



Some Like It Hot, but PFAS Does Not! Advancing  
Thermal Destruction of PFAS in Biosolids

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January 25, 2023

# Agenda

1. PFAS Regulatory Triggers
2. PFAS Destruction Technologies
3. SVCW and BioForce Tech
4. PFAS Study at SVCW

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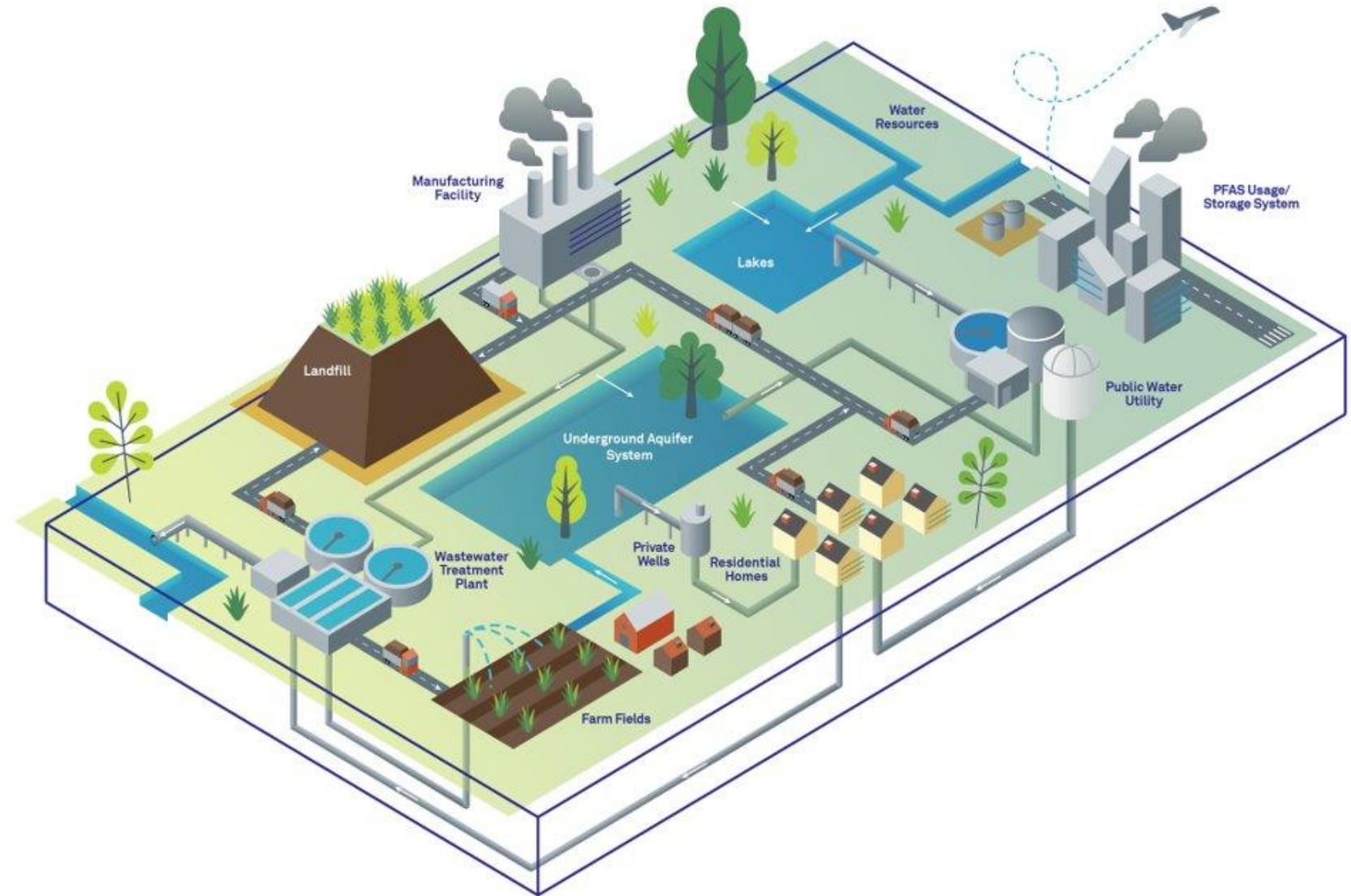
# PFAS Regulatory Triggers



# PFAS Impact the Entire Water Cycle

## Points of Human Exposure

- Air
- Consumer Products
- Private/Public Water
- Food and Food Wrappers



# Wastewater

## NPDES Permits Have New PFAS Requirements

### State Activities

- CA, CO, MI, MS, and NJ including monitoring requirements
- MI, NJ, VT, and WI developing water quality standards

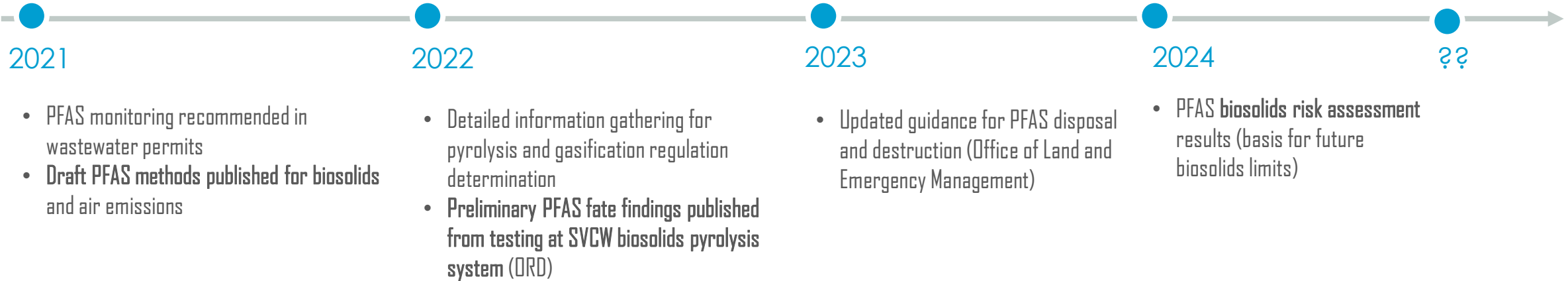
### National Activities

- 2020: **EPA recommends NPDES permit monitoring – monitoring requirements present in MA draft permits**
- EPA developing water quality criteria for human health and aquatic life (anticipated 2024)

# Biosolids

## National Overview

EPA ACTIONS



EPA investigating destructive technologies and detection methods for PFAS in biosolids as risk assessment work continues.

# Biosolids

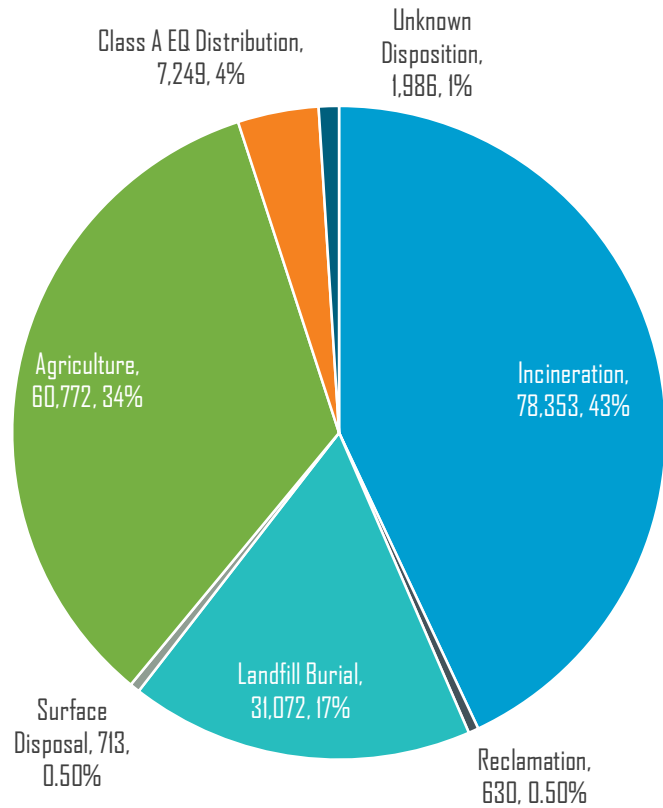
## Land Application is Being Challenged

### States

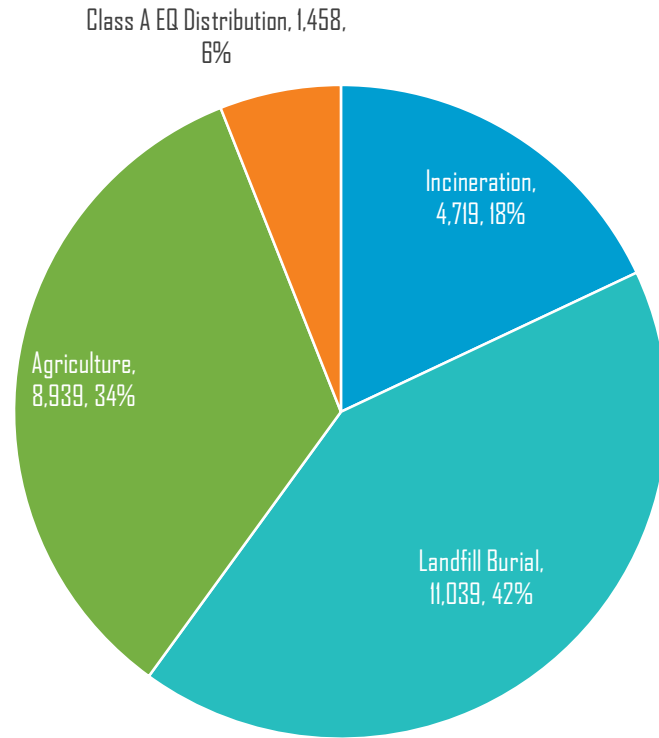
- ME biosolids land application ban
- Regulatory investigations underway in MA, NH, and VT
- **Increased costs** for solids disposal
- CA, IL, MI, CO, WA, and more gathering data



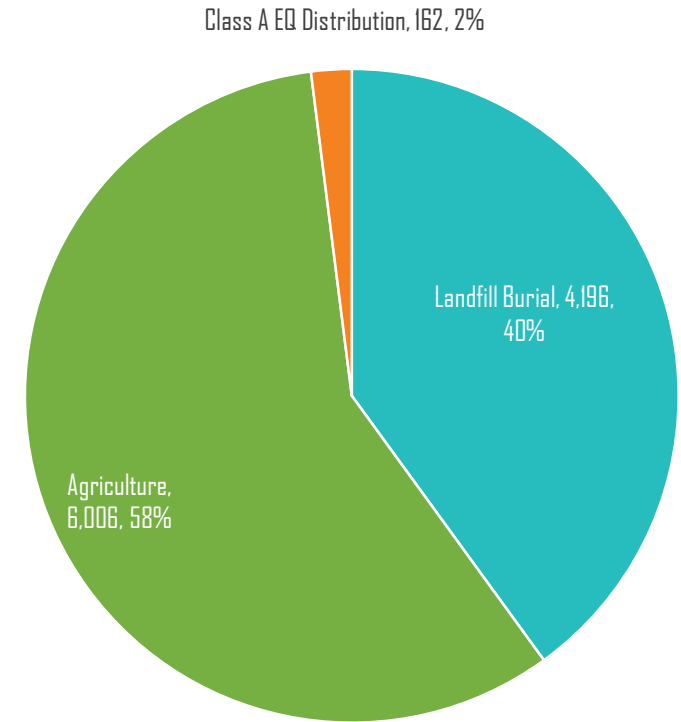
# Biosolids End Use in New England



Massachusetts



New Hampshire



Vermont





# A Long Brewing Crisis

- Well documented, long-standing lack of landfill capacity in the region
- Aging regional incinerators
- Lengthy permitting processes, involved public
- Lack of management capacity has led to both rapidly rising costs AND concerns about reliability of service/outlets

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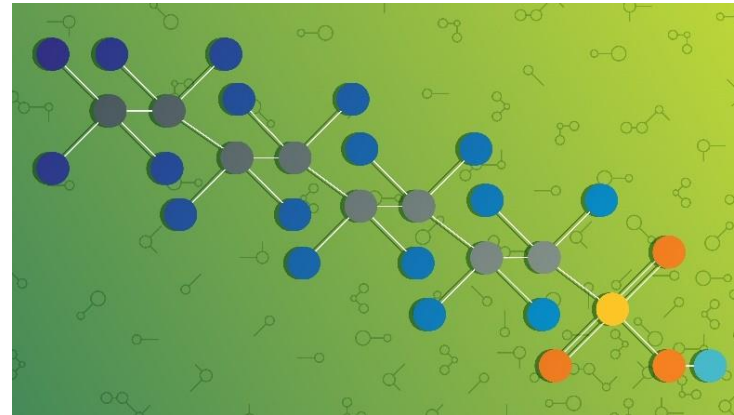
# PFAS Destruction Technologies



# PFAS Properties

The carbon structure of PFAS makes it very difficult to break down.

## Molecular Structure of PFOS



## Strongest Bond

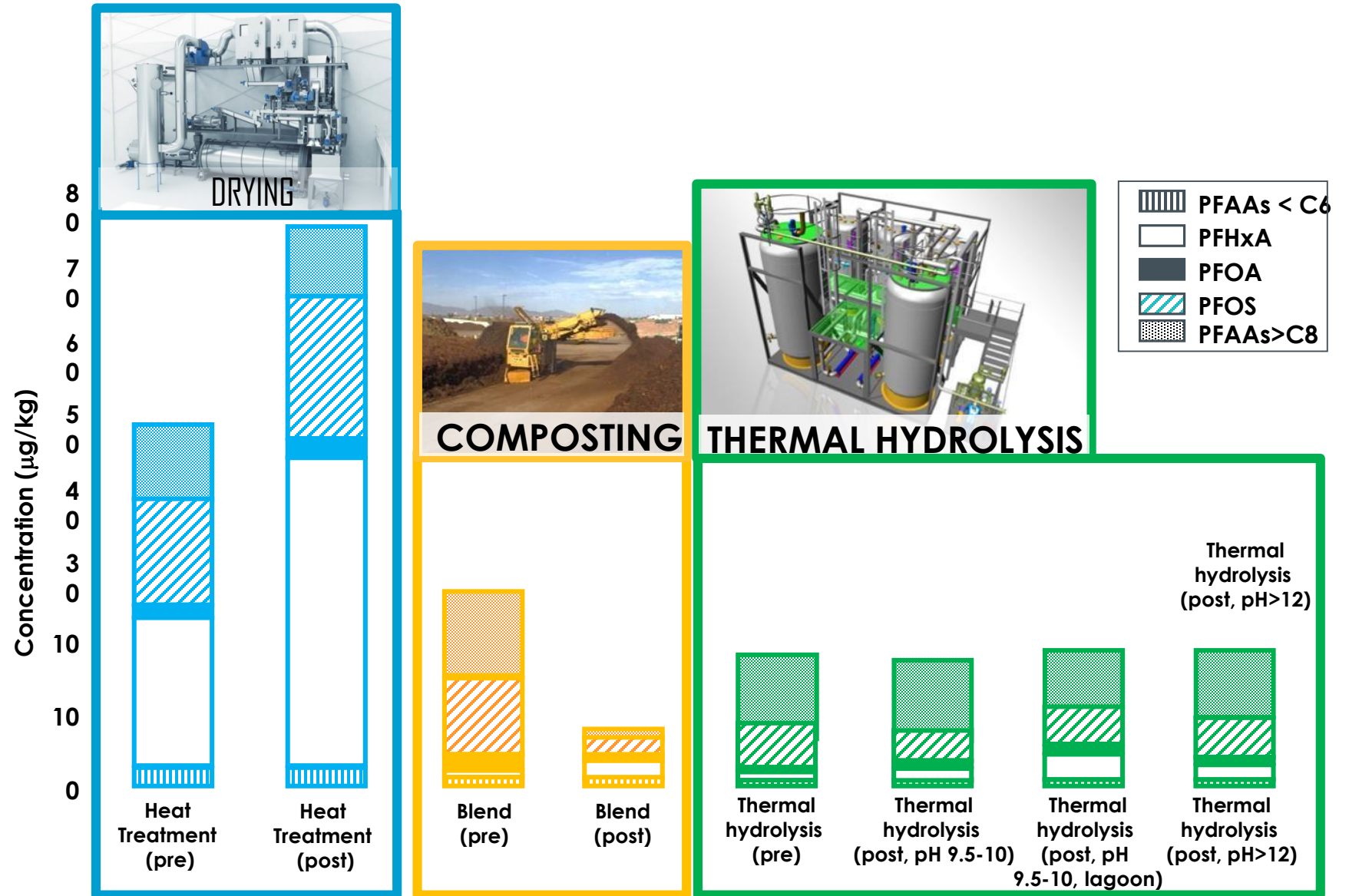
**kJ/mol of bonds**

<b>C-F</b>	<b>485</b>
C-H	436
C-C	346
C-Cl	339
C-N	305
C-Br	285
C-S	272

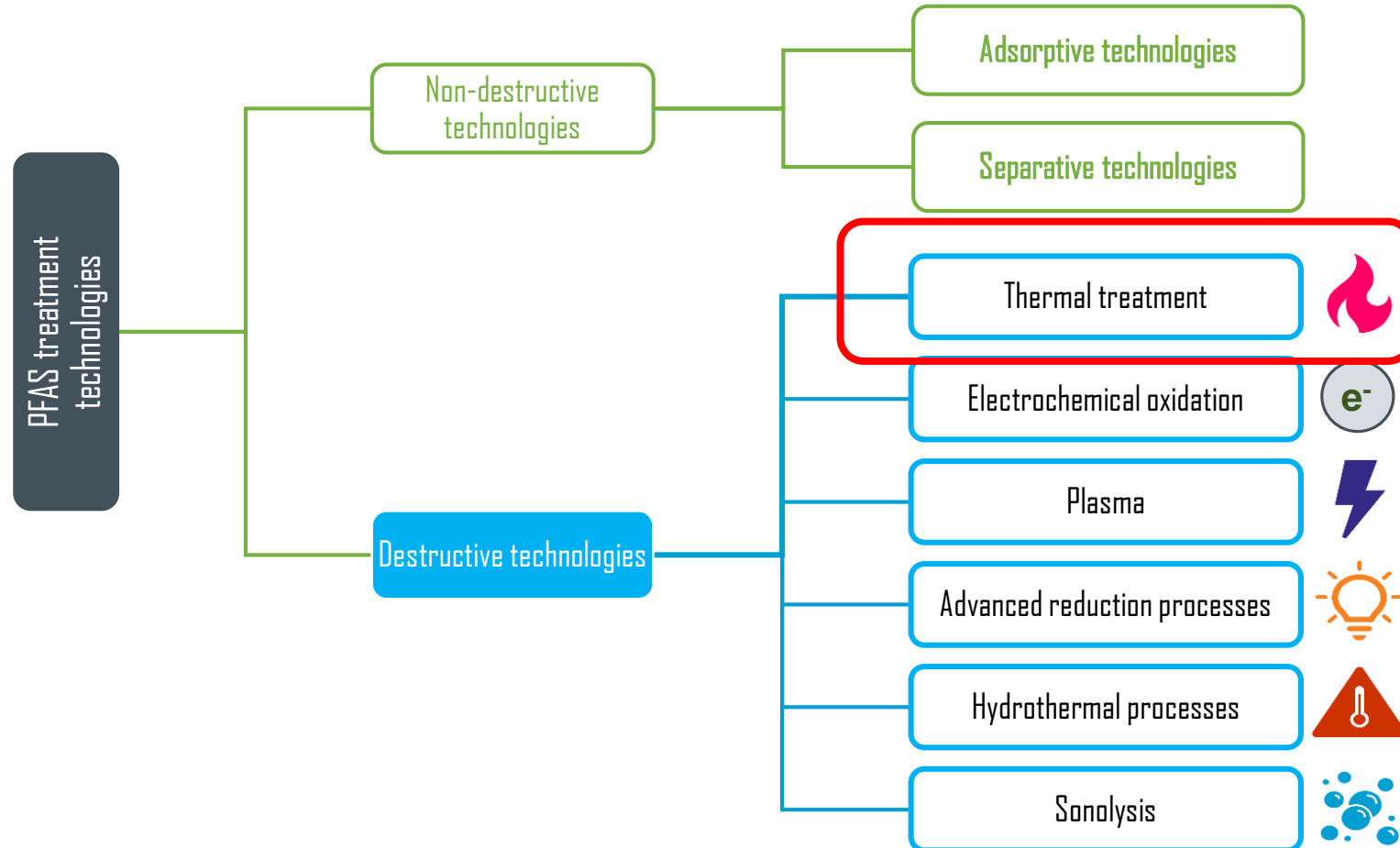
**High C-F Bond Energy**

# Common Solids Stabilization Processes Do Not Destroy PFAS

(Lazcano, Perre, Mashtare, Lee; 2019)



# PFAS Destructive Treatment Technologies



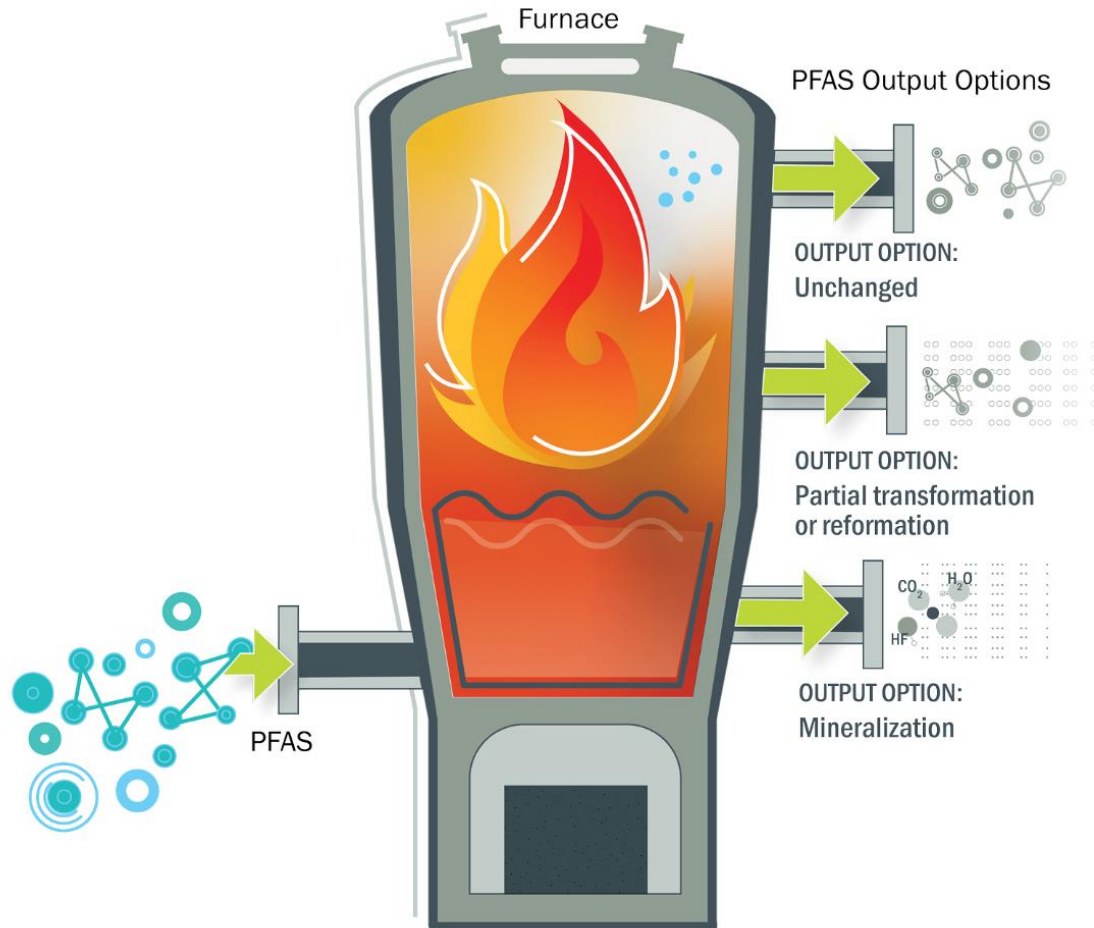
# Thermal Treatment

## Incineration/Pyrolysis/Gasification

	Incineration	Pyrolysis	Gasification
Air/Oxygen Requirement	> Stoichiometric amount	None	< Stoichiometric amount
Temperature	800°C - 900°C	300°C - 750°C (950 °C+ thermal oxidizer)	800°C – 1,000°C
Products	Heat, ash, carbon dioxide, and water	Heat, char, and hydrogen rich synthetic gas (syngas)	Heat and syngas, sometimes char

# Thermal Treatment

## Incineration/Pyrolysis/Gasification

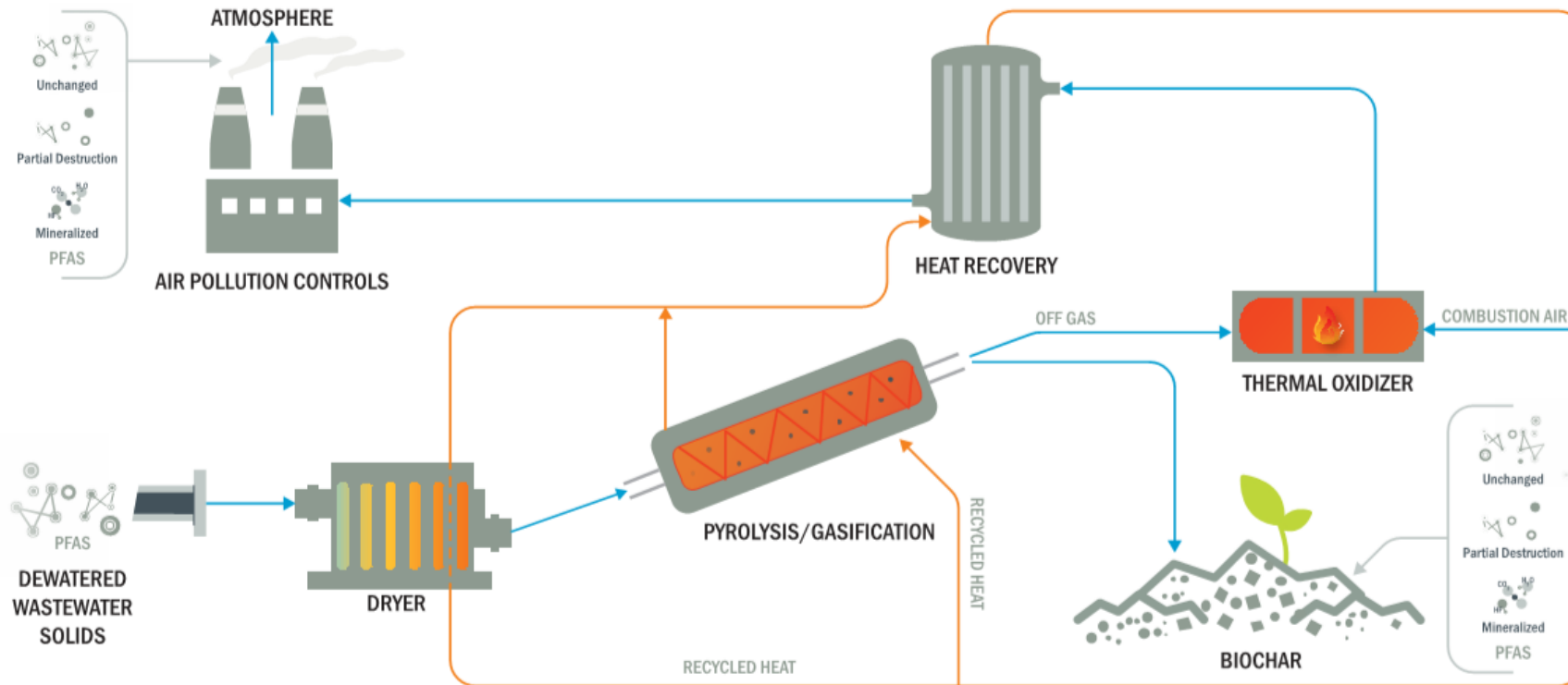


## How does it work?

- 3 T's:
  - Time
  - Temperature
  - Turbulence

Winchell, L.J., Wells, M.J., Ross, J.J., Fonoll, X., Norton Jr., J.W., Bell, K.Y. PFAS Thermal Destruction at Wastewater Treatment Facilities: A State of the Science Review. *Water Environ. Res.* <http://dx.doi.org/10.1002/wer.1483>

# Remaining Questions



Winchell, L.J., Ross, J.J., Brose, D. A., Pluth, T. B., Fonoll, X., Norton Jr., J.W., Bell, K.Y. High-temperature Technology Survey and Comparison among Incineration, Pyrolysis, and Gasification Systems for Water Resource Recovery Facilities *Water Environ. Res.* <http://dx.doi.org/10.1002/wer.10715>



# BC Thermal Treatment Research

## Sewage Sludge Incineration (SSI)



Project #5111

### Studying the Fate of PFAS through Sewage Sludge Incinerators



#### Per- and polyfluoroalkyl substances thermal destruction at water resource recovery facilities: A state of the science review

Lloyd J. Winchell ✉, John J. Ross, Martha J. M. Wells, Xavier Fonoll, John W. Norton Jr., Katherine Y. Bell

First published: 15 November 2020 | <https://doi.org/10.1002/wer.1483> | Citations: 4



#### Analyses of *per*- and polyfluoroalkyl substances (PFAS) through the urban water cycle: Toward achieving an integrated analytical workflow across aqueous, solid, and gaseous matrices in water and wastewater treatment

Lloyd J. Winchell <sup>1,2,✉</sup>, Martha J.M. Wells <sup>3,4,5</sup>, John J. Ross <sup>6</sup>, Xavier Fonoll <sup>7</sup>, John W. Norton Jr. <sup>8</sup>, Stephen Kuplicki <sup>9</sup>, Majid Khan <sup>9</sup>, Katherine Y. Bell <sup>6</sup>

## Pyrolysis/Gasification



### Developing a PFAS Destruction Protocol Through Pyrolysis and Thermal Oxidation (In Contracting, Opportunities for Additional Partners)



#### Pyrolysis and gasification at water resource recovery facilities: Status of the industry

Lloyd J. Winchell ✉, John J. Ross, Dominic A. Brose, Thais B. Pluth, Xavier Fonoll, John W. Norton Jr., Katherine Y. Bell

First published: 04 March 2022 | <https://doi.org/10.1002/wer.10701>



#### *High-temperature Technology Survey and Comparison among Incineration, Pyrolysis, and Gasification Systems for Water Resource Recovery Facilities (Manuscript in Publication)*

# Our Study in the Research Continuum

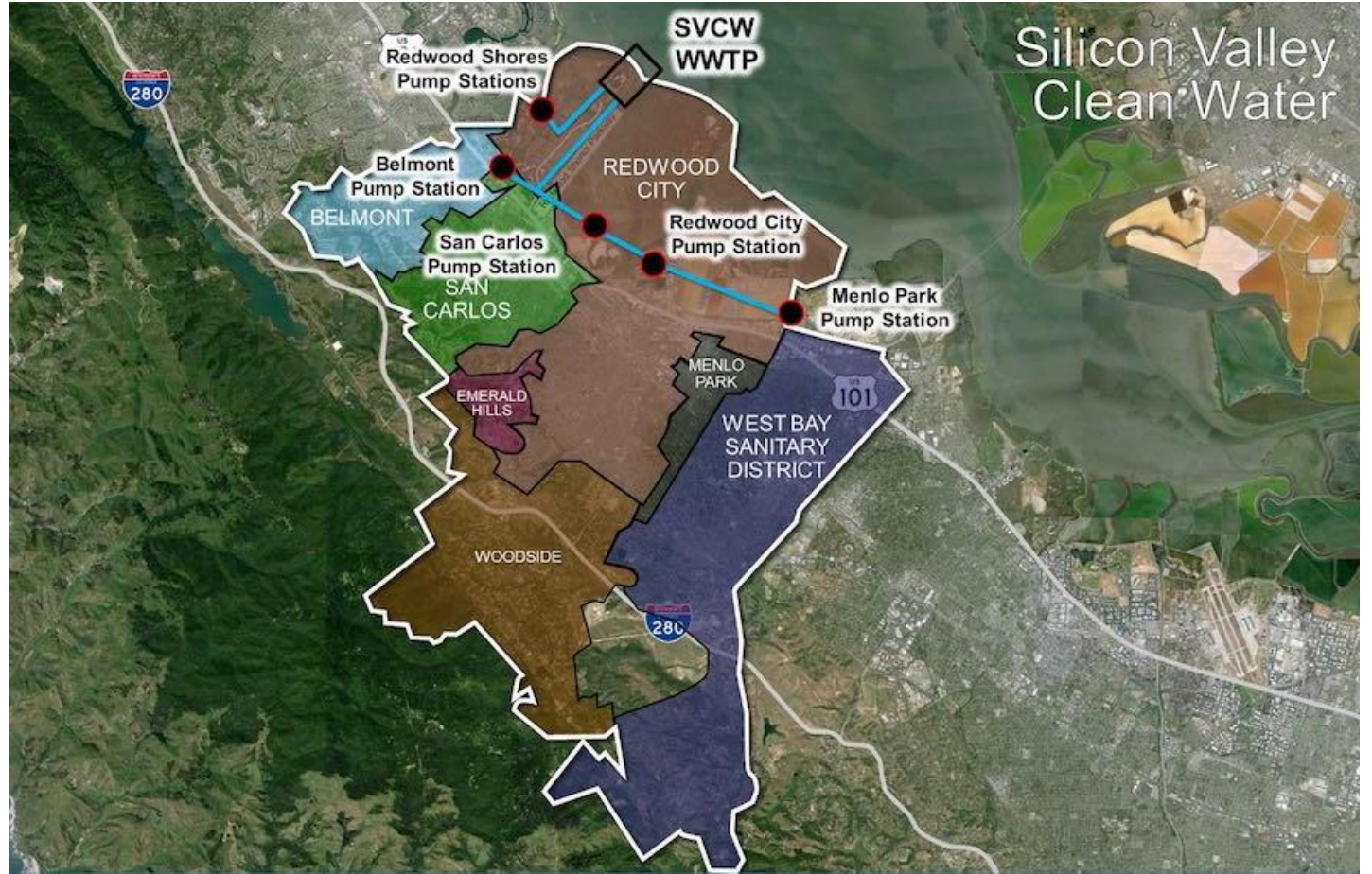
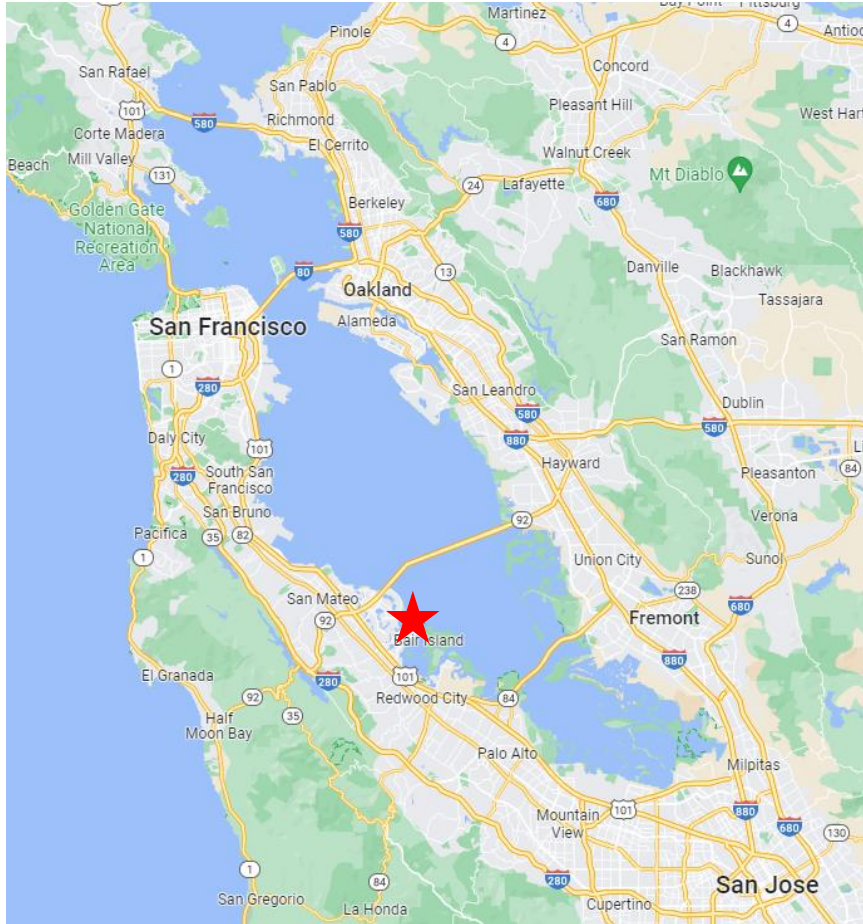
Studies	Status	Key Features
SVCW Field Testing (USEPA)	Field Work: Aug 2020 Publication: Feb 2022	<ul style="list-style-type: none"><li>- PFAS below MDLs in biochar</li><li>- Limited/inconclusive emissions testing</li></ul>
WRF 5111: SSI PFAS Fate Study (BC)	Awarded: 2021 Full-scale testing complete this week	<ul style="list-style-type: none"><li>- Full-scale PFAS fate study through two SSIs</li></ul>
WRF 5107: Understanding Pyrolysis for PFAS Removal (Hazen and MC)	Awarded: 2021 Full scale system in commissioning	<ul style="list-style-type: none"><li>- Full-scale PFAS fate study through pyrolysis with condenser</li></ul>
Current Study (SVCW and BC with WEF and partners)	Bench scale unit in commissioning	<ul style="list-style-type: none"><li>- Full- and lab-scale PFAS fate study through pyrolysis + thermal oxidizer</li></ul>

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# SVCW and BioForce Tech

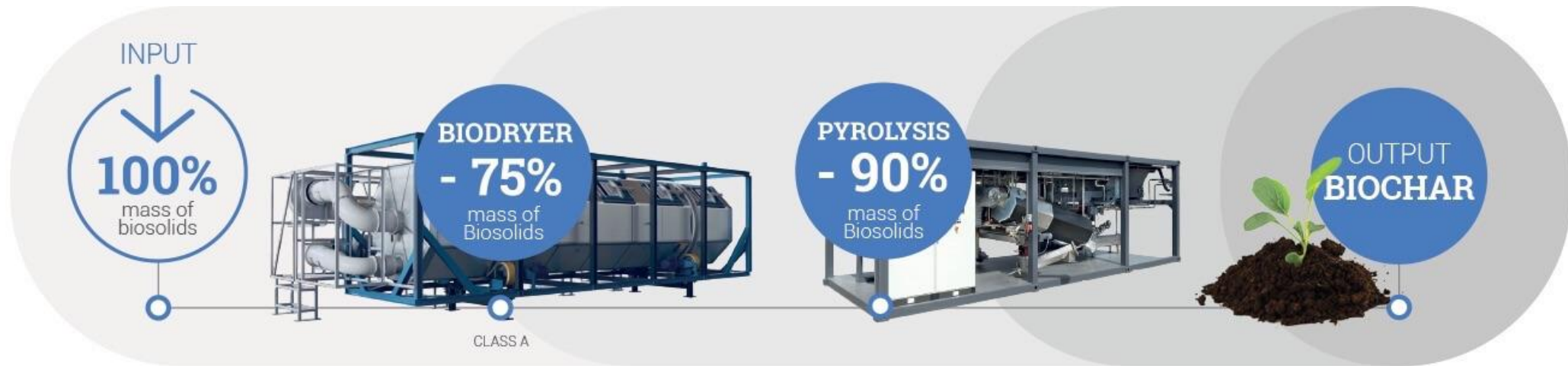


# Silicon Valley Clean Water (SVCW) Location



# BioforceTech Process

- BioDryers with Pyrolysis are sized to take 3,000 tons of 20% biosolids
  - Account for approximately 40% of SVCW's biosolids
- 300 tons of biochar can be produced



# PFAS Study Background

SVCW, which has one of the only large scale biosolids pyrolysis systems in the country and is an industry-leading wastewater treatment facility in California, has agreed to partner with BC on this project to advance the industry's knowledge on PFAS destruction.



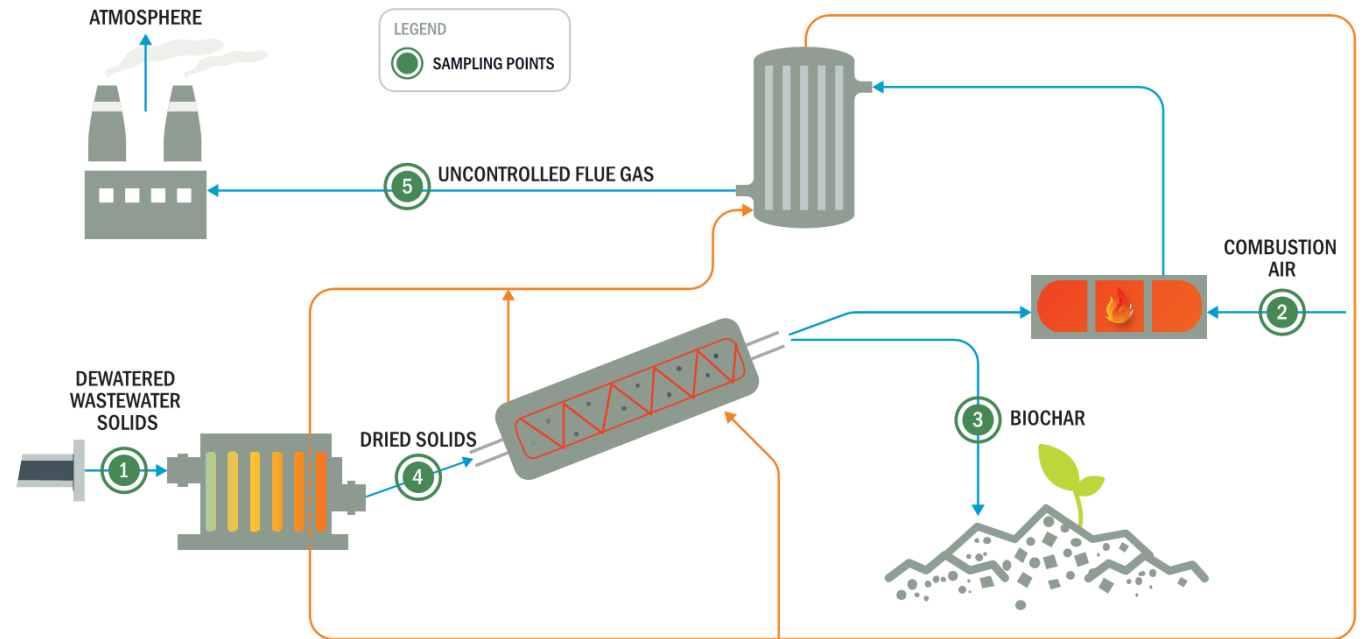


# Purpose

- Characterize the fate of PFAS through both a lab scale pyrolysis system and a full-scale system
- Approach a PFAS mass balance across pyrolysis system to include both the solid and gas-phases
- Gain a better understanding of the "3 T's"  
(time, temperature, turbulence) needed for PFAS destruction in pyrolysis systems

# General Approach

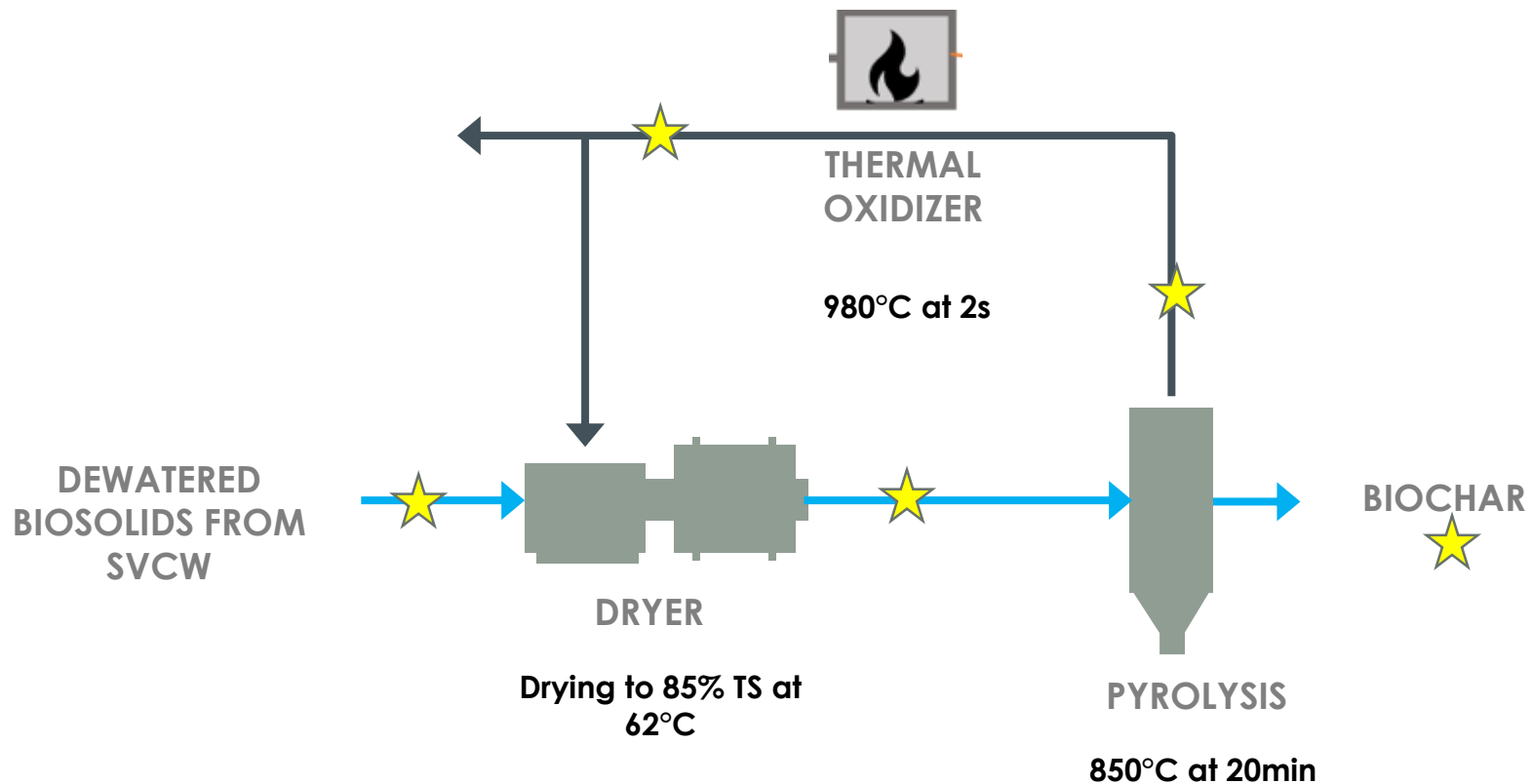
- All inputs and outputs (incl. stack emissions)
- Targeted PFAS Analysis
- Targeted Byproducts: CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>8</sub>
- Non-Targeted Analysis
- Total Organic Fluorine Balance





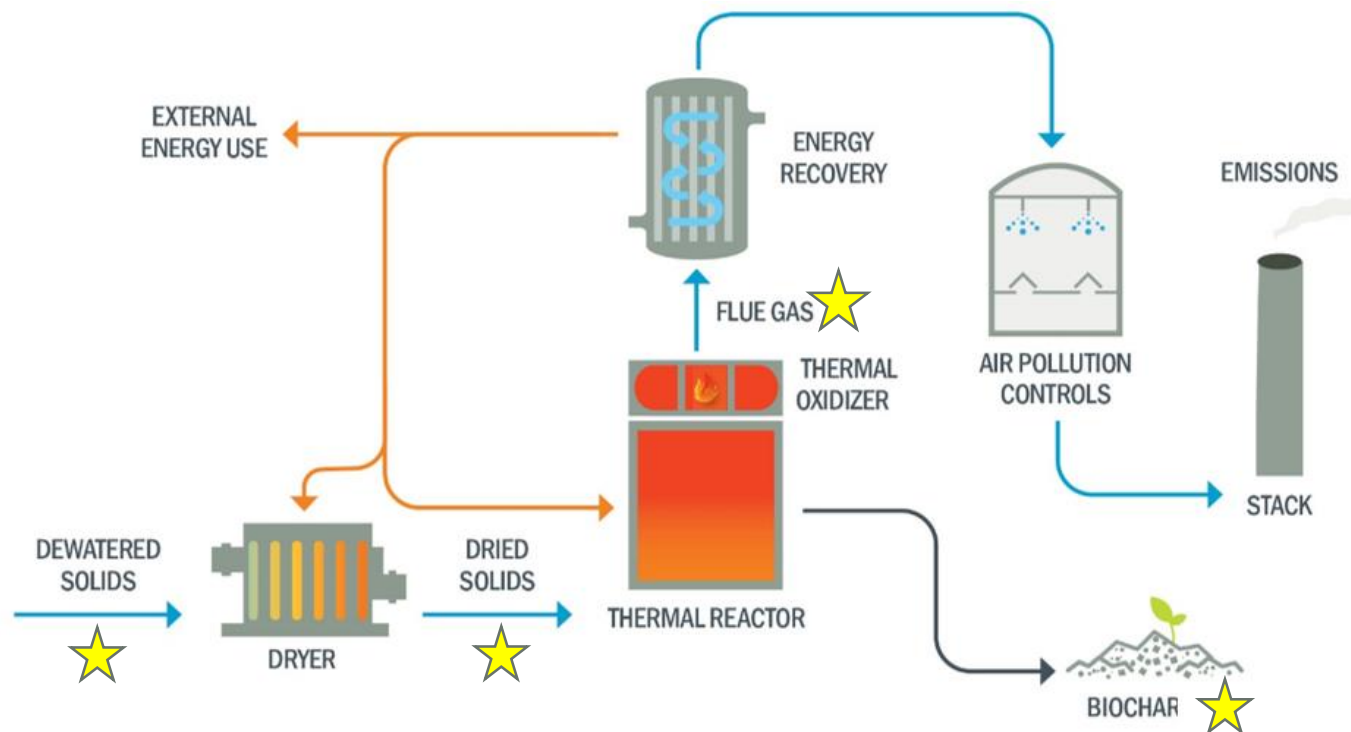
# Bench Scale Unit

Dewatered biosolids provided by SVCW will be dried and processed through a lab scale pyrolysis reactor with operating conditions similar to SVCW's current process.



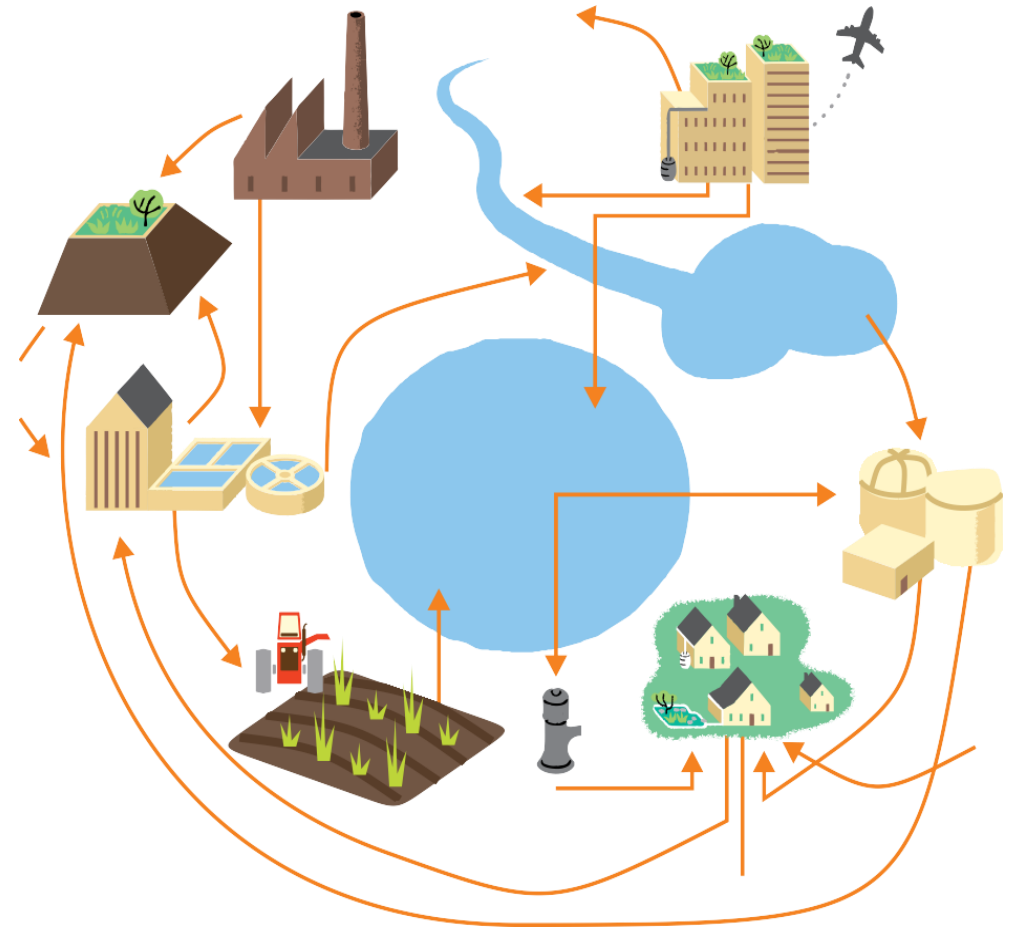
# Full-Scale

In parallel, dried biosolids will be processed through the full-scale pyrolysis system at SVCW and sampled for PFAS.



# Anticipated Benefits From PFAS Study

- Demonstrate whether current sampling and analytical approaches represent a mass balance around pyrolysis systems
- Show whether PFAS can survive through these thermal processes
- Economically conduct similar investigations





# Recap

- PFAS regulations around biosolids are evolving
- Important for utilities to have a flexible biosolids management plan to address PFAS
- Thermal destruction technologies are promising for PFAS destruction
- BC and SVCW's study will help answer questions around pyrolysis systems and PFAS destruction

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Q&A



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# Thank You

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The logo for Brown AND Caldwell is centered on a white background. It consists of the company name enclosed in a dark blue rectangular frame. The text 'Brown' is in a large, bold, sans-serif font, followed by 'AND' in a smaller, all-caps, sans-serif font. Below 'Brown AND' is the word 'Caldwell' in the same large, bold, sans-serif font as 'Brown'. To the right of the text, within the frame, are two small dark blue circles stacked vertically, with a vertical line segment below the bottom circle.

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