U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Cooling Data Centers with Warm Water

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Emerging Data Center Efficiency Technologies

- Redundancy in the Network rather than in the data center
- High voltage direct current (HVDC)
- Data centers as a hub for microgrids
- “Smart” AI enabled data centers
- Compressorless warm water cooling

Moving (Back) to Liquid Cooling

- As heat densities rise, liquid solutions become more attractive
- Volumetric heat capacity comparison:

(1.5 m^3)

Water

=

(5,380 m^3)

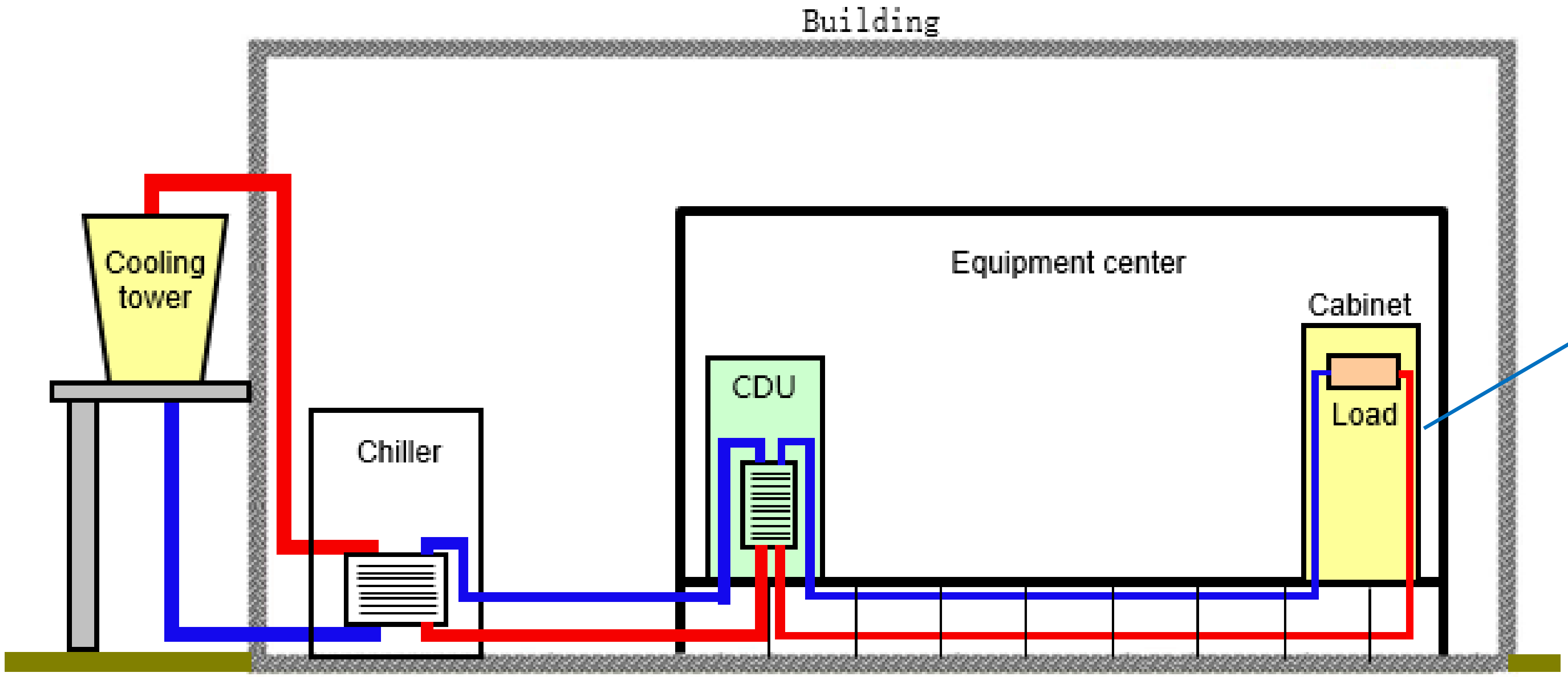
Air

Benefits of Liquid Cooling

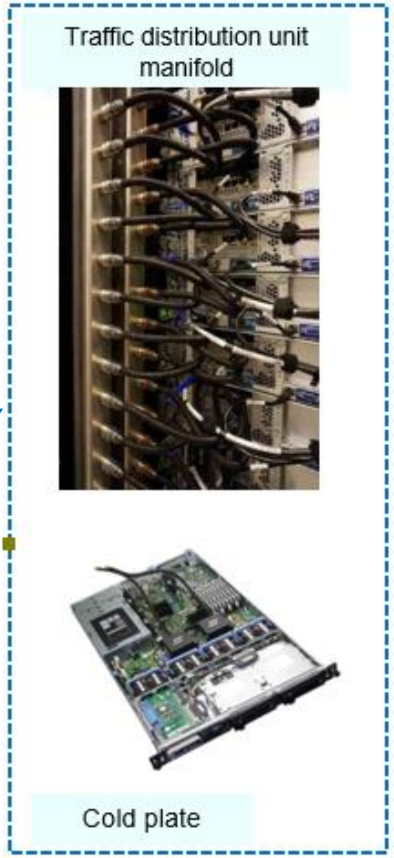
- **Higher compute densities**
- **Higher efficiency**
  - Cooling at higher temperatures
    - Improved cooling efficiency
    - Increased economizer hours
    - Potential use of waste heat
  - Reduced transport energy (x14)

➢ Vision: Eliminate compressor based cooling and water consumption

Typical Liquid Cooling Solution



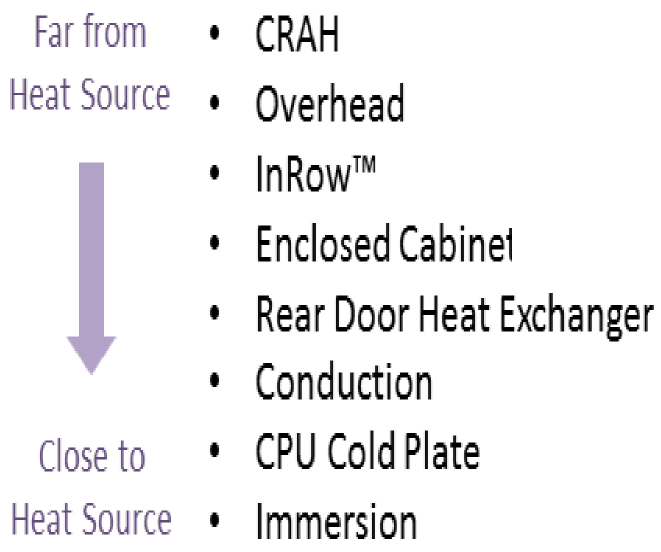
Typical liquid cooled equipment room, with external coolant distribution units (CDUs)



- For most locations data centers may be operated without chillers with a water-side economizer

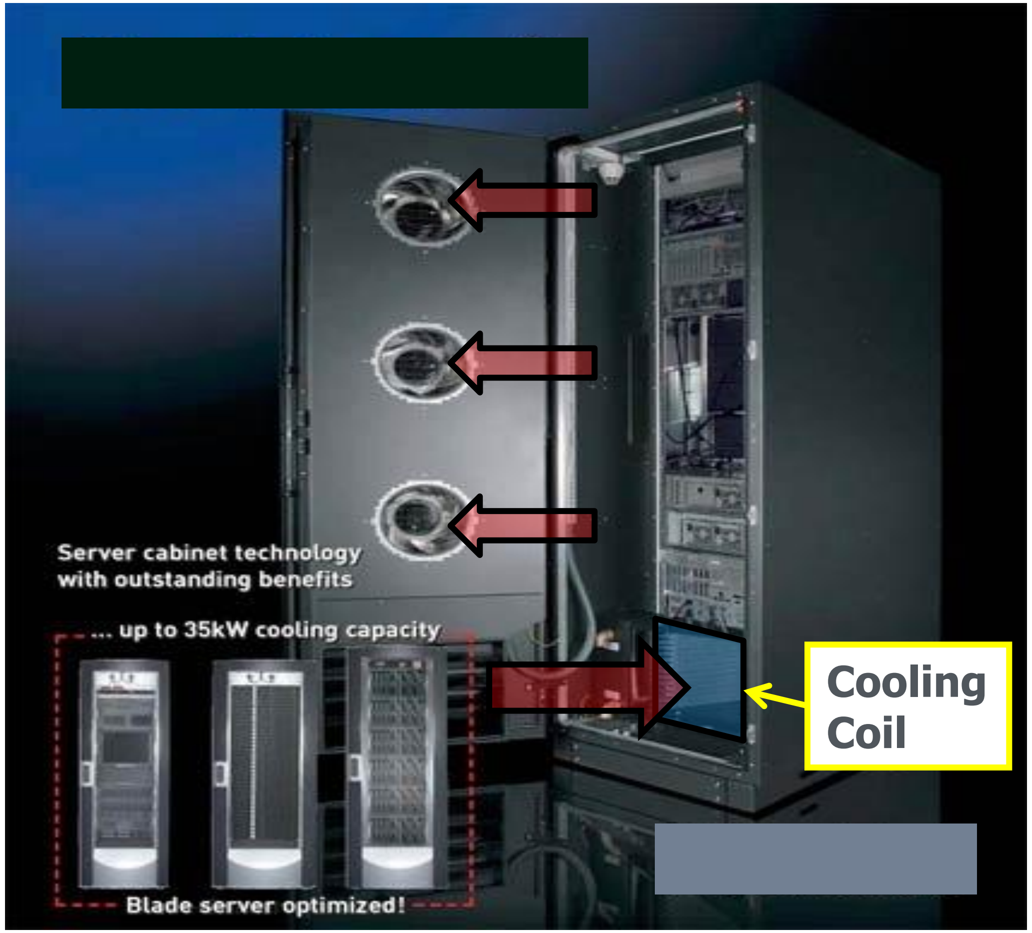
Liquid Cooling Techniques

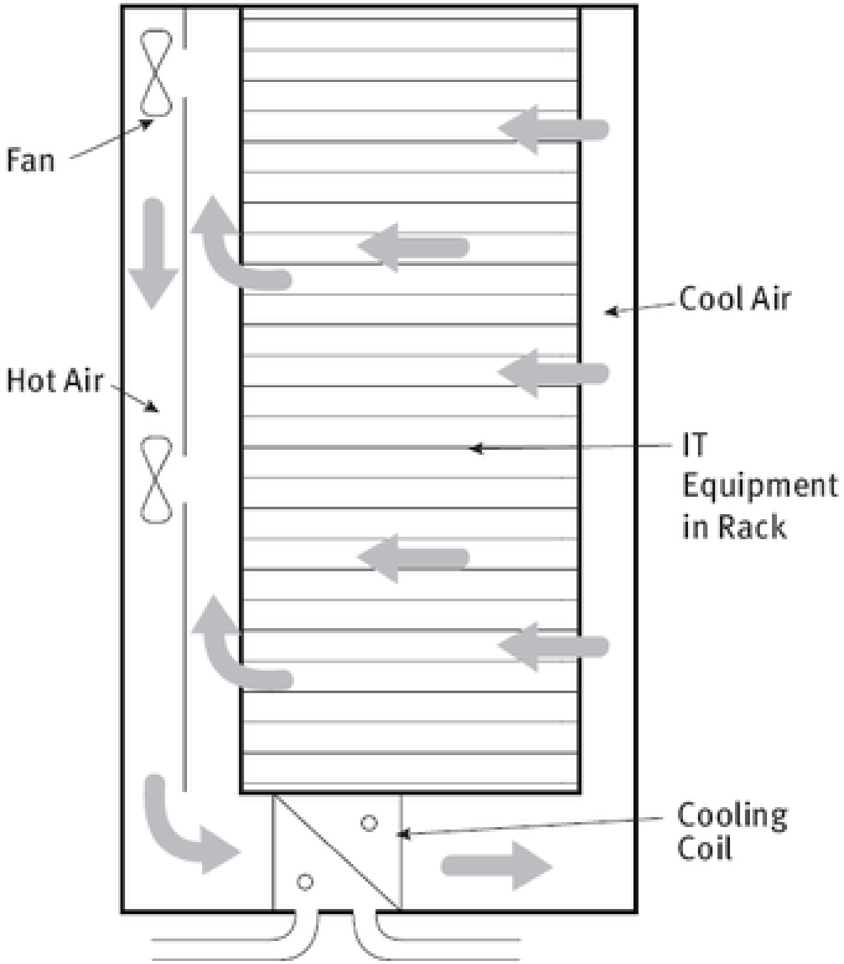
- CRAH, overhead, and in-row liquid cooling
- In-rack liquid cooling (enclosed cabinet)
- Rear door – passive and fan powered
- Cold plate
- Immersion



In-Rack Liquid Cooling

- Racks with integral coils and full containment:





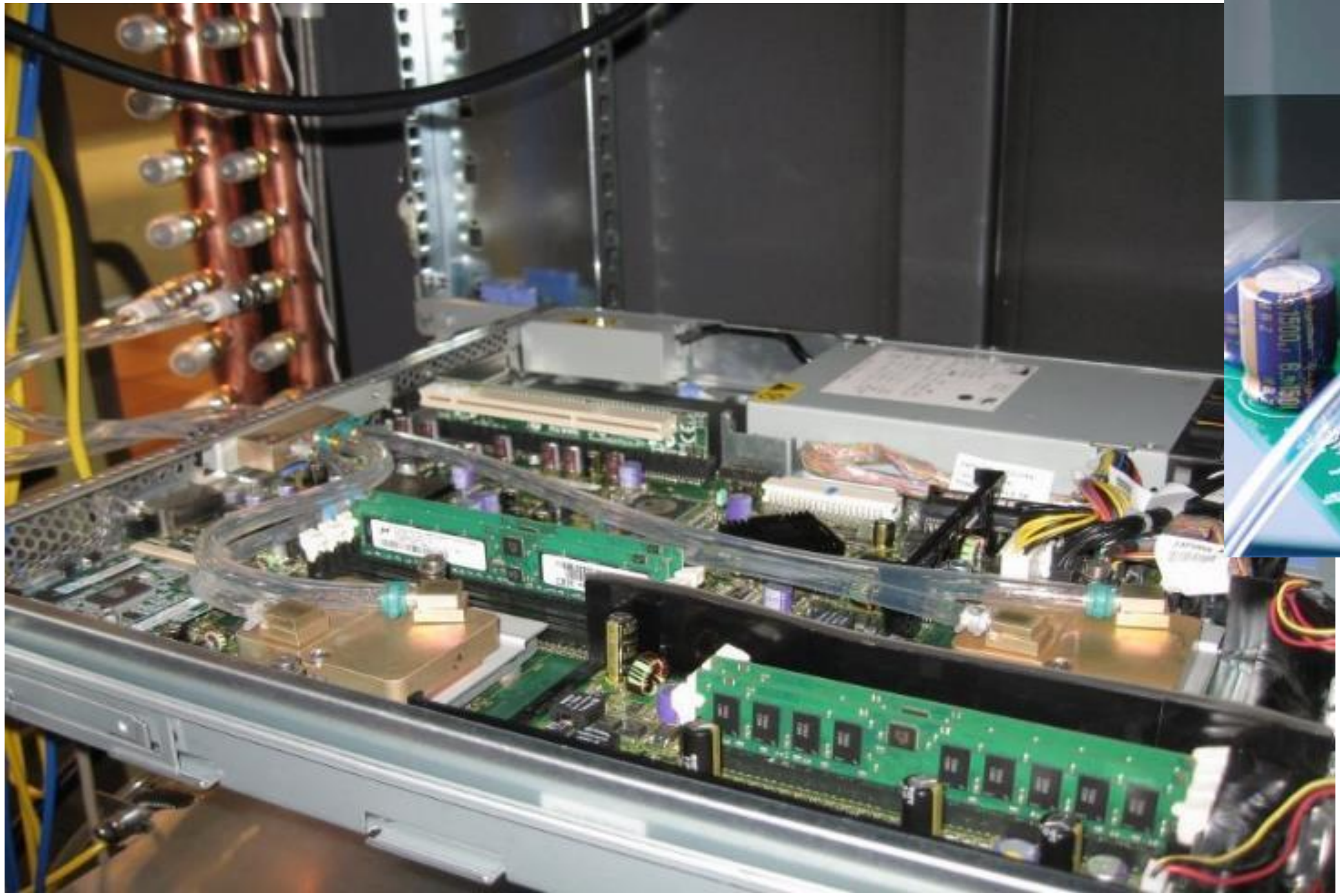
Rear-Door Heat Exchanger

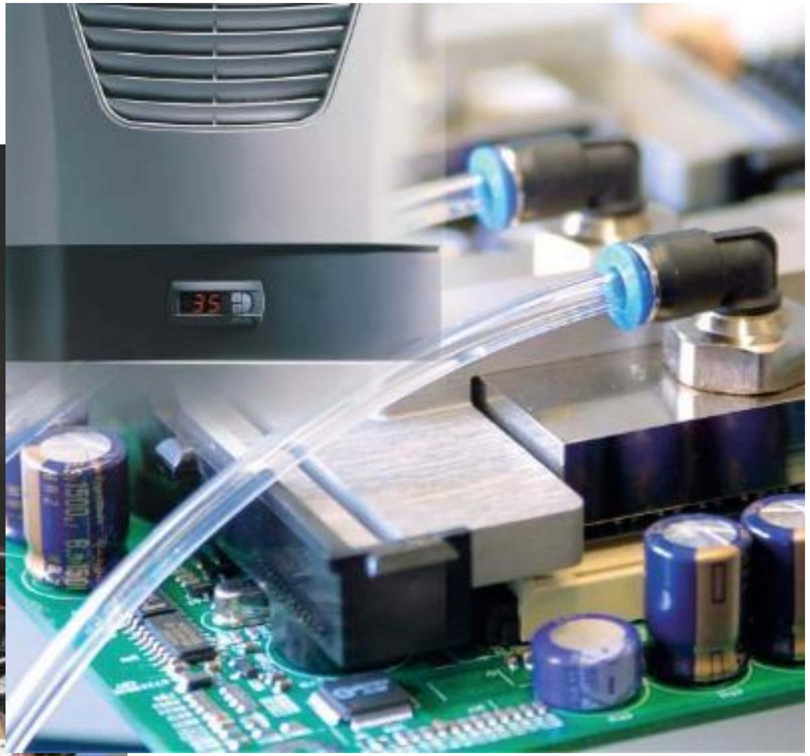
- Passive technology:
  relies on server fans for airflow
- Active technology:
  supplements server fans with external fans in door
- Can use chilled or higher temperature water for cooling

https://datacenters.lbl.gov/sites/default/files/rdhx-doe-femp.pdf

Photo courtesy of Vette

Liquid On-Board Cooling





Example: Maui DOD HPC Center Warm Water Cooling

Liquid cooled rack

- 90% water cooled
- 10% air cooled
- Cooling water temperature as high as 44°C

Water inside

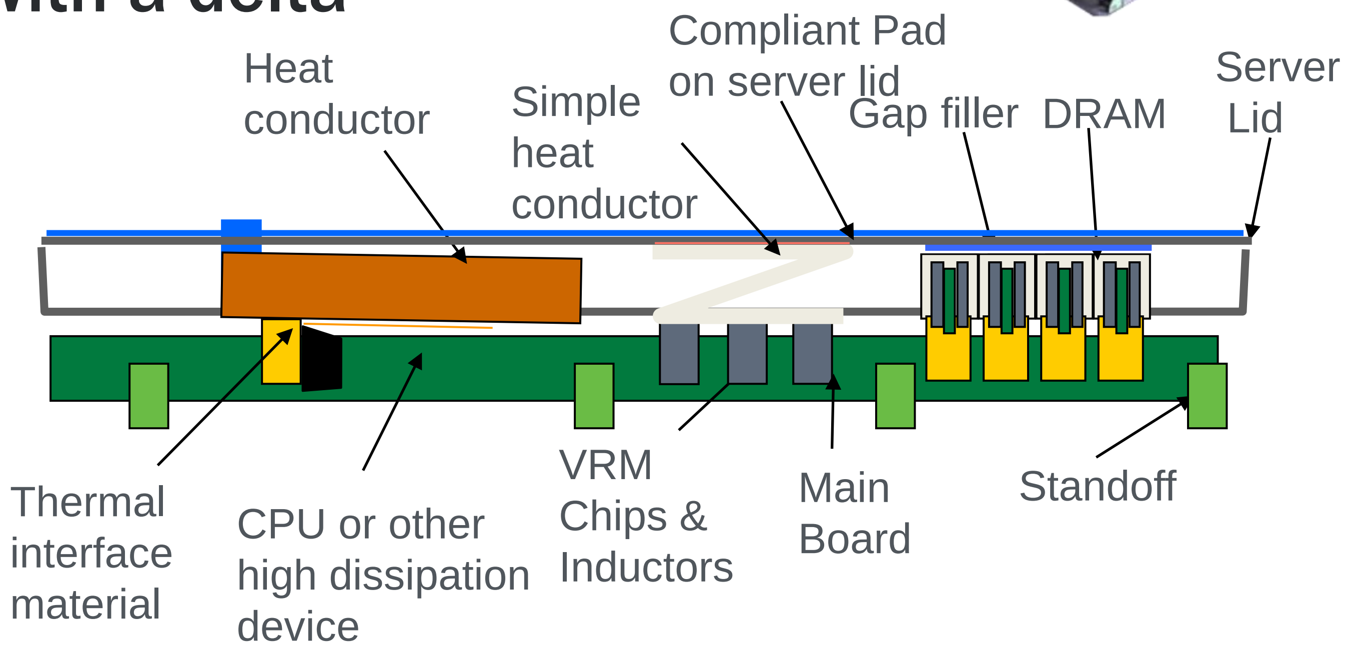
Dry Coolers, 10 kW each
compared to 100 kW Chillers

https://datacenters.lbl.gov/sites/default/files/MHPCC%20White%20Paper%20_Mahdavi-July%202014.pdf

Cold plate variation

- Heat exchanger plate covers top of server and heat risers connect
- Test at NREL and SNL
- Server fans removed, 90+% liquid cooled
- Nodes never throttled back while testing between 24C – 35C entering with a delta of 7 to 8 degrees

www.nrel.gov/docs/fy19osti/73356.pdf



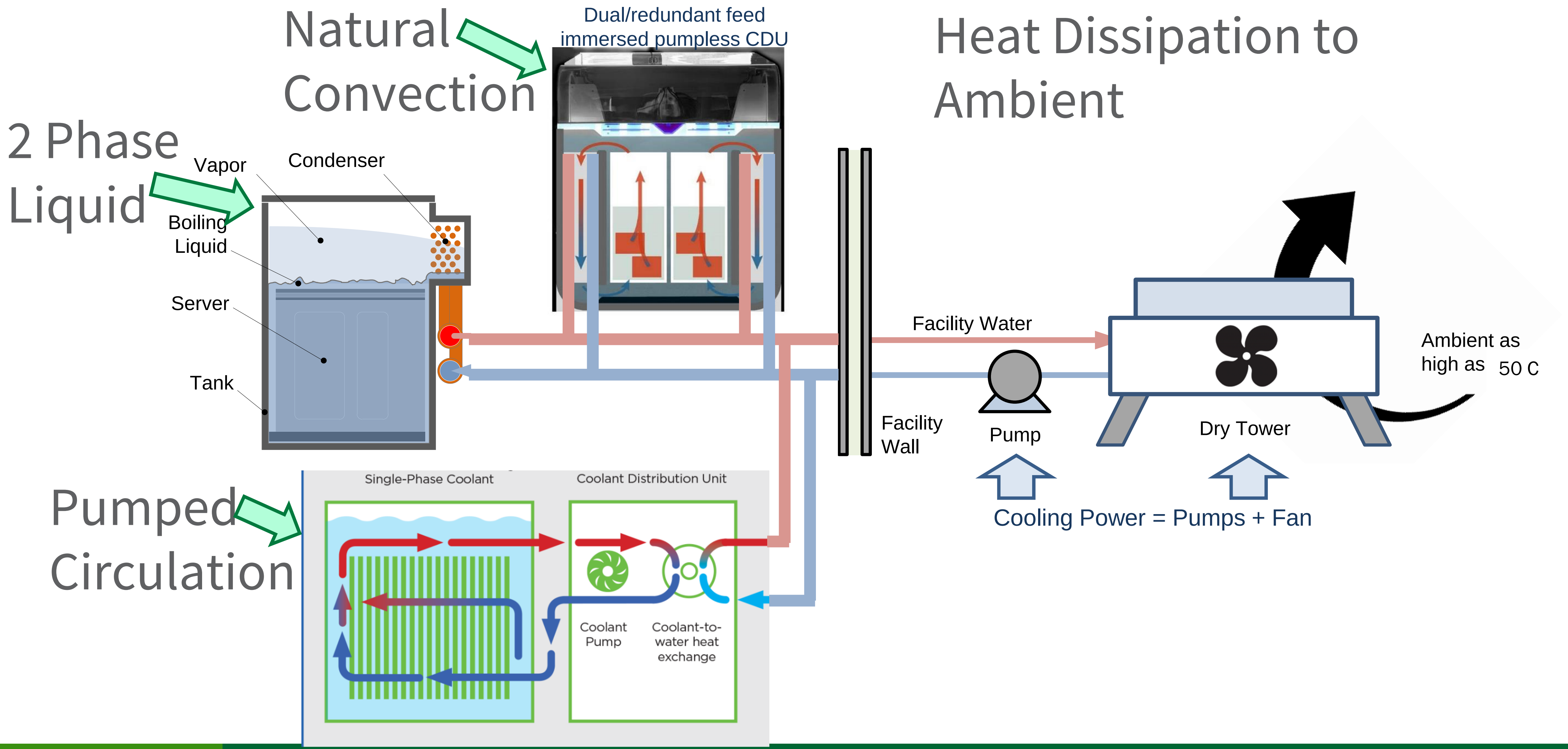
Cold plate variation

- Cold plates under negative pressure: Sandia National Lab Test
- ~30 kW per rack 12 volt DC (OCP Bus Bar)
- 70% liquid cooled, medium temp supply water 21 C, return water ~32 C, entering air temp 26 C

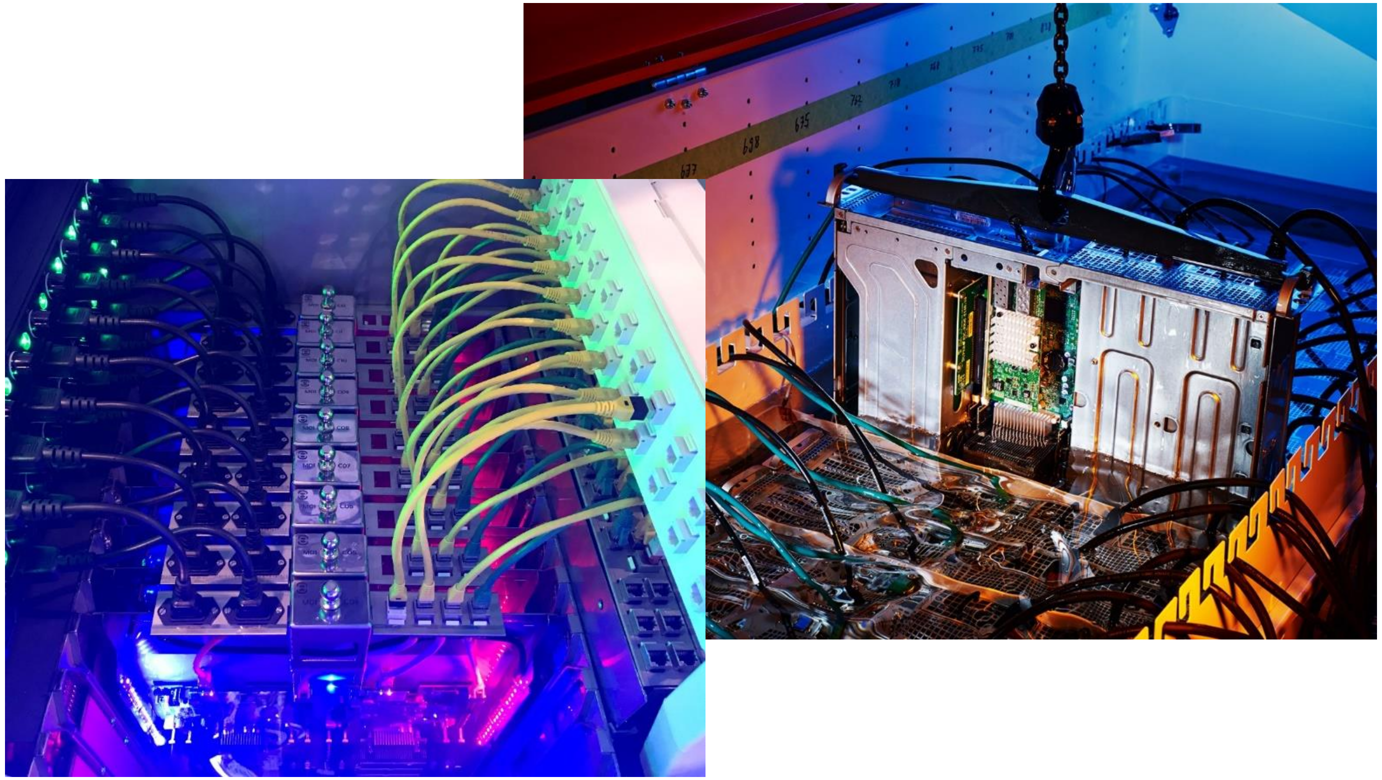
https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2020/206888r.pdf

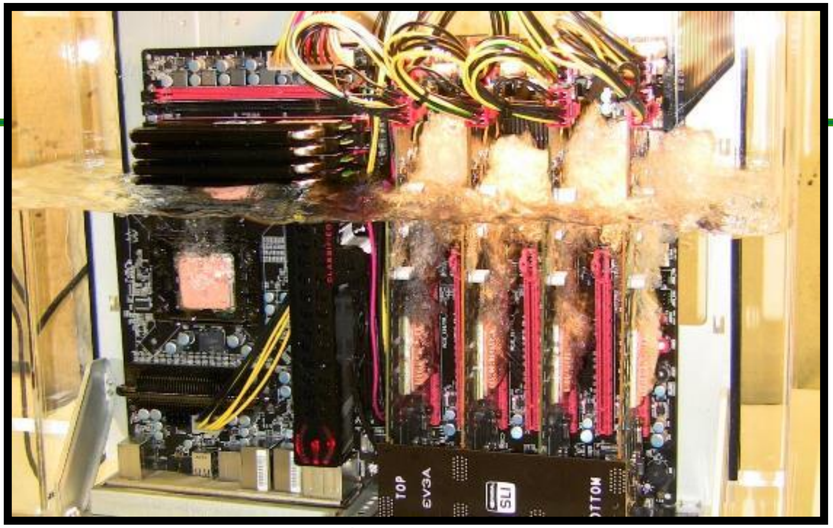
Negative pressure CDU

Liquid Immersion Cooling

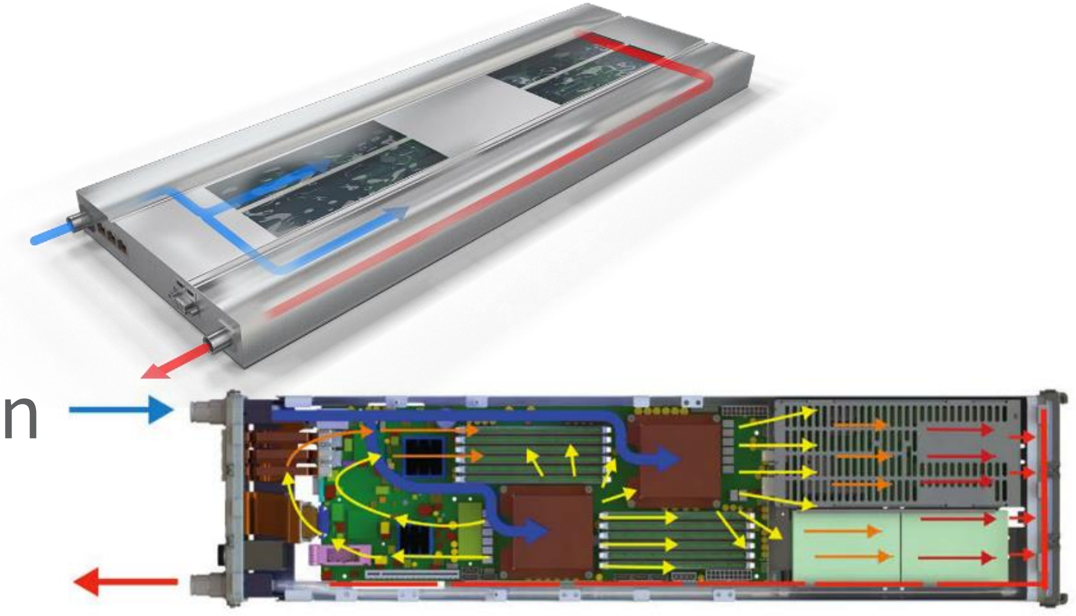


Liquid Immersion Cooling



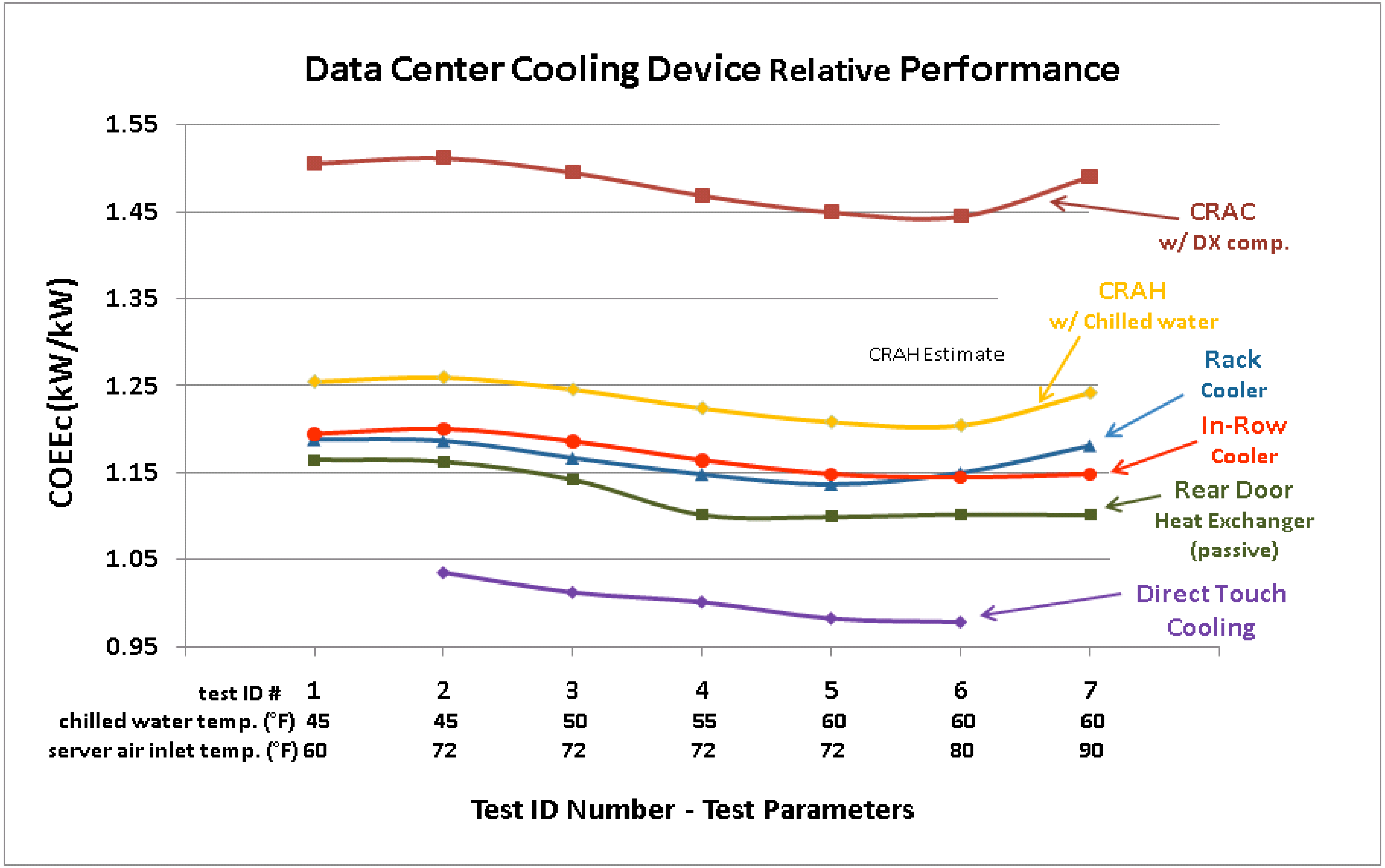


2-phase, fluorocarbon



Single phase, hydrocarbon or fluorocarbon in tank (above) or in “Clamshell” (to right)

"Chill-Off 2" Evaluation of Liquid Cooling Solutions



“Free Cooling” w/ Water-Side Economizers

- Cooling without Compressors
- Less space/easier retrofit
- Added reliability (backup in case of chiller failure)
- No contamination issues
- Put in series with chiller
- Uses tower or dry cooler

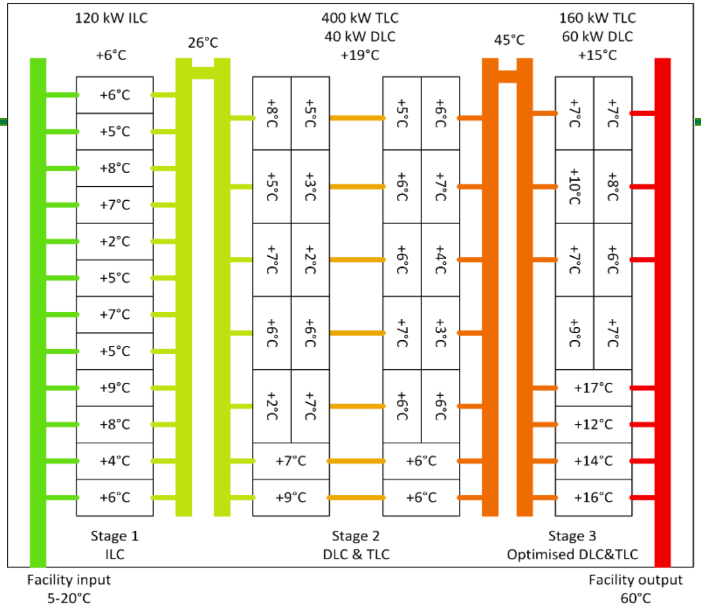
No or minimum compressor cooling

Cooling tower and HX = Water-side Economizer

Cascading Temperatures

TECHNOLOGY	TYPICAL INLET RANGE		"W" CLASS	LBNL ZONE
	NORMAL	EXTREME		
CRAH	6-18°C	21°C	1	1
Rear Door	18-23°C	29°C	2 & 3	2
Cold Plate	18-40°C	45°C	3 & 4	3
Immersion	18-40°C	55°C	4 & 5	3

"Extreme" is the maximum inlet temperature for specific systems and may not represent all available options



https://www.asperitas.com/wp-content/uploads/2019/03/Asperitas-The-Datacentre-of-the-Future.pdf

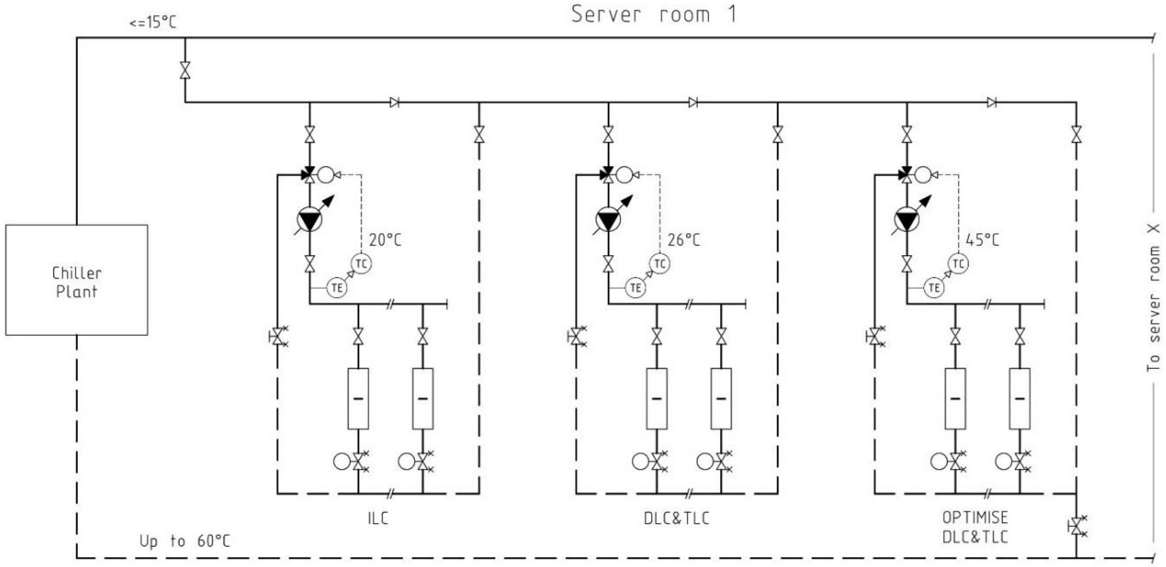


Image 11 Chiller based Temperature Chaining by Tebodin Bilfinger

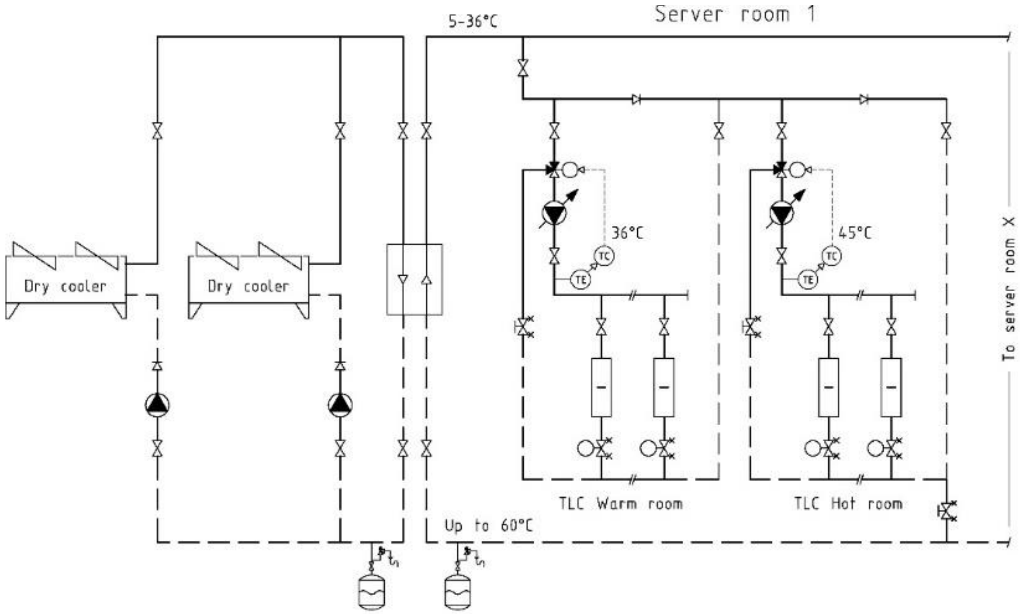


Image 12 Free Cooling based Temperature Chaining by Tebodin Bilfinger

Re-Use of Waste Heat

- **Heat from a data center can be used for:**
  - Heating adjacent offices directly
  - Preheating make-up air (e.g., "run around coil" for adjacent laboratories)
- **Use a heat pump to elevate temperature**
  - Waste heat from LBNL ALS servers captured with rear door coolers feeds a heat pump that provides hot water for reheat coils
- **Warm-water cooled computers are used to heat:**
  - Greenhouses, swimming pools, and district heating systems

Resources: Center of Expertise for EE in Data Centers

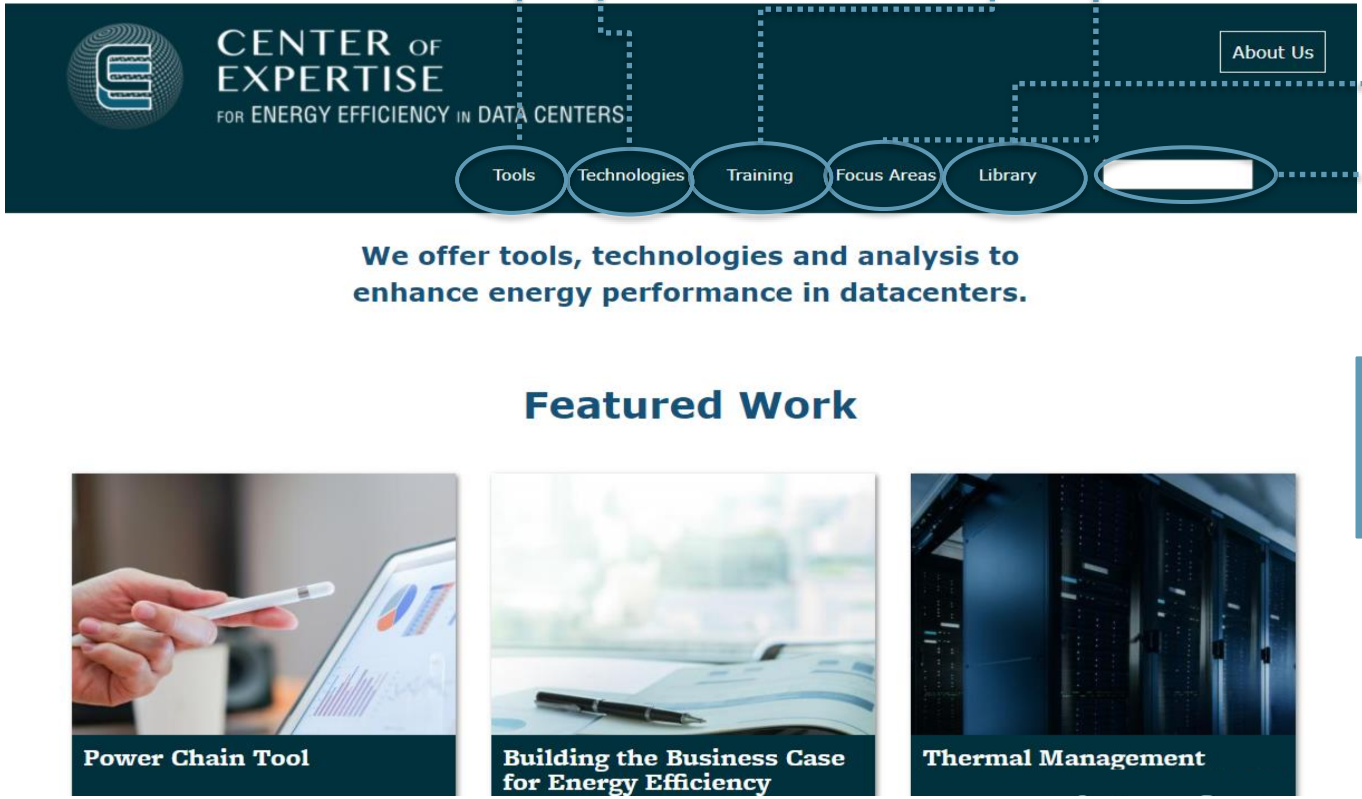
Use CoE's Energy Efficiency Toolkit.

Explore various EE technologies and solutions.

Choose from upcoming live webinars, pre-recorded trainings, and in-person Data Center Energy Practitioner (DCEP) trainings.

Explore the various focus areas of the CoE.

Filter CoE's many resources by type and topic.



Search resources by topics of interest.

Visit us at datacenters.lbl.gov

Conclusion

- Need to move to compressorless cooling
- Waterless and heat recovery are further goals
- Facility needs a “warm” water loop
  - ✓ Using chilled water doesn’t capture many of the benefits (efficiency, reliability, simplicity, first cost)
  - ✓ Can start with water fed CRAC units, move to rear doors (good transitional technology), and ultimately to cold plates and/or immersion

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