A White Paper from the Experts
in Business-Critical Continuity™

Energy Efficient Cooling Solutions for Data Centers

Introducing an Emerson Network Power tool for evaluating cooling system total cost of ownership

Liebert

EMERSON
Network Power

Executive Summary

Global electricity prices increased 56 percent[1] between 2002 and 2006, right along with a dramatic upswing in data center energy consumption. The financial implications are staggering, with annual power costs for U.S. data centers as high as $4.5 billion[2]. Beyond that, the environmental costs of data center energy demands also concern many organizations today. Whether the motivation is reducing costs, minimizing carbon footprint or both, many organizations are committed to finding solutions that help improve data center efficiency.

The data center cooling system is a primary target for energy efficiency improvements. Emerson Network Power analyzed data center energy usage and found that cooling systems — comprised of cooling and air movement equipment — account for 38 percent of energy consumption, as shown in Figure 1. Fortunately, cooling system technologies exist that can substantially slash costs from the data center electricity bill. Economizers and supplemental cooling systems are two such technologies that will be considered in this paper.

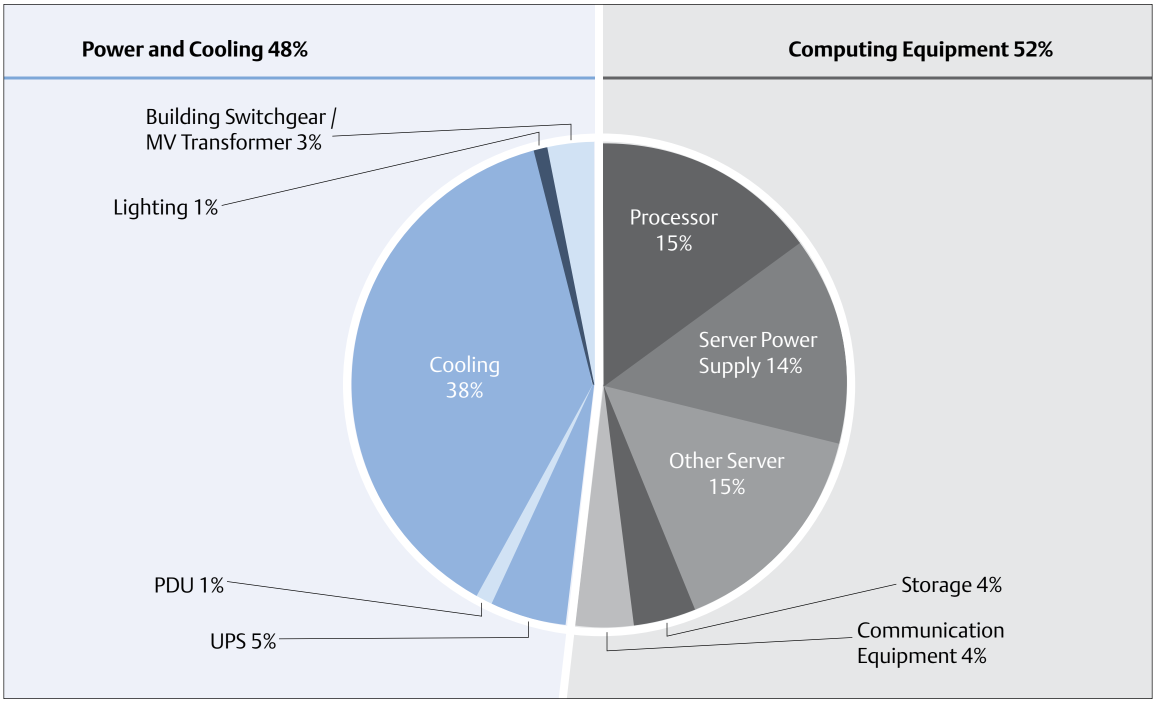

Figure 1. Typical power draw in a data center.
***Cooling load assuming chilled water based cooling system. Source: Emerson Network Power, November 2007.**

In certain climates, the use of economizer systems can lower energy usage and at the same time lessen wear on some components in the cooling equipment and decrease operational costs. Supplemental cooling, which concentrates cooling right next to the rack, is particularly effective in increasing cooling system energy efficiency in today's high density server environment. Used alone or in combination, they may be excellent choices for reducing energy consumption in your data center.

The purpose of this paper is to discuss the energy savings potential of these technologies and to show you how an interactive tool developed by Emerson Network Power can help you evaluate that potential in the real-world space of your own data center.

Economizer Systems and How They Improve Energy Efficiency

Economizer systems can have a significant impact on energy usage. In many locations, economizers can be used to allow outside cool air to complement data center cooling systems and provide "free cooling" during colder months. A study on building control systems conducted by Battelle Laboratories and reported by the National Building Controls Information Program, found that on average the normalized heating and cooling Energy Use Intensity (EUI) of buildings with economizers was approximately 13 percent lower than those without economizers.[3]

When an economizer system is operating, the use of an air conditioning system's compressor(s) and related electro-mechanical components is reduced or eliminated. This reduces energy consumption.

In fact, the effectiveness of economizers at reducing energy consumption has led to their use being mandated in some building codes since early 2000. Currently, the U.S. Department of Energy's Building Energy Codes Program mandates the use of economizers in certain geographies to assure compliance with the 2006 International Energy Conservation Code.[4]

Types of Economizers and How They Work

The two basic types of economizer systems are air economizers and fluid economizers. While both have the ultimate goal of free cooling, they possess fundamental differences that impact the environments in which each is most appropriately used.

The **air economizer** serves as a control mechanism to regulate the use of outside air for cooling in a room or building. It admits into the room the appropriate volume of outside air to satisfy cooling demands. Sensors on the air economizer measure the outside and inside air conditions. If outside conditions are suitable for the use of outside air for cooling[5], the economizer introduces the outside air for complete or partial cooling of the space. During the time these conditions exist, the need for the air conditioning system's chiller(s)/compressor(s) is reduced or eliminated, which results in significant energy savings.

Air economizers are available in two types: a "dry air" system and an "evaporatively conditioned" air system. The former is the most common, but its use is restricted to a few geographic locations because of contamination issues and the high cost of energy required to add moisture to the room when the outside humidity is too low or too high. The evaporatively conditioned system is an economical method for conditioning the air before it comes into the data center, but reliability issues (mildew concerns and high maintenance requirements) have generally made this approach unattractive to most data center operators.

In certain geographical locations, economizers can satisfy a large portion of data center cooling requirements. The Emerson Network Power TCO optimization tool allows you to compare multiple economizer alternatives to see which is best for your data center. Try the tool at www.liebert.com

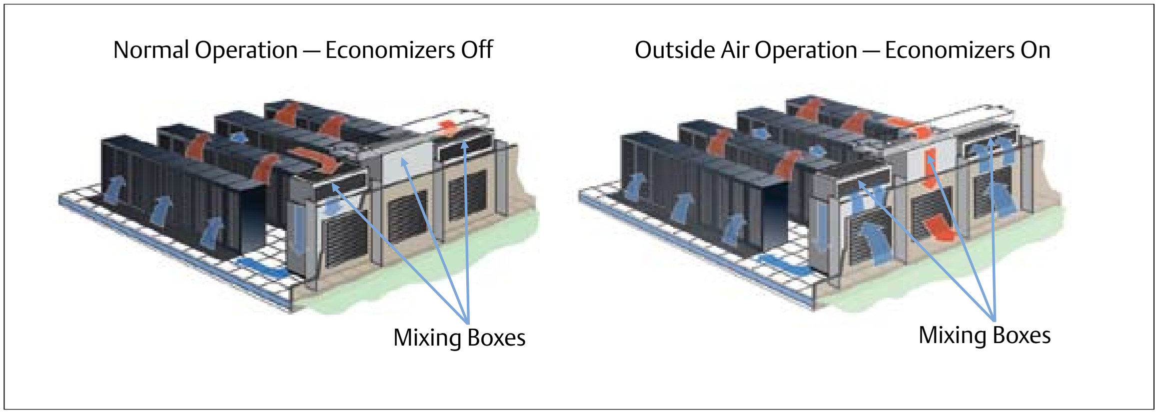

Figure 2. This data center cooling system incorporates economizers in modular mixing boxes mounted on top the computer room air handling units.

Air economizers can be incorporated into rooftop air handlers or mixing boxes mounted on each computer room air handling unit (CRAH). Economizers incorporated in CRAH mixing boxes, as shown in Figure 2, are modular, easy to deploy and less expensive than the alternative, but have greater architectural impact.

As its name would suggest, a **fluid economizer** system is typically incorporated into a chilled water or glycol-based cooling system. This type of economizer works in conjunction with a heat rejection loop consisting of a cooling tower or drycooler to satisfy cooling requirements. With the economizer operating, the fluid used in the cooling system passes through an additional heat exchanger/coil, minimizing the need for chiller/compressor operation.

During colder months, the glycol solution returning from the outdoor drycoolers or cooling tower feeding the CRAC units is routed to the second coil, which becomes the primary source of cooling for the room. As long as the "free cooling" fluid is 8 degrees Fahrenheit below the air temperature returning to the CRAC unit, there is some benefit for having the free cooling running, because it minimizes the load on the primary cooling method. Similarly in CRAH units, a secondary heat exchanger between the cooling tower fluid and the chilled water loop takes away part of the heat from the return water loop and reduces the load on the chiller.

Once the decision is made to use a fluid economizer, additional decisions about the type and configuration to use in your data center will need to be made. Fluid economizers are available in two types: direct and indirect. The direct type allows the cooling tower water to flow directly through the cooling loop. This approach is rarely used in data centers due to the desire to minimize the impact of contaminants on the copper piping. Most often water from the cooling tower will be used to indirectly produce chilled water that will then cool the data center. The indirect type of fluid economizer overcomes this by using a heat exchanger to isolate the open tower fluid loop from the other cooling loops.

Indirect fluid economizers may be organized in parallel or series configuration within the cooling system. The *parallel configuration* is most common in large building chiller plant installations and has lower initial capital costs. The cooling loop in a parallel economizer system is isolated from the chiller. This means it carries the entire cooling load when outside conditions allow free cooling. If it's too warm, the economizer is shut down entirely and the chiller takes over.

The *indirect series configuration* is always used on modular data center CRAH/CRAC units. This configuration also is used in building chiller plant installations when energy optimization is desired. A series economizer can continue operating at warmer temperatures than an economizer operating in parallel, because the series economizer is able to share the load with the chiller/compressor. Consequently, the series economizer results in free cooling a greater percentage of the year.

Choosing the Right Economizer for Data Center Applications

Theoretically, if the outside temperature is cool enough, 100 percent outside air can be used to meet cooling demand. In this case, an air economizer should be sufficient for the job. However, computer systems have stringent environmental requirements that make cooling computer rooms different from other commercial buildings.

Unlike the seasonal and intermittent heating and cooling requirements of office buildings in similar facilities, the controlled environment of a data center requires continuous, year-round cooling. This makes it an ideal candidate for economizer systems during the fall, winter and spring months in cold or temperate climates. Maintaining the consistent, acceptable temperature levels can be done with either an air or fluid economizer system, but humidity control becomes a significant challenge with the air economizer system.

A clean, filtered environment with control of humidity is mandatory in a data center. Ignoring the impact of humidity can result in serious short and long term problems, including damage to IT equipment and to the facility's infrastructure. In most cases, the optimal relative humidity (RH) range for a data center environment is 40 to 55 percent.[6]

Introducing outside air via an air economizer system in the cold winter months is fine from a temperature standpoint, but it can lower RH to unacceptable levels, causing electrostatic discharge that interferes with normal equipment operation. A humidifier must be used to compensate for this problem, but its operation offsets some of the energy savings provided by the economizer. Depending on the particular location of the data center, humidification costs could run into thousands of dollars per year to maintain the room conditions.

In contrast, fluid-side economizer systems use the cold outside air to cool the water/glycol loop in the cooling system, which in turn provides fluid cold enough for the cooling coils in the air conditioning system. This keeps the outside air out of the space and eliminates the need to humidify that air. Another advantage of not admitting

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outside air into the data center is preventing gaseous contaminants, dust and pollen from damaging sensitive electronics, as can happen when using an air economizer. Filtration systems can be added, but these do not always remove gaseous contaminants and their cost may minimize any gains from free cooling. Air economizers also are subject to higher filter replacement and maintenance requirements because of the problems associated with bringing in air from the outside.

Air economizers are effective when the conditions listed below are met:

- Full "free cooling" is attained when the outside air is 2 degrees Fahrenheit below the entering cold aisle temperature,
- Partial benefit is also attained when the outside air temperature is 2 degrees Fahrenheit lower than the air temperature returning to the CRAH, and
- Dewpoint is less than 60 and above 43 degrees Fahrenheit.

In reality, these conditions are met at a significant amount of time only along a thin band stretching inland about 25 miles from the Pacific Coast.

Fluid economizers, on the other hand, deliver greater value in a wider range of climates and are a better choice for data center cooling systems because they:

- Control humidity better,
- Prevent contaminants from entering the room, and
- Require less filter changing and maintenance.

A detailed technical discussion of air vs. fluid economizers is provided in the Liebert white paper *Utilizing Economizers Effectively in the Data Center*, available at **www.liebert.com**.

Supplemental Cooling

Supplemental cooling is "sensible only cooling" that is deployed to support the standard perimeter (under-floor) cooling units. Supplemental cooling systems bring cooling closer to the source of heat, reducing the amount of energy required for air movement. Supplemental cooling is a relatively new approach to data center cooling that was pioneered by Emerson Network Power with its Liebert XD System™. This approach overcomes the cooling capacity limitations of raised floor cooling systems in high heat density applications by using modules placed directly above or alongside high-density racks to supplement the air coming up through the floor. Being close to the source of the heat allows for immediate response to the load at the rack. Also, unlike the economizer solutions also discussed in this paper, the Liebert XD system is relatively easy to deploy at an existing operating site and can be added in a plug-and-play fashion as the data center needs change.

Overhead supplemental cooling systems utilize up to 32 percent less power than traditional floor-mounted precision air conditioners to cool 1 kW of sensible heat. One reason for this savings is the fan horsepower required to move the air is up to 65 percent less, because it has to move the air fewer than three feet against zero static pressure. The supplemental cooling modules provide 100 percent sensible cooling, which means no energy is wasted with inefficient latent heat removal. Additionally, those units using the waterless "two-phase" fluid utilize a new revolutionary micro-channel coil system that is twice as effective as a traditional tube and fin coil.

With supplemental cooling, you do not need to over chill the data center to eliminate hot spots, which is an issue with a raised floor cooling only approach. Additional energy savings is achieved because the cold aisle does not have to be cooled to 62 degrees Fahrenheit to maintain the desired 70 degrees Fahrenheit in other areas experiencing the hot bypass air.

For more information on supplemental cooling, see the white paper *Blade Servers and Beyond: Adaptive Cooling for the Next Generation of IT Systems*, available at **www.liebert.com**.

Cooling System Total Cost of Ownership Optimization Tool

We have focused thus far on two promising cooling system technologies to help achieve greater data center energy efficiency. When selecting the best cooling system for a new data center, however, energy efficiency may be only one business criterion that weighs into the decision. With this in mind, the cooling system total cost of ownership (TCO) optimization tool allows you to evaluate cooling system strategies for your data center location and design requirements based on the business criteria most important to data center management.

Cooling System Strategies

1. *Traditional*
   This strategy represents the traditional data center design, as shown in Figure 3, with standard CRAH units connected to a building chilled water (CW) system providing chilled water (supply CW) at 45 degrees Fahrenheit and return CW at 55 degrees Fahrenheit. The maximum kW per rack is limited to 5 kW.

2. *Standard Liebert XD System*
   Figure 4 illustrates this strategy, which adds a standard Liebert XD supplemental cooling system to the Traditional strategy. In the tool, the supply CW temperature is retained at 45 degrees Fahrenheit and the maximum rack heat density increased to 10 kW per rack to optimize the energy efficiency when using the Liebert XD system. While the Liebert XD system can support rack loads up to 30 kW per rack, at this time the TCO tool accepts up to 20 kW only.

The next four strategies allow the user to modify the above strategies by selecting certain options. These include the energy saving options of raising the temperature of the CW entering the data center cooling equipment to 50 or 55 degrees Fahrenheit and adding variable air flow to all the fan coil systems.

The cooling system total cost of ownership (TCO) optimization tool allows you to evaluate cooling system strategies for your data center location and design requirements based on the business criteria most important to data center management.

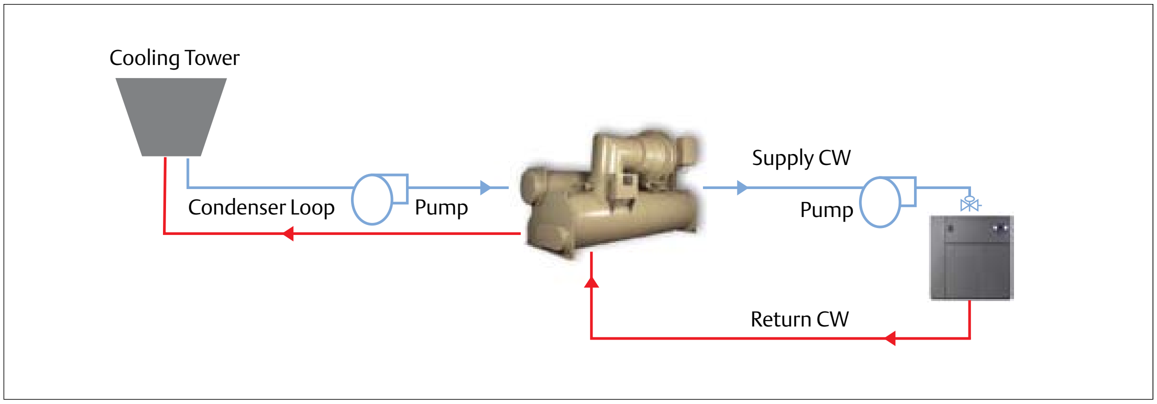


Figure 3. Traditional cooling strategy.

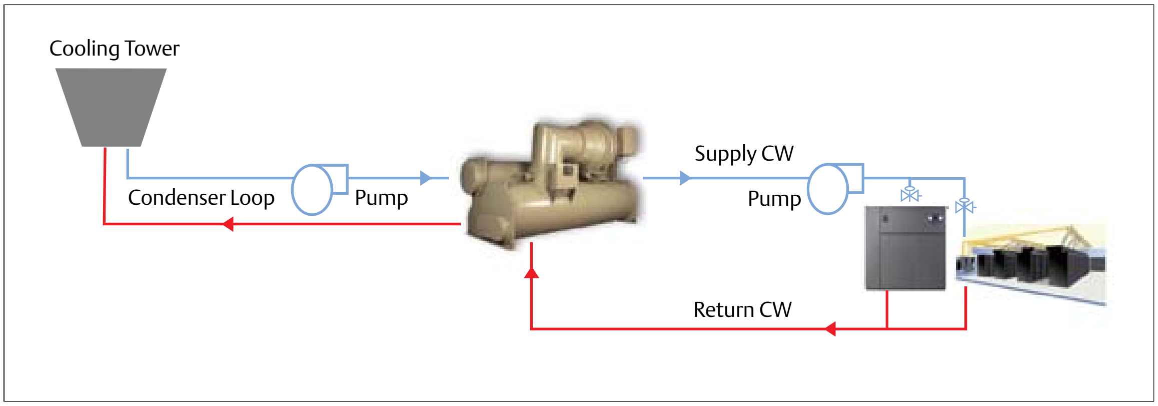


Figure 4. Standard Liebert XD system strategy.

3. *Optimized Traditional*
   For the purposes of this white paper, the traditional strategy is optimized for energy efficiency by adding a series fluid economizer to the building CW system. This is illustrated in Figure 5. (A series fluid economizer is used here and in strategy 5 below because, as discussed previously, it allows the economizer to be used more during the year than a parallel fluid economizer.) In addition, the supply CW temperature can be raised and variable air flow option added. With this approach and raised floor heights of 3 to 4 feet, you can attain a maximum of 8 kW per rack.

4. *Optimized Liebert XD System*
   This strategy optimizes the Liebert XD supplemental cooling system to include the optional variable air flow. It maintains the supply CW temperature at the standard 45 degrees Fahrenheit but allows the addition of up to 15 kW per rack. (Outwardly this strategy looks the same as strategy 2, shown in Figure 4.)

5. *Liebert XD System with Fluid Economizer*
   The Liebert XD system with fluid economizer strategy seeks maximum energy efficiency. It starts with all the options in strategy 4, adds an indirect series fluid economizer, as illustrated in

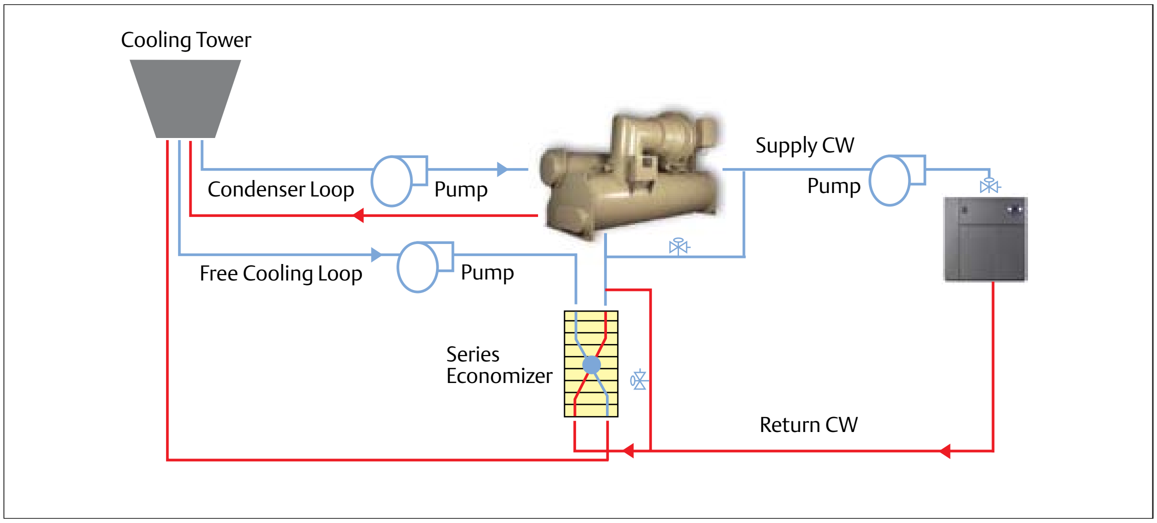


Figure 5. Optimized traditional strategy.

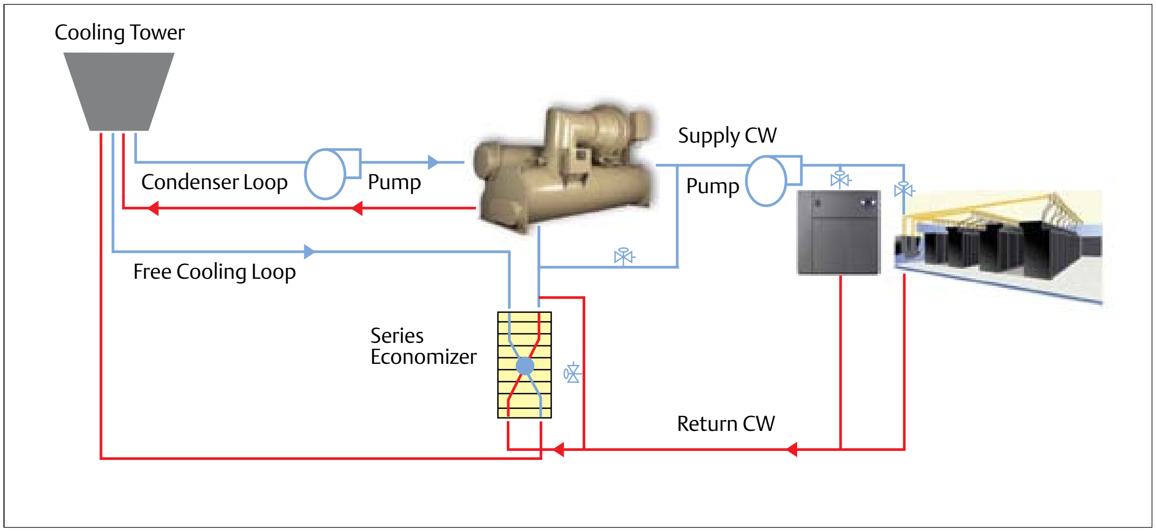


Figure 6. Liebert XD system with fluid economizer strategy.

Using the TCO optimization tool, you can compare the TCO, which includes the initial capital costs plus the net present value of future operating expenses.

Figure 6, and allows the CW temperature to be increased to maximize the operating time of the economizer. This strategy also allows up to 20 kW per rack to be supported.

6. *Air Economizer*
This strategy begins with the traditional strategy and adds an air economizer system, shown in Figure 7. It also supports up to 8 kW per rack, and includes the optional variable air flow and option to raise the supply CW temperature.

Using the TCO optimization tool, you can compare the TCO, which includes the initial capital costs plus the net present value of future operating expenses, for each of the above strategies. You will be able to compare these solutions after entering a number of variables specific to your data center, including:

- City in which the data center is located
- IT load between 2 and 5 mega watts (MW)
- Chilled water temperature (45, 50 or 55 degrees Fahrenheit)
- Maximum kW per rack up to 20 kW per rack (size of room shrinks when kW per rack is increased); future editions of this tool will allow for higher kW per rack
- Peak energy cost per kW hour
- Off peak energy cost per kW hour

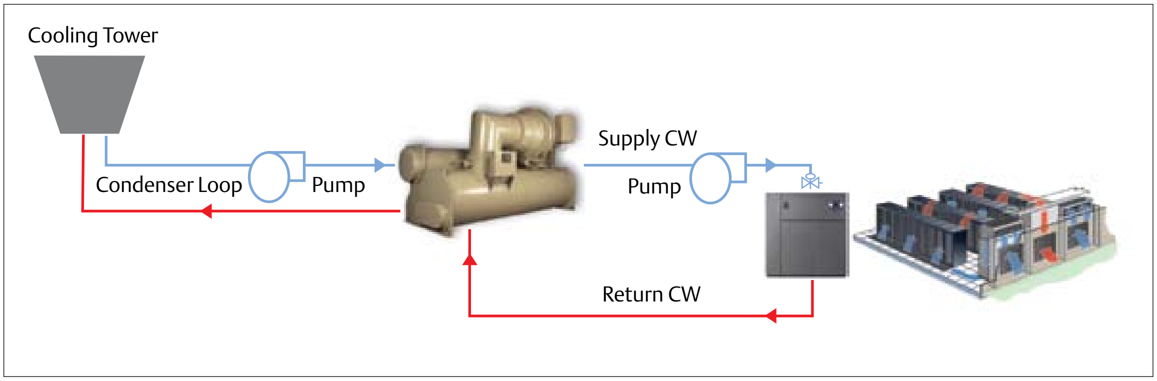


Figure 7. Air economizer strategy.

After the user selects or enters the required variables, the tool immediately will reveal the effective hours — or percentage of hours of operation of the economizer during the year — for four types of economizer.

- Added floor space above the minimum required for racks, PDUs, etc.
- Whether variable air flow is implemented on all fans
- Total cost of raised floor space per square foot
- Cost of adding a rack (rack plus cabling)
- TCO NPV number of years (5,10)
- TCO NPV discount rate

Economizer Results and Sample Reports

After the user selects or enters the required variables, the tool immediately will reveal the effective hours — or percentage of hours of operation of the economizer during the year — for four types of economizer. While common sense might dictate that an economizer would not be useful in cities such as Dallas, the tool will show that fluid economizers can be used in a wider range of climates than expected — more than current building code requirements would lead you to expect.

The table below shows the availability of economizers (in percent hours) for ten locations when the temperature of the chilled water supply is 50 degrees Fahrenheit. This table is based on U.S. Department of Energy bin data. The cities were chosen because of the concentration of data centers and wide range of climates.

In addition to determining economizer effective hours, the TCO optimization tool allows you to compare the six cooling strategies to determine the best solution for your data center depending on your particular business criteria, including:

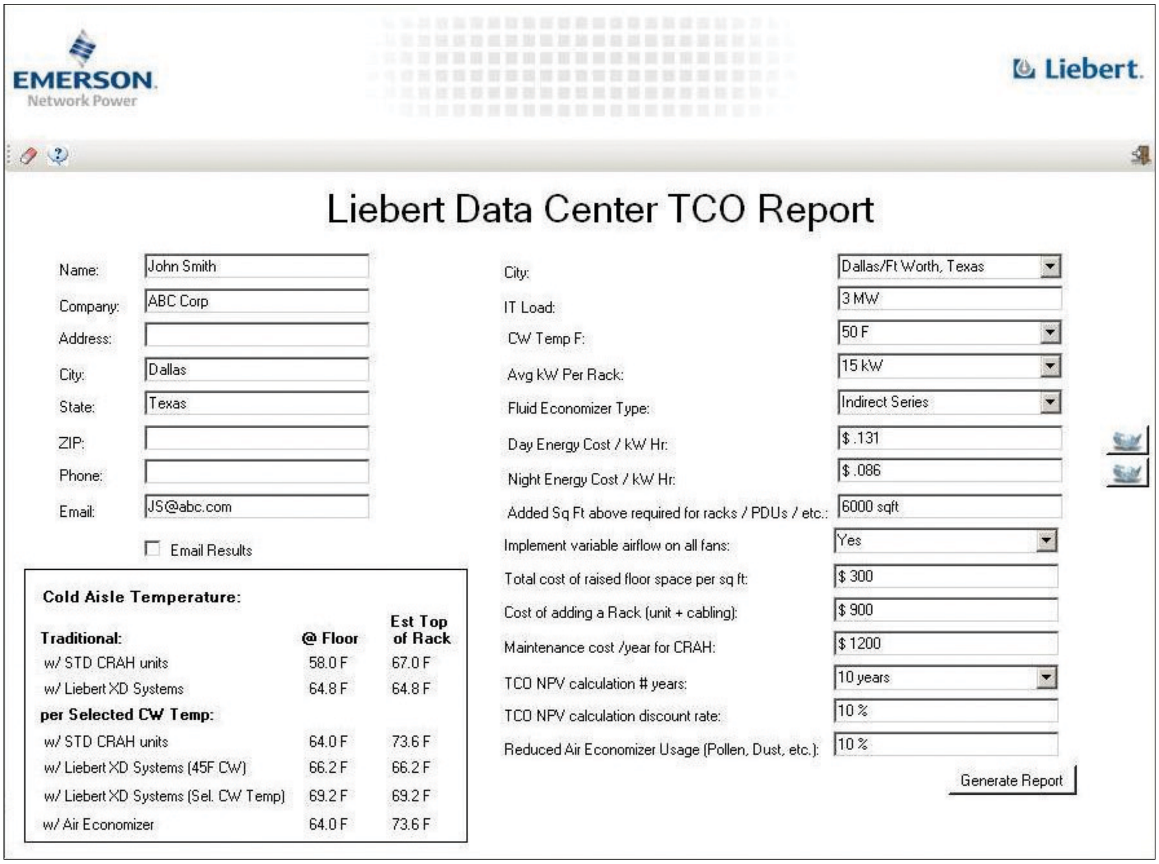
- Annual energy cost
- Energy efficiency
- Capital costs (including or excluding racks and floor space)
- Annual operating costs
- Total cost of ownership timeframe (five or 10 years)

Below we present several sample reports to demonstrate the usefulness of the TCO optimization tool in determining the best cooling strategy for your data center based on relevant business criteria.

City of Dallas

We created a hypothetical data center located in the city of Dallas. Figure 8 shows the parameters entered by the manager of our hypothetical data center. Figure 9 shows an overview of the parameters entered by the data center manager as they apply to each of the six cooling system strategies. The results show the most energy efficient is strategy 5, but it also has a higher capital

Location	Fluid Economizer (Direct Series Type)	Fluid Economizer (Indirect Series Type)	Fluid Economizer (Indirect Parallel Type)	Air Economizer
Atlanta	37%	22%	11%	26%
Boston	60%	45%	34%	29%
Chicago	58%	45%	35%	24%
Dallas	32%	18%	9%	28%
Houston	23%	11%	3%	23%
Los Angeles	59%	30%	2%	20%
Minneapolis	60%	48%	40%	26%
New York	58%	41%	28%	30%
San Francisco	46%	18%	2%	58%
Seattle	56%	34%	11%	58%



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Liebert Data Center TCO Report

Name: John Smith
Company: ABC Corp
Address:
City: Dallas
State: Texas
ZIP:
Phone:
Email: JS@abc.com
Email Results

City: Dallas/Ft Worth, Texas
IT Load: 3 MW
CW Temp F: 50 F
Avg kW Per Rack: 15 kW
Fluid Economizer Type: Indirect Series
Day Energy Cost / kW Hr: $ .131
Night Energy Cost / kW Hr: $ .086
Added Sq Ft above required for racks / PDUs / etc.: 6000 sqft
Implement variable airflow on all fans: Yes
Total cost of raised floor space per sq ft: $ 300
Cost of adding a Rack (unit + cabling): $ 900
Maintenance cost /year for CRAH: $ 1200
TCO NPV calculation # years: 10 years
TCO NPV calculation discount rate: 10 %
Reduced Air Economizer Usage (Pollen, Dust, etc.): 10 %
Generate Report

Cold Aisle Temperature:	@ Floor	Est Top of Rack
Traditional:		
w/ STD CRAH units	58.0 F	67.0 F
w/ Liebert XD Systems	64.8 F	64.8 F
per Selected CW Temp:		
w/ STD CRAH units	64.0 F	73.6 F
w/ Liebert XD Systems (45F CW)	66.2 F	66.2 F
w/ Liebert XD Systems (Sel. CW Temp)	69.2 F	69.2 F
w/ Air Economizer	64.0 F	73.6 F

Figure 8. Parameters for hypothetical Dallas data center.

Overview of Strategies Being Analyzed

ABC Data Center Dallas, Texas	**Strategy 1** Traditional	**Strategy 2** Standard Liebert XD System	**Strategy 3** Optimized Traditional	**Strategy 4** Optimized Liebert XD System	**Strategy 5** Liebert XD System with Economizer	**Strategy 6** Air Economizer Roof-top AH
Conditions						
CW EWT	45 °F	45 °F	50 °F	45 °F	50 °F	50 °F
CW delta T	10 °F	8 °F	12 °F	10 °F	10 °F	12 °F
Air return Temp	75 °F	75 °F	80 °F	75 °F	80 °F	85 °F
Air return RH%	45%	45%	30%	45%	30%	30%
System Being Compared						
Rack load (kW)	5	10	8	15	15	8
Fluid Economizer Type	No	No	Indirect Series	Indirect Series	Indirect Series	Air Economizer
Economizer Time	0%	0%	18%	0%	18%	28%
# Racks	600	300	375	200	200	375
Room sq ft	23,770	13,210	18,550	10,890	10,890	16,510
CRAC sensible rating (kW)	113	115	116	113	119	250
# Crack units (n+2) ex Liebert XD =n+1	32	2	32	2	2	15
Are variable speed fans used	No	No	Yes	Yes	Yes	Yes
Liebert XD Systems	-	25	-	24	28	-
Liebert XDV Modules	-	291	-	303	333	-
est. Cold Aisle Temp @ Floor	58.0 °F	64.8 °F	64.0 °F	66.2 °F	69.2 °F	64.0 °F
est. Cold Aisle @ Top of Rack	67.0 °F	64.8 °F	73.6 °F	66.2 °F	69.2 °F	73.6 °F
Redundancy	21%	24%	24%	24%	24%	25%

Figure 9. The data center parameters entered into the TCO optimization tool map to each of the six cooling strategies.

Figures 10 through 12 are examples of reports available using the cooling system TCO optimization tool. Again, these reports are specific to the hypothetical ABC data center located in Dallas.

Energy Costs Report

Energy Costs $000		Strategy 1 Traditional	Strategy 2 Standard Liebert XD System	Strategy 3 Optimized Traditional	Strategy 4 Optimized Liebert XD System	Strategy 5 Liebert XD System with Economizer	Strategy 6 Air Economizer Roof-top AH
Energy costs per year at .xx per kW / hr peak	$0.13						
Energy costs per year at .xx per kW / hr off peak	$0.09						
Chiller		$ 612	$ 531	$ 404	$ 502	$ 432	$ 378
Chiller pumps (kW)		$ 147	$ 122	$ 83	$ 122	$ 121	$ 76
Cooling tower (kW)		$ 47	$ 47	$ 49	$ 39	$ 46	$ 50
Chiller condenser pumps		$ 80	$ 66	$ 83	$ 66	$ 66	$ 85
Dehum equipment at xx w/ sq ft	2.8	$ -	$ -	$ 49	$ -	$ 29	$ 43
Liebert XDP		$ -	$ 25	$ -	$ 24	$ 13	$ -
Liebert XDV		$ -	$ 55	$ -	$ 58	$ 35	$ -
Rehumidification		$ 176	$ 1	$ -	$ 2	$ -	$ -
CRAC fans		$ 228	$ 14	$ 125	$ 14	$ 8	$ 121
Total Energy Costs		**$ 1,291**	**$ 860**	**$ 793**	**$ 826**	**$ 748**	**$ 753**
saved versus Traditional			**$ 430**	**$ 498**	**$ 465**	**$ 543**	**$ 538**
% change from Traditional			**33%**	**39%**	**36%**	**42%**	**42%**

Figures 10. Energy cost savings of strategies 2 – 6 compared to strategy 1.

Capital Costs Report

Capital Costs $000		Strategy 1 Traditional	Strategy 2 Standard Liebert XD System	Strategy 3 Optimized Traditional	Strategy 4 Optimized Liebert XD System	Strategy 5 Liebert XD System with Economizer	Strategy 6 Air Economizer Roof-top AH
Chiller		$ 511	$ 421	$ 450	$ 420	$ 393	$ 461
Economizer		-	-	$ 360	-	$ 315	$ 295
Chiller pumps (kW) at 2+1		$ 125	$ 103	$ 70	$ 103	$ 102	$ 64
Cooling tower (kW)		$ 114	$ 94	$ 98	$ 93	$ 93	$ 101
Chiller condenser pumps		$ 68	$ 55	$ 70	$ 55	$ 55	$ 72
CRAC units		$ 360	$ 23	$ 432	$ 27	$ 27	$ 523
Liebert XDP		$ -	$ 525	$ -	$ 569	$ 664	$ -
Liebert XDV		$ -	$ 322	$ -	$ 336	$ 394	$ -
HVAC Installation		$ 1,177	$ 1,246	$ 1,480	$ 1,286	$ 1,673	$ 1,515
Switchgear/UPS/Emerson Gen w/Install		$ 1,992	$ 1,793	$ 1,841	$ 1,777	$ 1,791	$ 1,884
Cost of raised floor at $xxx/sq ft	300	7,131	3,963	5,565	3,267	3,267	4,953
Cost of racks at $xxx/rack	900	540	270	337.5	180	180	377.5
Total Capital $		$12,016	$ 8,814	$10,704	$ 8,113	$ 8,953	$10,205
TCO		$17,365					
TCO savings from Traditional			29%	18%	34%	30%	22%
TCO period 5 years							
TCO discount rate 10%							

Figure 11. Capital costs savings of strategies 2 – 6 compared to strategy 1.

TCO Report

	Solution		Capital Cost $(000)	Capital Cost incl Floor Space $(000,000)	Utility Rebate basis kW Saved versus Traditional	Energy $(000)/yr	Total Operating Costs $(000)/yr	TCO savings versus Traditional incl Floor Space
Strategy 1	Traditional	5kW/rack	$4,345	$12,016	$1,357	$1,291	$1,411	$17,365
Strategy 2	Standard Liebert XD System	10kW/rack	5%	-27%	-33%	-33%	-34%	29%
Strategy 3	Optimized Traditional	8kW/rack	10%	-11%	-25%	-39%	-35%	18%
Strategy 4	Optimized Liebert XD System	15kW/rack	7%	-32%	-36%	-36%	-37%	34%
Strategy 5	Liebert XD System with Economizer	15kW/rack	27%	-25%	-34%	-42%	-41%	30%
Strategy 6	Air Economizer with rooftop AH	8kW/rack	13%	-15%	-18%	-42%	-39%	22%

Best Good Bad

Figure 12. TCO results for strategies 2 – 6 compared to strategy 1.

cost (including the raised floor space) versus strategy 4. This results in a TCO for strategy 4 being better than strategy 5. Strategies 1, 4 and 5 all are good solutions for this site, providing over 30 percent reduction in total cost of ownership.

10 Cities Comparison

Going back to the 10 U.S. cities covered in the economizer availability comparison chart, we ran a TCO analysis for each city (based on a five year timeframe and 10 percent NPV discount rate), summarized in the table on the following page.

These results show:

- In all the ten cities, using any of the energy saving options provides a reduction in total cost of ownership from a minimum of 17 percent to a maximum of 34 percent.
- The standard Liebert XD strategy provides a TCO reduction of 29 percent to 30 percent.
- The use of the optimized Liebert XD system strategy provides a 34 percent TCO reduction and is recommended for all ten cities. In addition, for cities such as Boston, Los Angeles, Minneapolis and New York, where energy rates are high, adding a fluid economizer further reduces TCO.
- The use of an indirect series fluid economizer and traditional CRAH units (strategy 3) provides a reduction of 17 percent (Atlanta) to 26 percent (New York).
- Air economizers provide a TCO reduction of 21 percent (Atlanta and Houston) to 31 percent (San Francisco).

The use of the optimized Liebert XD system strategy provides a 34 percent TCO reduction and is recommended for all ten cities. In addition, for cities such as Boston, Los Angeles, Minneapolis and New York, where energy rates are high, adding a fluid economizer further reduces TCO.

As organizations seek to improve data center efficiency, data center managers can take advantage of several cooling system strategies to combat data center energy consumption while meeting varying business criteria.

Location		Strategy 1 Traditional	Strategy 2 Standard Liebert XD System	Strategy 3 Optimized Traditional	Strategy 4 Optimized Liebert XD System	Strategy 5 Liebert XD System with Economizer	Strategy 6 Air Economizer Roof-top AH
Atlanta	TCO	$16,420	$11,704	$13,469	$10,902	$11,456	$12,941
	Reduction%		29%	18%	**34%**	30%	21%
Boston	TCO	$19,940	$14,019	$14,473	$13,142	$12,633	$14,885
	Reduction%		30%	27%	34%	**37%**	26%
Chicago	TCO	$16,611	$11,818	$13,013	$11,018	$11,143	$13,010
	Reduction%		29%	22%	**34%**	33%	22%
Dallas	TCO	$17,365	$12,339	$14,170	$11,508	$12,090	$13,482
	Reduction%		29%	18%	**34%**	30%	22%
Houston	TCO	$17,350	$12,345	$14,464	$11,502	$12,283	$13,683
	Reduction%		29%	17%	**34%**	29%	21%
Los Angeles	TCO	$19,528	$13,742	$14,705	$12,877	$12,803	$14,833
	Reduction%		30%	25%	**34%**	34%	24%
Minneapolis	TCO	$16,585	$11,799	$12,943	$11,001	$11,078	$12,932
	Reduction%		29%	22%	**34%**	33%	22%
New York	TCO	$20,636	$14,481	$14,902	$13,586	$13,083	$15,011
	Reduction%		30%	28%	34%	**37%**	27%
San Francisco	TCO	$19,523	$13,741	$15,243	$12,875	$13,169	$13,515
	Reduction%		30%	22%	**34%**	33%	31%
Seattle	TCO	$15,688	$11,199	$12,663	$10,426	$10,791	$11,883
	Reduction%		29%	19%	**34%**	31%	24%
Average of	TCO	$17,965	$12,719	$14,004	$11,884	$12,053	$13,597
10 Cities	Reduction%		29%	22%	**34%**	33%	24%

Conclusion

As organizations seek to improve data center efficiency, data center managers can take advantage of several cooling system strategies to combat data center energy consumption while meeting varying business criteria.
The use of economizers and supplemental cooling systems are two technologies that merit serious consideration. Fluid economizers bring free cooling or partial free cooling benefits to a wider range of geographic areas than commonly believed. Supplemental cooling, with or without a fluid economizer, provides substantial savings, depending on your business criteria. Beyond these technologies, additional energy savings can be gained by taking measures such as increasing supply chilled water temperature, using variable air flow and increasing the kW per rack in the servers.

Footnotes

1. Energy Information Administration, http://www.eia.doe.gov/emeu/international/elecprii.html, 2007.

2. A U.S. Environmental Protection Agency survey released in 2007 concluded that IT data centers consumed 61 billion kW of electricity at a total cost of $4.5 billion in 2006.

3. Battelle Pacific Northwest National Laboratory, 2003. *Characterization of Building Controls and Energy Efficiency Options Using Commercial Building Energy Consumption Survey*.

4. U.S. Department of Energy Building Energy Codes Program. *Commercial Mechanical Requirements of the 2006 International Energy Conservation Code*.

5. Outside conditions are suitable for outside air to be used for cooling when outside air enthalpy is less than the inside CRAH/CRAC return air enthalpy. Also, the outside air dewpoint must be above allowable limits.

6. ASHRAE thermal guidelines for data processing environments.

References

Emerson Network Power white paper, *Utilizing Economizers Effectively in the Data Center*, www.liebert.com, 2003.

Emerson Network Power white paper, *Blade Servers and Beyond: Adaptive Cooling for the Next Generation of IT Systems*, www.liebert.com, 2006.

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WP157-117
SL-24622