An aerial photograph of a forest. The trees are mostly green, but there are several dead, grey trees scattered throughout. The lighting is somewhat dim, giving the scene a dark, moody appearance. The text is overlaid on the center of the image.

# **Creating value from sewage**

**Nataliia Kasian**

**VOW**



<https://chronohunter.com/chronicles/rolex-daytona-waitlist-2023-why-is-there-a-minimum-5-year-wait>

A waiting list?



<https://chronohunter.com/chronicles/rolex-daytona-waitlist-2023-why-is-there-a-minimum-5-year-wait>

## A waiting list?



No poop for you: Manure supplies run short as fertilizer prices soar

reuters.com • 6 min read

"Manure is absolutely a hot commodity," said Kampschnieder, who works for Nebraska-based Nutrient Advisors.

"We've got waiting lists."

Vow<sub>ASA</sub>

Scanship AS

Vow Green Metals AS

Vow-US Inc.

Scanship Americas Inc.

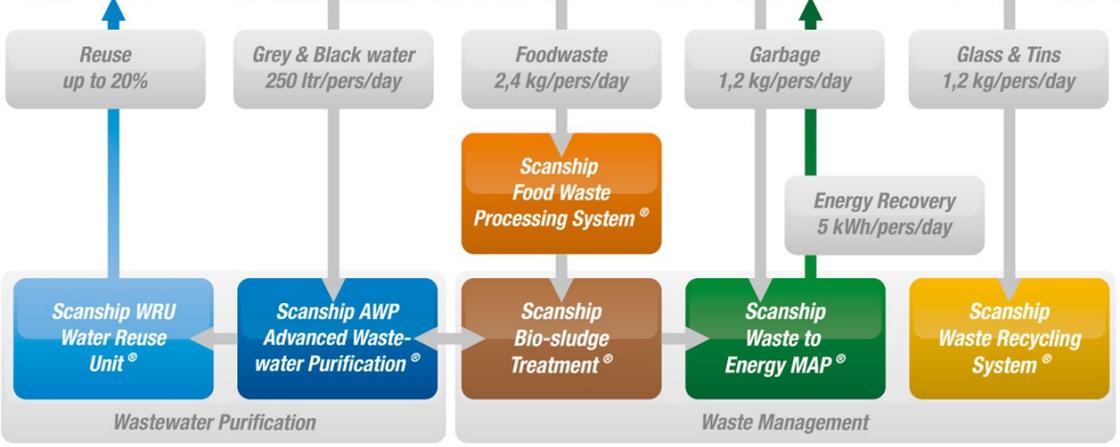
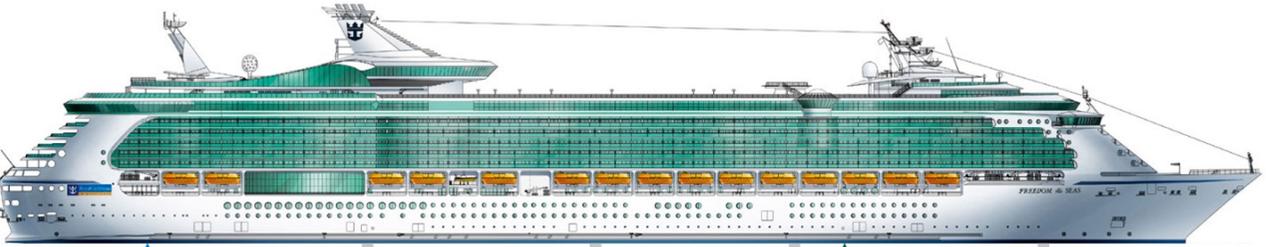
Scanship Poland

ETIA S.A.S

C.H. Evensen Industriovner AS

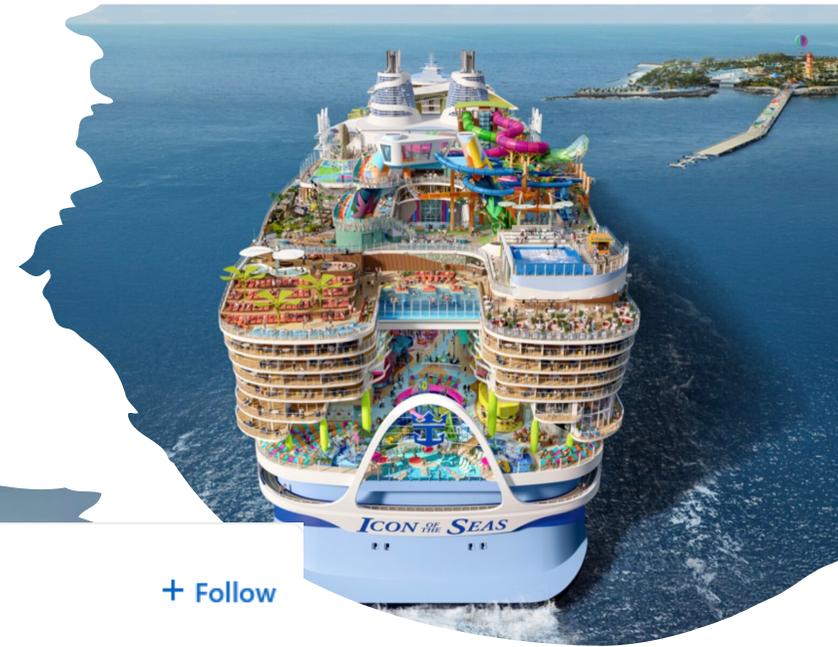
Vow Automation AS

Vow Industries AS



# MICROWAVE ASSISTED PYROLYSIS SYSTEM

- Reactor 30 kW MW
- 100 kg/h
- 650 deg C
  
- Activation section
- 900 deg C
- CO<sub>2</sub>, H<sub>2</sub>O, O<sub>2</sub>
  
- Compact
- Easy to operate
- Approved for marine operation
  
- First installation 2023 in Cruise Ship



Royal Caribbean Group

795,057 followers

6mo •

+ Follow

Today, Royal Caribbean Group announced the introduction of new systems that will take trash and convert it into energy that is then directly used on the ship. The systems will debut on two of our newest ships, **Royal Caribbean International's Icon of the Seas** and **Silversea Cruises' Silver Nova**, in our continued effort to innovate on the high seas and provide great vacation experiences, responsibly.

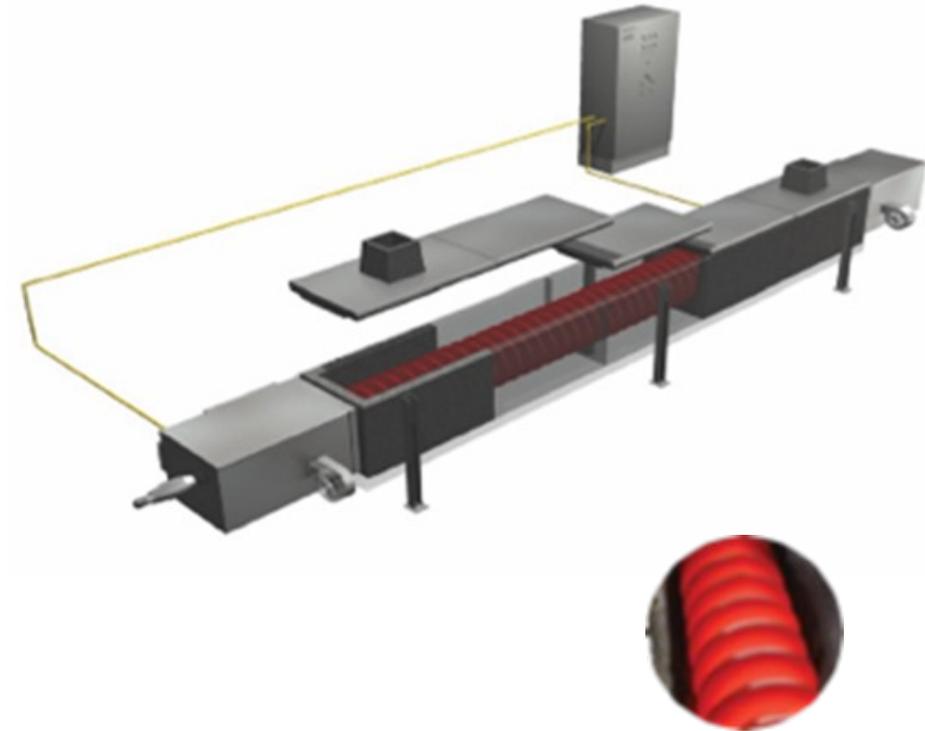
Read more: <https://lnkd.in/ecyfNgB4>

#SEAtheFuture



# ETIA ECOTECHNOLOGIES

- Over 30-year experience in electrically heated technology development
- 150 systems installed worldwide
- Leader in food sterilization technology utilizing Spirajoule
- Continuous pyrolysis (Biogreen) since 2003
- Vast knowledge base in pyrolysis process and output valorization
- Strategic partnerships in key thermochemical recycling projects:
  - Repsol (Spain) – pyrolysis of plastics for molecule recovery
  - Arcelor Mittal (Luxembourg) – pyrolysis of forestry waste to produce CO<sub>2</sub> neutral energy and biocarbon for metallurgy
  - GRTgaz (France) – upgrading pyrolysis gas for grid injection



# Sewage sludge - waste or valuable resource?

- Carbon
- Micro and macro nutrients
- Heavy metals
- PAH, PCDD/Fs and PCBs
- PFAS / The 'forever chemicals'
- Microplastic
- Pharmaceuticals
- Flame retardants



# Sewage sludge - wide variation in the destinations

Eurostat statistics:

- fertilizer for agriculture (Ireland, 89 %)
- composting (Hungary, 74 %)
- landfill (Malta, 100 %)
- incineration (Netherlands, 87 %)

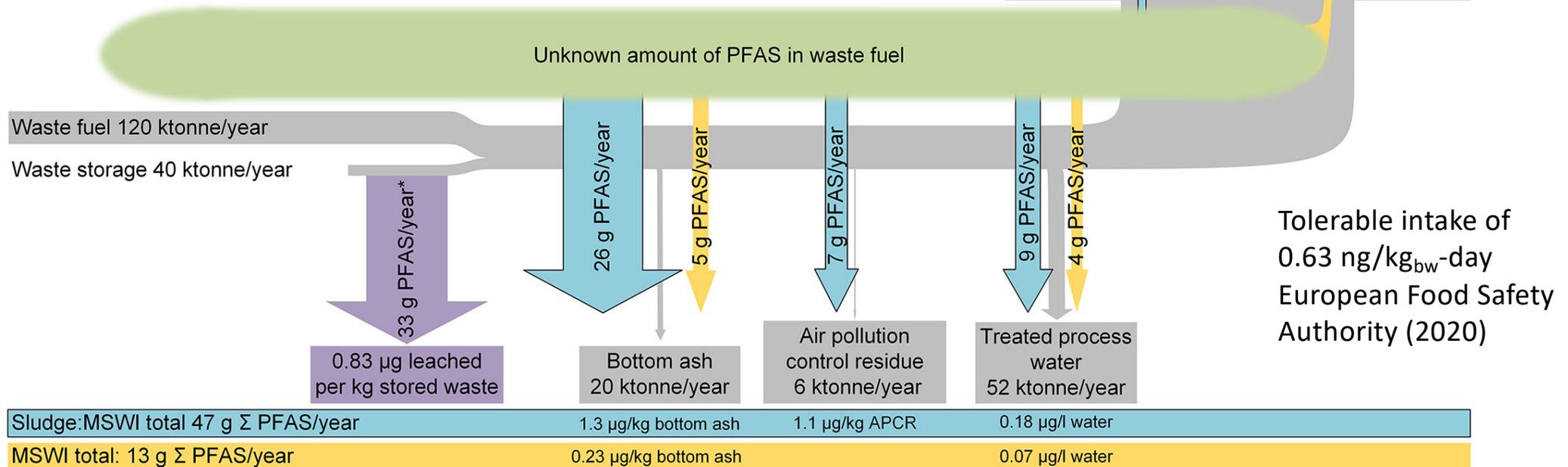
2018-2019 data



# PFAS fate during incineration

The 'forever chemicals'

Results demonstrate that some PFASs are not fully degraded by the high temperatures during full-scale waste-to-energy conversion and can be emitted from the plant via ash, gypsum, treated process water, and flue gas.

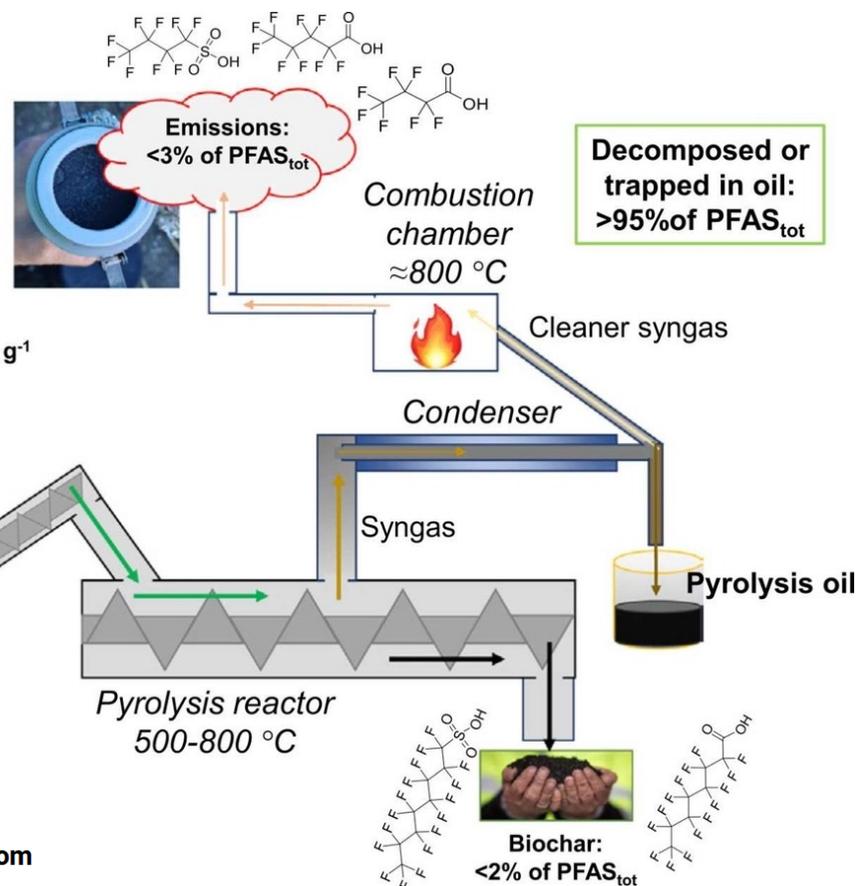
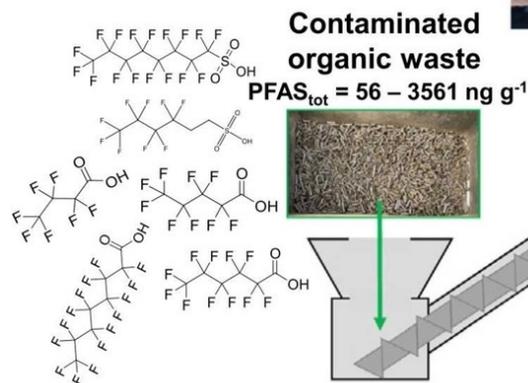


# PFAS fate during pyrolysis

The 'forever chemicals'

- Persistent / Mobile / Toxic
- > 15 000 compounds
- 40-60 PFAS compounds (standard lab methods / shortfalls in analytical methods)
- EOF (90% of the EOF could not be explained by the 40-60 compounds)
- Top assay (a new leading-edge approach, but lack of standardized methods)

**PFAS mass balance in the full-scale pyrolysis of organic wastes (56 congeners targeted)**



Journal of Hazardous Materials  
 Volume 454, 15 July 2023, 131447



Get e-Alerts

## Fluorine Mass Balance Analysis of Effluent and Sludge from Nordic Countries

Rudolf Aro, Ulrika Eriksson, Anna Kärman, Fangfang Chen, Thanh Wang, and Leo W. Y. Yeung\*

Cite this: *ACS EST Water* 2021, 1, 9, 2087–2096  
 Publication Date: August 5, 2021

The decomposition and emission factors of a wide range of PFAS in diverse, contaminated organic waste fractions undergoing dry pyrolysis

Erlend Sermo,<sup>a,b</sup> Gabriela Castro,<sup>c</sup> Michel Hubert,<sup>a,d</sup> Viktória Licul-Kucera,<sup>a,f</sup> Marjorie Quintanilla,<sup>g</sup> Alexandros G. Asimakopoulos,<sup>c</sup> Gerard Cornelissen,<sup>a,b</sup> Hans Peter H. Arp,<sup>a,c</sup>

# Ecotoxicity and environmental risks



Science of The Total Environment  
Volume 870, 20 April 2023, 161856



Analysis, occurrence and removal efficiencies of organophosphate flame retardants (OPFRs) in sludge undergoing anaerobic digestion followed by diverse thermal treatments

Gabriela Castro<sup>a</sup>, Erlend Sørmo<sup>b</sup>, Guanhua Yu<sup>a</sup>, Shannen T.L. Sait<sup>a</sup>, Susana V. González<sup>a</sup>, Hans Peter H. Arp<sup>a,b</sup>, Alexandros G. Asimakopoulos<sup>a</sup>

Pyrolysis at temperatures >500 °C effectively removed the OPFRs in the produced biochar.



Journal of Hazardous Materials  
Volume 461, 5 January 2024, 132546



Distribution of PAHs, PCBs, and PCDD/Fs in products from full-scale relevant pyrolysis of diverse contaminated organic waste

Erlend Sørmo<sup>a,b</sup>, Katinka M. Krahn<sup>c</sup>, Gudny Öyre Flatø<sup>d,e</sup>, Thomas Hartnik<sup>f</sup>, Hans Peter H. Arp<sup>a,g</sup>, Gerard Cornelissen<sup>a,b</sup>

Pyrolysis at  $\geq 500$  °C eliminated PCDD/Fs and PCBs (>99.9% removal efficiencies) in sewage sludge feedstocks

Pyrolysis at 600-800 °C: 2-23 mg/kg PAH (EBC-Agro limit 6 mg/kg)

Fate of Heavy Metals in Industrially Relevant Pyrolysis of Diverse Contaminated Organic Wastes: Phase Partitioning and Ph-Dependent Leaching

33 Pages • Posted: 23 Sep 2023

Erlend Sørmo  
Norwegian Geotechnical Institute

- Full-scale pyrolysis at 500-800 °C
- Heavy metal mass balance established for feedstock, biochar, condensate, and flue gas
- Biochar: Cu, Zn exceeded EBC-Agro threshold values
- Leaching tests show heavy metals are much more mobile in wood than sludge biochars (within the same order of magnitude or higher)
- Sewage biochar: relatively high total HM contents, but decreased leaching
- Wood biochar: low total HM contents, but increased leaching



# Clean up from contaminants



Journal of Hazardous Materials  
Volume 445, 5 March 2023, 130449



## Sewage sludge biochars as effective PFAS-sorbents

Katinka M. Krahn<sup>a, b, c</sup>, Gerard Cornelissen<sup>a, b</sup>, Gabriela Castro<sup>d</sup>, Hans Peter H. Arp<sup>a, d</sup>, Alexandros G. Asimakopoulos<sup>d</sup>, Raoul Wolf<sup>e</sup>, Rune Holmstad<sup>e</sup>, Andrew R. Zimmerman<sup>f</sup>, Erlend Sørmo<sup>a, b</sup>

Sorption effectiveness better for sewage sludge biochars than wood-based biochar and similar to activated carbons.



Master's Thesis 2023 60 ECTS  
Faculty of Environmental Sciences and Natural Resource Management

## Stabilization of PFAS contaminated soil with waste-based biochar sorbents

Waste/sludge-based biochars can be an effective alternative to e.g. fossil based activated carbon for remediation of PFAS contaminated soil.



Master's Thesis 2022 30 ECTS  
Faculty of Science and Technology

## Evaluation of sludge biochar for removal of PPCPs in treated greywater

Adsorption of pharmaceuticals and personal care products in treated greywater – Adsorption performance of sewage sludge biochar is similar to commercial activated carbon



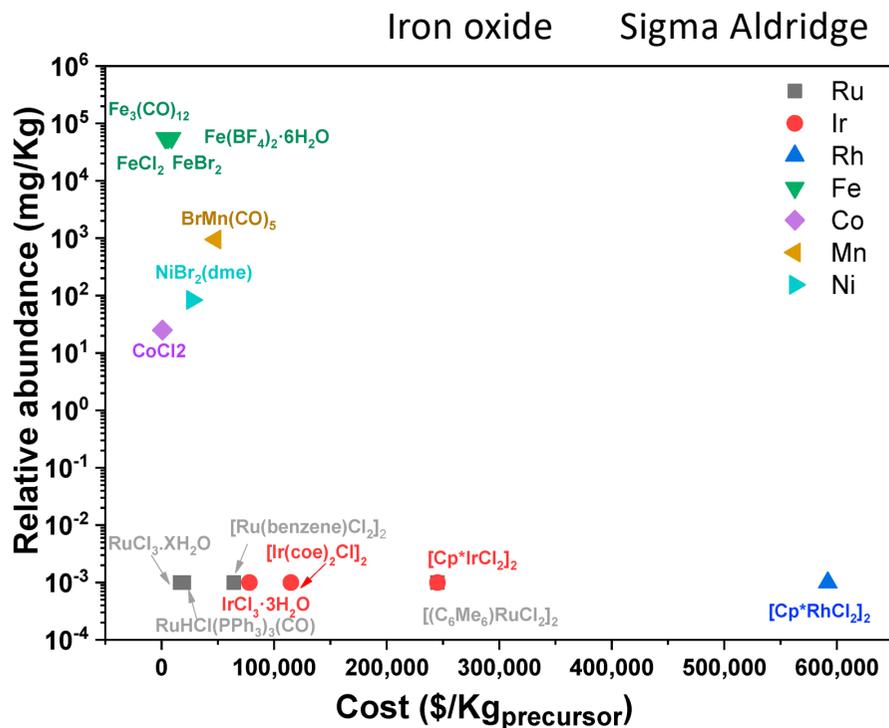
Master's Thesis 2023 30 ECTS  
Faculty of Science and Technology

## Sorption potential of sludge biochar for the removal of acetaminophen and carbamazepine from water

Sewage sludge biochar is a promising sorbent for removing pharmaceuticals (acetaminophen and carbamazepine) from water and its performance is slightly lower in comparison with activated carbon

# High-value adsorbents and catalysts/carriers

## Fe-catalyst 1000 - 10000 USD/t



### Cost Efficiency Analysis of $\text{H}_2$ Production from Formic Acid by Molecular Catalysts

by Maria Solakidou <sup>1</sup> Aikaterini Gemenetzi <sup>1</sup> Georgia Koutsikou <sup>1</sup>,  
 Marinos Theodorakopoulos <sup>1</sup> Yiannis Deligiannakis <sup>2</sup> and Maria Louloudi <sup>1,\*</sup>

### Examples of catalytic processes:

- advanced oxidation processes (AOPs) (sulfate activation system (Yu et al., 2019))
- Fenton-like system (Tu et al., 2012)
- photodegradation system (Mian and Liu, 2019)
- ozonation system (Huang et al., 2017b)
- electrocatalysis (Yuan and Dai, 2016)
- thermal catalysis (pyrolysis) (Qiu et al., 2020).



Chemosphere  
Volume 317, March 2023, 137929

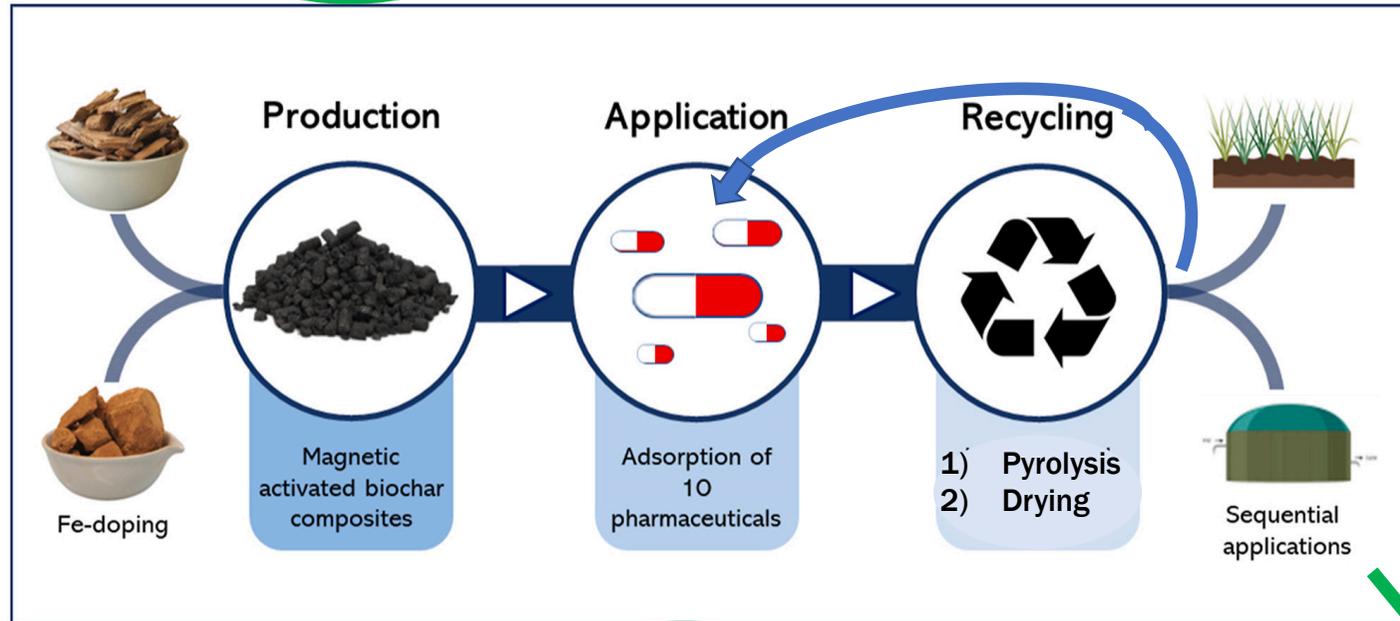


Co-pyrolysis technology for enhancing the functionality of sewage sludge biochar and immobilizing heavy metals

Zeyu Fan <sup>a</sup> , Xian Zhou <sup>a</sup> , Ziling Peng <sup>a</sup> , Sha Wan <sup>a</sup> , Zhuo Fan Gao <sup>a</sup> , Shanshan Deng <sup>a</sup> , Luling Tong <sup>b</sup> , Wei Han <sup>a</sup> , Xia Chen <sup>a</sup>

# Cascade biochar applications

- 1) Pyrolysis
- 2) Clean-up from contaminants (PAH/PFAS/pharmaceuticals etc)



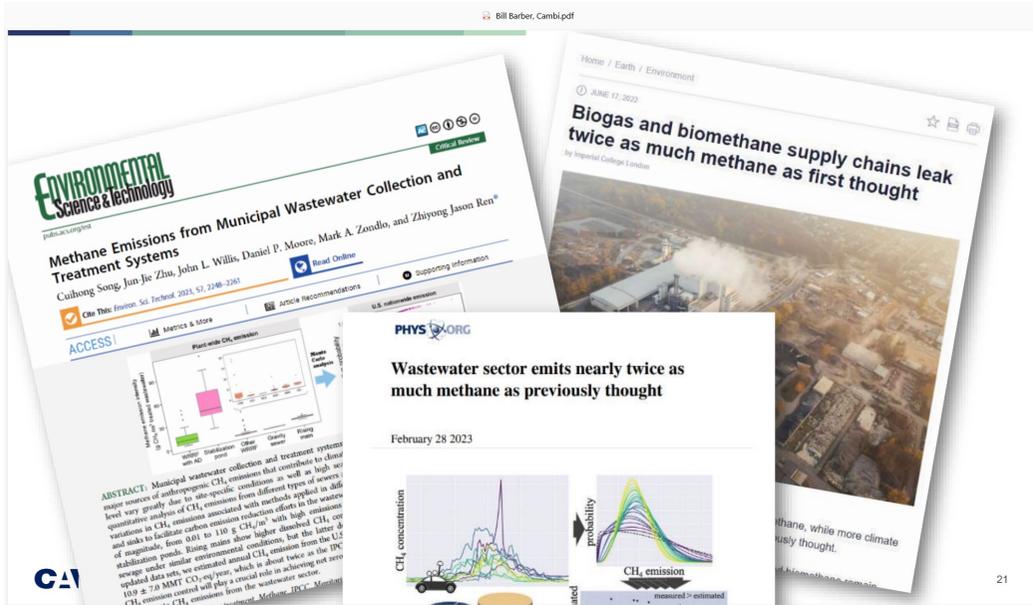
- Adsorption of PFAS, pharmaceuticals, heavy metals, Nutrients
- Catalysts

**C sink**



Sequential biochar system  
Christian Wurzer  
Ondřej Mašek  
UK Biochar Research Centre  
University of Edinburgh

# Synergy of pyrolysis and Biomethane and Biogas production



**European Biosolids & Bioresources  
Conference & Exhibition**  
19 -20 November 2024, The Point at Emirates Old Trafford, Manchester, UK /





[Home](#) / [News & Events](#) / Germany's CO<sub>2</sub> emissions drop...

This content is also available in: [German](#)

Press Release – 4 January 2024

## Germany's CO<sub>2</sub> emissions drop to record low but reveal gaps in country's climate policies

Germany's CO<sub>2</sub> emissions fell to their lowest level in 70 years in 2023. A large part of this reduction is due to an unexpectedly sharp decline in coal use. At the same time, emissions fell at the expense of energy-intensive industry as the economic situation and international crises prompted a drop in production. To achieve lasting emissions cuts, the German government must close gaps in its climate policies in 2024 - particularly in the transport and buildings sectors.

# Permanence?

Only about 15 percent of the CO<sub>2</sub> saved constitutes permanent emissions reductions resulting from additional renewable energy capacity, efficiency gains and the switch to fuels that produce less CO<sub>2</sub> or other climate friendly alternatives.

About half of the emissions cuts are due to short-term effects, such as lower electricity prices, according to the analysis.

# Assessing biochar's permanence: An inertinite benchmark



## Hamed Sanei

Professor

AARHUS UNIVERSITY

“Carbon Dioxide Removal (CDR) methods aim to replicate Earth's natural processes by extracting CO<sub>2</sub> from the atmosphere and preserving it in permanent, non-degradable forms. However, a critical aspect often overlooked is the Earth's "organic carbon pathway," which serves as a significant and effective means of natural carbon storage. Contrary to the prevailing understanding that mineralization is the sole permanent method of storing CO<sub>2</sub>, this presentation emphasizes the importance of the "organic carbon pathway.”

The Earth not only stores carbon through mineralization but also transforms biomass into inertinite macerals, highly carbonized organic forms that are virtually non-degradable. Once converted into inertinite, organic carbon transitions from the biosphere to the geosphere cycle, where it remains for multimillion-year timescales. This process is accountable for storing over 15,000,000 gigatons of organic carbon in sedimentary rocks.



International Journal of Coal Geology  
Volume 281, 5 January 2024, 104409



## Assessing biochar's permanence: An inertinite benchmark

Hamed Sanei<sup>a</sup>, Arka Rudra<sup>a</sup>, Zia Møller Møllersen Przyzwitt<sup>a</sup>, Sofie Kousted<sup>a</sup>, Marco Benkhettab Sindlev<sup>b</sup>, Xiaowei Zheng<sup>a</sup>, Søren Bom Nielsen<sup>a</sup>, Henrik Ingermann Petersen<sup>c</sup>

## Biochar Carbon Removals: Game-changing evidence

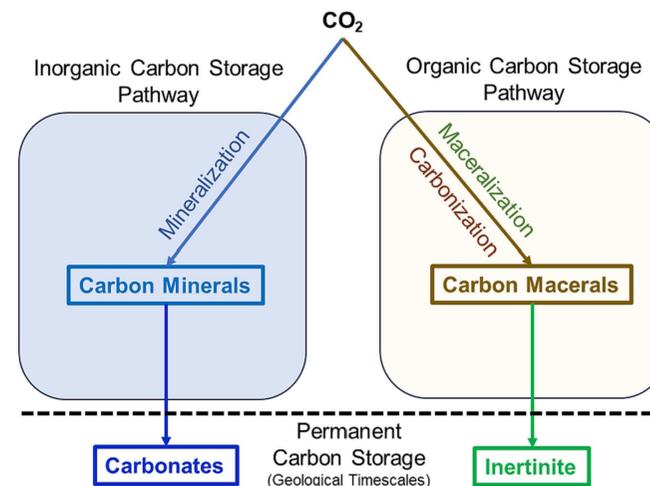
24/01/2024 at 11:40

11:40 title to follow, *Carbon Gap*

11:55 The next generation of biochar quality and carbon removal standards, *Carbon Standards International*

12:10 Biochar and a Paradigm Shift in Carbon Stewardship, *Aarhus University*

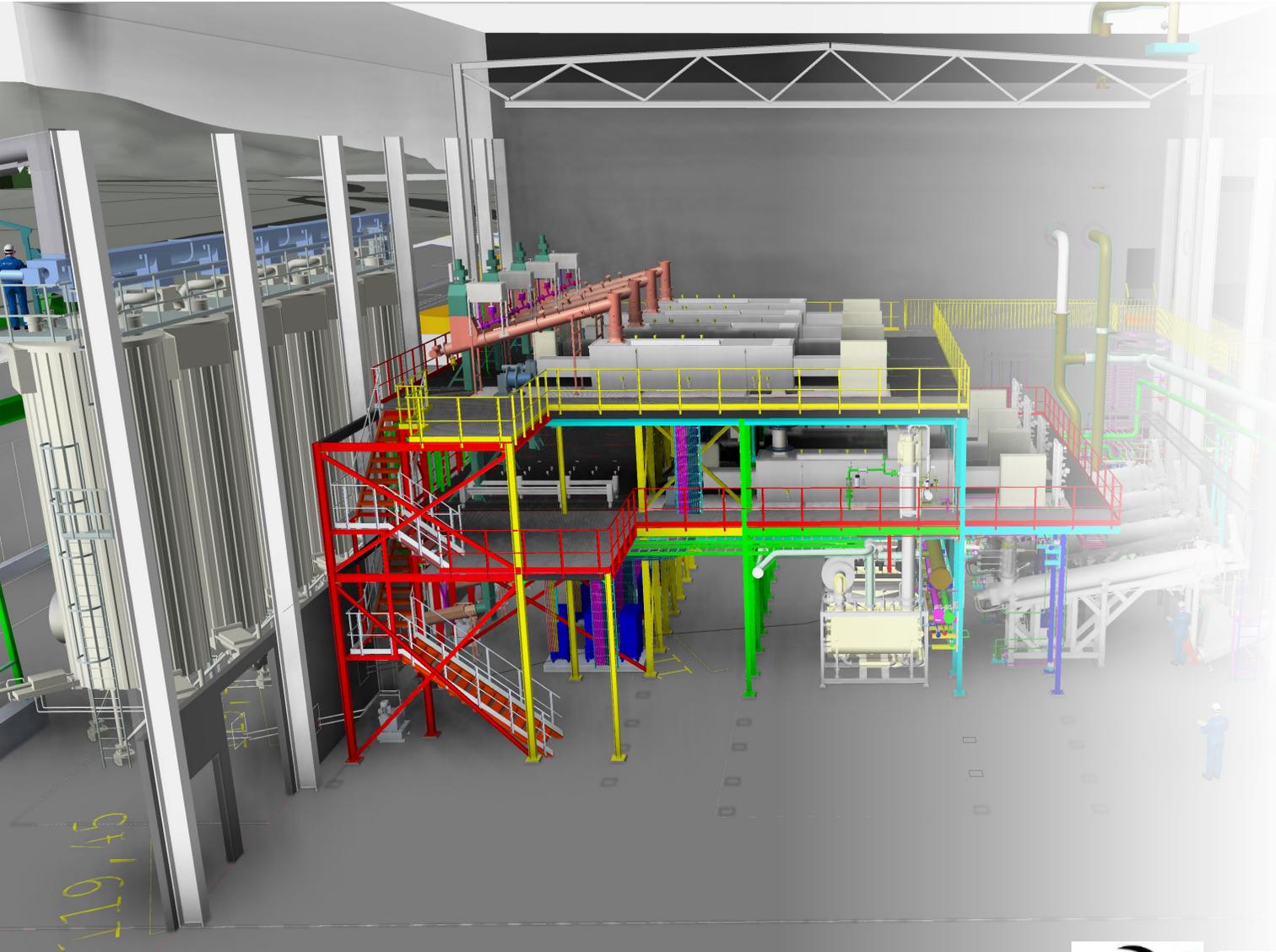
12:35 Open to the Floor



# Estimating value of sewage sludge

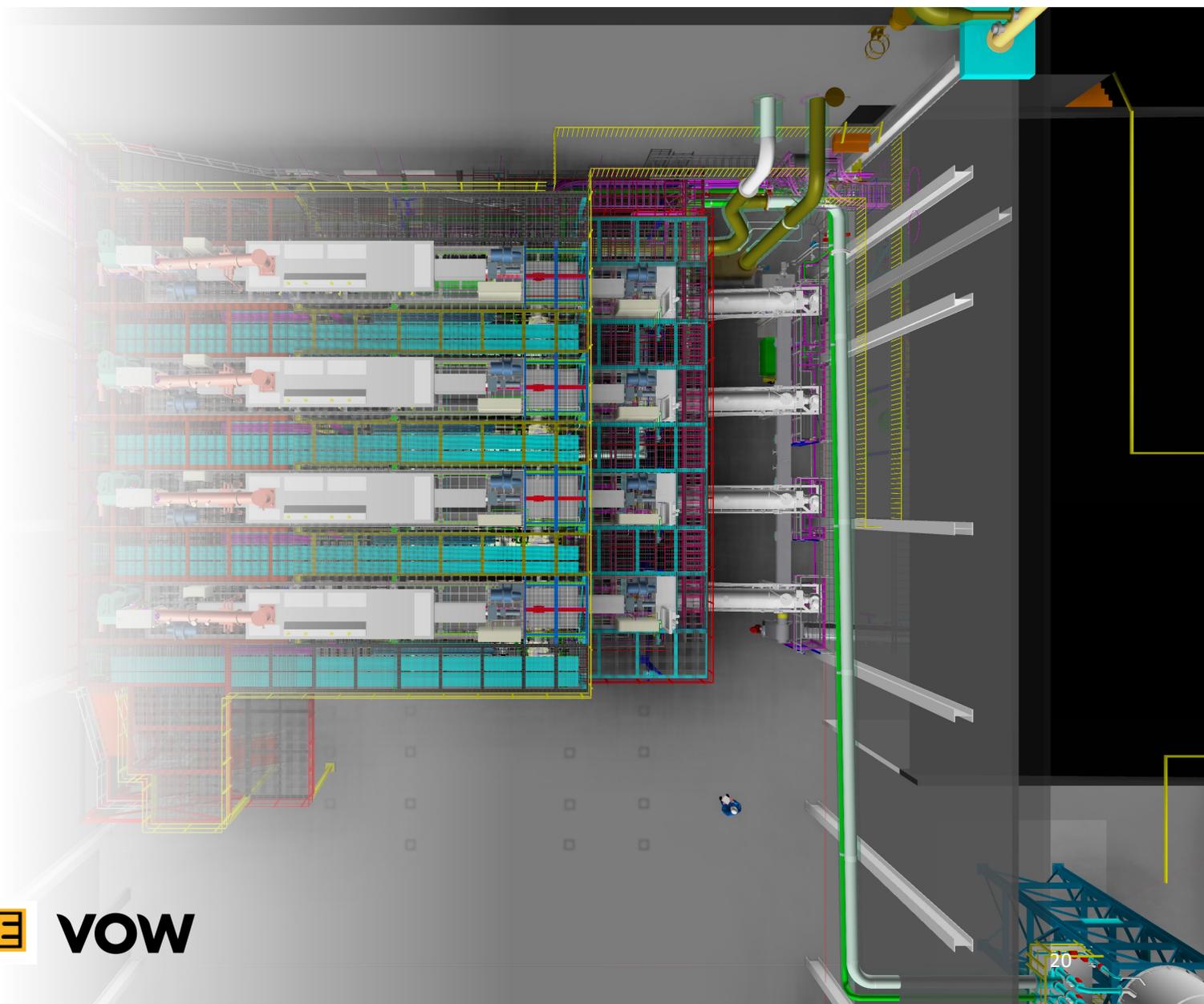
Fertiliser	250 – 600 EUR/t biochar
Adsorbent	500 – 2000 EUR/t biochar
Catalyst	1000 – 10000 EUR/t biochar
Carbon offsetting (permanent)	100 – 400 EUR/t biochar

- The European Commission estimated the sludge production in 2020 in the EU-27 countries to be around 2.6 million tonnes of dry solids per year (Eurostat, 2022).
- Pyrolysis: yield 50%, 20% C in biochar – 1 million tonnes CO<sub>2</sub>



**Vow Green Metals**  
**10,000-tonnes biocarbon**  
**production plant in Norway**

**Vow Green Metals**  
**10,000-tonnes biocarbon**  
**production plant in Norway**



**SCANSHIP**  
*for cleaner oceans*



**VOW**



Stand J41



ETIA groupe VOW



**Eduardo ARIZA**

*Business Development Manager*

ETIA



**Nataliia Kasian**

**VOW**

**[Nataliia.Kasian@scanship.no](mailto:Nataliia.Kasian@scanship.no)**

# Creating value from sewage

## VOW