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Integrated Assessment Case Studies

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Slides available at
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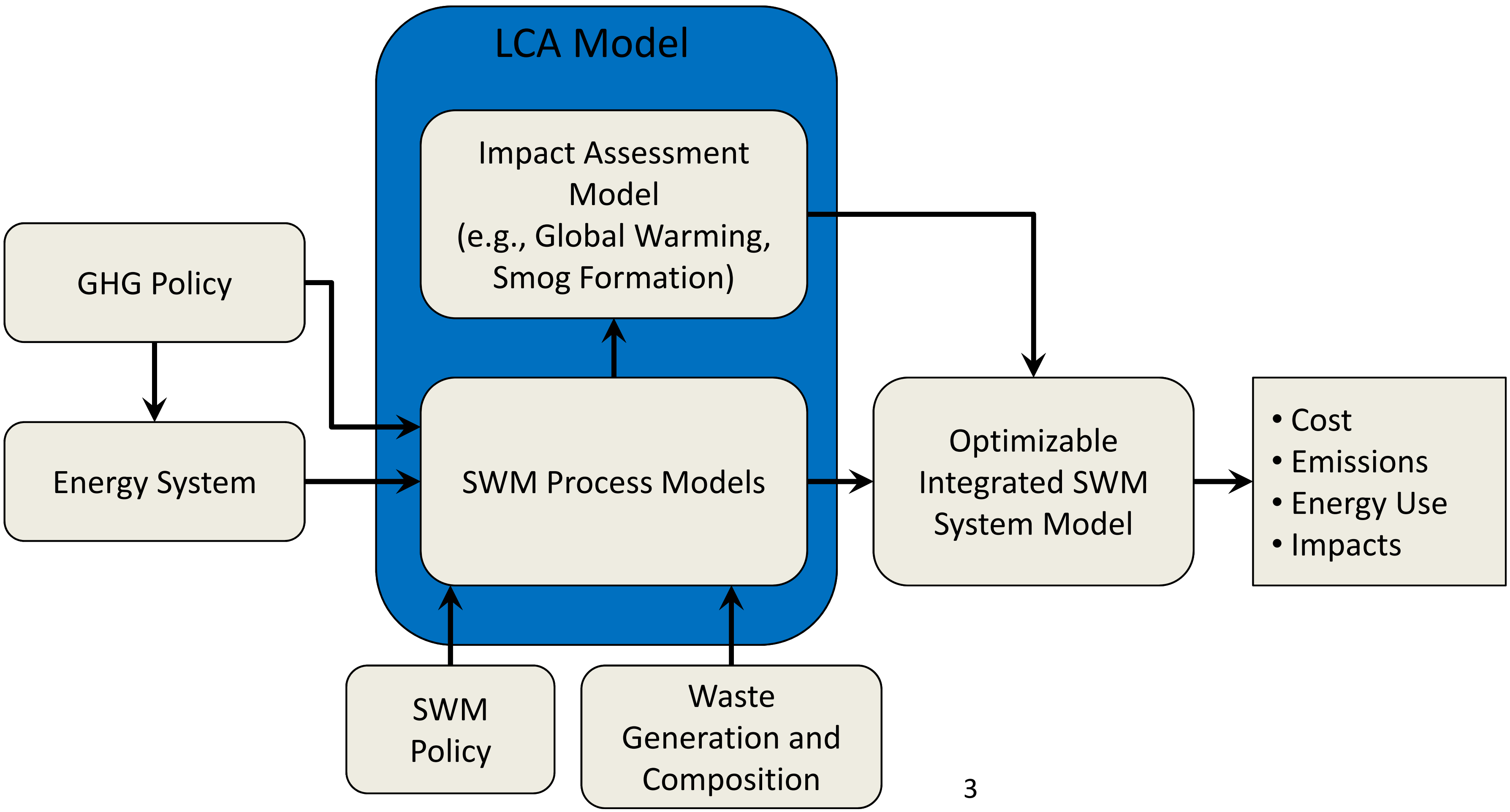
Research Background

- Appropriate selection of waste processing technologies and efficient waste management strategies can minimize environmental impacts, particularly through energy generation and materials recovery.
- A progressive solid waste management strategy must account for complex interrelationships among unit processes and competing management objectives.
- Solid waste generation and composition is changing and must be considered in future decisions (e.g., paper waste decreasing, food waste increasing).
- Potential changes in climate change mitigation policies and energy infrastructure will affect the optimal management of solid waste in the future.

SWOLF Research Objective

Evaluate system performance (i.e., economical, environmental) while accounting for changes to waste composition and generation, SWM policy, the U.S. energy system, and potential future GHG mitigation policies

Solid Waste Optimization Life-cycle Framework (SWOLF)



Benefits of Optimization Modeling

- How can net present cost be minimized over time?
  - While meeting diversion or greenhouse gas constraints
  - Considering existing infrastructure
- How can environmental benefits be maximized?
  - Minimize greenhouse gas emissions
  - Minimize fossil energy use
  - Maximize landfill diversion
  - Impose a budget constraints

Benefits of Optimization Modeling (cont'd)

- What are the mitigation costs ($/MTCO2E avoided) or trade-offs associated with adopting a specific technology or policy?
  - WTE combustion, composting, AD, gasification-to-biofuels, etc.
  - Landfill organics bans, diversion targets, combustion
- How do changes to the energy system affect these decisions?
- Can our system robustly adapt to changes in energy system, waste composition or waste generation?

Process Modeling

- Process level life-cycle assessment models form the foundation of this work
- Process models are developed “bottom-up” to determine the costs, emissions, and environmental impacts associated with each process in consideration of waste quantities and composition
- Process models are then linked using mass balance equations to develop full system models
- Included Processes
  - Collection
  - Transfer Stations
  - Material recovery facilities
  - Anaerobic Digestion
  - Composting
  - Landfills
  - Remanufacturing
  - Waste-to-energy
  - Gasification
  - RDF

How to best manage municipal solid waste in Wake County, NC?

Problem Statement

Evaluate strategies to cost-effectively improve the sustainability of Wake County's municipal solid waste management while considering

- changing population, waste generation and composition,
- landfill life,
- energy and material recovery, and
- environmental emissions and impacts

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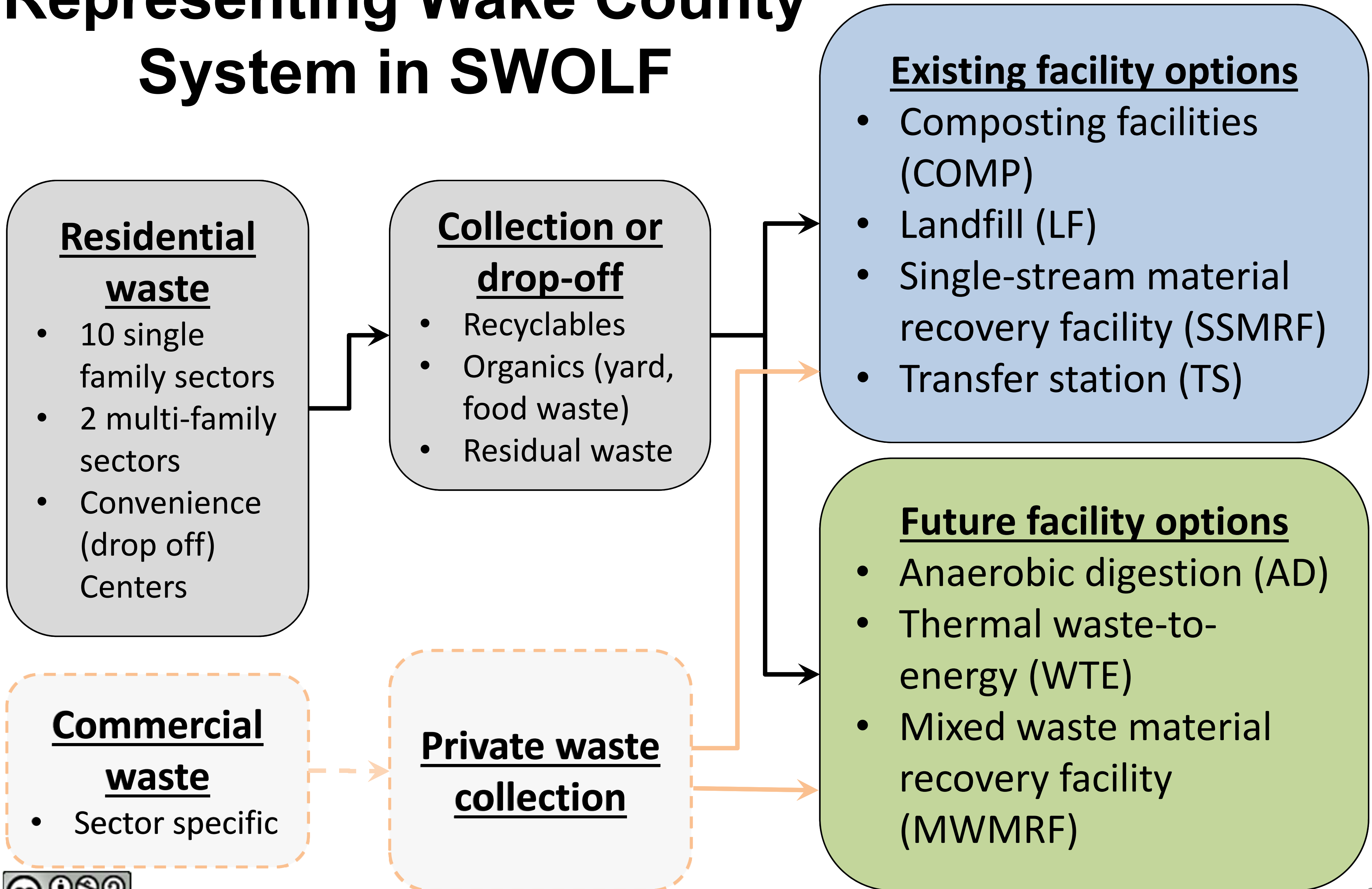
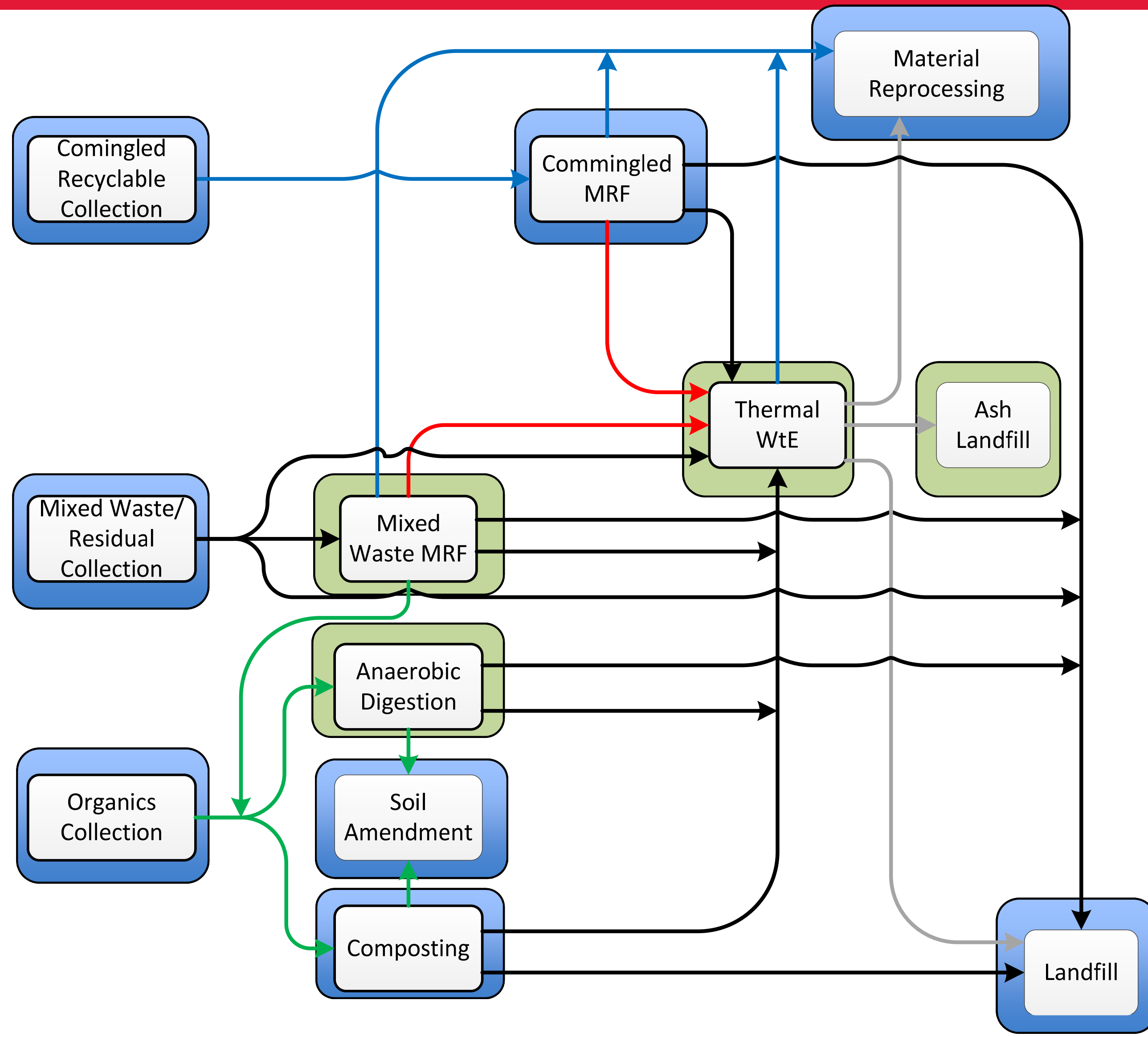
Representing Wake County System in SWOLF



Waste generation and composition



Potential Facilities

Existing Facilities

Mixed Waste → Recyclables → Combustibles → Organics → Ash →

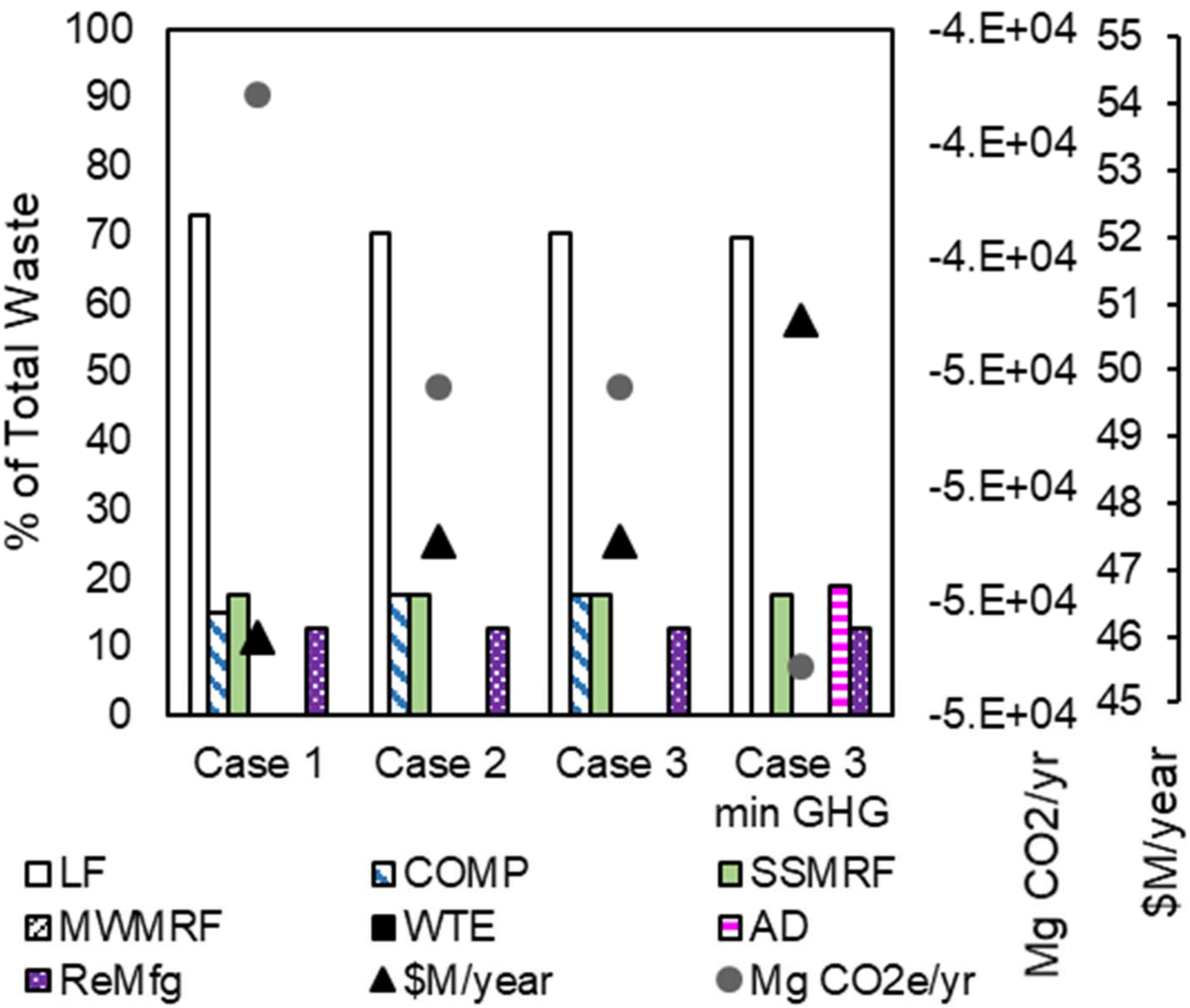
Scenarios

- Developed several scenarios to explore how new processes could be added to the existing solid waste system.

Scenarios	Description
Model Objective: Least Cost	
(1) Current practice	Separate collection of recyclables going to SSMRF and yard waste going to compost
(2) Current + food waste collection	As in case 1 plus food waste co-collected with yard waste
(3) Current + food waste collection + AD enabled	As in case 2 plus AD enabled
(4) Case 3 + MWMRF	As in case 1 plus MWMRF, AD enabled
(5) Case 3 + WTE	As in case 1 plus WTE, AD enabled
(6) Case 3 + WTE + MWMRF	As in case 1 plus WTE, MWMRF, and AD enabled

Adding FW collection to current system

- Because separate collection is already required, adding food waste to yard waste collection has a trivial impact on the average cost of collection ($/Mg)

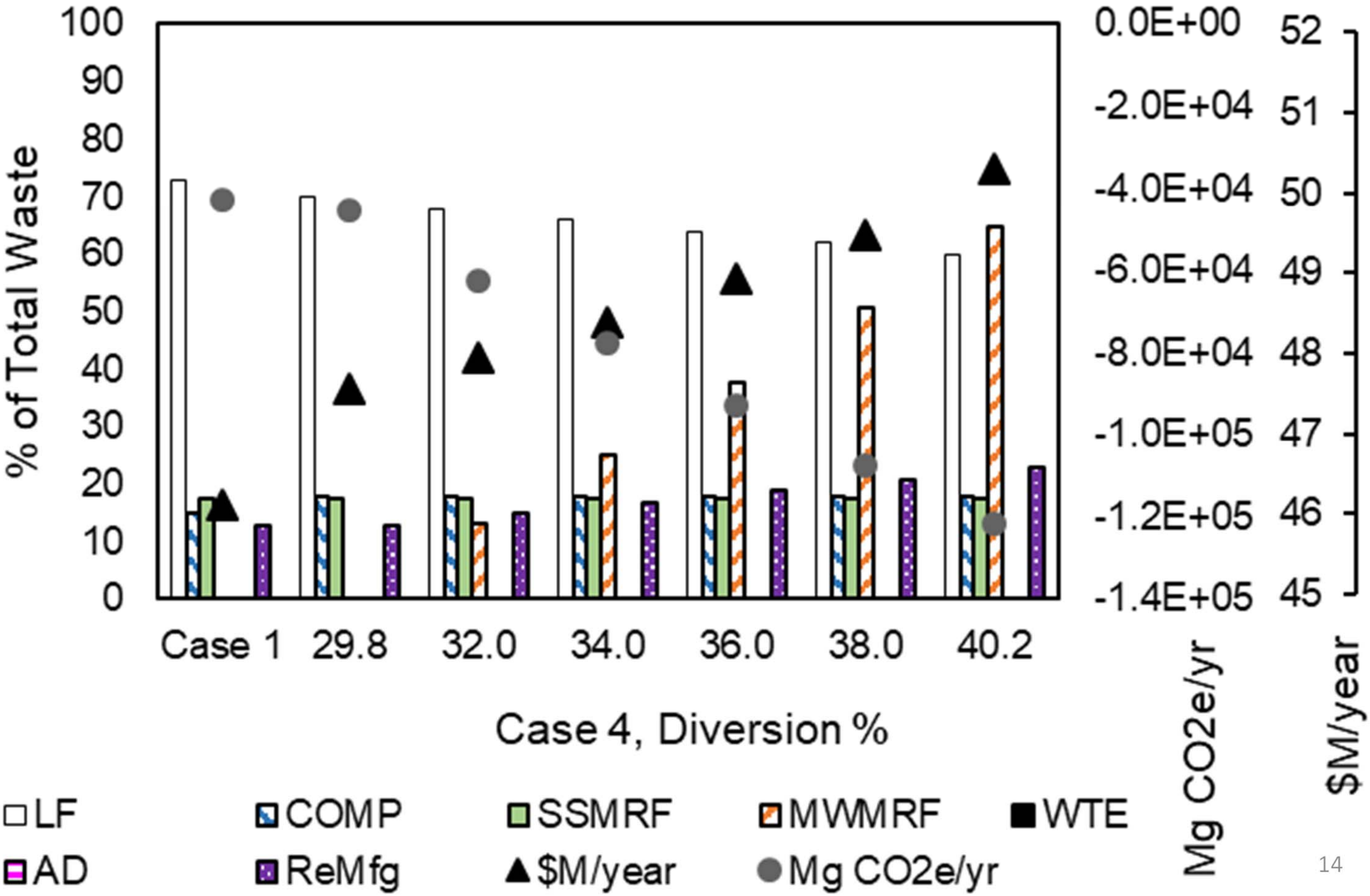


- Current case $46M
- Cases 2 and 3 are same solution, $47.6M
  - AD not chosen for cost-optimized solution
  - Mitg: $0.55/kg CO_2e
- Case 3 optimized for GHG uses AD for organics, $50.7M
  - Mitg: $0.92/kg CO_2e

Case 4: + MWMRF

- Current system + FW collection with AD enabled (optional) +MWMRF
- Separate collection of recyclables and yard/food waste required (3 separate collections)
- Set increasing diversion targets
  - Lowest target = diversion in min-cost solution
  - Highest target = diversion in max-diversion solution

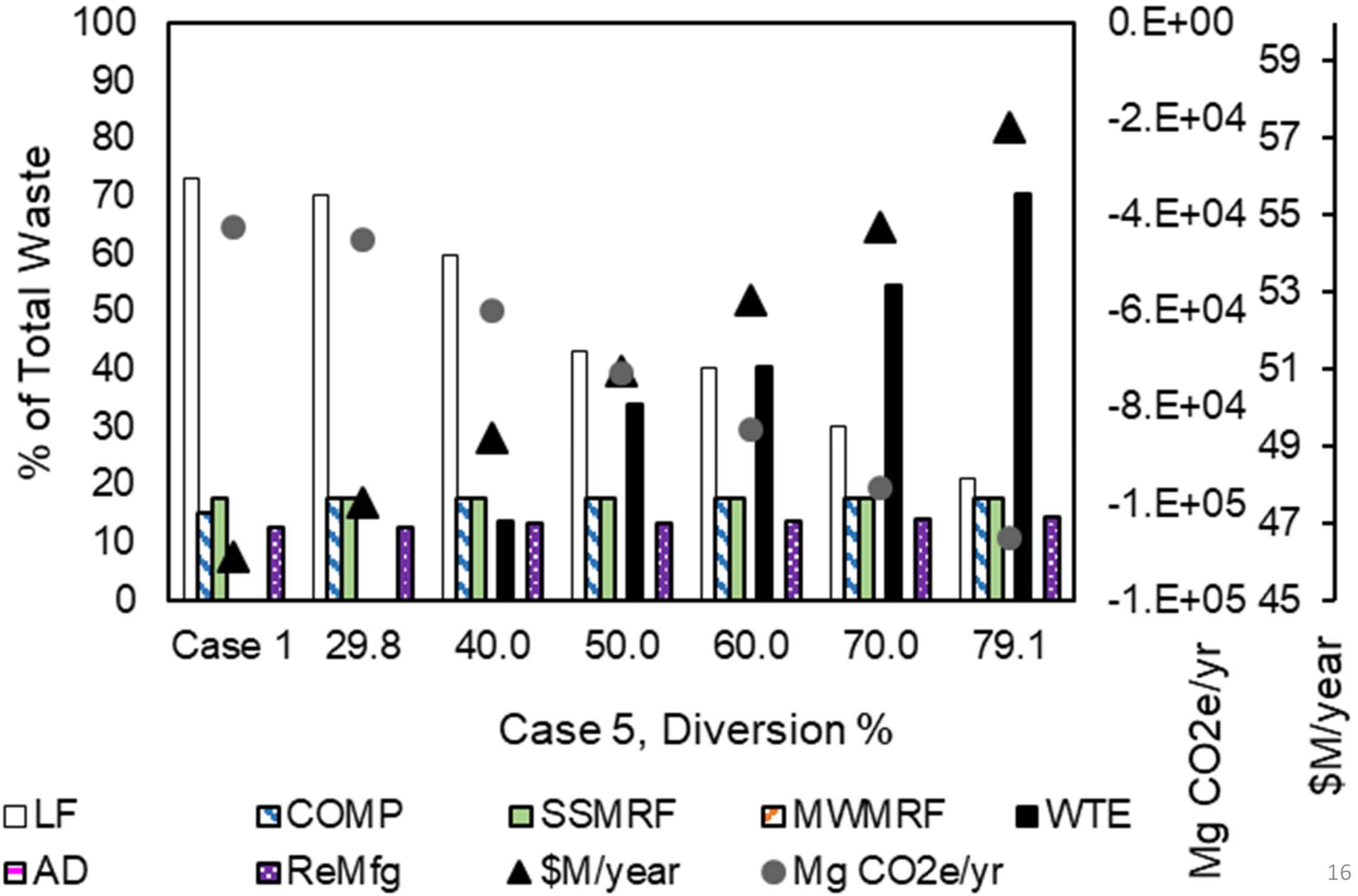
Case 4: + MWMRF


% of Total Waste
100
90
80
70
60
50
40
30
20
10
0
Case 1
29.8
32.0
34.0
36.0
38.0
40.2
Case 4, Diversion %
0.0E+00
-2.0E+04
-4.0E+04
-6.0E+04
-8.0E+04
-1.0E+05
-1.2E+05
-1.4E+05
Mg CO2e/yr
52
51
50
49
48
47
46
45
$M/year
LF
COMP
SSMRF
MWMRF
WTE
AD
ReMfg
$M/year
Mg CO2e/yr

Case 5: + WTE

- Current system + FW collection with AD enable (optional) +WTE
- Separate collection required
- Set increasing diversion targets
  - Lowest target = diversion in min-cost solution
  - Highest target = diversion in max-diversion solution

Case 5: + WTE

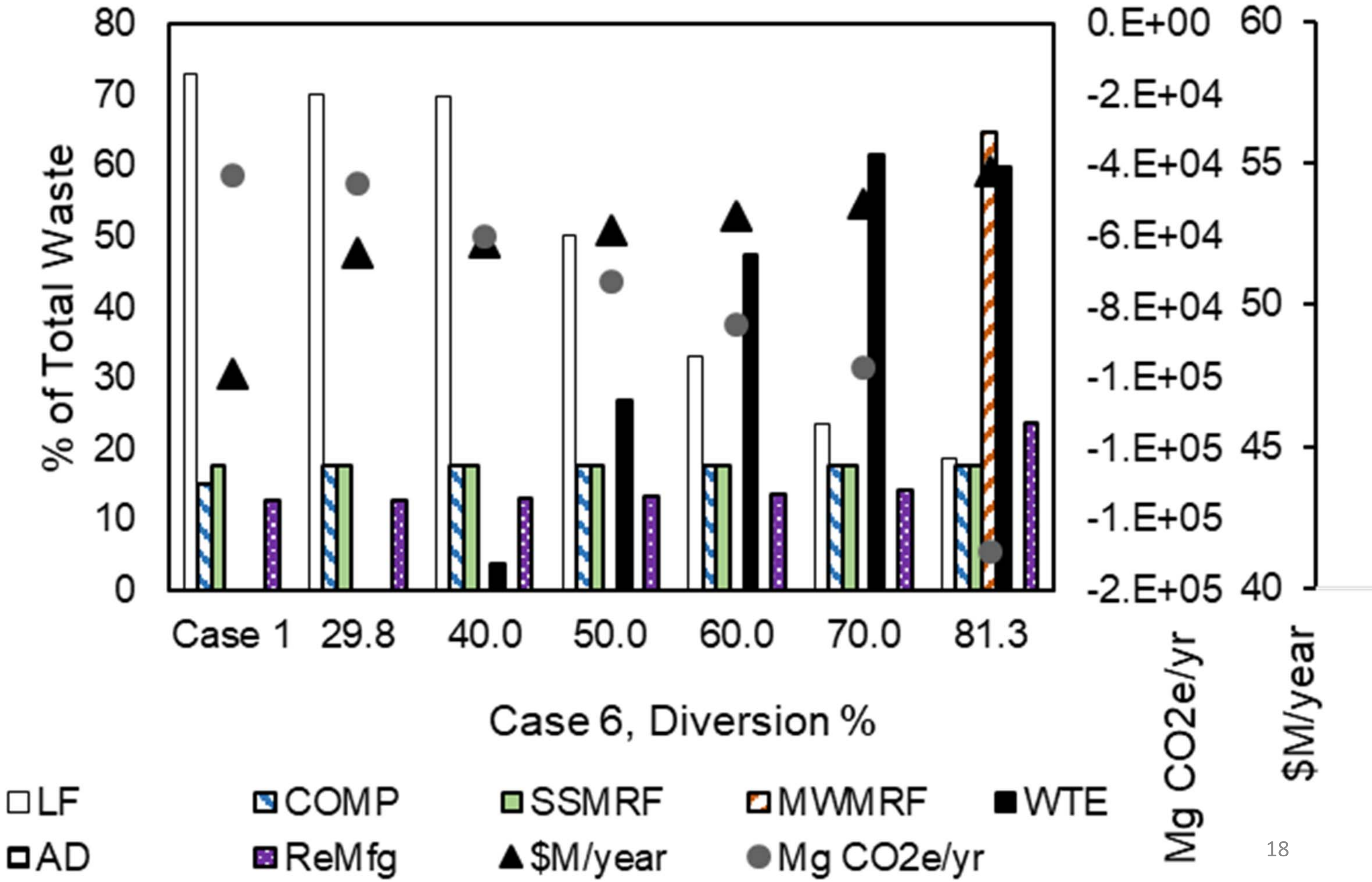


100
90
80
70
60
50
40
30
20
10
0
% of Total Waste
0.E+00
-2.E+04
-4.E+04
-6.E+04
-8.E+04
-1.E+05
-1.E+05
59
57
55
53
51
49
47
45
Case 1
29.8
40.0
50.0
60.0
70.0
79.1
Case 5, Diversion %
Mg CO2e/yr
$M/year
LF
COMP
SSMRF
MWMRF
WTE
AD
ReMfg
$M/year
Mg CO2e/yr

Case 6: + MWMRF + WTE

- Current system + FW collection with AD enable (optional) +MWMRF + WTE
- Separate collection of recyclables and yard/food waste required (3 separate collections)
- Set increasing diversion targets
  - Lowest target = diversion in min-cost solution
  - Highest target = diversion in max-diversion solution

Case 6: +MWMRF + WTE



Wake County - Discussion

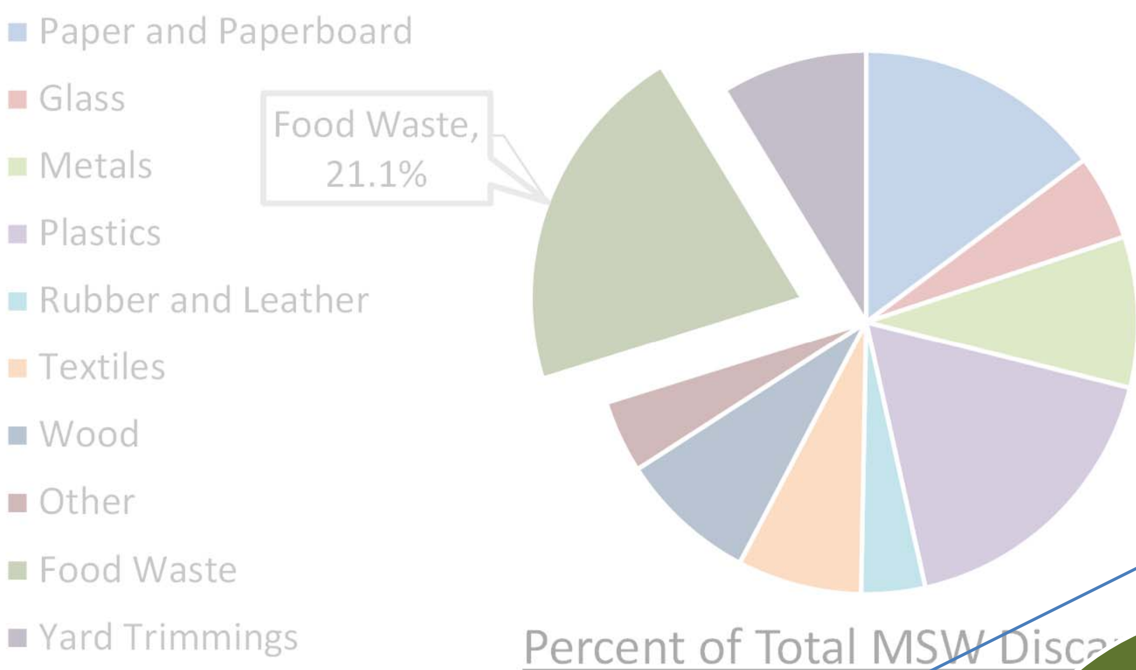
- Collecting residential food waste with yard waste is predicted to decrease landfill greenhouse gas (GHG) emissions by 12%, but has a modest effect on diversion rate and landfill life.
- Increasing residential recycling participation will decrease GHG emissions and increase landfill diversion.
- Increasing diversion does not necessarily decrease GHG emissions
  - Max diversion with Waste-to-Energy combustion is 81%
  - Min GHG emissions occur with 77% diversion
- County Commissioners are additionally concerned with extending landfill life

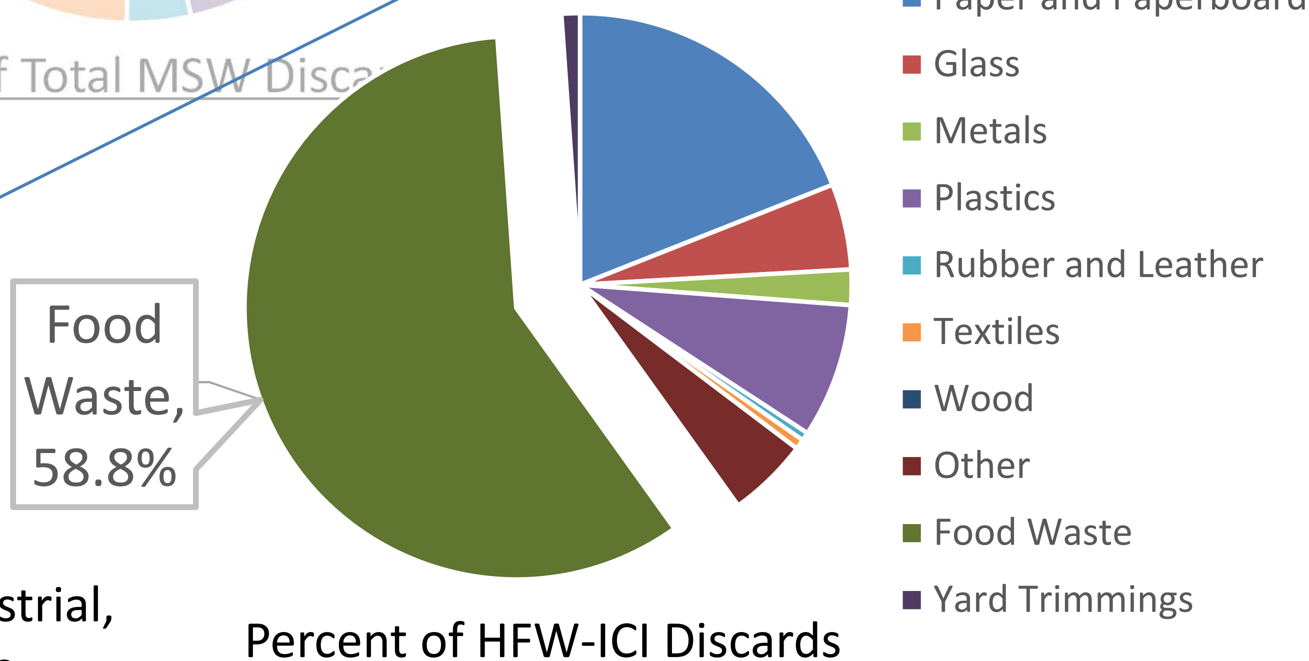
What is the most environmentally friendly way to manage commercial food waste?

Hodge, K. L., Levis, J. W., DeCarolis, J. F., Barlaz, M. A. (2016). A Systematic Evaluation of Industrial, Commercial, and Institutional Food Waste Management Strategies in the U.S., *Environ. Sci. Technol.* 50(16): 8444–8452, DOI: 10.1021/acs.est.6b00893.

Food Waste Composition

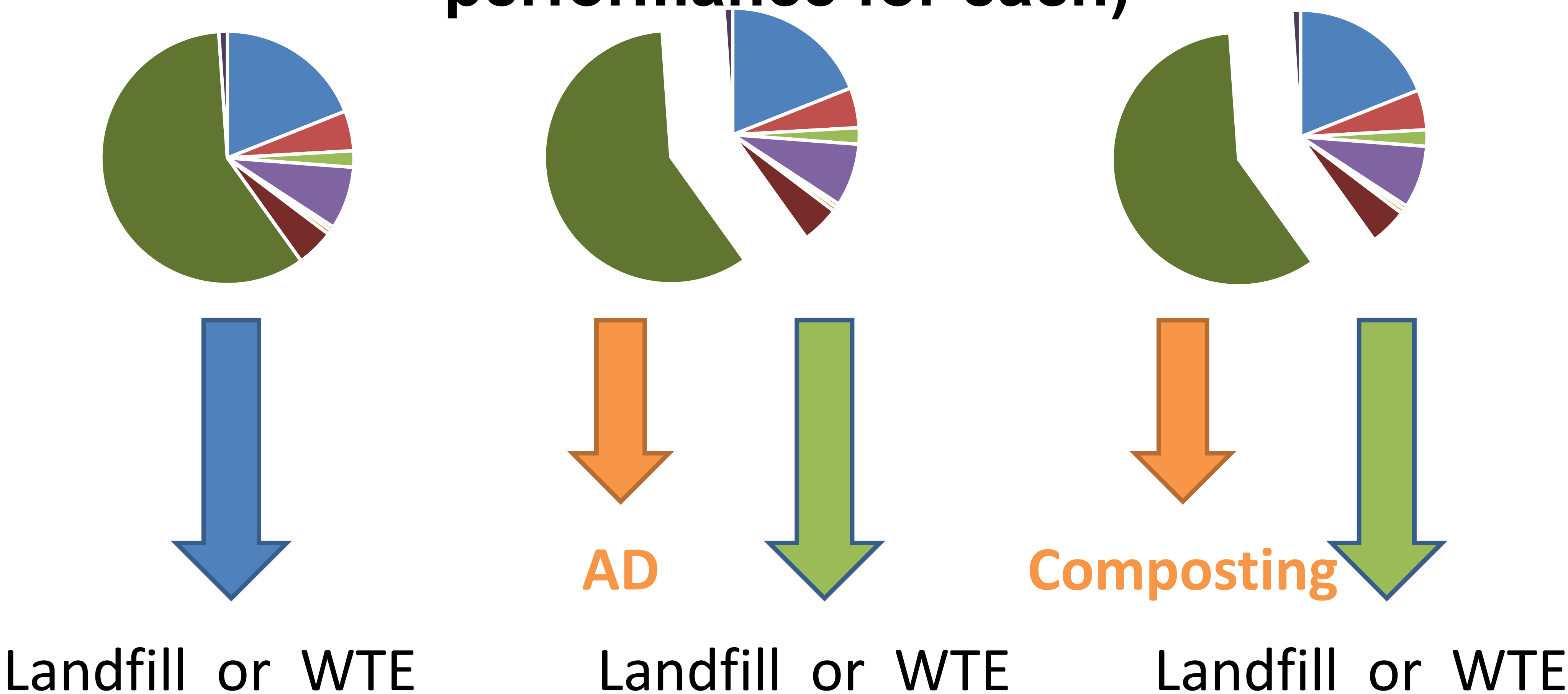
Compared treatment and disposal of 1 Mg of ***<u>HFW-ICI</u>*** *discards*





<u>HFW-ICI</u> – <u>H</u>igh <u>F</u>ood <u>W</u>aste – <u>I</u>ndustrial, <u>C</u>ommercial and <u>I</u>nstitutional waste

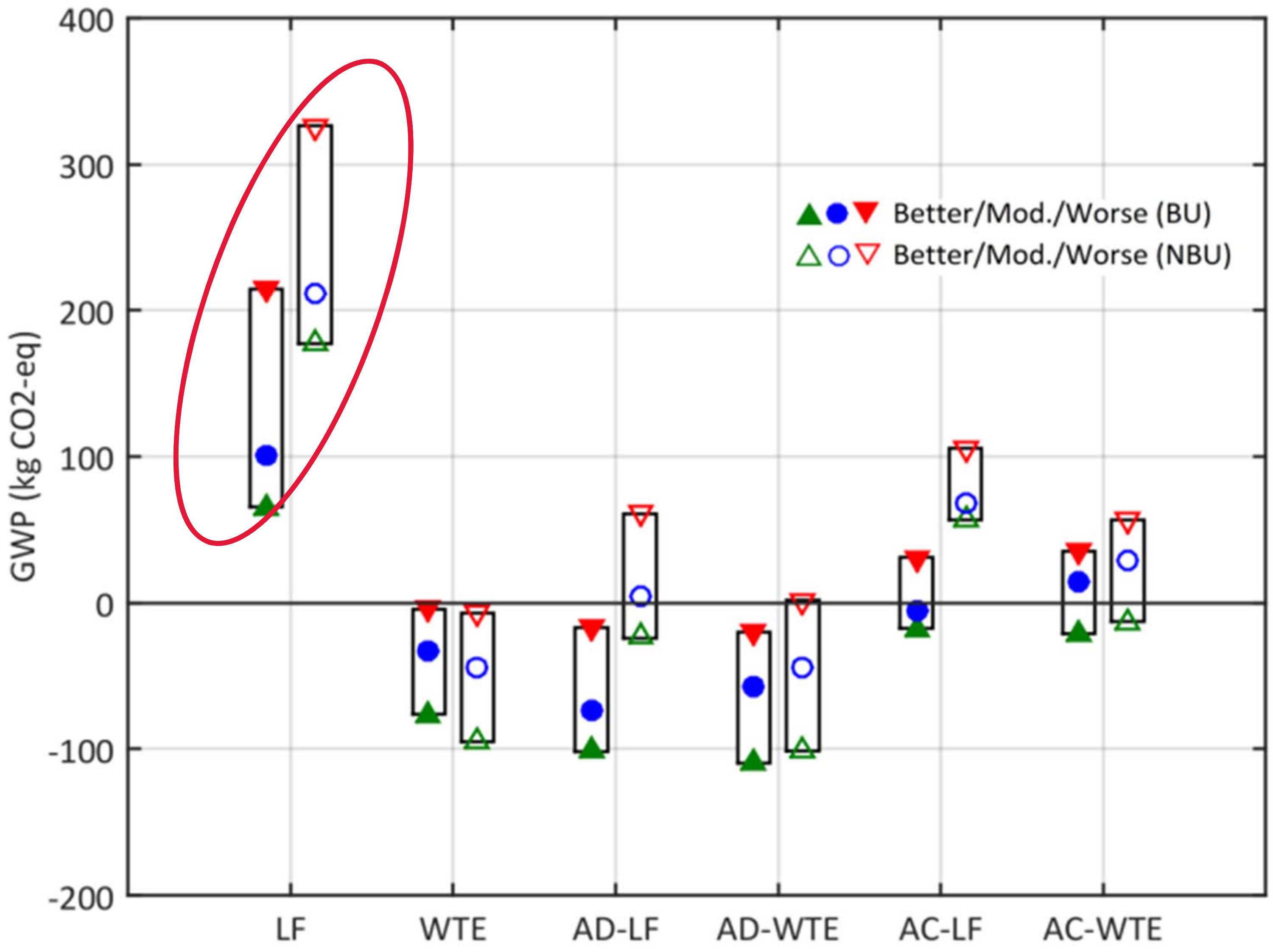
Six HFW-ICI waste scenarios represent real management choices (compared different levels of performance for each)



Source Separation Effectiveness:
80% of Food Waste, 5% of residuals

Base Case Results Confirm Landfilling is Least Preferable

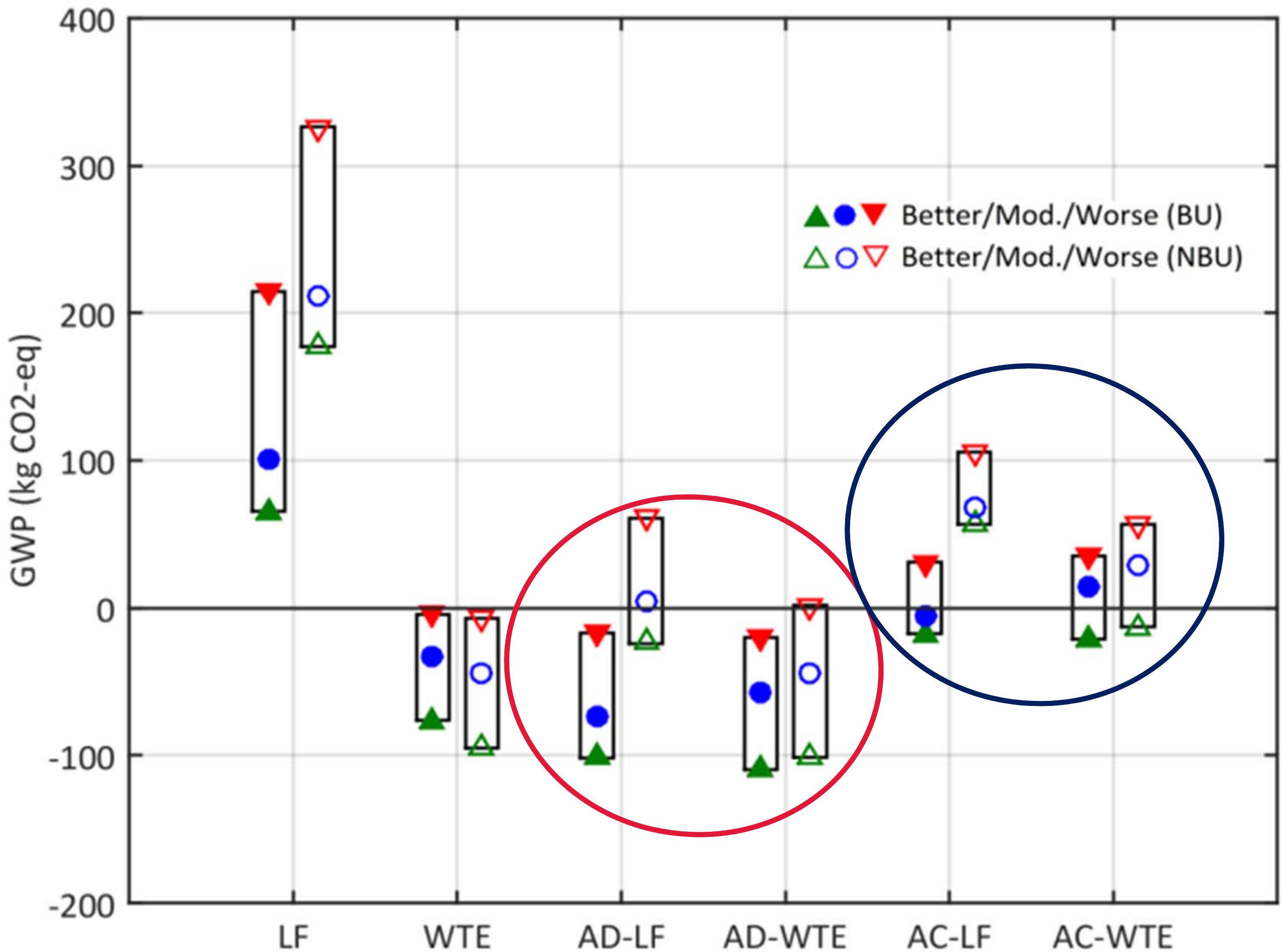
- LF – Landfill
- AC – Aerobic Composting
- BU – Beneficial Use
- NBU – No Beneficial Use



Base Case

AD is Generally Preferable to Composting

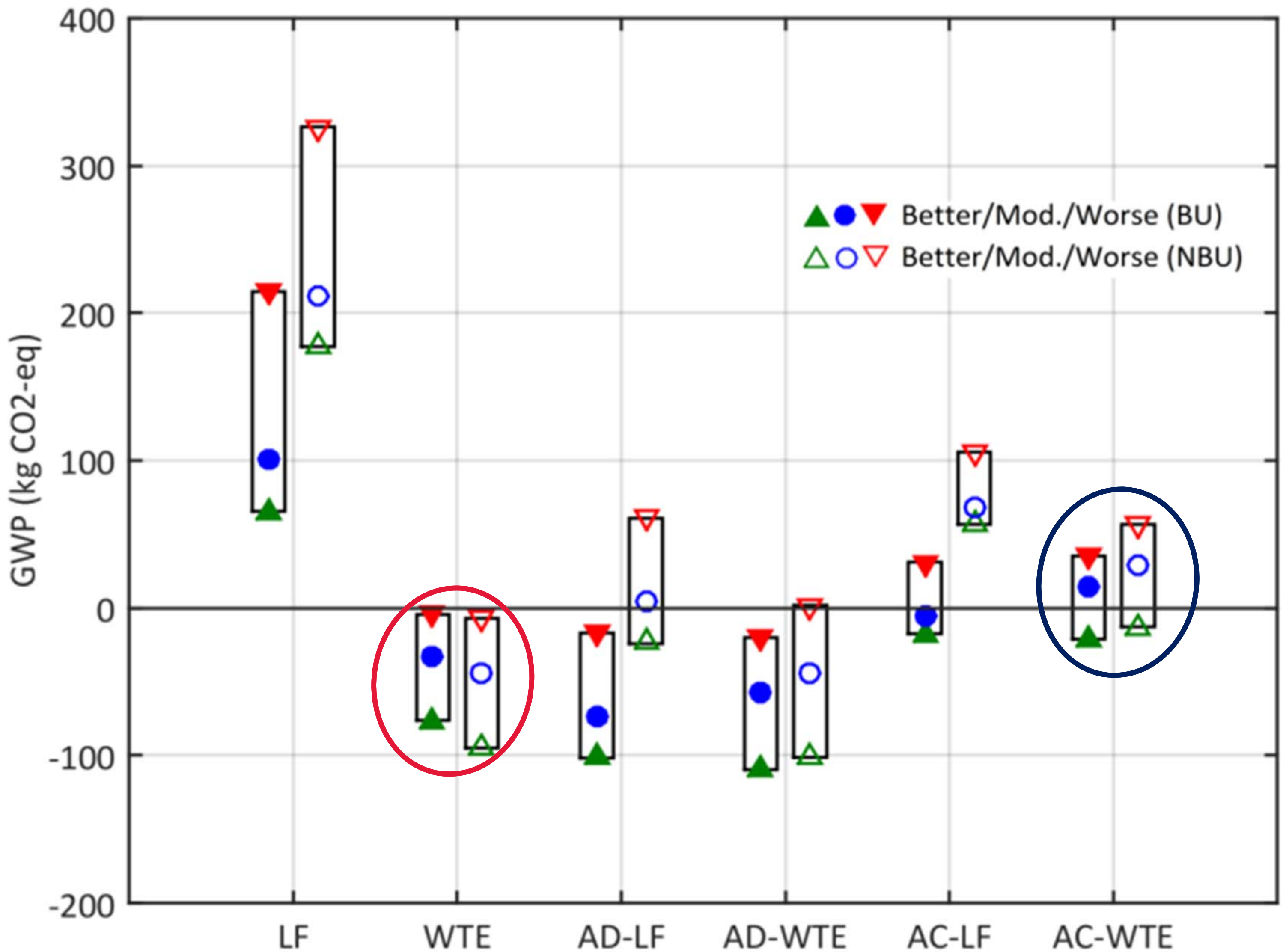
- LF – Landfill
- AC – Aerobic Composting
- BU – Beneficial Use
- NBU – No Beneficial Use



Base Case

Moving from WTE to Composting is Generally Detrimental

- LF – Landfill
- AC – Aerobic Composting
- BU – Beneficial Use
- NBU – No Beneficial Use

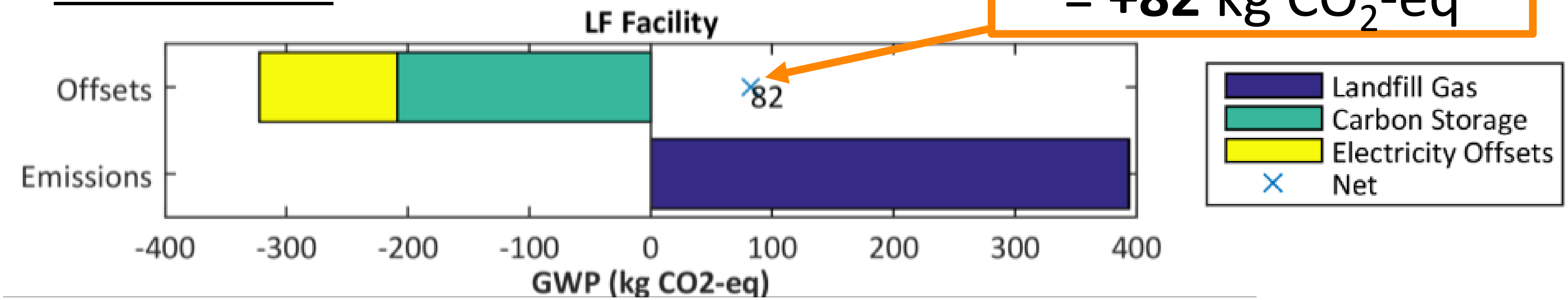


Base Case

Separately modeling waste components is essential

LF Facility Net GWP = **+82** kg CO_2-eq

LF Scenario



Comparing results to U.S. EPA Food Recovery Hierarchy

EPA

1. AD
2. AC
3. WTE
   LF

Base Case

1. AD
2. WTE
3. AC
4. LF

Food Waste Discussion

- U.S. EPA's "Food Recovery Hierarchy" is not necessarily universally applicable.
- Diverting food waste from landfills is generally beneficial, while diverting food waste from WtE may be detrimental to reducing emissions.
  - Relevant in MA and CT where WtE is not considered food waste diversion
- System performance and rankings are sensitive to food waste properties and energy offsets.
  - Regulators may wish to consider separate requirements for relatively wet or dry food waste.

Questions?

S WOLF

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Environmental Research & Education Foundation
EREF
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WHERE DISCOVERIES BEGIN

SWOLF-Related Publications

1. Levis, J. W., Weisbrod, A., Van Hoof, G., Barlaz, M. A. (2017) A Review of the Environmental Releases from Uncontrolled Solid Waste Disposal Sites. *Crit. Rev. Env. Sci. Tech.,* (*accepted*) DOI: 10.1080/10643389.2017.1342513.
2. Martinez-Sanchez, V. Levis, J. W., Damgaard, A., DeCarolis, J. F., Barlaz, M. A., Astrup, T. (2017) Evaluation of Externality Costs in Life-Cycle Optimization of Municipal Solid Waste Management Systems. *Environ. Sci. Technol.,* 51(6): 3119–3127, DOI: 10.1021/acs.est.6b06125.
3. Stanisavljevic, N., Levis, J. W., Barlaz, M. A., (2017). Life-Cycle Implications of Alternatives for Compliance with EU Directives for Municipal Solid Waste Management: A Case study from Serbia. *J. Ind. Ecol.,* DOI: 10.1111/jiec.12564
4. Hodge, K. L., Levis, J. W., DeCarolis, J. F., Barlaz, M. A. (2016). A Systematic Evaluation of Industrial, Commercial, and Institutional Food Waste Management Strategies in the U.S., *Environ. Sci. Technol.* 50(16): 8444–8452, DOI: 10.1021/acs.est.6b00893.
5. Jaunich, M. K., Levis, J. W., DeCarolis, J. F., Gaston, E. V., Barlaz, M. A., Bartelt-Hunt, S. L., Jones, E. G., Hauser, L., Jaikumar, R. (2016). Characterization of municipal solid waste collection operations. *Resourc. Conserv. Recyc.,* 114: 92–102, DOI: 10.1016/j.resconrec.2016.07.012.
6. Jaunich, M. K., Levis, J. W., Barlaz M. A., & Ranjithan, S. R., (2016). A Life-cycle Process Model for Municipal Solid Waste Collection, *J. Environ. Eng-ASCE.,* 142(8), DOI: 10.1061/(ASCE)EE.1943-7870.0001065.
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8. Pressley, P. N., Aziz, T. N., Decarolis, J. F., Barlaz, M. A., He, F., Li, F., & Damgaard, A. (2014). Municipal solid waste conversion to transportation fuels: A life-cycle estimation of global warming potential and energy consumption. *Journal of Cleaner Production*, *70*, 145–153. https://doi.org/10.1016/j.jclepro.2014.02.041
9. Levis, J. W., Barlaz, M. A., DeCarolis, J. F., Ranjithan, S. R. (2014). A Systematic Exploration of Efficient Strategies to Manage Solid Waste in U.S. Municipalities: Perspectives from the Solid Waste Optimization Life-Cycle Framework (SWOLF). *Environ Sci Technol.*48(7): 3625-3631, DOI: 10.1021/es500052h.
10. Levis, J. W., Barlaz, M. A., DeCarolis, J. F., Ranjithan, S. R. (2013). A generalized multistage optimization modeling framework for life cycle assessment-based integrated solid waste management. *Environ. Modell. Softw.*, 50(2013): 51-65, DOI: 10.1016/j.envsoft.2013.08.007.
11. 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.