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WaterSplit: Coordinated On-Site and Off-Site Water Allocation For Sustainable Datacenter Cooling




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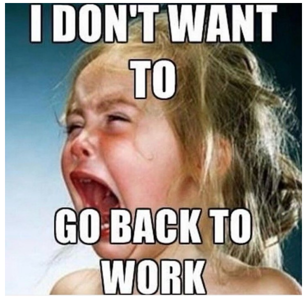
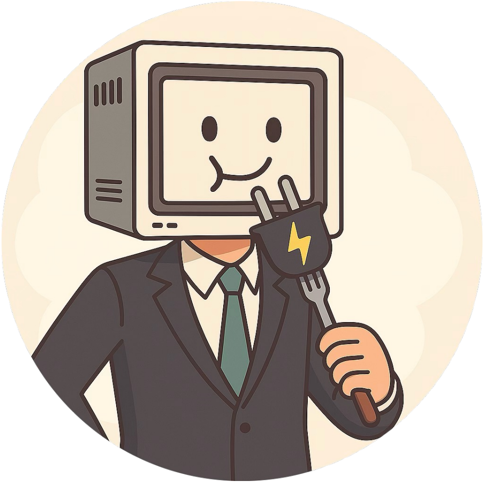
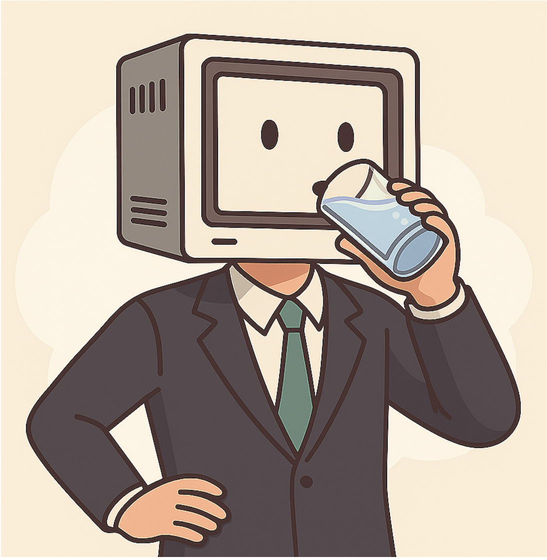
What if…





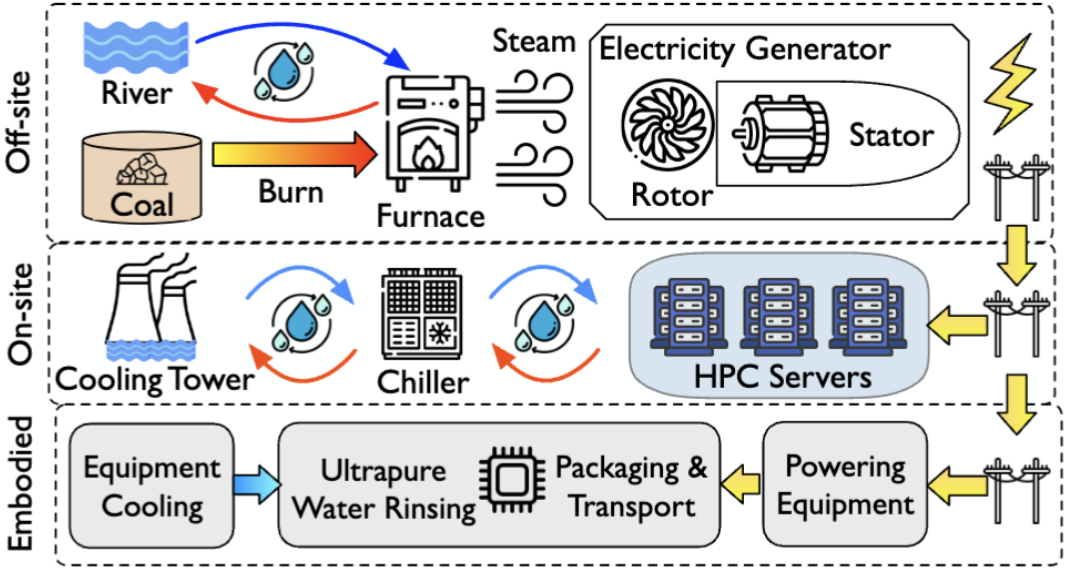
Datacenters Drink Huge Amounts of Water!



560 Billion Liters

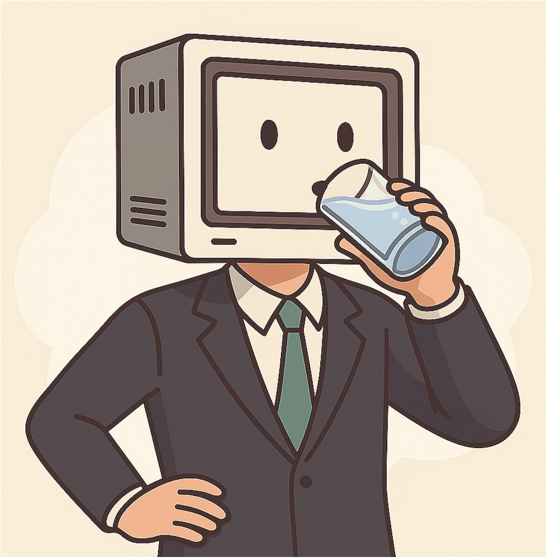
≈

224,000 



Datacenters consume huge amounts of water, the water footprint serves as a metric for quantifying total water consumption, encompassing the on-site, off-site, and embodied components.

Datacenters Are Going on a Water Diet




OUT TO SEA

Silicon Valley bets $200M on AI data centers floating in the ocean

Panthalassa aims to test floating AI computing nodes in the Pacific in 2026.

JEREMY HSU – MAY 5, 2026 5:41 PM | 147

Pathalassa's floating AI "node" consists of a large white sphere atop a vertical structure extending down below the water's surface. Credit: Panthalassa

Microsoft Unveils Zero-Water Datacenter Design to Slash Cooling Water Use

by ESG News • December 12, 2024

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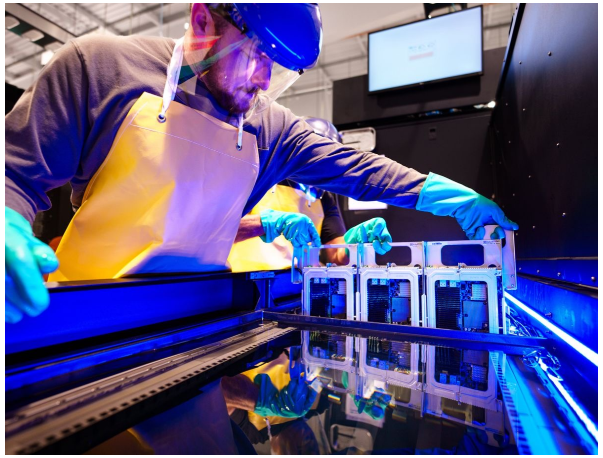
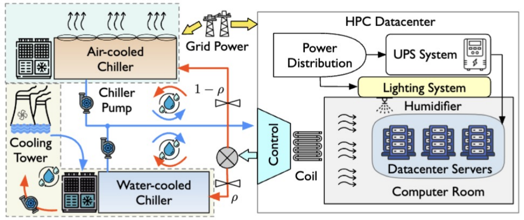
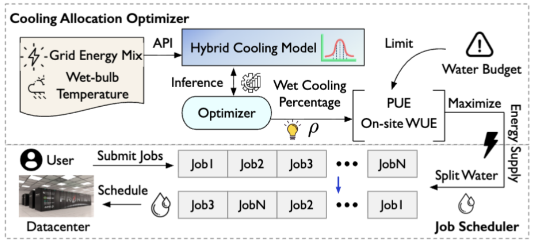


WaterSplit: Executive Summary

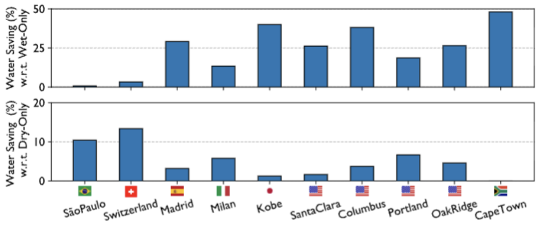
- ✓ **A Hybrid Cooling System Prototype:** Build a hybrid cooling model that integrates wet and dry cooling mechanisms with major datacenter infrastructure components.



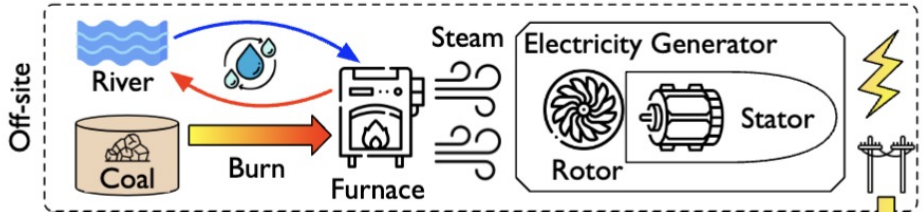
- ✓ **Two-level Water-aware Optimizer:** A two-level water-aware optimization framework that jointly manages cooling allocation and workload scheduling under limited water budgets.



- ✓ **Comprehensive Evaluations of WaterSplit:** Evaluated across 10 regions with real-world weather data, datacenter workloads, and workload traces; compared against three state-of-the-art baselines to show improved water-aware resource management.



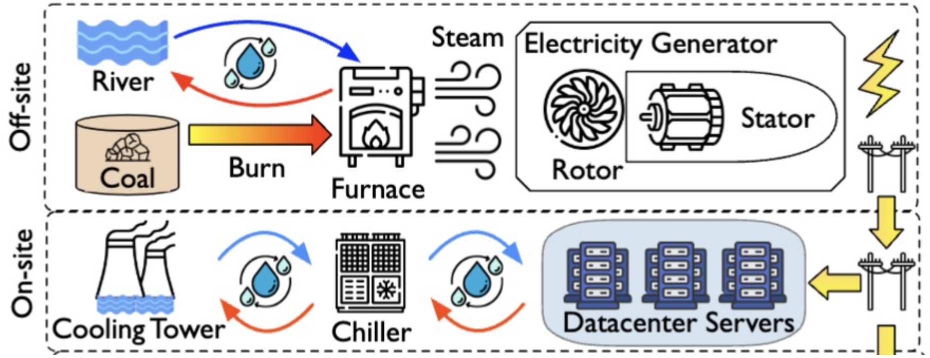
Introduction of Water Footprint



Off-site Water Footprint $W_{\text{off}} = \text{WUE}_{\text{off}} \cdot E_T \cdot \text{PUE}$

Off-site Water Footprint: Refers to the amount of water consumed during power generation. The off-site WUE is the metric that determines the off-site water footprint.

Introduction of Water Footprint

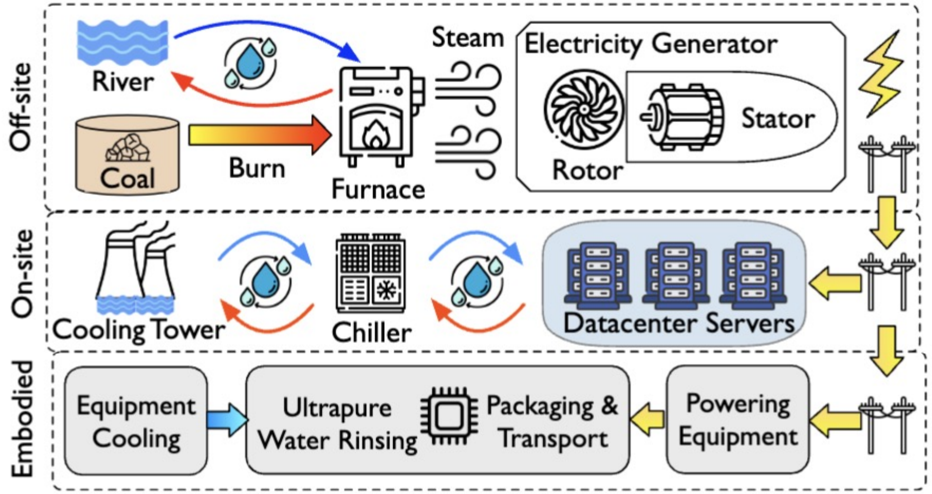


Off-site Water Footprint $W_{\mathrm{off}} = \mathrm{WUE}_{\mathrm{off}} \cdot E_T \cdot \mathrm{PUE}$

On-site Water Footprint $W_{\mathrm{on}} = \mathrm{WUE}_{\mathrm{on}} \cdot E_T$

On-site Water Footprint: is consumed during the cooling process in the systems. On-site WUE quantifies the amount of water needed to cool one unit of energy (lower is better).

Introduction of Water Footprint



Off-site Water Footprint $W_{\text{off}} = \text{WUE}_{\text{off}} \cdot E_T \cdot \text{PUE}$

On-site Water Footprint $W_{\text{on}} = \text{WUE}_{\text{on}} \cdot E_T$

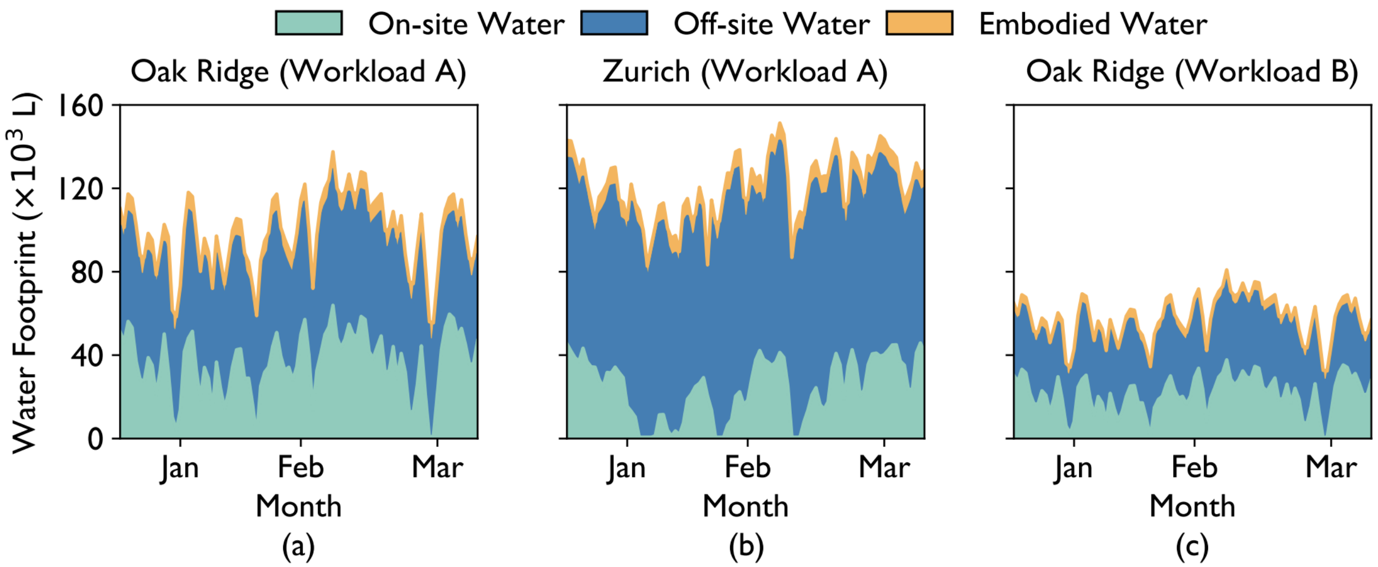
Embodied Water Footprint

Embodied Water Footprint: water consumed during hardware packaging and manufacturing.

Water Stress Factor: capture the regional scarcity of water usage

$$W^{\text{WSF}} = (W_{\text{on}} + W_{\text{off}}) \cdot \text{WSF}$$

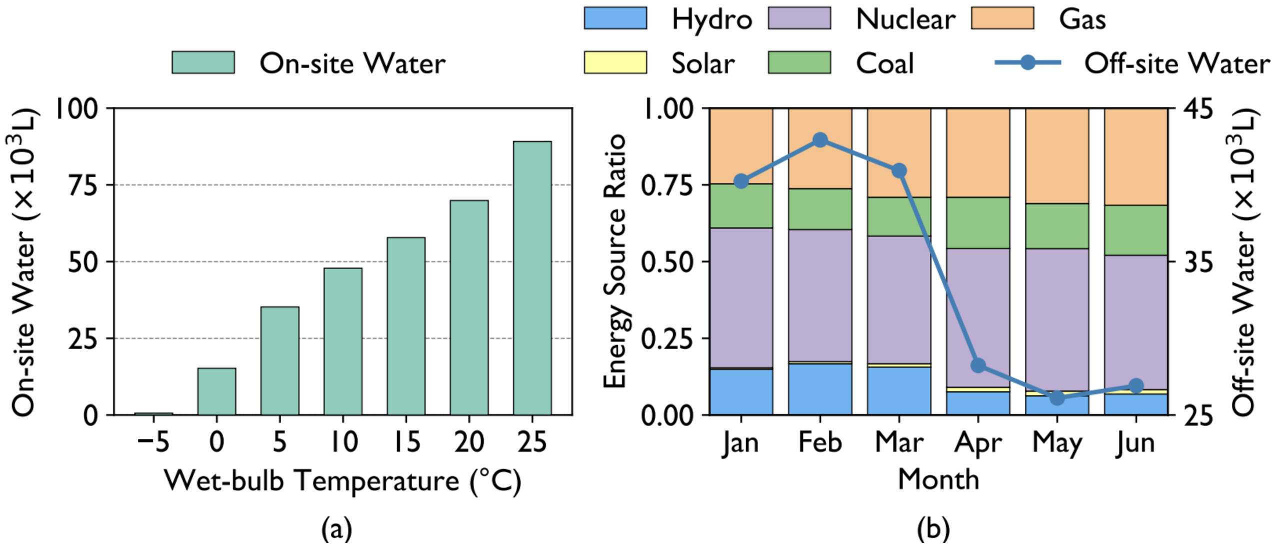
Water Footprint Components Inside Datacenter Systems



Applications	Metrics	Languages	Description
Mediawiki	Peak RPS	PHP, Hack	Web Serving (Facebook)
FeedSim	RPS under SLO	C++	Object Aggregation
DjangoBench	Peak RPS	Python, C++	Web Serving (Instagram)
VideoTranscodeBench	Throughput	C++	Video Processing
LLM-bench	Inference Latency	Python	LLM Inference using CPU

The water consumption in operating the datacenter system has three components: on-site water footprint (water for cooling), off-site water footprint (water for power generation), and embodied water footprint (water for hardware manufacturing).

Water Footprint Components inside Datacenter Systems



Energy Source	Hydro	Geothermal	Nuclear	Oil	Coal	Biomass	Gas	Solar	Wind
WUE_{off} (L/kWh)	17	5.8	2.6	1.79	1.51	1.14	1.02	0.06	0

The on-site water consumption is driven by local weather conditions. In contrast, the off-site water consumption varies due to the availability of the local energy mix and its respective off-site WUE. The usage of water-intensive energy sources for power generation impacts the off-site water.

Cooling System: A Real Water Bottleneck in Datacenter

Off-site ↓

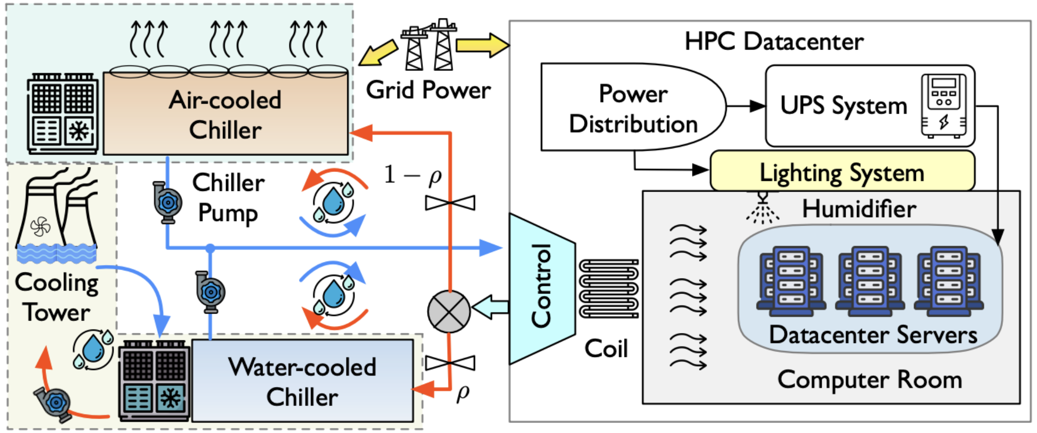
On-site ↑

Wet Cooling

Off-site ↑

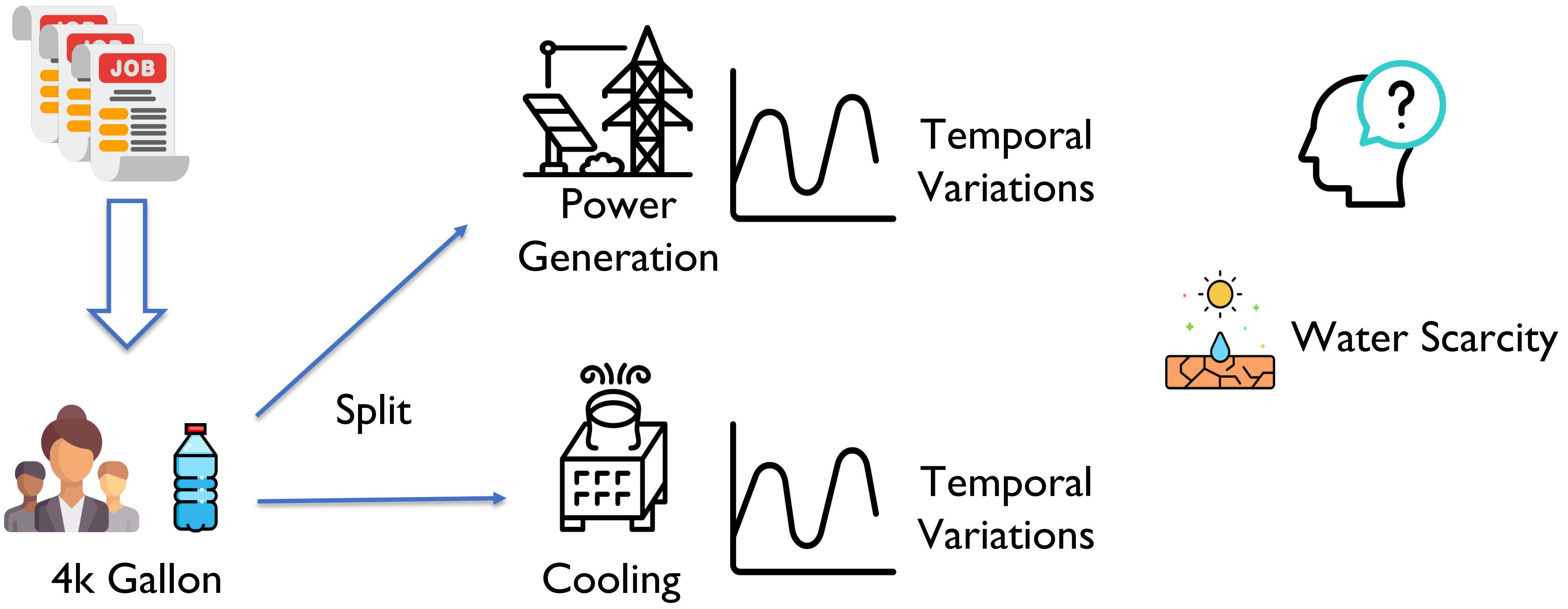
On-site ↓

Dry Cooling



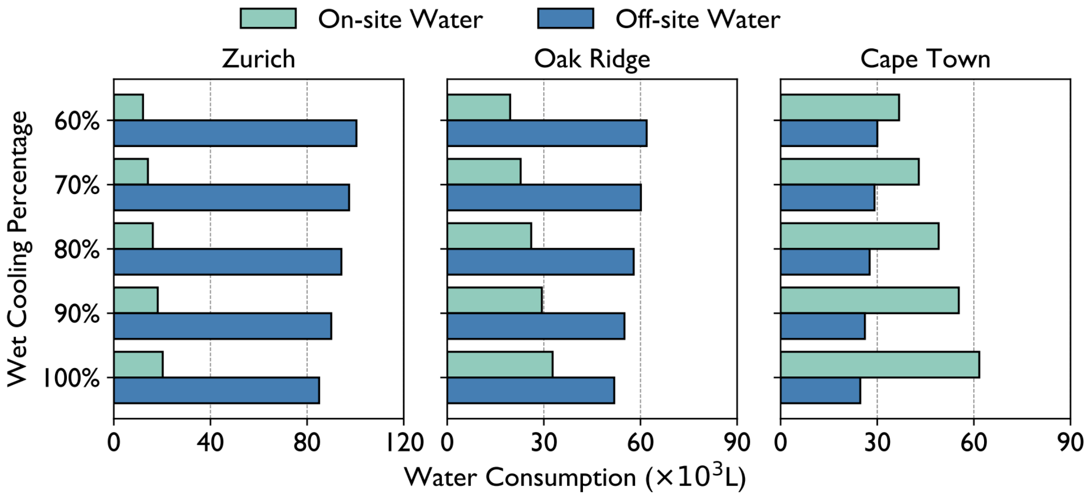
To mitigate the water footprint while maintaining energy efficiency, hybrid cooling systems have been proposed as a promising alternative.

How to choose different water diet?

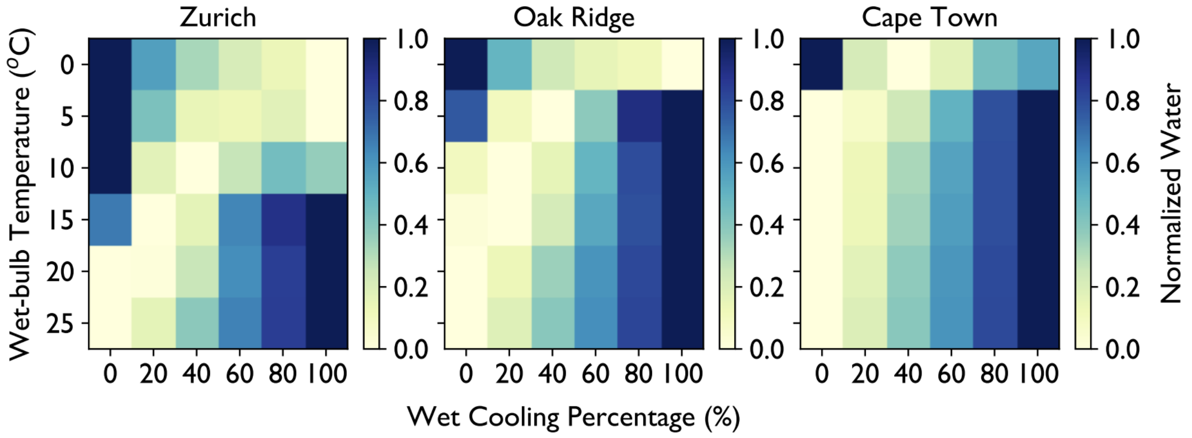


How to allocate limited water resources between power generation and cooling to maintain system efficiency?

Off-site Water vs On-site Water: Trade-offs

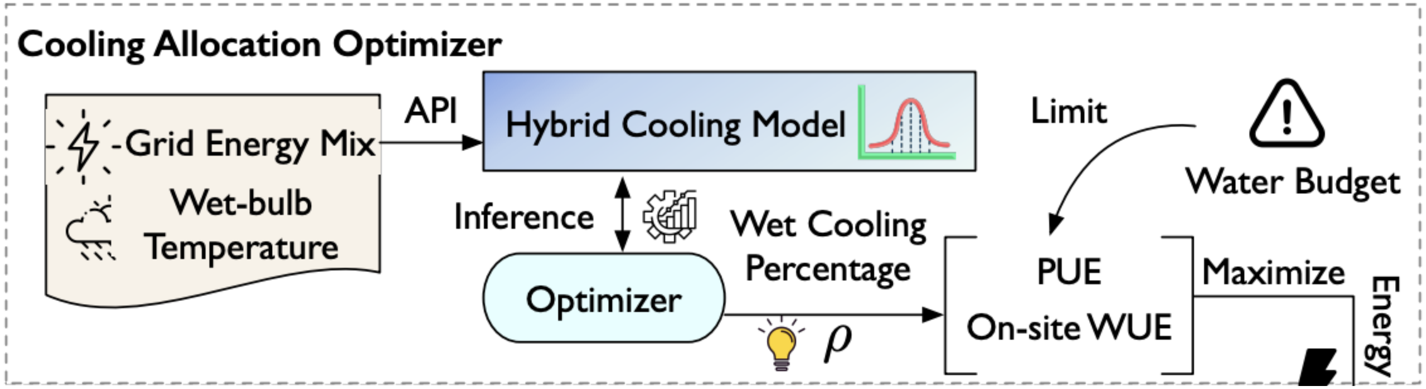


On-site and off-site water footprints have trade-offs: reducing on-site water usage can raise PUE, increasing power demand.



Optimizing datacenter water footprint is challenging because control knobs create trade-offs between on-site and off-site water use.

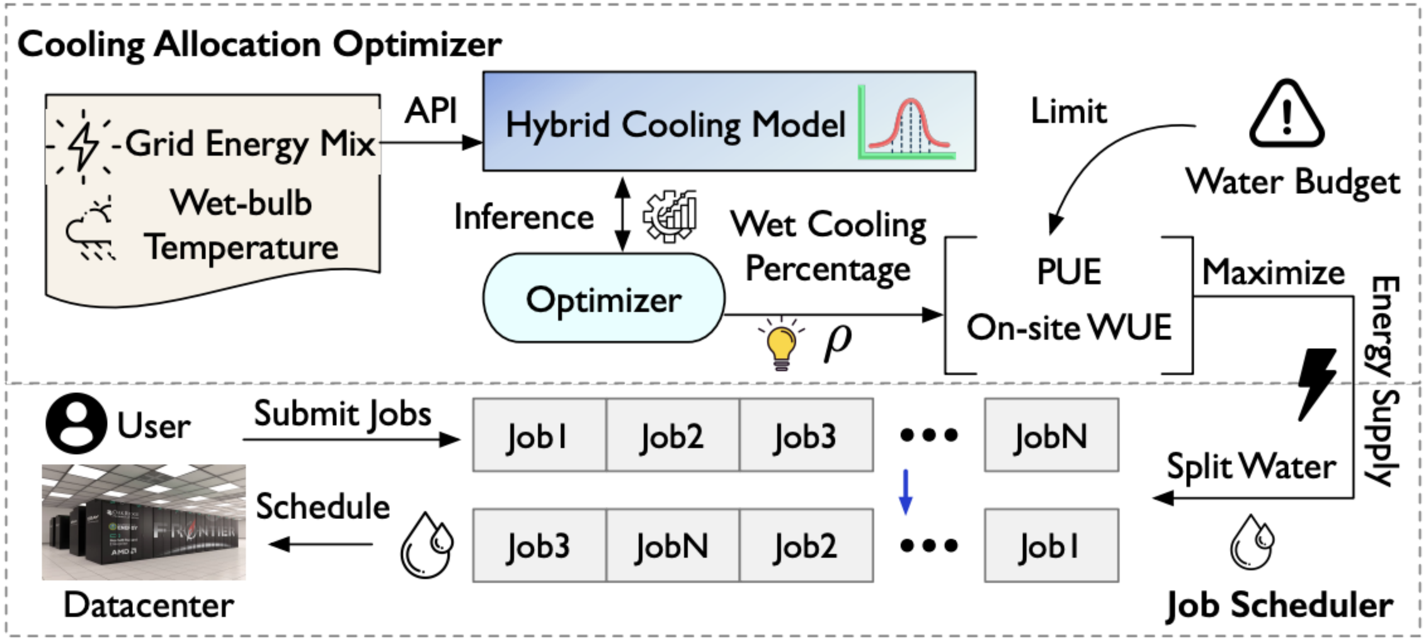
Design of WaterSplit



$$\sum_{t \in \mathcal{T}_k} (W_{\text{on}}^t + W_{\text{off}}^t) \le W_{\text{budget}}^T, \quad \forall k$$

$$f = \max_{\rho \in [0,1]} E_{\text{DC}}^T$$

Design of WaterSplit



$$\text{priority}(j_i) = \hat{W}_i - \gamma \times \text{Wait}\hat{\text{T}}\text{ime}$$

$$\max \sum_{j_i \in \mathcal{J}} \mathbb{1}_{\text{scheduled}(j_i)}$$

WaterSplit allocates water under a budget by choosing the wet-cooling percentage and job schedule to balance water use and energy supply.

Experimental Methodology

Setup

- AWS m5.metal
- Hybrid Cooling Model

Metrics

- Water Footprint
- Queuing Time

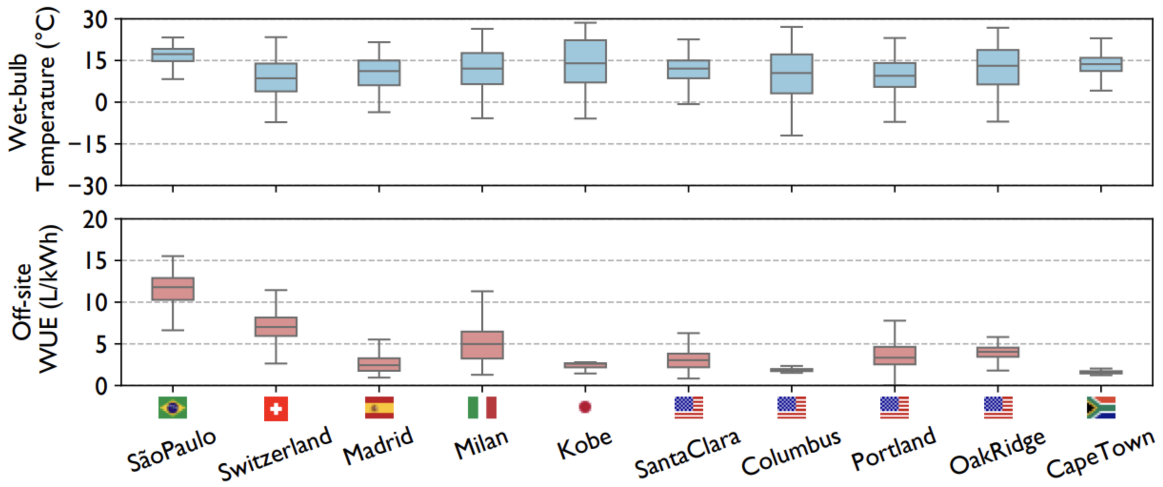
Workloads

- Meta DCPerf
- CPU-based LLM Serving

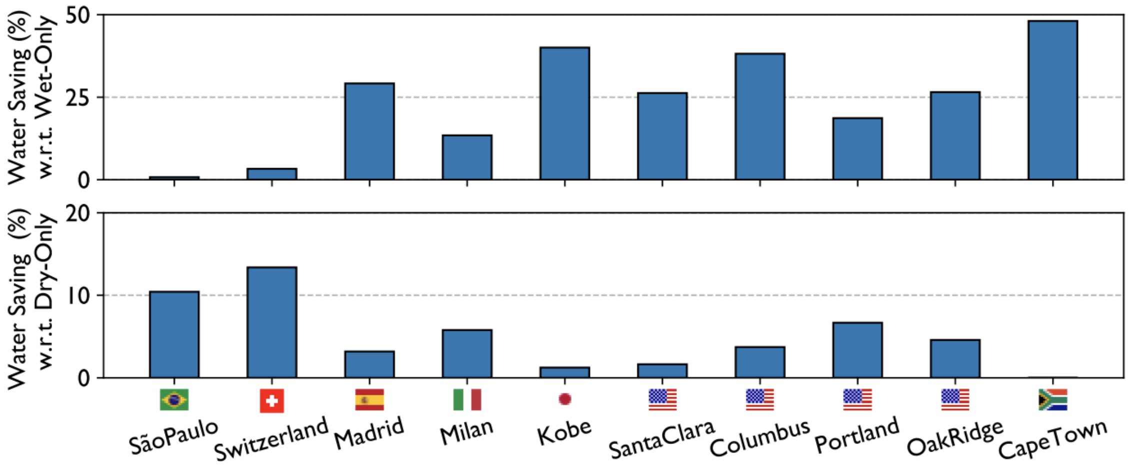
Schemes

- Dry-only, Wet-Only
- Static-Hybrid
- Temperature-Adaptive
- WaterWise, WACE, SLIT

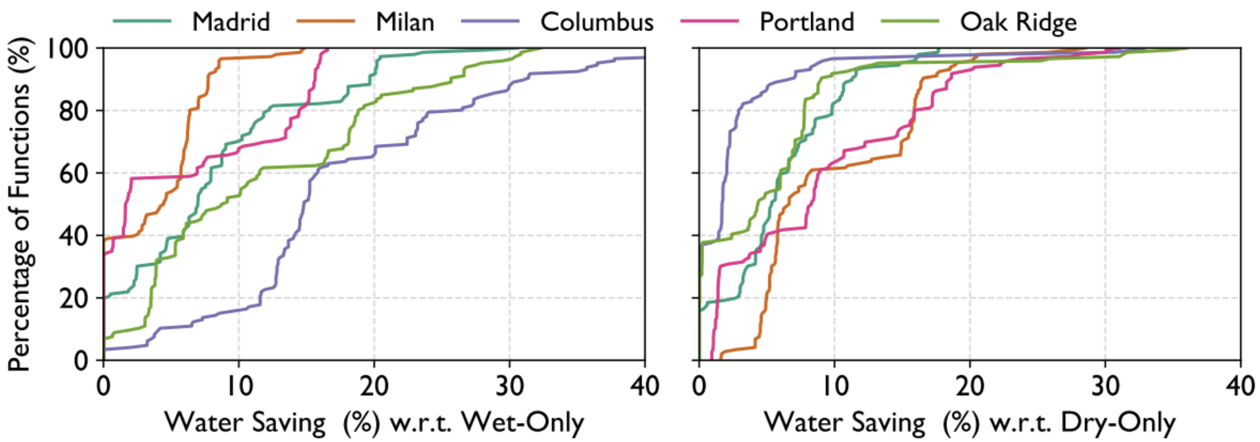
Real Outside Environmental Data



WaterSplit is Effective at Optimizing Water Footprint



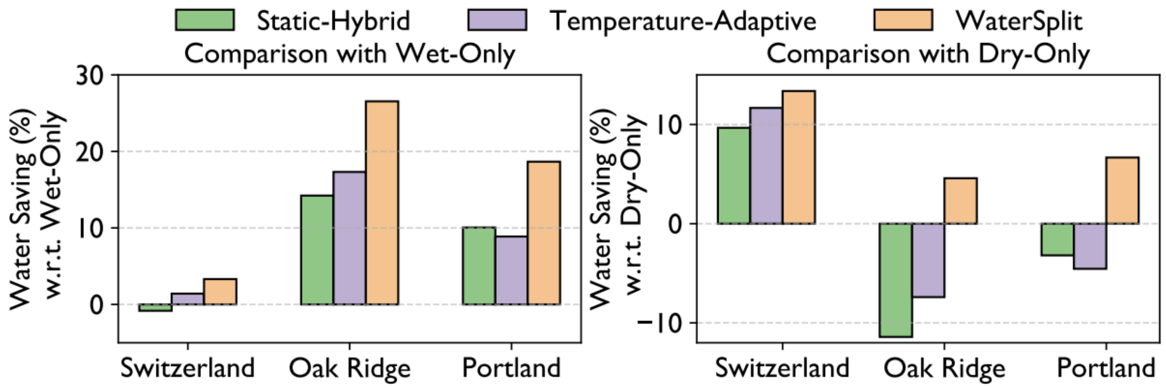
Overall Water Savings



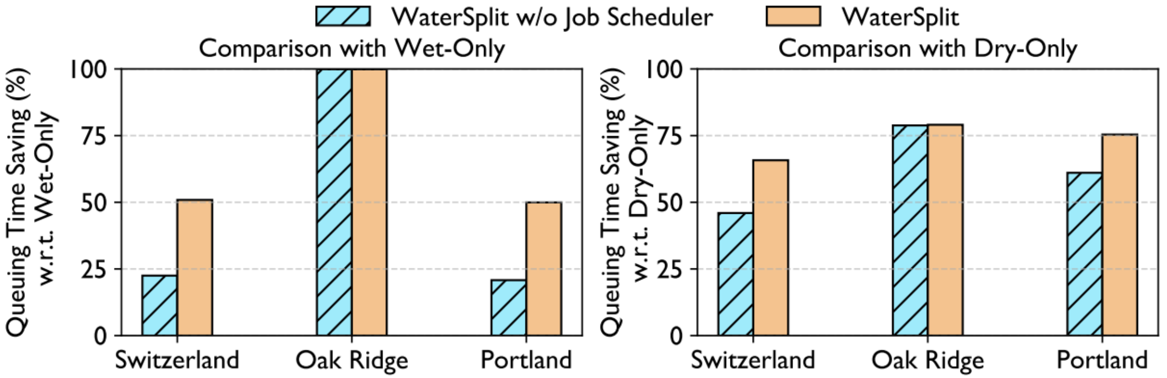
CDF

The effectiveness of hybrid cooling is region-dependent. Hybrid cooling provides benefits primarily in transitional climates, and its long-term suitability requires evaluation over extended observation periods (more than one year).

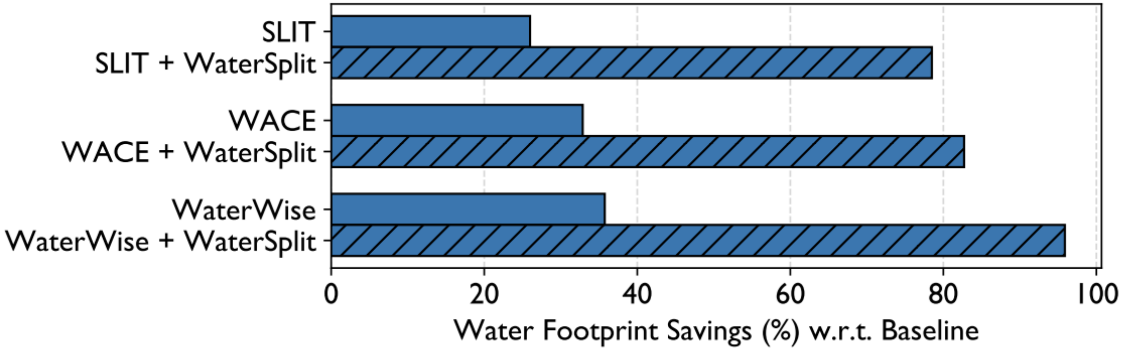
WaterSplit is Effective at Optimizing Water Footprint



WaterSplit achieves greater water savings than other hybrid cooling strategies.

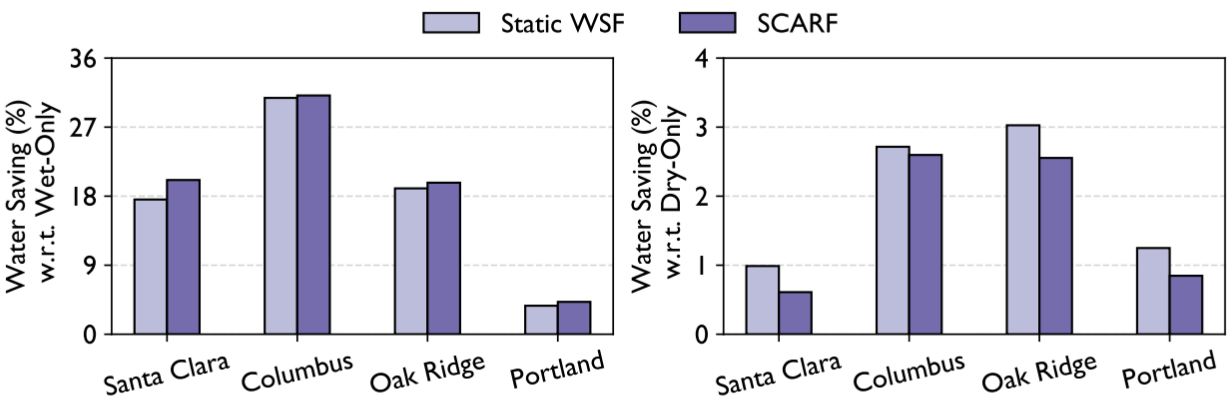


Water-aware Scheduler reduces the job queuing time.

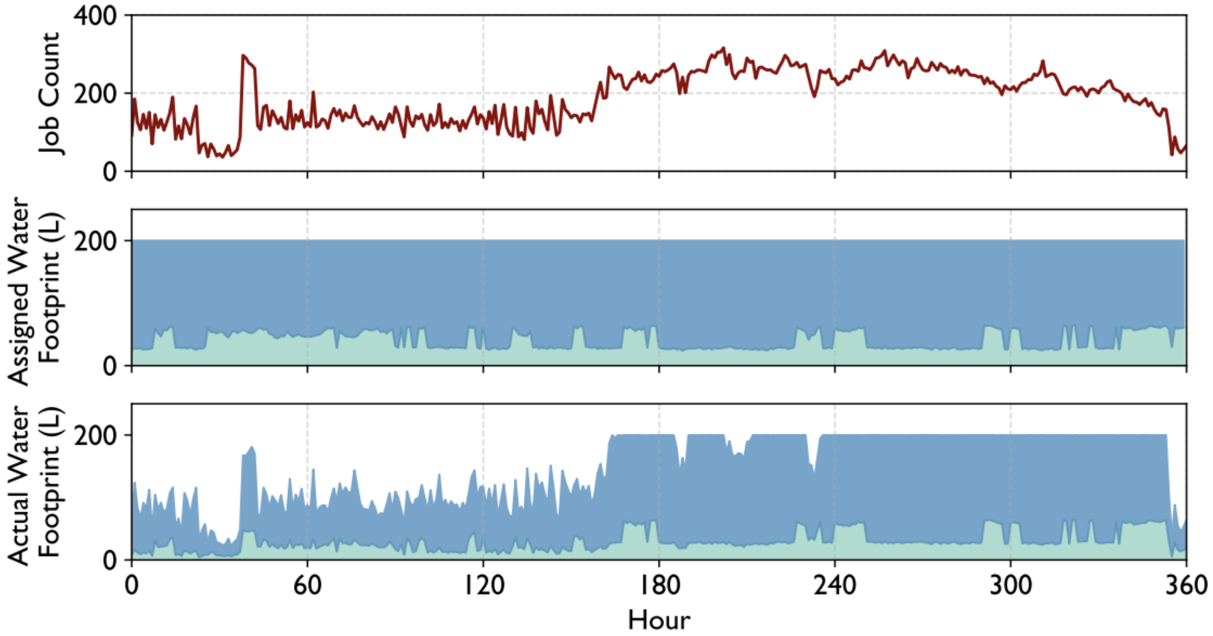


WaterSplit can further increase water savings compared to existing state-of-the-art approaches.

WaterSplit is Robust with Scarcity-Aware Water Budgets



WaterSplit is still effective after embedding different Water Stress Factors.



Water budget is useful to regulate and maintain a stable water usage, considering both on-site and off-site water footprint. However, it must be carefully managed to achieve acceptable queuing delays.

WaterSplit: Summary Key Contributions

- ✓ WaterSplit reveals the trade-off between on-site and off-site water footprints in hybrid-cooled datacenters.
- ✓ WaterSplit builds a hybrid cooling model to estimate PUE and on-site WUE under different wet-cooling percentages, using wet-bulb temperature and regional energy mix.
- ✓ WaterSplit introduces a two-level water-aware optimizer that jointly selects the wet-cooling percentage and schedules jobs under a water budget, improving throughput while avoiding starvation.
- ✓ WaterSplit reduces water footprint across diverse regions and can further improve existing water-aware schemes.

WaterSplit

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