# Choosing Between Room, Row, and Rack-based Cooling for Data Centers

## White Paper 130

Revision 2

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## > Executive summary

Latest generation high density and variable density IT equipment create conditions that traditional data center cooling was never intended to address, resulting in cooling systems that are oversized, inefficient, and unpredictable. Room, row, and rack-based cooling methods have been developed to address these problems. This paper describes these improved cooling methods and provides guidance on when to use each type for most next generation data centers.


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## Introduction

Nearly all of the electrical power delivered to the IT loads in a data center ends up as waste heat that must be removed to prevent over temperature conditions. Virtually all IT equipment is air-cooled, that is, each piece of IT equipment takes in ambient air and ejects waste heat into its exhaust air. Since a data center may contain thousands of IT devices, the result is that there is thousands of hot airflow paths within the data center that together represent the total waste heat output of the data center; waste heat that must be removed. The purpose of the air conditioning system for the data center is to efficiently capture this complex flow of waste heat and eject it from the room.

Link to resource
White Paper 55
*The Different Types of Air Distribution for IT Environments*

The historical method for data center cooling is to use perimeter cooling units that distribute cold air under a raised floor with no form of containment. This is known as targeted supply and flooded return air distribution as discussed in White Paper 55, *The Different Types of Air Distribution for IT Environments*. In this approach, one or more air conditioning systems, working in parallel, push cool air into the data center while drawing out warmer ambient air. The basic principle of this approach is that the air conditioners not only provide raw cooling capacity, but they also serve as a large mixer, constantly stirring and mixing the air in the room to bring it to a homogeneous average temperature, preventing hot-spots from occurring. This approach is effective only as long as the power needed to mix the air is a small fraction of the total data center power consumption. Simulation data and experience show that this system is effective when the average power density in data is on the order of 1-2 kW per rack, translating to 323-753 W/m² (30-70 W/ft²). Various measures can be taken to increase power density of this traditional cooling approach, but there are still practical limits. More information on the limitation of using traditional cooling can be found in White Paper 46 "*Cooling Strategies for Ultra-High Density Racks and Blade Servers*". With power densities of modern IT equipment pushing peak power density to 20 kW per rack or more, simulation data and experience show traditional cooling (no containment), dependent on air mixing, no longer functions effectively.

Link to resource
White Paper 46
*Cooling Strategies for Ultra-High Density Racks and Blade Servers*

To address this problem, design approaches exist that focus on room, row, and rack-based cooling. In these approaches the air conditioning systems are specifically integrated with the room, rows of racks, or individual rack in order to minimize air mixing. This provides much better predictability, higher density, higher efficiency, and a number of other benefits. In this paper, the various approaches are explained and contrasted. It will be shown that each of the three approaches has an appropriate application, and in general a trend toward row-based cooling for smaller data centers and high density zones and toward room-based cooling with containment for larger data centers should be expected.

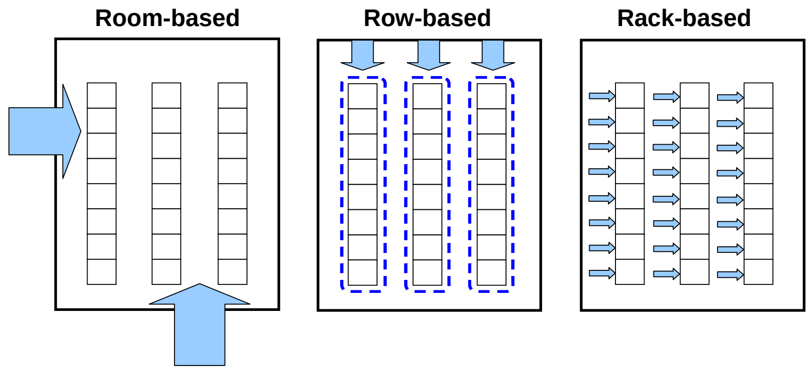
## Room, row, and rack-based cooling

Every data center air conditioning system has two key functions: to provide the bulk cooling capacity, and to distribute the air to the IT loads. The first function of providing bulk cooling capacity is the same for room, row, and rack-based cooling, namely, that the bulk cooling capacity of the air conditioning system in kilowatts must exhaust the total power load (kW) of the IT equipment. The various technologies to provide this function are the same whether the cooling system is designed at the room, row, or rack level. The major difference between room, row, and rack-based cooling lies in how they perform the second critical function, distribution of air to the loads. Unlike power distribution, where flow is constrained to wires and clearly visible as part of the design, airflow is only crudely constrained by the room design and the actual air flow is not visible in implementation and varies considerably between different installations. Controlling the airflow is the main objective of the different cooling system design approaches.

The 3 basic configurations are shown in the generic floor plans depicted in **Figure 1**. In the figure, black square boxes represent racks arranged in rows, and the blue arrows represent the logical association of the computer room air handler (CRAH) units to the loads in the IT racks. The actual physical layout of the CRAH units may vary. With room-based cooling, the CRAH units are associated with the room; with the row-based cooling the CRAH units are associated with rows or groups, and with rack-based cooling CRAH units are associated with the individual racks.

**Figure 1**

*Floor plans showing the basic concept of room, row, and rack-based cooling. Blue arrows indicate the relation of the primary cooling supply paths to the room.*




A summary of the basic operating principles of each method are provided in the following sections:

## Room-based cooling

Link to resource
White Paper 55
*The Different Types of Air Distribution for IT Environments*

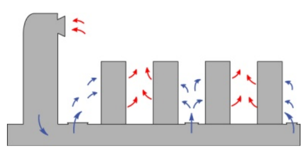
With room-based cooling, the CRAH units are associated with the room and operate concurrently to address the total heat load of the room. Room-based cooling may consist of one or more air conditioners supplying cool air completely unrestricted by ducts, dampers, vents, etc. or the supply and/or return may be partially constrained by a raised floor system or overhead return plenum. For more information see White Paper 55, *The Different Types of Air Distribution for IT Environments*.

During design, the attention paid to the airflow typically varies greatly. For smaller rooms, racks are sometimes placed in an unplanned arrangement, with no specific planned constraints to the airflow. For larger more sophisticated installations, raised floors may be used to distribute air into well-planned hot-aisle / cold aisle layouts for the express purpose of directing and aligning the airflow with the IT cabinets.

The room-based design is heavily affected by the unique constraints of the room, including the ceiling height, the room shape, obstructions above and under the floor, rack layout, CRAH location, the distribution of power among the IT loads, etc. **When the supply and return paths are uncontained, the result is that performance prediction and performance uniformity are poor, particularly as power density is increased.** Therefore, with traditional designs, complex computer simulations called computational fluid dynamics (CFD) may be required to help understand the design performance of specific installations. Furthermore, alterations such as IT equipment moves, adds, and changes may invalidate the performance model and require further analysis and/or testing. In particular, the assurance of CRAH redundancy becomes a very complicated analysis that is difficult to validate. An example of a traditional room-based cooling configuration is shown in **Figure 2**.

**Figure 2**

*Example of a traditional uncontained room-based cooling*



Another significant shortcoming of uncontained room-based cooling is that in many cases the full rated capacity of the CRAH cannot be utilized. This condition occurs when a significant fraction of the air distribution pathways from the CRAH units bypass the IT loads and return directly to the CRAH. This bypass air represents CRAH airflow that is not assisting with cooling of the loads; in essence a decrease in overall cooling capacity. The result is that cooling requirements of the IT layout can exceed the cooling capacity of the CRAH despite the required amount of nameplate capacity. This problem is discussed in more detail in White Paper 49, *Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms*.

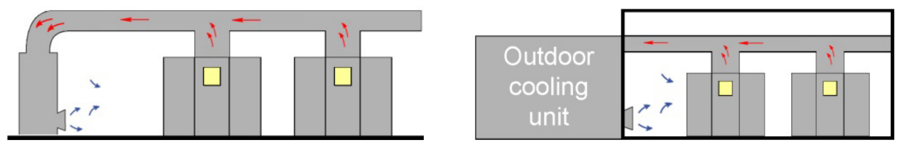
Link to resource
White Paper 49
*Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms*

For new data centers greater than 200 kW, room-based cooling should be specified with hot-aisle containment to prevent the issues discussed above. This method is effective with or without a raised floor and the cooling units can either be located inside the data center or outdoors. For existing data centers with room-based raised-floor cooling, cold aisle containment is recommended, since it is typically easier to implement. Both hot and cold aisle containment are being used to minimize mixing in data centers. Each of these solutions has its own unique advantages that are described in further detail in White Paper 135, *Impact of Hot and Cold Aisle Containment on Data Center Temperature and Efficiency*. **Figure 3** shows two examples of a next-generation room-based cooling.

Link to resource
White Paper 135
*Impact of Hot and Cold Aisle Containment on Data Center Temperature and Efficiency*

**Figure 3**

*Examples of next-generation contained room-based cooling*




## Row-based cooling

With a row-based configuration, the CRAH units are associated with a row and are assumed to be dedicated to a row for design purposes. The CRAH units may be located in between the IT racks or they may be mounted overhead. Compared with the traditional uncontained room-based cooling, the airflow paths are shorter and more clearly defined. In addition, airflows are much more predictable, all of the rated capacity of the CRAH can be utilized, and higher power density can be achieved.

Row-based cooling has a number of side benefits other than cooling performance. The reduction in the airflow path length reduces the CRAH fan power required, increasing efficiency. This is not a minor benefit, when we consider that in many lightly loaded data centers the CRAH fan power losses alone exceed the total IT load power consumption.

A row-based design allows cooling capacity and redundancy to be targeted to the actual needs of specific rows. For example, one row of racks can run high density applications such as blade server, while another row satisfies lower power density applications such as communication enclosures. Furthermore, N+1 or 2N redundancy can be targeted at specific rows.

For new data centers less than 200 kW, row-based cooling should be specified and can be implemented without a raised floor. For existing data centers row-based cooling should be considered when deploying higher density loads (5kW per rack and above). White paper 134, *Deploying High-Density Pods in a Low-Density Data Center* discussed the various approaches for deploying high density zones in an existing data center. Examples of row-based cooling are shown in **Figures 4a** and **4b**.

Link to resource
White Paper 134
*Deploying High-Density Pods in a Low-Density Data Center.*

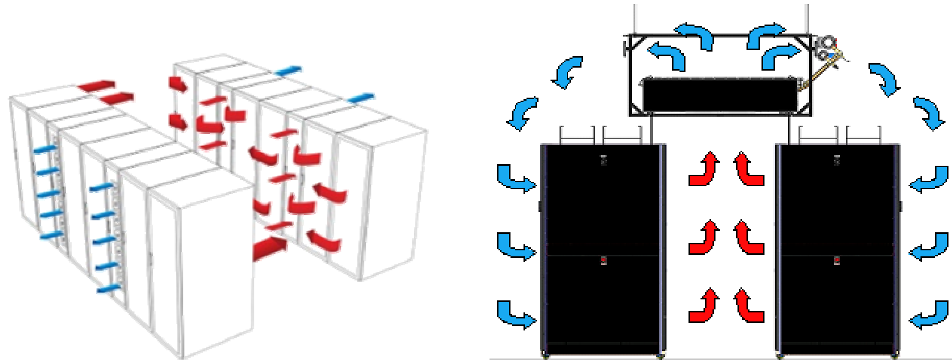


**Figure 4**

***4a (left)***
*Floor-mounted row-based cooling*

***4b (right)***
*Overhead row-based cooling*

Both the cooling systems in **Figure 4a** and **4b** can also be configured as a hot-aisle containment system that extends the power density capability. This design further increases the performance predictability by eliminating any chance of air mixing. The simple and pre-defined layout geometries of row-based cooling give rise to predictable performance that can be completely characterized by the manufacturer and are relatively immune to the affects of room geometry or other room constraints. This simplifies both the specification and the implementation of designs, particularly at densities over 5 kW per rack. The specification of power density is defined in detail in White Paper 120, *Guidelines for Specification of Data Center Power Density*.

Link to resource
White Paper 120
*Guidelines for Specification of Data Center Power Density*

## Rack-based cooling

With rack-based cooling, the CRAH units are associated with a rack and are assumed to be dedicated to a rack for design purposes. The CRAH units are directly mounted to or within the IT racks. Compared with room-based or row-based cooling, the rack-based airflow paths are even shorter and exactly defined, so that airflows are totally immune to any installation variation or room constraints. All of the rated capacity of the CRAH can be utilized, and the highest power density (up to 50 kW per rack) can be achieved. An example of a rack-based cooling is shown in **Figure 5**.

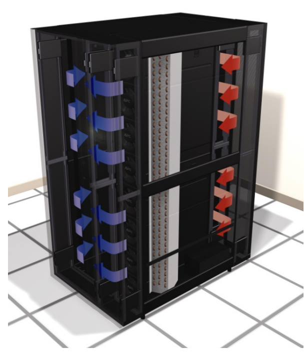


**Figure 5**

*Rack-based cooling with cooling unit completely internal to rack*

Similar to row-based cooling, rack-based cooling has other unique characteristics in addition to extreme density capability. The reduction in the airflow path length reduces the CRAH fan power required, increasing efficiency. As mentioned above, this is not a minor benefit considering that in many lightly loaded data centers the CRAH fan power losses alone exceed the total IT load power consumption.

A rack-based design allows cooling capacity and redundancy to be targeted to the actual needs of specific racks, for example, different power densities for blade servers vs. communication enclosures. Furthermore, N+1 or 2N redundancy can be targeted to specific racks. By contrast, row-based cooling only allows these characteristics to be specified at the row level, and room-based cooling only allows these characteristics to be specified at the room level.

As with row-based cooling, the deterministic geometry of rack-based cooling gives rise to predictable performance that can be completely characterized by the manufacturer. This allows simple specification of power density and design to implement the specified density. Rack-based cooling should be used in all data center sizes where cooling is required for stand-alone high-density racks. The principal drawback of this approach is that it requires a large number of air conditioning devices and associated piping when compared to the other approaches, particularly at lower power density.

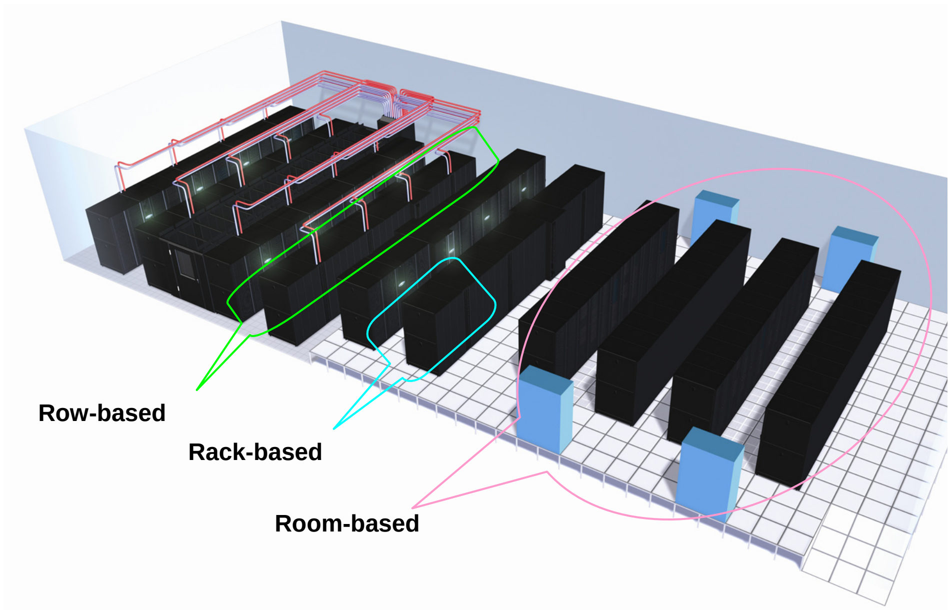
## Hybrid cooling

Nothing prevents the room, row, and rack-based cooling from being used together in the same installation. In fact, there are many cases where mixed use is beneficial. Placing various cooling unit in different locations in the same data center is considered a hybrid approach as shown in **Figure 6**. This approach is beneficial to data centers operating with a broad spectrum of rack power densities.

Another effective use of row and rack-based cooling is for density upgrades within an existing low density room-based design. In this case, small groups of racks within an existing data center are outfitted with row or rack-based cooling systems. The row or rack cooling equipment effectively isolates the new high density racks, making them “thermally neutral” to the existing room-based cooling system. However, it is quite likely that this will have a net positive effect by actually adding cooling capacity to the rest of the room. In this way, high density loads can be added to an existing low density data center without modifying the existing room-based cooling system. When deployed, this approach results in the same hybrid cooling depicted by **Figure 6**.

**Figure 6**

*Floor layout of a system utilizing room, row, and rack-based cooling simultaneously*




Another example of a hybrid approach is the use of a chimney rack cooling system to capture exhaust air at the rack level and duct it directly back to a room-based cooling system. This system has some of the benefits of a rack-based cooling system but can integrate into an existing or planned room-based cooling system. An example of this equipment is shown in **Figure 7.**

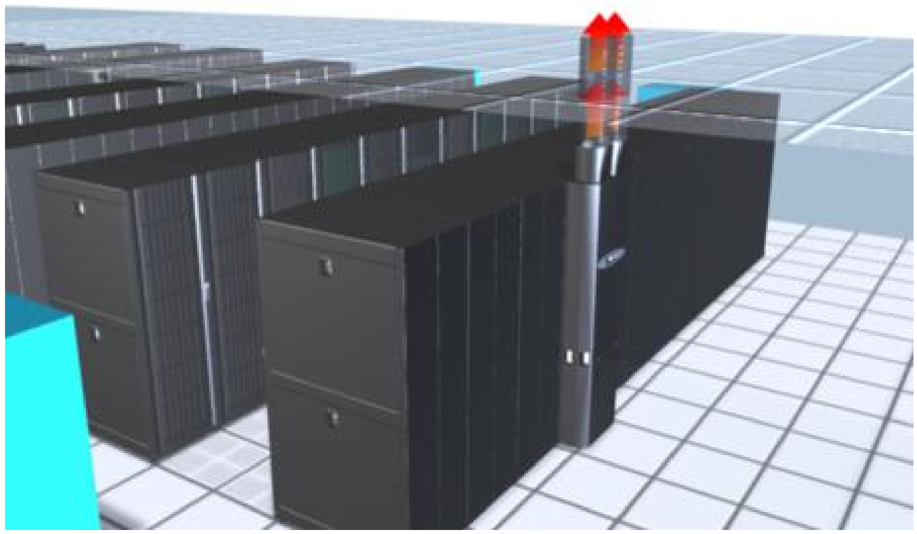


**Figure 7**

*Rack-level ducted exhaust into drop ceiling*

## Comparison of three cooling methods

To make effective decisions regarding the choice between room, row, or rack-based cooling for new data centers or upgrades, it is essential to relate the performance characteristics of the cooling methods to practical issues that affect the design and operation of real data centers.

This section compares the three cooling methods against various criteria commonly identified by data center users, including:

- Agility
- System availability
- Life cycle cost (TCO)
- Serviceability
- Manageability
- First cost
- Electrical efficiency
- Water piping or other piping near IT equipment
- Cooling unit location
- Redundancy
- Heat removal method

**Table 1** summarizes the first five criteria by showing the pros and cons comparison between rack, row and room-based cooling. The following conclusions can be summarized from the table:

- Rack-based cooling is the most flexible, fastest to implement, and achieves extreme density, but with additional expense.
- Row-based cooling provides many of the flexibility, speed, and density advantages of the rack-based approach, but with less cost.
- Room-based cooling allows for quick changes to the cooling distribution pattern by reconfiguring the floor tiles. Cooling redundancy is shared across all racks in the data center with low densities. This method offers cost and simplicity advantages.

**Table 1**

*Pros and cons of the rack, row, and room-based cooling.*
*Good performance highlighted.*

| Category | | Rack-based | Row-based | Room-based |
|---|---|---|---|---|
| Agility | Pros | Easy to plan for any power density; isolated from the existing cooling system | Easy to plan for any power density; cooling capacity can be shared | Quickly to change cooling distribution pattern for power density <3 kW |
| | Cons | Cooling capacity can't be shared with other racks | Requires hot and cold aisle layout | Less efficient when not containing the whole space |
| System availability | Pros | Close coupling eliminates hot spots and vertical temperature gradients; standardized solutions minimize human error | Redundant units can be shared across multiple racks in a pod; close coupling eliminates vertical temperature gradients | Redundant units can be shared across all racks in the data center |
| | Cons | Redundancy required for each rack | Redundancy required for each pod of racks | Containment required to separate air streams |
| Life cycle cost (TCO) | Pros | Pre-engineered system and standardized components eliminates or reduces planning and engineering | Ability to match the cooling requirements; planning and engineering can be eliminated or reduced | Easy to reconfigure perforated floor tiles |
| | Cons | Cooling system will likely be oversized and capacity will be wasted which can drive up first cost | First cost of this approach can be higher as the size of the data center increases | Air delivery dictates oversized capacity; pressure requirements for under floor delivery area are a function of the room size and floor depth |
| Serviceability | Pros | Standardized components reduce the technical expertise; in-house staff can perform routine service procedures | Modular components reduces downtime; standardized components reduce the technical expertise | Cooling equipment is placed on the perimeter or outside the room keeping technicians further away from IT equipment |
| | Cons | 2N redundancy required for concurrent system repair and maintenance | Cooling equipment is placed in the row where technicians will be working alongside IT equipment | Requires trained technician or experts to perform service |
| Manageability | Pros | Easy to navigate through menu interface and able to provide predictive failure analysis | Easy to navigate through menu interface able to provide near predictive failure analysis | Larger systems simplify the number of points to connect to and manage |
| | Cons | For large deployments requires many points of connectivity | For large deployments requires many points of connectivity | Require advanced service training; impossible to provide real-time analysis |

## First Cost

Most data center managers are concerned with the first cost of different cooling methods. An analysis is done to show how the first cost varies for the three different chilled water cooling methods as a function of rack power densities. **Figure 8** illustrates the results for a data center based on the assumptions in the side bar.

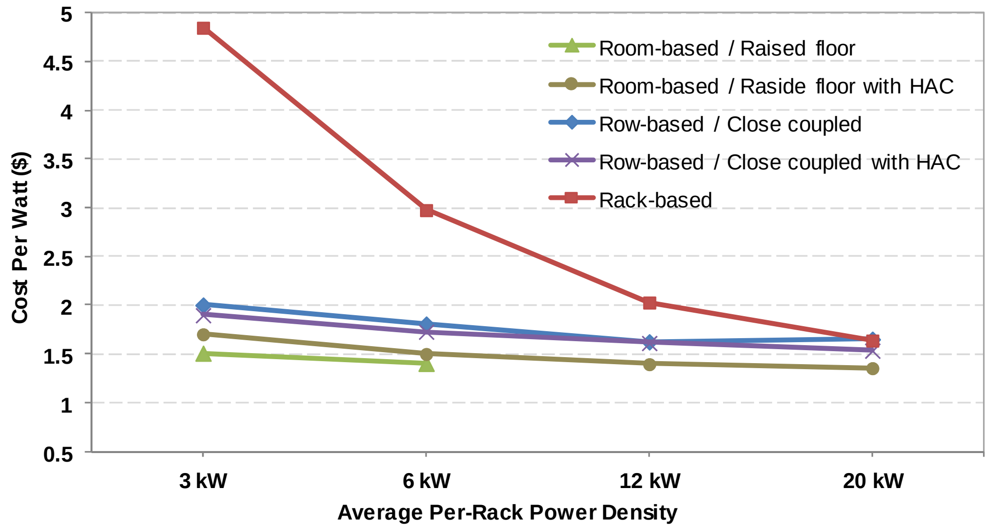



**Figure 8**

*First cost as a function of average rack power density for the three cooling methods*

**> Data center assumptions**

- IT load: 480 kW
- Location: St. Louis, MO
- Rack density: 3, 6, 12, 20 kW per rack (120 cfm/kW)
- Air mixing and cool air bypass for room-based without HAC: 125% of rated
- Piping costs based on RSMeans cost database: steel piping
- Cost of energy: $0.15/kWh
- First cost includes: cooling unit, piping, packaged chiller, installation and containment
- Annual electrical cost includes: cooling unit fan, chiller, and pumps
- Cooling redundancy: N

Room-based cooling has the lowest first cost because it has fewer cooling units and less piping. The cost decreases slightly as rack power density increases because, for the same data center capacity, the model assumes a smaller data center footprint as density increases. As a result, less raised floor and piping is required, hence the lower first cost. Note that the room-based electrical efficiency will be worse as the rack power density increases (discussed in the next section). HAC (hot aisle containment) increases rack power density for both cooling methods, and greatly reduces cooling system power consumption (discussed in the next section), although the first cost increases slightly due to the cost of containment.

Row-based cooling has a slightly higher first cost than room-based because the row-based has relatively more cooling units and more piping. The cost decreases as the rack power density increases for the same reason as room-based cooling except that the number of cooling units will also decrease with increasing density. HAC not only reduces row-based cooling power consumption, but also reduces the first cost as less cooling units are required.

The first cost for rack-based cooling is quite higher than room-based and row-based cooling at lower rack power densities. This is because the increase in the number of cooling units which increases capital cost of units and piping for the lower densities. For example, for the 3 kW per rack scenario the row-based cooling has a total of 48 cooling units, but the rack-based cooling will increase that to 160 units. Also the rack-based cooling requires front and rear containment for the rack and cooling unit, which adds extra first cost to the system. As density increases, the first cost improves dramatically because the number of cooling units will be reduced in order to optimize the first cost. So, the rack-based cooling is more economical for high rack power densities.

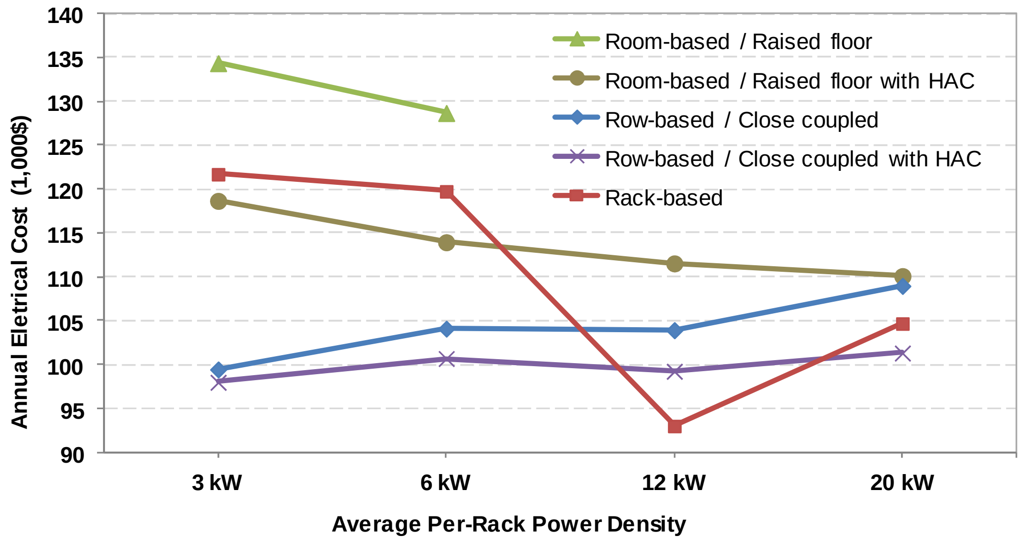
## Electrical efficiency

Electrical costs are becoming a larger fraction of total operating costs, due to increasing electric rates, the increase in electrical power required by the servers, and the increase of power density. While the dependency of electrical costs on electric rates and server power is well understood, the affect of power density on electrical costs is not generally considered.

**Figure 9** illustrates the effect of power density on annual electrical costs for three different chilled water cooling methods using the same assumptions of **Figure 8**.

**Figure 9**

*Annual electrical costs as a function of average rack power density for the three cooling methods*




The electrical costs for room-based cooling without HAC are highest because the room-based cooling needs to move more air over larger distances and the CRAH units need to consume power to stir or mix the air within the room to prevent hotspots. This electrical cost is reduced by using HAC due to the separation of airflows. As density increases, energy costs decrease slightly due to the shorter pipe lengths and the associated decrease in pump power consumption.

The electrical costs for a row-based cooling are consistently lower than room-based cooling because the CRAH units are closely coupled to the load, and sized to the load. Unnecessary airflow is avoided, which can save more than 50% fan power consumption compared with room-based cooling. The electrical cost will increase as rack power density increases, because the number of cooling units will be reduced, and more airflow and water flow is required for each cooling unit to achieve the required capacity to maintain the temperatures. The higher operating speed of the fan reduces the effective savings which can be achieved with variable speed fans. In this case, adding redundant units will actually lower the energy consumption but will result in higher first cost. In addition the higher water flow required to maintain capacity consumes additional energy.

The electrical costs for rack-based cooling are higher at low densities due to the increase in the number of cooling units which requires more power consumption to move air and water. Even with variable speed fans, the increase in cooling units at lower densities limits energy savings due to minimum fan speeds. At lower densities, the minimum fan speed provides more airflow than is required. In addition, more piping is required to push the water through. As rack power density increases, energy costs decrease. But, for high densities, the cost will start to increase because each rack has one cooling unit, and as the densities increase more airflow is required from each of the cooling units, the CRAH fans will approach the maximum operating speed which reduce the effective savings that can be achieved from the variable speed fans. Furthermore, the higher water flow required to maintain capacity also consumes additional energy.

## Water piping or other piping near IT equipment

Research shows that users are concerned with water or refrigerant piping co-located with IT equipment due to the possibility of fluid leaking onto IT equipment, and the associated downtime and/or damage.

Link to resource
White Paper 59
*The Different Technologies for Cooling Data Centers*

High-density data centers with multiple air conditioners generally use a chilled water cooling system and this trend is expected to continue due to environmental and cost concerns. Although refrigerants that have less possibility of damaging IT equipment exist, they are a more costly alternative to water. Concerns regarding availability and the drive toward higher densities have lead to the introduction of pumped refrigerant systems within the data center environment. These systems are typically composed of a heat exchanger and a pump which isolate the cooling medium in the data center from the chilled water and allows for oil-less refrigeration to reduce contamination in the event of a leak. However, the system could also isolate other cooling liquids such as glycol. See White Paper 59, *The Different Technologies for Cooling Data Centers*, for more information on pumped refrigerant systems.

## Cooling unit location

The location of an air conditioning unit can have a dramatic effect on the system performance.

In the case of rack-based cooling, this problem of performance predictability is completely eliminated since the exact location of the air conditioner to the target load is determined. The benefit is that the cooling performance can be completely characterized in advance. If a phased deployment is part of the system design, the location of future air conditioning units requires little planning or forethought, being automatically deployed with each rack.

Row-based cooling depends on simple design rules to locate air conditioners. The quantity and locations of row-based air conditioners are determined by rules that have been established through simulation and testing. Naturally this includes ensuring that the air conditioners are sufficiently sized to the row density specification. In addition, there are other rules, such as avoiding row end locations, which maximize the performance and capacity of the system. During future deployments, some location flexibility is retained up until the time of deployment. Average or peak-to-average rack power density of the row can be used to establish the quantity and locations of air conditioners in a just-in-time process. Row-based cooling is the most flexible compared to the rack-based approach, has a smaller footprint, and lower cost.

In the case of room-based cooling without containment, efficiency is greatly dependent on the location of the cooling units. For example, the most effective locations may not be feasible, due to physical room constraints including doorways, windows, ramps, and inaccessibility of piping. The result is typically a sub-optimal design even when considerable amounts of engineering are applied. In addition, the logistics of installing room-based air conditioners typically require that they be placed into the room in advance, comprehending all future IT deployment phases. Since the exact layout of future IT phases may not be known, the locations of the air conditioners are often grossly ineffective. This is why containment is so critical for modern room-based cooling designs. Containment allows much more flexibility in the placement of cooling units. Contained room-based cooling also permits the additional option of locating the CRAH units outside of the data center.

## Redundancy

Redundancy is necessary in cooling systems to permit maintenance of live systems and to ensure the survival of the data center mission if an air conditioning device fails. Power systems often use dual path feeds to IT systems to assure redundancy. This is because the power cords and connections themselves represent a potential single point of failure. In the case of cooling, N+1 design is common instead of dual path approaches because the common air distribution paths, being simply open air around the rack, have a very low probability of failure. The idea here is that if the system requires four CRAH units, the addition of a fifth unit to the system will allow any one of the units to fail and the total cooling load will be satisfied. Hence the name “N+1” redundancy. For higher power densities this simple concept of redundancy breaks down. The way redundancy is provided is different for the three cooling methods as explained below:

For rack-based cooling, there is no sharing of cooling between racks, and no common distribution path for air. Therefore, the only way to achieve redundancy is to provide an N+X or 2N dual path CRAH system for each rack, essentially at least two CRAH systems per rack. This is a severe penalty when compared with the alternative approaches. However, for isolated high density racks this is very effective as the redundancy is completely determined and predictable and independent of any other CRAH systems.

Row-based cooling provides redundancy at the row level. This requires an additional or N+1 CRAH unit for each row. Even though the row CRAH units are smaller and less expensive than room units, this is a significant penalty at light loads of 1-2 kW per rack. However, for higher density this penalty is eliminated and the N+1 approach is sustained up to 25 kW per rack. This is a major advantage when compared with either room or rack-based designs, which both trend to 2N at higher densities. The ability to deliver redundancy in high density situations with fewer additional CRAH units is a key benefit of the row-based cooling and provides it a significant total cost of ownership (TCO) advantage.

For room-based cooling, the room itself is a common air supply path to all the IT loads. In principle, this allows redundancy to be provided by introducing a single additional CRAH, independent of the size of the room. This is the case for uncontained room-based cooling at very low densities, and gives this approach a cost advantage at low densities. However, in uncontained room-based cooling at higher densities the ability of a particular CRAH to make up for the loss of another is strongly affected by room geometry. For example, the air distribution pattern of a specific CRAH cannot be replaced by a backup CRAH unit that is remotely located from the failed unit. The result is that the number of additional CRAH units that are required to establish redundancy increases from the single additional unit required at low densities to a doubling of CRAH units at densities greater than 10 kW per rack. This is not the case for a room-based cooling that uses containment because the supply and return air paths are separated.

## Heat removal method

Link to resource
White Paper 59
*The Different Technologies for Cooling Data Centers*

The special issues discussed in this section are influenced by the heat removal method. Direct expansion computer room air conditioners (CRAC) used to cool the data center operate differently than chilled water (CRAH) units. Using CRAC units in this way will affect their efficiency, humidification, redundant operation, etc. A design analysis must be done to comprehend the operation and controls of the specified cooling solution in a particular project. See White Paper 59, *The Different Technologies for Cooling Data Centers* for more information on heat removal methods.

## Conclusion

The conventional approach to data center cooling using uncontained room-based cooling has technical and practical limitations in next generation data centers. The need of next generation data centers to adapt to changing requirements, to reliably support high and variable power density, and to reduce electrical power consumption and other operating costs have directly led to the development of containment strategies for room, row, and rack-based cooling. These developments make it possible to address operating densities of 3 kW per rack or greater. The conventional room-based approach has served the industry well, and remains an effective and practical alternative for lower density installations and those applications where IT technology changes are minimal.

Contained room-based, row-based, and rack-based cooling provide the flexibility, predictability, scalability, reduced electrical power consumption, reduced TCO, and optimum availability that next-generations data centers require. Users should expect that product offerings from suppliers will utilize these approaches. It is expected that many data centers will utilize a mixture of the three cooling methods. Rack-based cooling will find application in situations where extreme densities, high granularity of deployment, or unstructured layout are the key drivers. Uncontained room-based cooling will remain an effective approach for low density applications and applications where change is infrequent. For most users with newer high density server technologies, contained room-based and row-based cooling will provide the best balance of high predictability, high power density, and adaptability, at the best overall TCO.


## About the author

**Neil Rasmussen** is a Senior VP of Innovation for Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for data centers.

Neil holds 25 patents related to high-efficiency and high-density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high-efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

After founding APC in 1981, Neil served as Senior VP of Engineering and CTO for 26 years, assuming his current role after APC joined Schneider Electric in 2007. He received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at the MIT Lincoln Laboratory on flywheel energy storage systems and solar electric power systems.

**Kevin Dunlap** is General Manager of Cooling Solutions at Schneider Electric. He holds a bachelor's degree in business, with emphasis on management information systems, from the University of Phoenix. Involved with the power management industry since 1994, Kevin previously worked for Systems Enhancement Corp., a provider of power management hardware and software, which APC acquired in 1997. Following the acquisition, Kevin joined APC as a product manager for management cards and then for precision cooling solutions following the acquisition of Airflow Company, Inc., in 2000.

Kevin has participated in numerous power management and cooling panels, industry consortiums, and ASHRAE committees for thermal management and energy-efficient economizers.

# Resources

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White Paper 55

**Cooling Strategies for Ultra-High Density Racks and Blade Servers**
White Paper46

**Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms**
White Paper 49

**Guidelines for Specification of Data Center Power Density**
White Paper 120

**Humidification Systems: Reducing Energy Costs in IT Environments**
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**Deploying High-Density Pods in a Low-Density Data Centers**
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