



Holistic Approach to Evaluating Technology Options for Materials and Waste Management

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What Drives the Technology Choices by Cities and Private Companies? – World Bank's Urban Week



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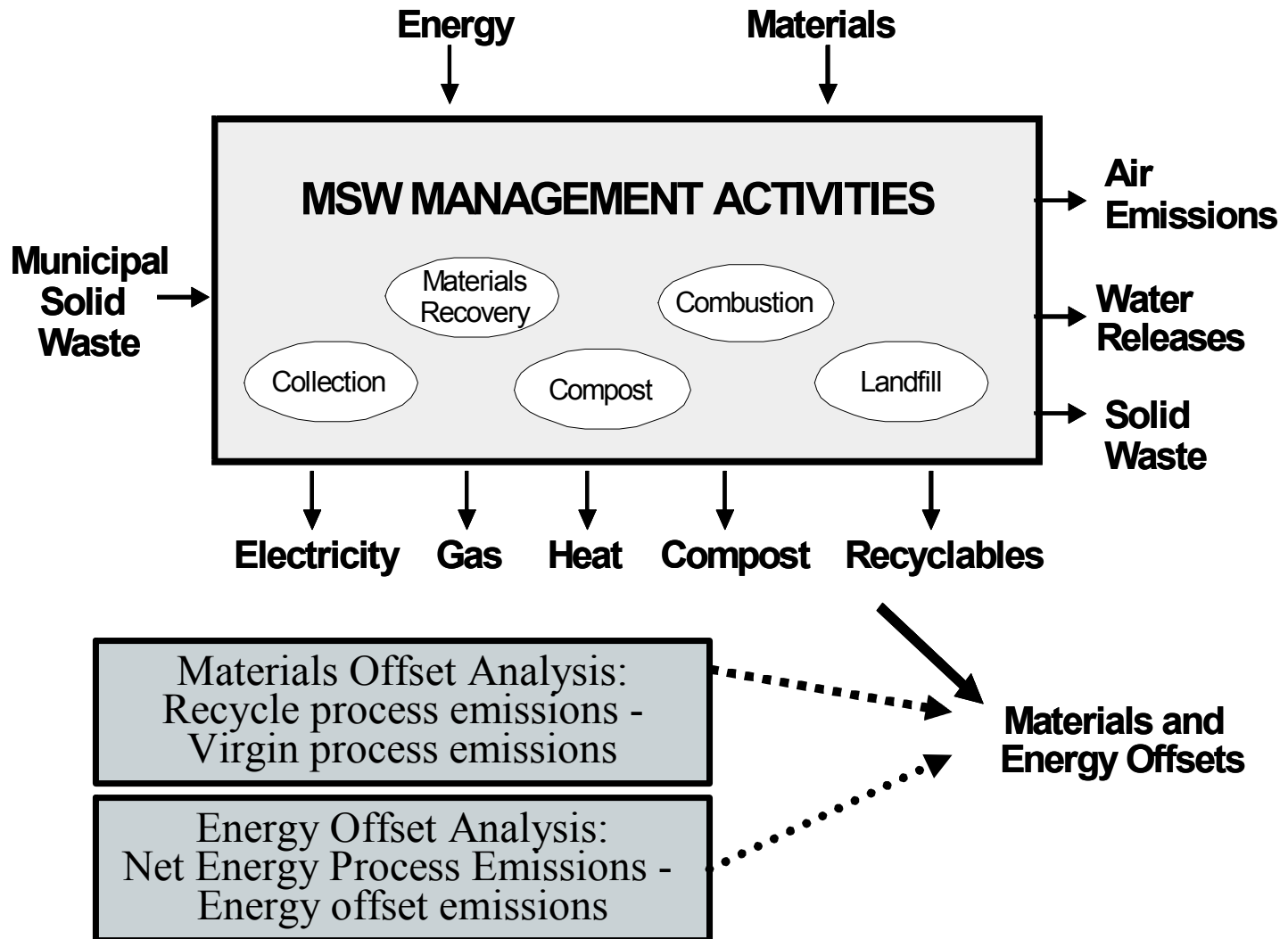
Why Use a Holistic Approach?

- Results can be counter intuitive. Need for credible and objective analysis.
- Most optimal solution may vary for different regions depending upon population density, energy offset, infrastructure, waste quantity and composition, proximity to facilities.
- Options can be interrelated:
 - Recycling vs. waste-to-energy for recyclable paper and plastics
 - Relative benefits of landfilling or composting yard waste if landfill methane is recovered for its energy potential
 - How do the cost and environmental emissions change as additional materials are included in a recycling program
- Different materials (steel, aluminum, glass, paper, plastics) have varying environmental burdens and revenue streams.
 - More effective programs account for these differences. Helps determine which materials to target for recovery.
- Important to consider emissions from transportation that may aggravate urban smog and air toxics.
- Results can be used to help benchmark current practices and document and communicate environmental improvement over time.

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
 - Identify an optimal solution
 - Model existing waste management system
 - Perform sensitivity and uncertainty analysis on key model inputs
 - Consider “unmodeled” factors such as equity, political feasibility, capital intensive, ability to site facility by evaluating less optimal solutions

Flow Diagram for Materials and Waste Management



Outline for Conducting a Study

- Modeling Approach
- 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
- Sensitivity and Uncertainty Analysis

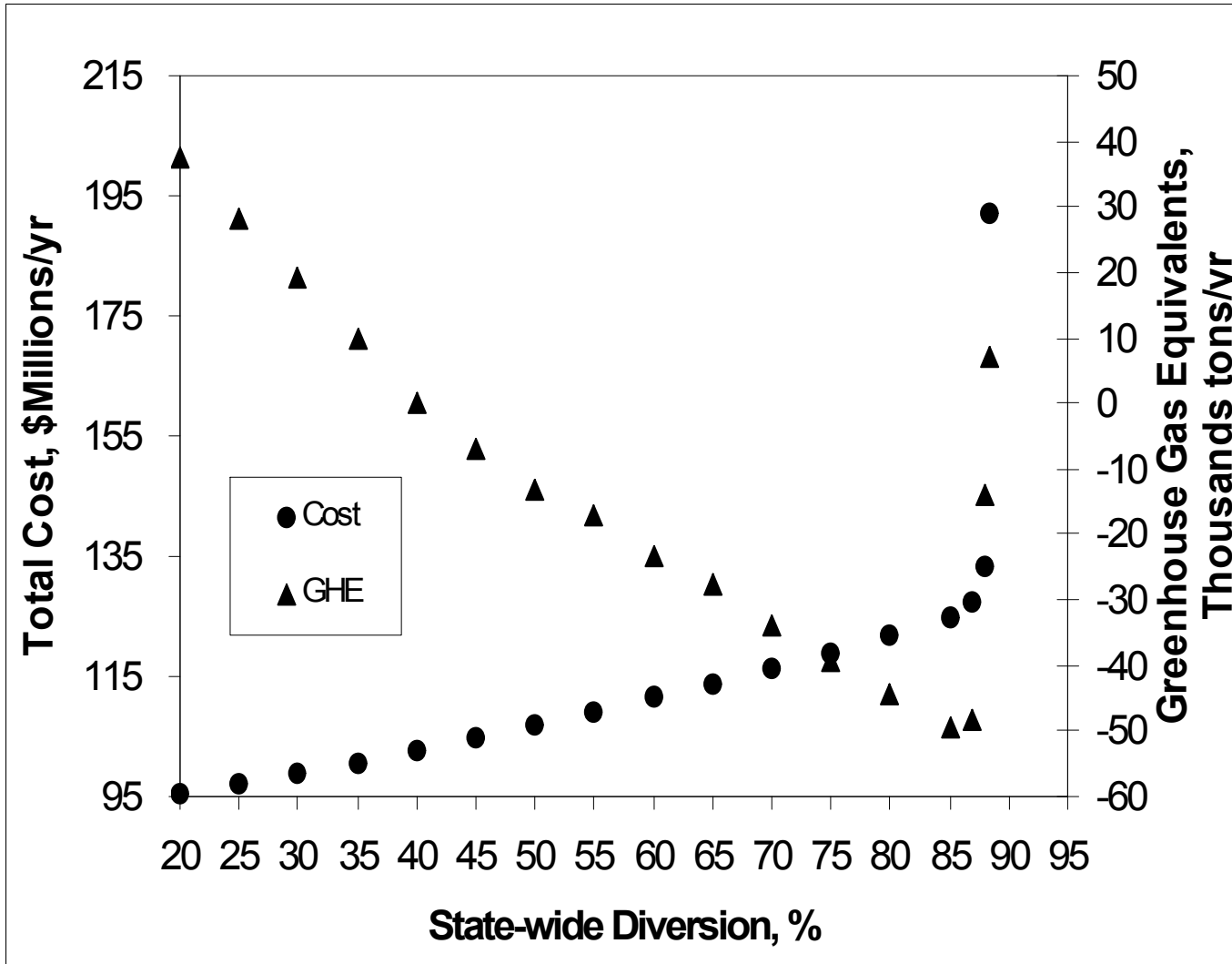
Example Study for State of Delaware to Compare Alternative Strategies^a

	Least-Cost					Least-GHG	
	I	II ^b	III	IV	V	VI	VII
Pre-sorted Recycling		X	X	X	X	X	X
Curbside Recycling			X	X	X	X	X
Mixed Waste Recycling			X	X	X	X	X
Yard Waste Composting				X	X	X	X
Waste-to-energy					X	X	
Landfill	X	X	X	X	X	X	X
Diversion, %	0	20	20-32	20-38	20-83	NA	NA

^aReference for study: 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.

^bStrategy II → current practice (20% diversion)

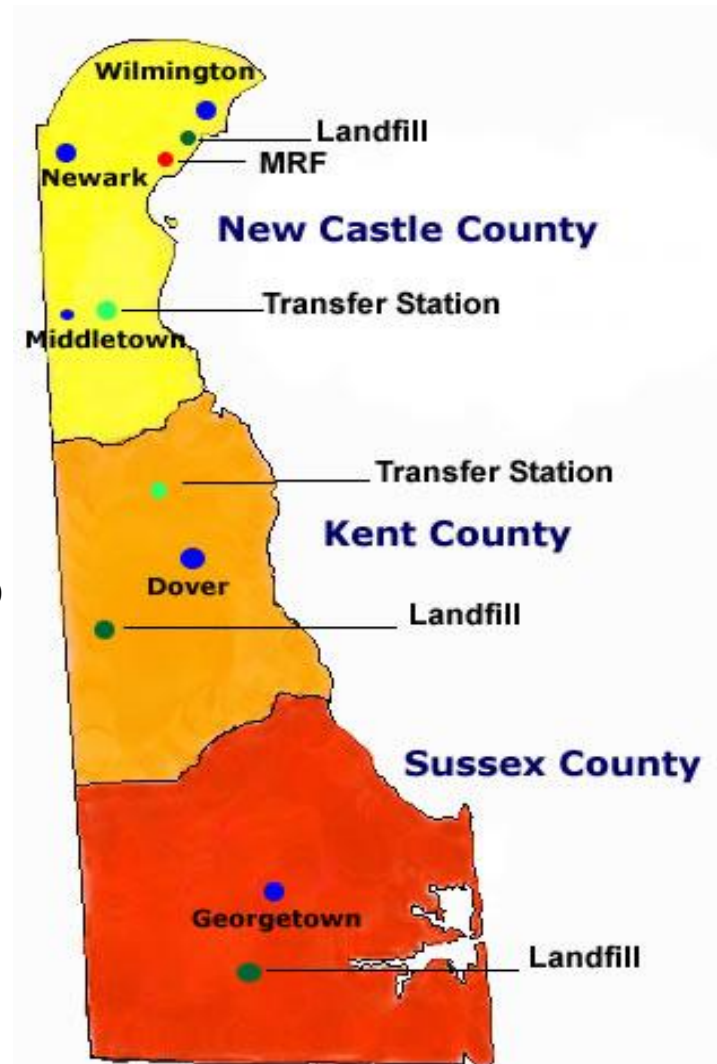
Example Study for Delaware Comparing Cost and GHG Emissions for Increasing “Diversion” Rates



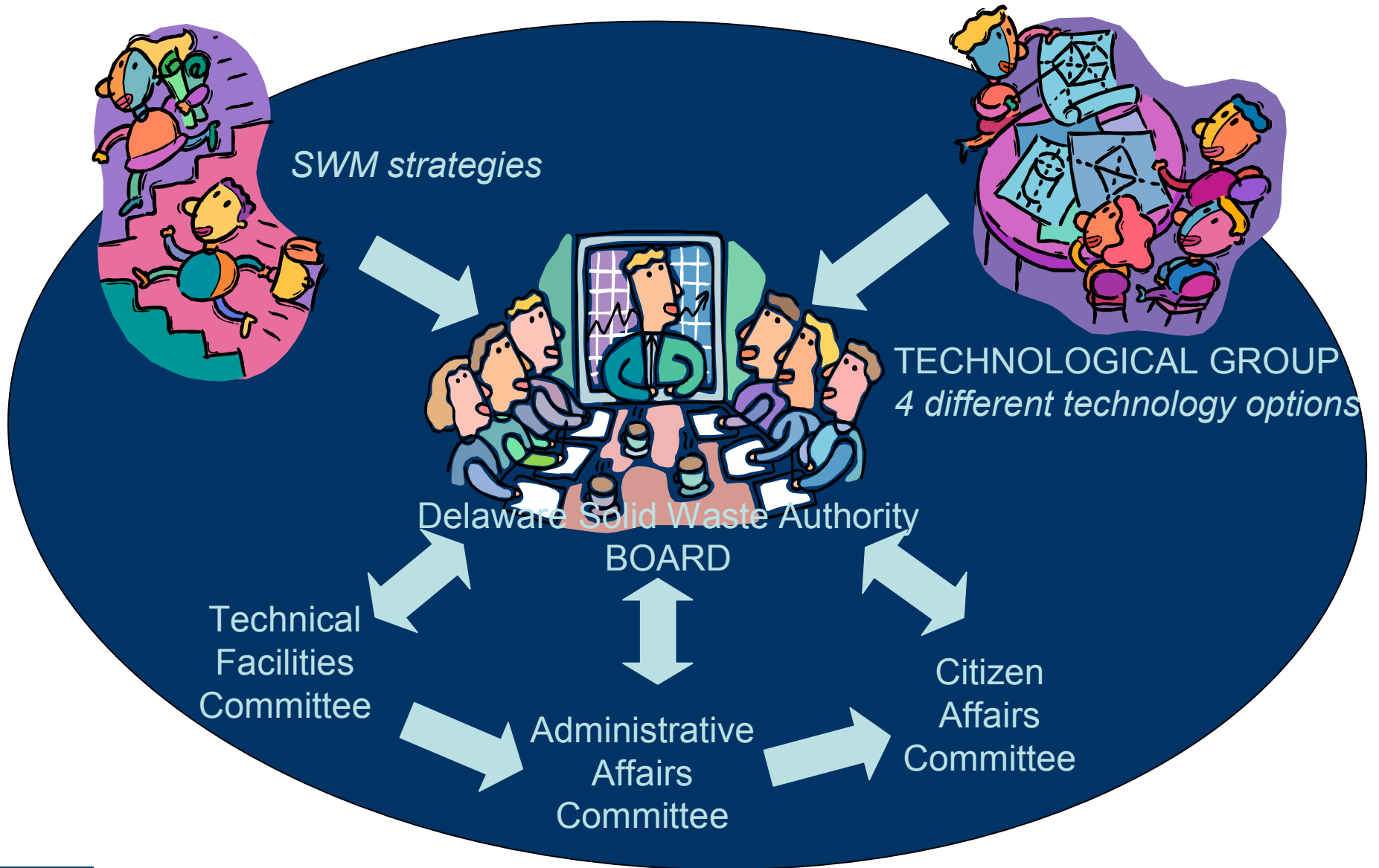
- Higher costs are due to implementation of composting and curbside recycling strategies to meet waste diversion targets

Summary for Delaware Study

- Tailored SMART-DST used for statewide analysis
- 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



How will Delaware make a decision?



What Drives the Technology Choices by Cities and Private Companies?

- Local energy and materials pricing?
- Investment climates?
- Waste characteristics?
- Regulations?
- Population Density?



➤ *All of these can be important – use of holistic tool (SMART-DST) provides a more sound basis for understanding and communicating differences among alternatives*

References from Recent Studies

- 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.
- Kaplan, P. O.; DeCarolis, J.; Thorneloe, S. (2009) Is It Better to Burn or Bury Waste For Clean Electricity Generation? *Environmental Science and Technology*, Web Publication Data: 10 February 2009.
- Thorneloe, S. A.; Weitz, K.; Jambeck, J. (2007) Application of the U.S. decision support tool for materials and waste management. *Waste Manage*, 27, 1006-1020.
- Kaplan, P.O., M.A. Barlaz, and S. R. Ranjithan (2004) A Procedure for Life-Cycle-Based Solid Waste Management with Consideration of Uncertainty. *J. of Industrial Ecology*. 8(4):155-172.

Available Documentation

- **Collection Model**

- Dumas, R. D. and E. M. Curtis, **1998**, “A Spreadsheet Framework for Analysis of Costs and Life-Cycle Inventory Parameters Associated with Collection of Municipal Solid Waste,” Internal Project Report, North Carolina State University, Raleigh, NC. (https://webdstmsw.rti.org/docs/Collection_Model_OCR.pdf)

- **Transfer Stations**

- https://webdstmsw.rti.org/docs/Transfer_Station_Model_OCR.pdf

- **Separation of recyclables and discards**

- Nishtala, S. and E. Solano-Mora, **1997**, “Description of the Materials Recovery Facilities Process Model: Design, Cost and Life-Cycle Inventory,” Project Report, North Carolina State University, Raleigh, NC. (https://webdstmsw.rti.org/docs/MRF_Model_OCR.pdf)

- **Treatment including refuse derived fuel, waste-to-energy, yard- and mixed-waste composting**

- Nishtala, S., **1997**, “Description of the Refuse Derived Fuel Process Model: Design, Cost and Life-Cycle Inventory,” Project Report, Research Triangle Institute, RTP, NC.
- Composting process model: https://webdstmsw.rti.org/docs/Compost_Model_OCR.pdf
- Harrison, K. W.; Dumas, R. D.; Barlaz, M. A.; Nishtala, S. R., A life-cycle inventory model of municipal solid waste combustion. J. Air Waste Manage. Assoc. **2000**, 50, 993-1003.

- **Disposal including traditional and wet landfills and ash landfill**

- Camobreco, V.; Ham, R; Barlaz, M; Repa, E.; Felker, M.; Rousseau, C. and Rathle, J. Life-cycle inventory of a modern municipal solid waste landfill. Waste Manage. Res. **1999**. 394-408.
- Eleazer, W. E.; Odle, W. S.; Wang, Y. S.; Barlaz, M. A., Biodegradability of municipal solid waste components in laboratory-scale landfills. Environ. Sci. Technol. **1997**, 31(3), 911-917.
- Sich, B.A. and M. A. Barlaz, **2000**, “Calculation of the Cost and Life Cycle Inventory for Waste Disposal in Traditional, Bioreactor and Ash Landfills,” Project Report, North Carolina State University, Raleigh, NC. (https://webdstmsw.rti.org/docs/Landfill_Model_OCR.pdf)

Available Documentation (Cont.)

- **Background process models to account for energy/electricity consumption and offsets, and remanufacturing of recyclables**
 - Dumas, R. D., **1997**, “Energy Consumption and Emissions Related to Electricity and Remanufacturing Processes in a Life-Cycle Inventory of Solid Waste Management,” thesis submitted in partial fulfillment of the M.S. degree, Dept. of Civil Engineering, NC State University.
 - Energy process model: https://webdstmsw.rti.org/docs/Energy_Model_OCR.pdf
 - Remanufacturing process model: https://webdstmsw.rti.org/docs/Remfg_OCR.pdf
- **Decision Support Tool, Optimization and Alternative Strategy Generation**
 - Harrison, K.W.; Dumas, R.D.; Solano, E.; Barlaz, M.A.; Brill, E.D.; Ranjithan, S.R. A Decision Support System for Development of Alternative Solid Waste Management Strategies with Life-Cycle Considerations. *ASCE J. of Comput. Civ. Eng.* **2001**, 15, 44-58.
 - Solano, E.; Ranjithan, S.; Barlaz, M. A.; Brill, E. D. Life Cycle-Based Solid Waste Management - 1. Model Development. *J. Environ. Engr.* **2002**, 128, 981-992.
 - Solano, E.; Dumas, R. D.; Harrison, K. W.; Ranjithan, S.; Barlaz, M. A.; Brill, E. D. Life Cycle-Based Solid Waste Management - 2. Illustrative Applications. *J. Environ. Engr.* **2002**, 128, 993-1005.
 - Kaplan, P.O., **2006**, “A New Multiple Criteria Decision Making Methodology for Environmental Decision Support,” Doctoral Dissertation, Dept. of Civil Engineering, North Carolina State University.
 - Manual: https://webdstmsw.rti.org/docs/DST_Manual_OCR.pdf
 - Tool Website: <https://webdstmsw.rti.org/resources.htm>
- **Uncertainty Propagation and Sensitivity Analysis Tools**
 - Kaplan, P. O., **2001**, “Consideration of cost and environmental emissions of solid waste management under conditions of uncertainty,” MS Thesis, Dept. of Civil Engineering, North Carolina State University.
 - Kaplan, P. O.; Barlaz, M. A.; Ranjithan, S. R. Life-Cycle-Based Solid Waste Management under Uncertainty. *J. Ind. Ecol.* **2004**, 8, 155-172.