Technoeconomic Analysis of a Regional SCWO Facility for PFAS-Laden Wastes

Ali Ling, PhD, PE

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UNIVERSITY OF St.Thomas

PFAS waste management

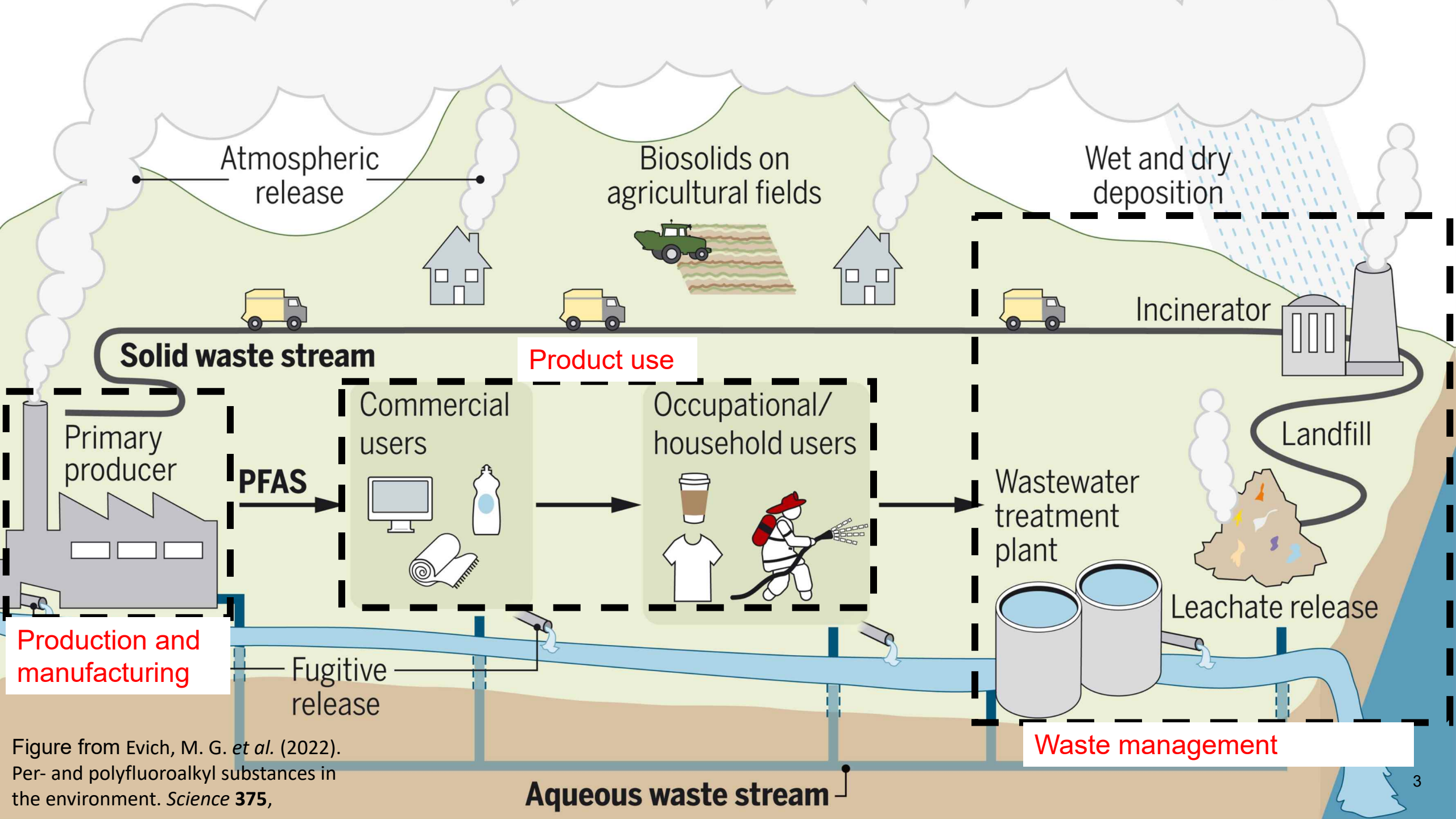


Figure from Evich, M. G. *et al.* (2022). Per- and polyfluoroalkyl substances in the environment. *Science* **375**,

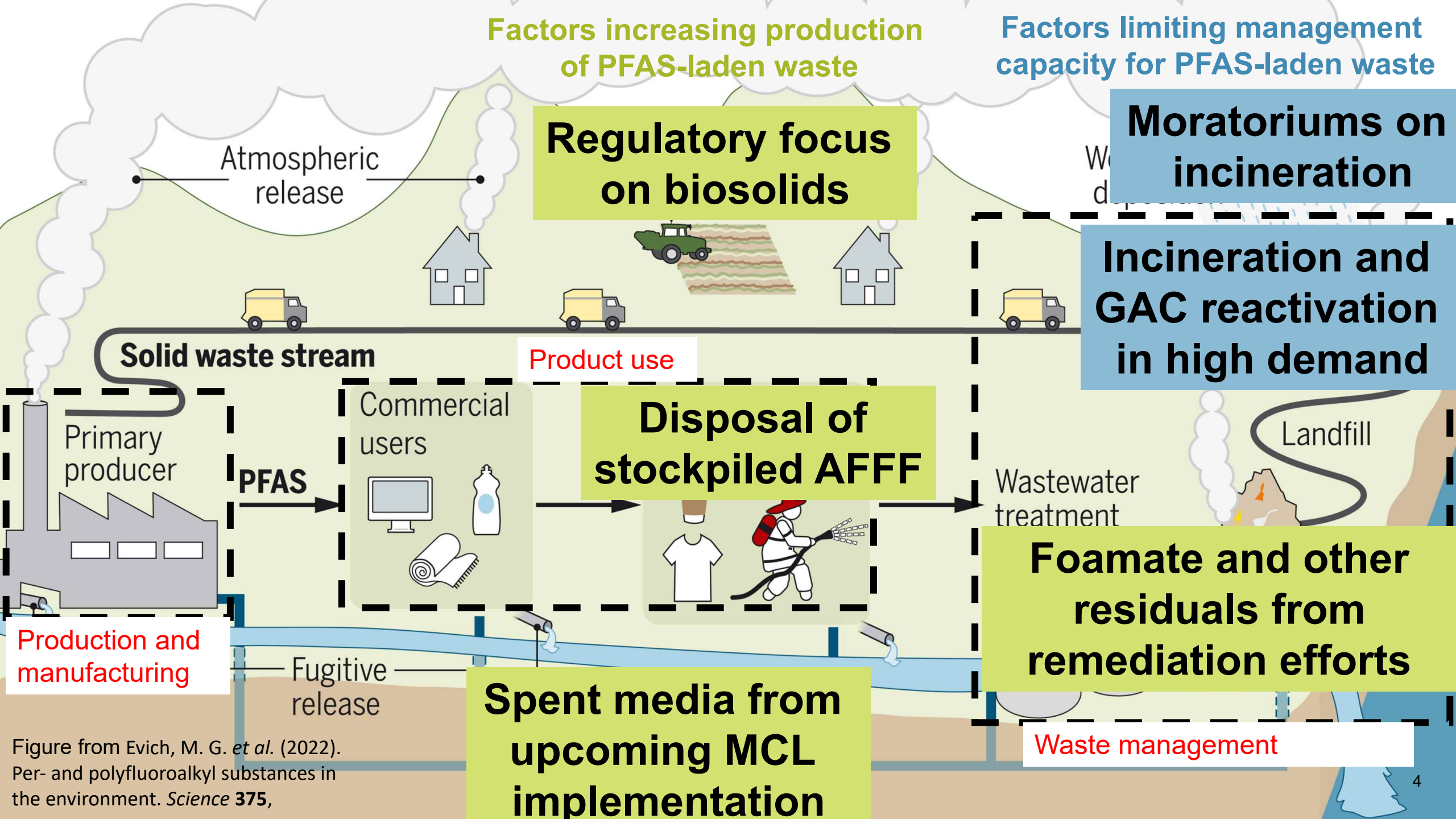


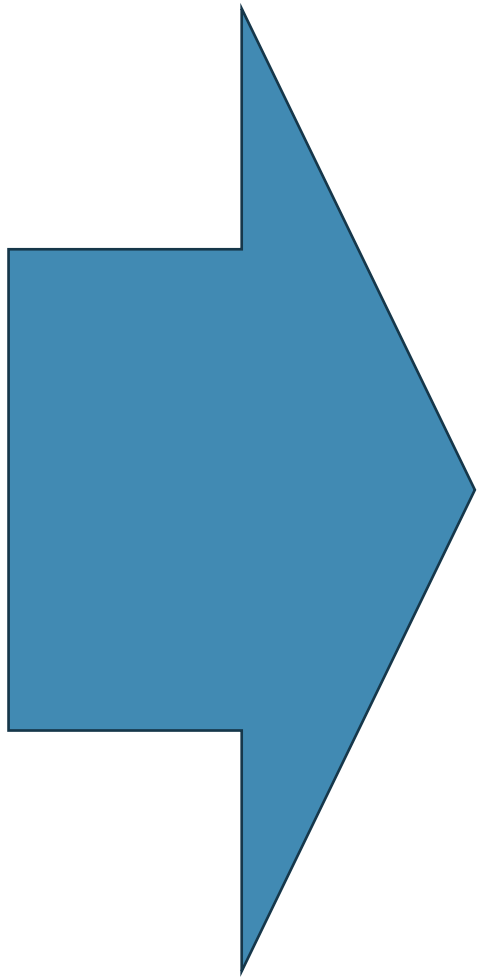
Figure from Evich, M. G. *et al.* (2022). Per- and polyfluoroalkyl substances in the environment. *Science* **375**,

Regulatory focus on **biosolids**

Disposal of stockpiled **AFFF**

Spent media from upcoming MCL implementation

Foamate and other residuals from remediation efforts



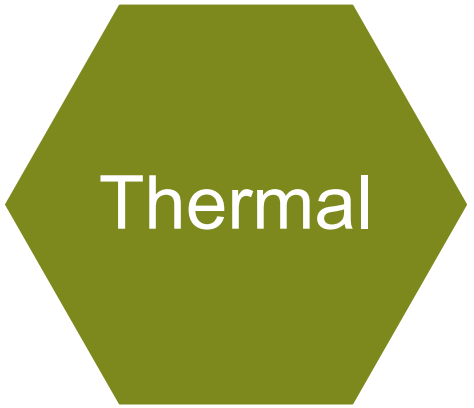
Regional facility accepting mixed wastes

<u>Wish list</u>:

1. Accepts mixed wastes
2. Energy-neutral or –positive
3. Beneficial reuse of end products

PFAS Destruction Technologies

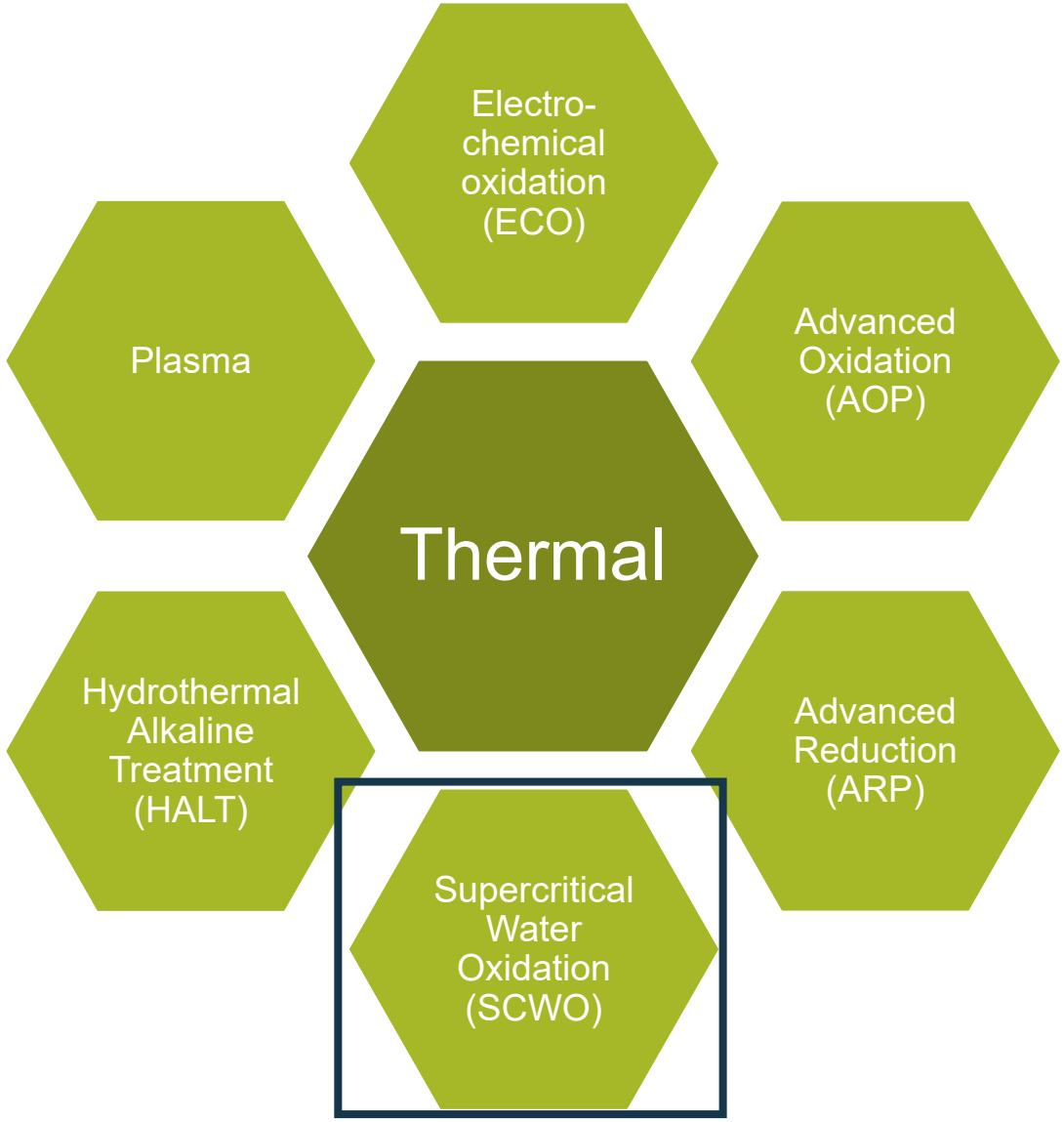
Thermal treatment the only destruction technology listed as developed in EPA's 2024 Disposal Guidance!



PFAS Destruction Technologies

Thermal treatment the only destruction technology listed as developed in EPA's 2024 Disposal Guidance!

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



Regional “SCWO Soup” Concept

SCWO Equipment Vendors

(Image credit: General Atomics

- 374Water – Duke University
  - AirSCWO
- General Atomics
  - iSCWO
- AquaCritox – ScFi
- Aquarden
  - PFASinator
- Revive Environmental – Battelle
  - PFAS Annihilator
  - 4Never (foam frac+SCWO)

(Image credit: Andy McCabe

Potential Benefits of SCWO

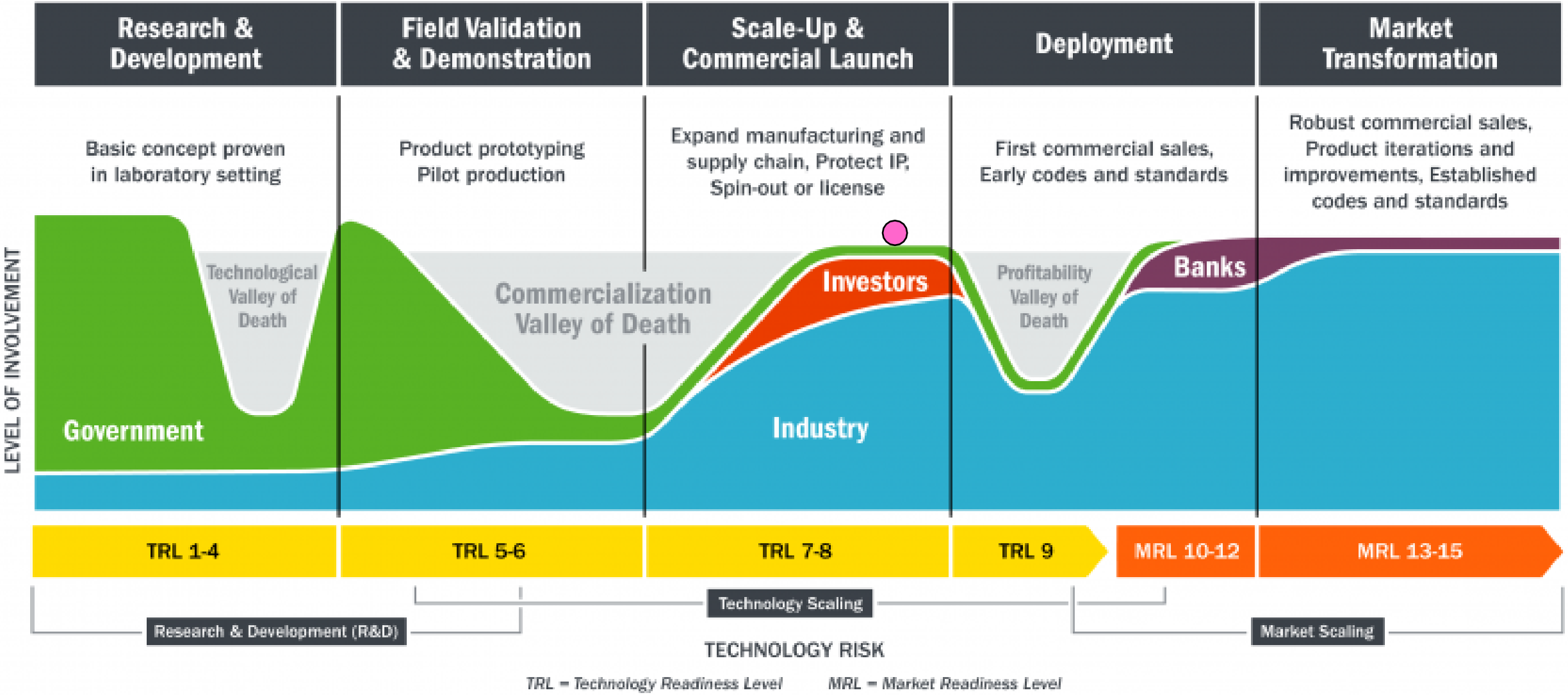


Image credit: Office of Energy Efficiency and Renewable Energy (https://www.energy.gov/eere/buildings/technology-market)

Potential Benefits of SCWO

Wish list:

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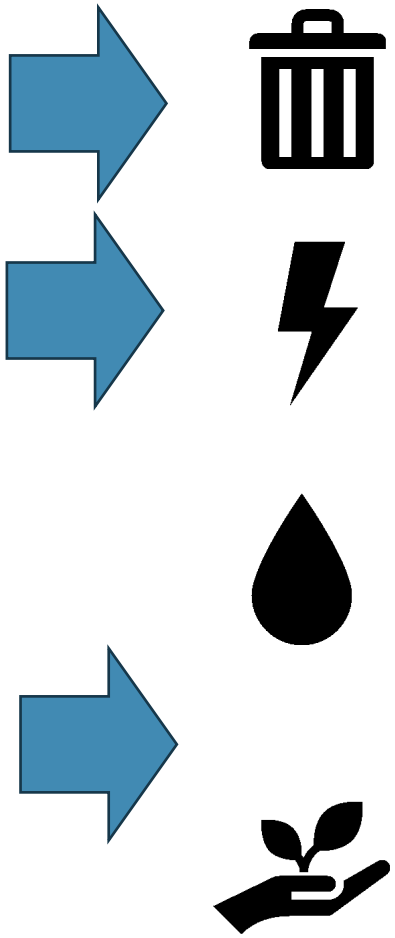


- Ability to accept mixed waste streams
- Energy recovery from high organic (calorific) wastes
- Recovery of clean condensate water that could be beneficially reused
- Recovery of nutrients (notably P) in the residual solids (‘minerals’)

What is supercritical water?

- Above supercritical pressure and temperature, water behaves more like a '**non-polar' solvent**
- **O**xygen (O_2) and organics become very soluble, and salts precipitate
- **highly oxidizing ->** most organics, including PFAS, are mineralized to CO_2

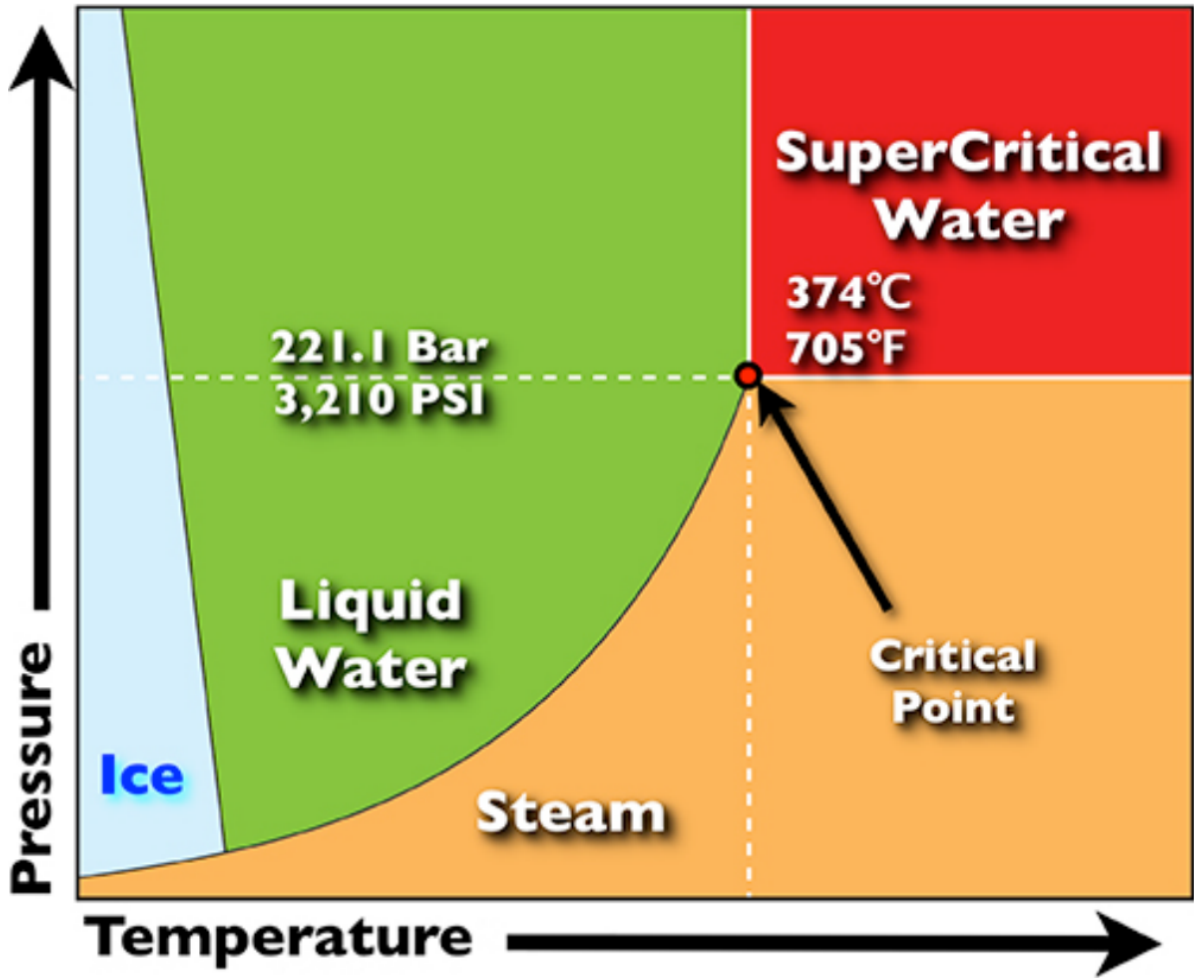
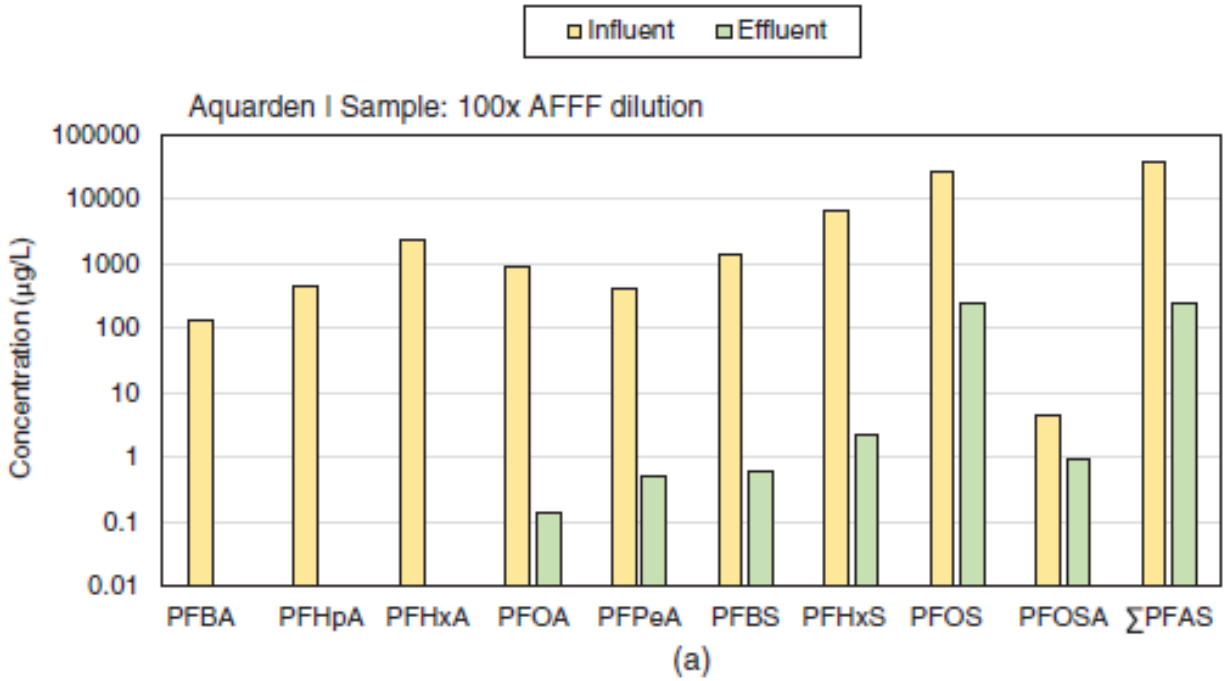
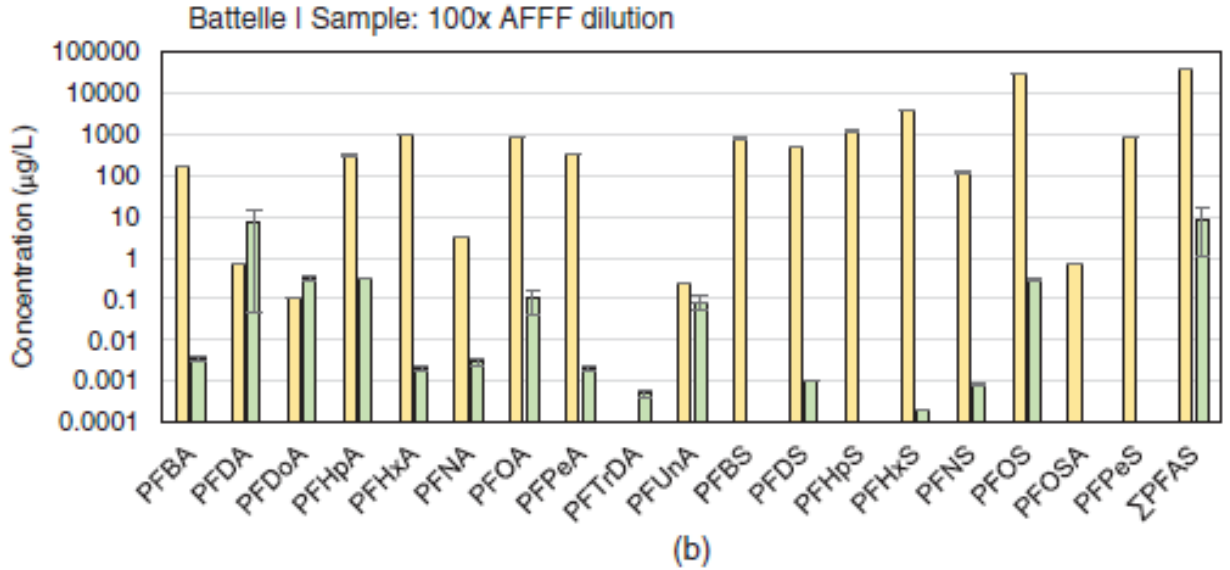


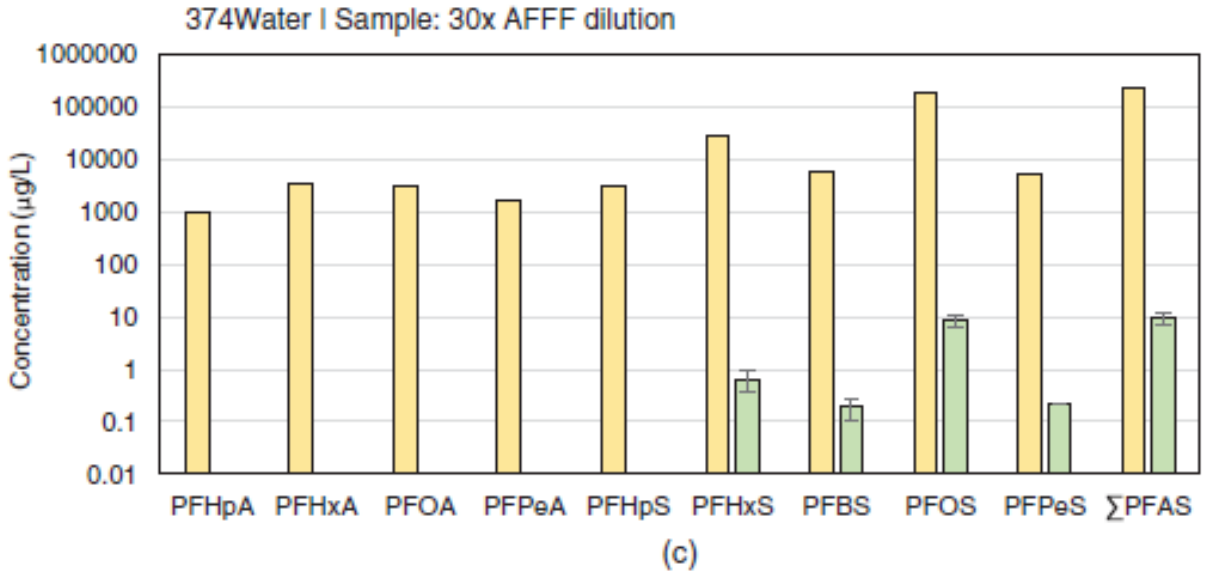
Image Credit: U.S. EPA PFAS Innovative Treatment Team. Potential PFAS Destruction Technology: Supercritical Water Oxidation. Research Brief. January 2021.

SCWO PFAS Removal

- Most studies on AFFF
- 2-5 log reduction for most PFAS
- Does not appear to be chain-length dependent

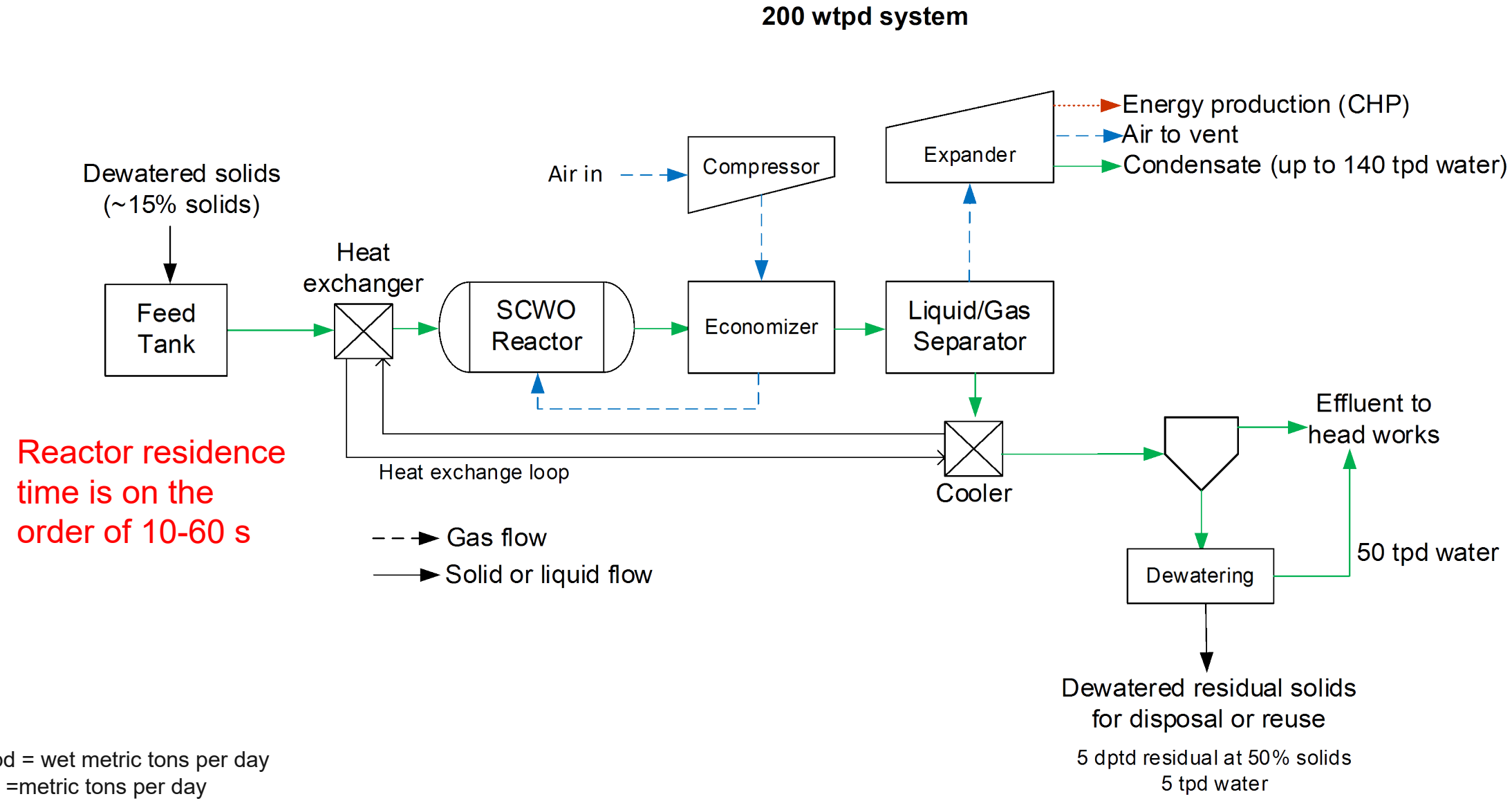






Reference: Krause et al. *J. Environ. Eng.*, 2022, 148(2): 05021006

SCWO Process Flow Diagram



wtpd = wet metric tons per day
tpd =metric tons per day

There's Energy in SCWO Soup

Increasing Energy Content = Self-Sustaining Operation/Energy Production

Variable but low

Concentrates (Foamate)

Image credit: EPOC

<1-2.5 MJ/kg

Landfill Leachate

2.5 MJ/kg threshold for self-sustaining SCWO operation

17 MJ/kg

Biosolids

25-35 MJ/kg

Spent Sorption Media

"SCWO Soup" Conceptual Design

Dewatered solids
(15% TS)
100 wtpd
(85 tpd water, 15 dtpd solids)

GAC/AER at 50% solids (w/w)
25 wtpd
(12.5 tpd water, 12.5 dtpd solids)

Foamate
5 tpd

200 wtpd system

Feed Tank

Make-up Water
(as required)

Air in

Compressor

Expander

Condensate (up to 140 tpd water)

Energy production (CHP)

Air to vent

Heat exchanger

SCWO Reactor

Economizer

Liquid/Gas Separator

Total input:

- 100 wtpd biosolids
- 25 wtpd GAC/AER
- 5 tpd foamate
- +Make-up water

Heat exchange loop

Cooler

Effluent to WRRF (or make-up water)

Dewatering

50 tpd water

Gas flow

Solid or liquid flow

Dewatered residual solids for disposal or reuse

5 dptd residual at 50% solids
5 tpd water

"SCWO Soup" Cost Estimates

Feedstock: 100 wtpd **biosolids** at 15% solids + 25 wtpd **media** at 50% solids + 5 wtpd **foamate**

Capital Costs

- SCWO equipment
- Treatment building
- Feed storage and mixing
- Brine management
- Allowances for mobilization, balance of plant, OH&P, engineering, permitting

O&M Costs

- Staffing
- Equipment maintenence
- Electrical and natural gas use
- Chemical use
- Residual disposal
- Assumes income and fees similar to hazardous waste incinerators

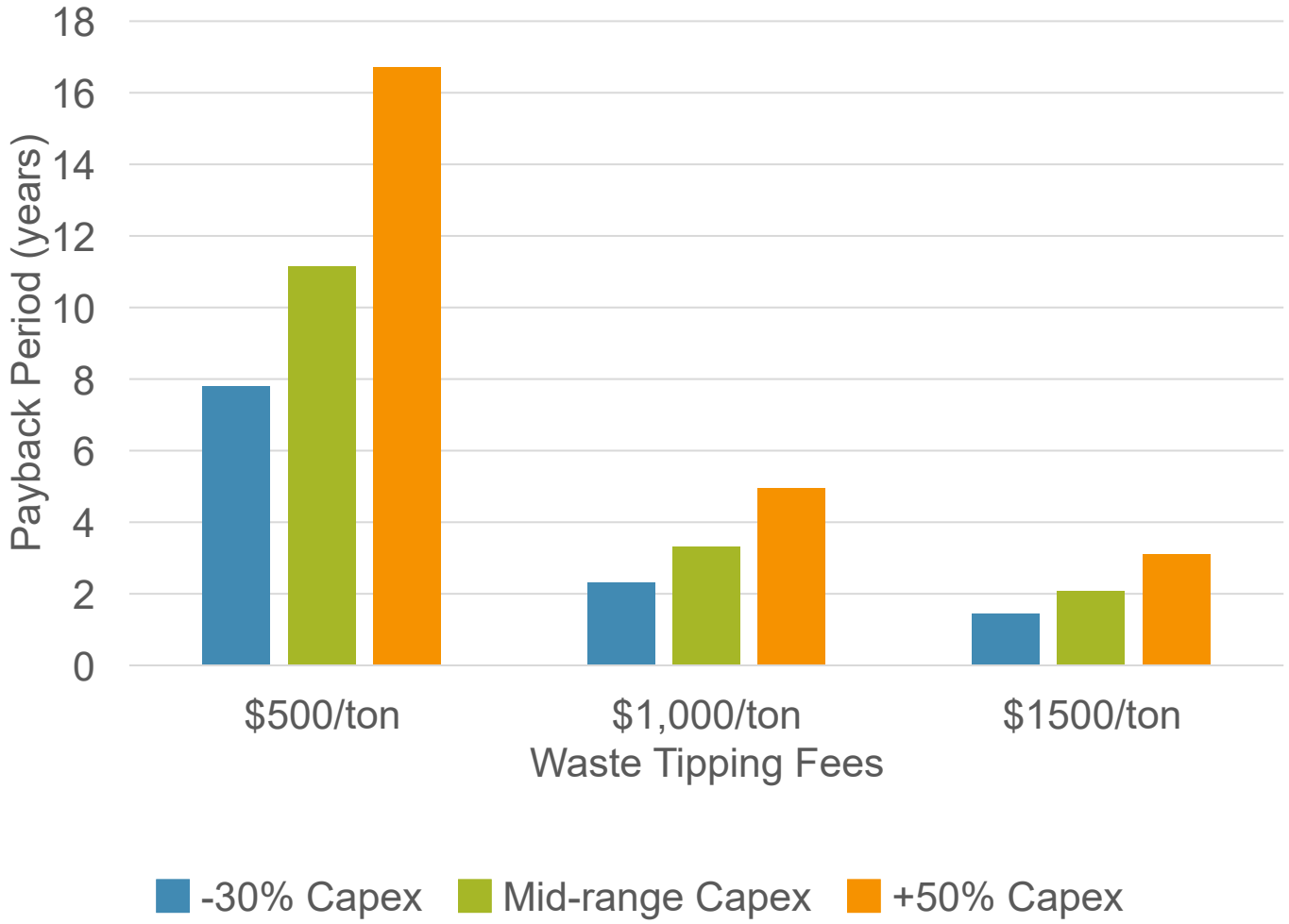
“SCWO Soup” Cost Estimates

Feedstock: 100 wtpd **biosolids** at 15% solids + 25 wtpd **media** at 50% solids + 5 wtpd **foamate**

20-year Present Value Costs (July 2023 basis)

Description	Low End	High End	Notes
Estimated Capital Costs	$62M	$134M	Uncertainty +50%/-30%
Estimated Annual O&M Costs	$3.2M	$13M	Uncertainty +100%/-50%
Estimated Annual income	$33M	$50M	At $1,000-$1,500/wet ton
20-year NPV	$152M	$393M	Less 21% federal income tax

Regional Facility Analysis Conclusions



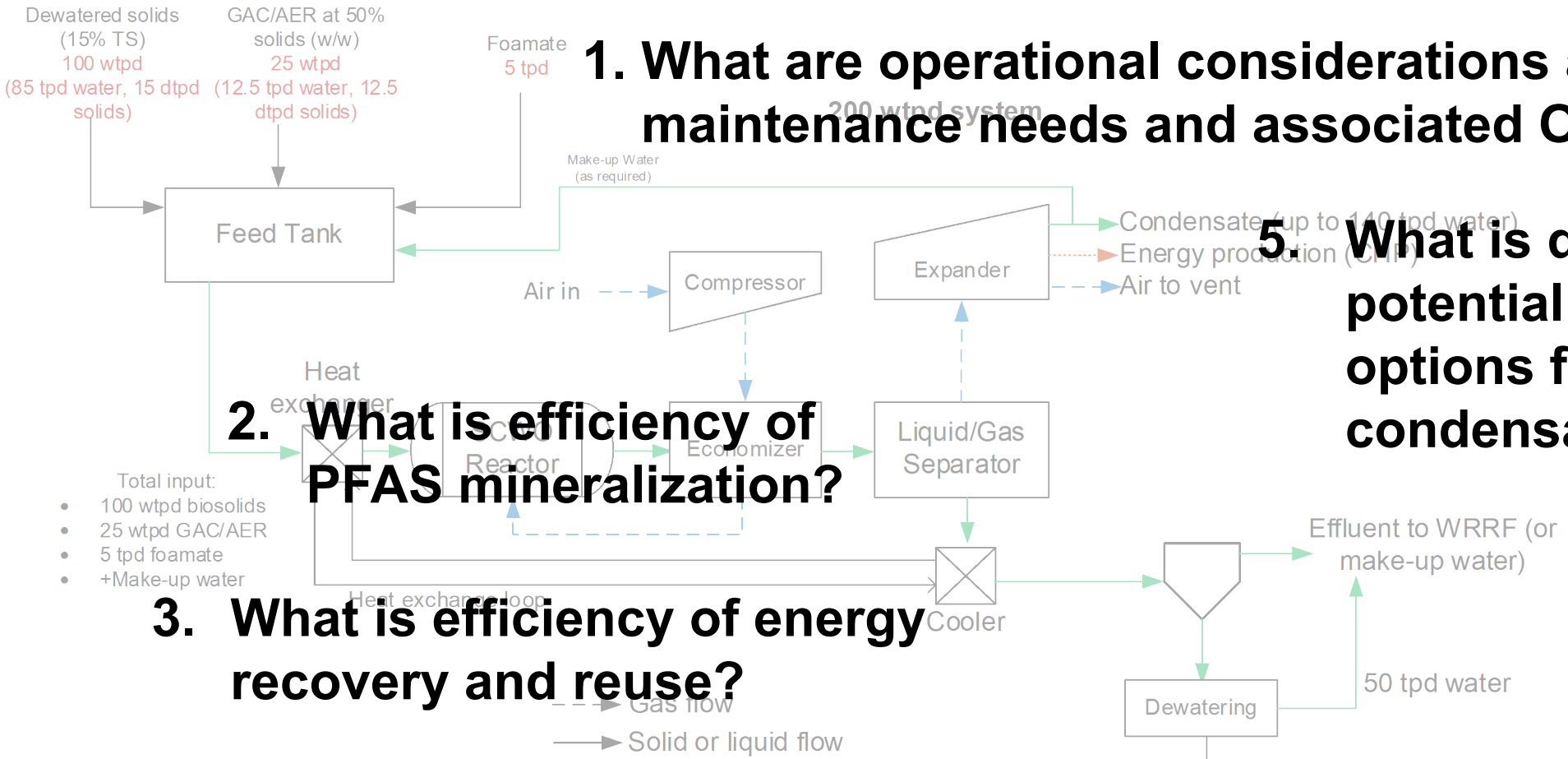
1. A regional SCWO facility accepting mixed, high-energy feedstocks could be **energy-neutral** and **economically viable**, with a payback period <5 years

Regional Facility Analysis Conclusions

2. Additional study is needed to further characterize:
   - Chemical use rates,
   - Monitoring needs,
   - Residual management,
   - Potential beneficial reuse opportunities,
   - Energy use and production, and
   - Long-term maintenance needs
3. Considerations related to permitting, logistics, and environmental justice should be further conceptualized through partnerships with communities, regulators, potential facility operators, and potential facility users

Proposed Regional SCWO Pilot for Mixed Wastes

Proposed Pilot Questions



1. What are operational considerations and maintenance needs and associated O&M costs?
2. What is efficiency of PFAS mineralization?
3. What is efficiency of energy recovery and reuse?
4. What are characteristics, nutrient content, and potential reuse options of residual solids?
5. What is quality and potential reuse options for condensate water?

Proposed Pilot Team

BARR

Project management and delivery
Sampling coordination
Pilot plant design support

UNIVERSITY OF St.Thomas

Experimental design
Data analysis and evaluation
Sampling activities

CITY OF ST.CLOUD MINNESOTA

Host site for pilot, biosolids feedstock
Pilot installation and operational support

374WATER

Pilot equipment
Pilot operation

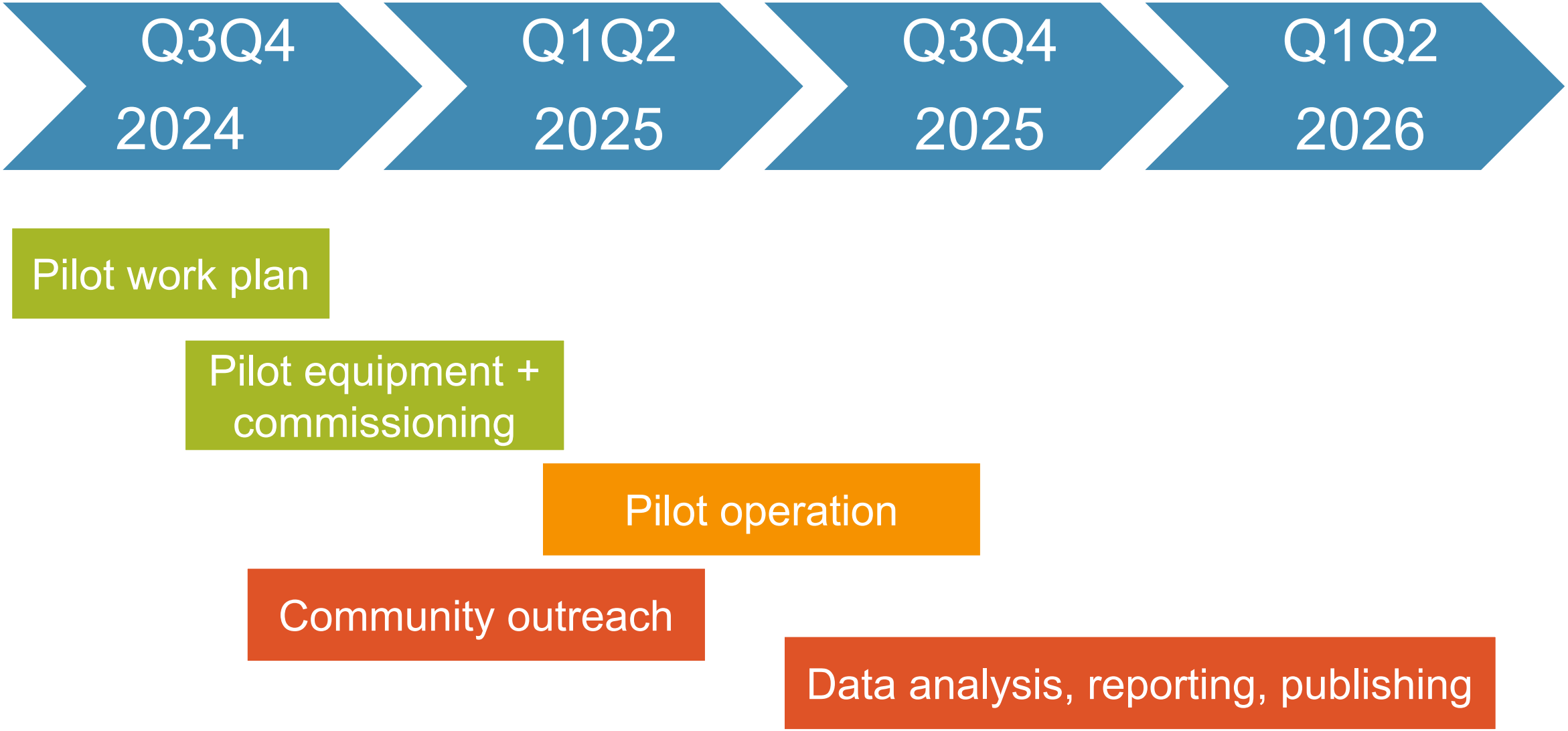
MnTAP

Communication and outreach
Sampling activities

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Funded by State of Minnesota
LCCMR Project 2024-257

Proposed Pilot Timeline



Ali Ling
Assistant Professor
Civil Engineering

aling@stthomas.edu

UNIVERSITY OF St.Thomas

Andy McCabe
Barr Engineering

BARR

Sudhakar Viswanathan
and David Garb
374Water

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Thank you!