



PFAS in Wastewater

Scott Kyser | Minnesota Pollution Control Agency

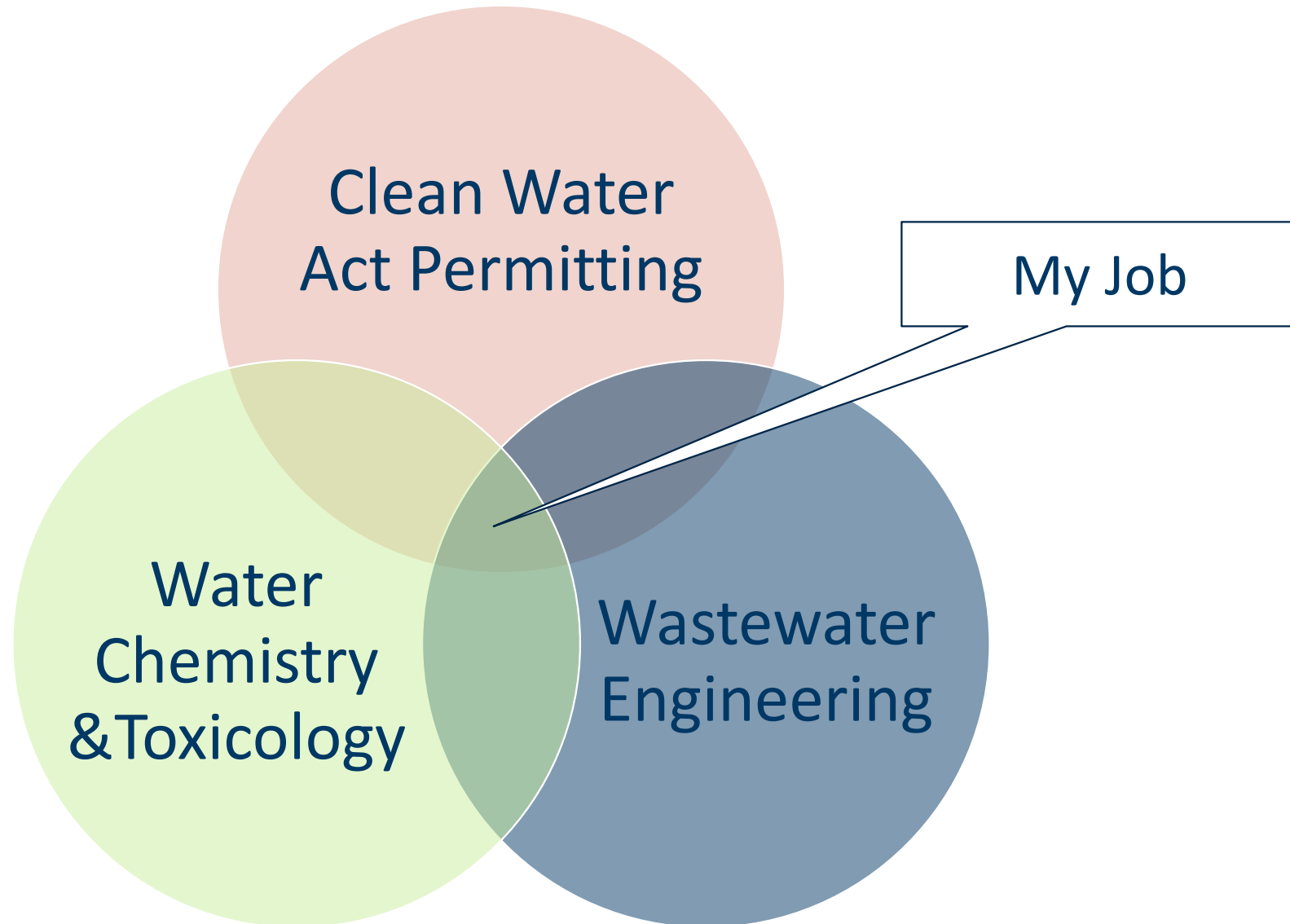


m1 AGENCY
LOGO HERE

Scott James Kyser

“Your favorite bureaucrats’, favorite bureaucrat”

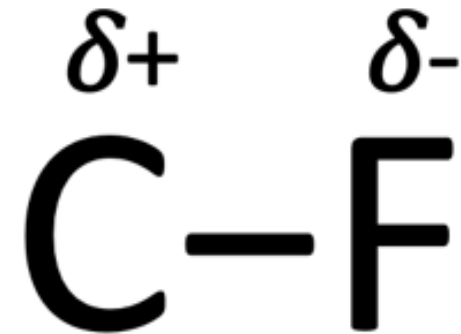
What do I do at the MPCA?



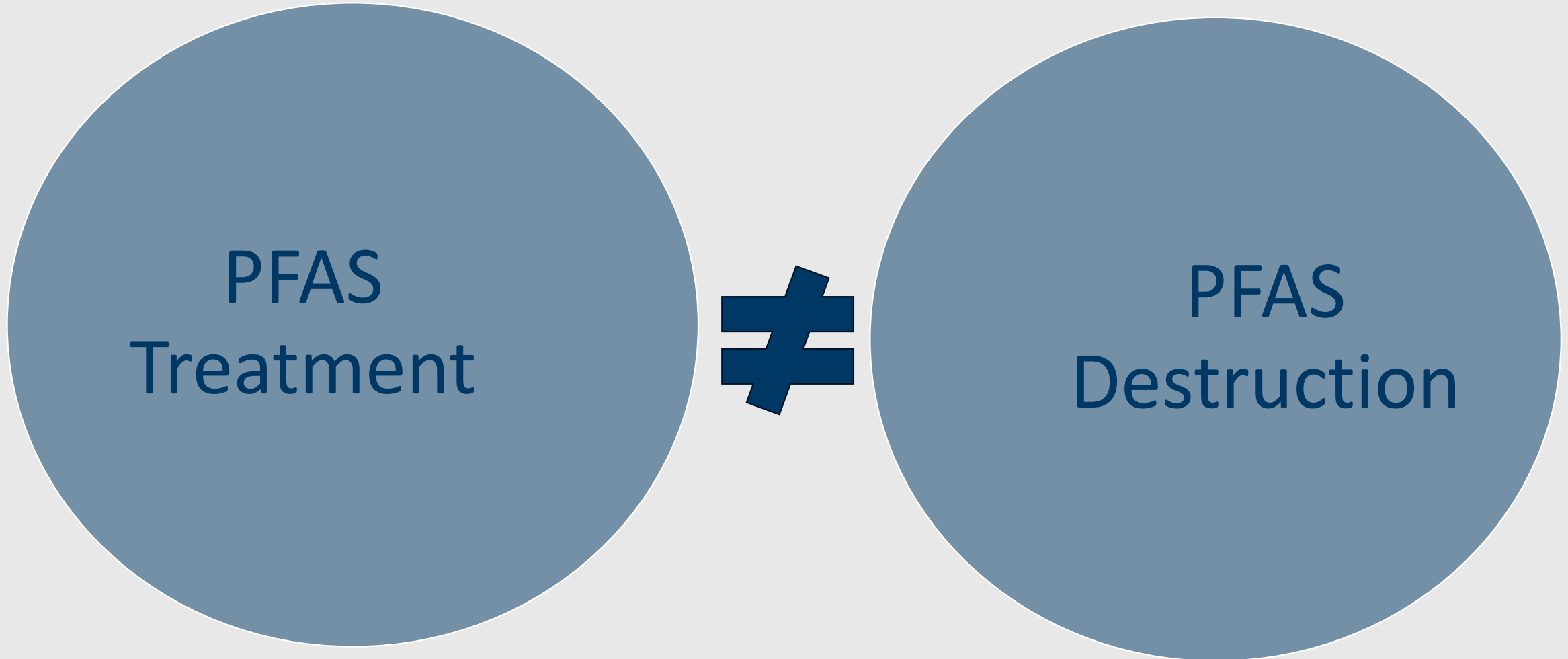
- What is PFAS wastewater treatment?
- What are PFAS wastewater treatment technologies?
- What are the costs of PFAS treatment?
- What about PFAS destruction?
- Is PFAS treatment and destruction “good”?

Why are PFAS so difficult to treat and destroy?

- PFAS are bad for engineers
 - Slippery
 - Functionally indestructible
 - Cannot biodegrade
 - Can biotransform
 - Partition both weirdly and poorly
 - Have low treatment targets
 - Are always present



What technologies can treat and destroy PFAS?



What does “PFAS treatment” even mean?

Removing >99% of PFOS from water?

Removing all PFAS to below reporting limits every single month forever?

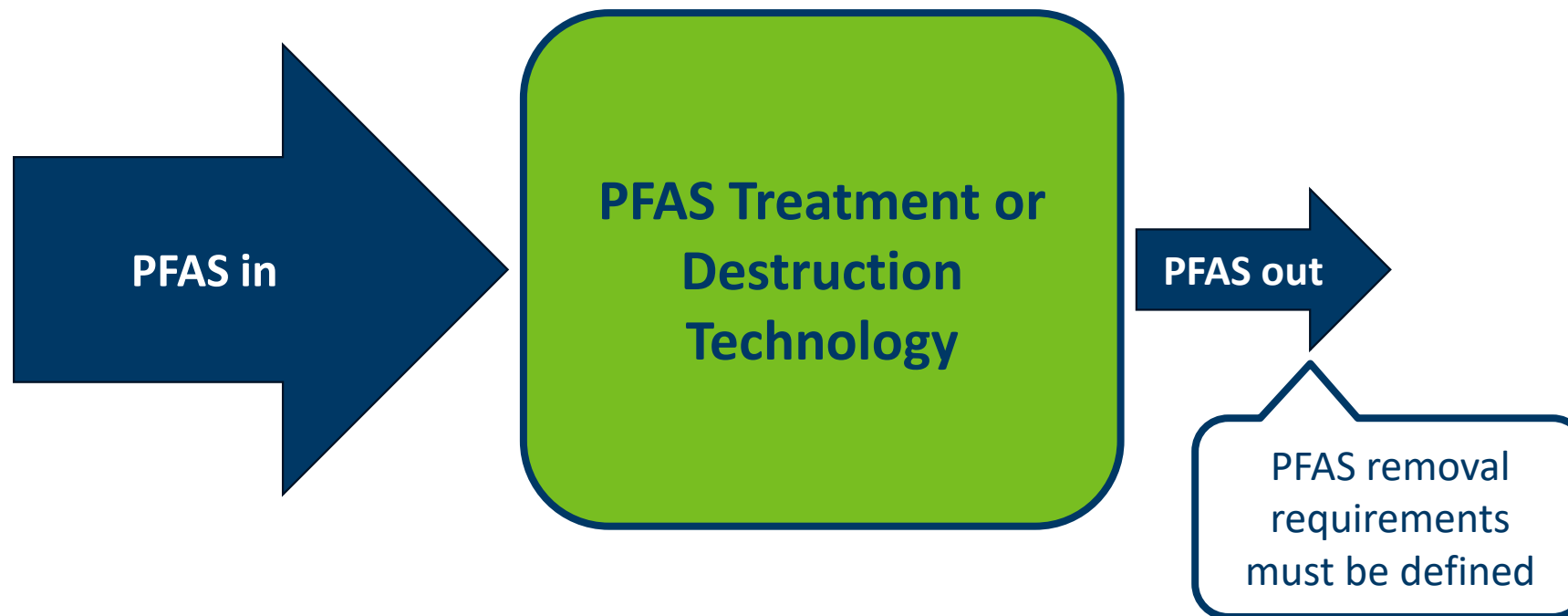
Whatever feels right?

Removing PFAS to levels required by applicable regulations in a currently effective control document?

Removing and destroying all PFAS?

Using the best available technology?

Engineers Need a Numeric Definition of Treatment

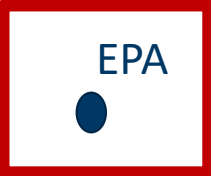
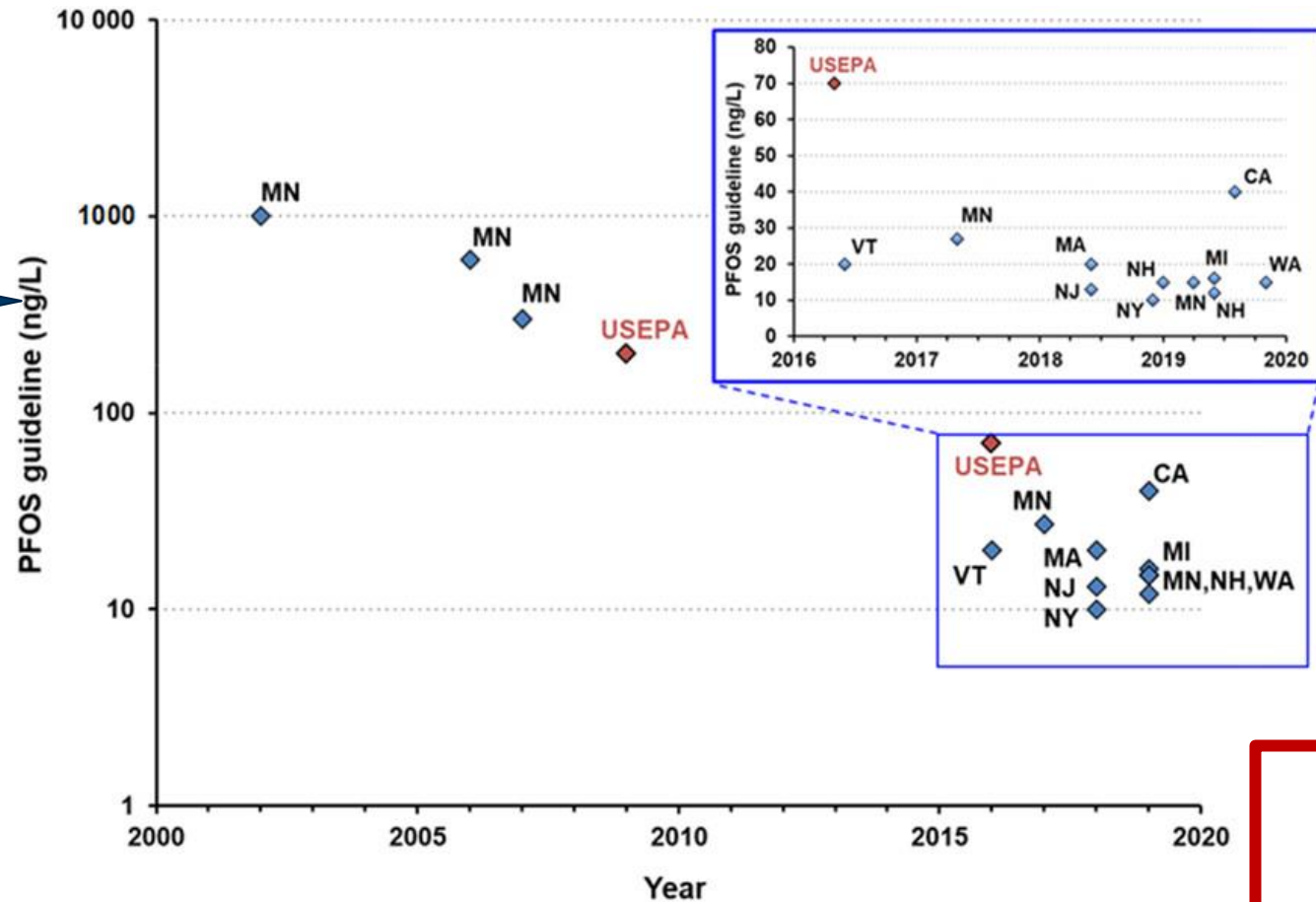


What are PFAS treatment targets?

f(Standards) = Limits in Permits

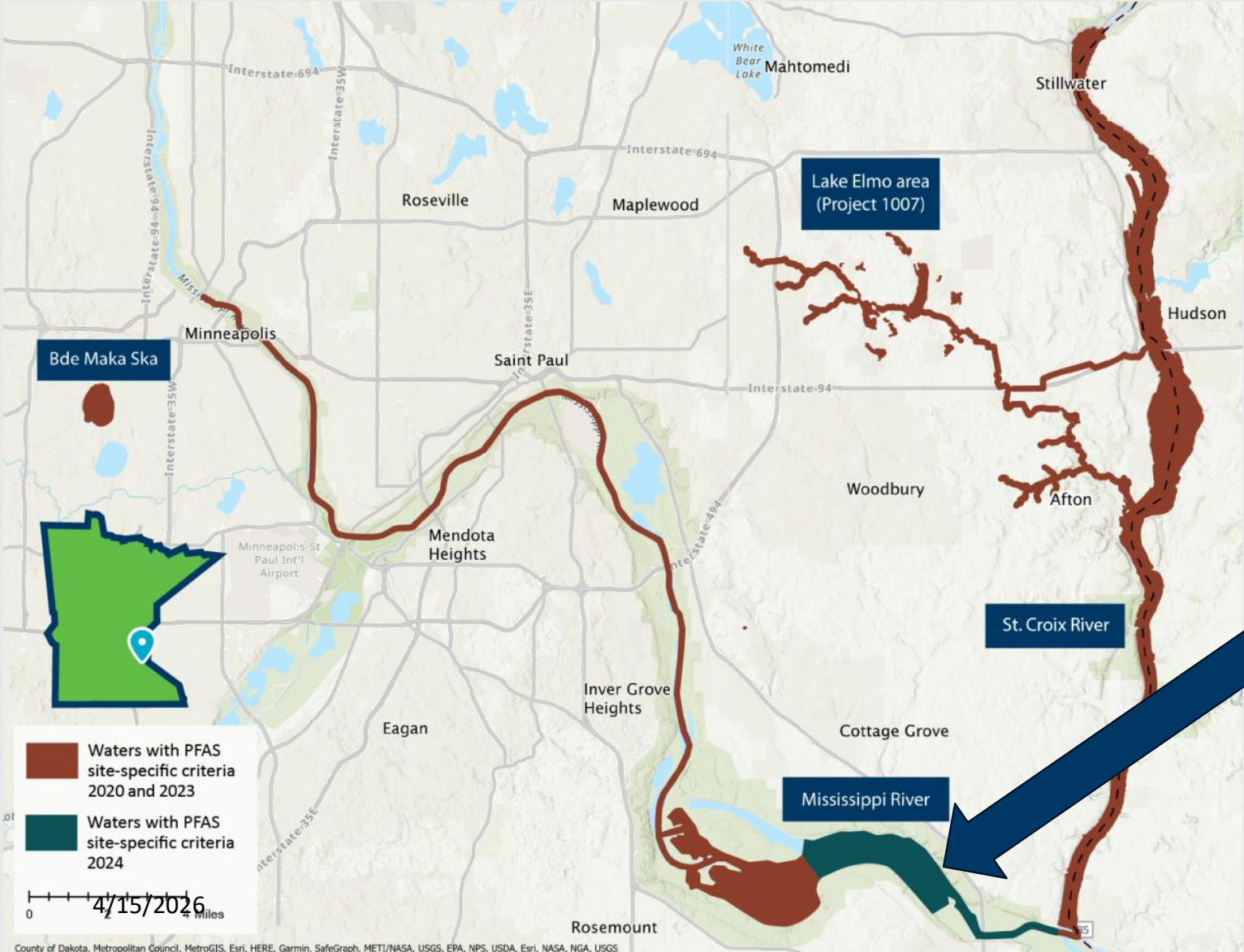
Look to Human Health Science for PFAS Treatment Targets

Safe level of PFOS for humans have gone from 1000 ng/L to ZERO with 20 years of research



Post, Gloria B. "Recent US state and federal drinking water guidelines for per-and polyfluoroalkyl substances." *Environmental Toxicology and Chemistry* 40.3 (2021): 550-563.

Minnesota's Site-Specific PFAS Criteria



Compound	Criteria
PFOS	0.027 ng/L
PFOA	0.039 ng/L
PFHxS	0.0087 ng/L
PFBS	6,700 ng/L
PFBA	55,000 ng/L



Comparing and Contrasting PFOS Criteria

Municipal WWTPs rarely discharge PFOS above these numbers***

Organization	Year	Designated Use	Draft or Final	Value (PPT)
EPA	2024	Aquatic Life	Final – National	250
EPA	2024	Human Fish Consumption	Draft - National	0.06
MPCA	2025	Human Fish Consumption	Final - Site-Specific	0.027
Wisconsin	2022	Human Fish Consumption	Final - Statewide	8

Municipal WWTPs almost always discharge PFOS above these numbers

What are the wastewater PFAS limits in MN?

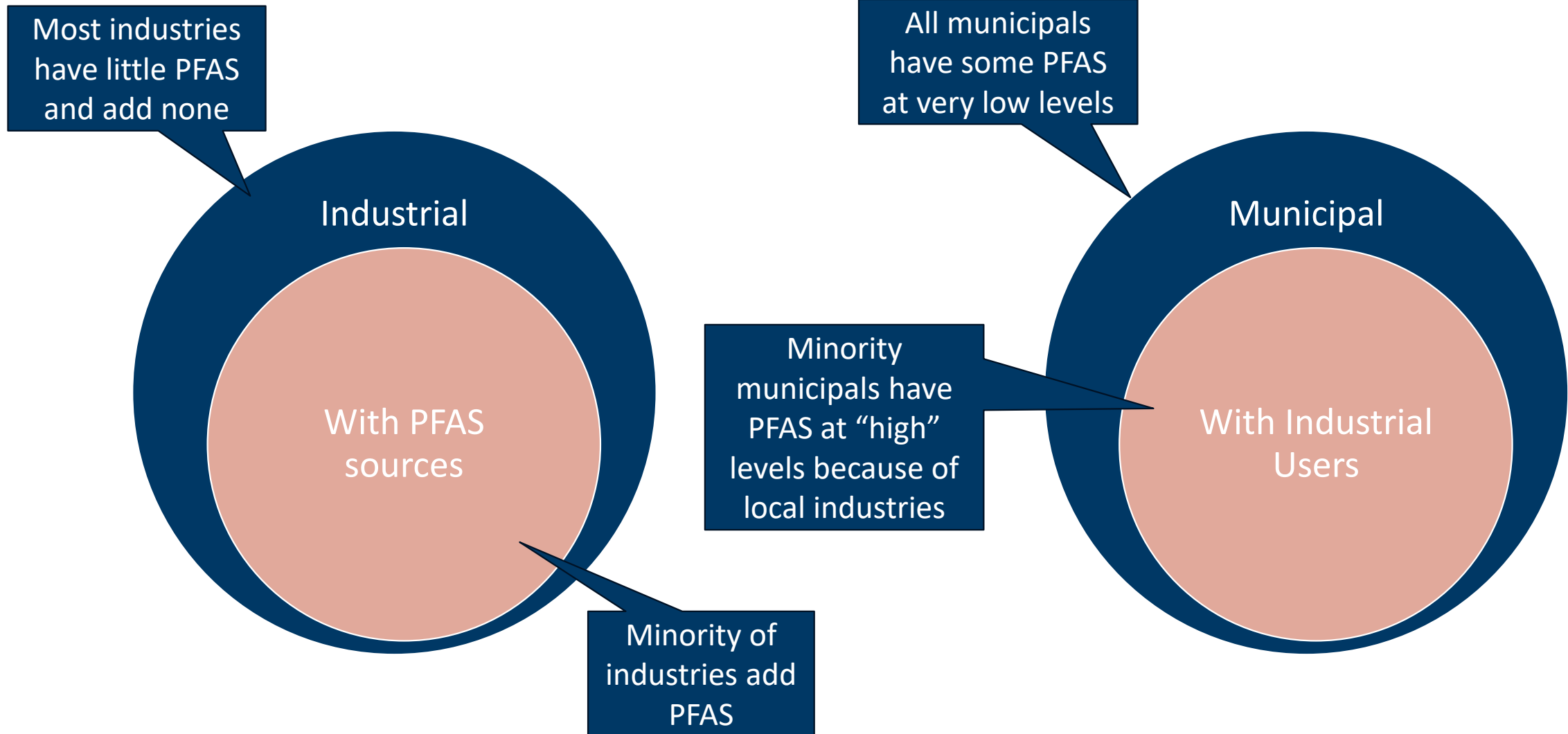


Municipal wastewater and PFAS

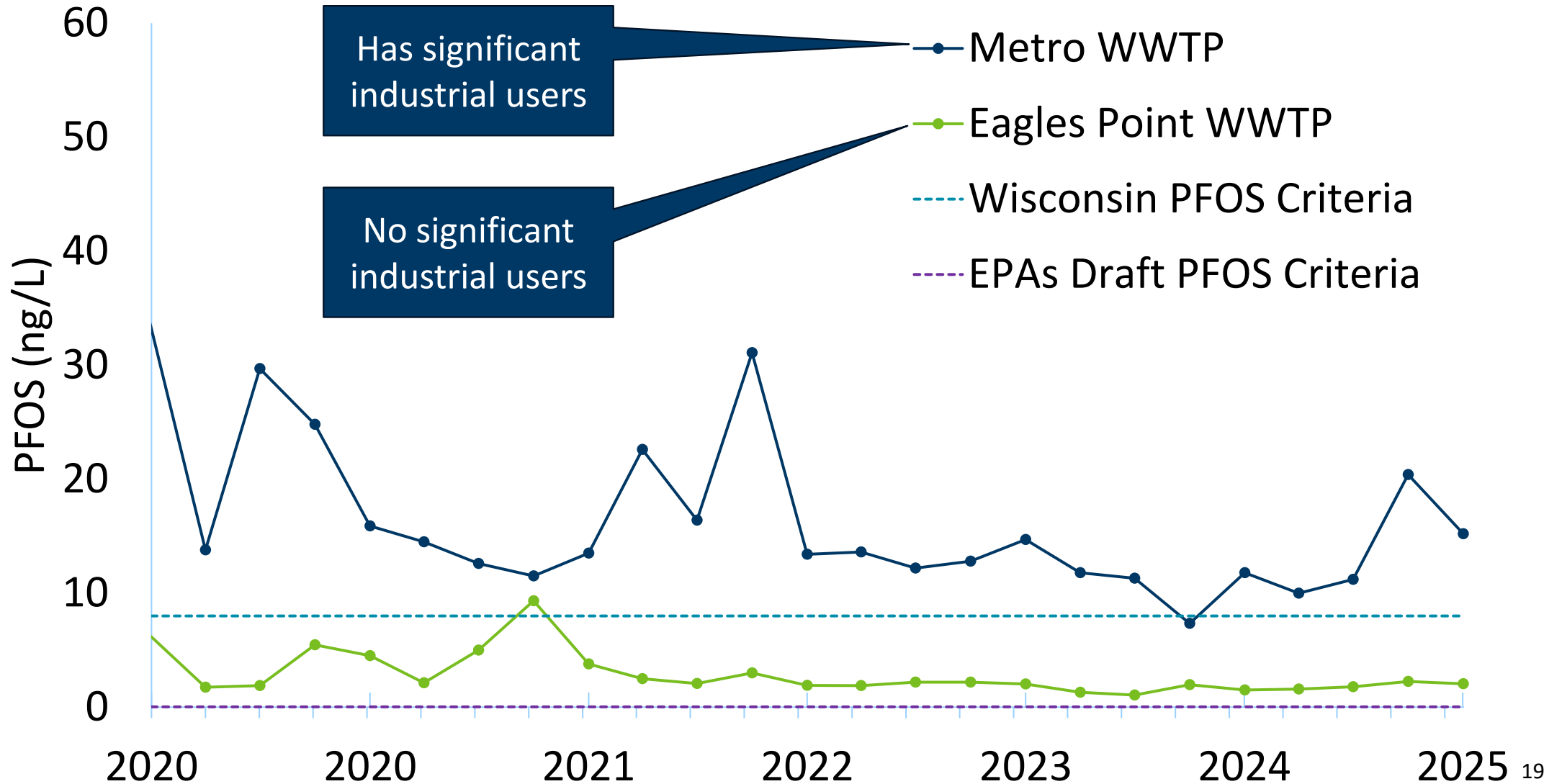
Municipal wastewater treatment plants do not produce PFAS, but they do receive wastewater that contains PFAS.



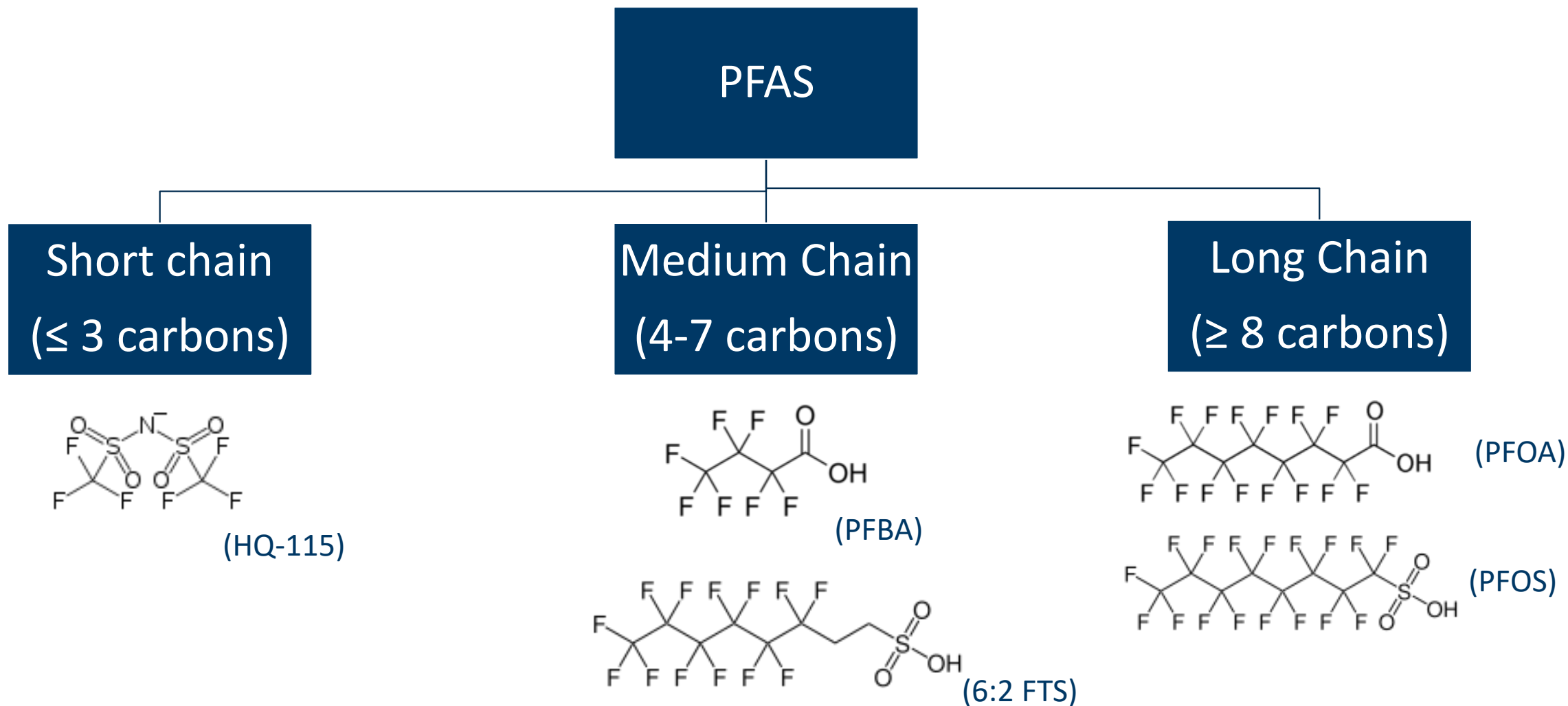
How much PFAS is in wastewater?



How much PFAS is in municipal wastewater?



Wastewater has many kinds of PFAS



Wastewater and PFAS

Basically none. Only some short chain PFAS have gas phase.

Gas

- Short and Medium chain PFAS predominate
- Variability is commonly high
- Concentrations in PPT

Untreated Water



Treated Water

PFAS biotransforms during treatment and can increase in measurable levels by up to 19X

Biosolids

- Biosolids accumulates long chain PFAS
- All biosolids have some PFAS

How much of a problem is PFAS in wastewater?

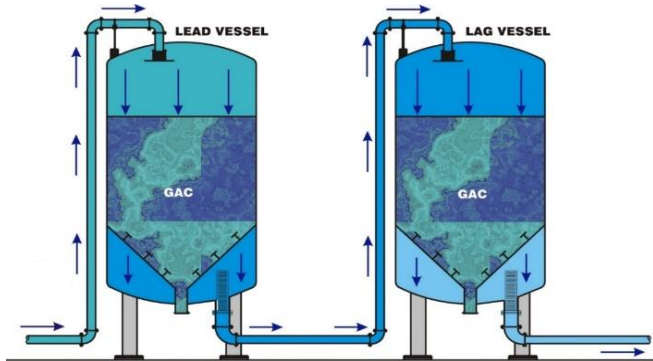
75% of landfills
send leachate
to WWRFs



20% of MN
biosolids is
landfilled

PFAS Treatment Technologies

Liquid to solid separation (media)



Granular activated carbon (GAC) media



Anion exchange (AIX) resin

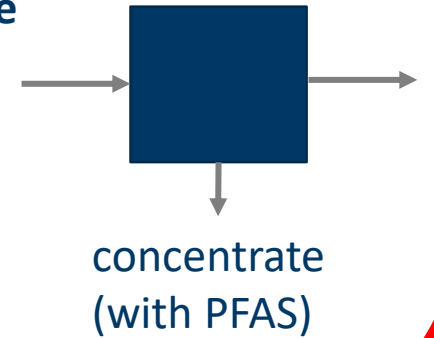


Modified clay media

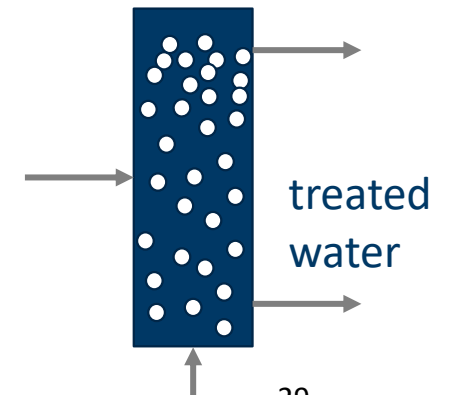


Liquid to liquid separation

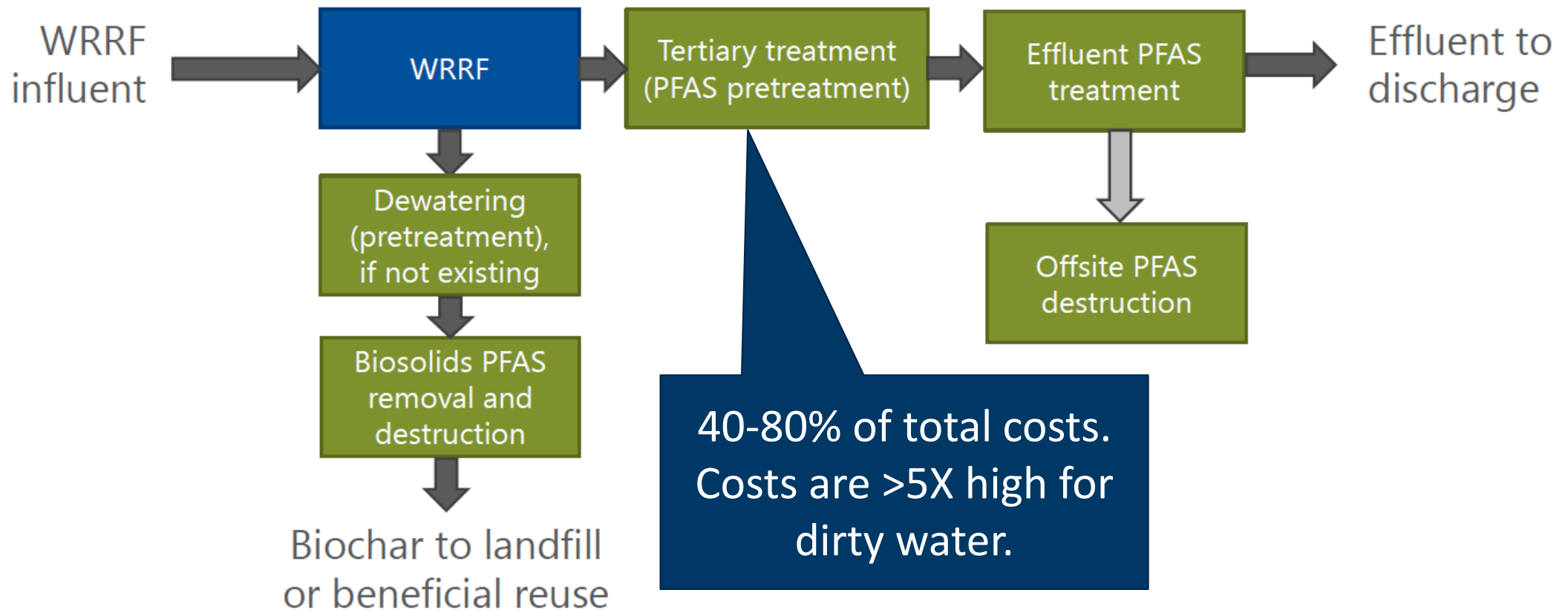
NF/RO membrane separation



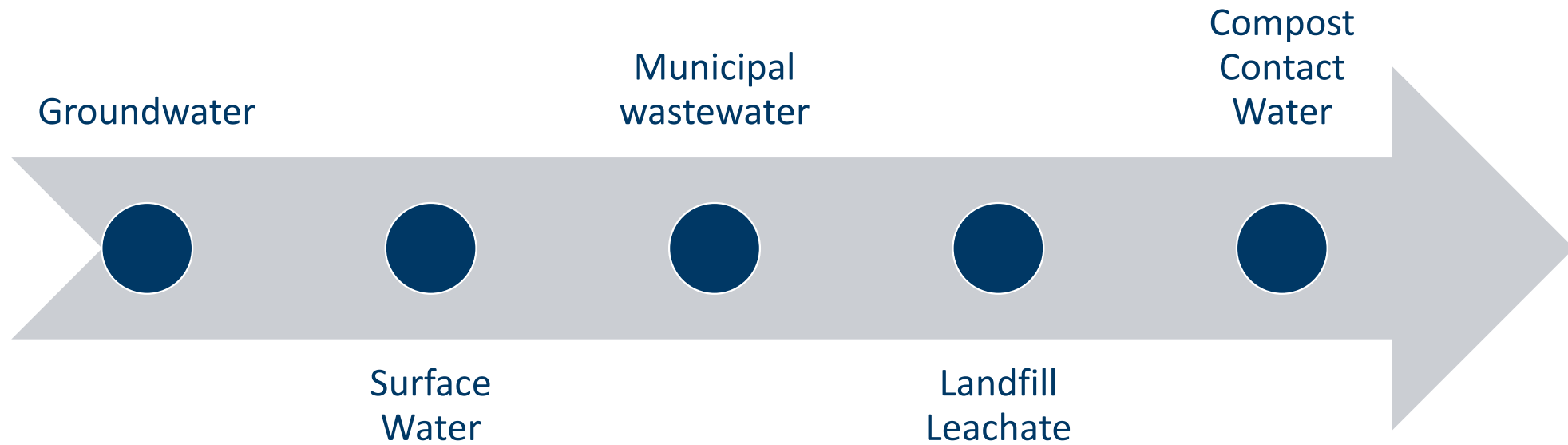
Foam fractionation



Municipal Wastewater flow diagram to treat PFAS



PFAS Removal Technologies – Pretreatment



Are any of these technologies being used at the full scale?

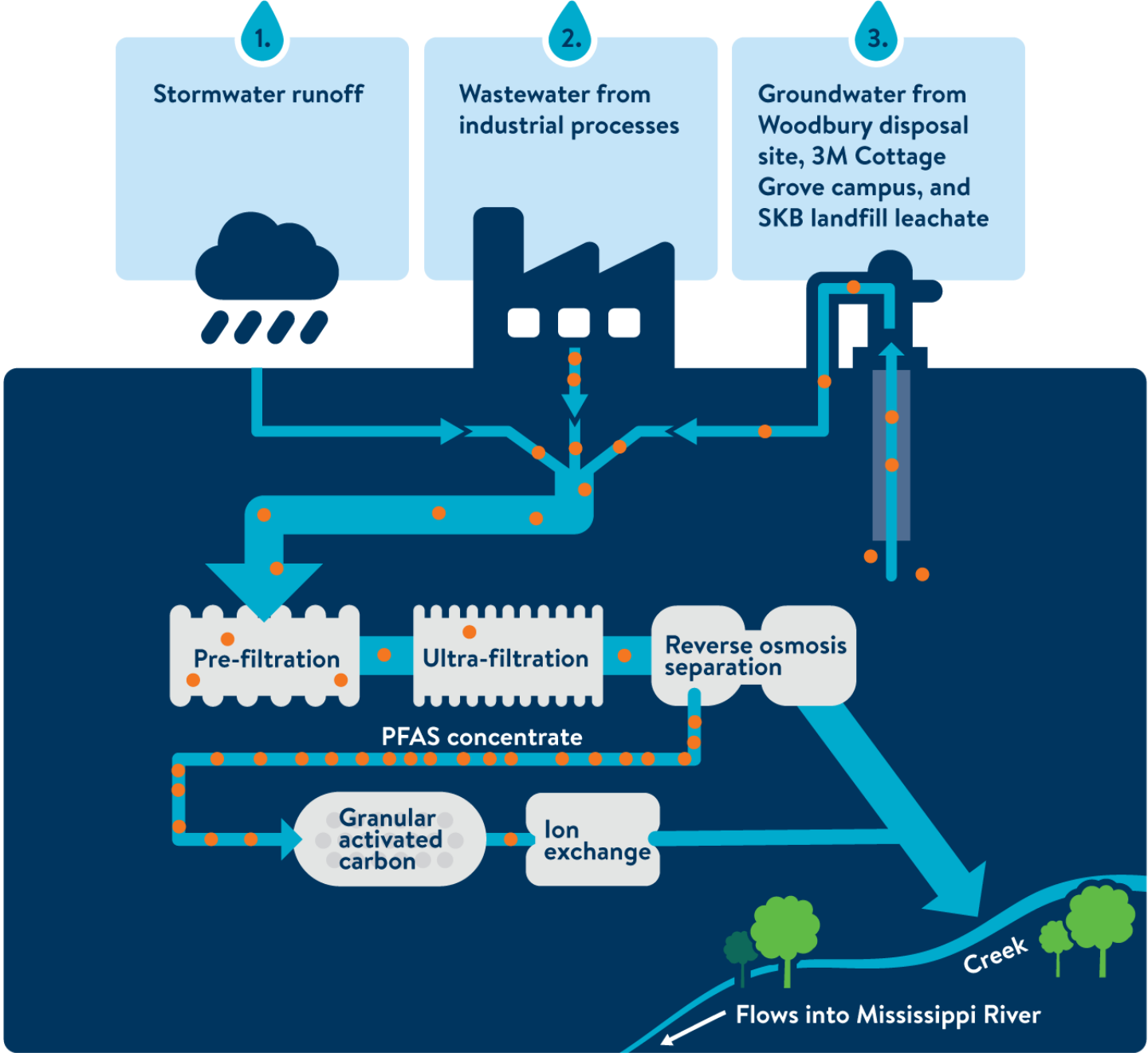


3M Cottage Grove

NPDES Permit re-issued in 2025 with lowest PFAS limits in the country



Water sources





m MINNESOTA POLLUTION
CONTROL AGENCY



MINNESOTA POLLUTION CONTROL AGENCY





MINNESOTA POLLUTION CONTROL AGENCY

ARTISAN INDUSTRIES INC

3M Cottage Grove PFAS Treatment Facts

- 3M chose to initiate design and construction prior to receiving PFAS limits
- \$300 million cost
- Several PhD level engineers involved in design
- New multi-million dollar PFAS analytical lab
- 20+ new employees needed to operate
- Currently removing ultra short PFAS to non-detect
- No PFAS destruction on-site

Statewide Municipal Wastewater PFAS Costs

Table ES-2 Summary of estimated 20-year costs for managing PFAS in targeted waste streams in Minnesota^[1]

Waste Stream	Estimated Number of Facilities	Range of Flows	Estimated 20-year costs for Minnesota (Millions of USD) ^[2]
Municipal WRRF effluent ^[3]	283	0.1–300 MGD	\$12,000–\$25,000
Municipal WRRF biosolids ^[4]	1 regional facility, plus 50 on-site facilities	50 dry tons of wastewater solids per day (dtpd) regional facility, on-site for 1–10 dtpd	\$1,600–\$3,300
Mixed MSW landfill leachate ^[5]	24	1–100 gpm	\$77–\$160
Compost contact water ^[6]	9	1–100 gpm	\$28–\$60

Why are PFAS so expensive to treat and destroy?

You can buy bulk PFAS for \$50-1000 per pound

The cheapest PFAS treatment solution **BY FAR** is to not add PFAS

Municipal WRRF facility size	0.1 MGD	1 MGD	10 MGD
	\$18.1M	\$6.8M	\$2.7M
Municipal WRRF biosolids production		1 DPTD	10 DPTD
		\$2.7M	\$1.0M
Municipal landfill facility size	1 GPM	10 GPM	100 GPM
	\$12M	\$1.4M	\$0.40M
Composting facility size	1 GPM	10 GPM	100 GPM
	\$39M	\$4.5M	\$1.3M

Digression on PFAS bans

Minnesota PFAS Rules

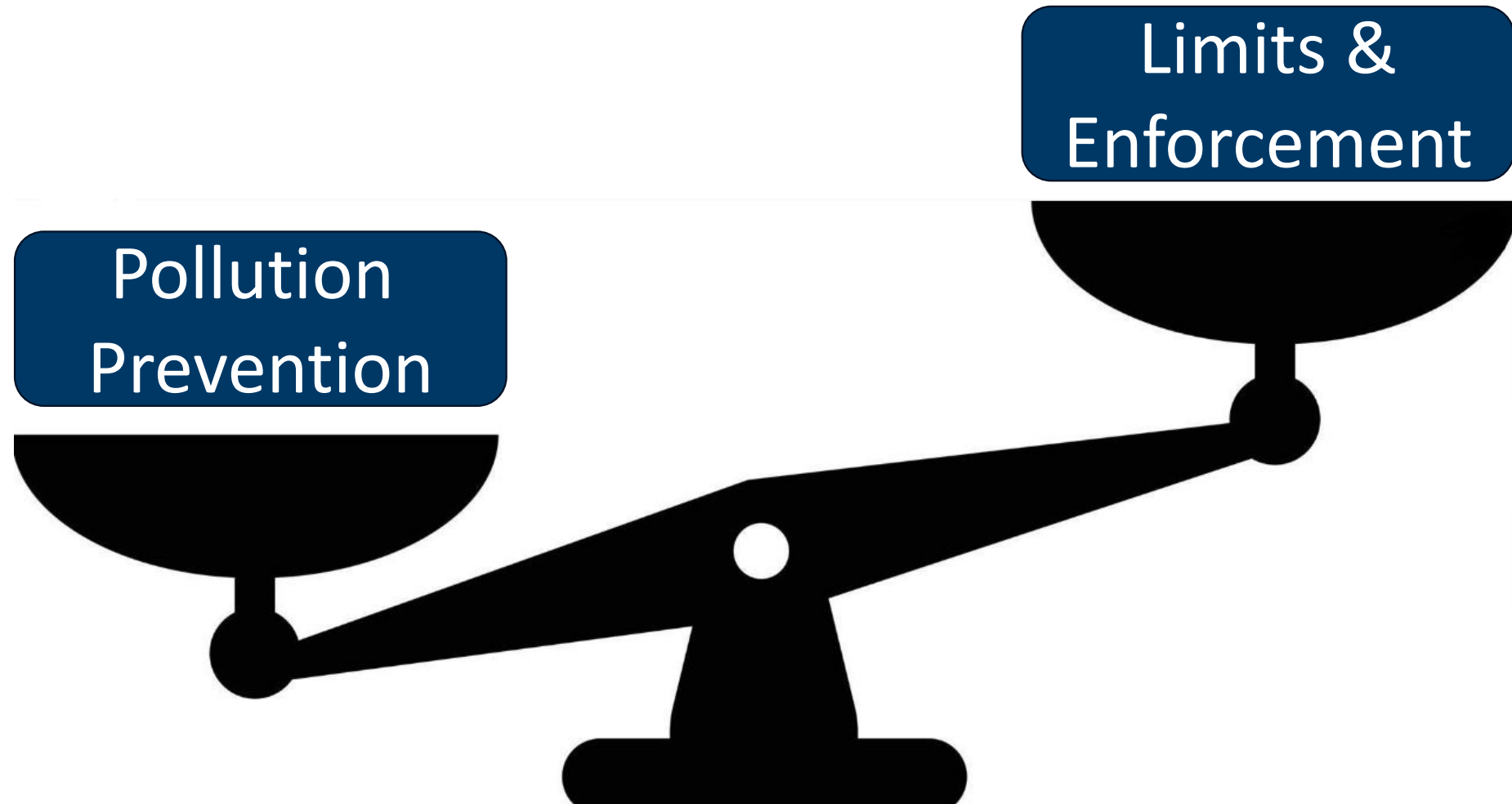
2025 bans • 2026 reporting • 2032 phase-out

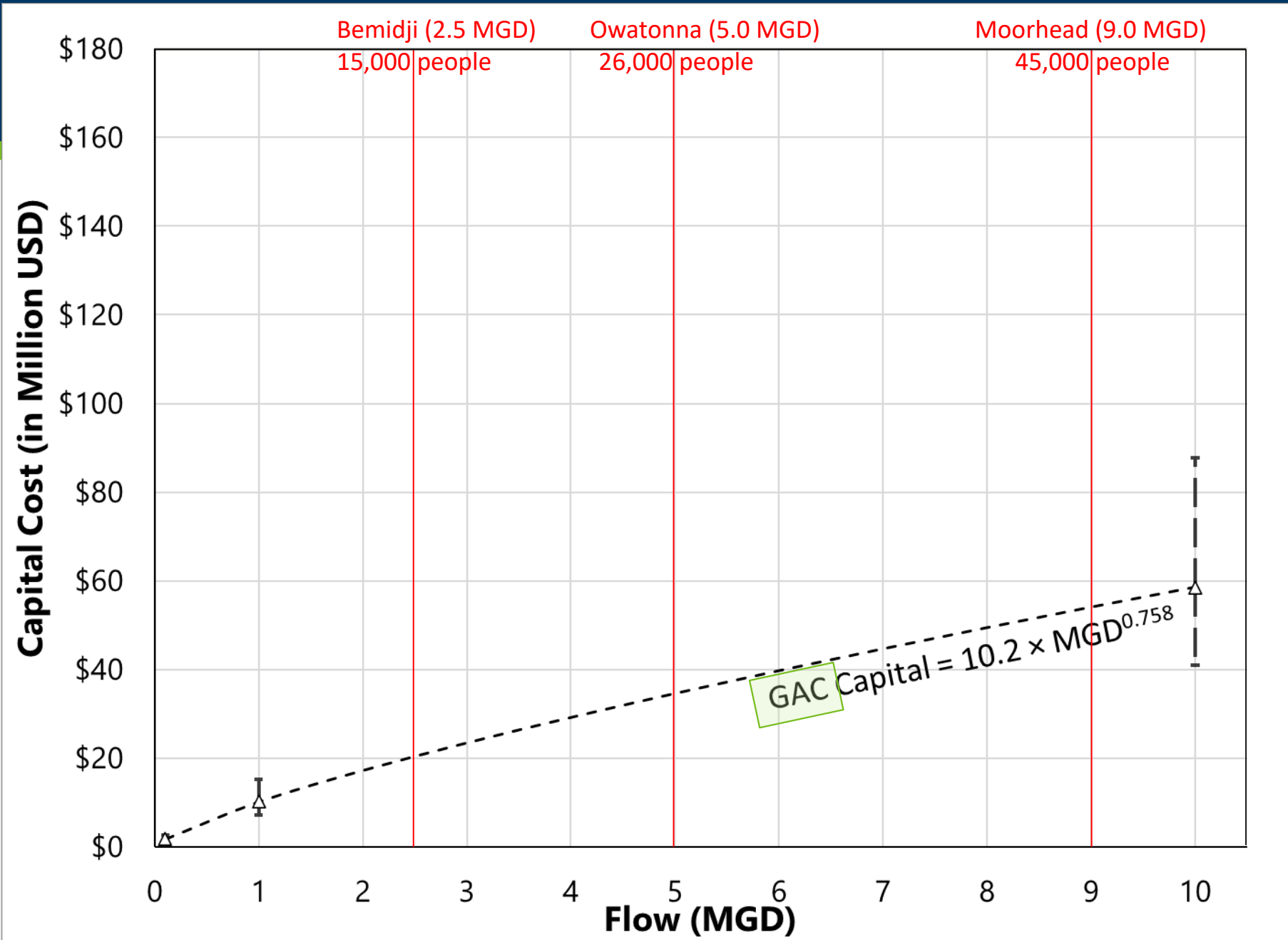
2025 update: internal/electronic components exempt from category bans

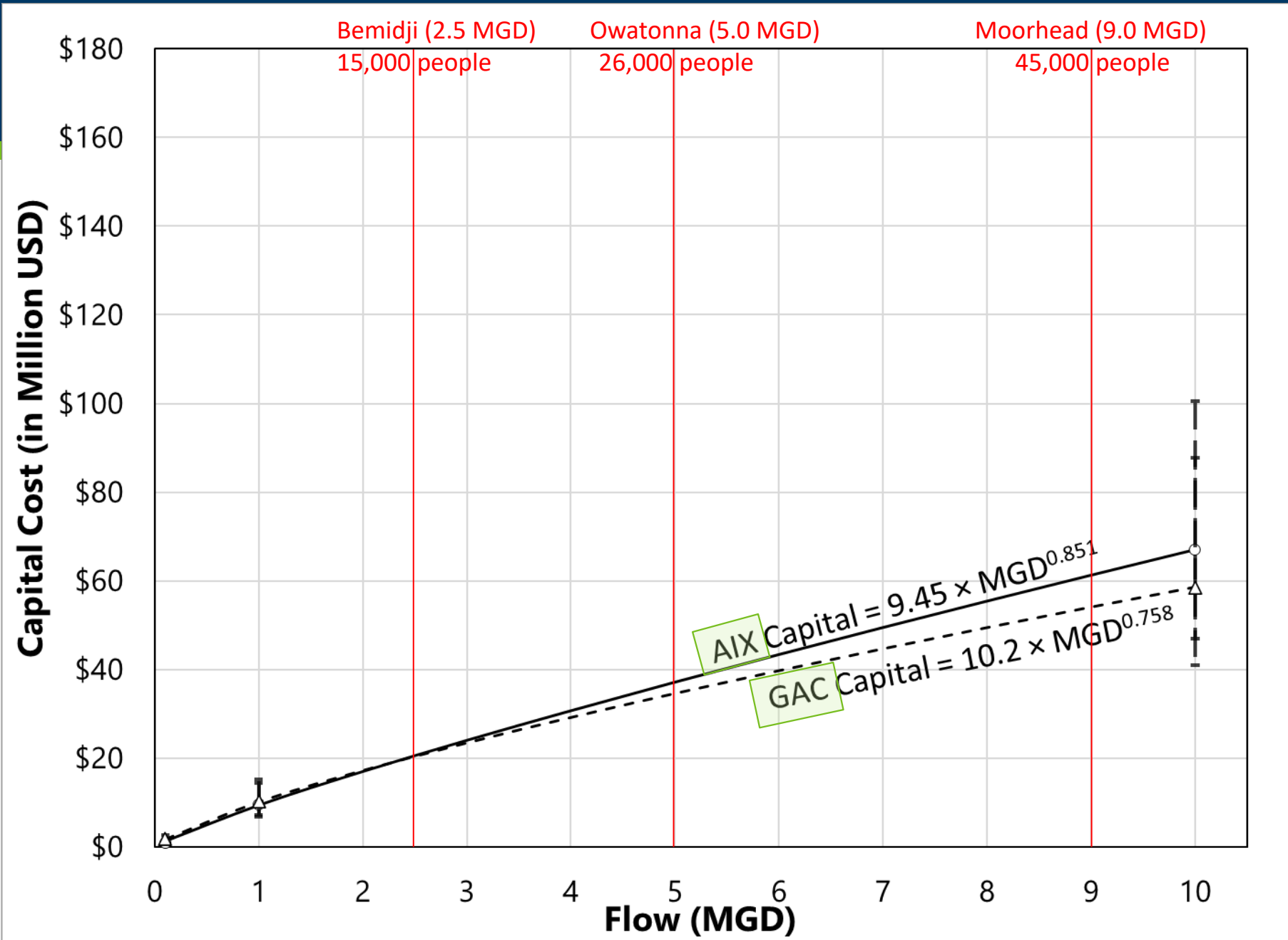


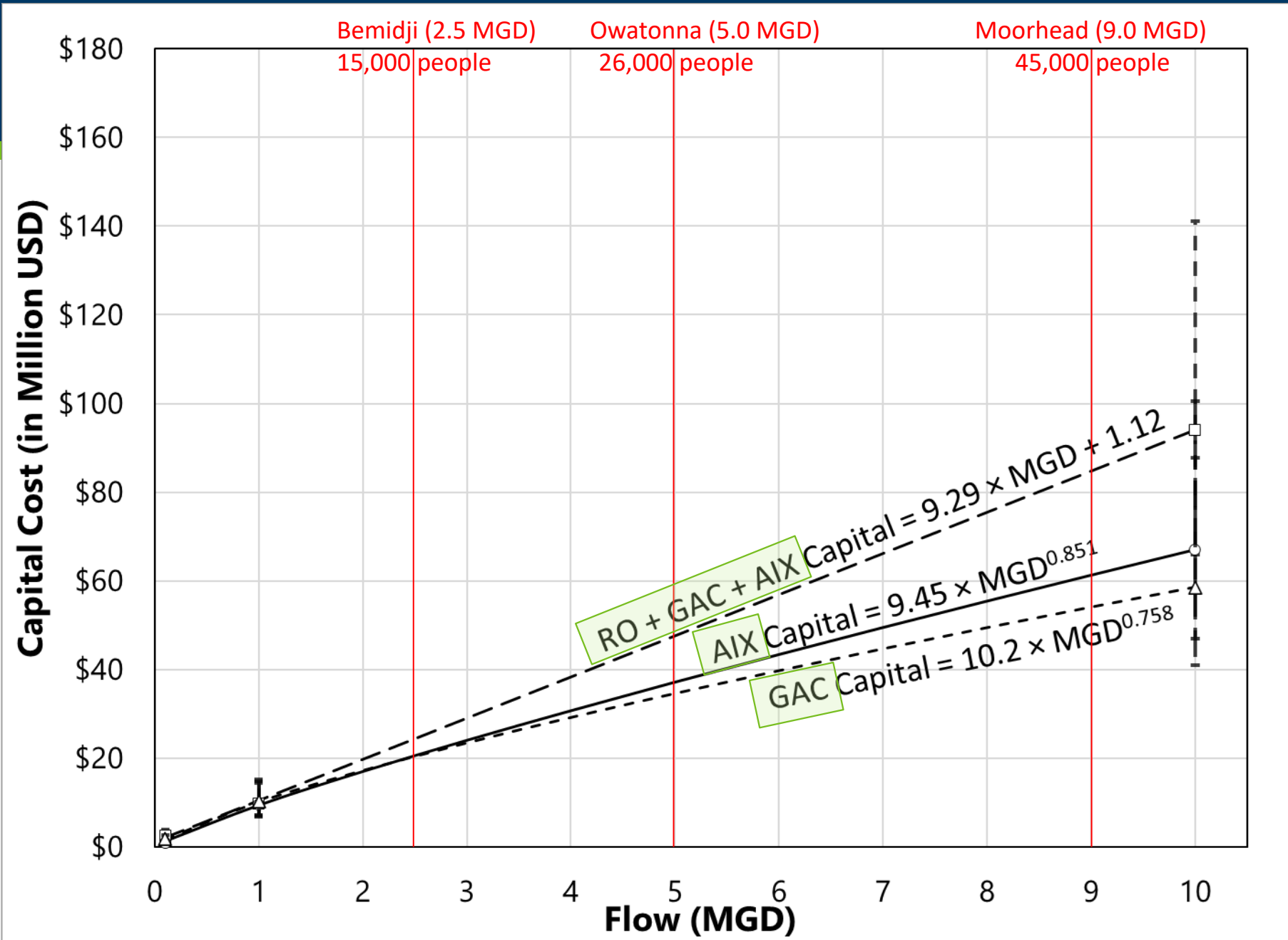
- Jan 1, 2025:** 11 category bans
- July 1, 2026:** Product reporting (PRISM)
- Jan 1, 2032:** Broad prohibition unless CUU
Airport hangar foam systems prohibition delayed to Jan.1.2028

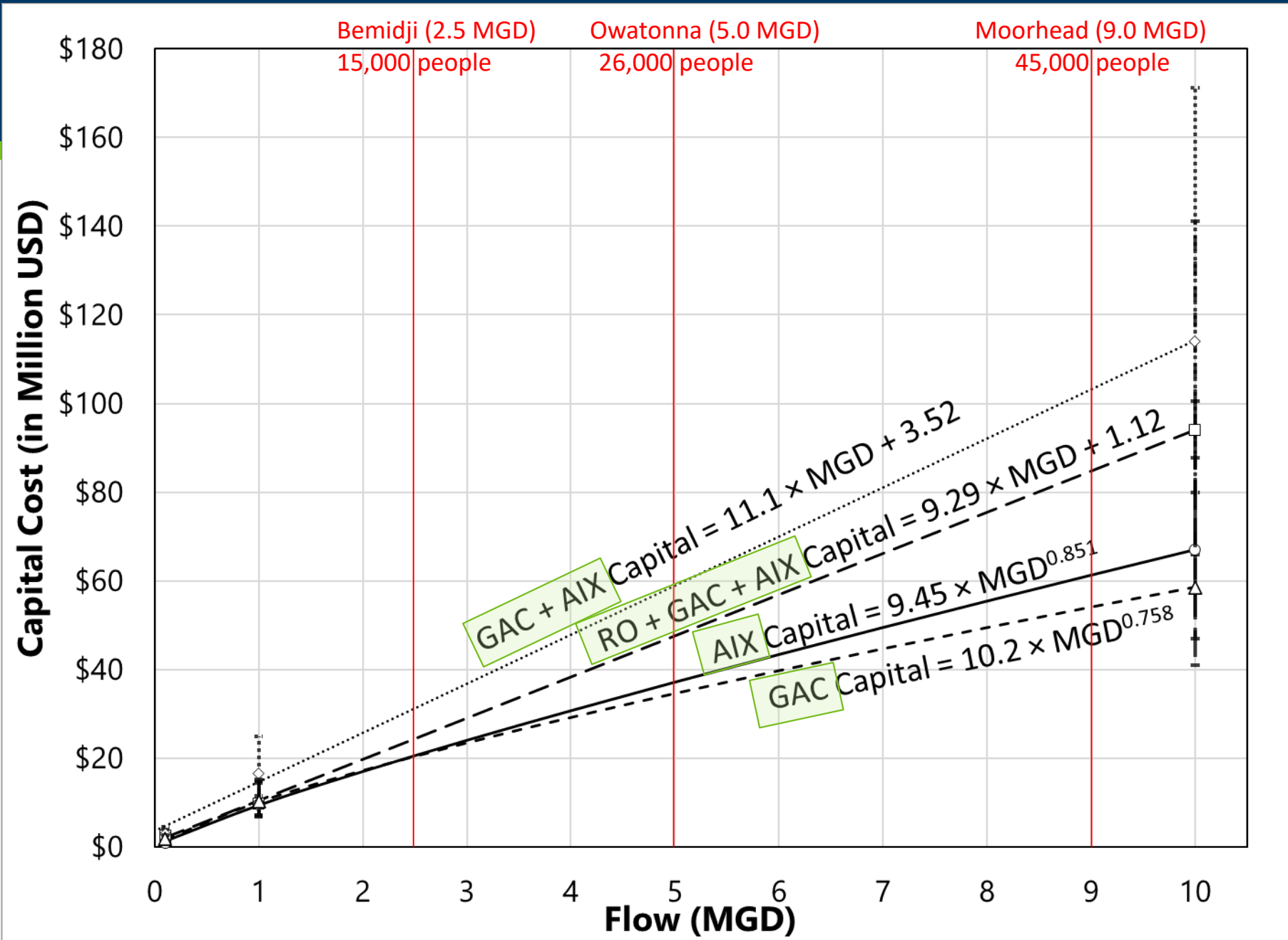
What is MPCAs PFAS wastewater strategy??

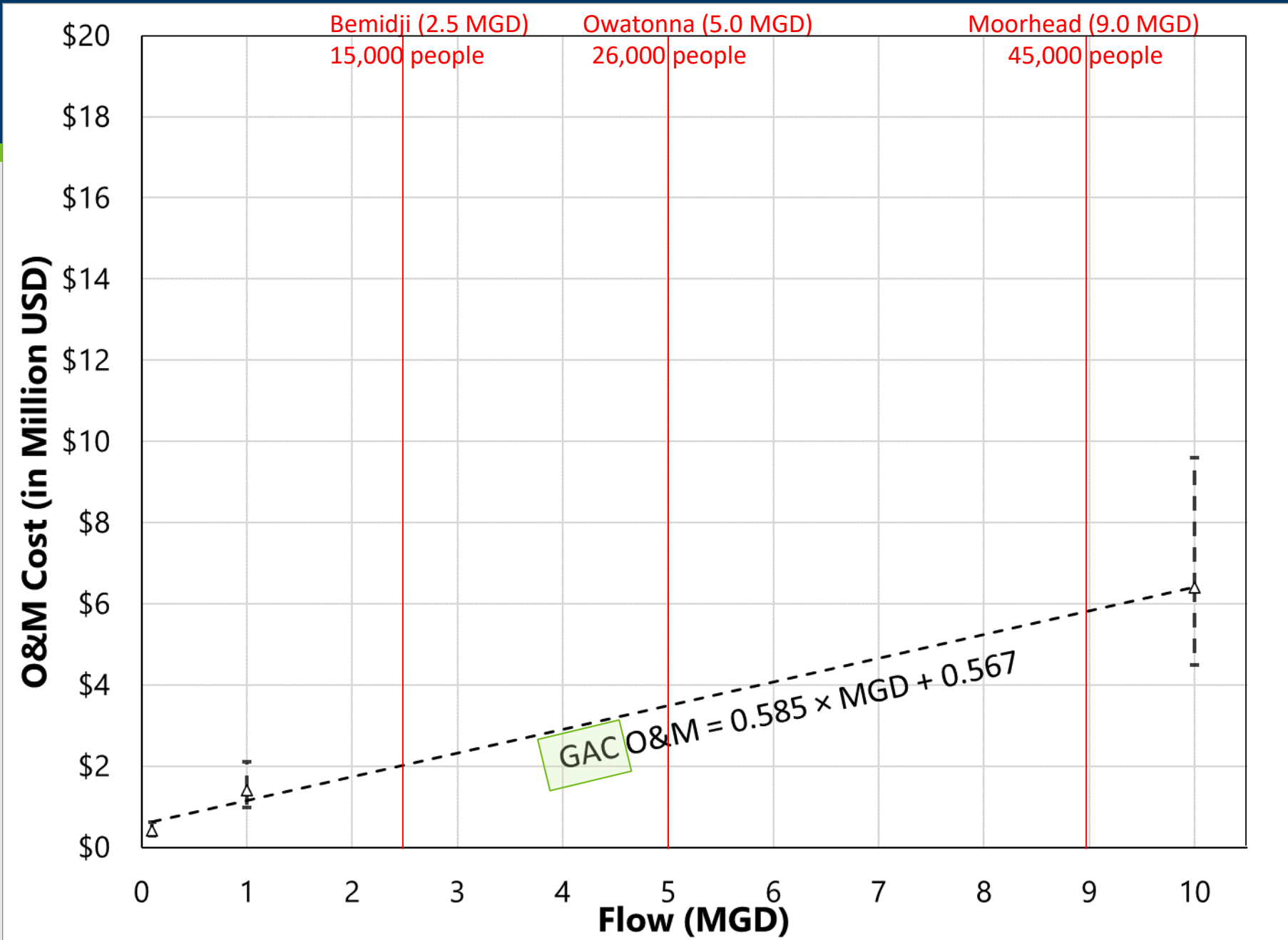


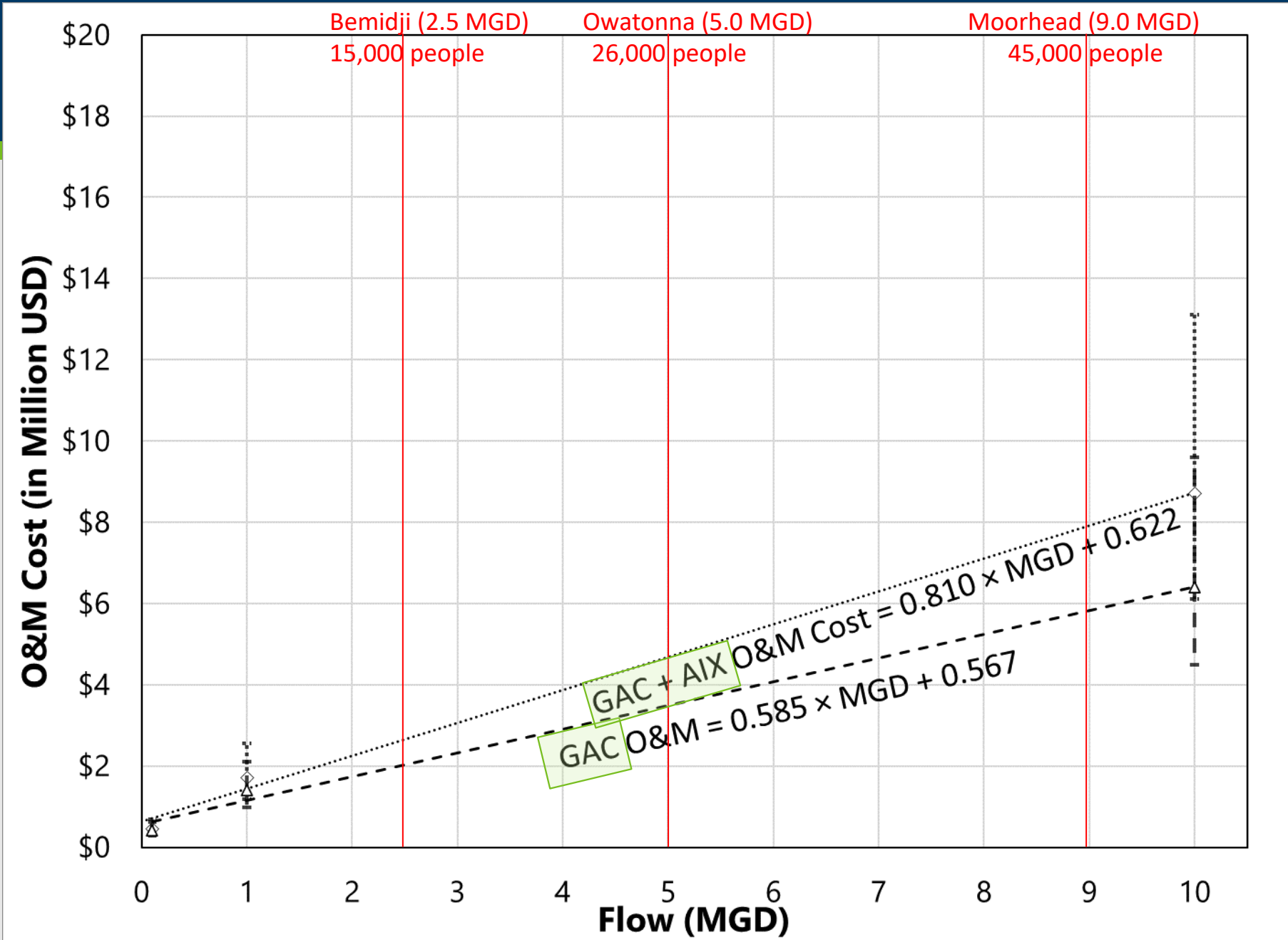


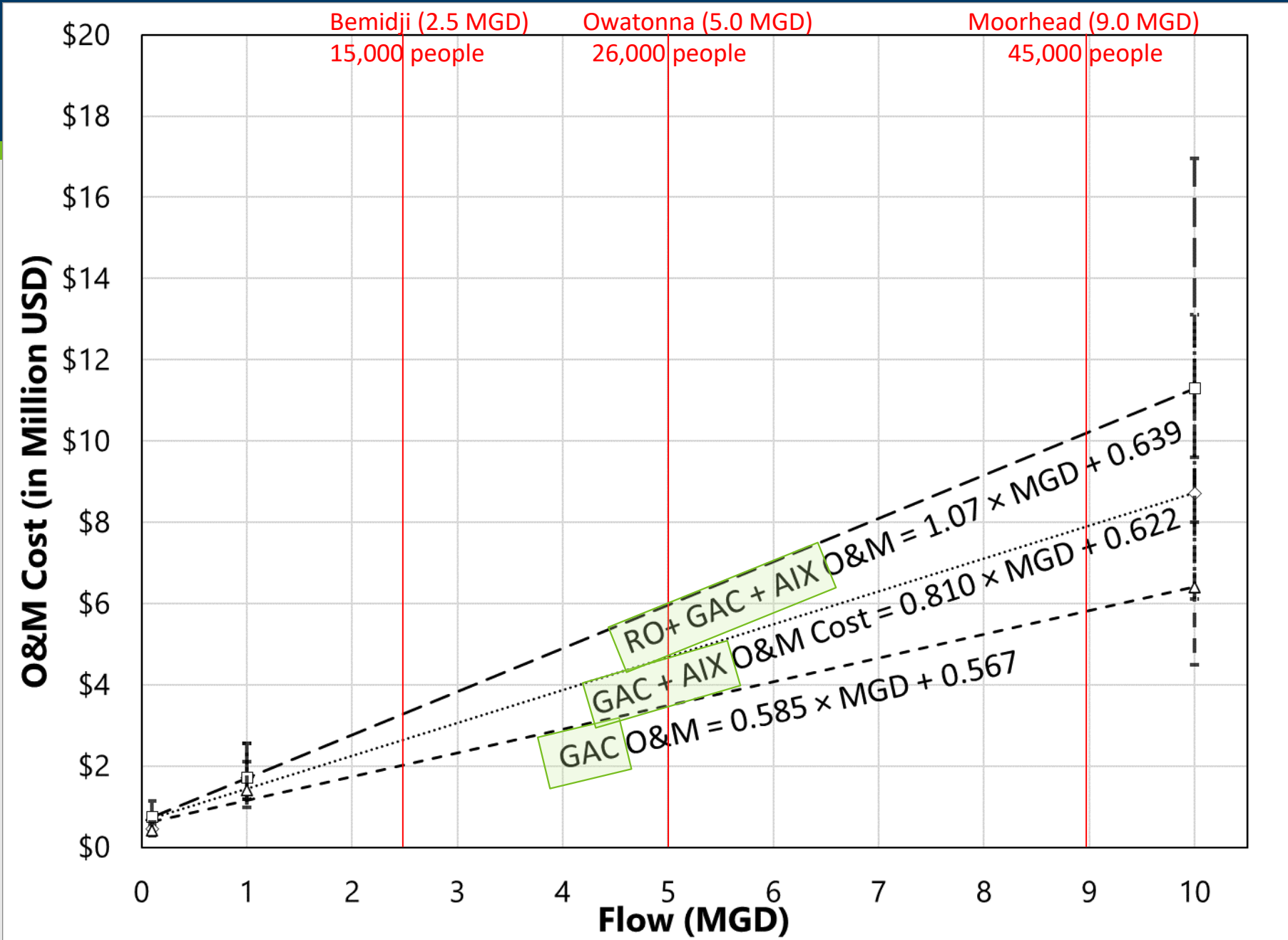


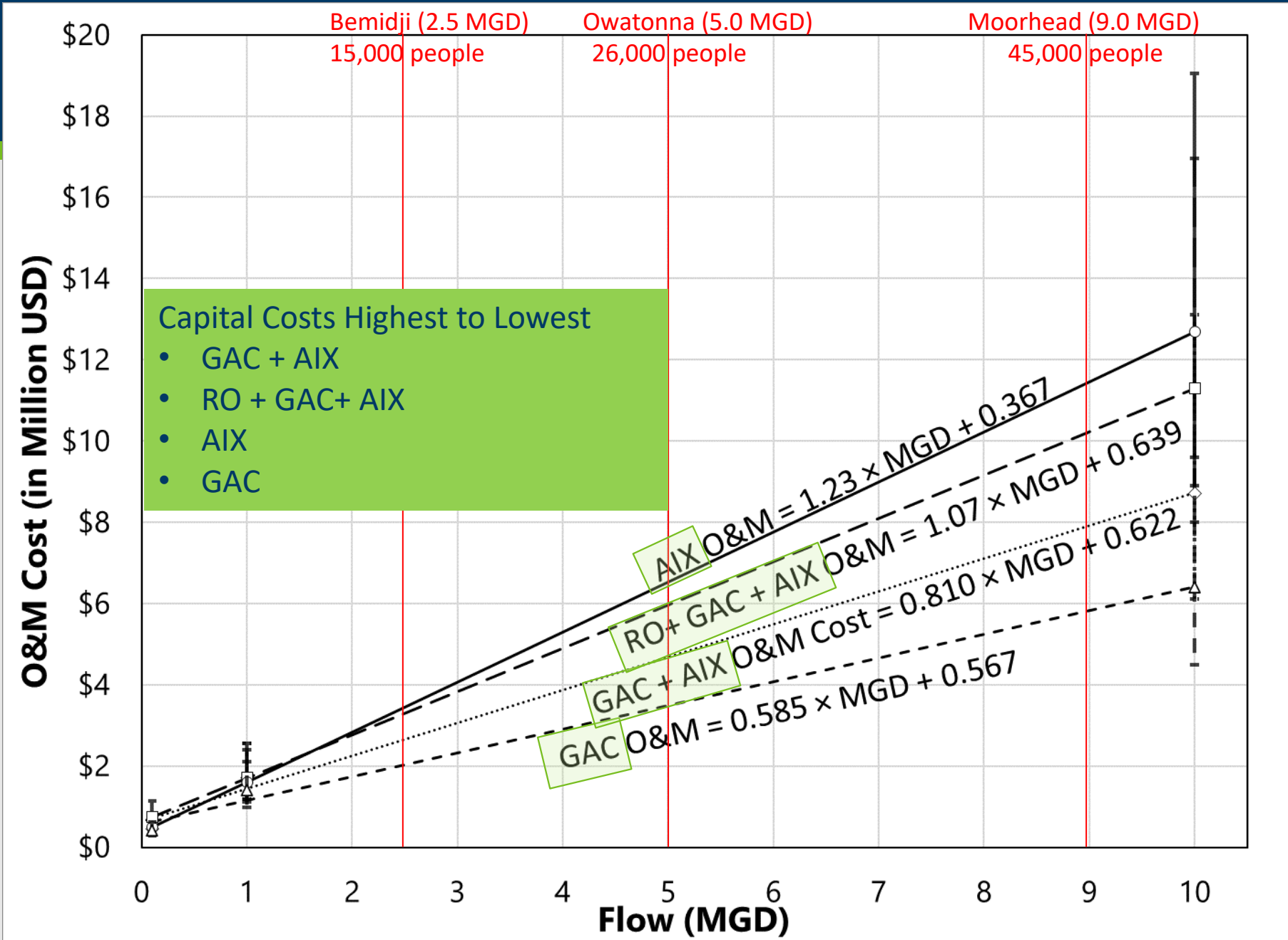




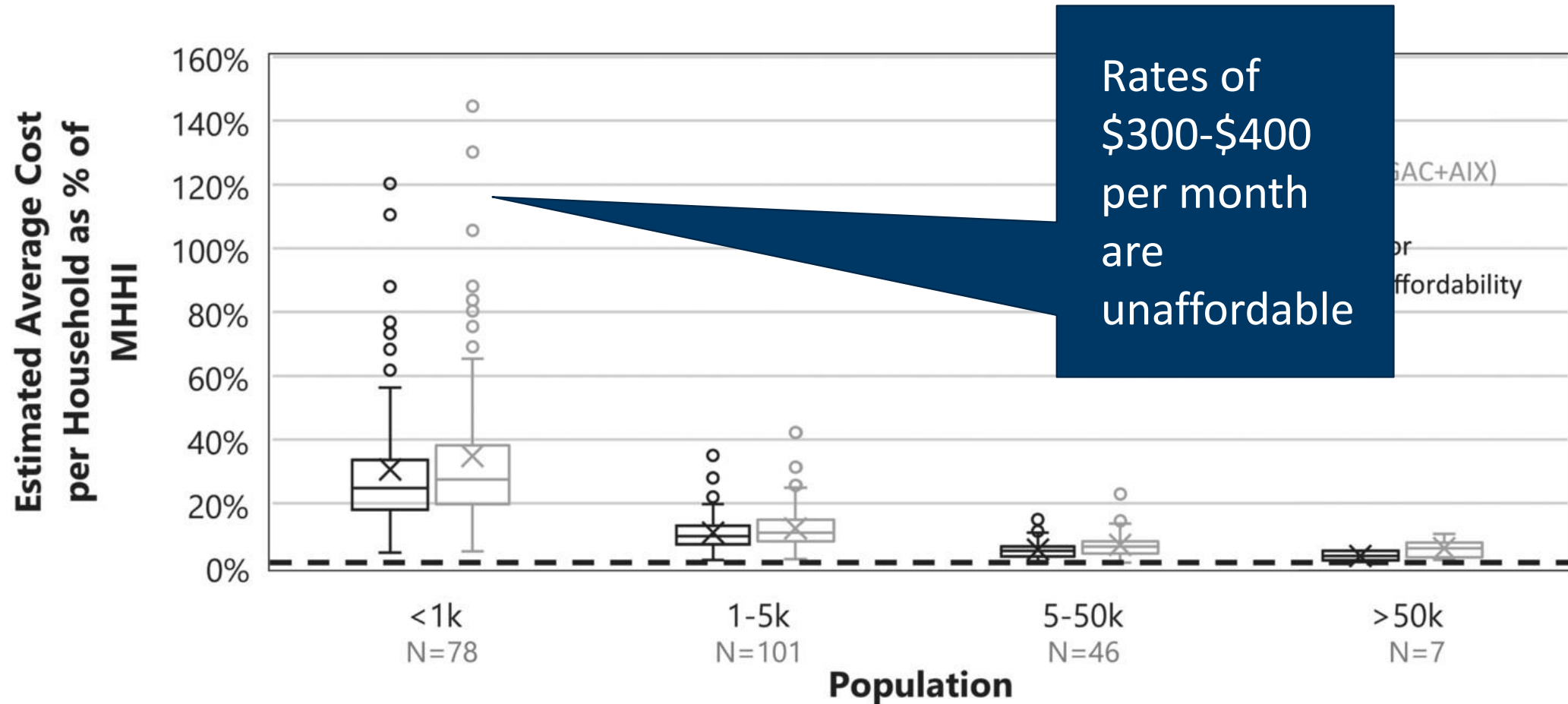








Are these PFAS treatment costs affordable?



Global PFAS Costs – All The Money



ELSEVIER

Science of The Total Environment

Volume 918, 25 March 2024, 170647

Discussion

Estimated scale of costs to remove PFAS from the environment at current emission rates

[Alison L. Ling](#)

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<https://doi.org/10.1016/j.scitotenv.2024.170647>

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Removing and destroying annually produced global PFAS costs more money than exists in the global economy



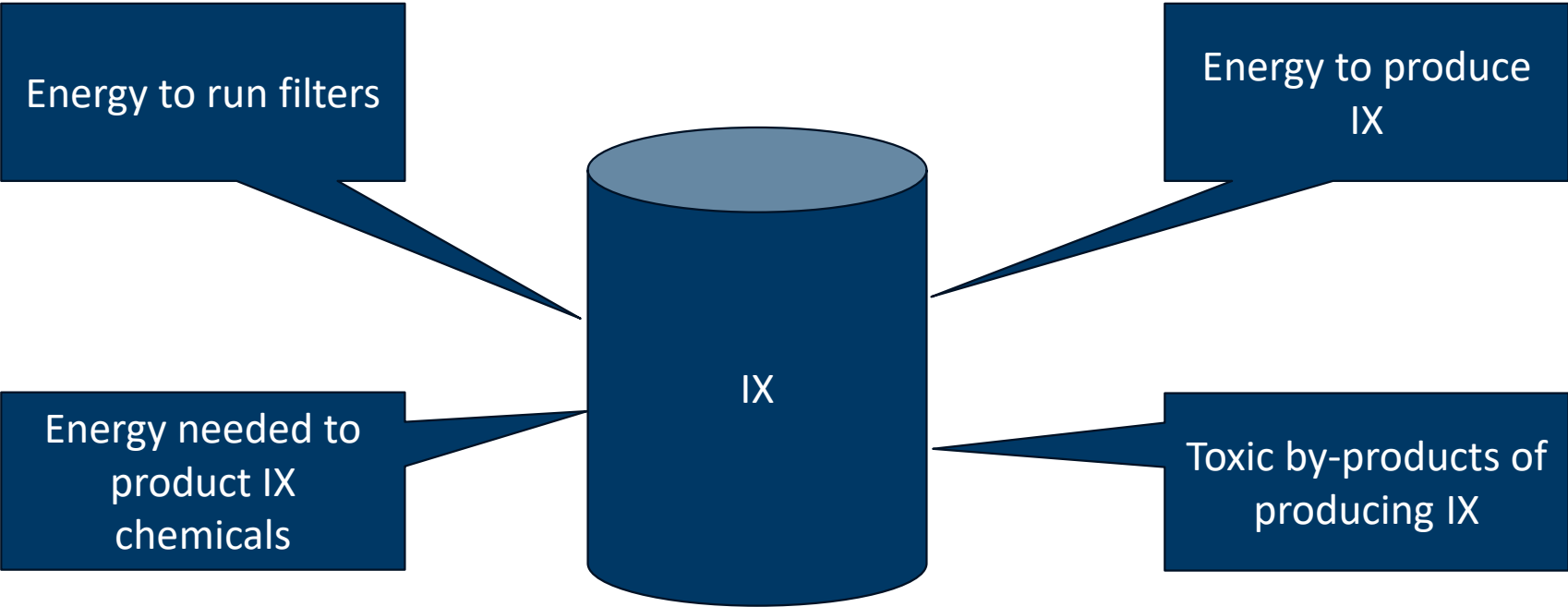
Ali Ling, PhD St. Thomas

Is municipal PFAS treatment practical?

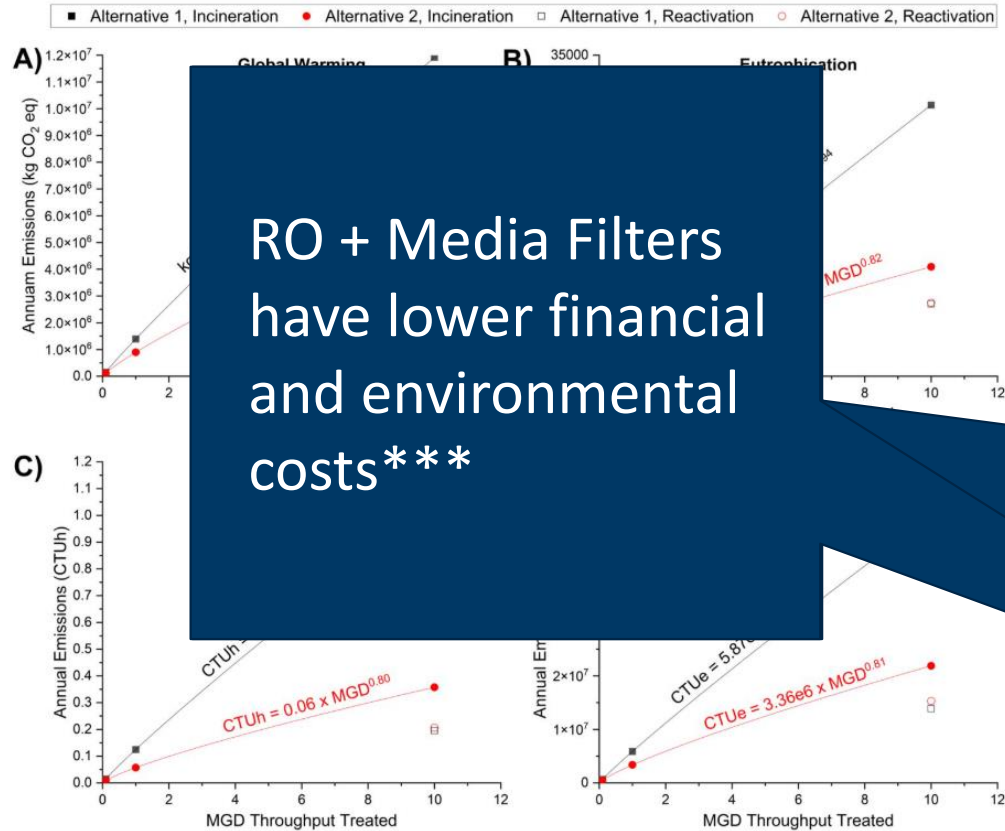


Around 400
60,000 lbs GAC vessels
needed to treat PFAS!
(4-5 acres of vessels)

Environmental Costs of PFAS Treatment



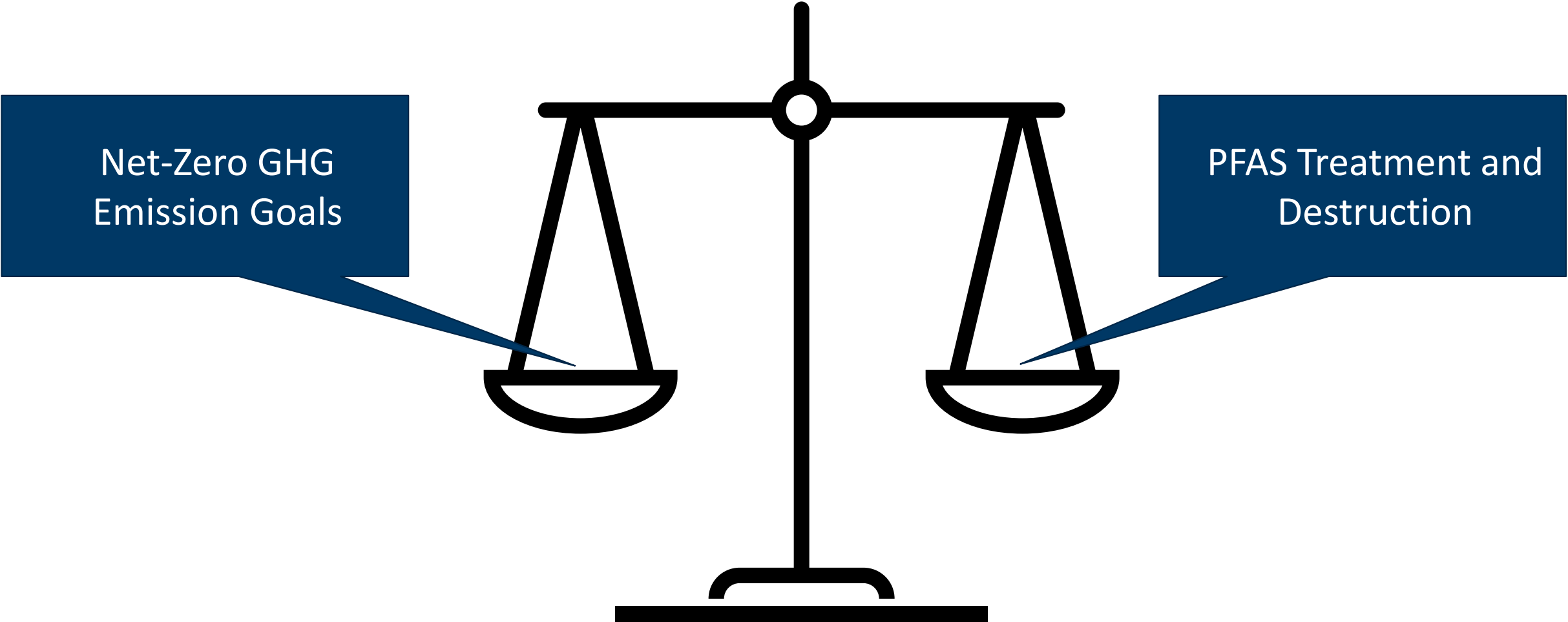
Lifecycle Costs of PFAS Treatment



**RO + Media Filters
have lower financial
and environmental
costs*****

	Design	PFAS Treatment Costs (20-yr NPE, \$Mil)	Social Cost of Carbon (20-yr NPE, \$Mil)	Ratio of Treatment Costs to Social Costs
Media Filters	0.1 MGD	\$8.5	\$0.69	12
	1.0 MGD	\$33	\$6.5	5.1
	10 MGD	\$217	\$55	3.9
	10 MGD with reuse	\$243	\$16	15
RO + Media Filters	0.1 MGD	\$14	\$0.53	27
	1.0 MGD	\$31	\$4.2	7.5
	10 MGD	\$126	\$29.25	4.3
	10 MGD with reuse	\$215	\$22.03	9.8

PFAS Treatment Environmental Trade-Offs



Summary So Far

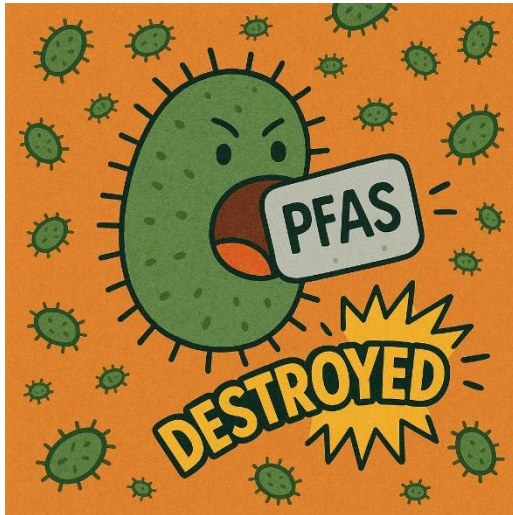
- Almost all MN WWTPs don't have PFAS limits and do not treat PFAS
- The “safe” levels of PFAS in a wastewater discharge are likely very low
- It is technically possible to remove PFAS from wastewater
- It is expensive (and often unaffordable) to remove PFAS from wastewater
- It can be impractical to remove PFAS from wastewater
- There are significant environmental trade-offs to treating PFAS
- The cheapest PFAS treatment option, is to not add PFAS

Wow! That all really seems quite depressing



- There are waters where it clearly makes sense to treat PFAS
- There are waters where it makes less sense to treat PFAS
- The costs and benefits of PFAS treatment should be weighed against each other
- Reasonable people will weigh the costs and benefits differently based on their values

What about PFAS Destruction?



How to break a Carbon-Fluorine Bond?

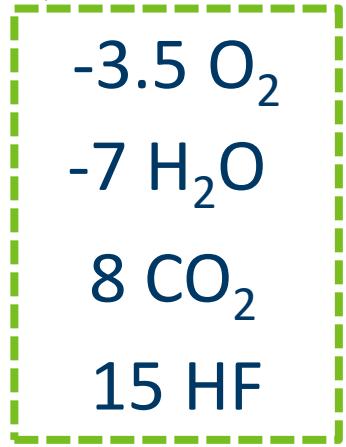
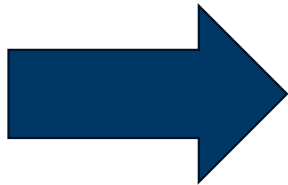
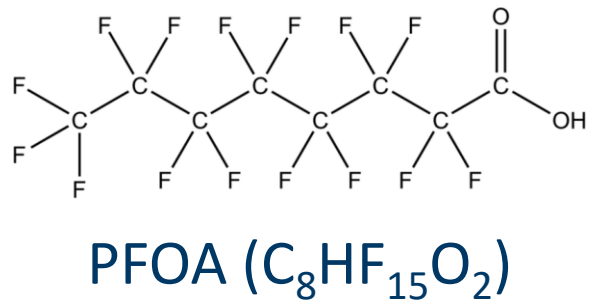


Strongest bond in environmental chemistry

Energy density needed must come from fossil fuels***

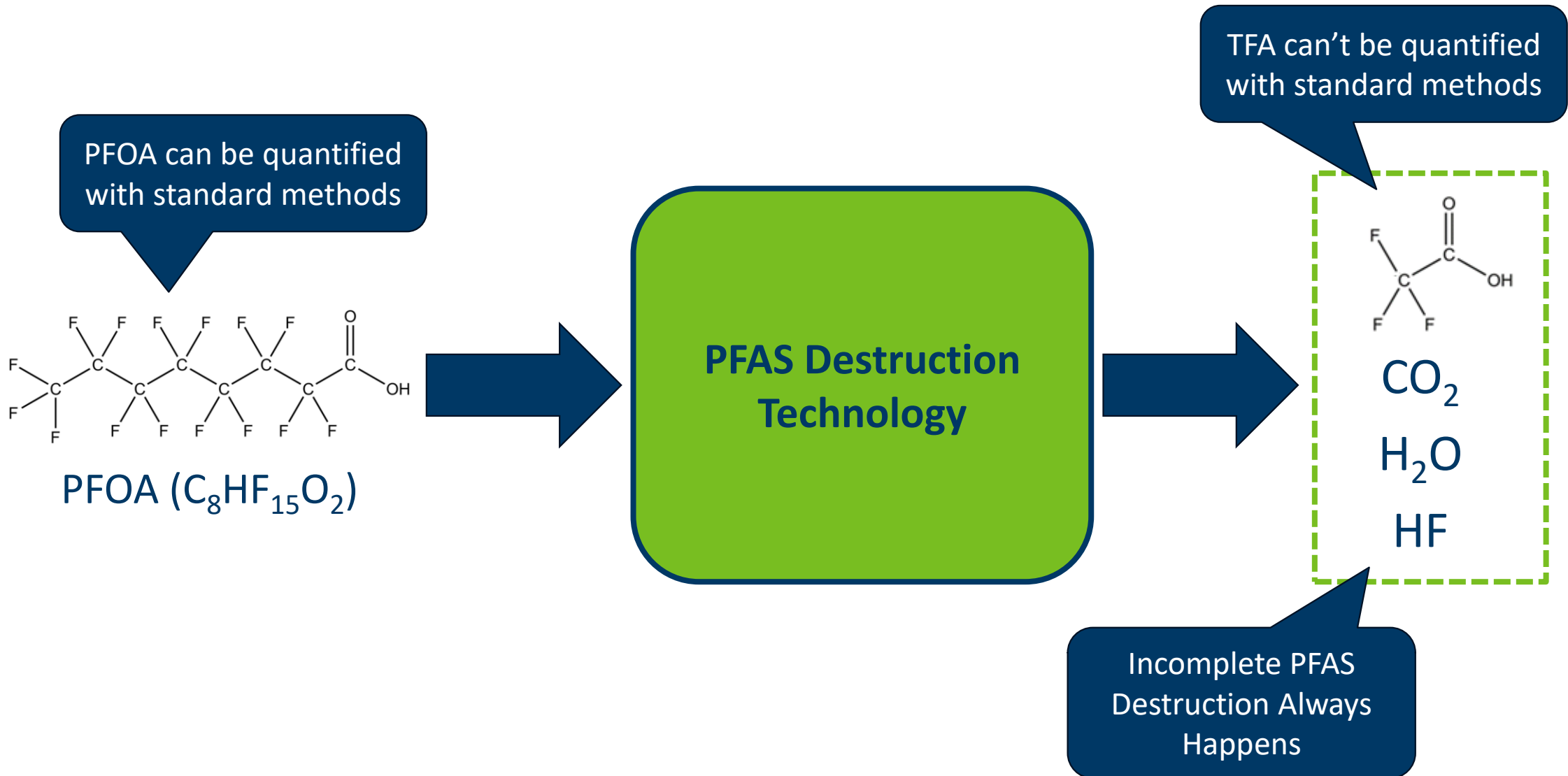
Chemical Bond	Bond Dissociation Energy (kJ/mol)
C-I	209
C-Br	280
C-H	337
C-Cl	397
C-F	536

Complete PFAS Destruction (Mineralization)

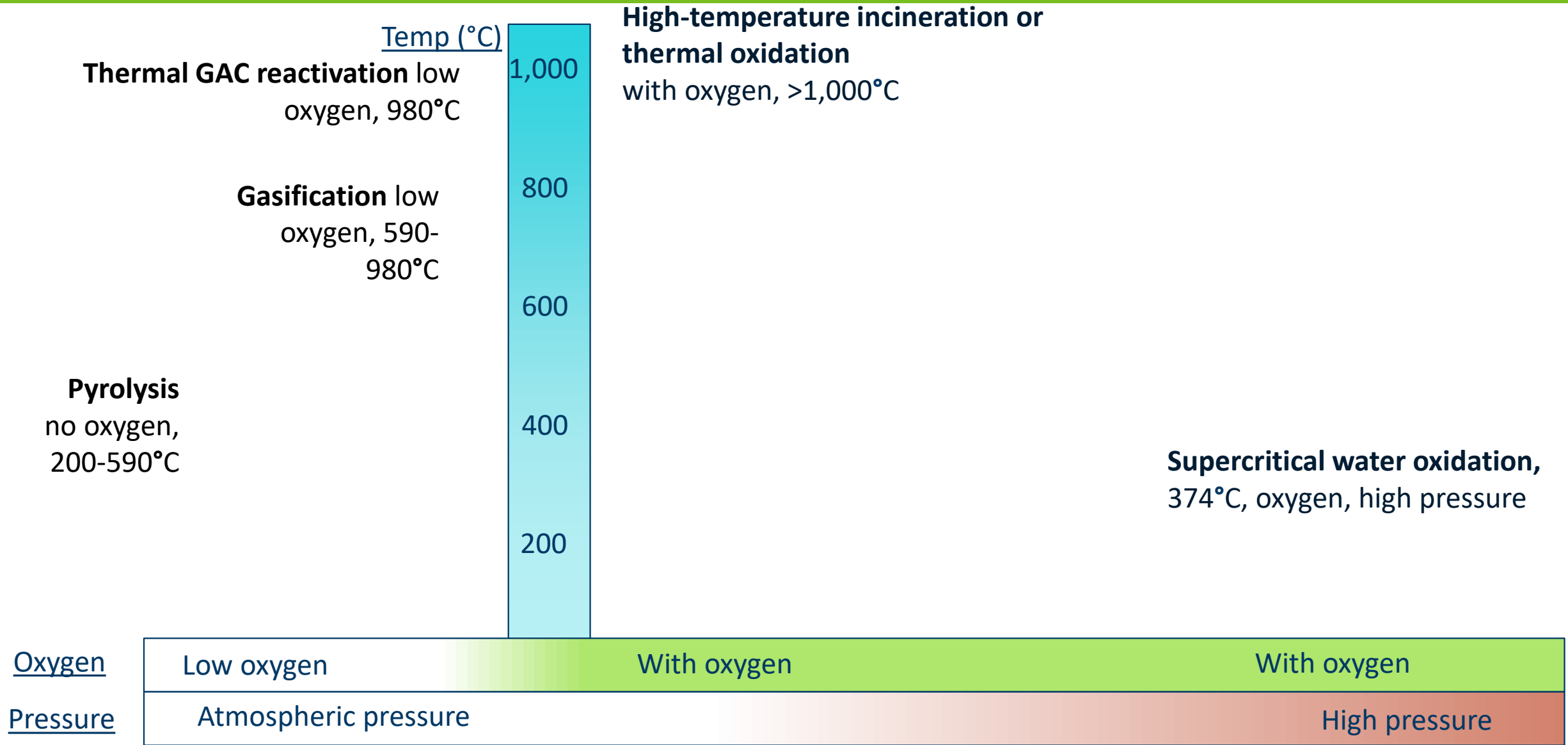


Full PFAS mineralization closes the mass balance for fluorine

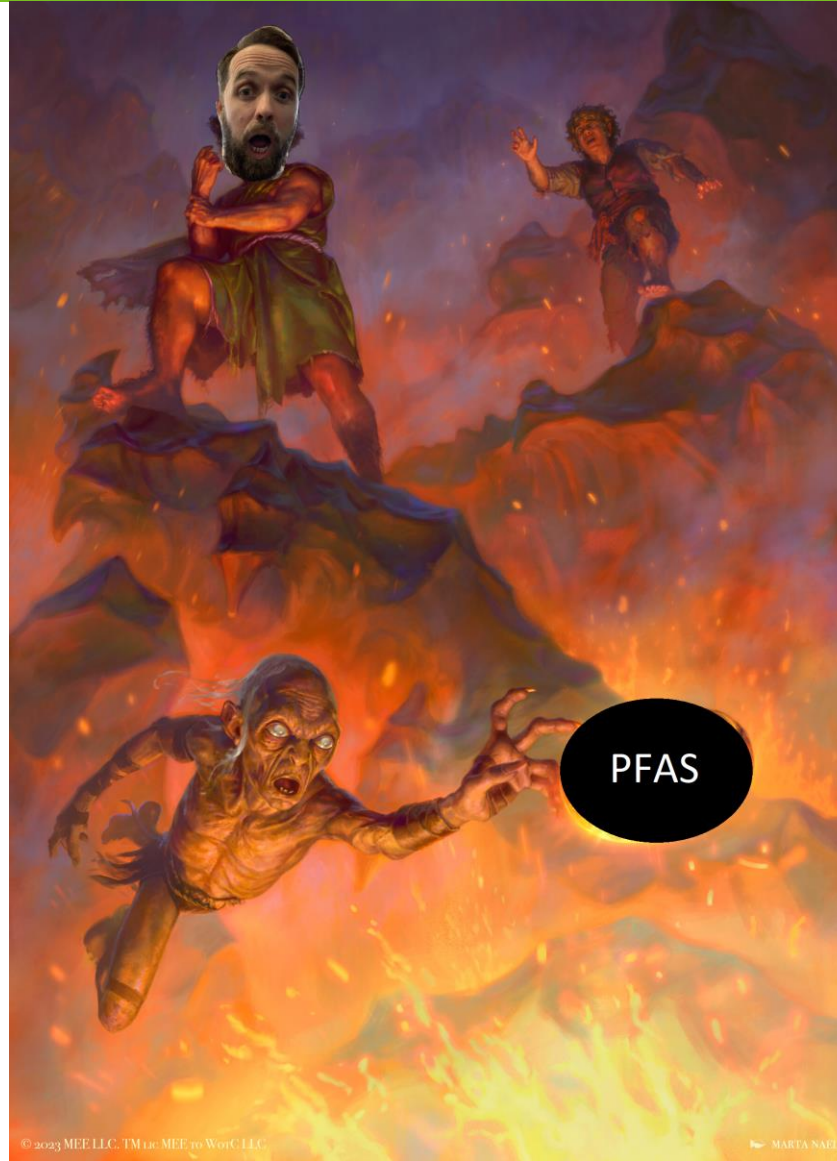
Incomplete PFAS Destruction



PFAS Destruction Technologies



Can you destroy PFAS in a volcano?



What do PFAS destruction technologies look like?



Supercritical water oxidation



Pyrolysis gasification

High Temperature Incineration



50,000 Ton per year Haz Waste Incinerator in
Utah (Aragonite)

Municipal Biosolids

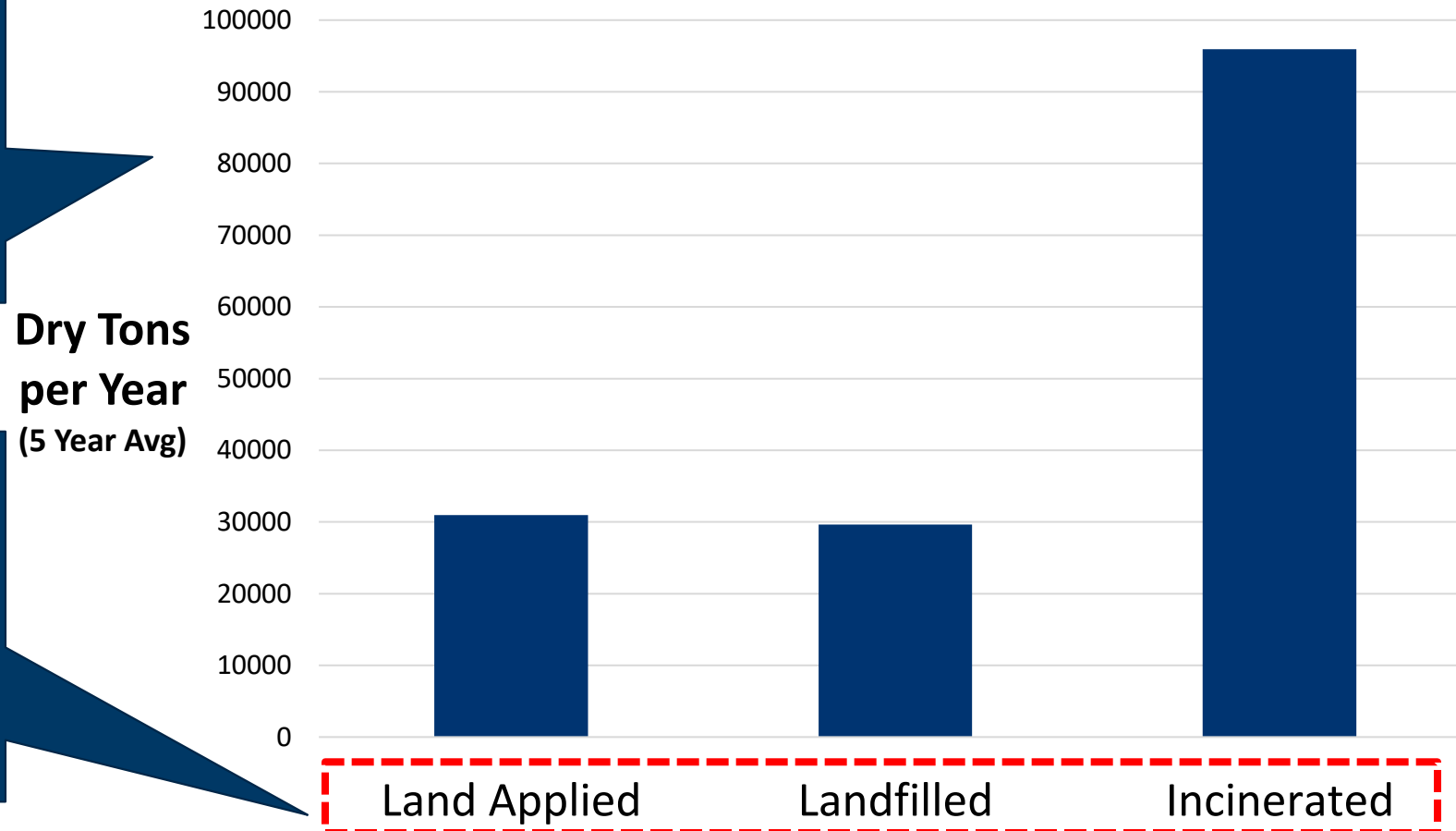


So Much Biosolids is Produced!

All municipal biosolids contains PFAS at low levels*

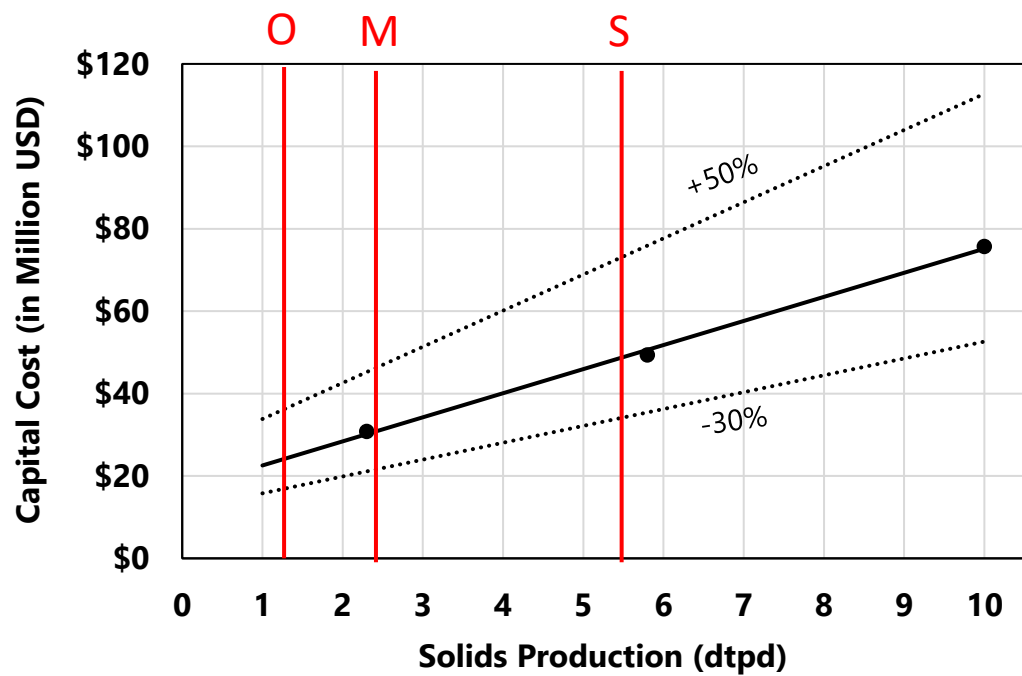
Current methods just move PFAS from one place to another

Minnesota Biosolids Production Rates

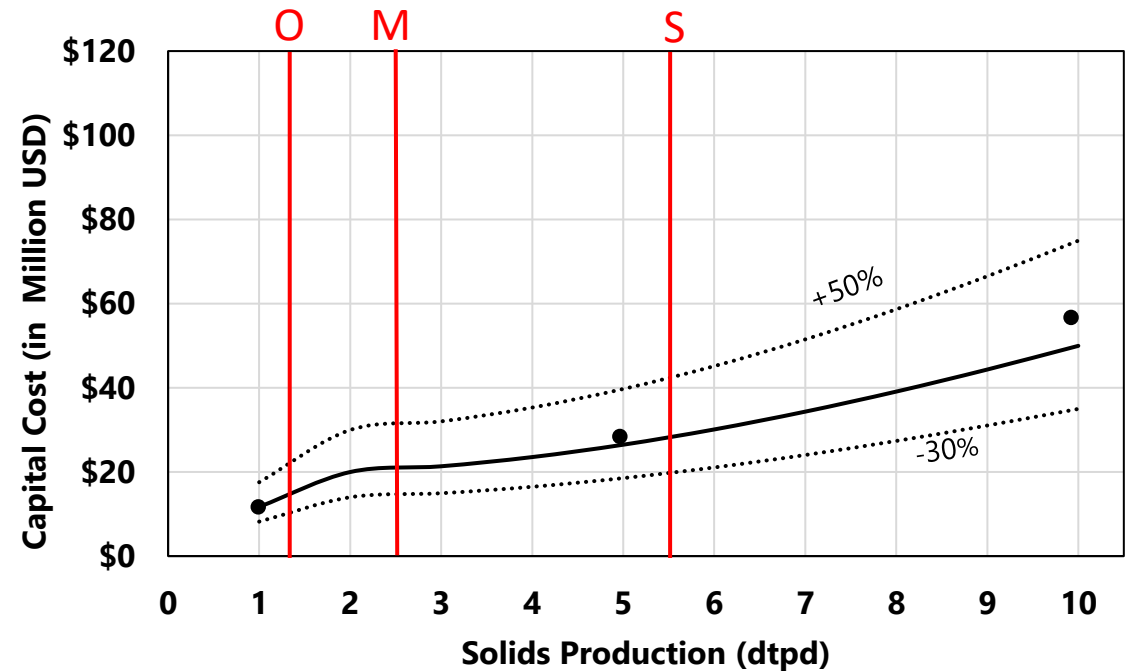


Biosolids Capital Cost Curves

Pyrolysis/Gasification with Thermal Oxidation



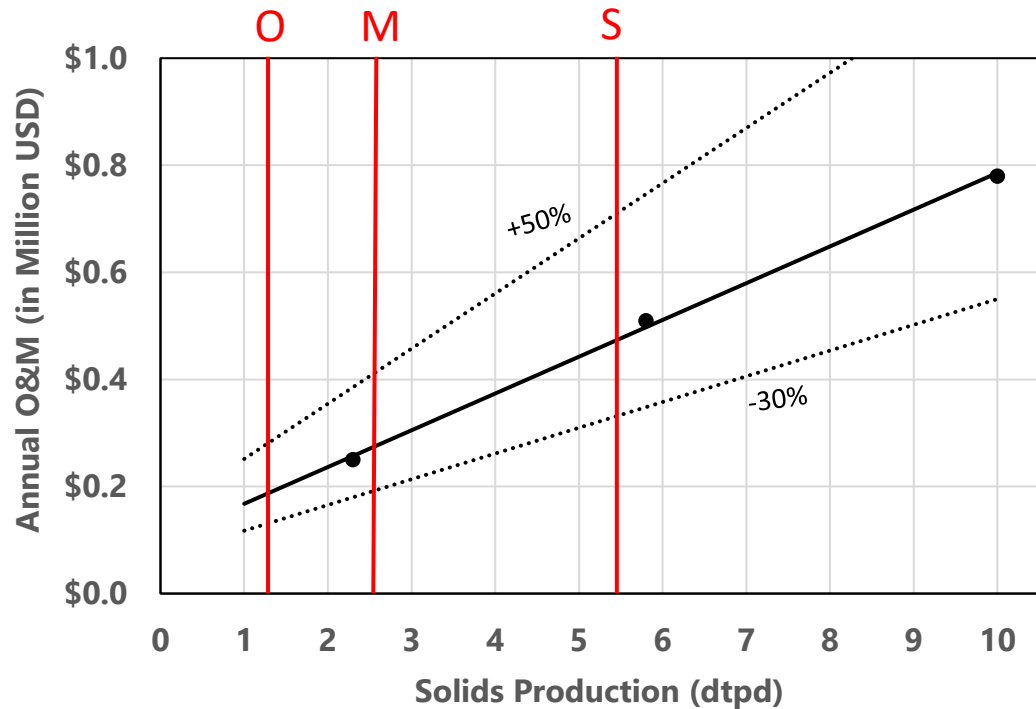
SCWO



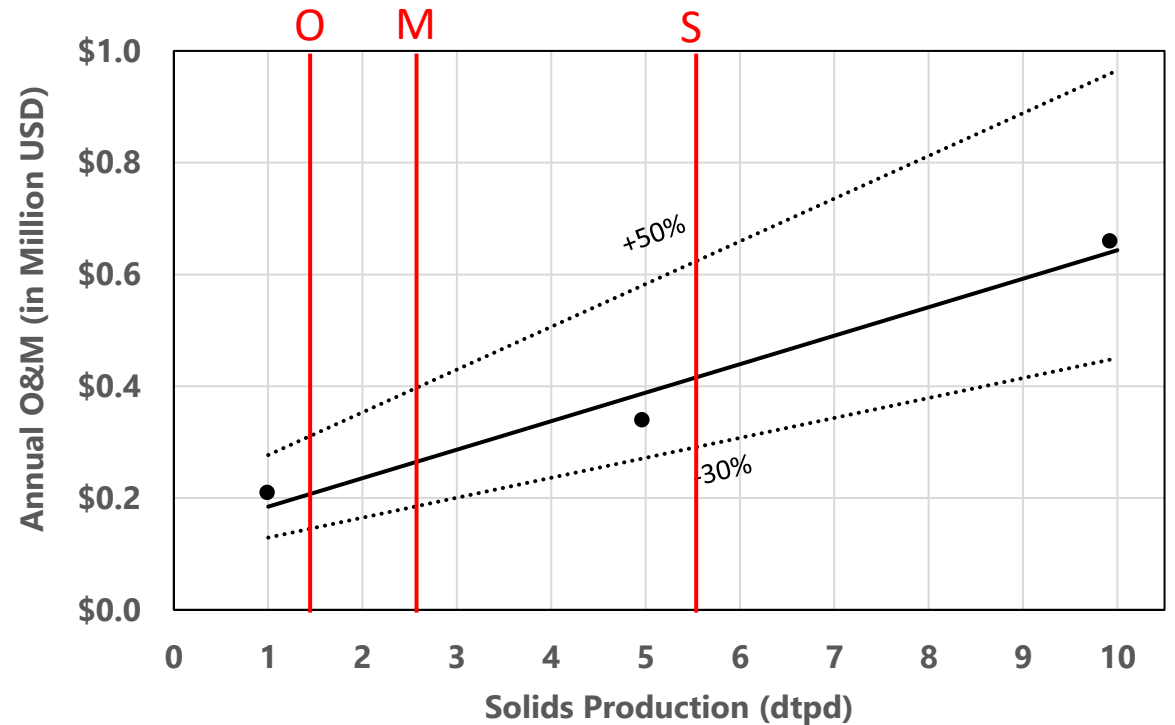
Owatonna – 1.3 dtpd (26,400 people)
Moorhead – 2.5 dtpd (44,700 people)
St. Cloud – 5.5 dtpd (68,500 people)

Biosolids Annual Operation & Maintenance Costs

Pyrolysis/Gasification with Thermal Oxidation



SCWO

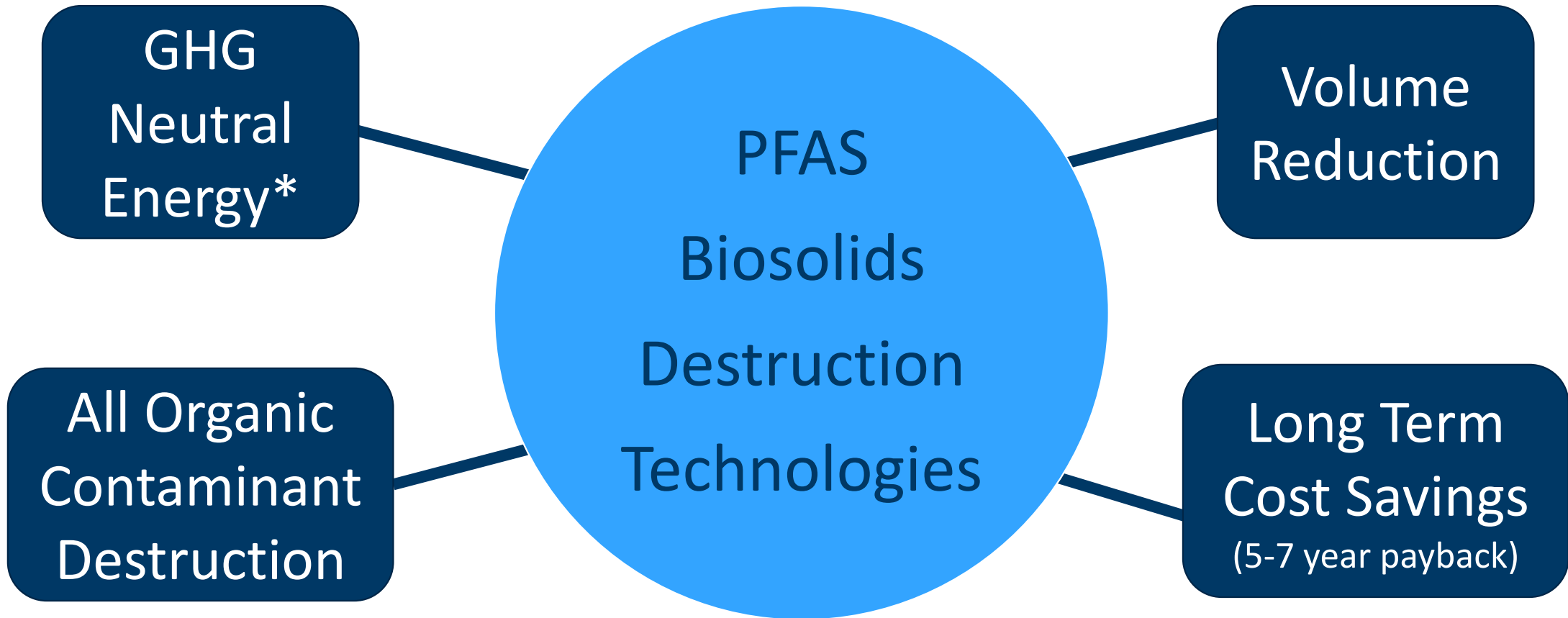


Owatonna – 1.3 dtpd (26,400 people)

Moorhead – 2.5 dtpd (44,700 people)

St. Cloud – 5.5 dtpd (68,500 people)

What about biosolids PFAS treatment and destruction tech?



Saint Cloud MN WWTP



Granite buildings
from local quarry!

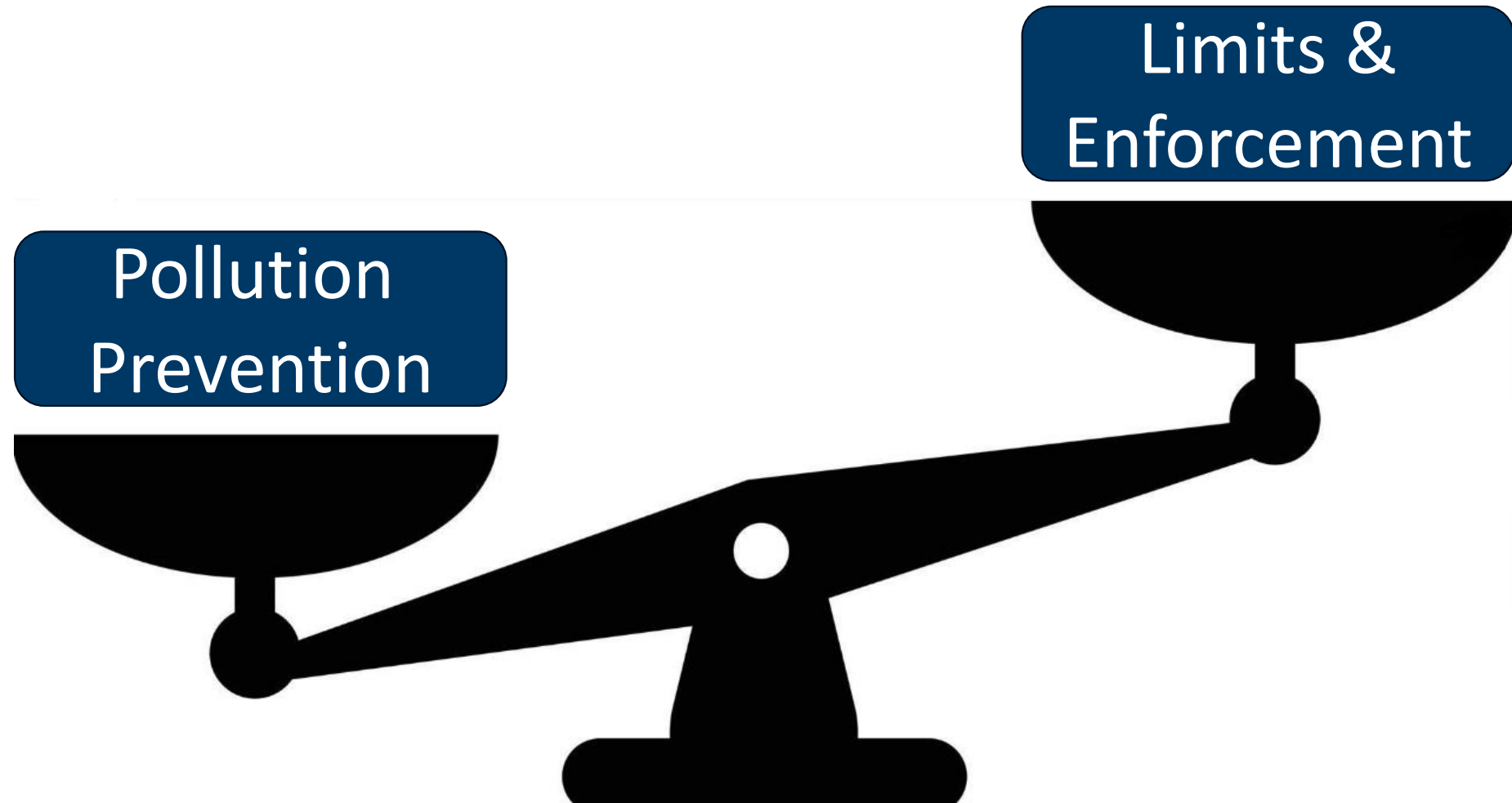
Nutrient (N-P)
harvesting

100% renewable
energy
(\$1 Mil annual
savings)

PFAS
Pre-treatment

\$1.4M SCWO
Biosolids Pilot Test

What is MPCAs PFAS wastewater strategy??



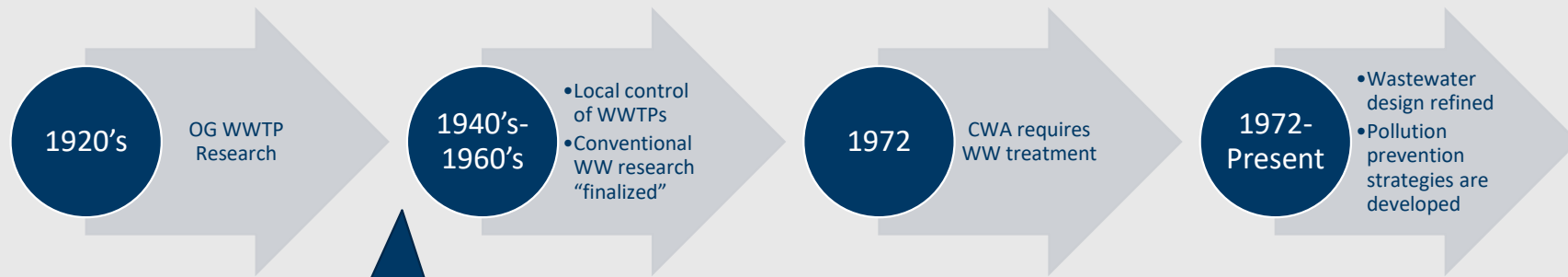
Summary

- PFAS are everywhere
- PFAS enter surface waters from many sources
- PFAS are hard to remove and destroy
- Safe PFAS toxicological numbers tend to zero over time
- It is possible but difficult to remove and destroy PFAS from water
- Engineers face uncertain design choices when designing a WWTP to remove and destroy PFAS
- A bunch of technical stuff about PFAS treatment and destruction
- Cute animals!
- MPCAs wastewater strategy is to focus on pollution prevention

Do you still feel a little confused and worried?

Yep!

Wastewater Historical Context



PFAS is around this stage

Main difference between PFAS and conventional wastewater pollutants is that PFAS have a more difficult chemistry

Sleeping elephants & MN Vikings



4/14/2026



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