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Comparative Life Cycle Assessment and Cost Analysis of Bath Wastewater Treatment Plant Upgrades

Ben Morelli [1], Sarah Cashman [1], **Xin (Cissy) Ma [2,*]**, Jay Garland [3], Jason Turgeon [4], Lauren Fillmore [5], Diana Bless [2] Michael Nye [3]

[1] Eastern Research Group
[2] United States Environmental Protection Agency, National Risk Management Research Laboratory
[3] United States Environmental Protection Agency, National Exposure Research Laboratory
[4] United States Environmental Protection Agency, Region 1
[5] Water Environment & Reuse Foundation

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A system is more than the sum of its parts.

- Aristotle (384-322 BC)

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New concepts

- Fit for purpose
  - Water reuse
- Source separation and resource recovery
  - Nutrient recovery
  - Energy recovery
- Decentralization

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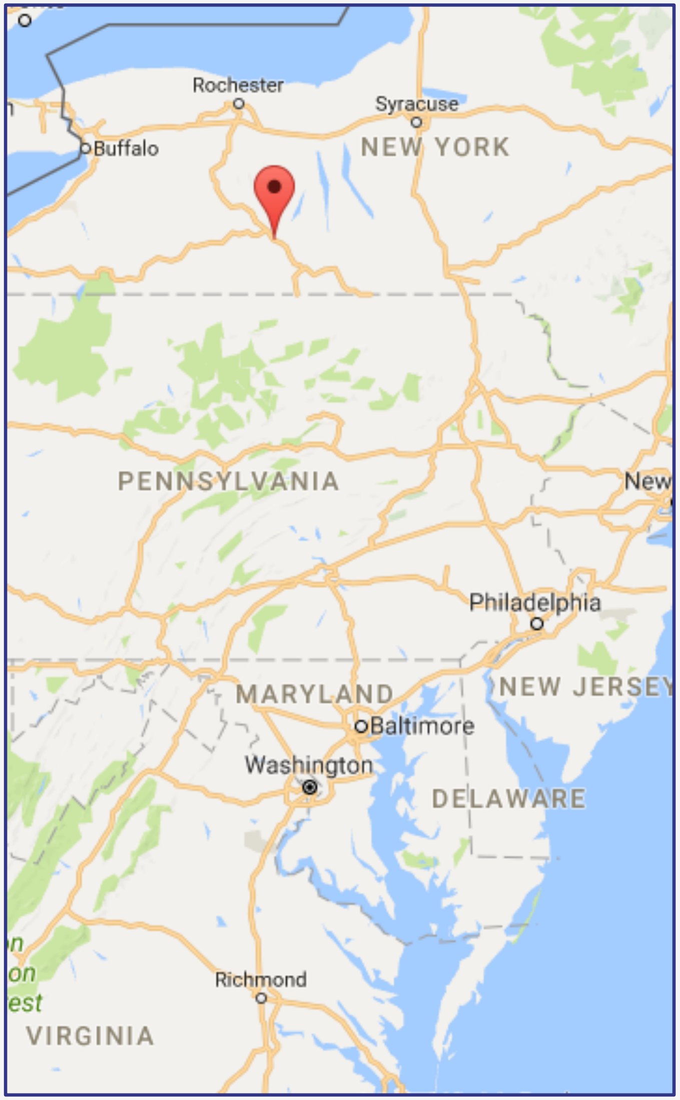
Environmental Life Cycle Assessment and Cost Analysis of Bath, NY Wastewater Treatment Plant:

Potential Upgrade Implications

Office of Research and Development
Washington, D.C.

Bath NY Community & Wastewater Treatment

- <u>Population</u>: 5,600
- <u>Flow Capacity</u>: 1 MGD
- <u>Legacy WWTP</u>: CAS
- <u>Upgraded WWTP</u>: MLE biological treatment



MGD – Million gallons per day
WWTP – Wastewater Treatment Plant
CAS – Conventional Activated Sludge
MLE – Modified Ludzack-Ettinger

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Bath NY Community & Wastewater Treatment

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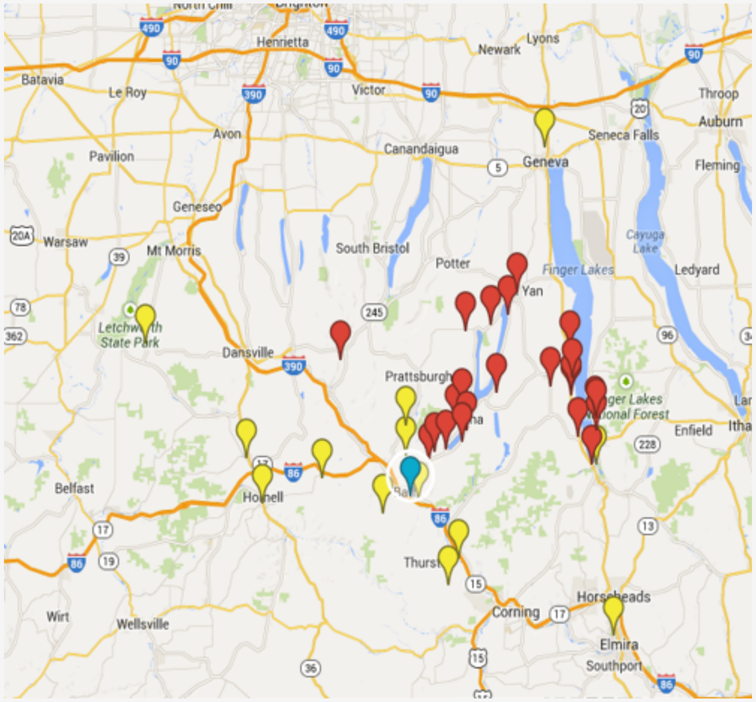

– *Bath wwtp*

– *Food manufacturers*

– *Beverage manufacturers*

MGD – Million gallons per day
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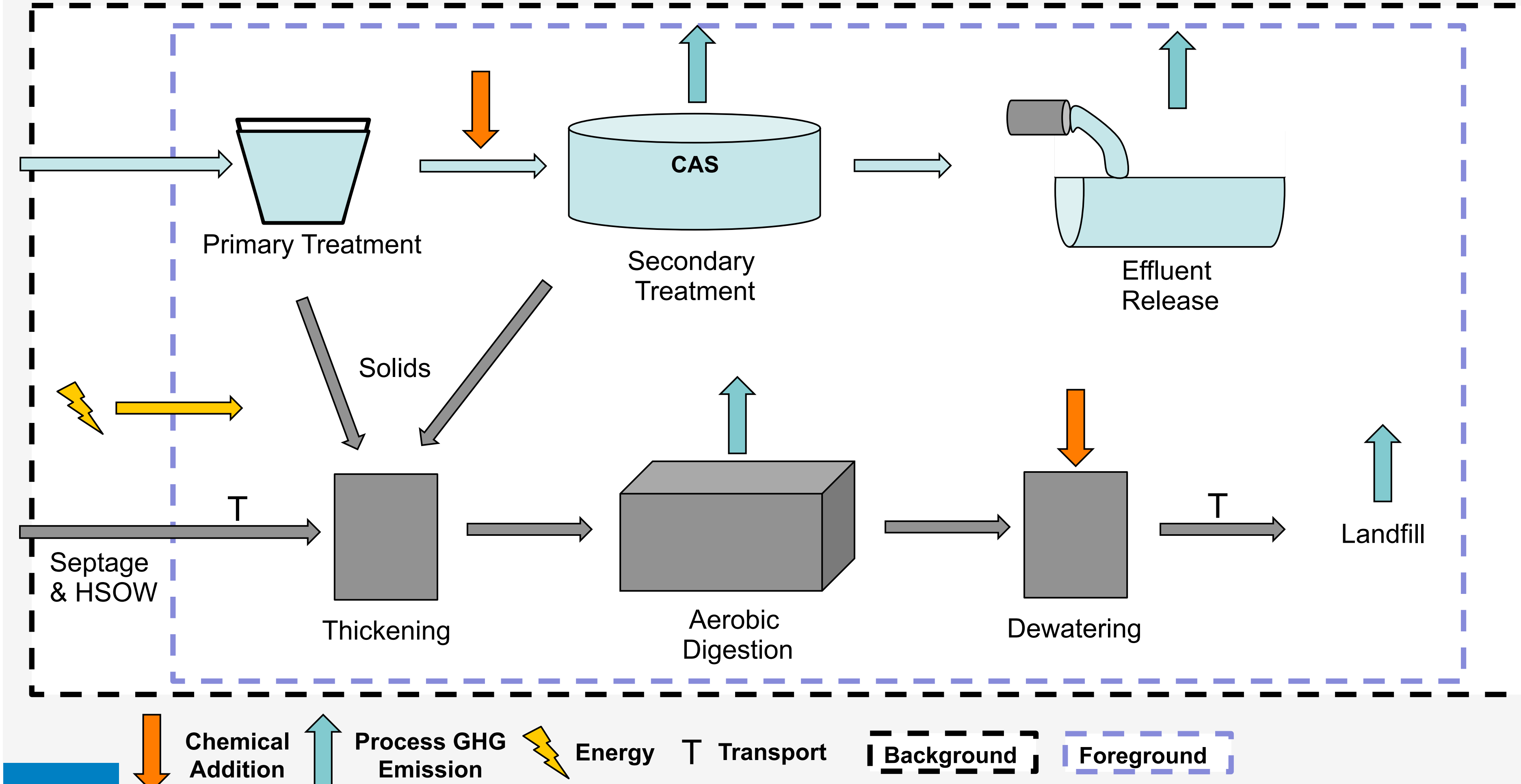
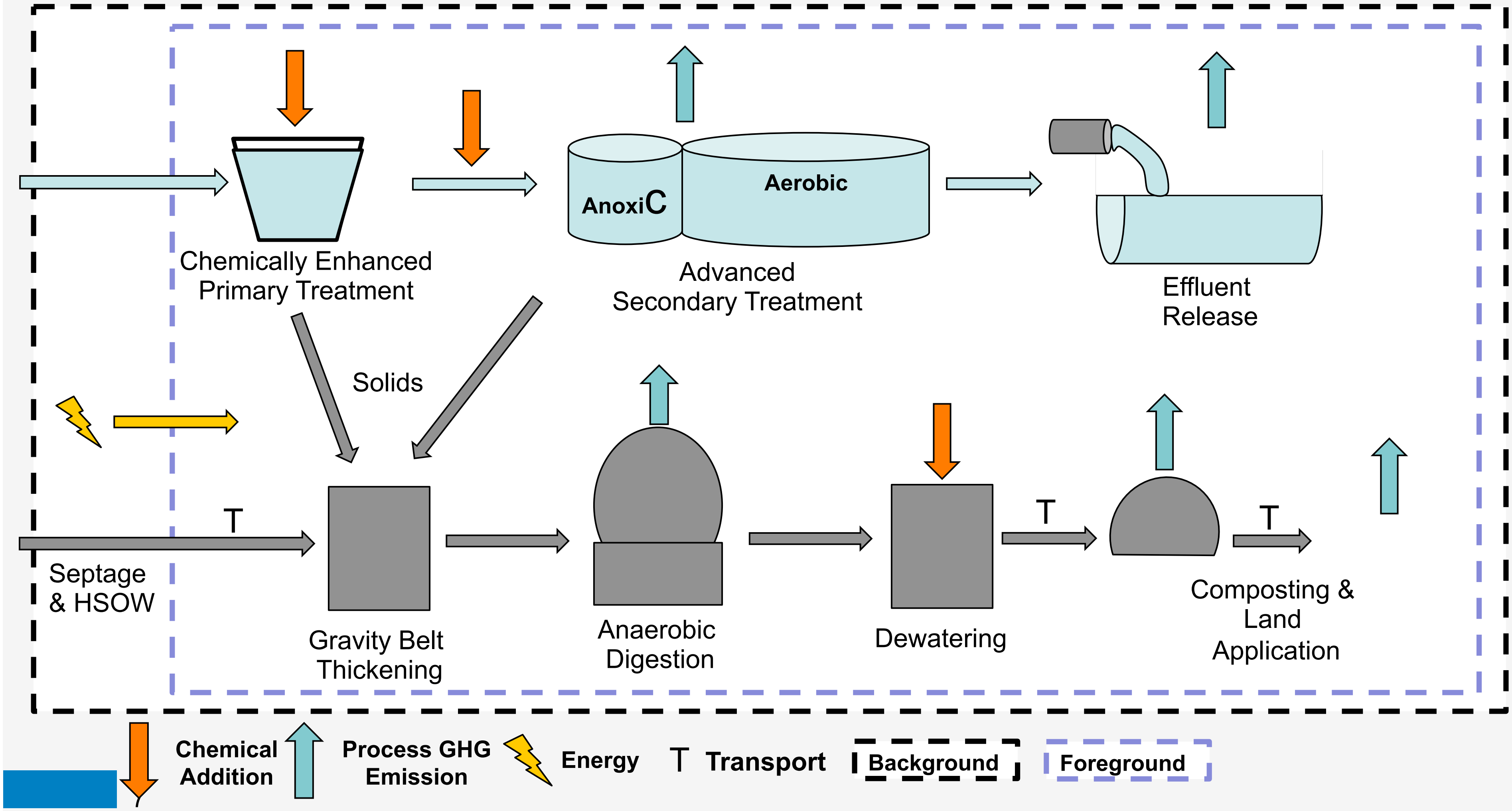
Legacy System Diagram

Plant Infrastructure Disposal, Sewer Maintenance, Electrical and Mechanical System Material



Upgraded System Diagram

Plant Infrastructure Disposal, Sewer Maintenance, Electrical and Mechanical System Material



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Bath NY Community & Wastewater

- Comparative analysis of legacy and upgraded WWTPs
- Energy recovery potential and avoided product benefits of Anaerobic Digestion (AD) and land application of compost
  - *Effect of adding High Strength Organic Waste (HSOW)*
- Calculate life cycle costs of upgraded system

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Influent & Effluent Characteristics

Characteristic	Influent	Effluent	
		Legacy	Upgraded
	(mg/L)		
Suspended Solids	437	7.9	5
Biological Oxygen Demand	323	8.5	2.3
Total Kjeldahl Nitrogen	56	16	4.4
Ammonia	32	6.7	3.6
Total Phosphorus	8	0.7	0.6
Nitrite	<1	2.8	0.8
Nitrate	<1	13	14
Organic Nitrogen	29	9	0.8
Total Nitrogen	61	31	20

** SPDES – State Pollutant Discharge Elimination System*

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Select LCI Calculations

- Electricity: calculated using a record of equipment use, horsepower, and run time
- Chemicals: via provided dosage rates
- Process GHGs
  - N_2O: based on TKN influent to secondary (Chandran 2012)
  - Methane: based on BOD influent to secondary (IPCC 2006)
    - Assigns methane correction factor for specific treatment units (Legacy – Czepiel 1993, Upgraded – Daelman et al. 2013)

Select LCI Calculations continued…

- Biogas Production (Upgraded Plant)
  - Based on Volatile Solids (VS) destruction assumption (ft^3/day)
- Landfill Emissions (Legacy Plant)
  - Regional and national average gas capture performance
  - Degradation via a first-order decay model
- Composting Emissions (Upgraded Plant)
  - Methane (0.11%, 0.82%, 2.5% of C)
  - Nitrous Oxide (0.34%, 2.68%, 4.65% of N)
  - Ammonia (1.2%, 6.7%, 12.74% of N)
  - Carbon Monoxide (0.04% of C)

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Life Cycle Costing

Total Costs = Σ (Annual Costs) + Σ (Amortized Capital Costs)

Total Capital Costs = Purchased Equipment Costs + Direct Costs + Indirect Costs

Total Annual Costs = Operation Costs + Replacement Labor Costs + Materials Costs + Chemical Costs + Energy Costs

Net Present Value $= \Sigma(Cost_x/(1+i)^x)$

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Anaerobic Digestion – Feedstock Scenarios

- 3 feedstock scenarios analyzed to determine variation in environmental and cost performance (300,000 gal tanks)

Waste Type	Base (gal/day)	Medium (gal/day)	High (gal/day)
Primary Sludge	17,654	17,654	17,654
Waste Activated Sludge	75,557	75,557	75,557
Septic Waste	14,000	14,000	14,000
Slaughterhouse Waste	-	1,000	4,000
Cheese Waste	-	2,000	3,000
Winery Waste	-	1,000	1,000
Portable Toilet Waste	2,000	2,000	2,000
Loading (lb VS/1000 ft^3/day)	130	158	205

Anaerobic Digestion – Performance Scenarios

		Low Yield	Base Yield	High Yield	
Parameter Name		Value	Value	Value	Units
Percent Volatile Solids Reduction		40	50	60	%
Biogas Yield	Base	12.0	15.0	24.5	ft^3/lb VS destroyed
	Medium	13.8	18.5	25.1	ft^3/lb VS destroyed
	High	15.7	22.2	27.3	ft^3/lb VS destroyed
Methane Content of Biogas		55	60	65	% w/w
Biogas Heat Content (MJ/ft^3)		0.59	0.64	0.68	MJ/ft^3
Electrical Efficiency		33	36	40	%
Thermal Efficiency		46	51	56	%
Reactor Heat Loss		Northern US	Northern US	Southern US	n.a.

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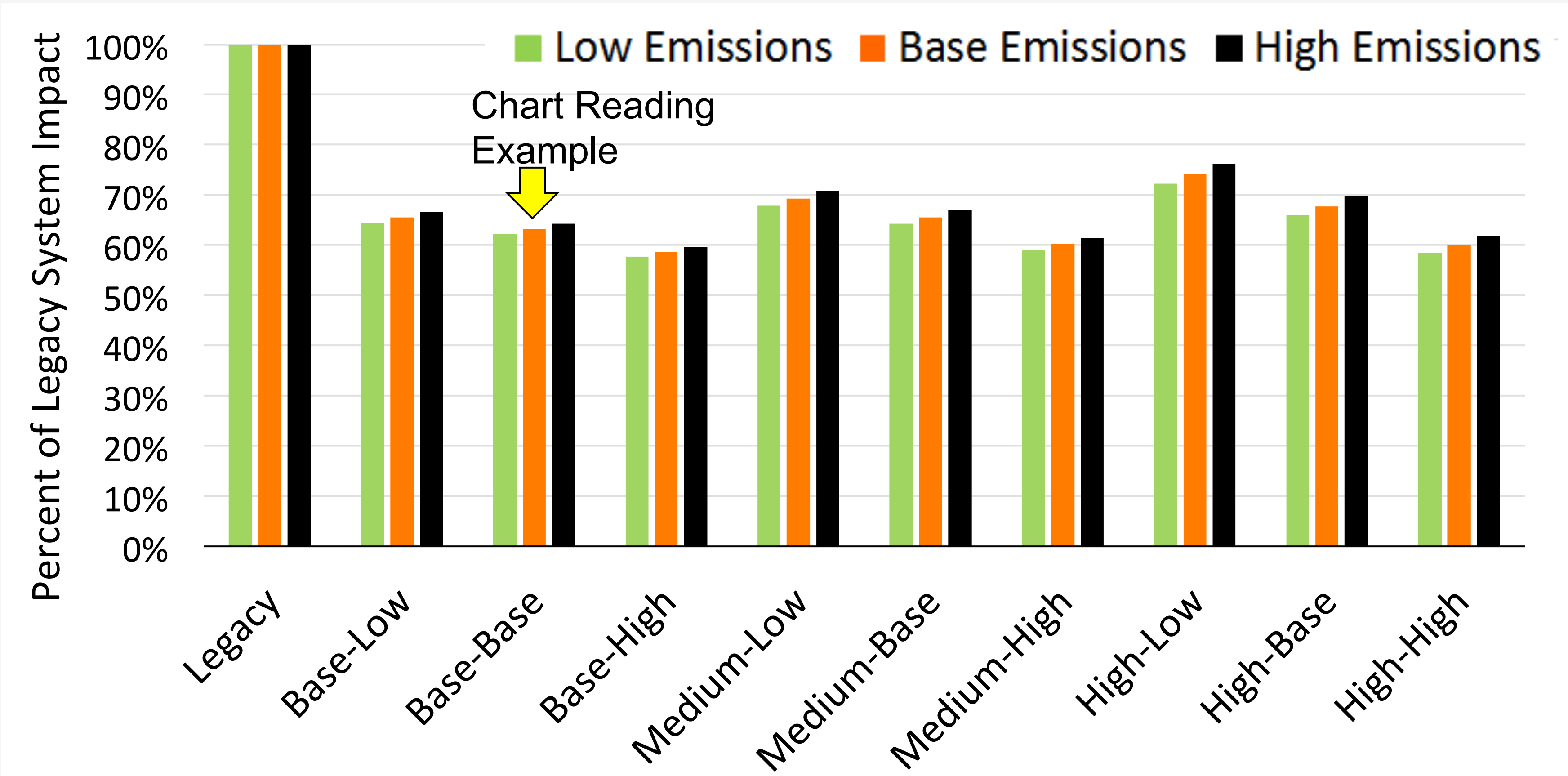
Compost Emission Scenarios

Emission Scenario	Emission Species	Element	Loss of Incoming Element to GHGs	Units
Low	CH_4	C	0.11%	incoming C lost as CH_4
Low	N_2O	N	0.34%	incoming N lost as N_2O
Base	CH_4	C	0.48%	incoming C lost as CH_4
Base	N_2O	N	2.68%	incoming N lost as N_2O
High	CH_4	C	1.70%	incoming C lost as CH_4
High	N_2O	N	4.65%	incoming N lost as N_2O

Eutrophication Scenarios

Percent of Legacy System Impact



Scenario Name: Feedstock – AD, i.e., base feedstock – base AD performance

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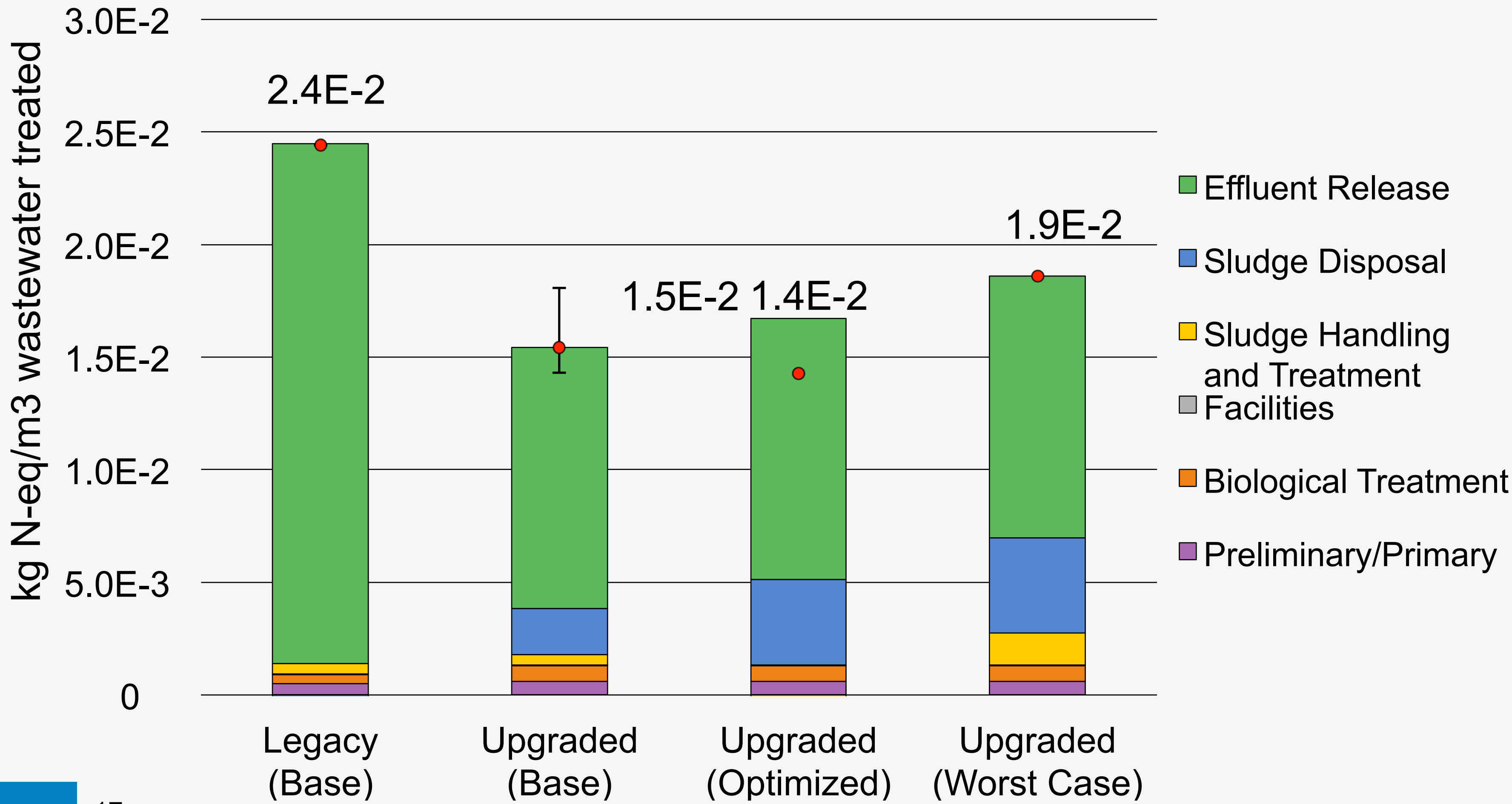
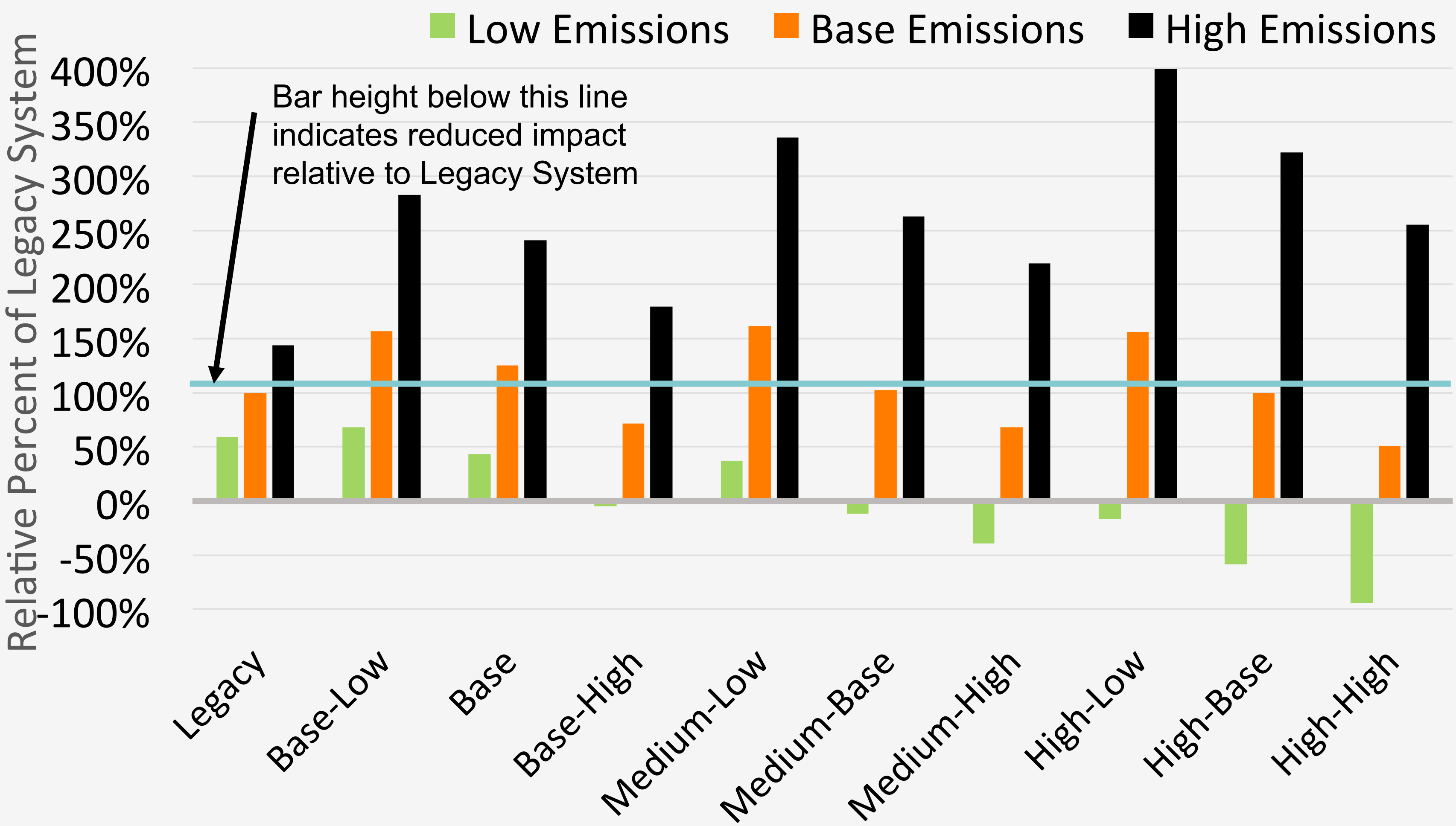
Eutrophication Potential

Process Contribution



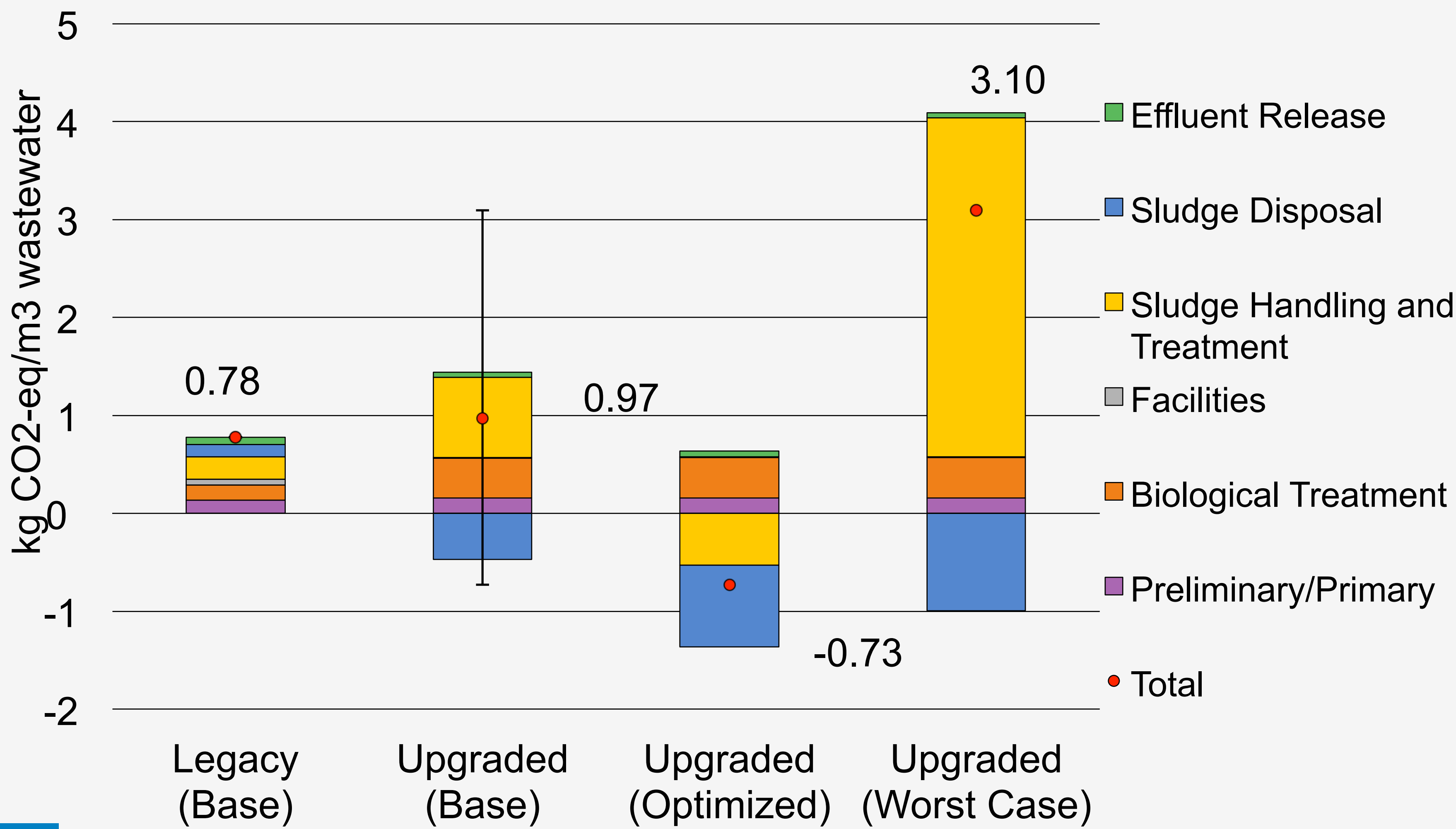
Global Climate Change Potential Scenarios



Scenario Name: Feedstock - AD

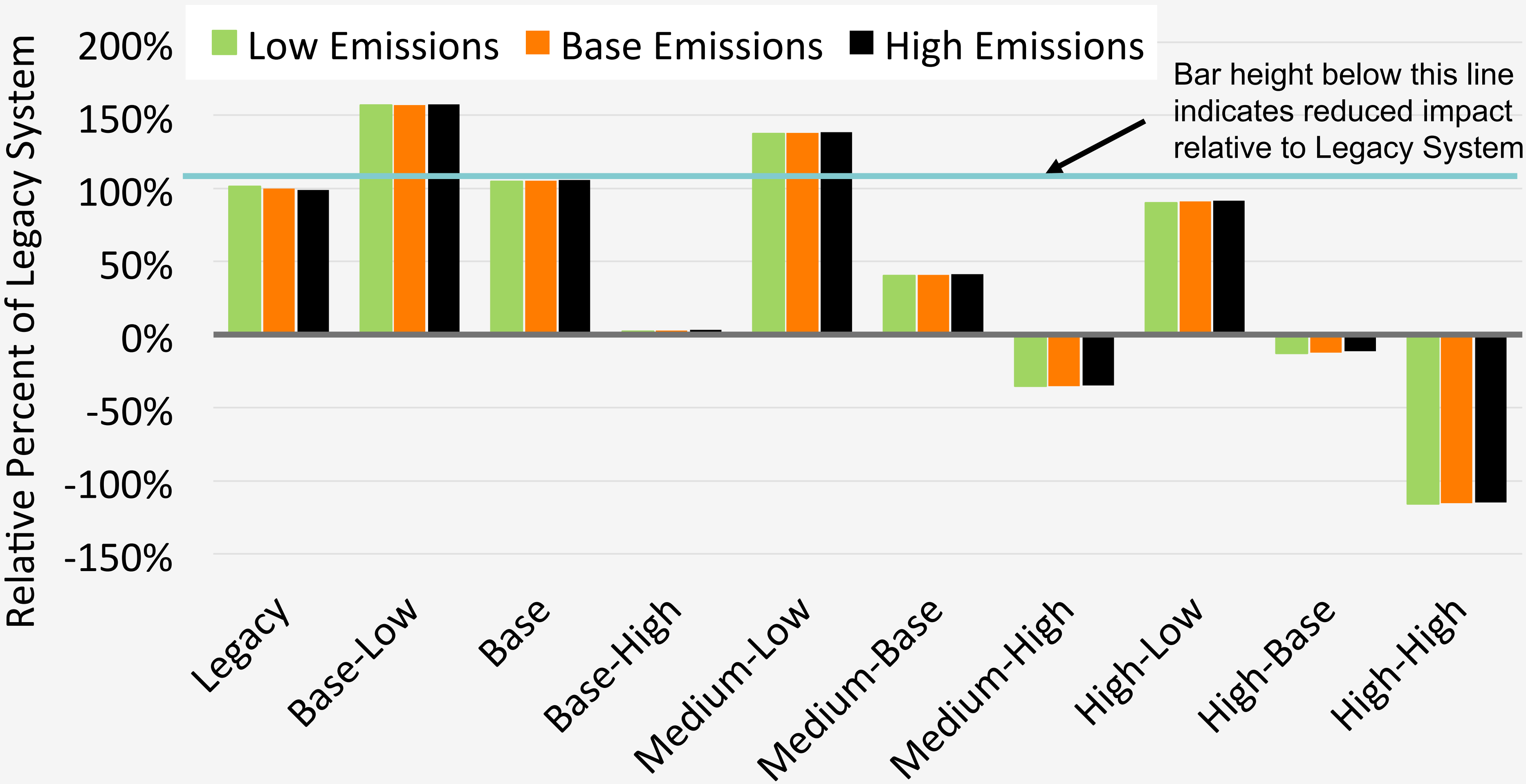
Global Climate Change Potential

Process Contribution



Cumulative Energy Demand Scenarios

Percent of Legacy System Impact



Scenario Name: Feedstock - AD

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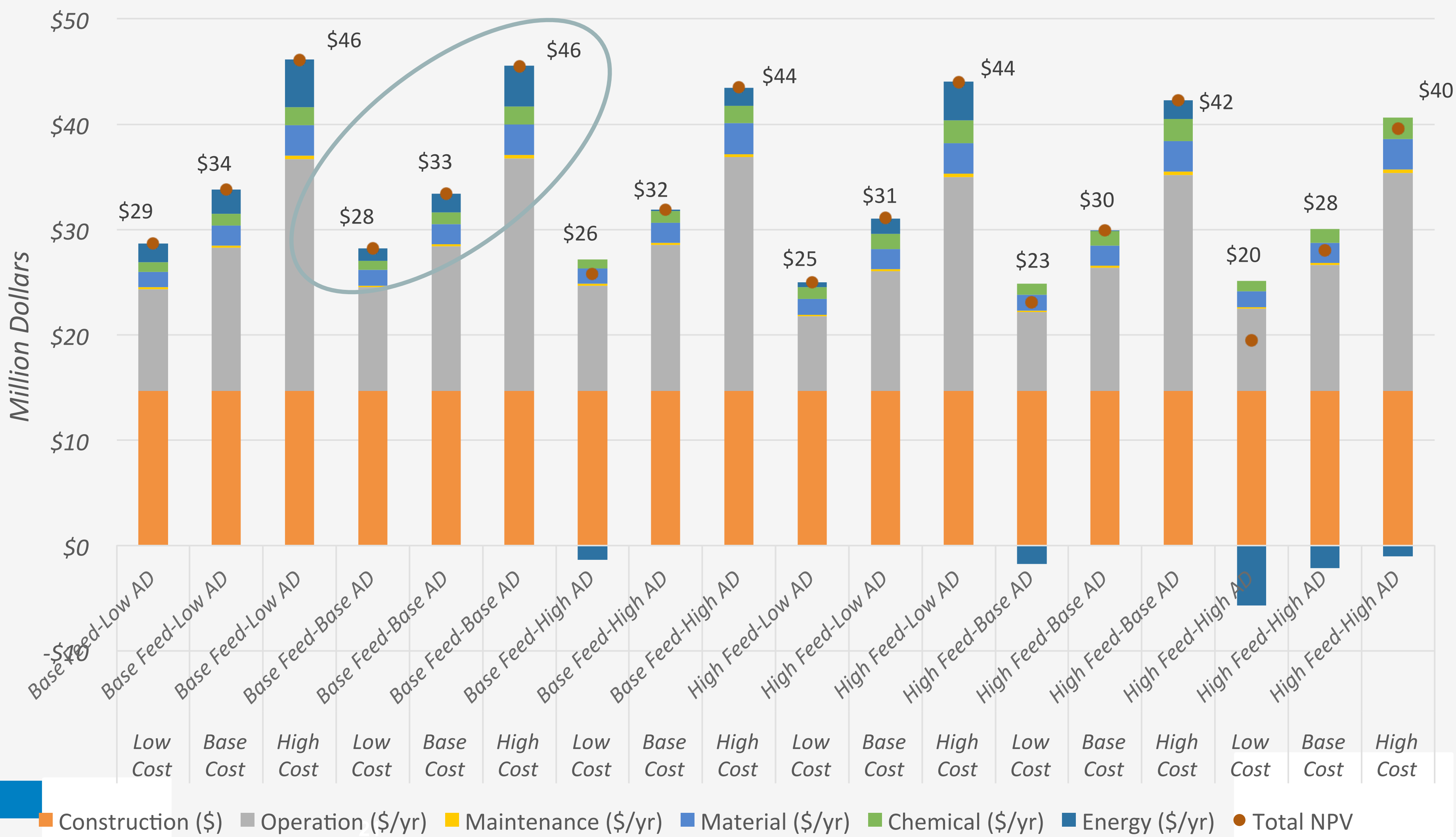
Cost Analysis

Upgraded System



AD and Compost Payback

- Difficult to achieve with low acceptance of high strength organic waste.

Scenario (Feedstock Scenario-Anaerobic Digester Scenario)	Low Cost Scenario		Base Cost Scenario		High Cost Scenario	
	Anaerobic Digester	Composting Facility	Anaerobic Digester	Composting Facility	Anaerobic Digester	Composting Facility
Base Feed-Low AD	None	None	None	None	None	None
Base Feed-Base AD	None	None	None	None	None	None
Base Feed-High AD	72	None	None	None	None	None
Medium Feed-Low AD	None	39	None	None	None	None
Medium Feed-Base AD	271	82	None	None	None	None
Medium Feed-High AD	32	440	177	None	None	None
High Feed-Low AD	219	**11**	None	None	None	None
High Feed-Base AD	40	**13**	251	None	None	None
High Feed-High AD	**16**	**18**	41	None	45	None

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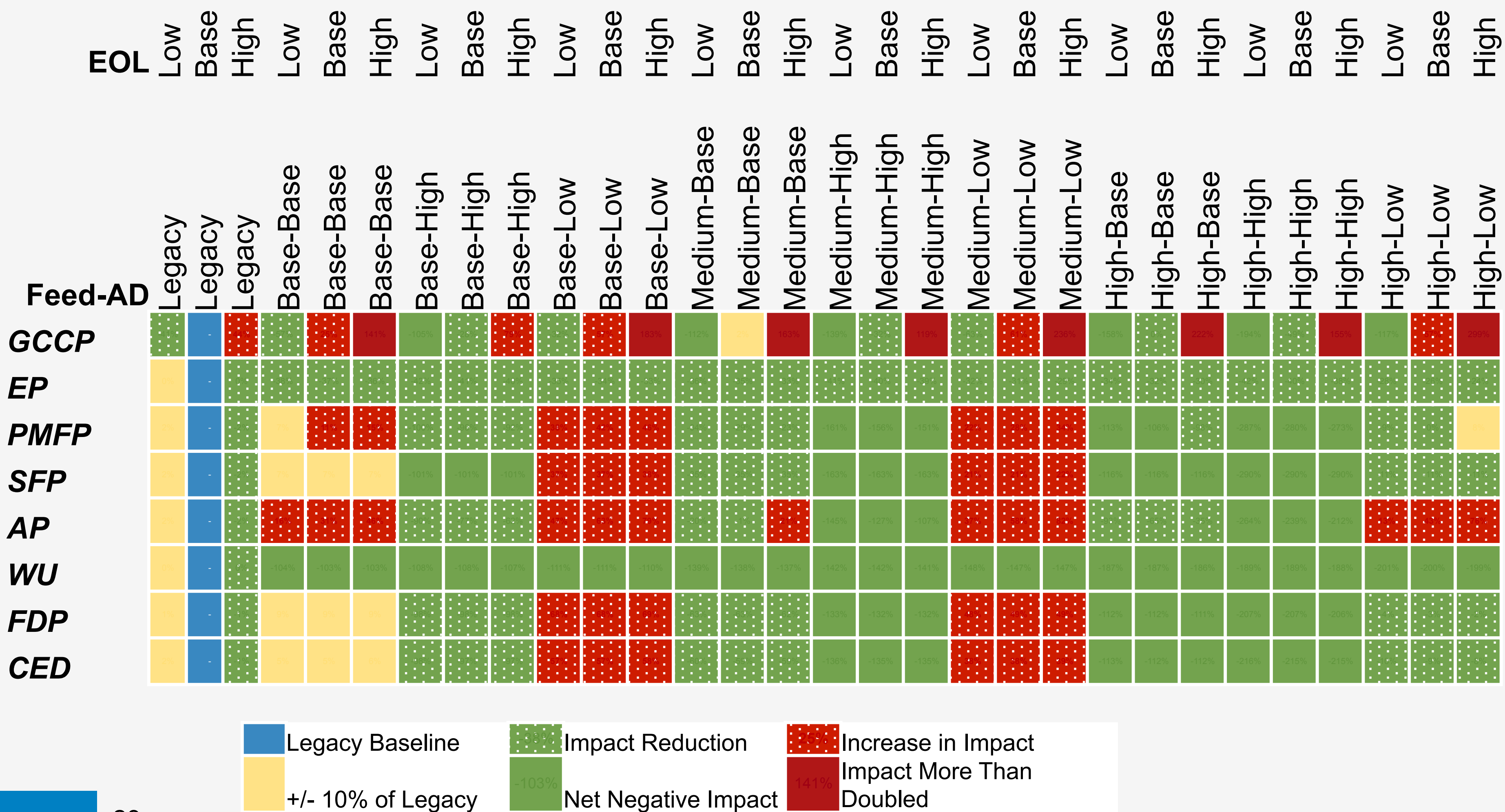
Summary of Relative Scenario Impacts



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Conclusions

- Clear Environmental Benefit of HSOW Acceptance
  - Maximize use of AD capacity
  - Low AD performance (avoidable), can lead to increases in environmental impact
- Benefit to Climate Change Potential depends strongly on composting system selection and management
- Simple payback of AD is challenging to achieve at small-scale, but the trend is towards decreasing cost
- Many impact categories positively influenced by avoided electricity and natural gas consumption
- Appropriate use of AD has the potential to reduce environmental impacts of achieving increased nutrient removal

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Contact Information

Xin (Cissy) Ma Ph.D, P.E.

Ma.cissy@epa.gov

Ben Morelli

ben.morelli@erg.com

Sarah Cashman

sarah.cashman@erg.com

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