PFAS Treatment:
The Current State of Play

Tackling PFAS Pollution, Antwerp, Belgium

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PFAS

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Agenda

Global Perspective

- Global Occurrence
- Regulatory Approaches

Treatment Concepts

- Site-Specific Considerations
- Technology Readiness
- Treatment Trains

Achieving Remediation Solutions

PFAS

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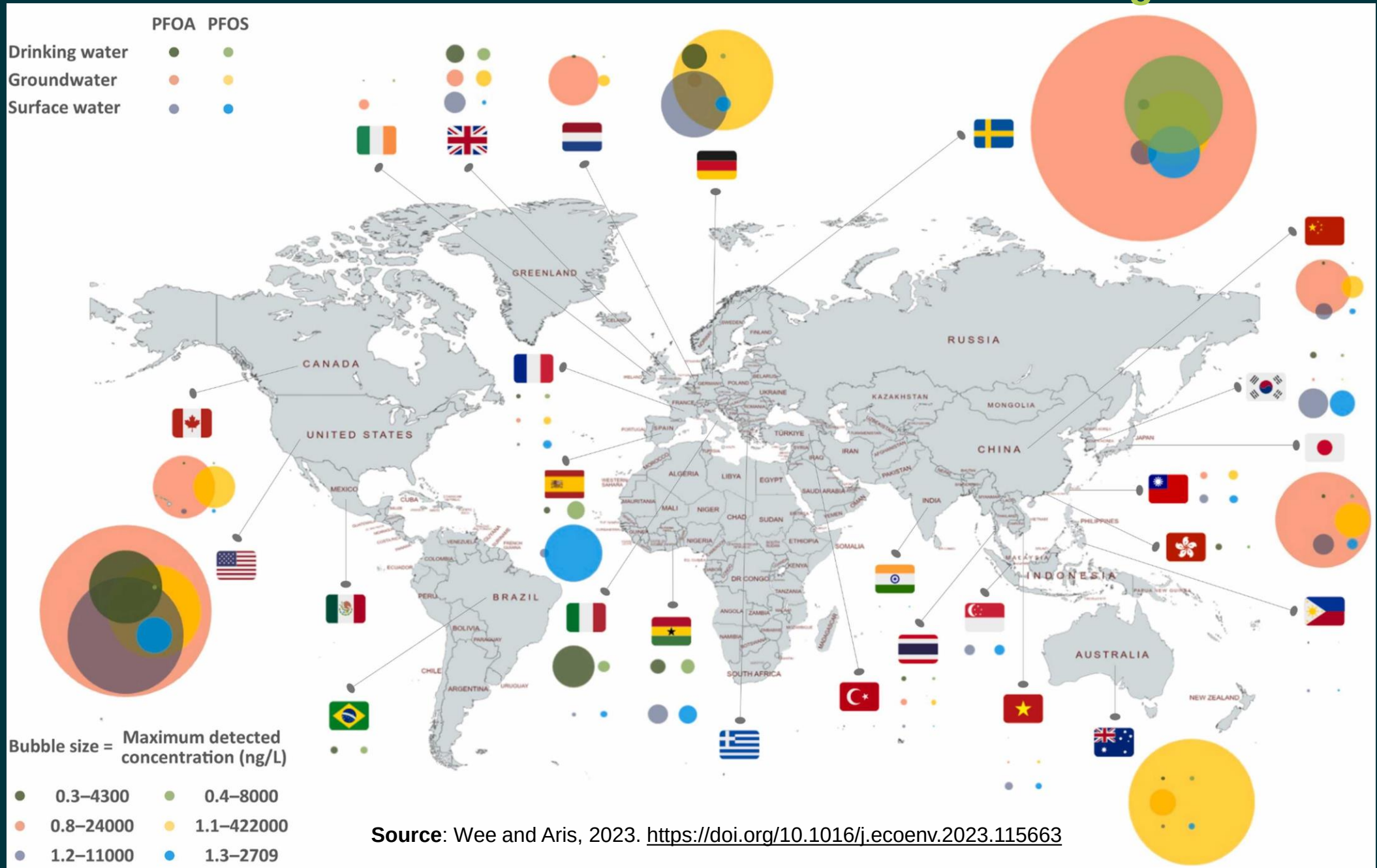
PFOA and PFOS: Maximum detected concentrations in global waters



Source: Wee and Aris, 2023. https://doi.org/10.1016/j.ecoenv.2023.115663

Comparison of US - AUS - EU Regulatory Approaches

Regulatory Action	US	EU	AUS
Overarching philosophy	Process driven regulatory response to manufacturing and environmental risks	Conservative, direct action on source reduction, focused on sustainability	Wholistic evaluation of exposures and solutions focused
Inventory & Restrictions on Importation /Manufacture/ Use	USEPA Toxic Release Inventory Toxic Substances Control Act (TSCA)	Registration, Evaluation, Authorisation & Restriction of Chemicals (REACH) Regulations	Recommendation for alternatives
Organizational Engagement	Federal/State Intergovernmental	Interjurisdictional	Federal/State Intergovernmental
Exposure-Based Approaches for: **- Food Ingestion**	Agency for Toxic Substances and Disease Registry (ATSDR) 2018 Tolerable **Daily** Intake PFOS - 20 ng/kg bw/day PFOA - 20 ng/kg bw/day	European Food Safety Authority (EFSA) 2020 Tolerable **Weekly** Intake PFOS, PFOA, PFHxS and PFNA 4.4 ng/kg body weight **per week**	Food Safety Australia and New Zealand (FSANZ) 2017 Tolerable **Daily** Intake PFOS+PFHxS - 20 ng/kg bw/day PFOA - 160 ng/kg bw/day
- Drinking Water	PFOS & PFOA < 4 ng/L PFNA, PFHxS, PFBS, GenX ΣHI = 1.0	Σ20PFAS > 100 ng/L	PFOS - 70 ng/L PFOA – 560 ng/L
	Individual States – compounds and criteria vary		

ng/kg bw= nanogram per kilogram body weight
ng/L = nanogram per liter

Site-Specific Considerations

Nature of PFAS release

Point of compliance

Treatment objectives

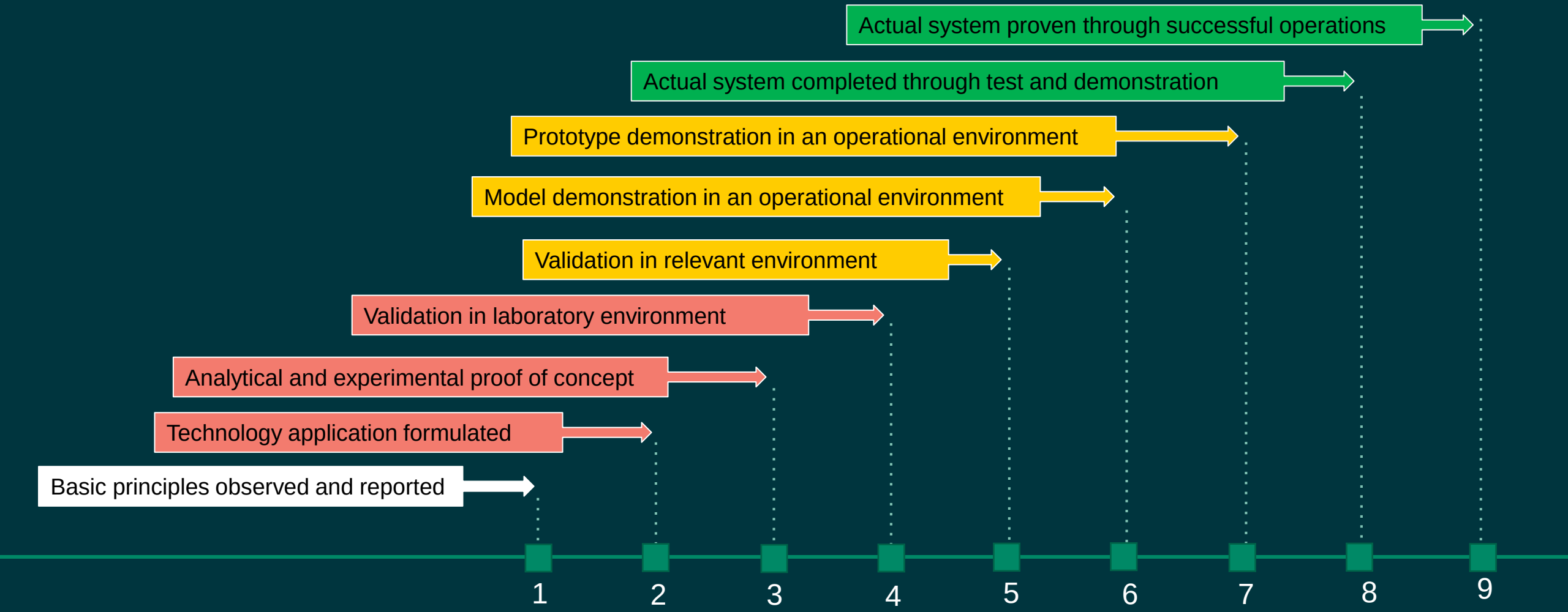
Technology considerations

- Target medium (soil, water)
- In situ or ex situ
- Commercial readiness

Engineering constraints

Technology Readiness Level Advancement

Reference: https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf



Status of PFAS Treatment Technologies

Soil/ Solid	In-Situ	Ex-situ	Mechanism	Readiness
Incineration		✓	Destruction	
Soil Washing		✓	Separation	
Ballmilling		✓	Destruction	
Sorption and Stabilization	✓	✓	Separation	
Thermal Desorption / Smoldering		✓	Separation	
Water/ Liquid	**In-Situ**	**Ex-situ**	**Mechanism**	**Readiness**
Incineration		✓	Destruction	
Ion Exchange (IX)/ Regenerable IX		✓	Separation	
Reverse Osmosis/ Nanofiltration		✓	Separation	
Foam Fractionation		✓	Separation/Concentration	
Granular Activated Carbon		✓	Separation	
Colloidal Activated Carbon	✓		Separation	
Supercritical Water Oxidation (SCWO)		✓	Destruction	
Plasma		✓	Destruction	
Electrochemical Oxidation		✓	Destruction	
Alkaline Hydrothermal Reaction (HALT)		✓	Destruction	
Biochar	✓	✓	Separation	
Novel Sorbents (Regenerable)		✓	Separation/Concentration	
Zeolite/ Clay Mineral	✓	✓	Separation	
Chemical Oxidation	✓	✓	Destruction	
Biodegradation	✓	✓	Destruction	
Coagulation/Flocculation		✓	Separation/Concentration	
Sonication		✓	Destruction	
Zero Valent Iron (ZVI)/ Doped ZVI	✓	✓	Destruction	

Commercially available

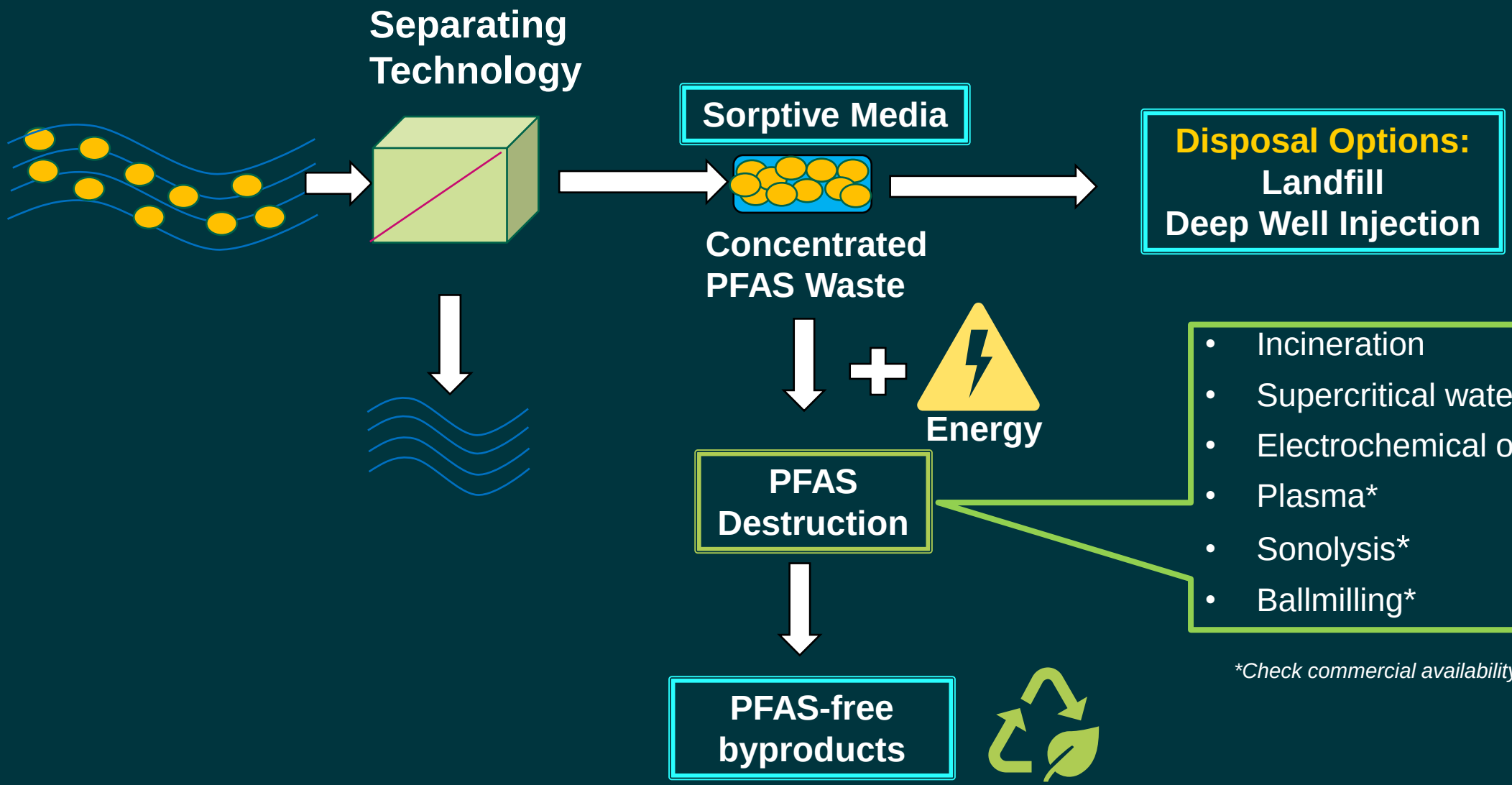
Field demonstrations ongoing

Effectiveness being tested

Adapted from Table 21-1
https://pfas-1.itrcweb.org/

Note:
Short chain PFAA and precursor treatment are not yet fully evaluated

Treatment Approach – Add Destruction for PFAS-free Solution



*Check commercial availability for full-scale applications

Achieving Viable PFAS Remediation Solutions

Protect human health and the environment

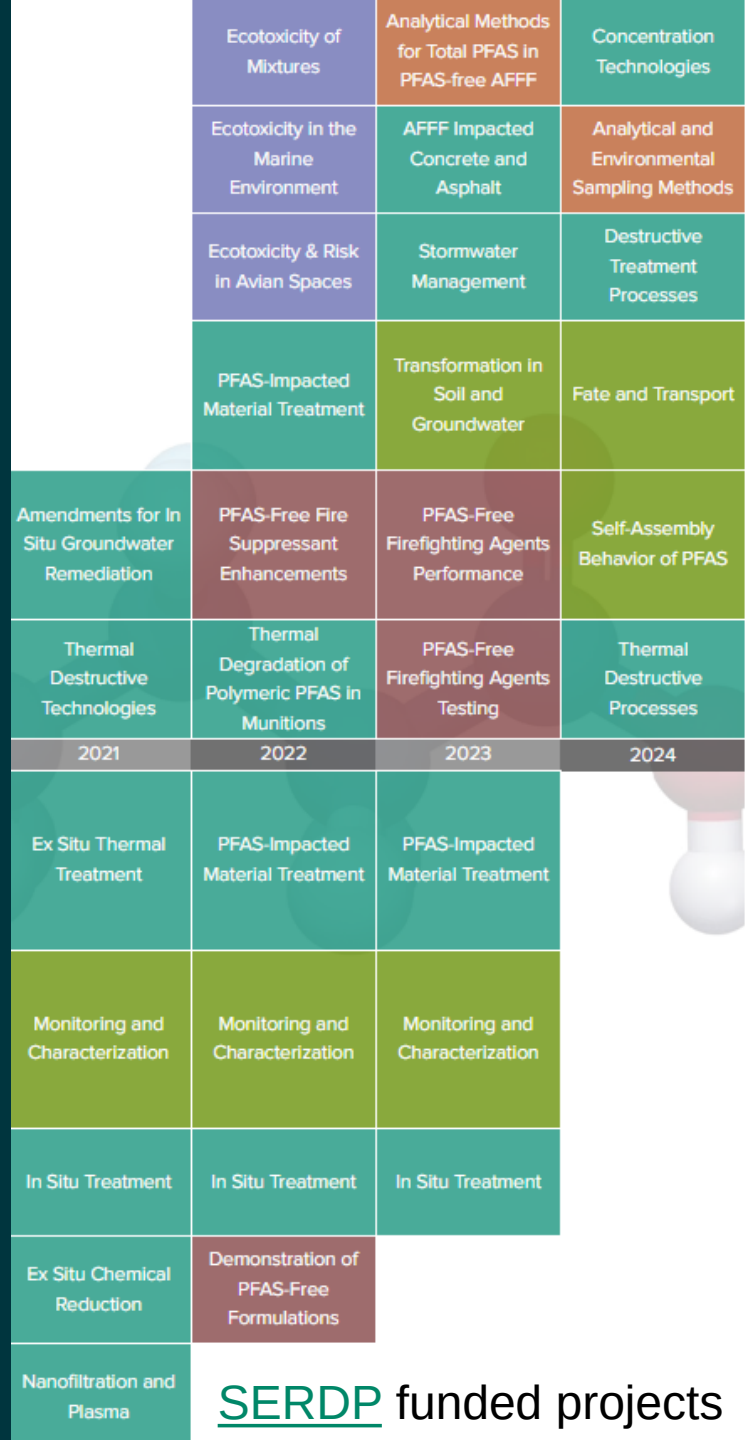
Identify targeted Highly Worrying Substances

Identify appropriate treatment end goals

Research, develop and demonstrate technology

- Flanders: KIS aka Knowledge Center for Innovative Remediation
- European Commission: Horizon Europe and LIFE
- US DOD: SERDP - ESTCP, branch-led demonstrations
- US EPA: PFAS research grants
- Australian Government: PFAS Research Program

DOD – Department of Defense
EPA – Environmental Protection Agency
ESTCP – Environmental Security Technology Certification Program
SERDP – Strategic Environmental Research and Development Program
KIS - Kenniscentrum Innovatieve Saneringstechnieken



SERDP funded projects

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THANK YOU.

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DEVELOPING TECHNOLOGIES – LIQUIDS AND SOLIDS

Adsorption	• Biochar • Coated Sand • Hydrogels and Fluorogels
Chemical/Physical Treatment	• Alkaline Hydrothermal Reaction • Redox Manipulation • Plasma Technology
Oxidation	• Electrochemical • Photolysis • Sonochemical/Ultrasound • Activated Persulfate • Catalyzed Hydrogen Peroxide • Ozone • High Energy Electron Beam
Physical Separation	• Precipitation/Coagulation/Flocculation
Reduction	• Alkaline Metal Reduction • Solvated Electrons • Zero Valent Iron/Doped ZVI
Thermal Treatment	• Thermal Desorption/In Situ Smoldering
Transformation	• Biodegradation

Source: Table 12-1. ITRC PFAS Technical and Regulatory Guidance Document