# Food waste, manure and digestate derived biochar to enhance biomethane potential in mesophilic anaerobic digestion of food waste

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# Introduction

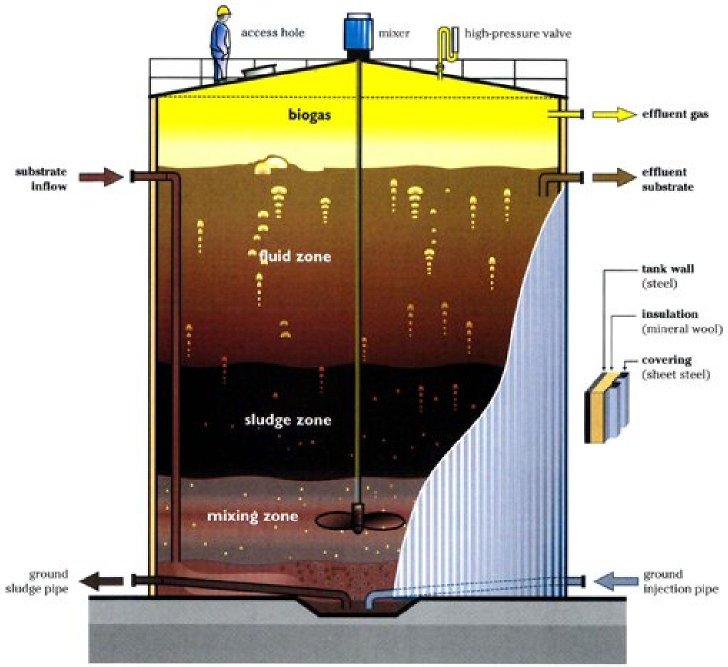
- Recent literature has shown that adding adsorbents to the anaerobic digestion process can increase biomethane potential.

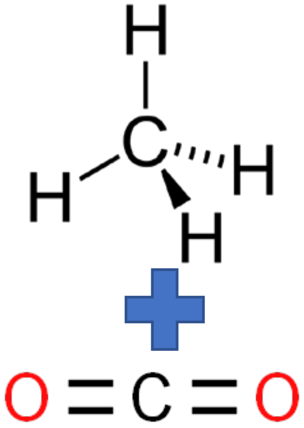
- Biochar can enhance AD because it:
  - Lowers the concentration of ammonia
  - Stabilizes the pH in the system
  - Creates a protective layer that promotes production of biomethane
  - Allows bacteria to propagate and better access digestable material in the substrate

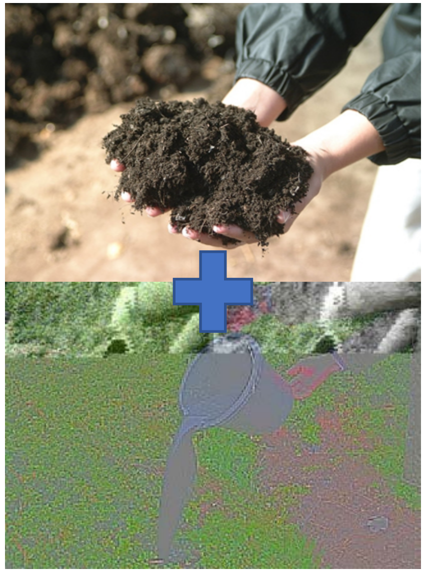
# Anaerobic Digestion (AD)

**Food Waste**

**Dairy manure**



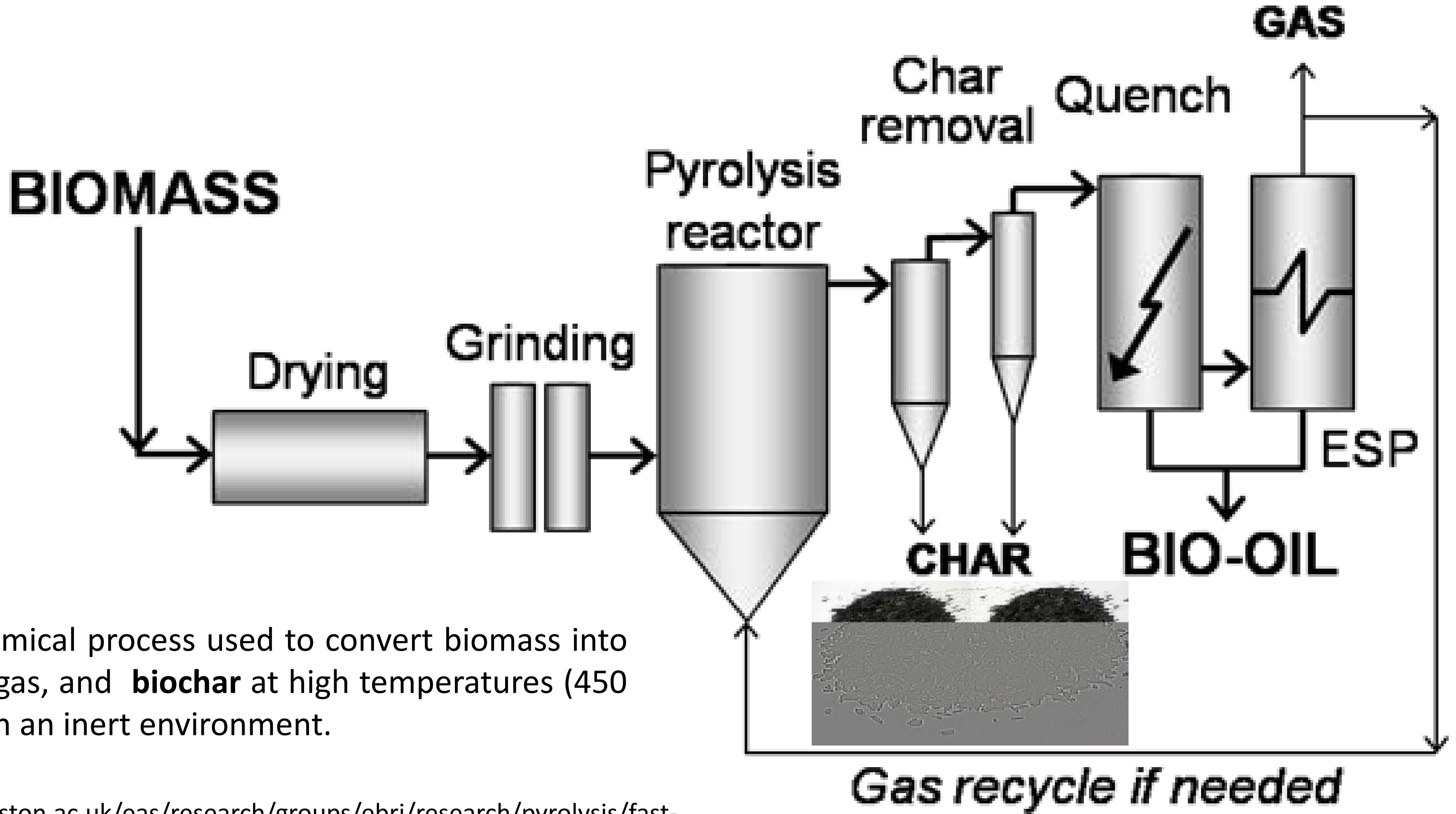





Bacteria in the AD hydrolyze the complex molecules in the substrate and then acidogenic bacteria further breaks them down into volatile fatty acids, acetic acid, hydrogen and carbon dioxide. The latter are then further produced during acetogenesis. Finally methanogenic bacteria further breakdown acetic acid into methane and carbon dioxide in the form of biogas.

https://www.daviddarling.info/encyclopedia/A/AE_anaerobic_digestion.html, Retrieved 04/16/2020

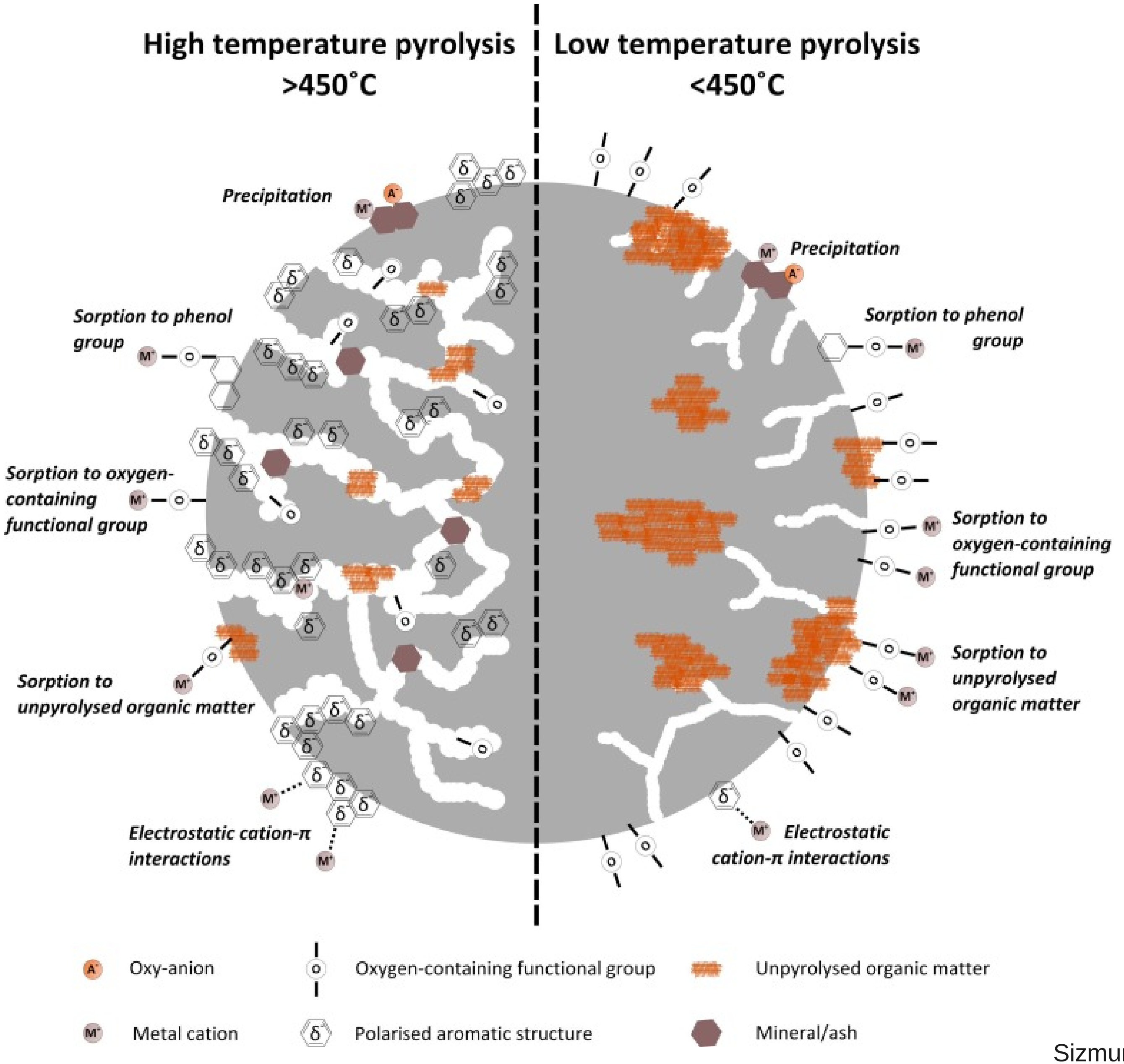
# Pyrolysis




Thermochemical process used to convert biomass into bio-oil, syngas, and **biochar** at high temperatures (450 – 1000$^{o}$C) in an inert environment.

https://www2.aston.ac.uk/eas/research/groups/ebri/research/pyrolysis/fast-pyrolysis, Retrieved 04/16/2020

# Biochar




Sizmur, T., Fresno, T., Akgül, G., Frost, H., & Moreno-Jiménez, E. (2017). Biochar modification to enhance sorption of inorganics from water. *Bioresource Technology*, *246*, 34-47.

# Research Gaps

Many feedstocks have been used to produce biochar and they all have different characteristics.

Similarly, prior studies have used many AD substrates, with only a few specifically focused on food waste.

Previous studies have mostly focused on low performing AD systems and found an increase in BMP.

No comprehensive analyses of environmental or economic benefits of biochar addition to AD.

# Research Questions

Will the addition of biochar to the anaerobic digestion of a model food waste increase production of biomethane?

What are the characteristics of our in-house produced biochar that help or hinder this process?

Is there a correlation between biochar surface area and/or loading and the increase in BMP?

Based on the empirical results, is there an economic incentive to apply biochar addition to food waste AD?

# Methods: Biochar Characterization

**Food Waste**

**Dry manure**

**Pre-treated Digestate**

**Pyrolysis**

Pyrolysis at 500 and 800°C in $N_2$ environment with 10 °C/min heating rate and 1 hour hold time

**Biochar**

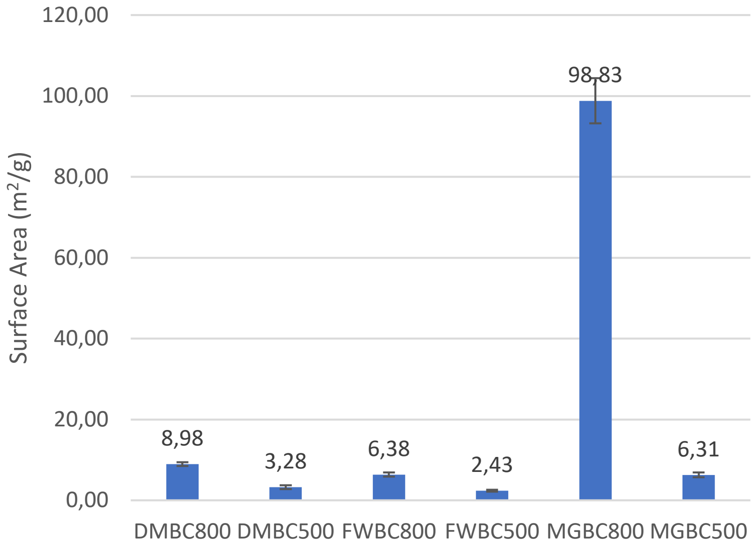
**Surface area measurement**

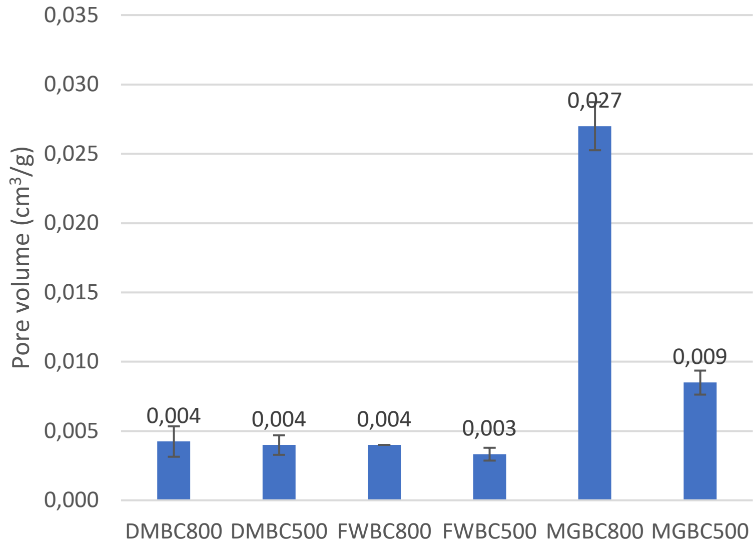
**Quantachrome**

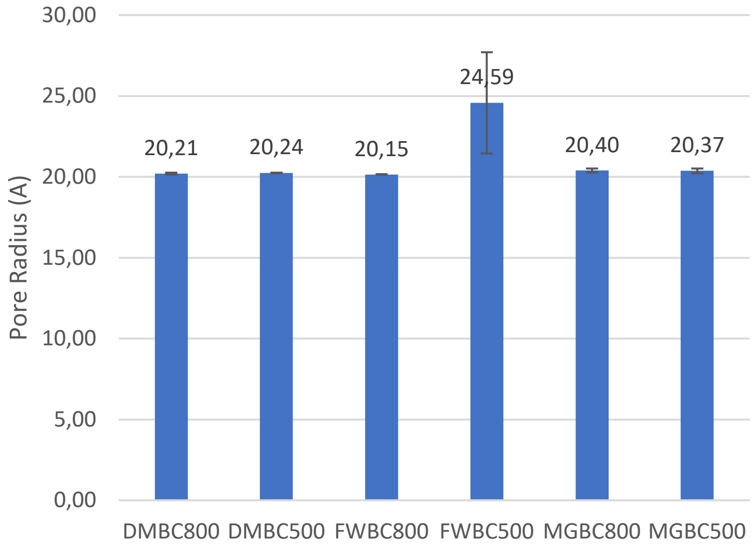
**pH measurement**

# Biochar Characterization Results

| Substrate | Pyrolysis Temperature (ºC) | Code | Yield (%w/w) | pH |
|---|---|---|---|---|
| Mixed Food Waste | 500 | FWBC500 | 33.53 | 8.94 |
| | 800 | FWBC800 | 28.20 | 10.24 |
| Dry Manure | 500 | DMBC500 | 31.48 | 9.66 |
| | 800 | DMBC800 | 29.05 | 11.54 |
| Digestate | 500 | MGBC500 | 62.00 | 10.65 |
| | 800 | MGBC800 | 48.73 | 12.10 |



# Methods: BMP Enhancement

- Food waste, dairy manure and pre-treated digestate were converted to biochar and analyzed prior to their addition to the digesters.
- Dog food was selected as a substrate for AD because its composition provides a consistent model substrate for mixed food waste.

**Food Waste**

**Dry manure**

**Pre-treated Digestate**

**Pyrolysis**

Pyrolysis at 500 and 800°C in $N_2$ environment with 10 °C/min heating rate and 1 hour hold time

**Biochar**

**AMPTS II system**

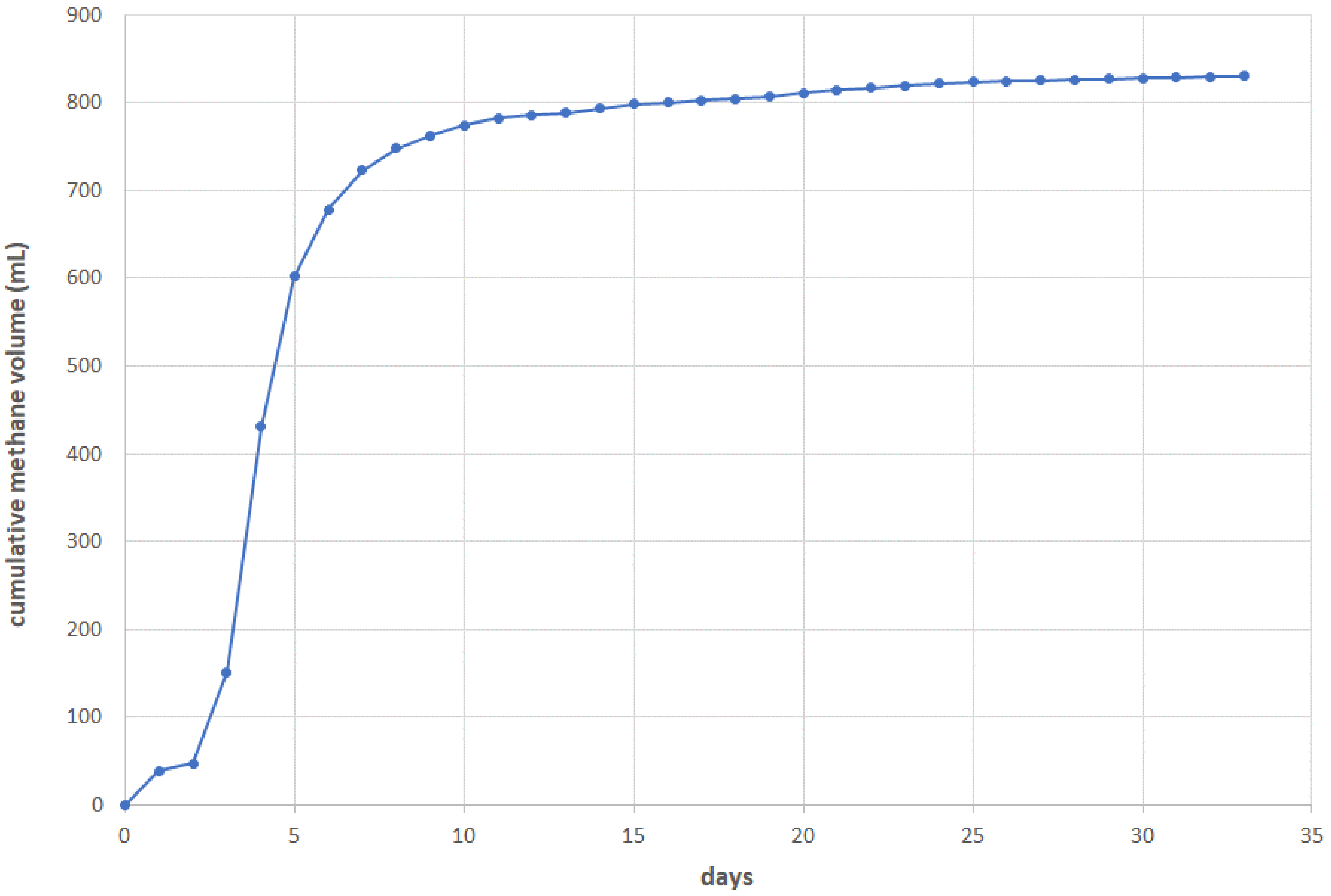
Different biochars were added to the digesters at 0.5, 1, and 2% loadings. Dog food slurry was used as the substrate, with I/S ratio 2:1

**Dog Food**

**Inoculum**

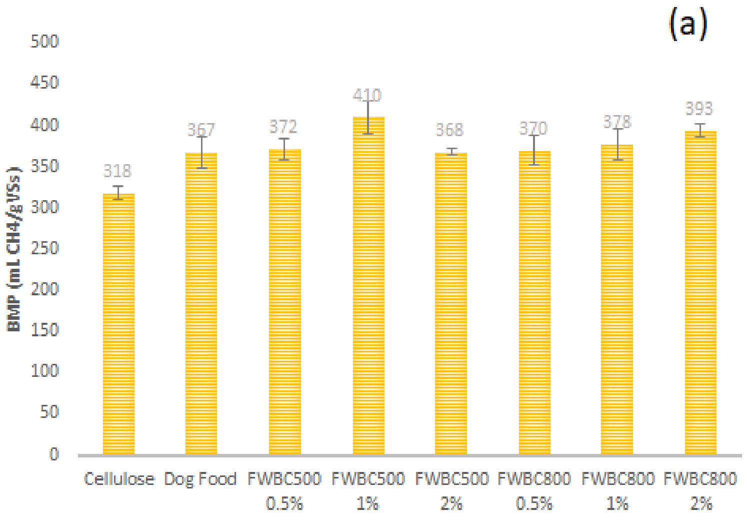
# BMP curve example

$$BMP\left[\frac{mL}{gVs}\right] = \frac{V_s - V_b \times \left(\frac{m_{Is}}{m_{Ib}}\right)}{m_{S_{s},V_s}}$$

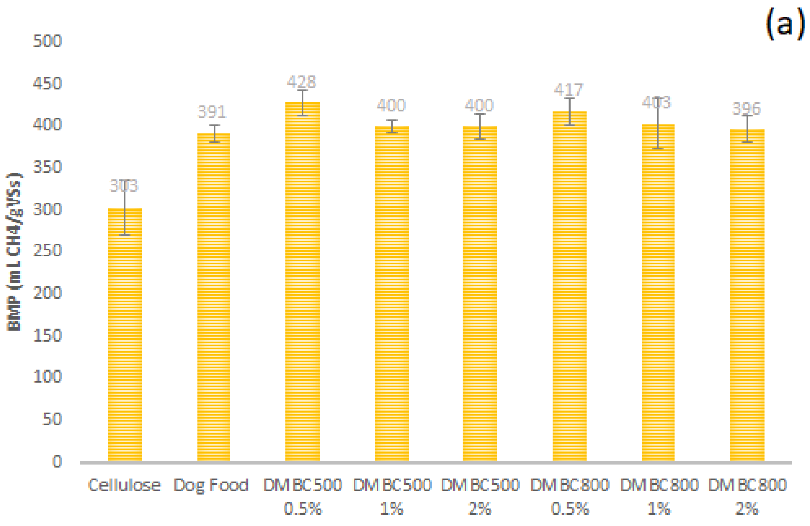


# Results: BMP

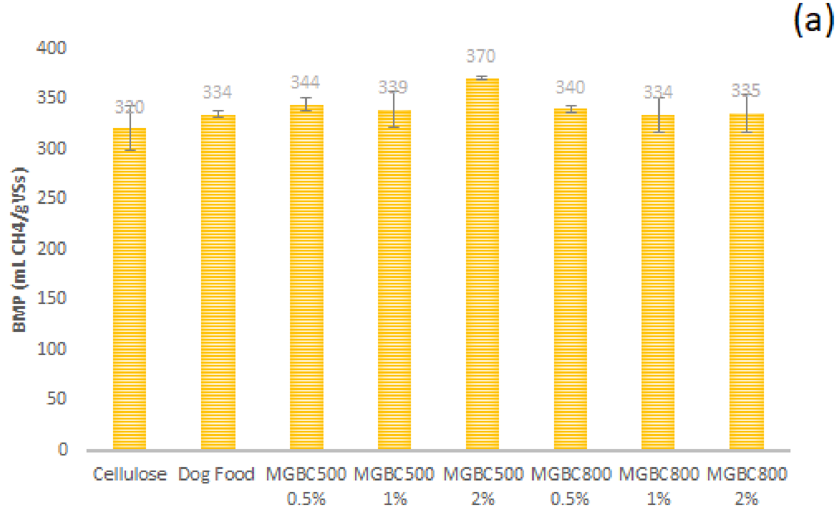
## Food Waste Biochar



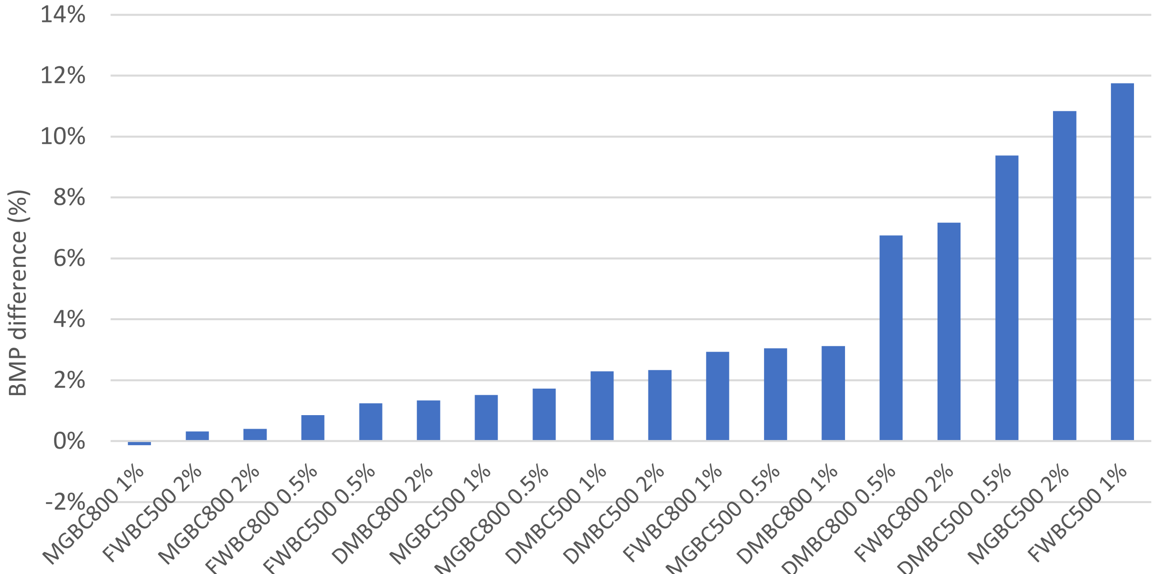

## Dry Manure Biochar




## Digestate Biochar



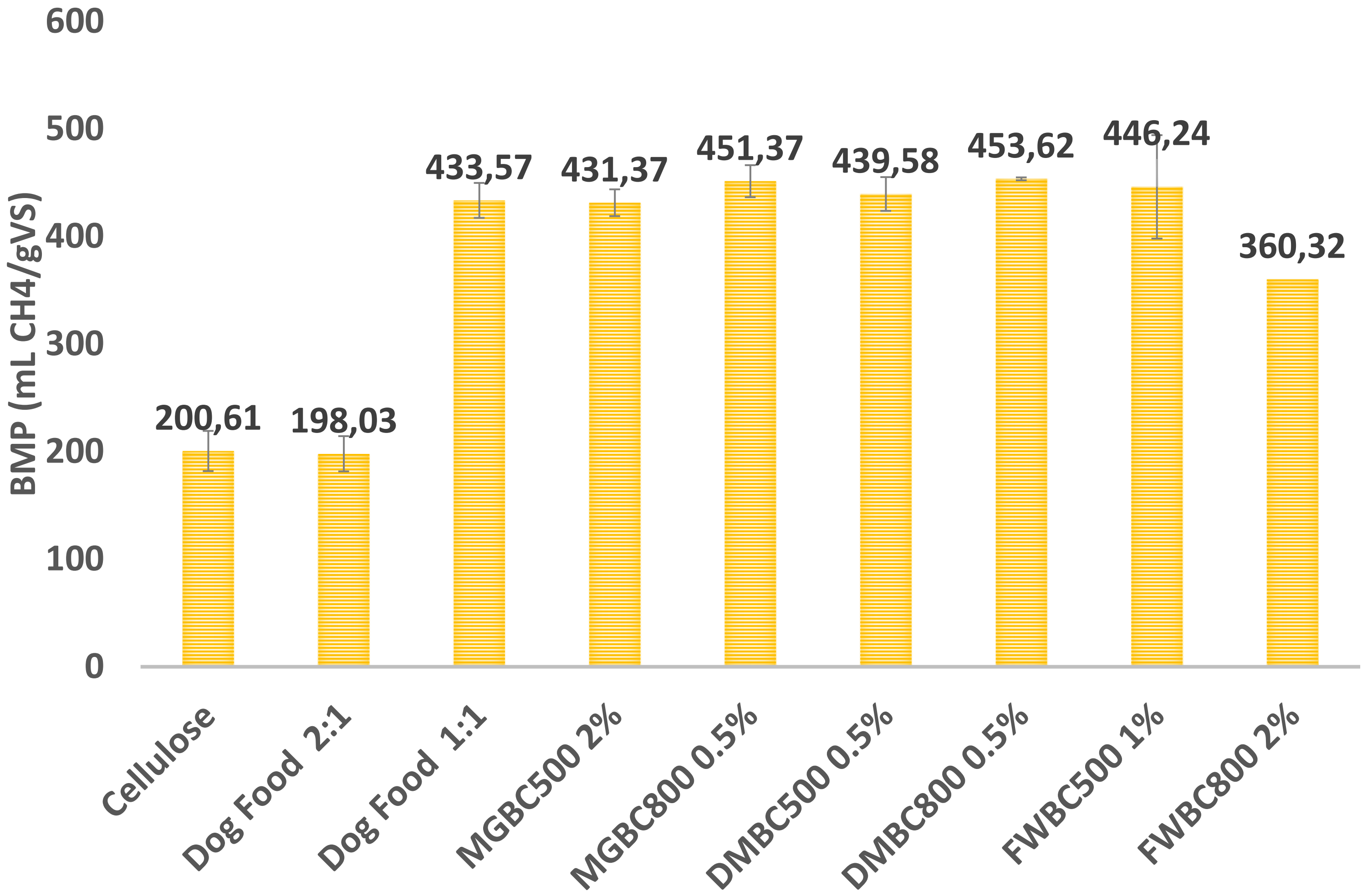

## % difference from baseline for all biochar addition runs



# Results: Stress conditions run

- Doubled the Inoculum to VS ratio in each system.
- Highest performing biochar loading for each biochar type.
- Experiment lasted **15 days**

**Results:**
- Doubling gVS doubled the BMP.
- At this point biochar increased BMP by up to 5%.
- FWBC800 2% had a negative impact



# Methods: Techno-economic Analysis

**Considered scenarios for TEA**

| Scenario | Food Waste Increase | | | | |
|---|---|---|---|---|---|
| Buy pyrolysis system | 0 % | 1 % | 5 % | 10% | 20% |
| Buy biochar: low price ($50/t) | | | | | |
| Buy biochar: mid price ($200/t) | | | | | |
| Buy biochar: high price ($1000/t) | | | | | |

**Table of main assumptions (based on New York market)**

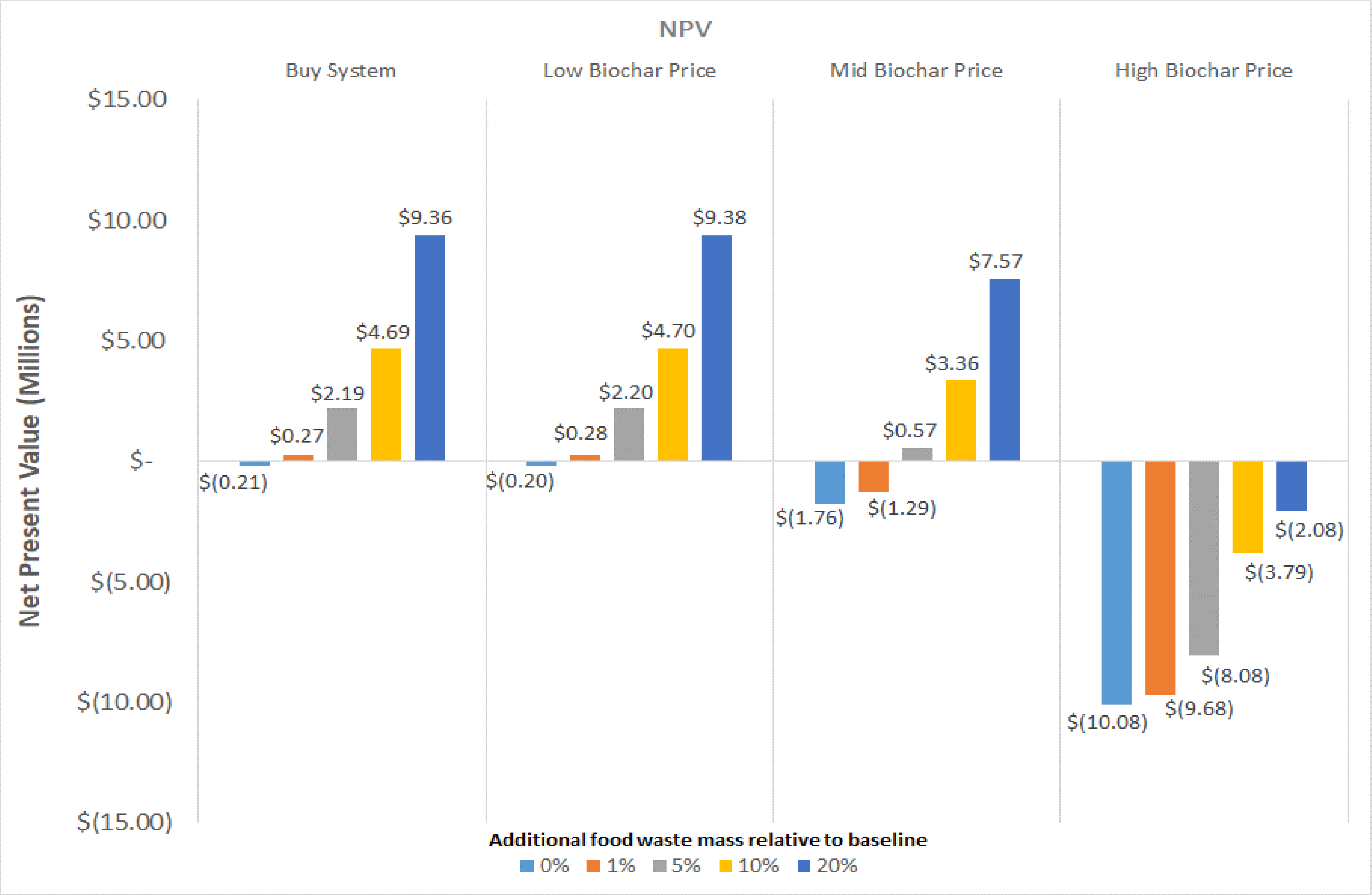
| Assumption | Value | Units |
|---|---|---|
| Capital cost of pyrolysis system | 200 | $/t feedstock/ yr |
| Biochar addition system | 50,000 | $ |
| Tipping fee | 52.62 | $/t |
| Wholesale electricity price | 0.03 | $/kWh |
| Wholesale natural gas cost | 2.56 | $/MMBtu |

The results from previous experimental research were used to model how the addition of biochar to AD will impact the economics in a working system.

**Assumed 1% biochar loading results in 10% BMP increase**

2019 data from local anaerobic co-digestion plant was also used to model the system

# Results: Net Present Value (NPV) with no incentives



# Conclusions

- Pyrolysis temperature influences the characteristics of the resulting biochar.
  - Higher temperature increased pH and surface area

- Addition of biochar to AD shows potential to provide:
  - Up to 10% increase in BMP
  - Enhanced stability in the system
  - Buffering
  - Adsorption of inhibitors

# Conclusions cont.

- Addition of biochar to AD provides economic benefits under some conditions in a working system.

- Biochar + AD coupling economics:
  - No way to control biochar market; commercial scale biochar price is unclear.
  - Building a pyrolysis system may be a good option, equivalent to purchasing low cost biochar ($50/ton).
  - Greatest benefit would come from increased food waste loading that generates additional tip fees.
  - The value of higher BMP without increased FW intake does not result in a favorable economic return.

# Future Work

- Characterization analysis using SEM for biochar samples
- More pyrolysis feedstocks and AD substrates with lower productivity than FW.
  - Similar experimental design and replacing the substrates
  - More stress runs studies
- Analysis of energy consumption and production of pyrolysis system
  - focus on the inclusion of the pyrolysis system energy usage and substrate costs

# Thank you!

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