Zero Waste by 2030: A system dynamics simulation tool for stakeholder involvement in Los Angeles' solid waste planning initiative

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Abstract

This paper describes a strategic level simulation model developed to help stakeholders understand the Los Angeles solid waste system. The model structure is based on a "recycling loop" incorporating five interconnected sectors: consumption, collection, processing, disposal, and production. The user interface includes eight strategic decision levers (product durability, waste in products and packaging, recycled content of products, product recyclability, consumption, consumer diversion rates, diversion processing capacity, alternative disposal capacity) and shows six output measures (waste sent to landfill, material diverted, diversion rate, relative greenhouse gas emissions, relative cost, and relative effort). Model analysis shows that maintaining the status quo erodes diversion rates, reducing upstream inputs to the waste stream (by reducing consumption, increasing product durability, increasing recycled content of products) yields the greatest improvements in waste reduction and lower greenhouse gas emissions, and that achieving desired changes with downstream levers requires using several levers in combination. The model also shows significant tradeoffs between reducing waste and the relative costs and effort required.

Keywords: solid waste, zero waste initiative, resource management, recycling

Introduction

The City of Los Angeles is one of many cities around the world that have committed to a Zero Waste Initiative. In LA's case, the city is aiming to send zero solid waste to landfills by 2030. Currently, 62 percent of the waste generated by residents and businesses is diverted from landfills. To increase diversions to 100 percent, the city has embarked on an intensive strategic planning and stakeholder involvement process. The first year of the Solid Waste Integrated Resource Planning (SWIRP) process is focused on stakeholder involvement. Between July 2007 and May 2008, the city is holding regional and citywide workshops to solicit stakeholder input on Guiding Principles for the strategic plan.

A few months into the stakeholder process, I responded to a request for proposals put out by the City's contracting firm, HDR Incorporated, to develop a systems based tool to help stakeholders understand the system and evaluate the consequences of strategic options for achieving zero waste. Between December 2007 and February 2008, I and a team of colleagues and graduate students at the University of Nevada Las Vegas' (UNLV's) Environmental Studies Department developed a simulation model, facilitated its use for 100 participants at the second citywide SWIRP conference, and used the conference to conduct research about the value of the simulation model for stakeholder involvement in public policy planning.

This paper gives an overview of the model structure, shows the results of key policy runs, and highlights some of the challenges encountered in developing the model. The aim of this paper is not to describe the model in detail, but to describe one approach for evaluating benefits and tradeoffs of strategic-level waste management options in a large city.

Model Purpose

The main purpose of this model was to raise stakeholder awareness of LA's solid waste system. The clients were more concerned with providing a tool to communicate system lessons to the stakeholders than creating an environment where stakeholders identified and evaluated potential solutions to the problem. The lead client had played the Beer Game and appreciated the simple lessons it conveys about system connections, uncertainty, and dynamic behavior. He wanted to create a similar experience for the Zero Waste stakeholders.

The client's goal was a model that would demonstrate the benefits and drawbacks of strategic choices over a 20-year period, help stakeholders understand uncertainty in the system, and illustrate the effect of taking no action. It was not meant to be a planning model, that is, it was not intended to include the level of detail necessary to make specific management decisions. Rather, it was to be a simplified, strategic-level model sufficient to allow non-expert stakeholders to compare the relative effect of major policy, program and facility decisions on critical performance measures. It was to include key policy levers that system managers might realistically use.

Description of the Problem

The focus of the model mirrors the goal of the strategic planning process: to reduce waste sent to landfills. Other key performance measures include cost, environmental effect, and social and political acceptability. The clients decided that the main environmental measure should be greenhouse gas emissions. They also wanted the model output to account for the social and political challenges associated with different strategies. For instance, strategies that require new disposal or processing facilities are likely to encounter resistance from local residents who don't want them in their neighborhoods.

Model Structure

The model structure is based on the flow of material through the system. It incorporates "upstream" sectors (product manufacturing and consumer consumption) as well as "downstream" sectors (consumer disposal, collection of discarded material, processing, and disposal). Figure 1 shows the "Recycling Loop" that integrates these sectors. The model structure was derived from the Recycling Loop.

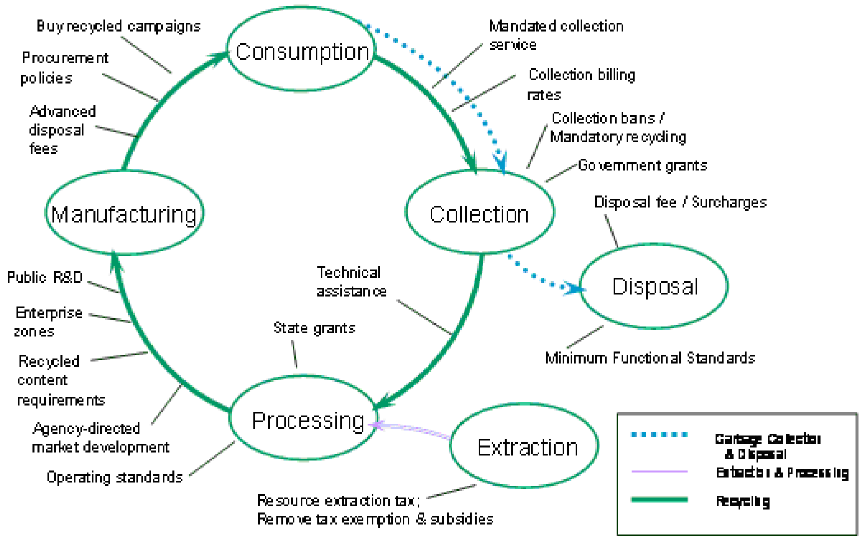

Figure 1. "Recycling Loop" (Source: HDR, Inc. project proposal page 2-19, obtained from client. Other versions of this diagram are available at: http://www.zerowaste.lacity.org)

Figure 2 shows the main material flow backbone of the model. The colored ovals indicate the sectors derived from Figure 1. New (virgin) material enters this stock-and-flow structure through the production, or manufacturing process in the lower left of the diagram, is transferred to consumers based on consumer demand, and, if it is not fully consumed, continues through the system when it is discarded by consumers. When consumers discard material, it enters one of three collection pathways: diversion to composting facilities, diversion to recycling facilities or transport to a transfer station or materials recovery facility (MRF). From the MRF, recoverable material can be diverted to composting or recycling facilities, or disposed in a landfill or alternative disposal facility. Material from composting or recycling facilities can continue back to the production sector to be reintegrated into new products.

Structural Assumptions

This model contains several important simplifications and assumptions which were supported by discussions with the clients and were considered relative to the model purpose. Some assumptions were based on what the clients think the city can influence with regulations or buying policies, for example. Major structural assumptions include:

Consumption and Production Sectors

1. Material consumed can be considered to come primarily from producers in the system.
2. Production can be considered internal to the system.
3. Recycled material used in production is generated internal to the system.
4. New (virgin) material used in production comes from outside the system.

The first three simplifications are clearly not an accurate representation of reality. Los Angeles residents and businesses import goods from many places outside the city – from other regions in California, other states, and other countries. However, the clients feel that with such a large consumer base, the city could potentially have a great influence on the characteristics of goods consumed, such as recycled content, recyclability of goods, and amount of packaging, for example. This influence could come from consumer demand, influenced by things like "buy recycled" campaigns, procurement policies for government/ institutional consumers, or mandated product "take-back" programs. Likewise, although recycled material used in producing goods outside the system would also come from sources outside the system, the structure represents the assumption that recycled material would eventually find its way into products if demand increases.

Collection Sector

5. All generators can be lumped together with respect to diversion.

Waste generators include residents in single-family homes, residents in multi-family units, institutions such as schools, and commercial enterprises of many types. The amount and characteristics of the material generated vary. For instance, single-family households generate more organic matter from yard waste than multi-family households. Food service businesses generate different types of waste than office buildings. A waste management model evaluating specific effects of different programs for residences and businesses would have to keep these sources separate. For this strategic model, the purpose is to evaluate the macro level consequences of overall changes in the waste stream, so combining the sources is sufficient.

6. Distinctions between municipal and private haulers can be ignored for strategic comparisons.
7. Self-haul by waste generators to MRF is relatively minor so is not included.

Waste in Los Angeles is collected both by the City's Bureau of Sanitation and by approximately 150 private haulers. Since the Zero Waste goal applies to all the waste going to the landfill regardless of source, and the strategic-level decisions the model is designed to evaluate also apply to all waste, the collection sector has been aggregated in this model.

Processing Sector

8. Processed compost/recycling does not leave the system (can stockpile).

This version of the model assumes that the market for recycled material is internal to the system. If producers in the system do not use it, it accumulates.

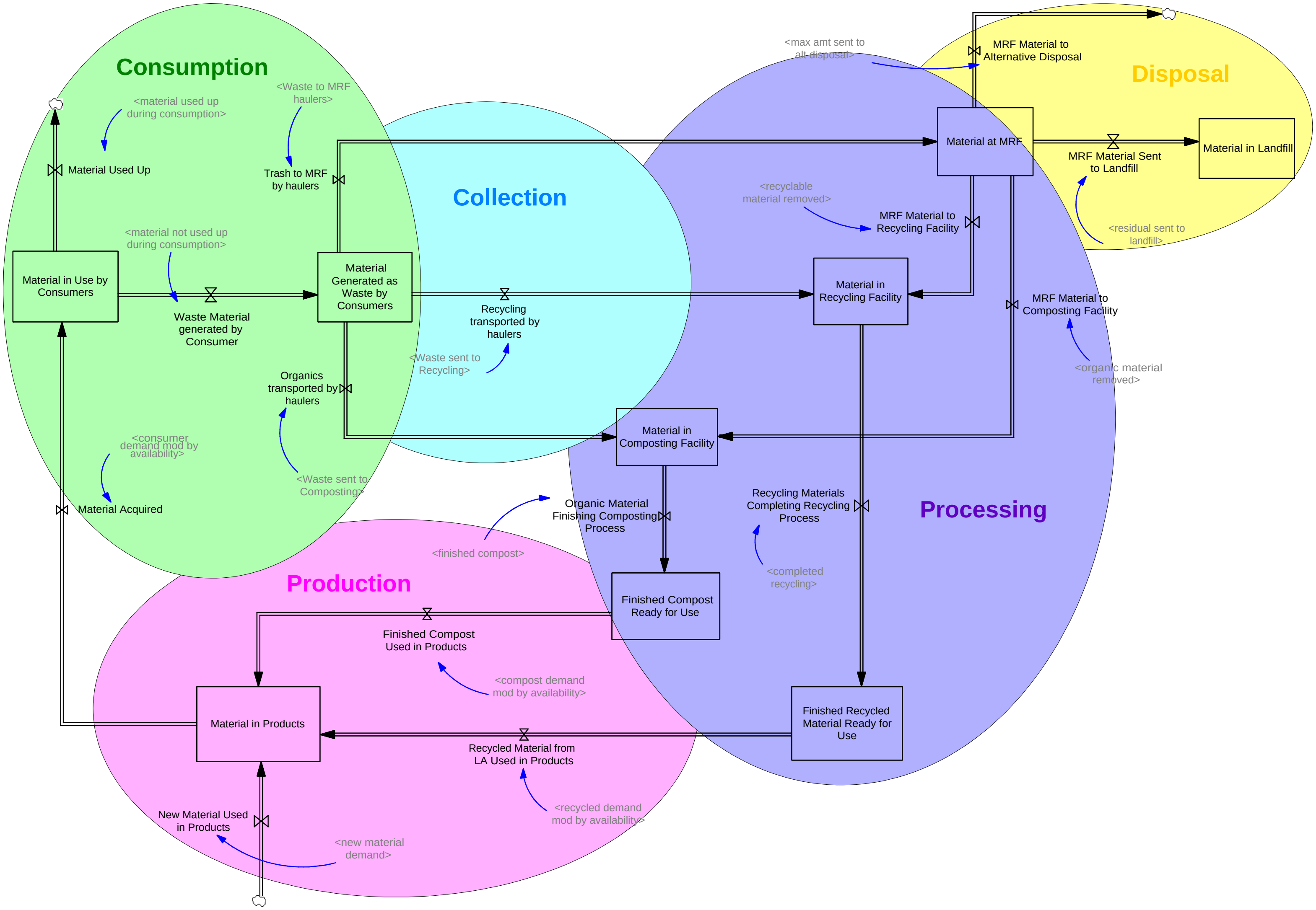

Figure 2. Material Flow backbone of the Zero Waste Model

Overview of Model Sectors

Consumption Sector

Material Acquired represents consumer demand for material. It is determined exogenously, based on projections of the number of consumers (single-family households, multifamily households, commercial employees) and estimated average material consumption rates per consumer (household and employee). *Waste Material generated by Consumer* is the material discarded after consumer use that must be disposed of in some fashion. It is a function of average product lifetime and the waste fraction of consumer material, that is, the portion of material that is not consumed during use.

Collection Sector

Discarded material is sent to a recycling, composting or trash processing facility depending on the consumer diversion rate, constrained by recycling and composting processing capacity.

Processing and Disposal Sectors

Processing rates at all facilities depend on capacity, inflows, and processing time. Waste is sent to the landfill only after all material that can be recovered (which is a function of processing capacity) is diverted, and the maximum amount that can be processed using alternative disposal technology is removed. Recycled material and compost accumulates until it is demanded by the production sector.

Production Sector

Inflows to production (*Material in Products*) from compost, recycling, and virgin materials are determined based on consumer demand for products and desired recycled content in products.

Decision Variables

The client for this model chose eight leverage points as a focus for model users in the conference. They introduced the leverage points as follows (LA SWIRP Citywide Conference 2 Policies, Program and Facilities worksheet):

UPSTREAM
Production Sector

1. What if we could increase the average useful lifetime of consumer products?

Examples:

- Increase product durability
- Educate consumers on the consequences of excess consumption
- Encourage repair and reuse

2. What if we could reduce the amount of waste in products and packaging?

Examples:

- Implement product and packaging bans or takebacks for on waste reduction
- Require manufacturers to reduce the weight of packaging

3. What if we could increase the recycled content of products and packaging?

Examples:

- Promote "buy recycled" campaign
- Require manufacturers to increase the use of recycled content in products and packaging

4. What if we could make products and packaging more recyclable?

Examples:

- Implement product and packaging bans or takebacks focused on recycled content
- Require manufacturers to change the content of their products and packaging to make them more recyclable

<u>DOWNSTREAM</u>

Consumption Sector

5. What if we could change the average amount of material consumed by each consumer?

Examples:

- Massive and sustained public outreach and education campaign focused on waste prevention (also called "source reduction")

Collection Sector

6. What if we could increase consumer diversion rates?

Examples:

- Massive and sustained public outreach and education campaign focused on recycling
- Mandatory participation in recycling and organics programs (single-family, multi-family, commercial) – no trash in the recycling and no recycling in the trash
- Roll-out recycling and organics containers to all multi-family buildings
- Roll-out recycling and organics containers to all commercial generators
- Roll-out recycling and organics containers to all schools in Los Angeles Unified School District

Processing Sector

7. What if we could increase the processing capacity for diverted materials?

Examples:

- Increase the presence of neighborhood scale facilities such as reuse centers and fix-it shops through technical assistance, grants, and incentives
- Increase the processing capacity of existing recycling and composting facilities through facility expansion or by adding more shifts
- MRF first (process residual waste prior to disposal to remove recyclables and compostables)
- Site new mulching and composting facilities
- Site new SAFE centers for collection of household hazardous waste and electronics
- Site new resource recovery parks for self-hauled materials

<u>RESIDUAL WASTE MANAGEMENT</u>

Disposal Sector

8. What if we could increase the capacity for alternative technologies?

Examples:

- Biological treatment of residual waste through anaerobic digestion
- Thermal treatment of residual waste through waste-to-energy
- Conversion of residual waste to biofuels

Figure 3 shows the user interface of the Zero Waste Model (version 2_22). The eight strategic leverage points with their initial values are shown in the center of the screen.

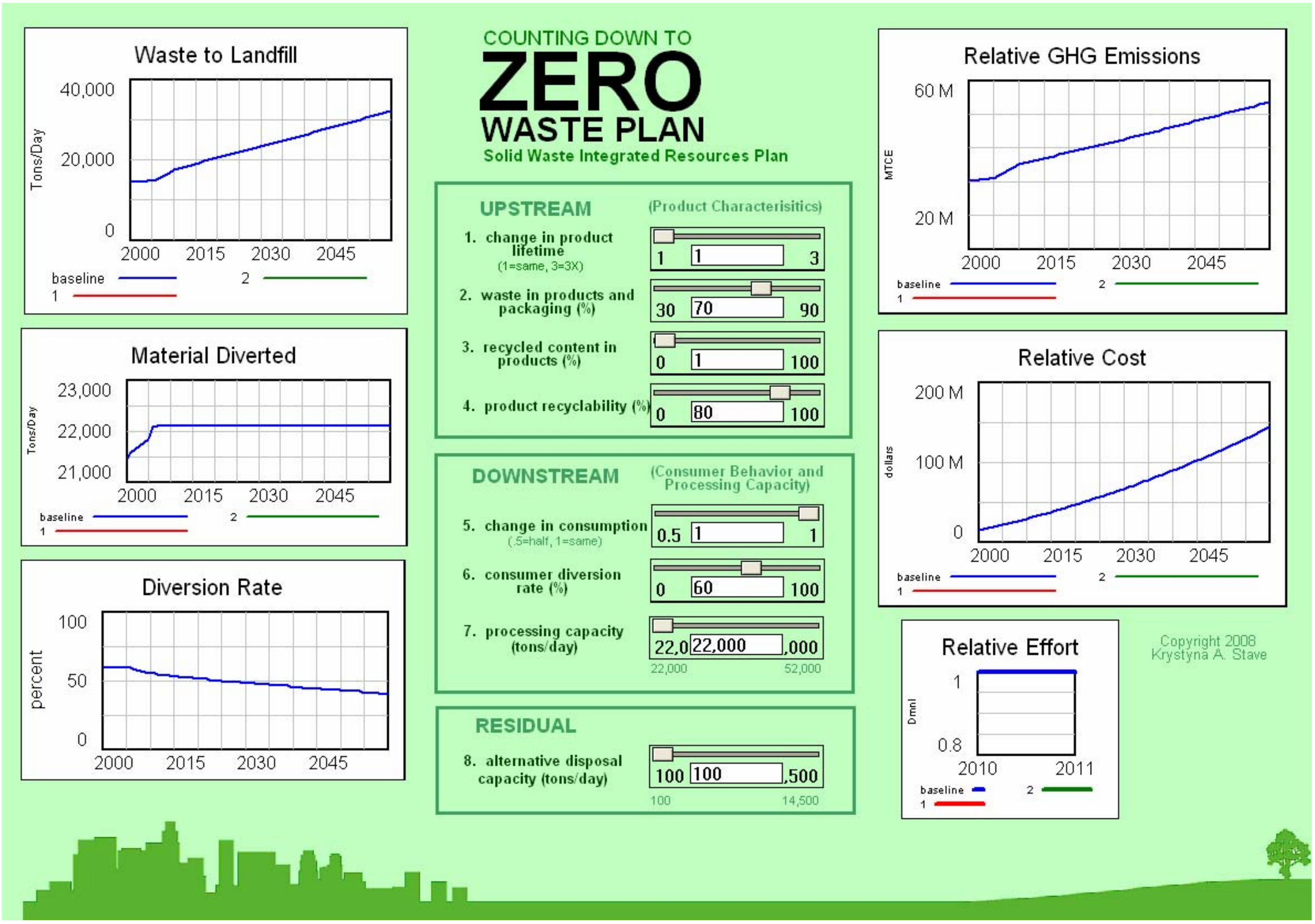

Figure 3. User Interface of Zero Waste Model

Output Measures

The client chose four basic measures for comparing the output of strategic decisions: amount of waste sent to the landfill, relative greenhouse gas emissions, relative cost, and relative effort required for implementation. During the model use at the conference, it became clear that processing capacity for diverted material was a serious limiting factor that stakeholders were having difficulty understanding. Therefore, two other measures – Material Diverted and Diversion Rate – were added after the model was used at the conference. The six output measures showing baseline conditions are displayed on the left and right sides of the screen in Figure 3.

Waste to Landfill displays the amount of residual material sent to the landfill each year (*MRF Material sent to Landfill* in Figure 2). The Zero Waste goal is for this line to reach zero by 2030.

Material Diverted shows the total amount of material diverted to recycling, composting, and alternative disposal.

Diversion Rate is the overall amount of material diverted throughout the system, including the amount diverted to recycling, composting, and alternative disposal, divided by the total amount discarded per year.

Relative GHG Emissions displays the greenhouse gas (GHG) emissions associated with a given scenario. The calculation includes greenhouse gases due to landfill disposal, alternative disposal, amount of compost used in products, amount of recycled material used in product, and amount of virgin material used in products. Greenhouse gases are generated for material sent to the landfill and virgin material used in production. Material deposited in the landfill emits greenhouse gases for the entire time it stays in the landfill. Every ton of virgin material used in products generates 71 times the amount of greenhouse gases that one ton in the landfill generates. This represents the waste generated upstream per ton of virgin material. By contrast, every ton of recycled or composted material used in production generates a relative GHG savings (negative GHG emissions relative to producing the same material using from new sources) as does alternative disposal. Alternative disposal is assumed to generate energy, and therefore saves the GHGs that would have been emitted if the energy was produced in other ways.

Relative Cost shows the total cost of the scenario, including the cost of landfill and alternative disposal, diversion processing, any new processing capacity added, and any programs to change consumer or producer behavior.

Relative Effort calculates a combined "overall effort required for implementation" by multiplying estimated index values for the social and political effort it would take to achieve increases in consumer diversion rates or decreases in waste in product packaging, for example. This index measure is a very rough "back-of-envelope" comparison the client wanted to include to give some indication of non-monetary costs.

Policy Analysis

1. Zero Waste by 2030?

It is clear from Figure 3 that maintaining the status quo will not achieve zero waste by 2030. Instead, the amount of waste sent to the landfill will continue to increase as the population increases and the amount of material discarded increases. The diversion rate will begin to erode when diversion capacity is reached.

So is the Zero Waste goal even possible? If so, how could it be achieved? Figures 4 and 5 show two possible scenarios. Figure 4 represents an emphasis on downstream technology, increasing processing and alternative disposal capacity to their maximum values. Waste does decrease to zero[1] as soon as the capacity comes on line, although it begins to increase eventually. (It can be kept at zero with other measures including increasing the consumer diversion rate, increasing product lifetime, decreasing waste in products, or decreasing consumption.)

Figure 4. Zero Waste by increasing processing capacity

Figure 5 shows a different scenario that focuses on changing product characteristics and consumer behavior. Waste in products is reduced to 30%, products are 100% recyclable and three times as durable, consumer diversion rates are increased to 100%, and consumption is cut in half. Without increasing processing capacity at all, waste is reduced to nearly zero.

The relative greenhouse gas emissions, cost, and effort, however, are significantly different between the two scenarios. Cost and effort is much lower in Figure 4 relative to Figure 5, but greenhouse gas emissions are hardly affected by the processing capacity solution. By contrast,

[1] Policy changes take place in 2010 and costs are incurred at that time. A more realistic version would phase in the changes and costs, but this representation is adequate for comparing relative effects between scenarios.

the behavioral and product characteristics solution cuts greenhouse gas emissions almost in half relative to the baseline conditions.

Figure 5. Zero Waste by changing consumer behavior and product characteristics

Discussion

The baseline graphs in Figure 3 and the two scenarios shown in Figures 4 and 5 reveal several key points about the waste system. First, without any action, zero waste is not possible. In fact, taking no action will erode the current 62% diversion rate of which Los Angeles is justifiably proud. Second, zero waste is possible by several means, but there are significant costs and tradeoffs in environmental impact and political/social effort required. Third, reducing greenhouse gases in any significant way requires reducing the material that enters the waste system. Because the largest amount of greenhouse gas emissions in this system is generated by virgin materials in the production of goods, any policy lever that reduces the amount of virgin materials used reduces greenhouse gas emissions. These include increasing product durability, increasing the recycled content of products, and reducing consumption. Even small changes in these parameters can have marked effects on GHG emissions.

A note about parameter estimation and relative measures

One of the more difficult aspects of developing this strategic level aggregated model was parameter estimation. Very little data exists in aggregate form for such things as consumer demand for material, average product lifetime, and average waste fraction for products used by municipal consumers. Almost no data exists for cost of programs to implement changes in things like consumer behavior or product characteristics. What is the cost, for example, of a public education campaign that will result in an increase of 10% in consumer diversion? Or the cost to enforce a mandated reduction in packaging waste? How much social or political effort would it take to site enough alternative disposal facilities to increase capacity by 10,000 tons/per day relative to the amount it would take to convince people to reduce their consumption by 10%? For many of the parameters in this model, these relative values were developed using thought experiments. The values reflect consistent assumptions in the thought experiments, and can be challenged and changed. They should be considered only relative to each other, however, and not in any absolute sense.

The model runs discussed above are only a few of the analyses possible with this model. As with other resource management models, the overall lesson is that there is no "silver bullet", no magic solution that will achieve everybody's goal with minimal cost, regardless of the specific parameters used.