Valorization of Data Center Heat to Support US AI Dominance

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Goal: Support US AI Leadership through Data Center Heat Valorization

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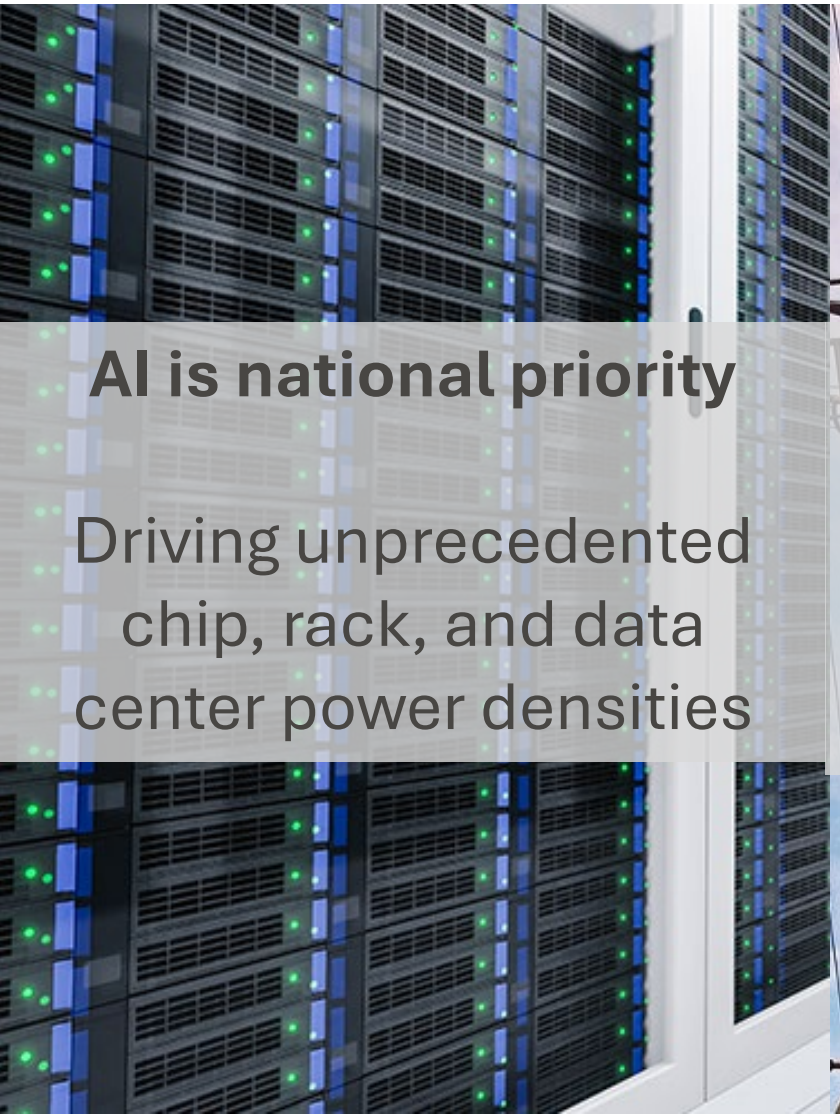
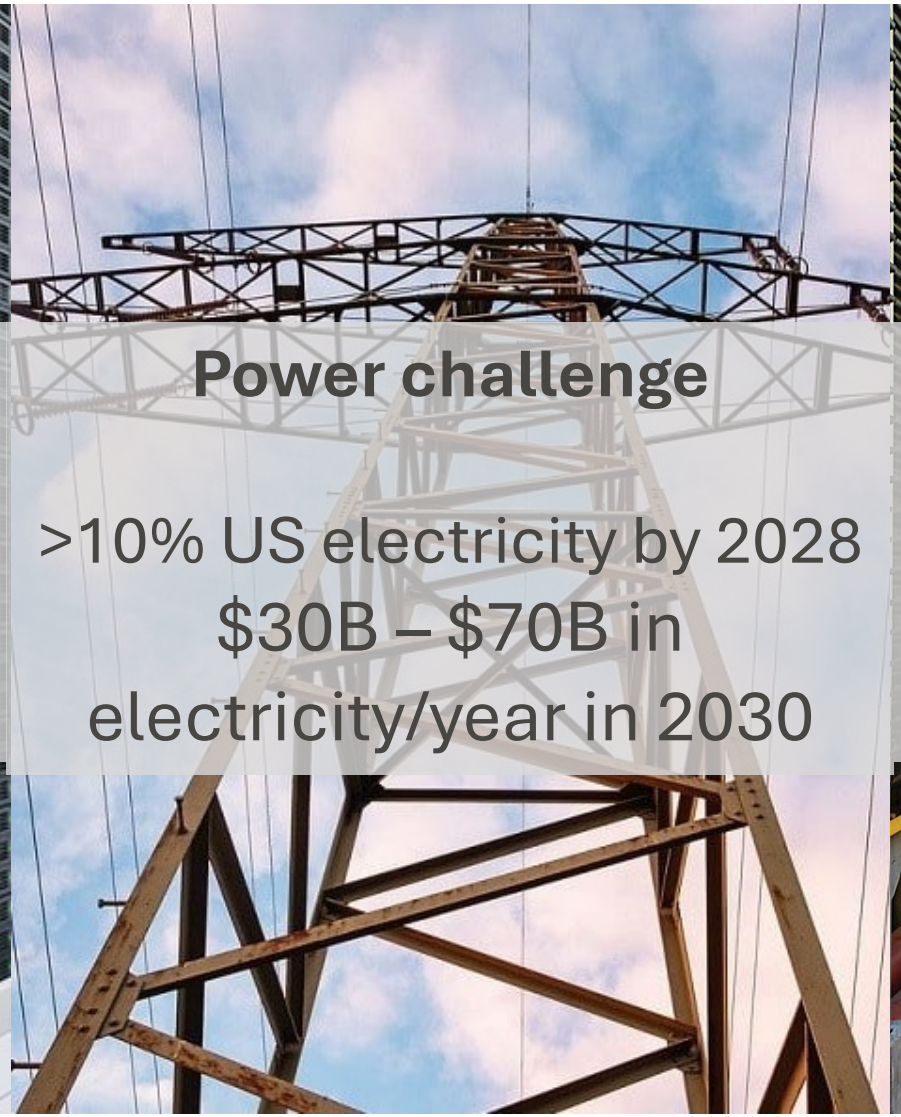
Data centers are a current priority and challenge



AI is national priority

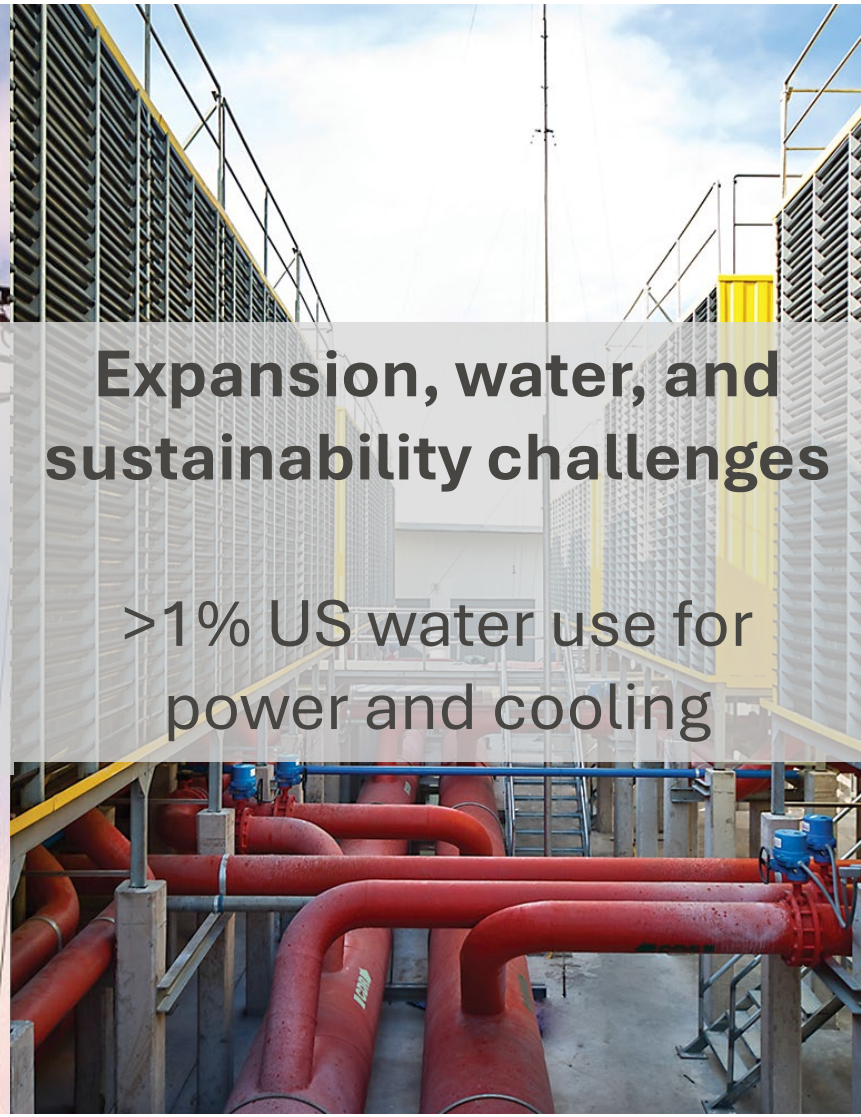
Driving unprecedented chip, rack, and data center power densities



Power challenge

>10% US electricity by 2028

$30B – $70B in electricity/year in 2030



Expansion, water, and sustainability challenges

>1% US water use for power and cooling

2025 NREL Partner Forum: Data Centers

Executive Summary

Digital Infrastructure industry top global challenges.

2024 **POWER** **PEOPLE** **PERCEPTION** **PLANET**

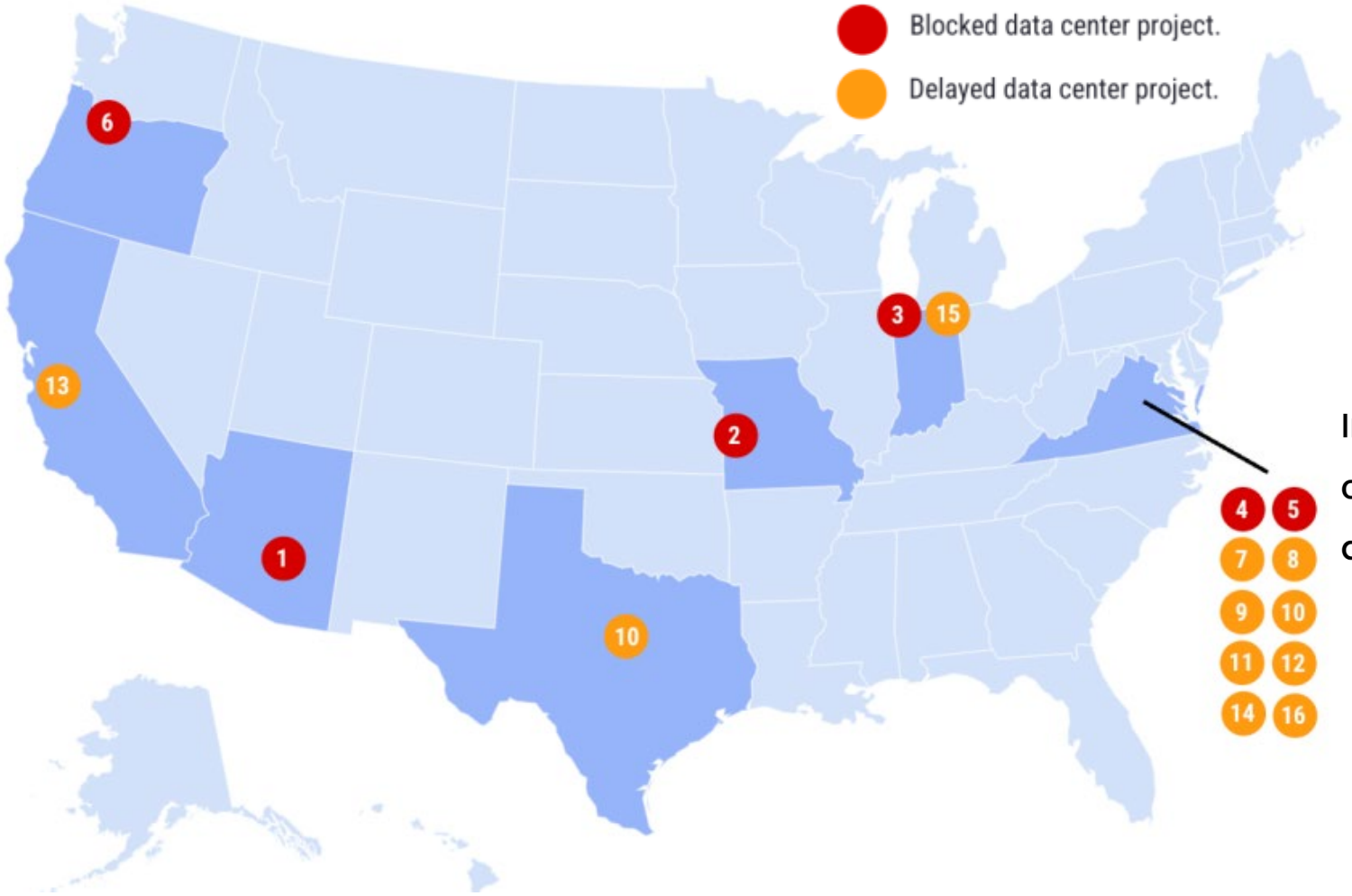
KEY TRENDS

- **Move the data center to the power** - The only way to meet growth.
- **Clean Energy Zones** - Master Planned Developments around clean energy.

Dean Nelson
Infrastructure Masons

Data center expansion is challenged by negative perception

>$64B data center projects blocked or delayed by local opposition in last 2 years



Main reasons: Air quality, water consumption, environmental impact

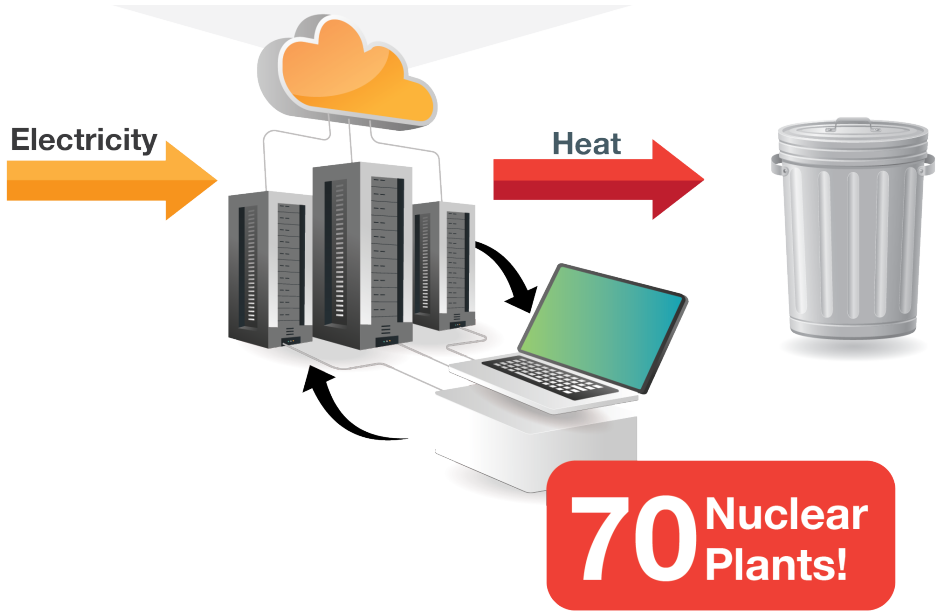
In Warrenton, Virginia, **residents voted out** all town council members who **supported Amazon's** proposed data center in the **November 2024** election.

Data Center Heat Valorization supports AI Infrastructure Deployment

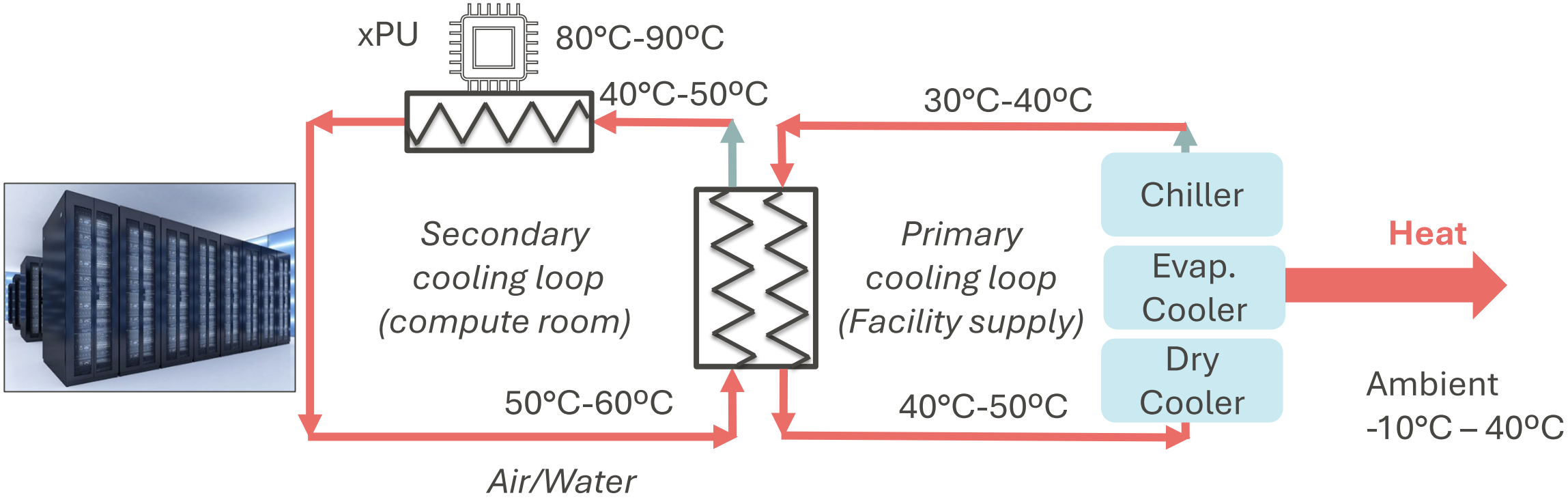
- Can data centers be engineered so they CONTRIBUTE to communities thereby minimizing opposition?

- Can data centers be engineered so they SOLVE problems instead of causing problems?

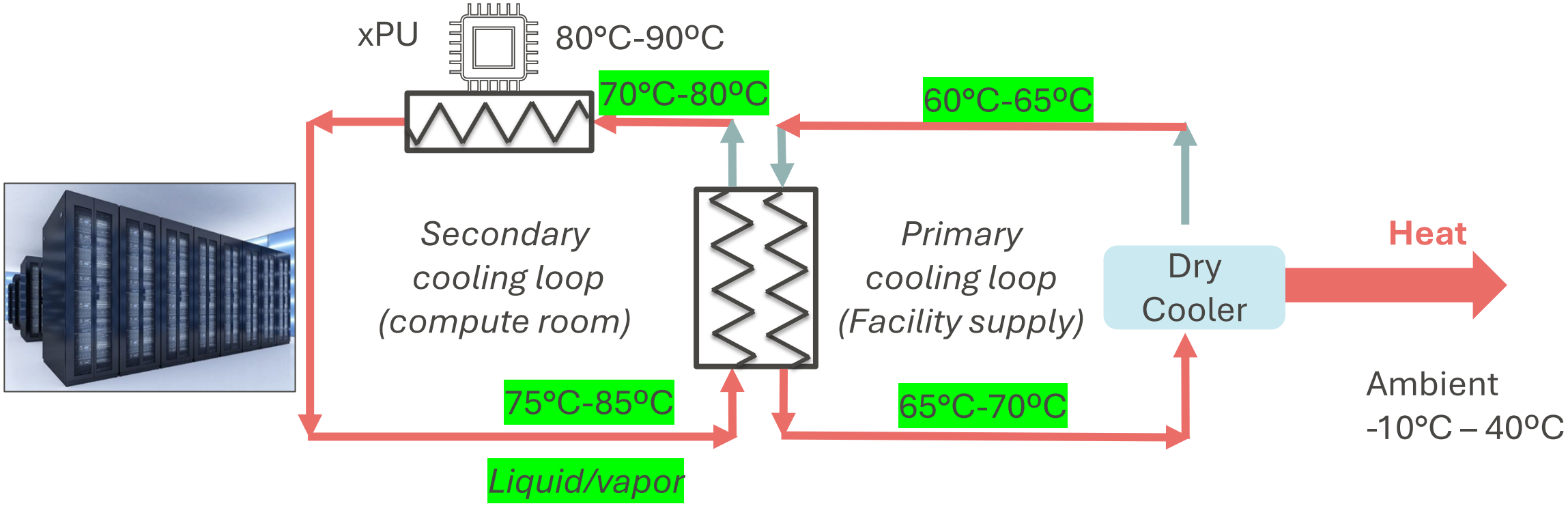
- Can data centers be become carbon negative? Water positive? Can we have our cake and eat it too?



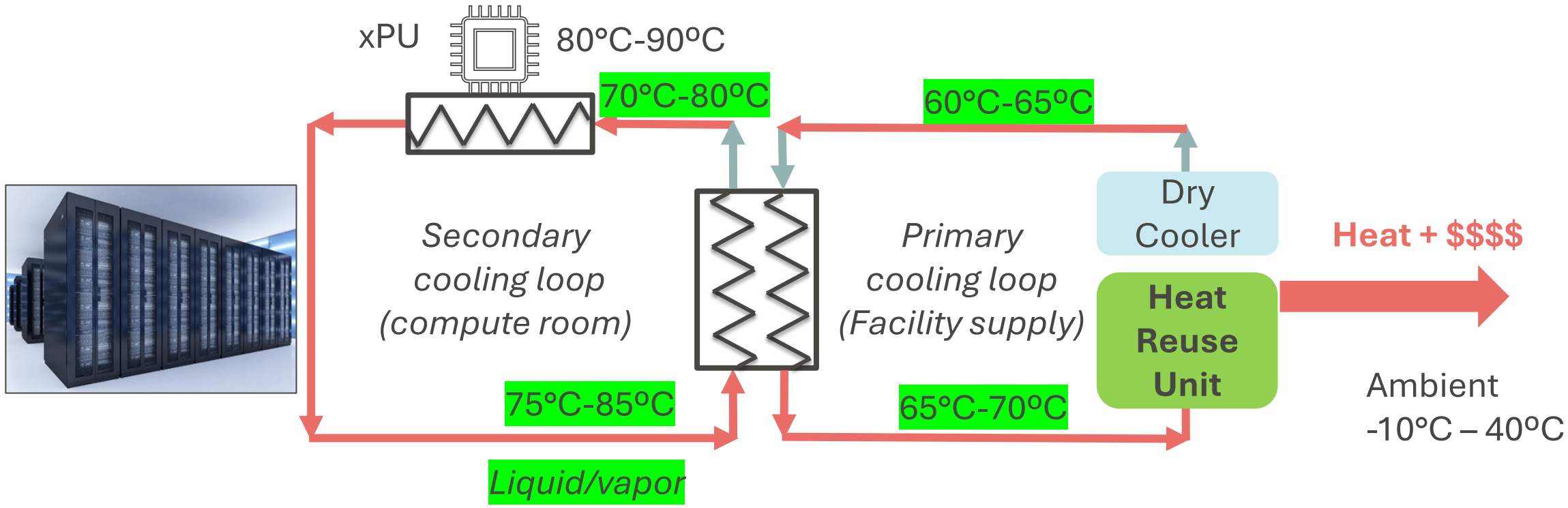
Data Center: Current Methods



Data center (COOLERCHIPS Goal)



Valorizing data center heat (our goal)

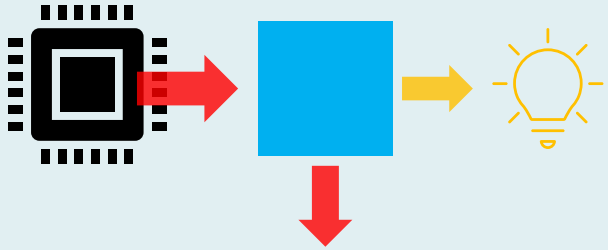


Considered six options for data center heat use

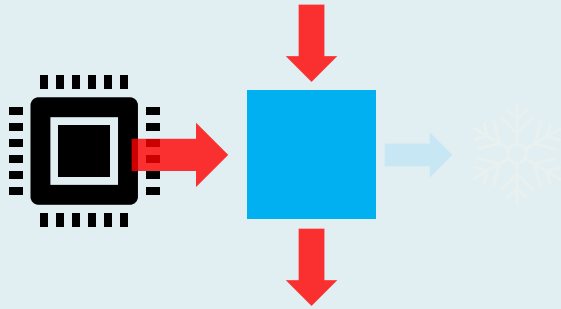
Conventional end uses

Direct heating

Conversion to electricity

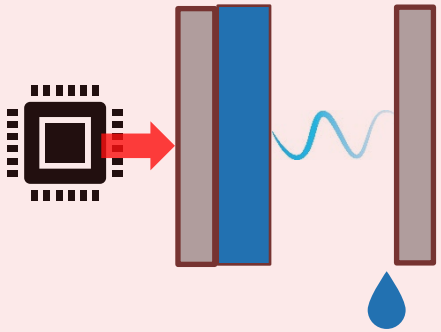


Cooling

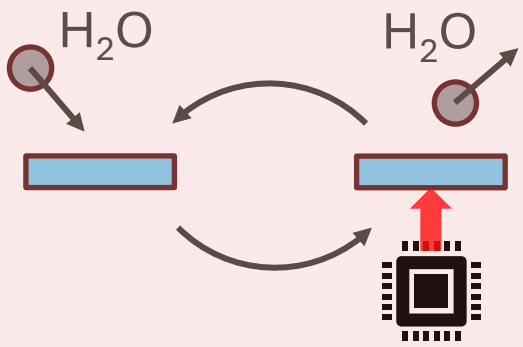


New potential end uses

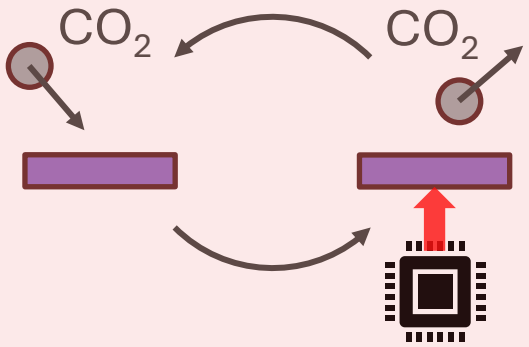
Water purification



Atmospheric water production



Carbon capture



Ideal uses produce a valuable product efficiently

Economic benefit ~ Efficiency · Product $$

Emissions avoided/removed ~ Efficiency · Product emissions

What we want:

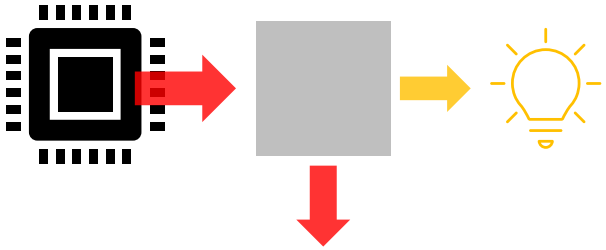
1. Efficient waste heat use
2. High value product
3. Replace emissions-intensive product

Direct heating

$$\text{Efficiency} \sim 0.75 - 1$$

$$\text{Product \$\$} \sim 0.05 \frac{\$}{\text{kWh}_{\text{th}}}$$

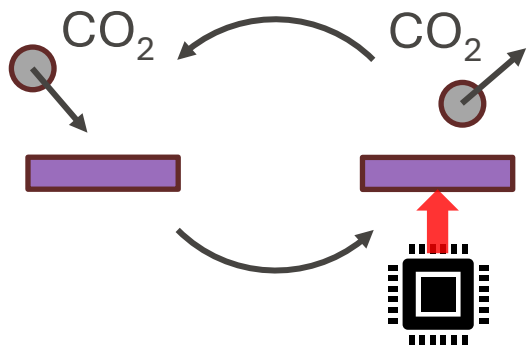
Conversion to electricity



$$\text{Efficiency} \sim 0.02 - 0.11$$

$$\text{Product \$\$} \sim 0.16 \frac{\$}{\text{kWh}}$$

Carbon capture



$$\text{Efficiency} \sim 0.3^{*} - 7.3^{**} \frac{\text{kg CO}_2}{\text{kWh}_{\text{th}}}$$

$$\text{Product \$\$} \sim 0.1 \frac{\$}{\text{kg CO}_2}$$

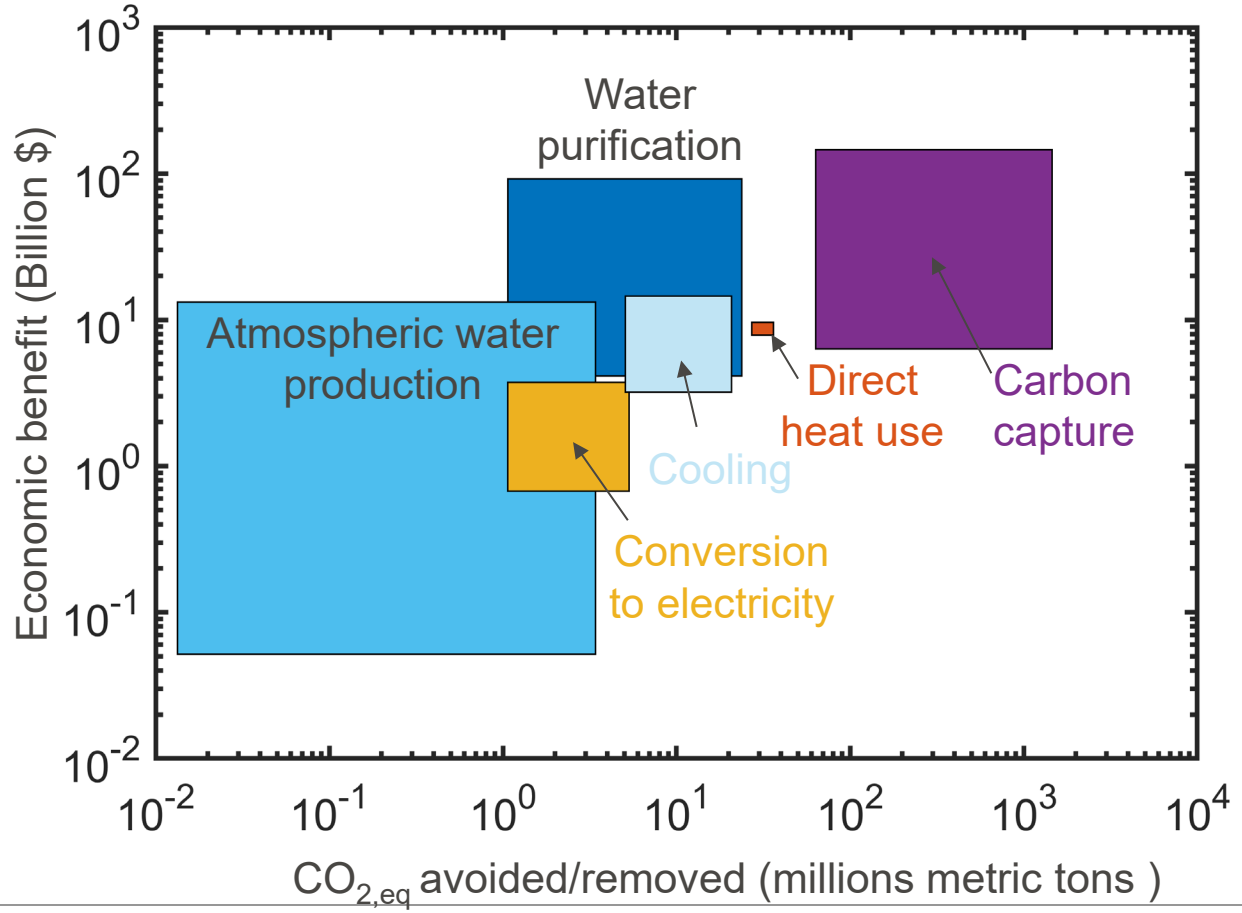
*Climeworks: Deutz *et al,* Nature Energy, 2021

**Ideal CO_2 separation from air

Carbon capture has the most economic and emissions impact

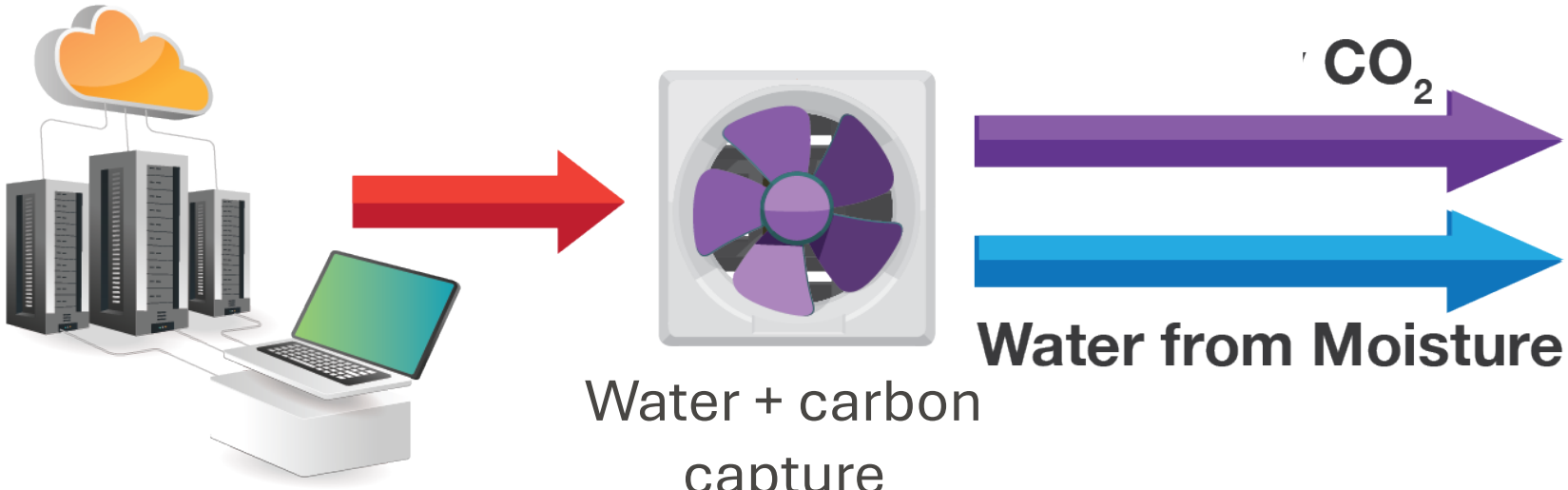
Economic benefit ~ Efficiency · Product $$

Emissions avoided/removed ~ Efficiency · Product emissions



Air capture makes AI cheaper and water-positive

1 GW data center



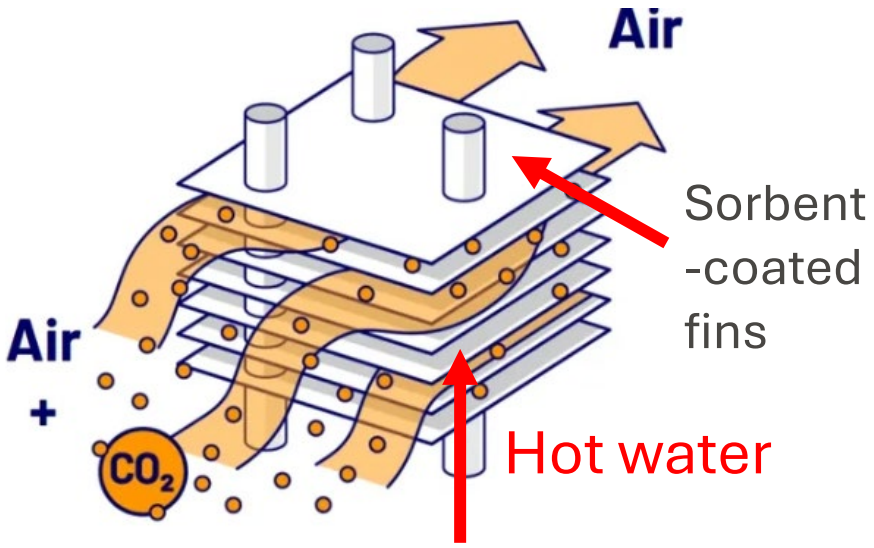
Currently	Valorizing heat with water and carbon capture	
- $0.5 Billion in electricity	+> $0.3 Billion selling CO_2	$ >60% "discount"
-3500M gal water	+1500M gal water	Water-Positive >12k homes/year

Whitespace | Materials, systems, processes

1. High performance sorbents at low temperatures

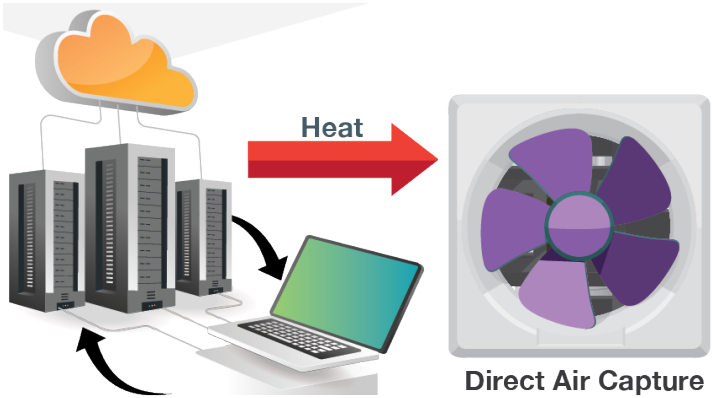
Zhou, *Nature*, 2024

2. Contactors and desorption methods without steam



Modified from Clean Capture Tech

3. Dynamic operation and design with available energy



Innovations in one or both needed for low temperature

Innovation needed for low electricity use, low cost