Energy Efficient HVAC Projects and Designs

Lee Eng Lock
Technical Consultant

Common Issues & Barriers to Energy Efficiency

- Gross Oversizing
- Can Afford poor efficiency on grossly oversize plant, can't afford right sized high efficiency plant
- Lack of transparency in the system
- One person can spread hysteria thoughout organisation, stop good ideas
- Lack of access to real operating sites and data to train operators, engineers, management
- **Lack of simple data which exists in many govt repositories eg electrical maximum demand vs installed transformer capacity (hospitals must now publish their rates for common procedures)**

Important issues for Owners and Engineers

- An engineer is someone who can do for 50 cents what any fool can do for $1.00
- Lifetime and spares/maintenance of equipment
- Noise and Vibration issues
- Minimum space and infrastructure used
- Practical environmental issues of concern to the country and the planet eg Global Warming
- Accurate data to support conclusions, not hand waving and sales talk

50 years of continuous operation……..

May 2011

CenTraVac™ chiller turns 50 years old, a testament to its quality design

The Trane CenTraVac™ chiller serving the Dallas Museum of Natural History recently turned 50 years old. Having received proper service and maintenance during its lifetime, the unit has run continuously for 50 years—that's over 438,000 hours! Alan Ash, systems applications leader for Trane's Texas/Oklahoma district, toasted the chiller alongside museum employees who celebrated the milestone. He credits the quality of the CenTraVac design for this unit's long life.



Employees of the Dallas Museum of Natural History recently celebrated the 50th birthday of the building's CenTraVac chiller.

Not Uncommon for Trane Chillers

Although the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defines the average life of a centrifugal chiller to be about 25 years, it's not uncommon for Trane chillers to far exceed that average.

"The average lifespan for Trane units is about 30 years, but that doesn't mean they can't last for 50 years or longer," Ash said. "Building owners will often replace units when they reach about 30 years of age—even if they work the way they're supposed to—because building owners want to invest in today's more energy-efficient equipment."

Ash sites another chiller about to turn 50 in Dallas' St. Paul Hospital. "These units just keep going, often longer than the competition's units, thanks to their quality design," Ash said. "The CenTraVac has a simpler, direct-drive design with no gears, less moving parts and only two bearings—in short, the unit was designed so there's less that can go wrong.

UWC Tampines:
An Example of Low pressure engineering

- Design already finished, Tender awarded
- Owner wanted Very High Efficiency HVAC at no increase in cost
- Main Civil construction already started
- Detailed design of air and water side, with heat load calculations
- Interesting negotiations with appointed contractor for new design
- UWC prepared to open the site and all data for benefit of Singapore architects, engineers, students, authorities
- Capital and Operating/maintenance Cost tightly controlled
- UWC is long term owner/tenant

From report for Seattle campus…..

Greening the Campus

Green Campus Strategies: 'Overdesign' Issue

"Would you wash your hands with a fire hose?" That's what we're getting with our designs."

Case Study

- ME consultant recommended 2000 tons of cooling
- Internal team recommended 300 tons (85% reduction).
- Actual use: building has not peaked above 40 tons

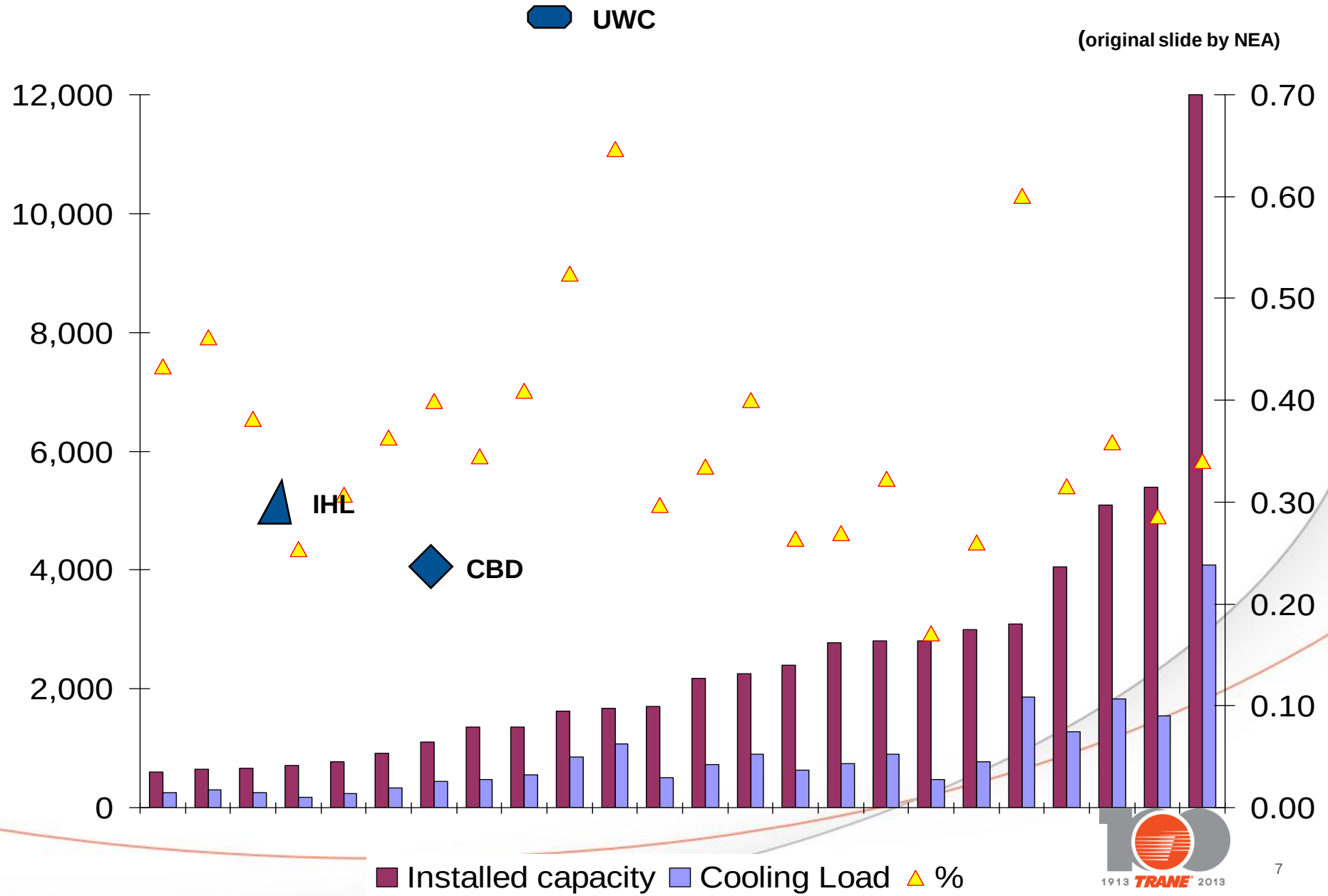
Analysis: ME consultant was off by a factor of 50.



"When it comes to energy, we often get the equivalent of a fire hose to wash our hands, if we're not careful."
- Richard Johnson

Installed Capacity vs Cooling Load

(original slide by NEA)



Typical overkill is educational…..



Cooling Tower



CWP



CHWP



Chiller 300 RT



Transformer 1,000 KVA



Cooling Tower



CWP



CHWP



Chiller 300 RT



Transformer 1,000 KVA



Cooling Tower



CWP



CHWP



Chiller 300 RT



Transformer 1,000 KVA

Total Electrical: 3000KVA

Total Cooling: 900RT (Actual Use= 250RT)

Electric Use: 350KVA (Best Practice= 200KVA)

Air Conditioning is Expensive

GIZMODO

51,[illegible]53 views, Jun 18, 2011 10:00 AM



MILITARY

Share Like 3K

Air Conditioning the Military Costs More Than NASA's Entire Budget

Kwame Opam —According to Steve Anderson, a retired brigadier general who served as Gen. Petraeus' chief logistician in Iraq, the Department of Defense spends $20 billion air conditioning tents and temporary structures for the military. That's more than NASA's entire $19 billion annual budget.

That cost comes out of the fuel needed to heat and cool tents on the front lines. However, the trucks that transport this fuel have become targets for IEDs used by the insurgency in Iraq and Afghanistan. According to Anderson, at least 1000 soldiers have been killed moving fuel.

Anderson believes that a simple solution would be to instead spray tents with polyurethane foam, kind of like the foam sealant you would use in your own home. In fact, an active $95 million contract to insulate tents is producing $1 billion in cost avoidance, proving it's both safer and greener than air conditioning the desert. Doing this while also searching for other energy-efficient solutions would save both money and lives.

The DOD just needs to hurry up and take on this kind of initiative. [The World via Grist, *Image Credit: mumbojumbo / Shutterstock.com*]

10xE: Factor Ten Engineering



Factor Ten Engineering (10xE) aims to help engineers, architects and their clients attack **resource-intensive** design problems, such as manufacturing processes, buildings and vehicles, using RMI's whole-system principles in order to produce fundamentally better results.

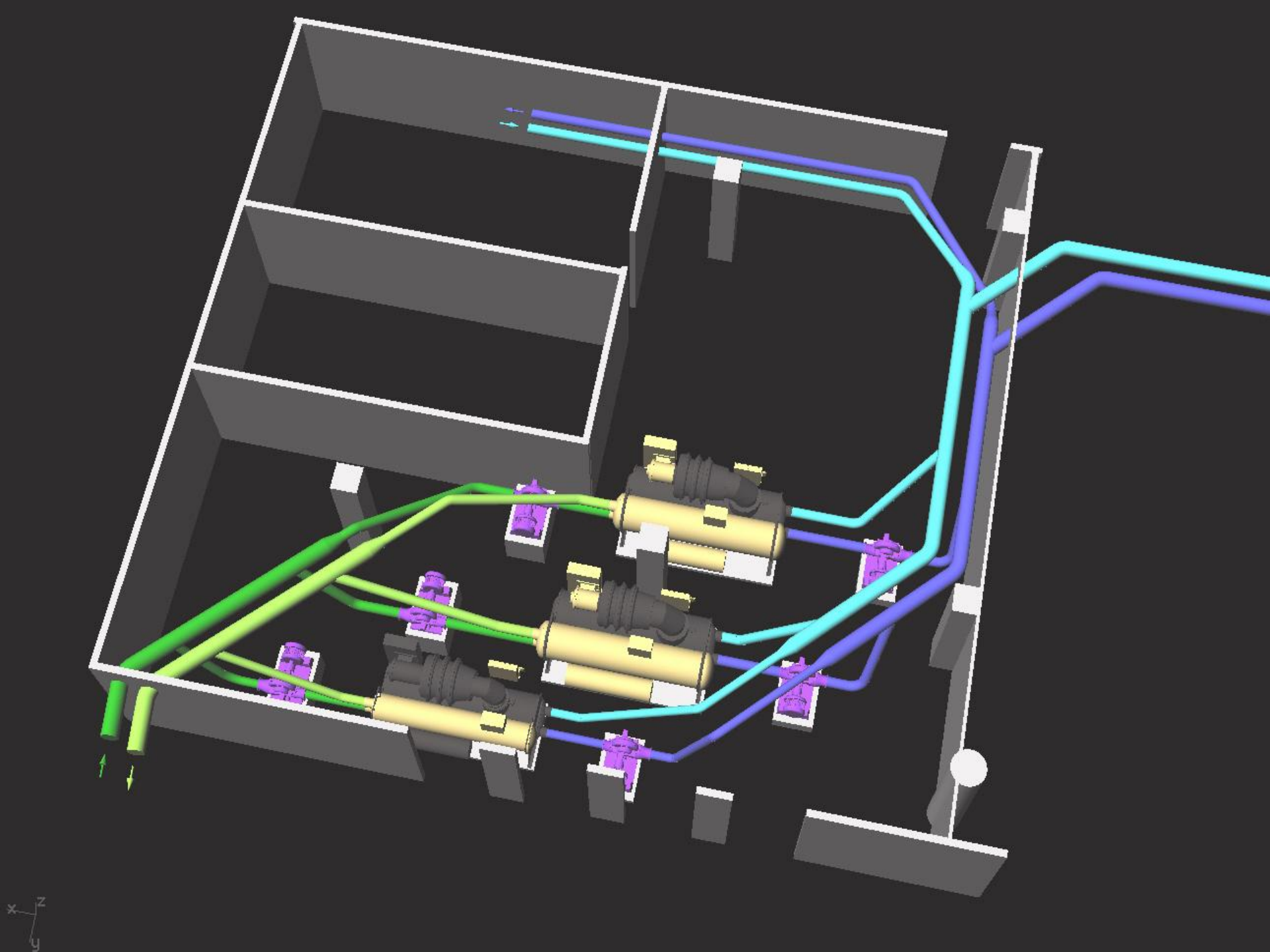
10xE currently offers design **principles** and a growing set of **case studies**—many of them derived from RMI's experience base. Rather than a rigid formula, 10xE is a set of ideas for shaping the design space and design approaches within it. These ideas will be used by those purchasing or approving design services, as well as design practitioners.

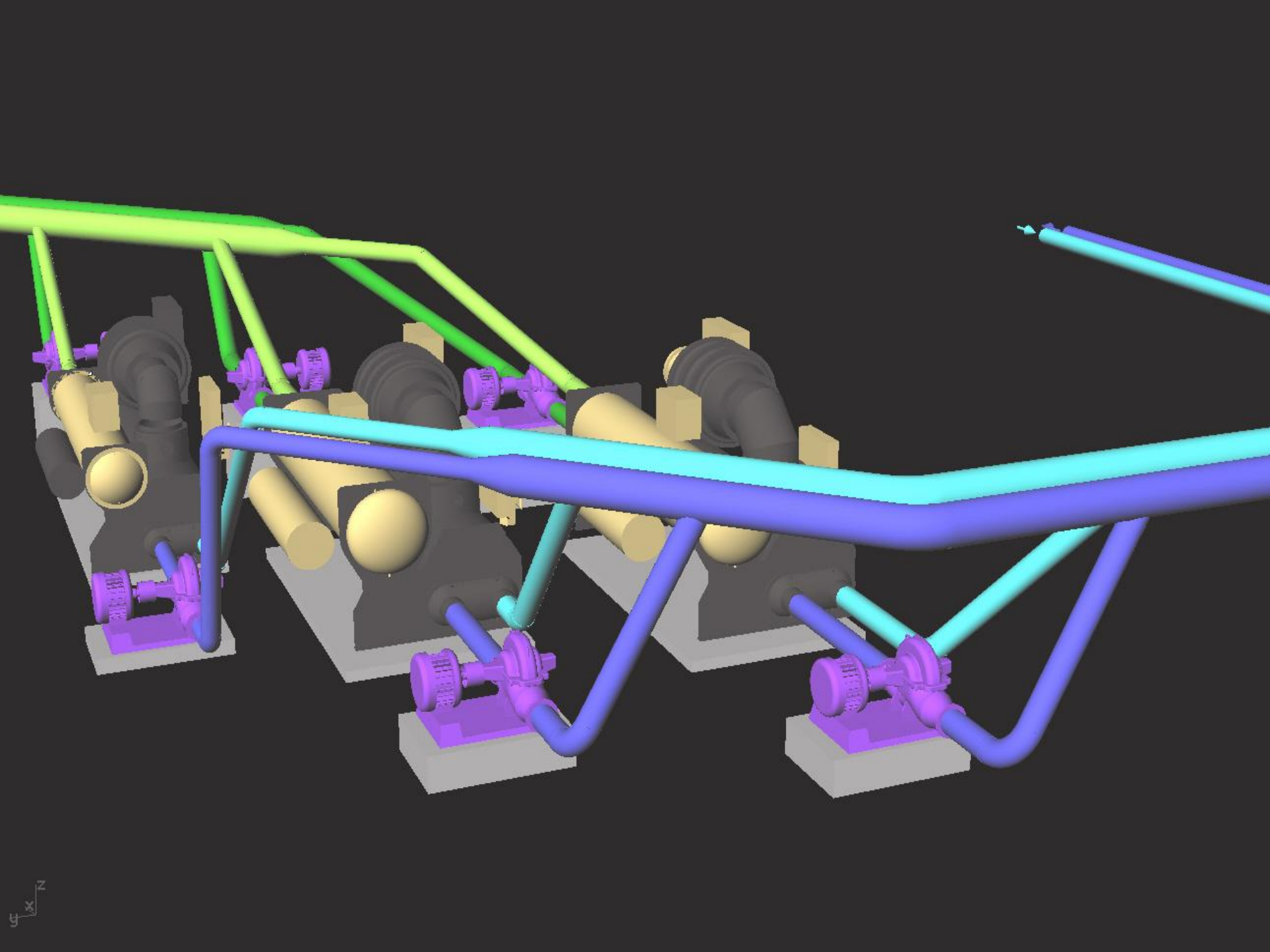
Watch video from Autodesk Sustainability Workshop on 10xE principles



(Watch more videos on **RMI TV**)





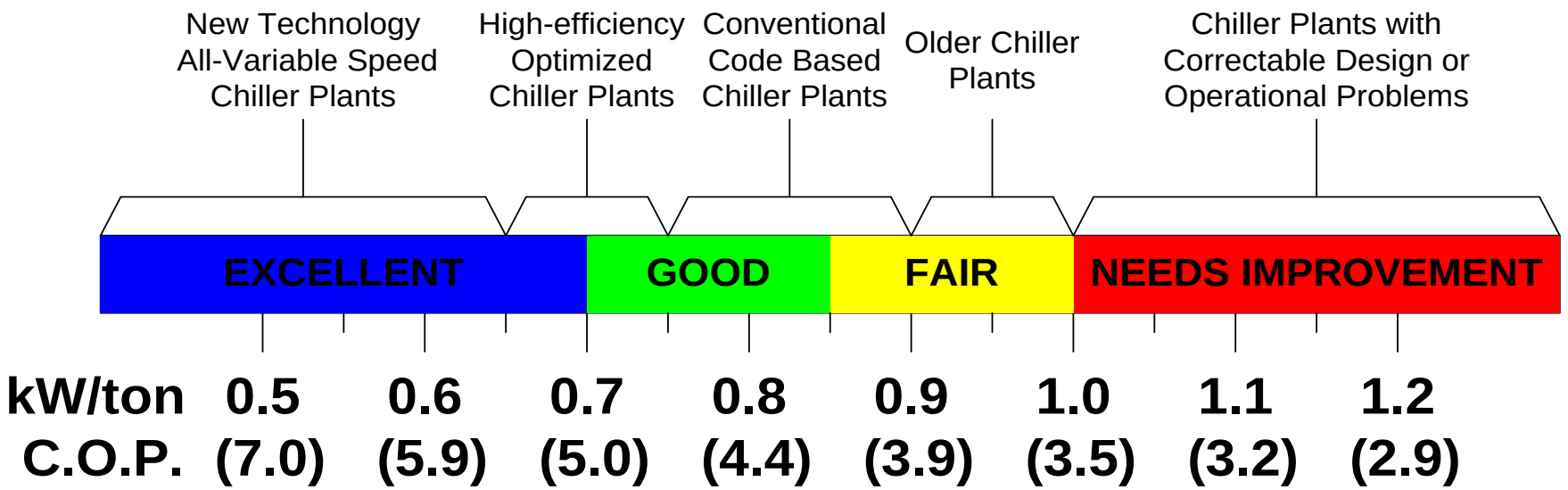




Good Copy



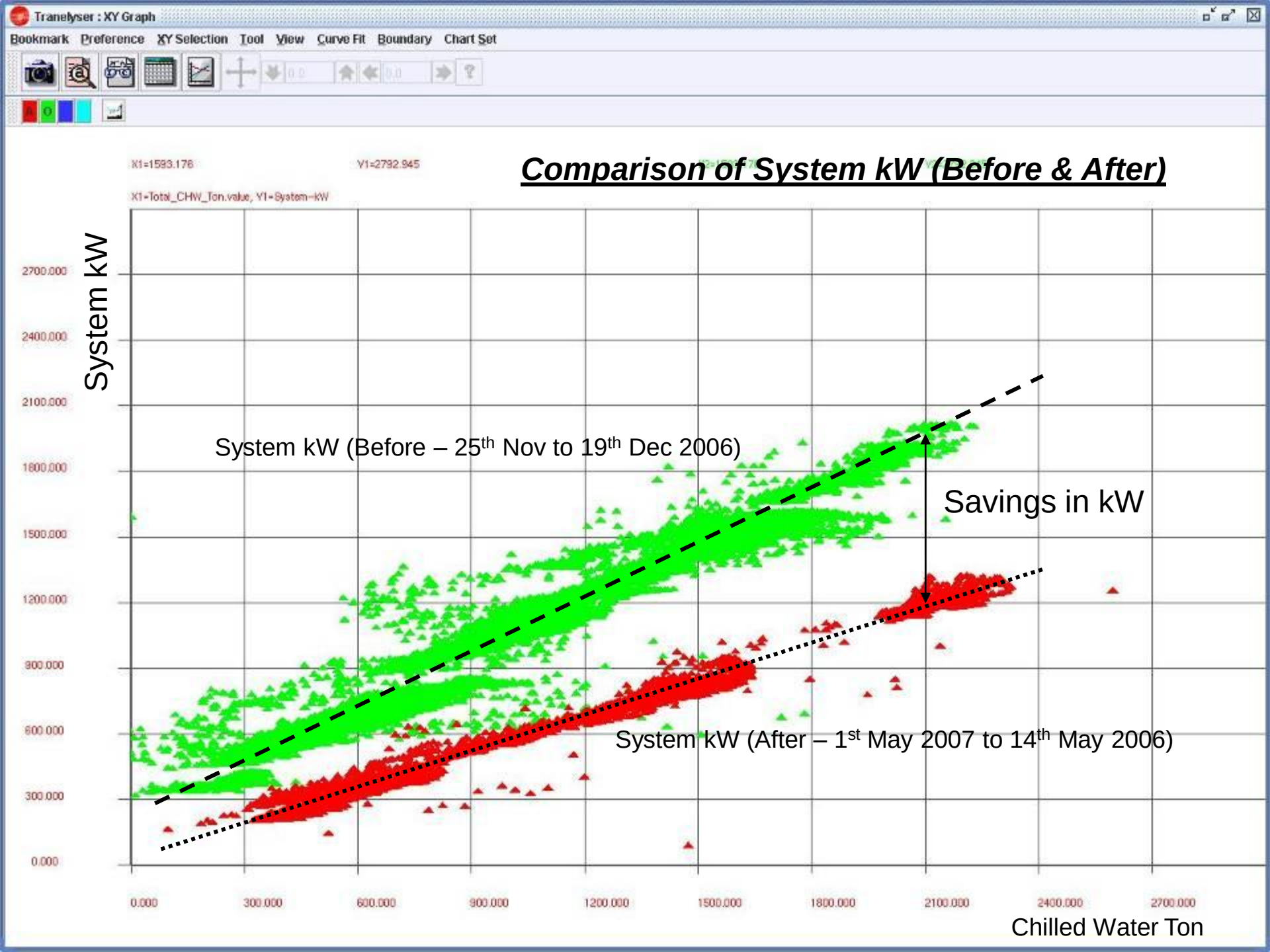
Ashrae--Chiller Plant Efficiency



AVERAGE ANNUAL CHILLER PLANT EFFICIENCY IN KW/TON (C.O.P.)

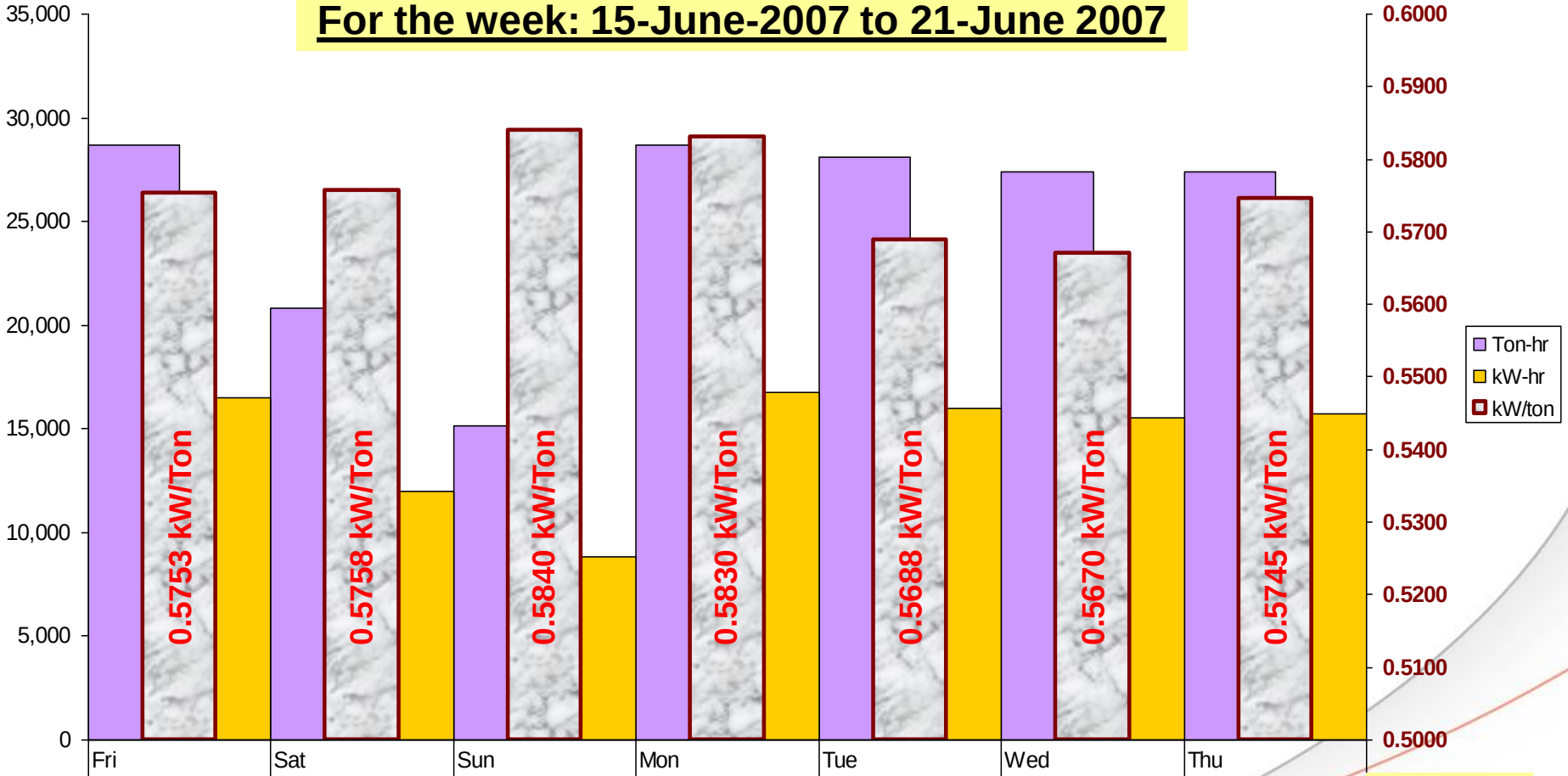
(Input energy includes chillers, condenser pumps, tower fans and chilled water pumping)

Based on electrically driven centrifugal chiller plants in comfort conditioning applications with 42F (5.6C) nominal chilled water supply temperature and open cooling towers sized for 85F (29.4C) maximum entering condenser water temperature and 20% excess capacity. Local Climate adjustment for North American climates is +/- 0.05 kW/ton


Tranelyser : XY Graph
Bookmark Preference XY Selection Tool View Curve Fit Boundary Chart Set
X1=1593.176 Y1=2792.945
X1=Total_CHW_Ton.value, Y1=System-kW
Comparison of System kW (Before & After)
System kW
2700.000
2400.000
2100.000
1800.000
1500.000
1200.000
900.000
600.000
300.000
0.000
System kW (Before – 25th Nov to 19th Dec 2006)
Savings in kW
System kW (After – 1st May 2007 to 14th May 2006)
0.000
300.000
600.000
900.000
1200.000
1500.000
1800.000
2100.000
2400.000
2700.000
Chilled Water Ton

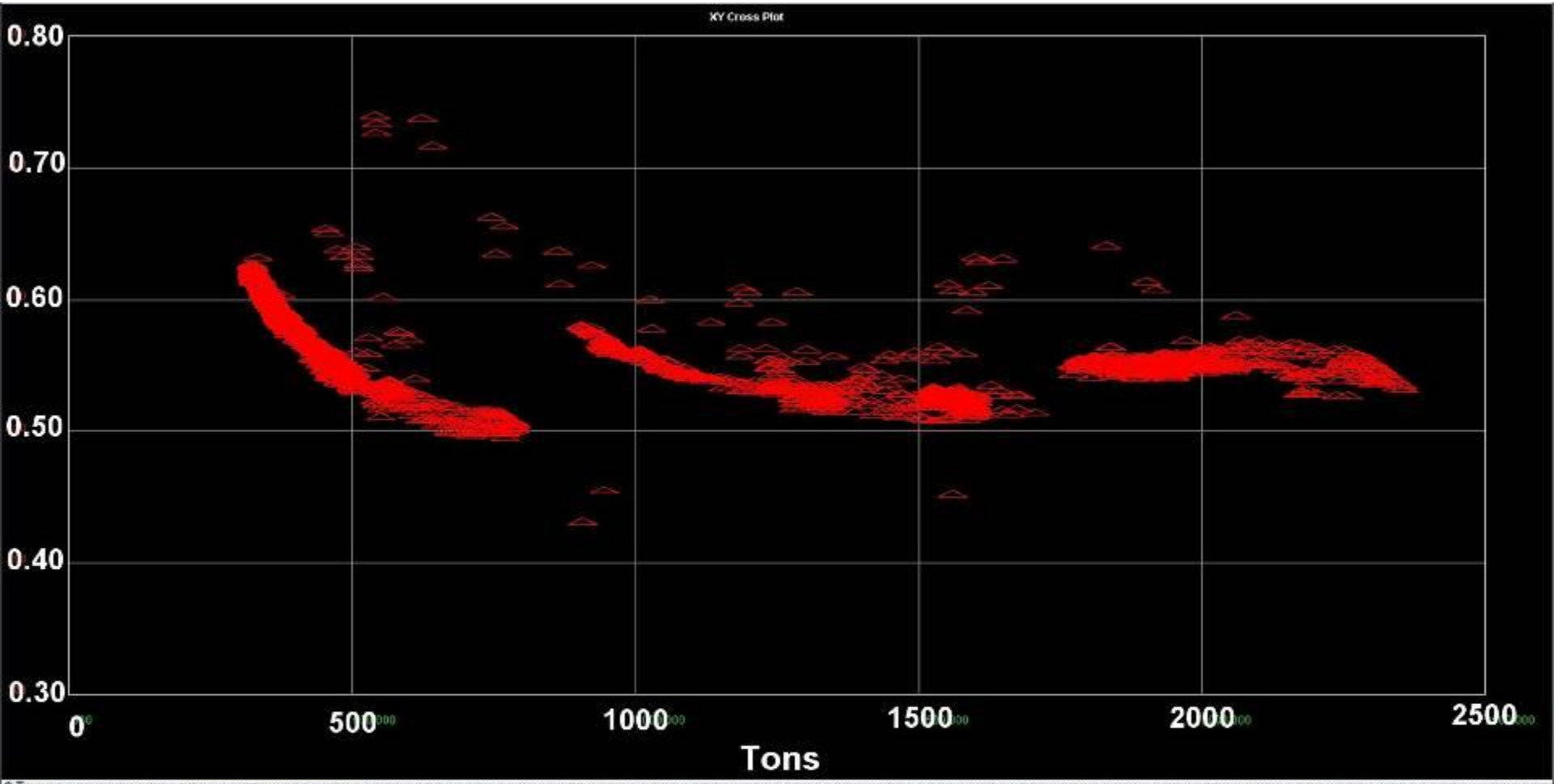
Singapore Post Centre
System Efficiency (kW/Ton) – Daily/Weekly Analysis

For the week: 15-June-2007 to 21-June 2007



	Fri 15-Jun-07	Sat 16-Jun-07	Sun 17-Jun-07	Mon 18-Jun-07	Tue 19-Jun-07	Wed 20-Jun-07	Thu 21-Jun-07	Average
Ton-hr	28,652	20,811	15,133	28,707	28,071	27,379	27,404	25,165
kW-hr	16,483	11,982	8,838	16,736	15,968	15,525	15,744	14,468
kW/ton	0.5753	0.5758	0.5840	0.5830	0.5688	0.5670	0.5745	0.5755

System kW/RT
SingPost 18~20 Feb 2008



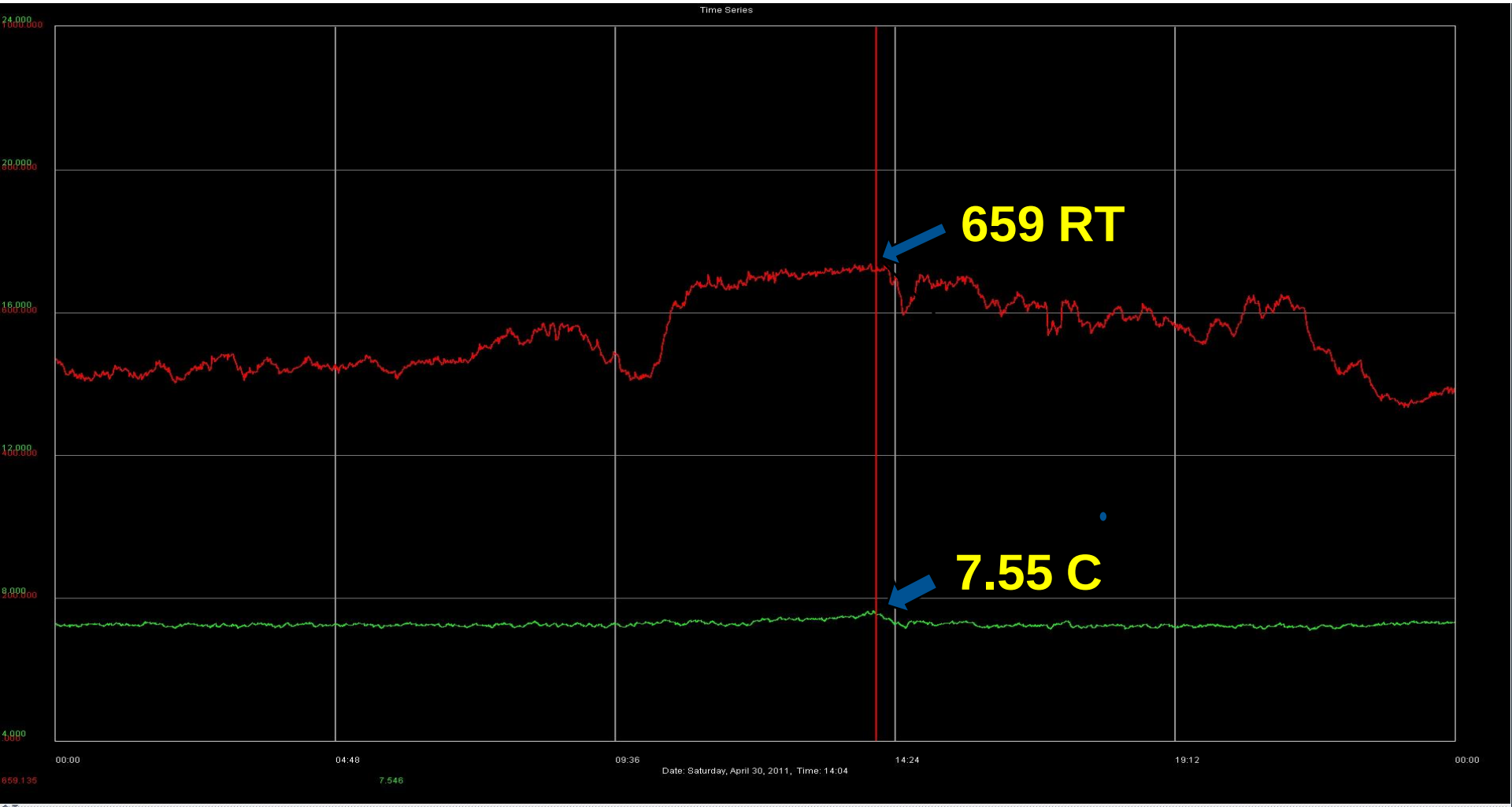
Feb 2008 Clear S.M.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

No.	Point Name	Start Date(mm..	End Date(mm-..	High Limit	Low Limit	LSL	USL	Sampling Rate	View Rate	Folder+Point
☑	System_Eff.value	01-01-2008	02-20-2008	0.8	0.3	20.0000	23.0000	1	1	/home/SingPost/Folder2008/+Effenciency+..
☐	Total_CHW_Ton.value	01-01-2008	02-20-2008	2500	0	20.0000	23.0000	1	1	/home/SingPost/Folder2008/+Tonnage+9,0..

Open Bookmark | Save Bookmark | Delete Bookmark | Remove Point(s) | Save Graph | Save Data | View Graph(s)

600 RT Chiller at 110 % Capacity



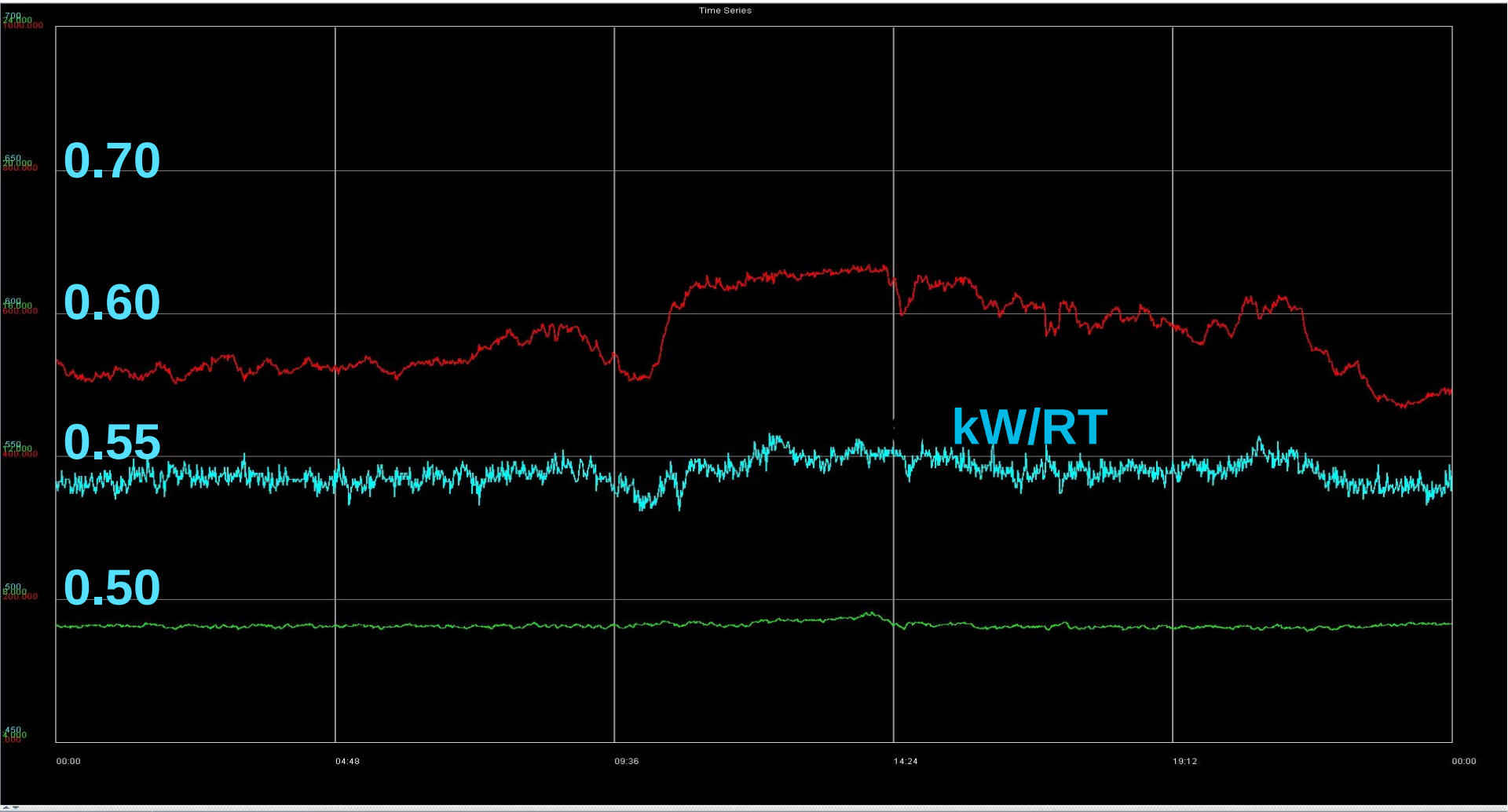
Apr 2011 Clear S.M.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

No.	Point Name	Start Date(mm...	End Date(mm-...	High Limit	Low Limit	LSL	USL	Sampling Rate	View Rate	Folder+Point
☐	Total_CHW_Ton.value	01-01-2011	06-20-2011	1000	0.0000	20.0000	23.0000	1	1	/home/Galen/Folder2011/+TotalTon+4.0-To...
☑	wwrchwst.value	01-01-2011	06-20-2011	24	4	20.0000	23.0000	1	1	/home/Galen/Folder2011/+Header+4.0-wwr...

Open Bookmark | Save Bookmark | Delete Bookmark | Remove Point(s) | Save Graph | Save Data | View Graph(s)

System kW/RT for 1 x 600 RT



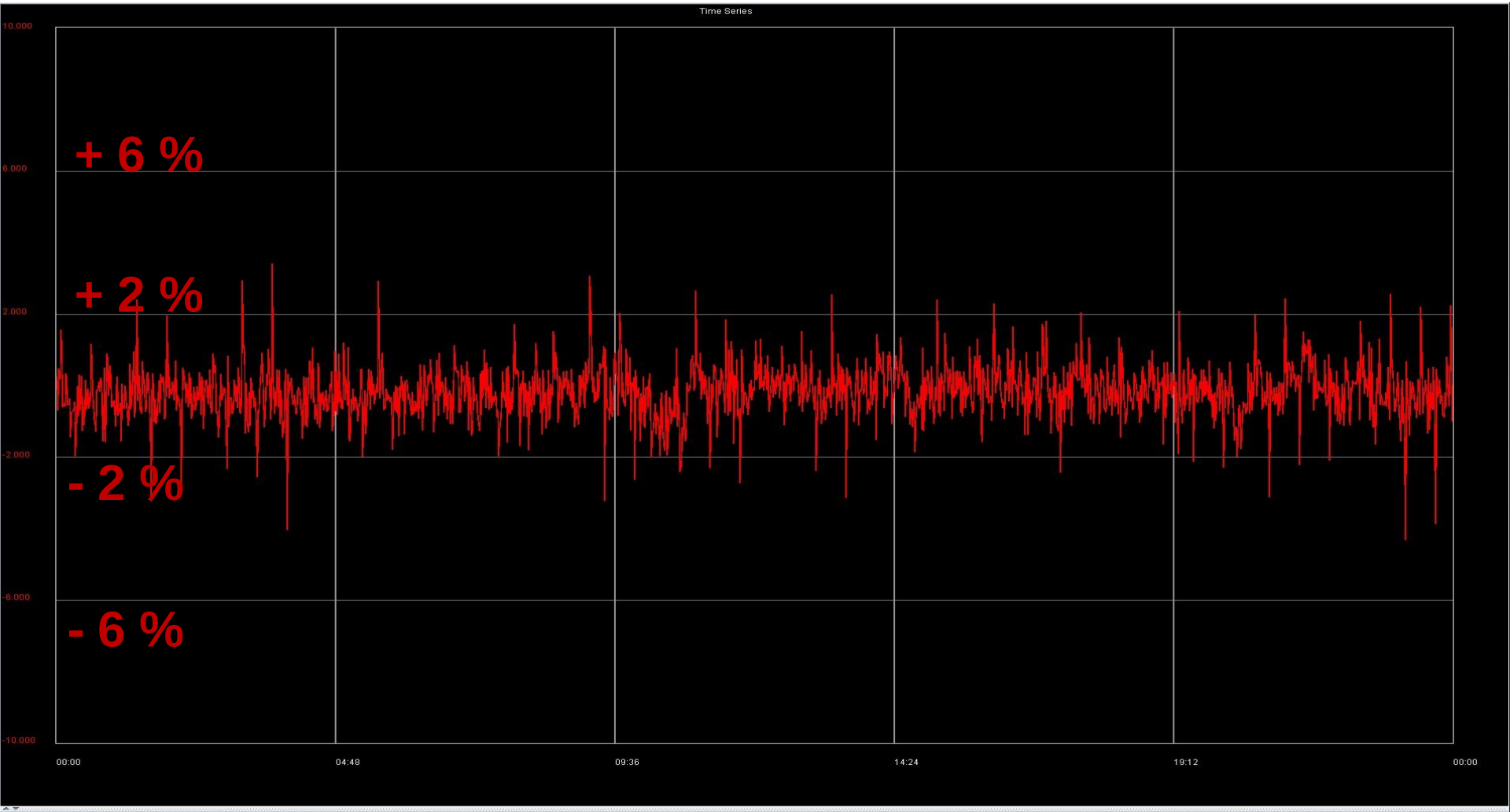
No.	Point Name	Start Date(mm...	End Date(mm-...	High Limit	Low Limit	LSL	USL	Sampling Rate	View Rate	Folder+Point
	Total_CHW_Ton.value	01-01-2011	06-20-2011	1000	0.0000	20.0000	23.0000	1	1	/home/Galen/Folder2011/+TotalTon+4,0-To...
	wwrchwst.value	01-01-2011	06-20-2011	24	4	20.0000	23.0000	1	1	/home/Galen/Folder2011/+Header+4,0-wwr...
✔	EFF_System.value	01-01-2011	06-20-2011	0.7	0.45	20.0000	23.0000	1	1	/home/Galen/Folder2011/+Efficiency+4,0-E...

Apr 2011 Clear S.M.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Open Bookmark | Save Bookmark | Delete Bookmark | Remove Point(s) | Save Graph | Save Data | View Graph(s)

Heat Balance for 1 x 600 RT

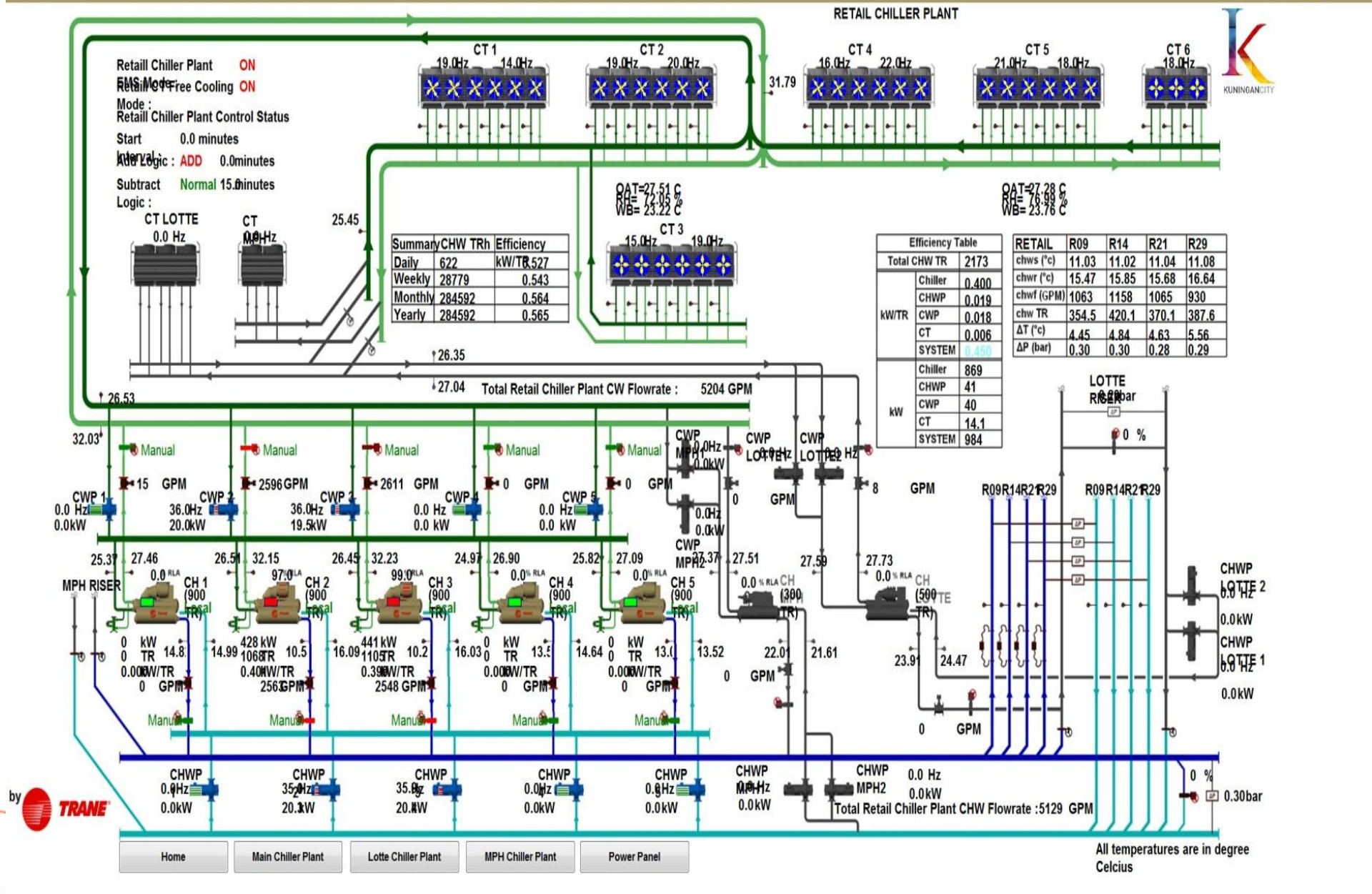


Apr 2011 Clear S.M.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

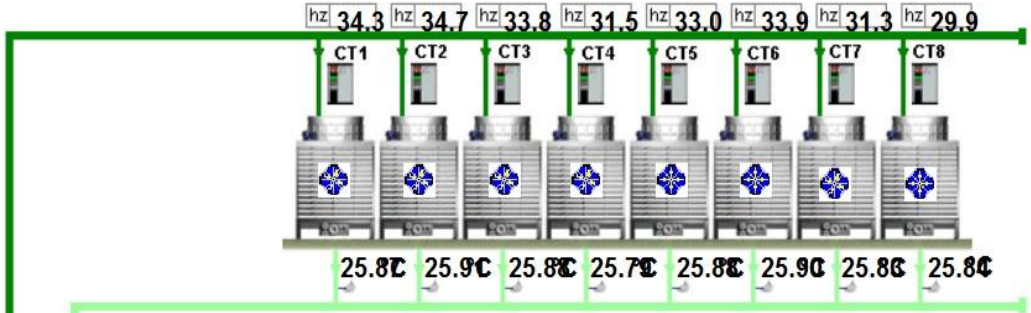
No.	Point Name	Start Date(mm...	End Date(mm-...	High Limit	Low Limit	LSL	USL	Sampling Rate	View Rate	Folder+Point
☑	CH4_HeadBal.value	01-01-2011	06-20-2011	10.0000	-10.0000	20.0000	23.0000	1	1	/home/Galen/Folder2011/+HeatBalance+3,...

Open Bookmark | Save Bookmark | Delete Bookmark | Remove Point(s) | Save Graph | Save Data | View Graph(s)


RETAIL CHILLER PLANT
Retaill Chiller Plant ON
Retaill Free Cooling ON
Mode :
Retaill Chiller Plant Control Status
Start 0.0 minutes
Interval :
Add Logic : ADD 0.0minutes
Subtract Normal 15.0minutes
Logic :
CT 1
CT 2
CT 3
CT 4
CT 5
CT 6
CT LOTTE
CT
OAT=27.51 C
RH= 72.05 %
WB= 23.22 C
OAT=27.28 C
RH= 76.99 %
WB= 23.76 C
Summary CHW TRh Efficiency
Daily 622 kW/TR 0.527
Weekly 28779 0.543
Monthly 284592 0.564
Yearly 284592 0.565
Efficiency Table
Total CHW TR 2173
kW/TR Chiller 0.400
CHWP 0.019
CWP 0.018
CT 0.006
SYSTEM 0.450
kW Chiller 869
CHWP 41
CWP 40
CT 14.1
SYSTEM 984
RETAIL R09 R14 R21 R29
chws (°c) 11.03 11.02 11.04 11.08
chwr (°c) 15.47 15.85 15.68 16.64
chwf (GPM) 1063 1158 1065 930
chw TR 354.5 420.1 370.1 387.6
ΔT (°c) 4.45 4.84 4.63 5.56
ΔP (bar) 0.30 0.30 0.28 0.29
Total Retail Chiller Plant CW Flowrate : 5204 GPM
Total Retail Chiller Plant CHW Flowrate :5129 GPM
LOTTE RISER
MPH RISER
CWP 1
CWP 2
CWP 3
CWP 4
CWP 5
CWP MPH1
CWP MPH2
CWP LOTTE1
CWP LOTTE2
CH 1 (900 TR)
CH 2 (900 TR)
CH 3 (900 TR)
CH 4 (900 TR)
CH 5 (900 TR)
CH (300 TR)
CH (500 TR)
CHWP 1
CHWP 2
CHWP 3
CHWP 4
CHWP 5
CHWP MPH1
CHWP MPH2
CHWP LOTTE 2
CHWP LOTTE 1
R09 R14 R21 R29
Manual
0.30bar
All temperatures are in degree Celcius
Home
Main Chiller Plant
Lotte Chiller Plant
MPH Chiller Plant
Power Panel

SCADA COMM. STATUS: UP

CHILLER PLANT SCHEMATIC



Weather Station

Dry Bulb Temp (°c)	28.15
Wet Bulb Temp (°c)	23.31
RH (%)	68.61

Average CWS Temp (°c)	25.9
WB + Approach Temp (°c)	25.8
Approach Temp (°c)	2.5

System Summary

TOTAL CHW TON	571
TOTAL CH KW	259.00
TOTAL CHWP KW	13.61
TOTAL CWP KW	14.97
TOTAL CT KW	15.66
TOTAL SYSTEM KW	304.61

EFFICIENCY (KW/TON)	
CHILLER	0.454
CHWP	0.024
CWP	0.026
CT	0.027
TOTAL SYSTEM	0.531

CWP 1 — hz 0.0

cws (°c)	28.22
cwr (°c)	31.06
cwf(lps)	0.00
cwf(usgpm)	0.00
cw Ton	0.00

CWP 2 — hz 50.0

cws (°c)	25.75
cwr (°c)	30.95
cwf(lps)	106.53
cwf(usgpm)	1690.99
cw Ton	658.87

CWP 3 — hz 0.0

cws (°c)	27.89
cwr (°c)	30.98
cwf(lps)	0.00
cwf(usgpm)	0.00
cw Ton	0.00

CH1

chws(°c)	22.17
chwr(°c)	15.41
chwf(lps)	0.00
chwf(usgpm)	0.00
chw Ton	0.00
kW/Ton	0.00

CH2

chws(°c)	8.10
chwr(°c)	13.64
chwf(lps)	86.53
chwf(usgpm)	1373.55
chw Ton	570.88
kW/Ton	0.45

CH3

chws(°c)	22.31
chwr(°c)	14.06
chwf(lps)	0.00
chwf(usgpm)	0.00
chw Ton	0.00
kW/Ton	0.00

CHWP 1 — hz 0.0

CHWP 2 — hz 43.4

CHWP 3 — hz 0.0

chws(°c) 8.09

CHWS

Bypass Valve

47.04kpa

DP 0.47bar

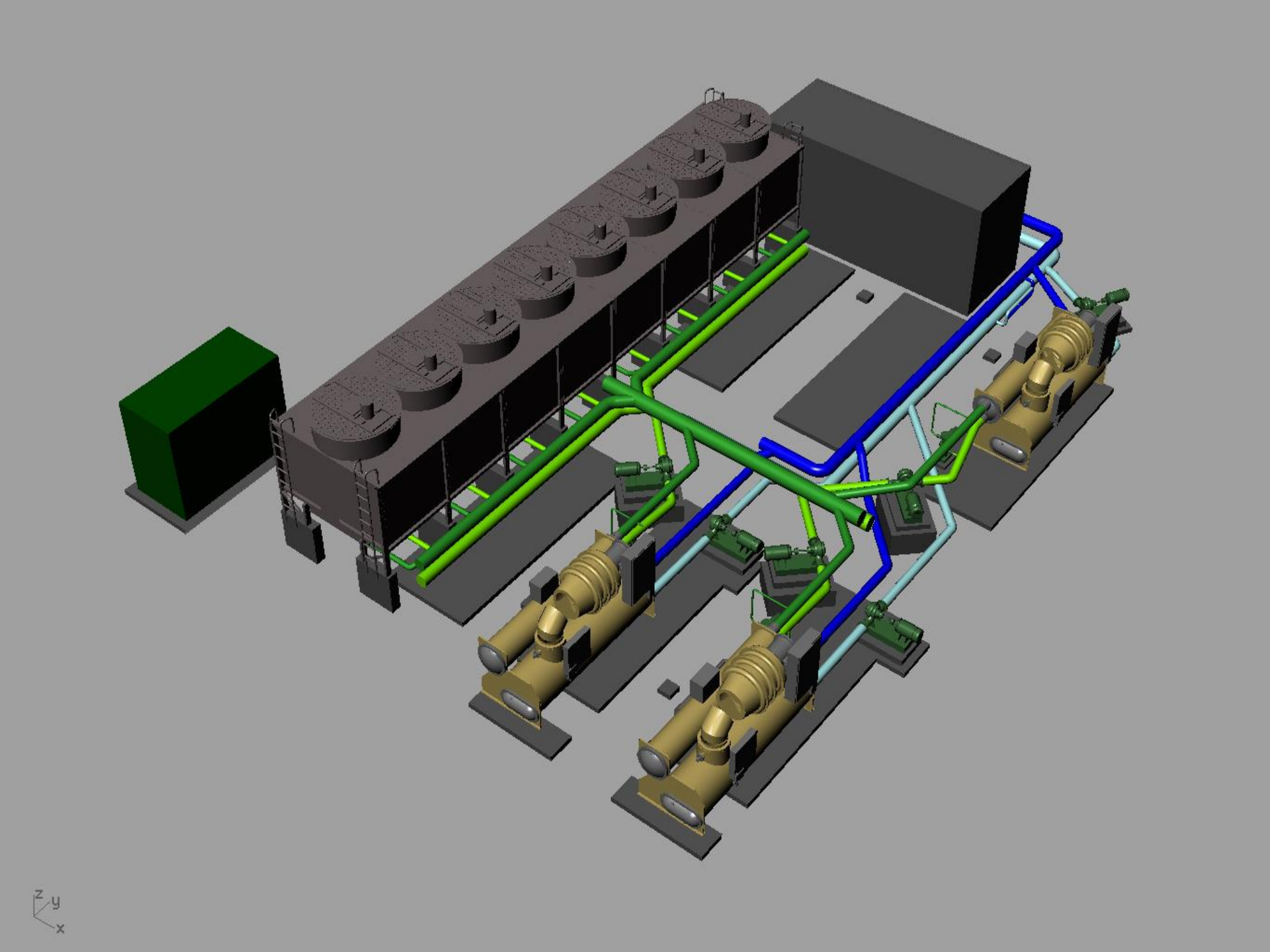
CHWR

chwr(°c)	13.52
chwf(lps)	81.16
chwf(usgpm)	1283.19

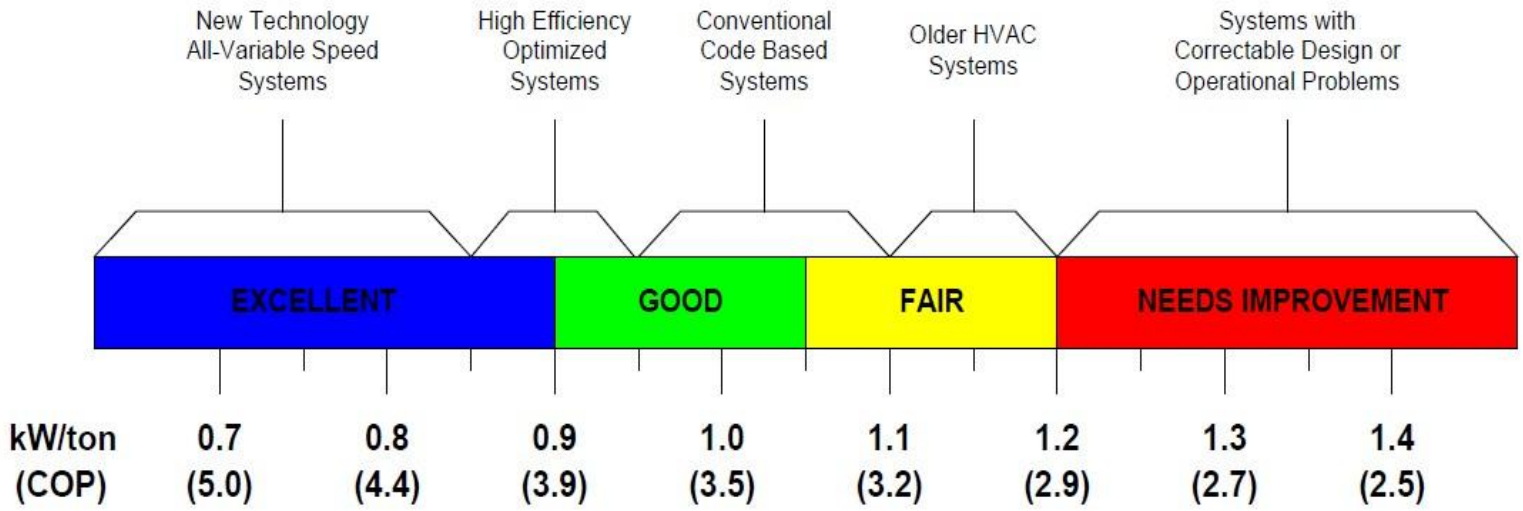
CHW Riser

chws(°c)	8.09
chwr(°c)	13.52
chwf(lps)	81.16
chwf(usgpm)	1283.19
chw Ton	523.19

Diff Pressure Setp	0.45
Chilled Water Cutln Setp	9.0
Chiller Cut-Out Temp Setp	8.5
Cut-in1 Ton Setpt:	550.0
Cut-in2 Ton Setpt:	1100.0
Cut-Out1 Ton Setp	560.0
Cut-Out2 Ton Setp	1000.0


z
y
x

Air + Water Side System Efficiency



AVERAGE ANNUAL HVAC EFFICIENCY IN KW/TON

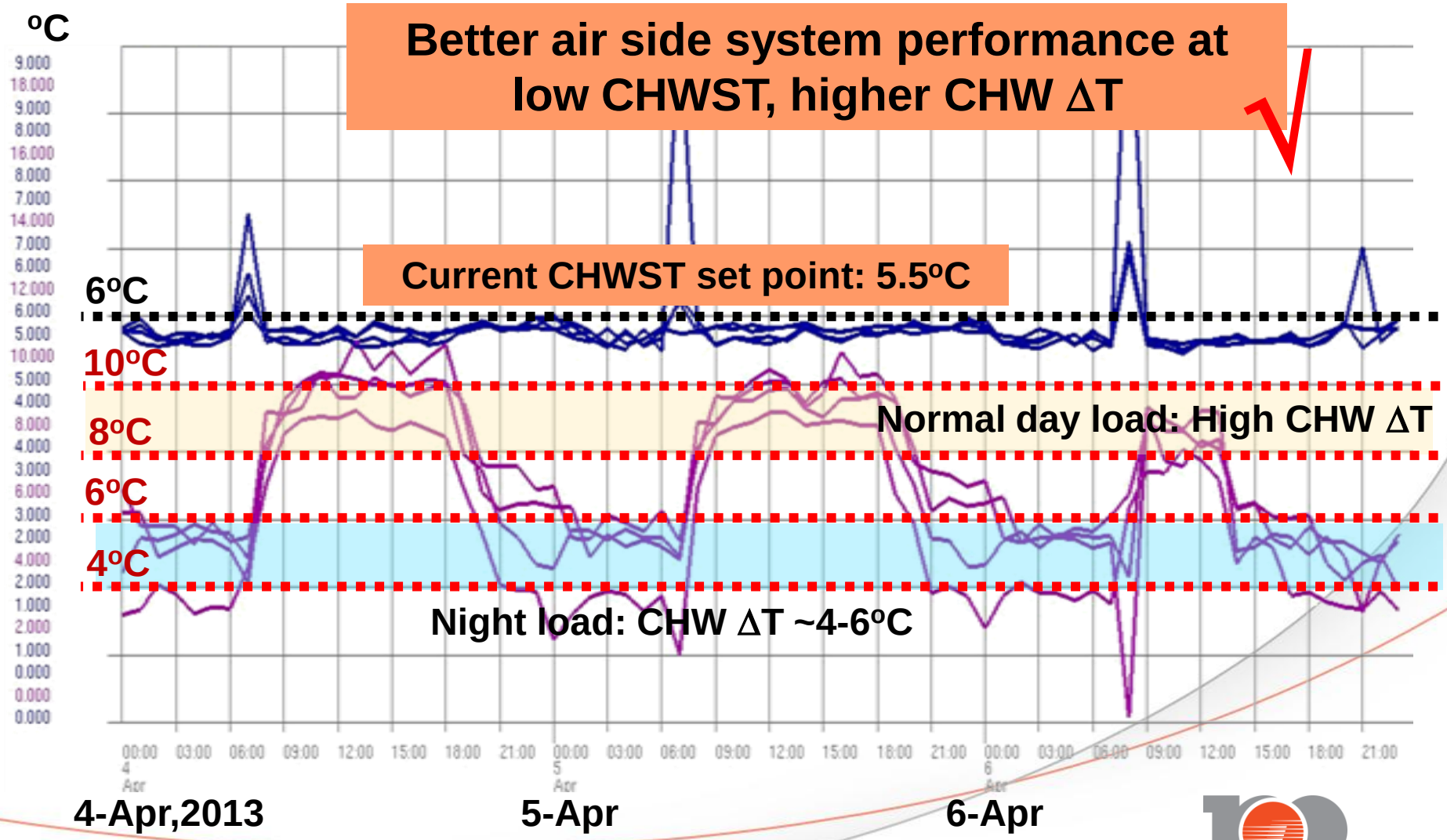
(Input energy includes all chillers, chilled water pumps, condenser water pumps, cooling tower fans, supply and return air-handler fans, and exhaust fans)

Based on electrically driven centrifugal chillers in comfort cooling applications with 42F nominal chilled water supply temperature and open cooling towers sized for 85F maximum entering condenser water temperature.

Figure 2: Total HVAC Energy Use Spectrum.

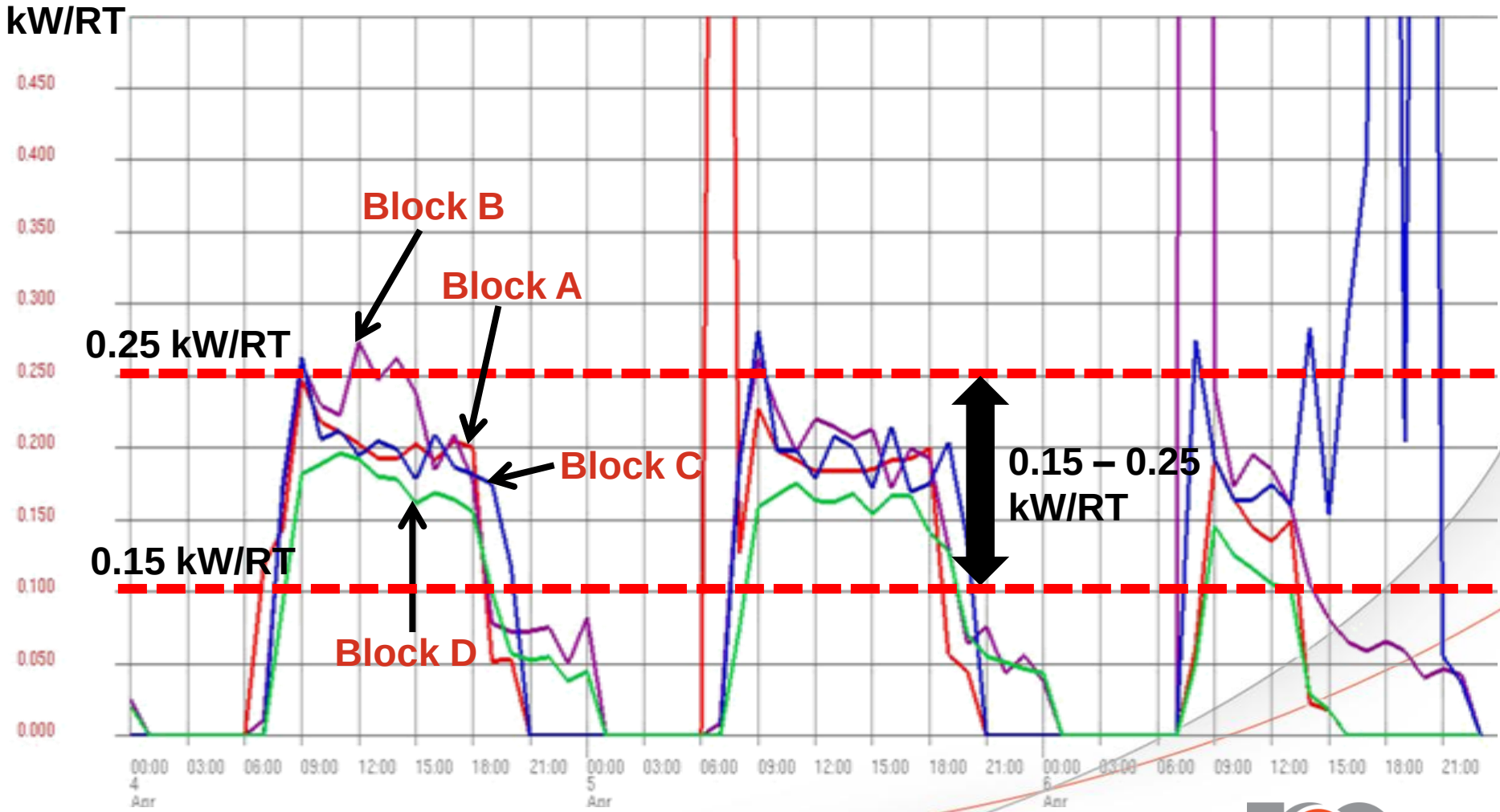
Improved Air Distribution System

Current CHWS Temperature and CHW ΔT

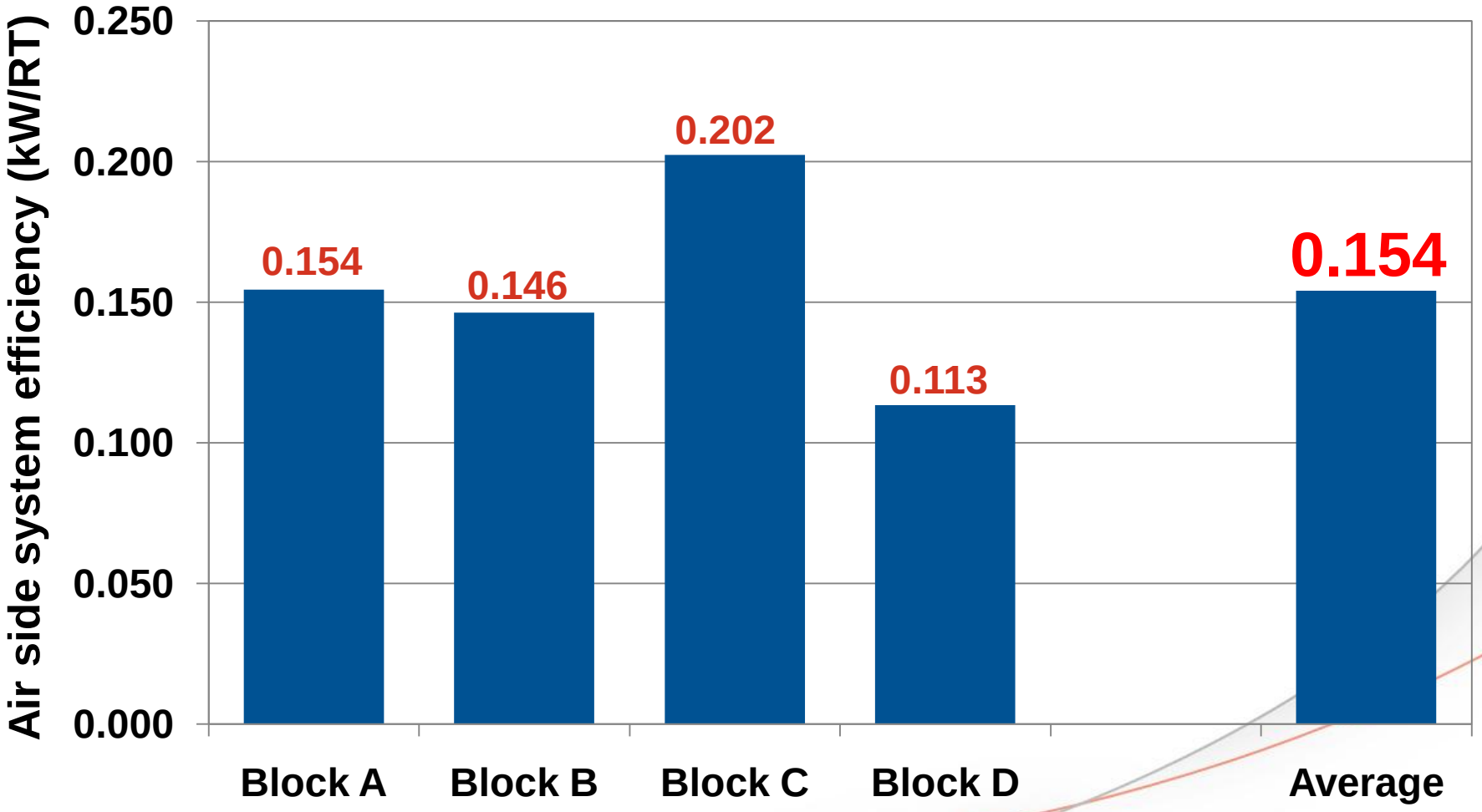


Improved Air Distribution System

Average System Efficiency for Individual Blocks



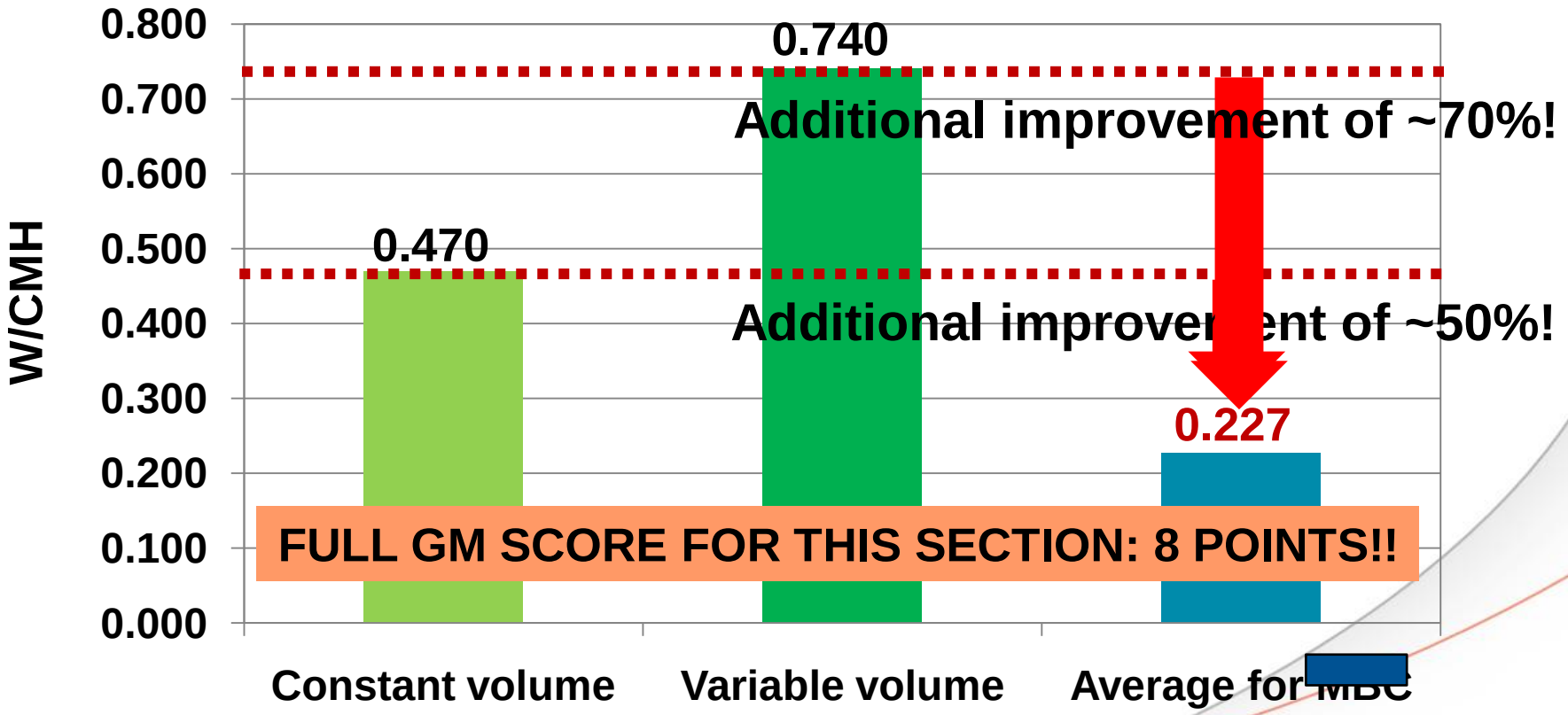
Improved Air Distribution System
Average System Efficiency <0.20 kW/RT



Improved Air Distribution System

>50% Better than baseline as per GM-ENRB V3.0

BCA Green Mark for Existing Non-Residential Buildings (Version 3.0)



Notes:

Baseline as per GM-ENRB v3.0 – Fan power limitation in air conditioning system (allowable nameplate motor power); The factor of 400 CFM/RT is used for conversion of air side system efficiency from kW/RT → W/CMH

The Shoemaker's children are barefoot..

- Which ministry is least green? The one that runs climate change
- Whitehall is criticised for its carbon footprint as an energy efficiency report on 267 government offices shows that one in three has lowest rating……
  One in three government buildings has the lowest possible rating for energy efficiency, according to official figures seen by the Observer, which show the Department for Energy and Climate Change is one of the worst offenders
-
- guardian.co.uk,17May2009



Defra head office

Energy efficiency rating: E

Annual C02 emissions: 1,322 tonnes of carbon

The government estimates that almost a fifth of all carbon dioxide emissions in the UK are caused by non-residential buildings. The findings are likely to embarrass the government, which has pledged to make all new public buildings zero carbon by 2018. The Department for the Environment's head office recorded an E

Photograph: Alisdair Macdonald/Rex Features





Performance metric : 9.58 secs/100 meters

MEWR HQ Retrofit

Target 0.60 kW/RT at
+- 0% tolerance @ 6.7degC

~ 800 RT centrifugal

Refrigerant R-123a

Real-time one-minute web access to key parameters for qualified engineers and institutions?

Duplicate/Triplicate sensors for high accuracy long term studies?



IDEAS SOUGHT FOR BETTER DESALINATION – Aug 2007 Business Times, Singapore

- The Environment and Water Resources Ministry is looking for better ways to make clean water out of seawater.
- Its Environment and Water Industry Development Council is asking all local and overseas institutes of higher learning, research institutes and private sector companies to submit proposals for technologies which can desalinate seawater using a total energy consumption of not more than 1.5 kWh per m3 of water produced - ***less than half the energy*** now used by other technologies.
- The closing date is Nov 2. For more information. go to www.mewr.gov.sg/ewi .

Cheaper way found to make sea water drinkable—Straits Times, 24June2008

…...Siemens Water Technologies team yesterday bagged a S$4 million grant from the Environment and Water Industry Development Council (EWI)…. used electricity instead of high pressure or heat to remove salt from sea water, and produced a cubic metre of pure drinking water on 1.5 kilowatt-hours (kWh) of power.

.

….PUB technology director Harry Seah described the novel approach as one which 'blows convention away'.

….Prof Lui …. 'This is what we call disruptive technology - and it's exactly what we're looking for.'

News of this new technology is a prelude to the cutting-edge technologies that will be on show at the Singapore International Water Week, which officially opens today.

.

Latest NEA guidelines for energy audits in Singapore—June 2009

- Chilled water plant system performance

- System performance measurement error shall not exceed ±5%._*This implies the use of high accuracy thermometry and calorimetry.*
- Detailed method statement explaining how the required degree of accuracy was achieved with the instruments and data acquisition hardware employed.
- Data required to establish system performance must be sampled and acquired simultaneously and continuously for a minimum of 1 week at one-minute intervals.

Simple Guide to retrofit success

- Ask for 1 minute trend data for chiller plant parameter eg tons, kw/ton, flow rates, kw, pressures, temperatures, ambient temp and wet bulbs for 3 months in spreadsheet format
- Ask for previous performance contract examples with bank guarantees
- Ask for online internet access to previous projects
- Ask for ARI-550 accuracy of +-5% for chiller plant efficiency, using as guides ASHRAE 14P & 22.
- Ask for 0.60 kW/RT or better for chiller plant

The Evolution of truth…

- All truth passes through three stages.
- First, it is ridiculed.
- Second, it is violently opposed.
- Third, it is accepted as being self-evident.

Arthur Schopenhauer
German philosopher (1788 - 1860)

"There are only two mistakes one can make along the road to truth; not going all the way, and not starting." -- Buddha



Thank You