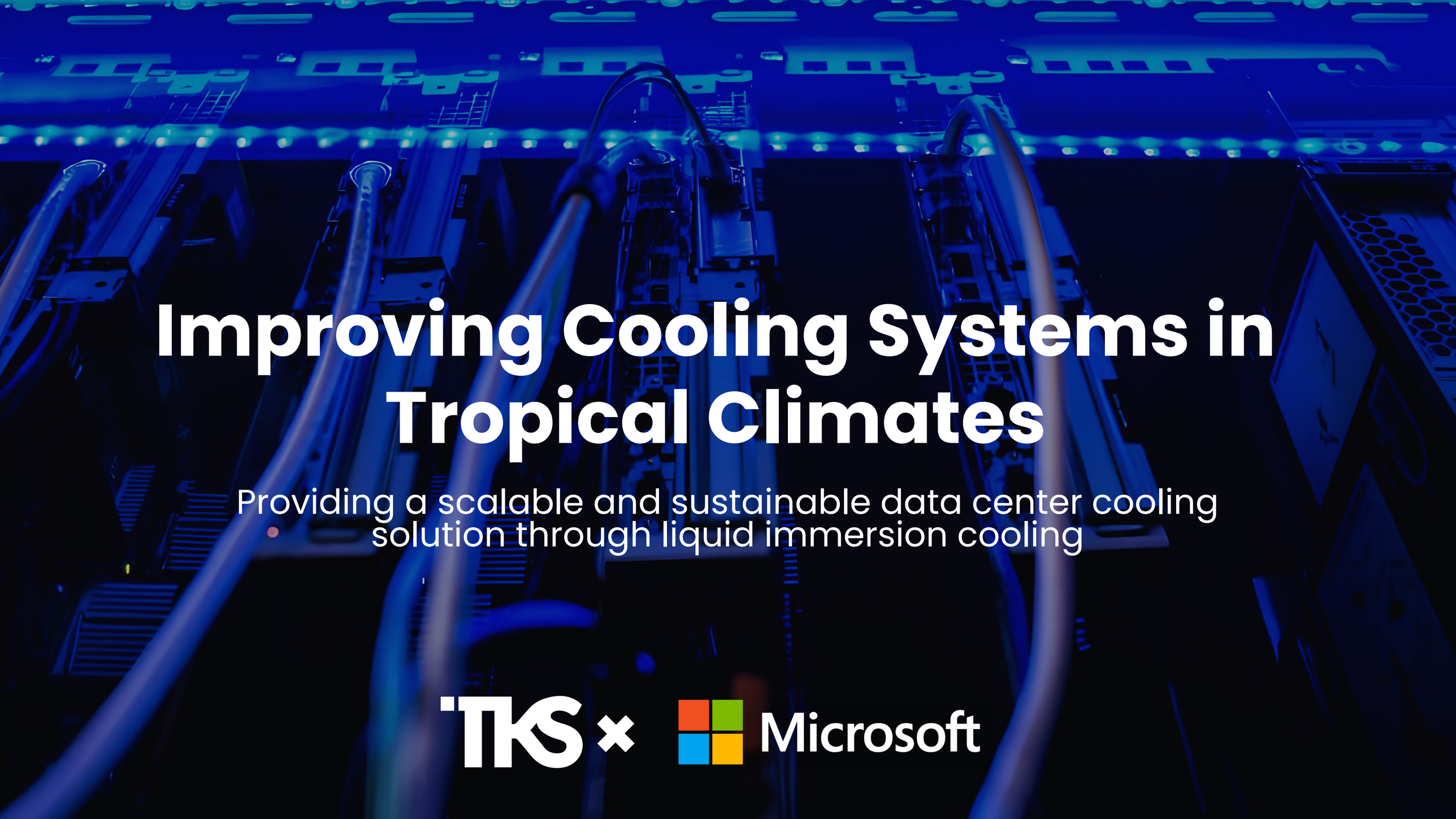


Improving Cooling Systems in Tropical Climates

Providing a scalable and sustainable data center cooling solution through liquid immersion cooling

TKS × Microsoft

Executive Summary

Objective

The AI market will expand **37.3% annually**, relying on data centers to support computation; however, these data centers, especially in warmer conditions, utilize cooling systems that consume excessive water and electricity, which strains local neighborhoods.

Recommendation

We recommend implementing **liquid immersion cooling** (LIC) systems for all future data centers in warm climates, such as in China (Hong Kong), India (Chennai / Dubai), and the US (California, Arizona), and also countries with water shortages like Singapore.

Outcome

LIC will reduce water usage from **311 megaliters** a year to **near zero** per data center, and reduce electricity consumption by **23.7%.** This will accelerate progress towards Microsoft's goals of water positive and **net zero** in 2030.

Artificial intelligence is growing, and so is demand for data centers.

$1,811.8
billion dollars market

AI is advancing and requires many data centers.

The global artificial intelligence market size is projected to expand at a **compound annual growth rate** of **37.3**% from 2023 to 2030. It is projected to reach **$1,811.8 billion** by 2030.

50-100 new data centers per year

Microsoft is providing these data centers to support accelerating advances in the AI market.

As of October 2023, Microsoft has **120 operational data centers**, and has plans to build another **46** in the near future. In fact, Microsoft had plans to create **50 to 100** data centers every year as of 2021.

Data centers have a heavy impact on the environment, especially in its electricity and water usage.

Annually, global data centers consume **460 TWh**, which can provide

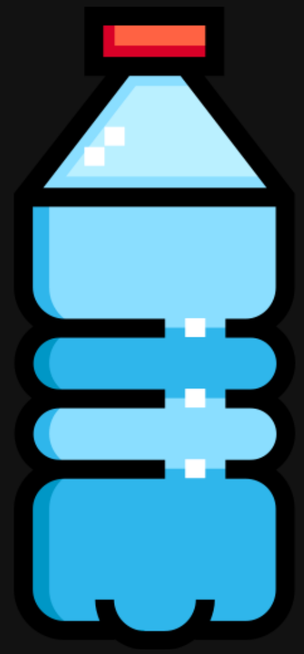
6.6 days of electricity

to the **entire globe**,

and **828 billion liters** which can provide

1.078 L of water

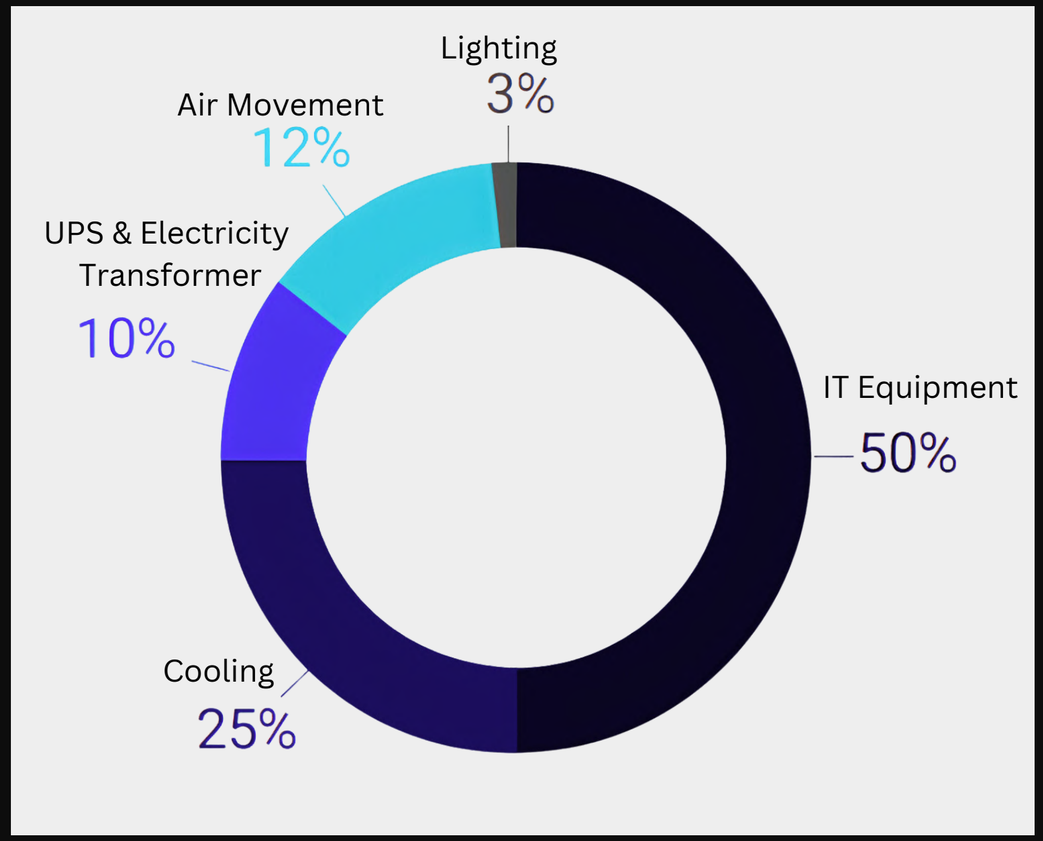
for the 2.11 billion people in the world who don’t have access to safe drinking water. Every. Single. Day.



It is important to address issues regarding the sustainability of data centers as demands for cloud computing services rise.

calculations

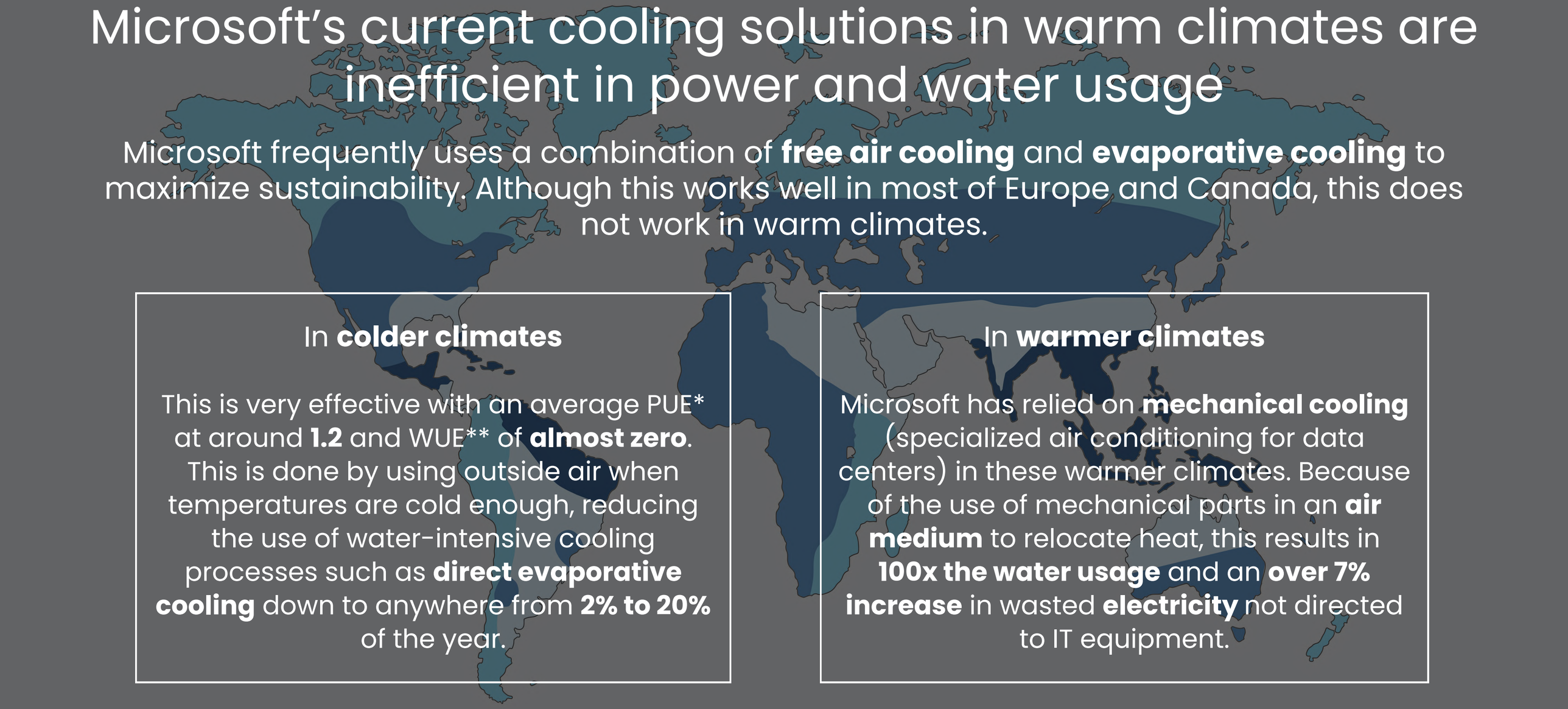
Cooling Systems are the main concern of data center sustainability



- Data centers require cooling systems to maintain constant temperature, which accounts for **25%** of data center energy consumptions.
- The total water usage in data centers are mostly attributed to cooling systems, with minor sources from humidification and maintenance.

Microsoft’s current cooling solutions in warm climates are inefficient in power and water usage

Microsoft frequently uses a combination of **free air cooling** and **evaporative cooling** to maximize sustainability. Although this works well in most of Europe and Canada, this does not work in warm climates.



In **colder climates**

This is very effective with an average PUE* at around **1.2** and WUE** of **almost zero**. This is done by using outside air when temperatures are cold enough, reducing the use of water-intensive cooling processes such as **direct evaporative cooling** down to anywhere from **2% to 20%** of the year.

In **warmer climates**

Microsoft has relied on **mechanical cooling** (specialized air conditioning for data centers) in these warmer climates. Because of the use of mechanical parts in an **air medium** to relocate heat, this results in **100x the water usage** and an **over 7% increase** in wasted **electricity** not directed to IT equipment.

* Power Usage Efficiency (PUE) is calculated by the formula Total Amount of Energy Used / IT Equipment Energy Usage.
** Water Usage Efficiency (WUE) is calculated by the formula Total Water Consumption / IT Equipment Output.

Mechanical cooling | High-efficiency mechanical cooling | Adiabatic cooling | Free air cooling

Untapped potential in innovative countries

The most powerful places of AI innovation, such as California, Tokyo, Hong Kong, Dubai, and Singapore, lie in **warmer climates** with **large talent populations** and severely **water-stressed** situations.

Contemporary Global Examples

- **India** has invested USD **$1.25 billion** to fund AI startups and developing AI applications.
- the **United Arab Emirates** have committed **$500 million** to accelerate AI research through the Falcon Foundation.

Cooling systems in warm climates have room to improve

The cooling systems of data centers in tropical climates consume large amounts of electricity and water, and are unsustainable in the status quo.

Water Usage

Compared to the data center in Wyoming, Microsoft's data center in Arizona (which is only about 10° south) uses **10x water**. Compared to the data center in Ireland, the one in Arizona uses **75x water**.
One Microsoft data center in Singapore has a WUE rating of **2.06 L/kWh**, which is equivalent to **311,600,000 liters** of water every year. That's the same as about **125** Olympic-sized swimming pools, or over **1 million** bathtubs full of water.

Electricity Usage

Compared to the data center in Wyoming, Microsoft's data center in Arizona (which is only about 10° south) uses **78%** more energy on non-IT processes like cooling.
Singapore's data center has a PUE rating of **1.358**, which correlates to **26.4%** of all energy used towards non-IT processes like cooling.

Diagnosis:

- Unsuitable cooling systems in tropical regions
- Lack of the implementation of choices/innovative approaches

Opportunities

#1

Making **cooling systems** in **warmer climates** more efficient helps Microsoft get one step closer to achieving **water positive** by 2030.

#2

There is space to improve in **energy usage**, which can allow data centers to have more **computing power** with the same amount of energy.

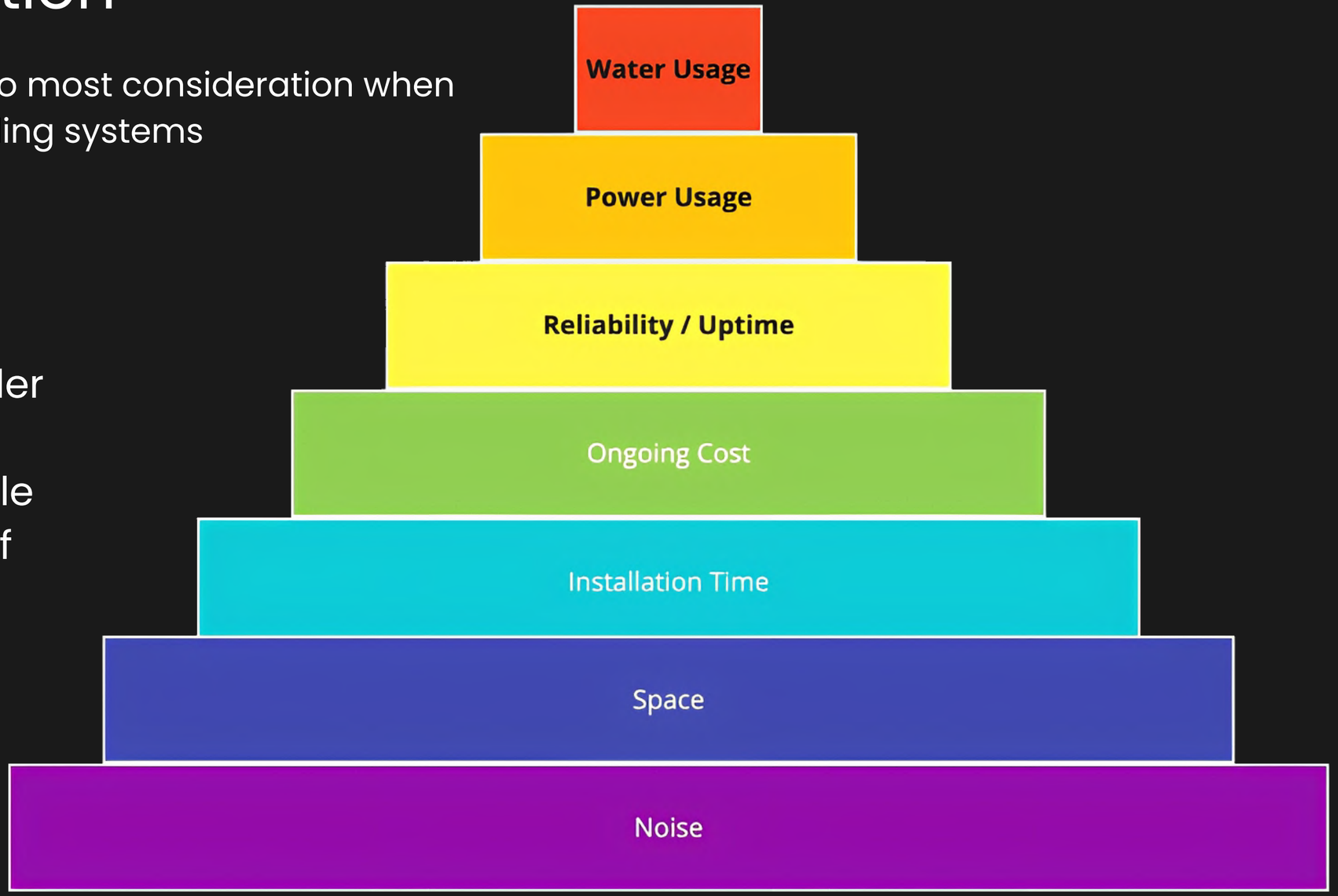
#3

Many **innovative** (California, Hong Kong) and populous (most of East and Southeast Asia) areas would benefit from more **efficient** data centers in their local region, and by taking advantage of these areas, Microsoft would take the **lead** in the **cloud computing sector**.

Criteria Prioritization

Factors that must be taken into most consideration when choosing the appropriate cooling systems

We choose to primarily focus on **WUE**, **PUE**, and **uptime** respectively in order to maximize progress towards sustainability while accelerating the growth of AI development.



Criteria Prioritization

7. Noise

Noise is a common ailment for workers in data centers, as **servers** (and their cooling systems) generate lots of noise that can be harmful to staff. However, this can easily be addressed with **proper PPE**, so this is the **least** valuable criteria that will be considered.

6. Space

The denser **chips** and **servers** can be packed together, the more capacity the data center can offer with a limited amount of real estate. Because of this, this **density** criteria is valued over noise.

5. Installation Time

In 2021, Microsoft made a commitment to create **50 to 100** new data centers **every year**. To make sure that this goal is being reached, the installation time is valued over space.

4. Ongoing Costs

To maintain **profitability** of data centers, the **revenue** generated must be greater than the **costs**. These daily costs are mainly due to the **ongoing costs** of maintenance and staffing, which makes this problem a long-term issue valued over the installation time.

Criteria Prioritization

3. Reliability/Uptime

Reliability is a measure of how consistent a data center is in providing services. If a cooling system is not reliable enough, then it may malfunction and servers can overheat and go down. A data center loses about $**5600 per minute** of **downtime**, which makes this hole a more important one to close up than ongoing costs.

2. Power Usage

PUE is an industry standard for measuring the **efficiency** of **energy usage**. It is a reliable metric for showing the progress in designing more efficient data centers. With recurrent electricity costs and the goal of reaching **net zero carbon emissions** by 2030, PUE is valued higher than reliability.

1. Water Usage

WUE is also an industry standard for measuring **water usage**. Currently, Microsoft has a goal of reaching **water positive*** by 2030. Considering that a single data center in Singapore, a considerably water-stressed country, already uses an Olympic swimming pool's worth of water **every three days**, water usage is placed at a higher priority than power usage.

***water positive**: to put back more water into freshwater sources than to extract

Liquid immersion cooling — the sustainable alternative to mechanical

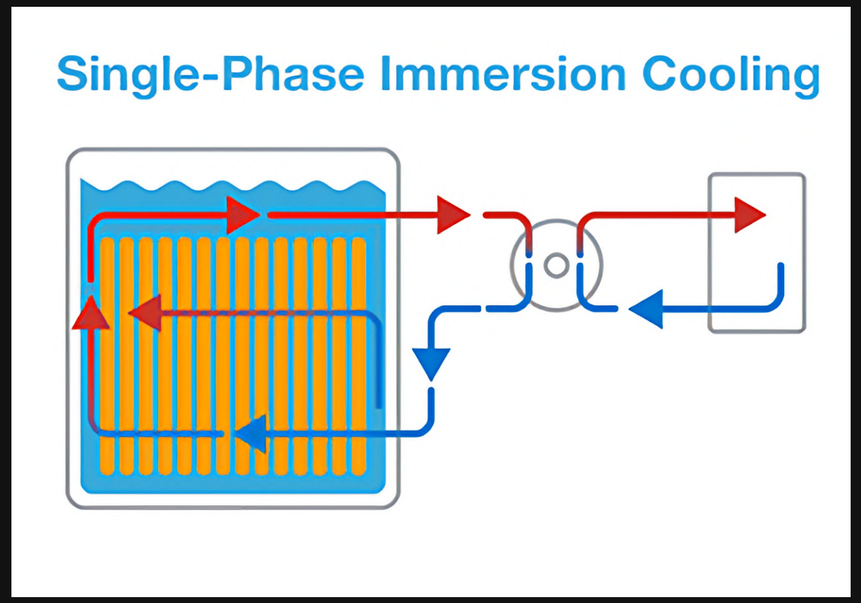
Liquid immersion cooling (LIC) directly submerges servers, electronic components, or even individual GPUs in a dielectric fluid. The dielectric fluid absorbs the heat produced by the submerged components, and either circulates or evaporates, depending on the type of LIC.

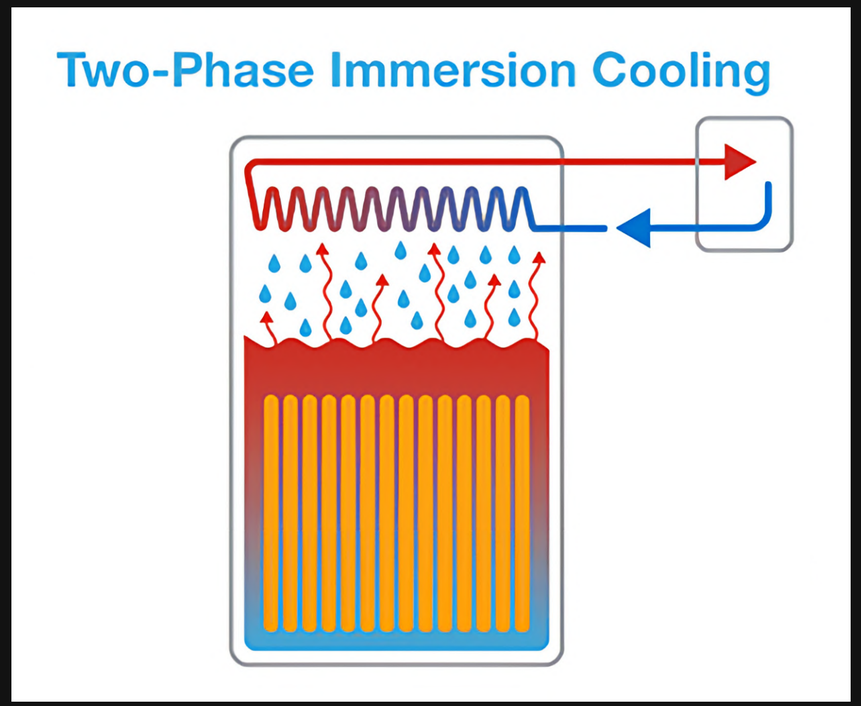
Single Phase LIC (SPIC)

The dielectric fluid stays in its liquid state, and circulates in order to relocate the heat outside of the data center. This circulation allows for easy filtering for maintenance.

Two Phase LIC (2-PIC)

The dielectric fluid evaporates at a certain temperature, removing additional heat from the electronic components. The vapor is then cooled by the above chiller, which drips the fluid back into the container.





For all future data centers placed around the **equator**, replace all **mechanical cooling** system designs with **liquid immersion** cooled designs

For future data centers

- Continue building **DEC** + **free air cooled** data centers in **colder** climates or when temperature differences allow.
- Work with LIC-providing companies (such as Mitsubishi and 3M) to implement **LIC-cooled designs** into future data centers with **warmer** climates, choosing between **SPIC** and **2-PIC** by **local demand** of cloud computing services.

For operational data centers

- Plan new data centers around operational data centers that currently use **mechanical cooling** to transition into a water positive region.
- Once sufficient data centers have been built around a mechanically-cooled data center, data can be **transferred over** to allow for near **zero-downtime retrofits**.

Single Phase Immersion Cooling Solution

We recommend implementing single phase cooling in:

- Developing suburbs with water constraints
- Climates where temperatures are warm but not too hot
- Smaller-scale data centers
- Places with less demand for cloud computing services

Implementing Single Phase LICs in Singapore

Nation AI Strategy 2.0

$ 1,000,000,000

- Singapore recently **launched Nation AI Strategy 2.0**, an investment of over **$1 billion** (740 million USD) in artificial intelligence over the next **five years**.
- However, Singapore is also one of the world's most **water-stressed** countries, with **two thirds** of its **land** being used as water catchment areas for rainwater, one of the Four **National Taps.**

Single Phase LICs

Although Microsoft currently uses **NEWater** (recycled treatment water), another Four **National Taps**, for their **mechanical cooling systems**, their data center in Singapore can greatly reduce water usages with a cheap implementation of **single phase LIC** systems. By having long-lasting dielectric fluid and low level of complexity in design, a SPIC-cooled data center is a great jumping-off point for Singapore's budding interests in artificial intelligence.

Two Phase Immersion Cooling Solution

We recommend implementing two phase immersion cooling in:

- Concentrated, urban areas of high innovative potential
- Very warm to hot climates
- Possible retrofits to older data centers when demand goes high

Silicon Valley, California

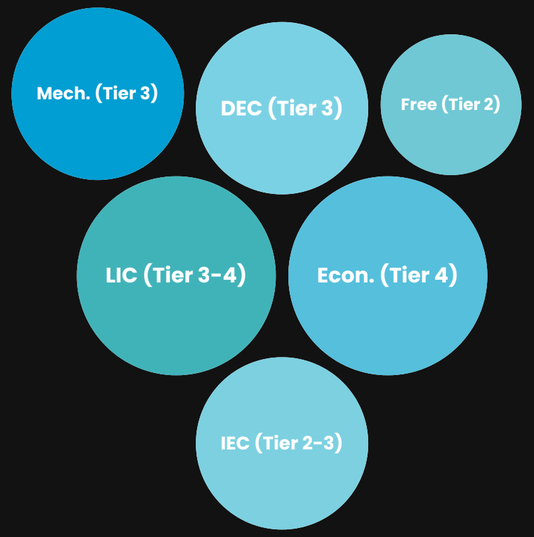
Installing Two Phase LIC in California

- **Silicon Valley** is home to the most famous tech companies: Apple, Google, Meta. Unsurprisingly, **35 of the top 50** AI companies in the world are currently in California.
- To provide for this spawning ground of AI startups, Microsoft has placed a **125 person-staffed** data center in the middle of California to contribute to the state-of-the-art push at the frontier of AI.
- By taking advantage of the extremely high power and water **efficiency** as well as the more **compact** design of **2-PIC**, Microsoft can maximize its data center's **capacity** to satisfy the demand in this highly-innovative and developed city.

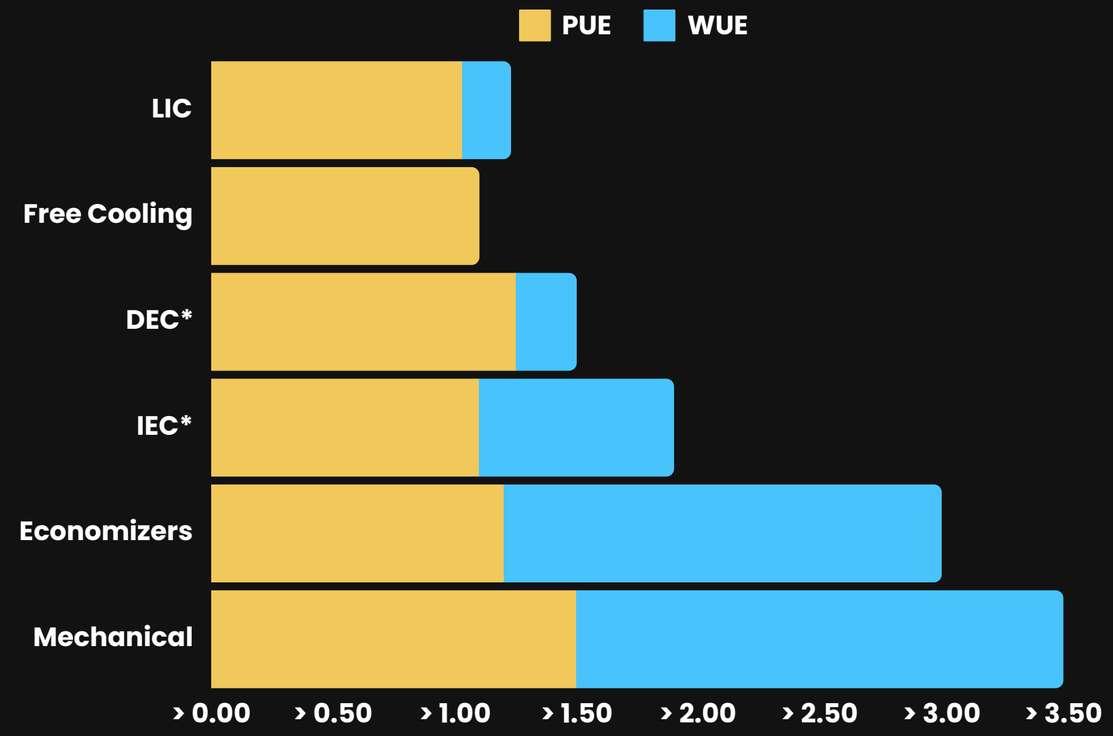
Assessing existing cooling techniques with prioritized criteria

Comparisons of PUE, WUE, and Uptime of 7 main forms of cooling.

System Uptime* (Tiers)



Liquid immersion cooling has the least PUE of 1.03, an substantially low WUE of 0.2L/KWh, as well as one of the highest uptimes (tier 3-4).



*__DEC__ (Direct Evaporative Cooling) *__IEC__ (Indirect Evaporative Cooling)
*__Uptime__ is measured in Tiers, an industry standard. The higher the tier, the more uptime.

sources

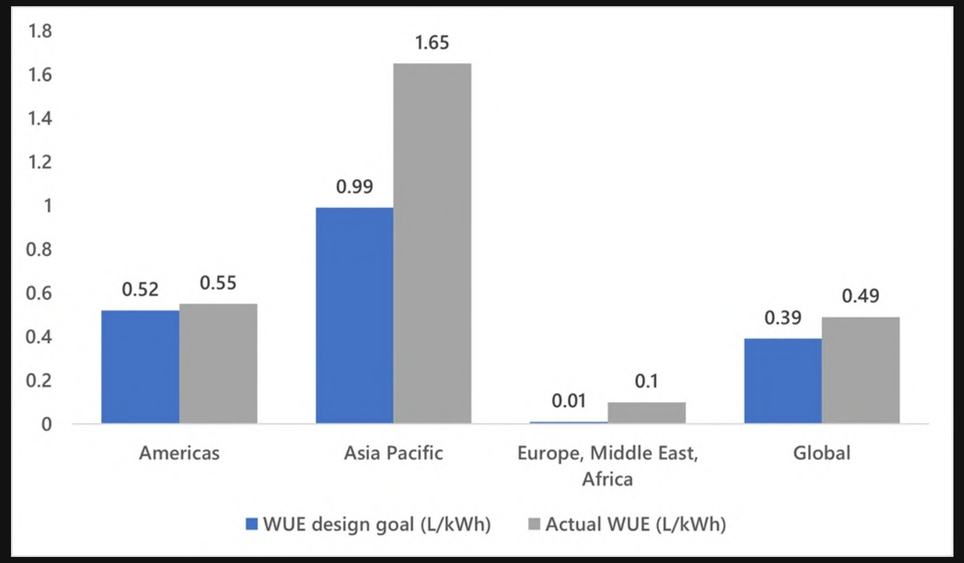
Single Phase vs Two Phase Immersion

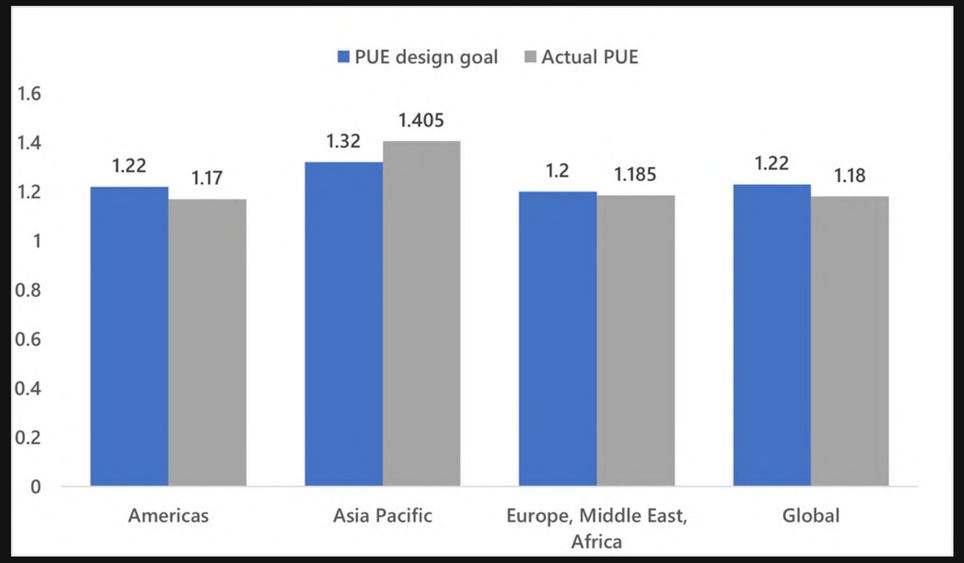
	Single-Phase LIC	Two-Phase LIC
PROS	• Cheaper • **15 year** coolant lifespan • Simpler design • Less frequent problems with maintenance	• Lower PUE rating (1.01-1.02) • More **efficient** and **powerful** cooling • Less **variation** in temperature • Easier maintenance when things go wrong
CONS	• Higher **PUE** rating • Not as strong cooling • Fluctuations in temperature • Maintenance problems are harder to deal with	• Need to replace fluid every **2 years** • Dangerous • Complex design • More frequent maintenance required

Success Metrics

If this recommendation is implemented, here's what we would consider to be a success:

- Microsoft's average **WUE** goes down from **0.39 L/kWh** to **0.1 L/kWh**, and achieves **water positive** by 2030 or earlier
- Microsoft's average **PUE** goes down from **1.18** to **1.05**, achieving **net zero** carbon emissions by 2030 or earlier





Case Studies: Immersion Cooling

59.7%
decrease in **electricity consumption**

10%+
reduction in **cost/watt**

100%
reduction in **direct water usage**

#1 - A study by Schneider Electric demonstrated a **10%** decrease in cost per watt in a **2x** denser rack compared to a traditional air cooled system.

#2 - Liquid Stack's case study proved a **91.1%** reduction in mechanical rooms with 2-PIC compared to air-cooled data centers (both 36MW IT Load), with **zero water** consumption and **59.7%** reduction in electricity consumption.

Understanding Key Supply Chain Risks in Liquid Immersion Cooling Deployment

Increased demand

Global LIC market is predicted to reach **$750 million** by 2027 as the attention on LIC grows. The surge in demand would quickly surpass the production capabilities of suppliers, causing **shortage** in supply and affecting progress in the installation of data centers.

Few large suppliers

Companies such as **Mitsubishi** and **3M** are primary suppliers of **specialized components** for LIC. As a result, there is a high **risk** of global supply chain disruption. For example, recently, 3M is working on its $6 billion settlement to veterans, which can greatly drive up the cost of coolants for 2-PIC.

Transparency

Due to the lack of sufficient experience or past examples with LIC systems, Microsoft faces uncertainties in the capabilities of their supplier in **mass production**. The difficult assessment of factors, such as **quality**, **reliability** and **capacity** of components may slow down the development process.

Building Resilient Partnerships for Long Term Supply Chain Success

By prioritizing LIC in an earlier stage, Microsoft would have more space to establish long-term relationship with key suppliers in the specialized components, fostering trust and collaboration for mutual benefits.

01 Identify Key Suppliers

The key **suppliers** for **LIC** should be based on areas where priority access is most important.

02 Offer incentives for partnership

Given Microsoft's financial resources and influence, the company is able to **incentivize** important suppliers of LIC components in the form of funding for research, long-term reliable customer, etc.

03 Collaboration frameworks

Develop a partnership agreement that outlines the collaboration. Set up collaborative groups for continuous communication and research development.

04 Partnership for Innovation

While having a supplier and customer relationship, encourage collaborative, **innovative** efforts to improve LIC technologies. Potential **breakthroughs** would give Microsoft a huge head start in the use of LIC.

Securing a Sustainable LIC Supply with 3M's Novec 7100

"A clear, colorless, non-flammable and low-odor fluid" that has extremely low impact on the environment.

WHY

Novec 7100 is a **competent** candidate for **LIC fluid** engineered by 3M. This is mainly due to its **low environmental impact** and toxicity and affordable pricing.

HOW

Microsoft can provide aid financially to 3M given their situation in addition to offering a long term partnership to **incentivize** collaboration.

RESULT

A collaboration with 3M would provide Microsoft with **consistent** supply of **reliable coolant** to facilitate data center developments, further securing Microsoft's lead in LIC.

Ozone Depletion Potential

0.00 ODP

320 GWP

Global Warming Potential

Acute lethal inhalation concentration

>100,000 ppm (4 hours)

Contacts

Here are some companies Microsoft should watch out for when looking for partnerships to transition to LIC.

People to contact to

Two Phase LIC

Mike Roman
Chairman and Chief Executive Officer at 3M

Emily Hong
Chair and Chief Strategy Officer at Wiwynn

Single Phase LIC

Eliot Ahdoot
Chief Innovation and Sustainability Officer at Hypertec Group

Mike Corbo
President & CEO at Mitsubishi Electric US

Companies

2-PIC

3M

2crsi

wiwynn

S-PIC

GRC
THE IMMERSION COOLING AUTHORITY®

Hypertec

MITSUBISHI ELECTRIC
HEATING & AIR CONDITIONING

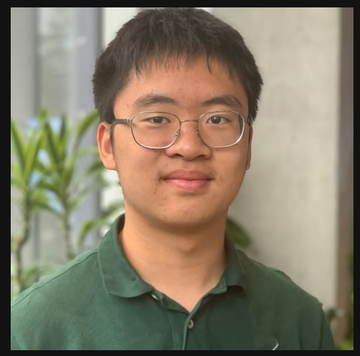
Personal Note

We would like to sincerely thank Microsoft for giving us this opportunity to contribute to this dual effort in AI and climate.

Feel free to contact us via email or LinkedIn if you have any questions or comments regarding our recommendation.

Best regards,
Bobby, Leonardo

Bobby Yang



Leonardo Zhou

Notion Page

Appendix