

**Supplementary Materials:**

1. Assumptions made in this study included:

- One beer barrel (BBL) of beer generates 5 BBL (31 gal) of wastewater.
- One barrel of beer requires 0.0012 tons of CO₂.
- HRT assumed is 10 days.
- The high heating value of methane used in this study is 1011 Btu/ft³.
- Waste management cost is estimated at \$48.91 per ton.
- Natural gas cost is assumed to be \$1.00 per therm.
- Electricity cost is set at \$0.07 per kWh.
- The price of CO₂ is considered to be \$100.00 per ton.
- All expenses should be taken into account with a variation of up to 15% in either direction.

2. Economic Analysis

The economic viability of a biogas facility is influenced by the processes, design, and size of the facility. To determine baseline capital costs, this study calculated the major expenses associated with each essential process at the biogas facility. Table S1 presents these costs, sourced from the EPA CoEAT model.

Table S1. Capital costs for AD plant.

Major costs for digestion	Cost per unit (\$/unit)
Software capable of running reports	\$10,000
PC computer	\$2,000
Odor control system	\$85,000
Pre-processing equipment	\$450,000
Pumps	\$90,000
Mixers	\$40,000
Gas collection equipment	\$75,000
Monitoring equipment	\$100,000
Engineering planning and design	\$250,000
New full solid waste permit	\$6,300
Land preparation	\$30,000
New water service	\$110
Anaerobic digester tank (\$/ft ³)	\$27

To validate the feasibility of utilizing the EPA CoEAT model for estimating installation costs of AD plants in craft breweries, the capital costs obtained from the model were compared with data from several real case studies.

Table S2. Comparison of capital costs using the CoEAT model and the actual construction costs from real case studies.

	Case study 1	Case study 2	Case study 3	Case study 4
Name of the brewery	Abita Brewing	Matt Brewing Company	Magic Hat Brewing	Bell's Brewing
Location	Covington, LA	Utica, NY	South Burlington, VT	Kalamazoo, MI
Zip	70433	13502	5403	49007
Construction Year	2017	2013	2010	2014
Brewery waste amount, gallons/day	75,000	150,000	30,000	100,000
Hydraulic retention time (HRT), days	10.1	10.1	16.4	10.0
Actual construction cost, \$ million	1.5	5.0	2.7	4.5
CoEAT model results, \$ million in 2022	1.8	6.2	3.2	4.7
Estimated construction cost based on the ENR construction cost index, \$ million in 2022	2.1	5.8	3.4	5.1
Percentage difference, %	14.3%	6.9%	5.9%	7.8%

3. Annual income and avoided costs based on different scales of AD.

Table S3. Annual income and avoided costs for varying production levels.

50,000 barrels	AD+RNG	AD+CHP	CO ₂ recovery	AD+RNG+ CO ₂	AD+CHP+CO ₂
Avoided waste management cost	\$ 77,483	\$ 77,483	\$ 77,483	\$ 77,483	\$ 77,483
Liquid digestate income	\$ 888	\$ 888	\$ 888	\$ 888	\$ 888
Avoided electricity costs	NA	\$ 1,045	NA	NA	\$ 1,045
Avoided natural gas costs	\$ 517	NA	NA	\$ 517	NA
Avoided CO ₂ costs	NA	NA	\$ 880,110	\$ 880,110	\$ 880,110
Tax credits	\$ 1,879	\$ 935	NA	\$ 1,879	\$ 935
Annual revenue	\$ 75,771	\$ 75,348	\$ 957,481	\$ 954,881	\$ 954,458

500,000 barrels	AD+RNG	AD+CHP	CO ₂ recovery	AD+RNG+ CO ₂	AD+CHP+CO ₂
Avoided waste management cost	\$774,831	\$774,831	\$774,831	\$774,831	\$774,831
Liquid digestate income	\$8,877	\$8,877	\$8,877	\$8,877	\$8,877
Avoided electricity costs	NA	\$10,452	NA	NA	\$10,452
Avoided natural gas costs	\$5,170	NA	NA	\$5,170	NA
Avoided CO ₂ costs	NA	NA	\$8,801,100	\$8,801,100	\$8,801,100

Tax credits	\$18,785	\$9,350	NA	\$18,785	\$9,350
Annual revenue	\$798,206	\$775,554	\$9,583,809	\$9,598,306	\$9,575,654

1 million barrels	AD+RNG	AD+CHP	CO ₂ recovery	AD+RNG+ CO ₂	AD+CHP+CO ₂
Avoided waste management cost	\$1,549,662	\$1,549,662	\$1,549,662	\$1,549,662	\$1,549,662
Liquid digestate income	\$17,755	\$17,755	\$17,755	\$17,755	\$17,755
Avoided electricity costs	NA	\$20,905	NA	NA	\$20,905
Avoided natural gas costs	\$10,340	NA	NA	\$10,340	NA
Avoided CO ₂ costs	NA	NA	\$17,602,200	\$17,602,200	\$17,602,200
Tax credits	\$37,571	\$18,700	NA	\$37,571	\$18,700
Annual revenue	\$1,600,912	\$1,553,561	\$19,168,617	\$19,202,112	\$19,154,761

2 million barrels	AD+RNG	AD+CHP	CO ₂ recovery	AD+RNG+ CO ₂	AD+CHP+CO ₂
Avoided waste management cost	\$3,099,325	\$3,099,325	\$3,099,325	\$3,099,325	\$3,099,325
Liquid digestate income	\$35,509	\$35,509	\$35,509	\$35,509	\$35,509
Avoided electricity costs	NA	\$41,809	NA	NA	\$41,809
Avoided natural gas costs	\$20,680	NA	NA	\$20,680	NA
Avoided CO ₂ costs	NA	NA	\$35,204,400	\$35,204,400	\$35,204,400
Tax credits	\$75,141	\$37,400	NA	\$75,141	\$37,400
Annual revenue	\$3,206,324	\$3,109,575	\$38,338,234	\$38,409,724	\$38,312,975

4 million barrels	AD+RNG	AD+CHP	CO ₂ recovery	AD+RNG+ CO ₂	AD+CHP+CO ₂
Avoided waste management cost	\$6,198,650	\$6,198,650	\$6,198,650	\$6,198,650	\$6,198,650
Liquid digestate income	\$71,018	\$71,018	\$71,018	\$71,018	\$71,018
Avoided electricity costs	NA	\$83,618	NA	NA	\$83,618
Avoided natural gas costs	\$41,360	NA	NA	\$41,360	NA
Avoided CO ₂ costs	NA	NA	\$70,408,800	\$70,408,800	\$70,408,800
Tax credits	\$150,282	\$74,799	NA	\$150,282	\$74,799
Annual revenue	\$6,417,148	\$6,221,602	\$76,677,468	\$76,824,948	\$76,629,402

6 million barrels	AD+RNG	AD+CHP	CO ₂ recovery	AD+RNG+ CO ₂	AD+CHP+CO ₂
Avoided waste management cost	\$9,297,975	\$9,297,975	\$9,297,975	\$9,297,975	\$9,297,975
Liquid digestate income	\$106,528	\$106,528	\$106,528	\$106,528	\$106,528
Avoided electricity costs	NA	\$125,427	NA	NA	\$125,427
Avoided natural gas costs	\$62,040	NA	NA	\$62,040	NA
Avoided CO ₂ costs	NA	NA	\$105,613,200	\$105,613,200	\$105,613,200

Tax credits	\$225,424	\$112,199	NA	\$225,424	\$112,199
Annual revenue	\$9,627,971	\$9,333,630	\$115,016,703	\$115,240,171	\$114,945,830

Table S4. Comparison of payback period with 20% hops waste and without hops.

Annual production, barrels	Without hop waste, years		With 20% hops waste, years		Percentage difference, %	
	AD+RNG	AD+CHP	AD+RNG	AD+CHP		
50,000	43	45.4	43.3	45.6	0.7	0.4
500,000	5.3	7.5	5.4	7.6	1.9	1.3
1,000,000	3.5	5.5	3.4	5.5	2.9	0.0
2,000,000	2.3	4.5	2.4	4.5	4.2	0.0
4,000,000	1.9	4	1.9	4	0.0	0.0
6,000,000	1.7	3.8	1.7	3.8	0.0	0.0