Understanding Life-Cycle Environmental Trade-offs for Diverting Materials from Landfills

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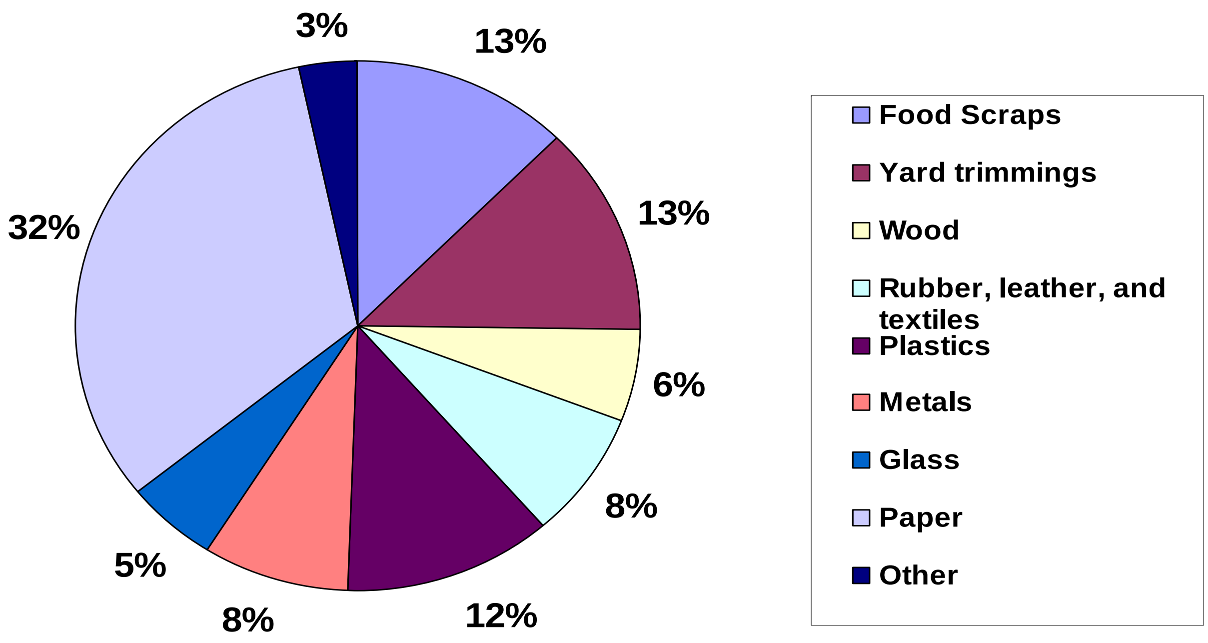
Office of Research and Development
National Risk Management Research Laboratory, Air Pollution Prevention and Control Division

Composition of U.S. Municipal Solid Waste*



*As of 2007, 254 million tons were generated in the U.S.

- The average national waste composition
  - 77% biogenic and 23% fossil origin
  - 5,300 BTU/lb on the average

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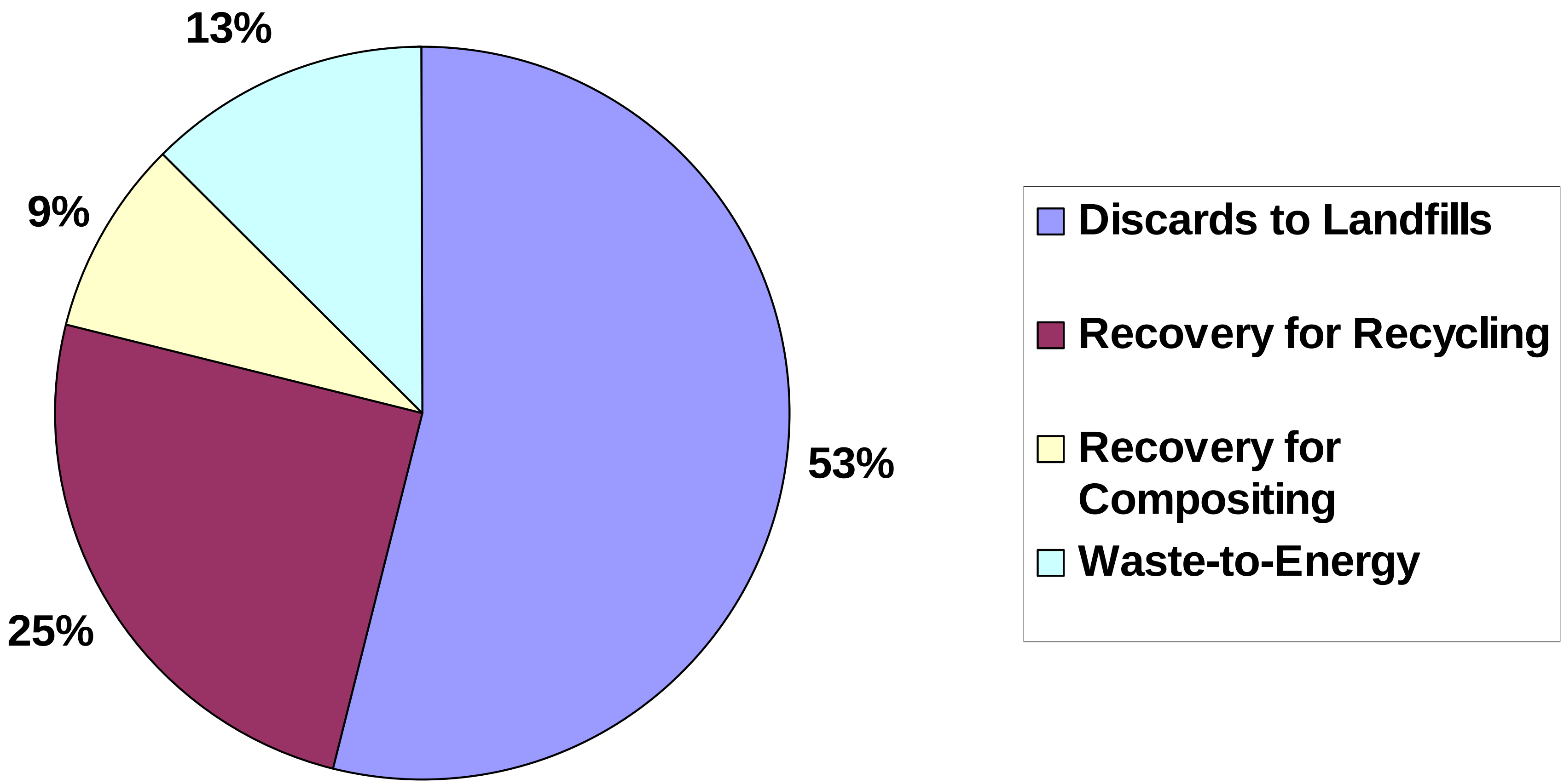
Management of U.S. MSW*



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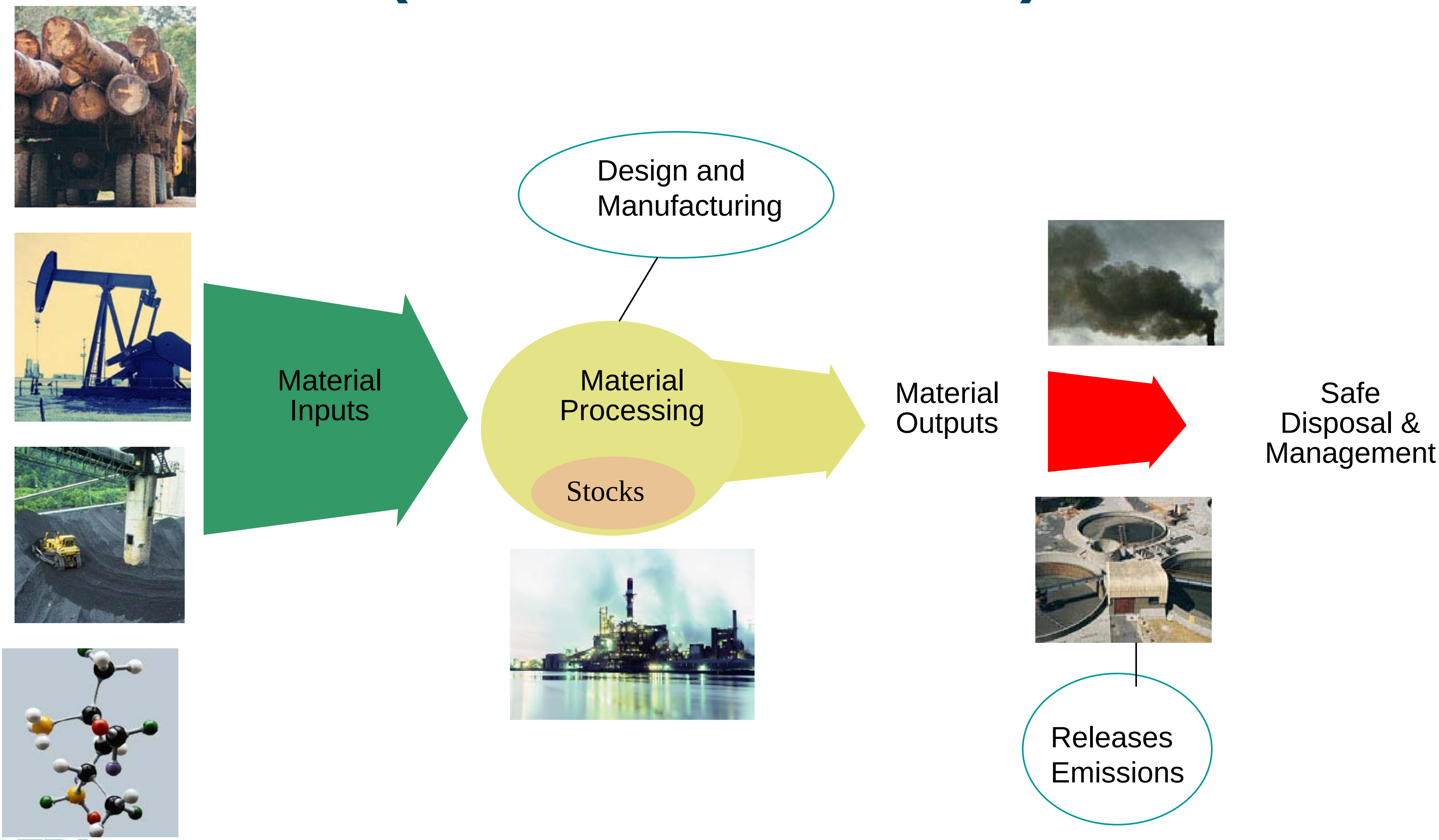
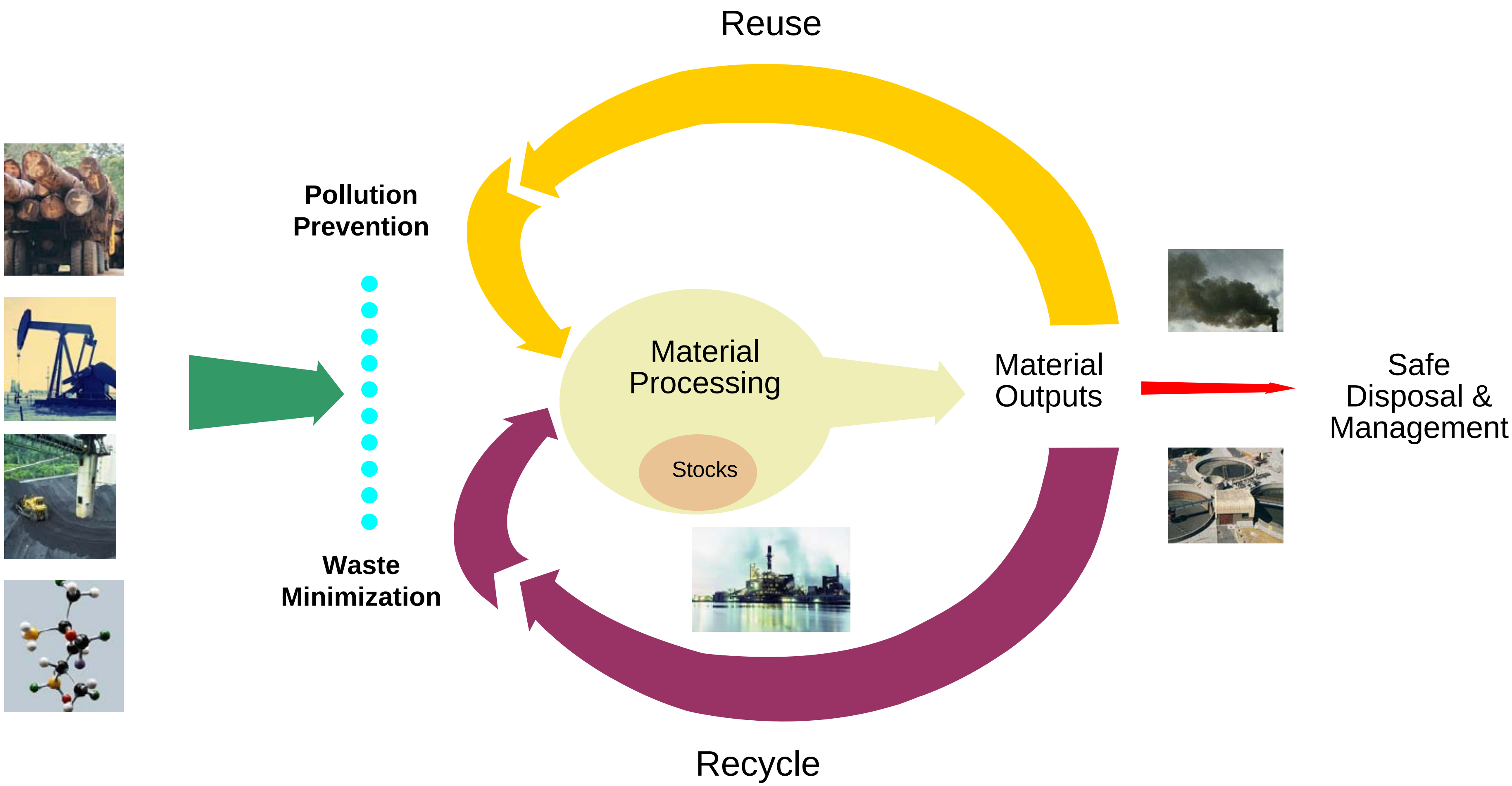
Resource Conservation Challenge

- Goals
  - –Prevent pollution and promote recycling and reuse of materials
  - –Reduce the use of chemicals at all life-cycle stages
  - –Increase energy and materials conservation
- 2020 Vision –
  - –Reduce wastes and increase the efficient sustainable use of resources

Inefficient Materials Management (Cradle – to – Grave)



Efficient Materials Management (Cradle – to – Cradle)



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To Evaluate Alternatives for Waste Management – A Holistic Approach is Needed

- Need for credible, objective analysis, science-based approach.
- Optimal solution may vary for different regions depending upon population density, energy offset, infrastructure, waste characteristics, and proximity to facilities.
  - E.g., Delaware Case Study
- Different materials (steel, aluminum, glass, paper, plastics) have varying environmental burdens and revenue streams.
- Options can be interrelated, and environmental benefits might be overlooked
  - Recycling vs WTE for paper and plastics
  - Composting vs LFGTE for food or yard waste
  - WTE vs. LFGTE to be included in renewable portfolio standards
- How do the cost and environmental emissions change as additional materials are included in a recycling program?

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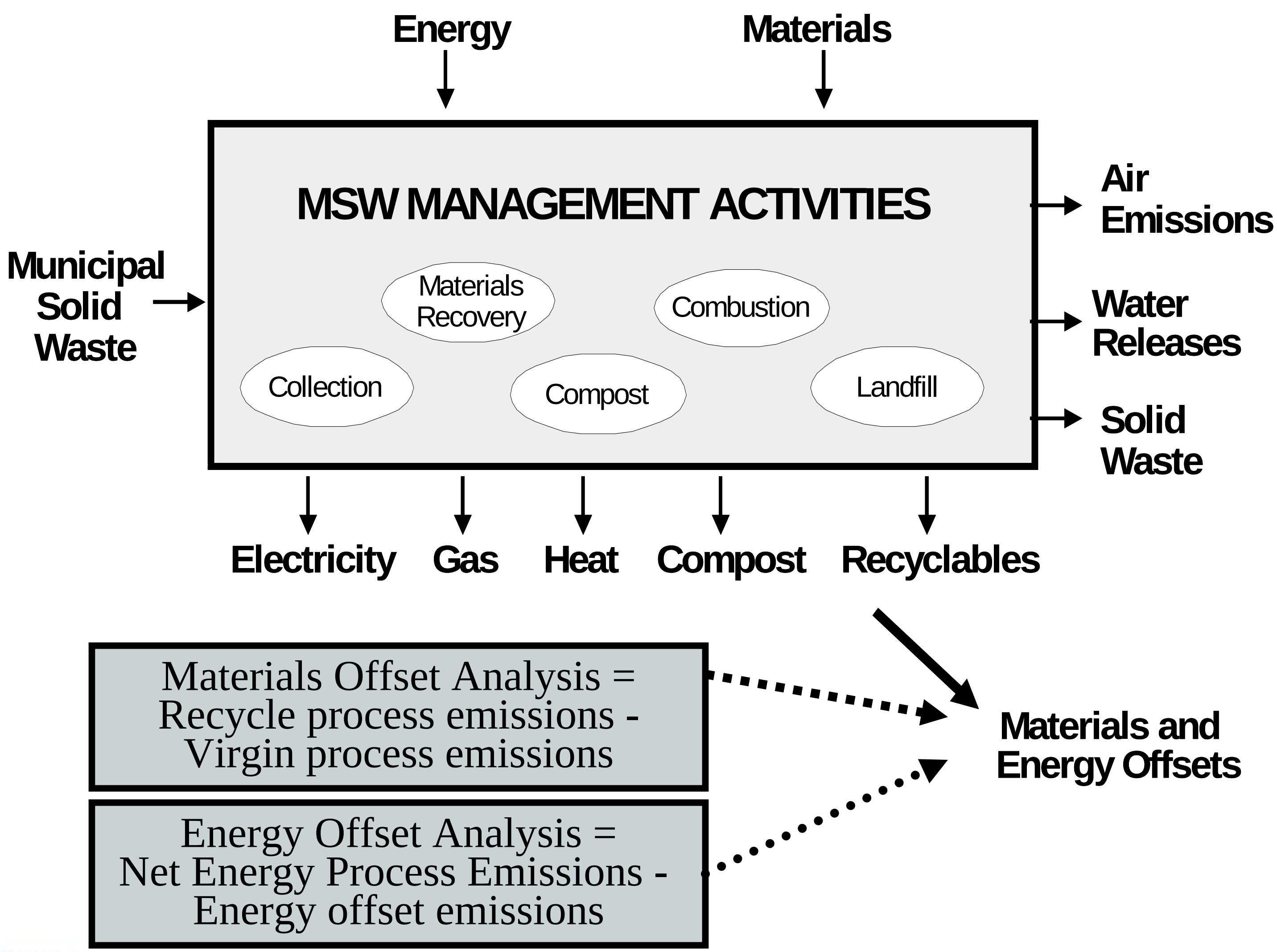
Sustainable Materials And Residuals managemenT Decision Support Tool (SMART-DST)

- A computer model to assist in decision making
  - Present quantitative information to screen management alternatives
    - Cost, energy consumption, emissions
    - Life-cycle methodology
      - Account for direct and indirect emissions from a management operation, such as collection or transportation
  - Compare many alternatives
    - Model existing waste management system
    - Identify an optimal solution with respect to cost or environmental emissions such as GHGs, energy, waste diversion targets
  - Perform sensitivity and uncertainty analysis on key model inputs
- Over ~80 studies conducted for regional, community, and national assessments of materials and discards management

Flow Diagram for Materials and Waste Management



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Recent Study Comparing LFGTE and WTE for Electricity Production

- Evaluated range of scenarios for both LFGTE and WTE
- Less variability in calculating emissions for WTE
  - Design and operation similar across facilities
  - Excellent dataset documenting emissions for 100% of U.S. facilities
- More variability for LFGTE
  - Modeling biological process
  - Less available data documenting emissions
  - More differences in design and operation than WTE
- Evaluated range of conditions for LFGTE & WTE

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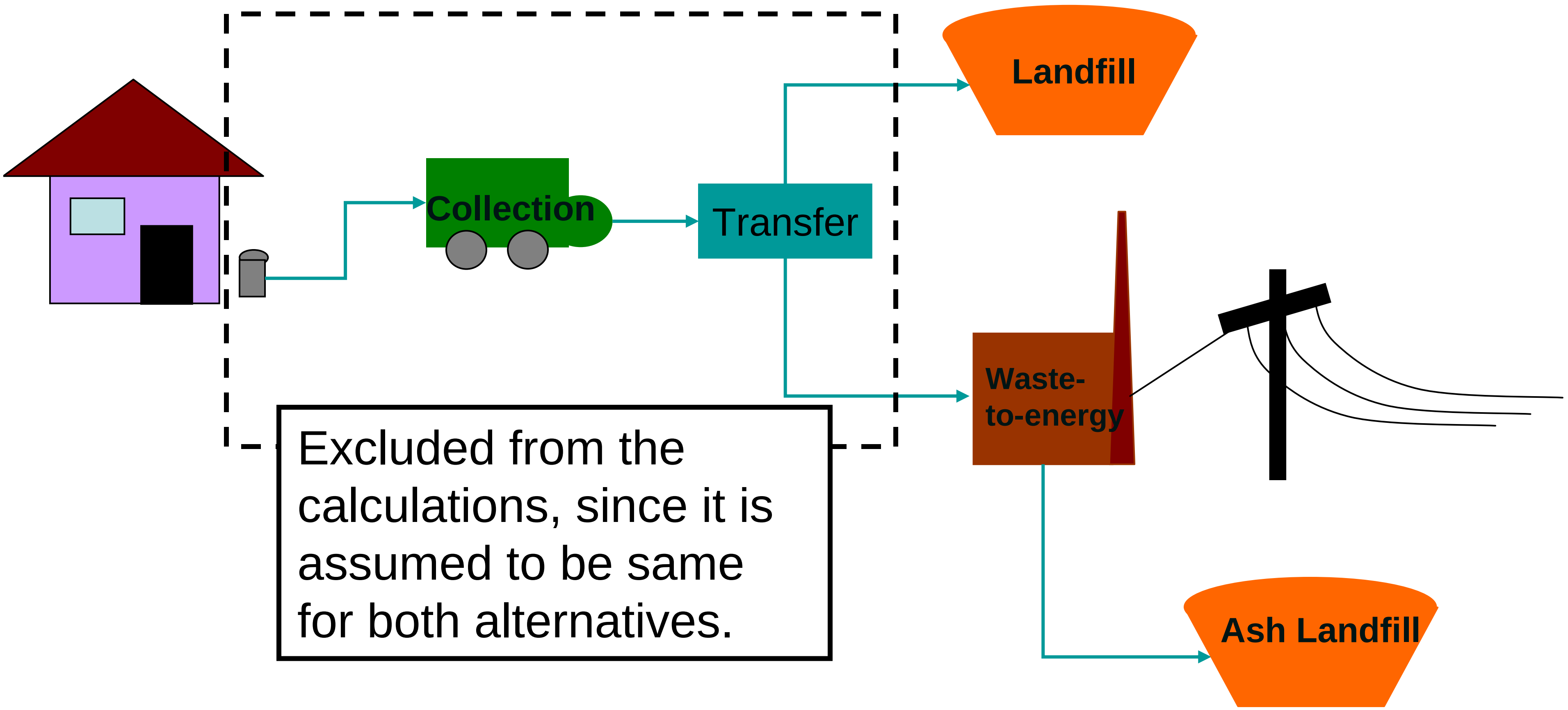
Assumed Boundaries for Waste Management System



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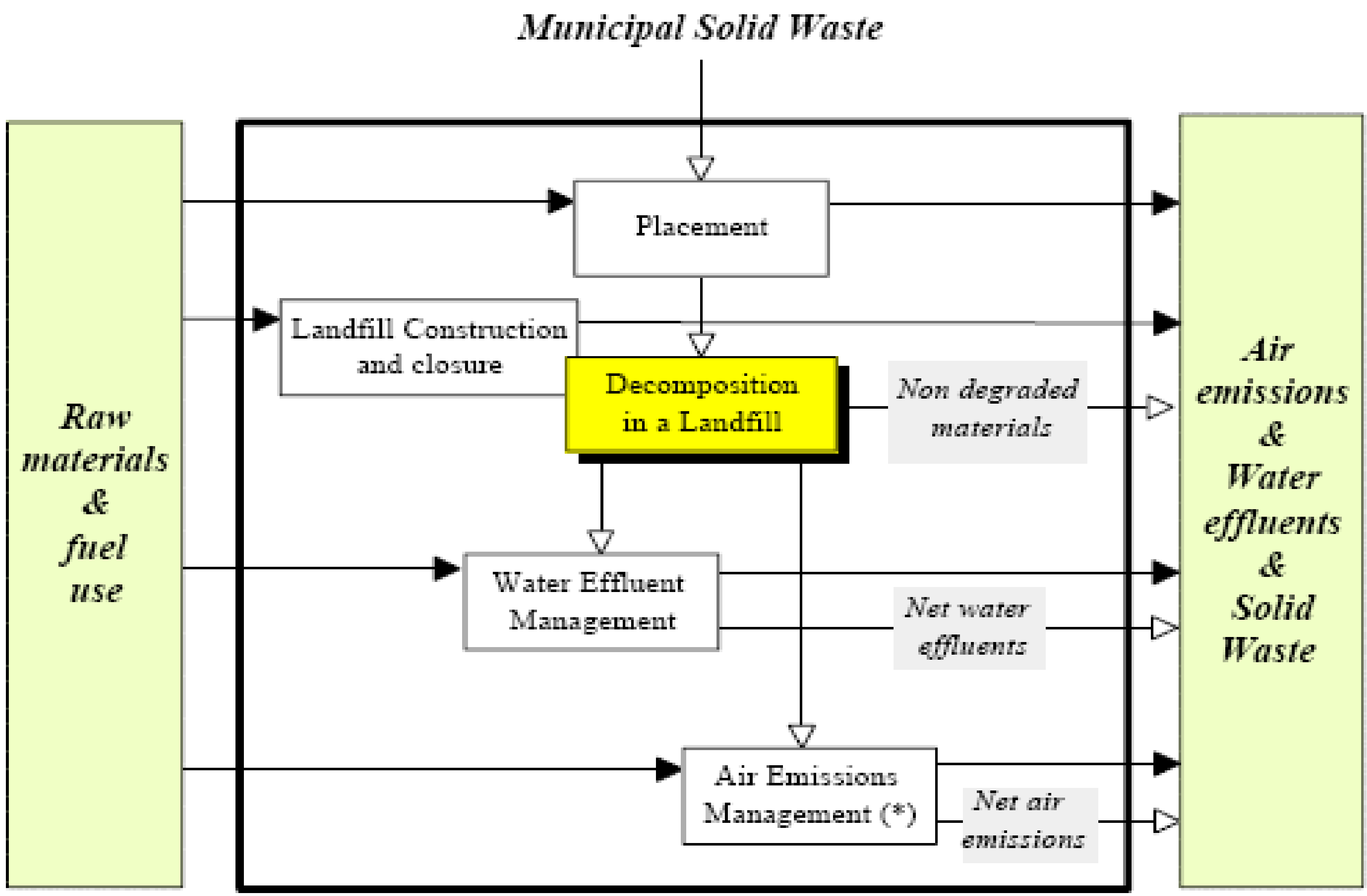
Baseline Assumptions for Landfills

- Considered a regional landfill that is subject to federal air emissions regulations
  - Operational LFG collection system
- Modeled a single cell in the regional landfill
  - Initial waste placement in a new cell was set to Year 0.
- Considered variety of LFG management schemes
  - combination of venting, flaring and energy recovery
- Energy recovered through an internal combustion engine (ICE)
  - 15 years of lifetime
  - Excluded the offline time that is required for the routine maintenance of the internal combustion engine
  - Emission factors for internal combustion engine (US EPA, 1998)
- Regardless of the duration of the energy project, the LFG will be controlled until Year 65, via either flaring devices or ICE

Conceptual Life-Cycle Model for Landfills



(*) includes energy recovery from methane emissions and the subsequent economies of emissions

Methodology – Landfill gas to energy

- The total LCI emissions are the summation of the emissions associated with:
  - –the construction, operation and post-closure operation of a landfill,
  - –the decay of the waste under anaerobic conditions,
  - –the equipment utilized during landfill operations and landfill gas management operations,
  - –the production of diesel required to operate the vehicles at the site, and
  - –the treatment of leachate

Ref: Camobreco et al. (1999)

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Baseline Assumptions for Waste to Energy

- Heat rate of 18,000 BTU/kWh (~19% system efficiency)
- Excluded steel recovery from baseline runs
- U.S. national average MSW composition used
- Derived stack emissions (g/ton of waste item)
  - Performance data and regulations on flue gas concentration limits
- Included full emission control equipment
  - Scrubbers for SOx emissions
- Included full LCI for the disposal of the ash

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Methodology – Waste to Energy

- The total LCI emissions are the summation of the emissions associated with:
  - the controlled stack gas emissions
  - the allocated emissions from the use of limestone in the scrubbers
  - the allocated emissions from the disposal of ash

Ref: Harrison et al. (2000)

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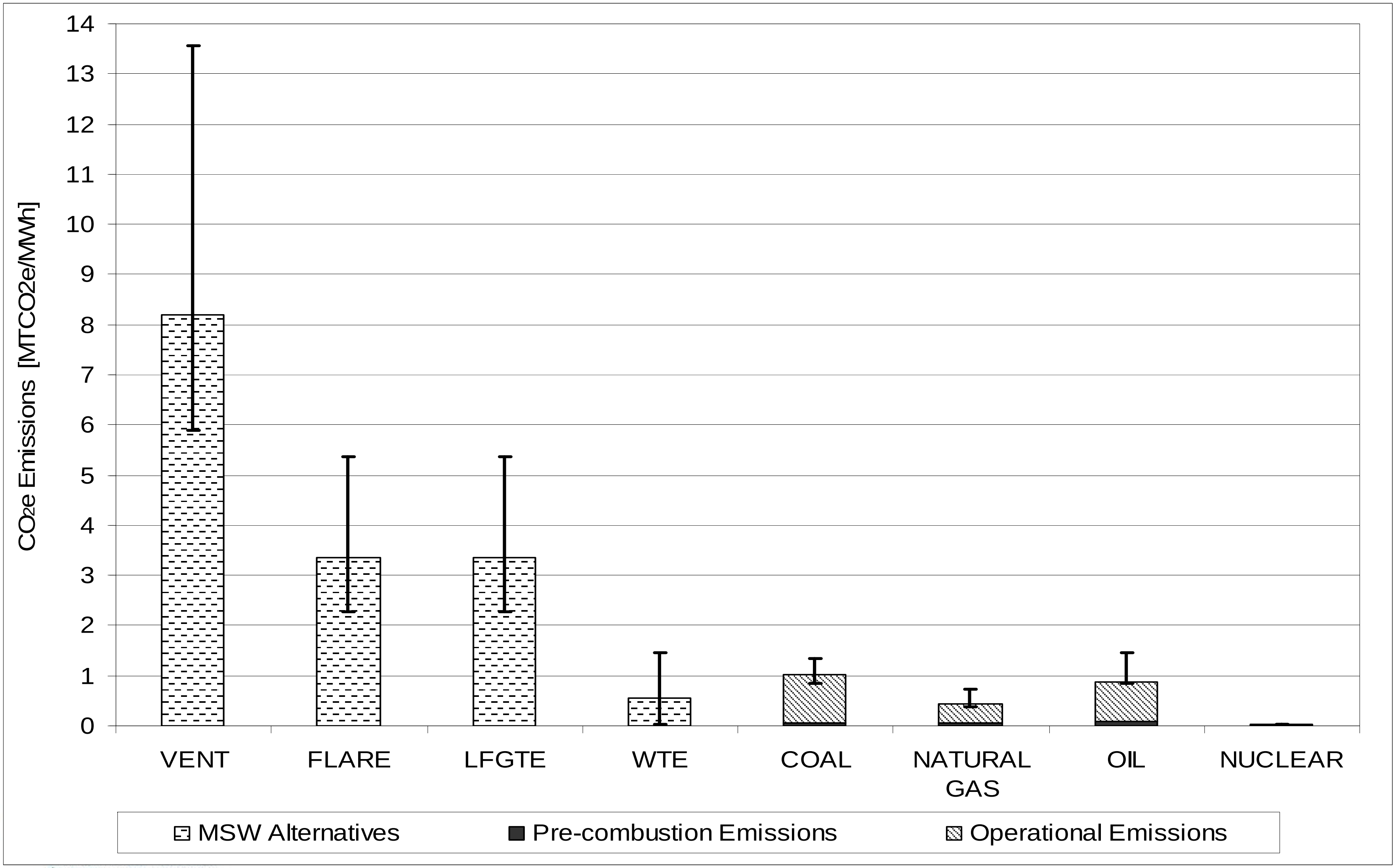
Comparison of MSW Discards Management to Conventional Electricity Generating Technologies



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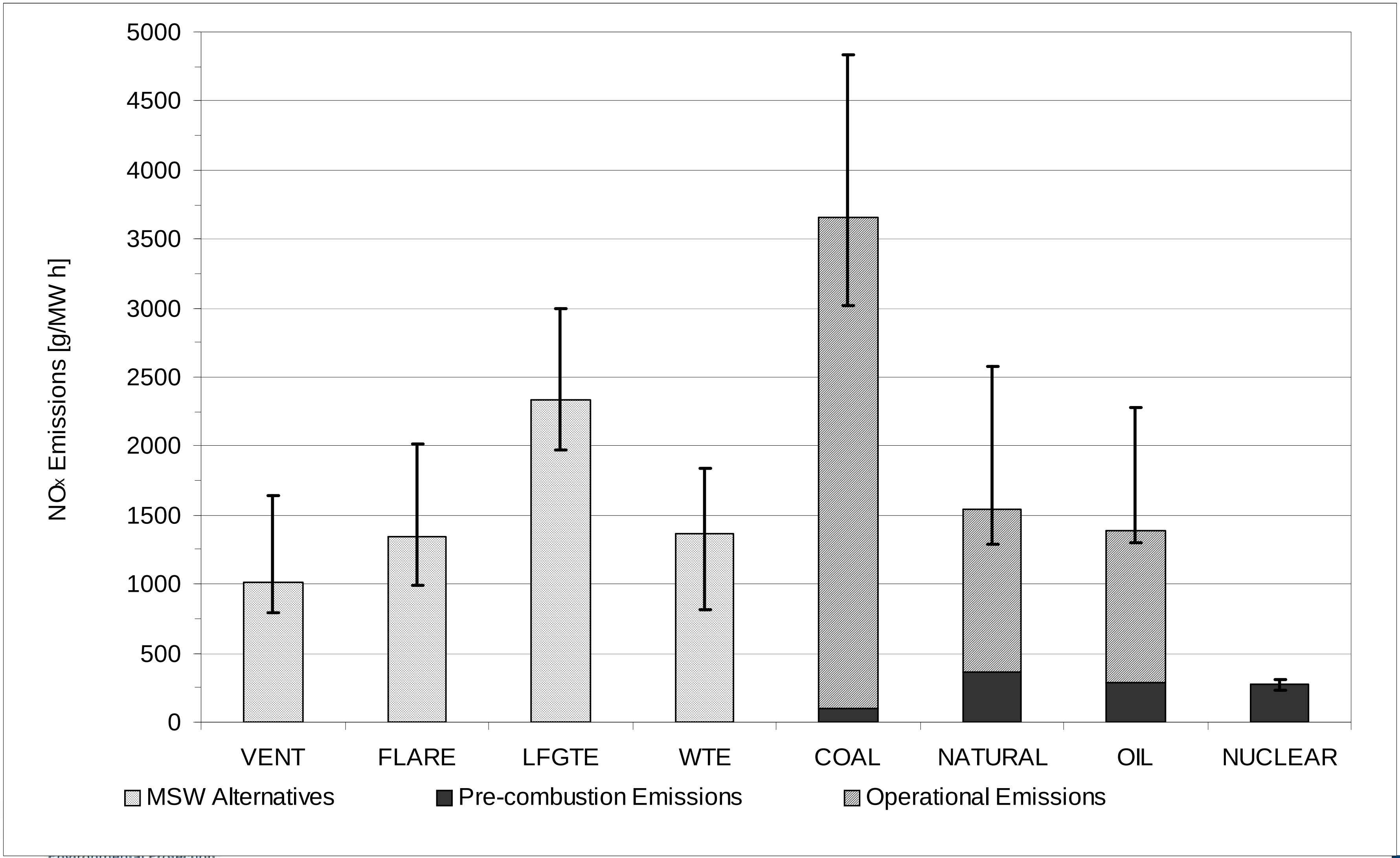
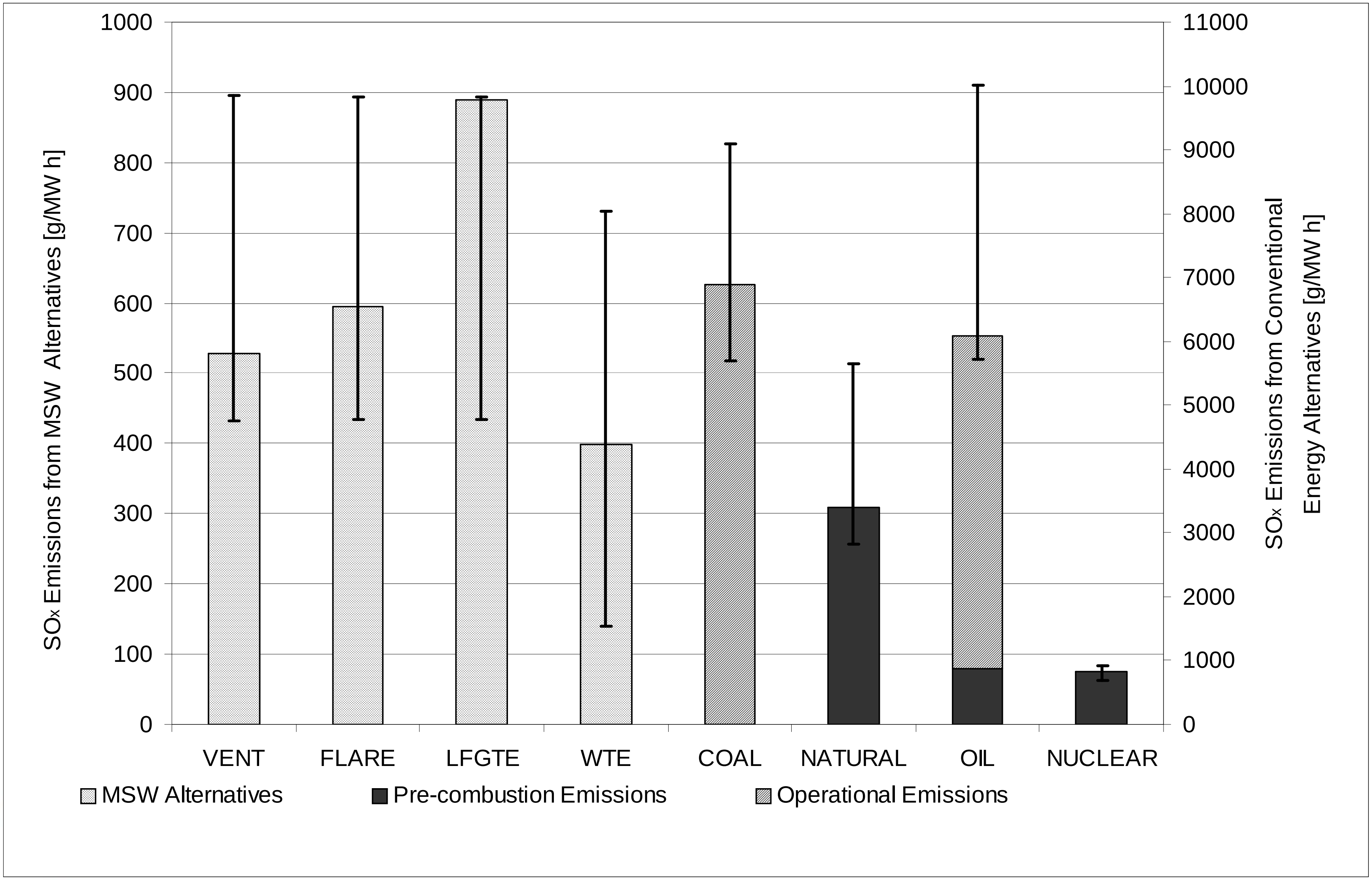


Comparison of MSW Discards Management to Conventional Electricity Generating Technologies



Sensitivity of Results

At landfill:

- Various landfill gas management scenarios, oxidations rates considered to estimate total CH_4 capture and use
  - From 2.3 to 8.2 MTCO2e/MWh

At waste-to-energy facility:

- The efficiency of the power plant varied from 15% to 30%
  - From 0.4 to 0.7 MTCO2e/MWh
- Biogenic and fossil content of the MSW varied while using the default efficiency of 19%
  - 0.02 MTCO2e/MWh for all biogenic composition
  - 1.5 MTCO2e/MWh for all fossil composition

Findings from Recent Study Comparing LFGTE and WTE for Electricity Production

- When comparing electricity (kWh) per ton of municipal waste, WTE is on average six to eleven times more efficient at recovering energy from wastes than landfills.
- For even the most optimistic assumptions about LFGTE, the net life-cycle environmental tradeoffs is 2 to 6 times the amount of GHGs compared to WTE.
  - GHGs for WTE ranged from 0.4 to 1.4 MT MTCO2e/MW h where as the most aggressive LFGTE scenario is resulted in 2.3 MTCO2e/MWh.
- In addition, WTE also produces lower NOx emissions than LFGTE, whereas SOx emissions depend on the specific configurations of WTE and LFGTE.

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Example Study for State of Delaware

- Help State of Delaware in their materials and waste management planning
  - Cost efficient waste management
  - Meeting state mandated recycling goals
  - Improved waste collection systems
  - Environmental impacts
- Generate multiple alternatives for solid waste management while considering
  - Greenhouse gas emissions
  - Other environmental emissions (local/regional)
  - Energy consumption and offsets
  - Policy implications of technology choices
  - Municipality budgets
  - Need for new facilities (e.g. new landfills)
  - Social preferences

SMART-Decision Support Tool was utilized

Outline for Conducting a Study

- Determine goals/objectives for study
  - To increase diversion rate? Decrease GHGs? Expand curbside collection? Determine least cost for discards management?
- Modeling approach
  - Boundary and scope definitions
- Data Collection
- Location-specific strategies
  - Residential and commercial waste
  - Least-cost and least environmental emissions scenarios
    - Combinations of curbside recycling, yard waste composting and combustion
  - Alternative strategies to consider “other” factors such as equity, political and economic feasibility, ability to site facility
- Sensitivity and Uncertainty Analysis

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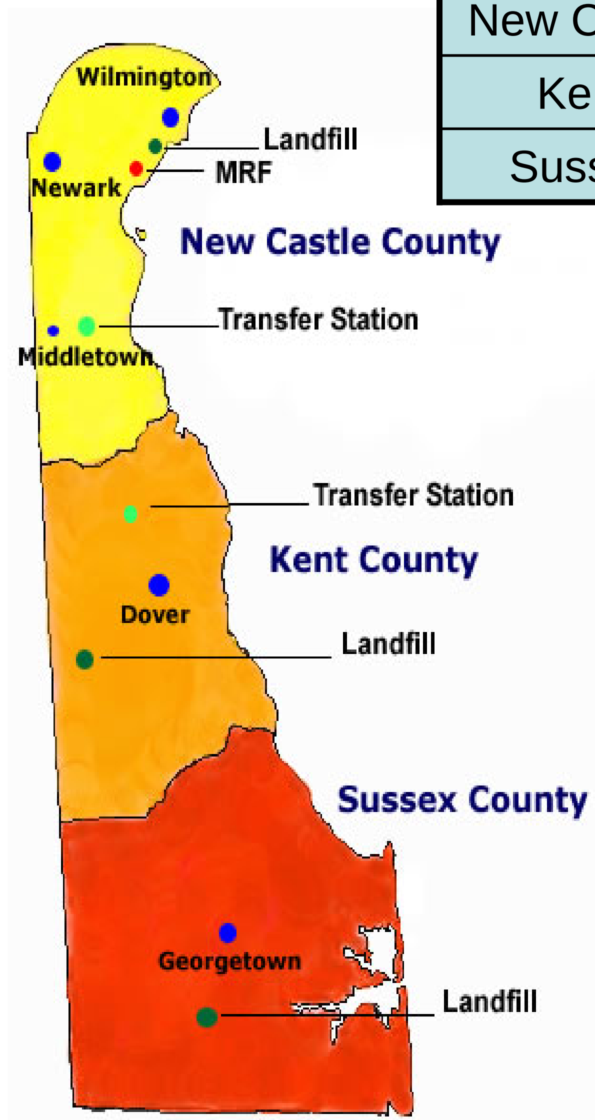
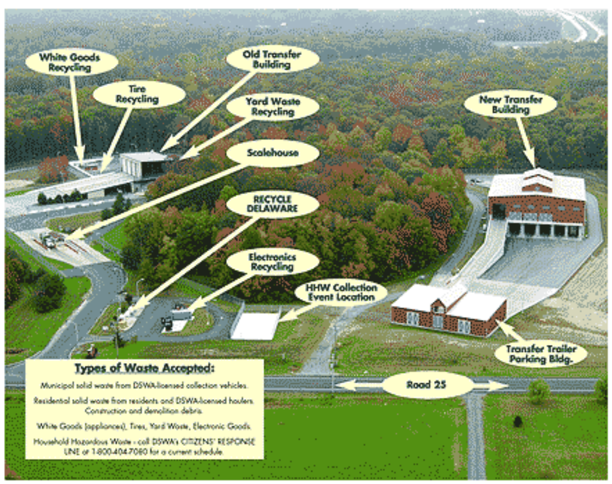
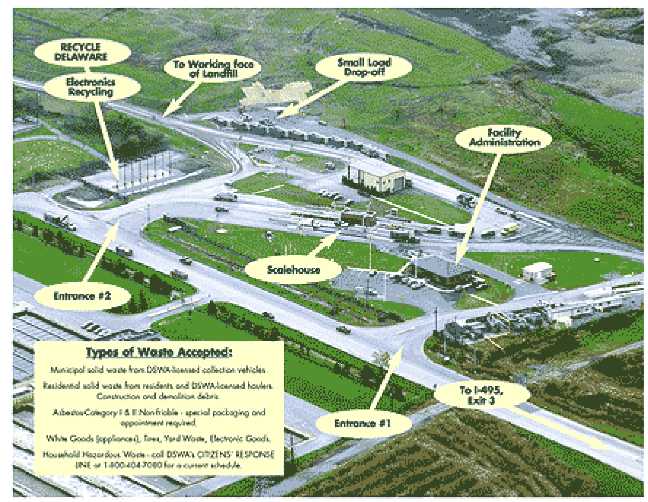
Modeling SWM System in Delaware

County	Population	
New Castle	64%	Urban
Kent	16%	Rural
Sussex	20%	Rural







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Example Scenarios for the Delaware Study[1]

	Waste diversion targets met based on least-cost of available options						Minimizing on GHE	
Scenario #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Pre-sorted Recycling	X	X	X	X	X	X	X	X
Curbside Recycling		X	X	X	X	X	X	X
Mixed Waste Recycling		X	X	X	X	X	X	X
Yard Waste Composting				X	X	X	X	X
Waste-to-energy					X	X		X
Landfill	X	X	X	X	X	X	X	X
Diversion, %	**20**	**25**	**28**	**35**	**30**	**88**	**31**	**85**

[1]**Reference:** Kaplan, P. O.; Ranjithan, S. R.; Barlaz, M.A. (2009) Use of Life Cycle Analysis To Support Solid Waste Management Planning for Delaware. ***Environmental Science and Technology***, 43 (5), 1264-1270, 29 Jan 2009.

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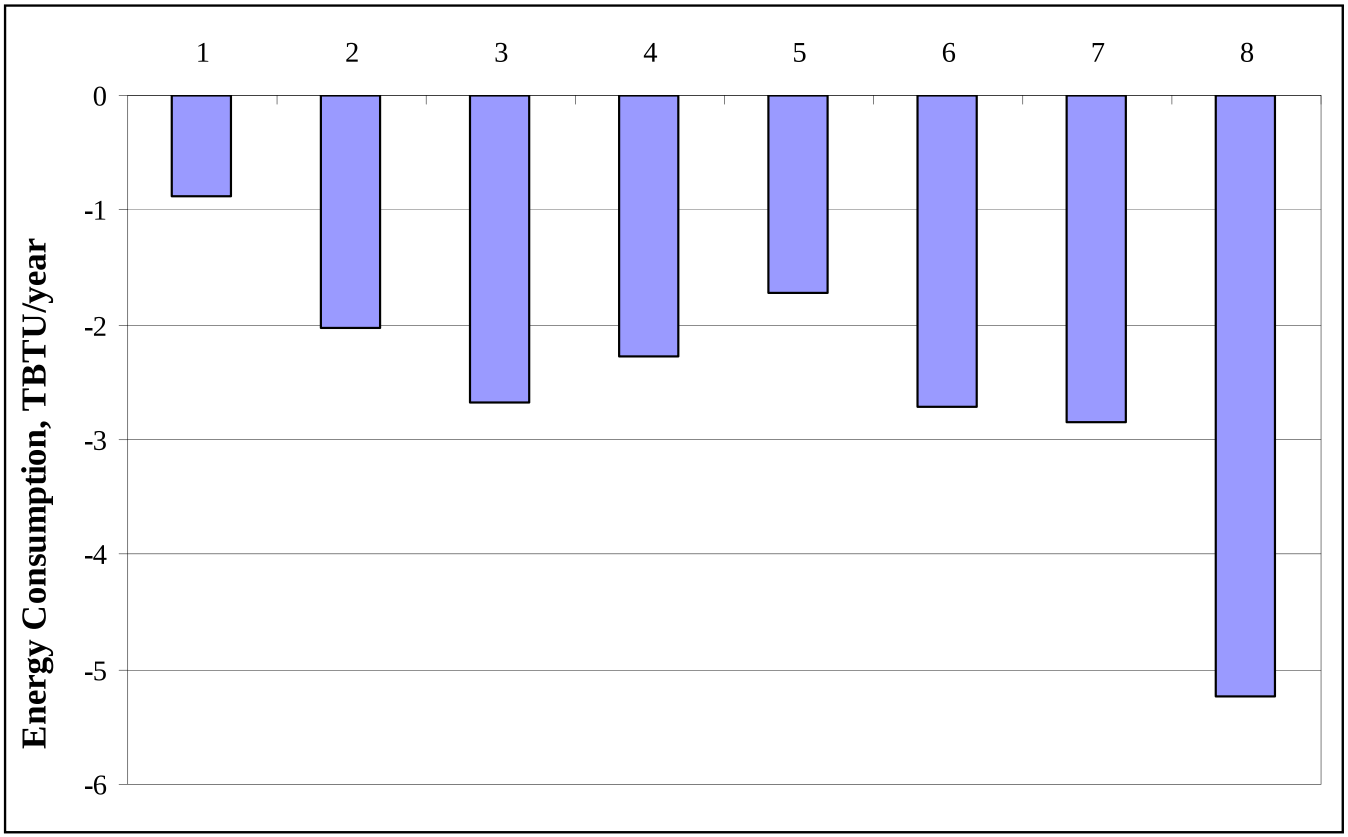
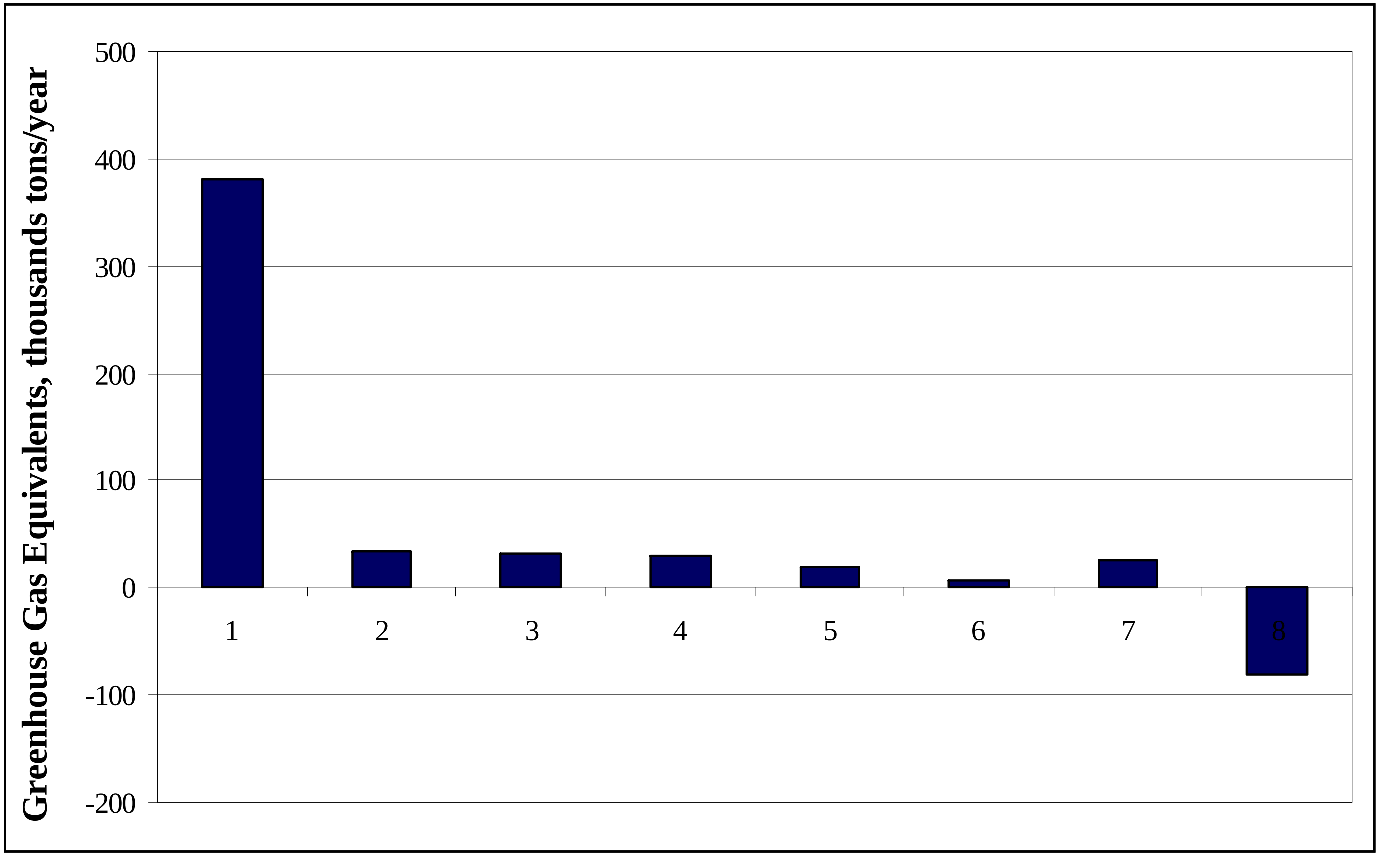
Comparison of Net Energy Consumption of Example Scenarios for Delaware Study



	Recycling	Composting	WTE	Objective	Diversion
1	X			COST	20
2	X				25
3	X				28
4	X	X			35
5	X	X	X		30
6	X	X	X		88
7	X	X		GHG	31
8	X	X	X		85

Comparison of Net GHG of Example Scenarios for Delaware Study



	Recycling	Composting	WTE	Objective	Diversion
1	X			COST	20
2	X				25
3	X				28
4	X	X			35
5	X	X	X		30
6	X	X	X		88
7	X	X		GHG	31
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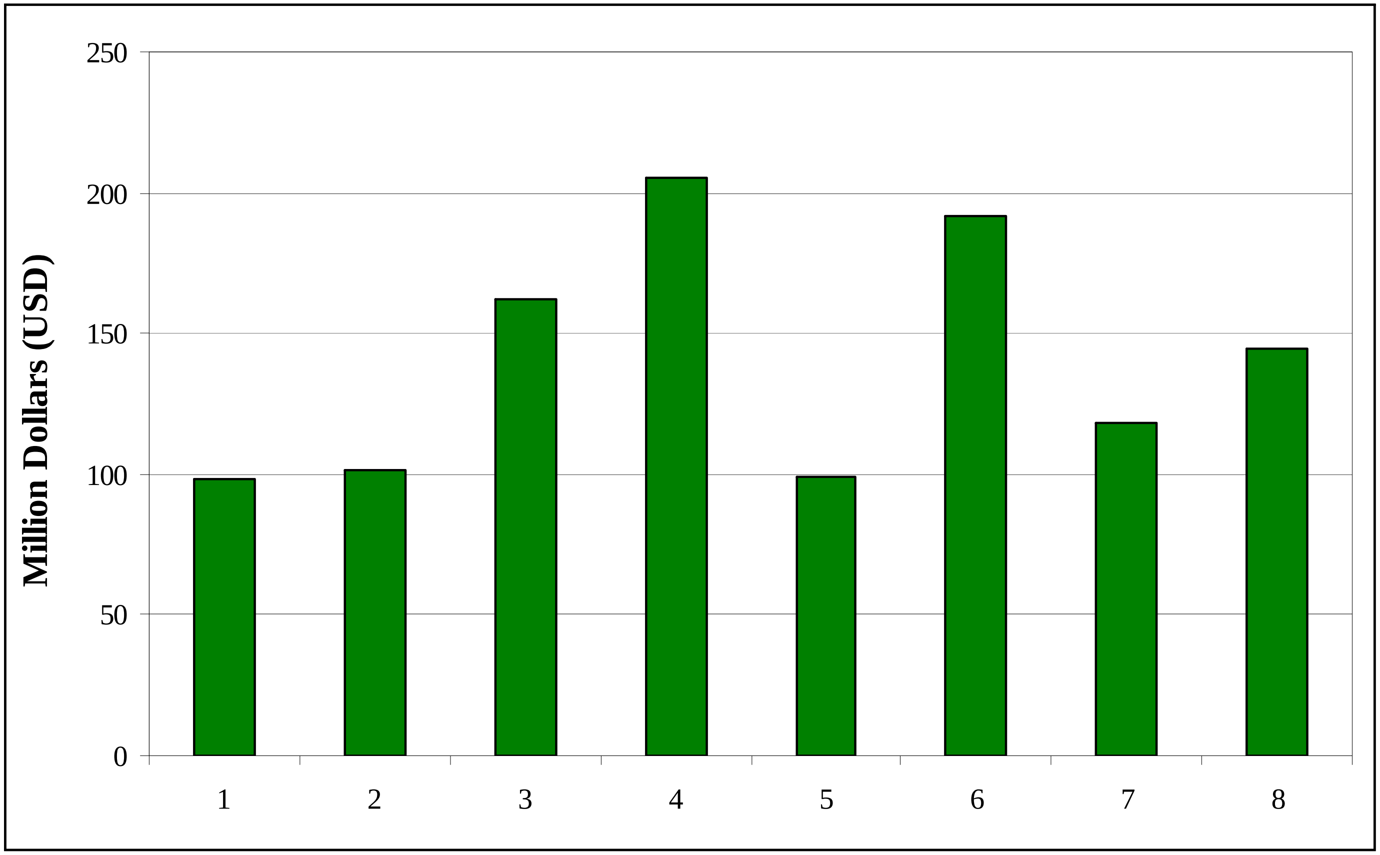
Comparison of Net Costs of Example Scenarios for Delaware Study



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1	X			COST	20
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5	X	X	X		30
6	X	X	X		88
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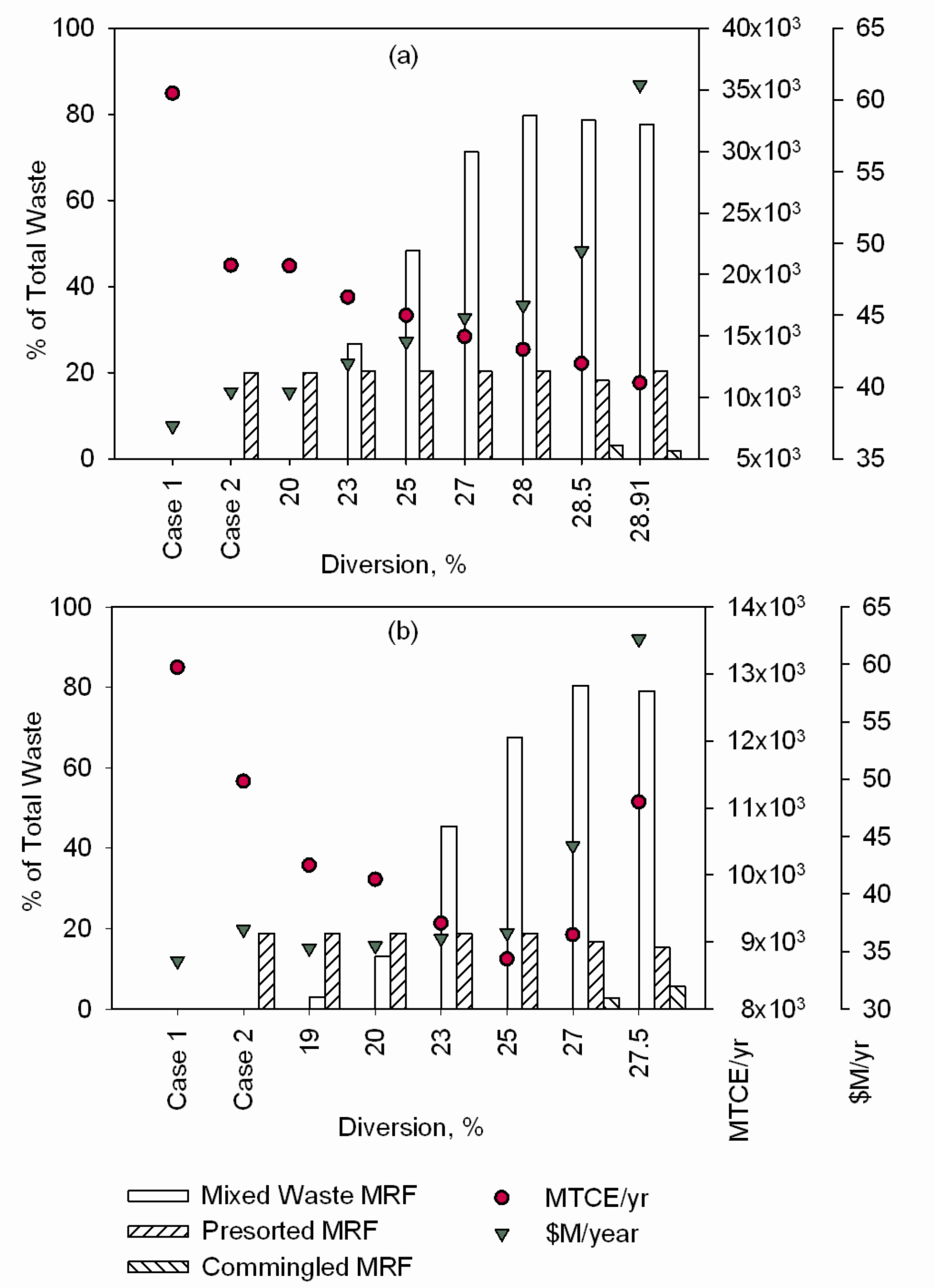
Recycling Scenarios

Variation of Mass Flows and GHE with Diversion

- Pre-sorted and mixed waste MRFs are utilized throughout
- Cheapest option to divert waste through mixed waste MRF
- Commingled recyclables only collected in max diversion case
- Cost escalates with implementation of curbside recycling
- In Sussex County, GHE decrease is minimal with use of curbside collection
- GHE decrease by 50% in New Castle County, compared to only a 10% decrease in Sussex County



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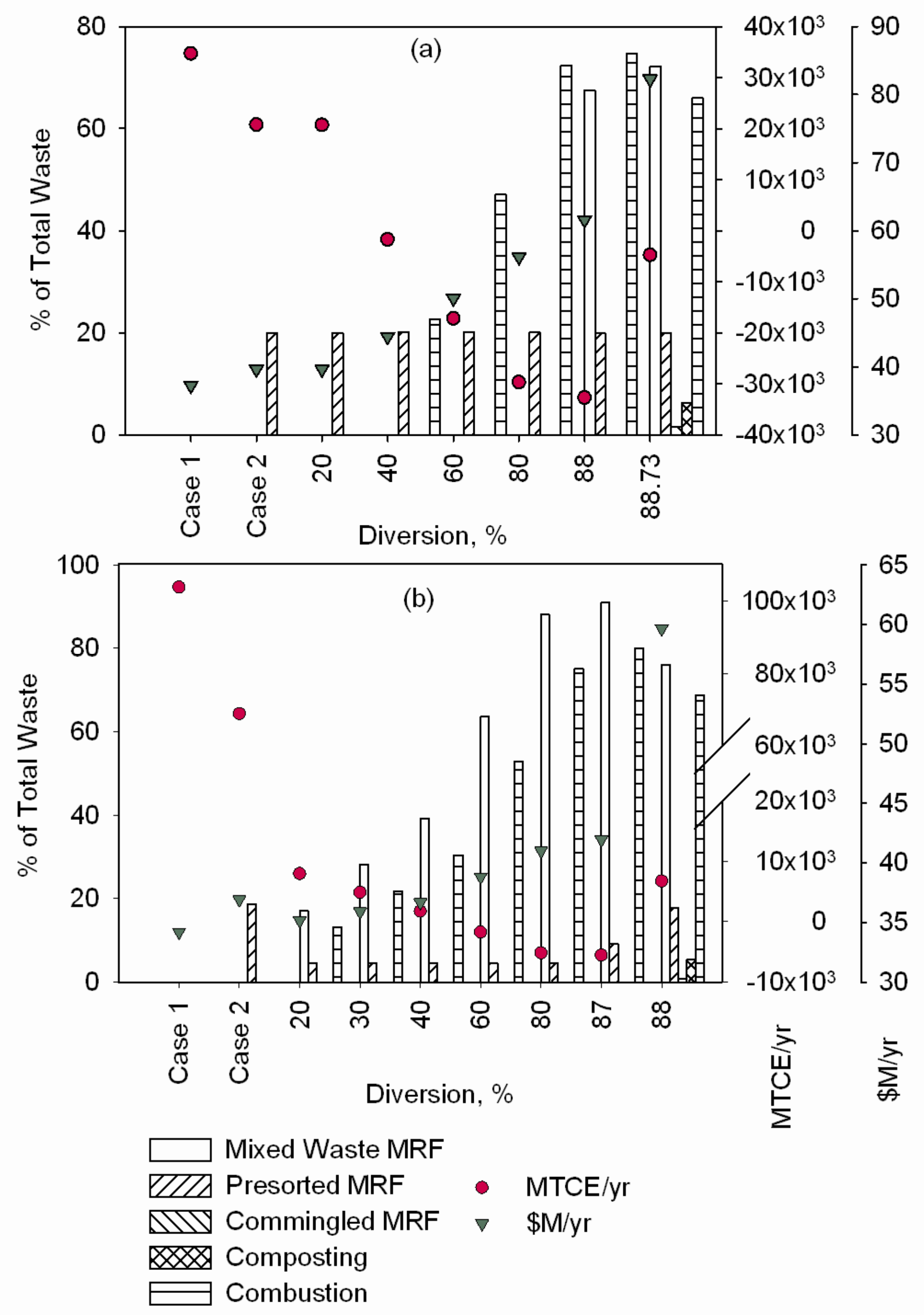
Recycling and Composting and Combustion Scenarios

Variation of Mass Flows and GHE w/ Diversion

- WTE is utilized to meet diversion constraint
  - estimated to be less expensive than alternatives
- GHE increases near maximum due to composting
- Cost and GHE increase near maximum case illustrate extremes of numerical solution
  - composting and curbside recycling
- Ash content of yard waste leads to use of composting
- In Sussex County, a mixed waste MRF is utilized upstream of WTE to reduce transport costs and capture valuable recyclables



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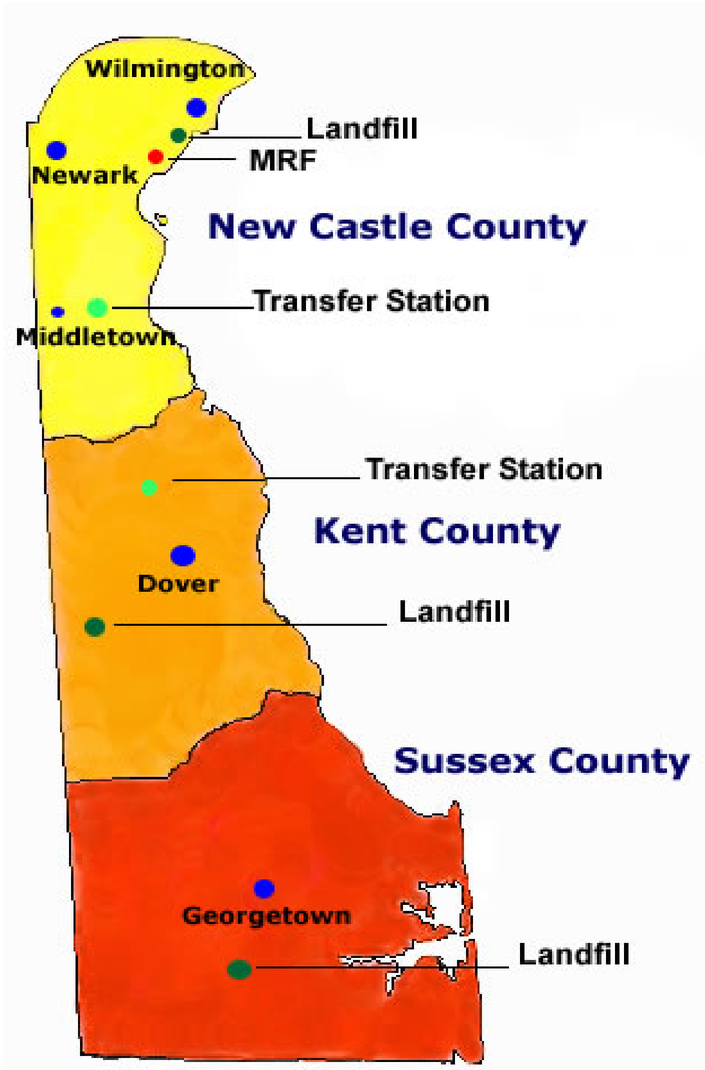
Summary for Delaware Study

- SMART-DST used for statewide analysis replacing default data with site-specific data
- Quantified tradeoffs among cost, waste diversion, and life-cycle emissions
- Provided counter-intuitive and creative results
  - A uniform statewide strategy will be sub-optimal
    - New Castle County contributed more to state-wide diversion
  - Effectiveness of yard waste composting influenced by transport distance
  - In least-cost strategies, combustion provides more diversion than recycling



Final Remarks

- To understand the energy benefits from materials and waste management, a holistic approach is needed that considers life-cycle environmental tradeoffs and moves toward cradle-to-cradle management
  - Differences occur for different materials (metals, paper, plastics, glass, yard and food waste)
  - Regional differences can occur based on population density and infrastructure
- Studies using the SMART-DST are providing information helpful in
  - making more informed decisions regarding materials and waste management
  - meeting waste diversion and environmental goals
- Analysis for discards management found WTE is on average is six to eleven times more efficient at recovering energy from waste than landfills.
  - However, results are sensitive to consideration of carbon storage credits in landfills and different MSW management schemes

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THANK YOU

QUESTIONS?

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