

FOREVER CHEMICALS COOL DATA CENTERS

By Lenny Siegel

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Opposition to the construction of data centers—warehouses of heat-generating computers used for generative artificial intelligence (AI), cryptocurrency “mining,” and other “cloud” functions—is bubbling up across the United States. It has finally gained the attention of the national media.

These electronic behemoths are gobbling up land, water, and electricity with, in many cases, little opportunity for the public to ask questions about their impacts, let alone participate in decision-making. They represent what may be the largest collective financial investment in human history, with little regard for the business cycle that inevitably will pop the AI bubble.

What most of the opponents don’t realize is that the industry, in an effort to reduce its electrical, fossil-fuel, and water use, is increasingly relying upon PFAS “forever chemicals” to chill their increasingly hot stacks of computer chips. We don’t know the full scope of this shift. It’s new. And there seem to be no requirements—federal, state, or local—to disclose these uses, let alone their environmental impacts.

I’ve been doing my best to collect information about data center forever coolants. Most of what I know is from the publications of vendors, and it’s far from complete. So I’m going to start with the promises of Chemours, which appears to be the largest PFAS producer in the world. The U.S. Justice Department just negotiated a \$450 million settlement with Chemours, known to moviegoers for its *Dark Waters* Washington Works in West Virginia, for its continuing pollution of water and air. It’s big, but I believe that it’s a sweetheart deal.

Chemours says, “While there is some uncertainty around what the future of the data center IT power densities may hold, the impending necessity for widespread liquid-based server cooling is almost universally accepted.” The form of liquid-based cooling that Chemours, among others, promotes is called **two-phase immersion cooling** (2-PIC). Chemours markets the Opteon™ family of coolants, based on the PFAS family known as hydrofluoroolefins (HFOs). The company asserts:

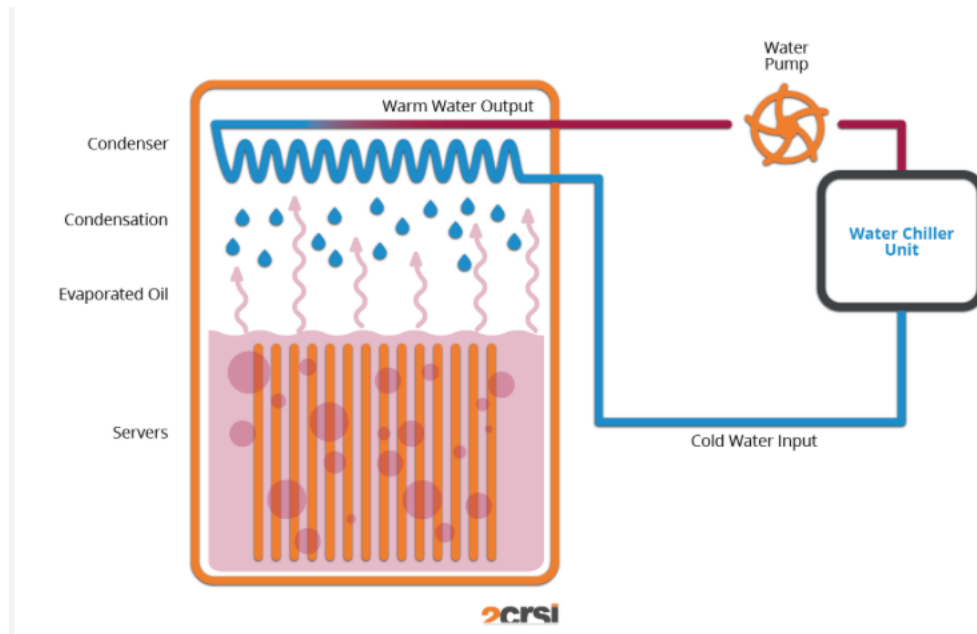
As an alternative to conventional air- and water-cooling technologies in data center applications, 2-PIC using Opteon™ 2P50 developmental immersion cooling fluid can help:

- Reduce cooling energy usage by more than 90%
- Nearly eliminate water use
- Enable up to a 60% reduction in the physical data center footprint¹

¹“Opteon™ 2P50 Developmental Dielectric Heat Transfer Fluid,” Chemours, <https://www.opteon.com/en/products/liquid-cooling/2p50>

How 2-PIC works

With two-phase immersion cooling, stacks of computer chips are placed into transparent tanks containing dielectric—that is, not conducting electricity—fluorocarbon liquids such as Opteon. As the chips give off heat, they boil the liquid, which bubbles up to make contact with coils of chilled water, which in turn absorb the heat as it is pumped to water chillers outside the tanks. The fluorocarbon gas condenses, returning to the liquid in which the electronics are immersed, while the water is chilled before returning it to the coils in the tank. It is designed as a closed-loop system, with no intended releases of fluorocarbons into the environment.



Opteon coolants are hydrofluoroolefins, which means they have at least one carbon-carbon bond, as well as the carbon-fluorine bonds that identifies them as PFAS (per- and polyfluoroalkyl substances). They are increasingly used as refrigerants because they do not deplete the ozone layer and, compared to other PFAS, they have a lower global warming potential (GWP). Chemours says Opteon 2P50 has a GWP of 10, which means it is ten times as powerful a greenhouse gas as carbon dioxide. Other fluorinated gases have GWPs running up into the thousands. In touting the relatively low GWP, Chemours and other suppliers are admitting that some of the liquid enters the atmosphere as a gas.

Chemours explains that the typical 2-PIC tank contains 1270 liters of Opteon,² enough to expand to over 300,000 liters of fluorinated gas. A typical hyperscale data hall contains hundreds of tanks.

Do They Leak?

Chemours reports a typical rate of evaporative loss per year of 0.7% for its product. That appear to mean, in the absence of unexpected releases, that typical tank could emit 2100 liters of

² “Comparison of Server Liquid-Cooling Technologies,” Chemours, <https://pages.chemours.com/ic-case-study-october-2024.html>

fluorinated gas annually. That's not much in the grand scheme of global warming, but in my view it's wishful thinking. The operators of data centers know how much coolant they have to replace in a year, but they aren't saying.

One vendor explains, "We often emphasize that everything leaks, even at a miniscule level," adding:

When leak testing is done in data center cooling systems, the materials are often quite sensitive and vulnerable to leaks, and the level of risk with a leak can be quite high. In these applications, leaks could pose severe safety concerns and costly hardware failures affecting people's daily lives across the globe. This is why the industry has such stringent requirements and evolving requirements as new technologies and cooling applications are introduced.³

With potentially hundreds of 2-PIC tanks in hundreds, if not thousands of data centers, the volume of HFOs soon to be enclosed in those tanks could be enormous. Not only do we not know how much gas is released in normal operations, but we don't know how much is lost in installation and maintenance. No one is saying what happens to the fluids when the chips are switched out with new, more powerful systems.

TFA

Vendors of HFO coolants argue that the environmental impacts of releases are minimal because they have low global warming potential. One company cooling-system provider, Accelsius, explains the fate and transport of its refrigerants:

In the event of a leak, the PFAS refrigerants vaporize and eventually make their way into the upper atmosphere. In the upper atmosphere, two things can happen based on the global warming potential (GWP) of the vaporized PFAS refrigerant.

1. For PFAS with high GWP, the PFAS remains in the upper atmosphere, where it has a high potential to warm the globe ...
2. For PFAS with low GWP, the PFAS substance breaks down in a matter of days into the naturally occurring compound trifluoroacetic acid (TFA)⁴

However, TFA is not naturally occurring, and of course, even if it were naturally occurring that would not mean that it is environmentally safe. Think lead, arsenic, etc. The HFOs from data center coolants end up as TFA on the land and in surface water.

Accelsius is correct that HFOs degrade into TFA, though there is at least one study that reports that the TFA can in turn break down into HFC-23, a greenhouse gas with a high GWP of about 12,000 (CO₂ equivalent).⁵ More widely, the unknown quantities of HFOs released from data center coolants can end up as TFA on the land and in surface water.

³Jeff McKee, "How to Determine Leak Rates in Data Center Cooling Systems," Cincinnati Test Systems, May 21, 2025, <https://www.cincinnati-test.com/blog/leak-rates-data-center-cooling-systems>

⁴Richard Bonner III, Bill Grieco, and Liz Cruz, "Understanding PFAS Concerns for Two-Phase Cooling of Data Centers, Accelsius, https://accelsius.com/wp-content/uploads/PFAS-Whitepaper-Feb_2024.pdf

⁵Gabriel Salierno, "On the Chemical Pathways Influencing the Effective Global Warming Potential of Commercial Hydrofluoroolefin Gases," *Chem-Sus-Chem*, April 4, 2024, <https://chemistry-europe.onlinelibrary.wiley.com/doi/10.1002/cssc.202400280>

What Does “Forever” Mean?

PFAS are colloquially known as “forever chemicals” because they are characterized by the carbon-fluorine bond, one of the strongest molecular bonds found in nature. While it is difficult (requiring significant energy) to break that bond, PFAS molecules can transform—combining, breaking down, or attaching or losing other atoms—into other PFAS. Trifluoroacetic acid, considered “ultrashort chain” because its molecules have only two carbon atoms, is extremely persistent and highly mobile in the environment.

Accelsius argues, “It should also be noted that many liquid and gaseous PFAS, regardless of their GWP, are routinely recycled at end-of-life, which eliminates any risk of environmental release or harm.” This is another case of wishful thinking. TFA is not considered as toxic as such well known and somewhat regulated PFAS such as PFOS and PFOA, but it is more prevalent in the environment and indeed, toxic. “The European Chemicals Agency (ECHA) has officially classified trifluoroacetic acid (TFA) as toxic to reproduction (Category 1B), concluding it ‘may damage the unborn child’ and is ‘suspected of damaging fertility.’”⁶

The European Pesticide Action Network has found that the chemical industry:

has systematically downplayed evidence of TFA’s harmful effects. Contrary to industry claims that TFA is toxic only at very high doses, a growing body of data consistently demonstrates that TFA causes serious developmental effects in foetuses at lower levels, as well as other adverse outcomes, including thyroid hormone disruption, liver toxicity, effects on the immune system and abnormalities in sperm quality and quantity. These are not isolated incidents, but consistent toxicological signals observed at different levels across species and studies.⁷

Furthermore, a team of European experts recently concluded, “TFA meets the criteria of a planetary boundary threat,” explaining:

Trifluoroacetic acid (TFA) is a persistent and mobile substance that has been increasing in concentration within diverse environmental media, including rain, soils, human serum, plants, plant-based foods, and drinking water. Currently, TFA concentrations are orders of magnitude higher than those of other per- and polyfluoroalkyl substances (PFAS). This accumulation is due to many PFAS having TFA as a transformation product, including several fluorinated gases (F-gases), pesticides, pharmaceuticals, and industrial chemicals, in addition to direct release of industrially produced TFA. Due to TFA’s extreme persistence and ongoing emissions, concentrations are increasing irreversibly.⁸

⁶ “Confirmed: ECHA classifies TFA as highly hazardous to early-life development - all PFAS pesticides must now be banned,” Pesticide Action Network-Europe, June 10, 2026, <https://www.pan-europe.info/press-releases/2026/06/confirmed-echa-classifies-tfa-highly-hazardous-early-life-development-all>

⁷ “Manufacturing Doubt: How the Industry Downplays TFA’s Toxicity,” September, 2025, <https://www.pan-europe.info/resources/reports/2025/09/manufacturing-doubt-how-industry-downplays-tfa-s-toxicity>

⁸ Hans Peter H. Arp *et al*, *The Global Threat from the Irreversible Accumulation of Trifluoroacetic Acid (TFA)*, *Environ. Sci. Technol.* 2024, 58, p. 19925, <https://pubs.acs.org/doi/10.1021/acs.est.4c06189>

Fluoropolymers

While PFAS liquids and gases play a growing role in data center cooling, PFAS solids—fluoropolymers—are also important. The producers of fluoropolymers assert:

Advanced Cooling Systems—AI workloads produce significantly more heat than traditional computing tasks. To help prevent overheating and maintain performance, data centers increasingly rely on liquid cooling systems. Fluoropolymer tubing is used to transport cooling fluids through high-temperature, high-pressure environments. These materials help resist chemical degradation, prevent contamination, and maintain integrity under extended extreme conditions.⁹

The industry also says that fluoropolymer equipment and piping is essential for the production of the chips that are the brains of data centers,¹⁰ and there is evidence that those polymers degrade and release debris during semiconductor wafer fabrication.

Life Cycle

PFAS releases from data center operations must be documented and regulated, but it's also essential to understand the environmental hazards posed by PFAS manufacture—including the production of fluoropolymer pipes and equipment—and their end-of-life disposition. This is also true for the computing devices themselves. The technologies associated with data centers, indeed all computing technology, are rapidly evolving, so we can expect the enormous construction and production challenges of today to soon become even greater challenges of treatment and disposal. Those challenges should be addressed before building data centers, to minimize in advance the hazards and costs of closing or re-building.

It's Not Too late

It's not too late to regulate the data center industry. The companies have choices to make about how they design their facilities, and those choices should be shaped by requirements that internalize the environmental costs. They are currently externalizing huge costs, not only through the use of water, energy, and land, but also the release and potential release of toxic substances and greenhouse gases into the environment.

When it comes to cooling, all data centers—proposed as well as those already in operation—should disclose:

1. What substances, and in what quantities are they using to cool their computer systems?
2. What quantity of those substances are being released into the environment?
3. What is being done to substitute environmentally friendly substances for hazardous substances and greenhouse gases?
4. What is being done to prevent environmental releases, either on site or at treatment facilities?
5. What are their plans for assuming responsibility for environmental damages they are causing?

⁹ “Fluoropolymer Chemistries Are Critical to America’s AI Future,” Performance Fluoropolymer Partnership, October 6, 2025, <https://fluoropolymerpartnership.com/fluoropolymer-chemistries-ai-future/>

¹⁰ Amy Feldman, “More Domestic Chip-Making Means More ‘Forever Chemicals,’” *Forbes*, October 5, 2023. <https://www.forbes.com/sites/amyfeldman/2023/10/05/more-domestic-chip-making-means-more-forever-chemicals/>

Only by getting clear answers, independently verified, to these questions will we know how to regulate data centers, and indeed, whether to allow, let alone subsidize, their construction.