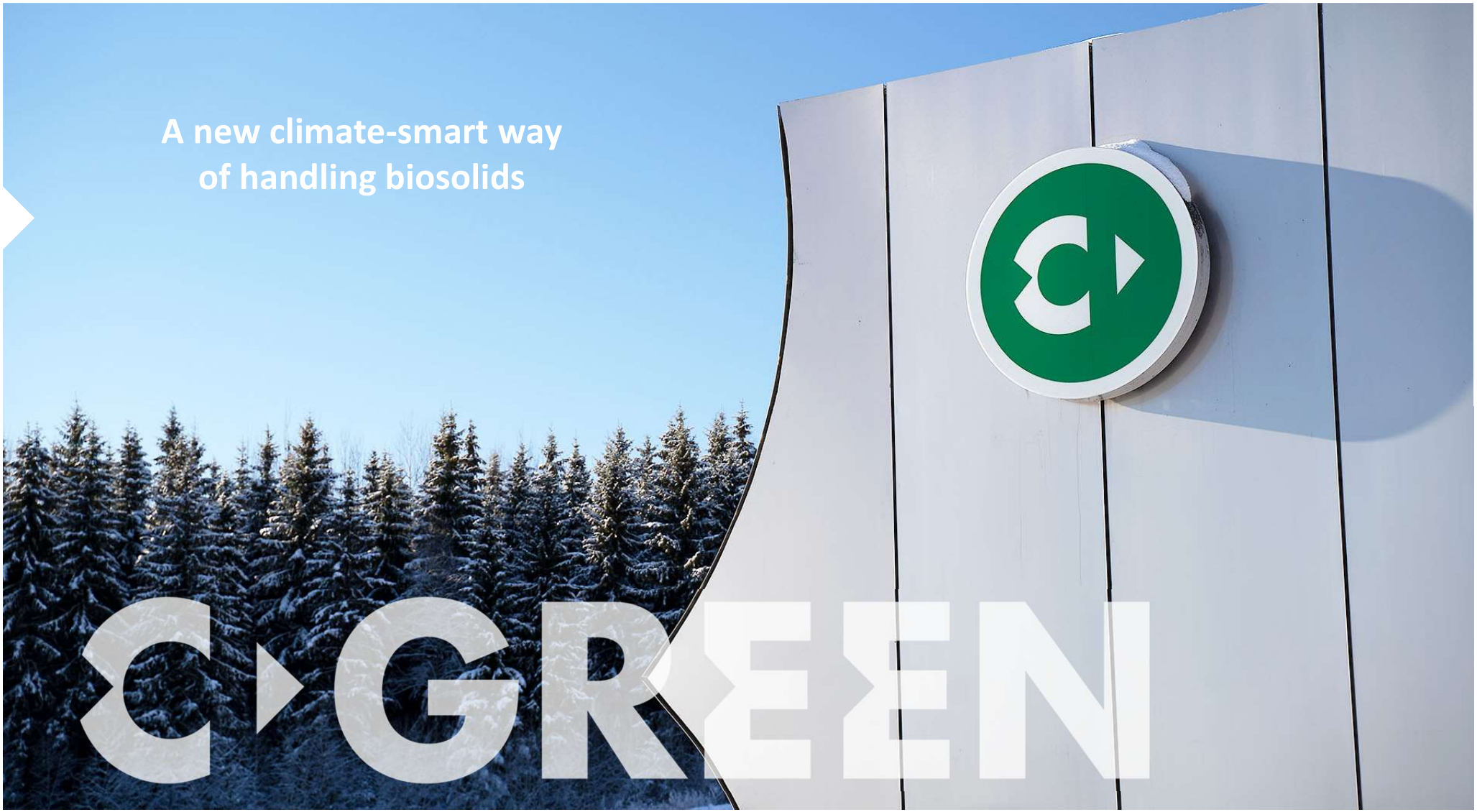

A new climate-smart way
of handling biosolids
C-GREEN

AGENDA

- C-Green's relationship with Next Rung Technology for the US
- Process overview
- Details on current installations
- Advantages offered by C-Green vs. other thermal technologies
- Q & A.

C-Green at a glance

» Swedish clean-tech company founded in 2015.

» HQ in Solna, near Stockholm. Equipped with a customized, state-of-the-art lab.

» C-Green is partnered with Next Rung Technology with the objective of commercializing the technology in the US

Team
35

US Partner
Next Rung Technology

C-GREEN'S OBJECTIVE:
Build the greatest wet waste recycling technology and inspire everyone to use it.

Source: Company information.

C-Green and Next Rung Technology

Next Rung Technology provides engineering, execution, operations & consulting services to organizations developing and delivering sustainable technologies.

Services Include:

- Strategic planning, road-mapping with an execution bias
- Technology development, scale-up and commercialization
- Project development, execution and management
- Organizational and operational leadership
- Manufacturing Sourcing and Scale-up

Located at:

Greentown Labs

CONTACTS:

John Ellersick – President, Next Rung Technology
jpellersick@nextrungtechnology.com

Susanne Feagin – Commercialization Program Manager
sfeagin@nextrungtechnology.com

C-Green

An innovation in wet waste refining technology

A unique patented combination of hydrothermal carbonization (HTC) and wet oxidation that can convert large amounts of wet organic waste into dry hydrochar

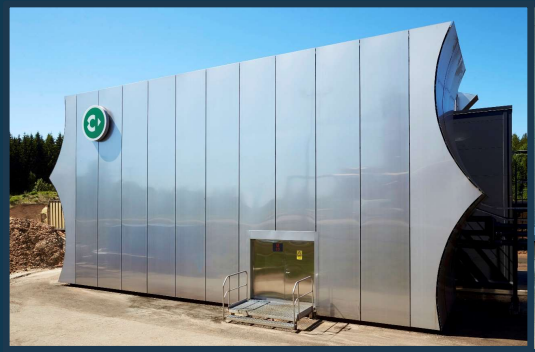
OXYPOWER™ HTC

From 5 tons of this...

To 1 ton of this...

OxyPower HTC™

Energy-efficient industrial hydrothermal carbonization of biosolids

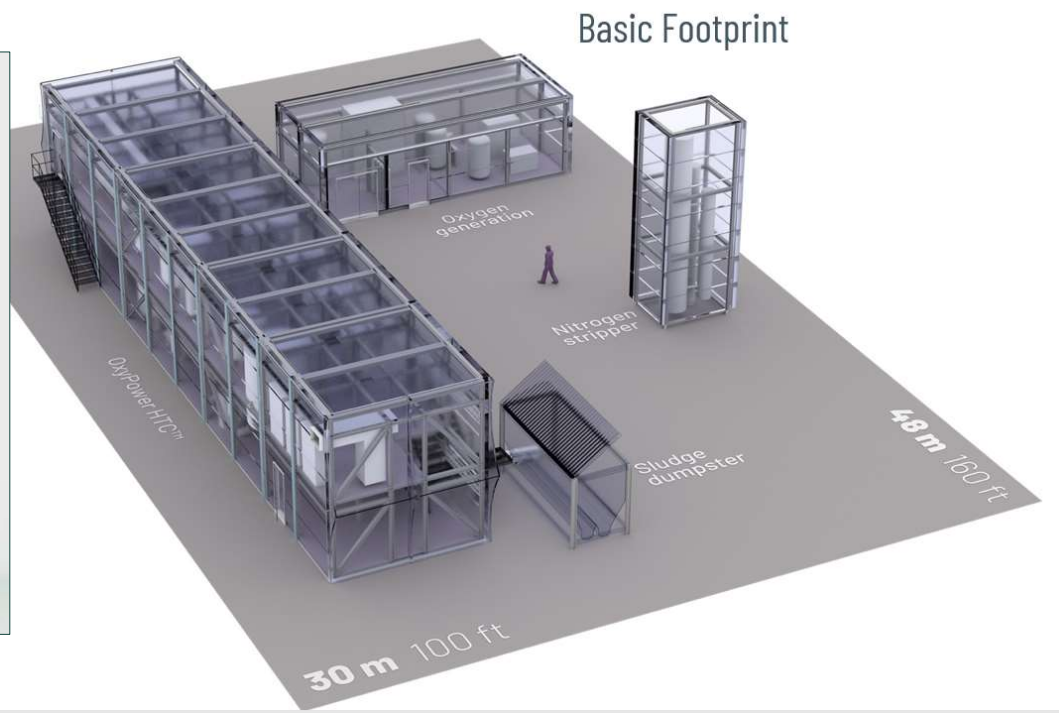


A standardized C-Green unit:

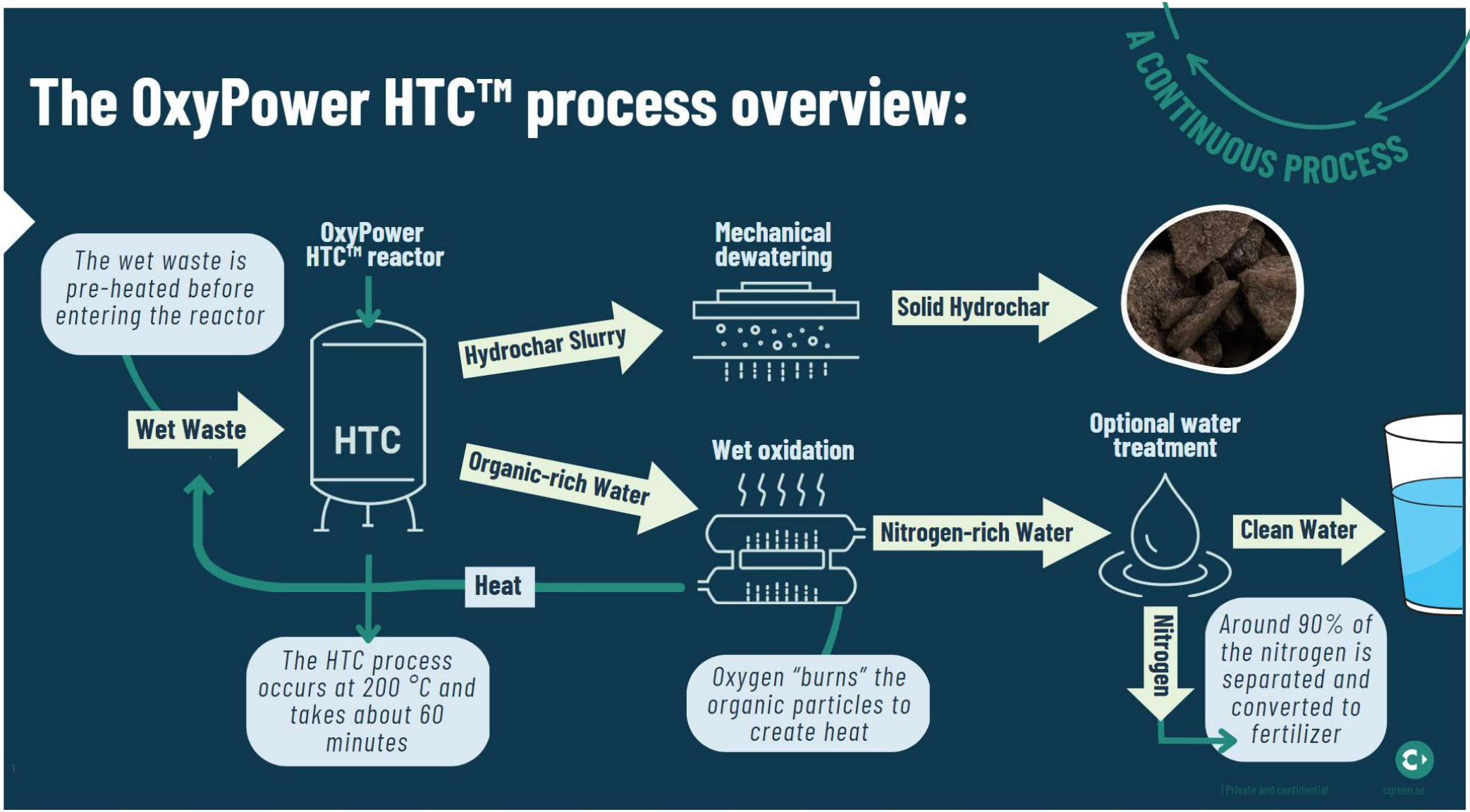
- Disposes of 25,000 tons of wet biosolids waste per year (**5000 tons DS**).
- Facilitates the recovery of phosphorus and nitrogen.
- Can increase biogas production in existing plants by **5-10 percent**.
- Ten patents for core technologies.
- Pre-manufactured in container-sized modules
- Small footprint
- Easy to deploy, operate, and maintain

Source: Company information.

Modular Construction

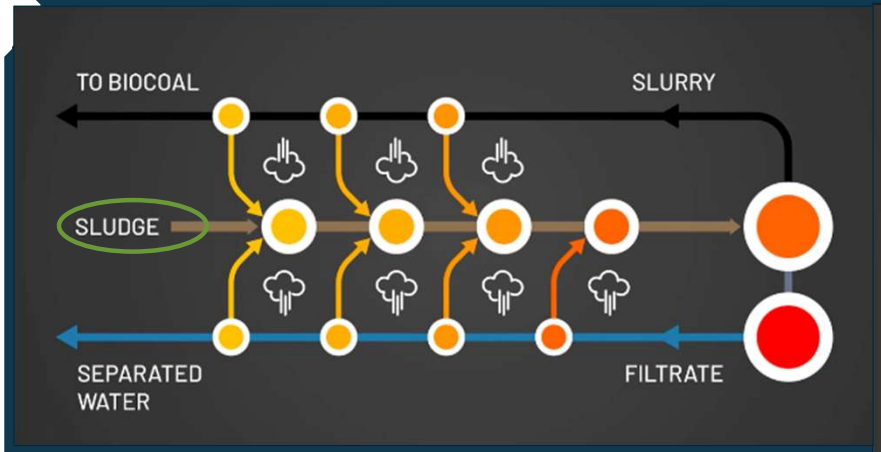


The OxyPower HTC™ process overview:

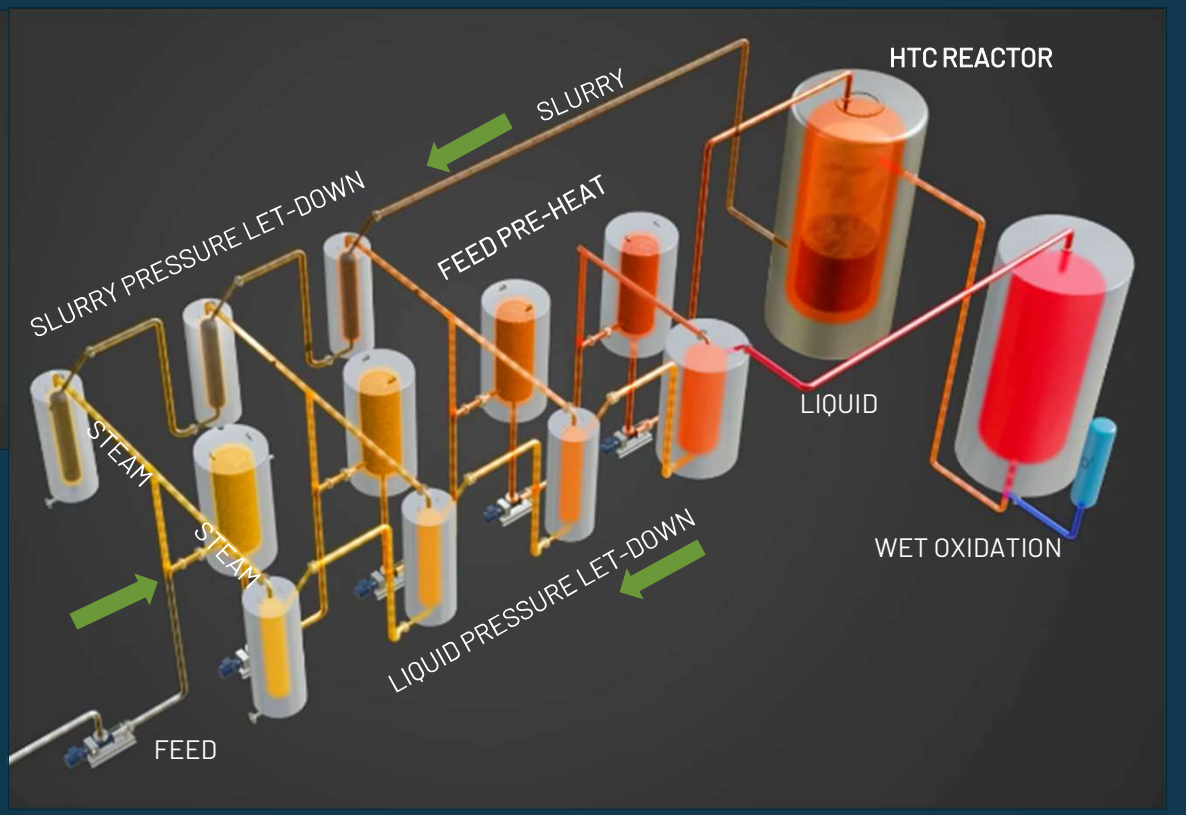


Feedstock Heating Process

Plan View – CC Heat Exchange

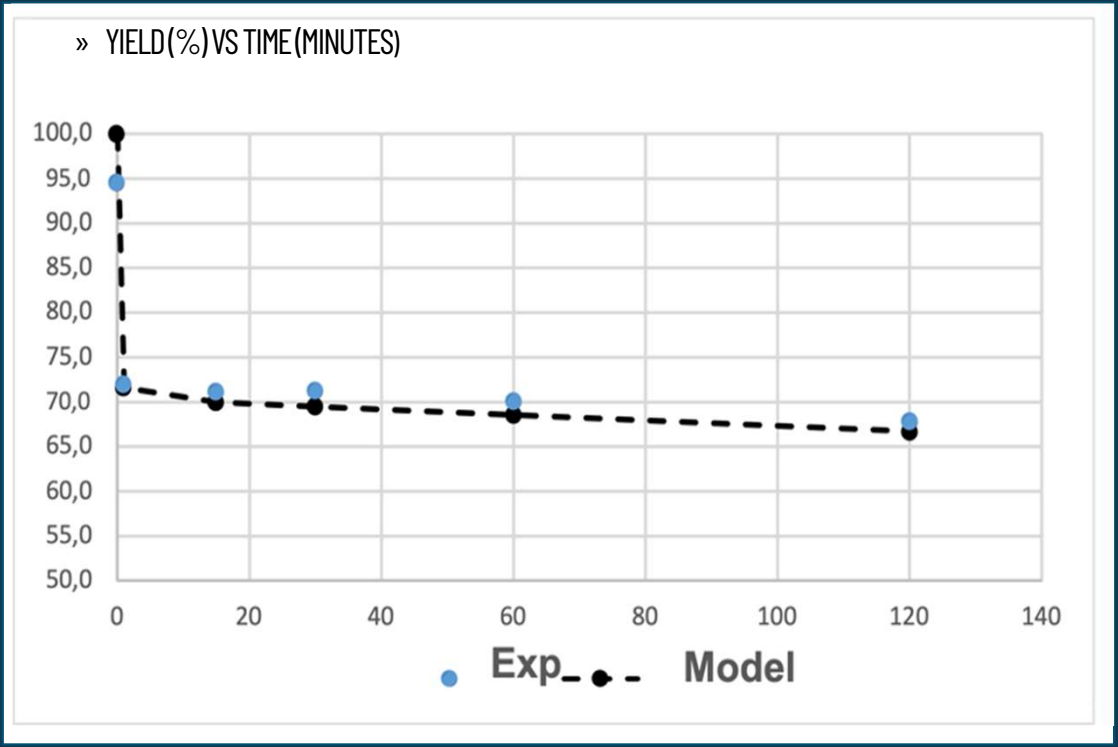


3-D View of Process



HTC kinetics at 200 °C

Reactions are rapid:



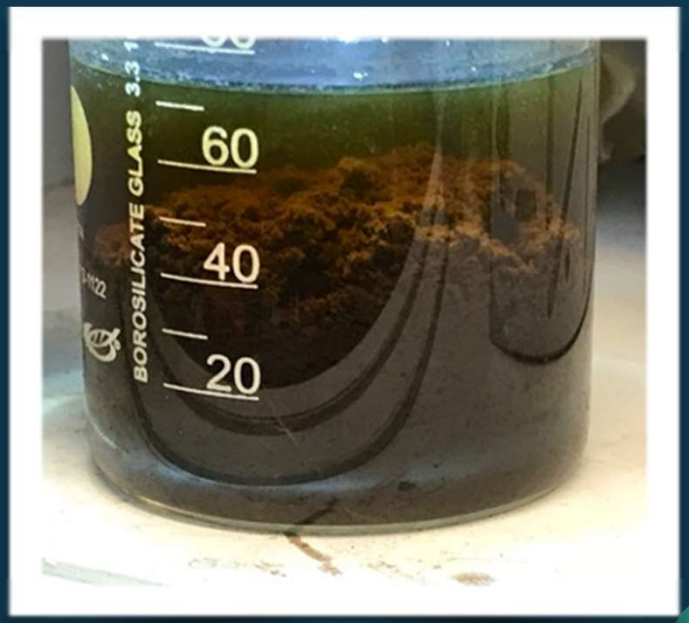
CHEMICAL REACTIONS:

Dehydration:

$C_2HOH \xrightarrow{\text{Acid}, \triangle} C_2 + H_2O$

Decarboxylation:

$RCOOH \longrightarrow R - H + CO_2$



Benefits of adding wet oxidation:

- Temperature increase from ~200°C to ~230°C
- COD reduced up to 99%
- Dramatic reduction of color and odor

Organic N:

- Standard OxyPower HTC – conversion to NH4
- Extended OxyPower HTC - conversion to N2

Typical Wet Oxidation Reactions:

Organics + O_2 ⟶ $CO_2 + H_2O$ + RCOOH*

Sulfur Species + O_2 ⟶ SO_4-2

Organic Cl + O_2 ⟶ Cl-1 + CO_2 + RCOOH*

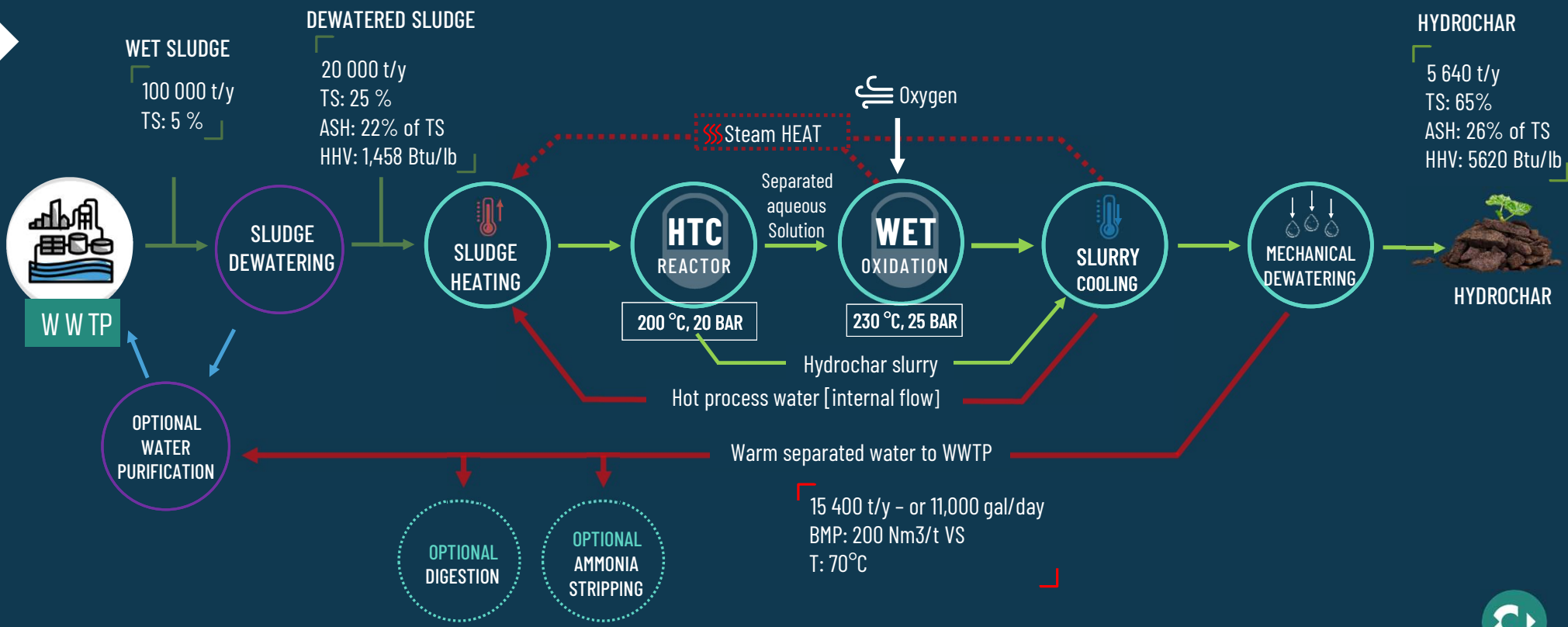
Organic N + O_2 ⟶ $NH_3 + CO_2$ + RCOOH*

Phosphorous + O_2 ⟶ PO_4-3

*Short chain organic acids such as acetic acid make up the major fraction of the residual organic compounds

OXYPOWER HTC™ - UNDIGESTED SLUDGE

Example mass & energy balance



NITROGEN

100% N_{tot}

HTC

During HTC, nitrogen is separated into the liquid phase and the hydrochar.

40-60% of the nitrogen ends up in the liquid phase. Nitrogen is present in different forms.

Wet oxidation

Wet Oxidation converts nitrogen into ammonium

Nitrogen stripping

Nitrogen stripping converts ammonium into ammonium sulphate $(NH_4)_2SO_4$

~ 10% of N_{tot}

$(NH_4)_2SO_4$

~ 40% of N_{tot}

40-60% of the total nitrogen ends up in the hydrochar.

~ 50% of N_{tot}

* If needed, the remaining 10% can be taken out with additional cleaning steps.

The wet oxidation in the OxyPower HTC process facilitates removal of 80-90% of the total nitrogen from the reject water.

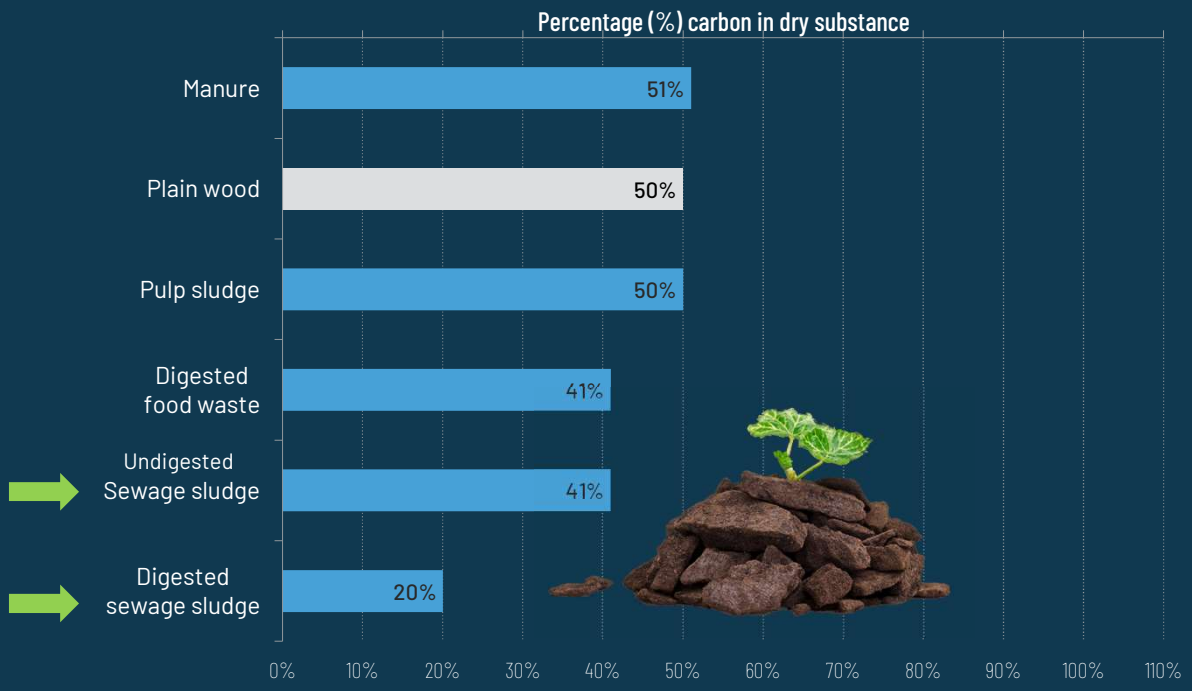
Burning the hydrochar will release 50% less NO_x to the atmosphere compared to burning sludge.

30-50% of the total nitrogen in the sludge can be recovered in the form of ammonium sulphate liquid ASL.


Hydrochar

Carbon content in hydrochar

The amount of carbon varies between different biosolids or biomass feedstocks.



Source: RISE analysis of OxyPower HTC™ hydrochar
SkogsSverige

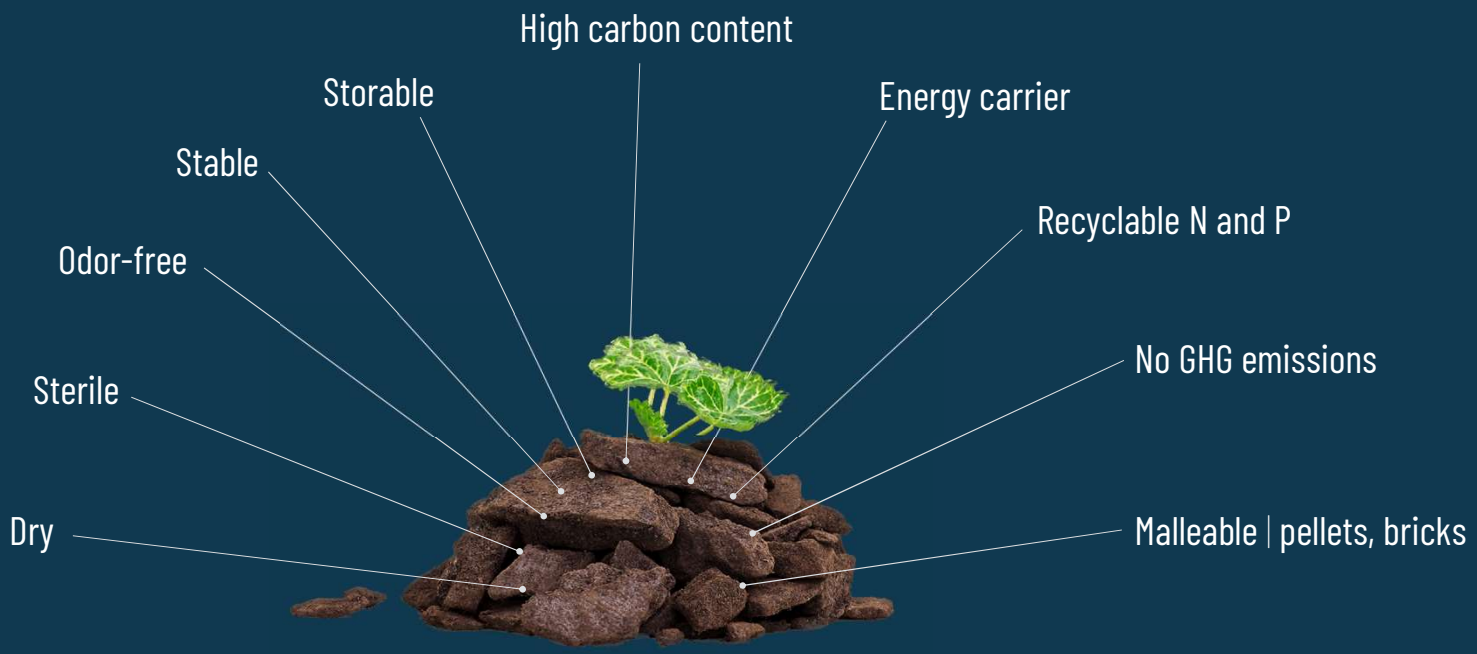
Hydrochar

– a new sustainable commodity

- A fossil fuel replacement
- A biofuel replacement
- An industrial feedstock
- For arable land development
- CO_2 A carbon sink

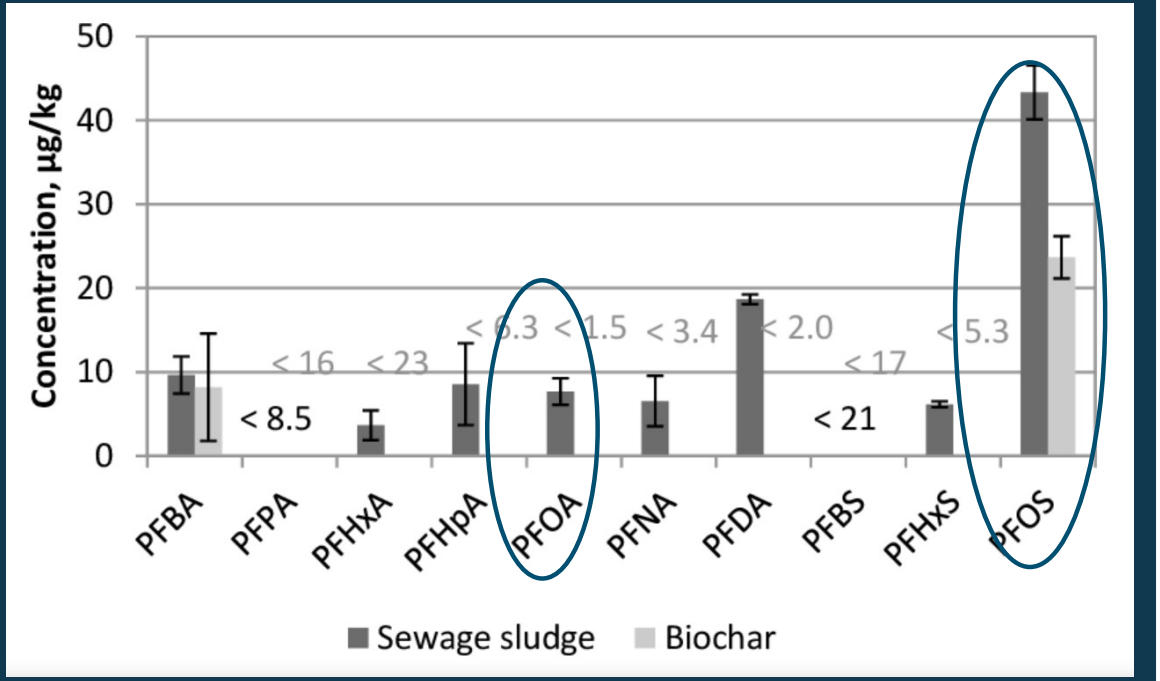
A Few Facts on hydrochar

Hydrochar is a useful product with many interesting characteristics and potential applications.



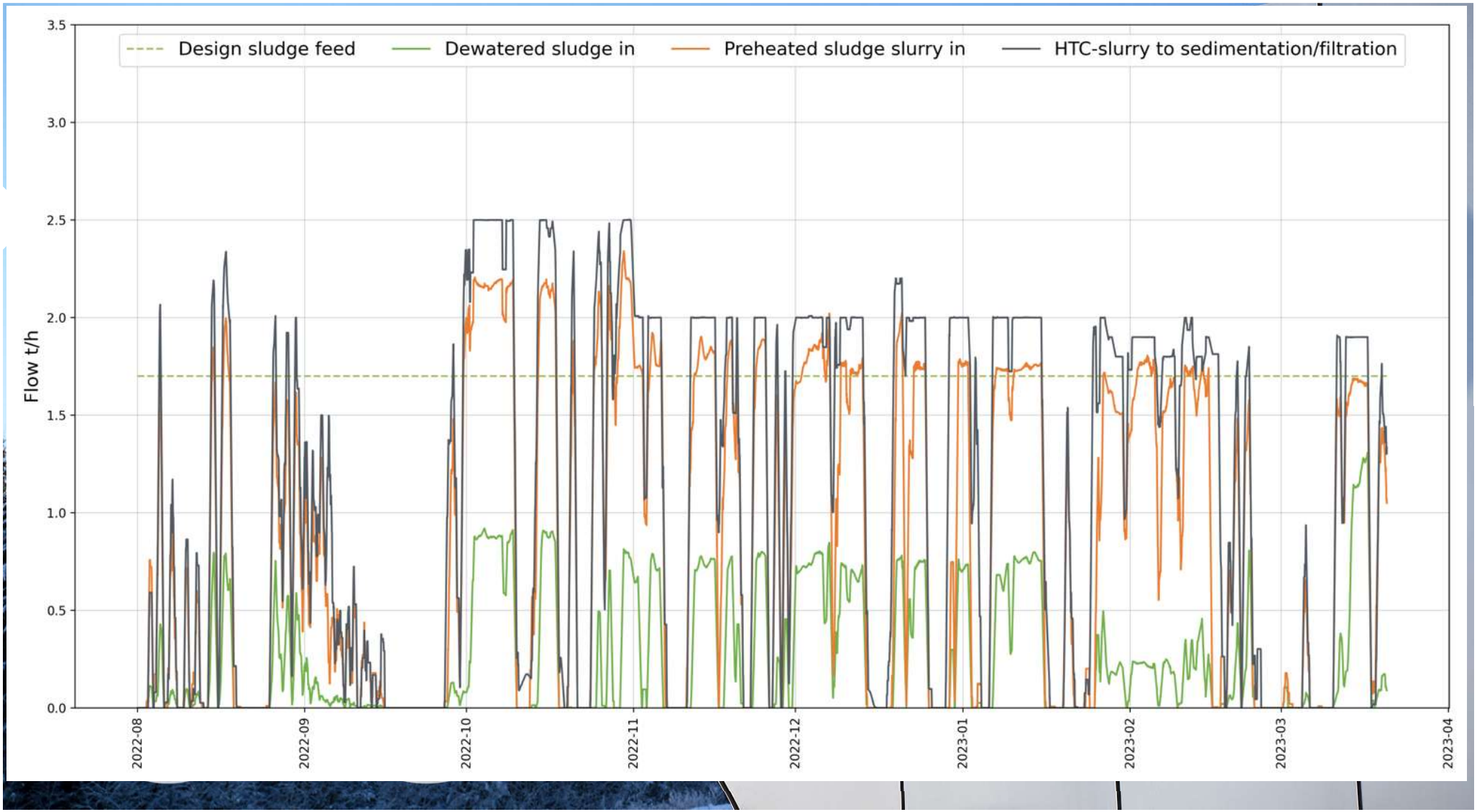
C-Green and PFAS

- Current data for PFAS testing of HTC is 'by others'
  - Indicates 2/3 reduction in total PFAs*
  - Complete removal of PFOA*
  - Testing on hydrochar only
- We are currently building out a C-Green lab in the US, and planning to perform PFAS testing later in 2023; potential testing on hydrochar and reject liquid
- Our current vision on management of PFAS.



** Behavior of Micropollutants during Hydrothermal Carbonization of Sewage Sludge. Claudia vom Eyser, 2016*


VOLVO
L120H


Design sludge feed
Dewatered sludge in
Preheated sludge slurry in
HTC-slurry to sedimentation/filtration
Flow t/h
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2022-08
2022-09
2022-10
2022-11
2022-12
2023-01
2023-02
2023-03
2023-04

Installations and Projects

Stora Enso – 2020

Heinola, Finland

Pulp & Paper

Status: Operational, in production

Demonstration, testing and optimization

18,000 ton/yr; reduces the mill's climate impact by an estimated minimum of 2,500 CO2eq per year.

REYM Rotterdam – Pilot and Full Scale

Waste recycling service, Netherlands

Pilot – 1 TPD – beginning March 2023

1 C-Green unit: Pre-project ongoing

Ragn-Sells - 2023

Sweden

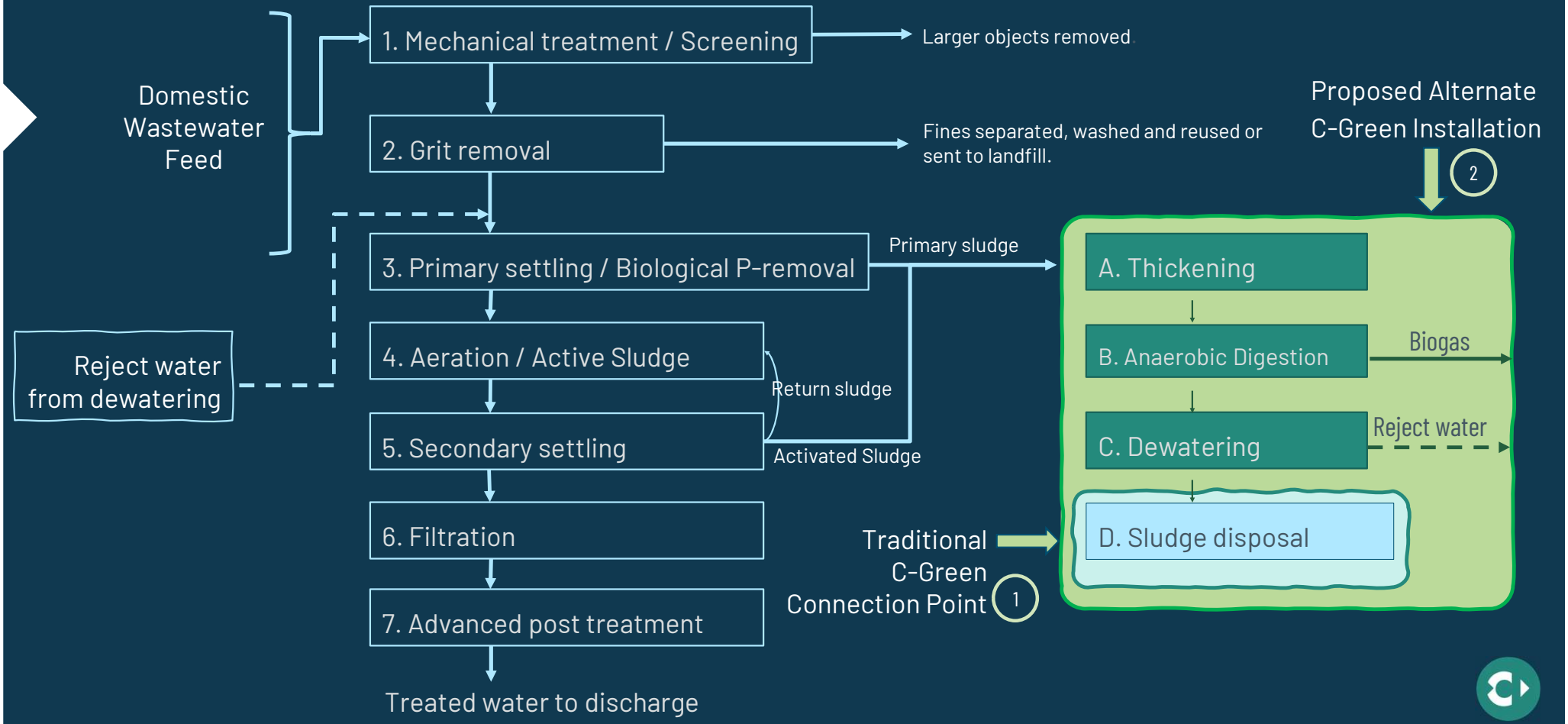
Waste recycling services

Commissioning: Q4-2023)

Status: Delivery project in progress

25,000 T/yr

Trials with REYM in Netherlands



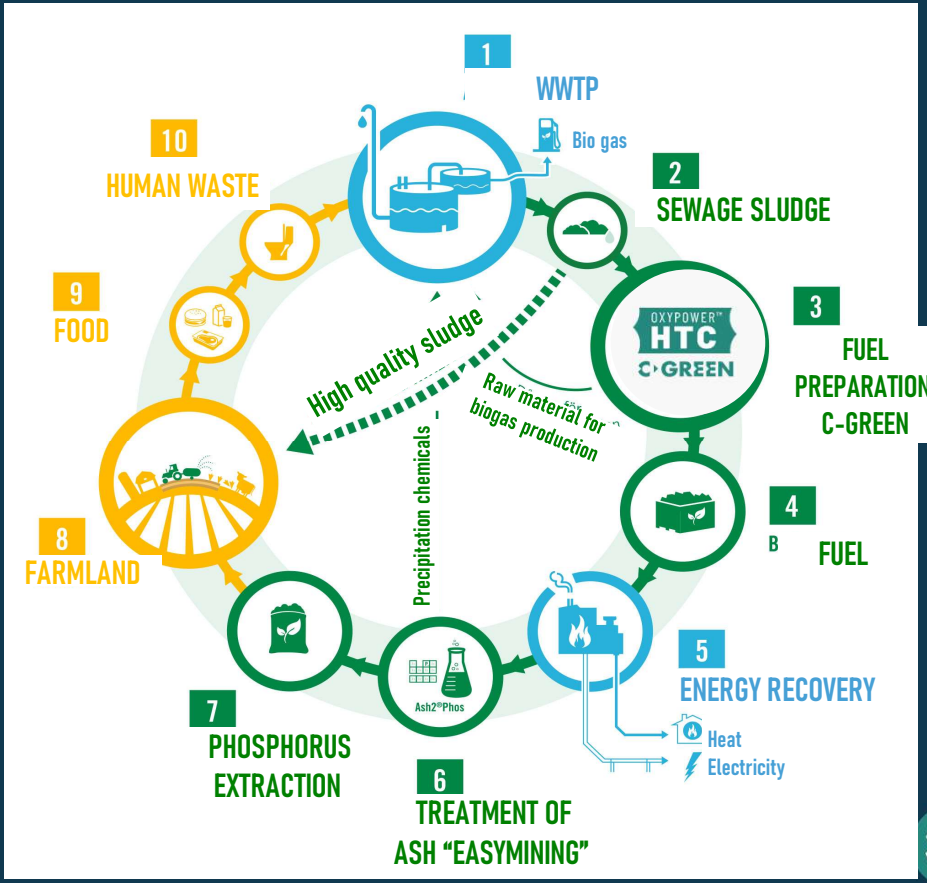
Collaboration with Ragn-Sells

New Installation in Q4 of 2023:

Collaboration to show that C-Green provides an alternative circular solution that enables the recovery of nutrients from biosolids that are not qualified for direct land application

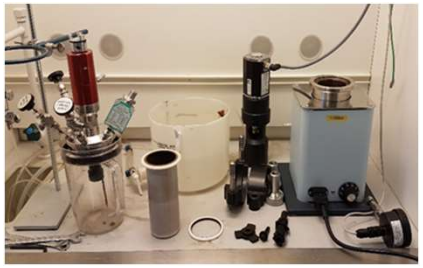
The Ragn-Sells Group (Scandinavia) - waste management, environmental services and recycling.

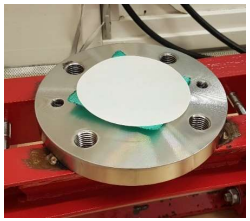
- 50% Nitrogen recovery
- Less NOx emissions compared to Incineration.
- Ash2Phos – patented Phosphorous recovery technology



THREE DIFFERENT SCALES FOR TRIALS

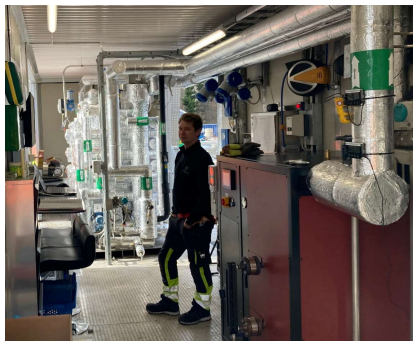
Lab with HTC / wetox reactor





- Lab trial of sludge samples, 1-5 kg (wet)
- Analysis of products / educts
- Basis for energy- and mass balance

Pilot plants HTC + wetox



- HTC pilot and wetox pilot
- Pilot scale trial of sludges, 200-400kg (wet)
- Production of hydrochar, HTC filtrate, reject water (wetox water) for application testing
- Demonstration of process in operation

Full-scale OxyPower HTC plant

- Full-scale demonstration plant in operation
- Capacity 18 000 tons wet sludge / year
- Pulp & Paper sludge
- Site integration on paper mill

Unique Advantages of C-Green Technology

Advantages of adding Wet Oxidation:

- No need for external heat
- Allows further treatment of organic compounds in filtrate
- WetOx can be tailored to meet specific needs of project (e.g., returning cleaner/purer water if required)

Advantages vs. pyrolysis and other high T processes:

- Allows feedstock to be converted without pre-drying.
- Does not produce particulate emissions (i.e. no combustion). Also 50% NOx reduction from biosolids to hydrochar.

Other Advantages:

- Potential for eliminating one or more traditional dewatering steps, treating sludge with much lower dryness – as low as 3-5%
- Nutrient recovery (NH4+ --> Nitrogen stripping); Recovering Phosphorous from ash
- Increased biogas production of 5-10% from return water (bio-methane potential)

Source: Company information.


Let’s decarbonize biosolids handling,
making it
circular and more efficient!
C-GREEN
OXYPOWER HTC