

## High-Density Cooling: From Discussion to Deployment

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For the past several years, IT equipment manufacturers and related service providers have been stressing the need for High-Density Cooling (HDC) solutions. Today, it can be said with a very high degree of certainty that the IT community is well aware of the critical issues of meeting the power and cooling requirements of the data center – in some cases, not having enough of one or the other or even both. And the discussions are continuing – from equipment vendors, to design engineers and consultants, facility personnel, various industry groups and even the government. All interested parties have their unique ideas and solutions, roadmaps and planning tools and new products that will address these needs. In the middle are the end users, trying to make sense of it all, keeping up with the latest advances and information and making sure they get the most cost-effective solution without penalizing performance.

And finally, this perseverance has paid off. ALL concerned parties recognize the needs for these solutions and realize the power and cooling issues will not go away and have the potential for becoming worse. The conversations have gone from “I may need this sometime in the future, call me then” to “OK, I need it NOW. What do I need to do?” And once implemented – “What benefits will I see to the bottom line? What’s my TCO and ROI?” With the current and future state of the data center in mind, this article will continue these conversations and review where we are, where we need to be and how, as an industry, we will get there.

### Technology Review

To begin, a brief review of current high density cooling systems is in order. Generally, there are three primary HDC solutions:

- Active air systems using directed airflow with or without supplemental fans to circulate air through enclosures and exhaust the warm air to the room or ceiling spaces. These systems will still require CRAC or CRAH units in place.
- Fluid-based systems using chilled water or refrigerant with a heat exchanger to transfer heat and remove it completely from the space through existing facility infrastructure. Depending on deployment, these systems may not require in room air conditioning.
- Chip cooling solutions mounting heat exchangers directly to processors, removing the heat through a secondary transfer system. See Chart 1 for relative cooling ranges.

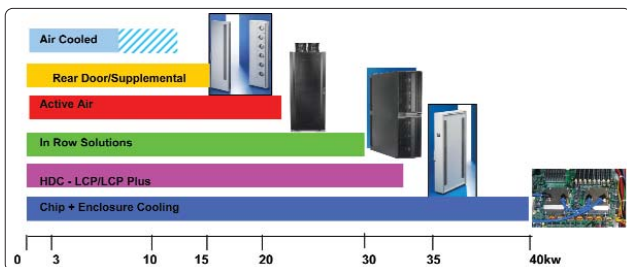


Chart 1: Cooling Ranges

Active air systems will still require a cold air supply in the IT space, traditionally provided by CRAC/CRAH units. Cold air, whether from cold aisles or under floor spaces, is directed to server air intakes and removed from enclosures via rear door or roof-mount fans. Added separation of hot and cold airflow paths may be provided with ducts to direct heated air up and away from the enclosure, usually to suspended ceiling spaces for return to CRAC intakes. With hot aisle containment systems, further separation of airflow paths can be achieved, preventing possible short cycling of heated exhaust air back to component intakes. These installations assume sufficient overhead clearance for return ducts and suspended ceilings as well as uniform enclosure heights and depths to install containment components.

Fluid-based systems are available in two basic configurations:

- Closed Loop/Close Coupled with circulating air remaining inside the equipment enclosure and transferred to a heat removal medium – chilled water or refrigerant.
- Open Loop/Close Coupled with heated air removed from the rear of equipment enclosures, passed over heat exchangers but returned to room spaces instead of directly to server air intakes. These systems are typically deployed as supplemental cooling systems, designed to reduce hot spots and to place cooling units closer to heat loads, yet still have them work with installed CRAC systems.

Closed loop systems are available in two basic designs: a sidecar unit with the heat exchangers separate from the equipment enclosure, or with the heat exchanger in the bottom of the same enclosure with the active hardware. In either layout, fans circulate air through active components and over the heat exchangers, either in the sidecar or rear door of the enclosure. The heat is transferred to the fluid and on to building refrigeration systems for ultimate dissipation to the atmosphere.

Open loop/supplemental systems are also available in four configurations – rear door mount, roof mount, ceiling mount and sidecar. Still using fans and heat exchangers, these systems return cooled back to the space where it may (or may not) return to the hotter enclosures. As with the closed loop systems, ultimately the heat is transferred to building systems via chilled water or refrigerant.

Is one design better than another? That is best determined by an individual installation or end user’s unique criteria. Each system has specific benefits, as well as potential disadvantages. An organization considering an HDC installation should weigh the pros and cons of each system, considering such variables as existing infrastructure, floor space availability, components to be installed, installation densities and plans for future technology deployments. The key recommendation here is for an end user to ensure communication through all project phases with parties involved in the design and installation of a high-density system. Those parties should include design and engineering firms, IT personnel, facilities personnel, installation contractors and component vendors. The stated goal is to make sure there are no unpleasant surprises along the way.

### Rittal LCP High Density Cooling System

The following is a brief review of the Rittal Liquid Cooling Package (LCP) high density cooling solution (See Figure 1): The LCP system is a sidecar based system using facility chilled water for heat transfer and removal. The sidecar design separates the cooling components from all active components in the attached equipment enclosure. Cold air is circulated in front of components across the full height of the system. Heated air is pulled in from the rear of the components with six fans where it is passed over the air to water heat exchanger for return to the front of the unit and a continuation of the cycle. Depending on chilled water supply temperature, 30 kW (or more) of heat can be

removed from a single enclosure. Higher loads may be achieved with colder chilled water and a higher Delta T across active components. For extreme loads, greater than 40 kW, two sidecars could be bayed to a single unit, one on each side to provide double the cooling capacity.

Additional benefits can be realized with floor space savings; higher heat loads can be achieved with higher component installation densities, reducing the total number of enclosures required to support a given number of devices. Greater redundancy can also be achieved, not only an N+1 configuration but even 2N, all while using less power and floor space than conventional cooling methods.

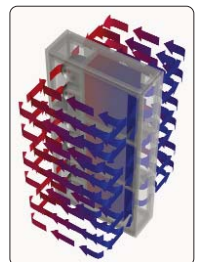


Figure 1: LCP System

### Analysis and Discussion

So, we finally come to the benefits of installing a high-density cooling system. While the results summarized below are for the Rittal LCP system, it is safe to say these benefits will be realized to some extent from other liquid-based high-density cooling systems.

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## A. Design Comparison

In the analysis, a design basis for comparison was established with initial costs for construction and equipment selection being concluded. A real estate comparison based on several market values and different cities was made and finally a total mechanical cooling system operating expense was presented on an average basis. Table 1 below shows the design parameters established for the comparison.

### DESIGN COMPARISON

		SCHEME 1A		SCHEME 1B		SCHEME 2A		SCHEME 2B	
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
<b>Data Center Power Load</b>	Total Power (KW)	470							
<b>Physical Data</b>	Length (Ft)	46	36	125	70				
	Width (Ft)	46	38	80	78				
	Area (Sqft)	2,116	1,368	10,000	5,460				
	Average Area Loading (W / Sqft)	222	344	216	396				
<b>Computer Density</b>	Number of Racks	56	30	405	144				
	Average Rack Loading (KW / Rack)	8.29	15.67	5.33	15.00				
<b>Computer Cooling Requirements</b>	Equipment Capacity (KW)	118	15	118	15				
	Minimum Cooling Unit (Qty)	3.97	31.33	18.25	144.00				
	Total Required Cooling Unit (Qty)	4	32	19	144				
	Redundancy	N+1	N+1	N+1	N+1				
	Redundant Unit (Qty)	1	4	1	18				
	Total Cooling Unit (Qty)	5	36	20	162				

**Table 1: Design comparison between the LCP and conventional cooling method**

The total area of the data center for a given number of IT components is calculated based on an equal total IT power consumption. Table 1 shows that LCP provides the benefits of a smaller footprint when compared to legacy cooled data centers. Data centers using LCP can achieve 35 to 45 percent savings in required real estate, depending on the facility size. This translates to a higher heat flux (higher density) per rack and per square foot. Considering an N+1 system, the total numbers of CRAH units and LCP racks were calculated for both sizes of data centers as presented above.

## B. Initial Costs

The principal costs associated with LCP as compared to a conventional raised floor cooling system are shown in Table 2.

### INITIAL COST ANALYSIS

Criteria		SCHEME 1A		SCHEME 1B		SCHEME 2A		SCHEME 2B		
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	
<b>Construction Cost</b>	Construction	\$317,400.00	\$205,200.00	\$1,500,000.00	\$819,000.00					
	Raised Floor Construction	\$31,740.00	\$16,416.00	\$150,000.00	\$85,620.00					
	Drop ceiling cost (plenum)	\$11,638.00	-	\$55,000.00	-					
	Drop ceiling return grills	\$250.00	-	\$1,250.00	-					
	Perforated tile cost	\$3,200.00	-	\$12,000.00	-					
	Mechanical Construction	\$89,081.00	\$173,832.00	\$370,000.00	\$810,285.00					
	Electrical wiring	7,100	19,900	16,500	84,000					
	<b>Total Construction Cost</b>	469,419	415,140	2,046,750	1,579,105					
	<b>Cooling Equipment cost</b>	CRAH	100,000	-	400,000	-				
		CRAH Installation	50,000	-	200,000	-				
LCP Cabinet cost		-	360,000	-	1,728,000					
LCP cabinet installation		-	15,000	-	72,000					
CDU		-	not required	-	not required					
CDU installation		-	not required	-	not required					
cabinet/rack cost		61,600	-	445,300	-					
cabinet/rack installation		28,000	-	202,500	-					
<b>Total Cooling Equipment Cost</b>		239,600.00	375,000.00	1,245,000.00	1,800,000.00					
<b>Total Initial Cost</b>		709,019.00	790,140.00	3,294,750.00	3,379,105.00					

**Table 2: Initial cost analysis**

In Table 2 several assumptions were made regarding construction costs, facility construction and layout and supporting hardware and infrastructure (CRAC units, piping, wiring, etc). Without going in to too much detail, these are in line with current industry practices and products.

## C. Real Estate Analysis

Table 3 compares real estate costs associated with leasing a space in office or industrial park areas in four different cities based on the required footprint as depicted in Table 1. For a small data center that could be housed in an office space, savings on the order of 30 percent should be expected. For a larger data center, where industrial park locations could be considered, an expected savings around 40 percent can be achieved in the same city.

### REAL ESTATE ANALYSIS

	Averaged Office Lease Rate	SCHEME 1A		SCHEME 1B		
		US \$ / sqft / Year	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
<b>Physical Data</b>	Length (Ft)		46	36		
	Width (Ft)		46	38		
	Area (Sqft)		2,116	1,368		
<b>Annual Real Estate Cost</b>	Chicago, US (Note 1)	\$28.6	\$60,412	\$39,056		
	Boston, US (Note 1)	\$43.2	\$91,327	\$59,043		
	Frankford, Germany (Note 2)	\$50.5	\$106,767	\$69,025		
	Hong Kong, China (Note 1)	\$55.2	\$116,712	\$75,455		
<b>Annual Real Estate Saving</b>	Chicago, US		\$21,355			
	Boston, US		\$32,284			
	Frankford, Germany		\$37,742			
	Hong Kong, China		\$41,257			

	Averaged Industrial Park / Warehouse Lease Rate	SCHEME 1A		SCHEME 1B		
		US \$ / sqft / Year	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
<b>Physical Data</b>	Length (Ft)		125	70		
	Width (Ft)		80	78		
	Area (Sqft)		10,000	5,460		
<b>Annual Real Estate Cost</b>	Chicago, US (Note 1)	\$4.4	\$285,500	\$155,883		
	Boston, US (Note 1)	\$6.9	\$431,600	\$235,654		
	Frankford, Germany (Note 2)	\$9.3	\$504,571	\$275,496		
	Hong Kong, China (Note 1)	\$13.7	\$551,568	\$301,156		
<b>Annual Real Estate Saving</b>	Chicago, US		\$129,617			
	Boston, US		\$195,946			
	Frankford, Germany		\$229,075			
	Hong Kong, China		\$250,412			

1. Averaged lease rate is based on CB Richard Ellis, Market View, First Quarter 2007.
2. Averaged lease rate is based on CB Richard Ellis, Market View, Third Quarter 2006.

**Table 3: Real estate analysis**

## D. Energy Analysis

The first portion of Table 4 shows the total fan power consumption associated with the conventionally CRAH cooled data centers compared to total fan power used in LCP cooled data centers. Fans are assumed at full load and at rated power consumption for both systems. There is also an associated saving in envelope and light load, leading to a total annual cost reduction of about 30 to 45 percent in related cost. In this calculation, it was assumed that lights are not activated by a motion sensor. In all energy calculations, \$0.10 kWh was the assumed cost from the utility company.

Please see Rittal continued on page 37

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## ENERGY ANALYSIS - UNIT, ENVELOPE & LIGHTS

		SCHEME 1A		SCHEME 1B		SCHEME 2A		SCHEME 2B	
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
Unit Fan Power Consumption	Unit Fan Power Consumption (kW)	11	1.2	11	1.2				
	Total Cooling Unit (Qty)	5	36	20	162				
	Total Fan Power Consumption (kW)	56	43	224	194				
Fan Energy Use	Per year (kWh/year)	489,924.90	378,432.00	1,959,699.60	1,702,944.00				
Fan Energy Cost	Per year (\$/year)	\$48,992.49	\$37,843.20	\$195,969.96	\$170,294.40				
Fan Energy Saving	Per year (\$/year)	\$11,149.29		\$25,675.56					
Lighting Power Consumption	1.8 kW/sqft (kW)	3830.0	2476.1	18100.0	9882.6				
Lighting Energy Use	Per year (kWh/year)	33550.4	21680.5	156800.0	85071.6				
Lighting Energy Cost	Per year (\$/year)	\$3,355.04	\$2,168.05	\$15,680.00	\$8,507.16				
Lighting Energy Saving	Per year (\$/year)	\$1,186.99		\$7,172.84					

## ENERGY ANALYSIS - CENTRAL PLANT

		SCHEME 1A		SCHEME 1B		SCHEME 2A		SCHEME 2B	
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
Data Center Power Load	Tower Power (kW)	470		2,150					
Unit Flow Rate	Flow Rate (GPM)	79.0	11.0	79.0	9.8				
	Total Cooling Unit (Qty)	5	36	20	162				
	Total Chilled Water Plant Flow Rate (GPM)	395.0	395.0	1,500.0	1,500.0				
Chilled Water	Entering Chilled Water Temperature (Deg F)	48.0	56.3	48.0	55.4				
	Entering Chilled Water Temperature (Deg C)	282.0	286.7	282.0	286.1				
	Differential Chilled Water Temperature (Deg F)	4.6	4.1	4.1	4.1				
Center Plant Power	Excellent (kW)	141.0	121.3	648.0	568.3				
	Average (kW)	258.5	222.4	1,188.0	1,041.9				
	Poor (kW)	611.0	525.0	2,000.0	2,462.6				
Center Plant Energy Use	Excellent (kWh/year)	1,235,160.0	1,062,855.2	5,676,480.0	4,978,273.0				
	Average (kWh/year)	2,264,460.0	1,946,567.8	10,406,880.0	9,176,833.8				
	Poor (kWh/year)	5,352,360.0	4,605,705.8	21,598,080.0	21,572,516.2				
Center Plant Energy Cost	Excellent (\$/year)	\$123,516.00	\$106,285.52	\$567,648.00	\$497,827.30				
	Average (\$/year)	\$226,446.00	\$194,656.78	\$1,040,688.00	\$912,683.38				
	Poor (\$/year)	\$535,236.00	\$460,570.58	\$2,159,808.00	\$2,157,251.62				
Center Plant Energy Saving	Excellent (\$/year)	\$17,348.48		\$45,876.70					
	Average (\$/year)	\$31,589.22		\$128,884.62					
	Poor (\$/year)	\$74,665.82		\$282,556.38					

Table 4: Energy Analysis

In calculating central plant power consumption, which includes all the components in the mechanical cooling system, the analysis considered an ecosystem approach looking at the overall power consumption of a given data center. This approach is termed a burden factor or power usage factor (PUE) and resultant global warming impact. Briefly, PUE is a metric that categorizes data centers based on total IT power consumption, mechanical power consumption, electrical power support from utility mains down to the PDUs, RPPs and also related power consuming systems.

When considering the overall savings for a given data center size, the chilled water savings and fan power savings, as well as envelope and lighting savings, need to be added. For an average efficiency data center, one would quickly calculate an annual savings of \$45,000 and \$160,000 for the small and large data centers considered in this study, respectively.

It should be pointed out that increased chilled water temperature has a positive impact on the water side economizer if the central chilled water plant is equipped with such technology. For a traditional water side economizer system, the number of economizer hours depends on the number of hours that the outside wet bulb temperature is less than chilled water setpoint. The exact impact depends on the climatic zone of the city of interest. With such systems in place, the energy savings mentioned above can be enhanced even further. A further step could be taken with the potential to simply turn off the chillers. In locations with suitable wet bulb temperatures, sufficient heat removal capacity could be achieved with ambient air. Chart 2 shows potential "Free Cooling" days based on these wet bulb temperatures and various air and water temperature setpoints.

There is one further point to consider regarding energy savings and the cost benefits. By deploying energy-efficient systems that demonstrate measurable savings, end users may be eligible for rebates from their electrical supplier. Many utilities have formal programs in place to measure energy savings from a variety of components installed in the data center and supporting facility. The greater the savings, the greater the potential rebates. Rittal Corporation encourages end users to contact their local utility to determine what programs are available, what products or technologies qualify for possible rebates and how to apply for these programs.

### Conclusion

Deploying a high-density cooling solution should be considered if:

A. Space limitations would limit the quantity of enclosures that could be deployed to support existing and planned hardware installations.

B. Existing facilities cannot add more in room cooling capacity but do have sufficient chiller plant capacity to support additional hardware.

C. There is or will be an installation of high-performance computing products such as blade server systems or high-density rack-mount products.

D. A review of the factors described above show the potential savings to be realized from a high-density cooling installation.

Deployment of a high-density cooling system can have a significant impact on an end user's ability to grow and meet greater demands for IT applications. These impacts may not only be limited to the actual

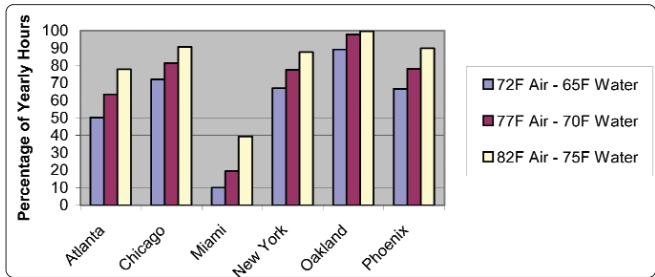


Chart 2: Water Side Free Cooling Potential

data center, but could have broader effects on an overall site, including chiller plants, power distribution, construction costs, etc. An additional benefit may be realized through improved hardware performance, reduced MTBF and shortened MTR of IT components. "Green" considerations can also be affected, again leading to costs savings and rebates, as well as compliance with current and proposed energy usage guidelines.

Rittal recognizes that not every site and every end user will need or benefit from deploying a high-density cooling system. Additionally, the results shown here are of a general nature, and individual results and performance parameters must be evaluated and may vary. However, for current, and, more importantly, future installations and deployment of next-generation technologies, a high-density cooling system will offer a viable solution to meet the ever increasing cooling demands of the IT world.

The focus must shift from "How?" to "Why?" The end user community should no longer consider whether these systems are feasible or practical but to what benefits can be gained. As more systems are brought on line, Rittal and other vendors will gain even more practical experience and data on costs savings. The goal is to identify the "Sweet Spot" – the point where it makes sense to install a high-density cooling system after looking at all the variables.

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