United States Environmental Protection Agency

FRANKLIN Associates
A Division of ERG

Life Cycle Assessment and Cost Analysis of Anaerobic Co-Digestion of Food Waste at a Medium-Scale Water Resource Recovery Facility

Ben Morelli[1], Sarah Cashman[1], Cissy (Xin) Ma[2], Jay Garland[3] and Jason Turgeon[4]

[1]Eastern Research Group, Inc.
[2] US EPA National Risk Management Research Laboratory
[3] US EPA National Exposure Research Laboratory
[4] US EPA Region 1

BioCycle West Coast
April 1-4, 2019
Portland, OR

Our question(s):

- Does it make sense to have resource recovery in wastewater treatment plants?
- Does anaerobic digestion make sense for food waste disposal?
  - Is it better than other options
  - Under what conditions
  - At what scale
  - Are there any trade-offs

EPA United States Environmental Protection Agency

Study Objectives

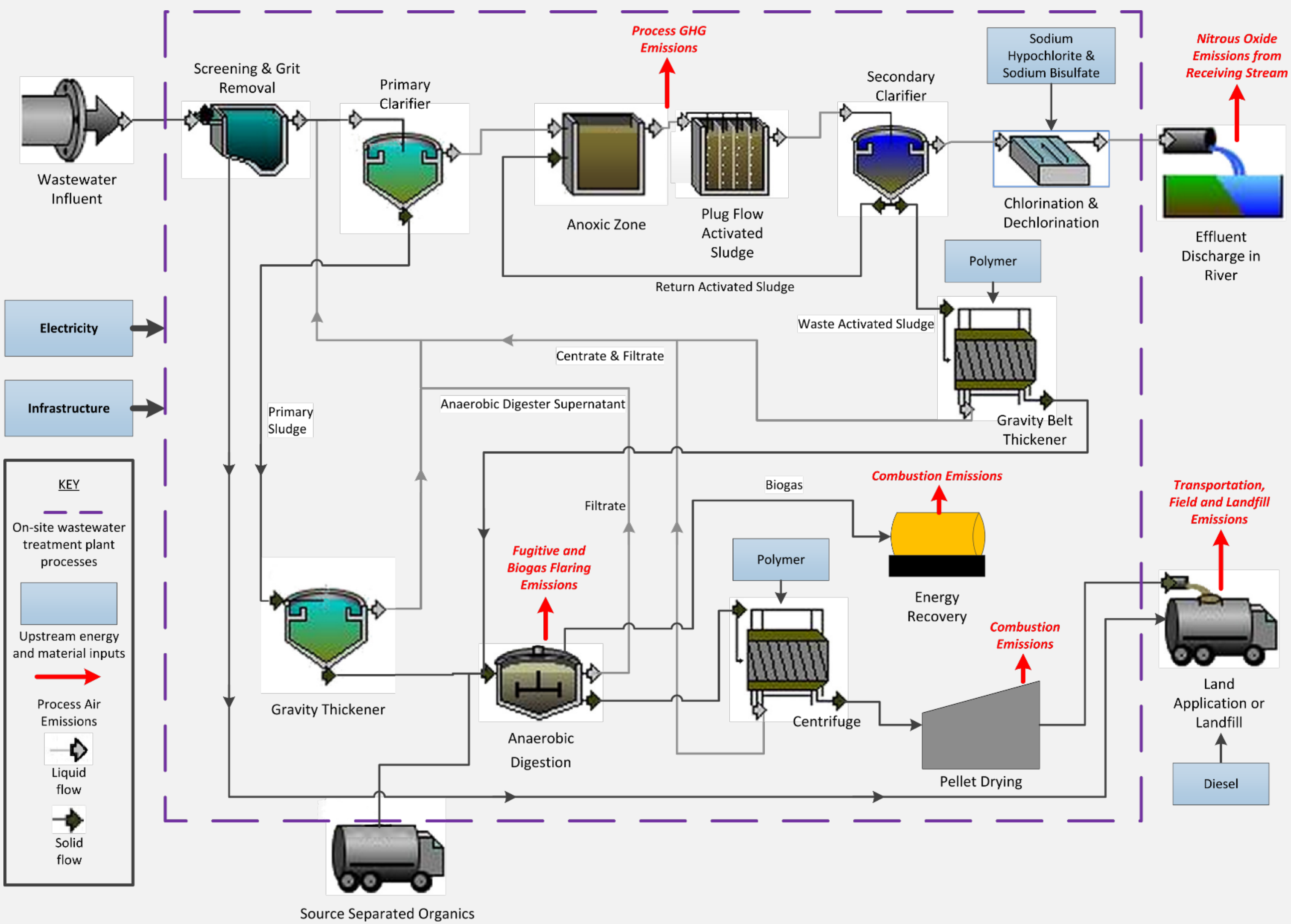
- Assess environmental and cost impact of:
  - Expanding anaerobic digester (AD) capacity for food waste co-digestion.
  - Installing combined heat and power (CHP).
  - Variable digester performance.
  - Avoided waste scenarios.

United States Environmental Protection Agency

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 climate change 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 a cubic meter of wastewater treated.

Process Flow Diagram



United States Environmental Protection Agency

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.

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.

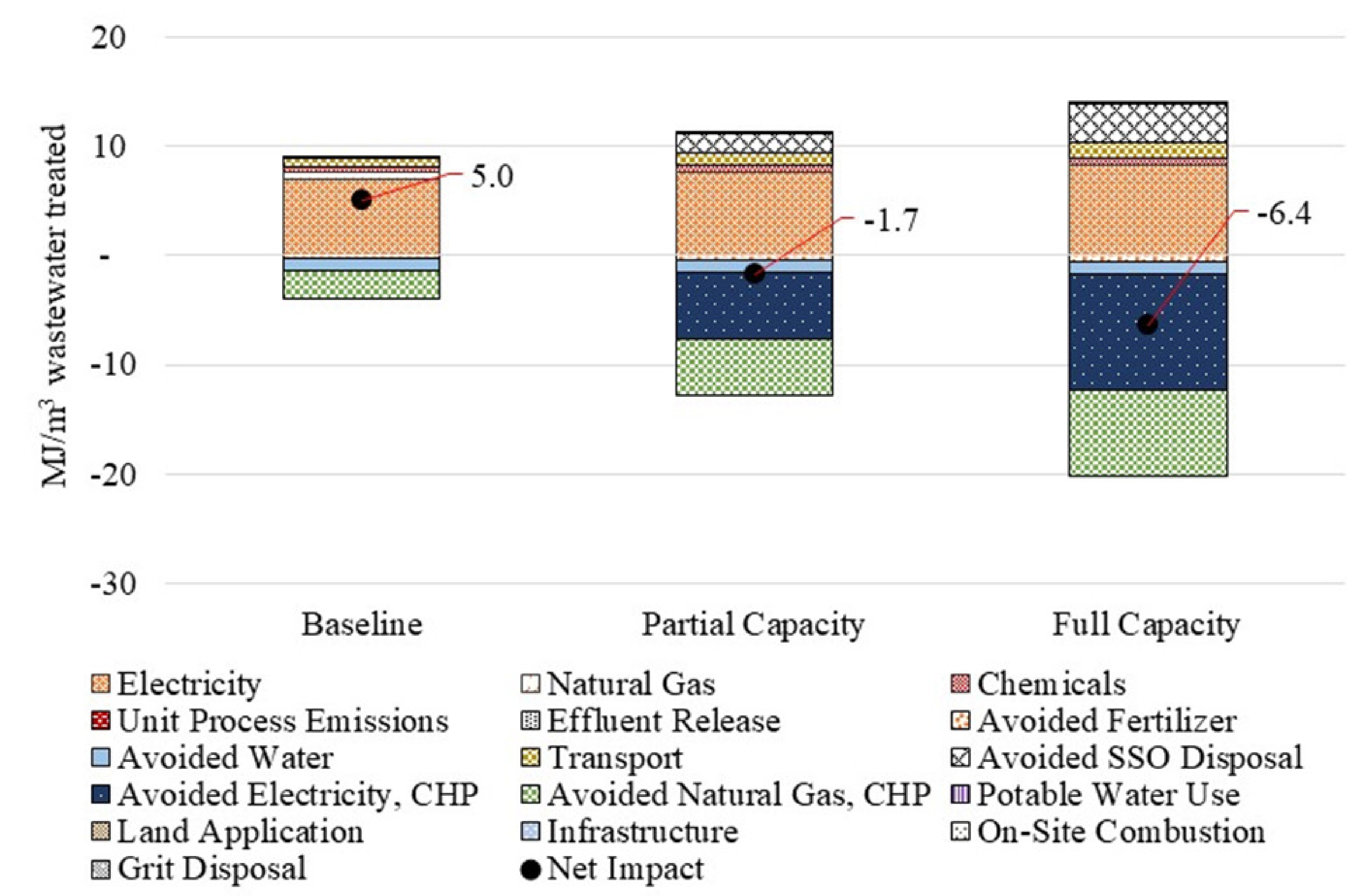
[3] personal communication with Lauren Fillmore

AD Performance Scenarios

Description	Base AD Performance			Low AD Performance		Unit
	Base	Partial Capacity	Full Capacity	Partial Capacity	Full Capacity	
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]*

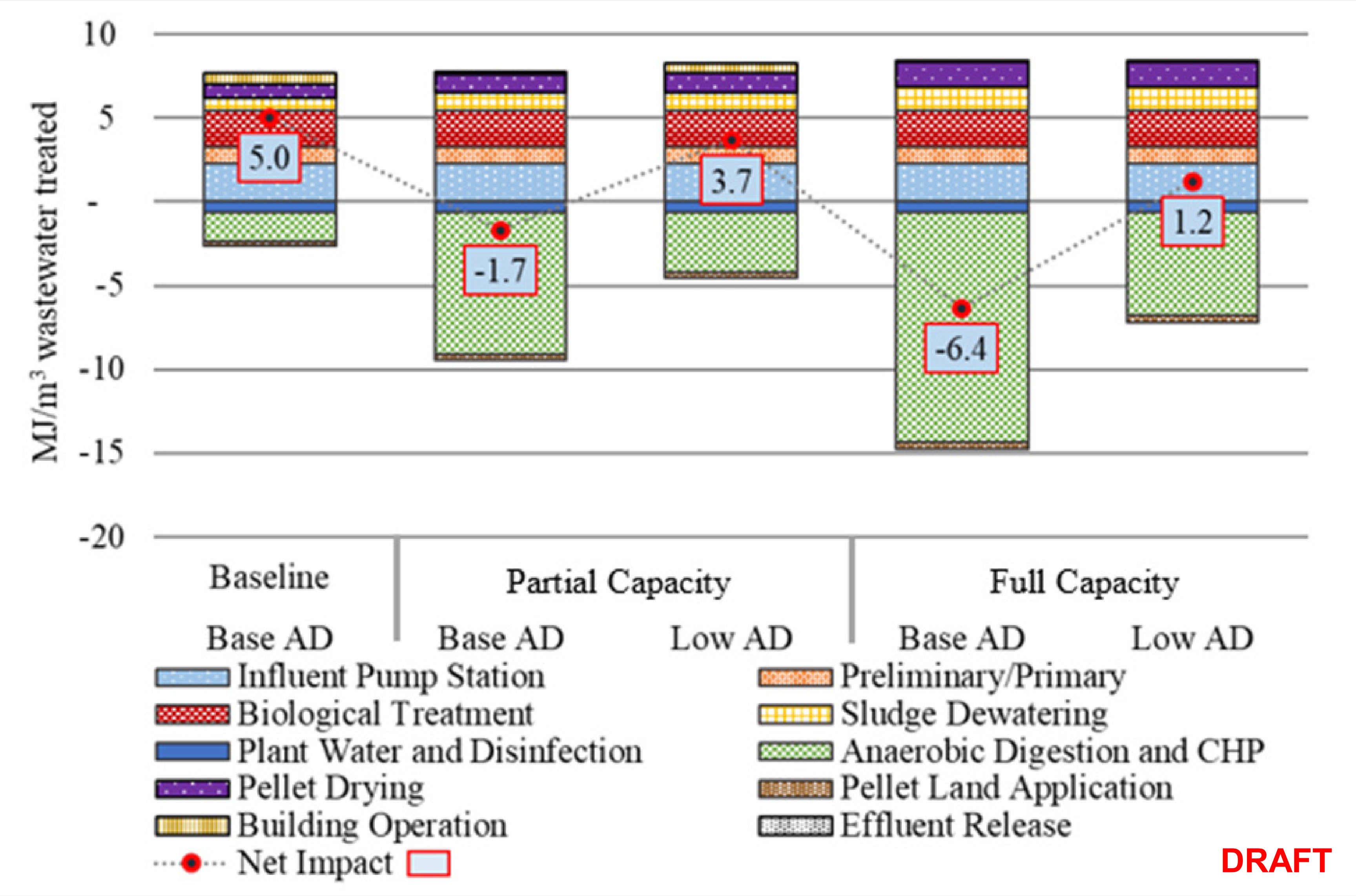
Cumulative Energy Demand
(Base AD Results by Process Category)



DRAFT

Cumulative Energy Demand

(Base AD Results by Treatment Group)



DRAFT

United States Environmental Protection Agency

Energy Production vs. Use

Energy Indicator	Base	Partial Capacity	Full Capacity	Units
Biogas energy recovery[1]	78%	81%	71%	of produced biogas energy
Electricity demand satisfaction	-	80%	100%[2]	of total facility demand
Heat demand satisfaction	79%	100%	100%	

[1] Includes energy loss associated with fugitive biogas/methane.

[2] The facility produces approximately 6.1 GWh of excess electricity annually.

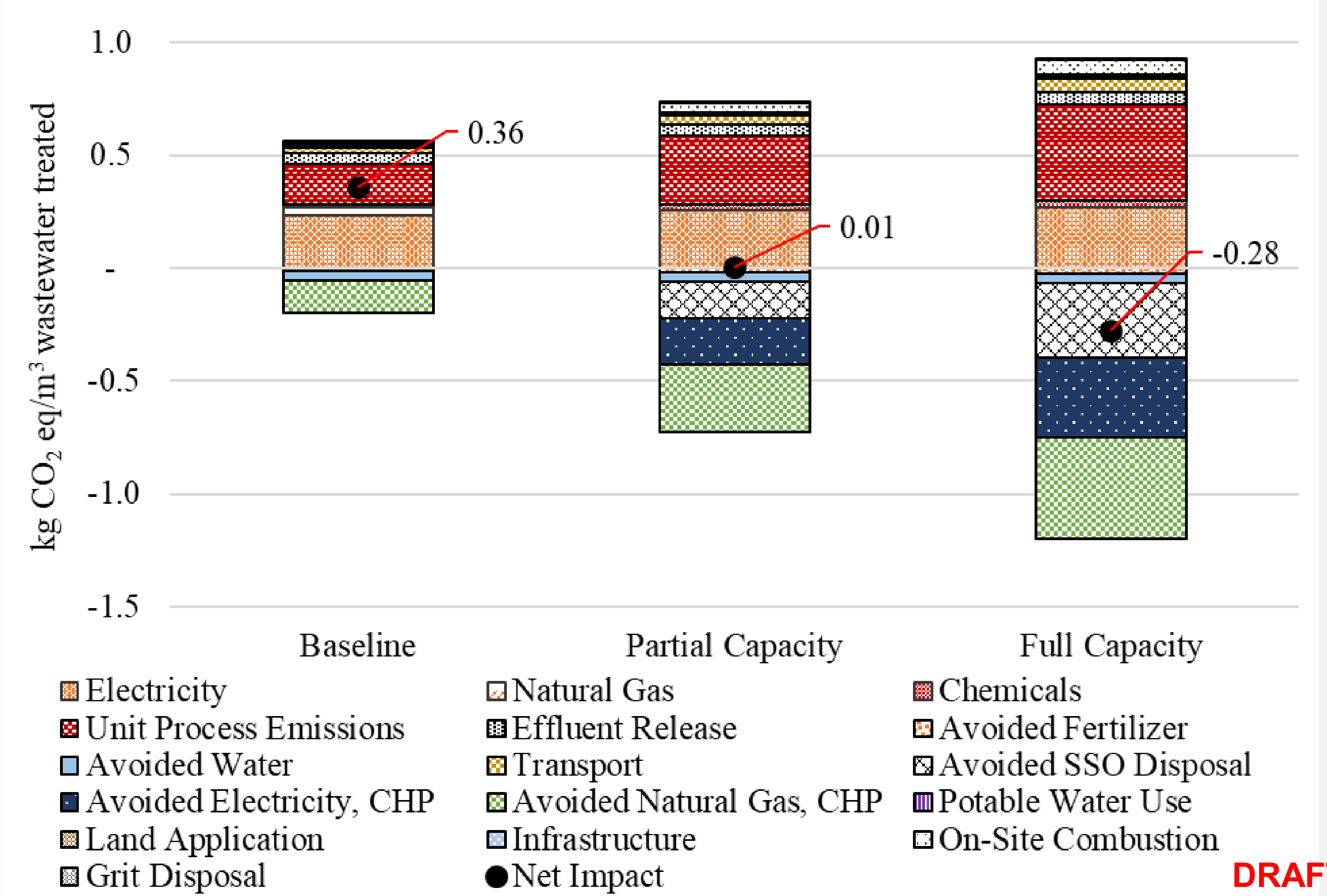
DRAFT

United States Environmental Protection Agency

CED Take-Away Message

- Full Capacity-Base AD scenario makes the facility a net energy producer.
- Avoided electricity production is the largest contributor to reduced energy demand.
- Avoided SSO disposal leads to increased CED.

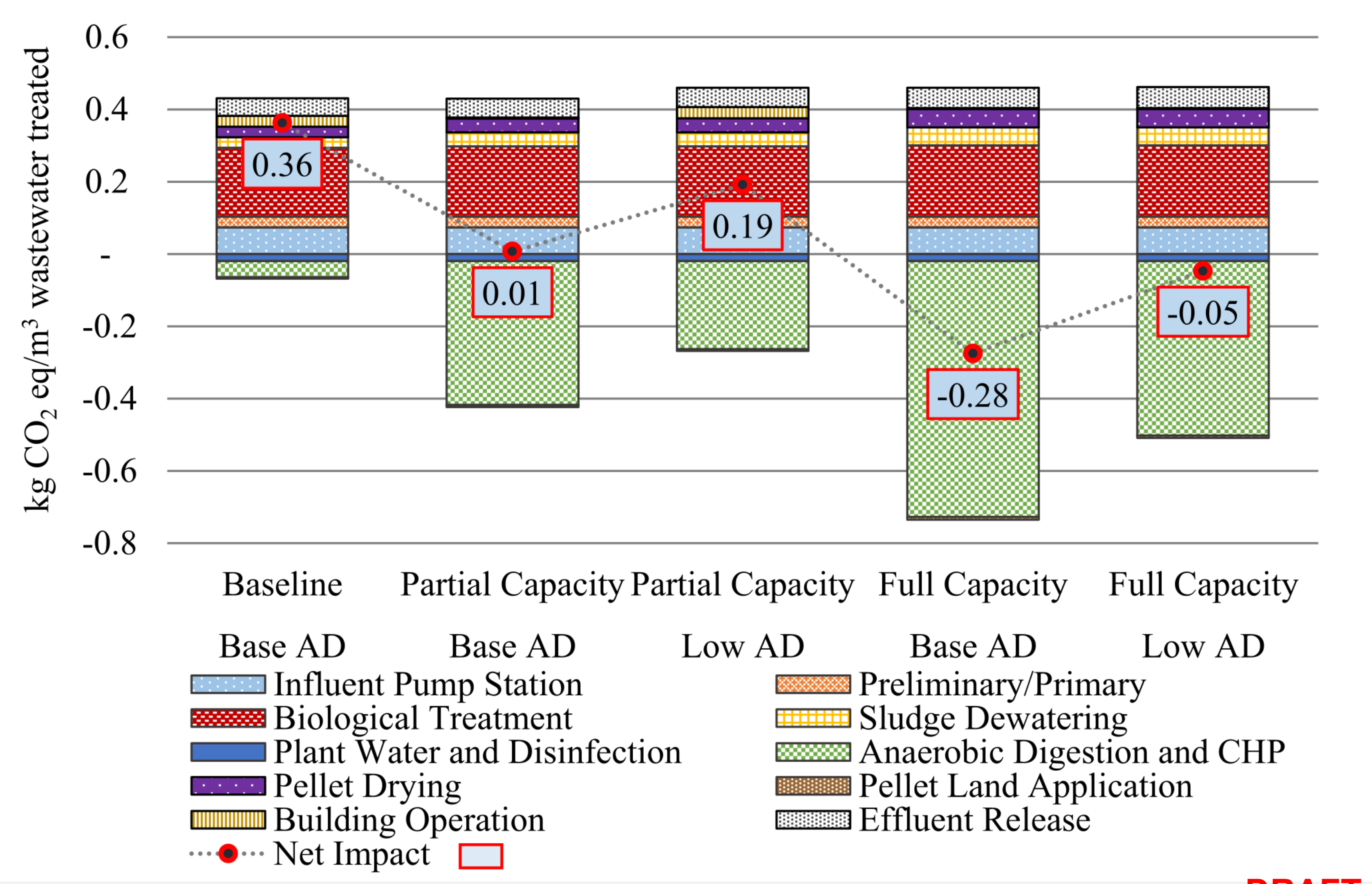
Global Climate Change Potential
(Base AD Results by Process Category)



DRAFT

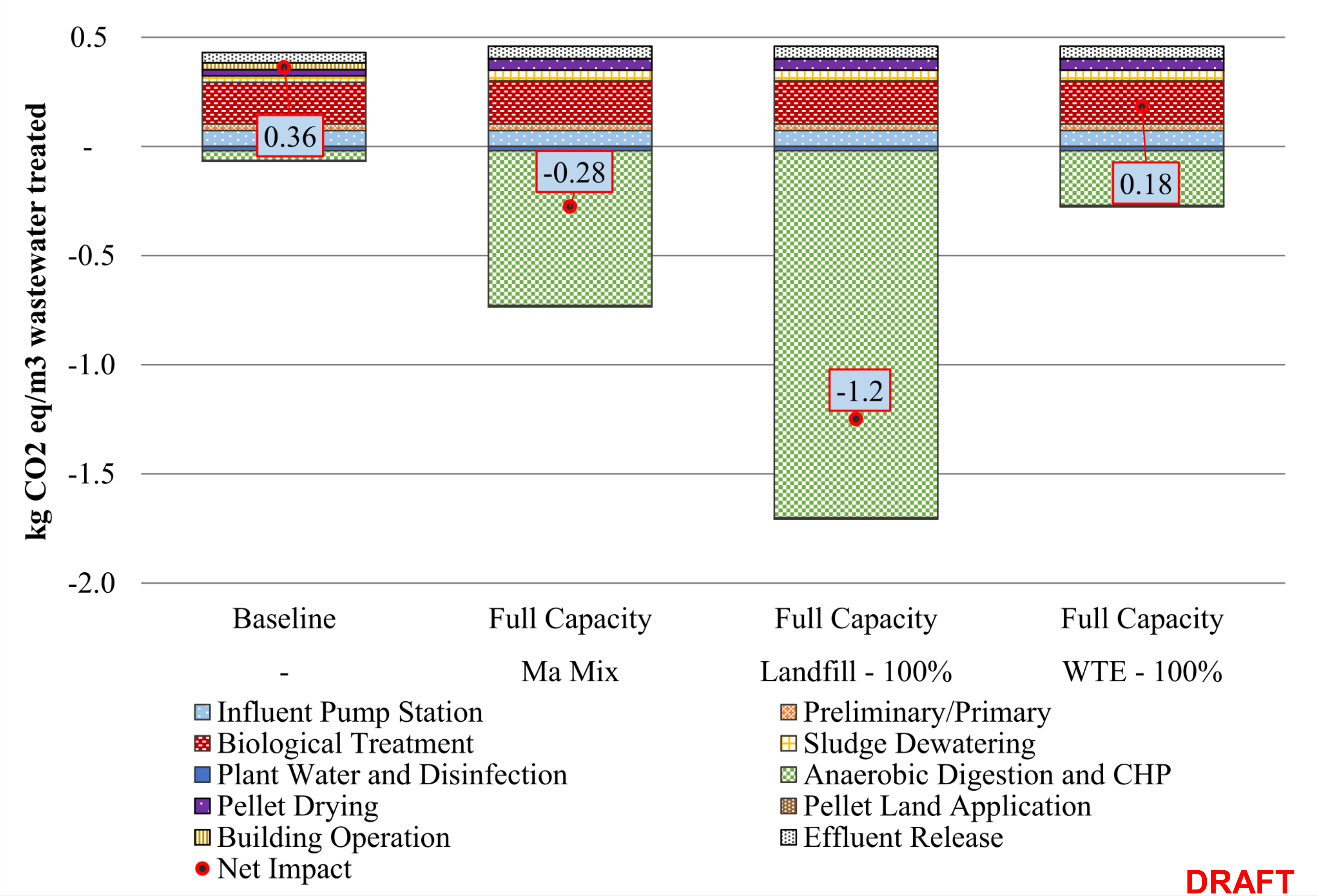
Global Climate Change Potential

(by Treatment Group)



DRAFT

Avoided EOL Process Sensitivity

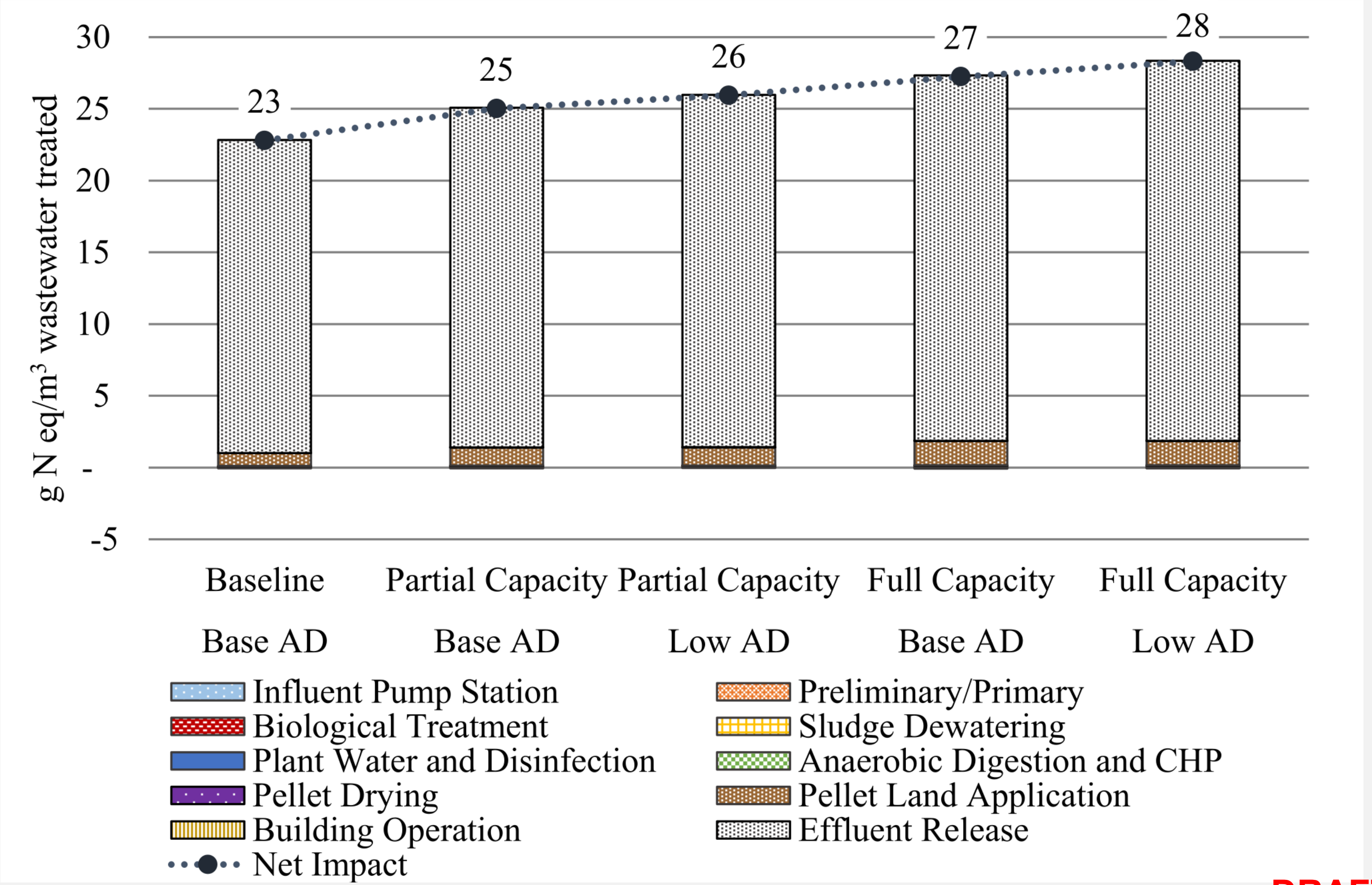


DRAFT

Climate Change Take-Away Message

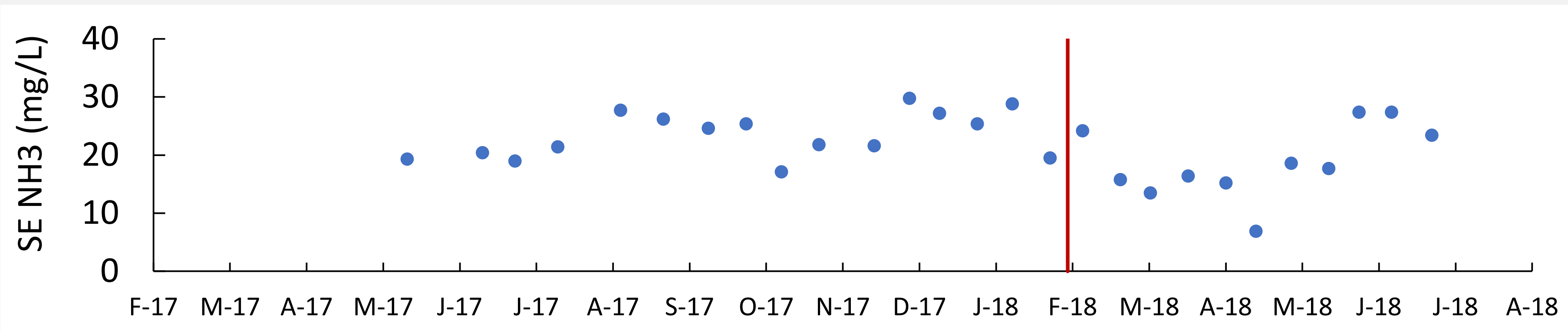
- Clear GCCP benefit from acceptance of SSO.
  - Particularly compared to landfill disposal.
- Diverting food waste from WTE production yields a net reduction in GCCP impact, despite GCCP benefit associated with WTE combustion.
- Avoided natural gas and electricity consumption and EOL disposal all contribute considerably to reduced GCCP.

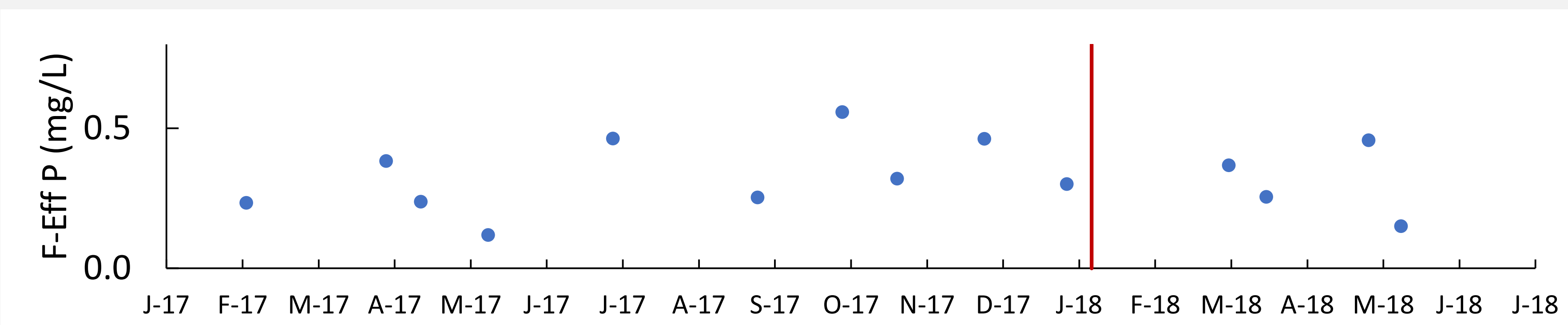
Eutrophication Results *(by Treatment Group)*



DRAFT

Analysis of Effluent Response to 20,000 gallons of SSO





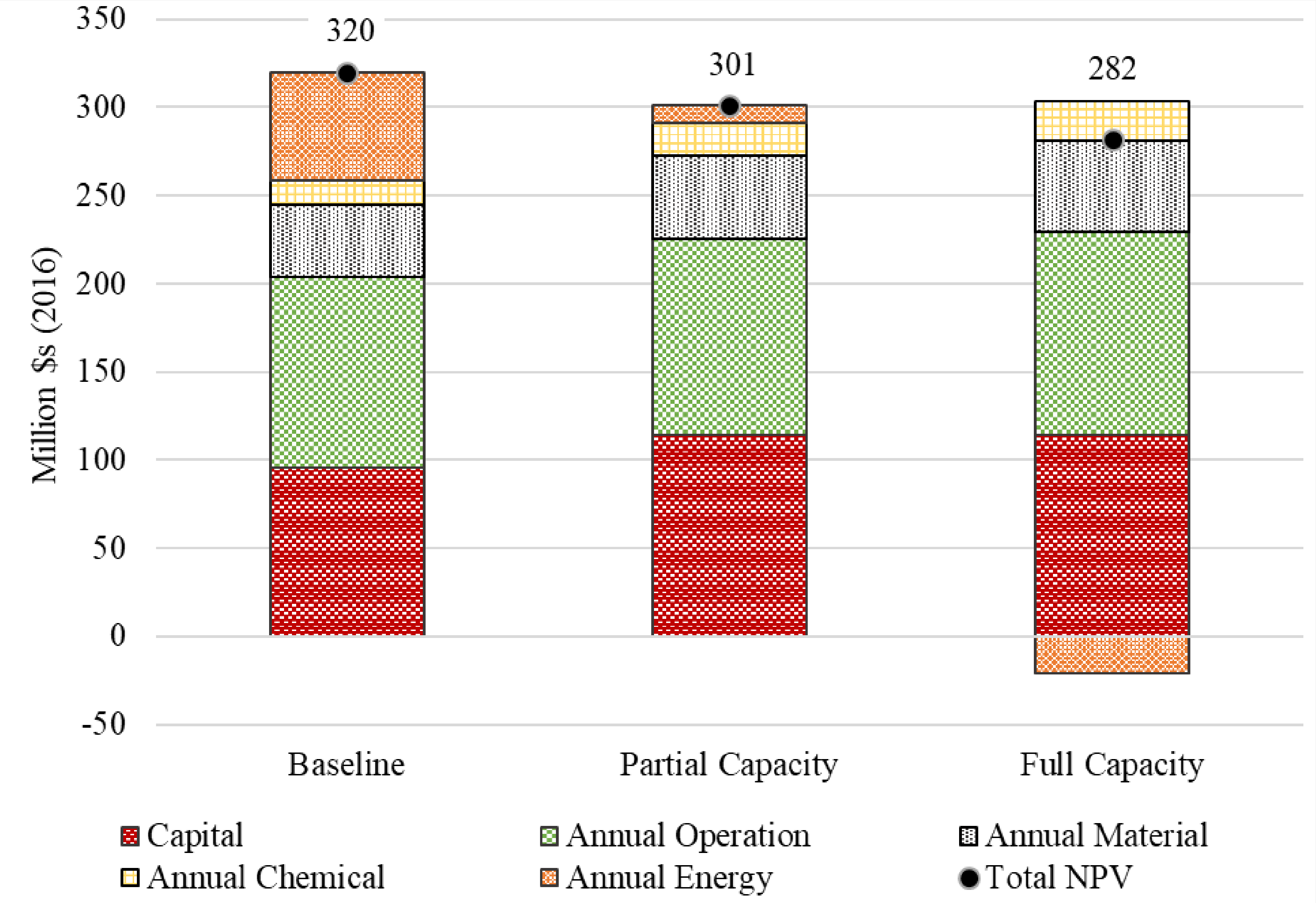
United States Environmental Protection Agency

Other Environmental Results

- AD expansion yields ***potential reductions in environmental impact*** for acidification (acid rain) potential and particulate matter formation potential (human health indicator).
- AD expansion yields ***potential environmental benefits*** in fossil fuel depletion, smog formation potential and water use.

Cost Analysis Results

- Indicate a 7 and 14 year payback period for the investment in AD and CHP systems for the full and partial capacity scenarios.



DRAFT

So, does it make sense?

- Yes, if steps are taken to control effluent nutrient concentrations.
  - Model appears conservative based on available effluent data.
- Yes, water resource recovery facility can be a net energy producer.
- Anaerobic co-digestion leads to reduced, plant GCCP and CED.
  - Trend is always towards decreasing impact as co-digestion increases.
  - Magnitude of decrease is sensitive to avoided treatment processes and AD performance
- Life cycle cost analysis indicates reasonable payback period at this scale.

United States Environmental Protection Agency

Disclaimer

This research was part of the U.S. Environmental Protection Agency (U.S. EPA) Office of Research and Development's Safe and Sustainable Water Resources (SSWR) Program. The research was supported by U.S. EPA contract EP-C-16-0015 to Eastern Research Group, Inc. Although the information in this document has been funded by the U.S. EPA, it does not necessarily reflect the views of the Agency and no official endorsement should be inferred.

United States Environmental Protection Agency

Contact

Ben Morelli

ben.morelli@erg.com

Sarah Cashman

sarah.cashman@erg.com

Cissy Ma

ma.cissy@epa.gov

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