1. **Title: Water Energy Planning Strategies to meet Emerging Load from Data Centers**

2. **Authors/Affiliations:**

Palash Bhowmik, Kara Cafferty – Idaho National Laboratory
Katherine Klise, Kyle Skolfield, Nicole Jackson – Sandia National Laboratories

3. **Focal Area(s):**

Water for Energy: This white paper addresses the growing need to innovatively manage energy and water use for data centers, with a focus on infrastructure planning and the potential need to plan for volatile and scarce water supply. It emphasizes tailoring data center designs to local and regional water and power constraints.

4. **Existing Challenge**

U.S. electricity demand is projected to rise by 35 to 40% by 2040, largely driven by the growth of artificial intelligence (AI) and the data centers that support it (American Clean Power Association, March 2025). Meeting this demand could require tens of trillions of gallons of water for cooling power and AI infrastructure. This volume of water simply is not available and would significantly impact other sectors (New York Times, 2025).

Data center developers recognize this limitation and are exploring air-cooled technologies. Air cooling consumes more energy and is less effective for compact, high-heat-load data centers. For instance, a new data center in Cheyenne, Wyoming, promises water-free operations, but it is located in a region with surplus power capacity—an exception rather than the rule.

Large water infrastructure projects of the 20th-century are not viable options for the urgent needs of datacenters, as they take decades to complete. Instead, there is growing opportunity for innovative, localized solutions—especially as data centers become essential to modern life.

Additionally, water and energy governance varies widely by state, both in implementation and interpretation. Many states have yet to explicitly recognize data centers, leaving decisions to local authorities—potentially helping or hindering utilities. These non-technical challenges must be addressed in coordination with technological innovation and integration. Effective partnerships are needed to align technologies with local and regional needs, while navigating institutional boundaries, legal frameworks, and financial constraints.

5. **Near-Term Opportunity**

There is significant need to evaluate data centers needs within larger infrastructure planning strategies. These strategies must evaluate tradeoffs, load growth forecasts, and cost-benefit analyses. Achieving this requires collaboration among data center operators, utilities, and research institutions—supported by robust modeling and analysis.

A key need to evaluate tradeoffs is forecasting energy and water demands across different data center types and operational conditions. Evaluations must consider long term projections of local populations and industries as data centers will impact long-term opportunities.

Data center types are typically measured by two metrics:

INL/PRO-25-88692

- Power Usage Effectiveness (PUE): Total facility energy divided by IT equipment energy.
- Water Usage Effectiveness (WUE): Annual water use divided by IT equipment energy.

Improving both PUE and WUE is key to efficient operations, but there are confounding relationships between water, energy, and infrastructure requirements. For example, air cooling has a WUE of zero but high energy consumption. Liquid, immersion, and direct-to-chip cooling reduce WUE but may increase PUE.

Both metrics, PUE and WUE, overlook embedded water and energy—such as water used in power generation or energy used in water treatment. These embedded factors must be included in tradeoff analyses in addition to data center type to fully understand local and regional impacts and the integrated strategies of infrastructure planning.

6. Success Measures

Success will be measured ultimately through the ability to deploy large data centers without significantly sacrificing other water uses. Achieving this will require several intermediate steps, represented by the following metrics:

- Creation of a local and regional frameworks and/or a technical playbook for replicating data center energy-water systems elsewhere.
- Increased acceptance and engagement across stakeholders
- Policy and planning coordination between energy and water system operators.
- Number of innovative system designs and operational models that co-benefit both infrastructure entities and surrounding communities. For example, RELIANT developed an economic model example—committing to local housing investments, adopting air-cooled systems to reduce water use, and implementing a power tariff structure to maintain affordable electricity for residents.

7. References

[1] Cafferty, K., Pacheco, C., Davis, D., Tidwell, V., and Snyder, S. (2023). Analysis of Water-Energy Issues for Nuclear Power Industry with Industry Perspective. INL/RPT-23-75383.

[2] Cafferty, K., Pacheco, C., Saulsbury, J., & Cogley, H. (2024). "Community Water-Power Resiliency: Ownership and Management Influence:" Idaho DEQ 35th Annual Water Quality Workshop

[3] Klise, K.A., Bynum, M., Moriarty, D., Murray, R. (2017). A software framework for assessing the resilience of drinking water systems to disasters with an example earthquake case study, Environmental Modelling and Software, 95, 420-431, doi: 10.1016/j.envsoft.2017.06.022. [Online WNTR user manual available at https://usepa.github.io/WNTR]

[4] Li, C., Conejo, A. J., Liu, P., Omell, B. P., Siirola, J. D., & Grossmann, I. E. (2022). Mixed-integer linear programming models and algorithms for generation and transmission expansion planning of power systems. *European Journal of Operational Research*, *297*(3), 1071-1082.

[5] https://www.energy.gov/articles/doe-announces-site-selection-ai-data-center-and-energy-infrastructure-development-federal

[6] https://www.energy.gov/articles/department-energy-announces-initial-selections-new-reactor-pilot-program

[7] Bhowmik, P. K. (2024). *NEXUS-DC: Nuclear Energy eXpedition for US Data Centers* (No. INL/MIS-24-82389-Rev000). Idaho National Laboratory (INL), Idaho Falls, ID (United States).