Compost and Anaerobic Digestion Process Modeling

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Objectives of Composting and AD

- Growing interest in diverting food waste from landfills.
- Food waste is the most discarded material in MSW.
- Food waste decays rapidly compared to other materials and therefore generates a significant fraction of methane prior to gas collection at landfills.
- Some food wastes contain significant quantities of N and P that can be recovered and returned to soil.

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Biodegradable Materials

MSW

- Yard waste (grass, leaves, branches)
  - Paper bags, biodegradable plastic bags
- food waste
- soiled paper (paper towels, tissues)

Additional Compostables

- sewage sludge (biosolids)
- special wastes
  - agricultural
  - food processing industry
    - seafood, vegetable canning, brewery, etc.

Feedstock purity affects everything from pre/post screening, emissions, potential markets, and benefits

Feedstock mix must account for moisture, C, N, and free air space

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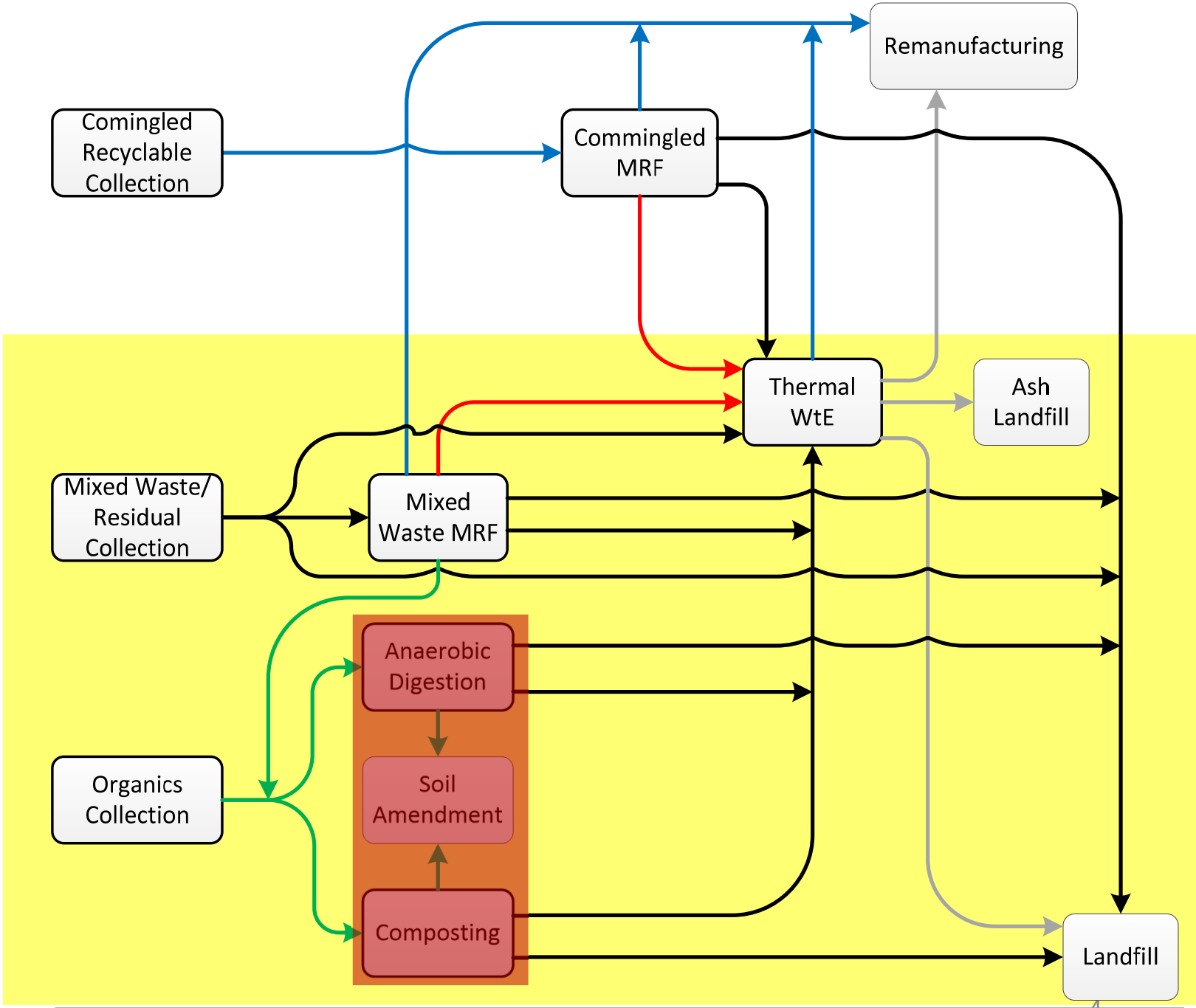
Solid Waste Systems



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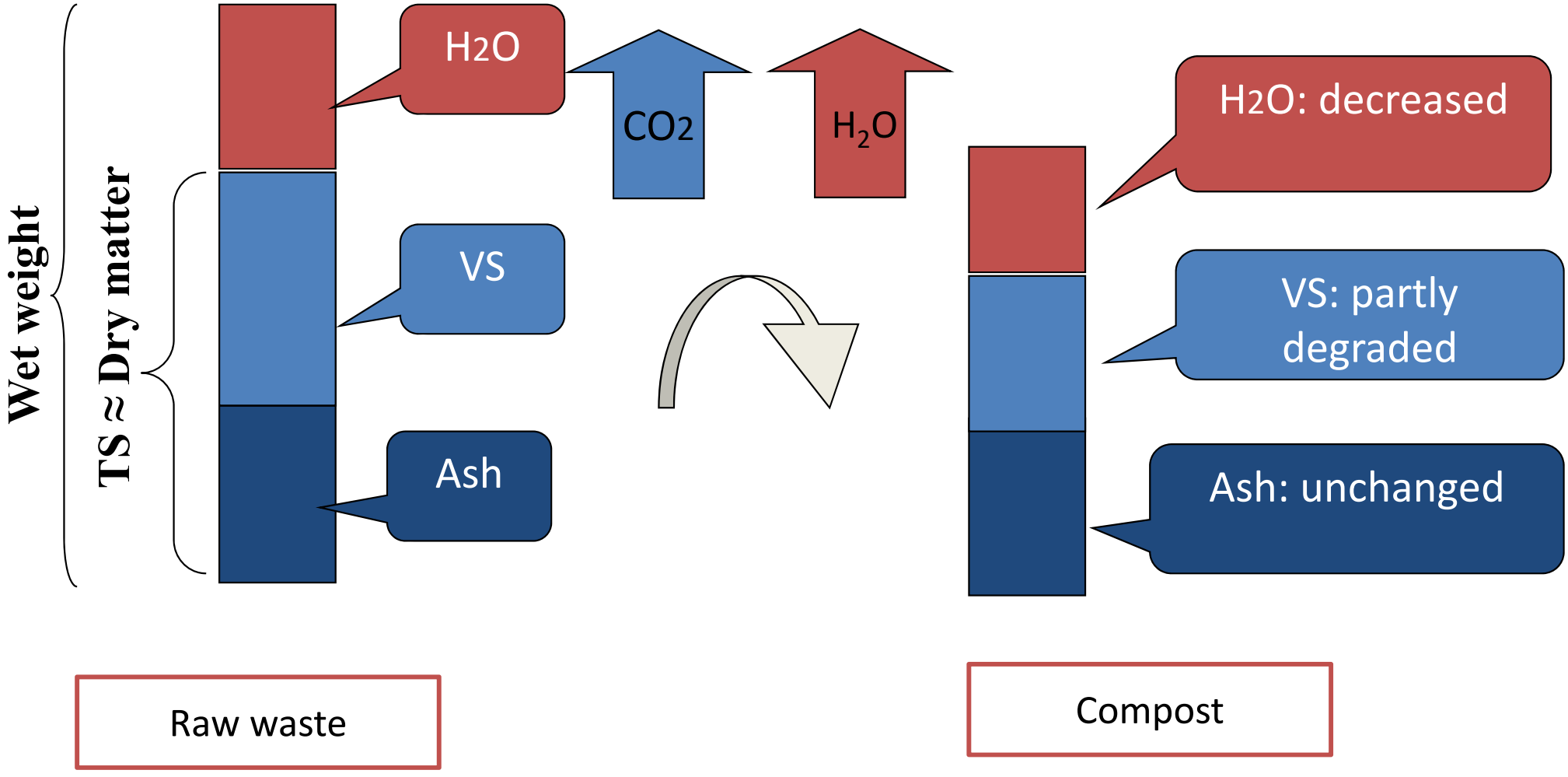
Composting

- A biological process in which organic matter is decomposed aerobically

Organic matter + O_2 ---> CO_2 + H_2O + heat + cell mass

Mass Transformation in Composting



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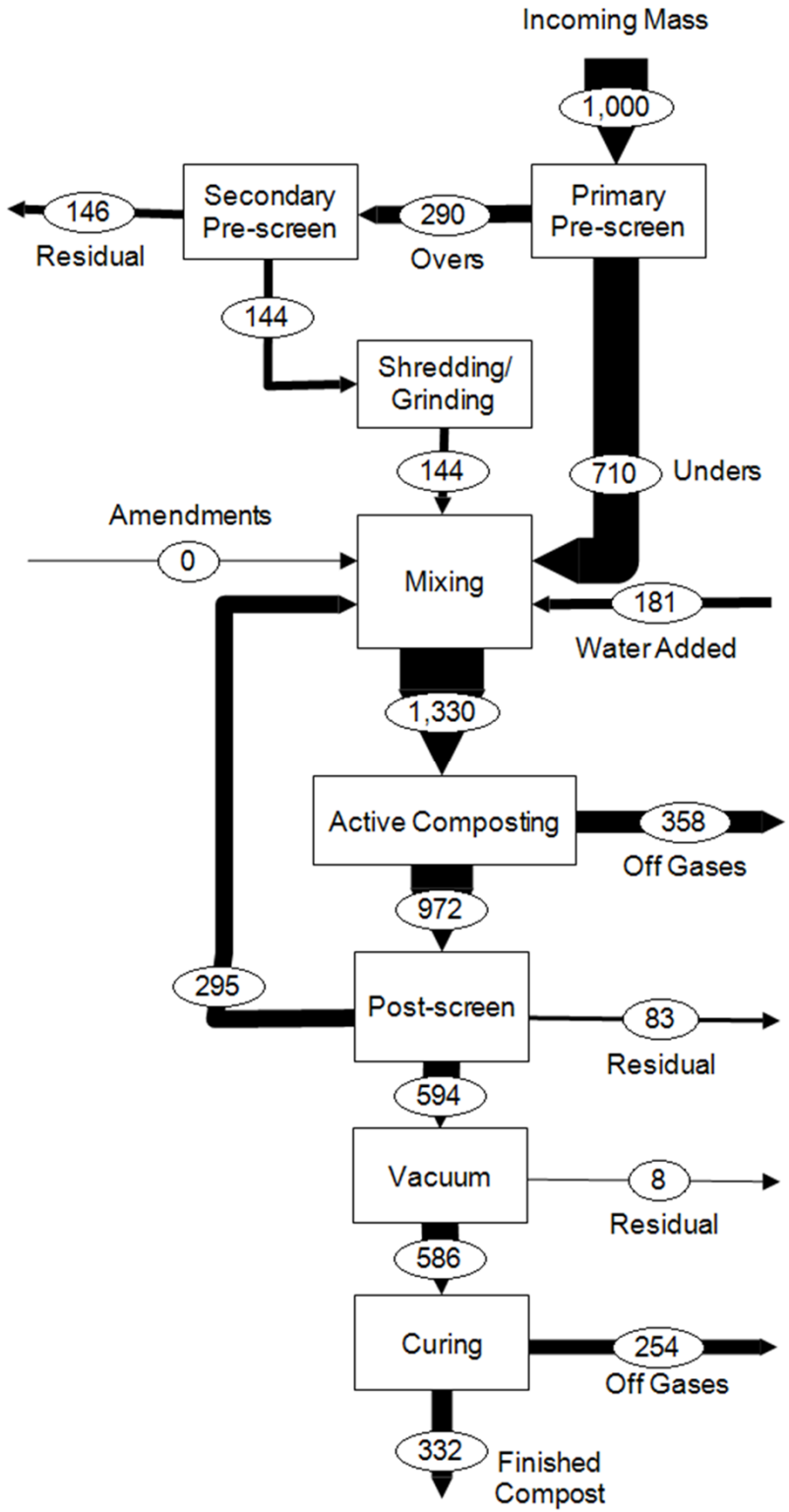
Composting Material Flow



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Key Inputs

Facility Operating Parameters	Units	Value
Time spent at tipping floor	Mg/day	1
Active composting time	Days	70
Curing time	Days	30
Equipment fuel and electricity use parameters	**Units**	**Value**
Grinder power rating.	kWh/Mg	10.6
Grinder fuel consumption	L/kWh	0.25
Windrow turner power rating	kWh/Mg	0.24
The fuel consumption of a windrow turner	L/kWh	0.127
Turning frequency	1/day	0.33
Energy required per wet weight of post-screened material	kWh/Mg	0.9
Frequency of turning during curing phase	1/day	0.14
Front end loader specific fuel consumption	L/kWh	0.26
General equipment fuel consumption.	L/kWh	0.26
Carbon and Nitrogen Balance During Composting	**Units**	**Value**
Proportion of incoming C emitted	-	0.58
Proportion of emitted C emitted as CH_4	-	0.017
Proportion of incoming N emitted as NH_3	-	0.04
Proportion of emitted N emitted as N_2O	-	0.004

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Compost Technologies

- Windrows
  - Cheapest\lowest tech
  - Least process or emission control
  - Higher retention time and land use

- Aerated static pile
  - More costly
  - More process and emission control potential
  - Lower retention time\reduced land use

- Gore Compost Covers
  - Mix of windrow/ASP

- In-vessel composting
  - Most costly
  - Most process and emission control potential
  - Lowest retention times and least land use

Choice of technology will depend on feedstocks

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Digestate/Compost Use

- Soil conditioner: high organic content increases moisture holding capacity of soil
- Nutrient content
  - depends on the starting material
  - nutrients and/or soil may be added for certain markets
- Markets (identify before producing compost)
  - landfill cover soil – mixed MSW
  - nurseries and landscapers for seedlings – yard waste
  - state roads and parks – yard waste
  - city residents (give away or sell) – yard waste
  - Agriculture IF the material is pure and has a nutrient value
- Model allows
  - No offset
  - Fertilizer offset (N,P,K)
  - Peat offset

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End Product Use Inputs

Compost Land Application Parameters	Units	Better	Typical	Worse
Distance to application site	km	20	20	20
Percent of applied N evaporated as N_2O	%	1.5	1.5	1.5
Percent of ammonia that evaporates	%	15	15	15
Percent N that is ammonia	%	50	50	50
Cured solids application diesel use	L/Mg solids	0.80	0.80	0.80
Percent of carbon in solids remaining after 100 years[b]	%	10	10	10
Nitrate leaching to groundwater	kg N/kg N applied	0	0.135	0.3
Nitrate run-off to surface water	kg N/kg N applied	0.04	0.14	0.87

Fertilizer Land Application Parameters	Units	Better	Typical	Worse
Diesel fuel for application per kg N	L/kg N	0.0029	0.0029	0.0029
Diesel fuel for application per kg P	L/kg P	0.0023	0.0023	0.0023
Diesel fuel for application per kg K	L/kg K	0.0016	0.0016	0.0016
Nitrate runoff to surface water	%	5.0	10.0	40.0
Nitrate leaching to ground water	%	5.0	10.0	40.0
N released as N_2O	%	0.1	2.3	5.8
N as NH_3	%	50	50	50
NH_3 evaporated	%	3.0	5.0	7.0

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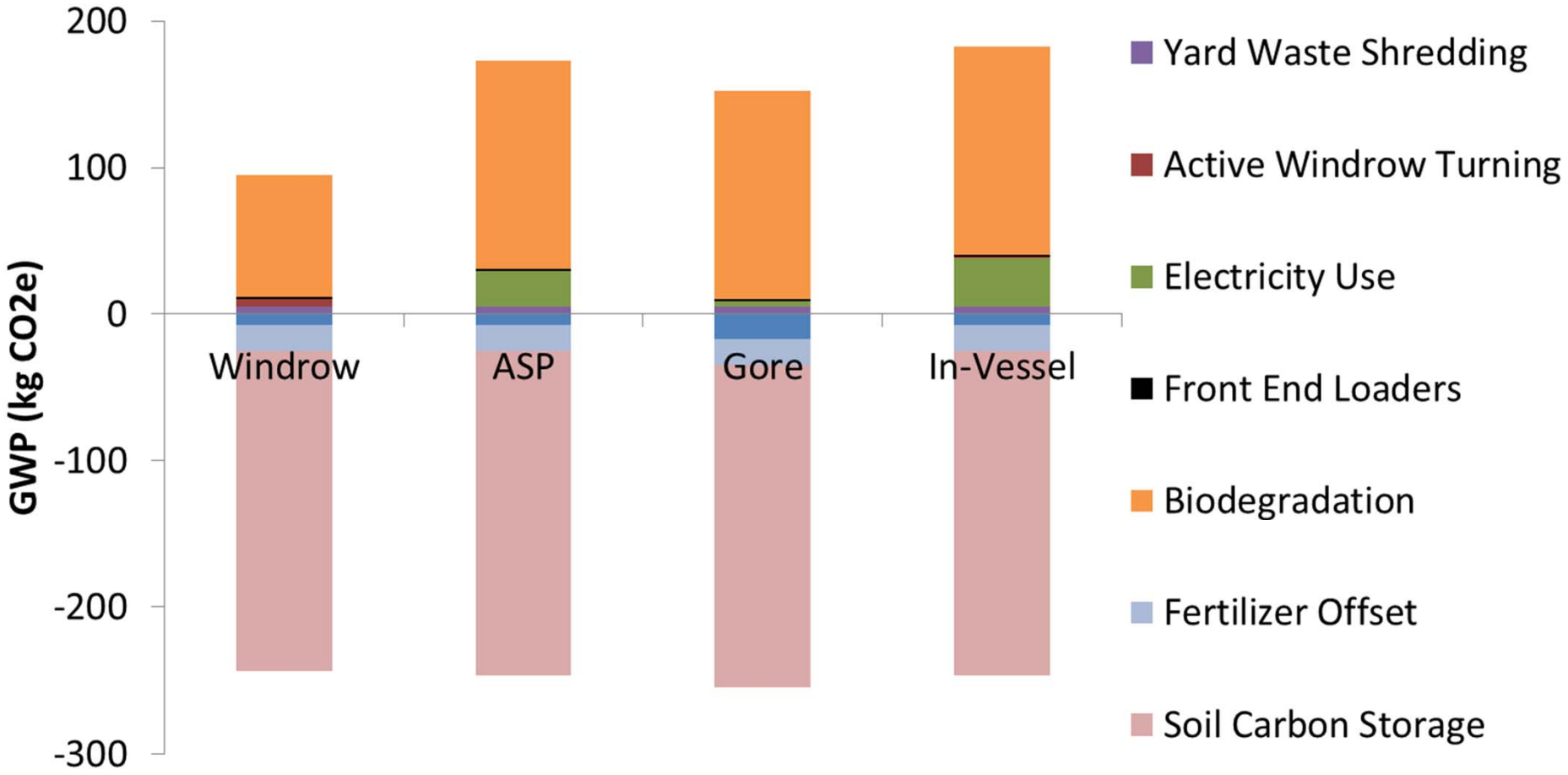
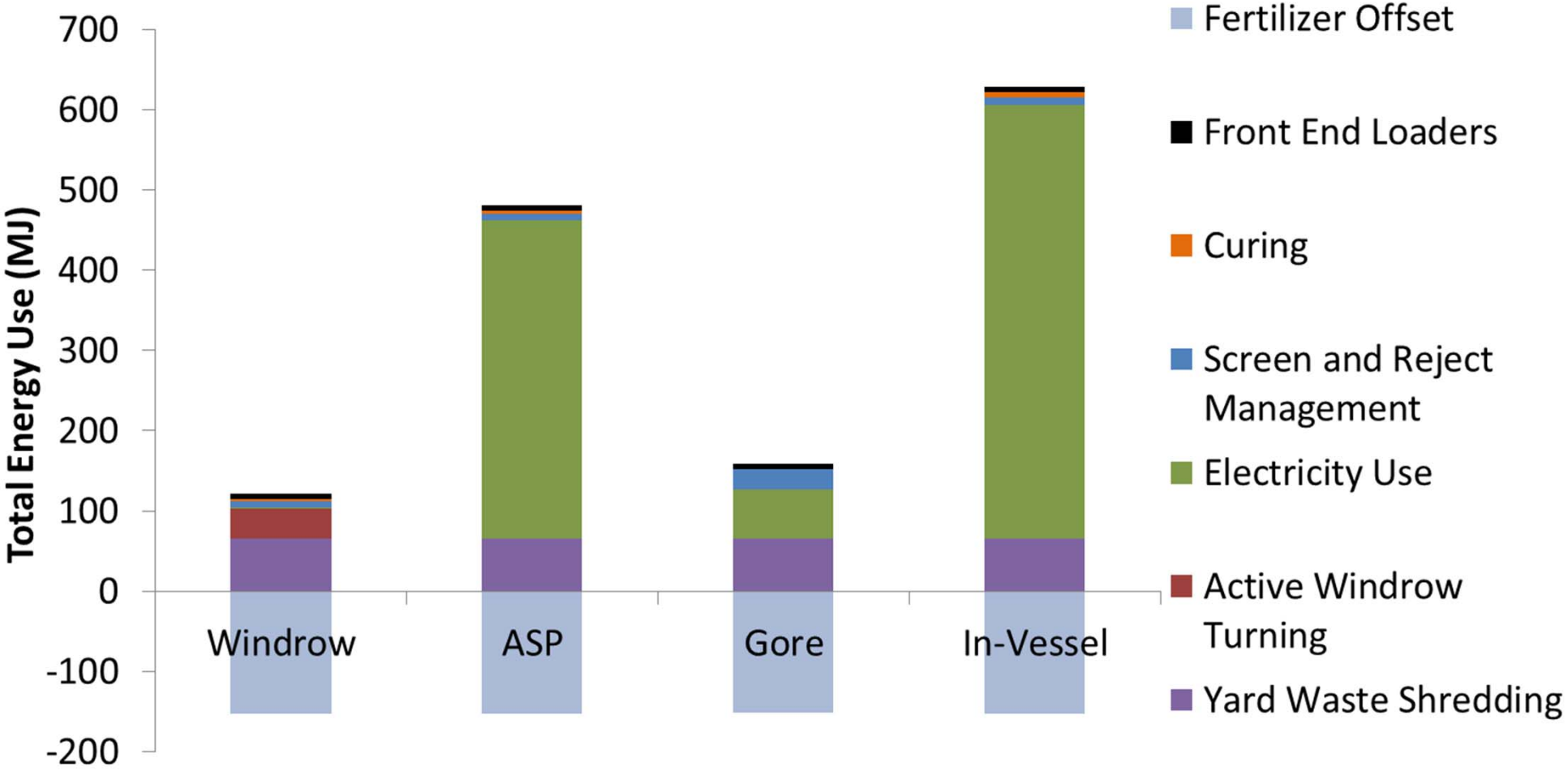
Illustrative Results (Fertilizer Offset) –GWP (1 ton food waste; 0.3 tons yard waste)



Levis, J. W., Barlaz, M. A. (2011). What is the Most Environmentally Beneficial Way to Treat Commercial Food Waste? *Environ. Sci. Technol.*, 45(17): 7438-7444. DOI: 10.1021/es103556m.

Illustrative Results (Fertilizer Offset) –Total Energy Use (1 ton food waste; 0.3 tons yard waste)



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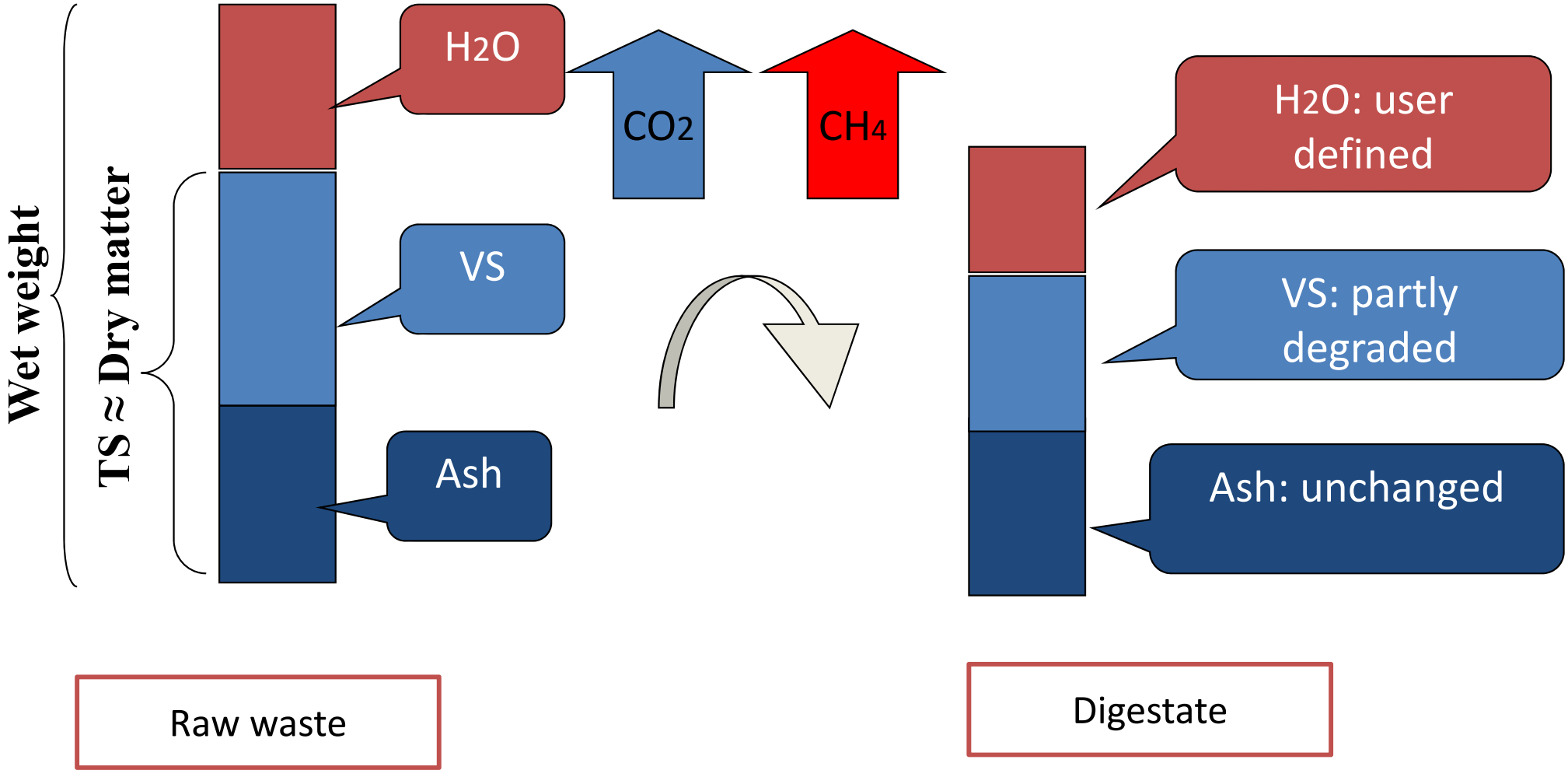
Anaerobic Digestion

- A biological process in which organic matter is decomposed anaerobically
  - Organic matter ---> $CO_2 + CH_4 + NH_3 + H_2S$ + cell mass

Degradation



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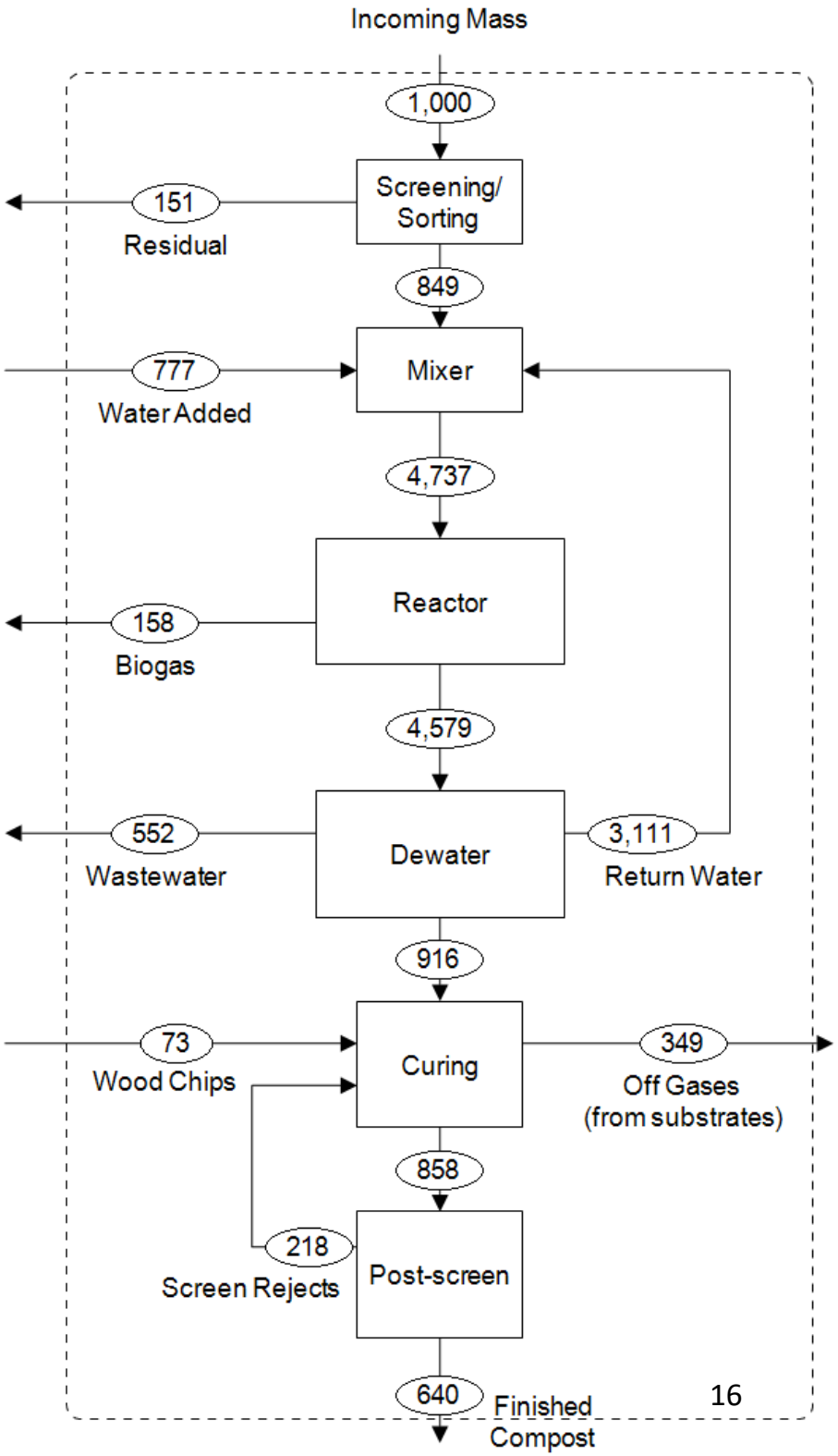
Anaerobic Digestion Material Flow



Base results using wet, single-stage, mesophilic default inputs

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Key Mass Flow/Process Default Inputs

Digester Operating Parameters	Units	Value
Reactor moisture content.	-	0.92
Facility specific electricity usage.	kWh/Mg	58
Biogas leakage rate	-	0.03
Proportion of gas that is flared without electricity generation.	-	0.05
Digestate Liquids Management	**Units**	**Value**
Amount of BOD in digestate	kg/L	0.0023
Total N	kg/L	0.00135
Percent of total N that is NH_3	%	50
Distance to liquids treatment facility	km	0
Electricity used per pound of BOD removed.	kWh/kg	1
BOD removal efficiency.	-	0.92
Digestate Solids Curing	**Units**	**Value**
Digestate moisture content after dewatering	-	0.6
Retention time in windrows	days	21
Turning energy required per ton of compost	kWh/Mg	0.24
The fuel consumption of a windrow turner	L/kWh	0.13
Turning frequency	1/days	0.43
Proportion of emitted C emitted as CH_4	-	0.017
Proportion of emitted N emitted as NH_3	-	0.04
Proportion of emitted N emitted as N_2O	-	0.004
VS reduction of digestate during curing	-	0.3

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AD Technologies

- Level of pretreatment (screening, shredding, sorting, etc.)
- Reactor
  - Solids Content
    - Dry (>20% solids) or Wet (<20% solids)
  - Temperature
    - Mesophilic (~36^{o}C) or Thermophilic (53-55^{o}C)
  - Number of stages
    - 1 or 2
    - Two is more expensive but provides more control
- Digestate management (screening, dewatering, curing, etc.)
- Biogas management (flare, energy)

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Biogas Beneficial Use in SWOLF

- Biogas production estimated using material-specific:
  - Methane potential
  - Percent of methane potential reached in modeled AD system

- Combustion for electricity production
  - Generation estimated using heating value of methane and heat rate of engine/turbine system.
  - System downtime, biogas leakage considered.
  - Offset electricity generation for chosen grid.

- Other biogas end uses not yet modeled in SWOLF.

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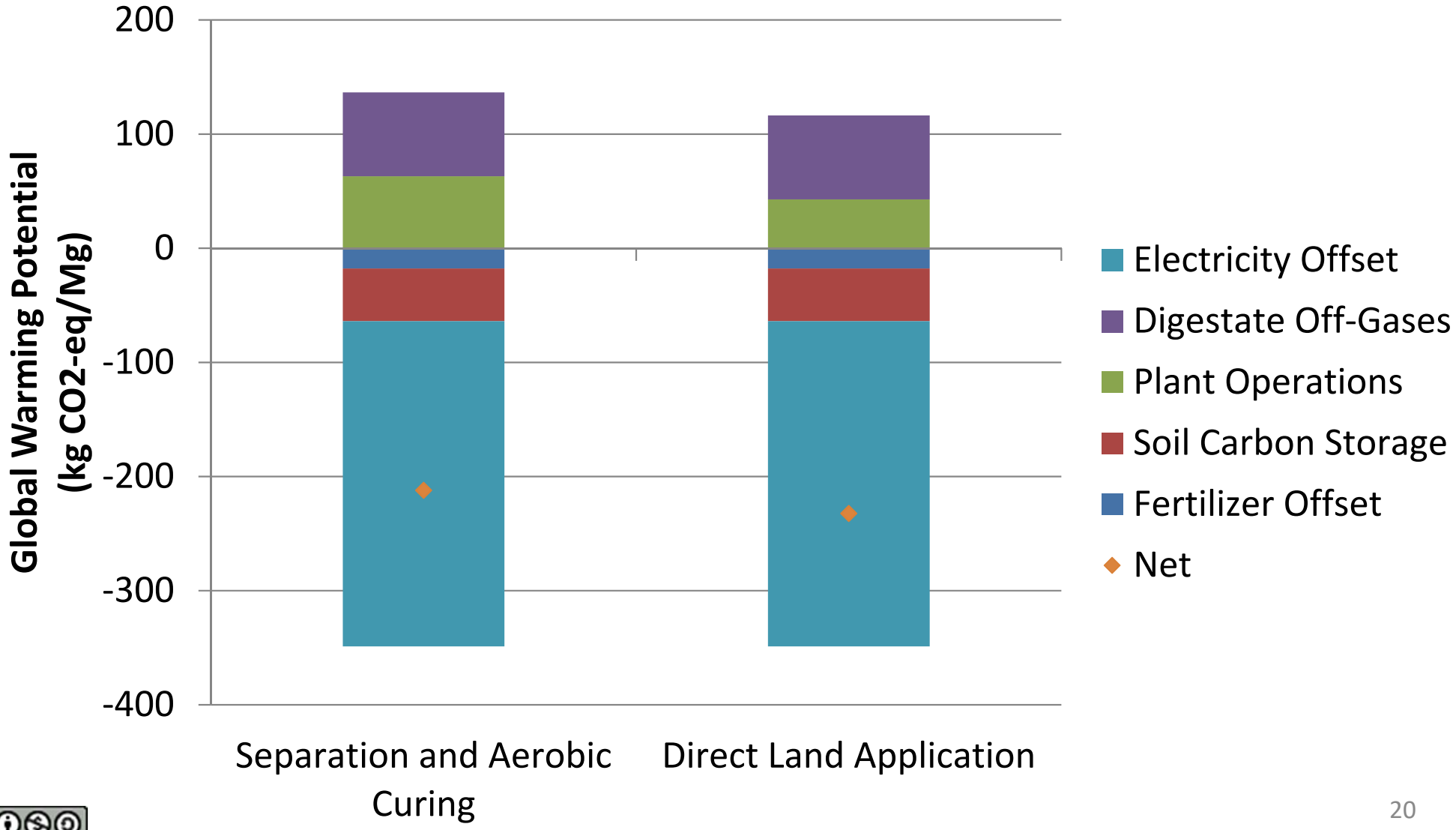
Illustrative Results – Comparison of Digestate Management



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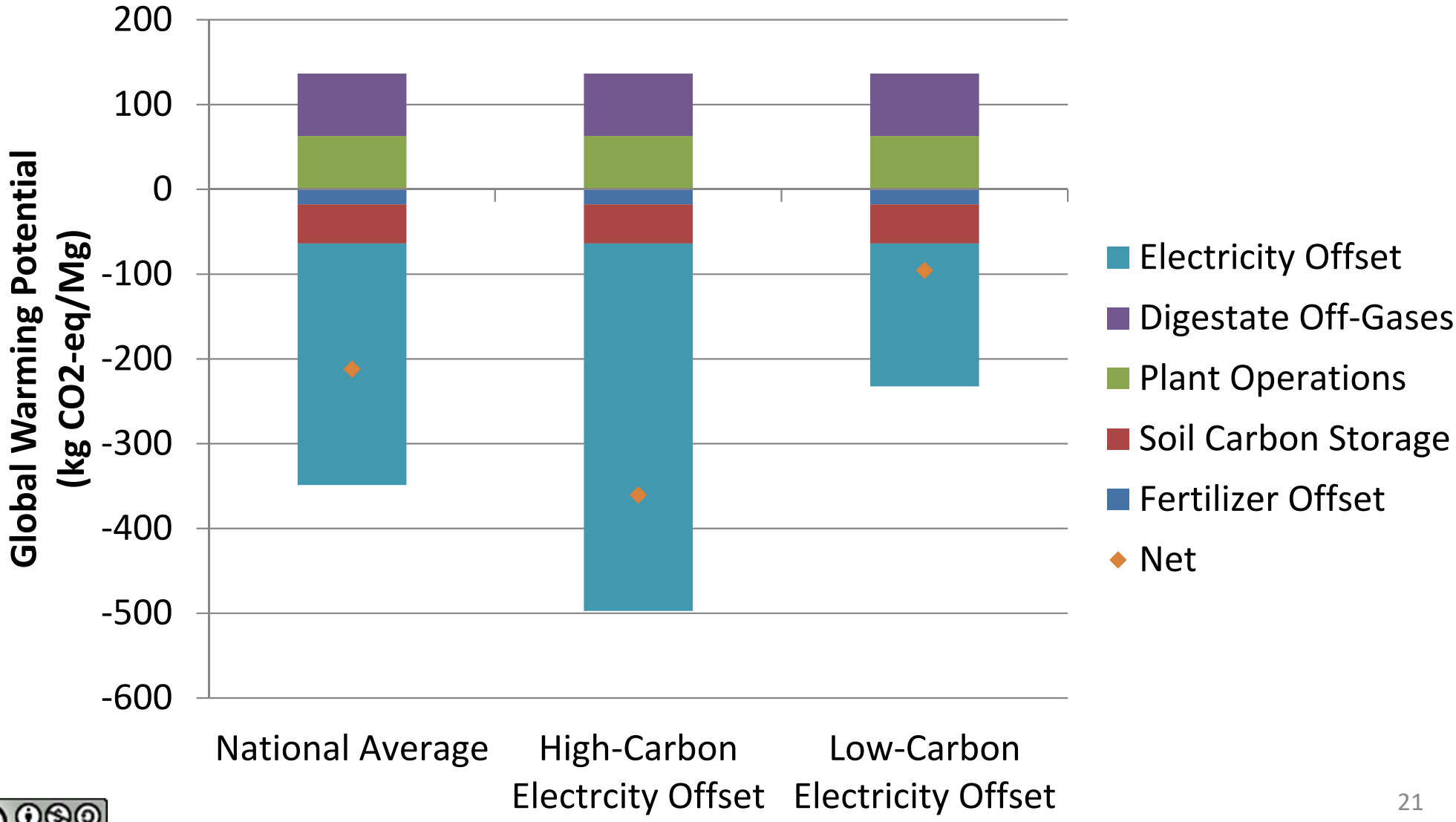
Illustrative Results – Influence of Electricity Offsets



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Research and Data Needs

- Better understanding of material substitution associated with beneficial use of compost/digestate
- Data on AD CH_4 leakage rates
- Understanding of C and nutrient flows from feedstocks to final compost
- Whether and how different AD reactor configuration affect CH_4 production

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Questions?

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Environmental Research & Education Foundation
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