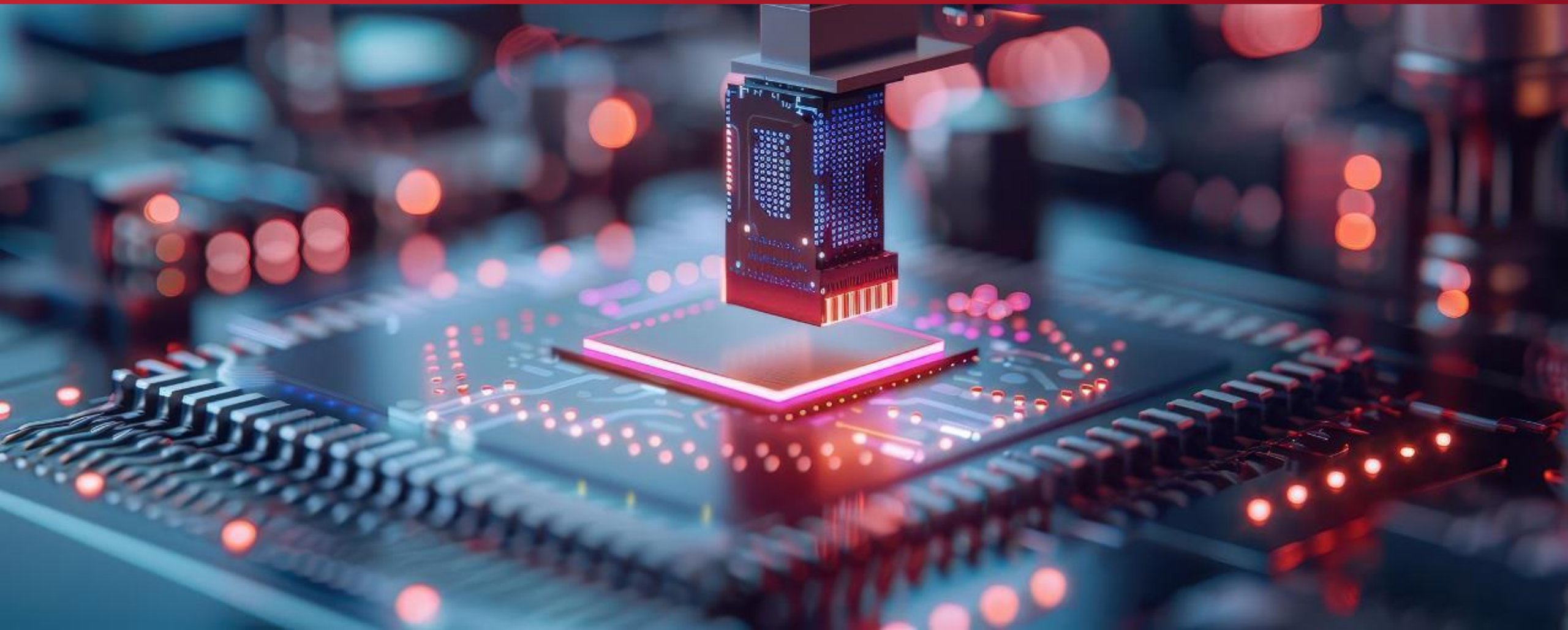
Identification, Understanding, Reduction

Edwards' Vision to Help the Semiconductor Industry Manage the PFAS Challenge

Chris Jones

February 19th, 2025



Edwards global presence

4	12	13	18	3
Core Technology Centres	Product Companies	Customer Centres	Service Technology Centres	Innovation Centers

1 Europe

- Cologne
- Dresden
- Dresden
- Brno
- Lutin
- Dublin
- Europe

2 United Kingdom

- Clevedon
- Eastbourne
- Burgess Hill Headquarters

3 North & Central America

- Haverhill, USA
- Hillsboro, USA
- Monterrey, MX
- North America
- Glenwillow, USA
- Nogales, MX
- Chandler, AZ

4 South America

- Sao Paulo
- South America

5 Middle East

- Qiryat Gat, IL

6 China

- China
- Qingdao
- Shanghai
- Xian
- Langfang
- Shanghai
- Shenzhen

7 Japan

- Yachiyo
- Ina
- Japan

8 Taiwan

- Jhunan
- Taiwan

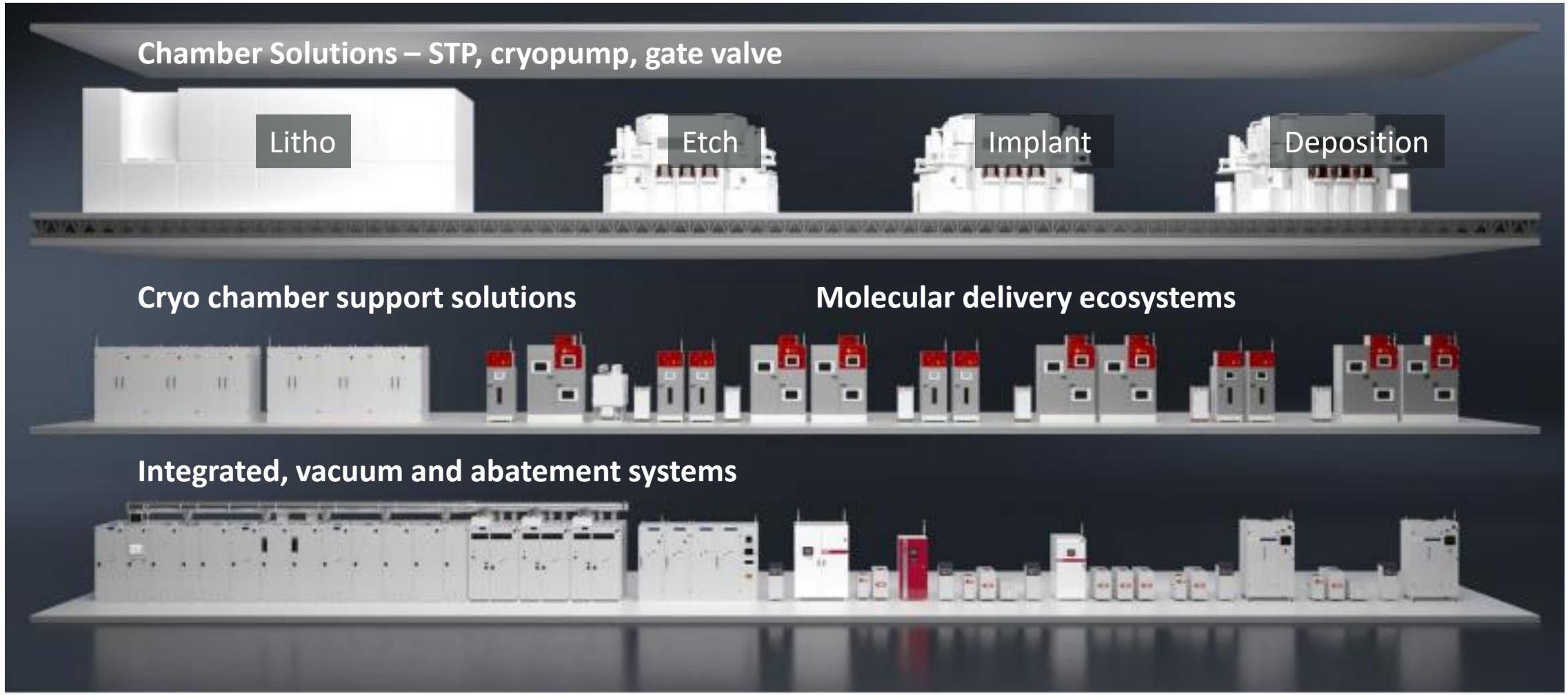
9 South Korea

- Korea
- Cheonan
- Asan
- Yongin

10 Southeast Asia & Pacific

- South Asia
- Southeast Asia
- Loyang, SG
- Kulim, MY
- Pune, IN

Typical fab layout - snapshot



Outline

Awareness

- What are PFAS?
- Their importance to the semiconductor industry
- Their challenges in use – persistence, mobility, bioaccumulation, toxicity, historical legal development in EU and US
- The impact of the phaseout of PFOS and PFOA

Activity

- Toxic Substance Control Act (TSCA) – where and what are PFAS in our products
- Managing PFAS out of our products
- Ongoing test work on PFAS during PFC treatment and the challenge of analysis
- A survey of PFAS in water from one of our facilities
- Future work planned on laboratory testing

What are PFAS? Per or Polyfluoroalkyl Substances

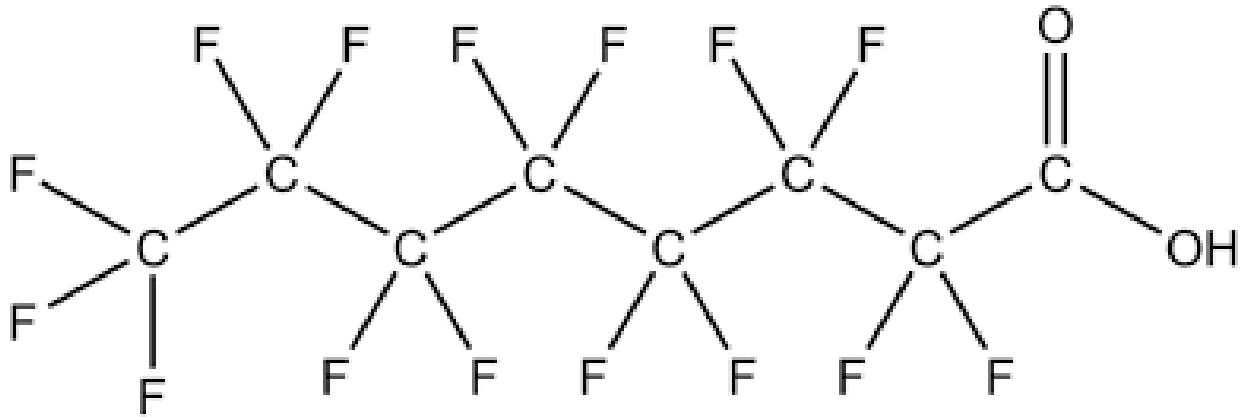
Polyfluoro

Many fluorinated

carbons connected

Perfluorooctanoic acid

C8, organic acid



Perfluoro

Carbons fully

Fluorinated

Polyfluoro “alkyl”

Many carbons connected

Thermal and Chemical Stability:
PFAS materials resist extreme temperatures and harsh chemicals, ensuring reliability in semiconductor processes

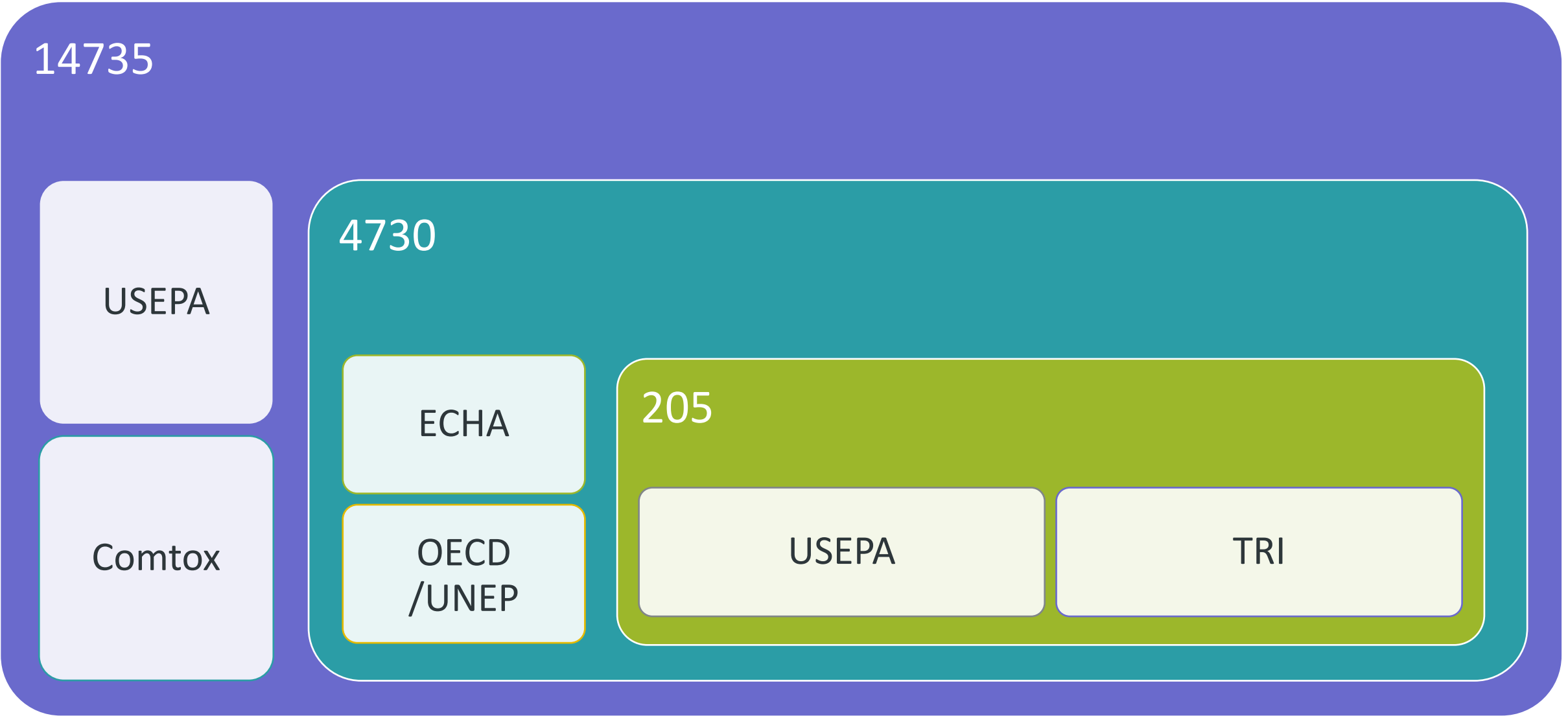
Non-Reactivity and Purity:
Their inert nature prevents contamination and unwanted reactions, maintaining high purity standards in fabrication

https://comptox.epa.gov/dashboard/chemical-lists/PFASSTRUCTV5

The Semiconductor Industry Uses PFAS Extensively: For Good Reasons

Photolithography:	PFAS enhance photoresist adhesion, durability, and thermal stability, enabling precise pattern transfer onto silicon wafers
Etching and Deposition Processes:	Fluorinated PFAS gases are used in plasma etching to create fine wafer patterns and in chamber cleaning to aid in thin-film deposition
Equipment Components:	PFAS materials are used in high-purity water systems, valves, pumps, and piping to maintain contamination-free fabrication environments
Heat Transfer Fluids:	PFAS-based fluids provide efficient thermal management in cooling systems, ensuring process stability
Lubricants and Sealants:	PFAS-based lubricants and sealants minimise friction and contamination in semiconductor manufacturing equipment

PFAS lists – not exhaustive, regularly revised



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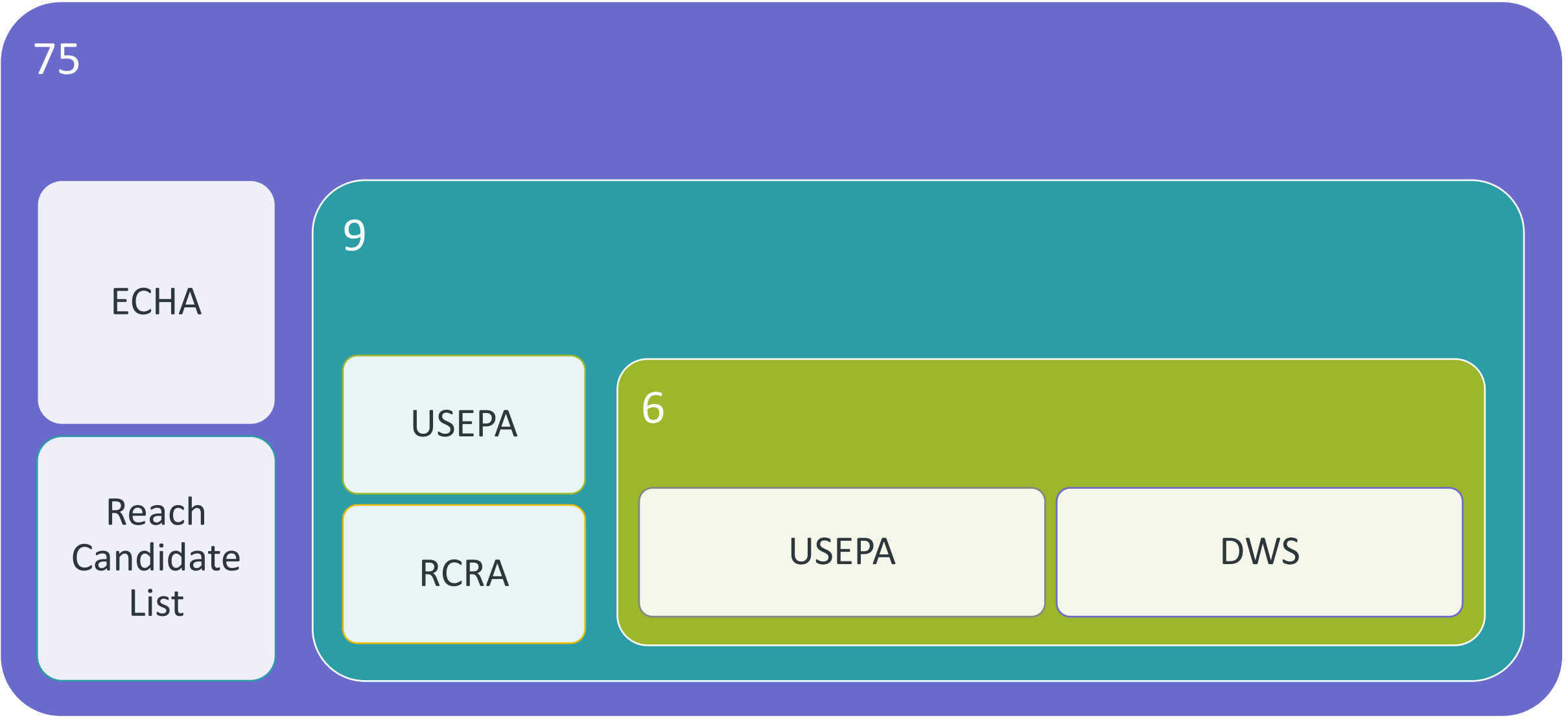
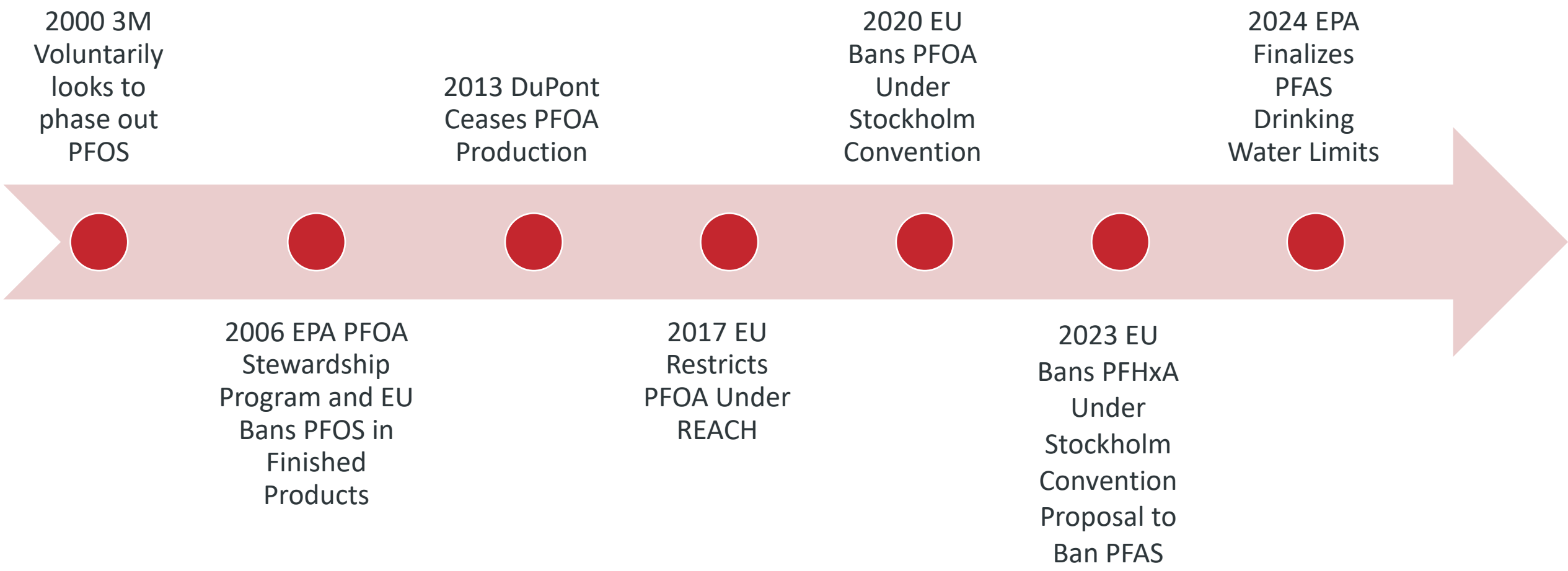


Environmental Challenge: Persistence, Mobility, Bioaccumulation, Toxicity

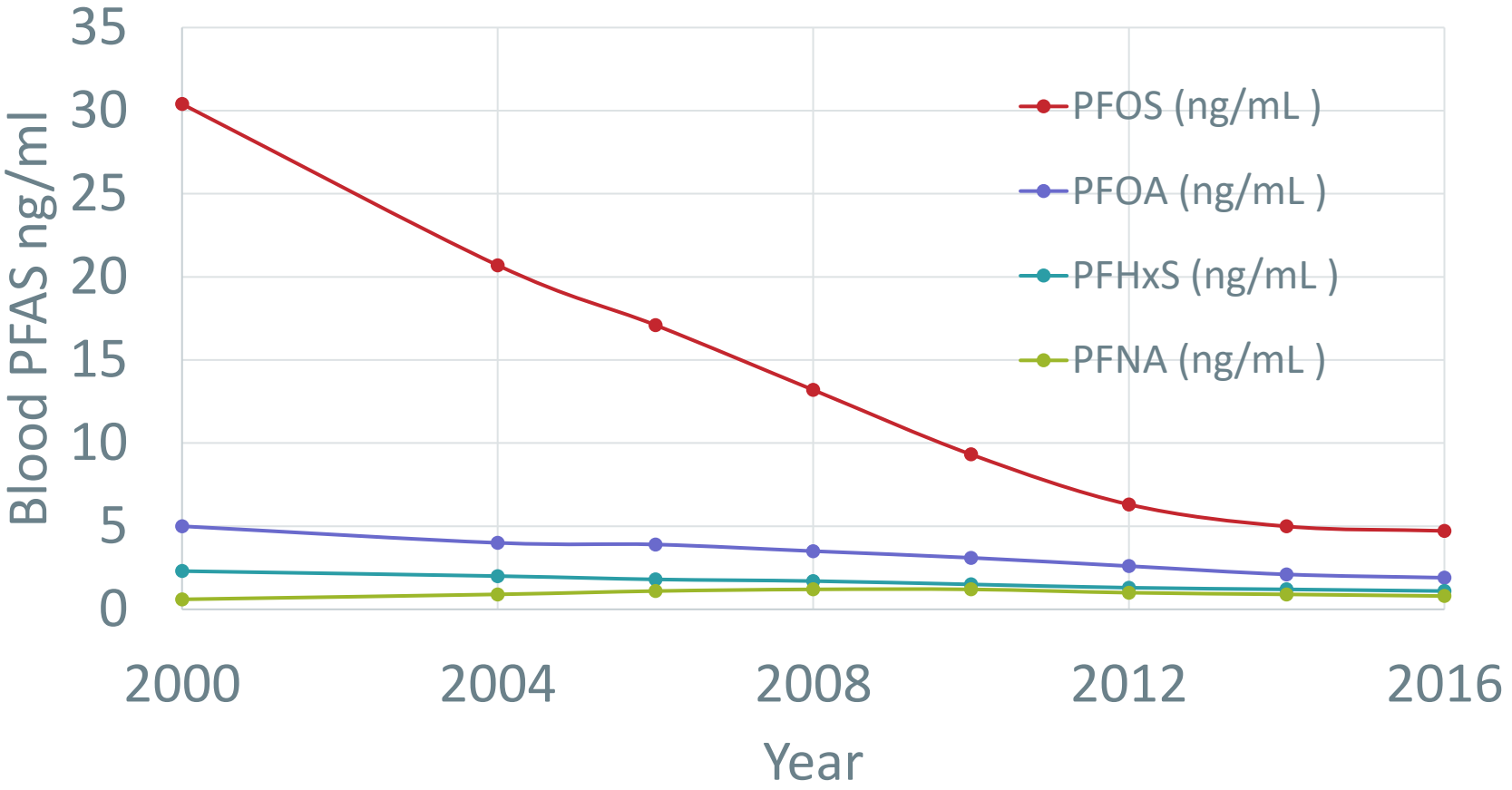
PFAS	Water Persistence (Years)	Body Persistence (Years)	Mobility (Log KOC)	Bioaccumulation (BAF)	Toxicity (Impact Scale)
PFOA	>90	2-10	1.8-2.3	300-700	3-5
PFOS	41-70	3-27	2.2-2.9	1000-4000	4-5
PFHxS	35-45	4-35	2.0-2.3	800-1500	3-4
PFNA	30-40	2.5-4.3	2.3-2.7	500-900	3-4
GenX (HFPO-DA)	0.1-1	0.1-1	1.2-1.5	20-60	2-3
PFBS	0.07-0.1	0.07-0.1	1.4-1.6	10-30	1-2
Rating	Very Low Risk	Low Risk	Moderate Risk	High Risk	

- For the compounds list in the DWS
- A complex picture with significant uncertainties.

Some Responses of Manufacturers and Regulators



The Impact of These Measure on Population Average Blood Levels (USA)



Recommendations for treating patients:

- Less than 2 ng/mL: No action needed; follow standard healthcare
- 2–20 ng/mL: Reduce exposure if a source is identified, especially for pregnant individuals
- ≥20 ng/mL: Prioritize exposure reduction. Screen for thyroid, kidney, testicular cancer, and ulcerative colitis symptoms

Guidance on PFAS Exposure, Testing, and Clinical Follow-Up. National Academies of Sciences, Engineering, and Medicine; Health and Medicinehttps://www.ncbi.nlm.nih.gov/books/NBK584702/

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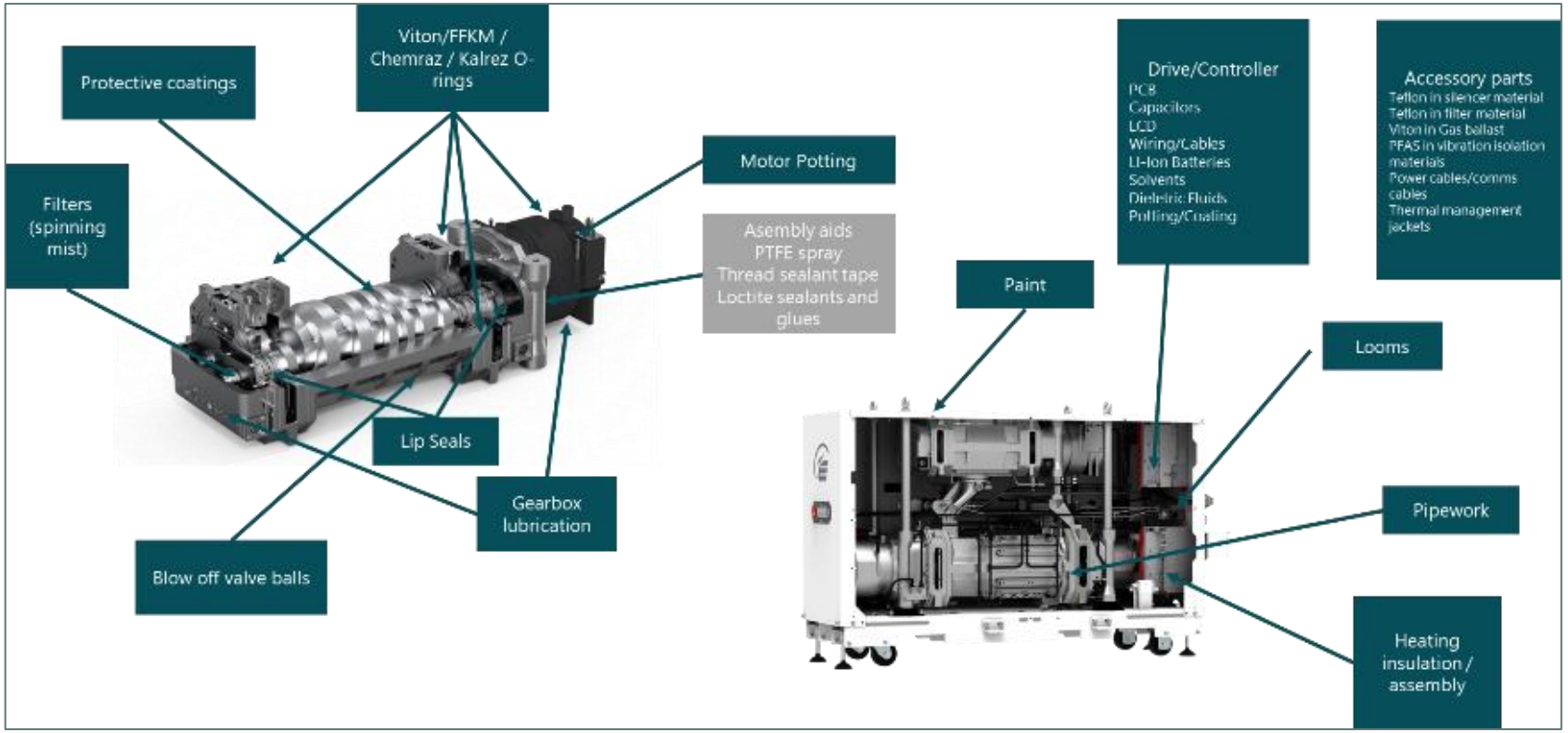
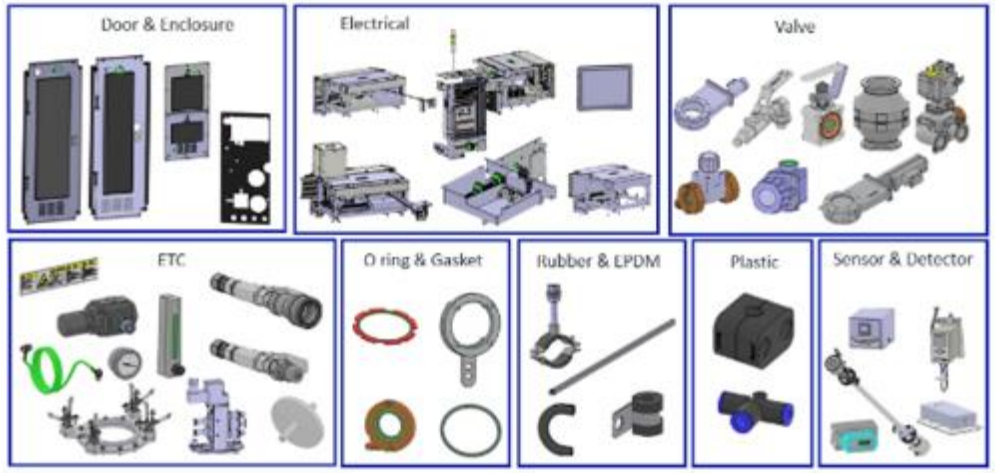
- Future work planned on laboratory testing

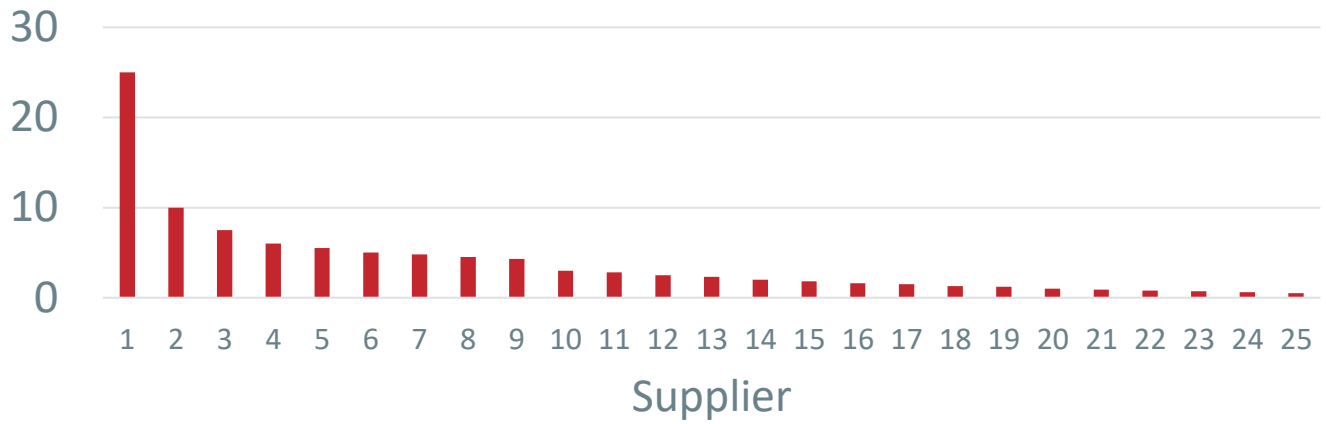
Edwards Products and PFAS Engineering focus: identify, reduce, remove

- Products need to operate at high temperature greater than 200C F_2 or Cl_2 FFKM current are the only materials that can operate in these environments and provide the expected service interval life
- These represent >20% of the market needs
- Customers may be conservative (copy exact) but may also repurpose for different duties
- There will be a need to apply pragmatism and exemptions to the designs, as suitable replacement materials are currently not available



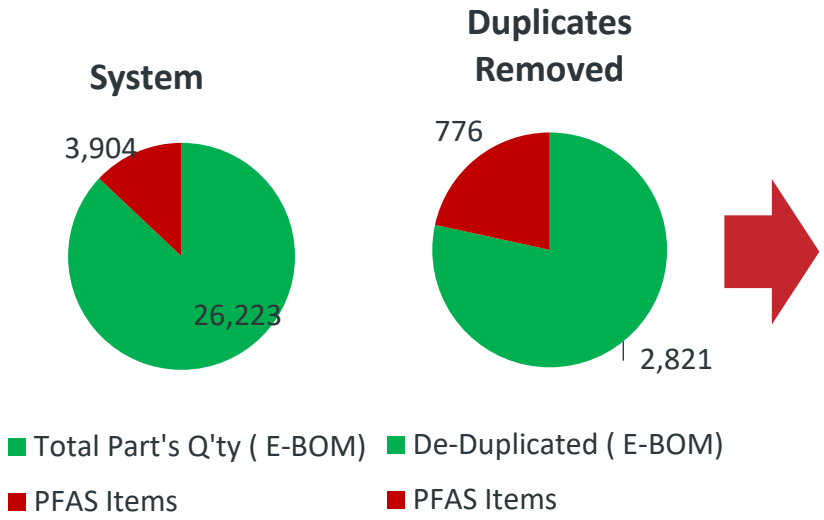
Toxic Substance Control Act – where are PFAS in our products?





System

Product No,	System			Total	%
Product Description	Details				
Total Part's Q'ty (E-BOM)	Mech	13,912		26,223	
	Elec	12,311			
PFAS Items	Mech	1,401	10.1%	3,904	14.9%
	Elec	2,503	20.3%		
Remove Duplication (E-BOM)	Mech	1,957		2,821	
	Elec	864			
PFAS Items	Mech	380	19.4%	776	27.5%
	Elec	396	45.8%		



Part Categorisation risk to functionality or performance

High Risk	Need new technical solution
Medium risk	Potential to impact functionality or performance and requires testing
Low risk	Alternative materials are available, "low hanging fruit"

PFAS Strategy and Example of Progress

Identify

- BOM interrogation tool
- Procurement survey feedback
- Pump and abatement testing
- 3rd party analysis house to identify PFAS and non PFAS electronic items

Justify conscious use

- All new product introduction projects exemption register
- Approval from VP of Engineering

Reduce

- Target NPI projects
- A&Ds
- Reductions during design
- Use existing alternative materials
- Define parts by risk of performance

Remove
Drive 2030 target

- New alternative materials via technology
- New design concepts, e.g. piston rings v PTFE lip seals

- **Example**: heat trace controller and power cables – identified PFAS parts virtually removed; working with connector supplier to complete the task
- **In progress**: replacing insulation jackets and changing the heater technology.

PFAS Strategy - Product Company Initiatives

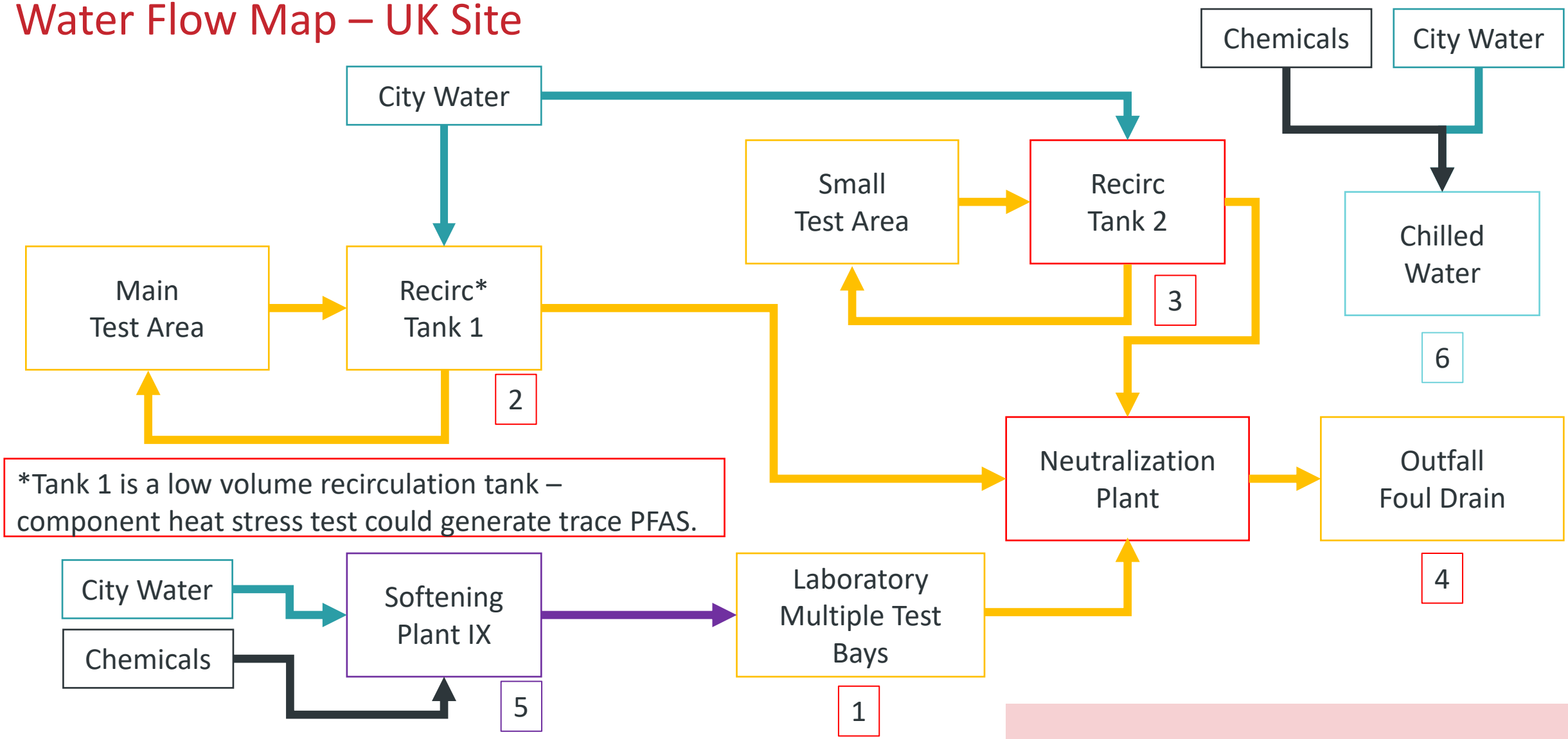
PC Asan supplier PFAS workshop - 64 suppliers attended

- Each product company has appointed a PFAS lead
- PCs driving initiatives;
  - Including activities in Operations
  - Supplier workshops and education sessions
  - Engineering team training and Product Commercialisation requirements

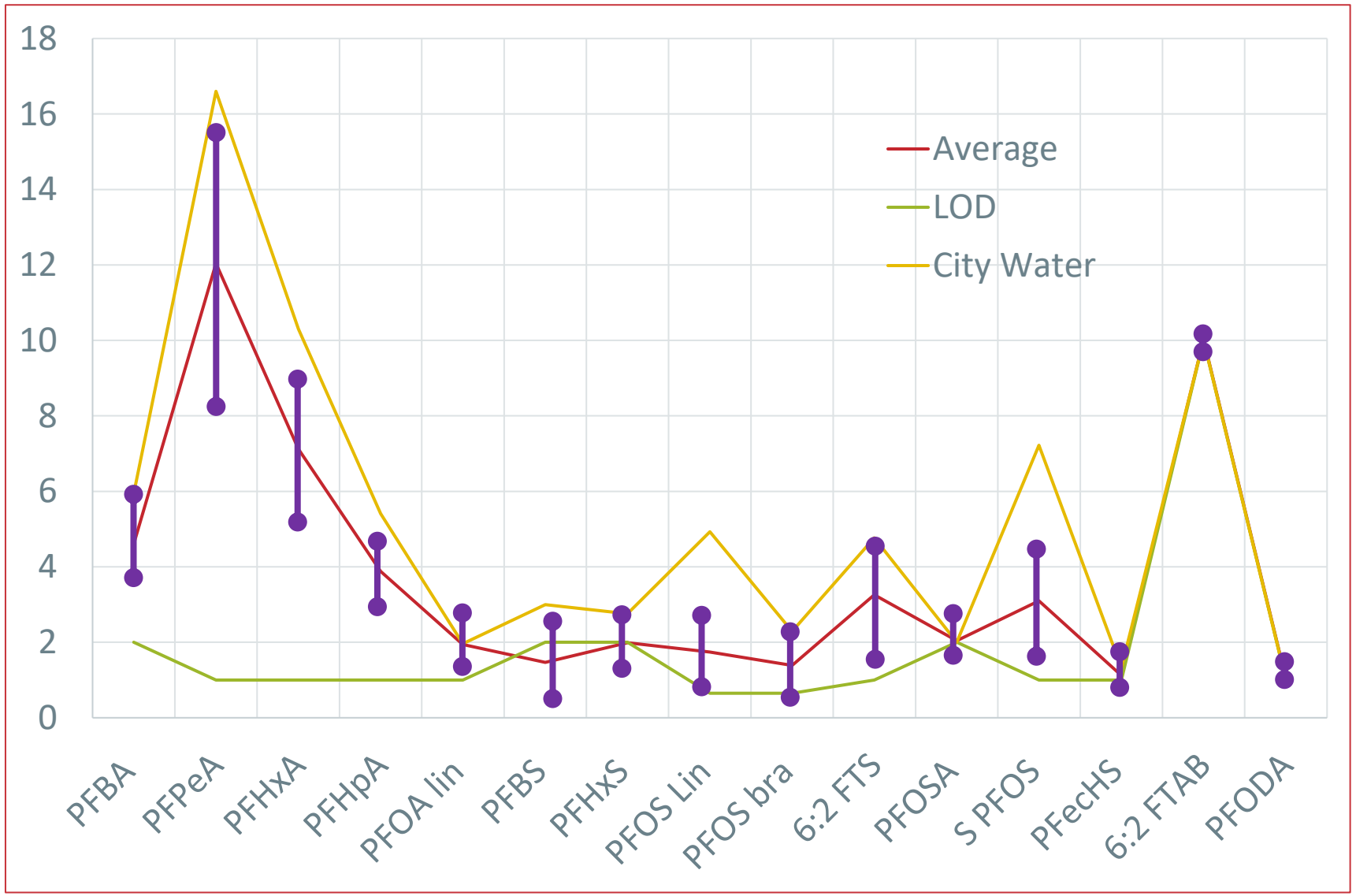
PFAS Task Force Team

Manufacturing PFAS investigation tours

Water Flow Map – UK Site

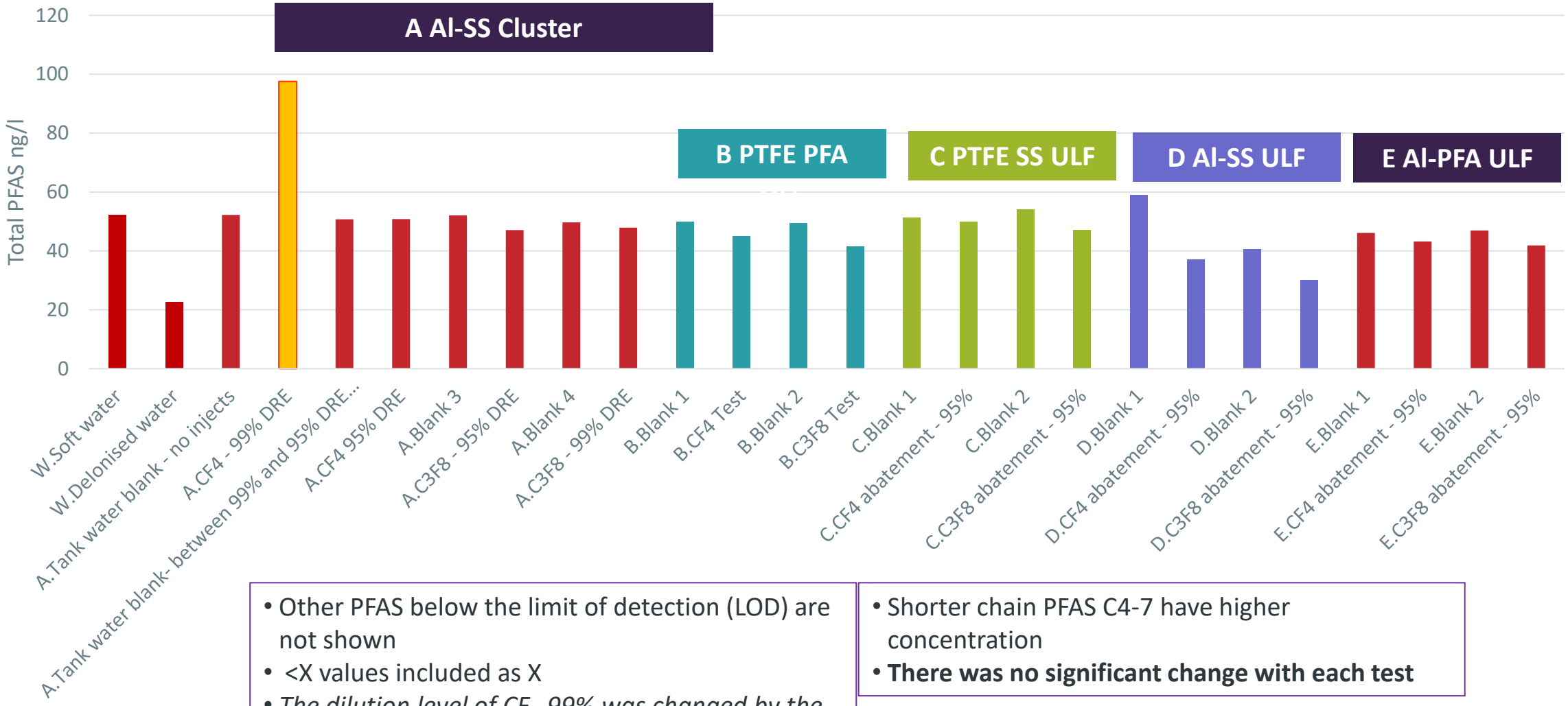


Lab Water Test (all other analytes <LOD)



- PFAS detected in incoming water—well below the UK drinking water limit of 100 ng/l
- Shorter-chain PFAS (C4-C7) have higher concentrations
- PFBA, PFPeA, PFHxA, PFHpA, PFOA(lin), PFOS(lin), PFOS(bra), 6:2 FTS, ΣPFOS – above LOD
- Softener is reducing PFAS level in lab water

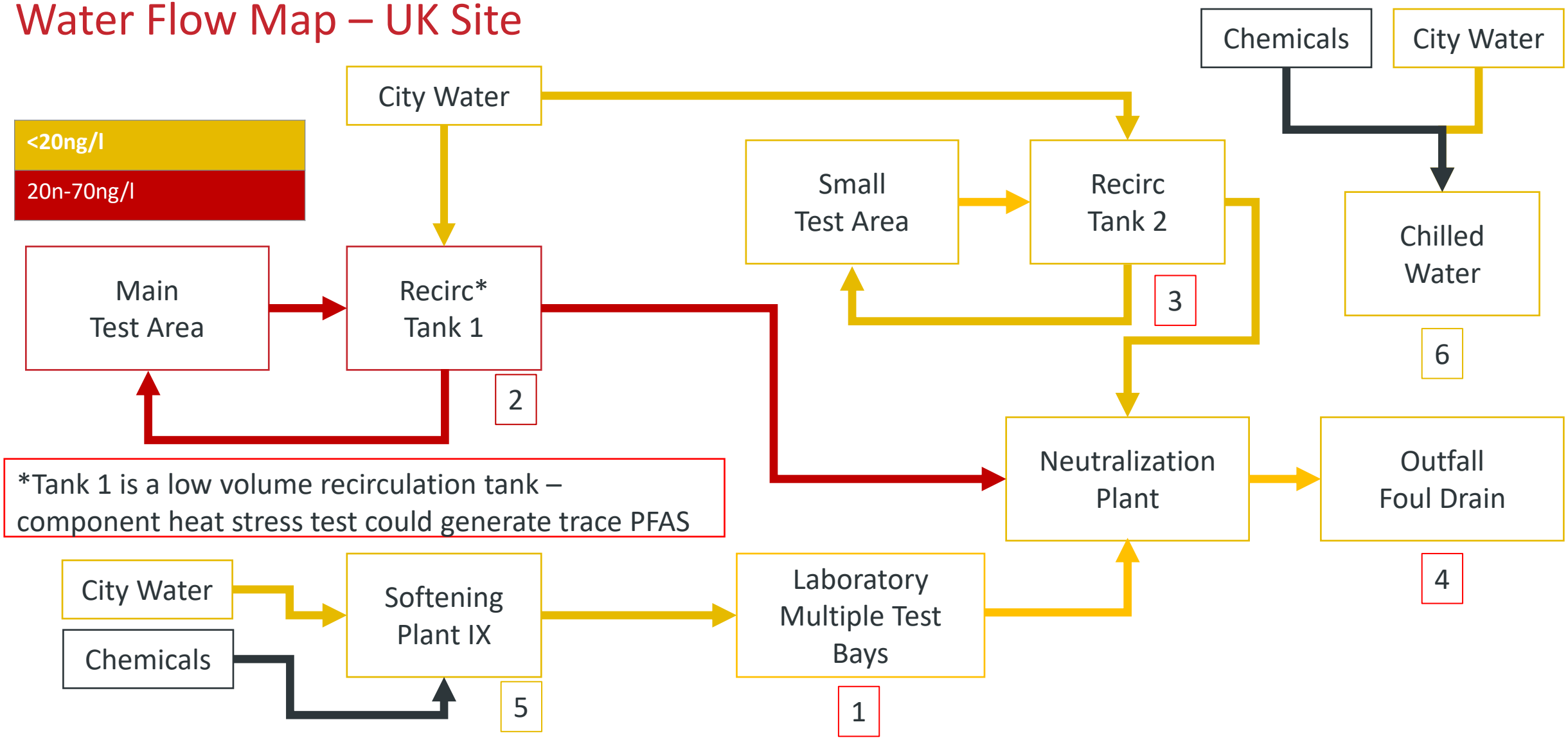
Laboratory Testing CF_4, C_4F_8, Materials Variations Σ>LOD (DI ΣLOD)



- Other PFAS below the limit of detection (LOD) are not shown
- <X values included as X
- *The dilution level of CF_4-99% was changed by the test lab, caused high result*

- Shorter chain PFAS C4-7 have higher concentration
- **There was no significant change with each test**

Water Flow Map – UK Site



Future Testing in Progress

- Abatement of long chain PFC – PFO
- C_4F_8 after passage of gas through a plasma (chamber surrogate)
- Abatement of post plasma C_4F_8 byproducts (chamber surrogate)
- Results to be reported at SESHA in April

Summary

PFAS in the Semiconductor Industry

- PFAS are used for their thermal stability, non-reactivity, and purity and are critical in our and other products – but their use raises environmental concerns

Environmental & Health Challenges

- PFAS are persistent, mobile, bioaccumulative, and toxic, and regulations are tightening

Edwards' Strategy

- Identify PFAS usage, Reduce reliance, Remove where possible with a target of 2030 for safer alternatives

Water Testing Findings

- PFAS detected (mainly C4-C7) coming from our city water
- PFC abatement and materials of construction do not add PFAS to the wastewater

Next Steps

- Continue testing & supplier collaboration

Part of Atlas Copco Group