STULZ Water-Side Economizer Solutions

*with STULZ Dynamic Economizer Cooling*

Optimized Cap-Ex and Minimized Op-Ex

STULZ Data Center Design Guide
Authors: Jason Derrick PE, David Joy
Date: January 16, 2014
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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:**

<table>
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<tr>
<th>DX Economizer Solutions</th>
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</tr>
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<table>
<thead>
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<th>CW Economizer Solutions</th>
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</thead>
<tbody>
<tr>
<td>Dual-Source Chilled Water Economizer</td>
</tr>
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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


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.

<table>
<thead>
<tr>
<th>What Has Changed</th>
<th>Inlet Air Temperature</th>
<th>Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 Recommended (old)</td>
<td>68-77.0°F DB</td>
<td>40% RH to 55% RH</td>
</tr>
<tr>
<td>2011 Recommended (new)</td>
<td>64-80.6°F DB</td>
<td>41.9°F DP to 60% RH &amp; 59°F DP</td>
</tr>
<tr>
<td>2011 Allowable (A1)</td>
<td>59-89.6°F DB</td>
<td>20-80% RH up to 62.1°F DP</td>
</tr>
</tbody>
</table>

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.

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.

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:

<table>
<thead>
<tr>
<th>CFD-230-C CRAH</th>
<th>Selection 1</th>
<th>Selection 2</th>
<th>Selection 3</th>
<th>Selection 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entering Air DB (°F)</td>
<td>75</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Entering Air WB (°F)</td>
<td>61.1</td>
<td>67.8</td>
<td>67.8</td>
<td>67.8</td>
</tr>
<tr>
<td>Coil Leaving Air DB (°F)</td>
<td>51.0</td>
<td>54.1</td>
<td>54.2</td>
<td>69.9</td>
</tr>
<tr>
<td>Coil Leaving Air WB (°F)</td>
<td>50.5</td>
<td>53.1</td>
<td>53.1</td>
<td>59.2</td>
</tr>
<tr>
<td>Gross Total Capacity (BTU/H)</td>
<td>513,800</td>
<td>755,700</td>
<td>503,400</td>
<td>464,800</td>
</tr>
<tr>
<td>Gross Sensible Capacity (BTU/H)</td>
<td>461,200</td>
<td>755,700</td>
<td>503,400</td>
<td>464,800</td>
</tr>
<tr>
<td>Net Total Capacity (BTU/H)</td>
<td>493,800</td>
<td>735,700</td>
<td>494,500</td>
<td>444,800</td>
</tr>
<tr>
<td>Net Sensible Capacity (BTH/H)</td>
<td>441,200</td>
<td>735,700</td>
<td>494,500</td>
<td>444,800</td>
</tr>
<tr>
<td>Air Flow (ACFM)</td>
<td>18,000</td>
<td>18,000</td>
<td>12,000</td>
<td>18,000</td>
</tr>
<tr>
<td>External Static Pressure (in)</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Altitude (ft)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Entering Fluid Temperature (°F)</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Fluid Type</td>
<td>Water</td>
<td>Water</td>
<td>Water</td>
<td>Water</td>
</tr>
<tr>
<td>Percent Glycol (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fluid Flow (GPM)</td>
<td>105</td>
<td>105</td>
<td>52</td>
<td>43</td>
</tr>
<tr>
<td>Leaving Fluid Temperature (°F)</td>
<td>55</td>
<td>59.7</td>
<td>64.7</td>
<td>77.1</td>
</tr>
<tr>
<td>Coil Fluid Pressure Drop (FT-H₂O)</td>
<td>10.2</td>
<td>10.2</td>
<td>2.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Unit Fluid Pressure Drop (FT-H₂O)</td>
<td>23.3</td>
<td>23.3</td>
<td>8.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Estimated Unit Power (kW)</td>
<td>5.3</td>
<td>5.3</td>
<td>2.6</td>
<td>5.3</td>
</tr>
</tbody>
</table>

**Selection 1**

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**

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**

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**

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.

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.

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 temperature 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.
Elevating Return Temperatures on a DX System

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Compressor Operation</td>
<td>53.0</td>
<td>8760</td>
<td>100%</td>
<td>463,930</td>
<td>55.7</td>
<td>5998</td>
<td>68%</td>
<td>333,789</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>39.2</td>
<td>1249</td>
<td>14%</td>
<td>48,923</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Cooling</td>
<td>22.7</td>
<td>1513</td>
<td>17%</td>
<td>34,330</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly Total Unit Power</td>
<td></td>
<td></td>
<td></td>
<td>463,930</td>
<td></td>
<td></td>
<td></td>
<td>417,042</td>
</tr>
<tr>
<td>Consumption (kW Hrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCOP</td>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### 30 ton CRAC: 80°F 30% RH Return Air

Baltimore, MD

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Compressor Operation</td>
<td>53.2</td>
<td>8760</td>
<td>100%</td>
<td>466,120</td>
<td>55.9</td>
<td>5272</td>
<td>60%</td>
<td>294,652</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>39.3</td>
<td>1975</td>
<td>23%</td>
<td>77,598</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Cooling</td>
<td>22.7</td>
<td>1513</td>
<td>17%</td>
<td>34,330</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly Total Unit Power</td>
<td></td>
<td></td>
<td></td>
<td>466,120</td>
<td></td>
<td></td>
<td></td>
<td>406,580</td>
</tr>
<tr>
<td>Consumption (kW Hrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCOP</td>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Savings Comparison**

- **Total kW Savings Per Year:** 46,888
- **Total Cost Savings Per Year:** $4,688

**Power Savings**

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Cooled Chiller Operation</td>
<td>46.2</td>
<td>8760</td>
<td>100%</td>
<td>404,362</td>
<td>47.0</td>
<td>6638</td>
<td>76%</td>
<td>311,654</td>
</tr>
<tr>
<td>Evaporative Cooling Tower Operation</td>
<td>-</td>
<td>11.3</td>
<td>24%</td>
<td>23,936</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td></td>
<td></td>
<td></td>
<td>404,362</td>
<td></td>
<td></td>
<td></td>
<td>335,590</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Cooled Chiller Operation</td>
<td>43.1</td>
<td>8760</td>
<td>100%</td>
<td>377,556</td>
<td>46.3</td>
<td>6245</td>
<td>71%</td>
<td>289,144</td>
</tr>
<tr>
<td>Evaporative Cooling Tower Operation</td>
<td>-</td>
<td>10.3</td>
<td>29%</td>
<td>25,804</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td></td>
<td></td>
<td></td>
<td>377,556</td>
<td></td>
<td></td>
<td></td>
<td>314,974</td>
</tr>
</tbody>
</table>

**Savings Comparison**

**Total kW Savings Per Year:** 68,771

**Total Cost Savings Per Year:** $6,877

### 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 Water-Side Economizers based on a CRAC with a Free Cooling Coil

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.

**Used with the following**

**STULZ Water-Side Economizers:**

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

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Tandem Compressor</th>
<th>Compressor 1a</th>
<th>Compressor 1b</th>
<th>Compressor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

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:
**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).

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

<table>
<thead>
<tr>
<th>CRAC with Constant Speed Pump and DryCooler</th>
<th>CRAC with Free Cooling Coupled with Constant Speed Pump and DryCooler</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode</strong></td>
<td><strong>kW</strong></td>
</tr>
<tr>
<td>Full Compressor Operation</td>
<td>53.2</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>-</td>
</tr>
<tr>
<td>Free Cooling</td>
<td>-</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>466,120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRAC with Constant Speed Pump and DryCooler</th>
<th>CRAC with Free Cooling Coupled with Constant Speed Pump and DryCooler</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode</strong></td>
<td><strong>kW</strong></td>
</tr>
<tr>
<td>Full Compressor Operation</td>
<td>54.6</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>-</td>
</tr>
<tr>
<td>Free Cooling</td>
<td>-</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>478,603</td>
</tr>
</tbody>
</table>

---

### Baltimore MD

- **Total kW Savings Per Year:** 59,540
- **Total Cost Savings Per Year:** $5,954

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

- **Total kW Savings Per Year:** 78,929
- **Total Cost Savings Per Year:** $7,892

### Portland, OR

- **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

<table>
<thead>
<tr>
<th>City</th>
<th>CRAC with Constant Speed Pump and DryCooler</th>
<th>CRAC with Free Cooling Coupled with Variable Speed Pump and DryCooler</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mode</td>
<td></td>
</tr>
<tr>
<td></td>
<td>kW</td>
<td>Hrs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltimore, MD</td>
<td>Full Compressor Operation</td>
<td>53.2</td>
</tr>
<tr>
<td></td>
<td>Free Cooling Assist</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Free Cooling</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>466,120</td>
</tr>
<tr>
<td></td>
<td>Total kW Savings Per Year:</td>
<td></td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>Full Compressor Operation</td>
<td>54.6</td>
</tr>
<tr>
<td></td>
<td>Free Cooling Assist</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Free Cooling</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>478,603</td>
</tr>
<tr>
<td></td>
<td>Total kW Savings Per Year:</td>
<td></td>
</tr>
<tr>
<td>Portland, OR</td>
<td>Full Compressor Operation</td>
<td>53.2</td>
</tr>
<tr>
<td></td>
<td>Free Cooling Assist</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Free Cooling</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>466,120</td>
</tr>
<tr>
<td></td>
<td>Total kW Savings Per Year:</td>
<td></td>
</tr>
</tbody>
</table>

- Based on 0.10 $/kWh
- 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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Compressor Operation</td>
<td>53.2</td>
<td>8760</td>
<td>100%</td>
<td>466,120</td>
<td>47.3</td>
<td>5028</td>
<td>57%</td>
<td>237,774</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30.7</td>
<td>1610</td>
<td>18%</td>
<td>49,411</td>
</tr>
<tr>
<td>Free Cooling</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.1</td>
<td>2122</td>
<td>24%</td>
<td>29,899</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>466,120</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>317,084</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Compressor Operation</td>
<td>54.6</td>
<td>8760</td>
<td>100%</td>
<td>478,603</td>
<td>49.4</td>
<td>3810</td>
<td>43%</td>
<td>188,271</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>32.8</td>
<td>2293</td>
<td>26%</td>
<td>75,245</td>
</tr>
<tr>
<td>Free Cooling</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16.2</td>
<td>2657</td>
<td>30%</td>
<td>43,083</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>478,603</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>306,599</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Portland, OR**

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Compressor Operation</td>
<td>53.2</td>
<td>8760</td>
<td>100%</td>
<td>466,120</td>
<td>47.3</td>
<td>6539</td>
<td>75%</td>
<td>309,229</td>
</tr>
<tr>
<td>Free Cooling Assist</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30.7</td>
<td>956</td>
<td>11%</td>
<td>29,340</td>
</tr>
<tr>
<td>Free Cooling</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.1</td>
<td>1265</td>
<td>14%</td>
<td>17,824</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>466,120</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>356,393</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>System kW Per Yr</th>
<th>Traditional Economizer Cooling</th>
<th>Variable Economizer Cooling</th>
<th>Evaporative Tower Economizer Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baltimore, MD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System kW Per Yr</td>
<td>466,120</td>
<td>406,580</td>
<td>323,476</td>
</tr>
<tr>
<td>System Operational Cost Per Yr</td>
<td>$46,612</td>
<td>$40,658</td>
<td>$32,348</td>
</tr>
<tr>
<td>% Reduced Energy</td>
<td>-13%</td>
<td>-31%</td>
<td>-32%</td>
</tr>
<tr>
<td><strong>Salt Lake City, UT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System kW Per Yr</td>
<td>478,603</td>
<td>399,674</td>
<td>322,258</td>
</tr>
<tr>
<td>System Operational Cost Per Yr</td>
<td>$47,860</td>
<td>$39,967</td>
<td>$32,225</td>
</tr>
<tr>
<td>% Reduced Energy</td>
<td>-17%</td>
<td>-33%</td>
<td>-36%</td>
</tr>
<tr>
<td><strong>Portland, OR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System kW Per Yr</td>
<td>466,120</td>
<td>414,583</td>
<td>332,012</td>
</tr>
<tr>
<td>System Operational Cost Per Yr</td>
<td>$46,612</td>
<td>$41,458</td>
<td>$33,201</td>
</tr>
<tr>
<td>% Reduced Energy</td>
<td>-11%</td>
<td>-29%</td>
<td>-24%</td>
</tr>
</tbody>
</table>

### 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.

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

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*STULZ Air Technology Systems, Inc.*

www.STULZ.com

14 | Page
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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Cooled Chiller Operation</td>
<td>43.1</td>
<td>8760</td>
<td>100%</td>
<td>377,556</td>
<td>46.3</td>
<td>6245</td>
<td>71%</td>
<td>289,144</td>
</tr>
<tr>
<td>Evaporative Cooling Tower Operation</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>10.3</td>
<td>2515</td>
<td>29%</td>
<td>25,804</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>377,556</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>314,947</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Cooled Chiller Operation</td>
<td>44.0</td>
<td>8760</td>
<td>100%</td>
<td>385,440</td>
<td>47.0</td>
<td>5624</td>
<td>64%</td>
<td>264,328</td>
</tr>
<tr>
<td>Evaporative Cooling Tower Operation</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>11.1</td>
<td>3136</td>
<td>36%</td>
<td>34,810</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>385,440</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>299,138</td>
</tr>
</tbody>
</table>

#### Portland, OR

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Cooled Chiller Operation</td>
<td>43.1</td>
<td>8760</td>
<td>100%</td>
<td>377,556</td>
<td>46.3</td>
<td>7357</td>
<td>84%</td>
<td>340,629</td>
</tr>
<tr>
<td>Evaporative Cooling Tower Operation</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>10.3</td>
<td>1403</td>
<td>16%</td>
<td>14,395</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>377,556</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>355,024</td>
</tr>
</tbody>
</table>
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

STULZ Dynamic Economizer Cooling

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.

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

<table>
<thead>
<tr>
<th></th>
<th>Baltimore, MD</th>
<th>Salt Lake City, UT</th>
<th>Portland, OR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRAH Coupled with Air-Cooled Chiller</strong></td>
<td><strong>STULZ Dynamic Economizer Cooling</strong></td>
<td><strong>STULZ Dynamic Economizer Cooling</strong></td>
<td><strong>STULZ Dynamic Economizer Cooling</strong></td>
</tr>
<tr>
<td><strong>Mode</strong></td>
<td><strong>kW</strong></td>
<td><strong>Hrs</strong></td>
<td><strong>% of Yr</strong></td>
</tr>
<tr>
<td><strong>Chiller</strong></td>
<td>43.1</td>
<td>8760</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Chiller Assist</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Wet Tower</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Dry Tower</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Yearly Total Unit Power Consumption (kW Hrs)</strong></td>
<td>377,556</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Yearly Total Unit Power Consumption (kW Hrs)</strong></td>
<td>385,440</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**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

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

### 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.
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).

### Test setup of Dynamic Economizer Cooling with optimized operating conditions

- **70°F (21°C) Supply Water**
- **75°F (24°C) Supply Air**
- **103°F (39°C) Return Air**
- **95°F (35°C) Return Water**
- **25°F (14°C) delta between the Supply Water and Return Water temp**
- **28°F (15°C) delta between the Supply Air and Return Air temp**
- **5°F (3°C) delta between Supply Water and Supply Air temp**
Closed-Loop Cooling Tower

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 sprayed 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.

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.

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 sprayed 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.
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.

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.
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.
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.

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.
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

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>Average kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>43.1</td>
<td>8760</td>
<td>100%</td>
<td>377,556</td>
<td>42.2</td>
<td>5</td>
<td>0.1%</td>
<td>211</td>
</tr>
<tr>
<td>Chiller Assist</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wet Tower</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.6</td>
<td>982</td>
<td>11%</td>
<td>8,458</td>
</tr>
<tr>
<td>Dry Tower</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.6</td>
<td>5443</td>
<td>62%</td>
<td>35,700</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>377,556</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>94,622</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode</th>
<th>kW</th>
<th>Hrs</th>
<th>% of Yr</th>
<th>Total kW Hrs</th>
<th>Average kW</th>
<th>Hours</th>
<th>% of Year</th>
<th>Total kW Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>44.0</td>
<td>8760</td>
<td>100%</td>
<td>385,440</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>0</td>
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<tr>
<td>Chiller Assist</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wet Tower</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.6</td>
<td>1807</td>
<td>21%</td>
<td>17,350</td>
</tr>
<tr>
<td>Dry Tower</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.1</td>
<td>5574</td>
<td>64%</td>
<td>39,884</td>
</tr>
<tr>
<td>Yearly Total Unit Power Consumption (kW Hrs)</td>
<td>385,440</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>92,104</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Baltimore, MD

- Total kW Savings Per Year: 282,934
- Total Cost Savings Per Year: $28,293

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

- Total kW Savings Per Year: 293,336
- Total Cost Savings Per Year: $29,334

### Portland, OR

- 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 Cooling Tower
- Power cost is $0.10 per kW-hr.
- Nominal 30 ton Chiller
- CRAC Coupled to Air-Cooled Chiller rated at 80°F/30% with 50°F EWT
- Using Fluid Water
- kW average shown as actual kW vary over ambient range
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.

### Summary:

<table>
<thead>
<tr>
<th>Location</th>
<th>kW Per Yr</th>
<th>Operational Cost Per Yr</th>
<th>Power (kW)</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore MD</td>
<td>406,580</td>
<td>$40,658</td>
<td>406,580</td>
<td>0</td>
</tr>
<tr>
<td>Salt Lake City UT</td>
<td>399,674</td>
<td>$39,967</td>
<td>399,674</td>
<td>0</td>
</tr>
<tr>
<td>Portland OR</td>
<td>414,583</td>
<td>$41,458</td>
<td>414,583</td>
<td>0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Comparison - 1 MW System - Baltimore, MD</th>
<th>CRAC DX FC</th>
<th>CRAH CW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return on Investment (Simple Payback)</td>
<td>CRAC with Glycol Cooled Condenser 80F / 30RH</td>
<td>CRAH with Air Cooled Chiller 80F / 30RH</td>
</tr>
<tr>
<td>First Year Savings (Cost)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CapEx Total</td>
<td>$358,300</td>
<td>$621,680</td>
</tr>
<tr>
<td>OpEx Annual</td>
<td>$425,270</td>
<td>$744,480</td>
</tr>
<tr>
<td>ROI</td>
<td>$544,471</td>
<td>$868,533</td>
</tr>
<tr>
<td>Traditional 80F / 30RH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CapEx Total</td>
<td>$382,185</td>
<td>$774,200</td>
</tr>
<tr>
<td>OpEx Annual</td>
<td>$304,071</td>
<td>$624,062</td>
</tr>
<tr>
<td>ROI</td>
<td>$128,035</td>
<td>$131,600</td>
</tr>
<tr>
<td>Variable 80F / 30RH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CapEx Total</td>
<td>$306,071</td>
<td>$624,062</td>
</tr>
<tr>
<td>OpEx Annual</td>
<td>$298,055</td>
<td>$624,062</td>
</tr>
<tr>
<td>ROI</td>
<td>$128,035</td>
<td>$131,600</td>
</tr>
<tr>
<td>Evaporative Tower 80F / 30RH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CapEx Total</td>
<td>$306,071</td>
<td>$624,062</td>
</tr>
<tr>
<td>OpEx Annual</td>
<td>$298,055</td>
<td>$624,062</td>
</tr>
<tr>
<td>ROI</td>
<td>$128,035</td>
<td>$131,600</td>
</tr>
</tbody>
</table>

- 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.