Top 10 Reasons to Consider Dell PowerEdge Energy Smart Containment Rack Enclosures

This Dell white paper lists multiple reasons why the Energy Smart rack is a good choice to help improve IT equipment density, cooling efficiency, and the effectiveness of raised-floor cooling and containment.
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Introduction

In today’s data centers, finding ways to operate more efficiently is a high priority. Addressing cooling concerns can be a big part of that challenge. One option for improving cooling and air distribution is to implement some form of containment for the racks in the data center. This can be implemented at the room, row, or rack level. The Dell™ PowerEdge™ Energy Smart containment rack enclosure has built-in cold-air containment that enables some unique opportunities for cooling in a raised-floor environment. This document highlights the top 10 reasons to consider this rack solution for your data center.

Top 10 reasons you should consider the Energy Smart rack

1. You want a cost-effective, easy-to-deploy containment solution and the benefits that come with it, like a 20% energy reduction in the bottom line.

Dell’s Energy Smart rack with built-in containment enables the IT fans within the rack-mounted equipment to integrate into the heating, ventilation, and air conditioning (HVAC) air distribution strategy in a data center using raised-floor cooling. Passive containment is provided with a solid front door that creates a vertical air channel (plenum) and a tight seal to the floor. Energy usage can be reduced up to 20% since there is no wasted air blowing past the rack and traveling back to the HVAC unit unused. By eliminating overprovisioning and wasted air, you can cool more equipment more efficiently with your existing HVAC configuration (see reason #4).

2. You don’t want to deploy pods of empty racks with aisle containment and have them sit empty for months until they are filled.

Some containment solutions require customization around a certain number of rack enclosures and integration with data center facilities, such as fire suppression systems. These tend to have
significant up-front costs and require extensive advance floor-planning, and they can’t be easily relocated. The Energy Smart rack can be easily and quickly deployed with no impact to facilities, and it can be placed practically anywhere in the raised-floor data center. Just position this rack directly over the ventilated tiles and start installing equipment. Since you can add one rack at a time, you can expand your deployment when you’re ready.

3. You like the flexibility of the raised floor for cooling and the capital cost of Computer Room Air Conditioner (CRAC) or Computer Room Air Handler (CRAH) units over other coil products.

It’s hard to beat the capital costs of the CRAC/CRAH form factor. It’s also hard to beat the flexibility of raised-floor distribution. Unlike in-row or active rack cooling, the raised floor allows you to easily reapporportion cooling capacity. This type of air distribution is also great for data centers that want to raise the air temperature and take advantage of chiller-less cooling (see reason #8).

4. You’d like to more effectively use the existing cooling infrastructure you have; you probably have enough CRAC/CRAH units, but just can’t get the air to the right places.

Hot spots exist when not enough cold air reaches all areas of the rack and some air gets pulled from the most convenient source, which is generally local exhaust air returning to the HVAC. The Energy Smart rack completely segregates the path to the server inlets. The server fans create a negative pressure in the front cavity that pulls the fresh air out of the floor. All equipment inlet temperatures are essentially the same (within a degree or so of each other), from the bottom to the top of the plenum. With the consistency of inlet temperatures the rack affords, you can also increase the facility temperature and reduce chilling cycles for even greater savings (see reason #8).

5. You would like to leverage a sub-floor pressure sensor to optimize air delivery, reduce air provisioning to save money, and recover stranded capability.

A very logical complement to the Energy Smart rack that can reduce both capital and operational expenses is to pair the containment rack with HVAC units operating volumetrically based on sub-floor pressure. The demand for air from the IT equipment causes the tightly coupled racks to affect the sub-floor pressure, and the HVAC can respond to fluctuations in pressure by adjusting the amount of air delivered. The rack effectively interacts with the HVAC system by using the common language of pressure to communicate volumetric airflow needs. Any Energy Smart rack that asks for more flow gets it. CRACs that are configured for pressure-sensing refill the floor to maintain the specified pressure set point.

6. You want the ability to more effectively handle the possibility of cooling failures.

With an N+X strategy, you presumably have enough airflow globally to handle the failure of x number of CRAC/CRAH units, but the failure may have a disproportionate effect at the local level if you are still depending upon sub-floor pressure for distribution. The Energy Smart rack overcomes local dead spots created by a CRAC/CRAH failure. In a catastrophic failure, where you lose all air movement, the Energy Smart rack still draws air from the raised-floor plenum and slows the increase in IT equipment inlet temperatures.

7. You would simply like to achieve higher rack density for the IT equipment you deploy.

Rack density is expandable in the Energy Smart rack since the IT systems in the rack can adjust the delivery from the floor due to their control algorithms responding to changes in workload to maintain component temperatures. Since the passive design does not include flow-limiting fans, the Energy Smart rack can achieve equipment densities exceeding 30kW. The servers do the work
to determine how much air they need; all you need to do is follow our guidance in the deployment white paper\textsuperscript{1}. It describes the relationship of the flow resistance of different vents to rack density limits and associated fan power increases to overcome the specific resistance.

8. You want to keep equipment temperatures more consistent than some other containment systems can, which yields a better opportunity to raise the data center temperature further. Or, you might even want to run a chiller-less facility.

In a chilled facility, if the data center temperature is raised from 55°F to 75°F, there can be large savings at the chiller plant. At $0.10 per kW-hr, a typical facility could save over $3000 per year for each 15kW rack\textsuperscript{2}.

With fresh air cooling, there is still a need for room level distribution, which is typically accomplished either by the raised floor or by overhead ductwork. The Energy Smart rack is an excellent solution for leveraging fresh air in the raised-floor data center because the tight containment maintains temperatures better than many aisle-level containment systems. It nicely complements the capabilities of the Dell PowerEdge 12\textsuperscript{th} generation servers that have been qualified to operate with temperature excursions up to 45°C.

9. You would like to simplify coil planning and buy coils “just in time”.

Capital expenses can be better managed because you can have the visibility to the capacity available. The number of HVAC units required in a typical data center with no containment is greater than the quantity needed with the Energy Smart containment racks. When you leverage volumetric pressure control with containment, you can more easily calculate the CRAC utilization in your facility and plan your upgrades more effectively.

10. That front plenum just looks so cool; you can’t believe someone didn’t think of this before.

It is impressive, isn’t it? The wavy design on the extension was created to communicate the air movement that is occurring inside the front plenum and add an element of visual interest to the cabinet; but it’s also practical. No other rack-level containment solution provides the same capabilities for high density, expense reductions, and ease-of-deployment.

Have we piqued your interest? Read further for more insights.

**A coil is a coil is a coil**

After conducting enough research to write a comparison paper on various coil products\textsuperscript{3}, Dell engineers came to the conclusion that although there are large relative energy differences between different coil products, the differences are fairly small considering total facility energy. From a passive rear door heat exchanger that uses no energy itself, to the least efficient cooling coil, the impact to the facility in an optimized version of either was only a few percent. When you also consider variable fan speed fan options, the energy differences between coils can start to blur. Rather than base a coil choice on energy, we like to base it on other differences such as room height or floor area. Although we’re still quite partial to the flexibility of the raised floor, there are cases where Dell favors a rack-based solution like a rear door heat exchanger or different instances where a row coil is more appropriate.

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\textsuperscript{1} Dell PowerEdge Energy Smart Containment Rack Deployment Guide, David Moss, 2011.

\textsuperscript{2} Data Center Operating Temperature: The Sweet Spot, David Moss, 2011.

Applying savings represented by the graph in Figure 3 of this paper and assuming the chiller-related savings are each applied to an original power-use effectiveness (PUE) ratio of 2.0.

\textsuperscript{3} A Comparison of Room-, Row-, and Rack-Based Data Center Cooling Products, David Moss, 2010.
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When comparing efficiencies, coil vendors may use “apples and oranges” assumptions against their competitors, like comparing a contained solution to a non-contained solution or comparing a low operating temperature to a high operating temperature. By using unequal characteristics they skew comparative energy analyses. When we look at an equal baseline, there is larger capital than operational differences, which brings us to the conclusion that “a coil is a coil”. It’s really how you use the coil that has a greater determination on any energy differences you’ll see.

Why do we even have all of these different coil types? Ten years ago a CRAH/CRAC was about the only choice. Row and rack cooling was born from the notion that the raised floor was incapable of cooling much more than 5kW per rack. Well, that myth has been disproved, and passive rack enclosures using raised-floor cooling have demonstrated the ability to handle IT loads beyond 25kW.

**Pros and cons of a row coil**

Row coils do provide an even distribution of air into the aisle. There is no delivery uncertainty due to floor pressure variance but there is still an opportunity for some cold and hot air mixing over or around the rack row ends. Row coils do typically experience higher return temperatures due to the proximity of their intakes to the IT equipment; the argument follows that they would typically operate closer to their rated capacity because of this. Both of these advantages can be matched with containment, which in our opinion should be a best practice followed for either raised-floor or row cooling. One true advantage that row systems have is in a height-restricted facility. The additional height required for a raised floor and/or a ceiling plenum will sometimes preclude CRAH/CRAC units.

There are only a few negatives with row cooling. Initial costs can be higher than for CRAH units. Flexibility to move cooling capacity around the room is not as simple. The movement of floor vents is certainly easier than the addition or a relocation of row coils. And if economization is in your future, a row cooling strategy will limit you to water economizers. Air economizers need a room-level distribution strategy.

**Pros and cons of a rear door coil**

The passive rear-door coil is a neat product. It has the best efficiency of any coil product since it uses the IT equipment fans to move air through it. It has integral containment as long as the rack it is paired with is designed properly to contain the air (most aren’t without modification). It delivers a known capacity, (which does vary somewhat based on the IT equipment airflow). Its greatest positive is that it is simple; there are no further decisions to make, like what containment solution to use. And unlike active systems, there is no challenge matching IT flow rates.

As for the negatives, it typically is fairly expensive relative to CRAH units mainly due to the cost of the intermediate coolant distribution unit (CDU). Because it is a fixed-capacity and the capacity is tied to the rack, it is easier to under-load and strand capacity. Redundancy is tricky. One strategy is to under-subscribe on each CDU circuit and interleave racks on adjacent circuits such that the failure of one circuit would only affect every n\(^{th}\) rack. Because of the under-subscription, exhaust air from the operational circuits’ racks could be lower than their entering air. Mixing with the hot exhaust from the failed circuit, any recirculation to rack inlets is marginally warmer if at all. The downside about this redundancy strategy is that it is fairly costly if n is small (in an n+1 strategy). And like row units, a water economizer is the only option.
The ideal fan-based coil strategy

If there is an ideal fan-based cooling strategy, what would it look like? We think it should have the following attributes:

- **Flexible density**
  - Minimal or no constraints where you position dense racks
  - The ability to handle high density and low density without waste or stranding cooling (contrast: same rear door heat exchanger cooling a 5kW rack and a 15kW rack)
  - Easy to move cooling capacity around

- **Air delivery matches IT air consumption with little to no waste**
  - Certainly no under-delivery (hot spots)
  - No wasted air bypassing IT and cooling down return air
  - Adjusts dynamically as servers adjust themselves
  - Adjusts automatically as new server racks are added
  - Reserve capacity is easily measured
    - Real-time monitoring of unused airflow
    - Real-time monitoring of unused temperature producing capacity

- **Containment is included; ideally it is not complicated**
  - Preferably not a lot of assembly
  - Preferably does not affect other areas of the data center (such as fire suppression or plenum grade wiring)

- **Maintains very consistent IT temperatures allowing the room temperature to be raised to optimal efficiency**

- **Makes full use of the coil units to minimize coil capital expenses**

- **Coil redundancy strategy is simple**

**Challenges to the ideal**

The biggest challenge is in controlling the airflow of the coil units. Typical products tie the coil flow rate to the capacity/temperature control. CRAH units, for example, typically use a default strategy that has the blower control tracking the chilled water valve. When the valve is at 80% open, for example, the blowers run at 80% speed. Because of this, variable speed CRAH units, for example, will have a constant ratio of flow (cubic feet per minute, or CFM) to heat (watt) absorption and a constant delta T (ΔT) capability. This is not only the case at lower loads where CRAH manufacturers limit the minimum fan/blower speed, but also at loads higher than the CRAH rating when fans have reached their maximum speed. IT equipment typically has a baseline CFM-to-watt ratio that varies between 60 and 120 CFM/kW. But the CRAH unit, whether operating at 60% or 100%, would have a constant ratio of CFM/kW, which is typically around 100. So, default volumetric control really doesn’t present the ability to adjust and match differing IT characteristics.
There are some coil systems that try to match a rack’s $\Delta T$ by measuring both entering and exiting air of the rack, and then varying the coil’s flow rate to provide an equal $\Delta T$. This might work well in a homogenous data center where all the racks look the same and are loaded similarly. It is difficult to make this type of system work with coils that cool several racks where $\Delta T$ varies from rack to rack and even within the rack.

**Energy Smart rack paired with sub-floor pressure control**

Paired with sub-floor pressure control, the Energy Smart containment rack puts a check by every one of the ideal bullets mentioned in the previous section. For a more technical description on how the rack works, see our technical papers on the rack. The rack extends the floor plenum up into the rack and completes the conduit between the IT systems and the coil units. The rack’s seal at the floor ensures that almost all of the air the rack receives is directly from the floor. Typical internal temperatures are no more than 1-2 degrees above the sub-floor temperature. Any temperature increase is the result of minor leaks at the floor seal and from internal recirculation between servers or blanking panels.

![Energy Smart rack operation in a raised floor environment](image)

Temperatures are consistent throughout the height of the rack’s plenum except, as mentioned, due to leaks between equipment. Relative to most aisle containment systems, the temperatures are much more consistent, which should allow room temperature to be raised to a higher level to save more energy.

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Maximizing cooling for every deployment

More equipment means higher flow rates. As mentioned earlier, rack equipment flow rates typically vary from 60 to 120 CFM per kW. So a 10kW rack might experience flow rates between 600 and 1200 CFM. Above 600 CFM, the front plenum of the Energy Smart rack typically experiences negative pressure. This means at flow rates of 600 CFM and above, the IT fans are taking a greater role in extracting air from the floor. Below 600 CFM, front rack pressures are typically positive. When the front plenum is positively pressured, the natural resistance of the IT systems limits any waste that would otherwise flow through the rack. So whether it is a low-density, low-flow deployment, or a high-density, high-flow deployment, the result out of the floor is a match to the needs of the IT equipment. Rack density is only limited by the IT systems’ ability to extract air from the floor.

Our general guidance is 25kW at 25°C (77°F), but there are instances where the rack can be loaded above 30kW. At 25°C, there is a considerable amount of reserve cooling capability in the servers to enable higher temperature operation (35°C/95°F or greater). Beyond extra fan capability reserved for temperature, there will also be reserves if either the server configuration or processing utilization is not at its maximum. The reserve capability for temperature alone is larger than what is needed by the server to draw against the negative pressure in a 25kW contained rack. This is not to say the Energy Smart containment rack cannot be operated above 25°C. 25°C is the value at which we’ve based our 25kW rule of thumb. The rack’s tight containment enables high-density deployments. You can locate that density anywhere on your raised floor positioned over a grate. You don’t even have to use hot/cold aisles; the room essentially becomes the hot zone since the cold air is contained under the floor and within the front of the rack. You can locate a dense rack next to a lighter-load contained rack, and neither precludes the other from working with the right amount of air needed for the IT equipment.

Managing CRAH flow rates

Since the IT systems in the rack govern how much air comes from the floor, adequate rack airflow is ensured. There will be no hot spots nor any waste of air. As compute needs change throughout the day, any flow rate adjustment up or down by the IT systems will result in a corresponding change in flow coming out of the floor. This is where the pairing with sub-floor pressure control of coil air delivery can enhance the solution. The Energy Smart racks have an effect on the pressure under the floor when they consume more or less air. By converting a variable volume CRAH unit to sub-floor pressure control, it can respond to pressure changes brought on by the Energy Smart racks. The CRAH units are, in effect, responding to replace the air taken out by the Energy Smart racks. CRAH flow rates are optimized (minimized) and match the aggregate consumption of the Energy Smart racks. CRAH fan energy is saved since there is no longer a need to push excess air under the floor.

Earlier, we stated that energy differences between different coils are relatively small. Why should we care about minimizing CRAH flow rates if coil fan energy really isn’t a very large piece of the facility energy pie? It is still a few percent that many wouldn’t consider negligible. There are other reasons, however, to minimize waste. Anytime the CRAH units produce more air than is consumed by the IT, the waste bypasses the IT equipment and serves to lower the return air temperature. This, in turn, lowers the coil’s cooling capacity. With lowered capacity, more CRAH units are needed; so the waste of air can result in higher capital costs.

There is one other really nice advantage to minimizing CRAH airflow through pressure control. In our lab environment, all of the CRAH units respond in tandem at the same level of operation. All seek to maintain a specific pressure. In the case of our 1000 square foot lab, it is a single pressure
measurement, but it could be multiple measurements in a larger facility treated with some form of averaging. At any point in time, the reserve airflow capability of a three-CRAH unit solution is a known quantity. If our CRAH units are running to an optimized delivery of 70%, for instance, we know they have 30% in reserve. By simply tracking the control percentage of the CRAH units as new equipment is added, we can get a very good projection of when they will run out of air capacity. The chilled water valves still operate independently seeking to maintain their own supply air temperature set point. Periodic checking of each valve position and the overall flow setting would indicate very precisely when cooling is about to run out.

Managing CRAH unit failures

We’ve checked off just about every bullet on our “ideal” list. There is only one item that we have not addressed, which is covered in more detail in one of the papers referenced earlier. In our lab, when we fail one of the three CRAH units, the drop in flow is not shared equally around the room. Due to the positioning of the CRAH units, there is a vortex of low pressure in both cold aisles. When the nearest CRAH unit is failed, the closest aisle’s vortex gets much larger and causes a severe drop in flow. If we had no containment or even if we had cold-aisle containment, flow rates would still rely on floor pressure. The drop in aisle flow due to the low pressure caused by the enlarged vortex is severe enough that the redundancy strategy would be forced into an N+2 situation to survive a loss of any one CRAH unit. Energy Smart racks can overcome the low pressure of a vortex, even a large one, and pull the air they need from the rest of the room. Rather than plan around N+2, a data center similar to our lab could instead use an N+1 strategy with the Energy Smart racks.

Adding Energy Smart racks to your data center

But what about a facility that already has a lot of racks? You can’t easily convert them to Energy Smart, can you? Some of the advantages can be obtained with cold-aisle containment and a bit more care at balancing flow. In an existing facility, you can add cold aisle containment to existing racks and purchase Energy Smart racks for future expansion with additional equipment. By experimenting with the number and type of vents in the captured cold aisles, you can optimize air flow. It should be done when the IT equipment is operating at its peak. You should probably also experiment with failing local CRAH units. Once the proper aisle flow is established, sub-floor pressure control should maintain it. With the exception of any overage applied to compensate for an enlarged vortex, a tuned cold-aisle containment pod operates almost as effectively as the Energy Smart containment racks. Of course, the contained cold aisles cannot enable CRAH units to respond to dynamic changes of airflow consumption unless the containment is very tightly sealed.

Summary

There is no one-size-fits-all solution. The Energy Smart containment rack is a simple, cost-effective solution that enables many advantages, as pointed out in this paper. It does, however, require the use of a raised-floor plenum for air distribution. The raised floor is a very flexible way to deliver air to IT equipment, and CRAC/CRAH units are still a predominant, as well as cost-effective, form factor in the industry. The raised floor supports very high densities when properly deployed. The Energy Smart rack offers a way to set up an “ideal” ecosystem that can reduce your cooling concerns.