TETRA TECH

Comparative Greenhouse Gas Emissions Analysis of Alternative Scenarios for Waste Treatment and/or Disposal

July 29, 2016

Acknowledgements

Study Commissioned By:

Los Angeles County Department of Public Works

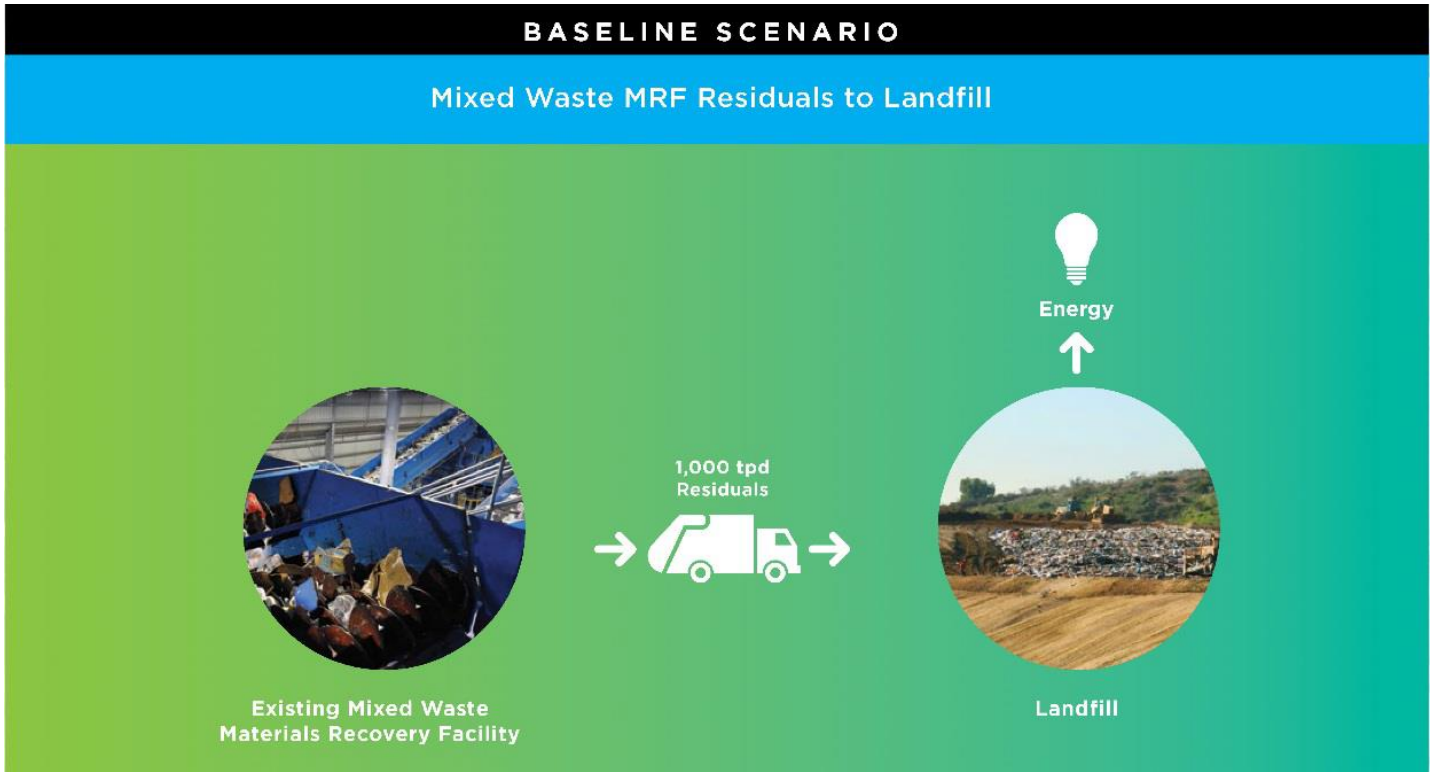
Consultant Team:

- Tetra Tech, Inc. (Project Management and Baseline Scenario Analyses)
- E. Tseng & Associates (Alternative Scenario Analysis)
- HDR Inc. (WARM Model Analysis for Gasification Technology Cross Check)
- UCLA Extension Student Researchers
- Peer Reviewers (31 Total)

Introduction

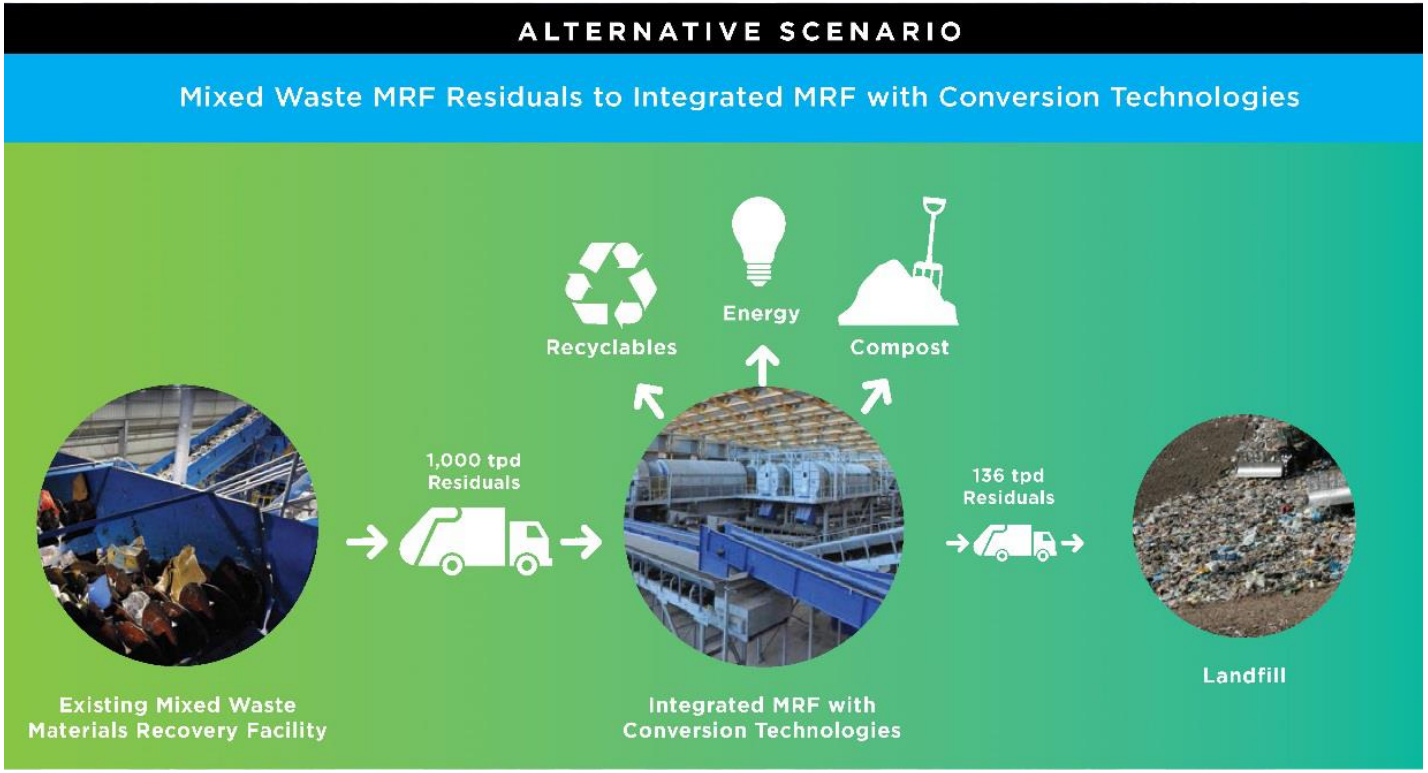
Comparison of the Net Greenhouse Gas (GHG) Emissions for Two Waste Management Scenarios

Scenario One



- 25 Years of Transport and Disposal to Out-of-County Landfill
- Truck Fleet with Better Emission Controls
- Landfill with Soil Cap
- Landfill with LFGTE
- 100 Additional Years Assumed for Decomposition in Landfill

Scenario Two



- 25 Years of Operation
- Mechanical Pre-Processing: Recover Additional Recyclables and Separate Wet & Dry Fraction
- Wet Fraction to AD and Composting
- Dry Fraction to Thermal Gasification with Ash Recovery
- Non-Processable Materials Disposed at Landfill

Integrated Approach

- Prioritize Recycling, Conversion Technologies and Composting; Landfilling as Final Option
- Consistent with the **"MRF-First"** policy of Recovering Marketable Recyclables to the Maximum Extent Reasonably Possible.
- Complies with regulatory drivers to reduce GHG emissions (AB32, AB341, AB 1826, AB1594)

Data Sources

- Modeled California Waste Composition Data (CalRecycle, 2006)
- Statewide Average Composition of Post-Recycled Residuals from a Mixed Waste MRF (After Being Source Separated Curb-Side) Going to Landfill

Table 18 - Estimated Residual Composition for California MRFs Receiving Mixed Waste, 2005

	Est. Pct.	+/-	Est. Tons
Paper	**33.1%**	**1.8%**	**2,213,130**
Uncoated Corrugated Cardboard	4.3%	0.4%	284,205
Paper Bags/Kraft	0.7%	0.1%	45,834
Newspaper	4.2%	0.5%	278,891
White Ledger	1.8%	0.3%	120,169
Colored Ledger	0.2%	0.0%	13,761
Computer Paper	0.0%	0.0%	1,676
Other Office Paper	2.5%	0.3%	166,522
Magazines/Catalogs	2.5%	0.4%	163,624
Phone Books/Directories	0.2%	0.1%	12,360
Other Misc. Paper	4.7%	0.4%	310,598
Remainder/Composite Paper	12.2%	1.1%	815,491
Glass	**1.9%**	**0.3%**	**128,415**
Clear Glass Bottles & Containers	0.8%	0.2%	54,896
Green Glass Bottles & Containers	0.2%	0.1%	15,722
Brown Glass Bottles & Containers	0.2%	0.1%	11,930
Other Colored Glass Bottles & Containers	0.0%	0.0%	519
Flat Glass	0.1%	0.0%	3,497
Mixed Cullet	0.4%	0.1%	25,861
Remainder/Composite Glass	0.2%	0.1%	15,991
Metal	**5.6%**	**0.8%**	**372,659**
Tin/Steel Cans	1.1%	0.2%	74,031
Major Appliances	0.2%	0.1%	10,799
Used Oil Filters	0.0%	0.0%	305
Other Ferrous	2.0%	0.5%	136,782
Aluminum Cans	0.3%	0.0%	18,331
Other Non-Ferrous	0.7%	0.2%	49,703
Remainder/Composite Metal	1.2%	0.3%	82,706
Electronics	**1.1%**	**0.3%**	**73,259**
Brown Goods	0.3%	0.1%	20,966
Computer-related Electronics	0.4%	0.1%	23,838
Other Small Consumer Electronics	0.4%	0.1%	28,122
TV's & Other CRTs	0.0%	0.0%	333
Plastic	**16.9%**	**1.1%**	**1,127,866**
PETE Bottles	0.7%	0.1%	43,746
Other PETE Containers	0.1%	0.0%	9,710
HDPE Natural Bottles	0.3%	0.1%	19,636
HDPE Colored Bottles	0.3%	0.1%	17,303
HDPE 5-gallon buckets (Food)	0.1%	0.0%	4,852
HDPE 5-gallon buckets (Non-Food)	0.3%	0.1%	21,262
Other HDPE Containers	0.1%	0.0%	6,097
#3-#7 Bottles	0.1%	0.0%	6,863
Other #3-#7 Containers	0.8%	0.1%	53,697
Plastic Trash Bags	1.3%	0.2%	87,248
Grocery/Merch. Bags	1.1%	0.2%	76,432
Non-bag Comm./Ind. Packaging Film	1.8%	0.4%	117,378
Film Products	0.1%	0.1%	8,592
Other Film	3.7%	0.4%	246,411
Durable Plastic Items	1.2%	0.2%	80,524
Remainder/Composite Plastic	4.9%	0.5%	328,115

	Est. Pct.	+/-	Est. Tons
Organic	**27.3%**	**2.4%**	**1,825,548**
Food	10.4%	1.3%	691,353
Leaves and Grass	7.9%	1.9%	530,628
Prunings & Trimmings	1.0%	0.3%	63,914
Branches & Stumps	0.3%	0.1%	22,940
Agricultural Crop	0.0%	0.0%	2,710
Manures	0.0%	0.0%	1,879
Textiles	2.4%	0.4%	163,550
Carpet	0.3%	0.1%	22,798
Remainder/Composite Organics	4.9%	0.7%	325,776
Construction & Demolition	**12.6%**	**2.0%**	**839,302**
Concrete	0.6%	0.2%	41,868
Asphalt Paving	0.0%	0.0%	215
Asphalt Roofing	0.2%	0.1%	12,605
Lumber	3.1%	0.6%	204,749
Treated Wood Waste	1.9%	0.4%	127,948
Gypsum Board	0.8%	0.3%	52,064
Rock, Soil, Fines	3.2%	0.6%	216,690
Remainder/Composite C&D	2.7%	0.8%	183,161
Household Hazardous Waste	**0.4%**	**0.1%**	**25,022**
Paint	0.0%	0.0%	1,232
Vehicle & Equip. Fluids	0.0%	0.0%	0
Used Oil	0.0%	0.0%	459
Batteries	0.3%	0.1%	19,319
Remainder/Composite HHW	0.1%	0.0%	4,012
Special Waste	**0.5%**	**0.4%**	**36,442**
Ash	0.0%	0.0%	1,111
Sewage Solids	0.0%	0.0%	0
Industrial Sludge	0.0%	0.0%	0
Treated Medical Waste	0.0%	0.0%	90
Bulky Items	0.0%	0.0%	0
Tires	0.0%	0.0%	1,566
Remainder/Composite Special Waste	0.5%	0.2%	33,675
Mixed Residue	**0.5%**	**0.2%**	**36,508**
Totals	**100.0%**		**6,678,151**
Sample count:	**120**		

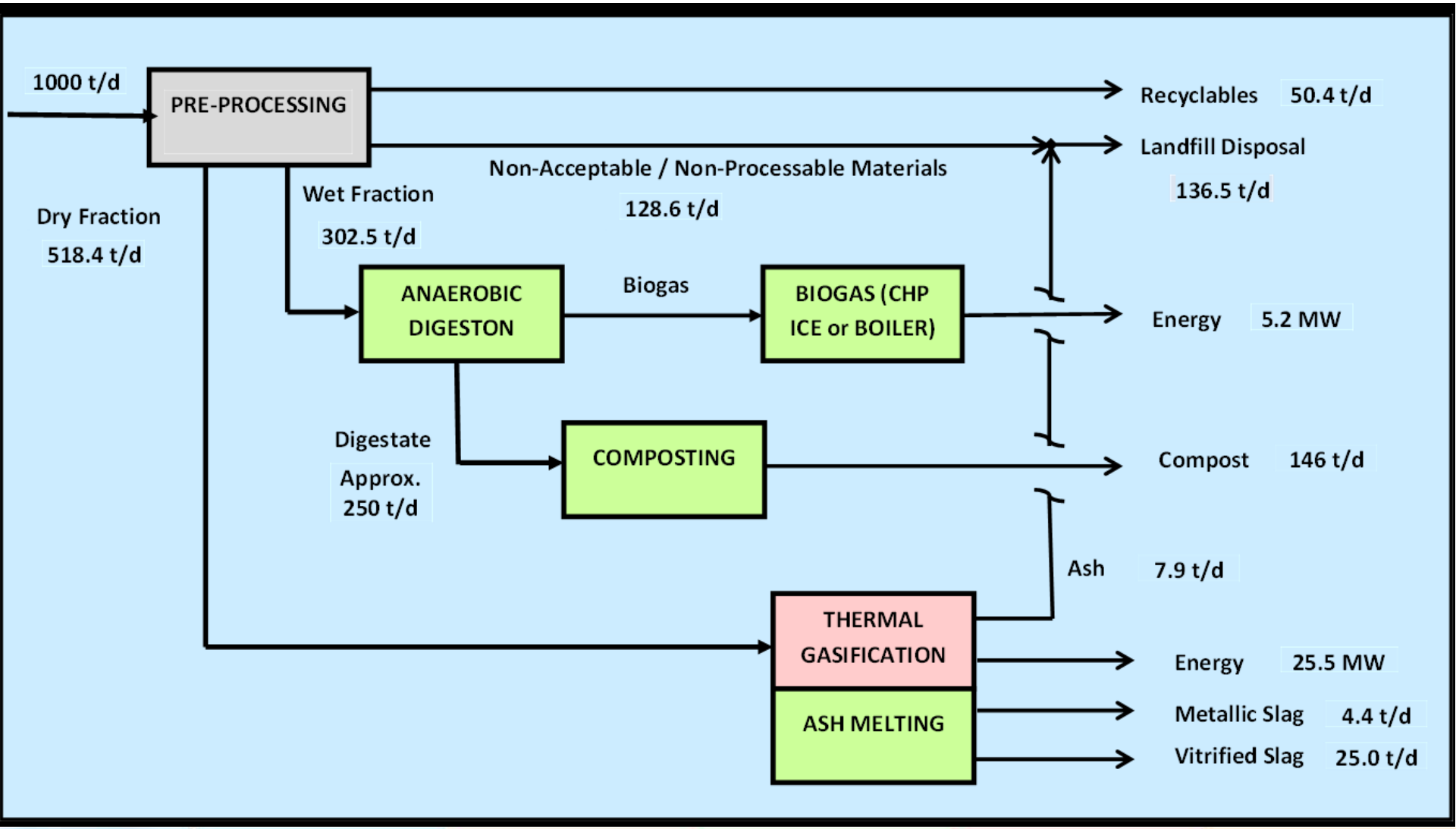
Data Sources

Post-Recycled Mixed Waste MRF Residuals Composition Separated Into Major Fractions to be Optimized for Further processing:

- Wet Fraction ("DC" for Digestible Component)
- Dry Fraction ("RDF" for Refuse-Derived Fuel)
- Landfill (Non-Processable/Non-Acceptable Materials)

Work Days/Year	365	Important Note: Lower and Upper Bounds for Major Materials and Total Are the Sum of Detailed Materials, Not Separatly Calculated Bounds.		AVERAGE					UPPER AND LOWER BOUND				
Short Tons/Day	1000			Process Category (Daily Short Tons)					Lower/Upper 90% Bound (Daily Short Tons)				
Material Group	Material	TOTAL PERCENT	TOTAL DAILY TONS	Recyclables	DC	RDF	Landfill	Reject	Recyclables	DC	RDF	Landfill	Reject
Paper		**33.1%**	**331.4**	**4.6**	**49.7**	**277.1**	**0.0**	**0.0**	**4.1 - 5.0**	**44.6 - 54.8**	**248.4 - 305.8**	**0.0 - 0.0**	**0.0 - 0.0**
1	OCC (Recyclable)/Kraft	4.9%	49.4	2.0	7.4	40.0	0.0	0.0	1.8 - 2.1	6.8 - 8.0	36.7 - 43.4	0.0 - 0.0	0.0 - 0.0
2	Newspaper	4.2%	41.8	1.3	6.3	34.2	0.0	0.0	1.1 - 1.4	5.5 - 7.0	30.1 - 38.3	0.0 - 0.0	0.0 - 0.0
3	High Grade Office Paper	4.5%	45.2	1.4	6.8	37.1	0.0	0.0	1.2 - 1.5	6.1 - 7.4	33.6 - 40.6	0.0 - 0.0	0.0 - 0.0
4	Mixed Recyclable Paper	7.3%	72.9	0.0	10.9	61.9	0.0	0.0	0.0 - 0.0	10.1 - 11.8	57.0 - 66.8	0.0 - 0.0	0.0 - 0.0
5	Compostable Paper	8.9%	89.0	0.0	13.4	75.7	0.0	0.0	0.0 - 0.0	11.9 - 14.8	67.7 - 83.6	0.0 - 0.0	0.0 - 0.0
6	Non-Recyclable Paper	3.3%	33.1	0.0	5.0	28.1	0.0	0.0	0.0 - 0.0	4.1 - 5.8	23.3 - 33.0	0.0 - 0.0	0.0 - 0.0
Plastic		**16.9%**	**168.9**	**6.1**	**2.0**	**153.0**	**7.5**	**0.3**	**5.0 - 7.2**	**1.8 - 2.2**	**139.3 - 166.7**	**6.8 - 8.2**	**0.2 - 0.3**
7	#1 PET Bottles/Containers (Deposit)	0.7%	6.6	2.9	0.0	3.6	0.0	0.0	2.5 - 3.4	0.0 - 0.0	3.1 - 4.2	0.0 - 0.0	0.0 - 0.0
8	#1 PET Bottles/Containers (Non-Deposi	0.1%	1.5	0.7	0.0	0.8	0.0	0.0	0.7 - 0.7	0.0 - 0.0	0.8 - 0.8	0.0 - 0.0	0.0 - 0.0
9	#2 HDPE Bottles	0.6%	5.5	2.5	0.0	3.0	0.0	0.0	1.9 - 3.1	0.0 - 0.0	2.3 - 3.8	0.0 - 0.0	0.0 - 0.0
10	Other Bottles/Containers	1.4%	13.9	0.0	0.0	12.2	1.4	0.3	0.0 - 0.0	0.0 - 0.0	11.0 - 13.5	1.2 - 1.5	0.2 - 0.3
11	Plastic Film/Wrap	8.0%	80.3	0.0	2.0	78.3	0.0	0.0	0.0 - 0.0	1.8 - 2.2	72.0 - 84.5	0.0 - 0.0	0.0 - 0.0
12	Other Plastic Products	6.1%	61.2	0.0	0.0	55.1	6.1	0.0	0.0 - 0.0	0.0 - 0.0	50.2 - 59.9	5.6 - 6.7	0.0 - 0.0
Metals		**5.4%**	**54.2**	**37.5**	**0.2**	**5.8**	**10.6**	**0.0**	**29.3 - 45.8**	**0.2 - 0.3**	**4.5 - 7.2**	**8.2 - 12.9**	**0.0 - 0.0**

Mass Balance of Integrated MRF with Conversion Technology



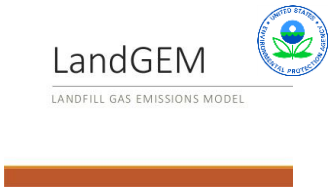
Calculation Methodologies for Baseline and Alternative Scenarios

Industry-Accepted Models to Calculate GHG Emissions for:

Transport:

Landfill Operations:

Buried Refuse:



MRF Pre-Processing, Anaerobic Digestion, and Composting:

Gasification Cross Check:

No Single GHG Emissions Calculation Model was Able to Address All of the GHG Emissions of the Various Components of the Study

Calculation Methodology for Alternative Scenario

Reference Model Data Based on Existing, Operating Facilities for:

- Process Design and Process Flow Data
- Mass and Energy Balance Data
- Emission Calculations Provided by:
    - Anaergia (Carlsbad, California)
    - JFE Engineering Corporation (Yokohama, Japan)

Results and Conclusion

Comparative GHG Emissions for Years 2014 to 2138 for the Treatment of 1,000 Tons per Day (for 25 Years) of Post-Recycled MRF Residuals (in Metric Tons of Carbon Dioxide Equivalent, MTCO2E)

SCENARIO	GHG EMISSIONS in $MTCO^2E$ (Years 2014 TO 2138)						
BASELINE SCENARIO: POST RECYCLED RESIDUAL TO LANDFILL (1000 TPD)	TOTAL EMISSIONS	BIOGENIC EMISSIONS	NON-BIOGENIC EMISSIONS	INDIRECT EMISSIONS	AVOIDED EMISSIONS	NET EMISSIONS (biogenic and non-biogenic)	NET EMISSIONS (only non-biogenic emissions)
Scenario One TOTAL OF TRANSPORTATION AND LANDFILL OPERATONS EMISSIONS (Cap / LFG-to-Energy)	5,357,275	2,479,735	2,877,540	0	1,241,000	4,116,275	1,636,540
ALTERNATIVE SCENARIO: INTEGRATED MRF WITH CONVERSION TECHNOLOGY	TOTAL EMISSIONS	BIOGENIC EMISSIONS	NON-BIOGENIC EMISSIONS	INDIRECT EMISSIONS	AVOIDED EMISSIONS	NET EMISSIONS (biogenic and non-biogenic)	NET EMISSIONS (only non-biogenic emissions)
Scenario Two TOTAL OF INTEGRATED MRF AND CONVERSION TECHNOLOGY COMPONENTS	8,931,770	5,462,299	3,266,635	202,835	4,135,493	4,796,277	(666,022)

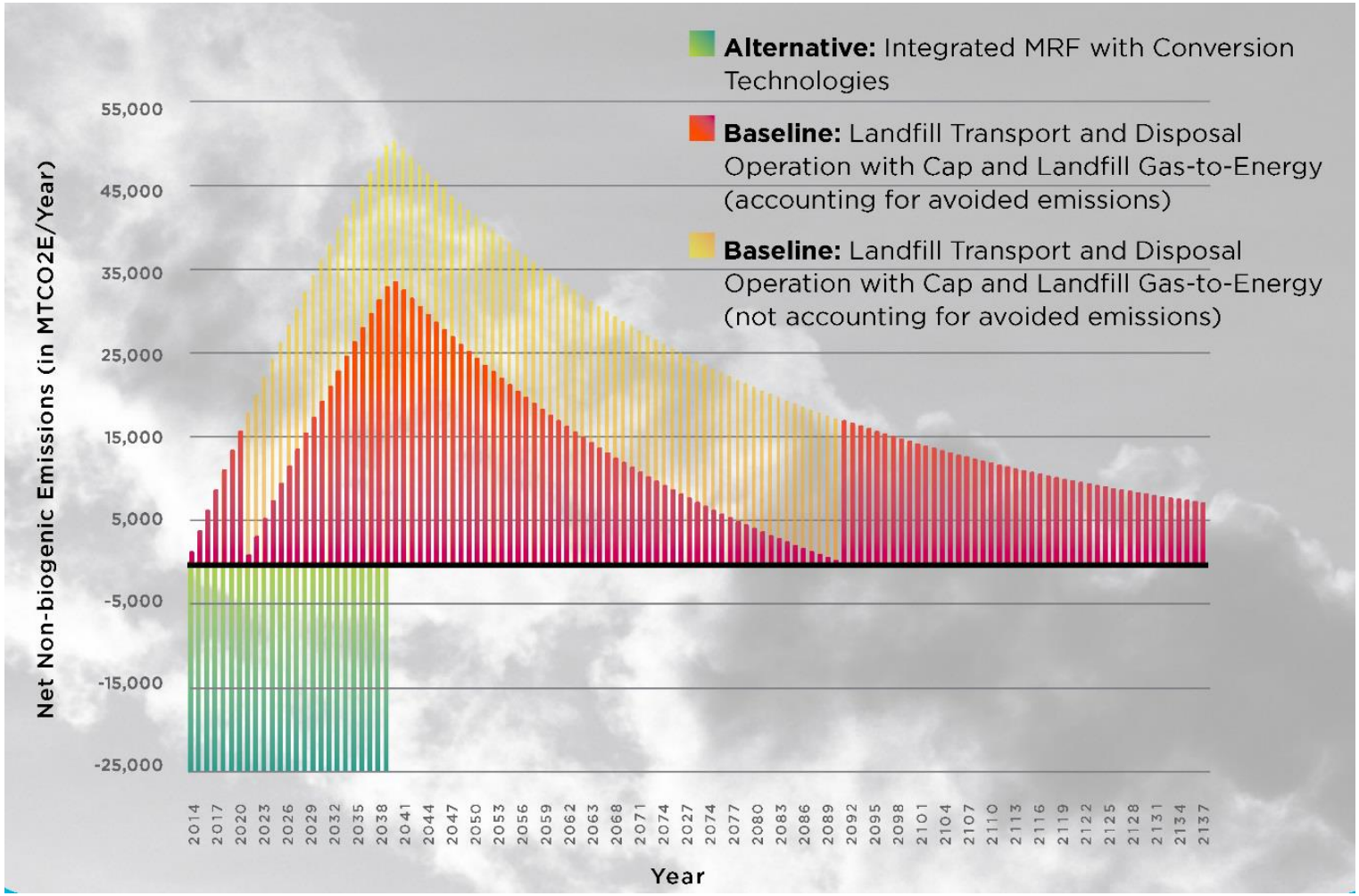
Total Emissions = Biogenic + Non-Biogenic + Indirect (Purchased Electricity, Heat or Steam)
Net Emissions = Total – Avoided Emissions

Findings

- Biogenic Emissions Higher for Alternative Scenario due to Gasification Process Converting Biogenic Components of RDF to Carbon Dioxide and Water
- Non-Biogenic Emissions Similar for Both Scenarios (Fugitive Methane Emissions from Landfills and Carbon Dioxide from Gasification Process)
- Avoided Emissions Much Greater for Alternative Scenario Due to Renewable Energy from AD and Gasification Replacing Fossil Fuel Use and Additional Recycling
- Avoided Emissions in Baseline Scenario Due to LFG-To-Energy Replacing Fossil Fuel Use

Results

- 1.64 Million MTCO2E Net GHG Emissions for the Baseline Scenario
- (.67) Million MTCO2E Net GHG Emissions for the Alternative Scenario



Results

Net GHG Emissions:

- Baseline Scenario = GHG Emissions of **1.64 Million MTCO2E** over a 125 Year Period, Comparable to 340,000 Passenger Vehicles Driven for One Year

- Alternative Scenario = Net Avoided GHG Emissions of **(0.67) Million MTCO2E** over a 25 Year Period, Comparable to 140,000 Fewer Passenger Vehicles Driven for One Year

Conclusion

- An Integrated Materials Recovery Facility (MRF) with Conversion Technologies will Achieve a Net Reduction in Cumulative Greenhouse Gas Emissions as Compared to Landfilling Post-Recycled Residuals from a Mixed-Waste MRF
- Net Reduction is Due to Higher Avoided Emissions for Renewable Energy Generation, Replacing Fossil Fuels, and Energy Savings from Additional Recycling

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QUESTIONS?

Thank you

CT Comparative GHG Analysis February 2016

Comparative GHG Emissions for Years 2014 to 2138 for the Treatment of 1,000 Tons per Day (for 25 Years) of Post-Recycled MRF Residuals (in Metric Tons of Carbon Dioxide Equivalent, MTCO2E)

SCENARIO	EMISSIONS (Years 2014 TO 2138): 125 Years						
BASELINE SCENARIO: POST RECYCLED RESIDUAL TO LANDFILL (1000 TPD)	TOTAL EMISSIONS	BIOGENIC EMISSIONS	NON-BIOGENIC EMISSIONS	INDIRECT EMISSIONS	AVOIDED EMISSIONS	NET EMISSIONS (biogenic and non-biogenic)	NET EMISSIONS (only non-biogenic emissions)
TOTAL OF TRANSPORTATION AND LANDFILL OPERATONS EMISSIONS (Cap / LFG-to-Energy)	**5,357,275**	**2,479,735**	**2,877,540**	**0**	**1,241,000**	**4,116,275**	**1,636,540**
Transportation to Landfill (25-yr Landfill Operation) (EMFAC2011)	25,946	-	25,946			25,946	25,946
Landfill Operation (with cap/LFG-to-energy) (CalEEMod, LandGEM) Lo = 100, Capture rate = 83%	5,331,329	2,479,735	2,851,594		1,241,000	4,090,329	1,610,594
ALTERNATIVE SCENARIO: INTEGRATED MRF WITH CONVERSION TECHNOLOGY	TOTAL EMISSIONS	BIOGENIC EMISSIONS	NON-BIOGENIC EMISSIONS	INDIRECT EMISSIONS	AVOIDED EMISSIONS	NET EMISSIONS (biogenic and non-biogenic)	NET EMISSIONS (only non-biogenic emissions)
TOTAL OF INTEGRATED MRF AND CONVERSION TECHNOLOGY COMPONENTS	**8,931,770**	**5,462,299**	**3,266,635**	**202,835**	**4,135,493**	**4,796,277**	**(666,022)**
MRF Preprocessing (Anaergia EpE) [a]	0	-	-	-	1,646,938	(1,646,938)	(1,646,938)
Anaerobic Digestion (Digestate to Composting) (EpE) [a]	842,815	740,338	102,477	-	563,389	279,426	(460,912)
Composting of Digestate (Anaergia EpE) [a]	342,435	177,942	164,493	-	9,667	332,768	154,826
RDF (Average) Gasification and Ash Melting	7,728,236	4,537,816	2,987,584	202,835	1,668,485	6,059,751	1,521,935
RDF, Slag and Metal Recycling from Ash Melting Process (Average) (WARM)	Included in Process	Included in Process	Included in Process	Included in Process	247,014	(247,014)	(247,014)
Landfill of Post Integrated MRF Residuals							
Transportation to Landfill (25-yr Landfill Operation) (EMFAC2011)	4,404		4,404			4,404	4,404
Landfill Operation (with cap/flare) (CalEEMod, LandGEM)	13,880	6,202	7,678			13,880	7,678

Emissions Definitions

- **Direct Emissions** – Directly Related to Solid Waste Management Activities
  - **Biogenic** – Emissions Naturally Cycle Through Atmosphere; Carbon Neutral
  - **Non-Biogenic** – Emissions from Combustion of Carbon Fuels, Materials of Fossil Fuel Origin and Other Non-Combustion Processes (Fugitive Methane Emissions from Landfill Operations)
- **Indirect Emissions –** From Purchased Electricity, Heat or Steam
- **Avoided Emissions -** Attributed to Displacing Purchased Power Generated by Fossil Fuel Combustion or Emissions Avoided by Recycling (Avoiding Processing Virgin Material)
- **Total Emissions** = Biogenic + Non-Biogenic + Indirect
- **Net Emissions** = Total – Avoided Emissions