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Commissioning test for existing large scale building using simulation modeling

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Introduction

Before an upcoming renovation of the existing building, various energy-saving effect items were examined and assessed on the 24th of the building office.

Since the result of the assessment was greater than expected, the analysis of the assessment result was conducted by using simulation to clarify the mechanism of the energy saving.

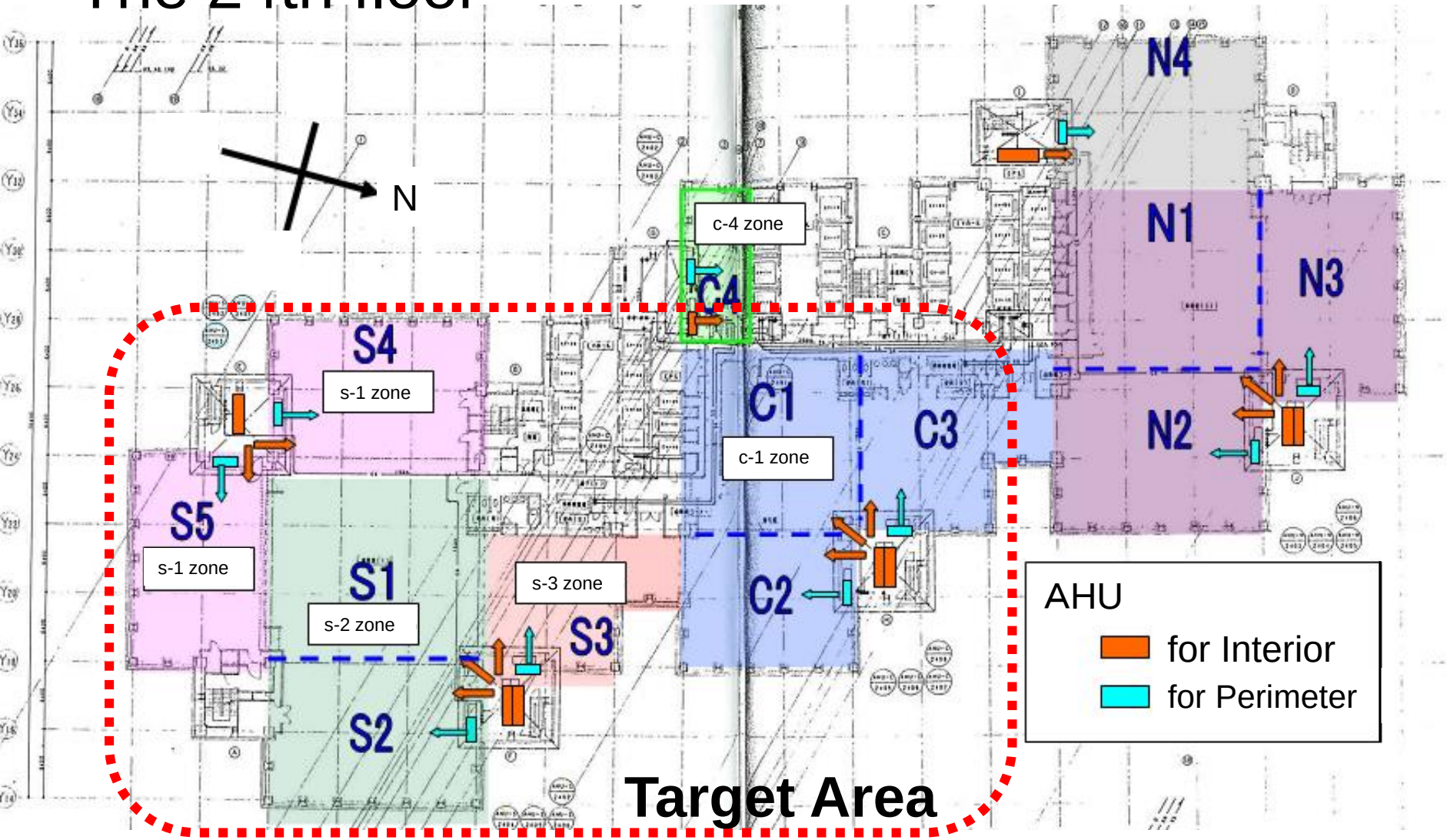
This presentation presents the energy-saving method and evaluation by BEMS data, and analytical method by using simulation and the calculation result.

Profile of the Building

Location	**Shinjuku-ku, Tokyo**
Scale	**The fifth floor under the ground The 52nd floor above the ground 235m in height**
Total floor area	**About 264,000m^2**
Completion	**Constructed in 1994**
Use	**Office : from 8th to 37th floor Hotel : from 39th to 52th floor Shop : from B1th to 7th floor**

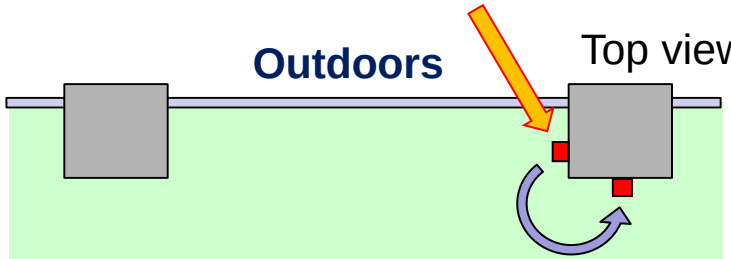
The Target Area

The 24th floor



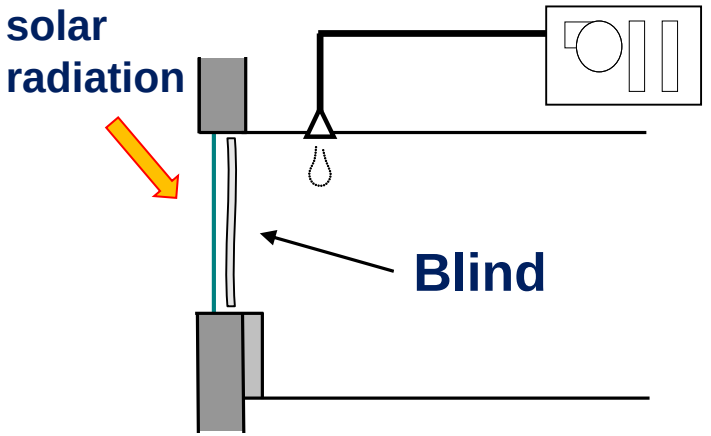
Improvement Item for Energy Saving -1

(1)Relocation of the Thermometer



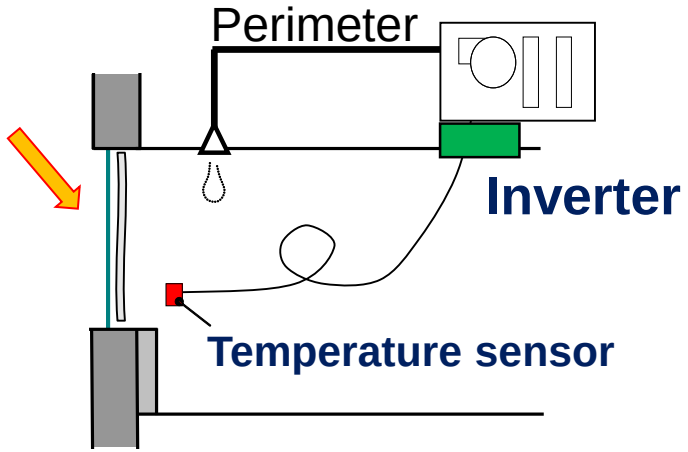
Remove Effect of the Solar Radiation

(2) High-performance Blind



Reduction of the Air Conditioning Load

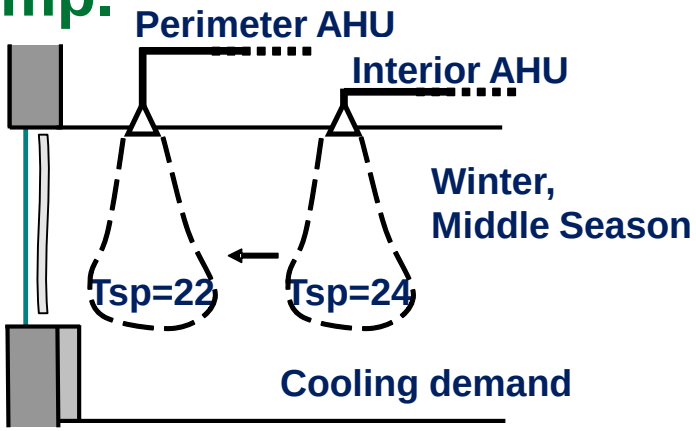
(3) Inverter Control of the Fan



Reduction of the Fan Electricity

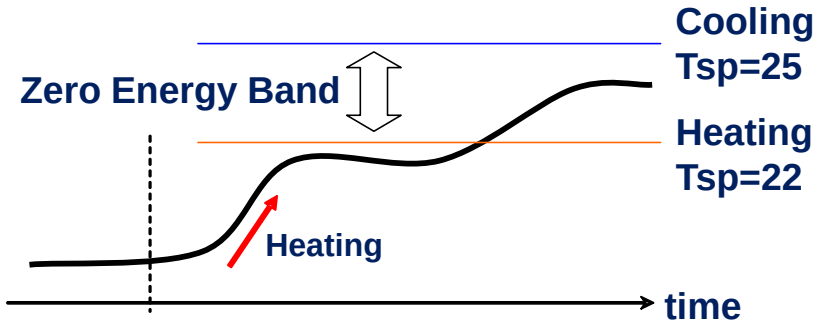
Improvement Item for Energy Saving -2

(4) Adjustment of the Setting Temp.



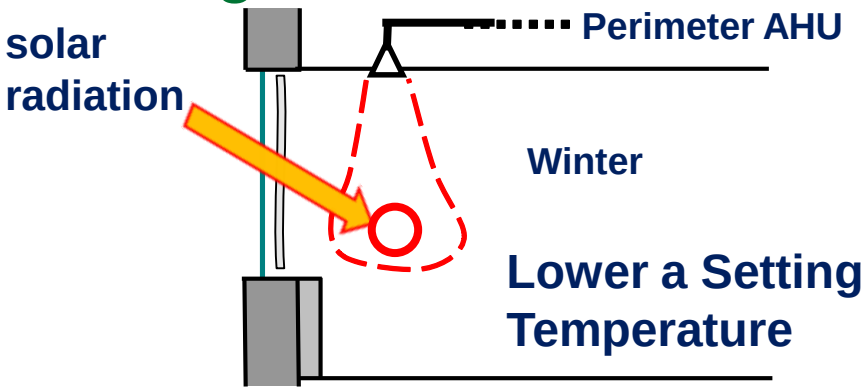
Reduction of the Mixing Loss

(5) Zero Energy Band for Perimeter AHU



Prevention of the Excessive Operation

(6) Temperature setting Using of Radiation heat



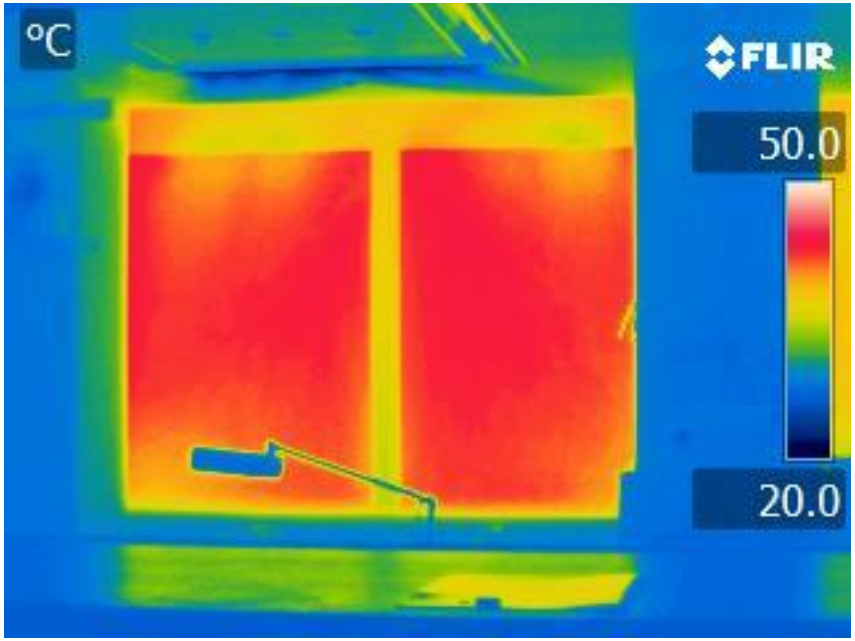
Reduction of the Air Conditioning Load

Verification of the Improvement - 1

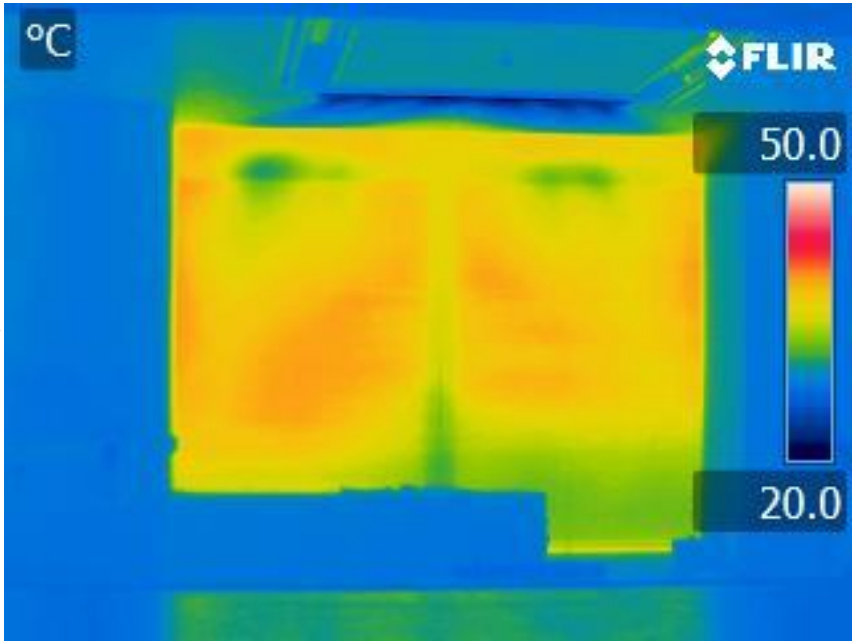
The effect of each improvement item were verified

Thermal Performance of the Blind

2013 August



Existing Rolling Screen

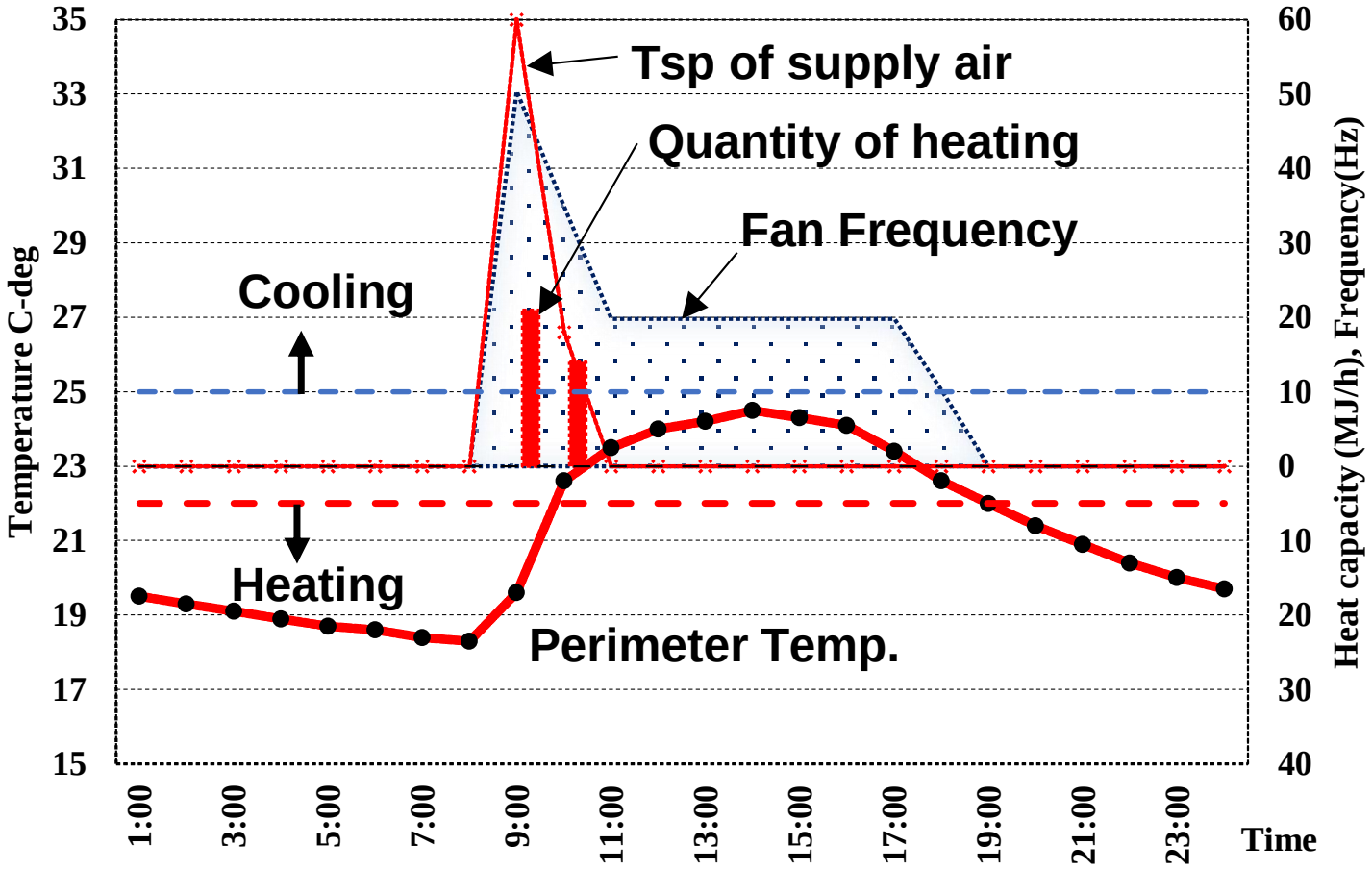


High-Performance Blind

Confirm the heat load reduction of the window

Verification of the Improvement - 2

Inverter Control of the Fan



Operation check of fan control, zero energy band

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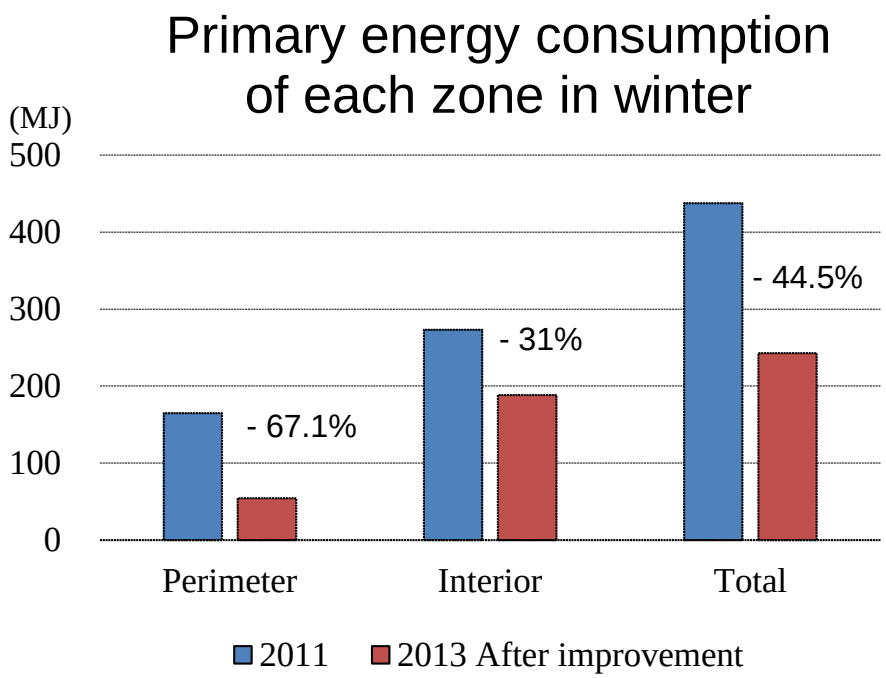
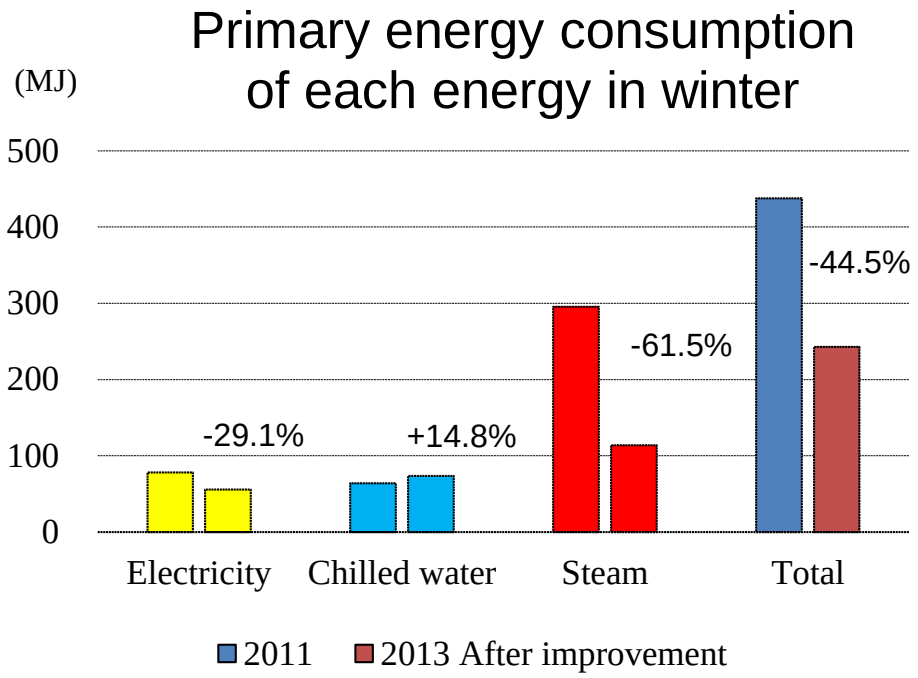
Verification of the Improvement Effect by the BEMS data

ESL-CY-14-09-32

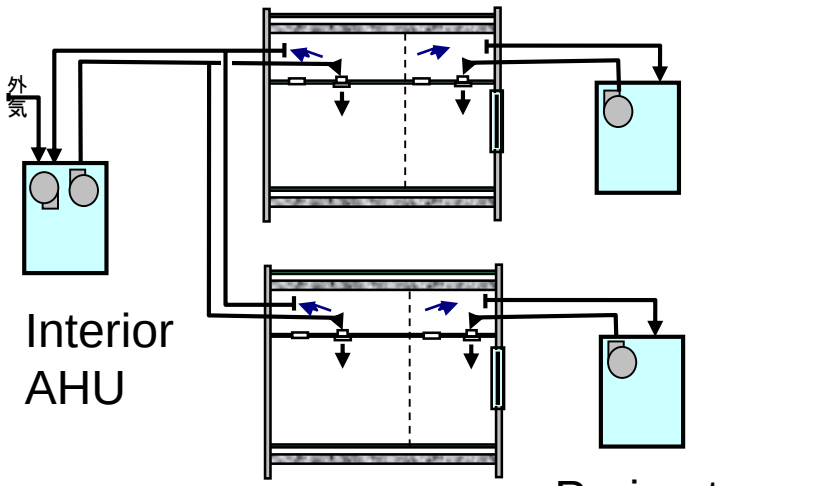
2011 : Before improvement
2013 : After improvement
Operational state is about the same





Explanation is impossible by big effect more than expected. >>> Analyze it by simulation

Analytic Target by the Simulation



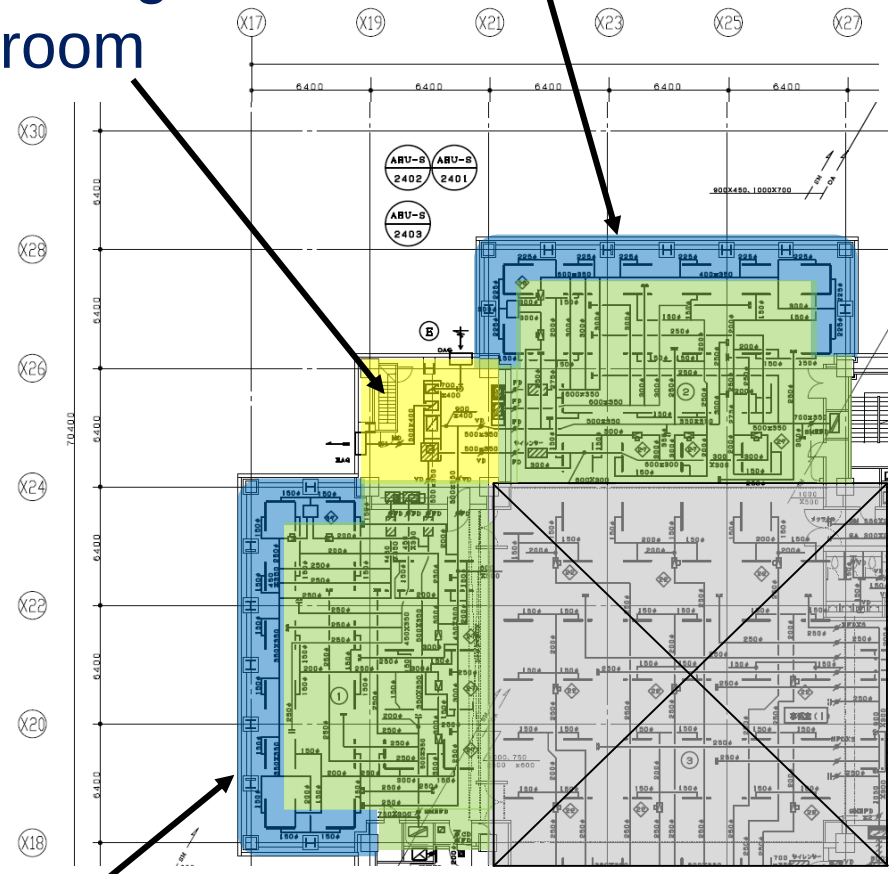
Peimeter
AHU ： West

Interior
AHU

Perimeter
AHU : South

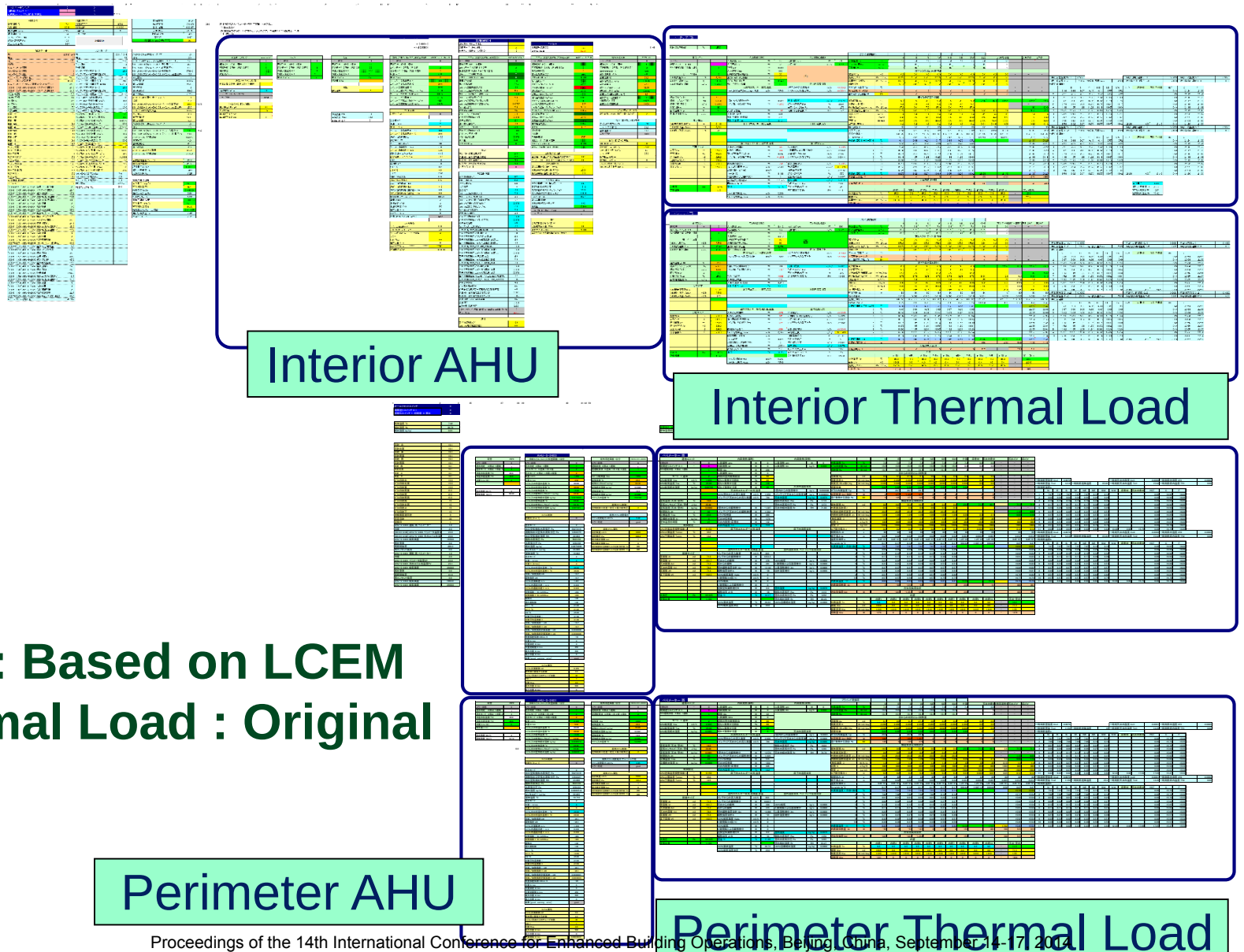
air conditioning
machine room

West Perimeter



South Perimeter

Simulation Tool of LCEM and Indoor Thermal Load



AHU : Based on LCEM
Thermal Load : Original

Thermal Load Program on the Spreadsheet

Heat Flow from Window

Ceiling chamber

Indoor air

通信ユニット		
ERROR	–	0
時間送りスイッチ 0:1	–	0
AC-3連転状態 0:停止 1:連転		0
モード 1:通常		2
AHU給気量 Vsa	m3/h	0
AHU給気温度 Tsa	℃	32.00
AHU給気絶対湿度	kg/kg	0.0000
還気温度(天井)	℃	22.8
還気エンタルピ(天井)	J/kg	46.56
還気湿度(天井)	kg/kg	0.0093
時間刻み dt	s	80
目標温度 Trsp	℃	25.5
目標絶対湿度 Xr	kg/kg	
制御設定		
AHU風量調整係数 k	–	0.010
AHU最大風量 Vamax	m3/h	4,500
AHU最小風量 Vamin	m3/h	0
部屋サイズ		
室面積 Ar	m2	226.6
室容積 Vr	m3	609.6
天井面積 Acl	m2	226.6
天井内容積 Vcl	m3	339.9
床面積 Afl	m2	226.6
床下容積 Vfl	m3	226.6
大気圧	Pa	101325
空気比重		1.16

内部発熱(顕熱)		
人員顕熱 qms	W	0
内部発熱 Qr	W	0
照明 Qlg	W	0
人員顕熱 Qps	W	0
照明の室内発熱割合	W	0
直ちに発熱する割合	%	80
直ちに発熱する量	W	0
遅れて発熱する量	W	0
天井内エネルギー収支,温度		
1AHU2402室内からの流入風量	m3/h	0
1ペリ南からの顕熱増分	W	−158
スラブ伝熱量	W	1,126
天井材伝熱量	W	−1,441
天井内発熱+床骨材	W	431
天井内温度 Tcl	℃	22.8
ペリAHUからの流入風量		0
ペリAHUからの流入顕熱		0
室内エネルギー収支,温湿量,室温		
天井からの顕熱	W	1,441
床からの顕熱	W	1,225
室内顕熱負荷合計 Qs	W	570
1ペリ南からの顕熱増分	W	0
顕熱負荷合計A	W	−644
1AHU給気風量 Vade	m3/h	0
X 隙間風(0.0回/h)	m3/h	0
1AHU給気	W	0
X 隙間風による顕熱増分	W	0
空調空気顕熱増分B	W	0.0
顕熱収支 A+B	W	−644
室温 Tr	℃	18.71
1AHU要求風量 Vad	m3/h	304
1AHU給気風量 Vade	m3/h	0

内部発熱(潜熱)		
人員潜熱 qml	W	0
人員潜熱 Xm	kg/h	0.000
南		
室内からの湿気増分	kg/s	0.0000
ペリ南からの湿度増分	kg/s	−0.0000
天井内温度	kg/kg'	0.0093
飽和水蒸気圧 Pas	Pa	2782
室内水蒸気分圧 Pa	Pa	1489
天井内相対湿度 Rr	RH	53.52
ペリAHUからの流入潜熱		0
室内エネルギー収支,室内湿度		
1AHU給気	kg/s	0.0000
X 隙間風による湿度増分	kg/s	0.0000
人員潜熱増分 Xm	kg/s	0.0000
ペリ南からの湿度増分	kg/s	0.0000
合計湿度増分	kg/s	0.0000
無結露湿度	kg/kg'	0.00734
内壁露点温度 ペリ	K	282.54
飽和水蒸気圧	Pa	1179
壁面飽和湿度	kg/kg'	0.00732
室内湿度	kg/kg'	0.00732
飽和水蒸気圧 Pas	Pa	2158
室内水蒸気分圧 Pa	Pa	1179
室内相対湿度 Rr	RH	54.62
結露フリ		1.0000

ブラインド閉鎖率			1	1	1	1	1	1	1					
			E	S	W	NE	SE	SW	什器	天井内骨材			天井ｽﾗﾌﾞ	床ｽﾗﾌﾞ
外気温度 To	℃	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–		–	–
ｶﾞﾗｽ日射量 Ra	W/m2	0	0	0	0	0	0	0	0	0	–		–	–
日射量 Ra	W/m2	0	0	0	0	0	0	0	0	0	–		–	–
窓からの対流とふく射熱量														
窓面積 Ag	m2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–	–	–
熱貫流率 K	W/m2/deg	1.520	1.520	1.520	1.520	1.520	1.520	1.520	1.520	0.0	0.0	–	–	–
熱貫流/内αk除く Kg	W/m2/deg	1.670	1.670	1.670	1.670	1.670	1.670	1.670	1.670	0.0	0.0	–	–	–
遮蔽係数	–	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0	0	–	–	–
ガラス内面温度 Tgi	℃											–	–	–
対流熱量 Qm+放射	W	0	0	0	0	0	0	0	0	0	0	–	–	–
直ぐ発熱する割合 %	80	0	0	0	0	0	0	0	0	0	0	–	–	–
躯体非定常熱計算														
躯体面積 As	m2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.5	219.8	226.6		226.6	226.6
外表面反射率 r	–	0.6	0.6	0.6	0.6	0.6	0.4	0.4					–	–
外側総括熱伝達率 αo	W/m2/deg	17.0	17.0	17.0									1.10	6.00
内側総括熱伝達率 αi	W/m2/deg	3.73	3.73	3.73									6.00	1.10
熱伝導率 λ	W/K/m	1.4	1.4	1.4									1.4	1.4
比熱 C	J/kg/K	880	880	800									880	880
密度 ρ	kg/m3	1900	1900	1900									1900	1900
コア部分厚み t	m	0.2	0.2	0.2									0.12	0.12
時間刻み dt	s	80	80	80								80	80	80
格子長さ dx	m	0.02	0.02	0.02										
温度伝導率 a		8.4E−07	8.4E−07	9.2E−07										
Cx=a*dt/dx^2		0.17	0.17	0.18										
外表面温度 1 日射+放射	℃	7.83	7.94	7.68										
2	℃	9.02	9.70	9.40										
3	℃	10.99	11.08	10.76										
4	℃	12.03	12.18	11.85										
5	℃	12.95	13.06	12.72	12.97	12.99	13.39	13.23					23.75	23.76
6	℃	13.67	13.79	13.44	13.68	13.71	14.12	13.95					23.76	23.76
7	℃	14.27	14.39	14.04	14.28	14.31	14.72	14.54		0.00			23.76	23.75
8	℃	14.76	14.89	14.54	14.78	14.80	15.22	15.03					23.75	23.74
9	℃	15.17	15.29	14.95	15.18	15.21	15.63	15.44					23.73	23.72
10	℃	15.49	15.62	15.28	15.51	15.53	15.94	15.75					23.70	23.69
11	℃	15.74	15.86	15.53	15.75	15.78	16.17	15.99	19.94		23.75		23.67	23.65
内表面伝熱量 Qi	W	0	0	0	0	0	0	0	725		431		1,126	1,225
方位別負荷合計														
方位別負荷 Qd	W	0	0	0	0	0	0	0	725				1,126	1,225
内壁														
		内壁1	内壁2	内壁3	内壁4	内壁5	内壁6	内壁7	内壁8	内壁9	内壁10		天井−室内	
外側温度 Tn	℃	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	–	18.7	
面積 Aiw	m2	51.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–	226.6	
熱貫流率 Kiw	W/m2/deg	1.610	15.0	10.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	–	1.55	
伝熱量 Qiw	W	−155	0	0	0	0	0	0	0	0	0	–	−1,441	

$$\rho c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\lambda \frac{\partial T}{\partial x}\right)$$

Calculate Crank Nicholson by finite volume method

humidity balance

sensible heat balance

Heat flow from Wall

Proportional control of air volume

$$V\rho c \frac{\partial T}{\partial t} = \Sigma Q + \rho c v (T_s - T_r)$$

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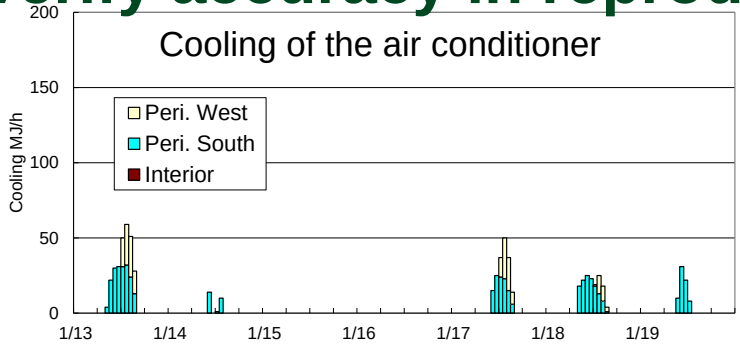
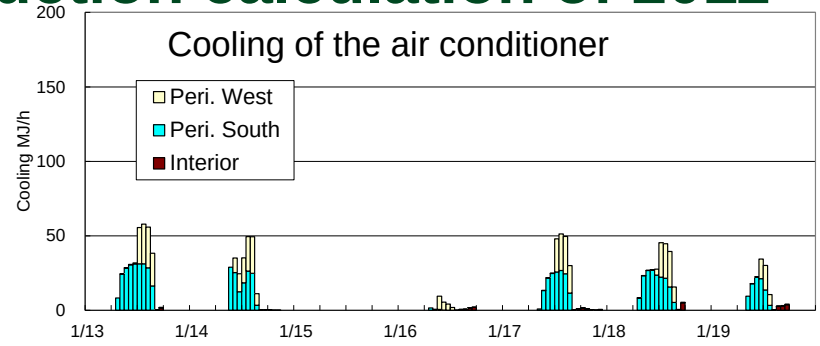
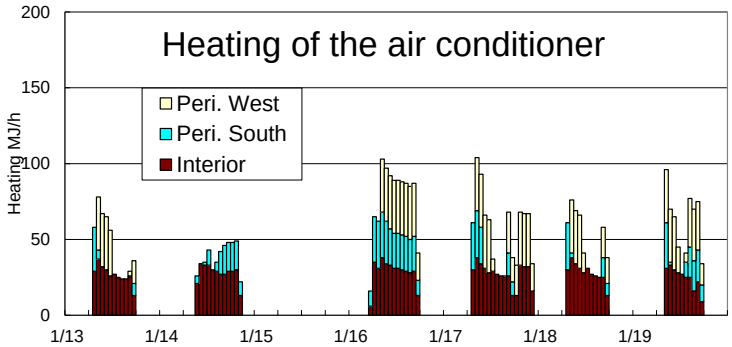
Time step = 80 seconds

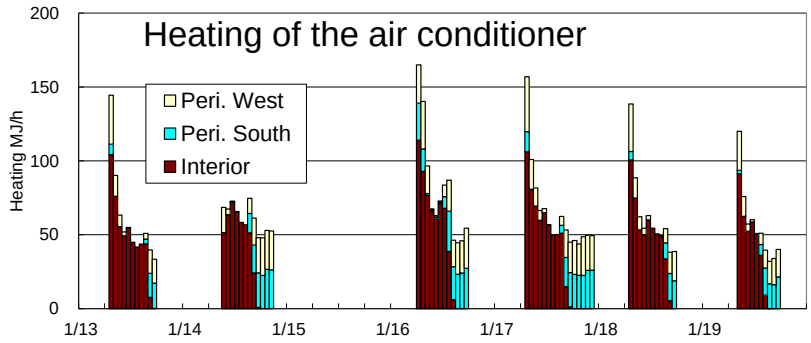
Verification of the calculation accuracy

Verify accuracy in reproduction calculation of 2011

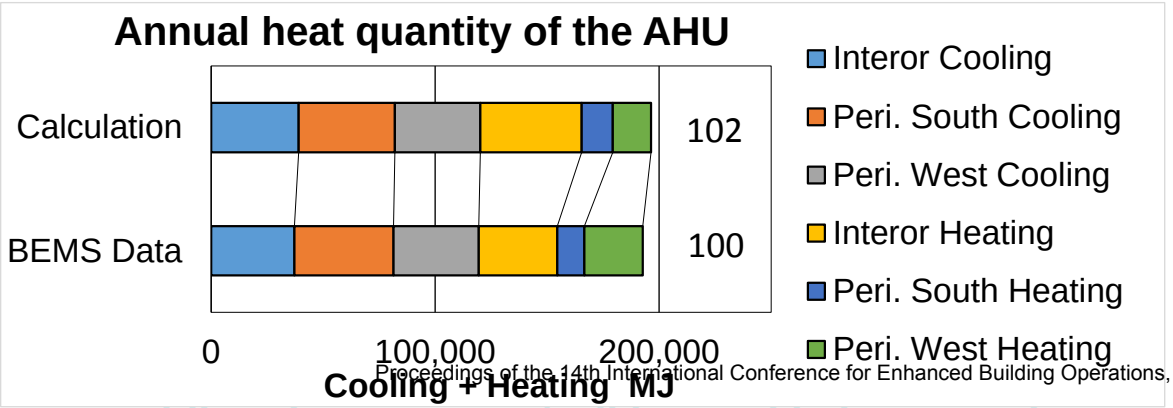








BEMS Data **Calculated Value**



The annual consumption accorded,
but further improvement is necessary

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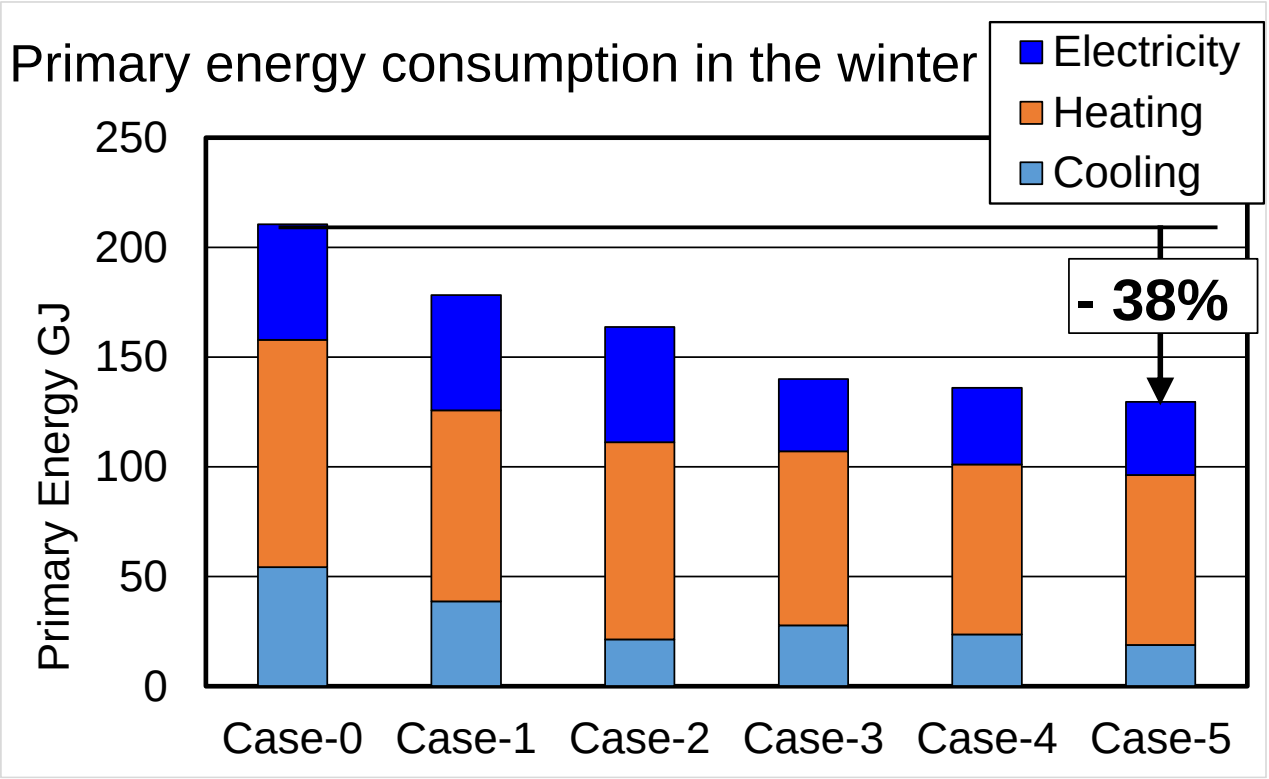
Analysis of the improvement effect by the simulation



No.	Item	%
C-0	Before improvement	100
C-1	Relocation of the Thermometer	85
C-2	High-performance Blind	78
C-3	Inverter Control of the Fan	67
C-4	Adjustment of the Setting Temp.	65
C-5	Zero Energy Band for Perimeter AHU	62
C-6	Temp. setting Using of Radiation	Not ready

Mixing loss disappeared by C-1

The thermostat of perimeter is heated in solar radiation, and cool too much it.
To disappear cool too much, the interior is heated too much.

Comparison between of 2011 and 2013 BEMS data
>>>> 43.5% Reduction

Calculation by case study
>>>> 38% Reduction

Conclusion

- The mechanism of the energy saving effect was clarified through simulation; a major contributing factor to energy saving was relocation of the temperature sensor which was conducted at lower cost.
- In the process of the analysis and the evaluation of the operation phase, this simulation method was shown to be valid.
- This assessment is continuing this summer to confirm the last year's results and conduct the energy saving effect evaluation in the summer.
- Furthermore, the thermal load calculation including the spatial distribution is under development to improve accuracy of the simulation.