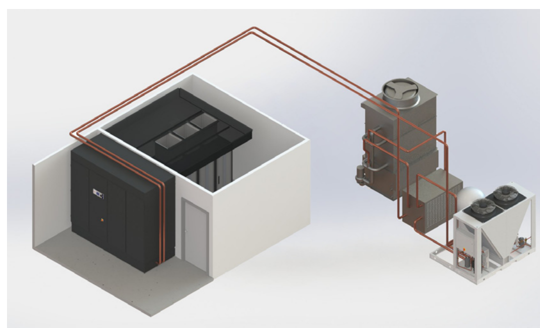

STULZ Water-Side Economizer Solutions

with STULZ Dynamic Economizer Cooling

Optimized Cap-Ex and Minimized Op-Ex

STULZ Data Center Design Guide

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STULZ®

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STULZ Water-Side Economizer

with STULZ Dynamic Economizer Cooling

- Optimized Cap-Ex
- Lowest Op-Ex

Technology Leader

STULZ has the broadest line of precision cooling equipment in the industry, from outdoor cooling, to indoor cooling, to retrofit and conditioning. STULZ is leading the way in energy efficient cooling solutions in the data center environment. All STULZ products can be applied to the latest ASHRAE standards and guidelines and used in water-side economizer solutions.

Leading the Way

As a leading manufacturer of precision cooling equipment, STULZ is able to support state-of-the-art energy efficient water-side economizer cooling solutions for data center applications. This design guide will develop why economizers are necessary, illustrate various designs of economizers, and focus on the latest leading-edge solution of STULZ Dynamic Economizer Cooling – including controls, and provides hard data on the tremendous value and cost savings that can be achieved.

STULZ Story of Innovative Economizer Cooling:

DX Economizer Solutions

- Traditional Economizer
- Variable Economizer
- Evaporative Tower Economizer

CW Economizer Solutions

- Dual-Source Chilled Water Economizer
- DEC Dynamic Economizer Cooling by STULZ
- DEC Dynamic Economizer Cooling by STULZ Optimized

STULZ provides industry leading DX and CW-based water-side economizer cooling solutions - detailed in this design guide. The state-of-the-art **"STULZ Dynamic Economizer Cooling"** solution represents an exciting new approach - with proven results.

Industry Standards

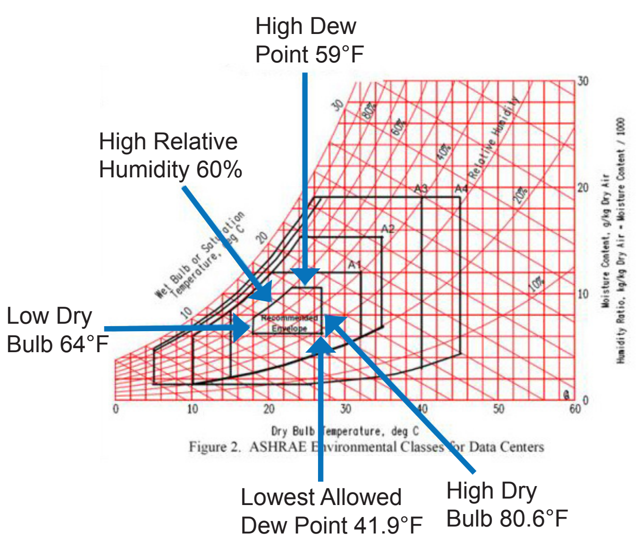
STULZ is an active participant in the ASHRAE TC9.9 and 90.1 standards committees. These standards are very important to the data center industry and are having a large impact on how data centers are being designed and operated.

ASHRAE TC9.9 2011

Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance - provides thermal guidelines for data processing environments. The 2011 guideline outlines changes for server inlet temperature and humidity.

These changes to server inlet temperatures, and the allowance for increased delta-T across the server equipment, offer an opportunity to raise the return air temperatures to the cooling equipment. The trend for maximum efficiency in the data center is to isolate the hot return air from the cold supply air preventing air mixing.

What Has Changed	Inlet Air Temperature	Moisture Content
2004 Recommended (old)	68-77.0°F DB	40% RH to 55% RH
2011 Recommended (new)	64-80.6°F DB	41.9°F DP to 60% RH & 59°F DP
2011 Allowable (A1)	59-89.6°F DB	20-80% RH up to 62.1°F DP



The opportunity is to raise the delta-T between the supply air temperature from the cooling equipment to the IT equipment and the return air temperature from the IT equipment to the cooling equipment. This is achieved by implementing hot aisle / cold aisle orientation of racks and optimized with various rack containment strategies.

In hot aisle containment configurations (Figure 1), the raised floor is pressurized with cold air from the precision cooling units, which passes through perforated floor tiles, taken into the servers, heated and exhausted into the contained hot aisle, directed back to the ceiling plenum, then returned to the CRAH units.

Perimeter Cooling w/raised floor and hot-aisle containment

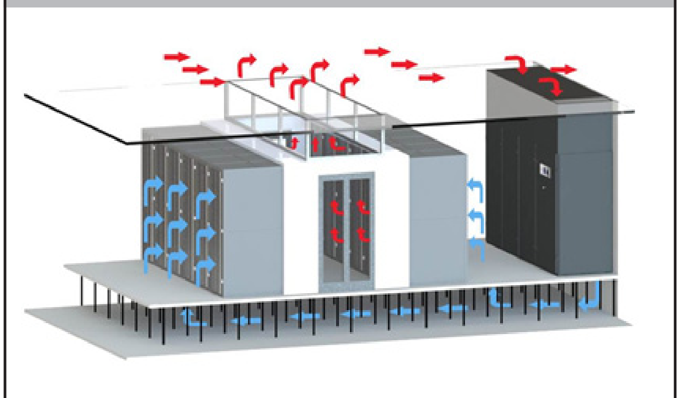


Figure 1

An alternate form of containment (Figure 2), is to utilize server racks that have a top ducted chimney connection. A CRAH with front discharge floods the space with cold air, allowing the servers to take cold air in from the front and discharge hot air out to the chimney. This hot air is discharged into a return duct or ceiling plenum and returned to the CRAH unit.

Perimeter Cooling w/slab floor and rack-containment

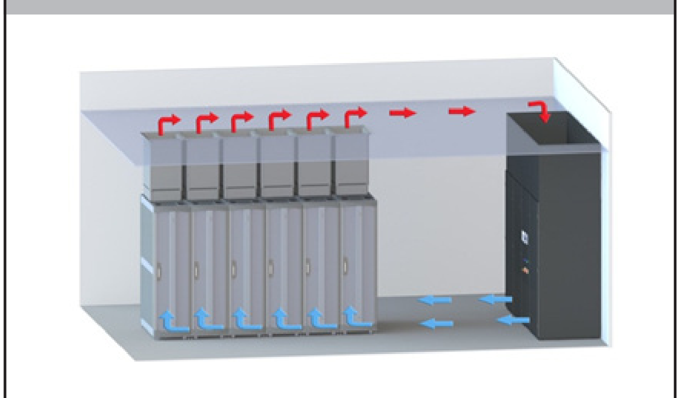


Figure 2

The Value of updates to ASHRAE TC9.9:

Higher return air temperature to the CRAC/CRAH equipment increases cooling efficiencies, as illustrated in the following coil calculation:

Coil Calculations based on different design conditions to achieve different system optimizations:				
CFD-230-C CRAH	**Selection 1**	**Selection 2**	**Selection 3**	**Selection 4**
Entering Air DB (°F)	75	95	95	95
Entering Air WB (°F)	61.1	67.8	67.8	67.8
Coil Leaving Air DB (°F)	51.0	54.1	54.2	69.9
Coil Leaving Air WB (°F)	50.5	53.1	53.1	59.2
Gross Total Capacity (BTU/H)	513,800	755,700	503,400	464,800
Gross Sensible Capacity (BTU/H)	461,200	755,700	503,400	464,800
Net Total Capacity (BTU/H)	493,800	735,700	494,500	444,800
Net Sensible Capacity (BTH/H)	441,200	735,700	494,500	444,800
Air Flow (ACFM)	18,000	18,000	12,000	18,000
External Static Pressure (in)	0.30	0.30	0.30	0.30
Altitude (ft)	0	0	0	0
Entering Fluid Temperature (°F)	45	45	45	55
Fluid Type	Water	Water	Water	Water
Percent Glycol (%)	0	0	0	0
Fluid Flow (GPM)	105	105	52	43
Leaving Fluid Temperature (°F)	55	59.7	64.7	77.1
Coil Fluid Pressure Drop (FT-H_2O)	10.2	10.2	2.7	1.9
Unit Fluid Pressure Drop (FT-H_2O)	23.3	23.3	8.6	7.0
Estimated Unit Power (kW)	**5.3**	**5.3**	**2.6**	**5.3**

Selection 1

Baseline

Shows a baseline standard unit selection for a CRAH, using standard conditions of 75°F entering air, a 52.2°F dew point, entering water of 45°F and leaving water temperature of 55°F.

Selection 2

Improved Net Sensible Capacity: **+66%**

Shows that an elevated return of 95°F at the same 52.2°F dew point and the same 105 GPM as the baseline selection provides an increase in capacity of **66%**.

Selection 3

Reduced Unit Power Consumption: **-51%**

Shows that an elevated return of 95°F at the same 52.2°F dew point and reduced airflow from 18,000 CFM to 12,000 CFM provides the same or better net sensible capacity as the baseline selection, and a reduction in unit power consumption of **51%,** and lowers the pump power required.

Selection 4

Increased Chiller Efficiency: **+22%**

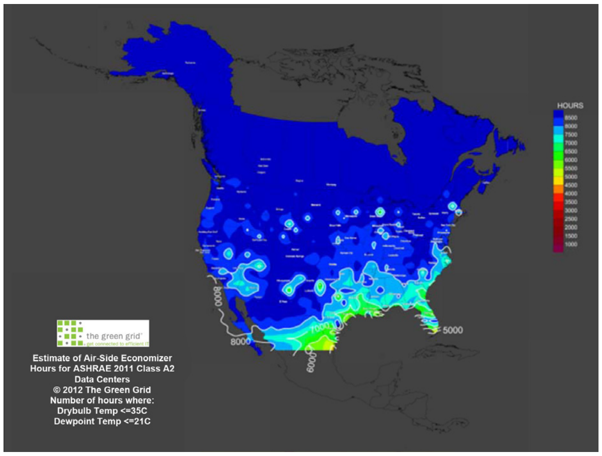
Shows that an elevated return of 95°F at the same 52.2°F dew point and increasing the entering water temperature from 45°F to 55°F provides the same or better net sensible capacity as the baseline selection, and increases the efficiency of chiller operation by more than **22%,** and lowers the pump power required.

Additional Benefits

By simply raising the air temperature entering the CRAH, tremendous benefits in efficiency can be accomplished. The scenarios shown can be mixed and matched to achieve optimal conditions. Results include more economizer hours, lower PUE, and lower energy costs.

ASHRAE 90.1- 2010

Energy Efficiency for Buildings - requires the use of air and water economizers in many locations. Since data centers have been identified to consume ~3% of the total energy produced in the U.S., the former process cooling exemption is gone. Water-side economizers must meet 100% of the expected load with cooling towers when operating at or above 40°F dry bulb / 35°F wet bulb and with dry coolers when operating at or below 35°F dry bulb.



The DOE is mandating that all states adopt ASHRAE 90.1-2010, or a more stringent standard, for new data center design and construction by October 2013.

These changes to ASHRAE standards mean that we will have to rethink how data centers are designed.

The Evolution of Measuring Efficiency

The efficiency of comfort air conditioners is typically rated by the Seasonal Energy Efficiency Ratio or SEER, which is the ratio of cooling in British thermal units (BTU) to the energy consumed in watts (W), generally calculated using an outside temperature of 95°F and a return air tempeature of 80°F and 50% RH. Following is a more accurate measurement for precision air conditioning.

The DOE is currently still referring to ASHRAE 127 – 2007 guideline for Sensible Coefficient of Performance (SCOP).

In this paper, STULZ is following ASHRAE 90.1 – 2010 guideline for SCOP.

Many engineers are already adapting the ASHRAE 127 – 2012 guideline for Net Sensible Coefficient of Performance (NSenCOP).

NSenCOP is a ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding re-heat and humidifiers) at any given set of rating conditions. The net sensible cooling capacity is the gross sensible capacity minus the energy dissipated into the cooled space by the fan system. This is the most accurate measurement for the performance of precision cooling equipment.

Economizers are generally described as one of two types:

Direct and Indirect Air-Side Economizer

Direct free cooling is directly introducing outside air into the space to cool the space. The downside of this is the requirement of high levels of filtration and the potential introduction of sulfides into the data center environment. This additional filtration requires the use of larger fan motors to move the required air to directly free cool the space. Another concern is humidity control.

When the air is cool enough to be used for economization, you still have a high percentage of time where the grains of moisture per pound are too low and require additional humidification. The solution is to either limit the outside air based on dew point, which will limit the economizer hours, or add additional humidification into the space, which could potentially offset the energy savings of being in economization mode of cooling.

STULZ offers direct and indirect air-side economizer cooling solutions with CW or DX mechanical cooling and/or direct or indirect adiabatic cooling.

Indirect Water-Side Economizer

Indirect free cooling can be achieved with a water/glycol fluid loop that is pumped through an external heat exchanger of some form, and then providing cooled fluid as a cooling medium to a water/glycol coil that absorbs heat from hot return air. This method is referred to as indirect because the intermediate fluid is contained in a closed system that is isolated from the data center white space. In this white paper, we illustrate how a water-side economizer can be used to achieve indirect free cooling.

There are several water-side economizer options that STULZ is able to support. Each of these designs can be integrated with STULZ indoor cooling (perimeter, row, or ceiling) or STULZ outdoor cooling (air handler unit or modular container unit).

The focus of this design guide is the various methods of Water-Side Economizer Cooling, with an emphasis on Dynamic Economizer Cooling.

When elevating the return air temperatures to a CRAC, both power consumption and SCOP are impacted. By adding a traditional economizer cooling coil to the CRAC, power consumption and SCOP are further impacted.

30 ton CRAC: 75°F 40% RH Return Air
Baltimore, MD

	CRAC with Constant Speed Pump and DryCooler				CRAC with Traditional Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hrs	% of Yr	Total kW Hrs
Full Compressor Operation	53.0	8760	100%	463,930	55.7	5998	68%	333,789
Free Cooling Assist					39.2	1249	14%	48,923
Free Cooling					22.7	1513	17%	34,330
Yearly Total Unit Power Consumption (kW Hrs)				463,930				417,042
SCOP				2.1				2.1

Savings Comparison

Total kW Savings Per Year: 46,888

Total Cost Savings Per Year: $4,688

30 ton CRAC: 80°F 30% RH Return Air
Baltimore, MD

	CRAC with Constant Speed Pump and DryCooler				CRAC with Traditional Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hrs	% of Yr	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	55.9	5272	60%	294,652
Free Cooling Assist					39.3	1975	23%	77,598
Free Cooling					22.7	1513	17%	34,330
Yearly Total Unit Power Consumption (kW Hrs)				466,120				406,580
SCOP				2.3				2.3

Savings Comparison

Total kW Savings Per Year: 59,540

Total Cost Savings Per Year: $5,954

Benefit of Increasing Return Air Temperature from 75°F 40% to 80°F 30%

Power Savings for CRAC with DryCooler	Power Savings for CRAC with Free Cooling
-0.5%	2.5%
SCOP 9.5%	SCOP 9.5%

- Based on 0.10 $/kWh
- Conditions are ASHRAE TC 9.9 2011 recommended
- Using Fluid Water
- Full compressor operation includes compressors, fan, and pump

When elevating the return air temperatures to a CRAH coupled with an air cooled chiller, power consumption is impacted. With a CRAH that has two coils, one coil coupled with an air cooled chiller, and one coil coupled with an evaporative cooling tower, power consumption is further impacted.

30 ton CRAH: 75°F 40% RH Return Air, 45°F Entering Water
Baltimore, MD

	CRAH Coupled to an Air Cooled Chiller				CRAH with Dual Coils Coupled to an Air Cooled Chiller & Coupled to an Evaporative Cooling Tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hrs	% of Yr	Total kW Hrs
Air Cooled Chiller Operation	46.2	8760	100%	404,362	47.0	6638	76%	311,654
Evaporative Cooling Tower Operation				-	11.3	2122	24%	23,936
Yearly Total Unit Power Consumption (kW Hrs)				404,362	-	-	-	335,590

Savings Comparison

Total kW Savings Per Year: 68,771

Total Cost Savings Per Year: $6,877

30 ton CRAH: 80°F 30% RH Return Air, 50°F Entering Water
Baltimore, MD

	CRAH Coupled to an Air Cooled Chiller				CRAH with Dual Coils Coupled to an Air Cooled Chiller & Coupled to an Evaporative Cooling Tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hrs	% of Yr	Total kW Hrs
Air Cooled Chiller Operation	43.1	8760	100%	377,556	46.3	6245	71%	289,144
Evaporative Cooling Tower Operation				-	10.3	2515	29%	25,804
Yearly Total Unit Power Consumption (kW Hrs)				377,556	-	-	-	314,974

Savings Comparison

Total kW Savings Per Year: 62,609

Total Cost Savings Per Year: $6,261

Benefit of Increasing Return Air Temperature from **75°F 40% to 80°F 30%**

Power Savings for CRAH 7.1%

Power Savings for CRAH with Dual Coil 6.1%

- Based on 0.10 $/kWh
- Conditions are ASHRAE TC 9.9 2011 recommended
- Pump is 65% efficient
- 1.23 kW per ton Air-Cooled Chiller
- Using Fluid Water

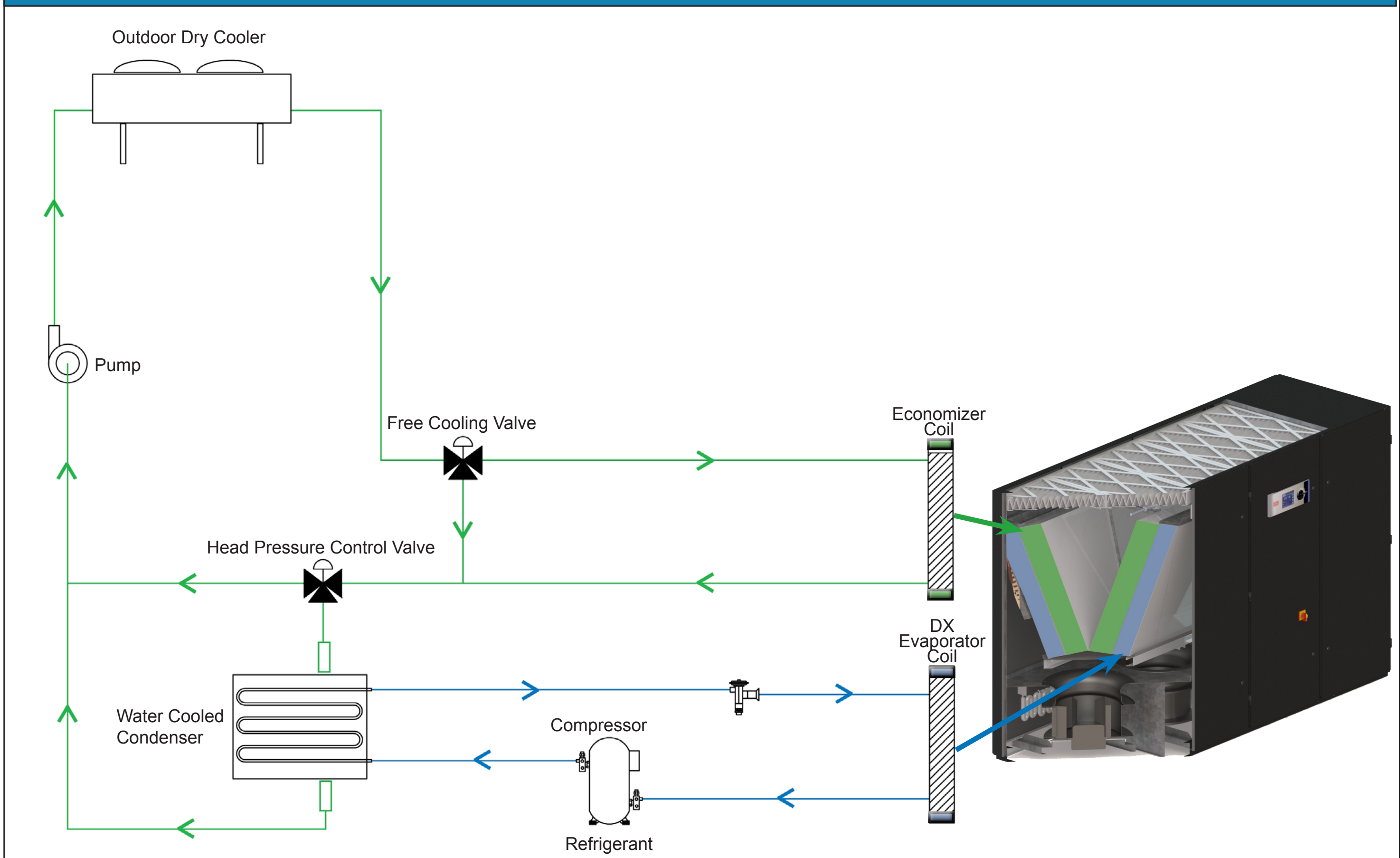
STULZ DX CRAC with Economizer Coil and Condenser Loop

A standard CRAC cooling unit with water-side economizer capability consists of a CRAC with a direct expansion (DX) coil and a chilled water / glycol coil.

When the fluid temperature is warm, the unit operates as a fluid cooled DX unit, rejecting the heat into a heat rejection device (dry cooler or closed loop cooling tower).

When ambient temperature drops, the flow of the resulting lower temperature fluid is diverted into the chilled water / glycol coil, providing a cooling assist mode of operation.

When the required data center cooling capacity can be satisfied using only the cooling fluid, then the CRAC will turn off its compressors and only cool using the chilled water / glycol loop.



STULZ is currently using highly efficient scroll compressors with available tandem and stepped capacity in 2, 3, or 4 stages of operation, each with a hot-gas bypass option. Following is a table that illustrates how this highly effective means of DX cooling works:

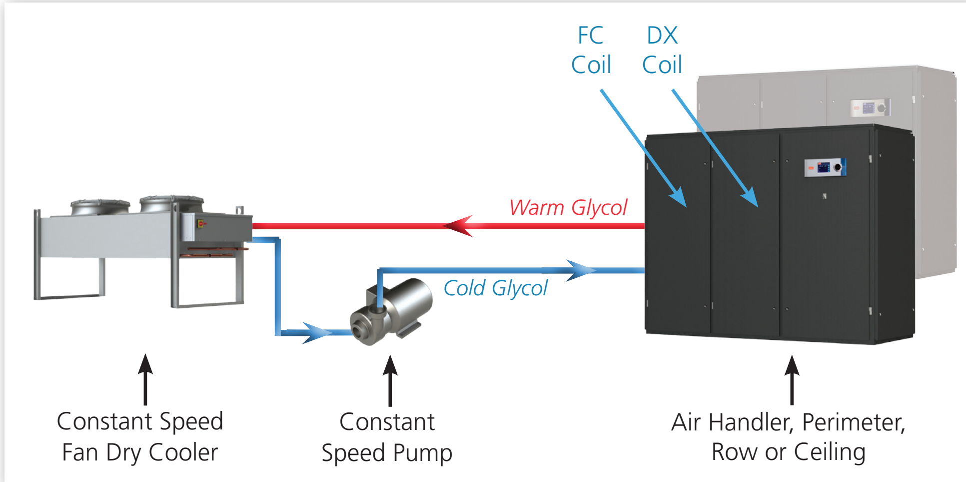
Capacity	Tandem Compressor		Compressor
	1a	1b	2
25%	X		
50%			X
75%		X	X
100%	X	X	X

Used with the following STULZ Water-Side Economizers:

- Traditional Economizer Cooling
- Variable Economizer Cooling
- Evaporative Tower Economizer Cooling

Traditional Economizer Cooling

Traditional Economizer Cooling is comprised of a constant fan speed dry cooler (with fans being cycled on and off based on fluid temperature), constant speed pumps, and water/glycol cooled free cooling CRACs (consisting of both a DX cooling coil and a water/glycol free cooling coil).



30 ton CRAC with FC Coil - 80°F 30% RH Return Air

Baltimore MD

	CRAC with Constant Speed Pump and DryCooler				CRAC with Free Cooling Coupled with Constant Speed Pump and DryCooler			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	55.9	5272	60%	294,652
Free Cooling Assist				-	39.3	1975	23%	77,598
Free Cooling				-	22.7	1513	17%	34,330
Yearly Total Unit Power Consumption (kW Hrs)				**466,120**	-	-	-	**406,580**

Total kW Savings Per Year: 59,540

Total Cost Savings Per Year: $5,954

Salt Lake City, UT (calculated at 4,500 ft altitude)

	CRAC with Constant Speed Pump and DryCooler				CRAC with Free Cooling Coupled with Constant Speed Pump and DryCooler			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	54.6	8760	100%	478,603	57.3	4491	51%	257,402
Free Cooling Assist				-	40.7	2369	27%	96,454
Free Cooling				-	24.1	1900	22%	45,819
Yearly Total Unit Power Consumption (kW Hrs)				**478,603**	-	-	-	**399,674**

Total kW Savings Per Year: 78,929

Total Cost Savings Per Year: $7,892

Portland, OR

	CRAC with Constant Speed Pump and DryCooler				CRAC with Free Cooling Coupled with Constant Speed Pump and DryCooler			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	55.2	4953	57%	273,455
Free Cooling Assist				-	39.3	3298	38%	129,578
Free Cooling				-	22.7	509	6%	11,549
Yearly Total Unit Power Consumption (kW Hrs)				**466,120**	-	-	-	**414,583**

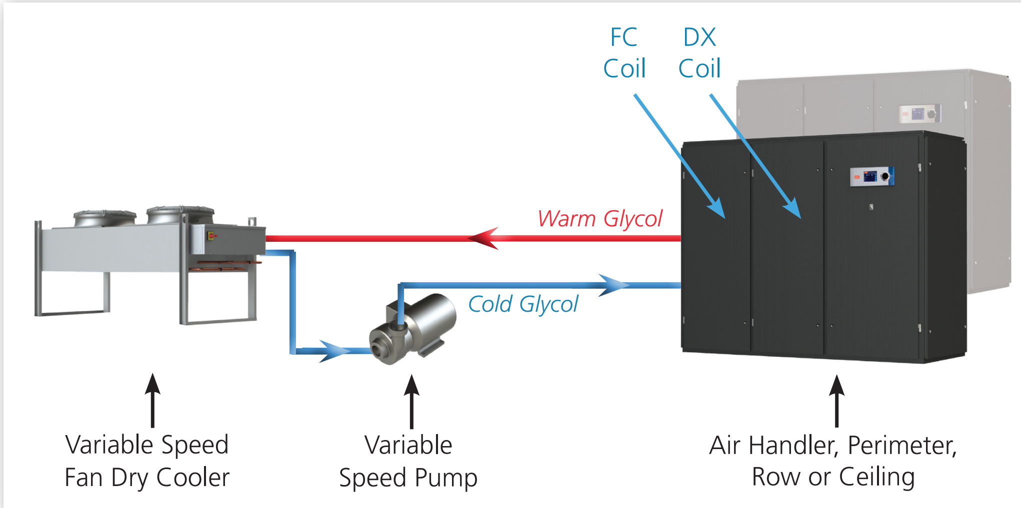
Total kW Savings Per Year: 51,537

Total Cost Savings Per Year: $5,153

- Based on 0.10 $/kWh
- Using a nominal Drycooler
- Using Pump Power for CRAC and Drycooler Pressure Drop
- Pump is 65% efficient
- Conditions are ASHRAE TC 9.9 2011 recommended
- Full compressor operation includes compressors, fan, and pump
- Using Fluid Water

Variable Economizer Cooling

Variable Economizer Cooling is comprised of a variable fan speed dry cooler (with fan speed controlled based on fluid temperature), variable speed pumps (controlled based on fluid temperature), and water/glycol cooled free cooling CRACs (consisting of both a DX and a water/glycol free cooling coil).



30 ton CRAC with FC Coil: 80°F 30% RH Return Air

Baltimore, MD

	CRAC with Constant Speed Pump and DryCooler				CRAC with Free Cooling Coupled with Variable Speed Pump and DryCooler			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	44.4	5557	63%	246,534
Free Cooling Assist				-	28.8	2080	24%	59,915
Free Cooling				-	15.1	1123	13%	17,028
Yearly Total Unit Power Consumption (kW Hrs)				**466,120**	-	-	-	**323,476**

Total kW Savings Per Year: 142,644

Total Cost Savings Per Year: $14,264

Salt Lake City, UT (calculated at 4,500 ft altitude)

	CRAC with Constant Speed Pump and DryCooler				CRAC with Free Cooling Coupled with Variable Speed Pump and DryCooler			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	54.6	8760	100%	478,603	46.0	4777	55%	219,601
Free Cooling Assist				-	30.5	2571	29%	78,437
Free Cooling				-	17.1	1412	16%	24,219
Yearly Total Unit Power Consumption (kW Hrs)				**478,603**	-	-	-	**322,258**

Total kW Savings Per Year: 156,345

Total Cost Savings Per Year: $15,634

Portland, OR

	CRAC with Constant Speed Pump and DryCooler				CRAC with Free Cooling Coupled with Variable Speed Pump and DryCooler			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	44.2	5243	60%	232,018
Free Cooling Assist				-	29.3	3239	37%	94,844
Free Cooling				-	18.5	278	3%	5,150
Yearly Total Unit Power Consumption (kW Hrs)				**466,120**	-	-	-	**332,012**

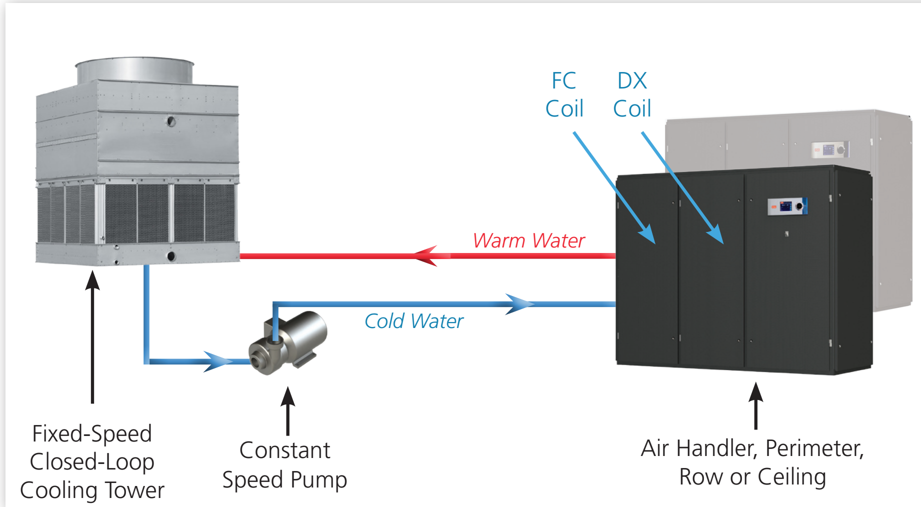
Total kW Savings Per Year: 134,108

Total Cost Savings Per Year: $13,410

- Based on 0.10 $/kW/h
- Nominal 30 ton Drycooler
- Using Pump Power for CRAC and Drycooler Pressure Drop
- Pump is 65% efficient
- Conditions are ASHRAE TC 9.9 2011 recommended
- Full compressor operation includes compressors, fan, and pump
- Using Fluid Water
- kW average shown as actual kW varies over ambient range

Evaporative Tower Economizer Cooling

Evaporative Tower Economizer Cooling is comprised of a closed loop evaporative cooling tower (controlled based on fluid temperature), a constant speed pump, and water/glycol cooled free cooling CRACs (consisting of both a DX and a water/glycol free cooling coil).



30 ton CRAC with FC Coil: 80°F 30% RH Return Air

Baltimore, MD

	CRAC with Constant Speed Pump and DryCooler				CRAC with free cooling coupled with fixed-speed closed loop cooling tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	47.3	5028	57%	237,774
Free Cooling Assist				-	30.7	1610	18%	49,411
Free Cooling				-	14.1	2122	24%	29,899
Yearly Total Unit Power Consumption (kW Hrs)				**466,120**	-	-	-	**317,084**

Total kW Savings Per Year: 149,036

Total Cost Savings Per Year: $14,904

Salt Lake City, UT (calculated at 4,500 ft altitude)

	CRAC with Constant Speed Pump and DryCooler				CRAC with free cooling coupled with fixed-speed closed loop cooling tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	54.6	8760	100%	478,603	49.4	3810	43%	188,271
Free Cooling Assist				-	32.8	2293	26%	75,245
Free Cooling				-	16.2	2657	30%	43,083
Yearly Total Unit Power Consumption (kW Hrs)				**478,603**	-	-	-	**306,599**

Total kW Savings Per Year: 172,003

Total Cost Savings Per Year: $17,200

Portland, OR

	CRAC with Constant Speed Pump and DryCooler				CRAC with free cooling coupled with fixed-speed closed loop cooling tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Full Compressor Operation	53.2	8760	100%	466,120	47.3	6539	75%	309,229
Free Cooling Assist				-	30.7	956	11%	29,340
Free Cooling				-	14.1	1265	14%	17,824
Yearly Total Unit Power Consumption (kW Hrs)				**466,120**	-	-	-	**356,393**

Total kW Savings Per Year: 109,727

Total Cost Savings Per Year: $10,973

- Based on 0.10 $/kW/h
- Nominal 30 ton Cooling Tower
- Using Pump Power for CRAC and Water Tower Pressure Drop
- Pump is 65% efficient
- Conditions are ASHRAE TC 9.9 2011 recommended
- Full compressor operation includes compressors, fan, and pump
- Using Fluid Water

Comparison of DX Economizer Cooling

30 ton CRAC with FC Coil: 80°F 30% RH Return Air

		CRAC with Constant Speed Pump & DryCooler	Traditional Economizer Cooling	Variable Economizer Cooling	Evaporative Tower Economizer Cooling
Baltimore MD	System kW Per Yr	466,120	406,580	323,476	317,084
	System Operational Cost Per Yr	$46,612	$40,658	$32,348	$31,708

% Reduced Energy

kW Per Yr & Associated Operational Cost Per Yr

- -13%
- -31%
- -32%

		CRAC with Constant Speed Pump & DryCooler	Traditional Economizer Cooling	Variable Economizer Cooling	Evaporative Tower Economizer Cooling
Salt Lake City UT	System kW Per Yr	478,603	399,674	322,258	306,599
	System Operational Cost Per Yr	$47,860	$39,967	$32,225	$30,660

% Reduced Energy

kW Per Yr & Associated Operational Cost Per Yr

- -17%
- -33%
- -36%

		CRAC with Constant Speed Pump & DryCooler	Traditional Economizer Cooling	Variable Economizer Cooling	Evaporative Tower Economizer Cooling
Portland OR	System kW Per Yr	466,120	414,583	332,012	356,393
	System Operational Cost Per Yr	$46,612	$41,458	$33,201	$35,639

% Reduced Energy

kW Per Yr & Associated Operational Cost Per Yr

- -11%
- -29%
- -24%

- Power Cost $0.10 per kWhr
- Indoor conditions are 80/30%
- Conditions are ASHRAE TC 9.9 2011 recommended

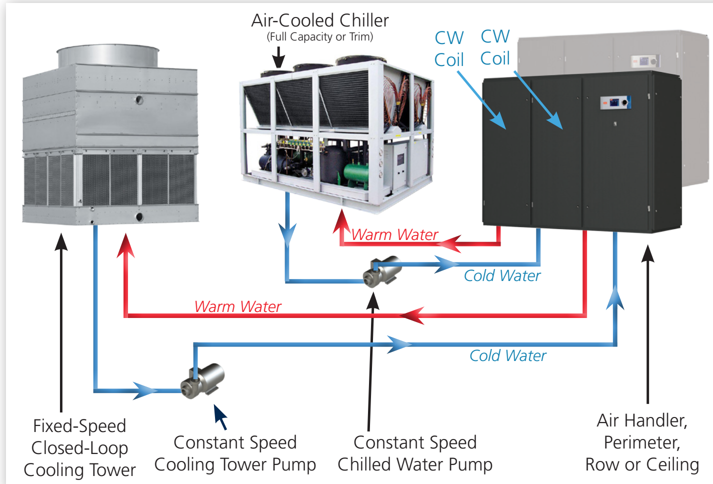
Summary: A summary of the various DX-based economizer solutions show how the different solutions compare with one another and how effective each is in different weather conditions. A further analysis of the return on investment (ROI) for each is provided in Appendix A.

STULZ Water-Side Economizers based on a CRAH with Single or Dual Circuit

Dual-Source Chilled Water Economizer Cooling

Dual-Source Chilled Water Economizer Cooling is comprised of an evaporative cooling tower (controlled based on fluid temperature), cooling tower pumps, chiller (controlled based on fluid temperature), chiller pumps, and a CRAH unit (with dual circuited interlaced chilled water cooling coil).

The solution data is based on operating only one circuit at a time. STULZ is able to provide software to do multi-circuit operation.



30 ton CRAH: 80°F 30% RH Return Air, 50°F Entering

Baltimore, MD

	CRAH Coupled with Air-Cooled Chiller				CRAH with Dual Coils Coupled with Air-Cooled Chiller and Evaporative Cooling Tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Air Cooled Chiller Operation	43.1	8760	100%	377,556	46.3	6245	71%	289,144
Evaporative Cooling Tower Operation				-	10.3	2515	29%	25,804
Yearly Total Unit Power Consumption (kW Hrs)				**377,556**	-	-	-	**314,947**

Total kW Savings Per Year: 62,609

Total Cost Savings Per Year: $6,261

Salt Lake City, UT (calculated at 4,500 ft altitude)

	CRAH Coupled with Air-Cooled Chiller				CRAH with Dual Coils Coupled with Air-Cooled Chiller and Evaporative Cooling Tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Air Cooled Chiller Operation	44.0	8760	100%	385,440	47.0	5624	64%	264,328
Evaporative Cooling Tower Operation				-	11.1	3136	36%	34,810
Yearly Total Unit Power Consumption (kW Hrs)				**385,440**	-	-	-	**299,138**

Total kW Savings Per Year: 86,302

Total Cost Savings Per Year: $8,630

Portland, OR

	CRAH Coupled with Air-Cooled Chiller				CRAH with Dual Coils Coupled with Air-Cooled Chiller and Evaporative Cooling Tower			
Mode	kW	Hrs	% of Yr	Total kW Hrs	kW	Hours	% of Year	Total kW Hrs
Air Cooled Chiller Operation	43.1	8760	100%	377,556	46.3	7357	84%	340,629
Evaporative Cooling Tower Operation				-	10.3	1403	16%	14,395
Yearly Total Unit Power Consumption (kW Hrs)				**377,556**	-	-	-	**355,024**

Total kW Savings Per Year: 22,532

Total Cost Savings Per Year: $2,253

- Pump is 65% efficient
- Chiller power is assumed as 1.23kW per ton
- Nominal 30 ton Chiller
- Nominal 30 ton Cooling Tower
- Power cost is $0.10 per kW-hr.
- Conditions are ASHRAE TC 9.9 2011 recommended
- Using Fluid Water

STULZ Dynamic Economizer Cooling

STULZ Dynamic Economizer Cooling is the latest state-of-the-art water-side economizer solution, and is comprised of an evaporative cooling tower, cooling tower pumps, air- cooled chiller, chiller pumps, control mixing valves, and chilled water cooled CRAHs.

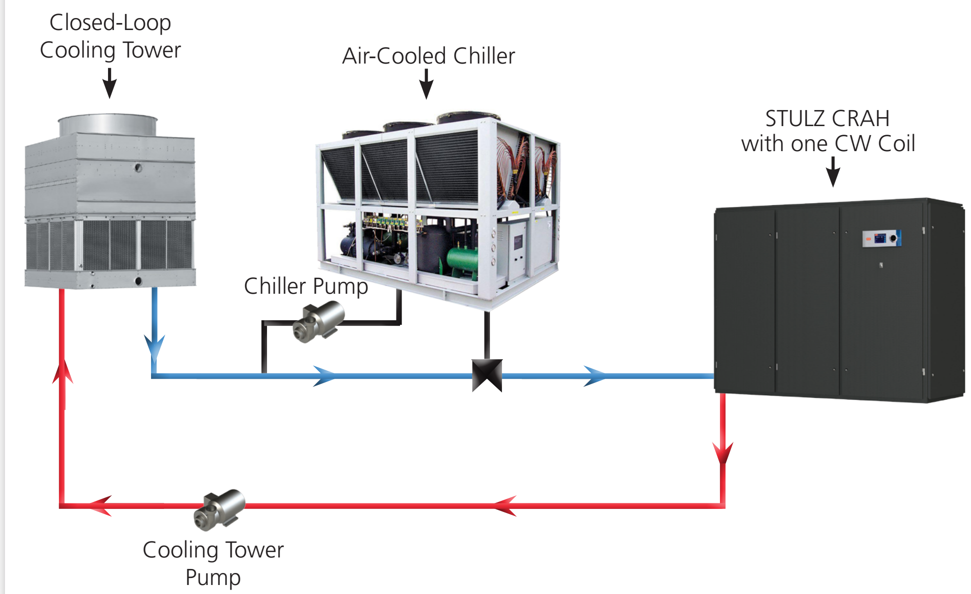
A working model of the STULZ Dynamic Cooling water-side economizer has been installed in the STULZ Mission Energy Laboratory in Frederick, Maryland.

The design of the system was developed in cooperation with RTKL Associates Inc. (an Arcadis Company) located in Baltimore, Maryland - a leading data center design firm (engineer) and inventor of Chiller Assisted Cooling® (a registered trademark - patent pending) and a leading multi-tenant / co-location data center provider for their new large data center in Northern Virginia.

Water Tower Cooling Mode and Chiller Assisted Cooling® Mode

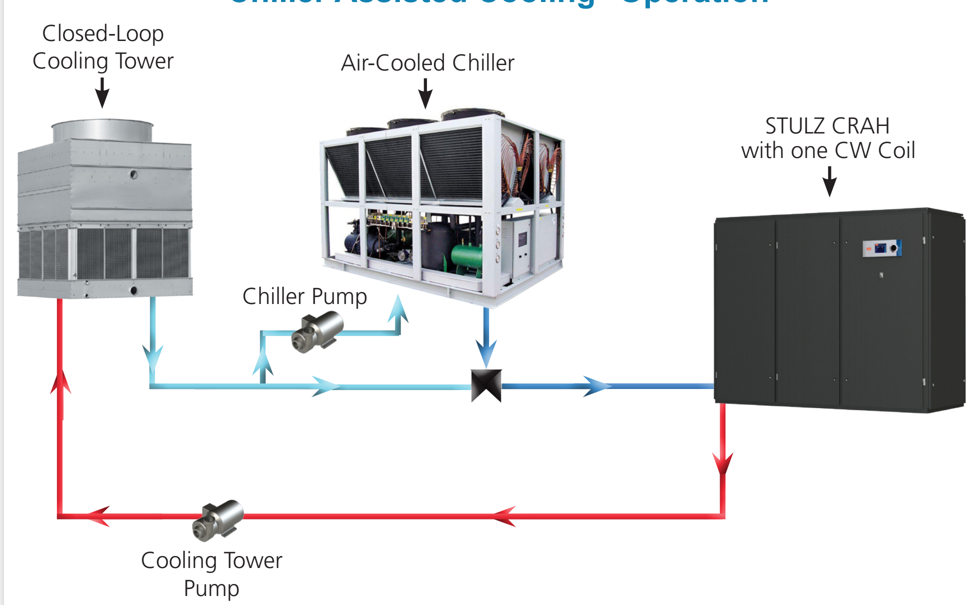
Water Tower Cooling Mode and Chiller Assisted Cooling® Mode

When ambient conditions are near or below required cooling fluid temperature, the Chiller Assisted Cooling® system operates in the cooling tower mode, providing cooling without energizing the chiller.



Water Tower Cooling Operation

If ambient temperature increases above the required cooling fluid temperature, flow from the tower is diverted to the chiller to provide the trim needed to maintain the cooling fluid temperature. This system is designed to minimize the hours of chiller operation and optimize opportunity for economization.



Chiller Assisted Cooling® Operation

30 ton CRAH: 80°F 30% RH Return Air, 50°F Entering Water

Baltimore, MD

	CRAH Coupled with Air-Cooled Chiller				STULZ Dynamic Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Chiller	43.1	8760	100%	377,556	43.8	4107	47%	179,895
Chiller Assist				-	24.5	2711	31%	66,364
Wet Tower				-	11.1	1135	13%	12,575
Dry Tower				-	9.5	807	9%	7700
Yearly Total Unit Power Consumption (kW Hrs)				**377,556**	-	-	-	**266,534**

Total kW Savings Per Year: 111,022

Total Cost Savings Per Year: $11,102

Salt Lake City, UT (calculated at 4,500 ft altitude)

	CRAH Coupled with Air-Cooled Chiller				STULZ Dynamic Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Chiller	44.0	8760	100%	385,440	44.7	3268	37%	146,077
Chiller Assist				-	23.3	3527	40%	82,259
Wet Tower				-	12.6	1038	12%	13,062
Dry Tower				-	11.0	927	11%	10,209
Yearly Total Unit Power Consumption (kW Hrs)				**385,440**	-	-	-	**251,607**

Total kW Savings Per Year: 133,833

Total Cost Savings Per Year: $13,383

Portland, OR

	CRAH Coupled with Air-Cooled Chiller				STULZ Dynamic Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Chiller	43.1	8760	100%	377,556	43.7	3362	38%	146,952
Chiller Assist				-	22.8	5098	58%	116,299
Wet Tower				-	11.5	262	3%	3001
Dry Tower				-	10.2	38	0.4%	388
Yearly Total Unit Power Consumption (kW Hrs)				**377,556**	-	-	-	**266,640**

Total kW Savings Per Year: 110,916

Total Cost Savings Per Year: $11,092

- Pump is 65% efficient
- Chiller power is assumed as 1.23kW per ton
- Nominal 30 ton Chiller
- Nominal 30 ton Cooling Tower
- Power cost is $0.10 per kW-hr.
- Conditions are ASHRAE TC 9.9 2011 recommended
- Using Fluid Water
- kW average shown as actual kW varies over ambient range

Summary: The STULZ Dynamic Economizer Cooling Solution provides good energy efficiency at a return air temperature of 80°F and an entering water temperature of 50°F, but the system efficiency can be optimized significantly further by elevating the return air temperature and supply water temperature, as shown in the example on page 24.

Comparison of Chilled Water Economizer Cooling

30 ton CRAH: 80°F 30% RH Return Air, 50°F Entering Air / 60°F Leaving Water

		CRAH Coupled with Air Cooled Chiller	CRAH with Dual Coils Coupled with an Air Cooled Chiller & Evaporative Cooling Tower	**STULZ Dynamic Economizer Cooling**
Baltimore MD	System kW Per Yr	377,556	314,947	266,534
	System Operational Cost Per Yr	$37,757	$31,495	$26,653
Salt Lake City UT	System kW Per Yr	385,440	299,138	251,607
	System Operational Cost Per Yr	$38,544	$29,914	$25,161
Portland OR	System kW Per Yr	377,556	355,024	266,640
	System Operational Cost Per Yr	$37,756	$35,502	$26,664

Baltimore MD — % Reduced Energy
kW Per Yr & Associated Operational Cost Per Yr
-17% (CRAH with Dual Coils vs. CRAH with Air Cooled Chiller)
-29% (STULZ Dynamic Economizer Cooling vs. CRAH with Air Cooled Chiller)

Salt Lake City UT — % Reduced Energy
kW Per Yr & Associated Operational Cost Per Yr
-22% (CRAH with Dual Coils vs. CRAH with Air Cooled Chiller)
-35% (STULZ Dynamic Economizer Cooling vs. CRAH with Air Cooled Chiller)

Portland OR — % Reduced Energy
kW Per Yr & Associated Operational Cost Per Yr
-6% (CRAH with Dual Coils vs. CRAH with Air Cooled Chiller)
-29% (STULZ Dynamic Economizer Cooling vs. CRAH with Air Cooled Chiller)

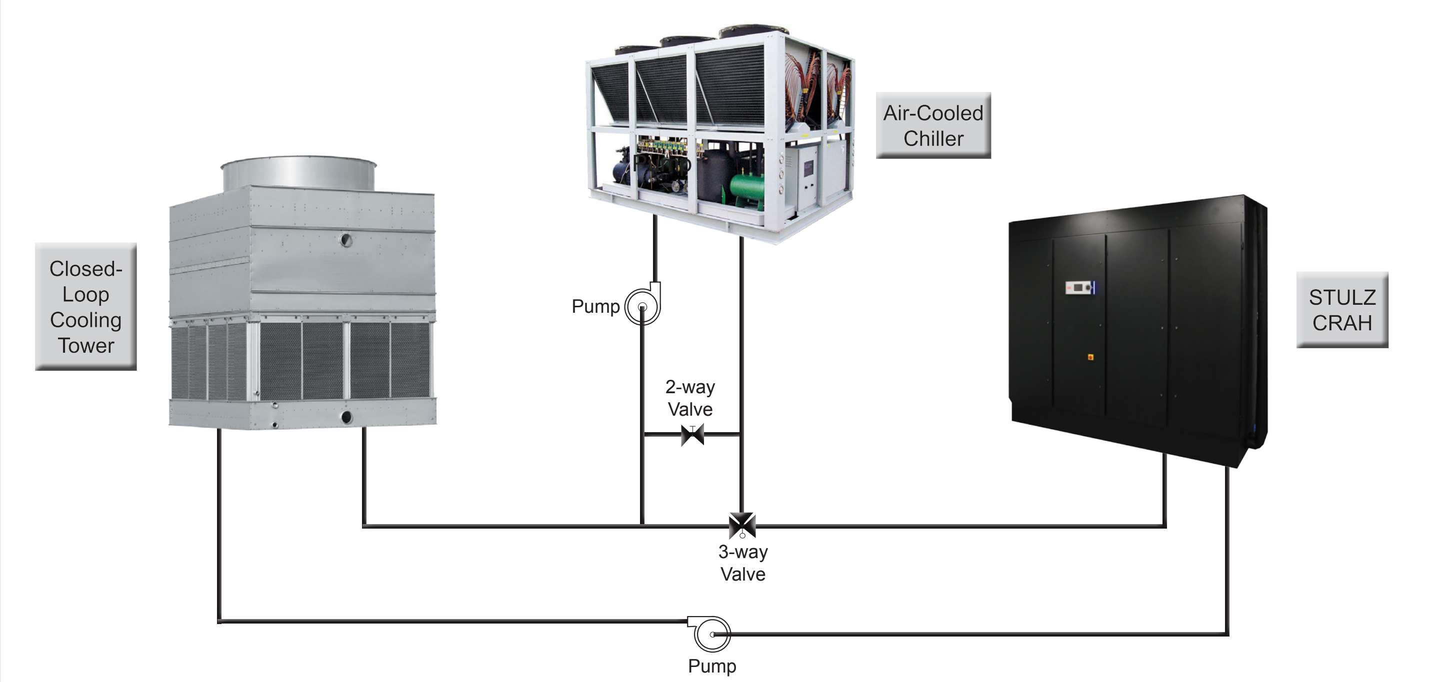
- Power Cost $0.10 per kWhr
- Indoor conditions are 80/30%
- Conditions are ASHRAE TC 9.9 2011 recommended

Summary: A summary of the various CW-based economizer solutions show how the different solutions compare with one another and how effective each is in different weather conditions. A further analysis of the return on investment (ROI) for each is provided in Appendix A. In the following pages, we focus in on how the STULZ Dynamic Economizer Cooling Solution can be optimized significantly further by elevating the return air temperature and supply water temperature.

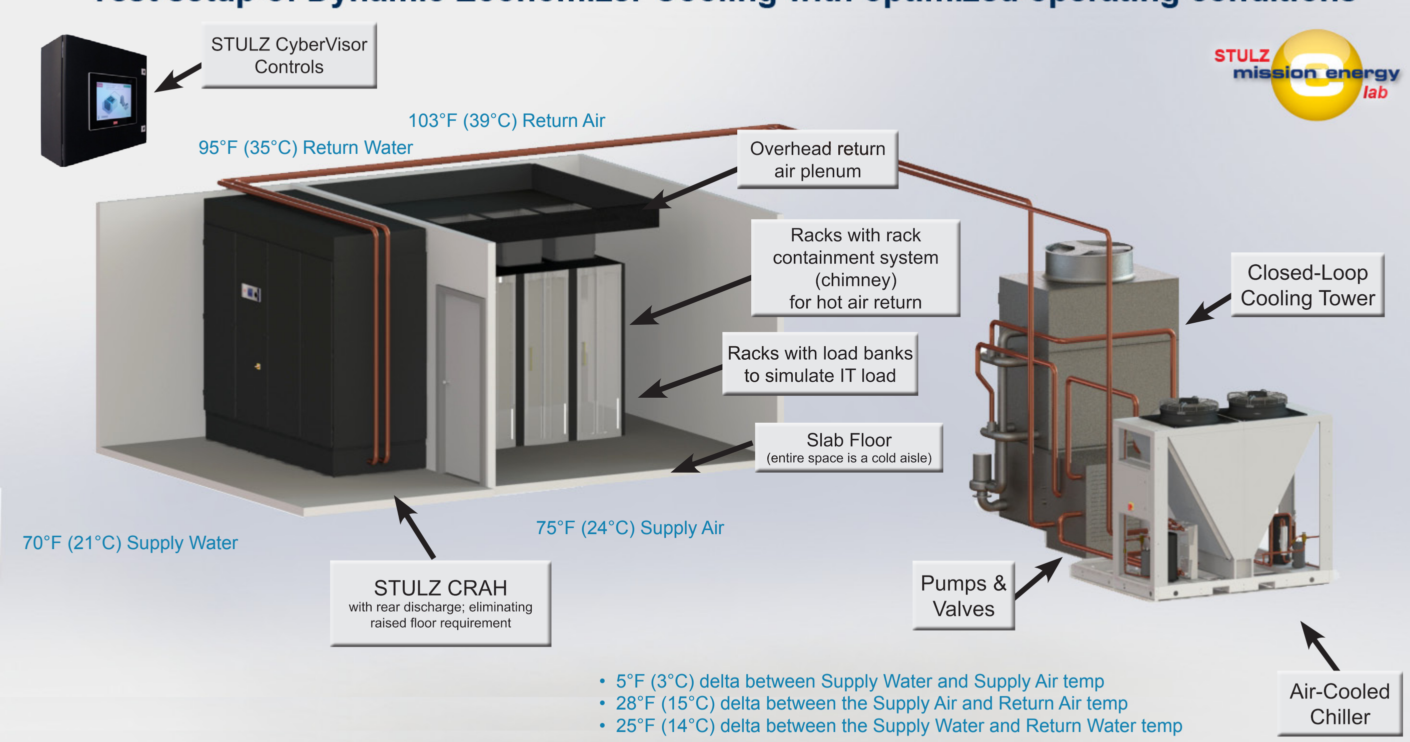
STULZ Dynamic Economizer Cooling with CyberVisor Controls

The **STULZ Dynamic Economizer Cooling System** achieves incredible efficiency by executing a carefully coordinated sequence of operations, where the functions of CRAH's, closed loop cooling towers, variable speed pump packages, modulating three-way valves, and supporting chillers are orchestrated by sophisticated STULZ CyberVisor controls. Raise the return air temperature to the CRAH (using containment) and providing a cooling coil that enables a large delta-T. The operating conditions can be modified to allow the use of 70°F supply water and 75°F supply air to the IT equipment (well within ASHRAE TC9.9 guidelines).

Mechanical System Schematic



Test setup of Dynamic Economizer Cooling with optimized operating conditions



- 5°F (3°C) delta between Supply Water and Supply Air temp
- 28°F (15°C) delta between the Supply Air and Return Air temp
- 25°F (14°C) delta between the Supply Water and Return Water temp

System Components

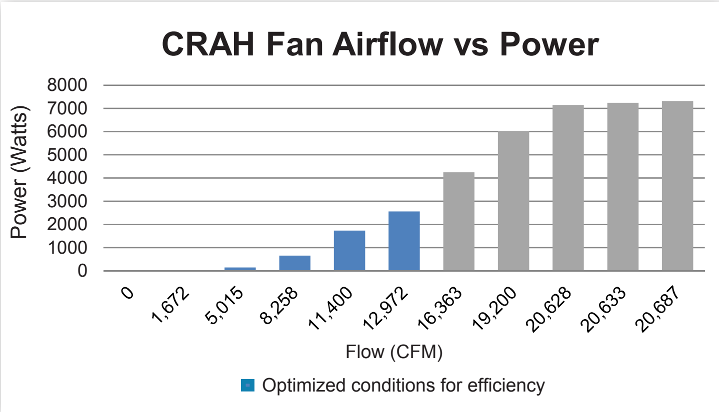
The STULZ Dynamic Economizer Cooling (Chiller Assisted Cooling®) is an infrastructure and control system that involves multiple heat rejection devices. Each device operates at varying loads depending on the ambient dry bulb and wet bulb conditions. The system consists of the following primary components:

1. STULZ CRAH with Optimized Coil and Fan Speed Provides Highly Efficient "Warm Water" Cooling

STULZ perimeter CRAH cooling units are ideal for "warm water" cooling. STULZ has designed a chilled water coil with circuiting that enables a large water-side delta-T over the coil (rows, passes, tubes, and fins). The coil is designed for the highest SHR, while maintaining face velocities below 500 feet per minute. Lower fan speeds promote additional energy savings. This contributes to significant cooling tower and chiller efficiency and energy savings.

STULZ has also designed the CRAH to have the option of an integrated floor stand, making it possible to have front or rear discharge from the CRAH and utilize a slab floor. This makes it possible to eliminate the raised floor and make the entire room the cold aisle.

The geometry of the fan location in the CRAH has been taken into careful consideration so that the EC fans provide the same highly efficient pressure and flow of air that you are used to with a STULZ CRAH with bottom discharge and a raised floor.

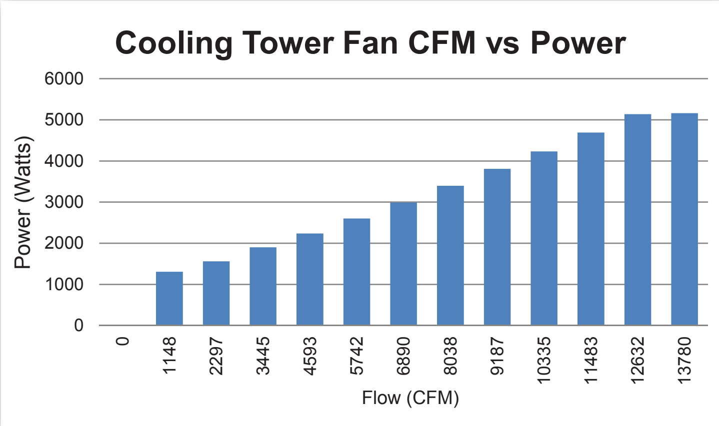


Graph based on 1 unit; scalable to multiple units

2. Closed-Loop Cooling Tower All-Year Primary Economizer Cooling

Dry Tower Mode:
In dry tower mode the ambient dry bulb temperature is well below the required cooling fluid temperature. In this mode, the leaving fluid from the CRAH unit is pumped through the closed loop cooling tower and back into the CRAH unit. The chiller and the chiller pump are not in use. This is referred to as dry mode because the needed heat rejection can be achieved without the sump on the cooling tower being used, thus the cooling tower can operate even when the ambient is below freezing.

Wet Tower Mode:
As the ambient temperature increases, the closed-loop cooling tower transitions from a dry operation to a wet operation. The wet operation of the closed loop cooling tower allows the tower to reject cooling fluid heat at a higher ambient temperature. This is achieved by an adiabatic cooling effect of small water droplets being pumped from the sump and spayed over the coil surface. The ability to reject the heat at a higher ambient temperature extends the amount of time you can operate without running the chiller and chiller pump, thus saving on compressorized cooling.



Graph based on 1 unit: multiple units would have additional efficiency benefits

3. Air-Cooled Chiller used for “Chiller Assisted Cooling®”

Sized to act as an assist device to provide additional (trim) capacity when the ambient conditions are unfavorable to run solely on cooling tower operation, or to maintain white space load should cooling tower fail.

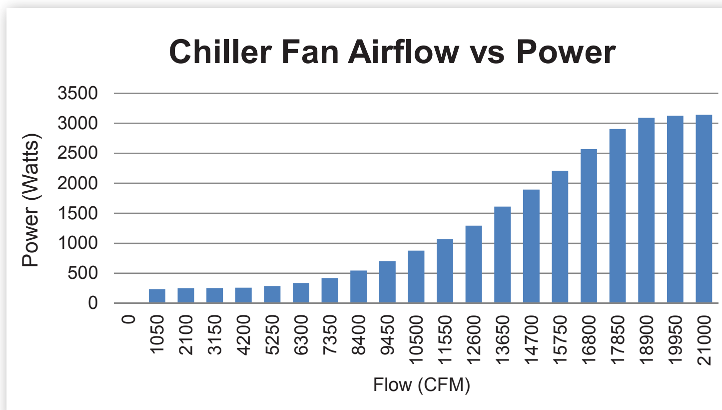
Chiller Assist Mode:

The Chiller Assist Mode is used when the ambient or internal load has increased to a point that the cooling tower can no longer maintain the required water temperature. The 3-way valves change positions from bypassing the chiller to allowing a small amount of flow to go through the chiller. The chiller pump turns on and runs at a minimum initial speed. The Chiller powers up and the compressor begins, fully unloaded, and then slowly loads up to maintain the required leaving water temperature.

As the water temperature increases, the flow being diverted to the chiller by the chiller three-way valve increases, as does the speed of the chiller pump. When the flow increases to the chiller, the compressors continue to increase loading to maintain the fluid temperature. This increase continues until fluid temperature is at set point or the chillers compressor is fully loaded.

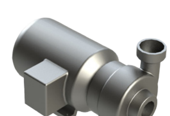
Compressorized operation uses significantly more power than just pumping a fluid or moving air with a fan. As such the cooling tower operation is always more efficient to operate than the compressors on the chiller.

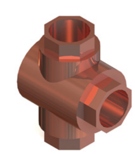
The reason the chillers must be present is because when the ambient WB approaches the fluid temperature, the efficiency and heat rejection capacity of the water tower decreases, thus making it impossible to maintain the data center white space temperature without some form of direct expansion cooling.



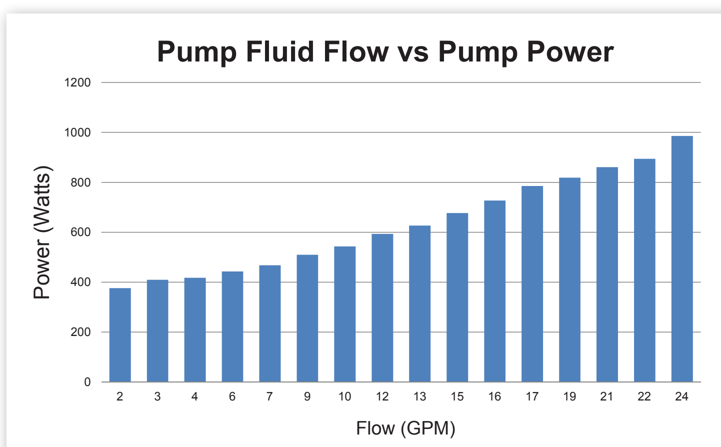
Graph based on 1 unit; scalable to multiple units

4. Pumps and Valves
Reduced Flow and High Delta-T





- Two variable speed pumps are used, one to provide flow to the cooling tower, and one to provide flow to the chiller.
- A three-way mixing valve is used to mix water from the cooling tower and chiller, or to bypass one device or the other.

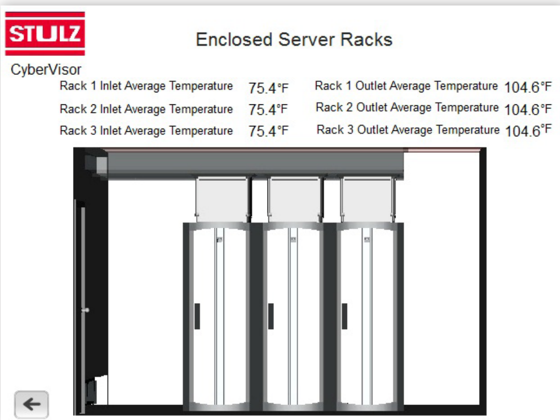


Graph based on 1 unit: multiple units would have additional efficiency benefits

STULZ CyberVisor Controller

Controls are the key element of this chiller assist cooling system and provide the link between the individual components. In order to ensure redundancy and fail-safe operation, the control structure is based on a supervisory approach with a “top-down” configuration. The supervisor has its own hardware platform and is linked to the individual component controllers via a communication protocol. In the event of a loss of communication, all component controllers switch to a fail-safe mode and continue local operation at a pre-defined component-specific set point. All local set-points are aligned with each other to allow uninterrupted operation. Only the system operation optimization is interrupted until operation of the supervisory controller can be restored.

Functionality of CyberVisor with Controller Screen Shots:

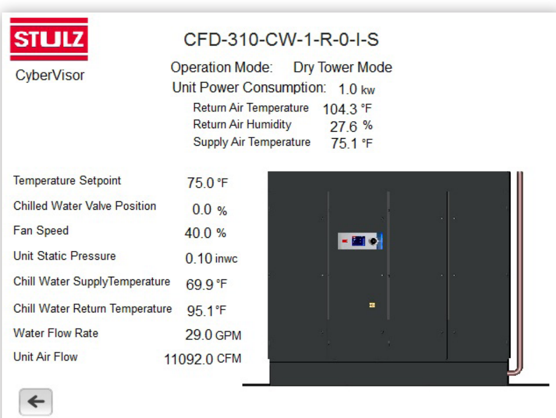


Racks (with load banks to simulate IT equipment)

1. Inlet Temperature: measures temperature into the rack, to determine if there is air leakage or additional ambient heat in the room
2. Rack Temperature: provides a profile of the cooling effect in the rack and how the temperature changes as the air moves through the rack
3. Power Monitoring: measures power consumption of the racks IT equipment to determine what internal heat load is being generated

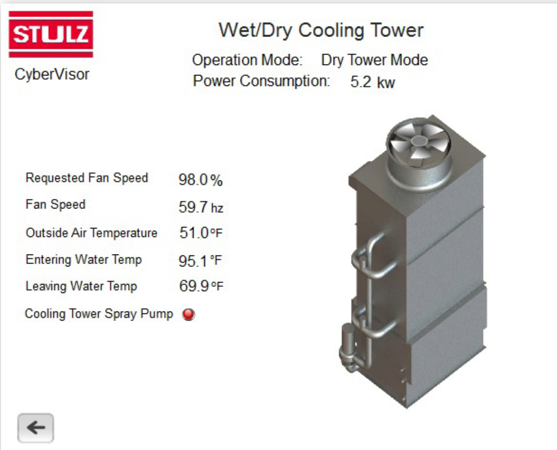
Outdoor Sensors

1. Ambient Temperature: measures the ambient DB (dry bulb) temperature to understand the effect on the outdoor equipment’s mode of operation
2. Ambient Humidity: measures the WB (wet bulb) and the potential for using the wet mode of operation on the cooling tower
3. Barometric Pressure: determines the air density



STULZ CRAH

1. Return Temperature Sensor: measures the return air temperature from the racks to ensure we are maintaining set point
2. Supply Temperature Sensor: measure the delta-T across the coil and is used to determine what temperature we are supplying to the racks
3. Fan Speed: used to determine CFM giving us the capacity of the unit when used in conjunction with the return sensor and supply sensor
4. Fluid Flow Meter: used to verify the flow rate, to see the effects on efficiency, and to increase the flow prior to increasing the fan speed on the cooling tower.
5. Power Monitoring: measures power consumption of the unit to help determine efficiency in different operating modes.

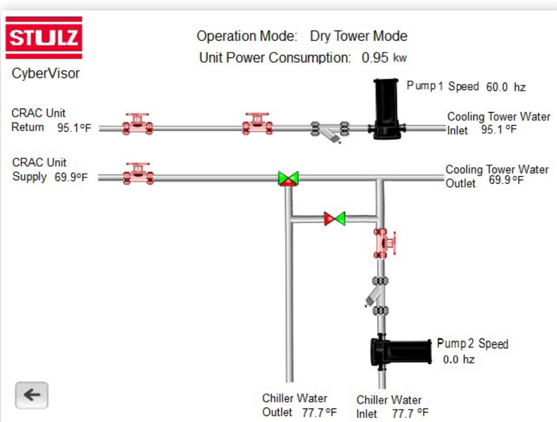


Cooling Tower Pump

1. VFD Percentage: determines the speed of the pumps
2. Power Monitoring: measures power consumption of the pump to determine efficiency in different operating modes

Cooling Tower

1. Inlet Fluid Temperature: measures fluid temperature returning from the CRAH
2. Outlet Fluid Temperature: determines the delta-T across the tower at varying ambient conditions
3. Fan Speed: determines fan speed and the fan speed effect on tower operation at varying ambient conditions
4. Sump On/Off: monitors and determines the optimal effect of operating the tower as a wet tower
5. Power Monitoring: measures power consumption of the cooling tower to help determine efficiency in different operating modes



Chiller Pump and Valves

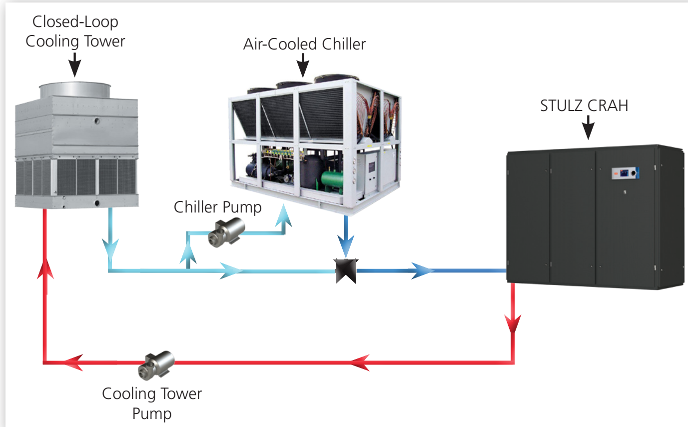
1. VFD Percentage: determines the speed of the pumps
2. Power Monitoring: measures power consumption of the pump to help determine efficiency in different operating modes

Chiller (Assist)

1. Inlet Fluid Temperature: measures fluid temperature returning from the Cooling Tower or the CRAH unit, depending on the mode of operation
2. Outlet Fluid Temperature: determines the delta-T across the chiller at varying stages of loading

STULZ Dynamic Economizer Cooling

With the STULZ Dynamic Economizer Cooling system operating under optimized conditions, it becomes clear that the system provide state-of-the-art efficiency and contribute to some of the lowest PUE numbers found in the industry. A further discussion of ROI and PUE can be found in Appendix A.



30 ton CRAH: 103°F 14% RH Return Air, 70°F Entering Water /95°F Leaving Water

Baltimore, MD

	CRAH Coupled with Air Cooled Chiller				STULZ Dynamic Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Chiller	43.1	8760	100%	377,556	42.2	5	0.1%	211
Chiller Assist				-	21.6	2330	27%	50,253
Wet Tower				-	8.6	982	11%	8,458
Dry Tower				-	6.6	5443	62%	35,700
Yearly Total Unit Power Consumption (kW Hrs)				**377,556**	-	-	-	**94,622**

Total kW Savings Per Year: 282,934

Total Cost Savings Per Year: $28,293

Salt Lake City, UT (calculated at 4,500 ft altitude)

	CRAH Coupled with Air Cooled Chiller				STULZ Dynamic Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Chiller	44.0	8760	100%	385,440	0	0	0%	0
Chiller Assist				-	25.3	1379	15%	34,870
Wet Tower				-	9.6	1807	21%	17,350
Dry Tower				-	7.1	5574	64%	39,884
Yearly Total Unit Power Consumption (kW Hrs)				**385,440**	-	-	-	**92,104**

Total kW Savings Per Year: 293,336

Total Cost Savings Per Year: $29,334

Portland, OR

	CRAH Coupled with Air Cooled Chiller				STULZ Dynamic Economizer Cooling			
Mode	kW	Hrs	% of Yr	Total kW Hrs	Average kW	Hours	% of Year	Total kW Hrs
Chiller	43.1	8760	100%	377,556	0	0	0%	0
Chiller Assist				-	19.7	692	8%	13,689
Wet Tower				-	8.6	1261	14%	10,871
Dry Tower				-	6.8	6807	78%	46,130
Yearly Total Unit Power Consumption (kW Hrs)				**377,556**	-	-	-	**70,692**

Total kW Savings Per Year: 306,864

Total Cost Savings Per Year: $30,686

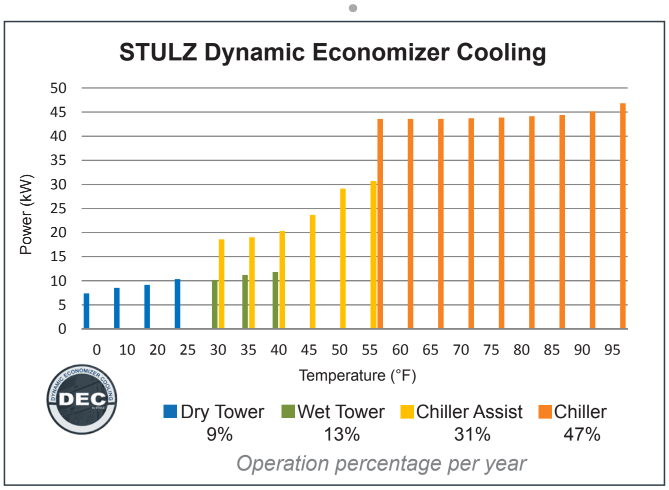
- Pump is 65% efficient
- Chiller power is assumed as 1.23kW per ton
- Nominal 30 ton Chiller
- Nominal 30 ton Cooling Tower
- Power cost is $0.10 per kW-hr.
- Conditions are ASHRAE TC 9.9 2011 recommended
- CRAC Coupled to Air-Cooled Chiller rated at 80°F/30% with 50°F EWT
- Using Fluid Water
- kW average shown as actual kW varies over ambient range

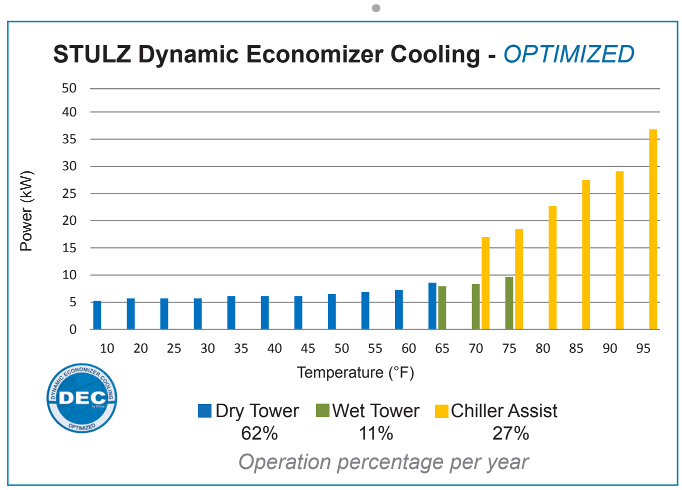
Comparison of Economizer Cooling

		CRAC DX			CRAH CW			
		80°F 30% RH Return Air			80°F 30% RH Return Air, 50°F Entering Water /60°F Leaving Water		103°F 14% RH Return Air, 70°F Entering/95°F Leaving	
		Traditional	Variable	Evaporative Tower	Dual-Source	STULZ Dynamic Economizer Cooling	**STULZ Dynamic Economizer Cooling**	
Baltimore MD	kW Per Yr	406,580	323,476	317,084	314,947	266,534	**94,622**	**-64%**
	Operational Cost Per Yr	$40,658	$32,348	$31,708	$31,495	$26,653	**$9,462**	
Salt Lake City UT	kW Per Yr	399,674	322,258	306,599	299,138	251,607	**92,104**	**-63%**
	Operational Cost Per Yr	$39,967	$32,226	$30,660	$29,914	$25,161	**$9,210**	
Portland OR	kW Per Yr	414,583	332,012	356,393	355,024	266,640	**70,692**	**-74%**
	Operational Cost Per Yr	$41,458	$33,201	$35,639	$35,502	$26,664	**$7,069**	

- Conditions are ASHRAE TC 9.9 2011 recommended
- Power cost is $0.10 per kW-hr.

Accumulation of Curves:





Summary: When comparing all the featured water-side economizer solutions, we see that each provides a benefit for each of the weather conditions selected. Selecting the optimal solution for your application depends on several factors, including: availability and cost of power, availability and cost of water, ability to maximize operating conditions, capital and/or operating budget, capability to support and service different equipment, etc. The charts illustrate just how much more efficiency can be achieved by operating the STULZ Dynamic Economizer Cooling system at optimized conditions.

Energy Measurement (PUE)

Power Usage Effectiveness or PUE was developed and recently clarified by Green Grid. PUE is a measurement for how efficiently a data center uses energy. It looks at how much energy is used by the computing equipment in contrast to cooling and power infrastructure and other overhead. In other words, PUE is a measure of the data center's effective use of power. It is the ratio of total amount of energy used by a computer data center facility to the energy delivered to computing equipment. PUE is dynamic and changes with outdoor temperature and humidity. Low PUE is the goal. The power used by mechanical cooling has represented a substantial portion of the overall data center power, however with the STULZ Dynamic Economizer Cooling System, PUE can be reduced significantly when deployed using optimized conditions.

PUE = Total Facility Energy / IT Equipment Energy. Greater than 2.0 is currently common. 1.6 is considered good. 1.2 or under is considered excellent.

STULZ economizer solutions help our customers achieve the lowest PUE's, and with the latest state-of-the-art economizer designs, customers can achieve PUE 's less than 1.2.

Return on Investment

Each of the water-side economizers detailed in this paper provide significant energy savings, but it is also necessary to look carefully at an overall return on investment (ROI) to determine which is right for you. Following is a table to help illustrate the potential ROI with each system based on weather conditions in Baltimore, MD:

Comparison - 1 MW System - Baltimore, MD				CRAC DX FC				CRAH CW			
Return on Investment (Simple Payback) **First Year Savings (Cost)**				CRAC with Glycol Cooled Condenser 80F / 30RH	Traditional 80F / 30RH	Variable 80F / 30RH	Evaporative Tower 80F / 30RH	CRAH with Air Cooled Chiller 80F / 30RH	Dual-Source 80F / 30RH	STULZ Dynamic Economizer 80F / 30RH	STULZ Dynamic Economizer 103F / 14RH
CRAC DX FC		CapEx Total		$ 358,300	$ 425,270	$ 544,471	$ 432,840	$ 621,680	$ 774,200	$ 757,780	$733,180
		OpEx Annual		$ 438,153	$ 382,185	$ 304,071	$ 298,055	$ 354,897	$ 296,053	$ 250,538	$88,943
	CRAC with Glycol Cooled Condenser 80F / 30RH	CapEx Total	$ 358,300		$ 66,970	$ 186,171	$ 74,540	$ 263,380	$ 415,900	$ 399,480	$374,880
		OpEx Annual	$ 438,153		-$ 55,968	-$ 134,082	-$ 140,098	-$ 83,256	-$ 142,100	-$ 187,615	-$ 349,210
		ROI			1.20	1.39	0.53	3.16	2.93	2.13	1.07
	Traditional 80F / 30RH	CapEx Total	$ 425,270			$ 119,201	$ 7,570	$ 196,410	$ 348,930	$ 332,510	$ 307,910
		OpEx Annual	$ 382,185			-$ 78,114	-$ 84,130	-$ 27,288	-$ 86,132	-$ 131,647	-$ 293,242
		ROI				1.53	0.09	7.20	4.05	2.53	1.05
	Variable 80F / 30RH	CapEx Total	$ 544,471				-$ 111,631	$ 77,209	$ 229,729	$ 213,309	$ 188,709
		OpEx Annual	$ 304,071				-$ 6,016	$ 50,826	-$ 8,018	-$ 53,533	-$ 215,128
		ROI					$ 117,647	- $ 128,035	28.65	3.98	0.88
	Evaporative Tower 80F / 30RH	CapEx Total	$ 432,840					$ 188,840	$ 341,360	$ 324,940	$ 300,340
		OpEx Annual	$ 298,055					$ 56,842	-$ 2,002	-$ 47,517	-$ 209,112
		ROI						-$ 245,682	-$ 339,358	6.84	1.44
CRAH CW	CRAH with Air Cooled Chiller 80F / 30RH	CapEx Total	$ 621,680						$ 152,520	$ 136,100	$ 111,500
		OpEx Annual	$ 354,897						-$ 58,844	-$ 104,359	-$ 265,954
		ROI							2.59	1.30	0.42
	Dual-Source 80F / 30RH	CapEx Total	$ 774,200							-$ 16,420	-$ 41,020
		OpEx Annual	$ 296,053							-$ 45,515	-$ 207,110
		ROI								$ 61,935	$ 248,130
	STULZ Dynamic Economizer 80F / 30RH	CapEx Total	$ 757,780								-$ 24,600
		OpEx Annual	$ 250,538								-$ 161,595
		ROI									$ 186,195
	STULZ Dynamic Economizer 103F / 14RH	CapEx Total	$ 733,180								
		OpEx Annual	$ 88,943								
		ROI									

• System pricing includes major mechanical cooling system components only.
Does not include piping, electrical support systems, freight, or installation costs.

Additional Capital Savings (Cap-Ex)

Using the STULZ Dynamic Economizer Cooling System, there were some very significant capital savings achieved at a major co-location data center in Northern, VA.

- The raised floor was eliminated by utilizing STULZ CRAH's with front discharge and racks with integrated hot air containment. The entire data center white space was used as a cold aisle.
- The chiller CapEx requirements and related maintenance was reduced, by specifying/sizing only for the minimum trim capacity required.
- The generator CapEx requirements and related maintenance was reduced, by specifying/sizing for the much lower energy required by the system.

Energy Rebates

STULZ water-side economizer solutions often qualify data center owners for significant energy rebates. Many utility companies are reaching high levels of capacity. They are offering incentives to companies that implement ways to save energy. With this guide, customers can demonstrate the tremendous energy savings that can be achieved. STULZ customers have received hundreds of thousands of $'s in rebates each year.

System Deployment

The first STULZ Dynamic Economizer Cooling System has been designed and implemented at a major co-location data center in Northern, VA with outstanding results!

Author Bio:

Jason Derrick is a licensed professional engineer who has worked in multiple engineering disciplines. Jason has been employed as an applications engineer at Stulz Air Technology Systems since February of 2007. He is an expert in all aspects of precision air conditioning and data center cooling with a specialty concentration in ultrasonic humidification and water side economization. Prior to joining the Stulz team Jason worked as a consulting engineer in the petrochemical industry. Jason holds a Bachelors of Science degree in Mechanical Engineering from West Virginia University.

Author Bio:

David Joy has over 15 years' experience supporting data center infrastructure. David currently works as VP of Sales and Marketing for Stulz, a global manufacturer of precision cooling products and solutions for data center applications. David's background includes 17 years in domestic and international sales and marketing roles at Rittal, a manufacturer of racks and cooling for industrial and IT applications, 5 years as VP of Product Marketing at Emerson Network Power-Liebert, a manufacturer of rack, power, and cooling products for data centers, and 2 years as VP/GM of Chiller Business at Daikin-McQuay, a manufacturer of comfort cooling products for commercial buildings. David holds a Master's Degree in Business Administration. He currently resides in Frederick, Maryland.

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