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David J. Tonjes
Department of Technology and Society, david.tonjes@stonybrook.edu

Krista L. Greene
SUNY Stony Brook, krista.thyberg@stonybrook.edu

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David J. Tonjes 1,2,3 *

Krista L. Greene 1,3

1 Department of Technology and Society

Stony Brook University

Stony Brook, NY 11794-3760

2 Waste Reduction and Management Institute

Stony Brook University

Stony Brook, NY 11794-5000

3 Center for BioEnergy Research and Development

Stony Brook University

Stony Brook, NY 11794-2275

* Corresponding author:

David J. Tonjes

Department of Technology and Society

Stony Brook University

Stony Brook, NY 11794-3760

david.tonjes@stonybrook.edu

P: 631-632-8518

F: 631-632-7809

Abstract:

Municipal solid waste (MSW) is generated in very large quantities (probably, between 200 and 400 million tonnes per year) in the United States (US). MSW is generated at millions of places and there is no one precise, general definition for MSW that is generally applied, despite US Environmental Protection Agency efforts. As an element of both commerce and politics, reporting may be framed towards particular ends. Therefore, the two best known assessments of the quantity of US MSW production differ by approximately 50%. The assessors understand some of the reasons for the differences, but our analysis suggests that there are profound factors, not openly discussed, that affect estimates of waste stream size. Many regulators propose that strict, universal formats be adopted so that there is consistency in waste reporting; we note that this will not change the materials requiring management, only what is counted. Therefore, the most accurate assessments may be those where controllable errors are minimized but which suffer from differing definitions of "MSW."

Keywords:

Municipal solid waste, United States, quantity, models, error, national assessments

Introduction

Large quantities of materials in the United States (US) become municipal solid waste (MSW) – 2-3 kg person^{-1} day^{-1}, incrementally amassing to 200-400 million tonnes each year. MSW management is an integral part of modern civic life, and is important to many Americans. Conventionally, husbands take out the trash several times a week, inevitably small children are fascinated by garbage trucks, and "more people recycle than vote" (attributed to Jerry Powell, Editor, Resource Recycling Magazine; first citation, Miller 2000).

The US Environmental Protection Agency (USEPA) defines MSW as materials that

"historically have been handled in the municipal solid waste stream–those materials from municipal sources, sent to municipal landfills … such as product packaging, newspapers, office and classroom papers, bottles and cans, boxes, wood pallets, food scraps, grass clippings, clothing, furniture, appliances, automobile tires, consumer electronics, and batteries. … [M]unicipal solid waste … does *not* [USEPA's emphasis] include construction and demolition debris, biosolids (sewage sludges), industrial process wastes, or a number of other wastes that … may go to a municipal waste landfill" (USEPA undated).

This definition differs slightly from that of the OECD:

"Municipal waste is waste collected and treated by or for municipalities … from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste … exclud[ing] waste from municipal sewage networks and treatment … [and] … construction and demolition activities" (OECD undated).

and also the European Union:

"waste generated by households and other wastes, which are similar in nature and composition, collected and managed by or on behalf of municipal authorities… [primarily] from households, though similar wastes from … commerce, offices and public institutions are included … including paper, plastics, food, glass, and household appliances" (Eurostat 2010).

Thus authorities do not exactly agree on the definition of MSW, and practitioners of waste management may not always count their wares in ways that agree with official definitions. Thus, it is not surprising that MSW in the US is difficult to track well. USEPA estimated that 249.6 million tons (226.4 million tonnes) of MSW were generated in the US in 2008 (USEPA 2009), which is 4.50 lbs person^{-1} d^{-1} (2.04 kg person^{-1} d^{-1}). BioCycle magazine found US MSW generation for 2008 to be 389.5 million tons (353.4 million tonnes) (van Haaren *et al*. 2010), 7.02 lbs person^{-1} d^{-1} (3.18 kg person^{-1} d^{-1}) – about 50% more. These differences have been noted for decades (Figure 1). Some reasons for the differences are well-known (e.g., Rathje 1989, Goldstein 2000, Miller 2007, Kaufman & Themelis 2009, Chowdhury 2009, USEPA undated, USEPA 2010); they partially stem from methodological differences in counting wastes – what USEPA (undated) distinguishes as "site specific" and "materials flow" approaches. We will also suggest there are some underlying uncertainties in how these methods generate their data. To approach this issue, first we describe how these surveys are conducted, and then we examine the bases of the processes they use.

USEPA (Franklin Associates) Materials Flow Quantifications

The formation of USEPA in 1970 moved federal regulation and oversight of solid waste management from the US Public Health Service (USPHS). From 1966 through 1970, USPHS engineers had estimated solid waste quantities (and composition) by using waste sorts conducted in support of incineration projects (Hickman 2003), work apparently conducted to optimize the combustion processes. USEPA recognized that waste sorts produce information of limited value; as waste stream sampling is valid only for particular places and times; it took until the 1990s for USEPA to define for itself a satisfactory sampling protocol to conduct waste composition audits (and also to sample waste generation at facilities without scales) (Klee 1992).

USEPA therefore worked with various environmental engineering firms and an economic analysis firm, Franklin Associates, to devise an "input/output" assessment model for estimating the composition of solid waste in a different fashion. The flow of materials from plants that manufacture goods was traced into finished products and then into the marketplace, including imports and excluding exports and process wastes; the residence time of those products in homes, businesses and institutions was estimated, as were the amount of materials set out for management, either through recycling and other recovery processes, or discard processes (landfilling and incineration). This was known as the "material flows" process (Smith 1975). Over time, Franklin Associates has refined data collection and the processes that drive the model. Better data mean that uncertainties that existed in the 1970s have been reduced, such as those regarding processing and distribution steps that affect the proportion of a material that becomes part of a product, or quantities of imports and exports (USEPA undated).

Clearly some solid wastes are not created in ways amenable to capture by the model, such as food and yard wastes. The earliest iterations of the model relied on one or two site specific sampling efforts of these materials that USEPA described as “being done well” (Smith 1975); currently, “selected waste sorts” are used to estimate waste quantities for yard and food wastes for the model. In the 2009 Waste Characterization report, food waste generation is documented by 69 references: 19 are reports or personal communications dated in 2009 or 2010, and six others are undated but likely to be up-to-date. The recent sampling efforts are for a range of sources, including businesses (e.g., Kroger supermarkets and Walmart), colleges and universities, municipalities (large cities like Boston or smaller areas such as Orange County, NC, for instance), or institutions (like hospitals). Approximately half of the references are from studies conducted before 2009, with one quarter of the references from the 1990s. The 75 references for yard waste include more late 2000s studies, and it is clear Franklin Associates contacted some state regulators directly for current information. However, all states were not contacted (or at least, all were not referenced), although a catch-all reference of Franklin Associates “surveys of selected state officials and websites” is included. The tables reflect that food waste increased by a little less than 1 million tonnes from 2008 to 2009, and yard wastes increased by nearly 300,000 tonnes (USEPA 2010).

Because the USEPA data are generated by the application of a materials flow input/output model, the data sets can change as the model is updated. Therefore, the amount of 2008 MSW reported in the 2008 report (249.61 million tons) (226.45 tonnes) (USEPA 2009) is different from the 2008 MSW reported in the 2009 report (251.02 million tons) (227.73 tonnes) (USEPA 2010), which may lead to confusion for those keeping track (even if only by 0.5%).

USEPA explicitly states that its assessments describe a specific set of materials: the wastes from residences, businesses, and institutions. This focus is on materials that are in commerce. The accounting does not include most hazardous wastes, construction and demolition debris (C&D), sewage sludges, and industrial process wastes. It is also noted that an undefined “number of other wastes that … may go to … landfill[s]” are not included – presumably, materials such as street sweepings, dredge spoils, etc., that are not part of general day-to-day activities associated with commerce. USEPA-defined MSW does not include junked cars and trucks and combustion ashes. The materials flow process does not allow for determinations of the source of wastes within the generator types (i.e., whether paper goes to residences or businesses or institutions) (USEPA 2010).

USEPA also reports on the management of the quantified wastes, through a process of elimination. Manufacturers provide data on the use of recovered materials, and this is supplemented by export data, which generally limns recycling. Composting is apparently determined from state information sources and industry reporting, such as in BioCycle; the sum of materials recovery and composting is the overall recovery total. Waste-to-energy incineration is determined through reviewing regulatory reporting. The gross tonnage is adjusted because some plants burn materials not considered to be MSW. Landfilling is determined from the remainder (USEPA 2010, H. Pillsbury, USEPA, personal communication, October 2010).

This model calculates the specific materials that comprise the waste stream. This makes it possible to track the material composition of MSW and to estimate the percentages of specific materials that are recovered and landfilled, although this subject is not covered here.

BioCycle Assessments (Site Specific Quantifications)

The editors of BioCycle Magazine conduct periodic waste assessment studies that differ from USEPA assessments in some ways, but are similar in others (Table 1). The 2008 national waste survey was said to be its 17th such survey, although only 16 years of reports (1989-2000, 2002, 2004, 2006, 2008) have been made. BioCycle bases its data on facility reports, aggregated by the states, so that waste generation is the sum of recycling, composting, incineration, and landfilling (recycling and composting can be considered together as an overall recycling value). Waste reduction is not addressed. Magazine staff compiled the data through 2000; for 2002 and subsequent biennial reports, Columbia University staff and students (under the direction of N. Themelis) were responsible (van Haaren *et al*. 2010).

The earliest surveys note various difficulties with the data – some data were collected in previous years, some were disposal tonnages only, some were estimates based on a variety of local information collected over lengthy intervals. However, BioCycle has consistently reported more waste than USEPA. One clear difference was that disposal tonnages at landfills, and sometimes recycling data, included waste elements USEPA did not allow in its assessments, such as C&D and automobile recycling, and C&D disposal (e.g., Goldstein 2000).

The Themelis group at Columbia University changed some previous data collection practices, emphasizing aggregated tonnage data for the management processes in place of calculations based on reported percentage rates applied to an overall generation tonnage (van Haaren *et al*. 2010). The Themelis group worked to identify misallocated C&D and other "non-MSW" (per USEPA), primarily by asking to have these excluded by respondents, and through close reading of reports. They also tracked exported and imported MSW to assign wastes to the generating state (Kaufman & Themelis 2009). Recycling at the state level was found to have the potential for great error (Simmons *et al*. 2006a, Kaufman & Themelis 2009), although one self-analysis generally found the reported tonnages were accurate (Simmons *et al*. 2006b).

The BioCycle reports, even under the direction of the Themelis group, have suffered from incomplete participation. For instance, the first Columbia-led assessment had to be adjusted because three states did not supply any data (these states, comprising only 3% of the US population, were assumed to generate and manage MSW similarly to the rest of the states), and three other states did not provide data in the requested formats. This latter category included the two largest states, California and Texas. California was assigned the same waste generation rate as Nevada, and Texas was assigned the average of the 44 remaining states, although reasons for these assignments were not provided (Themelis & Kaufman 2004). In 2004, only 39 states provided data that was in the requested formats. For states that did not provide data or did not conform with the format, tonnages for facilities within these states were estimated with the use of the Waste Business Journal "Directory and Atlas of Non-hazardous Waste Sites," coupled with further research efforts to collect reports from regulatory agencies (Simmons *et al*. 2006a). When the Waste Business Journal did not participate in later reports, "past data" were used to project waste generation for non-responding states. A report on Materials Recycling Facility tonnages within each state (the Berenyi GAA Survey) has also been used to estimate recycling; the researchers doubled the Berenyi GAA Survey state facility tonnage for non-reporting states, because a comparison between the reported recycling tonnages for states that responded to the Columbia researchers' inquiries were generally twice as great as the tonnages reported for those states in the Berenyi GAA reports (Arsova *et al*. 2008).

The BioCycle reports thus combine state data, adjusted state data, projections from past estimates, facility surveys, and projections from facility data.

State quantity assessment practices

Although the Themelis group processed state reports to generate its data, the raw data provided by such agencies were central to its procedure. The Themelis group has assessed disposal data as being generally accurate, because disposal sites regularly submit waste processing data to regulators as part of permit compliance. Recycling data for traditional (curbside) recyclables was considered less reliable, and composting data were the least reliable (Kaufman & Themelis 2009).

Here we review data compilations from four states, in particular: brief reviews of Oregon and Nevada (selected because they used differing albeit rather straightforward reporting procedures), California (selected for its very arcane reporting and because the Themelis group had specifically audited its recycling tonnages carefully for one year), and New York (which has evolved its reporting over the past 15 years for a variety of reasons, leading to some interesting findings) (see Table 2).

Oregon

Oregon calculates recovery rates each year based on data from designated “wastesheds” (geographic subdivisions of the state) (although state-wide per capita values are sometimes added if no particular source is responsible for tracking a type of waste). Reports from public and private recycling and disposal facilities are compiled, and extra credits for waste reduction and composting are given if certain criteria are met. Recycling reporting is voluntary. The sole

Oregon waste-to-energy incinerator receives certain recycling credits, mandated by law. Oregon aims to capture data on post-consumer wastes, and does not include industrial wastes; it also excludes out-of-state materials, inert materials (e.g., brick and concrete), and automobile scrap. Over half of the wastesheds received waste reduction credits; and 22% of recycling credits were from "combustion" (apparently mostly waste wood or tires burnt for energy). In 2008, Oregon reported generating 5,233,647 tons (4,747,965 tonnes), recovering 2,233,509 tons (2,026,239 tonnes) (Oregon Department of Environmental Quality 2009). BioCycle reported 13% lower waste generation (4,632,513 tons) (4,202,616 tonnes), which may be coincidentally similar to the 2009 Oregon state reported waste generation (4,671,845 tons) (4,238,298 tonnes) (Oregon Department of Environmental Quality 2010). To be consistent with their protocols, it appears that the BioCycle researchers should have moved the combustion data from recovery to disposal and excluded the waste reduction and incineration recycling credits.

Nevada

Nevada reports its waste stream biennially, as required by its legislature. Its constituent counties file reports using a specified format to ensure all data are comparable. In 2007, 3,245,596 tons (2,944,133 tonnes) of Nevada-generated wastes were disposed (excluding industrial and special wastes, and out-of-state wastes disposed in Nevada), and 894,652 tons (811,628 tonnes) were recycled. "Disposal" means materials disposed in a landfill that were generated within the surveyed county; industrial and special wastes (including C&D) are counted separately. Recyclables do not include C&D, but do include sewage sludge (called biosolids by Nevada); materials not specified on the reporting form can be counted on a special line, but no county used that option in 2006 and 2007 (Nevada Department of Conservation and Natural Resources undated). We could not find any on-line 2008 data. BioCycle reported in 2008 there were 3,299,832 tons (2,993,608 tonnes) of disposal, 229,128 tons (207,865 tonnes) of recycling, and 85,271 tons (77,358 tonnes) of composting. This is a much lower overall recycling total and a lower overall waste generation rate than Nevada had reported in 2007.

California

California is a special case. The legislature has passed a 50% disposal reduction mandate for all municipalities. Because waste diversion was recognized as being important, a waste generation rate in a base year (1990, originally) was set, against which progress would be measured towards waste diversions in subsequent years. A constant base waste generation does not reflect important waste generation issues, such as growth in local industries, changes in land use from commercial to residential, waste imports, or decreases in self-hauling (13% of all California waste was self-hauled in 1990, and state reports assume this rate has decreased since then). In 2000, an adjustment formula was created, and was used by 20% of the jurisdictions subject to the mandate. For California reporting purposes, waste generation is modeled, starting with the base waste generation as modified by population and economic changes. To compute compliance with the mandate, waste generation by regulated municipalities (cities or counties) is compared to disposal data, as reported in the state disposal tracking system. California includes inert materials (C&D materials, for instance) and special wastes (e.g., sludges including sewage sludge, ash including waste-to-energy incinerator ash, and asbestos) as materials subject to this assessment. Alternate cover material for landfills (e.g., C&D or composted yard wastes) is considered a recovered material (California Integrated Waste Management Board 2001). This makes California waste stream assessments different in many ways from those done in other states.

Kaufman & Themelis (2009) created a California waste definition that was similar to other state reports, using some unique reporting for 2005. They combined 2005 State-wide disposal tonnages with a disposal characterization report from 1999, and estimated 29% of California's reported disposal tonnage was not MSW (per USEPA's definition, which has been adopted for the BioCycle reports). Then, they back-calculated recycling tonnages based on a report on 2005 facility residuals and residual rates, adding in 20% of the nationwide total of a 2005 "direct to recycler" report. Finally, they used a 2005 state-wide mulch and compost production report, subtracting tonnages that were used for alternative landfill cover and agriculture and sewage sludge inputs. In this manner, the 2005 state-wide waste total was estimated to be 49,925,000 tons (45,300,000 tonnes) with a recycling rate of 38.9%.

New York

For many years New York State had two official waste stream assessments, one conducted by the legislature and the other by the executive branch (the State Department of Environmental Conservation – NYSDEC). In 1997 the reports covered the target tenth year of the State Solid Waste Management Plan. The Plan originally sought 50% recycling; in the mid-1990s, NYSDEC refined the goal to include waste reduction (predefined as an 8-10% effect, lacking any good baseline data), so that meeting the new recovery goal required a 42% recycling rate. Both assessments were based on reporting required from local municipalities, using State-generated standard forms, and sometimes followed up with telephone interviews; however, unlike Nevada, many responders used idiosyncratic methodologies to complete the forms.

In 1997 the two reports differed in important ways (Table 3). Although NYSDEC found a greater recycling rate than the legislature did, its 30% rate was less than the 1997 goal. NYSDEC concluded that some recycling had not been included, such as container deposit law returns (290,000 tons) (260,000 tonnes), metals (910,000 tons) (825,000 tonnes) and paper (1,400,000 tons) (1,250,000 tonnes) exported through New York harbor, and “beneficial use determination” materials (mostly alternate cover materials for landfills) (2,510,000 tons) (2,275,000 tonnes). These credits boosted the recycling total to 12.5 million tons (11.3 million tonnes), the total waste stream to 29.9 million tons (27.1 million tonnes), and the recycling rate to 42% (NYS Department of Environmental Conservation 1998). For 1998, NYSDEC estimated the State recycling rate would have been 36% compared to the reported 44% if it included only USEPA-defined MSW in its assessments (NYSDEC 2000). By 2006, although State population had not grown much at all since 1998, NYSDEC counted more than 40 million tons of waste generation (over 12 lbs person^{-1} d^{-1} [5.5 kg person^{-1} d^{-1}], more than 250% of the USEPA rate and more than 150% of the BioCycle rate), and the state recycling rate was set at approximately 50%. NYSDEC also computed a “traditional” recycling rate that was closer to 30%, although how that computation was made was never specified (data drawn from public meeting Powerpoint presentations by NYSDEC personnel, 2006-2008).

When it released its draft State Solid Waste Management Plan in 2010, NYSDEC had recalculated the size of the state waste stream. This was apparently done only using facility reports (from landfills, incinerators, recycling facilities, and transfer stations), rather than beginning with data from the constituent waste management authorities as had been the previous practice. The waste stream was found to be 17 million tons (a little more than 15 million tonnes), with 3 million tons (less than 3 million tonnes) recycled (a waste generation rate of 5.4 lbs person^{-1} d^{-1} [2.4 kg person^{-1} d^{-1}], and a recycling rate less than 20%). The waste generation rate exceeded USEPA’s nationwide rate, and the recycling rate was much less than USEPA calculated for the nation as a whole. State planners found this was a signal that New York needed to reconsider its previous waste management policies, which clearly had been ineffective (NYSDEC 2010).

Regional and local assessments

Large cities (such as New York, Chicago, or Los Angeles) or regions (like Long Island) that are smaller than states sometimes conduct waste assessments covering their jurisdictions. Stony Brook University has reported waste generation information for Long Island several times (Tonjes & Swanson 1994, Tonjes & Swanson 2000, Tonjes 2007). Some issues identified above for state-level assessments are also found in regional assessments, and other issues that are not apparent at the state-level can be discovered at smaller geographical scales (Table 4).

Some anomalies are introduced by facility practices (see below), but individual facility errors can be compounded by including reports from more than one facility. On Long Island, one important issue was double-counting. Tonnages might be reported by the responsible municipality, and also by a facility to which the materials were delivered. Transfer stations are a locus for this, as they may receive wastes reported by the MSW source, in turn report the wastes managed at the transfer station, and deliver the wastes to another facility, which also reports the tonnages. Another issue is to identify waste imports and account for exports. Determining what to count and what to ignore is another source of discrepancies. Waste stream heterogeneity and business practices mean that waste loads may not fall into a single, classic waste category; C&D and land-clearing debris are often mixed with other materials, for instance, or are counted as MSW without distinction. When recovery rate maximization is a goal, because much of these wastes can be diverted from disposal, our local reports show and our experiences with the Town of Brookhaven (New York) have been that they are often included in MSW recycling totals (other materials that avoid standard disposal routes, such as junked automobiles and other scrap materials, or hazardous household waste collections, can be also commonly included in recycling data). Ensuring reports are consistent is another problem. Wastes that should be counted may not be (often because they are not managed at facilities that report data in the solid waste system, as when corrugated cardboard is delivered directly from a generator to a paper broker). Composting often causes counting issues. Some municipalities compost yard wastes but do not compute the tonnages involved, some produce partial totals of composted wastes, some make only crude estimations, and others include land-clearing debris in yard waste assessments. Others sum the total of materials present at a site each year, but neglect to subtract holdover material from previous seasons (Tonjes & Swanson 1994, Tonjes & Swanson 2000, Tonjes 2007).

Demographics can cause problems. A common statistic in waste assessments is to calculate per capita waste generation rate. Long Island's east end is a popular summer resort, with summer weekends often resulting in doubled populations. Jones Beach State Park can have over 4 million annual visitors. Undocumented aliens are often not included in population data. All of these people generate MSW but are not included in census data, the most common source of population information. Thus, selection of the denominator for per capita rates is not simple (Tonjes & Swanson 1994, Tonjes & Swanson 2000, Tonjes 2007).

Facility reporting

At the base of all these data assemblages are reports from individual facilities. Landfills and incinerators, recycling facilities, compost sites, and transfer stations almost always report some form of waste receipt data to some authority. These reports are generally considered as being accurate as received, but our experience suggests this may be a faulty assumption (Table 4).

Measurement units can be an issue. An impetus for USEPA to adopt modeling was a general lack of scales at many facilities (Smith 1975). In the absence of actual weight data, estimates of weights based on volume (or other) conversions are often not accurate (Rushbrook & Ball 1988). When we began reporting on LI MSW in the early 1990s, many transfer stations did not have scales, and wastes deliveries were measured in volumes. Most waste fees were levied by volume, so these measurements supported the billing system. Outputs from transfer stations were in mixed units, as at some receiving facilities wastes or recyclables were charged or paid by weight; other facilities accepted materials by volumes, making accurate mass balances impossible to calculate (Tonjes & Swanson 2000). Some of these practices continue today. For instance, most C&D on Long Island is collected in uncompacted open containers, and pricing is by volume, so that received waste quantities are reported in cubic yards. Two C&D disposal landfills charge by volume, and one charges by weight. Therefore, wastes leaving C&D transfer stations may be reported both in cubic yards and tons, with those wastes delivered by volume also having been compacted, so that the reported total of managed volumes are less than the sum of received volumes. On Long Island, privately operated transfer stations often manage both MSW and C&D; outputs from facilities are often a combination of MSW sent to landfills, recyclables, and C&D residues. Materials collected as C&D may be managed as recyclables, C&D residues, and sometimes MSW (especially for some packaging materials); MSW may be parsed into recyclables, disposed MSW, and small amounts of C&D (wood wastes, for instance), if to do so is economically advantageous, and then various elements are measured by weight or volume (if by volume, likely at a different density than when received) (Tonjes 2007).

There are also systematic and often intentional errors in waste reports. Small businesses, including waste handling facilities, are known to hide substantial proportions of income (Feldman & Slemrod 2007), and so it is not certain that waste reporting, from which income may be deduced, is being made accurately. Bornstein (2011) suggested carters in Los Angeles regularly underreport waste tonnages because they pay a per ton fee to the City for managing wastes. On the other hand, Rathje (1989) assumed carters were predisposed to overreport wastes, since many are paid on the basis of the amount of wastes handled. On Long Island, this situation was further muddied by many decades of organized crime domination of private carting (Reuter 1987). So, waste tonnages may be misreported both high (so that rival firms do not try to underbid for a contract) or low (so as to misrepresent potential revenue streams), and thus economic incentive factors need to be understood in any accounting situation. On Long Island, carters collecting wastes under municipal contracts are, in some areas, charged no tip fee for wastes and recyclables, to ensure all municipally-collected wastes within the municipality come to the municipal facility (a form of economic flow control). However, this encourages the unauthorized collection of wastes from other areas or sites that should not receive the services, since the carters can thereby avoid paying a tip fee that might be due. One means of avoiding this system manipulation is for contractors to include a tip fee expense in their bid, and then pay a tip fee for all wastes brought to the municipal facility. But then the carter may then be tempted to divert wastes to lower cost facilities (without the municipality benefiting from the lower cost, nor receiving the revenue to balance the monies paid out to the carter under the contract). When recycling markets are strong, unlicensed scavengers increase their collection of set-out materials, or contract carters may divert recyclables themselves to enhance revenues. All of these “under the radar” practices can affect reports of waste generation.

In New York State, facilities are required to keep scalehouse receipts to support periodic audits, but overworked regulators generally do not check these records (although judicial oversight of the New York area waste industry in the 1990s incidentally improved waste data accuracy due to aggressive prosecution of organized crime). We have direct experience in identifying errors from our role as preparer of annual reports for the Town of Brookhaven on Long Island. The Town transfers its MSW elsewhere for incineration, with the transfer trailers weighed out of the Brookhaven transfer station and in at the incinerator. There are only small (tens of tonnes) differences between the two transfer tonnages on an annual basis (out of approximately 200,000 tonnes). However, incoming tonnage for the Brookhaven facility can be 1-3% greater than the outgoing tonnage (Table 5). Residential collection trucks, which bring 95% of the waste to the facility, weigh in, but pre-registered "tare" weights are used to minimize traffic on outbound scales. There is no apparent financial advantage, so there is no need to resolve the error, except to keep the books straight. Evaporation of moisture from the MSW, waste misdirection within the facility (the Town operates a landfill at the site, where residential MSW is not supposed to be disposed), copying errors when transferring data from one ledger to another, etc., have all been considered as sources of the discrepancies and dismissed. The main cause appears to be the tare weight system. Trucks are assigned a tare weight when initially placed in operation. However, the absence or presence of helpers on the truck, the amount of fuel in truck tanks, and, most probably, MSW adherence to the packer trucks (or liquid wastes that do not dump fully) – any error such that 50 kg truck trip^{-1} accrues – can easily create an accumulated annual difference of 2,000 tonnes or more. These data affect analyses of the residential waste collection system, but that has not caused a need to increase traffic on the outbound scales (which takes time away from collection routes and also slows all other traffic, as collecting fees makes for longer outbound transactions) to measure the actual unloaded packer truck weights.

The Town recycling facility managed only Town-generated materials for five years, but then the facility operator was encouraged to seek other sources of recyclables. We reported all facility data as Town-generated recyclables for a number of years, because at first the differences were inconsequential – and when the differences were noticeable, it required a change in well-established practices, and led to a decrease in reported Town recycling rates, which was not well-received. The facility receives mixed loads of materials from curbside set outs, but delivers individual materials to market. The Town has been reporting net tonnages of the individual materials. The Town therefore reports a smaller tonnage than its citizens set out for recovery, which is not the general practice in New York.

The Town landfill manages two classes of C&D materials. Finely ground C&D is received, technically, as an alternate daily cover. Coarser C&D is classified as a waste material. The Town, by permit, is limited to apply only a certain percent use of alternate cover material, which is not counted towards the permitted daily tonnage limit at the landfill. Operationally, because C&D is not especially putrescible, covering wastes is not a priority, although finer materials inhibit fires by reducing air penetration into the waste mass. The important distinction, from the Town perspective, is a tip fee difference. At the end of reporting periods, the Town must calculate the allowed cover material tonnage. This may require diverting materials from cover to waste categories, as a bookkeeping transfer, to ensure regulatory compliance. Similar category transfers probably occur at other facilities, and suggest category accounts may not be accurate.

Individual Waste Generators

Households, businesses, and institutions constitute the sources of MSW, and in the US there are more than a hundred million households, and millions of businesses and institutions. If a waste generation rate could be established for each or for general classes of generators, then waste generation values could be incrementally determined as an alternative to materials flow and site-specific reporting.

Individual and household waste generation was determined for Indianapolis in 1972, based on aggregated samples from groups of 60-90 households, constituting one of the first published surveys of waste generation in small samples. Income, household size, and the age distribution of the residents were found to affect waste generation rates (Richardson & Havlicek 1978). These findings generally agreed with Wertz's (1976) more theoretical findings that income (and the site, price, and frequency of garbage service) should affect waste generation. The Garbage Project at the University of Arizona began sorting and assessing individual household waste generation in Tucson in the early 1970s. It also assessed waste generation in a number of other locations. Amounts and types of wastes generated depended on a number of factors, most relating to socio-economics, but also including other human frailties and patterns of behavior (Rathje 1989, Rathje & Miller 2000). Pichtel (2005) collected data describing differences in per capita waste generation between single family housing and apartments, and by household and community size. Waste generation was also found to vary according to area of the country, and seasonally across years.

Waste generation in businesses and institutions has long been assessed. Data about generation rates by federal Standard Industrial Classification (SIC) codes or similar measures are not hard to find, as early as 1970 (an example is still cited in Tchobanoglous 2009). Rhyner & Green (1988) reviewed three of the more comprehensive efforts from the early 1970s; McBean & Fortin (1993) collected a series of similar studies from the late 1980s. The units to describe waste generation for establishments vary. They are usually given by employee numbers, floor area, or sales (Pichtel 2005). California commissioned a study of commercial waste generation, organized by functional groups (such as fast food and full service restaurants, food stores, large hotels, big box retail stores, other retail stores, etc), in four metropolitan regions. The data were characterized as generation according to representative characteristics (per employee, per square foot, per room, per visitor) (Cascadia Consulting Group 2006). Peterson *et al*. (1995) found that the number of employees in a firm affected per capita waste generation rates inversely, and that the size of a company was often more significant than SIC coding in predicting waste generation. Franchetti (2010) approached the issue differently. His survey of 400 companies in 65 SIC categories found that waste generation and composition within SIC groups was homogenous. For non-manufacturing businesses, the number of employees was a good predictor of waste generation (he did not analyze floor area or sales as predictors). Other models of industry waste generation depended on combinations of employee numbers, ISO 1400 status, and several other predictors to estimate waste generation in manufacturing fields (Franchetti 2009). The many consultants who have long assessed individual business's waste generation to establish recycling programs or otherwise control waste costs generally use simpler approaches, such as direct sampling and observation, or the multipliers discussed by Pichtel (2005) and Tchobanoglous (2009). The consultant data sets are not often published, however (see, for instance, a report on Los Angeles waste generation, prepared with Cascadia Consulting Group, at: http://www.zerowaste.lacity.org/files/info/fact_sheet/SWIRPGenDisposalFactSheet_032009.pdf) .

Rhyner & Green (1988) used a variety of estimation bases, primarily based on population, to model overall waste generation in a Wisconsin county. Some predictors had good results, but there were wide variations among the generated values. It is not clear how good estimators might be preselected. Kessler Consulting & Franklin Associates (undated) created a spread-sheet model for application in counties in Florida, adapting the USEPA model estimates using local inputs such as sampling data and SIC data. The Florida model can be recalibrated every time the USEPA model is iterated. Hockett *et al*. (1995) determined using linear regression that retail sales and tipping fees were significant predictors of variations in waste generation in North Carolina, but found a great deal of uncertainty, some based on the underlying waste accountings. McBean & Fortin (1993) created a model for Waterloo, Ontario, that used industry and household waste generation rates, and then conducted regression analyses using economic data to determine the effect on annual waste generation rates from economic variability. A model in Illinois, based on multivariate analysis of socioeconomic population descriptors, rank-ordered solid waste generation by county (Cailas *et al*. 1996), although it is not clear that meaningful State-level information is generated from rank ordering if the populations of the counties vary much.

Beigl *et al*. (2008) identified household-level models as one of the general classes of models that are created to understand waste generation. They believed that regression analyses on household descriptors could generate predictive models for waste generation, recycling, and waste composition.

Discussion

The two primary data collection efforts disagree on many statistics, and on basic waste infrastructure facts (Table 6). For 2008, USEPA and BioCycle disagree on the number of landfills by about 100, although USEPA used (and cited) a BioCycle value (Arasova *et al*. 2008). Similarly, although they agree on the general scope of composting (as USEPA relies on BioCycle's industry stature), they do not quite agree how much waste was composted (BioCycle found 24.5 million tons [22.2 million tonnes] and USEPA counted 22.1 million tons [20.0 million tonnes] in 2008). They do not agree on the number of incinerators; BioCycle found 115, although it noted two did not burn MSW, and USEPA cited a 2007 source, finding 87. They did not agree on the tonnage managed at these facilities (25.9 million tons [23.5 million tonnes] by BioCycle, 31.6 million tons [28.7 million tonnes] for USEPA) (van Haaren *et al*. 2010, USEPA 2010). Sewage sludge composting and incineration and clean wood incineration could be elements in the differences in data, although the Themelis group stresses it adjusts data so as to correspond with USEPA definitions. These differences suggest a more fundamental disagreement, that they are counting different things altogether. The incineration difference is striking – there are relatively few facilities in either assessment, and the smaller number of plants in the USEPA accounting managed a greater tonnage. Differences in landfilling tonnages are more understandable, especially since USEPA's landfilling value appears to be indirectly computed simply as a remainder of the total, minus recycling and waste incineration.

Rathje long criticized the USEPA methodology. He failed to find white goods in landfills, although USEPA data suggested they were being landfilled (because recycling data were less than modeled generation data), and he found C&D to be the greatest or second greatest single constituent in landfills. Errors and exclusions like these resulted in Rathje concluding that the USEPA data sets had little credibility (Rathje 1989, Rathje & Miller 2000). Alter (1989, 1993) suspected that the input-output analyses were insufficiently tested against actual waste stream data, but thought the data had the virtue of being "internally consistent." The Themelis group states the modeling approach is not very good at determining disposal tonnages, especially at landfills, where the greatest discrepancy between the BioCycle and USEPA data is. They think that the model does a credible job determining curbside recycling, but is poor at tracking organic waste recoveries (Kaufman & Themelis 2009).

Allen (2008) does not describe the USEPA waste descriptions as credible materials flow accounting, probably because it does not track materials prior to their incorporation into products. He found the Washington "Beyond Waste" tracking effort a better materials flow model. Washington State uses 12 indicators to track overall progress towards "sustainability" (Table 7), covering much more than waste management. Its materials flow conceptual model tracks inputs (raw materials, process goods that are not incorporated into finished goods, components of finished goods, and the finished goods themselves) and outputs (traditional wastes and other outputs, such as greenhouse gases, fertilizers, and product degradation), recognizing some goods are durable and remain as "stocks" (per Matthews *et al*. 2000) (Cascadia Consulting Group & Ross & Associates 2003a). Wernick & Irwin (2005) also did not find the USEPA approach comprehensive enough to fit their definition of materials flows accounts, because it could not track individual toxic substances from cradle to grave (for instance).

It is difficult for the USEPA model to assess food and yard waste generation on an annual basis. At best, it appears to be the result of "expert opinion" estimation. Food waste has been modeled by others: Hall *et al*. (2009) used Department of Agriculture data on food production and estimates of American metabolism rates and weight gain to estimate how much food was consumed and how much was sent to market without being eaten (i.e., wasted). Similarly, associating yard waste production to regional weather is a more objective means of varying waste generation rates (although changes in disposal set-outs would need to be determined).

Beigl *et al*. (2008) concluded, because waste generation occurs along parallel management tracks that limit direct quantification, that modeling is the only effective means to effectively evaluate its scope, and to support rational planning. However, Beigl *et al*. were skeptical that the data needed to support input-output models exist for national level assessments.

Data incongruities in the state assessments and regional accountings, along with the kind of problems found for facility accountings, show why USEPA attempted its model. The scope of data management by the Themelis group does not seem adequate to address the policy prisms affecting counting in New York and California, for instance. Estimates of waste generation in California increased by more than 20% from 2006 to 2008 as the researchers tried to apply reasonable factors to translate reported state data into values comparable to those reported by other states. However, as the waste managers in New York changed counting policies, waste generation values for New York decreased by more than 20% from 2006 to 2008 (and was down over 30% from the first tonnages computed by the Themelis group for 2002). The underlying errors and obfuscations that affect constituent facilities are opaque to the Themelis group. Therefore, it is clear that careful reworking of state data will not avoid some deep-seated sources of error. We like to think our local efforts have less error than some others, but it is clear that they too contain considerable uncertainties because the base reports are not reliable.

Chowdhury (2009) proposed that local waste generation data be generated through targeted sampling and then aggregated by authorities to the national level. Generation factors, as discussed above, could be created so that they address variations caused by local conditions. The periodic refinement of waste generation coefficients addresses the problem identified by McBean & Fortin (1993) that generation factors change with economic and demographic conditions. However, aggregation schemes, such as for Long Island, or even for the Themelis group, dealing with only 50 states, have not resulted in universal participation, suggesting widespread participation in creating such data may be difficult to ensure.

Beyond Waste (in Washington) (Cascadia Consulting & Ross & Associates 2003b) described four potential data collection means: mandatory reporting, voluntary reporting, direct monitoring, and extrapolation and estimation. Reporting reflects unintentional and willful errors; direct monitoring requires a large effort investment; and sampling, as Dangi *et al*. (2008) describe, has statistical pitfalls although the resulting errors can be reduced by increasing sampling effort or using more sophisticated sampling designs. Extrapolation and estimation depend on the validity of the estimators. One seemingly unavoidable data issue that is rarely discussed in MSW management is the presentation of data with improbable numbers of significant figures. For instance, in the BioCycle reports, 9 and 10 digit numbers with no rounding are presented as if all the values were significant (e.g., van Haaren *et al*. 2010), a result of adding together smaller values to generate a large sum (although many of the smaller values also have improbably large numbers of seemingly significant values). It is difficult to avoid this particular reporting trap.

Waste assessments are often used to assess environmental impacts. Thorneloe *et al*. (2002) created an early model of greenhouse gas emissions, for instance, and based the model on USEPA quantities and composition data. Since then, USEPA has created a more generic solid waste management greenhouse gas generation model (WARM) (USEPA 2006). The model is often used to estimate impacts for planning purposes (see NYSDEC 2010, for instance). WARM does not specify waste generation rates, but its inputs were determined, to some degree, based on considerations of the national waste stream. If USEPA data underlying the model are not sound, confidence in the model necessarily wanes. Also, if it is realized the one model from a source has tremendous flaws, then other efforts by the same group may also be perceived negatively, ipso facto.

Mostly, US national data, especially those from USEPA (which carry the imprimatur of the government) are used to set local values in context. Is our program as good-better-worse than the nation as a whole? Are Americans better/worse than others at waste generation, recycling, and management? Kinnaman (2009), in an assessment of economic factors affecting waste management, asserted that although such evaluations had long been limited by poor data sets, "the past decade has seen the emergence of high quality state-wide panel data in the United States." The availability of "high quality" data of any form in the US, at any level, is difficult to support.

Conclusions

It is unlikely the USEPA model accurately defines US MSW generation. Criticisms of the materials flow portion of the model, while they can be fairly described as nit-picking at specific elements of the model, highlight the difficulty of determining how long durable goods actually remain as stock between production and disposal. Too few details are provided for the estimation of food and yard wastes, and there seems to be little objective data to support the annual changes in generation rates for those materials. The distribution of wastes among recycling, incineration, and disposal seems poorly founded. In recycling, for instance, metals that are delivered for remanufacture do not necessarily originate as MSW. It seems likely that scrap dealers generate most of their materials from non-MSW sources, such as automobiles and C&D. Composting estimates are likely inaccurate, no matter what means is used to develop data, if our experiences on Long Island are applicable more broadly. Finally, the estimate of landfilling depends on the estimates for recycling. In addition, all data we have seen from state assessments, and nearly all assessments of local waste generation, find much higher waste generation than the model does. To be certain, all of these site specific assessments have many uncertainties associated with them, as well. However, it is disconcerting if there is essentially no agreement between them and the modeling data. USEPA says that the model is verified based on field surveys, but does not detail how this is done, or what constitutes verification. It is also disconcerting that every new report brings entirely new revised sets of US waste generation rates for previous years, based on that year's model refinements. On the other hand, as iterated results of a model, that approach is entirely appropriate. It's just bad form when creating national data bases.

The Themelis group-BioCycle reports are clearly flawed, as well. Incomplete responses mean that inconsistent data collection methodologies are used for each report. It is difficult to tell whether variations in the US waste total result from changes in waste generation, or in data collection methodologies. It is near-impossible to verify the raw data used as input into the analyses, and the Themelis group is not entirely transparent in discussing how state data is translated into USEPA-congruent data. It is clear that the differing approaches to data collection by the states also create uncertainty that the same waste stream types are being counted, and that extra elements have not been added, or certain things left out, despite the efforts of the analysts to manage the data sets. Errors and policy decisions that affect the state data compilations are troubling, as well. We also have showed that the reporting that the state compilations use is likely not accurate, sometimes unintentionally but also purposefully so.

The Themelis group approach has the virtue of being grounded in actual waste management practices. We think that the primary error in these assessments comes from editing actual activities because they do not fit a particular rubric. Residential garbage often contains wastes that, technically, are C&D – these wastes result from building renovation or repairs, and physically are indistinguishable from wastes generated at construction sites, although they are generated in smaller quantities. It is impractical to exclude these wastes from tonnage compilations. Carrying this conceptual understanding forward leads to a possibility of counting the solid wastes that are managed by certain kinds of facilities – landfills, recycling centers, transfer stations, compost sites, scrap metal dealers – and judiciously seeking to add materials that passed through residences, institutions and businesses but were not managed in the identified facilities. The data from site to site, and perhaps place to place, would not be congruent. Perhaps inventive data management approaches could address if not wholly resolve these kinds of "apples and oranges" issues.

It is impossible to say which of the two major assessments counts MSW better. We think that neither does a particularly good job on their own self-described tasks. It is difficult to even put error bounds on the results. Some of the facility scale results can be bounded – our tare weight error varied from nearly 0 to 3%, for instance. Others, such as the amount of wastes hidden for economic reasons, cannot be so simply defined. That does not mean it is not practical to count MSW "good enough." Clearly, counting waste well is important to size facilities correctly. However, there are few modern examples of bad errors in facility sizing. Partly this is engineering: facilities may be built to a site specification (compost sites or buildings such as transfer stations that are subject to zoning restrictions), or can be sized to accommodate maximum expected waste flows (transfer stations, landfills) (although most of these facilities are designed to fit an expected market). Waste processors (recycling centers, waste-to-energy plants of various kinds) need to be more carefully sized, but are often designed to have means of addressing sizing errors (large waste pits for incinerators, or tipping floors designed to hold weekly amounts of wastes for recycling facilities). Few facilities are constructed on the basis of a reported waste stream size; rather, often much effort is expended to independently estimate likely waste flows, or, better, contracts are crafted to ensure deliveries (or payment in lieu of waste deliveries).

Accurate waste accounting is also useful to create meaningful assessments of programs. Program attributes such as recycling rates and GHG release rates, which can be easily understood by the general public, depend upon accuracy in assessing overall waste generation. More esoteric evaluations, such as life-cycle assessments, also need good inputs in order to have much validity. This need for accuracy to support assessment processes holds for local, regional, state, and federal assessments. Whether all of these assessments need to be consistent is not entirely clear.

Data standardization is a common response to our embarrassment that we don't count wastes well (Vasuki 1998, California Integrated Waste Management Board 2001,Cascadia Consulting & Ross & Associates 2003b,Goldstein 2007, Kaufman & Themelis 2009, Dahlen *et al*. 2009, NYSDEC 2010), although the European Union seems almost sanguine that various member states do not count MSW entirely congruently (Eurostat 2010). Standardizing waste accountings either means idiosyncratic waste streams (and there are many) will not comply – or will be forcefitted to comply. If waste management practices are standardized to fit waste counting needs, the uncountable wastes may lack management options. In addition, setting standards does not address some underlying errors that arise at the facility level.

Sophistication in data collection could address some problems. Technology fixes, such as GIS-linked databases to more carefully track waste flows (electronic versions of hazardous wastes manifests) seem promising, but may have sociological issues. Regulation in the US, especially associated with greater oversight, is often perceived as government intrusion into private matters. Garbage is commerce, and finances are sensitive subjects; overt and active tracking of wastes may not be well-received.

Regulators and the regulated community should understand that accurately reporting waste management is a virtue; we would have all wastes be counted, and let clever accountants parse the reports into appropriate boxes. However, Thompson (1998) notes that if it is impossible to keep good accountings of valuable things (such as money), it is not surprising we do not track well something like MSW that has no positive value (until processing enables recovery of recyclables or energy). This facetious statement has a hard kernel of truth; there is an element to the inability to count waste well that springs from a perception that counting waste often doesn’t really matter much. Especially as most programs operate to meet local needs, the actual operation of waste systems does not require accurate descriptions of overall US waste generation. Waste generation and management are significant in many ways – but counting MSW accurately for the US as a whole doesn’t resolve any serious problems. There are substantial issues with how waste generation is assessed for the nation as a whole, but alleviating those concerns could have consequential effects that impact actual waste operations.

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Table 1. Comparison of USEPA and BioCycle Report Scopes

	USEPA	BioCycle
Primary Source	Model	State reports
Frequency	Annual	Biennial
Authors	USEPA staff	Columbia University researchers
US total generation totals and rates	Yes	Yes
State-regional generation totals	No	Yes
National management mode statistics	Yes	Yes
State-regional management mode statistics	No	Yes
National waste characterization	Yes	No
Waste characterization by management mode	Yes	No

Table 2. State-level waste assessment methodologies

	Nevada	Oregon	California	New York
Basis	Compiled forms	Compiled forms, additional research	Compiled forms	Compiled forms, additional research
Methodology consistent	Yes	Yes	Since 2001	No
Reporting mandatory	Yes	No	Yes	Yes (not enforced)
Frequency	Collected annually, published biannually	Annual	Annual	Collected annually, no longer published
Local disposal-recycling reported	Yes	Yes	Yes	Yes
Export-import accounted for	Yes	Yes	Yes	Yes
Other recycling-recovery credits counted	No	Yes	Yes	Sometimes
Total waste generation based on	Yes	Mostly	No, model	Yes

scale data				
Used for regulatory purposes	No	No	Yes	No

Table 3. 1997 New York State Waste Management Reporting (millions of tons)

Source	Landfilling	Incineration	Export	Recycling	Total	Recycling Percent
Legislature	9.1	3.7	3.7	5.2	21.6	24%
NYSDEC	9.3	3.3	4.5	7.4	24.5	30%

Table 4. Factors affecting accuracy of reported MSW management, Regional and Facility reports

Regional Reports	Facility Reports
Misallocation of materials as MSW (includes inappropriate recycling credits)	Misallocation of materials as MSW (includes inappropriate recycling credits)
Misallocation of materials as other than MSW (primarily disposal)	Misallocation of materials as other than MSW (primarily disposal)
Conversion of volume data to mass data	Conversion of volume data to mass data
Imports and exports	Determining composting credits
Non-reporting facilities/processes	Tax evasion
Double-counting	Underreporting wastes
Determining composting credits	Overreporting wastes
Demographic issues (for rates)	Economic incentives that encourage "cheating"
	Use of tare weights
	Double-counting, misappropriation of credits
	Bookkeeping transfers for regulatory compliance purposes

Table 5. Town of Brookhaven scale discrepancies (thousands of tons)

	Inbound	Outbound	Difference (% of inbound tonnage)
2002	216	212	2.0%
2003	228	223	2.0%
2004	233	228	2.1%
2005	230	227	1.4%
2006	228	226	1.0%
2007	219	216	1.3%
2008	218	211	3.0%
2009	212	211	0.6%
2010	201	199	1.4%

Table 6. Comparison of USEPA (2009) and BioCycle (van Haaren *et al*. 2010) 2008 data (in million tons) (with data sources)

	USEPA	BioCycle
Recycling (including composting)	82.9 (primarily end users survey)	93.8 (sum of compiled state data)
Composting	22.1 (report in 2008 Biocycle)	24.5 (sum of compiled State data
WTE Incineration	31.6 (regulator reports)	25.9 (sum of compiled State data)
Number of WTE Incineration facilities	87 (industry report)	113 or 115 (sum of compiled State data)
Landfilling	135.2 Modeled tons – Recycled tons - WTE incineration tons	269.8 (sum of compiled State data)
Number of Landfills	1,812	1,908

	(Arasova *et al*. 2008)	(sum of compiled State data)

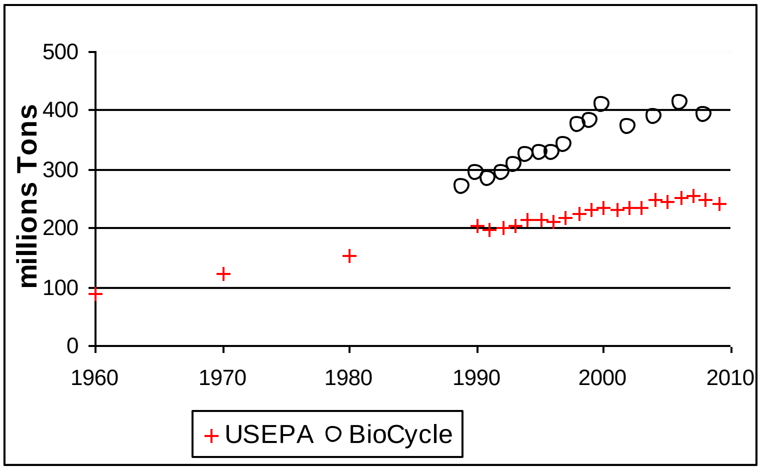
Table 7. Indicators used in *Beyond Waste* (Washington State) (http://www.ecy.wa.gov/beyondwaste/bwprog_sixteen.html)

Indicator	**Unit Used**
Consumer Climate Change Index	Index (2000 = 100) (modeled GHG emissions, based on consumer spending)
Consumer Ecosystem Toxicity	Index (2000 = 100) (modeled toxicity of releases, based on consumer spending)
Economic Value of Recyclables Disposed	Dollars (estimated disposal rates)
Electronics Recycling	Percent (from estimates of use and disposal)
Green Building	Percent (market share of new commercial and residential construction)
Hazardous Waste per Dollar State GDP	Pounds/Dollar (reported data from State manufacturers)
Hazardous Waste Generation	Pounds (reported data, organizations generating more than 2,640 lbs/yr)
Hazardous Waste Recycling	Pounds (recovery of wastes, excluding closed loop systems, for organizations generating more than 2,640 lbs/yr)
Lawn and Garden Pesticides Toxicity	Index (2000 = 100) (modeled toxicity of releases, based on consumer spending)
Mercury in Biosolids	Concentration (ppm) (samples from 6 facilities)
Organic Materials Recycling	Tons (tracked composting, recycling, and diversion of materials such as yard wastes, food wastes, and biosolids)
Paint Recycling	Percent (estimate based on HHW program reports)

Figure Captions:

Figure 1. Differences between USEPA and BioCycle total US waste stream sizes (USEPA data assembled from various reports)

Fig. 1.



500
400
300
200
100
0
millions Tons
1960
1970
1980
1990
2000
2010
USEPA
BioCycle