Introduction

The growth rate of data volume globally is nothing but astonishing. Information produced by the EU Commission as part of its EU Data Strategy illustrates a phenomenal 530% increase predicted from 2018 to 2025. Indeed, it is estimated that during the same timeframe, the value of the data economy to the EU will grow from €301 in 2018 to €828 billion by 2025 (Figure 1.0).

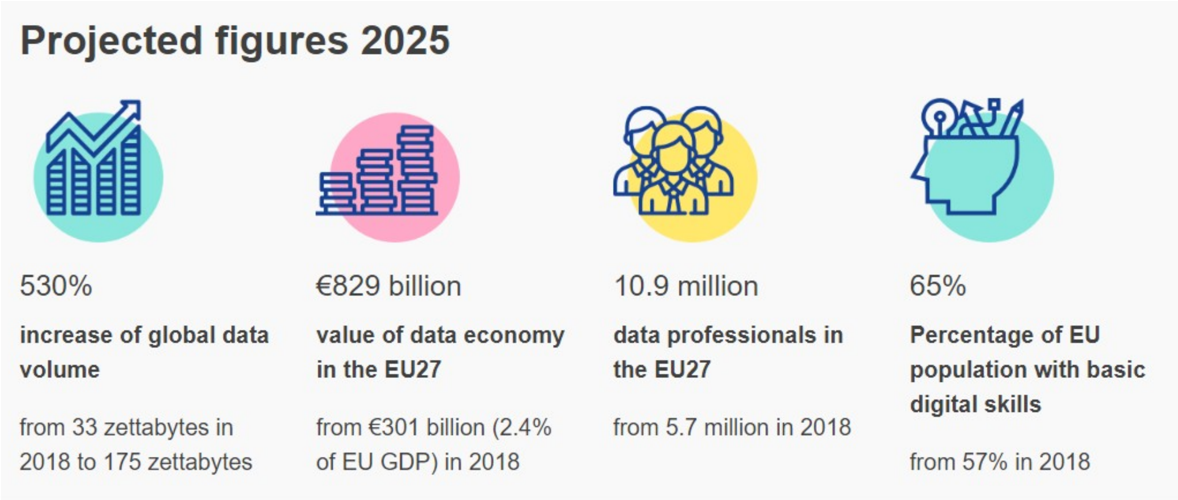

Figure 1.0 – EU Data Strategy projected figures for 2025

In an effort to sustain or meet such data demands, there needs to be an equivalent increase in computational power. It's not just a case of doing more of the same as what's been done in the past to augment the necessary computational power. The growth rate of Artificial Intelligence (AI) and high-performance compute has driven the need for more powerful processors and hardware accelerators. This has resulted in generating significant increases in silicon or processor thermal design power (TDP) beyond 1 kW/each processor and semiconductor package thermal density. To put it simply, the heat generated from these powerful semiconductor devices is also growing.

These semiconductor devices are housed in servers which in turn are accommodated in data centres. Simultaneously, there is regulatory focus on reduced energy consumption, increased energy efficiency at data centre level, reuse of waste heat from data centres as well as meeting sustainability goals. Together these trends are creating significant strain on today's data centres which require alternatives to today's state-of-the-art cooling technologies to handle the coming data demands.

Issues with Current Cooling Technologies

Cooling of data centres is frequently the largest energy loss in the facility and as such represents a significant opportunity to improve efficiency. The primary cooling methods employed in date centres are air and water based.

The objective of airflow management is to circulate only the necessary amount of air through the data centre at any time that is required to remove the heat actually created by the IT equipment. This means no air returns to the cooling system without absorbing heat and no air circulates more than one time through the IT equipment (JRC 2023). When considering water-based cooling methods, the water utilised needs to be sufficiently chilled which can have a significant impact on the data centre's energy efficiency. Due to the changing climate, water is becoming a precious commodity in several geographies across the globe including the EU and several regulations are being imposed on data centre operators to limit the use of water for data centre cooling applications such as towers or evaporative air cooling. Also, to cool high wattage processors, water needs to be chilled using chillers therefore reducing the overall efficiency of cooling solutions.

These air and water cooled methodologies are becoming increasingly inefficient with the cooling load required for the greater demands of server products. Consequently, alternative cooling methodologies have been investigated to cater for today's requirements but more importantly future needs as well.

Alternative Cooling Technologies

Unfortunately, there are no commercially available alternatives that address the future needs for high TDP, high heat flux silicon and global energy efficiency demands that have no PFAS chemistry. Traditional forced air cooling has already been optimised within the practical limits of data centre airflow delivery. Traditional propylene glycol-water based fluids support high TDP but fall short on supporting high package thermal density as compared to pumped refrigerant 2-phase cooling. Also, due to the lower effective heat transfer of legacy liquid cooling methods, more power is required for primary loop water chillers and secondary loop fluid pumps (Figure 2.0) when compared with the pumped refrigerant 2-phase cooling method (Figure 3). It's important to note that water or air chillers used for current data centre cooling is already or will be shortly using one of these hydrofluoroolefins (HFO) refrigerants.

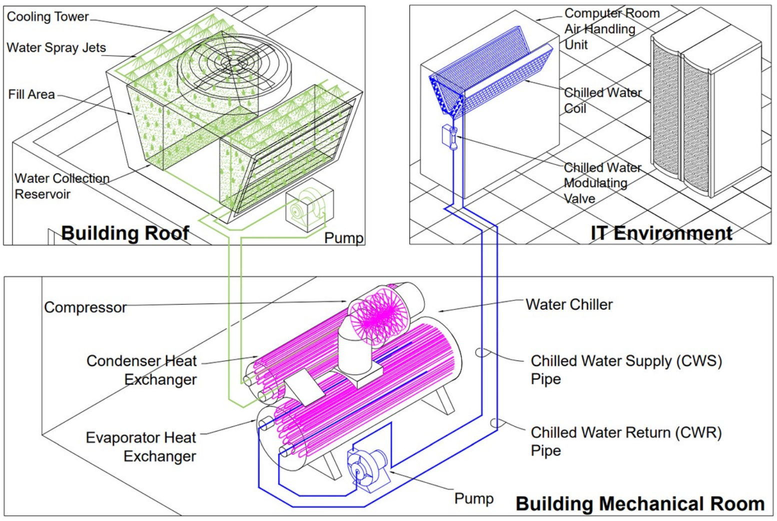

Figure 2.0 - Traditional air-cooled data centre using water-cooled chiller system.

(Image courtesy of Schneider Electric)

Put another way, refrigerant-based server level cooling allows deployment of AI silicon into markets where warm facility water usage is required to meet its energy efficiency and sustainability targets.

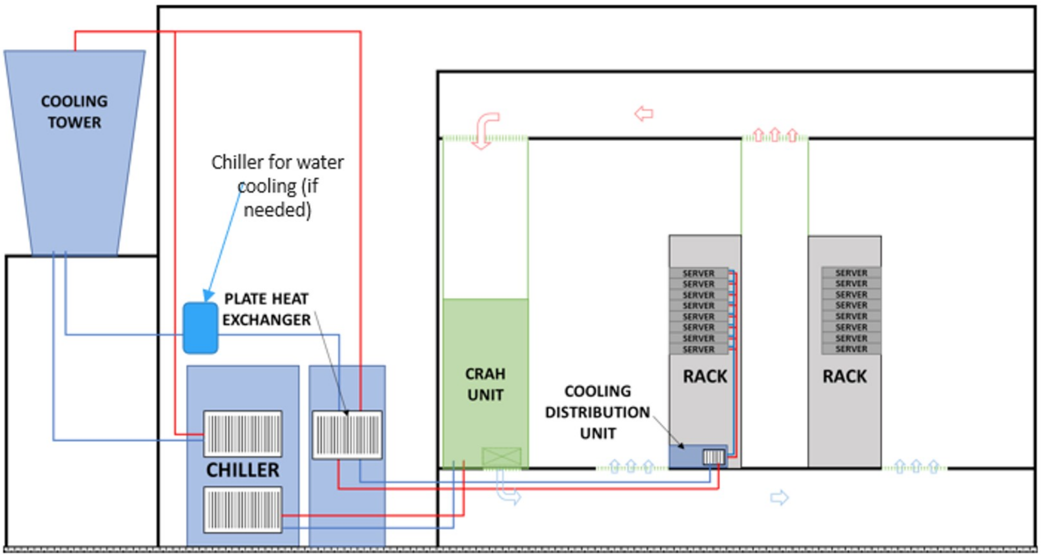

Figure 3.0 – Hybrid air cooled data centre using propylene glycol fluid in server racks with water cooled chiller system or pumped refrigerant fluid in server racks eliminating high power water-based chiller systems.

The use of F-gases particularly HFOs have shown to be extremely efficient in performing the required cooling of server products in data centres through this application known as two phase liquid-vapour cooling. This involves the circulation of low-to-medium pressure refrigerants (HFOs) through cold plates attached directly to high-powered AI silicon.

In this approach, the refrigerant is circulated through cold plates as a saturated liquid, absorbing heat from processors before it vaporizes. Due to higher latent heat of vaporization (compared to just sensible heat for single phase water-based cooling), the process requires relatively small pumping power and is vastly more capable and efficient than traditional air and water-based cooling methods. Please note this is a different technology to what is known as immersion cooling. The HFOs of interest that fulfil this cooling distribution function are captured in Table 1.0.

Table 1.0 – Suitable HFOs for Date Centre Cooling

Refrigerant	Pressure	Chemistry	GWP	ODP	Toxicity	Flammability
R513A	medium	HFC/HFO	573	0	low	zero
R515B	medium	HFO	299	0	low	zero
R1234ze	medium	HFO	6	0	low	mild
R1234yf	medium	HFO	<1	0	low	mild
R1233zd	low	HFO	1	0	low	zero

The characteristics of the HFOs outlined in Table 1.0 illustrate excellent global warming potential which significantly supports the EU's climate ambition's goals as the more typically utilised F-gases in data centres such as R134a and R410a have global warming potentials of 1,430 and 2,088 respectively. One major advantage of these medium pressure refrigerants is that their low boiling point (well below traditional atmospheric temperature) and hence if it did escape, it would immediately vaporize and not contaminate soil or ground water. Also, the half-life of these refrigerants is very short compared to traditional PFAS coatings and other compounds.

The cooling system itself is known as a cooling distribution unit (CDU) and is a closed system. This hardware utilises fluoropolymers such as gaskets and seals given their unique characteristics in addition to prolonging the service life of the CDU. There are no intentional releases of the HFOs with this technology. Currently there is less than one tonne of HFOs utilised globally for this application. These refrigerants are handled only by trained technicians as per HVAC industry protocols who have passed extensive certifications such as those outlined in the EU F-gases regulation, US EPA 608 etc. Hence, use and handling of these refrigerants is already being tracked and not undertaken by any non-certified technicians.

Suitability of Dossier Submitter Proposed Non-PFAS Alternatives

The Dossier Submitter in its Annex XV report proposed several non-PFAS alternatives for electronics cooling in data centres. Two of these proposed alternatives - Hydrocarbon Systems and Ammonia had been questioned by the Dossier Submitters themselves on grounds of flammability and toxicity issues which would reside inside the data centre hall. The other non-PFAS alternatives such as basic ventilation, small-scale air-conditioning systems and water are simply not feasible given the pending demands of cooling technologies with the anticipated growth in data volume.

Critique of Dossier Submitter Conclusions Concerning HFO Emissions

The HFOs outlined in Table 1.0 which are needed to run this cooling distribution technology are known to degrade in the atmosphere to trifluoroacetic acid (TFA). Although, the cooling technology is not designed to release HFOs, it is important to stress the degradation profile of these F-gases to illustrate the low risk they pose to the environment and consequently should be seen as a viable and pragmatic solution to the current and pending cooling demands within data centres.

The Dossier Submitter noted in the PFAS Annex XV report in the section dealing with PFAAs (arrowheads and precursors), "as most of these substances are expected to ultimately degrade in the environment to TFA (details in Annex B.4.1.), they will contribute to the overall exposure to and risks of PFAAs". Such a statement or indeed conclusion by the Dossier Submitter is not accurate when examined against the number of peer reviewed studies conducted on TFA. The United Nations Environment Programme (UNEP) in its Environmental Effects Assessment Panel in 2020 noted that "Historical and current measurements of TFA in soil and surface-water indicate de minimis risks when compared to no-effect-concentrations (NOECs) in laboratory and field-based testing". UNEP also called out what they identified as erroneous claims that TFA was toxic to plants, and to set the record straight stated that "There is no scientific basis for this conclusion and risks from current and future releases of TFA from the use of fluorinated precursors regulated under the Montreal Protocol to aquatic and terrestrial plants are de minimis".

In their 2022 report, UNEP highlighted that "There has been considerable discussion as to the inclusion of TFA in the class PFAS for regulatory purposes…We are of the opinion that the properties of TFA indicate that it should not be included in this class for the purposes of generic regulatory risk assessment".

It would appear that the Dossier Submitter and the United Nations Environment Programme have diametric opinions about TFA and consequently HFOs in terms of their risk and suitability for inclusion into a PFAS grouping effort for regulatory purposes.

EU Initiatives

The proposed cooling technology will fully support many of the EU Commission's priority policies. These include Energy and Climate policy, the vast number of initiatives captured under the Green Deal, EU Chips Act, Net Zero Industrial Act and indeed the Digital Decade.

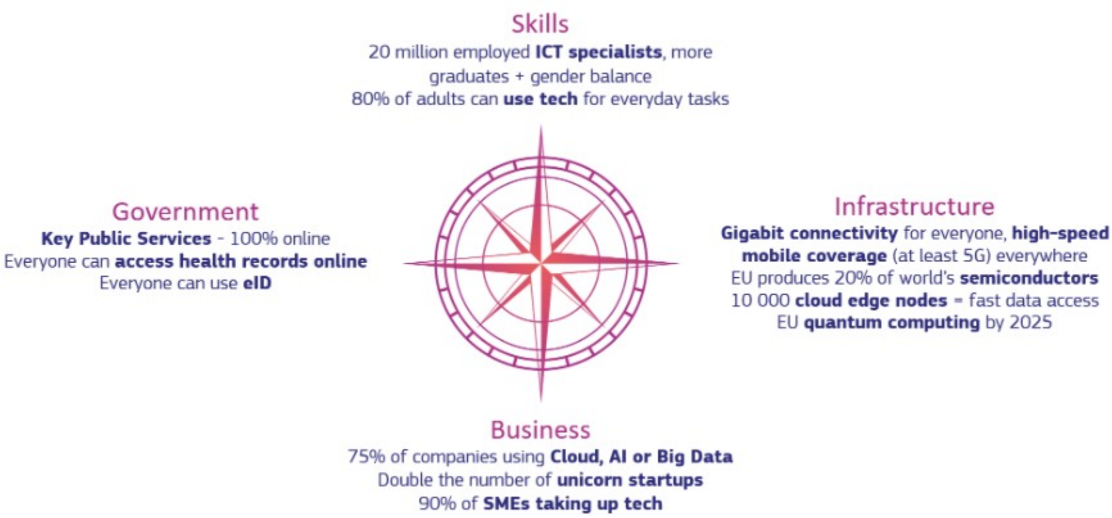

Figure 4.0 – Europe's Digital Decade Targets for 2030

Upon examining the primary strands of the Digital Decade, Figure 4.0 depicts the associated policy programme with targets and objectives for 2030. All of these - Skills, Infrastructure, Business and Government necessitate the use of data centres. It is imperative that these data centres utilise a superior and sustainable cooling technology such as that provided through the cooling distribution systems outlined.

Consequently, it is critically important that this technology including its refrigerant chemistries (HFOs) and hardware (fluoropolymers) are granted an appropriate derogation from the proposed REACH Restriction on PFAS. The requested derogation timeframe is 12-years.

References

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