Trends in Cooling of Data Centers

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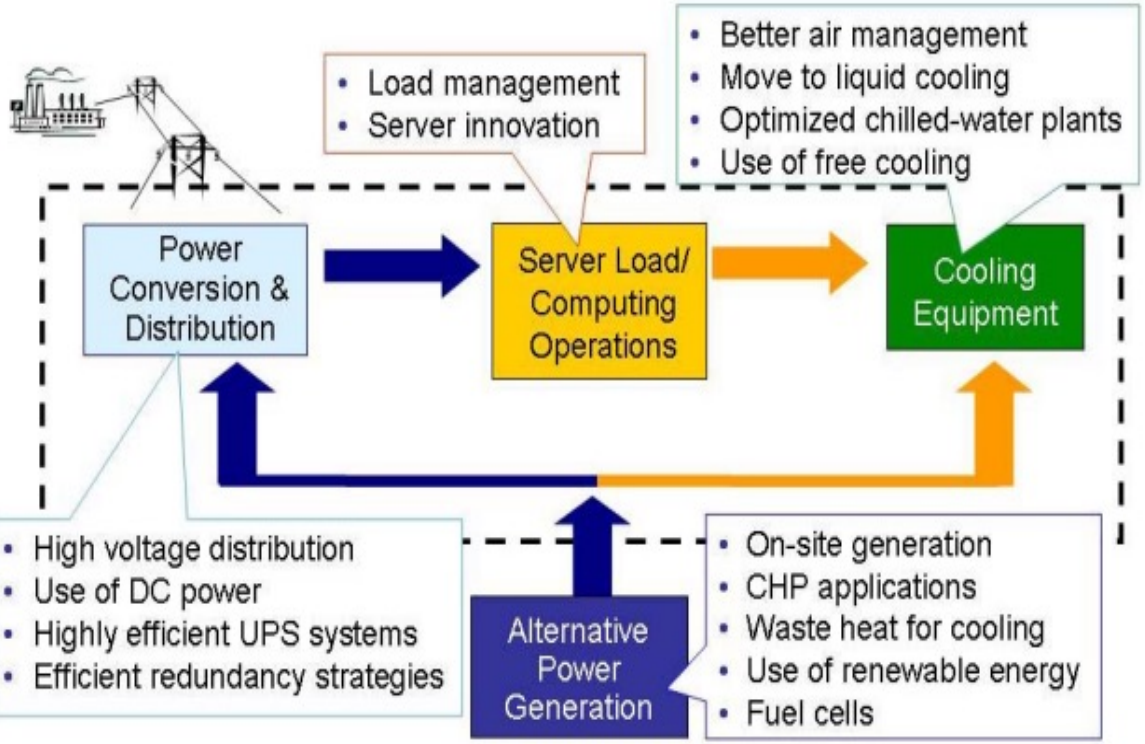
Topics

1. Cooling Needs in Data Centers- Background
2. Typical Cooling Systems used in Data Centers
3. New Needs Prompting Innovations
4. Solution: Liquid Cooling
5. Types of Liquid Cooling
6. Benefits of Liquid Cooling
7. Dominion Energy Incentives
8. Next Months Seminars
9. Contact
10. Q & A

Data Center Energy Efficiency Strategies - Overview



1. Cooling Needs For Data Centers

- Purpose is to removing heat from the IT systems
- 70 – 80% of the heat is generated by the CPU; rest by memory, power supply, hard drives and SSD (solid-state drive)
- There are as many as 13 different heat removal methods available for a data center
- Some relocate the refrigeration cycle components away from the IT environment
- Some add additional loops of water and other with liquids to aid in the process

2. Typical Cooling Systems Used in Data Centers

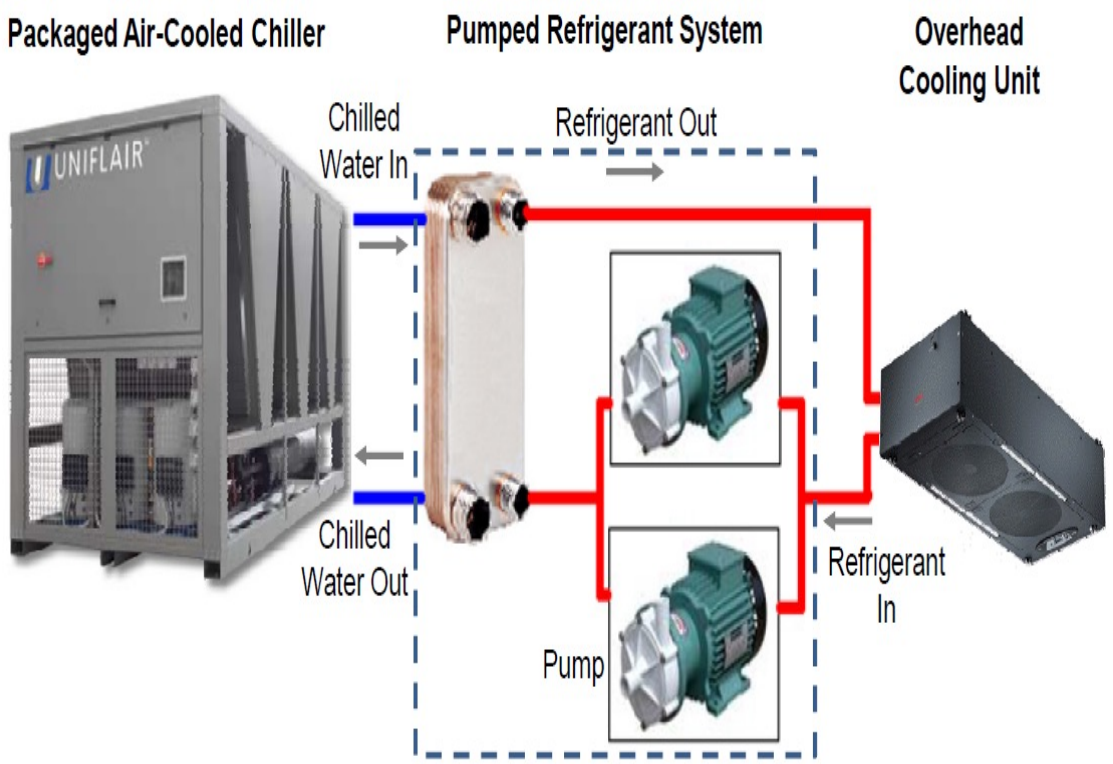
Small to medium sized data centers

CRAC unit

Air-cooled condenser

- Air Cooled
  - DX air conditions
    - Off-the shelf equipment manufacturers – CRAC units
  - Packaged RTU
    - Multiple and or variable speed compressors to improve part-load efficiency
    - Reject heat via an air-cooled condenser
    - Improvement for higher EE is air-cooled condenser with water over the condenser coils =➔ evaporative cooling
    - They also come with air-side economizers
  - Chillers
    - Larger data centers can use pumped refrigerant system connected to chilled water

Air-Cooled Chiller Providing Chilled Water For Cooling



Typical Cooling System Used in Data Centers (Contd.)

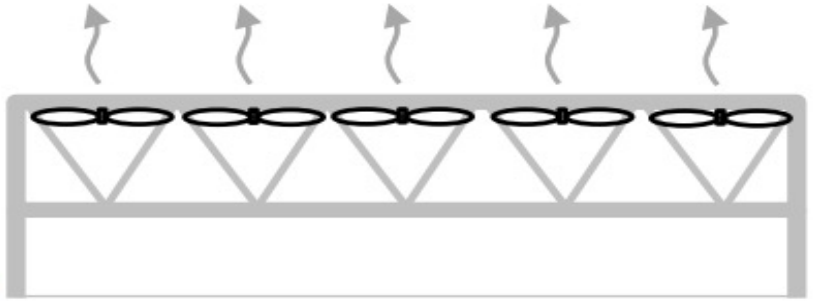
Larger data centers

- Water-Cooled:
  - A high-efficiency VFD-compressors
  - Oversized cooling towers with VFD-fans
  - Suitable air-side and water-side economizers for free-cooling
  - Thermal storage to store and use during peak demand periods or back-up make-up water for cooling towers
  - Chiller part-load efficiency optimized by high evaporator and low entering condenser water temps.

Air- and Water-Cooled System Options

Air-Cooled System

- Design day is based on **DRY BULB** temperature
- Consumes no water (no evaporative cooling)
- Large footprint/requires very large airflow rates.



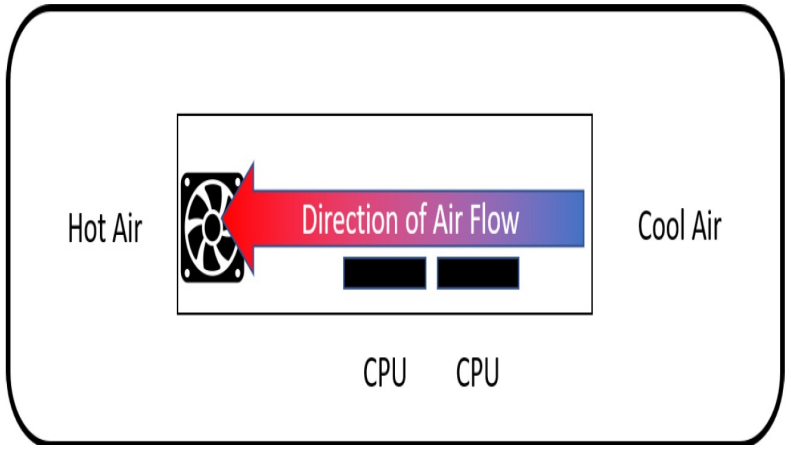
Water-Cooled System

- Design day is based on the lower **WET BULB** temperature
- Evaporative cooling process uses water to improve cooling efficiency
  - **80% LESS AIRFLOW → lower fan energy**
  - Lower cost and smaller footprint.
- Colder heat rejection temperatures improve system efficiency.

However, water-cooled systems depend on a reliable, continuous source of low-cost water.

3. New Needs Prompting Different Cooling Technologies

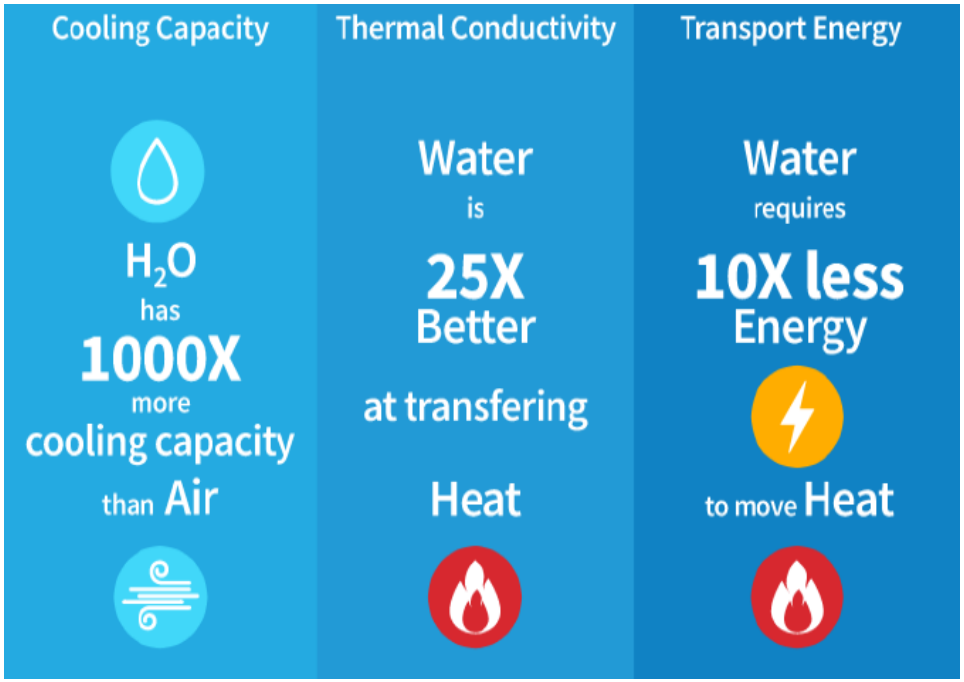
Air Flow within a Server



- Rising chip and rack densities with lower latency requirements
- Increasing GPU and CPU power consumption
- Pressure to reduce energy consumption
- Pressure to use floor space for computing power
  - Non-traditional spaces: network closets or branch offices
- Pressure to use less water

4. Solution - Liquid Cooling

Liquid over Air For High Cooling Capacity



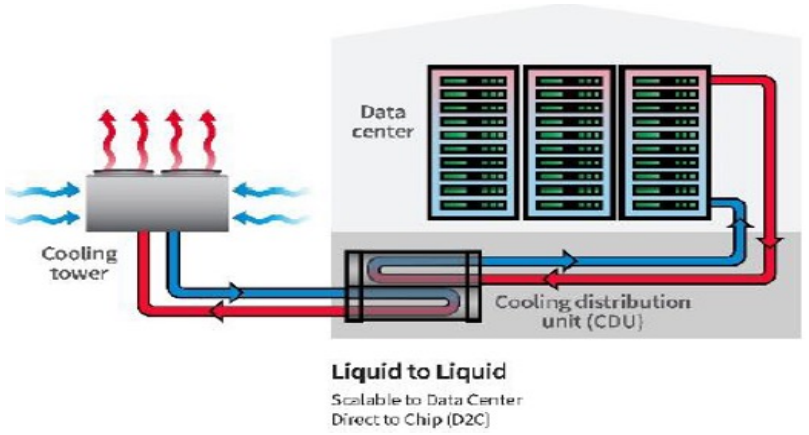
Air-Cooled to Liquid-Cooled Racks

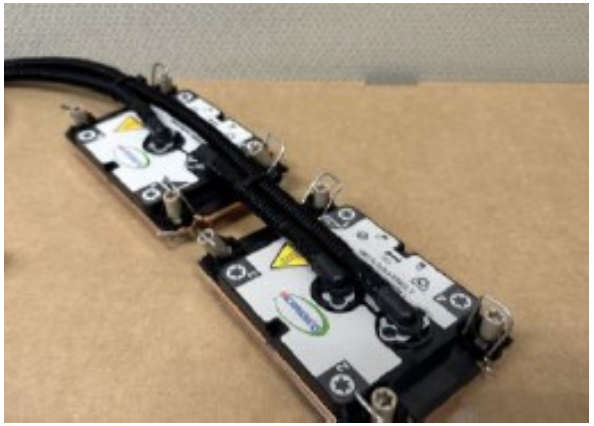
Traditional **air-cooled** allow for rack power densities of 1kW-5kW

Require **liquid-cooled** when rack power densities in 5–80kW range, have several options

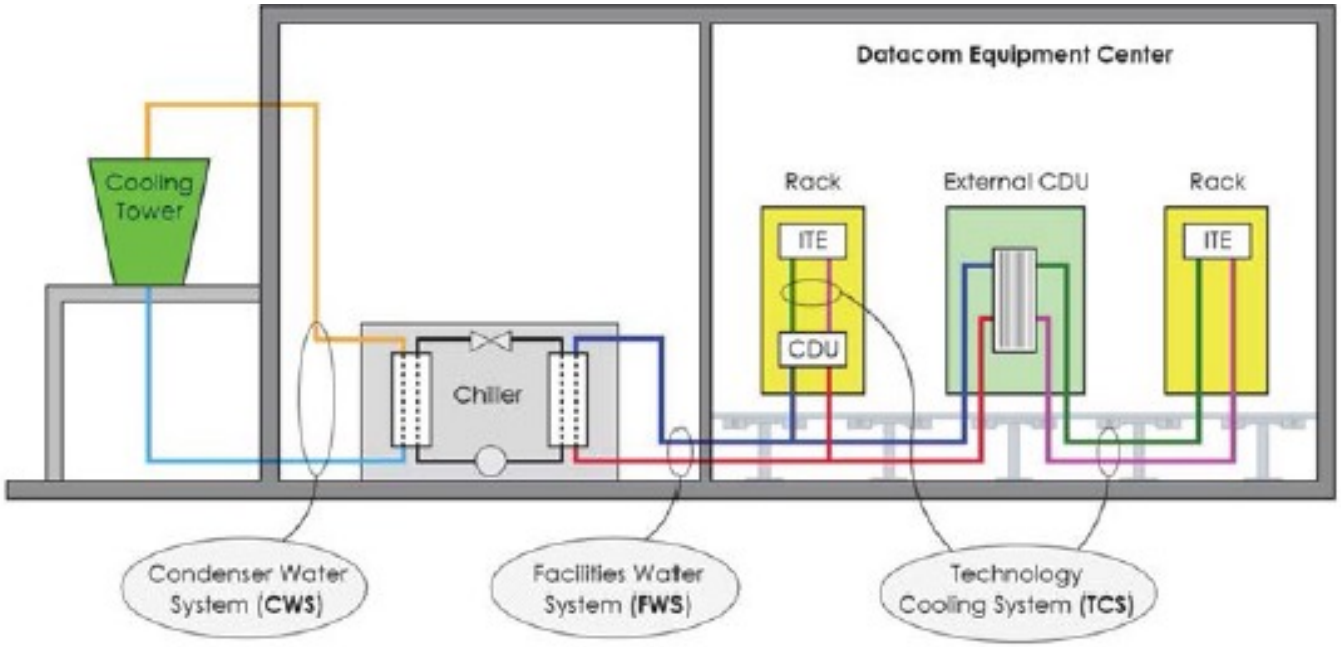
5a. Types of Liquid Cooling - Direct-to-Chip

- Cold plates which have liquid flowing through channels to remove heat replace the standard fin-based heat sinks on chips
- Solution generally involves a Cooling Distribution Unit (CDU)
- Variety of options exist; can be applied to memory and any other heat-producing components
- Fans are still required for the airflow through the server to remove the residual heat, but the conventional air-cooling is reduced.





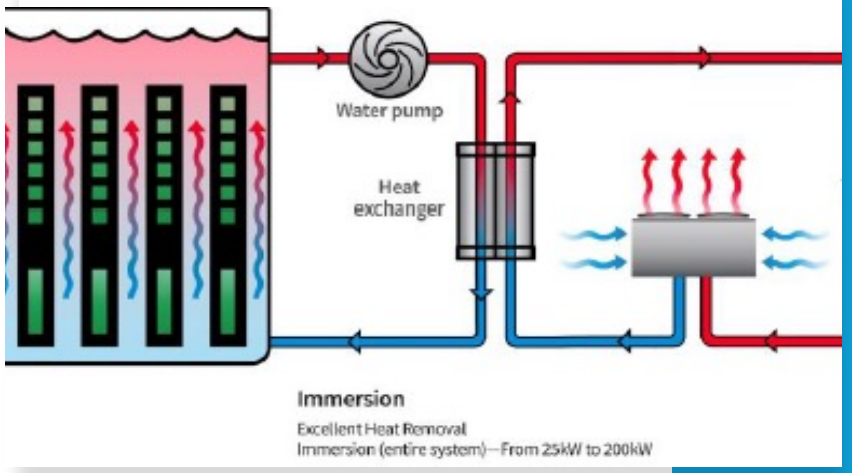
Cooling Distribution Unit (CDU) In a Data Center



Source: Emergence and expansion of Liquid Cooling in Mainstream Data Centers, ASHRAE

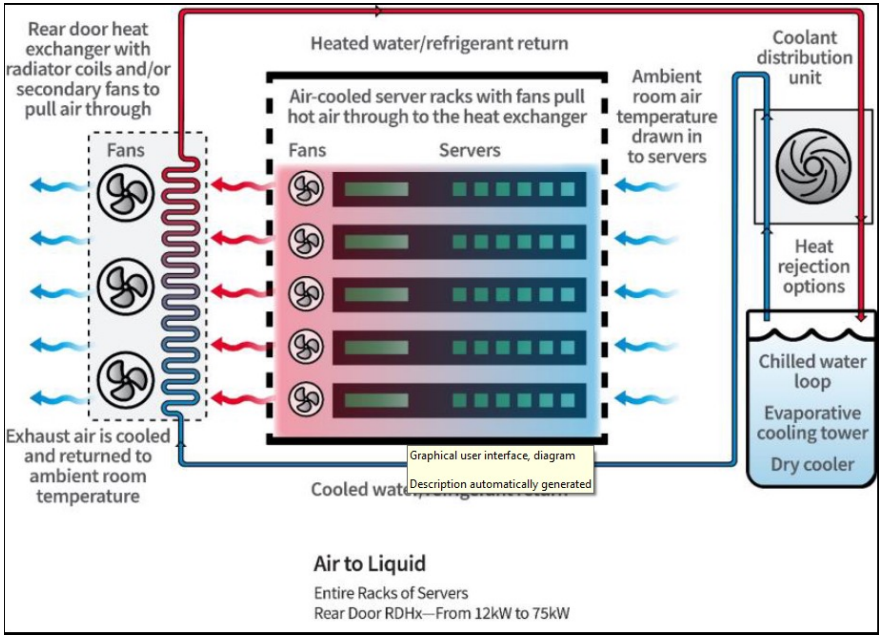
5b. Types of Liquid Cooling - Immersion

- Electronics are submerged in a non-conductive (dielectric) fluid.
- **Single Phase Immersion Cooling**: Heat load is transferred to dielectric fluid that is pumped around electronics by the CDU.
- **Two Phase Immersion Cooling**: The Dielectric fluid has a boiling point lower than the IT component's maximum operating temps.
  - The fluid removes the heat load and goes through a liquid-to-phase change.
  - The vapor transfers heat to a vapor-to-liquid heat exchanger which then condenses back to a liquid in a passive cycle.



5c.Types of Liquid Cooling - Rear Door Heat Exchanger

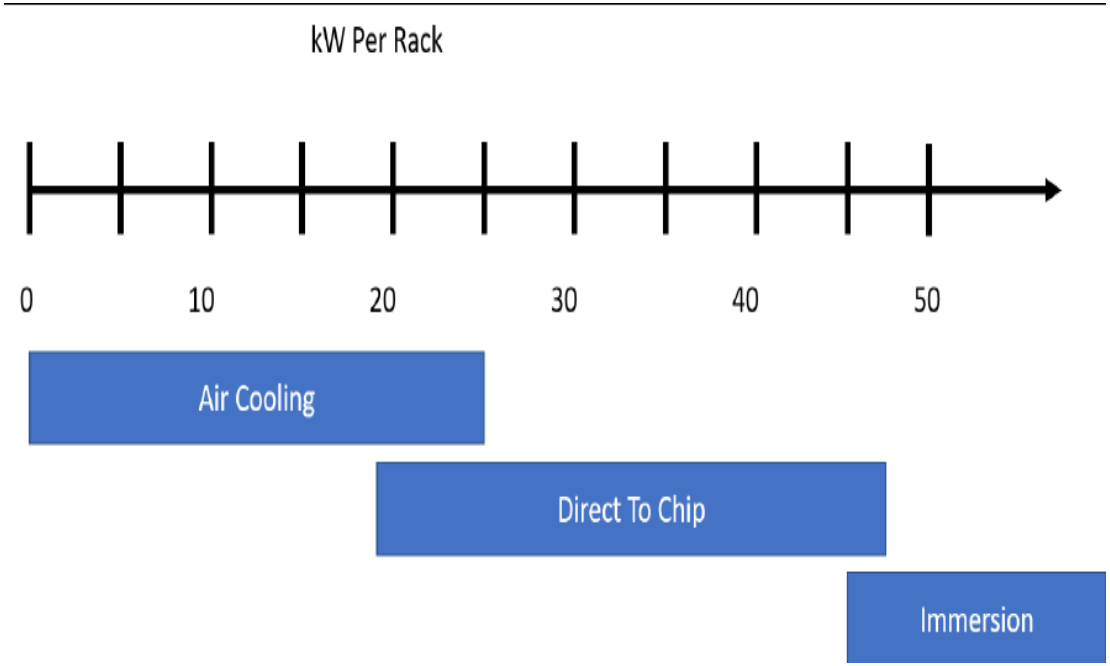
- Air-to-liquid heat exchanger is placed at the back of a server-rack that captures server heat.
- Variations: Rear-door heat exchangers, enclosed cabinet, in-row coolers, overheat coolers
- Options for cooling doors: active system where additional fans draw air through coils, or passive system where server fans move air through coils



6: Benefits of Liquid Cooling Options

Method of Cooling	Primary Benefit	Secondary Benefit
Direct To Chip	Range of Servers can be used	Lower fan speed, noise
Immersion	Most Efficient	Lowest/No Noise
Rear Door Heat Exchanger	Least Disruptive	Can be installed later

Benefits of Liquid vs Air Cooling



Benefits of Liquid Vs Air Cooling (Contd.)

Comparison of Cooling Modes for Air vs Liquid Cooled Servers			
Criteria	***Air-Cooled***	***Direct-to-Chip Liquid Cooled***	***Immersion Liquid Cooled***
Heat rejection from sever to space	Air, using onboard server fans	Forced convection heat transfer from processor cold plate to pumped liquid	Natural or forced convection heat transfer using dielectric fluid
Cooling medium	Fans or pumps for downstream for chilled water systems	Fans for residual air cooling, pumps for liquid	Pumps
Primary cooling equipment	DX CRAC units or chillers	Chillers with economizer available	Chillers with economizer when available
Heat Rejection to atmosphere	Condensers, cooling towers, dry coolers	Cooling towers or dry coolers	Cooling towers or dry coolers

Benefits of Liquid Cooling (contd.)

- Benefits:
  - Switching from Air-Cooling to Liquid Cooling reduces OPEX by ~ 40%
    - Liquid cooling saves energy
    - Additional power is saved by reducing system fan operation
  - Liquid cooling efficiency improves the PUE of data centers for high performance, esp. high power CPUs and GPUs
  - Liquid cooling lowers carbon emissions from reduced power usage
    - Enhances the sustainability of data centers
  - Liquid cooling promotes less jitter which occurs when CPUs or GPUs overheat or get close to their max. operating temperatures. The CPU will throttle back its performance to avoid damage to the chip.

Conclusion

- Selection of Cooling Types for a data center depends on the layout and the IT architecture
- Edge environments and old data centers are still air cooled
- However, for increased chip and rack power density and higher energy efficiency and cost focus, liquid cooling is the optimal cooling solution
- For retrofits, rack-based solutions like direct-to-chip and single-phase (IT chassis-based) immersive liquid cooling is easy to implement
- For new sites and harsh environments, immersive liquid cooling as it can capture all the heat and isolate IT from the surrounding air

6. Dominion Energy Incentives For Custom Cooling Solutions

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.

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