Data Center Energy Savings – By the numbers

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HP Critical Facility Services provided by EYP Mission Critical Facilities

"It is the sense of Congress that it is in the best interest of the United States for purchasers of computer servers to give high priority to energy efficiency as a factor in determining best value and performance for purchases of computer servers."

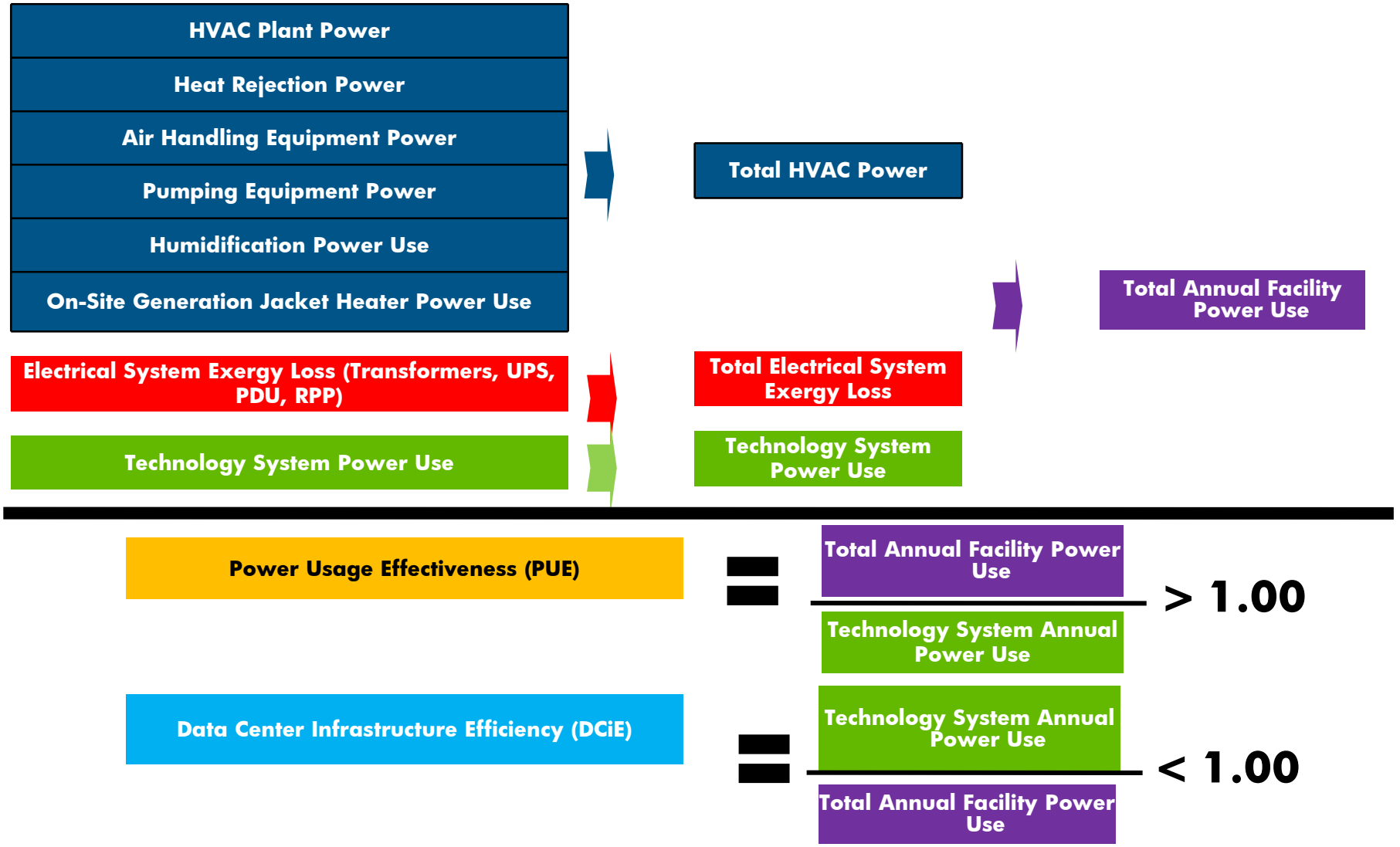
Speaker of the House of Representatives
Vice President of the United States and
President of the Senate
From H.R.5646

Environmental Envelope

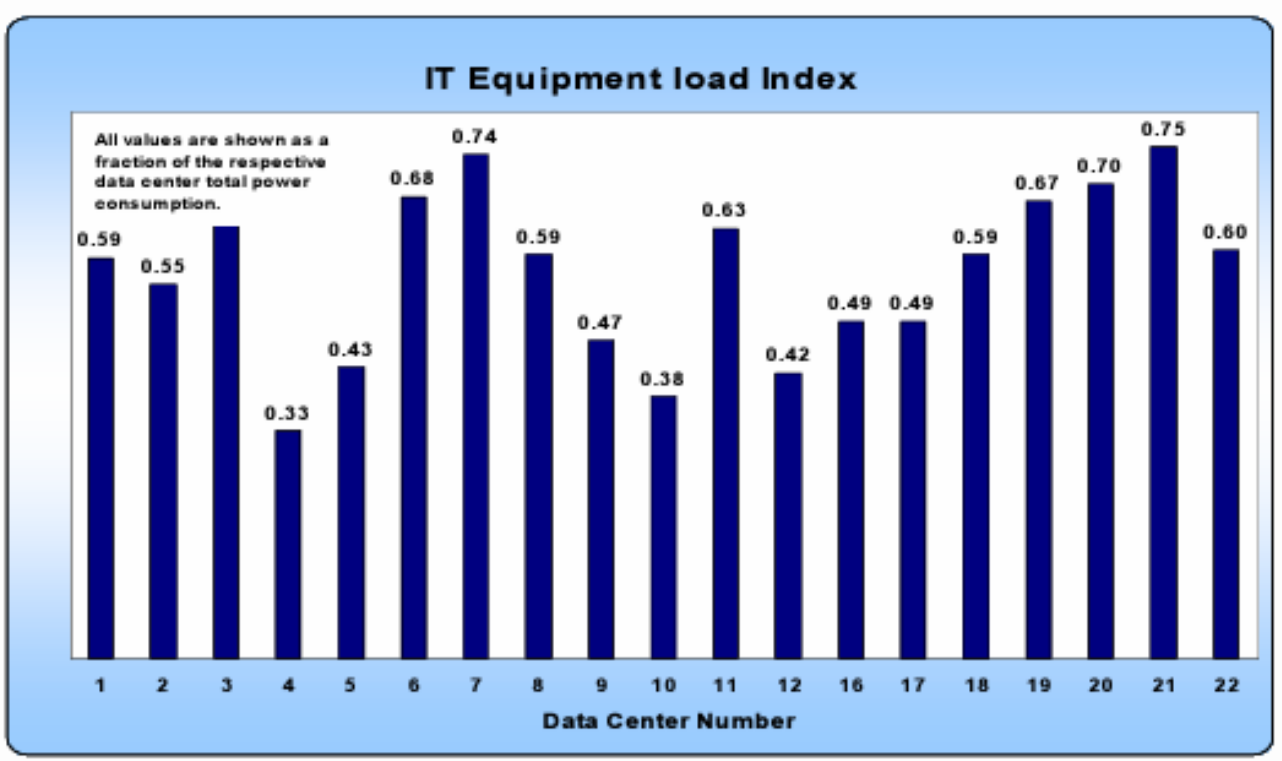
Class 1 Design Conditions			
Condition	**Class 1 Control Parameters**		
	Allowable Level	**2004 Recommended Level**	**2008 Recommended Level**
Temperature control range	59°F – 90°F (Class 1)	68°F – 77°F	64.4°F – 80.6°F
Maximum temperature rate of change	9°F. per hour		
Relative humidity control range	20% - 80% 63°F Max Dewpoint (Class 1)	40% - 55%	41.9°F – 59.0°F Dew Point 5.5°C – 15.0°C Dew Point Maximum 60% RH
Filtration quality	65%, min. 30% (MERV 11, min. MERV 8)		
These conditions are inlet conditions recommended in the ASHRAE Publication *Thermal Guidelines for Data Processing Environments*			

Power Usage Effectiveness (PUE)

Defining PUE and DCiE



	PUE Total	PUE Electrical	PUE Mechanical
Minimum	1.33	0.03	0.30
Average	1.90	0.09	0.81
Maximum	3.03	0.20	1.83



Source: Measuring Energy Consumption And Performance Of Data Centers And Servers, Jonathan Koomey

Data Center Power Allocation

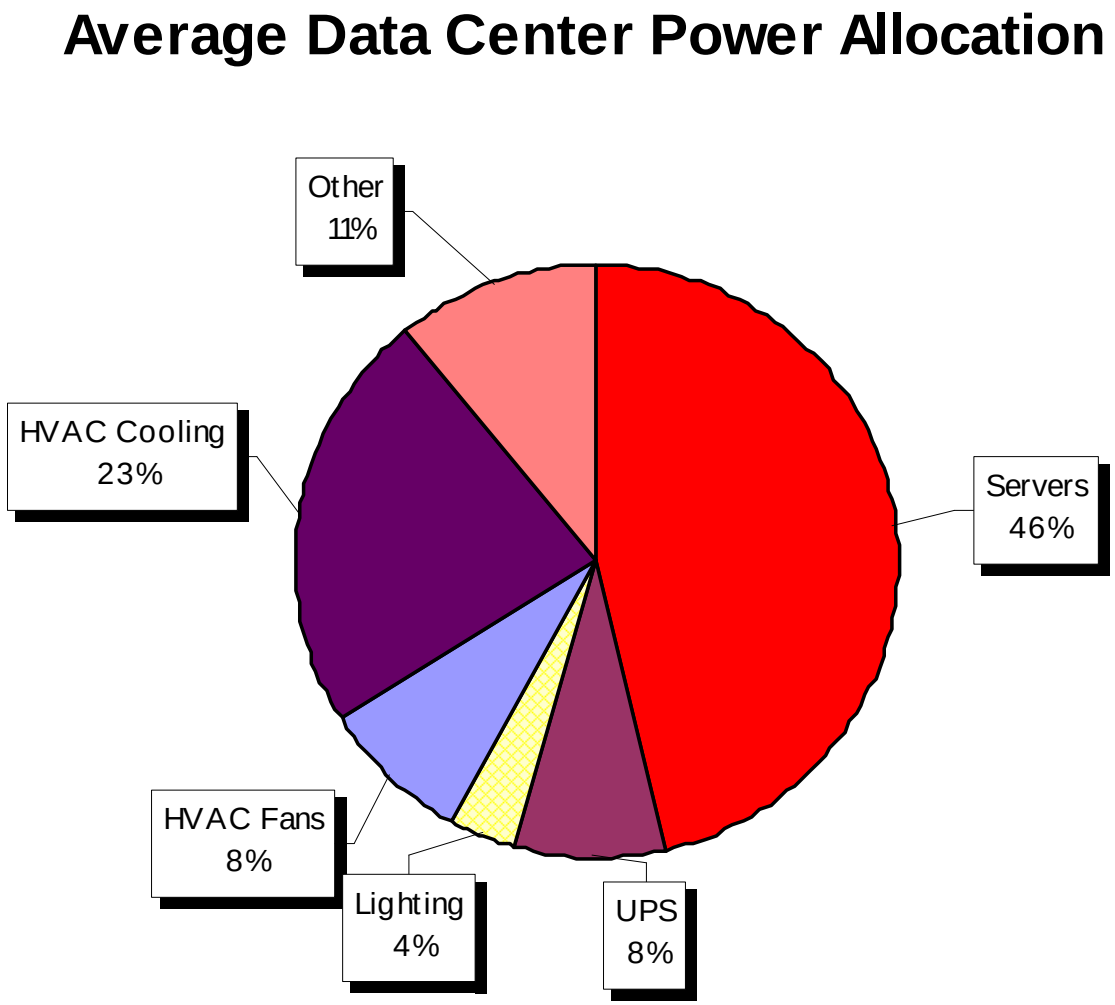
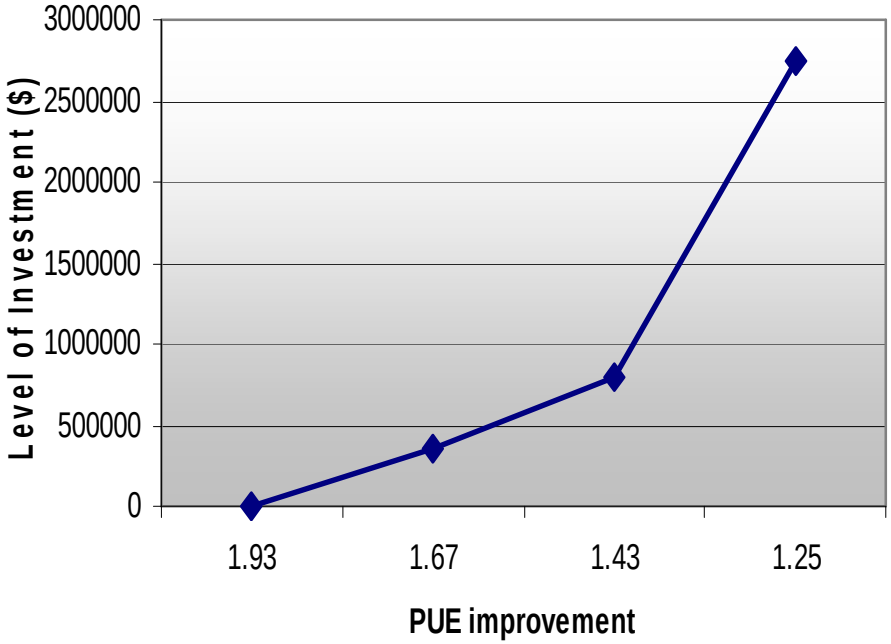
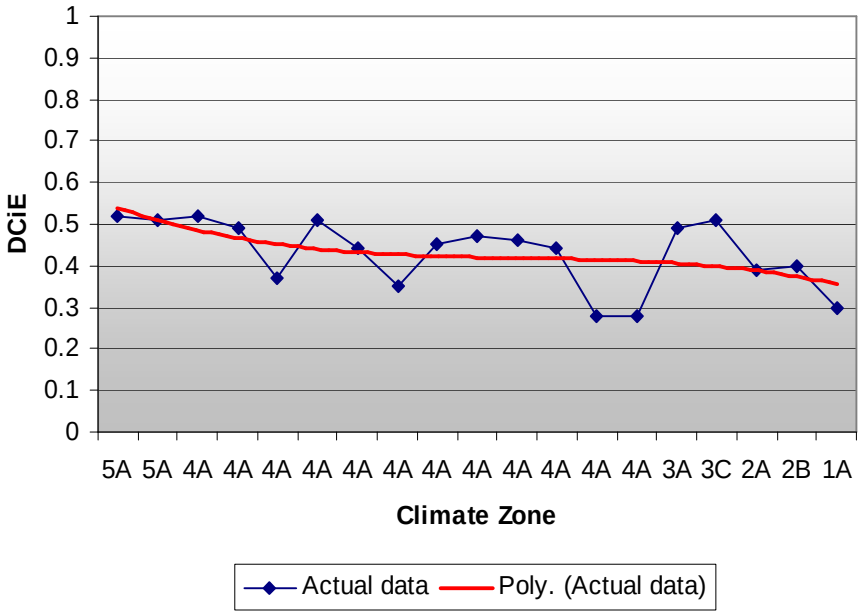


Fig. 1.4 Average Power Allocation for 12 Benchmarked Data Centers (source: LBNL 2007a)

Improve the PUE

Upgrade	DCiE	PUE	Rating	Cumulative[1] Cost	Simple payback[2] (years)
Current	**0.52**	**1.94**	**D**		
I	0.60	1.67	C	$300k - $400k	1.7
II	0.70	1.43	B	$600k - $1M	2.5
II	0.8	1.25	A	$2.5M-$3M	5.7

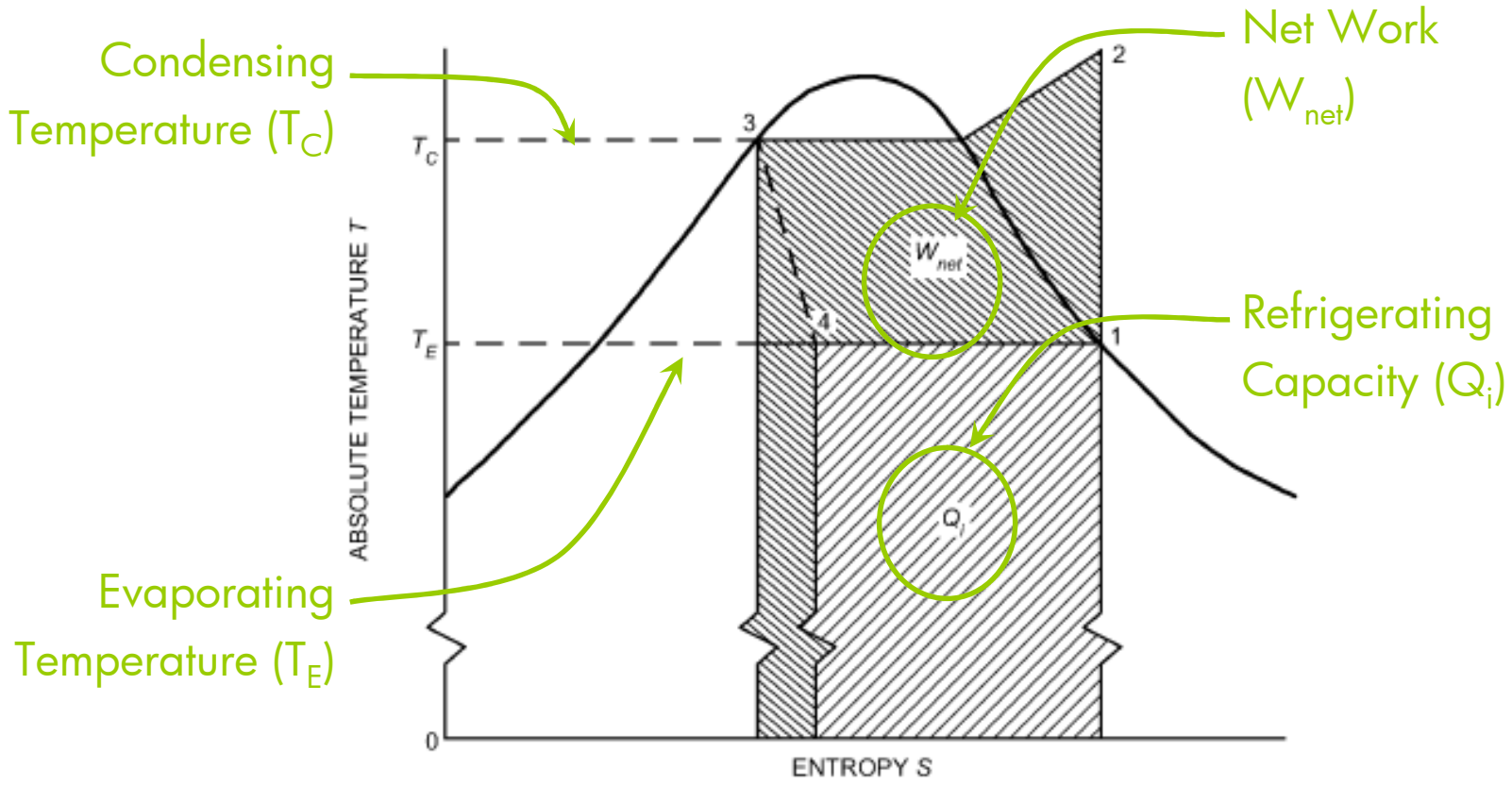




Centrifugal Chilled Water Plant Energy Efficiency

Primary Energy Reduction Strategies

Coefficient of Performance (COP) = Qi /Wnet



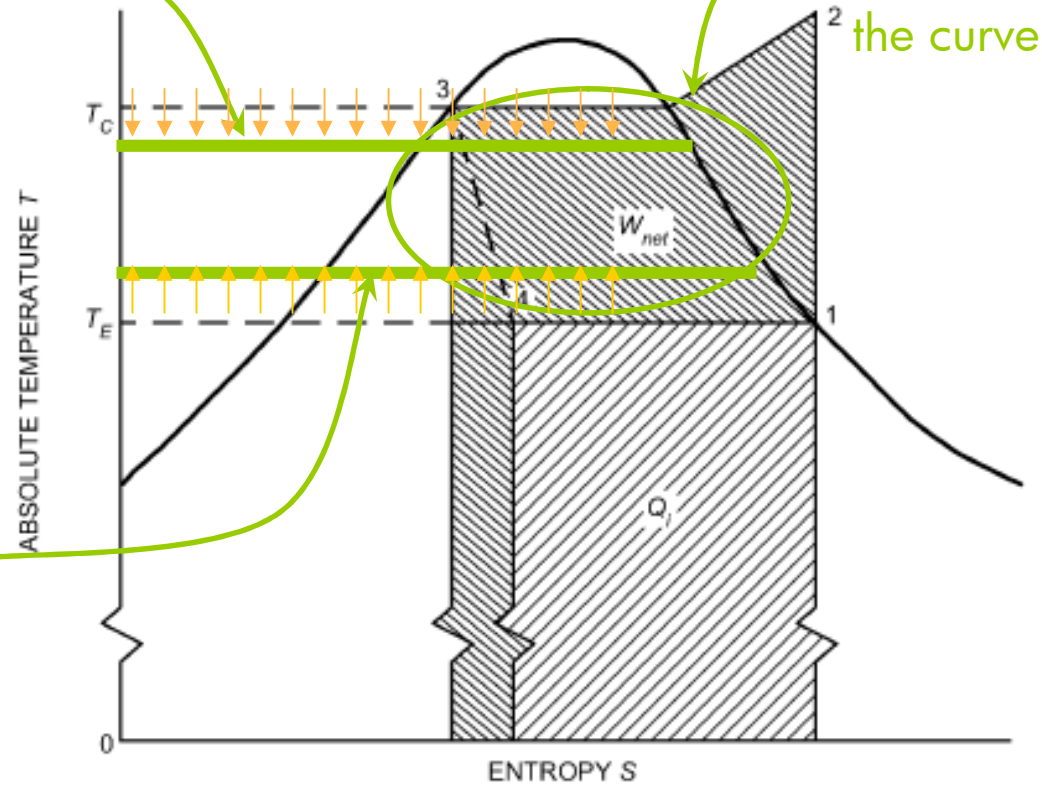
Energy Reduction Strategies: Mechanical

Coefficient of Performance = Q_i / W_{net} COPideal=$T_E/(T_C-T_E)$

Decreased Condensing Temperature (T_C)

Increased Evaporating Temperature (T_E)

Reduce the area under the curve = less power

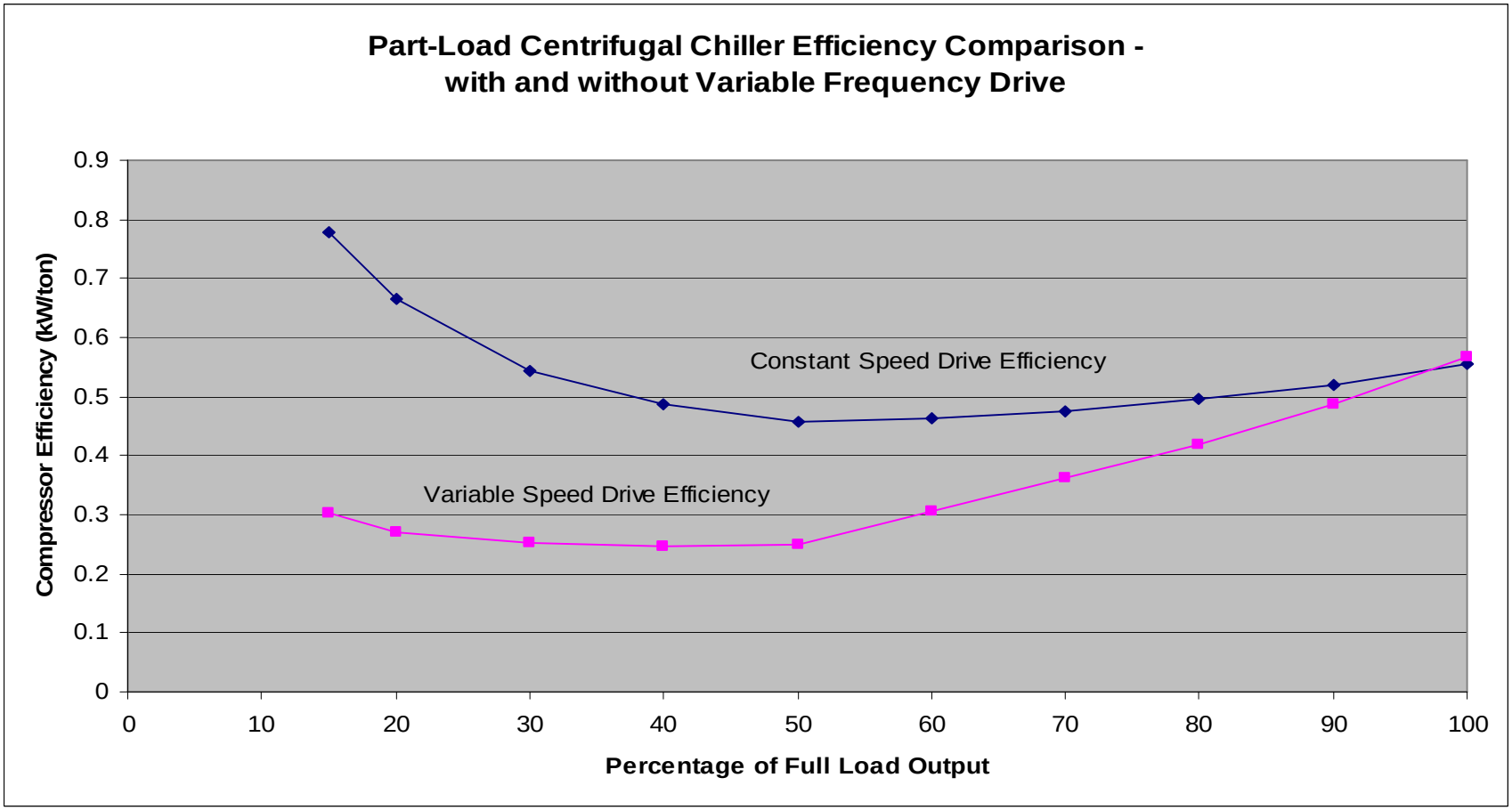


Chilled/Condenser Water Temperature and Efficiency

- 5% improvement for 2 deg F increase in chilled water temperature.
- 19% improvement for 10 deg decrease in condenser water temperature.

Energy (KW/Ton)					
Chilled Water Temperature (F)	Entering Condenser Water Temperature (F)				
	85	75	65	60	Integrated
45	0.565	0.463	0.376	0.338	0.369
47	0.535	0.439	0.353	0.315	0.346
49	0.509	0.414	0.332	0.289	0.321
51	0.483	0.387	0.309	0.271	0.301
53	0.459	0.367	0.288	0.262	0.287
55	0.432	0.346	0.267	0.256	0.275

Part Load Efficiency Curve



Sample Part-Load Centrifugal Chiller Efficiency with
and without Variable Frequency Drive (courtesy of ASHRAE)

Elevated Chilled Water Temperature Energy Savings

Elevated Chilled Water Temperature Annualized Energy Comparison					
Case	**Plant Description 2700 Ton Load**	**Energy Consumption Kilowatt - Hours**	**Annual Operating Cost**		
			Operating Cost / Year	**Differential $**	**Differential %**
Chilled Water = 45F	No Economizer	19211370	$ 2,041,137	Base	Base
Chilled Water = 50F	No Economizer	17948320	$ 1,914,832	$ (126,305)	-6%
Chilled Water = 55F	No Economizer	17062890	$ 1,826,289	$ (241,848)	-11%
Chilled Water = 60F	No Economizer	15940030	$ 1,714,003	$ (327,134)	-16%

Water Side Economizers

Water Side Economizers

- Use cold condenser water to generate chilled water
- Minimize or eliminate the requirement to operate the chillers when the ambient conditions permit
- The cooling towers generate the cold condenser water
- Energy savings dependent upon wet-bulb (moisture content of air)

Water Side Economizers

- Regions with lower wet-bulb are necessary
- Need approximately 7 to 10F “approach” (wet bulb must be 7 to 10F less than design chilled water temperature)
- Higher design chilled water temperature (above conventional 45F) extends use of economizer

Economizer Hourly Breakdown – Tallahassee

Annualized Economizer Hourly Comparison							
Case	**System**	**Mechanical Cooling**		**Partial Economizer**		**Full Economizer**	
Chilled Water = 45F	Water Side Economizer	7,090	Hrs	1,353	Hrs	285	Hrs
Chilled Water = 50F	Water Side Economizer	6,378	Hrs	1,757	Hrs	593	Hrs
Chilled Water = 55F	Water Side Economizer	5,490	Hrs	2,187	Hrs	1,051	Hrs
Chilled Water = 60F	Water Side Economizer	4,463	Hrs	2,627	Hrs	1,638	Hrs

Water Side Economizer Savings – Mid Atlantic States

Water Side Economizer Annualized Energy Comparison					
Case	**Plant Description 2700 Ton Load**	**Energy Consumption Kilowatt - Hours**	**Annual Operating Cost**		
			Operating Cost / Year	**Differential $**	**Differential %**
Chilled Water = 45F	No Economizer	19211370	$ 2,041,137	Base	Base
Alternate #1	Series Economizer	16633220	$ 1,783,322	$ (257,815)	-13%
Chilled Water = 50F	No Economizer	17948320	$ 1,914,832	Base	Base
Alternate #1	Series Economizer	15067700	$ 1,626,770	$ (288,062)	-15%
Chilled Water = 55F	No Economizer	17062890	$ 1,826,289	Base	Base
Alternate #1	Series Economizer	13291020	$ 1,449,102	$ (377,187)	-21%
Chilled Water = 60F	No Economizer	15940030	$ 1,714,003	Base	Base
Alternate #1	Series Economizer	12117970	$ 1,331,797	$ (382,206)	-22%

Air Side Economizers

Air Side Economizers

- Use outside air to directly cool the data center
- Energy savings dependent on dry-bulb (thermometer temperature) and wet-bulb (moisture content of air) temperature – enthalpy control
- Need to control supply air temperature to produce optimal dry-bulb and moisture content – don't want air too dry
- Equipment requirement to operate in 35% to 60% RH
- Adiabatic humidification required to leverage all available free cooling hours

Economizer Hourly Breakdown – Tallahassee

Annualized Economizer Hourly Comparison							
Case	**System**	**Mechanical Cooling**		**Partial Economizer**		**Full Economizer**	
Chilled Water = 45F Supply Air = 55F	Water Side Economizer	7,090	Hrs	1,353	Hrs	285	Hrs
	Air Side Economizer	4,463	Hrs	2,627	Hrs	1,638	Hrs
Chilled Water = 50F Supply Air = 60F	Water Side Economizer	6,378	Hrs	1,757	Hrs	593	Hrs
	Air Side Economizer	3,131	Hrs	3,247	Hrs	2,350	Hrs
Chilled Water = 55F Suply Air = 65F	Water Side Economizer	5,490	Hrs	2,187	Hrs	1,051	Hrs
	Air Side Economizer	3,131	Hrs	3,247	Hrs	2,350	Hrs
Chilled Water = 60F Supply Air – 70F	Water Side Economizer	4,463	Hrs	2,627	Hrs	1,638	Hrs
	Air Side Economizer	3,131	Hrs	2,359	Hrs	3,238	Hrs

Air Side Economizer Savings – Mid Atlantic States

Air Side Economizer Annualized Energy Comparison					
Case	**Plant Description 2700 Ton Load**	**Energy Consumption Kilowatt - Hours**	**Annual Operating Cost**		
			Operating Cost / Year	**Differential $**	**Differential %**
Chilled Water = 45F	No Economizer	19211370	$ 2,041,137	Base	Base
Alternate #1	Series Economizer	16633220	$ 1,783,322	$ (257,815)	-13%
Alternate #2	Air Side Economizer	15027018	$ 1,553,702	$ (487,435)	-24%
Chilled Water = 50F	No Economizer	17948320	$ 1,914,832	Base	Base
Alternate #1	Series Economizer	15067700	$ 1,626,770	$ (288,062)	-15%
Alternate #2	Air Side Economizer	12937855	$ 1,340,285	$ (574,546)	-30%
Chilled Water = 55F	No Economizer	17062890	$ 1,826,289	Base	Base
Alternate #1	Series Economizer	13291020	$ 1,449,102	$ (377,187)	-21%
Alternate #2	Air Side Economizer	11389777	$ 1,171,228	$ (655,061)	-36%
Chilled Water = 60F	No Economizer	15940030	$ 1,714,003	Base	Base
Alternate #1	Series Economizer	12117970	$ 1,331,797	$ (382,206)	-22%
Alternate #2	Air Side Economizer	10556990	$ 1,081,949	$ (632,054)	-37%

Variable Speed Drives to Reduce Supply Fan Energy

Variable speed drives and fan energy

- Power reduces by the cube of the speed reduction!
- For our 7500kW UPS load with 20% redundant CRAH's.
  - 68 - 110 kW CRAH units required to meet the load, 82 units total with redundancy.
  - All units provided with10 kW motors

Energy Reductions as function of speed reduction (7500 kW data center)

Case	Annual Cost	Differential	Percentage
All units run at full speed	$ 717,572	Base	Base
All units run with variable speed drives at 80%	$ 367,396	$ (350,176)	-48%
All units run with variable speed drives at 60%	$ 154,995	$ (562,577)	-78%
All units run with variable speed drives at 40%	$ 45,924	$ (671,648)	-94%

(Based on $0.10/kWh, 3% drive inefficiency)

Containers

Container - Interior view

Serviceable high efficiency heat exchangers (HEX) from HP MCS

Serviceable high efficiency, variable speed blowers from HP MCS

Standard 50U racks

Facilities management on exterior of cold aisle

Hot aisle with rear access through doors in the container

36" cold aisle can run at >90F