Generation and Disposition of Municipal Solid Waste (MSW) in the United States –A National Survey

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EXECUTIVE SUMMARY

In 2002-2010, the Earth Engineering Center (EEC) of Columbia University conducted a bi-annual survey on Municipal Solid Waste (MSW) Generation and Disposition in the U.S., in collaboration with Ms. Nora Goldstein of BioCycle journal. This survey, published in BioCycle journal as "State of Garbage in America" (SOG), was based on data provided by the waste management agencies of the fifty states. The SOG survey was not carried out in 2012 and in 2013 EEC and BioCycle agreed that the 2013 Survey of Waste Generation and Disposition in the U.S. will be undertaken solely by the Earth Engineering Center. The objective of this research study was to conduct a national survey of MSW generation and disposition, by compiling and analyzing waste management data provided by the waste management agencies of the fifty states of the Union. Furthermore, the study examined the national trend of waste generation and management since the beginning of this century and explored options for improved data collection and waste management at the state and national levels.

Another objective of this study was to understand and try to resolve the large data discrepancy between landfilling data provided by the waste management agencies of the states to the EEC Survey and the EPA annual reports on MSW Facts and Figures.

The EEC Survey Questionnaire submitted to the waste management department of each state requested for 2011 data. The Survey results showed that the U.S. generated a total of 389 million tons of MSW, corresponding to a per capita generation of 1.3 short tons (1.19 metric tons) of MSW. Of the total waste generated, 29% was either recycled or composted, 7.6 % was sent to WTE facilities, and 63.5% was landfilled. Nine of the fifty states (Alaska, Hawaii, Louisiana, Michigan, Missouri, Oklahoma, South Carolina, and West Virginia), representing 13% of the U.S. population, did not provide data for the survey and some other states were not able to provide recycling or composting data. In these cases, population-adjusted data from the 2010 Columbia/BioCycle SOG survey was used.

The national waste generation trend since the beginning of the 20th century was closely related to the national GDP trend. The total waste generation from 2011 has not increased much from 2008; however, the landfilled tonnage decreased by about 20 million tons while recycling increased by nearly the same amount This indicates that the national effort to divert wastes from landfills and recycle has made progress.

The landfilled MSW tonnage difference with EPA was even larger this year at about 113 million tons. Speculative reasons for the data discrepancy include residues from recycling facilities, wastes that are not captured in the material flows method used by EPA (e.g. packaging of imported goods), automobile shredder residue, ash residues ending up in landfills, household construction projects, and light industrial wastes that for lack of other means are disposed with MSW in MSW landfills.

The 2013 EEC Survey indicated clearly the need for financial and human resources to be provided at the state level to keep track of the ever increasing stream of solid wastes and advance sustainable waste management in the U.S. to the level of several leading developed nations in Europe and Asia.

ACKNOWLEDGEMENTS

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Most importantly this work would not have been possible without the help and support from the waste management agencies of states who kindly participated in the survey effort, and those who went beyond the survey to provide details on their waste management methods (Table A3).

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1. Introduction

It is a sad truth that the issue of waste management is not given as much attention as the global climate change and energy consumption. With climate change being the source of heated debate and concern, most associate sustainable management with improving energy efficiency and reducing green house gas emission. The notion of importance of waste reduction and resource conservation is certainly out there, but there has not been enough discussion to drive adoption of practical solution that addresses current issues of waste management.

The problem of waste management is dire and deserves much more attention than what has been given. As it is well known, global population is expected to grow even more rapidly. Combined with increasing consumer goods production and wasteful consumption, the landfilling of generated municipal solid waste (MSW) requires the use of land, competing with agricultural land and residential space. This problem, however, is well known and can be dealt with by means of sound management and policy implementation. A bigger problem with waste management is the fact that data collection and waste accounting are not conducted coherently. There is a gap, at the national level, in the knowledge of what types of wastes are being generated and where they end up. In other words, the national wastes are not "managed" well.

Of course, states and municipalities provide convenient services and facilities to their citizens for waste disposal. However, keeping the street clean and punctually collecting waste are only part of waste management. Without an accurate account of how much of the national MSW ends up in landfills, recycling plants, composting, or waste-to-energy (WTE) facilities, it is impossible to make specific and custom-fit policy decisions that would help each state manage its waste in the most efficient manner. The significance of this waste management problem is well shown through the data discrepancies of the two most cited waste generation statistics that are published by the Environmental Protection Agency (EPA; (US Environmental Protection Agency, 2013)) and by the bi-annual national surveys of the Earth Engineering Center (EEC) of Columbia University and BioCycle journal (van Haaren, Themelis, & Goldstein, 2010). For example, the total landfilled municipal solid waste tonnage, reported in these two studies for 2008, differed by about a hundred million tons, with EPA reporting much lower tonnage than EEC. Here, the misrepresented wastes (either the statistically missing wastes or the overestimated and underestimated wastes) are, in effect, the unmanaged wastes. The statistically missing or underestimated wastes do end up in the national landfills, but they are essentially invisible on key data available to state governments and are not considered in decision-making of state waste management plans and in state and national policy making. For example, the underestimated waste can cause states to prepare inadequately for greater landfill space demand in the future. Furthermore, without knowing the accurate tonnage, planning for recycling, compositing and WTE facilities is hampered, because one would not know what material to focus on or encourage industry to put effort into treating the MSW to be generated.

The objectives of this study were twofold: To conduct a national survey of MSW generation and disposition, by collecting data from the fifty states of the Union, and to explore possible reasons for the large data discrepancy between the EEC survey of 2011 data and the lasts Facts and Figures report of USEPA, especially in landfilling data; i.e., identifying the reasons for the "missing" (EPA report) or the "overestimated wastes" (EEC survey). Furthermore, the study explored options for better management at the national level. The study also investigated the national trend of waste generation and management since the beginning of this century.

2. The Means for Managing MSW

2.1. Definition of MSW

In order to understand how and in what point of waste management the MSW accounting should be improved, it is necessary to understand the current infrastructure of waste management in US.

Municipal solid wastes are defined by EPA as waste consisting of everyday items "used and then thrown away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries," which comes from "homes, schools, hospitals, and businesses (US Environmental Protection Agency, 2013)." This definition excludes biosolids, hazardous waste, construction and demolition (C&D) wastes and agricultural waste, which should have separate collecting facilities.

The management of MSW that has already been generated can be roughly divided into four methods: recycling, composting, thermal treatment with energy recovery, and landfilling. However, the generation of wastes can be reduced by various means, such as better design of products and packaging, and therefore "Reduction" is placed at the very top of the waste management hierarchy. As shown in Figure 1, Reduction is followed by Recycling and Reuse, then followed by Composting, energy recovery by combustion or gasification/combustion, commonly called waste-to-energy (WTE) and landfilling, ranging from the preferred sanitary landfills to the non-regulated waste dumps that are still used in many parts of the developing world.

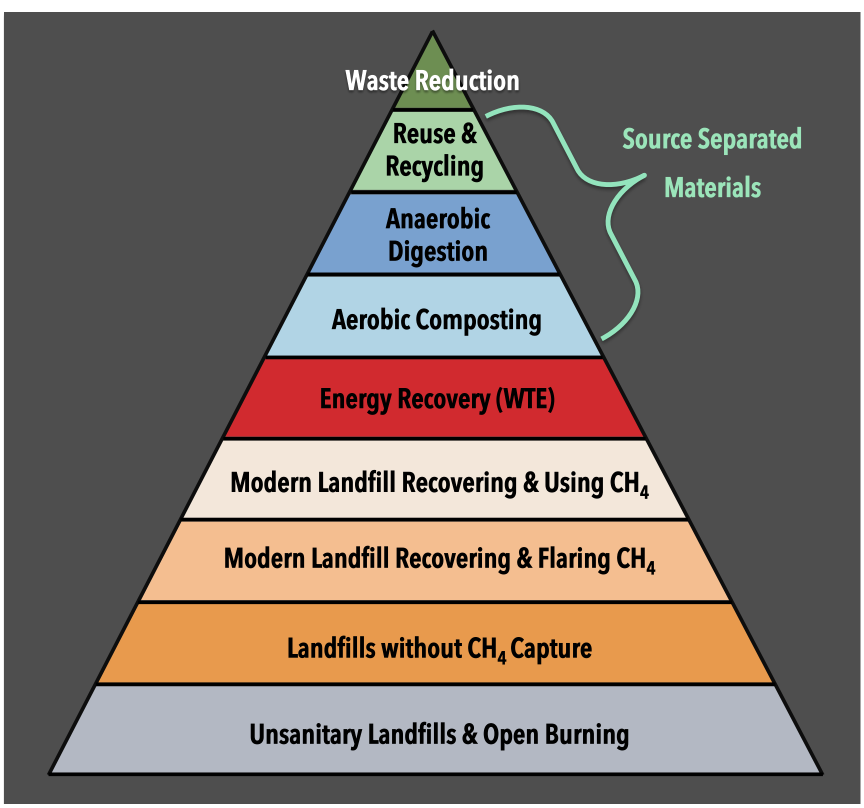


Figure 1. The EEC Hierarchy of Waste Management ***(Kaufman & Themelis, 2009)***

2.1.1. Source Reduction

In an effort to reduce the waste volume, many states have adopted various source reduction programs. For example, Minnesota has a material exchange service that connects organizations with reusable but unwanted goods to others who may need them (iWasteNot Systems Inc.). Many States have Pay-as-You-Throw (PAYT) programs, with Minnesota, California, Washington, Wisconsin, Iowa, and New York having most of these programs (US Environmental Protection Agency, 2012). For example, under the PAYT programs, people are asked to pay a flat fee for bins or trash bags and they are encouraged to generate less waste and thereby save money on the bins or trash bags. Some of these are also called Volume-Based-Waste-Fee (VBWF) programs.

A well-documented successful PAYT-VBWF program is the one implemented in the town of Sandwich, Massachusetts. In 2011, Sandwich changed its solid waste program to a program named WasteZero Trash Metering^{TM}. Residents of Sandwich have to purchase customized trash bags at local stores at prices of $1.20, $.60, and $.24 for 30-gal, 15-gal, and 8-gal bags, respectively. A study following the changes in waste disposal after the PAYT program took effect reports that the residents achieved 42% reduction of solid waste and increased their recycling rate of plastic, metals, and glass by 74%. The reduction also resulted in a decrease in solid waste disposal costs for the town of $10,000 (WasteZero, 2013). The outcome certainly makes initiation of PAYT program favorable to many municipalities and townships. If a nationwide adoption of the program can also result in similar waste reduction, PAYT program may be the most favorable solution to promote conservation of land used for landfill wastes.

Figure 2. PAYT (VBWF) program bags sold at local stores in Massachusetts *(Town of Needham, 2013) (WasteZero, 2013)*

2.1.2. Recycling

Recyclables are mainly collected in four types of methods in US: curbside collection, drop-off, buy-back, and deposit/refund programs (All-recycling-facts, 2013). Typically collected recyclables are paper fibers (office paper, newsprints, and cardboards), glass, metals (aluminum cans, ferrous and non-ferrous metals), plastic containers, consumer electronics, and tires. In general, collected recyclables are sent to material recovery facilities (MRFs) or to a transfer station where the small amounts of recyclables from various towns are gathered and sent to large MRFs. Materials sent to MRFs are first washed and sorted, and then finally sold to entities that buy the materials for production of goods. Clean MRFs accept recyclable materials that are already source separated. Clean MRFs are further divided into single and dual stream MRFs. Single stream MRFs collect all recyclable materials commingled and dual stream MRFs collect papers and cardboards on one side and other plastics, metals, and glass materials on the other. Occasionally there are multi-stream MRFs, which further differentiate collected materials by categories. Dirty MRFs receive general solid wastes and separate them into wastes that will be sent to landfills and wastes that can be recycled. According to the capacity of MRFs, the incoming recyclables are sorted, may be shredded, or sent to specialized facilities (e.g., for sorting of various types of plastics) for further processing. The product streams are sold to private entities that use the recycled materials as inputs to remanufactured goods. In some states, glass bottles are separately collected from other residential recyclables and wastes because of the danger of causing cuts among workers who handle the wastes. The non-usable residues of the MRFs are sent to landfills or WTE plants.

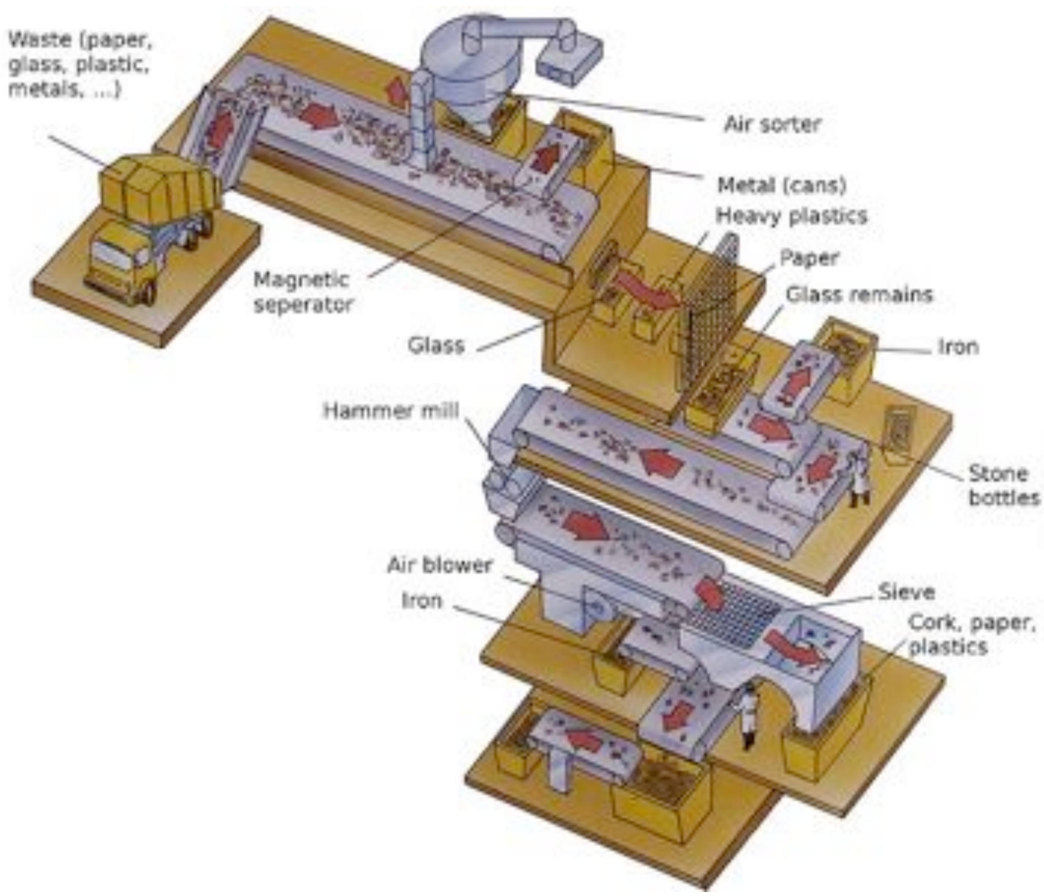


Figure 3. An Example of Material Recovery Facility Work Flow *(KVDP, 2009)*

Some of the MRFs and material processing facilities are not well equipped for proper waste accounting. Many do not have truck scales to measure the incoming recyclables and therefore do not measure the weight of the incoming stream. Others measure the materials in volume. Because the density of the incoming waste varies, converting the volume data to weight may result in weight data with a large margin of error.

Even if the wastes go through MRFs with scales, there is another problem in waste accounting because not all of the materials always go through MRFs. Homogeneous streams of recyclables, such as office papers, cardboard, and aluminum cans from the commercial sector, may go directly to private companies that use them as feedstock to their processes. Because these private companies are not required and sometimes are unwilling to report the tonnages of recyclables they process each year, the data for these materials go unrecorded.

2.1.3. Composting

Composting, or biological decomposing of organic wastes, in US is still not so prevalent, but California, Washington, and Minnesota are leading the way with the most curbside collection programs for compostables (Clark, 2013). Other states like New York operate some community drop-off programs for composting (Lower East Side Ecology Center, 2009). Backyard composting for individual households is also encouraged and promoted by EPA as it can be easily done on a very small scale. The most common small-scale composting options are backyard/on-site composting and vermicomposting. Backyard/on-site composting is ideal for households and institutions such as schools and hospitals. It is suitable for grass clippings and small amounts of food scraps. Grass clippings can simply be left in the backyard where it will decompose naturally and provide nutrient to the backyard. Dry leaves can be collected similarly for mulching. Vermicomposting relies on red worms to decompose organic wastes. It is smaller in scale and is suitable for individual households and small offices. While it requires very little to set up, it can be challenging to look after the set up as the worms are quite sensitive to temperature and moisture conditions.

Wastes collected for large composting facilities mainly consist of organics such as yard wastes, food scraps, and manure. These wastes are composted by microorganisms. Although some businesses and facilities regulate source separation of compostable materials, the waste stream contains non-compostable materials such as vinyl, glass, and heavy metal contaminants. Therefore the first step of large-scale composting consists of extensive material separation processes, such as screening, magnetic separation, eddy-current separation, air-classification, wet separation, and ballistic separation (Richard, 1996). Once the organic materials are sorted properly, they can be composted in several different ways. In the aerated windrow method, the organic wastes are made into rows of 4 to 8 feet piles, or “windrows”, and are periodically overturned for aeration. On the other hand, aerated static pile composting requires a single pile that is aerated by mixing with shredded paper fiber and wood. Lastly, in-vessel composting is becoming increasingly popular due to its flexibility in size and scale. This method composts wastes in well-controlled environment of drums, silo, or concrete trenches and is therefore subject to minimal odors and design flexibility. All of the mentioned large-scale methods are capable of composting yard or “green” wastes, such as leaves, grass, etc. Nevertheless they require close maintenance of temperature, moisture, and oxygen content, as well as the right balance of green (grass and food scraps) and brown organics (leaves and wood chips) input (US Envionmental Protection Agency, 2013).

Figure 4. Various Composting Facilities *(Duke University, 2013)*
a) windrow composting; b) static-pile composting; c) anaerobic digestion; d) in-vessel composting

National composting statistics are hard to capture due to the lack of policies requiring data collection from composting facilities. It is tougher to account for the MSW composted than recycled since there are many small-scale composting facilities whose throughput is not captured by states that do collect large-scale composting data. Especially, the tons of MSW composted at institutional facilities are largely unknown by the states' solid waste management agencies.

2.1.4. Waste-to-Energy

Despite some unfounded opposition, the number of waste to energy facilities is expected to increase over the next several years. With Florida, New York, and Minnesota leading the way (each state with ten or more facilities), about thirty more are planned to open in U.S. over the next couple years.

Combustion of waste with energy recovery is the only alternative to landfilling of post-recycling wastes. MSW can be collected in a similar way as the collection for landfilling or they can come from transfer stations and material recovery centers after sorting processes to remove recyclables. Burning the waste reduces the volume to one tenth of the original volume. The ash produced from burning is collected to recover metals and the rest are sent to monofills, which accepts only ashes, or to landfills to be used as alternative daily cover (ADC) or to be landfilled with the other wastes (Covanta Energy, 2013). When the ashes are used as ADC, they are not considered as MSW landfilled.

The collected MSW is first dumped into a storage pit or bunker. From there the waste is carried to a combustion chamber, as it is needed to maintain the furnace temperature. The composition of the waste is also monitored in order to prevent overshooting of the furnace temperature by burning materials with high heat content. The heat from the combustion is used to produce steam, which is directly used to generate electricity by running turbines. When industries using steam are nearby, such as pulp and paper plants, the steam can be sold for profit as well.

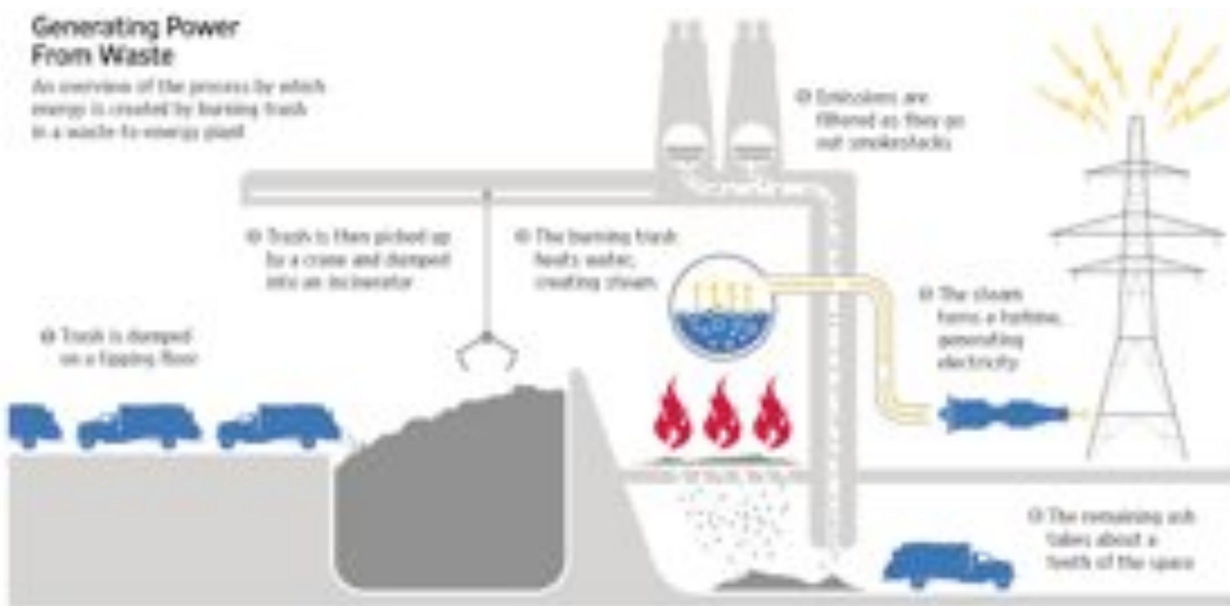


Figure 5. Typical Waste-to-Energy Facility Work Flow *(Brat, 2008)*

Modern WTE facilities are far from the traditional incinerators of the past. The storage pits are built to maintain negative pressures to prevent putrid smell from escaping. The plants are also equipped with gas scrubbers and hazardous particulate filters. Many plants boast of smoke-free stacks. As a result, vicinities of WTE plants are much cleaner than that of MRFs and do not reek of smells often associated with garbage. More public awareness of the cleanliness of WTE plants is needed to expand national waste disposal by combustion. With new technologies WTE has become a much cleaner and more efficient method of waste disposal than landfilling. While source reduction and recycling would always be better options, inevitably due to economical and infrastructural reasons a great proportion of wastes are disposed for landfills, which takes up valuable land space and excretes pungent bio-gases. When these wastes can be diverted to WTE plants, land-use and air pollution can be better managed while the national recycling rate slowly rises.

2.1.5. Landfilling

Landfilling is the ancient and most well established infrastructure for waste management in all fifty states. Curbside collection for residential waste is prevalent in most counties. It is very easy to spot waste collection trucks in any town and city. Incoming collection trucks are weighed at the entrances of landfills, as recording of incoming wastes tonnages is required for landfills. There are efforts to keep separate account of MSW-only tonnages, but many landfills accept combinations of

MSW and non-MSW materials. As a matter of fact, the majority of MSW-designated landfills are not exclusively MSW landfills. These sanitary landfills are allowed to accept combinations of few of the following (US Environmental Protection Agency, 1991):

- MSW
- Household hazardous waste
- Municipal sludge
- Municipal waste combustion ash
- Infectious waste
- Waste tires
- Industrial non-hazardous waste
- Conditionally exempt small quantity generator hazardous waste
- Construction and demolition debris
- Land clearing debris
- Agricultural wastes
- Oil and gas wastes
- Mining wastes

Therefore, unless the landfill facilities themselves put in the effort to weigh the incoming MSW separately from other wastes, it is impossible to gauge the accurate tonnages of just MSW, as defined by EPA.

Landfills can be constructed with area, trench, or ramp designs. With most states requiring liners and leachate collection, the area method is the preferred design since it involves compacting wastes on the ground, layered with liners. These liners typically comprise re-compacted clay and high-density polyethylene, or a combination of both. It prevents both leachate leakage and biogas migration. Trench and ramp methods do not necessitate liners and are therefore less desirable from an environmental protection standpoint. The trench method especially requires daily excavations to create space for a single day load of waste.

With the New Source Performance Standards and Emissions Guidelines set for landfills in 1996, new landfills and existing ones that started accepting wastes since 1987 have been responsible for landfill gas (LFG) collection as well. The guidelines not only mandate collection of methane, which can be used as an energy source, but also require 98% reduction of non-methane organic compounds (NMOCs) in collected landfill gas. Collected LFG can be either combusted with or without energy recovery (for steam or electricity generation) or refined to pipeline quality natural gas.

3. National Survey of MSW Generation and Disposition in 2011

Since 2002, the Earth Engineering Center (EEC) of Columbia University has been conducting, in collaboration with BioCycle journal, a biannual survey of national waste statistics called “State of Garbage in America”. The last edition of this survey was based on 2010 national data and was published in BioCycle in 2010 (van Haaren, Themelis, & Goldstein, 2010). There was no 2012 survey and, in agreement with BioCycle, the 2013 survey of U.S. waste management data was carried out solely by the Earth Engineering Center. However, the Office of Resource Conservation and Recovery of USEPA provided valuable guidance in the design of the questionnaire used in the 2013 survey.

The EEC survey was based on 2011 data submitted by the waste management agencies of the fifty states of the Union. As with the earlier Columbia-BioCycle surveys ("State of Garbage in America" or SOG), a survey questionnaires in excel and interactive format were provided to each state's solid waste management associates via email. They included each state's previous SOG data as a reference.

3.1. Survey Methodology

The excel-format survey includes questions on recycling, composting, combusting (Waste-to-Energy), and landfilling activities in the state. This breakdown and the order of questions in the survey reflect EEC's hierarchy of waste management. The method assumes a mass-balance approach where the sum of MSW recycled, composted, combusted, and landfilled is equal to the total MSW generated. For each of these criteria, basic infrastructure questions (e.g., how many MRFs are in the state) and disposed MSW tonnages were asked. A large part of the data analysis relied on state-provided data and explanations. However, for a few states with missing data, previous SOG survey data were used, as noted in the tables presenting the survey results. When available, secondary references were used to compare with the states-reported numbers.

In past SOG surveys, efforts were made to exclude non-MSW tonnages (industrial, C&D, hazardous, agricultural wastes, waste water treatment plant sludge, and biosolids) from the data reported by the states. This year, each state's waste management agency was urged to provide already filtered, MSW-only data. In case this was not possible to do, they were asked to leave comments as to their understanding what landfilling data, in MSW-designated landfills included. Most states kept separate tonnage data for C&D and industrial wastes, but few states provided only the combined tonnages of MSW and C&D wastes, making it not possible to discern how much of their reported tonnage was only MSW.

In this year's survey, the filter for recycling rates of individual commodities used in 2010 survey was not used. This filter was generated by using 2008 national per capita MSW generation and EPA's MSW Facts and Figures waste characterization report (US Environmental Protection Agency, 2013). Multiplying per capita generation rate with a state's population and with average percent composition of a particular commodity in MSW resulted in an estimate of the total generation of the particular waste commodity in the state. When a state reported recycling tonnage larger than the estimated total generation of a commodity (in other words more than 100 percent recycling rate), the recycling rate was lowered to 100 percent of the estimated waste commodity generation.

It is logical that a state cannot recycle more than what it generated as waste, and therefore the recycling rate should be deemed incorrect if it is more than the tons of commodity generated. However, the composition and amount of waste per capita may vary from state to state due to differences in commercial and residential development, as well as lifestyles. It is possible that some states' recycling rate may be skewed due to incomplete data collection and rough estimations, but it is still arbitrary to use the mentioned filter to cut out the state's recycling rate. Let us assume a hypothetical nation made up of two states where the national average of paper generation per capita is 0.3 ton/year. One state generates 0.2 ton/year and the other state generates 0.4 ton/year. Assume that both states recycle 80% of the paper waste generated. The per capita recycling of paper is 0.16 ton/year and 0.32 ton/year for the former and the latter state, respectively. Knowing these figures, it seems perfectly acceptable that the second state recycles 0.32 tons/year of paper. But the use of the national average filter would lower the second state's paper recycle to 0.3 tons/year. This arbitrarily decreases its actual recycling rate to 75% (recycling 0.3 ton out of 0.4 tons instead of 0.32 tons). At the same time it would be indicated in the report that the second state recycled 0.3 tons/year, corresponding to a 100% recycling rate, which is a misrepresentation of what is actually happening.

For this reason the filter was not used in this report. However, for states that could not provide recycling data for 2013 survey, the 2008 SOG data were used. Because the filter was used in 2008 SOG, for these states the filter may have been applied to their recycling numbers.

3.2. Survey Questions

The recycling section of the survey asked for the number of municipalities and populations provided with single or dual stream curbside collection of MSW recyclables. It also asked for tonnages of recyclables going to single stream and dual stream MRFs as well as that of recyclables bypassing MRFs and sent directly to third party recyclers. Recycled tonnages of individual commodities were separate questions. Additional questions on whether the state has an alternative to curbside collection and drop-off of recycling, such as pay-as-you-throw (PAYT) and volume-based-waste-fee (VBWF) programs, were asked towards the end of the survey.

The composting section asked for municipalities and populations provided with curbside collection of yard waste and food waste separately. States were also asked to provide number of aerobic composting and anaerobic digestion facilities in state. Tonnages for curbside collection of yard and food wastes were asked along with tonnages of organics composted at institutional facilities (schools, hospitals, and prisons).

In the energy recovery section, the states were asked to provide the number of WTE facilities, number of municipalities sending MSW to WTE facilities, the gate fee required by the facilities and the total feedstock to the WTE facilities. Also, WTE facility related information was requested, such as tons of ferrous and non-ferrous metal recovered after combustion, and heat and electricity generated by the facility.

The landfill section also asked basic infrastructural questions regarding the number of landfills in the state and the average gate fee required by the landfills. States were asked to report tons of landfilled MSW imported and exported to and from the state along with the total tons of MSW landfilled in state. There were additional questions about banned materials, remaining landfill capacity in state, and estimation of landfill gas (LFG) collected.

At the end of the survey, a pie chart representing percent recycling, composting, combusting, and landfilling in the state was set up to be automatically generated, on the basis of the data entered in the questionnaire. The results of the 2008 SOG Survey for the state were provided below the pie graph as a reference to help spot anomalies or errors in the input data.

3.3. Survey Response Rate and Reliability

As in the case of earlier SOG surveys, some states did not respond to the 2013 survey. Alaska, Oklahoma and Virginia responded that due to lack of information to fill the survey, they were not able to participate in the survey. Despite repeated contacts by phone and e-mail, EEC was not able to receive the survey on time from Hawaii, Louisiana, Michigan, Missouri, South Carolina, and West Virginia. In total there were nine states that could not participate in the survey. For these states, their 2008 SOG survey data, adjusted to reflect 2011 population growth, were used. When an outside source was available, such as state-published solid waste management report, appropriate data from the source was used and the source was noted in the tabulation.

3.3.1 Recycling Questions

The most problematic section of the survey was recycling. Many states commented that due to budget cuts and lack of human resources, no recycling data are collected in their states. Because there is no reporting requirement for recycling facilities, it is difficult to collect recycling data. Of the 41 states that submitted the survey, ten were unable to provide recycling data (AL, GA, IA, ID, IL, IN, MS, NE, TX, and WI). The majority of the 31 states that provided recycling data reported the total tonnages of recyclables collected in state and recycled tonnages of individual commodities. A few states, such as Colorado and Minnesota, were able to provide recycling information broken down into single and dual stream curbside collection tonnage and recycling tonnage that bypassed material recovery facilities; most states do not collect tonnage data of single and dual stream collections and have no method of tracking recyclables that by-pass MRFs and go directly to private recyclers. Instead, these states had combined tonnages of all curbside collected recyclable and tonnages of recyclables collected by all other methods such as drop-offs. On the other hand, 26 states provided complete data on tonnages of commodities recycled.

Of the states that provided recycling data, eight could not provide information on the number of municipalities in the state that provide curbside collection services. These eight states also did not state the number of MRFs in the state. It was a general pattern that a state either had comprehensive recycling data or bare minimum data.

For the purpose of comparing recycling rates across the states, the total tons of commodities recycled were used. In all other cases, the reported total tons of MSW recycled were compared. For the few states that could not provide recycling data, recycling data compiled in the 2008 SOG survey were used after population growth adjustment.

3.3.2. Composting Questions

Composting facilities are also not required by states to report processed compostable tonnages. Thus, it was no surprise to find that the same states that could not provide recycling data also could not provide composting data. Six states only provided combined total tonnages of yard and food (or all compostables including MSW wood waste) wastes. Most of the states reporting composting tonnages (21 states) provided tons of yard waste composted. 11 states also provided tons of food waste composted and eight states (AR, DE, KS, KY, NC, ND, RI, and WY) and Washington D.C. reported that they only compost yard waste and no food waste.

While the survey questions asked for tons of curbside-collected yard and food waste, the questions were rendered inadequate as none of the states collect composting data in this way. Most of the states have data on total yard or food waste composted, and do not have separate data for yard or food waste collected from curbside programs and from drop-off sites.

As noted earlier, it is difficult for the states to receive composting data from registered large-scale facilities. It is even more difficult if not impossible for them to estimate wastes composted at small institutional facilities such as schools and hospitals. Only Kansas and North Carolina had rough estimates. However, many states reported that there are institutional or other small composting facilities that are not registered through the state. Judging from this, the national composting rate compiled in this survey is probably understated.

Anaerobic digestion (AD) for agricultural waste, such as livestock manure, is widely used in the U.S. On the other hand, due to the high cost, AD for MSW is still not prevalent. But the number of AD facilities and the tonnages of MSW sent to AD facilities were requested in the Survey questionnaire, in order to gauge the growth of AD facilities. Three states, CA, DE, and NY, reported that they have 1, 2, and 3 AD facilities, respectively. Several other states (MA, MS, NC, OH, TN, VT, and WA) reported that they have AD facilities but they did not have information on how many tons were digested.

3.3.3. WTE Questions

There are 85 WTE operating facilities in the U.S., distributed among 23 states. Because all WTE facilities measure incoming waste tonnages and are regulated to report the data, all of the states that have WTE facilities were able to provide information, except Iowa. Fortunately, detailed information on each of the 85 WTE facilities is provided by Government Advisory Associates (GAA) in their report "2012-2013 Municipal Waste to Energy in the United States: Yearbook & Directory." The state-reported combustion tonnages were compared to the GAA report numbers and there was close agreement, indicating the reliability of the reported data. However, the numbers were not exactly the same, because the GAA report is based on 2010 data and the states provided 2011 data.

3.3.4. Landfilling Questions

All of the states who responded to the survey were able to provide the number of landfills in state and the total landfilled MSW tonnage because landfill facilities are required to report the incoming waste tonnages. Out of the 41 reporting states, 10 states (AZ, CA, CO, DE, FL, ID, NE, NV, and SD) and D.C. could only provide these two pieces of information. 21states also provided information on tons of MSW imported <u>and</u> exported from the state for landfilling. Alaska and Wyoming reported that there was no imported waste, and Montana, Texas, and Utah reported zero exported waste. Texas reported that a small amount of MSW from Mexico is landfilled in Texas. This was excluded from Texas' landfilled MSW since the survey is concerned only with U.S.-generated MSW. Texas also included C&D waste in the MSW landfill tonnages, but the reported tonnage of C&D waste was subtracted from the MSW landfill tonnages.

Only 25 states could provide the average gate fee for landfills (see Table 1). These gate fees were compared with the data reported from Waste & Recycling News ("Average Tipping Fee at

MSW Landfills"). Many of the state-reported gate fees were similar to that of the Waste & Recycling News report, but a few were significantly different. It is the expectation that these states may not have been able to gather information from all landfills in their states.

Table 1. Landfill Gate Fee of Each State in 2011 ($)

State	High[1]	Low[1]	Average[1]	State Reported Average USD/ton
Alabama	47.00	26.00	37.60	40
Alaska (4 Landfills) *	85.00	21.00	60.88	
Arizona	38.25	30.00	33.05	Unknown
Arkansas	43.00	33.00	36.50	Unknown
California	76.82	34.37	52.07	54
Colorado	66.00	28.00	49.60	30.47
Connecticut	57.15	57.15	57.05	Unknown
Delaware (3 Landfills)	84.00	84.00	84.00	82
Florida	83.92	25.50	43.65	Unknown
Georgia	45.00	30.55	38.27	35.97
Hawaii*	90.00	39.00	75.17	
Idaho	67.70	30.00	44.41	Unknown
Illinois	60.00	28.00	43.46	42.85
Indiana	60.10	32.00	44.20	Unknown
Iowa	40.50	25.00	34.15	38
Kansas	43.50	30.50	37.46	Unknown
Kentucky	55.00	33.50	44.69	31.37
Louisiana*	31.00	19.80	26.96	
Maine (4 Landfills)	115.00	72.00	91.00	Unknown
Maryland	70.00	52.00	62.70	58
Massachusetts	100.00	60.00	78.50	Unknown
Michigan*	88.00	25.00	46.82	
Minnesota	63.33	26.66	47.04	42.37
Mississippi	47.00	11.00	26.48	28 (estimate)
Missouri*	48.11	30.00	38.38	
Montana	31.05	16.50	25.51	35
Nebraska	45.00	21.00	31.13	35
Nevada	31.00	13.70	24.83	Unknown
New Hampshire	87.55	67.00	77.85	Unknown
New Jersey	96.00	44.31	72.39	74.88
New Mexico	62.01	14.98	33.80	25
New York	102.00	49.50	86.30	45.75
North Carolina (4 Landfills)	65.84	27.50	41.59	41.77
North Dakota	43.81	34.65	38.92	38
Ohio	52.80	30.00	39.66	34.7
Oklahoma*	50.29	25.75	38.31	
Oregon	83.75	28.50	55.74	Unknown
Pennsylvania	103.00	63.25	75.96	Unknown
Rhode Island (1 Landfill)	75.00	75.00	75.00	41
South Carolina*	66.00	29.00	42.61	
South Dakota	59.00	34.00	41.90	40.55
Tennessee	48.00	30.50	41.15	38
Texas	41.00	5.00	28.95	32
Utah	33.00	15.00	24.29	Unknown
Vermont (2 Landfills)	87.14	77.50	82.32	80
Virginia	66.00	32.00	46.11	(1)
Washington	142.01	28.80	70.44	65
West Virginia	69.25	41.75	49.46	(1)
Wisconsin	66.00	35.00	50.20	54
Wyoming	102.00	35.00	60.40	73
U.S. Average			**$49.78**	-

* State did not participate in the survey

[1] Data reported from Waste & Recycle News ("Average Tipping Fee at MSW Landfills")

With regard to additional landfill information, 30 states answered that landfill capacity is being added to their states while six states (CT, DE, MD, MA, RI, and SD) and Washington D.C.

responded that there was no such addition (AZ, IN, ME, and OR did not have the information). Of these states, 24 were able to provide landfill capacity remaining in their states. 34 states reported the number of biogas collecting landfills, and 17 of the 34 states were able to provide numbers for total amount of LFG collected. Nevada, New Mexico, Wyoming and Washington D.C. reported they have no landfills collecting gas.

3.4. Survey Result Analysis

3.4.1. National Overview

The survey results combined with secondary references and adjusted 2008 data indicated that in 2011, U.S. generated a total of 389 million tons of MSW. Dividing by the 2011 population of 311.6 million people, the U.S. per capita generation of MSW in 2011 was 1.3 short tons (1.19 metric tons per capita). In overall, 29% of the total MSW generated was either recycled or composted, 7.6 % was sent to WTE facilities, and 63.5% was landfilled (Table 2).

A detailed report of MSW generated in each state is shown in Table 3 and Table 4. Figure 7 shows the amount of MSW disposed by four methods in each state. The bottom most state, Connecticut, has the lowest percentage of MSW landfilled. The states have progressively higher percentage of landfilled MSW moving up the ladder.

Table 2. Total MSW Disposed by Method

Percent Recycled	Percent Composted	Percent Combusted	Percent Landfilled
22.58	6.34	7.59	63.50

National MSW disposal trend, broken down into the ten US EPA regions (see Figure 6), highlights key characteristics of waste infrastructure of the states. Combustion with energy recovery, or WTE, is most prevalent in the East Coast (Regions 1 through 4), with Region 1 having the highest proportion of MSW disposed by WTE. The rest of the regions has less than 2% of the waste going to WTE facilities or none at all. The Midwestern regions (Regions 5 to 8) are still very much reliant on landfilling, and have the lowest recycling rates. While both of the coastal regions have a high percentage of recycled MSW, the West Coastal states, Region 9 and 10, lead with over 30% recycling rates. Composting activity is highest in Region 6, with Regions 8 to 10 following closely. East Coast states have relatively lower composting activities at around 4%.

Figure 6.

Breakdown by EPA Regions

Recycling, composting, combusting, and landfilling rates by regions

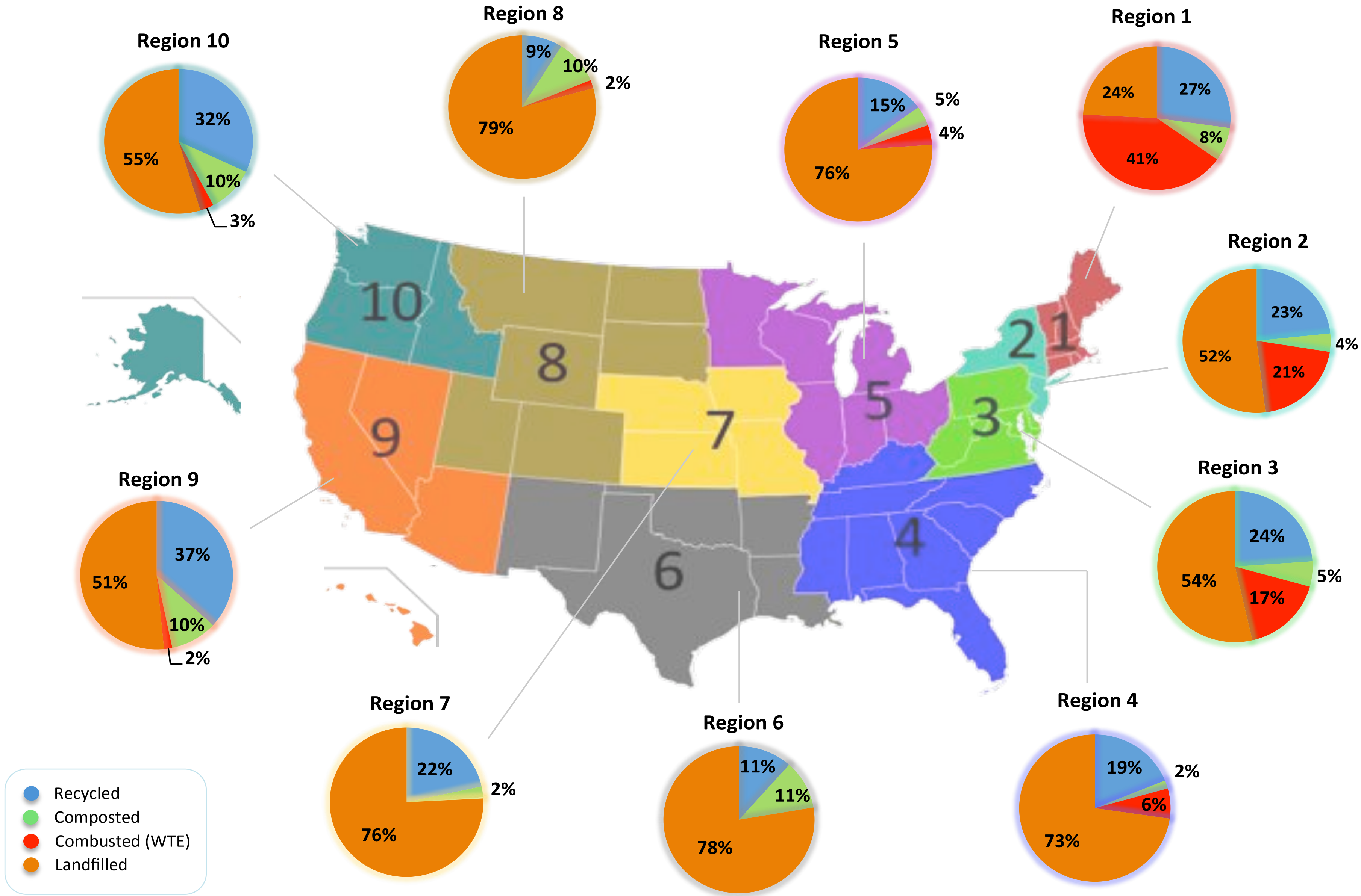


Table 3. Total Tonnages of MSW Recycled, Composed, Combusted and Landfilled in each State in 2011

State	Recycled	Composted	Combusted	Landfilled	Population	Per capita Gen
Alabama	486,260 [1]	n/a	178,690	4,730,330	4,802,740	1.12
Alaska*	30,166 [1]	[3]	0	647,227 [1]	722,718	0.94
Arizona	382,645	65,775 [1]	0	6,609,376	6,482,505	1.09
Arkansas	2,404,464	89,589	0	3,272,797	2,937,979	1.96
California	27,746,174	7,649,210	856,121	30,047,841	37,691,912	1.76
Colorado	1,745,860	177,880	0	6,138,752	5,116,796	1.58
Connecticut	532,888	273,841	2,154,044	247,995	3,580,709	0.90
Delaware	125,919	196,648	0	672,761	907,135	1.17
District of Columbia	20,122	5,881 [5]	216,903 [5]	228,524 [5]	617,996	0.76
Florida	7,365,857	n/a	5,798,975 [6]	13,877,987	19,057,542	1.39
Georgia	691,386 [1]	40,535 [1]	0	9,869,000	9,815,210	1.40
Hawaii*	612,907 [1]	273,261 [1]	545,830 [2]	2,452,165 [1]	1,374,810	2.82
Idaho	156,200 [1]	n/a	0	1,579,358 [1]	1,584,985	1.09
Illinois	1,000,877 [1]	496,175 [1]	0	12,132,946	12,869,257	1.06
Indiana	490,728 [1]	364,463	704,675	4,880,873	6,516,922	0.99
Iowa	942,760 [1]	252,501 [1]	38,814 [2]	2,696,788	3,062,309	1.28
Kansas	932,721	88,798	0	2,263,336	2,871,238	1.14
Kentucky	1,660,239	367,127	0	4,195,361	4,369,356	1.51
Louisiana*	30,908 [1]	586,185 [1]	0 [2]	5,166,775 [1]	4,574,836	1.26
Maine	674,258	52,499	472,478	212,836	1,328,188	1.06
Maryland	1,572,200	841,392	1,389,632	2,352,939	5,828,289	1.20
Massachusetts	2,152,212	660,888	3,174,603	1,533,068	6,587,536	1.14
Michigan*	833,589 [1]	[3]	993,990 [2]	11,952,630 [1]	9,876,187	1.40
Minnesota	2,556,996	223,102	1,145,487	1,784,719	5,344,861	1.07
Mississippi	131,602 [1]	5,197	0	2,729,305	2,978,512	0.96
Missouri*	967,814 [1]	[3]	0	3,965,327 [1]	6,010,688	0.82
Montana	252,734	75,123	0	1,366,226	998,199	1.70
Nebraska	333,207 [1]	[3]	0	2,219,461	1,842,641	1.39
Nevada	1,150,601	85,721	0	2,809,979	2,723,322	1.49
New Hampshire	466,707	23,825	251,539	402,497	1,318,194	0.87
New Jersey	4,346,256	0	2,129,852	4,384,975	8,821,155	1.23
New Mexico	339,590	67,960	0	1,981,884	2,082,224	1.15
New York	2,246,064	1,153,984	3,686,097	10,263,710	19,465,197	0.89
North Carolina	790,686	644,517	0	7,702,232	9,656,401	0.95
North Dakota	90,000	170,000	0	675,000	683,932	1.37
Ohio	2,461,594	1,141,002	0	9,126,809	11,544,951	1.99
Oklahoma*	176,961 [1]	[3]	204,633 [2]	4,397,372 [1]	47,789,66	1.21
Oregon	1,438,560	406,568	181,316	1,918,649	3,871,859	1.02
Pennsylvania	4,465,949	682,436	3,084,639	5,903,677	12,742,886	1.11
Rhode Island	64,480	65,000	0	793,000	1,051,302	0.91
South Carolina*	954,748 [1]	174,912 [1]	0 [2]	3,295,771 [1]	4,679,230	0.95
South Dakota	157,306	60,835	0	646,561	824,082	1.05
Tennessee	1,531,310	75,000	0	6,036,132	6,403,353	1.19
Texas	2,780,213 [1]	4,601,543 [1]	0	23,720,134	25,674,681	1.21
Utah	56,474	293,404	126,522	2,059,152	2,817,222	0.90
Vermont	120,009	36,411	0	379,005	626,431	0.85
Virginia*	2,830,702 [1]	395,858 [1]	2,037,401 [2]	10,095,859 [1]	8,096,604	1.92
Washington	3,244,620	1,166,224	276,753	4,113,753	6,830,038	1.29
West Virginia*	345,271 [1]	[3]	0	1,812,675 [1]	1,855,364	1.16
Wisconsin	843,934 [1]	548,649 [1]	76,000	4,181,867	5,711,767	0.99
Wyoming	46,400	72,855	0	610,080	568,158	1.28
Total	**87,808,128**	**24,646,893**	**29,507,191**	**246,997,177**	**Total MSW Generation**	**388,959,390**

* State did not participate in the survey
n/a Data not available
[1] 2008 data (used for non-participating states and states with limited data; adjusted to 2011 population)
[2] Tonnage data from 2010 GAA report on WTE in US (adjusted to reflect population change from 2010 to 2011)
[3] Composted ton included in the recycled tonnage
[4] State assumes total yearly tonnage of MSW generated in Idaho as 1688578 based on 1.09 tons/pp/yr (6lbs/pp/day)
[5] Composting is outsourced to Maryland and Combustion is outsourced to Virginia; the tonnages are not added to the total because they should already be accounted for in the outsourced states' tonnage reports
[6] Data fro Energy Information Administration

Table 4. Percent MSW Recycled, Composted, Combusted and Landfilled in each State in 2011

State	Estimated Total MSW Generation	% Recycled	% Composted	% Combusted	% Landfilled
Alabama	5,395,280	9.0	n/a	3.3	87.7
Alaska*	677,393	4.5	[1]	0.0	95.5
Arizona	7,057,796	5.4	0.9	0.0	93.6
Arkansas	5,766,850	41.7	1.6	0.0	56.8
California	66,299,346	41.8	11.5	1.3	45.3
Colorado	8,062,492	21.7	2.2	0.0	76.1
Connecticut	3,208,768	16.6	8.5	67.1	7.7
Delaware	1,022,328	12.7	19.8	0.0	67.6
District of Columbia^	471,430	4.3	1.2	46.0	48.5
Florida	27,040,919	27.2	n/a	21.4	51.3
Georgia	10,600,921	6.5	0.4	0.0	93.1
Hawaii*	3,884,163	15.8	7.0	14.1	63.1
Idaho	1,824,778	8.6	n/a	0.0	91.4
Illinois	13,629,998	7.3	3.6	0.0	89.0
Indiana	6,440,739	7.6	5.7	10.9	75.8
Iowa	3,930,863	24.0	6.4	1.0	68.6
Kansas	3,284,855	28.4	2.7	0.0	68.9
Kentucky	6,222,727	26.7	5.9	0.0	67.4
Louisiana*	5,783,868	0.5	10.1	0.0	89.3
Maine	1,412,071	47.7	3.7	33.5	15.1
Maryland	6,156,163	25.5	13.7	22.6	38.2
Massachusetts	7,520,771	28.6	8.8	42.2	20.4
Michigan*	13,780,215	6.0	[1]	7.2	86.7
Minnesota	5,710,304	44.8	3.9	20.1	31.3
Mississippi	2,866,104	4.6	0.2	0.0	95.2
Missouri*	4,933,141	19.6	[1]	0.0	80.4
Montana	1,694,083	14.9	4.4	0.0	80.6
Nebraska	2,552,668	13.1	[1]	0.0	86.9
Nevada	4,046,301	28.4	2.1	0.0	69.4
New Hampshire	1,144,568	40.8	2.1	22.0	35.2
New Jersey	10,861,083	40.0	0.0	19.6	40.4
New Mexico	2,389,434	14.2	2.8	0.0	82.9
New York	17,349,855	12.9	6.7	21.2	59.2
North Carolina	9,137,435	8.7	7.1	0.0	84.3
North Dakota	935,000	9.6	18.2	0.0	72.2
Ohio	12,729,405	19.3	9.0	0.0	71.7
Oklahoma*	4,778,966	3.7	[1]	4.3	92.0
Oregon	3,945,093	36.5	10.3	4.6	48.6
Pennsylvania	14,135,701	31.6	4.8	21.8	41.8
Rhode Island	922,480	7.0	7.0	0.0	86.0
South Carolina*	4,425,431	21.6	4.0	0.0	74.5
South Dakota	864,702	18.2	7.0	0.0	74.8
Tennessee	7,642,442	20.0	1.0	0.0	79.0
Texas	31,101,890	8.9	14.8	0.0	76.3
Utah	2,535,552	2.2	11.6	5.0	81.2
Vermont	535,425	22.4	6.8	0.0	70.8
Virginia*	15,359,820	18.4	2.6	13.3	65.7
Washington	8,801,350	36.9	13.3	3.1	46.7
West Virginia*	2,157,946	16.0	[1]	0.0	84.0
Wisconsin	5,650,450	14.9	9.7	1.3	74.0
Wyoming	729,335	6.4	10.0	0.0	83.6
Total	**388,959,390**				

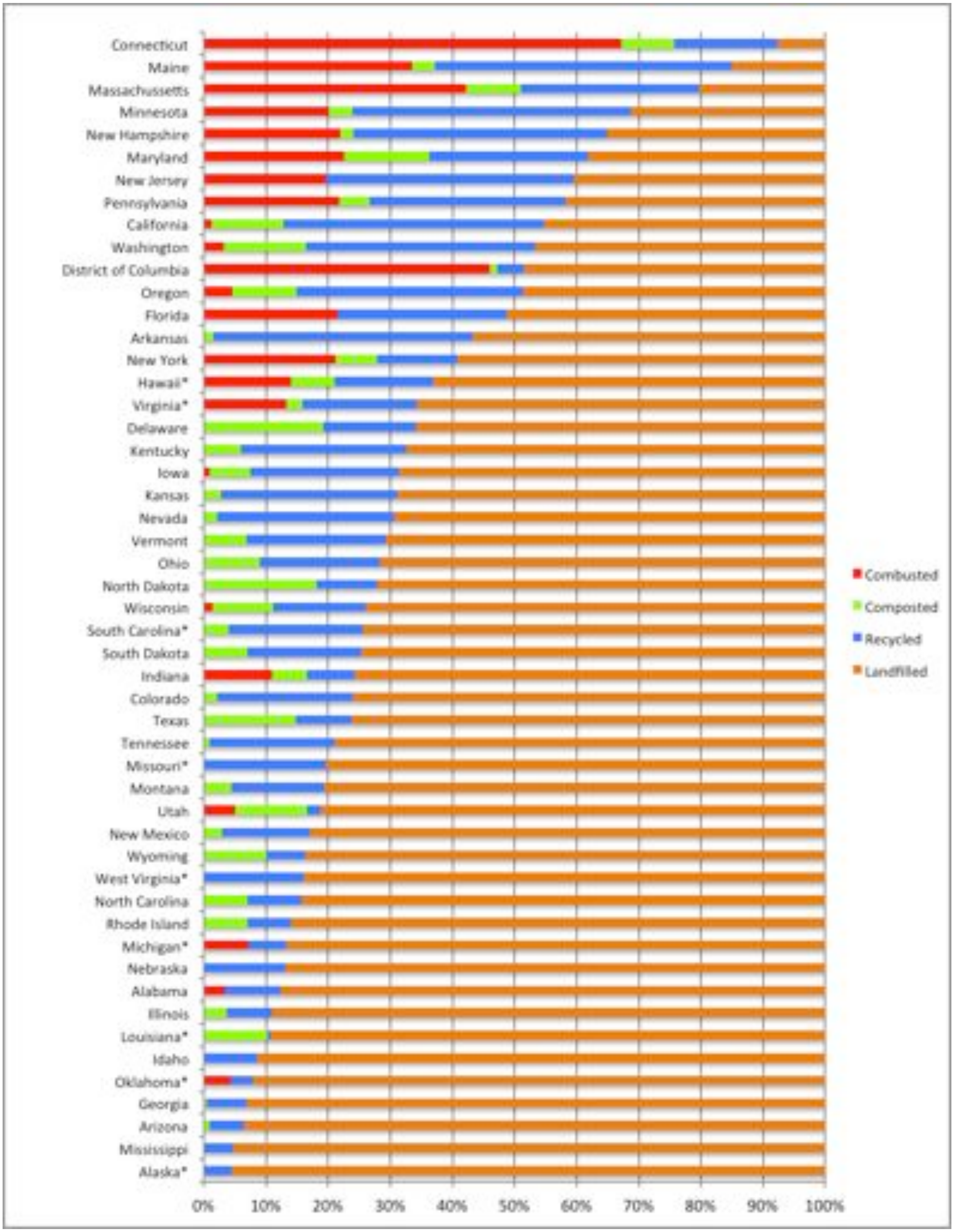
* State did not participated in the survey

n/a Data not available

^ Composted, combusted and landfilled wastes from D.C. is not added to the national total to eliminate double counting (D.C outsources MSW for composting, combusting and landfilling)

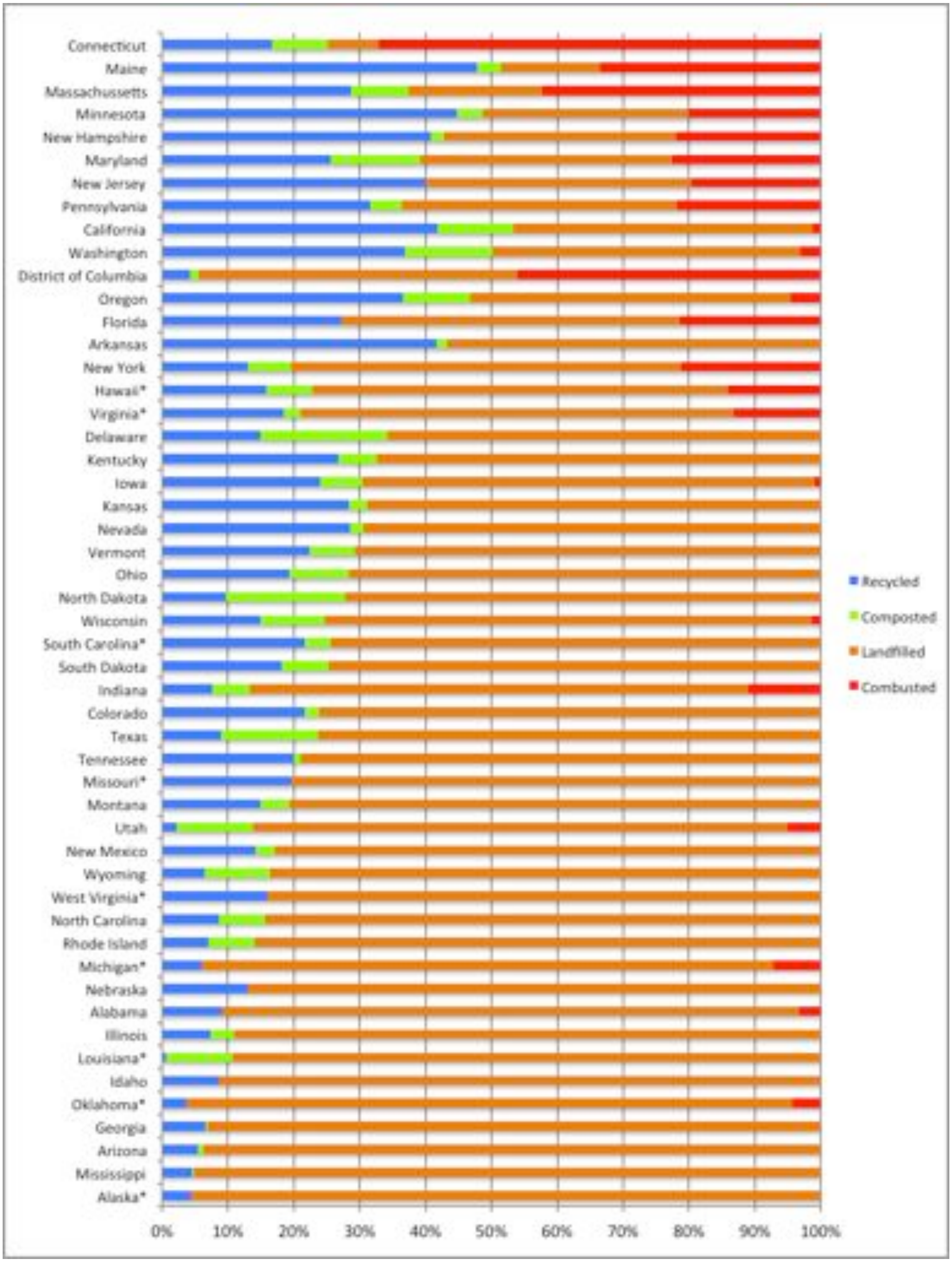
[1] Composted ton included in the recycled tonnage

Figure 7a. Percent Recycled, Composted, Combusted, and Landfilled by State in 2011



* State did not participate in the survey

Figure 7b. Percent Recycled, Composted, Combusted, and Landfilled by State in 2011



^ State did not participate in the survey

- *Recycling*

Total MSW recycled and composted nationally in 2011 was 87.8 million tons and 24.6 million tons, respectively. As noted earlier, for the nine states who did not participate in the 2013 survey, adjusted 2008 SOG survey numbers were used. However, in the 2010 SOG survey, of these non-participating states, Michigan, Missouri, Nebraska, Oklahoma, and West Virginia had provided data for combined tonnages of recycled and composted waste from 2006 surveys. Therefore, the aforementioned total recycled tonnage includes composted tonnages from these five states. In order to accurately gauge the recycling and composting rate and to make the data comparable to that of previous surveys, collected 2011 recycling and composting tonnages were added together. The resulting tonnage was 112.5 million tons and this combined tonnage reflects the recycling and composting from all states (Table 3).

It is important to note that some of the states' recycling numbers were considered by the states to be underreported, for the following reasons:

- Connecticut reported that their tonnages for commodities recycled do not include cans, plastic and glass bottles that are collected separately under the state's bottle deposit law. It also commented that its numbers for paper fibers and aluminum cans are not the tons of materials collected but the tons of materials sold in the state. Lastly, its E-waste recycled tonnages only included tons collected from residential areas.
- Mississippi provided only the tons of tires recycled; therefore, adjusted 2008 data was used instead.
- North Carolina indicated that while it has recycling data collected from state owned MRFs, private haulers also collect a large amount of recyclables. Because the state does not have information on materials collected by the private haulers, its reported tons are underestimated.
- Arizona only reported total co-mingled recyclables collected in state and therefore its number is also lower than the actually recycled tonnage.
- Massachusetts reported tons recycled broken down into commodities, but did not report any tonnages for metals, E-waste, and tires. Presumably these materials are indeed collected and recycled but the data is unknown to the state. Therefore, the state's recycling is likely to be underreported.
- South Dakota was missing information from multiple MRF facilities and warned EEC that the numbers are underreported.
- Utah also stated that could report only limited data on commodities recycled..

There are also some states that may have over-reported their MSW recycled data.

- Montana and Florida provided comments that their "other recyclables" under the commodities recycled part of the survey includes C&D wastes along with other miscellaneous MSW.
- In its tabulation of recycled tonnages for all materials, Tennessee included numbers from the industrial sector as well as commercial and residential sectors; therefore, the reported recycled tonnage of these states are probably overestimated.
- Wyoming's MSW recycled tons may also be over-reported because it could only provide total tons of recyclables collected, and not the total commodities recycled. This means that the Wyoming number includes recycling residues that actually go to landfills.

- Lastly, because California provided limited information as to the commodities recycled, this information could not be used to derive the state's total recycled tonnage. This state provided data for recyclables collected by means of single and dual stream collection and the total tons of other recyclables collected, which included both agricultural and industrial waste (but not C&D). Since the residential recyclables collected by single and dual stream services total about 4 million tons and the rest of the state's other recyclable streams, which includes agricultural and industrial waste, and amount to 23.6 million tons, the California number should be viewed as "aggregate solid waste recycled" rather than "MSW recycled. Because the state only indicated that the 23.6 million tons "does not include C&D, but include industrial, and recycling from all sources" minus the recyclables going through single and dual stream collection, it is impossible to determine what portion of the waste can be considered MSW. This is problematic since 23.6 million tons is almost 27% of the total MSW materials recycled in U.S. Depending on what portion of it can be counted as MSW, it can significantly affect the national recycling rate data. Additionally, California commented that the recycling numbers were estimated from its 2005 solid waste report. California has first used adjusted 2005 data in SOG published in 2008 (based on 2006 data), and used 2008 data for SOG 2010 (based on 2008 data). For both reports the estimation included agricultural and industrial wastes (19.4 million for SOG 2008 and 24.7 million for SOG 2010). This makes it hard to spot any drastic changes in California's recycling rate over the past years, during which the state has led the way in recycling and waste reduction.

Out of the 31 states that were able to provide recycling data, 28 states and the District of Columbia also provided recycled tons broken down into commodities. Table 5 shows the tons of commodities recycled in each state. Based on the completeness of the data and also the comments provided by the states, it was concluded that 22 states provided relatively accurate and comprehensive recycling data. These states were then selected to construct Table 6. Figure 3 shows graphically the percent of each commodity recycled in the states. As shown in the Figure, paper fiber and metal make up the majority of the recycled waste while plastics and glass represent a relatively small portion.

The relatively small quantity of recycled plastics raises concern since the U.S. generates over 33.6 million tons of plastic materials each year (Themelis, Castaldi, Bhatti, & Arsova, 2011). To get a rough estimation of tons of national plastics recycled from the limited data from 22 states, the following procedure was used.

(1) Populations of the 22 states were summed and percent representation of the 22 states' population out of the national population was estimated.

$$\%\,Population\ Represented = 100 \times \frac{Populations\ of\ the\ 22\ States}{U.S.\ Total\ Population}$$

(2) This percent was applied to the sum of plastics recycled by the 22 states to estimate total plastics recycled in U.S.

$$Est.Total\ Plastics\ Recycled = \frac{Plastics\ Recycled\ by\ the\ 22\ States}{\%\ Population\ Represented}$$

The resulting estimation is shown below

Population of the 22 States	122,905,310
U.S. Total Population	311,591,917
% Population Represented by the 22 States	39.44%
Plastics Recycled by the 22 States	890,523 tons
Estimated Plastics recycled in U.S.	2,257,670 tons

The 22 states with relatively accurate and comprehensive recycling data represented about 40% of the total U.S. population. Using the percent representation, it was estimated that 2,257,670 tons of plastics were recycled in U.S. in 2011. This matches closely with an estimation shown in the works of Themelis et al. The work states that the total plastics recycled in 2008 is about 2.2 million tons, with The American Chemistry Council reporting 1.82 million tons of non-durable plastics recycled and EPA reporting 0.39 million tons of durable plastics recycled.

The same estimation method for the plastics recycled was used for all other commodities to get total tons of recycled commodities in the U.S. The result for each commodity is shown on the last row of Table 6. The national total recycled MSW was estimated to be about 100 million tons. It is 1.3 million tons higher than the reported national total recycled MSW of 87 million tons. This result is not surprising as many of the states are expected to be underreporting their recycling rate due to lack of data. There is a possibility that the actual recycling achieved in U.S. is closer to the estimated 100 million tons if the 40% of the U.S. population represented by the 22 states closely reflect the national average recycling rate. Even if the estimation has a larger margin of error than hoped for, what is certain is that the reported 87 million tons is the lower limit of the total recycled MSW. Therefore, the actual recycled MSW can be expected to be higher than 87 million and around 100 million tons.

- *Composting*

Reported and estimated tons of total composted MSW in 2011 is 24.6 million tons. This is likely to be well under the actual composting activities in U.S., especially because for some of the non-reporting states, only 2006 data, which combines composted tonnage to recycled MSW, were available. Therefore the 24.6 million tons does not reflect composting from these states, which are Alaska, Missouri, Oklahoma, and West Virginia. Additionally, it was almost impossible for the states to capture institutional composting activities, although a couple of states could provide a rough estimate.

Most of the states also didn't have information on anaerobic digestion (AD) facilities. CA, DE, NY, MA, MS, NC, OH, TN, VT, and WA reported that they have AD facilities in state but only California, Delaware, and New York could provide how many tons of MSW went through their AD facilities in 2011. Together, the three states digested about 200 million tons.

According to the Renewable Waste Intelligence report (Renewable Waste Intelligence, 2013), there are in fact 192 AD systems operating in U.S. farms. However, most of the facilities deal with livestock manure and do not digest municipal yard or food wastes. There are also 1,500 AD facilities for wastewater treatment plants. It seems that due to the high cost of building and maintaining an AD facility, it is feasible for large-scale commercial livestock or wastewater treatment processes but not so much for food waste. Only a small portion of these facilities seems to be co-digesters, which accept residential food wastes. For example, East Bay Municipality Utility District in Oakland California digests both wastewater and food waste, and it digests about 22,000 tons per year. In the U.S., where most people are not used to separating out food waste from other household waste, it may be that for many states and cities, the diversion of food waste from landfilled MSW is not enough to build AD facility for, given the high cost of these facility.

Table 5. Individual commodities recycled in each state in 2011 (tons/year)

State	Paper fiber	Ferrous metals	Aluminum	Copper, copper alloys & other metals	Plastics	Glass	Electronic wastes	Tires	Other recyclables	**Total tons of recycled commodities**
Arkansas	183,929	901,217	124,539	794,822	45,142	1,111	4,404	12,562	336,738	2,404,464
California	n/a	n/a	n/a	n/a	n/a	n/a	98,500	358,000	468,750	925,250
Colorado	384,806	1,145,369	30,604	-	23,916	21,009	12,304	20,442	[3] 107,410	1,745,860
Connecticut [4]	420,198	49,201	494	-	21,691	30,723	3,812	63	6,706	532,888
District of Columbia	14,618	787	283	0	1,438	2,859	84	45	8	20,122
Delaware	80,299	21,847	728	-	3,260	208	2,123	7,820	9,634	125,919
Florida	1,743,473	1,862,028	38,826	348,416	131,355	110,282	-	60,353	[5] 3,070,119	7,364,852
Kansas	400,865	324,279	4,757	57,978	17,489	24,428	2,942	6,129	93,854	932,721
Kentucky	380,509	1,089,124	-	126,557	19,025	6,492	10,987	27,545	-	1,660,239
Massachusetts	1,005,089	721,148	-	-	121,026	192,189	-	-	112,759	2,152,212
Maryland	868,088	416,720	13,421	23,275	58,489	96,813	13,446	38,316	[6] 43,632	1,572,200
Minnesota	956,354	257,684	40,018	119,909	72,156	133,221	16,198	20,047	941,409	2,556,996
Mississippi	n/a	n/a	n/a	n/a	n/a	n/a	n/a	69,000	n/a	69,000
Montana	32,899	82,324	1,031	93,793	1,088	1,299	422	200	[7] 39,678	252,734
North Carolina [8]	344,758	44,530	7,016	n/a	36,670	96,819	14,688	121,552	124,653	790,686
New Hampshire	52,883	285,340	9,911	-	3,426	14,419	6,228	2,678	[9] 91,822	466,707
New Jersey	1,570,915	42,457	86,278	0	98,153	518,593	27,860	41,391	[10] 1,960,609	4,346,256
New Mexico	155,052	132,335	20,132	765	4,561	2,629	995	890	22,231	339,590
New York	1,805,314	294,832	-	-	114,403	177,193	9,375	0	[11] 21,559	2,422,676
Nevada	247,843	392,888	27,041	52,504	22,347	18,553	940	15,415	373,070	1,150,601
Ohio [12]	1,046,866	474,272	[1]	111,229	54,637	76,059	5,586	143,311	549,635	2,461,594
Oregon	598,913	559,455	19,985	-	54,252	114,981	19,676	14,020	57,278	1,438,560
Pennsylvania	1,199,566	1,900,807	52,326	64,414	62,429	33,879	7,761	71,245	1,073,521	4,465,949
Rhode Island	53,440	1,500	1,100	-	5,850	0	2,400	[13] 190	0	64,408
South Dakota	38,881	86,887	[14] 1,430	[2]	735	43	1,551	491	27,288	157,306
Tennessee [15]	503,774	727,393	-	84,646	75,244	70,979	5,202	64,072	-	1,531,310
Utah	18,654	n/a	n/a	n/a	1,263	n/a	n/a	36,557	n/a	56,474
Vermont	63,424	1,700	2,300	-	4,369	11,162	-	-	37,054	120,009
Washington	1,164,781	1,520,350	13,115	146,164	74,680	96,145	31,148	25,678	[16] 172,559	3,244,620

\- Criteria left blank

n/a Data not available or unknown

[1] Included in Copper, copper alloys and other metals; [2] Included in ferrous metals; [3] Includes MSW unsorted single stream, wood waste mulch, batteries, paint, textiles; [4] Does not include bottle bill plastics, aluminum, and glass; therefore, the numbers are lower than what is actually recycled; [5] Includes C&D, yard waste, white goods, food waste, textiles & misc; [6] 841,392 tons of composted and mulched wastes included in the "other recyclables" were taken out of reported number; [7] Includes C&D, textiles, carpet, batteries, WVO, Auto fluids; [8] Recycling tons only from local governments and not include recycling done by private sector recycling; [9] Includes mixed containers, textiles, dual stream and single stream recycling; [10] Includes antifreeze, used motor oil, leaves, brush, grass clippings, food waste, other glass, other plastics, and textiles; [11] Includes white goods and textiles; [12] 1,141,002 tons of yard waste composted were taken out of the "other recyclables" as it is included in the composting section; [13] State reported only 10% is reused and rest are sent to WTE facility; the number was adjusted to reflect only the 10% that was reused; [14] Data is missing from multiple facilities that did not report; [15] Numbers include recycled materials from all sources, including residential, commercial, and industrial; [16] Includes batteries, fluorescents, gypsum, photographic film, textiles, used oil

Table 6. Commodities Recycled in States with Comprehensive Recycling Data and Estimated Total Commodities Recycled in U.S. (tons/year)

State	Paper fiber	Metals	Plastics	Glass	Others	**Total tons of recycled commodities**	Population
Arkansas	183,929	1,820,578	45,142	1,111	353,704	2,404,464	2,937,979
Colorado	384,806	1,175,973	23,916	21,009	140,156	1,745,860	5,116,796
Connecticut	420,198	49,695	21,691	30,723	10,581	532,888	3,580,709
Delaware	80,299	22,575	3,260	208	19,577	125,919	907,135
District of Columbia	14,618	1,070	1,438	2,859	137	20,122	617,996
Florida	1,743,473	2,249,270	131,355	110,282	3,130,472	7,364,852	19,057,542
Kansas	400,865	387,014	17,489	24,428	102,925	932,721	2,871,238
Kentucky	380,509	1,215,681	19,025	6,492	38,532	1,660,239	4,369,356
Maryland	868,088	453,415	58,489	96,813	95,394	1,572,200	5,828,289
Minnesota	956,354	417,611	72,156	133,221	977,654	2,556,996	5,344,861
Montana	32,899	177,148	1,088	1,299	40,300	252,734	998,199
Nevada	247,843	472,433	22,347	18,553	389,425	1,150,601	2,723,322
New Hampshire	52,883	295,251	3,426	14,419	100,728	466,707	1,318,194
New Jersey	1,570,915	128,735	98,153	518,593	2,029,860	4,346,256	8,821,155
New Mexico	155,052	153,232	4,561	2,629	24,116	339,590	2,082,224
New York	1,805,314	294,832	114,403	177,193	30,934	2,422,676	19,465,197
Ohio	1,046,866	585,501	54,637	76,059	698,531	2,461,594	11,544,951
Oregon	598,913	579,440	54,252	114,981	90,974	1,438,560	3,871,859
Pennsylvania	1,199,566	2,017,547	62,429	33,879	1,152,527	4,465,949	12,742,886
Rhode Island	53,440	2,600	5,850	0	4,300	66,190	1,051,302
South Dakota	38,881	88,318	735	43	29,330	157,306	824,082
Washington	1,164,781	1,679,629	74,680	96,145	229,384	3,244,620	6,830,038
Total	13,400,492	14,267,549	890,523	1,480,938	9,689,542	39,729,044	122,905,310
Projected* National Total	33,973,186	36,171,364	2,257,670	3,754,504	24,565,114	100,721,837	311,591,917

*See page 25 for estimation method of projected national total recycled commodities

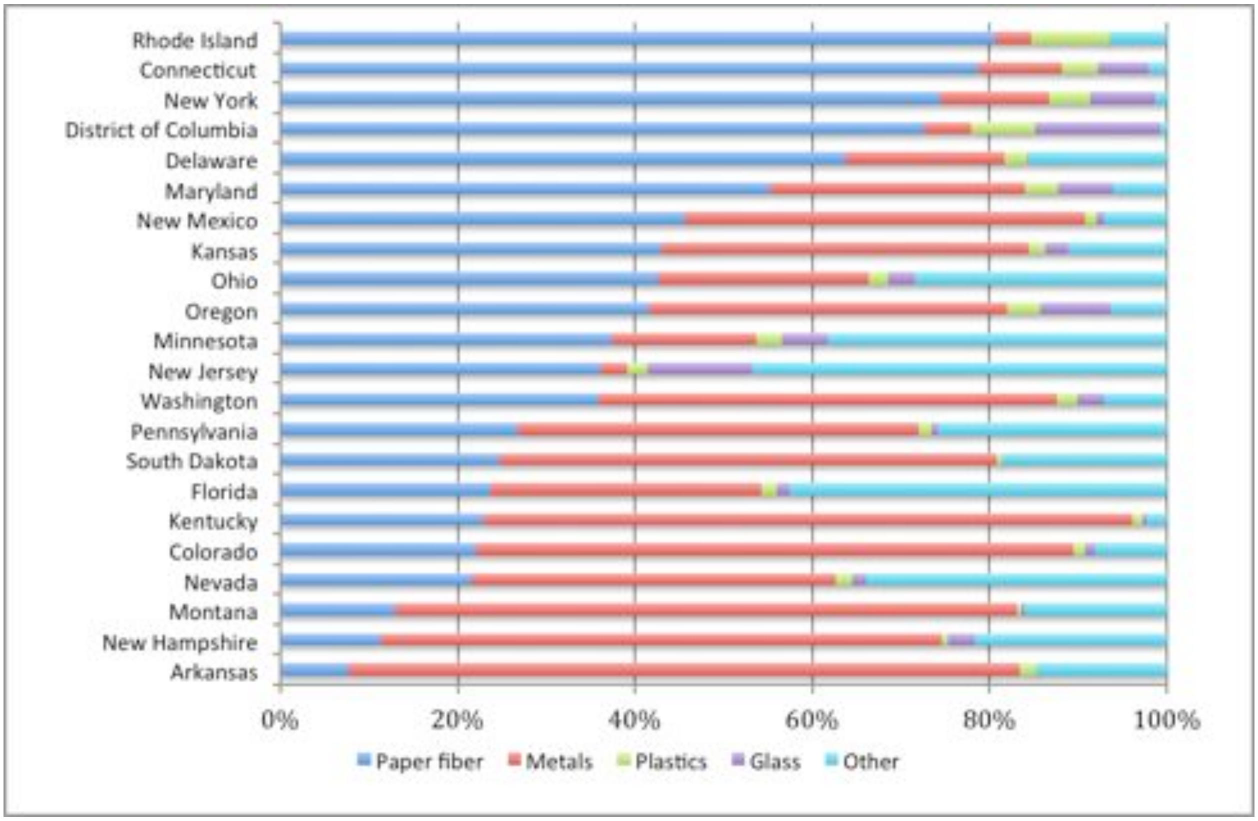


Figure 8. Percent Commodities Recycled in State with Comprehensive Data (2011)

Table 7. Tonnages of MSW Processed in Waste-to-Energy Facilities in each State in 2011

State	Number of Facilities	WTE (State-reported)	WTE (GAA, 2010)^
Alabama	**1**	**178,690**	**218,989**
Alaska*	0		0
Arizona	0	0	0
Arkansas	0	[1]	0
California	**3**	**856,121**	**856,121**
Colorado	0	0	0
Connecticut	**6**	**2,154,044**	**2,218,448**
Delaware	0	0	0
District of Columbia	0	216,903 [2]	0
Florida	**11**	**4,557,205**	**5,581,254**
Georgia	0	0	0
Hawaii*	**1**		**542,674**
Idaho	**0**	**0**	**0**
Illinois	0	0	0
Indiana	**1**	**704,675**	**695,275**
Iowa	**1**	**Unknown**	**38,706**
Kansas	0	0	0
Kentucky	0	0	0
Louisiana*	0		0
Maine	**4**	**472,478**	**692,558**
Maryland	**3**	**1,389,632**	**1,329,530**
Massachusetts	**7**	**3,174,603**	**3,180,168**
Michigan*	**3**		**997,557**
Minnesota	**10**	**1,145,487**	**1,013,481**
Mississippi	0	0	0
Missouri*	0		0
Montana	0	0	0
Nebraska	0	0	0
Nevada	0	0	0
New Hampshire	**2**	**251,539**	**265,389**
New Jersey	**5**	**2,129,852**	**2,148,851**
New Mexico	0	0	0
New York	**10**	**3,686,097**	**3,861,248**
North Carolina	0	0	0
North Dakota	0	0	0
Ohio	0	0	0
Oklahoma*	**1**		**202,466**
Oregon	**1**	**181,316**	**189,408**
Pennsylvania	**6**	**3,084,639**	**3,198,273**
Rhode Island	0	0	0
South Carolina*	0		0
South Dakota	0	0	0
Tennessee	0	0	0
Texas	0	0	0
Utah	**1**	**126,522**	**124,360**
Vermont	0	0	0
Virginia*	**5**		**2,022,589**
Washington	**1**	**276,753**	**281,813**
West Virginia*	0		0
Wisconsin	**2**	**76,000**	**87,065**
Wyoming	0	0	0
Total	**85**	**24,445,653**	**29,746,223**

^ GAA data were used to gauge the accuracy of the reported data; adjusted GAA data were used later on in the report for states that could not report WTE data

* State did not participate in the survey

[2] Outsourced to VA (not included in the total sum)

[1] State has 5 tire burners; no tonnage data available

- *Waste-To-Energy*

According to the GAA report, the total national MSW that went to WTE facilities in 2010 was 29,746,223 tons (see Table 7). The total combusted MSW reported by the states for 2011 was 28,568,163 tons. For Hawaii, Michigan, Missouri, and West Virginia who have WTE facilities in state but did not submit to the survey, the GAA 2010 report tonnages were used after adjusting for the population change from 2010 to 2011. Georgia, Louisiana, South Carolina, and Vermont had previously reported combusted MSW tonnages for 2008, but according to GAA report and the surveys received, they no longer had any operational WTE in 2011 and therefore did not combust MSW.

From Figure 6, it is easy to see that Northeastern states such as Connecticut, Massachusetts, Maine, and New Hampshire have a high percentage of their total MSW disposed to WTE facilities. The District of Columbia mostly outsources its waste and about half of its generated wastes go to WTE facilities.

It should be noted that the same northeastern states with a relatively high WTE disposal rate also exhibit relatively high recycling rates, ranging from 20-40% of total waste disposal.

- *Landfilling*

The total tonnage of landfilled MSW generated in each state in 2011 was 247 million tons (Adjusted 2008 landfilled data were used for AL, HI, ID, LA, MI, OK, SC, VA, and WV). This number differs from total sum of MSW actually landfilled in each states. The reason for this is revealed in the survey result of imported and exported waste (see Table 8). First of all, the sum of exported wastes and the sum of imported waste should match up, but the imported waste number is about 40% higher than the exported number. This is because states keep track of imported waste better than of exported waste. Some states also do not have information on imported landfilled waste and therefore the untracked imported waste may make up the tonnage difference between the reported imported and exported waste. However, the point is still the same: the difference in the reported exported and imported landfill waste tonnage is exactly the difference in tonnage between the total landfill MSW generated and total MSW actually landfilled. For this reason, the total sum of MSW landfilled better reflects the national landfilled MSW. However, for the states that accurately track imported and exported waste, the individual tons of landfilled MSW generated would provide a more accurate picture of MSW landfilled in these states.

It was noted that Michigan imported about 2.3 million tons of landfilled waste from Canada and Texas imported 1,569 tons from Mexico. For the purpose of national MSW analysis, these tonnages were excluded from the U.S. data of MSW generation and disposition.

Overall, California, Texas, Florida, Illinois and Michigan generated the most landfilled MSW in tons. However, when ranked in terms of percent share of the total MSW landfilled in the U.S., the five states with highest percent landfilled MSW were Oklahoma, Alaska, Mississippi, Arizona, and Georgia. Connecticut, Maine, Massachusetts, Minnesota, and Maryland had the lowest percent share of landfilled waste. (See Figure 6 for visual comparisons)

Table 8. Reported Tonnages of Imported and Exported Landfilled MSW and Estimated Total Landfilled MSW Generated in State in 2011

State	Tons of MSW reported by landfills in the State	Minus: tons of landfilled MSW imported from other States	Plus: tons of MSW exported to out-of-State landfills	**Total tons of landfilled MSW generated in the State**
Alabama	5,033,330	403,000	100,000	4,730,330
Alaska*	622,788	n/a	24,439	647,227
Arizona	6,609,376	n/a	n/a	6,609,376
Arkansas	3,124,012	0	148,785	3,272,797
California	29,798,820	56,812	305,833	30,047,841
Colorado	6,138,752	n/a	n/a	6,138,752
Connecticut	12,949	0	235,046	247,995
Delaware	672,761	0	0	672,761
District of Columbia	0	0	228,524	228,524
Florida	13,877,987	n/a	n/a	13,877,987
Georgia	11,671,171	1,802,171		9,869,000
Hawaii*	2,452,165	n/a	n/a	2,452,165
Idaho	1,668,578	n/a	n/a	1,668,578
Illinois	13,994,859	1,861,913	0	12,132,946
Indiana	7,377,835	2,496,962	0	4,880,873
Iowa	2,864,034	255,001	87,755	2,696,788
Kansas	2,784,343	594,722	73,715	2,263,336
Kentucky	5,045,034	1,194,345	344,672	4,195,361
Louisiana*	5,166,775	n/a	n/a	5,166,775
Maine	212,836	n/a	n/a	212,836
Maryland	740,838	53,599	1,665,700	2,352,939
Massachusetts	1,280,717	439,433	691,784	1,533,068
Michigan (8)	12,914,961	962,325	0	11,952,636
Minnesota	1,454,206	n/a	330,513	1,784,719
Mississippi	3,432,853	703,548	n/a	2,729,305
Missouri*	3,965,327	n/a	n/a	3,965,327
Montana	1,366,226	n/a	0	1,366,226
Nebraska	2,219,461	n/a	n/a	2,219,461
Nevada	3,070,537	260,558	0	2,809,979
New Hampshire	510,042	177,998	70,453	402,497
New Jersey(5)	2,012,124	254	2,373,105	4,384,975
New Mexico	2,591,548	609,664	0	1,981,884
New York	6,295,658	551,778	4,519,830	10,263,710
North Carolina	7,367,023	173,488	508,697	7,702,232
North Dakota	750,000	75,000	n/a	675,000
Ohio	11,653,602	2,839,257	312,464	9,126,809
Oklahoma*	4,397,372	n/a	n/a	4,397,372
Oregon	3,170,664	1,299,323	47,308	1,918,649
Pennsylvania	10,914,382	5,011,705	n/a	5,902,677
Rhode Island	793,000	0	0	793,000
South Carolina*	3,295,771	n/a	n/a	3,295,771
South Dakota	646,561	n/a	n/a	646,561
Tennessee	5,807,713	601,024	829,443	6,036,132
Texas (7)	23,842,499	122,365	0	23,720,134
Utah	2,071,372	12,220	0	2,059,152
Vermont	344,203	0	34,802	379,005
Virginia*	10,095,859	n/a	n/a	10,095,859
Washington	3,261,582	250,336	1,102,507	4,113,753
West Virginia*	1,812,675	n/a	n/a	1,812,675
Wisconsin	4,324,248	281,946	139,565	4,181,867
Wyoming	609,800	0	280	610,080
Sum Total	**256,141,229**	**23,090,747**	**14,175,220**	**247,225,701**

(1) Data from Alabama Department of Environmental Management ("Economic Impact of Recycling in Alabama and Opportunities for Growth"); (2) data from Georgia Department of Community Affairs "state of solid waste management in Georgia"; (3) data may included non MSW imported; (4) A total of 212,836 tons of Maine-generated MSW were landfilled in 2011; (5) 2,373,105 tons of MSW were disposed of out of State; no breakdown for the percentage to landfill v. RRF is readily available; (6) data from New York State Department of Environmental Conservation; (7) Texas imported 1569 from Mexico. This number was excluded; (8) data from Michigan department of environmental quality "Report of Solid Waste Landfilled in Michigan" FY 2011; Michigan imported 962,325 tons from other US states and 2,327,709 from Canada. Canadian wastes were excluded from the number

3.4.3. Ten-year MSW Management Trend

The changes in national total generation of MSW (Figure 9) over the past decade (data recorded biannually) show a distinctive pattern. From 2002 to 2006, the total generation of MSW changes with a constant 5-6% increase. In 2008, the number drops back 5%. From 2008 to 2011, there has only been a 0.3% increase per year. While there can be many more factors that influence the national MSW generation, the pattern roughly follows the U.S. economic pattern (GDP changes) over the 10 years as well as the unemployment rate (see Figure 10 and 11). From 2002 to 2006, U.S. kept an average GDP growth rate of about 3%, justifying the corresponding constant growth in waste generation. The 2008 recession is very likely to be the reason for the large drop in waste generation that year. However, part of the observed decrease may have been due to the EEC's improved effort to exclude non-MSW tonnages from the received survey data. Lastly, the very small change in MSW generation from 2008 to 2011 reflects the economy and unemployment rate, which have not fully recovered from the downturn. Nevertheless, the slight decrease in the total MSW generation from 2008 to 2011 is most likely due to incompleteness of recycling data. As mentioned in the previous section, many states indicated that they did not have the resources to collect data on private sector recycling.

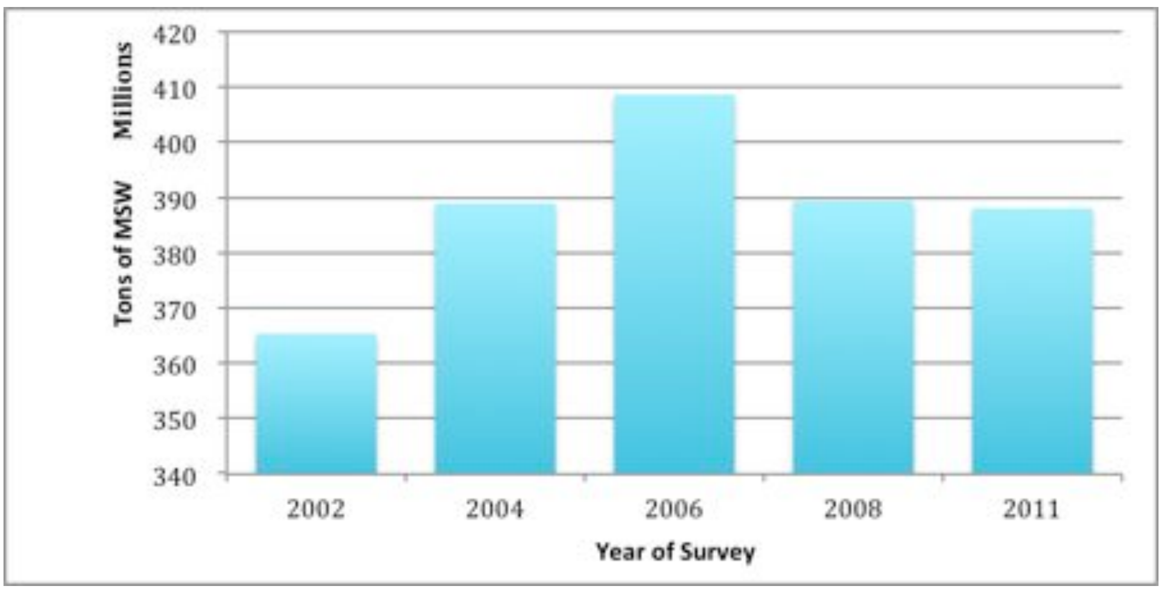


Figure 9. National Total MSW Generation Trend

The trend in total generation of MSW is relatively easy to understand; however, when the national numbers are broken down into tons recycled/composted, combusted, and landfilled, the trends can provide more insights. Figure 9 shows that the national rate of MSW combustion has stayed relatively constant except for a small dip in 2008 due to the economic recession. More interesting are the changes in landfill and recycling tonnages from 2008 to 2011. While the overall MSW generated increased over this period, landfilling decreased and this decrease was made up by an increase in recycled tonnage. If the landfill tonnage had followed the overall trend and only the recycling tonnage increased, the recycling tonnage would have been dubious, especially since many

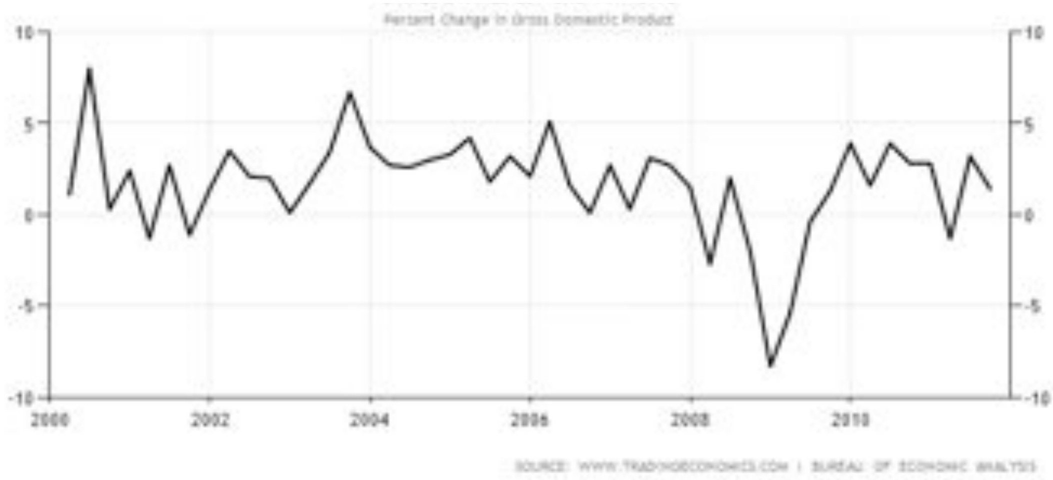


Figure 10. United States GDP Growth Rate

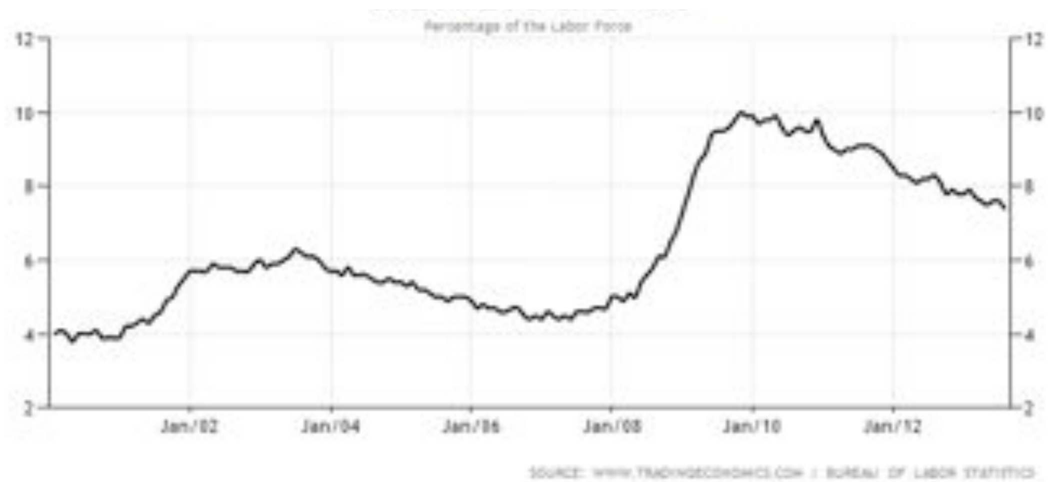


Figure 11. United States Unemployment Rate

states do not have comprehensive recycling data. However the recycling tonnages are higher than 2008 even as landfill tonnage decreased and several states are likely to have underreported their recycling tonnages. The recycling rate still remains higher than 2008 even when one assumes (arbitrarily) that only a third of 24 million tons of California's "other recyclables" (which includes C&D and industrial wastes) is MSW. Furthermore, the landfill tonnages are considered to be the most reliable data, since landfill facilities keep record of incoming wastes; therefore, the changes in these numbers from 2008 to 2011 indicate that the MSW diversion rate from landfilling has actually increased in response to the nationwide effort to recycle and reuse. Some of the examples of increased effort to recycle are San Francisco's Mandatory Recycling and Composting Ordinance that was passed in 2009 and the Massachusetts and Oregon's expansion of their Bottle Bill Law between 2008 to 2009 to include more container types.

Composting tonnage has not changed significantly from 2008, but may be higher than the reported number since several states explained that their data are from limited sources and may not reflect all composting facilities and activities in their state.

Table 9. National MSW Generation Trend by Disposal Method

Year	Total MSW Recycled & Composted	Total MSW Recycled only	Total MSW Composted only	Total MSW Landfilled	Total MSW Combusted	Total MSW gen
2002	98,675,222	n/a	n/a	238,226,550	28,479,635	365,381,407
2004	110,383,614	n/a	n/a	248,611,301	29,983,546	388,978,461
2006	113,934,200	n/a	n/a	266,412,964	28,394,109	408,741,273
2008	93,781,220	69,283,968	24,497,252	269,776,521	25,926,285	389,484,026
2011	112,455,021	87,808,128	24,646,893	247,225,701	28,082,628	387,763,351

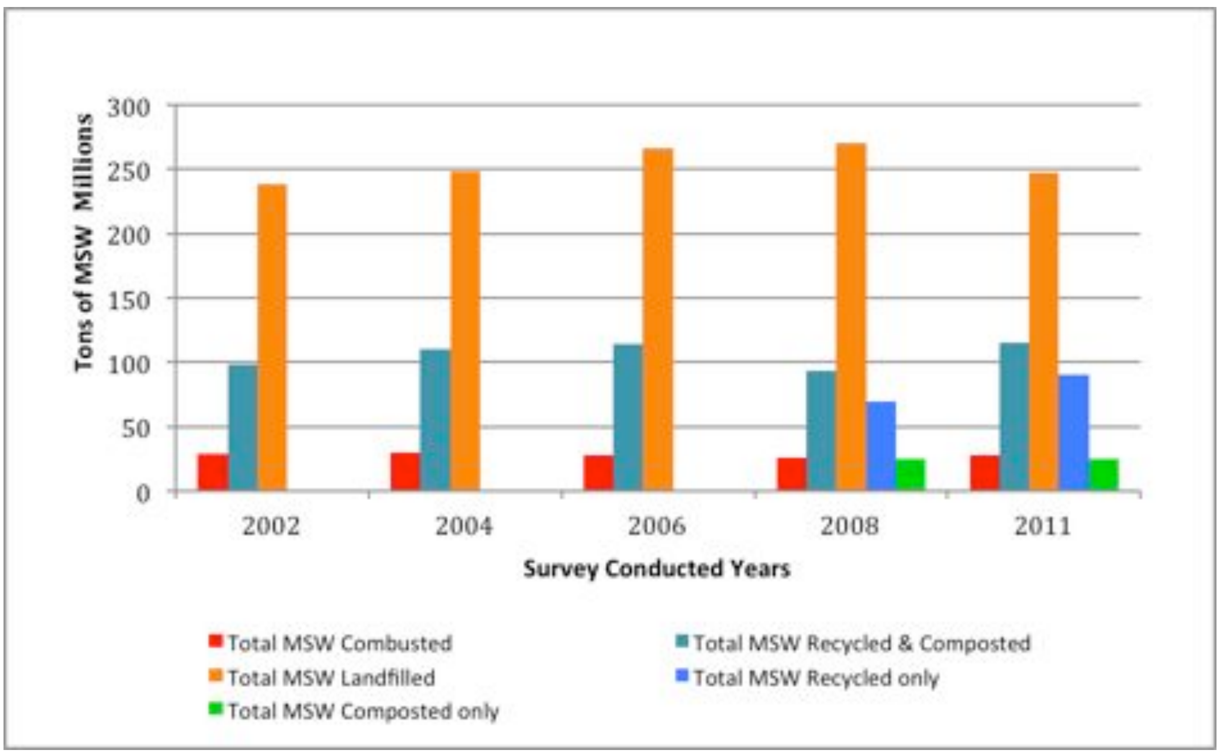


Figure 12. National MSW Generation by Disposal Method

4. EEC and EPA Method Comparison and Data Discrepancy

When policy makers and businesses are looking for national MSW data and trends, the most cited works are the EPA's "Municipal Solid Waste in United States: Fact and Figures" and BioCycle/EEC's "State of Garbage in America." The two reports use different methods of estimating national MSW data and each method has its own pros and cons. The problem is, however, that the final number reached by these two methods vastly differs. The difference in number is most apparent in national figures of total MSW landfilled (see Table 10). The tons of MSW combusted for energy recovery should be very close between EEC and EPA's number; the 960 thousand ton difference comes not from the data collection error but from the fact that EPA numbers include tons tires combusted at tire-only facilities, which were not included in the EEC's number.

Because these numbers are cited often, it is important to understand the sources of these numerical differences so as to better utilize the information for different situations.

Table 10. Comparison of EEC Survey of 2011 data with EPA 2011 Facts and Figures Report

EEC 2011	EPA 2011	Difference
Total MSW generated	Total MSW generated	EEC minus EPA
388,959,390	250,420,000	138,539,390
Recycled materials	Recovered materials	
87,808,128	66,200,000	21,608,128
MSW Composted	Organics composted	
24,646,893	20,700,000	3,952,774
MSW to WTE	MSW to WTE	
29,507,191	29,260,000	-247,191
MSW landfilled	MSW landfilled	
246,977,177	134,260,000	112,717,177

4.1. EPA Material Flows Method

4.1.1. Method Description

EPA has been developing and using a materials balance method to estimate generation of MSW in the U.S., since 1960. EPA determines the amount of different commodities generated and then determines how much of it was recovered, composted, or combusted. The difference of materials generated and materials recovered, composted, and combusted are assumed to be landfilled. EPA determines theses numbers based on data gathered from sources such as industrial associations, major companies, and government (i.e., Department of Commerce). It also makes adjustments to reflect U.S. imports and exports of goods. Because EPA gathers data on individual commodity basis, it is able to formulate detailed generated, recovered (recycled and composted), and landfilled waste composition in its yearly report, as shown in Figure 14. In order to determine the amount of MSW generation, EPA assigns product lifetimes (the average period the product is in use until it is finally discarded as waste) to each material. In its estimation of MSW generated, only the wastes from residential, commercial, and institutions are included. Since food and yard waste data cannot be estimated from materials flow methods, EPA uses data from various sampling and weighing studies. Most of the U.S. landfills are not perfectly categorized as MSW-only or as non-MSW landfills. While there are separate C&D, or industrial landfills with permits specifically for those wastes, many sanitary landfills accept what is called "subtitle D wastes, which may include wastes of non-municipal origin (see Figure 13). Therefore, at many landfills, some C&D and industrial waste residues may enter with MSW streams; however, the EPA estimate include strictly the materials that are listed under EPA's definition of MSW (US Environmental Protection Agency, 2013).

Subtitle D Wastes	
The Subtitle D Waste included in this report is Municipal Solid Waste, which includes:	
Containers and packaging such as soft drink bottles and corrugated boxes	
Durable goods such as furniture and appliances	
Nondurable goods such as newspapers, trash bags, and clothing	
Other wastes such as food waste and yard trimmings.	
Subtitle D Wastes not included in this report are:	
Municipal sludges	Agricultural wastes
Industrial nonhazardous process wastes	Oil and gas wastes
Construction and demolition debris	Mining wastes
Land clearing debris	Auto bodies
Transportation parts and equipment	Fats, grease, and oils

Figure 13. Subtitle D Wastes Considered MSW and Non-MSW by EPA

MATERIALS GENERATED* IN THE MUNICIPAL WASTE STREAM, 1960 TO 2011
(In thousands of tons and percent of total generation)

	Thousands of Tons									
Materials	**1960**	**1970**	**1980**	**1990**	**2000**	**2005**	**2007**	**2009**	**2010**	**2011**
Paper and Paperboard	29,990	44,310	55,160	72,730	87,740	84,840	82,530	68,430	71,310	70,020
Glass	6,720	12,740	15,130	13,100	12,770	12,540	12,520	11,780	11,530	11,470
Metals										
Ferrous	10,300	12,360	12,620	12,640	14,150	15,210	15,940	15,860	16,820	16,520
Aluminum	340	800	1,730	2,810	3,190	3,330	3,360	3,440	3,500	3,470
Other Nonferrous	180	670	1,160	1,100	1,600	1,860	1,890	1,900	2,000	1,960
Total Metals	*10,820*	*13,830*	*15,510*	*16,550*	*18,940*	*20,400*	*21,190*	*21,200*	*22,320*	*21,950*
Plastics	390	2,900	6,830	17,130	25,550	29,380	30,910	30,050	31,290	31,840
Rubber and Leather	1,840	2,970	4,200	5,790	6,670	7,290	7,500	7,350	7,400	7,490
Textiles	1,760	2,040	2,530	5,810	9,480	11,510	12,170	12,940	13,100	13,090
Wood	3,030	3,720	7,010	12,210	13,570	14,790	15,190	15,590	15,880	16,080
Other **	70	770	2,520	3,190	4,000	4,290	4,550	4,640	4,690	4,590
Total Materials in Products	54,620	83,280	108,890	146,510	178,720	185,040	186,560	171,980	177,520	176,530
Other Wastes										
Food Waste	12,200	12,800	13,000	23,860	30,700	32,930	33,560	35,270	35,740	36,310
Yard Trimmings	20,000	23,200	27,500	35,000	30,530	32,070	32,630	33,200	33,400	33,710
Miscellaneous Inorganic Wastes	1,300	1,780	2,250	2,900	3,500	3,690	3,750	3,820	3,840	3,870
Total Other Wastes	33,500	37,780	42,750	61,760	64,730	68,690	69,940	72,290	72,980	73,890
Total MSW Generated - Weight	88,120	121,060	151,640	208,270	243,450	253,730	256,500	244,270	250,500	250,420
	Percent of Total Generation									
Materials	**1960**	**1970**	**1980**	**1990**	**2000**	**2005**	**2007**	**2009**	**2010**	**2011**
Paper and Paperboard	34.0%	36.6%	36.4%	34.9%	36.0%	33.4%	32.2%	28.0%	28.5%	28.0%
Glass	7.6%	10.5%	10.0%	6.3%	5.2%	4.9%	4.9%	4.8%	4.6%	4.6%
Metals										
Ferrous	11.7%	10.2%	8.3%	6.1%	5.8%	6.0%	6.2%	6.5%	6.7%	6.6%
Aluminum	0.4%	0.7%	1.1%	1.3%	1.3%	1.3%	1.3%	1.4%	1.4%	1.4%
Other Nonferrous	0.2%	0.6%	0.8%	0.5%	0.7%	0.7%	0.7%	0.8%	0.8%	0.8%
Total Metals	*12.3%*	*11.4%*	*10.2%*	*7.9%*	*7.8%*	*8.0%*	*8.3%*	*8.7%*	*8.9%*	*8.8%*
Plastics	0.4%	2.4%	4.5%	8.2%	10.5%	11.6%	12.1%	12.3%	12.5%	12.7%
Rubber and Leather	2.1%	2.5%	2.8%	2.8%	2.7%	2.9%	2.9%	3.0%	3.0%	3.0%
Textiles	2.0%	1.7%	1.7%	2.8%	3.9%	4.5%	4.7%	5.3%	5.2%	5.2%
Wood	3.4%	3.1%	4.6%	5.9%	5.6%	5.8%	5.9%	6.4%	6.3%	6.4%
Other **	0.1%	0.6%	1.7%	1.5%	1.6%	1.7%	1.8%	1.9%	1.9%	1.8%
Total Materials in Products	62.0%	68.8%	71.8%	70.3%	73.4%	72.9%	72.7%	70.4%	70.9%	70.5%
Other Wastes										
Food Waste	13.8%	10.6%	8.6%	11.5%	12.6%	13.0%	13.1%	14.4%	14.3%	14.5%
Yard Trimmings	22.7%	19.2%	18.1%	16.8%	12.5%	12.6%	12.7%	13.6%	13.3%	13.5%
Miscellaneous Inorganic Wastes	1.5%	1.5%	1.5%	1.4%	1.4%	1.5%	1.5%	1.6%	1.5%	1.5%
Total Other Wastes	38.0%	31.2%	28.2%	29.7%	26.6%	27.1%	27.3%	29.6%	29.1%	29.5%
Total MSW Generated - %	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Generation before materials recovery or combustion. Does not include construction & demolition debris, industrial process wastes, or certain other wastes.
** Includes electrolytes in batteries and fluff pulp, feces, and urine in disposable diapers.
Details may not add to totals due to rounding.

Figure 14. Generated MSW composition reported on EPA's Facts and Figures *(US Environmental Protection Agency, 2013)*

4.1.2. Strengths and Weaknesses

Because of the nature of the material flow method, it gives EPA or any organization that uses the method certain independence in generating data. The "site-specific studies," which EPA presents as a contrasting method to the materials flow method, requires data gathering from all waste management facilities from all states. It is tough to achieve cooperation from all states to report their MSW information, and material flows method provides a way around this challenge. Furthermore, because the fundamental data used for the estimation of waste stems from industrial and business sources for individual waste materials, the method makes it very convenient to estimate the weight of only the desired waste materials categories (i.e., MSW).

The fact that EPA has been using the same method for over thirty years also adds great strength and reliability to the generated data. The methodology has been consistent and therefore EPA's Facts and Figures report provides excellent picture of national MSW generation trend since 1960. EPA has been making improvements to their databases, but when changes are made, they are applied to all of the past year data. Thus, the report from one year may have different numbers than later year reports, but the most up-to-date report would have a national MSW generation data from 1960 to current year with the modified method consistently applied to all of them.

Nevertheless, the EPA method also has several weaknesses. For example, as EPA states in their Facts and Figures report, the material flows method cannot capture the MSW weight that results from residues in containers, such as liquids lefts in soda cans or water bottles, paint left in paint cans, and food residues in plastic containers, all of which may add up to a significant weight percentage of MSW generated that is not counted in the materials flow method.

The materials flow method also has a potential to disregard wastes that are "invisible" to the data gathered from industrial, business, and governmental resources: All of these data lead EPA to focus on commercially traded products; however, there are many wastes that are generated under the radar of these databases, for example packaging wastes from international shipping, animal carcasses, and counterfeit good wastes, as will be discussed in a later section of this study.

There can also be limitations in the data collected from industries. With so many different consumer products being produced and each of these products wrapped in a variety of packaging materials, it is tough to account for all of them accurately.

4.2. EEC Survey Method

4.2.1. Method Description

As discussed in detail in the 2013 MSW survey section, the Earth Engineering Center Surveys (with BioCycle until 2008) rely heavily on state-provided information as to how they dispose MSW. The data are collected by distributing excel format interactive questionnaires that contain a variety of waste management questions on recycling, composting, combusting, and landfilling, as well as on the tons of MSW disposed by each of those methods. When the state-provided data is incomplete or is gathered from limited sources, secondary references are sought.

EEC makes adjustments to exclude non-MSW tonnages from the reported tonnages when the inclusion and weight of such wastes are specified by the state. When it is obvious that non-MSW weight is included in the reported waste tonnage but no tonnage data is available for the included non-MSW, the report indicates the possibility of waste being over-reported. For example, in the 2008 SOG report, the MRF capacity data, provided by GAA in a state-by-state survey, was used to estimate recycling tonnages for those states that could not provide recycling data; by comparing the recycling tonnages of states that provided the number with their yearly MRF capacity data from GAA, a general relationship was found that the total recycling rate in a state was about twice the MRF capacity in the state. This relationship was used for the states that did not have recycling data.

4.2.2. Strength and Weaknesses

The EEC survey method is a bottom-up approach, where the MSW generation information is gathered from individual states and added up to generate a national picture. When the waste accounting is well kept in each state, the survey method can provide excellent estimation of how much of the generated waste was managed by recycling, composting, combusting, or landfilling. While the past surveys did not include disposed wastes data by material category, the total tonnages data gathered from the surveys are straight forward in what they represent: the waste generated in and went through waste facilities in the state. The accuracy is especially high for tons of waste sent to sanitary landfills and WTE facilities, since these facilities track every ton of incoming wastes. Such data allows for a different accounting method of wastes. Instead of focusing on how much of the waste generated is MSW or non-MSW, the method puts importance on how much waste entered what are supposed to be MSW landfills facility and how much landfill space was taken. Thus, the EEC number for landfilled waste is more realistic for determining allocation of land for waste disposal in the future. After all, if industrial (e.g. automobile shredder residue) or some C&D waste (e.g. trash from demolition and construction projects) residues are entering MSW landfills, they take up MSW landfill space, and unless something can be done to completely prevent them from entering the landfill, they should be accounted for in estimating landfill space required. Also, wastes such as automobile shredder residue contain energy that could be recovered in a thermal treatment plant instead of taking up space in an MSW landfill.

The survey's weakness comes from the fact that the same cannot be said for the recycling and composting tonnages. Most recycling and composting facilities are not required to report processed tonnages and many states' solid management offices do not have any data, have partial data, or only have a rough estimate. Even when some of these states track tons of recyclables sent to MRFs, they still do not know the tonnage of recyclables collected by private haulers or sent directly to third party recycling processors. In this case, the reported recycling rate would be significantly underreported.

Tons of MSW composted are also not well tracked by some states. Furthermore, because there are many non-reported small-scale composting facilities, the actual national composting rate may be higher than reported. However, the estimation of composting tonnage is equally difficult with the EPA method because leaves, grass, etc., are difficult to capture in the material flow methodology.

What the EEC survey does provide, even with inadequate recycling and composting data, is a consolidated report of detailed waste management statistics of each state and a comparison of how well waste is managed and accounted. There are states that are excellent in tracking waste tonnages to all means of waste management and for those states the EEC Survey is a very good source of information. For the states who are missing a significant portion of their waste management data, the survey reveals specifically what information needs more rigorous tracking. This is simply a matter of state government being aware of the importance of sustainable waste management and ensuring that their environmental agencies have the resources for collecting reliable recycling and composting data. In sending out the Survey Questionnaire and publishing the results of this Survey, the Earth Engineering Center of Columbia University hopes to encourage more states to take action for improving their MSW data collection and, hence, their managing of wastes.

4.3. Methods Comparison and Data Discrepancy (Please note that in the following discussion, the EPA 2008 Facts and Figures Report were used).

4.3.1 Significance and Consequences of the Data Discrepancies

Both the EPA and the EEC surveys provide estimates of national waste generation and disposition. Marginal errors cannot be completely avoided and both methods have pros and cons. However, the data discrepancy between the two, amounting to over one hundred million tons of landfilling, is very large and should be examined closely. The right number can affect policymaking and efforts to bring waste management in the U.S. to the levels of other developed nations.

For example, let us assume that the landfilled waste tonnages, as reported by EPA, are underestimated. On the basis of the EPA estimate, a municipality plans in twenty years to landfill 100,000 tons, while in fact 180,000 tons will be generated. A policymaker then may plan to accommodate only a hundred thousand tons of wastes and allot the rest of the land to some other use. Also with underestimated landfilled waste, the recycling rate will appear to be higher than what it actually is. With such a distorted view of recycling rate of the state, a policymaker may think recycling rate is high and devise a less rigorous recycling regulation or none at all.

4.3.2. Improvement to be made

For improved accuracy of national MSW data, both the EPA and the EEC methodologies need reinforcements. The EPA materials flow method already has a robust database of how much of what materials are disposed each year. Nevertheless, the focus is primarily on commercially traded materials. Many materials are unaccounted for with this focus. More effort must be allotted for identifying such materials and collecting data on their generation as wastes.

The EEC method is in need of improved recycling and composting data in each state and within a state. For such improvements, EEC has to rely on the states themselves or for the federal government to provide regulations that require recycling and composting facilities to record and report processing data, as WTE plants and landfills are already doing. Even for landfilled waste tonnages, more care should be taken by the facilities to keep separate records of MSW and non-MSW tonnages.

What is really needed is a nationwide collaboration. The Office of Resource Recovery and Conservation of EPA and the waste management departments of the states need to work together as to the means for generating accurate recycling and composting data. Also, it is clear from the comparison of the two methods that some combination of the EEC Survey and the material flow method is required. For example, organic wastes, such as yard and food wastes, are difficult to estimate by the material flows method. Even though many states do not have a good tonnage tracking system for organic wastes going to composting facilities, such a tracking procedure is something that needs to be developed and improved in order to accurately estimate the composted wastes.

On the other hand, the generation of potentially recyclable materials can be estimated from the EPA method. However, because of the way that the recycling infrastructure has developed in U.S., it is currently difficult to track actually recycled tonnages. Recycling activities are increasingly outsourced to third-party, private haulers; therefore, even for states that put in much effort to track recycling activities in MRFs within the state cannot have a complete data set. With continued effort to bolster the database, industrial and government resources may be more reliable in estimating recycled materials in the country. At the same time, many state responses to the EEC survey indicated that lack of budget is one of the reasons why it is difficult for them to track recycled waste tonnage. With more illumination on the importance of the waste accounting and allocation of budgets for this purpose, better data could be gathered from each state.

With regard to WTE and landfill facilities, the existing requirement to record and report tonnages of incoming waste has been incredibly helpful in accounting for wastes that go through these facilities. Making good use of this requirement, the survey method is great for amassing the data, and gives accurate view of how much of land use is and would be allotted for landfill wastes. What this method lacks is the ability of material flows method to sort tonnages of MSW, C&D, industrial and other wastes separately, indicating clearly which sector should recycle or reduce waste more.

In order to achieve significant landfill data improvement and coherence between EPA and EEC data, extensive collaboration of the two methods is required. Currently there are two main error-causing factors: (1) non-MSW tonnage that may get included in MSW tonnage ("misplaced waste") and (2) materials that are not easily captured in material flows method database ("statistically missing waste"). There is a problem in solving the two problems because the current data discrepancies comprise both of the factors and it is not possible to separate one from the other. In order to address the two factors separately, the scope of waste management survey needs to be expanded to collect tonnage data from all types of landfills; the result should be examined in the light of the database of the material flows method. In this way, national aggregate solid waste tonnage estimated from the two methods can be properly compared. In this way, all waste materials, regardless of categories, can be comprehensively covered – it eliminates the tonnage difference arising from the misplaced waste. Then, the difference between the numbers of the two methods would represent only the statistically missing waste that does end up in U.S. landfills.

At the same time, breakdowns of the aggregate solid waste tonnage can be looked at in detail. To understand how this may be done, let us consider three hypothetical scenarios. It is assumed for simplification that the aggregate solid waste comprises MSW, industrial and C&D wastes. For these scenarios, reported estimation of C&D waste MSW tons were used, but due to the lack of data, industrial waste is left as "unknown." EPA (in 2003) estimates that U.S. generates about 170 million tons of C&D waste every year (Earth 911 Inc., 2013). Construction & Demolition Recycling Association, however, estimates a much higher number of 325 million tons per year (Construction & Demolition Recycling Association). For the scenario 1 shown below (Figure 15), the C&D Recycling Association number is used to represent the survey method since EEC does not have any C&D data of its own and because it is likely that the survey method would result in higher estimation of the C&D waste than that of EPA.

One possible scenario is that EPA has smaller tonnages for C&D waste and MSW than the EEC's survey results (Figure 15). In this scenario, the extent of the original MSW data discrepancy problem is not isolated but rather doubled since the C&D waste shows an equally severe data discrepancy. This would mean that a large amount of C&D waste and MSW are statistically missing, and effort should be focused on identifying the wastes that are entering the both C&D and MSW landfills. A second scenario may be that there is no significant difference between the EEC and EPA's tonnages for industrial and C&D wastes (Figure 16). In this case, MSW can be isolated as the main concern; the tonnage difference comes from statistically missing MSW. If this scenario were true, it would urgently call for re-evaluation of the material flows methodology database and identification of waste streams that are currently not accounted for. The third possible scenario is that EEC reports a lower C&D waste number than EPA (Figure 17). In this scenario, it is likely that some of the C&D category wastes end up in MSW waste streams. Thus, while there may still be statistically missing waste, misplaced wastes may be responsible for part of the large MSW tonnage difference between EEC and EPA's report. If this were to be the actual outcome, an extensive waste characterization study should be done to identify the extent of misplaced C&D wastes in MSW stream.

To eliminate all of these uncertainties and to clarify what action should be taken to resolve the problem, detailed waste characterization studies and material flow research should be carried out.

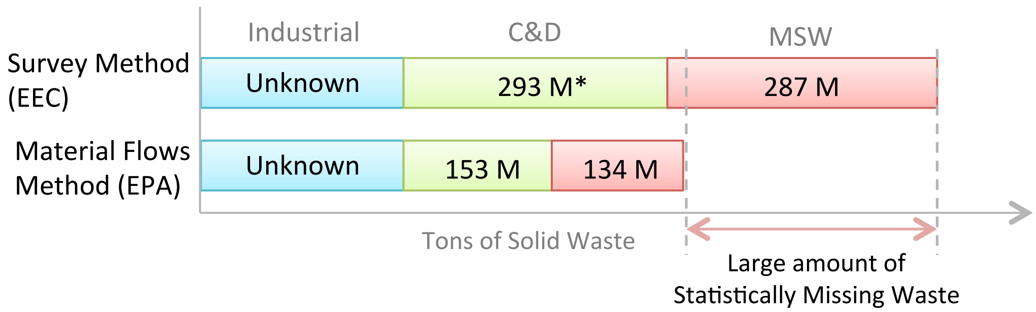


Figure 15. Possible Waste Disposal Scenario 1

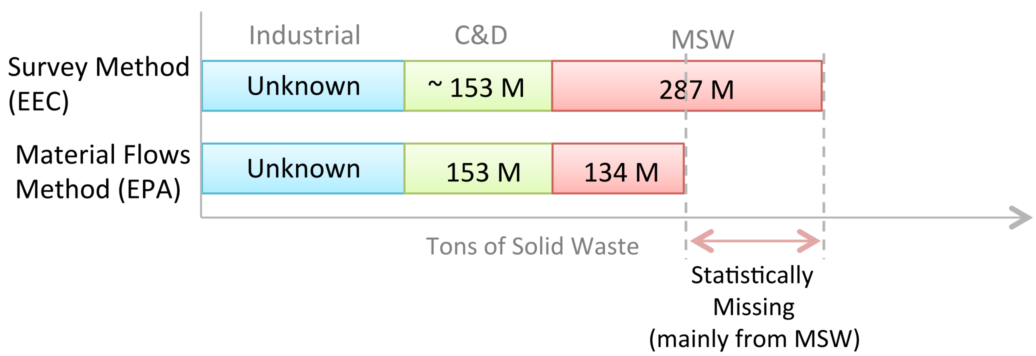


Figure 16. Possible Waste Disposal Scenario 2

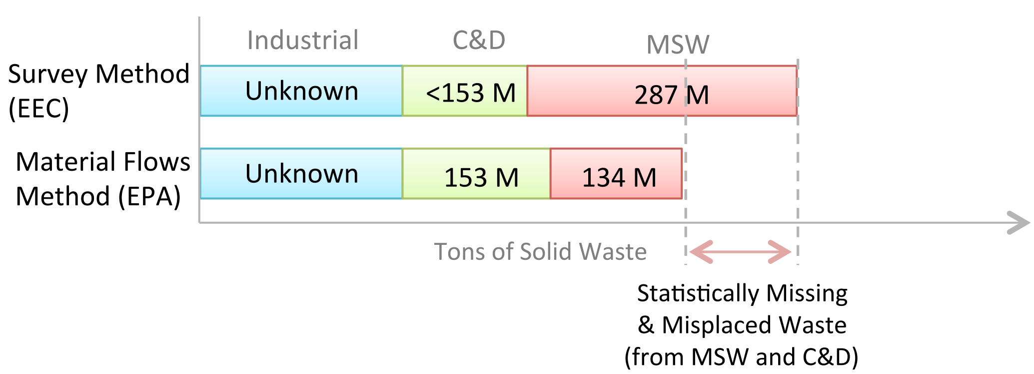


Figure 17. Possible Waste Disposal Scenario 3

5. Speculative Reasons for Landfill Data Discrepancies

This section explores various possible reasons for the 100-million ton of landfilled waste discrepancy between the EPA and EEC estimates. Even though some of these are speculative, they reveal research areas that should be delved into further in order to identify the causes of the data discrepancy.

5.1. Residual Problems

5.1.1. C&D and Industrial Waste Residues in Landfills together with MSW

As mentioned before, EPA categorizes wastes materials into MSW and non-MSW (C&D, industrial, biosolids, wastewater treatment sludge). Regardless of which landfills the materials end up in, if the material does not belong to the MSW category, its weight is not accounted for in the MSW tonnage. However, much of shredded or scrapped C&D and industrial waste residues that are not or cannot be recycled end up in the same landfills as MSW. These wastes are often, either by lack of effort or deliberately, not differentiated from the MSW stream. For this reason, facility reported landfill tonnages include weights of the C&D and industrial wastes residues.

It is also possible for C&D and light industrial wastes to be generated in the residential sector. Individuals may buy some raw materials for home-scale or do-it-yourself projects. Similarly, individuals may tear apart a portion of their house or garage for remodeling. Wastes produced from such projects (i.e., woods, PVC pipes, paint containers, and roof tiles) enter the MSW stream.

At this point, there is a need to clarify whether any waste generated in residential sector should be considered MSW regardless of the material categories. If these materials or waste are categorized as C&D under the EPA material flow methods, they are not included in the EPA number for tons of MSW.

5.1.2. ASR Residues

ASR (automobile shredder residue) is produced during the vehicle recycling process. Typically the recycling process includes de-polluting, dismantling, and shredding. The de-polluting stage first collects hazardous materials such mercury switches, air conditioning refrigerant, and gasoline. During the process car batteries are also removed for remanufacturing. The dismantling process removes parts that can be reused. After the vehicle is stripped of the useful parts, it is shredded in preparation for metal recovery. Steel shreds are separated magnetically, non-ferrous metals are recovered from eddy current separator, and lastly, stainless steel is recovered by an inductive sorter (Duranceau & Spangenberger, 2011). After all of these processes, what is left over is the ASR. Under current regulations, ASR are either landfilled or combusted, with a large fraction landfilled (Jody & Daniels, 2006). This ASR enters sanitary landfills along with MSW. EPA estimates that annually about 5 million tons of ASR is produced in U.S. This number, EPA states in its annual reports, is not included as part of MSW. Thus, this difference in accounting for ASR is likely to make up 5% of the data discrepancy between EPA and EEC landfilling numbers.

5.2. Wastes Likely to be Unaccounted for by Material Flows Method

As mentioned above, the material flows method utilizes industry, businesses, and governmental data to estimate waste generated in the country. The EPA database is robust and comprehensive and suitable for tracking commercially traded products. However, there are waste streams that this method cannot capture. The following sections explore possibly non--captured streams of wastes generated in U.S.

5.2.1. Road Kills (Wild Animal Carcass)

An example of something that is not commercially traded and therefore not quite captured in the materials flows method is animal carcasses on roadsides. With four million miles of roadways and 234 million total registered vehicles in U.S., it is estimated that about 1 million small and large animals are killed each day by car accidents (this number of daily road kill is high because it also includes small animals such as frogs and birds). A study done in 1993 estimated that annually car accidents kill 41 million squirrels, 26 million cats, 22 million rats, 19 million opossums, 15 million raccoons, 6 million dogs, and 350,000 deer. As there are more cars on the roads now then in 1993, the statistic may be higher. The protocol for taking care of the animal carcasses is moving them to a nearby site for burial and composting in the ground or sending them to landfills that are permitted to accept them. According to EPA, animal carcasses are considered agricultural wastes, and therefore not included in the MSW tonnages (US EPA (Hope Pillsbury), 2013). It is unclear whether the animal carcasses are always sent to landfills with permit that only accepts agricultural wastes. The estimation of weight of animal carcasses generated each year is shown in Table 11. Roughly estimated average weights for individual animals were used in the calculation. The number is not so large as to be responsible for a large portion of the data discrepancy, but this is a good example that may help people think more about wastes missed by materials flows method database.

Table 10. Animals Killed by Car Accidents in a Year (1993 Study)

	Average weight* (kg)	Number of death/year	Total weight (tons)
Squirrel	0.9	41,000,000	37,195
Cat	5.4	26,000,000	141,521
Rat	0.3	22,000,000	5,987
Opossum	3.6	19,000,000	68,946
Raccoon	6.4	15,000,000	95,254
Dog	9.1	6,000,000	54,431
Deer	50.8	350,000	17,781
Total			421,115 tons

*Average weight of the animals are rough estimates as the weight of the animals vary gender, age, and seasons

5.2.2. Underestimation of Food and Yard Waste

Food and yard waste, as well as street sweepings, are not tracked by the materials flows method. EPA explains in their methodology that food and yard wastes are estimated by data gathered from waste sampling studies. But the sampling studies are quite outdated and may require more recent study for increased accuracy. Additionally, since waste composition varies widely from state to state, it is possible that the estimated tonnages are substantially lower from the food actually discarded. Furthermore, yard waste and street sweepings may vary significantly from one season to another, especially if there are abnormally strong or frequent storms, such as hurricane Sandy, that increase the amount of debris and leaves.

5.2.3. Moisture Content of MSW and Liquid Residues in Containers

The moisture content of MSW may be one of the largest factors responsible for the landfill data discrepancy. Materials that are seemingly dry still have a certain level of moisture adsorbed to them and, as shown in Table 12, the weight increase because of moisture content can be appreciable (Table 12 is based on a moisture content study conducted in 2001 by the University of Central Florida). It can be speculated that EPA's estimation would include the moisture content of food, yard, and wood waste, because the tonnages for these waste categories are collected from waste sampling studies. However, it is unknown whether the moisture content of other waste materials is accounted for. It is likely that the materials have less moisture (thus have lower weight) when they are freshly produced and shipped out from the manufacturing facility. As these materials are used, thrown out and exposed to air, their moisture content increases.

Table 11. Moisture Content of Typical Landfilled MSW

Waste Component	% Content in typical MSW	% Moisture Content	Moisture Weight (ton)
Food waste	9%	70%	16,996,173
Paper	34%	6%	5,503,523
Cardboard	6%	5%	809,342
Plastic	7%	2%	377,693
Textile	2%	10%	539,561
Rubber	0.5%	2%	26,978
Leather	0.5%	10%	134,890
Yard waste	18.5%	60%	29,945,638
Wood	2%	20%	1,079,122
Glass	8%	2%	431,649
Tin cans	6%	3%	485,605
Aluminum	0.5%	2%	26,978
Other metals	3%	3%	242,802
Dirt, ashes, etc.	3%	8%	647,473
Total	100%		9,226,494

This is more certain when the waste materials are exposed to precipitation events prior to being landfilled. Because the landfill waste trucks are measured before entering the landfill, on a rainy day the measured weight would be a wet MSW heavier than MSW collected on a dry day. It is possible that the material flows methods uses dry weight of a material (weight of a material when it is freshly produced from a manufacturing facility), and it certainly does not have a way of incorporating the wet weight in case of rain event. This is not to say that the material flows method is wrong in not accounting for increased moisture content. The moisture content may affect the amount of leachate collected but may not necessarily have a big impact on the total volume that the waste takes up in the landfill; however, it can increase the weight of MSW entering a landfill.

The container residue problem that EPA points out also worsens the data gap. The Fact and Figures report states that residues such as paints in paint cans, left over food in plastic containers, liquids in drink cans and bottles are not accounted for in the MSW estimation. As a quick calculation exercise, let us assume that on the average 10% of the liquid content is left in plastic bottles that go to landfills. It is reported that in 2008, water bottle sales reached 30 billion in U.S. For the purpose of this exercise, let's assume 70% are recycled and remaining 30% ended up in landfills; this means 9 billion bottles went to landfills. Assuming these are 16oz bottles, 10% water left over means about 49 g of water is left in each bottle. Then this water residue is responsible for about 440 thousand tons of extra weight. The situation will be similar with soda cans (note 182 billion cans of soda are sold annually in U.S; (Philips, 2008)), food containers, paint cans, and any other containers: it can easily add up to several million tons of weight difference between the MSW entering landfills and EPA's "dry weight" estimates.

5.3. Statistically "Invisible" Wastes

5.2.4. International Parcel

An example of an apparent waste that may be unaccounted for in the material flows method is wrappings and fragile product packaging included in incoming international parcels to U.S. households or offices (relatively small-scale shipping that may not be included in import/export adjustment that EPA makes for the materials flows method). According to a report by Smirti et al., FedEx alone handles 11.5 million pounds (5,750 tons) of international packages every day (Smirti, Boubert, Calloud, & Papson, 2007). When shipping a parcel overseas, an individual is required to report the content of the parcel as well as the weight of the content. Also the overall package weight may be recorded but there is no way of knowing how much package wrapping or shock-absorbent materials are used and generated as waste from daily international shipping activities. It is also uncertain, due to lack of disclosure of methodology, whether the materials coming into the U.S. in this manner are included in EPA's database. It is possible that at least for commercial transactions (orders by online shoppers or business-to-business shipping) there is well-recorded data; however, for private shipping activities (i.e., gift to friends and family, bringing personal belongings from overseas) it is doubtful that the shipped materials are tracked with reasonable residence time applied to them.

5.2.5. Counterfeit Goods Waste

A type of invisible waste that is expected to contribute significantly to the data discrepancy is waste generation related to counterfeit or pirated goods. To those who are unfamiliar with the issues of counterfeit market, it may be difficult to believe that the market is so large that it would significantly affect waste generation; in fact, the U.S. is one of the largest counterfeit "markets with more than $287 billion being exchanged for counterfeit goods in a year (Thompson, Jr., 2004). This accounts for 63% of annual world trade in counterfeit goods (see Table 13).

Table 12. Counterfeit Trade in the World, U.S., and NY in 2003

Row	Region/Country	Value	Basis for Estimate
1	World	**$456 billion**	6% of $7.6 trillion world trade
2	U.S.	**$286.8 billion**	62.9% of $456 billion world trade
3	New York State	**$34.4 billion**	12.0% of $286.8 billion U.S. trade
4	New York City	**$22.9 billion**	8% of $286.8 billion U.S. trade

While there is no documented data as to how many tons and what types of counterfeit goods are coming into U.S., one can sense the sheer volume of it from the dollar exchange value associated with it. Such large inflow of counterfeit goods is a result of inadequate monitoring of large volume of legitimate imported goods (contained in about 8 million 40-foot containers). Considering that most of it is sold to consumers without seizure, these large volume of unregistered consumer goods enter the residential sector and are eventually discarded as MSW. A rather small portion of counterfeit or illegally traded goods is confiscated. The confiscated goods can be, if deemed useful, delivered to impoverished neighborhood or other countries as a form of aid. Otherwise, they are shredded into small pieces and sent to landfills (D'Eon, 2013).

The massive amounts of extra goods that flow into U.S. can also skew the recycling rates for some states. Given the diversity of the counterfeit goods, it is not hard to imagine that many of the goods enter the recycling stream (plastics, metals parts, e-waste, etc.). According to what can be statistically recorded, only so much materials are being produced and legally imported into the states, but off the record, there may be much more material that is recycled. Thus, to accurately gauge the generation of national MSW, counterfeit goods waste should be included in the material flows method database with proper residence times and weights assigned to each material; however, this is simply not possible to do since the trading occurs under the regulatory radar. In the foreseeable future, tonnages of counterfeit goods waste may only be identifiable as tonnage differences between surveyed landfilled wastes and material flows method estimation of landfilled waste.

5.2.6. Imported Glass Bottle and Other Packaging Wastes from Imports

A recent study conducted by the Container Recycling Institute (CRI) points to a large source of waste that may be entering the U.S. from foreign markets. The study predicts that when, for example, a large shipment of imported beer comes to the U.S., only the weight of the bottles and the liquid content inside is accounted for by EPA for the material flows method. There is a problem to this because when beer bottles are imported, they come in six-pack cardboard packaging. These six-pack beer bottles are again tightly contained in corrugated cardboard boxes, which are again put in large wooden containers for international shipment. All of the packaging materials also reach the national shores and have to end up in U.S. landfills or recycling facilities (Collins, 2013). For an accurate estimation of waste generated from imported beer, the associated packaging goods must be accounted for as well.

EPA reported that the packaging wastes from international shipping are accounted for in the materials flow methods for wooden crates, plastic packaging, and paper packaging. But at the same time it also noted the outdated data it has for wooden packaging wastes and the need to update. EPA also speculates that while the data for some of the international shipping packaging wastes may be lost, due to the light weight nature of most of the materials (plastic and paper packaging), it would not have a significant impact on the overall data (US EPA (Hope Pillsbury), 2013). Therefore, the significance of data discrepancy arising from the international shipping wastes depends on how outdated the wooden packaging data is. If large portion of the data is missing from the materials flow method database, it can amount to a significant weight as the U.S. Census Bureau reports about $2250 billion worth of consumption of imports in 2012 (U.S. Census Bureau, 2013).

6. Conclusions and Recommendations for Future National Surveys

The survey of National MSW Generation and Disposition conducted for 2011 data showed that the MSW generation has not changed much from 2008, but recycling and composting rates seem to be on the rise while landfilling decreased by about 20 million tons. However, in comparison to some European and Asian countries who were able to phase out most of landfilling by means of large investments in recycling, composting, and waste-to-energy (WTE), the United States of America still relies heavily on landfilling (63% of MSW disposal) and there is much room to increase the other three methods of MSW disposal. Land is already becoming increasingly scarce and the cost of landfilling is rising. Perhaps, this change alone may slowly increase waste diversion, but it is not enough. Increased public and policymaker awareness of the importance significance of recycling and massive investment and expansion of WTE facilities are needed to bring the U.S. to the level of leading nations in sustainable waste management.

The survey process also revealed that it has become increasingly difficult for the states to collect and compile rekiable recycling and composting data, especially since the economic downturn in 2008 that has played a big role in reducing state budgets and resources. For states to sustainably manage waste and plan ahead to accommodate for increasing waste generation, timely collection and accurate analysis of waste data are the key activities. At the state level, efforts must be made by the environmental agencies of some states to resolve the issue of lack of adequate recycling and composting data and develop systematic data reporting process for all types of waste managing facilities. Also, collaboration of state waste management agencies with the ten regions of the U.S.E.P.A., to develop such processes and standardize reporting format can dramatically improve data collection and analysis.

Meanwhile, in depth state-specific studies of waste infrastructure should be conducted to compare and contrast waste management in each state. This may identify key areas for improvement in future national surveys, and result in survey questionnaires that are customized for a particular group of states.

This study identified several types of wastes that, according to the EPA definition, are not considered to be MSW but they are disposed in MSW landfills. Further study of t is required to quantify the annual generation of these wastes and thereby devise strategies to reduce landfilling and increase resource recovery in the form of materials or energy.

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APPENDIX

Table A1. Recycling Program Options in states

State	Number of counties that rely SOLELY on drop-off recycling centers:*	Number of people served SOLELY by drop-off recycling programs:	Number of counties with PAYT or Volume Based Waste Fees programs that provide incentives to residents to recycle an/a compost:*	Number of people served by PAYT programs:
Alabama	0/67	0	0/67	0
Alaska*				
Arizona	n/a	n/a	n/a	n/a
Arkansas	10	750,000	10	800,000
California	1/58	13,853	262/536	16,596,791
Colorado	29/64	207,708	6/64	95,262
Connecticut	0/169	0	35/169	n/a
Delaware	0	n/a	0	0
District of Columbia	0	0	0	0
Florida	n/a	n/a	2/67	630,000
Georgia	n/a	n/a	n/a	n/a
Hawaii*				
Idaho	n/a	n/a	n/a	n/a
Illinois	n/a	n/a	n/a	n/a
Indiana	n/a	n/a	n/a	n/a
Iowa	304/944	n/a	600/944	n/a
Kansas	n/a	n/a	n/a	n/a
Kentucky	86/120	n/a	1/120	49,393
Louisiana*				
Maine	n/a	n/a	n/a	n/a
Maryland	1	1,732,940	0	n/a
Massachusetts	165/351 (1)	1270071	136/351 (1)	1,696,671
Michigan*				
Minnesota	n/a	n/a	n/a	n/a
Mississippi	22/82	938000	0	0
Missouri*				
Montana	13/56	154,025	1	62,240
Nebraska	n/a	n/a	n/a	n/a
Nevada	39,848	115,000	39,937	0
New Hampshire	n/a	n/a	31/234	164,500
New Jersey	0/21	n/a	0/21	80,251
New Mexico	26/33	971,719	1/33	29,514
New York	n/a	n/a	n/a	n/a
North Carolina	82/100	n/a	22	n/a
North Dakota	50	550,000	3	100,000
Ohio	18/88	879,295	33/88	n/a
Oklahoma*				
Oregon	0	731,074	1	3,831,074
Pennsylvania	4/67	1,881,251	n/a	n/a
Rhode Island	10/39	90,700	10/39	n/a
South Carolina*				
South Dakota	10/66	63,515	1/66	13,646
Tennessee	70/95	4,000,000	0/95	0
Texas	n/a	n/a	n/a	n/a
Utah	23/29	n/a	1	n/a
Vermont	7/15	98,400	n/a	n/a
Virginia*				
Washington	11/39	907,813	39/39	6,724,540
West Virginia*				

Wisconsin	n/a	n/a	n/a	n/a
Wyoming	17/23	290,000	39,866	90,000

*   State did not participate in the survey

n/a   data not available (state does not have the data)

(1) municipalities

Table A2. Banned Materials from MSW Landfills

State	Leaves	Grass	Brush	Recyclable Containers	Gas Bottles	Recyclable Paper	Whole Tires	Used Oil	Lead-Acid Batteries	White Goods	Electron-ics	C & D	Oth
Alabama	No	No	No	No	No	No	No	Yes	Yes	No	No	No	
Alaska*(1)								Yes	Yes				
Arizona	n/a	n/a	n/a	n/a	n/a	n/a	Yes(1)	Yes(1)	Yes(1)	n/a	n/a	n/a	
Arkansas	Yes	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
California	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	
Colorado	No	No	No	No	No	No	Yes	Yes	Yes	No	Yes	No	
Connecticut	No	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	No	[8
Delaware	Yes	Yes	Yes	No	No	No	Yes	Yes	n/a	No	No	No	
D.C.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Florida	No	No	No	No	No	No	Yes	Yes	Yes	Yes	no	Yes	
Georgia*[2]	Yes [3]	Yes	Yes				Yes	Yes	Yes				
Hawaii*							Yes*						
Idaho	No	No	No	No	No	No	Yes	n/a	Yes	No	No	No	
Illinois	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	
Indiana	Yes	Yes	Yes	n/a	n/a	n/a	Yes	n/a	n/a	n/a	n/a	n/a	
Iowa	Yes	Yes	Yes	No	Unknown	no	Yes	Yes	Yes	No	No	No	
Kansas	No	No	No	No	No	No	Yes	Yes	No	No	No	No	
Kentucky	No	No	No	No	No	No	Yes	No	Yes	Yes	No	No	
Louisiana* [1]							Yes	Yes	Yes	Yes			
Maine	n/a	n/a	n/a	n/a	n/a	n/a	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	n/a	
Maryland	Yes	Yes	Yes	n/a	n/a	n/a	Yes	Yes	n/a	n/a	n/a	n/a	[9
Massachusetts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Michigan*[2]	Yes	Yes	Yes	Yes[4]			Yes	Yes	Yes				
Minnesota	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	n/a	
Mississippi	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No	
Missouri*[1]	Yes	Yes	Yes				Yes	Yes	Yes	Yes			
Montana	No	No	No	No	No	No	No	Yes	No	No	No	No	
Nebraska	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	No	
Nevada	No	No	No	No	No	No	No	Yes	Yes	No	No	No	[1
New Hampshire	Yes	Yes	Yes	No	No	No	No	No	Yes	No	Yes	No	
New Jersey	Yes	No	No	No	No	No	No	No	No	No	Yes	No	
New Mexico	No	No	No	No	No	No	No	Yes	Yes	No	no	No	
New York	No	No	No	No	No	No	Yes	No	Yes	No	Yes	No	[1
North Carolina	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	[1
North Dakota	n/a	No	No	No	No	No	No	Yes	Yes	Yes	No	No	[1
Ohio	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	No	
Oklahoma*													
Oregon	no	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	[1
Pennsylvania	Yes	No	No	Unknown	No	Unknown	Yes	Yes	Yes	No	Yes	No	
Rhode Island	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
South Carolina* [1][5]	Yes	Yes	Yes				Yes	Yes	Yes	Yes			
South Dakota	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	No	
Tennessee	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No	
Texas	n/a	n/a	n/a	n/a	n/a	n/a	Yes	Yes	Yes	n/a	n/a	n/a	[1
Utah	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No	
Vermont	n/a	n/a	n/a	n/a	n/a	n/a	Yes	Yes	Yes	Yes	Yes	n/a	[1
Virginia*[1]							Yes		Yes		Yes		
Washington	No	No	No	No	No	No	No	No	No	No	No	No	
West Virginia^[2]	Yes[6]	Yes	Yes				Yes	Yes	Yes				
Wisconsin	Yes[1]	Yes[1]	Yes[1][7]	Yes[1]		Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]			
Wyoming	No	No	No	No	No	No	No	No	No	No	No	No	

* State did not participate in the survey
n/a did not provide an answer
[1] 2008 data
[2] 2006 data
[3] yard trimmings are banned from landfills designed and built to Subtitle D standards
[4] Beverage containers are banned
[5] Banned materials are banned from Class 3 disposal
[6] Landfills can get a waiver for yard trimmings if there is no composting facility nearby
[7] Brush with a diameter smaller than 6-inches is banned from disposal
[8] NiCd rechargeable batteries; automobiles; contained gaseous waste;friable asbestos; liquid wastes; mercuric oxide batteries; paint; untreated infectious wastes; mercury thermostats (banned from disposal starting July 1, 2014); hazardous waste; radioactive waste
[9] controlled hazardous substances, liquid waste, special medical waste, radioactive hazardous substances, automobiles, drums or tanks, animal carcasses, untreated septage or sewage, chemical or petroleum cleanup material
[10] Liquids
[11] Mercury containing products and bulk liquids
[12] Oil filters, oyster shells, wooden pallets
[13] Scrap metals
[14] Vehicles
[15] bulk & non containerized liquid waste
[16] Mercury added products, paint, rechargable batteries & nickel cadmium batteries, flourescent light bulbs, CRTs, untreated medical waste

Table A3. State Solid Waste Management Agencies and Representatives who Participated and Contributed to the 2013 National Solid Waste Survey Effort

Scott Story	**Alabama**	**Department of Environmental Management**
Robert Hunter	Arkansas	Department of Environmental Quality
Linda Mariner	Arizona	Department of Environmental Quality
Nancy Carr	California	CalRecycle, Policy Development and Analysis Office Knowledge Integration Section
Wolf Kray	Colorado	Department of Public Health & Environment Hazardous Material and Waste Management Division
Judy Belaval	Connecticut	
Hallie Clemm	District of Columbia	Department of Public Works Solid Waste Management Administration
Anne Germain	Delaware	Solid Waste Authority
Shannan Reynolds	Florida	Department of Environmental Protection Waste Reduction Section
Dean Ehlert	Idaho	Department of Environmental Quality Solid Waste Program
Ellen Robinson	Illinois	Environmental Protection Agency Bureau of Land #24, Waste Reduction & Compliance Section
Nicholas Staller	Indiana	Department of Environmental Management Office of Land Quality Regulatory Reporting Section
Becky Jolly	Iowa	Department of Natural Resources Land Quality Bureau, Environmental Services Division
Christine Mennicke	Kansas	Department of Health and Environment Bureau of Waste Management
Gary Logsdon	Kentucky	Recycling and Local Assistance Branch Division of Waste Management, Energy and Environment Cabinet
Carole Cifrino	Maine	Department of Environmental Protection
John Fischer	Massachusetts	Department of Environmental Protection
David Mrgich	Maryland	Department of Environment
Arlene Vee	Minnesota	Pollution Control Agency
Matt Flechter	Michigan	Department of Environmental Quality
Mark Williams	Mississippi	Department of Environmental Quality
Kathy O'Hern	Montana	Department of Environmental Quality
Steve Danahy	Nebraska	Department of Environmental Quality
Connie Pasteris	New Mexico	Environment Department Solid Waste Bureau
Scott Mouw	North Carolina	Department of Environment and Natural Resources
Steve Tillotson	North Dakota	Department of Health Division of Waste Management
Sharon Yergeau	New Hampshire	Department of Environmental Services Solid Waste Management Bureau, Waste Management Division
Ross M. Hull	New Jersey	Department of Environmental Protection Bureau of Recycling & Planning
Chester Sergent	Nevada	Division of Environmental Protection Bureau of Waste Management, Elite Solid Waste Branch
Richard Clarkson	New York	NYS Department of Environmental Conservation
Ernie Stall	Ohio	Environmental Protection Agency Division of Materials and Waste Management

Peter Spendelow	Oregon	Oregon Department of Environmental Quality
Michael Texter	Pennsylvania	Department of Environmental Protection Bureau of Waste Management
Mike McGonagle	Rhode Island	Resource Recovery Corporation
Steven Kropp	South Dakota	Department of Environment & Natural Resources Waste Management Program
Nick Lytle	Tennessee	Department of Environment & Conservation
Diane Barnes	Texas	Commission on Environmental Quality Municipal Solid Waste Permits Section, Waste Permits Division
Ralph Bohn	Utah	Department of Environmental Quality Division of Solid and Hazardous Waste
Bryn Oakleaf	Vermont	Agency of Natural Resources
Gretchen Newman	Washington	Department of Ecology Waste 2 Resources Program
Craig McOmie	Wyoming	Department of Environmental Quality