Background & Objectives

- New waste management methods are needed for Duke University to achieve the objectives set forth in the Duke Climate Commitment.
- Duke’s 2024 Carbon Neutrality goal currently relies on carbon offsets to mitigate 25% of its emissions from the 2007 baseline.¹
- Anaerobic digestion (AD) takes advantage of bacteria to transform food waste into energy.
- AD has three main benefits: Waste Management, GHG Emissions, and Natural Gas Offsets.

Build two iterative low-budget prototype anaerobic digesters to generate methane from Duke’s food waste.

Compare relative methane production rates over time with different feedstocks.

Examine benefits of using generated methane to offset natural gas usage for building heating via two separate scenarios.

Methods

- Three separate samples (Marketplace food waste, food waste + cow manure, and food waste + Duke Campus Farm compost) were digested in a prototype AD (shown in Figure 1).
- Biogas volumes and samples were collected during a period of three weeks. PPM values of methane and carbon dioxide in the biogas were determined using Gas Chromatography.

Biogas Analysis

Energy and Economic Analysis

- Bottom-up analysis: We calculated the energy content in one pound of steam used to heat buildings on campus, accounting for boiler efficiency. Then, we calculated the equivalent volume of methane from an AD required to meet the steam demand of any given building on campus.

Energy and Economic Analysis:

- Top-down analysis: We calculated the amount of food waste that would be required to run a boiler in the West Campus Steam Plant (WCSP).

Prototypes and Results

Use Estimates of Duke’s Food Waste to Size an Anaerobic Digester to Meet the Steam Demand of Specific Buildings on Campus

Three different waste amounts:
1) CompostNow: 288 tons per year
2) Duke Office of Sustainability: 659 tons per year
3) The arithmetic average: 474 tons per year

Steam Production from Proposed AD

<table>
<thead>
<tr>
<th>Biogas evolution of food waste</th>
<th>Methane composition of biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low 70.6</td>
<td>50% Methane</td>
</tr>
<tr>
<td>Medium 123.6</td>
<td>1.15 Methane</td>
</tr>
<tr>
<td>High 150</td>
<td>1.49 Methane</td>
</tr>
</tbody>
</table>

Steam production from the AD can be met with the digestor biogas production:
- Nasher Museum: 2.51 million lbs of steam
- Jordan Building (Duke Police Dept): 60,600 lbs of steam

Steam-equivalent weights produced by methane allows for comparison of buildings whose annual heating requirements can be met with the digestor biogas production:
- Nasher Museum: 2.51 million lbs of steam
- Jordan Building (Duke Police Dept): 60,600 lbs of steam

Economic, Environmental, and Location Analyses

- Economic Analysis:
  - A positive NPV is possible for both bottom-up and top-down scenarios, but only for a small CAPEX.
  - Grants and tax credits can be leveraged to reduce capital costs.
  - The analysis did not account for intangible benefits of an AD.

- Environmental Analysis:
  - Using the EPA Waste Reduction Model, from the bottom-up scenario with 474 tons of food waste, Duke’s net CO₂ emissions decrease by 165 MTCO₂.
  - From the top-down scenario, Duke’s net CO₂ emissions decrease by 23,056 MTCO₂.

- Location Analysis:
  - The optimal location for an AD is central campus
  - Central campus has undeveloped open space and is close to the identified loads of the Nasher Museum and the Jordan Building (Duke Police Station).

Conclusion

- Duke can feasibly implement an anaerobic digester on central campus to heat the Nasher Museum and the Jordan Building from Duke’s food waste.
- Duke could avoid annual emissions of 165 tons of CO₂ equivalent by sending all food waste generated on campus into an anaerobic digester.
- An AD feedstock of food waste + manure yielded 4x as much methane compared to only food waste, but methane production decreased rapidly because prototype 1 lacked mixing, heating, and feedstock replenishment capabilities.
- While expensive, an AD can provide intangible benefits, such as class learning module integration, research opportunities, the Campus-as-Lab initiative, and jobs for Durham residents.
- An AD on Duke’s campus can serve as a model for projects around the country and drive change for more sustainable use of organic waste.

References


Equation 2: Conversion from food waste weights to volumes of natural gas

Equation 3: Conversion from food waste weights to volumes of natural gas

Equation 1: Conversion from food waste weights to volumes of natural gas

Equation 4: Conversion from food waste weights to volumes of natural gas

References