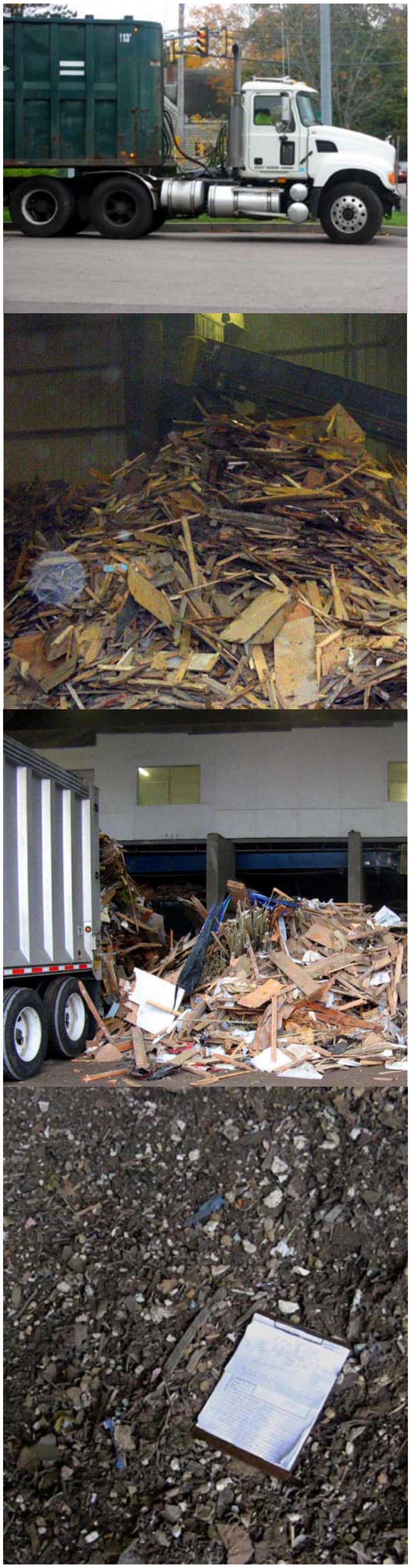

2007 MASSACHUSETTS CONSTRUCTION AND DEMOLITION DEBRIS INDUSTRY STUDY

FINAL REPORT

May 16, 2008

By

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DISCLAIMER

DSM Environmental Services, Inc. was contracted by the Massachusetts Department of Environmental Protection (MassDEP) to complete this study. The information collected and reported by DSM is the work of an independent contractor between September 2007 and January 2008. The opinions do not necessarily reflect MassDEP's policies.

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Executive Summary

Introduction

DSM Environmental Services (DSM) was contracted by the Massachusetts Department of Environmental Protection (MassDEP) to conduct an evaluation *"of the current and future status of construction and demolition (C&D) debris management in Massachusetts and the future status of wood, gypsum wallboard, and asphalt shingles."*

DSM concentrated its efforts on ***building debris***, excluding *infrastructure debris* (waste generated primarily from the construction and demolition of roads and bridges) and *land clearing debris*. The waste materials of primary concern to MassDEP – wood, gypsum, and asphalt shingles are found primarily in building debris.

DSM findings are summarized below.

C&D Waste Generation and Composition

Waste Generation

A review of recent C&D waste characterization studies from California, Clark and King Counties in Washington, Delaware, New Hampshire, Vermont and Wisconsin yielded an average C&D waste generation rate of 1.7 pounds of building debris per capita per day.[1] Multiplying this per capita rate times the 2006 Massachusetts population results in an estimated total annual generation for 2006 of 1.998 million tons of C&D wastes.

This can be compared with DSM's estimate, based on a rough mass balance of Massachusetts C&D waste flows, of 1.977 million tons of C&D waste for 2007. The mass balance is based on a compilation of annual reports submitted by solid waste facilities (including C&D processors and transfer stations) to MassDEP, combined with DSM surveys of in-state and out-of-state C&D processors, transfer stations and haulers.

The difference between the two estimates is roughly one percent. The close correlation between the two methods for estimating quantities provides DSM with confidence in the accuracy of the data on Massachusetts C&D waste generation and composition.[2]

C&D Waste Composition

Figure E.1 presents the average composition of C&D waste, using the same waste characterization studies described above. Of particular interest is that wood averages 31.5 percent of total C&D (building debris) waste, ranging from 20.2 to 45.3 percent. Further, gypsum (clean and painted) averages 9.5 percent, and roofing (including asphalt shingles) averages 11 percent.

It should be noted when reviewing Figure E.1 that the totals do not add to 100 percent. That is because Figure E.1 is based on averages of ranges from different studies, and is intended to present the materials of most significance to this study.

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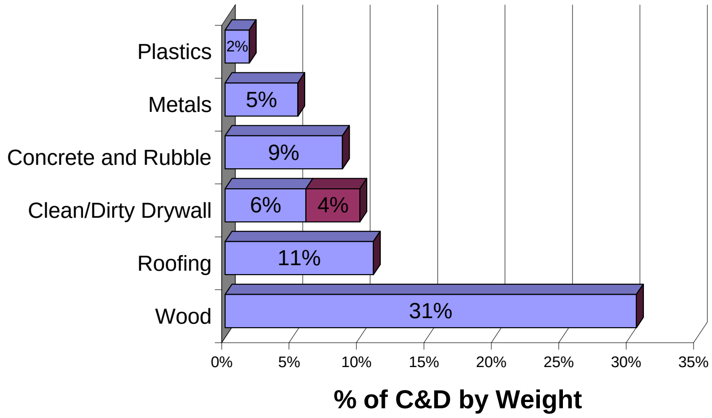
[1] Exclusive of infrastructure debris (primarily bridge, road, and other non-building structures) and land clearing debris.
[2] It should be noted that the waste "generation" coefficient should really be called the waste disposal coefficient. The waste characterization studies are based on C&D material going to landfill. However, because of the ban on certain components of the C&D waste (asphalt pavement, brick, concrete, metal and wood) to landfill in Massachusetts, it is necessary to include recycled and disposed C&D wastes in Massachusetts to be consistent with data from other states without a ban.

Figure E.1
Average of C&D Waste Characterization Study Results (percent by weight)

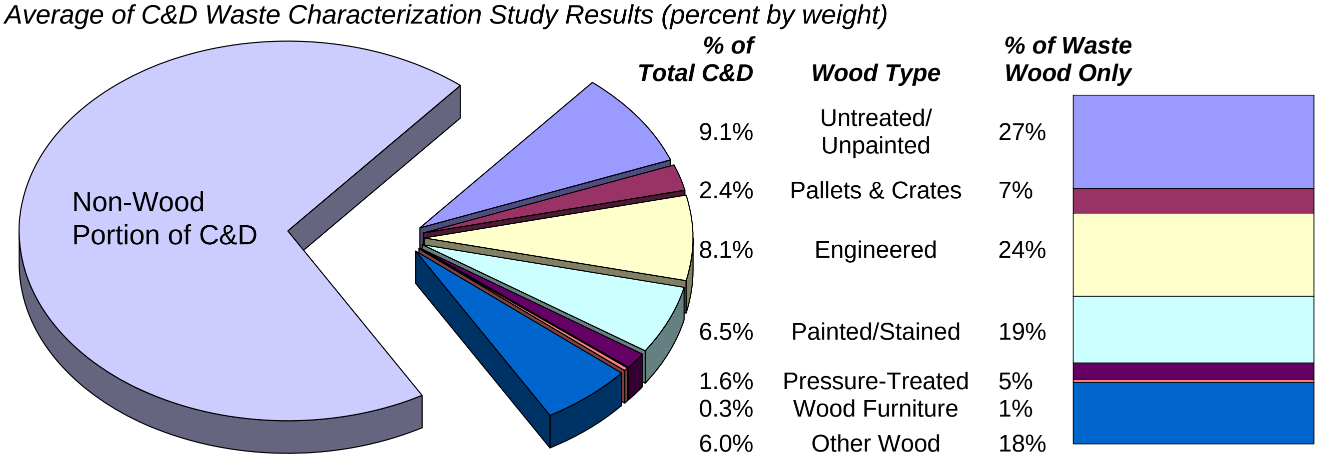


Waste Wood

Figure E.2 provides a more detailed examination of the average composition of waste wood – a key component for recycling of C&D wastes.

As illustrated by Figure E.2, *treated wood*[3] (a contaminant for most wood recycling alternatives) averages 1.6 percent of *all* C&D waste, but 5 percent of *waste wood only*. High grade wood, consisting of pallets and crates and other unpainted wood represents, on average, 11.5 percent of the total C&D waste stream, or 34 percent of waste wood only. This high grade wood is the most desirable waste wood, with significant demand in a number of potential recycling applications. Painted and stained, and engineered wood (including particle board) represents roughly 14.6 percent of the total C&D waste stream, or 43 percent of waste wood. The primary market for this waste wood component is currently for use as boiler fuel.[4]

Figure E.2
Average of C&D Waste Characterization Study Results (percent by weight)



[3] Treated wood refers *only* to pressure treated wood, excluding painted and stained wood.
[4] "Other Wood" is a catch-all for all other wood. It consists primarily of wood roofing and siding and mixed demolition wood that is too contaminated to be easily identified.

Applying the average C&D waste composition to the 2 million tons (rounded) of C&D waste generated in Massachusetts yields a total of 677,000 tons of waste wood potentially available for recovery from Massachusetts C&D waste in 2007. Table E.1 presents DSM's best estimate of the breakdown of the waste wood by type.

Table E.1
Estimated Annual Generation of Waste Wood, By Material Type, in Massachusetts
Based on Waste Characterization Studies

Wood	MA Estimate (tons)
High Grade (1)	230,000
Painted/Stained	129,000
Engineered Wood	161,000
Other Wood	126,000
Pressure-Treated Wood	31,000
	677,000

(1) Pallets and crates and untreated/unpainted wood

Mass Balance

DSM surveyed Massachusetts C&D processors, out-of-state processors handling Massachusetts C&D wastes, large C&D transfer stations, and C&D haulers. Table E.2 summarizes the management of Massachusetts C&D waste in 2007 based on DSM's surveys together with reports filed by processors and haulers with MassDEP.

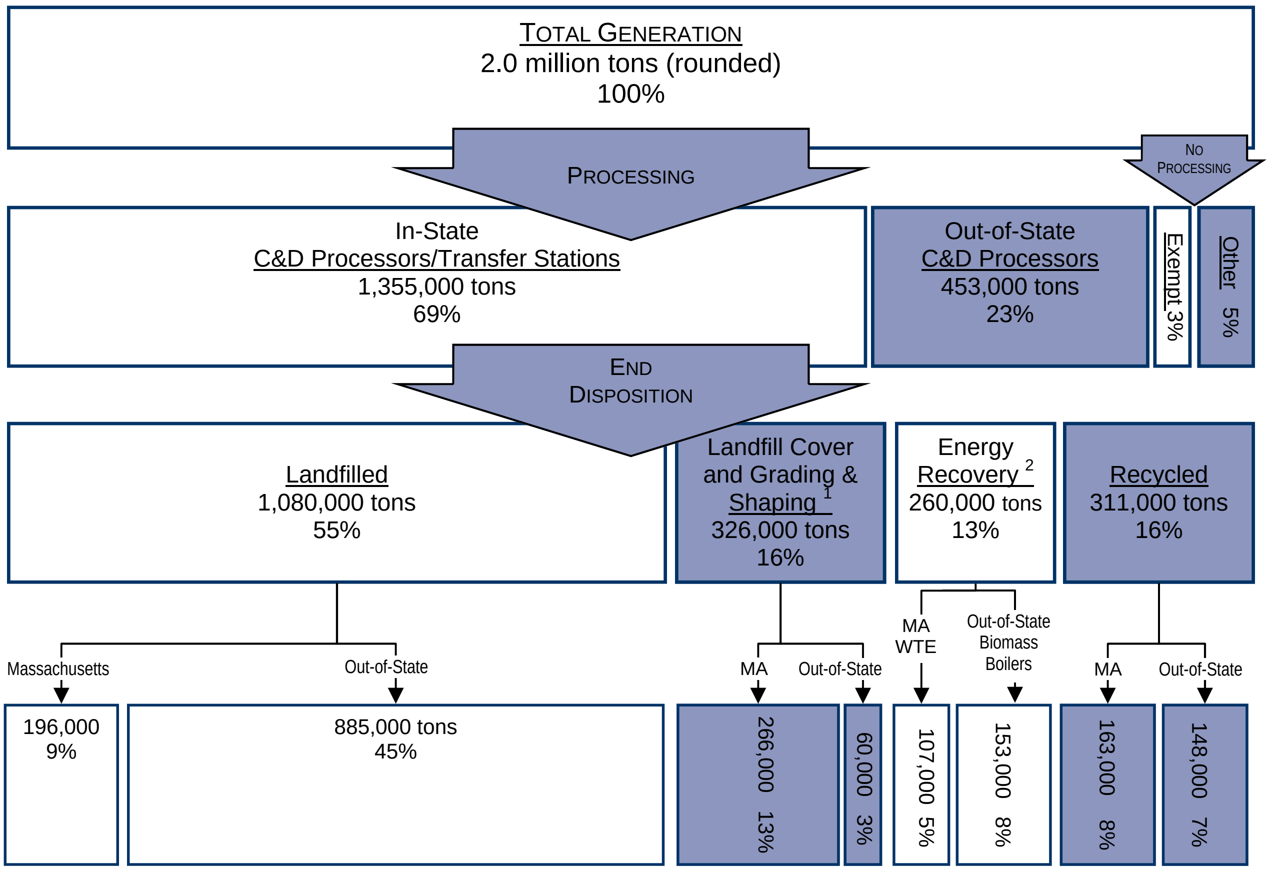
Table E.2
Summary of Management of C&D (Building Debris) from Massachusetts Generators in 2007

Handlers	Description	Tons of MA C&D Handled in 2007	Percent of Generated C&D
Massachusetts Processors (1)	Facilities in Massachusetts who sort C&D to generate marketable secondary material(s).	1,355,000	69%
Out-of-State Processors	Out-of-state processors who accept C&D from Massachusetts before any processing has been performed.	453,000	23%
Exempt Transfer Stations	Transfer stations separately collecting C&D and sending it directly for disposal. The material is exempt from the waste ban because they only accept material in loads of 5 cubic yards or less.	68,000	3%
Other C&D Handlers	C&D materials handled by transfer stations and haulers not otherwise accounted for. Some is source separated material for recycling, some is difficult-to-manage waste headed for disposal.	101,000	5%
	TOTAL:	**1,977,000**	**100%**

(1) "Massachusetts Processors" includes the 15 permitted Massachusetts "C&D Processing Facilities," as well as 6 other significant facilities that remove some portion of C&D material for recycling before transfer, or operate under a Determination of Need.

Figure E.4. presents DSM's best estimate of the end disposition of Massachusetts C&D waste handled by the four sectors presented in Table E.2 above. The results are also divided by whether the disposal or recovery of the C&D waste was carried out in Massachusetts or out-of-state.

Figure E.4
End Disposition of Massachusetts C&D (2007)



1. Used for ADC (alternate daily cover) or Grading and Shaping Material in a landfill.
2. In Massachusetts all energy recovery was at MSW waste-to-energy plants. Out-of-State, 92% was at wood-fired boilers and the remaining 8% at waste-to-energy plants.

Recycling

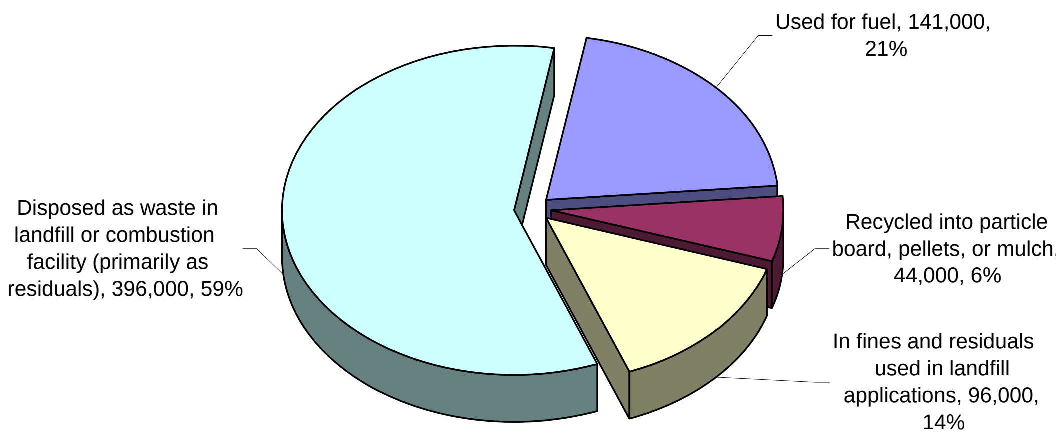
Table E.3 presents DSM's best estimate of the quantity of C&D wastes recycled in 2007.

Table E.3
Tons of MA C&D Recycled by Material, 2007

	Tons	%
Clean Wood to Pellets	9,000	3%
Wood to Particle Board	23,000	7%
Clean Wood to Mulch	12,000	4%
Gypsum Wallboard	2,000	1%
Metal	89,000	29%
ABC (Asphalt, Brick, Concrete)	58,000	19%
OCC (Cardboard)	20,000	6%
Asphalt Shingles	64,000	21%
Other (Rigid Plastics, Tires)	34,000	11%
Total Recycled:	311,000	100%

An additional 141,000 tons of waste wood were recovered for sale to biomass boilers in Maine and Canada.[5] Figure E.4 presents DSM's best estimate of the end disposition of waste wood from the Massachusetts C&D waste stream.

Figure E.5
End Disposition of C&D Waste Wood



[5] Another 119,000 tons of C&D waste (including waste wood as one component) were burned for energy recovery in combustion facilities in Massachusetts. The ban on disposal of waste wood from C&D waste does not include disposal at combustion facilities in Massachusetts.

Finally, Table E.4 presents DSM's best estimate of the recovery rate for C&D waste wood from Massachusetts. Table E.4 illustrates the difficulty faced by many C&D processors. The low recovery rate for "high grade" wood reflects the cost and difficulty associated with sorting to meet the clean wood specification. A significant amount of the wood is not positively sorted because it is too difficult to determine if it is clean wood or treated or stained wood. This is especially the case for demolition wood which has weathered. Even for boiler fuel spec wood, there are high labor costs associated with positively sorting for this material. As with high grade wood, the risk of exceeding the treated wood specification makes it difficult to recover a high percentage of the wood potentially available for boiler fuel.

Table E.4
Estimated Recovery of Waste Wood by End Use Market (2007)

Wood Category	MA Generation Estimate	MA Recovery	Recovery Rate
	(tons)	(tons)	(%)
High Grade (1)	230,000	44,000	19%
Boiler Fuel Specs (2)	290,000	141,000	49%
Subtotal:	520,000	185,000	36%
All other wood:	157,000	0	0%
Total Wood:	677,000	185,000	27%

(1) Pallets and crates and untreated/unpainted wood estimate
(2) Painted/stained and engineered wood estimate

Potential Demand for Materials Recovered from Massachusetts C&D Wastes

Commodity Markets for Metals and Paper

DSM estimates that approximately 50% of the old corrugated containers (OCC) and 80% of the ferrous metals in the Massachusetts C&D waste stream were recovered for recycling in 2007.

There are currently strong markets for OCC and metals.. While these are commodity markets where prices, and the acceptable contamination levels, change over time, both of these markets are expected to continue to exist at a level where it will be worth it for C&D processors to continue to manually or mechanically separate these materials.

Asphalt, Brick and Concrete

Whereas the primary driver for recycling of metals and paper is the value of the material, in the case of ABC wastes the primary driver is the high weight and resulting impact on trucking and landfill tipping fees associated with not separating these materials out for recycling. For this reason these wastes are typically reused at the job site or sent directly to facilities for grinding and reuse. Because there will always be a market for aggregate, it is likely that it will continue to be less costly for C&D processors to separate these materials out for sale to aggregate markets – even at low values – when compared to transporting to higher cost landfills.

Gypsum

Gypsum can be recycled back into the manufacture of new gypsum. It also has a number of other potential applications, including: use as a soil additive; in flea powder; as a bulking agent or sludge drying compound; and, as a flocculating agent in water treatment.

There are three potential limitations to significant increases in the recycling of gypsum. First, it is extremely difficult to recover gypsum once it has been mixed with other C&D wastes. It breaks very easily and disintegrates during handling of the C&D materials.

Second, while there are a number of uses for clean gypsum, the number of uses associated with painted or wallpapered gypsum is significantly less.

Third, new gypsum is a relatively low cost material. The cost of mined gypsum delivered to a wallboard manufacturing plant is roughly $10 per ton. More importantly, sulfur dioxide controls (flue gas desulphurization or FGD) on coal fired power plants result in a perfect gypsum slurry for use in gypsum wallboard manufacturing. Thus, a number of new gypsum wallboard plants are being constructed adjacent to coal fired power plants, where the gypsum slurry can be obtained for roughly one-half of the cost of mined gypsum.

At these low costs for the raw material associated with gypsum wallboard production, it is difficult to keep gypsum separate, crush it, remove the paper, and deliver the resulting material to a gypsum wallboard plant for a cost that is competitive with new gypsum. Thus, it is likely that significant quantities of gypsum will be recycled only if gypsum is not allowed in landfills due to H_2S issues.

Wood

DSM visited all of the known buyers of Massachusetts waste wood for biomass boilers in Maine and Quebec.

DSM estimates that total demand in 2007 for waste wood for boiler fuel was 225,000 tons (rounded) based on reported demand and openings and closures of plants in 2007. The maximum *potential* demand based on discussions with buyers at *existing plants* is estimated to be between 400,000 and 660,000 (rounded) tons per year. This is more than sufficient demand for all of the potential waste wood meeting boiler fuel standards generated from Massachusetts C&D wastes.

However, future demand will depend on continued regulatory approval (in Connecticut), and potential regulatory approval in Massachusetts, for waste wood to be considered an approved fuel for their Renewable Portfolio Standard. Negative future decisions by either Connecticut or Massachusetts would have significant negative impacts on the demand for waste wood.

The other potentially significant demand for waste wood is for production of particle board at the Tafisa plant in Quebec. Tafisa is currently in the final stages of construction of a new line which will have the capability to utilize up to 40 percent waste wood in the production of particle board. Tafisa has already sourced waste wood (some from Massachusetts) for use during start-up (currently expected to be during March, 2008). If start-up goes as planned, Tafisa believes that it will eventually have the capability to utilize up to 275,000 tons per year of waste wood. Some portion of this waste wood will be sourced from New England because Tafisa expects to backhaul waste wood after delivery of new particle board to New England locations.

While Tafisa has published initial specifications for waste wood, it is likely that final specifications (and total demand) will not be known for at least a year as Tafisa ramps up production and experiments with varying wood specifications.

Fines and Residuals

The production of wood for fuel from C&D waste processors necessarily generates fines – the material falling through screens prior to sorting of the wood for recovery, and residuals – the material falling off the end of the line, or sorted as waste material. Other than use as boiler fuel – which is still primarily speculative because of the availability of sufficient waste wood – the only other real use for the fines and residuals is for alternative daily cover and grading and shaping at landfills. However, until the issue of H_2S generation is more thoroughly researched, it is likely that the use of fines and residuals as alternative daily cover will be significantly curtailed. This is because the risk to a landfill operator associated with the potential installation of hydrogen sulfide control equipment exceeds the short term savings in soil purchases. Therefore, if Massachusetts is to continue with the ban on the landfilling of waste wood from C&D waste, it should actively participate in research designed to define how C&D fines can be safely used as alternative daily cover and in grading and shaping applications. This may involve requirements to keep gypsum separate from other C&D wastes, changes in the regulation of how fines and residuals are mixed with soil, and/or allowable screen size for C&D processors.

Conclusions

It is DSM's opinion that over 90 percent of Massachusetts C&D wastes are being processed, with banned materials sorted out before landfilling. However, the recovery rate for waste wood, estimated at 27 percent, is low, resulting in a significant amount of waste wood being landfilled as residuals.

Based on surveys of all of the major users of waste wood, and DSM's knowledge of the commodity markets, there appears to be sufficient demand for waste wood, corrugated, and metals separated from Massachusetts C&D waste. It is highly likely that asphalt pavement, brick and concrete will continue to be managed separately, given the demand for aggregate, and the high cost of landfilling this material.

Markets exist for asphalt shingles and, as is the case for asphalt pavement, brick and concrete, there will continue to be an incentive for roofing contractors to keep asphalt shingles separate. Gypsum is a more problematic material. While limited local markets exist for waste gypsum, the cost of keeping this material separate, and trucking it to the limited number of markets, will restrict separation of this material. It is likely that this situation will not change unless the construction and demolition industry addresses the recycling of gypsum wallboard waste and/or there is a ban on landfilling of gypsum wallboard.

The primary concern associated with the ban going forward is the resolution of the use of fines and residuals as alternative daily cover and grading and shaping material at landfills. In addition, fines and residuals are an inherent outcome of processing C&D waste. Failure to find alternate uses for these materials will increase the cost of C&D processing, and the recovery of wood. Wood recovery rates are already low (estimated at 27 percent), and are likely to be reduced further if alternative uses of fines and residuals are not developed.

An additional concern is the long-term regulatory climate for use of waste wood in biomass boilers. Resolution by the Massachusetts DOER concerning allowable use of waste wood as a component of the Renewable Energy Portfolio is critical, as is continued acceptance by Connecticut regulators of waste wood as "sustainable biomass."

Positive resolution of the fines and residuals issue, together with continued acceptance of waste wood by biomass boilers in Maine, are essential to the continued success of the ban on waste wood. The demand for boiler fuel can be reduced if there are positive results associated with ramping up the use of waste wood in particle board manufacturing at the Tafisa plant. However, it is too early to speculate as to the ultimate demand for, and specification for, acceptable waste wood at Tafisa.

Section 1
Introduction

The Massachusetts Department of Environmental Protection (MassDEP) amended its regulations at 310 CMR 19.017 in July 2006 to add asphalt pavement, brick and concrete (ABC waste), metal and wood to its list of materials banned from disposal. The ban was implemented after a three year planning process, which assessed the potential impact of the ban and potential markets for these materials. At the time the ban went into effect there were a number of construction and demolition (C&D) processing facilities operating in Massachusetts and in adjacent New Hampshire with the capability to separate out the banned materials from mixed C&D.

These facilities created fines and residuals during the grinding and sorting process which were used as alternative daily cover (ADC) and grading and shaping materials at landfills. Wood separated from the C&D waste stream was marketed, primarily as boiler fuel, for biomass furnaces in Maine.

In 2007, both the landfill uses and the boiler fuel markets collapsed. The Cottage Street landfill in Springfield (a primary recipient of fines and residuals), as well as the Thatcher Street landfill in Brockton and the Crow Lane landfill in Newburyport began experiencing hydrogen sulfide gas emission issues. The cause was thought to be gypsum in the fines. Therefore the Cottage Street landfill stopped accepting fines and residuals, and other landfills soon followed suit as hydrogen sulfide became an issue at landfills throughout New England.

In the summer of 2007, the primary purchaser of ground waste wood for fuel – Boralex – stopped co-firing ground waste wood with green chips at their biomass boilers in Maine. This was due to potential loss of energy revenue because of legislation in Connecticut (where Boralex was selling electricity) which stipulated that *"Sustainable biomass does not mean construction and demolition waste…"* The value of the Connecticut Renewable Energy Credit of roughly 5 cents per KWH was greater than the savings from burning waste wood instead of green chips, so Boralex switched to firing 100 percent green wood chips. This eliminated a significant market for wood coming out of the C&D processing facilities.

Given these events, the MassDEP concluded that it was necessary to assess the impact of the disposal ban on the C&D industry. In particular, the disposal ban on treated and painted wood has been raised as an issue of concern.

MassDEP included in the scope of the review an analysis of gypsum recycling because gypsum was thought to be the cause of the hydrogen sulfide emission problem in the fines. MassDEP also included in the scope an analysis of asphalt shingle recycling because asphalt shingles are typically also included in C&D waste, and potential markets exist for this material.

The purpose of this report, therefore, is to provide an evaluation *"of the current and future status of construction and demolition (C&D) debris management in Massachusetts and the future status of wood, gypsum wallboard, and asphalt shingles."*

Section 2
Scope of Work

DSM Environmental Services, Inc. (DSM) was contracted by MassDEP to carry out the following tasks as part of this analysis:

- Conduct a literature review of C&D waste generation rates and composition from other states for potential application to Massachusetts;
- Compile all available data maintained by MassDEP on C&D management in Massachusetts;
- Survey, through on-site visits, as many of the C&D processors in Massachusetts (and in surrounding states accepting Massachusetts C&D waste) as would allow DSM to make on-site visits;
- Based on compilation of available data and the surveys of processors, complete a rough mass balance of Massachusetts C&D generation, processing and disposal, accounting for the flow of recovered materials from the C&D waste stream;
- Compare the mass balance with estimated generation based on the literature review, to determine the potential accuracy of the mass balance on a material basis;
- Survey users of materials recovered from the Massachusetts C&D waste stream (especially waste wood) to determine the current demand from those markets;
- Investigate the potential for changes in existing markets looking forward;
- Investigate the potential for development of new markets looking forward, both for recovered wood, and for gypsum and asphalt shingles; and,
- Draw conclusions concerning the impact of the waste wood ban on C&D processors in Massachusetts and on end-markets in the region.

This report presents the results of DSM's analysis. In reviewing the numbers contained in this report, note that in many cases numbers are rounded (to emphasize they are estimates), and therefore calculations and percentages may not add exactly due to rounding.

Section 3
Estimating Massachusetts C&D Waste Generation and Composition Based on Data from the Literature

Introduction

There are two ways to determine quantities and composition of C&D waste generated in Massachusetts. The first is to use published data from other states and regions on per capita C&D waste generation and composition to develop Massachusetts generation and composition estimates. These generation and composition estimates for Massachusetts can then be compared against survey data and annual reports provided by Massachusetts C&D processors (the second way to estimate quantities) to determine the most reasonable estimate of annual quantities and composition for Massachusetts.

This section addresses estimates based on published data from other states.

Definitions

In general, there are three broad categories of waste that may or may not be considered part of the C&D waste stream:

- ***Infrastructure debris*** from the construction or demolition of bridges, roads and other non-building structures – this material typically consists of heavy asphalt, brick and concrete – which if included in the definition of C&D waste significantly increases total quantities;

- ***Land clearing and inert debris*** from clearing trees, stones, and dirt/soils from sites to prepare them for construction, or for excavation purposes; and,

- ***Building debris*** from the construction, renovation and demolition of residential and commercial buildings

Building debris waste can be further categorized by the type of activity: ***new construction; renovation to an existing building; and, demolition***. Within the building demolition category, the building structure (e.g. brick, wood or concrete) determines the composition of the debris. Different geographic regions of the country, depending on the typical construction materials used, can result in wide variations in building debris waste generation and composition.

The first problem associated with the use of published data to estimate Massachusetts C&D generation is that there is not one consistent definition of C&D waste. Inclusion and exclusion of potentially heavy materials, together with differences in what is "coded" at landfills as C&D, or reported as C&D in different states, can have significant impacts on reported generation and composition estimates.

The problems with C&D definitions are similar to the problems with the differences in the definition of "recycling" by different states, which has led to such large variations in reported recycling rates for municipal solid wastes.[6]

The State of Massachusetts' definition (from 310 CMR 19.006) states:

> "*Construction and Demolition Waste* means the waste building materials and rubble resulting from the construction, remodeling, repair or demolition of buildings, pavements, roads or other

[6] For example, inclusion or exclusion of junk automobiles or stumps and land clearing wastes can have a huge impact on a reported MSW recycling rate on a state-by-state basis.

structures. Construction and demolition waste includes but is not limited to, concrete, bricks, lumber, masonry, road paving materials, rebar and plaster."

"*Wood Waste* means discarded material consisting of trees, stumps, and brush, including but not limited to sawdust, chips, shavings and bark. Wood waste does not include new or used lumber or wood from construction and demolition waste and does not include wood pieces or particles containing or likely to contain asbestos, chemical preservatives such as creosote or pentachlorophenol, or paints, stains or other coatings."

This means that ***infrastructure debris is included*** in the Massachusetts definition, but that ***land clearing debris (****"wood waste", as defined above****) is excluded*** from the Massachusetts definition of C&D waste.

Because the vast majority of infrastructure debris (ABC) is not disposed of at landfills in Massachusetts (or in most other states) due to its' weight and cost, and because land clearing debris is excluded from Massachusetts' definition, DSM has concentrated on ***building debris*** for this analysis. This is the problematic material with respect to the disposal ban, and is the focus of the C&D processors in Massachusetts.

For purposes of this report, DSM has attempted to restrict its analysis to building debris related wastes, both during the literature review and in the subsequent mass balance analysis for Massachusetts. Therefore, when the report refers to C&D waste in Massachusetts, the C&D waste can be viewed as synonymous with building debris waste, and excludes both land clearing debris and infrastructure debris.[7]

Literature Review

DSM conducted a review of available literature on C&D waste characterization and generation. This included the following:

- Cascadia Consulting Group. *Targeted Statewide Waste Characterization Study. Detailed Characterization for Construction and Demolition Waste.* California Integrated Waste Management Board. June 2006.
- Cascadia Consulting Group. *King County C&D Waste Characterization and Recycling Industry Profile.* King County Solid Waste Division. 2002.
- Cascadia Consulting Group. *Wisconsin Waste Characterization Study*. Wisconsin Final Report. 2003.
- Cascadia Consulting Group, DSM Environmental Services, MSW Consultants. *Delaware Solid Waste Authority Statewide Waste Characterization Study,* 2006-07. Final Report.
- DSM Environmental Services. *Vermont Waste Composition Study*. Vermont Department of Environmental Conservation. June 2002.
- Franklin Associates under subcontract to TechLaw. *Characterization of Building-Related Construction and Demolition Debris in the United States***.** US EPA. June 1998. EPA 530-R-98-010
- *Generation and Composition of Construction and Demolition Waste in Florida*. Florida Center for Solid and Hazardous Waste Management, Gainesville, FL. February 27, 2003.
- Hinckley Center for Solid and Hazardous Waste Management. *Research Advancing the Management of Construction and Demolition Debris in Florida.* September 2007.
- Ottawa IC&I Waste Characterization Executive Summary. 2005.

[7] It should be noted that small quantities of ABC waste end up in building debris, and these small quantities are included in the definition of C&D waste.

C&D Waste Generation Data

The US EPA's 1998 report – *Characterization of Building-Related Construction and Demolition Debris in the United States* – summarized available data on waste generation from construction and demolition activity. Based on literature cited in the US EPA study, residential construction waste generation (from 1992 – 1997) averaged 4.38 pounds per square foot of new construction while nonresidential new construction activity averaged 3.89 pounds of waste per square foot constructed.

The study found that demolition debris per residential unit averaged 115 pounds per square foot, including the basement, and nonresidential debris averaged 155 pounds per square foot. Renovation or remodeling waste generation data were extremely limited and variable, ranging from 20 pounds (rounded) to 72 pounds per square foot of renovation, with the exception of 3.3 pounds per square foot for a renovation involving only a new roof.

EPA's extrapolation of these limited data, based on building and demolition permits, and on renovation dollars spent (not necessarily in the same year as the waste generation data) resulted in an estimate of total building related C&D generation (*building debris*) for the United States for 1997. Table 1, below, presents the breakdown of new construction, renovation, and demolition debris from residential and nonresidential construction in the United States, first by percent of total activity, and then by generator sector.

Table 1
Percentage of C&D Building Related Waste by Activity, and Total US C&D Waste in 1997 (Source: US EPA)

C&D Waste Type	Residential	Nonresidential	Total
New Construction	11%	6%	**8%**
Renovation	55%	36%	**44%**
Demolition	34%	58%	**48%**
Total (%):	*100%*	*100%*	*100%*
Total (tons):	*58,160,000*	*77,370,000*	*135,530,000*

Table 1 excludes *infrastructure debris* and *land clearing debris*. Thus it is consistent with DSM's attempt to analyze only building debris waste for Massachusetts.

Dividing the total C&D (*building debris*) waste generation (135.5 millions tons) from Table 1 by the 1997 US population yields a per capita C&D generation rate of **2.8 pounds per day in 1997.**

In contrast, researchers at the University of Florida estimated per capita C&D waste generation to be **1.4 pounds per day in 2000**. The University of Florida attributed the difference between their estimated per capita generation rate and the US EPA estimate to rapid residential development in Florida (large project builders can reduce waste generation per household) combined with a lack of an aging infrastructure in Florida, and therefore less demolition waste. New development and renovation projects contributed to 78% (rounded) of all Florida C&D waste,[8] as opposed to 52% for the United States (Table 1 above). This difference in new construction versus demolition could contribute to the reported lower per capita generation given the much lower generation per square foot for new construction than demolition.

Data from the US EPA and Florida can be compared with recent data from Delaware to illustrate the second important point about comparing waste generation data among states.

[8] *Generation and Composition of Construction and Demolition Waste in Florida*. Florida Center for Solid and Hazardous Waste Management, Gainesville, FL. February 27, 2003.

DSM participated in a four season waste characterization study at all Delaware Solid Waste Authority (DSWA) disposal facilities.[9] Delaware is unique in that DSWA owns all of the MSW landfills and transfer stations in the state and has agreements with all of the major haulers to deliver all MSW waste to DSWA landfills, making it easier to maintain records and track C&D waste disposal.[10]

If one were to include only C&D waste coded by DSWA as C&D waste by facility weigh masters in the estimate of total C&D generation for Delaware, the total for 2007 would be 137,695 tons or **0.9 pounds per capita per day**. However if the (roughly) 54,000 tons of self haul waste which is C&D waste but not coded as such is included, together with 97,000 tons of C&D waste from residential and commercial sources that was coded as MSW instead of C&D (typically because it was brought in with MSW), per capita generation in Delaware rises to **1.8 pounds per capita per day**. When all Delaware generated C&D disposed in DSWA's MSW landfills are included plus Delaware C&D waste disposed of at the one private C&D only landfill, per capita generation climbs to 454,000 (rounded) tons of C&D disposed, or **2.9 pounds per capita.**

The per capita generation rates for Delaware (0.9 – 2.9 pounds per capita) bracket the US EPA data and the Florida data and illustrate the challenges associated with estimating total C&D waste generation. Most facilities and states do not account for C&D waste delivered as MSW with residential and/or commercial waste when providing totals for C&D waste disposal, and many states are not capable of accurately tracking waste imports and exports. In addition, there are significantly greater changes in per capita C&D generation rates resulting from economic conditions over time, and geographic differences, than in MSW generation.

Compilation of Available Data to Develop a Per Capita C&D Generation Rate

Table 2 presents reported per capita C&D generation rates[11] based on recent waste characterization studies.

Table 2

Comparison of C&D Per Capita Waste Generation Rates As Reported In the Literature

State/Region	Material Included	C&D Waste Disposed	Population	Data Year	**Per capita**
		(tons)			(lbs/day)
California	All C&D Disposed	8,732,074	35,484,453	2003	1.3
Chittenden Cty, VT	Loads Coded As C&D Only	43,379	150,239	2005	1.6
Clark County, WA					1.4
Delaware	All C&D Disposed, including C&D landfills	453,946	853,476	2006	2.9
King County, WA	C&D Recovered and Disposed	774,000	1,750,000	2001	2.4
King County, WA	Disposed C&D Only	264,000	1,750,000	2001	0.8
New Hampshire	C&D Disposed and Recovered (Facility Reports)	388,073	1,314,895	2006	1.6
US EPA	C&D Disposed and Recovered, Estimation			1997	2.8
Vermont	C&D Loads Disposed Only	99,653	623,050	2005	0.9
Wisconsin	Loads Coded as C&D Only	1,116,341	5,364,000	2001	1.1
Wisconsin	All C&D Disposed	1,364,053	5,364,000	2001	1.4
	Average:	**1,960,904**	**6,437,193**		**1.7**

[9] Delaware Solid Waste Authority, *Statewide Waste Characterization Study,* October 2007.
[10] There is one private C&D landfill in Delaware, which is required to report quantities to the State.
[11] In some cases these are disposal rates (excluding C&D materials recovered for recycling and in some cases generation rates (total recycled plus disposed).

As illustrated in Table 2, the per capita C&D generation rate (more accurately, disposal rate) ranges from a low of .9 pounds per capita in King County, WA and the State of Vermont to a high of 2.9 pounds per capita (in Delaware).

As discussed above, the difference in generation rates presented in Table 2 is due to a combination of: what is and is not reported as C&D; geographic differences (fast and slow growing areas of the country); and, differences in the year that the data were gathered (thus differences in economic conditions).

Given the differences in rates, it appears reasonable to use the average from Table 2 to estimate total Massachusetts generation based on the literature. The **average** of the per capita estimates presented in Table 2 results in **1.7 pounds per capita per day.** Applying this estimate to Massachusetts' population for 2006 provides a total estimate of 1,998,600 tons (rounded) of C&D waste generated for disposal in Massachusetts. This calculation is shown by:

1.7 lbs/day x 365 days x 6,437,193 (Population 2006, US Census) / 2000 pounds =
***1,998,630 tons/year** (Estimated MA C&D Available for Processing/Disposal)*

C&D Waste Composition Data

Most of the waste characterization studies performed on C&D wastes are visual estimations based on volume. This is because it is difficult to physically sort C&D waste due to the heterogeneous nature of the waste (creating great variability in individual samples within a load), and the time and cost limitations associated with sorting whole loads of C&D (typically 30 cubic yard open top roll-offs). It can be assumed that error is greater in visual volumetric studies, with conversion to weight based on material density factors, as opposed to physical sorting and weighing. However the error associated with individual volumetric estimates can be reduced through the ability to conduct significantly greater sampling. This was demonstrated in the recent Delaware Waste Characterization Study, where physical sorting of a small sample of loads which had been visually characterized, were used to check the accuracy of the visual characterizations.[12]

Findings from a literature search of recent C&D waste characterization studies are shown below in Table 3 (next page). Note that not all materials characterized are included in Table 3 so percentages do not total 100.

[12] Delaware Solid Waste Authority, *Statewide Waste Characterization Study,* October 2007.

Table 3

Characterization of C&D Waste - Literature Review and DSM Data (percent by weight)

Study:	EPA	Florida	DSWA	Wisconsin	California	King Cty, WA	Ottawa
Year:	(1997)	(2003)	(2006 - 07)	(2003)	(2005)	(2002)	(2005)
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Concrete (and mixed rubble)	40–50	32.4	11.7	12.1	10.8	2.3	9
Wood	20–30	14.8	30.1	26.3	20.2	45.3	26
Drywall	5–15	11.7		4.1			10
Clean drywall			*9.8*		*4.5*	*2.6*	
Painted/demo drywall			(1)		*3.6*	*4.5*	
Roofing			15.3	22.1		11	
Asphalt roofing	*1–10*	*6.1*	(2)	(2)	*4.4*		*12*
Metals	1–5	5.4	2.9	3.9	4	10.9	9
Bricks	1–5		(3)	(3)	(3)	(3)	3
Plastics	1–5		1.6		0.8	3.1	

(1) Painted /demo drywall included in mixed C&D residues and not separately counted
(2) Asphalt roofing included in Roofing
(3) Included in concrete

The methodology used for DSWA, Wisconsin, California and King County are virtually the same, applying a consistent visual estimation technique to a random and statistically large number of C&D loads sent for disposal. C&D materials diverted for recycling, or for fill, are excluded. It is not known what the impact of this diversion is on the resulting composition of C&D materials disposed.

Concrete generation is included in the EPA study total, above, whether it went for disposal, fill or regrinding for reuse and recycling. This heavy material significantly alters the estimated percentages of all other materials in the waste stream allocation. The inclusion of the EPA data in Table 3 illustrates the important effect that inclusion of heavy materials, such as concrete or other ABC waste, can have on the resulting composition, when presented on percent weight basis (the typical method for reporting waste composition data).

Figure 4 (below) and Table 4 (next page) present the average composition of the C&D waste based only on characterization studies which followed the same methodology and characterized only C&D waste streams destined for disposal.

Figure 4

Average of C&D Waste Characterization Study Results (percent by weight)

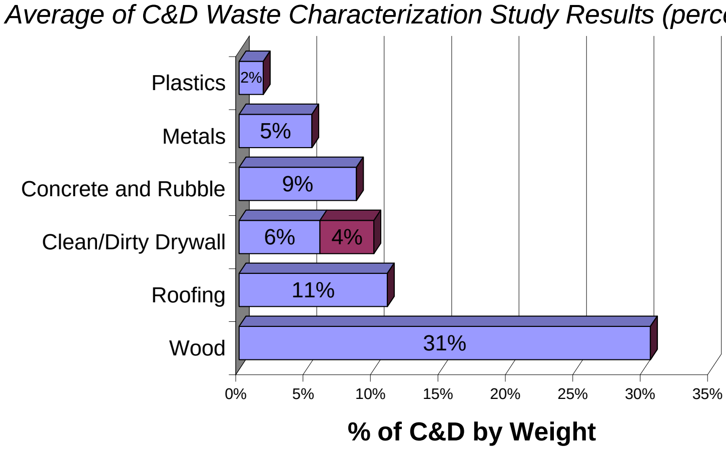


Table 4
Average of C&D Waste Characterization Study Results (percent by weight)

Study: / *Year:*	DSWA (2006 - 07)	Wisconsin (2003)	California (2005)	King County, WA (2002)	Average
	(%)	(%)	(%)	(%)	**(%)**
Concrete (and mixed rubble)	11.7	12.1	10.8	2.3	**8.7**
Wood	30.1	26.3	20.2	45.3	**30.5**
Drywall		4.1	8.1	7.1	**6.4**
Clean Drywall	*9.8*		*4.5*	*2.6*	***5.6***
Painted/demo drywall	*(1)*		*3.6*	*4.5*	***4.1***
Roofing	15.3	22.1		11	**11.0**
Asphalt roofing	(2)	(2)	*4.4*		***4.4***
Metals	2.9	3.9	4	10.9	**5.4**
Plastics	1.6		0.8	3.1	**1.8**

(1) Painted demo drywall included in residue
(2) Asphalt roofing included in Roofing

As Figure 4 and Table 4 illustrate, wood averaged 31% (rounded) of C&D waste sent for disposal. This is important because many processors with whom DSM met reported estimates of waste wood generation as high as 40%. It should also be noted that corrugated is a small but significant component of C&D waste. For example, in Delaware corrugated represented between 1.5 and 2.5 percent of total C&D waste. Much of this corrugated could be relatively easily separated at a C&D processing facility.

Characterization of Waste Wood

The composition of waste wood from C&D waste is important because it is one of the primary materials that can be recovered from C&D wastes, and its composition will determine how it can be marketed. There are many more markets for “clean” or “high grade” wood compared with wood which contains engineered woods and/or painted and stained wood. Market specifications for waste wood vary (as addressed in the Markets Section of this report) and not all wood can meet the specifications for some end markets.

DSM reviewed available literature/data on the composition of waste wood in C&D waste. While the Delaware (DSWA) study accounted for 7 different categories of wood, other studies had fewer categories, making comparison of wood composition from one study to the next difficult.

Table 5 presents a more detailed breakdown of the waste wood presented in Table 4. Note that Table 5 is a sub-set of Table 4. That is, only the 26.3 percent of total C&D waste reported for Wisconsin that is waste wood in Table 4, above is reported here. For this reason, while treated wood (for Wisconsin again) is only 1.3 percent of total C&D waste for Wisconsin, it is 4.9 percent of *waste wood only*, because waste wood is only 26.3 percent of total C&D waste.[13]

[13] For purposes of this report, treated wood refers to wood that has been pressure treated to make it resistant to rot. The chemicals used have changed over the years, with creosote and pentachlorophenol used originally, and subsequently replaced by other chemicals as environmental and health issues were raised with earlier treatment methods. Most pressure treated wood found in C&D waste today is chromated copper arsenic (CCA) wood. Pressure treated wood – where the wood is sealed in a tank with air extracted, creating a vacuum, and then the treatment chemicals are added and drawn deep into the wood – is different from wood where paint or stains are applied to the outside of the wood. Painted or stained wood are called painted or stained wood, not “treated wood” throughout this report.

Table 5
Wood as a Percent of Total C&D Waste Disposed (percent by weight)

Wood	Wisconsin (2003)	Delaware (2006 - 07)	California (2005)	King County, WA (2002)	Average (3)
	(%)	(%)	(%)	(%)	(%)
Treated Wood	1.3	2.6	0.3	2	**1.6**
Untreated Wood	25	27.5	19.9	43.3	**28.9**
Pallets & crates		2.5	1.8	3	**2.4**
Untreated/unpainted		9.4	9	8.8	**9.1**
Painted/stained		3.1	4.6	11.7	**6.5**
Engineered Wood		9.8	4.5	9.9	**8.1**
Plywood		*4.3*	*(1)*	*(1)*	
Oriented strand board		*4.7*	*(1)*	*(1)*	
MDF and particle board		*0.8*	*(1)*	*(1)*	
Wood furniture		0.1	(2)	0.5	**0.3**
Other wood (4)		2.6		9.4	**6.0**
Total Wood in C&D (3):	**26.3**	**30.1**	**20.2**	**45.3**	**30.5**
% of High Grade Wood (5):	*na*	*11.9*	*10.8*	*11.8*	*11.5*
% of Treated Wood in Waste Wood:	*4.9*	*8.6*	*1.5*	*4.4*	*4.9*

(1) Included in engineered wood
(2) Some may be included in untreated/unpainted or in engineered wood
(3) Averages shown are an average calculated for each type of wood, and an average of the totals of wood, to incorporate the Wisconsin study
(4) Other wood consists primarily of wood roofing and siding and mixed demolition wood that is too contaminated to be easily identified.
(5) Pallets and crates and untreated/unpainted wood excluding any engineered wood

As shown in Table 5, waste wood ranged from 20 to 45 percent of C&D waste disposed (averaging 30.5%). High grade wood (defined as pallets and crates and unpainted and untreated wood) made up between 10 and 11 percent (rounded) of C&D waste, or between 26 and 40 percent of waste wood. Treated wood (a problem wood for most markets) is only between 0.3 and 2.6 percent of *total* C&D waste, but is between 1 and 9 percent (rounded), or an average of just under 5 percent of *waste wood only*.

Massachusetts Waste Wood Generation and Composition Estimates

Using the data on waste wood composition from Table 5, and the average per capita C&D generation estimate of 1.7 pounds (from Table 2), per capita waste wood generation by material type is presented in Table 6. It should be noted here that the distinction between *generation* and *disposal* is blurred in Massachusetts when compared to other states from which data on C&D generation and composition are available. This is because the ban on disposal of wood from C&D waste is unique to Massachusetts, requiring that Massachusetts C&D waste be processed, with a certain percent of the wood removed for recycling, prior to disposal. Therefore, the valid comparison among states is *generation*, not *disposal*, even though DSM recognizes that some waste is recycled in other states and not included in the "waste generation" coefficients reported in Table 2 – which are typically based on data from landfill waste characterization studies.

Table 6
Estimated Annual Generation of Waste Wood, By Material Type, in Massachusetts Based on Composition Studies

Wood	C&D Composition	Per Capita Disposal (1)	MA Estimate (3)
	(% by weight)	(lbs/day)	(tons)
High Grade (2)	11.5	0.20	230,000
Painted/stained	6.5	0.11	129,000
Engineered Wood	8.1	0.14	161,000
Other Wood	6.3	0.11	126,000
Treated Wood	1.6	0.03	31,000
		TOTAL	**677,000**

(1) Includes recycling and disposal. Used total C&D per Capita Generation of 1.7 lbs/day.
(2) Pallets and crates and untreated/unpainted wood
(3) Based on the MA population estimate of 6,437,193 (Census, 2006)
NOTE: Numbers may not add due to rounding

Section 4
Estimating Massachusetts C&D Waste Generation and Composition Based on a Rough Mass Balance

As an alternative to estimating Massachusetts C&D generation using per capita generation estimates, as well as to gain an understanding of processors and markets in 2007, DSM attempted to track the flow of C&D through those who handle Massachusetts C&D, both in the state and in surrounding states. Handlers of C&D include haulers, transfer stations, processors, and end markets.

DSM was able to identify, through reports filed by all transfer, processing and disposal facilities in Massachusetts, and through interviews with handlers in the state, the following facilities handling Massachusetts C&D material:

- 4 significant haulers (without their own facility);
- 131 transfer stations (11 large ones surveyed by DSM, 64 transferring to processors – and therefore captured in the processor surveys, and 56 transferring exempt waste for disposal);
- 21 in-state “processors” (includes the 15 permitted Massachusetts “C&D Processing Facilities,” as well as 6 other significant facilities that remove some portion of C&D material for recycling before transfer, or operate under a Determination of Need);
- 9 out-of-state processors; and
- 6 users of C&D-derived secondary materials (e.g. users of wood for fuel, gypsum wallboard re-manufacturers).

DSM started by conducting site visits with 15 of the processors and handlers in the state (see Table 7, below), and was able to conduct detailed surveys over the telephone for 4 more. Two processors/handlers declined to participate.

Processors in New Hampshire, Rhode Island, Maine, New York, and Connecticut also process Massachusetts C&D wastes. DSM visited 4 of the 9 identified, and performed telephone surveys with the remaining 5.

DSM also visited 4 major end markets for Massachusetts C&D-derived waste wood in Maine and Quebec, as well as the largest landfill in Maine handling C&D waste and residuals. Telephone surveys were conducted of 19 other sites, including larger transfer stations, haulers, end markets, and disposal sites. DSM contacts are summarized in Table 7.

Table 7
Summary of Facilities DSM Surveyed (October 2007 – January 2008)

	Visited	Telephoned	Refused
Massachusetts Processors	15	4	2
Out-of-State Processors	4	5	-
Other C&D Handlers:			
Transfer Stations	-	11	-
Haulers	-	4	-
Disposal Sites	1	2	-
End Markets	4	2	-
TOTAL:	**24**	**27**	**2**

Each processor was asked to provide current annual quantities received, quantities of material separated, by material type, markets for the recovered materials, and a description of fines and residues, if screening and/or grinding was occurring.

Table 8 summarizes Massachusetts C&D waste disposition based on DSM's surveys and a compilation of reports filed with MassDEP. Estimated quantities in Table 8 include only C&D waste quantities which DSM has positively identified –through surveys and/or MassDEP reports, and therefore may slightly under-estimate total C&D waste managed in Massachusetts. Details regarding categorization and data quality are presented below.

Table 8

Summary of Estimated C&D (Building Debris) Generated in Massachusetts in 2007

Handlers	Description	Tons of MA C&D Handled in 2007	Percent of Generated C&D
Massachusetts Processors (1)	Facilities in Massachusetts who sort C&D to generate marketable secondary material(s).	1,355,000	69%
Out-of-State Processors	Out-of-state processors who accept C&D from Massachusetts before any processing has been performed.	453,000	23%
Exempt Transfer Stations	Transfer stations separately collecting C&D and sending it directly for disposal. The material is exempt from the waste ban because they only accept material in loads of 5 cubic yards or less.	68,000	3%
Other C&D Handlers	C&D materials handled by transfer stations and haulers not otherwise accounted for. Some is source separated material for recycling, some is difficult-to-manage waste headed for disposal.	101,000	5%
	TOTAL:	**1,977,000**	**100%**

(1) "Massachusetts Processors" includes the 15 permitted Massachusetts "C&D Processing Facilities," as well as 6 other significant facilities that remove some portion of C&D material for recycling before transfer,,or operate under a Determination of Need.

The total estimated C&D waste generation (building debris only) of 1,977,000 tons based on DSM surveys and reports to MassDEP can be compared with the total of 1,998,000 (rounded) tons calculated by multiplying the per capita waste generation estimate from Table 2. This is important because it demonstrates that reported Massachusetts generation is consistent with data on generation from other states. This also means that it is likely that the waste composition in Massachusetts is similar to the *average* composition reported in the literature (see Section 5, below).[14]

Massachusetts Processors

DSM defined processors as facilities accepting mixed C&D, and sorting the material to generate at least one recoverable material. Processors were, for the most part, supportive of the project and invited DSM to visit their facilities. Fifteen of the major processors in the state gave time to DSM to tour their facility and discuss estimated quantities, current and past processes, and ramifications of the waste ban on their

[14] It must be stressed again that generation and disposal are used interchangeably here because of the unique nature of Massachusetts generation and disposition due to the ban on disposal of wood from C&D wastes. This results in significantly greater diversion of this material in Massachusetts than is occurring in other states for which DSM has data.

facility. The estimates in this category are based on materials leaving the facility in 2007, which was very similar to the amount of waste entering the facilities because most facilities do not have large storage capacity.

Out-of-State Processors

An additional 23 percent (453,000 tons, rounded) of Massachusetts C&D waste material was hauled out-of-state to C&D processors in neighboring states. All nine identified facilities accepting this material were surveyed on-site (4) or via telephone (5). DSM estimates that the destination for the 23 percent of Massachusetts C&D waste sent to out-of-state processors in 2007 is as follows:

8.0% to New Hampshire
6.6% to Rhode Island
4.2% to New York
2.4% to Maine
1.7% to Connecticut

Exempt Waste

The Massachusetts ban on disposal of certain materials in C&D waste includes an exemption for facilities receiving C&D in loads of less than 5 cubic yards. This primarily applies to municipal transfer stations accepting self-hauled C&D waste. DSM did not contact these facilities for waste flow estimates, but instead relied on data from 2006 reports to the state. Exempt-waste transfer stations reportedly handled 68,000 tons (3%) of Massachusetts-generated C&D in 2007.

Other C&D

Finally, DSM attempted to locate and quantify C&D which was not showing up at large processors or in State reports. DSM contacted haulers, transfer stations, and disposal sites which may have been handling C&D not otherwise accounted for through processors on State reports. DSM's estimate for "Other C&D" waste quantities includes only C&D waste that was identified by DSM through these contacts, and therefore is likely to be underestimated. Fifteen entities were contacted, 10 of which were found to be handling a total of 101,000 tons (5%) of Massachusetts-generated C&D in 2007 which had not been previously accounted for. These included:

Haulers

DSM attempted to identify and contact haulers who transport Massachusetts-generated C&D waste directly to out-of-state locations not surveyed by DSM. Using word of mouth, MassDEP reports, and local listings, DSM contacted the four most potentially significant C&D haulers in an attempt to quantify how much C&D waste was headed for sites not surveyed by DSM. The total amount not otherwise accounted for was only 5,000 tons (0.3%).

Transfer Stations

DSM defined transfer stations as facilities accepting mixed C&D and transferring it with no sorting of the material beyond removal of items such as appliances, tires, and CRTs. MassDEP maintains a list of active facilities in the State and receives annual reports from these facilities, which includes the types of materials handled. Using the 2006 list and reported data, DSM was able to identify 131 transfer stations. Of the 131 facilities identified, 64 sent waste to C&D processors (included above) and 56 handled only exempt waste (included above). The remaining 11 were identified as requiring clarification and were surveyed by DSM. These surveys identified Massachusetts-generated C&D, not otherwise accounted for, in 2007 of 17,000 tons (0.9%) disposed at out-of-state landfills, 8,000 tons (0.4%) source-separated for recycling, and 6,000 tons (0.3%) disposed of at combustion facilities.

Disposal Sites

The Maine landfill estimated to be disposing of the largest quantity of Massachusetts C&D waste and residuals was visited by DSM in December, 2007. While the majority of material entering this landfill can be accounted for as residuals from C&D processing facilities, it is estimated that this landfill received an additional 65,000 tons (3.3%) of Massachusetts-generated C&D not otherwise accounted for.

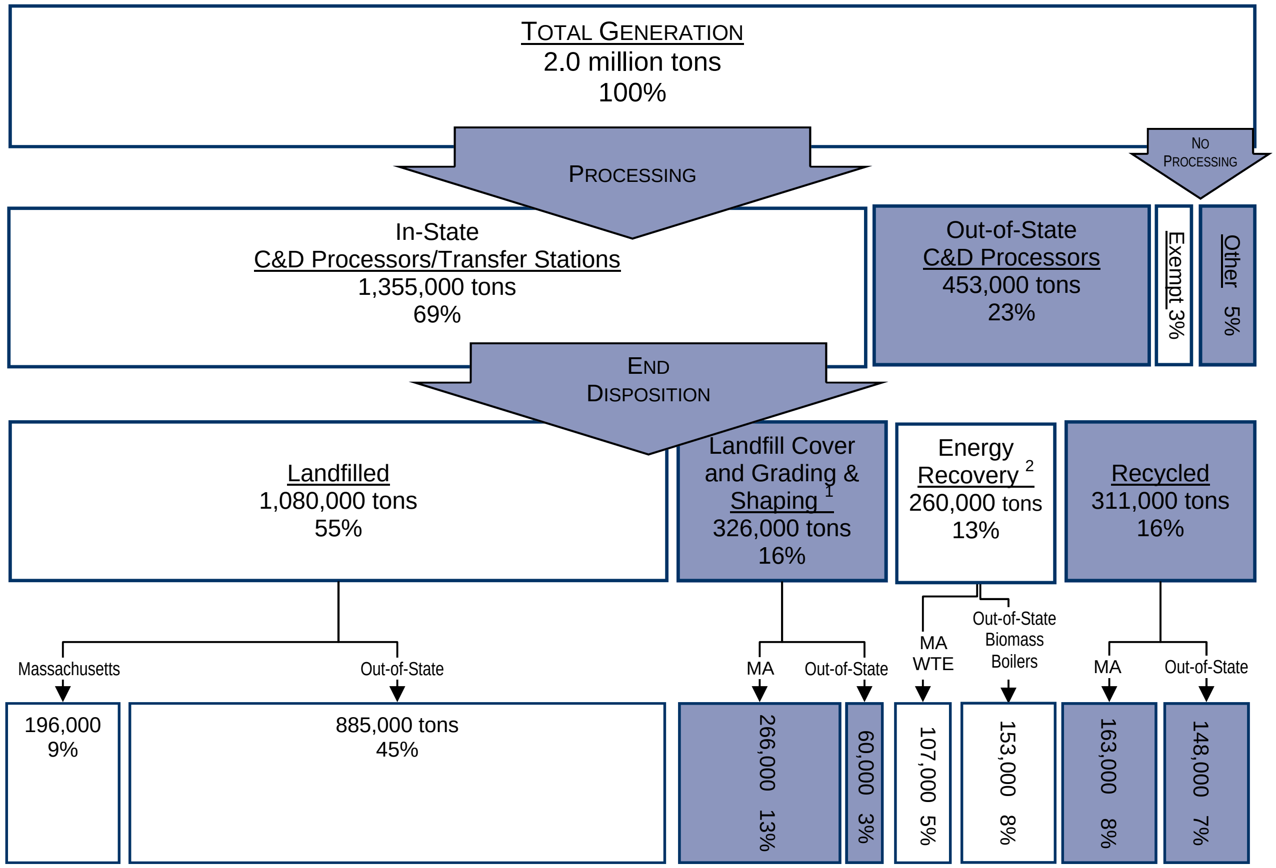
DSM also interviewed the owners of the largest New Hampshire landfill accepting Massachusetts waste, and conducted an extensive interview with a representative of the Ohio EPA, which is responsible for oversight of Ohio landfills accepting C&D wastes, including wastes from Massachusetts.

DSM was unable to obtain any information from the New Hampshire landfill as to acceptance of un-processed C&D waste material. At least one large landfill in Ohio has been accepting Massachusetts C&D from a C&D processor in Massachusetts. Data on quantities of Massachusetts C&D waste recovered and landfilled are included in Table 9, below.

End Disposition of C&D Materials

Table 9 presents DSM's best estimate of the amount of C&D landfilled as waste, used for ADC or grading and shaping material at landfills, used for energy recovery either at an MSW combustor or as fuel for wood-fired boilers, and recovered for recycling. The results are also divided by whether the disposal or recovery of the C&D waste was done in Massachusetts or out of state. Figure 5, next page, is a graphical representation of Table 9.

Figure 5
End Disposition of Massachusetts C&D (2007)



1. Used for ADC (alternate daily cover) or Grading and Shaping Material in a landfill.
2. In Massachusetts all energy recovery was at MSW waste-to-energy plants. Out-of-State, 92% was at wood-fired boilers, and the remaining 8% at waste-to-energy plants.

Table 9
End Disposition of Massachusetts C&D (2007)

	In Massachusetts		Out-of-State		Totals	
	(tons)	(%)	(tons)	(%)	(tons)	(%)
Landfilled	196,000	10%	885,000	45%	1,080,000	55%
Used for ADC/grading/shaping (1)	266,000	13%	60,000	3%	326,000	16%
Subtotal Ending in Landfills:	*462,000*	*23%*	*945,000*	*48%*	*1,406,000*	*71%*
Used for energy recovery (2)	107,000	5%	153,000	8%	260,000	13%
Recycled (Recovered)	163,000	8%	148,000	7%	311,000	16%
Subtotal Recovered & Diverted for Energy:	*270,000*	*14%*	*301,000*	*15%*	*571,000*	*29%*
TOTAL:	*731,000*	*37%*	*1,246,000*	*63%*	1,977,000	*100%*

(1) Fines and Residuals used for ADC (alternate daily cover) or grading and shaping material in a landfill.
(2) In Massachusetts all energy recovery was at MSW waste-to-energy plants;
Out-of-State 92% was wood-fired boilers, and 8% waste-to-energy plants
NOTE: Numbers may not add due to rounding

Landfilled as Waste

As Table 9 illustrates, 1,080,000 tons (55% of Massachusetts-generated C&D waste) is being landfilled as waste. Here DSM is defining “landfilled as waste” as direct landfilling—expressly omitting landfill applications such as ADC or grading and shaping. Included in the landfilled row in Table 9, above, are:

- Exempt C&D from small municipal transfer stations (61,000 tons);
- Mixed C&D which has been hauled directly from the point of generation to out-of-state disposal facilities, and thus has not been subject to the waste ban (87,000 tons); and
- Residuals from in-state and out-of-state processing facilities (932,000 tons).

It is these *post-processing* residuals (932,000 tons) which are truly driving the high percentage of C&D materials being disposed as waste.[15] Table 10 presents DSM’s best estimate of where these post-process residuals are being landfilled.

Table 10
Post-process Residuals Landfilled as Waste 2007

Landfilled in:	Tons	%
Maine	348,000	38%
Ohio	164,000	18%
New Hampshire	137,000	15%
New York	76,000	8%
Pennsylvania	61,000	6%
Rhode Island	11,000	1%
Subtotal Out-of-State:	*797,000*	*86%*
In Massachusetts	135,000	14%
TOTAL:	932,000	100%

[15] It is important to note here that DSM observed large variations in the extent of processing to recover banned materials at different C&D processors, with some processors really acting more like transfer stations, with only minimal recovery of materials, and other processors recovering much higher quantities of material.

ADC and Grading and Shaping Material

Use of fines and residuals for landfill applications such as ADC and grading and shaping material amounted to 332,000 tons (16%) of total Massachusetts-generated C&D in 2007. Fines accounted for 55 percent of this material, as presented in Table 11. It must be noted that Table 11 represents only the fines used for landfill applications. *More than* 178,000 tons of fines were generated in 2007. Excess fines which could not be marketed as ADC or grading and shaping material were landfilled as waste. DSM was unable to develop an estimate of the quantity of fines sent to landfills for disposal based on the data collected from processors.

Table 11
Fines and Residuals Used in Landfill Applications 2007

	Tons	%
Fines (1)	178,000	9%
Residuals	148,000	7%
	326,000	16%
TOTAL C&D:	1,977,000	100%

(1) Note that fines were generated in excess of this amount, but the excess was mixed with residuals landfilled as waste.

Energy Recovery

Roughly 13 percent of C&D material was burned to produce energy in 2007, with an important distinction between in-state and out-of-state combustion. In Massachusetts, all energy recovery was at WTE facilities because there is no market for biomass fuels in-state. However, because the waste ban excludes WTE facilities, unprocessed C&D can be disposed of at Massachusetts WTE facilities. Conversely, outside the state, the vast majority of energy recovery was through the use of waste wood in biomass boilers. Table 12 delineates DSM's best estimate of how and where the energy recovery took place.

Table 12
Breakdown of Energy Recovery Activity 2007

	WTE	Wood-Fuel
Maine		100,000
Canada		41,000
New York	8,000	
Other	4,000	
Subtotal Out-of-State:	*12,000*	*141,000*
Massachusetts	107,000	0
TOTAL:	119,000	141,000 (1)

(1) Note that total tons are slightly different from the MA vs. Out-of-State figures in Table 9. This is due to the fact that 12,000 tons went to WTE facilities outside MA, changing both figures by that amount.

Materials Recycling

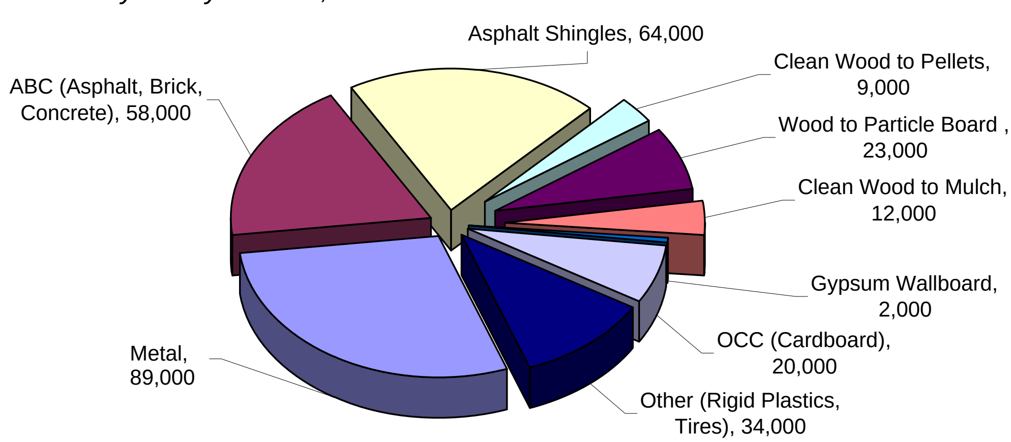
Markets for clean wood, ABC materials, metals, and OCC remain strong and abundant, so these materials were regularly removed for recovery. Table 13 presents DSM's best estimate of tons recycled in 2007 by material type. Figure 13 presents the same figures in graphical form.

Table 13
Tons of MA C&D Recycled by Material, 2007

	Tons	%
Clean Wood to Pellets	9,000	3%
Wood to Particle Board (1)	23,000	7%
Clean Wood to Mulch	12,000	4%
Gypsum Wallboard	2,000	1%
Metal	89,000	29%
ABC (Asphalt, Brick, Concrete)	58,000	19%
OCC (Cardboard)	20,000	6%
Asphalt Shingles	64,000	21%
Other (Rigid Plastics, Tires)	34,000	11%
Total Recycled:	311,000	100%
Total Generation:	1,977,000	
% Recycled:	16%	

(1) Some of this wood may have been used for test purposes. Some was burned as fuel, and some may be stockpiled for future use.

Figure 13
Tons of MA C&D Recycled by Material, 2007



Recovered Wood

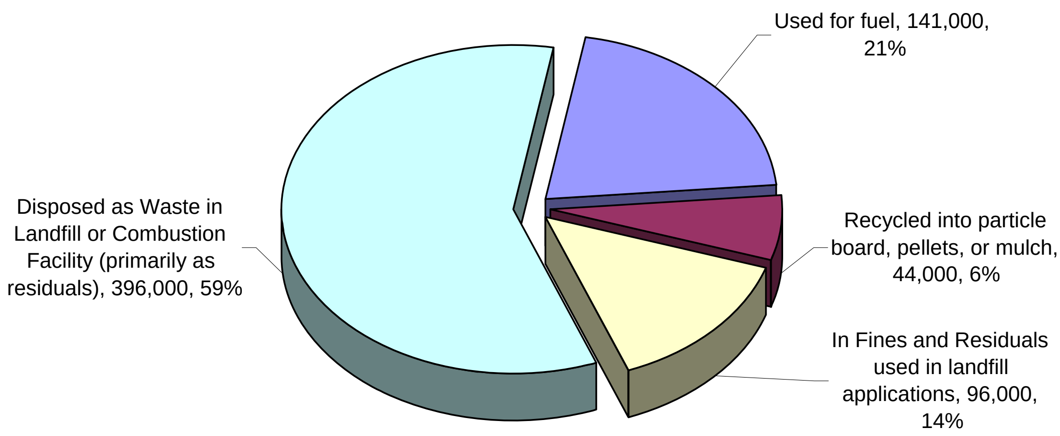
Because wood is the largest single component of building debris, it is important to estimate the disposition of wood from Massachusetts C&D materials. Certain uses (e.g., wood for fuel) were well documented by DSM, but other uses/disposition can only be estimated based on the expected composition of the wood, fines, and residuals. Table 14 presents DSM's *best estimate* as to the disposition of waste wood from Massachusetts C&D waste based on the generation estimate of waste waste shown in Table 6. Figure 14 presents the same figures in graphical form.

Table 14
End Disposition of C&D Wood

End Point	Tons	%
Used for fuel	141,000	23%
Recycled into particle board, pellets, or mulch	44,000	7%
In Fines and Residuals used in landfill applications (1)	96,000	15%
Disposed as Waste in Landfill or Combustion Facility (primarily as residual) (2)	396,000	55%
TOTAL (From Table 6):	677,000	100%

(1) Calculated using typical organic content for Massachusetts fines and residuals
(2) Calculated using characterization data net any wood removed for recovery

Figure 14
End Disposition of C&D Wood



Fines

Due to concerns about the potential hydrogen sulfide gas impacts associated with using fines for ADC, one of DSM's tasks was to research the generation and composition of fines associated with processing Massachusetts C&D wastes.

Fines were created at nine of the Massachusetts C&D processing facilities surveyed by DSM. The quantity and composition of fines varied among these facilities, and adjacent New Hampshire and Maine processing facilities, based on a number of factors, as described below.

Definition / Description

C&D "fines" (fines) are typically created when crushed or ground C&D wastes are run across a screen. Fines are the smaller-diameter material that drops through the screen.

The relationship between fines and residuals can be blurred depending on how facilities ultimately manage material and dispose of fines and residuals. However, in general, residuals can be distinguished from fines because residuals are typically the material falling off of the end of the sorting belt (meaning that they passed over the screen which fines were falling through), assuming a positive sort[16] for wood and other recoverable materials. However, in cases where wood is negatively sorted off of the end of the sorting belt, residuals may, like fines, be generated as the material falling through a screen (in this case, probably a screen with larger diameter openings). In this case, the smaller diameter material may be classified as fines and the larger diameter material may be classified as residuals. Residuals may also be generated by sorting of non-recycled materials (residuals) off of the sorting belt.

The characteristics of "fines" are dependent on:

- Materials entering the C&D processing facility;
- Materials recovered prior to screening;
- The type of size reduction equipment being used by the processor;
- Screen size; and,
- Whether size reduction occurs prior to the fines screen or after it.

Materials Entering the C&D Processing Facility

There will be a significant difference in the quantity of fines produced at a C&D processing facility depending on whether the processing facility primarily handles demolition wastes or new construction wastes. Demolition waste typically contains significantly more dirt and finely broken wood and gypsum than new construction waste, and therefore will generate significantly greater quantities of fines when the crushed material is run across a screen.

Materials Recovered Prior to Screening

C&D processing facilities that are diligently attempting to separate gypsum rich wallboard loads prior to processing will reduce the quantity, and change the composition, of fines compared to those facilities crushing or grinding all C&D materials.

Types of Size Reduction Equipment

While the majority of C&D processing facilities in Massachusetts were set up with front-end grinding equipment, a number of these facilities are no longer running the grinding equipment. Instead, they are simply running over the C&D waste with excavators to size reduce the material and to pick out metal and other large objects. In some cases this material is then placed on a conveyor for sorting and screening (which will produce fines). In other cases the partially crushed materials are simply loaded into rail cars or transfer trailers for landfilling. These latter facilities do not produce fines because they are not screening the waste.

Screen Sizes

The nine Massachusetts processors surveyed that are currently screening C&D, and therefore creating fines, use screen sizes ranging from 3/8" minus up to 3" minus. A 3/8" minus screen will create fines that are all smaller than 3/8's of an inch, while a 3" minus screen will create fines that are smaller then 3 inches The screen size has a large impact on the characteristics of the fines. Fines produced from a 3/8" - inch minus screen will appear very similar to a soil product in size and texture, while 1" minus screened

[16] In a "positive sort" the desired material is pulled off the sorting belt and the waste materials fall off the end of the belt, whereas in a "negative sort" waste materials are pulled off the sorting belt and the desired material falls off the end of the sorting belt.

fines look more like a lumpy compost product, and may contain larger pieces of recognizable materials such as plastic, paper, and brick. Fines generated by a 3-inch minus screening process can look more like a ground residuals product, with large chunks of wood readily apparent.

As can be expected, the screen size also has a large impact on sulfate and organics content. The smaller screen allows only smaller particle size material such as dirt to pass through while limiting the amount of wood and other larger particle size materials from passing through. However, a relatively large amount of gypsum wallboard particles will pass through even a small screen size because gypsum tends to disintegrate into relatively small particles. Therefore small screen sizes may increase the sulfate content in the material by limiting the amount of non-gypsum material falling through the screen.

Conversely, increasing the screen size increases the amount of wood in the fines, therefore increasing the organics content. Sulfate and organics content are factors in generating hydrogen sulfide (H_2S) which can cause subsequent odor problems in certain landfill applications. Essentially, organic matter is required for sulfate reducing bacteria to create H_2S, although research indicates the paper backing found in gypsum may provide enough organic content without the need for wood.

Fines Composition

DSM was unable to find any specific data on the composition of fines from Massachusetts processors. However, in general, there are two primary issues associated with the composition of fines. The first is the issue of the prevalence of gypsum in the fines. The second is the issue of potentially toxic materials (e.g., lead paint chips) in the fines.

The University of New Hampshire is taking the lead in relatively new research on fines, and their impact on H_2S production at landfills. Massachusetts is participating in this effort. It is expected that better data on fines composition will become available over the next several years. In the absence of data in the literature, the following observations can be made based on DSM's site visits to C&D processors and a review of the available literature.

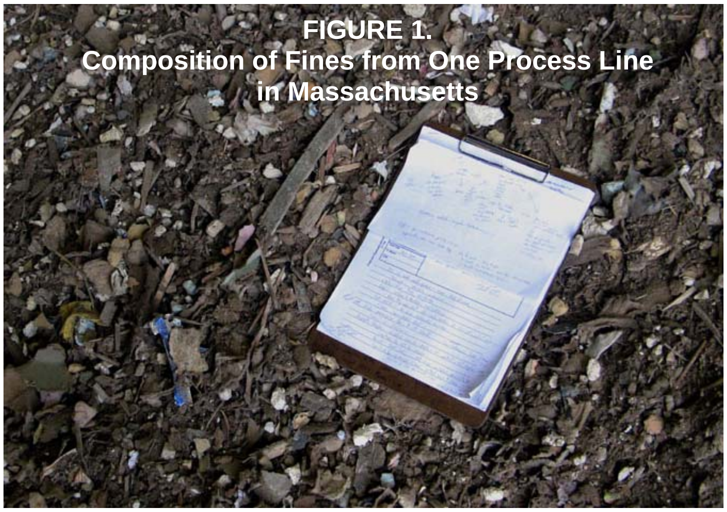


FIGURE 1. Composition of Fines from One Process Line in Massachusetts

The C&D materials most likely to end up as fines are those that are inherently small in diameter, or that break down easily. For example, dirt and gypsum wallboard typically fall through screens, while cardboard, pieces of wood, and rigid plastics pass over the screen. As a result, gypsum and dirt will always represent a higher percentage of fines than of the composition of the incoming C&D waste.

Based on the literature search on C&D composition, and assuming that gypsum wallboard is not sorted out before processing; fines could contain the majority of the gypsum inherent in the C&D waste. Results from research by Jang and Townsend from a "multiple batch test" indicated that the mass of the gypsum content in C&D debris fines ranged from 1.5% to 9.1%."[17] This compares with DSM's literature search indicating that incoming C&D waste might average 9.7% gypsum. Therefore, at the high end of the range reported by Jang and Townsend, virtually all of the gypsum could be found in the fines.

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[17] Jang, Y and Townsend, T. Sulfate Leaching from Recovered Construction and Demolition Debris Fines. *Advances in Environmental Research.* 2001.

Other materials typically found in fines include sand and dirt, wood, and small pieces of asphalt, brick, concrete, plastic, paper, insulation, glass and even metals. The percentage of wood might vary from a low of 5 – 10% to a high of more than 50% – again dependent on the screen size, with larger screen sizes allowing a greater percentage of the wood to pass through the screen.

Research on the toxicity of fines has been conducted by the Construction Materials Recycling Association (CMRA) and the University of Florida – Gainesville. Research by Green Seal Environmental for CMRA in 2005 concluded that C&D fines (or Recovered Screen Material – RSM) used as an ADC material in the states providing data (12 facilities and one state agency) is a non-hazardous material suitable for landfill applications and does not present a significant threat to public health and the environment.[18]

University of Florida – Gainesville researchers researched trace organic pollutants and risk from land applied fines concluding that the "organic chemicals in recovered soil fines from C&D debris recycling facilities were not of a major concern in terms of human risk and leaching risk to groundwater under reuse and contact scenarios."[19] They also looked at heavy metals in fines and concluded that arsenic presented the greatest limitation to reuse, but lead was not found to pose a major problem,[20] adding "likely because of the relatively new building infrastructure in Florida."

Fines Generation

Based on the processor survey, DSM estimates that roughly 190,000 tons (rounded) of fines were generated in 2007 from Massachusetts C&D waste. Of this, roughly 140,000 tons were generated from in-state processors with the balance generated from out-of state processing facilities handling Massachusetts waste. Overall, fines represent 20% of the Massachusetts material processed, or roughly 10% of all Massachusetts C&D material.

The composition of fines created from the 9 in-state and 4 out-of-state processors varied greatly based on the variables discussed above. Incoming C&D material leaving as fines ranged from a low of 7% at one facility to a high of 37% last year. DSM believes both the drop in wood markets, and the regional market demand for fines in landfill applications created this wide variation. Table 15 (next page) presents data collected on fine generation at facilities processing Massachusetts C&D waste in 2007.

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[18] Ibid.

[19] Yong-Chul Jang and Timothy G. Townsend. *Occurrence of Organic Pollutants in Recovered Soil Fines from Construction and Demolition Waste*. University of Florida, December 2000.

[20] Timothy Townsend, Thabet Tolaymat, Kevin Leo and Jenna Jambeck. H*eavy Metals in Recovered Fines from Construction and Demolition Debris Recycling Facilities in Florida.* Department of Environmental Engineering Sciences, University of Florida. March 2003.

Table 15
Estimated Annual Generation of Fines From MA C&D Material By Processing Facility (2007)

Processor (1)	Fines % (2)	Screen Diameter	Total Fines Generated
	(%)	(inches)	(tons)
M - 4	7%	1/2"	6,000
M - 9	10%	3"	10,000
M - 2	12%	1"	5,000
M - 3	12%	1"	8,000
O - 1	15%	3/8"	12,000
M - 5	20%	3"	18,000
M - 8	20%	NA	7,000
M - 7	21%	1"	15,000
O - 4	22%	2"	10,000
O - 2	24%	NA	8,000
M - 1	25%	2"	3,000
O - 3	25%	3/8"	20,000
M - 6	37%	3"	68,000
		TOTAL:	**190,000**

(1) M indicates facility located in Massachusetts, and O indicates an out-of-state facility
(2) Estimated fines as percentage of C&D waste delivered to processing facility

Of the 190,000 tons (rounded) of fines generated, an estimated 178,000 went to landfill applications in 2007. The balance was assumed to be disposed with other C&D.

Asphalt Shingles

Asphalt shingle recyclers in Massachusetts generally recycle asphalt shingles under a Determination of Need (DON) permit rather than a Beneficial Use Determination (BUD). Although there are at least three sites with DON permits for asphalt shingle recycling in Massachusetts, DSM identified and contacted the only two sites cited by those in the industry as significant recyclers. One other facility surveyed by DSM has a BUD permit to use asphalt shingles as road-building material at landfills. Table 16 presents tons of shingles from Massachusetts-generated C&D either recycled or used in landfill road-building in 2007.

Table 16
Approximate Tons of Asphalt Shingles
Recycled from Massachusetts-Generated C&D 2007

	Tons
Recycled in Massachusetts	42,000
Recycled out of Massachusetts	22,000
Used in Landfill Applications	6,000
TOTAL:	70,000
Total C&D:	1,977,000
Percent Recovered Shingles:	3.5%

Note: Table 13 does not report asphalt shingles used in landfill road construction as “recycling,” whereas they are included here.

The asphalt shingles recycled in Massachusetts are source-separated post-consumer asphalt roofing shingles as well as pre-consumer asphalt roofing shingles which are ground and used in asphalt plants, construction sites, aggregate processing facilities and shingle manufacturers.

DSM was unable to find reliable data on total generation of asphalt shingles in Massachusetts.

Section 5
Comparison of Massachusetts C&D Waste Composition Based on Waste Generation Coefficients from the Literature and the Mass Balance from Surveys

This section compares the waste composition estimates for Massachusetts based on literature results (Section 3) with what processors in Massachusetts reported in 2006-07 (Section 4).

Visual Survey Results

One Massachusetts processor provided DSM with visual load characterizations from over 1,100 loads. The processor followed a similar survey methodology as implemented in the waste characterization studies presented in Section 3, above. The results (Table 17) illustrate that waste wood totaled 34 percent of all waste (rounded), with treated wood making up 1.2 percent (or 3.6% of all wood) and clean wood making up 9.5 percent (or 28% of all wood). While the total waste wood results are slightly higher than DSM's estimate (31% versus 34%) the data are, in general, very similar to the estimates based on a survey of the literature as presented in Tables 5 and 6 in Section 3.

Treated wood at 1.2 percent of total C&D processed, or 3.6 percent of the waste wood, is similar to the data from the literature at 1.6 percent of total C&D or 4.9 percent of waste wood (Table 5, above). Clean wood, at 9.5 percent is slightly lower than the data from the literature, at 11.5 percent, but total untreated wood is similar at 28 percent and 28.9 percent, respectively.

Table 17
MA Processor Visual Estimate Survey Results

	Percentage by Volume	Density (1)	Percentage by Weight
	(%)	(lbs/yd^3)	(%)
ABC Waste	1.9%	850	9.1%
Wood			
Treated	1.3%	169	1.2%
Clean	10.1%	169	9.5%
Other Wood	25.2%	169	23.7%
Gypsum			
Clean	2.0%	467	5.3%
Dirty	11.7%	467	30.4%
OCC	13.7%	53	4.0%
Metals	15.1%	180	15.1%
Plastic	7.7%	40	1.7%

(1) CIWMB. Method of Visual Characterization for Disposed Waste from C&D Activities. October 2006.

Waste Wood Recovery Rates Based on Generation and Composition Estimates

The estimates of total waste wood generation, by type, in Massachusetts, from Table 6, can also be compared against the end disposition of C&D wood (Table 14). These estimated recovery rates are presented below in Table 18. Table 18 is instructive in that it illustrates the difficulty (and cost) that C&D processors face obtaining high grade, clean wood (only a 19% recovery rate), and even how much difficulty they have recovering wood that meets the much lower boiler fuel standard (less than 50% recovery rate). This is why such a large fraction of waste wood going through C&D processors ends up going to relatively low cost landfills.

Table 18

Estimated Recovery of Waste Wood by End Use Market (2007)

Wood Category	MA Generation Estimate (From Table 6)	MA Recovery (From Table 14)	Recovery Rate
	(tons)	(tons)	(%)
High Grade (1)	230,000	44,000	19%
Boiler Fuel Specs (2)	290,000	141,000	49%
Subtotal:	520,000	185,000	36%
All other wood:	157,000	0	0%
Total Wood:	677,000	185,000	27%

(1) Pallets and crates and untreated/unpainted wood estimate
(2) Painted/treated and engineered wood estimate

Section 6
Current Markets for Materials Derived From C&D Waste

As the previous sections of this report illustrate, approximately 2 million tons (rounded) of C&D waste material (exclusive of infrastructure and land clearing debris) were generated in Massachusetts in 2007.

Of this material, roughly 311,000 tons (clean wood, ABC materials, corrugated, metal, asphalt shingles, gypsum, plastic and tires) were recycled. Another 141,000 tons were burned in biomass boilers for energy recovery (primarily a mixture of clean and painted/stained wood), and another 326,000 tons were used as either alternative daily cover (ADC) or grading and shaping material. Finally, 119,000 tons went to WTE facilities for energy recovery, both in Massachusetts and out-of-state.

This section describes the status of existing markets for these materials. Section 7 describes potential future markets for these materials.

Costs

Before beginning the discussion of markets, it is instructive to provide a brief overview of costs associated with processing C&D wastes, and compare these costs to landfill costs. These costs influence the decision to process C&D for higher market prices or to send greater quantities of processed residuals to landfill.

Landfills in eastern Ohio currently charge approximately $20 per ton to accept C&D material – either in C&D landfills (lined and unlined) or in MSW landfills (lined).[21] C&D processors in Massachusetts report that they can tip, load, rail haul to Ohio, and dispose of Massachusetts C&D materials for roughly $55 to $60 per ton.

Many of the processors whom DSM surveyed were reluctant to report tipping fees at their facilities, or to discuss actual C&D processing costs. However, in general, tipping fees for C&D processors range from $70 (rounded) to $130 per ton, with an average of $100 per ton. Processing cost estimates reported to DSM ranged from $15 per ton for minimal processing, to $70 per ton, with an average of $35 per ton.

Fines and residuals used for ADC and landfill grading and shaping cost the processors between $25 and $50 per ton delivered to the landfill, and disposal costs for the remaining residuals cost between $55 and $85 (rounded) per ton. Assuming an average processing cost of $35 per ton, that means that disposing of material that has been processed as ADC costs the processor between $60 and $85 per ton. Residuals, the largest single material produced by C&D processors, cost between $90 and $120 per ton, well above the cost associated with simply shipping unprocessed C&D by rail to Ohio.

This means that the C&D processor must be able to recover a sufficient amount of material with value (i.e., corrugated, metal, wood) to offset the cost of processing and disposing of residuals.

[21] It is illegal for Ohio C&D landfill operators to accept ground C&D waste. Therefore, the majority of ground C&D waste going to Ohio must be landfilled in a lined, MSW landfill. However, Ohio EPA reports that MSW landfills are accepting C&D waste at roughly the same cost ($20 per ton) as unlined C&D landfills.

Material Recycling

Commodity Markets for Metals and Paper

DSM estimates that approximately 50 percent of the corrugated and 80 percent of the ferrous metals in the Massachusetts C&D waste stream was recovered in 2007.

There are currently strong markets for metals and old corrugated containers. While these are commodity markets where the price, and the acceptable contamination levels, changes over time, both of these markets are expected to continue to exist at a level where it will be worth it for C&D processors to continue to manually or mechanically separate these materials.

Because the corrugated has been mixed with C&D materials, and in some cases also gotten wet or covered in dust and dirt, it will have a potentially lower value than corrugated from residential and commercial waste streams, and in some cases will not be recoverable. However, because corrugated is a valuable paper grade, it is likely that the majority of the corrugated will continue to be separated and sold for recycling, although in times of weaker demand the quantities separated by the processors may be reduced.

Ferrous metals are not particularly impacted by contaminants and will, in most cases, continue to be separated, either through the use of magnets, or by positive hand sorting. As discussed below, if the markets for wood for energy recovery and/or particle board production continue to develop, there may also be more incentive for C&D processors to install eddy current separators to remove aluminum – which can be a problem in both energy recovery boilers and in particle board manufacturing.

Asphalt, Brick and Concrete

Whereas the primary driver for recycling of metals and paper is the value of the material, in the case of ABC wastes the primary driver is the high weight and resulting impact on trucking and landfill tipping fees associated with not separating these materials out for recycling. Because there will always be a market for aggregate, it is likely that it will continue to be less costly for C&D processors to separate these materials out for sale to aggregate markets – even at low values – when compared to transporting to higher cost landfills (especially in the east, where landfill costs are relatively high).

Clean Wood

DSM estimates that approximately 19% of the 230,000 tons of clean wood from Massachusetts C&D waste was recycled in 2007.

It is important here to discuss “clean wood” separately from the typical mix of clean and painted/stained wood that most of the C&D processors sell. There are a number of potentially strong markets for “clean wood”. The material can be ground and used for mulch (natural or colored), it can be pelletized for sale as fuel for pellet stoves, it can be used to produce particle board, and it can be burned as fuel. Therefore, the market demand can be assumed to be the sum of the boiler and particle board demand presented below (between 680,000 and 940,000 tons per year) plus at least 20,000 tons for mulch and fuel pellets (based on 2007 demand).

The problem with the market for clean wood is that, with the exception of boiler fuel, all other uses have very low tolerances for contaminants inherent in C&D materials (e.g., painted/stained wood, treated wood, plastics and metals). In most cases this means that clean wood must either be separated on-site by the generator or positively picked on a tipping floor or picking conveyor. In the case where it is positively picked on a picking conveyor a significant amount of clean wood will be missed because of uncertainty as to whether it is stained or treated as opposed to simply weathered. Thus yields will typically be low, with a significant amount of clean wood used as boiler fuel, or landfilled as residuals.

Mixed Clean and Painted/Stained Wood Used For Boiler Fuel

DSM estimates that roughly 49 percent of the 290,000 tons (rounded) of painted and stained wood was recycled in 2007.

Because of the difficulty of separating clean wood from painted/stained wood, the majority (roughly 70%) of wood recovered from C&D processors is being marketed as wood for boiler fuel.

DSM visited all of the known buyers of Massachusetts waste wood for biomass boilers in Maine and Quebec.[22] These included:

- Red Shield Environmental, Old Town, Maine
- KTI BioFuels, Lewiston, Maine[23]
- Boralex: Livermore, Maine[24]
- Sappi/S.D. Warren Company, Westbrook, Maine
- Tafisa, Lac Magentic, Quebec
- Kruger, Brompton, Quebec

A summary of the viability of using waste wood in biomass boilers is presented below based on our visits/meetings, discussions with State regulators in Maine, and a review of the literature.

Demand

DSM estimates that total demand in 2007 for waste wood for boiler fuel was 225,000 tons (rounded) based on reported demand and openings and closures of plants in 2007. The maximum *potential* demand based on *existing plants* is estimated to be between 400,000 and 660,000 (rounded) tons per year.[25]

The demand for waste wood for biomass boiler fuel is driven primarily by the higher BTU value of the waste wood when compared to green chips (7,380 BTU/lb for waste wood compared with 4,500 BTU/lb for green chips[26]) coupled with a lower price for the waste wood. That means that a buyer for a biomass boiler can purchase roughly 40 percent fewer tons of waste wood than green chips to supply the same amount of heat value to the boiler. This, when combined with a price per ton for waste wood which is reported to be about one-half of that for green chips means that a ton of waste wood is roughly 80 to 90 percent cheaper per BTU than a green chip.

It should be noted, however that the State of Maine regulations do not allow for substitution of more than 50 percent (on an annual average) of waste wood with green chips, so the saving in BTU costs are only available for one-half of the wood combusted.

There are also additional costs associated with the combustion of waste wood which remove some of the cost savings. First, and foremost, burning green chips without waste wood allows for sale of the resulting ash as a soil amendment. Once waste wood is added to the green chips, the resulting ash must be disposed of in an MSW landfill. DSM estimates that the difference in cost is between $40 and $50 per ton

[22] The buyer for Krueger/Brompton was interviewed by telephone, however Krueger and Tafisa have a joint agreement to purchase wood and the buyer for Tafisa was interviewed in person.
[23] KTI BioFuels is a waste wood processor supplying all of the fuel, under contract, to Red Shield Environmental.
[24] Boralex operates three biomass plants in Maine, however at this time only the Livermore facility co-fires waste wood with green chips.
[25] Maximum potential demand is based on interviews with biomass boiler operators as to how much they believe they could utilize going forward, as opposed to how much they actually used in 2007.
[26] *University of New Hampshire Life-Cycle Assessment of C&D Derived Biomass/Wood Waste Management,* September 7, 2007.

of ash. But since ash is roughly 10 percent of input, it is still worth burning the waste wood, assuming that the ash does not fail the US EPA TCLP test and require disposal as a hazardous waste.

As discussed below, while one biomass boiler in Maine (Red Shield) has failed the TCLP test for ash (on three occasions in 2007), discussions with Maine regulators, and the other biomass boiler facilities, indicates that this problem appears to be unique to Red Shield. Boralex has extensive experience burning waste wood at up to 50 percent of throughput at three plants (roughly 250,000 tons), and has not experienced any ash problems. And, Sappi, in Westbrook, has run significant test burns of waste wood with Maine DEP monitoring and does not expect to encounter air or ash permit issues.

Therefore, while it can be speculated that waste wood containing painted, stained and treated woods will increase the VOC and metals content of both the exhaust gas and the ash, a recent report by the University of New Hampshire[27] indicates that the use of waste wood may actually reduce overall air emissions, for two reasons. First, if combustion of waste wood reduces coal combustion, then the trace metals from coal combustion are eliminated. Alternatively, if the waste wood replaces green chips, which also contain trace quantities of heavy metals, the higher BTU value of the waste wood reduces total wood combusted, offsetting the potentially higher metal content of the waste wood.

This leaves the issue associated with glues in Oriented Strand Board (OSB), Medium Density Fiberboard (MDF) and particle board. The glues are primarily phenol and/or formaldehyde based glues. Because they are volatile, one would expect that under the high temperatures associated with waste wood combustion, these glues would burn off as hydrocarbons. This appears to be the case based on an analysis by Technical University of Zvolen, in Slovakia that found that at the temperatures typically found in a furnace, both phenols and formaldehyde are combusted, with non-detection of formaldehyde at 930 degrees C.[28]

Finally, waste wood also contains contaminants – especially aluminum nails – which can increase maintenance costs in the furnace/boiler. Slagging of metals on the grates or refractory can reduce boiler efficiency and availability. As discussed below, Sappi reports that if they are required to take their boiler out of service one more time per year due to increased maintenance from burning waste wood, the savings in wood purchase costs will be eliminated and it will not be worth continuing to burn waste wood.

Given the benefits and costs of waste wood when compared to green chips, the potential future demand is based on at least the following variables specific to the plants visited by DSM:

- Red Shield Environmental has struggled to meet ash quality standards. They have shut down three times in 2007 due to ash failing the US EPA Toxicity Characteristic Leaching Procedure (TCLP) test for lead. Failure of the TCLP test means that the ash can no longer be disposed in an MSW landfill, significantly increasing ash disposal costs. Red Shield reported to DSM that they believe they can solve the problem, both by closing the boiler more often for maintenance, and through potential changes to the ash handling system which they are currently considering implementing. It should be noted here that Casella has an exclusive agreement with Red Shield to supply all of the waste wood required by the Red Shield facility. KTI BioFuels is a subsidiary of Casella and is therefore the primary supplier of Red Shield.

- The Sappi/Westbrook paper mill has the potential to utilize relatively large quantities of waste wood. However they are currently only testing use of waste wood. They expect to ramp up use of waste wood in 2008, but will stop using waste wood if it causes excess maintenance on their boiler. Based on Maine DEP tests during co-firing of waste wood and chips, Sappi does not expect problems with ash or air quality permits.

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[27] *University of New Hampshire Life-Cycle Assessment of C&D Derived Biomass/Wood Waste Management,* Jambeck, J., Carpenter, A., Garner, K., September, 2007.
[28] *Investigation of Appropriate Conditions for Wood Waste Combustion on Basis of Emissions,* Ladomersky, J., Hroncova, E., Sumesova, D., Drewno, Volume 46, Number 170, p. 90 – 98, 2003.

- Boralex, like Sappi does not expect to have problems meeting ash or air quality permit conditions burning waste wood. However, Boralex stopped purchasing waste wood in the spring/summer of 2007, when Connecticut legislation specified that waste wood could not be burned as an approved fuel for their Renewable Portfolio Standard. This standard provides credits to electric suppliers of up to 5 cents per KW which is a significant source of revenue. The savings associated with burning waste wood (see below) were not sufficient to give up the credit. However, during the summer of 2007, Connecticut reversed its decision, allowing Boralex to begin to burn waste wood. Massachusetts DOER has yet to rule on a similar issue. Negative future decisions by either Connecticut or Massachusetts would have significant negative impacts on the demand for waste wood.

Mixed Wood for Use in the Production of Particle Board

Tafisa in Lac-Megantic, Quebec is the largest particle board production plant in North America. Tafisa is currently in the final stages of construction of a new line which will have the capability to utilize up to 40 percent waste wood in the production of particle board. Tafisa has already sourced waste wood (some from Massachusetts) for use during start-up (currently expected to be during March, 2008). If start-up goes as planned, Tafisa believes that it will eventually have the capability to utilize up to 275,000 tons per year of waste wood. Some portion of this waste wood will be sourced from New England because Tafisa expects to backhaul waste wood after delivery of new particle board to New England locations.

The use of waste wood for the production of new particle board would appear to be an environmentally preferable use of waste wood over combustion in that the fibers are reused again, and are still available for energy recovery at the end of the lifetime of the particle board. However, the final specification for waste wood that Tafisa will be able to use is still in development. The *expected* specification is compared in the following tables against the Maine DEP specification for boiler fuel.

State of Maine

Fuel Quality Standards for **CDD Wood** (1)	Composition
Non-combustible fraction exclusive of rocks, brick, and concrete	<1%
Plastics	<1%
CCA (chromated copper arsenate) treated wood	<1.5%
#4 minus fines (for publicly owned source) (2)	20%
#4 minus fines (for sources other than publicly owned)	10%
Asbestos	<1%
Fuel Quality Standards for **Blended Biomass Wood Fuel**	*mg/kg*
Arsenic	<50
Lead	<375
PCB	<0.74

(1) Maine Solid Waste Management Rules: Chapter 418, Beneficial Use of Solid Wastes (June 16, 2006)
(2) As regulated under the Maine solid waste management rule

TAFISA Particleboard Standard

Acceptable Materials
Particleboards, counter veneer, OSB, wafer board without edges or melamine in PVC
Packaging materials made out of wood
Wood with nails, screens, bolts not exceeding 10 mm in diameter
Untreated, without rot or mold
They must not be impregnated (treated) or oiled
Wood with aluminum or non-magnetic metals, such as foil or other coverage
Unacceptable Materials
Treated or impregnated wood (PCP, copper arsenate, creosote, etc.) or other chemical products (oil)
Construction and demolition wood contaminated with tar paper, plaster, concrete, wires, insulation materials, old paint
Rock, sand, brick, concrete, plastic, PVC or other foreign objects
Fruit and vegetable crates

A comparison of the Maine boiler fuel specification and the initial Tafisa specification indicates that the Tafisa specification is more difficult to meet and in most cases will probably require a positive sort, whereas the boiler fuel specification can be met with a negative sort.[29]

According to Tafisa's Wood Supply Manager, Tafisa will be capable of paying a sufficient premium for the waste wood when compared to boiler fuel to justify the higher cost of sorting. However, the question remains as to what the impact of the higher sorting will be on either the resulting residual levels of the processors, or the resulting boiler fuel. That is, as illustrated in Table 19, DSM's estimated current recovery rate for clean (Grade A) wood is less than 20 percent while the recovery rate for boiler fuel is 49 percent. This is indicative of the difficulty of identifying clean wood on a sort line. For example, it is often difficult to determine if a weathered board is treated, stained or simply weathered. If the specification prohibits treated or impregnated wood, then all woods that can not be clearly identified as clean wood will be left on the sorting belt and disposed of as residuals.

Alternatively, the C&D processor may attempt to maximize revenues by conducting a positive sort for a "Grade A" wood that will meet Tafisa specifications and either a second positive sort for boiler fuel, or more likely a negative sort for boiler fuel. However, once the positive sort for Tafisa has occurred, the percent of treated wood in the remaining waste wood will effectively double, which may make it difficult to meet the Maine boiler fuel standard of less than 1.5 percent for treated wood.

Treated Wood

There are no "markets" for treated wood. However, treated wood can be destroyed by sending it to Kruger in Quebec for grinding, with subsequent combustion in a Quebec cement kiln.[30] Two firms in New England that accept and transport treated wood to Quebec (Northern Wood and ARC) both report that it costs approximately $70 - $80 per ton to transport and dispose of the treated wood.

[29] KTI BioFuels uses a negative sort to produce fuel for Red Shield Environmental, and it is reported that ERCO can produce fuel and meet the Tafisa specification with a negative sort from wood rich loads.

[30] While the Kruger mill does have a biomass boiler burning waste wood, the treated wood is not burned at the Kruger mill, but instead is ground at Kruger and then shipped to the cement kiln.

Fines

Because fines contain gypsum, and potentially, heavy metals and VOC's associated with painted and stained wood, treated wood and engineered wood, markets for this material are limited. Two of the biomass boiler wood buyers stated that they believed that they could burn the fines and meet air and ash permit requirements, while one biomass boiler wood buyer stated that they could not meet ash permit requirements if they burned waste wood with a high level of fines.

Other than use as boiler fuel – which is still primarily speculative because of the availability of sufficient waste wood – the only other real use for the fines is for ADC and grading and shaping – as a substitute for soil. However, until the issue of H_2S generation is more thoroughly researched, it is likely that the use of fines at landfills will be significantly curtailed. This is because the risk to a landfill operator associated with the potential installation of hydrogen sulfide gas control equipment exceeds the short term savings in soil purchases for intermediate daily cover or grading and shaping. Therefore, if Massachusetts is to continue with the waste ban, it should continue to actively participate in research designed to define how C&D fines can be safely used as ADC. This may involve requirements to keep gypsum separate from other C&D wastes, or significant changes in the regulation of how fines are mixed with soil and/or the screen size allowable to produce fines.

Gypsum

Gypsum has become a significant issue associated with the recovery and disposal of C&D wastes. According to GreenYes Archives, March 2006, "*Gypsum has been identified as a leading contributor of H_2S production in landfills where it is disposed. H_2S is produced in a landfill when sulfur compounds decompose in the presence of moisture and absence of oxygen. Under anaerobic conditions, sulfate reducing bacteria produce H_2S from the sulfate (SO4-2) in gypsum and the organic carbon waste materials…*"

The issue of H_2S emissions from landfills has grown significantly with the grinding of C&D waste for use as alternative daily cover (ADC), and with the landfilling of fines from the grinding and processing of C&D wastes. This is because gypsum wallboard is friable and breaks into small pieces easily when ground or crushed with C&D materials. The resulting gypsum ends up mixed with small pieces of wood (organics) which is the second ingredient needed by the sulfate reducing bacteria.[31] The final ingredients are water and anaerobic conditions, both of which are present in abundance in eastern landfills.

H_2S is not only an aesthetic issue. In higher concentrations it can be a health hazard, both to workers on the landfill, and even to surrounding residences. The US EPA was forced to take corrective action against the Regus Industries landfill in Warren, Ohio due to hazardous levels of H_2S migrating off-site to neighboring residences. This landfill accepted ground C&D materials (in violation of Ohio EPA regulations), and landfilling was occurring below the water table.[32]

Recycling of Gypsum

Gypsum can be recovered for recycling. Most common uses include:

- Recycling to new gypsum wallboard (one firm in Massachusetts is accepting clean gypsum wallboard for recycling into new gypsum wallboard);
- Land application as a soil amendment (especially in high clay content soils where crusting is an issue);
- As an additive to compost; and,
- In cement production as an additive to stucco or gunite.

[31] It has been reported that the paper backing on the gypsum wallboard, by itself, may provide enough organic material for the sulfate reducing bacteria.
[32] Telephone conversation with Dan Harris, Technical Advisor, Division of Solid and Hazardous Waste, Ohio EPA, January 10, 2008.

Potential uses include:

- In flea powder;
- Mushroom compost;
- As a bulking agent or sludge drying compound;
- As a flocculating agent in water treatment; and
- As an oil and grease absorber

Paper, which represents between 10% and 15% of the gypsum wallboard, can also be recovered and used as animal bedding and/or pelletized for fuel pellets.

However, there are a number of issues associated with gypsum recycling which limit the success of gypsum recycling. First and foremost is that it is extremely difficult to recover gypsum once it has been mixed with other C&D wastes. It simply breaks too easily and disintegrates during handling of the C&D materials.

Second, while there are a number of uses for clean gypsum, the number of uses associated with painted or wallpapered gypsum is significantly less.

Third, gypsum is a relatively low cost material. The cost of mined gypsum delivered to a wallboard manufacturing plant is roughly $10 per ton[33]. More importantly, sulfur dioxide controls (flue gas desulphurization or FGD) on coal fired power plants results in a perfect gypsum slurry for use in gypsum wallboard manufacturing. Thus, a number of new gypsum wallboard plants are being constructed adjacent to coal fired power plants, where the gypsum slurry can be obtained for roughly one-half of the cost of mined gypsum and the gypsum has already been calcinated during the coal combustion.

At these low costs for the raw material associated with gypsum wallboard production, it is difficult to keep gypsum separate, crush it, remove the paper, and deliver the resulting material to a gypsum wallboard plant for a cost that is competitive with new gypsum. It has been reported to DSM that the maximum distance that recycled gypsum can be transported is roughly 30 miles before the transport cost alone makes recycling non-competitive. Thus, it is likely that significant quantities of gypsum will be recycled only if gypsum is not allowed in landfills due to H_2S issues.

Asphalt Shingles

Asphalt roofing shingles can be ground and used in asphalt plants, construction sites, aggregate processing facilities and shingle manufacturers. Asphalt plants use the ground shingles as an alternative feedstock in the manufacture of base-course bituminous concrete (i.e. asphalt pavement). Aggregate processing facilities use them as a base course on roadways (typically private roads and parking lots, and shingle manufacturers recycle them back into new shingles. Because of the weight of asphalt shingles, similar issues exist for asphalt shingles as for ABC. That is, if outlets for recycling exist, most roofing companies will attempt to avoid landfill disposal because of the high cost.

[33] *Gypsum,* Founie, A., hhttp://minerals.usgs.gov/minerals/pubs/commodity/gypsum/gypsumyb04.pdf

Section 7
Future Markets

As stated above, markets for metal and paper are not expected to change significantly in the future. Given the potential long term growth of developing countries such as China, India, and Vietnam, it is likely that these commodity markets will strengthen over time and that long term prices will continue to trend higher than they have in the past. Similarly, it is DSM's opinion that the markets for clean waste wood will continue to exist looking forward, with significantly more demand than supply. Finally, it is highly likely that the aggregate markets for ABC materials will also continue to exist, if for no other reason than the prohibitive cost for transporting and landfilling these heavy materials.

The key to the long-term viability of C&D processing will not, however, depend on markets for paper, metals, ABC materials, and clean wood. Instead, markets that will determine the long-term viability of C&D processing facilities will include:

- Markets/uses for fines;
- Markets/uses for gypsum; and,
- Markets for waste wood that contains painted and stained wood together with some acceptable, de-minimus quantity of treated wood.

Fines

As discussed in Section 6, above, future markets for fines will depend on current research on causes and control of H_2S emissions from landfills. Other than knowledgeable speculation by fuel buyers that fines could be burned in some biomass boilers, DSM has been unable to find any information in the literature that proposes viable alternative uses for fines other then for use as ADC. And, the research on controlling H_2S emissions is really just beginning. It is DSM's opinion that definitive answers to this issue are at least two to three years away. In the interim, fines will continue to be a significant problem, and most fines will probably be landfilled.

It should also be noted here that if the ultimate solution is to significantly reduce the screen size for material classified as "fines", this will have negative implications for the C&D processors. That is because if the C&D processors are required to grind to a much finer size, energy costs will significantly increase, further increasing C&D processing costs, especially in these times of increasing energy prices.

Gypsum Wallboard

It is DSM's opinion, based on interviews with gypsum users, both here in Massachusetts and in a separate project in North Carolina that DSM is involved with, that future markets for ground gypsum wallboard will continue to grow. However, C&D processors, as well as those who keep gypsum wallboard separate for recycling, will find that they will have to pay a tipping fee to deliver the separated gypsum wallboard to facilities willing to process the material. In addition, transport costs for hauling separated gypsum wallboard will become an issue.

This is because the cost of gypsum is relatively low, and is being driven lower due to the generation of FGD materials at coal fired plants which can be readily used for the production of new gypsum wallboard. Therefore, while many of the gypsum wallboard manufacturers may choose to incorporate recycled gypsum into their wallboard to meet LEED certification requirements or to be viewed as "green", the real growth in demand will be for alternative uses for the gypsum, which are currently under development by a number of gypsum recycling entrepreneurs. Many of these uses, and the equipment used to produce the requisite materials, are proprietary at this time.

Mixed Waste Wood Markets

Future markets for mixed waste wood, listed in order of current viability include:

- Biomass boilers
- Particle board manufacturers
- Gasification and pyrolysis facilities
- Cellulose ethanol production facilities

Each of these potential future uses will depend heavily on Federal and State legislative and regulatory initiatives, and the relative price of petroleum. It is beyond the scope of this report to speculate on either legislative or regulatory initiatives, or the future price of petroleum. While one can speculate that a new Congress in 2009?, combined with increasing fuel prices, will increase the demand for waste wood, Congress could fail to act, and a recession, either in the United States, or even a broader world-wide recession caused by a US recession could lead to significant declines in future energy prices.

Based on ***current trends*** it would appear likely that the following will occur to increase the demand for waste wood.

Biomass Boilers

The Sappi/Westbrook, Maine paper mill should significantly increase demand for waste wood during 2008. Boralex is also expected to ramp up demand, although probably not to levels achieved a few years ago. In addition, the new partnership between Tafisa and Kruger in Quebec should significantly increase demand for waste wood, both as boiler fuel and, hopefully, as particle board. It is difficult to speculate as to future prices for biomass fuel because there are so many variables that can affect future prices for green chips (which is the substitute for waste wood). As such it is probably safe to say that current prices (ranging from $15 - $30 per ton) for waste wood, depending on transport distance, will continue in the future. Closure of additional paper mills and/or saw mills could reduce the demand for green wood, reducing chip prices. Alternatively, higher fuel prices could increase the cost of green chips – but also the grinding and transport costs for waste wood.

According to Maine regulators, no new biomass boiler capacity is currently planned in Maine, due in part to political opposition to the existing combustion of waste wood from out-of-state sources. No waste wood combustion facilities will be developed in New Hampshire given the ban on combustion of waste wood in New Hampshire. DSM is not aware of any waste wood combustion facilities planned for Vermont, and the siting, permitting and construction of a facility in Vermont would take a minimum of three to five years given Vermont's regulatory process.

New biomass boilers have been proposed in Massachusetts and Rhode Island to take advantage of increased REC credits in Massachusetts. However, it will take a favorable ruling from the Massachusetts DOER on the use of waste wood as a qualifying biomass fuel for these to go forward. Even if this decision is positive, it is likely that design, financing, permitting, construction and shakedown would take a minimum of three years. While Connecticut now allows waste wood to qualify as a biomass fuel, DSM does not have information concerning the proposed development of facilities in Connecticut. And, if there were, it is likely that waste wood from Connecticut would be sufficient to supply the facility.

Particle Board Manufacture

According to the wood supply manager for Tafisa, Tafisa hopes to ramp up to a long term demand (probably over a three year period) of roughly 275,000 tons of waste wood per year sourced from Quebec and New England. Neither the price, or the final specifications, have been established, and probably will not for at least a year as Tafisa ramps up use of waste wood and learns what works and what does not. Therefore, DSM is not willing to speculate on what the final price or demand for this material will be.

New Technologies

Potential technologies for using wood include:

- Gasification;
- Pyrolysis; and
- Fermentation

Two gasification projects are currently either in the pilot stage (Ze-gen in New Bedford, Massachusetts) or being proposed at a commercial scale (Taylor Energy in Montgomery, New York). Development of commercial scale facilities will be capital intensive, and will likely require a combination of wood wastes and MSW. It is DSM's opinion that operation of a commercial scale facility with the ability to consume significant quantities of waste wood is at least three to five years off.

RSE Pulp & Chemical in Old Town, Maine, working with the University of Maine, is currently in the pilot stage of using fermentation to produce energy and pulp from green chips and waste wood. They have reported to DSM that they believe they demonstrated the commercial viability of the project, and that they expect to move to commercial production within the next several years. However, it is likely that the primary demand for waste wood will be for the Red Shield Environmental biomass boiler that will be producing energy for the project, and not for the fermentation portion of the project.

It should be noted here that while there is great interest in advancing ethanol production using cellulose other than corn, the economics have not yet been demonstrated, even for quick growing grasses for which the fermentation process is much better suited. Therefore, as with gasification, it is unlikely that fermentation of waste wood to produce energy will be commercially available for a minimum of five to ten years and should not be counted on as a potential intermediate term market for Massachusetts waste wood.

Pyrolysis, which is a thermal process that rapidly heats biomass in an oxygen free environment[34] has been available as a technology for processing waste since the early 1970's. In fact, a commercial scale pyrolysis plant was constructed and briefly operated in Baltimore before being torn down and replaced by a conventional WTE facility that still operates on the site today. Unfavorable economics and uncertainty over potential markets for the pyrolysis oil still exist today. As such, it is unlikely that pyrolysis will be a viable technology for Massachusetts waste wood within the next five to ten years unless there are significant changes in energy policy and tax law.

Conventional Landfill and WTE Capacity in Surrounding States

WTE facilities are unlikely to ever be a significant outlet for processed C&D materials. This is because WTE facilities get paid for their fuel and are BTU limited, meaning that they prefer a lower BTU value fuel because this allows them to increase tipping fee revenues while receiving a fixed energy revenue. Therefore, demand for higher BTU material like waste wood will continue to be limited as long as there is sufficient lower BTU MSW available. Given the current downturn in the economy – and therefore in the generation of MSW – it is possible that WTE facilities will increase their demand for C&D materials, but only until additional MSW is available.

Landfill capacity is more complex. In the short run, there is significant, low cost landfill capacity available in New Hampshire – with the closure of the Colebrook, New Hampshire landfill, and the expected closure of the Bethlehem, New Hampshire landfill. There is also significant, relatively low cost intermediate and potentially long term landfill capacity available in Milan, New Hampshire for unprocessed C&D waste, although transport costs may be high.

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[34] *Wood-Based Bio-Fuels, The Long Emerging Market*, Kingsley, E., Innovative Natural Resource Solutions LLC., November, 2006

Maine has banned the disposal of out-of-state C&D waste at State owned landfills. As such, only C&D materials processed by Maine processing facilities will be allowed to be landfilled once the Pine Tree landfill closes within the next 12 to 18 months.

There is limited capacity in Connecticut to landfill waste in general, so it is unlikely that Connecticut will be a potential outlet for Massachusetts C&D wastes.

There is only one landfill in Rhode Island, and it is owned by the Rhode Island Resource Recovery Corporation. It is prohibited from taking waste from outside of Rhode Island, and Rhode Island regulators have ruled (unlike Maine regulators) that this also prohibits landfilling of processing residues from Rhode Island processors processing waste from outside of the State.

Vermont has limited MSW landfill capacity and already exports a significant amount of waste. As such, it is unlikely that Vermont will have capacity for Massachusetts C&D waste.

Ultimately, low cost landfill capacity for Massachusetts C&D only exists in up-state New York, in Pennsylvania, and in Ohio. Other than Maine, Ohio is the primary outlet for Massachusetts C&D waste now. Ohio has banned the landfilling of "processed C&D", at unlined C&D landfills, but allows processed C&D to be landfilled in lined MSW landfills. Therefore, the lowest cost alternative would be to send unprocessed Massachusetts C&D waste to unlined Ohio C&D landfills. Alternatively, residuals from Massachusetts C&D processors can continue to be landfilled at lined MSW landfills in Ohio. According to Ohio EPA there is significant future capacity at these MSW landfills for Massachusetts C&D wastes.

Section 8
Effects of the Wood Disposal Ban

DSM estimates that roughly 1.9 million tons of C&D waste (exclusive of infrastructure and land clearing debris), were generated in Massachusetts in 2007. Of these 1.9 million tons, 677,000 tons were waste wood, of which 27 percent was recycled or burned for energy recovery.

The waste wood ban has had both positive and negative impacts. On the positive side, the waste wood ban has provided the majority of waste wood for biomass boilers in Maine, and, to a lesser extent, in Quebec. According to a University of New Hampshire study, the environmental and greenhouse gas benefits of burning waste wood in biomass boilers are significant.

The ban has also significantly increased the amount of C&D waste being processed, which has increased the sorting and recovery of OCC and metals in the C&D waste stream, with roughly 50 percent of all OCC and 80 percent of all ferrous metal being recovered in 2007. And, the ban has helped spur the development of a potentially large market for particle board manufacture using waste wood. This market would produce significant environmental benefits; if it is as successful as Tafisa (Lac-Megantic, Quebec) believes that it will be. As a consequence, both the biomass fuel market and the potential particle board market depend heavily on continuation of the Massachusetts ban.

On the negative side, the ban may have increased C&D management costs for Massachusetts generators because of the need to process C&D wastes before disposal. And, the ban has stimulated the generation of C&D fines (resulting from processing to recover wood) which, because of concerns about H_2S emissions, are now a significant environmental concern at some landfills. Because fines are an integral result of the production of waste wood for fuel, the ultimate resolution of the proper management of fines is critical to the long-term viability of the waste wood ban.