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An Index to Evaluate Energy Efficiency of the Entire Building HVAC System

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Outline

- Why we need the Energy/Load Ratio
- How to get the Energy/Load Ratio
- Methodology Adjustment
- Case Study
- Results Showed by tables and Plots

• Why we need the Energy/Load Ratio

1. Building

- Building sector consumes 40% of total energy usage in US (Residential buildings – 22%, Commercial building – 19%)

2. HVAC Systems

- HVAC systems typically consume 30% of the energy usage in a building (heating – 5%, cooling – 14%, ventilation – 12%)

3. Common Index

- Furnace/boiler: AFUE, HSPF
  Chiller: COP, EER, SEER
  Combined Index: Energy Delivery Efficiency

- How to get the Energy/Load Ratio

The energy/load ratio ELR can be expressed in terms of the different sources of energy (E_{BS}) required to meet the corresponding positive or negative loads (Q_{BSL}) of the entire building.

1. Definition

$$ELR = E_{BS}/Q_{BSL}$$

2. Formula

• How to get the Energy/Load Ratio

The building systems total load, Q_{BSL}, is defined as the sum of the envelope load (Q_{LEnv}), the load from internal gains (Q_{LGain}) and the ventilation air load on the secondary systems (Q_{LVent})

1. Definition

$$Q_{BSL} = Q_{LEnv} + Q_{LGain} + Q_{LVent}$$

$$Q_{LVent} = (e_{S,V} + e_{L,V}) \times A$$

$$e_{S,V} = 1.08 \times V_{OA} \times (T_{OA} - T_{RA})$$

$$e_{L,V} = 4840 \times V_{OA} \times (w_{OA} - w_{RA})$$

2. Formula

- # How to get the Energy/Load Ratio

The total energy input (E_{BS}) can be obtained by combining all the heating (E_{BHS}) and cooling (E_{BCS}) energy input costs (C_{BCS}/ C_{BHS})

$$C_{BCS} = C_{B,Fan} + C_{B,CHWPump} + C_{B,HHWPump} + C_{Chiller} + C_{CTFan} + C_{CTPump} + C_{CHWPump} + C_{HHWPump} + C_{Boiler}$$

$$C_{BHS} = C_{B,Fan} + C_{B,CHWPump} + C_{B,HHWPump} + C_{HHWPump} + C_{Boiler}$$

$$C_i = E_i \times P_i \qquad E_{BS} = C_{BS}/P_i$$

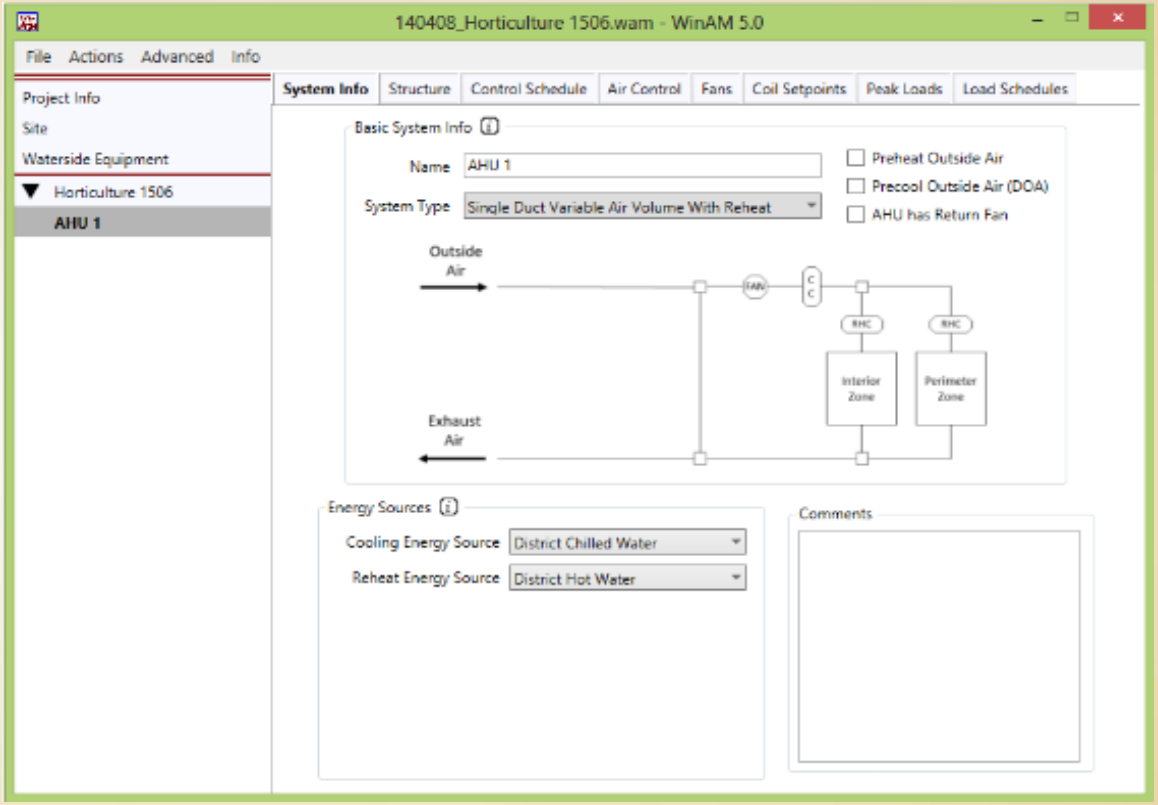
1. Definition

2. Formula

- How to get the Energy/Load Ratio

WinAM

•Create energy performance model
•Obtain the parameter details to calculate the load and building energy input



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• Methodology Adjustment

Campus buildings used for the case study in this paper are served by a central plant.

1. Price Input for Cooling

$$C_{Chiller} + C_{CTFan} + C_{CTPump} + C_{CHWPump} = C_{P,BS} = (R_{PC,E/L} \times Q_{BSL}) \times P_{ELE}$$

$R_{PC,E/L}$ is the entire plant average cooling energy/load ratio,
$E_{P,BS}$ is the plant energy input for building system.

2. Price Input for Heating

$$C_{HHWPump} + C_{Boiler} = C_H = E_{HHW} \times P_{HHW}$$

- Case Study

Plant Data

Main Campus:

- CUP&SUP3

West Campus:

- SUP1&SUP2

Plant Name	Chillers (No.)	Chilled Water Pumps (No.)	Cooling Towers (No.)
CUP	10	12	10
SUP1	6	3	7
SUP2	5	4	5
SUP3	4	4	4

- Buildings selected in west campus served by SUP1 and SUP2.

- Case Study

Data Used for Case Study: 9/1/2012 – 8/31/2013 (FY13)

Building No.	Gross Area	AHU Type	Maximum Supply Air Flow	Outside Air Flow	Space Heating	Space Cooling	Minimum Air Flow
	ft^2		cfm	cfm	° F	° F	%
A	19,132	SDVAV OAHU	32,000	10,484	70	75	70
		SDVAV	8,000	1,760			30
B	118,648	SDVAV	90,700	23,380			40

• Results Showed by tables and Plots

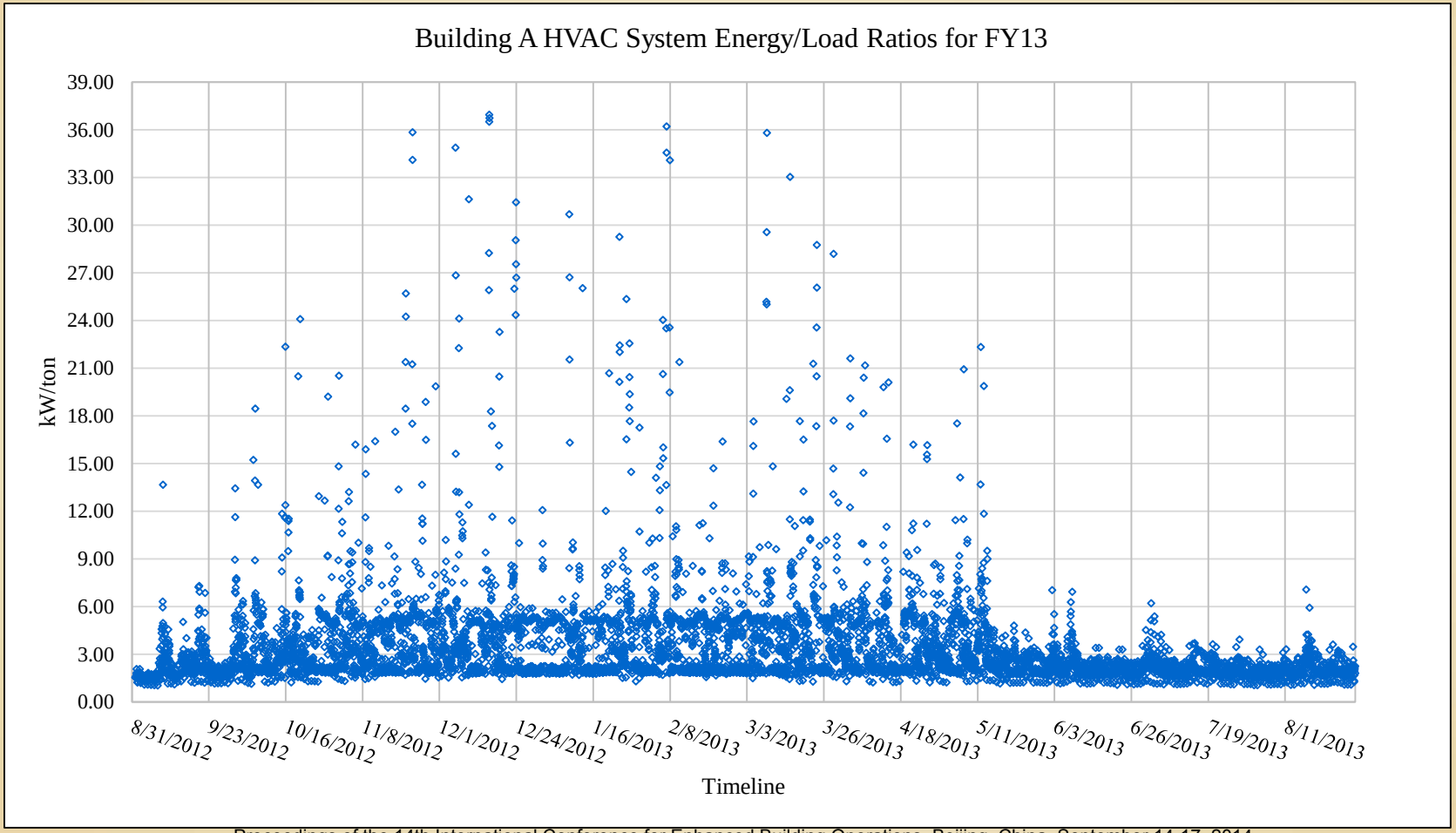
•Building A HVAC System Energy/Load Ratios of Each Component (FY13)

Name	Chiller	CHW Pump	CT Fan	CW Pump	B Fan	BCHW Pump	BHHW Pump	Gas
kW/ton	0.81	0.12	0.07	0.21	0.33	0.18	0.09	1.55
Percentage	24%	4%	2%	6%	10%	5%	3%	46%

- Average energy/load ratio for FY13: 3.36kW/ton

- # Results Showed by tables and Plots

Building A Plot



- Results Showed by tables and Plots

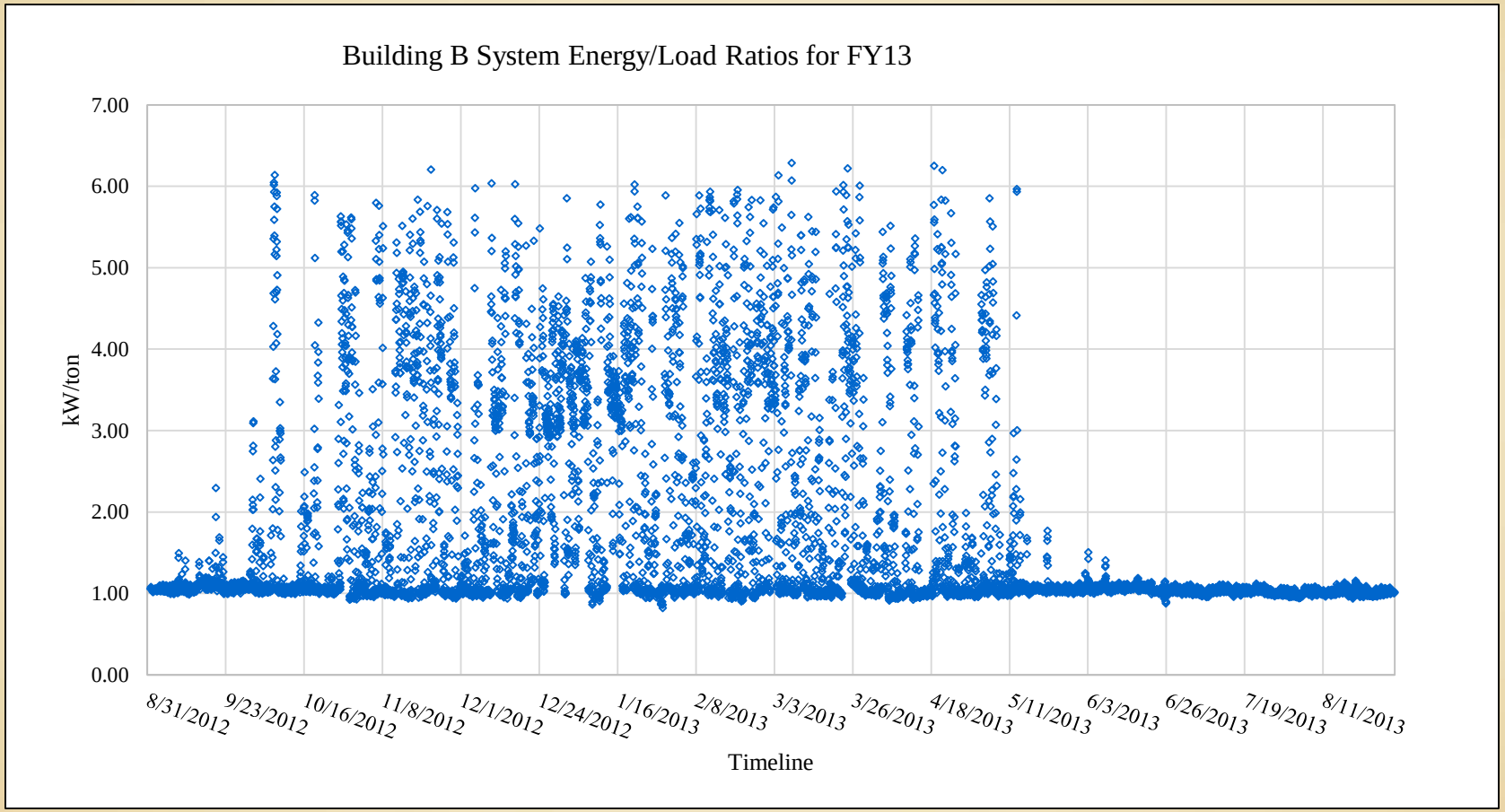
•Building B HVAC System Energy/Load Ratios of Each Component (FY13)

Name	Chiller	CHW Pump	CT Fan	CW Pump	B Fan	BCHW Pump	BHHW Pump	Gas
kW/ton	0.59	0.09	0.05	0.16	0.20	0.15	0.12	0.38
Percentage	34%	5%	3%	9%	11%	9%	7%	22%

- Average energy/load ratio for FY13: 1.73kW/ton

- # Results Showed by tables and Plots

Building B Plot



Thank you!

Questions?