Chill-Off 2 Presentation Outline

- Introduction
- Participants
- Acknowledgements
- Test Description (3 slides)
- Analysis (5 slides)
- Results
- Conclusions
- Recommendations

Introduction

History :	Initial planning November 2008 Testing July 2009 to January 2010
Goals:	Test a cross section of alternative cooling products and investigate cooling performance and energy efficiency differences using production software loads
Test Location:	SUN Microsystems Santa Clara

Participants

Rack Air Containment System (RACS)
Hot Aisle Containment System (HACS)

Vette RDHX
Passive Rear Door

LCP+
Contained Solution

Knürr CoolTherm
Knürr CoolLoop

iDataPlex

Liebert XDR Passive Rear Door
Liebert XDP/XDV/XDH

Sun Rear Door Cooling
Sun Modular Datacenter - (SunMD)

Direct Touch
Cooling Rack

Acknowledgements

(PDU equipment)

(remote sensors)

(complete data collection and reporting)

Western Allied Mechanical Inc.
(engineering and labor for CW infrastructure)

Redwood City Electric (electrical installation)

(servers and workload simulation)

(VFD equipment donation)

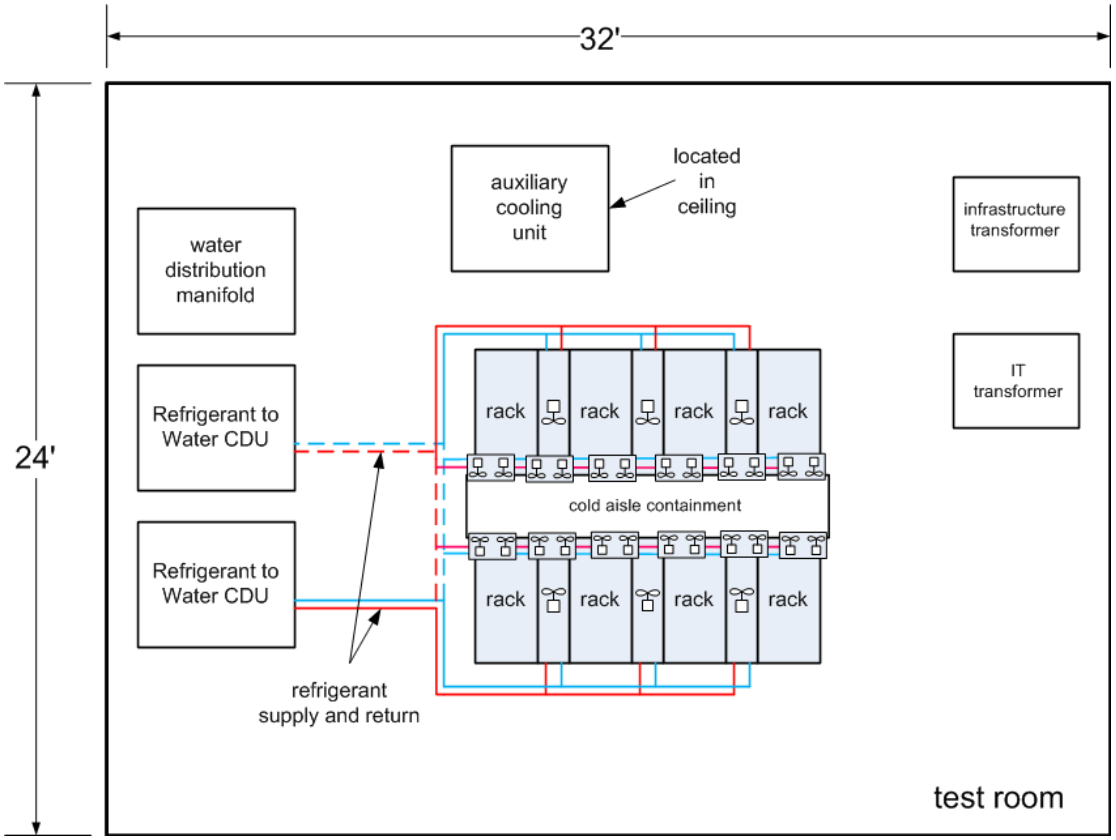
California Hydronics (chilled water pump donation)

(pipe insulation and labor)

(rack PDU's)

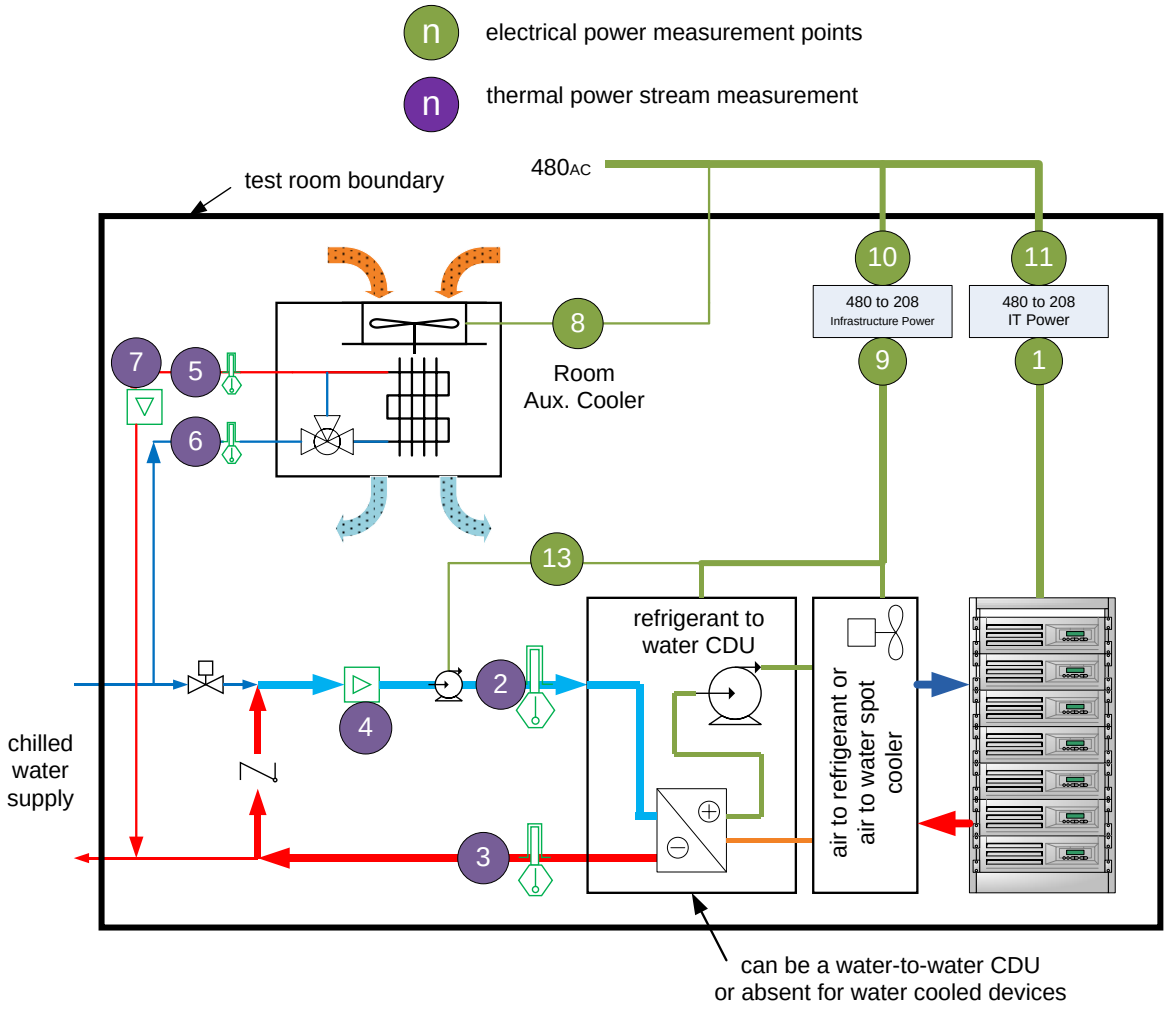
California Energy Commission

Chill-Off 2 Test Room



8 rack test, refrigerant row cooling shown as example

Chill-Off 2 Test Data Points



Chill-Off 2 Test Parameters

Test ID #	Chilled Water Temperature (F)	Server Air Inlet Temperature (F)
1	45	60
2	45	72
3	50	72
4	55	72
5	60	72
6	60	80
7	60	90

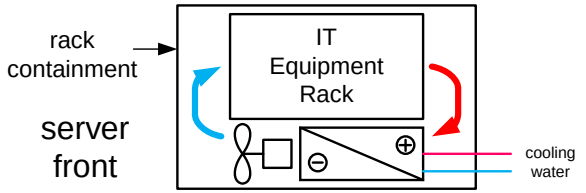
chilled water temperature constant

server air inlet temp. constant

3 Cooling Device Categories

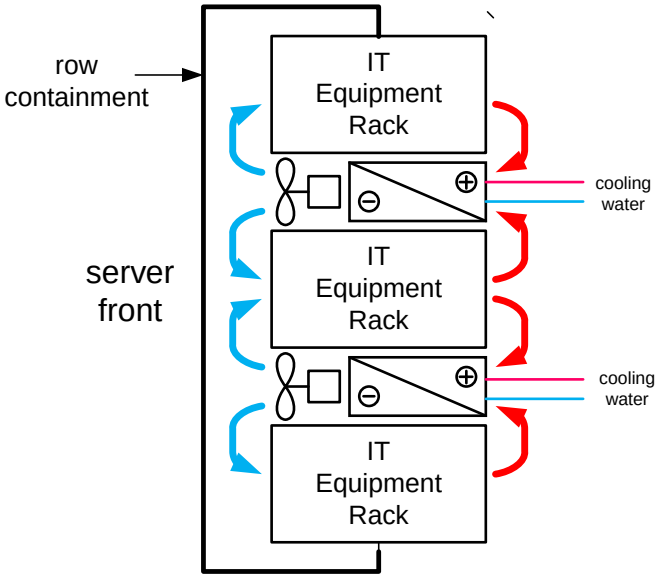
1 - Rack Cooler

- APC-water
- Knürr(CoolTherm)-water
- Knürr(CoolLoop)-water
- Rittal-water



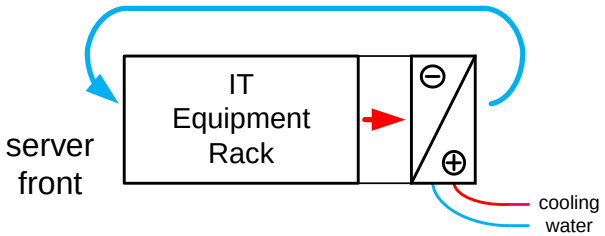
2 - Row Cooler

- APC(2*)-water
- Liebert-refrigerant



3 - Passive Door Cooler

- IBM-water
- Vette/Coolcentric-water
- Liebert-refrigerant
- SUN-refrigerant



Chill-Off 2 Energy Efficiency Performance Metrics

2 Types – **SCOP**, **COEE**

SCOP (**S**ensible **C**oefficient **o**f **P**erformance)
ASHRAE 127-2007

3 options – SCOP(a, b, c)

COEE (**C**hill **-** **O**ff **E**nergy **E**fficiency)
limited power component inclusion of PUE or pPUE

3 options – COEE, COEEc, COEEdt

Analysis

Sensible Coefficient of Performance

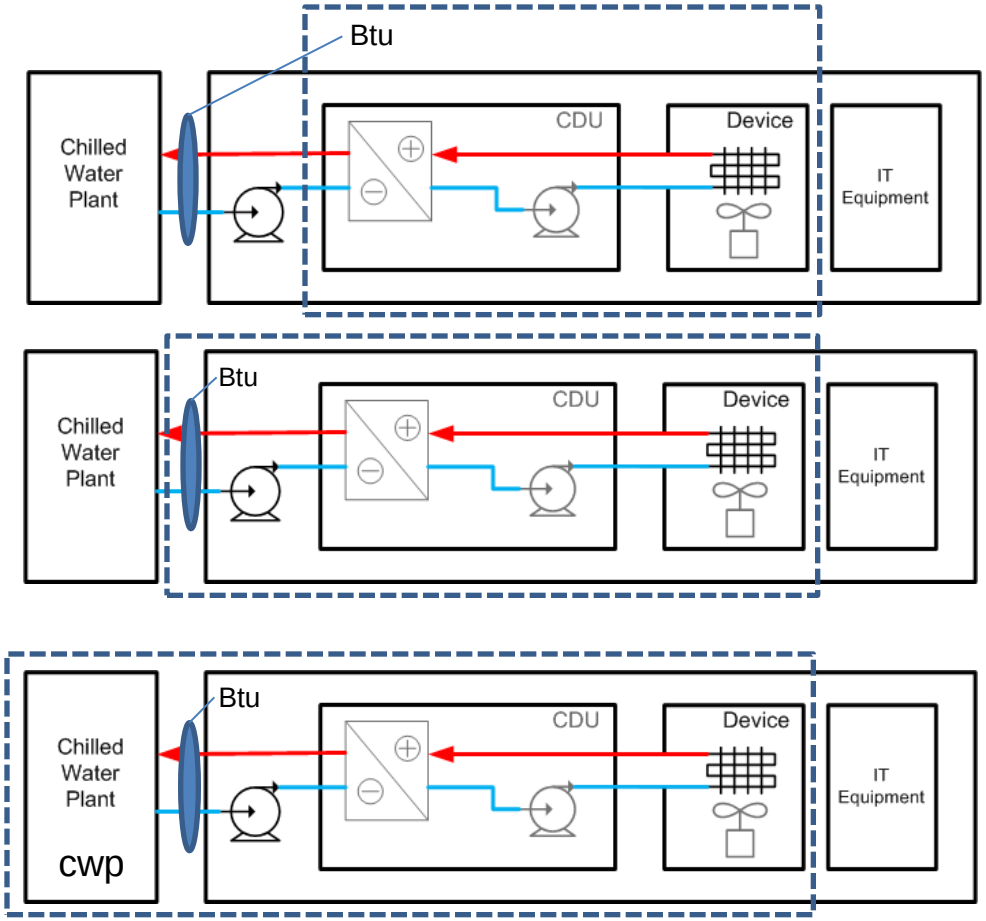
ASHRAE 127-2007

$$\text{SCOP} = \frac{\text{Cooling Provided}}{\text{Cooling Power Used}}$$

$$\text{SCOPa} = \frac{\text{Btu} - (\text{CDU+device})}{\text{CDU+device}}$$

$$\text{SCOPb} = \frac{\text{Btu} - (\text{CDU+device+pump})}{\text{CDU+device+pump}}$$

$$\text{SCOPc} = \frac{\text{Btu} - (\text{CDU+device+pump})}{\text{CDU+device+pump+cwp}}$$



Analysis

COEE = Chill-Off Energy Efficiency

Three Options

COEE $COEE_c$ (from SCOPc) $COEE_{dt}$ (direct touch)

COEE = (Total Power Needed for Cooling + IT Power) / IT Power

(may be similar to pPUE for evaluating a cooling device)

Uses measured and estimated data

$COEE_c = (1 / SCOPc) + 1$ credit Vic Mahaney (IBM)

Compensates for over or under cooling during tests uses SCOPc.

Example: Water Door Test ID# 2 (133% overcooling) COEE = 1.209, COEEc = 1.157

For cases with e.g. server fans removed.

Normalized Server Power = (tested power / (1 – ratio power saved))

$COEE_{dt} = ($tested server power * tested COEE$) /$ Normalized Server Power

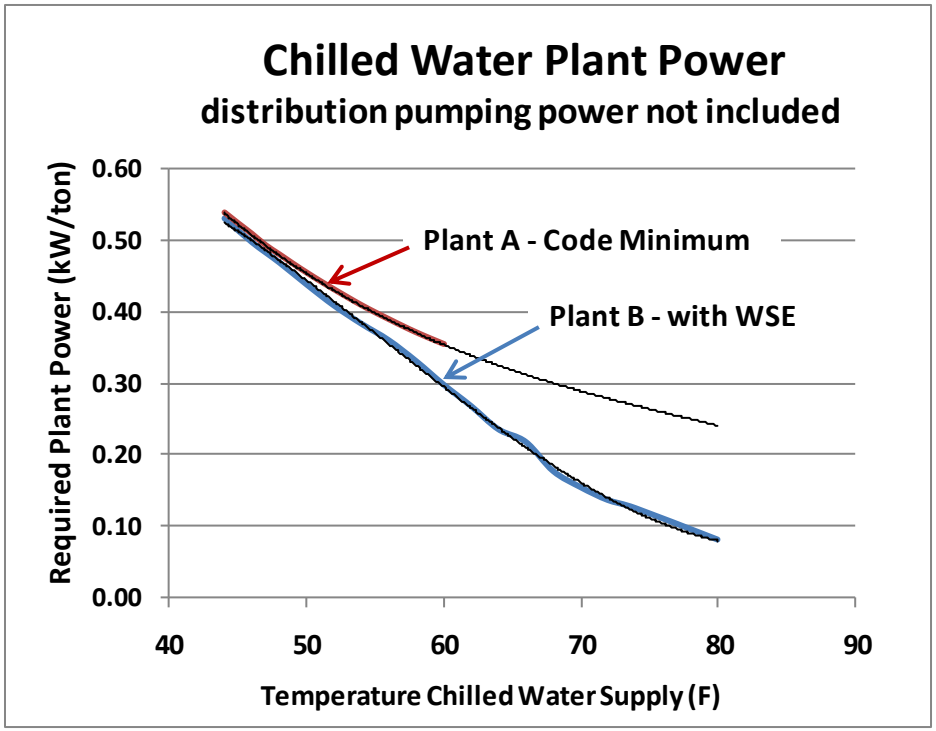
Compensates to compare equivalent IT power for equal compute delivered

Analysis

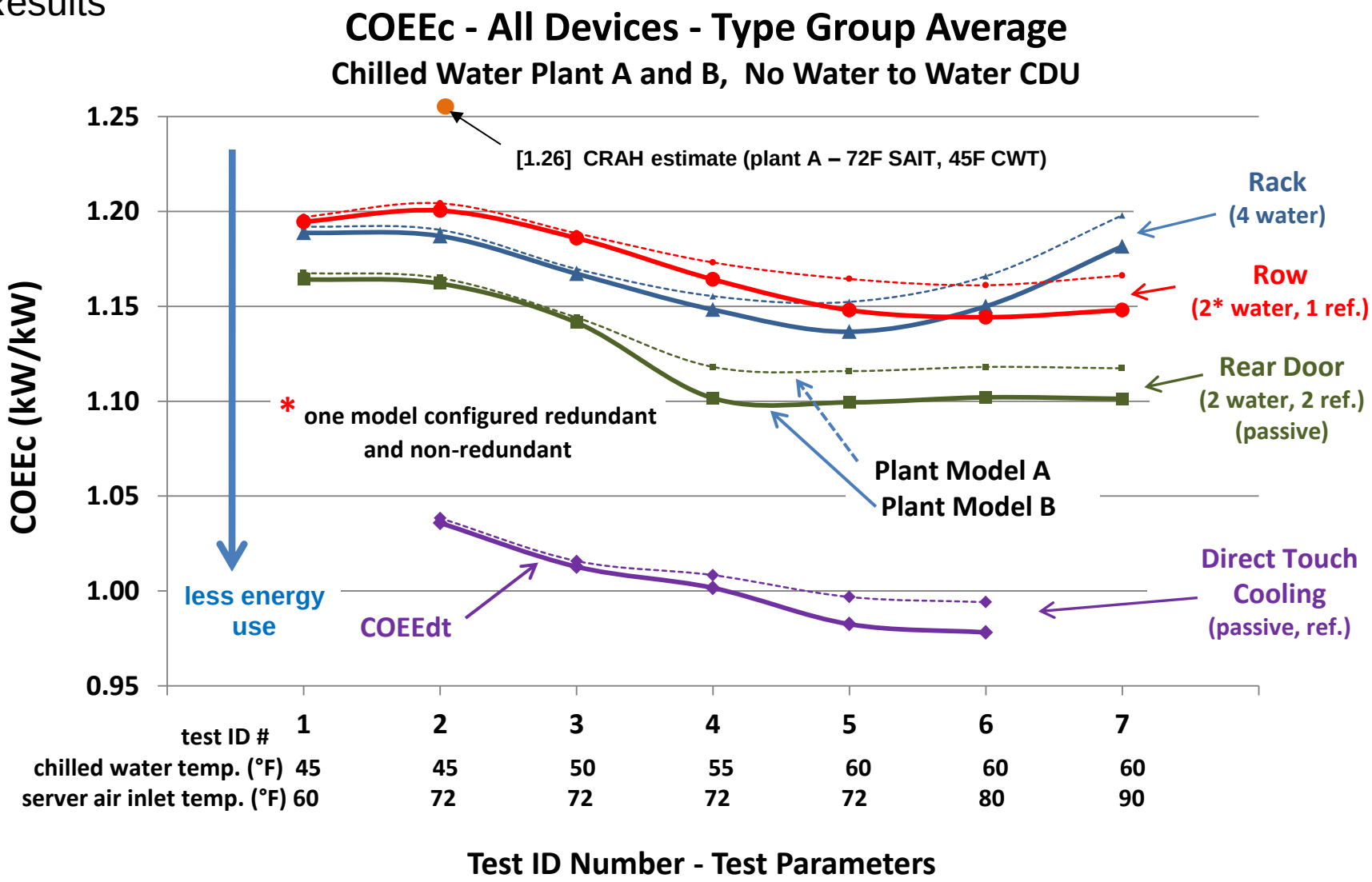
Two Chilled Water Plant Models Taylor Engineering

[ASHRAE 90.1 Chapter 11 (ECB) Rules followed where possible]

Plant A = code minimum
Plant B = code minimum with water side economizer (WSE)



Results


COEEc - All Devices - Type Group Average
Chilled Water Plant A and B, No Water to Water CDU
COEEc (kW/kW)
1.25
1.20
1.15
1.10
1.05
1.00
0.95
[1.26] CRAH estimate (plant A – 72F SAIT, 45F CWT)
Rack
(4 water)
Row
(2* water, 1 ref.)
Rear Door
(2 water, 2 ref.)
(passive)
* one model configured redundant
and non-redundant
Plant Model A
Plant Model B
less energy
use
COEEdt
Direct Touch
Cooling
(passive, ref.)
test ID # 1 2 3 4 5 6 7
chilled water temp. (°F) 45 45 50 55 60 60 60
server air inlet temp. (°F) 60 72 72 72 72 80 90
Test ID Number - Test Parameters

Conclusions

1. Using higher chilled water temperatures, for example from 45˚ F to 60˚ F, improved energy efficiency for all cooling device types tested.

2. Rear door coolers show a trend of better energy efficiency compared to the other cooler (rack, row) types

3. Rear door water coolers show a slight energy efficiency advantage compared to passive door refrigerant coolers when the water cooled doors are installed **without** a water to water CDU. Note: Many installations include a water to water CDU, but a CDU may not be necessary.

4. High server air inlet temperatures may cause reduced cooling energy efficiency if fan speed controls are not properly adjusted or designed for high (80˚ F-90˚ F) server inlet temperatures.

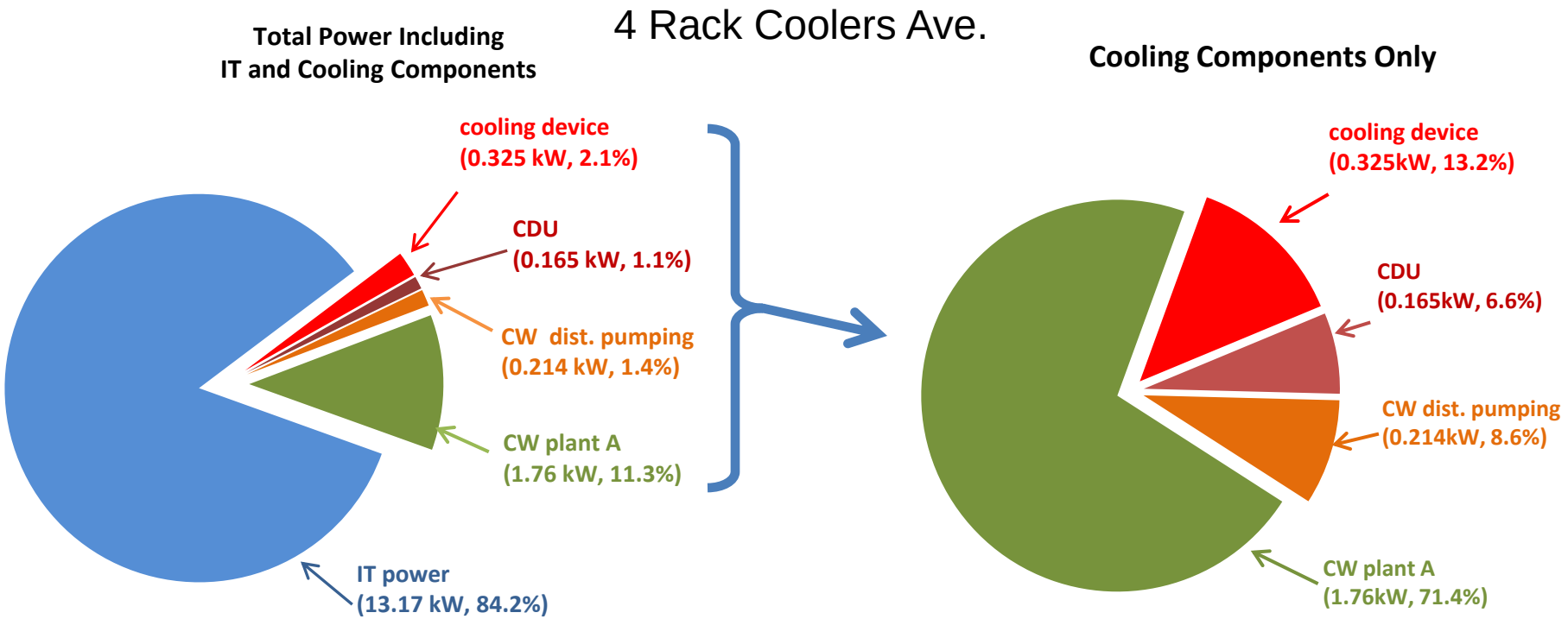
5. Testing of a prototype direct touch cooling system indicates additional gains in energy efficiency are possible compared to the other devices tested due to reduced server power per compute delivered and the possible use of high (>78F) chilled water temperature.

Chill-Off 2 final report - http://hightech.lbl.gov/library - 2010 Technical Publications

Clustered Systems final report - http://hightech.lbl.gov/library - 2010 Technical Publications (Alt. Cooling)

Recommendations

Look for energy use savings by reducing IT power and improving chilled water plant efficiency by e.g. operating at higher chilled water temperatures.

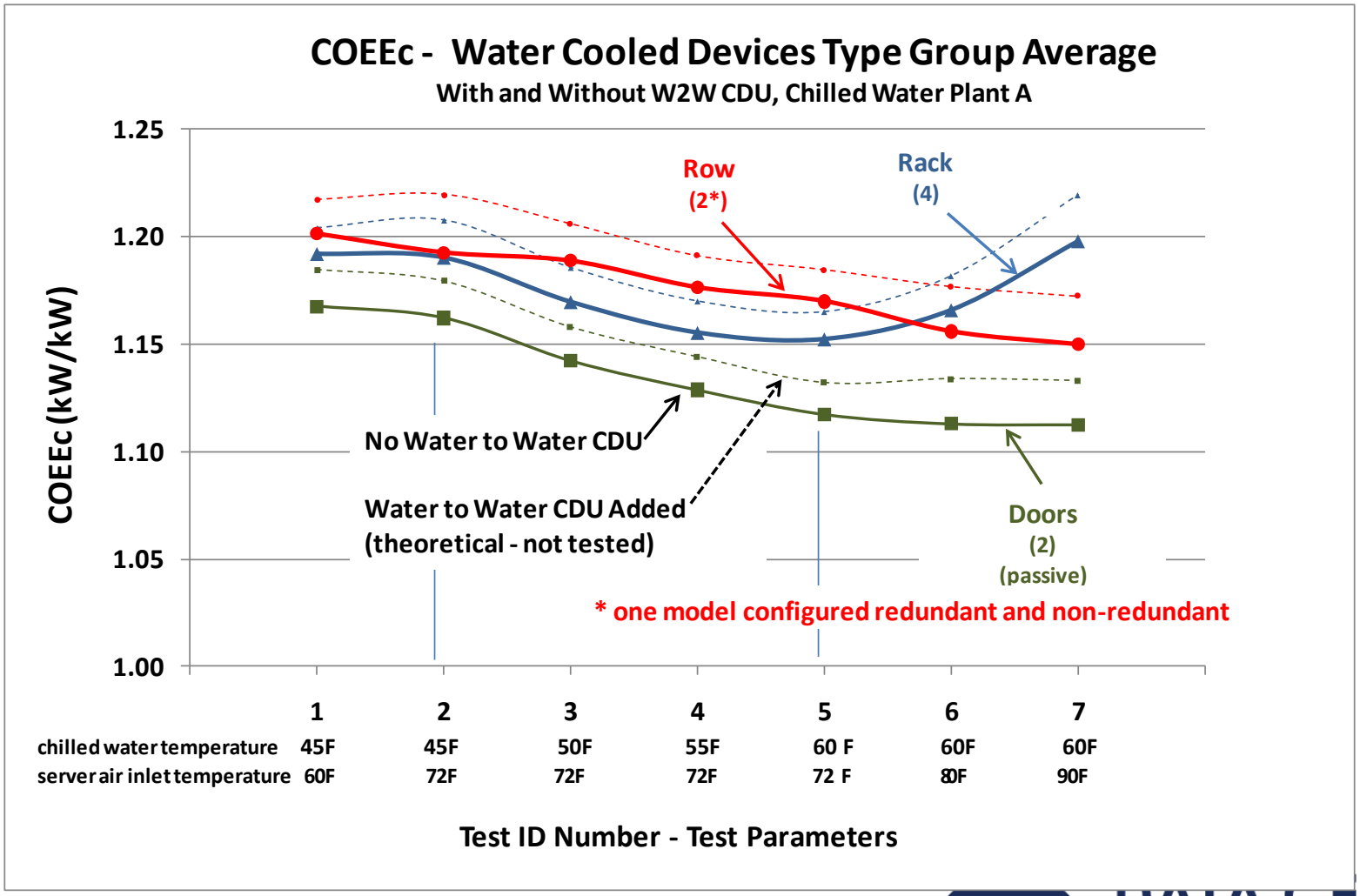


End of Presentation

Appendix – backup slides

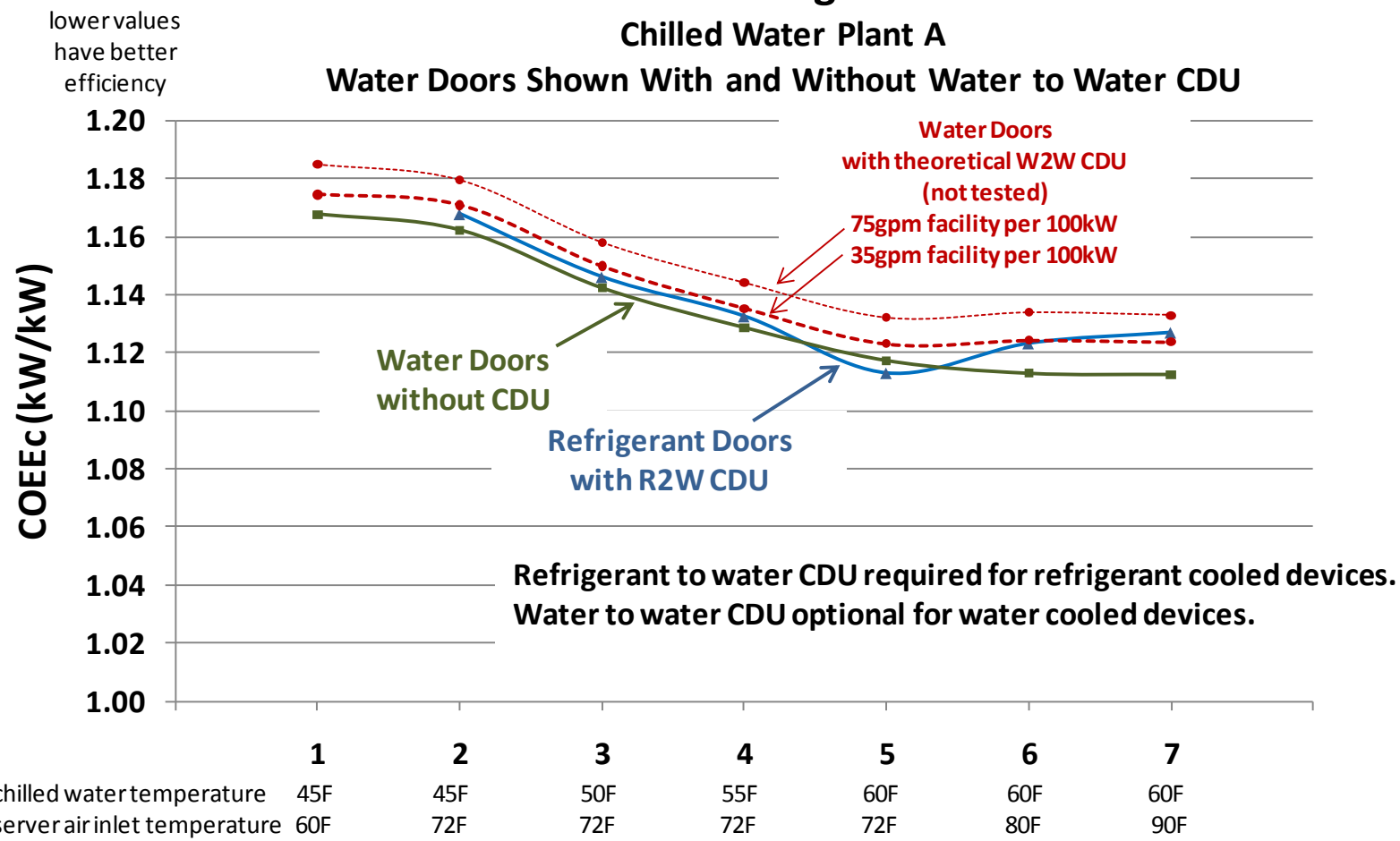
Water Cooled Devices

Compare with and without a CDU



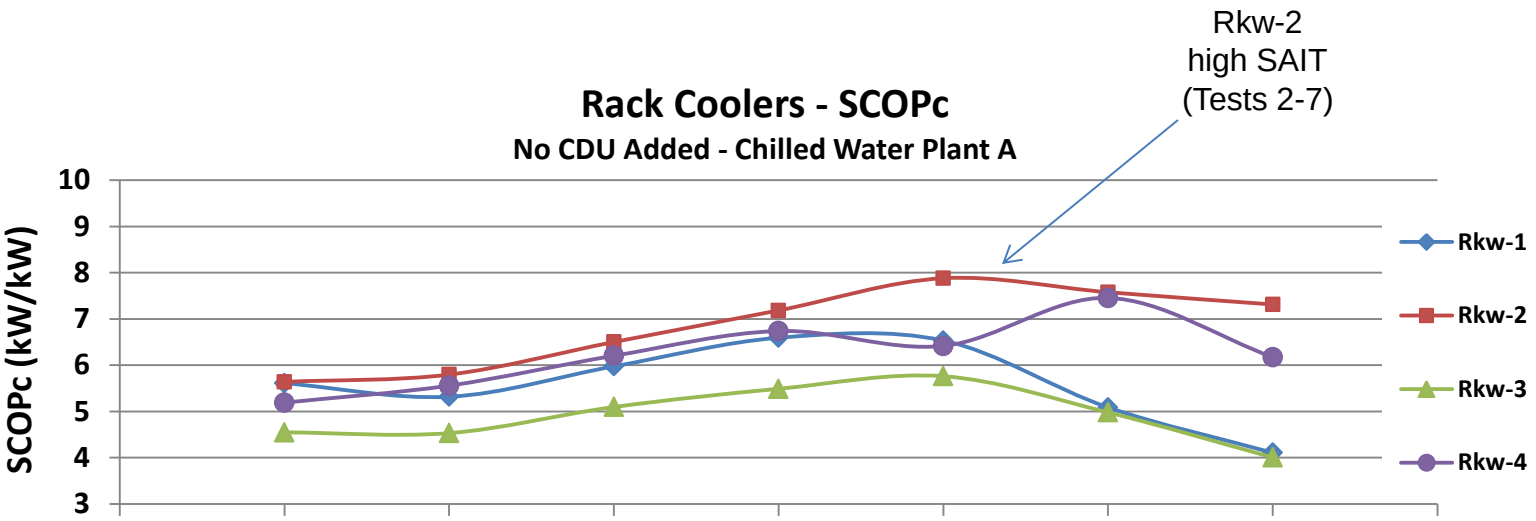
Passive Rear Doors Compared

Water doors shown with and without a CDU



Results

Rack Coolers - SCOPc

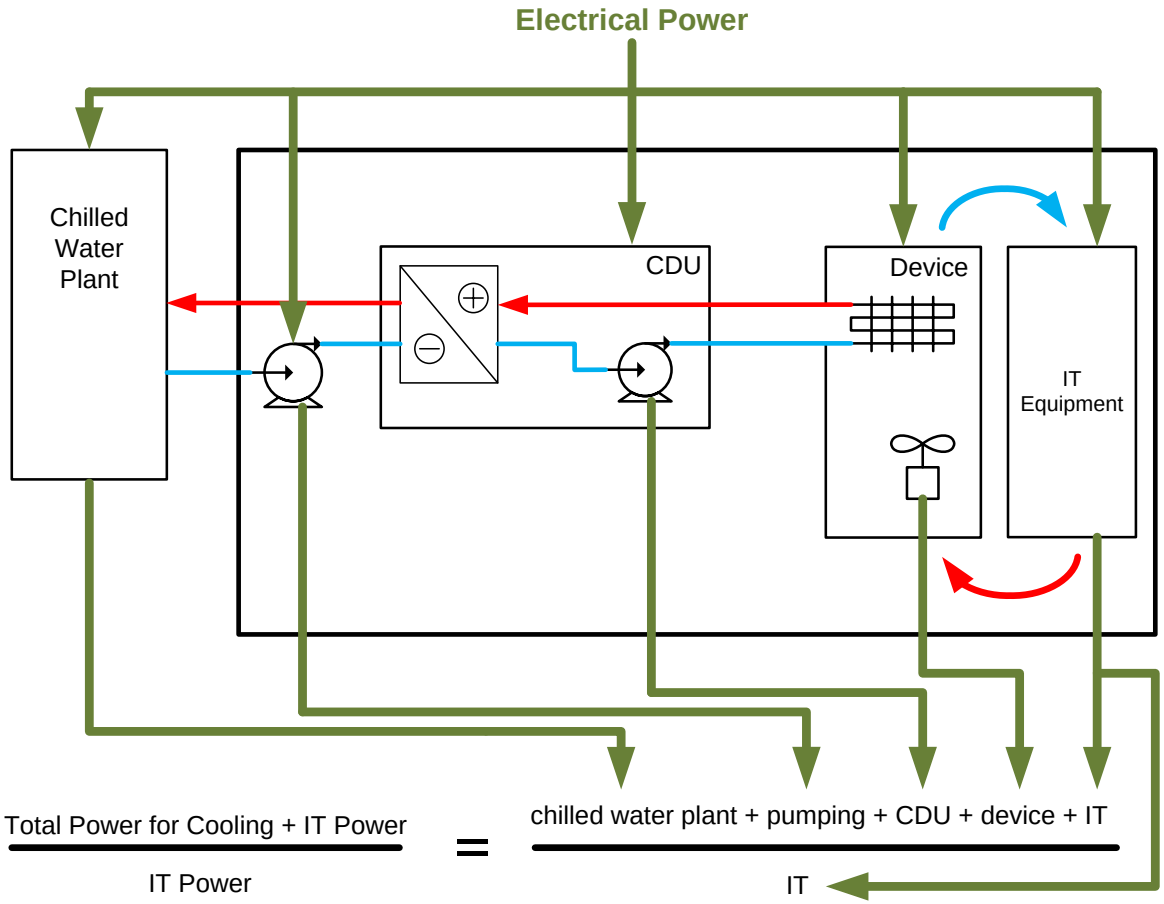


test ID #	1	2	3	4	5	6	7
chilled water temp. (° F)	45	45	50	55	60	60	60
server air inlet temp. (° F)	60	72	72	72	72	80	90

Chill-Off 2 Performance Metrics

Chill-Off 2 Metric	Electrical Power Consuming Components Included per Metric				
	cooling device power (kW)	CDU Power (kW)	chilled water distribution pumping power (kW)	chilled water plant power (kW)	IT Power (kW)
	(measured)	(measured and estimated)	(estimated) ASHRAE 90.1	(model)	(measured)
$SCOP_a$	Included	Included	not included	not included	not included
$SCOP_b$	included	included	included	not included	not included
$SCOP_c$	included	included	included	included	not included
COEE	included	included	included	included	included
$COEE_c$	included	included	included	included	included

COEE (Chill-Off Energy Efficiency) Metric

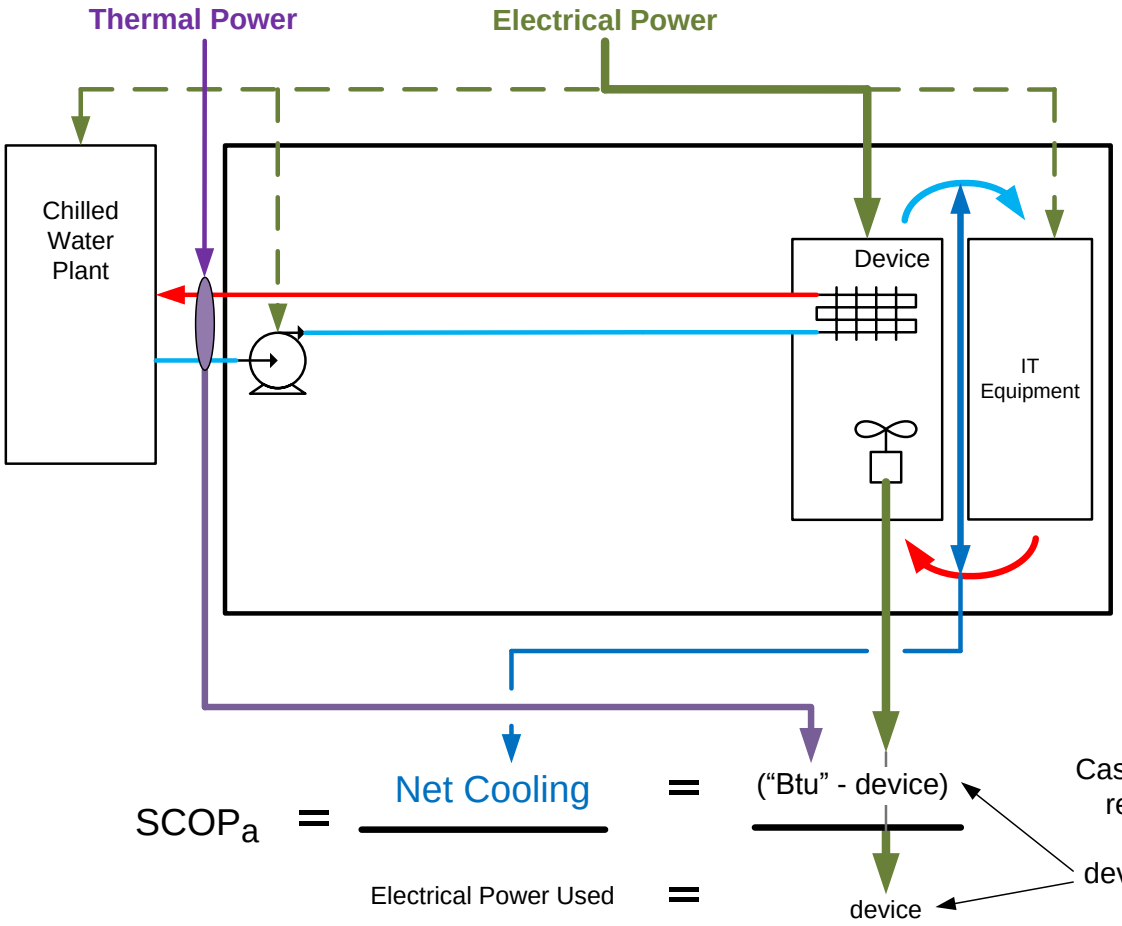


$$COEE = \frac{\text{Total Power for Cooling + IT Power}}{\text{IT Power}} = \frac{\text{chilled water plant + pumping + CDU + device + IT}}{\text{IT}}$$

Total Power Needed (cooling systems and IT) = IT x COEE

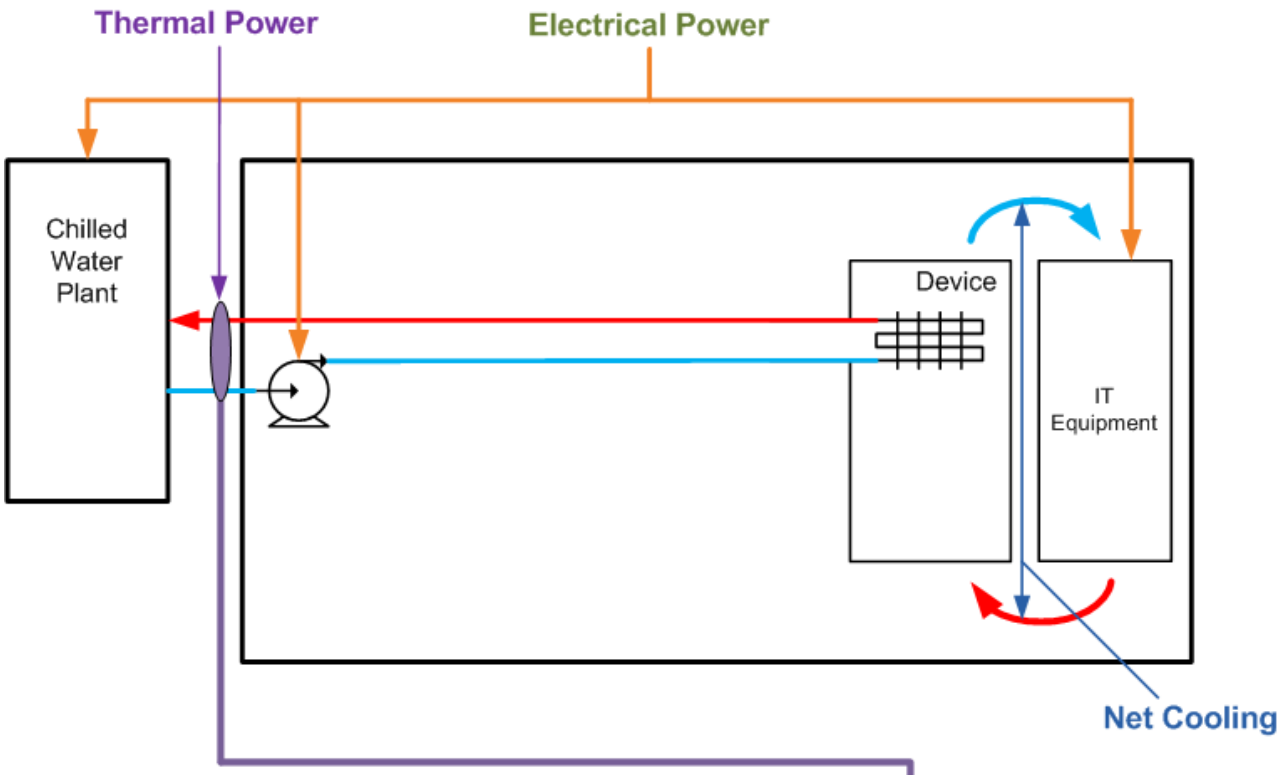
SCOPa Performance Metric

Sensible Coefficient of Performance "a" (SCOPa)
Cooling Device Consumes Power (fans)



Analysis

Performance Metric
Sensible Coefficient of Performance "a" (SCOPa)
Example: Passive Water Device without a CDU



$$SCOP_a = \frac{\text{Net Cooling}}{\text{Electrical Power Used}} = \frac{\text{"Btu"}}{zero} = \text{undefined}$$

Analysis

Data Reduction Assumptions

Building Side Chilled Water Distribution Pumping Power
- ASHRAE 90.1 75ft-head and 65% total pump efficiency

Water to Water CDU Estimates and Prorating
- Building Side – 75 gpm for 100kW
- Device Side –1.25kW pump power for 100kW
- Building Side Prorating – (IT power / 100% supported power) * 75 gpm * ASHRAE 90.1 specifications
- Device Side Prorating – (IT power / 100% supported power) * full CDU performance pump power

Refrigerant to Water CDU Prorating
- Building Side – 110 gpm for 160kW
- Device Side –0.821kW pump power for 160kW
- Building Side Prorating – (IT power / 100% supported power) * 110 gpm * ASHRAE 90.1 specifications
- Device Side Prorating – ((IT power / 100% supported power)/deployment factor(75%)) * 0.821kW

COEEc – Direct Calculation from SCOPc

credit – V. Mahaney (IBM)

When the server power = net cooling, COEEc can be directly calculated from SCOPc

SCOPc = Net Cooling (NC) / (Device + CDU + Feed + CWP)

Let A = (Device + CDU + Feed + CWP)

Rearranging: $1/ SCOPc = A / NC$

$NC / (SCOPc \times IT) = A / IT$

Given: $COEE = (A + IT) / IT = A/IT + 1$

Substitution: $COEE = (NC / (SCOPc \times IT)) + 1$

Rearranging: $COEE = (1 / SCOPc) \times (NC/IT) + 1$

If the net cooling equals the IT power the relation is simplified:

$COEEc = (1 / SCOPc) + 1$

SUN MD Water Temp. Stability