 and water transfer factor (WTF) is 11 based on the primary energy. The system COP of summer season was a little lower compared with that of winter season, so it is necessary to improve system COP of summer season by taking another look at the control of primary pump and cooling tower of RH1, 2. Moreover, the system COP in a low load season will be improved by reconsidering control of the secondary pump.

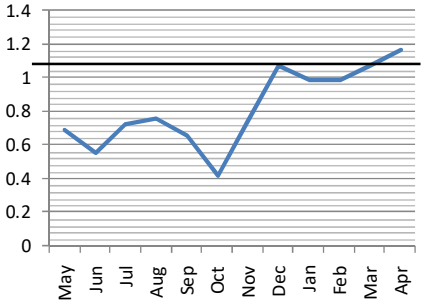


Figure 8. *System COP*

Conclusion of analysis on actual performance

The annual primary energy consumption of the study hospital which began to open in May 2015 was 50,089GJ/year and the share of the energy consumption related central heat source was 45% in the whole energy. Also, the produced energy from heat source side was almost equal to the consumed energy at air conditioner side, so the system worked property. About performance of each heat source, when there were enough load to treat, each heat source (absorption machine RH1,2 in summer and air source heat pump chiller HP1B in winter) operated at almost equal to rating COP. However when there was not enough load (ex. spring or autumn season), it's necessary to examine the control of system to improve the energy performance in the future.

RESULT OF SIMULATION

A problem in practical use was extracted by an analysis of actual measurement data until the previous chapter. When considering an approach of these problems, it is effective to utilize a system simulation. Therefore the precision (reproducibility) of simulation is examined as the first step to utilize simulation.

Overview of the system model

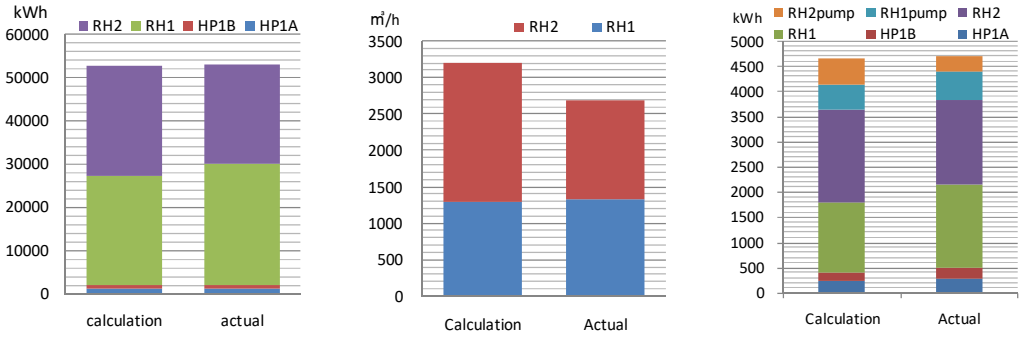
Performance of heat source system was simulated by using the free software of "LCEM tool" which is developed under supervision of Government Building Department, the Ministry of Land, Infrastructure, Transport and Tourism.

A representative week of August and December were chosen as cooling and heating period for simulation. As a boundary condition data, it is necessary to set data on the outside air temperature and humidity, cooling/heating load, and the return temperature from the secondary side. Heat extracted by domestic hot water tank from waste heat circuit of CGS is also given as a boundary condition. Furthermore, operation of each heat source was matched with the actual operating.

Result of simulation during a representative week in August

Figure 9 shows produced heat (same as cooling load which is boundary condition) and energy consumption in summer.

About gas consumption, the calculation result of RH1 almost agreed with actual value. The gas consumption of RH2 was larger in simulations, because it calculated in many hours at lower COP than actual. About electric consumption the calculation result agreed with the actual data.



(a) produced heat *(b) gas consumption* *(c) electric consumption*

Figure 9. *Produced heat amount and energy consumption of heat source (August)*

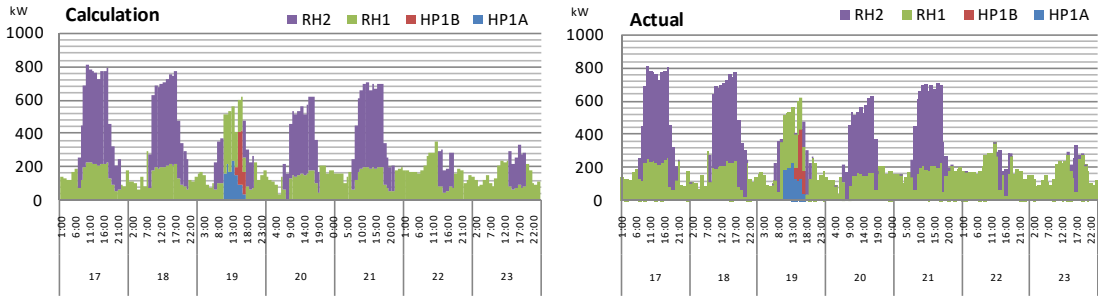


Figure 10. *Produced heat amount per day (Calculation / Actual)*

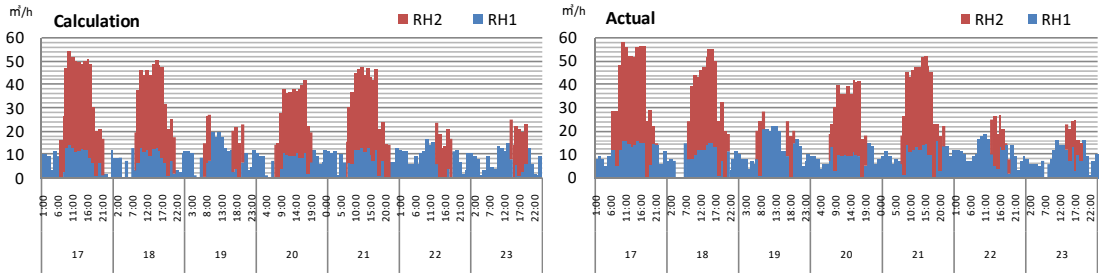


Figure 11. *Gas energy per day (Calculation / Actual)*

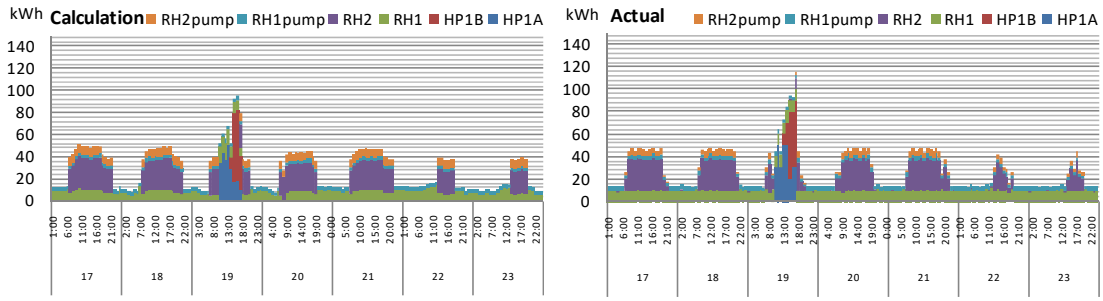
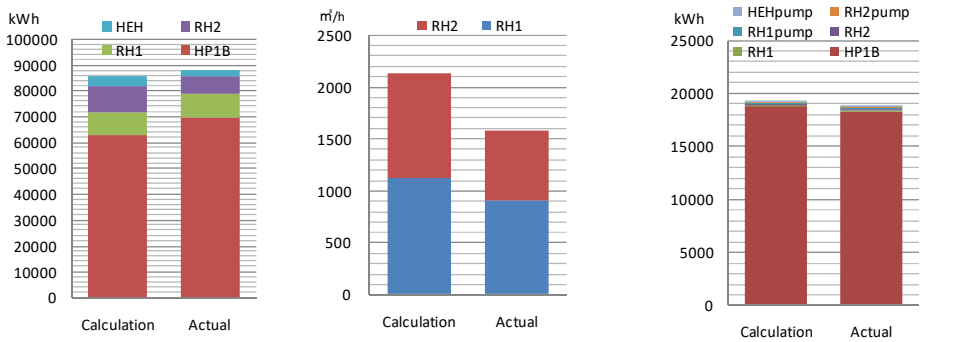


Figure 12. *Electric energy per day (Calculation / Actual)*

Result of simulation during a representative week in December

In heating mode, the first priority heat source was "HEH" and the second was "HP1B" for air-conditioning system. During a representative week (from 17th to 23th), total produced heat amounts of calculation and actual data were almost similar but distribution of heat amount treated by each heat source was different between actual and calculation. In calculation, each heat source treated load at the ratio of nominal flow rate. However, in actual operation, flow rate of each heat source was different from nominal value. Therefore the allotment percentage of the load of each heat source was different from actual operation in calculation. According figure13, about RH1 the produced heat amount of the calculation data was less than actual, but the gas energy was a little lager. It is due to the relation of COP and load factor as shown in figure 17. In the actual data, COP was higher than that of the calculation. About RH2 the gas consumption of the calculation data was high of 152% because its produced heat amount was high of 152%.



(a) produced heat *(b) gas consumption* *(c) electric consumption*

Figure 13. *Produced heat amount /gas energy / electric energy(17th~23th December)*

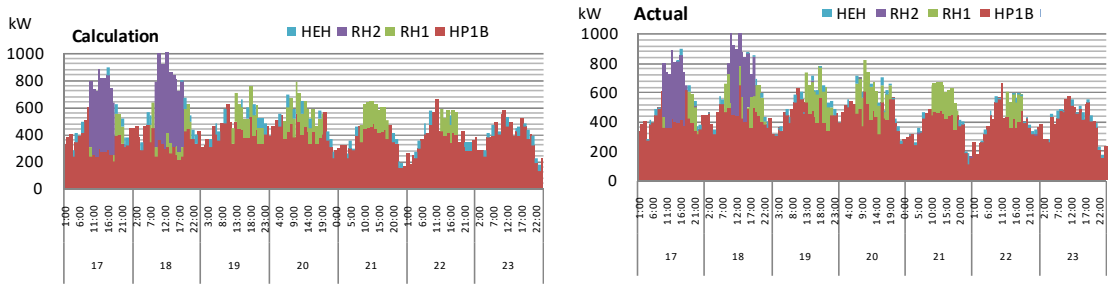


Figure 14. *Produced heat amount per day (Calculation / Actual)*

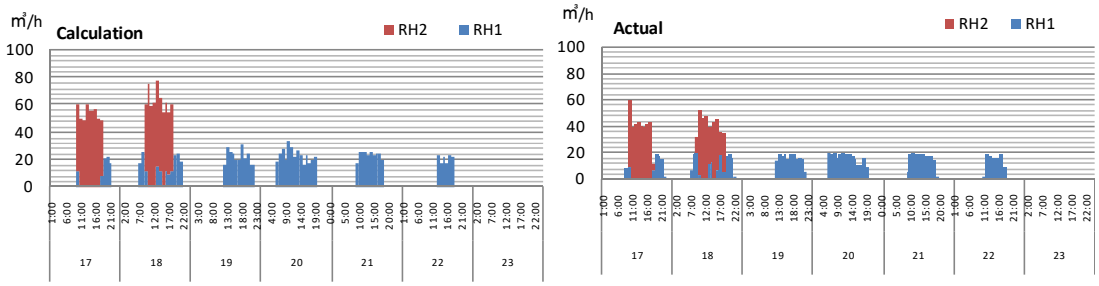


Figure 15. *Gas energy per day (Calculation / Actual)*

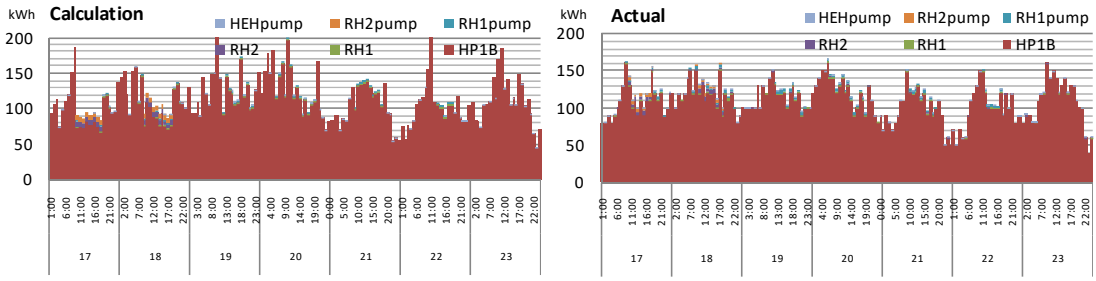


Figure 16. *Electric energy per day (Calculation / Actual)*

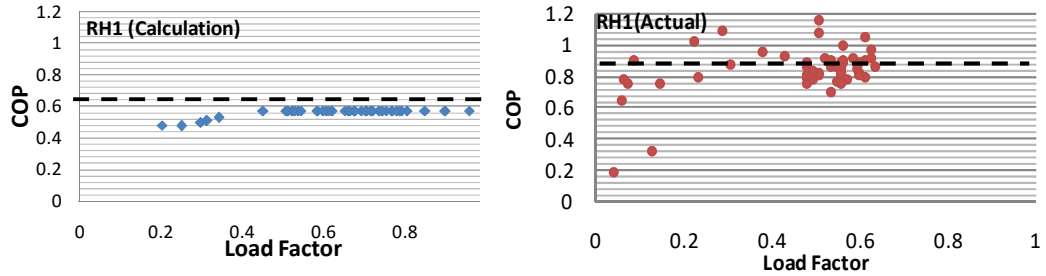


Figure 17. *Load factor and COP of RH1 (Calculation / Actual)*

Table 2. *Comparison with calculation and actual (gas energy / production energy)*

	kWh	LCEM	Actual	LCEM/Actual
gas energy	RH1	1187	908	131%
	RH2	1030	676	152%
produced energy	RH1	8468	9024	94%
	RH2	10125	6677	152%

CONCLUSION

In this paper, about the city hospital opened in May 2015, the annual energy consumption of the entire hospital and the heat source system and the COP of the heat source system were examined. The heat sources were worked property, but in the future, it is necessary to examine the peak demand of electric energy which is the important assessment index in summer season. About the reproducibility of system simulation around the heat source by LCEM tool, it is required to improve the accuracy by examining the characteristics of heat source, primary pump and cooling tower fan. Then, the analysis of the whole system including fun powers in air-conditioning side will be examined by using LCEM tool. Finally, some study and suggestion for energy saving by more effective operation of heat source will be conducted.

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