WHITE PAPER: EVALUATING LIMITS OF DOOR HX SOLUTIONS IN DIFFERENT APPLICATIONS

Advanced Cooling Solutions – Door Heat Exchangers

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Objectives & Scope

Assumptions:

- Conventional assumptions about Rear Door Heat Exchanger Operation:
  - Only suitable for W17/W27 systems
  - Limited heat transfer capacity due to dimensions and airflow rate
  - Relatively cold Inlet air temperatures of 20-25°C required
  - Not viable in datacenters designed for heat reuse

Objectives:

- To show that Rear Dood Heat Exchangers optimized for ORv3 can achieve:
  - Airside ∆T of 12-15°C with 30-35°C inlet temperatures
  - Reduced approach temperatures
  - Enhanced cooling capacity with warmer FWS supply temperatures, i.e. Up to W32 temperatures
  - Water outlet/return temperatures above 40°C (possible re-use for indoor heating)

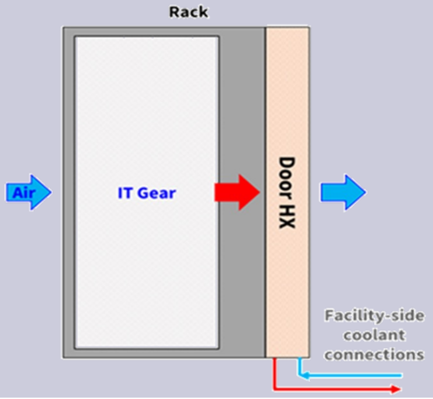
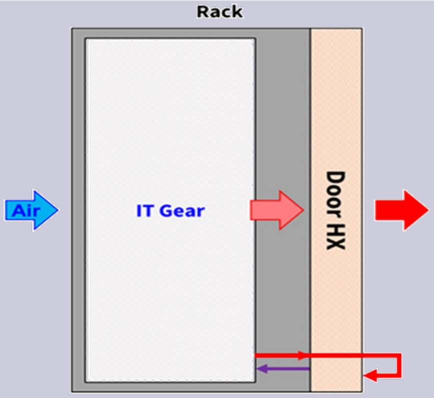
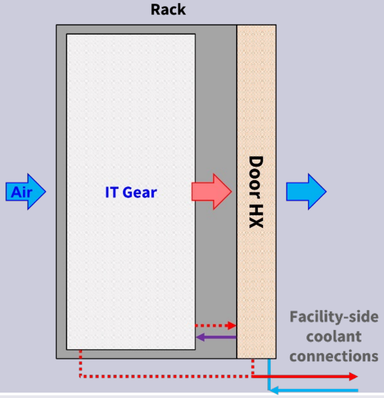
Scope of Analysis:

- Air-side operating conditions: 35°C ambient; sea-level operation; Target delta-T of 12°C - 15°C
- Liquid-side operating conditions: Treated water; W32 facility water system
- ORv3 Server Rack up to 33kW
- RDHx design parameters: approach T, airside delta-T, supply and return water temperatures

Facility Designs & Limitations

	Rear Door Heat Exchanger Advantages		
Facility Configurations and Limitations	Traditional	Hybrid	Air-Assisted
Air Economized • Limited to (<20 kW/rack) • Class A1-A4 Recommended (18°C-27°C air, -9–15°C max DP, 60% RH) • Server air ΔT of 21-28°C @ 25°C inlet T Room CRAH OR In-row CRAH both with Hot Aisle Arrangements • Limited to (<20W/rack) • 6°C – 9°C/15°C chilled water supply • Class A4 Allowable (5°C-45°C air, 24°C max DP, 8%-90% RH) • Server air ΔT of 15-22.5°C @ 35°C inlet T	-	-	• >10kW/rack additional cooling capacity • Additional server air ΔT of 12-15°C • Ability to position high-power racks next to lower-power, air-cooled racks. • N+1 or 2N redundancy is achievable for lower-power racks • Direct cooling of high-power IT equipment.
CRAH + No Aisles OR In-row CRAH • Limited to (20 kW/rack) • 6°C - 9°C chilled water supply • 6°C - 15°C with water optimized facilities • Class A4 Allowable (5°C-45°C air, 24°C max DP, 8%-90% RH) • Server air ΔT of 15-22.5°C @ 35°C inlet T	• >10 to 100kW/rack additional cooling capacity. • Additional server air ΔT of 12-15°C • Direct cooling of high-power IT equipment. • Ability to position high-power racks next to lower-power, air-cooled racks. • N+1 or 2N redundancy is achievable for lower-power racks		-

Comparing Door Heat Exchanger Solutions

<table>
<tr><th colspan="4">Summary of Thermodynamic Limitations</th></tr>
<tr><td rowspan="2">Technology</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Traditional</td><td>Air-Assisted</td><td>Hybrid</td></tr>
<tr><td>Consequences of Server Upgrades</td><td>More power density dissipated into the air</td><td colspan="2">Greater power density dissipated into the cold plates and air</td></tr>
<tr><td>Power Density</td><td>Medium</td><td>High</td><td>Very High</td></tr>
<tr><td>Limits</td><td>Performance limits on chip heat sinks</td><td>Very high airflow rate
Air velocities across servers and facilities</td><td>Air flowrate
For cooling secondary components</td></tr>
<tr><td>Challenge and Problem</td><td>Need to reduce air and water temperature. Refrigeration power consumption increases</td><td>Upgrading of cooling facilities. Maximum regional ambient temperature.</td><td>Water connections to the door</td></tr>
<tr><td>Efficiency</td><td>Low
Chiller Required</td><td>Very High
If only ambient air is used</td><td>High
Using free cooling to cool the cold plates</td></tr>
</table>

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White Paper Technical Analysis

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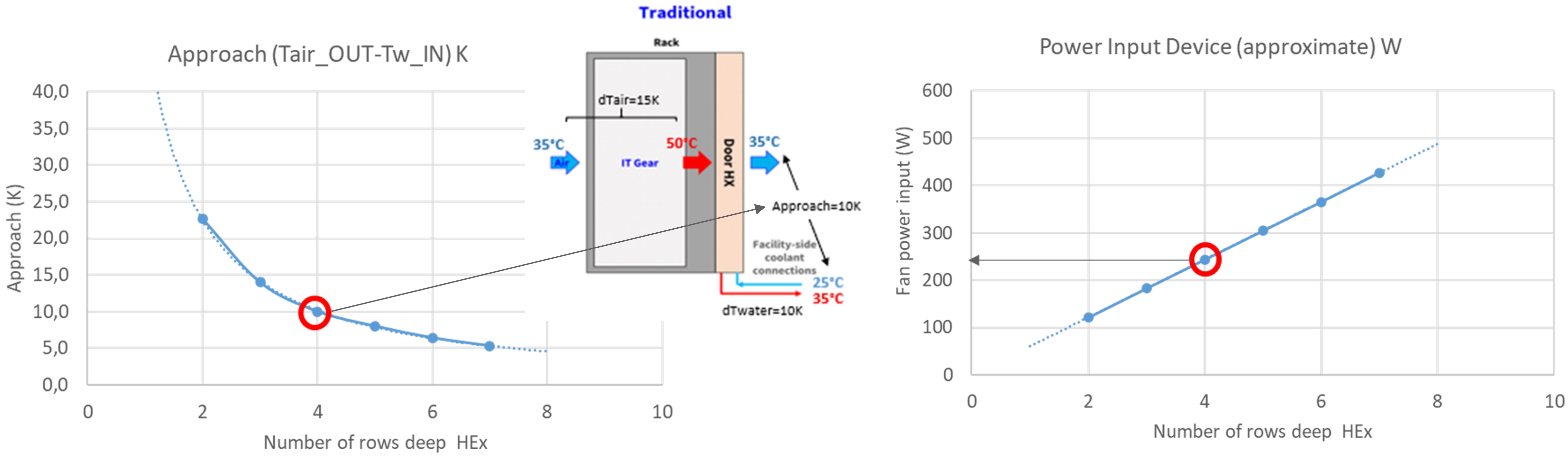
White Paper Technical Analysis

- Illustrating with two different Door HX designs
  - Standard/Off-The-Shelf vs Custom/Optimized for Open Rack V3
- Performance under specific applications
  - Traditional
  - Air-assisted
  - Hybrid
- Summary of benefits and limitations (of each of the three above)
- Next steps/takeaways/call-to-action

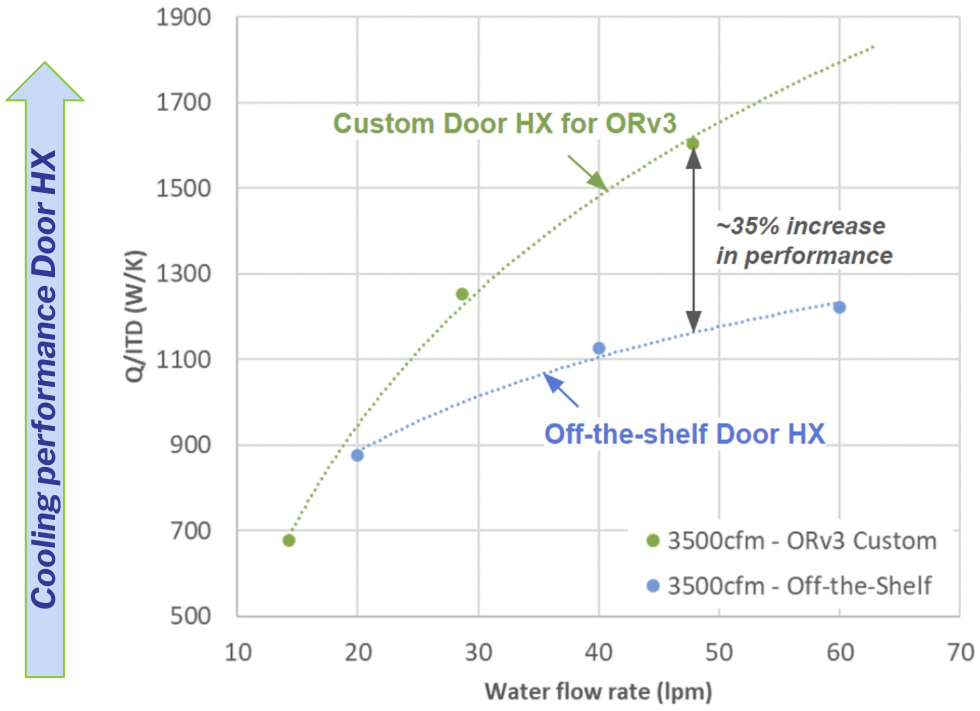
Performance Depends on HX Design



By increasing the size of the heat exchanger:
Increase the heat exchanger **performance**

By increasing the size of the heat exchanger:
Increase the **energy consumption of the fans**

Illustrating with Two Door HX Designs

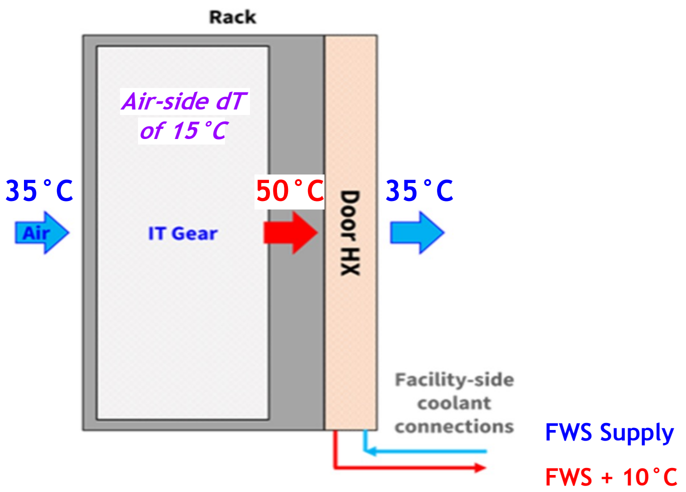


By optimizing the heat exchanger design, performance is improved.

Consequences:

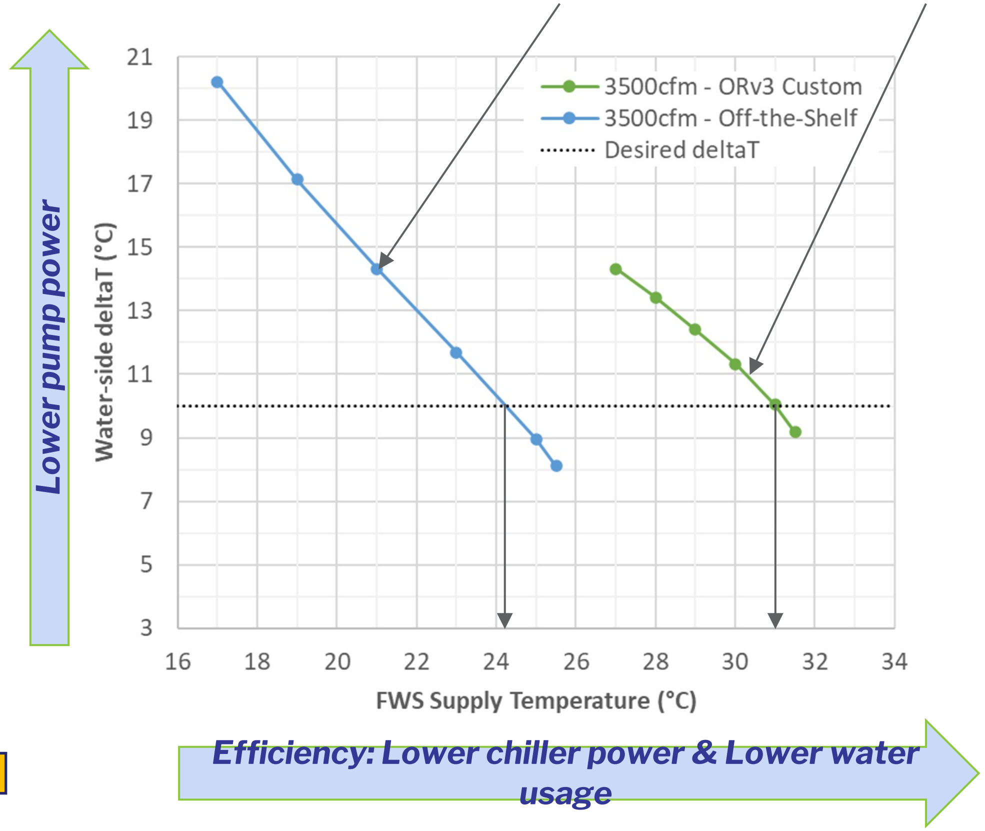
1. Increase of the maximum **cooling power per rack**.
2. Increase of the **energy efficiency** by increasing the air and water supply temperatures and the intensive use of **free cooling**.
3. Small increase of the **fan power** due to the increase of the air pressure loss in the heat exchanger.
4. Small increase in CAPEX, which is more than compensated for by energy efficiency (**better TCO**).

Application: Traditional Door HX

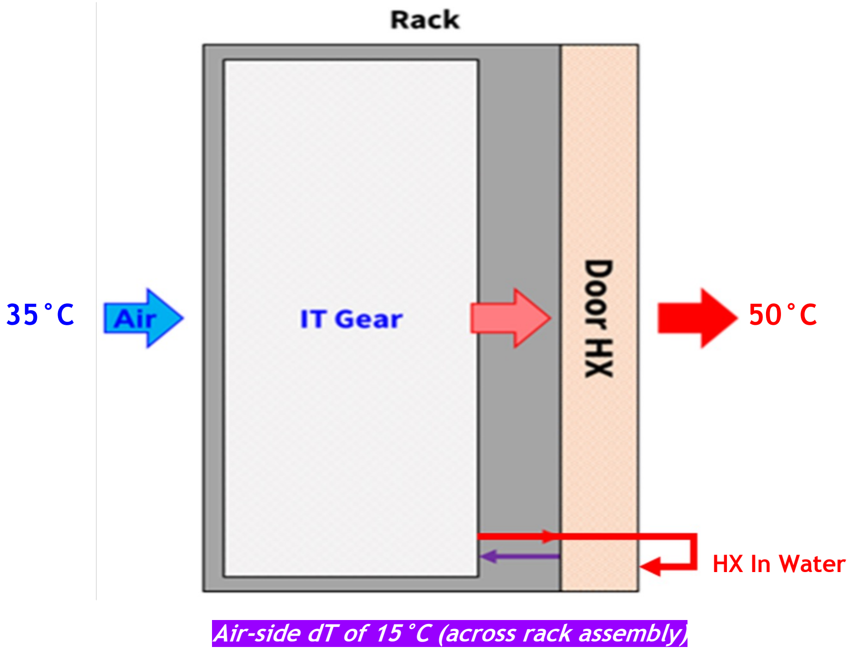


Traditional Door HX		
	Off-the-Shelf	Customized
Airflow (cfm)	3500	3500
Cooling Capacity (kW)	29.49	29.49
FWS Supply (°C)	24.2 →	31.0

Optimizing the heat exchanger allows us to increase the water temperature (6,8K) while maintaining the cooling capacity.

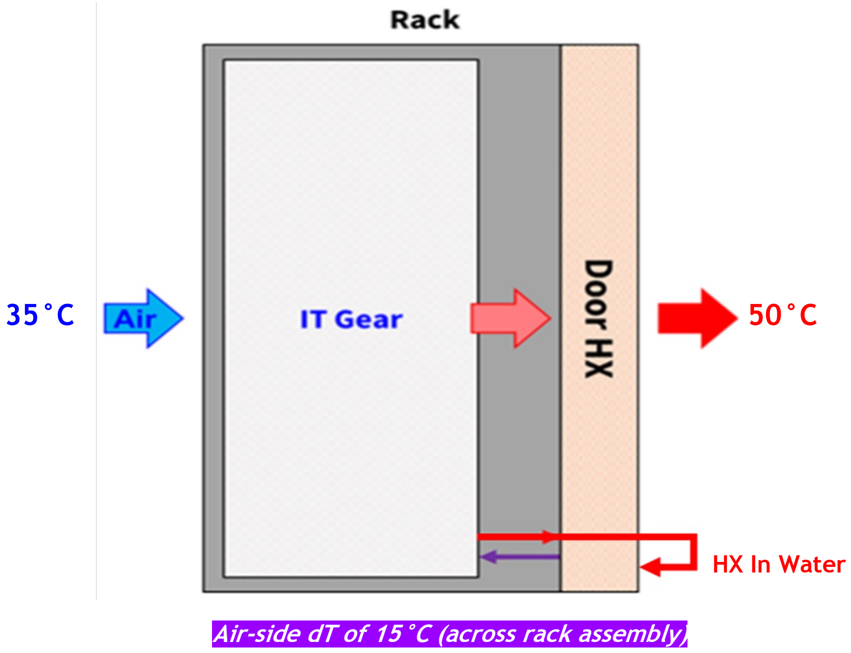


Application: Air-Assisted Solution

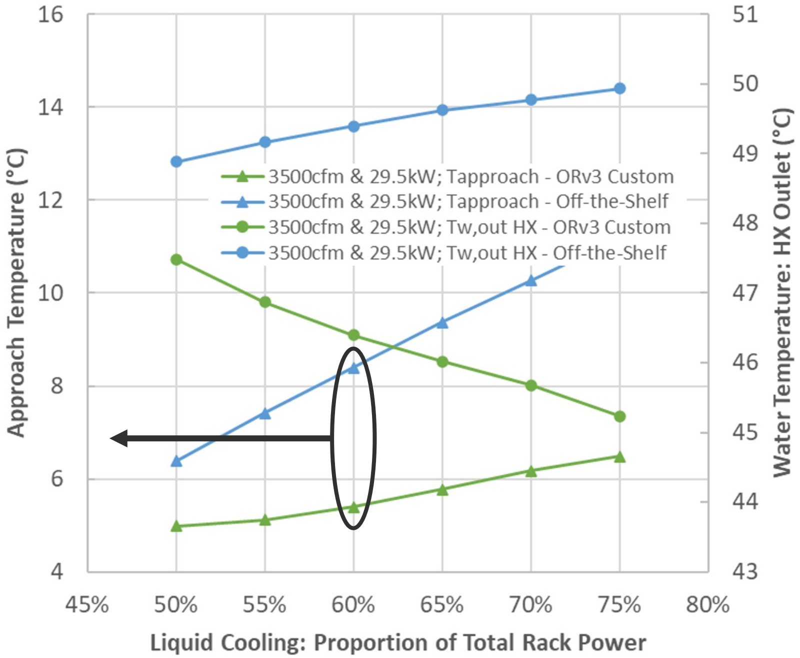


1. This technology is optimal for use in air-cooled data centers.
2. Consequences of increasing server inlet temperature to 35°C:
   - reduce the use of energy for air cooling
   - reduces water consumption
3. Consequences of optimizing the heat exchanger
   - Increased power dissipation limit on cold plates

Application: Air-Assisted Solution



By optimizing the heat exchanger; approach temperature is reduced

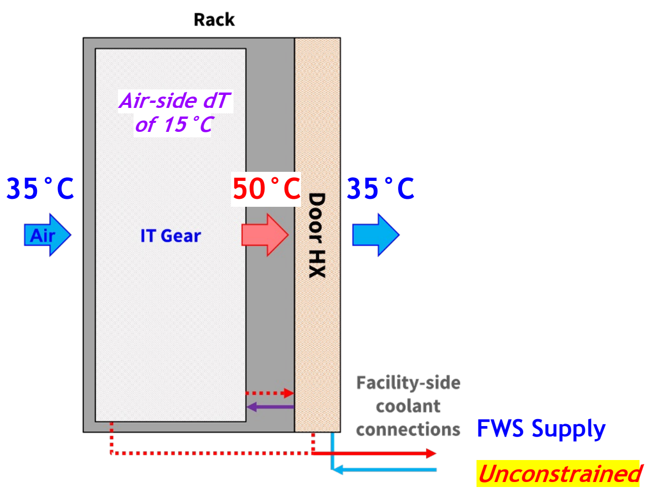


Performance scales with facility supply air/cold aisle temperature

Observations:

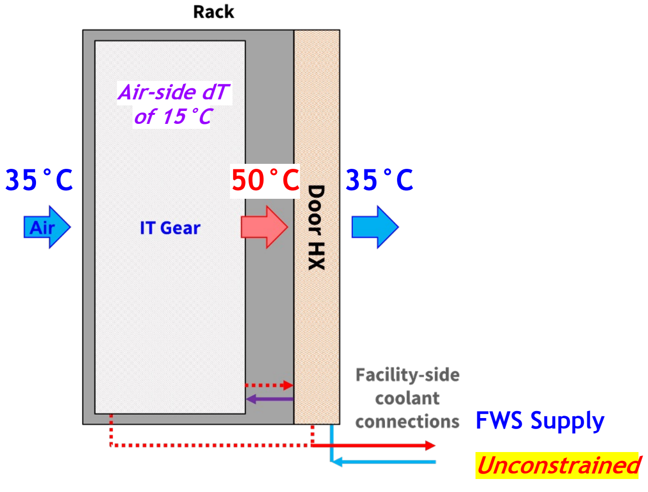
- [*Off-the-Shelf*] For 35˚C facility air supply, 48~50˚C water to cold plates is achievable for %LC between 50~75%
  - Considering a cold plate resistance (case-to-inlet) of ≤ 0.04˚C/W, a 500W component with a case temperature specification ≥ 70˚C could be supported
- Approach temperature varies significantly with LC load, but is counteracted by air-side preheat from IT gear
- [*ORv3 Custom*] Decreases water temperature to cold plates by 2~5˚C; gap is larger when %LC is higher

Application: Hybrid Solution

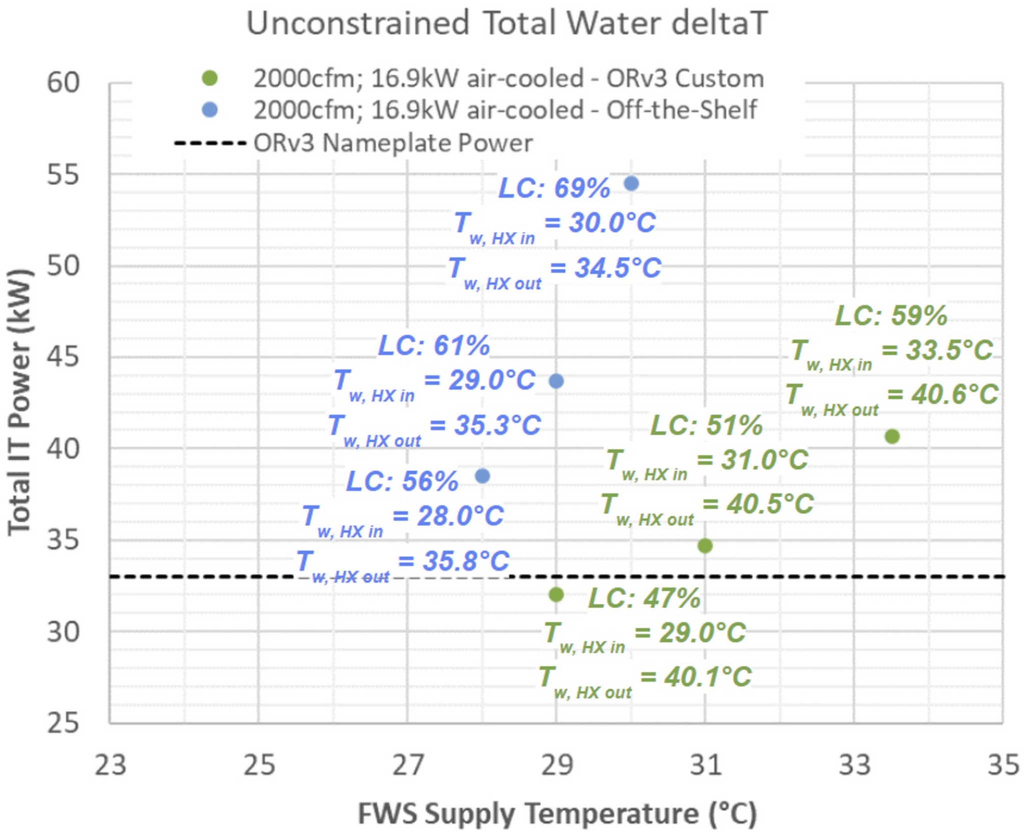


- Like the traditional application, the optimized heat exchanger allows us to work with higher fluid temperatures.
- The advantages are similar to the traditional one:
  1. Increase of the maximum **cooling power per rack**.
  2. Increase of the **energy efficiency** by increasing the air and water supply temperatures and the intensive use of **free cooling**.
  3. Small increase of the **fan power** due to the increase of the air pressure loss in the heat exchanger.
  4. Small increase in CAPEX, which is more than compensated for by energy efficiency (**better TCO**).

Application: Hybrid Solution



Unconstrained water-side dT (10˚C across IT gear liquid only)		
Airflow (cfm)	2000	2000
Max Cooling Capacity (kW)	54.5	40.7
Max FWS Supply (˚C)	30.0	33.5
Water to cold plates (˚C)	34.5	40.6



Summary of benefits and limitations

- Increasing the air temperature in the servers **increases facility energy efficiency and reduces water consumption**.
- A small increase in the size of the heat exchanger leads to a **large reduction in facility energy and water consumption**.
- A small increase in the size of the heat exchangers also **increases the power per RACK**.
- Limits: An excessive increase in the size of the heat exchanger greatly increases the **pressure losses** (increasing with the square of the air velocity) and thus the **consumption of fan power**.

Next steps/takeaways/call-to-action

Next steps: Define a new framework that redefines the boundary conditions in data centers.

Takeaways: A great increase in energy efficiency is possible with Door HX technology. Door HXs optimized for ORv3 can increase cooling capacity using facility air and water temperatures warmer than those currently existing.

Call-to-action: We ask all vendors and professionals interested in the development of this technology to help us improve and promote this working group.