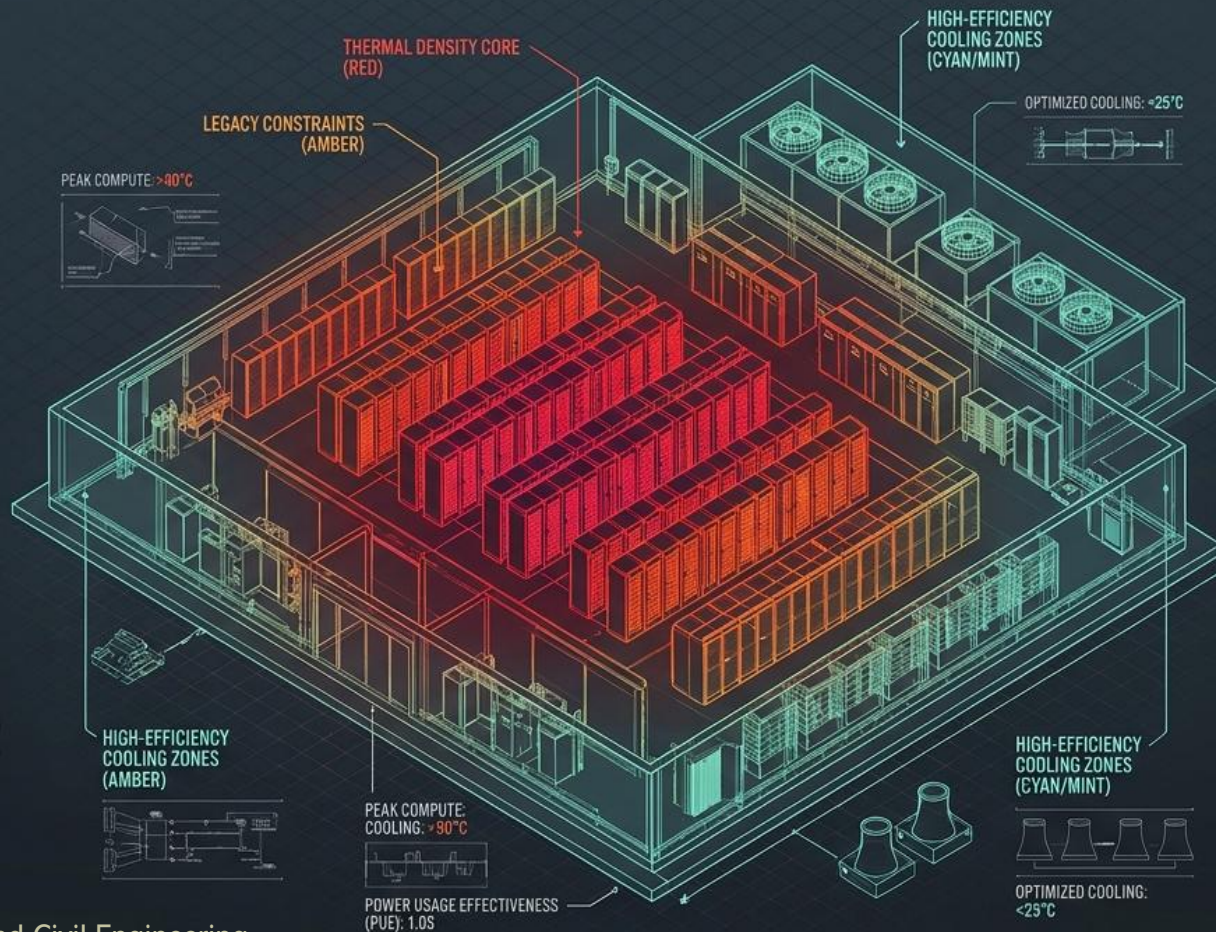


THE PHYSICAL LIMITS OF AI

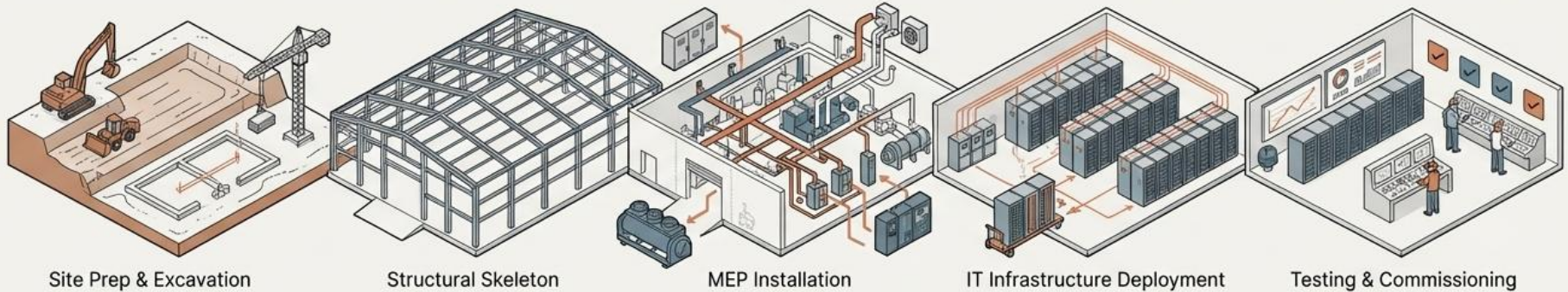
A STRATEGIC BLUEPRINT
FOR NEXT-GEN DATA CENTER
INFRASTRUCTURE

Dr. Dong Zhao

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Design & Build of Data Centers



THE ESCALATING PHYSICS OF AI COMPUTE

THE BASELINE (2014)

58 TERA-WATT-HOURS (TWH)
CONSUMED BY US DATA CENTERS

2014
BASELINE

2023
CURRENT

THE CURRENT STATE (2023)

176 TWH CONSUMED, REPRESENTING
4.4% OF TOTAL US ELECTRICITY

2028
PROJECTION

THE AI CATALYST & REGIONAL STRAIN

17 GIGAWATTS (GW) OF CAPACITY
REQUIRED FOR RECENTLY
ANNOUNCED AI JOINT VENTURES
ALONE.

VIRGINIA'S UNCONSTRAINED ENERGY
USAGE IS PROJECTED TO SPIKE
183% BY 2040.

THE 2028 PROJECTION

325 TO 580 TWH REQUIRED.
PROJECTED TO CONSUME UP TO
12% OF TOTAL US ELECTRICITY
SUPPLY.

A diagram of a server rack with eight horizontal server units. Each unit has a circular fan on the left and three dots on the right. Blue wavy lines on both sides of the rack represent airflow entering and exiting the units.

A diagram of a server rack with a central brain icon, representing AI processing and heat management. Red wavy arrows indicate airflow entering from the left and exiting to the right, illustrating the cooling process.

130 kW → 250kW-600kW → 1 MW
today forecast frontier

THE THERMODYNAMICS OF DENSITY: LIQUID VS. AIR

Legacy Air Cooling

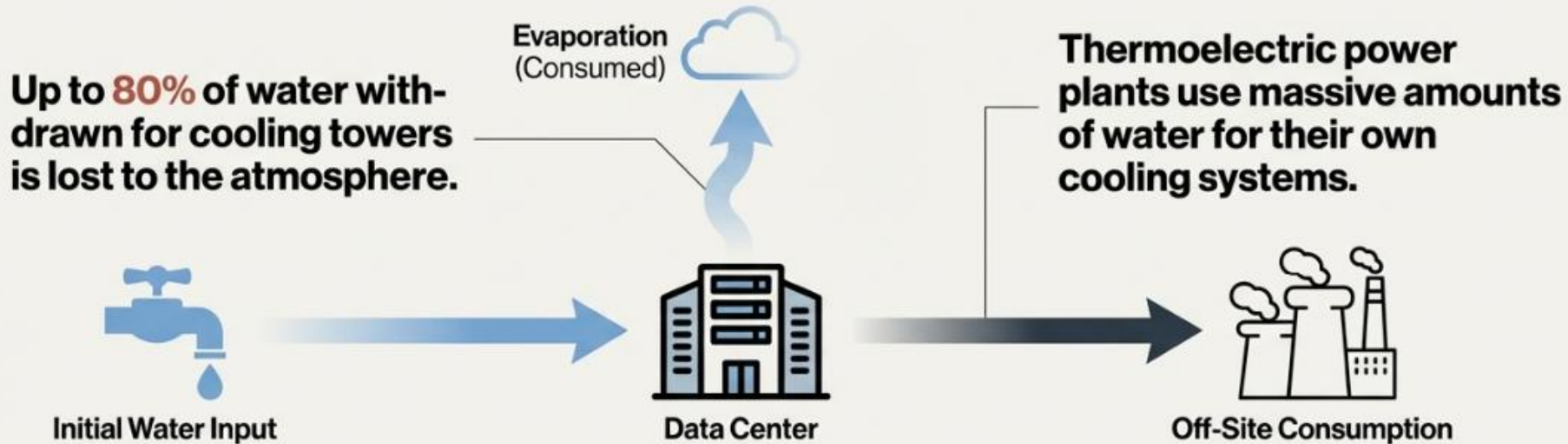
- Air has low specific heat capacity. This results in massive spatial sprawl, thermal throttling (CPUs reducing clock speeds to survive), and high Power Usage Effectiveness (PUE).

Next-Gen Liquid & Immersion

- Water's thermal conductivity is 25x greater than air, and specific heat capacity is 4x higher. Submerging servers radically compresses facility footprint, prevents hardware degradation, and massively lowers Total Usage Effectiveness (TUE).



Water Use



Training the GPT-3 model is estimated to have evaporated 700,000 liters of clean freshwater.

THE RESOURCE COLLISION

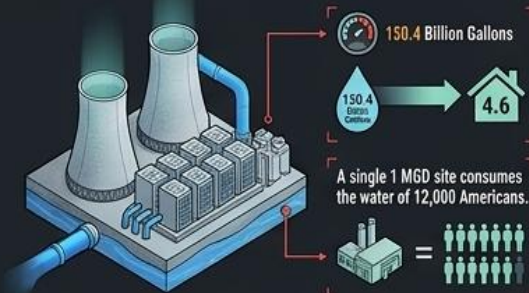
Water-Energy-Compute Nexus

Exponential
AI Demand

The Physical & Public Ceiling

THE WATER DEFICIT

Hyperscale facilities will withdraw 150.4 billion gallons by 2030 (equal to 4.6 million US households). A single 1 MGD site consumes the water of 12,000 Americans.



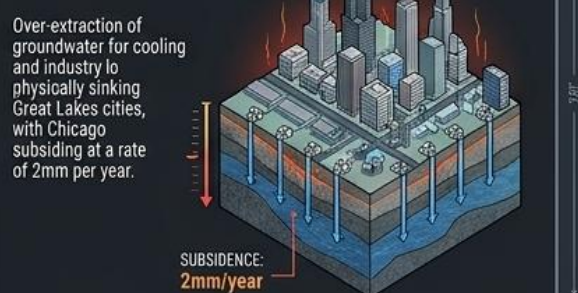
GRID & RATEPAYER BACKLASH

Data centers drove 62% of PJM capacity price increases. Utility commissions in OH and IN are proposing tariffs requiring developers to pay for a minimum of 90% capacity.

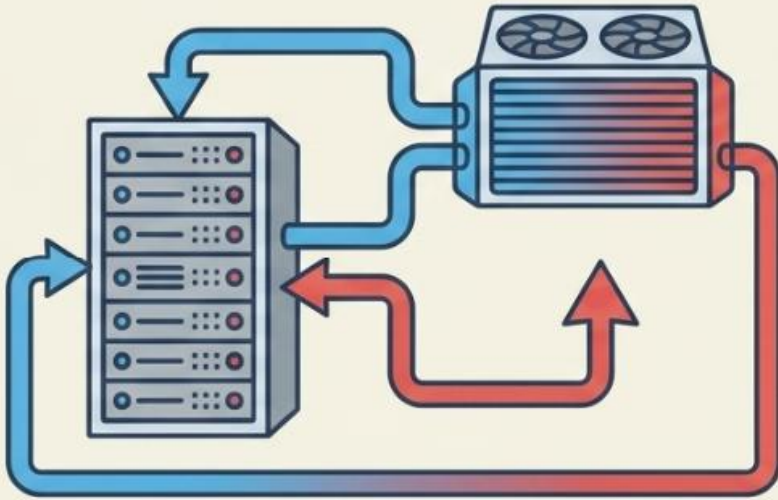


GEOGRAPHICAL PHYSICALITY

Over-extraction of groundwater for cooling and industry is physically sinking system.



Closed-Loop



Benefits of Closed-Loop Cooling

- **Zero Water Consumption:** Reuses the same liquid, eliminating the need for continuous municipal water.
- **Higher Efficiency:** Liquid is a more effective coolant than air, allowing for denser server configurations.
- **Reduced Environmental Impact:** Minimizes water strain on local communities and ecosystems.

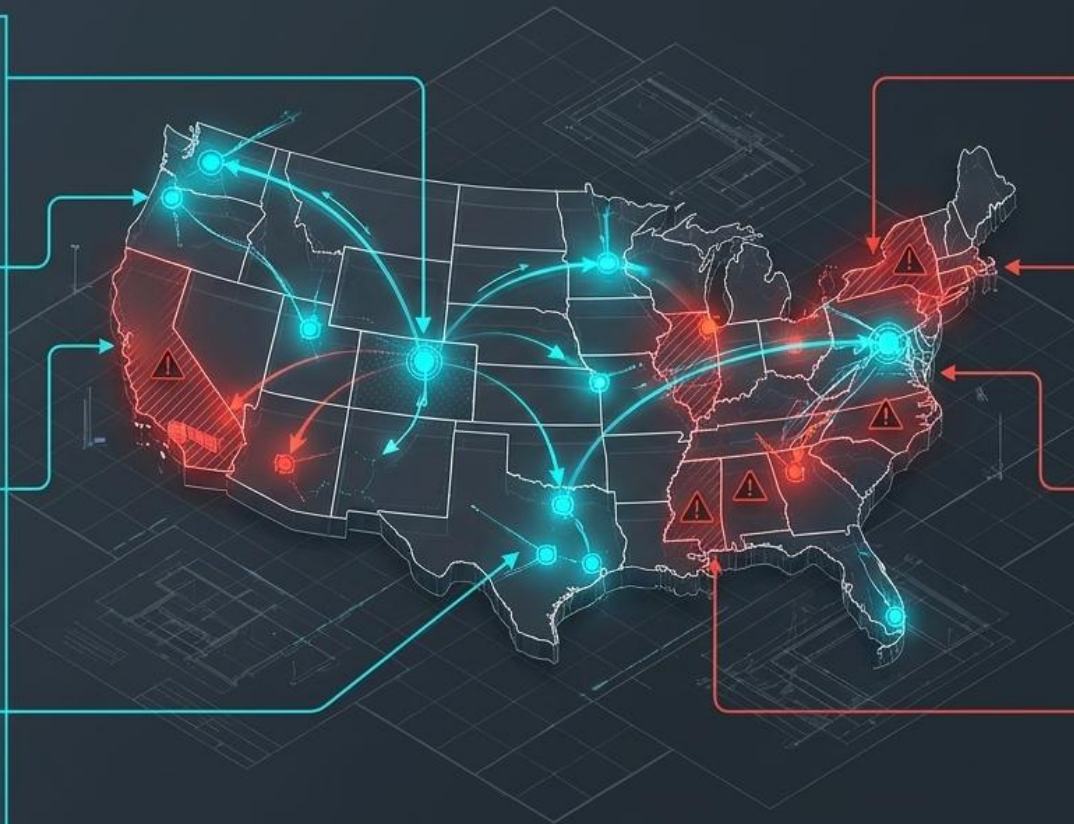
The Regulatory Reality: Acceleration vs. Friction

Federal Fast-Tracking

FAST-41 Executive Order:
Expedites federal permitting for data centers >100MW.

Endangered Species Act & DOD: Programmatic consultations and military land leasing.

EPA Prioritization:
Targeting Brownfield and Superfund sites for rapid facility reuse.



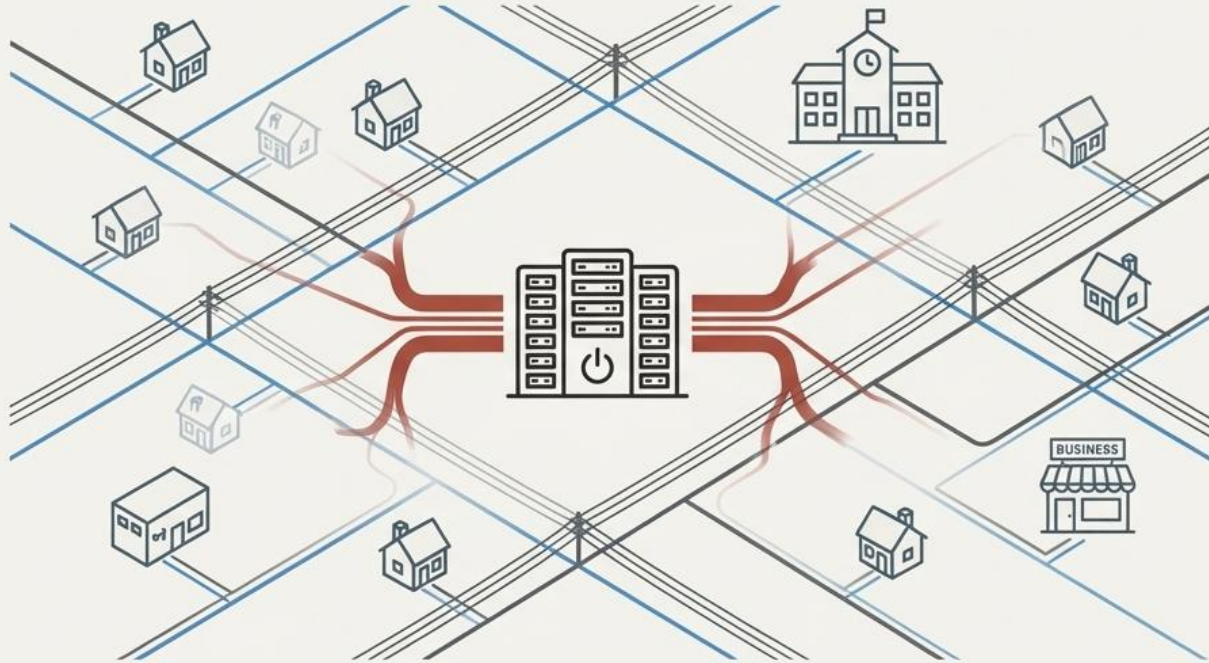
State-Level Headwinds

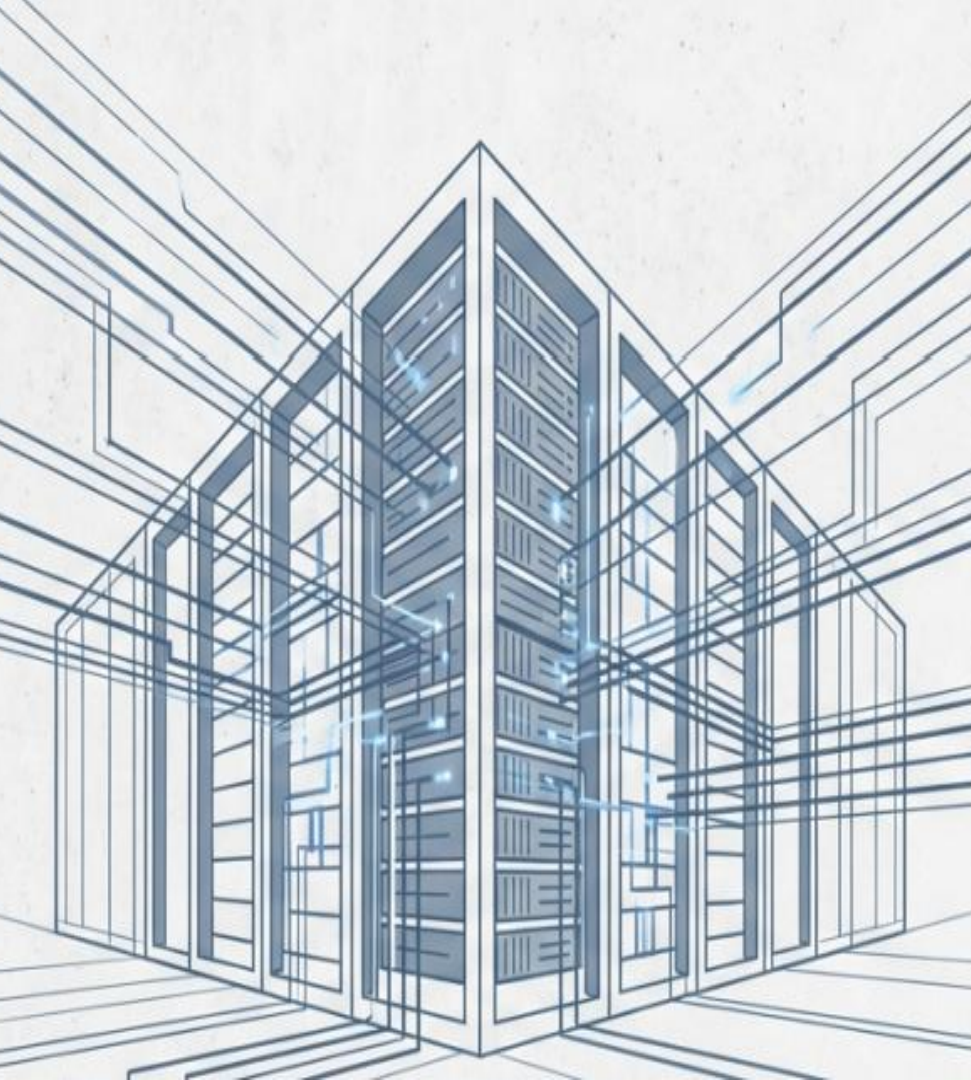
New York S6394A:
Requires emissions disclosures, mandatory renewable scaling by 2050, and bars discounted fossil-fuel agreements.

The Clean Cloud Act:
Federal proposals targeting strict emissions standards and mandated energy consumption reporting.

Community Pushback:
Dissolving NDAs and the rising requirement for binding Community Benefit Agreements (CBAs).

To Our Community?





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Human-Building
Systems Lab