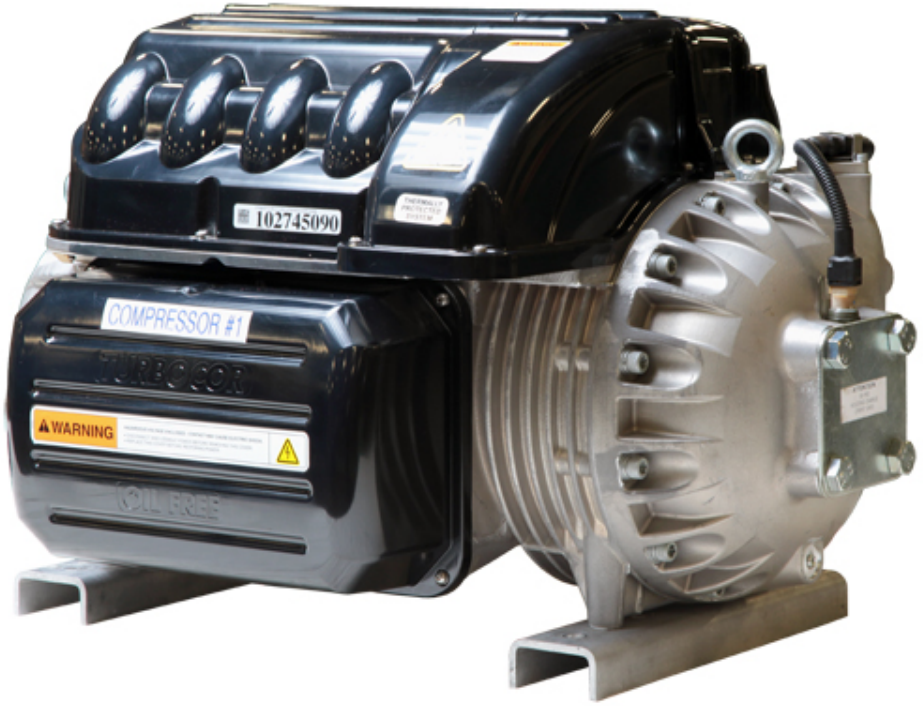
Leveraging Efficiency and Owner Value

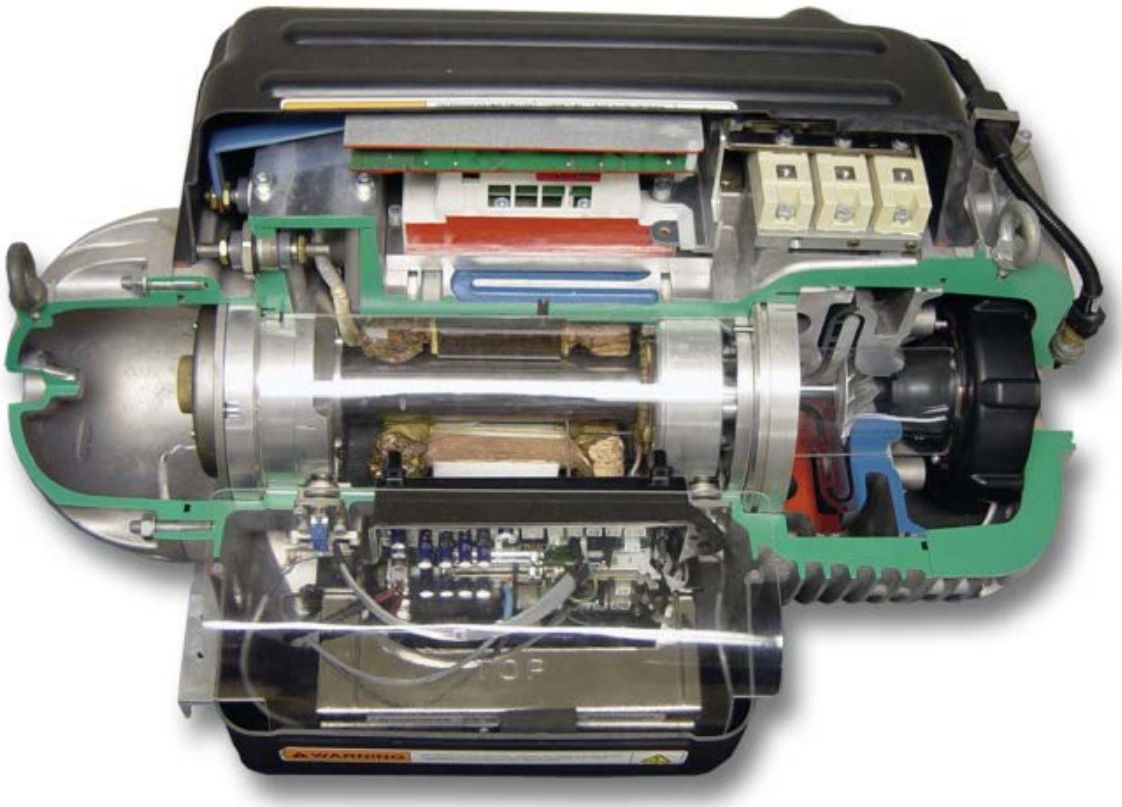
Latest Energy Studies - A Comparison by Compressor Types. Simple Energy, Effect of Oil, and Total Cost of Ownership Using Oil-Free Danfoss Turbocor Compressors.



Topics of Discussion

- **The Danfoss Turbocor Compressor Basic Owner Advantages**
- **Compressor and Chiller Controls – Chiller or Plant?**
- **Correlating Geographic, Building Load and Compressor Profiles**
- **Water versus Air Cooled Chillers – New paradigm emerging**
- **ASHRAE 90.1 – 2004 and 2010 – Path A and B**
- **Loading Chillers – Examples at 50% and elevated ChW Temps**
- **Building Type Energy Analysis - Study and Conclusions**
- **High Cost of Oil – Maintenance and Unsustainable U-Value**
- **Economizers and Adiabatic Assist for Air Cooled**
- **Reducing Noise and Raising Efficiency using Fan Diffusers**
- **Series-Counter-Flow Strategy and Effect on Lift**
- **Total Cost of Ownership Drivers**

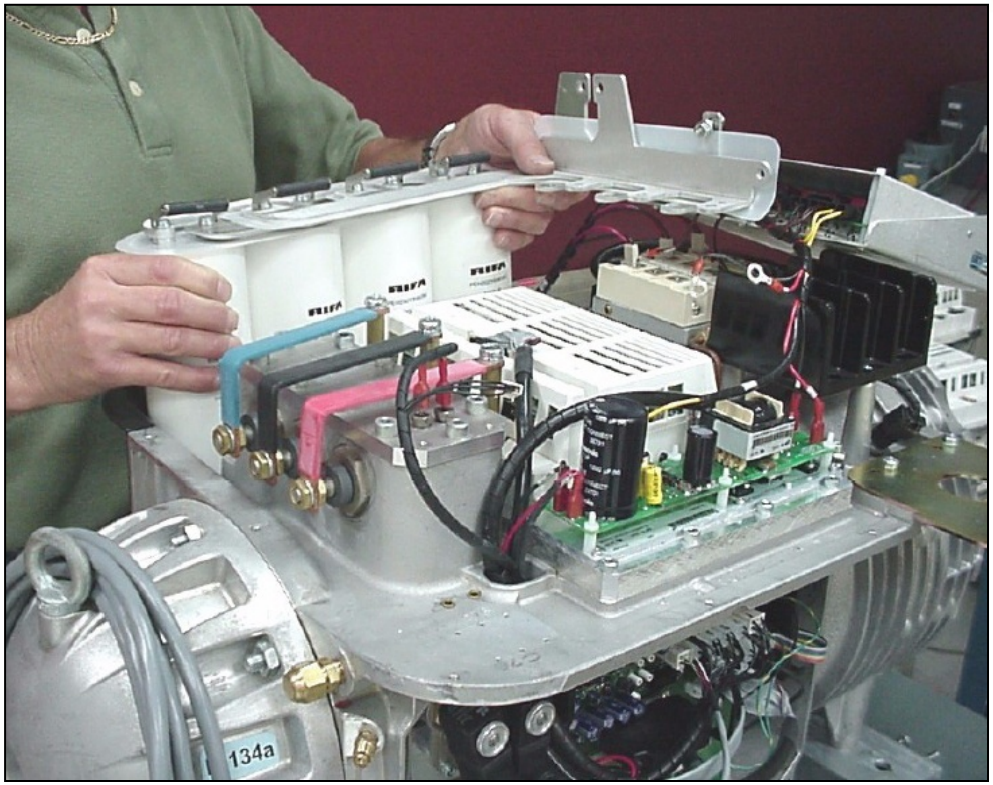
What is the Turbocor Compressor ?



- **100% Oil Free** Centrifugal eliminates friction and oil system maintenance costs.
- **R134a Refrigerant** meets Montreal protocol and is not subject to phase-out.
- **Magnetic Bearings** eliminate frictional losses and greatly reduces maintenance
- **SUSTAINABLE Efficiency** as low as .30 kw/ton NPLV.
- **Low 2-amp In-Rush Current** reduces installed cost and peak load. Reduces generator loads.
- **Lowest Noise** - Only 70 dBa.

Lowest Cost of Service Technology.

- **Annually check electronics for tight connections**
- **No oil service or oil disposal - EVER.**



- **Replace capacitors every ten years**

Lowest Noise and Vibration Levels

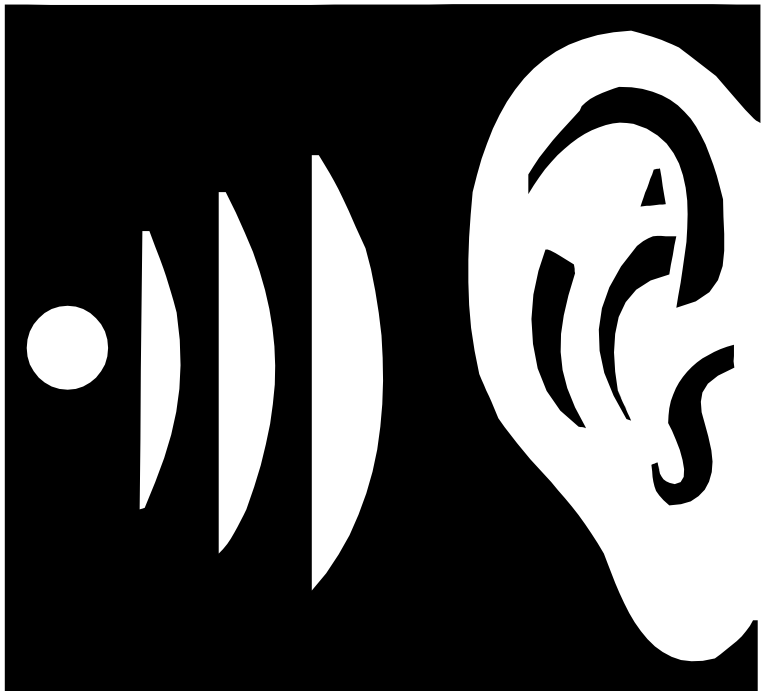
- "Best in Class" Sound levels.

No moving mechanical part touches any part of the housing or frame to transmit acoustic energy.

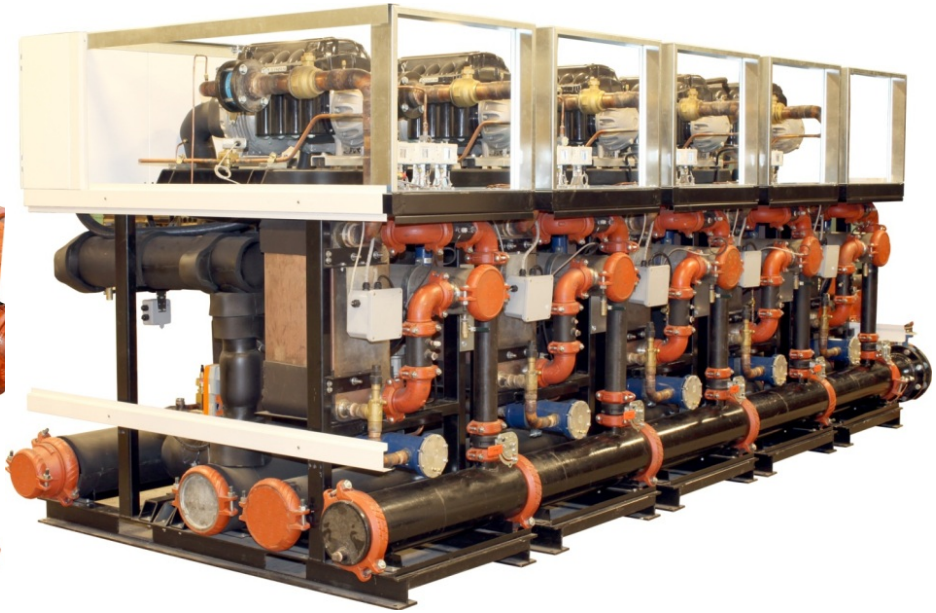
- Tested at 70 dBa at 1 meter with no sound attenuation.

- Vibration is essentially non-existent.

- 500 ton chiller operating at full speed produces 75 DB at 10 feet. Like a TV.



Flooded & DX Temperature Approach



Flooded Designs
With Shell and Tube

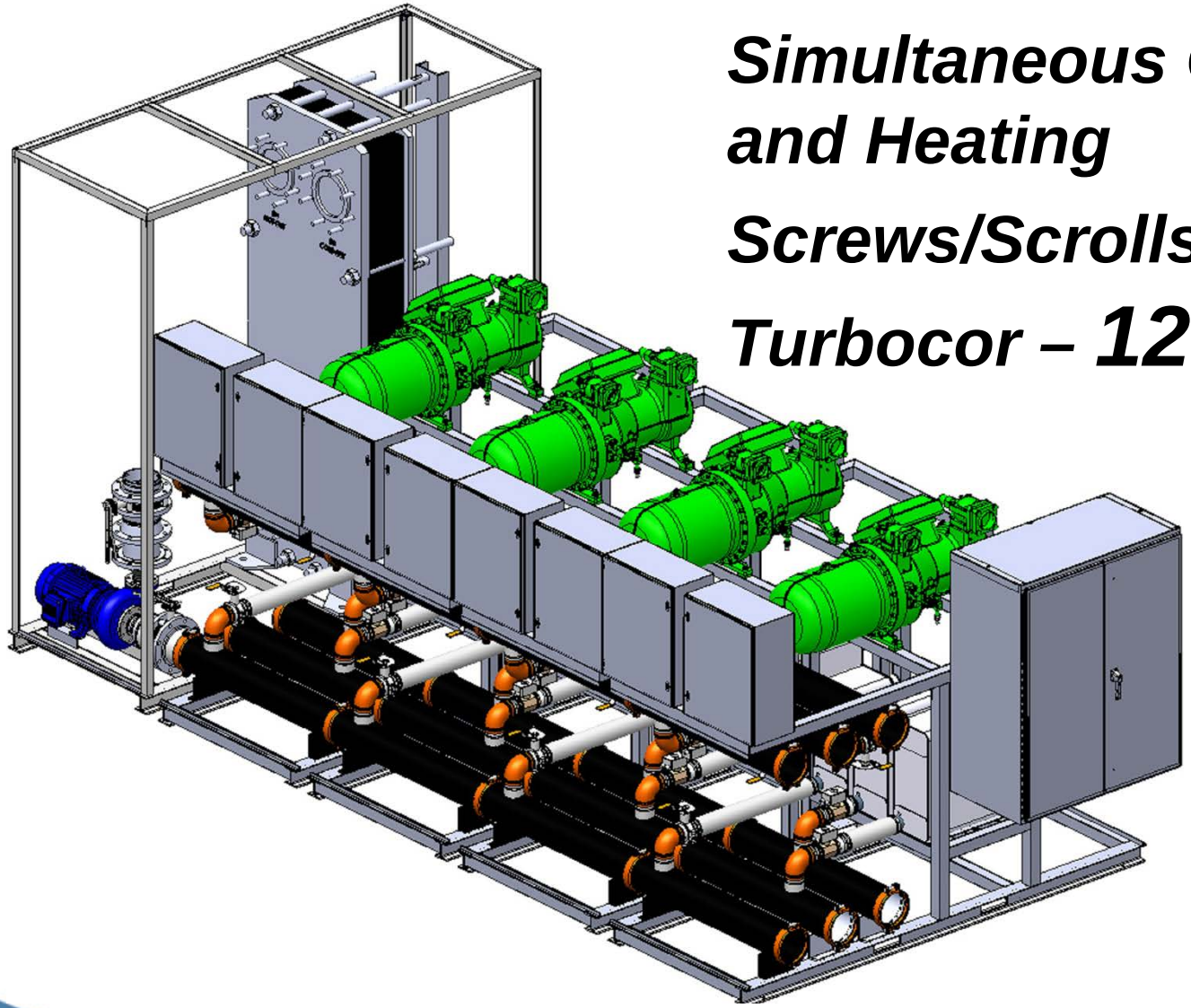
About 2° Approach

Direct Expansion With
Compact Brazed Plates

About 10° Approach

Range of Chillers Expanded Over Years

Cooling and Heating Systems



Simultaneous Cooling and Heating

Screws/Scrolls – 160°F

Turbocor – 120°F

Chiller Only or Plant Control?

Most manufacturers provide standard chiller controls that can operate cooling VSD tower fans and bypass valves. Perhaps resets.

Some manufacturers now offer chiller mounted Central Chiller Plant Energy Optimizing Controllers to directly correlate and optimize the entire chiller production around lowest total energy in Open-Protocol methods.

Native Tridium JACE Implications

Powered by Niagara AX FRAMEWORK®

Native systems run in "live-mode" on Tridium JACE hardware without Windows layer that slows execution rate and requires compiled code.

Controls contractors can easily connect to about anything.

Large and growing array of drivers and algorithms from a network of developers.

Correlating Performance and Value

- ***Determine the Real Opportunity -*** *determine the actual condensing temperature possible – water versus air cooled, evaporative condensing, adiabatic assist, sub-cooled design, free-cooling, rebates.*

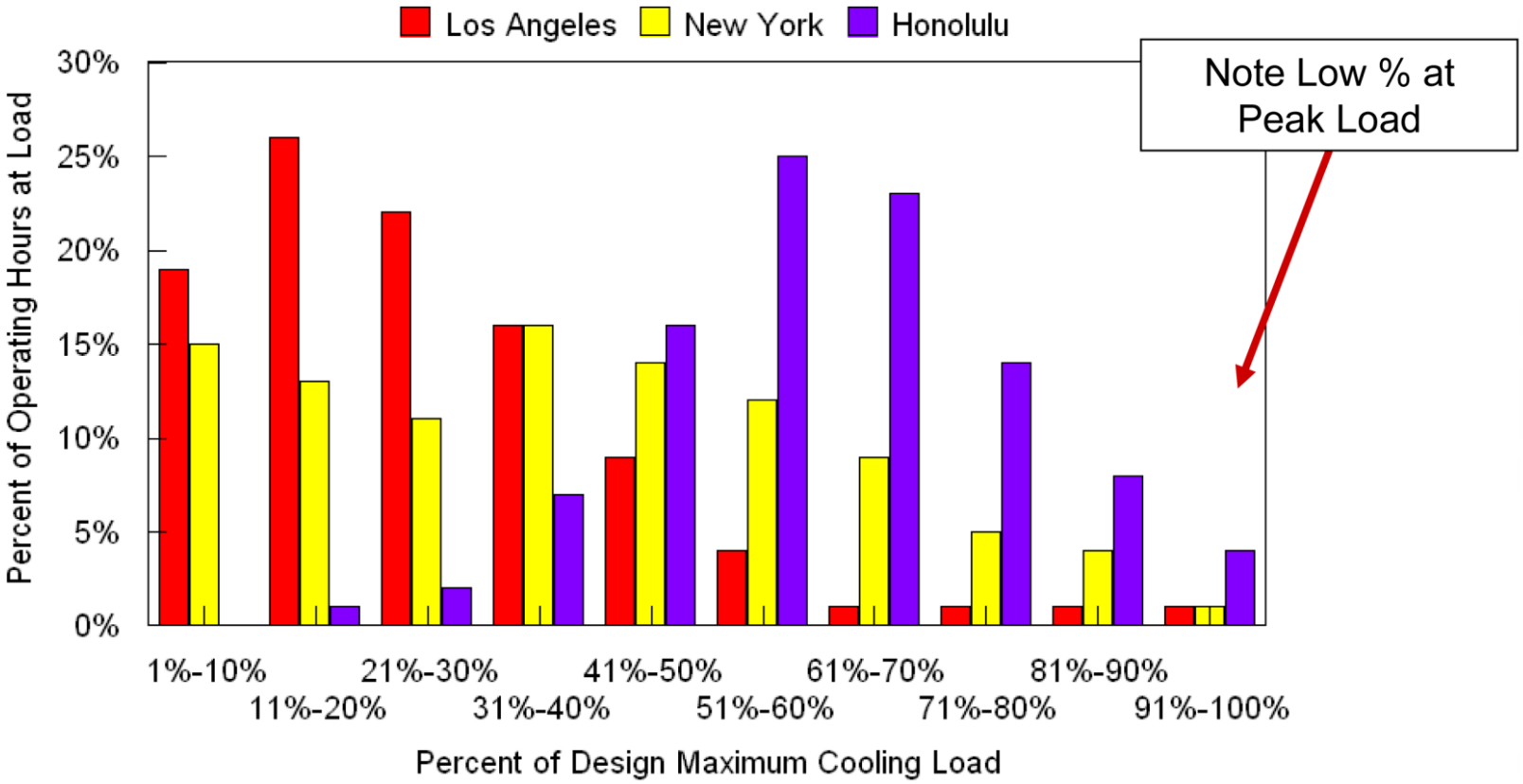
- ***Determine the Actual Load Profile*** *to correlate real run hours at 10% load points.*

- ***Correlate the RIGHT Chiller Energy Maps*** *Based on actual load and real opportunity kW at lowest.*

- ***LCC Effects of OIL, Maintenance. Real Costs*** *Long-Term, Sustainability, Carbon and LEED needs.*

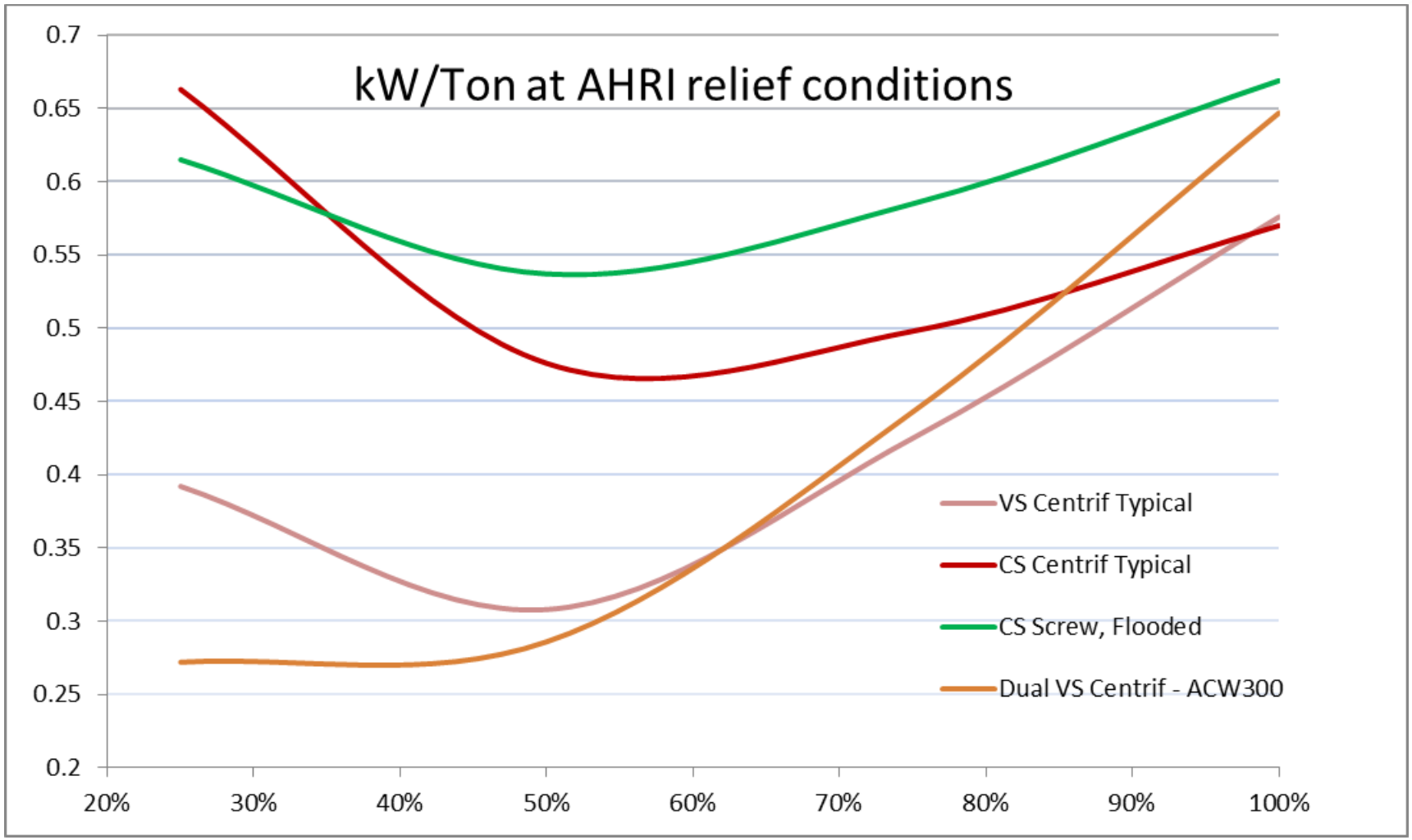
Load Profiles - Low Full Load Usage

Characteristics of Comfort Cooling Loads

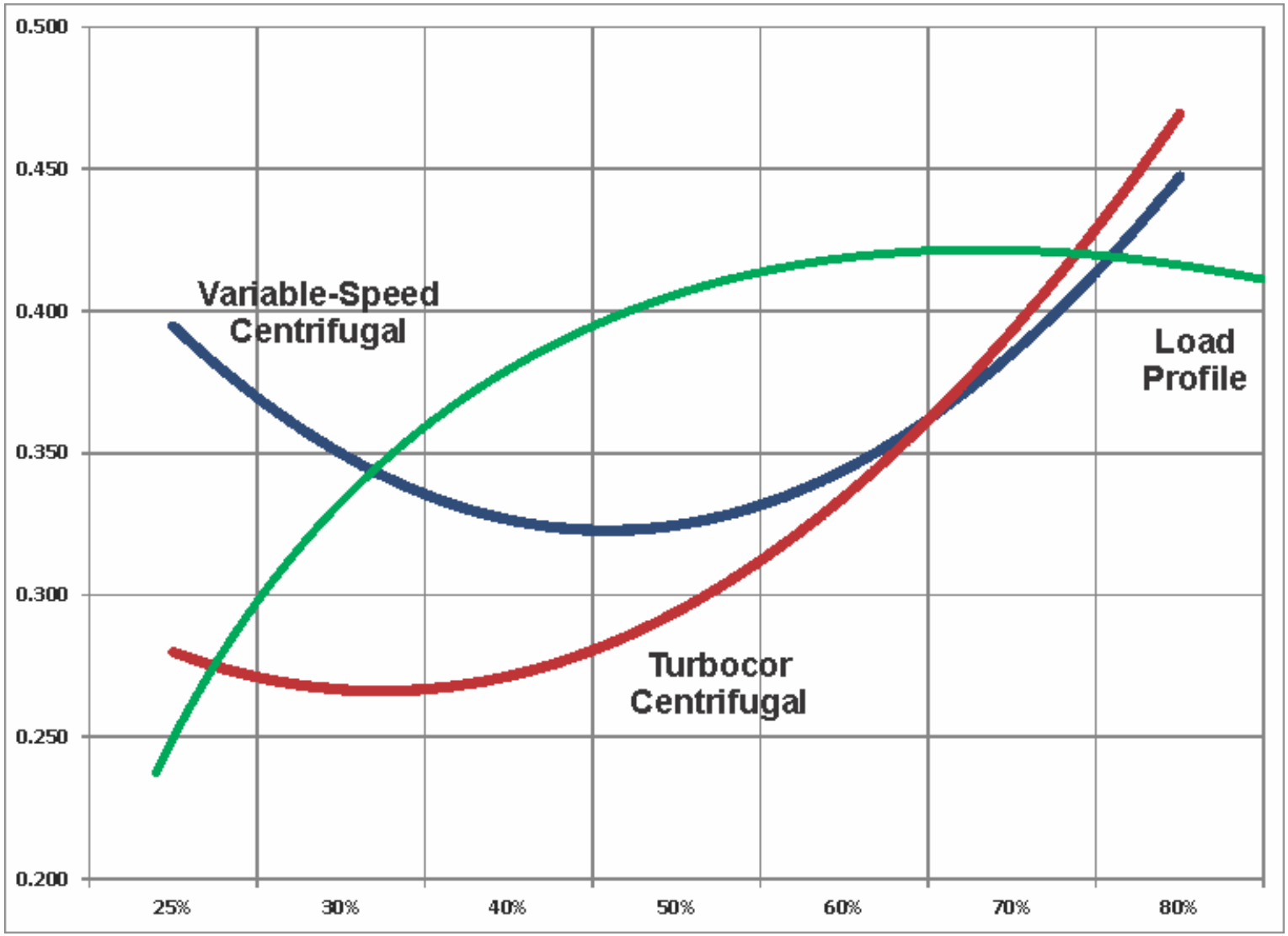


Courtesy Tom Hartman, The Hartman Company

Load Profiles for Compressors

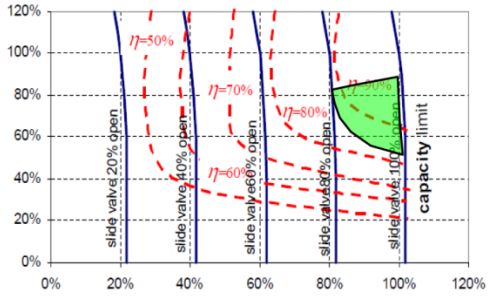


Energy With Actual Load Profile

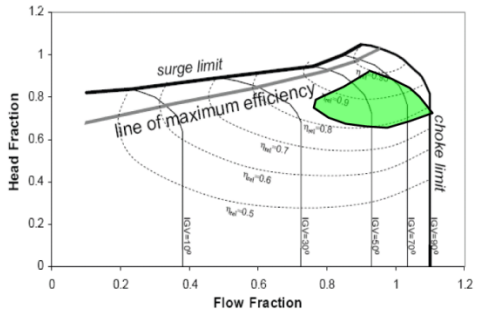


Efficiency Across a LARGER Envelope

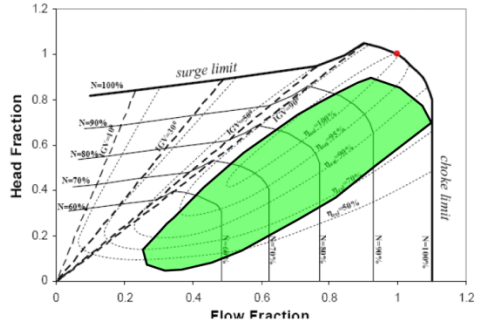
Map area with compressor efficiency within 10%
of full-load compressor efficiency



Screw



Fixed-speed centrifugal



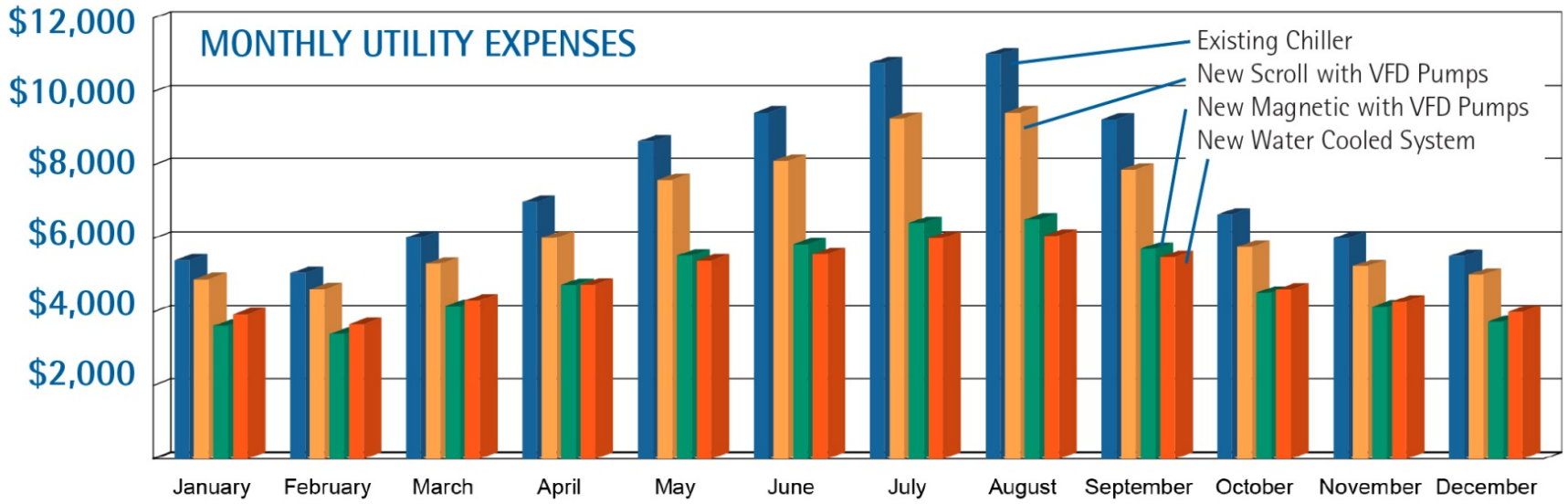
variable-speed centrifugal

Conclusion:

The variable-speed centrifugal compressor maintains peak efficiency over a much larger map area than either fixed speed centrifugal or screw compressors, explaining its excellent IPLV characteristics.

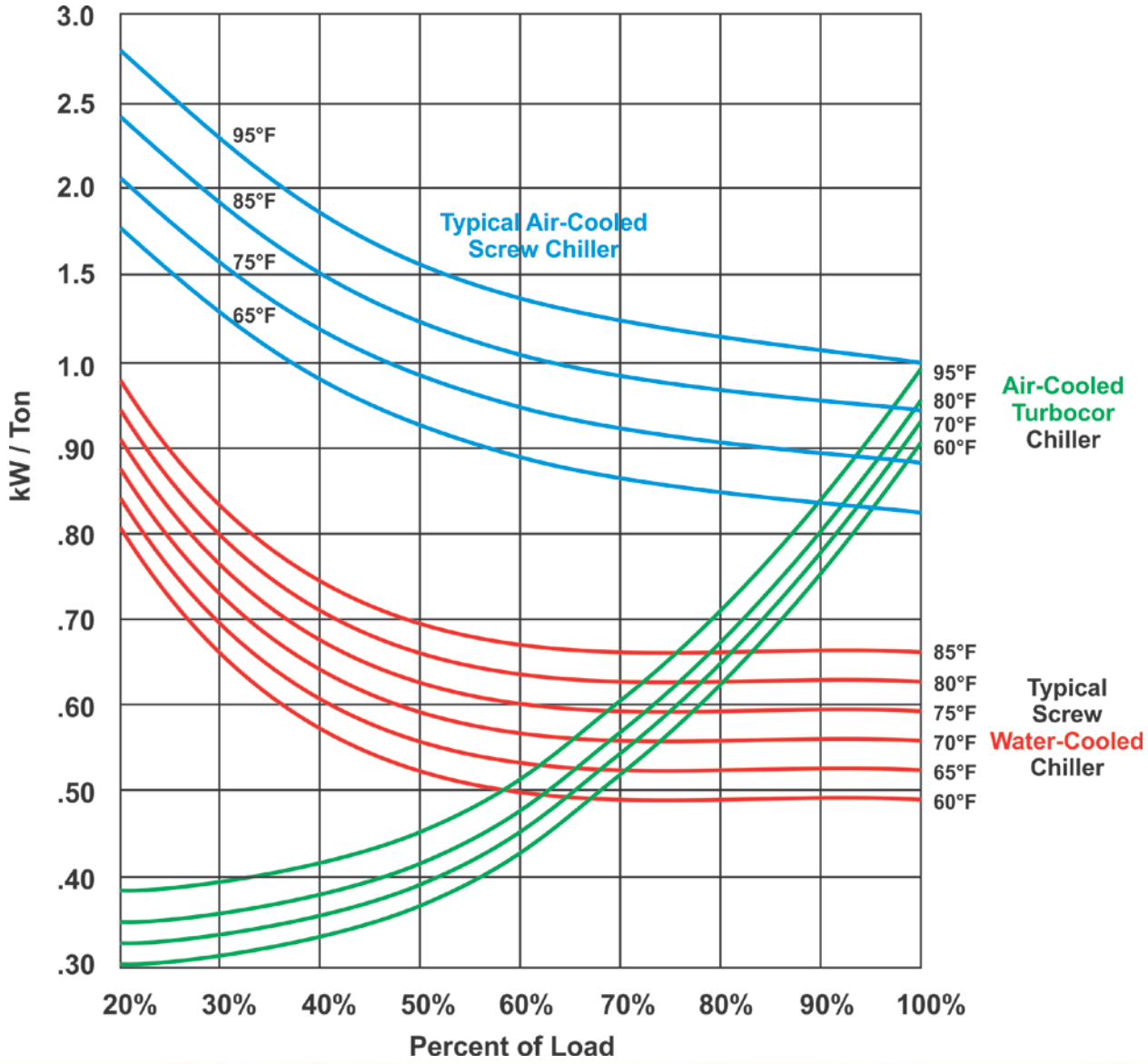
Load Profile and LCC Options

PRODUCT ALTERNATIVES	FIRST-COST DIFFERENCE	ANNUAL SAVINGS	CUMULATIVE CASH FLOW DIFFERENCE	SIMPLE PAYBACK (Years)	INTERNAL RATE OF RETURN	LIFE CYCLE COST ADVANTAGE
New Scroll versus Existing	$ 70,000	$ 11,639	$ 162,784	6.0	15.7%	$ 44,275
New Magnetic versus Existing	$ 163,000	$ 32,462	$ 486,249	5.0	19.3%	$ 155,721
New Water Cooled versus Existing	$ 258,000	$ 32,706	$ 396,119	7.9	11.1%	$ 63,111
New Magnetic versus New Scroll	$ 93,000	$ 20,823	$ 323,466	4.5	22.0%	$111,446
Water Cooled versus New Magnetic	$ 95,000	$ 243	$ -90,130	No payback	No payback	$ -92,609



Data and graphs provided by CDMtek, Austin, TX.

Water vs Air Cooled



ASHRAE 90.1 – Path B Reality

90.1, 2004 and the new 189.1, 2010 (Path B)

		Less than 150 Ton	150 to 300 Ton	300 to 600 Ton	> 600 Ton	
ASHRAE 189.1P, Path (B), 2010	Full Load	5.500	5.500	5.862	5.961	COP
		0.639	0.639	0.600	0.590	kW/Ton
	IPLV	7.816	7.816	8.792	8.792	COP
		0.450	0.450	0.400	0.400	kW/Ton
ASHRAE 90.1, 2004	Full Load	5.001	5.555	6.104	6.104	COP
		0.703	0.633	0.576	0.576	kW/Ton
	IPLV	5.250	5.900	6.400	6.400	COP
		0.670	0.596	0.549	0.549	kW/Ton

It's a Part-Load World

ASHRAE 90.1 – Path-B Reality

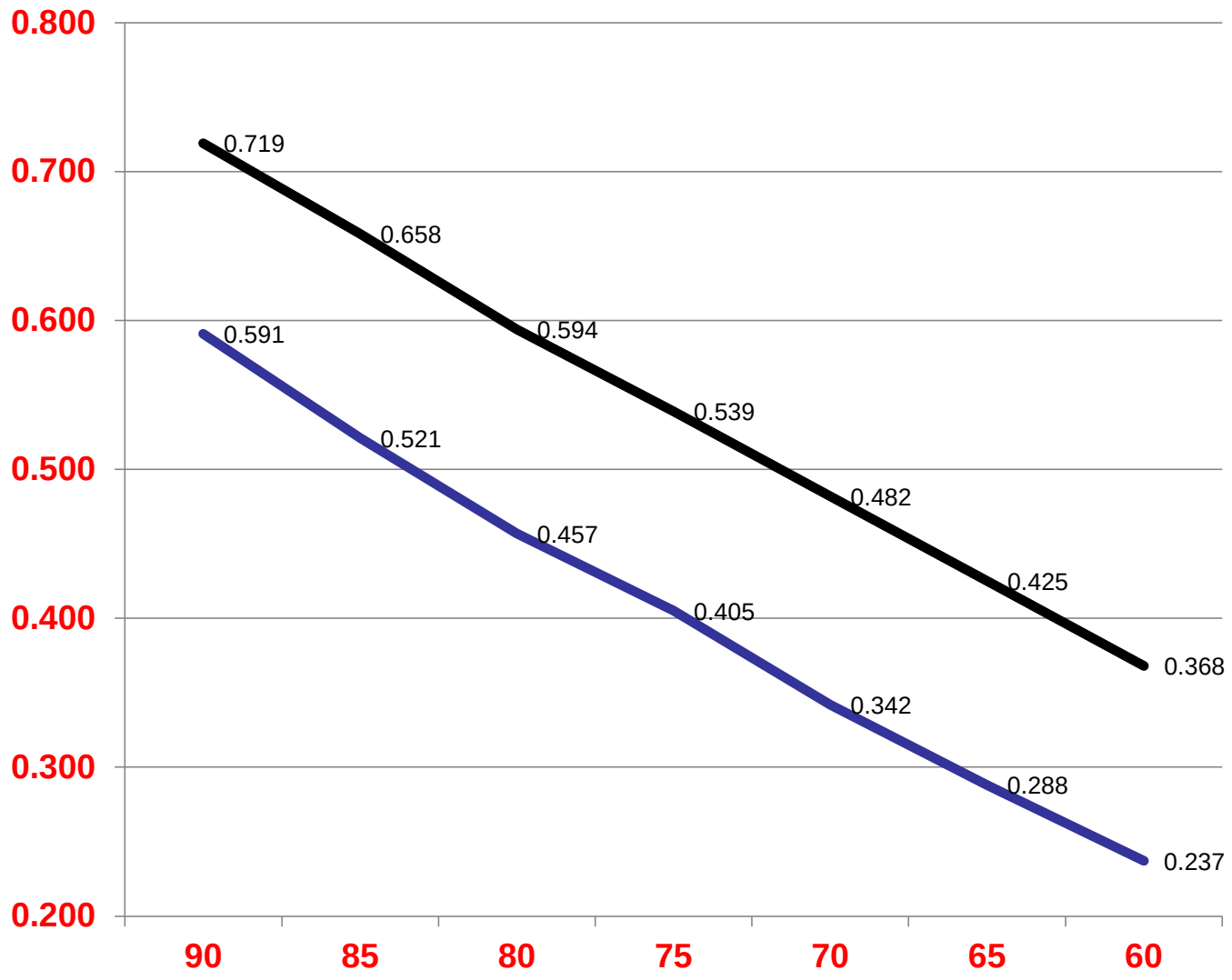
Implications for Path-A and Path-B Energy

- ***Constant-speed generally cannot meet Path-B.***

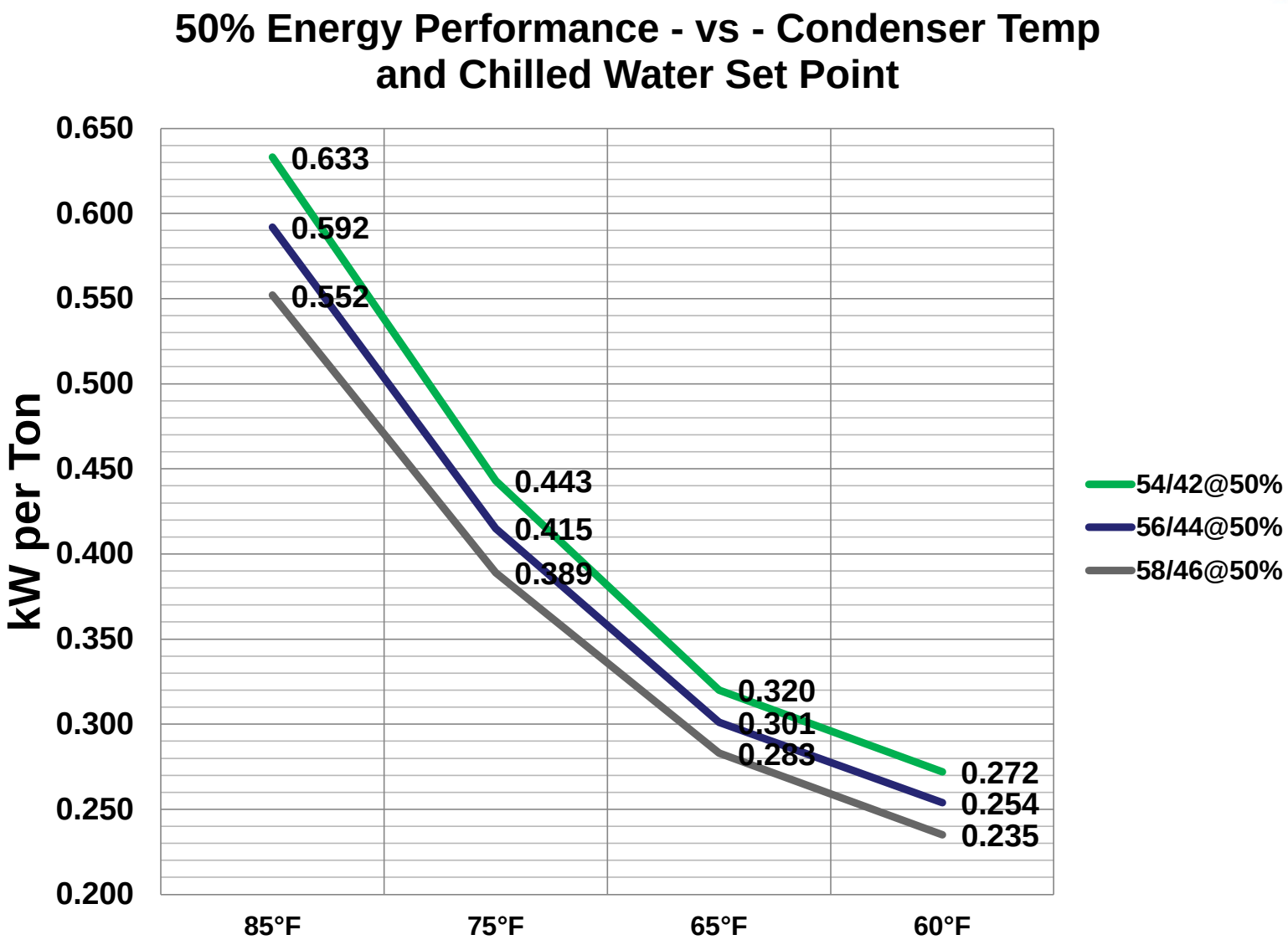
- ***Two chillers may BOTH meet ASHRAE 90.1 BUT one may be 22% More Efficient on Path-B!***

- ***Adding heat transfer surface and selecting correct full load point helps meet compliance.***

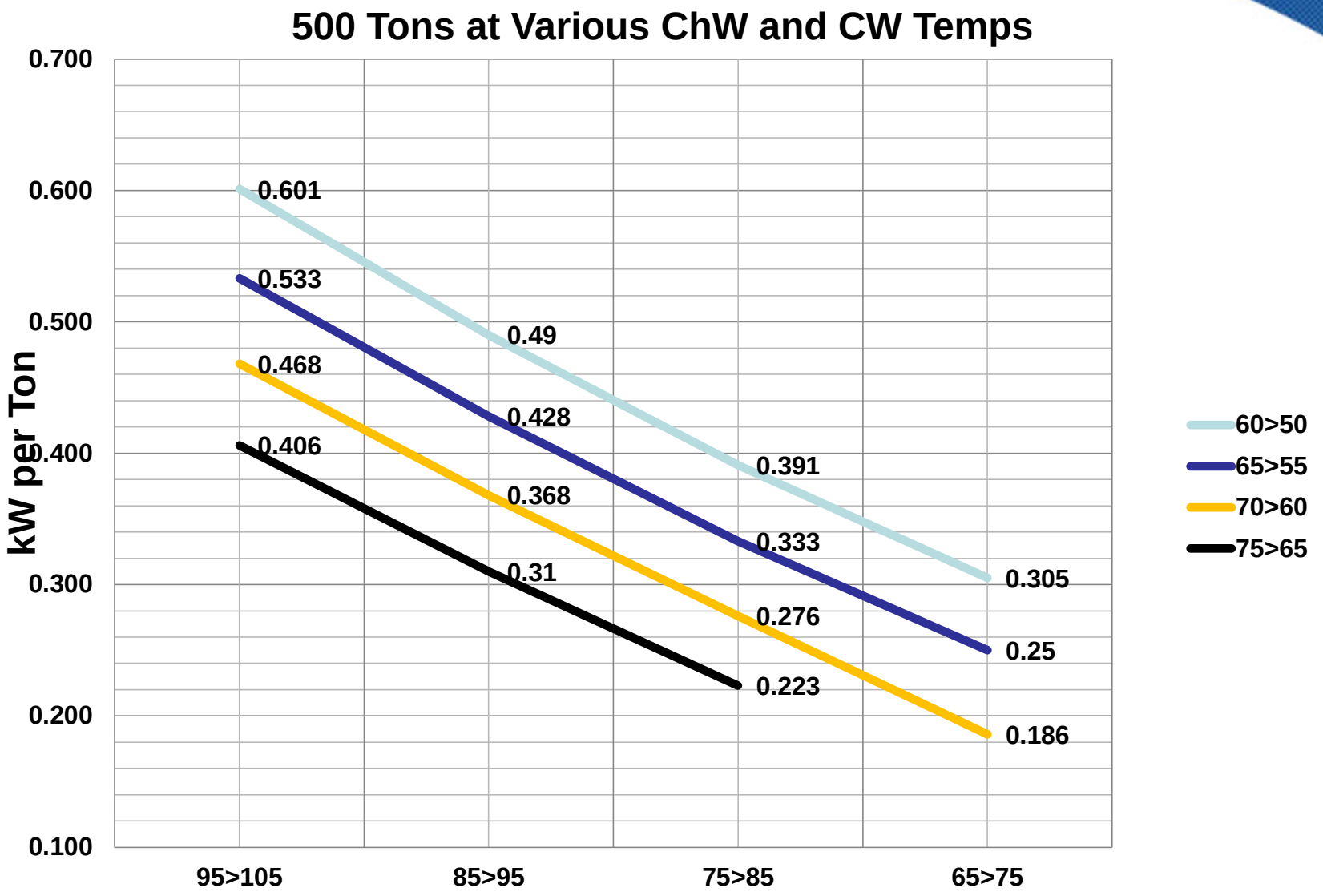
100% - vs - 50% Load



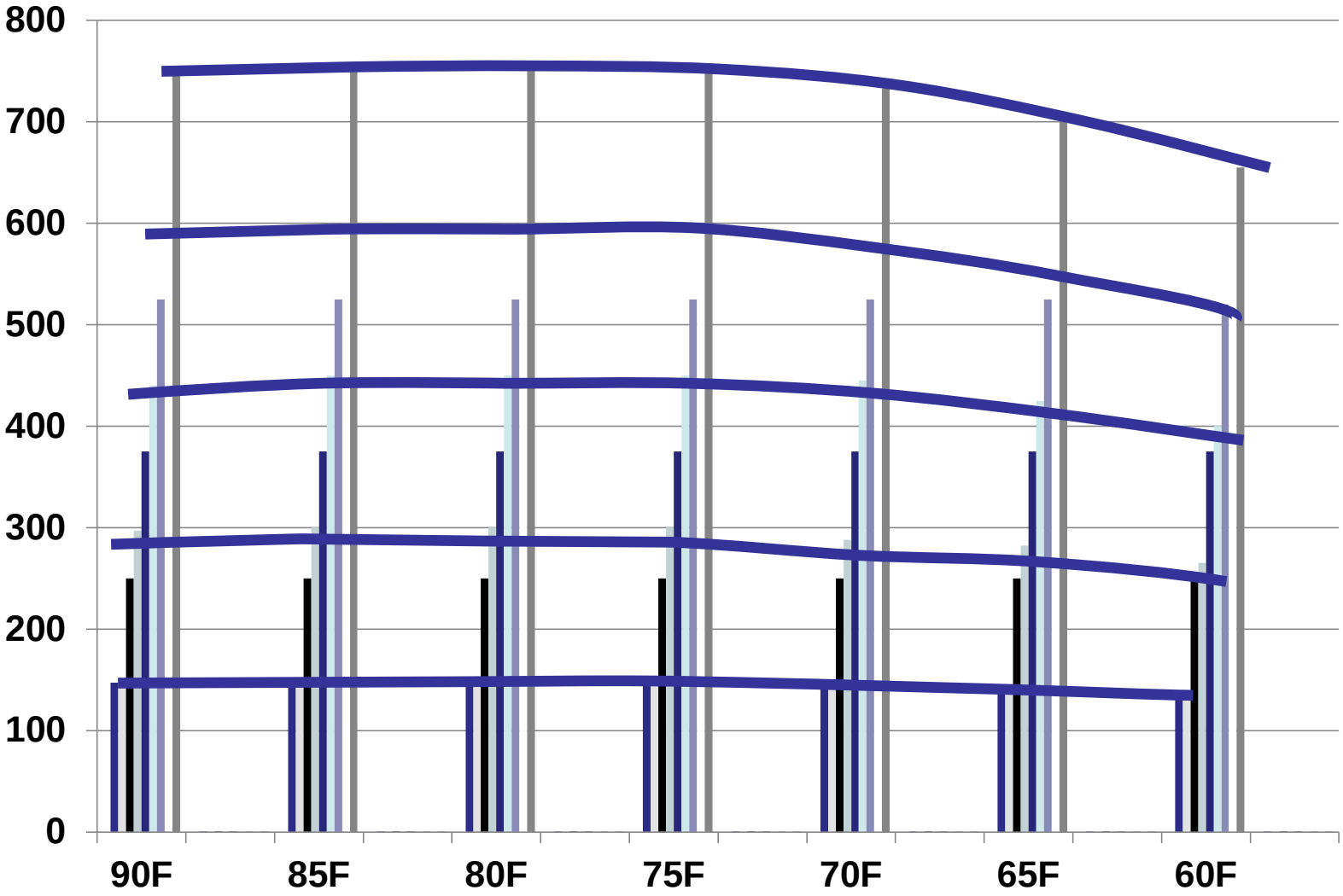
Energy for Turbocor Chillers



Energy Maps for Turbocor Chillers



Capacity vs Condenser Temp



Energy Cost Analysis

- **Houston**
- **St Louis**
- **Chicago**
- **Minneapolis**

Typical of Hot, Warm and Cold Cities.

- Fan, pump, cooling tower fan, electric heating, lighting and miscellaneous equipment energy consumption are excluded.
- The results shown are for chiller energy usage only.
- Electrical costs at $0.10 / kWh is shown.

Energy Analysis – Building Types

HLE –

- ***High internal load ratio***
- ***Low occupancy (ASHRAE Std. Office Building)***
- ***Economizer (airside)***
- ***Typical Office use***

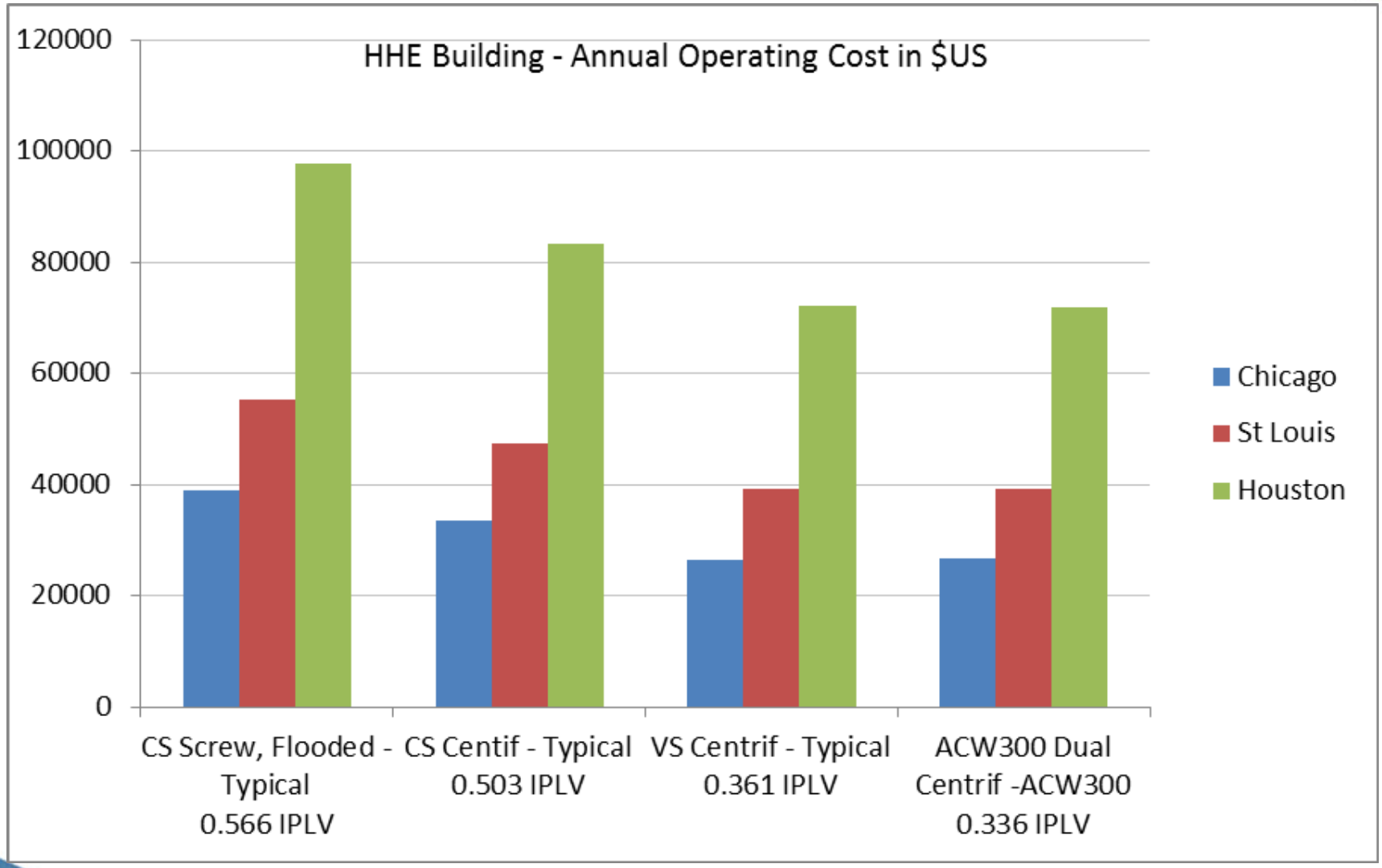
HHE –

- ***High internal load ratio***
- ***High occupancy - 24/7 operation***
- ***Economizer (airside)***
- ***Typical Hospital use***

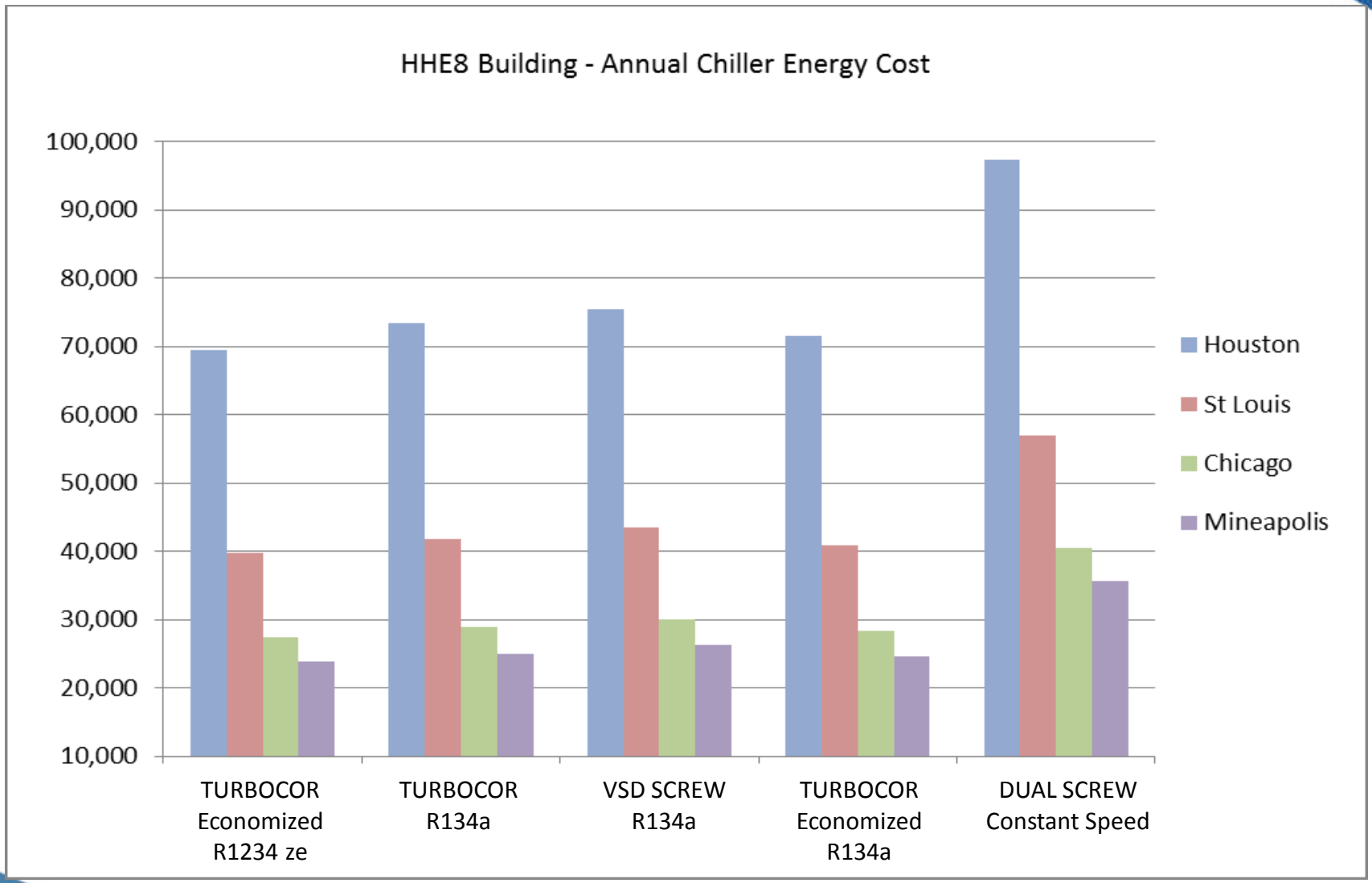
ASHRAE Standard Office Building

- Floor by floor VFD AHU with VAV electric reheat terminals
- Two equal parallel chillers with VSD pumps, VSD cooling tower fans
- Airside economizer option

Annual Energy Cost Comparison



Energy Analysis Air-Cooled



Energy Analysis Conclusions

		HLE Building			HHE Building		
		Chicago	St Louis	Houston	Chicago	St Louis	Houston
CS Screw, Flooded - Typical	0.566 IPLV	0%	0%	0%	0%	0%	0%
CS Centif - Typical	0.503 IPLV	13%	14%	15%	14%	14%	15%
VS Centrif - Typical	0.361 IPLV	31%	29%	26%	32%	29%	26%
ACW300 Dual Centrif -ACW300	0.336 IPLV	32%	31%	28%	31%	29%	27%

Air Cooled Chillers - Annual Energy Cost at $.10 per kW Hour - HHE8 Building				
	Houston	St. Louis	Chicago	Minneapolis
Constant Speed Dual Screw	$ 97,000	$ 57,000	$ 40,000	$ 35,000
Variable Speed Dual Screw	$ 76,000	$ 43,000	$ 30,000	$ 27,000
Turbocor Oil Free	$ 73,000	$ 41,000	$ 29,000	$ 25,000
Turbocor Oil-Free with Economizer	$ 71,000	$ 40,500	$ 28,000	$ 24,000
Turbocor Oil-Free with Economizer and R1234ze	**$ 69,000**	**$ 39,500**	**$ 27,000**	**$ 23,000**
LLC - SUSTAINABLE - U-Value Effect of Oil, No Oil Maintenance, No Bearing Replacements				

While the values differ by application, the relative differences are consistent across building types, systems and locations. Variable speed control offers the greatest step change in kWh and operating cost reduction.

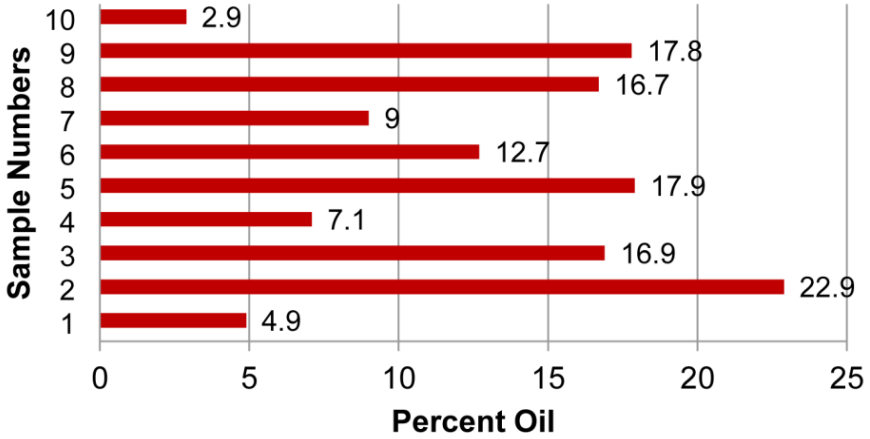
Oil-free makes it Sustainable and provides other LCC advantages.

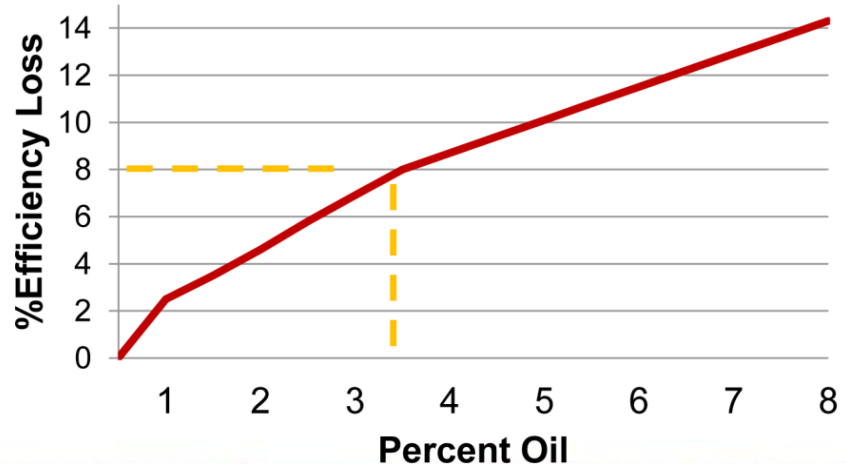
High Cost of Oil - Maintenance

Procedure	Daily	Weekly	Quarterly	Yearly
Record operating conditions (log)	X			
Check oil levels		X		
Check refrigerant levels		X		
Check oil return system			X	
Check operation of motor starter			X	
Check sump heater and thermostat			X	
Inspect and adjust safety controls			X	
Leak check and repair leaks			X	
Lubricate motor			X	
Check and tighten electrical connections				X
Megohm motor windings				X
Perform oil analysis on lube oil				X
Replace oil filter and return filter/dryers				X
Replace or clean starter air filters				X

Oil Results in Huge Life-Cycle Costs

The Effect of Oil in the System



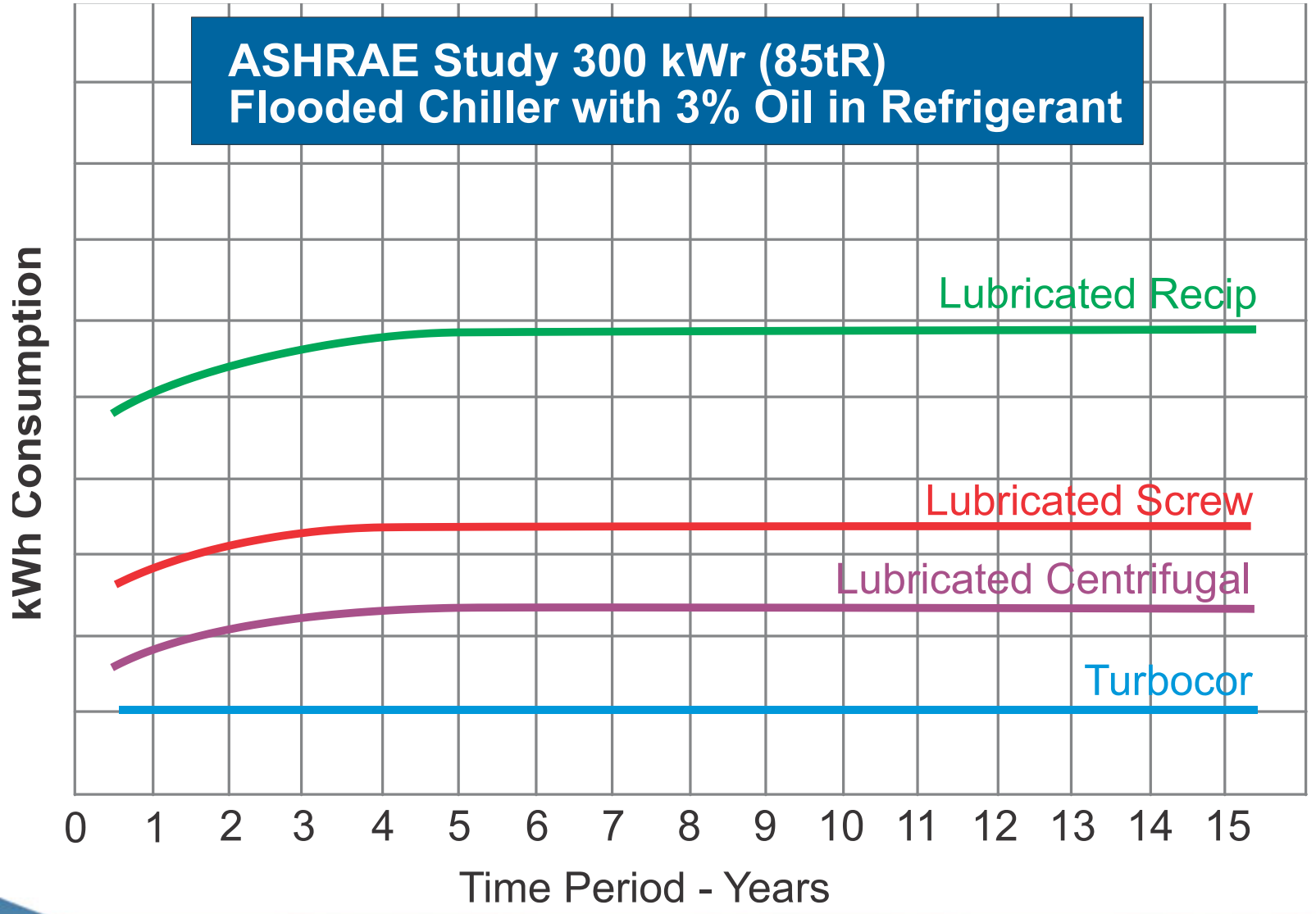


"An ASHRAE study determined that the vast majority of installed chillers have an excess amount of oil in the cooling system."

ASHRAE research study 601

3.5 % of oil in the refrigerant charge reduces system efficiencies by 8 %

Oil Results in Huge Life-Cycle Costs



High Cost of Oil - Logarithmic Effect!

BTUH = U * A * Log Mean Temp Difference

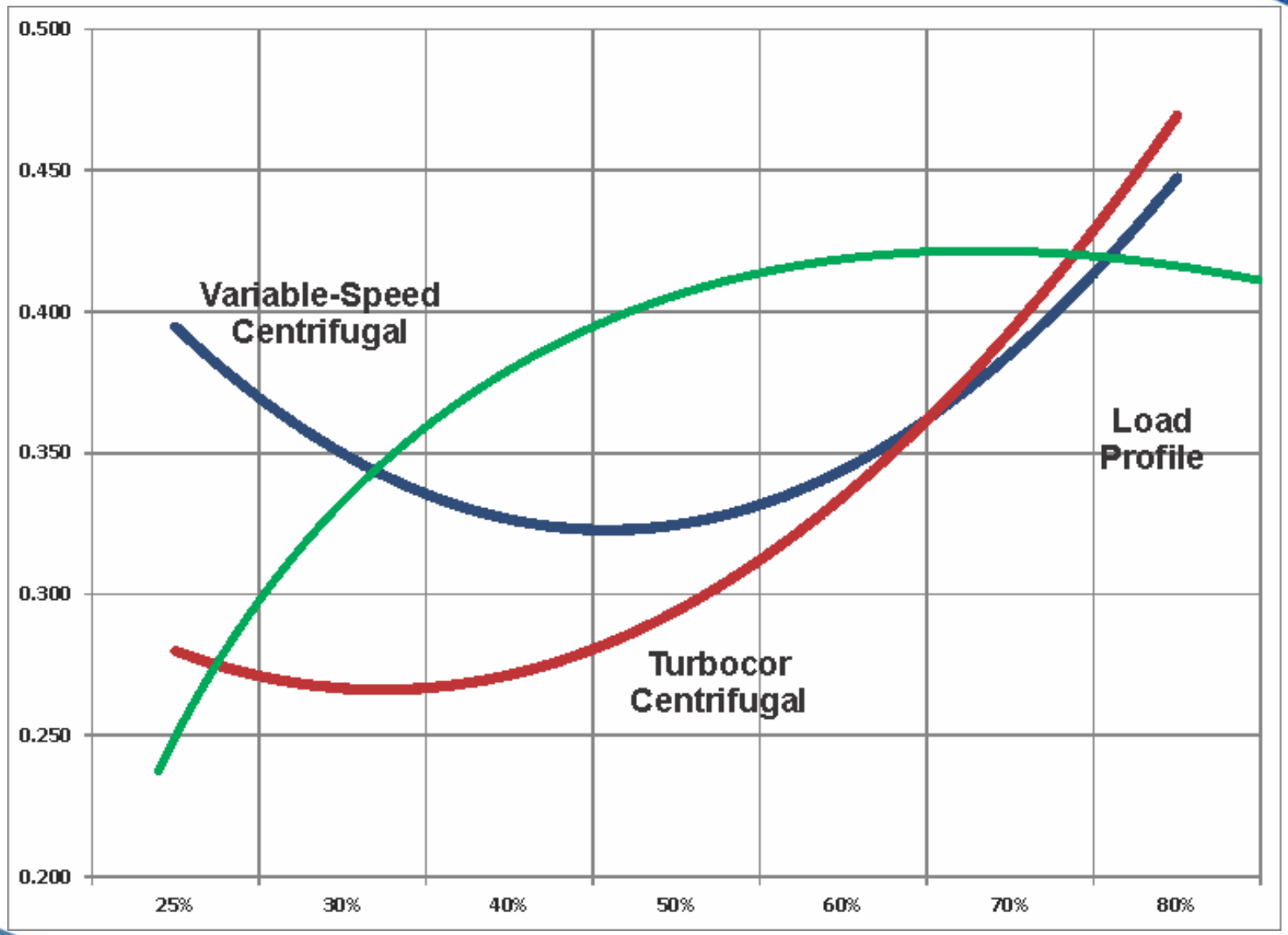
U - Heat Transfer Rate * A - Surface Area * LMTD

Degrading the U-Value just 8% forces the compressor to INCREASE its energy to compensate for the loss.

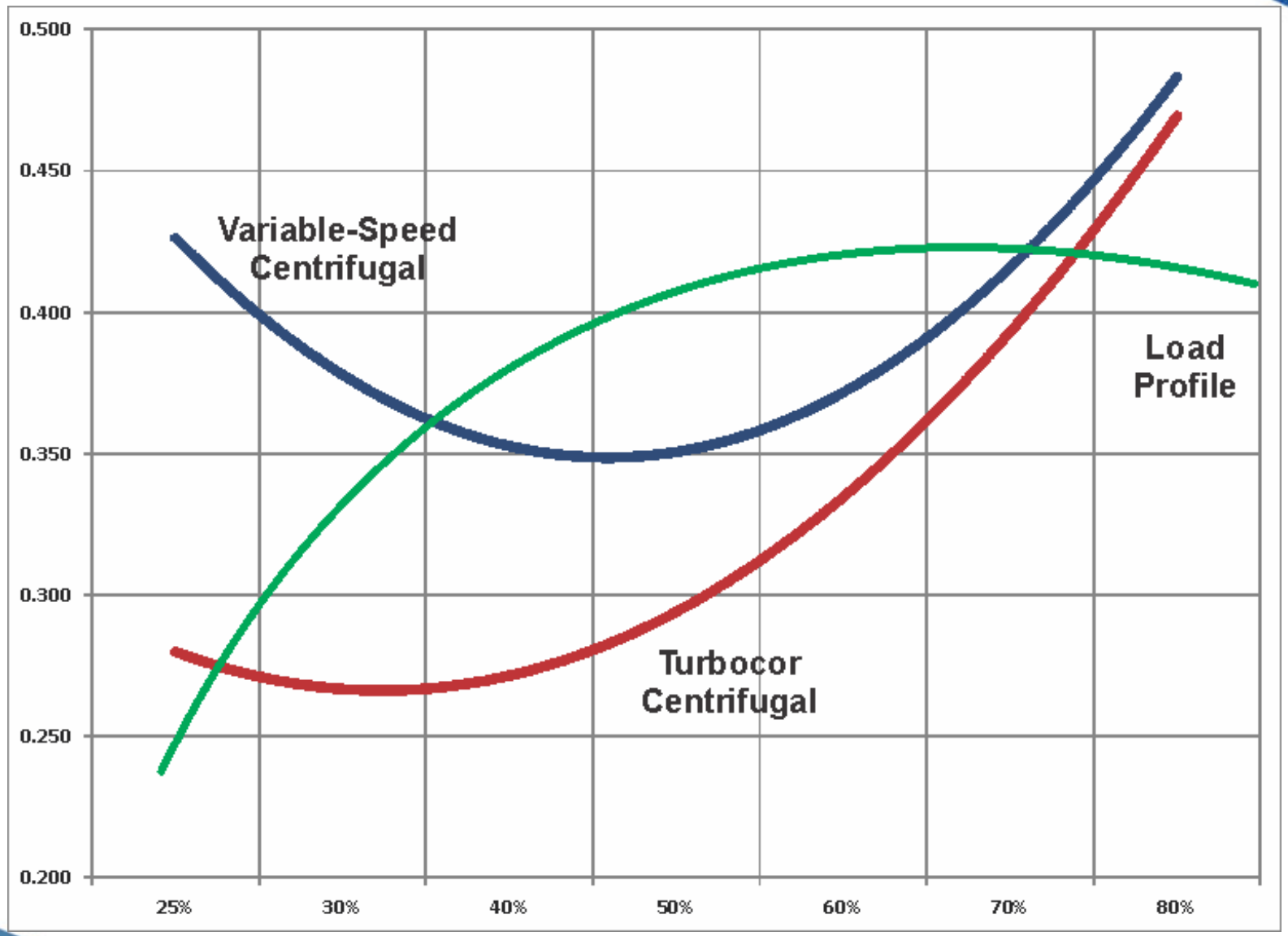
This is a logarithmic effect.

OIL IS NOT A SUSTAINABLE APPROACH!

Energy With Actual Load Profile



Energy – With 8% Loss from Oil

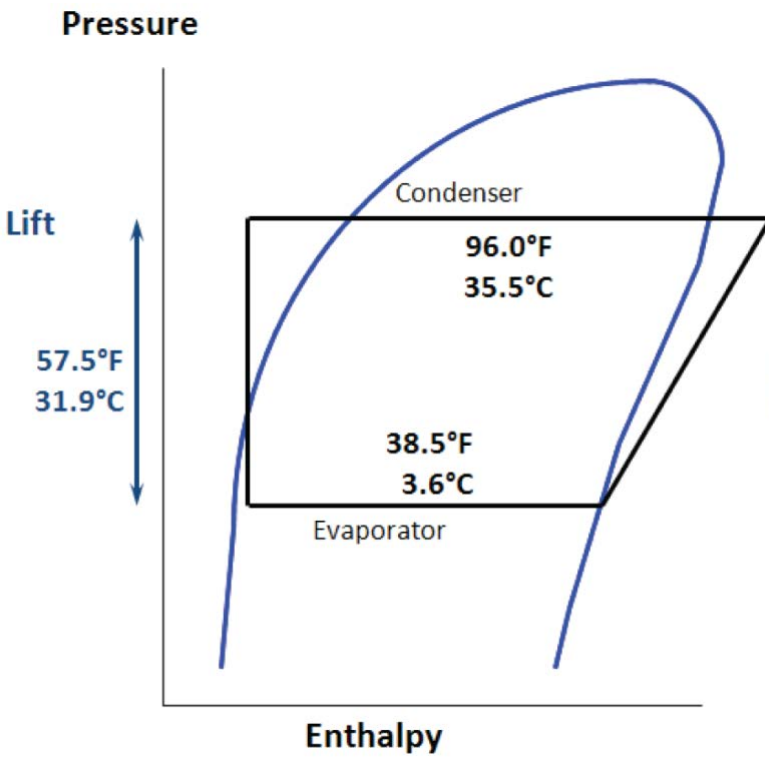


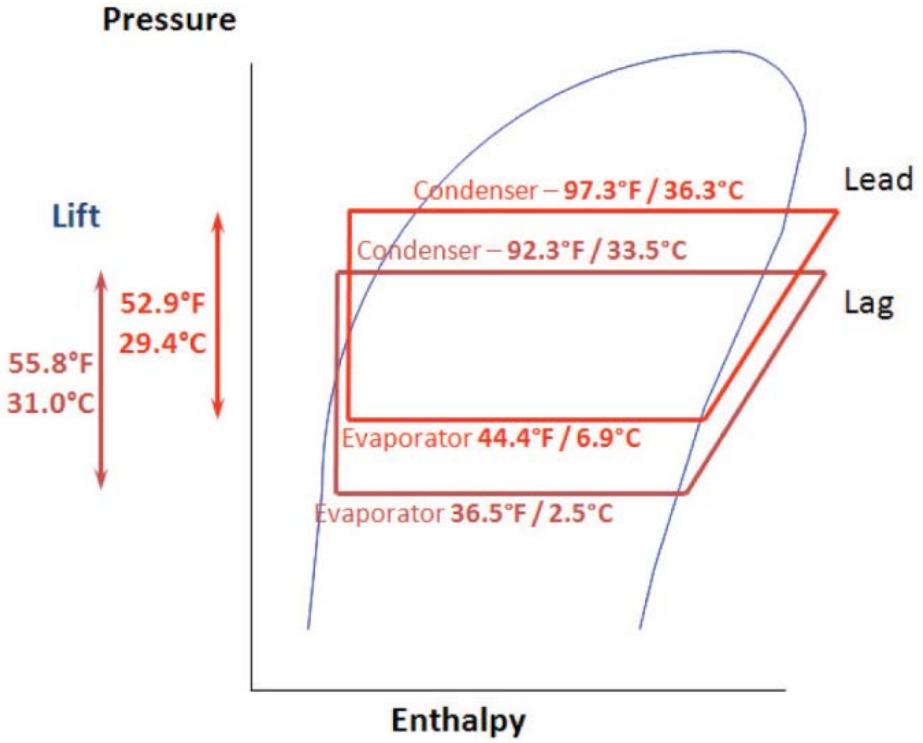
Key Things About Oil-Free Chillers

- **Oil can Never be Sustainable – U-Value loss for the remaining service life.**
- **Oil causes energy to shift upward across the entire load. Oil-free chillers have an effective payback at higher load points than when it was new.**
- **Outside of energy, oil-related service are the number one cost of owning a chiller. Lubricated part failure is the highest contributor to downtime.**
- **There are no compressor bearing inspections or periodic rebuilds. There is one moving part in the compressor. Capacitor change every 10 years.**
- **There is FAR less noise in magnetic bearings. 70 dB without attenuation.**
- **Service life may exceed fifty years with sustainable energy efficiency.**
- **The Reduced Carbon-Footprint of operating at lower energy is seen as a responsible environmental approach.**

Economizers Reduce Energy at Full Load

Series-Counter-Flow Reduces Lift





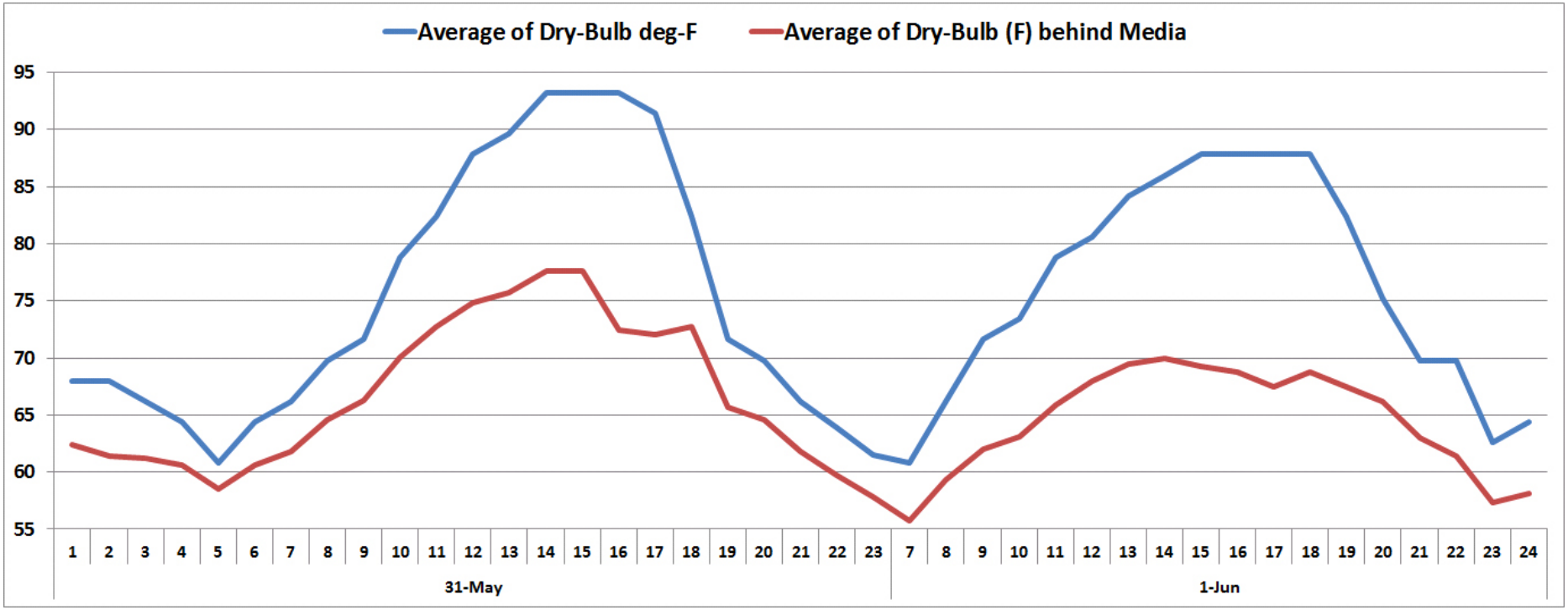
Chillers in parallel requires each to produce the total system lift.

Series counter-flow reduces the lift requirement for both chillers.

Air Cooled Evap-Assist Condensing

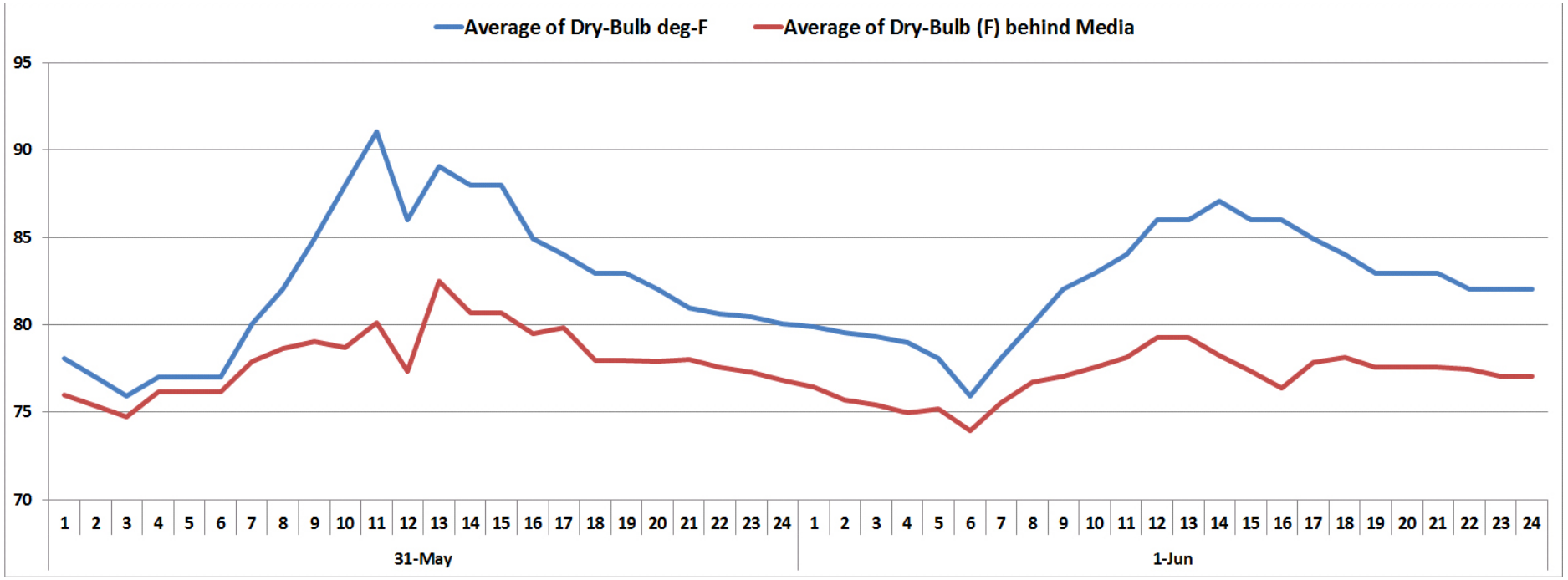
Air Cooled Evap-Assist Condensing

Sacramento CA



Air Cooled Evap-Assist Condensing

Miami FL



Air Cooled Evap-Assist Condensing

Las Vegas Result

Hours above 45°F – 6,302 Hours – 22.29° Avg WBD
Hours Above 60°F – 2,716 Hours – 28.13° Avg WBD
Average Utility Rate - $0.15 - Ambient 105°F.
Average Wet-Bulb Depression Effect = 20°F

3,000 Hours x $0.15 kW/Hr x 1.022 kW/ton = $114,975
3,000 Hours x $0.15 kW/Hr x .693 kW/ton = $77,963

Annual Energy Only Savings = $37,012

Requires no cooling tower, water treatment, water make-up or condenser pumps

Low-Noise and Higher Efficiency

Figure 1: Using a diffuser greatly reduces the losses experienced once the impeller has discharged the air

Fluid Coolers For Pre and Free Cooling

Its About Total Cost of Ownership

Energy ***– Correlated with True CW temps and Load Profiles and Optimized Chiller Loading***

Utility Rebates ***– Can Pay for Premium Cost***

Maintenance ***– No Oil, Rebuilds, Lowest Cost***

U-Value Degradation ***– 8% is common loss***

Lowest Noise - ***Technologies Available***

Air Cooled ***versus Water Cooled***

Oil-Free is the ONLY Sustainable Low Energy Chiller Approach

The Bottom Line About Creating Value

***The Economic Opportunity* May be Compelling...**

***Better Technology* Can Promote Change…**

***Regulations & Standards* Can Speed Change…**

***Environmental Responsibility* Suggest Change…**

Total Cost of Ownership Powers Change

Questions or Comments…

Questions ?

Jackson Ball, Group Vice President – Mobile 678-234-2821
Jacksonb@arcticchillergroup.com