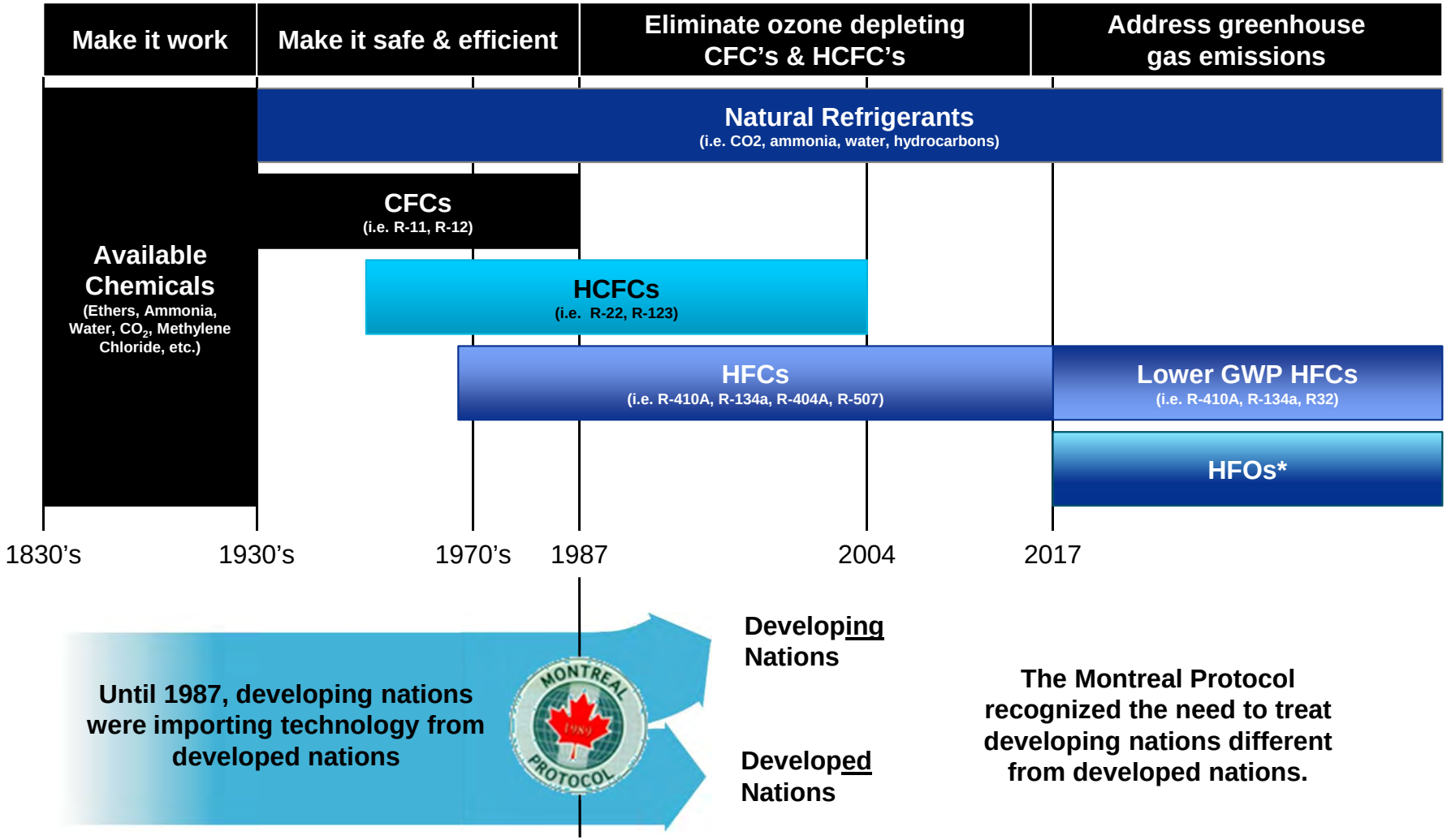


Technology & Solutions for Energy Efficient Healthcare Facilities

Johnson Controls

Industry Updates:
Refrigerant Legislation Overview and Update

Legislation has driven the refrigerant options.

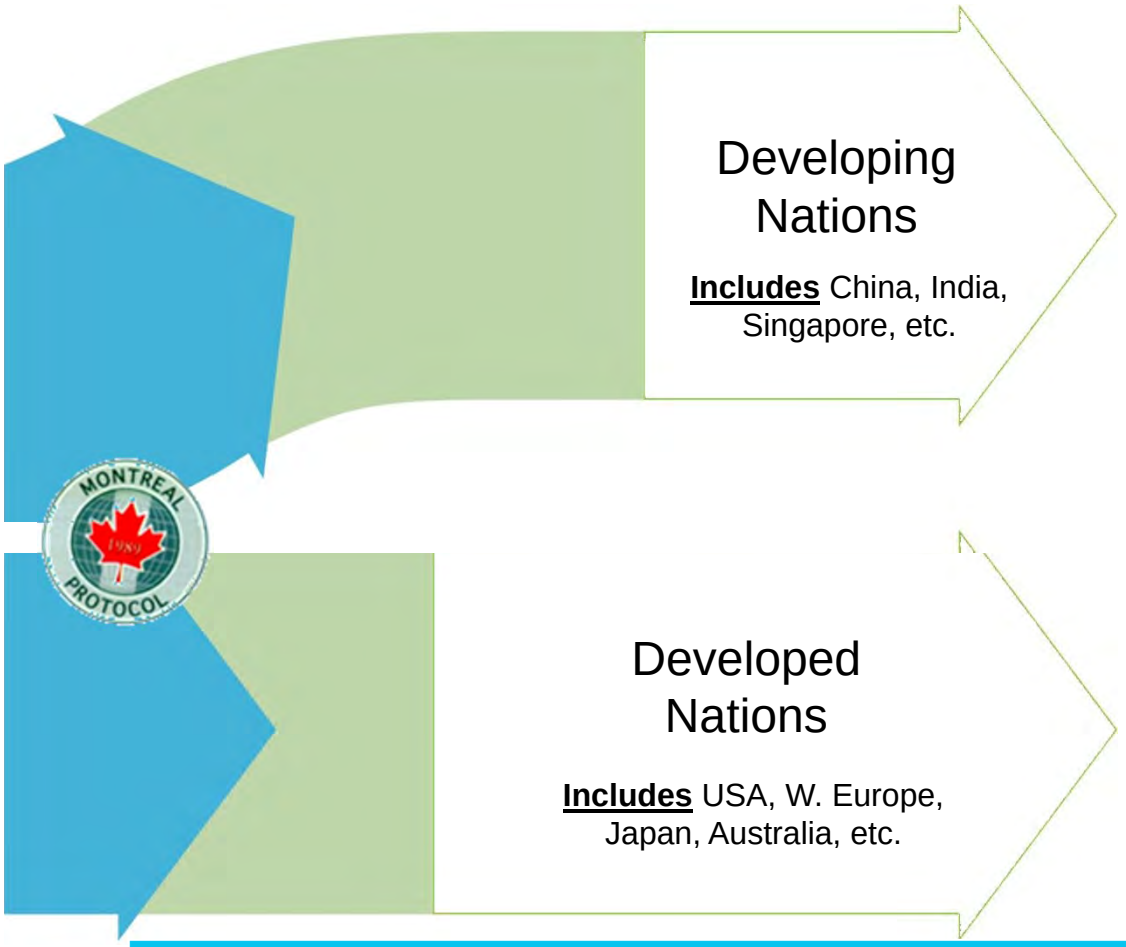


The Montreal Protocol recognized the need to treat developing nations different from developed nations.

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Globally, are less aligned on priorities than in the past.
All are likely to agree, but on different timelines.



- Committed to meeting Montreal Protocol commitments
- Expediting HCFC phase out under MP.
- Financial aid for implementation
- Import restrictions on HCFC from 2015. Phase out started.

- Near completion of meeting all obligations for ozone
- Shifting focus towards greenhouse gas emissions
- Shorter timelines
- Provide funding for developing nations

HCFC no more a viable option for both developed and developing nations

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Developed & Developing Countries – Initiatives ahead of MP



2006 HCFC phase out (elimination) steps

2015 – Saudi Arabia bans New equipment with HCFC

2015- R22 New model introduction ban China

2015 –HCFC Equipment import ban by Thailand, Indonesia, India &others (HCFC phase out mgmt. plan)

2000- New Equipment using HCFCs (e.g. R22, R123) banned in EU

2010- Virgin HCFCs (e.g. stockpiles R22, R123) banned in EU – only reclaimed

2020- HCFC production (e.g. R123, R22) banned

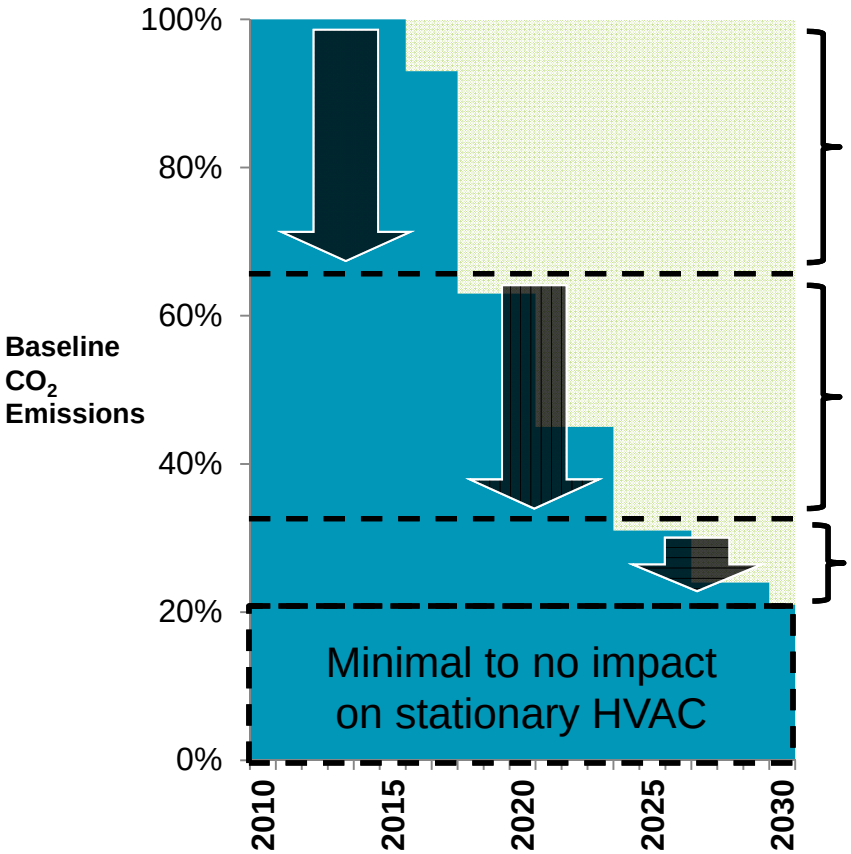
2015- All HCFCs reclaim use prohibited In EU

HCFC 123 supply getting scarce and manufacturers looking for alternatives

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Europe F-gas regulation –No impact on Chillers





Mobile AC
R134a → R1234yf or CO_2



Commercial Refrigeration
Eliminate high GWP emissions (R404A & 507)



Small Charge Systems (Charge <3Kg)
Switch over to low GWP (<750)



Stationary HVAC, chillers, etc.
Focus is on operation, maintenance & containment

R-134a and R-410A are not affected - Stationary air conditioning

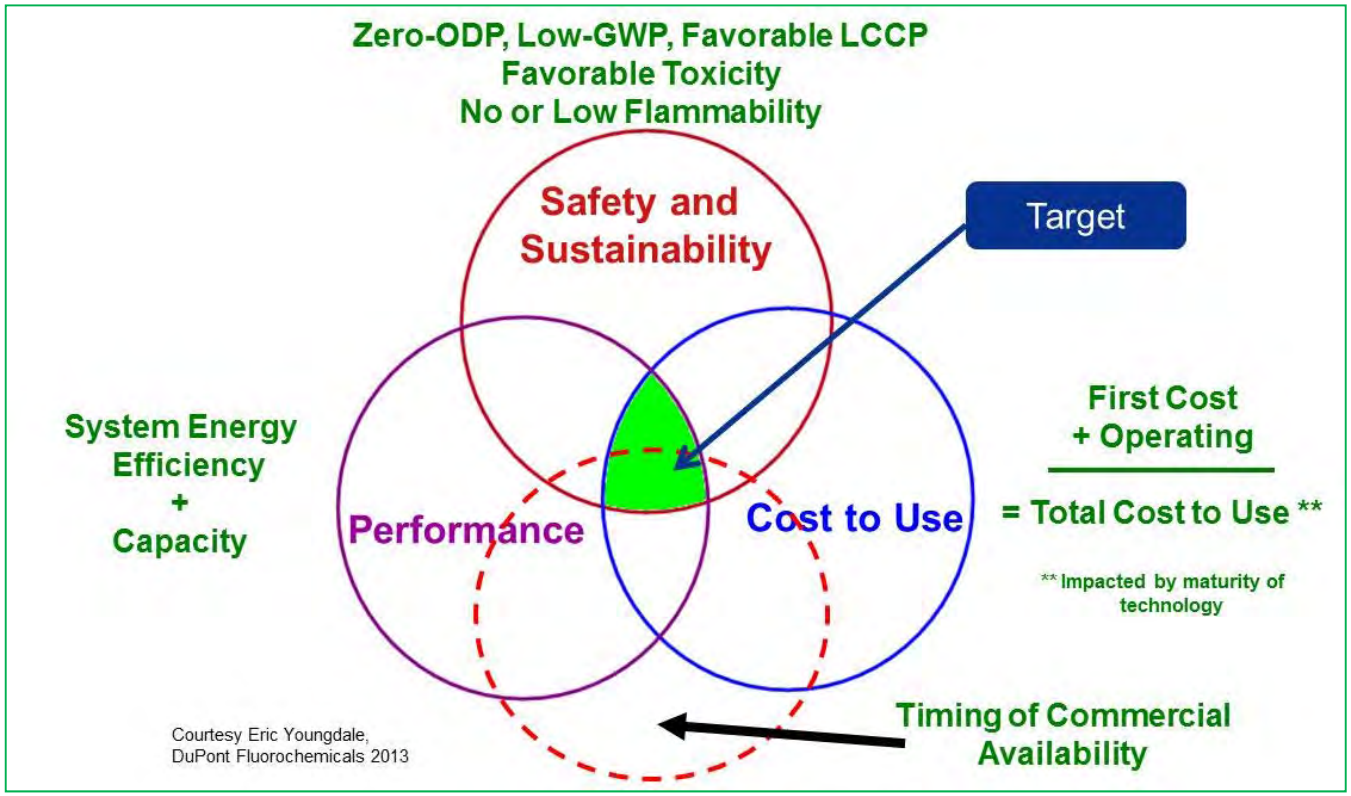
* F-gas is abbreviated to refer to greenhouse gases with fluorine in them

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Green Refrigerant Selections

Favorable Life Cycle Climate Performance [LCCP]

- LCCP considers all warming impacts
- Direct: Manufacture, transport, leakage risk
- Indirect: CO_2 emissions related to energy consumption of the product.



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Safety; local availability; product energy efficiency, system first cost, operating costs; and reliability all factor into proper refrigerant choice

	Low Pressure		Medium Pressure					High Pressure		
	HCFC 123	HFO 1233zd	HCFC 22	HFC 134a	HFO 1234yf	HFO 1234ze	HC's*	HFC 410A	HFC 32	CO2
Non-Flammable & Low toxicity		✓	✓	✓				✓		
Available				✓	✓		✓	✓	✓	✓
Efficient	✓	✓	✓	✓		✓	✓	✓	✓	
Cost Effective	✓		✓	✓			✓	✓	✓	
Reliable	✓		✓	✓			✓	✓		✓

* Hydrocarbons such as propane

R134a is the best solution as on date. HCFC123 though meets the Green Mark requirement, may not be available in near future.

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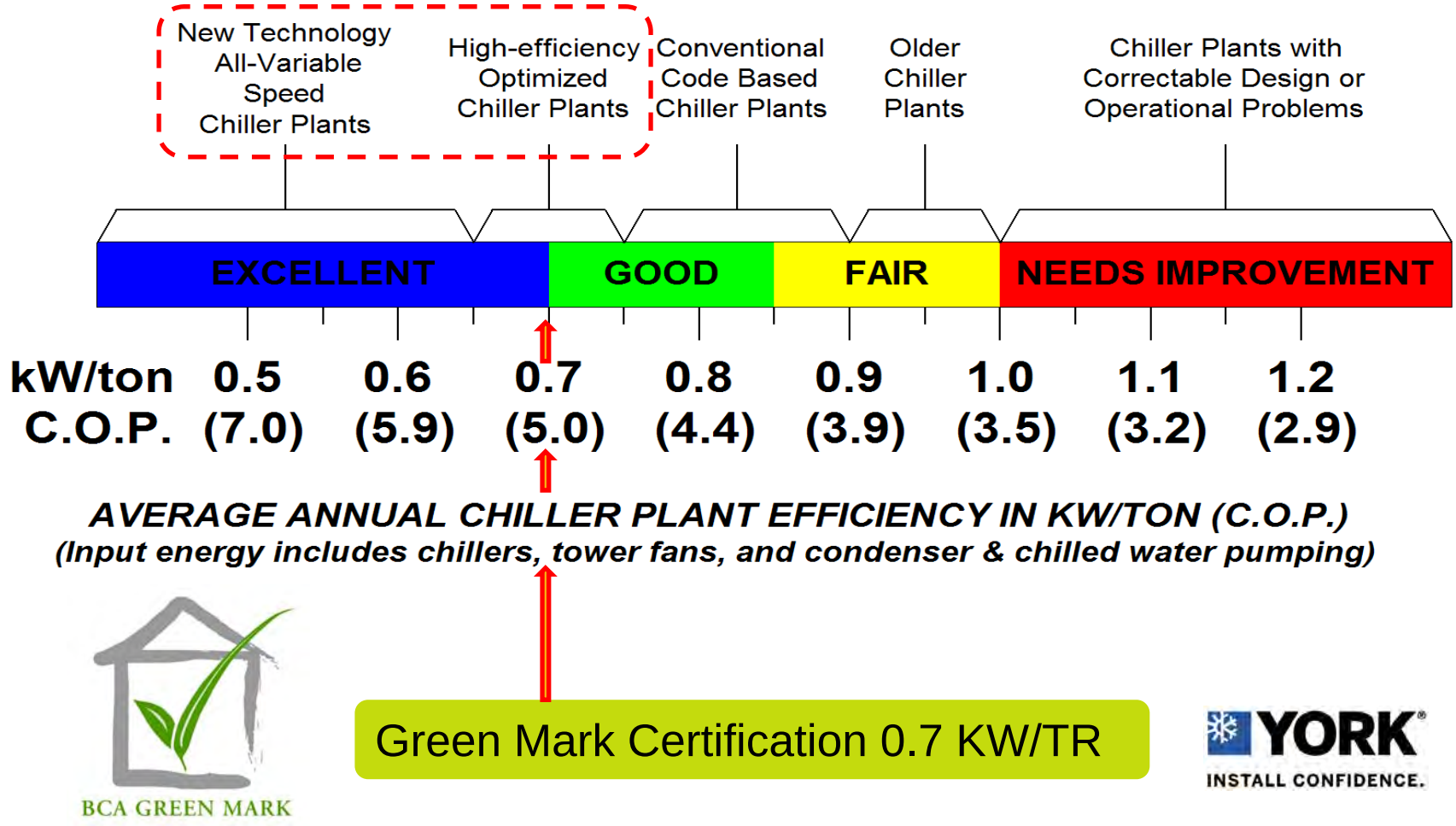
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Energy Efficiency
Green Mark HC-1.0
Healthcare Facility



BCA GREEN MARK

Plant room efficiency requirement



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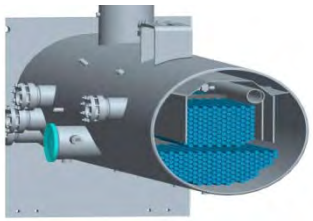
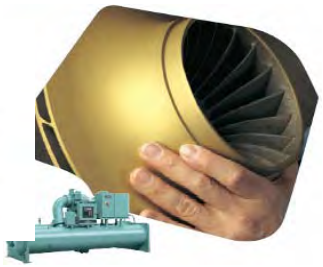
Chiller Technologies:
Enhancing Efficiency

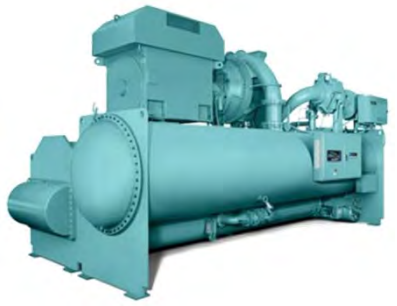
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Despite using more environmentally benign, yet less efficient refrigerants, chiller efficiency has improved significantly

In recent decades, significant gains in chiller efficiency at full & part load through advances in HX, compressor, motor, driveline, and economizers.





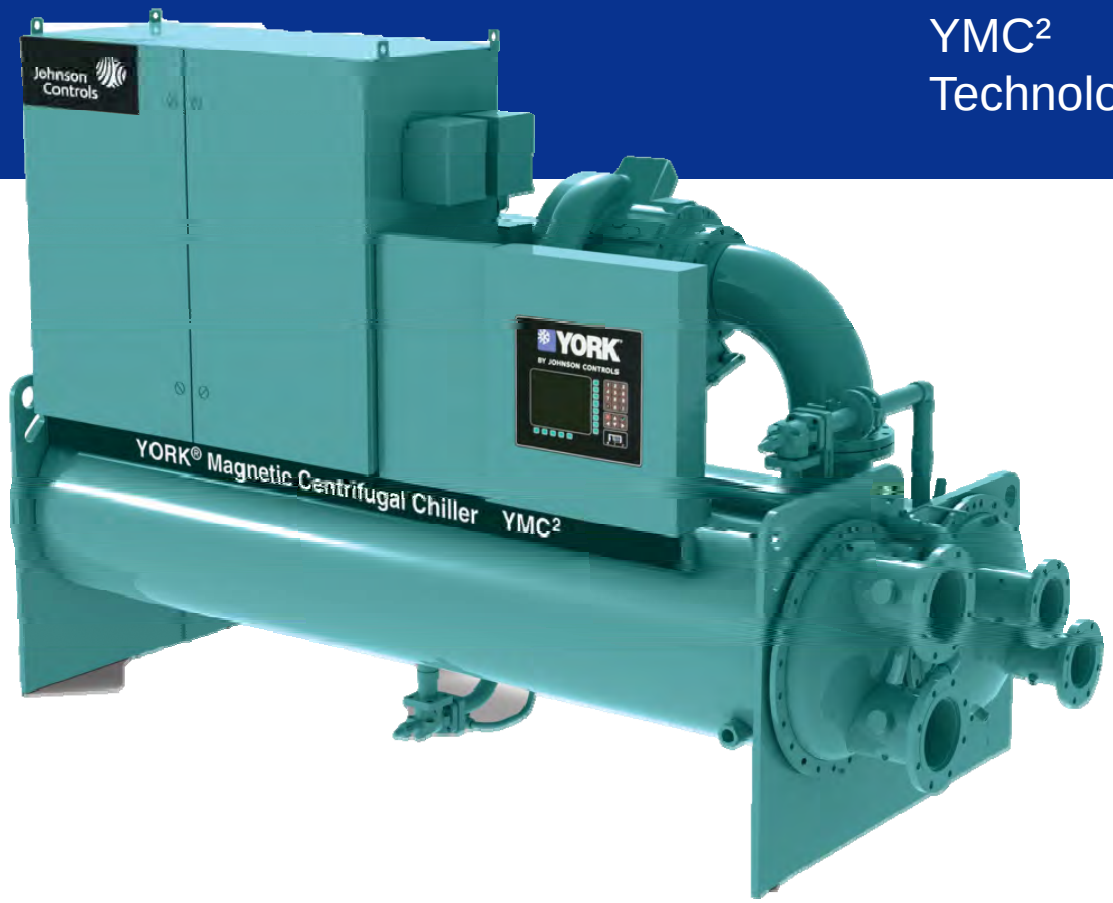
Over the last 25 years: Average energy efficiency has improved over **50%**

- Improved ***compressor aerodynamics*** (simulation tools)
- Improved ***tube geometry*** (enhanced tubes, micro-channel)
- Improved ***heat transfer technology*** (falling film)
- Improved ***control strategies*** (optimized control logic)
- Improved ***variable speed technology*** (reduced size and cost)
- ***Reduced*** parasitic ***losses*** (direct drive, mag bearing, oil-free)

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YMC²
Technology Leader



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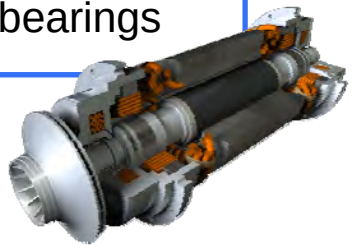
Employ Superior Efficiency

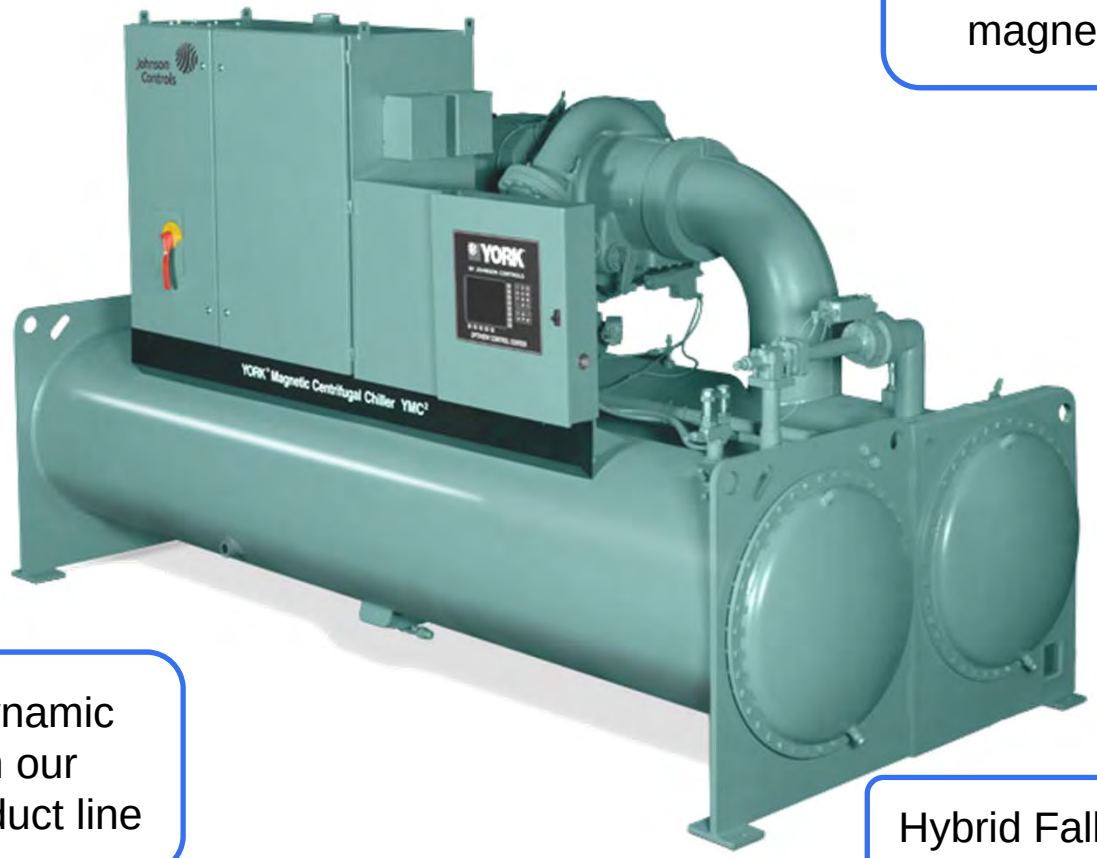


OptiSpeed™ Variable Speed Drive



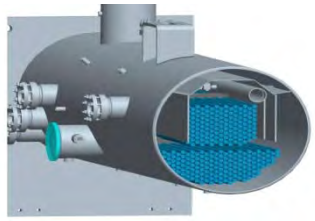
Permanent magnet motor with active magnetic bearings







Proven aerodynamic designs from our flagship YK product line



Hybrid Falling Film HX

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YMC² – YORK Magnetic Centrifugal Chillers

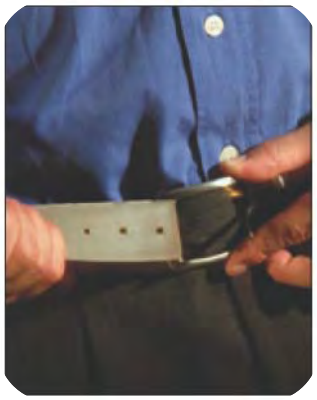
Four key benefits

1. **Efficiency –** Reduce your consumption
2. **Sustainability –** Improve your environmental equation
3. **Low Sound –** Save your voice
4. **Max uptime –** Increase your hours



73 dBA

Faster Return to Leaving Chilled Water Temperature





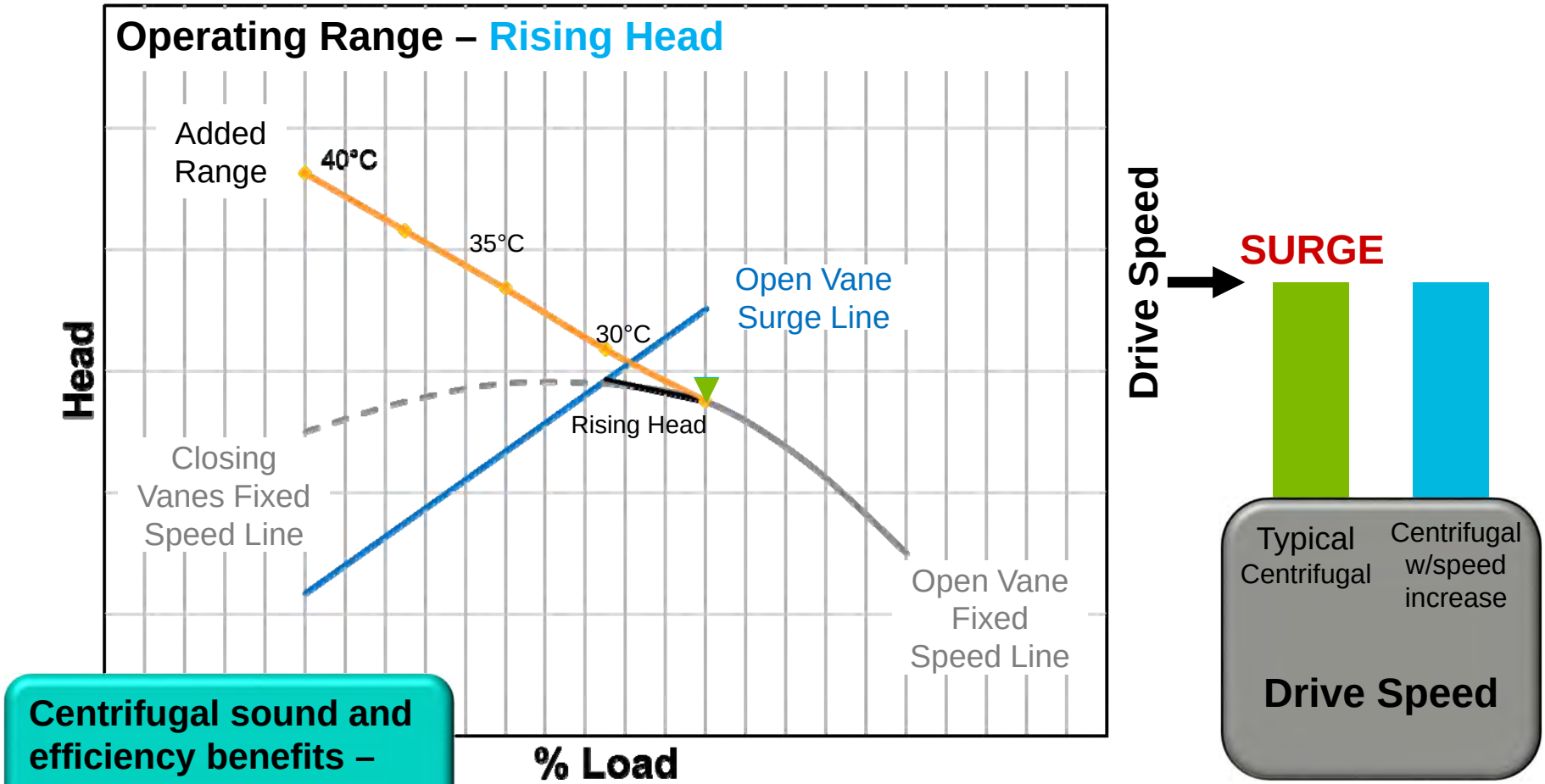




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“Surge Proof” Centrifugal Compressor

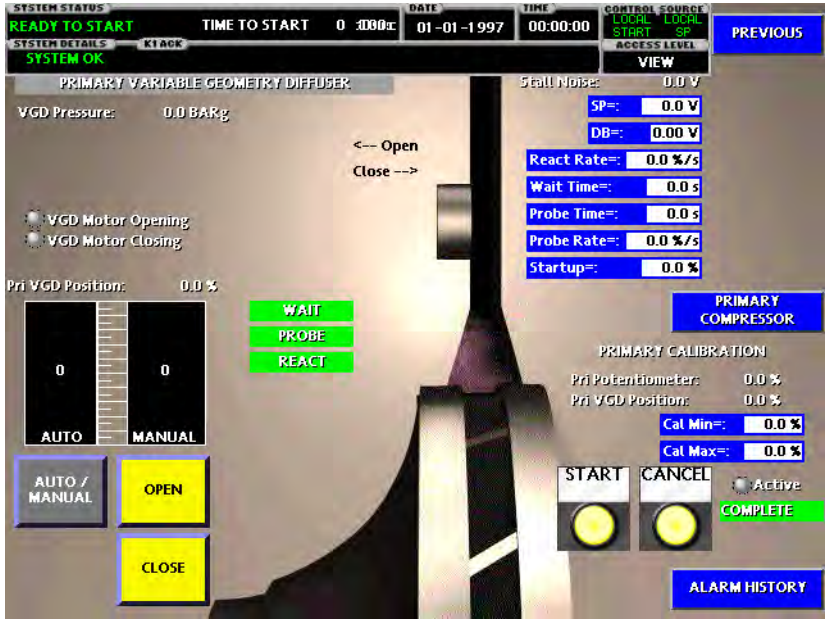


Centrifugal sound and efficiency benefits – flexibility of a screw

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Maximum Uptime and Plant Reliability – Expanded Map

- VGD control extends operating map
  - Low load with high lift
  - Stable operation with “excess lift”

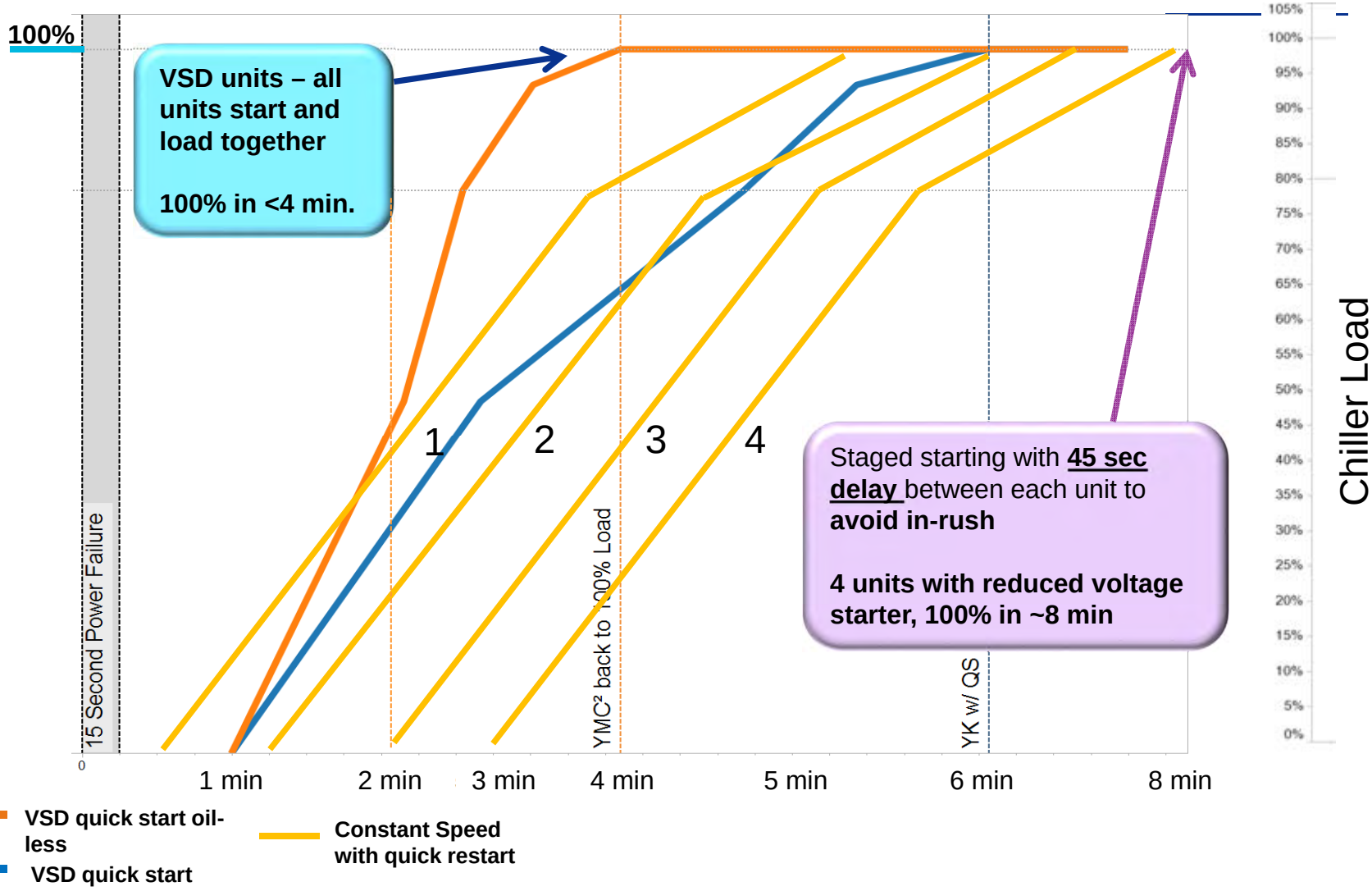


New Technology deliver stable operation when lift increases <u>5 deg C above the design point.</u>

Old technology chillers will shut down on surge protection

… the new chillers can remain on-line to deliver cooling even with hydronic system issues.

Capacity Recovery – All Chillers < 4 min (Critical Facility)



Delay in chilled water recovery can be critical to life

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Comparing Fixed Speed with Mag Bearing Chiller

		Traditional Approach – constant speed chiller				New approach – Taking advantage of available WBT relief with Mag Bearing VSD Chiller.							
		At Design conditions				At Off Design conditions							
			CSD	Mag			CSD	Mag			CSD	Mag	
Load%	LWT	EWT	YK	YMC2	% Diff	EWT	YK	YMC2	% Diff	EWT	YK	YMC2	% Diff
100	6.7	29.4	0.538	0.533	1%	27.0	0.496	0.484	2%	24.0	0.456	0.426	7%
90	6.7	29.4	0.531	0.518	2%	27.0	0.493	0.466	5%	24.0	0.456	0.407	11%
80	6.7	29.4	0.530	0.503	5%	27.0	0.495	0.452	9%	24.0	0.458	0.393	14%
70	6.7	29.4	0.540	0.496	8%	27.0	0.503	0.444	12%	24.0	0.466	0.384	18%
60	6.7	29.4	0.553	0.499	10%	27.0	0.517	0.441	15%	24.0	0.480	0.375	22%
50	6.7	29.4	0.580	0.511	12%	27.0	0.54	0.447	17%	24.0	0.500	0.380	24%
40	6.7	29.4	0.605	0.539	11%	27.0	0.565	0.466	18%	24.0	0.525	0.395	25%
30	6.7	29.4	0.660	0.596	10%	27.0	0.620	0.517	17%	24.0	0.580	0.425	27%

Mag Bearing saves up to 24% in Singapore condition

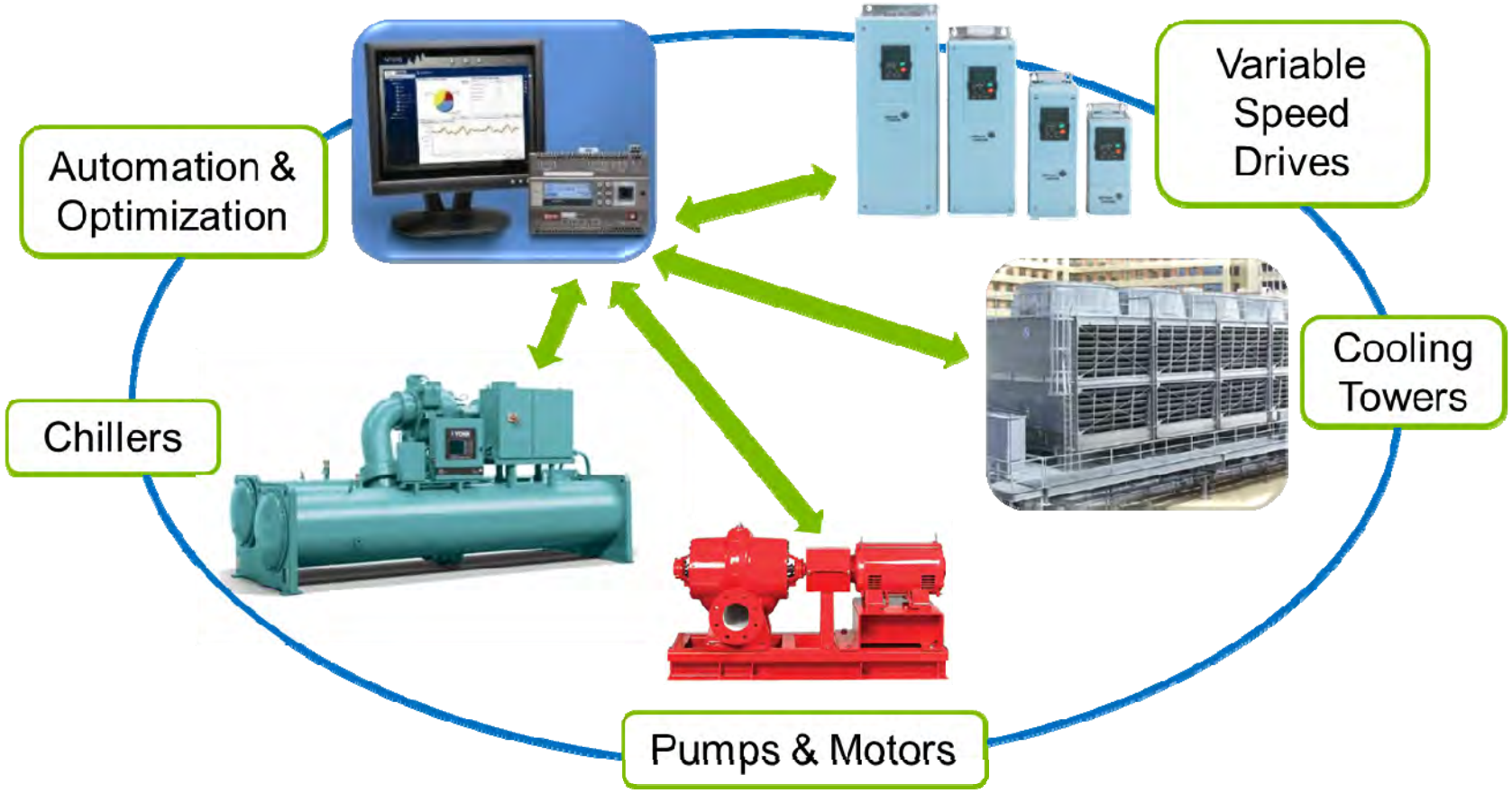
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Efficient systems require efficient components with right application and solution



System Efficiency – Solution Approach

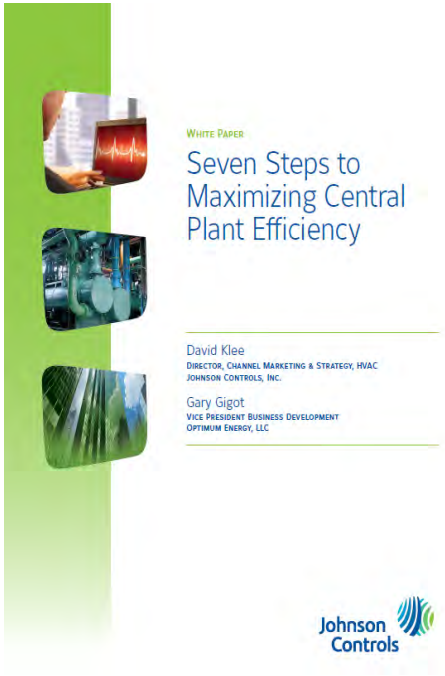


To maximize efficiency, plants should be designed and operated holistically

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Efficient chillers are a great foundation, but optimization is a process



Operating Decisions

Design Decisions

- **Measure & Verify**
- **Optimize System**
- **Automate System**
- **Apply components effectively, optimally**
- **Select components effectively, optimally**
- Design system infrastructure to maximize efficiency potential

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The innovation requirements of a green building is challenging traditional paradigms

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The key functional components of chiller plant optimization are the same irrespective of location or application

Apply variable speed drives

- Chillers
- Pumps
- Tower Fans

Reduce "lift"

- Lower CW temperatures
- Higher CHW temperatures

Reduce pump energy

- Wide delta T
- Variable flow

Efficient chiller staging

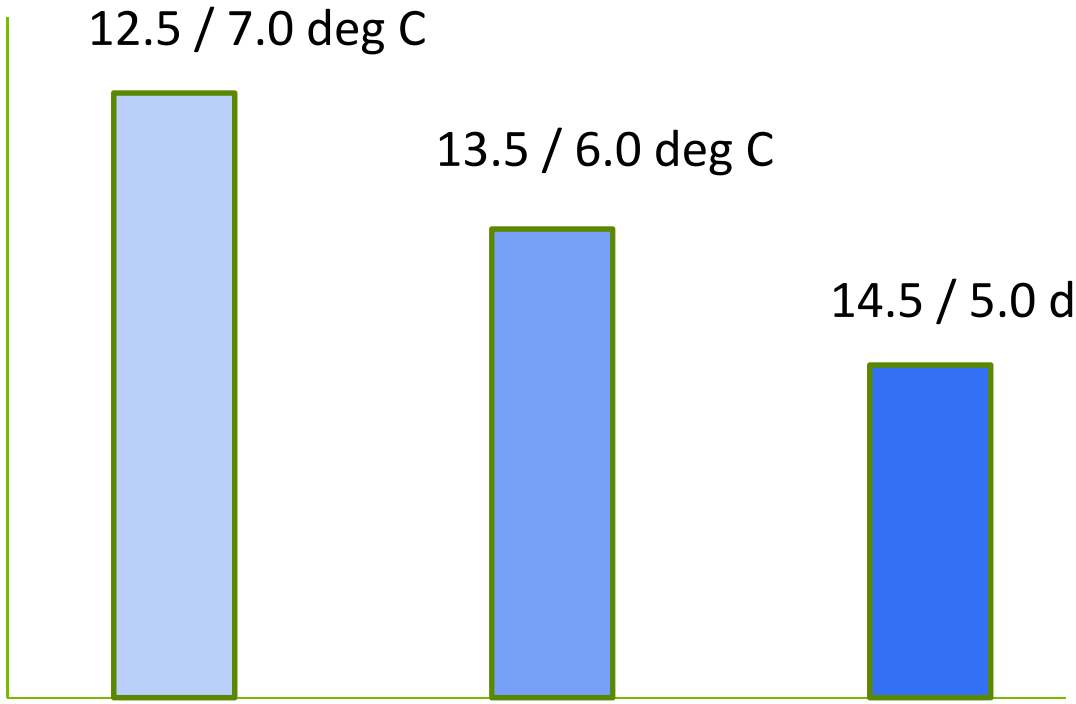
- Energy based vs load based



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Can we widen the CHW temperature range to 7-10 deg C?



Design delta T	5.5C	7.5C	9.5C
% Flow reduction	0	2/7.5 =**27%**	4/9.5 = **42%**

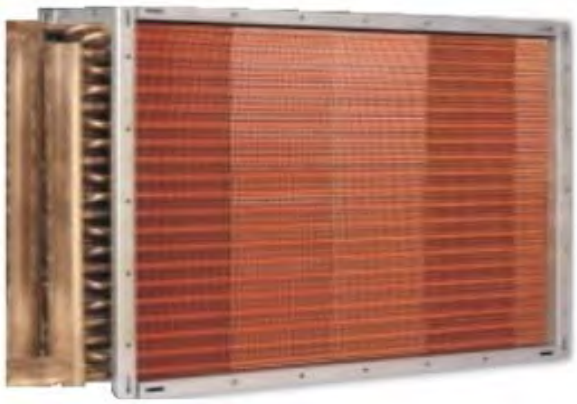
Wide delta T chilled water save pump energy with “similar” coil selections

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Can we raise CHW temps ?

Chiller HX approach temperatures <= >1 deg C





Conventional coil design = 2.5 m/s Face velocity & approach 6-7 deg C

Optimized coil design = < 1.5 m/s Face velocity & approach 3-4 deg C

1°C Rise in LCHW temp improve eff. by 4.0-4.5%

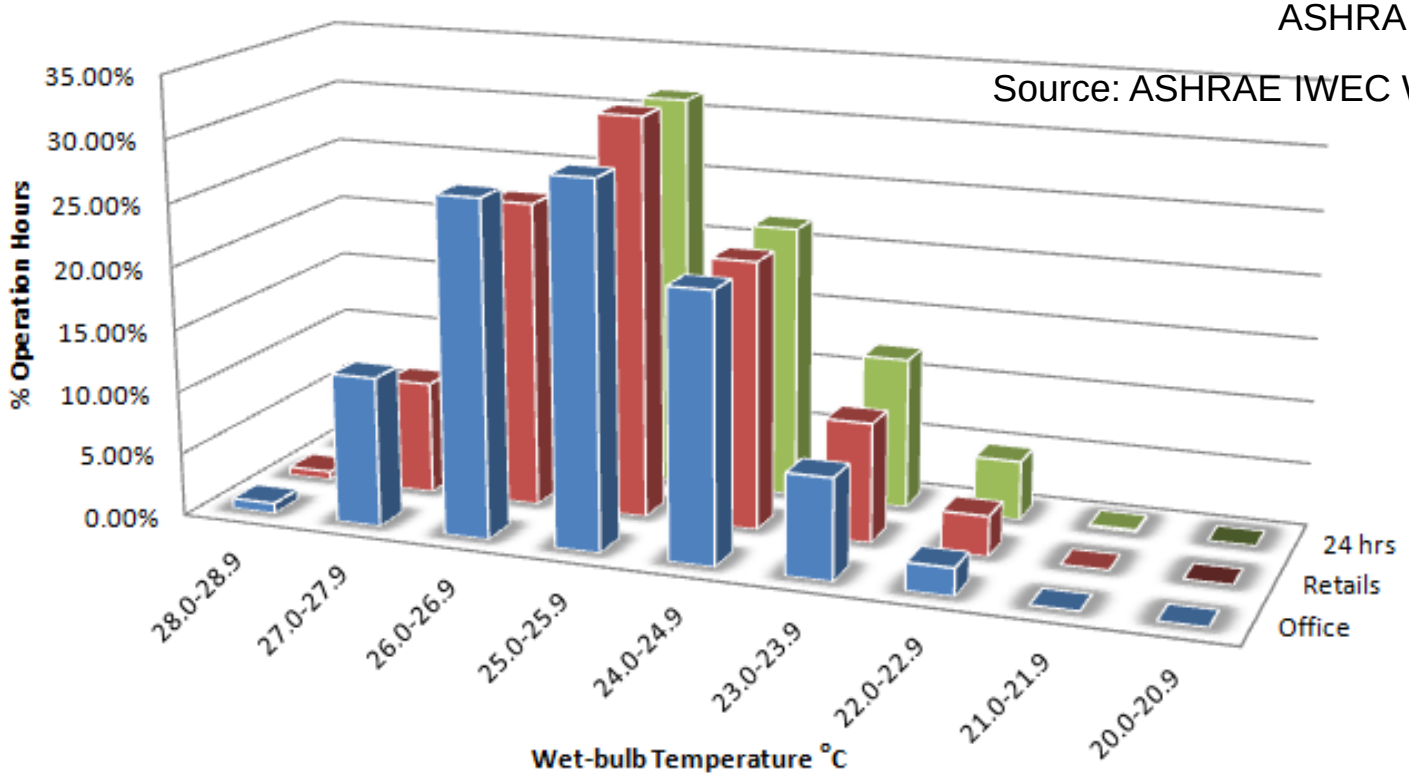
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Tropical Building Operation Profiles can take some advantage of ambient wet bulb relief

ASHRAE 32.8db / 27.3wb

Source: ASHRAE IWEC Weather Bin Data



Singapore water have 3 deg C to 5 deg C relief for 24/7 systems (Healthcare Facilities)

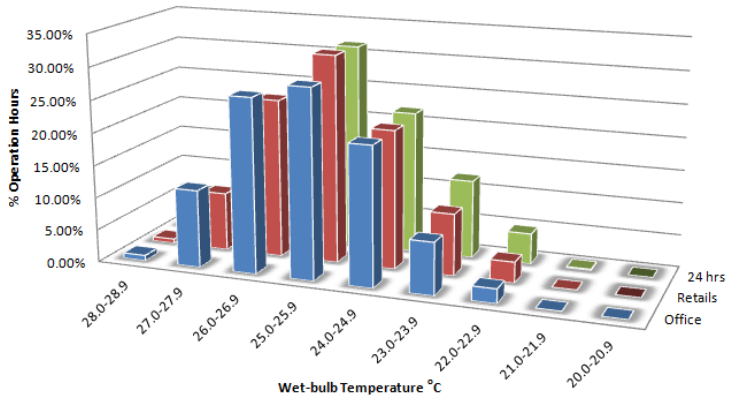
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Chiller condenser water set-point is determined by WBT

YORK BY JOHNSON CONTROLS

Hospital 24/7



WB Bin	HRS %
27-27.9	6.7%
26-26.9	22.5%
25-25.9	31.5%
24-24.9	21.9%
23-23.9	12.1%
22-22.9	4.7%
Annual HRS	8760
% < 24 WB	16.8%
HRS	**1471**

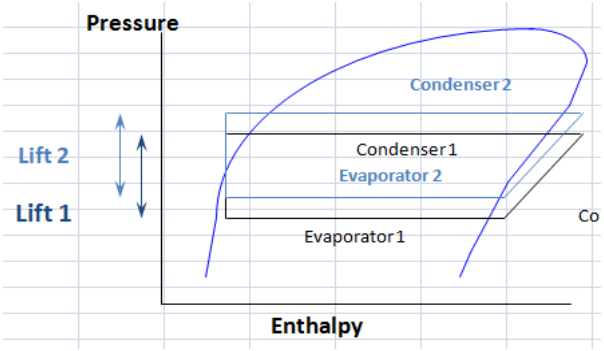
Singapore tower water will achieve 3 deg C of relief 54% time and 5 deg C for 17% time.

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Widen CHW delta T - to apply series counter-flow & VPF

VPF = variable primary CHW flow & fixed delta T



VPF





9 deg C

29 deg C



12.5 deg C

31.5 deg C



16 deg C

34.0 deg C

Lift is reduced 2.5 degrees C

Lift is reduced 3.5 degrees C

Dual Compressor Unit will not have lift advantage!

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Energy economics of a 9 /16 deg C Series /Counter Chilled Water [CHW] system against 7/12.5 deg C conventional design

Savings

- ⇔**21 %** CHW pump energy savings
- Downstream chiller at 9 / 31.5 deg C
- Downstream chiller ⇔ **15%** more efficient
- Upstream chiller at 12.5 / 34 deg C
- Upstream chiller ⇔**17.5%** more efficient

Costs

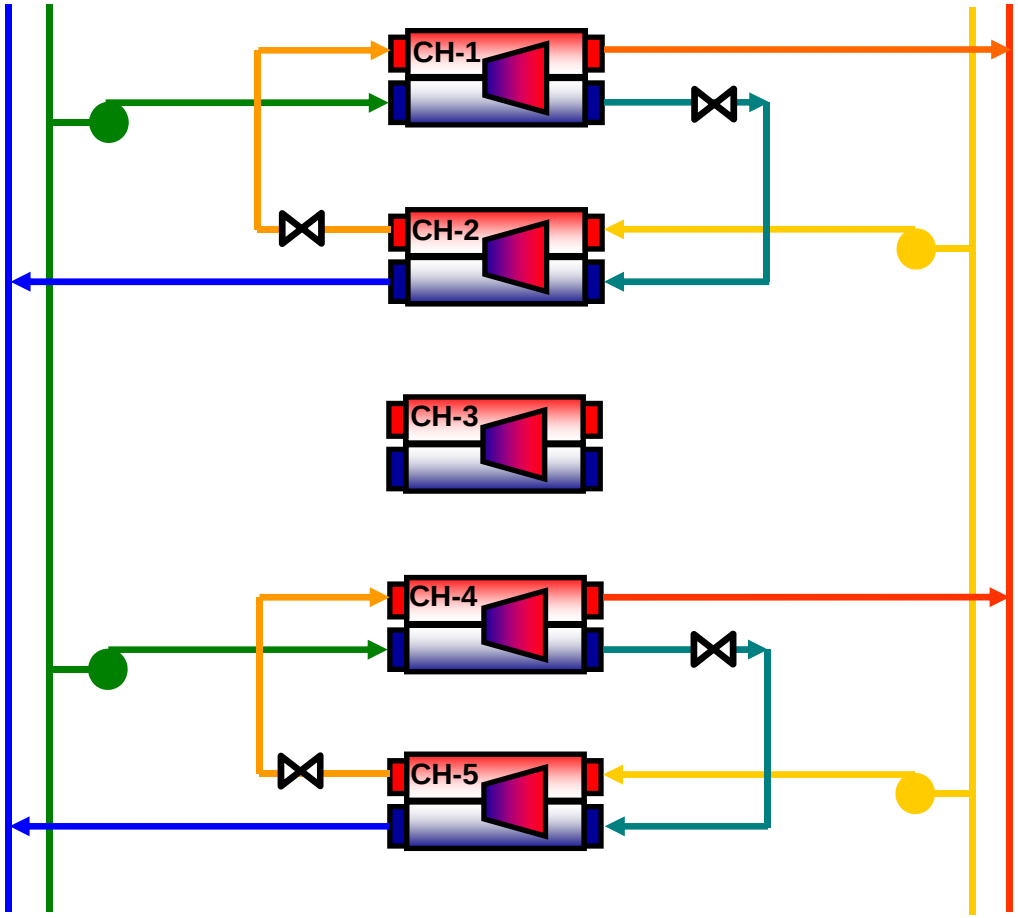
- **Marginally higher design water flow pressure drop with series Heat Exchanger that is offset by variable CHW flow with good 'range-ability'.**

S/C VSD Chillers ⇔ overall 15+% more efficient
Additional savings when lift can be further reduced

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How we can we add redundancy in SCF



SCF – NO redundancy

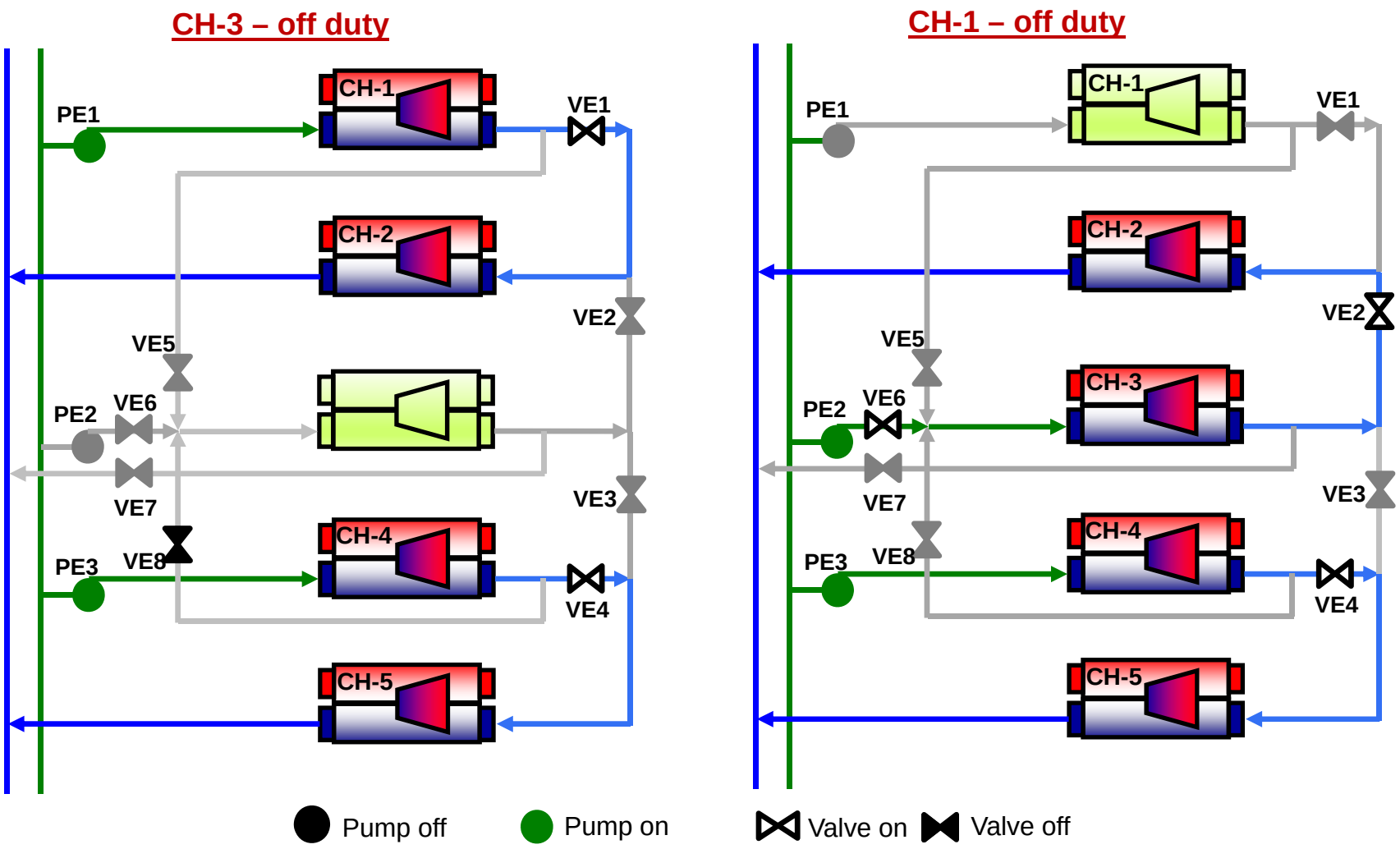
CH-1/CH-2 – Upstream/Downstream
CH-4/CH-5 – Upstream/Downstream

SCF – Adding Redundancy

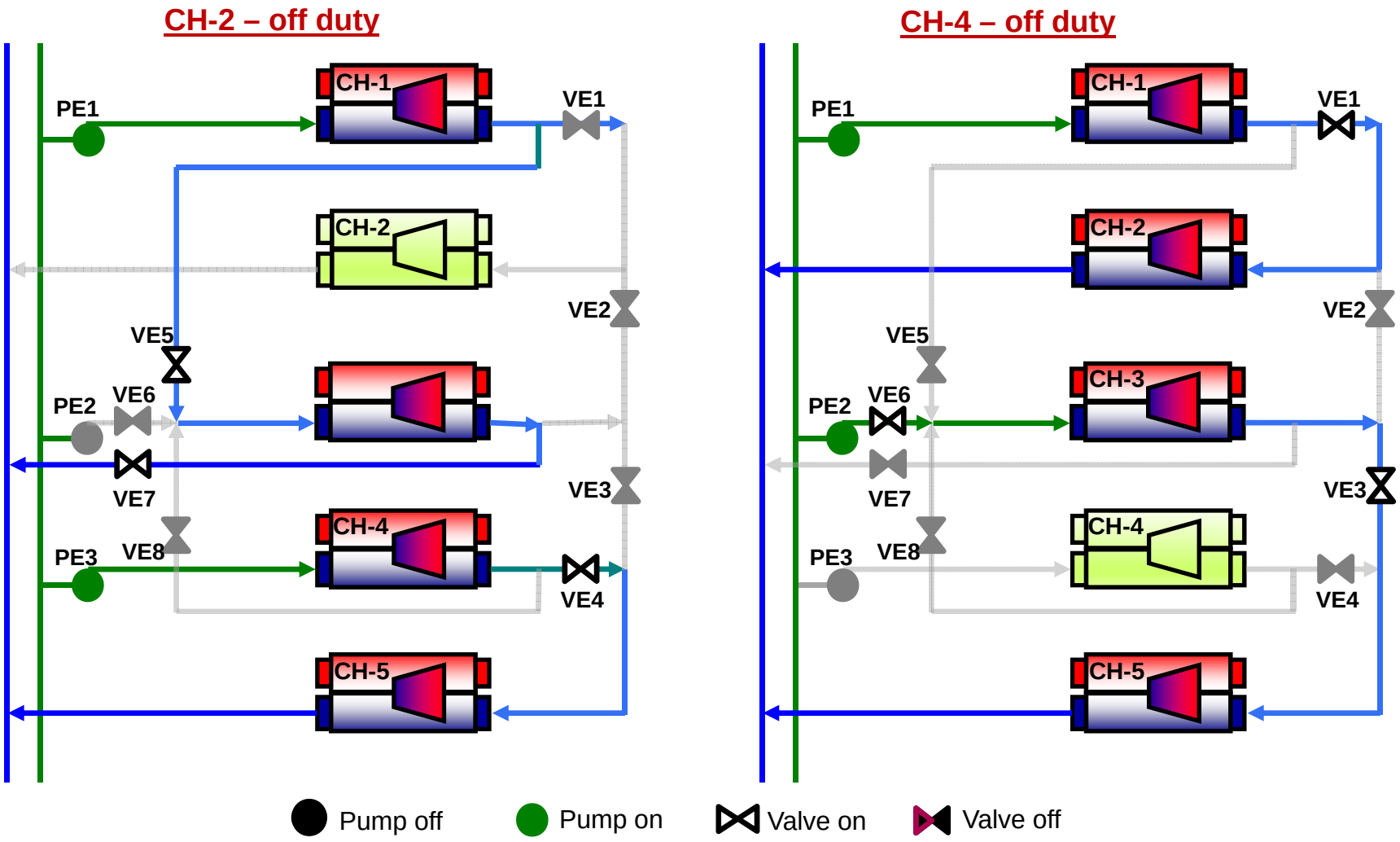
CH-1/CH-2 – Upstream/Downstream
CH-4/CH-5 – Upstream/Downstream
CH-3 – Standby

Few additional valves can provide redundancy and flexibility

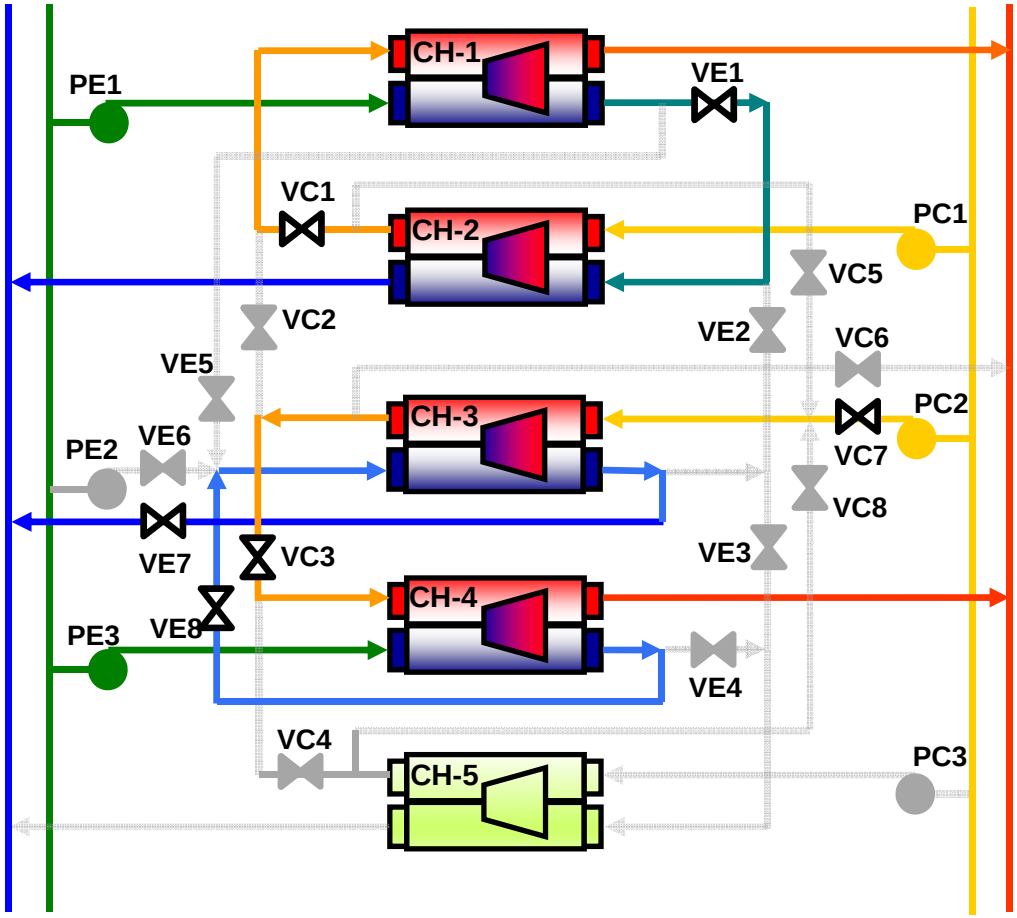
How we can we add redundancy in SCF



How we can we add redundancy in SCF



How we can we add redundancy in SCF



CH-5 – off duty

Serial Counter Flow

CH-1/CH-2 – Upstream/Downstream
CH-4/CH-3 – Upstream/Downstream
CH-5 – Off

Valve on

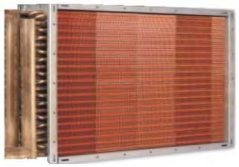
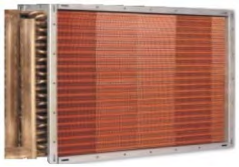
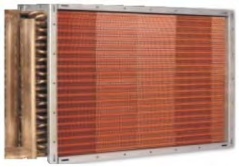
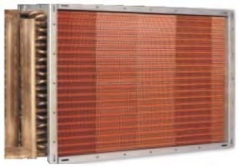
Valve off

Pump on

Pump off

Impact on coil with 9ºC CHW and 7ºC delta T ?

air ON dbt	**25**
air ON wbt	**18.5**
air OFF dbt	**12.5**
Air Qty l/s	**5,000**

	Selection 1	face velocity 2.31m/s	rows	4	APD	122	Pa
		CHW 6/12	fins/m	500	WPD	38	kPa
			coil sq m	2.16			
	Selection 2	face velocity 2.31m/s	rows	10	APD	216	Pa
		CHW 9/16	fins/m	400	WPD	35	kPa
			coil sq m	2.16			
	Selection 3	face velocity 1.65m/s	rows	8	APD	107	Pa
		CHW 9/16	fins/m	500	WPD	33	kPa
			coil sq m	3.02			
	Selection 4	face velocity 1.51m/s	rows	8	APD	88	Pa
		CHW 9/16	fins/m	400	WPD	26	kPa
			coil sq m	3.31			



Increase area & reduce coil velocity is key to equivalent performance

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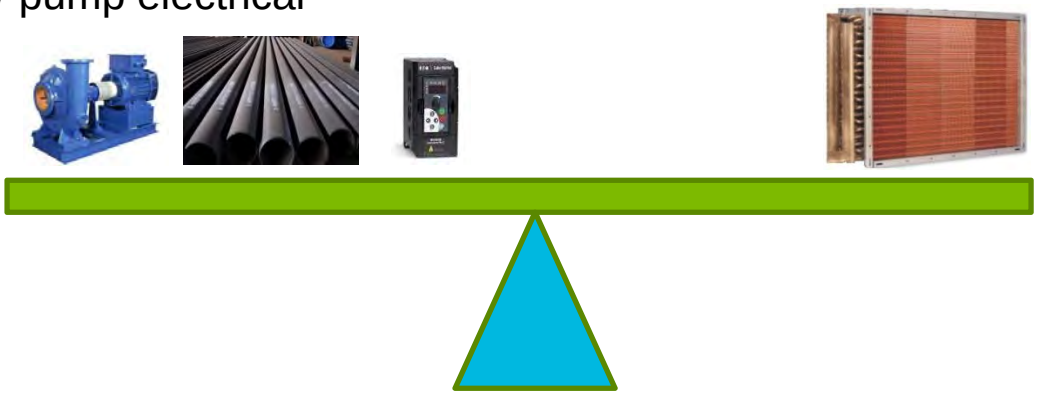
1st cost economics of a 9 /16 deg C CHW system

Savings

- Smaller CHW pipes
- Smaller CHW valves and fittings
- Reduced thermal insulation area
- Smaller CHW pumps, motor kW, and VSD's
- Smaller CHW pump electrical requirements

Costs

- Larger AHU coil HX areas and rows to achieve equivalent energy performance
- If the additional coil area cannot be accommodated in AHU height, the AHU footprint will increase



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9ºC LCHWT and 9/16 as ΔT saves power - OT temp. requirement ?

	Dry Bulb	Relative Humdity	Room ACH	Outdoor ACH	Outdoor Air
ASHRAE	(20°C-23°C)	30%-60%	25	5	20%
AIA	(20°C-23°C)	30%-60%	15	3	20%
VA	**(17°C-27°C)**	**45%-55%**	**15**	**15**	**100%**

Table 1: Temperature , Humidity and airchange requirements for surgery rooms

20ºC - OT

⇩

10.5ºC - Coil

⇩

6º/12ºC - CHW

Surgeons also have preferences when it comes to temperature and humidity conditions.... Often, ...the surgeon expects a lower room temperature than that stated in guidelines.



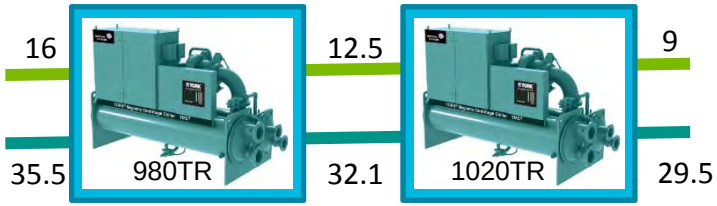
20ºC room temperature need ADP of 10.5ºC. Designing CHW at 6/12 will increase power consumption by 15%

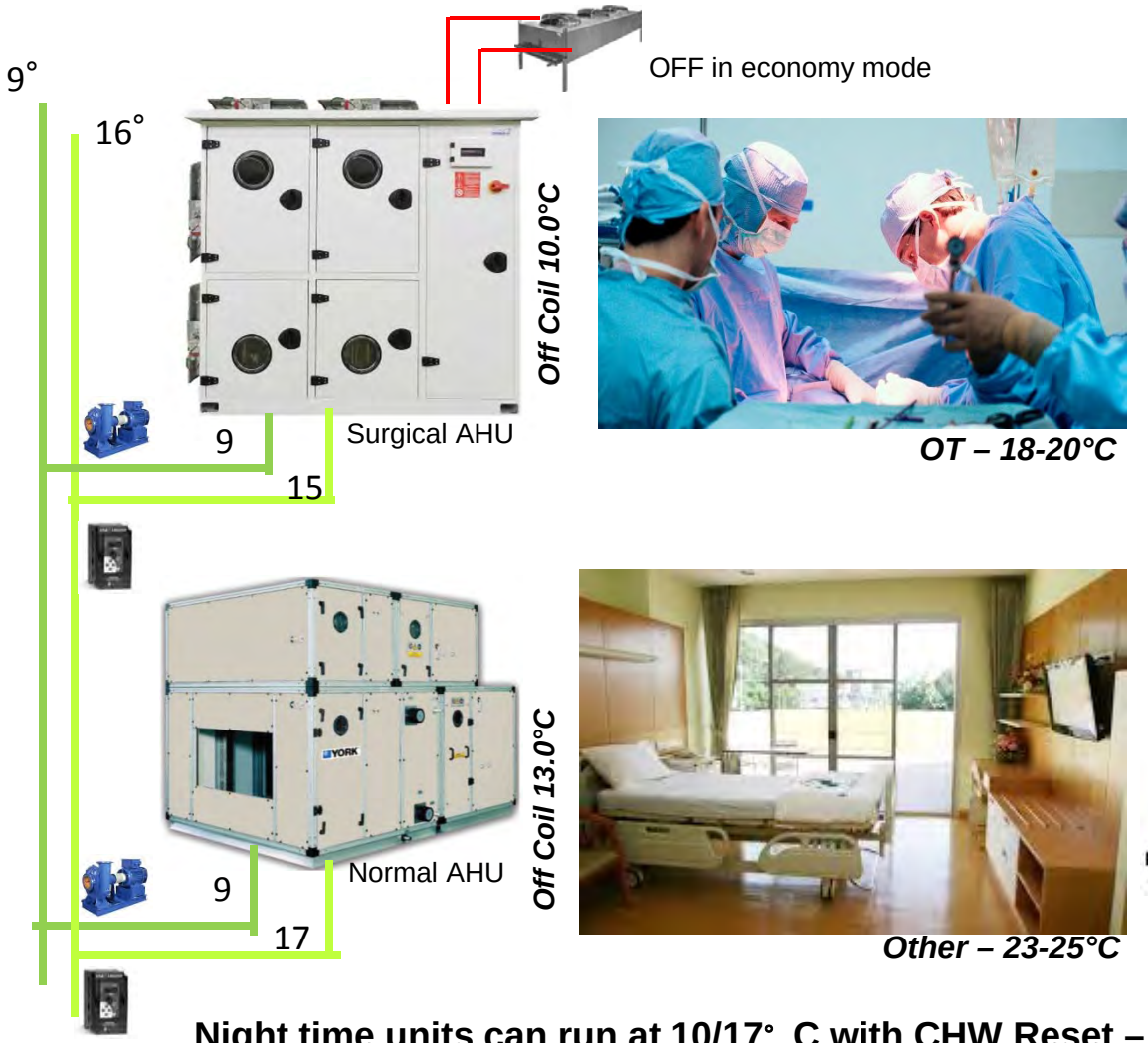
Need to design OT differently.

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Decoupling the OT Load with DX Coil

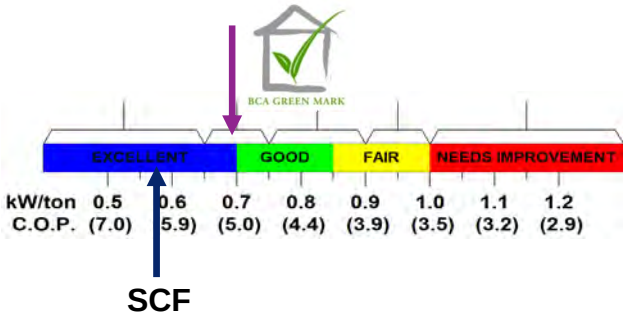




OT – 18-20°C

Other – 23-25°C

Equip.	KW/TR
Chiller Avg.	0.42
Pumps VPF	0.12
CT	0.02
Total	**0.56**



Night time units can run at 10/17° C with CHW Reset – Economy Mode (8hrs)

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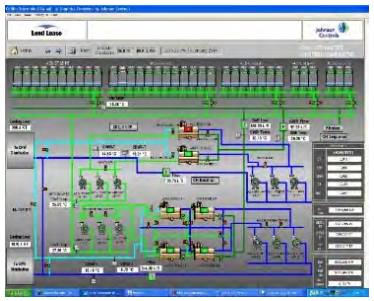
Chiller Plant Optimization - Advanced control strategies

METASYS BY JOHNSON CONTROLS

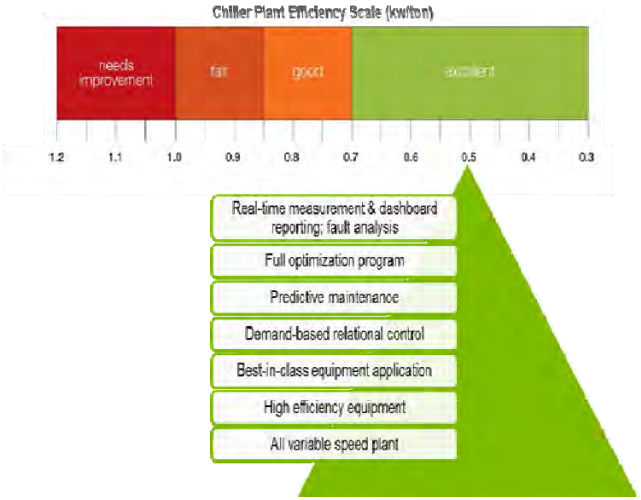




BACnet®



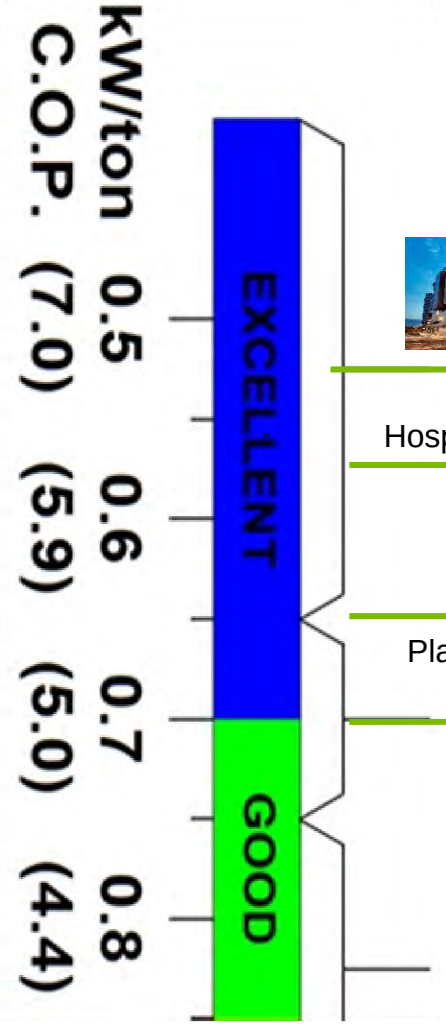
- **Series counter-flow chillers**
- **Chiller /Tower optimization**
- **Supply chilled water reset**
- **Variable primary CHW flow**
- **Efficiency based staging**



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JC Technology with Application and Solution –Setting Industry Benchmark



JEM Singapore
0.527



Hospital – 0.56

Control CPM



Solution-AHU



Application -SCF



Technology -Mag



Platinum & Gold Plus 0.65

Certification 0.70



- **Series counter-flow chillers**
- **YMC2 Mag Bearing**
- **Surgical AHU with DX Coil**
- **Variable primary CHW flow**
- **Efficiency based staging**

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Conclusion

- Mag bearing technology can met and exceed Greek Mark
- Solution approach to design for lower lift helps set new bench mark in industry.
- Johnson Controls is an

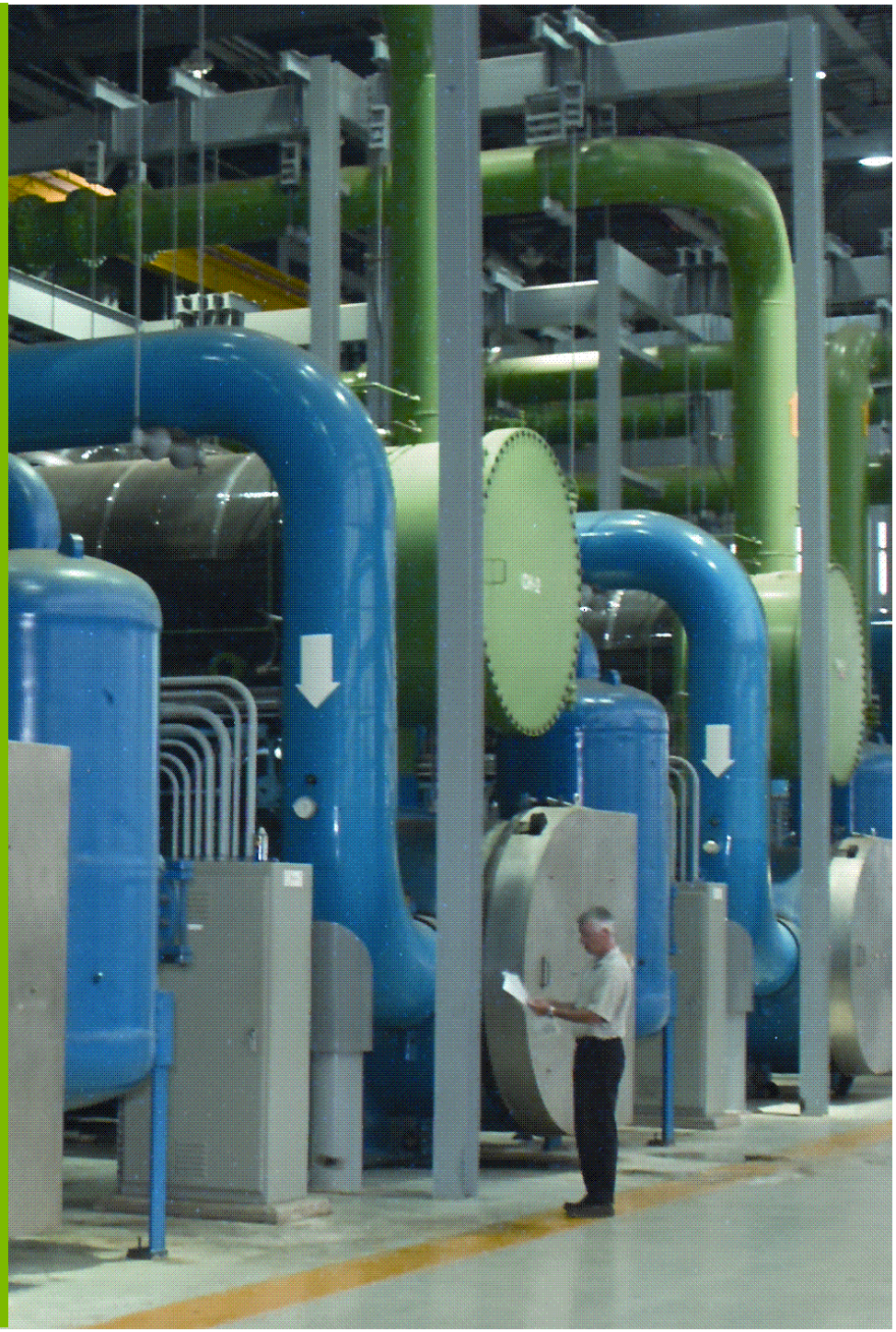
Integrated System Solutions Company

- **Not just highly efficient products**
- **Chillers + AHU + Controls + Strategies**

Smart Green
Integrated Sustainable Solutions

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Case Study
Hospital in Singapore



Case Study

Hospital	8000	TR
Configuration	4 x 2000 TR	
CHW In	13.7	°C
CHW Out	7.2	°C
Plant Eff.	0.625	KW/TR
Variable CHW Flow	30% Mini.	
AHUs	Heat Recovery	
OT	100% Fresh Air	
OT Temp.	18-24	°C

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Surgical AHU Selection with 8/14 CHW

Chilled Water Circuit (Performance as per EN14511)

100% Fresh Air with Heat Recovery

Air Entering Unit	DBT	35	°C	Total Cooling Cap.		132.1	KW
Air Entering Unit	WBT	29	°C	Water Temp. In		8	°C
Exhaust Air	DBT	18	°C	Water Temp. Out		14	°C
Exhaust Air	WBT	12.7	°C	Chilled Water Flow		18940	l/hr
Air Entering Cold Coil	DBT	26.8	°C	Coil Press. Drop		51.4	kPa
Air Entering Cold Coil	RH	99.9	%	Valve Press Drop		9	kPa
Air leaving Cold Coil		13.4	°C	Total Press. Drop		60.4	kPa
Air leaving Cold Coil		99.9	%				
EER		20.14		EER - Total cooling Capacity/ Fan Power Input			
Direct Expansion Coil (DX) Performance							
Refrigerant		R410A		Total Power		8.58	KW
Scroll Compressor		1		Nom Capacity		11	HP
Air Entering DX Coil	DBT	13.4	°C	Evaporating Temp.		6.7	°C
Air Entering DX Coil	WBT	13.4	°C	Condenser Temp.		48	°C
Air Leaving DX Coil	DBT	9.3	°C	Total Capacity		29.9	KW
Air Leaving DX Coil	RH	99	%	EER		3.48	
Supply Fan (EC Fan)							
Available Ext Static		500	kPa	Total Power Input		6.56	KW
Total Aiflow		9000	m3/hr	Fan Qty 2	RPM	85	%

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Surgical AHU Selection with 9/15 CHW

Chilled Water Circuit (Performance as per EN14511)

100% Fresh Air with Heat Recovery

Air Entering Unit	DBT	35	°C	Total Cooling Cap.		132.1	KW
Air Entering Unit	WBT	29	°C	Water Temp. In		9	°C
Exhaust Air	DBT	18	°C	Water Temp. Out		15	°C
Exhaust Air	WBT	12.7	°C	Chilled Water Flow		18940	l/hr
Air Entering Cold Coil	DBT	26.8	°C	Coil Press. Drop		51.4	kPa
Air Entering Cold Coil	RH	99.9	%	Valve Press Drop		9	kPa
Air leaving Cold Coil		14.3	°C	Total Press. Drop		60.4	kPa
Air leaving Cold Coil		99.9	%				
EER		19.28		EER - Total cooling Capacity/ Fan Power Input			
Direct Expansion Coil (DX) Performance							
Refrigerant		R410A		Total Power		8.58	KW
Scroll Compressor		1		Nom Capacity		11	HP
Air Entering DX Coil	DBT	13.4	°C	Evaporating Temp.		7.6	°C
Air Entering DX Coil	WBT	13.4	°C	Condenser Temp.		48	°C
Air Leaving DX Coil	DBT	10.2	°C	Total Capacity		30.9	KW
Air Leaving DX Coil	RH	99	%	EER		3.6	
Supply Fan (EC Fan)							
Available Ext Static		500	kPa	Total Power Input		6.56	KW
Total Aiflow		9000	m3/hr	Fan Qty 2	RPM	85	%

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Plant Room Energy Comparison

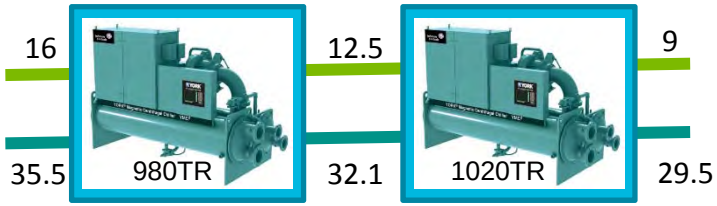
		Tender Design	Proposed Design	Saving
Equip.	Capacity	2000 TR	2000 TR	
	Type	Dual Comp	SCF Solution	
Cooler	CHW In	13.7 °C	15.0 °C	
	CHW Out	7.2 °C	9.0 °C	
	Flow	932 m3/hr	865 m3/hr	7.1%
	PD	67.5 kPa	47.7 kPa	
Condenser	Cond In	29.5 °C	29.5 °C	
	Cond Out	34.5 °C	35.5 °C	
	Flow	1363 m3/hr	1158 m3/hr	15.0%
	PD	89.4 kPa	41.7 kPa	
Eff @29.5°	100%@29.5	0.503 KW/TR	0.473 KW/TR	6.0%
	80%@29.5	0.500 KW/TR	0.428 KW/TR	14.4%
Eff @27°	100%@27	0.470 KW/TR	0.422 KW/TR	10.2%
	80%@27	0.468 KW/TR	0.377 KW/TR	19.4%
Plant IKW	Chiller Avg	0.475 KW/TR	0.420 KW/TR	11.6%
	Pumps VPF	0.130 KW/TR	0.118 KW/TR	9.2%
	CT	0.02 KW/TR	0.020 KW/TR	0.0%
	Total	0.625 KW/TR	0.558 KW/TR	10.7%

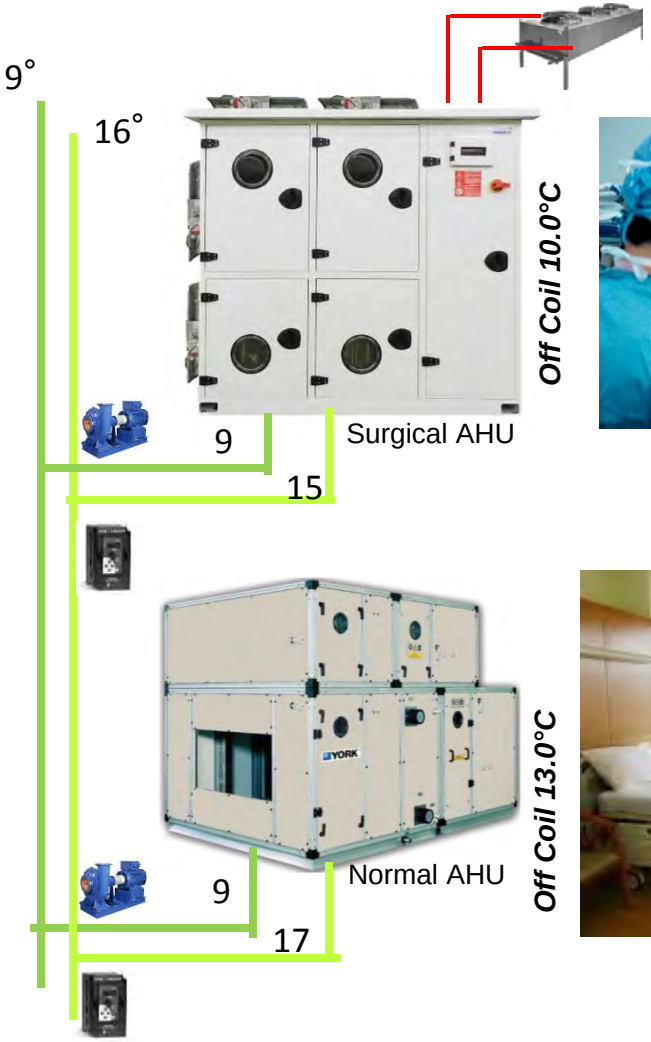
Savings can be higher than 10.7% with lower ECWT

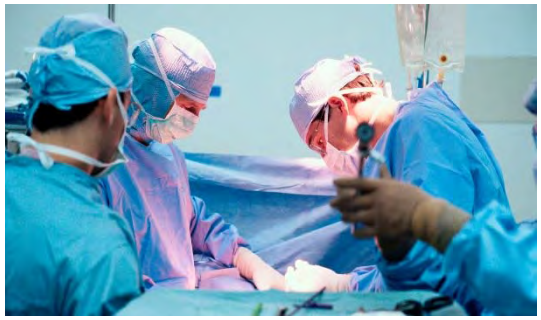
0.56 KW/TR

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Decoupling the OT Load with DX Coil





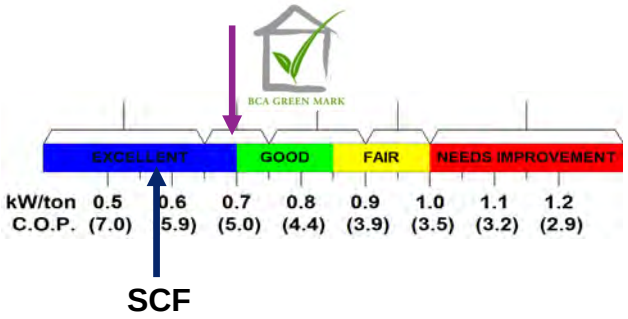


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Other – 23-25°C

Equip.	KW/TR
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Night time units can run at 10/17° C with CHW Reset – Economy Mode (8hrs)

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