More Jobs, Less Pollution:
Growing the Recycling Economy in the U.S.

Prepared by: Tellus Institute with Sound Resource Management

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KEY FINDINGS

This study provides strong evidence that an enhanced national recycling and composting strategy in the United States can significantly and sustainably address critical national priorities including climate change, lasting job creation, and improved health. Achieving a 75 percent diversion[1] rate for municipal solid waste (MSW) and construction and demolition debris (C&D) by 2030 will result in:

- A total of 2.3 million jobs: Almost twice as many jobs as the projected 2030 Base Case Scenario, and about 2.7 times as many jobs as exist in 2008. There would be a significant number of additional indirect jobs associated with suppliers to this growing sector, and additional induced jobs from the increased spending by the new workers.

- Lower greenhouse gas emissions: The reduction of almost 515 million metric tons of carbon dioxide equivalent ($eMTCO_2$) from diversion activities, an additional 276 million $eMTCO_2$ than the Base Case, equivalent to shutting down about 72 coal power plants or taking 50 million cars off the road.

- Less pollution overall: Significant reductions in a range of conventional and toxic emissions that impact human and ecosystem health.

- Unquantified benefits of reducing ecological pressures associated with use of non-renewable resources, conserving energy throughout the materials economy, and generating economic resiliency through stable, local employment.

EXECUTIVE SUMMARY

We face a series of crises in America today. Nationwide unemployment currently hovers just below 10 percent. Climate change is already disrupting the American economy and will have greater impacts in coming years, and a range of pollutants continue to degrade our ecosystems and burden public health. Transforming the "waste sector" into a "materials management sector" will create more jobs, reduce greenhouse gas emissions that cause climate change, and lower other types of pollution and related public health consequences.

While the vast majority of municipal solid waste can be readily recycled, re-used, or composted, only 33 percent is currently diverted from disposal. Most of our discards are still sent to landfills and incinerators.

While waste diversion nationally is relatively low, because of the sheer size of the waste stream, recycling has grown into an important part of the U.S. economy. Moreover, a number of cities have achieved considerably higher waste diversion rates and provide successful models that show a path to a significantly stronger recycling economy.

This report assesses the impacts of implementing a bold national recycling and composting strategy in the United States over the next two decades. Specifically, we explore the impact on jobs and environmental pollutants if the U.S. were to achieve a 75 percent national waste diversion rate by 2030.

The report analyzes both municipal solid waste (MSW), as well as construction and demolition debris (C&D). MSW is generated by households as well as commercial and institutional entities. It does not include industrial waste. C&D is generated from construction and demolition activities in the residential and commercial sectors. Although less visible than MSW, C&D debris is included in this analysis because of its importance relative to MSW (building-related C&D alone is roughly 70 percent as large as MSW generation) and because it presents strong opportunities for reuse and recycling.

To conduct the analysis, we compared two waste management scenarios: the "Base Case Scenario," characterized by a continuation of current practices and trends over the next two decades, and the "Green Economy Scenario," based on a national enhanced recycling and composting strategy that achieves an overall diversion rate of 75 percent by 2030.

THE CURRENT WASTE STREAM

In order to construct the alternative scenarios for 2030 we must first understand the magnitude and composition of the existing waste stream. In terms of MSW, five materials comprise about 77 percent of the almost 250 million tons of total MSW generated in 2008: paper and paperboard, yard waste, food scraps, plastics, and metals. Organic components made up about 64 percent of total 2008 MSW generation.[2]

Specific materials are recovered for recycling and composting at very different rates. As summarized in Figure ES-1, the U.S. diverted approximately 33 percent of MSW in 2008. This is considerably below the diversion rates of many cities and states with robust recycling and composting programs, leaving considerable room for additional diversion.

In addition to MSW, 178 million tons of C&D waste was generated in 2008. The C&D stream includes wastes generated from demolition, renovation, and new construction. Two materials dominate C&D waste and comprise roughly 70 percent of the total: concrete and mixed rubble (45 percent), and wood (25 percent). In 2008 approximately 30 percent of C&D debris generated in the U.S. was diverted (recycled) and 70 percent was disposed.[3] Virtually all recovered C&D waste was recycled; almost none was composted. Similarly, virtually all C&D disposal was via landfill and very little was incinerated. As with MSW, much higher C&D diversion rates have been achieved in various jurisdictions throughout the U.S., indicating that there are significant opportunities for increased diversion on a national scale.

2030 BASE CASE SCENARIO

The Base Case Scenario represents a "business as usual" approach to solid waste management in which current practices and trends continue until 2030. No major new policy interventions or lifestyle changes are introduced, and most basic assumptions remain unchanged.

Based on trends over the past decade, per capita MSW generation is projected to remain unchanged from 2008 levels (1,697 lbs. per person),[4] and population is expected to grow from 304 million in 2008 to 374 million in 2030.[5] Thus, the overall MSW stream is expected to grow at the rate of population growth, from 250 million tons in 2008 to about 314 million tons in 2030. In addition, the modest growth in the MSW diversion rate that has been experienced in the U.S. over the past decade (one percent per year) is assumed to continue, reaching 41 percent in 2030 in the Base Case Scenario.

Similar projections are made for C&D in the Base Case Scenario, based on the best available data. As a result, C&D generation is projected to reach almost 219 million tons in 2030. The diversion rate increases to 37 percent by 2030, accounting for almost 82 million tons, while 137 million tons of C&D continues to be disposed in landfills.

THE GREEN ECONOMY SCENARIO

The Green Economy Scenario is based on the same assumptions used in the Base Case in terms of the growth of MSW and C&D, driven by expected population growth through 2030. The fundamental difference is that the Green Economy Scenario **reflects an overall waste diversion rate of 75 percent**. This figure represents what is achievable through implementation of a set of enhanced policy, regulatory, and lifestyle changes to reach this level of recycling and composting. Though considered aggressive by today's practices, the policies, regulations and behavior changes driving this scenario are based on what are considered "best practices" currently in place in a number of jurisdictions in the U.S. and abroad.

While we do not attempt to provide detailed descriptions of each of the specific best practices and their respective impacts on emissions and jobs in the Green Economy Scenario, we do provide examples of the kinds of policy, regulatory, and lifestyle initiatives that will be necessary to achieve the higher level of recycling and composting in this Scenario.

Figures ES-1 and ES-2, below, provide a comparative summary of the MSW and C&D waste flows and management practices in 2008 and for the two scenarios in 2030.

Figure ES-1
U.S. MSW Waste Flows

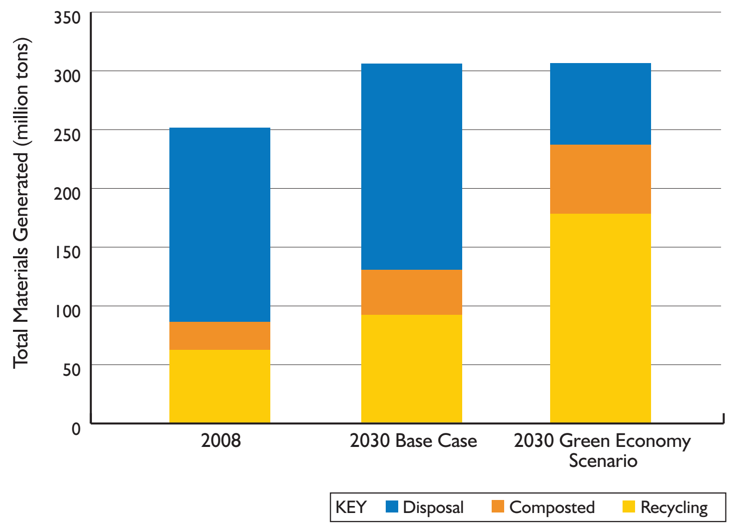
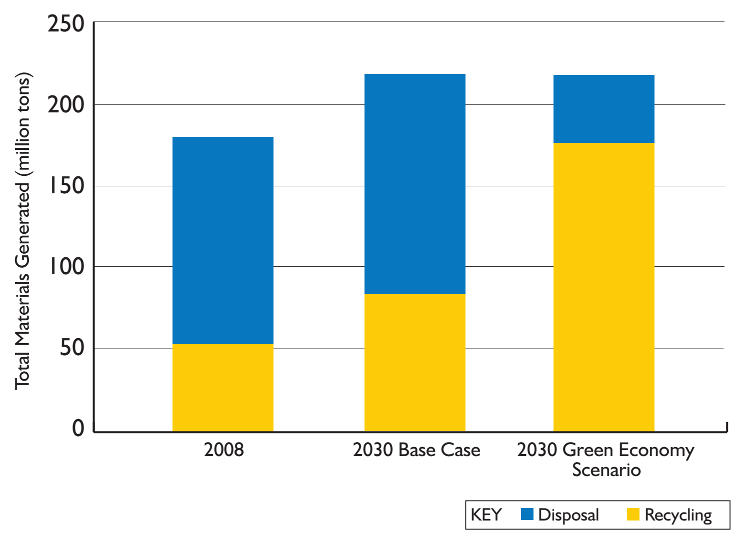


Figure ES-2
U.S. C&D Waste Flows



JOB CREATION IMPACTS

Based on the waste stream characteristics and management practices developed for the Base Case and Green Economy Scenarios, the employment implications of each scenario were analyzed. The analysis includes the various stages of materials management including collection, hauling, and processing (if any), as well as the ultimate disposition of the collected materials through reuse/remanufacturing, new product manufacturing, composting, or disposal via landfilling or incineration.

Based on several existing data sources[6] we derived estimates of jobs produced per 1,000 tons of MSW managed for each of the diversion and disposal management activities (collection, processing, manufacturing, reuse/remanufacturing, landfilling, and incineration), for each material in the waste stream (paper, glass, metals, plastics, rubber, textiles, wood, food scraps, yard trimmings, miscellaneous organic wastes, and other wastes).

In addition to job impacts from waste disposal (landfilling and incineration), we estimate job creation for three categories of recycling: (1) Recycling Industries, including collection and processing of recyclables to make them available for use in new industrial processes; (2) Recycling Reliant Industries, including industries that purchase secondary materials from the Recycling Industry; and (3) Reuse and Remanufacturing Industries, including those industries that directly reuse and/or remanufacture products for their original use.

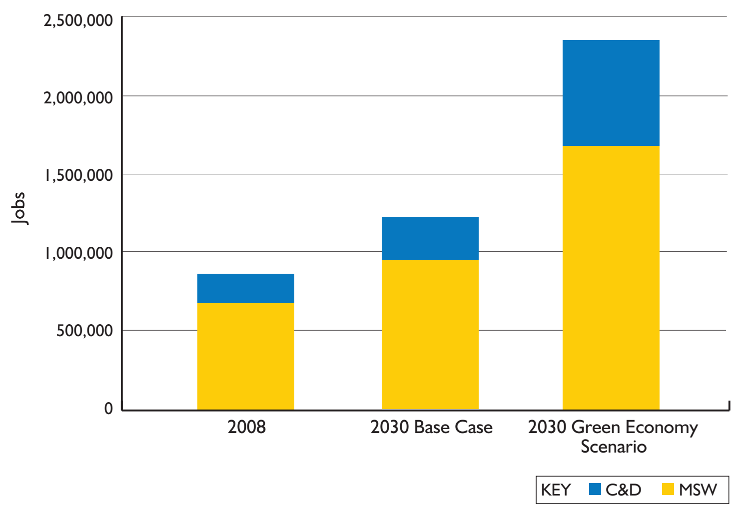
The job creation data reveal that waste disposal is not labor intensive and generates the fewest jobs per ton of waste (0.1 job per 1,000 tons) for the various management activities. This is not surprising given that the capital intensive equipment used at disposal facilities can handle large tonnages with few employees. Materials collection also generates relatively few jobs, but more than disposal.

> The Green Economy Scenario with a 75 percent diversion rate generates 2,347,000 total direct jobs—over 1.1 million more jobs than in the Base Case, and nearly 1.5 million more jobs than in 2008.

Processing of recyclables (2 jobs per 1,000 tons) and organics (0.5 jobs per 1,000 tons) is somewhat more labor intensive. Manufacturing using recycled materials creates a relatively high number of jobs per 1,000 tons, varying by material/sector (e.g., about 4 jobs per 1,000 tons for paper manufacturing and iron and steel manufacturing, and about 10 jobs per 1,000 tons for plastics manufacturing). Though relatively small tonnages of material are involved, MSW reuse and remanufacturing activities are particularly job intensive owing to the labor required for disassembly, inspection, repair/refurbishment, reassembly, and testing.

The job creation impacts of the Base Case and Green Economy Scenarios are summarized below in Figure ES-3.

Figure ES-3
Total MSW and C&D Job Impacts



In 2008 there were approximately 861,000 jobs directly associated with the management of MSW and C&D (666,000 and 195,000, respectively). Though more than two-thirds of MSW and C&D waste was disposed in 2008, only about 15 percent of the jobs associated with managing these wastes were from disposal related activities (collection and landfilling or incineration). By contrast, because of the labor intensity of waste diversion, 85 percent of the jobs were associated with various diversion activities (collection, processing, manufacturing with recycled materials, and composting). Jobs associated with manufacturing using recycled inputs accounts for about 44 percent of the total jobs created related to MSW management and 24 percent of C&D management related jobs. Recycled material collection and processing also creates a significant fraction of the overall jobs for both MSW (37 percent) and C&D (33 percent).

In the Base Case Scenario, due to growth in the waste stream and modest increases in the recycling and composting rate (from 33 percent to 41 percent), about 368,000 incremental jobs are created by 2030, resulting in a total of almost 1,229,000 jobs associated with the management of both the MSW and C&D waste streams. Due to the increase in the recycling rates, diversion related activities account for about 89 percent of the total jobs.

In contrast, **the Green Economy Scenario with a 75 percent diversion rate generates 2,347,000 total direct jobs in 2030—over 1.1 million more jobs than in the Base Case, and nearly 1.5 million more jobs than in 2008**. The combination of the higher diversion rate and the relative labor intensity of diversion activities means that in the Green Economy Scenario 98 percent of total waste management jobs are related to MSW & C&D diversion activities and only 2 percent are associated with disposal. Manufacturing jobs using recycled materials accounts for the largest share by far of the projected jobs in 2030; 49 percent of MSW management jobs and about 44 percent of C&D related jobs. We provide a detailed breakdown of job creation by management activity in the report.

ENVIRONMENTAL EMISSION IMPACTS

An increased diversion rate not only spurs job creation, but also significantly reduces greenhouse gas emissions that contribute to climate change, as well as emission of toxic pollutants that are dangerous to human lives and our ecosystems.

To assess the relative environmental impacts of the Base Case and Green Economy waste management scenarios in 2030 we utilized the Measuring Environmental Benefits Calculator (MEBCalc) model, a life-cycle assessment (LCA) tool.[7] The model employs a life-cycle approach to capture the input of energy and the output of wastes and pollution that occur not just at the end of use, but over the three phases of a material's or product's life cycle:

- Upstream phase: resource extraction, materials refining, and product manufacture;
- Use phase: product use; and
- End-of-life phase: management of product discards.

This approach accounts for how reuse and recycling eliminate the need for much of the upstream phase, thereby conserving energy and reducing waste and pollutants in the production of goods and services, in addition to the benefits achieved in the end of life phase.

> The Green Economy Scenario represents a powerful opportunity to reduce the human health and ecosystem impacts of pollution from waste management activities.

For key materials in the MSW and C&D streams the methodology aggregates pollutants for seven environmental impact categories in the following indicator pollutants:

- Climate change – carbon dioxide equivalents (eCO_2);
- Human health-particulates – particulate matter less than 2.5 microns equivalents ($ePM_{2.5}$);
- Human health-toxics – toluene equivalents (eToluene);
- Human health-carcinogens – benzene equivalents (eBenzene);
- Eutrophication – nitrogen equivalents (eN);
- Acidification – sulfur dioxide equivalents (eSO_2); and
- Ecosystems toxicity – herbicide 2,4-D equivalents (e2,4-D).

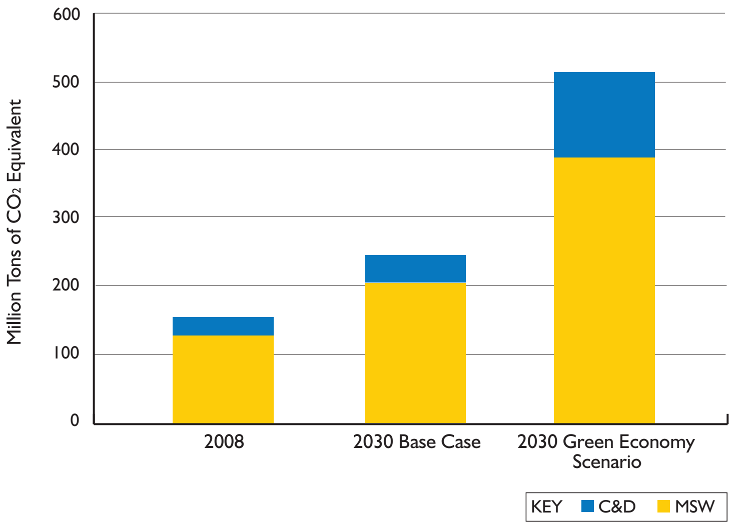
> The Green Economy Scenario avoids about 515 million $eMTCO_2$ in 2030, more than twice as much as the Base Case.

For each of the seven emissions categories modeled, the assessment indicates that recycling/composting reduces emissions considerably relative to waste disposal. These environmental benefits come primarily from pollution reductions in the manufacture of new products with recycled materials instead of virgin raw materials, and the replacement of synthetic petroleum-based fertilizers with compost. For most pollutants, the relative upstream benefits of diversion are quite dramatic. For example, recycling reduces energy-related eCO_2 emissions in the manufacturing process and avoids emissions from waste management. Moreover, in the case of paper, recycling maintains the ongoing sequestration of carbon in trees that would otherwise need to be harvested to manufacture paper. **Given the prominence of climate change in current U.S. and global policy debates, the impacts of the**

different waste management scenarios on greenhouse gas emissions is important.

Figure ES-4, below, presents the relative GHG savings that accrue from diversion activities in the MSW and C&D management systems.

Figure ES-4
Climate Change Emissions Reductions from Diversion



MSW and C&D diversion activities in 2008 reduced GHG emissions about 153 million $eMTCO_2$. In the Base Case Scenario the modest growth in recycling rates combined with a growing waste stream result in annual GHG emission reductions in 2030 of about 238 million $eMTCO_2$, while in the Green Economy Scenario GHG reductions of about 515 million eMTCO2 are achieved. This is equivalent to shutting down about 72 coal-fired power plants or taking 50 million cars off the road.[8]

The high organic content of MSW (paper and paperboard, yard waste, food scraps, and plastics) means that diversion of MSW accounts for the vast majority of GHG emission reductions. By contrast, C&D waste has a considerable fraction of inorganic material (concrete, rubble, brick), so C&D diversion contributes only about 15 percent of overall GHG reductions in the Base Case Scenario and 25 percent in the Green Economy Scenario. The somewhat higher fraction from C&D diversion in the Green Economy Scenario is driven by the increased recycling/reuse of wood and, to a lesser extent, plastics.

The results of the analysis are similar for human health and ecosystem related impacts. For example, Figures ES-5 and ES-6 summarize the relative emission reduction benefits of the Base Case and Green Economy Scenario for particulate emissions (less than 2.5 microns equivalents, $ePM_{2.5}$) associated with respiratory illnesses and for sulfur dioxide (eSO_2) that leads to ecosystem degradation in terms of acidification of water bodies. As with GHGs, the reductions in emissions of these pollutants in the Green Economy Scenario are significantly greater than those in the Base Case. This trend follows for the other pollutant emissions measured in this study. **The Green Economy Scenario, therefore, represents a powerful opportunity to reduce the human health and ecosystem impacts of pollution from waste management activities.**

Figure ES-5
Respiratory Emissions Reductions from Diversion

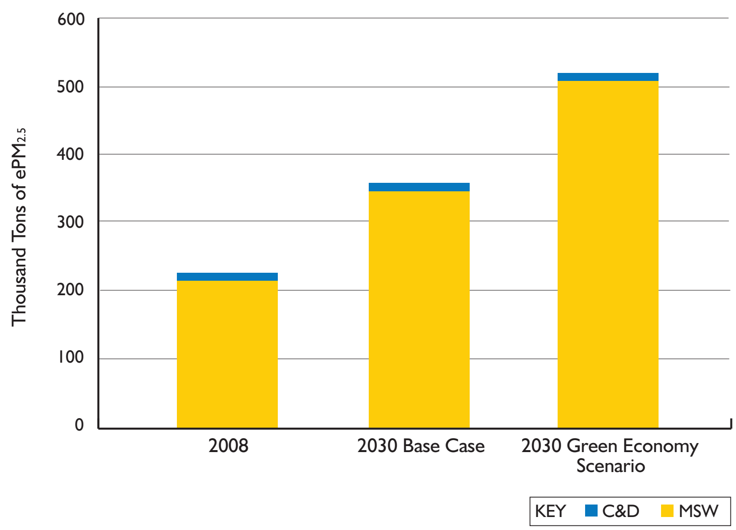
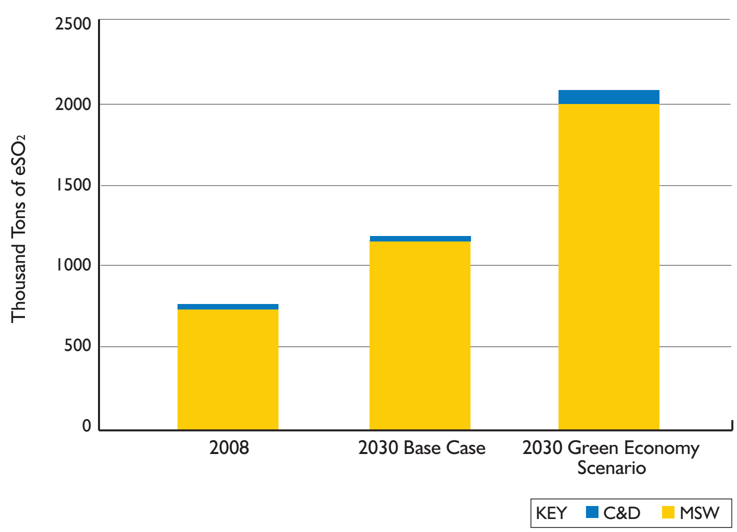


Figure ES-6
Acidification Emissions Reductions from Diversion



I. INTRODUCTION

There is growing recognition and urgency surrounding a series of environmental and economic challenges facing the United States. In the environmental arena these include climate change, natural resource depletion, an increasing proliferation of wastes, toxics contamination and destruction of essential ecosystems. On the economic front, they include volatile energy and commodity prices as well as continued high unemployment. These challenges are multifaceted and require new approaches that transform existing practices from those that are resource intensive, polluting, and produce few jobs to those that minimize use of virgin materials, are environmentally preferable and create significant job opportunities.

The current solid waste management system in the U.S. presents an excellent opportunity to encourage such a shift. A new "materials management" paradigm recognizes the important link between our consumption patterns, waste generation, environmental emissions and jobs. It places greater emphasis on reducing virgin material inputs; encompasses a deeper level of waste reduction through reuse, recycling and composting; and has the potential for significant reductions in greenhouse gas emissions (and other toxics), while at the same time creating large numbers of new jobs throughout the U.S.

This report assesses the impacts of implementing a bold national recycling strategy in the United States over the next two decades. Specifically, we explore the impacts on jobs and on certain environmental emissions of achieving a 75-percent waste diversion rate by 2030. By "diversion" we mean diversion from waste disposal either in landfills or incineration facilities. Waste diversion approaches include waste reduction, reuse and remanufacturing, recycling and composting.

To conduct the analysis, we compared two waste management scenarios, one based on continuing current practices, and the other reflecting 75-percent diversion through significantly enhanced recycling and composting efforts.[9]

There are many data gaps and related challenges in carrying out such an analysis. In conducting this study we have relied on existing data from federal, state and local agencies; non-governmental organizations; consultant reports; and academic papers. To the extent feasible, we used standard sources frequently cited in the field, such as information produced by the U.S. EPA, the U.S. Department of Labor, the U.S. Department of Commerce, the U.S. Census Bureau and various state environmental agencies, as well as data developed by the National Recycling Coalition and others.

ORGANIZATION OF THIS REPORT

Following this Introduction, Section II presents an overview of 2008 waste generation, composition and management practices for municipal solid waste (MSW) and construction and demolition (C&D) debris. It documents the specific materials that comprise each of these two waste streams, how much of each material type is generated, and how much of each material is recycled, composted and disposed. This provides the starting point for the assessment of alternative future scenarios.

Section III describes the "Base Case" Scenario in which the current waste generation, composition and management profile is projected to 2030. In the Base Case no major new policy interventions or lifestyle changes are introduced. Rather, it can be characterized as "business-as-usual," where current practices and trends continue. In Section IV, an alternative scenario is presented that reflects an overall waste diversion rate of 75 percent. This Green Economy Scenario is defined normatively, meaning it represents what is achievable through implementation of an enhanced set of policy, regulatory and lifestyle changes to achieve this level of recycling and composting.

Based on the profile of waste stream characteristics and management practices developed for the Base Case and Green Economy Scenarios, Section V assesses and compares the employment implications of each scenario. This analysis covers the various stages of materials management, including collection, hauling and processing, if any, as well as the ultimate management of the collected materials through reuse/remanufacturing, new product manufacturing, composting, or disposal via landfilling or incineration.

Section VI assesses the life-cycle environmental impacts of the alternative scenarios. By applying the Measuring Environmental Benefits Calculator (MEBCalc), it compares the emissions of greenhouse gases and various other pollutants associated with the alternative materials management practices of the two scenarios.

Finally, Section VII presents a summary of our findings, discusses key policy implications and identifies areas requiring further research.

II. CURRENT WASTE GENERATION, COMPOSITION & MANAGEMENT

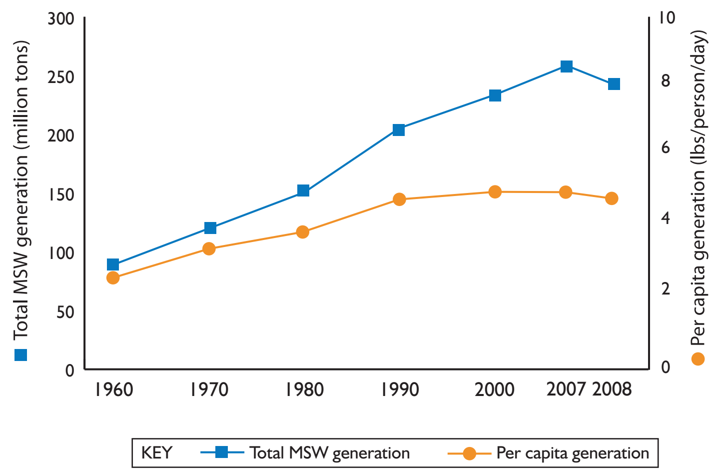
Before analyzing alternative waste management scenarios, we need to understand the magnitude and composition of the current municipal solid waste (MSW) and construction and demolition debris (C&D) waste streams and how they are managed. This involves characterizing the materials that comprise these waste streams, the tonnage of each material type that is generated, and how much of each material is currently recycled,[10] composted or disposed.

The waste streams considered include both MSW and C&D. It does not include industrial or agricultural wastes. As described in the report, MSW is generated by households as well as commercial and institutional entities. C&D is generated from construction and demolition activities in the residential and commercial sectors. Though it is often overlooked by the public and many policymakers, C&D debris is included in this analysis because of its importance in the overall waste stream: building-related C&D alone is roughly 70 percent as large as MSW generation.[11] Inclusion of C&D, therefore, is important in assessing alternative waste management scenarios and developing a comprehensive materials management program.

A. 2008 MUNICIPAL SOLID WASTE (MSW)

Total MSW generation in the U.S. has been steadily growing over the past several decades (notwithstanding a minor drop in 2008, likely related to the severe economic recession), with 2008 generation of about 250 million tons.[12] At the same time, per-capita generation has grown much more slowly, reaching 4.5 pounds per person per day (lbs/person/day) in 1990 and it has hovered between 4.4. and 4.6 lbs/person/day since that time (see Figure 1). Given the known demographic trends in the U.S. over the past 20 years, it appears that increases in MSW generation over this period have been driven primarily by population growth.

Figure 1
MSW Generation Rates, 1960 to 2008

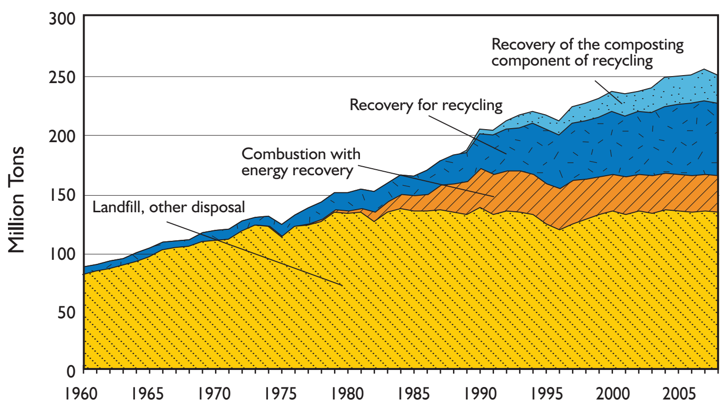


As summarized in Figure 2, the EPA data reveal several trends in U.S. waste management practices over the past several decades:

- Recycling played a minor role in waste management through the 1970s, grew rapidly in terms of tonnage and percent of the waste stream in the 1980s and 1990s, and has leveled off since about 2000. Recycling managed about 24 percent of the waste stream in 2008.
- Composting was negligible until the late 1980s, grew rapidly in the 1990s and has continued to grow modestly since 2000. Composting managed less than 9 percent of the waste stream in 2008.
- MSW incineration was minimal until the mid-1980s, when the vast majority of the plants currently operating were constructed, grew modestly in the 1990s, and has declined modestly both in terms of tonnage and percent of the waste stream since 2000, to less than 13 percent of the waste stream in 2008.
- As the waste stream has grown over the years, the

relative importance of landfill disposal in terms of the fraction of the waste stream managed declined rapidly in the 1980s and 1990s, with only very modest declines since 2000. As of 2008, landfills managed about 54 percent of the total waste stream. In terms of tonnage the amount sent to landfills has been remarkably stable since about 1980.

Figure 2
U.S. MSW Management, 1960 to 2008



A more detailed summary table of MSW generation and management by material type is included in Appendix A.

Figure 3
U.S. MSW Management, 2008
(1000 tons)

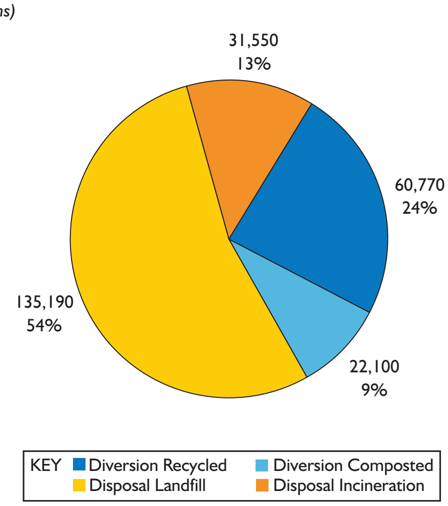


Table 1 provides a profile of more than a dozen major types of materials generated[13] and the tonnage for each material for 2008, the most recent year for which data are available.

Table 1
MSW Generation in the U.S. – 2008

MATERIALS	1000S OF TONS	SHARE OF TOTAL MSW
Materials in Products		
Paper & Paperboard	77,420	31%
Glass	12,150	5%
Metals		
Ferrous	15,680	6%
Aluminum	3,410	1%
Other Nonferrous	1,760	1%
Plastics	30,050	12%
Rubber & Leather	7,410	3%
Textiles	12,370	5%
Wood	16,390	7%
Other**	4,500	2%
Total Materials in Products	***181,140***	***73%***
Other Wastes		
Food Scraps	31,790	13%
Yard Trimmings	32,900	13%
Misc. Inorganic Wastes	3,780	2%
Total Other Wastes	***68,470***	***27%***
Total MSW Generated	**249,610**	**100%**

As summarized in Figure 3, of the 250 million tons of MSW generated in the U.S. in 2008, 63 percent was disposed of in landfills or incinerators while 37 percent was diverted through recycling or composting.

Key Points Regarding 2008 MSW Generation and Management

Based on the data summarized above, the following key points about MSW generation and management in 2008 should be highlighted:

- *Five materials comprise about 77 percent of the almost 250 million tons of total MSW generated in 2008:*

Material	*2008 Tonnage (millions)*	*% Total*
Paper and paperboard	*77*	*31%*
Yard waste	*33*	*13%*
Food scraps	*32*	*13%*
Plastics	*30*	*12%*
Metals (3 types)	*21*	*8%*
Totals	*193*	*77%*

- *Organic components of the waste stream (yard trimmings, food scraps, paper and paperboard, and wood) comprise approximately 64 percent of total 2008 MSW generation.*
- *Materials are recovered for recycling and composting at very different rates. For example, almost 69 percent of nonferrous metals and 55 percent of paper/paperboard is recycled, while only 7 percent of plastics and 10 percent of wood is recycled. About 65 percent of yard trimmings are composted compared with less than 3 percent of food scraps.*
- *A 33-percent MSW diversion rate lags well below what might be considered "best practice" in the U.S. Numerous municipalities and states (and other countries) have achieved much higher diversion rates, especially those adopting a "zero waste" or "materials management" policy framework (e.g., Massachusetts, Oregon, San Francisco, Seattle).*

This profile of existing generation and diversion by material type is critical input for identifying the target materials and programs that can lead to much more robust MSW recycling and composting, as described in the Green Economy Scenario in Section IV.

B. 2008 CONSTRUCTION AND DEMOLITION DEBRIS (C&D)

C&D debris is material that is generated in the construction, renovation or demolition of structures. C&D debris comprise a significant fraction of the overall solid waste stream[14] (40 percent or more in most estimates) and is, therefore, important to address in an assessment of the jobs and environmental impacts of alternative material management scenarios.

There is not, however, a consensus definition of what is included in the C&D waste stream and what is excluded. Broadly defined, structures that generate C&D include buildings (both residential and non-residential), as well as infrastructure such as roads and bridges. It may also include land-clearing debris related to construction-site preparation. Different jurisdictions have adopted different definitions, hampering consistent data reporting and collection. Moreover, even within building-related C&D, new construction, renovation and demolition each generate somewhat different waste streams, as do residential versus non-residential buildings. Further complicating the C&D data and analysis picture is the fact that sometimes, particularly in rural areas, C&D debris is comingled with MSW.

Thus, it is not surprising that unlike for MSW, there is not a single widely accepted source for up-to-date data on C&D debris generation, composition and management. For the current study, we have focused on building-related C&D, as this is included in virtually all definitions, and to date it has been the focus of EPA's efforts to assemble the disparate sources of data and analyze national C&D generation and management activities.

EPA acknowledges that "Limited information is available on the amount of C&D materials generated and managed in the U.S." and that "efforts to improve C&D measurement are currently hampered by a general lack of data. Thus, it should be recognized that the C&D materials estimates presented to date, including those [assembled by EPA]…have some level of uncertainty…Nevertheless, we believe that the estimates contained in this report reflect and are based on the best data that are currently available."[15, 16]

According to EPA data, demolition generates the largest share of building-related C&D (on the order of 50 percent), followed by renovation (as much as 40 percent), with new construction contributing the smallest share.[17] For construction and renovation, there is generally better data on residential buildings than non-residential buildings. The materials most common in residential construction debris are wood and drywall. By contrast, the C&D debris from building renovation is extremely diverse given that it is generated from all kinds of remodeling efforts – from kitchens and bathrooms to roofs and driveways – and includes both new construction waste and demolition debris. In terms of demolition, wood, concrete and drywall are the largest components of residential demolition debris while concrete and mixed rubble comprise the largest share of nonresidential demolition debris.[18]

Given the various state-level definitions for which materials are included in the C&D waste stream and the wide range of reporting methods, it is not surprising that there is no widely accepted standard source for national C&D composition data. For the purposes of the current analysis, C&D waste composition is based on estimates developed by U.S. EPA for building-related C&D.[19]

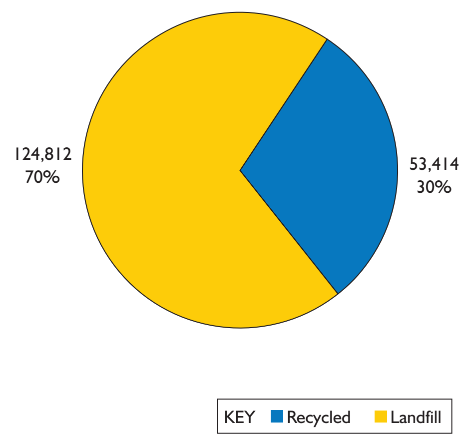
Diversion rates for specific materials found in C&D are not provided by EPA. This report estimates material-specific diversion rates based on EPA's overall C&D diversion estimate of 30 percent[20] and a variety of other sources, including EPA's 1998 and 2009 C&D studies, a study for the Massachusetts Department of Environmental Protection[21] and others.[22] Relatively high diversion rates (roughly 50 percent) are assumed for concrete and mixed rubble, bricks and metals, reflecting the ease and cost-effective manner with which these materials can be recycled in much of the U.S. and their prevalence at C&D recycling facilities as reported by various states.

While some wood is diverted from the C&D waste stream, it is difficult to recycle due to contamination by paint, preservatives or metals. Thus, some of the recovered wood is sent to industrial boilers and co-fired for energy production. According to U.S. EPA, certain states count this as diverted material; others do not.[23]

Drywall, asphalt roofing and plastics in the C&D stream have had very low diversion rates, partly due to the lack of processing-facility infrastructure that can cost-effectively separate these materials. A very small fraction (well under 5 percent) of drywall is recovered due to the lack of processing capacity and markets for recovered material.

As summarized in Figure 4, in 2008 approximately 30 percent of the 178 million tons of C&D debris generated in the U.S. was diverted (recycled) and 70 percent was disposed. Unlike other components in the MSW stream, virtually all recovered C&D waste was recycled; almost none was composted, as only the wood waste component of the C&D stream is compostable. Similarly, virtually all C&D disposal was via landfill and very little was incinerated, though small amounts of recovered wood and other high-BTU materials were used in industrial boilers.

Figure 4
U.S. C&D Management, 2008
(1000 tons)



A summary of the base year C&D waste generation and management situation by material type is presented in Table 2.

Table 2

C&D Generation and Management in the U.S. – 2008

(Thousands of Tons and Percentage of Total Generated)

MATERIALS	GENERATION [a]	DIVERTED [b]		DISPOSED [c]	
	Total	***Total***	***Diversion Rate***	***Total***	***Disposal Rate***
Concrete & Mixed Rubble	80,202	38,497	48%	41,705	52%
Wood	44,557	6,683	15%	37,873	85%
Drywall / Gypsum	17,823	178	1%	17,644	99%
Asphalt roofing	14,258	713	5%	13,545	95%
Metals	7,129	3565	50%	3,565	50%
Bricks	7,129	3,422	48%	3,707	52%
Plastics	7,129	356	5%	6,773	95%
Total	**178,226**	**53,414**	**30%**	**124,812**	**70%**

Key Points Regarding 2008 C&D Generation and Management

The data above illustrates the following key points about C&D generation and management in 2008:

- *Two materials dominate the C&D waste stream and comprise roughly 70 percent of the total 170 million tons generated: concrete and mixed rubble (45 percent), and wood (25 percent). Drywall (10 percent) and asphalt roofing (8 percent) are also important contributors.*
- *Less than a third (30 percent) of C&D debris is currently recycled or reused. Concrete and mixed rubble, bricks and metals are recovered at relatively high rates, around 50 percent. While roughly 15 percent of wood is recycled, recovery rates for drywall, roofing shingles and plastics are very low.*
- *The 30-percent national diversion rate for C&D lags well below what might be considered "best practice" in the U.S. Numerous municipalities and states have achieved much higher diversion rates (e.g., more than 60 percent in Massachusetts and about 80 percent in King County, Washington).*

This profile of existing C&D generation and diversion by material type is critical input for identifying the target materials and programs that can lead to a significantly higher diversion rate (see Section IV).

Figure 1 Source: "Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2008," U.S. EPA, November 2009.

Figure 2 Source: "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," U.S. EPA, November 2009, Figure 26, developed by Franklin Associates.

Figure 3 Source: Based on "Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2008," U.S. EPA, November 2009.

Figure 4 Source: Based on "Characterization of Building-Related Construction and Demolition Debris in the United States," (p. 3-9) prepared by Franklin Associates for U.S. EPA, June 1998.

Table 1 Source: Based on "Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2008," U.S. EPA, November 2009. Details might not add to totals due to rounding.

Table 2 Sources: [a]Total generation based on "Estimating 2003 Building-Related Construction and Demolition Materials Amounts," U.S. EPA, March 2009, escalated by U.S. Census Bureau population growth rate from 2003 to 2008. Allocation by material based on EPA ranges reported at www.epa.gov/epawaste/nonhaz/industrial/cd/basic.htm.

[b] Overall diversion rate based on range provided in "Characterization of Building-Related Construction and Demolition Debris in the United States," (p. 3-9) prepared by Franklin Associates for U.S. EPA, June 1998. Diversion rates for specific materials governed by EPA's national diversion estimate of 30 percent and based on Tellus estimates informed by C&D diversion data from EPA, Massachusetts and other states, plus personal communication with Kim Cochran, EPA Office of Resource Conservation and Recovery, 8/12/10.

[c] Disposed equals generation less diversion.

III. 2030 WASTE GENERATION, COMPOSITION & MANAGEMENT: BASE CASE ("BUSINESS AS USUAL") SCENARIO

The Base Case Scenario represents a "business as usual" approach to solid waste management in which current practices and trends continue. No major new policy interventions or lifestyle changes are introduced and most basic assumptions remain unchanged. The modest growth in the MSW diversion rate that has been experienced in the U.S. over the past decade (1 percent per year) is assumed to continue through 2030 in the Base Case Scenario.

A. 2030 BASE CASE – MSW

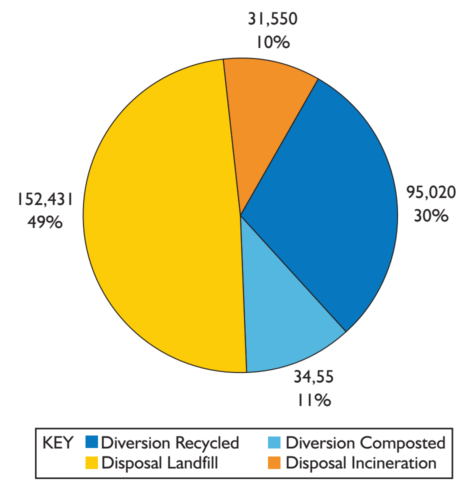
Projected waste generation figures to the year 2030 are driven by two primary factors: (1) expected per capita waste generation, and (2) changes in U.S. population. It is important to note that per capita waste generation is net of any source reduction that is achieved before materials enter the MSW management system.[24] While U.S. EPA estimates that source reduction increased through the 1990s, net per capita generation has remained relatively stable.

(1) **Projected per capita generation:** According to the U.S. EPA, per capita waste generation has remained relatively constant since 2000. Thus, for the Base Case Scenario we have used a generation figure of 4.6 lbs per capita per day or 1,697 lbs per year[25] from 2008 through 2030. This corresponds to the average per capita generation rate since 2000. Based on EPA's estimates of source reduction through 2000, this reflects a source reduction rate of about 19 percent.[26]

(2) **Projected U.S. population:** For U.S. population projections we have used the U.S. Census Bureau's 2008 national projections through 2050 for both scenarios.[27] These projections estimate that the U.S. population of 304 million in 2008 will grow to about 341 million in 2020 and to almost 374 million in 2030.

With constant per capita waste generation, overall Base Case waste generation grows at the same rate as the U.S. population. Thus, as Figure 5 shows, we project that total annual generation will grow from almost 250 million tons in 2008 to about 314 million tons in 2030. A more detailed summary of MSW Generation and Management by material type in the Base Case Scenario is included in Appendix B.

Figure 5
U.S. MSW Management, 2030 Base Case
(1000 tons)



Given that the Base Case is defined as a "business as usual" scenario, the diversion rates for each material and the overall diversion rate are assumed to continue to grow at 1 percent per year.[28] By 2030 the MSW diversion rate increases from 33.2 to 41.3

percent. This results in total diversion of almost 130 million tons of material, and total disposal of about 184 million tons.

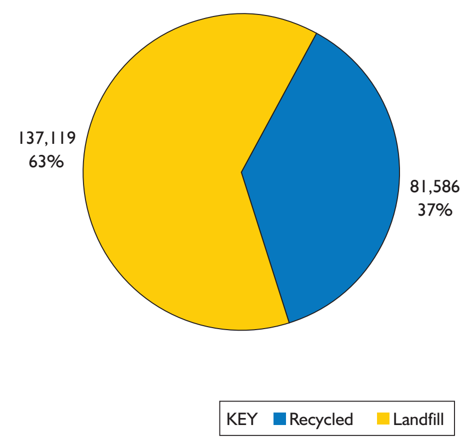
Similarly, the fraction of diverted material that is recycled (73 percent) versus composted (27 percent) is assumed to be the same as in 2008. In terms of disposal, the Base Case assumes that the same tonnage of material is incinerated (about 31.5 million tons per year), and that the additional tonnage requiring disposal is sent to landfills. This assumption implies that whatever incineration capacity is retired over the next two decades is replaced by an equal amount of capacity. It also recognizes that fluctuations in the tonnage of MSW disposed are more likely to impact the amount managed by landfills rather than incinerators. This is partly due to the relative difficulty of bringing new incineration capacity on line – because of siting issues, large capital requirements and the need for long-term disposal contracts – whereas expanding landfill capacity by opening new cells is comparatively "easier" and less costly.

B. 2030 BASE CASE – C&D

Similar to MSW, C&D generation in the Base Case is assumed to grow with U.S. population over the study period (slightly less than 1 percent per year). As described above in the discussion of C&D generation in 2008, this is likely a conservative assumption as to the size of the C&D waste stream in 2030 and is used in the current study for illustrative purposes.[29]

Similar to the Base Case assumptions for diversion of MSW in 2030, the C&D diversion rates for each material and the overall diversion rate is assumed to grow from the 2008 level.[30] As summarized in Figure 6 and Table 3, for the Base Case Scenario total C&D generation reaches almost 219 million tons in 2030. C&D diversion reaches 37 percent by 2030, accounting for almost 82 million tons of C&D, while 137 million tons continues to be disposed.

Figure 6
U.S. C&D Management, 2030
Base Case
(1000 tons)



The Base Case C&D waste stream profile for 2030 is assumed to be the same as in 2008. It is dominated by

Table 3
C&D Generation and Management in the U.S. - 2030 Base Case
(Thousands of Tons and Percentage of Total Generated)

MATERIALS	GENERATION [a]	DIVERTED [b]		DISPOSED [c]	
	Total	Total	Diversion Rate	Total	Disposal Rate
Concrete & Mixed Rubble	98,417	58,801	60%	39,616	40%
Wood	54,676	10,208	19%	44,468	81%
Drywall / Gypsum	21,870	272	1%	21,598	99%
Asphalt roofing	17,496	1,089	6%	16,407	94%
Metals	8,748	5,444	62%	3,304	38%
Bricks	8,748	5,227	60%	3,521	40%
Plastics	8,748	544	6%	8,204	94%
Total	**218,704**	**81,586**	**37%**	**137,119**	**63%**

two materials: concrete and mixed rubble, and wood, which comprise 70 percent of total generation. About 50 percent of concrete and mixed rubble, bricks and metals are assumed to be recovered, while diversion rates for drywall, roofing shingles and plastics remain very low.

As mentioned, this relatively low diversion rate for C&D is well below rates achieved in jurisdictions with more effective C&D diversion programs and it contrasts with the rate projected to be achieved through the set of policy, regulatory and lifestyle changes in the Green Economy Scenario, described next.

Figure 5 Sources: 2030 generation based on 2008 generation from "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," U.S. EPA, November 2009, times the projected population growth rate from the U.S. Census Bureau's "Table 1. Projections of the Population and Components of Change for the United States: 2010 to 2050 (NP2008-T1)," Release Date: August 14, 2008. Diversion rate assumed to grow 1 percent per year from 2008 levels. No net change in waste incineration tonnage is assumed.

Figure 6 Sources: Total generation as derived from "Estimating 2003 Building-Related Construction and Demolition Materials Amounts," U.S. EPA, March 2009, escalated by U.S. Census Bureau population growth rate from 2003 to 2030. 2030 diversion rate based on range provided in "Characterization of Building-Related Construction and Demolition Debris in the United States," (p. 3-9) prepared by Franklin Associates for U.S. EPA, June 1998. No change in diversion rate assumed in Base Case.

Table 3 Sources: [a] Total generation based on "Estimating 2003 Building-Related Construction and Demolition Materials Amounts," U.S. EPA, March 2009, escalated by U.S. Census Bureau population growth rate from 2003 to 2030. Allocation by material based on EPA ranges reported at www.epa.gov/epawaste/nonhaz/industrial/cd/basic.htm.

[b] Overall diversion rate based on range provided in "Characterization of Building-Related Construction and Demolition Debris in the United States," (p. 3-9) prepared by Franklin Associates for U.S. EPA, June 1998. Diversion rates for specific materials governed by EPA's national diversion estimate of 30 percent and based on Tellus estimates informed by C&D diversion data from EPA, Massachusetts and other states, plus personal communication with Kim Cochran, EPA Office of Resource Conservation and Recovery, 8/12/10.

[c] Disposed equals generation less diversion.

IV. 2030 WASTE GENERATION, COMPOSITION & MANAGEMENT: THE GREEN ECONOMY (75 PERCENT DIVERSION) SCENARIO

The Green Economy Scenario presented in this section reflects an overall waste diversion rate of 75 percent. This alternative scenario represents what is achievable through implementation of a set of enhanced policy, regulatory and lifestyle changes to achieve this level of recycling and composting. The policies, regulations and behavior changes driving this scenario are based on what are considered "best practices" currently in place in various jurisdictions in the U.S. and abroad.

While the Green Economy Scenario does not attempt to provide detailed descriptions of each of the specific best practices and their respective impacts on emissions and jobs, examples of the kinds of policy, regulatory and lifestyle initiatives that will be necessary to achieve the level of recycling and composting in the Green Economy Scenario are highlighted below. In addition, detailed descriptions of three leading waste diversion programs (Massachusetts C&D, San Francisco mandatory recycling and Seattle food composting) are provided at the end of this section.

Policy Examples

- Pay As You Throw (PAYT) programs to incentivize recycling and composting, now in place in thousands of communities throughout the U.S.
- Resource Management Contracting to incentivize commercial waste generators and their waste management contractors to reduce disposal.
- Grants, expedited permitting and other support for the development of MSW and C&D recycling and composting infrastructure as well as recycling-based manufacturing.

Regulatory Examples

- Mandatory recycling and composting laws such as the one adopted by San Francisco in 2009 (described below).
- Disposal bans on recyclable materials, including certain unprocessed materials in the C&D waste stream, such as those in place in Massachusetts for several years (described below).
- Extended producer responsibility (EPR) regulations to encourage changes in product and packaging design that reduce volume/weight and toxicity and enhance recyclability or compostability.
- A (national) bottle bill covering not only carbonated beverages such as soda and beer, but also bottled water, sports drinks, fruit juice, teas, etc., as has been adopted in California, Hawaii and Maine.

Lifestyle Examples

- Purchasing practices that give preference to products that have less packaging and are recyclable or compostable or contain high levels of recycled material.
- Conscientious participation in local recycling and composting programs by residents and businesses.

A. 2030 GREEN ECONOMY SCENARIO - MSW

The Green Economy Scenario assumes the same generation and material composition as in the Base Case Scenario for 2030. Total generation is almost 314 million tons, with paper/paperboard, yard waste and food scraps, and plastics and metals (in order) having the largest shares. However, unlike the 41-percent diversion rate associated with business-as-usual practices in the Base Case Scenario, through implementation of a coordinated suite of policy, regulatory and lifestyle initiatives such as summarized above, the Green Economy Scenario achieves a 75-percent MSW diversion rate.

CASE STUDY:

Achieving High Rates of Construction and Demolition Debris Recycling: The Massachusetts C&D Recycling Program

Massachusetts has implemented one of the most successful statewide construction and demolition (C&D) recycling programs in the U.S. Informed by a broad stakeholder consultation process, the state's Department of Environmental Protection (MassDEP) accomplished this through a coordinated effort comprising technical assistance, market development and a ban on unprocessed disposal of selected C&D waste materials.

In an effort to reach its goal of reducing non-municipal solid waste by 88 percent by 2010, as laid out in MassDEP's *Beyond 2000 Solid Waste Master Plan*, the department instituted a disposal ban on select C&D materials in July 2006. The banned materials are asphalt paving, brick, concrete, metal and wood. Massachusetts has the only statewide ban and regulations on disposing unprocessed C&D waste (for specified materials) in the country. DEP estimates that in 2010, out of 3.8 million tons of C&D debris generated, more than 3 million tons were diverted for an overall diversion rate of about 80 percent.

To develop the ban, MassDEP established a subcommittee of the agency's Solid Waste Advisory Committee in 2001. By 2010 this subcommittee had 160 members, comprised of architects, engineers, building owners, contractors, haulers, C&D processors, landfill owners, transfer station owners, municipalities, environmental groups and trade associations. The subcommittee ultimately recommended a phased-in ban of the specific materials mentioned above rather than all unprocessed C&D debris. These materials were targeted because recycling and reuse markets exist for each of them. In addition, once the subcommittee recommended the ban, several businesses established additional facilities to recycle and/or reuse these materials, further enhancing not only the recycling and reuse markets but also the job creation potential of such a ban. Though this stakeholder process was successful, it took a considerable amount of time. From writing regulations to infrastructure and market development, it took more than four years for MassDEP to institute the ban.

To ensure the ban's success, MassDEP provided financial and technical assistance to develop infrastructure for diversion through reduction, reuse and recycling. As of 2010, Massachusetts had more than 15 C&D processing and/or recycling facilities, which recover recyclable materials from mixed C&D debris for reuse, sale or further processing. Massachusetts also has the first gypsum recycling facility in the U.S., modeled after a successful Scandinavian program that processes gypsum wallboard waste to produce new wallboard. The state now has one of the best C&D processing infrastructures in the country. Although the number of direct and indirect jobs associated with this C&D infrastructure has not been quantified, numerous jobs are supported in operating facilities, processing materials and manufacturing products from recycled materials.

MassDEP reviews and approves solid waste facility waste ban compliance plans and inspects solid waste facilities to ensure they are in compliance with monitoring, inspections, record keeping and other facility waste ban requirements. Businesses and municipalities that do not divert banned items from their waste run the risk of having solid waste facilities reject their waste and charge additional handling fees, as well as potential enforcement penalties from MassDEP.

MassDEP has made available several case studies that demonstrate the waste diversion and economic benefits of the ban. Clarke Corporation, a wholesale distributer of kitchen appliances, renovated and expanded its distribution center in Milford, Mass. Ninety-eight percent of materials generated on site were recycled or reused, resulting in cost savings of $259,043. In another case, recycling during the commercial demolition of the Massachusetts Institute of Technology (MIT) Media Lab in Cambridge resulted in 96 percent waste reduction and cost savings of $17,684. For more information and the C&D recycling case studies, see http://www.mass.gov/dep/recycle/reduce/managing.htm.

Sources: http://www.mass.gov/dep/recycle/priorities/08swdata.pdf, p. 10 and http://www.gypsumrecycling.us/Pages/News/6712-1-280/

The diversion rates differ by material type, depending on a number of factors including ease of recycling or composting, processing infrastructure and market value. Thus, materials such as yard waste (90 percent), paper/paperboard (85 percent), and metals (80 percent) are assumed to have high recycling/composting rates, while materials such as textiles (50 percent), rubber and leather (50 percent), and plastics (65 percent), are assigned lower recycling rates. These diversion rates are informed by estimates of realistic potential diversion developed by Tellus Institute for the Massachusetts Department of Environmental Protection[31] and are updated to reflect a planning horizon to 2030, the likely regulation of greenhouse gas emissions in the U.S., and an assumption that commodity prices will increase in real terms over this two-decade planning period.

Thus, in the Green Economy Scenario by 2030 fully 75 percent (more than 235 million tons) of the waste generated is either recycled or composted, and only 25 percent (78 million tons) is disposed. A summary of the 2030 waste management situation in the Green Economy Scenario is presented in Figure 7. A more detailed presentation of the MSW Generation and Management by material type in the Green Economy Scenario is included in Appendix C.

A comparison of the MSW flows and management activities in the Base Case versus the Green Economy Scenarios is presented in Figure 8.

Figure 7
U.S. MSW Management, 2030
Green Economy Scenario
(1000 tons)

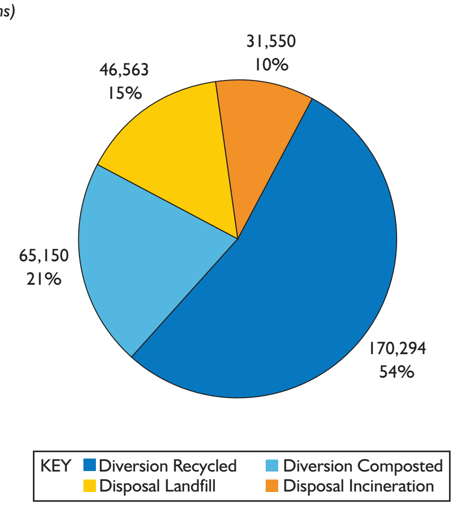
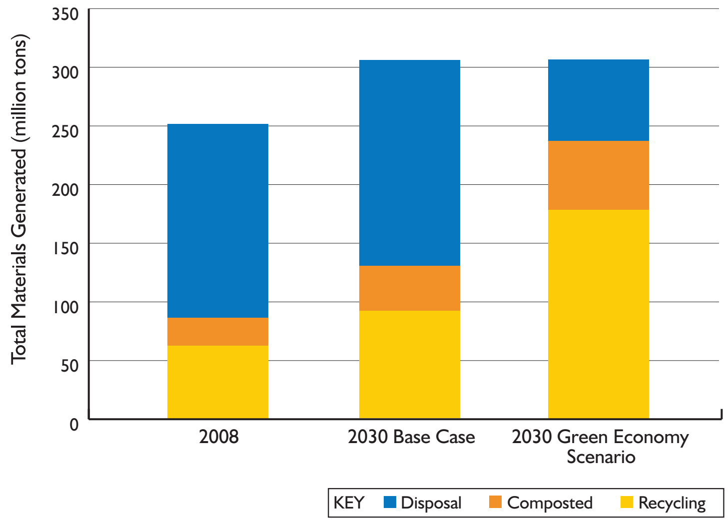


Figure 8
U.S. MSW Waste Flows



B. 2030 GREEN ECONOMY SCENARIO – C&D

As with MSW, 2030 C&D generation and composition in the Green Economy Scenario is assumed to be the same as in the Base Case. However, our higher diversion scenario assumes a set of policy and regulatory initiatives that significantly boosts C&D material recovery. In the regulatory arena a key driver would be adoption of disposal bans for certain unprocessed C&D materials (e.g., asphalt paving, brick, concrete, metal, wood), as has been in place in Massachusetts for several years. Such bans would need to be complemented by policy initiatives to establish C&D processors and build markets for the recycled materials. Certain materials such as concrete/rubble, bricks and metals are projected to be recycled at very high rates (90 percent), while materials such as drywall (60 percent) and wood (70 percent) achieve somewhat more modest diversion rates owing to factors such as lack of processing infrastructure or contamination.

As summarized in Figure 9, an overall C&D diversion rate of 80 percent is achieved by 2030 in the Green Economy Scenario. This relatively high diversion rate is due to the fact that the C&D waste stream is dominated by materials that are readily recycled and reused, and the availability of workable policy and regulatory tools to incentivize recycling.

The specific diversion rates by component of the C&D waste stream is presented in Table 4. As discussed, all diverted waste is assumed to be recycled and all disposed waste is assumed to be landfilled. The variance in

CASE STUDY:

Creating Jobs and Saving Money: Advancing Commercial Recycling and Composting in San Francisco

Passage of San Francisco's Mandatory Recycling and Composting Ordinance in 2009 has measurably enhanced the various benefits of the city's already impressive solid waste management system. In addition to environmental protection, these programs are resulting in cost savings for businesses and the creation of private sector jobs. The mandatory ordinance has increased participation in waste sorting programs and the city's diversion rate is now the highest of any major city in the United States.

California law requires each jurisdiction to achieve at least 50 percent waste diversion, and many cities and counties have set higher diversion goals. San Francisco set goals in 2002 to achieve 75 percent diversion by 2010 and zero waste by 2020. In 2010, it exceeded its goal with a 77 percent diversion rate.

San Francisco requires everyone to separate refuse into recyclables, compostables and trash, and all property owners are required to subscribe to an adequate collection service. For most businesses, reaching high diversion is achievable because so many materials in the waste stream are recyclable, compostable or reusable. Incentives in the cost structure for collection mean businesses can save up to 75 percent of service costs by participating in recycling and composting programs.

Since the ordinance passed there has been a 50-percent increase in businesses using the compost collection service and a 300-percent increase in the number of apartments using the service. As a result, the collection of compostable materials has increased by 45 percent so that nearly 600 tons per day of food scraps, soiled paper and yard trimmings are sent to composting facilities. Keeping organics out of landfills is key to reducing methane generation and reducing climate change. During the recent economic downturn, the overall amount of waste generated in San Francisco declined but the amount of recyclable materials has remained steady.

According to San Francisco Department of Environment Director Melanie Nutter, "If we captured everything going to landfill that can be recycled or composted in our programs, we'd have a 90-percent recycling rate, but we will need to work on the state and federal level to require that packaging and products are manufactured with minimal waste and maximum recyclability."

Because more recycling and composting means more jobs, San Francisco's recycling achievements have been a bright spot in a gloomy global economy. Recology, the city's primary recycling, composting and waste company, employs more than 1,000 workers who are represented by the Teamsters. Some 118 new employees have been hired in recent years to sort recyclables and monitor the collection routes in order to meet San Francisco's aggressive recycling goals. The ordinance includes fair standards for janitorial workers who are on the front lines of office waste separation.

"San Francisco is showing once again that doing good for our environment also means doing right by our economy and local job creation," said former Mayor Gavin Newsom. "For a growing number of people, recycling provides the dignity of a paycheck in tough economic times. The recycling industry trains and employs men and women in local environmental work that can't be outsourced and sent overseas, creating 10 times as many jobs as sending material to landfills."

Two recent ordinances have diverted additional waste items. The Construction and Demolition (C&D) Debris Recovery Ordinance of 2006 made recycling of C&D debris mandatory. San Francisco now sends 20 percent fewer tons of C&D waste to landfills. The Food Service Waste Reduction ordinance of 2006 bans polystyrene food take-out containers and requires containers to be recyclable or compostable in the city's programs. Almost all restaurants are now participating in this program.

The city focuses on education and assistance through free trainings for businesses and apartment buildings to implement the Mandatory Recycling and Composting Ordinance. In 2010, the city worked directly with approximately 300 apartment buildings (encompassing 21,000 units), 800 commercial accounts, 4,000 food establishments and more than 100 of the largest events. The city government is leading by example, training more than 4,000 city employees to help ensure recycling and composting in city buildings. This has resulted in savings of more than half a million dollars in city trash service fees and other efficiencies.

Following San Francisco's lead, the California Department of Resources Recycling and Recovery began developing a Mandatory Commercial Recycling Measure in 2009 to help meet the state's greenhouse gas reduction goals, and the measure is expected to go into effect in 2012. This measure will require that all businesses in the state have a recycling program. The commercial sector generates more than half of the solid waste in California, and approximately 68 percent of waste disposed. This measure presents significant job growth opportunities statewide.

Sources:
San Francisco Department of Environment: www.sfenvironment.org
Recology: www.recyclingmoments.org
California Department of Resources Recycling and Recovery (CalRecycle): http://www.calrecycle.ca.gov/Climate/Recycling/

CASE STUDY:

From Food Scraps to Compost: Waste Diversion and Job Creation in Seattle

While separating bottles and cans from garbage for recycling is common practice in the US, it has become clear that composting of organic waste – food scraps, soiled paper and yard debris – is the critical next step to significantly increase waste diversion rates, and reduce greenhouse gas emissions and other hazards of landfilling.

Hundreds of organics composting programs have been established in the US, including one in Seattle. Under such programs, residential and commercial customers separate food scraps and yard debris from recyclables and other solid waste. It is then collected and transported to large-scale composting operations, which turn the waste into marketable compost and fertilizer products. Because organic matter buried in landfills releases the potent greenhouse gas methane as it decomposes, the diversion of organic waste for composting not only reduces the volume of waste going to landfills, but also helps combat climate change.

Seattle has a 60 percent waste diversion goal and, as of 2009, achieved an estimated overall diversion rate of 51.1 percent. Key to these high diversion rates is the city's food scrap diversion program, which began in 2007 and became mandatory for single-family homes in 2009. Residents separate waste into three containers: recyclables, organic matter and all other trash. In 2009, nearly 100,000 tons of organic waste was diverted from landfills by the city of Seattle's program. Approximately one third of this consisted of food scraps and soiled paper, the rest was yard trimmings.

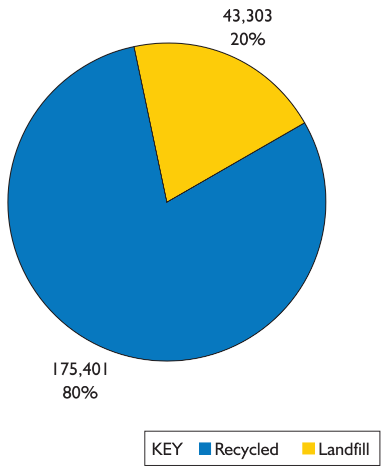
Seattle contracts with Cedar Grove Composting, Inc., which operates a major composting facility in Maple Valley, Wash. to compost yard waste and food scraps from commercial and residential customers. Cedar Grove has a long-standing contract with the city of Seattle to compost yard waste, and received a permit from the state of Washington to compost food scraps in 2009. Residential food waste now represents about 10 percent of Cedar Grove's collection volume, and they produce a wide range of products, including topsoil, garden fertilizer, compost and mulch for use by homeowners, gardeners, developers and contractors.

The city of Seattle's waste diversion efforts not only benefit the environment, but also sustain family-supporting jobs for the more than 1,000 solid waste and recycling drivers and transfer station employees in Seattle and King County who are represented by the Teamsters Union.

Teamster recycling and solid waste drivers enjoy good wages, health insurance and pension benefits. Harold Barcelou, a five-year driver at Cedar Grove Composting, said, "I'm proud to be a Teamster and proud to be helping Seattle to reach its waste reduction goals. My Teamster membership means I can afford good health care for my family and can take the time to do the job safely." According to Brent Barrett, a Teamster member and shop steward at Waste Management, "Teamster representation ensures high safety and operational standards for employees, the company and the community."

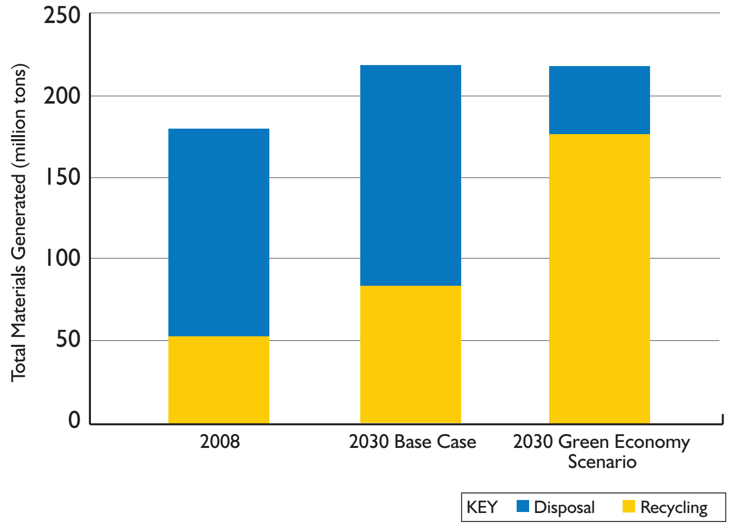
Environmental organizations are enthusiastic about Seattle's composting initiative. "Seattle is proving that organics composting is viable on a city-wide basis," said Mo McBroom, Policy Director of the Washington Environmental Council, "Keeping organic waste and the methane it generates out of our landfills is critical to combating climate change."

Figure 9
U.S. C&D Management, 2030 Green Economy Scenario
(1000 tons)



A comparison of the C&D flows and management activities in the Base Case versus the Green Economy Scenarios is summarized in Figure 10.

Figure 10
U.S. C&D Waste Flows



diversion rates by material relates to differences in available processing infrastructure and markets for the material.

Table 4
C&D Generation and Management in the U.S - 2030 Green Economy Scenario
(Thousands of Tons and Percentage of Total Generated)

MATERIALS	GENERATION [a]	DIVERTED [b]		DISPOSED [c]	
	Total	*Total*	*Diversion Rate*	*Total*	*Disposal Rate*
Concrete & Mixed Rubble	98,417	88,57	90%	9,842	10%
Wood	54,676	38,273	70%	16,403	30%
Drywall / Gypsum	21,870	13,122	60%	8,748	40%
Asphalt roofing	17,496	13,122	75%	4,374	25%
Metals	8,748	7,873	90%	875	10%
Bricks	8,748	7,873	90%	875	10%
Plastics	8,748	6,561	75%	2,187	25%
Total	**218,704**	**175,401**	**80%**	**43,303**	**20%**

Figure 7 Sources: 2030 generation based on 2008 generation from "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," U.S. EPA, November 2009, times the projected population growth rate from the U.S. Census Bureau's "Table 1. Projections of the Population and Components of Change for the United States: 2010 to 2050 (NP2008-T1)," Release Date: August 14, 2008. Overall diversion rate of 75 percent is average of material-specific diversion rates as informed by "Waste Reduction Program Assessment & Analysis for Massachusetts," prepared by Tellus Institute for the Massachusetts Department of Environmental Protection, February 2003, updated to reflect 2030 planning horizon. No net change in waste incineration tonnage is assumed.

Figure 8 Sources: See Figures 3, 5 and 7.

Figure 9 Sources: Total generation as derived from "Estimating 2003 Building-Related Construction and Demolition Materials Amounts," U.S. EPA, March 2009, escalated by U.S. Census Bureau population growth rate from 2003 to 2030. Overall C&D diversion rate of 80 percent in 2030 is average of material-specific diversion rates informed by Tellus Institute's review of "best practices," including programs in Massachusetts and King County, Wash.

Figure 10 Sources: See Figures 4, 6 and 9.

Table 4 Sources: Total generation as derived from "Estimating 2003 Building-Related Construction and Demolition Materials Amounts," U.S. EPA, March 2009, escalated by U.S. Census Bureau population growth rate from 2003 to 2030. Overall C&D diversion rate of 80 percent in 2030 is average of material-specific diversion rates, which are estimates informed by Tellus Institute's review of "best practices," including programs in Massachusetts and King County, Wash.

V. EMPLOYMENT IMPACTS: BASE CASE AND GREEN ECONOMY SCENARIOS

Based on the profile of waste stream characteristics and management practices developed for the Base Case and Green Economy Scenarios, this section compares the employment implications of each scenario. The analysis covers the various stages of materials management including collection, hauling and processing, if any, as well as the ultimate disposition of the collected materials through reuse/remanufacturing, new product manufacturing, composting, or disposal via landfilling or incineration.

A. METHODOLOGY

A number of state and national studies have been conducted to estimate the level of economic activity and employment of the recycling industry. Two primary approaches have been used. The first is a "bottom-up" approach whereby the relevant business categories are identified and data on their direct activity is gathered from existing sources (e.g., U.S. Census Bureau's Economic Census and others) on the number of establishments, employment and payroll. For those business categories where existing data is limited, surveys of establishments and statistical analysis of the results have been used, or estimates have been derived from a variety of sources such as trade organizations, industry experts and literature reviews. The frequently-cited *U.S. Recycling Economic Information Study* (2001) published by the National Recycling Coalition with U.S. EPA support used this approach.[32] In 2009, the Northeast Recycling Council produced the *Recycling Economic Information Study Update* (REI Update) for five states in the Northeast, using a modified version of this methodology.[33]

The second is a "top-down" approach in which surveys are conducted of various recycling and reuse business sectors, defined by material, to collect data on tonnages managed and employment at each establishment. From these data, estimates of jobs per tonnage are derived for each of the relevant sectors. In the 1990s the Institute for Local Self Reliance (ILSR) used this approach to develop a set of job production estimates for 11 recycling/reuse/processing business categories as well as for composting, landfilling and incineration.[34] These job production estimates are still widely cited in assessments of job impacts of various solid waste management alternatives.[35]

Unfortunately, neither approach provides a comprehensive data set that matches the EPA material categories discussed in the previous sections of this report or the full range of management activities discussed below. Thus, there are no ready-made standardized national data sets that can be used directly, nor are there comprehensive and up-to-date state or other sub-national data sources or job production estimates[36] available that would allow us to estimate the economic and job impacts of current and expanded recycling/reuse/composting activity in the U.S.

Therefore, we have used a hybrid approach in the current analysis, relying on a combination of the key sources mentioned above. Each of these sources has limitations. The challenge was to use the existing studies in new ways that produce reasonable, defensible estimates of the likely economic and job impacts. In order to conduct scenario analyses, we derived estimates of jobs produced per 1,000 tons of MSW managed for each of the diversion and disposal management activities – collection, processing, manufacturing, reuse/remanufacturing, landfilling and incineration. We derived these estimates for each material disposed – paper, glass, metals, plastics, rubber, textiles, wood, food scraps, yard trimmings, miscellaneous organic wastes and other wastes. These job production estimates are summarized in Table 5.

In evaluating the jobs and direct economic impacts of the Green Economy Scenario, we adopted the three categories used in the 2009 REI Update that characterize the economic activity associated with materials management:[37]

1. Recycling Industries: includes collection and processing of recyclables to make them available for use in new industrial processes. (Referred to as the "Supply Side" of the "Recycling Industry" in 2001 REI Study.) These include the following:

- Municipal residential recycling collection
- Private recycling collection
- Compost/organics processors
- Materials Recovery Facilities (MRFs, where recyclables are sorted)
- Recyclable materials wholesalers
- Plastics reclaimers

2. Recycling Reliant Industries: includes industries that purchase secondary materials from the Recycling Industry (referred to as the "Demand Side" of the "Recycling Industry" in the REI 2001 Study). Note that often these manufacturing industries can use both virgin and recycled or "secondary" material inputs, rather than exclusively recycled materials. These include the following:

- Glass container manufacturing plants
- Glass product producers
- Nonferrous secondary smelting and refining mills
- Nonferrous product producers
- Nonferrous foundries
- Paper and paperboard mills/deinked market pulp producers
- Paper-based product manufacturers
- Pavement mix producers (asphalt and aggregate)
- Plastic product manufacturers
- Rubber product manufacturers
- Steel mills
- Iron and steel foundries
- Other recycling processors/manufacturers

Note that our employment impact analysis for the Base Case and Green Economy Scenarios for 2030 assumes that the materials recovered through recycling remain in the U.S. and are utilized as inputs by domestic manufacturers. While we recognize that this is not the case today, it is consistent with a variety of potential policy or regulatory developments such as: an industrial policy that promotes use of recycled inputs by U.S. manufacturers (through favored tax treatment, for example); implementation of procurement standards requiring a certain percentage of post-consumer recycled fiber in various types of paper (at the state level, for example); and climate change legislation that results in recognition of the upstream benefits of recycling and increasing the cost of long-distance shipment of recycled fiber.

3. Reuse and Remanufacturing Industries: includes those industries that directly reuse and/or remanufacture products for their original use. (The same name was used in the REI 2001 report.) These include the following:

- Computer and electronic appliance demanufacturers (includes remanufacturers)
- Motor vehicle parts (used)
- Retail used merchandise sales
- Tire retreaders
- Wood reuse
- Materials exchange services
- Other reuse

To derive the job production factors and estimate the number of jobs produced by sector and material we relied on a combination of sources. The National Recycling Economic Information Study (2001) was the most complete source of data for most Recycling Industries and Recycling-Reliant Industries. We combined various waste categories (using weighted averages based on tonnage) to match the jobs production estimate with the material categories from the EPA MSW generation data discussed in previous sections of this report.

The REI approach has been criticized for not distinguishing economic activity and jobs in certain manufacturing sectors (e.g., glass) that use both virgin and recycled material inputs,[38] which resulted in all jobs in those manufacturing sectors being considered "recycling" jobs, whether or not the jobs processed recycled materials. We have addressed this issue by deriving job estimates per ton by material from the REI data and applying these estimates only to the tons of waste that

In-Building Job Creation from Enhanced Commercial and Institutional Recycling and Composting Programs

As discussed above, enhanced recycling and composting programs create a large number of jobs in collection, processing, composting, manufacturing and reuse/remanufacturing. For the commercial/institutional sector to achieve high levels of waste diversion of high quality materials requires increased training for employees as well as additional in-building collection and handling. Where such programs exist, employees no longer simply toss all waste in a single trash can, and maintenance and custodial staff no longer collect a single stream of waste. Moreover, to enhance the likelihood of high employee participation rates and maximum diversion, experience has shown that recycling and composting waste needs to be made at least as convenient as disposing it. While source-separated programs require more effort, they result in higher quality recyclables with greater value in the marketplace.

To operate these programs effectively in terms of diverting a high fraction of waste and maintaining good quality recyclable streams with minimum contamination requires additional in-building maintenance and/or custodial staff who are trained to: (1) collect from two or three receptacles at each work station or other location (classroom, conference room, lunch room, bathroom, etc.) instead of one trash can; (2) aggregate the materials collected (still in separate streams) so they can be picked up by haulers for recycling or composting; and (3) perform inspection and quality-control activities to ensure minimal contamination of the various waste streams (e.g., wet food waste is not mixed in with either recyclables or the non-divertible waste stream, inorganic wastes are not mixed in with compostable materials, etc.).

To date, no reliable data that can be generalized has been developed that estimates the in-building job creation impacts of enhanced recycling/composting programs. What is clear is that multiple bins with separate waste streams alter the nature and time requirements of in-building waste collection. A countervailing impact is that trash is greatly reduced and that may allow for less frequent collection of that stream (not so for food/organic waste, which must be collected on a daily basis).

The city of San Francisco provides an excellent example of an enhanced recycling and composting program and the potential for creating additional jobs. As described elsewhere in this report, the city passed a Mandatory Recycling and Composting Ordinance in late 2009. The ordinance requires residents and businesses to separate refuse into recyclables, compostables and trash, and all property owners to subscribe to an adequate collection service. In 2010, San Francisco exceeded its ambitious goals and achieved a 77-percent diversion rate.

Though it is too early to have a good sense of the numbers of additional in-building jobs created by the significant increase in commercial and institutional recycling and composting, and much depends on the specific collection practices adopted, there are some early indications of job growth. For example, a handful of large office buildings have hired sorters to ensure minimal contamination of the collected material streams. In addition to quality control, they prepare the materials for hauling. It remains to be seen the degree to which additional staff will be required in the long term, after a mandatory program is in place for some time and considered standard practice.

are recycled and used as inputs in manufacturing processes.[39] This is one of the reasons why our new estimates of jobs in the recycling sector are lower than the jobs estimated in the 2001 REI Study.

For the Reuse and Remanufacturing Industries, there was only employment-per-tonnage data available from ILSR in a series of reports since the 1990s. We have mapped these categories to the materials that are being reused/recycled (and thus bypassing the collection/processing stages).

Finally, the REI studies do not address the economic activity or jobs related to waste disposal. Thus, for landfilling and incineration we have used the ILSR disposal jobs per tonnage estimates.

The job production estimates used in our analysis are summarized in Table 5. As indicated, waste disposal is not labor intensive and generates the fewest jobs per ton of waste (0.1 jobs per 1,000 tons). This is not surprising given that the capital intensive equipment used at disposal facilities can handle large tonnages with few employees. Materials collection also generates relatively few jobs. Based on detailed data collected in 2010 by CM Consulting on behalf of the Container Recycling Institute for a forthcoming report on job creation, we have assumed that 1.67 jobs are created per 1,000 tons of material collected for recycling or composting and 0.56 jobs per ton for disposal. Note that the collection job production estimate for recyclables is expected to decline to 1.23 jobs per 1,000 tons by 2030 as single-stream recyclables collection continues to grow. These figures reflect the fact

Table 5

Job Production Estimates by Management Activity - MSW

(Jobs per 1000 Tons)

	DIVERTED WASTE					DISPOSED WASTE		
	Collection 2008	Collection 2030	Processing	Manufacturing	Reuse/ Remanufacture	Collection	Landfill	Incineration
	Jobs per 1000 tons	*Jobs per 1000 tons*	*Jobs per 1000 tons*	*Jobs per 1000 tons*	*Jobs per 1000 tons*	*Jobs per 1000 tons*	*Jobs per 1000 tons*	*Jobs per 1000 tons*
MATERIALS								
Paper & Paperboard	1.67	1.23	2.00	4.16	N/A	0.56	0.10	0.10
Glass	1.67	1.23	2.00	7.85	7.35	0.56	0.10	0.10
Metals								
Ferrous	1.67	1.23	2.00	4.12	20.00	0.56	0.10	0.10
Aluminum	1.67	1.23	2.00	17.63	20.00	0.56	0.10	0.10
Other Nonferrous	1.67	1.23	2.00	17.63	20.00	0.56	0.10	0.10
Plastics	1.67	1.23	2.00	10.30	20.00	0.56	0.10	0.10
Rubber & Leather	1.67	1.23	2.00	9.24	7.35	0.56	0.10	0.10
Textiles	1.67	1.23	2.00	2.50	7.35	0.56	0.10	0.10
Wood	1.67	1.23	2.00	2.80	2.80	0.56	0.10	0.10
Other	1.67	1.23	2.00	2.50	N/A	0.56	0.10	0.10
Other Wastes								
Food Scraps	1.67	1.23	0.50	N/A	N/A	0.56	0.10	0.10
Yard Trimmings	1.67	1.23	0.50	N/A	N/A	0.56	0.10	0.10
Misc. Inorganic Wastes	1.67	1.23	0.50	N/A	N/A	0.56	0.10	0.10

that job creation related to materials collection varies by material type (mixed waste versus mixed recyclables versus source-separated recyclables) and that less labor per ton collected is required for mixed waste loads (slated for disposal) than for recyclables/compostables collection.

Our assumption for processing of recyclables (two jobs per 1,000 tons) and organics (0.5 jobs per 1,000 tons) may also be somewhat conservative as the 2009 REI Update for five northeastern states estimated 2.73 jobs per 1,000 tons processed.

Job estimates derived from the REI Study for the various manufacturing sectors that use recyclable materials demonstrate the labor intensity of manufacturing. These job production estimates vary greatly by material/sector: from less than three jobs per 1,000 tons for wood and textiles, to about four jobs per 1,000 tons for paper as well as iron and steel manufacturing, to about 10 jobs per 1,000 tons for plastics and more than 17 jobs per 1,000 tons for nonferrous metals.

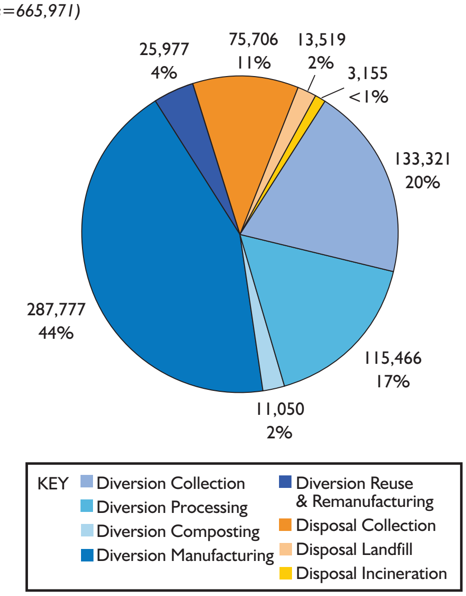
Reuse and remanufacturing activity is particularly labor intensive with job production estimates of more than seven jobs per 1,000 tons for several material/product categories and around 20 jobs per 1,000 tons for metal products.[40] Such high job production estimates for reuse and remanufacturing are consistent with the significant labor required for disassembly, inspection, repair/ refurbishment, reassembly and testing.

B. JOBS RELATED TO CURRENT (2008) MSW MANAGEMENT SYSTEM

In 2008 an estimated 666,000 direct jobs were associated with MSW management in the U.S. This figure is based on the job production estimates presented in Table 5 applied to the current waste generation and management system described in Section II.A and summarized in Figure 5. As summarized in Figure 11, of the approximately 666,000 jobs related to MSW management in 2008, the vast majority (about 574,000 jobs, or 86 percent) are associated with recycling and composting, and only a small fraction (about 92,000 jobs, or 14 percent) with disposal through landfilling and incineration. Recall that in terms of tons managed in 2008, recycling and composting accounted for only about 33 percent of total MSW generated and about 67 percent was disposed through landfilling or incineration.

Of the jobs associated with recycling and composting, manufacturing using recycled materials is dominant (accounting for almost 288,000 jobs), followed by collection (133,000) and materials processing (115,000 jobs). There are far fewer jobs associated with reuse and remanufacturing (26,000 jobs) and composting (11,000). This reflects the product of the relative intensity of these management activities and the magnitude of the waste flows handled by each activity.

Figure 11
U.S. Jobs by MSW Management Activity, 2008
(Total jobs=665,971)



A more detailed presentation of job creation by management activity and material is included in Appendix D.

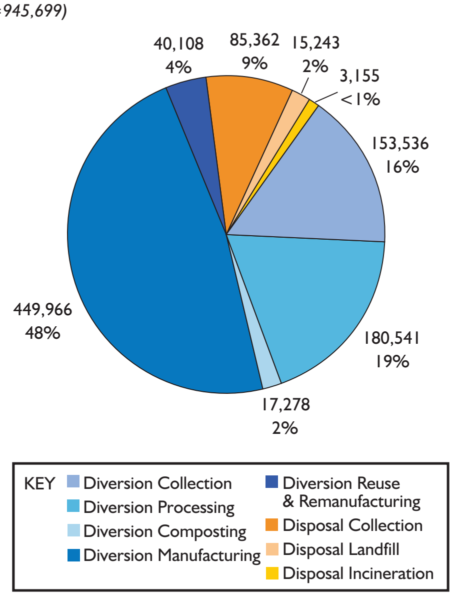
With the large discrepancy in job creation per ton between recycling and composting on the one hand, and disposal on the other, increasing diversion rates has a very significant impact on job creation. This is summarized in the discussion of the Base Case and Green Economy Scenarios in 2030.

C. BASE CASE SCENARIO – MSW MANAGEMENT JOB CREATION (2030)

As described in Section III, Base Case waste generation projections to 2030 are driven by two primary factors: population growth and per capita generation. In the base case, population is assumed to grow by about 23 percent to almost 374 million by 2030, while per capita generation is expected to remain constant at 1,697 pounds per year. In terms of waste management and job creation, a third factor, the rate of waste diversion versus disposal, is important. Based on recent trends in national waste management practices, the diversion rate is assumed to grow modestly over this period from 33 percent in 2008 to 41 percent in 2030.[41]

Figure 12 presents a summary of the number of jobs by MSW management activity in the Base Case in 2030. Due to an increase in overall tonnage managed and the increase in the diversion rate between 2008 and 2030, the number of total jobs grows in the Base Case from 666,000 to almost 946,000 jobs (growth of about 280,000 jobs, or 42 percent).

Figure 12
U.S. Jobs by MSW Management Activity, 2030 – Base Case
(Total jobs=945,699)

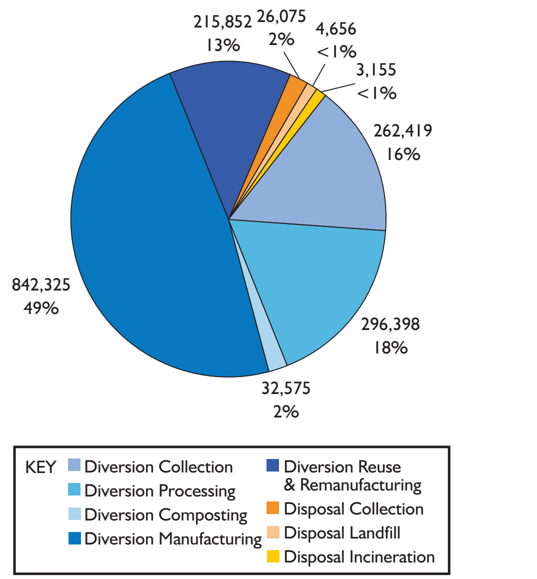


Virtually all of this growth results from waste diversion activity. While there is very modest absolute tonnage growth in waste disposal in 2030, this generates only 11,000 additional jobs. On the other hand, there is approximately 47-percent growth in recycling-related jobs. In absolute terms this is again dominated by recycling-based manufacturing,[42] as well as recyclables processing. Collection, reuse and remanufacturing, and to a small extent composting, also contribute to Base Case job growth in 2030.

D. GREEN ECONOMY SCENARIO – MSW MANAGEMENT JOB CREATION (2030)

The Green Economy Scenario is characterized by an aggressive recycling and composting program that results in a 75-percent overall waste diversion rate (see Section IV). The growth in the overall waste stream is identical to the Base Case. The achievement of 75-percent diversion through a comprehensive set of programmatic, regulatory and policy measures results in dramatic increases in employment.

Figure 13
U.S. Jobs by MSW Management Activity, 2030 – Green Economy Scenario
(Total jobs=1,683,456)

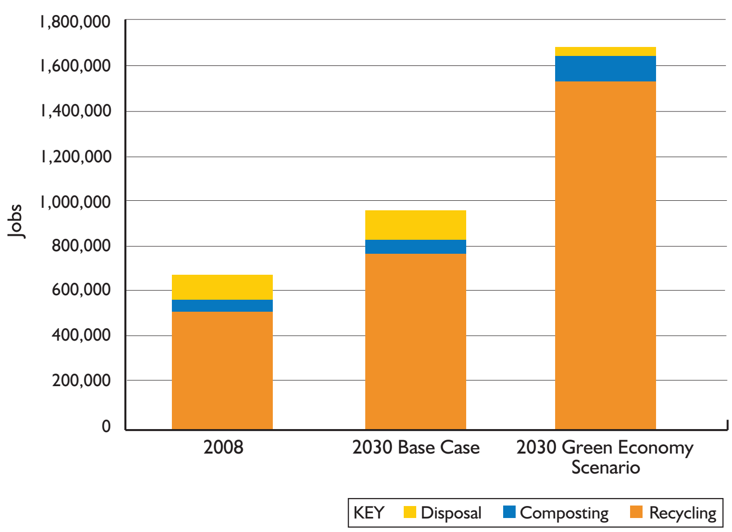


As summarized in Figure 13, total employment in MSW management reaches almost 1.7 million in the Green Economy Scenario. Whereas the Base Case Scenario generates about 280,000 incremental jobs by 2030 (946,000 minus 666,000), the Green Economy Scenario generates more than 1 million (1,017,000) incremental jobs (1,684,000 minus 666,000). This is 739,000 jobs more than the Base Case.

Note that our jobs analysis does account for direct job losses in waste collection for disposal and at the disposal facilities themselves. However, it does not account for the upstream job losses in mining and processing associated with the substitution of recycled for virgin material inputs in manufacturing. Unfortunately, standard data for all materials and processes to make such job loss estimates is not available. Based on the limited data for a small number of materials reviewed for the current study, these losses appear to be relatively small, and a significant fraction will occur outside of the U.S. Also, we have not assessed any negative employment changes that might occur as a result of income going away from capital toward labor—but evidence suggests that there would be a net positive gain in jobs due to the higher labor intensity of the Green Economy.[43]

On a percentage basis the programmatic and policy efforts in the Green Economy Scenario result in very significant increases in reuse and remanufacturing as well as composting. Thus, 2030 reuse and remanufacturing employment grows from about 41,000 in the Base Case to almost 216,000 in the Green Economy Scenario. Composting-related jobs grow from 17,000 to almost 33,000. In absolute terms, recycling-based manufacturing still comprises the largest share of additional jobs in 2030.[44]

Figure 14
U.S Jobs by MSW Waste Flow

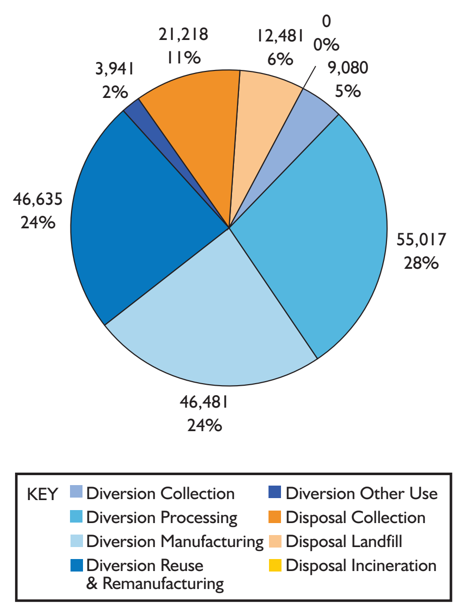


Not only are all the new jobs generated in recycling and composting related activities, there is a noticeable drop in the already small fraction of jobs related to disposal. Thus, disposal jobs decline from about 104,000 in 2008 to 34,000 in 2030. A comparative summary of job creation in the Base Case and Green Economy Scenarios is presented in Figure 14.[45]

E. JOBS RELATED TO CURRENT (2008) C&D MANAGEMENT SYSTEM

In 2008 an estimated 195,000 jobs were associated with the C&D management system in the U.S. This figure is based on the current C&D waste generation and management system described in Section II.B and summarized in Figure 6, plus the job production estimates presented in Table 5. As summarized in Figure 15, of the approximately 195,000 jobs related to C&D management in 2008, the vast majority (about 83 percent) are associated with diversion, and only a small fraction (about 34,000 jobs, or 17 percent) with collection and disposal through landfilling. Recall that in terms of tons managed in 2008, recycling and composting accounted for only about 30 percent of total C&D generated and about 70 percent was disposed through landfilling or incineration.

Figure 15
U.S. Jobs by C&D Management Activity, 2008
(Total jobs=194,854)



Of the jobs associated with C&D recycling, processing of recyclables and use of recycled materials in manufacturing accounts for more than half of total jobs related to C&D management (28 percent and 24 percent, respectively), followed by reuse (24 percent). This reflects the product of the labor intensity of these management activities and the magnitude of the waste flows handled by each activity.

Job Creation Opportunities from Deconstruction: An Alternative to Demolition and C&D Landfilling

Each year hundreds of thousands of residential and commercial buildings are demolished in the U.S., with the vast majority of the demolition waste disposed in landfills. While certain high-value materials such as metals are sometimes removed prior to demolition, particularly from commercial buildings, generally the entire building is taken down and landfilled as undifferentiated C&D waste. Following preparatory work to remove hazardous materials such as asbestos and to disconnect utilities, demolition is usually a fast process in which a site with a home or small building can be cleared for new structures in one or two days. Larger buildings may require the use of a wrecking ball or other heavy equipment but the aim is the same: remove the structure as quickly as possible. The speed and ease of readying a site for a new use is a key advantage of demolition.

At the same time, demolition generates large quantities of waste that must be disposed and can be costly, particularly in terms of landfill tip fees. Moreover, demolition relies on machines such as cranes, excavators and/or bulldozers, and most projects require only a small number of workers/operators for short periods.

In contrast, deconstruction involves taking a building apart while carefully preserving valuable elements for re-use and recycling. Deconstruction is often described as “construction in reverse,” where materials within a building are given a new life. In addition to windows, doors, flooring, appliances and bathroom fixtures, among the materials most readily reclaimed are brick, stone and wood. Materials are removed and segregated by material type for reuse or recycling. Carefully planned deconstruction projects have achieved upwards of 90-percent landfill diversion rates.

While deconstruction is an old practice, for decades it has been a marginal activity accounting for only a tiny fraction of building removals.[46] In recent years, however, the sustainability and green building movements have revived interest in deconstruction due to its environmental benefits, particularly the capture and reuse of embedded energy and the reduction in greenhouse gas emissions, as well as the diversion of large quantities of materials from landfills and the recovery and use of recycled materials in place of virgin resources. Another potential benefit is the United States Green Building Council's LEED (Leadership in Energy and Environmental Design) building certification program, which offers a number of credits for reusing recovered materials.

Given that deconstruction generally occurs on-site and is relatively labor-intensive, there are important local economic benefits, including the creation of "green jobs." Though reliable data are not readily available, and the current report does not explicitly consider the job creation potential of deconstruction, a recent analysis assessed the relative job-creation impacts of deconstruction versus demolition and concluded that "for every one demolition job lost, approximately 5 to 7 deconstruction jobs were created."[47] The Institute for Local Self Reliance (ILSR) estimates that nationally deconstruction "could create as many as 200,000 full-time equivalent jobs each year."[48] The Deconstruction Institute (a Sarasota-based partnership of the Florida Department of Environmental Protection, the University of Florida and others) estimates that "deconstruction of a 2,000 square foot home will create 38 more worker-days at a living wage than would demolition."[49] The institute has developed an online benefit calculator so users can estimate the land use, economic (including jobs), energy and greenhouse gas benefits of building deconstruction relative to demolition.

Deconstruction also presents an excellent on-the-job training opportunity for apprentices or trainees in the building trades, as taking down a structure teaches workers a variety of skills required in building construction. Moreover, deconstruction has been recognized as a contributor to community development and can be used in federally funded public housing and urban revitalization projects, providing further training and employment opportunities.

The economics of deconstruction vary by project. The time required and labor costs are the main drawbacks. The deconstruction process for small buildings can take weeks, whereas demolition may be completed in a day or two. The higher labor costs can be offset to a lesser or greater degree depending on a number of factors, including: the degree to which the recovered materials can be reused on-site (e.g., in a new structure), the regional market for reclaimed materials, the potential for donating materials to local non-profits (e.g., Habitat for Humanity's ReStore) for income tax write-offs, and the cost of landfill tipping fees that are avoided.

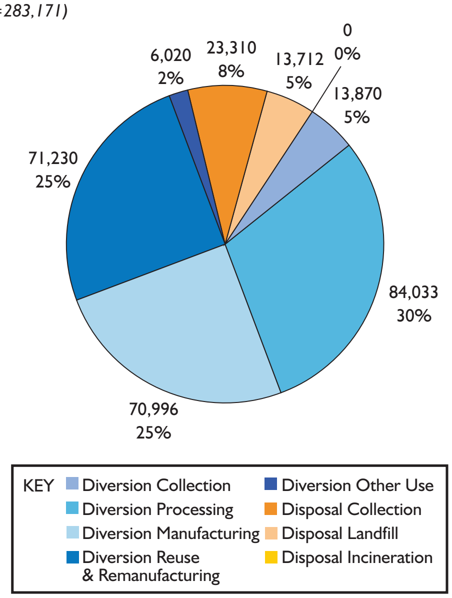
The development of a range of new equipment and facilities has allowed for the easier segregation of waste types and materials processing. Some reclaimed materials, such as demolished concrete may be crushed and reused on-site (for ground stabilization or as aggregate in the mixing of concrete), while much is transported off-site for processing. Wood waste, for example, can be reused for its original purpose, or processed and used to manufacture engineered wood products such as fiberboard and chipboard, or composted.

The existence of markets for the recovered material is an important component of a successful deconstruction program. These might include commercial architectural salvage businesses, reclamation yards and not-for-profit salvage warehouses. According to ILSR there are now more than 400 deconstruction businesses in the U.S. This has led to the establishment of the Building Materials Reuse Association, a trade group for the industry. Municipalities and states can promote deconstruction and the development of processing capacity and end markets through a variety of regulatory measures (e.g., the ban on landfilling of unprocessed C&D waste in Massachusetts) and incentives, such as support favorable tax treatment for investment in new processing facilities.

F. BASE CASE SCENARIO – C&D MANAGEMENT JOB CREATION (2030)

As described in Section III, Base Case C&D waste generation projections to 2030 are driven primarily by population growth, and the C&D diversion rate grows from 30 to 37 percent throughout the period. Figure 16 presents a summary of the number of jobs by MSW management activity in the Base Case in 2030. Due to an increase in overall tonnage managed and the increase in the diversion rate between 2008 and 2030, the number of total jobs grows in the Base Case from about 195,000 to 283,000 jobs (growth of more than 88,000 jobs, or 45 percent).

Figure 16
U.S. Jobs by C&D Management Activity, 2030
Base Case
(Total jobs=283,171)



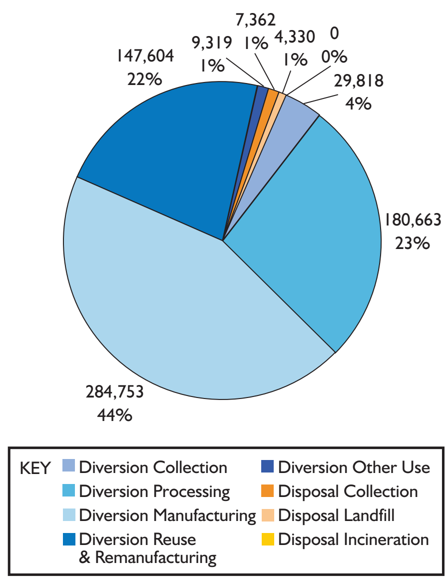
As summarized in Figure 16, of the approximately 283,000 jobs related to C&D management in 2030, the vast majority (about 87 percent) are associated with diversion, and only a small fraction (about 37,000 jobs, or 13 percent) with collection and disposal through landfilling. Recall that in terms of tons managed in 2008, recycling and composting accounted for only about 30 percent of total C&D generated and about 70 percent was disposed through landfilling or incineration.

Of the jobs associated with C&D recycling, material processing and use of recycled materials in manufacturing accounting for 55 percent of total jobs related to C&D management, followed by reuse (25 percent). This reflects the product of the labor intensity of these management activities and the magnitude of the waste flows handled by each activity.

G. GREEN ECONOMY SCENARIO – C&D MANAGEMENT JOB CREATION (2030)

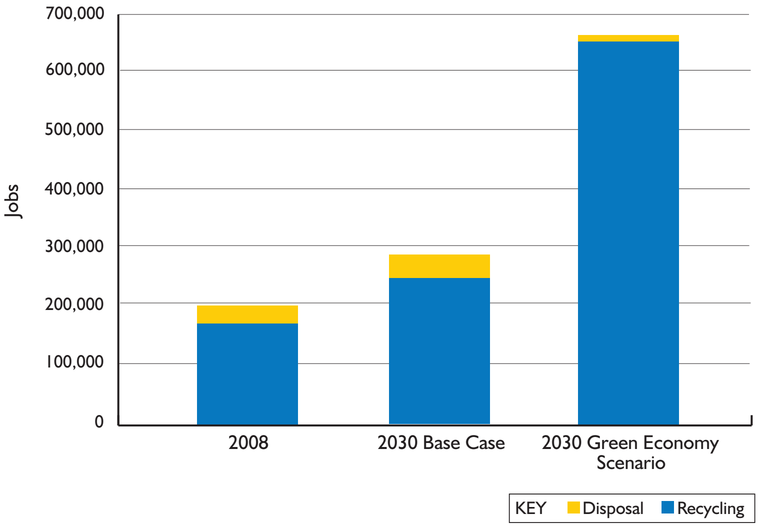
The Green Economy Scenario is characterized by an aggressive C&D recycling program that results in an 80-percent overall waste diversion rate (see Section IV.B). The growth in the overall C&D waste stream is identical to the Base Case. The achievement of 80-percent diversion through a comprehensive set of programmatic, regulatory and policy measures results in dramatic increases in employment.[50]

Figure 17
U.S. Jobs by C&D Management Activity, 2030
Green Economy Scenario
(Total jobs=663,849)



As summarized in Figure 17, total employment in C&D management reaches almost 664,000 jobs in the Green Economy Scenario. With significantly higher material recovery rates, jobs associated with C&D disposal decline to just 2 percent (about 12,000 jobs) of the total C&D related workforce. Whereas the Base Case Scenario generates about 88,000 incremental C&D management jobs by 2030, the Green Economy Scenario generates 469,000 incremental jobs, more than a five-fold increase. Jobs related to manufacturing of C&D recycled materials account for about 44 percent of these jobs, while about 27 percent are associated with materials processing, and 22 percent with reuse.

Figure 18
U.S. Jobs by C&D Waste Flow



In summary, the Green Economy Scenario for the C&D waste stream results in more than 380,000 more jobs than the Base Case Scenario in 2030. This comparison is summarized in Figure 18.

H. SUMMARY: TOTAL MSW AND C&D JOB IMPACTS IN 2030, BASE CASE AND GREEN ECONOMY SCENARIO

Processing and recycling or composting discarded materials creates far more jobs than disposing of them. This is true for both MSW and C&D debris. The use of recycled materials in the manufacture of new products is particularly labor intensive. With the large discrepancy in job creation per ton between recycling and composting on the one hand, and disposal on the other, increasing diversion rates has a very significant impact on job creation.

Table 6 and Figure 19 summarize the total employment from MSW and C&D management (diversion and disposal) in 2008 and in 2030 for both the Base Case and Green Economy Scenario. In 2008, total employment to manage the MSW and C&D streams was approximately 861,000. Relative to 2008 levels, in 2030 the Base Case produces an estimated additional 368,000 direct jobs, driven primarily by population growth and a modest increase in the diversion rate. In contrast, by 2030 the Green Economy Scenario creates an estimated 1.5 million additional jobs compared with 2008, more than 1.1 million more jobs than in the Base Case.

Table 6
Total MSW and C&D Job Impacts
(Number of Jobs)

	2008	2030 BASE CASE	2030 GREEN ECONOMY SCENARIO
MSW Diversion	573,591	841,940	1,649,569
MSW Disposal	92,380	103,760	33,886
C&D Diversion	161,154	246,149	652,157
C&D Disposal	33,699	37,022	11,692
Total Jobs	**860,825**	**1,228,870**	**2,347,305**

Figure 19
Total MSW and C&D Job Impacts

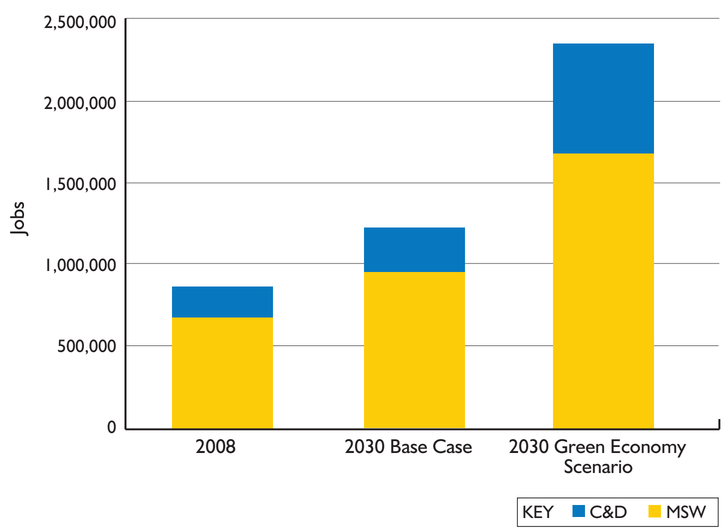


Table 5 Sources: These job production estimates were derived based on the following sources: U.S. Recycling Economic Information Study, prepared for the National Recycling Coalition, Inc. by R.W. Beck, Inc., 2001; Recycling Economic Information Study Update: Delaware, Maine, Massachusetts, New York, and Pennsylvania, prepared for the Northeast Recycling Council by DSM Environmental and MidAtlantic Solid Waste Consultants, February, 2009; Resource Management in the State of Delaware, prepared for the Delaware Natural Resources and Environmental Control by The Institute for Local Self-Reliance, 2007; and data collected in 2010 by CM Consulting on behalf of the Container Recycling Institute for a forthcoming report on job creation from recycling.

Table 6 Sources: See Figures 11 – 13 and 15 -17.

Figure 11 Source: Based on job production estimates summarized in Table 5, applied to 2008 waste generation and management system as summarized in Figure 3.

Figure 12 Source: Based on job production estimates summarized in Table 5, applied to 2030 Base Case waste generation and management system as summarized in Figure 5.

Figure 13 Source: Based on job production estimates summarized in Table 5, applied to 2030 Green Economy Scenario waste generation and management system as summarized in Figure 7.

Figure 14 Source: Based on job production estimates summarized in Table 5, applied to 2008 and the 2030 Base Case and Green Economy Scenario waste generation and management systems as summarized in Figure 3, 5 and 7, respectively.

Figure 15 Source: Based on job production estimates summarized in Table 5, applied to 2008 C&D waste generation and management system as summarized in Table 2.

Figure 16 Source: Based on job production estimates summarized in Table 5, applied to 2030 C&D waste generation and management system as summarized in Table 3.

Figure 17 Source: Based on job production estimates summarized in Table 5, applied to 2030 Green Economy Scenario waste generation and management system as summarized in Table 4.

Figure 18 Source: Based on job production estimates summarized in Table 5, applied to 2008 and the 2030 Base Case and Green Economy Scenario waste generation and management systems as summarized in Tables 2, 3 and 4, respectively.

Figure 19 Sources: See Figures 14 and 18.

VI. ENVIRONMENTAL EMISSIONS IMPACTS: BASE CASE AND GREEN ECONOMY SCENARIO

A. METHODOLOGY

To assess the relative environmental impacts of the alternative waste management scenarios in 2030 for the U.S., we utilized the Measuring Environmental Benefits Calculator (MEBCalc™) model, a life-cycle assessment (LCA) tool developed by team member Jeffrey Morris. The model employs a life-cycle approach to capture the input of energy and the output of wastes and pollution that occur over the three phases of a material's or product's life cycle:

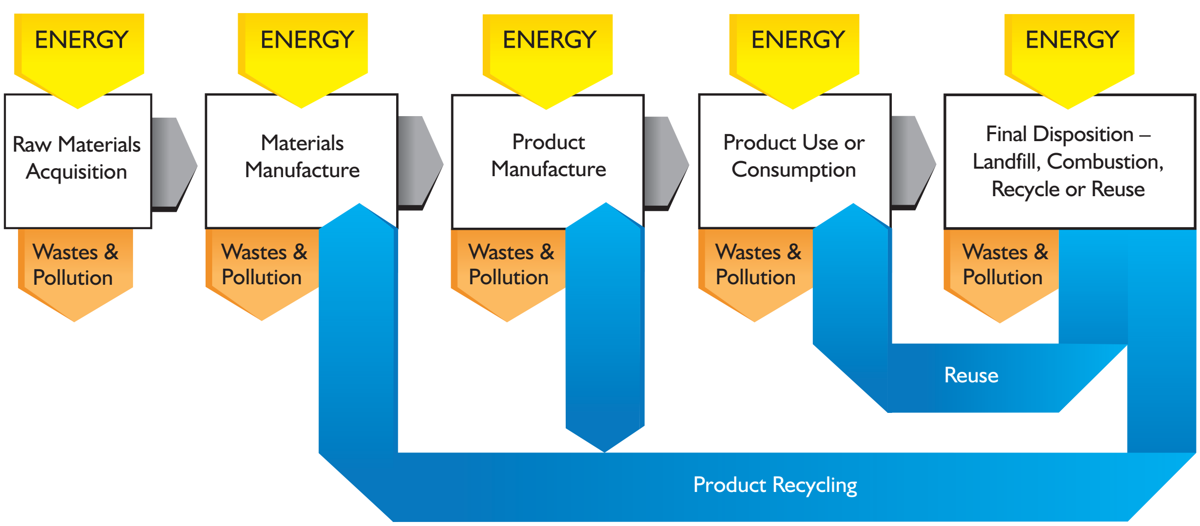
- Upstream phase – resource extraction, materials refining and product manufacturing;
- Use phase – product use; and
- End-of-life phase – management of product discards.

The LCA approach employed in MEBCalc™ is shown in Figure 20. It depicts how reuse and recycling eliminate the need for the upstream phase, thereby conserving energy and reducing releases of waste and pollutants in the production of goods and services. Most of this environmental value comes from pollution reductions in the manufacture of new products made possible by the replacement of virgin raw materials with recycled materials and the replacement of synthetic petroleum-based fertilizers with compost.

The model utilizes the best data sources available, relying on the following:

- US EPA WAste Reduction Model (WARM)
- US EPA MSW Decision Support Tool (DST)

Figure 20
Schematic of a Life-Cycle Assessment



OPEN-LOOP RECYCLING: One or limited number of return cycles into product that is then disposed.
CLOSED-LOOP RECYCLING: Repeated recycling into same or similar product, keeping material from disposal.

- Carnegie Mellon University Economic Input-Output Life Cycle Assessment (EIO-LCA) model
- Washington State Department of Ecology Consumer Environmental Index (CEI) model
- Peer-reviewed journal articles authored by team member Jeffrey Morris

The environmental benefits estimates are based on pollution reductions that decrease the potential for seven categories of damage to public health and ecosystems:[51, 52]

- Climate change
- Human disease and death from particulates
- Human disease and death from toxics
- Human disease and death from carcinogens
- Eutrophication
- Acidification
- Ecosystems toxicity

Life cycle analysis and environmental risk assessments provide the methodologies for connecting pollution of various kinds to these seven categories of environmental damage. For example, releases of various greenhouse gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and others – cause global warming which leads to climate change. The United Nations Intergovernmental Panel on Climate Change (IPCC) has thoroughly reviewed the scientific data to determine the strength of each pollutant relative to carbon dioxide in causing global warming. Based on these global warming potential factors the emissions of all greenhouse gas pollutants are aggregated into CO_2 equivalents (eCO_2).

Similar scientific efforts enable the quantity of pollutant releases to be expressed in terms of a single indicator for the other six categories of environmental damage. This greatly simplifies reporting and analysis of different levels of pollution. By grouping pollution impacts into a handful of categories, environmental costs and benefits modeling is able to reduce the complexity of tracking hundreds of pollutants. This makes the data far more accessible to policy makers. For this process the Measuring Environmental Benefits Calculator relies on the methodologies used in U.S. EPA's TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) model and the Lawrence Berkeley National Laboratory's CalTOX model.[53, 54]

For key materials in the MSW and C&D streams the methodology aggregates pollutants for each environmental impact category in terms of the following indicator pollutants:

- Climate change – carbon dioxide equivalents (eCO_2)
- Human health-particulates – particulate matter less than 2.5 microns equivalents ($ePM_{2.5}$)
- Human health-toxics[55] – toluene equivalents (eToluene)
- Human health-carcinogens – benzene equivalents (eBenzene)
- Eutrophication – nitrogen equivalents (eN)
- Acidification – sulfur dioxide equivalents (eSO_2)
- Ecosystems toxicity – herbicide 2,4-D equivalents (e2,4-D)

Additional documentation of the model is provided in Appendix E, Documentation for the Measuring Environmental Benefits Calculator model, which references the supporting documentation for the other tools and sources mentioned previously.

Key Modeling Assumptions

The model was applied to the U.S. waste stream tonnages and material composition as reported in Section II: 2008 current system, Section III: 2030 Base Case Scenario, and Section IV: 2030 Green Economy Scenario. The management systems for each material in the various scenarios are summarized in figures and tables in their respective sections.[56]

Note that the following definitions and assumptions are used in the MEBCalc™ model to calculate the results reported in this section:

- Recycling: closed loop material recycling
- Composting: aerobic composting
- WTE Incineration: mass burn thermal conversion/advanced thermal recycling (offset to natural gas powered electricity generation)
- Landfill Energy: 75 percent methane capture and conversion to electricity in an internal combustion engine (offset to natural gas electricity)

- Recycled: closed loop discarded-materials-content products
- Virgin: newly extracted raw-materials-content products

Key assumptions used in the MEBCalc™ model for calculating the life-cycle emissions include the following:

- All emissions resulting from landfilling a particular waste material that will occur over a hundred-year time period as a result of burying that material are modeled as if they occur at the time of landfilling.
- Material decomposition rates are taken from the WARM model and are based on national dry-tomb standard landfills.
- Similarly, carbon storage rates for each waste material are based on the WARM model.
- Net GHG emissions are based on (1) gross GHG emissions per ton MSW, including transport related emissions; (2) any increases in carbon stocks due to waste management practices (e.g., landfilling results in continued carbon storage as a portion of the organics disposed in a landfill do not decompose); and (3) energy generation from waste that displaces fossil fuel consumption and related emissions. This approach is the same as that used by EPA and can be summarized as follows: Net GHG emissions = Gross GHG emissions – (Increase in carbon stocks + Avoided utility GHG emissions).
- CO_2 emissions from biogenic waste (e.g., paper, yard trimmings, food discards) are accounted for according to IPCC guidelines and consistent with EPA's approach in WARM and DST. That is, carbon emissions from biogenic sources are considered as part of the natural carbon cycle – returning CO_2 to the atmosphere that was removed by photosynthesis – and their release does not count as adding to atmospheric concentrations of carbon dioxide, except that waste management activities that maintain storage of previously sequestered biogenic carbon over the 100-year time period of the climate impacts analysis are credited for that continued storage in comparison to waste management activities that result in the release of that previously sequestered carbon. Conversely, CO_2 emitted by burning fossil fuel, is counted because it enters the cycle due to human activity. Similarly, methane emissions from landfills are counted (even though the carbon source is largely biogenic) because the methane is generated only as a result of the anaerobic conditions that human landfilling of waste creates.[57]
- A landfill gas (LFG) capture rate of 75 percent is assumed. This is consistent with the default capture rate used in EPA's WARM model.[58]
- Landfilling of municipal waste combustion ash is considered in the model, including emissions from transport to an ash landfill. Virtually all carbon is assumed to be combusted in the incineration process. Thus, for modeling purposes MWC ash contains no carbon.
- Traditional MWC reduces the volume of waste by 90 percent. This is consistent with the assumptions used in U.S. EPA's Decision Support Tool.
- For MWCs, 70 percent of ferrous metal is assumed to be recovered from ash and recycled. This is consistent with the DST assumptions.
- Emissions from operational activities at landfills and MWC facilities, such as use of heavy equipment as well as landfill leachate and MWC ash management, are based on the DST and taken into account.
- The generation of electricity from landfill gas is assumed to be done using internal combustion engines.
- Collection, transfer and transport distances are assumed to be similar across disposal technologies. Waste transport of up to 200 miles by truck and 400 or more miles by rail is modeled for transport emissions calculations.
- Recycled materials are assumed to be hauled up to 200 miles one-way by truck from MRF to end use, up to 3000 miles by rail, or up to 7,000 miles by ship or barge, depending on the particular material recycled.

B. RESULTS: COMPARISON OF EMISSION REDUCTIONS FOR EACH SCENARIO

The MEBCalc™ model was used to calculate the relative emissions of the various waste management approaches under consideration in this report: 2008 current system, 2030 Base Case Scenario and 2030 Green Economy Scenario. Table 7 presents a summary of the life-cycle emissions per ton of solid waste as calculated using the MEBCalc™ model (based on the 2030 Green Economy waste management system).

Table 7
Summary of Per Ton Emissions by Management Method
(Pounds of Emissions (Reductions)/Increase Per Ton)*

MANAGEMENT METHOD	Climate Change	Human Health – Particulates	Human Health – Toxics	Human Health – Carcinogens	Eutrophication	Acidification	Ecosystem Toxicity
	(eCO_2)	*($ePM_{2.5}$)*	*(eToluene)*	*(eBenzene)*	*(eN)*	*(eSO_2)*	*(e2,4-D)*
Recycle/Compost	(3,800)	(5.00)	(1,400)	(0.47)	(1.80)	(20.0)	(5.90)
Disposal	(112)[59]	0.61	301	0.06	0.16	3.8	0.46

Based on Green Economy composition of recycled/composted materials and of disposed materials. Disposal emission factors are the Green Economy Scenario weighted average (by tonnage) of those for landfilling and incineration. See Appendix E for MEBCalc™ documentation.

It is important to note that for modern landfills and waste-to energy incinerators the emission factors used to compare environmental performance are based largely on modeling and/or vendor claims for modern, state-of-the art facilities, as opposed to actual operational data from real-world experience. This puts these facilities in the best light possible from an environmental performance standpoint.

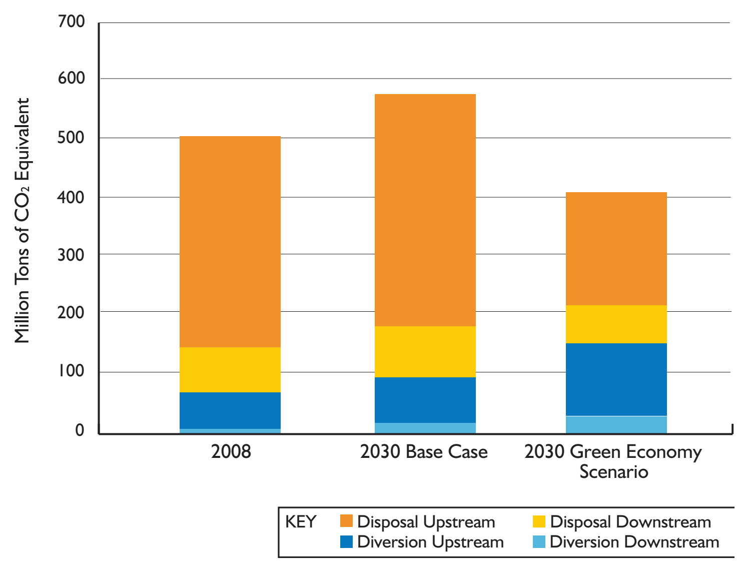
For each of the seven major emissions categories modeled, recycling/composting reduces per ton emissions considerably more than the waste disposal technologies. Most of these benefits come from pollution reductions in the manufacture of new products made possible by the replacement of virgin raw materials with recycled materials plus the replacement of synthetic petroleum-based fertilizers with compost. For most pollutants, the relative benefits of upstream diversion are quite dramatic. For example, recycling reduces energy-related eCO_2 emissions in the manufacturing process and avoids emissions from waste management. Moreover, paper recycling maintains the ongoing sequestration of carbon in trees that would otherwise need to be harvested to manufacture paper. On a per ton basis, recycling saves more than 30 times more eCO_2 than disposal.

It should be noted that the lack of comprehensive data for disposal facility emissions profiles, other than for GHGs,[60] makes results for the other six environmental impacts – acidification, eutrophication, releases of particulates damaging to human health, and releases of toxics and carcinogens damaging to human health and ecosystems – less certain.

Greenhouse Gas Emissions

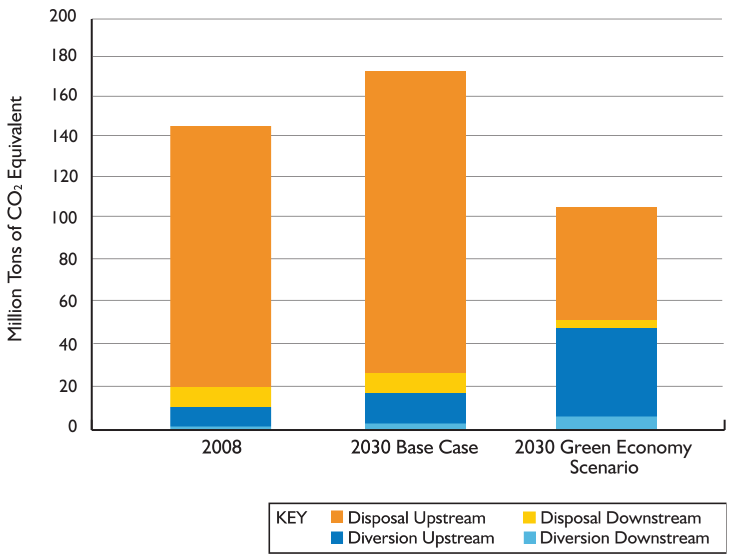
Figure 21 presents a comparison of the total GHG emissions from MSW management in 2008 and in 2030 for the Base Case and Green Economy Scenario (referred to as an emissions inventory). The 2030 Base Case emissions reflect a larger overall waste stream due to projected population growth, and an increase in the diversion rate from about 33 to 41 percent. The 2030 Green Economy Scenario has the same growth in the waste stream, but the diversion rate increases to 75 percent. In 2030 Base Case GHGs total 572 million metric tons CO_2-equivalent ($MTCO_2e$), a net increase of 71 million $MTCO_2e$ over 2008 levels, while total GHGs in the Green Economy Scenario decline to about 405 million $MTCO_2e$, 167 million $MTCO_2e$ less than in the Base Case.

Figure 21
U.S. Total GHG Emissions from MSW



Figures 21 and 22 distinguish GHG generation in terms of disposal versus diversion for each scenario as well as "upstream" versus "downstream" sources. Downstream refers to GHGs associated with collection, processing, hauling and disposal, whereas upstream refers to GHGs from raw material extraction and refining and manufacturing. Not surprisingly, the bulk of the net reductions in GHG generation from MSW and C&D in the Green Economy Scenario results from less waste being disposed.

Figure 22
U.S. Total GHG Emissions from C&D

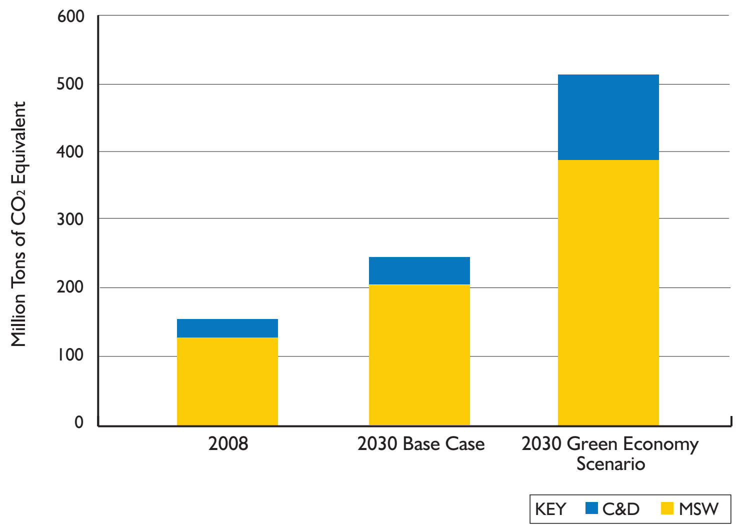


The GHG emissions inventory for the C&D management system is presented in Figure 22. It shows a similar pattern whereby total net GHG emissions in 2030 increase in the Base Case (from 145 million MTCO$_2$e in 2008 to 172 million MTCO$_2$e in 2030), while in Green Economy Scenario they decline considerably to 105 million MTCO$_2$e, almost 39 percent below the Base Case emissions.

Figure 23 presents the GHG emissions data in an alternative format, showing GHG savings that accrue from diversion activities in the MSW and C&D management systems, respectively. For MSW, diversion activities in the Base Case scenario reduce GHG emissions by about 202 million MTCO$_2$e, while the Green Economy Scenario avoids about 387 million MTCO$_2$e, almost twice the reductions as in the Base Case.

For C&D, diversion activities in the Base Case scenario reduce GHG emissions by about 36 million MTCO$_2$e, while the Green Economy Scenario avoids about 128 million MTCO$_2$e, about three and a half times the reductions as in the Base Case.

Figure 23
Climate Change Emissions Reductions from Diversion



The combined additional GHG reductions achieved in 2030 in the Green Economy Scenario relative to the Base Case total 276 million MTCO$_2$e (185 million tons from MSW and 91 million tons from C&D). These reductions are equivalent to shutting down about 72 coal-fired power plants or taking 50 million cars off the road.[61]

Other Emissions Impacting Human Health and Ecosystems

As described above, in addition to assessing emissions of greenhouse gases, we have estimated the relative environmental benefits of the different waste management scenarios for the six other emission categories. Three impact public health in terms of human disease and death (particulates, toxics and carcinogens), and three damage ecosystems (eutrophication from nitrogen equivalents, acidification from sulfur dioxide equivalents and ecosystem toxicity from herbicide 2,4-D equivalents). To simplify reporting and analysis the quantity of each pollutant category is expressed in terms of a single indicator. A detailed explanation of the methodology is provided in Appendix E.

For each of the other pollutant categories, Figures 24 - 29 present the comparative results of the analysis in terms of estimated pollution reduction associated with each scenario. Since these are expressed as emission reductions, larger numbers represent less pollution. Note that for all of these pollutants except CO_2, the contribution in emissions reductions from C&D recycling is negligible. This is largely due to the fact that much of this material is inert and that the material disposed in landfilled rather than incinerated.

For all pollutants, the Green Economy Scenario produces far greater emission reductions in 2030 than the Base Case, resulting in reduced threats to human health in terms of respiratory disease, cancer, and other impacts of toxics, as well as improved ecosystem health.

Figure 24
Respiratory Emissions Reductions from Diversion

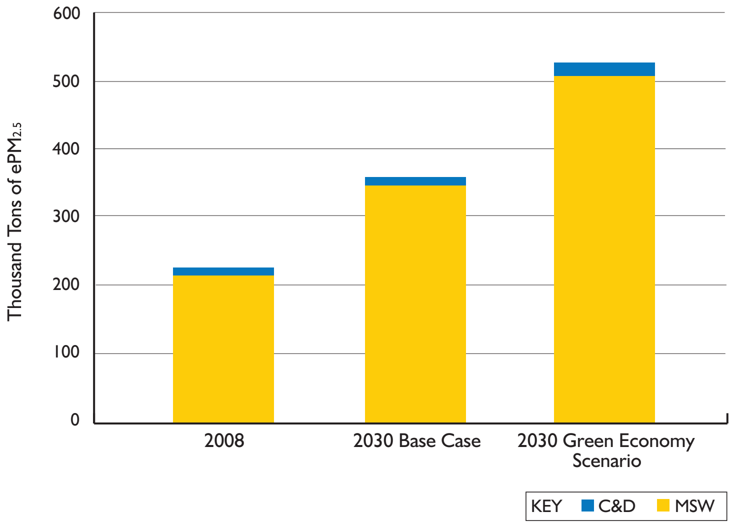
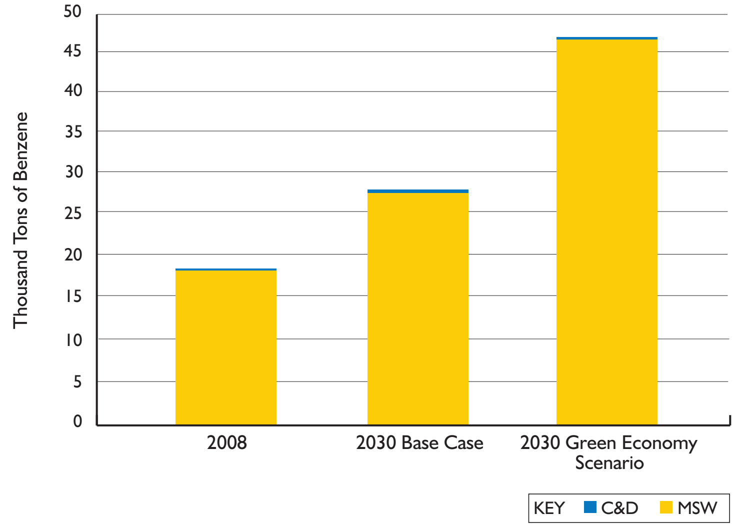
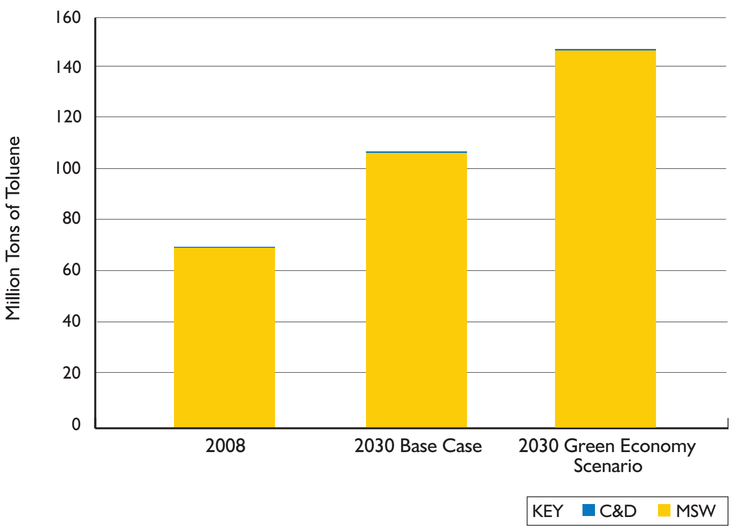


Figure 26
Carcinogenic Emissions Reductions from Diversion



Note: The carcinogenic emissions impacts from C&D are negligible and do not show up on this scale.

Figure 25
Toxic Emissions Reductions from Diversion



Note: The toxic emissions impacts from C&D are negligible and do not show up on this scale.

Figure 27
Eutrophication Emissions Reductions from Diversion

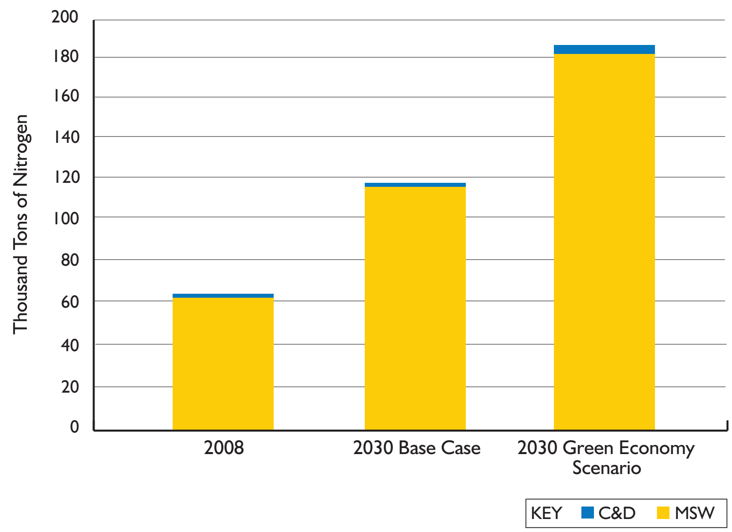


Figure 28
Acidification Emissions Reductions from Diversion

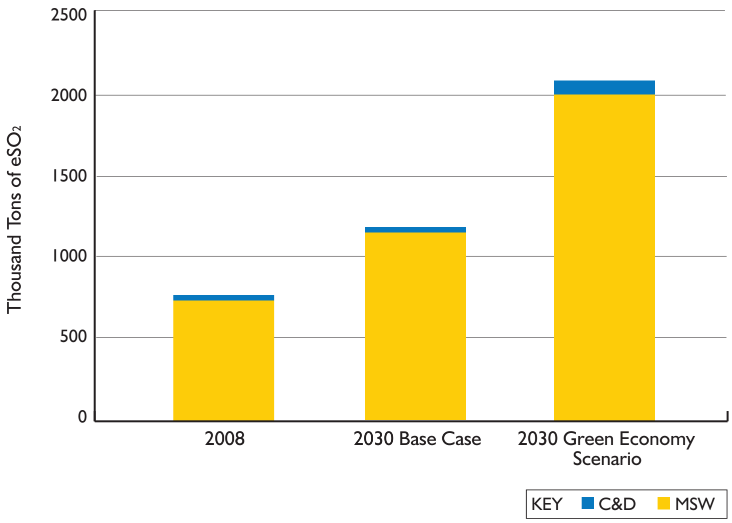
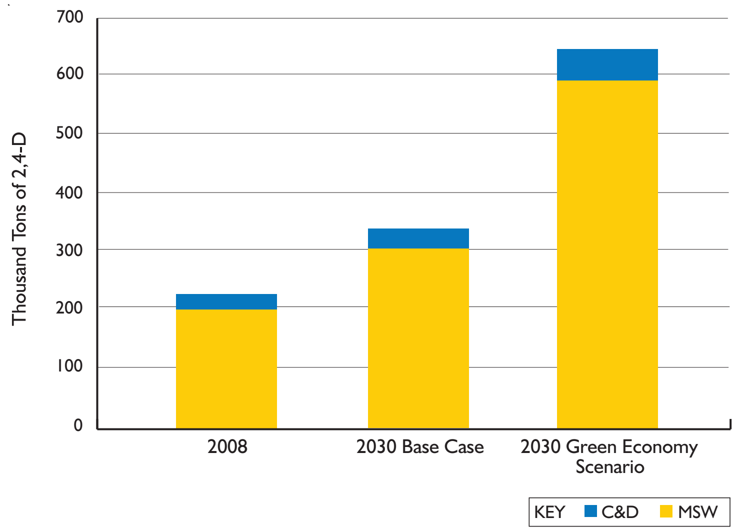


Figure 29
Ecosystems Toxic Emissions Reductions from Diversion



Environmental Emissions Impacts Summary
As summarized in the results described above, the Green Economy Scenario represents a powerful opportunity to reduce the human health and ecosystem impacts of pollution from waste management activities.

Figure 21-29 Sources: Based on applying material-specific emission factors in MEBCalc™, aggregated and summarized in Table 7, to the waste generation and composition data for the three scenarios detailed in Sections II, III and IV.

VII. REFERENCES

1. By "diversion" we mean diversion from waste disposal either in landfills or incineration facilities. Waste diversion approaches include waste reduction, reuse and remanufacturing, recycling and composting.
2. Based on "Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2008," U.S. EPA, November 2009.
3. Based on "Characterization of Building-Related Construction and Demolition Debris in the United States," prepared by Franklin Associates for U.S. EPA, June 1998.
4. Background data table from "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," U.S. EPA, November 2009.
5. Table 1. Projections of the Population and Components of Change for the United States: 2010 to 2050 (NP2008-T1), Population Division, U.S. Census Bureau, Release Date: August 14, 2008.
6. U.S. Recycling Economic Information Study, National Recycling Coalition, July 2001. Prepared by R.W. Beck; Recycling Economic Information Update: Delaware, Maine, Massachusetts, New York, and Pennsylvania, Northeast Recycling Council (NERC), February 2009. Prepared by DSM Environmental Services, Inc. (DSM) and MidAtlantic Solid Waste (MSW) Consultants; and Resource Management in the State of Delaware, Report to the Secretary, Delaware Natural Resources and Environmental Control, prepared by Neil Seldman and Richard Anthony, The Institute for Local Self-Reliance, 2007.
7. MEBCalc was developed by team member Jeffrey Morris. The model utilizes the best data sources available and has been utilized in numerous government sponsored studies concerning the environmental impacts of recycling and composting. See Section VI for details.
8. GHG reduction equivalents based on U.S. EPA figures at: http://www.epa.gov/cleanenergy/energy-resources/refs.html#coalplant and http://www.epa.gov/otaq/climate/420f05004.htm.
9. Throughout this report, we use the terms "national recycling strategy," "75-percent diversion," and "Green Economy Scenario" interchangeably. They all are shorthand for a multi-faceted effort that includes the full range of diversion methods.
10. As above, "recycled" refers to source reduced, reused/remanufactured and recycled.
11. Based on 2008 MSW data from: "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," U.S. EPA, November 2009, Table 1, and 2003 C&D data from "Estimating 2003 Building-Related Construction and Demolition Materials Amounts," U.S. EPA, 2009, p. 17.
12. U.S. EPA, *Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2008*, p. 1, November 2009.
13. Generation refers to total waste produced prior to recycling or composting.
14. As described above, for this analysis the overall solid waste stream comprises MSW and C&D debris; it does not include industrial, agricultural, or other waste streams.
15. U.S. EPA, "Estimating 2003 Building-Related Construction and Demolition Materials Amounts." March 2009 at p. 2. We have escalated EPA's 2003 C&D generation estimate to 2008, based on population change over this period. C&D waste generation is driven by a variety of economic and social factors such as general economic conditions; the level of activity in the construction industry; demographic changes such as population growth and shifts in terms of household size. EPA's report on 2003 C&D (p. 25) acknowledges that changes in building activity and construction spending do not necessarily correlate to increased material use because these measures can reflect inflation, profit and other factors. Thus, for the current study we have simply scaled C&D generation with population as a conservative estimate of projected C&D generation.
16. The approach used by EPA to estimate C&D generation relies on national statistics including typical waste generation estimates during building construction, renovation, demolition, or maintenance activities. For diversion estimates EPA relied on 2003 data reported by state environmental agencies which, as noted above, vary widely based on different definitions of C&D waste. While this wide range of estimates reflects the overall weakness of C&D data, several factors can be identified that contribute to significant differences in C&D generation, composition and management among the states: regional differences in C&D composition owing to varying climactic conditions and construction practices; dissimilar data collection and reporting protocols; and differences in the degree to which C&D diversion policies and infrastructure are in place.
17. For a summary of the EPA data see "Analyzing What's Recyclable in C&D Debris," Ken Sandler, *Biocycle*, November 2003, pp. 51-54.

18. Ibid.

19. See www.epa.gov/epawaste/nonhaz/industrial/cd/basic.htm.

20. "Characterization of Building-Related Construction and Demolition Debris in the United States," (p. 3-9) prepared by Franklin Associates for U.S. EPA, June 1998.

21. "2007 Massachusetts Construction and Demolition Debris Industry Study," DSM Environmental, May 2008.

22. "Construction & Demolition Waste Management in the Northeast 2006," Northeast Waste Management Officials' Association, 2009; "2005-2007 C&D Diversion, Revised," provided by Kinley Deller, Waste Reduction Specialist, King County, Washington, July 2010.

23. U.S. EPA, "Estimating 2003 Building-Related Construction and Demolition Materials Amounts." March 2009 at p. 22.

24. As defined by U.S. EPA: "Source Reduction activities reduce the amount or toxicity of wastes before they enter the municipal solid waste management system. Source reduction, also known as waste prevention, occurs before waste generation is measured." http://www.epa.gov/osw/conserve/rrr/pubs/r99034.pdf

25. Background data table from "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," U.S. EPA, November 2009, titled "Annual gen, recv, disposal data 11_25_09.xls."

26. According to EPA "Reduce & Reuse" website: http://www.epa.gov/osw/conserve/rrr/reduce.htm "More than 55 million tons of MSW were source reduced in the United States in 2000, the latest year for which these figures are available." Using EPA's estimated 2000 MSW generation of 239 million tons, the source reduction rate can be calculated as 55 ÷ (55+239) = 19%. http://www.epa.gov/wastes/nonhaz/municipal/pubs/msw2008rpt.pdf.

27. "Table 1. Projections of the Population and Components of Change for the United States: 2010 to 2050 (NP2008-T1)," Population Division, U.S. Census Bureau, Release Date: August 14, 2008. http://www.census.gov/population/www/projections/files/nation/summary/np2008-t1.xls

28. The assumed 1-percent annual growth in the recycling rate in the Base Case (1.01 times the previous year's rate) is somewhat higher than has been experienced since 2000, and is therefore a conservative assumption for the present analysis.

29. If the change in C&D waste generation were based on some measure of economic activity or construction industry activity, the annual growth rate to 2030 would likely be higher.

30. Unlike for MSW, where detailed trend data is available on diversion rates, there is no widely accepted national data source that provides similar data for C&D.

31. "Waste Reduction Program Assessment & Analysis for Massachusetts," prepared by Tellus Institute for the Massachusetts Department of Environmental Protection, February 2003.

32. *U.S. Recycling Economic Information Study*, National Recycling Coalition, July 2001. Prepared by R.W. Beck.

33. *Recycling Economic Information Update: Delaware, Maine, Massachusetts, New York, and Pennsylvania*, Northeast Recycling Council (NERC), February 2009. Prepared by DSM Environmental Services, Inc. (DSM) and MidAtlantic Solid Waste (MSW) Consultants.

34. See "The Economic Benefits of Recycling," by Brenda Platt and David Morris, Institute for Local Self-Reliance, 1993.

35. *Resource Management in the State of Delaware*, Report to the Secretary, Delaware Natural Resources and Environmental Control, prepared by Neil Seldman and Richard Anthony, The Institute for Local Self-Reliance, 2007.

36. "Job factors" refers to estimates of jobs produced per tonnage of materials managed.

37. The 2009 REI Update divides the jobs and economic data into three categories instead of two and is a clearer and more useful delineation of the various materials management related activities.

38. For a summary and evaluation of the critiques of the REI methodology, see "Evaluation of the Recycling Economic Information (REI) Study Methodology," ERG for U.S. EPA, n.d. http://www.epa.gov/osw/conserve/rrr/rmd/rei-rw/pdf/evaluation_508.pdf

39. Note that to be conservative in the analysis for plastics manufacturing using recycled input we used the derived job factor based on the 2009 REI Update (10.3 jobs per 1,000 tons), rather than the job factor based on the 2001 REI Study (69.2 jobs per 1,000 tons).

40. Note that many high-value products that are reused or remanufactured (e.g., computers and auto parts) are made of several materials, so the job production estimates are not precisely linked to specific materials. Rather, they relate to product categories in which certain materials dominate (e.g., metals for auto parts).

41. The growth rate for diversion in the base case is 1 percent per year and is consistent with the historical trend since 2003 as documented in U.S. EPA's "Municipal Solid Waste Generation, Recycling and Disposal in the United States, Detailed Tables and Figures for 2008," Table 2, November 2009.

42. The job growth estimates for the recycling-based manufacturing industry are based on all recycled materials being used by domestic manufacturers. While currently a significant fraction of recycled material (e.g., paper) is exported to China and elsewhere, the 2030 scenarios assume that several factors contribute to this material staying in the U.S.: implementation of climate legislation resulting in a carbon tax or

cap and trade program; significantly higher transportation costs; and adoption of a U.S. industrial policy aimed at retaining/growing domestic manufacturing that results in recycled materials staying in the U.S. for processing and use as inputs to manufacturing. These assumptions are particularly consistent with the policy and regulatory initiatives that characterize the Green Economy Scenario.

43. This requires an assumption that there is some structural unemployment in the economy from which to hire additional workers, which is the case.

44. See footnote 49.

45. Note that the current study did not analyze the job impacts of alternative scenarios in which the resources expended on the policy and regulatory initiatives associated with the Green Economy Scenario were spent elsewhere in the economy.

46. For example, the Institute for Local Self Reliance (ILSR) reports that in many cities the ratio of home demolition to deconstruction is on the order of 250 to 1. See: www.ilsr.org/recycling/decon/new-developments.html.

47. Chase, Thomas. "Building Deconstruction in New Haven, Connecticut: A Systems Dynamics Analysis and Policy Tool," Master's Project, Yale School of Forestry and Environmental Studies, Fall 2010.

48. See: www.ilsr.org/recycling/decon/economicbenefits.html.

49. See: www.deconstructioninstitute.com/calc3.php.

50. The Green Economy Scenario does not include widespread implementation of building deconstruction practices. If deconstruction were to be broadly practiced, job creation would be even greater and the quality of certain recovered materials would also improve.

51. For a detailed description and discussion of these environmental impact categories see Bare, Jane C., Gregory A. Norris, David W. Pennington and Thomas McKone (2003), TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. *Journal of Industrial Ecology* 6(3-4): 49-78, and Lippiatt, Barbara C. (2007), BEES 4.0 *Building for Environmental and Economic Sustainability, Technical Manual and User Guide*, US Department of Commerce Technology Administration, National Institute of Standards and Technology, Publication NISTIR 7423, May 2007.

52. MEBCalc™ does not include the environmental impacts of dioxin/furan emissions from WTE incineration or from other waste management activities that are involved with recycling or disposal of waste materials. There are available estimates of dioxin/furan emissions from WTE incinerators. There are not such estimates for the reciprocating engines used to generate electricity from collected LFG at landfills. Nor are there readily available and statistically robust estimates of dioxin/furan emissions from upstream resource extraction, refining, and manufacturing activities for all waste materials, or from the shipping of recyclables to end markets. This lack of dioxin/furan emissions data for all waste management activities is particularly problematic because the relative environmental impacts of these pollutants are quite large. Including dioxin/furan emissions for just one or a few activities will greatly exaggerate the relative environmental impacts of those activities in comparison to the activities for which dioxin/furan emissions are unavailable. Until dioxin/furan emissions for all or at least the most significant waste management activities become available, these pollutants will not be included in the environmental impact calculations in MEBCalc™. Because dioxins and furans have severe environmental impacts, the user is advised to remain continually cognizant of this omission in the current MEBCalc™ model.

53. Bare, Jane C. (2002), *Developing a Consistent Decision-Making Framework by Using the U.S. EPA's TRACI, U.S. Environmental Protection Agency*, Cincinnati, OH; and Bare, Jane C., Gregory A. Norris, David W. Pennington and Thomas McKone (2003), TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. *Journal of Industrial Ecology* 6(3-4): 49-78.

54. See a description of the CalTOX model, references, and downloadable manual and software at http://www.dtsc.ca.gov/AssessingRisk/caltox.cfm.

55. See footnote 52.

56. For the 2008 current system, see Figure 3 and Table 2 for MSW and C&D, respectively; for the 2030 Base Case Scenario, see Figures 5, 6 and Table 3; and for the Green Economy Scenario see Figures 7, 9 and Table 4.

57. U.S. EPA, *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks*, May 2002, p. 12.

58. It also is a mid-range value between those landfill experts who claim a modern landfill gas collection system will capture 95 percent of LFGs, and those who claim that the effective LFG collection efficiency is 50 percent or less because installation of the gas collection system is typically delayed until some months or more after a landfill cell begins receiving waste and because there is no guarantee that the LFG collection system will continue to operate after landfill closure for as long as LFGs continue to be generated.

59. The net eCO_2 emissions reduction from disposal is based on: (1) gross GHG emissions per ton, including transport related emissions; (2) any increases in carbon stocks due to waste management practices (e.g., landfilling results in continued carbon storage as a portion of the organics disposed in a landfill do not decompose); and (3) energy generation from waste that displaces fossil fuel consumption and related emissions.

60. The carbon content of disposed materials is relatively well understood and documented, as is whether CO_2 is biogenic or anthropogenic. For an extensive discussion of the climate impacts of disposal, see Morris, J, Bury or Burn North American MSW? LCAs Provide Answers for Climate Impacts & Carbon Neutral Power Potential, *Environmental Science & Technology*, 2010, 44(20), 7944-7949.

61. GHG reduction equivalents based on U.S. EPA figures at: http://www.epa.gov/cleanenergy/energy-resources/refs.html#coalplant.

APPENDICES

Appendix A: 2008 MSW Generation and Management by Material Type

Appendix B: 2030 MSW Generation and Management by Material Type, Base Case Scenario

Appendix C: 2030 MSW Generation and Management by Material Type, Green Economy Scenario

Appendix D: 2008 Job Creation by Management Activity and Material

Appendix E: Measuring Environmental Benefits Calculator (MEBCalcTM), Model Documentation

Note that the appendices are not included in the main body of the report.
All appendices are available at: www.recyclingworkscampaign.org

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