ECHA PFAS Annex XV Response

Derogation for Electronics and semiconductors, Annex E.2.11, Electronics and Semiconductors:

Annex XV claims: "Sufficiently strong evidence that technically feasible alternatives exist for heat transfer fluids for immersion cooling" and as conclusion: "High substitution potential at EiF for heat transfer fluids for immersion cooling {sufficiently strong evidence] and liquid crystal displays [weak evidence]".

Summary:

1.) There is a distinct difference between single phase immersion cooling (1-PIC) using forced convection and two-phase immersion cooling (2-PIC) with passive evaporative cooling.
2.) While there may be alternative heat transfer fluids for 1-PIC, there are no suitable non-flammable, non-toxic, low GWP (Global Warming Potential) alternative fluids available for 2-PIC with much more cooling capacity to address the ever-increasing TDP (Thermal Design Power) of new AI (Artificial Intelligence) and HPC (High Performance Computing) chips, such as CPUs (Central Processing Units), GPUs (Graphics Processing Units) and other accelerator chips.
3.) 1-PIC is inadequate in cooling modern AI and HPC chips, while there is a very rapid and increasingly widespread deployment of such high-powered chips worldwide, while 2-PIC is the most effective cooling method for such AI and HPC chips.
4.) Data centers are already consuming a significant portion of the world's electricity production out of which over a third are for cooling. Many countries also have a very high ratio of around two thirds of electricity being generated by burning fossil fuels. A direct link can be made between inefficient air or 1-PIC data center cooling and carbon emissions contributing significantly to global warming.
5.) 2-PIC is proven to reduce carbon emissions substantially not only with operating, but also in the total life-cycle of a data center.
6.) The effects of global warming are mostly already proven, and much more severe for health and for a much wider global population, than potential PFAS concerns could be, and without proof for over 10,000 substances.
7.) Hence, a derogation for immersion cooling of electronics and semiconductor is being applied to avert a much larger and imminent global warming risks for human health.

Detailed Explanation:

1.) There is a distinct difference between single phase immersion cooling (1-PIC) using forced convection and two-phase immersion cooling (2-PIC) with passive evaporative cooling:

    a.) 1-PIC uses heat transfer fluids with relatively high boiling temperature (e.g. 150C+) which usually need to be actively pumped to generate flow across heat generating electronics and therefore requires more electricity and higher carbon emissions for pumping.

b.) 2-PIC in contrast, uses low boiling temperature heat transfer fluids (e.g. around 50C-60C), which doesn't have to be actively pumped, but the heat transfer inside the immersion cooling bath can be completely passive with evaporative boiling.

c.) More differences are explained further in the other points.

2.) Many 1-PIC fluids are flammable or have auto-ignition temperatures, which could be triggered by burning cables and other components.

Like many other heat transfer fluids, 2-PIC heat transfer fluids for electronics and semiconductors should have also multiple key properties, like being dielectric (not conducting electricity), having a low dielectric constant of below 3.5 or ideally below 2, non-flammable, non-toxic, having low GWP, etc. One of the key properties of fluorinated fluids is also chemical stability and inertness. If the heat transfer fluid is not stable or (biologically) inert[1], then those fluids are not suitable as electronics, semiconductors, or biological organisms could react with it. Unfortunately, several suitable 2-PIC heat transfer fluids fall under the very wide definition of the proposed PFAS classification covering over 10,000 chemicals, even though it has not been proven yet, that such fluids really do harm to human health. There are currently no other suitable alternative 2-PIC heat transfer fluids than for example certain HFO (Hydrofluoroolefins), HFE (Hydrofluorethers) chemicals and other types.

3.) Single phase heat transfer is significantly lower than two-phase heat transfer, ranging from 100x to 2.5x lower in heat transfer coefficient[2]. 1-PIC heat transfer fluids also have a higher viscosity impacting the maximum flow-rate and have typically a lower specific heat to absorb and transport the heat away. Maximum flow rate could furthermore be limited to avoid cavitation. All these points in combination result in limitations of maximum heat flux which 1-PIC could cool. Various scientific papers indicate a maximum TDP (Thermal Design Power) of around 350W with a heat-flux of less than 88W/cm^2 [3]. This is incompatible with the latest CPUs and GPUs if considering various chip and respective TDP roadmaps[4]. 400W CPUs and 700W GPUs already exist, while 1000W chips have already been presented and will be deployed in Q2 2024[5].

4.) The carbon footprint of data centers is enormous, especially if considering the entire life-cycle, not only the actual operation, but also the necessary emissions related to the supply chain of computer hardware and cooling components, down to the construction of a data center.

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[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8775225/

[2] https://www.nuclear-power.com/nuclear-engineering/heat-transfer/convection-convective-heat-transfer/convective-heat-transfer-coefficient/

[3] https://keep.lib.asu.edu/items/187566

[4] https://wccftech.com/gigabyte-server-power-consumption-roadmap-points-600w-cpus-700w-gpus-by-2025/

[5] https://dataconomy.com/2023/08/09/nvidia-gh200/

Data centers “are estimated to be responsible for up to 3% of global electricity consumption today and are projected to touch 4% by 2030”[6]. Data centers in some countries like Singapore are responsible even for 7% of the entire electricity consumption, so that they have introduced power caps to limit the growth of new data centers being set up[7]. This however, doesn’t address the issue that most countries still generate electricity by burning fossil fuels with 60-80% of the total electricity production[8] [9]. The 7% data center electricity consumption, paired with Singapore’s electricity being generated almost 100% by burning fossil fuels indicated the excessive carbon footprint of data centers[10] [11]. It is especially concerning if (inefficient) cooling can account for 40% of a data center’s electricity usage[12].

1-PIC frequently requires 32C entering water cooling temperature. If considering that summer temperatures of most data center locations can easily exceed 32C, this cooling technology requires either very significant water usage for evaporation or refrigeration (water chiller) with substantial amount of F-gas refrigerants to achieve [13]sufficiently cooled water to cool the immersion cooling heat transfer fluids[14]. Various 1-PIC systems for example can only offer limited cooling performance with 32C entering water temperature, while higher cooling performance can only be achieved with chilled water at e.g. 13C entering water temperature. In almost all industrialised countries’ climates, this requires water chiller systems with fluorinated refrigerants.

Some air-cooled and 1-PIC data centers claim to be able to achieve very low PUE (Power Usage Effectiveness) as a common metric to compare data center energy-efficiency. But very often, these very low PUE figures can only be achieved in colder climates, or by using a lot of water for evaporative cooling. The vast amounts of water of for example 11-19 million litres[15] per day or 5.7 billion litres of water per year[16] used by data centers to facilitate inefficient air-cooling, are posing an increasing challenge to many communities in the vicinity of data centers.

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[6] https://datacentremagazine.com/articles/efficiency-to-loom-large-for-data-centre-industry-in-2023

[7] https://www.datacenterdynamics.com/en/news/singapore-could-miss-out-on-demand-if-it-doesnt-move-to-greener-data-centers-warns-keppel-corp/

[8] https://www.iea.org/energy-system/electricity

[9] https://www.eesi.org/topics/fossil-fuels/description

[10] https://www.eia.gov/international/analysis/country/SGP

[11] https://ourworldindata.org/energy/country/singapore

[12] https://www.informationweek.com/sustainability/data-center-cooling-technologies-target-sustainability

[13] https://www.nbcnews.com/tech/internet/drought-stricken-communities-push-back-against-data-centers-n1271344

[14] https://www.nature.com/articles/s41545-021-00101-w

[15] https://www.nbcnews.com/tech/internet/drought-stricken-communities-push-back-against-data-centers-n1271344

[16] https://southdfwnews.com/stories/532463935-utility-files-suit-to-keep-google-from-annually-using-1-5-billion-gallons-of-water-for-proposed-red-oak-data-center

If a data center is located in a hot climate, then the PUE figures and carbon intensity (due to more electricity used for cooling) are substantially worse[17]. But because of low latency (speed to access data), data residency (government restrictions), etc. it is often not possible to relocate to a data center far away. Even though Singapore for example has a tropical climate and requires a lot of energy for data center cooling and has therefore a higher PUE, it is still a major data center hub. Low PUE claims of air cooling and 1-PIC deployments are often made in colder climates. This highlights the importance of energy-efficient cooling of data centers as an inevitable priority.

The significantly lower heat transfer capability of 1-PIC subsequently requires heat sinks with better thermal conductivity to increase the heat transfer surface area for high heat flux electronics like computer CPUs, GPUs and other accelerator chips. Due to lower costs and weight, most heat sinks are made out of aluminium[18]. Most aluminium heat sinks are made in China, which can have a carbon footprint of 20 tonnes of CO2 emissions per tonne of aluminium produced[19]. Such heat sinks are transported either separately or together with the AI/HPC chips to end-users in the USA or Europe. A recent report named “Cloud and Data Center” from Omdia in September 2023 highlighted that only in the second quarter of 2023, it is estimated that more than 900 tons of 300,000x H100 GPUs have been shipped with an estimated weight of each H100 heat-sink at about 3 kg. The volume of GPU shipments is expected to grow at double digit percentage year on year, while data centers are already responsible for 3.7% of all carbon dioxide emissions[20] [21] with an estimated 14% by the year 2040[22].

Since Air cooling and 1-PIC both require massive heat sinks, this also leads to additional carbon footprint created by the larger sheet metal cases for the servers housing the heat sinks. Additional resources for manufacturing and transportation of the fault-tolerant redundant arrays of multiple high-speed server and PSU (Power Supply Unit) fans can consume 10% or more of the total server electricity consumption, and is typically not even considered and measured separately or considered with the widely used metric PUE to compare data center energy efficiency[23].

Very large data centers also require a lot of concrete to build. Some data centers have 7-10 million square feet of footprint with respectively massive amounts of concrete and therewith cement as its key component[24]. “The cement industry is

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17 https://www.climatiq.io/blog/measure-greenhouse-gas-emissions-carbon-data-centres-cloud-computing

18 https://www.semiconductorforu.com/extruded-heat-sink-materials-aluminum-alloys-vs-copper/

19 https://alupro.org.uk/sustainability/fact-sheets/carbon-footprint/

20 https://theshiftproject.org/en/article/lean-ict-our-new-report/

21 https://www.theregister.com/2023/09/19/900_tons_nvidia_servers/

22 https://www.computerworld.com/article/3431148/why-data-centres-are-the-new-frontier-in-the-fight-against-climate-change.html

23 https://www.missioncriticalmagazine.com/articles/93896-beyond-pue

24 https://analyticsdrift.com/largest-data-centers-in-the-world/

responsible for approximately 5% of global anthropogenic carbon dioxide emissions", and it "emits nearly 900 kg of CO_2 for every 1000 kg of cement produced" according to a study published in the Greenhouse Gas Control Technologies[25]. Other sources indicate even 1.25 tons if CO_2 for every ton of cement and that concrete accounts for 40% of the carbon footprint of a data center's construction, while structural and reinforcement steel can account for 20%[26]. With 60% of carbon footprint for only concrete and steel without even considering aluminium heat sinks, larger metal sheet casing for servers, etc. it becomes quite apparent how much of a carbon footprint air cooled and 1-PIC data centers make, simply by using bulky and heavy heat sinks.

In addition, there is a heavy burden of E-Waste like frequently broken fans, much larger PCBs (Printed Circuit Boards) to accommodate the larger heat sinks, out of which about 70% are toxic waste and accounting for between 20-50 million metric tons of data centers[27].

5.) 2-PIC allows entering cooling water temperatures as warm as 48C. This allows many more data center locations in the world to use 'free cooling' with dry coolers at hot ambient air temperature, without the use of evaporative water cooling and without refrigeration[28].

Studies have shown two-phase immersion cooling systems with as low as PUE (Power Usage Effectiveness) of 1.01 even in sub-tropical climate of Hong Kong by using dry coolers only[29] and without additional water chillers, nor water intensive evaporative cooling versus a local average PUE of 1.62[30]. This is an enormous reduction of carbon emissions while operating such data center.

According to a study by the architecture and engineering firm Page Southerland, "31.76% reduction in Lot Area, and 60.9% reduction in data center building size" could be achieved by using 2-PIC technology vs. air cooling. Similar figures could be applied to 1-PIC as well due to the often exactly same sized heat sinks as for air cooling. As per explanations in 4.), the excessive carbon emissions of building materials like cement and steel, could be massively reduced by replacing big and bulky heat sinks, shrinking the servers by more than 75% in volume, and therefore leading to the aforementioned reduction in Lot Area and data center building size and respective carbon emissions.

The latest 2-PIC systems are employing the latest fluid and vapour containment technology. It starts with almost emission-free transfer of 2-PIC heat transfer fluids via vapour traps from fluid containers into 2-PIC systems. Those 2-PIC systems are

[25] https://www.sciencedirect.com/science/article/abs/pii/B9780080442761501574?via%3Dihub
[26] https://www.datacenterdynamics.com/en/analysis/sustainable-data-centers-require-sustainable-construction/
[27] https://www.techbusinessnews.com.au/blog/environmental-impact-of-data-centres/
[28] https://www.science.org/doi/10.1126/science.1182769
[29] https://www.hpcwire.com/off-the-wire/allied-control-announces-datatank-1-4mw-container-datacenter/
[30] https://cloudscene.com/market/data-centers-in-hong-kong/all

hermetically sealed and tested for leaks with Helium leak test detectors at very sensitive level to ensure that the system is gas-tight. Multi-layer condensation coils can achieve very little emissions when operating and maintaining such systems. Maintenance on open systems is possible with minimal emissions[31]. Annual emissions are significantly less than 0.85% per year, while some system designs even allow annual emissions to go closer to 0% with completely hermetically sealed systems[32].

6.) Excessive carbon emissions from data centers of 3.7% of the global total, and an estimated 14% by 2040 as described in 4.), contribute massively to overall Global Warming. The health effects can be very severe. It is not a future scenario, but Global Warming induced heat waves have already led to an estimated 61,672 heat-related deaths in Europe in a relatively short time span between 30 May and 4 September 2022[33], while around 20,000 deaths per year are attributed to hot temperatures in North America[34]. It is expected that more heat waves and adverse weather events will be affecting human health globally in the next years to decades. The WHO (World Health Organization) estimates that climate change "is expected to cause approximately 250,000 additional deaths per year" and "every additional tenth of a degree of warming" on top of 1.5C of global warming above pre-industrial levels "will take a serious toll on people's lives and health"[35].

Global warming also leads to melting of glaciers[36], which in turn release toxic substances like mercury, arsenic, cobalt, etc. via glacial melt-water run-off to very wide geographical areas in Europe and Asia with substantial impact on drinking water supply[37], and more severely also the food chain taking up the contaminated water.

Predominantly fossil-fuel powered electricity generation as mentioned in 4.) is causing bad air quality in many countries. Many countries have studies about the health effects due to bad air quality. Better air quality in Hong Kong could "avoid 1335 deaths, 60,587 hospital bed days, and 6.7 million doctor visits for respiratory complaints each year"[38].

Above is only a small selection of proven immediate impact on human health caused by global warming and burning fossil fuels, significantly contributed by the use of inefficient data center cooling technology. This is in stark contrast to the proposed very broad definition of PFAS substances, including some 2-PIC heat transfer fluids for which there are no suitable alternatives, for which it is not even proven yet if such substances would have harmful effects for human beings.

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[31] https://patents.google.com/patent/US20210153386A1/en
[32] https://patents.google.com/patent/US20170325355A1/en
[33] https://www.nature.com/articles/s41591-023-02419-z
[34] https://time.com/6198720/heatwave-health-death-toll/
[35] https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
[36] https://www.frontiersin.org/articles/10.3389/feart.2020.00128/full
[37] https://www.sciencedirect.com/science/article/abs/pii/S0269749116319765?via%3Dihub
[38] https://pubmed.ncbi.nlm.nih.gov/18569625/