SoMax

Hydrothermal Carbonization at the Borough of Phoenixville WWTP

Jeremy Taylor
Chief Sustainability Officer
SoMax Circular Solutions

NORTH EAST RESIDUALS & BIOSOLIDS CONFERENCE
Sponsored by NEWEA AND NEBRA
2022 SPECIALTY CONFERENCE & WORKSHOP SERIES
NEWEA WORKING FOR WATER QUALITY
25th Anniversary 1997–2022 nebra North East Biosolids & Residuals Association

Agenda

- Intro to SoMax
- Fundamentals of Hydrothermal Carbonization (HTC)
- Hydrothermal Carbonization and the Status Quo
- Development of SoMax HTC at the Borough of Phoenixville WWTP

SoMax Circular Solutions

2015
Partnered with Villanova Sustainable Engineering

2018
3rd Generation Reactor Design

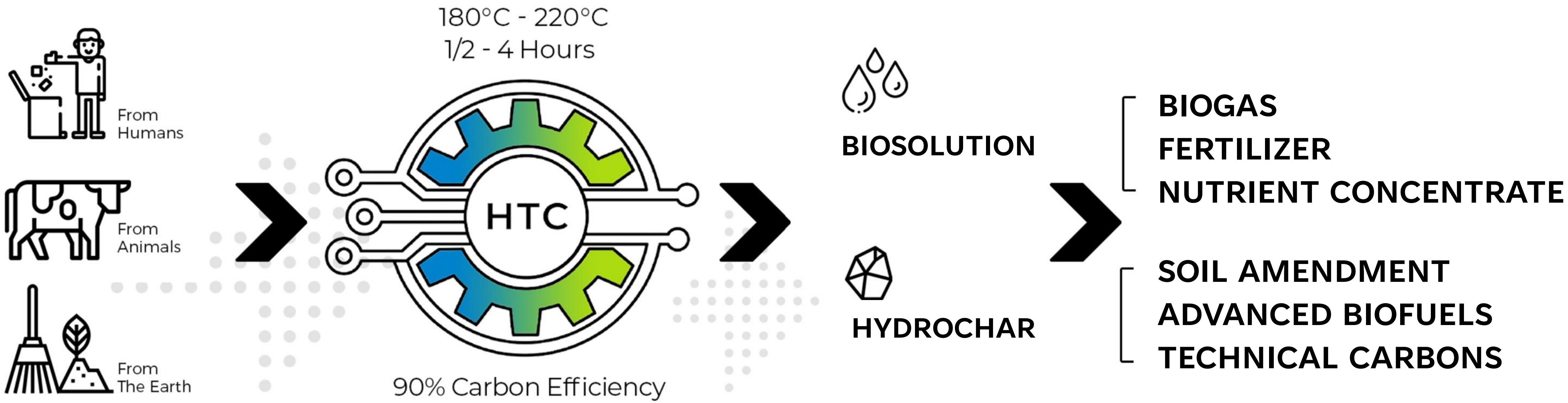
2019
Awarded design-build contract for 1st HTC plant in North America

2019
Finalist – The Manure Challenge
The Yield Lab Institute

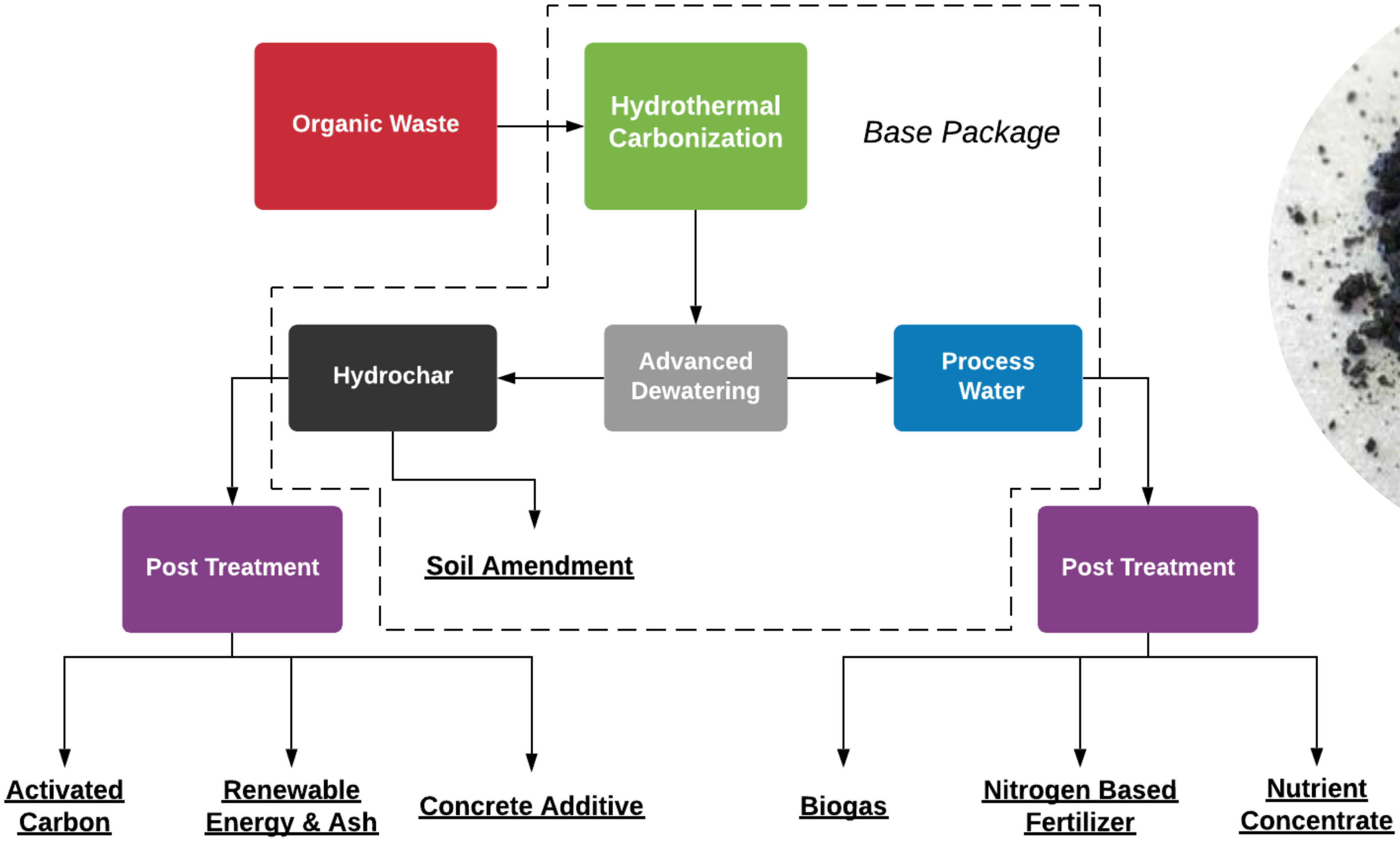
2021
Winner – Water Resource Recovery Prize
U.S. Department of Energy
Seeking scalable and repeatable solutions for implementation at WWTP across U.S.

2021
Winner – Diageo's Low Carbon Heat Challenge
Integrating Hydrothermal Carbonization as a closed loop solution for Spent Distillers Grains

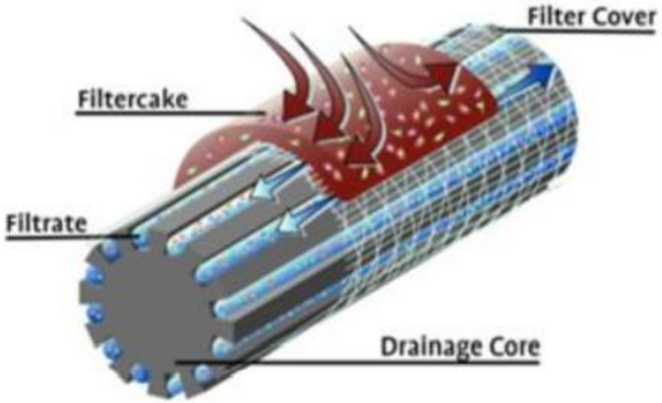
Hydrothermal Carbonization



Commercial Process Overview



Advanced Dewatering – Bucher Press



- Slow Rotating Body – Hydraulic Filter Press
- **Polymer Free Dewatering**
- > 99% solids capture with <100mg/L TSS in the filtrate
- 50-65% TS hydrochar dewatering
  - 70%+ TS from pilot unit w/acid addition

HTC’s Impact on Sludge and Biosolids

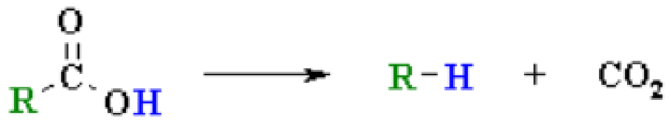
Pre HTC
~20% TS Primary Sludge

Post HTC
Hydrochar Product Slurry

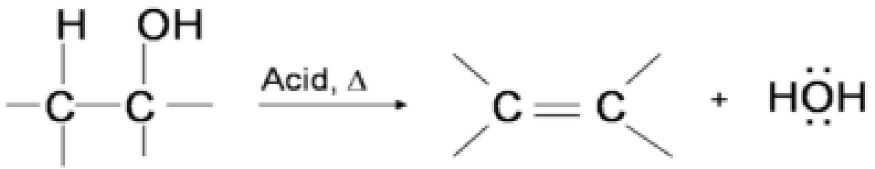
- 70 – 80% Sludge Reduction
- Improves Dewatering Efficiency
- Increases Energy Density and Carbon Concentration
- No Sticky Phase
- Pathogen Free
- Pharmaceutical and PFAS Reduction

Reaction Mechanisms – Carbon

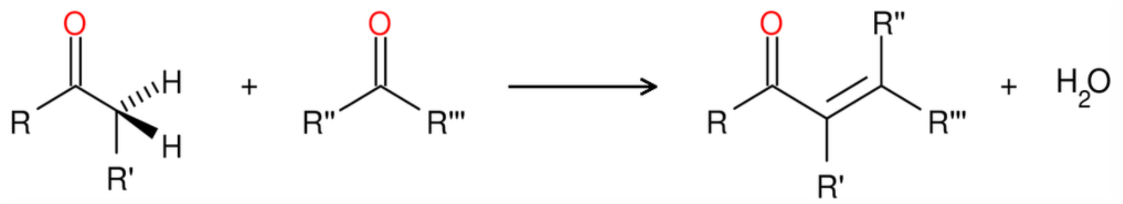
Hydrolysis – Cleaves large molecules



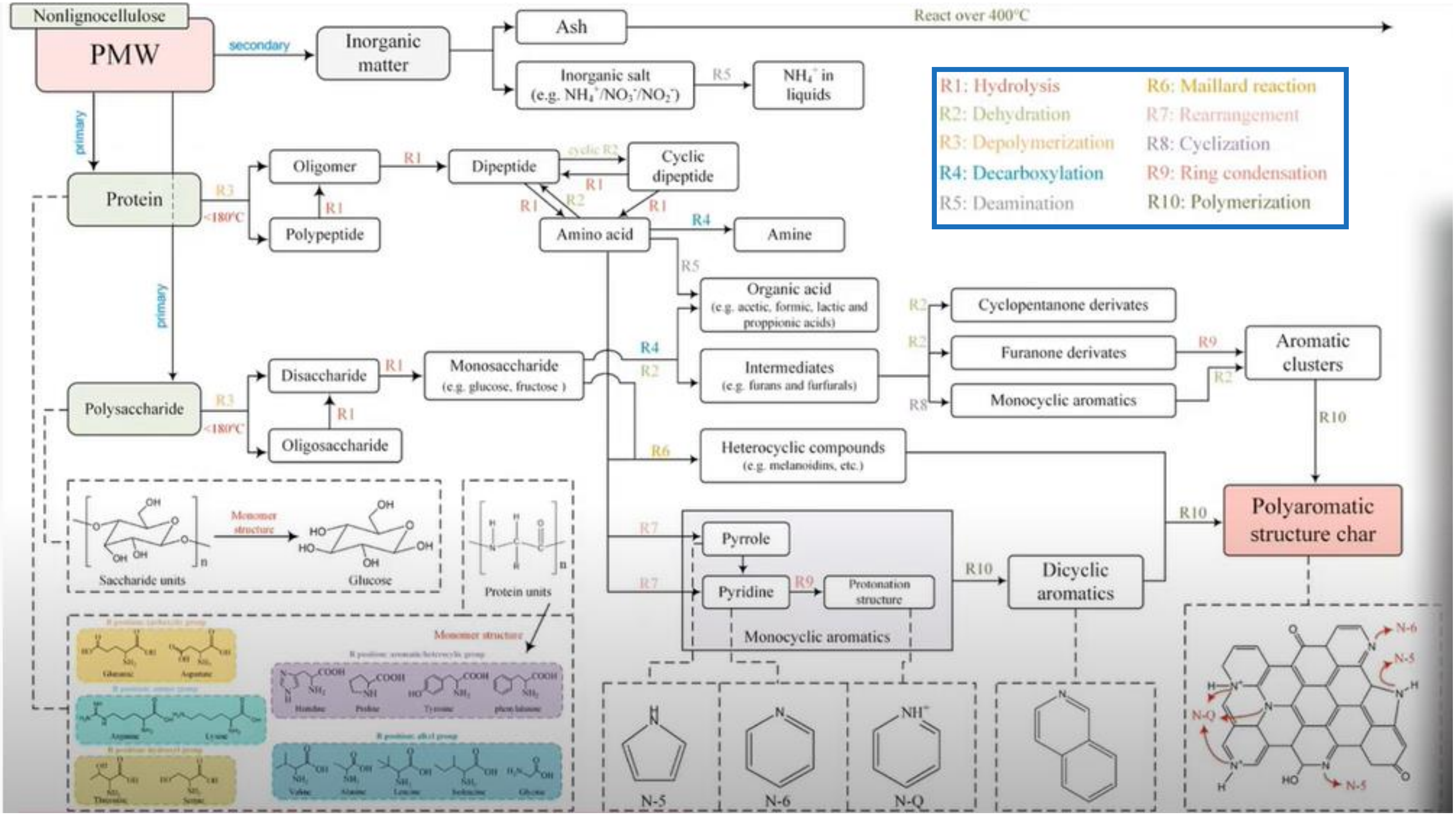
Decarboxylation – Creates CO_2 gas



Dehydration – Creates water

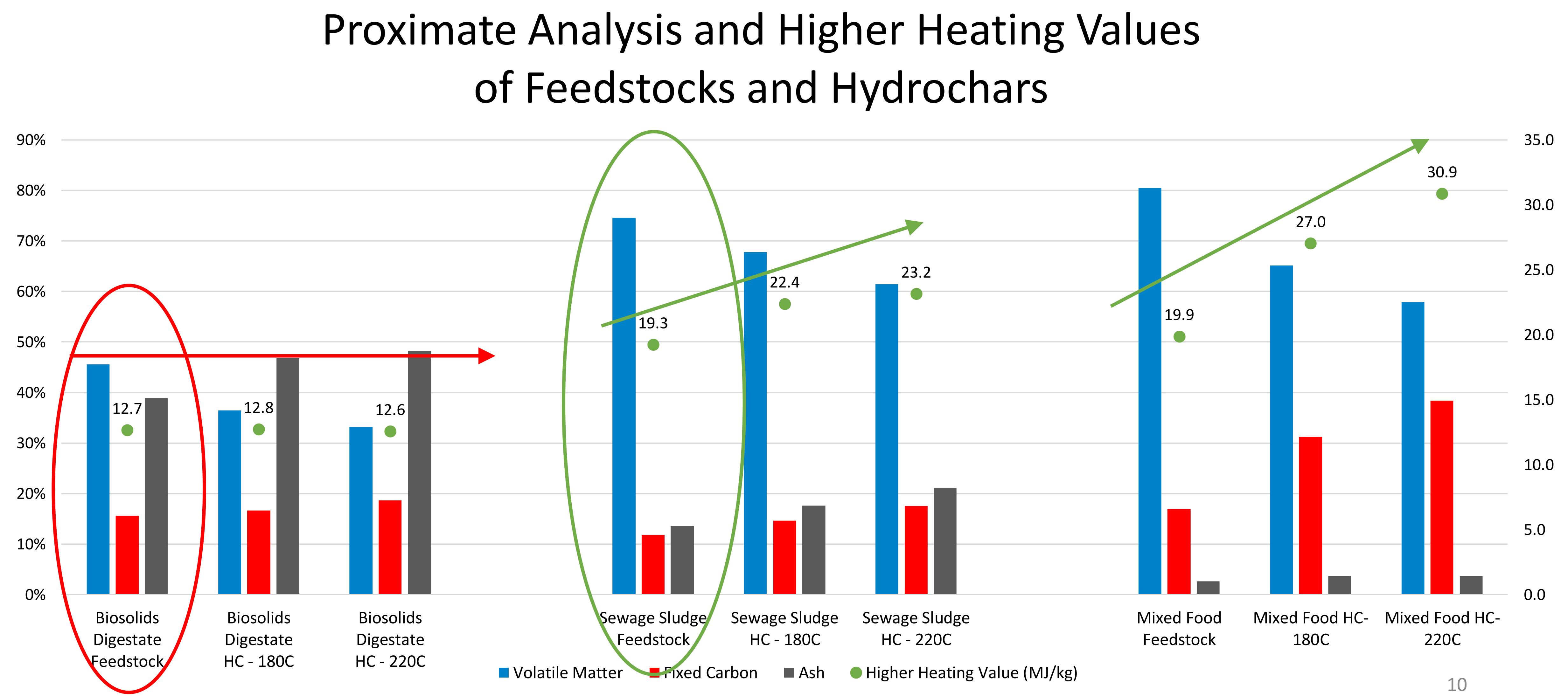


Condensation – Creates larger molecules and water



https://www.youtube.com/watch?v=QX2A95eSv9I – Prof. Stergios Vakalis

Reaction Trends - TGA and HHV



Hydrochar aka Bio(*genic*) Coal

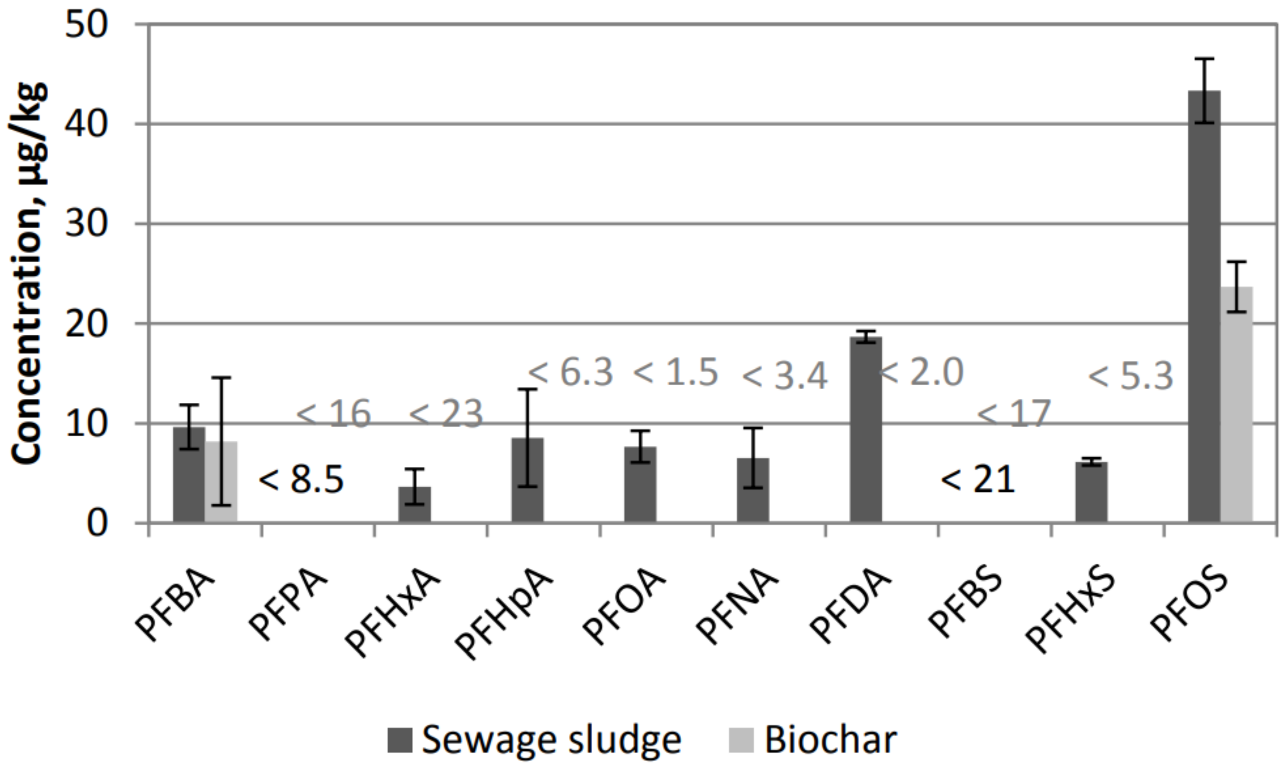
	BioCoal (Spent Grain)	Anthracite	Bituminous	BioCoal (Mixed Food)	Sub-Bituminous	BioCoal (Raw Sewage)	Lignite
Heat Content (BTU/lb)	14,000 - 16,000	13,000 - 15,000	11,000 - 15,000	11,500 - 13,300	8,500 - 13,000	9,000 - 10,300	4,000 - 8,300
Fixed Carbon	20 – 30%	85 – 98%	45 – 85%	30 – 40%	35 – 45%	15 – 20%	25 – 35%
Ash	0.5 – 1.5%	10 – 20%	3 – 12%	2 – 5%	<10%	15 – 20%	10 – 50%
Formation Time	3 Hours	350,000,000 Years	300,000,000 Years	2 Hours	100,000,000 Years	1 Hour	60,000,000 Years

BioCoal heating values range between 9,000 – 16,000 BTU/lb and has a **Net Zero** Carbon emission factor.

https://www.purdue.edu/discoverypark/energy/assets/pdfs/cctr/outreach/Basics8-CoalCharacteristics-Oct08.pdf

HTC and PFAS

- HTC parameters of 210°C and 4 hours
- Sum of all PFAs in Sewage Sludge: 104 µg/kg_{DM}
- Sum of all PFAs in Hydrochar: 32 µg/kg_{DM}
- **2/3 reduction in total PFAs**
- Complete removal of PFOA
- HTC process water/filtrate not tested



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

HTC and Pharmaceuticals

- HTC parameters of 210°C and 4 hours
- Decomposition Temperature not indicative of removal
- Concentrations of 6 of the tested pharmaceuticals were below LOQ
- HTC process water not tested

	Measured concentration in spiked sewage sludge $\mu g/kg_{DM}$	Concentration after HTC $\mu g/kg_{DM}$	Removal during HTC %
Ibuprofen	350 ± 33	130 ± 15	63
Phenazone	210 ± 33	230 ± 6	No removal
Carbamazepine	560 ± 23	< 20	> 98
Bezafibrate	180 ± 8	< 40	> 89
Fenofibric acid	340 ± 23	< 20	> 97
Metoprolol	650 ± 96	400 ± 23	39
Propranolol	360 ± 120	70 ± 14	81
Clarithromycin	220 ± 55	< 20	> 95
Roxithromycin	190 ± 63	< 10	> 97
Erythromycin	180 ± 24	< 10	> 98

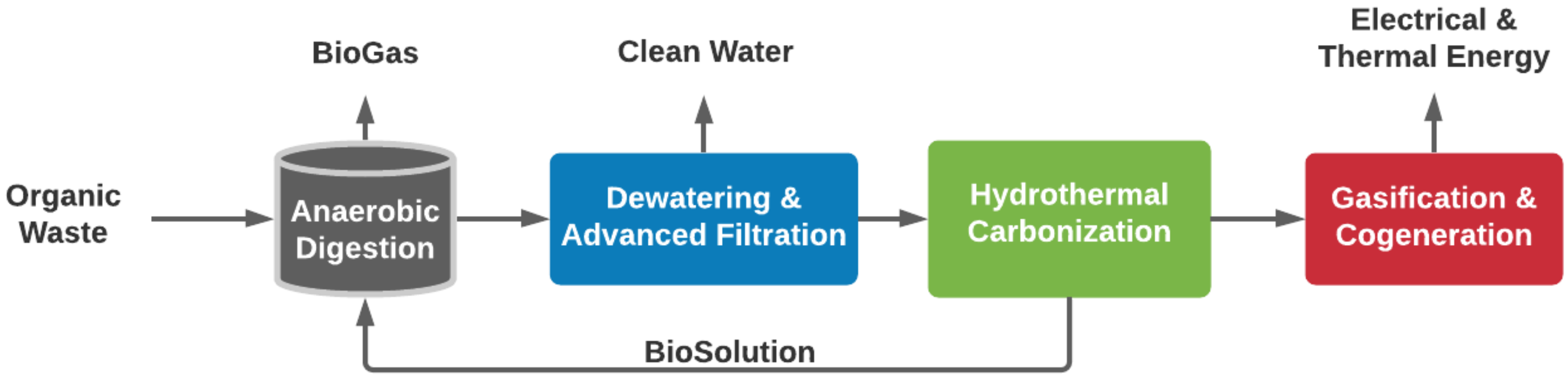
Behavior of Micropollutants during Hydrothermal Carbonization of Sewage Sludge. Claudia vom Eyser, 2016

HTC vs. Standard Organic Waste Solutions

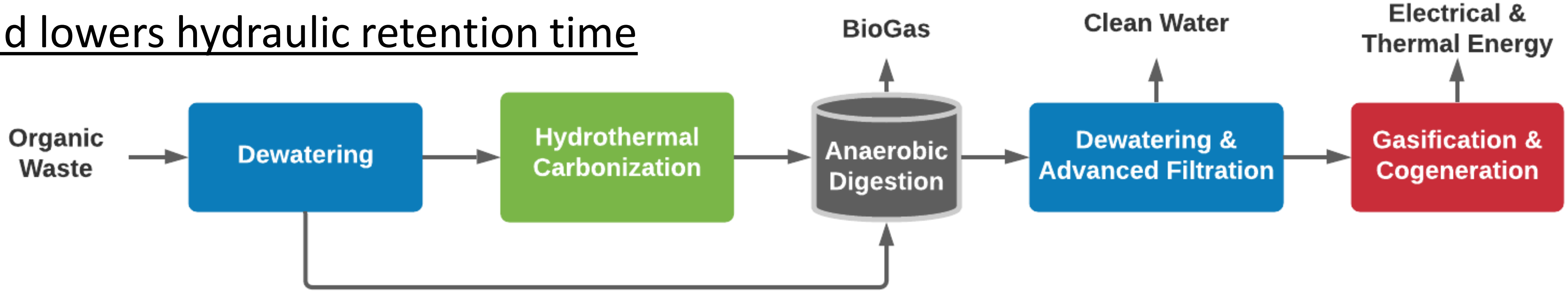
Process	Carbon Efficiency	Process Duration	Final Product
Landfill	0%*	Months-Years	Landfill Gas, Leachate
Composting	10%	12 Weeks	Soil Amendment
Anaerobic Digestion	50%	15-40 Days	Biogas – 60% Methane, 40% CO_2
Hydrothermal Carbonization	**Up to 90%**	**30 Minutes – 4 Hours**	**Hydrochar**

HTC + Anaerobic Digestion

Produces up to **30% more Biogas**



Produces up to **300% more Biogas** and lowers hydraulic retention time

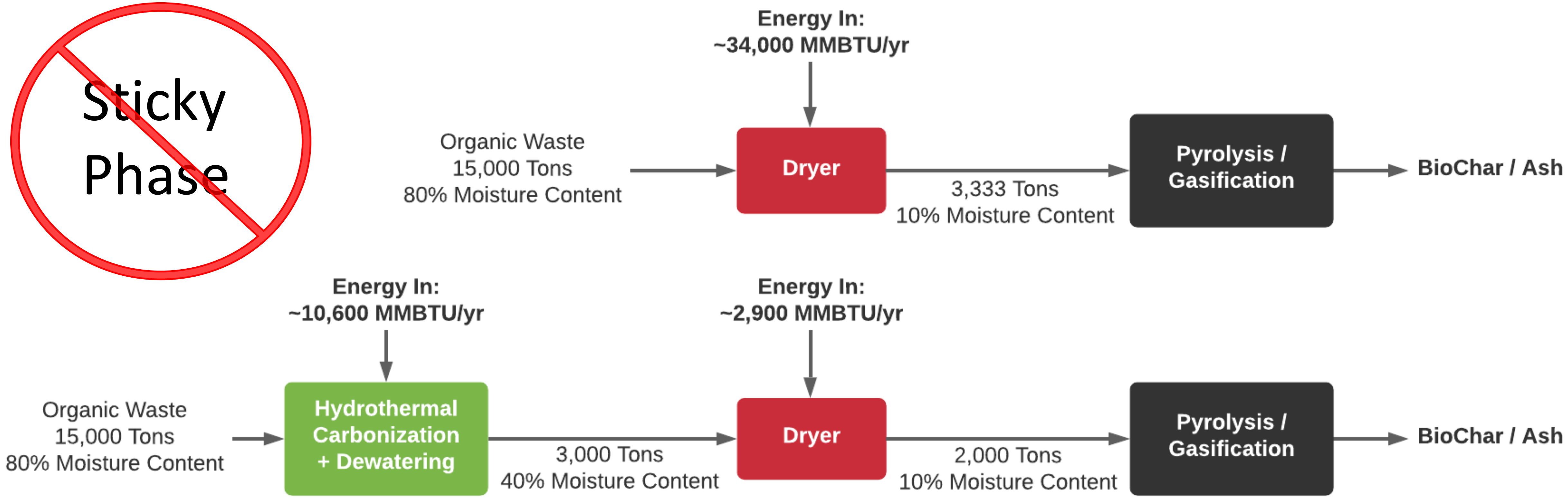


Lucian, M. et al (2020)

HTC + Pyrolysis/Gasification

HTC + Drying uses **60% less** energy of drying of wet waste for Pyrolysis/Gasification

HTC + Drying reduces the dryer unit size by **80%** and Pyrolysis/Gasification unit size by **40%**



PXVNEO

PHOENIXVILLE NEW ENERGY OPTIMIZATION

HYDROTHERMAL CARBONIZATION FACILITY

www.PXVNEO.com

Borough of Phoenixville, PA

First Municipality in Pennsylvania to pledge 100% Clean and Renewable Energy Goal by 2035

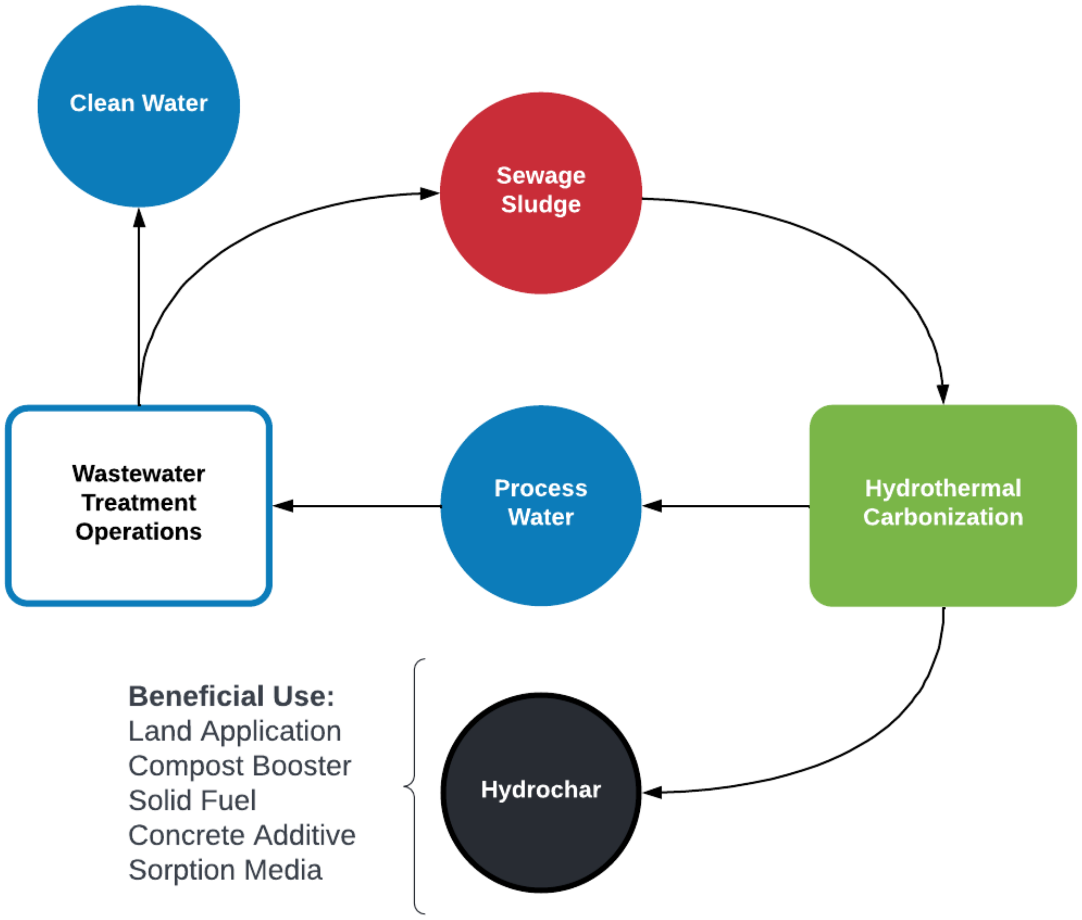
Borough of Phoenixville WWTP

Population:	~17,000
Rated Cap.:	4 MGD
Ave. Cap.:	1.75 MGD
Product:	Class B Biosolid
Method:	AD
Volume:	1618 tons @ 25% TS
Disposal Cost:	$46.90/ton

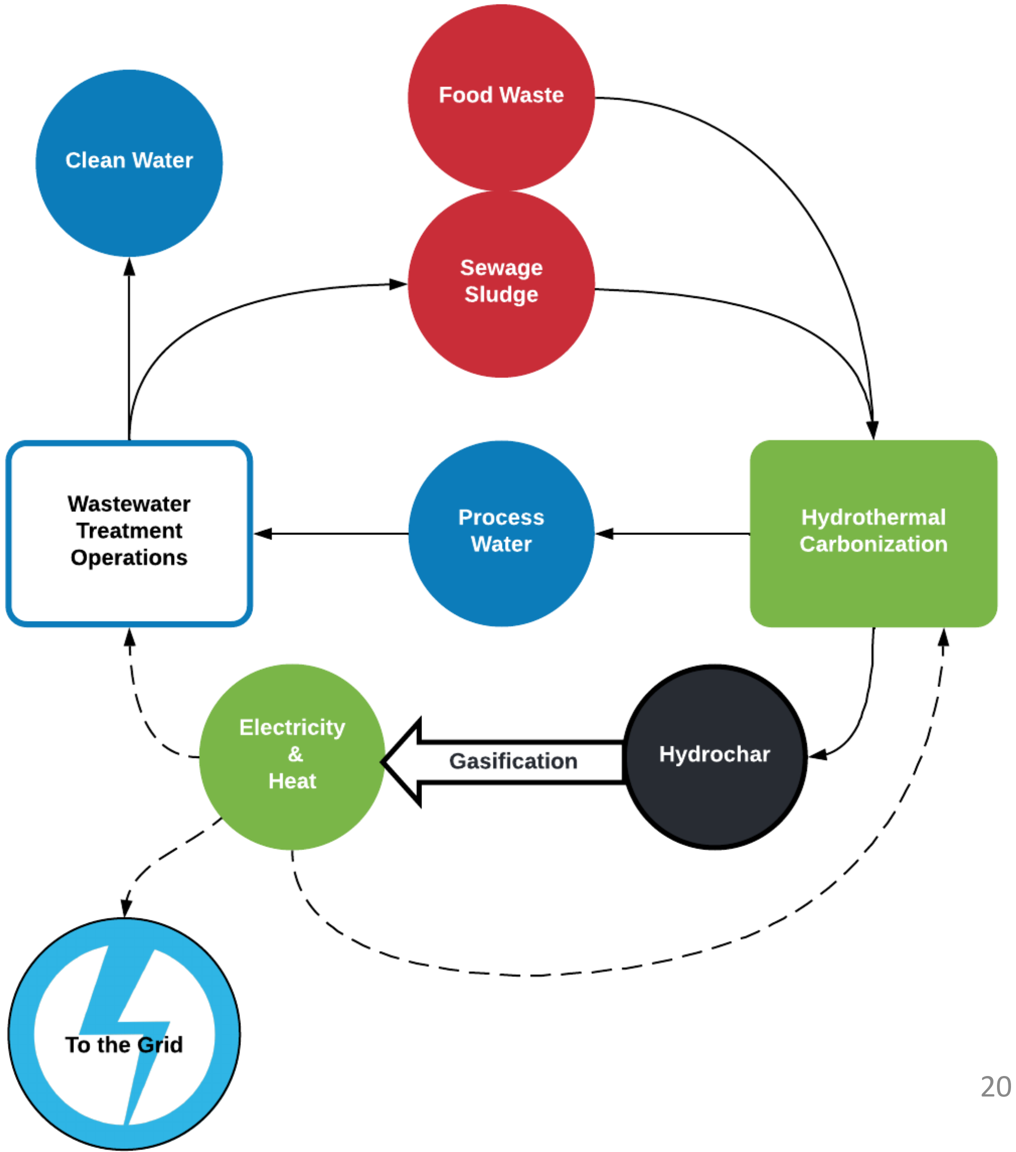
Phoenixville HTC Project Timeline

- April 2019 – HTC Engineering and Design
- May 2021 – Present – Greenhouse Slab Upgrades
- June – August 2021 – Equipment Purchasing
- Q1/Q2-2022 – Equipment Arrival and Construction
- Q1 2023 – HTC Process Commissioning
- 2023 – Prove and Permit Beneficial Use Cases & Apply for a PA General Permit
- 2024/2025 – Phase 2 – Combine Food Waste as a feedstock and include Gasification for Carbon Neutral Electricity Generation

Phase 1 – HTC



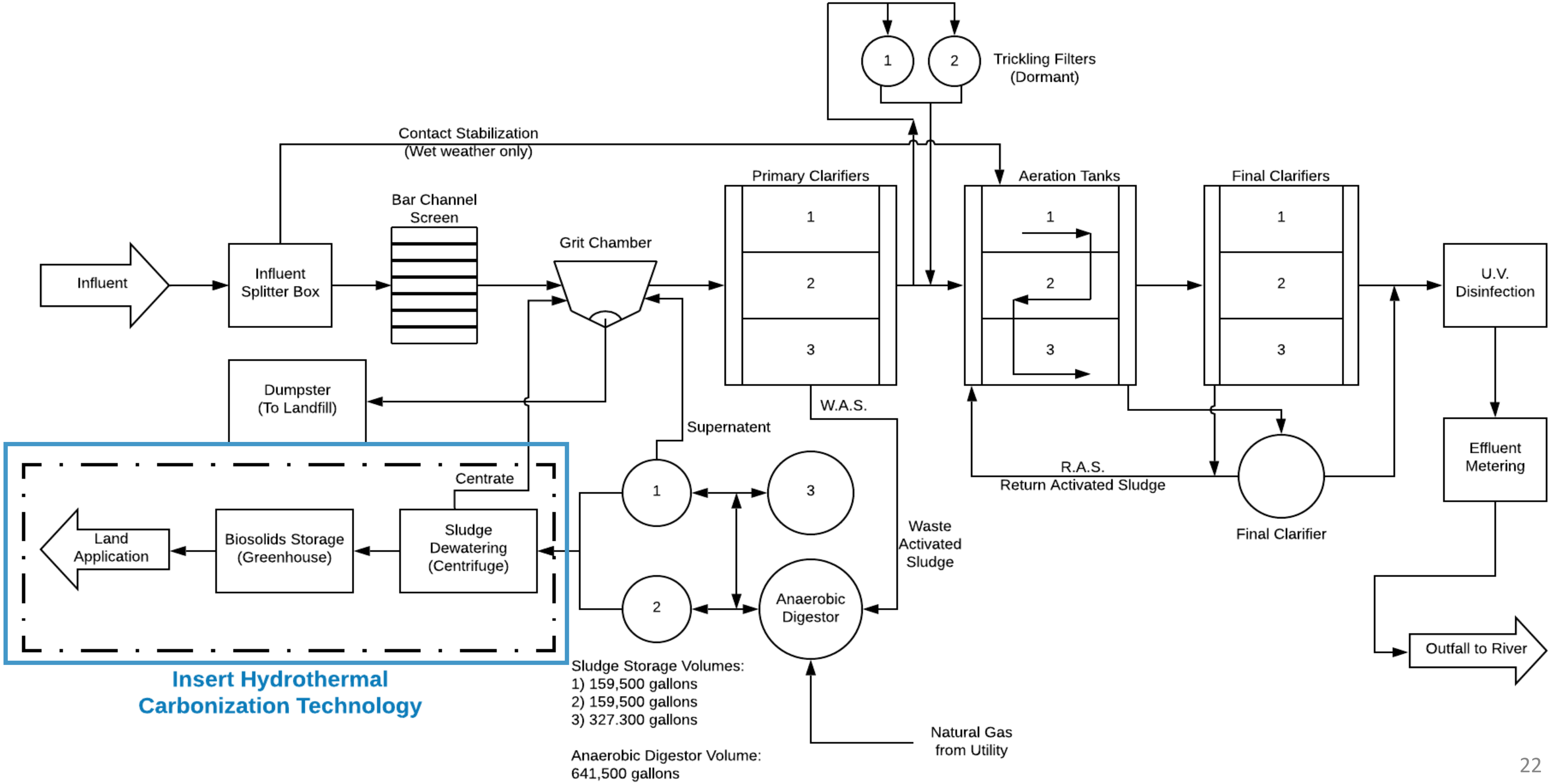
Phase 2 – HTC + Gasification



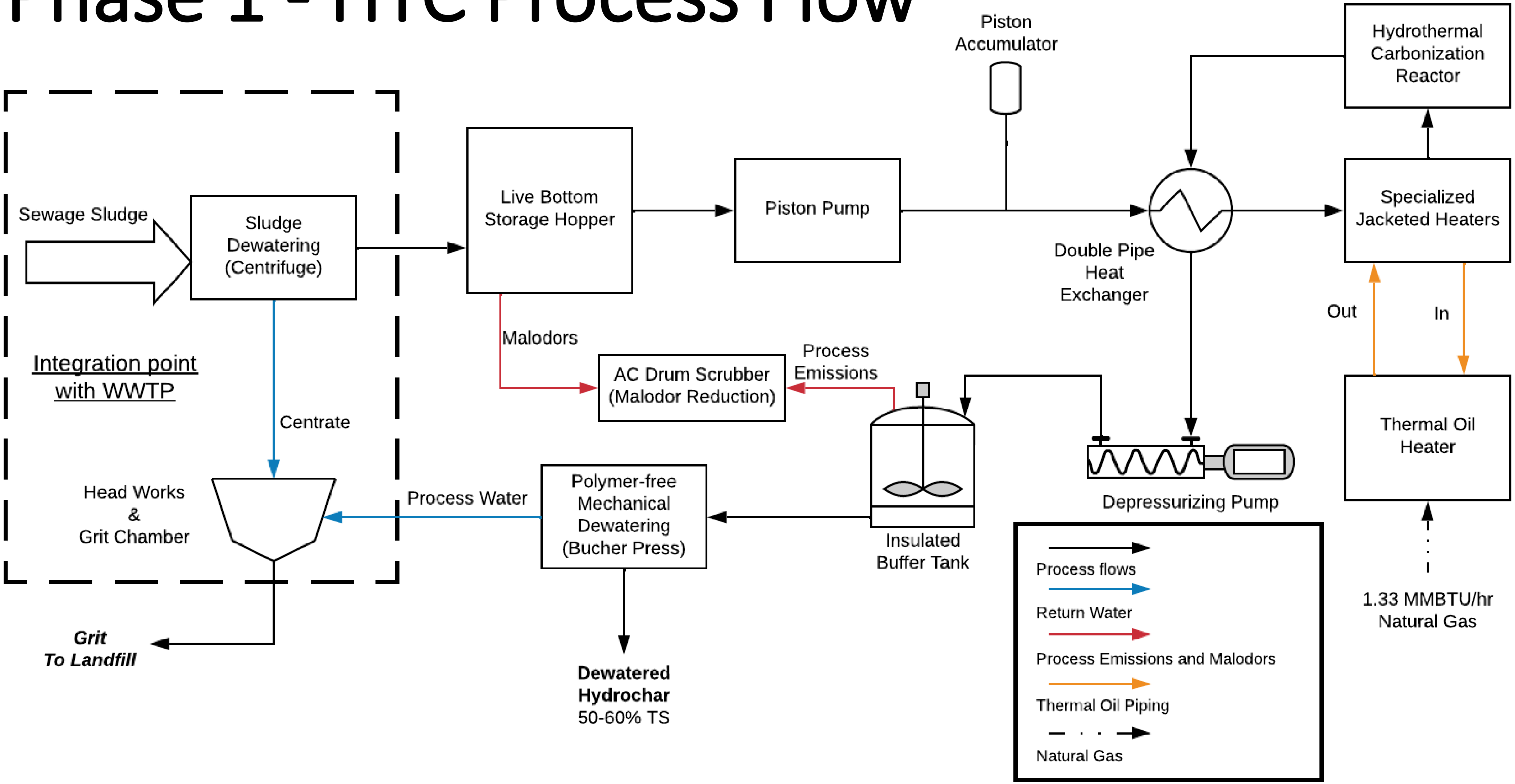
PA DEP Permitting

- February 10, 2022 – Approved as a Permit-By-Rule (PBR) captive municipal waste processing facility
- Initially hydrochar is **WASTE** and must be stored on site
- Landfill and land application will need to be approved
  - Goal is Class A EQ improving from Class B
- Solid fuel requirement easily met at 5,000 BTU/lb
- Beneficial use testing at pilot scale will began for utilizing hydrochar as a concrete additive, asphalt additive, and sorption media
- Hydrochar can be ‘dewasted’ for beneficial use with an Individual or General Permit

WWTP Process Flow Diagram



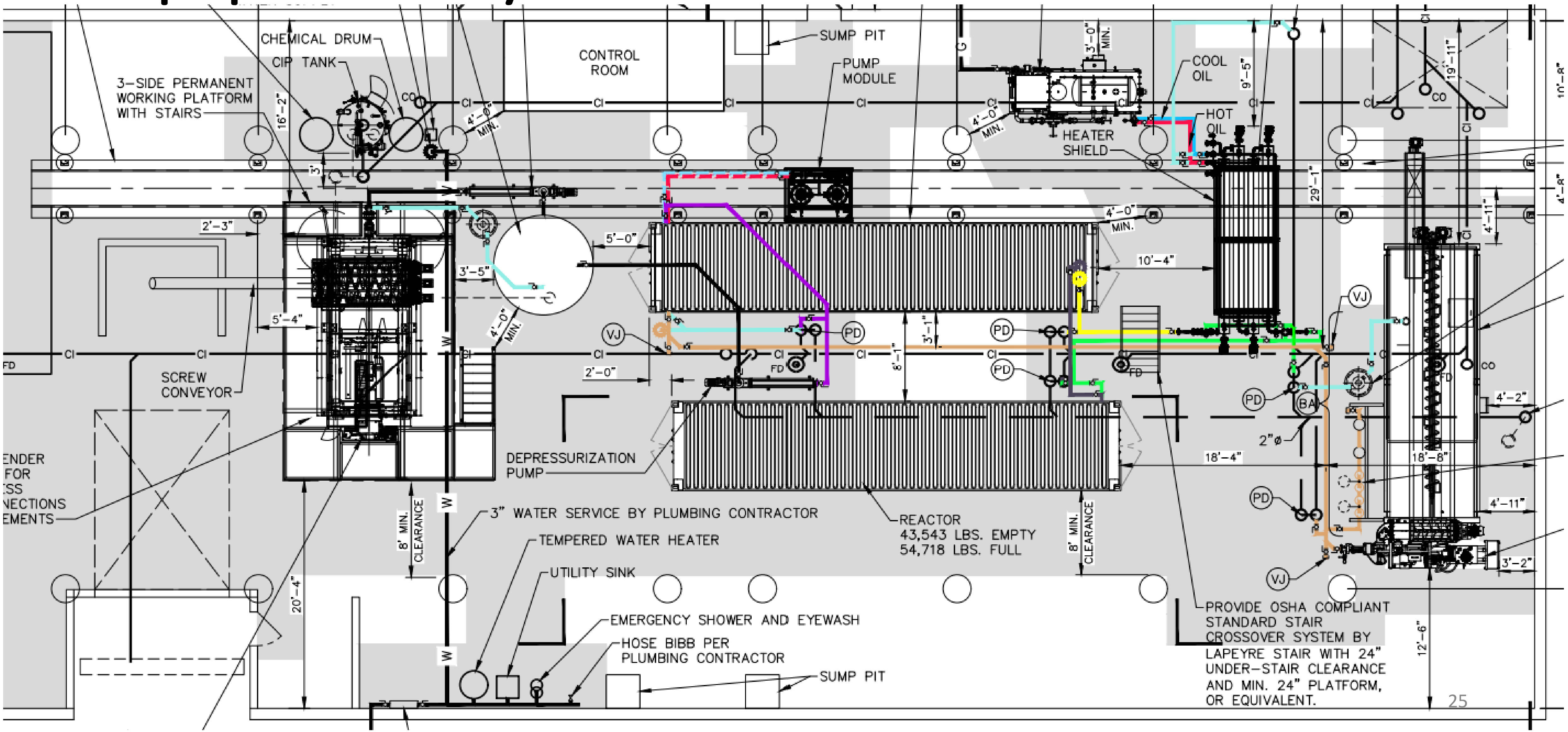
Phase 1 - HTC Process Flow



Equipment placement began April 13, 2022.

The HTC Process will take up ~1/2 of the greenhouse.

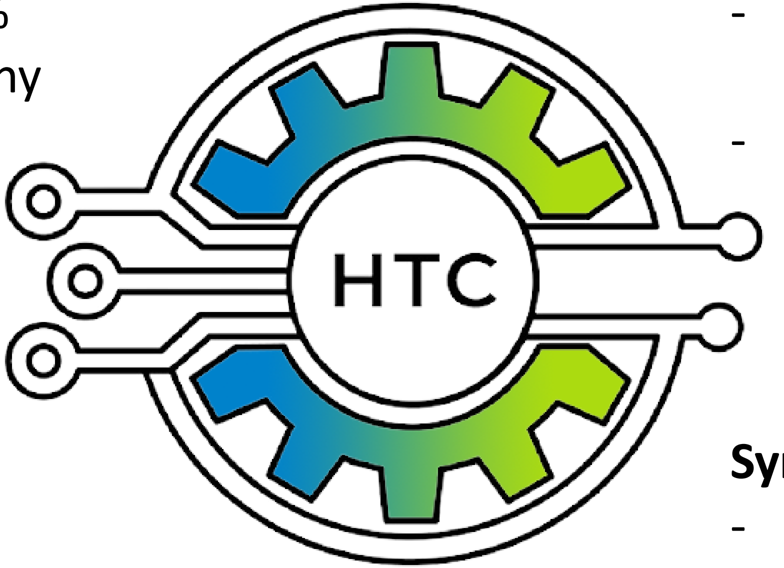
Equipment Layout



HTC at the Borough of Phoenixville WWTP

Industry Leading Carbon Efficiency:
- Carbon Efficiency up to 90%
- Lowest GHG emissions of any biomass conversion

Efficient Energy Recovery (w/Phase 2)
- Generates up to 10X more electrical energy than HTC consumes
- Creates up to 150% of the WWTP energy demand



Barrier Breaking Innovations
- Polymer-free dewatering of hydrochar to over 50% solids
- Source reduction up to 80%

Synergies with other Treatment Processes
- Increases Biogas production
- More efficient drying for pyrolysis/gasification

SoMax

For Additional Information:

Jeremy Taylor

(918) 607-2902

Jeremy@somaxhtc.com

www.SoMaxHTC.com

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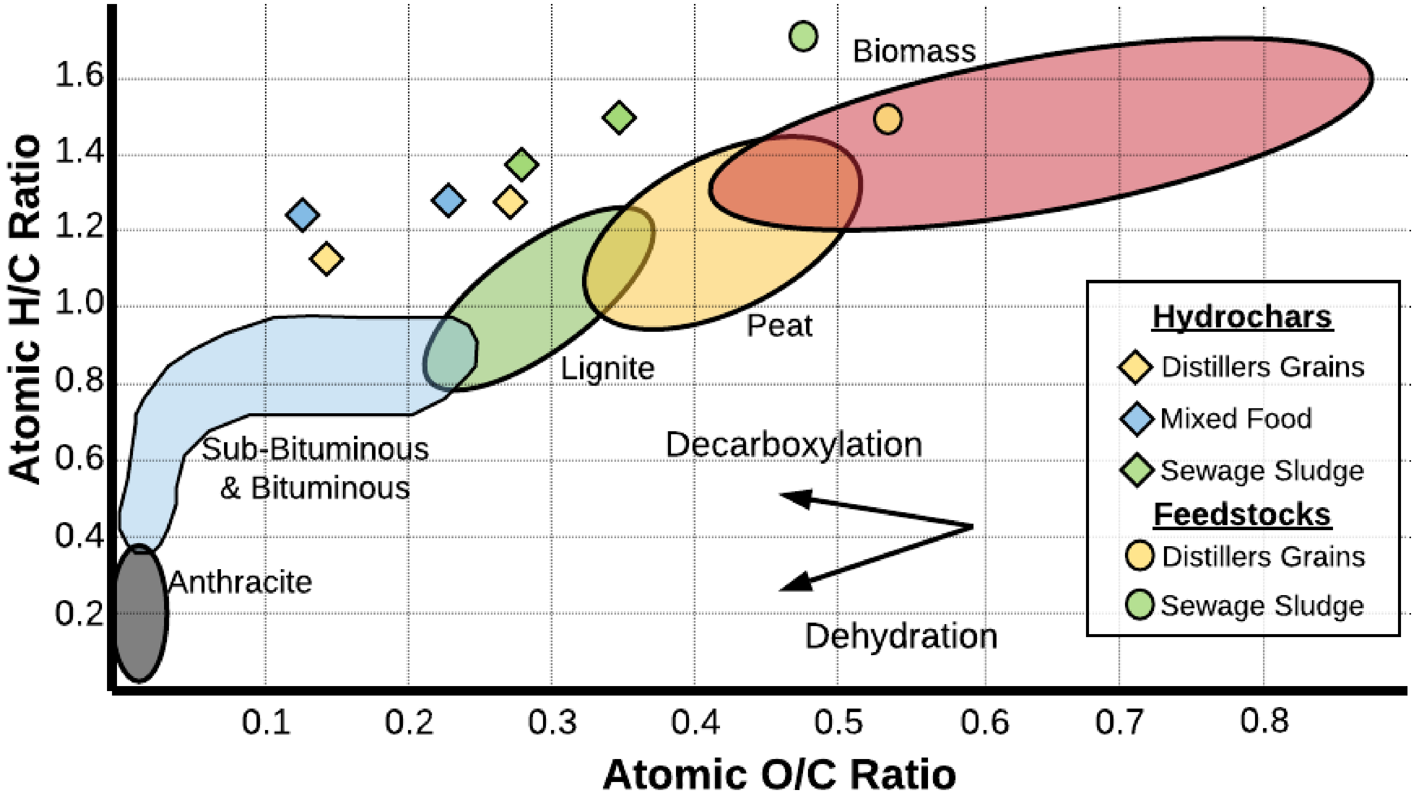
Appendix

Visualizing HTC Reactions – Van Krevelen



Hydrochars:

Our Hydrochars – $C_{4-6}H_{6-12}O_{1-1.5}$

Typical Literature – $C_{5-6}H_{12-14}O$

Coals:

Lignite: $C_{39}H_{35}O_{10}$

Bituminous – $C_{137}H_{97}O_{9}$

High-grade Anthracite – $C_{240}H_{9}0_{4}$

https://www.purdue.edu/discoverypark/energy/assets/pdfs/cctr/outreach/Basics8-CoalCharacteristics-Oct08.pdf