A. 2010 Wyandotte – List of Sample Analysis Costs R-1

SGS - using 2008 prices

Total Number of Samples		**9**
TOTAL ANALYSIS COST (w/o sample prep fee)	**$**	**11,227**
TOTAL ANALYSIS COST (w/ sample prep fee)	**$**	**11,632**

Revised estimate of cost:

	$	7,312
Prep.	$	405
G.Total =	$	7,717

Red Text indicates estimated costs

Sample Prep Fee ($/sample)	$	45	
Coal			
Fusion (8-Point, Reducing and Oxidizing on same sample)	$	113	
Proximate plus Ultimate	$	181	
Analysis of Ash, 8 major elements plus Mn3O4, BaO, SrO, P2O5, SO3	$	294	
Chlorine, Total	$	47	
Mercury (low level ng/g)	$	74	
Michigan '12' metals - As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Ag, Zn	$	410	
	$	80	
Number of Samples		3	Composite the two belts to one sample
Total Cost (w/o sample prep)	$	3,597	Then three (3) samples total
Biomass			
Fusion (8-Point, Reducing and Oxidizing on same sample)	$	158	
Proximate plus Ultimate	$	223	
Analysis of Ash, 8 major elements plus Mn3O4, BaO, SrO, P2O5, SO3	$	294	
Chlorine, Total	$	47	
Mercury	$	74	
Michigan '12' metals - As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Ag, Zn	$	410	
	$	80	
Number of Samples		2	
Total Cost (w/o sample prep)	$	2,572	
Tires			
Fusion (8-Point, Reducing and Oxidizing on same sample)	$	211	
Proximate plus Ultimate	$	244	
Analysis of Ash, 8 major elements plus Mn3O4, BaO, SrO, P2O5, SO3	$	380	
Chlorine, Total	$	62	
Mercury	$	74	
Michigan '12' metals - As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Ag, Zn	$	410	
	$	80	
Number of Samples		1	Composite the existing six (6) samples to
Total Cost (w/o sample prep)	$	1,461	one (1) sample for analysis
Ash (assuming coal prices)			
Fusion (8-Point, Reducing and Oxidizing on same sample)	$	113	
Proximate plus Ultimate	$	181	
Analysis of Ash, 8 major elements plus Mn3O4, BaO, SrO, P2O5, SO3	$	294	
Chlorine, Total	$	47	
Mercury	$	74	
Michigan '12' metals - As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Ag, Zn	$	410	
TCLP test on Michigan '12' metals	$	80	
Number of Samples		3	Composite the hopper #1 & #5 into one sample
Total Cost (w/o sample prep)	$	3,597	We appear to be missing one ash sample for the 15% biomass run. This should be three (3) samples, but will only be two(2) with the materials we have.

B. 2010 Wyandotte – Wyandotte Fuel Specifications

CLIFFS

Renewafuel Plant Samples

10/15/09

10/28/09

10/15/09

CTG Renewafuel Cube Physical Testing											CTG Leco	
		ASTM Tumble Test	Drop Test	Water Absorp.	Bulk Density	Cube Density	Shear	H_2O CTG	H_2O TPT	Cube Length Avg.	Gross Btu per lbs	% Ash
Sample Name	Date	% +1/2" A.T.	% +1/2"	%+1/2"	lbs/ft^3	g/cm^3	lbs	%	%	(cm)		
Sample #1	10/15/09	65.5	85.9	60.9	30	1.13	97	8.9	8.6	5.3	7,849	0.84%
Sample #2	10/15/09	61.0	86.7	92.3	31	1.17	29	9.0	8.9	5.2	7,941	0.22%
Sample #3	10/15/09	51.4	84.8	74.0	31	1.14	36	8.3	8.5	5.0	7,570	0.38%
Sample #4	10/15/09	62.8	94.9	69.2	34	1.15	51	7.9	7.0	5.6	8,085	0.18%
Average		**60.2**	**88.1**	**74.1**	**31**	**1.15**	**53**	**8.5**	**8.3**	**5.3**	**7,861**	**0.40%**

CLIFFS

10/15/09

Twin Ports- Renewafuel Ultimate & Proximate Analysis												
		As Received-%										
	Date	%H2O	Ash	Vols.	Fixed C	Total	S	Gross Btu/lbs	C	H	N	O
Sample #1	10/15/09	8.63	1.46	73.00	16.91	100.00	0.023	7,794	47.74	5.16	1.01	35.98
Sample #2	10/15/09	8.94	1.35	70.98	18.73	100.00	0.021	7,791	47.20	5.20	1.42	35.87
Sample #3	10/15/09	8.51	0.41	71.22	19.86	100.00	0.018	8,109	49.53	5.27	0.54	35.72
Sample #4	10/15/09	7.00	0.60	72.20	20.20	100.00	0.021	8,101	49.01	5.38	1.20	35.79
	Average	**8.27**	**0.96**	**71.85**	**18.93**	**100.0**	**0.021**	**7,949**	**48.37**	**5.25**	**1.04**	**35.84**

CLIFFS

10/15/09

		Reducing Atmosphere °F				Oxidizing Atmosphere °F			
	Date	Initial Def.	Soft Temp	Hem. Temp	Fluid Temp	Initial Def.	Soft Temp	Hem. Temp	Fluid Temp
Sample #1	10/15/09	>2700	>2700	>2700	>2700	>2700	>2700	>2700	>2700
Sample #2	10/15/09	>2700	>2700	>2700	>2700	>2700	>2700	>2700	>2700
Sample #3	10/15/09	>2700	>2700	>2700	>2700	>2700	>2700	>2700	>2700
Sample #4	10/15/09	>2700	>2700	>2700	>2700	>2700	>2700	>2700	>2700
		Average	>2700	>2700	>2700	>2700	>2700	>2700	>2700

CLIFFS

10/28/09

CTG Renewafuel Cube Physical Testing				
		ASTM Tumble Test	Drop Test	Water Absorp.
Sample Name	Sample Date	% +1/2" A.T.	% +1/2"	%+1/2"
60% Pine 40% Red Oak	10/28/09	79.3	97.0	94.1

Excellent cube quality

CLIFFS

10/28/09

CTG Renewafuel Cube Physical Testing						
		Bulk Density	Cube Density	Shear	H_2O CTG	Cube Length Avg.
Sample Name	Sample Date	lbs/ft^3	g/cm^3	lbs	%	(cm)
60% Pine 40% Red Oak	10/28/09	40	1.26	**	3.5	4.0

Very high bulk density and specific gravity

CLIFFS

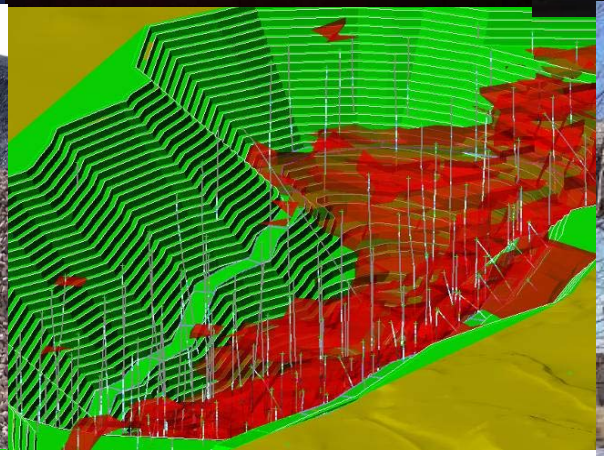
10/28/09

CTG Proximate					
Sample Name	Sample Date	Btu/lb	% Ash	% C	% S
60% Pine 40% Red Oak	10/28/09	8,409	0.34		0.057

High Btu's due to very low moisture

CLIFFS

Cliffs Technology Group



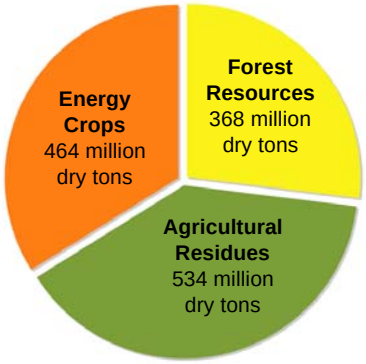
CLIFFS

C. Biomass, Biofuels, and Bioenergy Feedstock Opportunities in Michigan

Biomass, Biofuels and Bioenergy:
Feedstock Opportunities in Michigan

Robert E. Froese, Ph.D., R.P.F. – froese@mtu.edu – **February 2007**

Forest Resources & Environmental Science
Michigan Tech



The US Department of Agriculture and Department of Energy estimate that enough biomass is available from urban waste, agricultural and forest sources in the United States to produce enough biofuels to displace 30% of current gasoline consumption. Of the 1.3 billion dry tons per year potentially available, dedicated energy crops and forest resources contribute 464 and 368 million dry tons per year, respectively.

Forecast Bioenergy Feedstock Supply in Michigan in dry tons per year.

Biomass Feedstock		Potential Supply	Currently Available and Unutilized	Available at $25/ton Farmgate Price
Forestry	Sawmill and pulp mill residues	1,764,796	Negl.	405,903
	Logging residues	869,468	869,468	113,031
	Thinning residues	1,875,978	1,875,978	243,877
Forestry Total		4,510,243	2,745,447	762,811
Urban Wood Waste		1,311,382	1,311,382	314,732
Dedicated Energy Crops		4,418,226	Negl.	44,182
Grand Total		10,239,851	4,056,829	1,121,725

Sources: USDA, DOE, Walsh (2006) and Michigan Technological University.

Supply of lignocellulosic (woody plant source) feedstocks depends on many assumptions. The potential assumes all land is available and energy crops are substituted for some food crops. Only forestry sources and urban wood waste are currently unutilized and available. The DOE has used a price of $25 per dry ton in feasibility analyses but at this price only a fraction of the potential is forecast to be actually available. Forecasts are currently very preliminary and reducing uncertainty in price and supply are critical to reduce risk and uncertainty that limit investment.

Among potential bioenergy feedstocks, forestry sources have some of the best attributes in terms of feasibility and environmental sustainability. Corn, for example, requires extensive cultivation, fertilization and pest control to ensure high productivity. In Michigan our forests, while not as productive per acre as corn, are extensive and largely unutilized as biomass sources. Extracting forest residues can be done sustainably with existing low-impact harvesting technologies creating essentially a new product from an existing resource.

Corn is energy and cultivation intensive - forest residues are not.

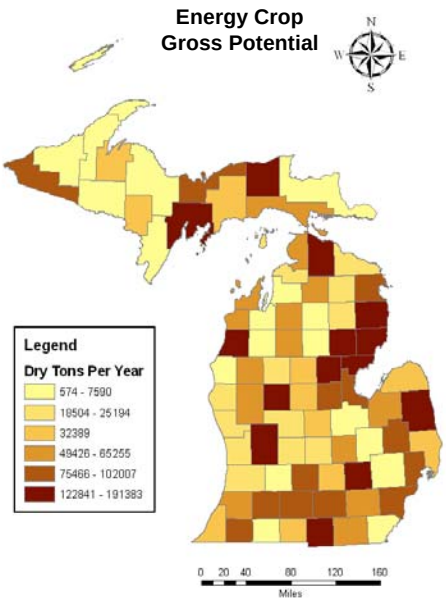
The Ideal Biomass Crop?	Forest Residues	Corn	Short-rotation Woody Crops	Perennial Grasses
Highly productive	no	yes	yes	yes
Widely available	yes and unutilized	limited	near none	near none
Site impact	low	very high	low	low
Low energy inputs	very low	very high	low-moderate	low
Noninvasive	yes	not relevant	genetically-modified	usually
Few pests or disease	usually	no	moderately	usually
Uses existing technology	yes	yes	somewhat	somewhat
Need storage facilities	harvest year-round	yes	harvest year-round	yes

With an extensive forest and agriculture landbase, Michigan has the potential to be one of the leading states in biomass feedstock production. In Michigan, forestry sources alone could supply over 4.5 million dry tons per year of feedstock, enough to support on a continuous basis six commercial-scale ligno-cellulosic ethanol refineries, each producing more than 50 million gallons of ethanol per year.

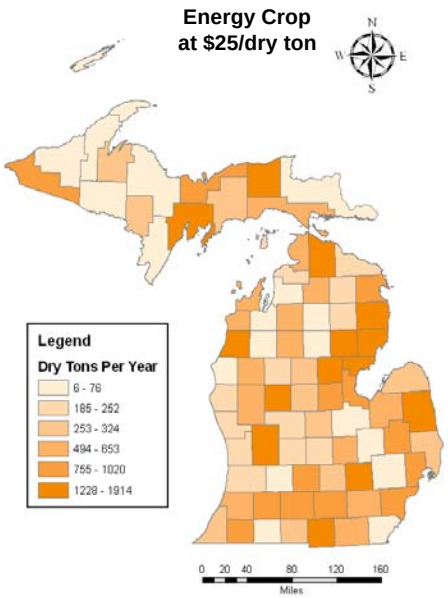
Estimating supply and inventory of biomass feedstocks is complex, and the quality of estimates varies by feedstock type. Some feedstocks, like forest residues, are readily estimated with high precision at the scale of a county or larger from existing forest inventory databases. Because energy crops are mostly grown only in test plots and compete for land currently in food production, supply depends on land substitution and modelled estimates of productivity.

Estimating feedstock price is more complicated that gross potential supply. This is because assumptions are needed about production and harvest cost components, practical rather than theoretical availability, environmental constraints and willingness of producers to substitute one agricultural crop for another depending on selling price. Price estimates for forest residues are some of the poorest because little current market data exist and little research has been done. Furthermore, inventory, technical and environmental constraints are spatially very variable and simply not available at scales finer than the county level.

Energy Crop Gross Potential



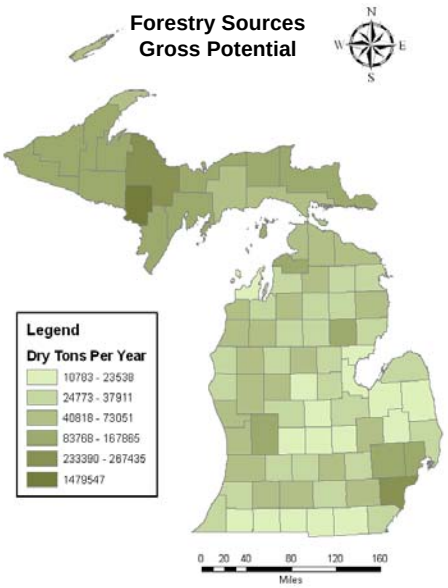
Energy Crop at $25/dry ton



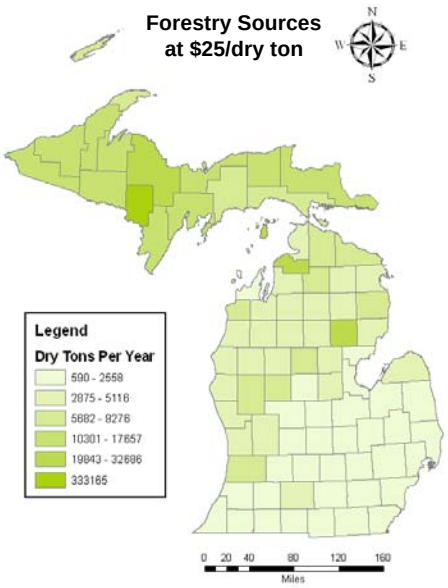
The maps above show forecast supply of biomass from dedicated energy crops (perennial grasses and hybrid or genetically-engineered poplar) in Michigan. Supply is concentrated in counties with existing agricultural lands or lands readily converted to tree plantations.

The maps below show supply of biomass from forestry sources, which includes logging and thinning residues and mill waste. Supply is concentrated in forested counties and those that have processing facilities at present.

Forestry Sources Gross Potential



Forestry Sources at $25/dry ton



"The lack of credible data on price, location, quality and quantity of biomass creates uncertainty for investors and developers of emerging biorefinery technologies."

— Office of the Biomass Program, U.S. Department of Energy (2005).

D. Clean Energy from Wood Residues in Michigan

Clean Energy from Wood Residues in Michigan

Michigan Biomass Energy Program
Dulcey Simpkins, Coordinator

Discussion Paper
June 2006

Clean Energy from Wood Residues in Michigan
A Report of the Michigan Biomass Energy Program

The goal of the Michigan Biomass Energy Program (MBEP) is to encourage increased production and/or use of energy derived from biomass resources through program policies, information dissemination, and state and regionally funded research and demonstration projects. Electronic copies of the paper are available on the MBEP website. Comments and requests for copies of this report, or for information concerning biomass energy development in Michigan, may be sent to:

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The views expressed in this paper are those of the MBEP staff and do not necessarily reflect the views of the U.S. Department of Energy or the Michigan Department of Labor & Economic Growth—Energy Office.

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Introduction: Renewable Energy on the Policy Agenda

The United States hosts only 8% of the world's population, but consumes almost 25% of world energy production.[1] Due to the energy intensity of modern living in the United States, having a reliable and affordable energy supply is integral to economic stability. However, there is a growing awareness that the energy strategy currently pursued by the United States is not sustainable. Falsified reserve estimates for both oil and natural gas, increased instability in the Middle East and Venezuela, and the Iraq war have highlighted the vulnerability of US energy markets.[2] It is now an increasingly common assertion among American citizens and government officials alike that true energy security lies in reducing dependence on fossil-based fuels and focusing on renewable energy.

The boundaries of the growing debate over an appropriate national energy strategy range from a status quo fossil fuel-based energy portfolio on the one hand, to an efficiency and renewables-based portfolio that promotes investment in solar, wind and biomass energy on the other. Market-based assessments of fossil fuel resources suggest that higher demand will spark technological innovation in reserve identification and extraction, allowing a continual increase in the petroleum and natural gas supply; this cornucopian view urges restraint with regard to state support for a shift to renewable energy. Simultaneously, in these same commercial and finance sectors, there are voices arguing for a different strategy that fosters innovation in renewable energy production and reduces the traditional dominance of fossil fuels in the marketplace. Public opinion echoes these voices: Consistently over the last 20 years, polls demonstrate majority opinions in favor of not drilling for more oil and of increased investment in energy efficiency and renewable energy.[3]

State legislatures are responding to popular opinion, supporting renewable energy portfolio standards, creating tax incentives for renewable energy production and use, and implementing public benefits funds for future investment in renewable energy projects. Success in moving renewable energy closer to center of state and national political debates since 2004 has indeed been an important development. Still, the modest support generated for tax rebates on biofuels and wind energy production remain far less substantial than envisioned by the champions of renewable energy. More far-reaching renewables strategies promote dramatic investments in alternative transportation fuels and a rapid decentralization of energy production to local,

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[1], *Annual Energy Review 2003*, Figure 11-3 World Primary Energy Consumption., US Department of Energy, Energy Information Administration. Online at www.eia.doe.gov.

[2] SEC v. Royal Dutch Petroleum Co., et al. before the US District Court for the Southern District of Texas, Houston Division [http://www.sec.gov/litigation/complaints/comp18844.pdf]; "Report: Investigation targets former El Paso employees," USA Today (Reuters), Posted 8/11/04 [http://www.usatoday.com/money/industries/energy/2004-08-11-el-paso_x.htm]; Jad Mouawad, "With Geopolitics, Cheap Oil Recedes Into Past," *The New York Times*, January 3, 2005; "Natural gas prices not expected to relent: History—EIA"; Projections: Short-Term Energy Outlook, Energy Information Administration, US Department of Energy, August 2004. For more information on oil, see "International Energy Outlook 2004: World Oil Markets," Energy Information Administration, US Department of Energy. Online at http://www.eia.doe.gov/oiaf/ieo/oil.html.

[3] For example, the January 2004 Zogby International survey for the Wilderness Society documented that only 36% of 1,000 likely voters surveyed felt the Arctic National Wildlife Refuge (ANWR) should be opened for drilling, and only 10% felt that drilling more was the answer to our energy problems. "More than 75% of voters in every region of the country and in all education, age and income subgroups choose conservation/fuel efficiency or alternative energy sources as the best way to reduce oil imports. Some of the strongest support comes from Independents (92%), Women (87%), Union households (85%), and NASCAR fans (81%). More than 3 of 4 Republican voters (77%) also choose either conservation/fuel efficiency or alternative energy over more oil drilling (17%)." Online at http://www.zogby.com/news/ReadNews.dbm?ID=789. A December 2005 survey on the question of drilling versus alternatives showed similar results: only 38% of those polled favored opening ANWR, and an increased (but still quite low) 17% felt drilling was a sustainable energy policy. Online at http://www.zogby.com/Soundbites/ReadClips.dbm?ID=10890.

preferably renewable resource bases. Proponents of these strategies warn of dire consequences for mainstream Americans as oil production passes its peak—generally estimated to lie within the next twenty years, if it has not already arrived.[4]

Wood Residue as a Renewable Energy Resource: Outline of Discussion

In this context, it is critical for states to understand their indigenous resources when considering their energy options. This report explores the potential for biomass energy in Michigan by focusing on wood residue as an energy feedstock. Wood residue is a convenient, physically well-understood feedstock. However, despite its abundance, it is difficult to make an argument to modify infrastructure, educate consumers and utilities, and invest in new energy planning and processes without first understanding the cleaner emissions, sustainable renewable capacity, domestic economic benefits, and associated land use and carbon balance benefits that this renewable biomass fuel provides. This paper is intended to provide background on residue wood energy for policy makers, businesses, academics, and citizens interested in exploring alternatives to our fossil fuel-based energy production and transmission system. It provides:

1. an introduction to biomass energy;
2. a background on wood energy in the US and Michigan;
3. a discussion of characteristics of wood energy feedstocks;
4. an explanation of wood to energy pathways with associated harvesting, transport and storage considerations;
5. a presentation of options for energy conversion technology;
6. a comparison of environmental impacts of wood energy versus coal and natural gas;
7. an assessment of potential economic and energy supply impacts; and
8. an outlook for the future of wood energy in Michigan, including a discussion of the role of policies, initiatives and incentives that could advance cleaner, reliable, domestic and renewable resources as part of our mainstream energy portfolio.

This paper also provides policy recommendations based upon the weight of the evidence in current research about the environmental and economic impacts of biomass energy production. No fuel source is perfect, and decision-makers should not approach any energy source as a cure-all, devoid of negative impacts. The Second Law of Thermodynamics tells us that nothing new can be created in the universe, and converting matter into energy always requires some energy to perform the conversion. But how much useful energy is lost, and what sort of byproducts of that conversion we must deal with, are two outcomes that research, policy and investment choices can influence. There are many favorable aspects of wood energy production that should inform state-level policy formation to address our current energy crisis by diversifying our energy resources to include more wood residues.

[4] Richard Heinberg, *The Party's Over: Oil, War, and the Fate of Industrial Societies* (Gabriola Island, British Columbia, 2003). Heinberg focuses on "Hubbert's Peak" geologists whose research forecasts the world oil production peak in the early 21st century, between 2006 and 2012. Peak oil timing is debatable for a wide variety of methodological reasons (not to mention the difficulty in obtaining accurate reserve numbers), but its inevitability is noted by the US Department of Energy: a 2004 report titled *Long-Term World Oil Supply Scenarios*, by John Wood, Gary Long, and David Morehouse (EIA-DOE) assigns the highest probability of peak oil to the year 2026.

Preview of Findings and Recommendations

- Michigan has ample wood residue resources, and already has some working examples of wood-to-energy facilities.

- Much of the wood residue generated by the forest products industry is utilized on-site to heat and/or power its plants and facilities. However, many of their boilers are nearing retirement age. Upgrading old boilers presents an opportunity for deploying more efficient conversion technologies.

- Research in many states highlights urban tree residues (UTR) as an untapped resource that could more than double the wood residue available for profitable use. For example, more efficient separation of urban wood residue, forestry cuttings, and yard waste from municipal solid waste can lead to creation of a profit center for selling mulch, or a profitable contract from selling an energy feedstock to a local wood-fired plant.[5] Collection and processing infrastructure for UTR will require an investment by cities, counties and industries. Educational campaigns and new regulations may also be necessary to foster an ethic of wood residue recycling in the current environment of dispersed dumping of individual yard waste—an important component of UTR. Increased tipping fees can also help redirect wood residues out of landfills and into more immediately productive uses.

- Wood energy technologies are either well-commercialized (boilers) or entering commercialization (gasifiers, pyrolysis).
    - Caveat: Wood's potential use as a feedstock for *transportation* fuels is not based upon currently commercial technologies. However, in the near- to medium- term, cellulosic ethanol conversion technologies have the potential to help reduce U.S. dependence on foreign oil.

- Wood and other biomass feedstocks are more difficult to transport than liquid fuels, and are more challenging to store than coal. In addition, because wood has a lower energy content than coal, it takes a larger volume of wood to generate the same energy as a given volume of coal. Consequently, biomass feedstocks like wood are best suited to localized energy production.
    - Caveat: Wood residue densification into pellets or briquettes is energy intensive. However, densification creates wood-based fuel with approximately 20% more energy output per unit volume than logs or wood chips themselves. In addition, regularly-shaped densified fuels are much easier to transport and store, which helps overcome the energy costs of creating the denser fuel (see Table 2: Wood Energy Characteristics, Merits, and Technology Options on page 18).

- Wood-fired boiler, gasification, and pyrolysis technologies are cleaner than coal in emissions of most criteria pollutants regulated under the Clean Air Act (e.g. sulfur, particulates), as well as in emissions of mercury and other heavy metals produced by coal combustion.

---

[5] St. Paul, Minnesota is home to a 25 megawatt (MW) wood-waste fired facility that supplies 75% of the thermal energy required by district heating and cooling customers. Planning for the system began in 1999, and it opened in 2003. Clean Energy Resource Teams, Community Energy Case Study: "District Energy St. Paul: CHP District Energy Fueled by Biomass," The Minnesota Project, July 2003, online at http://www.cleanenergyresourceteams.org/metro/CS-District%20Energy%20St.%20Paul.pdf.

- Emissions from the production of wood-based energy compare favorably with natural gas emissions—but wood is a renewable resource whereas natural gas is not.

- Wood energy can be managed as a carbon neutral feedstock: replanting trees neutralizes carbon dioxide emitted from wood fuels. However, fossil-derived oil, coal, and natural gas are net carbon producers, increasing greenhouse gases without any possible regenerative offset.

- Distributed generation is desirable as a solution to offset the high degree of centralization of energy production, as well as capacity problems throughout the United States. The 2003 blackout affecting the Midwest and East Coast demonstrated the extreme vulnerability of our state and region to centralized energy's tenuous infrastructure. While wood is difficult to transport to centralized energy plants, coal is similarly difficult to ship in a decentralized context. Because wood is locally abundant in outlying areas as well as in cities, it is a preferred source of energy for distributed generation utilizing smaller, less centralized energy production facilities.

- Economies of scale for large utilities allow them to negotiate a low price for coal. Wood fuels are more competitive choices for smaller power producers—which again could support a more efficient, robust and localized energy distribution system.

- Technology promotion, policy changes and financial tools are needed to help increase the amount of biomass energy produced in Michigan. Michigan policymakers could enable a significant shift in Michigan's energy portfolio toward renewable energy from wood in a variety of ways, such as by incentivizing biomass energy production, and by requiring utilities to integrate wood energy and other forms of biomass power into their production portfolio.

Michigan has tremendous potential to further develop both solid and liquid fuel applications of wood residue. There are clear opportunities for urban areas, industries, and even private citizens to capitalize on potential energy uses of wood residues. In addition, biomass-based ethanol and synthetic liquid transportation fuels (syn-fuels) have the potential to revolutionize the American love affair with their personal vehicles without ending it.[6] This paper focuses primarily on opportunities for biopowered heat and electricity in Michigan, but it also has implications for biofuels.

[6] In a landmark article linking energy and national security, former CIA chief James Woolsey and Senator Richard Lugar (R-Indiana) explain how ethanol from wood and other organic matter has the potential to significantly reduce our energy insecurity due in part to dependence on foreign oil: "Ethanol has always provided an alternative to gasoline. In terms of environmental impact and fuel efficiency, its advantages over gasoline substantially outweigh its few disadvantages. But until now it has only been practical to produce ethanol from a tiny portion of plant life -- the edible parts of corn or other feed grains. …Recent and prospective breakthroughs in genetic engineering and processing, however, are radically changing the viability of ethanol as a transportation fuel. New biocatalysts -- genetically engineered enzymes, yeasts, and bacteria -- are making it possible to use virtually any plant or plant product (known as cellulosic biomass) to produce ethanol. This may decisively reduce cost—to the point where petroleum products would face vigorous competition." From "The New Petroleum," *Foreign Affairs*, January/February 1999.

Wood as a Biomass Energy Resource

Wood is a form of biomass, and as such can be understood as an energy resource in the context of biomass energy. **Biomass fuels include any organic matter that is available on a renewable basis** including forest residues, wood product residues, agricultural field residues and processing wastes, animal wastes, agricultural and woody crops grown for fuels, and municipal solid waste (MSW). Implicit in this definition is the need not only for the organic energy resource itself, but also for an ongoing feedstock management plan in order to make the renewable aspect a reality.

Biomass fuels produce very low emissions, generate relatively few acid rain- and smog-causing particles, and have a minimal impact on the environment when converted to energy correctly (using proper practices and best available technologies; see Environmental Impacts for detailed information). In addition, all share the characteristic that they can be regenerated relatively quickly to provide a reliable energy feedstock over time. Biomass energy can be derived from almost any configuration of organic components of flora and fauna. Petroleum and coal are also organically derived fuels, but they are derived from fossilized flora and fauna of earlier eras, and consequently are not renewable (in a practical timeframe for our civilization).

Biomass feedstocks are not homogenous, and their physical characteristics vary widely. They may have high moisture content like some animal wastes, or low moisture content like wheat straw; or, any one kind of biomass—like wood—can be green (newly cut from live specimens) and high in moisture, or dried and lower in moisture. The single most important characteristic of biomass feedstocks, from the perspective of energy production, is their moisture content. Biomass heating values are determined by their moisture content, but are consistently lower in energy density than coal or petroleum, which often limits the distance over which biomass can be transported economically. Biomass resources can be further categorized as solid fuels that can be used as they are without modification, or as gaseous fuels such as methane from anaerobic digestion of manure or MSW, and synthetic gas (syn-gas) from gasification.

While there is no universally shared categorization of biomass resources, this paper relies on the eight biomass categories used by the Michigan Renewable Energy Program, which was commissioned by the Michigan Public Service Commission in 2004[7]:

1. Wood and wood residue: The oldest biofuel, wood still provides heat and cooking fuel to the majority of the world's population, and also remains useful for citizens of advanced industrialized countries living in the higher latitudes over cold months. Wood residue (harvesting, urban trees, post-processing, land clearing, demolition, pallets) is also in this category, and has more diverse pathways to energy use than forest-felled wood.
2. Traditional agricultural commodities: Corn and soybeans are the most well-known crops that produce biomass energy, as they are feedstocks for ethanol and biodiesel respectively. Canola, sunflowers, and other oilseed crops are also used.
3. Energy Crops: Certain species of grasses and trees can be utilized specifically as energy crops. Fast-growing willow (*Salix*) and poplar (*Populus*) can be grown as short-rotation woody crops. Similarly, switchgrass (*Panicum virgatum*) and other prairie species like little Bluestem and Indian Grass (*Schizachyrium scoparium, Sorghastrum nutans*), as well as fast-growing *Miscanthus* varieties, serve as excellent sources of "cellulosic" biomass. In addition, traditional food and feed crops can also overlap with

[7] For more information on the Michigan Renewable Energy Program, and to view annual reports, go to http://www.michigan.gov/mrep/.

energy crops: while corn is viewed as both a food crop and an energy feedstock in the ethanol industry, it can also be used in direct combustion in a corn stove or boiler, a technology currently enjoying tremendous appeal in Midwestern states with cold winters.

4. Animal Waste: Manure is used for fuel in much of the developing world; yet in the United States it has primarily served as a helpful soil amendment despite its use by early settlers as a fuel. Agriculture is taking a new look at anaerobic digestion to help address groundwater resource contamination from an overabundance of manure nutrients in contemporary commercial livestock operations. In addition, mortality, rendering, blood, and other animal parts also can be utilized in anaerobic digestion to produce methane, or to provide grease sources for biodiesel.
5. Landfill Gas-to-Energy (LFGTE): Containment and channeling of landfill methane to energy producing facilities has saved cities, industries, and others millions of dollars while displacing tremendous volumes of greenhouse gas emissions of methane produced by organic waste decomposition in the landfill's anaerobic environment.
6. Municipal solid waste (MSW) and waste water: Anaerobic digestion (AD) of biosolids has great potential for increasing the value of human-produced waste, but concerns about actual methane productivity of the various technologies, and about ammonia and other substances generated by AD processes will need to be addressed. Despite the fact that methane production in anaerobic environments is well proven, many waste water projects simply consider AD as a treatment option and do not design plants to capture the energy potential. Similarly, organics diversion from municipal solid waste for use in a "community" anaerobic digester can give us energy today, as opposed to landfill gas months or years from now. Diversion can also reduce waste volumes enough to prevent increased land use for waste management.
7. Agricultural and industrial residues: Other organics such as corn stover, grass cuttings, tree clearings, food processing and rendering waste are potential energy resources.
8. Tire waste: While viewed only partially as a renewable resource, scrap tires do have an organic component and can serve as an energy feedstock. Using the appropriate emissions control technologies, tire waste used in cofiring helps put unattractive public health threats to work in a function where they have value.[8]

Wood is the most commonly used biomass resource. Wood can be used in solid form or processed and pelletized for use for residential, institutional, and commercial heating. Chipped wood can be utilized as a stand-alone fuel for boilers and gasifiers, or it can be co-fired with coal or other biomass. Modern technologies enable us to extract more energy per unit volume of wood; future technologies will allow wood residues to be processed into a syn-gas for internal combustion engines, fuel cells, or natural gas power plants. Finally, more advanced technologies can generate a variety of liquid fuels from cellulosic materials found in wood.

This paper examines wood-to-energy possibilities in Michigan, focusing on the production of electricity and/or heat. However, the resource assessment and decentralization principles that guide this paper also apply to the potential for wood as a transport fuel feedstock in the future.

[8] *Culex spp.* mosquitoes carrying the West Nile virus breed in locations where there is ample standing water—such as in piles of waste tires. See "West Nile Virus: Information for Scrap Tire Owners," Emerging Disease Issues, State of Michigan website, 2004; online at http://www.michigan.gov/emergingdiseases/0,1607,7-186-25805_25824-75812--,00.html. Tire piles are also vulnerable to fire, which can spread uncontrolled, unfiltered toxics over a wide area. Tires are also being used to fire cement kilns, partially because the tire-derived ash has value in the cement manufacturing process (Phil Badger, General*Bioenergy, personal communication, October 30, 2005).

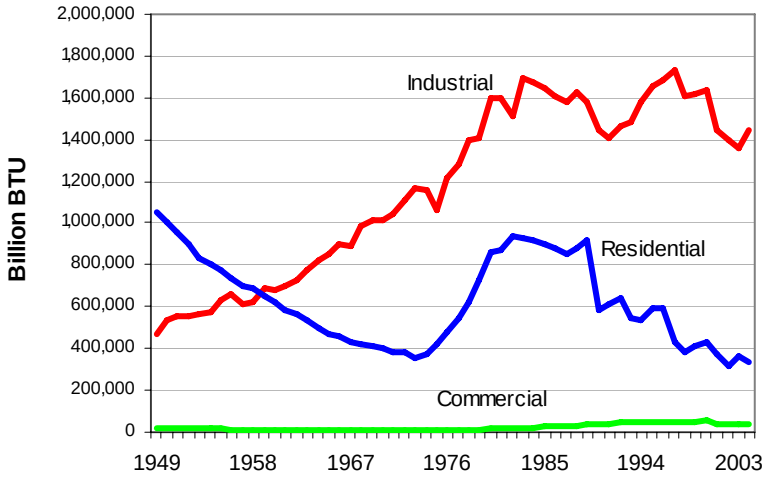
History of Wood Energy in the United States

Wood and wood byproducts are the oldest and most commonly used biomass feedstock in the United States. In 1880, nearly 60% of the energy produced in the United States came from wood. This was soon to change due to technological innovation, the popularization of new energy sources, and political factors.

Economics and regulations enhanced the attractiveness of other fuel sources in the early 1900s. Petroleum monopolies emerged at the turn of the century, and oil products became widely and cheaply available as the United States was the leading oil producer. Furthermore, liquid petroleum was quite easily transported as compared to the irregular bulk of wood products, making it the preferred choice for home heating boilers. Coal had been used since the 1700s for direct heating, similar to the uses of wood. However, the development of steam engines boosted coal use. By the 1880s, coal was used to fire electric power plants, beginning the system of large centralized coal-fired power production system we rely on today.[9]

Figure 1--Changes in Sectoral Wood Use, US 1949-2002

Source: Energy Information Administration at www.eia.doe.gov.



Petroleum and coal have approximately 60-90% more energy stored in each unit of volume than wood.[10] The high "energy intensity" of fossil fuels made them extremely popular, and wood did not remain competitive despite its widespread availability. When coal-fired electrification became cheaper and infrastructure more extensive in the late 1940's, residential use of wood for energy decreased dramatically. Natural gas was popularized when pipelines became commercially viable after World War II. The ability to transport natural gas also helped displace wood and led to a dramatic rise in use for home heating; currently up to 55% of all US households heat with LNG.[11] Its high energy intensity, clean burning properties, ease of use, and domestic abundance also made it a favorite of industry. Figure 1 above details the changes in wood energy use by sector, showing the marked decline of residential wood use after a brief resurgence brought on by the energy crisis of 1973.[12] At the same time, it also documents industry's growing use of wood, which is reviewed in the policy history below.

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[9] Robert Porter, "The History of Coal Use," US DOE Office of Fossil Energy, accessed on February 4, 2005; online at http://www.fe.doe.gov/education/energylessons/coal/coal_history.html.

[10] "Fuel Value Calculator," 5th Edition, produced by USDA Forest Service, Forest Products Laboratory, and the Pellet Fuels Institute; accessible at the US Forest Service website: http://www.fpl.fs.fed.us/documnts/techline/fuel_value_calculator.pdf.

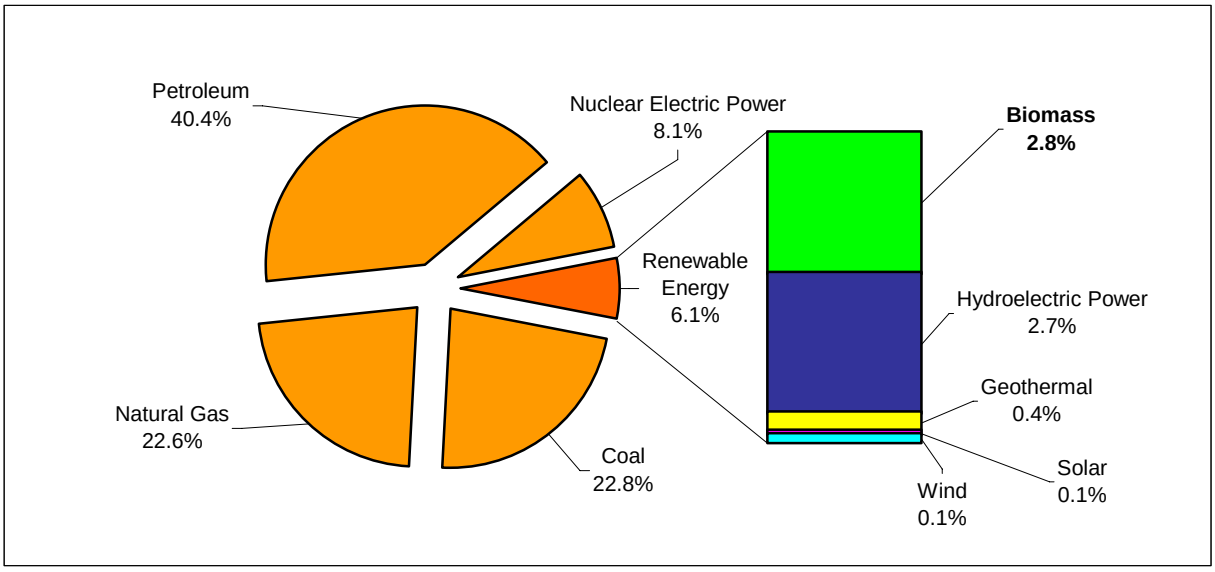
[11] "History," Natural Gas.org website, accessed February 4, 2005, online at http://www.naturalgas.org/overview/history.asp. See also "Natural Gas," Environmental Literacy Council, accessed February 2, 2005, online at http://www.enviroliteracy.org/.

[12] Colin High and Kenneth Skog, "Current and Projected Wood Energy Consumption in the United States," p.232; from Donald L. Klass, ed. Energy from biomass and wastes 23. Proceedings of IGT's conference; 1989 February 13-17; New Orleans, LA. Chicago, IL: Institute of Gas Technology; 1990: pp.229-260.

There has been progress in the development of renewable energy resources in the US. Non-renewable resources such as oil, coal, petroleum and natural gas (fossil fuels) make up the majority of our current energy supply, but now 6% of US energy comes from renewable sources. Traditionally, hydroelectric power supplied the majority of renewable energy, but biomass energy recently surpassed hydroelectric to supply nearly 3% of national energy needs. This is a notable increase from the 1% of total national energy use supplied by biomass in 1994. Of that biomass energy, 83% came from wood residue (Figure 2). Since the mid-twentieth century, wood energy has regained a profile as a significant energy feedstock in certain niche markets—particularly in the forest products industry and some utility-scale facilities. Over the last thirty-five years in particular, major policy changes and economic signals have dictated how wood energy has fared in competition with traditional coal-fired electricity and natural gas power. The impact of these sometimes contradictory influences is discussed below.

Figure 2—US Energy Consumption by Source, 2005

Source: Energy Information Administration at www.eia.doe.gov.



1970s: Clean Air Policies and Renewable Energy Incentives

In the 1970s, OPEC cartel restrictions and natural gas shortages intensified efforts to conserve energy as well as to develop renewable energy sources. Residential use of wood again picked up around the same time, due to the oil crisis and a strong emphasis on conservation and domestic fuels during the Carter Administration (1976-1980). In 1978, passage of the Public Utility Regulatory Policies Act (PURPA) obliged U.S. electric utilities to purchase onsite energy production surpluses at their state regulated avoided cost rate, thereby encouraging the forest products industry's use of wood residue for fuel. In addition, renewable energy tax credits and related financial incentives drove investments on the part of Independent Power Producers (IPPs). Some of the early adopters were industrial facilities that could utilize some of their own residues as fuel for cogeneration systems that also provided steam for industrial process use. Many utilities, including Consumers Energy in Michigan, locked into long term contracts with IPPs, for the purchase of electric power generated from wood and other biomass residues.[13]

[13] Thomas Stanton, Competitive Energy Division, MPSC, personal communication, March 22, 2005.

Also during the 1970s, environmental degradation caused by emissions from power plants, industry, and transportation prompted the first national attempts to regulate the quality of our energy production. The Clean Air Act, first passed in 1970 and amended in 1990, established mandated quality levels for the criteria pollutants sulfur dioxide, nitrogen dioxide, suspended particulates, carbon monoxide, ozone and lead. These levels were set with reference to ambient levels that would result in harm to humans and the environment.[14] The act was to have a positive overall impact on the long-term growth of biomass energy production despite the short-term vagaries of energy markets: while the cost savings of wood energy rose and fell in relation to fossil fuels, the environmental benefits persisted. In recent years these benefits have been shown to be more valuable than first realized, as the rapidly increasing cost of health care in the United States has paralleled the rising rate of respiratory and other illness associated with air pollutants.[15]

1980s: Incentives Sunset and Fossil Fuel Prices Decline

Both heating oil and natural gas prices had risen steeply in the late 1970s, heightening the appeal of wood. Increased attention to air quality —particularly sulfur emissions responsible for acid rain—had also encouraged business and residential sectors to embrace wood energy. Despite wood's appeal, research on wood energy consumption during that era revealed how promising advances in biomass energy were abandoned when oil prices fell: "The use of wood for energy [had] expanded beyond forest products industries and the residential sector to include commercial and institutional use, industrial steam production, electric cogeneration, and electric utility power production. Research and development work was in progress in both the public and private sectors to commercialize wood gasification, methanol and ethanol production, and synthetic petroleum fuels production. However, the fall in oil prices since 1985 ... significantly reduced commercial interest in much of this work although considerable technical progress has been made in most areas."[16] In addition, renewable tax credits were phased out and avoided cost rates dropped significantly in many states during the Reagan Administration.[17] The decline of PURPA-based incentives, in combination with a steep drop in both natural gas and oil prices, rapidly defused the momentum behind a growing biomass energy sector.

1990s: The Natural Gas Decade

In 1992, the first Gulf War highlighted the insecurity of world oil markets, prompting President George H.W. Bush to initiate the Energy Policy Act (EPAct), which promoted renewable domestic sources of energy. Alternative transportation fuels, for which wood can also be a feedstock, became a focus of government and industry attention. However, as the war's impacts on markets faded, the heightened interest in fuel conservation and security faded as well. Some incentives for transport fuels remained in place, but renewables as a whole were de-emphasized throughout the prosperous 1990s. Under President Bill Clinton, natural gas received considerable attention as prices hovered around $2 per million cubic feet (Figure 3).

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[14] Z. Plater et al, *Environmental Law and Policy: Nature, Law and Society*, St.Paul, MN: West Publishing Co, 1992, p.773.

[15] The US Environmental Protection Agency's website provides comprehensive background on the Clean Air Act. The *Plain English Guide to the Clean Air Act*, posted on EPA's site, is a helpful primer on the role of states, federal government, industry and the public; the problems caused by different kinds of pollutants, the permitting process, air toxics, and mobile sources.

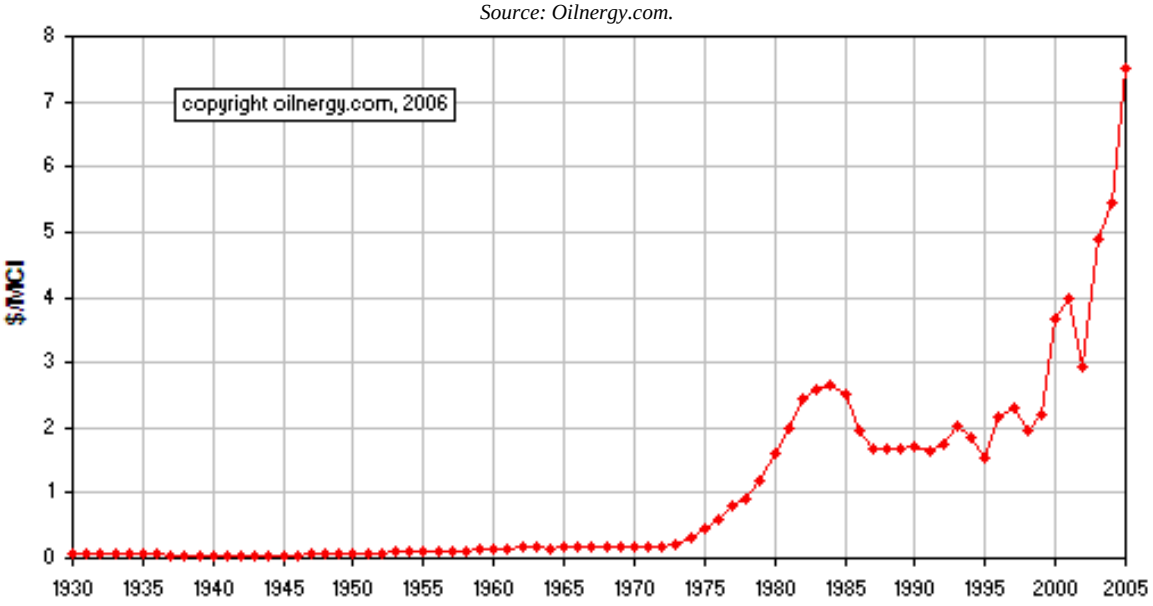
[16] High and Skog, "Wood Energy Consumption," p.232.

[17] Ausilio Bauen, Jeremy Woods and Rebecca Hailes, *Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020*, Imperial College London, Centre for Energy Policy and Technology and E4tech (UK) Ltd, April 2004; *Urban Wood Waste in Michigan* 1994, p.14.

It was also attractive because it was seen as the environmentally friendly solution to the problem of coal due to its clean burning properties and lack of sulfur emissions.

Figure 3—US Wellhead Natural Gas Price, 1930-2005 ($/million cubic feet)

Source: Oilnergy.com.



However, the Clinton Administration also fostered biomass energy. EPAct continued putting attention on biofuels, but more importantly a new executive order placed more emphasis on biomass energy and bio-based products. President Clinton's August 12, 1999 Executive Order on Bio-based Products and Bioenergy authorized new funding for research on biomass energy. It also established the Interagency Council on Biobased Products and Bioenergy, with representation from the heads of the federal Agriculture, Commerce, Energy and Interior departments, the Environmental Protection Agency, the Office of Management and Budget, the National Science Foundation among others.

Partnership between USDA and DOE has generated significant opportunities for research, development and deployment in the biomass field through a biomass grant offered by the two agencies. President Clinton also proposed a five-year extension of EPAct's 1.5-cent/kW hour tax credit for electricity produced from biomass. The measure expanded the types of biomass eligible for the credit to include certain forest-related, agricultural and other resources. In addition, a one-cent/kW hour tax credit would be given for electricity produced by cofiring biomass in coal plants.[18] While the increased attention on the importance of biobased products initiated useful programs that remain in operation today, the level of funding was inadequate, and no PURPA-like incentives were advanced that would promote integration of biomass energy production into utility portfolios.

Wood versus Natural Gas in Michigan

Case studies of Michigan-based wood energy production demonstrate the legacy of PURPA. PURPA incentives had made wood energy popular again after a century of decline (Figure 4). Michigan demand for residual wood rose as new utility scale plants were built in Grayling (1991)

[18] Dave Block, "Executive Order and Proposed Bill Will Boost Biobased Products and Bioenergy," *Biocycle*, Vol. 40, No. 9, September 1999. Online at http://www.environmental-expert.com/magazine/biocycle/september/article4.htm.

and Flint (1996). The increased demand in turn raised the price of wood fuels. As growing markets increased the value of residual wood supplies, quantities available at zero- or low-cost declined. Plants that were built in the 1980s when wood residue was much cheaper faced new competition for the procurement of fuel supplies.

Yet during the same decade, a significant decline in the price of natural gas made it the new fuel of choice for heating in both residential and some industrial sites. As natural gas is the cleanest-burning fossil fuel given current technology, shifting from biomass to natural gas did not undo the move toward lower emissions instigated by the Clean Air Act—but it did help defuse the momentum towards faster renewable energy development, and eventually began to undermine wood energy production. This was due to both the simple dynamic of pricing for wood, and to the more complex interests of utilities in marketing natural gas to gain larger clients while prices were attractive.

Two case studies of non-utility wood energy plants demonstrate how the changing energy market dynamics, in combination with utility preferences for fossil fuels, influenced the fate of wood-fired power in Michigan. Central Michigan University (CMU) and Dow Chemical of Midland (1982-1996) both invested in wood-fired energy systems for heating in the 1980s. Each had arrangements with various contractors to deliver wood residue. The low- to no-cost resource itself, plus transportation expenses, cost less than natural gas.[19] So long as natural gas remained at or near 1980s prices, wood was a competitive fuel. However, natural gas prices declined through the 1990s from $5.5/MBtu to $2.7/MBtu—a drop of nearly 50% (1997 dollars).[20] In addition, the new utility-scale wood-fired plants in Grayling and Flint put upward pressure on wood residue prices. Dow entered into a special contract for electricity with Consumers Energy in order to obtain the stability of a long-term contract price for electricity, but one provision of that contract was a requirement for Dow to shut down its wood energy plant.[21] Dow closed its wood energy system and sold it to a Canadian pulp and paper company. Wood residue that was previously being used close to the source in Midland was then able to supply nearby Flint's Genesee Power facility—a utility-scale wood energy plant enabled by PURPA. However, local wood supplies for CMU did not increase. After opening in 1985, CMU's wood fired plant then shut down in 1990 because wood residue became more expensive than natural gas. Fortunately for CMU, the wood boiler remained functional, and the university's administration decided not to sell it. The buyers' market for natural gas, supported by its low emissions and domestic abundance, has suddenly become a sellers' market in the early 21st century. Natural gas prices moved rapidly to record highs in 2002, and turning back to wood energy has saved CMU over $1 million per year.[22]

[19] Wood residues have long been considered "wastes." During the mid-1980s, wood residue was low- to no-cost primarily because there were few local uses for it. Depending on the context, wood residues can be very high cost. Due to a proliferation of uses for it—in addition to the growing attractiveness of renewable energy—wood residue in the 21st century is rarely a "waste" product except in the most remote settings.

[20] Danny Aerts and Kenneth Ragland, "Case Study of Successful Wood-Fired Co-Generation Power Plant 1982-1996," Mechanical Engineering Department, University of Wisconsin-Madison, no date.

[21] Michigan Public Service Commission Docket No. U-10997: Consumers Power Company, approval of special energy contracts with Dow Corning Corporation and Hemlock Semiconductor Corporation, issued 12/07/1995.

[22] Andy Vajcner, "CMU Wood Fueled Steam Boiler and General Utility Overview," Internal Document, December 21, 2004.

Figure 4— Facilities Producing Electric Power from Wood Fuel in Michigan

Utilities using wood (general location indicated below) have a combined capacity of 173,000 kW, or approximately half of Michigan's wood-based energy. All of Michigan's utility-scale wood energy plants are combustion-based. There are 20 to 30 jobs per plant. No new biomass electric plants have been brought on-line since 1996. Another 195,000 kW are produced by the forest products industries and other businesses using wood for on-site energy production. Data for both types of facilities can be found at the National Renewable Energy Laboratory's Renewable Electric Plant Information System [http://www.nrel.gov/analysis/repis/].

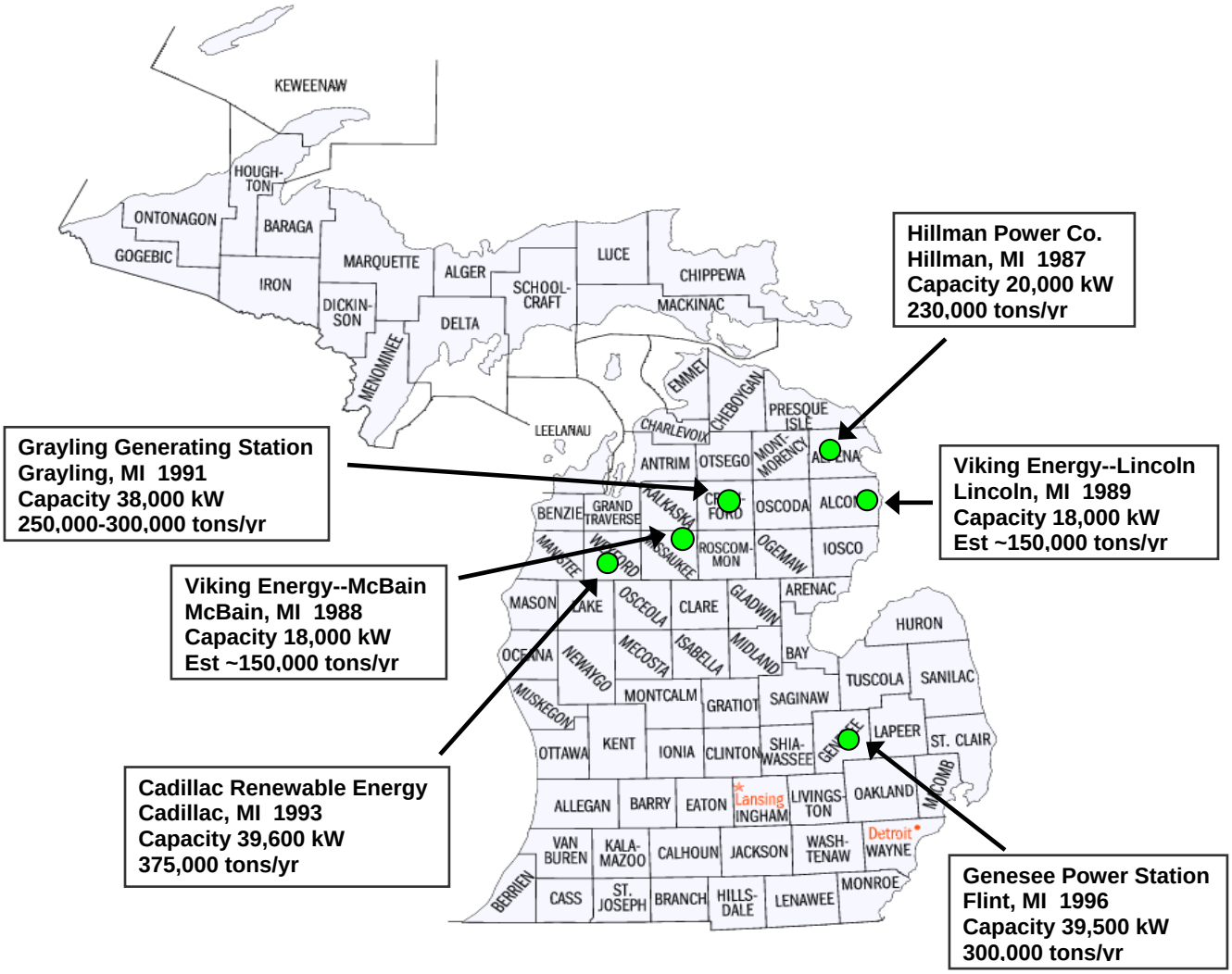


Table 1—Facilities Producing Electric Power from Wood Fuel in Michigan

Source: REPiS, online at http://www.nrel.gov/analysis/repis/.

Type	Capacity (kW)
Michigan Total	368,170
Utility (six sites)	173,100
On-site Upper Peninsula	150,800
On-site Lower Peninsula	44,270

The 21st Century: Energy Diversity through Renewables

Despite success stories like CMU's, the overall story of renewables in Michigan is one of lost opportunities. Both short term price pressures and longer term utility strategies based upon traditional fossil fuels created disincentives for investment in renewable energy production in general. PURPA-based initiatives began to have an impact on Michigan's energy landscape, with some decentralized wood based or wood-coal co-fired plants. However, emphasis on fossil fuels—specifically on natural gas energy production that easily met Clean Air Act standards—defused the movement toward renewables support among policymakers and the public. Both in Michigan and nationwide, lessons about diversification and investment in indigenous renewables that were forced upon the United States in the 1970s did not have the wide-reaching impact they might have had.

The 2005 Energy Policy Act (EPAct) includes some measures to promote biomass energy. Grants were authorized for:

- Rural and remote communities using biomass, landfill gas, and livestock methane,
- Facilities producing electricity, heat, or fuels from forest thinnings,
- Creating valuable products from local, renewable biomass resources, and
- Producers of cellulosic biomass ethanol.

Wood residues are possible feedstocks for each of these funding opportunities. In addition, tax incentives may be offered for cellulosic biofuels, small renewable systems, and gasification projects—all of which could utilize wood.[23] The production tax credit for electricity produced from renewable energy provides a ten-year credit of 0.9 cents per kilowatt-hour for sources including open-loop biomass (like wood residues), and 1.9 cents per kilowatt-hour for closed-loop biomass (like energy crops). However, authorization of these important opportunities has not been followed by appropriation of necessary funding.[24] Environmentalists and fiscal conservatives criticized the new act for directing tens of billions of dollars toward "royalty relief, tax credits, loan guarantees, and other forms of support for the oil, gas, coal, and nuclear industries at a time of high energy prices and record profits."[25] In sum, EPAct authorizes some small steps to help diversify our energy portfolio, but the energy crisis facing Michigan and the United States may require more significant initiatives to resolve.

Despite some promising measures, EPAct 2005 reflects the lack of consistent and adequate funding for renewable energy after the 1970s oil crisis. This inconsistency deterred investors

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[23] "EPAct calls for many incentives programs, including multiple changes to the Internal Revenue Service Tax Code. To reach the goal of producing the first one billion gallons of annual cellulosic biofuels production by 2015 an incentive program will be established at DOE for the production of cellulosic biofuels. Additionally, the DOE may provide loan guarantees to carry out demonstration projects for cellulosic biomass, the construction of facilities for converting municipal solid waste (MSW) into ethanol and other byproducts, demonstration projects for ethanol derived from sugarcane and bagasse, and rebates for a renewable energy system connected to a house or small business. EPAct calls for credits for vehicles capable of operating on a renewable fuel, alternative refueling stations, investments in gasification projects converting product from biomass." From USDA-DOE Biomass Research Development Initiative, "Biomass Provisions in the Energy Policy Act of 2005," September 2005, accessed online at http://www.bioproducts-bioenergy.gov/news/DisplayRecentArticle.asp?idarticle=205.

[24] Despite the promise of closed-loop biomass energy production, no operations in the United States currently utilize this system and claim the higher tax credit (Phil Badger, General*Bioenergy, personal communication, October 30, 2005; Dr. Kenneth Ragland, Emeritus, University of Wisconsin, personal communications, July 2005). The time required to establish energy crops varies from 2-3 years for switchgrass, and 4-10 years for poplar and willow; Kelly Launder, *Energy Crops and their Potential Development in Michigan*, Michigan Biomass Energy Program, August 2002, pp. 3-4. This timeframe deters investors from closed-loop biomass systems, particularly given the more immediate returns of investment in wood-fired heat or electricity, or the emergent market for cellulosic ethanol; Bruce Woodry, Sigma Capital Investments, personal communication, May 11, 2006.

[25] Jennifer Weeks, "National Energy Bill Boosts Bioenergy, But…," *Biocycle*, September 2005, pp. 67-70.

and potential consumers alike, and undermined what was a promising start for renewable energy in the United States. Now, instead of facing price volatility and international instability of oil-producing nations from a position of strength, many states that have not created renewables programs find themselves vulnerable to high prices and volatility in both oil and natural gas markets in the early 21st century. They are now threatened by potential price increases of 50% or more on natural gas use this winter. Furthermore, since the September 11, 2005 terrorist attacks on New York City, and the subsequent invasion of Afghanistan and Iraq, oil prices have become more unstable. The US imports more than half of the oil it consumes, while the price of oil has topped $70 per barrel. The growing insurgency in Iraq has made oil infrastructure protection difficult, and the overall security of petroleum resources in the Middle East less certain. Given that authoritarian or semi-authoritarian regimes govern oil producing countries such as Saudi Arabia, Nigeria, and Iran, and that these regimes either face internal strife or do not favor United States policies, volatile pricing caused by international instability will continue to plague oil markets.

Upward price pressures on all fuels have been intensified by the devastating effects of Hurricane Katrina in September 2005. Prices for oil, natural gas, and propane surged in the wake of infrastructure damage and supply constriction in the Gulf. Even when repairs to supply chains are complete, the need for energy resource investment to repair New Orleans and other damaged areas will continue. Hurricane damage to energy infrastructure in 2005 put a spotlight on our vulnerability to unforeseen natural disasters caused by dependence on energy imports. Climate scientists have linked more intense and therefore more damaging storms to warming oceans. Upcoming temperature increases will generate stronger storms, which increases the likelihood that we will experience more of these disasters in the future. And whether or not we have a national disaster in 2006, or 2007, the finite nature of fossil fuels dictates that their prices will continue to rise over time.

In order to create a flexible energy portfolio to meet our needs throughout this century, as well as to provide ourselves with greater energy security, this discussion paper promotes diversity of fuel sources as the healthiest long-term strategy.[26] Such diversity comes from increased policy focus on and investment in renewable energy production. Federal and state governments are re-investigating how renewable energy from biomass, solar and wind might help their current energy dilemmas, and many states are already implementing policy initiatives to increase renewable energy production and use.[27]

Wood Resources Old and New

When considering wood residue utilization for the production of renewable energy, much of the low-hanging fruit has already been picked. Many sawmills already use their onsite residues for their own energy needs: overall, the industry obtains more than 50% of its electrical and thermal capacity from biomass.[28] The remainder of the convenient centralized wood residue resources not used at forest products industry facilities is being used by utilities.

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[26] Amory and Hunter Lovins, *Brittle Power: Energy Strategy for National Security*, Rocky Mountain Institute, 1982 (www.rmi.org). This report, commissioned by the Pentagon, recommended strong moves toward renewable energy production from biomass, solar and wind. It also promoted the concept of distributed generation on the premise that highly centralized systems, when they fail, fail spectacularly—but networks of self-contained energy production nodes can provide the same amount of energy more efficiently and more securely.

[27] See the Database of State Incentives for Renewable Energy (DISRE); http://www.dsireusa.org. See also Michigan Renewable Energy Program Web site: http://www.michigan.gov/mrep.

[28] DOE figures for the US Pulp and Paper industry report that it uses biomass to create more than 7,500 MW of electricity for its own use. EERE estimates that at least that amount of power could be generated by unused mill wastes and urban wood wastes.

Currently in Michigan there is increased demand for wood residue, due in part to a reduction in available residues from the forest products industry. Foreign competition is impacting the wood products industry. Low priced furniture, furniture component parts, and pulp from foreign suppliers has reduced demand for some Michigan wood products. Decreased production may account for some of the reduction in wood residues from mills. Improved sawmill efficiency and improved utilization of all components of currently harvested trees may also account for some of the reduction in wood residue availability.[29]

While forest products residues have decreased, growing pressure to divert organic materials from landfills has *increased* the availability of some urban wood residues.[30] However, the overall theme of new and improved uses for wood residues also holds true outside the forest products industry: an increased number of uses for these residues have multiplied, and they are frequently higher value uses than energy depending on the local context.

For example, innovation in the construction supply industry has enabled the use of some kinds of wood residue in production of oriented strand board (OSB), now the standard for housing construction. As builders moved to OSB and other products, they were able to make more commercial use of smaller bits of wood. Pellet manufacturing and animal bedding suppliers have also increased demand on wood residues. Finally, landscaping has also become a major competitor for wood residue resources. Over the last five years, landscaping trends turned toward higher end products such as colored mulches. Mulches decompose over time and continue to provide nutrients as well as keep down weeds—two qualities desired by landscapers and homeowners. The mulch industry has grown up to 10% per year in sales volume, continually increasing pressure on wood residue prices.[31]

Given increased reuse and recycling by forest products firms and secondary/tertiary wood products manufacturers, and the growing number of uses for that residue, the value of wood residue is higher than it was in the PURPA era, when wood residuals were frequently thought of as waste. Higher costs require higher value secondary and tertiary uses. Today, residue from the wood-based economic sector is no longer a free byproduct that nobody wants, which is how "waste" is traditionally conceived.

However, there are other wood residues that have not been subject to increasing competition for their use. Because of the cost of intermediary businesses or new city/county functions to retrieve, sort and aggregate it, urban tree residue is a fundamentally different resource than industry or other urban wood residues. Diffuse in nature, these residues sometimes find their way to wood residue processors, but are more often mixed with municipal solid waste or simply dumped. Some localities have yard waste ordinances that ban wood residues in the solid waste stream, but these ordinances are very difficult to enforce. Urban wood residues, if aggregated, could provide fuel for wood energy applications in or near cities throughout the state. The next section highlights important characteristics of wood residue, noting the potential of redirecting urban tree residues toward energy resource pathways.

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[29] The US Forest Service's *National Report on Sustainable Forests 2003* highlights the dramatic increase in recycling in forest products industries since the 1970s (Indicator 33—Degree of Recycling of Forest Products).

[30] "Wood Recyclers Embrace Municipal Market," James I. Miller, *American Recycler*, July 2004, accessed online at http://www.americanrecycler.com/0704wood.shtml.

[31] Judd Hart, CEO of J.H. Hart Urban Forestry, Personal Communication, September 30, 2005.

Characteristics of Wood Energy Feedstocks

Forest Residues: Forest residues include material not harvested or removed from logging sites in commercial hardwood and softwood stands, as well as material resulting from forest management operations such as pre-commercial thinnings and removal of dead and dying trees.[32] Forest residues may include logging residues, rough rotten salvageable dead wood, and excess small diameter trees. At the initial harvest, up to 50% of the tree (leaves, tops, branches, stump) may not be useful to a particular industry.[33] There is potential here for recovering some of the harvesting residue for energy, while still leaving a suitable amount of material to assist in soil recovery and nutrient flows. In fire dependent ecosystems harvest residues can create increased fire hazard and this is reduced if the material is removed. In such fire dependent ecosystems, the elimination of fire from the system and the build-up of understory fuels can also increase fire hazard. Current strategies to lower fire danger focus on reducing these fuel levels through thinning. This "fuel reduction" thinning process could provide an energy resource in some parts of Michigan. However, the specifics of what, when, where and how much is to be harvested remains a matter of intense debate.[34] Most forest residues are suitable for energy conversion, but they may have high moisture content and may require some energy intensive drying (see processing) depending on the conversion system to be used.

Primary Residues: Mill or processing residues are also divided into two categories, primary and secondary. Primary industrial mill residues are wood residues from manufacturing facilities that process logs or roundwood (i.e. pulp, paper, lumber veneer, and board plants). Primary residues are predominantly green, with moisture content between 40 and 50%. These residues take the form of chips, sawdust, and bark. In certain instances these primary residues may include stumps. Unlike secondary industrial mill residues, the creation of primary residues requires the harvesting of trees.[35] Depending on conversion rates and process efficiencies, up to 40% of the primary mill's inputs may become primary mill residue.

Secondary Residues: Secondary residues, also referred to as dry mill residues, are the by-product of the wood products industries that utilize kiln-dried material or refined fibers to manufacture consumer and industrial goods. They are generally characterized by their cleanliness, relatively low moisture content, freedom from bark and relatively high energy content.[36] Several of the most common types of secondary mill residues are sawdust, chips

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[32] US Department of Energy, Energy Efficiency and Renewable Energy, Feedstock Composition Glossary, online at http://www.eere.energy.gov/biomass/feedstock_glossary.html.

[33] Tom Stanton, "Biomass Energy: It's not just for breakfast any more," Michigan Public Service Commission, 1995; Anthony Weatherspoon, Forest Products Technical Services Specialist, Michigan Department of Natural Resources, personal communications, October 2004.

[34] The importance of managing forests simultaneously for biodiversity, non-consumptive uses, and for industry requires a sustainability based approach that considers intergenerational consequences. The publication *National Report on Sustainable Forests 2003* (USDA Forest Service, FS 766, February 2004) presents the case for increased research and program development to maximize sustainable forest management through these considerations. At the same time, mitigating forest fire disasters requires short term action with an eye toward tree removal and industry value-added through that process. These two missions do not share a timeframe, which exacerbates the potential conflict between "forest management" and industry profitability. Western states have more national forest lands than Midwestern states, so they will be a laboratory for experiments in "harvesting" wood for energy uses. Many biomass energy projects using wood have been initiated since the passage of the Healthy Forests Act, particularly in western states which have significantly more forested public lands. The upcoming years will reveal whether and how sustainability practices will influence the increased use of wood as an energy feedstock. However, this paper is primarily concerned with urban wood residues and other residuals outside of forests, based on the premise that large volumes of non-forest wood waste are present and could be harvested with an investment of money and energy in order to reduce organics in our waste streams as well as to reduce our dependence on non-renewable fossil fuels.

[35] *Urban Wood Waste in Michigan*, September 1994, p.8.

[36] Phillip C. Badger, *Processing Cost Analysis for Biomass Feedstocks*, Oak Ridge National Laboratory, 2002.

and shavings. Yet another 30% of the original tree will end up as secondary residue. Most secondary residues are suitable for energy conversion. In the case of Michigan, most of the mill and manufacturing residues have been recognized as energy or other assets and are not considered "available": nearly 98 percent of all mill residues are currently used as fuel or to produce other fiber products.[37]

Urban Wood Residue: Urban wood residue is a collective reference for wood residue present in municipal and commercial solid waste. It includes urban tree residue (UTR—woody yard and right-of-way trimmings, leaves, tree company and municipal/park trimmings), discarded wood products (scrap lumber, pallets, crates, wooden packing material), and municipal solid waste (MSW) such as fencing, poles, cable reels, furniture, toys, cabinets, seasonal trees and brush trimmings.[38] It may also include chips and grindings of clean, non-hazardous wood from construction, renovation, and demolition activities and storm-generated wood.

Historically, most urban wood residue has been buried or dumped. However, the advent of recycling and composting, in tandem with increased tipping fees for landfills and PURPA-inspired biomass burning plants, have raised the value of wood residues, causing more wood to be diverted from landfills to other uses. Not all of these "uses" are productive. In order to avoid tipping fees, burying wood or dumping it on less visible properties are still common practices in places far from any readily available wood using enterprise.[39] In addition, not all urban wood residues are suitable for energy conversion. Some residues are treated with chemicals that are not compatible with typical wood-to-energy conversion systems, and that can produce emissions harmful to public health and the environment.[40]

Table 2—Wood Energy Characteristics, Merits, and Technology Options

Resource	Energy Characteristics	Advantages	Disadvantages	Technology
Wood and wood residue	▪ green wood: 4,800 Btu/lb (45% moisture content, wet basis) ▪ dry mill residue (brown wood): 6930 Btu/lb (13% moisture content, wet basis) ▪ pellets or briquettes: 8000-9000 Btu/lb (8% moisture content, wet basis ▪ wood-to-ethanol life cycle fossil energy ratio: 14-29:1	▪ renewable, locally abundant ▪ dispatchable (storable), not intermittent (solar, wind) ▪ known technology for heating, boilers, co-firing ▪ much cleaner than coal, carbon neutral if harvested sustainably ▪ pollution prevention for wood industry and processing ▪ prevents landfilling of organics ▪ improved forest health, reduced impact of fires, insects, diseases	▪ lower energy content than non-renewable fossil fuels ▪ can be expensive to transport ▪ requires storage space ▪ must be dried for some energy applications ▪ can be contaminated ▪ lack of consensus on sustainability	**NOW** ▪ wood fired boilers ▪ wood and coal co-fired boilers ▪ co-firing with other biomass ▪ pyrolytic oils (bio-oils) **FUTURE** ▪ wood-to-ethanol ▪ syn-fuels

[37] Marie Walsh et al., "Biomass Feedstock Availability in the United States: 1999 State Level Analysis," Primary Mill Residues section, January 2000, Oak Ridge National Laboratory, online at http://bioenergy.esd.ornl.gov/resourcedata/index.html.
[38] Badger 2002.
[39] Anthony Weatherspoon (MDNR), Thomas Stanton (MPSC) and Sam Sherrill (University of Cincinnati), personal communications, August and September 2004.
[40] Some treated wood, such as creosote-coated railroad ties, can be used for energy in larger plants that have invested in specially designed burner and emissions control systems.

Green and Brown Residues

Another important categorization of wood residues that cross-cuts the categories above is determined by moisture content. Green residues are typically undried (moisture content of 25-45%), and can include primary residues as well as urban tree residues and energy crop cuttings. Brown residues are dried (moisture content 0-15%) and usually processed. Brown residues encompass secondary residues such as shavings, sawdust, trimmings, composites, pallets, crating, and construction and demolition residues (both clean and treated). In addition, urban tree residues can be brown, such as dead trees, downed limbs, and dried trimmings. Urban wood residues in general include furniture, fixtures, and other brown wood products that become residues when consumers have finished using them.

Clean versus Treated/Contaminated Wood Residues

The quality of wood residue going into a combustion or gasification system determines what comes out—in terms of energy, emissions and non-combusted residues/ash. The use of certain waste streams such as sewage sludge, recovered domestic and municipal waste and construction wood residue are particularly prone to contamination.[41] In addition, even small amounts of some contaminants can lead to significant toxic emissions and health hazards, depending on the technology in use.

Treated woods in particular contain chemicals that create dangerous emissions and have other harmful properties to the energy process. Surveys of wood users in Michigan and other states demonstrate that secondary wood users (including wood energy producers) do not accept wood contaminated by treatments. In addition, the simple economics of protecting a major capital investment create incentives to screen wood fuels, because contaminants can adversely affect machinery necessary to keep boilers running.

Urban Tree Residue (UTR) Versus Other Wood Residue

Compared with other forms of urban wood residue, UTR has no particular resonance with socio-cultural norms of preservation. Harvesting trees for energy resonates with incidences of wholesale forest clear-cutting without necessarily preserving or replanting; indeed, energy policies encouraging wood utilization could lead to that outcome. Forests are complex natural systems that people value not only for their material products but also for their recreational or conservation values and other intangibles—forests are valuable for simply existing. The use of UTR for energy presents a sharp contrast with the use of forest residuals: people are "getting rid" of UTR because it is surplus to their needs, and they do it every year because it grows back. "Harvesting" UTR for energy production does not prioritize its energy values over other values, as often there are no other values. If UTR is unclaimed by another use like composting or landscaping chips, then it actually has a negative value because it will be landfilled or dumped on land that could be used otherwise. There are large volumes of UTR entering landfills that could otherwise be useful for energy or other uses; up to 200 million cubic yards of UTR are removed each year in the United States; this figure is approximately 30% of the total of US hardwood lumber supplies.[42]

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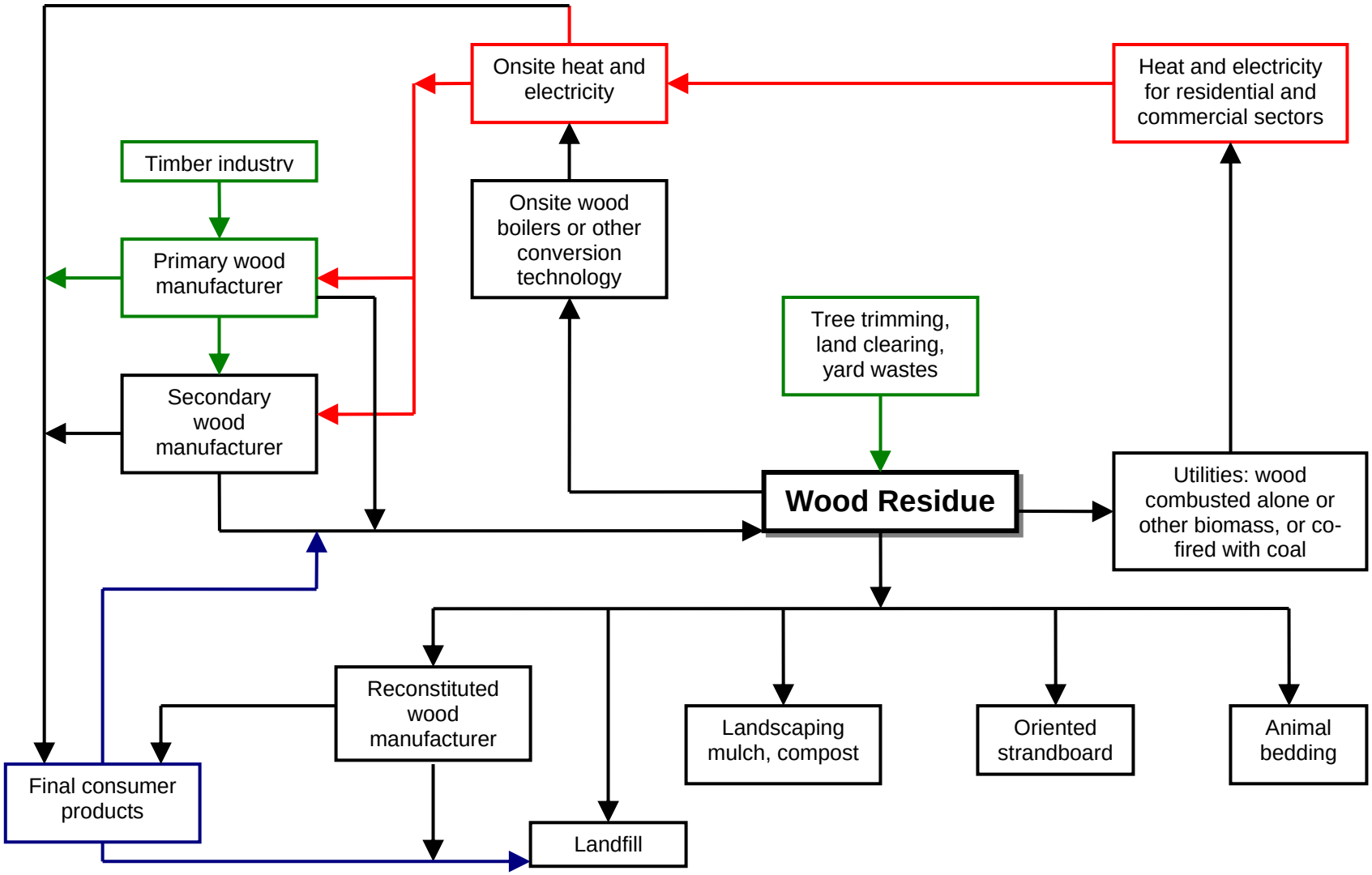
[41] Ausilio Bauen, Jeremy Woods and Rebecca Hailes, *Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020*, Imperial College London, Centre for Energy Policy and Technology and E4tech (UK) Ltd, April 2004, p.33.

[42] Steve Bratkovich, *Utilizing Municipal Trees: Ideas from Across the Country*, Newtown Square, PA: U.S. Dept. of Agriculture, Forest Service, 2001. Available online at http://www.treesearch.fs.fed.us/pubs/11059.

Using UTR is beneficial because it diverts this tremendous volume of organics from landfill spaces, prevents potent greenhouse gases like methane coming from decomposing organics over time, reduces consumption of fossil fuels and production of their associated emissions, and moves communities toward a renewable energy cycle that is locally sustainable and more secure from global economic and political disruptions. The next section explores how we attempt to quantify available wood resources, including UTR, in the United States and in Michigan.

Figure 5—Wood Residue Pathways[43]

Note: Wood and wood products can become wood residue at almost any point on the pathway—just as they can be landfilled at nearly any point. However, all possible paths were not charted in order to maintain the figure's visual clarity. The chart assumes that landfilling occurs when all other options are exhausted, whereas in reality locational variables may determine that there are no options aside from landfilling due to high transportation costs to an alternative user.



[43] This figure is based in part on wood residue generation and use mapping by Bibhakar Shakya in *Directory of Wood Manufacturing Industry of Ohio*, Ohio Biomass Energy Program, August 1997.

Wood Residue Quantity and Price

Good data on wood residue is hard to find.[44] Oak Ridge National Laboratory (ORNL) has utilized models programmed into its BIOCOST software to generate state level estimates of various biomass feedstocks available at different prices. The feedstocks include Urban Wood Residue, Mill Residue, Forest Residue, Energy Crops, and Agricultural Residue; for the purposes of this report, only the first three categories are relevant.[45] While there are some solid assumptions behind these models, there are also shortcomings. ORNL data relies on estimates provided by other government agencies or generated by other studies. In other words, ORNL's estimates are generated by secondary or even tertiary data, as opposed to estimates derived directly from the field through interviews and surveys. Forest residues are assessed using the 1984 McQuillan model, and then adjusted downward to account for presence of roads, slopes, equipment availability. This model does not account for ecosystem values, soil erosion, or site-specific requirements. It also does not explain how "salvageable" dead wood should be distinguished from dead wood necessary for habitat requirements, nutrient management, and soil protection.[46]

Table 3—Annual Biomass Quantities in Michigan (est. dry tons), by Type and Delivered Price[47]

Biomass Type	< $20/dry ton	< $30/dry ton	< $40/dry ton	< $50/dry ton
Urban Wood Residue	495,734	**826,224**	826,224	826,224
Mill Residue	10,000	932,000	*1,248,000 (est)*	1,564,000
Forest Residue	0	710,000	1,034,000	1,327,900
Energy Crops	0	0	1,154,228	4,179,308
Ag Residues	0	0	680,783	4,265,671

It also does not account for sporadic influxes of large volumes of wood residue created by natural disasters—tornadoes, hurricanes, infestations, and "acts of God." These volumes can be large enough to provide a glut of wood residue at the local level, and at the same time affect national market prices for wood products. We can estimate the wood residue through the demand for replacement wood, but still the actual volume of downed trees and limbs, wood from destroyed homes, and other sources will never be known. These volumes require intensive effort for local processing and utilization, and their unpredictable nature causes price effects to vary, both locally and nationally.

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[44] Wood wastes that are part of urban waste streams suffer from similar problems in quantification: "The absence of hard data, for example, is not just a Michigan problem—it is, in fact, a problem with solid waste and recycling statistics in every state. The EPA, the most quoted source of waste and recycling statistics in the nation, ultimately bases its estimates of MSW generation on initial reports made in the late 1970s. In recent years, updates of the EPA's numbers have been the result of a slow migration of 'best guesses' from the states. Moreover, the states have not devoted enough resources to uncovering what is really going on within their boundaries in the generation, collection and recycling of their waste streams." From *Waste: A Hidden Resource*, Special Report 112: Status and Potential of Michigan Natural Resources (SAPMINR), Michigan Agricultural Experiment Station, MSU, March 2000, p.12.

[45] Energy crops include both grasses and trees, many species of which could thrive in Michigan. However, such crops would not be considered wood waste, as they are deliberately planted and harvested on a regular basis and the markets for these crops would be clearly defined.

[46] Marie Walsh et al., "Biomass Feedstock Availability in the United States: 1999 State Level Analysis," Updated January 2000, Oak Ridge National Laboratory, online at http://bioenergy.esd.ornl.gov/resourcedata/index.html.

[47] Ibid.

More accurate information is available for mill residues. Forest products industries report production data to the USDA as part of the periodic national forest inventory process. Residue production is relatively constant given particular industry practices. Aside from these mill figures, other wood residues including urban wood residue quantities are notoriously difficult to quantify. Many states record or estimate construction, demolition, and solid waste itself differently. Again, quantities were estimated in wet tons, and then corrected to dry tons by assuming 15% moisture content by weight. Similarly, As a result, the ORNL data cannot incorporate the subtleties of the state-specific or feedstock-specific studies.

Since 1994, there have been no Michigan-specific studies of wood residue, nor have there been any Great Lakes regional assessments of the amounts, uses of, or markets for wood residue.[48] However, a notable attempt to use state and regional data to create metrics for national mill residues and wood residue was commissioned by the Northeast Regional Biomass Program and completed by Fehrs in 1999. It aggregates results from seven reports on wood residues from other states and regions, and selects the data about specific waste categories best represented in each study for a summary analysis. This table helpfully breaks out many categories of wood residue that are frequently subsumed under the label "urban wood residue" (which arguably includes woody municipal solid wastes, yard trimmings, UTR, used pallets, and some percentage of land clearing, construction and demolition).

Table 4—Wood Residue Quantities and Prices in the United States[49]

compiled data from 1992-1998 (tons/year)

Wood Residue Type	Total Generation (tons/yr)	Available up to $10/ton (tons/yr)	Available up to $20/ton (tons/yr)	Available above $20/ton [(c)]
Secondary mill	15,644,000	1,342,000	3,783,000	6,101,000
Construction	16,726,000	2,796,000	7,882,000	12,712,000
Demolition	26,400,000	1,742,000	4,910,000	7,920,000
MSW[(a)]	11,800,000	1,999,000	5,633,000	9,086,000
Yard trimmings	6,300,000	1,199,000	3,379,000	5,450,000
Urban tree residues (UTR)	51,455,000	9,962,000	28,074,000	45,280,000
Used pallets[(b)]	6,544,000	230,000	647,000	1,044,000
Railroad ties	1,688,000	na	na	na
Land clearing	na	na	na	na
Used utility poles	na	na	na	na
TOTAL (tons/year)	<136,557,000	<19,270,000	<54,308,000	<87,593,000

(a): Includes used pallets that are disposed in landfills.
(b): Includes used pallets that are repaired, refurbished, or recycled. Used pallets are disposed in landfills are included as MSW wood residue.
(c): The methodology used to estimate quantities and prices equates wood residue available at $20 and above with that that potentially available for fuel. Wood residue potentially available as fuel is defined as the quantity generated less that used by high value markets and that which is commingled, inseparable, or contaminated.
na: Data not available.

This compiled research on various wood residue stocks over the last decade shows that urban tree residues (UTR) from landscaping, yard management, municipal forestry and utility clearing operations have been underestimated by other official sources. Prior DOE estimates put urban

[48] *Urban Wood Waste in Michigan: Supply and Policy Issues*, Public Policy Associates, 1994. While dated, this is the only existing study of wood residue in Michigan. Later in 2006, a detailed study of wood residues in Southeastern Michigan will be published by the USDA Forest Service.

[49] Jeffrey Fehrs, *Secondary Mill Residues and Urban Wood Waste Quantities in the United States*, prepared for the Northeast Regional Biomass Program, 1999, p. 46.

wood residues in general at 36.8 million tons per year, while the meta-study suggests that only urban tree residues—a subset of all urban wood residue—totaled over 51 million tons, and is at least as abundant as all other wood residue categories combined.[50] Further adding to the confusion, a 1999 *Biocycle* analysis shows a drop in wood available from 42.3 million tons in 1990 to 29.6 million tons in 1999, noting that the drop is almost entirely due to recycling of pallets and a decline in woody yard trimmings.[51] The *Biocycle* study documents 25.2 million tons of woody yard trimmings generated annually, where the Fehrs study provides for only 6.3 million tons—but Fehrs also gives the 51 million ton figure for urban tree residue, some of which might be counted in the *Biocycle* study category for woody yard trimmings.

Taking into consideration the shortcomings of various estimates, and also incorporating the understanding that the amount of urban wood residue is generally underestimated, the ORNL data can be accepted as a conservative estimate of available urban wood residue that could be used to produce energy. The ORNL results for Michigan suggest that at $20 or less per ton, 495,734 tons of urban wood residue is available; at $30 per ton, all 826,224 tons of urban wood residue becomes available.

Energy Potential from Urban Wood Residues

How much energy could this volume of urban wood residues create? In 2000, the State of Michigan consumed over 3,092 trillion Btu's of energy[52], of which 41 trillion Btu's (1.4%) were imported. If all available urban wood residue resources at $30/ton could be converted to energy, Michigan would reduce energy imports by approximately 5.28 trillion Btu's.[53] Substituting 1/8 of our energy imports with domestic wood energy production would increase the amount of money in the Michigan economy, provide job support to renewable energy in Michigan, reduce organics from our waste streams, create a healthier emissions profile for Michigan energy production, provide a better carbon balance, and reduce GHG emissions. These figures only include potential energy production from urban wood residue; there is more surplus wood in construction, land clearing, and even in industry. Harvesting these other wood residue resources could displace more imported energy.

Similarly, an NREL study on urban wood residues that surveyed 30 metropolitan areas found significant local benefits from wood energy production. Diverting wood residues to energy uses could support between 0.4% to 4% of an urban area's electricity needs, simultaneously reducing waste volumes and carbon dioxide emissions from energy production, as well as producing jobs and enhancing the local economy.[54]

Competition for Wood Residue

However, energy is not always the highest value use for wood residues, particularly when the environmental and health benefits of wood energy are not quantified in monetary terms. The phrase "available wood" at any given price implies that some end users will pay more for wood than others. As noted above, the ORNL figures for wood residue show that it is the most available residue type at $20 per dry ton in that analysis. But increased competition would bid the market higher, and available wood residues would then become scarcer. Innovation and

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[50] US Department of Energy, Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/resources_estimates.html. Information on secondary mill residues and manufacturing residues was not available at the time of this study; Fehrs, December 2001.

[51] David McKeever, "How Woody Residuals are Recycled in the United States," *Biocycle*, December 1999, pp. 33-44.

[52] US Department of Energy, Energy Information Administration, "Energy Consumption Estimates by Source, Selected Years, 1960-2000, Michigan," online at http://www.eia.doe.gov/emeu/states/sep_use/total/use_tot_mi.html.

[53] Using conversion factor of 6,400 Btu's per pound.

[54] George Wiltsee, *Urban Wood Waste Resource Assessment*, NREL/SR-570-25918, November 1998, pp.3-4.

waste reduction have created other high value markets for these residues. A "high value market" refers to the industries that manufacture specialty goods for secure markets, such as paper, pulping, and composite materials like OSB. Even higher value markets are available for the larger tree portions of urban tree residues, which can be converted into lumber and high-end wood products such as customized cabinets and furniture. Now competition for more readily available wastes has intensified further. All interview sources in government agencies and the energy industry identified the landscaping industry as a major competitor with energy producers for wood residue. Landscaping has become the highest value use for wood residue chips in urban and suburban areas.[55] In light of tightening wood residue markets, any feasibility assessment for a new wood-to-energy or wood-to-fuel must factor in the market environment and other pressures on the wood residue feedstock.

Location, Location, Location: Distinguishing Residues from Wastes

Despite the information just presented about the value of wood residues for various industries including energy, frequently wood "waste" is landfilled. This counterintuitive phenomenon is tied to the locationally specific nature of biomass. As mentioned earlier, biomass is difficult to handle and transport when compared to liquid or gaseous fuels. Biomass fuels like wood are best utilized close to their source. If a major land clearing operation must dispose of wood, but is 150 miles from the nearest wood energy production facility, and the wood is not needed by the local mulch industry, landfilling is the likely course of action. The transportation costs required for moving wood to distant energy production facilities, pellet plants, or other industries are often prohibitive. So while in theory wood has a value, in practice the markets for wood are driven by demand locations and not necessarily by supply sites. This being the case, prices for wood can be very high in some places featuring the competition described above, yet surplus wood volumes are landfilled, burned, or illegal dumped in others. As tipping fees increase, transportation costs become less of a factor, and two related yet contradictory trends may occur: (1) the effective radius of biomass feedstocks become larger—or it is cheaper to transport biomass fuels relative to landfilling, and (2) the desirability of moving wood at all becomes less appealing than creating an industry to take advantage of that feedstock in situ—perhaps by building a small or medium-sized (5-15 KW) wood power plant, or a cellulosic ethanol biorefinery.

Landfills and Tipping Fees

Michigan landfills do not accept the green waste called "yard clippings." Wood fragments under 4 feet in length and 2 inches in diameter fall into the yard clippings classification.[56] Wood residues that have been chipped or ground technically fall under the definition of yard clippings, but in practice this definition is not strictly enforced. Some landfills even accept chipped wood at no- or low-cost as an alternative daily cover. Most other forms of wood residues are not banned from landfills in Michigan: stumpage, whole trees, and construction and demolition waste are all eligible for landfilling. EPA waste management guidelines allow for wood waste to go into inert landfills, which are less expensive to operate than Subtitle D MSW landfills. However, depending on the state, landfilling can be such a costly option as to encourage residue producers to seek alternative uses for wood residues.

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[55] One source recommended that, if the renewable energy industry in Michigan wants to make wood residues more available for combustion, it should consider hiring consultants to redirect landscaping tastes back to the 1970s and 1980s: "We need to revive interest in those white rocks."

[56] "Part 115, Solid Waste Management: Statute and Rules Impacting Composting," Michigan Department of Environmental Quality (DEQ) Web site at http://www.michigan.gov/deq. Legal provisions that apply generally to composting are included in Part 115, Solid Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451 (NREPA).

Most states have legislated a surcharge on waste deposits to landfills in order to encourage diversion, re-use and recycling. Landfills pass along this surcharge with fees and transport surcharges encompassed in what is called a tipping fee. Low surcharges lead to correspondingly low tipping fees.[57] Michigan imposes a very low surcharge of $0.07 cent per cubic yard ($0.21 per ton). Correspondingly, Michigan's low-end tipping fees are around $11 per cubic yard. Midwestern tipping fees are among the lowest in the nation—$15-$16 per ton versus $40-$50 per ton in the eastern US.[58] The fact that most states have much higher surcharges helps explain why Michigan is currently among the top five waste importing states.[59] Both Democrat and Republican state legislators have started initiatives to raise this surcharge, but so far no legislative action has been taken. Without stronger incentives to move wood residues out of waste streams, Michigan landfills will continue to absorb large volumes of wood that has great value as a renewable and clean energy resource.

[57] Matt Flechter, Recycling and Composting Coordinator, Michigan Department of Environmental Quality, personal communication, September 27, 2005.

[58] Tom Henry, "Trash in, cash out: Landfills want to expand, but garbage imports rankle," *The Toledo Blade*, Environment Special Report, July 7, 2002.

[59] "Economics of Wastes/Residues in Food Processing and Food Service Facilities: Costs of Disposal of Wastes and Residues," Table 4.3—Solid Waste Tipping Fees of Landfills, Incinerators and Waste-to Energy (W-T-E) Plants, and Processing Facilities, December 2001), Kansas State University Online Text Modules, available online at http://www.oznet.ksu.edu/swr/Module4/Costs_of_Disposal.htm.

Wood-to-Energy Markets

The feasibility of energy extraction from any resource base depends not only on the technological efficiency of processing it, but also on extraction and transportation costs. Steps in the conversion of wood to energy include harvest and collection of the residues; transportation to facilities where the residues can be preprocessed (dried or ground) if necessary; and then storage prior to delivery to a plant for energy conversion. The type of processing and storage of any given operation must meet the requirements of the conversion technology in question. Moisture levels of wood fuel in turn will determine the processing specifications and storage dimensions of the biomass energy facility.

Harvesting

Wood is a renewable resource, if it is harvested at a sustainable rate using proper methods.[60] Harvesting, used in the traditional sense of gathering mature crops for human use, is a term more appropriate for the forest products industry or for energy crop plantations. In application to wood residue, it means the method of collecting the wood residues and gathering them at a central facility for processing. Mill and industry wood residue are often used on-site, removing the "harvesting" step from the costs of the fuel. Unlike forest products industry residues, urban wood residues are often dispersed, of varying quality, and erratic in flow. At the same time, yard waste, and urban tree trimmings—a significant portion of urban wood residue—grow back, so a reasonable estimate of a sustainable medium-term flow of the feedstock can be identified with enough detailed information of the local area. However, knowing how much UTR is available does not solve the problem of actually designing and implementing a harvesting strategy.

The problem of harvesting urban wood residues is similar to the problem that faced early recycling policies: the most effective way to get dispersed wastes organized and diverted is to encourage individuals to value them.[61] This educational strategy eventually worked with recycling newspapers, aluminum cans, glass and finally plastics. Incentives for cans and from "bottle bills" encouraged people to participate in recycling for material rewards, but not everyone requires that motivation. People are, in fact, willing to spend some of their time and/or money for a cleaner environment, which bodes well for the future of urban wood diversion from the waste stream to energy uses. However, there will still be a need for outreach, which will likely fall to various levels of government to meet.

Other mechanisms for encouraging diversion of wood residue from the solid waste stream include penalties. As noted earlier, tipping fees help raise the value of wood residues. Rather than pay for disposal of "waste," residue producers must consider how it might otherwise be used to avoid that fee. For large wood residue producers, penalties and tipping fees do have an

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[60] "Harvesting" can mean removal of wood residues from primary and secondary wood processing waste reserves: power plants cannot be built for a particular capacity if the waste wood to fuel them cannot meet the demand. Harvesting also can mean forest thinning of deadwood or of specific species. Finally, harvesting can also mean planned rotational cutting of dedicated energy crops such as poplar and willow. Oak Ridge National Laboratory (ORNL) data demonstrate that there are prices at which energy crops will displace traditional crops on some agricultural lands.

[61] In *The Tipping Point* (Back Bay Books, 2002), Malcolm Gladwell studies watersheds of behavior change in US policy settings. His work is designed to help explain questions such as "Why did recycling become mainstream?" What was the pivotal event, or when was critical mass of opinions reached, that led to shared norms and understandings about a new definition of waste? It is important for renewable energy to consider studies like his. The needed shift away from standard ingrained patterns of energy use will require similar outreach to that which went into changing individual/household/municipal waste management processes and institutions so that they normalized recycling behavior.

effect. Construction and clearing operations need to find a taker for their wood residues or face the costs of landfilling tremendous volumes. Organics diversion has helped wood disposal companies, cities and other organizations value wood residues and take notice of energy producing facilities that might pay them for it. The emerald ash borer (EAB) infestation in Michigan has created tremendous volumes of wood residues which will only increase over the next five years at least, prompting wood disposal procedures that simplify harvesting. EAB residues disposal needs have already improved the reliability of supply to wood fired electrical generation in Southeast Michigan.

Transportation

The feasibility of energy extraction from any resource base depends not only on the technological efficiency of processing it, but also on how much it will cost to get it to the efficient technology, how much of the resource there is, where it is, and, and the cost of extracting it from that location and delivering it to the end user—in the desired useful form. Because biomass has a relatively low energy density compared to conventional fuels such as oil or coal, it is best used as a local resource. Transportation distances from the resource supply to the power generation point must be minimized, with the maximum economically feasible distance being less than 100 miles round trip. Transporting more than 50 miles is usually not cost effective because more energy is expended to transport the wood to the facility than the wood can generate, although this general rule can vary based upon local conditions and the availability of backhaul commerce for the delivery company.[62]

There are some exceptions to this rule: depending upon the ability of parties involved to creatively merge different shipping needs on the same routes, wood residue delivery trucks do not necessarily have to drive back empty. Wood residues from manufacturing in southern Michigan are hauled to Alpena's wood-fired power plant, but other products are loaded onto the empty trucks for the backhaul. Similarly, Genessee Power in Flint receives shipments of emerald ash borer and other residues from a Detroit area marshalling yard, and delivery trucks recoup transportation costs on return deliveries.[63] However, in general, the most economical conditions exist when the energy use is located at the site near where the biomass residue is generated or aggregated, such as a wood product manufacturing site, or a municipal organics collection site.[64] Densification of woody biomass into pellets or briquettes can make transportation over longer distances affordable due to the higher energy content of smaller volumes, and due to the ease of packing these regularly-shaped feedstocks (see Wood Residue Densification below). However, densification is only cost effective in cases where the wood residues have been previously reduced in particle size by other wood processing processes.

Handling and Storage

The necessity of on-site processing and storage of wood residue requires careful planning and attention to spatial considerations not normally applicable to traditional fuels. Handling and storage can be a major portion of the expense of a biomass energy system (20-40% of total

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[62] Techline, Wood for Biomass Energy, USDA Forest Products Laboratory, online at http://www.fpl.fs.fed.us/documnts/techline/Wood_Biomass_for_Energy.pdf; M.K. Mann and P.L. Spath, "A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant," *Clean Production Processes 3* (2001), p.84.

[63] Jessica Simons, SE Michigan Resource Conservation and Development, personal communication, September 9, 2005; Anthony Weatherspoon, MDNR, personal communication, September 23, 2005.

[64] *Lessons Learned from Existing Biomass Power Plants*, Appel Consultants, prepared for NREL, EPRI, and Western Regional Biomass Program, No Date, online at www.westbioenergy.org/lessons/les01.htm; see also http://www.eere.energy.gov/biomass/biomass_feedstocks.html.

costs), so it is important to integrate these steps into the overall design of a biomass energy system.[65] Incoming wood must be weighed, offloaded, stored for processing, screened for size reduction and metals/non-wood materials removal, stored longer term, metered as fuel, and conveyed into the conversion system. There are generally two ways of storing wood residue: covered storage such as open sided buildings, bins or silos; and outdoor storage in piles on concrete or gravel pads.[66] The specific type of storage will depend on required moisture content, frequency and reliability of deliverables, climatic conditions, and the on-site volume of wood residue required by the design and function of the conversion system itself. An optional step in handling between offloading and energy production is drying, which would be located just before the boiler or gasifier to treat the wood immediately before conversion.

Wood Residue Densification

There are ways to increase wood's energy density and thus make each transported pound worth more, while at the same time making the shape of the biomass fuel easier to transport in bulk. In some places where the economics of energy and relative abundance of wood have created a market for wood residue products that can be transported over long distances, it has proven worthwhile to expend energy to densify wood. Densification is the process of taking wood residue and/or by-products and processing them into a product that has a higher Btu content per unit of weight or volume. This can be done by processing wood residue into uniformly sized particles that are then compressed into pellets or briquettes; or it can be done by processing these particles into a liquid through a pyrolysis process.

When wood residues are densified, their Btu content is enhanced and handling, transportation and feeding of combustion systems are also improved.[67] One benefit of densification is shown in residential pellet systems where densified fuels has enable the conversion technology to dramatically reduces emissions as compared to standard fireplace and stove technology (see Table 4).[68] The cleanliness and efficiency of pellets and briquettes indicates their potential utility in small scale bioenergy for businesses, local governments, public institutions (schools, hospitals, universities), and small industry.

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[65] Phillip C. Badger, *Processing Cost Analysis for Biomass Feedstocks*, Oak Ridge National Laboratory, 2002, p.15.

[66] C.H. Murray, *Energy Conservation in the Mechanical Forest Industries*, Food and Agriculture Organization of the United Nations, Forestry Department 1993, online at http://www.fao.org/docrep/T0269e/t0269e08.htm.

[67] "Wood Densification," Publication No. 838, West Virginia University Extension Service, Southeastern Regional Biomass Energy Program, 1988; "Heating your home with wood pellets," Wisconsin Focus on Energy, 2002, online at www.focusonenergy.com.

[68] David Broderick and James Houck, *Emissions Inventory Improvement Program (EIP) Residential Wood Combustion Coordination Project*, OMNI Consulting Services, Inc., prepared for Mid-Atlantic Regional Air Management Association (MARAMA), October 13, 2003.

Table 5—Wood Combustion Emissions by Technology[69]

Wood Burning Equipment	Emissions Factors (pounds per ton burned)					
	PM10[d]	NO_x	CO	VOC	SO_2	NH_3
Fireplaces; Outdoor Equipment[a]	34.6	2.6	252.6	229	0.4	1.8
Non-Catalytic Woodstoves: Conventional[b]	30.6	2.8	230.8	53	0.4	1.7
Non-Catalytic Woodstoves: Low-Emitting[b]	15.4	2.0	123.9	13.5	0.4	0.9
Non-Catalytic Woodstoves: Pellet-fired[c]	**4.2**	**13.8**	**39.4**	**N/A**	**0.4**	**0.3**
Boilers and Furnaces	28.8	2.6	252.6	229	0.4	1.8

[a] Includes masonry heaters. Masonry heaters were not broken out from fireplaces in the survey. Includes all outdoor wood-burning equipment (e.g. fireplaces, chimneys, barbecues, fire pits). Emission factors for fireplaces are used.

[b] These source classification codes are proposed for non-certified and certified woodstoves, respectively.

[c] These include both certified and exempt pellet stoves. PM10/PM2.5 and CO emission factors are for certified pellet stoves based on the review by OMNI (1998). Emission factors for NO_x and SO_2 are taken for certified pellet stoves (emission factors for exempt stoves not available).

[d] This study equates particulate matter emissions at the 10 micron and 2.5 micron level. However, most transport studies distinctly separate them, and Clean Air Act regulations require measurement of both types separately to determine compliance (attainment).

Pelletizing wood and other biomass feedstocks is a technique widely used in Japan, Scandinavia, and parts of Europe that has helped overcome the barriers to transportation of wood fuels.[70] Other countries have greenhouse gas and pollution taxes that are far more restrictive than in the United States, creating incentives to embrace biomass fuels that might seem too expensive in our domestic context. However, as long-term patterns in US pollution policy tend to mimic European standards, it is instructive to note that affordability is not inherent in the feedstock itself, but in how energy itself is regulated and valued at the local, state and national levels. In addition, changing markets for heating oil and natural gas have inspired changes in energy use: pellet manufacturers in the US have grown at over 30% per year, and pellet stove sales soared over 50% in 2005.[71]

[69] Megan Schuster and Stephen Roe, "Survey of Residential Wood Combustion Activity and Development of an Emissions Inventory for the MANE-VU Region," prepared for the National Emissions Inventory Conference, June 10, 2004 (www.marama.org).

[70] Matthew Griffiths, "Pellets appeal," *Renewable Energy World*, February 3, 2005.

[71] Paula Tracey, "Jaffrey firm puts mills' byproducts to good use," *New Hampshire Union Leader*, May, 9, 2005; Katharine Webster, "Wood pellet stoves selling fast as home heating oil prices rise," Associated Press, September 13, 2005.

Conversion Technologies

Plants convert solar energy into chemical energy via photosynthesis. In order to animate the various appliances, machinery, and amenities of their daily lives, humans design methods to convert that stored chemical energy into power—also defined as the ability to do work. Conversion processes release the energy locked inside organic materials through the use of heat and pressure, making it available for human use. There are several processes for converting biomass to energy including direct combustion, co-firing, gasification, and pyrolysis. Moisture content of the fuel has implications for how much of the energy embodied in biomass can be converted to useful work. The following section briefly explains the role of moisture content and provides an overview of conversion technologies.[72]

Moisture Content and Energy Content

The ease with which different types of wood residues are processed and converted to energy varies depending on the type of residue and its moisture content. Moisture content affects handling costs and conversion efficiency. Moisture content (MC) is the percentage of wood mass that is water. Vaporizing water to steam requires a heat input of 1000 Btu's per pound. This means that a portion of the energy in the wood is used to eliminate the water. Consequently, lower moisture content implies higher energy content. Freshly cut wood can have a moisture content of almost 50% and significantly lower energy content per unit of weight.[73] Green chips (45% MC) have a gross heating value of 4,800 Btu's per pound. Dry sawdust (13% MC) has a gross heating value of 7,000 Btu's per pound. Dense and/or wet wood weighs more than dry wood, and consequently is more costly to transport. Densified fuel such as wood pellets normally contains about 8,000 Btu's per pound (8% MC). Unless otherwise mentioned, the report uses a 20% moisture estimate as a standard wood fuel condition.

Direct Combustion

Direct combustion—the burning of biomass materials—is the primary process used to convert biomass into useful energy. A furnace and heat exchanger together make a boiler system; wood fuels combusted in the boiler create heat. The heat itself can be used in cooler climes, such as with water pipe indoor heating. Alternately, steam produced during the combustion process can be used to turn a turbine and generate electricity.

The surplus heat escaping from the process can be used for space heating of associated plant spaces, used to power industrial processes, or directed to turn a turbine for electricity generation.[74] These systems that both produce electricity and capture waste heat are called combined heat and power (CHP) systems. While there are methods for boosting energy conversion efficiency to 40%, actual boiler efficiencies typically range around 20-22% efficiency for electricity.[75] However, when used in a CHP application, wood-to-energy systems can have conversion efficiencies of over 60%.[76]

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[72] This section draws on J. Aabakken, *Power Technologies Data Book, 2003 Edition*, National Renewable Energy Laboratory Publication TP-620-36347, June 2004.

[73] "Fuel Value Calculator," 5th Edition, produced by USDA Forest Service, Forest Products Laboratory, and the Pellet Fuels Institute; accessible at the US Forest Service website: http://www.fpl.fs.fed.us/documnts/techline/fuel_value_calculator.pdf.

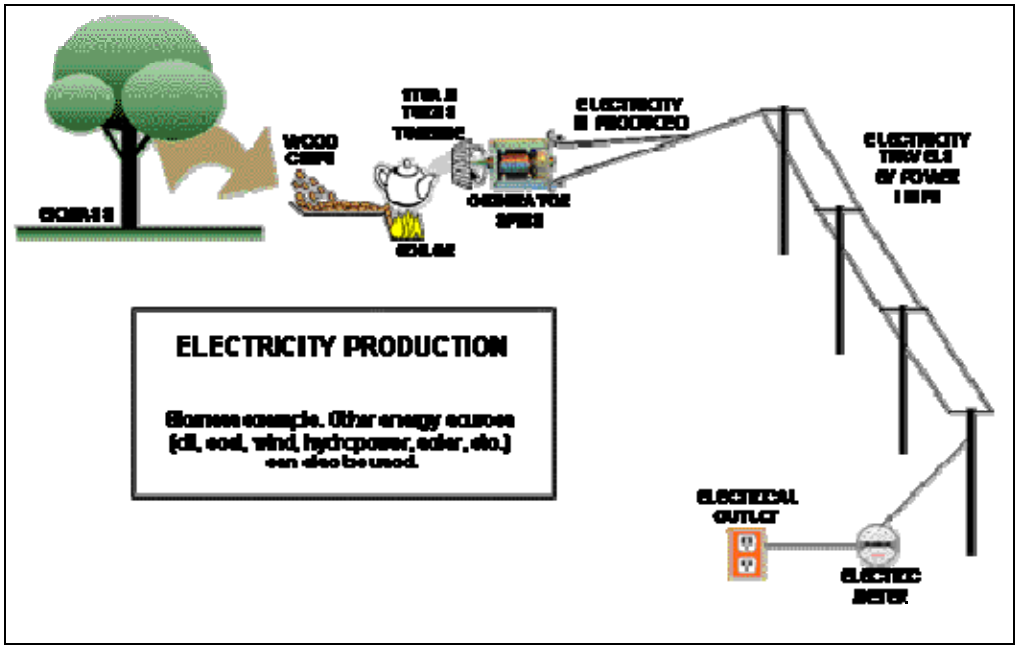
[74] Biomass Energy Technology, Wood Energy Data, Regional Wood Energy Development Programme in Asia, online at http://www.rwedp.org/d_technodc.html.

[75] Renewable Energy Technology Characterizations, EPRI Topical Report # TR109496, December 1997, "Direct Fired Biomass" and "Gasification-Based Biomass"; online at www.eere.doe.gov/consumerinfo/tech-reports.html.

[76] Lew McCreary, USDA Forest Service, personal communication, September 30, 2005.

Figure 6—Electricity from Wood Combustion

Source: State of Hawaii, Department of Energy.



The four major burner types associated with combustion are described below[77]:

Pile burner: Used in boilers burning wood with up to a 65% relative moisture content, pile burners are fed as biomass is dumped down a chute onto a pile. The biomass is dried in the heat in the refractory-lined chamber. Biomass is partially burned by underfire air, and the volatile gasses are driven off to be burned in a secondary chamber by an overfire air injection.

Grate burner: In this most common type of burner, combustion takes place, combined with stokers, on a grate. The types of grates used to support fuel beds include reciprocating, stationary, sloping, and moving grates. The thin pile of fuel on a grate burner allows more uniform air distribution compared to a heaped pile. In this situation, combustion rates can be increased more rapidly, eliminating particulate problems related to fuel dropping onto the fire. There are four main types of stokers: spreader, underfeed, traveling grate, and sloped grate stokers – the spreader stoker being most commonly used. As biomass is fed into the furnace, some of it burns in suspension while the larger pieces fall onto the grate where it burns. The ash on the grates and air blowing through the grate keeps the grate cool.

Fluidized bed: Fluidized bed burners burn the wettest and dirtiest fuels and can take fuels with a wide variety of particle sizes. The bed is comprised of an inert material like sand or limestone. The biomass is injected into the bed (which was initially preheated) where it is ignited by contact with the hot bed.

[77] Appalachian Hardwood Center, "Overview of Wood-Fired Boiler Use in West Virginia," Fact Sheet 16, April 1998; online at http://www.wvu.edu/~agexten/forestry/fact16.pdf.

Combustion air is added to the furnace under pressure greater than the pressure required to cause the bed to levitate, which forces the bed into a fluidized motion. Provided combustion temperatures are kept low, this system prevents the production of NO_x. Exhaust gases, however, still contain more particulate matter than other types of furnaces. Fluidized bed burners are rapidly becoming the preferred technology for plants >10MW because of their clean and efficient combustion characteristics.[78]

Suspension burner: Combustion occurs when biomass particles are suspended pneumatically in air. Biomass will have to be passed through a hammer mill, reducing particle size, in order to use densified biomass. Wood chips and green mill residue must be dried and sized, as particle size of biomass is crucial. A pinhole grate may be installed to catch biomass that falls to bottom of the furnace without being burned. Suspension burners usually burn at 80 percent efficiency.

Co-firing

Co-firing involves the simultaneous combustion of different fuels in the same boiler. While the capacity of the boiler does not change, the amount of emissions generated by creating the same amount of energy decreases. Biomass substitution usually ranges from 10-15% of required fuel supply.[79] Because clean biomass feedstocks like wood are relatively low in sulfur and other harmful materials, they have often been mixed with coal firing to reduce sulfur dioxide emissions that contribute to acid rain. In addition, because biomass grows through the utilization of carbon dioxide, the (sustainable) use of biomass feedstocks is considered carbon neutral and does not contribute to greenhouse gas emissions.[80] Biomass co-firing has been successfully demonstrated in the full range of coal boiler types, including pulverized coal boilers, cyclones, stokers, and bubbling and circulating fluidized beds. Co-firing biomass feedstocks, such as wood residue, with more traditional fossil fuels, such as coal, assists in emissions reduction for the fossil fuel. Fluidized bed combustors can achieve emission factors of half or less than grate burners for all monitored pollutants in a co-firing scenario.[81] The energy conversion efficiency of biomass-coal co-firing ranges between 33-37%.

Gasification

Gasification systems operate differently than boilers in biomass-only or co-firing systems that directly burn the biomass. Gasification requires the use of high temperatures [yet below that required for combustion] and an oxygen-starved environment to convert biomass into a gaseous mixture of hydrogen, carbon monoxide, and methane). The product gas can be used to generate heat and electricity by direct firing in engines, turbines and boilers after it is “scrubbed” to remove particulates and problem chemicals. Alternatively, the product gas can be reformed to produce fuels such as methanol and hydrogen for fuel cells.[82] The cleaned gas can then be used to fuel combined cycle (IGCC) power generation systems, which are up to three times more efficient than combustion systems (60% conversion efficiency for combined cycle versus

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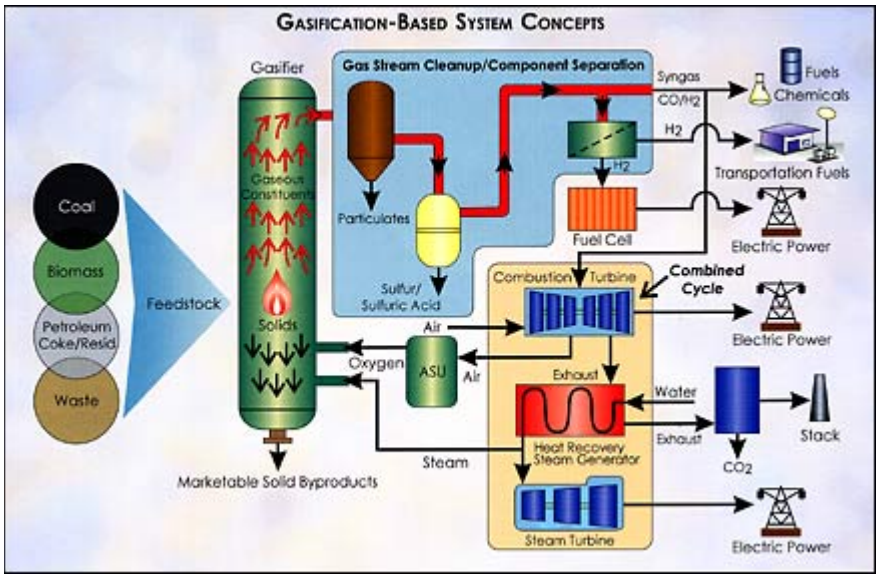
[78] *Bioelectricity Vision*, 2004, pp.5-6.
[79] Renewable Energy Technology Characterizations, December 1997, “Biomass Co-firing.” Online at www.eere.energyh.gov/consumerinfo/pdfs/bio_co_fire.pdf, p.2-35.
[80] M.K. Mann and P.L. Spath, “A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant,” *Clean Production Processes 3* (2001), p.81-2.
[81] G. Morris, “The Value of the Benefits of US Biomass Power,” Green Power Institute, Berkeley, CA; NREL, 1999.
[82] *Bioelectricity Vision*, 2004, p.6

20% for combustion).[83] Gasification-based systems may present advantages compared to combustion in terms of clean and efficient operation and economies of scale.

Figure 7—Gasification System Process Flow

Source: US Department of Energy.



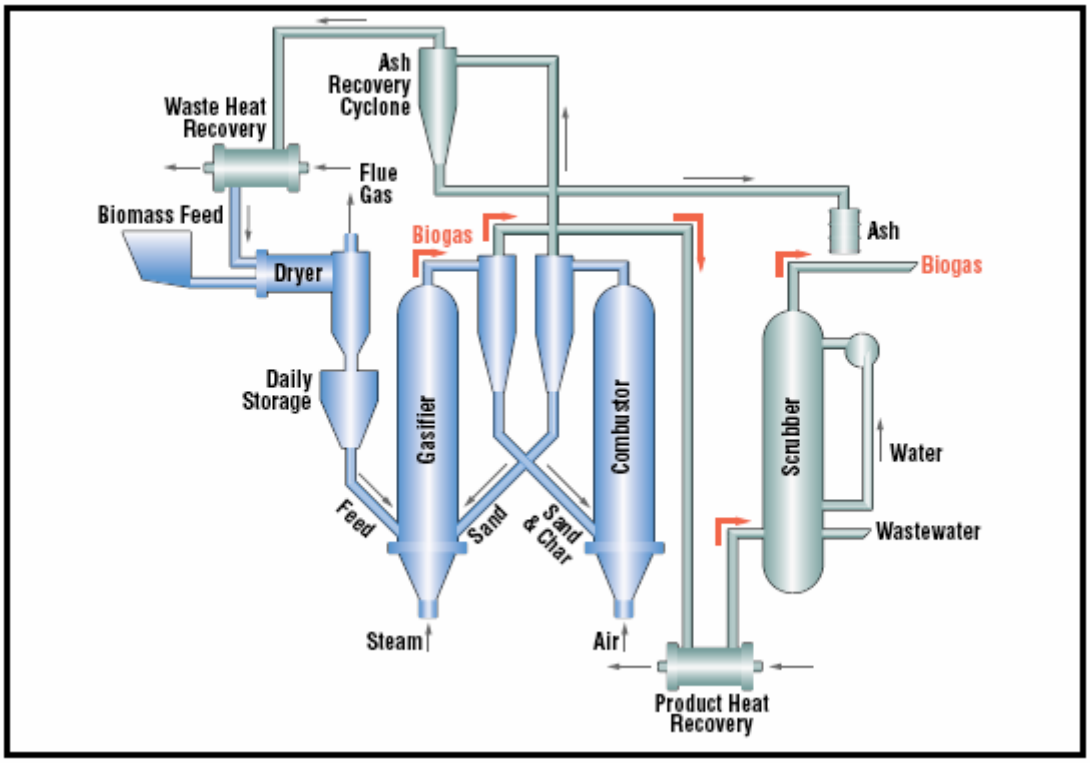
Internationally, gasification has provided hope for clean energy systems based on biomass. As reported in WWF *Bioelectricity Vision*: "Hundreds of small-scale fixed bed gasifiers are in operation around the world, in particular in developing countries. Recent gasification activities, mainly in industrialised countries, have focused on fluidised bed systems, including circulating fluidised bed systems. Larger systems coupling combined cycle gas and steam turbines to gasifiers (biomass integrated gasification combined cycle, BIG/CC) are at the demonstration stage. BIG/CC systems could lead to electrical efficiencies of about 50%."[84] With such successes worldwide, in combination with significant investment in gasification technologies by the US Department of Energy, gasification seemingly should be more prevalent in the United States. However, investment does not necessarily lead to deployment: Few gasification systems operate commercially in the US.

One notable example is the Vermont Battelle/FERCO project. This installation employs the low-pressure Battelle gasification process in which the biomass is converted into a gas and residual char at a temperature of 850°C, and a combustion reactor burns the residual char to provide heat for gasification. Circulating sand between the gasifier and combustor provides heat transfer between the reactors. This project has proved reliable, but the overall reliability of gasifiers has not been consistent enough at large-scale facilities to encourage more investment.

[83] The same quantity of biomass utilized would create nearly twice as much energy (10-20% boiler efficiency vs. 25-40%+ gasifier efficiency; R. Sims and J. Gigler, "The Brilliance of Bioenergy," *Renewable Energy World*, Jan-Feb 2002.
[84] *Bioelectricity Vision*, 2004, p.6.

Figure 8—Vermont Battelle/FERCO Gasifier

Source: National Renewable Energy Laboratory.



Pyrolysis

Like gasification, pyrolysis is thermal decomposition occurring in the absence of oxygen. The processes are similar enough that the reaction temperature and the composition of the byproducts are the main indicators of difference. Lower temperatures and a short vapor residence time in the processor define the "fast pyrolysis" reaction, which produces bio-oils that can be used for heating or transportation. Conversely, higher temperatures and long residence times characterize gasification. Fast pyrolysis for liquids production is of particular interest currently as the liquids are transportable and storable. These features allow biomass to be converted into bio-oil at one location and used for energy or chemicals in another location, something that gasification or direct combustion processes cannot do.

Table 6—Typical yields from different modes of wood pyrolysis (dry wood basis)

Source: IEA Biomass Pyrolysis Network.

Mode	Conditions	Liquid	Char	Gas
Fast pyrolysis	moderate temperature, short residence time (particularly vapour)	75%	12%	13%
Carbonization	low temperature, very long residence time	30%	35%	35%
Gasification	high temperature, long residence times	5%	10%	85%

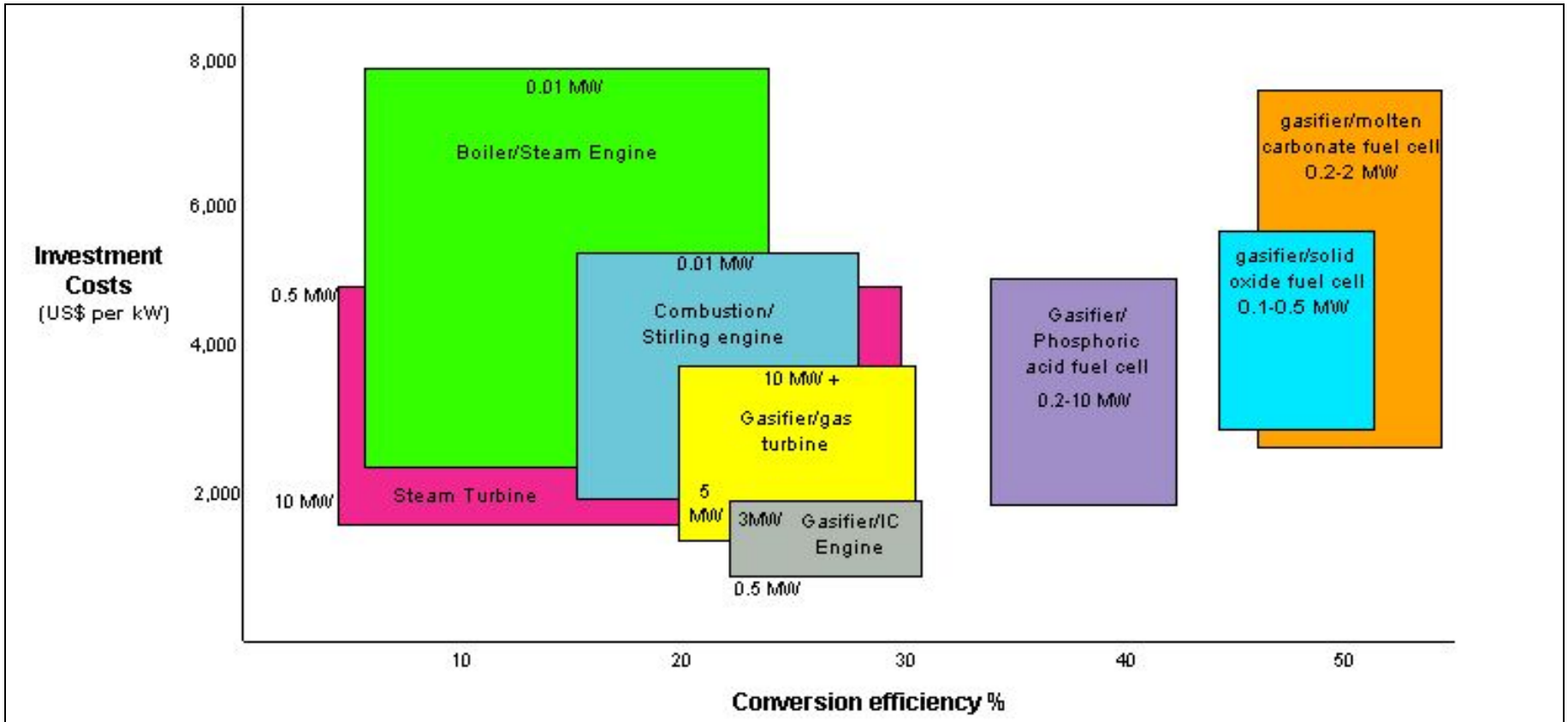
Pyrolysis requires finely ground, very dry feedstocks. While most work has been carried out on wood due to its consistency, virtually any form of biomass can be considered for fast pyrolysis. The ability of mobile pyrolysis units to convert wood residues to a densified bio-oil while operating in the field makes it an excellent prospect for addressing invasive woody species removal or reducing the wood processing burden caused by pests like the emerald ash borer.

Economies of Scale and Economies of Efficiency

Technology choices require assessment of available capital and equipment cost, combined with specifications for the appropriate size. In general, steam turbines and boilers have been the most popular mechanisms for converting wood to energy. These technologies both benefit significantly from economies of scale. Figure 9 displays the costs of various conversion technologies over a range of conversion efficiencies, focusing on small scale bioenergy (<10MW). At this scale, small boilers can be incredibly expensive per kilowatt investment. However, gasifiers are not subject to strict economies of scale. Figure 9 also shows that at any efficiency, gasifier prices increase with size. Therefore, while boilers are well-tested and versatile, returns to scale can make smaller boilers expensive. Gasifiers can be economically justified in a variety of sizes, making them more modular and ideal for less centralized energy production throughout cities or rural areas.

It is also important to note that scale and capital cost are not the total determinants of the cost of energy produced. This figure clearly shows that gasification technology has higher conversion efficiency on average than boiler technology, although the two technologies do overlap in price and efficiency options. While a 10MW steam turbine system can be built for less than $2,000/kw, the conversion efficiency on such a technology might be at the lower end of boiler technology options—less than 10%. At the same time, a 10MW gasifier could cost twice as much, but may have double or more the conversion efficiency, making the difference between the options less obvious without more information about other factors such as fuel options and availability.

Figure 9—Comparison of cost, efficiency, and size for a range of small-scale bioenergy technology systems



Source: R. Sims and J.Gigler, "The Brilliance of Bioenergy," *Renewable Energy World*, Jan-Feb 2002.

Benefits of Wood Residue versus Standard Fossil Fuels

Environmental impacts

The potential environmental benefits that can arise from utilizing well-managed biomass energy feedstocks as opposed to fossil fuels include:

- lower emissions of certain criteria pollutants compared certain fossil fuels;
- lower emissions of criteria pollutants and greenhouse gas emissions compared to other wood residue uses;
- CO_2 neutrality.[85]

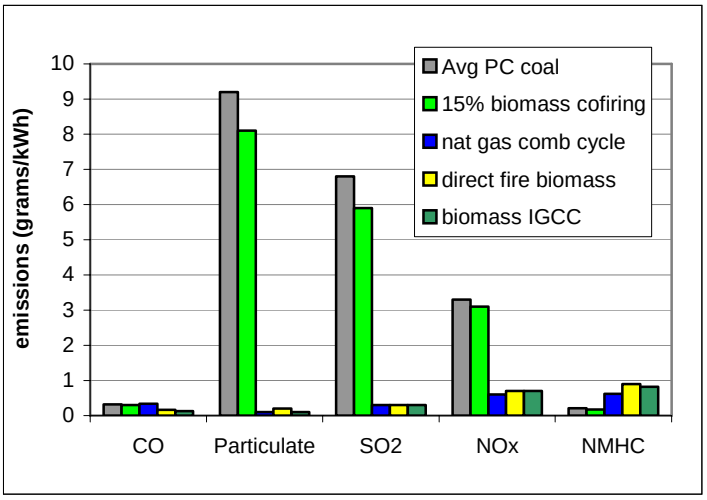
This section explores each of these benefits in turn.

Air pollution: Wood Residue versus Fossil Fuel Feedstocks

The actual "greenness" of biomass fuels such as wood is frequently called into question due to perceptions of biomass energy emissions. In some cases, the negative perception that using biomass for fuel is highly polluting are well-founded: open burning and residential firewood use have exacerbated smog in many cities and prompted no-burn days announced by local weather stations. Clearly, biomass energy technologies do not involve open burning. Nevertheless, combustion of any material creates some quantity of harmful emissions. Given this reality, the questions we need to ask about wood residue energy to assess its impact on the environment are: (1) what is the life-cycle emissions profile of biomass energy production in comparison to the coal or natural gas energy for which it would substitute; and (2) are there remedies for emissions generated by biomass energy production?

Figure 10—Biomass Energy Life Cycle Emissions

Source: Mann and Spath, 2004.



With regard to the first question, biomass energy resources like wood residue compare quite favorably with coal and natural gas in terms of their contribution to criteria pollutant emissions regulated by the Clean Air Act. NREL research demonstrates that, with the exception of non-methane hydrocarbons, biomass combustion or dedicated biomass IGCC dramatically decrease emissions criteria pollutant emissions when compared to a coal emissions baseline.[86] In fact, in all criteria pollutant categories, the biomass energy technologies are almost identical to the emissions for natural gas, which is touted as the cleanest fuel available today. Replacing coal with biomass nearly

[85] *Bioelectricity Vision*, 2004, p.35. The use of forestry residuals and select debris can reduce forest fire risk; in addition, if energy crops are utilized on degraded or partially agricultural lands, other benefits include soil and watershed protection, and enhanced habitat to protect biodiversity

[86] Margaret Mann and Pamela L. Spath, "A Comparison of the Environmental Consequences of Power from Biomass, Coal and Natural Gas," Presentation at the Energy Analysis Forum (Golden, CO, May 29-30, 2002); online at www.nrel.gov/analysis/pdfs/m_mann.pdf.

eliminates particulate and sulfur emissions. Co-firing only 15% biomass with coal can reduce emissions of coal-fired power plants between 6 and 20 percent.[87]

Table 7—Co-firing and Biomass Combustion Emissions *Reductions* compared to Pulverized Coal (grams/kWh)

Source: Mann and Spath, 2004.

Technology	CO	Particulate	SO_2	NO_x	NMHC
15% biomass cofiring	6%	12%	13%	6%	19%
100% biomass	50%	98%	96%	79%	-329%

Other data from advanced industrialized countries demonstrate some variation from these findings in that NO_x and CO emissions from biomass are greater than that of coal, depending on the technology used. European cases suggest that well managed biomass plants tend to hold close to coal-fired emissions in NO_x and CO, however, and the overall pattern of low particulates, very low sulfur, and low volatile organic compounds still holds.[88]

With regard to the second question of emissions unique to woody biomass, there are valid concerns regarding non-regulated pollutants from any form of combustion. Wood that contains certain preservatives or that contains certain contaminants from industrial processes can cause environmental risks if added to the combustion process. When exposed to heat, the contaminants volatilize into toxins harmful to human health. These materials also prevent the processing and use of ash, char, and other combustion products that may have commercial value.[89]

For clean and efficient energy production, the best practice is to prevent contaminated materials from entering the wood residue-to-energy supply chain. There are also strong short-term, direct incentives to energy producers and their suppliers for careful oversight of feedstock supply: Treated wood materials can also transform into chemical compounds that corrode or otherwise damage the conversion facility itself. Wood energy facilities in Michigan and nationwide have well-established practices of manual inspection at offloading, in which even a very small amount of a suspicious substance can merit turning away contaminated loads.[90] There are also metals screening techniques that remove nails and other contaminants as the wood residue is sorted by size and processed before conversion. Finally, most wood energy facilities will not accept any sort of demolition wood, and often bar generally cleaner construction residues as well.[91]

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[87] "Wood energy can compete well with oil, natural gas and coal. The prices paid by fuel users invariably do not reflect society's total cost of production and consumption. These additional costs, known as externalities, include the costs of air and water pollution and hazardous and non-hazardous waste disposal. When these externalities are counted in energy costs, wood fuel becomes even more inexpensive. Estimated environmental costs from wood were less than 1 cent per kilowatt hour, higher only than solar and wind energy." *Waste: A Hidden Resource*, Special Report 67: Status and Potential of Michigan Natural Resources (SAPMINR), Michigan Agricultural Experiment Station, MSU, January 1995, online at http://www.msue.msu.edu/msue/imp/modsr/03239567.html.

[88] *Bioelectricity Vision*, 2004, p.36-7.

[89] Lew McCreary, USDA Forest Service, personal communication, September 30, 2005.

[90] Andy Vajcner, Central Michigan University Plant Manager, personal communication, December 2004; Westbioenergy, *Lessons Learned from Existing Biomass Power Plants*, Appel Consultants, prepared for NREL, EPRI, and Western Regional Biomass Program, No Date, online at www.westbioenergy.org/lessons/les01.htm; Badger 2002.

[91] Some large recycling companies have the capital and workforce to accept C&D residues. Tierra Verde Industries (TVI) helps smaller California municipalities meet California's 50% waste diversion goals (50%). While its primary feedstock is green residues from land clearing, landscaping, and residential wastes, it also has high-technology screening equipment that makes

Ultimately, the efficiency of the conversion technology used determines emissions levels. When the biomass fuel is combusted most thoroughly given the optimal air flow and temperature, fewer emissions result. [92] In addition, large-scale biomass energy production facilities include best available technologies such as scrubbers in order to capture particulates and other pollutants that do result from combustion.

Gasification technology is not commercially deployed in Michigan at this time. However, information from gasification projects in other states and countries demonstrate that emissions from gasification are lower than from combustion of fossil or biomass fuels.[93] Specifically, the lower temperatures needed for the initial stages of gasification prevent the formation of nitrous oxides, and the conversion of biomass to gaseous form allows more complete combustion.

Air pollution: Wood Residue-to-Energy versus Other Waste Outcomes

The above examples compare emissions by energy conversion technology and feedstock. However, in considering wood residues and biomass residues more generally, it is important to consider the pollution consequences of **not** using these residues for energy. In a 1999 study for the National Renewable Energy Laboratory, extensive data from the large California biomass energy market demonstrated that using biomass for energy diverts wastes from more polluting fates in landfills or even open burning.[94] This includes pollution from forest fires compared to capturing and using the understory fire load to fuel a boiler that has good emission controls.

Greenhouse Gases and Carbon Balance

Burning both biomass and fossil fuels causes carbon dioxide (CO_2) emissions. However, unlike fossil fuels, biomass fuel feedstocks grow back and absorb about the same amount of CO_2 emitted. Sustainable biomass resource production through residuals processing or energy crops production will produce few, if any, CO_2 emissions above that which are taken in during the biomass life-cycle.[95] As a result, biomass co-firing has been embraced by many industries as a voluntary means for reducing their greenhouse gas emissions.[96] This could create tax credits for power plants if legislation is passed for CO_2 and/or other greenhouse gas emissions.[97]

Another less frequently mentioned benefit aside from reducing coal-based greenhouse gas emissions is the diversion of biomass from other end uses that produce even more greenhouse

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C&D residues an acceptable input to some of their products; Larry Trojak, "The Many Shades of Green," *Biocycle*, September 2005, pp.27-28.

[92] The exception to this rule is emissions of nitrous oxides (NO_x). Higher temperatures can combust biomass more thoroughly, but are also conducive to NO_x formation.

[93] "Biomass Gasification," DOE-EERE, online at http://www1.eere.energy.gov/biomass/gasification.html.

[94] G. Morris, *The Value of the Benefits of Biomass Power*, NREL/SR-570-27541, November 1999.

[95] "A major benefit of substituting biomass for fossil fuels is that, if done in a sustainable fashion, it would greatly reduce emissions of greenhouses gases. The amount of carbon dioxide released when biomass is burned is very nearly the same as the amount required to replenish the plants grown to produce the biomass. Thus, in a sustainable fuel cycle, there would be no net emissions of carbon dioxide, although some fossil-fuel inputs may be required for planting, harvesting, transporting, and processing biomass. Yet, if efficient cultivation and conversion processes are used, the resulting emissions should be small (around 20 percent of the emissions created by fossil fuels alone). And if the energy needed to produce and process biomass came from renewable sources in the first place, the net contribution to global warming would be zero." From "Environmental Impacts of Renewable Energy Technologies," Union of Concerned Scientists, updated 2002, online at www.uscusa.org.

[96] *Renewable Energy Technology Characterizations*, December 1997, "Biomass Co-firing," pp.2-37, online at www.eere.energy.gov/consumerinfo/pdfs/bio_co_fire.pdf.

[97] "Fossil CO_2 reductions are currently being pursued voluntarily by utilities in the U.S. through the federal government's Climate Challenge program. These utilities may be able to receive early credit for their fossil CO_2 emission reductions for future use in the event that legislation is passed which creates market value for CO reductions." Ibid.

gases than using them for energy.[98] As with other emissions mentioned above, overall greenhouse gas emissions from biomass fuels are less than from other transformations of that same biomass. In the short term, biomass used for fuel will add more atmospheric CO_2 than if it were buried in landfill, but over time the landfill will out-gas CO_2. In addition, landfills also emit methane (CH_4), and its greater radiative effectiveness as a greenhouse gas creates a more serious long-term burden.

Employment Impacts

As noted earlier, wood residue feedstocks are ideal for smaller, decentralized systems where conversion facilities are located near the biomass resource itself. Biomass energy facilities utilizing wood residue can help bolster jobs in rural areas with resource-dependent economies, which are usually characterized by slow economic growth. An analysis of biomass energy potential in OECD countries suggested that a shift to biopower would help rural economies:

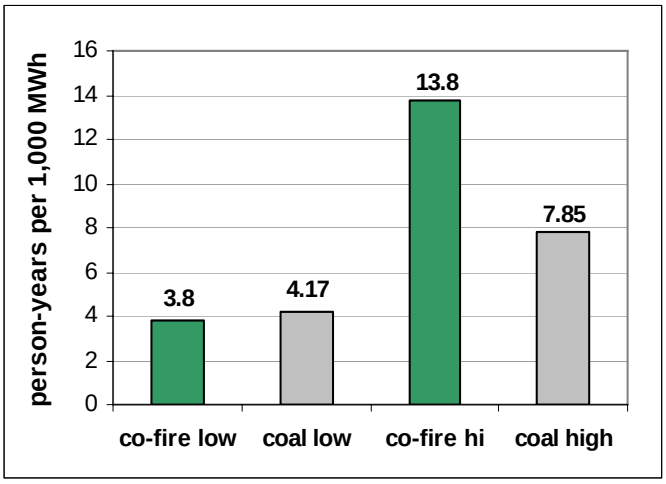
> *"…the use of biomass energy has some employment benefits over using fossil fuels at a national level if there is a substantial employment generation effect from producing the biomass fuel, especially if it substitutes imported fuels. But, the greatest value of bioelectricity schemes with regard to employment lies in the fact that quality jobs could be generated where there is great need for them, in particular in rural areas where job maintenance and creation and economic growth are of issues of concern."*[99]

Recent studies using only data from the United States show that both power plants and fuel production operations provide rural jobs with good comparative wages and benefits. In addition, there are almost twice as many supporting jobs than in the plants themselves, with total employment equal to 4.9 fulltime jobs per each megawatt of net plant generating capacity.[100]

Despite the fact that co-firing uses biomass feedstocks with coal requires far less biomass feedstock than coal, the utilization of up to 10-20% biomass also enhances local economies. Figure 11 compares biomass co-firing needs with coal mining needs, since both require essentially the same plant type and job functions after the fuels are processed. The low labor scenarios for biomass co-firing include mill residues and some types of urban wastes; high labor scenarios include biomass plantation operations involving larger-scale and more frequent transportation and processing. One study also notes that labor-intensity of coal production dropped 39% from 1988 to 1998, and is estimated to fall another 36% by 2008.[101]

Figure 11—Biomass Co-Firing vs. Coal Mining, Low and High Labor Scenarios

Source: Singh and Fehrs, 2001.



[98] Margaret Mann and Pamela L. Spath, "A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant," Clean Production Processes 3, (2001) pp. 81-91; the authors highlight that cofiring biomass prevents the methane formation that would otherwise occur if that same volume of wood underwent decomposition in mulch applications or in a landfill.

[99] *Bioelectricity Vision*, 2004, p.26.

[100] Morris 1997.

[101] Virinder Singh and Jeffrey Fehrs, *The Work That Goes Into Renewable Energy*, Renewable Energy Policy Project Report #13, November 2001; labor figures p. 21.

Consequently, the numbers in Figure 11 are likely to shift more in favor of biomass co-firing. Finally, coal mining is a dangerous industry whose regulations are poorly enforced. Death on the job, long-term respiratory illness, and destruction of community water supplies and ecosystems are the hallmarks of coal extraction.[102] In terms of quality of life, biomass clearly benefits local communities and workers more than coal.

While more attention has been focused on the need for steady jobs in rural areas, there are also opportunities for some urban jobs. Utilization of UTR could help provide a boost to employment to urban areas which are also host to unemployment problems. Municipalities and counties that design and implement UTR collection systems and support locally-based power production can also increase their employment figures while addressing landfill and energy problems.

Efficiency and Reliability Impacts

Employment is only one economic benefit provided by investing in biomass energy from wood residue. Local biomass feedstocks actually help produce cheaper energy for rural areas, creating a locally shared economic benefit. As energy production becomes less centralized, overall production becomes more labor intensive—but also more reliable and efficient in transmission.[103] For example, coal-based electricity costs run higher to remote areas due to the extra expense of transmission lines and infrastructure. It is also more expensive because the further electricity travels, the more is lost in transmission--which means **all** customers are paying the price for wasted energy. Up to 70% of electricity can end up as line losses—energy lost in transmission. Localized energy production in rural areas using biomass can help overall economic health of a region or state by enhancing systemic energy efficiency. Using locally based systems that complement highly centralized standard energy production is called distributed energy (DE) or distributed generation (DG).

A 1999 study of 275 DG systems found that electricity supply needs and deferral of transmission/distribution system upgrades were the two primary reasons for supporting distributed energy.[104] DG is also an excellent opportunity for integrating locally based biomass energy systems into the overall energy infrastructure. The shortcomings of biomass fuels due to transportation difficulties and being more closely "tied to the land" are much less of an issue when viewed from the perspective of the need for decentralized infrastructure that lets customers get what they pay for, instead of paying the majority of their bill for energy lost in transmission. Basing power on locally based biomass energy plants in this fashion would contribute to better power reliability and quality, lower energy costs, more choice in energy supply options, and greater predictability of energy costs (lower financial risk) with renewable energy systems.[105]

Such transformations will not be seamless. A shift toward biomass energy raises the prospect of dramatic structural shifts in fuel consumption patterns. Rural areas will take on a larger energy load, and centralized energy producers must adapt to new patterns of load and consumption in the overall system.[106] Yet over the longer term, significant use of renewable technologies would relieve fuel supply challenges with cleaner biomass feedstocks.

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[102] Jeff Goodell, "Cooking the Climate with Coal," *Natural History*, May 2006, online at www.naturalhistorymag.com.
[103] Tom Stanton, Michigan Renewable Energy Program, MPSC, personal communications, January 2005.
[104] "Distributed Energy Basics: The DE Solution," Energy Efficiency and Renewable Energy, Department of Energy, online at http://www.eere.energy.gov/de/basics/der_basics_dersol_bene_major.shtml.
[105] Ibid.
[106] "Executive Summary," *Distributed Energy: Towards a 21st Century Infrastructure*, p. 7, Consumer Energy Council of America, accessed February 9, 2005 online at http://www.cecarf.org/Publications/MiscPub/DEExecSummary.pdf.

Outlook for Wood Energy in Michigan

Barriers to Wood Energy

If wood energy has so many potential benefits, the natural question is why isn't everyone using it? The more widespread adaptation of wood energy has been limited by certain physical properties of the wood itself, as well as by political and economic factors.

Energy Content: The primary conversion technologies currently used to extract energy from solid wood only reach 15-20% conversion efficiency. Newer technology is more efficient, and gasification shows even more promise. However, people will continue to view fossil fuels as a better investment because they can produce tremendous amounts of energy per volumetric unit conveniently and (at least until recently) cheaply.

Market accounting versus social accounting: Not all costs and benefits are incorporated in energy's costs. The cost of fossil-based electricity could be taxed to reflect higher public health costs imposed on society. Conversely, the cost of wood energy could be subsidized to reflect the need to continually replenish wood resources for a sustainable energy system.[107] The perception of fossil fuel energy as the most efficient and effective may change when environmental and public health costs can be incorporated into the price of energy and cease being considered externalities whose cost is displaced onto society.

Tastes and Preferences: People do not have to change any of their standard operating procedures to use fossil fuels even if they do cost more. In economic terms, demand for fossil fuels is somewhat inelastic, such that when prices increase people still will pay for that product because there are no substitutes. This can mean there really are no substitutes physically existing, or it can mean that there are no products that are considered substitutes because they are unacceptable for some reason in the eyes of consumers. These reasons can include simple inconvenience. This is true both of consumers, who are not actively seeking substitutes for fossil fuel-based heat or electricity, and of utilities, who are not actively prospecting wood resources to establish wood energy production facilities. Neither utilities nor consumers need change their standard operating procedures to use fossil fuels, even if they do cost more than wood systems will—once established. Change in itself is perceived as highly costly, and this perception helps explain why more effort has not been directed toward renewables by utilities that have specialized in non-renewables for decades.

Centralization: By their very nature, biomass fuels (excluding liquid fuels) are difficult to transport. Given our highly centralized and inefficient energy production/distribution systems, it is difficult to integrate biomass energy without higher transport and storage costs. Biomass fuels are by their nature more suitable to distributed generation systems. Transporting wood fuels over long distances is generally not economically prudent. Because of its handling and storage requirements, the initial cost of a wood biomass energy system is approximately 50% higher than that of a fossil fuel system, making a renewable energy system a more daunting investment prospect. Consequently, most wood energy systems require a systems approach to their design as an accessory to another function. In their daily operations, forest industries produce enough wood residue to fuel their own operations by installing wood-fired boilers or gasifiers. They thus avoid both higher energy costs as well as the time and costs associated with disposal of a "waste" product. Aside from forest products industries that often use wood

[107] Robert Costanza et al., "The value of the world's ecosystem services and natural capital," *Nature* 387: 253-260, 1997; Reid J. Lifset, "Full Accounting: Where Industry Meets Ecology," *Journal of Industrial Ecology*, New York Academy of Sciences May/June 2000, online at http://www.greenbiz.com/toolbox/howto_third.cfm?LinkAdvID=23883.

on-site, many potential wood energy users are far removed from potential sources of waste or surplus wood that they might use. Decentralization of wood resources presents challenges to an effective supply chain, and in turn innovation and demand are depressed when obstacles seem too great to overcome.

Burden of the Past: Historically, there have been grave environmental and public health consequences from free wood burning, including dangerous particulate and air toxics emissions. Newer boiler technologies can prevent the majority of harmful emissions, and high-temperature gasification almost completely combusts wood feedstocks, leaving only small quantities of ash for disposal. While new combustion systems are cleaner and gasification is cleaner still, there is still a perception that wood energy might not be "clean enough" to be green. There is also the argument for natural gas. Despite clear emissions benefits over coal, there are still more emissions from wood as compared to natural gas. Natural gas is an abundant resource that does not contribute to our dependence on foreign oil, and that emits far fewer harmful substances than coal. Yet it is a still non-renewable resource whose price has become quite volatile. In northeastern and Midwestern states we see institutions with boilers switching to wood as a replacement for natural gas.

Unsustainable practices: If not harvested sustainably, wood feedstocks could erode and worsen the carbon balance. For wood energy to be truly renewable, sufficient planning and timing must accompany harvesting and processing in order to maintain or reduce greenhouse gas emissions. Without management, harvesting will cause further decline of forested areas that play a critical role in moderating climate change. In addition, the role of trees as part of functioning natural ecosystems maturing under particular local conditions must be respected if wood is to become a more useful energy feedstock in the United States without the destruction of valuable existence values of forests as whole entities that preserve biodiversity, atmospheric quality, critical landscape buffers against heat, wind and erosion, and as greenhouse gas sinks.

Benefits of Wood Energy

Despite the drawbacks, this report argues for the investment of time, money, and planning effort in policy development to support of wood residue-to-energy projects. Why should we invest in this form of biomass energy?

Energy security: International instability and volatile petroleum prices have raised questions about the wisdom of reliance on foreign energy resources. Wood is relatively plentiful in the United States, is suited to local energy production in a secure distributed generation framework, is available at low cost or no cost in urban areas as waste, and can also be made more plentiful through deliberate plantation planning as an energy crop.

Climate change and environmental quality: Standard fossil fuels generate carbon dioxide emissions that contribute to global climate change, but wood fuels emit less than 90% of the carbon dioxide than petroleum or coal. If wood replacement rates are correctly applied, wood energy can be carbon neutral. As for criteria emissions, newer technologies have reduced emissions from wood firing dramatically, and in the case of gasification, most emissions are nearly eliminated. Furthermore, wood and energy crop resources are relatively sulfur-free.

Sustainability: Wood can also be managed as a carbon-neutral renewable energy resource—otherwise known as closed-loop biomass fuel. Management considerations include a sustainable rate of harvesting forest scrub or damaged trees, as well as replanting to maintain carbon cycling at the pre-harvest rate. "Energy crop plantations" of poplar or willow have been

successfully deployed outside the United States as closed loop biomass resources that extract as much carbon as is released by wood combustion or gasification. Ecosystem values, which are less quantitative but more critical in terms of species diversity and long-term forest health, are often considered a criterion for renewable resources.

Ecosystem Health: Distributed biomass markets can help provide local markets for woody biomass removed from forests to improve forest health. Removal of woody biomass can reduce hazards associated with wildfires, can make forests more insect and disease resistant, and can enable the removal of invasive species. Removal of this biomass material can also improve growth rates and increase removal rates for greenhouse gases.

Socio-cultural compatibility: Wood is the oldest and most well understood biomass resource next to manure. Both have been used for home heating cooking in pre-industrial societies worldwide, from ancient tribes in Europe and Africa, to early American settlers during the great Westward expansion, to rural settlements in Asia and Latin America today. Today, many citizens of industrialized countries still understand wood as a fuel, and some even use it regularly for heating and cooking in more remote areas or colder climes. They are disposed to accept wood (as opposed to manure, another traditional fuel) as a viable fuel option in lieu of petroleum or coal-based energy sources.

On-demand: Wood is a dispatchable energy resource, meaning it is available on-demand from a physical storage site, like gasoline and coal. Other renewables such as solar and wind energy are not dispatchable but intermittent. Some solar and wind energy may be stored in batteries, but the energy sources themselves cannot be controlled or stored. In other words, they are more of a “use it or lose it” source of energy, whereas wood and other forms of biomass can be set aside and protected for use in the future.

In summary, there is no silver bullet for our energy crisis. Yet despite the drawbacks, there are many compelling reasons to invest in wood residue-to-energy projects. Based upon its clean, renewable, and reliable energy characteristics, Michigan decision makers need to understand what wood residue resources we have, and what steps we can take to make them easier to use. The next section provides recommendations for growing the contribution of wood residues to Michigan’s energy portfolio.

Recommendations

Given the benefits illustrated above, combined with the presentation of proven and near-market technologies that can produce clean energy from biomass, what actions could foster increased biomass use in Michigan’s energy portfolio? In order to take concrete steps to increase biomass energy in Michigan, we must first assess Michigan’s level of wood energy readiness through resource and facility inventories and target market identification.

1. Michigan Wood Residue Inventory

While many studies of wood residue quantities have been conducted nationwide, Michigan does not have a recent study. For estimating renewable energy resource potentials, clearly there is a need for a more recent inventory of wood residues in Michigan. It would be even better to create a system for gathering this sort of information on a routine basis. Initial investment in information gathering will also help educate producers and consumers about alternative uses, and clarify the importance of energy conversion as part of an overall wood recycling program.

More importantly, a well-designed, replicable study of wood supply is necessary to support increased interest and investment in wood as an energy resource.

The response to the emerald ash borer infestation currently plaguing Southeast Michigan provides an opportunity for such a study. With money from USDA-USFS, the Southeast Michigan Resource Conservation and Development Office, in collaboration with MDNR, MDEQ, and MBEP, announced a request for proposals for study of urban wood residue with a focus on the dramatic growth in wood residue supply due to the emerald ash borer epidemic. This study will further the work done in *Urban Wood Residue in Michigan* (1994). However, due to resource constraints, this report will not be able to comprehensively establish wood residue market information throughout the state, as interviews and surveys only covered quarantined counties in southeast to middle-lower Michigan. Ongoing efforts to work with DNR and to conduct research through the Michigan Biomass Energy Program will be necessary to extract information about markets, prices and supply dynamics in more detail. This detail will hopefully create opportunities for brokers to aggregate and extract energy or other uses from hitherto undervalued wood residues. The SEMI-RCD wood residue assessment is expected in fall 2006. See Appendix B for more details.

2. Boiler Inventory

Boiler replacement is an ideal time for inserting biomass-ready technologies. An inventory of existing boilers in Michigan would identify boiler age and type. Some facilities have the types of boilers (under-fire stoker, traveling grate) that can use biomass fuels like wood with no or minimal modifications. Alternatively, more advanced technologies might replace the wood-to-energy systems dominated by these older boilers. Replacing them with advanced boiler systems, modern turbines, or even gasification- or pyrolysis-based power systems would nearly double energy production capacity from the same volume of feedstock. In these replacement scenarios, financial assistance from grants, loans, tax credits or bonding could be invaluable.

3. Wood Energy Target Markets

Looking at wood residue not primarily as a source of electricity, but as an opportunity fuel for replacement of heating oil and natural gas, specific energy users with long time horizons are prime candidates for conversion to wood energy systems. Schools, hospitals, prisons, cities, and other non-profit organizations do not operate on a three- to five-year payback mentality. Because they have a longer time horizon than business, they can look out fifteen or twenty years and appreciate the life-cycle costing and price stabilization that biomass energy systems can provide. They also have more to gain by investing in their communities. The Biomass Energy Resource Center of Montpelier, Vermont, helped Vermont schools pioneer the "Fuels for Schools" program 15 years ago; currently 10% of the state's students are warmed by wood heat—and wood chip prices have increased less than 1% per year.[108] The program has expanded to five Rocky Mountain States as well. The model for institutional use of wood energy exists. In the current context of volatile gas and oil prices, many Michigan institutions could capitalize on the Fuels for Schools experiences in pursuit of stable prices with a renewable energy supply. The Michigan Biomass Energy Program can provide outreach and grant funding to help demonstrate the feasibility of institutional wood boilers. Incentives such as tax credits for biomass heating/cooling or "green" bonding of biomass boilers could advance such wood energy projects on a larger scale.

[108] "School Wood Energy Programs," Biomass Energy Resource Center, online at http://www.biomasscenter.org/services/school-wood-heat.html.

These first three items identify what Michigan already has—the ingredients, the existing technology, and target markets for small- and medium-scale wood use. The next six recommendations highlight processes, policies and incentives that can make conversion of wood residues to energy more feasible in Michigan.

4. Green Permitting

Some US cities allow for quicker building permitting if the project has a green component. For example, Chicago, IL and Madison, WI have streamlined "green permitting" processes that move such projects to the front of the permitting line. The State of Michigan might consider a similar sort of permitting shift for renewable energy projects. Specifically, if a boiler will be using renewable energy feedstocks like wood, and it is a proven technology with adequate emissions testing as approved by the DEQ-Air Quality Division, such projects could be promoted to a fast track, or be processed within a given timeframe, in order to provide incentives to would-be wood energy project developers in both the public and private sectors.[109] Some of the precursors to such a process, including the aggregation of testing information on biomass combustion technologies, are currently underway as part of a collaborative effort between MBEP and MDEQ begun in 2006.[110]

5. Higher Tipping Fees and Banning Wood from Landfills

Urban wood residue is the most underutilized and least understood category of wood residue. At the same time, urban wood residue/UTR has the most potential, and is conveniently located within jurisdictional boundaries of cities that already have waste management systems. The development of recycling systems for paper, glass, plastic and other materials took time, and was not free, yet recycling has become so popular and important to communities that people support it even at times when it loses money, as in New York. Similarly, some communities have initiated urban organic residue collection such as curbside leaves in autumn and grass clippings/yard trimmings in summer. However, such programs require a variety of education, incentives and penalties to achieve compliance before they become self-sustaining. This more comprehensive approach to recycling requires more time and money from the average citizen: recycling bags cost money, the service itself adds a fee to their waste management costs, and gathering the organics requires work—although perhaps not more work than it would take to put them into a dumpster or landfill.

One way to motivate communities and waste management concerns to re-use and recycle in productive uses like energy is to raise the state's surcharge on landfilling, which would in turn raise tipping fees. Higher disposal costs will inspire innovation and redirect resources to higher value uses; ultimately, some communities, schools and institutions may even start their own wood energy projects in order to take advantage of wood residues in a context where they are too expensive to dump. In addition, banning wood from landfills altogether has been done in some states. Michigan could follow suit in order to target wood residues more specifically for diversion from the waste stream.

[109] Thanks to Derek Price at Weston Solutions, Inc. for this concept.

[110] Randy Telesz, Michigan Department of Environmental Quality—Air Quality Division, personal communications, April and May 2006.

6. Net Metering

The production of energy by local facilities with abundant natural resource feedstocks can be fostered by net metering. A net metering consent agreement (Case No. U-14346) was filed with the Michigan Public Service Commission, and comment period closed on February 1, 2005. Net metering tariffs for some of Michigan's state-regulated electric utilities have already been accepted by the Commission Staff, and work is proceeding to finalize tariffs for the rest.[111] However, the resulting value of net excess generation (approximately three to six cents per kilowatt-hour) in combination with restrictions on production size to less than 30kW, and lack of assistance for integration of independent generation to the grid make this provision far less powerful than net metering rules in other states. In order to incentivize independent power production with clean, renewable biomass resources, six to seven cents has been the standard for net metering elsewhere. Michigan can learn from states that have been successful in diversifying their energy production, and a higher value on avoided costs of energy production for utilities is an important ingredient in the recipe for renewables.

7. Production Tax Credits

Renewable energy production tax credits provide incentives to developers that help buy down the cost of excess capital for new technologies. In the case of biomass, other special investments for fuel and ash handling fuel/ash handling must also be undertaken, and credits can reduce the burden of transitioning to biomass energy from wood residues. Tax credits have been pivotal to the establishment of the wind industry in the United States, and the continual battle to have the credits extended created instability and unwillingness to invest in the wind energy market periodically over the last 17 years since the credit was first established at the federal level by the Energy Policy Act of 1992. A long-term tax credit at the state level for biomass and other renewable energy projects is a low-cost incentive that legislators could authorize, that would help generate jobs, cleaner air, and energy security in Michigan.

8. Renewable Portfolio Standard (RPS)

An RPS is a market standard requiring the production of a set amount of renewable energy. While it is a form of mandate, the role of government is not to dictate who shall produce what energy, but only to provide the means for certifying that it is in fact produced. Renewable Energy Credits are tradable forms of proof that renewable energy has been generated; "The RPS requires all electricity generators (or electricity retailers, depending on policy design) to demonstrate, through ownership of Credits, that they have supported an amount of renewable energy generation equivalent to some percentage of their total annual kWh sales."[112] Investors and energy generators make decisions about how to comply with the RPS, and because it applies to all energy generators it is not an anti-competitive measure.

An RPS is a mandate, but the state's role is merely to certify production of renewable energy, and enforce penalties for non-compliance with renewables requirements. Some states have set parameters for which sorts of energy (biomass, wind, solar, hydro) will qualify and under what conditions, but aside from setting the ground rules there is little bureaucratic role in the renewable energy credits market once established. The state does not engage in dissemination

[111] Michigan Public Service Commission, "Case No. U-14346—Net Metering Consensus Proposal," online at http://www.michigan.gov/mpsc/0,1607,7-159--105908--,00.html. The Michigan Renewable Energy Program also has a Net Metering section at http://www.michigan.gov/mrep.

[112] "The Renewables Portfolio Standard: How It Works and Why It's Needed," American Wind Energy Association 1997, online at http://www.awea.org/policy/rpsbrief.html#What.

of funds or promote any particular project, but the establishment of the credits market provides long-term security for project planning and investment. This long-term feature of Michigan's energy markets will attract large-scale energy producers to biomass energy production as they seek to improve their market position and develop an interest in driving down the cost of renewable energy through their own investment patterns and partnerships.[113]

Renewable portfolio standards focus on electricity generation, but creative arrangements could also be made to require a certain percentage of thermal energy be produced from renewables as well. Wood and other biomass are well-suited for heating since they have a stable price relative to fossil fuels and they can be stored more effectively than wind and solar energy. A thermal component of Michigan's RPS would provide tremendous incentives for collaboration on wood energy projects between utilities and larger consumers who are seeking ways to avoid the tremendous price risks of the volatile natural gas market.

9. Distributed Generation

Identifying the best applications of wood energy brings home the importance of "acting locally." Biomass resources are intimately linked to their local area. Precisely because oil and natural gas are easier to move, modern society broke the historical link with local energy production in the industrial age. We now have an overburdened and somewhat incoherent centralized energy infrastructure dominating all our productive activities in the United States. Our energy infrastructure is not very flexible, not responsive to local resource endowments, and not manageable in a modular way— in other words, vulnerable to accident or attack.[114] However, our federal system is based in part on the fact that lower levels of government are good at addressing tasks that require maximum flexibility. Similarly, many smaller units of energy production would add up to a large quantity of energy production, but being "distributed" among localities would make that energy more responsive to local conditions. In addition, local energy production is more "democratic" in that costs and benefits of that energy system are linked more closely to the service area itself. We need to reconceptualize energy in order to take advantage of a wealth of resources currently undervalued at these local production levels, and develop the security and flexibility of distributed generation.

There has been discussion of distributed generation (DG) and localized energy production in the Michigan legislature and at the Michigan Public Service Commission, yet there has been little in the way of policy changes to date, to stimulate the growth of DG installations.[115] The work of the Capacity Need Forum to identify indigenous energy resources and document available and emergent technologies that could assure adequate capacity in Michigan is a step toward the "inventory" requirement recommended earlier.[116] However, legislators could empower the Michigan Public Service Commission to support the development of a more robust decentralized energy production and distribution system in Michigan through funding programs or regulatory measures.

Establishing requirements for decentralized energy should not be viewed as uneconomic simply because these requirements would entail new investments. The prospect of making investments

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[113] Ibid.
[114] *Brittle Power*, 1982.
[115] Thomas Stanton, Competitive Energy, MPSC, March 3, 2005.
[116] The Michigan Public Service commission authorized the collaborative work of the Capacity Need Forum (CNF) to project Michigan's electrical generation capacity needs over the short and long term. "The goal is to provide policy recommendations within the current scope of the Commission's jurisdiction and under currently existing legislation, in order to assure that additional generation could be built if needed." CNF report online at http://www.cis.state.mi.us/mpsc/electric/capacity/cnf/.

in biomass energy production are often argued unaffordable, usually without incorporating the relative cost of a new biomass plant as opposed to a new coal, nuclear, or natural gas plant. Comparing new biomass facilities to existing facilities is erroneous, however, as electricity and natural gas industries are already established, and their capital costs already sunk. Policy makers need to consider the question: "Per kilowatt, how much is the investment in a **new** plant of each type?" In addition, they should also consider the costs of not investing in biomass energy: what are the costs of pollution, especially in terms of lost worker productivity and higher medical costs? Finally, as noted in Economic Impacts, investing in local energy production systems based on biomass such as wood residue would help address Michigan's economic woes through both the use of local resources that can create local jobs, and through the confidence businesses and citizens would have in reliable energy supplies.

10. Future Options: Energy Crops and Ethanol

Fast-growing trees and grasses can be managed to enrich degraded sites such as mining areas, degraded pastures, and formerly cropped fields—and can also be harvested as energy crops. The opportunity of some value-added to farmers or rural communities who engage in carefully planned wood management regimes for energy purposes could help sustain local biomass energy systems and provide income support in traditionally more depressed rural sectors. Michigan can benefit from the demonstration projects for energy crops in Iowa, Wisconsin and other states, and capitalize on lessons learned to integrate energy cropping into domestic agriculture and energy practices.

Ethanol production from cellulosic materials like wood residues (as opposed to corn) is approaching maturity in Canada and in the European Union.[117] Michigan, as the automotive design, engineering, and manufacturing capital of the world, should seriously consider the possibilities of being on the cutting edge of transport fuel technology and processing. Cellulosic biomass as transport fuel feedstock is not highly commercialized yet, but it is coming soon. Investing in systematic identification and collection of biomass residue feedstocks like wood wastes further both the near-term goal of making ethanol from cellulose, and the longer term goal of moving to renewable fuels. As with using wood residues for heat and electricity productions, using wood for biofuels reduces our dependence on high emission, nonrenewable, carbon dioxide-emitting fossil fuels that take money out of the Michigan economy.

Michigan's auto industry itself should also consider the tremendous potential of the flex-fuel vehicle market, and of the "plug-in flex fuel" movement gaining momentum throughout the United States. Some vehicles already exist that can be plugged into the electric grid to charge their battery for backup power—and at the same time rely on liquid fuels for their primary power. However, a vehicle that is able to run on biofuel and to plug in to the electric grid could theoretically be operated on entirely domestic resources. Furthermore, wind, solar, and biomass resources can all be utilized to create electricity, creating a context where plug-in flex-fuel hybrid vehicles could run entirely on renewable domestic energy.[118]

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[117] Iogen Corporation of Ottawa, Ontario, owns the world's largest cellulosic ethanol demonstration plant. Iogen's process makes ethanol from wheat straw: www.iogen.ca.

[118] David Morris, founder of the Institute for Local Self Reliance, commonly promotes plug-in flex-fuel hybrids as an industrial revolution that could revitalize Michigan and re-invest in American communities by growing the renewable fuels and renewable energy sectors. He spoke on this topic at Michigan's First Annual Harvesting Agri-Energy Conference, March 15, 2006. Proceedings available online at http://www.michigan.gov/deq/0,1607,7-135-3585_4129_4183-140646--,00.html. More resources are available at www.newrules.org.

Michigan Energy Policy Today: Prospects for Renewables

Unlike many other states, Michigan has yet to develop a renewable portfolio standard, public benefits fund, or green credits to facilitate a shift toward renewable energy: Michigan has only three of twelve possible policy incentives recorded by the Database of State Incentives for Renewable Energy, and only three of ten types of financial incentives.[119] Nor has it invested in education, outreach or institution building to enhance consumer interest and participation in whatever renewables programs do exist.

There are positive policy trends, however. The Michigan Renewable Energy Program has engaged in ongoing efforts to inventory renewable energy options and make recommendations to the Michigan Public Service Commission. A Net Metering Order was issued by the Michigan Public Service Commission in March 2005. The Capacity Needs Forum commissioned by MPSC completed a report in late 2005 which assessed the need for more electrical production capacity in Michigan, and highlighted the availability of renewable energy options for preventing that shortfall.[120] And perhaps most surprisingly, given the overall lack of a coordinated energy strategy and a related lack of organized demand for one from the public, the Michigan State House of Representatives convened a special committee to examine the possible impacts of a renewable portfolio standard in 2005 and continuing through 2006. However, more concerted policy efforts and public mobilization will be required to help Michigan go past leaning toward renewables and actually move toward embracing them and integrating them more fully into Michigan's energy profile.

New developments in statewide energy planning may change Michigan's static position of dependency on non-renewable energy imports. Governor Jennifer Granholm's Executive Directive 2006-2 provides guidance and authorization for the Michigan Public Service Commission to design a renewable portfolio standard and an entire "21st Century Energy Plan," both of which will actively pursue some of the recommendations described above.[121]

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[119] For a full listing of all state initiatives concerning renewable energy incentives, by type, see the Database of State Initiatives for Renewable Energy (DSIRE) at www.dsireusa.org.

[120] See the Capacity Needs Forum report online at http://www.cis.state.mi.us/mpsc/electric/capacity/cnf/.

[121] Governor Granholm's Executive Directive 2006-2 charges MPSC Chairman Peter Lark with creating a comprehensive energy plan that can meet Michigan's capacity needs with renewable energy and energy efficiency strategies. A report on this "21st Century Energy Plan" is due December 31, 2006. For more information, see the MPSC's website at www.michigan.gov/mpsc.

Appendix A: Tools for Understanding and Using Wood for Energy

Technical Tools

U.S Forest Service Fuel Value Calculator
http://www.fpl.fs.fed.us/documnts/techline/fuel_value_calculator.pdf

Wood Fueled Boiler Financial Feasibility Program
http://www.forest.wisc.edu/extension/boilermanual.htm

Michigan Forest Products Industry Directory
http://www.michigandnr.com/wood/

2004 Michigan Recycled Materials Market Directory
http://www.deq.state.mi.us/documents/deq-ess-recycle-rmmd-pallets.pdf

U.S. EPA Wood Recycling Resources
http://www.epa.gov/epaoswer/non-hw/recycle/jtr/comm/wd-info.htm

RET Finance http://analysis.nrel.gov/retfinance/
Calculates cost of energy of renewable electricity generation technologies.

RETScreen® International http://retscreen.gc.ca
Free software from Natural Resources Canada that provides tools for evaluating energy production, life-cycle costs and greenhouse gas emissions reduction for various renewable energy technologies (RETs).

Real Options Analysis Center http://www.nrel.gov/realoptions/
Information center, modeling environment and virtual community for research related to the advanced financial valuation of renewable energy technologies.

BIOCOST http:// bioenergy.ornl.gov/papers/misc/biocost.htm
An Excel-based program designed by Oak Ridge National Laboratory. Allows the user to select a region and specify values for several variables including expected yields, land rents, labor costs, and chemical, fertilizer, fuel, and planting stock prices. Several key management options also available.

Pellet Fuels Institute (US) http://www.pelletheat.org/2/index/index.html

European Pellet Centre http://www.pelletcentre.info/CMS/site.asp?p=878

Renewable Energy Websites

Michigan Biomass Energy Program http://ww.michigan.gov/biomass

US Department of Energy Biomass Program http://www.eere.energy.gov/biomass/

USDOE/USDA Biomass Research & Development Initiative http://www.bioproducts-bioenergy.gov/

International Energy Administration “About Bioenergy” http://aboutbioenergy.org

Renewable Energy Policy Project http://www.repp.org

Great Lakes Biomass State Regional Partnership http://www.cglg.org/biomass/index.html

Database of State Incentives for Renewable Energy (DSIRE) http://www.dsireusa.org

Renewable Energy Glossary of Terms http://egov.oregon.gov/ENERGY/RENEW/glossary.shtml

Appendix B: Emerald Ash Borer Infestation Overview

The emerald ash borer (EAB) is an invasive beetle that preys on North American ash trees, which have no natural resistance to this exotic insect from Asia. It is estimated that the insect arrived in North America in untreated wood packing materials from China in the early to mid-1990s. The EAB was first identified in Michigan in the summer of 2002. By 2006, an estimated 15 million ash trees had been identified as dead or dying in twenty counties in the southeastern portion of the state (the primary quarantined area). In addition, approximately 30 small outlier quarantines have been established in other areas of Lower Michigan, with another 20 sites soon to be designated. Regions of Ohio, Indiana, and Ontario have also reported significant EAB outbreaks. In June 2006 the first outbreak in Illinois was reported in the one of Chicago's suburban communities. A small amount of affected nursery stock was transported to Virginia and Maryland, but was intercepted before infestation could occur in the New England states.

The widespread destruction caused by the EAB has resulted in enormous costs for local communities (due to the expense of removal, disposal, and replanting efforts) and has produced large quantities of ash wood residues in need of disposal. According to the Michigan Department of Agriculture, in a one-year period from June 2004 to June 2005, nearly 300,000 tons of ash tree residues had been processed at state-run disposal sites alone. [300,000 tons is equivalent to 35,000-45,000 KW, depending on the conversion technology used.] This amount of ash residue does not account for dead or dying ash trees still standing due to lack of funds for removal. It also excludes ash wood residue that is being dumped, landfilled or buried in order to avoid transport and processing costs.

The Michigan Department of Agriculture (MDA) is primarily responsible for implementing the state's EAB eradication program. This program mandates that the movement of all ash woody material be regulated and prohibits the movement of untreated/unprocessed items from inside the quarantine area to outer regions. Numerous state and federal agencies throughout Michigan and neighboring areas, non-profit organizations, and research universities have formed collaborative partnerships to address the EAB issue. Extensive research programs have been implemented, addressing EAB biology (host selection, dispersal range, natural enemies), eradication strategies (monitoring, trapping, live tree and log treatments), and utilization alternatives.

MBEP has partnered with MDNR, MDEQ, the Southeast Michigan Resource Conservation and Development Council, and other state agencies as well as federal research labs in order to aggregate the best available information on wood residue market dynamics and technological advances, in order to make itself a resource for economic development and long-term energy planning at the state level. This team of partners, through funding from the USDA Forest Service, coordinated a study of wood residue generation in Southeast Michigan. This inventory includes wood residues from EAB-related removals, other urban tree residues, and wood wastes from manufacturing and other industrial sectors. The results of this survey are expected in fall 2006.

For more information: www.emeraldashborer.info.

Clean Energy from Wood Residues in Michigan (Discussion Paper MBEP-3)
Printed June 2006
Cost of printing 150 copies: $1581.92 or $10.55 per copy.

The Michigan Department of Labor & Economic Growth does not discriminate on the basis of race, national origin, gender, religion, age, or disability in employment or the provision of services. This report will be made available in alternate formats upon request.

E. Measures of Wood Resources in Lower Michigan Paper

Measures of Wood Resources in Lower Michigan: Wood Residues and the Saw Timber Content of Urban Forests

May, 2007

This study was funded by the Southeast Michigan Resource Conservation and Development Council and the U.S. D.A. Forest Service.

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SUMMARY

Fifteen hundred interviews were conducted in the early spring of 2006 with a random sample of businesses in fourteen counties that include and surround Detroit, Ann Arbor, and Lansing, Michigan. The purpose of the survey is to determine the type and number of companies that either generate or use eight types of wood residue for the calendar year 2005. An equally important purpose is to provide recommendations regarding questions and sample design to those considering conducting urban wood residue surveys in the future.

In the summer of 2005, a ground survey of urban trees was conducted to determine the potential saw log content of the urban forests in the same area. Knowledgeable observers report the loss of saw logs contained in trees felled by natural occurrences, such as the EAB, and by human actions, such as residential and commercial development. The prevailing view is that urban saw logs are of little if any value. This survey provides estimates of the actual abundance, distribution, quality, and accessibility of urban saw timber.

The results of these surveys provide aggregate estimates for 2005 of the flow of wood residue through businesses and the stock of urban saw timber contained in the area's trees. For both Michigan businesses and state and local governments, the results could identify where opportunities exist to make the better use of underutilized wood fiber. Another issue raised by this study is the need in urban areas for a coordinated system that routinely monitors and supports the recovery of wood residue from all sources.

Business Survey

Survey Respondents

Approximately one out of three businesses were randomly selected from the list of 20,101 businesses thought to be potential generators or users of wood residue. The sample was stratified by county to insure that each was represented in the sample. The gross sample size is 7,007. Of the 2,373 contacts made by telephone, 1,500 agreed to be interviewed while 873 refused to participate. Of the completed 1,500 interviews, 420 (28%) indicated that they either generated or used wood residue. The remaining 1,080 (72%) stated that they did not do either. The distributions at the most specific Line-of-Business level for refusals and for respondents were statistically the same. For this reason, estimates of totals include refusals.

Sufficient data were obtained on 5 of the 8 residues: pallets, skids, and shipping crates, edgings and cutoffs, chips and shavings, construction debris, and tree trunks, limbs, and stumps. Data collected on dunnage were insufficient for analysis. Separate attempts were made to contact six railroad companies operating in the study area. Only two responded: one uses the rail lines of other companies and the other could not separate tie replacements for the study area from their national data. The rest did not return the calls. Utility companies did not return calls either, so there are no data on utility poles removed from service in 2005.

Just over one-third of the respondents (36.2%) are in the construction industries. Another one-fourth (26.7%) are in machinery manufacturing. Along with companies in freight transportation (13.4%) and building materials (6.1%), these four industries account for just over 8 out of 10 (82.4%) of the respondents to the survey. The rest are spread out over 16 other industry groups.

Down to the Line-of-Business level, respondents in each of five major industries reported both generating and not generating residue. This is most puzzling for building construction

companies all of whom presumably use the same basic wood materials. For several reasons, claims by construction companies that they generated no residue are not treated as plausible and these companies are treated as generators in some residue estimates.

Residue Generated in 2005

Excluding railroad ties and utility poles, approximately 2,600 companies in total generated about 7.5 million cubic yards of residue in the fourteen county study area in 2005. This amount would fill 354 football fields to a depth of 10 feet (the height of the crossbar on the goal posts). About half (51%) was construction debris while just over one-third (35%) was edgings and cutoffs. The rest consisted of pallets (7%), chips and shavings (6%), and tree debris (1%). Among those companies that paid for removal, the total was $8.8 million.

As shown in the Table below, less than one-fifth of pallets were discarded while over four-fifths of pallets were reused or recycled. Sixty percent of edgings and cutoffs were discarded as waste while the remaining 40% was reused. Sixty-three percent of the construction debris was discarded while the remaining 37% went to other companies and individuals. Just over half of chips and shavings were discarded while the rest was used. For tree debris, 61% was discarded while 39% was used.

Residue	Total Amount Generated (cubic yards)	Percent Used	Total Amount Used (cubic yards)	Percent Discarded	Total Amount Discarded (cubic yards)	Of Total Amount Discarded, Amount Sent to Landfills (cubic yards)	Percent of Total Discarded Residue Sent to Landfills
Pallets, Skids, Shipping Crates	505,000	84%	424,000	16%	81,000	15,000	19%
Edgings and Cutoffs	2,646,000	40%	1,058,000	60%	1.588,000	675,000	43%
Chips, Shavings, Sawdust	480,000	48%	230,000	52%	250,000	108,000	43%
Construction Debris	3,828,000	37%	1,416,000	63%	2,412,000	1,302,000	54%
Tree Trunks, Limbs, Stumps	84,000	53%	45,000	47%	39,000	5,000	13%
Totals	7,543,000	42%	3,173,000	58%	4,370,000	2,105,000	48%

In total, just under 4.4 million cubic yards of residue were discarded as waste in 2005, 58% of the total 7.5 million cubic yards generated. Of the 4.4 million cubic yards discarded, just over 2.1 million cubic yards, or about 48%, ended up in landfills. The rest of what was discarded was either burned or disposed of in other unspecified ways. Of the total 7.5 million cubic yards generated, 2.1 cubic yards, or 28%, went to area landfills.

Pallets, Skids, and Shipping Crates

All companies together generated about 3 million pallets in 2005. Automobile manufacturers alone generated an estimated 1.9 million pallets. Probably 90% of these were reused or recycled. All the other companies generated about 1.1 million. Based on 6 pallets per cubic yard, a total of 505,000 cubic yards were generated. Just over three-fourths of the generators were machinery manufacturers, lumber dealers, construction companies, freight haulers, and furniture stores. Among them, 73% of the pallets were reused or recycled while 27% went to landfills, were burned, or were otherwise disposed of as waste. For all the companies together, 84% of the pallets were reused, 16% were not.

Other than the automobile manufacturers (for whom no expenses were reported or estimated), generating companies spent less than $1 million in 2005 on disposal. They avoided removal costs by giving the pallets away (limited anecdotal evidence suggests the automobile manufacturers gave theirs away at no cost to themselves). The large majority of pallets were taken by other companies. In general, pallets are either repaired and reused or ground into mulch. Hauling distance averaged 10 miles. Many companies also reused their own pallets as pallets.

Companies interviewed that accepted pallets were not in the recycling industry (none of those companies agreed to participate). Instead, most are machinery manufacturers. One possible reason that these companies accept pallets is that they are engaged in an ancillary business activity that reduces disposal costs or even generates a small profit, not too unlikely since recycling is reported to be the most profitable part of the wood pallet business. However, as a group, they are not as adept as recyclers, often accumulating large inventories. Several report not being able to find pallet recyclers. An opportunity exists here for recyclers to focus more on this industry as a source.

Edgings and Cutoffs

A total of 615 companies generated just over 2.6 million cubic yards of edgings and cutoffs. Not surprisingly, two-thirds of the companies are in the construction business. Two-thirds of all 615 companies paid an estimated total of $1.4 million for removal. The remaining third paid nothing. Among those who paid, just over one-third used their own trucks for hauling an average distance of 12 miles to disposal sites. Among those who did not pay, about three-fourths avoided removal costs by giving the material away. An estimated 40% of the material was reused while the 60% was not. About two-thirds of all of the companies did make some use of their own edgings and cutoffs, the rest did not. The main uses were as building materials and heating fuel.

Chips and Shavings

Overall, 324 companies generated 480,000 cubic yards of chips and shavings. Just under half was reused while just over half was discarded as waste. Three-fourths of these companies were either in construction, wood products manufacturing, or industrial machinery manufacturing. About 4 out of 10 companies paid just under one-half million dollars to dispose the material they generated. The other 6 out of 10 either gave the material away or, in a minority of cases, were paid for it. Among those that disposed of their chips and shavings as waste, about three-fourths used landfills. About 1 out of 4 recycled, mainly as mulch.

Construction Debris

An estimated 1,161 companies, mostly in building construction, generated about 3.8 million cubic yards of construction debris. Only one-third was reused, the other two-thirds were discarded. Three-fourths of these companies paid about $5.4 million for disposal. The other one-fourth paid nothing, mainly by giving the debris away. Among those who paid, about one-third used their own trucks for hauling while the rest relied on other companies. The average hauling distance was 58 miles, far more than the distances traveled by companies that generated other kinds of residue. Most of the discarded debris went to landfills. Roughly half the companies did not reuse while the others did, mainly as building material.

Trees, Trunks, and Stumps

An estimated total 96 companies, mainly in the construction business, generated about 84,000 cubic yards of tree debris. Just over half were used while the rest was discarded. Just under half paid for removal -- about $700,000 in total. Slightly more than half disposed of the debris at no cost to themselves, mainly by burning. Half hauled the debris to disposal sites in their own trucks, the other half in trucks belonging to other companies. The average hauling distance was 9 miles. Just over half made no use of the tree debris. Among those that did, the most frequent use was firewood. There is no clear indication of whether more or less ash trees were removed in 2005 compared to the previous year, probably because companies were unable to distinguish ash from other hardwood species.

Wood Residue Market

Just over 6 out of 10 (62.4%) responding companies stated there was no market for their residue. About 2 out of 10 (20.9%) thought a market either existed or was developing. The rest did not know. The most frequently cited reason for no market is that the wood cannot be separated from the foreign material to which it is attached.

Among the 61 companies that believed a market was developing, just over three out of ten (34.4%) indicated that identifying buyers was the principal impediment to further market development.

Among the companies that indicated there was a developed or developing market, just over half (53.4%) thought residue prices varied less than gasoline prices. Far fewer (15.9%) thought residue prices varied about as much or more. Price volatility is not an impediment to the further development or operation of the residue market.

Well over half (61.4%) of the 88 companies felt they were getting enough price information. But 24 companies, just over another one-fourth (27.3%), felt they were no getting enough. The rest (11.4%) did not know. Among the 24 not getting enough information, somewhat over half (54.2%), cited identifying buyers as the single most important additional information they needed.

Sampling and Questionnaire Recommendations

1. When defining the study population, the list of businesses to be sampled for major urban areas can be with little loss limited to the following:

tree service companies (SIC 0783);
construction (SIC's 15, 16 and 17);
machine manufacturing (SIC 35);

lumber and wood products (SIC 24);
wood furniture (SIC 25);
freight transportation (SIC 42);
building supply and mobile home companies (SIC 52);
food stores (SIC 54); and,
home furniture stores (SIC 57).

2. The sample should be stratified by SIC codes to insure that all potential generators and users of residue are drawn into the sample. To insure an adequate number of responses consideration should be given to disproportionate sampling among strata with few companies. Stratifying by region is far less useful than by industry when estimating total residues generated and used.

3. When considering companies to supply a list of businesses, request totals for the study area by two-digit SIC code for the same time to see if there is much variation. If the numbers are about equal in total and across SIC codes, consider the company with the lowest price per business that provides names, addresses, and telephone numbers. Lower prices may available from companies that do not draw samples. (The organization conducting the interviews should be able to draw a sample from the population list.) No matter how often companies update their roster of businesses, there will be a substantial number that can never be contacted owing to wrong numbers and business failure. In addition, some listed as businesses that have telephone numbers can never be reached bringing into question whether these are real businesses.

4. In addition to companies drawn into a sample, other companies that generate and accept substantial amounts of residue should be separately identified and included in estimates of totals. While their selection is deliberate and not part of the sampling procedure, they should not be excluded, especially if they are very unlikely to be selected. The major examples in this study are the three major automobile manufacturers, railroad companies, and utility companies. This applies to all areas for utility poles and railroad ties since the companies that generate them are so few in number compared to the study population that they are unlikely to be selected into the sample. In general, regional industry specialties that may be substantial generators or users, such as the automobile industry in southern Michigan, should be included.

5. Select a sample size at least sixteen times the target number of completed interviews with generators and users. In this study, completed interviews with 1,000 generators and users would have required a total sample size of about 16,000 businesses.

6. To forestall possible confounding interpretations, the first question used in this survey to determine whether a company is a generator or user of wood residue could have been even more precise by indicating that ownership of the waste and responsibility for disposal are irrelevant: what counts is whether the respondent's company engaged in work that produced wood waste or whether the company's business is to accept and process wood waste (such as pallet recyclers). This could be further specified by a preceding question that asks whether wood is any part whatsoever of the company's production process. Respondents in industries that are likely generators who give a negative answer should be asked how they are able to conduct their business without generating wood waste.

7. Questions should be added that directly request of all responding companies the amounts of residues they send to landfills, burn, and otherwise discarded as waste.

8. Although they are similar in function, pallets/skids and shipping crates are not the same in form and should be treated in separate sets of questions.

9. Dunnage should be included only when warranted by the industry base of the urban area being surveyed.

10. Railroad and utility companies should be selected and contacted separately. To increase the likelihood that these companies will respond to calls and requests for data, senior governmental officials should make initial calls to company executives requesting their co-operation.

Urban Tree Survey

Harvesting saw timber from urban trees puts the trees to their highest end-use. Currently, however, most urban wood ends up in landfills or is used for wood chips or biomass fuel. Recent economic losses imposed by the Emerald Ash Borer highlight the well known value of urban forests, not the least of which is their value as a source of lumber.

To assess the general feasibility of harvesting urban wood, a regional estimate of urban saw timber quantity, quality, and availability was developed for the 13-county area in southeastern Lower Michigan. Four types of urban areas were selected and separately sampled: low-intensity, high-intensity, roads and paved areas (such as parking lots), and parks and golf courses.

The total standing urban saw timber in 2005 in the 13 counties was about 327 million board feet. Of this total, 72% percent, or 235 million board feet, was judged as accessible. About 56% was easily accessible while another 16% was moderately so, meaning that some extraction costs and risks would be incurred but neither would be prohibitive. The remaining 28% was rated difficult, essentially so costly and risky as to be inaccessible.

More specifically, 93.5% of all saw timber on parks and golf courses is judged easily accessible while less than 1% is difficult to access. Almost 90% of saw timber along roads and in paved areas was rated as easily accessible, although street trees are about 4 times (2.1% versus 0.5%) more likely to be rated as difficult than trees on parks and golf courses. The main complication is extracting wood from large trees whose crowns are closely intertwined with utility wires. High intensity urban areas pose a greater challenge, although less than 4% of this saw timber is considered difficult to access. By sharp contrast, about half of all saw timber in low intensity urban areas is rated as difficult.

Conservatively, about 4.7 million board feet is estimated to come available each year in the study area from dead and dying trees. This is enough to supply the minimum annual needs of 5 small saw mills. This amount would be enough to build 362 average-sized homes.

Wood quality of urban hardwoods was comparable to that found in Michigan's forests, although the absolute volume was nine times less. While there are many potential concerns with harvesting urban trees for saw timber: low availability, poor wood quality and logistical concerns regarding harvesting urban wood, the results of this study suggest that many of them may be unfounded. The quality of wood in urban softwoods was generally low, but then softwoods comprised only 10% of urban wood.

The strength of some urban wood may be less than their forest counterparts primarily because of the greater quantity of juvenile wood found in open grown urban trees. This was not examined in this study and would require additional research to confirm.

While arborists and small private landowners may not be able to bear the costs of harvesting urban saw timber, governmental agencies and departments could expand their efforts to utilize urban wood to offset tree removal costs and as a material source for public park furniture and

buildings. A step in this direction would be to train municipal foresters to grade trees thereby identifying those of saw log quality.

The economics of commercial timber harvesting versus harvesting urban timber suggest that urban wood should be viewed as a supplemental source of lumber and not as a replacement. Its use can support the costs of tree removal and replacement and disposal. If the 13 county area here in Michigan is similar to other urban areas across the nation, there is a substantial amount of available for wood products.

Part One: Wood Residues

Study Purpose

Fifteen hundred interviews were conducted in the early spring of 2006 with a random sample of businesses in fourteen counties that include and surround the Detroit, Ann Arbor, and Lansing Michigan areas. Listed in Table 1 below are the counties that were among twenty that at the time of selection were under a state imposed quarantine to prevent the spread of the Emerald Ash Borer (EAB).

The primary purpose of this survey is to determine for the calendar year 2005 the type and number of companies that either generate or use nine distinct types of wood residue, including that generated by the loss of ash trees to the EAB, and to estimate the amounts they generated and used for 2005.[1]

Michigan Counties Selected for the 2006 Wood Residue Business Survey

U.S. Census Bureau, Census 2000

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[1]The phrase "wood waste" was used in the questionnaire. The phrase "wood residue" used in its place in this report has the same meaning.

An equally important purpose is to provide recommendations regarding questions and sampling to those considering urban wood residue surveys. This is the first study of its kind for an urban area. Several important lessons were learned that could improve future surveys based on telephone interviews and samples drawn from commercial business lists.

In the summer of 2005, a ground survey of trees was conducted to determine the potential saw log content of the Detroit, Ann Arbor, and Lansing urban forests. The tree survey area covered of all of the counties listed above in the map except Saginaw which was added to the business survey after the field work for tree survey had been completed.

Urban foresters, tree service companies, utility companies, and land developers, among others familiar with urban trees, often report the loss of saw logs contained in trees felled by natural occurrences, such as the EAB, and by human actions, such as residential and commercial development. Even so, the prevailing view is that, compared to commercial logging, urban saw logs are of much less value because of the foreign material embedded in them, possible inherent structural weakness of trees that grow in open spaces, supply that is irregular and difficult to predict, and the expense of transporting to saw mills small numbers of logs scattered widely throughout a large urban area. This part of the study addresses these issues for urban wood in the thirteen county area by directly estimating the actual abundance, distribution, quality, and accessibility of urban saw timber.

Together, the results provide aggregate estimates for 2005 of the flow of wood residue through businesses and the stock of urban saw timber contained in the area's trees. For both Michigan businesses and state and local governments, the results identify where markets have already developed for wood residue and where opportunities might still exist to make both the best private and public use of wood fiber still being underutilized or discarded. The urban forest survey reflects a change in the conventional view that only standing urban trees have value and that once down what is not discarded as green waste in urban landfills is at most only good for firewood and mulch. Knowing the stock provides a basis for estimating the amount of lumber that could flow into the area's stream of usable wood fiber.

This study arose from an immediate goal among federal, state, and local governments to contain the EAB and thereby save as many of Michigan's ash trees as possible. A related and equally important goal is to put to best use what cannot be saved.

From a broader perspective, this report highlights the value and uses of urban wood fiber from major sources: where it is in use and where better use might be made of it. From the broadest perspective, this report should draw attention to possible ways government and business can best use the only indigenous natural resource available in the nation's urban areas.

The long-run issue raised by this study is the need in urban areas across the nation for a coordinated system, in place and active, that routinely supports and provides incentives for the recovery of wood residue from all sources. This system can be comprised of local and regional agencies acting through coordinating groups such as the Southeast Michigan Resource Conservation and Development Council in southeastern Michigan. In the short-run, such organizations can quickly disseminate information about what can be done with extraordinary supplies of wood residue created by episodic storms and infestations. Over the long run, and aside from natural disasters, they can support both public uses and the private market utilization of the more predictable flow of wood residue from all sources.

Finally, for those interested in conducting equivalent surveys in other urban areas, this project provides a comprehensive wood residue questionnaire and identifies business sampling

methods and survey costs that should be kept in mind. The urban forest survey method is described but not recommended except to those who have both the highly specialized knowledge needed to draw a satellite-based multi-stage area probability sample and have trained crews that can apply the sampling technique and measurement methods on the ground. The description of the methods does provide enough information to judge proposals from those who might be capable of conducting such a survey.

In the following sections, sampling methods are described as are the respondents to the business survey by type of wood residue. The methods and results of the urban forest survey are then described. The report closes with a summary and implications of the study findings.

II. Study Population, Sample Selection, and Responses by County and Type of Business

In survey research, the study population consists of members of a precisely defined group all of whom are the subjects of the study. Among the many possibilities, study populations can consist of individuals, families, governmental agencies, private companies, or urban trees. Whatever its membership, the study population must be precisely defined: there can be no ambiguity about who, or what, belongs. The definition is most often based on what and where something is: in this study, urban trees and businesses that generate or use wood residue in the selected counties in and around Detroit, Ann Arbor, and Lansing.

Information about the study population can be gathered from either a census of the entire population or from a random sample of it. Unless the population is small relative to the amount of funds and time available for a study, the usual procedure is to draw a random sample from the population. Information is then collected from only those drawn into the sample. Survey results based on sample data and statistics are generalized to the population as study findings.

Survey measures are also anchored in time. Both the business and tree surveys are cross-sectional. While both apply to 2005, they are based on information available at the time of collection: early spring of 2006 for the business survey and mid-summer of 2005 for the tree survey. A single cross-sectional sample, like a photograph, captures a moment in time and is not well-suited to measuring changes over time. Measures of changes in the flow of wood residue through businesses in southeastern Michigan or changes in the quantity, quality, and accessibility of urban tree saw logs would require a longitudinal study based on either multiple cross-sectional samples of businesses and urban trees conducted over a period of years or panels each consisting of one-time samples of businesses and urban trees followed for a period of years.

At its simplest, a sampling frame consists of a direct list or combined lists of the population members from which a final sample is drawn in a single round or stage of selection. When such a list is not available, more complex frames can include indirect lists and related information for a multi-stage selection of the final sample. Lists of businesses in the United States are available and are used as sampling frames. By contrast, there are no lists or inventories of individual urban trees. Here, the sampling frame consists of stages of collection that start with satellite images and end with the on-ground random selection of individual trees into a sample of urban trees.

Regardless of how a study population is ideally defined, the sampling frame established by actual contacts sets the population boundaries because the frame consists of those who can be actually or at least possibly be reached or those things such as trees that can actually be directly measured. Most often the frame does not consist of everything we want but just what we can actually get to. The difference between the two is the coverage rate. A 100 percent rate means that the ideal and actual are equal. Under-coverage refers to a sampling frame that does not

include all the members who belong to the study population while over-coverage refers to the inclusion of those who did not belong.

Sampling Frame

The ideal sampling frame for the business survey is a complete roster by name, address, telephone number, industry, and county of all those legitimate and operating businesses that either generated or used wood residue in 2005. A random sample would be drawn from this roster and representatives of each business would be interviewed by telephone. Under ideal circumstances, an interview would be completed with every business. Both the coverage rate and the response rate would equal 100 percent. Rarely, if ever, do surveys meet this ideal.

While there are companies throughout North America that sell lists or directories of business that include each firm's name, address, telephone number, location, county, and industry (as well as other kinds of information such as number of employees and year started), none provide the very specific information that would allow companies generating or using wood residue to be distinguished from all the others who do not. The closest piece of information that can be used to make this distinction is the Standard Industrial Classification (SIC) code number.

Originally created in 1937 and last updated in 1987, SIC codes were used by the U.S. Government to categorize companies by the primary and secondary products and services they produce. The original SIC system consists of four hierarchically arranged categories beginning with the letters A through K that represent eleven distinct divisions: for example, A represents Agriculture, Forestry, and Fishing. Thereafter, two, three, and four-digits progressively represent more specific categories of companies whose products and services are increasingly similar: for example, 01 is the Major Group for Agricultural Production Crops, 018 is the Industry Group for Horticultural Specialties, and 0181 is the Industry for Ornamental Floriculture and Nursery Products.

The original SIC four-level code has been extended by companies offering business financial and marketing services. One of if not the most widely used is from D&B (formerly Dun & Bradstreet). D& B added two sets of two-digits each to more narrowly categorize companies offering similar products and services. The first two-digit code is sub-industry and the second set is line-of-business code, the most specific: for example, 0181 99 02 is the D&B code for Sod Farms. While the original SIC code is no longer maintained by the U.S. Government (which began in 2000 to switch to the NAICS code as part of the NAFTA Agreement), the D& B's extended version is widely used by companies in the U.S., around the world, and still by some agencies and departments of the U.S. Government. Many companies, including the one that supplied the list for this study, use the D&B extended code.

The extended SIC codes can be used to approximately identify Industries, Sub-Industries, and Lines-of-Business that are likely generators and users. What we considered likely for this study was based in part on a state-wide wood residue survey conducted via mailed questionnaire by the Wisconsin Department of Natural Resources in 1992.[2] Responses by industry to that survey permitted us to eliminate some industries at the two-digit level (for example, medical services) as likely generators or users. At the same time, the study also allowed us to identify likely generators and users.

[2]Vern A. Everson and Nicholas R. Hubing. October, 1993. *Wisconsin Wood Residue Study*, Bureau of Forestry, Wisconsin Department of Natural Resources, Publ-FR-075-93.

In addition, we relied on a panel of employees of the State of Michigan who as a group are familiar both with recycling in general and with wood fiber recycling in particular. An employee of the USDA Forest Service, also very familiar with urban wood residue issues, served on the panel. The panel relied on a consultant who has over ten years experience searching for wood residue sources throughout southern and central Michigan to supply fuel for a 40 MW wood-fired power plant in Genesse County. His list of specific companies, identified by SIC code, was an important contribution to the sampling frame for this survey.

Using the D& B extended SIC code, specific codes were selected that would generate a sampling frame list of businesses consisting of the most likely generators and users of wood residue. Overall, our aim was to be specific as possible while erring on the side of being too inclusive. We ended up using only four and eight-digit codes representing industries and lines-of-businesses, respectively. The four-digit code was used when there was doubt about what Line-of-Business to select and the eight-digit code when we felt most confident about the Line-of-Business. Listed in Table 1 are the codes and corresponding Major Groups and Lines-of-Businesses for the fourteen county study area. Only primary product and service codes were used.

This list was not tailored to the types or distribution by type of businesses specifically expected in the survey area. Nevertheless, given the size of the combined Detroit, Ann Arbor, and Lansing area, most though not necessarily all should be represented in the sample.[3] In general, most should be represented in samples for large urban areas the size of Detroit while fewer, perhaps far fewer, could be expected for samples of smaller urban areas, cities, and towns.

The study population is specific businesses not specific employees of each business. Interviews were conducted with those who answered the telephone call and were willing to answer the questions. In a few cases, call-backs were made to reach the most informed employees if those who answered first did not feel they could answer the questions. The interview began with a screening question intended to separate businesses that either generated or accepted wood residue in 2005 from those that did not.

At the time the initial sample was drawn, there were 20,101 telephone numbers of businesses in the fourteen counties whose primary SIC codes matched the sampling frame codes. Table 2 gives the distribution by county of the sampling frame list of businesses. About eight out of ten are in a half of the fourteen counties (in bold): 81.4% are in Oakland, Wayne, Macomb, Genesee, Washtenaw, Livingston, and Ingram. Table 3 gives the distribution by two-digit SIC codes for Major Groups. Three Major Groups (in bold) account for just under three-fourths of the total: 72.8% are in Building Construction (15), Industrial & Commercial Machinery & Computer Equipment (35), and Motor Freight Transportation (42).

Though the total for this survey is exact, totals will vary across companies that supply these lists owing to differences in data collection methods, sources of business information, and the timing of updates. Prices per business selected also vary, often substantially, depending on what information is requested. When considering companies to supply a list of businesses, request totals for the study area for the same point in time to see if there is much variation. Totals are

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[3] Only 10 of the 162 different codes in the sampling frame were absent from the actual list of businesses. Missing are those that produce Glass Containers (3221), Structural Clay Products (3259), Vitreous China (3262), Mining Machinery and Equipment (3532), Cordwood (50990201), Logs, hewn ties, posts, and poles (50990204), Pulpwood (50990205), Roundwood (50990206), and Supermarkets greater than 100,000 square feet, not otherwise part of a chain of stores (54110102). The three most likely reasons why these ten are missing are either that there are none of these businesses in the fourteen counties, the company, InfoChase that supplied the list inadvertently missed some or all of them, or the companies by their own actions kept themselves off of all such listings.

Table 1
SIC Codes and Related Industries and Lines-of-Businesses for the Fourteen County EAB Survey Area

SIC	Industry
01	**Agricultural Production**
01819902	Sod Farms
07	**Agricultural Services**
07830104	Pruning Services, Ornamental Trees
07830105	Tree Trimming Services for Public Utility Lines
15	**Building Construction**
1521	Single Family Construction & Remodeling
1522	Residential Construction
1531	New Housing Speculative Builders
16	**Heavy Construction, Other than Building**
1611	Highway &Street Construction
16290100	Dams, waterways, docks, & other marine construction
16290101	Caisson drilling
16290102	Canal construction
16290103	Dam construction
16290104	Dock construction
16290105	Drainage system construction
16290106	Dredging contractor
16290107	Harbor construction
16290108	Irrigation system construction
16290109	Levee construction
16290110	Marine construction
16290111	Pier construction
16290113	Waterway construction
16290200	Railroad &subway construction
16290201	Cutting of right-of-way
16290202	Railroad Railway Roadbed Construction
16290104	Dock Construction
16290111	Pier Construction
16290400	Land Preparation Construction
16290404	Timber Removal
16299903	Land Clearing Contractor
17	**Construction, Special Trade Contractors**
1751	Cabinet Building &Installation, On-Site
17949901	Excavation &Grading, Building Construction
17959902	Demolition, Buildings & Other Structures
24	**Lumber &Wood Products, except Furniture**
2421	Sawmills & Planing Mills
2426	Hardwood Dimension & Flooring Mills
2429	Special (Wood) Products Mills
2431	Wood Window Manufacturing
2434	Cabinet Building, Stock & Custom
2435	Hardwood Veneer & Plywood
2436	Softwood Veneer & Plywood
2439	Engineered Wood Members &Trusses
2448	Wood Pallets, Skids, Containers
2451	Mobile Home Manufacturers
2452	Prefabricated Wood Buildings
2491	Wood Preservation
2493	Reconstituted Wood Products
2499	Wood Products, NEC
25	**Furniture & Fixtures**
2511	Cabinet, Household, Freestanding
2512	Upholstered Furniture
2515	Mattresses & Bedsprings
2517	Wood TV, Radio, Sewing Machine Cabinets
2521	Wood Office Furniture
2531	Institutional Furniture
2541	Wood Partitions & Fixtures
2591	Blind & Shade Manufacturers
2599	Furniture & Fixtures, NEC
26	**Paper & Allied Products**
2611	Pulp Mills
2621	Paper Mills
2653	Corrugated & Solid Fiber Boxes
32	**Stone, Clay, Glass, & Concrete Products**
3211	Flat Glass
3221	Glass Containers
3229	Glass, Pressed & Blown
3231	Glass Products Made of Purchased Glass
3241	Hydraulic Cement
3251	Brick & Structural Clay Tile
3253	Ceramic Wall & Floor Tile
3255	Clay Refractories
3259	Structural Clay Products
3261	Vitreous China - Plumbing
3262	Vitreous China - Table & Kitchenware
3263	Fine Earth-Ware
3264	Porcelain Electrical Supplies
3269	Pottery Products
3271	Concrete Block & Brick
3272	Concrete Products, except Block & Brick
3273	Ready-Mix Concrete
3274	Lime
3275	Gypsum Products
3281	Cut Stone & Stone Products
3291	Abrasive Products
3292	Asbestos Products
3295	Minerals & Earths, Ground, Crushed, Pulverized
3296	Mineral Wool
3297	Non-Clay Refractories
3299	Nonmetallic Mineral Products, NEC

33	**Primary Metal Industries**
3399	Primary Metal Products
35	**Industrial & Commercial Machinery and Computer Equipment**
3511	Steam, Gas, & Hydraulic Turbines, and Turbine Set Units
3519	Internal Combustion Engines, NEC
3523	Farm Machinery & Equipment
3524	Lawn & Garden Tractors & Home Lawn & Garden Equipment
3531	Construction Machinery & Equipment
3532	Mining Machinery & Equipment (except Oil & Gas)
3533	Oil & Gas Field Machinery & Equipment
3534	Elevators & Moving Stairways
3535	Conveyors & Conveying Equipment
3536	Overhead Travel Cranes, Hoists, & Monorail Systems
3537	Industrial Trucks, Tractors, Trailers, & Stackers
3541	Machine Tools, Metal Cutting
3542	Machine Tools, Metal Forming
3543	Industrial Patterns
3544	Special Dies & Tools, Die Sets, Jigs, and Fixtures & Industrial Molds
3545	Cutting Tools, Machine Tool Accessories and Machinist Precision Measuring Devices
3546	Power-Driven Hand tools
3547	Rolling Mill Machinery & Equipment
3548	Electric & Gas Welding & Soldering Equipment
3549	Metalworking Machinery, NEC
3552	Textile Machinery
3553	Woodworking Machinery
3554	Paper Industries Machinery
3555	Printing Trades Machinery & Equipment
3556	Food Products Machinery
3559	Special Industry Machinery, NEC
3561	Pumps & Pumping Equipment
3562	Ball & Roller Bearings
3563	Air & Gas Compressors
3564	Industrial & Commercial Fans & Blowers & Air Purification Equipment
3565	Packaging Machinery
3566	Speed Changers, Industrial High-Speed Drives & Gears
3567	Industrial Process Furnaces & Ovens
3568	Mechanical Power Transmission Equipment, NEC
3569	General Industrial Machinery & Equipment, NEC
3571	Electronic Computers
3572	Computer Storage Devices
3575	Computer Terminals
3577	Computer Peripheral Equipment, NEC
3578	Calculating & Accounting Machinery, except Computers
3579	Office Machines, NEC
3581	Automatic Vending Machines
3582	Commercial Laundry, Dry Cleaning, & and Pressing Machines
3585	Air-Conditioning & Warm Air Heating Equipment & Commercial & Industrial Refrigeration Equipment
3586	Measuring & Dispensing Pumps
3589	Service Industry Machinery, NEC
3592	Carburetors, Piston Rings, & Valves
3593	Fluid Power Cylinders & Actuators
3594	Fluid Power Pumps & Motors
3596	Scales & Balances, except Laboratory
3599	Industrial & Commercial Machinery & Equipment, NEC
37	**Transportation Equipment**
3711	Motor Vehicles & Passenger Car Bodies
39	**Miscellaneous Manufacturing Industries**
3944	Games, Toys, & Children's Vehicles
42	**Motor Freight Transportation**
4212	Local Trucking, Without Storage
4213	Trucking, Except Local
4214	Local Trucking, With Storage
49	**Electric, Gas, & Sanitary Services**
4911	Electric Services, Power Generation
49530302	Sanitary Landfills
50	**Wholesale Trade, Durable Goods**
50990200	Wood & wood by-products
50990201	Cordwood
50990202	Cork products, fabricated
50990203	Firewood
50990204	Logs, hewn ties, posts, & poles
50990205	Pulpwood
50990206	Roundwood
50990207	Shavings, wood
50990208	Timber products, rough
50990209	Wood chips
52	**Building Materials, Hardware, Garden Supply &Mobile Home Dealers**
5211	Lumber & Other Building Materials
Dealers	
54	**Food Stores**
54110100	Supermarkets
54110101	Supermarkets, Chain
54110102	Supermarkets, Greater than 100,000 Square Feet (Hypermarket)
54110103	Supermarkets, Independent
54110104	Supermarkets, 55,000 - 65,000 Square Feet (Superstore)
54110105	Supermarkets, 66,000 - 99,000 Square Ft.
57	**Home Furniture, Furnishings & Equipment Stores**
5712	Furniture Stores
59	**Miscellaneous Retail**
59899902	Fuel, Wood
59991200	Swimming Pools, Hot Tubs, &Sauna Equipment &Supplies

Table 2

Distribution of Study Population by County

County	Number	Percent
Genesee	1,405	7.0%
Ingram	826	4.1%
Jackson	661	3.3%
Lapeer	435	2.2%
Lenawee	430	2.1%
Livingston	841	4.2%
Macomb	3,244	16.1%
Monroe	524	2.6%
Oakland	4,752	23.6%
Saginaw	624	3.1%
Shiawassee	282	1.4%
St. Clair	766	3.8%
Washtenaw	1,153	5.7%
Wayne	4,158	20.7%
Total	20,101	99.9%

usually provided free-of-charge. Some companies can draw samples while others cannot. The cost for a complete list from those that cannot could be more than from companies that charge more per business selected but can draw a sample. In this study, InfoChase, the company selected to provide the list of Michigan businesses, could not draw a sample. After being asked, they agreed to provide the entire list at a substantial discount. Being more exact in the use of four-digit to eight-digit codes further reduces the cost of a list by reducing the number of businesses selected into that sample that are not likely generators or users of wood residue.

Sample

Approximately 1 out of 3 businesses was randomly selected from the 20,101 business in the study population for a total sample size of 7,007. A large sample was drawn with the aim of ultimately conducting 1,000 to 1,200 interviews. The company conducting the interviews was able to reach 1,500 businesses, 25% more than the maximum target of 1,200. However, of the 1,500 interviewed, 420 (28%) indicated that they either generated or used wood residue. The remaining 1,080 (72%) stated that they did not do either. For three possible reasons explained in the section below on the industry by industry responses, the percentage of those who do generate or use may be larger than 28%.

Based on the results of this survey, future surveys that utilize a study population defined by the SIC codes in this study should select a sample size at least sixteen times the target number of completed interviews with generators and users. In this study, completed interviews with 1,000 generators and users would have required a total sample size of about 16,000 businesses.

Table 3

Distribution of Study Population by Two-Digit SIC Code

SIC	Major Industry Groups	Frequency	Percent
01	Agricultural Production	28	0.1%
07	Agricultural Services	30	0.1%
15	**Building Construction**	**8,802**	**43.8%**
16	Heavy Construction, other than Building	405	2.0%
17	**Construction, Special Trade Contractors**	**1,428**	**7.1%**
24	Lumber &Wood Products, except Furniture	499	2.5%
25	Furniture &Fixtures	239	1.2%
26	Paper &Allied Products	75	0.4%
32	Stone, Clay, Glass, &Concrete Products	506	2.5%
33	Primary Metal Industries	13	0.1%
35	**Industrial & Commercial Machinery & Computer Equipment**	**3,327**	**16.6%**
37	Transportation Equipment	156	0.8%
39	Miscellaneous Manufacturing Industries	73	0.4%
42	**Motor Freight Transportation**	**2,495**	**12.4%**
49	Electric, Gas, and Sanitary Services	138	0.7%
50	Wholesale Trade, Durable Goods	16	0.1%
52	**Building Materials, Hardware, Garden Supply & Mobile Home Dealers**	**831**	**4.1%**
54	Food Stores	289	1.4%
57	Home Furniture, Furnishings & Equipment Stores	710	3.5%
59	Miscellaneous Retail	41	0.2%
	Totals	**20,101**	**100.0%**

The sample is stratified by county, otherwise businesses in smaller counties might not have been selected. The assumption made here is that having a business name, a SIC classification, and a working business telephone number did not constitute a legitimate and operating business unless a representative of that business could be contacted directly by voice by telephone (after a maximum of six attempts) during the usual weekday business hours. A business cannot do business if customers cannot communicate with it by telephone.

Even when frequently updated, business lists and the samples drawn from them include former businesses whose telephone numbers are no longer in service as well as those who still have working numbers but are either going out or are out of business. Because of collection or recording errors, lists and samples contain both fax and residential numbers as well. And, there are business numbers where no contact is ever possible; many of these may not be legitimate or real businesses. Numbers that fall into these categories are listed as Unusable in Table 4. Of the base sample of 7,007, 1,531 numbers, or almost 22%, were classified as Unusable. The complete disposition by category of the sample is given below in Table 4.

Sample Disposition

Out of 16,361 calls, a total of 2,373 business contacts were made: on average, about seven calls were required per contact. Of the total, 1,500 interviews were completed with businesses that generated or accepted residue and those that did not. The rest consisted of 873 refusals; 780 upon answering plus 93 terminated before the interview got underway.

The distribution of refusals by county is in Table 5 and by two-digit SIC codes in Table 6.

The remaining 3,101 numbers are classified as possible contacts. Some probably are not functioning businesses and could be treated as Unusable.

The American Association of Public Opinion Research has identified six different methods of calculating a survey response rate.[4] The methods are based on the following three kinds of surveys: household (not business) surveys where selection is done by the random digit dialing (RDD) method of sampling, in-person household surveys, and mail surveys of specifically named persons.

The minimum rate is the number of completed interviews (I) divided by the sum of completed and partially completed interviews (I + P) plus the number of refusals and terminations and non-contacts and others (R + NC + O) plus all cases of unknown eligibility and other unknowns (UH + UO).

$$RR1_{min} = \frac{I}{(I + P) + (R + NC + O) + (UH + UO)}$$

The maximum rate is the number of completed and partially completed interviews (I + P) divided by the same (I + P) plus refusals and non-contacts and other unknowns (R + NC + O).

$$RR6_{max} = \frac{(I + P)}{(I + P) + (R + NC + O)}$$

[4]The American Association for Public Opinion Research. 2004. *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys. 3rd edition*. Lenexa, Kansas: APPOR, 28 - 29.

Table 4

Final Disposition of Total Business Sample

Unusable	Number	
Number no longer in service/disconnected	699	
Wrong number/ residential number	152	
Out-of-business	129	
Fax modem	159	
Always no answer	271	
Respondent unreachable	115	
Duplicate number	6	
Other	2	
Subtotal	1,533	21.9%
Usable		
Possible contacts: no answer, answering machine, respondent not available after six callbacks	3,101	
Refusal upon contact	780	
Termination after initial questions	93	
Subtotal for all refusals	873	
Subtotal for Usable	3,974	56.7%
Completed Interviews	1,500	21.4%
Total Base Sample	7,007	100.0%

There were no partially completed interviews, hence P = 0 and has no effect on the rate. The number of refusals and mid-interview terminations are known, are greater than 0, and are a straightforward part of this calculation. Other (O) equivalent cases include households where no interview is possible because of death, physical or mental inabilities, or language problems. For business surveys, this would include businesses closed by retirement or death of the owner or business failure. These are already included in the Unusable category.

What is less straightforward is how to treat the non-contacts (NC). In household surveys based on RDD sampling, NC consists of confirmed households with working telephone numbers where a respondent is never available after the maximum number of callbacks has been made. There is no compelling reason for anyone in a household to ever be available for telephone calls for interviews, or for any other reason. Many probably screen calls using caller ID and do not answer when either they do not recognize the number or when the number is not given. The household can continue to exist without anyone ever answering the telephone for it. This is not so for businesses, at least those that use telephones to directly communicate with current and potential customers. Customers who cannot reach a particular business by telephone to inquire about prices and availability, make purchases, check on the status of orders, or discuss billing problems will soon go to a competitor. And, businesses cut off from customers will soon go out of business, or they are not legitimate and operating businesses to begin with.

Table 5

Distribution of Refusals by County

County	Frequency	Percent
Genesee	**65**	**7.5%**
Ingham	**43**	**4.9%**
Jackson	20	2.3%
Lapeer	14	1.6%
Lenawee	23	2.6%
Livingston	**40**	**4.6%**
Macomb	**139**	**15.9%**
Monroe	29	3.3%
Oakland	**216**	**24.7%**
Saginaw	27	3.1%
Shiawassee	13	1.5%
St. Clair	28	3.2%
Washtenaw	**53**	**6.1%**
Wayne	**163**	**18.7%**
Totals	873	100.0%

In this survey, at most the 3,101 Possible Contacts (no answer, answering machine, and respondent not available after six callbacks) could be considered NC's. As shown in Table 7, treating them all this way yields a minimum response rate of 27.4%. Going strictly by the assumption that a telephone number does not represent a legitimate and operating business unless a representative of that business can be directly contacted by telephone during weekday business hours, all 3,114 are unusable category and are dropped from the calculation. This yields a maximum response rate of 63.5%. Midway between these two extremes is a rate of 38.2% which is based on 50% of the possible contacts being dropped following the assumption about operating businesses.

As previously noted in the discussion of the sample, assuming the fourteen county area is at least somewhat representative of other large American cities, an initial sample of 16 businesses for every 1 business that either generates or uses residue is prudent. Completed interviews with 1,000 of these businesses would require an initial sample of about 16,000. The initial sample size should even be higher for smaller urban areas, cities, and towns.

In this study, sample numbers of companies used to estimate the total number of companies in the 14 county area that generated and accepted wood residues is multiplied by the population-to-sample ratio of 3 to 1. Rounded to the nearest whole number, this is the ratio of the initial population of 20,101 to the initial sample of 7,007.

Sample Distribution by County

As calculated from the data in Table 2, among the fourteen counties, seven (in bold) account for about eight out of ten businesses in the study population: 81.4% of the businesses are in Oakland, Wayne, Macomb, Genesee, Washtenaw, Ingham, and Livingston counties. As

calculated using the data in Table 8, the same seven counties in the same order are where most of the responding businesses are located as well. They account for 79.4% of the 1,500 responding

Table 6

Distribution of Refusals by Two-Digit SIC Code

SIC	Major Industry Groups	Frequency	Percent
01	Agricultural Production	1	0.1
07	Agricultural Services	0	0.0
15	**Building Construction**	**296**	**33.9**
16	Heavy Construction, other than Building	11	1.3
17	**Construction, Special Trade Contractors**	**57**	**6.5**
24	Lumber &Wood Products, except Furniture	25	2.9
25	Furniture &Fixtures	9	1.0
26	Paper &Allied Products	6	0.7
32	Stone, Clay, Glass, &Concrete Products	27	3.1
33	Primary Metal Industries	0	0.0
35	**Industrial &Commercial Machinery & Computer Equipment**	**188**	**21.5**
37	Transportation Equipment	18	2.1
39	Miscellaneous Manufacturing Industries	3	0.3
42	**Motor Freight Transportation**	**97**	**11.1**
49	Electric, Gas, and Sanitary Services	8	0.9
50	Wholesale Trade, Durable Goods	0	0.0
52	Building Materials, Hardware, Garden Supply & Mobile Home Dealers	45	5.2
54	Food Stores	39	4.5
57	Home Furniture, Furnishings & Equipment Stores	40	4.6
59	Miscellaneous Retail	3	0.3
	Totals	**873**	**100.0%**

businesses. The probability of getting this 2 percentage point difference (81.4% - 79.4%) by chance is .028 or slightly less than 3 out of 100: not statistically different at a significance level of .05 but different at .01 and .001.[5] As a group, the counties are equally proportionately represented among the responding businesses.

[5]A single sample proportion test was used.

As also shown in Table 8, out of the 1,500 completed interviews, 28% (420) either generated or used wood residue while 72% (1,080) did not. The same seven counties in the same order account for 78.8% of businesses that either generate or use wood residue and 79.7% of those that did not. The probability of getting this 0.90% difference (79.7% - 78.8%) by change is .350.[6] This difference is not even close to being significantly different at .05, .01, or .001. The same seven counties are also equally proportionately represented among those businesses that did generate and use wood residue and those that did not.

The refusals are also a close match with businesses that responded. The seven counties accounted for 82.4% of the refusals and 79.4% of the responding businesses. The probability of getting the three percentage point difference (82.4% - 79.4%) between them is .034 which is insignificant at .05 but significant at .01 and .001.

Table 7

Response Rates by Disposition of Possible Contacts

Minimum Rate: All Possible Contacts Included		
Completed Interviews	1,500	27.4%
Refusals and mid-interview terminations	873	16.0%
Possible contacts (NC)	3,101	56.7%
Totals	5,474	100.1%
Mid-Rate: One-Half Possible Contacts Included		
Completed Interviews	1,500	38.2%
Refusals and mid-interview terminations	873	22.3%
Possible Contacts (NC)	1,551	39.5%
Totals	3,924	100.0%
Maximum Rate: No Possible Contacts Included		
Completed Interviews	1,500	63.5%
Refusals and mid-interview terminations	873	36.5%
Possible Contacts (NC)	0	0.0%
Totals	2,373	100.0%

The distribution by county of those who were contacted but refused to be interviewed is in Table 4. The same seven counties in the same order account for 82.4% of the total refusals. Compared to the proportion of these counties in the study population, the difference of1 percentage point (82.4 -81.4) is statistically insignificant at the three significance levels. The probability of getting this difference by chance is .228.

Overall, among the fourteen counties the same group of seven is about equally represented in the study population, businesses that did and did not generate and use wood residues, as well as among businesses that both responded and refused to respond to the survey.

[6] A two-sample difference-of-proportions test was used.

Table 8

Businesses That Did and Did Not Generate/Use Wood Residue by County

County	Generate/Use Wood Residue	Do Not Generate/Use Wood Residue	County Subtotals and Totals for All Counties
Genesee	**46**	**65**	**111**
	11.0%	**6.0%**	**7.4%**
Ingham	**26**	**39**	**65**
	6.2%	**3.6%**	**4.3%**
Jackson	15	40	55
	3.6%	3.7%	3.7%
Lapeer	6	27	33
	1.4%	2.5%	2.2%
Lenawee	13	25	38
	3.1%	2.3%	2.5%
Livingston	**19**	**45**	**64**
	4.5%	**4.2%**	**4.3%**
Macomb	**50**	**184**	**234**
	11.9%	**17.0%**	**15.6%**
Monroe	12	32	44
	2.9%	3.0%	2.9%
Oakland	**85**	**245**	**330**
	20.2%	**22.7%**	**22.0%**
Saginaw	21	37	58
	5.0%	3.4%	3.9%
Shiawassee	8	13	21
	1.9%	1.2%	1.4%
St. Clair	14	45	59
	3.3%	4.2%	3.9%
Washtenaw	**30**	**59**	**89**
	7.1%	**5.5%**	**5.9%**
Wayne	**75**	**224**	**299**
	17.9%	**20.7%**	**19.9%**
Total Numbers	**420**	**1080**	**1500**
Totals Percentages	**100.0%**	**100.0%**	**100.0%**

Sample Distribution by Business Category

As calculated from the data in Table 3, among the twenty Major Industry Groups in the study population, five (in bold) account for just over eight out of ten businesses: 84.0% are in Building Construction (15), Construction, Special Trade Contractors (17), Industrial & Commercial Machinery & Computer Equipment (35), Motor Freight Transportation (42), , and Building Materials, Hardware, Garden Supply & Mobile Home Dealers (52).

Table 9

Distribution of All Respondents by Major Industry Group

SIC	Major Industry Groups	Frequency	Percent
01	Agricultural Production	5	0.3
07	Agricultural Services	3	0.2
15	**Building Construction**	**435**	**29.0**
16	Heavy Construction, other than Building	23	1.5
17	**Construction, Special Trade Contractors**	**85**	**5.7**
24	Lumber &Wood Products, except Furniture	48	3.2
25	Furniture &Fixtures	25	1.7
26	Paper &Allied Products	10	0.7
32	Stone, Clay, Glass, &Concrete Products	54	3.6
33	Primary Metal Industries	1	0.1
35	**Industrial &Commercial Machinery & Computer Equipment**	**401**	**26.7**
37	Transportation Equipment	5	0.3
39	Miscellaneous Manufacturing Industries	4	0.3
42	**Motor Freight Transportation**	**201**	**13.4**
49	Electric, Gas, and Sanitary Services	11	0.7
50	Wholesale Trade, Durable Goods	4	0.3
52	**Building Materials, Hardware, Garden Supply &Mobile Home Dealers**	**92**	**6.1**
54	Food Stores	22	1.5
57	Home Furniture, Furnishings & Equipment Stores	66	4.4
59	Miscellaneous Retail	5	0.3
	Totals	1500	100.0

As calculated from the data in Table 9, the same five account for 80.9% of the responding businesses. The probability of getting the 3.1 percentage point difference (84.0 - 80.9)between the2 percentages by chance is .0005, below .05, .01, and .001. The difference as statistically significant.

Compared to the study population, both Building Construction and Industrial & Commercial Machinery & Computer Equipment industry groups are underrepresented in the sample of respondents: a fifteen percentage point gap for Building Construction and a ten percentage point gap for Industrial & Commercial Machinery. For both the percentages are greater in the population than the respondent sample. Variations in response rates across Major Industry Groups are not surprising: type of business, revenue, and number of employees all help explain the variation in a willingness to be interviewed.[7]

[7]Petroni, Rita, Richard Sigman, Diane Willimack, Steve Cohen, Clyde Tucker. December 14, 2004. *Response Rates and Nonresponse in Establishment Surveys -- BLS and Census Bureau*, paper presented to the Federal Statistics Advisory Committee (FESAC).

What was unanticipated is that there would be substantial numbers of companies in the Major Industry Groups that reported they generated or used wood residue and others in the same Group who reported they did not. As shown in Table 10, this applies to 5 Groups out of 20 that in total account for about 8 out of 10 (80.9%) of all the businesses in the sample of respondents. By percentage of generators, they line up in the following descending order:

Building Construction (15): 43.0% indicated that they generated or used residue while the remaining 57.0% reported that they did not;

Building Materials, Hardware, Garden Supply & Mobile Home Dealers (52): 39.1% did generate and 60.9% did not;

Construction, Special Trade Contractors (17): 38.8% did generate and 61.2% and did not;

Industrial and Commercial Machinery (35): 15.5% did generate while 84.5% and did not;

Motor Freight (42): just 8% indicated that they did generate while the other very large majority of 92% indicated that they did not.

How could some businesses in the same Group -- who offer similar products and services and who presumably receive and use similar materials in production -- generated wood residue in 2005 while others did not? One possible answer is that a diverse mix of somewhat similar businesses is aggregated in the broad two-digit Group: those that all generate residue are included along with others who did not. Perhaps at the most specific Line-of-Business level, businesses are all either generators or not generators. The split at the Group level may be much reduced or even eliminated at the eight-digit Line-of-Business level when only the same businesses are in the same category together.

At this most specific level, a reasonable expectation is that businesses producing the same or nearly the same products and services would use the same materials in production and, therefore, would all either generate or not generate wood residue as a by-product.

Building Construction

This expectation is not supported by the data for the Building Construction (15) Major Industry Group. As shown in Table 11, the Group was disaggregated into its fifteen constituent eight-digit Line-of-Businesses and partitioned by whether or not the respondent indicated the businesses generated wood residue in 2005.

There is no split for five Lines-of-Businesses (in bold) where there are just a handful or less of respondents. Two of them are split.

In the other eight, where the numbers are greater, there is a split between those who reported generating residue and those who did not. The split is fairly even for businesses that construct single-family homes, remodel and repair single-family homes, do new single-family construction, and other residential construction.

Especially for Building Construction especially, these are perplexing numbers. With a very few exceptions, lumber and plywood are the two most common wood materials used in construction, remodeling, and repair, especially of stick-built single-family homes. Both materials come in standard sizes and must be trimmed to fit, hence, there must be waste that in the questionnaire is covered by two categories: construction debris and edgings and cutoffs. There should have been no confusion about what these categories included.

Table 10
Businesses That Did and Did Not Generate/Use Wood Residue by Major Industry Groups

SIC	Major Industry Groups	Generate Wood Residue	Do Not Generate Wood Residue	SIC Subtotals and SIC Percentages of Total Sample
1	Agricultural Production	1	4	5
		0.2%	0.4%	0.3%
7	Agricultural Services	3	0	3
		0.7%	0.0%	0.2%
15	**Building Construction**	**187**	**248**	**435**
		44.5%	**23.0%**	**29.0%**
16	Heavy Construction, other than Building	5	18	23
		1.2%	1.7%	1.5%
17	**Construction, Special Trade Contractors**	**33**	**52**	**85**
		7.9%	**4.8%**	**5.7%**
24	Lumber &Wood Products, except Furniture	31	17	48
		7.4%	1.6%	3.2%
25	Furniture & Fixtures	11	14	25
		2.6%	1.3%	1.7%
26	Paper & Allied Products	5	5	10
		1.2%	.5%	0.7%
32	Stone, Clay, Glass, & Concrete Products	7	47	54
		1.7%	4.4%	3.6%
33	Primary Metal Industries	1	0	1
		0.2%	0.0%	0.1%
35	**Industrial &Commercial Machinery & Computer Equipment**	**62**	**339**	**401**
		14.8%	**31.4%**	**26.7%**
37	Transportation Equipment	1	4	5
		0.2%	.4%	.3%
39	Miscellaneous Manufacturing Industries	1	3	4
		.2%	0.3%	0.3%
42	**Motor Freight Transportation**	**16**	**185**	**201**
		3.8%	**17.1%**	**13.4%**
49	Electric, Gas, and Sanitary Services	1	10	11
		0.2%	.9%	0.7%
50	Wholesale Trade, Durable Goods	1	3	4
		.2%	0.3%	0.3%
52	**Building Materials, Hardware, Garden Supply & Mobile Home Dealers**	**36**	**56**	**92**
		8.6%	**5.2%**	**6.1%**
54	Food Stores	3	19	22
		0.7%	1.8%	1.5%
57	Home Furniture, Furnishings & Equipment Stores	14	52	66
		3.3%	4.8%	4.4%
59	Miscellaneous Retail	1	4	5
		0.2%	0.4%	0.3%
	Totals	**420**	**1080**	**1500**
		100.0%	**100.0%**	**100.0%**

Table 11

Businesses That Did and Did Not Generate/Use Wood Residue by Building Construction (15) Line-of-Business

SIC	Line-of-Business	Generate/Use Wood Residue	Do Not Generate Wood Residue	Totals by Line-of-Business
15210000	Single-Family Housing Construction	73	84	157
		46.5%	53.5%	100.0%
15210100	Single-Family Home Remodeling and Repairs	16	16	32
		50.0%	50.0%	100.0%
15210101	General Remodeling, Single-Family Housing	34	31	65
		52.3%	47.7%	100.0%
15210102	Mobil Home Repair, On-Site	1	1	2
		50.0%	50.0%	100.0%
15210103	Patio and Deck Construction and Repair	2	7	9
		22.2%	77.8%	100.0%
15210104	**Repairing Fire Damage, Single-Family Houses**	**0**	**5**	**5**
		.0%	**100.0%**	**100.0%**
15219901	New Construction, Single-Family Houses	41	58	99
		41.4%	58.6%	100.0%
15220000	Residential Construction, NEC	17	34	51
		33.3%	66.7%	100.0%
15220101	**Apartment Building Construction**	**0**	**3**	**3**
		.0%	**100.0%**	**100.0%**
15220103	**Condominium Construction**	**0**	**2**	**2**
		.0%	**100.0%**	**100.0%**
15220107	**Multi-Family Dwellings, New Construction**	**0**	**1**	**1**
		.0%	**100.0%**	**100.0%**
15220200	**Hotel/Motel & Multi-Family Home Renovation & Remodeling**	**0**	**1**	**1**
		.0%	**100.0%**	**100.0%**
15220201	Remodeling Multi-Family Dwellings	1	1	2
		50.0%	50.0%	100.0%
15310000	Operative Builders	1	2	3
		33.3%	66.7%	100.0%
15319904	Speculative Builders, Single-Family Houses	1	2	3
		33.3%	66.7%	100.0%
	Totals	187	248	435
		43.0%	57.0%	100.0%

One possible explanation is that as a way of getting out of the interview, some respondents selected "No" as their answer to the first question about whether they generated or used wood waste; that is, they used it as a soft refusal. At most, this would seem to apply only to a few respondents since refusing to participate in a telephone interview is easy -- all one has to do, at

most, is indicate an unwillingness to participate or continue and then hang up. Since the interview is not face-to-face, where some additional degree of politeness could be expected, being polite about abruptly terminating a telephone interview is not a problem for respondents.

A second explanation is those answering simply did not know that the businesses that employed them produced wood residue. How one can work in this line of business and not know residue is generated is hard to fathom.

A third possibility is that the "No" respondents, working as subcontractors, interpreted the question to mean that the residue generated was not theirs in the sense that neither they personally nor their companies were responsible for disposal. Even though the question is specific with the use of the phrase "... did your company here in Michigan either generate or accept any wood waste..." , these respondents nevertheless might have thought that the residue was generated by the contractor and not by themselves. Nothing in the results of the questionnaire pre-test suggested that respondents would interpret the question in this manner.

A fourth possibility is that a few companies are using wood material already cut to exact specifications so that little residue is generated in construction and installation.

Even so, to forestall possible confounding interpretations in future surveys, the existing question could be narrowed by indicating that responsibility of disposal is irrelevant. What counts is whether the respondent's company actually engaged in work that produced wood waste. This could be further specified by a preceding question that asks whether wood is any part whatsoever of the company's production process. Since this is a key question, it should be extensively pre-tested to establish its content validity. In addition, respondents in Building Construction who indicate that they generate no residue should be asked a follow up questions on how they are able to build and install without generating debris or edgings and cutoffs.

The split at the Line-of-Business level between those who say they do and do not generate residue is important because it raises the question of whether to include businesses who claim not to generate residue in the estimates of the total amounts of residue generated for 2005 in the fourteen counties. Because the "No" response does not seem plausible, they are included. How they enter the estimates is explained in the sections on responses by types of residues.

Building Materials, Hardware, Garden Supply and Mobile Home Dealers

As given in Table 12, almost 4 out of 10 (39.1%) of the Building Materials businesses represented in the sample of responding businesses generated wood residue while the remaining 6 out of 10 (60.9%) did not.

Among the twenty-two Lines-of-Businesses that comprise the responding businesses in this Group, the 8 (in bold) that produced lumber and lumber products, doors, windows, and garage doors, kitchen cabinets, and home centers account for almost three-fourths (73.9%) of the total. There are splits between those who report generating and not generating residue among all eight. The splits for businesses whose primary products are doors, window, garage doors, and even kitchen cabinets are plausible since not all of these products involve wood. That some home centers do not generate residue because they charge and give customers the cutoffs from lumber and plywood cut to size while others charge only for what is cut and discard the rest plausibly explains this split. The split for Lumber and Other Building Materials is nearly as perplexing as the one for Building Construction businesses. Both handle wood products in standard sizes that have to be trimmed to fit, hence, there must be some residue in the form of cutoffs. Even though a "No" response does not seem very plausible, all Lumber and Other Building Materials businesses will be treated as non-generators.

Table 12

Building Materials, Hardware, Garden Supply, and Mobile Home Dealers That Did and Did Not Generate/Use Wood Residue by Lines-of-Business

SIC	Line-of-Business	Generate Wood Residue	Do Not Generate Wood Residue	Totals by Lines-of-Businesses
52110000	**Lumber and Other Building Materials**	**9**	**19**	**28**
		32.1%	**67.9%**	**100.0%**
52110100	**Lumber Products**	**4**	**1**	**5**
		80.0%	**20.0%**	**100.0%**
52110101	Flooring, Wood	1	0	1
		100.0%	.0%	100.0%
52110104	Planing Mill Product and Lumber	0	1	1
		.0%	100.0%	100.0%
52110105	Siding	0	2	2
		.0%	100.0%	100.0%
52110200	**Door and Window Products**	**3**	**5**	**8**
		37.5%	**62.5%**	**100.0%**
52110201	**Door, Storm: Wood or Metal**	**1**	**2**	**3**
		33.3%	**66.7%**	**100.0%**
52110203	**Garage Doors: Sales and Installation**	**2**	**2**	**4**
		50.0%	**50.0%**	**100.0%**
52110207	**Windows, Storm: Wood or Metal**	**1**	**2**	**3**
		33.3%	**66.7%**	**100.0%**
52110400	Prefabricate Buildings	0	1	1
		.0%	100.0%	100.0%
52110402	Modular Homes	0	1	1
		.0%	100.0%	100.0%
52110500	Masonry Materials and Supplies	1	1	2
		50.0%	50.0%	100.0%
52110501	Brick	2	0	2
		100.0%	.0%	100.0%
52110502	Cement	0	3	3
		.0%	100.0%	100.0%
52110506	Sand and Gravel	0	2	2
		.0%	100.0%	100.0%
52110507	Fencing	0	2	2
		.0%	100.0%	100.0%
52119901	Bathroom Fixtures, Equipment, and Supplies	0	1	1
		.0%	100.0%	100.0%
52119902	**Cabinets, Kitchen**	**2**	**4**	**6**
		33.3%	**66.7%**	**100.0%**
52119903	Closets, Interiors and Accessories	1	0	1
		100.0%	.0%	100.0%

	52119906	Electrical Construction Materials	1	0	1
			100.0%	.0%	100.0%
	52119907	Fencing	2	2	4
			50.0%	50.0%	100.0%
	52119908	**Home Centers**	**6**	**5**	**11**
			54.5%	**45.5%**	**100.0%**
Totals			36	56	92
			39.1%	60.9%	100.0%

Table 13

Construction and Special Trade Contractors (17) That Did and Did Not Generate/Use Wood Residue by Lines-of-Business

SIC	Line-of-Business	Generate Wood Residue	Do Not Generate Wood Residue	Totals by Lines-of-Businesses
17510000	**Carpentry Work**	**11**	**24**	**35**
		31.4%	**68.6%**	**100.0%**
17510100	**Cabinet and Finish Carpentry**	**4**	**3**	**7**
		57.1%	**42.9%**	**100.0%**
17510101	**Cabinet Building and Installation**	**3**	**2**	**5**
		60.0%	**40.0%**	**100.0%**
17510102	**Finish and Trim Carpentry**	**1**	**2**	**3**
		33.3%	**66.7%**	**100.0%**
17510200	**Window and Door Installation and Erection**	**0**	**2**	**2**
		.0%	**100.0%**	**100.0%**
17510201	Garage Store Installation or Erection	4	3	7
		57.1%	42.9%	100.0%
17510202	**Window and Door (Prefabricated) Installation**	**3**	**5**	**8**
		37.5%	**62.5%**	**100.0%**
17519901	**Framing Contractor**	**0**	**1**	**1**
		.0%	**100.0%**	**100.0%**
17949901	Excavation & Grading, Building Construction	5	8	13
		38.5%	61.5%	100.0%
17959902	Demolition, Buildings & Other Structures	2	2	4
		50.0%	50.0%	100.0%
	Totals	33	52	85
		38.8%	61.2%	100.0%

Construction and Special Trade Contractors

By its very nature carpentry involves wood, work that no matter how precisely it is done still generates wood residue. As can be seen in Table 13, that about two-thirds of the businesses in Carpentry Work (17510000) report not generating residue is, on the face of it, not plausible either. The same can be said of the rest of these Lines-of-Business with the possible exception of Garage Door Installation (17510201), Excavation and Grading (17949901), and Demolition (17959902), all three of which could be done without generating wood residue. As with Building Construction and Lumber and Other Building Materials, these businesses, minus the three exceptions, are included in the residue estimates for the fourteen counties.

Industrial & Commercial Machinery & Computer Equipment

The expectation that all of the same businesses either generate or do not generate residue was not contradicted as much by the data for Industrial & Commercial Machinery & Computer Equipment (35).

The splits between generators and non-generators are not nearly as pronounced as they are in Building Construction. The total 401 responding businesses are spread over 128 Lines-of-

Table 14

Industrial & Commercial Machinery and Computer Equipment (35) Businesses That Did and Did Not Generate/Use Wood Residue by Selected Lines-of-Business

SIC	Industry Groups	Generate Wood Residue	Do Not Generate Wood Residue	Totals by Lines-of-Businesses
35410000	Metal Cutting Machine Tools	2	8	10
		20.0%	80.0%	100.0%
35430000	Industrial Patterns (for forming and molding metal)	4	9	13
		30.8%	69.2%	100.0%
35440000	Special Dies, Tools, Jigs, and Fixtures	3	30	33
		9.1%	90.9%	100.0%
35440100	Special Dies and Tools	1	28	29
		3.4%	96.6%	100.0%
35449902	Industrial Molds	1	9	10
		10.0%	90.0%	100.0%
35990303	Machine Shops, Jobbing and Repair	17	72	89
		19.1%	80.9%	100.0%
	Totals for Selected Six Lines-of-Business	28	156	184
		15.2%	84.8%	100.0%
	Totals for Entire Group	62	339	401
		15.5%	84.5%	100.0%

Business, too many to be presented in a single table. However, the individual Lines were examined. Twenty-eight out of 128 are split while the other 100, in each numbering no more than a handful at most, were not. Of the 28 that are split, the half-dozen Lines with the most respondents account for fewer than one-half (45.9%) of the total. As can be seen in Table 14, the splits between those who generated and those who did not in the six Lines tilts toward those who did not.

Given the nature of these businesses, that a few could generate residue while the majority did not is plausible. Perhaps only a few generated wood residue (15.2%) in preparing machines for shipment or receiving parts packed in crates and on pallets that required disposal. In their own view, the rest (84.8%) used or received so little wood that they did not deem the amounts, if any, worth reporting.

Motor Freight Transportation

As shown in Table 15, of the 201 responding Motor Freight businesses, only 16 (8.0%) generated residue while the other 185 (92.0%) reported that they did not. While these generating businesses will be included in the estimates of residue for the fourteen counties, future residue surveys could eliminate this Group as a significant source.

All Other Industry Groups

Out of the twenty Major Industry Groups listed in Table 9, the five discussed above account for 8 out of 10 (80.9%) of the total sample. Because of the small numbers involved, the other fifteen Groups that account for the remaining 2 out of 10 (19.1%) are not described.

Table 15

Motor Freight Transportation That Did and Did Not Generate/Use Wood Residue by Lines-of-Business

SIC	Line-of-Business	Generate Wood Residue	Do Not Generate Wood Residue	Totals by Lines-of-Businesses
42120000	Local Trucking, With Storage	3	62	65
		4.6%	95.4%	100.0%
42120101	Animal Transport	0	1	1
		.0%	100.0%	100.0%
42120200	Liquid Transfer Services	0	1	1
		.0%	100.0%	100.0%
42120202	Petroleum Haulage, Local	0	1	1
		.0%	100.0%	100.0%
42120400	Moving Services	1	12	13
		7.7%	92.3%	100.0%
42120401	Furniture Moving, Local, Without Storage	0	1	1
		.0%	100.0%	100.0%
42129903	Delivery Service, Vehicular	1	9	10
		10.0%	90.0%	100.0%
42129905	Dump Truck Haulage	0	7	7
		.0%	100.0%	100.0%

	42129906	Garbage Collection and Transport, No Disposal	1	1	2
			50.0%	50.0%	100.0%
	42129907	Hazardous Waste Transport	0	1	1
			.0%	100.0%	100.0%
	42129908	Heavy Machinery Transport, Local	0	2	2
			.0%	100.0%	100.0%
	42129909	Light Haulage and Cartage, Local	2	5	7
			28.6%	71.4%	100.0%
	42129910	Mail Carriers, Contract	0	1	1
			.0%	100.0%	100.0%
	42129912	Steel Hauling, Local	0	3	3
			.0%	100.0%	100.0%
	42129913	Truck Rental, With Drivers	0	2	2
			.0%	100.0%	100.0%
	42130000	Trucking, Except Local	2	42	44
			4.5%	95.5%	100.0%
	42139901	Automobiles, Transport and Delivery	1	8	9
			11.1%	88.9%	100.0%
	42139903	Contract Haulers	2	8	10
			20.0%	80.0%	100.0%
	42139904	Heavy Hauling, NEC	0	3	3
			.0%	100.0%	100.0%
	42139905	Heavy Machinery Transport	0	2	2
			.0%	100.0%	100.0%
	42139906	Household Goods Transport	0	1	1
			.0%	100.0%	100.0%
	42139907	Less-Than-Truckload (e.g., FedEx)	0	1	1
			.0%	100.0%	100.0%
	42139909	Mobile Homes Transport	1	0	1
			100.0%	.0%	100.0%
	42140000	Local Trucking With Storage	1	11	12
			8.3%	91.7%	100.0%
	42149901	Furniture Moving, Local, With Storage	1	0	1
			100.0%	.0%	100.0%
Totals			16	185	201
			8.0%	92.0%	100.0%

III. Responses by Wood Residue Category

The first question asked of businesses contacted by telephone was whether they primarily generated or accepted wood waste in the following eight categories:

1. Pallets, skids, and shipping crates;
2. Dunnage (wood used in packing to support and protect items being shipped);
3. Edging and cutoffs (for example, either from making wood products such as trim and molding or cutting those products to length);
4. Chips, shavings, and sawdust (for example, from making wood products such as lumber);
5. Tree residues -- that is, tree trunks, limbs, and stumps;
6. Construction debris (for example, cutoffs from framing and wood sheathing);
7. Railroad ties, and
8. Telephone poles.

Out of the total 1,500 businesses contacted, 420 (28%) indicated that they did one or the other during the calendar year 2005. Of the 420, 373 (88.8%) primarily generated and 47 (11.2%) primarily accepted wood waste.

As shown in Table 16, an adequate number of responses were obtained from the 373 businesses that primarily generated residue for 5 of the 8 categories: pallets, skids, and shipping crates, edgings and cutoffs, chips and shavings, tree residue, and construction debris. Only 4 businesses generated dunnage. In future surveys, dunnage could be included in a separate category or combined with shipping crates.

None of the responding companies either generated or accepted railroad ties or telephone poles. The reason both are absent is that the Major Groups, Railroad Transportation (SIC 40), and Communications (SIC 48), were inadvertently omitted from the sampling frame. However, because only a handful of railroad and utility businesses would have been included, the probability of one or more being selected into the sample is very small.

This raises an important issue for future urban residue surveys. Railroads, utilities, and any other individual companies who are few in number but likely large generators should be separately identified and included in the sample even though this violates the basic requirement of probability sampling that every member of the study population have the same known chance of being selected into the sample as every other member. Because the companies are deliberately included, the chance of being selected is 1.0, whereas the chance for all the other businesses is less, perhaps considerably less, than 1.0.[8] Even so, being likely large contributors warrants their separate selection. That this has been done should be clearly explained.

As given in Table 17, pallets, skids, and shipping crates (hereafter, pallets) made up three-fourths (74.5%) of the total among the 47 companies that primarily accepted residue. The remaining one-fourth was thinly spread across the other six categories. No one accepted tree trunks, limbs, and stumps.

[8] This is a variation on a stratified sample where the known probabilities of selection across the strata would be directly weighted by the amount of residue generated in each stratum: specifically, the chances of selection would be directly proportional to the amounts generated. However, if the amounts generated were known there would be no need for a survey. The second best procedure is to include those thought to be major contributors and query them separately.

Table 16

Businesses That Primarily Generate Wood Residue

Response	Frequency	Percent
Chips, shavings, sawdust	62	16.6%
Construction debris	136	36.5%
Dunnage	4	1.1%
Edgings, cutoffs	74	19.8%
Pallets, Skids, Shipping Crates	83	22.3%
Railroad ties	0	0.0%
Telephone poles	0	0.0%
Tree trunks, limbs, and stumps	14	3.8%
Subtotal	373	100.1%
Primarily accepts wood residue	47	11.2%
Primarily generates wood residue	373	88.8%
Totals	420	100.0%

Table 17

Businesses That Primarily Accept Wood Residue

Response	Frequency	Percent
Chips, shavings, and sawdust	1	2.1%
Construction debris	5	10.6%
Dunnage	1	2.1%
Edgings and cutoffs	1	2.1%
Pallets, Skids, Shipping Crates	35	74.5%
Railroad ties	1	2.1%
Telephone poles	3	6.4%
Tree trunks, limbs, and stumps	0	0.0%
Subtotal	47	99.9%
Primarily accepts wood residue	47	11.2%
Primarily generates wood residue	373	88.8%
Totals	420	100.0%

Types of Residue

Businesses that identified themselves as primary generators were all asked questions in the following categories (see Appendix A for the specific questions and Appendix C for the frequency distributions by question):

1. How was the amount of wood residue disposed of measured?
2. How much was disposed of?
3. Were payments made for removal or were the companies paid for the residue?
4. What were the amounts paid for removal or residue?
5. Did the responding company or some other company transport the residue?
6. Was any of the material sent to a landfill?
7. If so, how far away is the landfill?
8. How much was reused by the company and how was it reused?

Businesses that accepted residue were also asked how they measured the amounts they received, what and how much they accepted, major sources, how much is and is not reused, what the reuses are, and reasons for not re-using more. They were also asked what, if anything, government could do to encourage greater usage.

Of the 8 types of wood residue identified in the survey, an adequate number of responses were obtained for five:

1. pallets;
2. edgings and cutoffs;
3. chips, shavings, and sawdust;
4. tree residues; and,
5. construction debris.

Only 4 companies indicated that they generated dunnage, too few to be statistically meaningful. Unless a survey such as this one is being conducted in major port of entry, where both dunnage and familiarity with it are common, this category should be either dropped or combined with shipping crates. The combination would require measures only by volume or weight since dunnage is not a distinct structure like a pallet and cannot be counted in discrete numbers.

No responses were obtained for either railroad ties or utility poles. The results reported below are for the five categories for which adequate numbers were obtained.

Adjustments to the Number of Respondents

Adjustments for Question Non-Response

For estimates of totals, adjustments in the number of reporting companies are made for Don't Know (DK) and Refusal responses to specific questions (hereafter, question non-response refers to either DK, Refusals, or both). In general, question non-responses are allocated among the responses by the distribution across the responses. For example, to a specific question, if 5 companies answered "Yes", 10 answered "No", and 6 did not respond, then 2 would be added to 5 and 4 added to 10 reflecting the one-third/two-thirds division among those who answered the question with either a "Yes" or "No". The adjusted distribution would be 7 "Yes" and 14 "No". The total number remains the same. Question non-responses are not allocated among responses where non-response is worth noting as a separate answer to a question.

Adjustments for Survey Refusals

A total of 873 companies refused to be interviewed. The frequencies for the survey refusals across the 20 Major Industry Groups that are part of the sampling frame for this study are given in column C in Table 21 (and in Table 16).

Among the 373 companies that were primary generators, 30 also generated specific secondary residues in addition to and different from their primary residues. Together, 373 companies totaled 403 (373 + 30) sources of primary and secondary residue. Because the numbers are too small to use, 7 dunnage generators were subtracted leaving a net total of 396 primary and secondary sources (given by Major Industry Group in column E in Table 21).

Of the 1,500 companies that responded to the survey, 26.4% (396/1,500) were sources of residue. Assuming 26.4% of the refusals also would have been primary and secondary sources initially adds another 230 (.264 x 873). When these 230 sources are distributed across the 20 Major Industry Groups and then apportioned for each Group by residue type the total increases to 236 (the reason for the increase by 6 and the details of the calculations are both provided in footnote 2 in Table 21). The total number of actual and possible sources of residue is 632.

When made, adjustments for question non-response and survey refusals are based on the assumption that the distribution of answers among non-respondents to specific questions as well as among those who refused to be interviewed would be the same as those who did respond to the questions and did participate in the survey. That they did not respond to a question or participate in the survey sets these companies apart from those who did. The risk in making this assumption is that had they responded they might have given answers different from those who participated. However, leaving them out would have created residue and expenditure estimates that are far too conservative. The choice here is to include them and accept the risk of the assumption.

Adjustments for survey refusals are not made when only the numerical or percentage frequencies for a question are examined. Since adding survey refusals increases the totals but leaves the percentages unchanged except for rounding, there is no point in doing so when totals are not being examined.

The distributions for survey refusals (column C, Table 21) and respondents (column E) who generated residue were compared for the 20 Major Industry Groups using the Kolmogorov-Smirnov (K-S) two-sample test.[9] As applied here, for a given significance level, the K-S test determines whether two independent samples came from two separate populations (survey refusals and respondents) that share the same distribution for a particular measure. In this case, the measure is the frequencies across the 20 Major Industry Groups. Using a two-tailed test and a significance level of .05 (.05/2 or .025 for each tail of the distribution), the probability of getting a K-S Z statistic of 0.949 is 0.329, well above .025. Given the closeness of the sample distributions, the two separate population distributions by Major Groups for survey refusals and

[9] The χ^2 test is widely used to determine whether two or more independent samples have been drawn from the same population or from two or more populations with the same distribution for the variable being examined. One drawback to this test is that the frequency per cell (the intersection of a row and column) should not be less than 5. Several distributions in this study have cell frequencies below this minimum. Since the K-S test is based on a cumulative frequency distribution, there is no minimum per cell. In addition, the test has high power-efficiency and is in all cases more powerful that the χ^2 test. For confidence intervals, a confidence level of 95% is used. For single sample tests and comparisons of two samples, the two-tailed K-S test is used with a significance level of .05. This means that the probability of getting the K-S Z statistic must be below .025 (.05/2) to be considered statistically significant. See Sidney Siegel and N. John Castellan, Jr. *Nonparametric Statistics for the Behavioral Sciences*, 2nd edition, McGraw-Hill, Boston, 1988, pgs. 144-151.

residue generators are statistically the same. This lends indirect support to the assumption that the distribution of answers among survey refusals would be the same as those for residue generating sources.

Companies That Primarily Generate Pallets, Skids, and Shipping Crates[10]

Disposal Measures and Amounts

Eighty-five companies disposed of pallets. For 83, these were primarily what they disposed of while for the remaining2 pallets were secondary.

As given in Table 18, of the 85 companies, 33 (40.0%) are in Industrial & Commercial Machinery and Computer Equipment, 11 (14.1%) are Lumber & Other Building Materials Dealers, 8 (9.4%) in Building Construction, and 6 each (7.1%) for Motor Freight Transportation and Furniture Stores. These 5 Major Industry Groups account for just over three-fourths (77.7%) of companies in all the other remaining Groups. The other 19 (22.4%) are spread out in very small numbers across 11 other Major Industry Groups.

The additional 54 sources bring the total to 139. Multiplying by the population-to-sample ratio of 3 to 1 yields a population estimate of 417 sources of pallets in the 14 county area in 2005.

Table 18
Disposition of Pallets by Major Industry Group/Industry

SIC	Major Industry Group/Industry	Frequency	Percent
35	Industrial & Commercial Machinery and Computer Equipment	34	40.0%
52: 5211	Building Materials, Hardware, Garden Supply & Mobile Home Dealers: Lumber &Other Building Materials Dealers	12	14.1%
15	Building Construction	8	9.4%
42	Motor Freight Transportation	6	7.1%
57: 5712	Home Furniture, Furnishings & Equipment Stores: Furniture Stores	6	7.1%
	Subtotal	66	77.7%
	All Others	19	22.4%
Totals		85	100.1%

As shown in Table 19, among those who identified how pallets were measured, the most frequent answer is by number. By about a two-to-one ratio (31 ÷ 15), more pallets were counted than were measured by truck/container loads. Only 1 company measured by weight. However, the largest percentage, 42.4%, did not know (DK) how the pallets were measured and another 2.4% refused to answer. A total of 38 companies gave these two answers.

[10] Both pallets and skids are in form and function near-perfect substitutes for one another, hence, they can validly be counted together. While wooden shipping crates perform a similar function, by form they are not close substitutes because they are differently and often custom constructed and are not as easily reused in their original form. Crates are sufficiently different that counting them with or as pallets and skids is open to question. Since a typical crate requires more wood than a typical pallet, counting crates as pallets leads to a consistent underestimate of the amount of wood residue generated and accepted. In this report, all three are lumped together which results in the treatment of crates as if they were pallets in the calculation of amounts generated and received. Worth considering in future residue surveys is creating a separate category for crates with questions tailored to their form, construction, quantity of wood content, and ease of recycling and reuse.

The 38 question non-responses are allocated on the same 2 to 1 ratio between numbers of pallets and truck/container loads. These adjusted numbers, shown also in Table 19, are based on the assumption that the disposal proportions for the non-respondents are the same as those who answered. As adjusted, about two-thirds counted pallets while the remaining companies measured by truck/container loads.

Table 19
Disposition of Pallets by Type of Measure:
Unadjusted and Adjusted for Question Non-Response

Measured by:	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Number of pallets, skids, shipping crates	31	36.5%	57	67.1%
Truck/container loads	15	17.7%	27	31.8%
Weight	1	1.2%	1	1.2%
DK	36	42.4%		
Refusal	2	2.4%		
Totals	85	100.2%	85	100.1%

After allocating the 38 companies that did not know or refused to answer among the three measurement methods, 57 counted by number, 27 by truck/container loads, and1 by weight. The amount by weight is trivial compared to the others and is not included in subsequent estimates.

The 54 additional companies who refused to be interviewed are allocated by type of measure using the adjusted percentages in Table 19. This raises the total for those who measure by number to 93, by truck load to 44, and by weight to 2. The results shown in Table 20.

Table 20

Disposition of Pallets Type of Measure:
Adjusted for Survey Refusals

Measured by:	Frequency	Percent
Number	93	66.9%
Truck/container loads	44	31.7%
Weight	2	1.4%
Total	139	100.0%

As shown in Table 22, among the adjusted total of 93 who measured by numbers of pallets, 78 disposed of between 0 and 200 pallets during a typical month. Three disposed of between 200 and 400 and 3 more between 400 and 600. The remaining 9 responded with numbers for the entire year. Since their yearly totals are trivial compared to the yearly estimate, they are not included in the total calculation.

Table 21

Survey Refusals, Residue Generators, and Adjusted Total Generators by Major Industry Groups and Types of Residue

(A) SIC	(B) Major Industry Groups	(C) Survey Refusals	(D) Possible Primary & Secondary Residue Sources Among Survey Refusals	(E) Actual Primary & Secondary Residue Sources	(F) Pallets, Skids, Shipping Crates (5)	(G) Edgings, Cutoffs (4)	(H) Chips, Shavings, Sawdust (1)	(I) Tree Trunks, Limbs (8)	(J) Construction Debris (2)
01	**Agricultural Production**	1	1	1	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
07	**Agricultural Services**	0	3	4	0 (0)	0 (0)	3 (2)	1 (1)	0 (0)
15	**Building Construction**	296	111	190	8 (5)	45 (26)	15 (9)	14 (8)	108 (63)
16	**Heavy Construction, other than Building**	11	3	4	1 (1)	0 (0)	0 (0)	2 (1)	1 (1)
17	**Construction, Special Trade Contractors**	57	19	32	3 (2)	10 (6)	4 (2)	1 (1)	14 (8)
24	**Lumber /Wood Products, except Furniture**	25	19	33	0 (0)	9 (5)	22 (13)	0 (0)	2 (1)
25	**Furniture &Fixtures**	9	6	10	3 (2)	3 (2)	2 (1)	0 (0)	2 (1)
26	**Paper &Allied Products**	6	2	3	1 (1)	0 (0)	2 (1)	0 (0)	0 (0)
32	**Stone, Clay, Glass, & Concrete Products**	27	3	5	4 (2)	0 (0)	1 (1)	0 (0)	0 (0)
33	**Primary Metal Industries**	0	1	1	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
35	**Industrial & Commercial Machinery & Computer Equipment**	188	29	48	34 (20)	3 (2)	10 (6)	0 (0)	1 (1)
37	**Transportation Equipment**	18	1	1	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)

39	**Miscellaneous Manufacturing Industries**	3	1	1	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
42	**Motor Freight Transportation**	97	7	12	6 (4)	0 (0)	0 (0)	2 (1)	4 (2)
49	**Electric, Gas, and Sanitary Services**	8	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
50	**Wholesale Trade, Durable Goods**	0	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
52	**Building Materials, Hardware, Garden Supply &Mobile Home Dealers**	45	19	34	12 (7)	9 (5)	4 (2)	0 (0)	9 (5)
54	**Food Stores**	39	2	3	2 (1)	0 (0)	1 (1)	0 (0)	0 (0)
57	**Home Furniture, Furnishings & Equipment Stores**	40	8	13	6 (4)	3 (2)	4 (2)	0 (0)	0 (0)
59	**Miscellaneous Retail**	3	1	1	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
	Subtotals	**873**	**236**	**396** [1]	**85**	**82**	**68**	**20**	**141**
	Possible Source Subtotals			**236**[2]	**54**	**48**	**40**	**12**	**82**
	Total: Actual + Possible			**632**	**139**	**130**	**108**	**32**	**223**

[1] A total of 373 companies generated primary wood residue. Among these, 32 companies generated secondary residue as well. Of the 32 secondary generators, 30 identified the types of residue while 2 did not. The total for primary and secondary sources is 405. Minus the 2 DK's and another 7 for dunnage, excluded because of the small number reporting, leaves a net total of 396 primary and secondary residue sources.

[2] The 396 sources are 26.4% of the 1,500 companies interviewed. Using this percentage to initially estimate the number of potential sources among the refusals yields 230 (.264 x 873). The 230 potential sources are distributed across the 20 Major Industry Groups using the percentage for each Group of the total 396 for all the Groups. For example, 47.98% (190/396 x 100) of all actual sources are in Building Construction (SIC 15). Among the 230 possible sources, 110 are in Building Construction (.4798 x 230). The initial 230 possible sources are apportioned across the other 19 Major Groups the same way. The results are in column D. The estimates of possible residue sources by Major Group were then further apportioned across the five types of residue using the percentage for each residue of the total of all actual residue sources by Major Group. For example, the 45 actual sources of Edgings and Cutoffs in Building Construction are 23.68% of the 190 total sources of all five residues for Building Construction. Multiplied by the 110 possible sources of Edgings and Cutoffs in Building Construction yields 26 possible sources of Edgings and Cutoffs in Building Construction. These calculations were done for all five residue types across all Major Groups. The possible number of sources is given in parentheses for each residue type by Major Group. Due to rounding, the total for all possible sources is 236, 6 more than the initial estimate of 230.

Table 22

Disposition of Pallets by Number:
Unadjusted and Adjusted for Survey Refusals

Number of Pallets	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
0 - <200	26	83.9%	78	83.9%
200 - <400	1	3.2%	3	3.2%
400 - <600	1	3.2%	3	3.2%
Totals for 2005	3	9.7%	9	9.7%
Total	31	100.0%	93	100.0%

The sample average for companies that count numbers of pallets is 121 pallets per firm per month.[11] When multiplied by 84 (the number of companies reporting monthly amounts) and then by 12 (months in a year), the total to the nearest 1,000 for the sample companies is 122,000 pallets.

Table 23

Disposition of Pallets by Number of Truck/Container Loads:
Adjusted for Question Non-Response and Survey Refusals

Number of Loads	Frequency	Percent
0 - <10	36	81.8%
20 - <30	4	9.1%
30 - <40	4	9.1%
Totals	44	100.0

Using the adjusted number from Table 20, 44 companies measured their monthly disposal by truck/container loads. As shown in Table 23, of these, 36 (81.8%) disposed of up to 10 truckloads on average per month. The remaining 8 were equally divided between 20 to 30 and 30 to 40 loads. Rounded to the nearest whole load, the sample average for these companies is 8 loads per company per month. When multiplied by 44 (the adjusted number of companies) and then by twelve (months), the estimate for 2005, rounded to the nearest 100, is 4,200 loads.

To the nearest cubic yard, the average volume of trucks hauling pallets is 10 cubic yards. Assuming 6 pallets (6" x 3' x3') fit into a cubic yard, a truck or container with a 10 cubic yard capacity can carry 60 pallets per load. Multiplied by 4,200 loads, yields a total of 252,000 pallets generated by the sample companies who measure by the truck and container load.

Together the sample companies that measured by number and volume generated a total of 374,000 pallets. Multiplied by the population-to-sample ratio of 3 to 1 yields a population total of 1,122,000 pallets.

[11]Unless otherwise noted, averages are calculated from grouped data using mid-point values for the ranges in each distribution. For example, in Table 22, the mid-points are 100, 300, and 500, respectively, for the three ranges 0 - <200, 200 - <400, and 400 - <600.

Automobile Manufacturers

The nation's largest domestic automobile manufacturers have plants in the study area. Given the size of their operations, they are likely generators of large amounts of pallets. Eighty-three companies and company divisions were listed among the roster of all companies selected by SIC as the sampling frame for this survey. Of those, 32 (38.6%) were drawn into sample. This percentage is slightly greater than the sampling percentage of 34.9% (7007/20101). Of the 32, one answered No to the generation question and the rest were non-respondents.

Given their size and their initial refusal to participate in the survey, a separate attempt was made to obtain data from each company on the quantity of pallets they generated in 2005. A General Motors representative reported that GM generated 11,462 tons in all of their Michigan facilities. Using an average of 30 pounds per pallet, they generated about 764,000 pallets in 2005. Essentially all of their pallets were either recycled, reused, or reclaimed: only a very few (0.3% of the total) ended up in landfills. No data were provided on exactly who accepted the pallets or whether GM paid for removal or was paid for the pallets (or both).[12] GM also reported generating 4,667 tons of other wood residue. Neither the types of residue nor the disposition were reported.

A representative of the Ford Motor Company declined to provide information. The representative of Daimler-Chrysler did respond but could not provide any data on either pallets or wood waste in general. Nevertheless, these two companies generated and disposed of a substantial number of wood pallets. Based on the experience of a major pallet recycler in Detroit, the assumption here is that Ford generated one-half of the amount in 2005 that GM did (382,000) and that Daimler-Chrysler generated about the same amount as GM (another 764,000).[13] The total for the three companies is 1,910,000 pallets, an amount that significantly exceeds the estimated total for all of the rest of the companies in the study area combined.

Including the separate estimate for the automobile companies, an estimated total of 3,032,000 pallets were generated in the 14 counties in 2005. Assuming 6 pallets to a cubic yard, an estimated total of 505,000 cubic yards were generated.

Disposal Payments and Removal

Only three companies reported being paid for their pallets and the amounts were negligible. The standard procedures are either to pay for pallets to be removed or to give them away at no removal cost.

The total number of companies is adjusted upward by the 54 companies who are likely pallet generators among the 873 who refused to respond to the survey. This raises the total to 139 sources. The adjusted distribution by type for the 139 sources is given in Table 25. Payments by

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[12]From a different source, GM reported that in 2005 pallets and other wood residue from its facility in Pontiac, Michigan were accepted by a company is southeast Michigan that produced mulch (http://www.gm.com/company/gmability/sustainability/reports/05/600_environment/5_fifty/650na.html).

[13]Provided by Chuck Foster of Auto Pallets and Boxes of Detroit by telephone conversation February 14, 2007. Mr. Foster believes the estimate for all companies other than the three automobile manufacturers is low because both the number of pallets per load and the number of loads per average month in 2005 are far too low. Based on his experience, an average load of 300 pallets (versus 60) and 100 loads per month (versus 8) would be typical for 2005. The total generated using these numbers is roughly 16 million pallets. Mr. Foster's company is one of the largest and his monthly figures are far above the average based on this survey. Nevertheless, his experience suggests that the 3 million pallet estimate is conservative.

adjusted frequencies are given in Table 26 where the original distribution, adjusted for question non-responses, was used to allocate the 57 companies across the three payment ranges.

As given in Table 24, a little more than one-third (35.3%) of the companies disposing of pallets paid for removal. By contrast, almost exactly half (50.6%) either incurred no expense or were paid for the pallets. The rest (14.2%) indicated that they either did not know (11.8%) or they refused to answer the question (2.4%). The 12 companies that selected the last two responses were allocated among those that did respond. These adjusted numbers are also adjusted frequencies are given in Table 26 where the original distribution, adjusted for question non-responses, was used to allocate the 57 companies across the three payment ranges.

Based on frequencies given in Table 26, removal payments by companies averaged $382/month. When multiplied by 57 (the adjusted number of companies) and 12 (months in a year), the total for 2005 is $261,300 for the companies in the sample. Multiplied by the population-to-sample ratio of 3 to 1, the total is about $784,000. This excludes the unknown amount spent by the three automobile manufacturers.

Table 24

Pallet Disposal by Type of Removal:
Unadjusted and Adjusted for Question Non-Response

Type of Removal	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Company paid for removal	30	35.3%	35	41.2%
Removed at no cost to company	39	45.9%	45	52.9%
Another company paid	4	4.7%	5	5.9%
DK	10	11.8%		
Refusal	2	2.4%		
Totals	85	100.1%	85	100.0%

Table 25

Pallet Disposal by Type of Removal:
Adjusted for Survey Refusals

Type of Removal	Frequency	Percent
Company paid for removal	**57**	41.0%
Removed at no cost to company	**74**	53.2%
Another company paid	8	5.9%
Totals	139	100.%

About one-fifth (19.1%) of the companies in the unadjusted sample used their own trucks to haul pallets to another site. The remaining four-fifths (81.0%) relied on trucks provided by others. The average hauling distance was 10 miles.

Sixteen out of 21 companies that paid for removal sent their pallets to landfills (question 7.A.1.). Seven out of 39 that avoided disposal costs burned or otherwise disposed of their pallets

(question 7.B.). In total, a confirmed 23 out of 85 sample companies (27.1%) treated pallets as waste while the other 62 (72.9%) did not. Using these two percentages and the 1,122,000 pallets generated by the 617 companies, about 818,000 pallets were reused and about 304,000 were discarded (these calculations are based on the assumption that the percentages reused and discarded are the same as the percentages of companies that reused and discarded). The best evidence is that the three automobile companies reused or recycled 90% of the pallets they generated. This means that of the estimated 1,910,000 they generated, 1,719,000 were reused and 191,000 were not. Taken together, all 620 companies reused or recycled 2,538,000 (83.7%) and discarded 494,000 (16.3%). In cubic yards, using 84% and 16%, respectively, they reused or recycled 424,000 cubic yards and discarded 81,000 cubic yards. Of the amount discarded, 15,000 cubic yards, or 18.8% (16/85), were disposed of in landfills.

As shown in Table 27, the 74 sample companies that avoided removal costs did so by giving away about three-fourths (74.4%) of the pallets to individuals and to other companies. Adding the 5.4% that were recycled or reused, almost 80% were reused in some fashion. Less than one-fifth (17.6%) were burned or tossed instead of being reused. By contrast, among those that paid for removal, about three-fourths sent their pallets to landfills.

Table 26

Company Paid For Removal:
Adjusted for Question Non-Response and Survey Refusals

Removal Payments	Frequency	Percent
$0 - <$500	51	89.5%
$1,000 - <$1,500	3	5.3%
$1,500 - <$2,000	3	5.3%
Totals	**57**	100.1%

Among the original 85 responding companies in the sample, just over two-thirds (69.4%) indicated that they did reuse their own pallets while just over one-fourth (27.1%) did not. The rest (3.5%) did not know. Among the 55 companies that did make use of their own pallets, reuse averaged almost half (47.5%). The large majority (85.5%, adjusted for non-response) reused pallets as pallets, the rest were reduced to parts and fiber for other uses such as heating fuel and land cover (questions 9 and 9.A.).

Table 27

How Pallets Are Removed At No Cost to Companies:
Adjusted for Survey Refusals

Type of Removal	Frequency	Percent
Given away to public/employees	44	59.5%
Given away to other companies	11	14.9%
Burned	9	12.2%
Trashed/dumped/thrown away	4	5.4%
Recycled/reused	4	5.4%
DK	2	2.7%
Totals	**74**	100.1%

Overall in 2005, an estimated 420 companies (including the 3 automobile manufacturers) in the 14 county area generated just over 3 million pallets. Excluding the three automobile manufacturers, about three-fourths of the pallets were generated by companies that manufacture machinery and computer equipment, sell lumber and other building materials, construct buildings, haul freight, and sell furniture. About 6 out of 10 of these companies disposed of their pallets at no cost to themselves while the remaining 4 out of 10 paid in total about three-quarters of a million dollars for removal. Among the majority of companies that incurred no disposal cost, about three-fourths did so by giving their pallets away. Among those who reused pallets, about two-thirds reused them as pallets. The rest were reduced to parts and fiber.

Companies That Primarily Accept Pallets, Skids, and Shipping Crates

Of the 420 companies that either generated or accepted wood waste, 47 (11.2%) reported they accepted. Of the 47, 35 (74.5%) primarily accepted pallets. The remaining 12 companies were almost evenly spread out over the other categories in numbers too small to be statistically useful. Hence, the analysis that follows is only for pallets. None of the accepting companies were asked whether they secondarily accepted another kind of wood waste.

As shown in Table 28, 40% of the companies that accepted pallets are in the Major Industry Group that manufactures Industrial & Commercial Machinery & Computer Equipment (SIC 15). Other than a slight concentration in Building Construction (14.3%), the rest of the companies are spread thinly across the remaining 9 Major Industry Groups. The distribution of companies was statistically even based on a one-sample K-S test (the K-S Z = .121, well above .025) across the 29 Line-of-Businesses, the most specific 8-digit code. This means that the slight concentration in Building Construction occurred by chance alone and has no statistical significance. In the study population, companies would be spread evenly across all Line-of-Businesses.

SIC code 2448 that includes companies that recycle pallets was included in the sampling frame. Eighteen companies were drawn into the sample from the 53 in the study population Four were contacted. Two refused to be interviewed and the other two indicated that they neither generated nor accepted wood waste.

None of the companies that stated they primarily accepted pallets are in Major Industry Groups or Lines-of-Business that one would expect. They are all in businesses that also generate pallets. Nevertheless, not only did the 35 companies indicate that they primarily accepted pallets but they also answered all of the additional questions about how they measured what they accepted, how much they received on a monthly basis, their major sources, what they did with what they accepted, why more is not reused and recycled, and what government might do to encourage recycling. There is no indication that either the initial and subsequent questions were misunderstood. Each question about wood waste accepted clearly refers to what was accepted, not generated. Nevertheless, there is a possibility that those responding for accepting firms did not fully understand the intent of the initial question about generating versus accepting wood waste in general and pallets in particular. The distributions for both the two-digit Major Industry Group (K-S Z = .880) and the eight-digit Line-of-Business (K-S Z = .307) for the 83 that generated and the 35 that accepted pallets are statistically the same. Thus, a reasonable inference is that these are the same kinds of companies whose representatives in the survey followed two different interpretations of the same question.

Table 28

Companies That Primarily Accept Pallets as Wood Waste by Major Industry Group

SIC	Major Industry Group	Frequency	Percent
15	**Building Construction**	5	14.3%
16	**Heavy Construction, other than Building**	1	2.9%
17	**Construction, Special Trade Contractors**	1	2.9%
25	**Furniture &Fixtures**	2	5.7%
26	**Paper &Allied Products**	2	5.7%
32	**Stone, Clay, Glass, & Concrete Products**	2	5.7%
35	**Industrial & Commercial Machinery & Computer Equipment**	14	40.0%
42	**Motor Freight Transportation**	2	5.7%
49	**Electric, Gas, and Sanitary Services**	1	2.9%
52	**Building Materials, Hardware, Garden Supply &Mobile Home Dealers**	3	8.6%
57	**Home Furniture, Furnishings & Equipment Stores**	2	5.7%
	Totals	**35**	**100.0%**

And additional explanation is that some though not all of the 35 companies have through experience developed ways of handling pallets to the point where they accept and process some of what they accept from other companies. This is certainly plausible since, as noted in the section above, some generators also reused their pallets. Nine out of 35 (25.7%) reported making further use of pallets as building materials, fuel, mulch, and as pallets. Of these, 3 completely reused the pallets they accepted while the other 6 partially reused theirs. There was no clear pattern among the small number of responses on reasons pallets were not fully reused. That pallet recycling is not these companies primary or secondary line-of-business does not prevent them from reusing and recycling what they can as an ancillary business activity that reduces disposal costs or even generates a small profit. Bush, Reddy, and Araman (1998) report that the National Wooden Pallet and Container Association has identified pallet recycling as the most profitable sector in the wood pallet industry.[14] Some of these companies might have developed ways to capture these profits for themselves.

[14]Robert J. Bush, Vijay S. Reddy, and Philip A. Araman. 1998. *Pallets: A Growing Source of Recycled Wood*, paper presented at The Use of Recycled Wood and Paper in Building Applications Conference, Madison, WI, September, 1996, p. 26.

Sixteen out of the 35 companies (45.7%) reported that they accepted and permanently held pallets as waste. Ten of the 16 (62.5%) stated that some or all of what they held was reusable while the remaining 6 (37.5%) indicated that none were. Since a substantial majority felt that some to all were reusable, the question is why did they not either reuse them or send them to recyclers who would. The same question can be asked of the 6 who held pallets they felt to be unusable. (The other 10 out of 35 did not know what became of the pallets their companies accepted.)

When all 35 were asked how much could be reused, one-third (12) thought none could while two-thirds felt that all or some could. The single most frequently cited reason (8 companies) why more pallets are not reused is the expense of hauling to recyclers. Among ways more pallets could be reused, the most frequent cited answer was finding new uses. Though listed as an answer, finding a recycler was not mentioned. About half (17) of the 35 responding companies felt that the most important action that state and local governments could take to promote greater use of wood waste in general is to provide more market information.

Worthwhile follow-up question in future surveys should address why these companies apparently made no attempt to dispose of their pallets, how many they tend to hold, and what happens when the inventory eventually exceeds storage space and must be reduced. A key question is why they simply did not contact nearby recyclers since this information is readily available in phone books, on the Internet, and from governmental sources such as the Michigan Department of Environmental Quality. This question also can be asked about the 13 generating companies that disposed of pallets as waste (Table 27). Five respondents among receiving companies thought government might provide more information about recycling. No one mentioned government regulations as an obstacle to disposal.

Regrettably, the survey data do not reflect practices among pallet recyclers since none agreed to participate. The data instead reflect practices among companies that are not primarily or secondarily in this business. Since data from and comparisons with pallet recycling companies would have been very useful, future surveys should disproportionately sample SIC 2448 to increase the chances that at least some recyclers are found who would be willing to participate in a survey.

The 35 companies that accepted pallets are 2.3% of the 1,500 companies interviewed. Multiplied by 873 survey refusals yields an additional 20 companies that possibly would have accepted pallets in 2005. Adding the 20 possible companies to the 35 that responded brings the total to 55 companies in the Major Groups listed in Table 28. When multiplied by the population-to-sample ratio of 3 to 1, the total is 165.

The 53 companies in the study population that are in the pallet business (SIC 2448) are separate from the 165 possible plus interviewed total. Adding these 53 brings the total population of companies that actually and would have possibly accepted pallets in 2005 to 218. The estimates below are based only on what the 55 sample companies did and would have done with the pallets they accepted. Since recyclers are likely to follow very different practices they are not included.

Of the 218, approximately 1 out of 4 companies that accept pallets is in the business of recycling and re-using them. Falk and McKeever (2004)[15] have concluded that pallet recycling

[15]Robert H. Falk, David B. McKeever. "Recovering Wood for Reuse and Recycling: A United States Perspective", Proceedings, European COST E31 Conference, *Management of Recovered Wood*, Christos Th. Gallis (ed.), April 22-24, 2004, Thessaloniki, Greece, p 37.

is among the most notable successes in solid wood recycling. They report that less than 1% of recovered pallets end up in landfills as solid waste. If this applies to the pallet recycling companies in the study area then essentially no pallets accumulate as waste, are burned, or go to landfills. Three out of four of the 218 companies that are not in the pallet recycling business nevertheless do recycle and reuse some but not all of what they accept. An important question, already raised above, is why the three-fourths majority have not found a way to connect with the one-fourth that would accept and fully use the majority's pallets. Such a market connection would both divert pallets from landfills and reduce if not eliminate the inventory of pallets held as waste.

Table 29

Acceptance of Pallets by Type of Measure:
Unadjusted and Adjusted for Survey Refusals

Measured by:	Unadjusted Frequency	Percent	Adjusted Frequency
Number	24	68.6%	38
Truck/container	8	22.9%	13
Weight	3	8.6%	4
Total	35	100.1%	55

Measures of Amounts Accepted

As shown in Table 29, about two-thirds of the companies measured pallets they accepted by the number. Just over one-fifth measured by the truckload while the rest measured by weight proportions across the three ways of measuring are statistically the same as the one for companies that accept pallets (Table 21). The probability of getting a K-S Z statistic of .408 is .996, far above .025.

As shown in Table 30, among the adjusted total of 38 who measured the number of pallets, 22 accepted between 0 and 200 during a typical month. One each accepted between 200 and 400 and 1,400 and 1,600, respectively. No yearly totals were reported. The average for companies that count pallets is 182 pallets per company per month. When multiplied by 38 (companies) and by 12 (months), the total to the nearest 1,000 is 83,000 pallets.

Table 30

Number of Pallets Accepted in an Average Month:
Unadjusted and Adjusted for Question Non-Response and Survey Refusals

Pallets Accepted per Month	Unadjusted Frequency	Adjusted Frequency: Non-Response	Adjusted Frequency: Survey Refusals	Adjusted Percent: Survey Refusals
0 - <200	21	22	35	89.7%
200 - <400	1	1	2	5.1%
1,400 - <1,600	1	1	2	5.1%
DK	1			
Total	24	24	38 (39)*	99.9%

*Rounding of frequencies adjusted for survey refusals based on percentages adjusted for question non-response yields a sum of 39. The average and standard deviation were calculated using the sum of 39. The other calculations are based on a sum of 38.

As shown in adjusted numbers in Table 31, 8 companies accepted between 0 and 20 truckloads and 3 between 20 and 40. Two accepted 400 or more (treated as 400 in the calculation of the grouped average). Rounded to the nearest whole load, the average for these companies is 27 loads per company per month. When multiplied by 13 (companies) and 12 (months) the total is 4,212 truck and container loads of pallets.

Based on the adjusted frequencies in Table 32, to the nearest cubic yard, the average volume of trucks and containers hauling pallets to these companies is 24 cubic yards (the "100 or more" responses are treated as 100 in the calculation). Assuming as before that 6 pallets fit into a cubic yard, trucks and containers with a 24 cubic yard capacity can carry 144 pallets per load. Multiplied by the number of loads yields a total to the nearest 1,000 of 607,000 pallets.

Adding the number and truckloads yields about 690,000 pallets for the sample companies. Multiplying by the population-to-sample ratio of 3 to 1 yields a total of about 2.1 million pallets.

Table 31

Number of Truck/Container Loads Accepted in an Average Month: Unadjusted and Adjusted for Question Non-Response and Survey Refusals

Number of Loads	Unadjusted Frequency	Adjusted Frequency: Non-Response	Adjusted Frequency: Survey Refusals	Adjusted Percent: Survey Refusals
0 - 20	4	5	8	61.5%
20 - 40	2	2	3	23.1%
400 or more	1	1	2	15.4%
DK	1			
Total	8	8	13	100.0%

Table 32

Truck/Container Volume in Cubic Yards: Unadjusted and Adjusted for Survey Refusals

Cubic Yards	Unadjusted Frequency	Percent	Adjusted Frequency: Survey Refusals	Adjusted Percent: Survey Refusals
0 - <10	5	62.5%	8	57.1%
10 - <20	1	12.5%	2	14.3%
30 - <40	1	12.5%	2	14.3%
100 or more	1	12.5%	2	14.3%
Total	8	100.0%	13 (14)*	100.0%

*Rounding of frequencies adjusted for survey refusals yields a sum of 14. The average and standard deviation were calculated using this total. The other calculations are based on a total of 13.

Table 33

Major Sources of Accepted Pallets

Pallet Sources	Unadjusted Frequency	Percent
Michigan businesses	14	40.0%
Businesses in other states	14	40.0%
Michigan governments	2	5.7%
Other state governments	1	2.9%
Other	4	12.4%
Total	35	101.0

An estimated 165 companies accepted 2.1 million pallets in 2005 while 420 companies generated about 3 million pallets. The 2.1 million estimate understates the total accepted because none of the 53 pallet recycling companies responded; hence, their total is not included. That what they accepted exceeds what is generated is reflected in the 42.9% of pallet sources reported to be from sources outside Michigan (40.0% for outside businesses and 2.9% for outside governments).

Though the survey data provide no direct way of measuring the amounts available, the opportunity seems to exist for recyclers to obtain more pallets from the companies that accept but do not recycle as a primary business, especially from those who hold pallets as waste. From the perspective of the companies not in the recycling business, finding recyclers and the cost of transportation seem to be the major barriers that separate them from recycling companies.

Finally, to the extent that state and local governments can do anything to tighten the market connections, providing additional information, especially on how transportation costs might be reduced, seems most promising. With some encouragement and modest support from government, recyclers themselves could also make additional efforts to connect, focusing also on ways both to reach companies that hold pallets and to reduce transportation costs.

Edgings and Cutoffs

Disposal Measures and Amounts

As given in Table 34, 82 companies primarily and secondarily disposed of edgings and cutoffs. Not surprisingly, 55 or two-thirds (67.1%) of them are in the construction industries. Nine companies (11.0%) manufacture wood products while another 9 (8.1%) sell lumber and other building materials. The remaining 9 are split evenly between makers of wood partitions and fixtures, manufacturers of metal and woodworking machinery, and furniture stores.

Another 48 companies also generated edgings and cutoffs when survey refusals are added, bringing the sample total to130 (see Table 21 above for the calculation).

As discussed earlier (page 33), that 248 companies in the Building Construction Group (SIC 15) did not generate any residue does not seem plausible given the essential role of wood in the very nature of what these companies do. The split between generators and non-generators persisted down to the 8-digit Line-of-Business level. To the same degree, this argument applies to the Construction, Special Trade Contractors Group (SIC 17) as well. To a lesser degree, it also applies to Industrial & Commercial Machinery & Computer Equipment (SIC 35), Motor Freight Transportation (SIC 42), and to Building Materials, Hardware, Garden Supply & Mobile Home Dealers (SIC 52). However, using only the numbers for the two construction Groups, the sample total is raised by 75 to 205.[16] Multiplied by the population-to-sample ratio of 3 to 1 yields a conservative population estimate of 615 companies in the fourteen county area that generated edgings and cutoffs in 2005.

Table 34

Disposition of Edgings and Cutoffs by Major Industry Group and Industry

SIC	Major Industry Group/Industry	Frequency	Percent
15: 1521, 1522, 1531	Building Construction: Single Family Construction & Remodeling, Residential Construction, New Housing Speculative Builders	45	56.8%
17: 1751	Construction, Special Trade Contractors: On-Site Cabinet Building & Installation	10	13.5%
24: 2421, 2426, 2431, 2434, 2452	Lumber and Wood Products, except Furniture: Sawmills & Planing Mills, Hardwood Dimension & Flooring Mills, Hardwood Dimension & Flooring Mills, Special (Wood) Products Mills, Wood Window Manufacturing, Cabinet Building, Stock & Custom, Prefabricated Wood Buildings	9	8.1%
25: 2541	Furniture & Fixtures: Wood Partitions & Fixtures	3	2.7%
35: 3535, 3541, 3553	Industrial & Commercial Machinery and Computer Equipment: Conveyors & Conveying Equipment, Machine Tools, Metal Cutting, Woodworking Machinery	3	4.1%
52: 5211	Building Materials, Hardware, Garden Supply & Mobile Home Dealers: Lumber & Other Building Materials Dealers	9	12.2%
57: 5712	Home Furniture, Furnishings & Equipment Stores: Furniture Stores	3	2.7%
Totals		82	100.1%

[16]Of the 190 primary (175) and secondary (15) sources of residue in SIC 15, 45 (23.7%) generated edgings and cutoffs. That percentage of the 248 companies who indicated that they did not generate residue is 59. Of the 32 primary and secondary sources of residue in SIC 17, 10 (31.3%) generated edgings and cutoffs. That percentage of the 52 companies who indicated that they did not generate residue is 16. The sum of the two is 75 companies.

As shown in Table 35, the question non-responses are allocated between the two ways of measuring amounts of edgings and cutoffs generated by primary and secondary sources using the proportions for those that responded. These adjusted percentages were then used to calculate the division between truck loads and weight shown in Table 36 for the total adjusted for survey refusals and non-generators.

Table 35

Disposition of Edgings and Cutoffs by Type of Measure: Unadjusted and Adjusted for Question Non-Response

Type of Measure	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Truck/container	54	65.9%	78	95.1%
Weight	3	3.7%	4	4.9%
DK	25	30.5%		
Totals	82	100.1%	82	100.0%

Table 36

Disposition of Edgings and Cutoffs by Type of Measure: Adjusted for Survey Refusals and Non-Generators

Type of Measure	Frequency	Percent
Truck/container loads	195	95.1%
Weight	10	4.9%
Total	205	100.0%

Table 37
Disposition of Edgings and Cutoffs by Number of Truck/Container Loads: Unadjusted and Adjusted for Question Non-Response, Survey Refusals, and Non-Generators

Number of Loads	Unadjusted Frequency	Unadjusted Percent	Adjusted	Percent
>0 - <20	37	77.1%	155	79.5%
20 - <40	4	8.3%	16	8.2%
40 - <60	2	4.2%	8	4.1%
80 - <100	2	4.2%	8	4.1%
220 - <240	1	2.1%	4	2.1%
280 - <300	1	2.1%	4	2.1%
DK	1	2.1%		
Subtotal	48	100.1%	195	100.1%

Using the adjusted frequencies in Table 37, the sample average is (to the nearest whole load) 27 loads per company per month. When multiplied by the 195 companies, by 12 months, and then rounded to the nearest 1,000 loads, the total is 63,000 loads.

Table 38

Volume of Trucks or Containers Used to Haul Edgings and Cutoffs: Adjusted for Question Non-Response

Cubic Yards	Unadjusted Frequency	Percent	Adjusted Frequency	Percent
0 - <10	22	40.7%	26**	48.2%
10 - <20	10	18.5%	11	20.4%
20 - <30	11	20.4%	12	22.2%
30 - <40	3	5.6%	5	9.3%
100 or more*	2	3.7%		
DK	6	11.1%		
Totals	54	100.0	54	100.1%

* Two respondents reported volumes for trucks and containers that were too large for what actually exists. The two were placed in the 30 to 40cubic yard interval, the largest otherwise mentioned.
**Initial rounding of frequencies left the total at 53. The frequency for the lowest range is increased by 1 to bring the total to 54.

Using the frequencies in Table 38, the average volume of trucks and containers used to haul edgings and cutoffs is (to the whole cubic yard) 14 cubic yards. Assuming full truck and container loads, the average for the 195 sample companies is 882,000 cubic yards.[17] Multiplied by the population-to-sample ratio of 3 to 1 yields a total of 2,646,000 cubic yards of edgings and cutoffs.

Disposal Payments and Removal

As given in Table 39, adjusted for question non-response, almost exactly two-thirds of the sample companies paid for removal while the remaining one-third incurred no expense. Adjusted for survey refusals and non-generators in Table 40, 135 companies paid for removal, 67 disposed of edgings and cutoffs at no cost to themselves, while 3 were paid.

Table 39

Edgings and Cutoffs Disposal by Type of Removal: Unadjusted and Adjusted for Question Non-Response

Type of Removal	Unadjusted Frequency	Percent	Adjusted Frequency	Adjusted Percent
Company paid for removal	53	64.6%	54	65.9%
Removed at no cost to company	27	32.9%	27	32.9%
Another company paid	1	1.2%	1	1.2%
DK	1	1.2%		
Totals	82	99.9%	82	100.0%

[17] Using an equal mix of plywood (776 pounds/cubic yard) and Douglas fir (891 pounds/cubic yard) as representatives by weight of edgings and cutoffs, a cubic yard would weight 834 pounds. Multiplied by 4,158,000 cubic yards yields a total estimated weight of about 1.7 million tons. The total estimated weight for the all companies that measured edgings and cutoffs by weight is trivial compared to the estimated weight for those who measured by truck or container load. The same is so if weight was converted to cubic yards. Hence, the estimated amount for those who measured by weight is excluded.

Table 40

Edgings and Cutoffs Disposal by Type of Removal:
Adjusted for Question Non-Response, Survey Refusals, and Non-Generators

Type of Removal	Adjusted Frequency	Adjusted Percent
Company paid for removal	135	65.9%
Removed at no cost to company	67	32.9%
Another company paid	3	1.2%
Totals	205	100.0%

Table 41

Company Paid for Removal:
Adjusted for Question Non-Response, Survey Refusals, and Non-Generators

Removal Payments	Unadjusted Frequency	Percent	Adjusted Frequency	Adjusted Percent
>$0 - < $500	43	81.1%	127	94.1%
$500 - < $1,000	2	3.8%	5	3.7%
$1,000 - <$1,500	1	1.9%	3	2.2%
DK	7	13.2%		
Totals	53	100.0%	135	100.0%

Among the 135 who paid for removal, the average monthly payment was $291 per company per month. When the average is multiplied by 135 (the adjusted number of companies), 12 (months), and then rounded to the nearest $1,000, the total is $471,000. Multiplied by the population-to-sample ratio of 3 to 1, 405 companies in the fourteen county area in 2005 spent a total of $1,413,000. Another 201 disposed of theirs at no cost to themselves. No data on payments either way are available for 9 companies**.**

Table 42

How Edgings and Cutoffs Are Removed At No Cost to Companies:
Adjusted for Survey Refusals

Type of No Cost Removals	Frequency	Percent
Given away to public/employees	120	58.5%
Given away to other companies	32	15.6%
Burned	26	12.7%
Trashed/dumped/thrown away	11	5.4%
Recycled/reused	11	5.4%
DK	5	2.4%
Totals	205	100.0%

As shown in Table 42, about three-fourths (74.1%) of the companies who avoided removal costs did so by giving the material away to the public, their own employees, and to other companies. Just 11 companies (5.4%) specifically recycled while 37 companies (18.1%) burned or discarded the material. No company was paid for its edgings and cutoffs.

Thirty-four out of 53 companies that paid for removal sent their edgings and cutoffs to landfills (question 15.A.2.). Fourteen out of 27 that avoided disposal costs did so by burning or otherwise disposing of the material as waste (question 15.B.). A confirmed total of 48 out of 80 companies, 60.0%, discarded edgings and cutoffs as waste while the other 40% did not. Thirty-four out of 80 (42.5%) sent their edgings and cutoffs to landfills. Assuming these percentages reflect the percentages for the amounts reused and discarded means that about 1,058,000 were used and 1,588,000 cubic yards were discarded. Of the latter, 675,000 cubic yards, or 42.5%, went to landfills.

Thirty-seven percent of the companies in the unadjusted sample used their own trucks to haul edgings and cutoffs to other places. The remaining 63% used trucks provided by other companies.[18] Based on numbers adjusted for question non-response (question 15.A.3.), edgings and cutoffs were hauled to landfills that were on average 12 miles away. Worth noting here is that the average 10 mile drive to dispose of pallets does not statistically differ from the average 12 mile drive to dispose of edgings and cutoffs.[19] Even thought these companies are in different industries and may be distributed differently throughout the 14 county area, they are driving about the same distance to dispose of their respective wood residues.

About one-third (34.2%) of the companies in the unadjusted sample of 82 reported that they made no use of their edgings and cutoffs while the remaining two-thirds (65.9%) did find uses (question 16). Companies that did averaged reusing just over one-third (37.0%). Just over one-fourth (27.8%) reused the material as heating fuel while the largest percentage, 29.6%, used or reused the material in building (question 17). Two other reported uses are as land cover and mulch.

Overall, an estimated 615 companies generated just over 2.6 million cubic yards of edgings and cutoffs in the 14 county area. Not surprisingly, two-thirds were in the construction business. Close to 1.6 million cubic yards was discarded and just over 1 million was used reused. Two-thirds of all 615 companies paid an estimated total of $1.4 million for removal. The remaining third paid nothing. Among those who paid, just over one-third used their own trucks for hauling an average distance of 12 miles to disposal sites. Among those who did not pay, about three-fourths avoided removal costs by giving the material away. Only 1 out of 20 companies recycled whereas 1 out of 5 burned or otherwise disposed of the material as waste. About two-thirds of all of the companies did make some use of their own edgings and cutoffs, the rest did not. The main uses were as building materials and heating fuel.

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[18] One company split hauling fifty-fifty with another company and the other used a dumpster. Both are classified as having used hauling services provided by other companies.

[19] The difference-of-means test for statistically independent samples was used to compare the average driving distances. The probability of getting the 2 mile difference by chance is .143 assuming equal population variances and .120 assuming unequal population variances. Either way, the probability is clearly greater than the usual significance levels for either a two-tailed or one-tailed test.

Chips and Shavings

Disposal Measures and Amounts

As shown in Table 43, among the 68 sample companies that disposed of chips and shavings, 28.0% are in construction, 32.4% in lumber and wood products manufacturing, and 14.7% in industrial, commercial, and computer equipment manufacturing. These three together account for three-fourths (75.1%) of all the companies that generated chip and shavings. The rest are spread in small numbers across 8 other industry groups.

Another 40 also generated chips and shavings when survey refusals are added. This brings the sample total to 108 (see Table 21 for the calculations). Multiplied by the population-to-sample ratio of 3 to 1 raises the total estimated population of companies in the 14 county area to 324.

Table 43

Disposition of Chips and Shavings by Major Industry Group and Industry

SIC	Major Industry Group/Industry	Frequency	Percent
07: 0783	Agricultural Services: Pruning and Trimming Services	3	4.4%
15: 1521, 1522	Building Construction: Single Family Construction & Remodeling, Residential Construction	15	22.1%
17: 1751	Construction, Special Trade Contractors: On-Site Cabinet Building & Installation	4	5.9%
24: 2421, 2426, 2429, 2431, 2434, 2452, 2499	Lumber and Wood Products, except Furniture: Sawmills & Planing Mills, Hardwood Dimension & Flooring Mills, Special Wood Products Mills, Wood Window Manufacturing, Cabinet Building, Prefabricated Wood Buildings, Wood Products NEC	22	32.4%
25: 2521	Furniture and Fixtures: Wood Office Furniture	2	2.9%
26: 2621, 2653	Paper & Allied Products: Paper Mills, Corrugated & Solid Fiber Boxes	2	2.9%
32: 3272	Stone, Clay, Glass, & Concrete Products: Concrete Products, except Block and Brick	1	1.5%
35: 3524, 3543, 3553, 3569, 3599	Industrial & Commercial Machinery and Computer Equipment: Lawn & Garden Tractors & Home Lawn & Garden Equipment, Industrial Patterns, Woodworking Machinery, General Industrial Machinery & Equipment, NEC, Industrial & Commercial Machinery & Equipment, NEC	10	14.7%
52: 5211	Building Materials, Hardware, Garden Supply & Mobile Home Dealers: Lumber & Other Building Materials Dealers	4	5.9%
54: 5411	Food Stores: Supermarkets	1	1.5%
57: 5712	Home Furniture, Furnishings & Equipment Stores: Furniture Stores	4	5.9%
Totals		68	100.1%

As shown in Tables 44 and 45, about three-fourths of the sample companies measured the amount of chips and shavings they disposed of by truck and container. The remaining one-fourth measured by weight.

Using the frequencies in Table 46, the average number of loads (to the nearest whole load) is 16 per company per month. When multiplied by 83 companies, 12 months, and then rounded to the nearest 1,000 loads, the total is 16,000 loads for the sample companies in 2005.

Table 44

Disposition of Chips and Shavings by Type of Measure: Unadjusted and Adjusted for Question Non-Response

Type of Measure	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Truck/container	33	48.5%	52	76.5%
Weight	10	14.7%	16	23.5%
DK	24	35.3%		
Refusals	1	1.5%		
Totals	68	100.0%	68	100.0%

Table 45

Disposition of Chips and Shavings by Type of Measure: Adjusted for Survey Refusals

Type of Measure	Frequency	Percent
Truck/container loads	83	76.5%
Weight	25	23.5%
Total	108	100.0%

From the frequencies in Table 47, the average volume of trucks and containers used to haul chips and shavings is to the whole cubic yard 10 cubic yards. Assuming full truck and container loads, the total for the 83 sample companies is 160,000 cubic yards.[20] Multiplied by the population-to-sample ratio of 3 to 1 yields a total of 480,000 cubic yards of chips and shavings.

Disposal Payments and Removal

As given in Table 48, adjusted for survey refusals, half of the sample companies disposed of chips and shavings at no cost to themselves. Four out of ten paid for removal while the remaining 1 out of 10 was paid by other companies.

From the distribution in Table 49, for the 44 companies who paid for removal, the average monthly payment was $284 per company per month. Multiplied by the 44 who paid, 12 (months), and then rounded to the nearest $1,000, the total is $150,000. Multiplied by the population-to-sample ratio of 3 to 1, 132 companies in the 14 county area spent $450,000. Thirty companies received a total of about $74,000 in payments from other companies (calculated from question 19.C.). The remaining 162 companies disposed of their chips and shavings at no cost to themselves.

[20] Adjusted for survey refusals, 25 companies disposed of a total of about 15 tons. Assuming an equal mix of chips and shavings weighs 470 pounds per cubic yard (metrokc.gov/dnrp/swd/business/documents/Conversions.pdf), 624,000 cubic yards would weigh about 147,000 tons. The amount measured by weight is trivial by comparison and is not included in the total.

Table 46
Disposition of Chips and Shavings by Number of Truck/Container Loads: Unadjusted and Adjusted for Survey Refusals

Number of Loads	Unadjusted Frequency	Percent	Adjusted for Question Survey Refusals	Percent
>0 - <20	26	86.7%	71*	85.5%
20 - <40	1	3.3%	3	3.6%
40 - <60	1	3.3%	3	3.6%
120 - <140	1	3.3%	3	3.6%
220 - <240	1	3.3%	3	3.6%
Totals	30	99.9%	83	99.9%

*Initial rounding of frequencies left the total at 72. The frequency for the lowest range range is reduced to 71 to bring the total to 83.

Table 47

Volume of Trucks or Containers Used to Haul Chips and Shavings: Adjusted for Question Non-Response and Survey Refusals

Cubic Yards	Unadjusted Frequency	Percent	Adjusted Frequency	Percent
0 - <10	23	69.7%	64	77.1%
10 - <20	3	9.1%	8	9.6%
20 - <30	1	3.0%	3	3.6%
30 - <40	1	3.0%	8	9.6%
100 or more*	2	6.1%		
DK	3			
Totals	33	99.9%	83	99.9%

*Two respondents reported volumes for trucks and containers that were too large for what actually exists. The two were placed in the 30 to 40 interval, the largest otherwise mentioned.

Table 48

Chips and Shavings Disposal by Type of Removal: Adjusted for Survey Refusals

Type of Removal	Adjusted Frequency	Adjusted Percent
Company paid for removal	44	40.7%
Removed at no cost to company	54	50.0%
Another company paid	10	9.3%
Totals	108	100.0%

Among the 26 companies that paid for chips and shavings removal, 20 used landfills (question 19.A.2.). Of the 34 that incurred no disposal cost, 11 either burned or otherwise disposed of theirs (19.B.). Out of 60 companies that reported, 31, or 51.7%, discarded while 29, or 48.3%, did not. Twenty-six out of 60 (43.3%) companies sent their chips and shavings to landfills. Projecting these percentages onto the total of 480,000 cubic yards generated, about 230,000 were used and 250,000 were discarded. Among the latter, 108,000 (43.3%) cubic yards were sent to landfills.

Table 49

Company Paid for Removal:
Adjusted for Question Non-Response and Survey Refusals

Removal Payments	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
>$0 - < $500	24	85.7%	42	95.5%
$500 - <$1,000	1	3.6%	1	2.3%
$1,000 - <$1,500	1	3.6%	1	2.3%
DK	2	7.1%		
Totals	28	100.0%	44	100.1%

Just over 4 out of 10 companies (42.6%) avoided disposal costs by giving their chips and shavings away to the public, their own employees, and to other companies. Just over 3 out of 10 (31.5%) either burned or disposed of the material as waste. Among those that disposed, just over three-fourths sent their material to landfills. The remaining companies (25.9%) either recycled or reused their chips and shavings. And, among these companies, just over half (54.6%) used the material as mulch. Just over a fifth (22.7%), used the material as heating fuel. Minor uses were made as animal bedding and land cover.

About three-fourths (76.9%) relied on other companies to haul their material to disposal sites. The remaining one-quarter used their own trucks. Based on numbers adjusted for question non-response (question 19.A.3.), to nearest mile, the average distance to disposal sites is 18 miles, 6 miles further than the average for companies that generated edgings and cutoffs and 8 miles further than companies that generated pallets. The distances for companies that generated edgings and cutoffs and chips and shavings are about the same. The driving distance for pallets is less than it is for chips and shavings.[20]

[21] The difference-of-means test for statistically independent samples was used to compare the average driving distances. The probability of getting by chance the 6 mile difference between companies that generated edgings and cutoffs versus those that generated chips and shavings is .020, assuming equal population variances, and .034, assuming unequal population variances. At a significance level of .05 for a two-tailed test, the difference is just barely significant assuming equal population variances. Assuming unequal variances, the difference is not significant. Both drive about the same distance. Compared to companies that generated pallets, the probability of getting an 8 mile difference by chance is .015 for equal variances and .011 for unequal variances. Either way, the difference is significant. Companies that generated chips and shavings drove further than those that generated pallets.

Table 50

How Chips and Shavings Are Removed At No Cost to Companies: Adjusted for Survey Refusals

Type of No Cost Removal	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Given away to public/employees	13	38.2%	21	38.9%
Given away to other companies	1	2.9%	2	3.7%
Burned	6	17.7%	9	16.7%
Trashed/dumped/discarded	5	14.7%	8	14.8%
Recycled/re-used	9	26.5%	14	25.9%
Totals	34	100.0%	54	100.0%

Overall, an estimated 324 companies generated 480,000 cubic yards of chips and shavings in the 14 county area. Three-fourths of these companies were either in construction, wood products manufacturing, or industrial machinery manufacturing. About 4 out of 10 companies paid just under one-half million dollars to dispose the material they generated. The other 6 out of 10 either gave the material away or, in a minority of cases, were paid for it. Among those that disposed of their chips and shavings as waste, about three-fourths used landfills. About 1 out of 4 recycled, mainly as mulch.

Construction Debris

Disposal Measures and Amounts

As shown in Table 51, among the 141 sample companies that disposed of construction debris, the large majority (76.6%) are in Building Construction (SIC 15). When the other two construction Groups, SIC 16 and 17, are added the total comes to 87.2 %. The remaining 12.7% is spread in across the five other Groups.

Another 82 also generated construction debris when survey refusals are added. This brings the sample total to 223 (see Table 21 for the calculations).

As discussed previously (page 33), that 248 companies in the Building Construction Group (SIC 15) did not generate any residue does not seem plausible given the essential role of wood in the very nature of what these companies do. As also noted previously, the split between generators and non-generators persisted down to the 8-digit Line-of-Business level. This also applies to the 52 companies in Construction, Special Trade Contractors Group (SIC 17) who claimed they did not generate wood residue. Using only the numbers for the two construction Groups, the sample total is raised by 164 to 387.[22] Multiplied by the population-to-sample ratio of 3 to 1 yields a population estimate of 1,161 companies in the fourteen county area that generated construction debris in 2005.

Table 51

Disposition of Construction Debris by Major Industry Group and Industry

SIC	Major Industry Group/Industry	Frequency	Percent
15: 1521, 1522, 1531	Building Construction: Single Family Construction & Remodeling, Residential Construction, Residential Construction, New Housing Speculative Builders	108	76.6%
16: 1611	Heavy Construction, Other Than Building: Highway & Street Construction	1	0.7%
17: 1751, 1795	Construction, Special Trade Contractors: Cabinet Building & Installation, On-Site, Demolition, Buildings & Other Structures	14	9.9%
24: 2431, 2499	Lumber and Wood Products, except Furniture: Wood Window Manufacturing, Wood Products, NEC	2	1.4%
25: 2511, 2541	Furniture and Fixtures: Cabinet, Household, Freestanding, Wood Partitions & Fixtures	2	1.4%
35: 3599	Industrial & Commercial Machinery and Computer Equipment: Industrial & Commercial Machinery and Computer Equipment, NEC	1	0.7%
42: 4212, 4213	Motor Freight Transportation: Local Trucking, Without Storage, Trucking, Except Local	4	2.8%
52: 5211	Building Materials, Hardware, Garden Supply & Mobile Home Dealers: Lumber & Other Building Materials Dealers	9	6.4%
Totals		141	99.9%

[22]Of the190 primary (175) and secondary (15) sources of residue in SIC 15, 108 (56.8%) generated construction debris. That percentage of the 248 companies who indicated that they did not generate residue is 141. Of the 32 primary (31) and secondary (1) sources of residue in SIC 17, 14 (43.8%) generated edgings and cutoffs. That percentage of the 52 companies in SIC 17 who indicated that they did not generate residue is 23. The sum of non-generators is 164 companies.

As shown in Tables 52 and 53, the distribution by type of measure, adjusted for question non-response, survey refusals, and non-generators, overwhelmingly favors trucks/containers: just under 9 out of 10 use trucks/containers while only about 1 out of 10 weigh the debris they generate.

Table 52

Disposition of Construction Debris by Type of Measure: Unadjusted and Adjusted for Question Non-Response

Type of Measure	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Truck/container	88	62.4%	125	88.7%
Weight	11	7.8%	16	11.4%
DK	41	29.1%		
Refusal	1	0.7%		
Totals	141	100.0%	141	100.1%

Table 53

Disposition of Construction Debris by Type of Measure: Adjusted for Survey Refusals and Non-Generators

Type of Measure	Frequency	Percent
Truck/container	343	88.6%
Weight	44	11.4%
Totals	387	100.0%

Table 54

Disposition of Construction Debris by Number of Trucks/Container Loads: Unadjusted and Adjusted for Question Non-Response, Survey Refusals, and Non-Generators

Number of Loads	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
0 - <20	69	78.4%	304	88.6%
20 - <40	5	5.7%	23	6.7%
40 - <60	2	2.3%	8	2.3%
80 - <100	1	1.1%	4	1.2%
100 - <120	1	1.1%	4	1.2%
Total for 2005*	2	2.3%		
DK	8	9.1%		
Totals	88	100.0	343	100.0%

*Placed in the 0 to 20 interval.

Based on the adjusted frequencies from Table 53, the sample companies averaged 14 loads per company per month. For 2005, rounded to the nearest 1,000 loads, the average is 58,000 loads for the 343 sample companies.

Table 55

Volume of Trucks or Containers Used to Haul Construction Debris: Unadjusted and Adjusted for Question Non-Response, Survey Refusals, and Non-Generators

Cubic Yards	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
0 - <10	30	34.1%	125	36.4%
10 - <20	10	11.4%	43	12.5%
20 - <30	23	26.1%	93	27.1%
30 - <40	12	13.6%	50	14.6%
40 - <50	3	3.4%	12	3.5%
70 - <80	1	1.1%	20*	5.8%
80 - <90	1	1.1%		
140	1	1.1%		
1,800	1	1.1%		
4,800	1	1.1%		
DK	4	4.6%		
Refusal	1	1.1%		
Totals	88	99.8 %	343	99.9%

*Four respondents reported volumes for trucks and containers that were too large for what actually exists. These were placed in the 70 to 80 cubic yard interval, the largest that seems to be in use on US highways.

Using the adjusted frequencies from Table 55, the average volume for truck and containers to the nearest cubic yard is 22 cubic yards. Assuming full loads, the average for the 343 sample companies is 1,276,000 cubic yards. Multiplied by the population-to-sample ratio of 3 to 1 yields a total of 3,828,000 cubic yards of construction debris generated in 2005. [23]

Disposal Payments and Removal

A very large majority (85.1%) paid for the removal of the debris they generated, averaging $514 per month per company. Only a relatively few (13.1%) disposed of debris at no expense to themselves. And, only a handful was paid (1.5%), and it was a negligible amount.

Table 56

Construction Debris Disposal by Type of Removal: Unadjusted and Adjusted for Question Non-Response, Survey Refusals and Non-Generators

Type of Removal	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Company paid for removal	117	83.0%	292	85.1%
Removed at no cost to company	19	13.5%	46	13.4%
Another company paid	2	1.4%	5	1.5%
DK	2	1.4%		
Refusal	1	0.7%		
Totals	141	100.0%	343	100.0%

[23] As with the other types of debris, the amount measured by weight is negligible and not included.

The total amount paid by the 292 sample companies was $1,801,000. Multiplied by the population-to-sample ratio of 3 to 1, 876 companies spent $5,403,000.

Table 57

Construction Debris Removal Payments:
Adjusted for Question Non-Response, Survey Refusals, and Non-Generators

	Removal Payments	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
	>$0 - < $500	82	70.1%	226*	77.4%
	$500 - $1,000	15	12.8%	42	14.4%
	$1,000 - <$1,500	4	3.4%	10	3.4%
	$1,500 - <$2,000	2	1.7%	5	1.7%
	$3,500 - <$4,000	2	1.7%	5	1.7%
	$4,000 - <$4,500	1	0.9%	2	0.7%
	$6,500 - <$7,000	1	0.9%	2	0.7%
	DK	10	8.6%		
	Totals	117	100.1	292	

*To compensate for a rounding error, adjusted up by 1for a total of 292.

Just under one-third (31.8%) of the companies in the unadjusted sample used their own trucks to haul their debris to disposal sites. The rest (68.2%) relied on trucks provided by other companies. Based on numbers adjusted for question non-response, the average driving distance to the sites was about 58 miles, far greater than for the other types of debris discussed above. As between other companies and landfills, a large majority (84.1%) of the debris was hauled to landfills.

Of the 117 companies that paid for removal, 73 sent their debris to landfills (question 29.A.2.). Of the 19 that avoided disposal costs, 12 burned or otherwise disposed of their debris (question 29.B.). In total, 85 out of 136 companies (62.5%) discarded their debris while the remaining 51 (37.5%) did not. Seventy-three out of 136 (53.7%) sent their debris to landfills. Projecting the percentage division between those who did and those who did not discard debris onto the total of 3,828,000 cubic yards generated, about 1,416,000 cubic yards were reused and 2,412,000 cubic yards were not. Of the amount discarded, 1,285,000 (53.7%) cubic yards went to landfills.

Among the 51 sample companies who avoided disposal costs, just over one-third (36.8%) did so by giving the debris to employees and other companies. Just under two-thirds (63.2%) either burned or discarded their debris as waste.

Adjusted for question non-response, just over half (52.5%) of the companies did not reuse any of the debris they generated. The rest averaged reusing only about one-fifth (21.6%) of what they generated. Of what was reused, 40% of the debris was as building materials, 17.1% in other unidentified ways, and 15.7% as heating fuel.

An estimated 1,161 companies, mostly in building construction, generated about 3.8 million cubic yards of construction debris in the 14 county area. Three-fourths of the companies paid about $5.4 million for disposal. The other one-fourth paid nothing, mainly by giving the debris away. Among those who paid, about one-third used their own trucks for hauling while the rest relied on other companies. The average hauling distance was 58 miles, far more than the

distances traveled by companies that generated pallets, edgings and cutoffs, and chips and shavings. Most of the discarded debris went to landfills. About 2.4 million cubic yards were discarded and 1.4 cubic yards were reused.

Tree Trunks, Limbs, and Stumps

Disposal Measures and Amounts

As shown in Table 58, 17 of the 20 (85.0%) sample companies that primarily and secondarily generate tree debris are in the construction industries. Only 2 are in motor freight and only 1 is in the tree care industry. A likely and simple explanation of construction company involvement is that they must remove trees to make way for whatever they are building.

A useful source of information on tree residue is companies in the tree removal business. To be as specific as possible in this study, only companies in the eight-digit line-of-business Pruning Services for Ornamental Trees (SIC 07830104) and Tree Trimming Services for Public Utilities (07830105) were included. The purpose of being this specific was to avoid the extra expenses of mailing cover letters and making telephone calls to a great many (probably a majority of) companies in the Ornamental Shrub and Tree Services Industry (SIC 0783) whose business does not include tree removals. The consequence of being this specific is that only 30 companies were included in the study population. Of the 30, 10 were drawn into the sample, consistent with a one-third sampling of the population. Of the 10, 3 were interviewed (2 placed themselves in the category of primary generators of chips and shavings), 1 number was no longer in service, and 6 were working numbers where no one was contacted before the survey ended.

In the future, those conducting telephone-based urban wood residue surveys should consider the option of defining the study population to include all of the Ornamental Shrub and Tree Services Industry. However, while this option may garner more companies involved in tree removal it will also raise the project cost for cover letters and, more significantly, for many more telephone calls made to companies who will not qualify. Based on the questions used in this survey, tree care companies that do remove trees should fall into the group of those who accept debris, not generate it, as long as they interpret the question to mean that they accept tree debris as their primary business and are not generating companies (such as those in construction) that create the need for removal or own what needs to be removed.

Table 58

Disposition of Tree Trunks and Limbs by Major Industry Group and Industry

SIC	Major Industry Group/Industry	Frequency	Percent
07: 07830105	Agricultural Services: Tree Trimming Services for Public Utility Lines	1	5.0%
15: 1521, 1522, 1531	Building Construction: Single Family Construction & Remodeling, Residential Construction, New Housing Speculative Builders	14	70.0%
16: 1611	Heavy Construction, Other Than Building: Highway & Street Construction	2	10.0%
17: 1794	Construction, Special Trade Contractors: Excavation & Grading, Building Construction	1	5.0%
42: 4212, 4213	Motor Freight Transportation: Local Trucking, Without Storage, Trucking, Except Local	2	10.0%
Totals		20	100.0%

Another 12 companies also generated tree residue when survey refusals are added, bringing the total to 32 (see Table 21 above for the calculation). Multiplied by the population-to-sample ratio of 3 to 1 yields a population estimates of 96 companies that generated tree debris.

As shown in Table 59, question non-responses are allocated between the two ways of measuring the amount of tree residue, truck/container and weight, using the proportions of those that responded to the question. Consistent with the other types of debris, the large majority of companies (90.6%) measured by the truck/container load. Only 3 measured by weigh. The amounts were trivial and not included in the estimates of total amounts generated.

Table 59

Disposition of Tree Trunks and Limbs by Type of Measure:
Unadjusted and Adjusted for Question Non-Response and Survey Refusals

Type of Measure	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Truck/container	10	50.0%	29	90.6%
Weight	1	5.0%	3	9.4%
DK	9	45.0%		
Totals	20	100.0%	32	100.0%

Table 60

Disposition of Tree Trunks and Limbs by Number of Truck/Container Loads:
Adjusted for Question Non-Response and Survey Refusals

Number of Loads	Frequency	Percent
>0 - <20	29	100.0%

Using the frequency for the single interval in Table 60, companies disposed of 10 loads per month. For all companies, the total to the nearest 100 loads is 3,500 for 2005.

Table 61

Volume of Trucks/Containers Used to Haul Tree Trunks and Limbs:
Adjusted for Question Non-Response and Survey Refusals

Cubic Yards	Adjusted Frequency	Adjusted Percent
0> - <10	23	79.3%
10 - <20	3	10.3%
20 - <30	3	10.3%
Totals	29	99.9%

Using the frequencies in Table 61, the average volume of the trucks and containers used to haul tree debris (to the nearest whole cubic yard) 8 cubic yards. Assuming full truck and container loads, the average for the 29 sample companies is 28,000 cubic yards. Multiplied by the population-to-sample of 3 to 1 yields a total of 84,000 cubic yards of tree debris.

Disposal Payments and Removal

As given in Table 62. just over 4 out of 10 (43.8%) companies paid for removal. Their payments averaged $1,393 per company per month. The total for the 14 sample companies is $234,000. Expanded by the population-to-sample ratio of 3 to 1, the total is $702,000 for all of 2005. Exactly half incurred no expense while just a few (6.3%) were paid ($78,000 in total for the year).

Among the 7 companies that paid for removal, 2 used landfills (question 23.A.2.). Five of 8 who avoided disposal costs burned or otherwise discarded their debris (question 23.B.). Seven of 15, or 46.7%, disposed of tree debris as waste while the remaining 8, or 53.3%, did not. Two of 15 (13.3%) companies used landfills. Projected onto the total of 84,000 cubic yard, about 45,000 cubic yards were used and 39,000 were not. Of the latter, about 5,200 (13.3%) cubic yards went to landfills.

Table 62

Tree Trunk and Limb Disposal by Type of Removal:
Adjusted for Question Non-Response and Survey Refusals

Type of Removal	Unadjusted Frequency	Unadjusted Percent	Adjusted Frequency	Adjusted Percent
Company paid for removal	7	35.0%	14	43.8%
Removed at no cost to company	8	40.0%	16	50.0%
Another company paid	1	5.0%	2	6.3%
DK	4	20.0%		
Totals	20	100.0%	32	100.1%

Table 63

Company Paid for Removal:
Adjusted for Survey Refusals

Removal Payments	Frequency	Percent
<$0 - <$500	10	71.4%
$3,000 - <$3,500	2	14.3%
$5,000 - <$5,500	2	14.3%
Subtotal	14	100.0%

Table 64

How Tree Trunks and Limbs Are Removed At No Cost to Companies: Adjusted for Question Non-Response and Survey Refusals

Type of No Cost Removal		Frequency	Percent
	Given away to public/employees	2	12.5%
	Burned	10	62.5%
	Trashed/dumped/discarded	2	12.5%
	Recycled/re-used	2	12.5%
	Totals	16	100.0%

About half used their own trucks to haul tree debris away while the other half relied on trucks provided by other companies. Based on numbers adjusted for question non-response, the average hauling distance is 9 miles (to the nearest mile). This distance does not differ significantly from either the average 10 mile drive to dispose of pallets or the 12 mile drive to dispose of edgings and cutoffs. It does differ significantly from the 18 and 58 mile drives to dispose of chips and shavings and construction debris, respectively.

Eleven of the 20 (55.0%) companies in the unadjusted sample made no use of the tree debris. Of the 9 who did, 4 used it as firewood and 1 for mulch. None of the companies sawed any of the tree trunks into lumber.

In the unadjusted sample, the split was about even on whether more or less ash trees had been removed in 2005 compared to the previous year. Ten of the unadjusted sample of 20 companies did not know, a reflection perhaps of their not being able to identify the species as ash. When asked what they did with the ash (a question asked of all respondents regardless of whether they could identify the species), almost half of the companies (45.0%) in the unadjusted sample did not know. A fourth sold the debris as firewood. Again, no company sawed the logs into lumber.

An estimated total of 96 companies, mainly in the construction business, generated about 84,000 cubic yards of tree debris in 2005. Just under half paid for removal -- about $700,000 in total. Slightly more than half disposed of the debris at no cost to themselves, mainly by burning. Half hauled the debris to disposal sites in their own trucks, the other half in trucks belong to other companies. The average hauling distance was 9 miles. Just over half made no use of the tree debris. Of the slightly less than half that did, most used the debris as firewood. There is no clear indication of whether more or less ash trees were removed in 2005 compared to previous year, probably because companies were unable to distinguish ash from other hardwood species. Though the project cost would be greater, those conducting urban wood residue surveys should consider including the entire Ornamental Shrub and Tree Services Industry in the study population. Using the questions from this survey, qualifying companies would be classified as accepting not generating tree debris.

Markets and Prices for Wood Residue

All 420 companies who generated wood residue were asked whether there was either no market, a developing, or a fully developed market for their particular residue. Of all the companies, 262 saw no market while 88 indicated that there was either a developing or developed market. Sixty-one companies did not know and 9 refused to answer. In terms of percentages, as given in Table 65, about 6 out of 10 (62.4%) judged there to be no market. About 2 out of 10 (20.9%) thought a market either existed or was developing.

Reasons for No Wood Residue Market

As given in Table 66, among the 262 companies that saw no market, 11.5% identified foreign materials attached to wood residue as the reason their residue lacked market value. Another 16.8% see the expense of separating the residue from other material as a barrier. Between the two groups, just over 1 out of 4 (28.3%) believe there is no market because of the foreign material attached to the wood and the cost of removing it. Other than the expense of separating wood from other materials, the two major reasons are the low volumes produced by individuals companies (15.3%) and the perception (17.9%) that there are no products for which this residue is a usable resource input.

Transporting the residue is not much of a problem: only a dozen companies (4.6%) identified this as an issue. About as many see poor quality and small pieces (a total of 10.3%) as reasons for no market.

Adding the question non-responses to those that had not considered whether there was a market, at most 14.9% have not given this any thought. This means that 85.1%, a very strong majority, have given the possibility of a market at least some thought.

In Table 67, market possibilities are cross-tabulated by Major Industry Group. The most frequently cited reasons for no market among companies who indicated there was no market was calculated for the largest number of companies by individual and grouped SIC codes. Construction companies were grouped together as were lumber and wood products and furniture companies.

In the combined construction industries (SIC 15, 16, 17), just under two-thirds (63.1%) of the 142 companies see no market for the residue they generated. The most frequently cited reason (21.1%) is that there is no cost-effective way to separate the wood residue from other material.

Among the lumber and wood products (SIC 24) and furniture (SIC 25) companies, just under two-thirds (64.3%) of the 27 companies indicated that they felt there was no market for their residue. Two near equally cited reasons are low volume (22.2%) and no products for which this material is a usable input (25.9%).

Among the 36 companies in the industrial and commercial equipment industry (SIC 35), the same two reasons were cited almost equally: low volume (27.8%) and no end-use products (22.2%).

Finally, among the 28 companies in building materials (SIC 52), one-fourth (25.0%) cited a lack of a cost-effective way to separate wood from non-wood waste. Just under one-fifth (18.5%) cited no end-use products.

Developing and Developed Markets

Among the 61 companies that believed a market was developing, just over three out of ten (34.4%) indicated that identifying buyers was the principal impediment to market development. By contrast, only 2 companies (3.3%) though finding sellers was a problem. About two out of ten (21.3%) did not identify a reason while about 1 out of 10 (9.8%) identified high transportation costs. The remaining companies gave a variety of answers in small numbers for each.

Among the 88 companies that indicated there was either a developing or developed market, just over half (53.4%) thought residue prices varied less than gasoline prices. Far fewer (15.9%) thought residue prices varied about as much as gasoline and only a very few (2.3%) thought residue prices varied more. A significant minority (28.4%) did not know which varied the most. The 16 companies that thought residue prices varied as much or more than gasoline prices were asked to identify reasons. Six (37.5%) identified unpredictable swings in supply and demand as the reason. The rest of the responses were thinly spread out over other answers and non-response.

Well over half (61.4%) of the 88 companies felt they were getting enough price information. But 24 companies, just over another one-fourth (27.3%), felt they were no getting enough. The rest (11.4%) did not know whether they were getting enough information. Among the 24 not getting enough information, somewhat over half (54.2%), cited identifying buyers as the single most important additional information they needed. This answer stands out in that none of the other responses were cited nearly as many times. As significant is the response to the question about how likely these companies would be to recycle if they had more information, principally about buyers. Nearly all (91.3%) indicated they would be more likely to recycle if they had the information they needed. As one respondent stated it:

> To be able to coordinate and bring together buyers and seller. Not sure how to inform buyers that there are sellers and to inform sellers that there are buyers. Needs to be some kind of clearing house for that information.

Table 65

Market for Wood Residue

Market for Wood Residue		Frequency	Percent
	No market	262	62.4%
	Developing market	61	14.5%
	Fully developed market	27	6.4%
	DK	61	14.5%
	Refusal	9	2.1%
	Total	420	100.0%

Table 66

Reasons for No Market for Wood Residue

Reasons	Frequency	Percent
Contains preservative	4	1.5%
Coated with paint	3	1.2%
Contains glue	2	0.8%
Attached to metal, shingles, non-wood material	5	1.9%
Contains metal & non-wood material	16	6.1%
No cost-effective way to sort wood from non-wood waste	44	16.8%
Wood waste too expensive to transport	12	4.6%
Other: low volume	40	15.3%
Other: no good end product	47	17.9%
Other: poor quality (rotten)	13	5.0%
Other: not profitable	11	4.2%
Other: pieces too small	14	5.3%
Other: never considered & not aware of options	10	3.8%
Other: miscellaneous	12	4.6%
DK	26	9.9%
Refusal	3	1.2%
Totals	262	100.1%

Table 67

Market for Wood Residue by Major Industry Group

SIC	Major Industry Group	No Market	Developing Market	Developed Market	Don't Know	Refusal	Subtotals By SIC
01	Agricultural Production	1	0	0	0	0	1
		100.0%	.0%	.0%	.0%	.0%	100.0%
07	Agricultural Services	1	2	0	0	0	3
		33.3%	66.7%	.0%	.0%	.0%	100.0%
15	Building Construction	115	31	11	25	5	187
		61.5%	16.6%	5.9%	13.4%	2.7%	100.0%
16	Heavy Construction, other than Building	3	1	0	1	0	5
		60.0%	20.0%	.0%	20.0%	.0%	100.0%
17	Construction, Special Trade Contractors	24	2	1	5	1	33
		72.7%	6.1%	3.0%	15.2%	3.0%	100.0%
24	Lumber &Wood Products, except Furniture	20	6	1	4	0	31
		64.5%	19.4%	3.2%	12.9%	.0%	100.0%
25	Furniture & Fixtures	7	2	2	0	0	11

			63.6%	18.2%	18.2%	.0%	.0%	100.0%
	26	Paper & Allied Products	2	1	2	0	0	5
			40.0%	20.0%	40.0%	.0%	.0%	100.0%
	32	Stone, Clay, Glass, & Concrete Products	4	1	2	0	0	7
			57.1%	14.3%	28.6%	.0%	.0%	100.0%
	33	Primary Metal Industries	1	0	0	0	0	1
			100.0%	.0%	.0%	.0%	.0%	100.0%
	35	Industrial &Commercial Machinery & Computer Equipment	36	7	4	14	1	62
			58.1%	11.3%	6.5%	22.6%	1.6%	100.0%
	37	Transportation Equipment	0	0	1	0	0	1
			.0%	.0%	100.0%	.0%	.0%	100.0%
	39	Miscellaneous Manufacturing Industries	0	0	0	1	0	1
			.0%	.0%	.0%	100.0%	.0%	100.0%
	42	Motor Freight Transportation	9	3	1	1	2	16
			56.3%	18.8%	6.3%	6.3%	12.5%	100.0%
	49	Electric, Gas, and Sanitary Services	0	1	0	0	0	1
			.0%	100.0%	.0%	.0%	.0%	100.0%
	50	Wholesale Trade, Durable Goods	0	1	0	0	0	1
			.0%	100.0%	.0%	.0%	.0%	100.0%
	52	Building Materials, Hardware, Garden Supply & Mobile Home Dealers	28	2	1	5	0	36
			77.8%	5.6%	2.8%	13.9%	.0%	100.0%
	54	Food Stores	1	0	0	2	0	3
			33.3%	.0%	.0%	66.7%	.0%	100.0%
	57	Home Furniture, Furnishings & Equipment Stores	9	1	1	3	0	14
			64.3%	7.1%	7.1%	21.4%	.0%	100.0%
	59	Miscellaneous Retail	1	0	0	0	0	1
			100.0%	.0%	.0%	.0%	.0%	100.0%
Subtotals by Response			262	61	27	61	9	420
			62.4%	14.5%	6.4%	14.5%	2.1%	100.0%

Additional Comments

The final question asked in each interview was whether respondents wanted to add to their answers or make suggestions or comments about the subjects covered by the survey. The purpose of this question is to allow respondents an opportunity to mention anything that occurred to them during the interview that was not covered by the questions asked. Of 420 companies, 340, or about eight out of ten (81.0%), had nothing to add. Eighty (19.0%) chose to make additional comments. The general tenor of the comments on wood residue (not all respondents stayed on this subject) and what happens to the residues is that they wished more of what they generated could be recycled and reused. Cost-effective ways to separate wood from other

materials and to transport small amounts seem to be issues of main concern as well. A flavor of their views can be gained from the following verbatim comments.

> "I think it would (be) worthwhile to investigate the ability for people with a small business to be able to bring their small amount of wood waste to a central location. I think this would be more cost effective for the small business owner than taking it to a landfill or paying to have someone come and dispose of it."

> "I wish someone would come up with a use for the pallets so they don't have to go to the landfills."

> "If there was a local drop off point to bring pallets to so people could just use them again or for some other type of project."

> "They want us to do something about the waste but they want to charge to dispose of the wood waste. They need to make it cost efficient for the consumer to dispose of the wood waste. If I could I would rather burn it than to pay for a dump truck to take it to a land fill. And, they need to have numerous places for people to be able to take their wood waste to a close facility. With the cost of gas it is not worth paying for gas to dispose of wood waste."

> "The only thing I could say is that contractors bring their wood waste to the landfill because they don't know of any other thing to do with it except burn it. It is such a waste of wood. I was at the landfill one day dumping my wood waste and someone was there that told me about a place that recycled wood waste and that it was not expensive. It would be nice if more information was provided to companies about places that recycle wood waste."

> "The most expensive cost in construction is removal of the construction debris. If a lower cost could be provided for removal of the debris it would be helpful for the consumer. I think that Michigan should look into the waste cap in Wisconsin because they provide low cost disposal of wood waste for the consumer."

> "I don't know if wood could be used as a fuel. We take all our steel to a steel yard and (it) gets melted down and reused. It would be nice if wood could be (used) as fuel if we could drop it off at a wood salvage yard. After they burn it down they could dispose of the nails."

> "It would be nice if there were a free recycling center and not have to pay. The city picks up the cardboard for free and it would be nice if they would also pick up the wood for free."

> "(I) want someone to invent a car to run on waste wood."

Part Two: Saw Timber Content of Urban Forests

Introduction

The value of trees in urban areas has been given considerable attention, in particular for improving aesthetics, environmental quality (McPherson et al. 1999) and property values (Scott and Betters 2000). For example, recent studies have highlighted the significant contribution of urban trees to carbon sequestration (Johnson and Gerhold 2001, Nowak and Crane 2002). The wood products potential of urban trees is typically not fully realized (Bratkovich 2001, Solid Waste Association of North America, 2002, Sherrill 2003), although sometimes among the listed values for them (Scott and Betters 2000), often related to a perceived lack of quality wood in urban trees, logistical issues associated with harvesting commercial wood that may make it economically unattractive or infeasible, and an associated lack of social infrastructure geared toward utilizing or recycling urban wood.

The perceived lack of value for urban trees comes from legitimate concerns about foreign objects in urban trees such as nails, stone or even signage (Sherrill 2003). However, the advent of portable saw mills with inexpensive and easy to change blades (e.g., Wood-Mizer®, Bratkovich 2001), as well as routine metal detection equipment on saw mill feed lines (Kerry Murphy, Weyerhauser Inc. personal communication), greatly reduces the impact of foreign objects in urban tree wood. Wood quality is also an important issue, however. Many urban trees are not growing under optimal conditions for saw timber production due to stressful site conditions and exhibit an open growth form that promotes short bole lengths and large branch knots which reduces wood quality (DeBell et al. 1994, Uusitalo and Isotalo 2005). The main logistical problem for harvesting urban wood is that it primarily comes available through the random death of trees and is only in abundant supply via catastrophic mortality events, e.g., the recent large-scale mortality of urban trees caused by exotic, invasive tree pests, including emerald ash borer (*Agrilus plannipennis*) (Poland and McCullough 2006) and Asian long-horned beetle (*Anoplophora glabripennis*) (Nowak et al. 2001). Other logistical concerns relate to the accessibility of urban trees for commercial harvest, since they may have to be cut into small sections to be removed safely; felling urban trees in log lengths may create excessive liability due to nearby hazards (but see Sherrill 2003 for suggestions on efficient and safe removal).

Recent studies by Bratkovich (2001) and Sherrill (2003) have compiled evidence suggesting that harvesting urban saw timber is not only feasible, but may also be profitable. However, no previous study has systematically estimated both the potential availability and quality of urban saw timber over a geographic region. Without specific information regarding wood quality and availability, it is difficult to generalize about the potential for harvesting saw timber from urban trees.

The goal of this study was to quantify the abundance, quality and accessibility of urban saw timber urban wood in southeastern Lower Michigan using systematic inventory procedures across different urban land types and land ownerships (both public and private land). Motivation for this research arose from an immediate need to address economic losses associated with an abundance of dead and dying street, park and backyard trees, killed by emerald ash borer in southeastern Lower Michigan, and a general desire to comprehend the potential scope of recovering urban saw timber.

Methods

Study Area

The study area was comprised of urban portions of 13 counties in southeastern lower MI (Table 1, listed in descending order of urban land cover), which constitute the core 13 counties quarantined by the Michigan Department of Agriculture to control the spread of emerald ash borer (the beetle has since spread beyond this region). A statewide land use / land cover (LULC) classification system (IFMAP, MDNR 2003) was used to define urban areas in the 13-county region. Four of thirty-seven IFMAP classes were deemed to represent an "urban" condition: (1) Low-intensity urban; (2) High-intensity urban; (3) Roads / Paved (which includes areas appurtenant to roads and large paved areas such as parking lots) and (4) Parks and Golf Courses; the first three explicitly comprise urban types in IFMAP and the last was added to represent developed green space appurtenant to urban land use. The remaining IFMAP classes were combined into one "non-urban" stratum that was not considered as part of potential sample space (Table 1). For this study, only roads and paved areas associated with urban areas were of interest; wood from trees representing other roads and paved areas (e.g., roads traversing farm fields) was not of interest. The fraction of all roads and paved areas that were urban, as opposed to other roads, was approximated as proportional to the total land area that was under high intensity and low intensity urban land use (Table 1). Thus, the total urban land area was estimated for each county as the sum of high and low intensity land use, parks and golf courses and "urban" roads and paved areas (Table 1).

Inventory Methods

A stratified, multi-stage sampling technique (Shiver and Borders 1996) was used to assess the quality and quantity of saw timber over different portions of the urban landscape. An accuracy assessment by NOAA CSCC-CAP (2003) suggested that IFMAP most accurately represented LULC types when classified map pixels (30 m x 30m) were aggregated into larger homogeneous blocks (at least 90m x 90m). Thus, the grid of Michigan public survey quarter-quarter sections (QQSs) were chosen to define large (402m x 402m) primary sample units from which representative urban areas could be selected.

Random QQSs were chosen within the 13-county area. If the randomly selected QQS was composed of a relatively homogeneous block of one of three urban types (either high-intensity urban, low-intensity urban or parks and golf courses), then it was accepted as a sample location; if not it was rejected. The roads & paved LULC type was excepted because it never formed relatively homogeneous blocks but was a linear network which traversed portions of QQS blocks. Instead, roads & paved areas were sampled within randomly selected blocks dominated by either high intensity or low intensity urban areas, such that only urban roads and paved areas would be sampled (as described previously).

Field crews visited each selected QQS sample unit and systematically sampled a variable number of variable-area plots that combined to cover urban portions of the total QQ area. The field crew began from an arbitrarily determined point along the edge of a QQS (generally determined by road access) and then moved across the QQS systematically in a serpentine pattern. Permission to sample on private land was obtained in the field, or occasionally in advance; a portion of potential sample space was not sampled due to lack of landowner permission. Variable area rectangular plots were systematically established using one of the following three methods applied to the four different IFMAP LULC classes:

Table 1

Urban Land Use Composition in 13 Counties in Southeastern Lower Michigan Based on a Statewide Classified Satellite Image (IFMAP, MDNR 2003)

County	Area (ha)	Parks & Golf Courses	High Intensity Urban	Low Intensity Urban	Roads and Paved Areas Urban	Roads and Paved Areas Other	Percent Urban	Percent Non-urban
Wayne	166,482	2.24%	15.29%	13.17%	5.72%	14.37%	36.42%	63.58%
Macomb	125,359	1.99%	8.62%	10.53%	2.13%	9.01%	23.27%	76.73%
Oakland	234,912	1.89%	5.93%	8.72%	1.33%	7.72%	17.87%	82.13%
Genesee	168,203	0.60%	4.06%	6.69%	0.69%	5.75%	12.04%	87.96%
Ingham	145,169	0.54%	3.16%	3.32%	0.33%	4.70%	7.34%	92.66%
Washtenaw	187,041	0.93%	2.14%	2.65%	0.22%	4.38%	5.94%	94.06%
Livingston	151,581	0.55%	1.77%	2.26%	0.16%	3.88%	4.74%	95.26%
Monroe	144,466	0.07%	2.12%	2.08%	0.20%	4.60%	4.47%	95.53%
Jackson	187,313	0.55%	1.08%	2.31%	0.12%	3.49%	4.05%	95.95%
St. Clair	190,407	0.22%	1.20%	2.02%	0.12%	3.61%	3.56%	96.44%
Shiawassee	140,056	0.05%	1.18%	1.18%	0.09%	3.90%	2.51%	97.49%
Lenawee	197,129	0.00%	0.71%	1.29%	0.07%	3.66%	2.08%	97.92%
Lapeer	171,666	0.05%	0.40%	1.18%	0.04%	2.40%	1.66%	98.34%
13-county area	2,209,786	0.77%	3.61%	4.44%	0.51%	5.82%	9.32%	90.68%

1. If the area was either high or low intensity urban residential or commercial, each ownership was considered a variable area plot. Lot dimensions (property boundaries within the QQS) were approximated by a rectangle and all trees inside the rectangle were part of the potential sample population (including all buildings, paved and mowed areas within the property boundaries).

2. Roads / Paved areas were measured as variable area rectangles bounded by the outer edge of sidewalks, curbs or pavement; as such they included, pavement sidewalks, and mowed areas, if they were between the sidewalk and the curb or pavement. Trees that were growing outside of this envelope (most typically trees that were planted along the sidewalk, between the sidewalk and a lawn or structure) were not considered as road trees / paved area trees (these trees ended up in one of the other urban stratum).

3. If the area was a park or a golf course, then, beginning from an arbitrary starting point along the edge of the QQS the field crew defined a series of plot boundary lines that were approximately equidistant between two areas of treed space (e.g., two rows of planted trees along a fairway) creating variable area rectangular plots which included intervening areas between groups of trees or isolated trees (e.g., mowed grass).

The third stage of sampling involved selecting sample trees of all species within plots that were ≥ 20 cm (8”) stem diameter at breast height (1.37m (4.5 ft.)). A 20 cm diameter was chosen as a typical cutoff for defining a saw log. Live, dying and standing dead trees were all measured; stumps were also measured at stump height (typically about 10 to 20 cm (4 to 8”)). On each tree selected, the following was recorded for estimating saw timber quantity, quality and accessibility: species (if identifiable, e.g., on stumps and dead trees), diameter at 1.37m above ground height, total tree height, total merchantable saw timber log length to an approximately 20

cm top diameter outside bark (DOB) (measured with a Wheeler® pentaprism), and the number of 2.4 m (8') merchantable branch logs in a tree's crown with a minimum 20 cm small end diameter DOB in the tree's crown (8' is the standard log length on Michigan timberlands).

To assess wood quality a saw log grade was assigned using six grading classes for hardwoods (Rast et al., 1973), (0) no saw volume, (1) grade 1 saw timber, (2) grade 2 saw timber, (3) grade 3 saw timber, (4) construction grade and (5) local use class, which aligned with tree grading classes used by the U.S.D.A. Forest Service in the national forest inventory (Miles et al., 2001). Only four grading classes were used for softwoods: (0) no saw volume, (1) grade 1 saw timber, (2) grade 2 saw timber, and (3) grade 3 saw timber, consistent with common softwood grading rules (Avery and Burkhart, 1994). Crown logs were not graded due to lack of an objective standard for doing so (e.g., Rast 1973).

To assess the accessibility of merchantable wood in it, each tree was classified into one of three accessibility classes representing the effort that would be involved in extracting the timber from the tree:

1. Easily accessible = tree could be cut into relatively long sections and could be felled with minimal risk of property damage; cut sections could be loaded readily onto a vehicle for transport.

2. Moderately accessible = tree could be cut into merchantable-length sections, but would require additional effort with enhanced risk of property damage to access; cut sections would have to be transported a modest distance to be loaded onto a vehicle for transport (a truck could not drive up near the tree).

3. Difficult to access = much of the tree would have to be cut into sub-merchantable lengths to remove and/or trees could not be accessed without major effort (e.g., a large tree build into a deck) or a high likelihood of property damage.

Data Analysis

Tree Wood Volume Estimation

Stem measurements were used to estimate the total merchantable saw timber round wood volume (m^3) in each sample tree from 0.15 cm stump height to an approximate 20 cm top diameter outside bark, with Smalian's formula (Avery and Burkhart 1994). An individual taper model for each tree derived from its top diameter and DBH was used to account for stem taper during volume calculations (change in stem diameter over log length was extrapolated to predict stump diameter outside bark for each tree). A species-level constant bark factor model, predicting wood volume inside bark from wood volume outside bark, was used to estimate solid wood and bark volumes from total volume (Smith 1985). Exotic tree species were assigned a bark factor of a species in the same genera with an equivalent bark type. Recovered sawn lumber volume in standing trees was computed using the tree's taper model and the International ¼" Board-foot rule for variable length logs (Freese, 1973), so that recovered saw lumber could be compared to cubic round wood volume estimates (i.e., accounting for losses due to sawing). Crown wood board-foot volume was estimated using a model relating the basal area (BA_i, ft^2) and the number of merchantable 8' saw logs (L_i) in the crown of a tree to its International rule ¼" board foot volume (V_{Si}): $V_{Si} = 19.30\ (BA_i\ L_i)^{0.74}$, derived from felled and dissected trees on MI DNR timberlands (MacFarlane, unpublished).

Scaling Up Individual Tree Estimates to the 13-County Region

Average saw timber volume per hectare (m^3 and board feet) was estimated from the number of sample trees ≥ 20 cm DBH on a sample plot with an area a_i. The contribution of each sample tree to per hectare estimates were weighted according to its selection probability, which was proportional to the size of the variable area plot on which it occurred (Shiver and Borders 1996); the variance of sample means was also weighted in the same way. Estimates from each of the LULC classes were then combined to estimate the overall urban condition for the 13-county region, using typical procedures for combining stratum in stratified sampling (Shiver and Borders 1996), with contributions of plots from each LULC weighted by the fraction of urban area they comprised (Table 1).

Results

Overall, 76 urban QQSs were surveyed and 1,887 stems & stumps ≥ 20 cm were measured, translating into a mean density of 12.8 [± 2.1 standard error] stems & stumps ha^{-1} (5.8 [± 0.8 se] ac^{-1}) across the 13-county urban area; 89.7% were healthy, live trees, 6.3% were classed as dying, 3.7% were stumps and 0.3% were dead, standing trees. Estimated density values for LULC's were 9.5 [± 3.1], 13.7 [± 3.5], 18.8 [± 4.2] and 20.3 [± 3.7] stems & stumps ha^{-1}, for high intensity urban, low intensity urban, parks and golf courses and roads and paved areas, respectively. At least 68 species (with ≥ 20 cm) representing 36 genera were found (some trees were only identified to their generic scientific name and species could not be identified for all stumps); each was assigned to a species-product class (see Appendix D) based on USDA Forest Inventory and Analysis groupings (Miles et al. 2001) for analysis.

Urban Wood Volume Grade and Species Products

The mean urban (round) wood volume across the 13-county area in tree stem sections ≥ 20 cm DBH was estimated to be 7.9 [± 1.3] m^3 ha^{-1}(117.2 ± 19.9 ft^3 ac^{-1}), about 31% of which was graded as having no saw timber value (grade 0, Table 2) due to major rot, defects and other problems (see Rast et al. 1973). Approximately 56% of all graded (not including crown wood) softwood volume per acre was deemed as having no saw timber value, while only 35% of potentially commercial hardwood stems were graded as unfit for saw timber products (Table 2). About 73% of all stems of “non-commercial” species (Table 1) were rated as unsuited for saw timber. Less than 5% of red oak, white oak and walnut wood were rated as having no value, while a large proportion of hard (58%) and soft maple (42%) wood was graded as having no saw timber value.

About 60% of mean urban wood volume was saw timber grade (grades 1 through 5, Table 2) amounting to 4.7 m^3 ha^{-1} [± 0.9] (67.7 [± 13.3] ft^3 ac^{-1}). Mean saw timber (round) wood volume translated into 1,364 board feet per urban hectare (552 bd.ft. ac^{-1}) of sawn lumber using the International ¼” rule (a conversion ratio of 290 bd.ft. per cubic meter of wood (8.2 bd.ft. per ft^3)). Most (93%) of urban softwood saw timber volume was graded in the lowest class (grade 3). This was likely was due to the greatly increased size and density of branch knots in open-grown coniferous trees which are reflected in softwood grading rules (DeBell et al. 1994, Uusitalo and Isotalo 2005). In general, a smaller proportion of urban hardwood saw timber volume was in lower grade classes than in higher grade classes (11% grade 1, 13% grade 2, 24% grade 3 and 48% grade 5) except for grade 4, construction grade, which comprised only 4%. The latter reflects reservations by field technicians regarding the potential strength and durability of urban-grown saw timber trees (i.e., these were conservatively placed in grade 5).

Table 2

Mean Volume (m^3 ha^{-1}) of Tree Stem and Branch Sections ≥ 20 cm Diameter in Urban Areas of SE Lower Michigan by Species-Product Class and Wood Products Grade (Crown Logs Were Not Graded)

	Volume (m^3 ha^{-1})									
	Main stem						Crown	Total Volume	Total Saw Grade (1-5)	Percent Crown Wood
	grade									
Spp-product class	0	1	2	3	4	5				
Softwoods										
spruce-fir	0.3177	0.0000	0.0021	0.2831	0.0000	0.0000	0.0000	0.6029	0.2852	0.00%
white-red pine	0.1619	0.0000	0.0035	0.1128	0.0000	0.0000	0.0032	0.2812	0.1162	1.13%
other pine	0.1218	0.0079	0.0193	0.0173	0.0000	0.0000	0.0012	0.1675	0.0445	0.74%
other softwoods	0.0046	0.0000	0.0000	0.0389	0.0000	0.0000	0.0002	0.0437	0.0389	0.44%
Douglas-fir	0.0025	0.0000	0.0000	0.0040	0.0000	0.0000	0.0000	0.0065	0.0040	0.00%
All softwoods	0.6084	0.0079	0.0249	0.4560			0.0046	1.1018	0.4887	0.42%
Hardwoods										
soft maple	1.0385	0.0032	0.0737	0.0918	0.0069	0.8172	0.4131	2.4444	0.9928	16.90%
poplar	0.0951	0.2366	0.1398	0.2550	0.0034	0.0390	0.0586	0.8275	0.6738	7.08%
red oak	0.0070	0.0309	0.1040	0.2458	0.0210	0.2405	0.0000	0.6494	0.6423	0.00%
ash	0.0718	0.0924	0.0853	0.0203	0.0164	0.2527	0.0162	0.5550	0.4670	2.92%
other soft hardwoods	0.1844	0.0179	0.0000	0.1010	0.0229	0.2421	0.0505	0.6188	0.3839	8.16%
white oak	0.0130	0.0181	0.0130	0.1157	0.0352	0.1037	0.0596	0.3583	0.2856	16.65%
hickory	0.0555	0.0000	0.0017	0.0956	0.0371	0.0308	0.0152	0.2359	0.1652	6.44%
walnut	0.0016	0.0248	0.0747	0.0254	0.0000	0.0329	0.0037	0.1632	0.1578	2.26%
other hard hardwoods	0.0810	0.0050	0.0088	0.0333	0.0101	0.0928	0.0424	0.2735	0.1501	15.52%
hard maple	0.2082	0.0013	0.0175	0.0376	0.0184	0.0622	0.0142	0.3594	0.1370	3.96%
basswood	0.0399	0.0142	0.0197	0.0019	0.0000	0.0657	0.0209	0.1624	0.1016	12.88%
birch	0.0064	0.0000	0.0000	0.0000	0.0000	0.0622	0.0024	0.0710	0.0622	3.34%
yellow poplar	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.00%
All hardwoods	1.8025	0.4444	0.5383	1.0235	0.1715	2.0418	0.6969	6.7189	4.2195	10.37%
Non-commercial	0.0633	0.0000	0.0089	0.0056	0.0000	0.0094	0.0116	0.0989	0.0239	11.75%
All spp-product classes	2.4742	0.4523	0.5721	1.4851	0.1715	2.0512	0.7131	7.9196	4.7322	9.00%

About 89% of all saw timber volume (4.2 m^3 ha^{-1}) was comprised of wood from commercially recognized hardwood species, 10% from commercial softwood species (0.5 m^3 ha^{-1}) and the remaining 1% from non-commercial species (Table 2). About one-quarter of all commercial hardwood saw timber was comprised of soft maple alone, and nearly two-thirds was comprised of soft maple, poplar, ash and red oak (Table 2). Urban walnut, red oak and poplar trees had more than double the average proportion of high grade wood (grades 1-3) in them, whereas the majority of saw timber from soft maples (silver, red and Norway) and other hard- and other soft- hardwood species (mostly honey locust and elm, respectively) was rated in the lowest lumber grade classes (4 and 5; Table 2). More than three-quarters of all softwood saw timber was comprised of spruce-fir and white and red pines of low quality.

Across all species product-classes about 9% of mean urban wood volume (Table 2) was composed of crown logs of variable (unknown) quality amounting to 0.7 [±0.2] m^3 ha^{-1} (10.2 [±2.4] ft^3 ac^{-1}] of saw timber volume. The 0.7 m^3 ha^{-1} of crown wood translated into 176 board feet ha^{-1} (72 bd.ft. ac^{-1}) of ungraded urban saw timber. Over half of this (0.4 m^3 ha^{-1}) was found in the crowns of soft (mostly silver) maples trees. Honey locust, cottonwood, elm, and white oak trees also had significant amounts of saw grade branch wood. Non-commercial species (mostly

willow, and ornamental apple and cherry trees) had a significant proportion of their potential sawn timber in their crowns, but the absolute amounts were trivial. Urban softwoods also had insignificant amounts of saw grade branch wood (Table 2), which was not surprising given their naturally excurrent growth form.

Regional Urban Saw Timber Abundance

The overall weighted mean urban saw timber volume for stem and crown wood in the 13-county area was estimated to be 5.4 m^3 ha^{-1}, or 1,540 board feet ha^{-1} accounting for conversion of round wood to dimensional lumber. There was considerable variation in saw timber volume both between and within different urban LULC's. Mean graded saw timber volume was 3.0 [± 1.2], 5.3 [± 1.6], 7.8 [± 2.1] and 7.4 [± 1.7] m^3 ha^{-1}, respectively, for high intensity urban, low intensity urban, parks and golf courses and roads and paved areas. Estimated crown wood saw timber volume for high intensity urban, low intensity urban, parks and golf courses and roads and paved areas was 0.4 [± 0.2], 0.7 [± 0.3], 1.0 [± 0.3] and 2.1 [± 0.6] m^3 ha^{-1}, respectively. Scaled up to the 13- county region this amounts to a total standing volume of 1.15 million m^3 of urban saw timber (about 327 million board feet of dimensional lumber). See Table 3 below.

Accessibility

In order to successfully recover saw timber from a tree, the tree must be accessible, i.e., able to be felled, cut in sections of merchantable length and delivered to a sawmill (in urban areas portable sawmills can ease the latter burden). Accessibility was not equal across all urban land types (Obviously, it should be much easier to harvest wood from street and parkland trees then from around homes and offices). About 93.5% of all saw timber on parks & golf courses was considered easily accessible and less than 1% difficult to access. Almost 90% of saw timber along roads and paved areas was rated as easily accessible, although street trees were about 4 times (2.1% versus 0.5%) more likely to be rated as difficult to access than trees on parks and golf courses, with the main complication being extracting wood from occasional large trees whose crowns are closely intertwined with utility wires. High intensity urban areas posed a greater challenge for extracting saw timber from trees, although less than 4% of this saw timber was considered difficult to access. By sharp contrast, about half of all saw timber in low intensity urban areas was rated as difficult to access. This reflects the close proximity of many large trees to hazards (sense Matheny and Clark 1994), such as homes or fences, in low intensity urban areas, that would necessitate extraordinary measures to harvest trees in standard log lengths. Based on the weighted contribution of each of the four urban LULC's to total urban area (Table 1), it was estimated that about 56% of all urban saw timber in the 13-county area was easily accessible, another 16% would require some additional measures to extract that would add additional costs (moderately accessible) and the remaining 28% difficult (for most intents and purposes considered inaccessible). As shown in Table 3, of the total standing urban saw timber about 72% was considered accessible for extraction, amounting to 825 thousand m^3 of urban saw timber (about 235 million board feet of dimensional lumber).

Annual Yield

The 825 thousand m^3 of urban saw timber that is accessible in the 13-county areas, includes all standing trees, virtually all of which would not be harvested until the trees that contain them were dead, or at minimum dying. Thus, to calculate the availability of urban saw timber on an annual basis, it was necessary to estimate the rate at which trees would become available. However, mortality rates and removal rates could not be directly assessed from the data collected for this study (stumps, e.g., represent death events from different years and may be ground up and seeded over, and thus, might not be tallied at all). Instead, recent estimates by Nowak et al.

(2004), on general trends and specific tree removal and mortality rates were combined with the data presented here and used to make reasonable estimates of urban saw timber availability on an annual basis.

Table 3

Saw Timber Volume Estimates for Urban Portions of 13 Counties in Southeastern Lower MI

	Saw Timber Volume (m^3)		
County	Total Standing	Accessible	Annual Yield
Genesee	109,358	78,738	1,575
Ingham	57,569	41,450	829
Jackson	41,013	29,529	591
Lapeer	15,426	11,107	222
Lenawee	22,094	15,908	318
Livingston	38,813	27,945	559
Macomb	157,526	113,419	2,268
Monroe	34,835	25,081	502
Oakland	226,736	163,250	3,265
Shiawassee	18,971	13,659	273
St. Clair	36,594	26,348	527
Washtenaw	60,017	43,212	864
Wayne	327,415	235,739	4,715
13-county area	1,146,368	825,385	16,508

Nowak et al. (2004) suggested that standing trees in apparently good condition die at a rate of about 1.4% per year. The latter rate was used to describe mortality in the “live” category in this study; 1.4% of the 89.7% of urban stems per acre or 1.3%. Trees with crown deterioration, equating roughly to “dying” trees in this study, had a mortality rate of about 6.4% (Nowak et al. 2004), which equates to 0.4% more of the trees in this study. Ignoring the stumps, another 0.3% can be tallied from dead standing trees that have not yet be removed. All totaled, it can be expected that about 2% of the accessible volume would come available annually, which translates into about 16,500 m^3 (or about 4.7 million board feet) of urban saw timber per year available in the 13-county study area (Table 3).

Discussion

The methods presented here allowed for a regional estimate of urban saw timber to be developed, extrapolated via urban land area estimates derived from satellite photography. Data describing urban land cover are generally widely available (e.g., the entire U.S., Nowak et al. 2006), thus, these methods could be replicated almost anywhere. To the extent that average per hectare estimates derived from urban areas in southeastern lower Michigan are representative of broader regional species composition and urban tree demographic structure, these specific estimates could be further extrapolated outside of this specific region. However, the overall weighted-estimates are also sensitive to the relative make-up of urban areas (e.g., a different ratio of high- versus low- intensity urban areas), such that per hectare estimates for urban LULC's would need to be re-weighted accordingly.

Over 16 thousand m^3 of urban saw timber is estimated to come available each year in the 13-county study area. To put this number in perspective, small modern saw mills process about 3 to 10 thousand m^3 of wood per year annually (Pascal Kamdem, Michigan State University, personal communication). Assuming a minimum of 3 thousand m^3 to remain viable, all of the potentially available wood in the 13 counties that comprise southeastern Lower Michigan could support the minimum annual needs of 5 of these mills. The 4.7 million board feet of lumber annually available in urban trees in this region is equivalent to the amount of wood used to build 362 average-sized homes (Falk 2002).

The quality of wood in urban softwoods was generally low based on the grading standards applied, which was not surprising given the importance of maintaining small branch knots along the main stem of coniferous trees to softwood quality; a condition most likely to be met when trees are forest grown (DeBell et al. 1994, Uusitalo and Isotalo 2005). However, most urban saw timber (~90%) inventoried came from commercially viable hardwood timber species, 60% of which was considered saw grade quality. While *non-commercial* species comprise a trivial proportion of large trees, wood from exotic species did comprise a substantial proportion of urban wood (e.g., Siberian elm, Norway maple and horse chestnut), raising potential concerns regarding their utilization (e.g., commercial kiln drying procedures have not been developed for them). However, wood from many of these species are already commercially viable (Norway maple is considered a valuable hardwood in Germany; Jurek and Wihs 1998) and some North American vendors have been able sell wood from exotic tree species at a premium (http://www.urbantreesalvage.com/support.html).

One aspect of urban wood quality, not addressed in this study, is that of the mechanical properties of urban wood. Mackes et al. (2005) found that the modulus of rupture and modulus of elasticity were both lower in open grown trees, primarily due to a greater quantity of juvenile wood, which suggests a potentially lower strength for "urban" wood. Further research would have to be done to specifically measure wood properties of urban versus forest –grown trees.

The estimates of urban saw timber presented here are likely conservative, based on the definitions of urban area used in this study. The use of a land use/land cover image to define urban areas likely underestimates the number of trees in urban areas, relative to definitions based on political boundaries such as city limits or census districts (e.g., Nowak et al. 2006), which, if used, would have included wood from trees growing in forested areas within urban zones. In a recent study Fang et al. (2006) demonstrated that land use maps were more likely to misclassify urban areas (in Chicago) as forested than the reverse, because of the fact that many houses were beneath a canopy of trees. Hence, the population of urban trees was narrowly defined on an area basis.

Estimates were also likely conservative based on definitions of what portion of urban wood qualified as extractable sawn wood products. Low intensity urban areas comprised almost half of all urban area in the 13-county region (Table 1) and almost 50% of the wood in these areas was rated as difficult to access, due to a frequent close proximity of large trees to potential hazards (e.g., homes). Sherrill (2003) proposed reasonable guidelines for safely extracting urban wood and commercial arborists safely remove such trees all the time; thus, a larger proportion of wood from these trees may actually be accessible. Advances in sawing technology might also allow portions of some of the wood rated as grade 0 to be utilized for saw timber. Typical modern saw mills often dissect logs into a variety of component parts of different grades, such that the visually-based whole log or tree stem grading rules employed (e.g., Rast et al. 1973) may be overly conservative. Estimates also did not include the solid wood products potential of trees smaller than 20 cm diameter. Advances in wood technology have greatly expanded the potential for smaller trees (LeVan-Green and Livingston 2001). However, by extrapolating volume

estimates for trees of different sizes measured in this study it was estimated that trees < 20 cm contribute only about 3% to the total unprocessed volume, thus smaller diameter urban trees would likely contribute very little additional lumber.

Since most saw timber is harvested from forest-grown trees, it may be useful to compare the quality and availability of urban saw timber with that available from forests. Based on data from the U.S.D.A. Forest Inventory and Analysis program (Unit 4, Michigan, cycle 6, 2004), 5,055 board feet ac^{-1} (12,486 bd.ft. ha^{-1}) of graded saw timber is available on an average forested acre in southern Lower Michigan, which is about 9 times what was estimated for an average urban acre (552 bd.ft. ac^{-1}). Ignoring softwoods in our study, which were not graded into all 5 USDA Forest Services tree grades (see Methods), about 59% of all forest-grown board feet were in factory grade classes (1, 2, and 3) and 41% in the construction and local use classes (grades 4 and 5), compared to 54% and 46%, respectively for urban hardwood saw timber volume. Within the upper saw grades, forest- versus urban- grown hardwood saw timber volume was 14% vs. 10% in grade class 1, 19% vs. 12% in grade class 2 and 27.0% vs. 32% for grade class 3, respectively. Thus, in an absolute sense, there are clearly many more saw timber quality trees in forested vs. urban areas, but these results suggest only a small difference in wood quality relative to large (900%) decrease in wood quantity, when one harvests hardwood trees in urban versus forested areas.

Despite the potential availability of urban saw timber wood demonstrated here, there are still outstanding logistical problems regarding successful capitalization of it, including costs of extraction, handling and variation in supply. One fact regarding urban trees is the inevitability of their removal once they become dead or diseased, because they represent a liability (a hazard, sense Matheny and Clark 1994) as well as diminishing aesthetic values (Scott and Betters 2000). Nowak et al. (2004) estimated that 17% of all dead standing trees in Baltimore, Maryland were removed over a two-year period, or about 8.5% per year. This suggests some consistent level of urban wood will be available for harvest over time.

While it may not be realistic to expect arborists and small, private landowners to bear the logistical or financial burden of harvesting urban saw timber, clearly public entities could expand the current level of efforts. For example, the Community and Urban Forest Inventory and Management (computer) Program was recently created to help communities in California to inventory tree volume and calculate value for their urban forests (Pillsbury and Gill 2003). It has already been demonstrated on smaller scales that internal utilization of dead and dying municipal trees can offset the costs of tree removal and allow reduced infrastructural costs, such as the purchase of wood for park benches and picnic pavilions (Bratkovich 2001). Training municipal foresters to grade trees would be an important first step toward differentiating the value of dead and dying trees. The alternative is to continue to put valuable wood products contained in urban trees to some lesser use (e.g., firewood), or, as a worst case, into a landfill (urban wood waste comprises about 17% of all waste received at U.S. landfills; Solid Waste Association of North America, 2002).

Conclusion

Recent economic losses associated with the destruction of urban trees by wood-boring forest pests such as the emerald ash borer highlights the well known value associated with urban forests, not the least of which may be the valuable wood in the trees. While there are many potential concerns with harvesting urban trees for saw timber: low availability, poor wood quality and logistical concerns regarding harvesting urban wood, the results of this study suggest that many of them may be unfounded. Harvesting urban wood is certainly less efficient relative to commercial logging in forests because, even if abundant, urban wood may be scattered around

a large metropolitan area in smaller saleable units, greatly increasing the cost of consolidating and transporting it. However, it may not be prudent to view urban wood as an alternative to wood derived from forests. Rather it might best be viewed as a supplementary source of wood that may help to offset the social and economic costs of urban tree removal and urban wood waste disposal to private landowners and government entities. Clearly, if southeastern Lower Michigan is similar to other regions nationwide, a substantial amount of wood products volume is available for use in urban areas.

APPENDIX A

EAB SURVEY QUESTIONNAIRE

Just recently, your company received a letter indicating that a survey would be conducted among businesses in southern Michigan on the use and disposal of wood waste. I am calling to ask about the amount of wood waste your company generates or receives and what happens to it. We are interested in amounts and disposal for the last calendar year, 2005, at your company's location or locations here in southern Michigan.

For our survey, wood waste falls into eight categories:

1. Pallets, skids, and shipping crates;
2. Dunnage (wood used in packing to support and protect items being shipped);
3. Edging and cutoffs (for example, either from making wood products such as trim and molding or cutting those products to length);
4. Chips, shavings, and sawdust (for example, from making wood products such as lumber);
5. Tree residues -- that is, tree trunks, limbs, and stumps;
6. Construction debris (for example, cutoffs from framing and wood sheathing);
7. Railroad ties, and
8. Telephone poles.

We are interested only in your company's places of business or business locations, such as plants, in this or nearby counties in southern Michigan. (Interviewer: if asked, specific counties are the following:

Genesse	Livingston	Shiawassee
Jackson	Macomb	St. Clair
Lenawee	Monroe	Washtenaw
Ingham	Oakland	Wayne
Lapeer	Saginaw	

1. Over the entire year of 2005, did your company here in southern Michigan either generate or accept any wood waste in the form of pallets, dunnage, edging and cutoffs, chips and shavings, tree trunks and limbs, construction debris, railroad ties, or telephone poles?

- ☐ Yes. **Go to Q. 2.**
- ☐ No. **Thank you for your time. Goodbye.**
- ☐ DK. **Interviewer arrange for callback.**
- ☐ Refusal. **Thank you for your time. Goodbye.**

2. Does your company primarily accept wood waste in some form from other companies, organizations, or governmental agencies?

- ☐ Yes. **Go to Q. 3.**
- ☐ No. **Go to Q. 5.**
- ☐ Refusal. **Thank you for your time. Goodbye.**

3. What does your firm <u>primarily</u> accept? (Read List).

- ☐ Pallets, skid, and containers
- ☐ Dunnage
- ☐ Edgings and cutoffs
- ☐ Chips, shavings, and sawdust
- ☐ Tree trunks, limbs, and stumps
- ☐ Construction debris
- ☐ Railroad ties
- ☐ Telephone poles
- ☐ Accept two/more equally (do not mention option; if selected, ask for one type.)
- ☐ DK. **Interviewer arrange for callback.**
- ☐ Refusal. **Go to Q4.**

4. Does your company measure the quantity of wood waste it accepts primarily by volume hauled in by truck or in containers, or by its weight, or by the counted number (e.g., 1000 pallets, skids, and containers or 500 railroad ties or 800 telephone poles)?

- ☐ Primarily by truck or container: **Go To Q. 4.A.**
- ☐ Primarily by weight: **Go to Q. 4.B.**
- ☐ Primarily by the number: **Go to Q. 4.C.**
- ☐ DK. **Interviewer arrange for callback.**
- ☐ Refusal. **Go to Q. 4.D.**

4.A. Thinking now of the trucks or containers that bring wood waste to your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Interviewer arrange for callback.**

☐ Refusal. **Go to Q. 4.D.**

4.A.1 During a typical (average) month in 2005, about how many truckloads or containers of wood waste would you say your company accepted?

☐	>0 - < 20	☐	200 - <220
☐	20 - < 40	☐	220 - <240
☐	40 - < 60	☐	240 - <260
☐	60 - < 80	☐	260 - <280
☐	80 - <100	☐	280 - <300
☐	100 - <120	☐	300 - <320
☐	120 - <140	☐	320 - <340
☐	140 - <160	☐	340 - <360
☐	160 - <180	☐	360 - <380
☐	180 - <200	☐	380 - <400

☐ 400 or more , number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q.4.D.**

☐ Refusal. **Go to Q.4.D.**

Go to 4.D.

4.B. During a typical (average) month in 2005, about how many pounds of wood waste, to the nearest thousand, would you say your company accepted?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ 50,000 or more , number given _____ pounds

☐ Total for 2005 (if only figure available)_____pounds

☐ DK. **Go to Q.4.D.**

☐ Refusal. **Go to Q.4.D.**

Go to 4.D.

4.C. During a typical (average) month in 2005, in total, about how many of these did your company accept?

☐	>0 - 200	☐	2000 - 2200
☐	200 - 400	☐	2200 - 2400
☐	400 - 600	☐	2400 - 2600
☐	600 - 800	☐	2600 - 2800
☐	800 - 1000	☐	2800 - 3000
☐	1000 - 1200	☐	3000 - 3200
☐	1200 - 1400	☐	3200 - 3400
☐	1400 - 1600	☐	3400 - 3600
☐	1600 - 1800	☐	3600 - 3800
☐	1800 - 2000	☐	3800 - 4000

☐ Over 4000, number given _____.

☐ Total for all of 2005 (if only figure offered)_____.

☐ DK. **Go to Q.4.D.**

☐ Refusal. **Go to Q.4.D.**

4.D. What <u>one</u> source provided most of the wood waste your company accepted in 2005? We are interested in business and government sources both in and outside of the State of Michigan as well as outside the U.S.

☐ Businesses in Michigan

☐ Businesses from other U.S. states outside Michigan

☐ Canadian businesses

☐ Michigan state and local governments

☐ State and local governments from other U.S. states outside Michigan

☐ State and local governments in Canada

☐ Other_____

4.E. Does your company use most of the wood waste it accepts to make products or does your company permanently hold most of the wood as waste? By products we mean fuel for heat, electric power generation,

mulch, compost, firewood, pallets, skids, containers, or dunnage, wood products such as lumber and plywood, or building material such as joists.

☐ Uses most of wood to make products. **Go to Q. 4.E.1, 2, 3.**

☐ Permanently holds most wood as waste. **Go to Q. 4.F.**

☐ DK. **Go to Q.4.F.**

☐ Refusal. **Go to Q.4.F.**

4.E.1 What is the primary product does your company makes from the wood waste it accepts?

☐ Fuel for heat

☐ Fuel for electric power generation

☐ Mulch

☐ Compost

☐ Firewood

☐ Pallets, skids, shipping containers, or dunnage

☐ Composite wood products such as fiberboard or plywood

☐ Building material such as joists or framing studs

☐ Lumber

☐ Other_____

☐ DK. **Go to Q.4.E.2.**

☐ Refusal. **Go to Q.4.E.2.**

4.E.2. In terms of expense, what is the single most important reason that the rest of the wood waste is not being re-used or recycled?

☐ No reason, our company uses nearly all or all of what we receive

☐ Wood contains preservatives (for example, Wolmanized, creosote, CCA)

☐ Wood is coated with paint

☐ Wood is a glued product (for example, plywood or medium density fiberboard)

- ☐ Wood is attached to or contains metal, shingles, or other non-wood material
- ☐ Wood waste too expensive to haul to a recycler
- ☐ Laws or regulatory rules make recycling/re-use too difficult
- ☐ Too difficult (expensive or requires to much labor) to separate wood waste into different types or categories
- ☐ Other_____
- ☐ DK. **Go to Q.4.E.3.**
- ☐ Refusal. **Go to Q.4.E.3.**

4.E.3. In your judgment, what is the single most important action, if there is one, that state or local governments could take to promote the greater use of wood waste?

- ☐ None: there is nothing state or local governments can do.
- ☐ Provide more information on market for wood waste
- ☐ Reduce regulations governing wood waste disposal (write in regulation if identified by respondent) _____
- ☐ Other_____
- ☐ DK. **Go to Q.4.F.**
- ☐ Refusal. **Go to Q.4.F.**

4.F. From what you and others in your company have observed, how much of the wood waste your company accepts and holds do you think could be re-used or recycled?

- ☐ Little or none. **Go to Q. 4.G.**
- ☐ About one-third. **Go to Q. 4.G.**
- ☐ About one-half. **Go to Q. 4.G.**
- ☐ About two-thirds. **Go to Q. 4.G.**
- ☐ All or nearly all of it. **Go to Q. 4.I.**
- ☐ DK. **Go to Q. 4.G.**
- ☐ Refusal. **Go to Q. 4.G.**

4.G. In terms of expense, in your judgment, what is the single most important reason that more wood waste is not being re-used or recycled?

- ☐ Wood contains preservatives (for example, Wolmanized, creosote, CCA)
- ☐ Wood is coated with paint
- ☐ Wood is a glued product (for example, plywood or medium density fiberboard)
- ☐ Wood is attached to or contains metal, shingles, or other non-wood material
- ☐ Wood waste too expensive to haul to a recycler
- ☐ Laws or regulatory rules make recycling/re-use too difficult
- ☐ Other_____
- ☐ DK. **Go to Q.4.H.**
- ☐ Refusal. **Go to Q.4.H.**

Go to Q. 4.H.

4.H. What single most important way, if any, could more of the wood be re-used or recycled (examples, if needed, are to make wood products, fuel, mulch, lumber or re-use in existing form)?

- ☐ None, more cannot be re-used or recycled.
- ☐ Find a way to remove chemicals such as preservatives, paint, glue
- ☐ Find way to remove non-wood material such as metal or shingles
- ☐ Find cost effective way to sort wood waste from non-wood waste
- ☐ Lower costs of transporting waste wood to/from where generated
- ☐ Help in finding local or area recycler
- ☐ Other_____
- ☐ DK. **Go to Q.4.I.**
- ☐ Refusal. **Go to Q.4.I.**

4.I. In your judgment, what is the single most important action, if there is one, that Michigan state or local governments could take to promote the greater use of wood waste?

- ☐ None: there is nothing state or local governments can do.

- ☐ Provide more information on market for wood waste
- ☐ Reduce regulations governing wood waste disposal (write in regulation if identified by respondent)_____
- ☐ Other_____
- ☐ DK. **Go to Q.41.**
- ☐ Refusal. **Go to Q.41.**
- ☐ NA. **Go to Q.41.**

Go to Q. 41.

5. As wood waste, what does your company <u>primarily</u> dispose of ? By <u>primary</u> I mean what your company disposes of the most.

- ☐ Pallets, skids, and shipping crates. **Go to Q. 6.**
- ☐ Dunnage. **Go to Q. 10.**
- ☐ Edgings and cutoffs. **Go to Q. 14.**
- ☐ Chips, shavings, and sawdust. **Go to Q. 18.**
- ☐ Tree trunks, limbs, and stumps. **Go to Q. 22.**
- ☐ Construction debris. **Go to Q. 28.**
- ☐ Railroad ties. **Go to Q. 32.**
- ☐ Telephone poles. **Go to Q. 36.**
- ☐ DK. Arrange for callback.
- ☐ Refusal. **Thank you for your time. Goodbye.**

6. Does your company measure the amount of pallets, skids, and shipping crates it disposes of primarily by their total number, or by the volume hauled by truck or in containers, or by their weight?

- ☐ Primarily by number: **Go To Q. 6.A**
- ☐ Primarily by truck or container: **Go To Q. 6.B.**
- ☐ Primarily by weight: **Go to Q. 6.D.**
- ☐ DK. Interviewer arrange for callback.
- ☐ Refusal. **Go to Q. 7.**
- ☐ None. **Go to Q. 8.**

6.A. During a typical (average) month in 2005, in total, how many pallets, skids, and shipping crates did your company dispose of as wood waste?

☐	>0 - 200	☐	2000 - 2200
☐	200 - 400	☐	2200 - 2400
☐	400 - 600	☐	2400 - 2600
☐	600 - 800	☐	2600 - 2800
☐	800 - 1000	☐	2800 - 3000
☐	1000 - 1200	☐	3000 - 3200
☐	1200 - 1400	☐	3200 - 3400
☐	1400 - 1600	☐	3400 - 3600
☐	1600 - 1800	☐	3600 - 3800
☐	1800 - 2000	☐	3800 - 4000

☐ Over 4000, number given _____.

☐ Total for all of 2005 (if only figure offered)_____.

☐ DK. **Go to Q. 7**

☐ Refusal. **Go to Q. 7**

Go to Q. 7.

6.B. Thinking now of the trucks or containers used to haul pallets, skids, and shipping crates away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. Interviewer arrange for callback.

☐ Refusal. **Go to Q. 7.**

6.C. During a typical (average) month in 2005, about how many truckloads or containers of pallets, skids, and shipping crates would you say your company disposed of?

☐	>0 - < 20	☐	100 - <120
☐	20 - < 40	☐	120 - <140
☐	40 - < 60	☐	140 - <160
☐	60 - < 80	☐	160 - <180
☐	80 - <100	☐	180 - <200

☐	200 - <220	☐	300 - <320
☐	220 - <240	☐	320 - <340
☐	240 - <260	☐	340 - <360
☐	260 - <280	☐	360 - <380
☐	280 - <300	☐	380 - <400

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 7.**

☐ Refusal. **Go to Q. 7.**

Go to Q. 7.

6.D. During a typical (average) month in 2005, about how many pounds of pallets, skids, and shipping crates to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ DK. **Go to Q. 7.**

☐ Refusal. **Go to Q. 7.**

7. Did your company pay to dispose of the pallets, skids, and crates, were they mainly removed at no cost to your company, or was your company paid for them? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Our company paid for removal. **Go to Q. 7.A.**

☐ Removed at no cost to our company. **Go to Q. 7.B.**

☐ Another company paid for them. **Go to Q. 7.C.**

☐ DK. **Go to Q. 8**

☐ Refusal. **Go to Q. 8**

7.A For that typical month, about how much did your company pay for removal (in dollars)?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Total for 2005 (if only figure available)_____

☐ Over $10,000/month, amount given_____

☐ DK. **Go to Q. 8.**

☐ Refusal. **Go to Q. 8.**

7.A.1. Did your company use its own trucks to transport most of the material to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

7.A.2. Was most of the material sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

7.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes (one-way, if asked).

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 100

☐ Over 100 miles, amount given_____

☐ DK. **Go to Q. 8.**

☐ Refusal. **Go to Q. 8.**

Go to Q. 8.

7.B. What was the primary way the pallets, skids, and crates were disposed of at no cost to your company?

☐ Given away to public and/or employees

☐ Given away to other private companies

☐ Other_____

☐ DK. **Go to Q. 8.**

☐ Refusal. **Go to Q. 8.**

Go to Q. 8.

7.C. For that typical month, about how much was your company paid (in dollars)?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Total for 2005 (if only figure available)_____

☐ Over $10,000/month, amount given_____

☐ DK. **Go to Q. 8.**

☐ Refusal. **Go to Q. 8.**

8. For a typical (average) month, what percentage of the total number of pallets, skids, and shipping crates would you say your company was able to re-use?

☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ >0 - 10
☐ 10 - 20
☐ 20 - 30
☐ 30 - 40
☐ 40 - 50
☐ 50 - 60

☐ 60 - 70
☐ 70 - 80
☐ 80 - 90
☐ 90 - 100

☐ DK **Go to Q. 9**

☐ Refusal. **Go to Q. 9**

9. Did your company re-use most of the pallets, skids, and shipping crates for shipping and storage or did your company reduce most of them to parts or wood fiber and use that material for something other than shipping and storage?

☐ Reused most in original form. **Go to Question 40 on Primary and 41/42 on Secondary**

☐ Reduced most to parts/fiber and used for something else. **Go to Q. 9.A.**

☐ DK **Go to Question 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Question 40 on Primary and 41/42 on Secondary**

9.A. What was the primary use your company made of the parts and fiber?

☐ Mulch

☐ Livestock bedding

☐ Land cover or fill

☐ Heating fuel

☐ Other_____

☐ DK. **Go to Question 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Question 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

10. Does your company measure the amount of dunnage it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the wood waste it disposes of by weight?

☐ Primarily by truck or container: **Go To Q. 10.A.**

☐ Primarily by weight: **Go to Q. 10.C.**

☐ DK. **Go to Q 11**.

☐ Refusal. **Go to Q 11**.

10.A. Thinking now of the trucks or containers used to haul the dunnage away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q.11**.

☐ Refusal. **Go to Q.11.**

10.B. During a typical (average) month in 2005, about how many truckloads or containers of dunnage would you say your company disposed of?

☐	>0 - < 20	☐	200 - <220
☐	20 - < 40	☐	220 - <240
☐	40 - < 60	☐	240 - <260
☐	60 - < 80	☐	260 - <280
☐	80 - <100	☐	280 - <300
☐	100 - <120	☐	300 - <320
☐	120 - <140	☐	320 - <340
☐	140 - <160	☐	340 - <360
☐	160 - <180	☐	360 - <380
☐	180 - <200	☐	380 - <400

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 11**

☐ Refusal. **Go to Q. 11**

Go to Q.11

10.C. During a typical (average) month in 2005, about how many pounds of dunnage to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	12,000 - <14,000
☐	2,000 - < 4,000	☐	14,000 - <16,000
☐	4,000 - < 6,000	☐	16,000 - <18,000
☐	6,000 - < 8,000	☐	18,000, - <20,000
☐	8,000 - <10,000	☐	20,000 - <22,000
☐	10,000 - <12,000	☐	22,000 - <24,000

☐	24,000 - <26,000	☐	38,000 - <40,000
☐	26,000 - <30,000	☐	42,000 - <44,000
☐	30,000 - <32,000	☐	44,000 - <46,000
☐	32,000 - <34,000	☐	46,000 - <48,000
☐	34,000 - <36,000	☐	48,000 - <50,000
☐	36,000 - <38,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available)_____ pounds

☐ DK. **Go to Q. 11**

☐ Refusal. **Go to Q. 11**

11. Did your company pay to dispose of the dunnage, was it mainly removed at no cost to your company, or was your company paid for it? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for removal. **Go to Q. 11.A.**

☐ Removed at no cost to company. **Go to Q. 11.B.**

☐ Another company paid for them **Go to Q. 11.C.**

☐ DK. **Go to Q. 12**

☐ Refusal. **Go to Q. 12**

11.A For that typical month, about how much did your company pay for removal?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Total for 2005 (if only figure available)_____

☐ Over $10,000/month, amount given_____

☐ DK. **Go to Q. 12**

☐ Refusal. **Go to Q. 12**

11.A.1. Did your company use its own trucks to transport most of the dunnage to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

11.A.2. Was most of the dunnage sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

11.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where over 50% of your dunnage goes.

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 100

☐ Over 100 miles, amount given_____

☐ DK.

☐ Refusal.

Go to Q.12

11.B. What was the primary way the dunnage was disposed of at no cost to your company?

☐ Given away to public and/or employees

☐ Given away to other private companies

☐ Other_____

☐ DK. **Go to Q. 12.**

☐ Refusal. **Go to Q. 12.**

Go to Q. 12.

11.C. For that typical month, about how much was your company paid?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ DK. **Go to Q. 12.**

☐ Refusal. **Go to Q. 12.**

12. What percentage of the total dunnage would you say your company was able to reuse?

☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ >0 - 10
☐ 10 - 20
☐ 20 - 30
☐ 30 - 40
☐ 40 - 50
☐ 50 - 60
☐ 60 - 70
☐ 70 - 80
☐ 80 - 90
☐ 90 - 100

☐ DK **Go to Q. 13.**

☐ Refusal. **Go to Q. 13.**

13. Did your company re-use most of the dunnage for shipping and storage or did your company reduce most of it to its parts or to wood fiber and use that material for something other than shipping and storage?

☐ Reused most in original form. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Reduced to parts/fiber and used for something else. **Go to Q. 13.A.**

☐ DK **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

13.A. What was the primary use your company made of the parts or fiber?

☐ Mulch

☐ Livestock bedding

☐ Land cover or fill

☐ Heating fuel

☐ Other_____

☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

14. Does your company measure the amount of edgings and cutoffs it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the wood waste it disposes of by weight?

☐ Primarily by truck or container: **Go To Q. 14.A.**

☐ Primarily by weight: **Go to Q. 14.C.**

☐ DK. **Go to Q. 15.**

☐ Refusal. **Go to Q. 15.**

14.A. Thinking now of the trucks or containers used to haul edgings and cutoffs away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q. 15.**

☐ Refusal. **Go to Q. 15.**

14.B. During a typical (average) month in 2005, about how many truckloads or containers of edgings and cutoffs would you say your company disposed of?

☐	>0 - < 20	☐	100 - <120
☐	20 - < 40	☐	120 - <140
☐	40 - < 60	☐	140 - <160
☐	60 - < 80	☐	160 - <180
☐	80 - <100	☐	180 - <200

☐	200 - <220	☐	300 - <320
☐	220 - <240	☐	320 - <340
☐	240 - <260	☐	340 - <360
☐	260 - <280	☐	360 - <380
☐	280 - <300	☐	380 - <400

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available from respondent)_____

☐ DK. **Go to Q. 15.**

☐ Refusal. **Go to Q. 15.**

Go to Q.15

14.C. During a typical (average) month in 2005, about how many pounds of edgings and cutoffs to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available from respondent) _____

☐ DK. **Go to Q. 15.**

☐ Refusal. **Go to Q. 15.**

15. Did your company pay to dispose of edgings and cutoffs, was it mainly removed at no cost to your company, or was your company paid for it? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for removal. **Go to Q. 15.A.**

☐ Removed at no cost to company. **Go to Q. 15.B.**

☐ Company was paid for them. **Go to Q. 15.C.**

☐ DK. **Go to Q. 16**

☐ Refusal. **Go to Q. 16**

15.A For that typical month, about how much did your company pay for removal?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available from respondent)_____

☐ DK. **Go to Q. 16.**

☐ Refusal. **Go to Q. 16.**

15.A.1. Did your company use its own trucks to transport most of the edgings and cutoffs to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

15.A.2. Were most of the edgings and cutoffs sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

15.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes.

☐	> 0 - 5	☐	>25 - 30
☐	> 5 - 10	☐	>30 - 35
☐	>10 - 15	☐	>35 - 40
☐	>15 - 20	☐	>40 - 45
☐	>20 - 25	☐	>45 - 50

☐	>50 - 55	☐	>75 - 80
☐	>55 - 60	☐	>80 - 85
☐	>60 - 65	☐	>85 - 90
☐	>65 - 70	☐	>90 - 95
☐	>70 - 75	☐	>95 - 100

☐ Over 100 miles, amount given_____

☐ DK. **Go to Q. 16.**

☐ Refusal. **Go to Q. 16.**

Go to Q. 16.

15.B. What was the primary way the edgings and cutoffs were disposed of at no cost to your company?

☐ Given away to public and/or employees

☐ Given away to other private companies

☐ Other_____

☐ DK. **Go to Q. 16.**

☐ Refusal. **Go to Q. 16.**

Go to Q. 16.

15.C. For that typical month, about how much was your company paid?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 16.**

☐ Refusal. **Go to Q. 16.**

16. What percentage of the total amount of edgings and cutoffs would you say your company was able to reuse?

☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ >0 - 10
☐ 10 - 20
☐ 20 - 30
☐ 30 - 40
☐ 40 - 50
☐ 50 - 60
☐ 60 - 70
☐ 70 - 80
☐ 80 - 90
☐ 90 - 100

☐ DK **Go to Q. 17.**

☐ Refusal. **Go to Q. 17.**

17. What was the primary use your company made of the edgings and cutoffs?

☐ Mulch

☐ Livestock bedding

☐ Land cover or fill

☐ Heating fuel

☐ Other_____

☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

18. Does your company measure the amount of chips and shavings it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the chips and shavings it disposes of by weight?

☐ Primarily by truck or container: **Go To Q. 18.A.**

☐ Primarily by weight: **Go to Q. 18.C.**

☐ DK. **Go to Q. 19.**

☐ Refusal. **Go to Q. 19.**

18.A. Thinking now of the trucks or containers used to haul chips and shavings away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q. 19.**

☐ Refusal. **Go to Q. 19.**

18.B. During a typical (average) month in 2005, about how many truckloads or containers of chips and shavings would you say your company disposed of?

☐	>0 - < 20	☐	200 - <220
☐	40 - < 60	☐	220 - <240
☐	60 - < 80	☐	240 - <260
☐	80 - <100	☐	260 - <280
☐	100 - <120	☐	280 - <300
☐	120 - <140	☐	300 - <320
☐	140 - <160	☐	320 - <340
☐	160 - <180	☐	340 - <360
☐	180 - <200	☐	360 - <380
☐	200 - <220	☐	380 - <400

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 19.**

☐ Refusal. **Go to Q. 19.**

Go to Q. 19

18.C. During a typical (average) month in 2005, about how many pounds of chips and shavings to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available)_____ pounds

☐ DK. **Go to Q. 19.**

☐ Refusal. **Go to Q. 19.**

19. Did your company pay to dispose of the chips and shavings, were they mainly removed at no cost to your company, or was your company paid for them? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for removal. **Go to Q. 19.A.**

☐ Removed at no cost to company. **Go to Q. 19.B.**

☐ Company was paid for them. **Go to Q. 19.C.**

☐ DK. **Go to Q. 20.**

☐ Refusal. **Go to Q. 20.**

19.A For that typical month, about how much did your company pay for removal?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available respondent)_____

☐ DK. **Go to Q. 20.**

☐ Refusal. **Go to Q. 20.**

19.A.1. Did your company use its own trucks to transport most of the chips and shavings to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

19.A.2. Were most of the chips and shavings sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

19.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes.

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 100

☐ Over 100 miles, amount given_____

☐ DK. **Go to Q. 20.**

☐ Refusal. **Go to Q. 20.**

Go to Q. 20.

19.B. What was the primary way the chips and shavings were disposed of at no cost to your company?

☐ Given away to public and/or employees

☐ Given away to other private companies

☐ Other_____

☐ DK. **Go to Q. 20.**

☐ Refusal. **Go to Q. 20.**

Go to Q. 20.

19.C. For that typical month, about how much was your company paid?

$_____/typical month.

☐ DK. **Go to Q. 20.**

☐ Refusal. **Go to Q. 20.**

20. What percentage of the total amount of chips and shavings would you say your company was able to reuse?

- ☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

- ☐ >0 - 10
- ☐ 10 - 20
- ☐ 20 - 30
- ☐ 30 - 40
- ☐ 40 - 50
- ☐ 50 - 60
- ☐ 60 - 70
- ☐ 70 - 80
- ☐ 80 - 90
- ☐ 90 - 100

- ☐ DK **Go to Q. 21.**

- ☐ Refusal. **Go to Q. 21.**

21. What was the primary use your company made of the chips and shavings?

- ☐ Mulch
- ☐ Livestock bedding
- ☐ Land cover or fill
- ☐ Heating fuel
- ☐ Other_____
- ☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**
- ☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

22. Does your company measure the amount of trunks, limbs, and stumps, it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the trunks, limbs, and stumps it disposes of by weight?

- ☐ Primarily by truck or container: **Go To Q. 22.A.**
- ☐ Primarily by weight: **Go to Q. 22.C.**
- ☐ DK. **Go to Q. 23.**
- ☐ Refusal. **Go to Q. 23.**

22.A. Thinking now of the trucks or containers used to haul trunks, limbs, and stumps away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q. 23.**

☐ Refusal. **Go to Q. 23.**

22.B. During a typical (average) month in 2005, about how many truckloads or containers of trunks, limbs, and stumps would you say your company disposed of?

☐	>0 - < 20	☐	220 - <240
☐	40 - < 60	☐	240 - <260
☐	60 - < 80	☐	260 - <280
☐	80 - <100	☐	280 - <300
☐	100 - <120	☐	300 - <320
☐	120 - <140	☐	320 - <340
☐	140 - <160	☐	340 - <360
☐	160 - <180	☐	360 - <380
☐	180 - <200	☐	380 - <400
☐	200 - <220		

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 23.**

☐ Refusal. **Go to Q. 23.**

Go to Q. 23.

22.C. During a typical (average) month in 2005, about how many pounds of trunks, limbs, and stumps to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	12,000 - <14,000
☐	2,000 - < 4,000	☐	14,000 - <16,000
☐	4,000 - < 6,000	☐	16,000 - <18,000
☐	6,000 - < 8,000	☐	18,000, - <20,000
☐	8,000 - <10,000	☐	20,000 - <22,000
☐	10,000 - <12,000	☐	22,000 - <24,000

☐	24,000 - <26,000	☐	38,000 - <40,000
☐	26,000 - <30,000	☐	42,000 - <44,000
☐	30,000 - <32,000	☐	44,000 - <46,000
☐	32,000 - <34,000	☐	46,000 - <48,000
☐	34,000 - <36,000	☐	48,000 - <50,000
☐	36,000 - <38,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available)_____ pounds

☐ DK. **Go to Q. 23.**

☐ Refusal. **Go to Q. 23.**

23. Did your company pay to dispose of the trunks, limbs, and stumps, were they mainly disposed of at no cost to your company, or did another company buy them? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for disposal. **Go to Q. 23.A.**

☐ Removed at no cost to company. **Go to Q. 23.B**

☐ Another company bought them. **Go to Q. 23.C.**

☐ DK. **Go to Q. 24.**

☐ Refusal. **Go to Q. 24.**

23.A For that typical month, about how much did your company pay for disposal of the trunks, limbs, and stumps?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 24.**

☐ Refusal. **Go to Q. 24.**

23.A.1. Did your company use its own trucks to transport most of the them to a disposal site or did another company provide trucks?

- ☐ Our company provided the trucks
- ☐ Another company provided the trucks
- ☐ Other _____

23.A.2. Were most of them sent to a landfill or to another company?

- ☐ Landfill
- ☐ Another company
- ☐ Other_____

23.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes.

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 100

- ☐ Over 100 miles, amount given_____
- ☐ DK. **Go to Q. 24.**
- ☐ Refusal. **Go to Q. 24.**

Go to Q. 24.

23.B. What was the primary way the trunks, limbs, and stumps were disposed of at no cost to your company?

- ☐ Given away to public and/or employees
- ☐ Given away to other private companies
- ☐ Other_____
- ☐ DK. **Go to Q. 24.**
- ☐ Refusal. **Go to Q. 24.**

Go to Q. 24.

23.C. For that typical month, about how much was your company paid?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 24.**

☐ Refusal. **Go to Q. 24.**

24. What percentage of the total amount of the trunks, limbs, and stumps would you say your company was able to reuse?

☐ None. **Go to Q. 26.**

☐ >0 - 10
☐ 10 - 20
☐ 20 - 30
☐ 30 - 40
☐ 40 - 50
☐ 50 - 60
☐ 60 - 70
☐ 70 - 80
☐ 80 - 90
☐ 90 - 100

☐ DK **Go to Q. 25.**

☐ Refusal. **Go to Q. 25.**

25. For that typical month in 2005, what did your company do with most of the trunks limbs, and stumps? Were they cut up for firewood to sell? Ground into mulch to sell? Were they sawed into lumber to sell?

☐ Over half cut up for fire wood to sell or,

☐ Over half ground for mulch to sell, or

☐ Over half sawed into lumber to sell, or

☐ Over half sold for other use_____

☐ Over half given away to other private companies to be used for _____

☐ Over half given away to the public to be used for _____

☐ Over half used by company and/or its employees (Interviewer: ask most frequent use: could be for fuel, source of lumber or mulch, or given to employees).

_____

☐ DK. **Go to Q. 26.**

☐ Refusal. **Go to Q. 26.**

So far, my questions have been about all species of trees disposed of as wood waste. At this point, I would like to ask two questions about ash trees in particular because of the Emerald Ash Borer infestation here in southern Michigan.

26. Compared to this time last year, is your company getting more ash trees, about the same number as last year, or less?

☐ More ash trees compared to this time last year

☐ About the same number as this time last year

☐ Less than this time last year

☐ DK. **Go to Q. 27.**

☐ Refusal. **Go to Q. 27.**

27. For that typical month in 2005, what did your company do with over half the ash tree trunks, limbs, and stumps? Was this material cut up for firewood to sell? Ground up for mulch to sell? Or were they sawed into lumber to sell?

☐ Over half cut up for fire wood to sell or,

☐ Over half ground for mulch to sell, or

☐ Over half sawed into lumber to sell, or

☐ Over half sold for other use_____

☐ Over half given away to other private companies to be used for _____

☐ Over half given away to the public to be used for _____

☐ Over half used by company and/or its employees (Interviewer: ask most frequent use: could be for fuel, source of lumber or mulch, or given to employees).

_____

☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

28. Does your company measure the amount of construction debris it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the debris it disposes of by weight?

☐ Primarily by truck or container: **Go To Q. 28.A.**

☐ Primarily by weight: **Go to Q. 28.C.**

☐ DK. **Go to Q. 29.**

☐ Refusal. **Go to Q. 29.**

28.A. Thinking now of the trucks or containers used to haul construction debris away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q. 29.**

☐ Refusal. **Go to Q. 29.**

28.B. During a typical (average) month in 2005, about how many truckloads or containers of construction debris would you say your company disposed of?

☐	>0 - < 20	☐	220 - <240
☐	40 - < 60	☐	240 - <260
☐	60 - < 80	☐	260 - <280
☐	80 - <100	☐	280 - <300
☐	100 - <120	☐	300 - <320
☐	120 - <140	☐	320 - <340
☐	140 - <160	☐	340 - <360
☐	160 - <180	☐	360 - <380
☐	180 - <200	☐	380 - <400
☐	200 - <220		

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 29.**

☐ Refusal. **Go to Q. 29.**

Go to Q. 29.

28.C. During a typical (average) month in 2005, about how many pounds of construction debris shavings to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available)_____ pounds

☐ DK. **Go to Q. 29.**

☐ Refusal. **Go to Q. 29.**

29. Did your company pay to dispose of the debris, was it mainly removed at no cost to your company, or was your company paid for it? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for removal. **Go to Q. 29.A.**

☐ Removed at no cost to company. **Go to Q. 29.B**

☐ Company was paid for them. **Go to Q. 29.C.**

☐ DK. **Go to Q. 30.**

☐ Refusal. **Go to Q. 30.**

29.A For that typical month, about how much did your company pay for removal?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ DK. **Go to Q. 30.**

☐ Refusal. **Go to Q. 30.**

29.A.1. Did your company use its own trucks to transport most of the debris to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

29.A.2. Was most of the debris sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

29.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your debris goes.

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 100

☐ Over 100 miles, amount given_____

☐ DK. **Go to Q. 30.**

☐ Refusal. **Go to Q. 30.**

Go to Q. 30.

29.B. What was the primary way the debris was disposed of at no cost to your company?

- ☐ Given away to public and/or employees
- ☐ Given away to other private companies
- ☐ Other_____
- ☐ DK. **Go to Q. 30.**
- ☐ Refusal. **Go to Q. 30.**

Go to Q. 30.

29.C. For that typical month, about how much was your company paid?

$_____/typical month.

- ☐ DK. **Go to Q. 30.**
- ☐ Refusal. **Go to Q. 30.**

30. What percentage of the total amount of construction debris would you say your company was able to reuse?

- ☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

- ☐ >0 - 10
- ☐ 10 - 20
- ☐ 20 - 30
- ☐ 30 - 40
- ☐ 40 - 50
- ☐ 50 - 60
- ☐ 60 - 70
- ☐ 70 - 80
- ☐ 80 - 90
- ☐ 90 - 100

- ☐ DK **Go to Q. 31.**
- ☐ Refusal. **Go to Q. 31.**

31. What was the primary use your company made of the debris?

- ☐ Mulch
- ☐ Livestock bedding
- ☐ Land cover or fill

☐ Heating fuel

☐ Other_____

☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

32. Does your company measure the amount of railroad ties it disposes of primarily by their total number, or by the volume hauled by truck or in containers, or by their weight?

☐ Primarily by number: **Go To Q. 32.A**

☐ Primarily by truck or container: **Go To Q. 32.B.**

☐ Primarily by weight: **Go to Q. 32.D.**

☐ DK. **Go to Q. 33.**

☐ Refusal. **Go to Q. 33.**

32.A. During a typical (average) month in 2005, in total, how many railroad ties did your company dispose of as wood waste?

☐	>0 - 200	☐	2000 - 2200
☐	200 - 400	☐	2200 - 2400
☐	400 - 600	☐	2400 - 2600
☐	600 - 800	☐	2600 - 2800
☐	800 - 1000	☐	2800 - 3000
☐	1000 - 1200	☐	3000 - 3200
☐	1200 - 1400	☐	3200 - 3400
☐	1400 - 1600	☐	3400 - 3600
☐	1600 - 1800	☐	3600 - 3800
☐	1800 - 2000	☐	3800 - 4000

☐ Over 4000, number given _____.

☐ Total for all of 2005 (if only figure offered by respondent)_____.

☐ DK. **Go to Q. 33.**

☐ Refusal. **Go to Q. 33.**

Go to Q. 33.

32.B. Thinking now of the trucks or containers used to haul the railroad ties away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q. 33.**

☐ Refusal. **Go to Q. 33.**

32.C. During a typical (average) month in 2005, about how many truckloads or containers of railroad ties would you say your company disposed of?

☐	>0 - < 20	☐	220 - <240
☐	40 - < 60	☐	240 - <260
☐	60 - < 80	☐	260 - <280
☐	80 - <100	☐	280 - <300
☐	100 - <120	☐	300 - <320
☐	120 - <140	☐	320 - <340
☐	140 - <160	☐	340 - <360
☐	160 - <180	☐	360 - <380
☐	180 - <200	☐	380 - <400
☐	200 - <220		

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 33.**

☐ Refusal. **Go to Q. 33.**

Go to Q. 33.

32.D. During a typical (average) month in 2005, about how many pounds of railroad ties to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available)_____ pounds

☐ DK. **Go to Q. 33.**

☐ Refusal. **Go to Q. 33.**

33. Did your company pay to dispose of the ties, were they mainly removed at no cost to your company, or was your company paid for them? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for removal. **Go to Q. 33.A.**

☐ Removed at no cost to company. **Go to Q. 33.B.**

☐ Company was paid for them. **Go to Q. 33.C.**

☐ DK. **Go to Q. 34.**

☐ Refusal. **Go to Q. 34.**

33.A For that typical month, about how much did your company pay for removal?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available)_____

☐ DK. **Go to Q. 34.**

☐ Refusal. **Go to Q. 34.**

33.A.1. Did your company use its own trucks to transport most of the ties to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

33.A.2. Were most of the ties sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

33.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes.

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 10

☐ Over 100 miles, amount given_____

☐ DK. **Go to Q. 34.**

☐ Refusal. **Go to Q. 34.**

Go to Q. 34.

33.B. What was the primary way the ties were disposed of at no cost to your company?

☐ Given away to public and/or employees

☐ Given away to other private companies

☐ Other_____

☐ DK. **Go to Q. 34.**

☐ Refusal. **Go to Q. 34.**

Go to Q. 34.

33.C. For that typical month, about how much was your company paid?

$_____/typical month.

☐ DK. **Go to Q. 34.**

☐ Refusal. **Go to Q. 34.**

34. What percentage of the total amount of the ties would you say your company was able to reuse?

- ☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

- ☐ >0 - 10
- ☐ 10 - 20
- ☐ 20 - 30
- ☐ 30 - 40
- ☐ 40 - 50
- ☐ 50 - 60
- ☐ 60 - 70
- ☐ 70 - 80
- ☐ 80 - 90
- ☐ 90 - 100

- ☐ DK **Go to Q. 35.**

- ☐ Refusal. **Go to Q. 35.**

35. What was the primary use your company made of the ties?

- ☐ Mulch
- ☐ Livestock bedding
- ☐ Land cover or fill
- ☐ Heating fuel
- ☐ Landscaping
- ☐ Other_____
- ☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**
- ☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

Go to Q. 40 on Primary and 41/42 on Secondary

36. Does your company measure the amount of telephone poles it disposes of primarily by their total number, or by the volume hauled by truck or in containers, or by their weight?

- ☐ Primarily by number: **Go To Q. 36.A**
- ☐ Primarily by truck or container: **Go To Q. 36.B.**
- ☐ Primarily by weight: **Go to Q. 36.D.**
- ☐ DK. **Go to Q. 37.**
- ☐ Refusal. **Go to Q. 37.**

36.A. During a typical (average) month in 2005, in total, how many telephone poles did your company dispose of as wood waste?

☐	>0 - 200	☐	2000 - 2200
☐	200 - 400	☐	2200 - 2400
☐	400 - 600	☐	2400 - 2600
☐	600 - 800	☐	2600 - 2800
☐	800 - 1000	☐	2800 - 3000
☐	1000 - 1200	☐	3000 - 3200
☐	1200 - 1400	☐	3200 - 3400
☐	1400 - 1600	☐	3400 - 3600
☐	1600 - 1800	☐	3600 - 3800
☐	1800 - 2000	☐	3800 - 4000

☐ Over 4000, number given _____.

☐ Total for all of 2005 (if only figure offered by respondent)_____.

☐ DK. **Go to Q. 37.**

☐ Refusal. **Go to Q. 37.**

Go to Q. 37.

36.B. Thinking now of the trucks or containers used to haul the telephone poles away from your company, what would you say is the typical (average) volume in cubic yards they hold?

☐	0 - <10	☐	50 - <60
☐	10 - <20	☐	60 - <70
☐	20 - <30	☐	70 - <80
☐	30 - <40	☐	80 - <90
☐	40 - <50	☐	90 - <100

☐ If over 100 cubic yards, ask for respondents' estimate of typical volume of truck or container_____

☐ DK. **Go to Q. 37.**

☐ Refusal. **Go to Q. 37.**

36.C. During a typical (average) month in 2005, about how many truckloads or containers of telephone poles would you say your company disposed of?

☐	>0 - < 20	☐	120 - <140
☐	20 - < 40	☐	140 - <160
☐	40 - < 60	☐	160 - <180
☐	60 - < 80	☐	180 - <200
☐	80 - <100	☐	200 - <220
☐	100 - <120	☐	220 - <240

☐	240 - <260	☐	320 - <340
☐	260 - <280	☐	340 - <360
☐	280 - <300	☐	360 - <380
☐	300 - <320	☐	380 - <400

☐ Over 400, number given _____

☐ Total for 2005 (if only figure available from respondent)_____

☐ DK. **Go to Q. 37.**

☐ Refusal. **Go to Q. 37.**

Go to Q. 37.

36.D. During a typical (average) month in 2005, about how many pounds of telephone poles to the nearest thousand, would you say your company disposed of?

☐	0 - < 2,000	☐	24,000 - <26,000
☐	2,000 - < 4,000	☐	26,000 - <30,000
☐	4,000 - < 6,000	☐	30,000 - <32,000
☐	6,000 - < 8,000	☐	32,000 - <34,000
☐	8,000 - <10,000	☐	34,000 - <36,000
☐	10,000 - <12,000	☐	36,000 - <38,000
☐	12,000 - <14,000	☐	38,000 - <40,000
☐	14,000 - <16,000	☐	42,000 - <44,000
☐	16,000 - <18,000	☐	44,000 - <46,000
☐	18,000, - <20,000	☐	46,000 - <48,000
☐	20,000 - <22,000	☐	48,000 - <50,000
☐	22,000 - <24,000		

☐ Over 50,000, number given _____ pounds

☐ Total for 2005 (if only figure available)_____ pounds

☐ DK. **Go to Q. 37.**

☐ Refusal. **Go to Q. 37.**

37. Did your company pay to dispose of the poles, were they mainly removed at no cost to your company, or was your company paid for them? (If respondent indicates that two or three responses apply, ask about the most frequent practice.)

☐ Company paid for removal. **Go to Q. 37.A.**

☐ Removed at no cost to company. **Go to Q. 37.B.**

☐ Company was paid for them. **Go to Q. 37.C.**

☐ DK. **Go to Q. 38.**

☐ Refusal. **Go to Q. 38.**

37.A For that typical month, about how much did your company pay for removal?

☐	>0 - 500	☐	5,000 - 5,500
☐	500 - 1,000	☐	5,500 - 6,000
☐	1,000 - 1,500	☐	6,500 - 7,000
☐	1,500 - 2,000	☐	7,000 - 7,500
☐	2,000 - 2,500	☐	7,500 - 8,000
☐	3,000 - 3,500	☐	8,000 - 8,500
☐	3,500 - 4,000	☐	8,500 - 9,000
☐	4,000 - 4,500	☐	9,000 - 9,500
☐	4,500 - 5,000	☐	9,500 - 10,000

☐ Over $10,000/month, amount given_____

☐ Total for 2005 (if only figure available from respondent)_____

☐ DK. **Go to Q. 38.**

☐ Refusal. **Go to Q. 38.**

37.A.1. Did your company use its own trucks to transport most of the poles to a disposal site or did another company provide trucks?

☐ Our company provided the trucks

☐ Another company provided the trucks

☐ Other_____

37.A.2. Was most of the poles sent to a landfill or to another company?

☐ Landfill

☐ Another company

☐ Other_____

37.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of the poles go.

☐	> 0 - 5	☐	>50 - 55
☐	> 5 - 10	☐	>55 - 60
☐	>10 - 15	☐	>60 - 65
☐	>15 - 20	☐	>65 - 70
☐	>20 - 25	☐	>70 - 75
☐	>25 - 30	☐	>75 - 80
☐	>30 - 35	☐	>80 - 85
☐	>35 - 40	☐	>85 - 90
☐	>40 - 45	☐	>90 - 95
☐	>45 - 50	☐	>95 - 100

☐ Over 100 miles, amount given_____

☐ DK. **Go to Q. 38.**

☐ Refusal. **Go to Q. 38.**

Go to Q. 38.

37.B. What was the primary way the poles were disposed of at no cost to your company?

☐ Given away to public and/or employees

☐ Given away to other private companies

☐ Other_____

☐ DK. **Go to Q. 38.**

☐ Refusal. **Go to Q. 38.**

Go to Q. 38.

37.C. For that typical month, about how much was your company paid?

$_____/typical month.

☐ DK. **Go to Q. 38.**

☐ Refusal. **Go to Q. 38.**

38. What percentage of the total amount of the poles would you say your company was able to reuse?

☐ None. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ >0 - 10
☐ 10 - 20
☐ 20 - 30
☐ 30 - 40
☐ 40 - 50
☐ 50 - 60
☐ 60 - 70
☐ 70 - 80
☐ 80 - 90
☐ 90 - 100

☐ DK **Go to Q. 39.**

☐ Refusal. **Go to Q. 39.**

39. What was the primary use your company made of the poles?

☐ Mulch

☐ Livestock bedding

☐ Land cover or fill

☐ Heating fuel

☐ Landscaping

☐ Building construction

☐ Other_____

☐ DK. **Go to Q. 40 on Primary and 41/42 on Secondary**

☐ Refusal. **Go to Q. 40 on Primary and 41/42 on Secondary**

40. I've asked about the <u>primary</u> wood waste your company disposes of. Does your company also dispose of significant quantities of other kind's wood waste as well? By significant I mean more than 10 percent of the total wood waste your company disposed of in 2005.

☐ Yes, company disposes of other wood wastes. **Go to Q. 40.A.**

☐ No, none or 10 percent or less. **Go to Q. 41.**

☐ DK. **Go to Q. 41.**

☐ Refusal. **Go to Q. 41.**

40.A. I'm interested only in the second largest amount of wood waste your company disposed of in 2005. What type of wood waste was it? [Interviewer can read list again. There will be a provision in the questionnaire software that prevents the same type from being selected twice and upon completion of questions for the second type will send the interviewer to Q. 41, not Q. 40.]

☐ Pallets, skids, and shipping crates. **Go to Q. 6.**

☐ Dunnage. **Go to Q. 10.**

☐ Edgings and cutoffs. **Go to Q. 14.**

☐ Chips, shavings, and sawdust. **Go to Q. 18.**

☐ Tree trunks, limbs, and stumps. **Go to Q. 22.**

☐ Construction debris. **Go to Q. 28.**

☐ Railroad ties. **Go to Q. 32.**

☐ Telephone poles. **Go to Q. 36.**

☐ DK. **Go to Q. 41**

☐ Refusal. **Go to Q. 41**

Now, I would like to ask just a few final questions about the market for wood waste.

41. From your company's experience in 2005, in your judgment is there no market for the kind of waste wood your company accepts or generates, a developing market, or a fully developed market for that wood? By market, we mean that there are buyers for the wood waste and ongoing amounts available from suppliers.

- ☐ No market. **Go to Q. 41.A.**
- ☐ A developing market. **Go to Q. 41.B.**
- ☐ A fully developed market. **Go to Q. 41.C.**
- ☐ DK. **Go to Q. 42.**
- ☐ Refusal. **Go to Q. 42.**

41.A. What is the single most important reason, in your judgment, that there is no market for the kind of wood waste your firm accepts or generates?

- ☐ Can't use wood containing preservatives
- ☐ Can't use wood coated with paint
- ☐ Can't use wood containing glue
- ☐ Can't use wood is attached to metal, shingles, or other non-wood material
- ☐ Can't use wood containing metal or other foreign material that cannot be easily removed
- ☐ No cost effective way to sort wood waste from non-wood waste
- ☐ Wood waste too expensive to transport (relative to value)
- ☐ Other_____
- ☐ DK. **Go to Q. 42.**
- ☐ Refusal. **Go to Q. 42.**

Go to Q. 42.

41.B. In your judgment, what is the single most important part of the market that is as yet not fully developed?

- ☐ Difficult to identify/contact buyers
- ☐ Difficult to identify/contact sellers
- ☐ Difficult to get prevailing market prices
- ☐ Transportation costs too high

☐ Waste wood more expensive to use than alternative materials

☐ Governmental regulations (write in regulation if mentioned by respondent) _____

☐ DK. **Go to Q. 42.**

☐ Refusal. **Go to Q. 42.**

Go to Q.42

41.C. From month to month since the beginning of 2005, are the prices for wood waste accepted or generated by your company relatively stable or do the prices vary widely? As a standard of comparison, use gasoline prices at the pump.

☐ Prices vary less than gasoline prices. **Go to Q. 41.D.**

☐ Prices vary about as much as gasoline prices. **Go to Q. 41.C.1.**

☐ Prices vary more than gasoline prices. **Go to Q. 41.C.1.**

☐ DK. **Go to Q. 41.D.**

☐ Refusal. **Go to Q. 41.D.**

41.C.1. What do you think is the primary cause of price fluctuations?

☐ Unpredictable swings in the supply of waste wood

☐ Unpredictable swings in the demand for waste wood

☐ Inadequate information about supply available

☐ Inadequate information about quantity demanded
☐ Other_____

☐ DK. **Go to Q. 41.D.**

☐ Refusal. **Go to Q. 41.D.**

41.D. As a participant in the waste wood market, do you feel that your company is getting as much market information as it needs to operate efficiently?

☐ Yes. **Go to Q. 42.**

☐ No. **Go to Q. 41.D.1.**

☐ DK. **Go to Q. 42.**

☐ Refusal. **Go to Q. 42.**

41.D.1. What is the single most important kind of additional information could your company use?

- ☐ Market prices
- ☐ Identity of users/buyers
- ☐ Identity of sources/sellers
- ☐ Transportation costs
- ☐ Explanation of governmental regulations
- ☐ New uses for wood waste
- ☐ New technology/machinery for processing wood waste at lower cost
- ☐ Other_____
- ☐ DK. **Go to Q. 42.**
- ☐ Refusal. **Go to Q. 42.**

41.D.2 Do you think if your company had the additional information you just identified, it would be more likely to recycle its wood waste, about as likely to recycle as it is now, or less likely to recycle its waste?

- ☐ More likely to recycle. **Got to Q. 42.**
- ☐ About as likely to recycle as now. **Go to Q. 41.D.3.**
- ☐ Less likely to recycle. **Go to Q. 41.D.3.**

41.D.3. Why do you think your company would recycle no more than it does now or even less than it does now even with the additional information?

_____

42. Now, my last question: is there anything you would like to add to your answers? Or, do you have any suggestions or comments you would like to make about the subject of our interview today?

- ☐ Yes. **Go to Q. 42.A.**
- ☐ No. **Thank you for your time. Goodbye.**

42.A. Additions, comments, or suggestions:

_____

APPENDIX B

SURVEY COVER LETTER

Southeast Michigan
Resource Conservation
& Development Council

7203 Jackson Road Ann Arbor MI 48103-9506
Phone: (734) 761-6722 X 105 Fax: (734) 662-1686
Web Site: www.semircd.org

Serving Lenawee, Macomb, Monroe, Oakland, St. Clair, Washtenaw and Wayne Counties

January 12, 2006

Dear Michigan Business Owner or Manager:

Some Michigan businesses have found ways to economically dispose of their wood waste while others have not. Local and state government agencies are frequently asked what Michigan businesses can do to lower disposal costs and to make the best use of their wood waste. The problem is all the more pressing and answers more important since the Emerald Ash Borer infestation was discovered several years ago here in southern Michigan.

With support from the USDA Forest Service, the Southeast Michigan Resource Conservation and Development Council is conducting a survey among businesses in fourteen of Michigan counties. We will be asking about the amount of wood waste being generated and identifying how it is used and disposed of. Our interest is in pallets, dunnage (packing material), chips and shavings, edgings and cutoffs, tree debris, construction debris, railroad ties, and telephone poles. Your answers will help us determine what we can do together to reduce costs and make the best use of this wood.

The survey will be conducted by professional telephone interviewers and will take only a few minutes of your time. Your company was specifically selected to participate and your answers are very important to the success of this survey. So when our interviewer calls please take a few minutes to answer our questions. Your answers will remain completely confidential. In advance, please accept our appreciation for your participation.

Please contact me if you have any questions about the survey. You may call Cooper Research at 1-800-743-3003 (study number 2903) to answer our questions at your convenience.

If you have questions about the Southeast Michigan Resource Conservation and Development Council, or about wood waste, please call Jessica Simons at 1-734-761-6722, ext. 105. You can also go to the Council's website at www.semircd.org. For information about making the best use of urban trees, go to www.harvestingurbantimber.com.

Sincerely,

Sam Sherrill, Ph.D.
Survey Director
(513) 248-0509
samuel.sherrill@uc.edu

APPENDIX C

FREQUENCY DISTRIBUTIONS BY QUESTION

1. Over the entire year of 2005, did your company here in southern Michigan either generate or accept any wood waste in the form of pallets, dunnage, edging and cutoffs, chips and shavings, tree trunks and limbs, construction debris, railroad ties, or telephone poles?

Code/Response		Frequency	Percent
1	Yes	420	28.0
2	No	1,080	72.0
	Total	1,500	100.0

2. Does your company primarily accept wood waste in some form from other companies, organizations, or governmental agencies?

Code/Response		Frequency	Percent
1	Yes	47	11.2
2	No	373	88.8
	Total	420	100.0

3. What does your firm primarily accept?

Code/Response		Frequency	Percent
1	Chips, shavings, and sawdust	1	0.2
2	Construction debris	5	1.2
3	Dunnage	1	0.2
4	Edgings and cutoffs	1	0.2
5	Pallets, skid, and containers	35	8.3
6	Railroad ties	1	0.2
7	Telephone poles	3	0.7
8	Tree trunks, limbs, and stumps	0	0.0
	Subtotal	47	11.2
	Primarily generate wood waste	373	88.8
Total		420	100.0

4. Does your company measure the quantity of wood waste it accepts primarily by volume hauled in by truck or in containers, or by its weight, or by the counted number (e.g., 1000 pallets, skids, and containers or 500 railroad ties or 800 telephone poles)?

Code/Response		Frequency	Percent
1	Truck/container	16	3.8
2	Weight	5	1.2
3	Number	26	6.2
	Subtotal	47	11.2
	Primarily generate wood waste	373	88.8
Total		420	100.0

4.A. Thinking now of the trucks or containers that bring wood waste to your company, what would you say is the typical (average) volume in cubic yards they hold?

Code/Response		Frequency	Percent
1	0 - <10	10	2.4
2	10 - <20	2	0.5
3	20 - <30	1	0.2
4	30 - <40	1	0.2
11	100 or more (DK exact amount)	2	0.5
	Subtotal	16	3.8
	Other measures + generate wood waste	404	96.2
Total		420	100.0

4.A.1 During a typical (average) month in 2005, about how many truckloads or containers of wood waste would you say your company accepted?

Code/Response		Frequency	Percent
1	0 - < 20	9	2.1
2	20 - <40	2	0.5
3	40 - < 60	1	0.2
21	More than 400	1	0.2
34	DK	3	0.7
	Subtotal	16	3.8
	Other measures + generate wood waste	404	96.2
Total		420	100.0

4.B. During a typical (average) month in 2005, about how many pounds of wood waste, to the nearest thousand, would you say your company accepted?

Code/Response		Frequency	Percent
1	0 - <2,000	2	0.5
3	4,000 - <6,000	1	0.2
34	DK	1	0.2
35	Refusal	1	0.2
	Subtotal	5	1.2
	Other measures +	415	98.8

	generate wood waste		
Total		420	100.0

4.C. During a typical (average) month in 2005, in total, about how many of these did your company accept?

Code/Response		Frequency	Percent
1	0 - <200	22	5.2
2	200 - <400	1	0.2
8	1,400 - <1,600	1	0.2
34	DK	2	0.5
	Subtotal	26	6.2
	Other measures + generate wood waste	394	93.8
Total		420	100.0

4.D. What <u>one</u> source provided most of the wood waste your company accepted in2005? We are interested in business and government sources in and outside of the State of Michigan as well as outside the U.S.

Code/Response		Frequency	Percent
1	Michigan businesses	20	4.8
2	Businesses in other states	15	3.6
3	Canadian businesses	1	0.2
4	Michigan governments	2	0.5
5	Other state governments	1	0.2
6	Governments in Canada	0	0.0
21	Other	7	1.7
23	DK	1	
	Subtotal	47	10.9
	Other measures + generate wood waste	373	89.1
Total		420	100.0

4.E. Does your company use most of the wood waste it accepts to make products or does your company permanently hold most of the wood as waste? By products we mean fuel for heat, electric power generation, mulch, compost, firewood, pallets, skids, containers, or dunnage, wood products such as lumber and plywood, or building material such as joists.

Code/Response		Frequency	Percent
1	Used to make products	13	3.1
2	Permanently holds as waste	18	4.3
11	DK	14	3.3
12	Refusal	2	0.5
	Subtotal	47	11.2
	Other measures + generate wood waste	373	88.8
Total		420	100.0

4.E.1 What is the primary product your company makes from the wood waste it accepts?

Code/Response		Frequency	Percent
1	Building materials	4	1.0
2	Composite wood products	0	0.0
3	Compost	0	0.0
4	Firewood	2	0.5
5	Fuel for electric power	0	0.0
6	Fuel for heat	0	0.0
7	Lumber	1	0.2
8	Mulch	3	0.7
9	Pallets, skid, containers	3	0.7
	Subtotal	13	3.1
	Other measures + generate wood waste	407	96.9
Total		420	100.0

4.E.2. In terms of expense, what is the single most important reason that the rest of the wood waste is not being re-used or recycled?

Code/Response		Frequency	Percent
22	No reason, use all	2	0.5
1	Regulations make recycling too difficult	2	0.5
2	Too difficult to separate wood into different categories	1	0.2
7	Too expensive to haul to recycler	2	0.5
21	Other	5	1.2
23	DK	1	0.2
	Subtotal	13	3.1
	Other measures + generate wood waste	407	96.9
Total		420	100.0

4.E.3. In your judgment, what is the single most important action, if there is one, that state or local governments could take to promote the greater use of wood waste?

Code/Response		Frequency	Percent
1	Provide more information	5	1.2
2	Reduce regulations	2	0.5
21	Other	2	0.5
22	None	2	0.5
23	DK	2	0.5
	Subtotal	13	3.1
	Other measures + generate wood waste	407	96.9
Total		420	100.0

4.F. From what you and others in your company have observed, how much of the wood waste your company accepts and holds do you think could be re-used or recycled?

Code/Response		Frequency	Percent
1	Little or none	15	3.6
2	About one-third	4	1.0
3	About one-half	5	1.2
4	About two-thirds	3	0.7
5	All or nearly all	15	3.6
11	DK	4	1.0
12	Refusal	1	0.2
	Subtotal	47	11.2
	Generate wood waste	373	88.8
Total		420	100.0

4.G. In terms of expense, in your judgment, what is the single most important reason that more wood waste is not being re-used or recycled?

Code/Response		Frequency	Percent
1	Regulations make recycling too difficult	1	0.2
2	Too difficult to separate wood into different categories	6	1.4
3	Wood contains preservatives	1	0.2
4	Wood is glued product	2	0.5
5	Wood is attached to metal, etc.	3	0.7
6	Wood is coated with paint	0	0.0
7	Too expensive to haul to recycler	4	1.0
21	Other	10	2.4
34	DK	4	1.0
35	Refusal	1	0.2
	Subtotal	32	7.6
	Other measures + generate wood waste	388	92.4
Total		420	100.0

4.H. What single most important way, if any, could more of the wood be re-used or recycled (examples, if needed, are to make wood products, fuel, mulch, lumber or re-use in existing form)?

Code/Response		Frequency	Percent
1	Find way to remove chemicals	0	0.0
2	Find cost-effective way to sort wood waste from non-wood waste	2	0.5
3	Find way to remove wood from non-wood waste	3	0.7
4	Help finding recycler	1	0.2
5	Lower cost of transporting to/from where generated	2	0.5
6	Find new use for wood waste	12	2.9

21	Other	2	0.5
22	None, more cannot be re-used	1	0.2
	Subtotal	23	5.5
	Other measures + generate wood waste	397	94.5
Total		420	100.0

4.I. In your judgment, what is the single most important action, if there is one, that Michigan state or local governments could take to promote the greater use of wood waste?

Code/Response		Frequency	Percent
1	Provide more information on wood waste market	20	4.8
2	Reduce regulations	1	0.2
21	Other	3	0.7
22	None: nothing else to do	4	1.0
34	DK	18	4.3
	Subtotal	46	11.2
	Other measures + generate wood waste	374	88.8
Total		420	100.0

5. As wood waste, what does your company <u>primarily</u> dispose of? By <u>primary</u> I mean what your company disposes of the most.

Code/Response		Frequency	Percent
1	Chips, shavings, sawdust	62	14.8
2	Construction debris	136	32.4
3	Dunnage	4	1.0
4	Edgings, cutoffs	74	17.6
5	Pallets, skids, crates	83	19.8
6	Railroad ties	0	0.0
7	Telephone poles	0	0.0
8	Tree trunks, limbs,, stumps	14	3.3
	Subtotal	373	88.8
	Accept wood waste	47	11.2
Total		420	100.0

NOTE: In the following tables for wood wastes disposals, the Subtotals are slightly greater than the totals by type of wood waste in the table for Question 5 above. The reason for the difference is that 32 of the responding firms also disposed of other types of wood waste in addition to their primary type. For example, pallets, skids, and crates were primarily disposed of by 83 firms, as shown in the table above, and secondarily by 2 other firms, bringing the total to 85, as shown in the table immediately below. The distribution by type for secondary disposal is in the table for Question 40.A.

6. Does your company measure the amount of pallets, skids, and shipping crates it disposes of primarily by their total number, or by the volume hauled by truck or in containers, or by their weight?

Code/Response		Frequency	Percent
1	Number	31	7.4
2	Truck/container	15	3.6
3	Weight	1	0.2
34	DK	36	8.6
35	Refusal	2	0.5
	Subtotal	85	20.2
	Not pallets, skids, crates	335	79.8
Total		420	100.0

6.A. During a typical (average) month in 2005, in total, how many pallets, skids, and shipping crates did your company dispose of as wood waste?

Code/Response		Frequency	Percent
1	0 - <200	26	6.2
2	200 - <400	1	.2
3	400 - <600	1	.2
33	Total for 2005 (sum of 3 = 44)	3	.7
	Subtotal	31	7.4
	Truckload, weight	389	92.6
Total		420	100.0

6.B. Thinking now of the trucks or containers used to haul pallets, skids, and shipping crates away from your company, what would you say is the typical (average) volume in cubic yards they hold?

Code/Response		Frequency	Percent
1	0 - <10	9	2.1
3	20 - <30	1	.2
4	30 - <40	1	.2
23	DK	3	.7
24	Refusal	1	.2
	Subtotal	15	3.6
	Number or weight	405	96.4
Total		420	100.0

6.C. During a typical (average) month in 2005, about how many truckloads or containers of pallets, skids, and shipping crates would you say your company disposed of?

Code/Response		Frequency	Percent
1	0 - <20	10	2.4
2	20 - <40	1	.2
	Subtotal	11	2.6
	Number or weight	409	97.4
Total		420	100.0

6.D. During a typical (average) month in 2005, about how many pounds of pallets, skids, and shipping crates to the nearest thousand, would you say your company disposed of?

Code/Response		Frequency	Percent
1	0 - <2,000	1	.2
	Number or truckload	419	99.8
Total		420	100.0

7. Did your company pay to dispose of the pallets, skids, and crates, were they mainly removed at no cost to your company, or was your company paid for them.

Code/Response		Frequency	Percent
1	Company paid for removal	30	7.1
2	Removed at no cost to company	39	9.3
3	Another company paid	4	1.0
34	DK	10	2.4
35	Refusal	2	.5
	Subtotal	85	20.2
	Not pallets, skids, crates	335	79.8
Total		420	100.0

7.A For that typical month, about how much did your company pay for removal (in dollars)?

Code/Response		Frequency	Percent
1	0 - <500	19	4.5
2	1,000 - <1,500	1	.2
4	1,500 - <2,000	1	.2
34	DK	9	2.1
	Subtotal	30	7.1
	Not pallets, skids, crates + removed at no cost + another company paid for them	390	92.9
Total		420	100.0

7.A.1. Did your company use its own trucks to transport most of the material to a disposal site or did another company provide trucks?

Code/Response		Frequency	Percent
1	Our company provide truck	4	1.0
2	Another company provided trucks	17	4.0
	Subtotal	21	5.0
	Not pallets, skids, crates +	399	95.0
Total		420	100.0

7.A.2. Was most of the material sent to a landfill or to another company?

Code/Response		Frequency	Percent
1	Landfill	16	3.8
2	Another company	1	.2
21	Other	1	.2
23	DK	3	.7
	Subtotal	21	5.0
	Not pallets, skids, crates	399	95.0
Total		420	100.0

7.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes (one-way)?

Code/Response		Frequency	Percent
1	0 - < 5	4	1.0
2	5 - <10	3	.7
3	10 - <15	4	1.0
4	15 - <20	2	.5
6	25 - <30	1	.2
34	DK	7	1.7
	Subtotal	21	5.0
	Not pallets, skids, crates	399	95.0
Total		420	100.0

7.B. What was the primary way the pallets, skids, and crates were disposed of at no cost to your company?

Code/Response		Frequency	Percent
1	Given away to public/employees	23	5.5
2	Given away to other companies	6	1.4
3	Burned	5	1.2
4	Trashed/dumped/thrown away	2	.5
5	Recycled/reused	2	.5
34	DK	1	.2
	Subtotal	39	9.3
	Not pallets, skids, crates	381	90.7
Total		420	100.0

7.C. For that typical month, about how much was your company paid (in dollars)?

Code/Response		Frequency	Percent
1	0 - <500	3	.7
34	DK	1	.2
	Subtotal	4	1.0
	No cost /company paid for removal	416	99.0
Total		420	100.0

8. For a typical (average) month, what percentage of the total number of pallets, skids, and shipping crates would you say your company was able to re-use?

Code/Response		Frequency	Percent
1	None	23	5.5
2	0 - 10	20	4.8
3	11 - 20	4	1.0
4	21 - 30	3	0.7
5	31 - 40	0	0.0
6	41 - 50	3	0.7
7	51 - 60	2	0.5
8	61 - 70	1	0.2
9	71 - 80	6	1.4
10	81 - 90	5	1.2
11	91 - 100	15	3.6
34	DK	3	.7
	Subtotal	85	20.2
	Not pallets, skids, crates	335	79.8
Total		420	100.0

9. Did your company re-use most of the pallets, skids, and shipping crates for shipping and storage or did your company reduce most of them to parts or wood fiber and use that material for something other than shipping and storage?

Code/Response		Frequency	Percent
1	Re-used in original form	47	11.2
2	Reduced to parts/fiber for other uses	8	1.9
11	DK	6	1.4
12	Refusal	1	0.2
	Subtotal	62	14.8
	Did not re-use	23	5.5
	Not pallets, skids, crates	335	79.8
Total		420	100.1

9.A. What was the primary use your company made of the parts and fiber?

Code/Response		Frequency	Percent
1	Heating fuel	3	0.7
2	Land cover/fill	3	0.7
21	Other	1	0.2
34	DK	1	0.2
	Subtotal	8	1.9
	Not pallets, skids, crates + not re-use parts/fiber	412	98.1
Total		420	100.0

10. Does your company measure the amount of dunnage it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the

wood waste it disposes of by weight?

Code/Response		Frequency	Percent
1	Truck/container	3	0.7
2	Weight	0	0.0
34	DK	4	1.0
	Subtotal	7	1.7
	Not dunnage	416	98.3
Total		420	100.0

NOTE: frequency distributions for questions 10 through 13 on dunnage are omitted owing to an inadequate number of responses.

14. Does your company measure the amount of edgings and cutoffs it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the wood waste it disposes of by weight?

Code/Response		Frequency	Percent
1	Truck/container	54	12.9
2	Weight	3	.7
34	DK	25	6.0
	Subtotal	82	19.5
	Not edgings/ cutoffs	338	80.5
Total		420	100.0

14.A. Thinking now of the trucks or containers used to haul edgings and cutoffs away from your company, what would you say is the typical (average) volume in cubic yards they hold?

Code/Response		Frequency	Percent
1	0 - <10	22	5.2
2	10 - <20	10	2.4
3	20 - <30	11	2.6
4	30 - <40	3	0.7
11	100 or more	2	0.5
23	DK	6	1.4
	Subtotal	54	12.9
	Not edgings/ cutoffs + weight	366	87.1
Total		420	100.0

14.B. During a typical (average) month in 2005, about how many truckloads or containers of edgings and cutoffs would you say your company disposed of?

Code/Response		Frequency	Percent
1	>0 - <20	37	8.8
2	20 - <40	4	1.0

3	40 - <60	2	.5
5	80 - <100	2	.5
12	220 - <240	1	.2
15	280 - <300	1	.2
34	DK	1	.2
	Subtotal	48	11.4
	Not edging/ cutoffs + weight	372	88.6
Total		420	100.0

14.C. During a typical (average) month in 2005, about how many pounds of edgings and cutoffs to the nearest thousand, would you say your company disposed of?

Code/Response		Frequency	Percent
1	0 - <2,000	1	.2
24	50,000 or more	1	.2
34	DK	1	.2
	Subtotal	3	.7
	Not edging/ cutoffs + volume	417	99.3
Total		420	100.0

15. Did your company pay to dispose of edgings and cutoffs, was it mainly removed at no cost to your company, or was your company paid for it?

Code/Response		Frequency	Percent
1	Company paid for removal	53	12.6
2	Removed at no cost to company	27	6.4
3	Another company paid	1	0.2
34	DK	1	0.2
	Subtotal	82	19.5
	Not edging/ cutoffs	338	80.5
Total		420	100.0

15.A For that typical month, about how much did your company pay for removal?

Code/Response		Frequency	Percent
1	>0 - <500	43	10.2
2	500 - <1,000	2	.5
3	1,000 - <1,500	1	.2
34	DK	7	1.7
	Subtotal	53	12.6
	Not edging/cutoffs + removed at no company cost + another company paid for them	367	87.4
Total		420	100.0

15.A.1. Did your company use its own trucks to transport most of the edgings and cutoffs to a disposal site or did another company provide trucks?

Code/Response		Frequency	Percent
1	Our company provided trucks	17	4.0
2	Another company provided trucks	27	6.4
21	Other	2	0.5
	Subtotal	46	11.0
	Not edging/cutoffs + removed at no company cost + another company paid for them	374	89.0
Total		420	100.0

15.A.2. Were most of the edgings and cutoffs sent to a landfill or to another company?

Code/Response		Frequency	Percent
1	Landfill	34	8.1
2	Another company	3	0.7
21	Other	1	0.2
23	DK	8	1.9
	Subtotal	46	11.0
	Not edging/cutoffs + removed at no company cost + another company paid for them	374	89.0
Total		420	100.0

15.A.3. How far (to the nearest mile) would you say the disposal site is where most (over 50%) of your material goes.

Code/Response		Frequency	Percent
1	0 - <5	9	2.1
2	5 - >10	8	1.9
3	10 - <15	2	0.5
4	15 - <20	6	1.4
5	20 - <25	5	1.2
6	25 - <30	3	0.7
34	DK	12	2.9
35	Refusal	1	0.2
	Subtotal	46	11.0
	Not edging/cutoffs + removed at no company cost + company paid for them	374	89.0
Total		420	100.0

15.B. What was the primary way the edgings and cutoffs were disposed of at no cost to your company?

Code/Response		Frequency	Percent
1	Given away to public/employees	11	2.6

2	Given away to other companies	1	0.2
3	Burned	9	2.1
4	Trashed/dumped/discarded	5	1.2
34	DK	1	.2
	Subtotal	27	6.4
	Not edgings/cutoffs + company paid for removal + company paid for edgings/cutoffs	393	93.6
Total		420	100.0

15.C. For that typical month, about how much was your company paid?

Code/Response		Frequency	Percent
34	DK	1	.2
	All other	419	99.8
Total		420	100.0

16. What percentage of the total amount of edgings and cutoffs would you say your company was able to reuse?

Code/Response		Frequency	Percent
1	None	28	6.7
2	0 - 10	16	3.8
3	11 - 20	4	1.0
4	21 - 30	5	1.2
5	31 - 40	2	0.5
6	41 - 50	5	1.2
7	51 - 60	2	0.5
8	61 - 70	1	0.2
9	71 - 80	3	0.7
10	81 - 90	2	0.5
11	91 - 100	6	1.4
34	DK	8	1.9
	Subtotal	82	19.5
	Not edgings/cutoffs	338	80.5
Total		420	100.0

17. What was the primary use your company made of the edgings and cutoffs?

Code/Response		Frequency	Percent
1	Heating fuel	15	3.6
2	Land cover/fill	4	1.0
3	Livestock bedding	0	0.0
4	Mulch	1	0.2
5	Building materials	16	3.8
6	Re-use	10	2.4
21	Other	3	0.7
34	DK	5	1.2

	Subtotal	54	12.9
	Not edgings/cutoffs + company did not use edgings/cutoffs	366	87.1
Total		420	100.0

18. Does your company measure the amount of chips and shavings it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the chips and shavings it disposes of by weight?

Code/Response		Frequency	Percent
1	Truck/container	33	7.9
2	Weight	10	2.4
34	DK	24	5.7
35	Refusal	1	0.2
	Subtotal	68	16.2
		352	83.8
Total		420	100.0

18.A. Thinking now of the trucks or containers used to haul chips and shavings away from your company, what would you say is the typical (average) volume in cubic yards they hold?

Code/Response		Frequency	Percent
1	0 - <10	23	5.5
2	10 - <20	3	0.7
3	20 - <30	1	0.2
4	30 - <40	1	0.2
11	100 or more	2	0.5
23	DK	3	0.7
	Subtotal	33	7.9
	Not chips/shavings + weight	387	92.1
Total		420	100.0

18.B. During a typical (average) month in 2005, about how many truckloads or containers of chips and shavings would you say your company disposed of?

Code/Response		Frequency	Percent
1	>0 - <20	26	6.2
2	20 - <40	1	0.2
3	40 - <60	1	0.2
7	120 - <140	1	0.2
12	220 - <240	1	0.2
	Subtotal	30	7.1
	Not chips/shavings + volume	390	92.9
Total		420	100.0

18.C. During a typical (average) month in 2005, about how many pounds of chips and shavings to the nearest thousand, would you say your company disposed of?

Code/Response		Frequency	Percent
1	0 - <2,000	8	1.9
2	2,000 - <4,000	1	0.2
34	DK	1	0.2
	Subtotal	10	2.4
		410	97.6
Total		420	100.0

19. Did your company pay to dispose of the chips and shavings, were they mainly removed at no cost to your company, or was your company paid for them?

Code/Response		Frequency	Percent
1	Company paid for removal	28	6.7
2	Removed at no cost to company	34	8.1
3	Another company paid	6	1.4
	Subtotal	68	16.2
	Not chips/shavings	352	83.8
Total		420	100.0

19.A For that typical month, about how much did your company pay for removal?

Code/Response		Frequency	Percent
1	>0 - <500	24	5.7
2	500 - <1,000	1	0.2
3	1,000 - <1,500	1	0.2
34	DK	2	0.5
	Subtotal	28	6.7
	Not chips/shavings + removed at no company cost + another company paid for them	392	93.3
Total		420	100.0

19.A.1. Did your company use its own trucks to transport most of the chips and shavings to a disposal site or did another company provide trucks?

Code/Response		Frequency	Percent
1	Our company provided trucks	6	1.4
2	Another company provided trucks	20	4.8
	Subtotal	26	6.2
	Not chips/shavings + removed at no company cost + another company paid for them	394	93.8
Total		420	100.0

19.A.2. Were most of the chips and shavings sent to a landfill or to another company?

Code/Response		Frequency	Percent
1	Landfill	20	4.8
2	Another company	2	0.5
21	Other	1	0.2
23	DK	3	0.7
	Subtotal	26	6.2
	Not chips/shavings + removed at no company cost + another company paid for them	394	93.8
Total		420	100.0

19.A.3.How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes.

Code/Response		Frequency	Percent
1	0 - <5	3	0.7
2	5 - >10	2	0.5
3	10 - <15	3	0.7
4	15 - <20	4	1.0
5	20 - <25	2	0.5
6	25 - <30	2	0.5
13	60 - <65	1	0.2
34	DK	9	2.1
	Subtotal	26	6.2
	Not chips/shavings + removed at no company cost + another company paid for them	394	93.8
Total		420	100.0

19.B. What was the primary way the chips and shavings were disposed of at no cost to your company?

Code/Response		Frequency	Percent
1	Given away to public/employees	13	3.1
2	Given away to other companies	1	0.2
3	Burned	6	1.4
4	Trashed/dumped/discarded	5	1.2
5	Recycled/re-used	9	2.1
	Subtotal	34	8.1
	Not chips/shavings + paid for removal + another company paid	386	91.9
Total		420	100.0

19.C. For that typical month, about how much was your company paid?

Code/Response		Frequency	Percent
1	>0 - <500	3	0.6
6	3,000 - <3,500	1	0.2
15	8,000 - <8,500	1	0.2

	DK	1	0.2
	Subtotal	6	1.2
	Not chips/shavings + paid for removal + removed at no cost	414	98.6
	Total	420	100.0

20. What percentage of the total amount of chips and shavings would you say your company was able to reuse?

Code/Response		Frequency	Percent
1	None	46	11.0
2	>0 - 10	5	1.2
3	11 - 20	3	0.7
4	21 - 30	1	0.2
6	41 - 50	2	0.5
9	71 - 80	2	0.5
10	81 - 90	1	0.2
11	91 - 100	8	1.9
	Subtotal	68	16.2
	Not chips/shavings	352	83.8
Total		420	100.0

21. What was the primary use your company made of the chips and shavings?

Code/Response		Frequency	Percent
1	Heating fuel	5	1.2
2	Land cover/fill	2	0.5
3	Livestock bedding	1	0.2
4	Mulch	12	2.9
5	Building materials	1	0.2
34	DK	1	0.2
	Subtotal	22	5.2
		398	94.8
Total		420	100.0

22. Does your company measure the amount of trunks, limbs, and stumps, it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the trunks, limbs, and stumps it disposes of by weight?

Code/Response		Frequency	Percent
1	Truck/container	10	2.4
2	Weight	1	0.2
34	DK	9	2.1
	Subtotal	20	4.8
	Not trunks, limbs, stumps	400	95.2
Total		420	100.0

22.A. Thinking now of the trucks or containers used to haul trunks, limbs, and stumps away from your company, what would you say is the typical (average) volume in cubic yards they hold?

Code/Response		Frequency	Percent
1	0> - <10	6	1.4
2	10 - <20	1	0.2
3	20 - <30	1	0.2
23	DK	2	0.5
Subtotal		10	2.4
Not trunks, limbs, stumps + weight		410	97.6
Total		420	100.0

22.B. During a typical (average) month in 2005, about how many truckloads or containers of trunks, limbs, and stumps would you say your company disposed of?

Code/Response		Frequency	Percent
1	>0 - <20	8	1.9
Not trunks, limbs, stumps + weight		412	98.1
Total		420	100.0

22.C. During a typical (average) month in 2005, about how many pounds of trunks, limbs, and stumps to the nearest thousand, would you say your company disposed of?

Code/Response		Frequency	Percent
4	6,000 - <8,000	1	0.2
Not trunks, limbs, stumps + trucks		419	99.8
Total		420	100.0

23. Did your company pay to dispose of the trunks, limbs, and stumps, were they mainly disposed of at no cost to your company, or did another company buy them?

Code/Response		Frequency	Percent
1	Company paid for removal	7	1.7
2	Removed at no cost to company	8	1.9
3	Another company paid	1	0.2
34	DK	4	1.0
	Subtotal	20	4.8
	Not trunks, limbs, stumps	400	95.2
Total		420	100.0

23.A For that typical month, about how much did your company pay for disposal of the trunks, limbs, and stumps?

Code/Response		Frequency	Percent
1	<0 - <500	5	1.2
6	3,000 - <3,500	1	.2
10	5,000 - <5,500	1	.2
	Subtotal	7	1.7
	Not trunks, limbs, stumps + paid for removal + another company paid	413	98.3
Total		420	100.0

23.A.1.Did your company use its own trucks to transport most of them to a disposal site or did another company provide trucks?

Code/Response		Frequency	Percent
1	Our company provided trucks	4	1.0
2	Another company provided trucks	3	0.7
	Subtotal	7	1.7
	Not trunks, limbs, stumps + removed at no company cost + another company paid	413	98.3
Total		420	100.0

23.A.2.Were most of them sent to a landfill or to another company?

Code/Response		Frequency	Percent
1	Landfill	2	0.5
2	Another company	4	1.0
23	DK	1	0.2
	Subtotal	7	1.7
	Not trunks, limbs, stumps + removed at no company cost + another company paid	413	98.3
Total		420	100.0

23.A.3.How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your material goes.

Code/Response		Frequency	Percent
1	>0 - <5	1	0.2
2	5 - <10	2	0.5
3	10 - <15	1	0.2
5	20 - >25	1	0.2
34	DK	2	0.5
	Total	7	1.7
	Not trunks, limbs, stumps + removed at no company cost + another company paid	413	98.3
Total		420	100.0

23.B. What was the primary way the trunks, limbs, and stumps were disposed of at no cost to your company?

Code/Response		Frequency	Percent
1	Given away to public/employees	1	0.2
3	Burned	4	1.0
4	Trashed/dumped/discarded	1	0.2
5	Recycled/re-used	1	0.2
35	Refusal	1	0.2
	Subtotal	8	1.9
	Not trunks, limbs, stumps + paid for removal + another company paid	412	98.1
Total		420	100.0

23.C. For that typical month, about how much was your company paid?

Code/Response		Frequency	Percent
6	3,000 – <3,500	1	.2
	Not trunks, limbs, stumps + paid for removal + another company paid	419	99.8
Total		420	100.0

24. What percentage of the total amount of the trunks, limbs, and stumps would you say your company was able to reuse?

Code/Response		Frequency	Percent
1	None	11	2.6
9	71 - 80	3	0.7
10	81 – 90	1	0.2
11	91 - 100	4	1.0
35	Refusal	1	0.2
	Subtotal	20	4.8
	Not trunks, limbs, stumps	400	95.2
Total		420	100.0

25. For that typical month in 2005, what did your company do with most of the trunks, limbs, and stumps? Were they cut up for firewood to sell? Ground into mulch to sell? Were they sawed into lumber to sell?

Code/Response		Frequency	Percent
1	Cut up for firewood sales	4	1.0
2	Ground for mulch sales	1	0.2
3	Sawed into lumber sales	0	0.0
4	Sold for other uses	0	0.0
5	Given away to other companies	0	0.0
6	Given away to public	2	0.5
7	Used by company/employees	1	0.2
35	Refusal	1	0.2

	Subtotal	9	2.1
	Not trunks, limbs, stumps + none reused	411	97.9
Total		420	100.0

26. Compared to this time last year, is your company getting more ash trees, about the same number as last year, or less?

Code/Response		Frequency	Percent
1	More than last year	3	0.7
2	About the same	4	1.0
3	Less than last year	2	0.5
34	DK	10	2.4
35	Refusal	1	0.2
	Subtotal	20	4.8
	Not trunks, limbs, stumps	400	95.2
Total		420	100.0

27. For that typical month in 2005, what did your company do with over half the ash tree trunks, limbs, and stumps? Was this material cut up for firewood to sell? Ground up for mulch to sell? Or were they sawed into lumber to sell?

ode/Response		Frequency	Percent
1	Cut up for firewood sales	5	1.2
2	Ground for mulch sales	1	0.2
3	Sawed into lumber sales	0	0.0
4	Sold for other uses	1	0.2
5	Given away to other companies	0	0.0
6	Given away to public	1	0.2
7	Used by company/employees	1	0.2
34	DK	9	2.1
35	Refusal	2	0.5
	Subtotal	20	4.8
	Not trunks, limbs, stumps	400	95.2
Total		420	100.0

28. Does your company measure the amount of construction debris it disposes of primarily by volume hauled away in trucks or containers or does your company primarily measure the debris it disposes of by weight?

Code/Response		Frequency	Percent
1	Truck/container	88	21.0
2	Weight	11	2.6
34	DK	41	9.8
35	Refusal	1	0.2
	Subtotal	141	33.6
	Not construction debris	279	66.4
Total		420	100.0

28.A. Thinking now of the trucks or containers used to haul construction debris away from your company, what would you say is the typical (average) volume in cubic yards they hold?

Code/Response		Frequency	Percent
1	0 - <10	30	7.1
2	10 - <20	10	2.4
3	20 - <30	23	5.5
4	30 - <40	12	2.9
5	40 - <50	3	.7
8	70 - <80	1	.2
9	80 - <90	1	.2
11	100 or more	3	.7
23	DK	4	1.0
24	Refusal	1	.2
	Subtotal	88	21.0
	Not construction debris + by weight	332	79.0
Total		420	100.0

More than 100 cubic yards

Response		Frequency	Percent
	140	1	0.2
	1,800	1	0.2
	4,800	1	0.2
	Subtotal	3	0.7
	Not construction debris + more than 100 + by weight	417	99.3
Total		420	100.0

28.B. During a typical (average) month in 2005, about how many truckloads or containers of construction debris would you say your company disposed of?

Code/Response		Frequency	Percent
1	0 - <20	67	16.0
2	20 - <40	5	1.2
3	40 - <60	2	.5
5	80 - <100	1	.2
6	100 - <120	1	.2
33	Total for 2005	2	.5
34	DK	5	1.2
	Subtotal	83	19.8
	Not construction debris + by weight	332	80.2
	Non-Response for Question 28.A.	5	
Total		420	100.0

Totals for 2005

Response		Frequency	Percent
	1 truckload for 2005	1	0.2
	3 truckloads for 2005	1	0.2
	Subtotal	2	0.5
	Not construction debris + monthly averages	418	99.5
Total		420	100.0

28.C. During a typical (average) month in 2005, about how many pounds of construction debris to the nearest thousand, would you say your company disposed of?

Code/Response		Frequency	Percent
1	0 - <2,000	4	1.0
2	2,000 - <4,000	2	0.5
3	4,000 - <6,000	1	0.2
5	8,000 - <10,000	1	0.2
8	14,000 - <16,000	1	0.2
34	DK	2	0.5
	Subtotal	11	2.6
	Not construction debris + by truckload	409	97.4
Total		420	100.0

29. Did your company pay to dispose of the debris, was it mainly removed at no cost to your company, or was your company paid for it?

Code/Response		Frequency	Percent
1	Company paid for removal	117	27.9
2	Removed at no cost to company	19	4.5
3	Another company paid	2	0.5
34	DK	2	0.5
35	Refusal	1	0.2
	Subtotal	141	33.6
	Not construction debris	279	66.4
Total		420	100.0

29.A For that typical month, about how much did your company pay for removal?

Code/Response		Frequency	Percent
1	>0 - <500	82	19.5
2	500 - <1,000	15	3.6
3	1,000 - <1,500	4	1.0
4	1,500 - <2,000	2	.5
7	3,500 - <4,000	2	.5
8	4,000 - <4,500	1	.2
12	6,500 - <7,000	1	.2
34	DK	10	2.4
	Subtotal	117	27.9

	Not construction debris + removed at no cost + another company paid	303	72.1
Total		420	100.0

29.A.1. Did your company use its own trucks to transport most of the debris to a disposal site or did another company provide trucks?

Code/Response		Frequency	Percent
1	Our company provided trucks	34	8.1
2	Another company provided trucks	72	17.1
21	Other	1	0.2
	Subtotal	107	25.5
	Not construction debris + removed at no cost + another company paid	313	74.5
Total		420	100.0

29.A.2. Was most of the debris sent to a landfill or to another company?

Code/Response		Frequency	Percent
1	Landfill	73	17.4
2	Another company	9	2.1
21	Other	5	1.2
23	DK	20	4.8
	Subtotal	107	25.5
	Not construction debris + removed at no cost + another company paid	313	74.5
Total		420	100.0

29.A.3. How far (to the nearest mile, if asked) would you say the disposal site is where most (over 50%) of your debris goes.

Code/Response		Frequency	Percent
1	>0 – <5	8	1.9
2	5 - <10	17	4.0
3	10 - <15	16	3.8
4	15 - <20	12	2.9
5	20 - <25	9	2.1
6	25 - <30	6	1.4
7	30 - <35	2	0.5
8	35 - <40	4	1.0
9	40 - <45	2	0.5
10	45 - <50	2	0.5
12	55 - <60	2	0.5
34	DK	27	6.4
	Subtotal	107	25.5
	Not construction debris + Another company + Other	313	74.5
Total		420	100.0

29.B. What was the primary way the debris was disposed of at no cost to your company?

Code/Response		Frequency	Percent
1	Given away to public/employees	4	1.0
2	Given away to other companies	3	0.7
3	Burned	4	1.0
4	Trashed/dumped/ discarded	8	1.9
	Subtotal	19	4.5
	Not debris + paid for removal + another company paid	401	95.5
Total		420	100.0

29.C. For that typical month, about how much was your company paid?

Response		Frequency	Percent
	100	1	0.2
	6,400	1	0.2
	Subtotal	2	0.5
	Not debris + paid for removal + removed at no cost	418	99.5
Total		420	100.0

30. What percentage of the total amount of construction debris would you say your company was able to reuse?

Code/Response		Frequency	Percent
1	None	71	16.9
2	>0 - 10	33	7.9
3	11 - 20	9	2.1
4	21 - 30	6	1.4
5	31 - 40	1	0.2
6	41 - 50	5	1.2
7	51 - 60	1	0.2
9	71 - 80	2	0.5
10	81 - 90	5	1.2
11	91 - 100	2	0.5
34	DK	5	1.2
35	Refusal	1	0.2
	Subtotal	141	33.6
	Not debris	279	66.4
Total		420	100.0

31. What was the primary use your company made of the debris?

Code/Response		Frequency	Percent
1	Heating fuel	11	2.6

2	Land cover/fill	7	1.7
3	Livestock bedding	0	0.0
4	Mulch	3	0.7
5	Building materials	28	6.7
6	Re-use	12	2.9
21	Other	5	1.2
34	DK	3	0.7
35	Refusal	1	.2
	Subtotal	70	16.7
	Not debris + company did not use	350	83.3
Total		420	100.0

NOTE: None of the responding companies disposed of either railroad ties (questions 32 through 35) or telephone poles (questions 36 through 39).

40. I've asked about the <u>primary</u> wood waste your company disposes of. Does your company also dispose of significant quantities of other kind's wood waste as well? By significant I mean more than 10 percent of the total wood waste your company disposed of in 2005.

Code/Response		Frequency	Percent
1	Yes	32	7.6
2	No	323	76.9
11	DK	14	3.3
12	Refusal	4	1.0
	Subtotal	373	88.8
		47	11.2
Total		420	100.0

40.A. I'm interested only in the second largest amount of wood waste your company disposed of in 2005. What type of wood waste was it?

Code/Response		Frequency	Percent
1	Chips, shavings, sawdust	6	1.4
2	Construction debris	5	1.2
3	Dunnage	3	0.7
4	Edgings, cutoffs	8	1.9
5	Pallets, skids, containers	2	0.5
6	Railroad ties	0	0.0
7	Telephone poles	0	0.0
8	Tree trunks, limbs, stumps	6	1.4
34	DK	2	0.5
	Subtotal	32	7.6
	No second wood waste	388	92.4
Total		420	100.0

41. From your company's experience in 2005 and through this year, in your judgment is there no market for the kind of waste wood your company accepts or generates, a developing market, or a fully developed market for that wood? By market, we mean

that there are buyers for the wood waste and ongoing amounts available from s suppliers.

Code/Response		Frequency	Percent
1	No market	262	62.4
2	Developing market	61	14.5
3	Fully developed market	27	6.4
11	DK	61	14.5
12	Refusal	9	2.1
	Total	420	100.0

41.A. What is the single most important reason, in your judgment, that there is no market for the kind of wood waste your firm accepts or generates?

Code/Response		Frequency	Percent
1	Contains preservative	4	1.0
2	Coated with paint	3	0.7
3	Contains glue	2	0.5
4	Attached to metal, shingles, non-wood material	5	1.2
5	Contains metal & non-wood material	16	3.8
6	No cost-effective way to sort wood from non-wood waste	44	10.5
7	Wood waste too expensive to transport	12	2.9
8	Other: low volume	40	9.5
9	Other: no good end product	47	11.2
10	Other: poor quality (rotten)	13	3.1
11	Other: not profitable	11	2.6
12	Other: pieces too small	14	3.3
13	Other: never considered & not aware of options	10	2.4
21	Other: miscellaneous	12	2.9
34	DK	26	6.2
35	Refusal	3	0.7
	Total	262	62.4
	There is developed/developing market/DK/Refusal	158	37.6
Total		420	100.0

41.B. In your judgment, what is the single most important part of the market that is as yet not fully developed?

Code/Response		Frequency	Percent
1	Difficult to identify/contact buyers	21	5.0
2	Difficult to identify/contact sellers	2	0.5
3	Difficult to get prevailing prices	2	0.5
4	High transportation costs	6	1.4
5	Wood waste more expensive to use than alternatives	3	0.7
6	Governmental regulations	3	0.7

21	Miscellaneous other	11	2.6
34	DK	13	3.1
	Subtotal	61	14.5
		359	85.5
Total		420	100.0

41.C. From month to month since the beginning of 2005, are the prices for wood waste accepted or generated by your company relatively stable or do the prices vary widely? As a standard of comparison, use gasoline prices at the pump.

Code/Response		Frequency	Percent
1	Prices vary less	47	11.2
2	Prices vary about as much	14	3.3
3	Prices vary more	2	0.5
11	DK	25	6.0
	Subtotal	88	21.0
	No market + developing market	332	79.0
Total		420	100.0

41.C.1. What do you think is causing price fluctuations?

Code/Response		Frequency	Percent
1	Unpredictable swings in supply	4	1.0
2	Unpredictable swings in demand	2	0.5
3	Inadequate information on available supply	1	0.2
4	Inadequate information about quantity demanded	1	0.2
21	Other	6	1.4
34	DK	2	0.5
	Total	16	3.8
		404	96.2
Total		420	100.0

41.D. As a participant in the waste wood market, do you feel that your company is getting as much market information as it needs to operate efficiently?

Code/Response		Frequency	Percent
1	Yes	54	12.9
2	No	24	5.7
11	DK	10	2.4
	Subtotal	88	21.0
	Not wood waste market participant	332	79.0
Total		420	100.0

41.D.1. What is the single most important kind of additional information could your company use?

Code/Response		Frequency	Percent
1	Market prices	1	0.2
2	Identity of users/buyers	13	3.1
3	Identity of sources/sellers	1	0.2
5	Explanation of governmental regulations	1	0.2
6	New uses for wood waste	4	1.0
7	New technology/ techniques for processing wood waste	1	0.2
21	Other	2	0.5
34	DK	1	0.2
	Subtotal	24	5.7
		396	94.3
Total		420	100.0

41.D.2 Do you think if your company had the additional information you just identified, it would be more likely to recycle its wood waste.

Code/Response		Frequency	Percent
1	More likely to recycle	21	5.0
2	About as likely as now to recycle	1	0.2
3	Less likely to recycle	1	0.2
	Subtotal	23	5.5
		397	94.5
Total		420	100.0

NOTE: there were no responses to question 41.D.3.

42. Now, my last question: is there anything you would like to add to your answers? Or, do you have any suggestions or comments you would like to make about the subject of our interview today?

Code/Response		Frequency	Percent
1	Yes	80	19.0
2	No	340	81.0
	Total	420	100.0

APPENDIX D

Study Species and FIA Species-Product Class Assignments

FIA species-product group	Common name	Latin name
ash	ash, European	*Fraxinus excelsior*
	ash, green	*Fraxinus pennsylvanica*
	ash, white	*Fraxinus americana*
basswood	basswood, American	*Tilia americana*
	linden, littleleaf	*Tilia cordata*
birch	birch, river	*Betula nigra*
	birch, paper	*Betula papyrifera*
Douglas-fir	Douglas-fir	*Pseudotsuga menziesii*
hard maple	maple, black	*Acer nigrum*
	maple, hedge	*Acer campestre*
	maple, sugar	*Acer saccharum*
hickory	hickory, bitternut	*Carya cordiformis*
	hickory, pignut	*Carya glabra*
	hickory, shagbark	*Carya ovata*
	hickory, shellbark	*Carya laciniosa*
non-commercial	apple	*Malus spp.*
	ornamental cherry / plum	*Prunus spp.*
	gingko	*Ginkgo biloba*
	hawthorn	*Crataegus spp.*
	mountain ash, American	*Sorbus americana*
	pear, callery	*Pyrus calleryana*
	olive-tree, Russian	*Elaeagnus angustifolia*
	Tree-of-heaven	*Ailanthus altissima*
	willow	*Salix spp.*
	willow, black	*Salix amygdaloides*
other hard hardwoods	chestnut	*Castanea spp.*
	honeylocust	*Gleditsia triacanthos*
	locust, black	*Robinia pseudoacacia*
other pine	pine, Austrian	*Pinus nigra*
	pine, Scotch	*Pinus sylvestris*
other soft	baldcypress	*Taxodium distichum*
	red cedar, eastern	*Juniperus virginiana*
	white-cedar, northern	*Thuja occidentalis*
other soft hardwoods	buckeye	*Aesculus spp.*
	catalpa, Northern	*Catalapa speciosa*
	cherry, black	*Prunus serotina*
	elm, American	*Ulmus americana*
	elm, Siberian	*Ulmus pumila*
	hackberry	*Celtis occidentalis*
	horse chestnut	*Aesculus hippocastanum*
	plane tree, London	*Platanus acerifolia*
	mulberry, red	*Morus rubra*
	sassafras	*Sassafras albidum*
	sweetgum	*Liquidambar styraciflua*

	sycamore	*Platanus occidentalis*
poplar	aspen, bigtooth	*Populus grandidentata*
	aspen, quaking	*Populus tremuloides*
	cottonwood, eastern	*Populus deltoides*
red oak	oak, black	*Quercus velutina*
	oak, northern red	*Quercus rubra*
	oak, pin	*Quercus palustris*
	oak, shingle	*Quercus imbricaria*
soft maple	box elder	*Acer negundo*
	maple, Norway	*Acer platanoides*
	maple, red	*Acer rubrum*
	maple, silver	*Acer saccharinum*
spruce fir	fir, white	*Abies concolor*
	spruce, Colorado blue	*Picea pungens*
	spruce, Norway	*Picea abies*
	spruce, white	*Picea glauca*
walnut	walnut, black	*Juglans nigra*
white oak	oak, bur	*Quercus macrocarpa*
	oak, English	*Quercus robur*
	oak, swamp white	*Quercus bicolor*
	oak, white	*Quercus alba*
white-red pine	pine, eastern white	*Pinus strobus*
	pine, red	*Pinus resinosa*
yellow poplar	yellow-poplar	*Liriodendron tulipifera*

APPENDIX E

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F. Measures of Wood Resources in Lower Michigan

Measures of Wood Resources in Lower Michigan: Wood Residues and the Saw Timber Content of Urban Forests

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Study Purposes: Residue Survey

The purpose of the residue survey is to determine the kinds and number of companies that either generated or used eight types of wood residue and the amounts they generated in 2005.

The eight wood residue types are:

1. **Pallets, skids, and shipping crates**
2. **Dunnage**
3. **Edgings and cutoffs**
4. **Chips, shavings, and sawdust**
5. **Tree trunks, limbs, and stumps**
6. **Construction debris**
7. **Railroad ties**
8. **Utility poles**

An equally important purpose is to provide recommendations regarding sample design and the questionnaire to those considering conducting urban wood residue surveys.

Study Area

Fifteen hundred interviews were conducted in the early spring of 2006 with a random sample of businesses in fourteen counties that include and surround Detroit, Ann Arbor, and Lansing, Michigan.

Genesee
Ingram
Jackson
Lapeer
Lenawee
Livingston
Macomb
Monroe
Oakland
Saginaw
Shiawassee
St. Clair
Washtenaw
Wayne

Study Population, Sample Size, and Responses

Approximately one out of three businesses were randomly selected from the list of 20,101 businesses thought to be potential generators or users of wood residue.

The gross sample size is 7,007.

The sample was stratified by county to insure that each county was represented in the sample.

From over 16,000 separate telephone calls, 2,373 contacts were made.

1,500 agreed to be interviewed while 873 refused to participate.

Of the completed 1,500 interviews:

420 (28%) indicated that they either generated or used wood residue

1,080 (72%) stated that they did not do either.

Responses by Industry

Just over one-third of the respondents (36.2%) are in the construction industries.

Another one-fourth (26.7%) are in machinery manufacturing.

Along with companies in freight transportation (13.4%) and building materials (6.1%), these four industries account for just over 8 out of 10 (82.4%) of the respondents to the survey.

The rest are spread out over 16 other industry groups.

Types of Residue

Sufficient data were obtained on 5 of the 8 residues:

pallets, skids, and shipping crates,
edgings and cutoffs,
chips and shavings,
construction debris, and
tree trunks, limbs, and stumps.

Data collected on dunnage were insufficient for analysis.

Separate attempts were made to contact four railroad companies operating in the study area. Only two responded: neither could provide data on the number of ties replaced in the 14 counties in 2005.

Calls to Detroit Edison were not returned either, so there are no survey data on utility poles removed from service in 2005. *

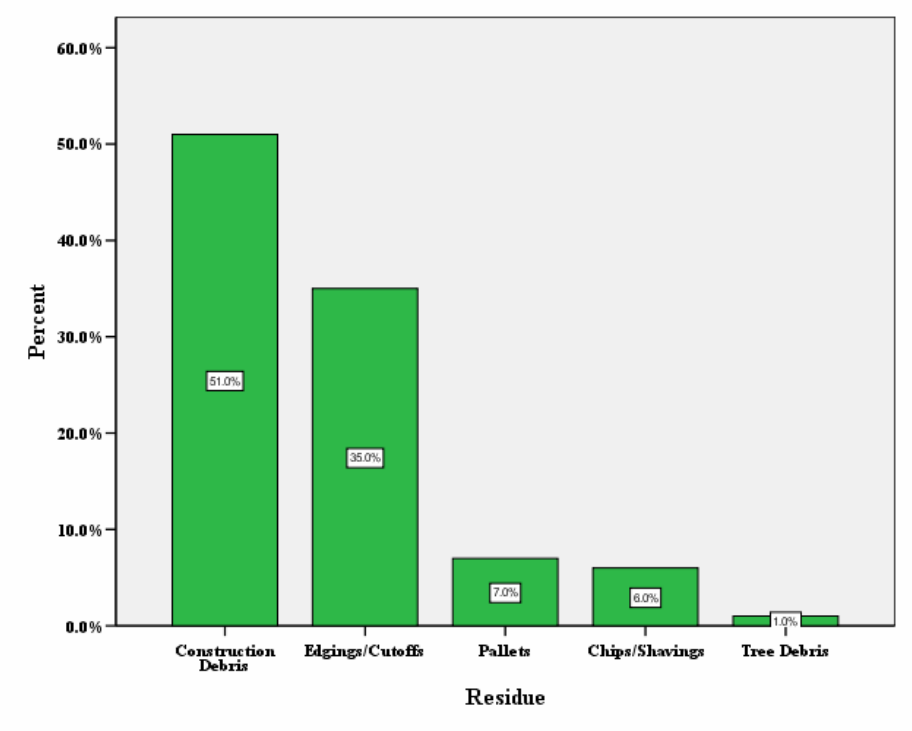
Residue Generated in 2005

Excluding railroad ties and utility poles, approximately 2,600 companies in total generated about 7.5 million cubic yards of residue in the fourteen county study area in 2005.

This amount would fill 354 football fields to a depth of 10 feet (the height of the crossbar on the goal posts).

About half (51%) was construction debris while just over one-third (35%) was edgings and cutoffs. The rest consisted of pallets (7%), chips and shavings (6%), and tree debris (1%).

Among those companies that paid for removal, the total was $8.8 million.



Residue Generated, Used, and Discarded in Landfills

Less than one-fifth (16%) of pallets were discarded while over four-fifths (84%) of pallets were reused or recycled.

Sixty percent of edgings and cutoffs were discarded as waste while the remaining 40% was reused.

Sixty-three percent of the construction debris was discarded while the remaining 37% went to other companies and individuals.

Just over half (52%) of chips and shavings were discarded while the rest was used.

For tree debris, 61% was discarded and 39% was used.

Residue	Total Amount Generated (cubic yards)	Percent Used	Total Amount Used (cubic yards)	Percent Discarded	Total Amount Discarded (cubic yards)	Of Total Amount Discarded, Amount Sent to Landfills (cubic yards)	Percent of Total Discarded Residue Sent to Landfills
Pallets, Skids, Shipping Crates	505,000	84%	424,000	16%	81,000	15,000	19%
Edgings and Cutoffs	2,646,000	40%	1,058,000	60%	1.588,000	675,000	43%
Chips, Shavings, Sawdust	480,000	48%	230,000	52%	250,000	108,000	43%
Construction Debris	3,828,000	37%	1,416,000	63%	2,412,000	1,302,000	54%
Tree Trunks, Limbs, Stumps	84,000	53%	45,000	47%	39,000	5,000	13%
Totals	7,543,000	42%	3,173,000	58%	4,370,000	2,105,000	48%

Residue Discarded

In total, just under 4.4 million cubic yards of residue were discarded as waste in 2005.

This is 58% of the total 7.5 million cubic yards generated.

Of the 4.4 million cubic yards discarded, just over 2.1 million cubic yards, or about 48%, ended up in landfills.

The rest was either burned or disposed of in other unspecified ways.

Of the total 7.5 million cubic yards generated, 2.1 million cubic yards, or 28%, went to area landfills.

Disposal by Type of Residue

Pallet, skids, shipping containers

A total of 420 companies generated about 3 million pallets in 2005.

> **Automobile manufacturers alone generated an estimated 1.9 million pallets. Probably 90% of these were reused or recycled.**
>
> **All the other companies generated about 1.1 million. About 84% were reused.**

Other companies spent less than $1 million in 2005 on disposal. They avoided removal costs by giving the pallets away. The large majority were taken by other companies.

In general, pallets are either repaired and reused or are ground into mulch. Many companies also reused their own pallets as pallets.

Edgings and Cutoffs

A total of 615 companies generated just over 2.6 million cubic yards of edgings and cutoffs.

Two-thirds of the companies are in the construction business.

Two-thirds of all the companies paid an estimated total of $1.4 million for removal. The remaining third paid nothing.

About two-thirds of all of the companies did make some use of their own edgings and cutoffs, the rest did not. The main uses were as building materials and heating fuel.

Disposal by Type of Residue

Chips and Shavings

Overall, 324 companies generated 480,000 cubic yards of chips and shavings.

Three-fourths of these companies were either in construction, wood products manufacturing, or industrial machinery manufacturing.

Just under half of chips and shavings were reused while just over half were discarded as waste.

Among those that disposed of their chips and shavings as waste, about three-fourths used landfills. About 1 out of 4 recycled, mainly as mulch.

About 4 out of 10 companies paid just under one-half million dollars to dispose the material they generated. The other 6 out of 10 either gave the material away or, in a minority of cases, were paid for it.

Disposal by Type of Residue

Construction Debris

An estimated 1,161 companies, mostly in building construction, generated about 3.8 million cubic yards.

Only one-third was reused, the other two-thirds were discarded.

Just over half of the discarded debris ended up in landfills.

Roughly half the companies did not reuse while the others did, mainly as building material.

Trees, Trunks, and Stumps

An estimated 96 companies generated about 84,000 cubic yards of tree debris.

Just over half were used while the rest was discarded. Just under half paid for removal.

Just over half made no use of the tree debris. Among those that did, the most frequent use was firewood.

There is no clear indication of whether more or less ash trees were removed in 2005 compared to the previous year.

Market for Wood Residue

Just over 6 out of 10 (62.4%) responding companies stated there was no market for their residue.

About 2 out of 10 (20.9%) thought a market either existed or was developing (the rest did not know).

The most frequently cited reason for no market is that wood cannot be separated from attached foreign material.

Among those who believed a market was developing, one-third indicated that identifying buyers was the principal impediment to further development.

Price volatility was not a problem for the residue market, nor was inadequate price information.

Sampling and Questionnaire Recommendations

1. When defining the study population, the following SIC codes can be used:

   tree service companies (SIC 0783)
   construction (SIC's 15, 16 and 17)
   machinery manufacturing (SIC 35)
   lumber and wood products (SIC 24)
   wood furniture (SIC 25)
   freight transportation (SIC 42)
   building supply and mobile home companies (SIC 52)
   food stores (SIC 54)
   home furniture stores (SIC 57).

2. The sample should be stratified only by SIC codes to insure that potential generators and users of residue are drawn into the sample.

3. To insure an adequate number of responses by SIC, consideration should be given to disproportionate sampling among strata with few companies.

4. Companies that generate or accept substantial amounts of residue should be separately identified and selected for interviewing. The major examples in this study are the three major automobile manufacturers, railroad companies, and the major utility company.

   To increase the likelihood that these companies will respond to calls and requests for data, senior governmental officials should make initial calls to company executives requesting their co-operation.

Recommendations

5. **Select a sample size at least sixteen times the target number of completed interviews with generators and users. Completed interviews with 1,000 generators and users would require a gross sample size of about 16,000 businesses.**

6. **The first question should begin by stating that ownership of the wood waste and responsibility for disposal are irrelevant: what counts is whether the respondent's company engages in work that produces wood waste or whether the company's business is to accept and process wood waste.**

7. **Respondents who give a negative answer to the first question should be asked how they are able to engage in their work without generating wood waste.**

8. **Questions should be added that directly request the amounts of residues companies send to landfills, burn, and otherwise discard as waste.**

9. **Pallets/skids and shipping crates should be covered by separate sets of questions.**

10. **Dunnage should be included only when warranted by the industry base of the urban area being surveyed.**

G. MI SO2 1866-2009

Michigan Department Of Environmental Quality
Air Quality Division

CAIR Sulfur Dioxide Budget Permit
Permit No. MI-SO2-1866-2009

Permittee	Wyandotte Municipal Service-Power Plant
Address	2555 Van Alstyne, Wyandotte, MI
SRN	B2132
ORIS code	1866
Issue Date	May 18, 2009
Expiration	This permit shall expire when the facility's Renewable Operating Permit (ROP) expires in accordance with 40 CFR 97.221(b).
ROP No.	MI-ROP-B2132-20XX

This permit incorporates automatically the definitions of terms under Air Pollution Control Rule 336.1420.

This permit incorporates automatically, upon recordation by the EPA Administrator in accordance with 40 CFR part 97 subpart FFF, GGG, or III every allocation, transfer, or deduction of a SO2 allowance to or from the compliance accounts of the CAIR SO2 unit(s) covered by the permit.

The owners and operators of the source must comply with the standard requirements and special provisions set forth in this permit.

This permit incorporates any attached comments, notes or justifications regarding permit decisions and changes made to the permit application forms during the review process.

Units covered under this permit

AQD Unit ID	Unit Type			
EUUnit5BLR	**X** Stationary Boiler	☐ Combined Cycle System	☐ Combustion Turbine	☐ Other
EUUnit7BLR	**X** Stationary Boiler	☐ Combined Cycle System	☐ Combustion Turbine	☐ Other
EUUnit8BLR	**X** Stationary Boiler	☐ Combined Cycle System	☐ Combustion Turbine	☐ Other

Permit Application:

CAIR SO2 Annual Permit application submitted September 12, 2008

Standard requirements

(a) Permit requirements.

(1) The CAIR designated representative of each CAIR SO2 source required to have a ROP and each CAIR SO2 unit required to have a ROP at the source shall:

(i) Submit to the permitting authority a complete CAIR permit application under § 97.222 in accordance with the deadlines specified in § 97.221; and

(ii) Submit in a timely manner any supplemental information that the permitting authority determines is necessary in order to review a CAIR permit application and issue or deny a CAIR permit.

(2) The owners and operators of each CAIR SO2 source required to have a ROP and each CAIR SO2 unit required to have a ROP at the source shall have a CAIR permit issued by the permitting authority under subpart CCC of 40 CFR part 97 for the source and operate the source and the unit in compliance with such CAIR permit.

(b) Monitoring, Reporting, and Recordkeeping Requirements.

(1) The owners and operators, and the CAIR designated representative, of each CAIR SO2 source and each CAIR SO2 unit at the source shall comply with the monitoring, reporting, and recordkeeping requirements of subpart HHH of 40 CFR part 97.
(2) The emissions measurements recorded and reported in accordance with subpart HHH of 40 CFR part 97 shall be used to determine compliance by each CAIR SO2 source with the CAIR SO2 emissions limitation under paragraph (c) of this permit.

(c) Sulfur Dioxide Emission Requirements.

(1) As of the allowance transfer deadline for a control period, the owners and operators of each CAIR SO2 source and each CAIR SO2 unit at the source shall hold, in the source's compliance account, a tonnage equivalent in CAIR SO2 allowances available for compliance deductions for the control period, as determined in accordance with § 97.254(a) and (b), not less than the tons of total sulfur dioxide emissions for the control period from all CAIR SO2 units at the source, as determined in accordance with subpart HHH of 40 CFR part 97.
(2) A CAIR SO2 unit shall be subject to the requirements under paragraph (c)(1) of this section for the control period starting on the later of January 1, 2010 or the deadline for meeting the unit(s monitor certification requirements under § 97.270(b)(1),(2), or (5) and for each control period thereafter.
(3) A CAIR SO2 allowance shall not be deducted, for compliance with the requirements under paragraph (c)(1) of this section, for a control period in a calendar year before the year for which the CAIR SO2 allowance was allocated.
(4) CAIR SO2 allowances shall be held in, deducted from, or transferred into or among CAIR SO2 Allowance Tracking System accounts in accordance with subparts FFF, GGG, and III of 40 CFR part 97.
(5) A CAIR SO2 allowance is a limited authorization to emit sulfur dioxide in accordance with the CAIR SO2 Trading Program. No provision of the CAIR SO2 Trading Program, the CAIR permit application, the CAIR permit, or an exemption under § 97.205 and no provision of law shall be construed to limit the authority of the United States to terminate or limit such authorization.
(6) A CAIR SO2 allowance does not constitute a property right.
(7) Upon recordation by the Administrator under subpart FFF, GGG, or III of 40 CFR part 97, every allocation, transfer, or deduction of a CAIR SO2 allowance to or from a CAIR SO2 source's compliance account is incorporated automatically in any CAIR permit of the source.

(d) Excess emissions requirements.

If a CAIR SO2 source emits sulfur dioxide during any control period in excess of the CAIR SO2 emissions limitation, then:
(1) The owners and operators of the source and each CAIR SO2 unit at the source shall surrender the CAIR SO2 allowances required for deduction under § 97.254(d)(1) and pay any fine, penalty, or assessment or comply with any other remedy imposed, for the same violations, under the Clean Air Act or applicable State law; and
(2) Each ton of such excess emissions and each day of such control period shall constitute a separate violation of this subpart, the Clean Air Act, and applicable State law.

(e) Recordkeeping and Reporting Requirements.

(1) Unless otherwise provided, the owners and operators of the CAIR SO2 source and each CAIR SO2 unit at the source shall keep on site at the source each of the following documents for a period of 5 years from the date the document is created. This period may be extended for cause, at any time before the end of 5 years, in writing by the permitting authority or the Administrator.

(i) The certificate of representation under § 97.213 for the CAIR designated representative for the source and each CAIR SO2 unit at the source and all documents that demonstrate the truth of the statements in the certificate of representation; provided that the certificate and documents shall be retained on site at the source beyond such 5-year period until such documents are superseded because of the submission of a new certificate of representation under § 97.213 changing the CAIR designated representative.
(ii) All emissions monitoring information, in accordance with subpart HHH of 40 CFR part 97, provided that to the extent that subpart HHH of 40 CFR part 97 provides for a 3-year period for recordkeeping, the 3-year period shall apply.
(iii) Copies of all reports, compliance certifications, and other submissions and all records made or required under the CAIR SO2 Trading Program.
(iv) Copies of all documents used to complete a CAIR permit application and any other submission under the CAIR SO2 Trading Program or to demonstrate compliance with the requirements of the CAIR SO2 Trading Program.

(2) The CAIR designated representative of a CAIR SO2 source and each CAIR SO2 unit at the source shall submit the reports required under the CAIR SO2 Trading Program, including those under subpart HHH of 40 CFR part 97.

(f) Liability.

(1) Each CAIR SO2 source and each CAIR SO2 unit shall meet the requirements of the CAIR SO2 Trading Program.
(2) Any provision of the CAIR SO2 Trading Program that applies to a CAIR SO2 source or the CAIR designated representative of a CAIR SO2 source shall also apply to the owners and operators of such source and of the CAIR SO2 units at the source.
(3) Any provision of the CAIR SO2 Trading Program that applies to a CAIR SO2 unit or the CAIR designated representative of a CAIR SO2 unit shall also apply to the owners and operators of such unit.

(g) Effect On Other Authorities.

No provision of the CAIR SO2 Trading Program, a CAIR permit application, a CAIR permit, or an exemption under § 97.205 shall be construed as exempting or excluding the owners and operators, and the CAIR designated representative, of a CAIR SO2 source or CAIR SO2 unit from compliance with any other provision of the applicable, approved State implementation plan, a federally enforceable permit, or the Clean Air Act.

H. National Oceanic Atmospheric and Administration Weather Data

These data are preliminary and have not undergone final quality control by the National Climatic Data Center (NCDC). Therefore, these data are subject to revision. Final and certified climate data can be accessed at the NCDC - http://www.ncdc.noaa.gov.

Climatological Report (Daily)

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CLIMATE REPORT
NATIONAL WEATHER SERVICE DETROIT/PONTIAC MI
211 AM EDT WED JUN 9 2010


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...THE DETROIT MI CLIMATE SUMMARY FOR JUNE 8 2010...

CLIMATE NORMAL PERIOD 1971 TO 2000
CLIMATE RECORD PERIOD 1874 TO 2010


WEATHER ITEM   OBSERVED TIME   RECORD YEAR NORMAL DEPARTURE LAST
                VALUE   (LST)  VALUE       VALUE  FROM      YEAR
                                                 NORMAL
.................................................................
TEMPERATURE (F)
 YESTERDAY
  MAXIMUM         69   1147 AM 100    1933  77     -8       74
  MINIMUM         51    526 AM  39    1949  57     -6       57
  AVERAGE         60                         67     -7       66

PRECIPITATION (IN)
  YESTERDAY        0.05          2.00 1906   0.12  -0.07     0.27
  MONTH TO DATE    3.17                      0.92   2.25     0.54
  SINCE JUN 1      3.17                      0.92   2.25     0.54
  SINCE JAN 1     14.47                     13.33   1.14    15.85

SNOWFALL (IN)
  YESTERDAY        0.0           0.0    MM   0.0    0.0      0.0
  MONTH TO DATE    0.0                       0.0    0.0      0.0
  SINCE JUN 1      0.0                       0.0    0.0      0.0
  SINCE JUL 1     43.7                      44.0   -0.3     65.7
  SNOW DEPTH       0

DEGREE DAYS
 HEATING
  YESTERDAY        5                          2      3        0
  MONTH TO DATE   10                         20    -10       28
  SINCE JUN 1     10                         20    -10       28
  SINCE JUL 1   5668                       6396   -728     6371

 COOLING
  YESTERDAY        0                          4     -4        1
  MONTH TO DATE   31                         27      4        3
  SINCE JUN 1     31                         27      4        3
  SINCE JAN 1    137                         75     62       35
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WIND (MPH)
  HIGHEST WIND SPEED    25   HIGHEST WIND DIRECTION     N (340)
  HIGHEST GUST SPEED    40   HIGHEST GUST DIRECTION    SE (120)
  AVERAGE WIND SPEED     5.3


SKY COVER
  POSSIBLE SUNSHINE  MM
  AVERAGE SKY COVER 0.7


WEATHER CONDITIONS
 THE FOLLOWING WEATHER WAS RECORDED YESTERDAY.
  LIGHT RAIN
  FOG
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  HAZE


RELATIVE HUMIDITY (PERCENT)
 HIGHEST    93          1100 PM
 LOWEST     52          1000 AM
 AVERAGE    73

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THE DETROIT MI CLIMATE NORMALS FOR TODAY
                          NORMAL    RECORD    YEAR
 MAXIMUM TEMPERATURE (F)   78        93       1976
                                              1968
 MINIMUM TEMPERATURE (F)   57        40       1988


SUNRISE AND SUNSET
JUNE  9 2010..........SUNRISE   557 AM EDT   SUNSET   909 PM EDT
JUNE 10 2010..........SUNRISE   557 AM EDT   SUNSET   909 PM EDT


-  INDICATES NEGATIVE NUMBERS.
R  INDICATES RECORD WAS SET OR TIED.
MM INDICATES DATA IS MISSING.
T  INDICATES TRACE AMOUNT.
&&

TEMPERATURE DATA...
MONTHLY AVERAGE......... 67.3
DEPARTURE FROM NORMAL... 1.1



DETROIT CITY AIRPORT HIGH AND LOW FOR YESTERDAY.... 68/50
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CLIMATE INFORMATION FROM THE NATIONAL WEATHER SERVICE FORECAST
OFFICE IN WHITE LAKE MICHIGAN FOR YESTERDAY...

TEMPERATURE:

HIGH... 68 LOW.... 43

PRECIPITATION:

DAY.... 0.03 MONTH.... 2.10 YEAR.... 15.23

SNOWFALL:

DAY.... 0.0 MONTH.... 0 SEASON.... 46.7

DETROIT SNOW DEPTH IS MEASURED AT 7 AM.
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The U.S. Naval Observatory (USNO) computes astronomical data. Therefore, the NWS does not record, certify, or authenticate astronomical data. Computed times of sunrise, sunset, moonrise, moonset; and twilight, moon phases and other astronomical data are available from USNO's Astronomical Applications Department (http://www.usno.navy.mil). See http://www.usno.navy.mil/USNO/astronomical-applications/astronomical-information-center/litigation for information on using these data for legal purposes.

These data are preliminary and have not undergone final quality control by the National Climatic Data Center (NCDC). Therefore, these data are subject to revision. Final and certified climate data can be accessed at the NCDC - http://www.ncdc.noaa.gov.

Climatological Report (Daily)

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CDUS43 KDTX 110610
CLIDTW

CLIMATE REPORT
NATIONAL WEATHER SERVICE DETROIT/PONTIAC MI
210 AM EDT FRI JUN 11 2010


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...THE DETROIT MI CLIMATE SUMMARY FOR JUNE 10 2010...

CLIMATE NORMAL PERIOD 1971 TO 2000
CLIMATE RECORD PERIOD 1874 TO 2010


WEATHER ITEM   OBSERVED TIME   RECORD YEAR NORMAL DEPARTURE LAST
                VALUE   (LST)  VALUE       VALUE  FROM      YEAR
                                                 NORMAL
.................................................................
TEMPERATURE (F)
 YESTERDAY
  MAXIMUM         77    507 PM  95    1911  78     -1       73
  MINIMUM         62    523 AM  38    1980  58      4       57
  AVERAGE         70                        68      2       65

PRECIPITATION (IN)
  YESTERDAY        0.00          1.65 1920   0.12  -0.12     0.01
  MONTH TO DATE    3.28                      1.16   2.12     0.55
  SINCE JUN 1      3.28                      1.16   2.12     0.55
  SINCE JAN 1     14.58                     13.57   1.01    15.86

SNOWFALL (IN)
  YESTERDAY        0.0           0.0    MM   0.0    0.0      0.0
  MONTH TO DATE    0.0                       0.0    0.0      0.0
  SINCE JUN 1      0.0                       0.0    0.0      0.0
  SINCE JUL 1     43.7                      44.0   -0.3     65.7
  SNOW DEPTH       0

DEGREE DAYS
 HEATING
  YESTERDAY        0                         2     -2        0
  MONTH TO DATE   10                        24    -14       28
  SINCE JUN 1     10                        24    -14       28
  SINCE JUL 1   5668                      6400   -732     6371

 COOLING
  YESTERDAY        5                         4      1        0
  MONTH TO DATE   41                        35      6        5
  SINCE JUN 1     41                        35      6        5
  SINCE JAN 1    147                        83     64       37
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WIND (MPH)
  HIGHEST WIND SPEED    18   HIGHEST WIND DIRECTION    NW (320)
  HIGHEST GUST SPEED    23   HIGHEST GUST DIRECTION     W (290)
  AVERAGE WIND SPEED     8.7


SKY COVER
  POSSIBLE SUNSHINE  MM
  AVERAGE SKY COVER 0.6


WEATHER CONDITIONS
 THE FOLLOWING WEATHER WAS RECORDED YESTERDAY.
  NO SIGNIFICANT WEATHER WAS OBSERVED.
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RELATIVE HUMIDITY (PERCENT)
 HIGHEST     73           100 AM
 LOWEST      46           700 PM
 AVERAGE     60

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THE DETROIT MI CLIMATE NORMALS FOR TODAY
                          NORMAL    RECORD    YEAR
 MAXIMUM TEMPERATURE (F)   78        97       1933
 MINIMUM TEMPERATURE (F)   58        36       1972


SUNRISE AND SUNSET
JUNE 11 2010..........SUNRISE   557 AM EDT   SUNSET   910 PM EDT
JUNE 12 2010..........SUNRISE   556 AM EDT   SUNSET   910 PM EDT


-  INDICATES NEGATIVE NUMBERS.
R  INDICATES RECORD WAS SET OR TIED.
MM INDICATES DATA IS MISSING.
T  INDICATES TRACE AMOUNT.
&&

TEMPERATURE DATA...
MONTHLY AVERAGE......... 67.8
DEPARTURE FROM NORMAL... 1.3



DETROIT CITY AIRPORT HIGH AND LOW FOR YESTERDAY.... 79/63
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CLIMATE INFORMATION FROM THE NATIONAL WEATHER SERVICE FORECAST
OFFICE IN WHITE LAKE MICHIGAN FOR YESTERDAY...

TEMPERATURE:

HIGH... 74 LOW.... 54

PRECIPITATION:

DAY.... T MONTH.... 2.33 YEAR.... 15.46

SNOWFALL:

DAY.... 0.0 MONTH.... 0 SEASON.... 46.7

DETROIT SNOW DEPTH IS MEASURED AT 7 AM.
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