AI and HPC Water Usage: Findings from 11 Leading Supercomputing Centers

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Abstract—High-density artificial intelligence (AI) and high-performance computing (HPC) workloads generate increasing thermal loads, making water availability, permitting, and local resource impacts important facility considerations. This poster establishes an operational baseline from 11 global supercomputing centers. A 35-question survey examined cooling architectures, annual water consumption, Water Usage Effectiveness (WUE), cooling tower blowdown, water quality, and barriers to conservation. Across the surveyed sites, cooling architecture was more closely associated with WUE than local water stress. Two of the three hybrid/adiabatic sites reported the lowest WUE values (<0.5 L/kWh), where lower WUE indicates better water efficiency. At evaporative sites, cooling tower blowdown accounted for approximately 15%–33% of facility makeup water. Higher Cycles of Concentration (CoC) reduce blowdown and can reduce water use, but water chemistry can limit how high CoC can be maintained. The survey also identified a water-energy trade-off: some approaches to reducing water use require additional energy. Finally, closed-loop liquid cooling within IT racks does not by itself eliminate on-site water use; total water use also depends on how heat is rejected outside the facility.

Index Terms—artificial intelligence, high-performance computing, water usage effectiveness, cooling systems, water conservation

I. INTRODUCTION

The increasing thermal density of AI and HPC workloads has made water availability, permitting, and local resource impacts important facility considerations. While energy metrics such as Power Usage Effectiveness (PUE) are widely tracked, water monitoring remains less consistent. Data centers have historically used evaporative cooling towers because they can reduce cooling energy, but they also consume water. This study examines operational data from 11 global HPC facilities to establish a baseline for cooling infrastructure, water consumption, metering, water sources, water chemistry, and conservation practices.

II. METHODOLOGY AND RESPONDENT FACILITIES

A 35-question survey was developed by a collaborative group of HPC practitioners, facility managers, vendors, and academic researchers. The survey covered facility power, cooling systems, PUE, water consumption, WUE, water sources and costs, chemical treatment, blowdown, and barriers to additional conservation. Because power metrics were omitted from the survey, TOP500 HPL peak power was used as a standardized proxy for flagship system scale. This single-system peak value may not correspond directly to the IT energy boundaries used by facilities to calculate reported WUE.

The survey was distributed to 23 major supercomputing sites. Twelve sites responded. One response was excluded because the facility was still under construction, leaving 11 operational sites. The sites included LLNL (El Capitan), ORNL (Frontier), RIKEN (Fugaku), CSCS (Alps), KAUST (Shaheen III), LANL (Venado), TU Dresden (Capella), INL (Teton), LRZ (SuperMUC-NG), NLR (Kestrel GPU), and ECMWF (HPCF).

III. OPERATIONAL CHARACTERISTICS AND WATER EFFICIENCY

Across the surveyed sites, cooling architecture showed a stronger relationship with WUE than local water stress, based on the WRI Aqueduct 4.0 classification. Lower WUE indicates better water efficiency. Two of the three hybrid/adiabatic sites reported the lowest WUE values: TU Dresden reported 0.44 L/kWh and ECMWF reported 0.471 L/kWh. Evaporative sites reported higher WUE values, including 4.2–4.7 L/kWh at RIKEN, and above 1.5 L/kWh at LANL and ORNL

Water measurement remains limited. Three of the 11 facilities did not report WUE and 6 out of 11 sites reported that they do not measure WUE.

CSCS is also an unusual case: it uses lake water in a once-through cooling system, with approximately 8 million m^3/y passing through the facility and returning directly to Lake Lugano.

IV. BLOWDOWN, WATER QUALITY, AND CONSERVATION BARRIERS

In evaporative systems, cooling tower blowdown accounts for approximately 15%–33% of facility makeup water. Blowdown relates to Cycles of Concentration (CoC). As CoC increases, water can be recirculated more times before blowdown is required, reducing water loss. Only 4 of the 9 evaporative sites track blowdown and CoC.

NLR provides an example. At approximately CoC 7, it uses 32,986 m^3/y of makeup water and reports 4,744 m^3/y of blowdown, or 14.4% of makeup water. At CoC 3, the calculated blowdown fraction would increase to approximately 33%.

Water chemistry can limit CoC. Corrosion was reported at 7 sites, scale at 5 sites, and microbiological growth at 4 sites. These conditions can affect heat transfer, equipment reliability, and the ability to operate at higher CoC.

The survey also identified a water-energy trade-off. Some approaches to reducing water use, such as dry cooling or reverse osmosis, can increase energy use. The balance can change with weather and operating conditions. Some facilities use dry cooling for much of the year and add water-based cooling during periods of high outdoor temperature.

Physical space and cost were each identified as barriers to additional water conservation at 7 of the 11 sites. Reported water prices varied substantially among the five sites that provided cost data.

V. CONCLUSION

Water use in AI and HPC facilities depends in part on how heat is rejected outside the IT system. In this survey, two out of three hybrid/adiabatic sites reported the lowest WUE, while evaporative sites generally reported higher WUE. For evaporative cooling, increasing CoC can reduce blowdown and water use, but water chemistry can limit operation. Measurement is also a gap: three sites do not measure WUE, and only four of nine evaporative sites track blowdown and CoC.

The results also show that water and energy should be considered together. Some strategies that reduce water use require additional energy, and the balance can change with operating conditions. Finally, closed-loop liquid cooling at the IT level does not by itself determine site water use; the outdoor heat-rejection system remains an important factor.