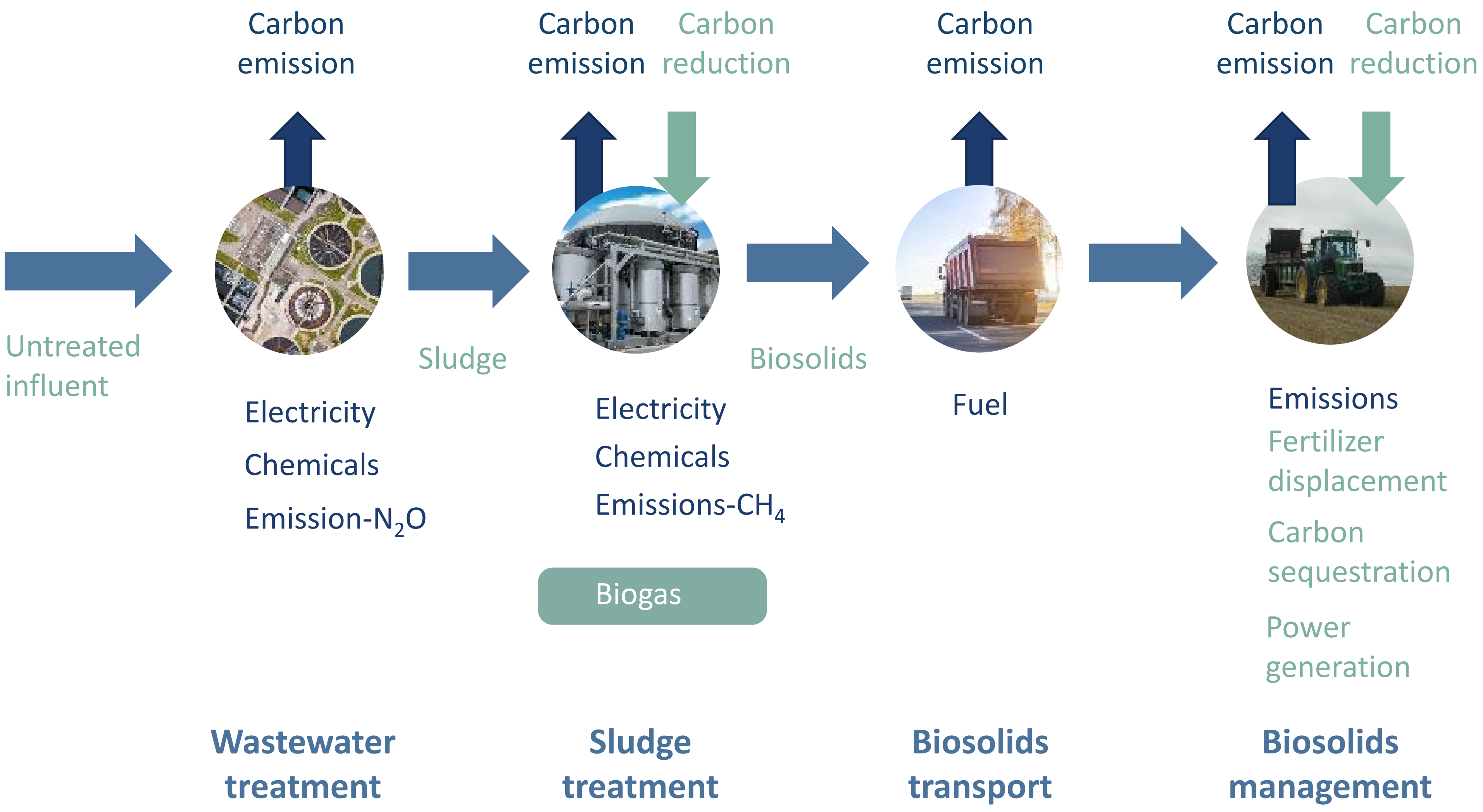
CAMBI

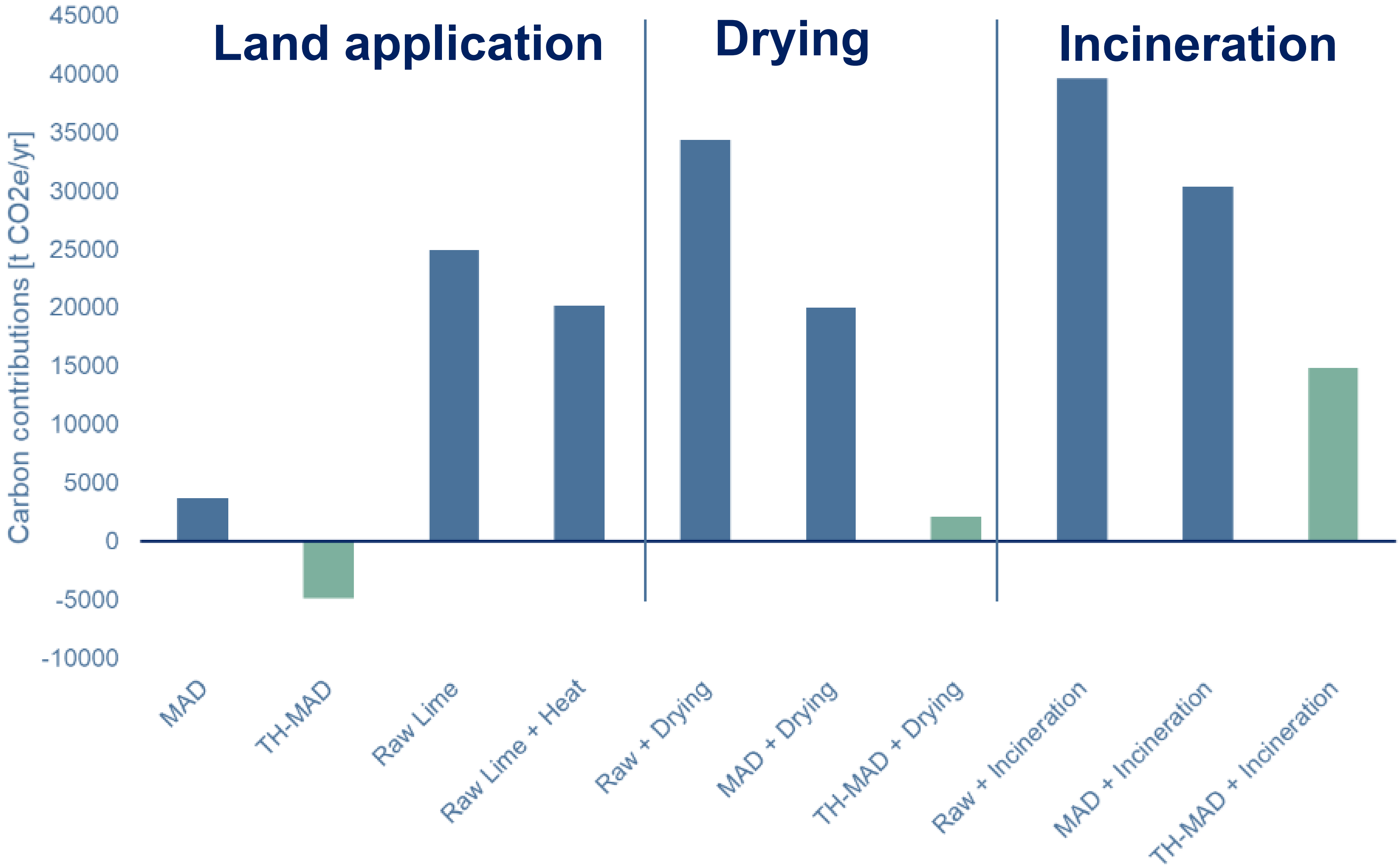
Comparing the carbon footprint of removing perfluorinated compounds from biosolids with direct land application of cake

Dr Bill Barber
Cambi

Carbon footprint of wastewater management



Operating carbon footprint of various biosolids management options



Having anaerobic digestion is preferable to not having it

Thermal processes higher than cake application to land

Thermal processes are typically throughput related

PFAS

Chemical companies' PFAS payouts are huge - but the problem is even bigger

Tom Perkins

3M, DuPont, Chemours and Corteva have agreed s... billions for polluting drinking water with 'forever...

The 3M global headquarters in Maplewo... PFAS drinking water claims. Photogr... giant 3M agr...

MONEYWATCH ›

U.S to crack down on toxic "forever chemicals" in drinking water

CLIMATE & ENVIRONMENT

EPA warns toxic 'forever chemicals' more dangerous than once thought

The guidance may spur water utilities to tackle PFAS, but health advocates are still w...

By Dino Grandoni

Updated June 15, 2022 at 5:35 p.m. EDT | Published June 15, 2022 at 9:00 a.m. EDT

EPA proposes bold new limits for tackling 'forever chemicals' in drinking water

WASHINGTON – Today the Environmental Protection Agency **unveiled unprecedented new limits** on the toxic "**forever chemicals**" known as PFAS as a way to tackle drinking water contamination. The proposal targets six notorious PFAS – PFOA, PFOS, GenX, PFBS, PFNA and PFHxS.

The limits, known as **maximum contaminant levels**, or MCLs, are the highest level of a contaminant allowed in drinking water. In addition to weighing health, these limits take water treatment costs and feasibility into consideration. The MCLs announced are 4 parts per trillion, or ppt, for PFOA and 4 ppt for PFOS, currently the limit of detection for both chemicals. For the other four PFAS chemicals, the EPA is proposing a "hazard index," which is a tool the agency uses to address cumulative risks from mixtures of chemicals.

ECONOMY & POLICY

Forever Chemicals Are Everywhere. Compar... Need to Get Their Houses In Order.

COMMENTARY By Peter Schramme Aug. 2, 2023 12:27 pm ET

Carbon footprint of PFAS removal from biosolids

- Very little work done
- Most studies oblivious to the environmental impacts
- Even recent research proposals and grants not looking at carbon impacts
- But there is a clear carbon impact of removing PFAS and similar chemicals from biosolids

Do the perceived health benefits of not applying biosolids to land due to concerns of perfluorinated chemicals outweigh the environmental impact of doing so?

Reported Concentrations in Biosolids

Year Sampled	PFOA (ng/g dry wt)	PFOS (ng/g dry wt)	Reference
2001	12 - 70	308 - 618	Venkatesan, 2013
2004-2007	8 - 68	80 - 219	Sepulvado, 2011
2005	16 - 219	8.2 - 110	Loganathan 2007
2005	18 - 241	<10 - 65	Sinclair, 2006
2006		81 - 160	Schultz, 2006
2006-2007	18 - 69	31 - 702	Yu, 2009
2007	20 -128	32 - 418	Yoo, 2009
2011	1 - 14	4 - 84	Navarro, 2016
2014	10 - 60	30 - 102	Mills, Dasu (in prep)
2018	1-11	2 – 1,100	EGLE, 2020

- Does not include other PFAS and precursors that may have been present

10

Source: Session 6: PFAS Treatment in Biosolids –*State of the Science* M. Mills
US EPA Office of Research and Development
PFAS Science Webinars for EPA Region 1 and State & Tribal Partners
September 23, 2020

PFAS and similar compounds in biosolids applied to agriculture

> Except for a few, rare worst-case scenarios involving industrially impacted biosolids*, **the literature does not show cases of excessive human exposure** associated with the use of biosolids in agriculture.

Distinguished Professor Linda Lee, Perdue University, May 2023

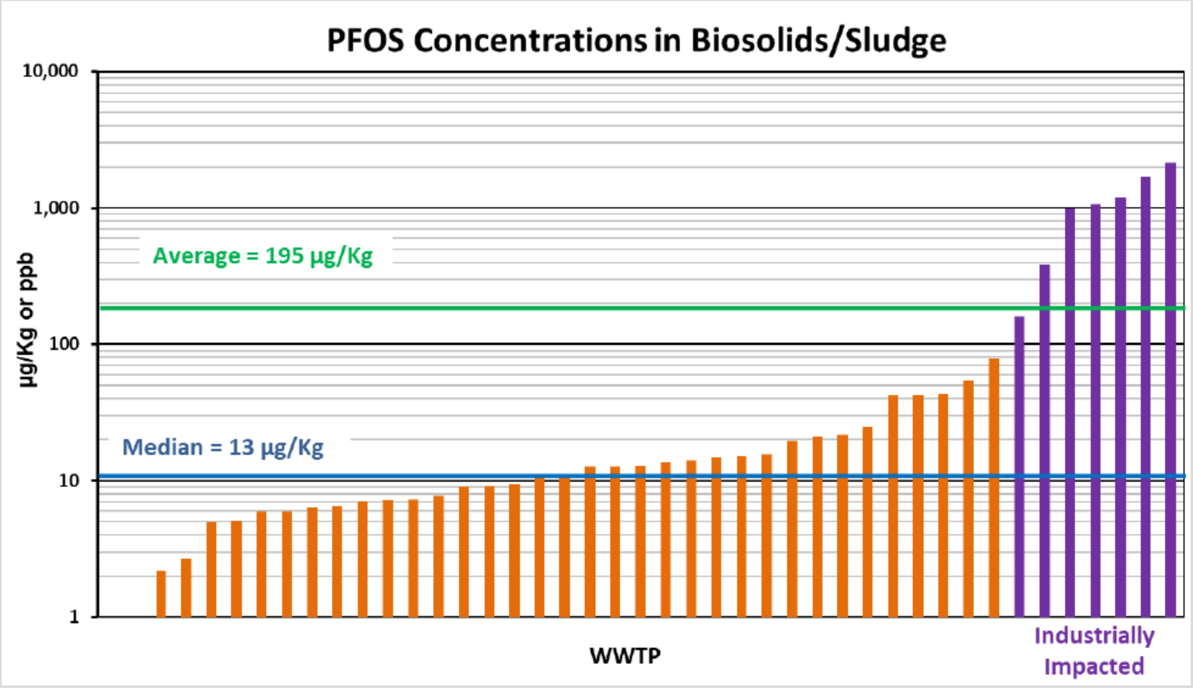
*

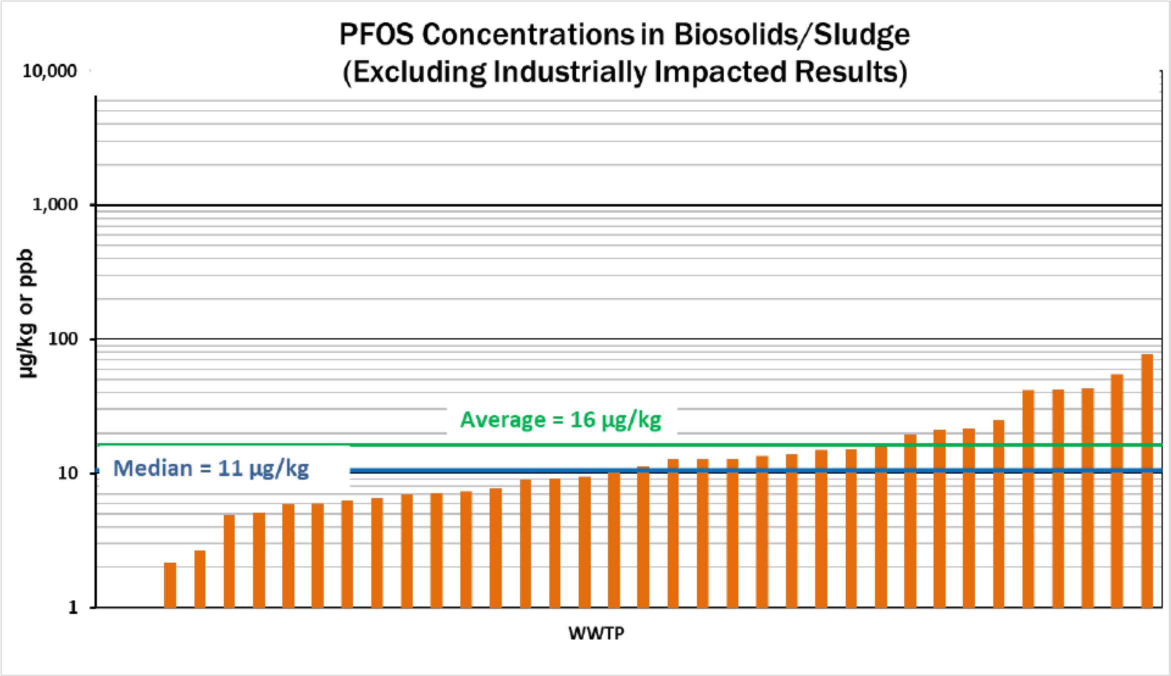
- Military sites using **AFFF****s
- Airports using **AFFF**
- Industrial sludge most often from **PFAS producing facilities**
- Land-disposed industrial wastes most often **PFAS using facilities**
- Biosolids impacted by **highly PFAS-contaminated** industrial discharge into WWTPs

** Aqueous Film Forming Foam

Source: PFAS (Per- & Polyfluoroalkyl Substances) and Biosolids Perspectives in Context, Distinguished Professor Linda Lee, Perdue University, Presented at VWEA Education Seminar, May 2023

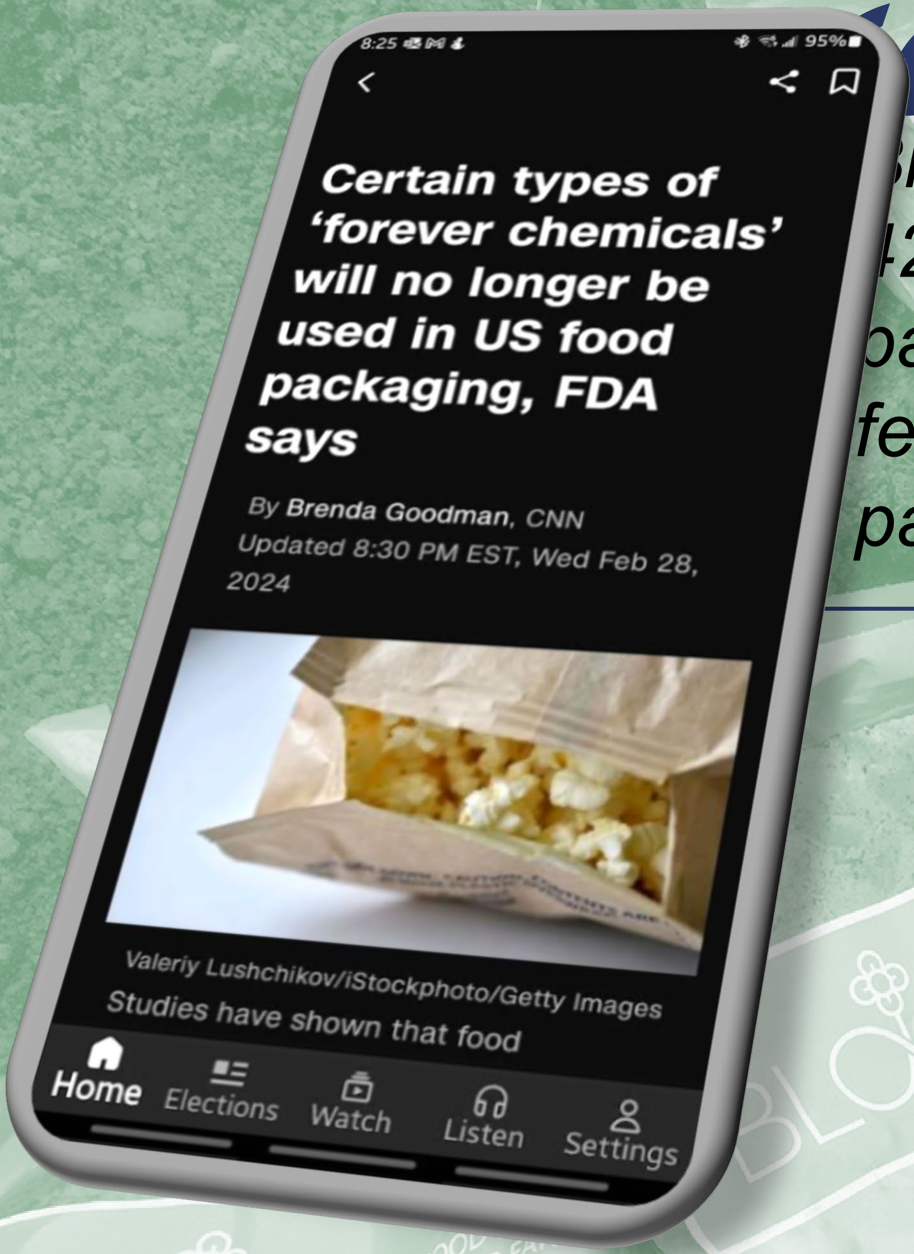
PFAS in biosolids





Average	= 195 µg/kg	Average	= 16 µg/kg
Median	= 13 µg/kg	Median	= 11 µg/kg

Source: EGLE (Michigan Department of Environment, Great Lakes, and Energy) Summary Report: Initiatives to Evaluate the Presence of PFAS in Municipal Wastewater and Associated Residuals (Sludge/Biosolids) in Michigan, June 2020



*"Bloom's total combined PFAS levels average 42 ppb, which is **<u>1/2,400th</u>** of the food packaging limits set in California, one of the few states to restrict the compounds in packaging.*

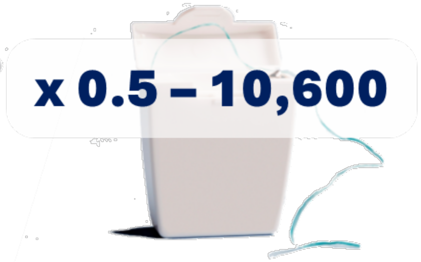
C. Peot, DC Water

Numbers refer to concentrations compared to biosolids

PFAS

Perfluoroalkyl and Polyfluoroalkyl substances

FOOD CONTAINERS



DENTAL FLOSS

PAPER PRODUCTS


SPORTS EQUIPMENT

CARPETS/RUGS


COOKING UTENSILS

FOOD

MAKE UP


ELECTRONIC COMPONENTS

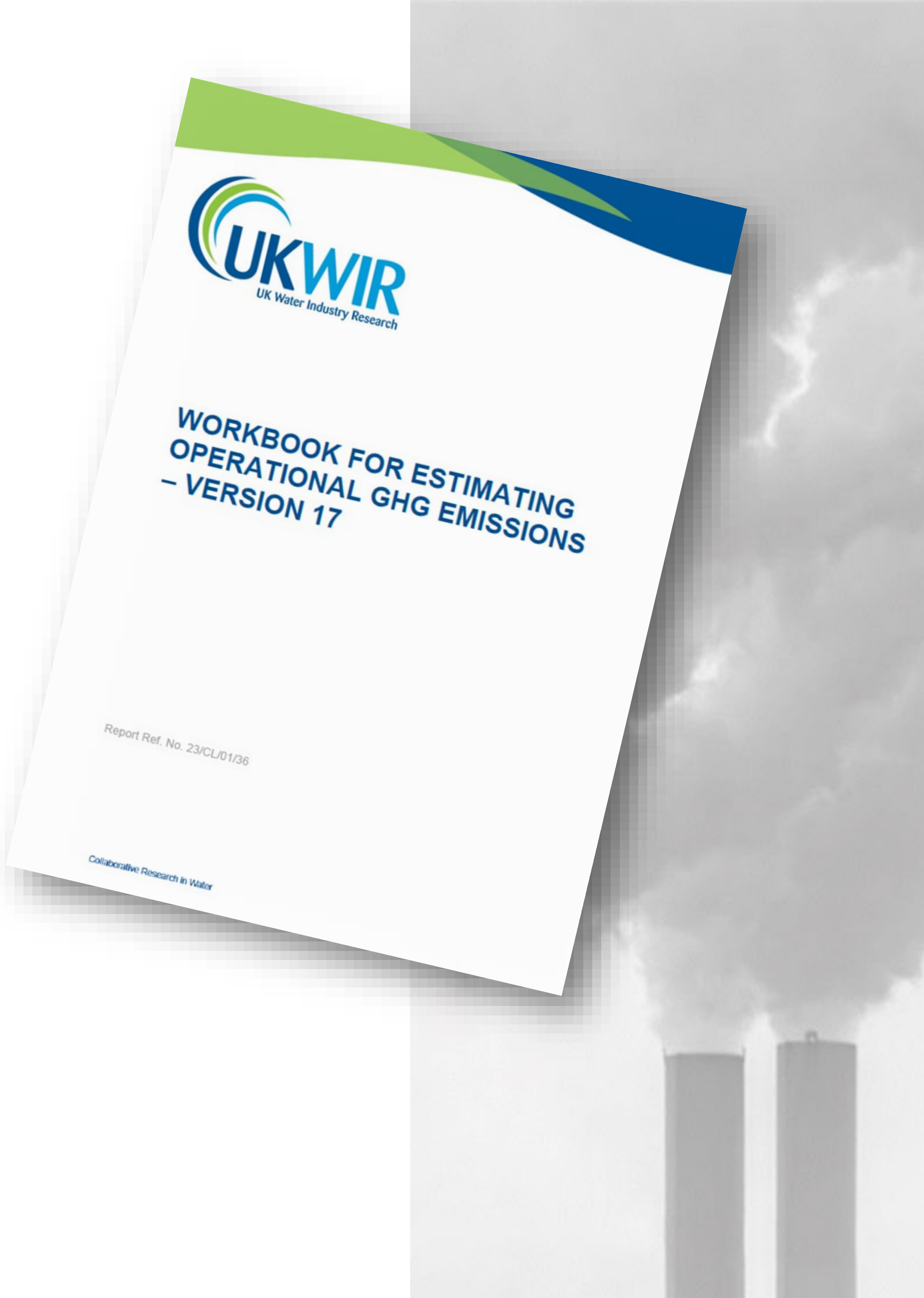

RAINPROOF CLOTHING/SHOES

PET FAECES

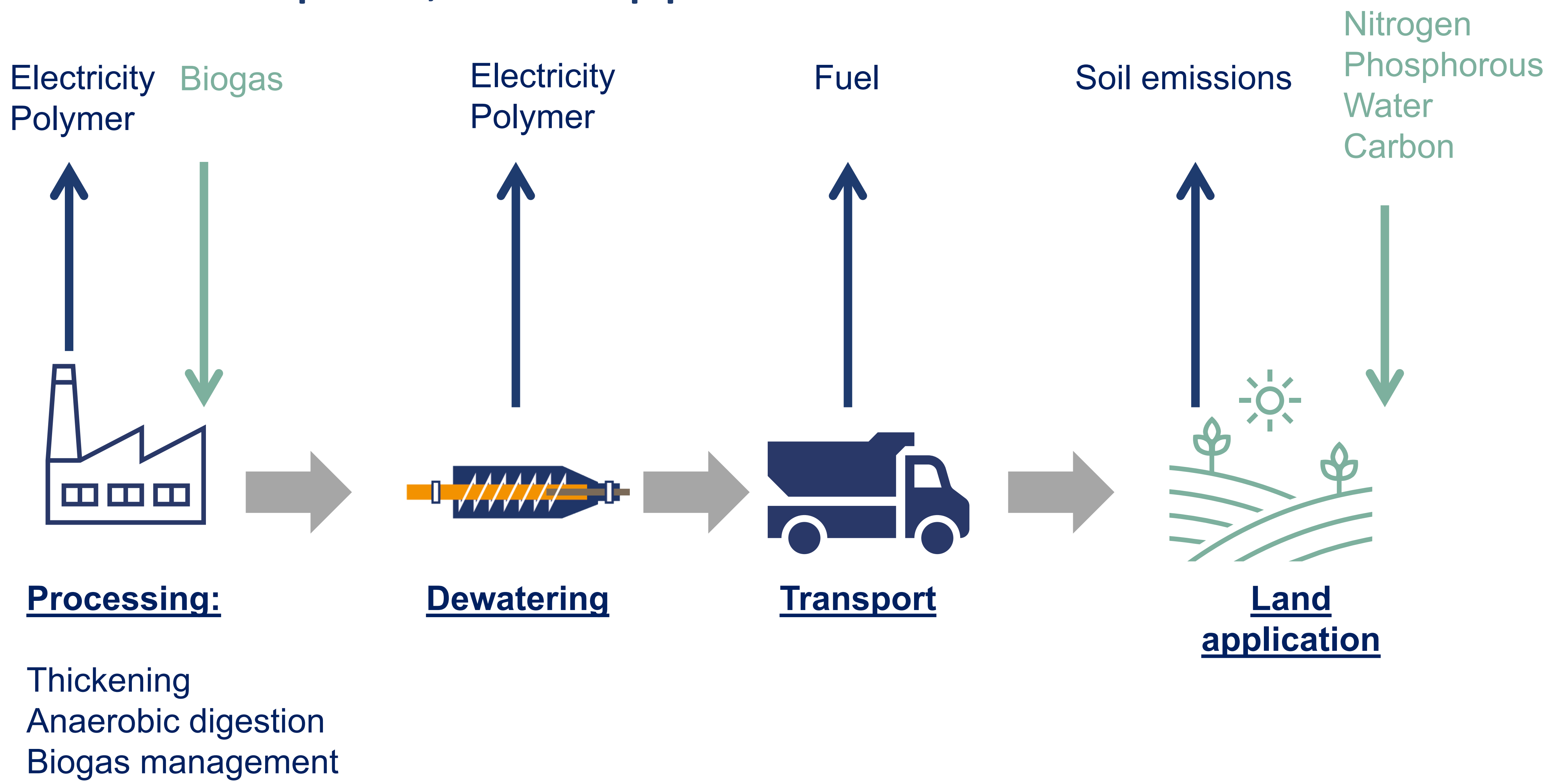

I ♥
PFAS

Carbon modelling

- UK models since 2005
  - UKWIR CAW
  - Current version 17
- BEAM 2011
  - 2^{nd} revision 2022
  - Pyrolysis module
- Differences between the above and this exercise
  - Detailed mass and energy balance compared to user input
  - Liquid and solids treatment included
  - Includes inter-process pumping
  - Includes co-generation use and biogas management
  - Based (where possible) on first principles rather than empirical input
  - Difference in some emission factors

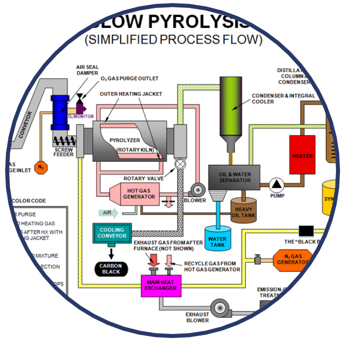


Carbon footprint, land application of cake



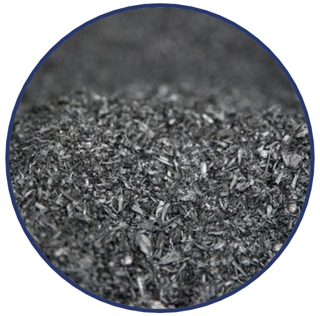
Pyrolysis

- Known process
  - However, still much work to do

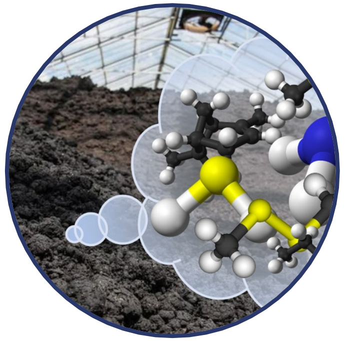


Picture remidiationearth.com

- Makes biochar which sequesters carbon*, and makes syngas and bio-oil from which energy can be recovered

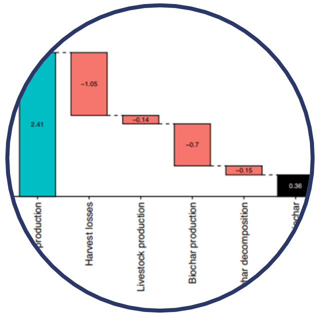


- Many contaminants can be transformed/removed/destroyed from biochar
  - Can make metals inert even though metals will accumulate in biochar

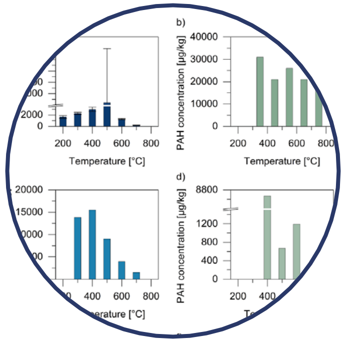


Picture Atlas of Science

Some biochars known to have positive impacts on soil health when applied*



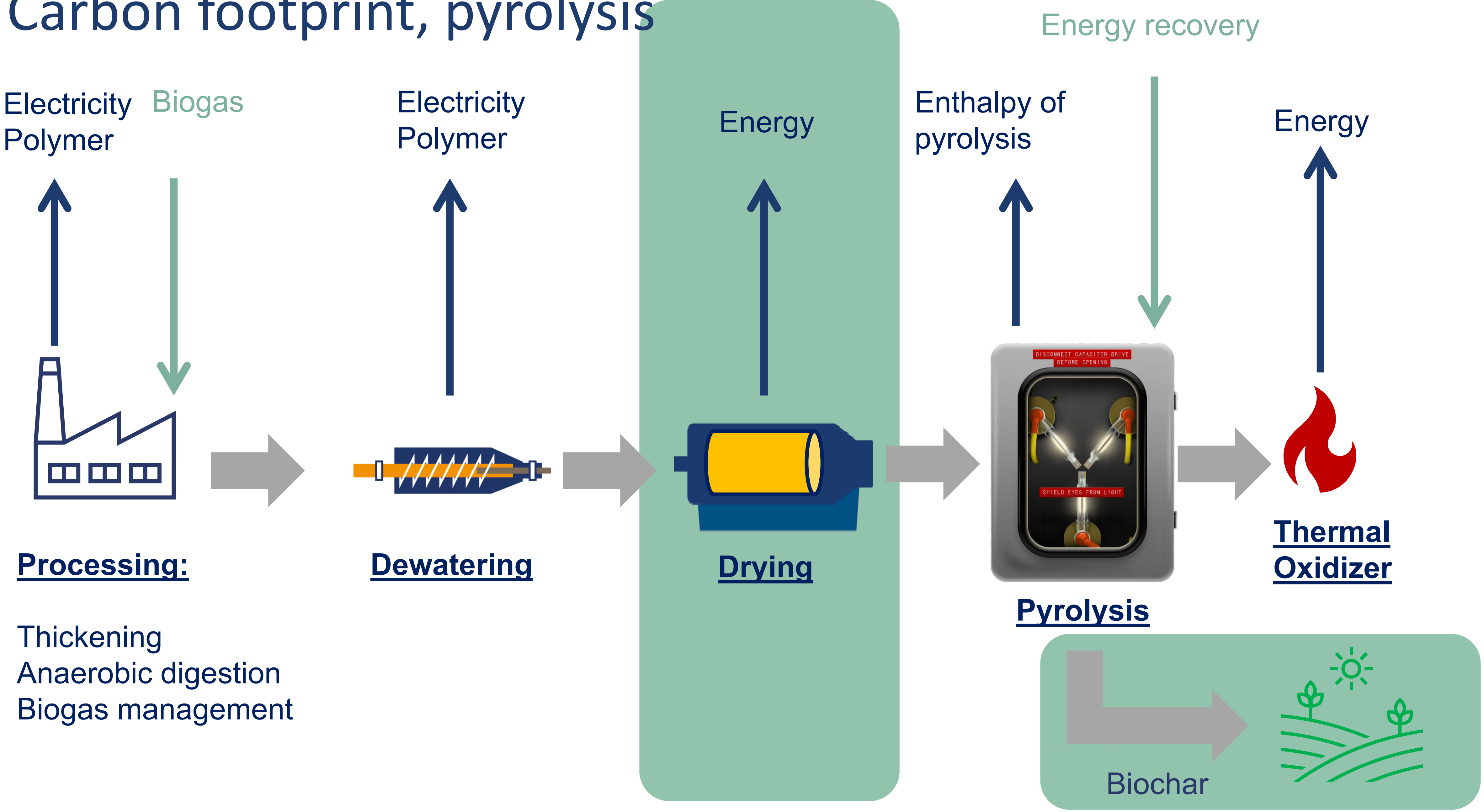
- Quantity and quality of outputs *<u>fundamentally dependent on feedstock and pyrolysis configuration</u>* and operating conditions*



Sources:

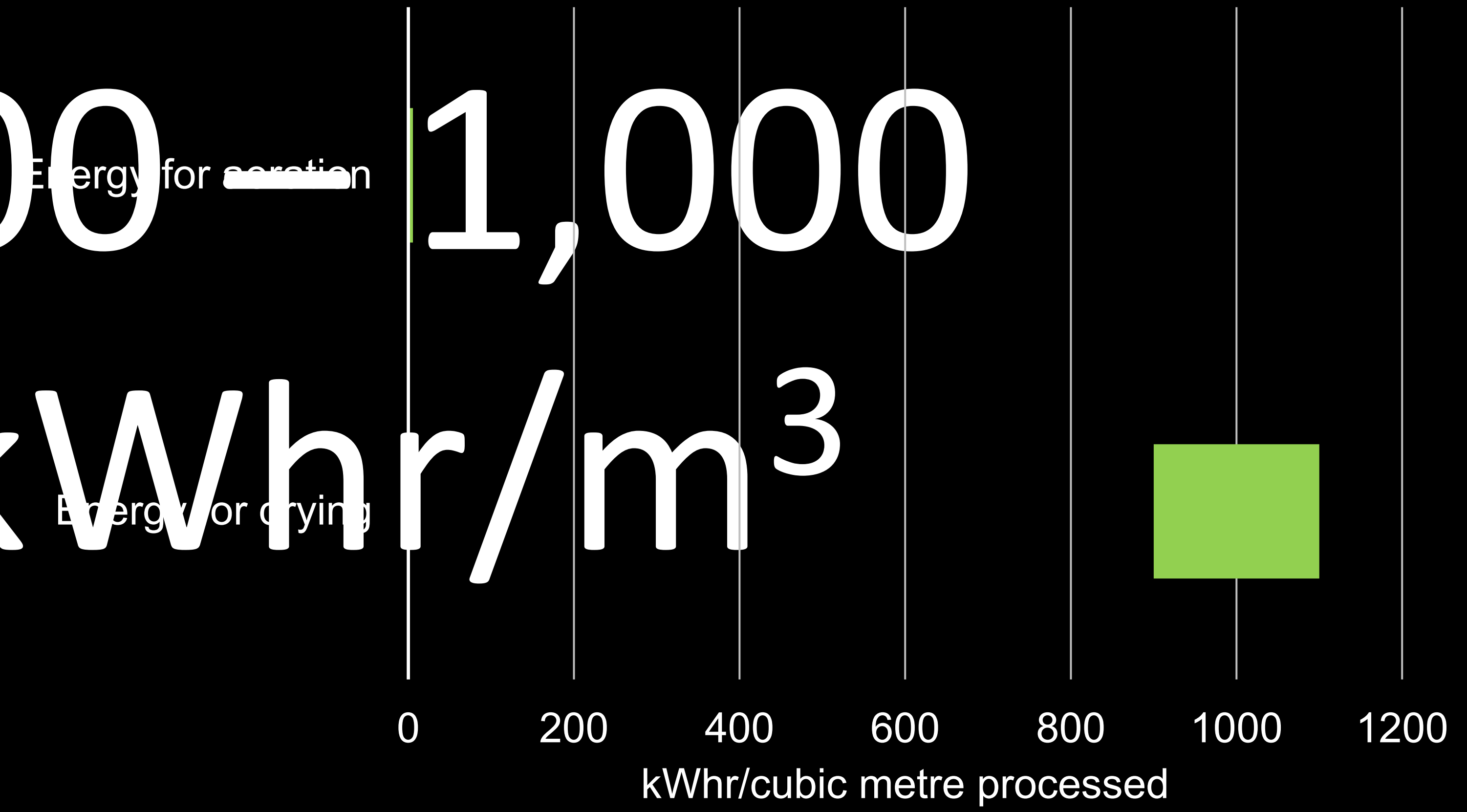
- Lehmann *et al*., Biochar in climate change mitigation, Nature Geoscience, 2018
- Woolf *et al*., Biochar for Climate Change Mitigation. Navigating from Science to Evidence-Based Policy, Chapter 8 of Soil and Climate, (2018)
- Schlederer *et al*. Micropollutants in biochar produced from sewage sludge: A systematic review on the impact of pyrolysis operating conditions, Waste Management 174, 618 - 629 (2024)

Carbon footprint, pyrolysis



Energy needed for drying

900 – 1,000 kWhr/m^3



Energy balance

0.41 kWhr /passenger/km

United States Department of Transportation, Bureau of Transportation and Statistics

274 m^3/methane

2,924 kWhr

2.9 t water

1 tonne dewatered dry solids needs approximately **275 m^3** methane to dry

1 t DS
5% DS
20 wet tonne

Dewatering

16 wet tonne

1 t DS
25% DS
4 wet tonne

Drying

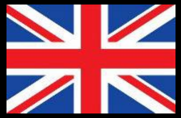
1 t DS
93% DS
1.1 wet tonne

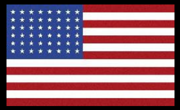
BRITISH COLUMBIA
SASKATCHEWAN
Edmonton
Calgary
Vancouver
ONTARIO
3,918.60 mi
NORTH DAKOTA
MINNESOTA
North Pacific Ocean
Hilo
Atlanta
POOP AIR
We run on renewable gas
name
Ms/Mr.
Mr. Fango
from
There
to
Here
date
flight
PA 002
seat
1A
service information
You have earned 2,451
Brownie Points for this trip
gate
boarding time
class
name
from
to
date
flight
seat
gate
No. 2
boarding time
Wait, it's leaving already?!
class

Not all sludge is the same

…..same applies to (bio)char

International Biochar Initiative
Standarized Product Definition and Product Testing Guidelines for Biochar Used In Soils
2015




International Biochar Initiative

Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil

Type of Document:	Product Definition and Specification Standards
Status of Document:	Final
Version Number:	2.1
Version Date:	23 November 2015
Document Reference Code:	IBI-STD-2.1

NOTE TO USERS: The International Biochar Initiative may update this manual as necessary. Please make su[re you] are using the latest version available at http://www.biochar-international.org/characterizationstandard.

© International Biochar Initiative - November 2015

Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil (aka IBI Biochar Standards) Version 2.1

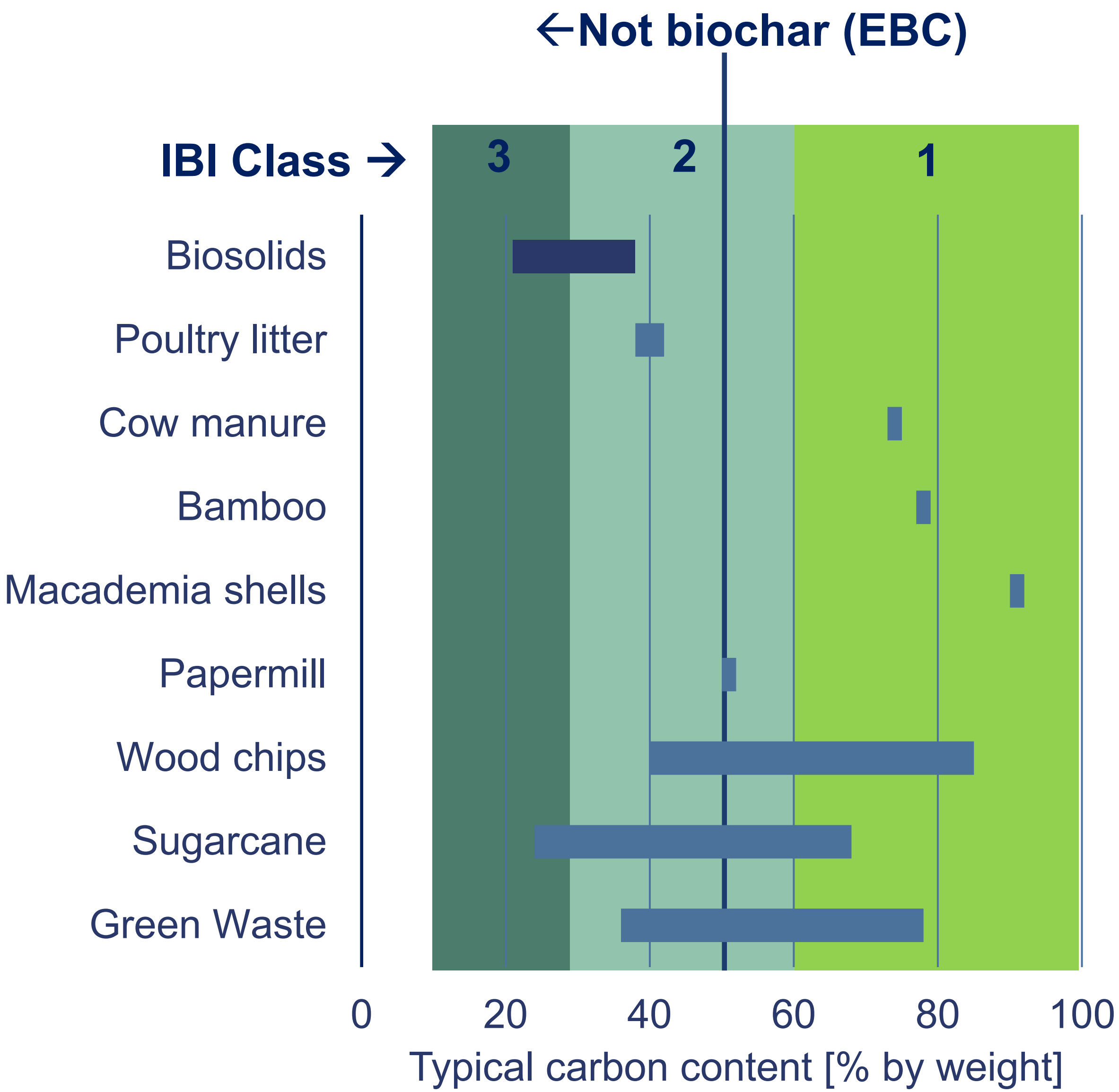
1

European Biochar Certificate: Guidelines for a sustainable production of biochar
2023

Version 10.3E of 5th April 2022

Please cite as:
EBC (2012-2023) 'European Biochar Certificate - Guidelines for a Sustainable Production of Biochar.' Carbon Standards International (CSI), Frick, Switzerland. (http://european-biochar.org). Version 10.3 from 5th Apr 2022

Biochar and Sewage Sludge Derived Biochar (SSDB)



- **SSDB compared to other biochars**
  - Low carbon
  - Concerns related to microcontaminants
  - Limited adsorption capacity
  - Cost of processing
  - Lack of standardization
  - Knowledge gaps
  - Small quantity and low market influence

Sources:

- Technical Evaluation Report, Compiled by Savan Group for the USDA National Organic Program (2021)
- Khan *et al.* (2023) Sewage sludge derived biochar and its potential for sustainable environment in circular economy. Advantages and challenges, Chemical Engineering Journal, 471.

European Regulations on biochar use in agriculture

> Sewage sludge is and should remain excluded from the list because it is, for the moment, unclear whether contaminants of emerging concern, such as pharmaceuticals, contained therein are completely eliminated following the processing methods for pyrolysis and gasification materials.

— materials originating from mixed municipal waste,

— sewage sludge, industrial sludge or dredging sludge, and

— animal by-products or derived products within the scope of Regulation (EC) No 1069/2009

European Commission

Sources: No 2019/1009 of the European Parliament and of the Council for the purpose of adding pyrolysis and gasification materials as a component material category in EU fertilising products

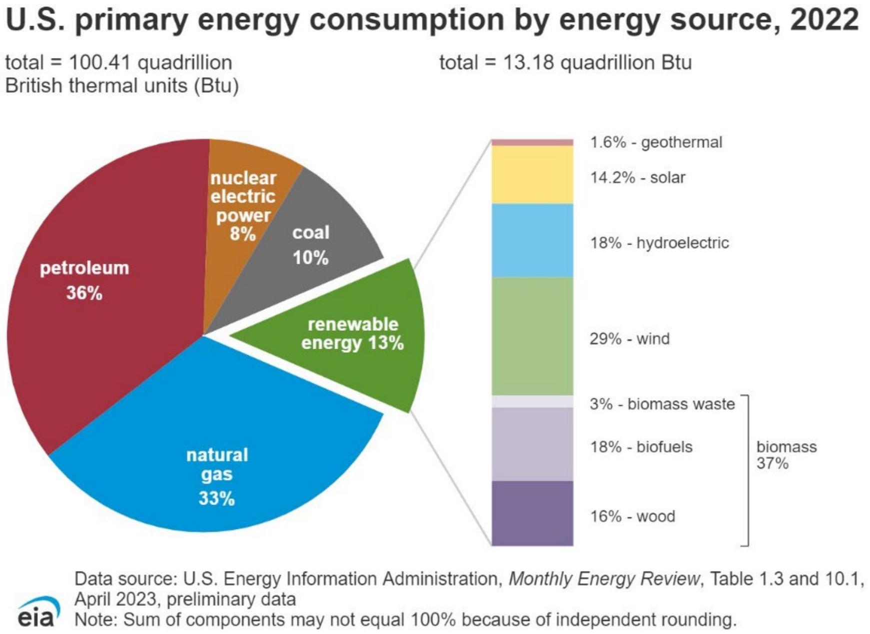
Schlederer *et al*. Micropollutants in biochar produced from sewage sludge: A systematic review on the impact of pyrolysis operating conditions, Waste Management 174, 618 - 629 (2024)

Carbon Footprint Analysis

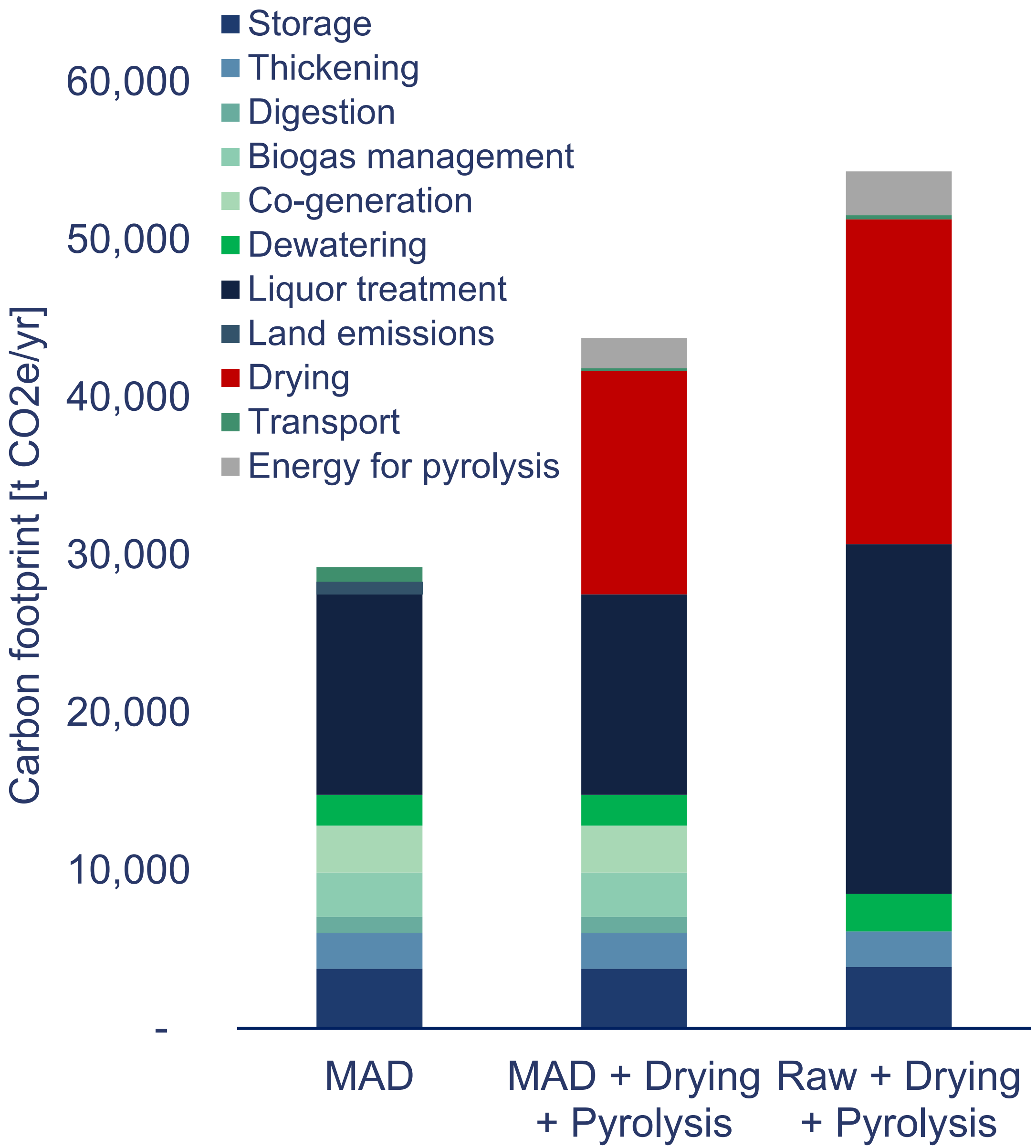
1	Standard MAD followed by dewatering to make cake for land application
2	Standard MAD followed by dewatering, drying to 85%, pyrolysis, (thermal oxidation of flue gas), partial energy recovery, use of char

- **Technical assumptions**
  - VSR in MAD = 50%
  - Biogas used in co-gen
  - Dry solids in dewatering = 25%
  - Pyrolysis temperature = 500°C
  - SSDB yield = 40%
  - Recovered energy from pyrolysis = 50%
  - Carbon content of raw sludge VS = 50%, calculated for digested by elemental balance

- **Carbon calculations**

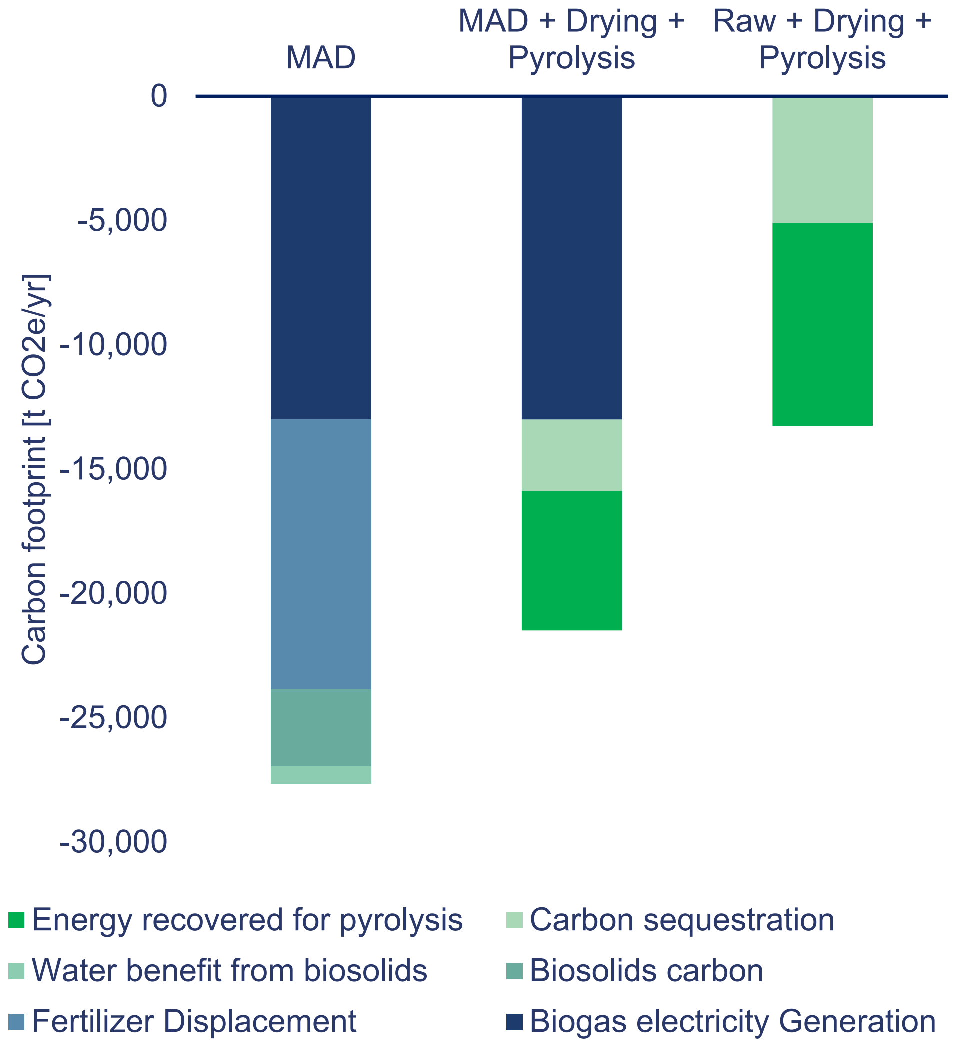


Carbon footprint contributions



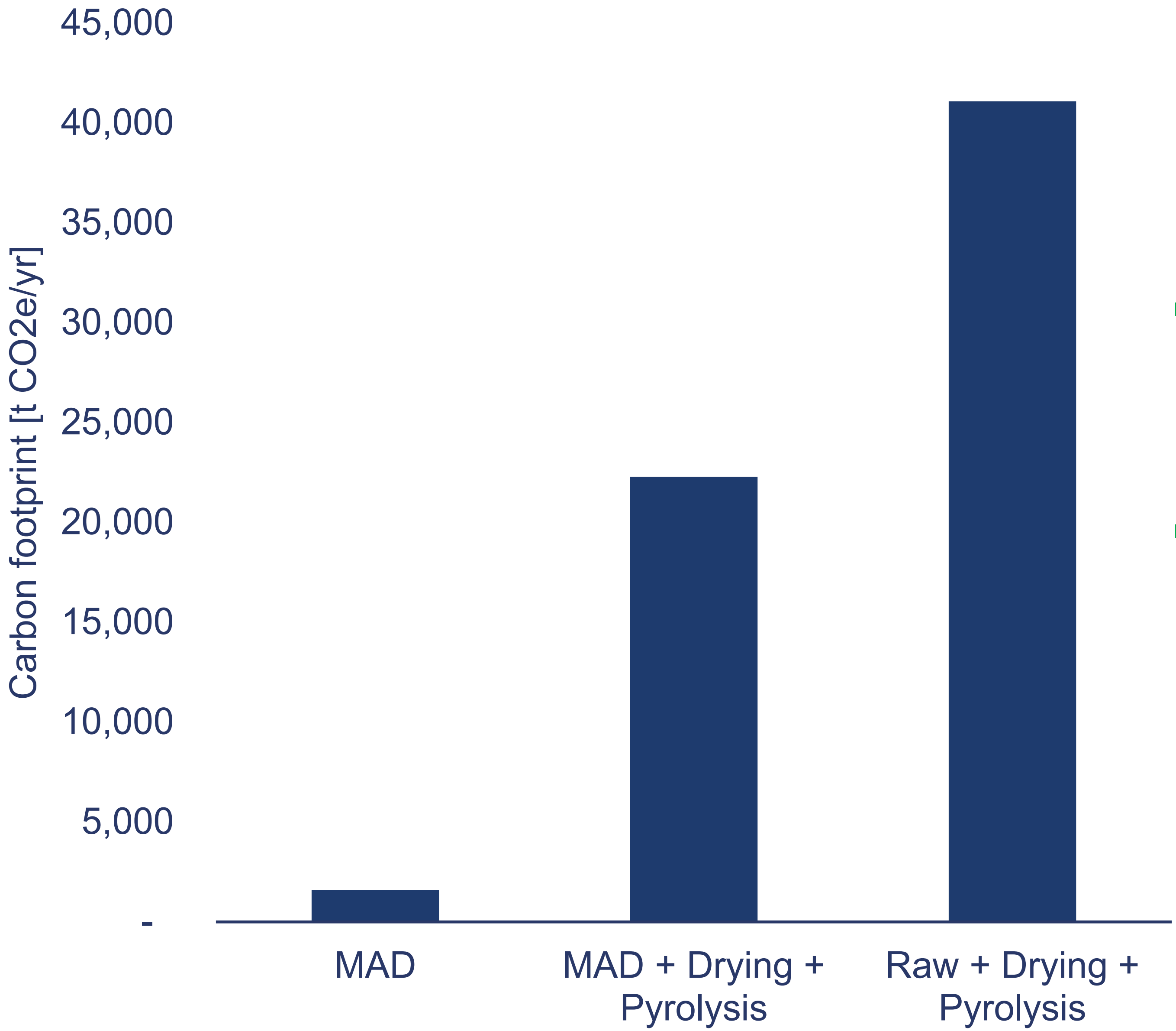
- Adding pyrolysis increases contributions
  - Mainly from drying (gas and electricity)
- Removing digestion increases contributions
  - More sludge to process
- Liquor treatment is significant
- Pyrolysis is not substantial
  - However, carbon footprint associated with use of syngas for energy recovery, nor downtime, nor thermal oxidation included yet in the analysis

Carbon footprint benefits



- Adding pyrolysis loses the carbon benefits of biosolids use
  - Loss of agricultural value, nutrients, soil carbon and water
  - (other value such as drought resistance, micro- and macro-nutrients, changes in crop yield not evaluated)
- Sewage sludge derived biochar (SSDB) provides carbon sequestration benefits

Overall carbon footprint



- With respect to operating carbon footprint comparing MAD with cake application to land
  - Adding pyrolysis, carbon footprint increases **x 10**
  - Adding pyrolysis removing digestion increases **x 20**
- The benefits of removing digestion to get a better quality SSBC not justified
- Work ongoing
  - Does not include energy demands for thermal oxidation
  - Does not account for downtime due to siloxanes in syngas
  - Firm up energy balance
  - Does not include embodied carbon footprint

Possible solutions

Regulations

- Focus on specific areas only (military, airports, PFAS production facilities, industrial discharge from PFAS using facilities)
- Maine. Ban
  - Gone from state with one of the highest biosolids recycling rates in New England, higher than US average (75%) to total ban*
- EGLE (Environment, Great Lakes and Energy) - Michigan

Concentration (ppb = μg/kg)	Application
> 125	Prohibited Need to notify, effluent sampling, need alternative treatment
50 – 125	Can apply, Requires risk mitigation strategy
20 – 50	Can apply
<20	Can apply

- NY State

Concentration (PFOS/PFOA) (ppb = μg/kg)	Application
> 50	Prohibited
20 – 50	Can apply. Requires sampling, soil concentration <20 after 1 year or will be prohibited
<20	Can apply

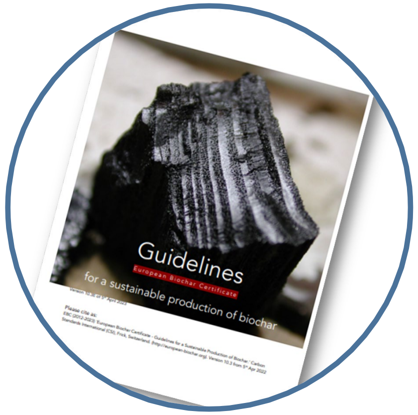
Source:

- Brown, S. (2022) Unpacking Maine's New Ban on Biosolids use due to PFAS, Biocycle Magazine

Conclusions

PFAS

- Health concerns in drinking water
- However, PFAS in biosolids very low compared to other everyday materials
- Source control – (us)



Pyrolysis

- Potential for PFAS “removal” combined with thermal oxidation
- Sewage sludge derived biochar (SSDB) not a valuable resource compared with other biochars
- Insufficient data which prevents use in Europe

Environmental impact

- Pyrolysis needs drying which has high energy demand
- By moving away from land application, intrinsic value of biosolids are lost
- Perceived health benefits of not applying biosolids to land versus climate change impacts

Bill Barber, Phd
Technical Director

bill.barber@cambi.com

IWA PUBLISHING
the international water association

Thank you