

California Environmental Protection Agency



Air Resources Board

Low Carbon Fuel Standard

**High Solids Anaerobic Digestion
Pathway for the Production of
Renewable Natural Gas**

**DIGESTING URBAN ORGANIC RESIDUALS FORUM
SACRAMENTO, CALIFORNIA**

**ARB Staff Presentation
Stationary Source Division (Fuels Evaluation Section)
May 30, 2012**

Background Information

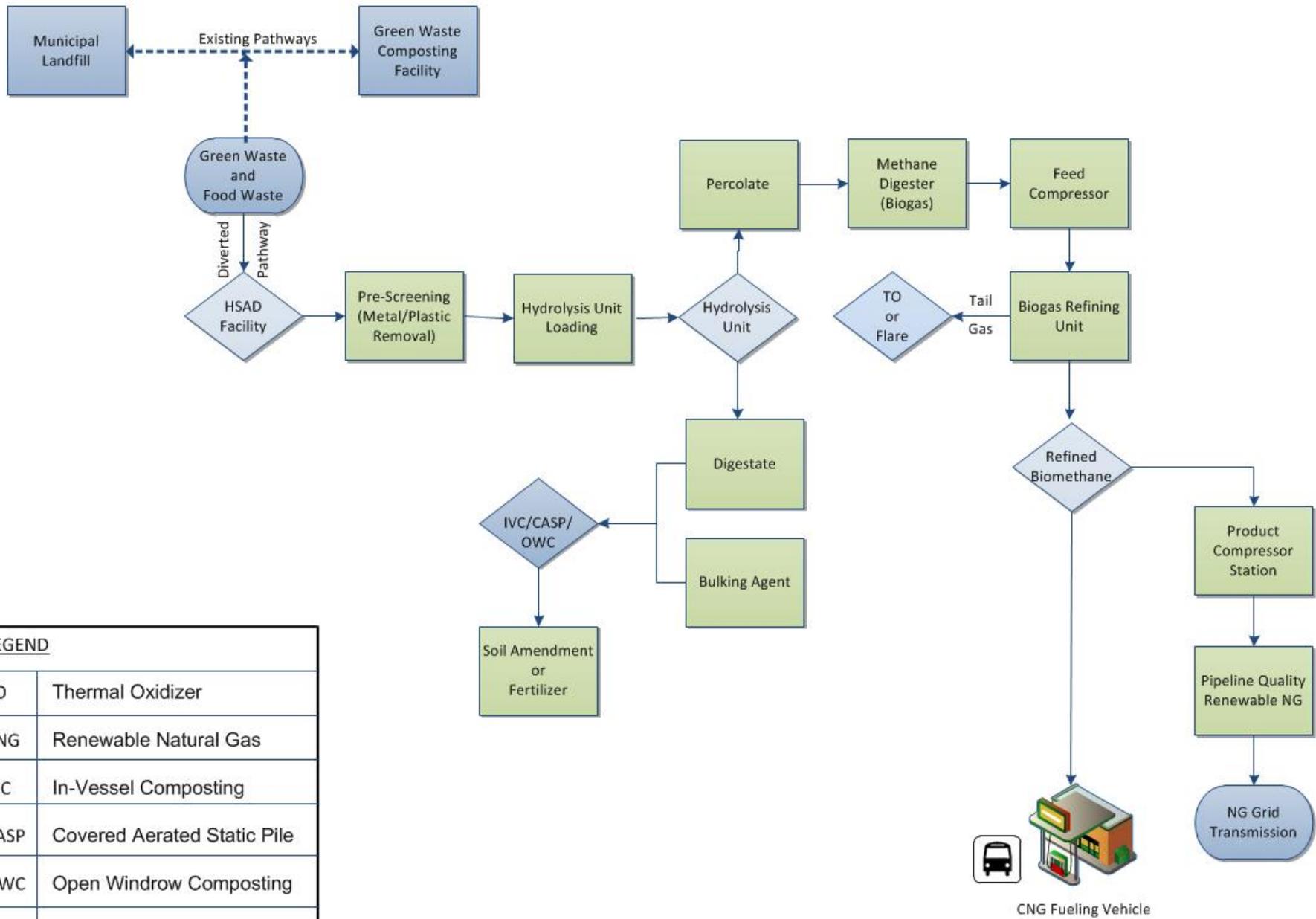
Low Carbon Fuel Standard (LCFS)

- Component of the Global Warming Solutions Act of 2006 (AB 32)
- Requires Ten Percent Reduction in the Carbon Intensity (CI) of California's Transportation Fuels by 2020
- What is Carbon Intensity? Measure of Lifecycle GHG Emissions Per Unit of Fuel Energy, Expressed in g CO₂e / MJ
- Basis for Regulation: CIs for Diesel and Gasoline Over 2010-2020
- Applicability of Regulation to Ultra Low Sulfur Diesel Fuel (ULSD)
 - ULSD CI is 94.71 g CO₂e / MJ (Year 2010 Established as Baseline Year)
 - Average CI Requirements for ULSD and Diesel Substitutes in Year 2020 is $94.71 \times 90\% = 85.24$ g CO₂e / MJ
- Accelerated Rate of Compliance in Latter Years to Meet Goals
- Performance-Based Incentives for Development of Low Carbon Fuels

LCFS Lifecycle Analysis

Fuel's Well-to-Wheels Analysis for Carbon Intensity Determination

- **CI is Determined from Full Lifecycle Analysis of Aggregate Direct and Indirect GHG Emissions**
 - Example of Direct Emissions: Result From Process Fuel Use
 - Example of Indirect Emissions: Result From Land Use Changes
- **Direct GHG Emissions Referred to as Well-to-Wheels (WTW) Analysis (2 Components)**
 - Well-to-Tank (WTT) Accounts for Energy Use and Emissions from Supply of Feedstocks to the Distribution of the Finished Fuel
 - Includes Upstream (Fuel Cycle) Emissions
 - Tank-to-Wheels (TTW) Accounts for the Emissions from Actual Combustion of the Fuel in a Motor Vehicle Used for Motive Power
- **Mass Values for All GHG are Adjusted to Account for their Global Warming Potentials (GWP)**
 - Example: CH_4 Emissions \times 25 GWP = CO_2 Equivalent Emissions



LEGEND	
TO	Thermal Oxidizer
RNG	Renewable Natural Gas
IVC	In-Vessel Composting
CASP	Covered Aerated Static Pile
OWC	Open Windrow Composting
NG	Natural Gas

Schematic of HSAD Pathway

HSAD Pathway Description

Key Characteristics....1

- **Proposed Pathway Produces Renewable Natural Gas (RNG) from the High Solids Anaerobic Digestion (HSAD) of Food and Green Wastes**
 - Modeled a Multi-Stage, Mesophilic, Batch Process
 - “Dry Fermentation” Process, No Slurrying or Grinding
 - Feedstock is 40 Percent Food Waste, 60 Percent Green Waste
 - Can be Augmented with 5 – 10 Percent FOG, Soiled Paper
- **Biogas Produced is Refined to 99 Percent Biomethane**
 - Pressure Swing Adsorption (PSA) or Comparable Technology
 - Meets Specification for California CNG Motor Fuel
 - Can Conform to Standards for Pipeline Quality Natural Gas (NG)

HSAD Pathway Description

Key Characteristics....2

- **Co-Product Produced from Waste Residue (Digestate) is Marketed as a Soil Amendment**
 - **CASP / IVC / or Open Windrow Composting Mechanisms**
- **Total Energy Requirements (100,000 Tons Feedstock Per Year)**
 - **No. 2 Diesel (ULSD) - Front End Loader, Windrow Turner**
 - **Grid Electricity - Process Equipment and Instrumentation**
 - **Natural Gas - Heat Digesters (No CHP)**
- **Product Yields**
 - **240 Million SCF RNG Per Year**
 - **50,000 Tons Finished Compost Per Year**
- **First of “Negative Carbon” Transportation Fuels in California**
 - **Synthesis of Carbon Intensity (CI) Value for RNG will be Discussed**

Feedstock and Biogas Yields

Suitable Feedstock for HSAD Process and Biogas Generating Potential

- Pre-Consumer Industrial Food Waste, Commercial Food Waste from Grocery Stores, Cafeterias (Institutional) and Restaurants
- Residential Food Waste When Collection and Diversion Programs Develop in Localities Across California
- May be Augmented with 5-10 Percent FOG, Soiled Paper
- Leaves, Grass, and Brush (Curbside Yard Waste)

Feedstock	Low (m ³ / mt), wet	High (m ³ / mt), wet	Model Average (m ³ / mt)
Food / Household Waste	135	361	215
Green Waste	63	118	90
FOG	790	1,658	612 (50%)
Mixed Paper	189	390	289

Motor Fuel (CNG)

California Specifications for Compressed Natural Gas Motor Fuel

- California Code of Regulations, Title 13, Division 3, Chapter 5, Article 3, Section 2292.5
- Minimum Methane (CH₄) Quality of 88 Percent
- Sum of CO₂ and N₂ Not to Exceed 1.5-4.5 Percent
- Sulfur Content Not to Exceed 16 ppm (vol)
- Other Requirements for Odorants and Impurities

Pipeline Quality Natural Gas

Typical Specifications for Biomethane Gas Delivery

- San Diego Air Pollution Control District (SDAPCD) Rule
- Rule 30 Biomethane Gas Delivery Specifications Limits and Action Levels
 - Higher Heating Value (HHV) Between 990-1,150 Btu / cf
 - Wobbe Number (WN) Between 1,279-1,385
 - CO₂ Content Not to Exceed 3 Percent
 - H₂S Limit of 0.25 gr / 100 scf (8 ppm, Mass Basis)
 - Must be Commercially Free of Siloxanes
 - Other Requirements for Total S, Vinyl Chloride, and Water Vapor

Biogas Purification, Compression, and Transmission

Transportation Fuel Requirements

- **State Requirement to Refine Biogas for it to be Sold as a Transportation Fuel**
- **Several CO₂ Removal Technologies Viable**
 - **Pressure Swing Adsorption (PSA)**
 - **Amine Scrubbing (MEA)**
 - **Water Scrubbing**
- **Impurities Such as H₂S, Siloxanes Must be Removed**
- **Most Biogas Purification Systems Produce Biomethane of Comparable Quality**
- **Product Gas Compression May be Required for Pipeline**
- **Meet Utility Company Specifications for Transmission to Grid**

Co-Product Production

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Soil Amendment / Fertilizer from Composting Digestate

- **The Digestate or Residue from Hydrolysis Unit of the HSAD Process is Composted to Produce Fertilizer (Co-Product)**
- **Three Common Composting Methods**
 - **Open Windrow Composting (OWC)**
 - **Covered Aerated Static Piles (CASP)**
 - **In Vessel Composting (IVC)**
- **District Requirements to Control VOC Emissions from Compost Piles, Applications of Biofilter**
 - **SJVUAPCD Rule 4566: Organic Material Composting Operations**
 - **SCAQMD Rule 1133: Composting and Related Operations**
- **Modeled Post-AD Finished Compost Yield of 50 Percent (With Bulking Agent)**

Estimated Fossil Fuel and Electrical Energy Use

Model HSAD Process

- **Annual Fuel Requirements for 100,000 TPY Model HSAD Process Include ULSD, Natural Gas, and Grid-Based Electricity**
 - **ULSD for Front-End Loader (Waste Loading and Composting), Windrow Turners, and Water Trucks**
 - **Natural Gas for Digester Heating Requirements (Parasitic)**
 - **Grid-Based Electricity for Process Equipment, Biogas Purification, Biomethane Compression and Transmission**

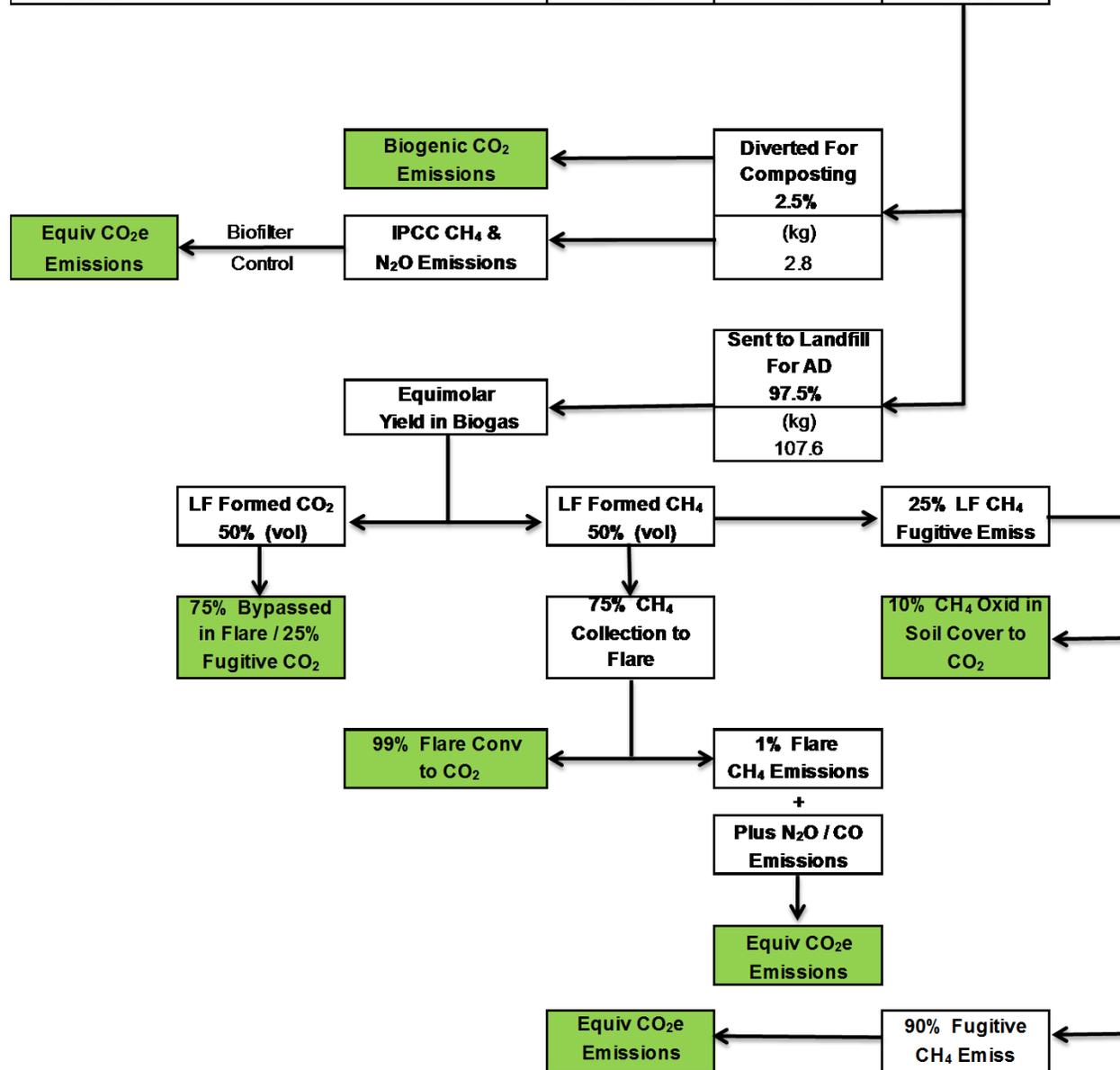
Pathway Unit	ULSD (gal)	Electricity (kWh)	Natural Gas (scf)
Wastes Loading	17,400	-	
AD Process	-	1,881,500	4,927,500
Biogas Purification	-	4,610,500	-
Composting (CASP/IVC)	18,240	164,000	-
Or Composting (OW)	54,500	-	-
TOTAL (Annual)	72,000 gallons	6.5 million kWh	5 million scf

Carbon Credits....1

Avoided Landfilling and Composting Emissions

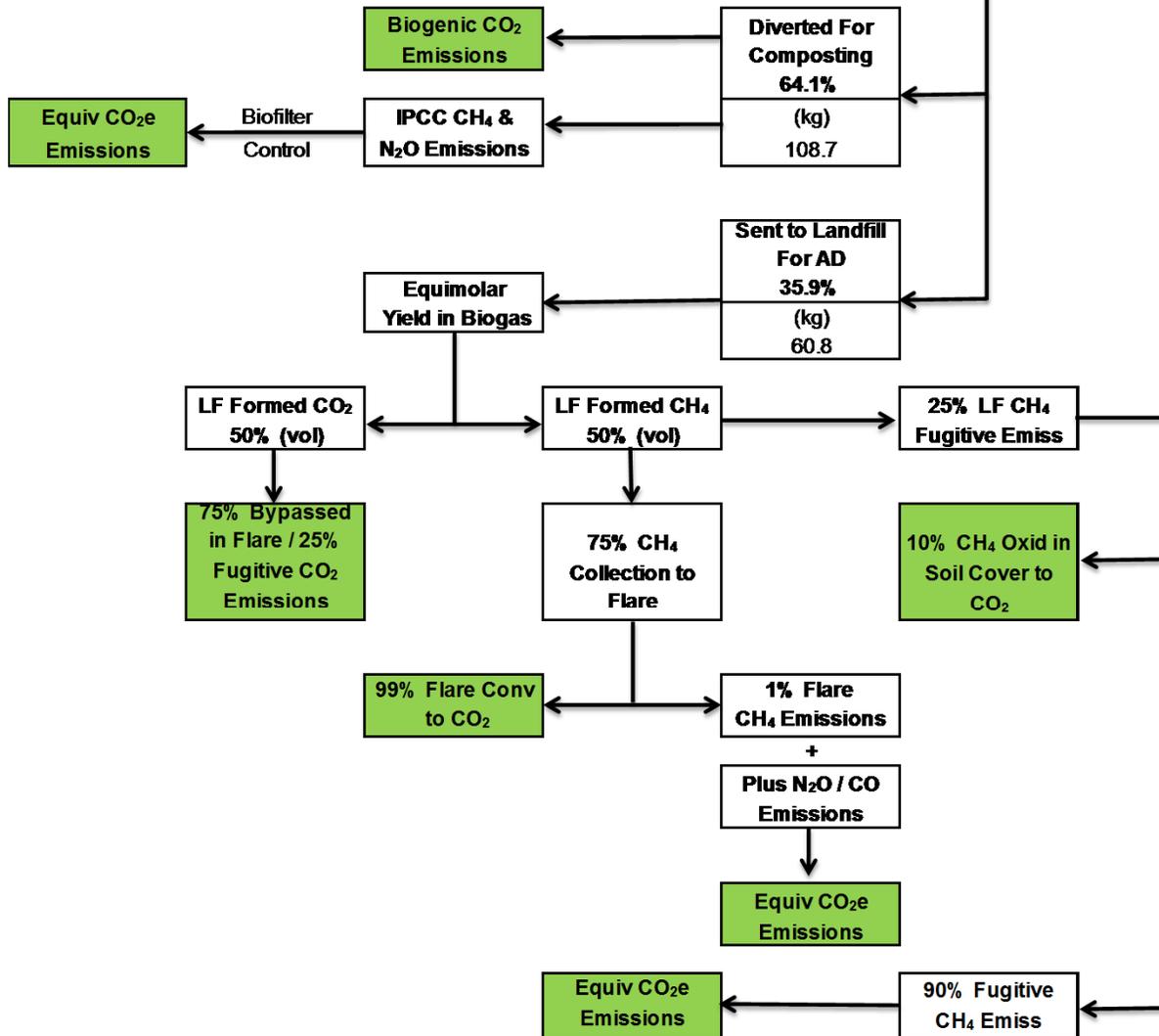
- Landfill Gas (LFG) to CNG / LNG LCFS Pathways Credit Avoided Flare Emissions from Collected LFG
- Diversion of Wastes to AD Facility Further Reduces Fugitive GHG Emissions (Uncollected LFG) Impact to Atmosphere
- Premise for Larger WTW Carbon Credit than Flaring LFG Alone
- Based on USEPA Studies:
 - 97 Percent of Food Waste Destined for Landfill
 - 36 Percent of Green Waste Destined for Landfill
 - 64 Percent of Green Waste Destined for Compost Facility
- LFG Collection Efficiency of 75 Percent (USEPA)
- Applicable Carbon Credits (Avoided CO₂, CH₄, and N₂O Emissions)
 - Food Waste: 776,000 g CO₂e / Metric Ton (Wet Basis)
 - Green Waste: 554,000 g CO₂e / Metric Ton (Wet Basis)

Basis: 1 Metric Ton Organic Wastes Feed (Wet Basis) (Diverted from Landfill)	Fraction Carbon 12.0%	Inactive Carbon 8.0%	Total Available Carbon 92.0%
(kg) 1000.0	(kg) 120.0	(kg) 9.6	(kg) 110.4



Credit Based on Fate of Carbon in Food Waste

Basis: 1 Metric Ton Organic Wastes Feed (Wet Basis) (Diverted from Landfill / Composting Facility)	Fraction Carbon 26.7%	Inactive Carbon 36.4%	Total Available Carbon 63.6%
(kg)	(kg)	(kg)	(kg)
1000.0	266.7	97.2	169.5



Credit Based on Fate of Carbon in Green Waste

Carbon Credits....2

LCFS Co-Product Credit for Displaced Synthetic Fertilizer

- **Fertilizer / Soil Amendment Produced from Composting of Digestate Qualifies for LCFS Co-Product Credit**
- **Examples of Other Co-Products**
 - **Spent Distillers Grain (Dry / Wet DGS) in Corn Ethanol Production**
 - **Glycerin from FAME Biodiesel Production Process**
 - **Electricity Cogenerated from Bagasse Combustion**
- **Co-Products Displace Energy and Emissions from Synthetically Manufactured Fertilizer**
- **Fertilizer Carbon Credit Based on Compost Emissions Reduction Factor (ARB) and Displacement Ratio**
 - **Staff Determined GHG Credit of 54,700 g CO₂e / Metric Ton Waste**

Recap of Operating Conditions

- **RNG Produced from High Solids (Dry) Anaerobic Digestion**
 - Mesophilic, Multi-Staged, Batch Process
- **Organic Waste Feedstock**
 - Food and Green Wastes in a 40:60 Proportion, May be Augmented With FOG / Soiled (Food Contaminated) Paper
 - Minimum 30,000 Tons Per Year Throughput
- **Grid-Based Electricity (California Marginal Mix) or Parasitic Generation**
- **Biogas Purification Technology**
 - Methane Capture and Recovery Efficiency of Pressure Swing Adsorption or Comparable Technology
- **Meet California Specifications for CNG Motor Fuel (CCR)**
- **Product Gas Discharge Pressure Less than 800 psig**
- **CASP / IVC / or Open Windrow Composting Mechanisms**
- **Employ Bio filters During Active Composting Phase**

RNG Fuel Carbon Intensity

Proposed CI Based on WTW Analysis

- Fuel Energy Based on 242 million scf RNG Produced Yearly
- Process Emissions from Fossil Fuel-Based Energy Consumption
- Totality of All Emissions Considered, Including Biogenic CO₂
- TTW Emissions from Combustion of RNG in HDV
- Applicable Carbon Credits (Avoided Emissions and Co-Product)
- Proposed RNG CI of -14.84 g CO₂e / MJ

Estimated Net Annual Biomethane Production	Fuel Energy Value	No. 2 Diesel Use	Grid Electricity Use	Natural Gas Use
242,776,257.75 scf / year	238,199,925.30 MJ / year	(gal / year)	(kWh / year)	(scf / year)
HSAD Process GHG Emissions	24,497,676,429.42 g CO ₂ e / year		6,491,985.09	4,927,428.53
HSAD Process Heat Loading Requirements	267,388,042.71 g CO ₂ e / year			
HSAD Compost GHG Emissions	14,706,483,259.80 g CO ₂ e / year			4,927,428.53
HSAD Wastes Loading Fossil Fuel Use & Emissions	174,566,466.15 g CO ₂ e / year	17,404.43		
HSAD Compost Fossil & Electric Fuel Use & Emissions	546,746,602.06 g CO ₂ e / year	54,511.12		
HSAD Plant Load & Composting Energy Use				
Total Fuel Cycle Electric Emissions:	2,457,710,906.40 g CO ₂ e / year			
Total No. 2 Diesel WTT Emissions:	197,919,953.52 g CO ₂ e / year			
Total HSAD Process Emissions	42,848,491,660.05 g CO ₂ e / year			
GHG Emissions from CNG Combustion in HDV (TTW)	13,726,092,811.35 g CO ₂ e / year			
Less Carbon Credit from "MODEL"	55,398,857,357.40 g CO ₂ e / year			
Less Compost Emissions Reduction Factor (CERF)	4,711,783,026.21 g CO ₂ e / year			
Net Annual GHG Emissions	(3,536,055,912.22) g CO₂e / year			
Proposed HSAD Pathway Carbon Intensity Value:	(14.84) g CO₂e / MJ	71,915.55	6,491,985.09	4,927,428.53

Additional Proposed Pathways

Related Pathways to be Considered for Development

- **High Solids Anaerobic Digestion of Food and Green Wastes for the Production of Liquefied Natural Gas (LNG)**
- **Wet Anaerobic Digestion of Municipal Wastewater Biosolids and Food Wastes for the Production of Renewable / Liquefied Natural Gas (RNG / LNG)**
- **Open to Suggestion**

Acknowledgements

LCFS HSAD Pathway Development Partners

- Harvest Power
- Zero Waste Energy
- Guild Associates
- CalRecycle
- EBMUD
- FOG Energy
- UC Davis
- Recology
- Edgar & Associates
- Planning & Technical Support Division (ARB)
- Stationary Source Division (ARB)



Air Resources Board

For More Information

- **LCFS LINK TO ARB PATHWAYS**

<http://www.arb.ca.gov/fuels/lcfs/workgroups/workgroups.htm#pathways>

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