Updated: 6 December 2019

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CEE 370 Environmental Engineering Principles

Lecture #33

Solid Waste I:

Quantities, Characteristics, Processing

Reading: Mihelcic & Zimmerman, Chapt 10

Reading: Davis & Cornwall, Chapt 9-1 to 9-3

Reading: Davis & Masten, Chapter 13-1 to 13-6

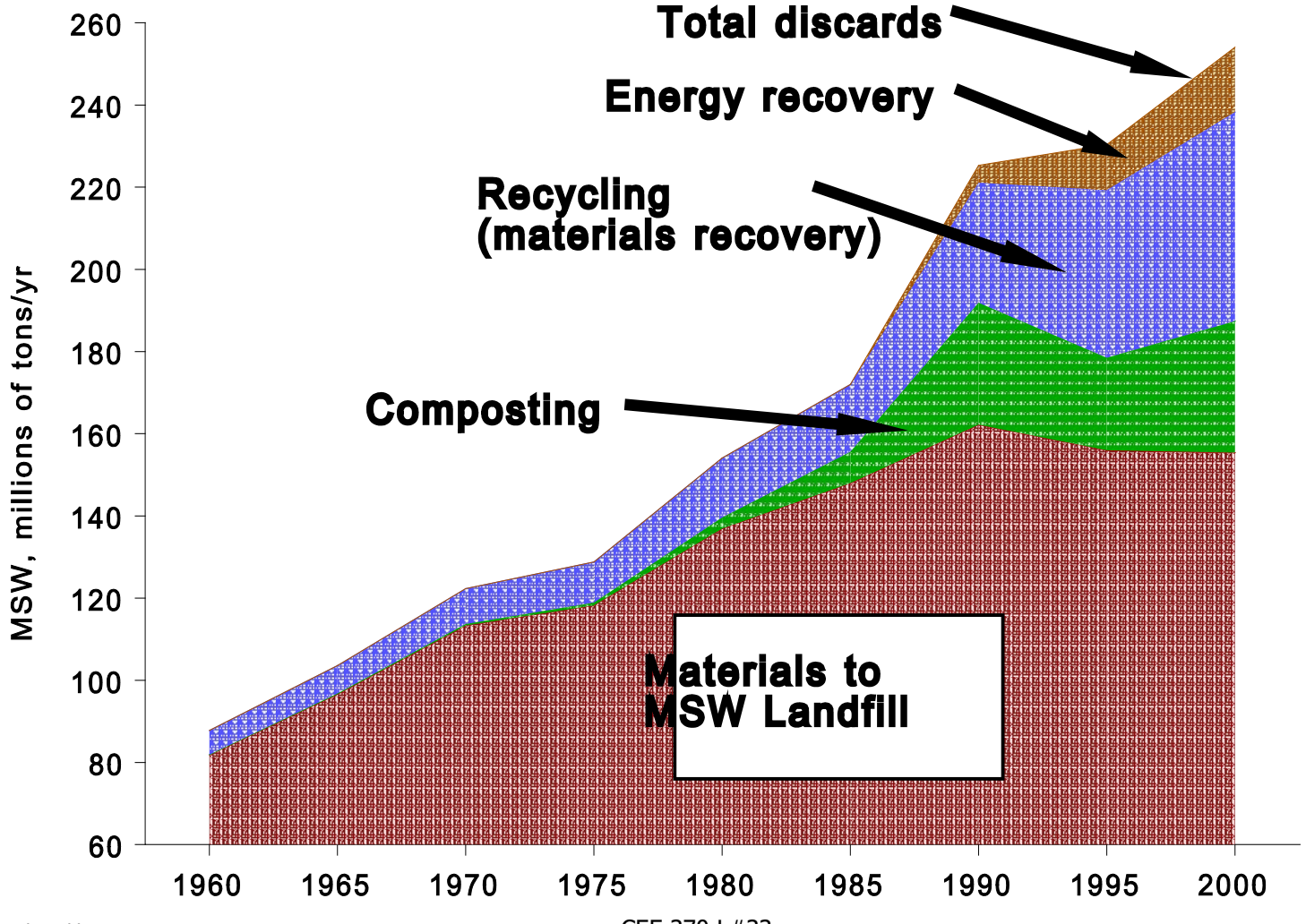
Solid Waste Disposal

- Sources
- Disposal Regulations
- Recycling
- Composting
- Collection
- Processing
- Landfilling
- Incineration

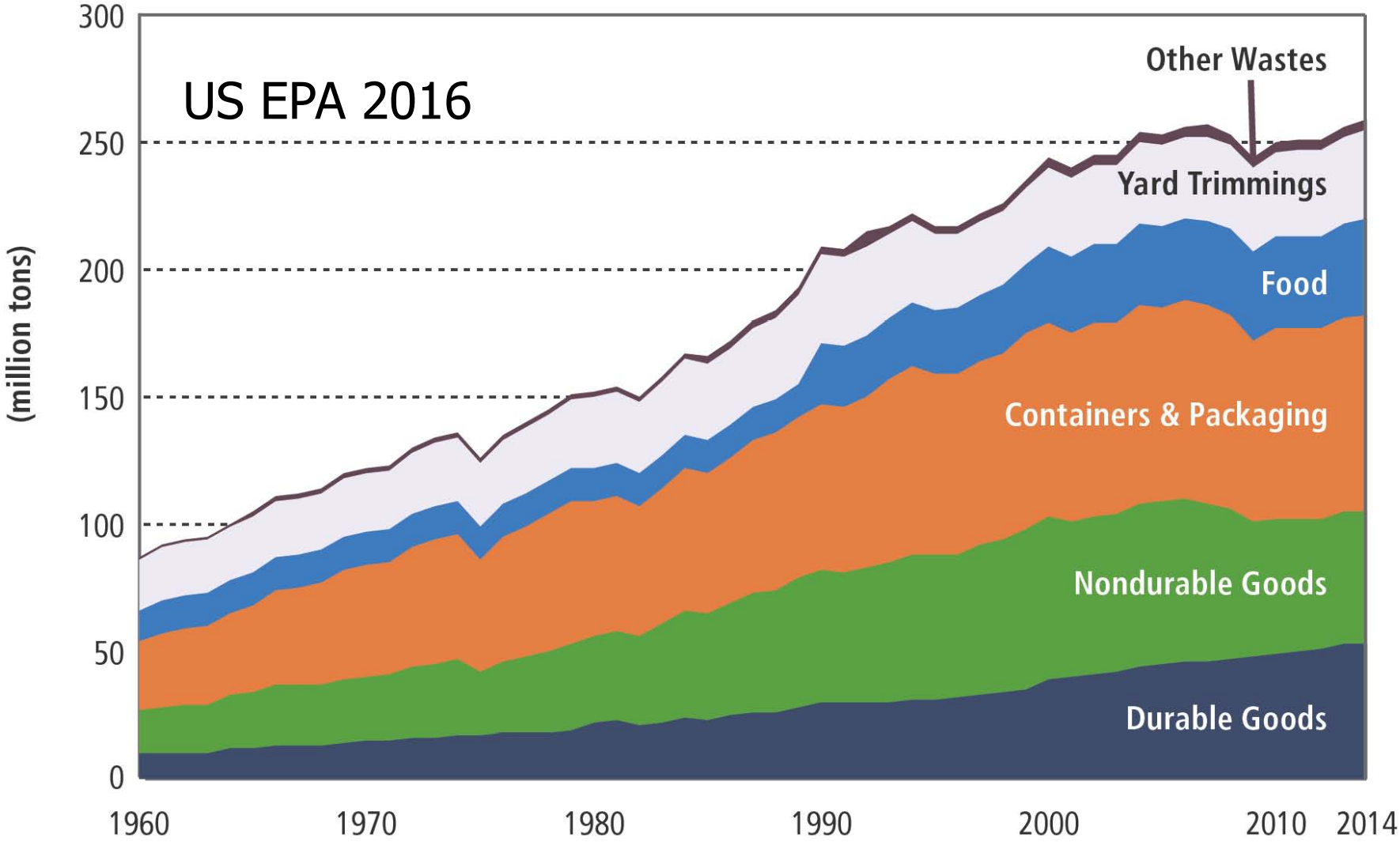
Sources

- Municipal Wastes: 24 lb/capita/day
  - metal wastes
  - plastic wastes
  - food wastes
  - paper wastes
  - yard wastes
  - glass wastes
- Industrial Wastes
- Agricultural Wastes
- Mining Wastes

MSW Disposal in US



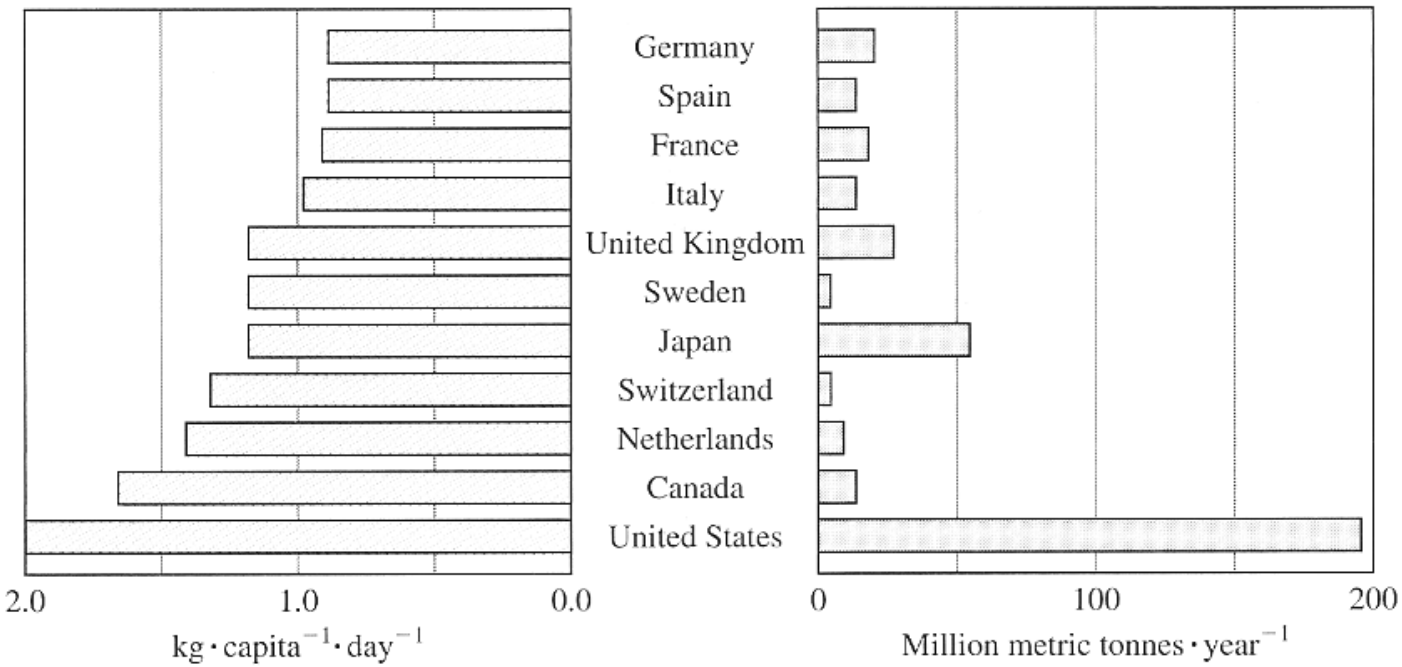
US solid waste generation



MSW mass by country

FIGURE 12–1

Variability of the masses of MSW generated by major country. (*Source: Characterization of Municipal Solid Waste in the United States: 1999 Update, Executive Summary.* EPA 530-July 1999.)



MSW recycling by country

FIGURE 12–2

Variability of recycling patterns of MSW by major countries. (*Source: Characterization of Municipal Solid Waste in the United States: 1999 Update, Executive Summary.* EPA 530-July 1999.)

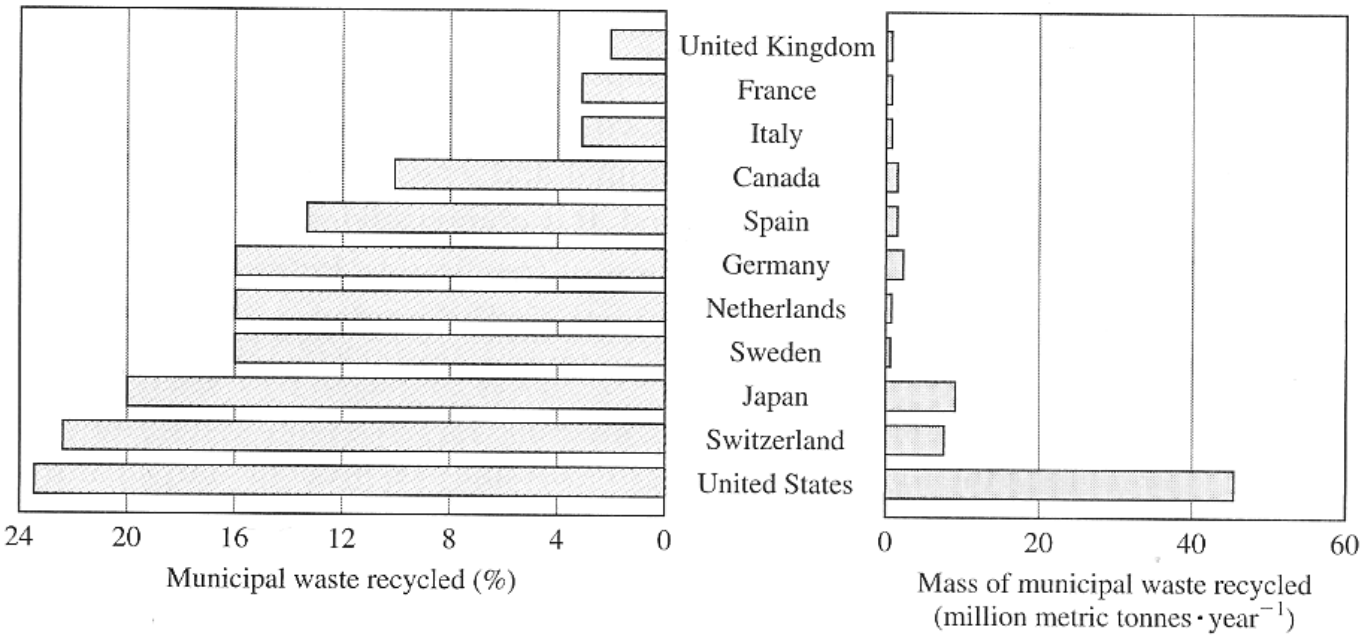


TABLE 12–1 Sources of Solid Wastes Within a Community

Source	Typical Facilities, Activities, or Locations Where Wastes Are Generated	Types of Solid Wastes
Residential	Single family and multifamily detached dwellings, low-, medium-, and high-rise apartments, etc.	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metals, ashes, street leaves, special wastes (including bulky items, consumer electronics, white goods, yard wastes collected separately, batteries, oil, and tires), household hazardous wastes
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, service stations, auto repair shops, etc.	Paper, cardboard, plastics, wood, food waste, glass, metals, special wastes (see above), hazardous wastes, etc.
Institutional	Schools, hospitals, prisons, governmental centers	As above in commercial
Construction and demolition	New construction sites, road repair/renovation sites, razing of buildings, broken pavement	Wood, steel, concrete, dirt, etc.
Municipal services (excluding treatment facilities)	Street cleaning, landscaping, catch basin cleaning, parks and beaches, other recreational areas	Special wastes, rubbish, street sweepings, landscape and tree trimmings, catch basin debris, general wastes from parks, beaches, and recreational areas
Treatment plant sites; municipal incinerators	Water, wastewater, and industrial treatment processes, etc.	Treatment plant wastes, principally composed of residual sludges
Municipal solid waste[a]	All of the above	All of the above
Industrial	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants, power plants, demolition, etc.	Industrial process wastes, scrap materials, etc. Nonindustrial wastes including food wastes, rubbish, ashes, demolition and construction wastes, special wastes, hazardous wastes
Agricultural	Field and row crops, orchards, vineyards, dairies, feedlots, farms, etc.	Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes.

[a]The term *municipal solid waste* (MSW) normally is assumed to include all of the wastes generated in a community with the exception of industrial process wastes and agricultural solid wastes.

Source: G. Tschobanoglous, H. Theisen, and S. Vigil, *Integrated Solid Waste Management,* McGraw-Hill, New York, 1993, p. 41.

MSW composition by material

FIGURE 12–3

Typical composition of MSW. Other includes miscellaneous inorganic wastes and electrolytes from urine and feces in disposable diapers. (*Source: Characterization of Municipal Solid Waste in the United States: 1999 Update, Executive Summary.* EPA 530- July 1999.)

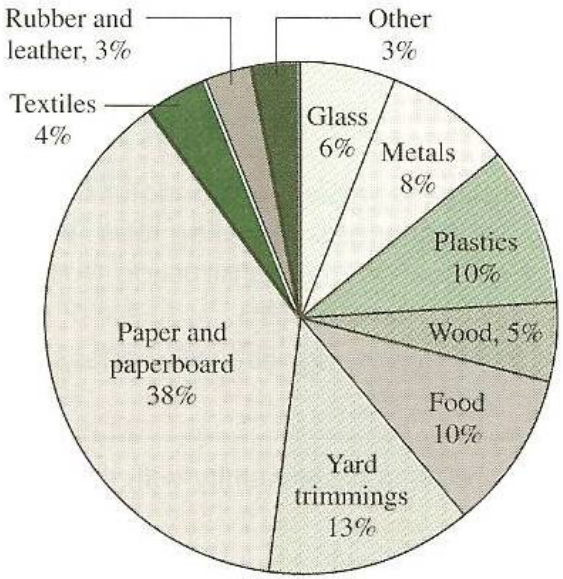
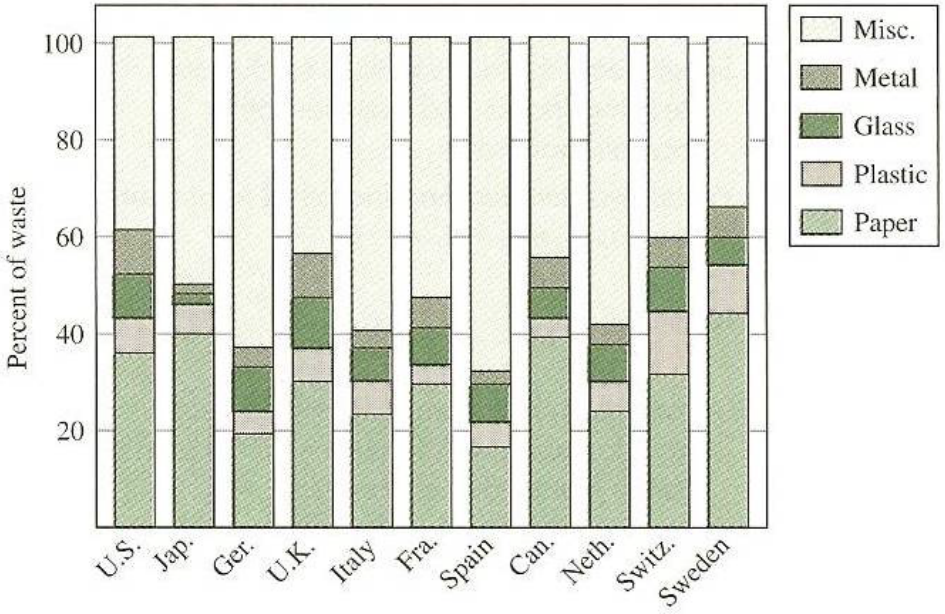


FIGURE 12–4

Variable composition of MSW across the globe. (*Source: Characterization of Municipal Solid Waste in the United States: 1999 Update, Executive Summary.* EPA 530- July 1999.)



Municipal Waste by type

- paper wastes: 32%
  - newspapers, books, magazines, packaging
  - good recycling potential
- yard wastes: 19%
  - grass clippings, brush, leaves
  - varies seasonally & geographically
- glass wastes: 7%
  - bottles, glass jars
  - almost all can be recycled
- metal wastes: 8%
  - beverage & food containers, scrap appliances
  - good recycling potential
- plastic wastes: 10%
  - recycling programs developed
  - recycling codes
- food wastes: 8%
  - declined from 15% in '85
  - affected by garbage disposals

Toxics in Municipal Sludge

- Problem with buildup of heavy metals in soil receiving sludge
- Landfilling is an option
- Leachate treatment to reduce volume and stabilize

Constituent	Range, mg/dry kg	Typical, mg/dry kg
Chromium	10-99,000	500
Copper	84-17,000	800
Nickel	2-5300	80
Zinc	101-49,000	1700
Cadmium	1-3410	10
PCBs	1.5-9.3	3.8
Lindane		0.8
Chlordane	0.6-19	4.8
Hexachloro-benzene		0.6

Industrial Classes

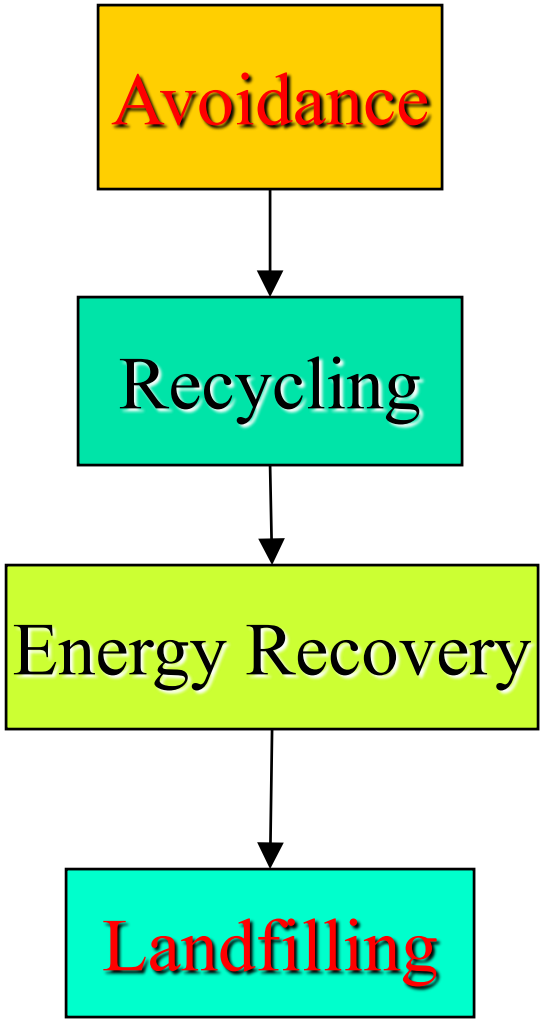
US Dept. of Commerce, Standard Industrial Classification (SIC)

Industry	Total, 1000 ton/yr
Organic Chemicals	2138
Ferrous Metals	9892
Ag. Chemicals	11365
Electric Power	54612
Plastics & Resins	4270
Inorganic Chemicals	44651
Clay, Glass, Concrete	16806
Pulp and Paper	16284
Nonferrous Metals	10512
Food	79993
Water Treatment	9121
Petroleum Refining	747
Rubber & Misc.	630
Transportation	880
Other Chemicals	548
Textile Mfg.	159
Leather	20
TOTALS	262628

SW Regulations

- 1965: Solid Waste Disposal Act
  - early recognition of MSW
  - promoted better management
  - supported R&D
- 1970: Resource Recovery Act
  - more emphasis on recycling & energy recovery
  - PHS investigated disposal of hazardous wastes
- 1976: Resource Conservation & Recovery Act (RCRA)
  - control of hazardous waste storage, treatment and disposal
  - has been amended and reauthorized many times

Solid Waste Hierarchy



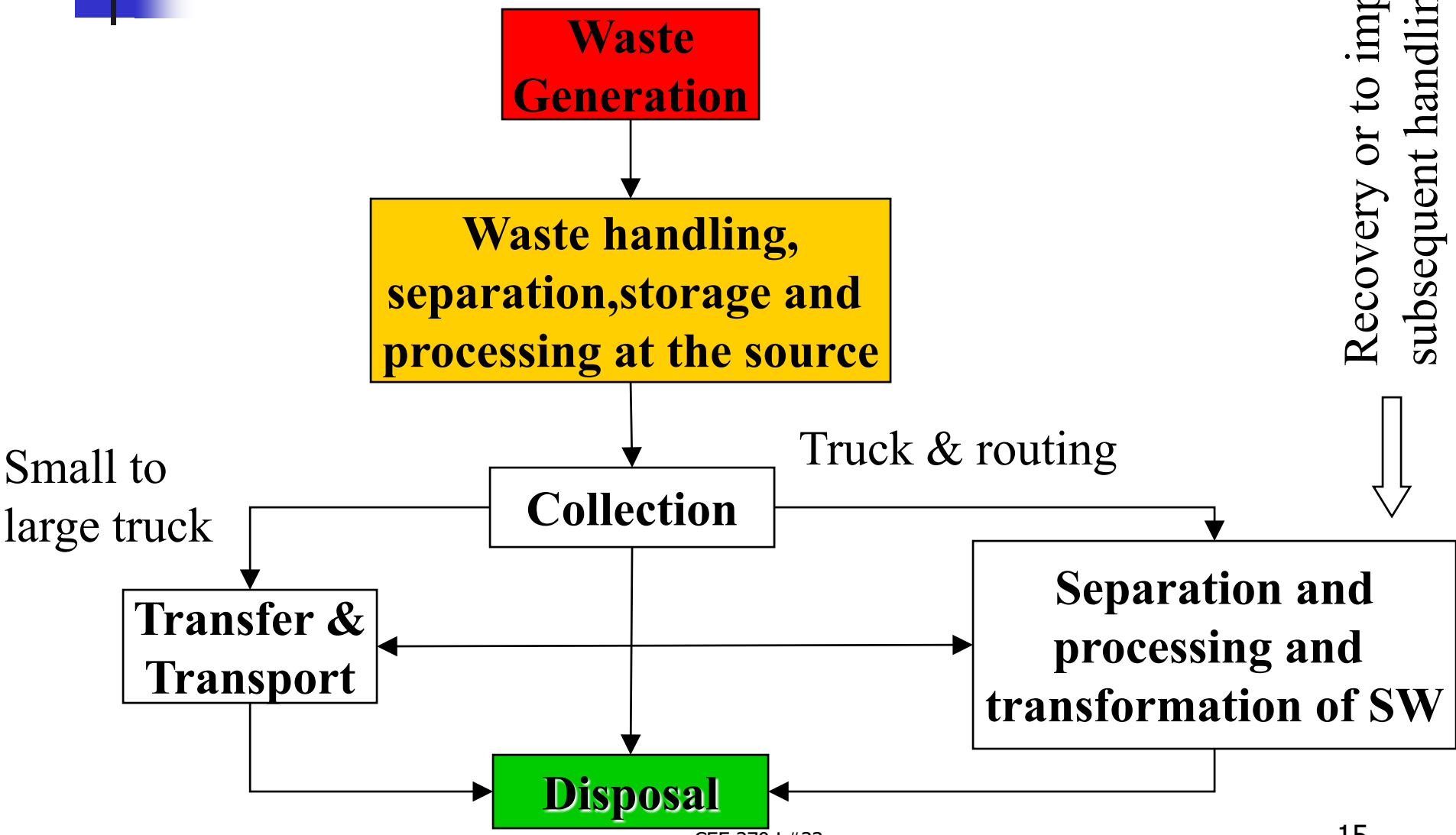
Source Reduction

Materials recovery

Or transform to a product

Lowest in hierarchy

Functional Elements of a SW Management System



Composting

- controlled aerobic partial degradation of organic wastes
- natural microbial processes: fungi, bacteria, protozoa
- especially useful for leaves that used to be burned
- waste volume reductions of 40-75%
- wastes placed in windrows which are periodically mixed

Elements of Composting

- Collection
  - curbside, drop-off, required public education
- Preprocessing
  - grinding, separating, wetting, screening
- Composting Parameters
  - oxygen: supplied by natural aeration
  - nitrogen: C/N ratio varies with season
  - temperature: heat release
  - moisture: at least 50%

Physical Properties of SW

- Moisture

$$moisture\ content = \frac{mass\ of\ moisture}{total\ mass\ of\ waste}$$

  - Important for composting

M&Z, equ. 10.1

- Dry Mass

$$dry\ mass = total\ mass\ of\ waste\ x\ (1 - moisture\ content)$$

Compare: M&Z, equ. 10.2

- Density
  - Important for calculating space requirements

See: Mihelcic & Zimmerman, Section 10.2.5

Elements of Composting (Cont.)

- Multi-Level Composting
  - Minimal-Level: 12x24 ft. windrows turned annually, center become anaerobic, 3 yrs.
  - Low-Level: 6x12 ft. windrows mixed monthly to quarterly, watered, 1.5 yrs.
  - Intermediate-Level: same but turned weekly, specialized equipment, 5 wks.
  - High-Level: 10x200 ft., forced air, water & N added, 2-10 wks., then left for 3-12 month.
- Compost Uses: landscaping, gardening, farming

Collection

Collection Service	Description	Cost
Curbside	Resident responsible for placing trash containers at curbside and returning them after collection.	Low
Backyard Carry	Collection crew responsible for entering residents property, transporting containers to collection vehicle and returning them to storage location.	High
Alley	Resident responsible for placing trash containers by alley and returning them after collection.	Low

Collection Vehicles

Commonly used for trash collection

Also used where recyclables are collected

Vehicle Type	Capacity, yd^3
Rear loaded compactor	20 to 25
Front loaded compactor	30 to 40
Side loaded compactor	25 to 35
Multi-bin recycle	20 to 30
Hauled container bins	20 to 40

Compression to 50%

Solid Waste Processing

- Sorting
  - at point of generation, transfer station, or at landfill
  - mechanical or manual
    - magnets, compressed air, inertia devices
- Compaction
  - low pressure in collection vehicle
  - high pressure at transfer station or landfill
- Shredding

Recycling

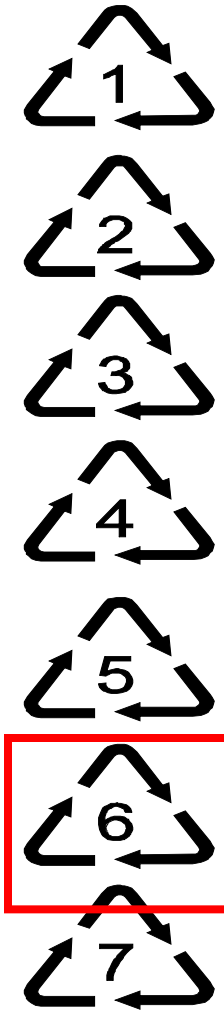
Recycling is the recovery and reuse of a product which would otherwise be thrown away.

Preliminary steps for a recycling program:

- **An accurate analysis of the sources and content of the solid waste stream.**
- **Evaluation of any existing recycling programs. Existing programs must be integrated into the new or expanded program.**
- **Identification of public attitudes about recycling.**
- **Determine what markets exist for the potential recycled materials. (It does no good to collect materials for recycling if no market exists for their use!)**
- **Determine the best recycling options.**

See: Mihelcic & Zimmerman, Table 10.9

Plastic Recycling Codes



- Polyethylene terephthalate, PET
  - Soft drinks, food jars
- High-density polyethylene, HDPE
  - Milk bottles, grocery bags
- Polyvinyl chloride, PVC
  - Blister packs, pipe, bags for bedding
- Low-density polyethylene, LDPE
  - Bags for dry cleaning, frozen foods
- Polypropylene, PP-5
  - Take-out containers
- Polystyrene, PS-6
  - Styrofoam cups, plates, packaging
- Other, 7

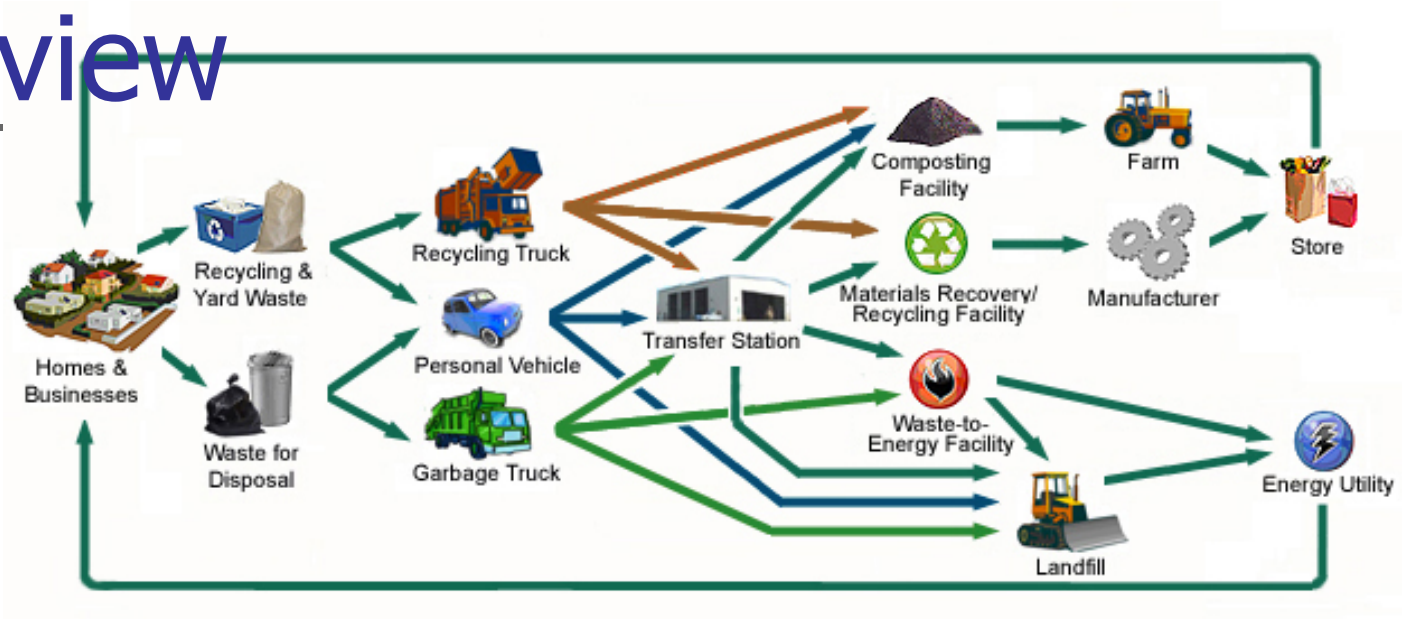
Not acceptable at MRF

Recycling Options

- Drop-off Centers
  - can be staffed or unstaffed
- Curbside Collection
  - more effective, but more expensive
- Voluntary vs. Mandatory Recycling
  - enforcement?

Overview

- The network



Recycling by category

TABLE 12–2 Recycling Rates for Some MSW Components

Material	1990 Recycling Rate (%)[a]	1997 Recycling Rate (%)[b]	2000 Projected Recycling Rate (%)[b]
Paper and paperboard	28.6	41.7	44–46
Glass	19.9	24.3	29–33
Steel	23.0[c]	38.4	41–46
Aluminum	NA	31.2	37–39
Plastics	2.2	5.2	6–7
Yard trimmings	12.0	41.4	52–54
Rubber and leather	NA	11.7	14.5–15.9
Wood	NA	5.1	8.6–10
Clothing and other textiles	NA	12.9	13–14.7

NA = Data not available

[a] U.S. EPA *Reusable News*, Fall 1992.

[b] Characterization of MSW in the U.S.: 1998 Update, US EPA, Washington, DC.

[c] Combined data for all metals.

- MRF, Springfield

Unacceptable – Why?

- **Plastic Bags:** These cannot be recycled through your recycling program because they wrap around the conveyor belt at the recycling facility, which causes the line to be shut down in order to strip away all the bags. Bags CAN be recycled through your local grocery stores.
- **Bagged Materials:** These cannot be recycled both because they include plastic bags (see above) but also because they would need to be opened by hand to sort materials. There is neither the time nor the personnel to accommodate this. Bagged materials will be THROWN AWAY.
- **Items that Wrap and Tangle:** Includes items such as hoses, light strings, anything which could wrap around a conveyor belt (think of materials which clog up a lawnmower, for instance). These materials are both non-recyclable and cause the line to be shut down at the recycling facility.
- **Syringes:** These are a bio hazard and pose a danger to workers. Needles of any kind should be disposed of properly through a municipal or other safe SHARPS disposal program. Contact your local municipality for options.
- **Food Waste:** Food Waste should never be left inside of recyclables, nor placed in a recycling collection bin. Think of the icky mess and the sorters having to handle the waste! Food waste CAN BE COMPOSTED. Check with your municipality for options including compost bin purchase programs.
- **Hazardous Waste Containers:** Hazardous chemicals leach into plastics, rendering the plastic unfit for other uses. Please deposit empty containers which have held hazardous chemicals into the trash.
- **Styrofoam:** Expanded polystyrene (EPS, trademarked 'Styrofoam') is not accepted at local recycling facilities, as its light weight makes it too costly to ship. However, EPS can be shredded and compressed into blocks to be transformed into pellets for recycling into picture frames and car bumpers. Please check the Springfield MRF website for Styrofoam recycling options.

Unacceptable – Why? (cont.)

- **Plastic cups**: Such as Solo cups are categorized as a # 6 plastic. This is the same category as Styrofoam, polystyrene, and expanded polystyrene. There is no market for these items, please deposit in trash.

- **Light bulbs:** Incandescent light bulbs have a different type of glass from regular bottles and jars, which makes them unrecyclable, plus they invariably break making them a hazard for workers. These should be deposited in the trash. Fluorescent light bulbs contain mercury and should be properly recycled. Several large home improvement stores accept fluorescent bulbs free of charge. Please also check with your municipality to see if they collect fluorescent light bulbs.

- **Pots, pans and scrap metal:** These items get caught in the conveyor belts at the recycling facility. Please check your municipality for scrap metal and swap shop options.

- **Dishes:** Ceramics and other materials which make up dishware is not recyclable. Please check with your municipality for swap shop options; otherwise please place in the trash. **Electronics:** Electronics contain some hazardous chemicals and sometimes leaded glass.

- Electronics should be properly recycled; please check with your municipality for electronics recycling options.

From: http://springfieldmrf.org/whats-recyclable-at-the-mrf

Processing

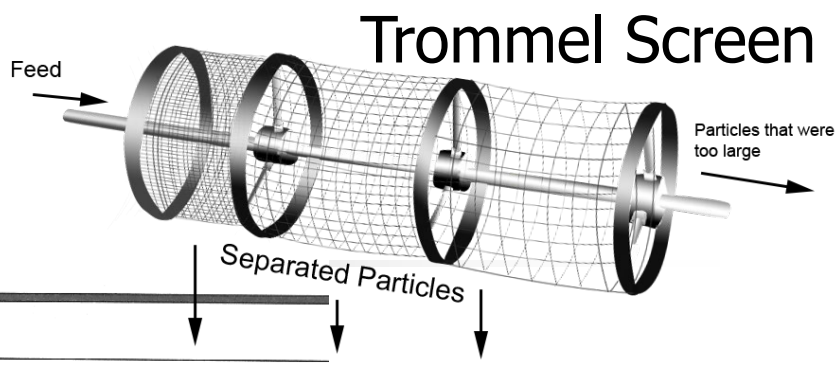
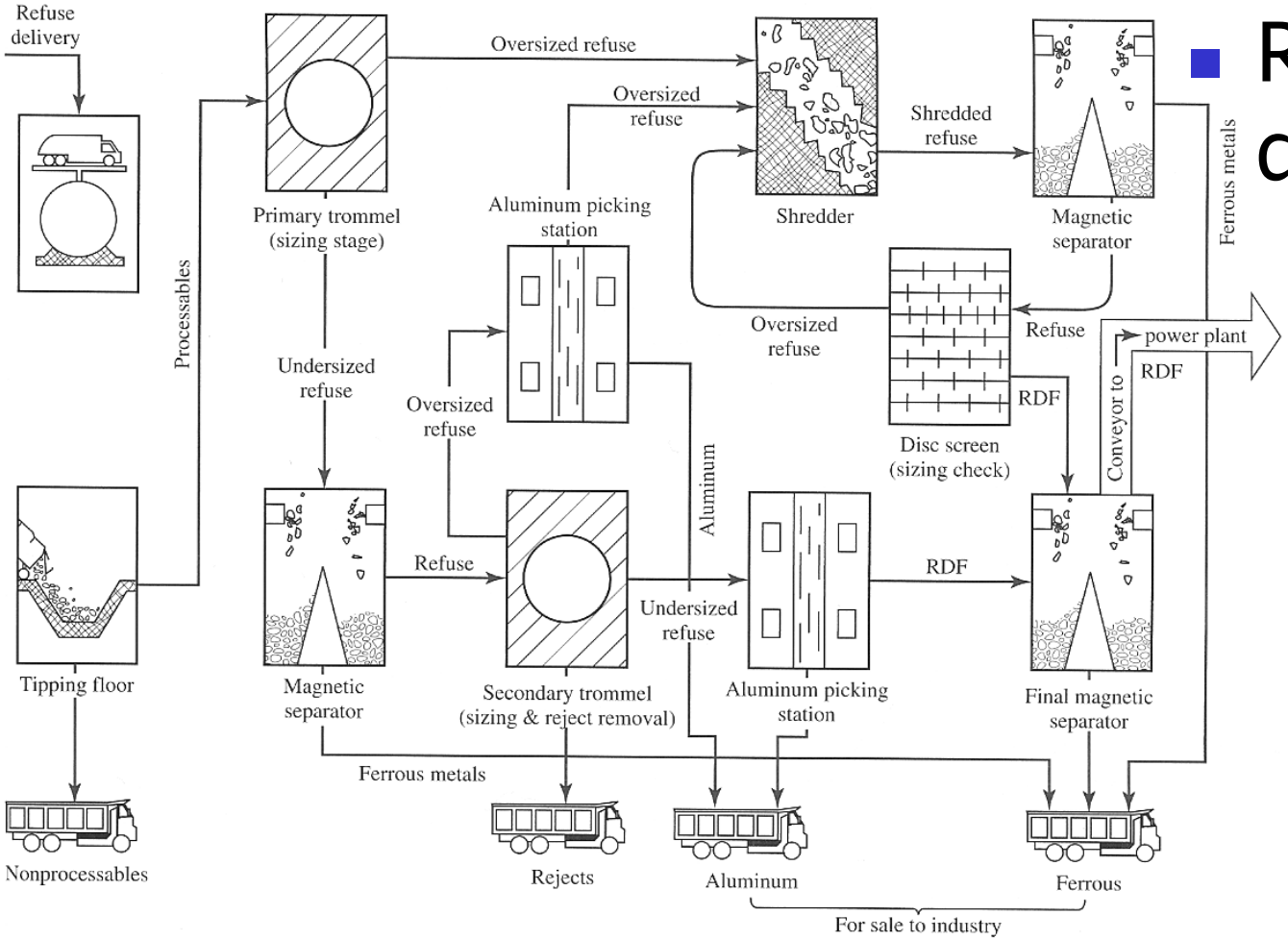


FIGURE 12–10

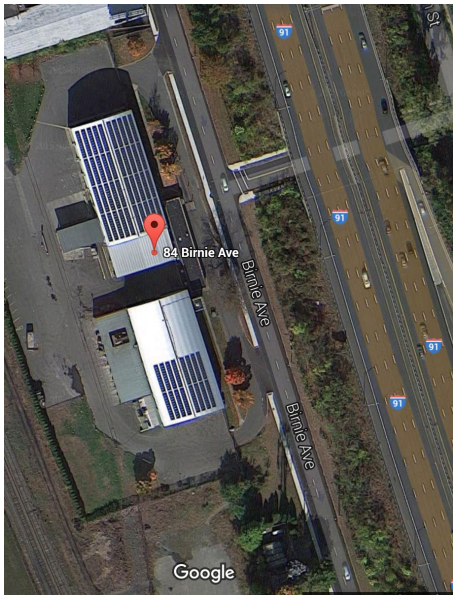
Southeastern Virginia Public Service Authority's RDF plant.

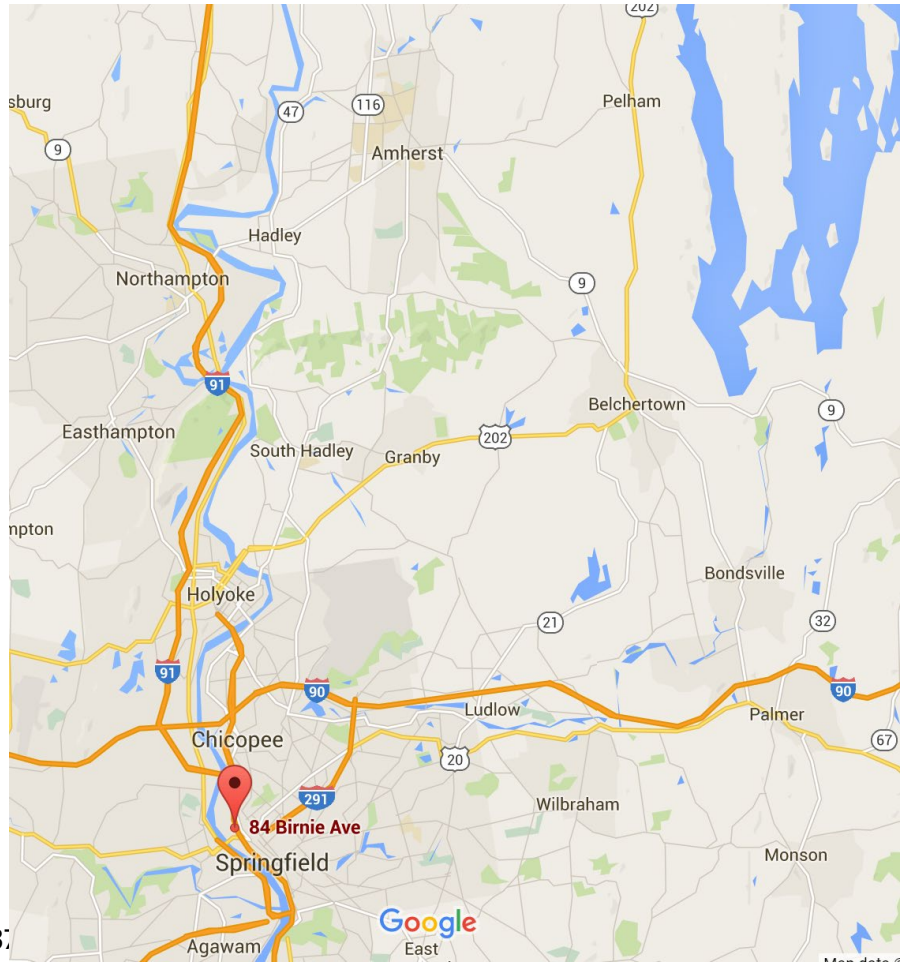


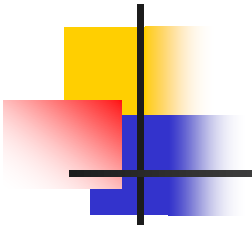
- RDF: refuse-derive fuel

Regional recovery facilities

- Springfield MRF
  - Serves 78 communities in Western MA
  - Operating since 1990
  - http://springfieldmrf.org/







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