Anaerobic Digestion at UCSD: A Feasibility Study

UNIVERSITY OF CALIFORNIA Carbon Neutrality Initiative

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Introduction

- In 2013 UC President Janet Napolitano announced the creation of the Carbon Neutrality Initiative (CNI)
- UC campuses have committed to achieving carbon neutrality in Scope 1 and 2 emissions by 2025
- Scope 1 and 2 emissions refer to GHGs produced from sources directly owned by the University (on-campus electricity generation equipment, campus vehicle fleet) and sources related to the electricity purchased by the University, respectively
- My fellowship focused on researching the feasibility of an anaerobic digestion facility at UCSD in order to reduce Scope 1 and 2 emissions and divert organic waste
- This project was inspired by the UC Davis Renewable Energy Anaerobic Digester (READ), a facility with a processing capability of 50 tons of organic waste per day and an energy production capability of 12,000kWh/day of carbon neutral electricity (pictured in Figure 1)

Figure 1: READ facility as seen from the entrance gate

Anaerobic Digestion

- Anaerobic digestion (AD) is the facilitation of anaerobic decomposition, or the breakdown of organic material in the absence of oxygen via microbial processes
- This digestion occurs in large tanks where optimum conditions for bacterial activity can be maintained in order to maximize anaerobic decomposition and produce beneficial products
- There are a great variety of anaerobic digestion technologies on the market, each with specific advantages
- Key features of an AD technology are the feedstock moisture content range, processing temperature, and number of reactor tanks (to separate reaction stages)

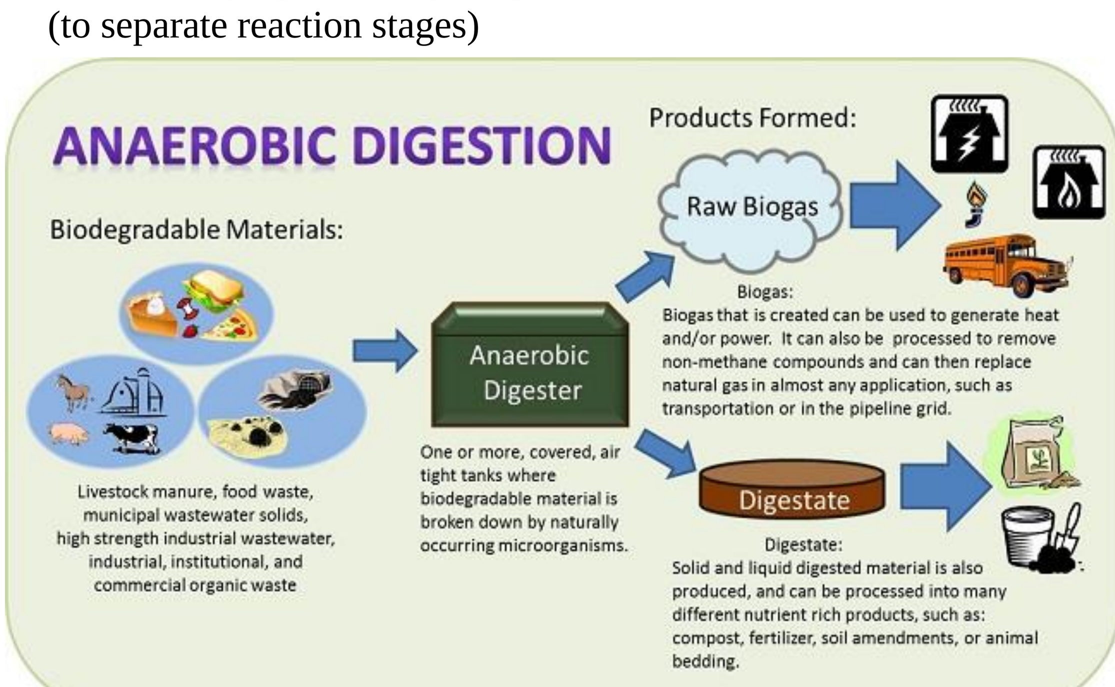

Figure 2: Diagram explaining anaerobic digestion (5)

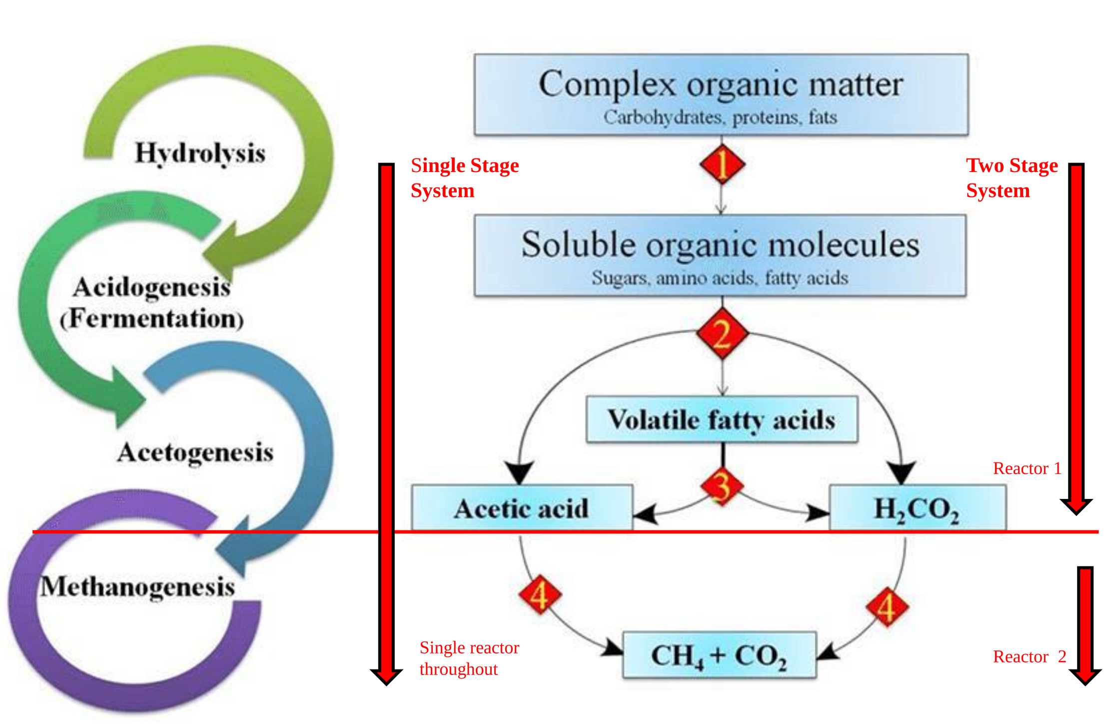

Figure 3: Diagram of anaerobic digestion processes (modified from 6)

Methods

- Most technical information and cost estimates were able to be extracted from the feasibility study for the READ facility and a similar feasibility study done by the City of Palo Alto
- Data more specific to a UCSD AD facility was gathered by referencing other studies and documents, including AD biogas production statistics for brewery spent grain and paper products
- 10 local craft breweries were contacted in order to research the brewery spent grain market in San Diego
- A tour of the READ facility was organized through the CNI fellowship program

Results and Findings

- General statistics for potential feedstock constituents were complied in order to assess constituent viability and determine the best anaerobic digestion technology for use at a UCSD anaerobic digestion facility

Feedstock constituent	Moisture content (%)	VS/TS	VS (% of total weight)	Biodegradability (%)	Biogas Yield (m^3/kg)
Food Waste (1)	69	85.3	26.4	81	0.113 (2)
Green Waste (1)	75	87.6	21.6	79	0.041 (2)
Paper (3)	10.2	96.4	75.9	82	0.178 (2)
Cardboard (3)	5.2	94.0	77.5	47	0.125 (2)
Wet Brewery Spent Grain (4)	76.3	96.1	22.8	79.5	0.472 (4)

Table 1: General statistics for potential feedstock constituents (approximate values)

- During the time of the CNI fieldtrip the READ facility was nonoperational due to tank corrosion (brown rings in picture below), speculatively caused by particulate contaminants
- Campus food waste is likely to have a high contamination rate, so only technologies robust to contaminants were considered

Figure 4: Inside the READ facility hydrolysis tank

- The DRANCO system is a Belgian AD technology that is capable of producing 80-120m^3 biogas per ton feedstock and allows for 80% of energy to be exported (2)
- It is a single stage (single tank for all processes) technology without internal mixing equipment (i.e. no mixing blades as seen above), making it very robust to contaminants (2)
- It is capable of processing a wide variety of feedstocks

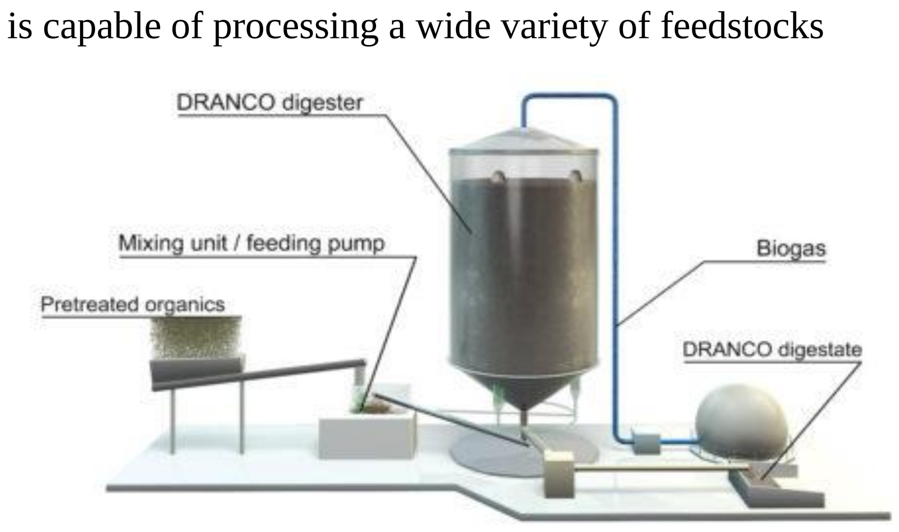

Figure 5: Diagram of DRANCO AD system (7)

- In an effort to research the brewery spent grain market in San Diego, inquiries about spent grain production and disposal methods were sent out to 35 local breweries
- 10 breweries responded, as summarized in the following table

Brewery Name	Spent Grain Production	Pickup Details
New English Brewing	4-10 lbs/week	Farmer collects for free
Rough Draft Brewery	(No data)	Farmer collects for free, spent grain is highly variable week to week
32 North	3,500 lbs/week	Farmer collects for free
Division 32	1000 lbs/week	Farmer collects for free
Pure Brewery	(No data)	Farmer collects for free
AleSmith	Approximately 20,000 to 110,000 lbs/week	Farmer collects for free, spent grain production is highly variable week to week
Little Miss Brewing	(No data)	Farmer collects for free
Protector	500 lbs/week	Farmer collects for free
Council	Several 55 gallon tubs weekly	Farmer collects for free
White Labs	(No data)	Wilbur Ellis agricultural company takes for free

Table 2: Spent grain data from local craft breweries

- Although most breweries have mutually beneficial deals with farmers regarding spent grain disposal, some complain about collection consistency
- Building an AD facility at Elliot Field (labeled below) will allow for great proximity to potential feedstock sources such as the Miramar Marine Base, a host of local breweries, and the UCSD campus

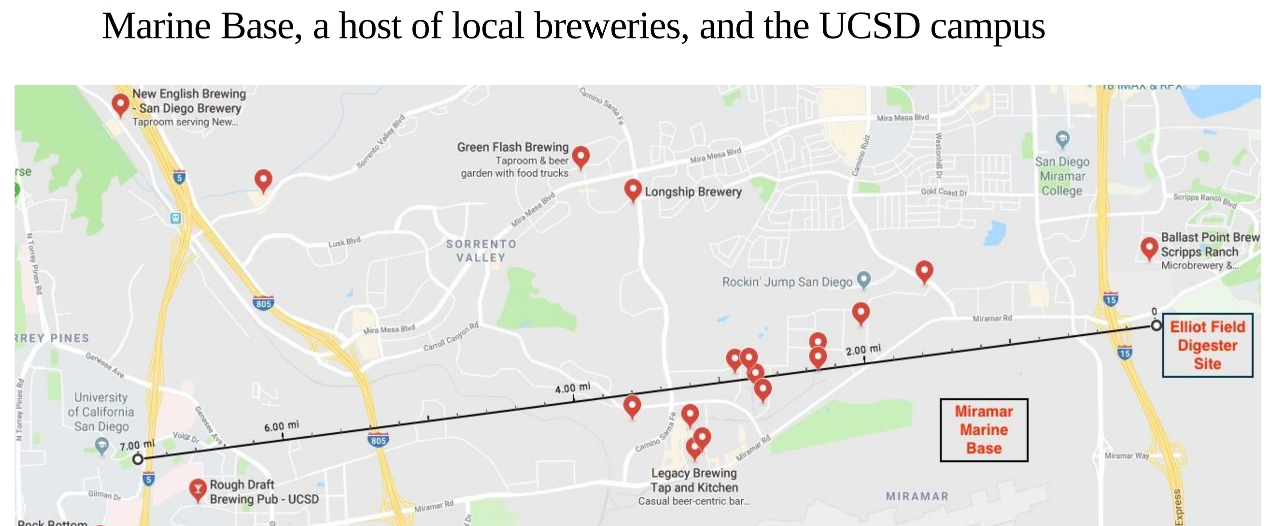

Figure 6: Map of potential digester location and feedstock sources

- A financial analysis of a potential UCSD AD facility was conducted, which is summarized in Table 3
- An AD facility must process greater than 20.6 tons feedstock per day in order to be profitable (assuming $30/ton tipping fees)

Daily Organic Waste Capacity	Equipment	Instillation/ Construction	Total Capital Cost	Operational Costs (1 year)	Electricity Savings (1 year)	Tipping Fees (1 year)	Fertilizer Sales (1 year)	Annual Profits (revenues-operational costs)	Years Until Capital Cost is Paid Off (total investment/annual profit)
1 Ton (Projected)	1,207,000/ $(27/1)^{0.6}$= **(167,000)**	1,766,000 · (1/27)= **(65,000)**	1.25(167,000+65,000)+ (1,002,000)(1/27)= **(327,000)**	0.03(167,000)+ 223,500+ 0.05(327,000)+ 15,000= **(260,000)**	12,000· (1/50) kWh/day @ $0.12/kWh= **11,000**	1 Ton/day @ $30/ ton= **11,000**	27· (1/50) Tons NH_3/year @ $600/ton= **324**	(11,000+ 11,000+ 324)- 260,000= **(238,000)**	N/A (Operational costs exceed revenues)
27 Tons (Based on CA Energy Commission Report) (1)	**(1,207,000)** (1)	**(1,766,000)** (1)	1.25(1,207,000+1,766,000)+ (1,002,000)= **(4,718,000)** (1)	0.03(1,207,000)+ 223,500+ 0.05(4,718,000)+ 15,000= **(511,000)** (1)	12,000· (27/50) kWh/day @ $0.12/kWh= **284,000**	27 Tons/day @ $30/ ton= **296,000**	27· (27/50) Tons NH_3/year @ $600/ton= **9,000**	(284,000+ 296,000+ 9,000)- 511,000= **78,000**	4,718,000/ 78,000= **60**
50 Tons (Estimated READ values)	1,207,000· $(50/27)^{0.6}$= **(1,747,000)**	1,766,000 · (50/27)= **(3,270,000)**	1.25(1,747,000+3,270,000)+ (1,002,000)(50/27)= **(8,127,000)**	0.03(1,747,000)+ 223,500+ 0.05(8,127,000)+ 15,000= **(697,000)**	12,000kWh/day (19) @ $0.12/kWh= **526,000**	50 Tons/day @ $30/ ton = **548,000**	27 Tons NH_3/year @ $600/ton (20)= **16,000**	(526,000+ 548,000+ 16,000)- 697,000= **393,000**	8,127,000/ 393,000= **21**
100 Tons (Projected)	1,207,000· $(100/27)^{0.6}$= **(2,648,000)**	1,766,000 · (100/27)= **(6,541,000)**	1.25(2,648,000+6,541,000)+ (1,002,000)(100/27)= **(15,197,000)**	0.03(2,648,000)+ 223,500+ 0.05(15,197,000)+ 15,000= **(1,078,000)**	12,000· (100/50) kWh/day @ $0.12/kWh= **1,051,000**	100 Tons/day @ $30/ ton= **1,095,000**	27· (100/50) Tons NH_3/year @ $600/ton= **32,000**	(1,051,000+ 1,095,000+ 32,000)- 1,078,000= **1,100,000**	15,197,000/ 1,100,000= **14**

Note: all bolded values are in dollars and rounded to the nearest $1,000

Table 3: Financial analysis table outlining calculation results

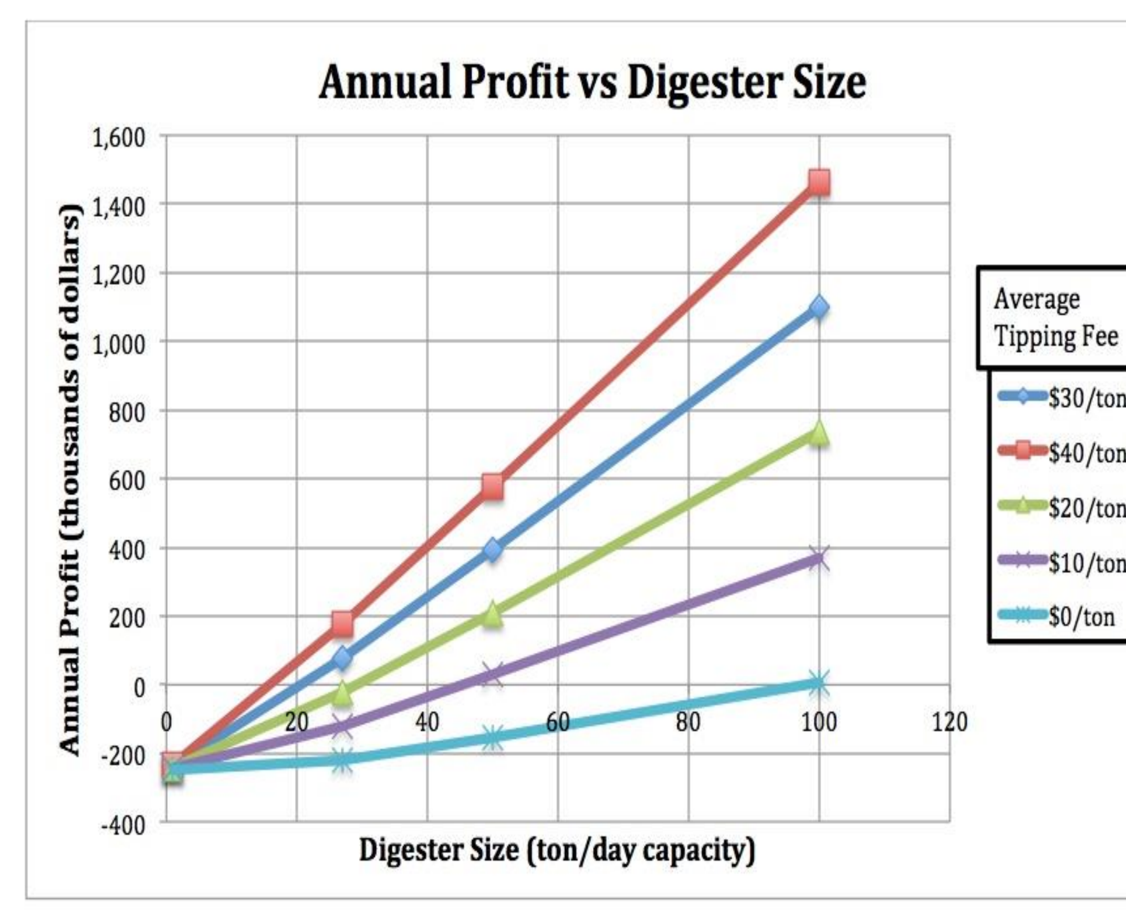

Figure 7: Annual AD facility profits as a function of digester size and average tipping fee received

Conclusions and Next Steps

- The greatest challenge for a UCSD AD facility will be securing a stable supply of feedstock materials at sufficient tipping fee rates to keep the project financially viable
- Once a viable feedstock is identified, it should be tested at the Anaerobic Digestion Lab Test Network (ADTLN) to determine future biogas yield and parasitic interactions
- Feedstock guarantee contracts, a project timeline, and a detailed project budget will need to be submitted to the Cal Recycle Grant program
- A third party owner and operator will need to be identified in order to reduce University financial risk and ensure electricity deliverance

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