# Chemistry 321

# 6. Waste

# Overview

1. Introduction
2. Carbon footprints
3. Waste management
4. Domestic waste
5. US government regulations

# 6.1. INTRODUCTION

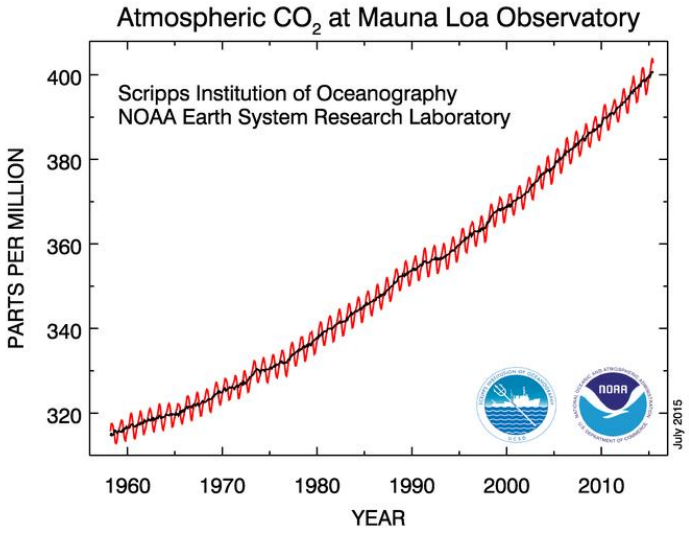
# What is waste?

- ***Waste*** and ***wastes*** are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or it is worthless, defective and of no use. (Wikipedia)
- "materials that are not prime products (that is products produced for the market) for which the initial user has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose." (UN Statistics Division)

# 6.2. CARBON FOOTPRINTS

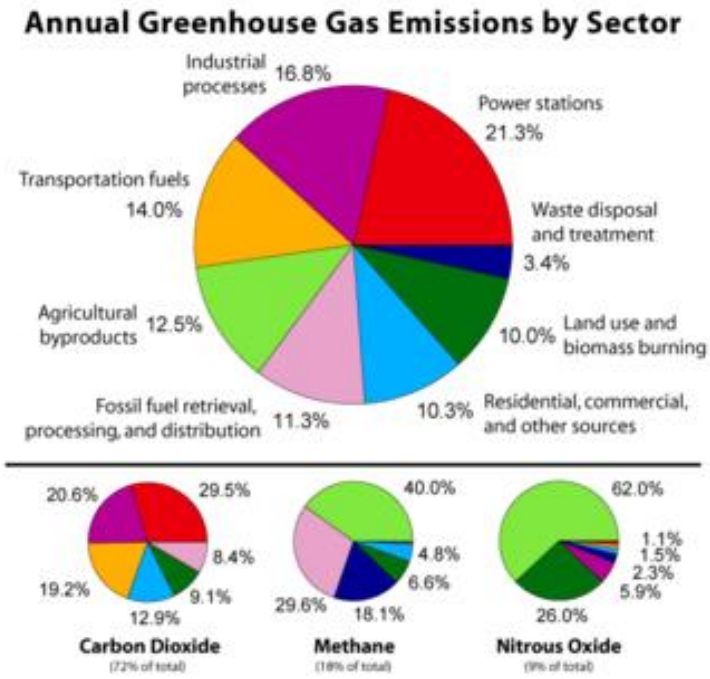
# Carbon dioxide ($CO_2$) as waste

- When we think of waste, we often visualize either domestic waste (garbage), or of industrial pollution. However, processes may produce less obvious things like carbon dioxide which are invisible and odorless. But our (previously ignored) carbon dioxide waste (from burning gasoline, coal or natural gas) is building up, and is now considered to be the major cause of global climate change.




Graph from US NOAA

# Carbon footprint




Graphic by Robert A. Rohde, CC-BY-SA license

A carbon footprint is traditionally defined as "the total sets of greenhouse gas emissions caused by an organization, event, product or person." Natural sources of these greenhouse gases (GHGs) must be allowed for. It may sometimes ignore non-carbon greenhouse gases such as nitrous oxide, which may be significant.

# Carbon footprint

Picture of Ferrybridge power station, UK, by Dave Bevis CC-BY-SA license

There are more obvious, *direct* sources of GHGs, such as the gasoline engine in our car. However, life-cycle analysis tells us we must look cradle to grave, and include *indirect* sources. This might include (for example) the effects of fuel used to fertilize and harvest the corn we are eating, or in generating electricity used to run a refrigerator, or the impact from transporting and disposing of an old sofa in a landfill.

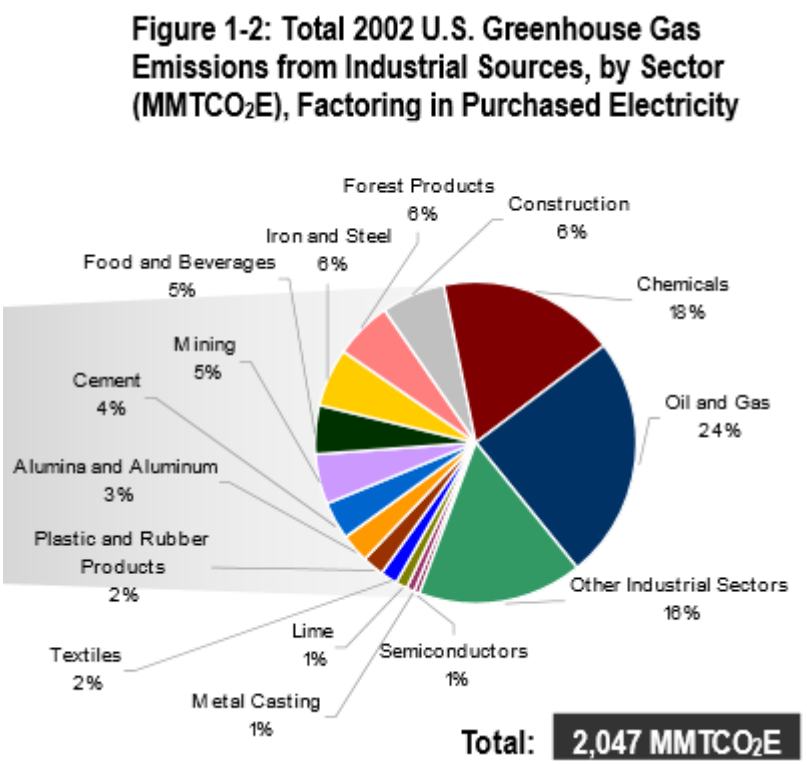
# Not just energy

Picture of Lynemouth aluminium plant, UK, by Ian S
CC-BY-SA license

Material processes may produce GHGs without involving obvious fuel or electricity sources.

- For example, aluminum production usually uses renewable hydro power for electricity. However, $CO_2$ is produced from the oxidation of the anode, and the very powerful GHG carbon tetrafluoride is an unwanted by-product.
- Production of concrete or steel involves decomposing limestone and thereby releasing $CO_2$. See p 108 in Hill.

# Life Cycle Impact Assessment




As mentioned in previous units (e.g., Unit 4), LCIA should normally include both direct and indirect sources for the carbon footprint. See pp111-112 of Hill. The EPA has attempted to quantify greenhouse gas emissions by various sectors for this purpose.

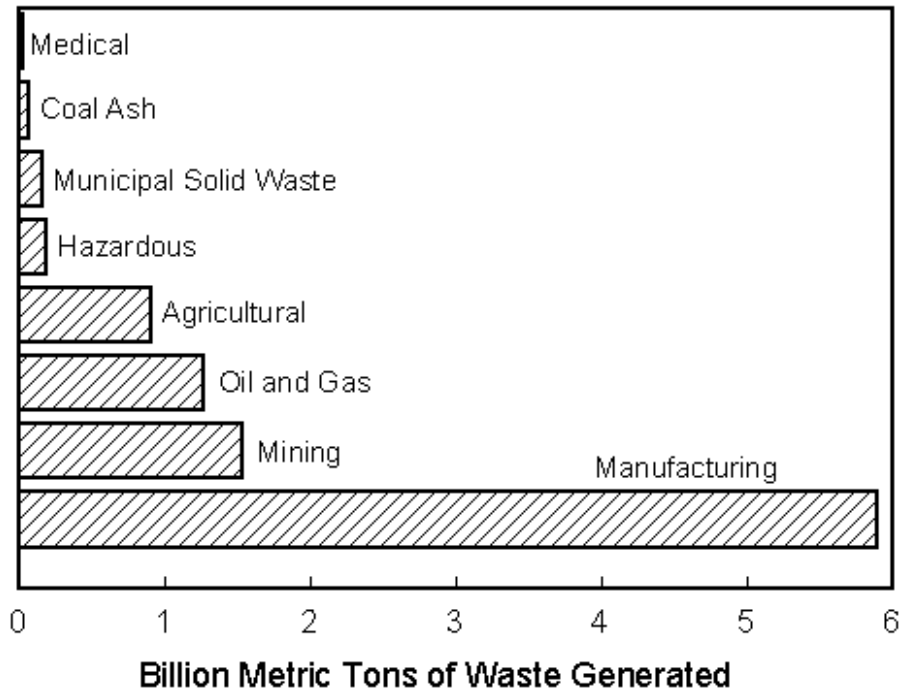
# 6.3. WASTE MANAGEMENT

# Waste Management

- Traditionally done as an afterthought
- With much tighter regulations now, waste management now taken seriously, as both a legal and an economic issue.
- We can classify waste as hazardous and non-hazardous.
- Alternatively may classify as controlled and uncontrolled.

# US waste production (1985)

**Figure 8. Major Waste Types by Weight in the United States (1985).**



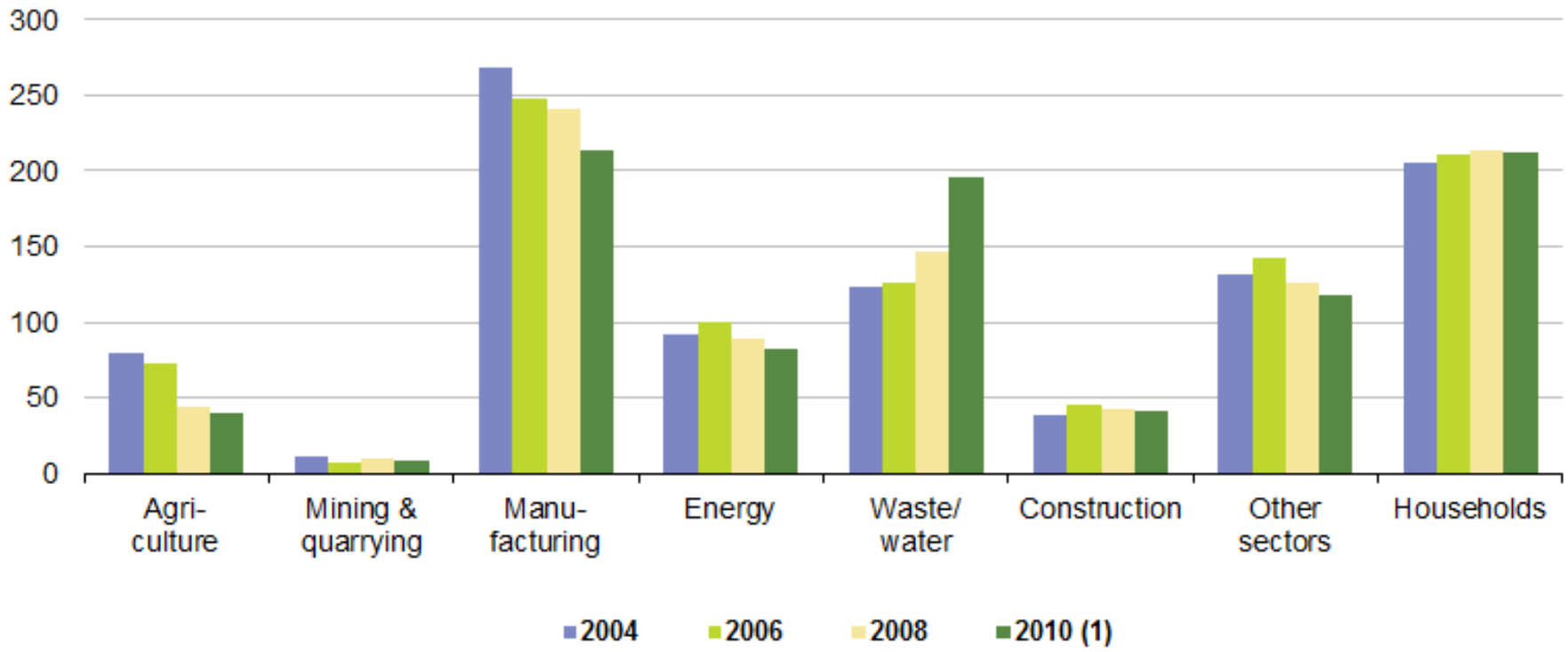

**Note: A large fraction of the total weight in the industrial categories is water. Dry weight of industrial wastes can be as low as 10 percent of the total.**

**Source: US Congress, Office of Technology Assessment, *Managing Industrial Solid Wastes from Manufacturing, Mining, Oil, and Gas Production, and Utility Coal Combustion*, OTA Report No. OTA-BP-O-82 (Washington, D.C.: US Government Printing Office, 1992).**

Figure taken from "Materialization and Dematerialization: Measures and Trends"
IK Wernick et al, Rockefeller Univ
*Daedalus* 125(3):171-198
(Summer 1996)
Sorry I don't have newer data!

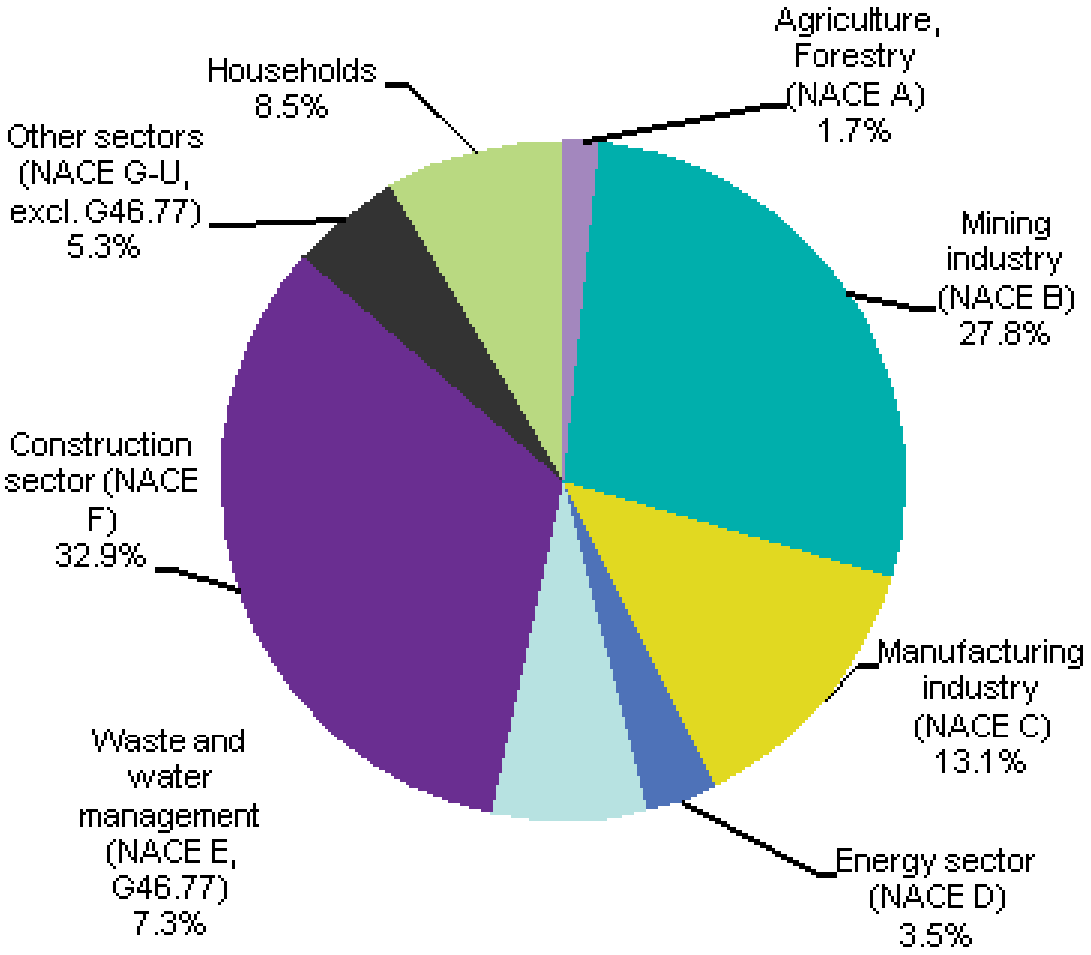
# Waste production in the European Union (EU-27) (2010)

excluding mineral wastes. Population = 503 million



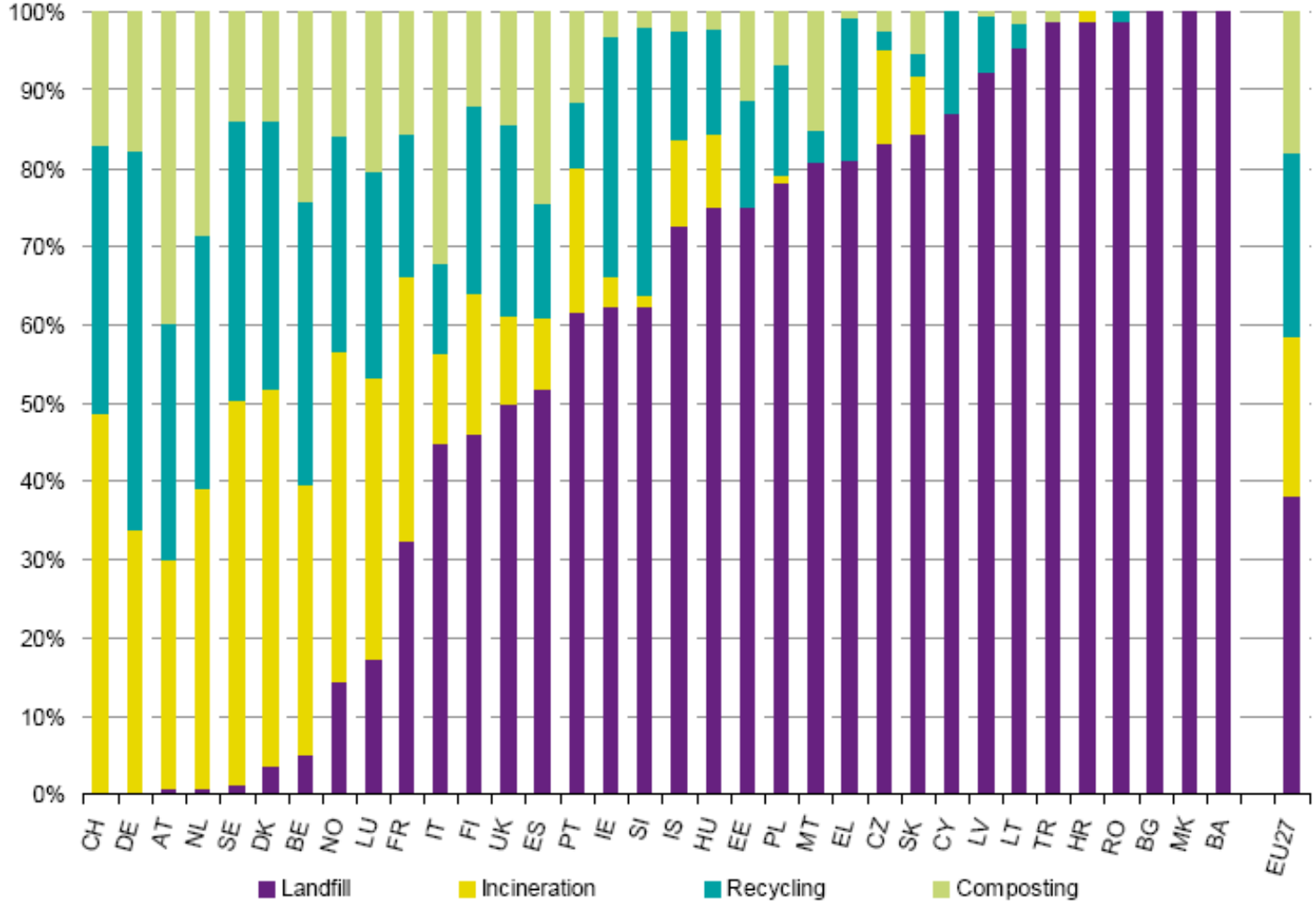

Figures in millions of tonnes, taken from [EU waste statistics page]

# Total of waste production in the European Union

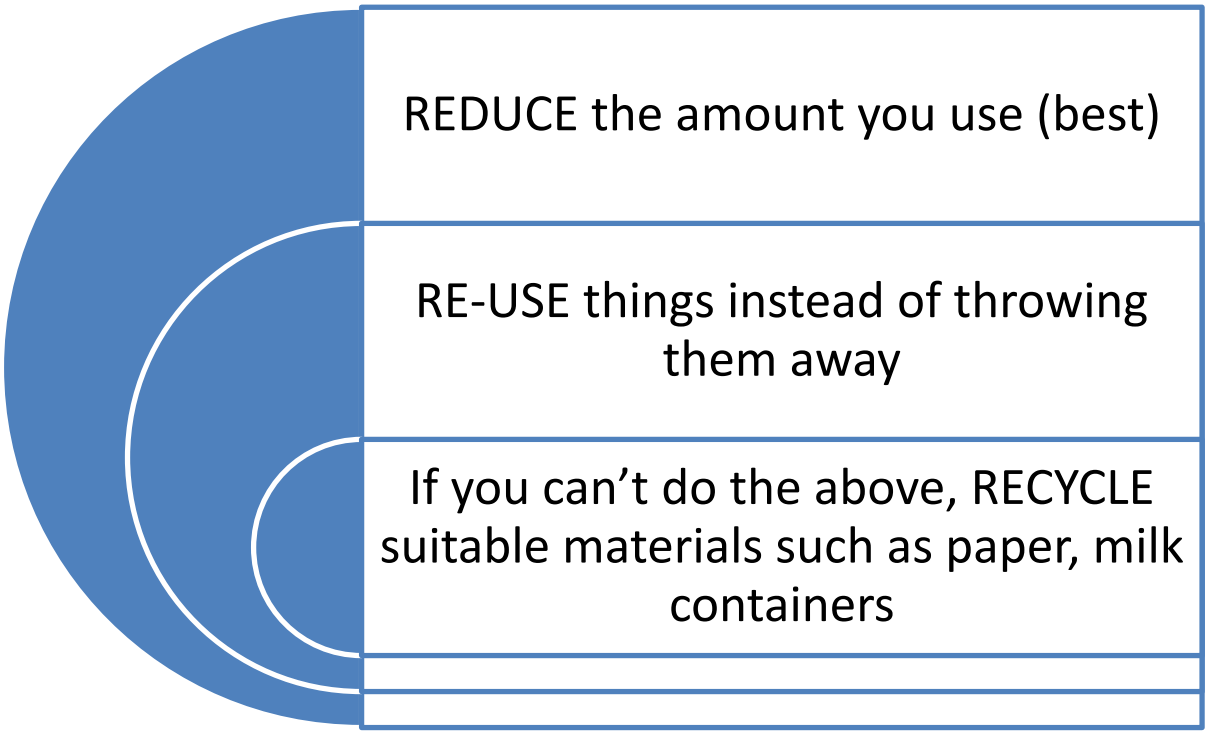



Graph taken from [EU waste statistics page]

# MSW recycling/composting rates in the EU-27 vary a lot by country

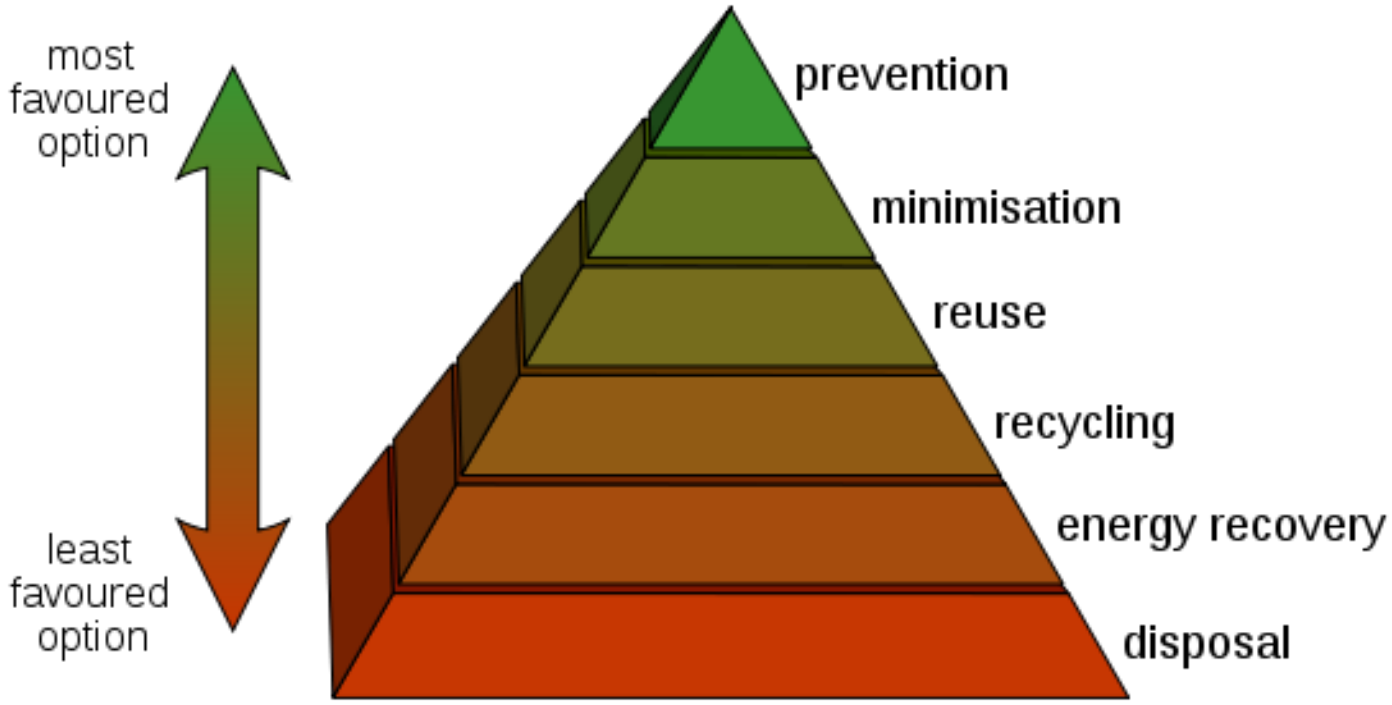


# Waste hierarchy – the three Rs




Rag and bone man. Picture by Aviad2001, CC0 license

# The waste hierarchy:




Graphic by Drstuey, Stannered, from Wikimedia Commons, CC license

# Waste as a resource

- Recycling waste can both reduce waste going into the environment, and also reduce the amount of resources used in manufacturing.
- However, there is a cost- it can be expensive to do the conversion- e.g. to convert old milk cartons back to ethylene gas ready for re-use. Sometimes it may cost more in energy/materials than you save!
- With a focus on recycling R&D, new techniques are being found and developed.

# Assimilative capacity of nature

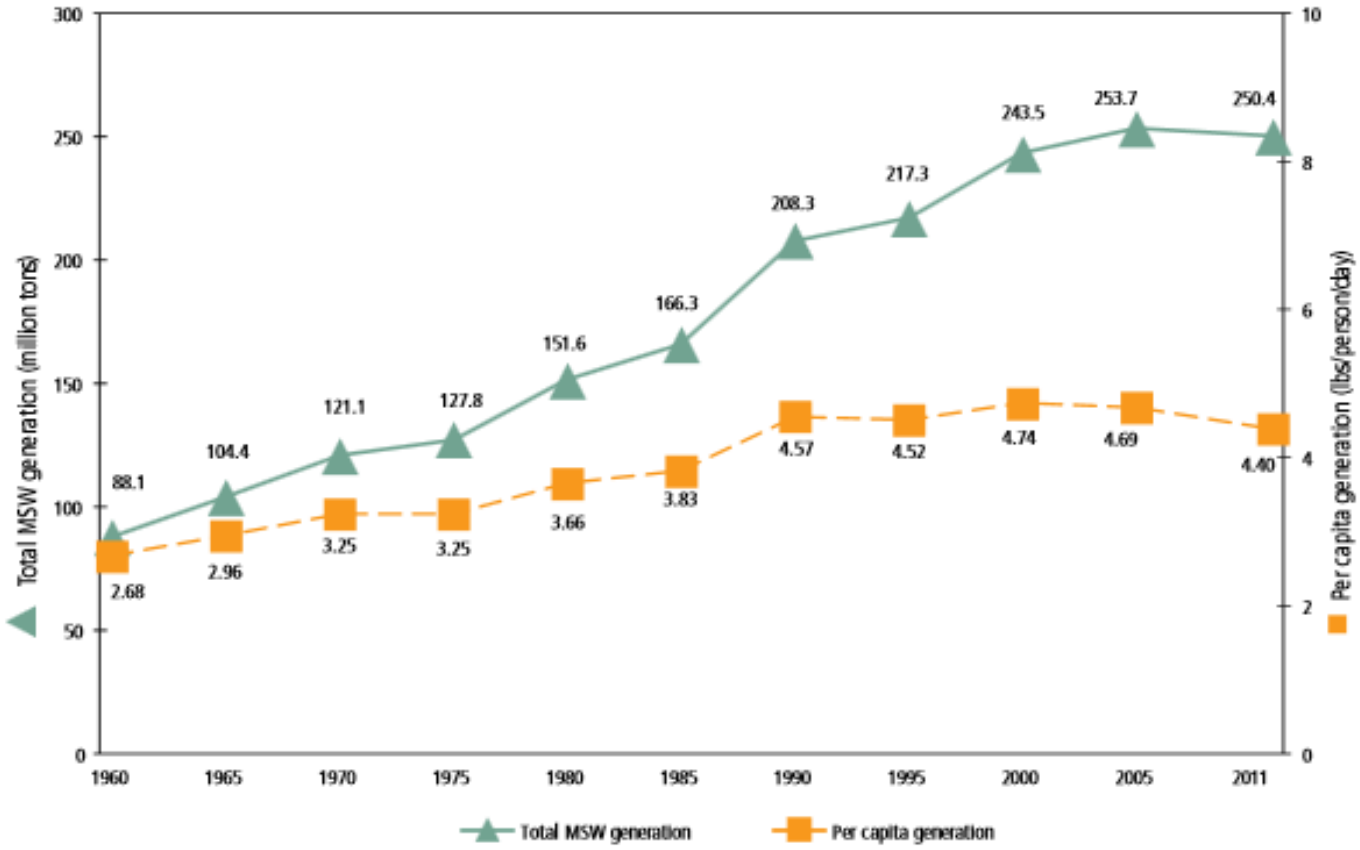
- Part of the natural capital of an ecosystem is its ability to “assimilate” waste (i.e., to absorb and process it).
- If there is too much waste for an ecosystem to handle (e.g. the Hudson?), then the carrying capacity of that ecosystem has been exceeded.
- Either waste prevention/reduction is needed, or waste must be transported to other places.
- The assimilative capacity of the environment must be protected, as it provides a massive economic benefit to humankind.

# 6.4. DOMESTIC WASTE


Landfill in Western Australia. Picture by Ashley Felton, Public Domain

# US Municipal Solid Waste (MCW) is finally beginning to fall

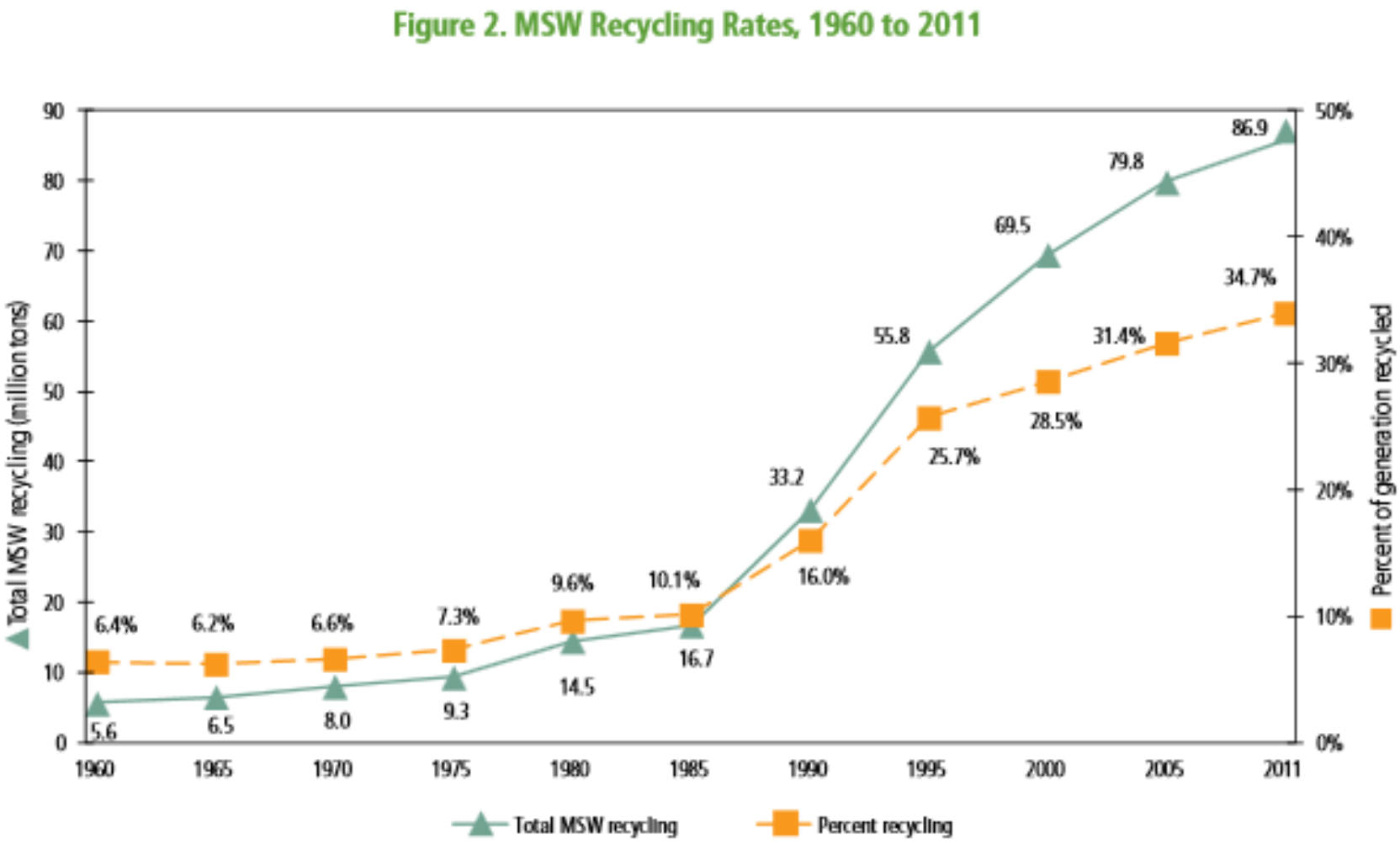
Figure 1. MSW Generation Rates, 1960 to 2011




[1] U.S. short tons unless specified.

Data taken from [this 2011 EPA document]

# Better US recycling may be the reason



# Paper, yard waste and metals make up bulk of MSW-recycled materials in the US

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

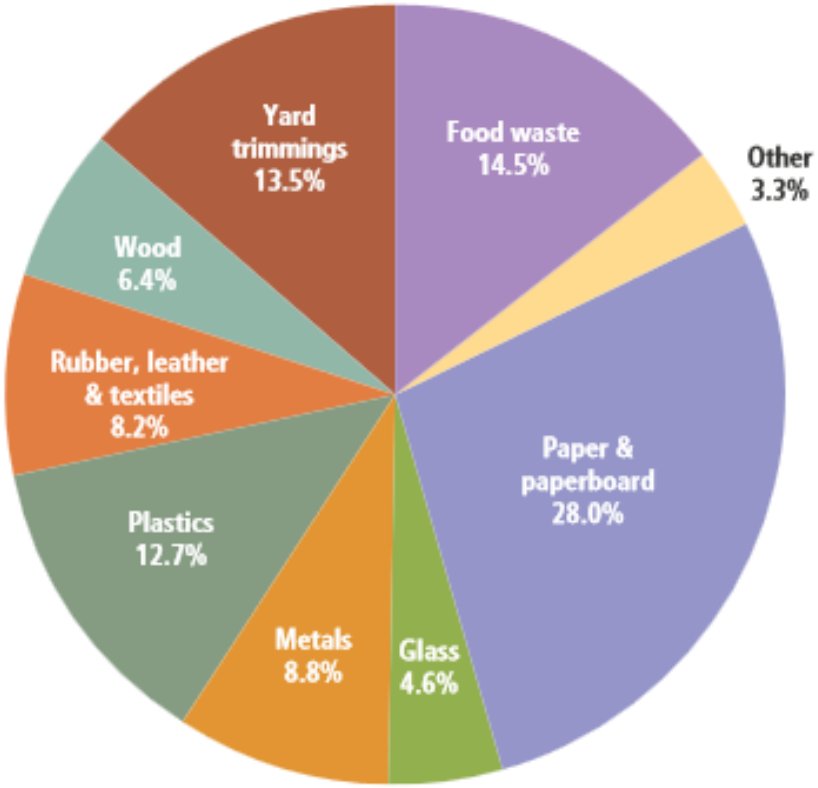
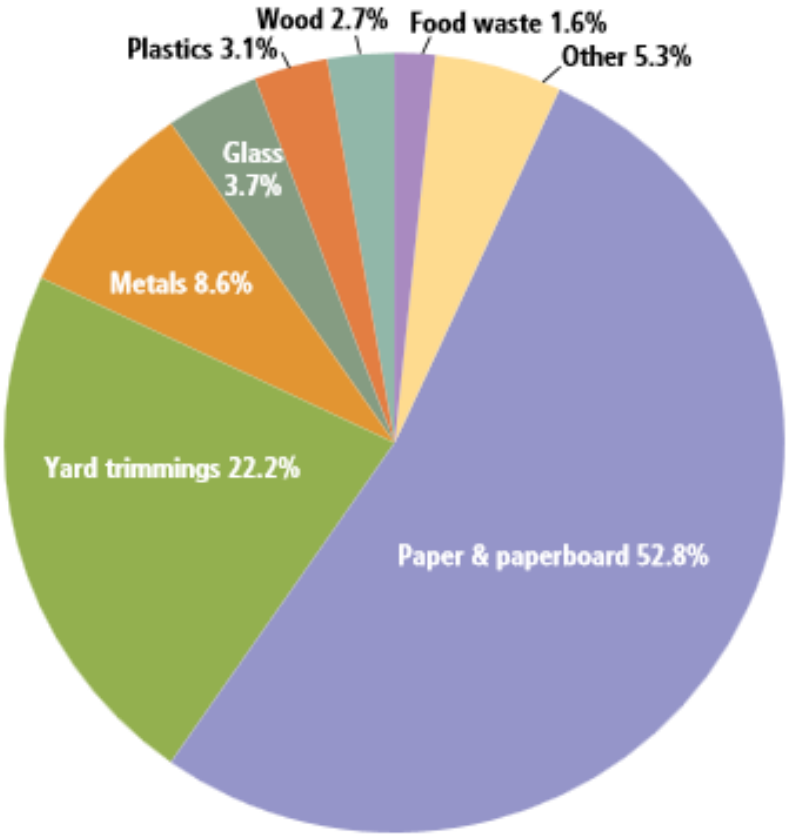



Figure 6. Total MSW Recovery (by material), 2011
87 Million Tons



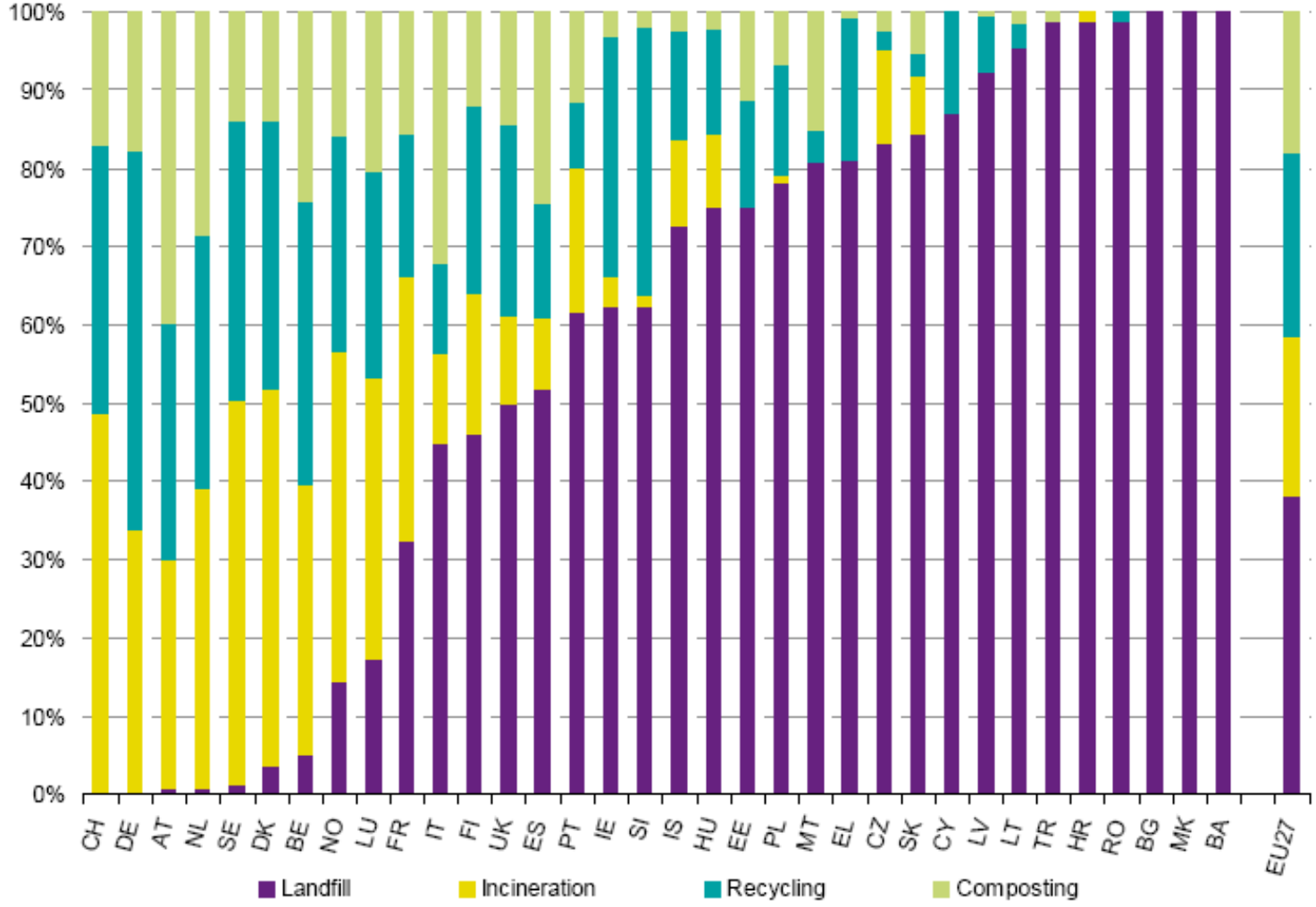
# US domestic waste (2010)

The EPA estimates that

- Americans generated around 250 million tons of waste, of which around 85 million tons (~34%) was recycled (65 Mt) or composted (20 Mt). 29 million tons was combusted for energy recovery.
- In 1980, 89% of MSW ended up in a landfill; by 2010, this had fallen to 54%.
- Composting rates have increased five-fold since 1990
- Recycling and composting more than 85 million tons of MSW saved the equivalent of over 229 million barrels of oil

Data from EPA factsheet, 2010

# MSW recycling/composting rates in the EU-27 vary a lot by country!



# 6.5. US GOVERNMENT REGULATIONS

# 6.5. US Government Regulations

- Clean Water Act (CWA)
- Clean Air Act (CAA)

These two serve as “umbrella” legislation for:

- Resource Conservation & Recovery Act (RCRA)
- Superfund
- Toxic Substances Control Act (TSCA)
- Pollution Prevention Act
- Occupational Safety and Health Act (OSHA)

# Clean Water Act (CWA)

- 1972 Origins (despite veto by Nixon!)
- 1977 Amended, became the CWA.
- EPA to implement pollution control programs (eg for industrial wastewater).
- Banned discharge of pollutants into navigable waters
- Funded construction of sewage treatment plants
- List of specific pollutants that are controlled (129 substances in 1982).

# Clean Water Act

- Every industrial facilities that discharge into surface waters must obtain a National Pollutant Discharge Elimination System (NPDES) permit.
- Traditional focus on chemical integrity of water, but now more emphasis on physical and biological aspects.
- If waters do not meet quality standards, then states must develop a "Total Maximum Daily Load" (TMDL)- this is the amount of a pollutant that a waterbody can receive and still meet standards.
- Many effluents may be treated before discharge, to neutralize them or to remove highly toxic pollutants (use BATNEEC principle).

# Clean Air Act (CAA)

Various laws since 1955, original form 1970, aiming to achieve by 1975 "National Ambient Air Quality Standards" (NAAQS) to protect public health and the environment.

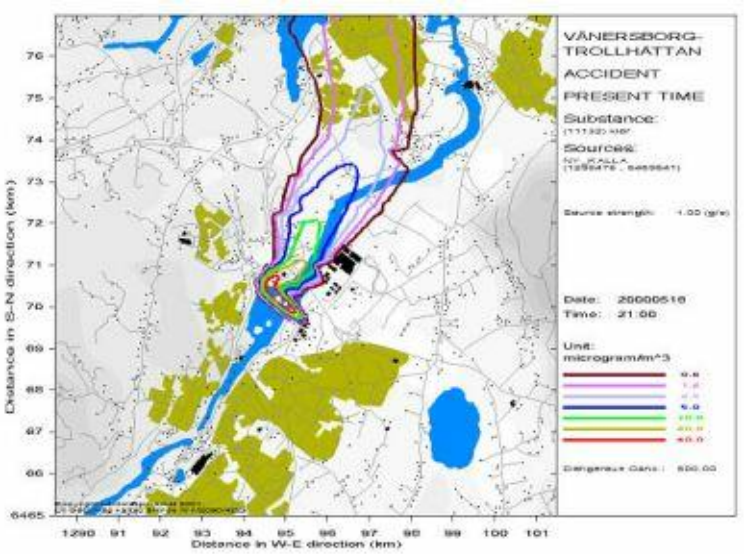
- 1977- amendments/new goals, since many areas had failed to meet deadlines.
- 1990- amendments to include acid rain, ozone/CFC's, air toxics.

# Clean Air Act (CAA)

- Emission permits required, with "emissions trading" allowed.
- Limits set for various classes of hazardous air pollutants (HAP's), e.g. "Miscellaneous Organic National Emission Standard for Hazardous Air Pollutants" (MON).

# Clean Air Act (CAA)

- Risk Management Planning (RMP, 1996): to protect communities from accidental release of HAP's. Facilities need to disclose what would happen in the event of a possible accident, and to work towards preventing such an accident.



# CWA and CAA

- These form legislation that is in effect an “umbrella” for many smaller pieces of environmental legislation, for example on waste management.  We will now cover a few of the most important of these.

# Resource Conservation & Recovery Act (RCRA): Introduction

- 1976 Introduced, pronounced "rick-rah."
- 1984 Hazardous & Solid Waste Amendments (HSWA). Phased out disposal of hazardous waste in landfills, more stringent rules on hazardous waste management and a program for underground storage tanks.

# Resource Conservation & Recovery Act (RCRA)

- Hazardous waste tracked "cradle-to-grave," including generation, transportation, treatment, storage and disposal.
- Also says how best to dispose of non-hazardous waste.
- Only covers waste currently being produced, not historical sites (see Superfund, 11.4.).

# Hazardous Waste Identification Rule (HWIR)

- Part of RCRA, deals with 2 separate types of waste, process waste and contaminated media. Contains concentration limits for particular constituents, below which waste is no longer hazardous- a departure from traditional practice.
- Problem if materials deemed "waste" are to be recycled.

# Superfund (CERCLA & SARA)

- 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) introduced, original form of Superfund legislation.
- 1986 SARA introduced, amended to include lessons learnt.
- These acts deal with problems caused by pollution *in the past* (c.f. RCRA)- they mainly deal with long-term problems, but may also tackle immediate problems if necessary.

# Superfund

- A trust fund was set up and received funds (ca. $1.5bn annually) from the petroleum & chemical industries at large until December 1995, when the tax authorization ran out and was not renewed.
- Stresses the need for a permanent solution.
- Sites on the National Priorities List (NPL) are assessed using the Hazard Ranking System (HRS) for their relative risk to human health & the environment.
- Title III of SARA is known as the Emergency Planning & Community Right to Know Act (EPCRA), includes plans for response to chemical emergencies. Some facilities file reports on all releases of certain chemicals (~650) on the Toxic Release Inventory (TRI).

# Toxic Substances Control Act (TSCA)

- 1976 Introduced.
- Main purpose is to track 75,000 industrial chemicals in the US.
- Supplements other statutes such as the Toxic Release Inventory (TRI) (see 11.4).

# Pollution Prevention Act (1990)

- Focuses on reducing pollution through cost-effective changes in production, operation and raw materials use.
- Approach is "Waste Reduction At Source" (WRAS) rather than on waste treatment & disposal. Includes reduction of use of resources such energy, water, etc.

# Occupational Safety and Health Act (OSHA)

- Very important *within* the facility, focuses on worker/workplace safety & health, for example by restricting exposure to toxic chemicals.