Supporting Information for

CARBON FOOTPRINT AND ENERGY ANALYSIS OF BIO-CH_4 FROM A MIXTURE OF FOOD WASTE AND DAIRY MANURE IN DENVER, COLORADO

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Links to **Section-1**, **Section-2**, **and Section-3, Section-4:** in the S.I document.

Section-1:

AD Bio-CH_4 Pathway Calculations and Eco-profiles:

This part of the section gives the information on the calculations for the AD Bio-CH_4 Pathway (cradle to grave).AD Bio-CH_4 Pathway has different process operations involved which includes:

1. Eco-profile used for transportation is ‘Transport, freight, lorry 16-32 metric ton, EURO4 | market for | Alloc Def, S’
2. Eco-profile used for natural gas use in the AD process is ‘Heat, natural gas, at boiler condensing modulating >100kW/US- US-EI U’

This eco-profile (Table 1) was created in SimaPro to estimate the emissions from the combustion of Bio-CH_4. Stoichiometric emission factors for Bio-CH_4 are determined in Table 3.

Table 1. Eco profile for CH_4 emissions Bio-CH_4 Combustion (Basis 1kg Biogas)

Processes	Amount	Unit	Basis
Carbon Dioxide	44/16 = 2.75	kg	1 kg of Bio-CH_4

This eco-profile (Table 2) is created to estimate the CO_2 emissions from AD process

Table 2. Eco profile CO_2 Emissions from AD process (Basis 1kg Biogas)

Processes	Amount	Unit	Basis
Carbon Dioxide	1.23	kg	1 kg of Bio-CH_4 (.526 CO_2 kg per kg of 0.425 BioCH_4)

The densities used in the above mentioned eco-profiles are calculated depending on the biogas composition (on volume basis) [1]

Table 3. Density calculations:

Volume			M.W		Mass of Component	M.W*P*V/R*T	
Biogas	1	m^3			Normal Conditions	Units	
Methane	0.65	m^3	16	g/mol	P	1	atm
Carbon Dioxide	0.29	m^3	44	g/mol	T	298.15	K
H_2O	0.06	m^3	18	g/mol	R	82.057	cm^3*atm/K*Mol.

Mass of CH_4	0.000425	$g*m^3/cm^3$
	0.425092	kg
Mass of CO_2	0.000522	$g*m^3/cm^3$
	0.521555	kg
Mass of H_2O	4.41E-05	$g*m^3/cm^3$
	0.044144	kg
Total mass of biogas	0.990791	kg
Density of Biogas	0.990791	kg/m^3

A Colorado electricity grid was created in SimaPro to estimate the emissions from the consumption of electricity at the AD facility for both internal processes and for distribution of liquid digestate to local agricultural fields through pipelines.

Table 4. Eco-profile for the AD (Anaerobic Digestion) process electricity use is taken from "Colorado grid" Basis 1kWh Energy. Renewable is assumed to be equal portion of hydro, biomass, wind, and solar.

Processes	Amount	Unit
Electricity, natural gas, at power plant/US	0.22	kWh
Electricity, bituminous coal, at power plant/US	0.6	kWh
Electricity from hydroelectric power plant, AC, production mix, at power plant, < 1kV RER S	.18/4	kWh
Electricity, biomass, at power plant/US	.18/4	kWh
Electricity from wind power, AC, production mix, at wind turbine, < 1kV RER S	.18/4	kWh
Electricity, low voltage {RoW}| electricity production, photovoltaic, 3kWp facade installation, multi-Si, laminated, integrated | Alloc Def, S	.18/4	kWh

It is assumed that the compost produced from AD has a moisture content of 50% and 50% by dry weight elemental carbon. Only 48% of the carbon is active and emitted as CO_2 [2] . An eco-profile was created in SimaPro to determine these emissions.

Table 5. Eco-profile for CO_2 emissions from AD compost soil application: Basis 1kg wet compost

Processes	Amount	Unit	Basis
Carbon Dioxide	.48*.5*.5*44/12= 0.44	kg	1kg wet compost, 50% moisture, 50% elemental carbon, 48% active carbon [2]

The emission factor for N_2O from the application of liquid AD digestate to agricultural fields near LaSalle, CO is taken from the IPCC and includes both direct and indirect emissions [3].

Table 6. Liquid digestate N_2O emissions on field application: Basis 1kg N in liquid digestate

Processes	Amount	Unit	Basis
Dinitrogen Monoxide	0.01325*44/14= 0.04164	kg	IPCC factor for N_2O Emissions from Fertilizer land use. .01325 kg N in N_2O / N in digestate applied to soil. 44 is MW of N_2O, 14 is for N.

Landfill pathway eco-profiles:

This part of the section gives list of all the calculations and eco-profiles for the emissions from landfill for both steady-state case and transient scenario with gas collection, without gas collection and gas collection with electricity generation are listed below. References to the calculations described in section-2.

Table 7. Landfill Emissions without Gas Collection System (uncontrolled) steady state (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	79730.50024/365 /216.63 44397=1.01	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 79730.50024 tons for 1 year) (A+D in Table 32)
Methane	23721.47/365/21 6.6344397=0.29	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 23721.47 tons for 1 year) (E in Table 32)

Table 8. Landfill Emissions Gas Collection System (GCS) steady state (Basis: 1 kg of dry food waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	128112 /365/216.63443 =1.62	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 128112 tons for 1 year: (A+B+D in Table 31)
Methane	6128/365/216.63 44397 =0.077	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 6128 tons for 1 year) (C+E in Table 31)

Table 9. Landfill Emissions Gas Collection System and electricity generation (GCSE) steady state (Basis: 1 kg of dry food waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	128112 /365/216.6344 =1.62	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 128112 tons for 1 year: (A+B+D in Table 31)
Methane	6128/365/216.6 344397 =0.077	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 6128 tons for 1 year) (C+E in Table 31)

Electricity generation from Natural gas	104025/365= 287	MWh	104025 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 10. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 1 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	9015.890148/365 /216.6344397=0.114	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 9015.890148 tons for 1 year) (A+D in Table 32)
Methane	2682.413598/365 /216.6344397=0.034	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 2682.413598 tons for 1 year) (E in Table 32)

Table 11. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 5 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	35973.47396/365 /216.6344397=0.45	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 35973.47396 tons for 1 year) (A+D in Table 32)
Methane	10702.85176/365 /216.6344397=0.13	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 10702.85176 tons for 1 year) (E in Table 32)

Table 12. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 10 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	55716.13506/365 /216.6344397=0.704	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 55716.13506 tons for 1 year) (A+D in Table 32) (E in Table 32)
Methane	16576.70134/365 /216.6344397=0.21	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 16576.70134tons for 1 year)

Table 13. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 20 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	72497.51245/365 /216.6344397=0.91	kg	Daily Basis 216 tons of dry waste CO_2 (from section-2 calculations CO_2 emissions are 72497.51245tons for 1 year) (A+D in Table 32)
Methane	21569.50783/365 /216.6344397=0.27	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 21569.50783tons for 1 year) (E in Table 32)

Table 14. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 30 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	77551.96618 /365/216.6344397=0.98	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 77551.96618 tons for 1 year) (A+D in Table 32)
Methane	23073.31225/365 /216.6344397=0.29	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 23073.31225tons for 1 year) (E in Table 32)

Table 15. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 40 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	79074.33839/365 /216.6344397=1.000035	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 79074.33839 tons for 1 year) (A+D in Table 32)
Methane	23526.24944/365 /216.6344397=0.298	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 23526.24944 tons for 1 year) (E in Table 32)

Table 16. CH_4 and CO_2 emissions from landfill without gas collection (uncontrolled) year 50 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	79532.86809/365 /216.6344397=1.01	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 79532.86809 tons for 1 year) (A+D in Table 32)

Methane	23662.6715/365/ 216.6344397=0.299	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 23662.6715 tons for 1 year) (E in Table 32)

Table 17.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 1 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	14486.90/365/216.6344397= 0.1832	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 14486.90 tons for 1 year) (A+B+D in Table 31)
Methane	692.96/365/216.6344397= 0.00876	Kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 692.96 tons for 1 year) (C+E in Table 31)

Table 18.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 5 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	57802.83/365/216.6344397 = 0.731	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 57802.83 tons for 1 year) (A+B+D in Table 31)
Methane	2764.90/365/216.6344397 = 0.034967	Kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 2764.90 tons for 1 year) (C+E in Table 31)

Table 19.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 10 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	89525.70/365/216.6344397 = 1.13221	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 89525.70 tons for 1 year) (A+B+D in Table 31)
Methane	4282.31/365/216.6344397 = 0.054157	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 4282.31 tons for 1 year) (C+E in Table 31)

Table 20.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 20 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	116490.32/365/216.6344397 = 1.473226	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are

			116490.32tons for 1 year) (A+B+D in Table 31)
Methane	5572.12/365/216.6344397 = 0.0704693	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 5572.12 tons for 1 year) (C+E in Table 31)

Table 21.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 30 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	124611.91/365/216.6344397 = 1.575938	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 124611.91 tons for 1 year) (A+B+D in Table 31)
Methane	5960.61/365/216.6344397 = 0.075382	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 5960.61 tons for 1 year) (C+E in Table 31)

Table 22.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 40 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	127058.08/365/216.6344397 = 1.606874	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 127058.08 tons for 1 year) (A+B+D in Table 31)
Methane	6077.61/365/216.6344397 = 0.076862	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 6077.61 tons for 1 year) (C+E in Table 31)

Table 23.CH_4 and CO_2 emissions from landfill with gas collection and flaring year 50 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	127794.86/365/216.6344397 = 1.61619	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 127794.86tons for 1 year) (A+B+D in Table 31)
Methane	6112.86/365/216.6344397 = 0.0773	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 6112.86 tons for 1 year) (C+E in Table 31)

Table 24.CH_4 and CO_2 emissions from landfill with gas collection and electricity generation year 1 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	14486.90/365/216.6344397= 0.1832	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions

			are 14486.90 tons for 1 year) (A+B+D in Table 31)
Methane	692.96/365/216.6344397= 0.00876	Kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 692.96 tons for 1 year) (C+E in Table 31)

Electricity generation from Natural gas	104025/365= 287	MWh	11773.93 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 25. CH_4 and CO_2 emissions from landfill with gas collection and electricity year 5 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	57802.83/365/216.6344397 = 0.731	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 57802.83 tons for 1 year) (A+B+D in Table 31)
Methane	2764.90/365/216.6344397 = 0.034967	Kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 2764.90 tons for 1 year) (C+E in Table 31)

Electricity generation from Natural gas	104025/365= 287	MWh	46978.08 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 26. CH_4 and CO_2 emissions from landfill with gas collection and electricity year 10 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	89525.70/365/216.6344397 = 1.13221	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 89525.70 tons for 1 year) (A+B+D in Table 31)
Methane	4282.31/365/216.6344397 = 0.054157	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 4282.31 tons for 1 year) (C+E in Table 31)

Electricity generation from Natural gas	104025/365= 287	MWh	72760.19 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 27. CH_4 and CO_2 emissions from landfill with gas collection and electricity year 20 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	116490.32/365/216.6344397 = 1.473226	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 116490.32tons for 1 year) (A+B+D in Table 31)
Methane	5572.12/365/216.6344397 = 0.0704693	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 5572.12 tons for 1 year) (C+E in Table 31)
Electricity generation from Natural gas	104025/365= 287	MWh	94675.14 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 28. CH_4 and CO_2 emissions from landfill with gas collection and electricity year 30 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	124611.91/365/216.6344397 = 1.575938	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 124611.91 tons for 1 year) (A+B+D in Table 31)
Methane	5960.61/365/216.6344397 = 0.075382	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 5960.61 tons for 1 year) (C+E in Table 31)
Electricity generation from Natural gas	104025/365= 287	MWh	101275.80 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 29. CH_4 and CO_2 emissions from landfill with gas collection and electricity year 40 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	127058.08/365/216.6344397 = 1.606874	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 127058.08 tons for 1 year) (A+B+D in Table 31)
Methane	6077.61/365/216.6344397 = 0.076862	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 6077.61 tons for 1 year) (C+E in Table 31)

Electricity generation from Natural gas	104025/365= 287	MWh	103263.88 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Table 30.CH_4 and CO_2 emissions from landfill with gas collection and electricity year 50 (Basis: 1 kg of dry waste)

Processes	Amount	Unit	Comment
Carbon Dioxide	127794.86/365/ 216.6344397 = 1.61619	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CO_2 emissions are 127794.86tons for 1 year) (A+B+D in Table 31)
Methane	6112.86/365/21 6.6344397 = 0.0773	kg	Daily Basis 216 tons of dry waste (from section-2 calculations CH_4 emissions are 6112.86 tons for 1 year) (C+E in Table 31)

Electricity generation from Natural gas	104025/365= 287	MWh	103862.68 Mwh electricity is generated/year from collected CH_4 annually (see Table 46 for calculations)

Peat pathway:

This part of the section gives the information on calculations of Peat pathway emissions included in SimaPro. The calculations for the peat pathway emissions are based on the results of a study [4] and are considered as an eco-profile of CO_2 equivalent factor in each stage of overall lifecycle.

Table 31. Emissions from peat moss manufacturing, transport and use (Basis 1 m^3 peat-moss)

Category	Unit	Harvest	Package	Transport	Soil application	In-situ decomposition
GHG Emissions	kg CO_2 equivalent	4.03	2.53	15.63	183	60.79

Composting pathway:

This section gives the information on calculations of composting pathway emissions included in SimaPro.

Table 32. Eco-profile for composting decomposition emissions (CH_4 & N_2O). These factors are taken from IPCC biogenic report [3].

CH_4 emission factor for composting	0.004	kg CH_4/kg waste wet basis (From IPCC)
N_2O emission factor for composting	0.0003	kg N_2O/kg waste wet basis (From IPCC)

Table 33. Eco-profile for composting decomposition emissions (CO_2). This factor is taken from IPCC biogenic report [3].

CO_2 emission factor for composting	0.44	kg CO_2/kg dry solid waste (From IPCC)

Table 34. Eco-profile for CO_2 Emissions from Compost Land Application:

Processes	Amount	Unit	Basis
Carbon Dioxide	.48*.5*.5*44/12=0.44	kg	1kg wet compost, 50% moisture, 50% elemental carbon, 48% active carbon [2],

Table 35. Diesel Used in tractor for Heartland LCA Composting (Basis: 0.0435 kg diesel)

Processes	Amount	Unit	Comment
Diesel {Europe without Switzerland} market for | Alloc Def, S	0.00740066809700986	kg	From SimaPro Database
Diesel {RoW}| market for | Alloc Def, S	0.0361993319029901	kg	From SimaPro Database

Synthetic fertilizer pathway:

The eco-profile used for P fertilizer is Phosphate fertilizer, as P_2O_5 | market for | Alloc Def, S. The eco-profile used for K fertilizer is Potassium fertilizer, as K_2O | market for | Alloc Def, S.

Table 36. Eco-profile for US mix fertilizer is" US_Mix_ecoprofile" Basis 1kg Nitrogen Fertilizers, as N US Mix (Heartland Project), S

Processes	Amount	Unit	Comment
Ammonia, liquid | market for | Alloc Def, S	.308*17/14 =0.374	kg	.308 from Adom supplementary; 17/14 converts to N basis
Ammonia, liquid | market for | Alloc Def, S	.008*17/14 =0.0097	kg	.308 from Adom Supplementary for ammonia aqua; 17/14 converts to N basis
Ammonium nitrate, as N | market for | Alloc Def, S	0.038	kg	
Ammonium sulfate, as N | market for | Alloc Def, S	0.025	kg	
Urea, as N | market for | Alloc Def, S	0.166	kg	Nitrogen Solution Component
Ammonium nitrate, as N | market for | Alloc Def, S	0.132	kg	Nitrogen Solution Component
Potassium nitrate | market for | Alloc Def, S	0.0003	kg	for Sodium nitrate
Urea, as N | market for | Alloc Def, S	0.237	kg	

Urea, as N | market for | Alloc Def, S	0.086/3=0.0287	kg	0.086 is other fertilizers from liquid ammonia, ammonium nitrate, and urea
Ammonium nitrate, as N | market for | Alloc Def, S	0.086/3=0.0287	kg	0.086 is other fertilizers from liquid ammonia, ammonium nitrate, and urea
Ammonia, liquid | market for | Alloc Def, S	0.086/3=0.0287	kg	0.086 is other fertilizers from liquid ammonia, ammonium nitrate, and urea

Table 37. Emissions of N_2O from synthetic N fertilizer applied to Field: (Basis: 1kg synthetic N fertilizer)

Processes	Amount	Unit	Basis
Dinitrogen oxide	0.01325*44/14=0.042	kg	IPCC factor for N_2O Emissions from Fertilizer land use. .01325 kg N in N_2O / N in digestate applied to soil. 44 is MW of N_2O, 14 is for N.,

Manure pathway:

Table 38. Manure lagoon Emissions (N_2O, CH_4 and CO_2) (Basis: 1kg dry manure)

Processes	Amount	Unit	Comment
Carbon Dioxide	368/2284.73=0.161	kg	368 kg CH_4/hd/year for 2284.73 kg manure/hd/year [5]
Methane	687/2284.732824=0.301	kg	yearly 687 kg CH_4/hd for 2284.73 kg manure/hd/year [5]
Dinitrogen mono oxide	0.9/2284.732824=0.000394	kg	0.9 kg N_2O/hd/year for 2284.73 kg manure/hd/year [5]

Table 39. Manure slurry storage Emissions (N_2O, CH_4 and CO_2) (Basis: 1kg dry manure)

Processes	Amount	Unit	Comment
Methane	101/2284.73=.0442	kg	yearly 101 kg CH_4/hd for 2284.73 kg manure/hd/year [5]
Dinitrogen mono oxide	0.3/2284.73=0.000131	kg	0.3 kg N_2O/hd/year for 2284.73 kg manure/hd/year [5]

Table 40. Manure lagoon Emissions (N_2O, CH_4 and CO_2) (Basis: 1kg dry manure)

Processes	Amount	Unit	Comment
Carbon Dioxide	754/2284.73=0.161	kg	754 kg CH_4/hd/year for 2284.73 kg manure/hd/year [5]
Methane	13/2284.732824=0.00569	kg	yearly 13 kg CH_4/hd for 2284.73 kg manure/hd/year [5]
Dinitrogen mono oxide	1.1/2284.732824=0..000481	kg	1.1 kg N_2O/hd/year for 2284.73 kg manure/hd/year [5]

Natural gas pathway:

1. Eco-profile used for natural gas extraction, process and distribution is 'Heat, central or small-scale, natural gas {RoW}| market for heat, central or small-scale, natural gas | Alloc Def, S'

Table 41: Heartland Phase 1B Water Balance in AD Bio-CH_4 pathway.

Heartland Phase 1B Water Balance		
Digester Feed	Gallons per day	Total Solids
Total Manure	157,475	11.0%
Total Paunch	48,482	23.7%
Total FOG Substrate	98,953	27.9%
Total Non-FOG Substrate	67,992	30.3%
Total CWCWD Water	42,658	0.1%
Total Lagoon Water Recycle	61,000	1.5%
Total Centrate Recycle	44,000	2.1%
Total Condensate/Once-Thru Recycle	12,960	0.1%
	533,520	14.8%

Table 42: Calculation for Heartland biogas Project daily feedstock on Dry Mass Basis

Wx1	48482	gallons
density	8	lb/gallon
solid fraction	0.237	
	0.000453592	Mg/lb
Total Paunch	41.69502576	Mg (dry basis)
Wx2	98953	gallons
density	8	lb/gallon
solid fraction	0.279	
	0.000453592	Mg/lb
Total fog Substrate	100.1817334	Mg (dry basis)
Wx3	67992	
density	8	lb/gallon
solid fraction	0.303	
	0.000453592	Mg/lb
Total non-fog substrate	74.75768049	Mg (dry basis)
Total Wx	216.6344397	Mg (dry basis)

Table 42a: Calculation for Carbon, CH_4, CO_2 potential in landfill

MCF	1	Generally, 1 for managed landfills
DOC	0.5	We assume, on dry basis food waste is 50% C so DOC is 0.5.
DOCF	1	We assume all the Carbon in the food waste is metabolized in the landfill by bacteria so DOCF is 1.
F	0.5	Generally assumed to be 0.5
M'=MCF*DOC*DOCF*F	0.25	Mg C / Mg waste (dry basis)
L'=M'*16/12	0.333333333	Mg CH4 / Mg waste (dry basis)
K'=M'*44/12	0.916666667	Mg CO2 / Mg waste (dry basis)
M=M'*Total W_x	54.15860	Mg C / day (dry basis)
L =L'*Total W_x	72.2114799	Mg CH4 / day (dry basis)
K=K'*Total W_x	198.5815697	Mg CO2 / day (dry basis)

M =Rate of food waste C (carbon) input to Landfill (Mg C /Mg waste)

M' = C generation potential factor (Mg C/Mg waste)

L' = CH_4 generation potential factor (Mg CH_4/Mg waste)

K'=CO_2 generation potential factor (Mg CO_2/Mg waste)

MCF = CH4 correction factor (fraction), typically 1 for managed landfills

DOC = degradable organic carbon [fraction (Mg C in waste/Mg waste)]

DOCF = fraction of DOC decomposed (fraction),

F = fraction by volume of CH4 in landfill gas

Section-2

Section-2 gives information on calculation of landfill emissions in both steady state and time-dependent state of two scenarios with uncontrolled and gas collection and flaring landfill systems.

1. Model derivation for the transient calculations of landfill anaerobic digestion (AD) emissions:

Carbon input rate to the landfill from food waste = a constant M [Metric tons carbon / Year] (refer table 42a) in an amount equal to the annual input of Denver food waste to the LaSalle AD facility.

Amount of carbon depending on time = $\frac{d\mu}{dt}$, where μ is the amount of food waste carbon in the landfill at any time.

Degradation rate for carbon in landfill follows first order kinetics = kμ, where k/ is a first order degradation constant [yr^{-1}]. k=0.12 /yr. [3]

Carbon Balance on food waste transient emissions from a landfill:

(Rate of accumulation of carbon in landfill) = (rate of carbon input) – (rate of degradation of carbon by AD)

$\frac{d\mu}{dt} = M - k\mu$ => $\frac{d\mu}{dt} + k\mu = M$

Which is in the form of $\frac{dy}{dx} + p(x)y(x) = Q(x)$

The solution for y(x) for such an equation is given by $y(x) = e^{-\int pdx}(\int e^{\int pdx}Q(x)dx + C)$

So the solution for $\mu(t)$ is $\mu(t) = e^{-\int kdt}(\int e^{\int kdt}M\,dt + C)$

$\mu(t) = e^{-kt}(\int e^{kt}M\,dt + C)$ => $\mu(t) = e^{-kt}(\frac{e^{kt}}{k}M + C)$

Then $\mu(t)$ can be modified as $\mu(t) = \frac{1}{k}M + C\,e^{-kt}$

When t=0, the amount of food waste carbon in the landfill is zero, $\mu(t) = 0$, then the expression becomes $0 = \frac{1}{k}M + C$

Which gives for the integration constant, C= -$\frac{1}{k}M$

Then the expression for $\mu(t) = \frac{1}{k}M - \frac{1}{k}M\ e^{-kt}$

$$\mu(t) = \frac{1}{k}M(1 - e^{-kt})$$

The avoided carbon emissions from time dependent landfill are $k\mu$

$$= M(1 - e^{-kt})$$

The avoided CH_4 emissions from time-dependent landfill if 50% of food waste carbon is converted through AD to CH_4 is given by

$$= M/2(1 - e^{-kt}) * 16/12$$

The avoided CO_2 emissions from time-dependent landfill if 50% of food waste carbon is converted through AD to CO_2 is given by

$$= M/2(1 - e^{-kt}) * 44/12$$

Steady-state emissions occur when time goes to infinity, in which case the term e^{-kt} becomes zero and therefore steady-state CH_4 emissions are M/2 * 16/12 and for CO_2 steady-state emissions are M/2 * 44/12. Figures 1 & 2 flow diagram shows the landfill CO_2 and CH_4 generation and emission scenarios for both uncontrolled and controlled landfill systems.

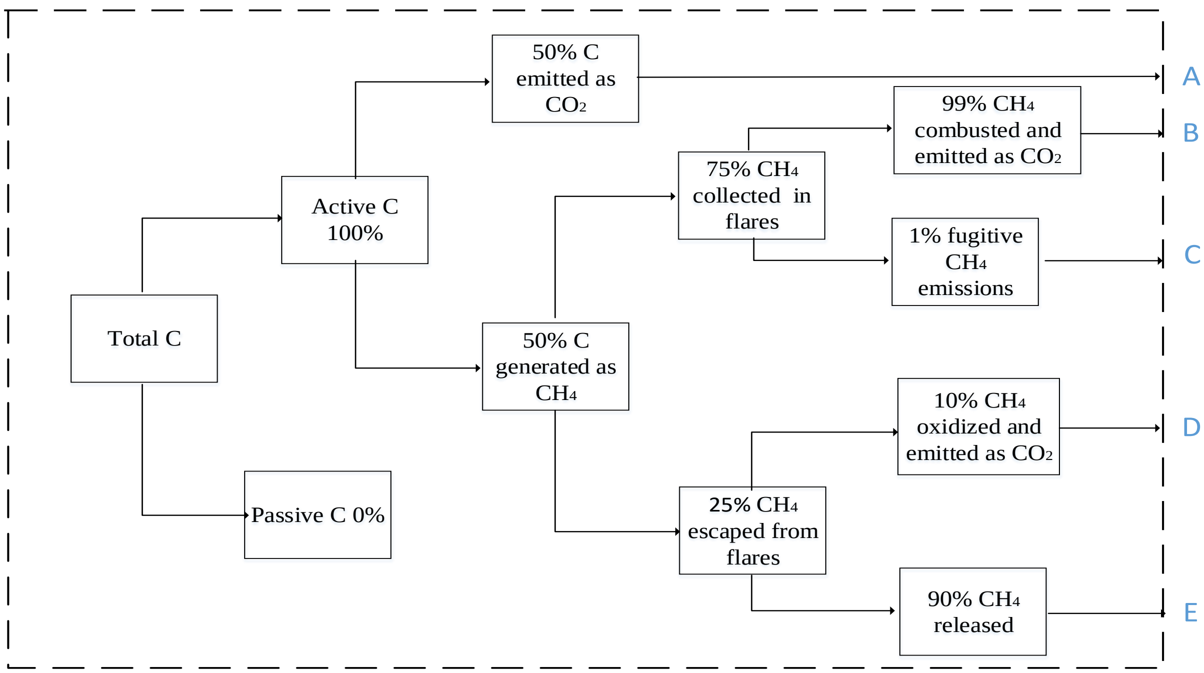

Figure 1: Flow diagram of landfill emissions with gas collection system and flaring

Table 43. Landfill emissions with gas collection system and flaring

Pathway(landfill gas collection and flaring)	A (Mg CO_2/ year)	B (Mg CO_2/ year)	C (Mg CH_4/ year)	D (Mg CO_2/ year)	E (Mg CH_4/ year)
Year1	8196.2	6085.7	22.3	204.9	670.6
Year5	32703.1	24282.0	89.1	817.5	2675.7
Year10	50651	37608.3	138.1	1266.2	4144.1
Year20	65906.8	48935.8	179.7	1647.6	5392.3
Year30	70501.7	52347.5	192.2	1762.5	5768.3
Year40	71885.7	53375.1	196.0	1797.1	5881.5
Year50	72302.6	53684.6	197.1	1807.5	5915.6
Steady state	72482.2	53818	197.6	1812.0	5930.3

99% of the collected methane is used to produce the electricity so the collected methane is B1 in the Table 44

Table 44. Landfill emissions with gas collection system and electricity generation

Pathway(landfill gas collection and flaring)	A (Mg CO_2/ year)	B1 (Mg CH_4/ year) for electricity	C (Mg CH_4/ year) Fugitive emissions	D (Mg CO_2/ year)	E (Mg CH_4/ year) oxidation emissions
Year1	8196.2	2212.99	22.3	204.9	670.6
Year5	32703.1	8829.85	89.1	817.5	2675.7
Year10	50651	13675.78	138.1	1266.2	4144.1
Year20	65906.8	17794.84	179.7	1647.6	5392.3
Year30	70501.7	19035.48	192.2	1762.5	5768.3
Year40	71885.7	19409.16	196.0	1797.1	5881.5
Year50	72302.6	19521.70	197.1	1807.5	5915.6
Steady state	72482.2	19767.89	197.6	1812.0	5930.3

Electricity generation is calculated based on the efficiency of IC engine, which is assumed 35% efficient and the heating value of methane is 37 MJ/m^3 with density 0.656 kg/m^3 and Calculation for the electricity generation with collected methane in landfill for case 2 scenario 3:

Table 45. Calculation for electricity generation from a Landfill with gas collection system and electricity generation

Heating Value of CH_4	37	MJ/m^3
Density of CH_4	0.656	kg/m^3
Efficiency of I.C engines	0.35	35% efficient in general
joule	0.00027	wh
Electricity produced	0.00532	Mwh/kg CH_4

Table 46. Year wise electricity generation from a Landfill with gas collection system and electricity generation.

Pathway (landfill gas collection and electricity generation)	B1 (Mg CH_4/ year) for electricity	Electricity produced in Mwh /year
Year1	2212.99	2212.99*0.00532*1000 =11773.93
Year5	8829.85	8829.85*0.00532*1000 =46978.08
Year10	13675.78	13675.78*0.00532*1000 =72760.19
Year20	17794.84	17794.84*0.0053*1000

		=94675.14
Year30	19035.48	19035.48*0.00532*1000 =101275.80
Year40	19409.16	19409.16*0.00532*1000 =103263.88
Year50	19521.70	19521.70*0.00532*1000 =103862.68
Steady state	19767.89	19767.89*0.00532*1000 =104025

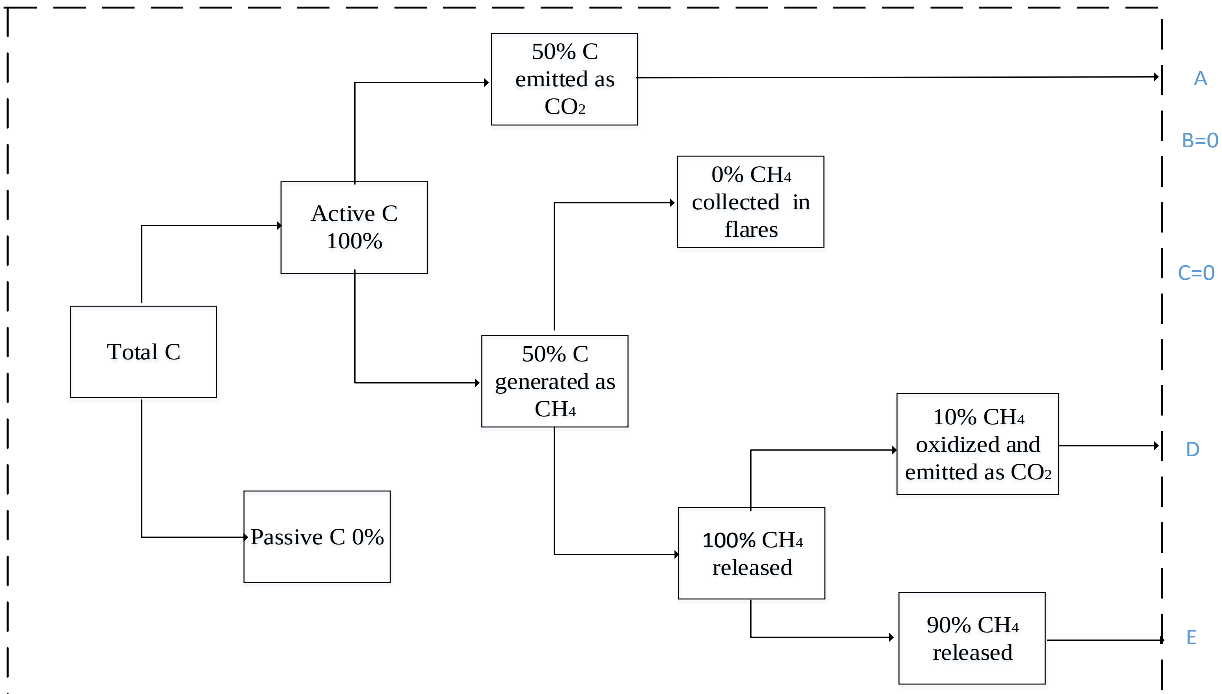

Figure 2: Flow diagram of Landfill emissions without gas collection system

Table 47. Landfill emissions without gas collection system

Pathway (uncontrolled landfill system)	A (Mg CO_2/ year)	D (Mg CO_2/ year)	E (Mg CH_4/ year)
Year1	8196.2	819.6	2682.4
Year5	32703.1	3270.3	10702.8
Year10	50651.0	5065.1	12174.9
Year20	65906.8	6590.6	21569.5
Year30	70501.7	7050.1	23073.3
Year40	71885.7	7188.5	23526.2
Year50	72302.6	7230.2	23662.6
Steady state	72482.2	7248.2	23721.4

Section-3

Section-3 gives more information on calculations of inputs to the analysis in SimaPro. The inputs for the AD Bio-CH_4 pathway shown in Table 48 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 1-6, 41.

Table 48 Case 1: AD Bio-CH_4 pathway:

All the input data for AD Bio-CH_4 pathway provided by Jim Potter, Ag Energy LLC.

Pathway	Process	Amount	Unit	Comment
AD Bio-CH_4 pathway	1.Manure transportation	114000*8/2.205/ 1000*7*1.62 = $4.69 x 10^3$	t*km	7 miles distance from farm to facility (A total manure transported is 114,000 gallons/day, assumed 8lb/gallon as density of substrate)
		114000*8/2.205/ 1000*7*1.62*0.8 =$3.75 x 10^3$	t*km	Return trip is empty, the truck uses 80% of the fuel
	2.Food waste transportation	200000*8/2.205/ 1000*49*1.62 = $5.76 x 10^4$	t*km	49 miles distance from Denver to AD facility (total food waste transported from Denver is 200,000 gallons, assumed 8lb/gallon as density of substrate)
		200000*8/2.205/ 1000*49*1.62*0.8 =$4.61 x 10^4$	t*km	Return trip is empty, the truck uses 80% of the fuel
	3.AD process; electricity and heating of inlet food waste and manure	5.5*24 = 132	MWh	AD facility used 5.5 MW line, Colorado grid eco-profile used (provided in Table 4)
		533520*8*1*(125-50) = $3.2 x 10^8$	btu	Natural gas emissions: 533520 gallons/day in section 1 table 41. (Phase 1B Water balance), 8 lb. / gallons, 1 btu / (lb. F). 125 F for AD temp. 50 F for Colorado Average
	4.Bio-CH_4 Combustion	4700*1054.8/50= 99151.2	kg	4700dekatherms,1054.8MJ/dekatherm, Lower heating value 50MJ/kg (Biogas composition 65% CH_4, 29% CO_2, 6% H_2O by volume).

				Eco profile listed in Table 1 is used.
	5. CO_2 Emissions from AD	4700*1054.8/50= 99151.2	kg	4700dekatherms,1054.8MJ/dekatherm, Lower heating value 50MJ/kg (Biogas composition 65% CH_4, 29% CO_2, 6% H_2O by volume). Eco profile listed in Table 1 is used.
	5. Transportation of compost from AD to Denver	244.66*500*49*1.62/1000=9.71 x10^3	t*km	320 cu.yd. of compost is transported from AD facility to Denver market. Density-500 kg/m^3. Denver city 49 miles away from AD facility.
		.8*244.66*500*49*1.62/1000=7.77 x10^3	t*km	From Facility to Denver 80% of the fuel consumed on offload truck
	6. Digestate land application of N	217*23.74 = 5.15 x10^3	lb.	217000 gallons/day digestate 23.74lb N content as N fertilizer/1000 gallons digestate, which emits as N_2O on land application (N_2O emission factor of 0.01325 is used) Eco profile listed in Table 6 is used [3]
	7. Compost field application	320*500*0.76455 = 1.22 x10^5	kg	320 cubic yards of solid compost, 500 kg/m^3 density, 0.764555 m^3/cubic yard Eco profile listed in Table 5 is used.

The inputs for the BAU peat pathway shown in Table 49 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Table 31.

Table 49 Case 1: Peat pathway:

Pathway	**Process**	**Amount**	**Unit**	**Comment**
Peat pathway	1.Emissions from peat moss manufacturing, transport and use	790.63-244.66=546	m^3	320 cu. yd. of compost from AD, 790.63 cu. meter. of compost from composting process. Difference of 546 m^3 is replaced by Peat-Moss, conversion factor= 218/500

				[4]. Eco profile listed in Table 31 is used.
	2. Transportation of Peat-Moss from Canada to Denver	546*218*1200/1000=1.43 x 10^5	t*km	1200 km from Saskatchewan to Denver city, Peat transported from Saskatchewan to Denver market. Density - 218 kg/m^3 ,
		.8*546*218*1200/1000=1.14 x 10^5	t*km	Return trip is empty, the truck uses 80% of the fuel

The inputs for the BAU compost pathway shown in Table 50 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 32-35.

Table 50 Case 1: BAU composting pathway:

Pathway	Process	Amount	Unit	Comment
Composting pathway	1.Manure transportation	62/(1-0.85)*7*1.62=4.6 x 10^3	t*km	62Mg of dry manure transported from 7 miles (1.62 km/mile)) 85% moisture
		.8*62/(1-0.85)*7*1.62=3.73 x 10^3	t*km	On empty return trip, 80% of fuel is used.
	2.Wood pallets transportation	44.26*5 = 221.3	t*km	44.26 Mg of pallets transported from 5 km distance from composting facility
		0.8*44.26*5 = 177	t*km	On empty return trip 80% of fuel is used.
	3.Food waste transportation	216/(1-.7)*70*1.62 = 8.11 x 10^4	t*km	216 of food waste transported from 70 miles, 70% moisture content
		0.8*216/(1-.7)*70*1.62=6.49 x 10^4	t*km	On empty return trip 80% of fuel is used.
		5909.4*0.832 = 4.92 x 10^3	kg	5909.4 liters of diesel is used by process equipment

	4.Diesel used in tractor for composting			and petroleum diesel has a density of 0.832 kg/liter [5] Eco profile listed in Table 35 is used
		20.2*0.832=16.8	kg	Diesel used by turner [5] Eco profile listed in Table 35 is used
		713.8*0.832=594	kg	Diesel used for grinding [5] Eco profile listed in Table 35 is used
	5.Composting decomposition emissions (CO_2)	322.94	ton	Decomposition emissions from feedstock 1. Food waste -216 Mg 2. pallets- 44.26 Mg 3.manure 62 on dry basis manure 413.675904 on wet basis (15% solids) Eco profile listed in Table 33 is used [3]
	6.Composting decomposition emissions (CH_4&N_2O)	1180.05	ton	Decomposition emissions from feedstock 1.biowaste- 722.1103 Mg 2.pallets- 44.26 Mg (Supporting docs) 3.manure- 413.675904 on wet basis Eco profile listed in Table 32 is used [3]
	7.Compost land application	1180*.335= 395.3	ton	33.5% of initial feedstock is converted to compost, a total of 1180 tons of feedstock [6] Eco profile listed in Table 34 is used.

The inputs for the BAU synthetic fertilizer pathway shown in Table 51 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 36, 37.

Table 51 Case 1: BAU synthetic fertilizer pathway:

Pathway	Process	Amount	Unit	Comment
Synthetic fertilizer pathway	1.Emissions from synthetic fertilizers manufacturing process and market	217000/1000*23.74=5.15 x10^3	lb.	This N fertilizer is amount that would be displaced by digestate. Ammonium-N (lb/1000/gal)
		217000/1000*7.63=1.66 x10^3	lb.	This N fertilizer is amount that would be displaced by digestate. Eco profile used: Phosphate fertiliser, as P_2O_5 | market for | Alloc Def, S
		217000/1000*29.55=6.41 x10^3	lb.	This N fertilizer is amount that would be displaced by digestate. Eco profile used: Potassium fertiliser, as K_2O | market for | Alloc Def, S
	2. Transportation of synthetic fertilizers from LaSalle market to fields	13200*0.000453592*7.5=44.9	t*km	7 miles from LaSalle market to farm lands, 217000/1000*29.55+217000/1000*7.63+217000/1000*23.74=13200 0.000453592 Metric tons/lb. 4.7 miles = 7.5 km
		.8*13200*0.000453592*7.5=35.9	t*km	Return trip is empty, the truck uses 80% of the fuel
	3. Synthetic fertilizers land application	217*23.74 = 5.15 x10^3	lb.	217000 gallons/day digestate 23.74lb N content as N fertilizer/1000 gallons digestate, which emits as N_2O on land application (N_2O emission factor of 0.01325 is used) Eco profile listed in Table 37 is used.[3]

The inputs for the BAU natural gas pathway shown in Table 52 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1.

Table 52 Case 1: BAU natural gas pathway:

Pathway	Process	Amount	Unit	Comment
Natural gas pathway	1.Emissions from natural gas extraction processing, distribution and usage	4700*1055.06*.8=3.97 x10^6	kg	4700 dekatherms/ day 1055.06 MJ/Dekatherm. 0.8 is heat conversion efficiency.

The inputs for the avoided landfill without gas collection system (uncontrolled) pathway shown in Table 53 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs are shown in Section 1 in Tables 7,10-16

Case 2: Avoided pathways to AD Bio-CH_4 pathway:

Table 53 Avoided landfill pathway without gas collection system(uncontrolled)

Avoided	Process	Amount	Unit	Comment
Landfill pathway with gas collection and flaring	1.Transportation of food waste	216.6*2*12*1.62=8.42 x10^3	t*km	216.6 Mg dry basis, 2 is for 50% moisture, 12miles up, 1.62 km/mi
		.8*216.6*2*12*1.62=6.74 x10^3	t*km	Return trip is empty, the truck uses 80% of the fuel
	2. CH_4 and CO_2 emissions from landfill without gas collection and flaring	216.6344	tons	Total Dry mass 216.63444 which accounts the emissions Eco profile listed in Table 7,10-16 is used

The inputs for the avoided landfill with gas collection and flaring pathway shown in Table 54 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 8, 17-23.

Table 54 Avoided landfill pathway with gas collection system and flaring

Avoided	Process	Amount	Unit	Comment
Landfill pathway with gas collection and flaring	1.Transportation of food waste	216.6*2*12*1.62=8.42 x10^3	t*km	216.6 Mg dry basis, 2 is for 50% moisture, 12miles up, 1.62 km/mile
		.8*216.6*2*12*1.62=6.74 x10^3	t*km	Return trip is empty, the truck uses 80% of the fuel
	2. CH_4 and CO_2 emissions from	216.6344	tons	Total Dry mass 216.63444 which accounts the

	landfill with gas collection and flaring			emissions Eco profile listed in Tables 8,17-23 is used

The inputs for the avoided landfill with gas collection and electricity generation pathway shown in Table 55 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 9, 24-30.

Table 55 Avoided landfill pathway with gas collection system and electricity generation

Avoided	Process	Amount	Unit	Comment
Landfill pathway with gas collection and electricity generation	1.Transportation of food waste	216.6*2*12*1.62=8.42 x10^3	t*km	216.6 Mg dry basis, 2 is for 50% moisture, 12miles up, 1.62 km/mile
		.8*216.6*2*12*1.62=6.74 x10^3	t*km	Return trip is empty, the truck uses 80% of the fuel
	2. CH_4 and CO_2 emissions from landfill with gas collection and electricity generation	216.6344	tons	Total Dry mass 216.63444 which accounts the emissions Eco profile listed in Tables 9,24-30 is used
	3. Electricity generation from Natural gas	Varies over time	Mwh	Total electricity generated over 50 years starting from year 1 till the steady state is listed from Tables 9,24-30

The inputs for the avoided synthetic fertilizer pathway shown in Table 55 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 36, 37.

Table 56 Avoided synthetic fertilizer pathway

Avoided	Process	Amount	Unit	Comment
Synthetic fertilizer pathway	1.Emissions from synthetic fertilizers manufacturing process and market	217000/1000*23.74=5.15 x10^3	lb.	This N fertilizer is amount that would be displaced by digestate. Eco profile used: Nitrogen Fertilizers, as N US Mix (Heartland Project), S in Table 36
		217000/1000*7.63=1.66 x10^3	lb.	This N fertilizer is amount that would be displaced by digestate.

				Eco profile used: Phosphate fertiliser, as P_2O_5 | market for | Alloc Def, S
		217000/1000*29.55=6.41 x10^3	lb.	This N fertilizer is amount that would be displaced by digestate. Eco profile used: Potassium fertiliser, as K_2O | market for | Alloc Def, S
	2. Transportation of synthetic fertilizers from LaSalle market to fields	13200*0.000453592*7.5=44.9	t*km	4.7 miles from LaSalle market to farm lands, 217000/1000*29.55+217000/1000*7.63+217000/1000*23.74=13200; 0.000453592 Metric tons/lb.; 4.7 miles = 7.5 km;
		.8*13200*0.000453592*7.5=35.9	t*km	Return trip is empty, the truck uses 80% of the fuel

The inputs for the avoided peat pathway shown in Table 57 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Table 31.

Table 57 Avoided peat pathway

Avoided	**Process**	**Amount**	**Unit**	**Comment**
Peat pathway	1.Emissions from peat moss manufacturing, transport and use	244.66	m^3	320 cu. yd. of compost from AD, Which displaces the equivalent peat production on volume basis of peat to compost assumed 1:1[6] Eco profile listed in Table 31 is used
	2. Transportation of Peat-Moss from Canada to Denver	244.66*218*1200/1000=6.4 x10^4	t*km	1200 km from Saskatchewan to Denver city, Peat transported from Saskatchewan to Denver market. 218 kg/m^3 ,
		.8*244.66*218*1200/1000= 5.12 x10^4	t*km	Return trip is empty, the truck uses 80% of the fuel

The inputs for the avoided manure pathway shown in Table 58 along with comments on the assumptions, conversion factors, and other values. Eco-profiles for each of these inputs shown in Section 1 in Tables 38-40.

Table 58 Avoided manure pathway

Avoided	**Process**	**Amount**	**Unit**	**Comment**
Manure pathway	1.Anaerobic lagoon storage emissions	62.05*.65= 40.3	tons	62.05 metric tons of manure stored in lagoons daily if not transported to AD- 65% of dry mass diverted to lagoon [5]. Eco profile listed in Table 38 is used
	2.Slurry storage emissions	62.05*.1= 6.21	tons	62.05 tons of manure stored in slurries if not transported to AD facility 5-10 of dry mass % is sent to slurry tank Eco profile listed in Table 39 is used
	3.Solid pile emissions	62.05*.25= 15.5	tons	62.05 tons of manure stored in slurries if not transported to AD facility 25% in Colorado the manure sent to solid pile [5]. Eco profile listed in Table 40 is used

Section-4

Table 59: Calculation of overall nationwide resource assessment on diversion of food waste and manure to Bio-CH_4 system.

99.15	tons Bio-CH4/216 tons of dry food waste	
From Jim Potter Heartland biogas data:		
4700	Dekatherms Bio-CH_4 / 278 tons of dry food waste and manure	
1054.8	MJ/Dekatherm	
4957560	MJ Bio-CH_4/216 tons dry food waste and 62 tons of manure.	
Natural gas calculation:		
47.4	MJ/kg	Lower Heating Value
1000	kg/ton	
105.17	tons Natural gas eq./ 278 tons of dry food waste & manure	
4.03	Million metric tons of natural gas eq. / 8.28 million tons of dry food waste (36 million tons food waste /year in US 2015, 23% solids blended with 2.38 million tons of dry manure)	
Total Natural gas consumption	27,457,587	million cubic feet/year in US (2015 EPA)
0.044	lb/ft3	
1,208,133.83	Million lb/year	
548.0	million metric tons/year	
0.0074	Ratio of eq. Natural gas produced through Bio-CH_4 to US Natural Gas demand on equal energy basis	
0.74	% of total consumption displaced by food waste and manure through AD process.	

Calculation for estimating GHG emission savings nationwide in US:

On diversion of food waste from uncontrolled landfill saves 17.76 kg CO_2 eq./kg Bio-CH_4 and avoiding gas collection and flaring landfills saves 5.49 kg CO_2 eq./ kg Bio-CH_4

There are a total of 1908 landfills in the US under operation, out of which 400 are uncontrolled and 850 with gas collection and flaring, rest gas collection and electricity generation with a savings of 3.51 CO_2 eq. /kg Bio-CH_4

So overall savings are $= \frac{400*17.76+850*5.49+658*3.51}{400+850+658} = 7.37$ kg CO_2 eq. / kg of Bio-CH_4

8.28 million tons of dry food waste and 2.38 million tons of dry manure produces 3.8 million tons of Bio- CH_4. 3.8 million tons saves 7.37*3.8 million tons of CO_2=28.01 million tons of CO_2

There are about an overall 7 billion tons of CO_2 eq. in US and the savings from AD (Anaerobic digestion) on diverting the food waste and manure from landfills and manure piles would account for a savings of 0.41 % of overall GHG emissions.

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