PDHonline Course G451V (2 PDH)

Recycling: From Waste to Usable Products (Video Course)

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Recycling: From Waste to Useable Products

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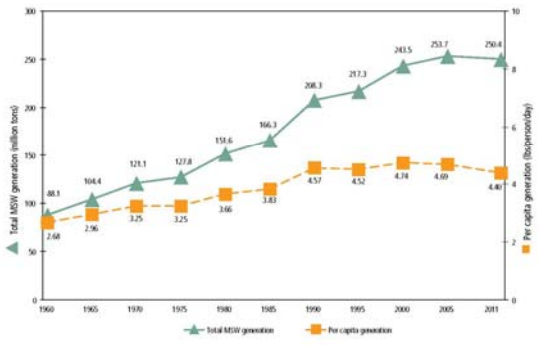
Basic Municipal Solid Waste Statistics

Figure 1. MSW Generation Rates, 1960 to 2011



Over the last few decades, the generation, recycling, composting, and disposal of MSW have changed substantially. Solid waste generation per person per day peaked in 2000 while the 4.40 pounds per person per day is the lowest since the 1980's. The recycling rate has increased–from less than 10 percent of MSW generated in 1980 to over 34 percent in 2011. Disposal of waste to a landfill has decreased from 89 percent of the amount generated in 1980 to under 54 percent of MSW in 2011.

Figure 4. Management of MSW in the United States, 2011

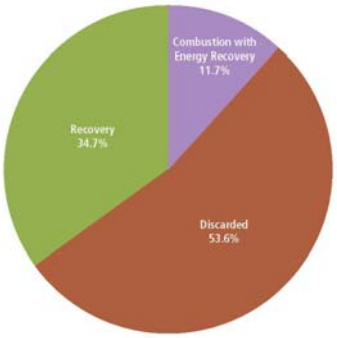
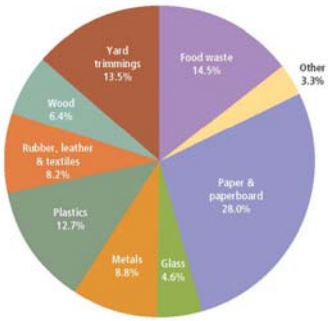
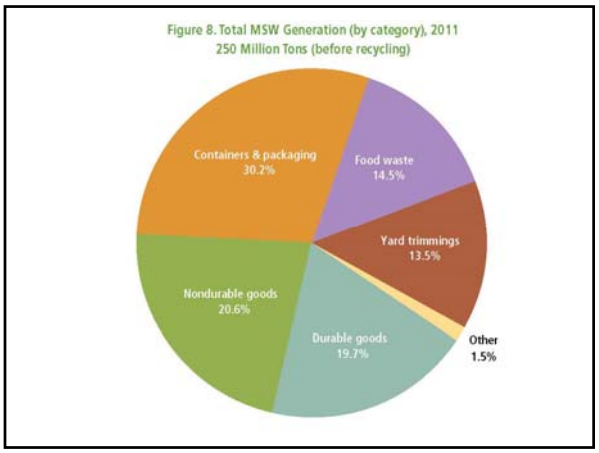
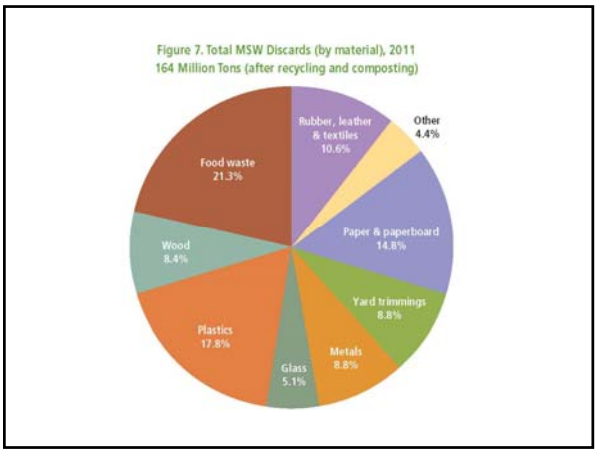
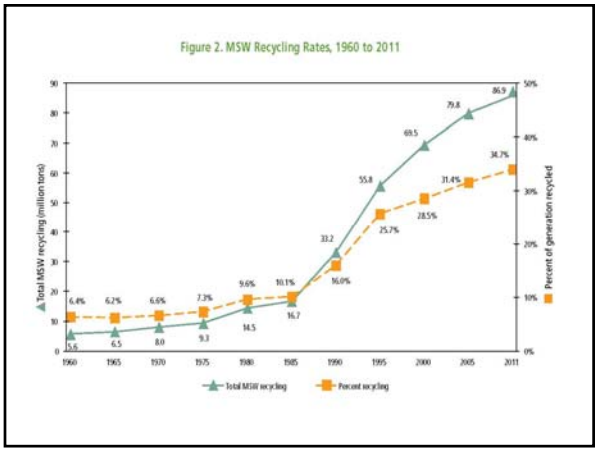


Figure 5. Total MSW Generation (by material), 2011
250 Million Tons (before recycling)









Recycling Trends

In percentage of total MSW generation, recovery for recycling (including composting) did not exceed 15 percent until 1990. Growth in the recovery rate to current levels (34.7 percent) reflects an increase in infrastructure and market demand for recovery over the last decade.

Nationally, we recycled and composted almost 87 million tons of municipal solid waste. This provides an annual benefit of more than 183 million metric tons of carbon dioxide equivalent emissions reduced, comparable to the annual GHG emissions from over 34 million passenger vehicles.

Recycling and composting almost 87 million tons of MSW saved more than 1.1 quadrillion Btu of energy; that's the same amount of energy consumed by over 10 million U.S. households in a year.

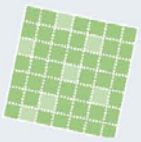


Figure 6. Total MSW Recovery (by material), 2011
87 Million Tons

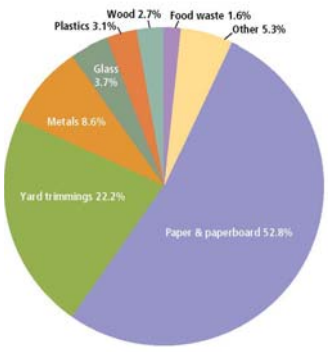
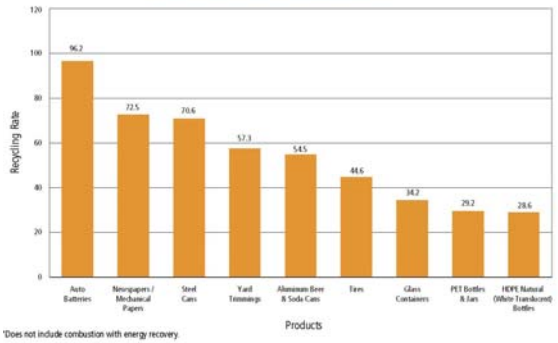


Figure 3. Recycling Rates of Selected Products, 2011**



**Does not include combustion with energy recovery.

Table 1. Generation, Recovery, and Discards of Materials in MSW, 2011*
(in millions of tons and percent of generation of each material)

Material	Weight Generated	Weight Recovered	Recovery as Percent of Generation	Weight Discarded
Paper and paperboard	70.02	45.90	65.6%	24.12
Glass	11.47	3.17	27.6%	8.30
Metals				
Steel	16.52	5.45	33.0%	11.07
Aluminum	3.47	0.72	20.7%	2.75
Other nonferrous metals†	1.96	1.34	68.4%	0.62
Total metals	**21.95**	**7.51**	**34.2%**	**14.44**
Plastics	31.84	2.65	8.3%	29.19
Rubber and leather	7.49	1.31	17.5%	6.18
Textiles	13.09	2.00	15.3%	11.09
Wood	16.08	2.38	14.8%	13.70
Other materials	4.59	1.28	27.9%	3.31
Total materials in products	**176.53**	**66.20**	**37.5%**	**110.33**
Other wastes				
Food, other‡	36.31	1.40	3.9%	34.91
Yard trimmings	33.71	19.30	57.3%	14.41
Miscellaneous inorganic wastes	3.87	Negligible	Negligible	3.87
Total other wastes	**73.89**	**20.70**	**28.0%**	**53.19**
Total municipal solid waste	**250.42**	**86.90**	**34.7%**	**163.52**

* Includes waste from residential, commercial, and institutional sources.
† Includes lead from lead-acid batteries.
‡ Includes recovery of other MSW organics for composting.
Details might not add to totals due to rounding.
Negligible = Less than 5,000 tons or 0.05 percent.

Table 2. Generation, Recovery, and Discards of Products in MSW, 2011*
(in millions of tons and percent of generation of each product)

Products	Weight Generated	Weight Recovered	Recovery as Percent of Generation	Weight Discarded
Durable goods				
Steel	14.34	3.88	27.1%	10.46
Aluminum	1.43	Negligible	Negligible	1.43
Other non-ferrous metals†	1.96	1.34	68.4%	0.62
Glass	2.19	Negligible	Negligible	2.19
Plastics	11.42	0.74	6.5%	10.68
Rubber and leather	6.44	1.31	20.3%	5.13
Wood	6.03	Negligible	Negligible	6.03
Textiles	3.84	0.52	13.5%	3.32
Other materials	1.69	1.28	75.7%	0.41
Total durable goods	**49.34**	**9.07**	**18.4%**	**40.27**
Nondurable goods				
Paper and paperboard	31.99	17.24	53.9%	14.75
Plastics	6.52	0.11	1.7%	6.41
Rubber and leather	1.05	Negligible	Negligible	1.05
Textiles	8.95	1.48	16.5%	7.47
Other materials	3.10	Negligible	Negligible	3.10
Total nondurable goods	**51.61**	**18.83**	**36.5%**	**32.78**

Containers and packaging				
Steel	2.18	1.57	72.0%	0.61
Aluminum	1.85	0.72	38.9%	1.13
Glass	9.28	3.17	34.2%	6.11
Paper and paperboard	38.02	28.66	75.4%	9.36
Plastics	13.90	1.80	12.9%	12.10
Wood	10.00	2.38	23.8%	7.62
Other materials	0.35	Negligible	Negligible	0.35
Total containers and packaging	**75.58**	**38.30**	**50.7%**	**37.28**
Other wastes				
Food, other‡	36.31	1.40	3.9%	34.91
Yard trimmings	33.71	19.30	57.3%	14.41
Miscellaneous inorganic wastes	3.87	Negligible	Negligible	3.87
Total other wastes	73.89	20.70	28.0%	53.19
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Table 3. Generation, Materials Recovery, Composting, Combustion With Energy Recovery, and Discards of MSW, 1960 to 2011 (in millions of tons)

Activity	1960	1970	1980	1990	2000	2005	2007	2009	2010	2011
Generation	88.1	121.1	151.6	208.3	243.5	253.7	256.5	244.3	250.5	250.4
Recovery for recycling	5.6	8.0	14.5	29.0	53.0	59.2	63.1	61.6	65.0	66.2
Recovery for composting*	Negligible	Negligible	Negligible	4.2	16.5	20.6	21.7	20.8	20.2	20.7
Total materials recovery	5.6	8.0	14.5	33.2	69.5	79.8	84.8	82.4	85.2	86.9
Discards after recovery	82.5	113.1	137.1	175.1	174.0	173.9	171.7	161.9	165.3	163.5
Combustion with energy recovery†	0.0	0.4	2.7	29.7	33.7	31.6	32.0	29.0	29.3	29.3
Discards to landfill, other disposal‡	82.5	112.7	134.4	145.3	140.3	142.3	139.7	132.9	136.0	134.2

* Composting of yard trimmings, food waste, and other MSW organic material. Does not include backyard composting.
† Includes combustion of MSW in mass burn or refuse-derived fuel form, and combustion with energy recovery of source separated materials in MSW (e.g., wood pallets, tire-derived fuel).
‡ Discards after recovery minus combustion with energy recovery. Discards include combustion without energy recovery.
Details might not add to totals due to rounding.

Table 4. Generation, Materials Recovery, Composting, Combustion With Energy Recovery, and Discards of MSW, 1960 to 2011 (in pounds per person per day)

Activity	1960	1970	1980	1990	2000	2005	2007	2009	2010	2011
Generation	2.68	3.25	3.66	4.57	4.74	4.69	4.66	4.36	4.44	4.40
Recovery for recycling	0.17	0.22	0.35	0.64	1.03	1.10	1.15	1.10	1.15	1.16
Recovery for composting*	Negligible	Negligible	Negligible	0.09	0.32	0.38	0.39	0.37	0.36	0.37
Total Materials Recovery	0.17	0.22	0.35	0.73	1.35	1.48	1.54	1.47	1.51	1.53
Discards after recovery	2.51	3.03	3.31	3.84	3.39	3.21	3.12	2.89	2.93	2.87
Combustion with energy recovery†	0.00	0.01	0.07	0.65	0.66	0.58	0.58	0.52	0.52	0.51
Discards to landfill, other disposal‡	2.51	3.02	3.24	3.19	2.73	2.63	2.54	2.37	2.41	2.36
Population (millions)	179.979	203.984	227.255	249.907	281.422	296.410	301.621	307.007	309.051	311.592

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‡ Discards after recovery minus combustion with energy recovery. Discards include combustion without energy recovery.
Details might not add to totals due to rounding.

Table 5. Greenhouse Gas Benefits Associated with Recovery of Specific Materials, 2011* (in millions of tons recovered, $MMTCO_2E$ and in numbers of cars taken off the road per year) **

Material	Weight Recovered (millions of tons)	GHG Benefits $MMTCO_2E$	Numbers of Cars Taken Off the Road per Year
Paper and paperboard	45.9	134.5	28 million
Glass	3.17	1	210 thousand
Metals			
Steel	5.45	9	1.9 million
Aluminum	0.72	6.4	1.3 million
Other nonferrous metals†	1.34	5.2	1 million
Total metals	**7.51**	**20.6**	**4.2 million**
Plastics	2.65	3.1	640 thousand
Rubber and leather‡	1.31	0.6	130 thousand
Textiles	2	5.1	1 million
Wood	2.38	4.2	1 million
Other wastes			
Food, other^	1.40	1.1	230 thousand
Yard trimmings	19.3	0.8	170 thousand

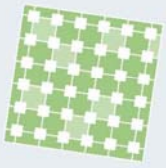
* Includes materials from residential, commercial, and institutional sources.
** These calculations do not include an additional 1.28 million tons of MSW recovered that could not be addressed in the WARM model. $MMTCO_2E$ is million metric tons of carbon dioxide equivalent.
† Includes lead from lead-acid batteries. Other nonferrous metals calculated in WARM as mixed metals.
‡ Recovery only includes rubber from tires.
^ Includes recovery of other MSW organics for composting.
Source: WARM model (www.epa.gov/warm)

Every ton of mixed paper recycled can save the energy equivalent of 165 gallons of gasoline.

Recycling and Composting Collection Programs[3]

- Over 9,800 curbside recycling programs exist nationwide, up from 8,875 in 2002.
- About 3,090 community composting programs were documented in 2011, a decrease from 3,227 in 2002.

Recycling just 1 ton of aluminum cans conserves more than 153 million Btu, the equivalent of 26 barrels of oil, or 1,665 gallons of gasoline.



Energy Recovered from Waste Combustion

- In 2011, over 29 million tons of materials, or 11.7 percent, were combusted for energy recovery.
- MSW combustion for energy recovery has decreased from about 34 million tons in 2000 to 29 million tons in 2011.

Let's Follow the Solid Waste Trail

Where does your waste go?

Where does your waste go?

- Garbage truck.

Where does your waste go?

- Drives to landfills.

What happens to the paper you put in a recycling bin?

What happens to the paper you put in a recycling bin?

- Collect the paper

What happens to the paper you put in a recycling bin?

- Make sure it is sorted

What happens to the paper you put in a recycling bin?

- Collect the paper
- Make sure it is sorted
- Bale the paper

What happens to the paper you put in a recycling bin?

- We collect the paper
- Make sure it is sorted
- Bale the paper
- Ship it by the truck load to a paper mill

What happens to the paper you put in a recycling bin?

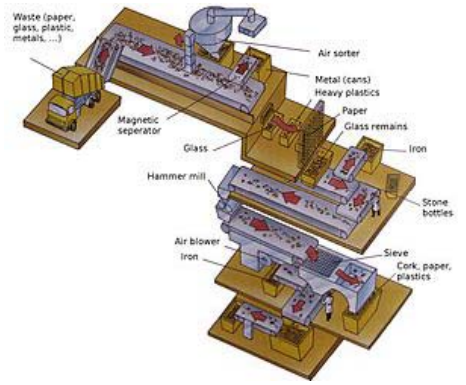
- We collect the paper
- Make sure it is sorted
- Bale the paper
- Ship it by the truck load to a paper mill

Annually recycles over

- 100 tons of junk mail
- 400 tons of newspaper
- 1,300 total tons of paper

Let's Follow the Recycling Trail

Materials Recovery Facility (MRF)



Types of Facilities

- Clean
- Dirty
- Wet

Clean Facility

- Accepts recyclable commingled materials that have already been separated from other sold wastes
- Most common are single stream or dual stream facilities
- Materials are delivered in a mixed container stream
  - Glass
  - Ferrous metals
  - Aluminum
  - Paper
- Material is then sorted
- Should have only 10% nonrecoverable materials

Dirty Facility

- Municipal solid wastes and recyclables are commingled and must be separated
- Combination of manual and automatic sorting
- May undergo additional processing to meet technical specifications
- Recovers between 5% and 45% of incoming materials as recoverable

Wet Facility

- New technology that uses mechanical biological treatment
- Combines a dirty facility with water
- Densifies, separates and cleans material output
- Hydrocrushes and dissolves biodegradable materials to make them suitable for anaerobic digestion

Paper Drop-offs

Newspaper only
All types of paper

Curbside Recycling

Blue bins take:

- Paper
- Plastic (#1 and #2)
- Metal
- Glass

What happens to curbside recycling?

Curbside Recycling

- It gets delivered to a sorting facility

Curbside Recycling

- It gets delivered to a sorting facility.
- Then dumped into a big pile.

Curbside Recycling

- It gets delivered to a sorting facility.
- Then dumped into a big pile.
- Sorted by hand from a conveyor belt.

Curbside Recycling

- It gets delivered to a sorting facility.
- Then dumped into a big pile.
- Sorted by hand from a conveyor belt.
- Pushed into piles.

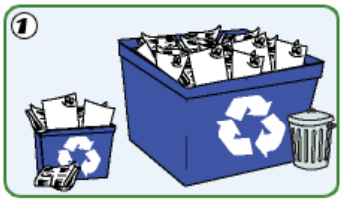
Curbside Recycling

- It gets delivered to a sorting facility.
- Then dumped into a big pile.
- Sorted by hand from a conveyor belt.
- Pushed into piles.
- Stacked in bales.

Curbside Recycling

- It gets delivered to a sorting facility.
- Then dumped into a big pile.
- Sorted by hand from a conveyor belt.
- Pushed into piles.
- Stacked in bales.
- And then shipped to a paper making plant.

Steps to Recycle Paper

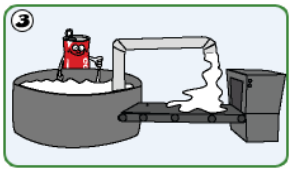


Step 1:

Paper is taken from the bin and deposited in a large recycling container along with paper form other recycling bins

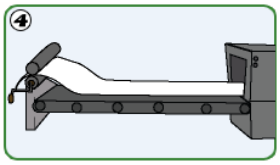
Step 2:

The paper is taken to a recycling plant where it is separated into types and grades



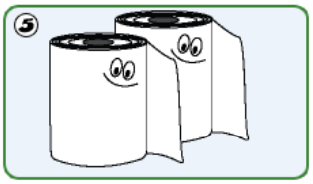
Step 3:

The separated paper is then washed with soapy water to remove inks, plastic film, staples and glue. The paper is put into a large holder where it is mixed with water to create a slurry



Step 4:

By adding different materials to the slurry, different paper products can be created, such as cardboard, newsprint an office paper



Step 5:

The slurry is spread using large rollers into thin sheets.

Step 6:

The paper is left to dry, and then rolled up ready to be cut and sent back to the shops for sale and/or use

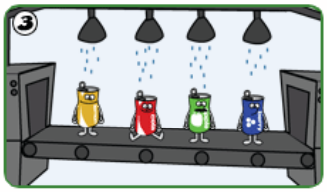
Steps to Recycle Aluminum Cans

Step 1:

The consumer throws aluminum cans and foil into a recycle bin

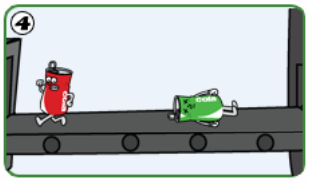
Step 2:

The aluminum is then collected and taken to a treatment plant



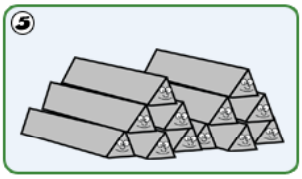
Step 3:

In the treatment plant, the aluminum is sorted and cleaned to be ready for reprocessing



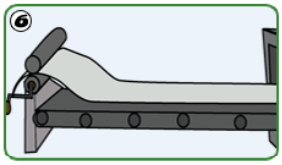
Step 4:

The aluminum goes through a re-melt process and is turned into molten aluminum, this removes the coatings and inks that may be present on the aluminum



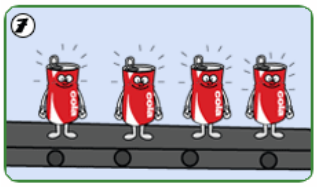
Step 5:

The aluminum is then made into large blocks called ingots. Each ingot contains about 1.6 million drink cans



Step 6:

The ingots are sent to mills where they are rolled out, this fives the aluminum greater flexibility and strength.



Step 7:

The aluminum is then made into various products such as cans, chocolate wrappers and ready meal packaging material

Step 8:

In as little as 6 weeks, the recycled aluminum products are then sent back to the stores ready to be used again.

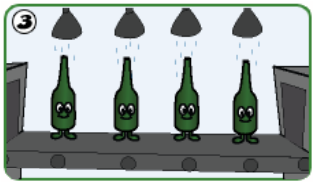
Steps to Recycle Glass

Step 1:

The consumer throws glass into a recycle bin

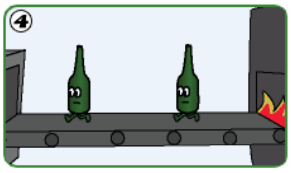
Step 2:

The glass is taken from the bin to a treatment plant



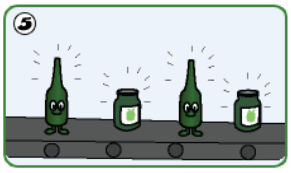
Step 3:

The glass is sorted by color and washed to remove any impurities.



Step 4:

The glass is then crushed and melted, then molded into new products such as bottles and jars. Or it may be used for alternative purposes such as brick manufacture or decorative uses.



Step 5:

The glass is then sent back to the shops ready to be reused.

Step 6:

Glass does not degrade through the recycling process, so it can recycled over and over.

Steps to Recycle Plastics

Step 1:

The plastic is sorted into the various types

Step 2:

The plastic material is washed to remove paper labels, adhesives and other impurities after they are crushed and baled

Step 3:

The plastic material is dry cleaned and sorted using an optical beam which separates the different types of plastic. The plastic is shredded by loading it onto conveyor belts or through huge hoppers that funnel the clean scrap towards rotating metal teeth that rip the plastic into flakes, which are washed and sorted again.

Step 4:

The flakes are chemically tested and labeled as to its exact specification. A chemical solution decontaminates the flakes. They may also be melted down and sieved to form beads as the plastic cools.

Step 5:

The shredded plastic is melted and extruded to form the pellets which go into the manufacture of the next lot of plastic products

Example Products Using Recycled Plastic

- Bottles
- Bags
- Garden furniture (such as park benches)
- Clothes (as a textile substitute), such as t-shirts
- Parking lot bumpers, etc.
- Signs
- Pipe

Green Waste (Yard Waste) Drop-off

Takes:

- **grass clippings**
- **leaves**
- **branches**

No stumps

No large tree trunks

Curbside Recycling

Green bins take:

- Grass
- Leaves
- Branches

Curbside Recycling

Christmas trees are picked up curbside throughout during last week in December and the first week of January

Yard Waste

- What is included in yard waste
  - Grass
  - Leaves
  - Pruning
  - Brush
  - Shrubs
  - Garden Material
  - Christmas Trees
  - Tree Limbs up to 4 inches in diameter

Ways to Treat Yard Waste

- Burning (traditional, causes air pollution)
- Landfilling (banned in some states, DE)
- Composting

Types of Composing

- Aerobic (oxygen added)
- Anaerobic (lack of oxygen)
- Vermicomposting (worm composting)

What can be Composted

- Leaves
- Grass
- Woodchips
- Pet manure
- Food wastes
- Paper
- Coffee grounds
- Wastewater sludges

Composting Methods

- Bins

- Piles

Key Composting Criteria

- Proper mix of carbon rich and nitrogen rich materials
- Carbon rich (green), 1/4
  - Vegetable scraps
  - Coffee grounds
  - Grass clippings
  - Manure
- Nitrogen rich (brown), 3/4
  - Leaves
  - Shredded paper
  - Wood pellets/chips
  - Sawdust

How Composting Works

- Microorganisms eat the organic (carbon containing) waste
- Organic materials broken to their simplest parts
- Produces fiber-rich carbon-containing humus
- Humus contains nutrients such as nitrogen, phosphorous, potassium
- Microorganisms give off carbon dioxide and heat
- The more heat generated, the quicker the decomposition occurs
- Need to mix contents at least weekly

What is Compost Used for?

- Fertilizer
- Soil conditioner
- Mulch

Other materials that can be recycled

- Automotive
  - Fluids
  - Batteries
  - Tires
  - Used motor oil and filters

- Metal
  - Aerosol cans
  - Tin or steel cans
  - Wire
- Construction debris
  - Carpet
  - Packaging
  - Wood
  - Bricks
  - Pallets
  - Siding
  - Roofing

- Electronics
  - CD/DVD/Blu-ray disks
  - Cell phones
  - Computer monitors
  - Inkjet/laserjet cartridges
  - Rechargeable batteries
  - Single use batteries
  - Small appliances
  - Small electronics
  - Computers

- Household hazardous waste
  - CFLs
  - Items containing mercury
  - Medical sharps
  - Paints
  - Pesticides and containers
  - Unwanted/expired medications
  - Solvents
  - Cleaning products

- Household materials
  - Clothing
  - Jewelry
  - Cooking oil
  - Cookware
  - Corks
  - Fluorescent tubes
  - Incandescent bulbs
  - Furniture
  - Mattresses
  - Carpet

Waste Economics

How to figure the cost of recycling?

Does recycling have to make a profit or does it just need to cost less than garbage collection and disposal?

Waste Economics - Garbage

1. Waste placed in trash can
2. Custodian collects and puts in dumpster – cost of custodian
3. Garbage truck picks up – cost of truck operation ($100/hr)
4. Drives 10 miles to transfer station – cost of truck operation
5. Garbage dumped and repacked on larger truck – cost of "tipping" ($27 per ton here)
6. Garbage driven 25 miles to landfill – cost of truck operation
7. Garbage buried – cost of land use

Waste Economics - Recycling

1. Paper put in recycling bin
2. Custodian collects – cost of custodian
3. Recycling truck picks up – cost of truck operation
4. Drives 2 miles to recycling facility – cost of truck operation
5. Paper is dumped, sorted and baled – cost of sorting
6. Paper is sold and shipped to paper mills on west coast or overseas – revenue from paper, savings of not paying to put in landfill, cost of shipping
7. Made into new paper – how does cost of recycled paper compare to cost of cutting trees down for paper?

THANK YOU!