NC STATE UNIVERSITY

Waste generation and characterization

- Outline
  - Why do we need waste generation data
  - How much waste is generated
  - What is the purpose of waste characterization
    - What are the challenges
  - What kind of data is needed
  - Waste Characterization Analysis
    - Material Flow Methodology (MFA)
    - Sorting and Sampling
  - Examples

NC STATE UNIVERSITY

Why do we need waste generation data?

Data are needed to address a problem or an issue – on all levels; for example:

- National policy
- Regional and local planning of waste management
- Legal aspects
- Administration
- Cost accounting
- Design and operation of facilities
- Environmental assessment

US Waste generation (EPA numbers)

Generation - National average lb/capita - day :

1960 - 2.66

1980 - 3.7

1990 - 4.5

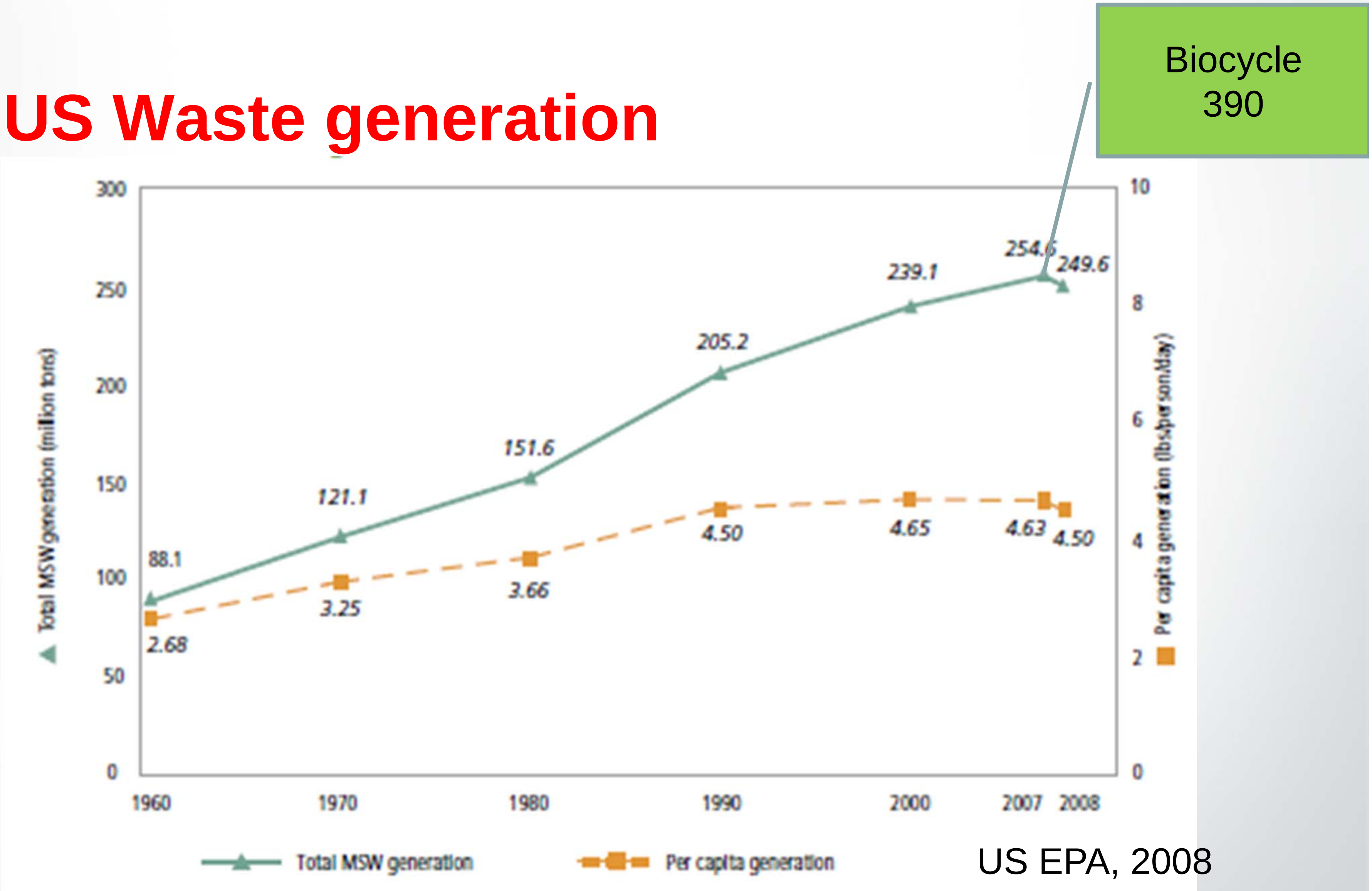
1999 - 4.62 (3.33 after recycle/compost)

2007 – 4.62 (3.08 after recycle/compost)

2008 – 4.50 (3.00 after recycle/compost)

2010 – 4.43 (2.92 after recycle/compost)

US Waste generation



US EPA, 2008

NC STATE UNIVERSITY

What is included in these numbers? -1

- Residential and multi-family
  - Excludes backyard composting
- Commercial
  - Waste generated in stores, offices, restaurants
  - Boxes, food waste, office paper, disposable tableware
- Institutional
  - waste generated in hospitals, prisons, school
- Industrial
  - waste generated at a manufacturing facility (non-process)
  - boxes, cafeteria waste, pallets, office, paper, plastic films

What is included in these numbers? - 2

Rough Estimate
- Residential & multi-family
  - 55 - 65%
- Commercial, institutional, industrial
  - 35 - 45%

What is not included in these numbers?

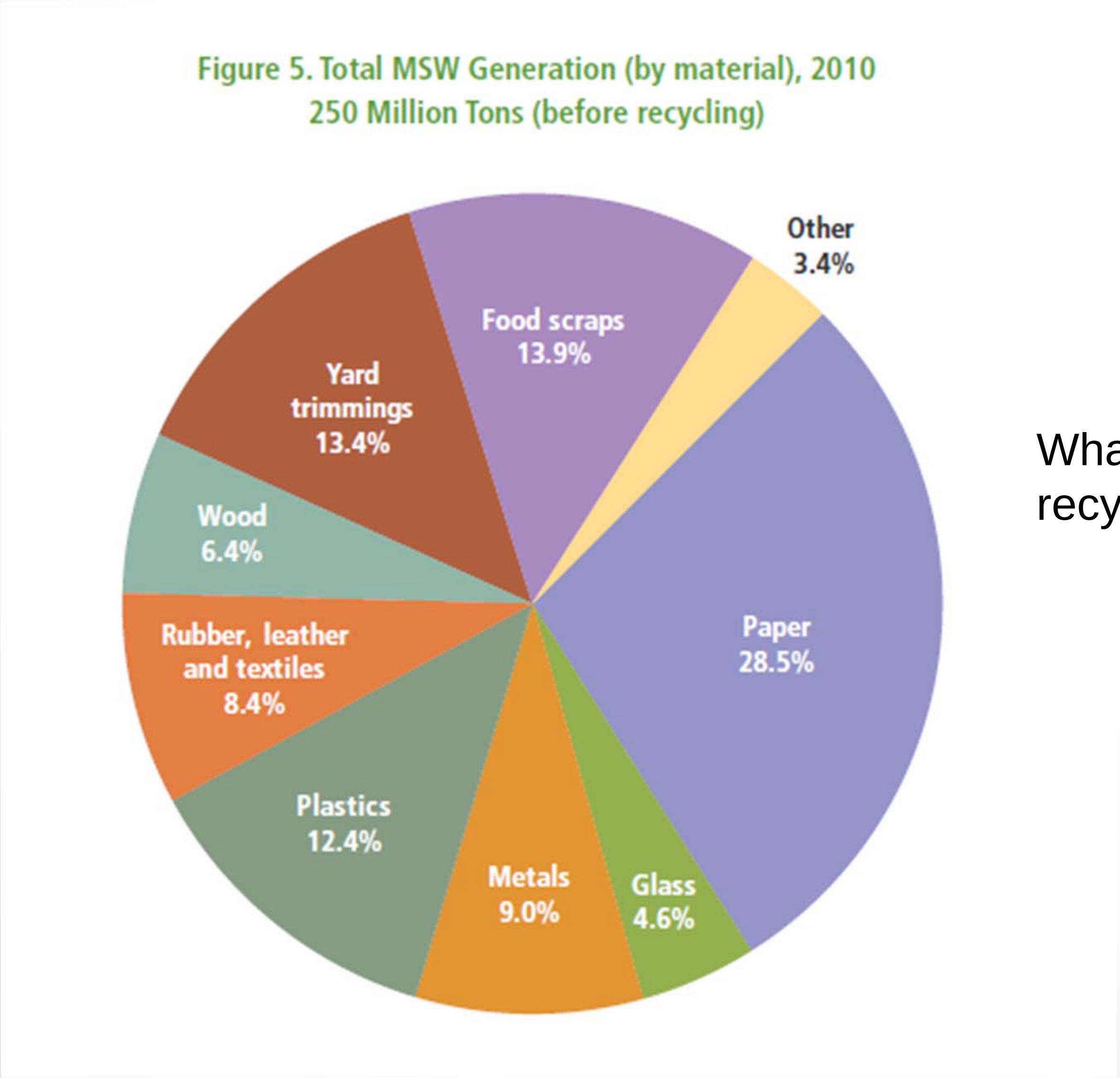
EPA definition of MSW does not include:

- MSW combustion ash
- Biosolids
- Construction & demolition waste (C&D)
- Non-hazardous industrial process waste
- Auto salvage waste

US Waste Composition as Generated

Component	1960	1980	1994	1999
Food	13.9	8.7	6.7	10.9
Yard	22.8	18.2	14.6	12.1
Paper	34.1	36.1	38.9	38.1
Glass	7.6	9.9	6.3	5.5
Metals	12	9.5	7.6	7.8
Fe	11.3	7.6	5.5	
Al	0.5	1.2	1.5	
Other	0.2	0.7	0.6	
Plastics	0.5	5.2	9.5	10.5
Rubber,Leather,Textles	4.3	4.5	6.1	6.6
Wood	3.4	4.5	7	5.3
Other	0.1	1.9	3.2	3.2

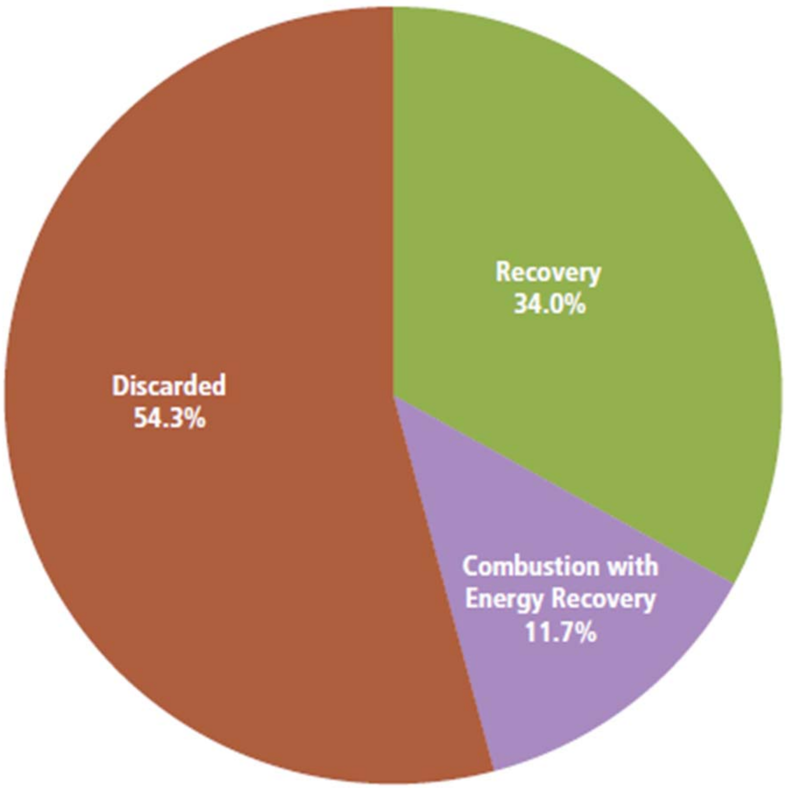
* After source reduction



What happens as more fiber is recycled?

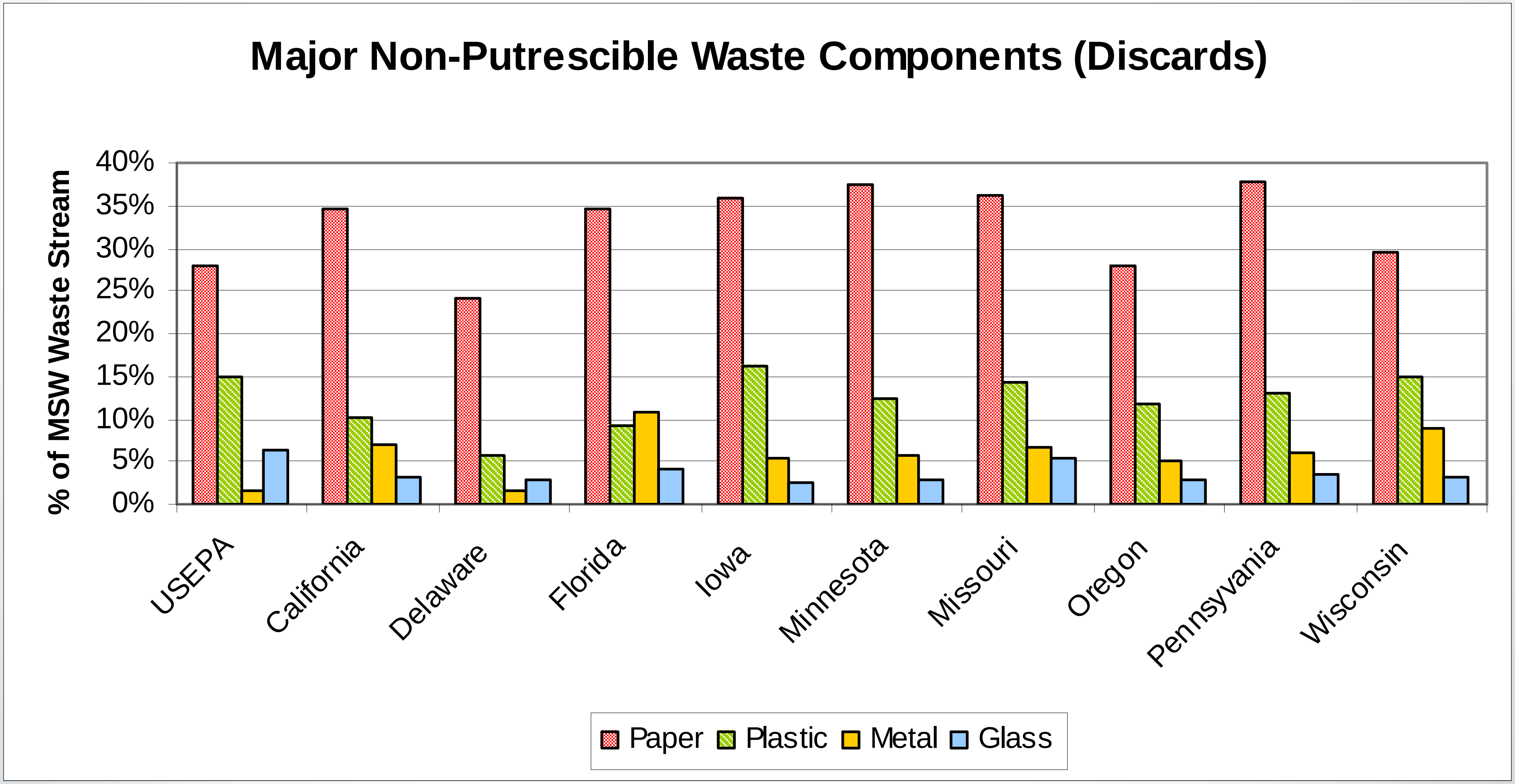
How Is The Waste Managed?

Figure 4. Management of MSW in the United States, 2010

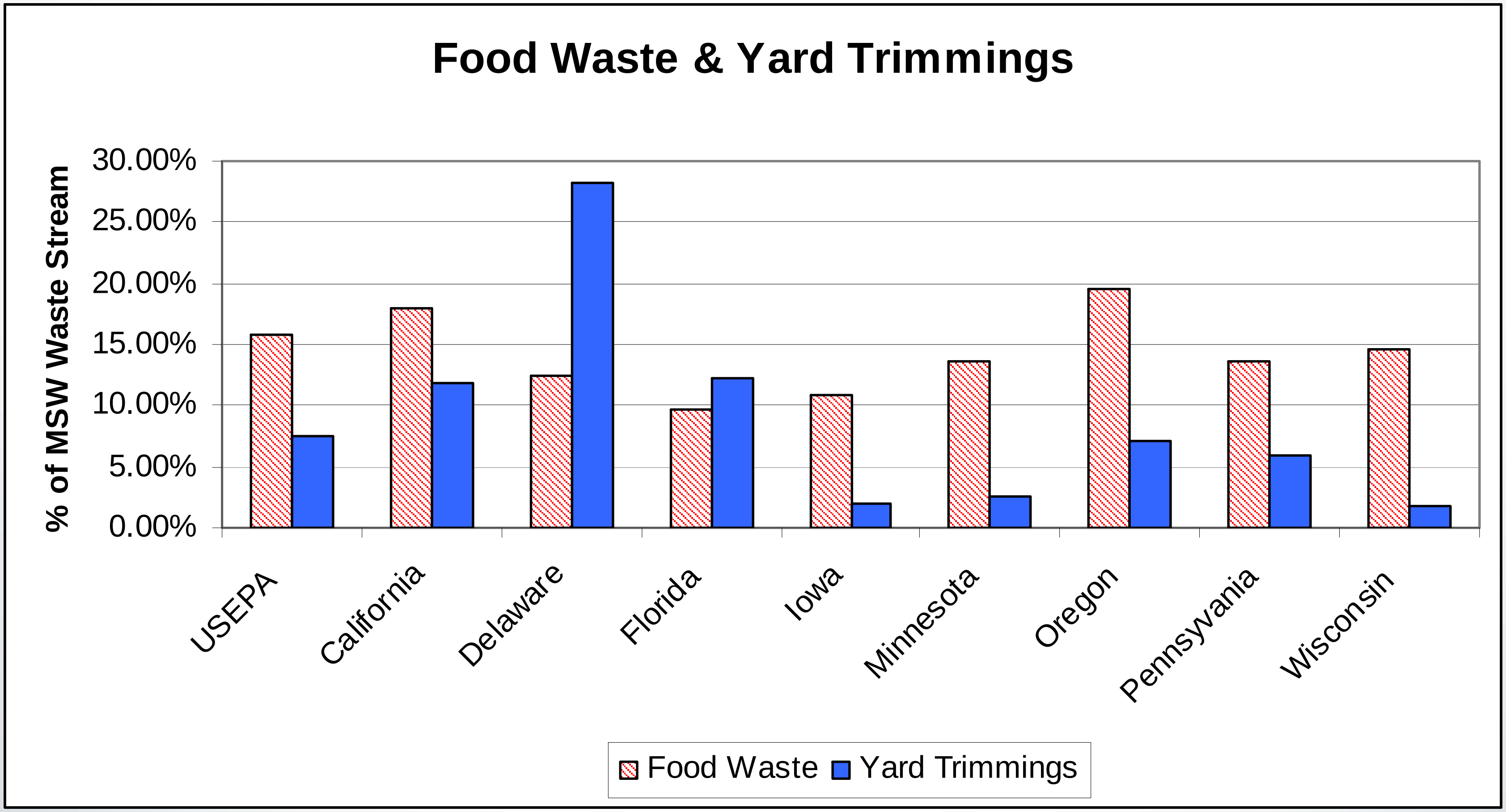


Recycling + Composting

- 1970 - 6.6% (8 million tons)
- 1980 - 9.6% (14.5 million tons)
- 1990 - 16.2% (29 million tons)
- 2003 – 30.6% (55.4 million tons)



Major Non-Putrescible Waste Components (Discards)
% of MSW Waste Stream
40%
35%
30%
25%
20%
15%
10%
5%
0%
USEPA
California
Delaware
Florida
Iowa
Minnesota
Missouri
Oregon
Pennsyvania
Wisconsin
Paper
Plastic
Metal
Glass


Food Waste & Yard Trimmings
% of MSW Waste Stream
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
USEPA
California
Delaware
Florida
Iowa
Minnesota
Oregon
Pennsyvania
Wisconsin
Food Waste
Yard Trimmings

Comparison of Waste Characterization By Weight And Volume

Component	Weight % (Discarded)	Volume % (As landfilled)	Ratio
Paper PaperBoard	31.7	30.2	1.0
Plastics	11.5	23.9	2.1
Yard wastes	16.2	8.1	0.5
Metals			
-Fe	5.9	7.9	1.3
-Al	1.2	2.4	2.0
Rubber,Leather Textiles,Other	10.7	15.4	1.4
Food	8.5	3.2	0.4
Glass	6.6	2.2	0.3
Wood	7.6	6.8	0.9

Variation in Waste Composition With Income

Component	Low	Middle	Upper
Food	40-85	20-65	6-30
Yard	1-5	1-10	2-20
Paper	1-10	15-40	20-60
Glass	1-10	1-10	4-16
Metals	1-5	1-5	2-8
Plastics	1-5	2-6	2-8
Rubber,Leather Textiles	1-5	1-4	0-2
Dirt/Other	1-40	1-30	0-20

Ref: Tchobanglous et al. 1993

Waste characterization – Purpose 1

- The first step in many engineering problems is to quantify the problem, i.e. how much and what is the composition
  To classify waste as hazardous or non-hazardous waste according to national regulation, which will determine the legal framework for the handling of the waste
- To provide data on waste quantities and composition for use in local, regional or national waste statistics as a basis for policy setting on recycling
- To document adherence to specified quality criteria for recycled materials, for example, according to metal scrap categories set by the metal scrap industry

Waste characterization – Purpose 2

- To determine the efficiency of an introduced recycling scheme by quantifying recovered and non-recovered material
- To determine waste generation rates for residential waste for the forecasting of waste quantities according to population growth
- To characterize waste quantity and composition for the design of a waste incinerator

Challenges in waste characterization

- Spatial variation: The geographical area must be defined. Spatial variations should be characterized or represented in the average characterization
  - Stadiums, vacation areas, residential, commercial

Challenges in waste characterization
Temporal variation

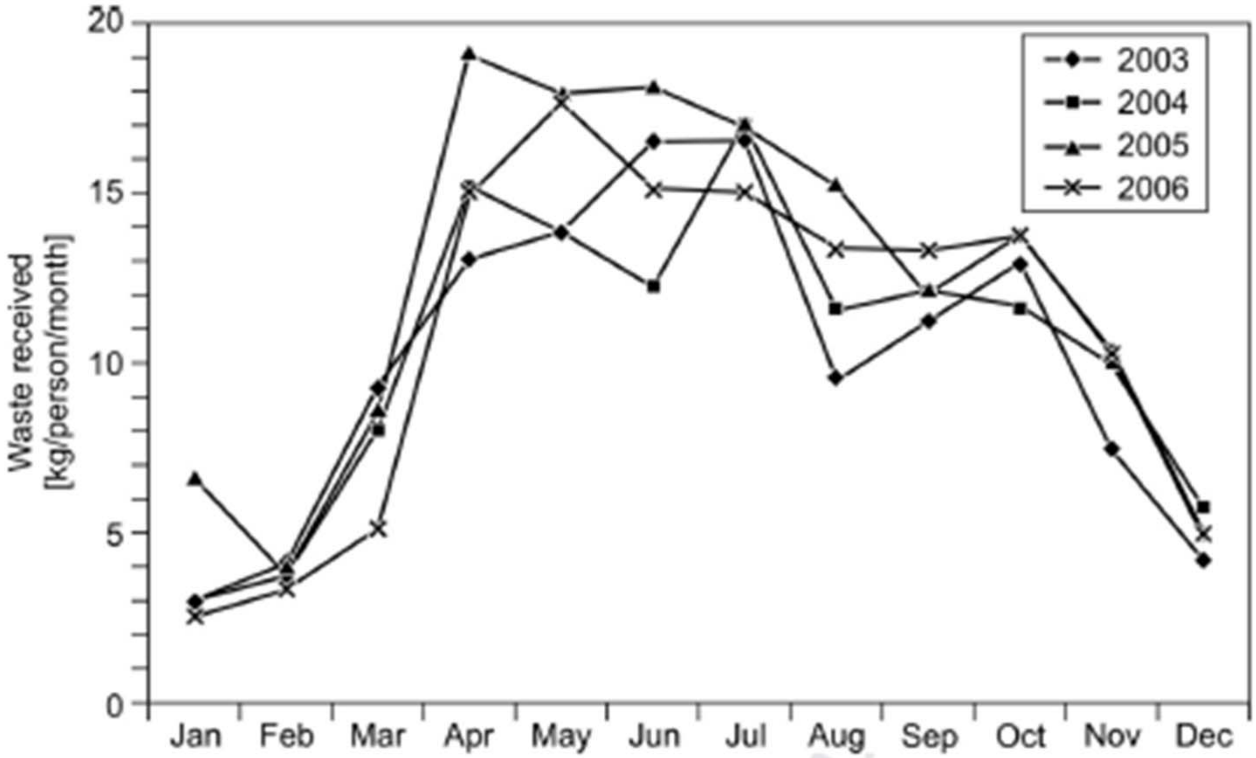


Figure 2.2.3 Monthly variations in garden waste received at the municipal composting site in Aarhus, Denmark (data provided by the Municipality of Aarhus, Denmark).

Challenges in waste characterization

- Uncertainty or fundamental variation: Although spatial and temporal representations may be properly addressed, the heterogeneity of waste is still significant and any characterization will be associated with substantial uncertainty.
- Locality Specific perturbations
- Potential for an atypical day
- Potential for magnification of error to project MSW for state or Country
- Weather/Moisture not uniform across U.S.

What kind of data might we need: 1

For each waste type:

- Sources: Where and when
- Amount: by weight
  - Volume is often not useful
- Material fractions: Volume and/or weight distribution
- Handling/process parameters: density, particle size, energy content, moisture content
- Environmental parameters: trace metal content, trace organic content, pathogens

What kind of data do we need: 2

- Weight: Prefer dry weight, but usually only available as wet waste.
- Weights should be expressed as ”Unit generation rates”:
  - Data from a small study need to be generalized
  - Useful for planning

Examples: kg waste/capita/year; kg waste/employee/year, kg waste/ m^2 of building demolition; kg waste/ hospital bed/year.

Units should be related to waste generation directly

What kind of data do we need: 3

- Monitoring is expensive and often specifically targeted to specific problems (e.g. source separation of organic household waste)
- Consequently we have only few (old) data sets of sufficient quality

What kind of data do we need: 4

- Waste collection data: Usually the most feasible, best for quantities, less suitable for characterization of composition
- Large scales are usually available at treatment facilities
- No large scales available: Load-count analysis: Count number of loads categorized in terms of type of vehicle and weight a few of the loads
- Problems are that waste may take other routes and that the number of source units may be imprecise.

What kind of data do we need: 5

- Waste characterization by UNIT GENERATION RATES is **wet weight**, as measured at the scale after collection
- Chemical data are usually produced on small samples (few grams) on a **dry weight basis** (dry matter, dry solids, total solids)
- Representative sampling is a major issue

Example 1: picking analysis for material fraction distribution

Example 2: characterization of source-separated organic household waste

NC STATE UNIVERSITY

What kind of data do we need: 6 Physical Characteristics of MSW

- Moisture
- Density / Compaction

<u>Moisture</u>

- moisture content typically reported on a wet weight basis
- Typical Value: 15 - 20%

$$\frac{\text{Mass } H_2O}{\text{Mass wet refuse}} \times 100\ \% = \%\ H_2O$$

Moisture

Sources of variation

- Refuse Composition
- Season
- Weather

Important For:

- Energy value
- Leachate Production
- Biodegradation

Density and compaction

- Important for:
  - Storage requirements
  - Collection
  - Volume in landfills

Density and compaction: 2

Typical values:

- Delivered in compactor truck: 550-900 lb/yd3
- After compaction in a landfill: 1100 - 1400 lb/yd3
- Compaction ratio - initial vol. /final vol.

$$\frac{\text{Initial Vol.-Final Vol}}{\text{Initial Vol}} \text{ X } 100$$

Waste Characterization Alternatives

A. Material flow analysis
B. Sampling and Sorting

Materials Flow Methodology - 1

Use industrial data to estimate the amount of solid waste generated

Used by US EPA

Advantages

– Representative of entire country
– Less expensive
– Provides a constant benchmark

Disadvantages

- No local information
- Not possible for food and yard waste
- Many approximations required

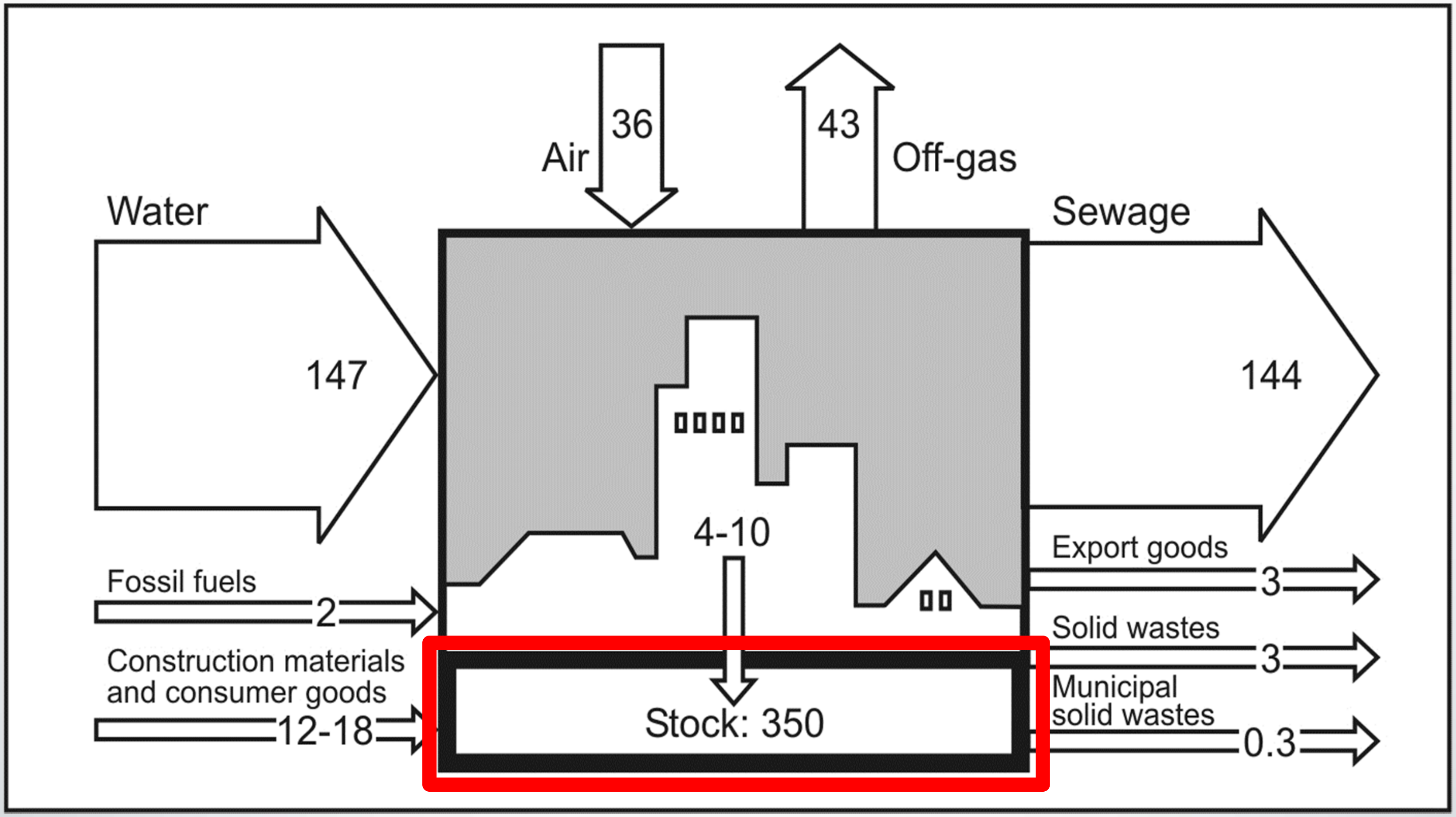
Materials Flow Methodology - 2

Table 4

PAPER AND PAPERBOARD PRODUCTS IN MSW, 2008
(In thousands of tons and percent of generation)

Product Category	Generation (Thousand tons)	Recovery (Thousand tons)	Recovery (Percent of generation)	Discards (Thousand tons)
Nondurable Goods				
Newspapers				
Newsprint	6,290	5,510	87.6%	780
Groundwood Inserts	2,510	2,220	88.4%	290
Total Newspapers	8,800	7,730	87.8%	1,070

Materials Flow Methodology - 3



Waste Sampling: 1 Analysis and testing

- Physical and Visual/Fractional
  - Material fraction distribution (glass, metal, plastic, etc.)
  - Particle size distribution
  - density
- Chemical
  - Specific organic and inorganic analysis
  - pH / alkalinity
  - Heating value
  - Elemental (ultimate) C, O, N, S, Fe, Cu, Cd, Hg
- Performance
  - Compressibility
  - Leaching
  - Respiration
  - Biochemical methane potential

Waste Sampling: 3 - Sampling Plans

1. No sampling around holidays, verify nothing unusual about a load
2. Plan for differentiation of residential, commercial and industrial waste
3. Collection

    residential vs. multi-family vs. commercial

Sample size (see chapter 2.1 in Christensen et al. 2010):

- Subsampling
- Number of samples

Waste Sampling: 4 - Sampling Plans

Industrial/Special Waste (city specific)

- Non-hazardous industrial waste
- Demolition waste
- Land debris (limited by regulation in some states)
- Could include office and cafeteria waste

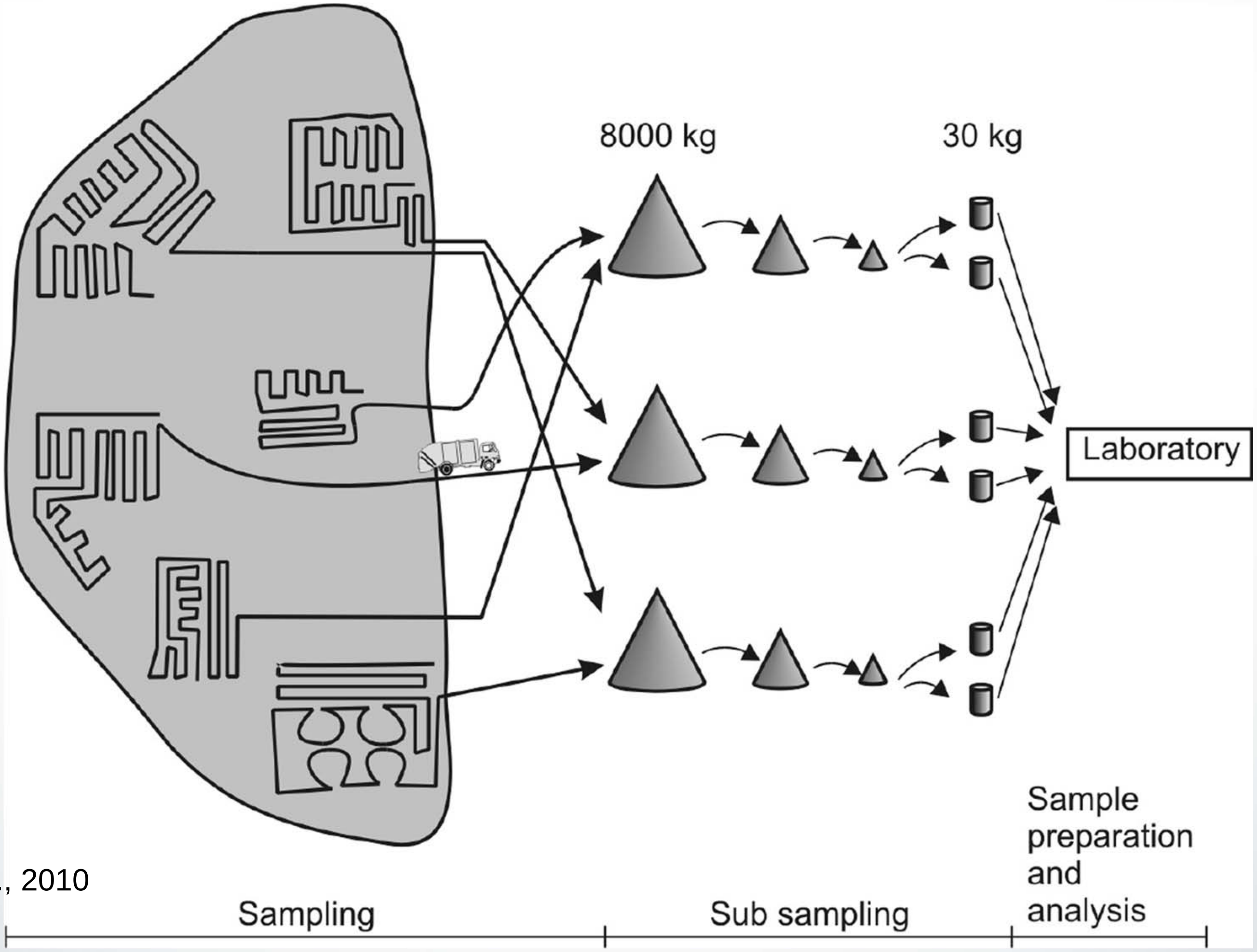
Waste Sampling: 5 - Sorting

Sorting

Sorted about 500 lbs/sample (reduced from 2000 pounds)

- Visual classification sort and weigh
- Elemental or chemical analysis
- Quarter to reduce 200 lbs to 10 to 15 pounds
- Dry, Grind to ~ 5mm particle size

Waste Sampling: 6
Pooling and Subsampling



Ref. Christensen et al., 2010


Picking analysis: material fraction distribution


CATTY

Data – Examples: 2 – Elemental Analysis

Carbon	46.2 wt % including water
Hydrogen	6.2
Oxygen	40.7
Nitrogen	0.9
Sulfur	0.2
Ash	5.8

Energy content can be estimated from elemental analysis

Data – Examples: 3 – Elemental Analysis

BTU/lb = 145.4C + 610(H_2 - 0.125 O_2) + 40S+10N
where elements are in %

Calculate - 5772 BTU/Wet lb

Rhode island reports 4145 - 5234 BTU/lb which is a typical range

Industry standard is about 5000

Data – Examples: 4 – Elemental Analysis

- Relevance to source reduction
- Study on amount of Pb, Hg, Cd in MSW
  - Electronic equipment:
  - 27% of Pb
  - These type of data can provide information for targeting a recycling or source reduction program
    - reduction in quantity or toxicity
    - quantity vs. release to environment

Source reduction

Includes mass, volume and toxicity (environmental impact) reduction

- light weighting a newspaper or box
- kg material/ m^3 refrig. space
- email
  - computers on all the time
- less Hg in batteries?
- a lighter car

Source reduction: 2

- It is hard to know if it has occurred, estimated in waste characterization
- Often there is a reason a specific toxic is present in a product - must evaluate:
  - technical feasibility and environmental performance of substitutes
  - CFCs, backyard compost
- Public health benefits
  - DDT, tetrapack