Hot aisle/Cold Aisle Containment in Data Centers For Most Energy Efficiency

Nandini Mouli, Ph.D.
eSai LLC
Contractor to TRC
Dominion Energy-VA Programs
6/24/25

Topics

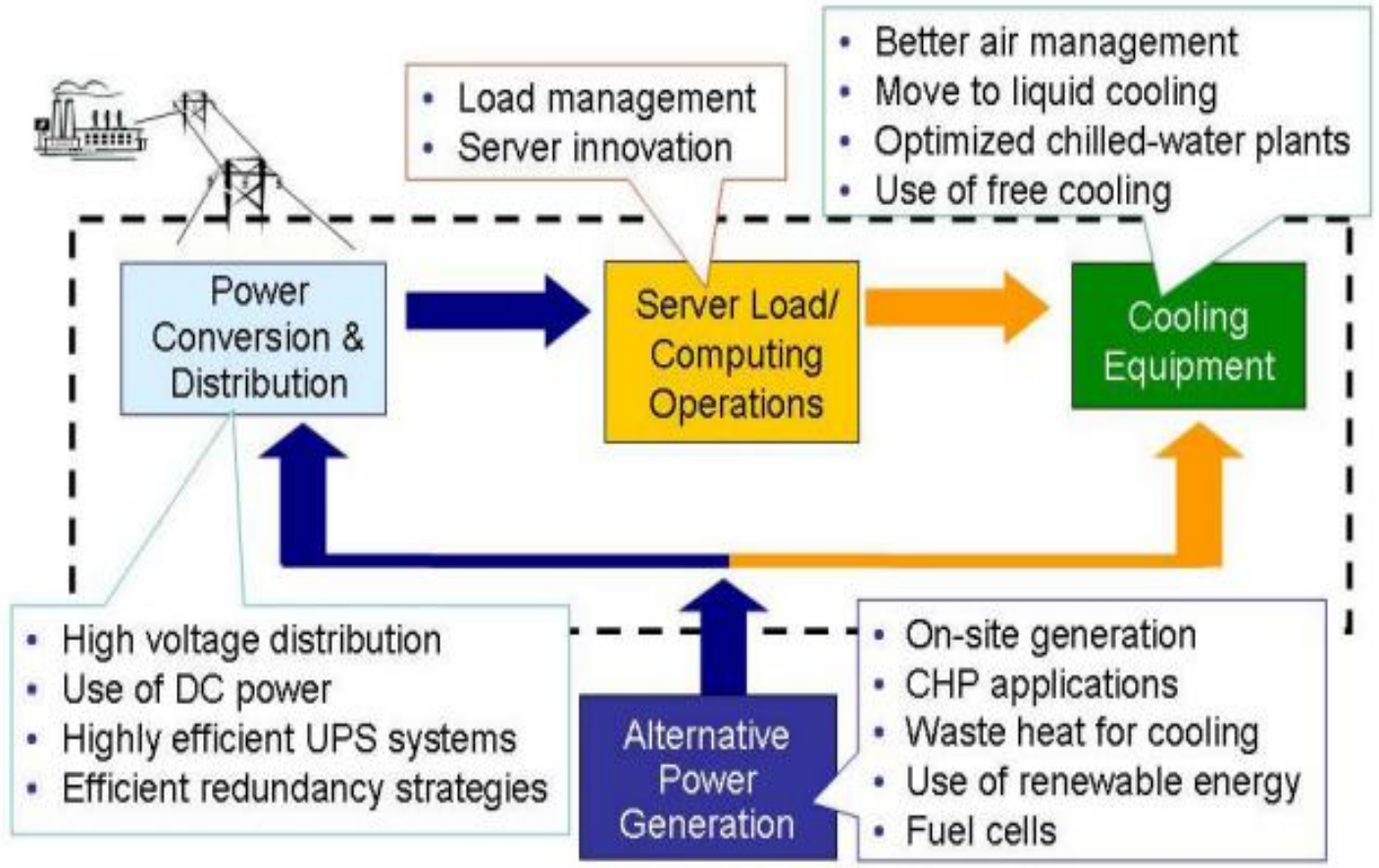
1. Why is energy efficiency important for data centers?
   Basics of Airflow Management for Data centers
2. Hot and Cold Aisle Containment - Configurations
3. Hot Aisle vs Cold Containment - Benefits
4. Hot Aisle vs Cold Aisel Containment – Challenges
5. Case studies
6. Dominion Energy Incentive Program
7. Q & A

Energy Efficiency in Data Centers

Energy Profile of Data Centers

- Data Center is the fastest growing sectors globally
- In the US, 5 states are showing rapid growth
- Northern VA has the highest concentration of data centers **globally** and remains the fastest-growing market
  - **70% of global internet traffic flows through Northern VA**
    - Most facilities are served by Dominion Energy.
    - Loudoun county itself has 181 data centers and the total Northern VA has 3X than the II runner-up in the US
  - The rapid expansion has driven a significant uptick in electricity demand in VA
    - Dominion forecasting a demand **reaching 9 GW by 2035.**
  - Data center growth is impacting PJM region as well.
  - It is therefore prudent to use energy efficiency as a strategy in data centers

Data Center Energy Efficiency Strategies



Energy Efficiency of Data centers

$$\text{IT CFM} = \text{IT load (kW)} * 130 \text{ (CFM per kW)}$$

Cooling CFM Estimate

Total Cooling (Tons) x 550 = Total Supplied Cooling Airflow (CFM_{Supply})

IT Equipment CFM Estimate

Total IT Load (kW) x 130 = Total IT Airflow (CFM_{IT})

$$\%\ \text{Surplus Air} = \frac{CFM_{Supply} - CFM_{IT}}{CFM_{IT}}$$

- A data center's 40 – 50% total electrical load is due to cooling equipment
  - IT equipment is the rest
- Waste reduction in the cooling system is very critical & airflow management is a part of it.

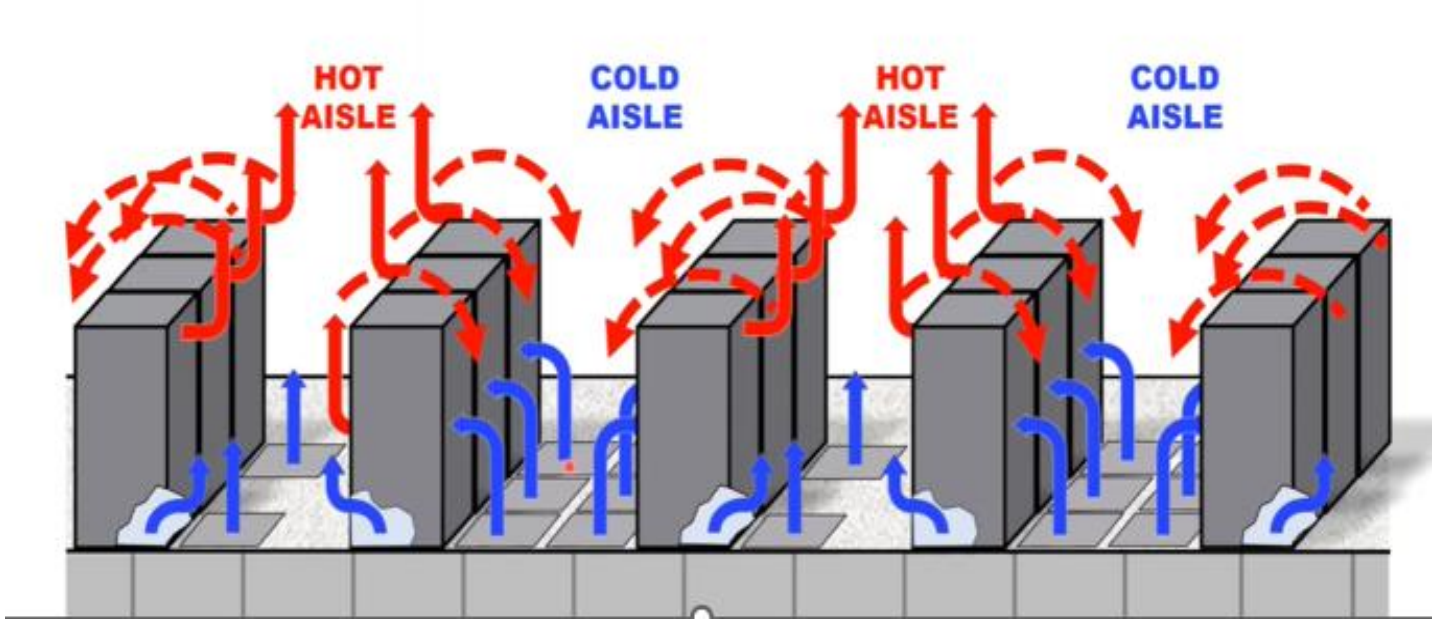
The Basics of Airflow Management

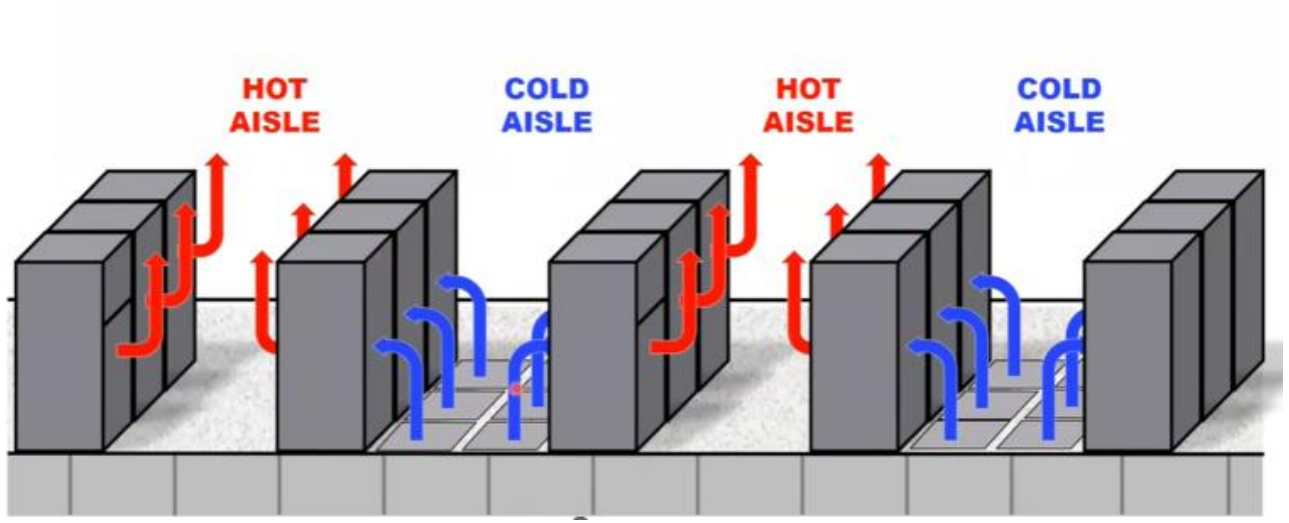
- With so many variables affecting airflow within a data center, it can be daunting to know where to start and how to get the most of airflow management improvements
- The 4R's of Airflow Management: Is a good methodology for identifying and implementing changes to optimize the data center's cooling infrastructure and realize energy savings.
- The 4R's are: Raised floor, the Rack, the Row and the Room

2. Hot Aisle/Cold Aisle Containment - Configuration

Typical Hot and Cold Aisles

- With poor airflow management
- We want to go away from this

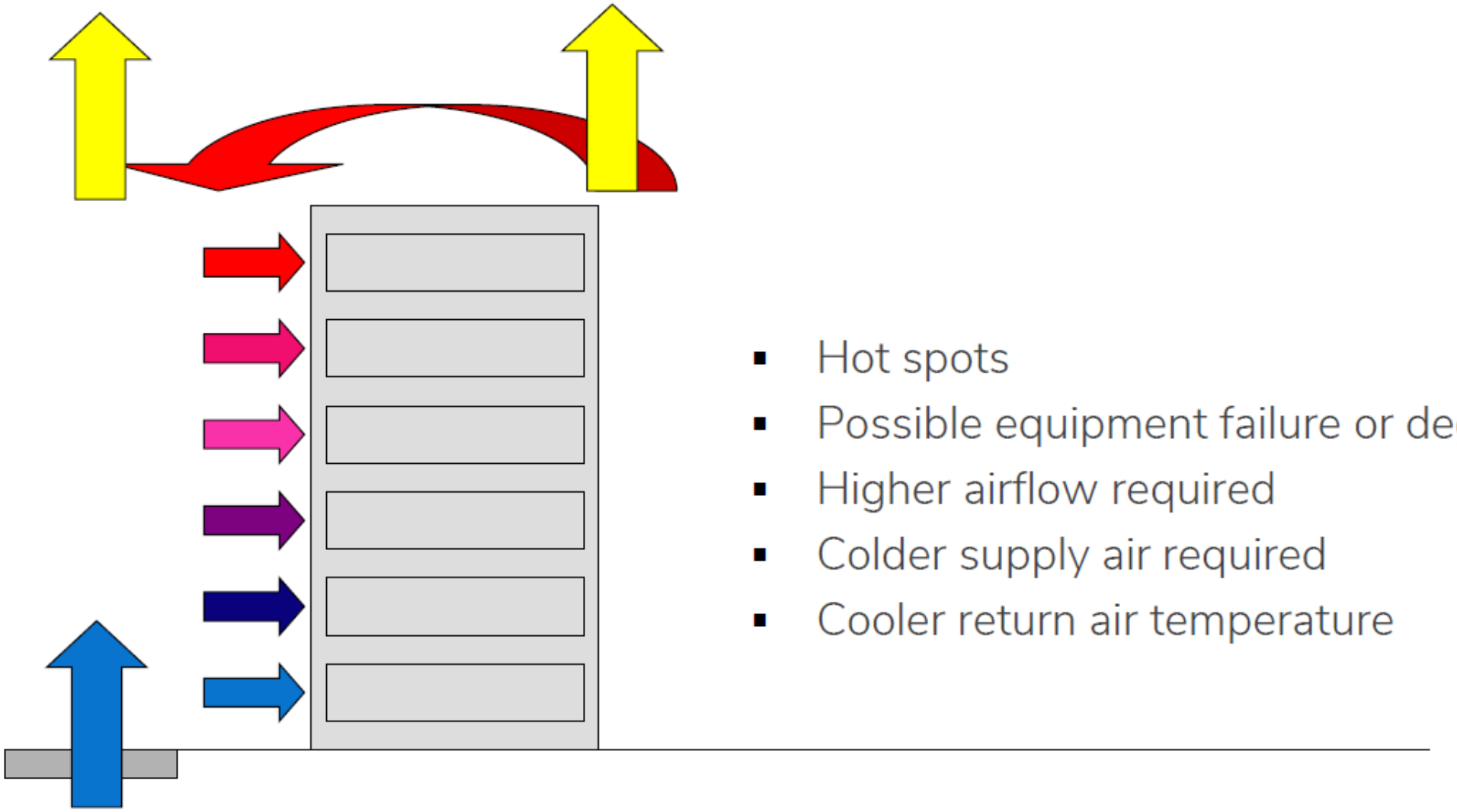




Ideal Hot and Cold Aisle Configuration

With good airflow management

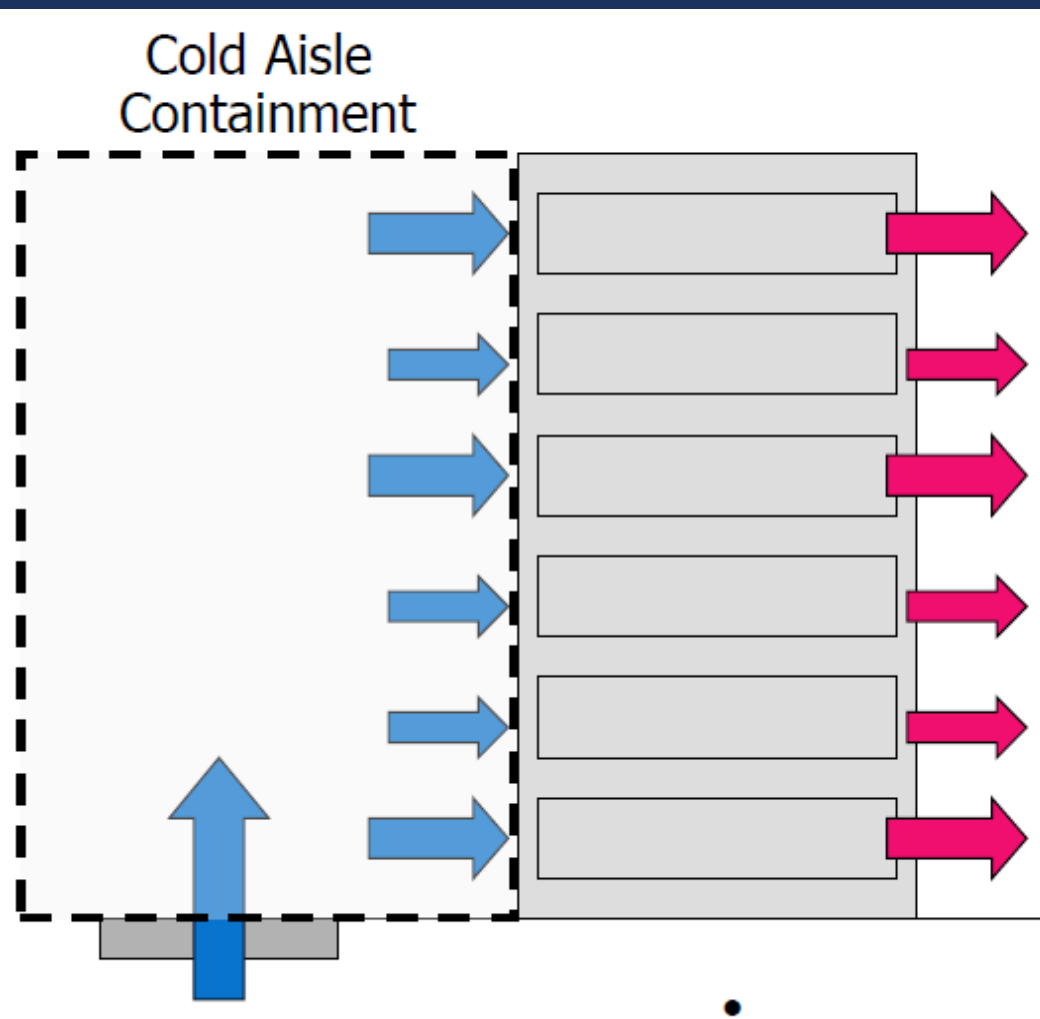
What happens with uncontained data centers?



- Hot spots
- Possible equipment failure or degradation
- Higher airflow required
- Colder supply air required
- Cooler return air temperature

$$\dot{V}_{HVAC\_Supply} \gg \sum \dot{V}_{Servers}$$

Containment allows you to better match IT rack airflow



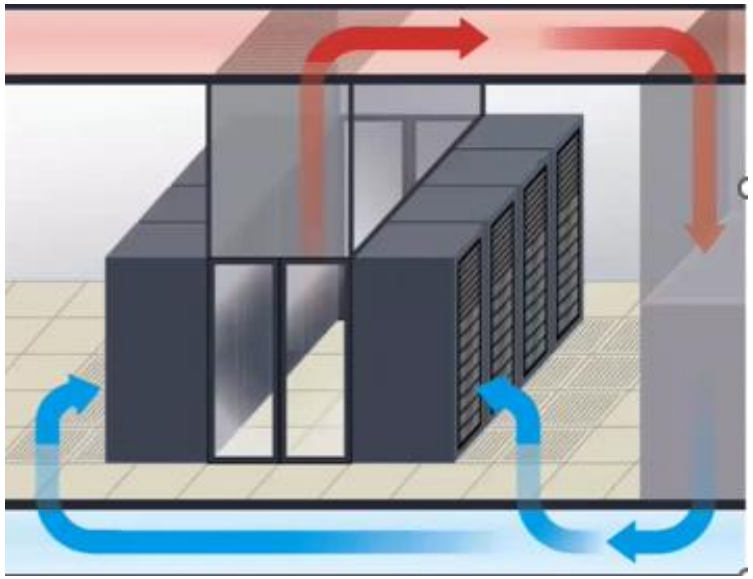
- Fewer hot spots
- Less equipment failure or degradation
- lower airflow required
- warmer supply air required
- hotter return air temperature

$$\dot{V}_{HVAC\_Supply} \approx \sum \dot{V}_{Servers}$$

How does containment save energy?

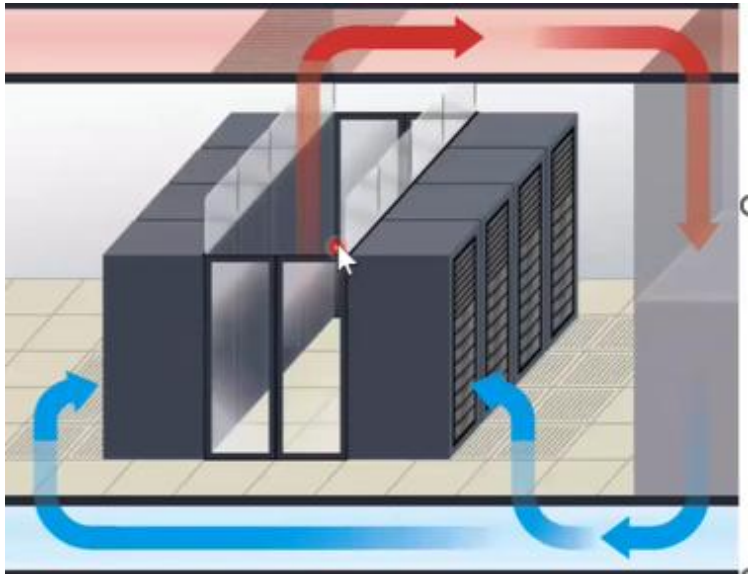
- Data center without containment shows server inlet temperature over ASHRAE-recommended 80.6 ° F due to recirculated air
- There is excess of cold supply air aimed at avoiding IT equipment overheating. This is wasted energy
- According to US GSA for every 1 ° F of increased server inlet temperature 4 -5 % energy costs can be saved.

Legacy Hot Aisle Containment



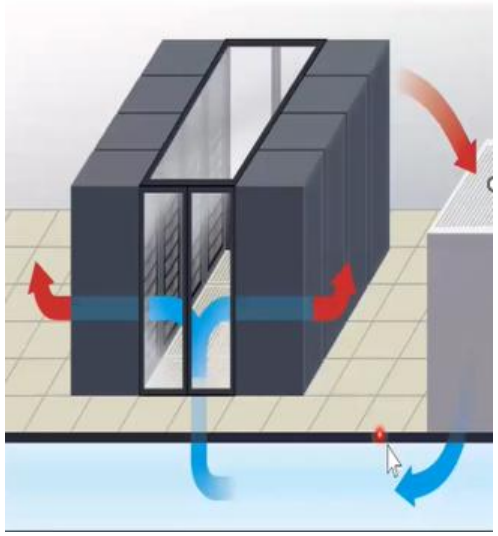
- Requires full ducting of racks to the ceiling plenum as well as ducting the returns of CRAC/CRAH units to the same overhead plenum
- Requires installation crew for construction – either internal crew with required skill set or experienced 3rd party or vendor

Modular Hot aisle Containment



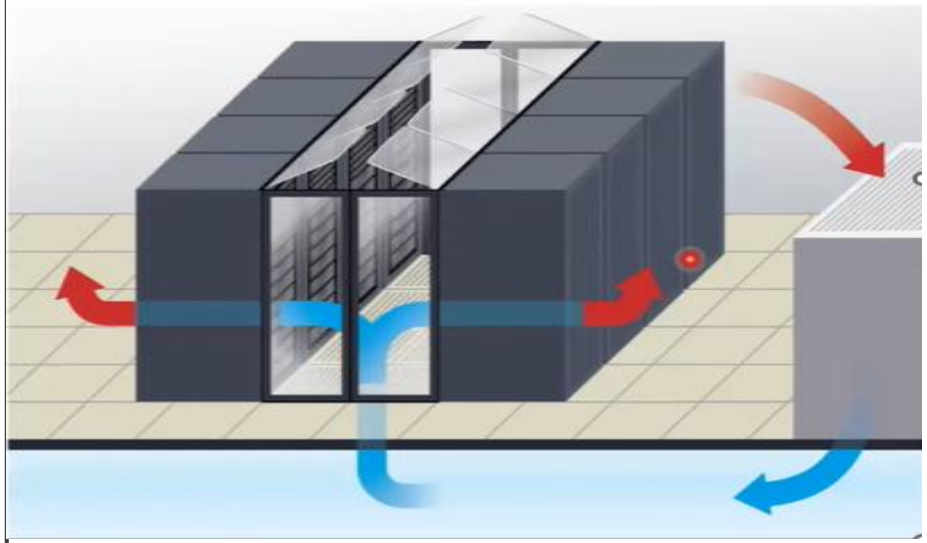
- Offers the core benefits of hot aisle containment with greater flexibility and at a lower cost
- Doors and baffles attach magnetically, eliminating the need for 3rd party installation
- Can be installed, removed and reinstalled by on-staff team members.

Legacy Cold Aisle Containment



- Utilizes aisle-end doors and optional drop-away “roof” panels that cap the cold aisle for complete cold-aisle containment
- Requires installation crew for construction-either internal crew with required skill set or experienced 3rd party vendor

Modular Cold Aisle Containment



- Offers the core benefits of cold aisle containment with greater flexibility and at a lower cost
- Doors and baffles attach magnetically, eliminating the need for 3rd party installation
- Can be installed, removed, and reinstalled by on-staff team members

3. Hot Aisle/Cold Aisle Containment Benefits

Hot Aisle Containment - Benefits

- Open area of room is the “cold” environment
- Leakage from raised floor openings in the larger area of the room goes into the cold space
- Generally, more effective, more likely to be implemented fully
- Hot aisle containment will be more forgiving for network racks and stand-alone equipment
- With a well-designed space, a standard grid fire suppression system could be installed around a hot aisle containment array of barriers and meet code

Cold Aisle containment-Benefits

- Generally easier to implement
- Only requires doors at aisle ends and cap on top
- Generally, less expensive to implement
- Cold aisle is typically easier to retrofit in an existing data center
- It does not absolutely need to be on a raised floor, but typically is because of challenges associated with delivering supply air to the contained spaces

4. Hot Aisle/Cold Aisle Containment- Challenges

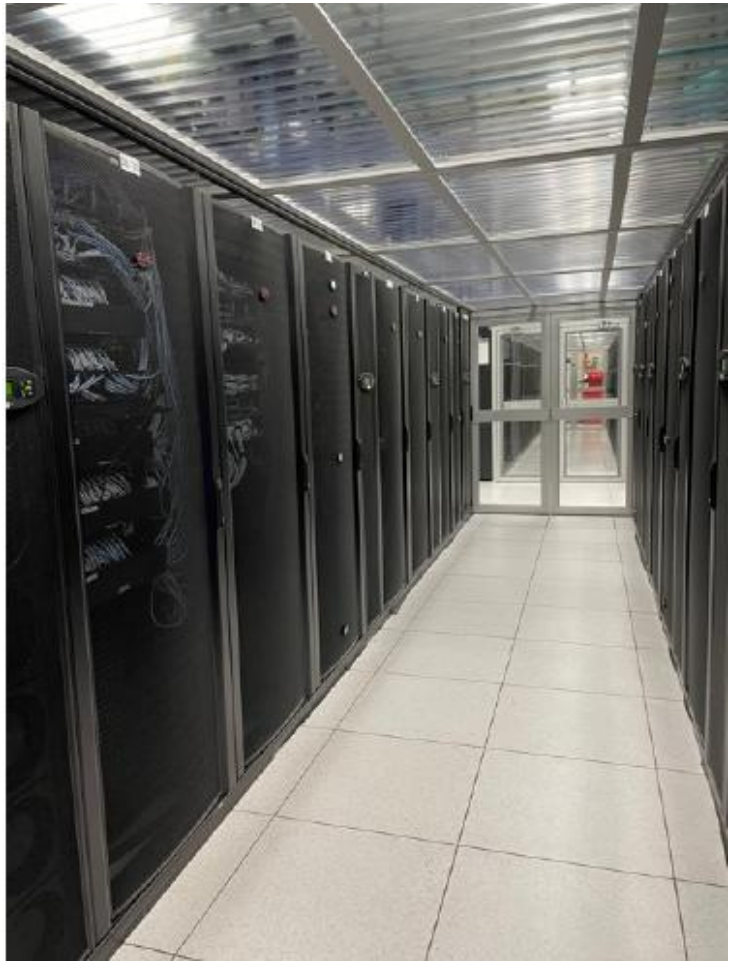
Hot Aisle Containment - Challenges

- Requires a contained path for air flow from the hot aisle back to the cooling units
- Generally more expensive
- May require modifications to fire suppression system, more gas required
- High temperatures in the hot aisle create uncomfortable conditions for technicians working on IT gear

Cold Aisle Containment - Challenges

- Remainder of data center becomes the hot aisle and that space will be dramatically hot
- There may not be any space with a suitable temperature profile for equipment that is not compatible to be placed in the containment
- Conditioned air leaking from the raised floor enters the exhaust air paths returning to cooling units
- Requires consideration of fire suppression system (drop away panels, mechanical system opens ceiling upon smoke detection)

5. Case Study of a Cold Aisle Containment for Energy Efficiency



Case study-A large data center in a Financial Institution, Baltimore-Maryland

- Premise and Methodology
- Baseline
- Proposed
- Energy Savings
- Results

Premise and Savings methodology

Installation of cold aisle containment will reduce mixing of hot air into the cold aisle

1. Supply air temp. from the cooling units can be increased while providing cooler air to the servers

    Energy savings will be achieved by the chillers due to the higher chilled water supply setpoint

2. Containment helps in increase of capacity and efficiency of the chiller
3. Decreased air flow rate also contributes to the fan energy savings
4. Additional savings accrued by turning off multiple CRAC units due to decreased cooling requirements

Baseline System

- Chillers:
  - Three 225 ton Air cooled chillers; 208.7 ton capacity
  - EER: 9.8, evap. flow rate 311.7 gpm at 95 o F
- In-Row Cooling units – IRCs:
  - Running at ~ 40% speed
  - Discharge air temp. setpoint 65 o F
- Supply air temp. is 55 o F but the hot exhaust air recirculation due to mix of streams increases the air temp. feeding the server racks
  - CFD simulation: 9 Racks with server-side inlet temp. above ASHRAE recommended max. of 80.6 o F

Proposed System

- Full Cold Aisle Containment (CAC)
- Rearrange perforated raised floor tiles based on CFD to optimize the airflows to the server racks
- Goal is to keep server inlet temp. below 80.6 o F (ASHRAE)
- A CFD simulation predicted that with a new chilled water temp. of 65 o F will give a discharged air temp. entering a server rack below 80 o F
- Therefore, the supply air temp. leaving the cooling units can be raised from 55 o F. to 65 o F
- 6 of 10 CRAC will be turned off after installation of cold air containments

Energy Savings

1. Modeling showed that the supply air temp. of the CRAC can be increased by 13 ° F.

   For every 1 ° F increase from CRACs and IRCs, there will be an estimated savings between 1.6% to 5% in overall energy cost to operate the data center

2. A regression equation was developed for calculating kW/ton based on outside air and chilled water supply temp.

   Actual tonnages were calculated based on the % utilization of chillers, supply and return temps. of chilled water loop

3. Fan energy consumption was calculated by using the no. of fans running, kW/cfm specs and their VSD speeds

Results

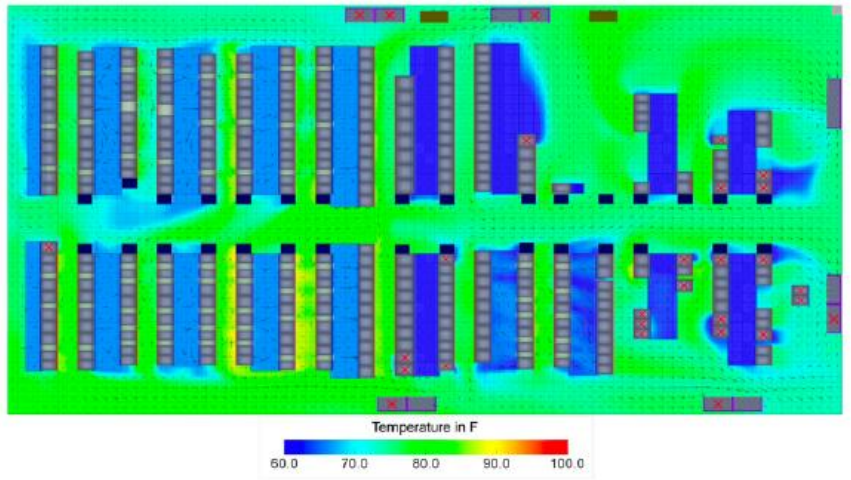
- Savings: 1,681,920 kWh/year
- PUE dropped from 1.9 to 1.6 from cold aisle containment

Sysems	IT Load kW	IT Load in tons	Chiller Load in ton hrs	Avg EER kW/ton	Fan CFM	Fan kW/cfm	Annual IT kWh	Annual Chiller kWh	Annual Fan kWh	Annual Total kWh	Annual Max kW	Annual Savings kWh	Annual Savings kW
Baseline	666	189.366	6,796,340	0.810736	145,177	0.000309	5,018,578	5,731,495	1,189,790	11,939,863	774.1		
				(CFM from CFD Model)									
After Installation	666	189.366	6,413,336	0.664202	128,577	0.00026	5,018,578	4,461,120	884,949	10,364,647	701.3	**1,575,216**	**72.9**
												1,681,920	192

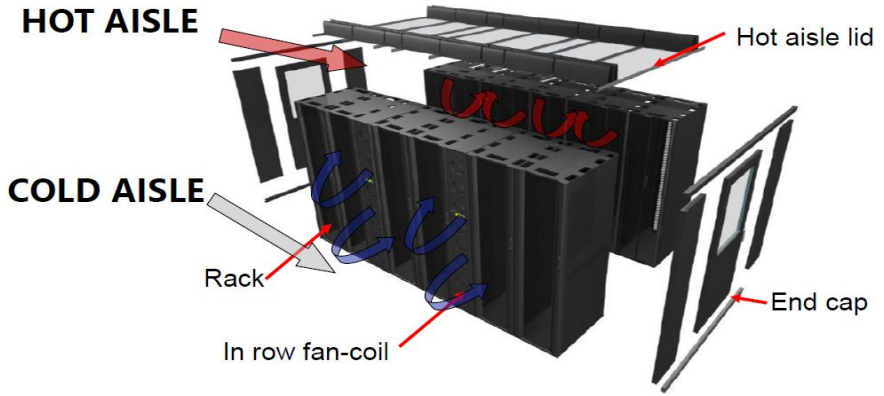
Post-Installation

COMPUTATIONAL FLUID DYNAMICS REPORT

Model #3: Horizontal Temperature Plane @ 6'



th hot aisle containment, the general data center is neutral (70-



6. Dominion Energy Incentive Programs For Data Center Airflow Management

Commercial & Industrial Energy Solutions Program

Custom incentives are calculated based on your project's projected calculated savings for the first 12 months after installation at $0.12/kWh.

Custom Airflow/HVAC Measure

Measure must be pre-approved by program staff

Measure savings must be demonstrated with information provided to the program. Based on the review of information, final measure eligible and incentivized savings will be determined by program staff. Interested customers should review specific documentation requirements with a program representative.

Contact

Nandini Mouli, Ph.D.
Consultant to TRC-Dominion Energy Programs
Nandini@eSai.Technology
443 691 7664

Hannah Aiken
Outreach/Inspection Specialist
Haiken@TRCcompanies.com
414 339 1608

Hannah Kelley
Outreach Specialist
Hkelley@trccompanies.com
203 550 6427

Travis Clemens
Energy Advisor/Outreach Specialist
TClemans@TRCcompanies.com
434 989 9412

Thanks for joining!