Food Waste End-of-Life Management: Comparing Co-Digestion at a Wastewater Treatment Facility with Composting, Landfilling, and Waste-to-Energy Combustion

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US EPA Office of Research and Development, Center for Environmental Solutions and Emergency Response

[3] US EPA Region 1

Cambridge City Council Meeting
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Office of Research and Development
Center for Environmental Solutions and Emergency Response

Research Background:

Many municipalities and states such as Massachusetts are passing ordinances or developing programs to keep food waste out of municipal landfills. Alternative disposal options need a comprehensive evaluation to ensure that environmental and economic goals are met.

Research Question:

What are the comparative environmental impacts and economic costs of using food waste as a feedstock for anaerobic co-digestion or composting, as compared to landfilling and waste-to-energy disposal?

Study Objectives

- Focus wastewater facility = Greater Lawrence Sanitary District
- Assess environmental and cost impact of:
  - Expanding anaerobic digester capacity for food waste co-digestion with energy recovery.
  - Composting food waste using windrow or aerated static pile methods.
  - Compare beneficial reuse options to landfill and waste-to-energy combustion.
- Not an either-or proposition
  - MassDEP estimates food waste comprises more than 25% of solid waste stream.
  - State has a goal to divert 35% of food waste by 2020 (approx. 350,000 tons per year).
  - Currently, generation of food waste exceeds combined capacity of compost and digester facilities regionally.

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Life Cycle Approach

- Assess cradle-to-grave impacts for all processes, products, and services associated with the system for the following metrics:
  - Cost [U.S. Dollars 2016]
  - Global warming potential [kg CO2 equivalent (eq.)]
  - Eutrophication potential [kg N. eq]
  - Cumulative energy demand [MJ (renewable and non-renewable)]
  - Particulate matter formation potential [kg PM2.5 eq.]
  - Smog formation potential [kg O_3 eq.]
  - Acidification potential [kg SO_2 eq.]
  - Water use [cubic meters water]
  - Fossil depletion potential [kg oil eq.]
- Standardize annual facility impacts to a functional unit basis of one kg of food waste management.

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Inventory Development

Anaerobic Co-Digestion	▸ Facility Data ▸ GPS-X™ Simulations
Composting	▸ Literature
Waste-to-Energy Combustion	▸ Municipal Solid Waste Decision Support Tool (MSW DST)
Landfilling	▸ MSW DST Tool

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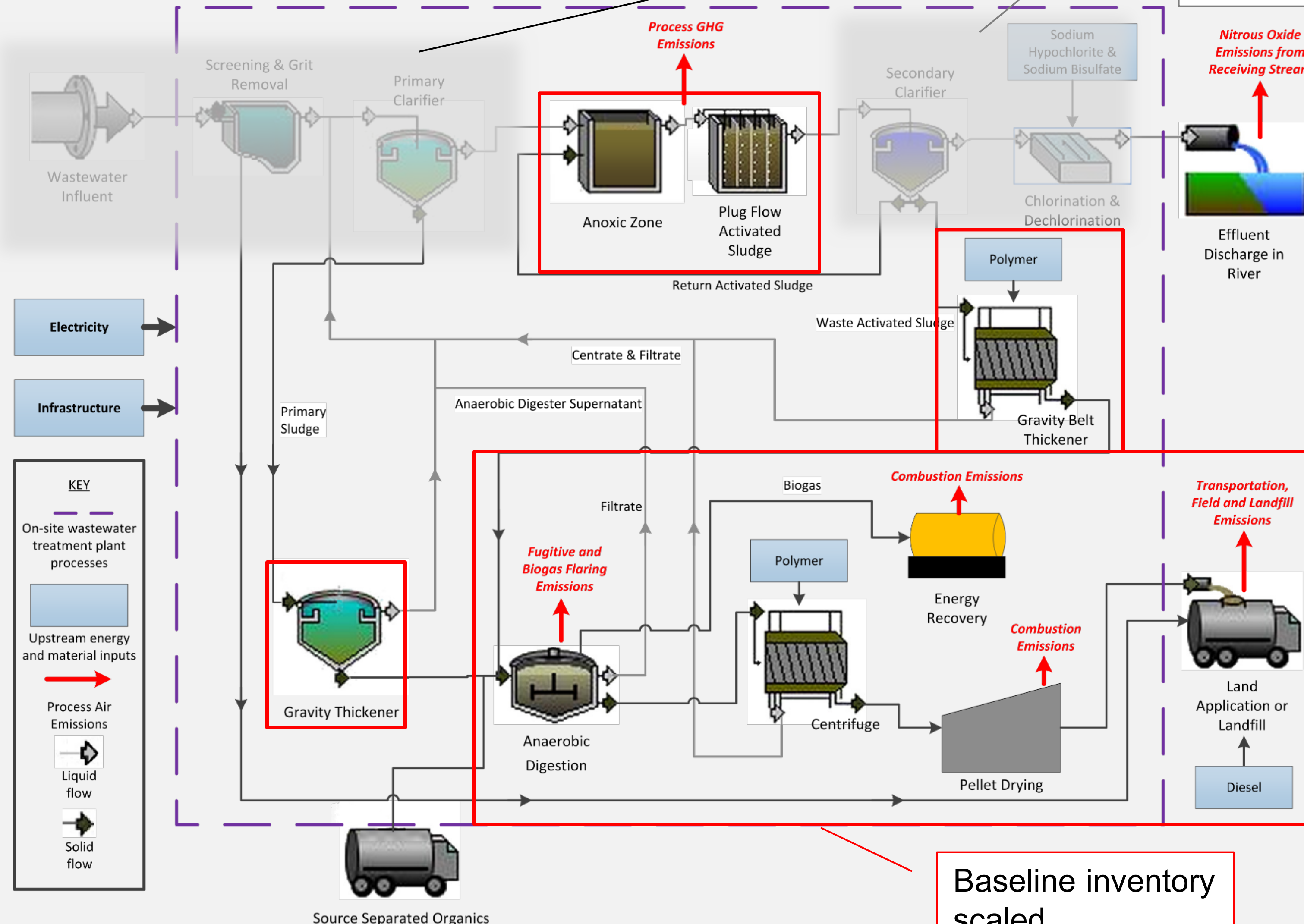
WWTP Flow Diagram

Not strongly affected by food waste acceptance



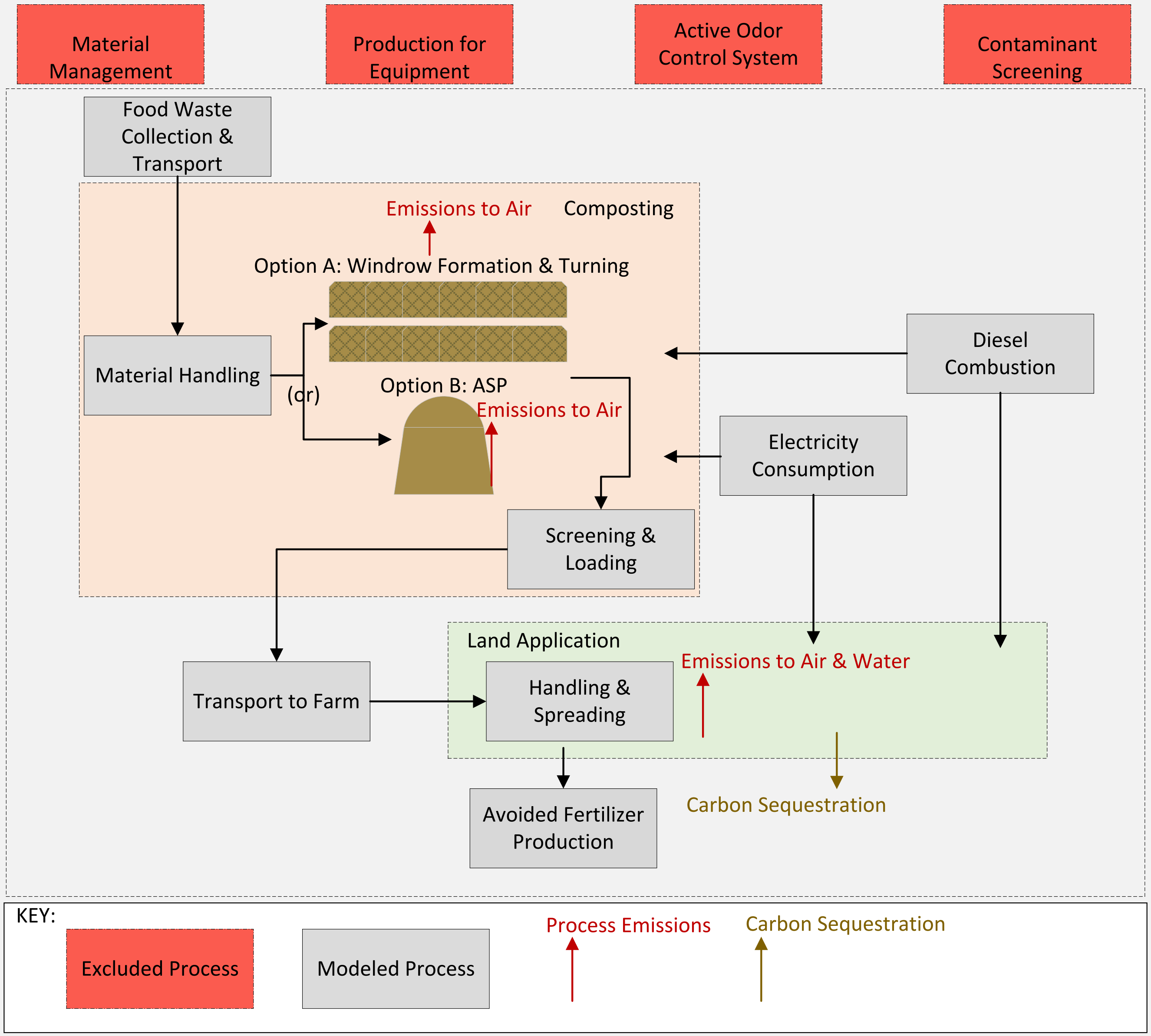
Baseline inventory scaled

Energy Production vs. Use at WWTP

Energy Indicator	Legacy	Full Capacity Anaerobic Digestion (AD)	Units
Biogas energy recovery[1]	78%	71%	of produced biogas energy
Electricity demand satisfaction	-	100%[2]	of total facility demand
Heat demand satisfaction	79%	100%	

[1] Includes energy loss associated with fugitive biogas/methane.
[2] The facility produces approximately 6.1 GWh of excess electricity annually.

Compost Flow Diagram



Scenarios Considered

Co-Digestion

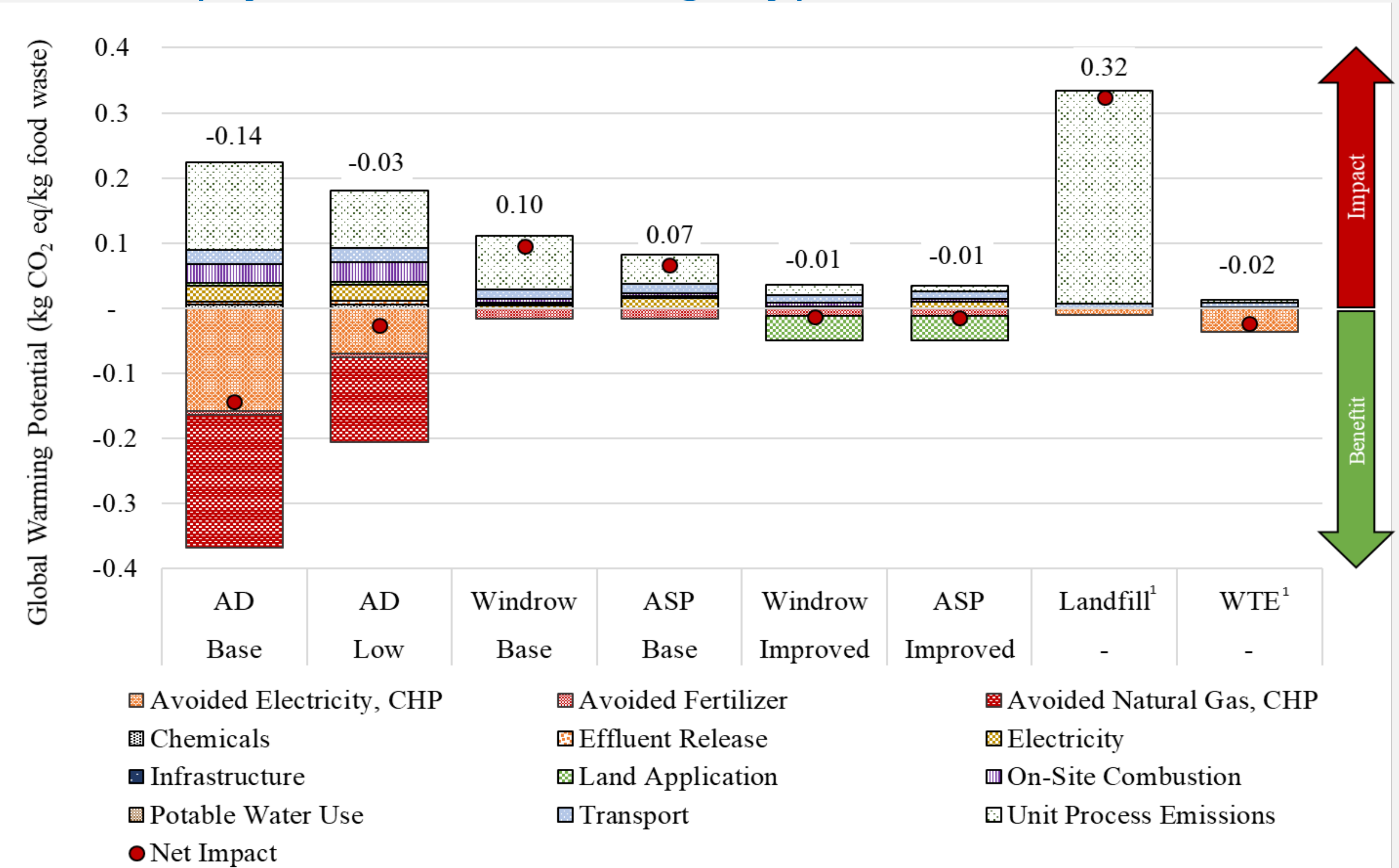
- AD Performance
  - Biogas yield
  - VS reduction
  - Flare rate

Compost

- Method
  - Windrow
  - Aerated Static Pile
- Emissions to nature & energy
  - Base estimate
  - Improved estimate
- Transport Distance

Global Warming Potential

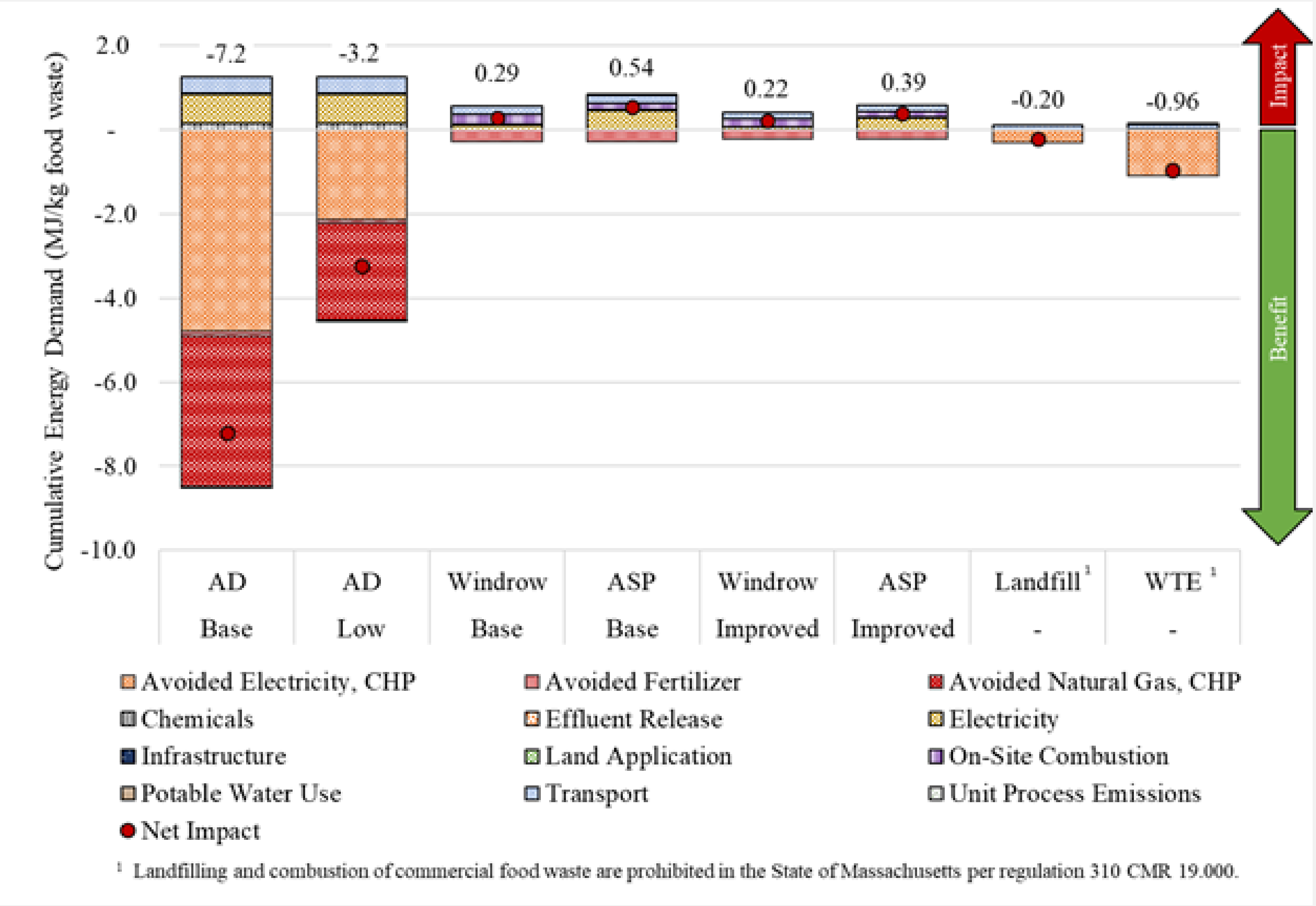
(by Process Category)



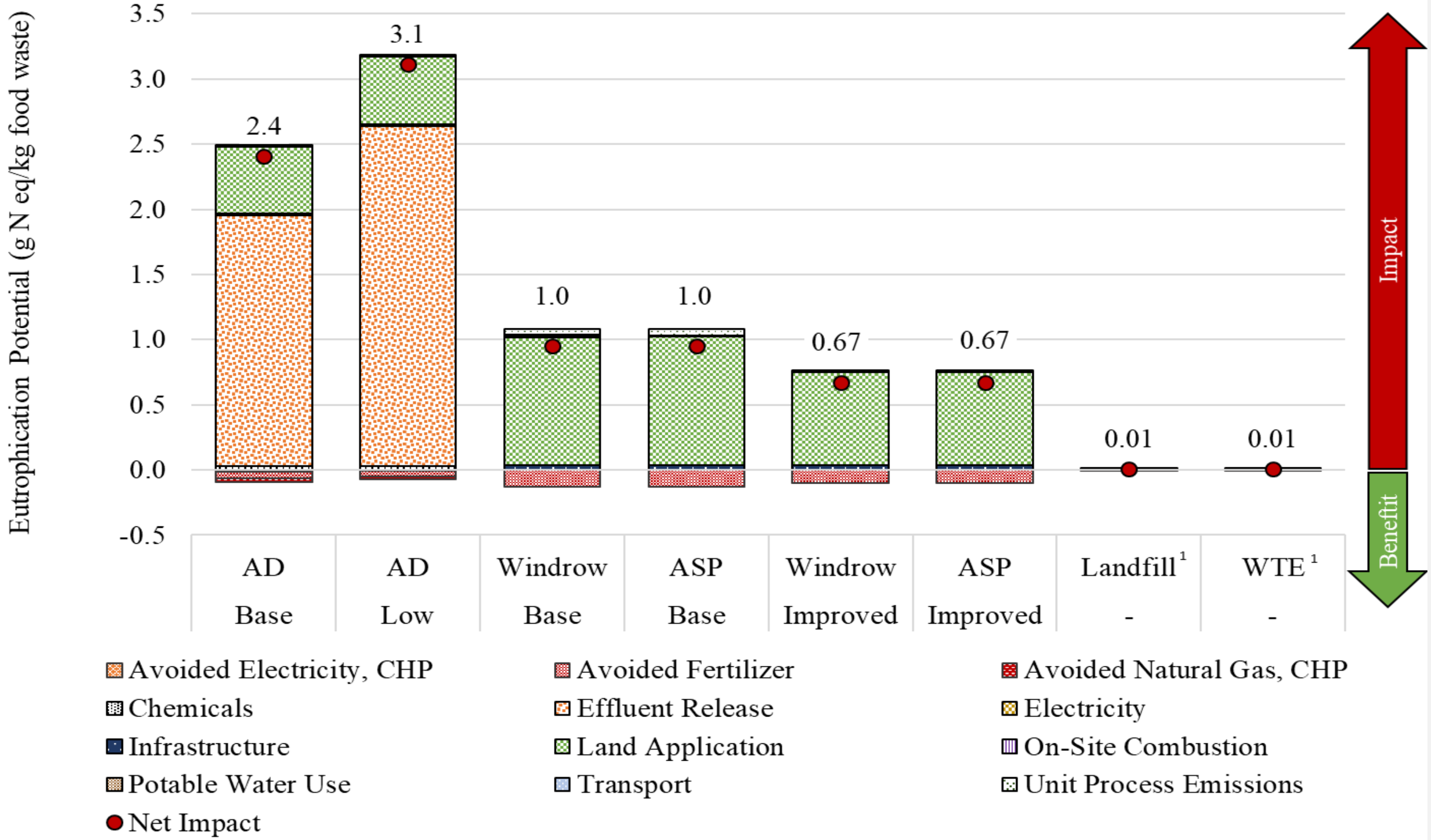
[1] Landfilling and combustion of commercial food waste are prohibited in the State of Massachusetts per regulation 310 CMR 19.000.

Cumulative Energy Demand

(By Process Category)

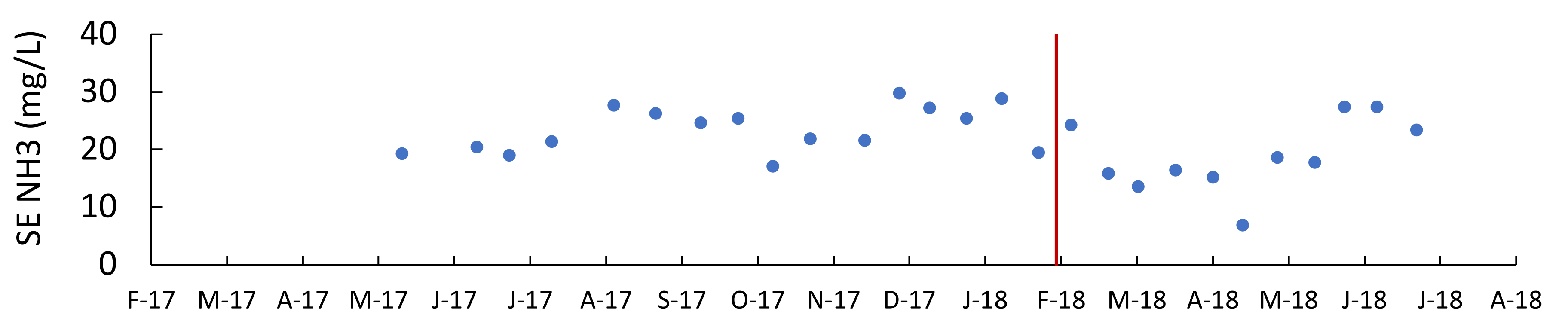


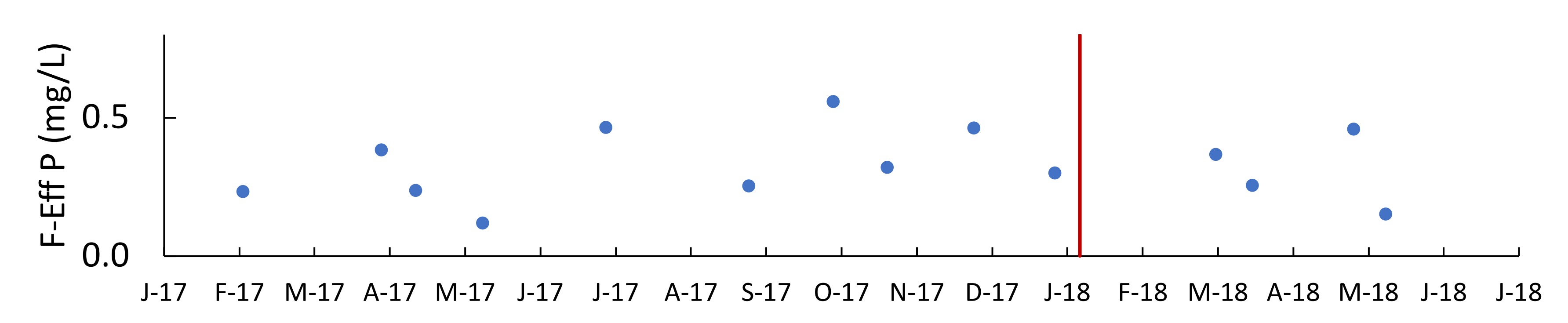
Eutrophication Results
(by Process Category)



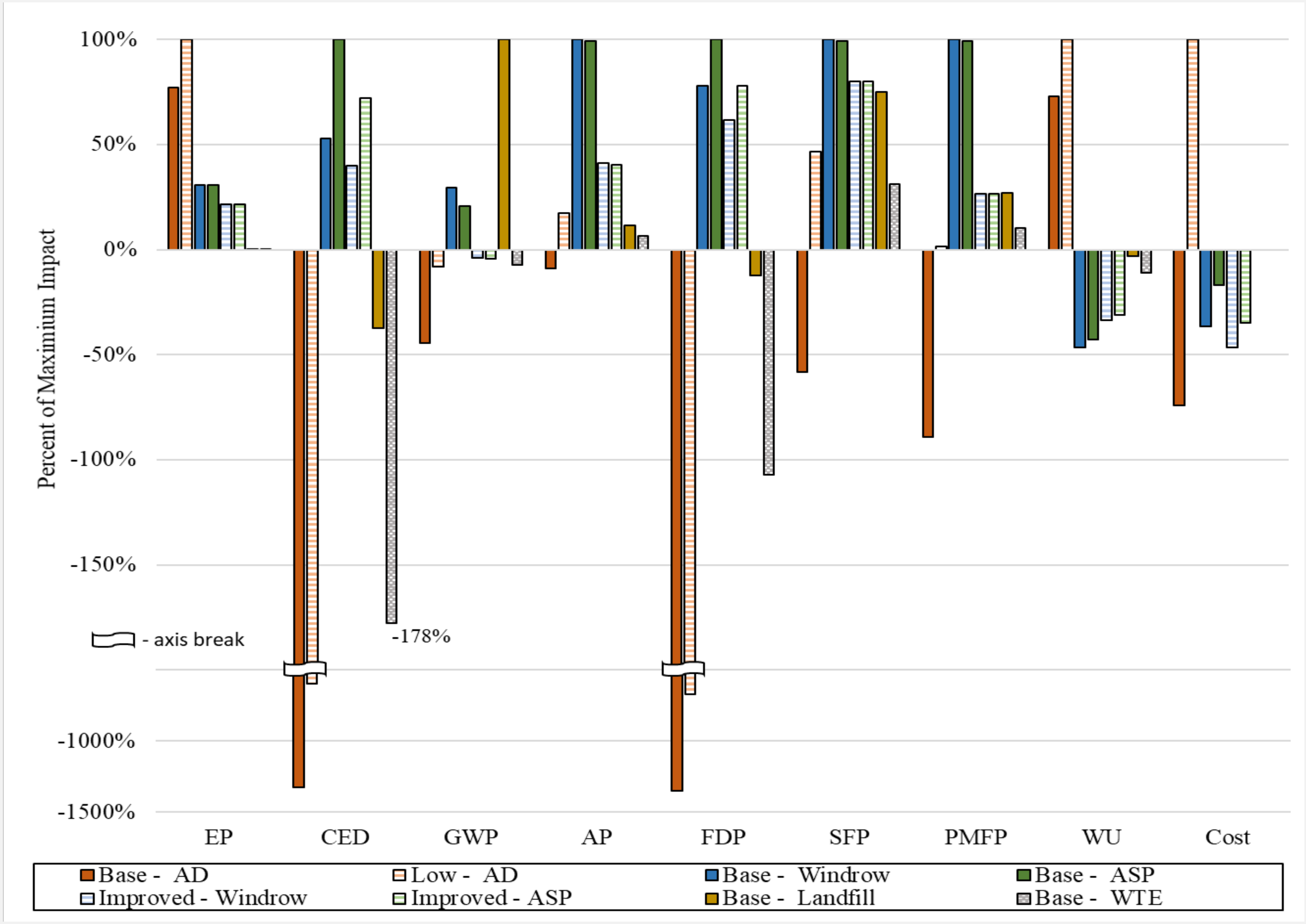
[1] Landfilling and combustion of commercial food waste are prohibited in the State of Massachusetts per regulation 310 CMR 19.000.

Analysis of Effluent Response to 20,000 gallons of SSO





Summary LCA Results



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Key Environmental Conclusions

- Co-digestion outperforms other disposal options in seven of nine results categories.
- Global warming potential is considerably reduced when either digestion or composting replace landfill disposal.
- Composting sacrifices energy recovery opportunity – reducing potential environmental benefits.
- Both co-digestion and composting allow for additional nutrient cycling benefits compared to landfill or WTE.

Disclaimer

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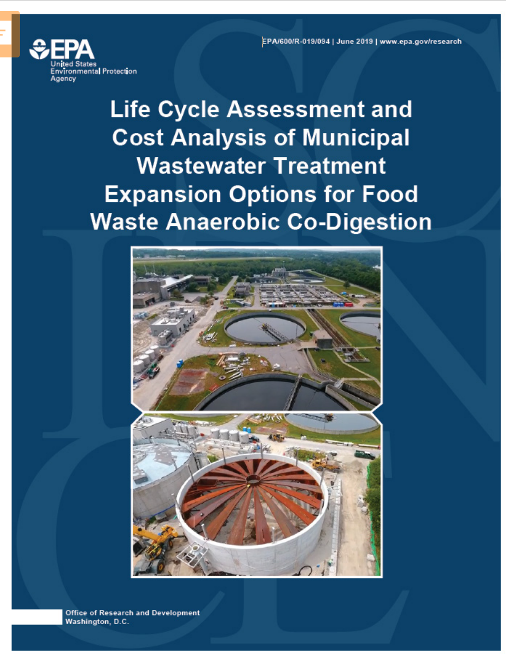
- *Chris Muller, of Brown and Caldwell, provided useful insight on biogas production and nutrient feedback related to anaerobic co-digestion.*

Additional Resources

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Environmental and cost benefits of co-digesting food waste at wastewater treatment facilities

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Abstract

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BioCycle THE ORGANICS RECYCLING AUTHORITY SINCE 1960

Food Waste Recycling — Environmental And Economic Assessment

- EPA report available – EPA/600/R-019/094
  - Comparative analysis of food waste management options in Massachusetts is provided in Appendix A.
- Two-part Biocycle Article
  - Easier Read!
- Water Science & Technology Journal Article

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Toxicity Impacts

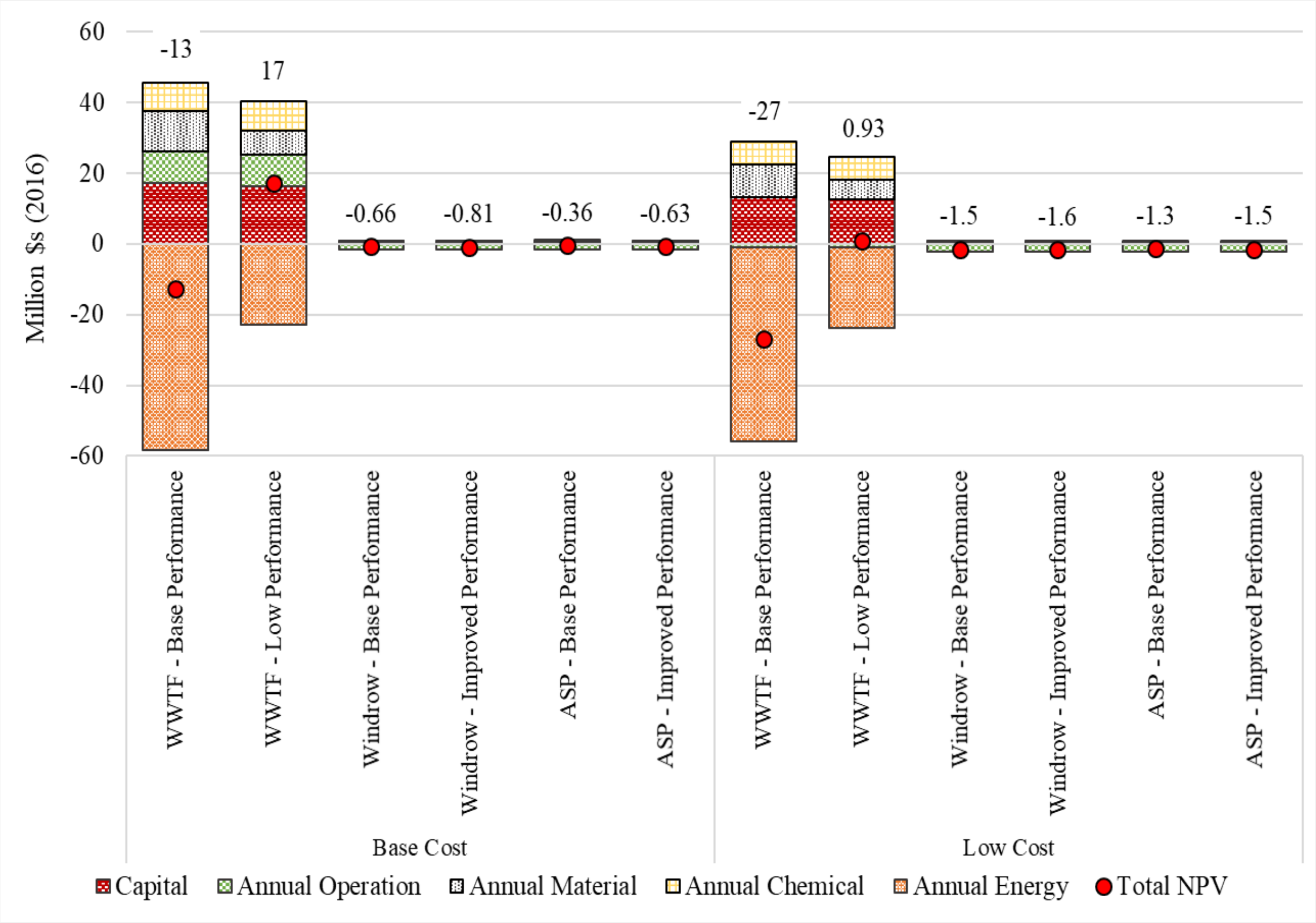
- Not looked at explicitly in this study.
- MassDEP's comments to City Council:
  - Sludge is tested monthly to meet specific limits for a number of parameters that address environmental and human health risk. GLSD's results have consistently complied with the requirements.
  - Sludge is classified as Type I, allowing for the 'least restricted uses.' Such as on a farm or home garden.

Toxicity Impacts

- North East Biosolids and Residuals Association
  - There have been two National Academy of Sciences reviews that confirmed “negligible risk” and that current regulations have not failed to protect public health. Every U. S. state allows biosolids recycling to soils, and decades of experience have also not shown any significant negative impacts.

Cost Analysis Results

- Composting and base performance co-digestion scenarios lead to net negative life cycle costs (revenue) over 30-year system lifespan.



Wastewater Treatment Plant Food Waste Inventory

Treatment Group	Unit Process Name	Compost Comparison Adjustment
Influent pump station	Influent pump station	Excluded
Preliminary/primary	Screening and grit removal	Excluded
	Primary clarification	Excluded
Biological treatment	Pre-anoxic tank	Scaled[1]
	Aeration basins	Scaled[1]
	Secondary clarification	Excluded
Plant water and disinfection	Plant water and disinfection	Excluded
Sludge dewatering	Gravity belt thickener	Scaled[1]
	Gravity thickener	Scaled[1]
	Centrifuge	Scaled[1]
Anaerobic digestion and CHP	SSO transport and processing	Included
	Anaerobic digestion	Scaled[2] [Base AD factor – 78%] [Low AD factor – 69%]
	Combined heat and power	
Pellet drying	Biosolids drying and pelletization	Scaled[1]
Land application	Land application of biosolids pellets	Scaled[1]
Effluent release	Effluent release; to surface water	Scaled[1]
Building operation	Administration building utilities	Excluded

[1] Food Waste LCI value = (Full Capacity LCI value – Baseline LCI value)

[2] Food Waste LCI values affected by the installation of CHP are scaled based on food waste's fraction of biogas production, which are 78 percent and 69 percent in the base and low AD performance scenarios, respectively. Food Waste LCI value = (Full Capacity LCI value * ($Biogas_{FC}$-$Biogas_{base}$)/$Biogas_{FC}$)). $Biogas_{FC}$ = biogas production in the full capacity scenario, $Biogas_{base}$ = Biogas production in the baseline scenario.

Waste Scenarios Analyzed

	Scenario	Waste Type	Quantity (gpd)
	All Scenarios	Septage	80,000
		Municipal Solids*	8,000
	Scenario 1: Base (2016)	Primary & WAS	172,000
		SSO	-
Partial Capacity	**Scenario 2: 50% SSO Capacity**	Primary & WAS	179,000
		SSO	46,000
Full Capacity	**Scenario 3: 100% SSO Capacity**	Primary & WAS	188,000
		SSO	92,000

***Municipal Solids:** Trucked in primary and waste activated sludge.

AD Performance Scenarios

Description	Base AD Performance: Base	Base AD Performance: Partial Capacity	Base AD Performance: Full Capacity	Low AD Performance: Partial Capacity	Low AD Performance: Full Capacity	Unit
VS reduction	55%	69%	72%	61% *[-10%]*[1]	63% *[-11%]*[1]	of influent VS
Biogas yield	17.4	18.4	18.5	15 *[-18%]*[1]	15 *[-18%]*[1]	ft^3/lb VSS destroyed
Biogas, methane content	59.2	59.4	59.9	59.4	59.9	% v/v
Fugitive methane loss	5% for all scenarios					of total
Biogas production	413	1,170	1,870	840 *[-26%]*[1]	1,340 *[-27%]*[1]	thousand ft^3/day
Flared biogas	20%	10%	10%	20%	20%	of biogas prod.

[1] *[Decrease in Low AD parameter value, relative to base scenario]*

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Septage, Primary Sludge, WAS and SSO Characteristics

Characteristic	Feedstock			Unit
	Septage[1]	Trucked Municipal Solids[2]	SSO[3]	
TSS	15,000	22,500	137,000	mg/L
VSS	10,000	16,500	124,000	mg/L
VSS/TSS	67	73	90	%
Total Nitrogen	750	600	3,800	mg N/L
Total P	375	210	620	mg P/L
COD	17,000	29,000	216,000	mg COD/L
Density	1,020	1,030	1,050	kg/m^3

[1] (U.S. EPA 1984)

[2] (Tchobanoglous et al. 2014), assumes 67 percent primary solids and 37 percent WAS by mass.

[3] personal communication with Lauren Fillmore

Cost Scenarios - Compost

Cost Parameters	Low Cost	Base Cost	Units
Tipping fee, food waste	0.044	0.033	$/kg food waste
Compost value	0.019	0.015	$/kg compost sold
Construction interest rate	3%	5%	of capital cost

Cost Scenarios – Co-digestion

Parameter Value	Low Cost	Base Cost
Planning period (years)	30	30
Real discount rate (%)	5%	3%
Electricity cost ($/kWh)[1]	0.143	0.143
Electricity, avoided cost ($/kWh)[2]	0.129	0.123
Renewable energy credit ($/MWh)[3]	25	12
Alternative energy credit ($/MWh)[3]	20	14
Natural gas cost ($/DTH)[4]	10.5	9.88
SSO tipping fee ($/gallon)	0.02	0.005

Key Environmental Assumptions

- 5% of produced biogas lost as fugitive emissions
- Flaring rate (currently between 10 and 20%)
- CHP efficiency
  - Electrical efficiency: 40%
  - Thermal efficiency: 39%
- Biogas Use Hierarchy
  - Flared fraction
  - Second satisfy pellet drier demand
  - The rest is sent to CHP