Big-Picture Cost Considerations for PFAS Management

Ali Ling, PhD, PE

June 21, 2024

UNIVERSITY OF St.Thomas

Agenda

- What makes PFAS unique as an environmental hazard
- Mass balance and steady-state treatment costs
- Status of PFAS use restrictions
- Big-picture cost considerations

What's Unique about PFAS?

What's Unique about PFAS?

Persistent and Mobile

- Affects environmental fate and transport

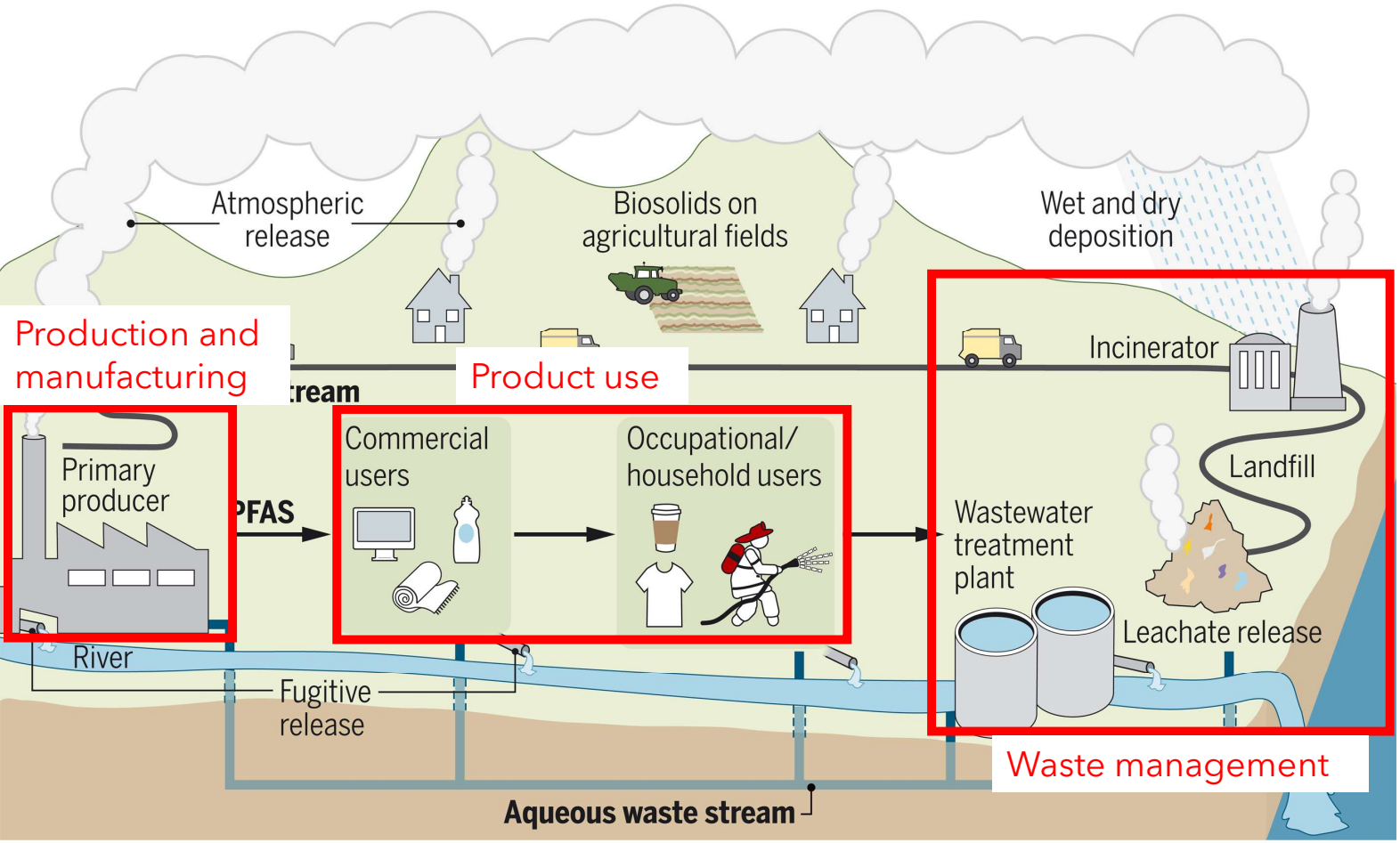
Ubiquitous

- In so many products
- Phase-out will be complicated

So Many Compounds

- >10,000 used
- Difficult to measure and regulate
- Lots of uncertainties about compounds that are not well-studied

Persistent/Mobile – Fate and Transport



- Present in rainwater and in water/soil on all continents
- In most living things, including humans and polar bears

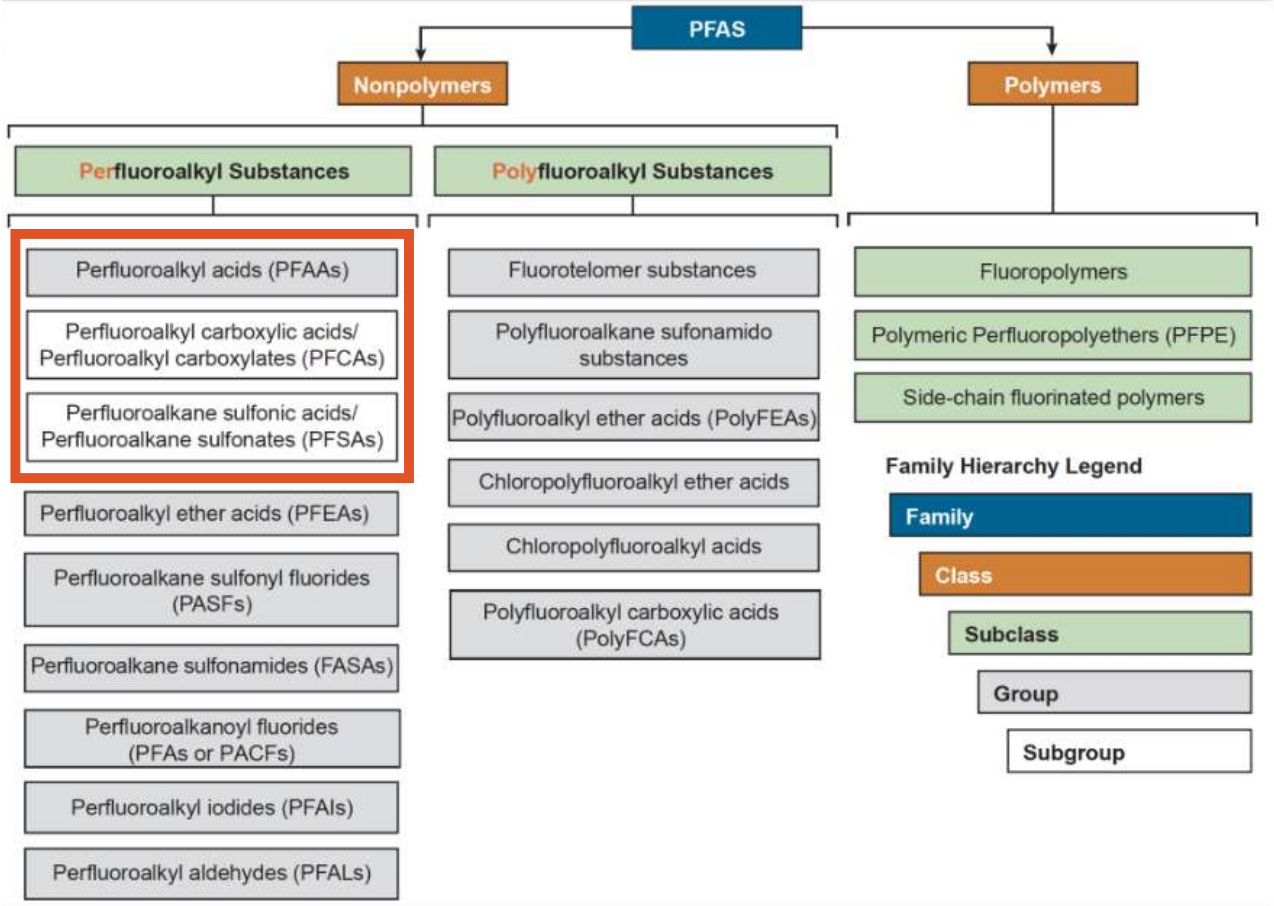
Figure from Evich, M. G. *et al.* (2022). Per- and polyfluoroalkyl substances in the environment. *Science* **375**,

Ubiquity - Types of Products with PFAS

Not included in photo

- Building materials
- Outdoor equipment
- Food (uptake from soils? leach from packaging?)
- Food packaging

>10,000 PFAS in use



>10,000 PFAS in use

Why lots of compounds complicates things:

Hard to Measure

Uncertainties

- Most toxicity, treatment, and fate data is for PFAAs like PFOA/PFOS

  How toxic are all the other PFAS? Can we predict it?

- Generally, cannot close fluorine mass balance due to analytical limitations

  We don't know how much PFAS come out high-temperature incineration stacks!

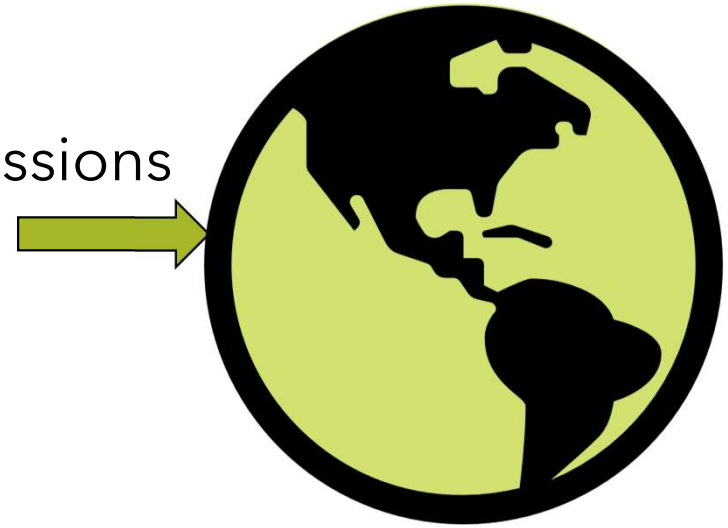
Mass Balance and Estimated Steady-State Costs

($ per year)

The Problem with Persistence

Global PFAS Stocks
in Environment

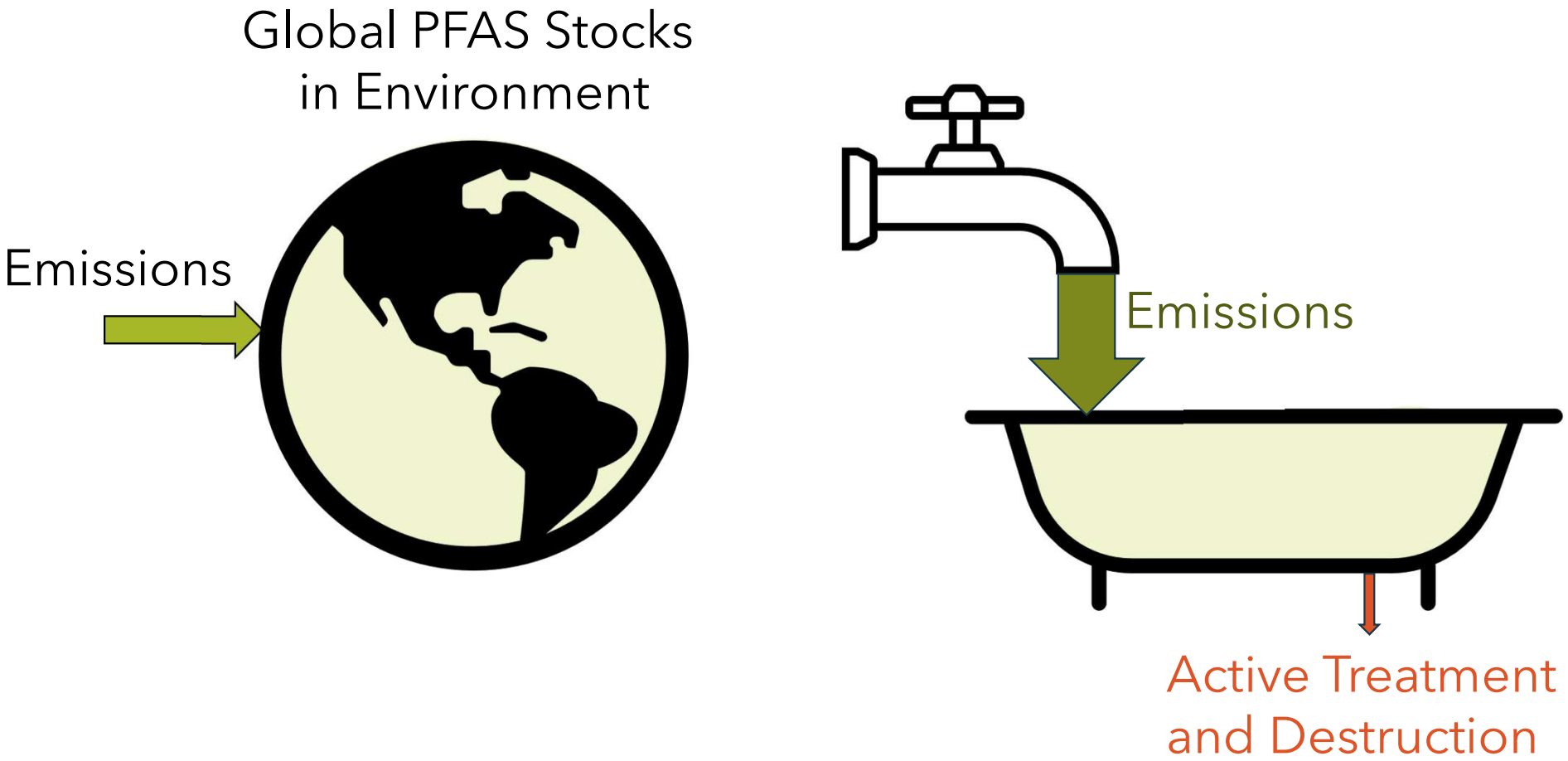
Emissions



Consistently increasing mass stocks and concentrations in environmental media

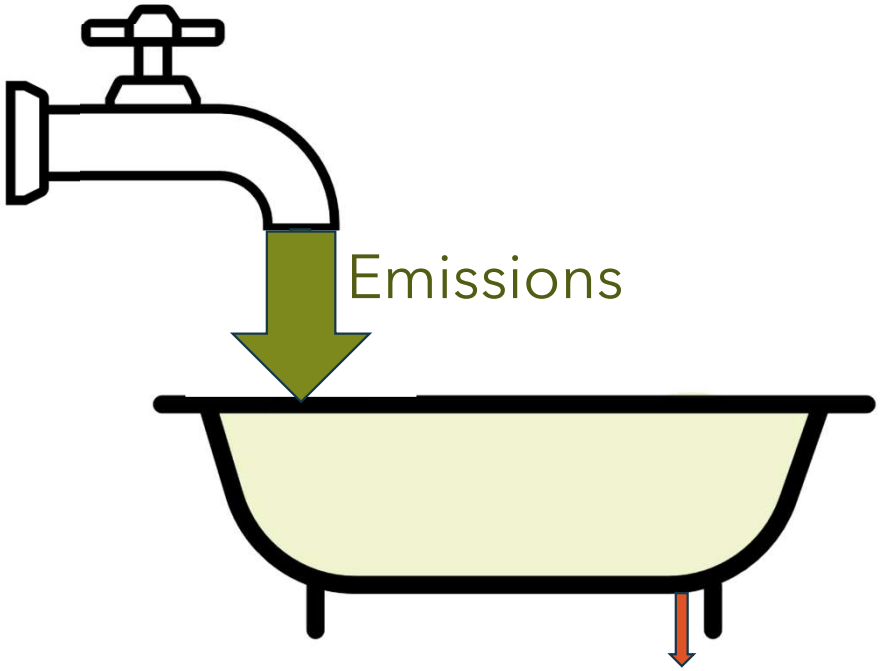
Increased potential to exceed known and unknown thresholds to impact human and environmental health

The Problem with Persistence



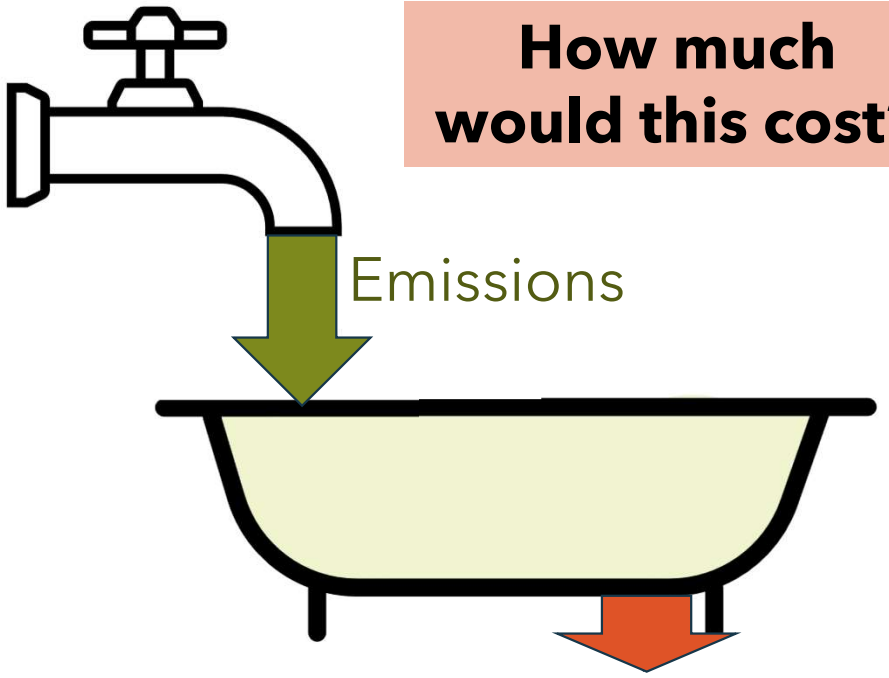
Steady-State Costs Approach

Significantly Reduce PFAS Made, Used, and Emitted



Increase Treatment to Match Emissions

How much would this cost?



Steady-State Costs Approach

Estimate Emissions	Assess Technologies	Technology Costs	Global Costs for Environmental Remediation
How much PFAS are currently emitted from all sources?	What technologies are currently demonstrated and available at relevant scale?	How much does it cost to destroy a kg of PFAS starting from environmental media for each?	How much does it cost to maintain global steady-state? Emissions (mass per year) x Technology costs ($ per mass) Steady state costs ($ per year)

Exceeds global GDP

Ling, 2024. *Sci. Tot. Environ.*
DOI: 10.1016/j.scitotenv.2024.170647

Costs for What Type of PFAS?

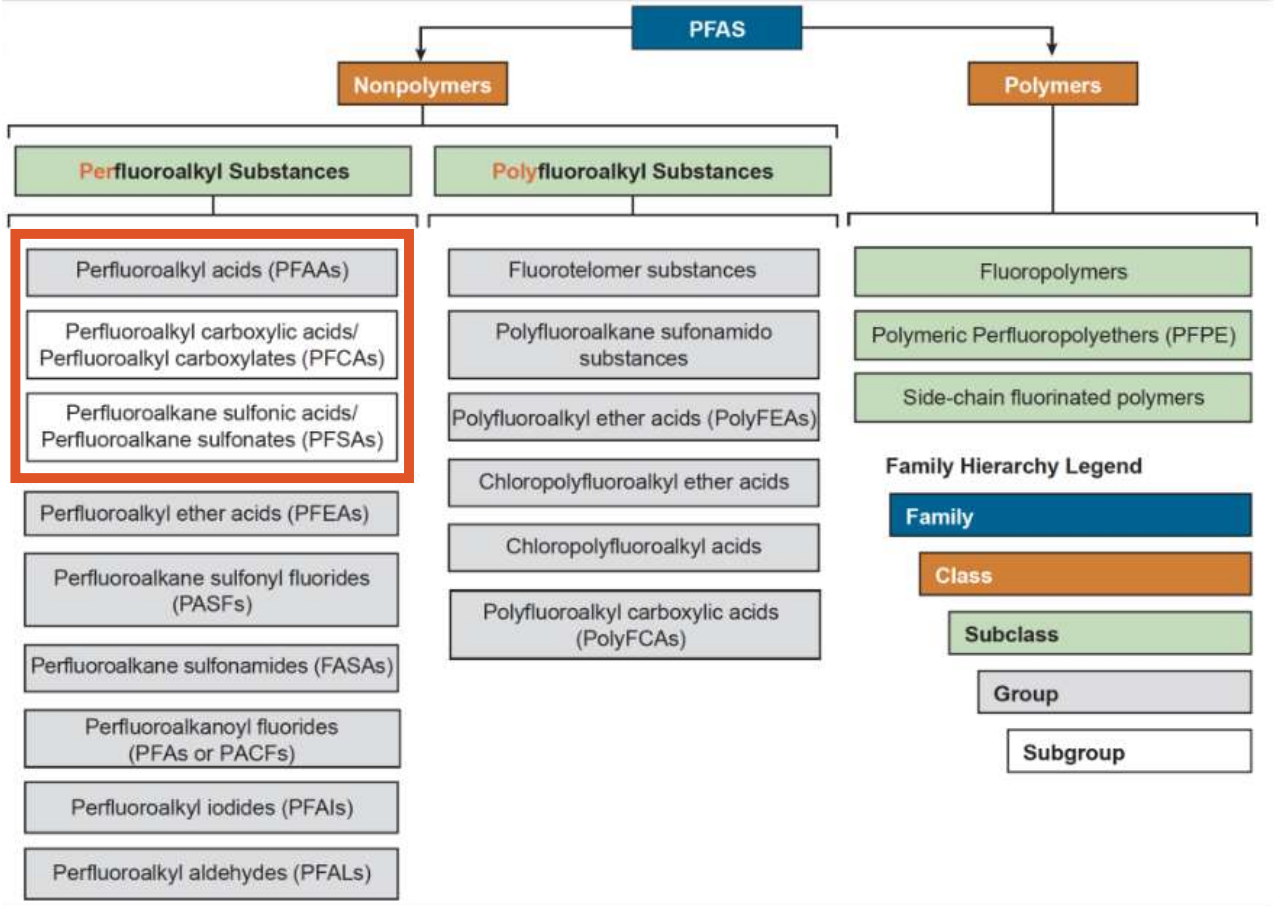


Figure from ITRC Website: PFAS chemistry, terminology, and acronyms

Target PFAAs

- Established technologies to treat them
- More widely reported and measured in treatment applications

Steady-State Costs for PFAAs

PFAS produced and emitted

1,000 to 10,000 tonnes PFAAs/year

X

Active treatment and destruction

$0.9 to $65 million USD/kg PFAA removed and destroyed from environmental media

Current PFAA production rates

Increase treatment to match production rate

= $1 trillion to $600 trillion USD/year for PFAAs alone

(Global GDP ~ $106 trillion)

Ling, 2024. *Sci. Tot. Environ.*
DOI: 10.1016/j.scitotenv.2024.170647

Costs for What Type of PFAS?

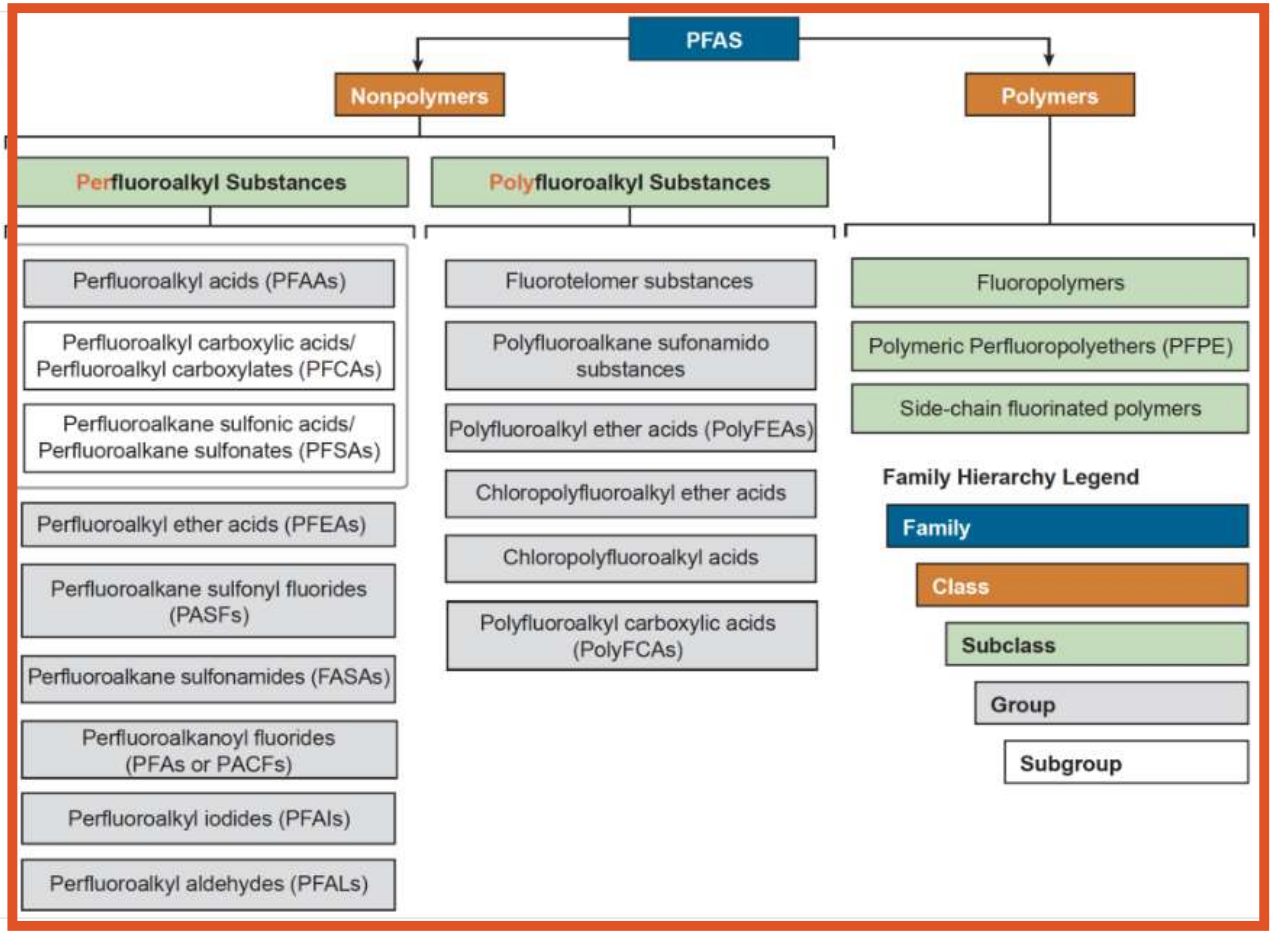


Figure from ITRC Website: PFAS chemistry, terminology, and acronyms

Target PFAAs

- Established technologies to treat them
- More widely reported and measured in treatment applications

Steady-state cost for all PFAS

Current PFAA production rates →  → Increase to match production rate.

$1 trillion to $600 trillion USD/year
for PFAAs alone

x100

Total PFAS production over 100x PFAA production

x2 or more

Other PFAS more costly to separate from environment (don't know by how much)

= $200 trillion to $100,000 trillion USD/year
for all PFAS

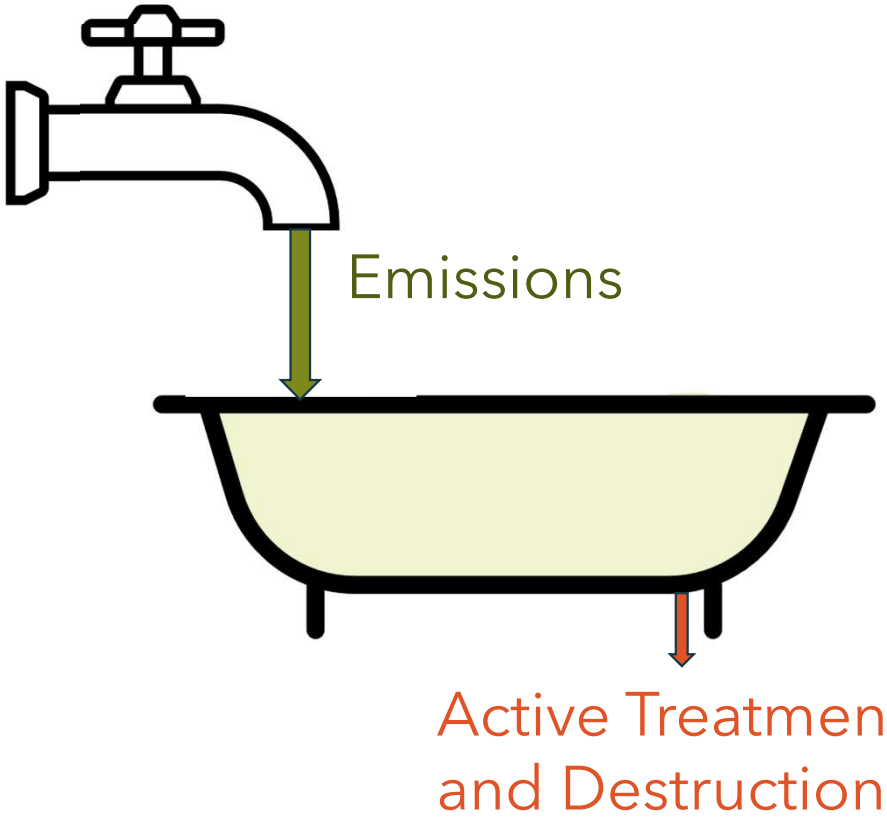
(Global GDP ~ $106 trillion)

Ling, 2024. *Sci. Tot. Environ.*
DOI: 10.1016/j.scitotenv.2024.170647


There is not enough money in the world to remove PFAS from the environment as fast as we are adding it right now.
Not even close.

Options for Reducing Emissions

Significantly Reduce PFAS Made, Used, and Emitted



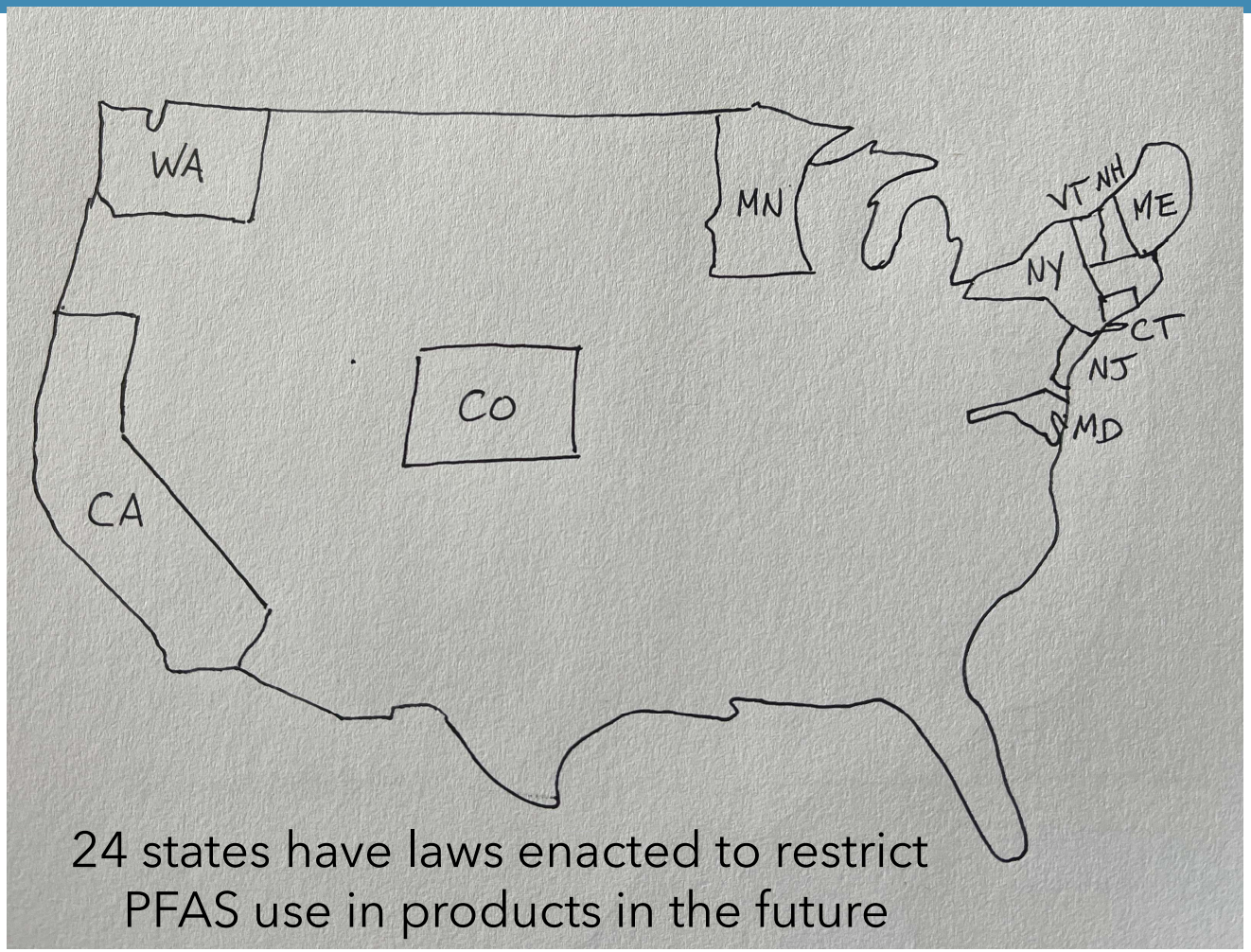
1. Reduce **PFAS use** in products
   - PFAS use restrictions

2. Reduce **PFAS emissions** from point sources
   - NPDES pre-treatment (but not at WRRF)
   - Air emission control

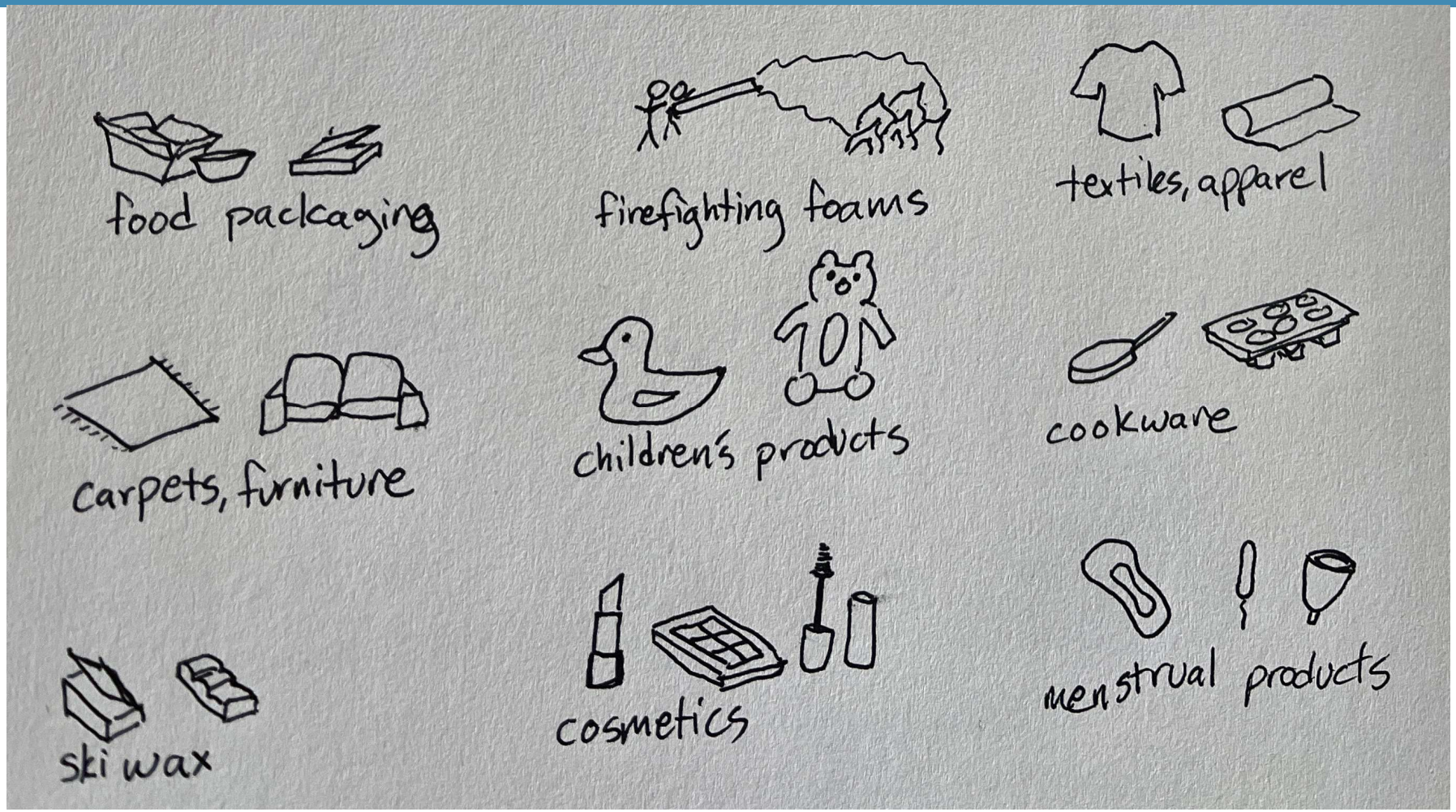
Regulatory Status of PFAS Use Restrictions

Source Reduction

States with Current PFAS Use Restrictions



Product Categories with Alternatives



Needs for PFAS Use Restrictions

Non-specific

- Should target persistent PFAS as a class
- Similar to EU and product bans in specific states

"Essential-use" considerations

- Include derogations for essential uses to limit immediate economic and societal impacts

Evolving

- Ongoing re-evaluation of essential uses
- Investment in chemical engineering to develop non-PFAS alternatives

Minnesota's PFAS Use Restrictions

Minnesota has just become the world leader in legislation to protect its people from PFAS "forever chemicals."

2024 (in place) – ban "intentionally added" PFAS in food packaging

2025 - ban "intentionally added" PFAS in 11 product categories

2026 – require additional reporting on PFAS in products

2032 – ban PFAS use in other categories that are not "currently unavoidable"

Bans "Intentionally Added"

- Most PFAS probably not "intentionally added"
- Example from Keen Footware – 100 components with PFAS before phase-out

Bans "Intentionally Added"

Removing PFAS from supply chains requires companies to first identify PFAS in their supply chains

Incentives:

State Requirements

- Part of MN PFAS Ban
- Requires reporting of PFAS in supply chains by 2026

Federal Requirements

- TSCA Section 8(a)(7)
- By 2025, PFAS since 2011
- Data to be collected and reported include PFAS type, amount used, product types, byproducts, worker exposure, and fate/disposal.

Exempts "Currently Unavoidable"

MPCA to determine what's "currently unavoidable" before 2032 deadline

"Essential Use" from Montreal Protocol

A controlled substance qualifies as essential only if:

1. It is **necessary for the health and safety**—or is critical for the functioning—of society (encompassing cultural and intellectual aspects).
2. There are **no available technically and economically feasible alternatives** or substitutes that are acceptable from the standpoint of environment and health.

Environmental Science Processes & Impacts

CRITICAL REVIEW

View Article Online

Check for updates

Cite this: *Environ. Sci.: Processes Impacts*, 2019, **21**, 1803

The concept of essential use for determining when uses of PFASs can be phased out

Ian T. Cousins, †*[a] Gretta Goldenman,[b] Dorte Herzke,[c] Rainer Lohmann,[d] Mark Miller,[e] Carla A. Ng,[f] Sharyle Patton,[g] Martin Scheringer,[h] Xenia Trier,[i] Lena Vierke,[j] Zhanyun Wang[h] and Jamie C. DeWitt[j]

Other Resources for Use Restrictions

- OECD
  - Portal on PFAS Alternatives – links to resources: https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/alternatives/
- ChemSec
  - PFAS Guide – identify and find PFAS in products: https://pfas.chemsec.org/
  - Marketplace – identify vendors for parts without PFAS: https://marketplace.chemsec.org/
- EU REACH Documents
  - EU's detailed proposal for PFAS use restrictions, including appendices on PFAS uses and economic impacts of proposed restrictions: https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e18663449b

Cost Considerations for PFAS Management Options

How much does it cost?

How much does WHAT cost?

BENEFIT:

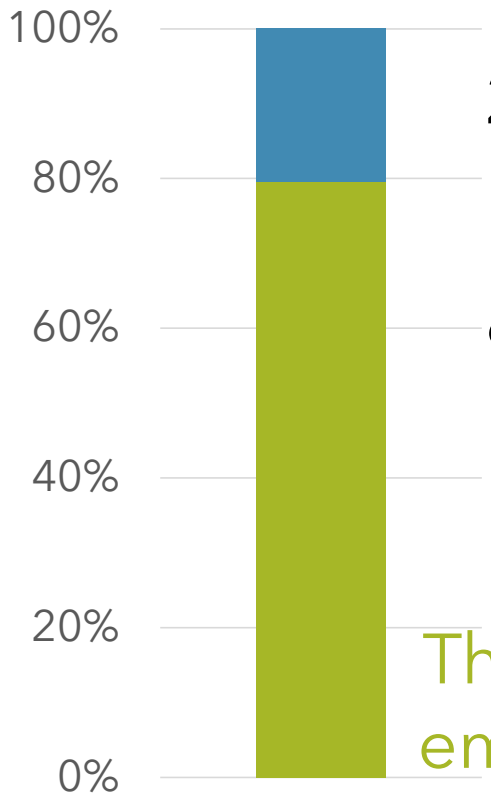
targeting improvements to

a.) current and future human health

b.) mass of PFAS in the environment

a.) Human Health Risk

Estimated PFAS Exposure Routes[1]



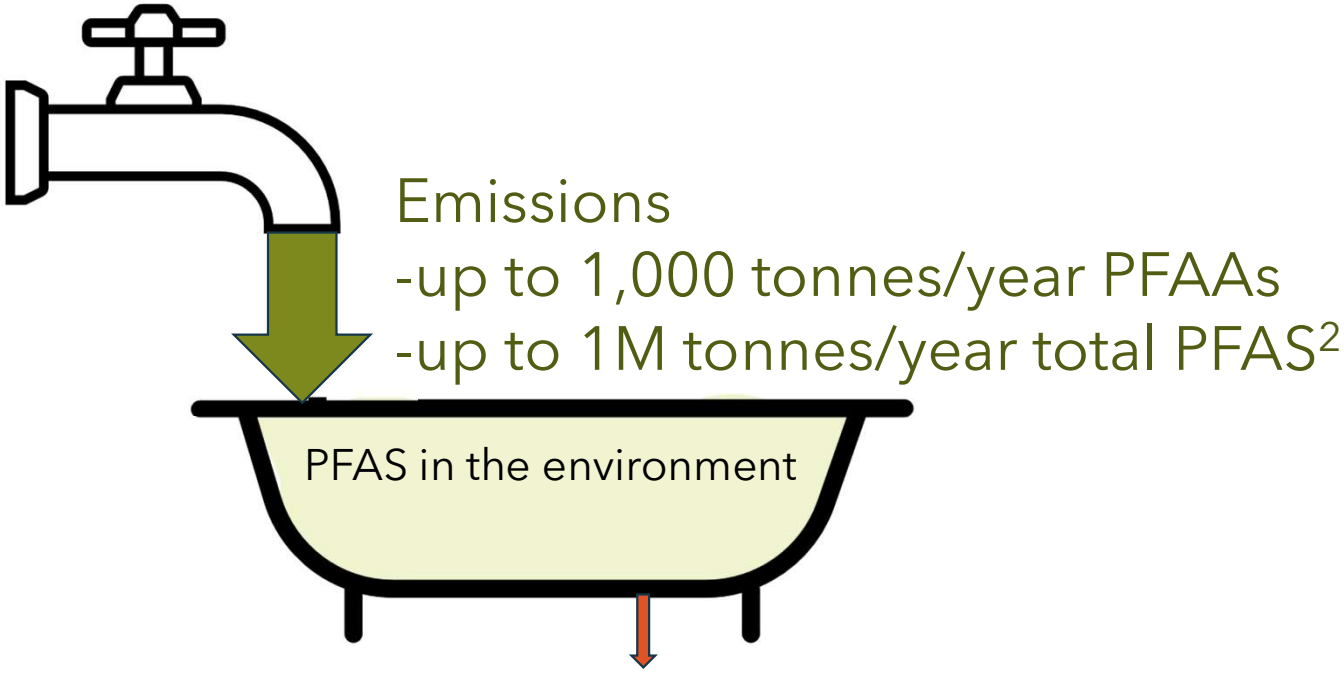
20% from drinking water

80% from other sources
- food ingestion
- dust inhalation

These exposures more related to PFAS use and emissions than to environmental contamination

[1]EPA, 2022. Interim Drinking Water Health Advisory for PFOS and PFOA

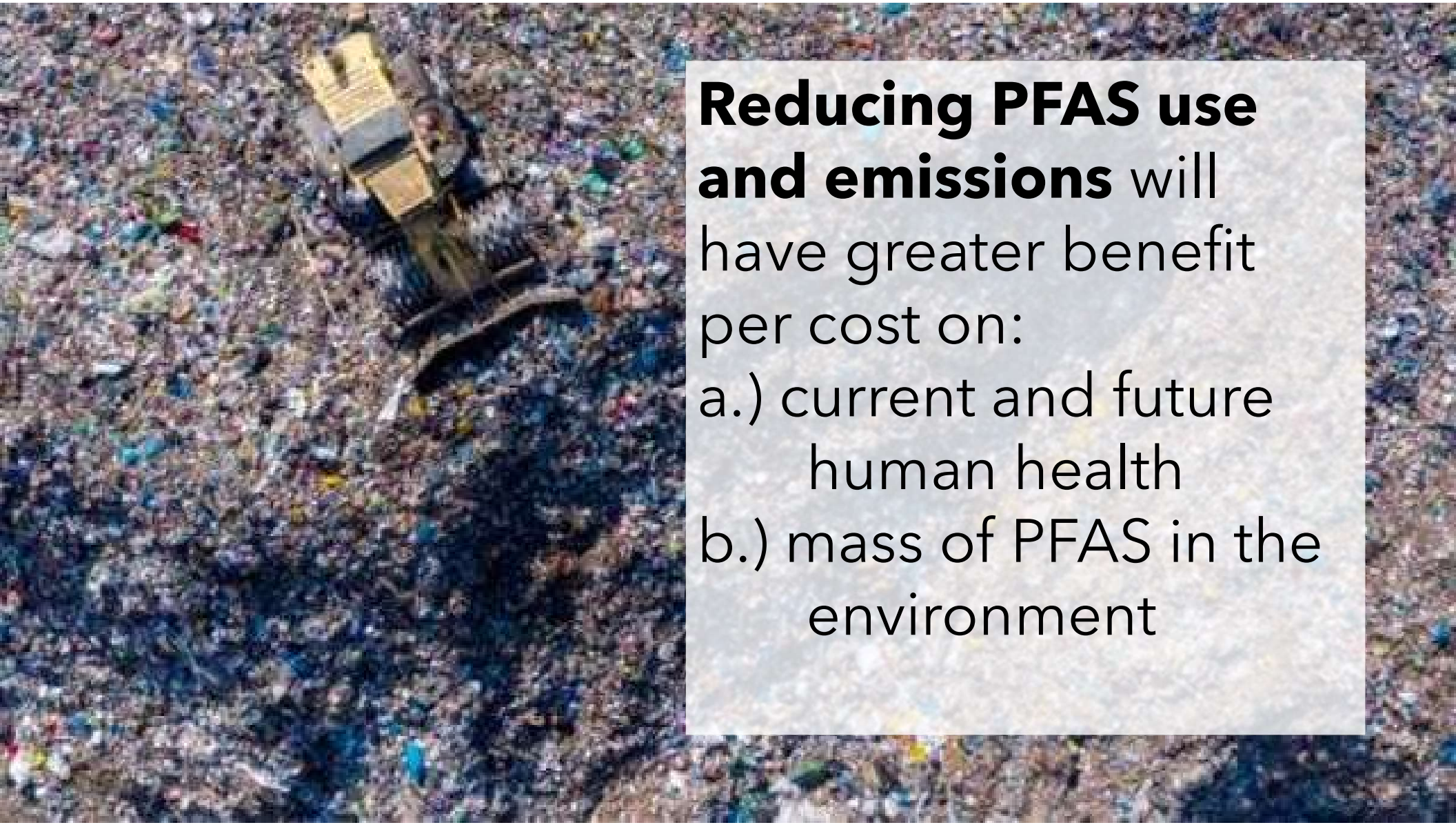
b.) Mass of PFAS in the Environment



We cannot afford to increase remediation rates enough to match current PFAS emission rates[3]

[2]Evich et al., 2002. *Science*. DOI: 10.1126/science.abg9065
[3]Ling, 2024. *Sci. Tot. Environ.* DOI: 10.1016/j.scitotenv.2024.170647


We need
remediation to solve
environmental PFAS,
but we *cannot* rely on
remediation alone



Reducing PFAS use and emissions will have greater benefit per cost on:

a.) current and future human health

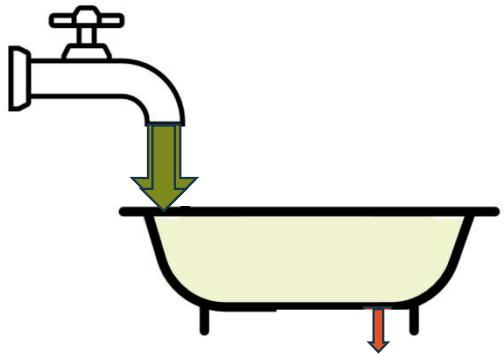
b.) mass of PFAS in the environment

Reduce PFAS Use and Emissions:
NET COSTS: ECHA is evaluating, but need more work here

SOCIETAL COSTS of health/ environmental impacts

Example mapping of specific project

SOCIETAL COSTS for remediation



No Action
COSTS: health risks, environmental harm (estimated near $50B annually each for USA and EU)

Remediation after release to environment
COSTS: remediation and destruction $1M-$65M/kg PFAAs

Ali Ling
Assistant Professor
Civil Engineering

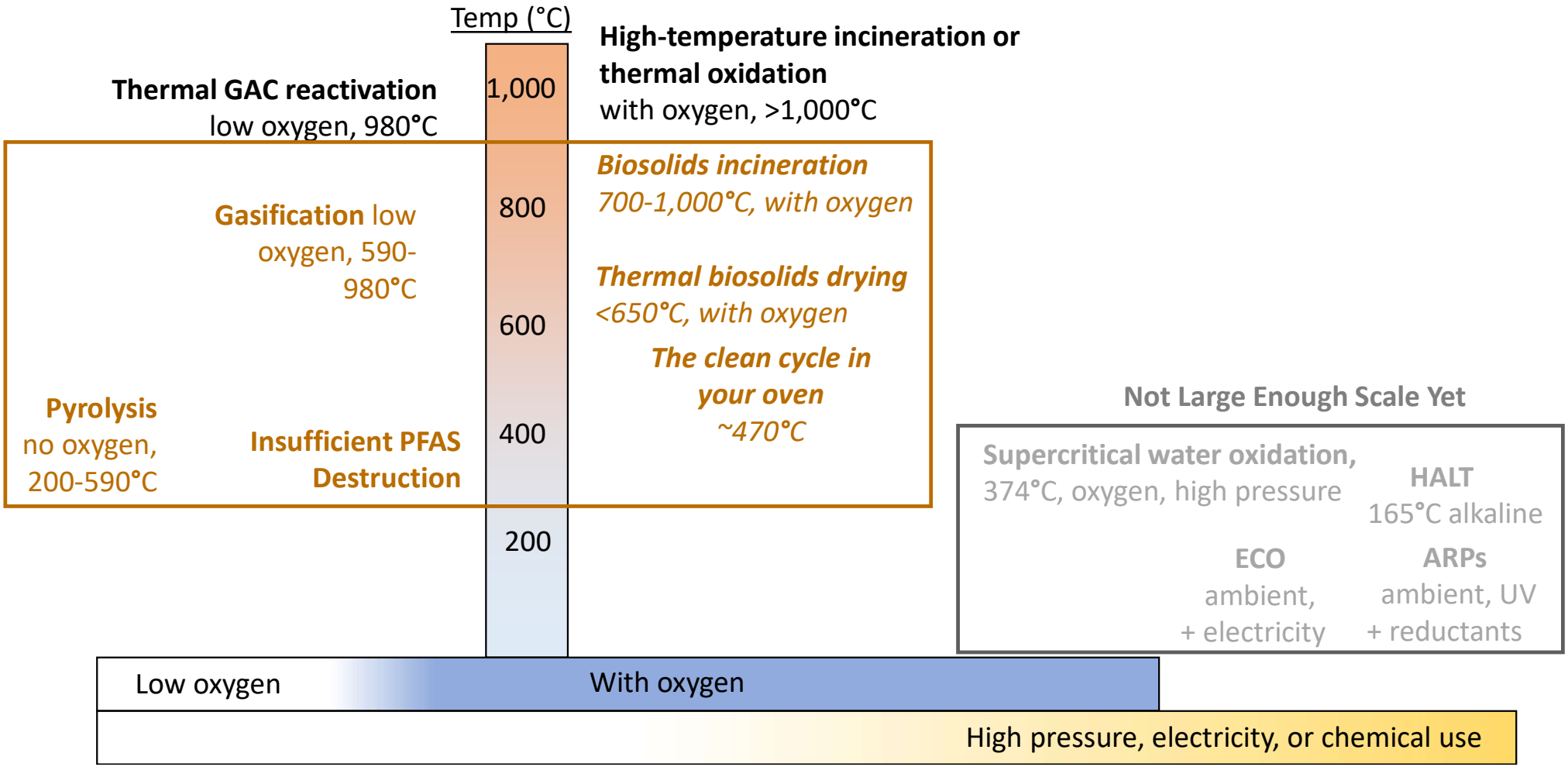
aling@stthomas.edu

UNIVERSITY OF St.Thomas

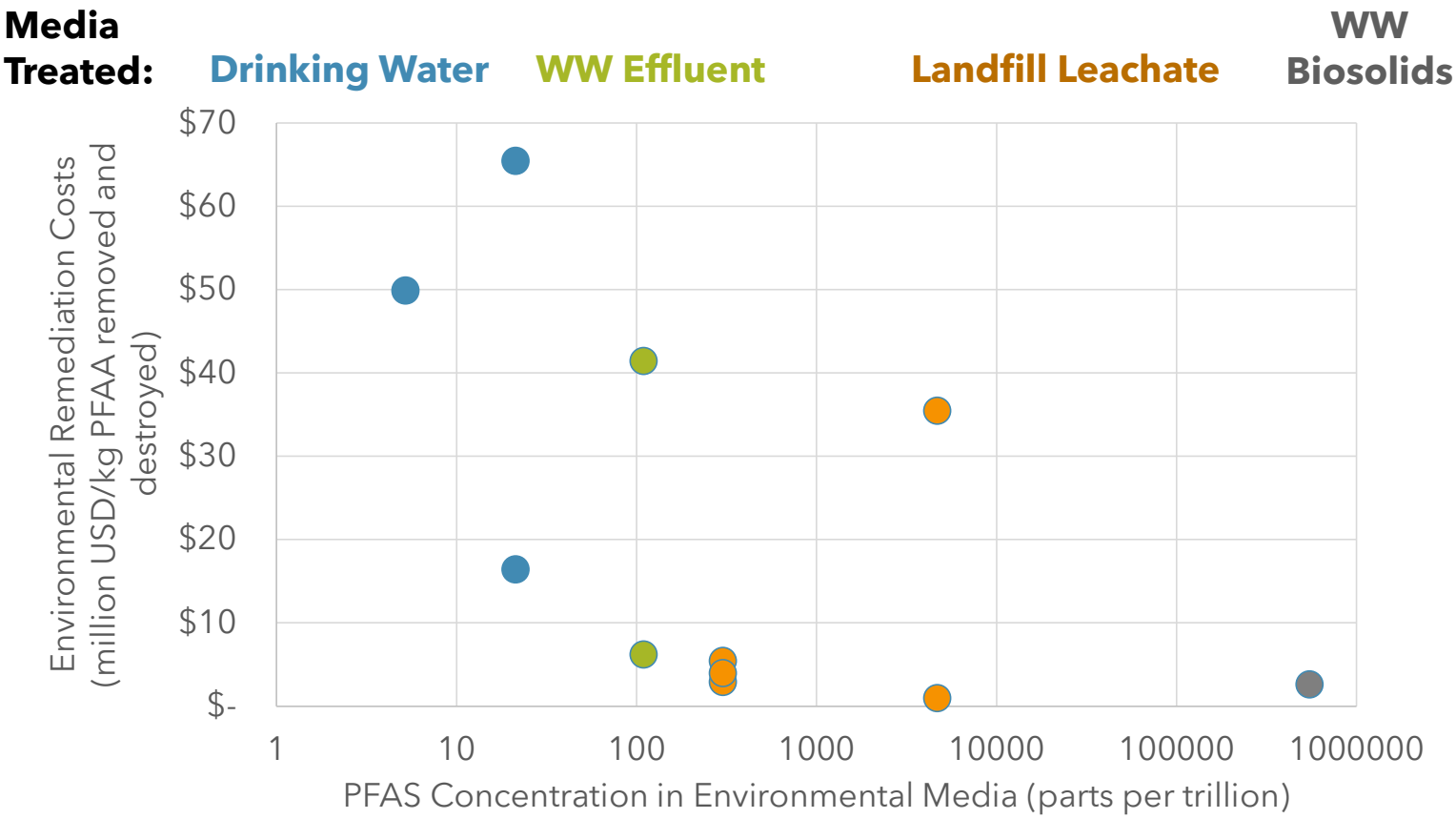
Thank you

Treatment Technology Status

PFAS Destruction Technologies



Costs per Mass



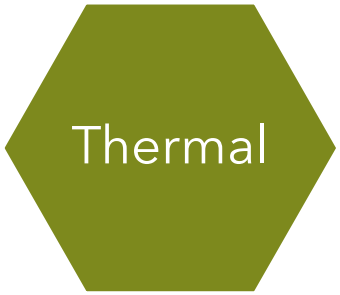
Higher cost per mass PFAS for lower concentrations (because need to treat larger mass of media)

Needs for Emerging Technologies

Separation Technologies

- Need more technologies with demonstrated:
  - PFAS separation/ destruction efficacy
  - Full-scale operational data and guidance
  - **Full-scale cost estimates**

Destruction Technologies



Needs for Emerging Technologies

Separation Technologies

Destruction Technologies