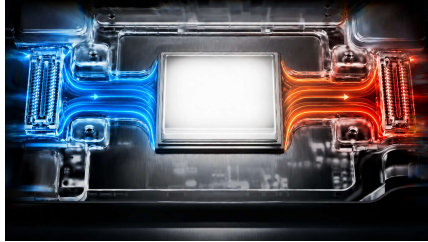


Decoding Data Centers: Near-Term Engineering Realities and Policy Pathways for Connecticut



Baikun Li, Ph.D. PE
Professor
School of Civil and Environmental Engineering
University of Connecticut

September 28 2026



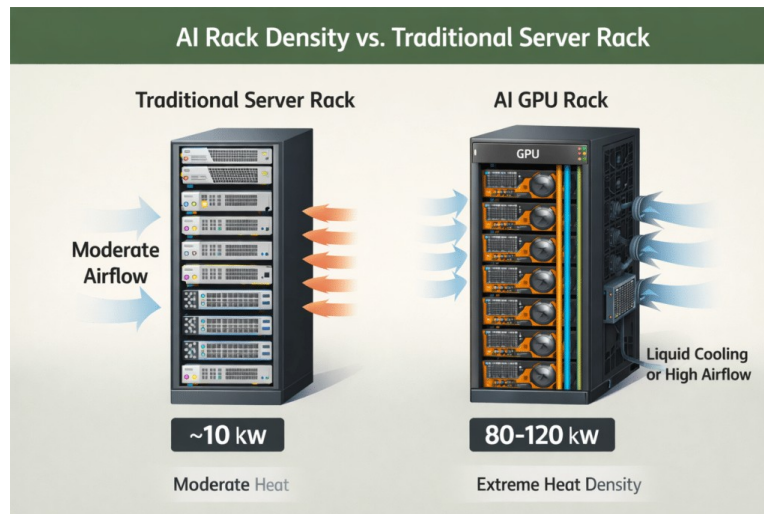
1

Data Centers at a Crossroads: Technology Shift & Connecticut Baseline

2

Traditional Data Centers vs AI Data Centers: The Architectural Shift

1



<https://shrinkthatfootprint.com/ai-data-centers-water-usage/>

- * Air-Cooled: Relies on massive outdoor chillers & fans.
- * Low Density: Standard 5–10 kW per rack.

- * Liquid-Cooled: Direct-to-chip heat removal.
- * Ultra-High Density: Surges to 80–120 kW per rack.

3

Difference between Traditional Data Centers and AI Data Centers

2

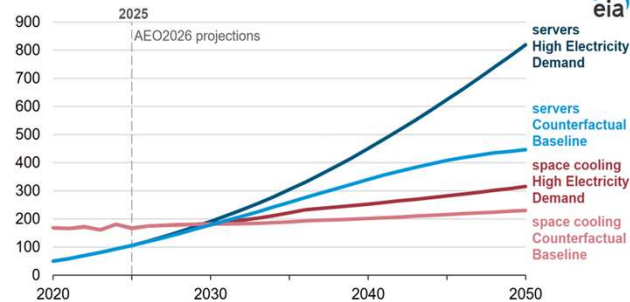
Metric	Traditional Data Center	AI Data Center
Chip Power Demand	200 – 400 W	1,000 W+ (Surging)
Rack Power Density	5 – 15 kW	100 – 200 kW+ (10x jump)
Cooling Medium for Chips	Air-cooled (High water/power loss)	Liquid-cooled (Direct-to-chip)
Water Consumption	~200,000 Gal/Day	>1,000,000 Gal/Day (5x jump)
Cooling Return Temp (Waste heat)	25°C – 35°C (Low Grade)	50°C – 60°C (High Grade Asset)
Typical Load Fluctuations for grid	5%-10% (Stable)	10%-100% (Instantaneous)

4

Cutting Through the Noise: Linear Extrapolation vs. Efficiency Scaling

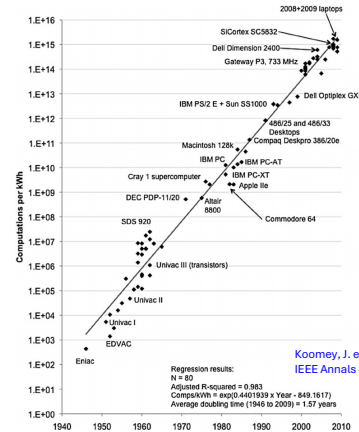
3

Data center server and cooling electricity use in the U.S. commercial sector (2020–2050)
billion kilowatthours



Static Demand Forecast (EIA AEO2026)

- **Premise:** Assumes minimal hardware innovation and endless exponential power growth.
- **Reality Check:** Treats computing as a rigid, inflexible electric block.



Logarithmic Scaling

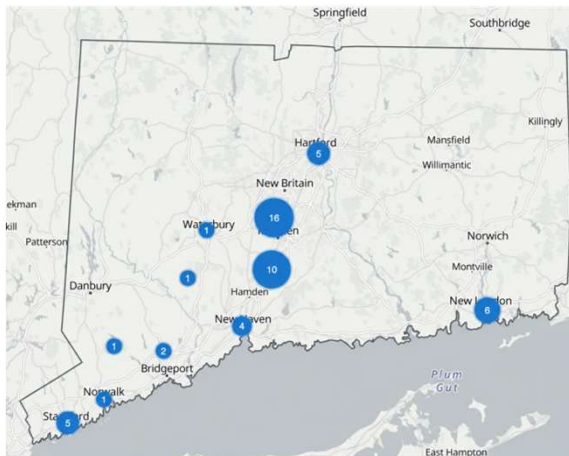
- **Koomey's Law:** Compute efficiency doubles every ~1.6 years.
- **Engineering truth:** Software and microarchitectural breakthroughs constantly flatten power curves.

- Sound policy cannot be built on static linear panic.
- Regulate for workload elasticity, liquid-cooling efficiency, and peak-shaving response, not blunt moratoria.

5

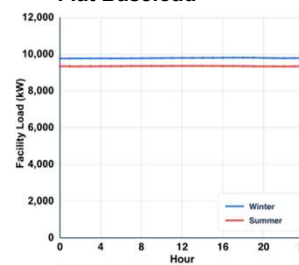
Connecticut's Crossroads: Data Centers

4



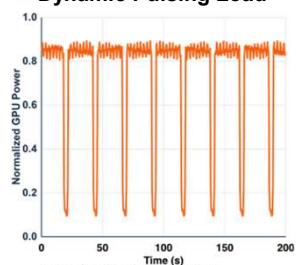
<https://www.datacentermap.com/usa/connecticut/>

Traditional Data Center:
Flat Baseload



Source: Ghatikar et al. (2010), LBNL-3047E, Fig. 4

AI Training Cluster:
Dynamic Pulsing Load



Source: Choukse et al. (2025), Fig. 1

https://escholarship.org/content/qt8991w2jw/qt8991w2jw_noSplash_2bd5756c276a01389499a1b13913b3fb.pdf; <https://arxiv.org/pdf/2508.14318>

- **Fleet Baseline:** Connecticut hosts 52 small/mid data centers (180–220 MW total, ~4% of state grid).
- **High Local Concentration:** Over 60% clustered along the fragile SouthWest CT (SWCT) corridor.
- **The AI Shift:** Upcoming AI facilities are not flat baseload; their surging dynamic loads require active management.

6

Connecticut's Crossroads: Community Issues (Heat & Acoustics)

7

Community Impact Domain	Current Unmitigated Impact	Engineering Solution
Thermal Waste (DEEP & Local Climate)	Vents 2.5T BTUs/yr into air; creates local heat islands	50°C–60°C return water directly fuels municipal digesters & district heating
Acoustic Noise (CT Regs § 22a-69 & Zoning)	65–85 dBA continuous chiller/fan hum breaches property limits	Liquid cooling eliminates rooftop fans; berms buffer low frequencies (<45 dBA)

- Noise and heat trigger local zoning bans.
- **Solution:** Policies that encourage that closed-loop liquid cooling eliminates acoustic drone and turns waste heat into a municipal asset.

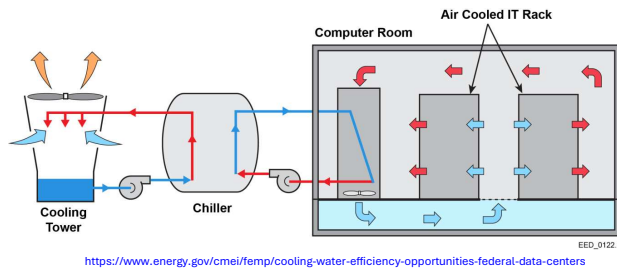
9

Engineering Solutions:
Converting Data Center Liabilities into Assets

10

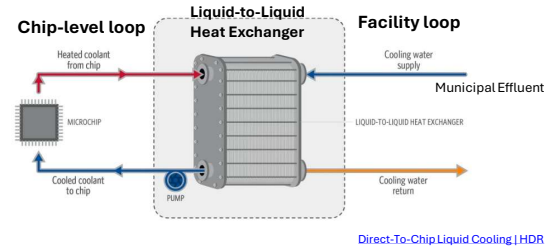
8

Water Innovation: Closing the Loop with Municipal Effluent (Co-location)



Conventional Cooling: Double Waste

- ✗ **Potable Depletion:** Consumes 100k+ gallons/day drinking water.
- ✗ **Parasitic Electric Load:** Chillers add 30%–40% electric load (Power Usage Effectiveness (PUE) > 1.5).



Liquid Cooling + WRRF Effluent

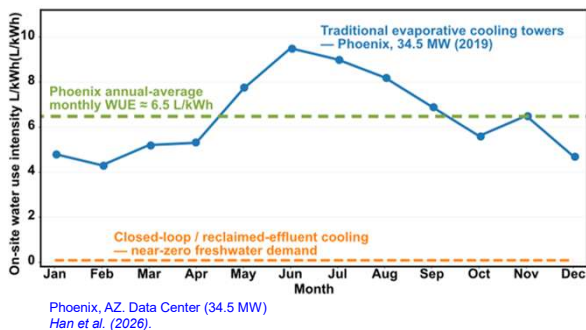
- ✓ **Zero Potable Draw:** Uses non-potable treated wastewater effluent.
- ✓ **Zero Contamination:** 100% physically isolated loops, zero atmospheric water loss (Water Usage Effectiveness (WUE) < 0.1).

- Restrict open evaporative towers on public water supplies.
- Expedite permits for closed-loop effluent cooling.

11

9

Water Innovation: Closing the Loop with Municipal Effluent (Co-location)



Effluent Cooling Advantage:

- **Zero Drinking Water Draw:** WUE < 0.1 L/kWh year-round.
- **No Evaporation Loss:** Closed-loop plate heat exchange.

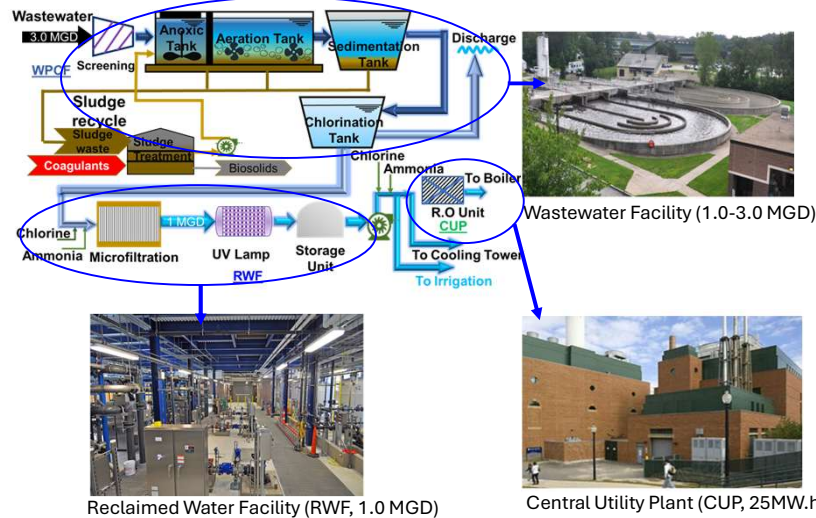
- Conventional cooling spikes water use to 10 L/kWh (WUE) in summer.
- Closed-loop effluent cooling maintains < 0.1 L/kWh (WUE).

12

10

Water Innovation: UConn Water Reuse Testbeds

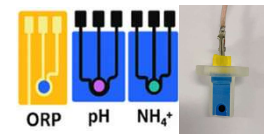
UConn Water Pollution Control Facility



Pilot-scale Water Reuse System



Pilot-scale Wastewater System



Milli-electrode Array Sensors

Reclaimed Water Facility (RWF, 1.0 MGD)

Central Utility Plant (CUP, 25MW.h).

UConn Track Record: 1B+ Gallons Recycled

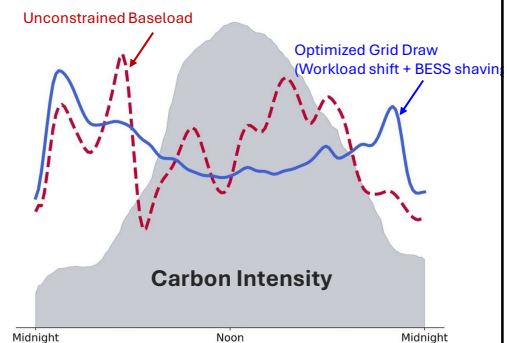
13

11

Multi-Scale Flexibility: Turning into Grid Assets

Milliseconds (DVFS Hardware)	Minutes (Checkpointing & Pausing)	Hours (On-Site Microgrids & BESS)
Instant 20% power cut via chip regulating (zero job loss).	Pauses batch AI workloads during ISO-NE peak hours (20%–40% shed).	Full grid-islanding using on-site storage & clean baseload.

DVFS: Dynamic Voltage and Frequency Scaling
BESS: Battery Energy Storage System



AI training can dynamically shed load during peak demand hours (12 PM–6 PM).

Takci, M., et al. *Energy Reports* (2025).
DOI:10.1016/j.egyr.2025.03.020

- High-density AI loads are not static loads. They are dynamically adjustable.
- Automated peak-shaving can protect Connecticut's grid during heatwaves and freezes.

14

Thermal Circularity: Turning into Heating Assets

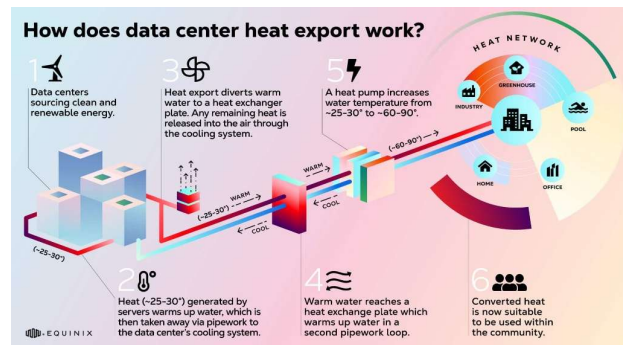
12

A 20 MW Data Center

- ≈1.3 B BTU/day recovered heat.
- Heats 2,500—2,600 New England homes in winter.

A 100 MW Hyperscale Center

- ≈6.5 Billion BTU/day recovered heat.
- Heats 13,000 -- 26,000 homes (replaces fossil fuel boilers).



Liquid-Cooling Advantage: 50°C–60°C direct return heat -- no heat pumps required.

Nkonge, N. (2024). What Is Data Center Heat Export and How Does it Work?

- Encourage "District Heat-Ready" connections for data centers > 20 mW.
- Capture 50°C–60°C waste heat to local heating and/or municipal wastewater digestion.

15

Action Agenda for Connecticut: The STOP–CONTINUE–START Framework

----A Science-Led Roadmap Balancing Economic
Growth, Grid Resilience, and Environmental Protection

16



Reckless Expansion & Blanket Bans: Regulate via Engineering Standards

13

Regulatory Dimension	Existing Gap (PA 21-1) (Effective July 2021)	Reactionary Ban (SB 245) (2026 Legislative Session)
Water (WUE)	Unconstrained potable draw for evaporative cooling	Blanket moratorium stalls digital economy
Efficiency (PUE)	No baseline; allows legacy, high-heat air cooling	Indiscriminately strips tax incentives
Grid Access	Unconditional tie-in; overloads substations	Closed door; loses tech investment & jobs
Ratepayer Shield	Zero protection; grid expansion socialized to residents	Blunt penalties bypass delivery bottlenecks

- Unchecked expansion under PA 21-1 risks resources; blanket bans under SB 245 impedes economic growth.

17



Reckless Expansion & Blanket Bans: Regulate via Engineering Standards

13

Regulatory Dimension	Existing Gap (PA 21-1) (Effective July 2021)	Reactionary Ban (SB 245) (2026 Legislative Session)	Science-Led Framework (SB 1292 / HB 5076/ HB 5469) (2025-2026 Legislative Session)
Water (WUE)	Unconstrained potable draw for evaporative cooling	Blanket moratorium stalls digital economy	WUE < 0.1: Prioritize closed-loop effluent; zero drinking water
Efficiency (PUE)	No baseline; allows legacy, high-heat air cooling	Indiscriminately strips tax incentives	PUE ≤ 1.2: Encourage direct-to-chip liquid cooling & heat reuse
Grid Access	Unconditional tie-in; overloads substations	Closed door; loses tech investment & jobs	Bring Your Own Power (BYOP): Encourage on-site microgrids & ≥20% peak-shaving
Ratepayer Shield	Zero protection; grid expansion socialized to residents	Blunt penalties bypass delivery bottlenecks	No Cost-Shifting: Developers fund 100% of substation & line upgrades

- Unchecked expansion under PA 21-1 risks resources; blanket bans under SB 245 impedes economic growth.
- Science-based performance standards protect ratepayers while embracing clean innovation.

18



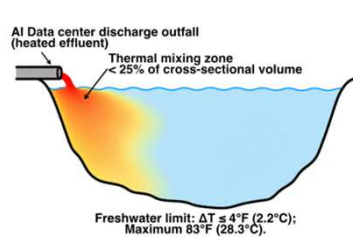
What Connecticut Should CONTINUE Doing

14

SHIELD 1: WATER QUALITY

CT DEEP NPDES Standards

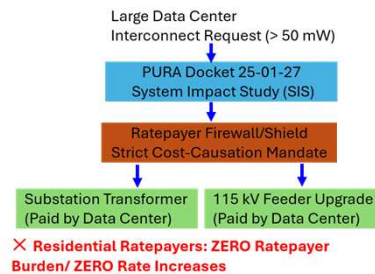
- Thermal Mixing capped at at $\leq 25\%$ river flow;
 $\Delta T \leq 4^\circ\text{F}$ (2.2°C) max rise.



SHIELD 2: RATEPAYER SHIELD

PURA Docket 25-01-27 Framework

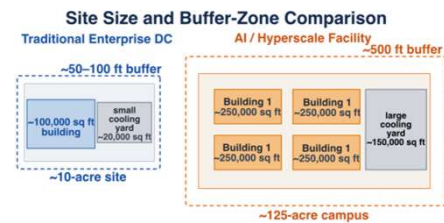
- 100% developer cost-causation; zero ratepayer subsidization; System Impact Study (SIS) to block grid congestion.



SHIELD 3: COMMUNITY HEALTH

CT Regs § 22a-69 Noise/Zoning

- Town Zoning & Noise: Encourage 200–500 ft vegetative buffers; enforce 45 dBA night limits.



Strictly enforce current laws: Zero cost-shifting to Connecticut ratepayers.

19

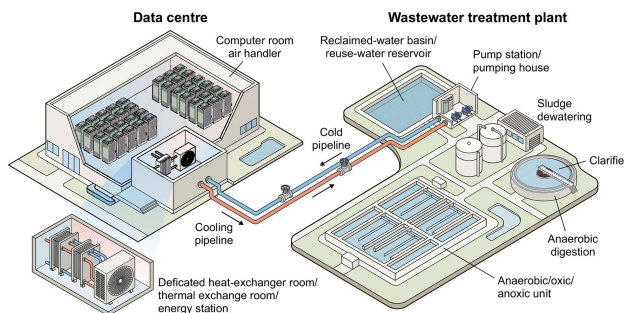


What We Should START Doing

--Water & Heat Integration

15

CO-LOCATION ARCHITECTURE



Wang et al. (2026). *Environmental Science and Ecotechnology*. DOI 10.1016/j.ese.2026.100702

LEGISLATIVE POLICY ACTIONS

- START: Effluent Cooling Sandbox**
 - Expedited permitting for data center piping to municipal facilities.
 - Target : WUE < 0.1 L/kWh.
- START: District Heat-Ready Standards**
 - Encourage 50°C – 60°C liquid-cooled headers for data centers ≥ 20 MW.
 - Route thermal output to supports local heating and municipal digesters.

Policy Path: Turn municipal wastewater treatment plants from disposal sites into clean cooling and heating hubs.

20



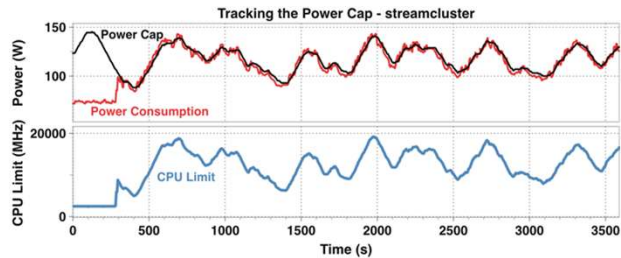
What We Should START Doing

--Grid Flexibility & Clean Energy

16

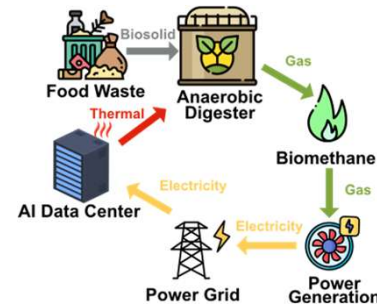
DYNAMIC PEAK SHAVING

- **Standardize OpenADR interfaces** for Large industrial loads ≥ 50 MW.
- **Incentivize DVFS throttling:** Cut facility power by $\geq 20\%$ during grid peaks without job abortion.



BIO-MICROGRID NEXUS

- **Leverage PA 13-285:** Co-locate with food waste & Biosolid anaerobic digestion.
- **Encourage firm on-site power:** Biomethane generation provides local peak mitigation.



Policy Path: Incentivize dynamic load flexibility to protect Connecticut's grid during demand peaks.

21

Empowering Connecticut's Clean AI Future: Science-Led Decision Making

17



PILLAR 1

Reject False Binary
Strict standards over blanket bans

PILLAR 2

Deploy Proven Engineering
Closed-loop effluent cooling
>20% grid peak shaving

PILLAR 3

Anchor in Science & Engineering
UConn/CASE empirical authority
Unbiased guidance

UConn Engineering Joint Taskforces:

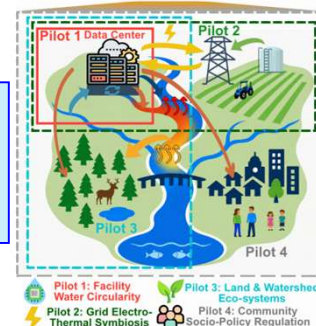
• Symbiotic Data Center (SDC) Working Group

Lead: Baikun Li, 20+ Faculty across Institute of the Environment and Energy (IoEE)

• Data Center Power Supplies & Grid Working Group

Lead: Emmanouil Anagnostou, Faculty across College of Engineering (COE)

Institutional Partners: CASE | Eversource Energy Center (EEC) | C2E2 | IoEE



Set rigorous standards. Welcome innovations. Protect our communities.

22

Thank you!

Email: baikun.li@uconn.edu

<https://cee.engr.uconn.edu/people/li-baikun>



UConn Tech Park (IPB)



Water Reuse Pilot Testbed



Eversource Energy Center (EEC)