# Rittal White Paper 508: Economized Data Center Cooling—Defining Methods & Implementation Practices

By: Daniel Kennedy

## Executive Summary

Data center owners and operators are in constant pursuit of methods to further reduce their energy costs and negative impact on the environment. For many years, economizing methods have been used in conjunction with cooling systems found in both commercial and industrial settings to cut energy consumption. More recently, the application of these technologies to the data center environment has also been widely practiced, although primarily in large data center spaces. This paper explores the methods of economized cooling that can be used in the small-to-medium size data centers that are more prevalent in the industry today than their larger counterparts. A brief overview of system implementation is also included.

## Common Economized Cooling Systems

In regards to the data center environment, economized cooling systems are basically just simple heat exchangers and typically take two forms. They are usually referred to in terms of the medium they use to remove energy (heat) from the data center. These common mediums, water and air, give rise to the terms “water-side economizing” and “air-side economizing.”

The primary difference between these economizing methods, as alluded to above, is that to remove the heat energy from a data center a water-side economizing system utilizes water and an air-side system utilizes air from the outdoor space.

## Water-side Economizing Systems

Water-side economizing systems cool the chilled water used in the data center by using the outside environment. The water is cooled to appropriate levels simply by passing through the outside air without actively expending energy (refrigeration) to chill the water.

An understanding of typical chilled water systems is important to fully comprehend the method often used to cool data centers without economizing systems. See figure 1 below to see the operating cycle of a typical small scale chilled water system utilizing an air cooled chiller and a typical computer room air handler.

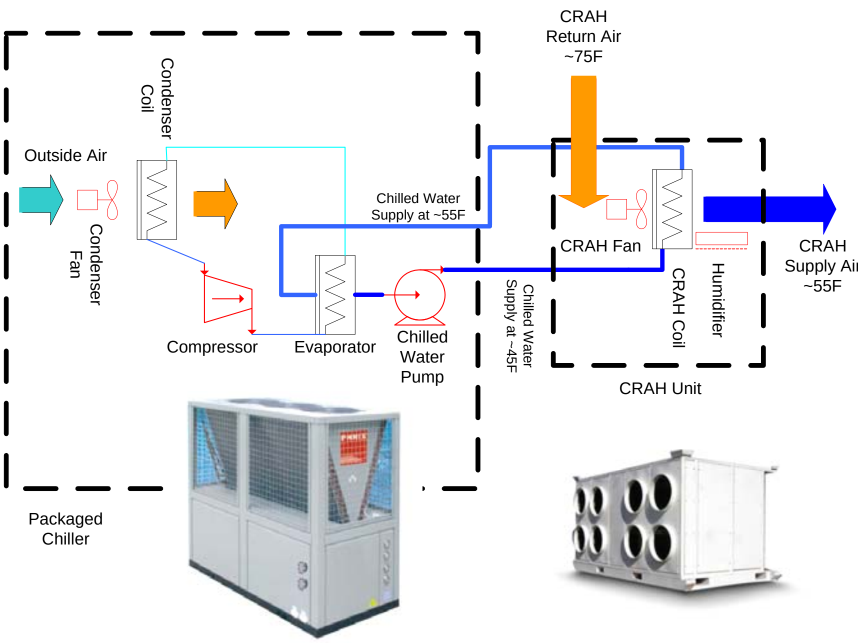


**Figure 1: Typical Chilled Water System Block Diagram**

The packaged chiller removes heat energy from the water through the use of a refrigeration cycle, rejecting it to the environment on the condensing side of the refrigeration cycle. The chilled water is passed into the data center where it picks up energy from the air in the data center generated by the IT load and passes back to the chiller where the cycle is repeated.

The simplest water-side economizers take over the function of the chiller when the temperature in the ambient environment allows. See figure 2 for a simple block diagram of this system.

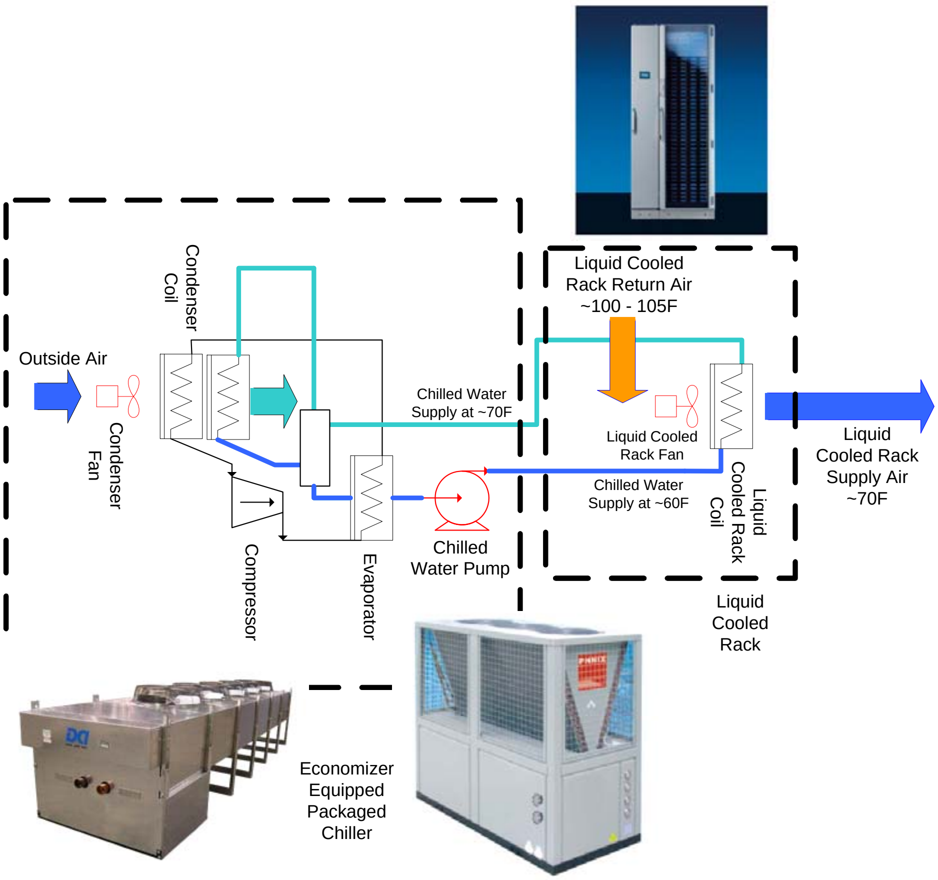


**Figure 2: Simple dry cooler utilized to provide water-side economizing**

In the configuration above, a simple radiator equipped with fans, often referred to as a "dry cooler," is installed in parallel with the chiller. When the ambient temperature drops to the point where the chilled water can have all energy removed from it using only economized cooling, the system is switched from the chiller to the dry cooler, allowing it to reject heat directly to the outside environment.

The economizing systems referred to thus far use air as the principle method to reject heat, either on the chiller side or on the dry cooler side. The most popular of the remaining economizing methods is an "evaporative-type" system.

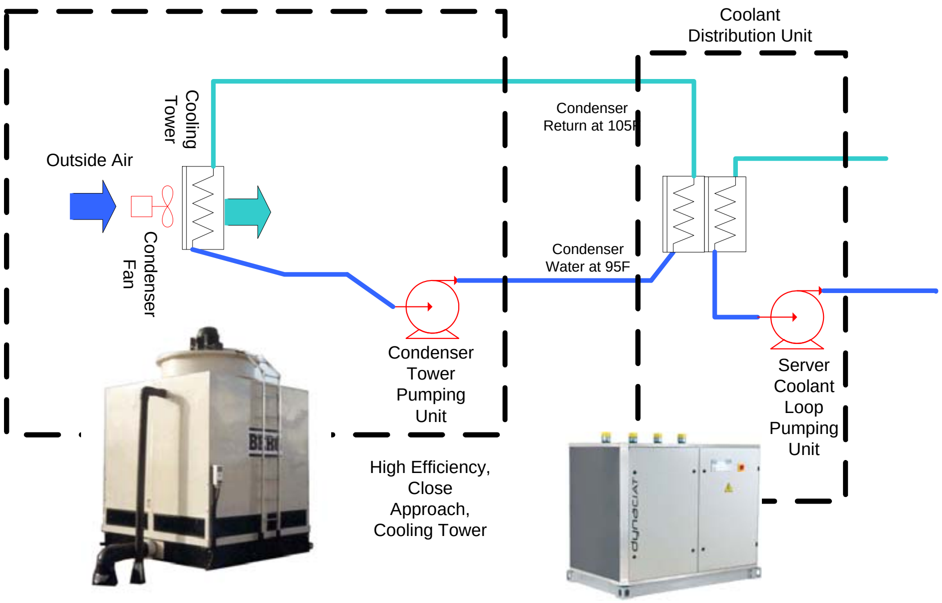


**Figure 3: Evaporative Cooling Systems**

Evaporative systems work similarly to dry cooling systems, but allow for a wider window of functionality because they are less dependent upon environmental conditions. These systems use the evaporative process to cool a water loop that is used in conjunction with the standard chiller systems like those shown in figures 1 and 2 by inundating the circulating water with warmer water to create evaporation. In a typical layout, the remainder of the standard chiller system would be found to the right of the components shown in Figure 3 above.

Other methods of water-side economizing are a bit more extreme. Some systems utilize direct energy exchange via a geothermal approach. These systems can often produce chilled water temperatures above what is typically used in data center cooling applications (systems that can utilize this water temperature directly are covered in other Rittal Corporation white papers).

There are also systems that reject their heat into large bodies of water such as lakes, or even oceans, for direct transfer. These systems often produce water warmer than that typically used in conventional cooling approaches, but as in the case of geothermal systems, newly advancing cooling solutions are equipped to take advantage of these economizing methods.

## Air-side Economizing Systems

Air-side economizing systems have been utilized for many years in building air conditioning (HVAC) applications, but these systems are quickly gaining favor in today's data center environments as well.

These systems typically pull outside air into the data center space, may or may not condition this air, pass it to the equipment to be cooled and then reject the heated air back to the outside environment. This approach is the most direct economization method currently in widespread use. Figure 4 is an example of the  process that is generally employed.

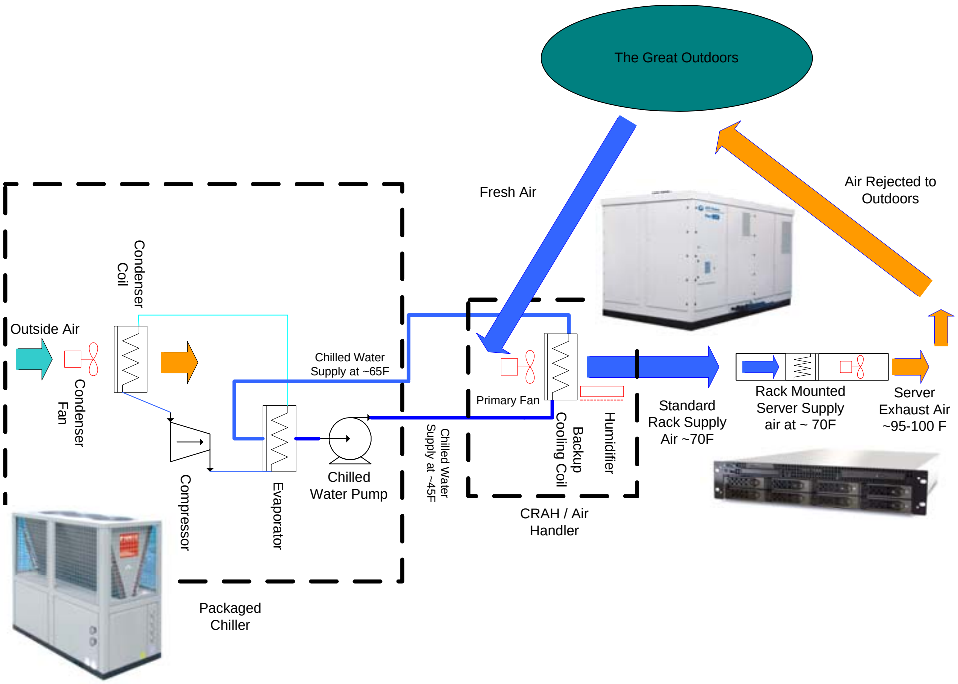


**Figure 4: Air-side Economization**

As shown in the diagram, it is customary for a "primary cooling" system to be in place to handle the heat load when the outdoor ambient air is outside of the required data center specifications. The conditioning of or use of the outside air is dependent upon the user's requirements.

## Economizing Considerations and Benefits

### Water-side

The water-side economizing approach minimizes the interaction of the outside environment with internal data center air, while also working in conjunction with often pre-existent data center cooling infrastructures. The system's functionality is directly related to the required water temperature needed for the cooling system utilized in the data center and the ambient environment used for heat rejection. See figure 5 for a comparison showing the number of hours of operation for an economizing system utilizing a standard dry-type cooler at a 45°F supplied chilled water temperature vs. 60°F supplied chilled water temperature. Figure 5 also compares the impact of using close-coupled cooling systems that have the ability to accept warmer chilled water (up to 65°F) while still maintaining 2008 ASHRAE standards.

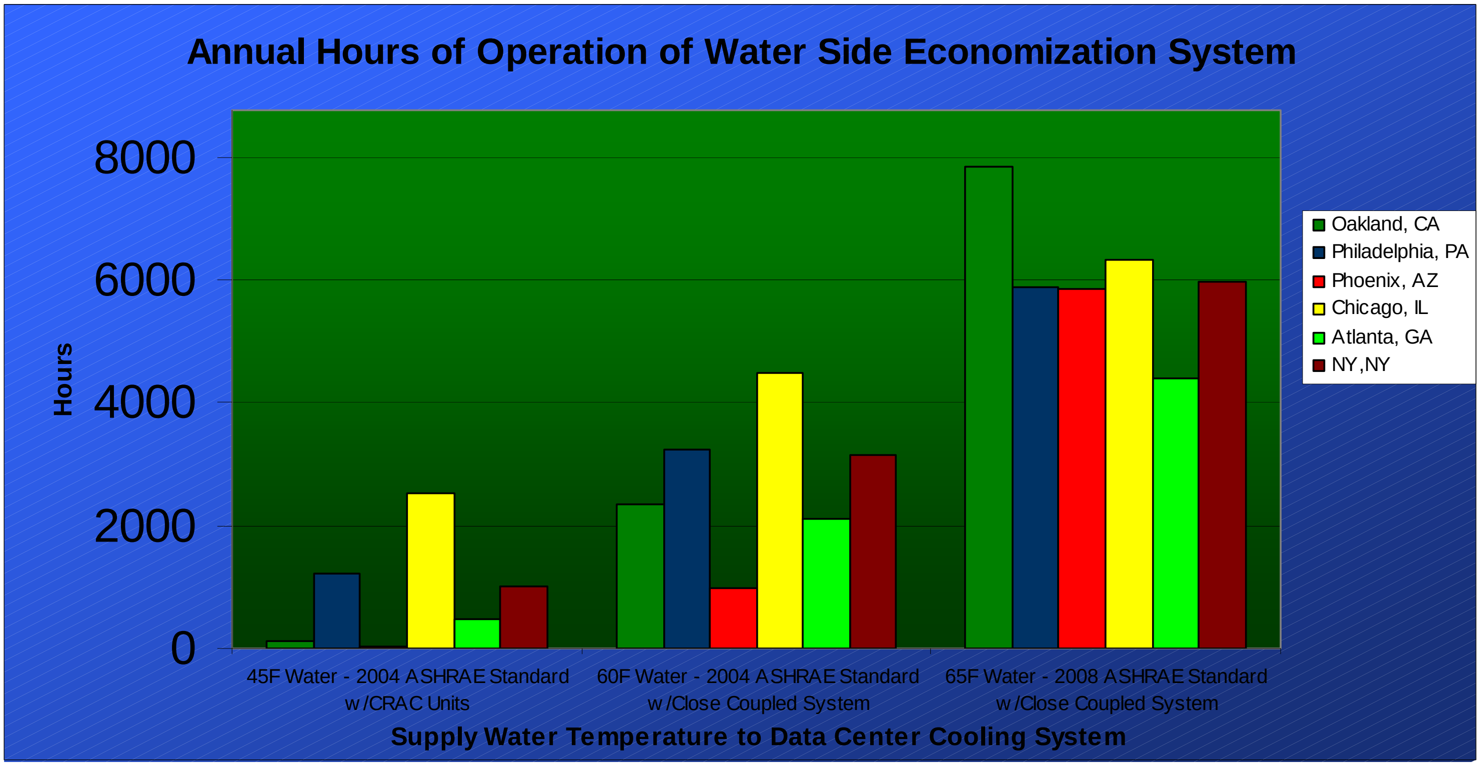


**Figure 5: Impacted of increased supply water temperature on economizing system operation**

As can be seen above, the typical impact of increasing the supply water temperature to the cooling equipment in the data center is often a doubling of the operational hours of the economization system. The impact of moving closer to the median outdoor temperature is quite large. Simply stepping from a 60°F chilled water temperature to a 65°F chilled water temperature doubles the hours of economizing available in most of the sites selected. The assumed ambient dry bulb temperature at the 60°F water is 53°F, and at 65°F, 58°F dry bulb. This increase can only be realized in systems that can operate at these levels. The data was acquired from NOAA (National Oceanic and Atmospheric Administration) temperature data for the year 2007.[1]

The true impact of this has to do with the elimination of the chilled water system refrigeration system. While the economization system is operational, the refrigeration circuit in the chilled water system is offline, resulting in large energy savings via the chilled water system (quantification of these energy savings can be found in other Rittal Corporation white papers).

In practice, water-side economization systems do add some additional day-one cost to the build-out of a chilled water system, and geographical location does have an impact on such a system (as seen in figure 5), but on average, Rittal has found that most systems pay for themselves in less than 3 years. The return on investment (ROI) of an economizing system can be calculated by determining the number of annual hours the system will be in operation, the energy savings when the system is in operation and the total cost of the energy saved during that time period.

Due to water-side economization's uncoupled approach to the cooling infrastructure, the risks associated with it are small. Additional controls are required to allow for the switch-over to the economization system, but failures should be minimal as the chilled water system provides a "safety net" to return to the standard operating mode if something were to ever go awry.

### Air-side

The window of operation for air-side economization is highly dependent on the data center operator's allowable temperature and humidity variances in the data center space. These values are typically prescribed by ASHRAE, and have recently been expanded to allow for greater temperature variances.

In the past, data centers were operated with very low entering air temperatures to the servers, or leaving air temperatures from the cooling units. A typical set point might have been a 55°F desired temperature. Humidity was also very closely controlled, often striving for levels between 40-50% relative humidity. The ASHRAE standards of 2008/2009 greatly expanded this range, allowing for further increases in the operation of air-side economization systems. These changes allow for temperature variations between approximately 64-80°F, and relative humidity specified by dew point values of between 42-59°F, versus 68-77°F, and relative humidity values of between 40-55%.[2]

For the purposes of this paper, and to illustrate the impact of air-side economization in the data center, the same 6 cities used in figure 5 were chosen to illustrate the impact of these changes in ASHRAE's specifications. Dry bulb temperatures were allowed to drop below the minimum values, as it was felt that inlet temperatures could be boosted when required by re-circulating exhaust air from the servers to achieve the desired inlet air temperatures. For the sake of energy savings, any humidity values that exceeded or fell below ASHRAE specifications were not counted in the total economization hours value. Figure 6 demonstrates the effect of ASHRAE's changes.

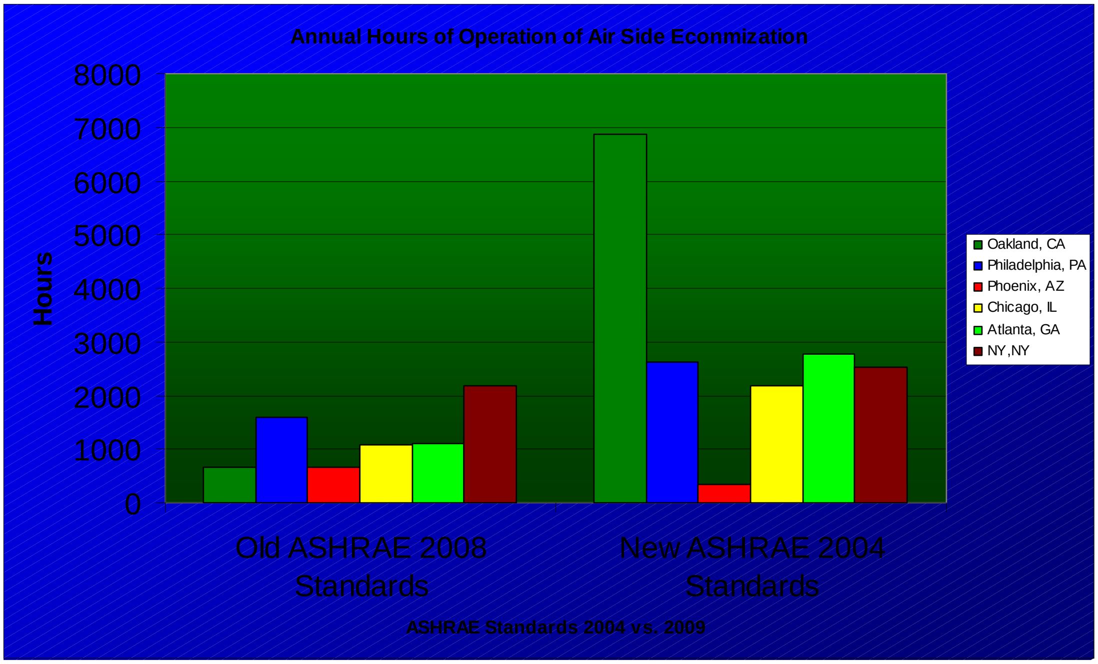


**Figure 6: Impacted of new ASHRAE TC9.9 environmental values**

Figure 6 shows that the impact of the ASHRAE standards is quite beneficial in all cases except the Phoenix area—due in part to the low number of hours either standard would allow for.

The impact of air-side economization on the data center may be larger than that for water-side economization. Switchover to the air-side economization could be achieved with controls no different than those required for water-side economization. It's true that the introduction of outside air directly into the data center space in large volumes increases the risk of contamination from the environment, but these risks can be mitigated by filtration if the user requires. Response to other environmental changes, such as fire, chemical or other hazards would require additional monitoring. Additionally, other factors such as air salinity or other unknown, and possibly difficult to remove pollutants, could impact server reliability. These limitations would require further investigation, however some existing studies of the reliability of data center hardware in non-data center environments suggest that servers are more capable of handling pollutants and other physical particulates than previously thought.[3]

## Conclusion

Cooling system economization in the data center is highly dependent upon geographical location, but in many cases is a worthwhile pursuit to reduce energy consumption in the data center space. Proper evaluation of each approach requires a study of the location, as well as a full understanding of any possible risks associated with the method chosen.

**Sources:**


1. NOAA: National Climatic Data Center Station Database, Retrieved on 5/29/2009 http://www.ncdc.noaa.gov/oa/ncdc.html
2. ASHRAE Publications: 2008 ASHRAE Environmental Guidelines for Datacom Equipment , Retrieved on 5/29/2009 http://tc99.ashraetcs.org/documents/ASHRAE_Extended_Environmental_Envelope_Final_Aug_1_2008.pdf
3. Miller, Rich: Data Center Knowledge, *New from Microsoft: Data Centers In Tents* Retrieved 5/28/2009 http://www.datacenterknowledge.com/archives/2008/09/22/new-from-microsoft-data-centers-in-tents/


## About the Author

**Daniel Kennedy** is Rittal Corporation’s RimatriX Solution Center Coordinator and has been with the company since 2003. He holds a degree in Electrical Engineering and is the lead engineer for the design, implementation and support of high density IT deployments in North America.