Mining & chemicals

1. MINERAL RESOURCES

Introduction

Picture by User H, from Wikimedia Commons, CC license.

- Minerals are natural materials with a characteristic composition, for example fluorite (shown) is mainly calcium fluoride (CaF_2).
- Since they often represent concentrated sources of particular elements or organic molecules, they provide the original raw materials (metals, acids, oil, etc.) for nearly all of manufactured products.
- They are extracted by mining.

Mineral resources and human development

Bronze Age weapons. Picture courtesy of the Romanian govt. Public domain.

- **Human development has often been defined by the material resources being used – e.g., the Stone Age, Bronze Age, Iron Age.**
- **Even today, our world might be defined as the "Petroleum Age."**

The three Rs

- ***Reserve(s)*** represent the "mineral resources that can now be economically and legally extracted."
- The ***Reserve Base*** has a reasonable potential for becoming economic within planning horizons.
- ***Resources*** (in this context) are natural concentrations of materials, for which extraction is economically feasible.

Based on definitions found in Craig, Vaughn & Skinner

Abundant metals

Pictures from Metallium, Inc

- Typically constitute >0.1% of the Earth's crust.
- Include iron, aluminum, silicon, manganese, magnesium and titanium.
- These metals are plentiful enough that the World's resources are still vast compared to human usage.

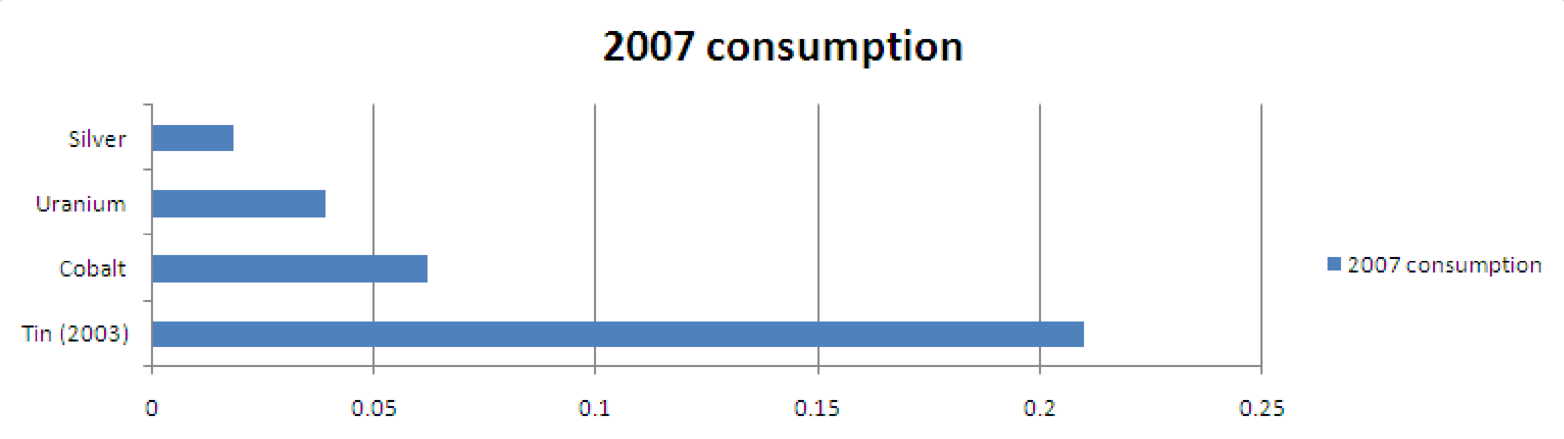
Scarce metals

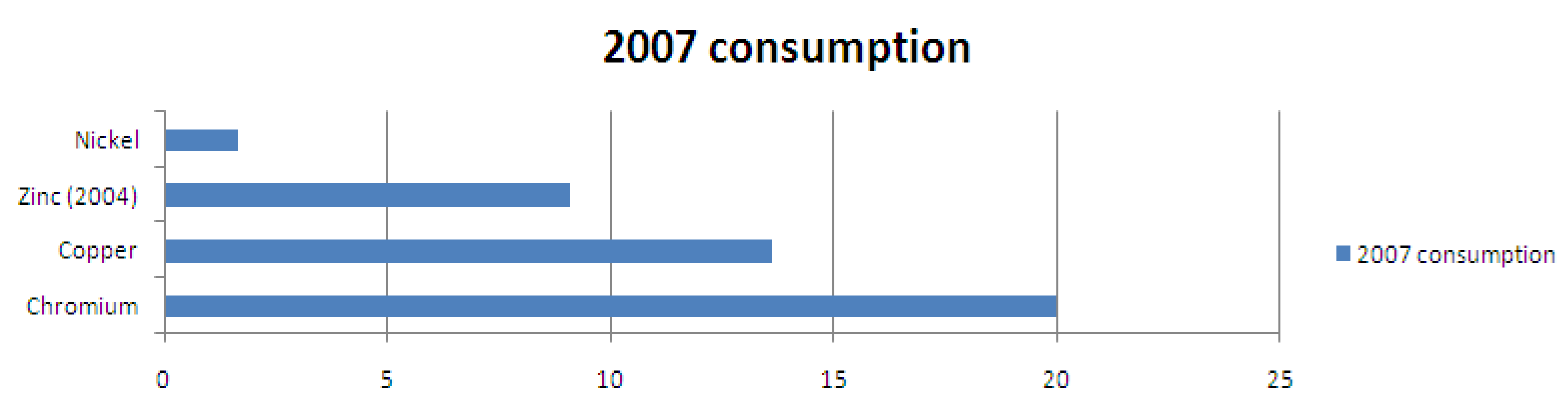
Pictures from Metallium, Inc

- Less than 0.1% of Earth's crust.
- Examples include copper, nickel, silver, molybdenum, lead, zinc, tin.
- It is possible for such metals that we could exhaust our current supply. This would most likely lead to a massive rise in price, as low-grade minerals become economic.

How fast are we using up our scarce metal resources?

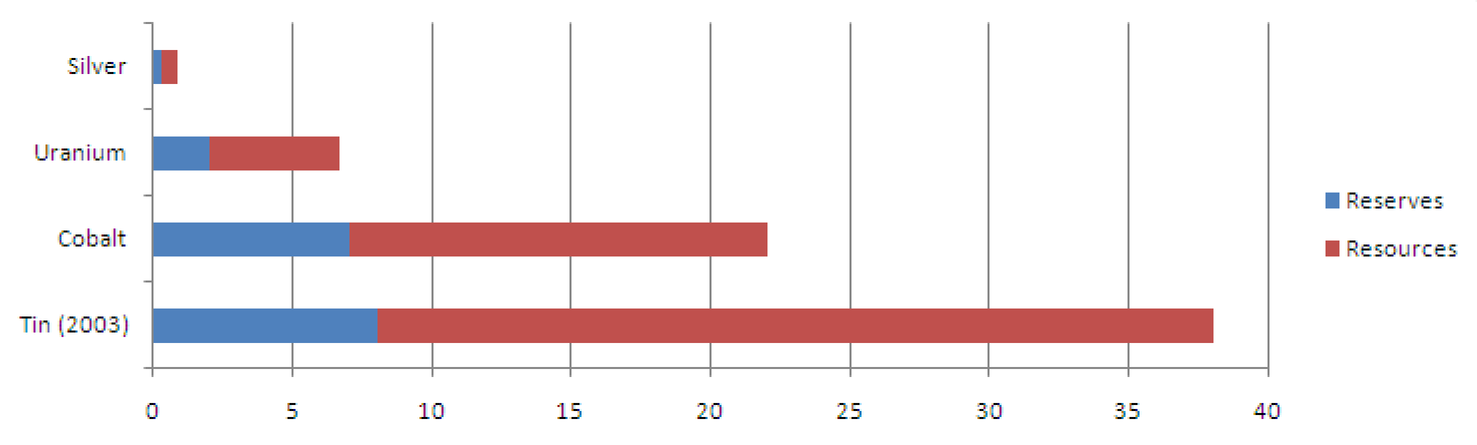
For eight typical scarce metals. Figures are in millions of tonnes/year.

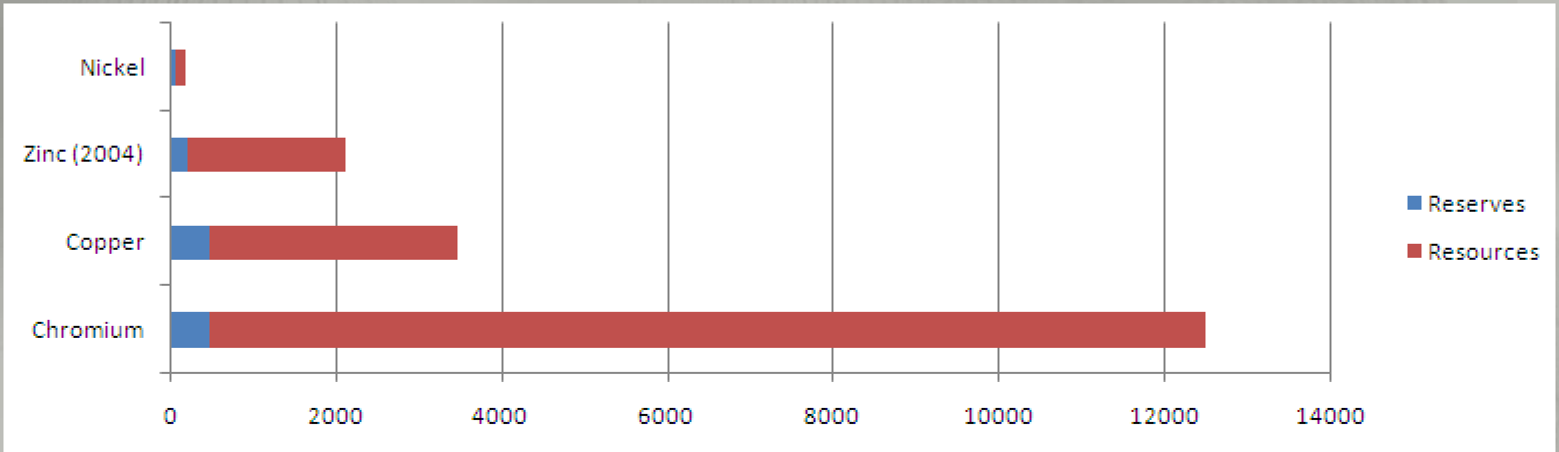




Scarce metals: Reserves and resources

Figures are in millions of tonnes

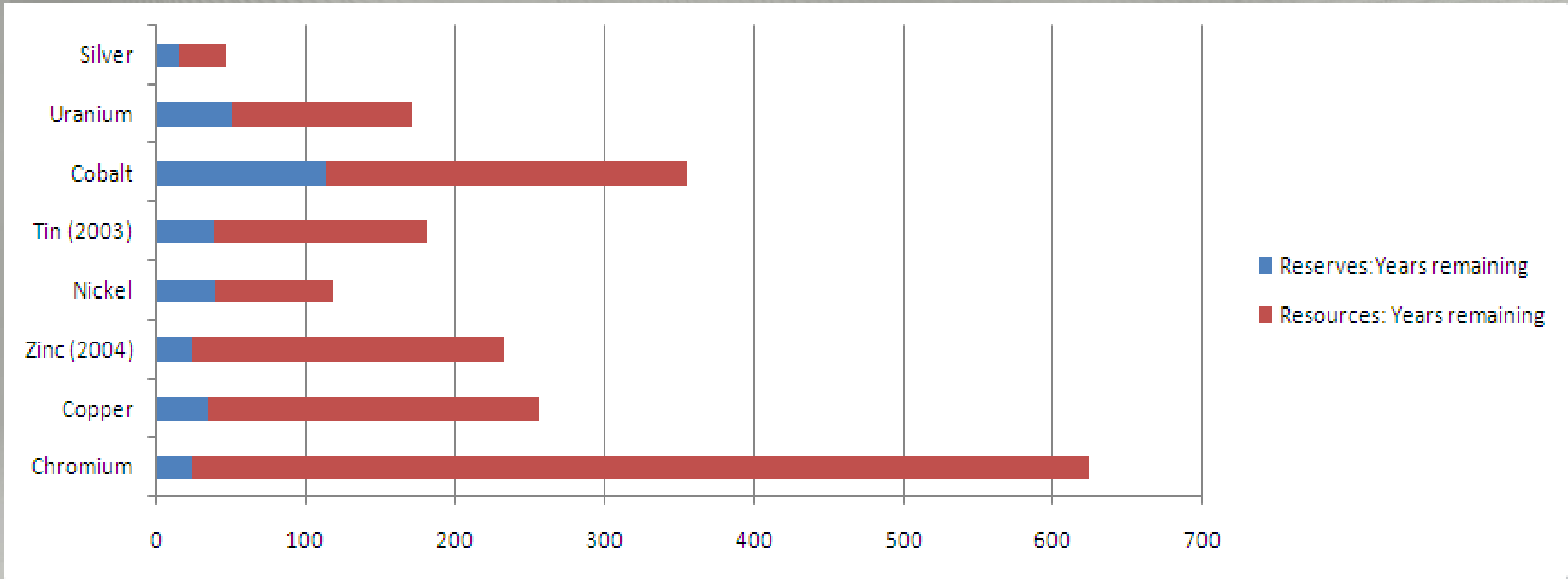




Graphs by Martin Walker, based mainly on USGS data

How long will these resources last?

- **Based on current consumption rates, there are adequate resources for most metals (except silver). However, if demand for certain metals rises dramatically, we could be in trouble…..!**



Graphs by Martin Walker, based mainly on USGS data

Petroleum, coal & natural gas

This "nodding donkey" is used to extract petroleum. Picture by US Dept. Energy.

- Very important minerals, which we discussed earlier under "energy" in Unit 7.
- These are principally made up of carbon and organic compounds, principally hydrocarbons, so there is no metal to be isolated.
- Refined at oil refineries or chemical plants. Ultimately used as fuels, or as feedstock for chemicals & plastics. Coke is made from coal; it is used for making steel.

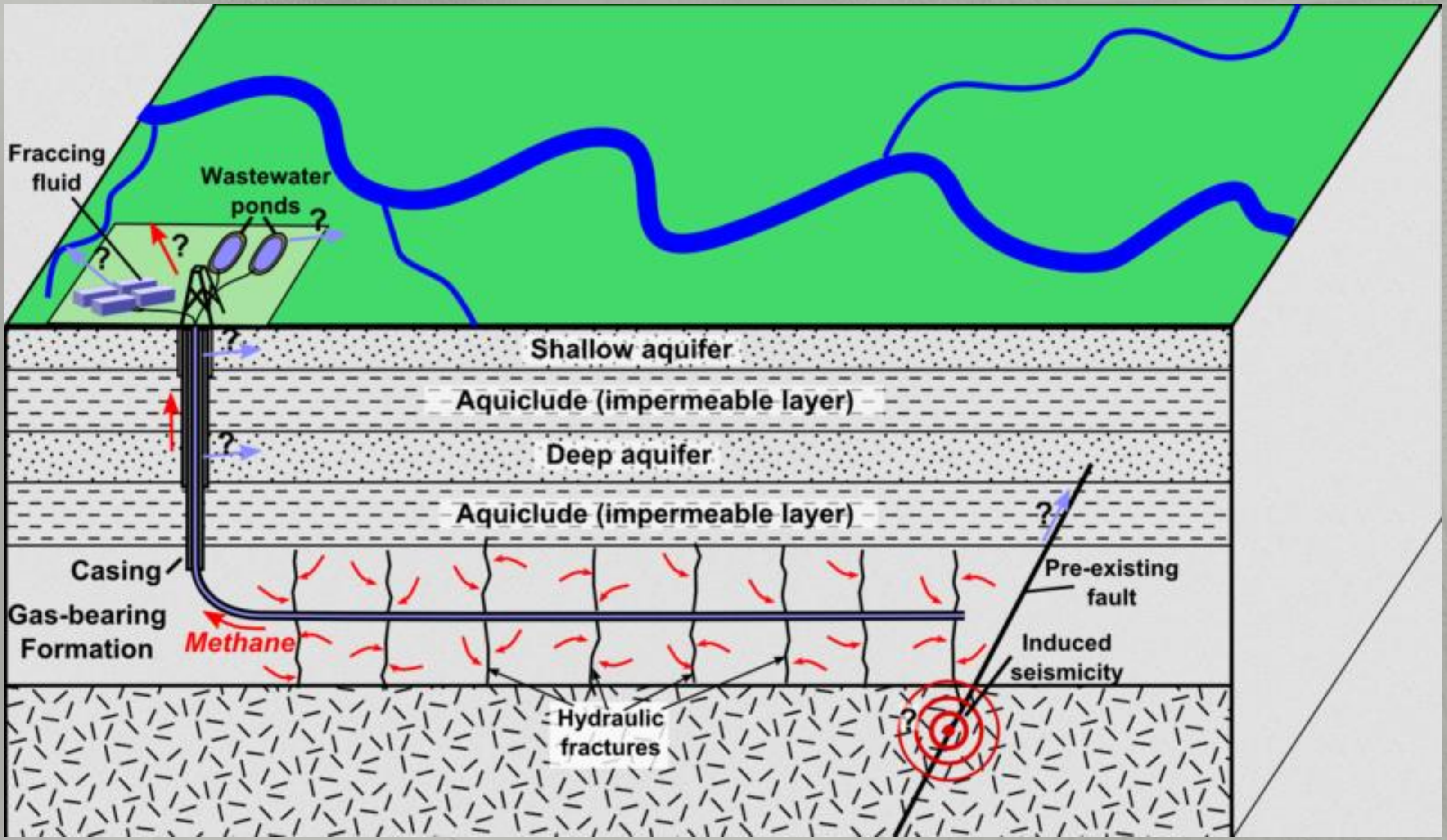
Hydraulic fracturing (fracking)

Fracking in the Bakken field, North Dakota
Picture by Joshua Doubek, CC license

After a vertical borehole is created, then a "fracking fluid" (based on water & sand) is injected into the rock horizontally to create fractures in the rock. Natural gas and/or petroleum are released, and can be extracted from the well.

This does allow oil & gas reserves to produce more, but it adds to the cost of extraction. There are also concerns about fugitive release of methane, groundwater contamination, and a risk of inducing seismic activity.

Hydraulic fracturing (fracking)



Alluvial deposits

A gravel pit in Rokitki, Poland.
Picture by Taw, GFDL license.

- Sand and gravel are produced on a massive scale representing (for example) around two-thirds (by mass) of all mined materials in Canada.
- Typically produced by surface mining, they have lower waste than rock minerals, though particulates can be an air pollution hazard.

2. MINING

The life cycle of a mine

- ***Exploration*** **will involve use of geochemical/physical methods to locate ores, followed by drilling.**
- ***Development*****: Preparing the minesite.**
- ***Extraction*** **occurs at the mine.**
- ***Benificiation*** **occurs nearby, the bulk of the waste material ("gangue") is removed.**
- ***Refining*** **is often done elsewhere, to produce the pure metal or material.**
- ***Decommissioning*** **once the mine is exhausted.**

Extraction methods

- **Underground mining produces less waste rock than surface mining, but minerals are less accessible, and workers are at more risk.**
- **Non-entry mining methods are safer for workers, and may be used to reduce waste and surface disturbance, but they are only applicable in certain cases such as oil extraction or mining of sulfur.**

Benificiation

Spinning ore crushers from a gold mine In Alaska. Picture by Nick Bonzey, CC license

- Removal of other rock, near the mining site, is a key part of the process.
- Flotation is the widely-used method. This uses vast amounts of water, though much of this is recycled.
- Large amounts of waste (gangue) are produced, and sometimes these may be toxic.
- Waste heaps etc. may also be a safety hazard (e.g., the Aberfan disaster, which killed 145).

Refining

Molten steel at the Allegheny Ludlum Steel plant in PA, 1944. Picture from Lib. Congress.

- **Many processes involve pyrometallurgy – the metal is isolated using high temperatures.**
- **Much waste is produced in the form of solids (slag) or gases (which may be acidic gases or greenhouse gases).**
- **Other common methods such as hydrometallurgy (using water) also produce much waste ("tailings").**
- **Many processes require consume much energy.**

Decommissioning

- The ore body will become exhausted – sometimes after >100 years, sometimes <10 years.
- Often it is impossible to return the site to its original condition.
- Slope stability and subsidence are a problem long after the mine has closed.
- There may be high concentrations of toxic materials remaining, preventing a simple return to use for agriculture or housing.

Spoil heaps from a lead mine in Co. Durham, UK. This is about 15 miles from my mother's house! Picture by Oliver Dixon CC license.

Conclusion

- Mining and refining are an essential part of human civilization, providing all the materials we use every day.
- However, these industries also have a massive environmental impact in terms of land damage and waste. Often this is ignored, because few people see these industries regularly.
- Much can be done to reduce the environmental impact, by
  - Using full cost accounting methods to factor in the true costs of waste.
  - Promoting use of “green” technologies.

Bibliography

- *Resources of the Earth*, by James R. Craig, David J. Vaughan, Brian J. Skinner. Prentice Hall, 1988.
- Environmental Effects of Mining, by Earle A. Ripley, Robert E. Redmann, Adele A. Crowder. St. Lucie Press, Delray Beach, FL, 1996.

CHEMICAL MANUFACTURING

Chemical manufacturing defined our development

- **Chemical manufacturing began in prehistoric times, when processes for making metals - first bronze, then iron - were discovered. These discoveries were so revolutionary the historical eras are referred to as the Bronze Age and Iron Age. Even in our modern era, steel and aluminum are key materials.**

Bronze cup from National Museum in Prague
Picture by Kozuch

C19th: The industry takes off

- **The chemical industry began to take off in the 19th century when processes were developed for cheap manufacture of sodium hydroxide (lye, for soapmaking), sodium carbonate (soda for glassmaking) and other valuable chemicals. Fertilizers followed soon afterwards.**
- **Around 1860, organic chemicals began to be mass produced, to be used for dyeing clothes, then later for pharmaceuticals and early plastics. Much of Germany's power & wealth stemmed from its chemical industry. The raw materials mainly came from coal at this time.**

Indigo is a plant dye used for blue jeans, but synthetic indigo began to be produced in Germany in 1897 and made the dye much cheaper. Picture by gitane, CC license

Early C20th: Plastics begin

Bakelite radio
Picture by Robneild
CC license

- **The chemical industry continued to expand and diversify. In the US, petroleum replaced coal as the main source for organic chemicals**
- **Plastics began to be mass produced; initially bakelite and celluloid, then in the 1930s came nylon, acrylics and polyethylene.**

In 1939, when nylon stockings were first made, women went crazy for this latest fashion!
Picture from Piroska, no license given

Postwar boom

Valium "happy pills" became popular in the 1960s
Picture by ML5, PD

Spraying crops near Bratislava, 1951
Picture from German Fed. Archive, CC license

- **A plentiful supply of cheap petroleum (for raw materials), combined with prosperity in the West, led to a massive growth in the industry. Many new polymers and pharmaceuticals were commercialized, including the first oral contraceptives. Pesticides began to be used widely.**

Industry matures, but criticism begins

- **In the 1960s, after the thalidomide tragedy and publication of "Silent Spring", the "hi-tech" image of the industry providing "wonder drugs and wonder materials" began to pale. Pollution became a problem in industrial areas. The public began to question widespread use of pesticides and drugs, and this led to the foundation of the Environmental Protection Agency (EPA) in the US. Disasters at Love Canal and Bhopal made the industry an object of hate.**

Chemical pollution
1972 picture by
Marc St. Gil for EPA

Bhopal protests
Picture by Obi
CC license

The industry today

- The industry is slowly rebuilding its image, and is “cleaning up its act”. Chemical pollution is now much less, and safer/greener products & processes are being developed. However, there is still some way to go.
- In 2007, the industry’s sales were estimated to be around $676.9 billion worldwide, making it a significant part of all manufacturing. Whether we like it or not, we depend on chemicals!

Strem Chemicals, Newburyport, MA
Picture by Rifleman82, PD
I used to work across the street from here!

Some common terms

- **A chemical process involves a chemical reaction that converts the starting chemicals into useful products.**
- **The *raw materials* or *feedstocks* are the starting chemicals put into a process.**
- **Chemists typically use heat, pressure and catalysts to drive reactions more quickly.**
- **Waste is an inherent and natural part of any chemical process, though chemists try to minimize it. It used to be frequently piped to the river or ocean, or dumped out at sea. Now, most waste is treated or (if safe enough) put into landfill. All waste is tracked from cradle to grave.**

Sectors of the chemical industry

A standard 55 gallon chemical Drum. Picture by Meggar, CC license

- **Basic chemicals** (commodity chemicals) – cheap, common chemicals for which there is a large market. Often divided into organics (petrochemicals, etc.) and inorganics (often used for fertilizers, etc)
- **Agricultural chemicals** – pesticides, herbicides
- **Polymers** – used for plastics, rubbers, paints, coatings, etc.
- **Pharmaceuticals** – high value, complex molecules made under very strict conditions.
- **Fine chemicals** (such as Acme) - high priced intermediates, often used to make pharmaceuticals.
- **Performance chemicals** – used for specific applications (e.g., computers, automobiles)