



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.



Dean Nelson
Infrastructure Masons

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.

2025

POWER

PERCEPTION

PEOPLE

PLANET

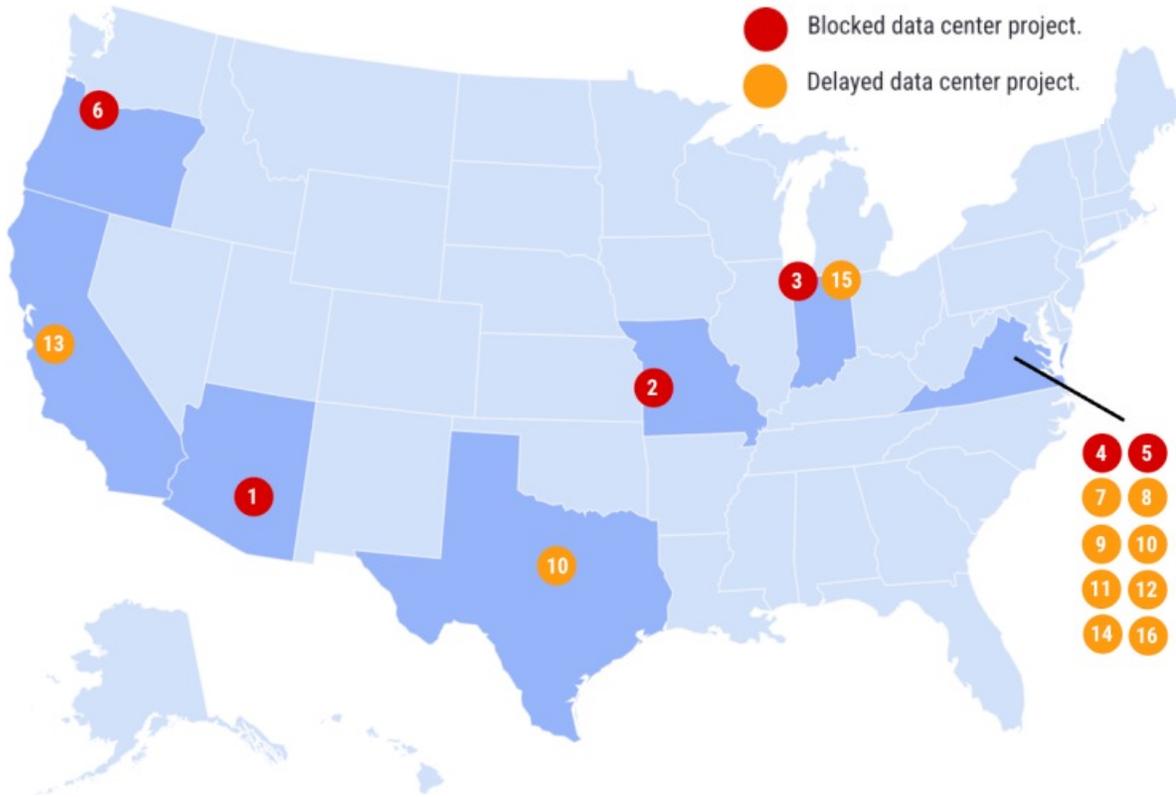
PRIVACY

KEY
TRENDS

- **Social Accord** - Barrier to sustainable growth is community pushback. How we become “of the community” versus “in the community”.
- **Data Oasis** - Data Protection. Data Safe Harbor / Data Embassy drives Clean Energy Zones.
- **AI Workload Shift** - 90% training 10% inference today will flip to 90% inference by 2030. Largest consumer will be enterprise companies. Edge (near/far) will become pervasive.

Data center expansion is challenged by negative perception

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

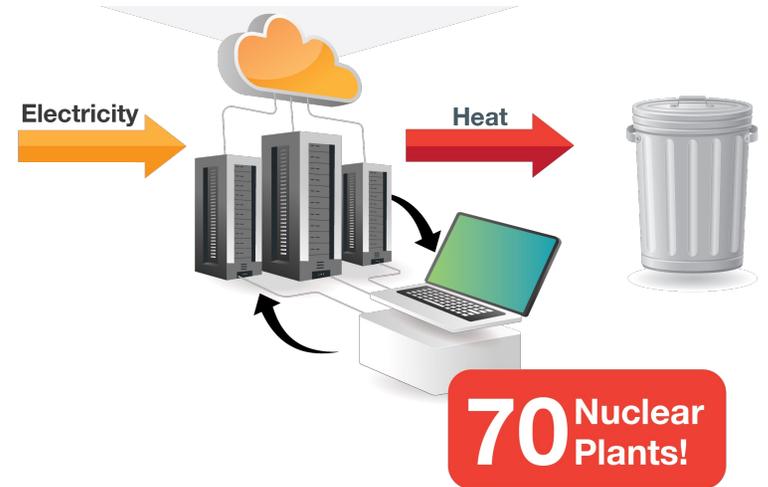


Main reasons: Air quality, water consumption, environmental impact

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

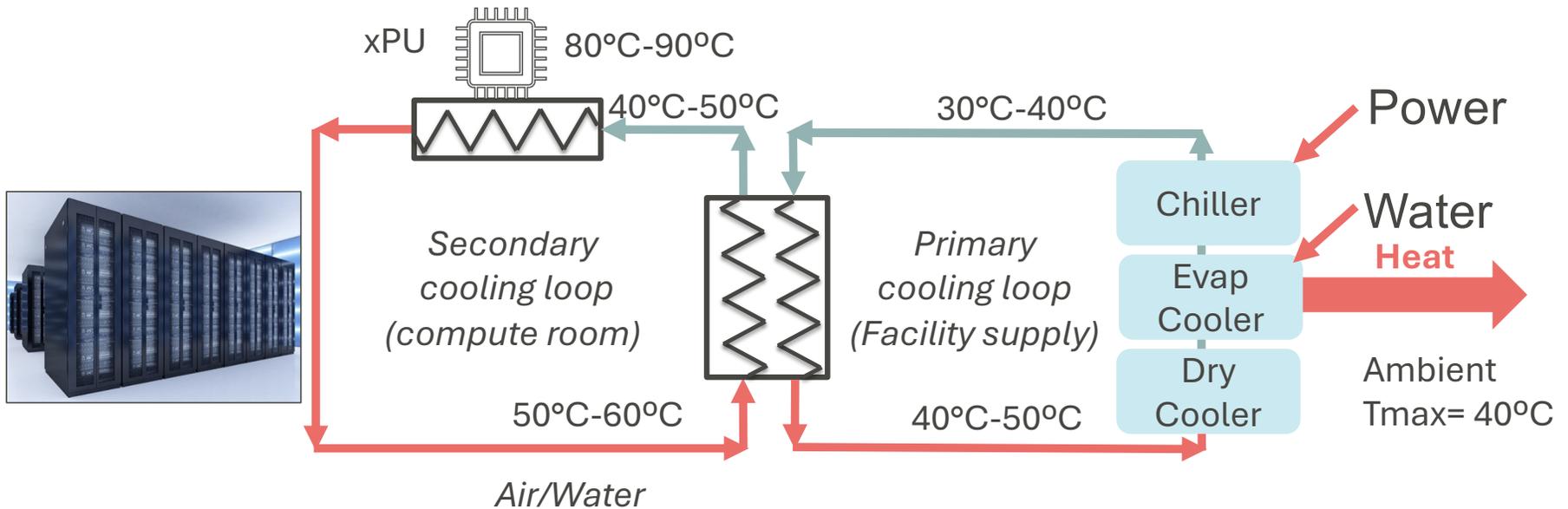
Data Center Heat Valorization supports AI Infrastructure Deployment

- 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?



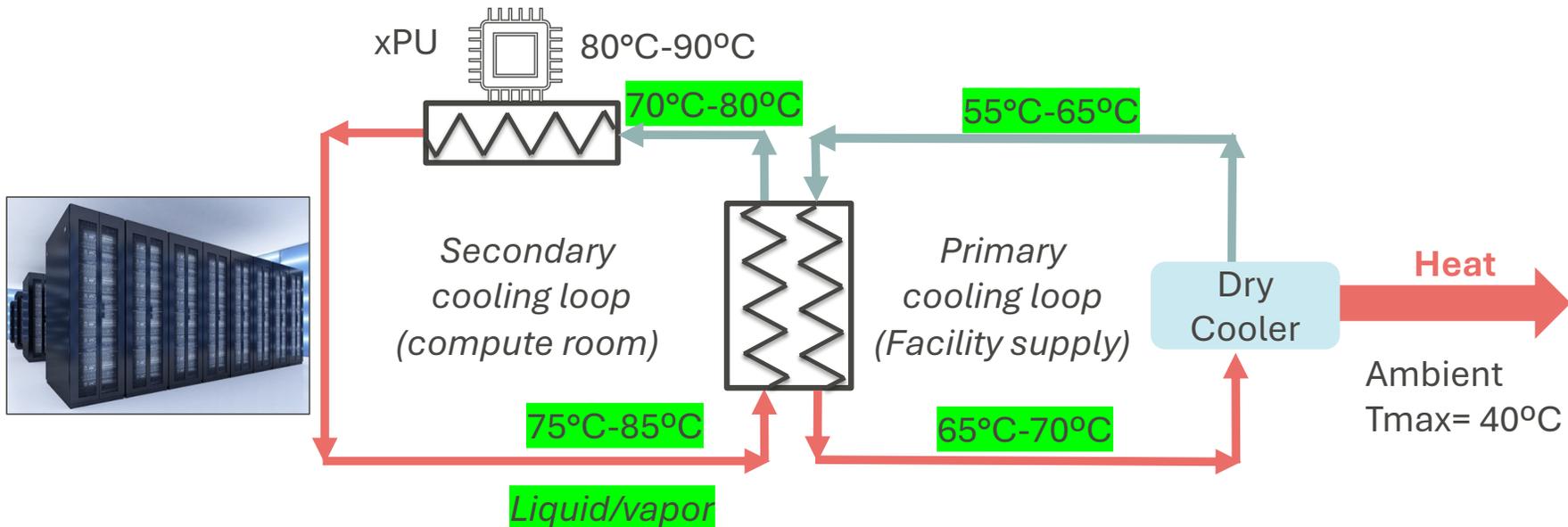
Current Methods for Data Center Cooling Example

- PUE/TUE~1.3-1.5

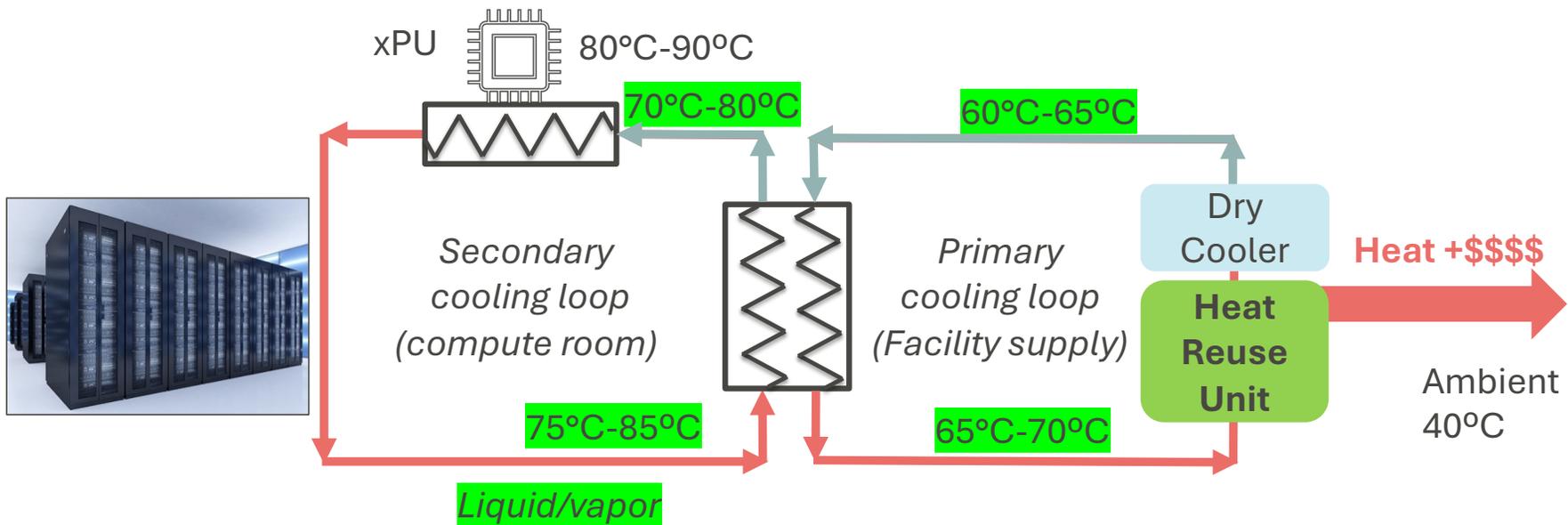


COOLERCHIPS Goal Example

- PUE/TUE < 1.05 when $T_{amb} = 40^{\circ}\text{C}$ and 60% RH
- Power density > 80 kW/m³ (120 KW/rack) (OBSOLETE!)

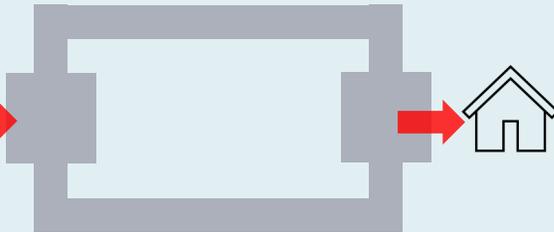
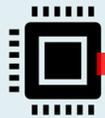


Valorizing data center heat (our goal)



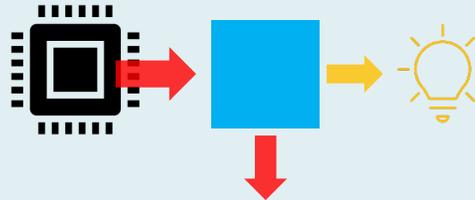
Some options for data center heat use

Conventional
end uses

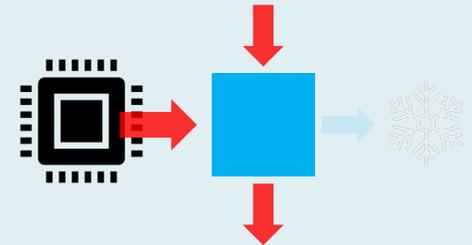


Direct heating

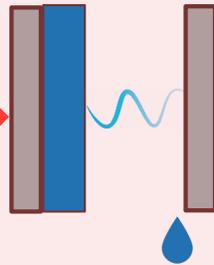
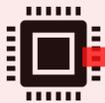
Conversion to electricity



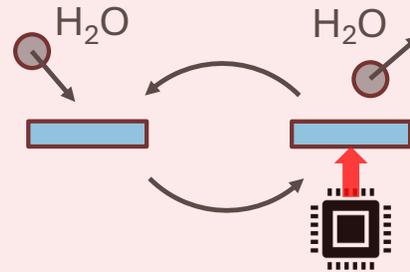
Cooling



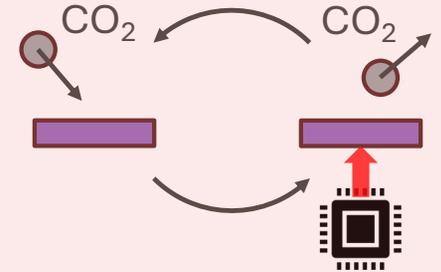
New potential
end uses



Water purification



Atmospheric water
production



Carbon
capture

Ideal uses produce a valuable product efficiently

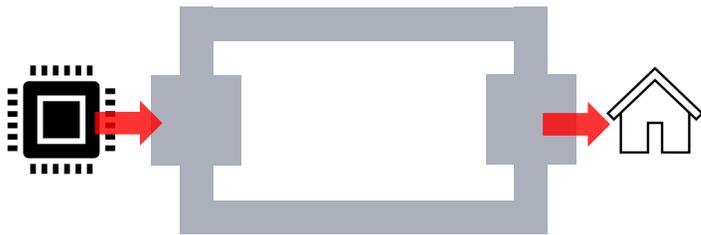
Economic benefit \sim Efficiency \cdot Product \$\$

Emissions avoided/removed \sim Efficiency \cdot Product emissions

What we want:

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

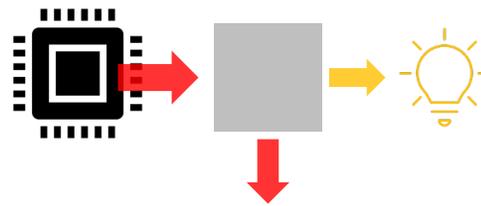
Direct heating



Efficiency $\sim 0.75 - 1$

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

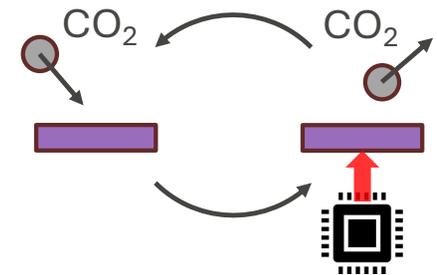
Conversion to electricity



Efficiency $\sim 0.02 - 0.11$

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

Carbon capture



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

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

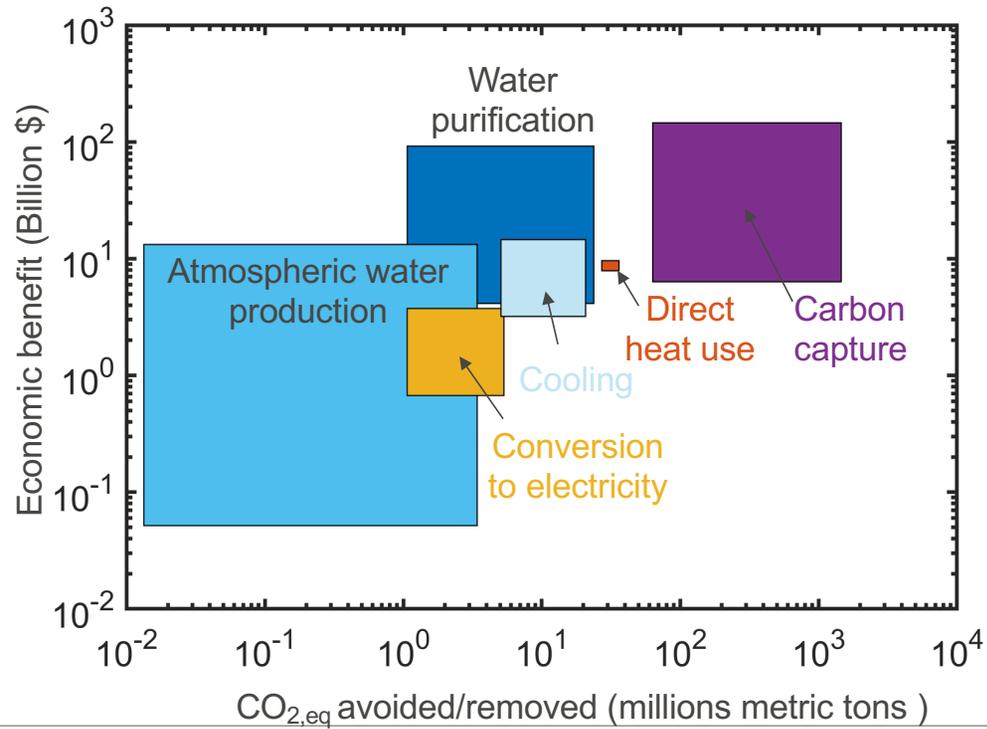
*Climeworks: Deutz *et al*, Nature Energy, 2021

**Ideal CO₂ separation from air

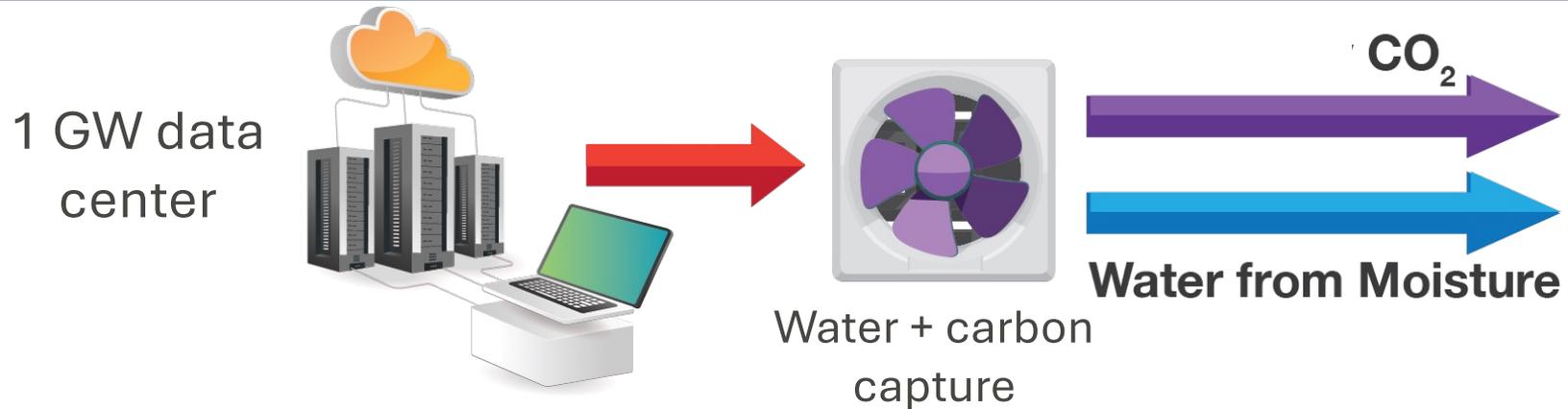
Carbon capture has the most economic and emissions impact

Economic benefit \sim Efficiency \cdot Product \$\$

Emissions avoided/removed \sim Efficiency \cdot Product emissions



Air capture makes AI cheaper and water-positive



Currently

**- \$0.5 Billion in
electricity**

-3500M gal water

**Valorizing heat with water and
carbon capture**

**+> \$0.3 Billion
selling CO₂**

+1500M gal water

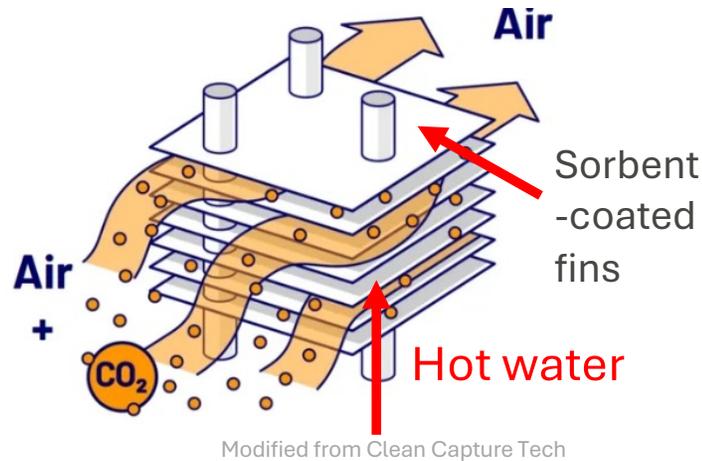
Whitespace | Materials, systems, processes

1. High performance sorbents at low temperatures

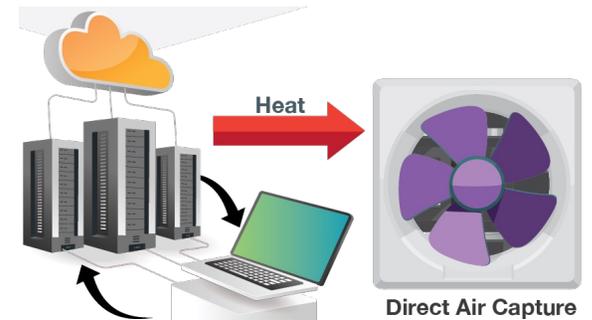


Zhou, *Nature*, 2024

2. Contactors and desorption methods without steam



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