Clean Water and a Warming Planet: Are Low-Level PFAS Regulations and Greenhouse Gas Reduction Goals Compatible?

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  - Onur G. Apul, Assistant Professor
  - Jean MacRae, Associate Professor
- Trihydro
  - Sam Ross, Staff Geologist, Cincinnati, Ohio

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PART 1: BACKGROUND

1. Background
2. Maine Study – Assessment Methods
3. Results – GHG and PFAS standards
4. Conclusions/Implications

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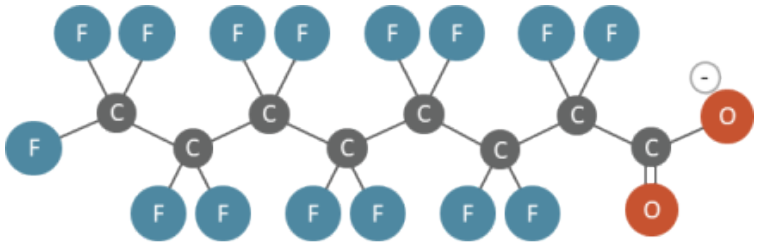
PROJECT OBJECTIVES

- **PFAS**: Drinking water standards (or advisory levels) are trending to lower, unprecedented levels
- **Climate Change**: "EPA is … addressing some of our nation's largest sources of both climate- and health-harming pollution, such as the transportation, oil and natural gas, and power sectors" (epa.gov)
- Current analysis focuses on the State of Maine
- Objective: what is the greenhouse gas (GHG) footprint for treating drinking water to low-ppt levels for PFAS?



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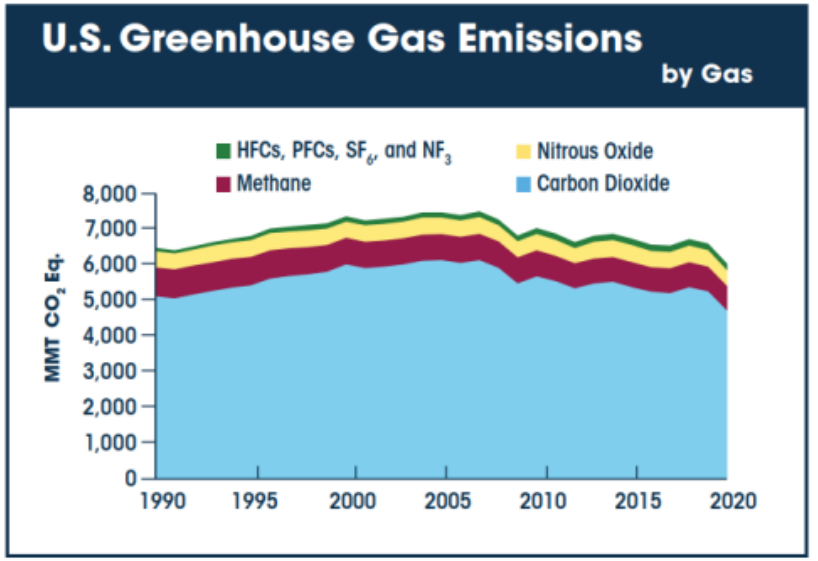
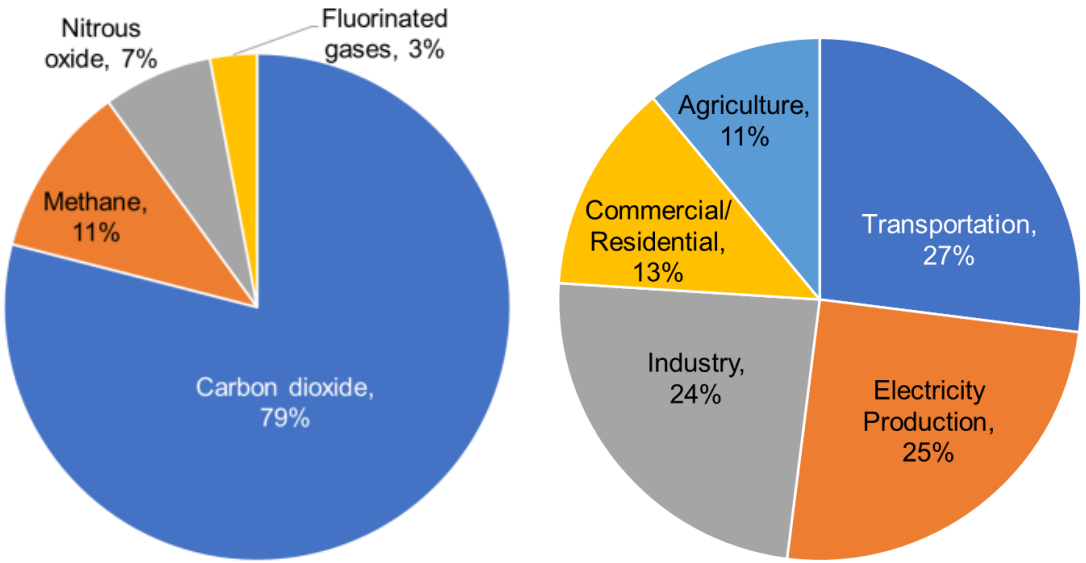
GREENHOUSE GAS (GHG) EMISSIONS

Meanwhile…

- Maine's climate plan
  - "Climate change represents the greatest threat of our age"
  - Reduction targets in GHG
- Several EPA GHG-reduction initiatives; Inflation Reduction Act (Greenhouse Gas Reduction Fund)
- Per capita CO_2-equivalent footprint in U.S. is 15 metric tons per year (MTY)





Data from: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

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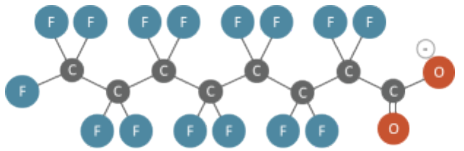
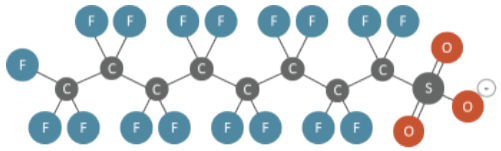
MAINE ANALYSIS

- State of Maine is evaluating a maximum contaminant level (MCL) based on Σ6 PFAS
  - Interim Drinking Water Standard: 20 ng/L
  - PFOA, PFOS, PFNA, PFHxS, PFHpA, PFDA
- State also has plan for 'aggressive' reduction in GHG emissions
- Goal: ensure GHG consideration is included in the PFAS MCL discussion
- Evaluation conducted expeditiously to ensure the GHG is considered in Maine's PFAS MCL discussion

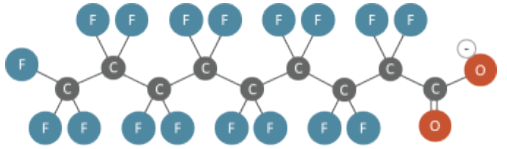
PFOA



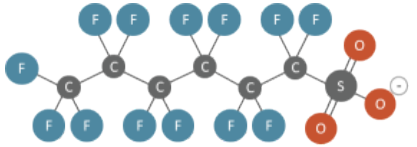
PFOS



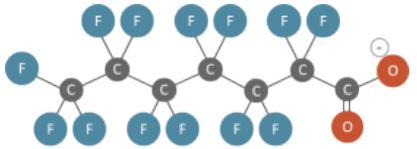
PFNA



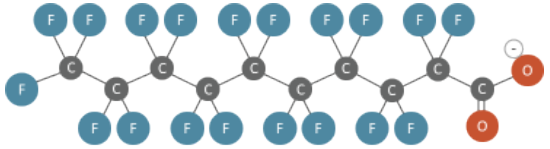
PFHxS



PFHpA



PFDA



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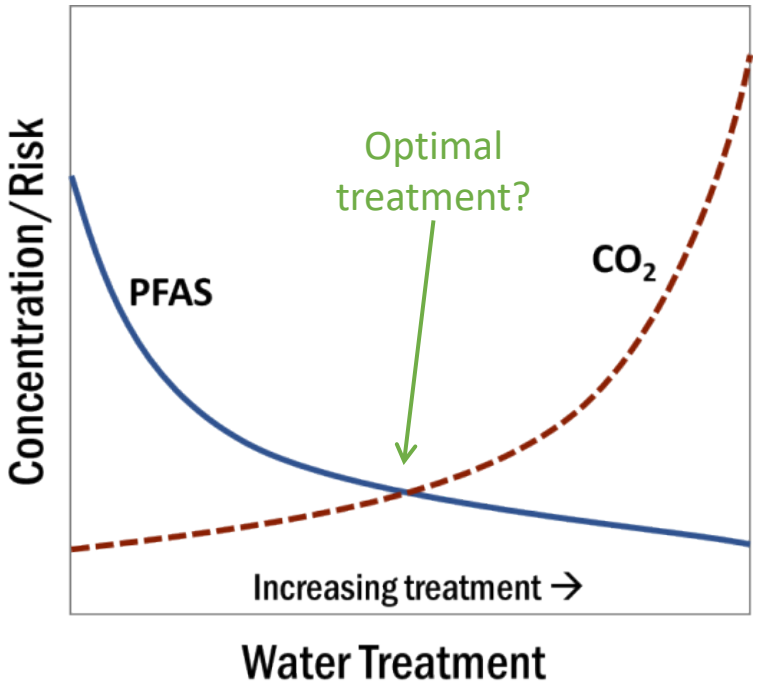
MAINE ANALYSIS

Hypothesis: CO_2 footprint blows up at ultra-low PFAS target treatment levels, providing a 'hidden' cost to society



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PART 2: ASSESSMENT METHODS

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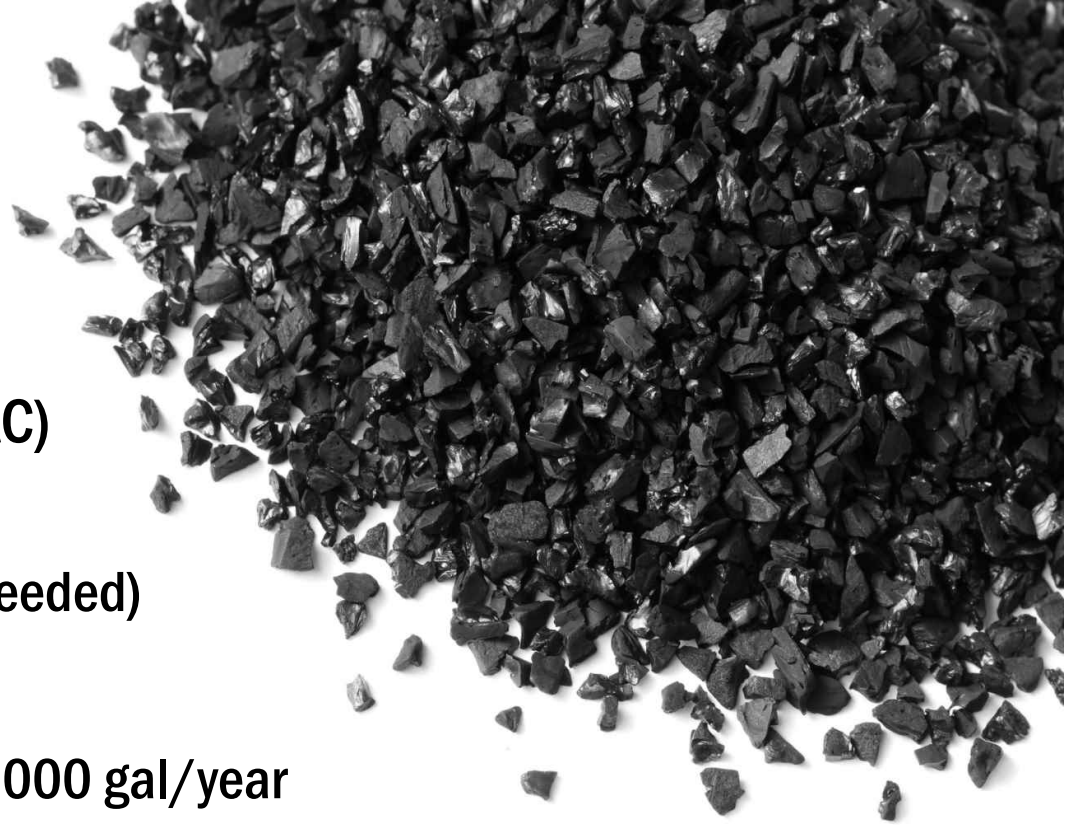
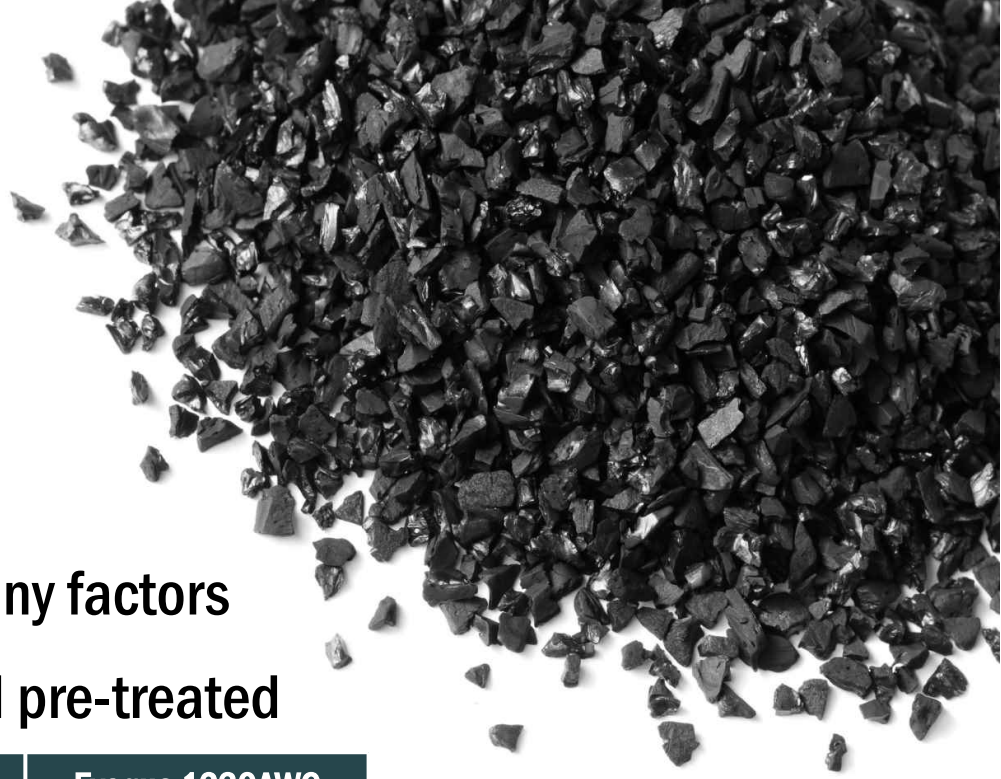
SCENARIOS



- DW treatment using granular activated carbon (GAC)
  - Coal vs coconut based
  - Assuming GAC not currently used (i.e., new vessels needed)
- Scenarios
  - Municipal supply: 19,000 users;700 gpm; 367,000,000 gal/year
  - Domestic well: 4 users @ 49 gpd;70,000 gal/year
- PFAS concentrations from state database
- Treatment goal: 20 ng/L Σ6 PFAS
  - 2, 10, 20, 40, and 200 ng/L

McAlexander, Benjamin L. , Onur G. Apul, Mitchell R. Olson, and Jean MacRae. "Estimated Greenhouse Gas Emissions from PFAS Treatment of Maine Drinking Water." Maine Policy Review 31.1 (2022) : 39 -47, https://digitalcommons.library.umaine.edu/mpr/vol31/iss1/4.

GAC MODELING



- Freundlich Isotherm modeling

$$q_e = K_F C_e^{1/n}$$

- GAC sorption parameters may vary widely based on many factors
- This is a 'best case' scenario in which water is assumed pre-treated

Constituent	Calgon Filtrasorb 400 (Coal-sourced) K_F $[(mg/g)(L/mg)^{-1/n}]$	Calgon Filtrasorb 400 (Coal-sourced) 1/n	Evoqua 1230AWC (Cocunut-sourced) K_F $[(mg/g)(L/mg)^{-1/n}]$	Evoqua 1230AWC (Cocunut-sourced) 1/n
PFOA	8.95	0.7	3.96	0.51
PFOS	79.3	1.00	4.54	0.4
PFNA	9.43	0.70	9.91	0.72
PFHxS	21.6	0.85	24.3	0.88
PFHpA	1.8	0.3	1.85	0.31
PFDA	3.9	0.51	4.56	0.54

Values from: Burkhardt et al. 2022. "Modeling PFAS Removal Using Granular Activated Carbon for Full-Scale System Design." Journal of Environmental Engineering

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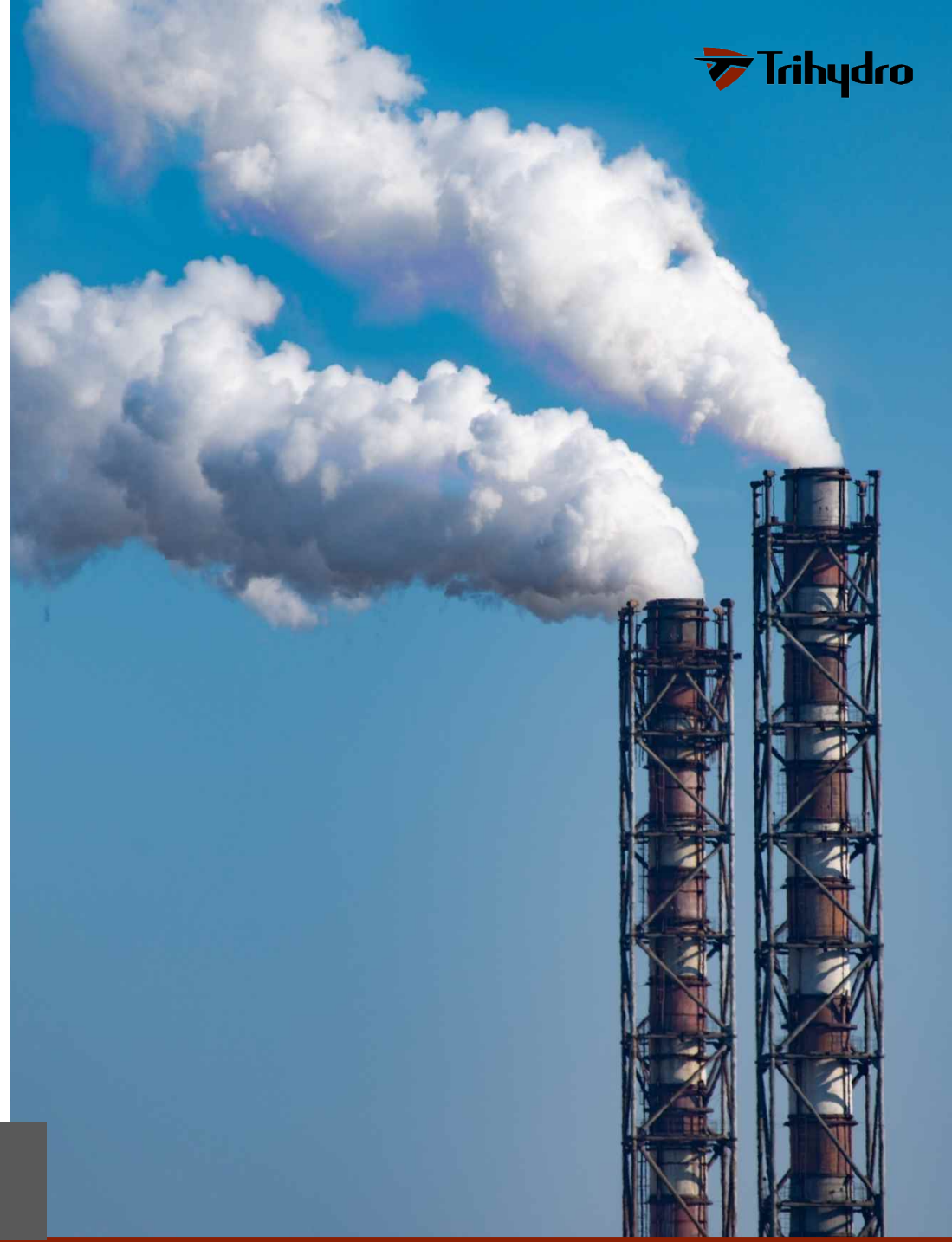
CO_2 EQUIVALENT

- SiteWise® software & published LCA values
- GAC footprint components
  - Production – coal vs coconut/biomass
  - Transportation – per-ton, mobilization from PA
  - Storage vessel – 5 yr amortization
  - Recycling – GAC regenerated for other use
- Ultimate PFAS destruction not included

https://www.sustainableremediation.org/guidance-tools-and-other-resources



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CO_2 EMISSION FACTORS

DESCRIPTION	VALUE	UNITS	SOURCE
ACTIVATED CARBON GENERATION			
Coal-based activated carbon generation	18.28	kg CO_2 eq / kg AC	Gu et al. (2018)
Woody biomass - based activated carbon generation	8.6	kg CO_2 eq / kg AC	Gu et al. (2018)
ACTIVATED CARBON TRANSPORTATION FROM VENDOR			
Coal-based activated carbon transport	0.95	kg CO_2 eq / kg AC	SiteWise
Coal-based activated carbon transport	1.13	kg CO_2 eq / kg AC	SiteWise
Coconut-based activated carbon transport	0.92	kg CO_2 eq / kg AC	SiteWise
Coconut-based activated carbon transport	1.0	kg CO_2 eq / kg AC	SiteWise
ACTIVATED CARBON REGENERATION			
Activated carbon regeneration	0.7	kg CO_2 eq / kg AC	He (2012)
AC VESSEL INSTALLATION			
Steel	1.77	kg CO_2 eq / kg steel	SiteWise
AC vessel, large	682	kg steel	https://recofiltration.com/liquid-scrubbers
AC vessel, large	1,207	kg CO_2 eq / AC vessel, large	Calculated
AC vessel shipping, large	5,438	kg CO_2 eq / AC vessel, large	SiteWise
Fiberglass (E-glass)	0.158	kg CO_2 eq / kg fiberglass	Dai et al. (2015)
AC vessel, small	23	kg fiberglass	General Carbon Corporation interview of staff
AC vessel, small	3.6	kg CO_2 eq / AC vessel, small	Calculated
AC vessel shipping, small	1,130	kg CO_2 eq / AC vessel, small	SiteWise

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AC - activated carbon
CO_2 eq - CO_2 equivalent global warming potential

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PART 3: RESULTS

1. Background
2. Maine Study – Assessment Methods
3. Results – GHG and PFAS standards
4. Conclusions/Implications

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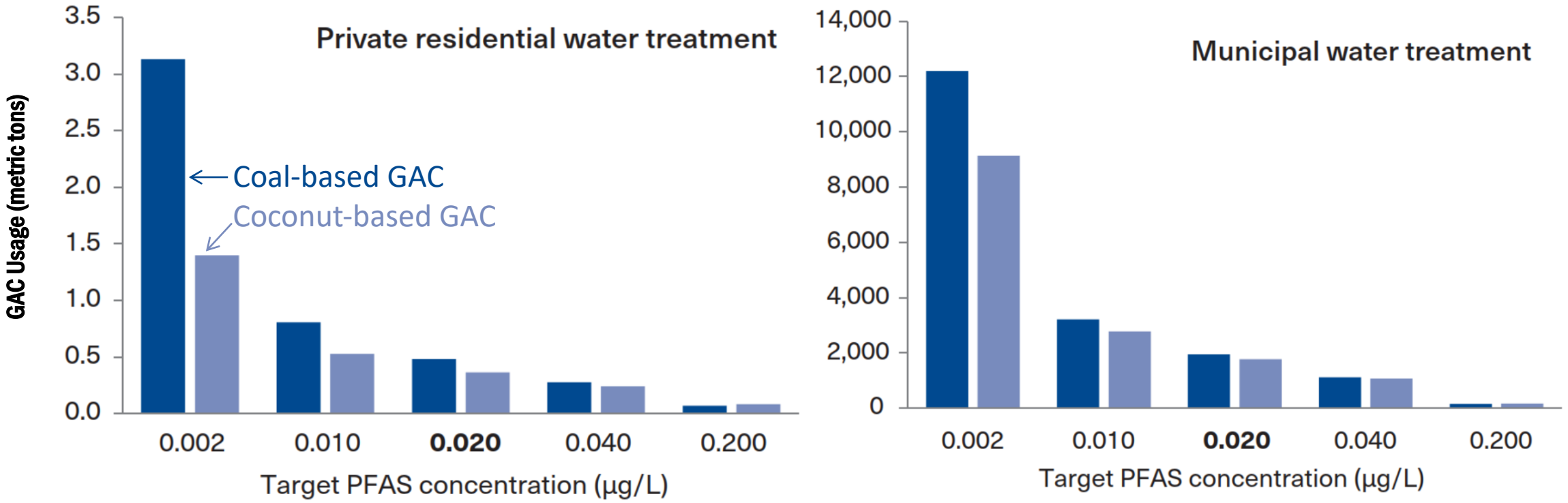
MODEL OUTPUT: GHG EMISSIONS



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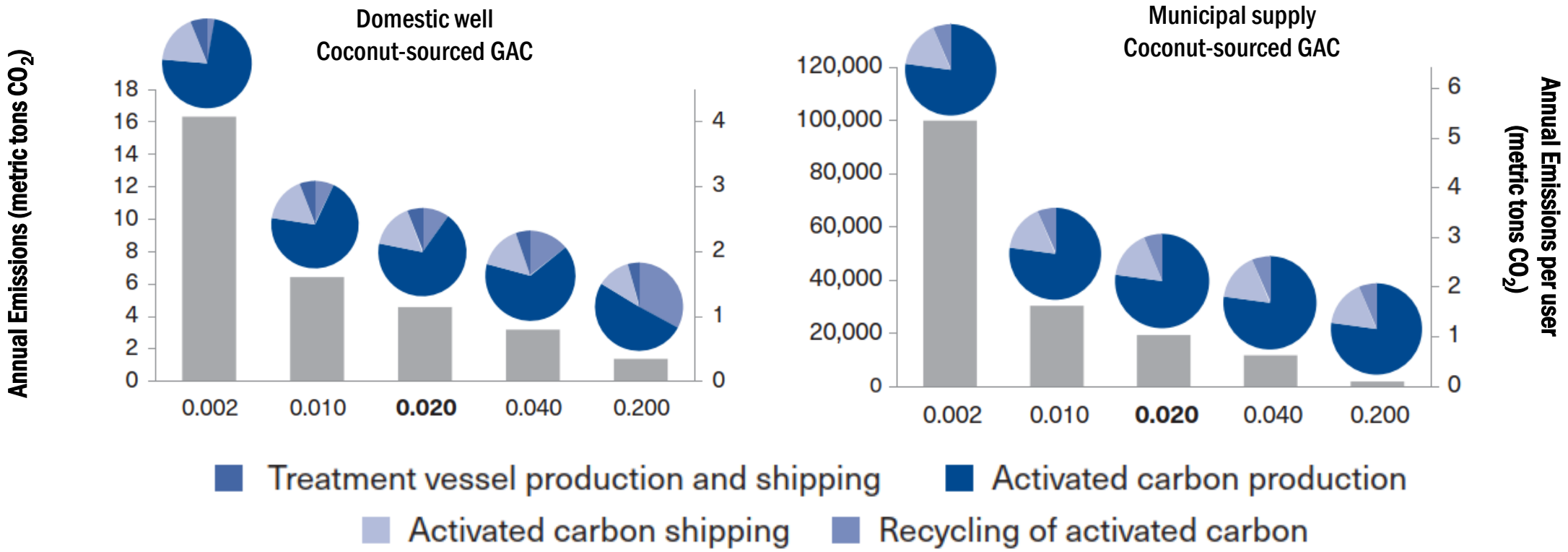
GHG EMISSIONS: SOURCE EVALUATION



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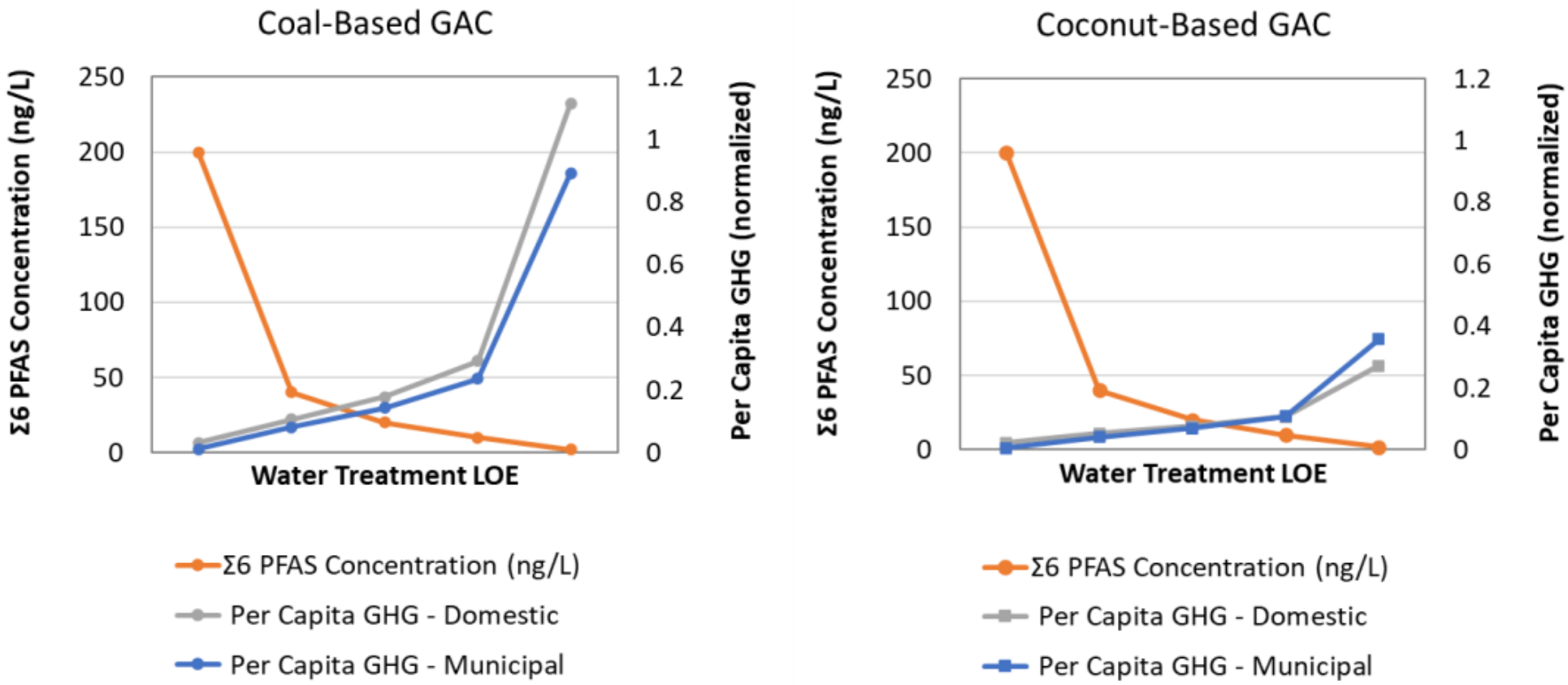
RESULTS



CO_2 footprint normalized to U.S. average (15 metric tons CO_2 equivalent)

LOE – level of effort

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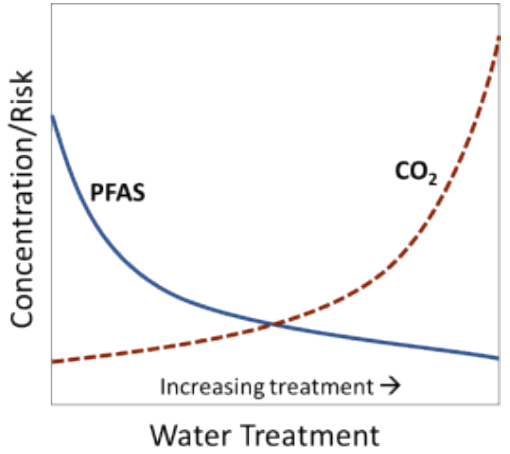
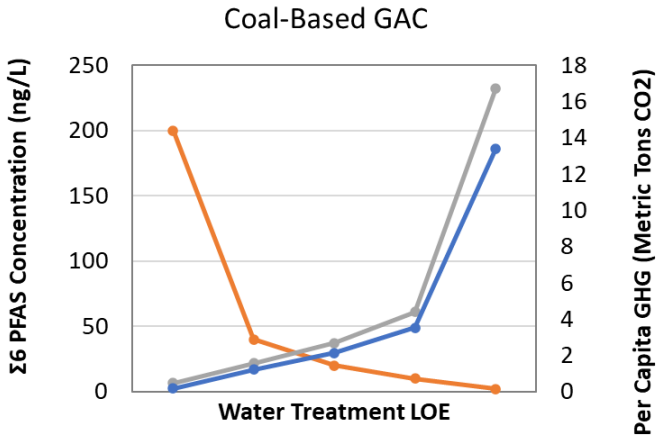
PART 4: CONSLUSIONS/ IMPLICATIONS

1. Background
2. Maine Study – Assessment Methods
3. Results – GHG and PFAS standards
4. Conclusions/Implications

MAINE EVALUATION CONCLUSIONS

- CO_2 footprint can be significant, particularly at ultra-low ppt levels (2 ng/L)
- GAC CO_2 footprint primarily associated with production
- GAC sorption sites distributed relatively evenly between species (all long chain PFAS)
- Overall pattern follows hypothesis
- Note need to normalize y-axes for risk





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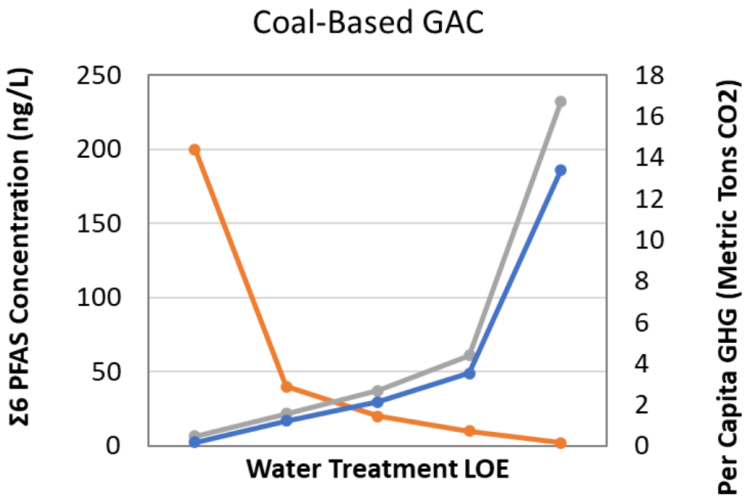
PATH FORWARD

- Project team is exploring an expanded analysis with partners
- Unifying the y-axes (risk associated with PFAS and CO_2)
- Enhancing the evaluation
  - Broader assessment – IX, RO, NF
  - Other states/nation-wide analysis
- Footprint for cleaning up PFAS in the environment
  - Pump-and-treat
  - PFAS destruction via incineration
  - Stabilization versus destruction
- Non-ideal scenarios
  - Water matrix effects (groundwater/wastewater/leachate)
  - Include short-chain PFAS



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CONCLUDING THOUGHTS

- What PFAS treatment levels are warranted based on toxicology data?
- Is it fair to accept some PFAS risk in exchange for reduced GHG footprint?
- Other considerations
  - Improve carbon use efficiency
  - Alternatives to GAC

QUESTIONS?

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