High Solids Anaerobic Co-Digestion of Biosolids with Food Waste & Yard Waste: Experimental, Economic & Life Cycle Assessment

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UNIVERSITY of SOUTH FLORIDA

High Solids Anaerobic Digestion (HS-AD) of the Organic Fraction of MSW

- Common in Europe, increasing in US
- Yard waste, food waste & biosolids diversion to AD:
  - Enhanced energy recovery.
  - Higher quality biogas than landfill gas.
  - Digestate as soil amendment.
  - Extends landfill life.
  - Reduces fugitive GHG emissions.
  - Decrease landfill leachate strength.
  - Offsets impacts of energy and fertilizer production.

Attero, Venlo, Netherlands

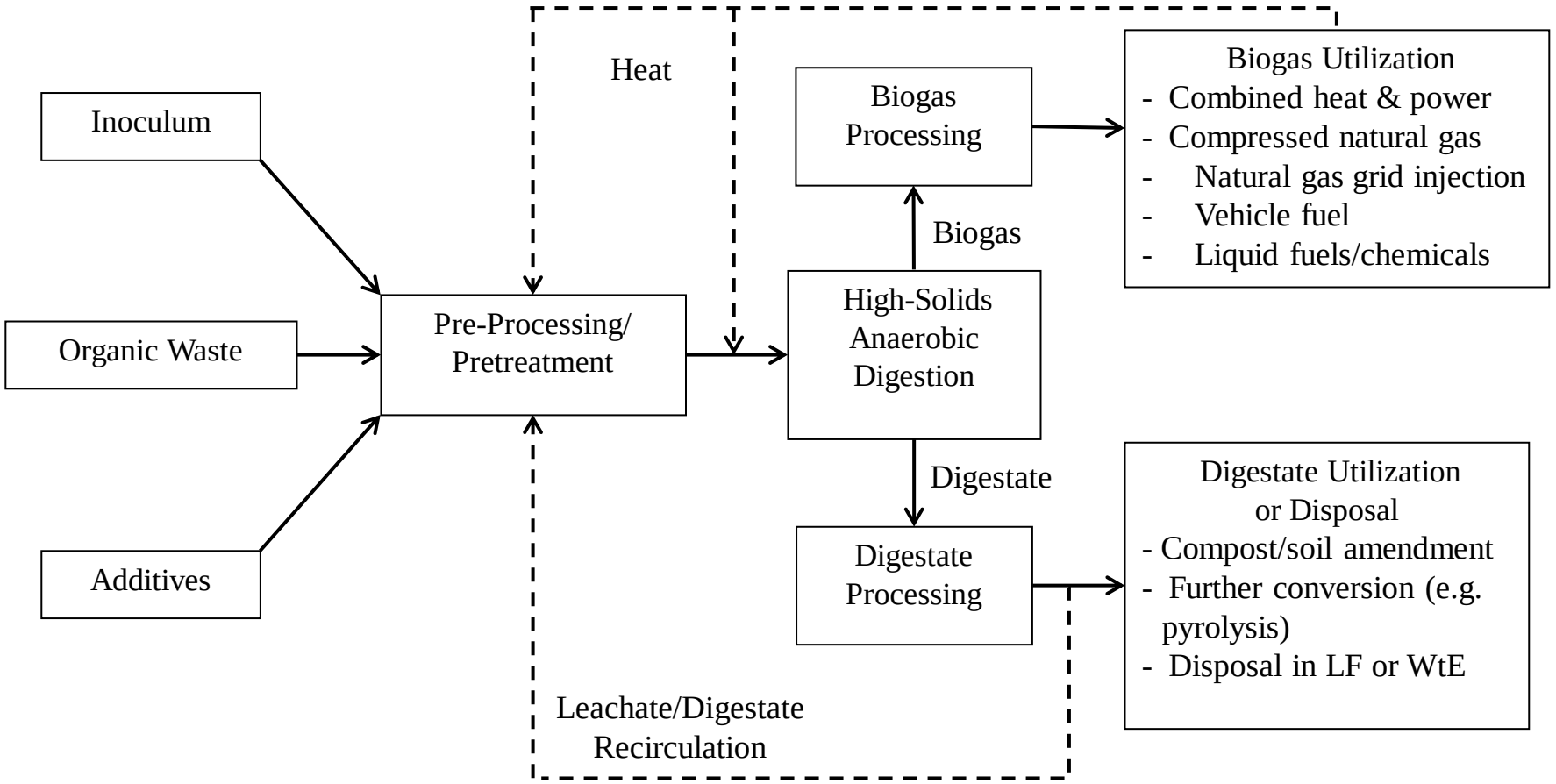
HS-AD vs. “Wet”- AD

- High Solids - 15-40% TS content.
- “Stackable” waste feedstocks – moved with conveyers, front-end loaders.
- Reduced bioreactor energy demands.
- Reduced reactor volume requirements.
- Reduced post-processing of compost.
- Reduced water use and sidestream production - retains nutrients in compost.
- Co-digestion of MSW and biosolids can improve overall economics.

Sordisep Process, Brecht

BioFERM UW Oshkosh

HS-AD Process Schematic



Zero Waste Energy, Monterey CA

Photos by Greg Hinds

Research Objectives

Assess environmental and economic sustainability of a HS-AD of MSW and biosolids in Florida:

- Evaluate technologies, locations & incentives needed for implementing HS-AD of organic waste in Florida.
- Investigate methane yields and nutrient recovery from HS-AD of food waste (FW), Yard Waste (YW) and Biosolids (BS).
- Assess environmental impacts of HS-AD using life cycle assessment.
- Use life cycle cost analysis to compare HS-AD with landfilling, thermal waste to energy, and composting.

Potential for HS-AD Implementation in Florida

- Promising for Florida:
  - Substrate availability, warm climate, high energy demands in urban areas.
  - Lack of L-AD infrastructure at POTWs.
- Key factors affecting economics:
  - Quality, quantity, and proximity of organic wastes.
  - Tipping fees, compost markets, energy costs, existing infrastructure.
- Most promising locations:
  - Miami-Dade, Broward, Palm Beach, Hillsborough, Orange, Pinellas, Duval, Lee and Alachua counties.

Potential for HS-AD Implementation in Florida *cont*.

- Compatible with landfill-gas-to-energy & composting infrastructure.
- Batch-type, thermophilic systems most appropriate.

Hillsborough county YW and BS composting facility.

- Incentives needed:
  - Organic waste landfill bans.
  - Large generator source-separation mandates.
  - Policies promoting compost use and renewable energy production.
  - Public-private partnerships.
- Research on co-digestion of MSW and Biosolids.

Experimental Methods

Food Waste

Yard Waste

Biochemical Methane Potential (BMP) Assays

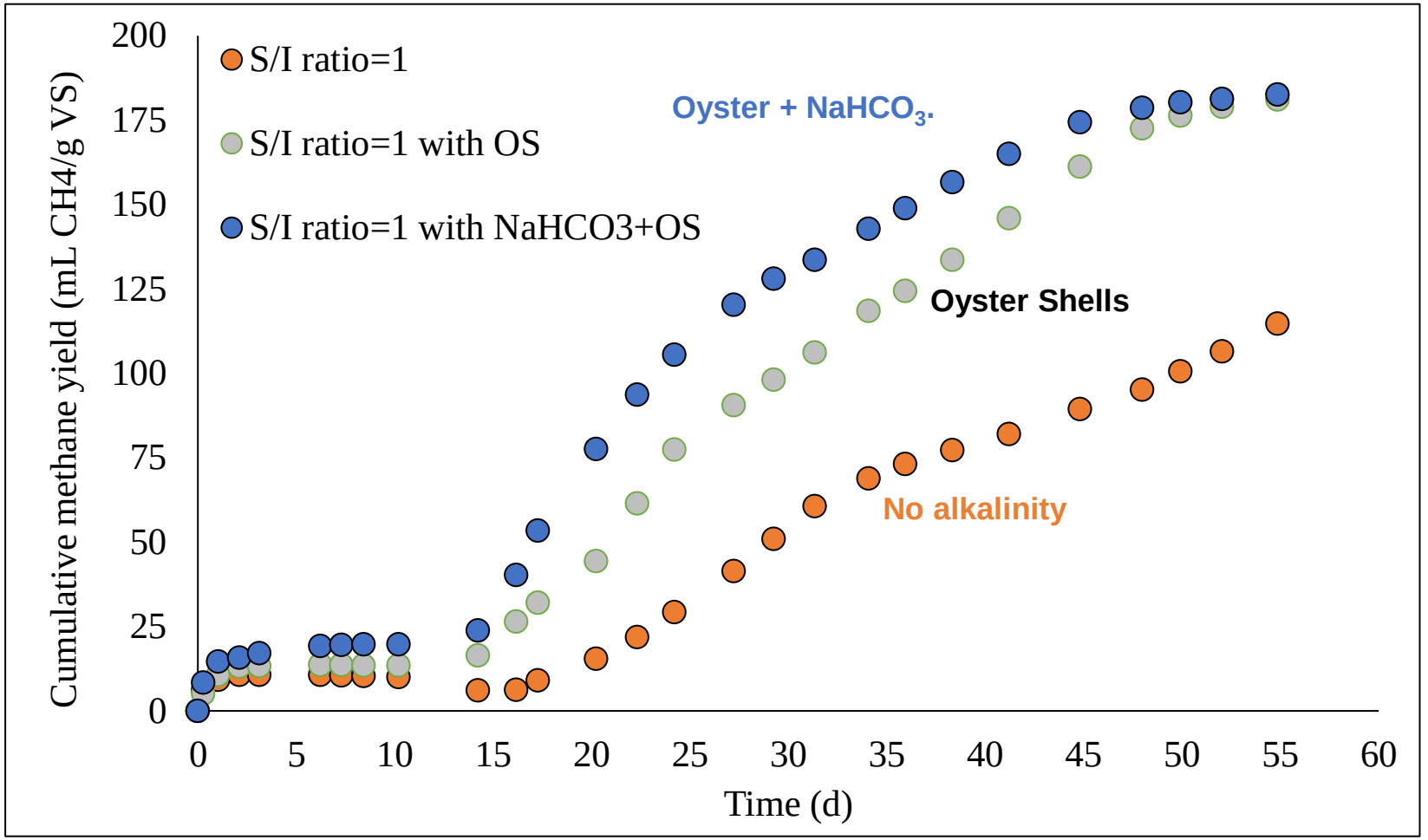
Biosolids – Hillsborough Co WAS
Inoculum – Clearwater AD

Oyster Shells

Semi-Continuous Reactor Studies

BMPs: Effect of Alkalinity Source

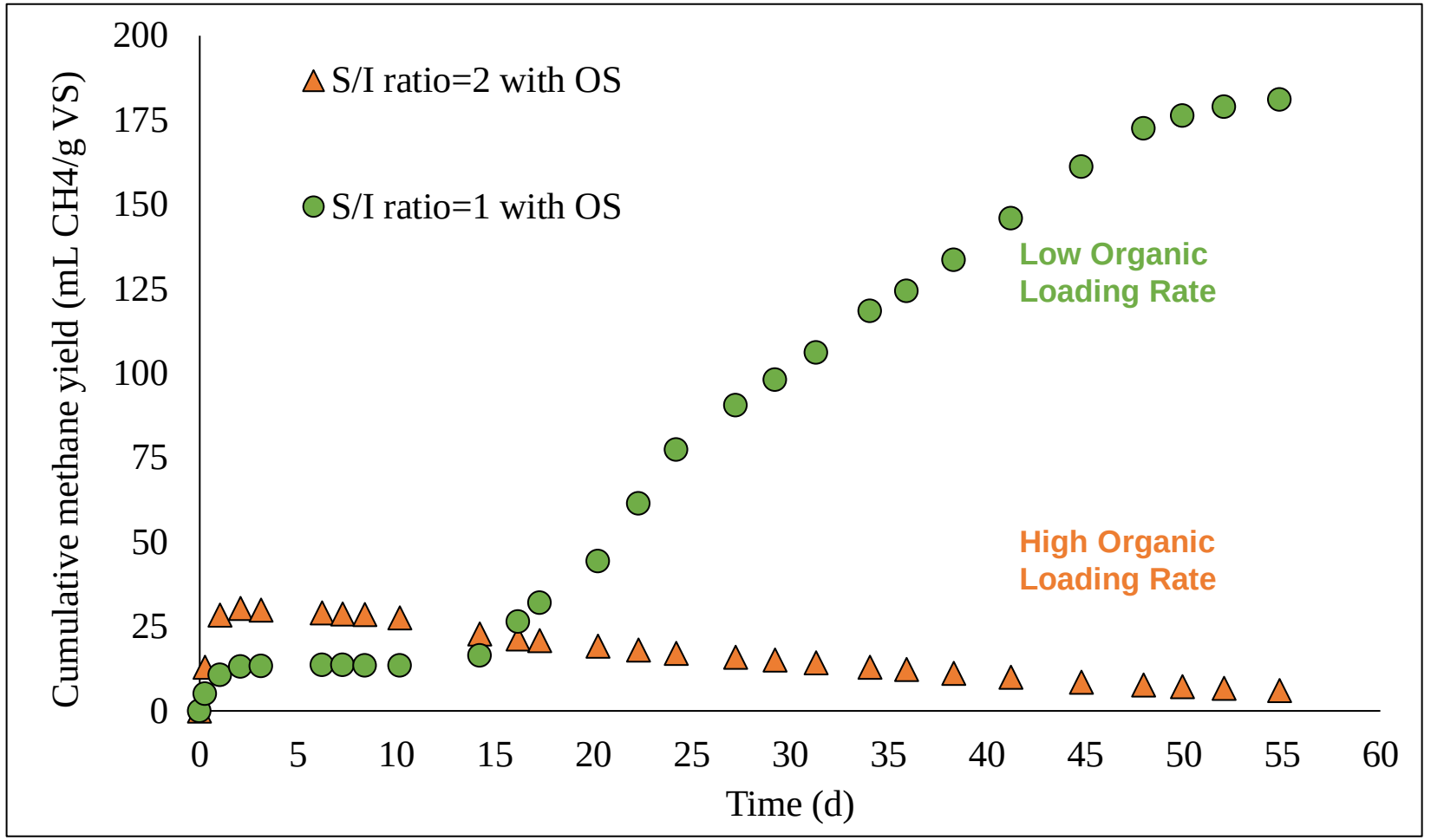
- Best CH_4 yield with mix of $NaHCO_3$ and Oyster Shells.
- Both fast and slow alkalinity sources.
- Oyster shells – low cost waste product.



Lee et al., *Waste Management*.

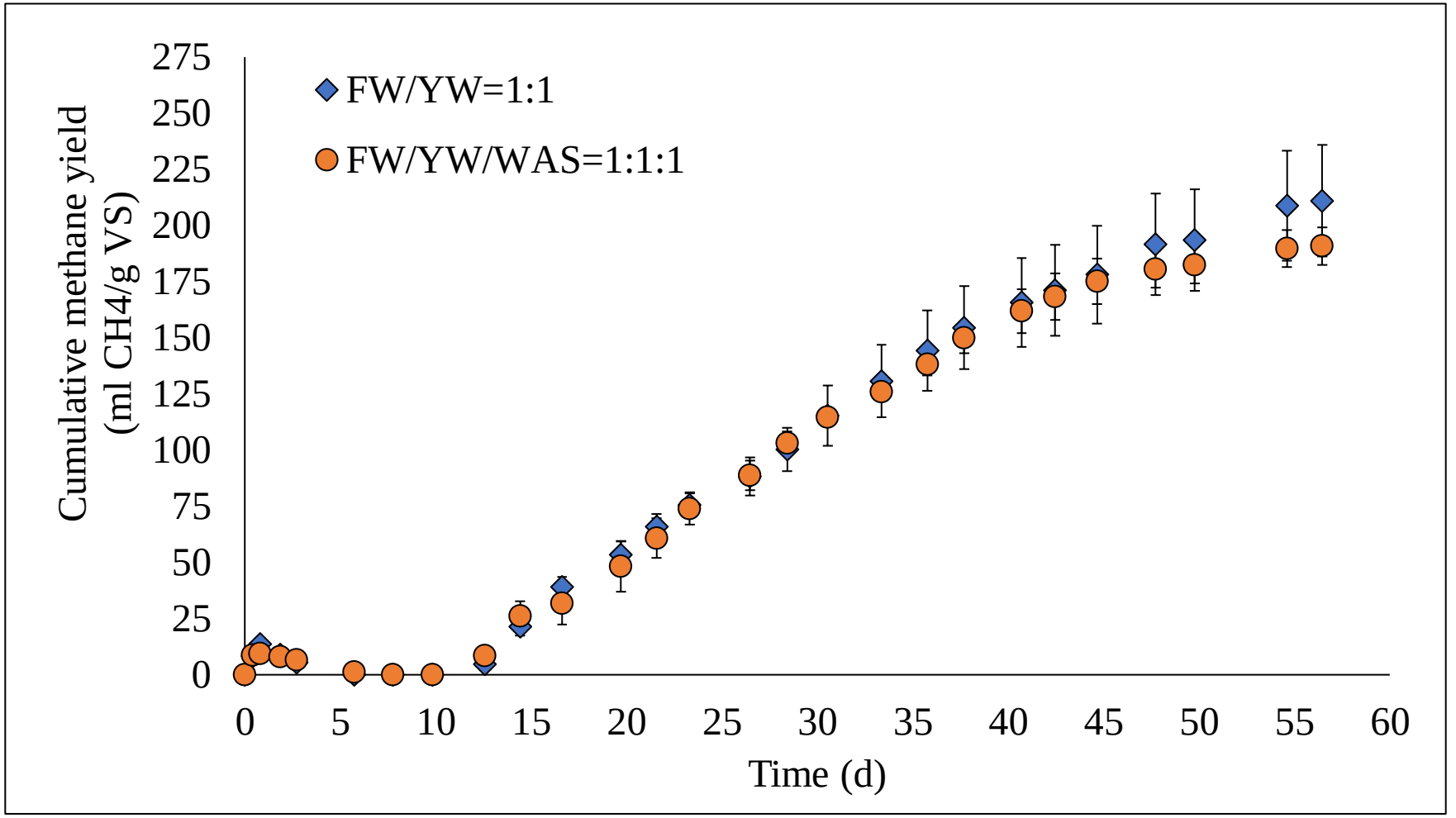
BMPs: Effect of Organic Loading Rate (OLR)

- At high OLR, volatile fatty acid accumulated and methanogenesis was inhibited.
- Reduced lag phase and improved CH_4 yields observed with acclimated inoculum.

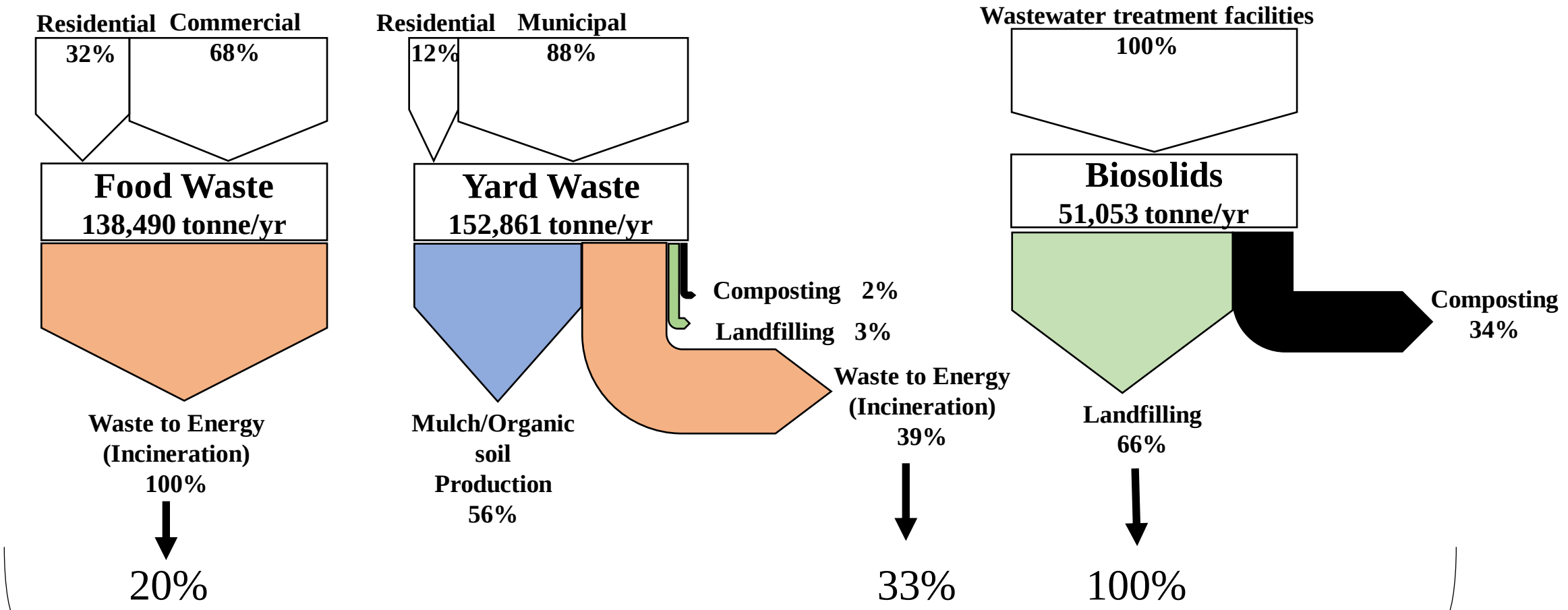


BMPs: Effect of Biosolids Addition to MSW

- Slightly higher CH_4 yield and VSR without biosolids addition.
- Improved pH buffering capacity with biosolids.
- Greater NH_4^+ concentrations with biosolids.

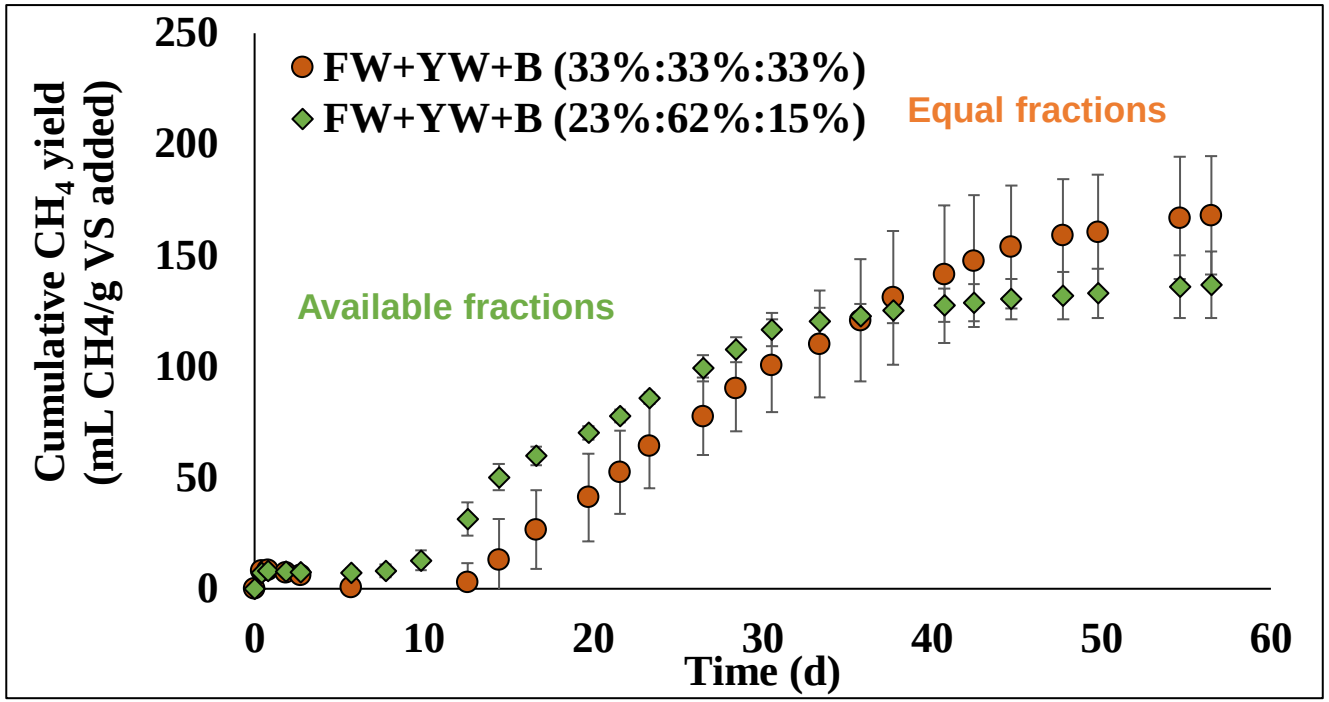


Hillsborough County Available Waste

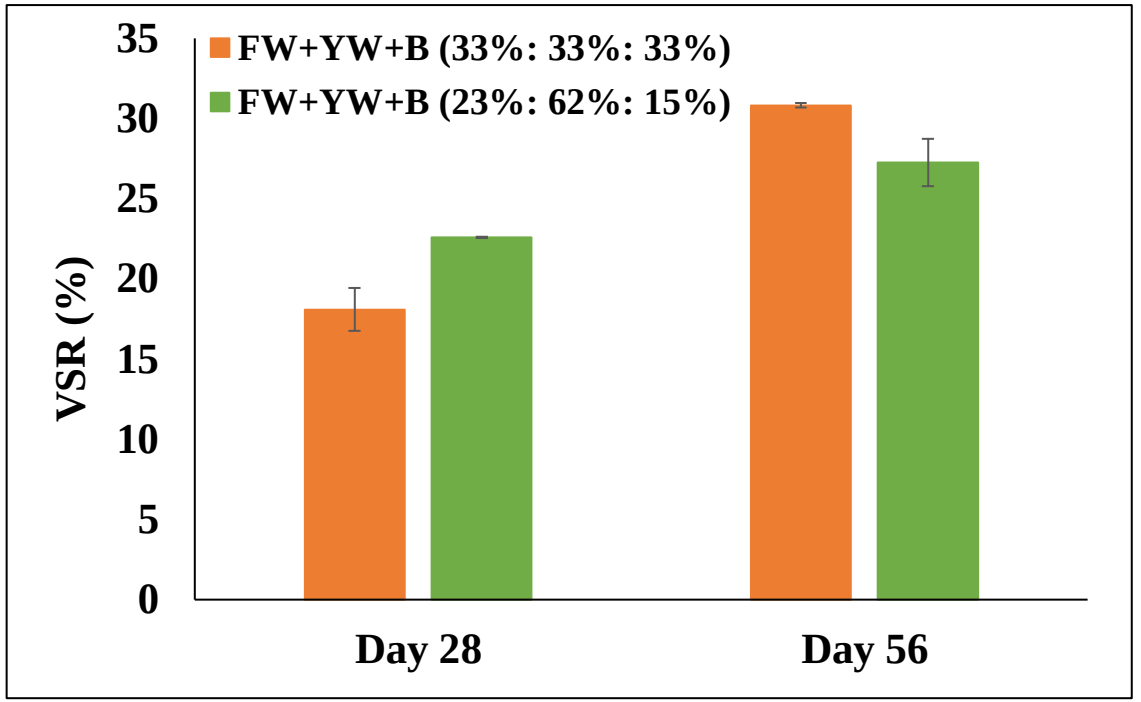


BMPs: Effect of Substrate Mixing Ratios

Methane (CH_4) Yields

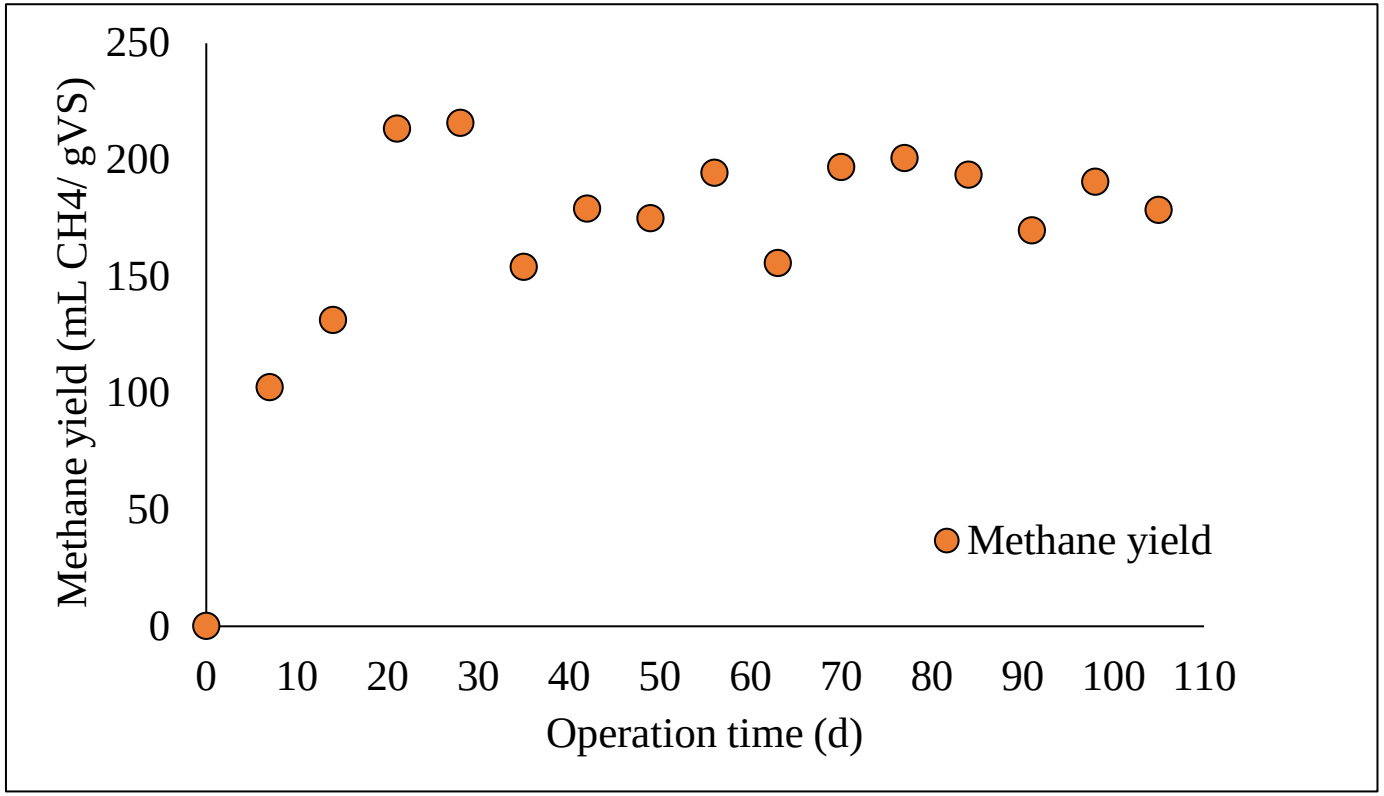


Volatile Solid Reduction (VSR)



- Substrate ratios based on FW, YW and BS in Hillsborough County had higher initial CH_4 yield, lower final CH_4 yield and VSR

Semi-Continuous Reactor Studies



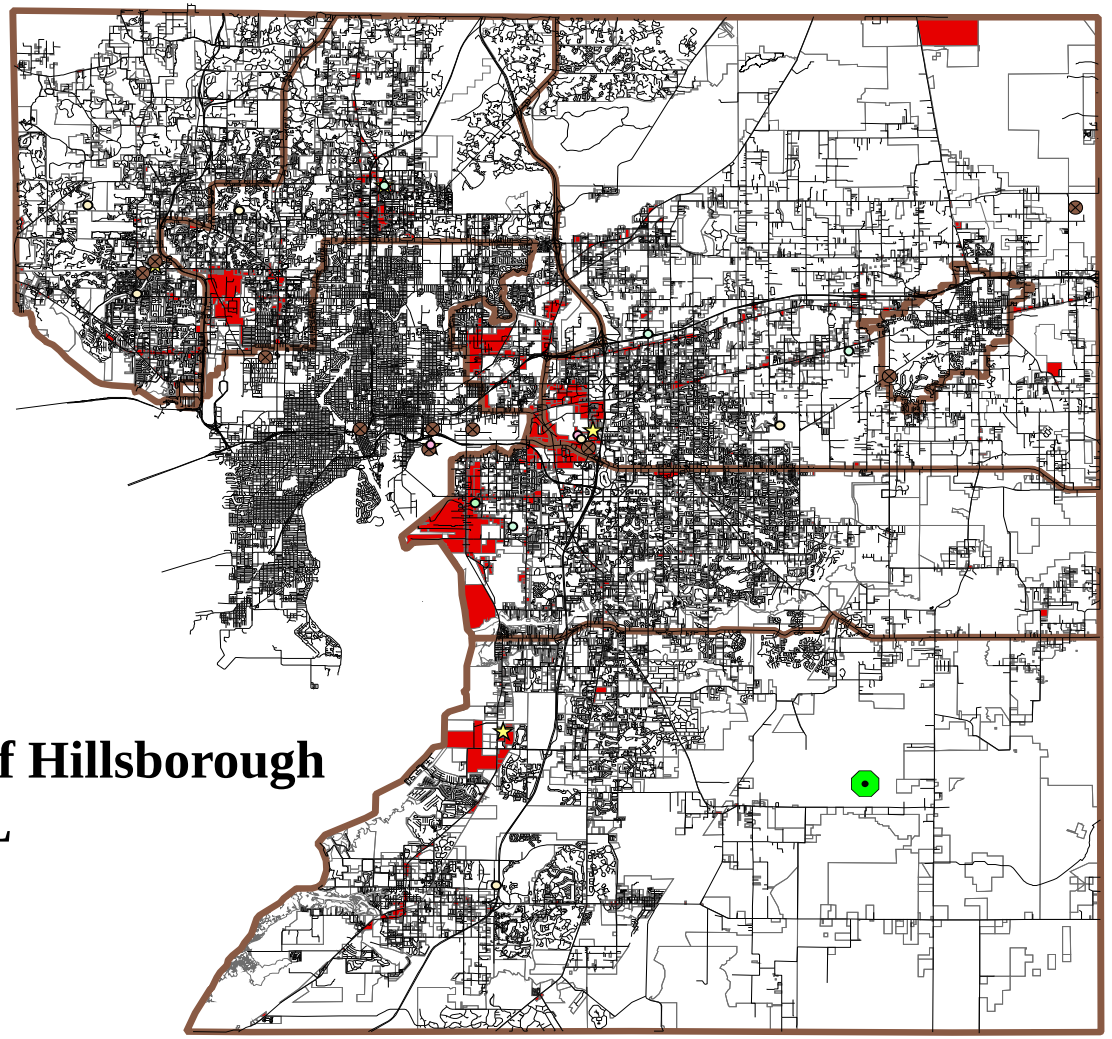
Item	TN (%)	TP (%)	TK (%)
YW + FW	2.76	2.06	0.53
Hillsborough Mix	2.84	2.38	0.44
Bioorganic fertilizer	1.6	2.55	1.9

- Average CH_4 yield 186 L CH_4/kg VS
- Average VSR 38%.

- Digestate with biosolids - higher N and P.
- Higher N, lower K, similar P as organic fertilizer.

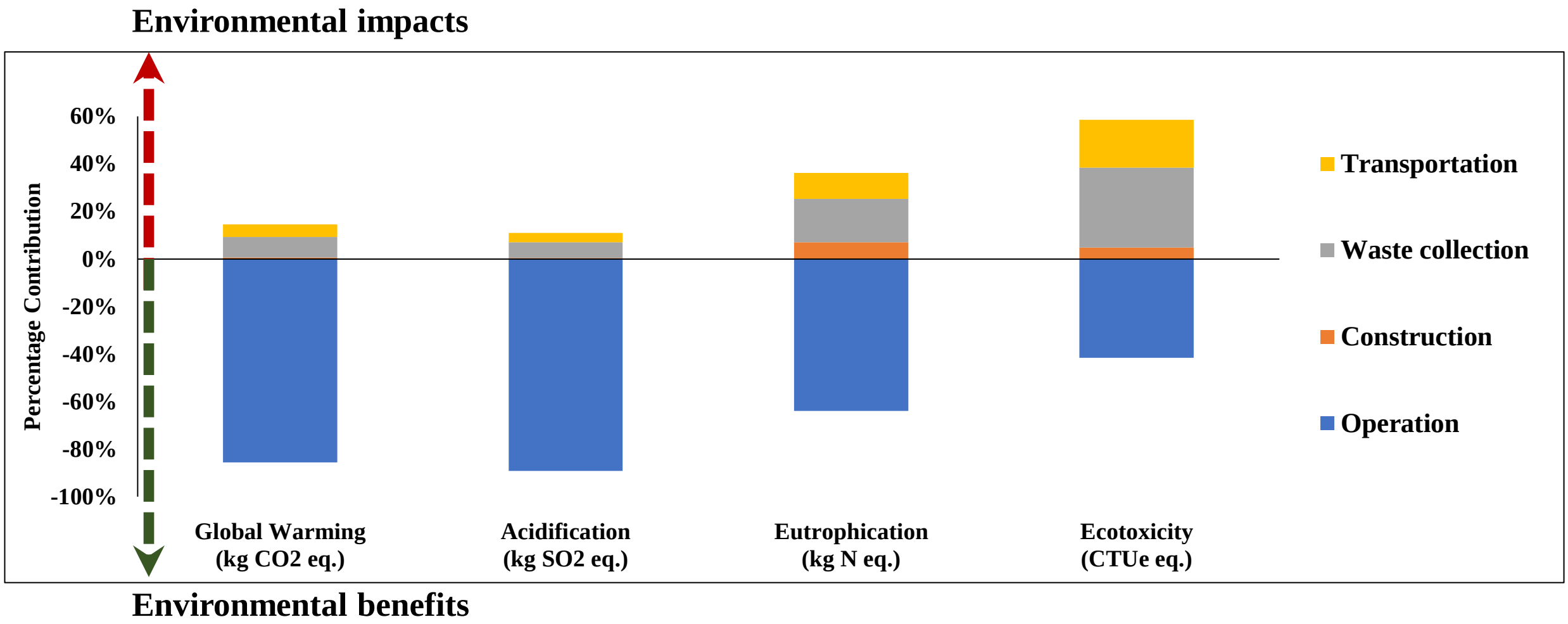
Life Cycle Assessment Studies

- Study area: Hillsborough County, FL
- Life Cycle Inventory:
  - Published papers and reports
  - Ecoinvent equipment data
  - Experimental data from lab
- Functional Unit:
  - 1L CH_4 produced
  - 20 year life span
- System Boundary:
  - Waste collection (large sources)
  - Waste transportation
  - HS-AD construction
  - HS-AD operation

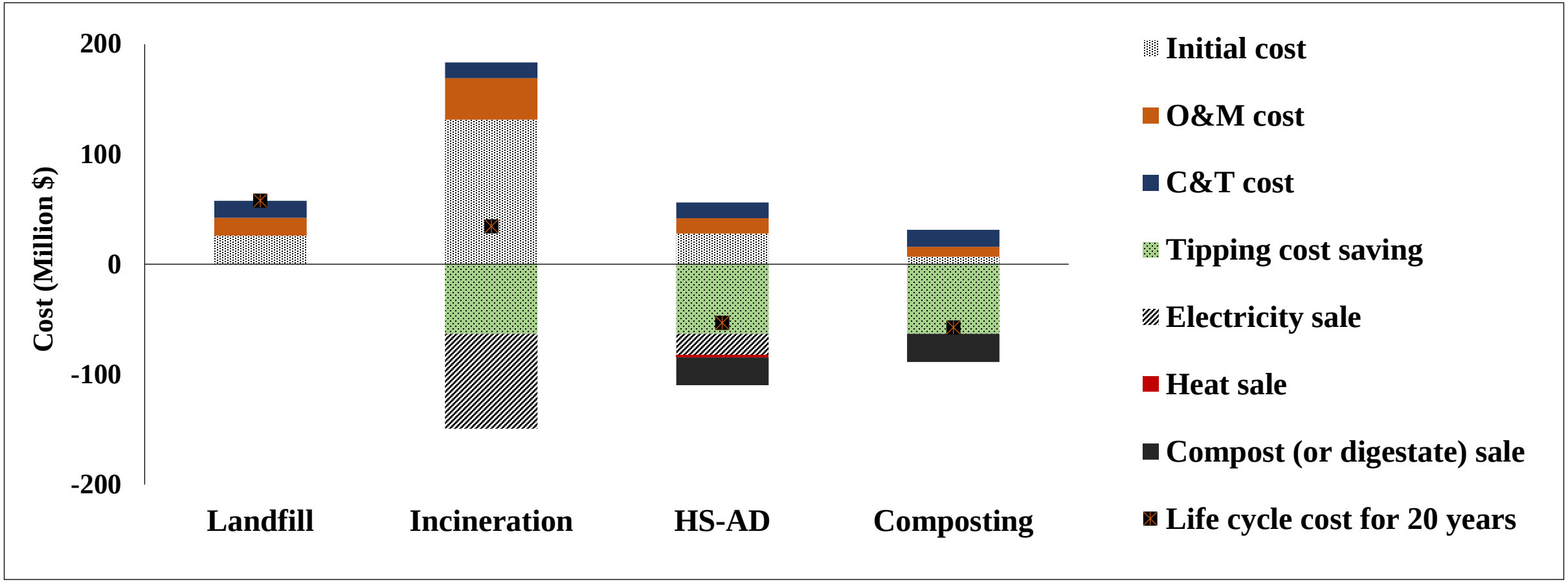


GIS map of Hillsborough County, FL

Life Cycle Environmental Impacts & Benefits



Comparative Life Cycle Cost Assessment



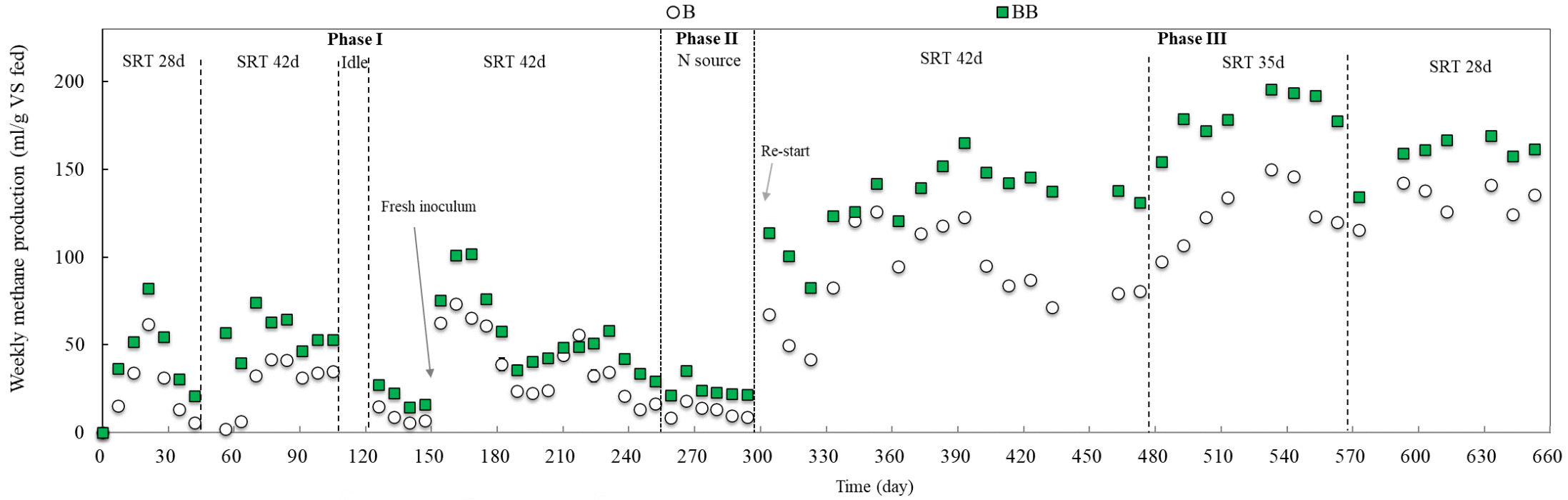
LCA and Economic Assessment

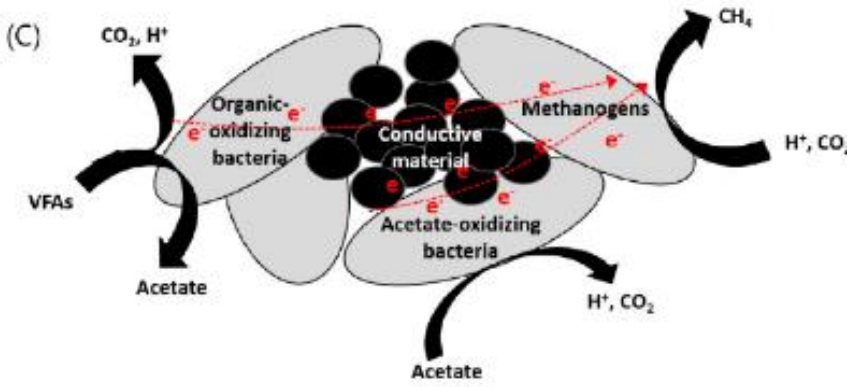
- HS-AD Environmental Impacts:
  - Waste collection & transportation - greatest impact of all categories considered.
  - Environmental impact of operation offset by energy and nutrient recovery benefits.
- Comparative LCCA with landfilling, incineration and composting:
  - Savings from tipping fees and revenues from compost and energy offset capital and O&M costs.
  - HS-AD slightly less economical than composting (if land acquisition not included) but more advantageous than landfilling or incineration.

Conclusions

- HS-AD of organic solid waste and biosolids promising for Florida due to substrate availability, warm climate, high energy demands and compatibility with existing infrastructure.
- More incentives needed, such as RECs, organic waste bans from landfills and mandated organic waste separation for large sources.
- Good CH_4 generation rate, volatile solids reduction and nutrient value of digestate for HS-AD of FW, YW & biosolids when S/I and alkalinity optimized.
- LCA and LCCA showed environmental and economic benefits due to energy and nutrient recovery.
- Additional benefits: near elimination of sidestream generation and improved landfill leachate quality.

Biochar enhances methane production in HS-AD





Direct Interspecies Electron Transport (DIET)

For more information:

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Biogas production from high solids anaerobic co-digestion of food waste, yard waste and waste activated sludge

Eunyoung Lee [a], Paula Bittencourt [b], Lensey Casimir [a], Eduardo Jimenez [a,c], Meng Wang [a,d], Qiong Zhang [a], Sarina J. Ergas [a,*]

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Comparative environmental and economic life cycle assessment of high solids anaerobic co-digestion for biosolids and organic waste management

Eunyoung Lee [a], Deborah Stolte Bezerra Lisboa Oliveira [b], Luiza Stolte Bezerra Lisboa Oliveira [b], Eduardo Jimenez [a, c], Youngwoon Kim [a], Meng Wang [a, d], Sarina J. Ergas [a], Qiong Zhang [a, *]

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Effect of Substrate to Inoculum Ratio on Bioenergy Recovery from Food Waste, Yard Waste, and Biosolids by High Solids Anaerobic Digestion

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sustainability

MDPI

Article

Enhancement of System and Environmental Performance of High Solids Anaerobic Digestion of Lignocellulosic Banana Waste by Biochar Addition

Xia Yang, Qiong Zhang and Sarina J. Ergas *

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Questions?

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