

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

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A system is more than the sum of its parts.

– Aristotle (384-322 BC)

New concepts

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

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



Bath NY Community & Wastewater Treatment

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

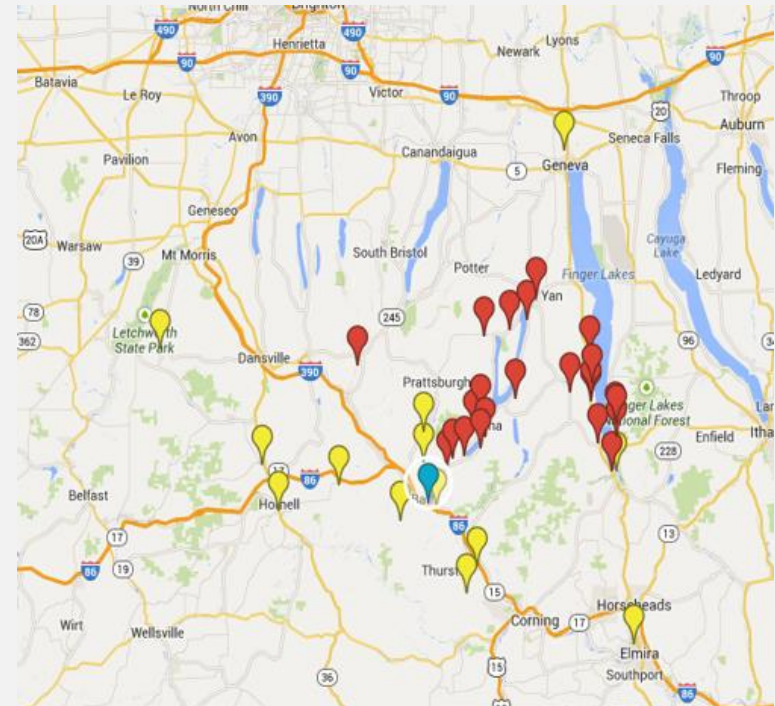
*MGD – Million gallons per day
WWTP – Wastewater Treatment Plant
CAS – Conventional Activated Sludge
MLE – Modified Ludzack-Ettinger*



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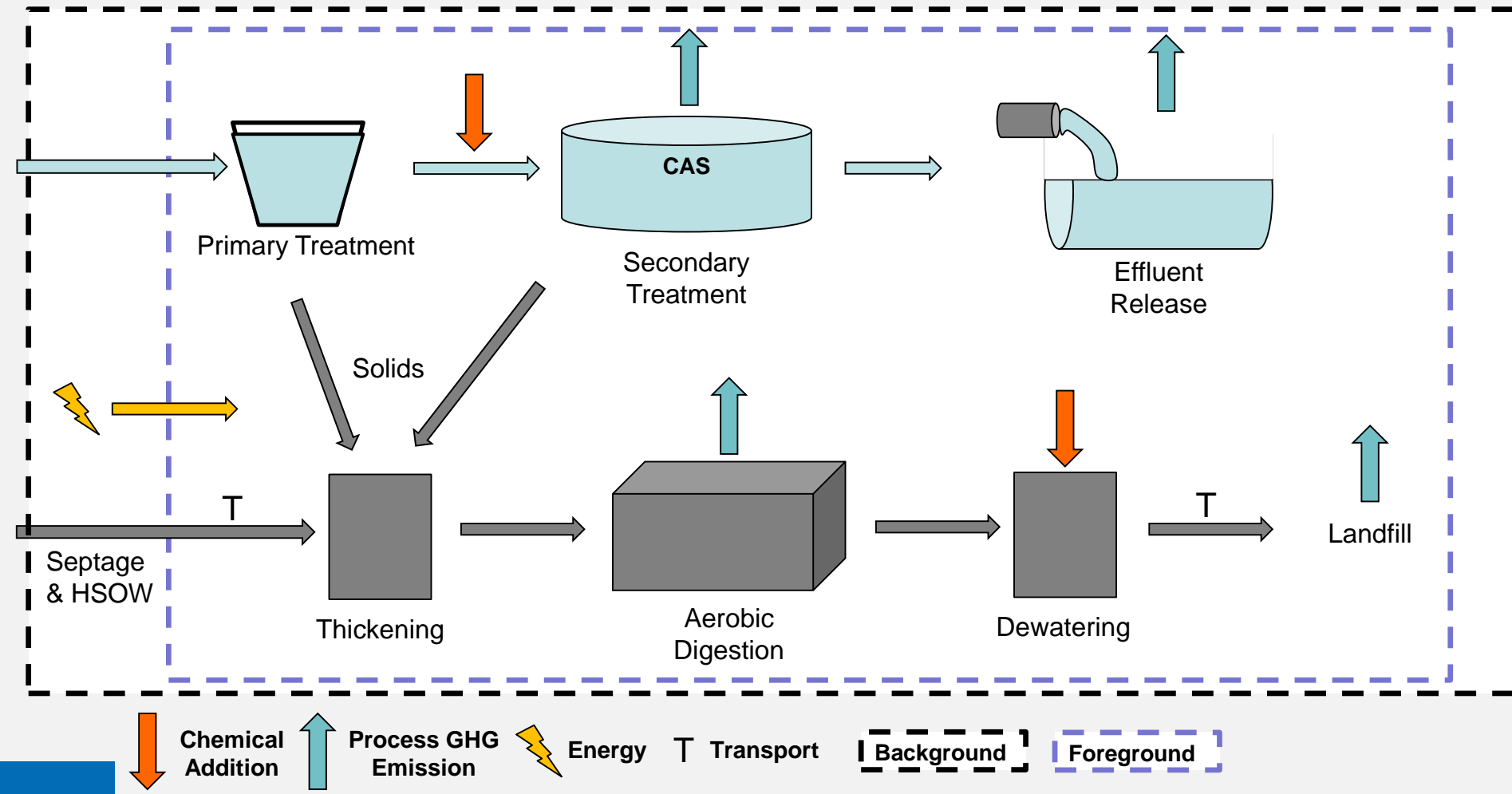
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- Bath wwtp
- Food manufacturers
- Beverage manufacturers

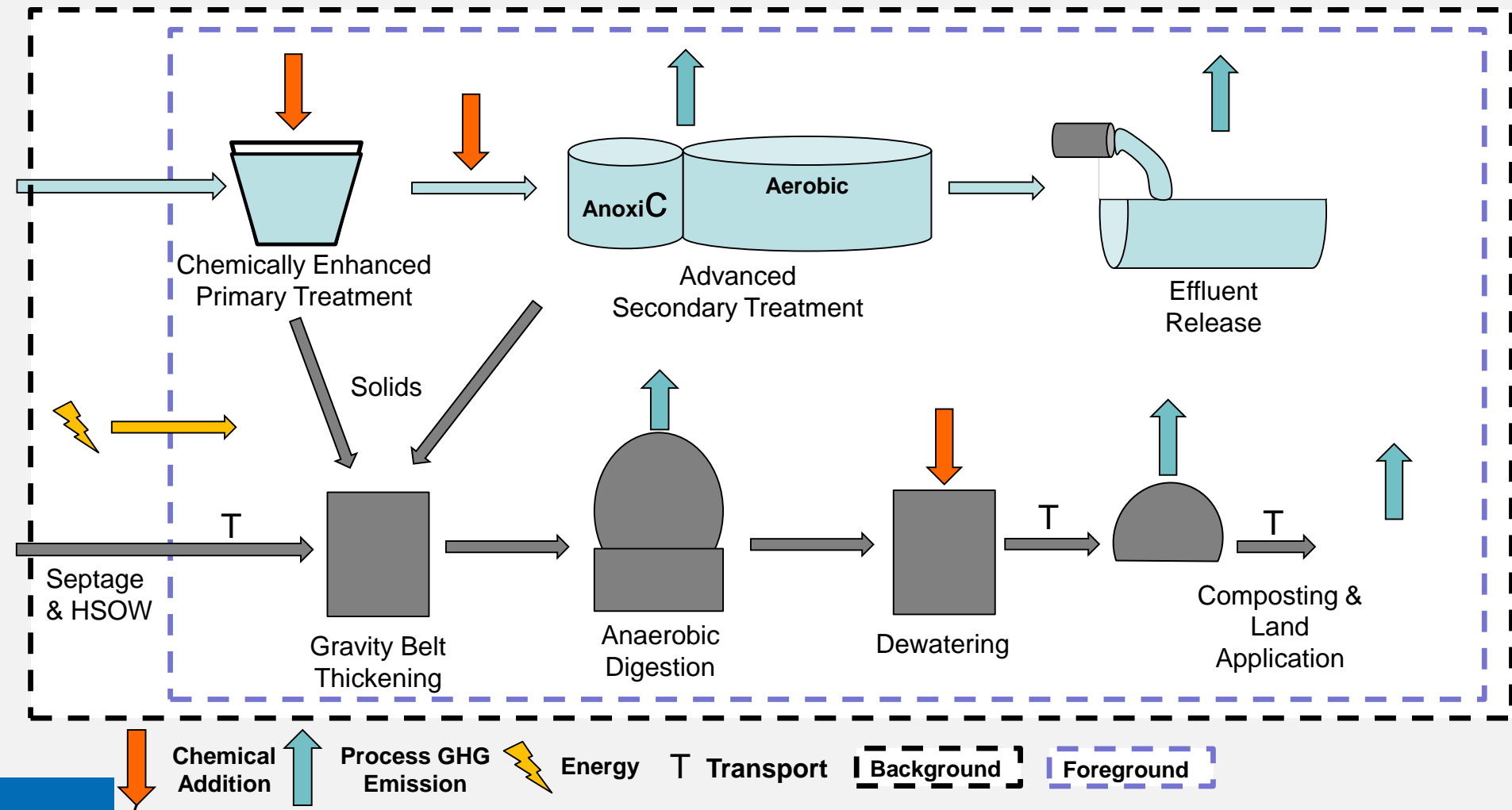
Legacy System Diagram

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



Upgraded System Diagram

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



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

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

Select LCI Calculations

- Electricity: calculated using a record of equipment use, horsepower, and run time
- Chemicals: via provided dosage rates
- Process GHGs
 - N₂O: 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 (ft³/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)

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 = $\Sigma(\text{Cost}_x / (1+i)^x)$

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 ft³/day)	130	158	205

Anaerobic Digestion – Performance Scenarios

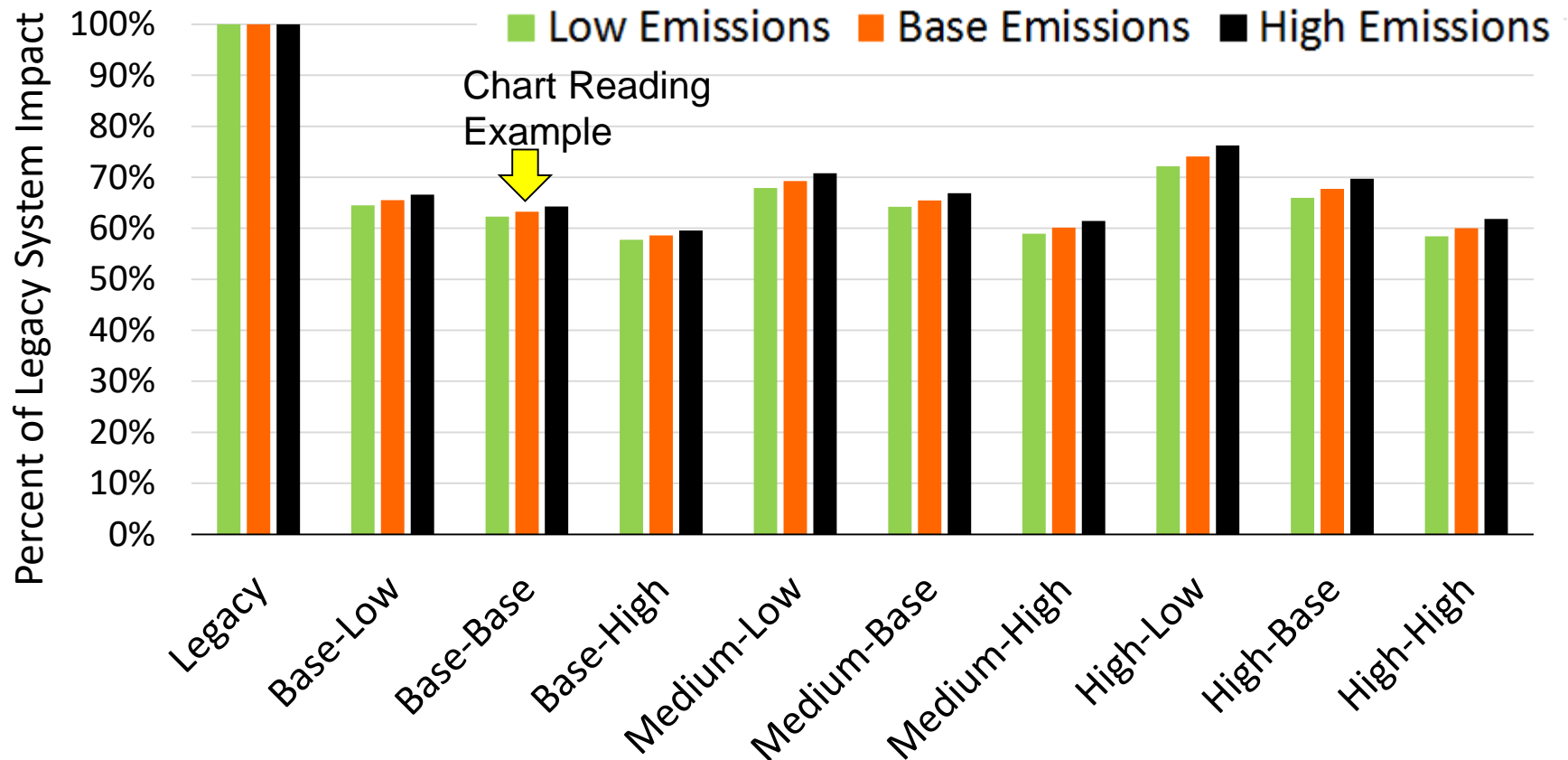
Parameter Name		Low Yield Value	Base Yield Value	High Yield Value	Units
Percent Volatile Solids Reduction		40	50	60	%
Biogas Yield	Base	12.0	15.0	24.5	ft ³ /lb VS destroyed
	Medium	13.8	18.5	25.1	ft ³ /lb VS destroyed
	High	15.7	22.2	27.3	ft ³ /lb VS destroyed
Methane Content of Biogas		55	60	65	% w/w
Biogas Heat Content (MJ/ft³)		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.

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 ₂ O	N	0.34%	incoming N lost as N ₂ O
Base	CH ₄	C	0.48%	incoming C lost as CH ₄
Base	N ₂ O	N	2.68%	incoming N lost as N ₂ O
High	CH ₄	C	1.70%	incoming C lost as CH ₄
High	N ₂ O	N	4.65%	incoming N lost as N ₂ O

Eutrophication Scenarios

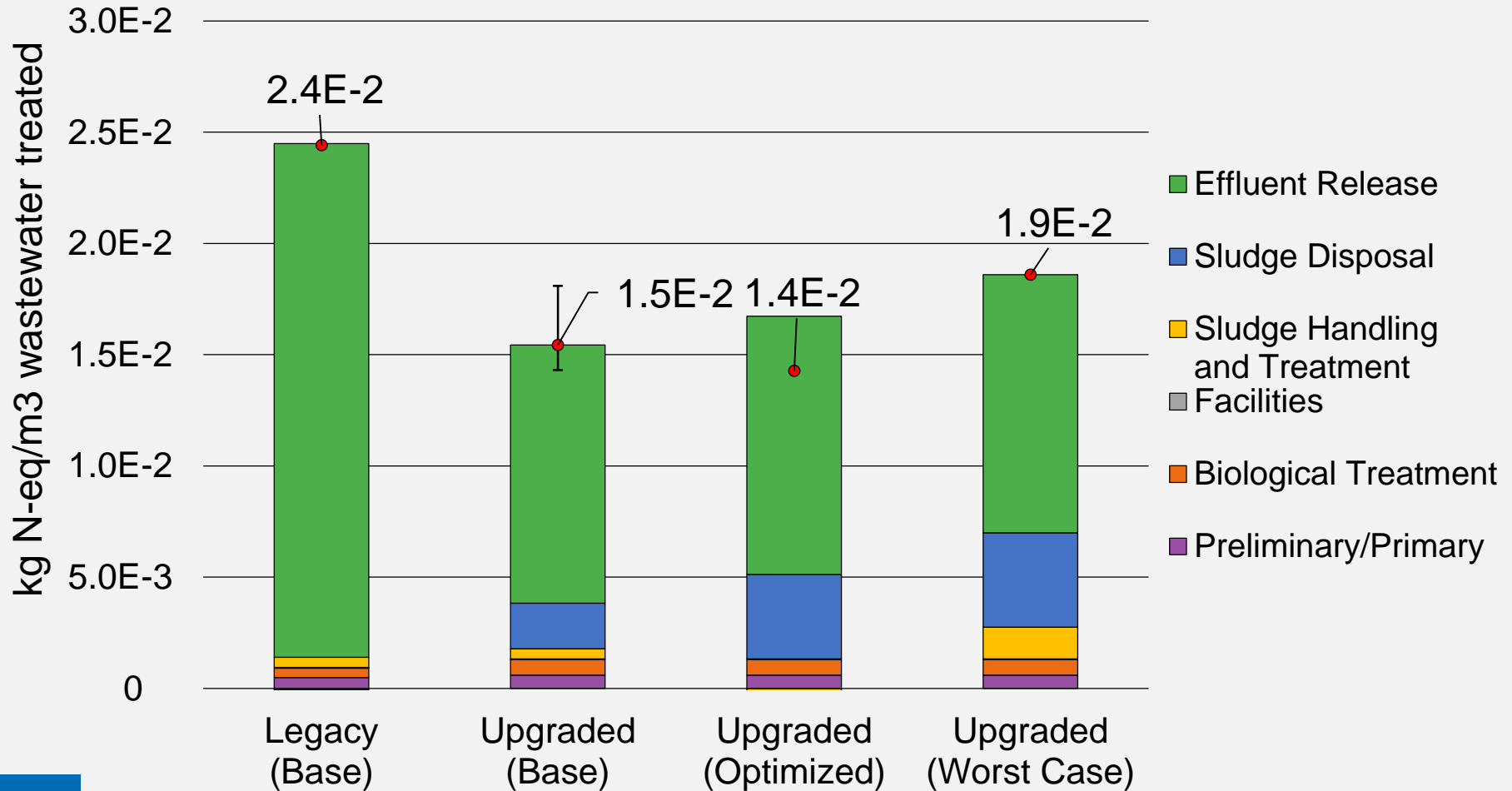
Percent of Legacy System Impact



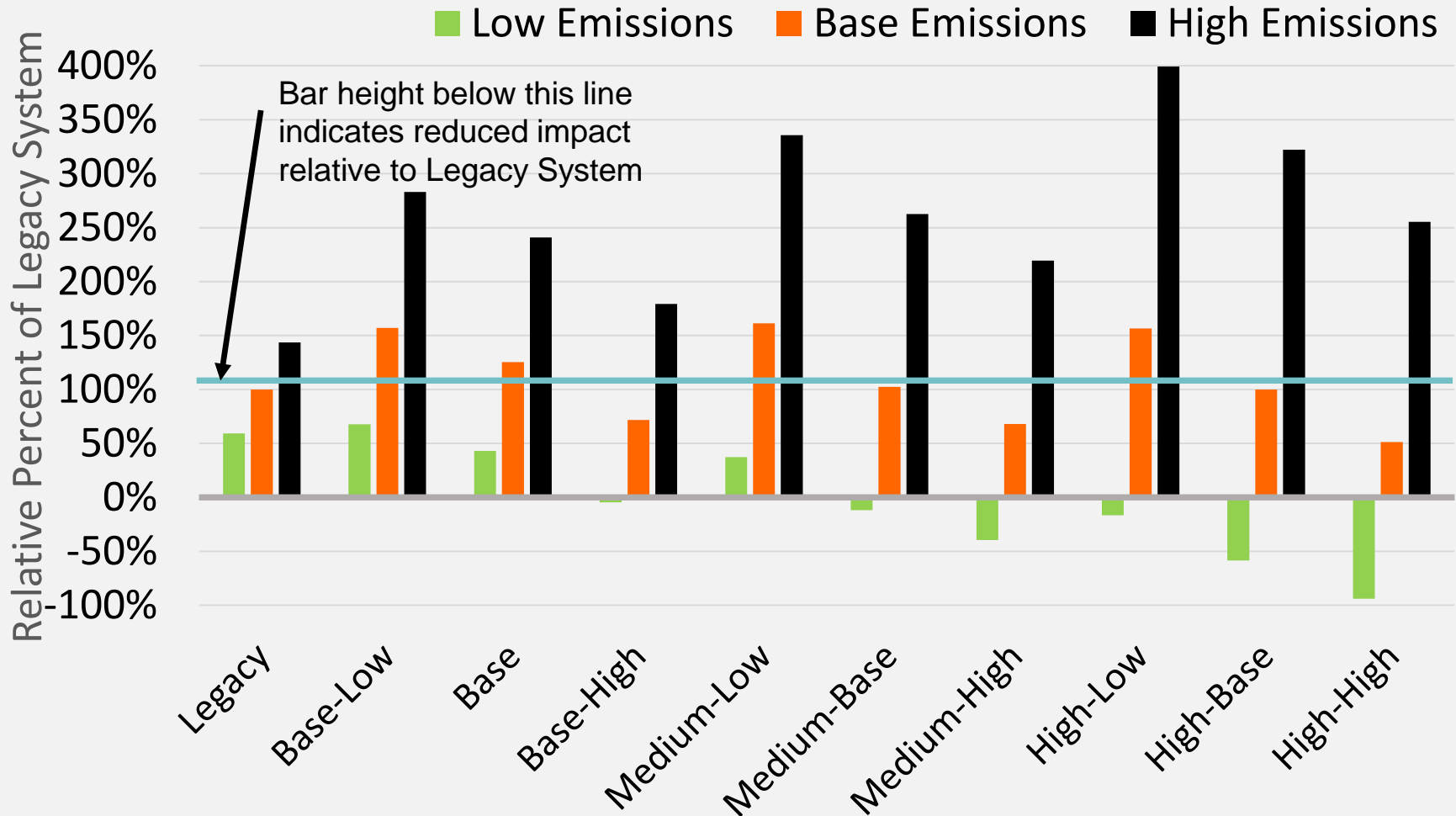
Scenario Name: Feedstock – AD, i.e., base feedstock – base AD performance

Eutrophication Potential

Process Contribution

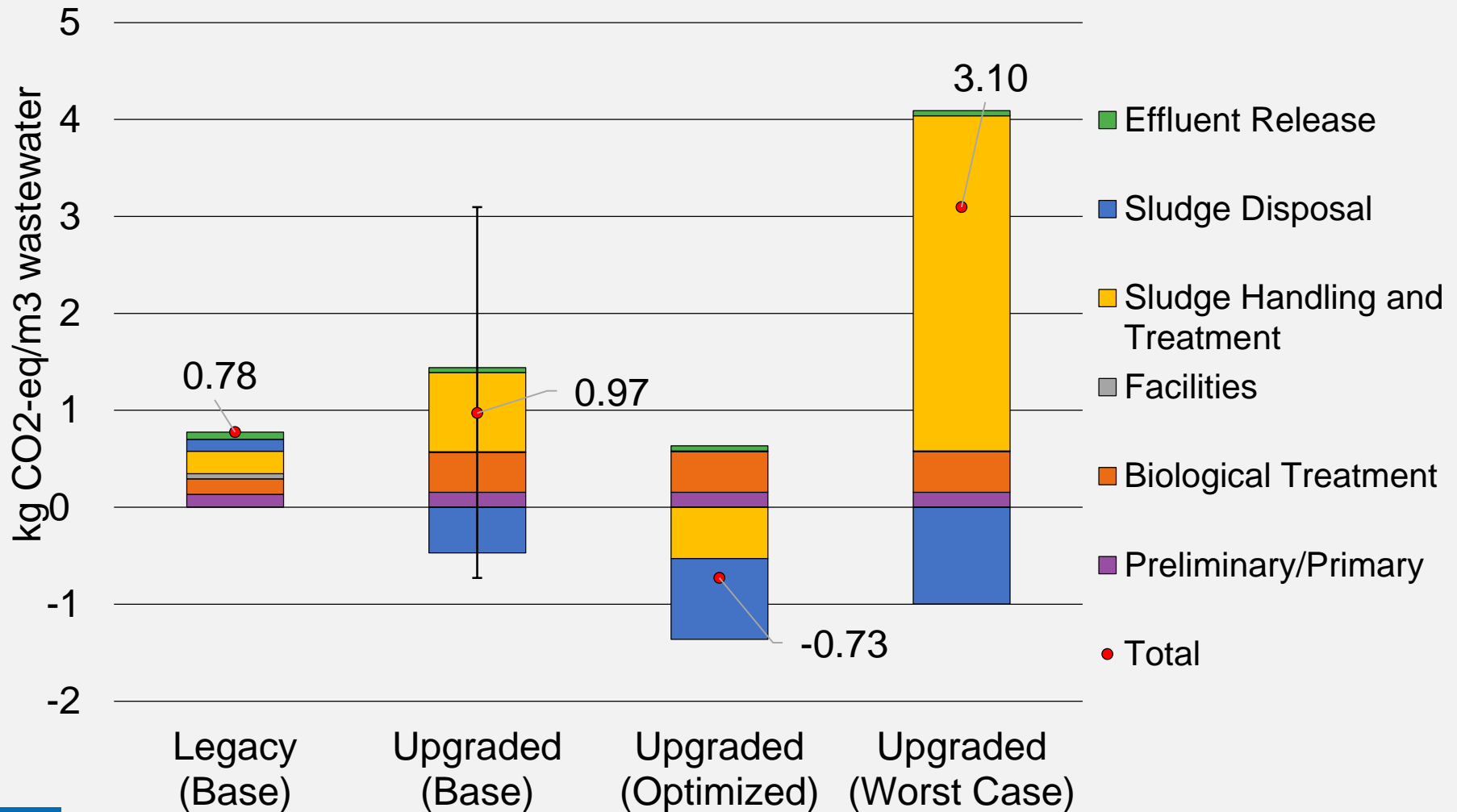


Global Climate Change Potential Scenarios



Global Climate Change Potential

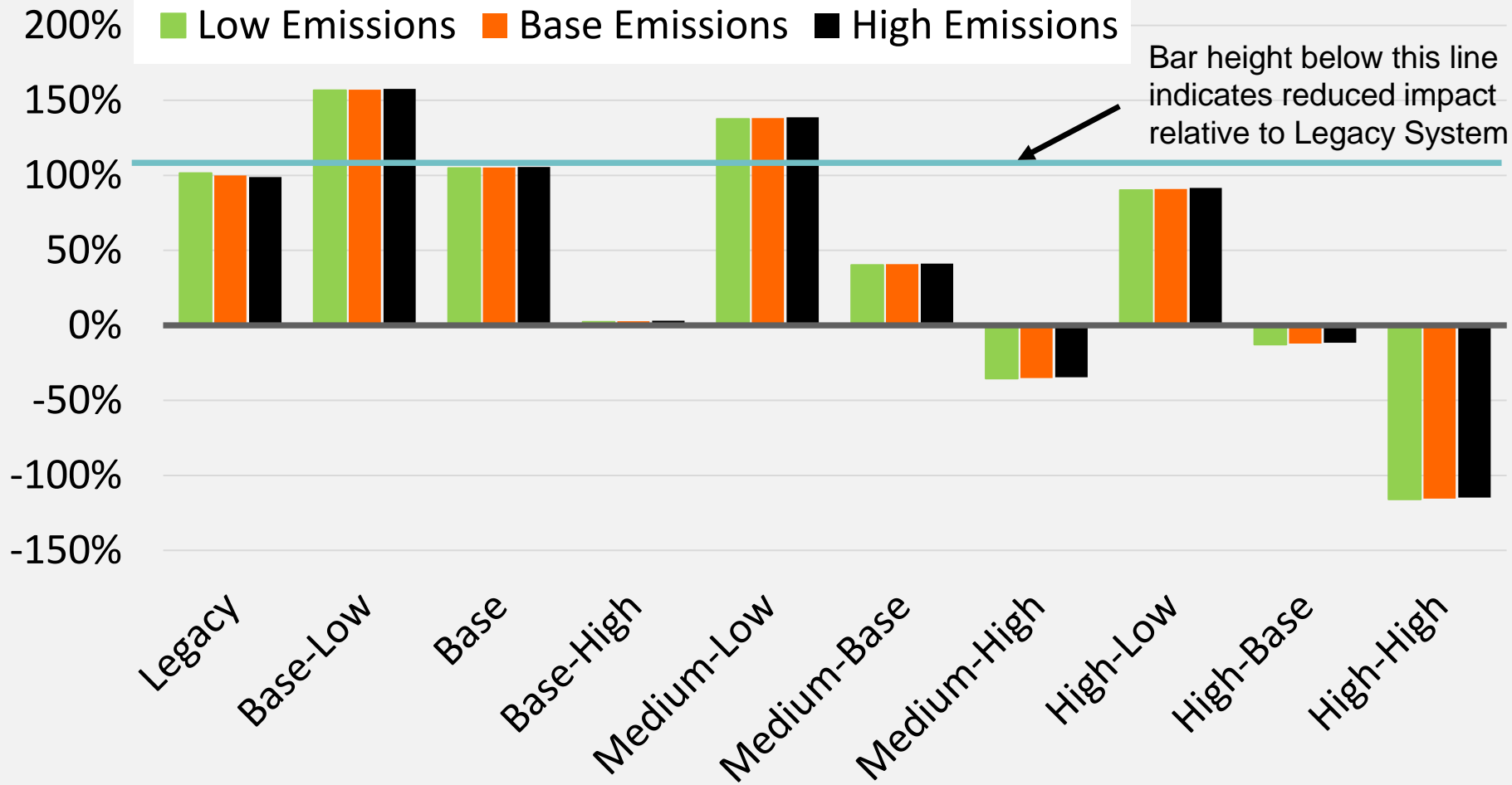
Process Contribution



Cumulative Energy Demand Scenarios

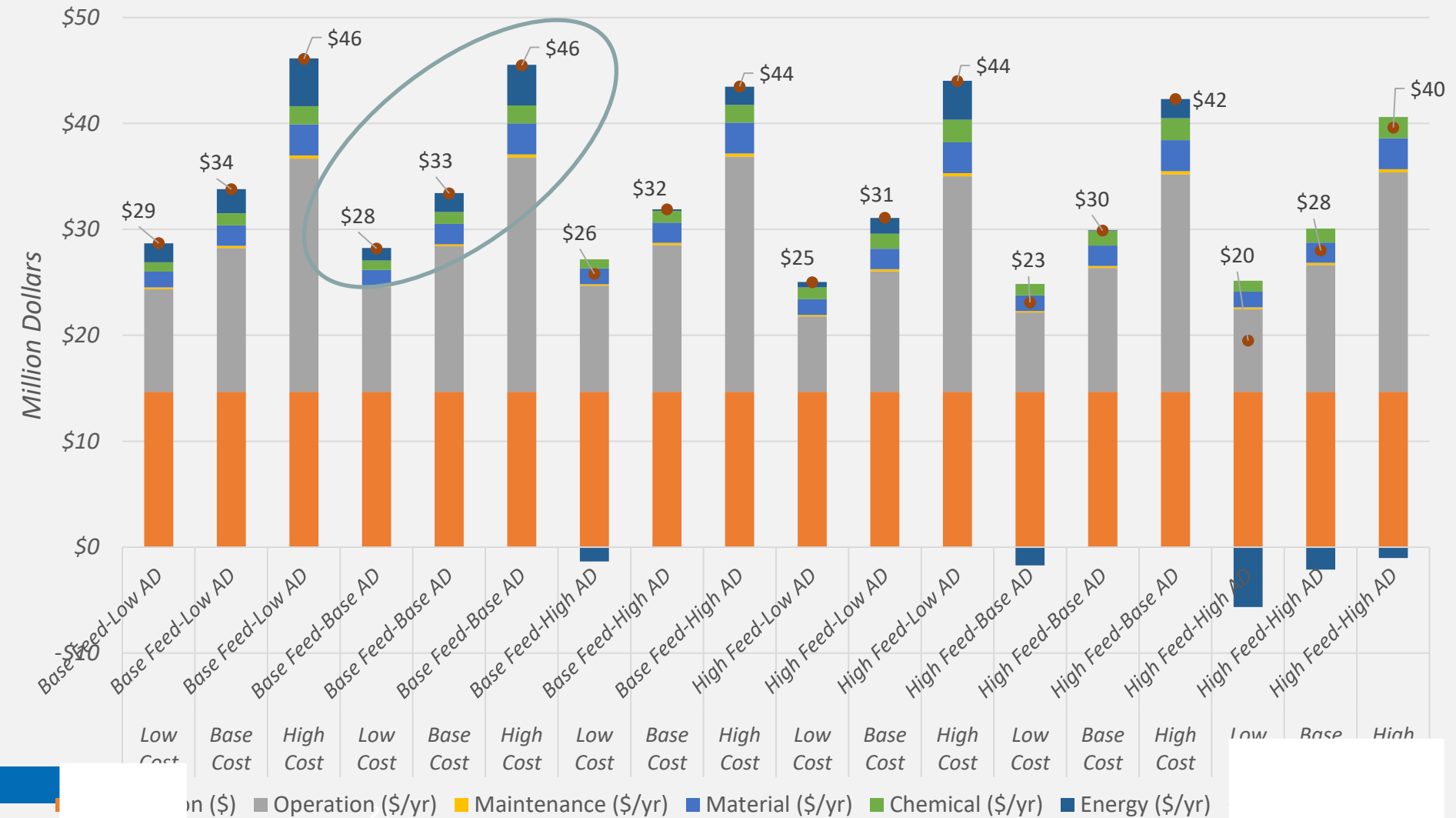
Percent of Legacy System Impact

Relative Percent of Legacy System



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



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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