Industrial Waste Management

Byproduct

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Seminar and Training Workshop, Gandhinagar, India, January 27, 2014

Environmental Pollution

Domestic

Industrial

Agriculture

Transportation

SOURCES

- Toxic Chemicals
- Air Contaminants
- Greenhouse Gases
- Hazardous Wastes
- Nonhazardous Wastes
- Radioactive Wastes

Environmental Pollution

AIR

WATER

SOIL

ENVIRONMENT

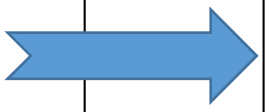
INDUSTRIAL WASTE

Multiple Forms:

Air Pollutants
- Gases
- Aerosols

Water Pollutants
- Primary
- From Atmosphere

Solid Waste

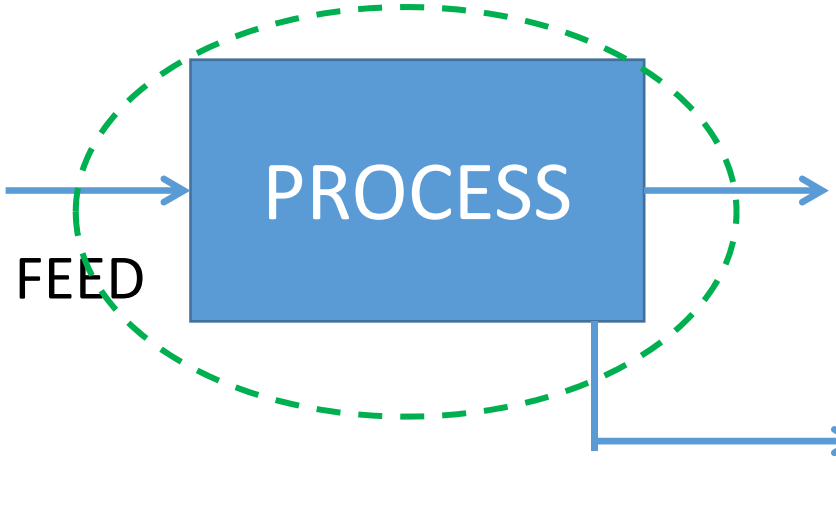


Impacts the Environment
(Atmosphere, Water Bodies, Soil)

Should we call these pollutants or waste ?
Or a byproduct, and a potential resource ?

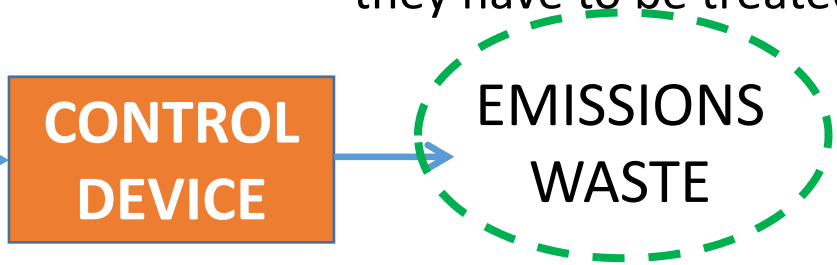
A New Paradigm

CONVENTIONAL PARADIGM



NEW PARADIGM

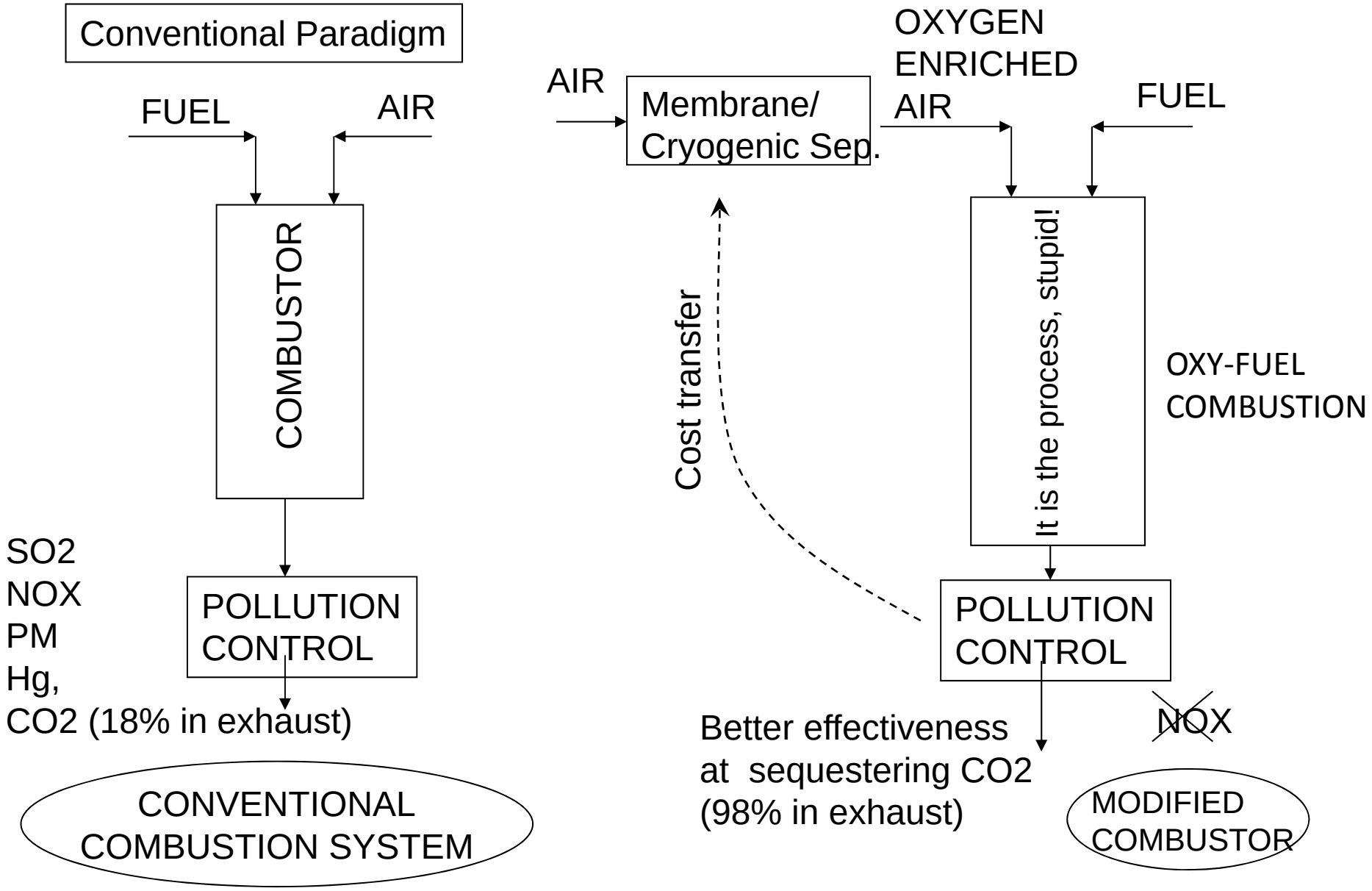
Not much focus on Process Byproducts considered to be a "waste" – cost sink as they have to be treated



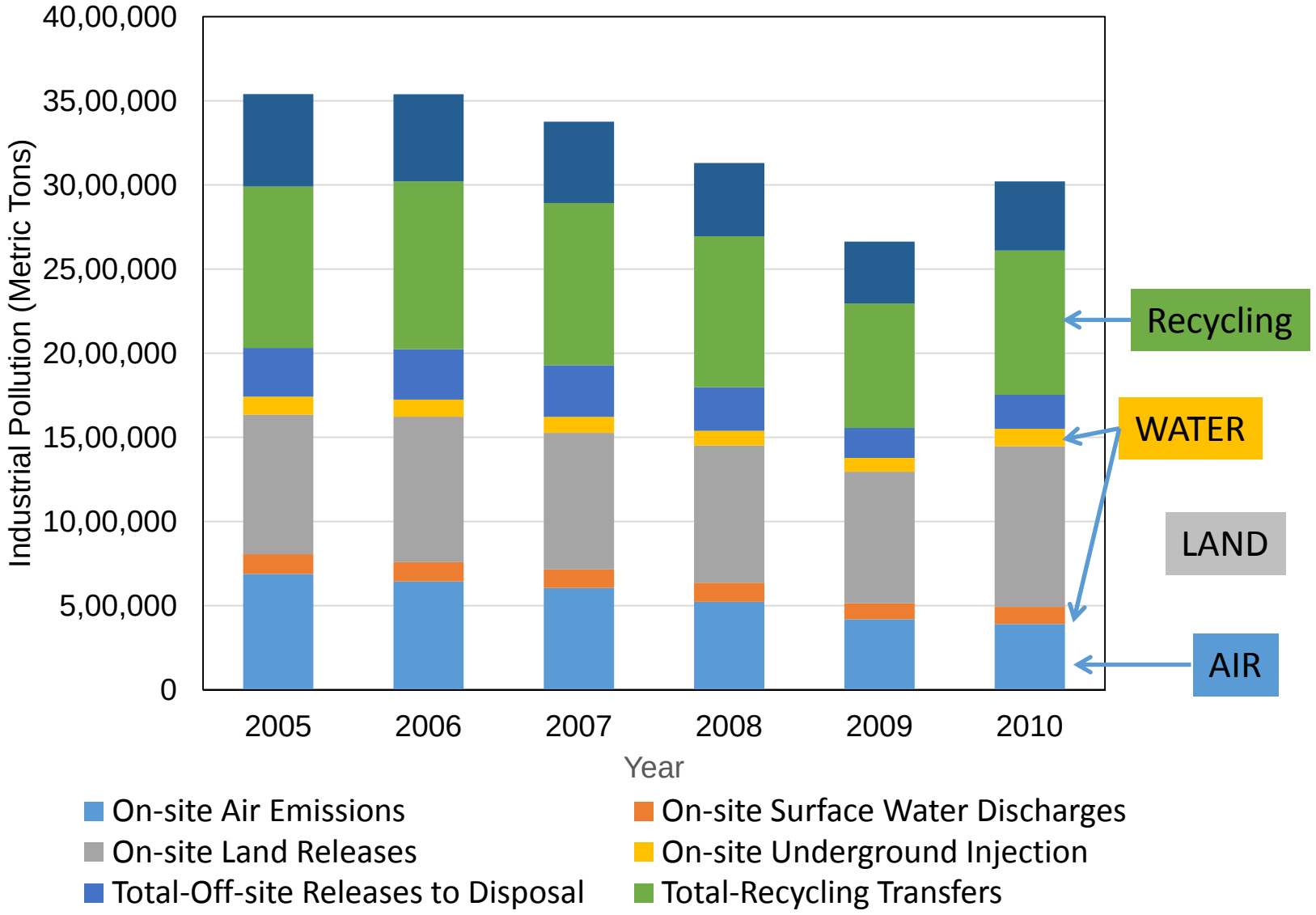
EVALUATE PROCESS:
IMPROVE EFFICIENCY, MINIMIZE WASTE
WASTE= BYPRODUCT (CAN WE REUSE OR RECYCLE?)

IMPORTANT THERMODYNAMIC CONSTRAINT:
EMISSIONS OR WASTE CANNOT BE ELIMINATED ENTIRELY
NOR REUSED OR RECYCLED COMPLETELY
INDUSTRIAL WASTE MANAGEMENT STRATEGY IMPORTANT

New Paradigm for Fossil Fuel Combustors

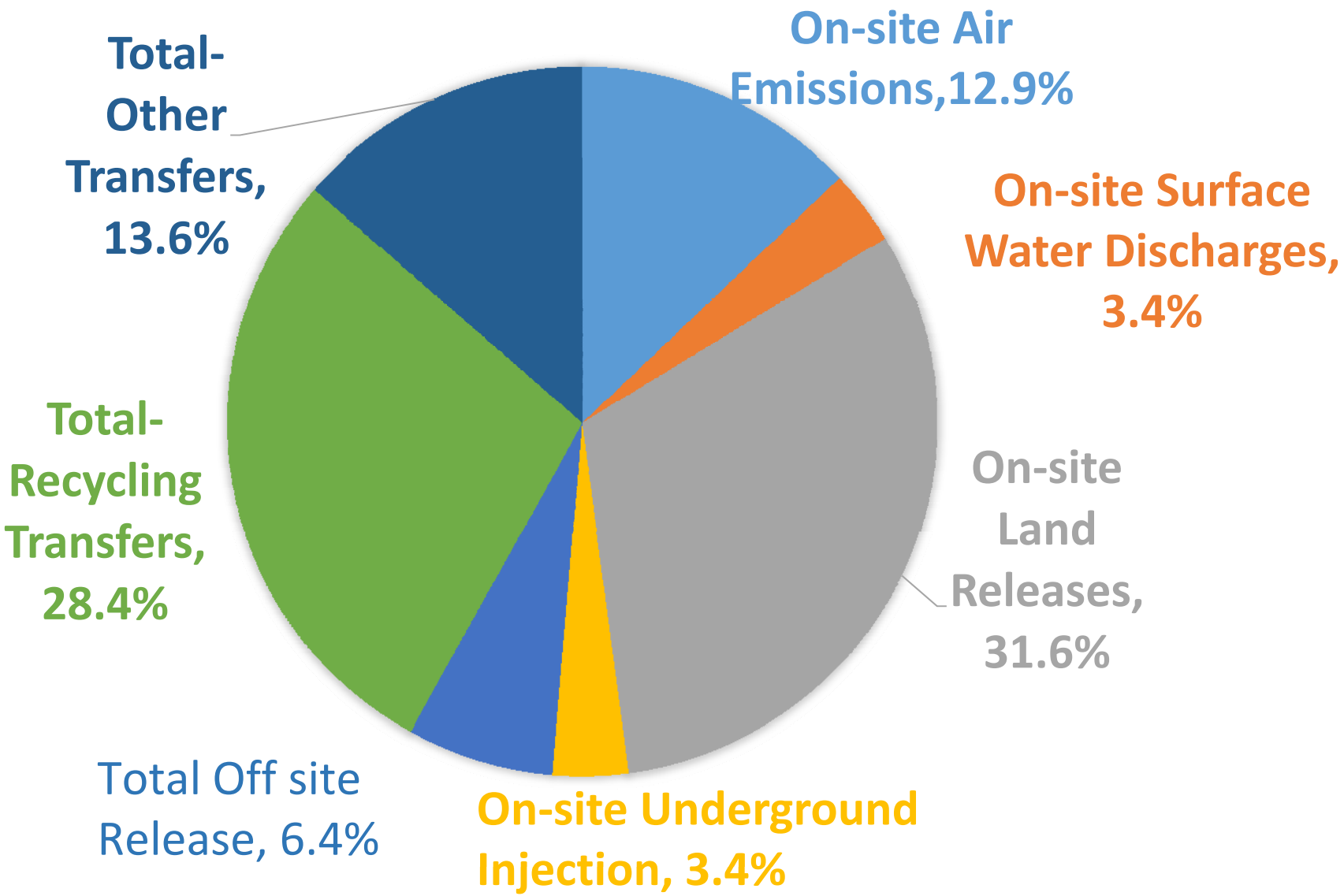


US Industrial Pollution 2005-2010



Source: Commission for Environmental Cooperation

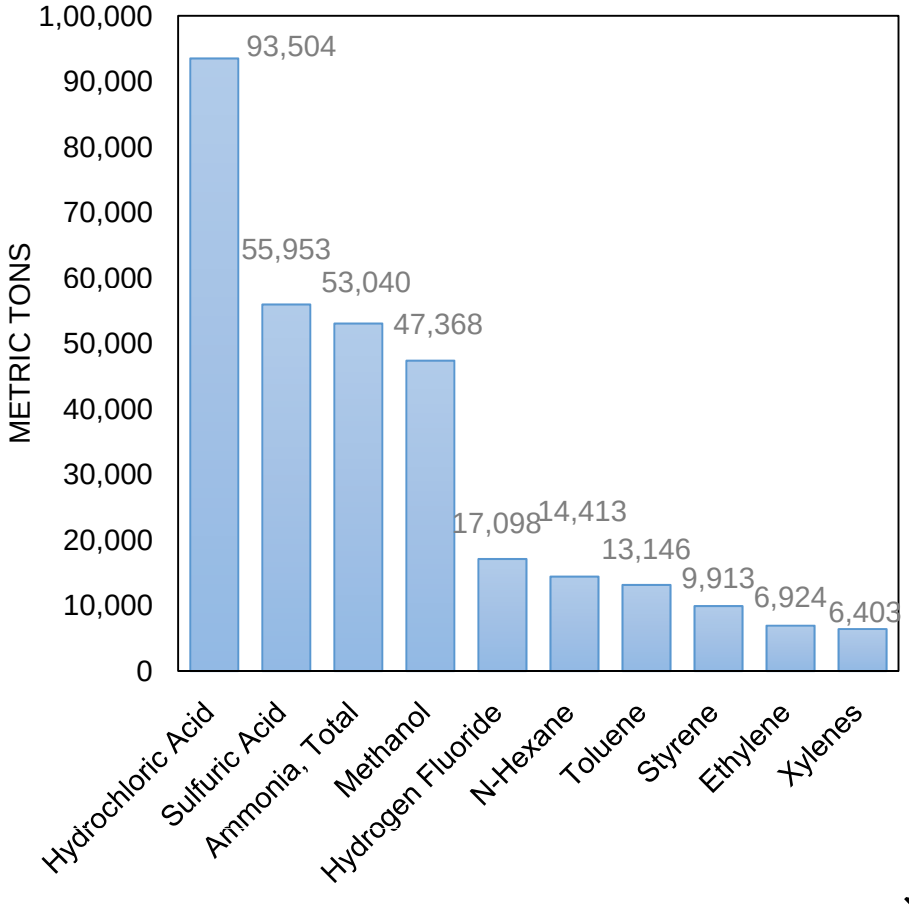
US 2010 Industrial Pollution Release or Transfer



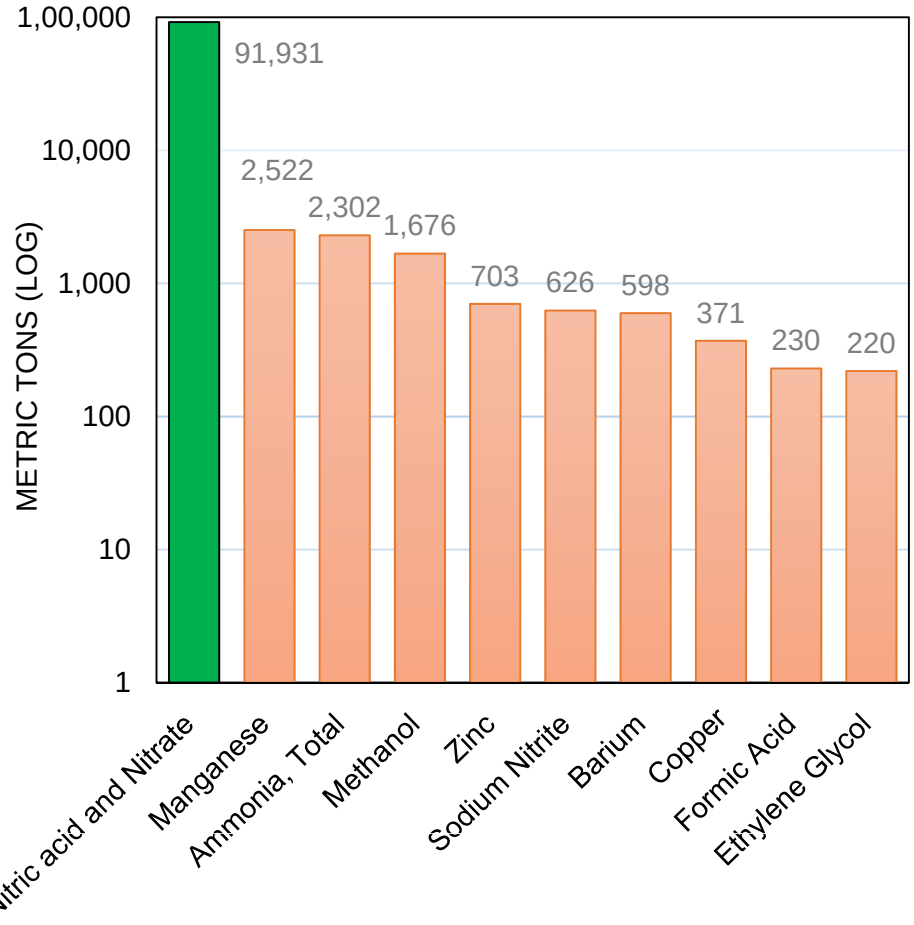
Source: Commission for Environmental Cooperation, Taking Stock Database

Top Air/Water Industrial Pollutants 2010

Top 10 Air Pollutants



Top 10 Water Pollutants

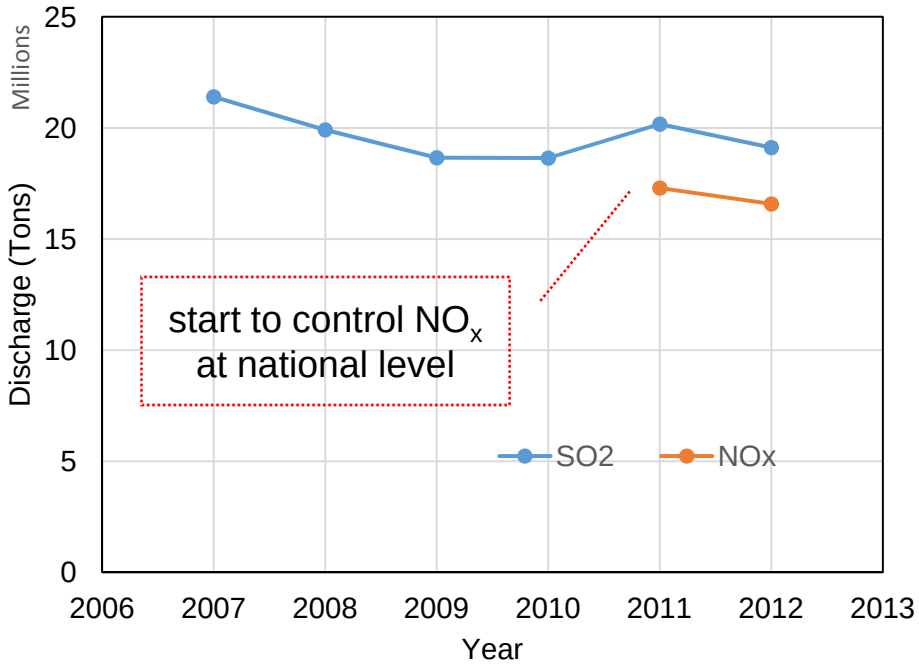


- Only account for **1.3%** of total pollutants
- Account for **24.3%** of total pollutants

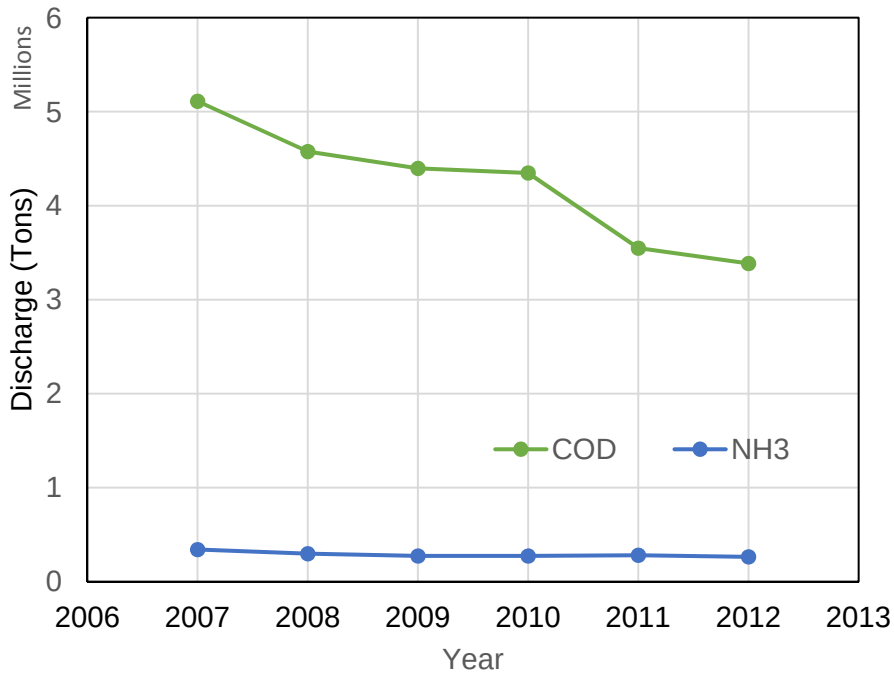
Source: Commission for Environmental Cooperation, Taking Stock Database

Industrial Air/Water Pollution in China

SO_2 and NO_x emissions from Industrial Sources

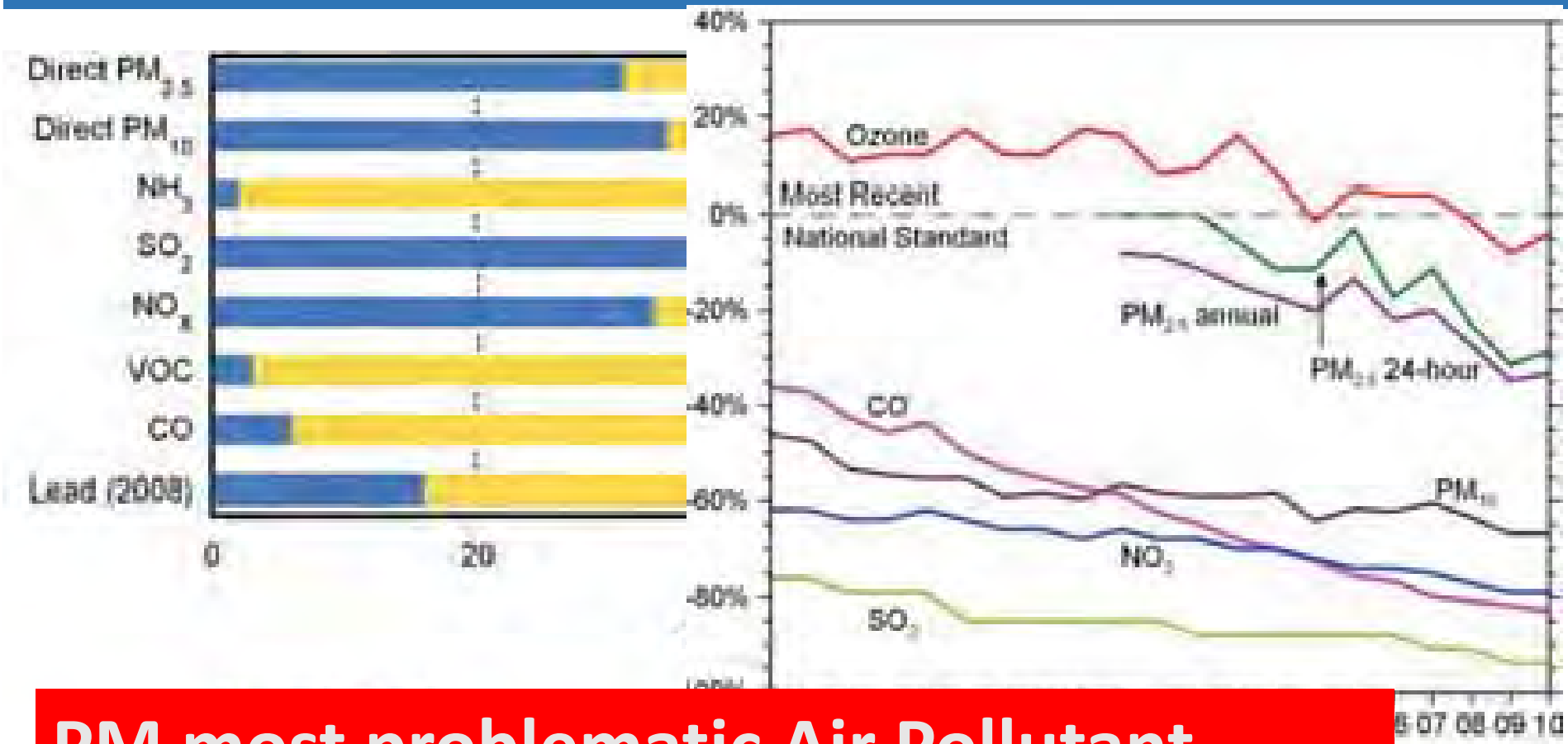


COD and NH_3 Discharges from Industrial Sources



Source: State of the Environment Report, MEP, China

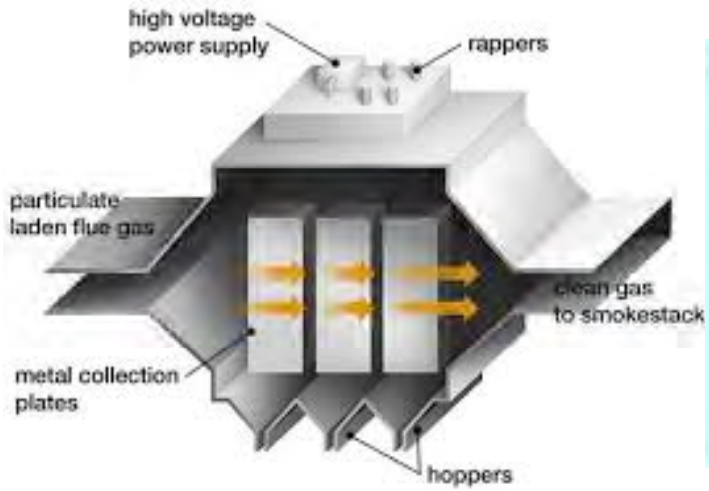
US Air Pollution

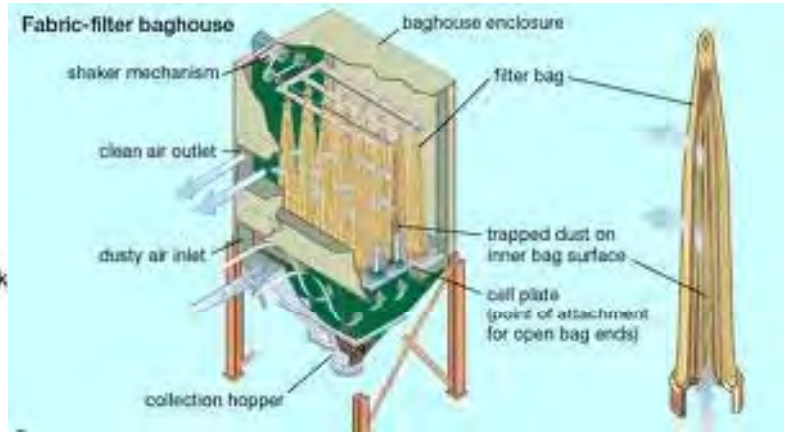


PM most problematic Air Pollutant
Major fraction – secondary,
biogenic interacting with anthropogenic

Source: USEPA, 2013

AIR POLLUTION CONTROL DEVICES





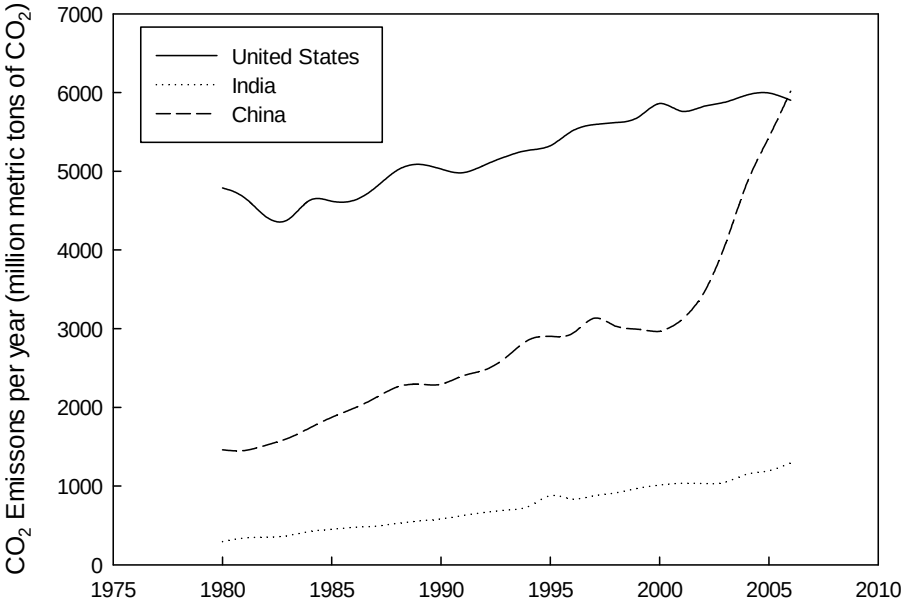
PARTICULATE MATTER CONTROL

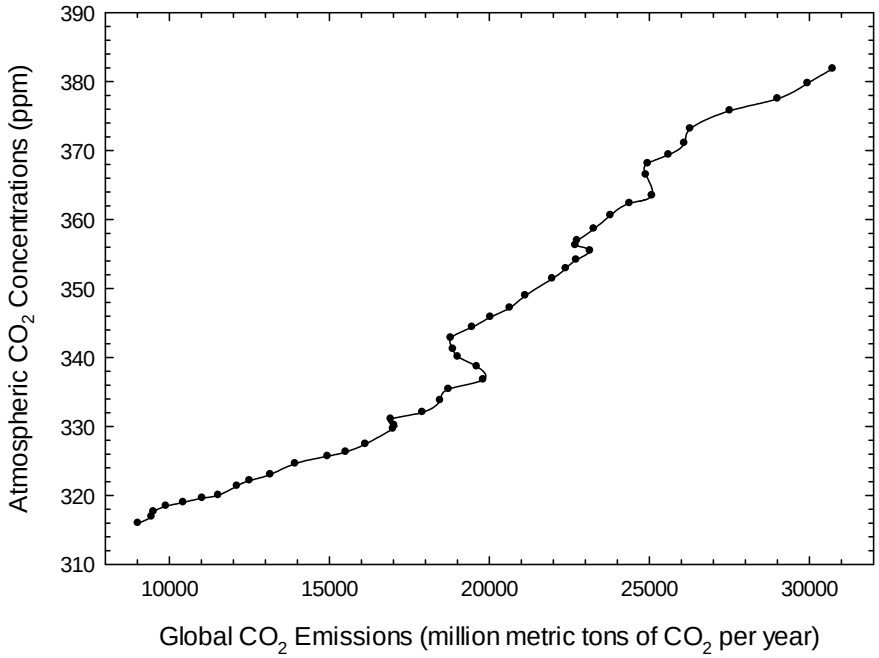
CONTINUOUS EMISSION MONITORING (SHOULD BE DONE)

- PERFORMANCE OF EMISSION CONTROL DEVICES
- REAL TIME PROCESS MONITORING
- INITIAL COST RECOVERED (ACTIVE PROCESS CONTROL)

GASEOUS EMISSION CONTROL

CO2 is now considered an Air Pollutant ?





CO2 can be converted to useful products:

- Very energy intensive
- Nanotechnology offers hope:

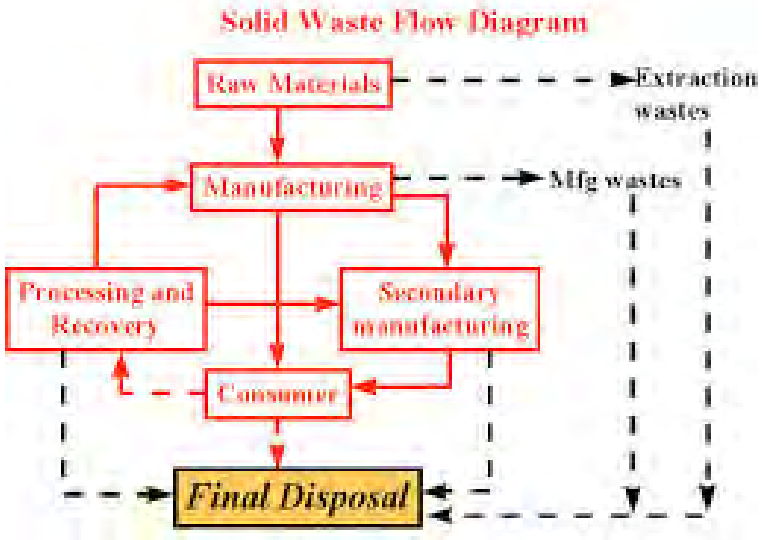
Convert to Fuels, to Chemicals – use Solar Energy

Wang, Biswas (2012) *Journal of the American Chemical Society,* **134**(27): 11276-11281.

SOIL POLLUTION

VARIOUS TYPES
SOME ARE

* SOLID WASTE
    * DOMESTIC, INDUSTRIAL
- CHEMICALS
    - PESTICIDES, FERTILIZERS
    - NUCLEAR



7.6 Billion Tons of Industrial Solid Waste Generated in USA

Much of the solid waste is disposed in Landfills

Can also Incinerate (Waste to Energy)

Recycling "Energy Content"

Need State of the Art Air Pollution Control Devices

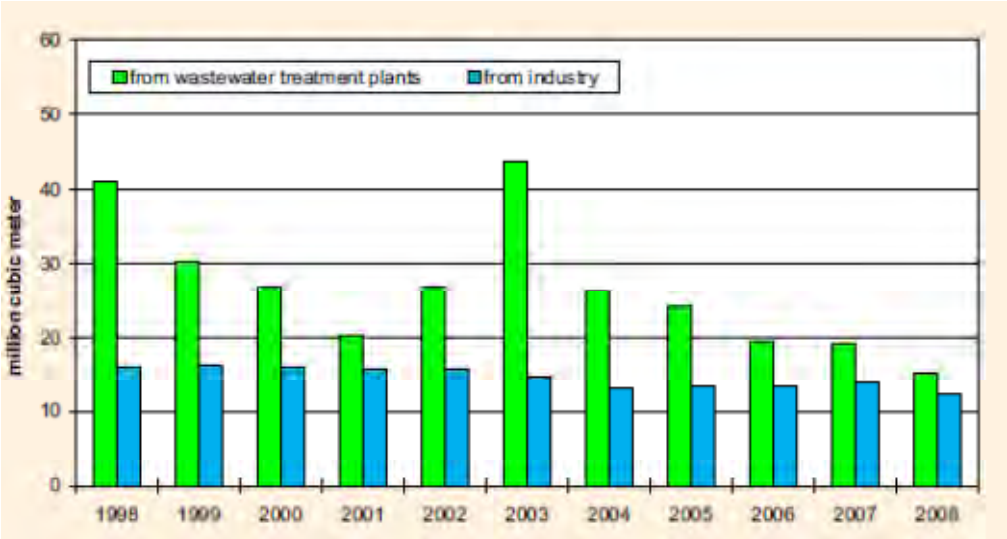
ELECTRONIC WASTE (E-WASTE)

Could be considered Municipal Waste but linked to Industrial Production

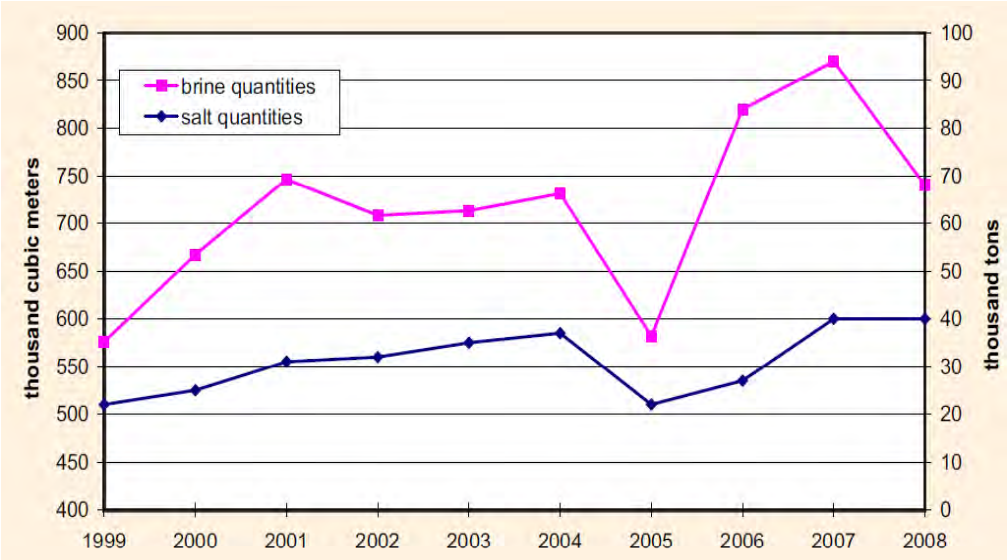
- 80 to 85 percent of electronic products were discarded in landfills or incinerators, which release certain toxics into the air.
- E-waste represents 2 percent of America's trash in landfills, but it equals 70 percent of overall toxic waste (e.g. lead)
- 20 to 50 million metric tons of e-waste are disposed worldwide every year. Only 12.5% E-waste is recycled
- Cell phones and other electronic items contain high amounts of precious metals like gold or silver. US cell phones discarded contain over $60 million in gold/silver every year.
- Recycling 1 million laptops saves the energy equivalent to the electricity used by 3,657 U.S. homes in a year.
- It takes 539 pounds of fossil fuel, 48 pounds of chemicals, and 1.5 tons of water to manufacture one computer and monitor

Industrial Wastewater Pollution in Israel

Wastewater discharged to Sea



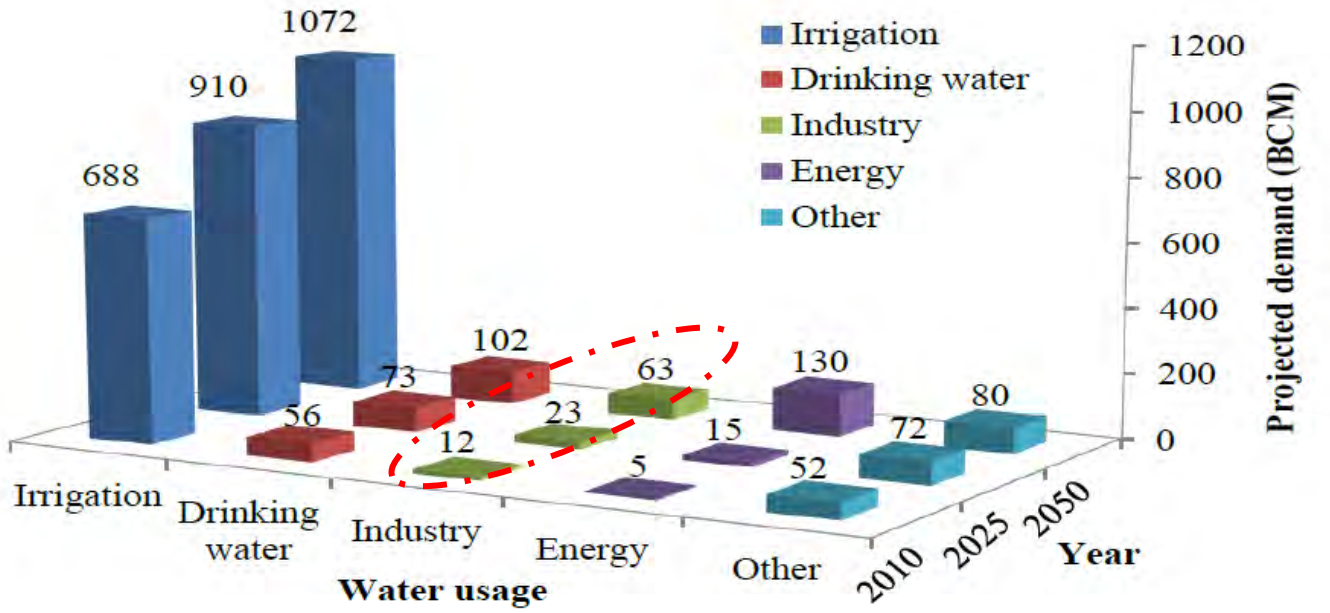
Brine Quantities discharged to the Sea and their Salt Quantities



Source: State of the Environment in Israel-Indicators, Data, and Trends,2010, MEP, Israel

Industrial Wastewater Pollution in India

Projected Water Withdraws for Each Sector



- By 2050, the industrial wastewater production could reach **~48 billion m^3** per year (Bhardwaj, 2005)
- 2009 production estimated ~ 5 billion m^3 (UN Water)

Source: Central Water Commission, 2010, India

Industrial Wastewater Production

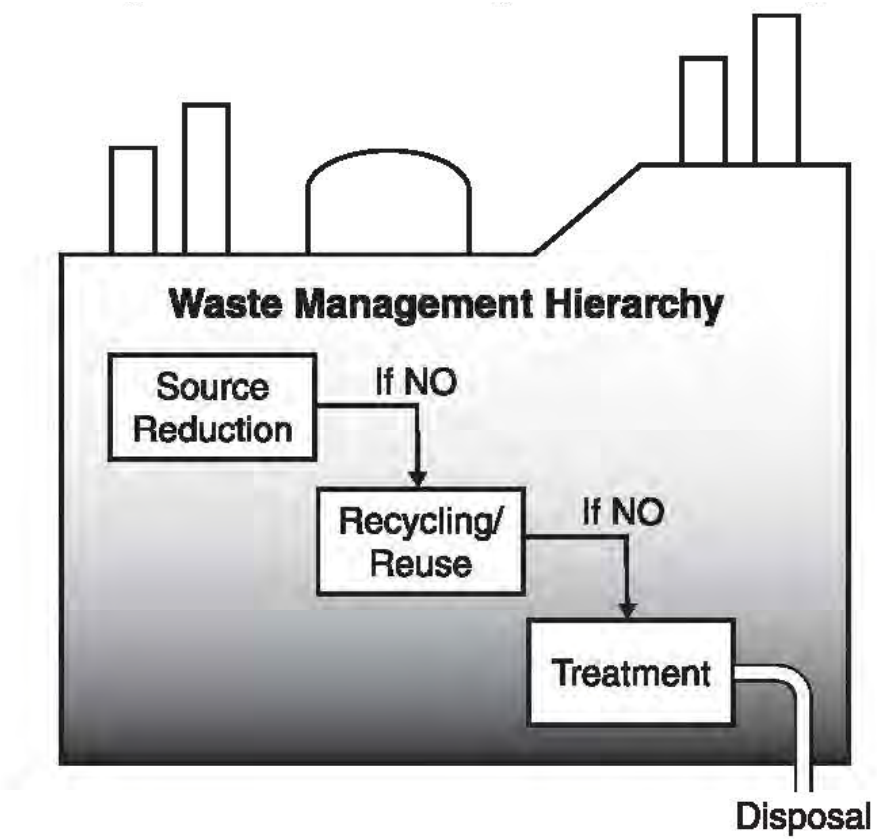
- US: 352 billion m^3; est. 2.6 billion m^3 from Oil & Gas industry: Hydraulic Fracturing)
- China: 23.8 billion m^3
- India: 4.9 billion m^3 , ~ 60% treated
- Israel: 8-9 million m^3 , > 80% recovered for agricultural use

Source: Water Environmental Foundation; State of the Environment Report, MEP, China; UN Water Country Report India; State of the Environment in Israel-Indicators, Data, and Trends,2010, MEP, Israel

USEPA GUIDE TO INDUSTRIAL WASTE MANAGEMENT

- Protecting Human Health and Environment
  - Sound management with a multi-media approach
  - Presents a comprehensive framework of technologies and practices
- Tailoring Management Practices to Risk
  - Provides simple to use modeling tools to tailor management practices
- Affirming State and Tribal Leadership
  - Complements state and local programs
- Fostering Partnerships
  - Public, Facility Managers, Government, Tribes, Industry

Industrial Waste Management Hierarchy

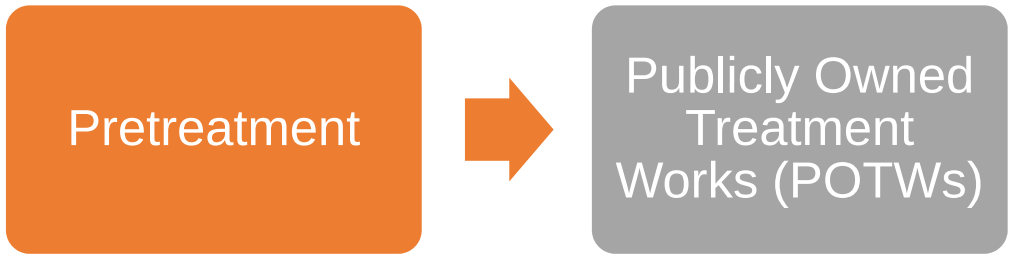


Source Reduction
(reduce amount of contaminant entering waste stream)

Recycling
(reuse materials)

Treatment
(reduce the volume and toxicity of a waste)

Industrial Wastewater Pretreatment



Control and/or limit certain pollutants (particularly toxic ones) discharged to the sewer system

Pretreatment technologies are industry-based, and combination of multiple technologies.

Industry	Major Targets	Pretreatment Processes
Pharmaceuticals	BOD	Evaporation, Drying
Metal-plating	Acidity, heavy metals	Neutralization, sedimentation, chemical precipitation
Plastics and resin	High or low pH, VOCs	Neutralization, biological treatment

Water Treatment Technologies

To name a few…

Adsorption
Sedimentation
Electrocoagulation
…

Membrane Technologies

- Microfiltration membrane
- Ultrafiltration membrane
- Nanofiltration membrane
- RO
- …

Advanced Oxidation Process

- Ozonation
- UV/H_2O_2
- Photocatalytic oxidation
- Electrochemical Oxidation
- Fenton's reagent
- …

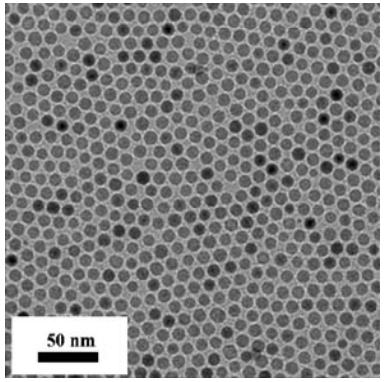
Microbial Processes

- Bioreactor
- Activated Sludge Systems
- Microbial Fuel Cell
- Membrane Bioreactor
- …

Addressing water challenges call out for **less chemically, energetically and operationally intensive** water purification methods. *(Shannon, et al., 2008)*

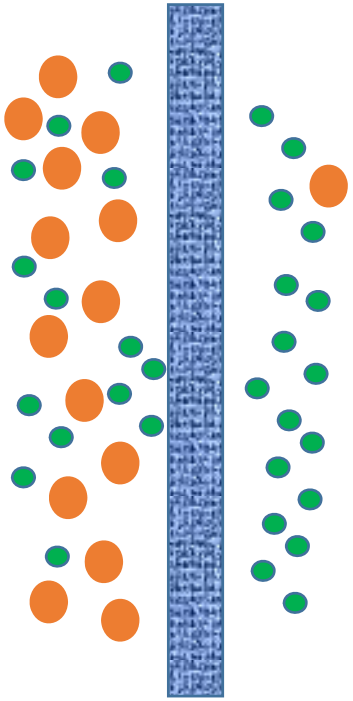
Nanotechnology – can play a major role!

- Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers
- At this scale, materials have novel properties; they can be tuned to meet a functionality
- 1 Trillion $ Industry by 2015; offers great potential for Industrial Wastewater Treatment
- Sensing, Detection, Treatment and Remediation
- Work at WUStL with Graphene Oxide, Titania Membranes for filtration and chemical conversion

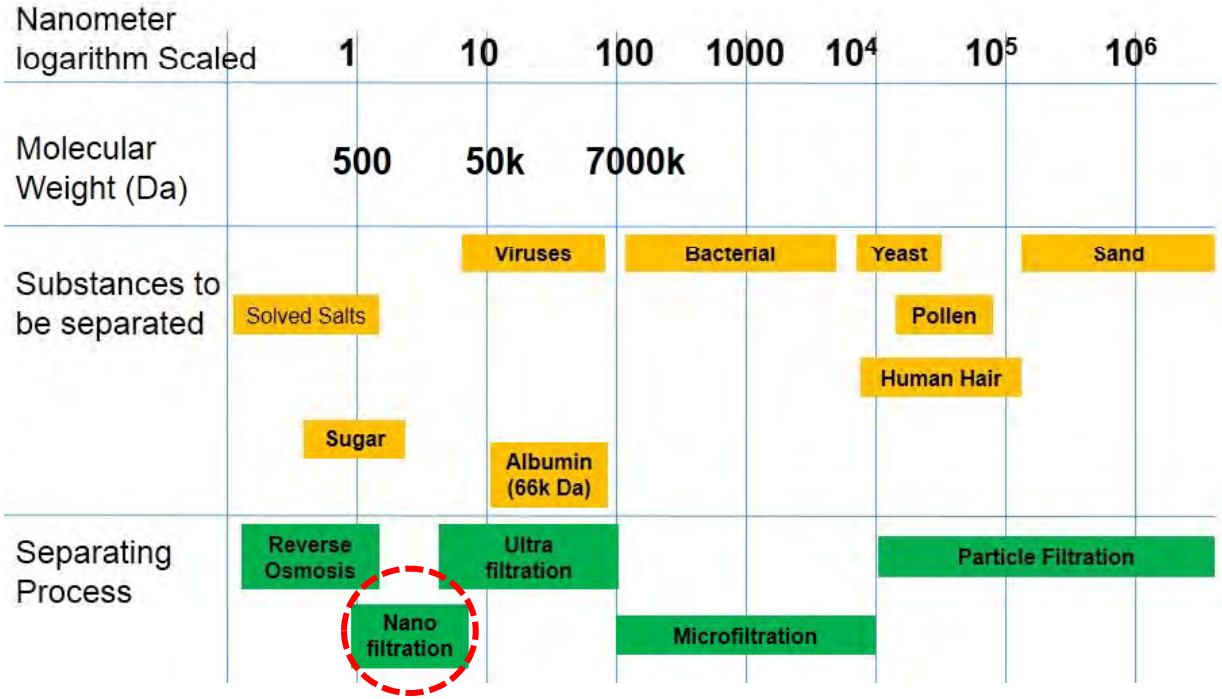


Membrane Technologies

Schematic Diagram of Membrane



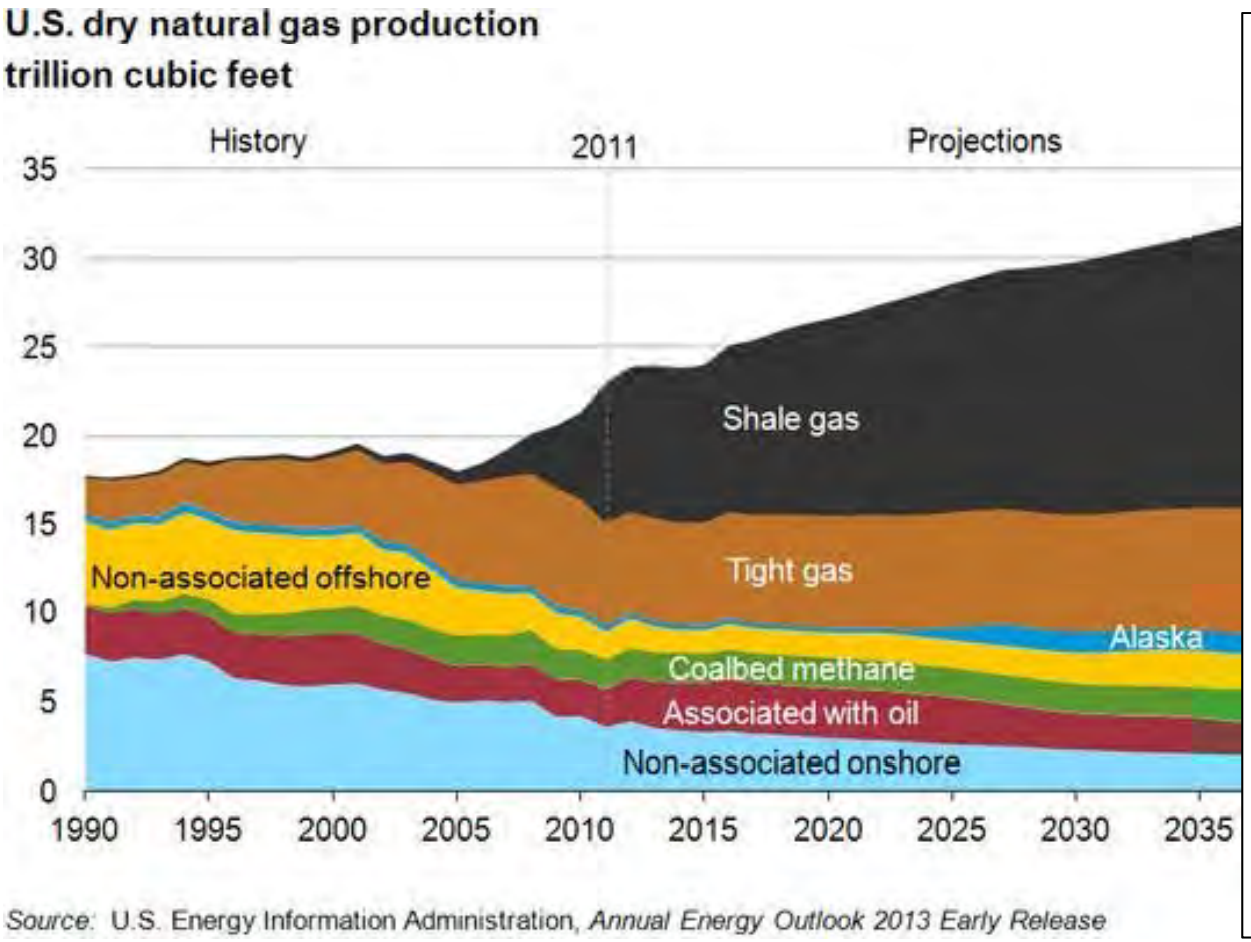
Cut-offs for Filtration Technologies



Performance $\text{Permeability} = \frac{K\,D}{t}$ vs. $\text{Selectivity (Rejection)} = 1 - \frac{C_{out}}{C_{in}}$

Functionality: Reactive? Antimicrobial ?

Wastewater Reuse in Oil/Gas Industry in US



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

Oil and gas production associated water management

- 21 billion barrels of wastewater per year
- $31 billion spent, only <10% on recycling

Zero Discharge Water Management for Horizontal Shale Gas Well development

Source: Bloomberg New Energy Finance

A Regional Perspective-North America Example

Commission for Environmental Cooperation (CEC)

- an intergovernmental organization, financially supported by the three governments.
- comprises a **Council** (governing body, cabinet-level representative from each country), a **Secretariat** (technical, administrative and operational function) and a **Joint Public Advisory Committee** (five citizens from each country).
- facilitates collaboration and public participation to protect environment from North American regional perspective

Sound Management of Chemicals program

Priorities:

- develop comparable tools, data and expertise for the assessment and management of industrial chemical substances (such as the database: *Taking Stock*).
- capacity building in monitoring, reporting and management.
- identifying and addressing unique challenges in specific industrial sectors, such as mercury in health care sector.

Discharge Permitting System in US

Permit issuance:

- discharge to surface waters and ground waters: usually issued by Department of Environmental Protection's Industrial Wastewater Program
- discharges to domestic wastewater treatment facilities: regulated under the Industrial Pretreatment component of the Department's Domestic Wastewater Program

Industrial wastewater directly discharged under National Pollutant Discharge Elimination System (NPDES) may be subject to federal Effluent Limitations Guidelines (ELG).

Effluent guidelines standards are technology-based (i.e. they are based on the performance of treatment and control technologies); they are not based on risk or impacts upon receiving waters. (and also industry-specific).

Compliance & Enforcement

Integrated Compliance Information System (ICIS)

- companies being issued permits to discharge wastewater into rivers.
- when a permit was issued and expires
- how much the company is permitted to discharge.
- the actual monitoring data showing what the company has discharged.

Enforcement Actions

Civil Administrative Actions: non-judicial enforcement actions, such as:

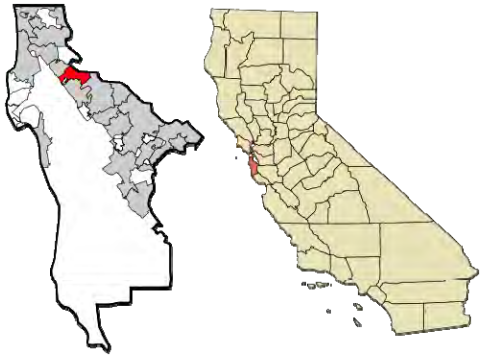
- A notice of violation or a Superfund notice letter
- An administrative order or order (either with or without penalties) directing an individual, a business, or other entity to take action to come into compliance, or to clean up a site.

Civil Judicial Actions: formal lawsuits, filed by the U.S. Department of Justice on behalf of EPA and, in regulatory cases, by the State's Attorneys General for the states.

Criminal Actions: usually reserved for the most serious violations, those that are willful, or knowingly committed. A court conviction can result in the imposition of fines or imprisonment.

Public Private Partnership (PPP)

A public-private partnership



Burlingame, California

Area: 15686 km2
Population: 28806 (2010)
Per capita income: $46,573 (2009)

Veolia Water North America

the world leader in water and wastewater services and technological solutions

Burlingame-Veolia Partnership: launched in 1972, being the first and longest-running public-private partnership in the U.S. for management of the city's wastewater treatment facility

An option for providing wastewater treatment services
realize cost savings, utilize expertise, achieve efficiencies in construction and operation, access private capital, and improve the quality of water and wastewater services.

http://water.epa.gov/grants_funding/cwf/privatization.cfm

SUMMARY

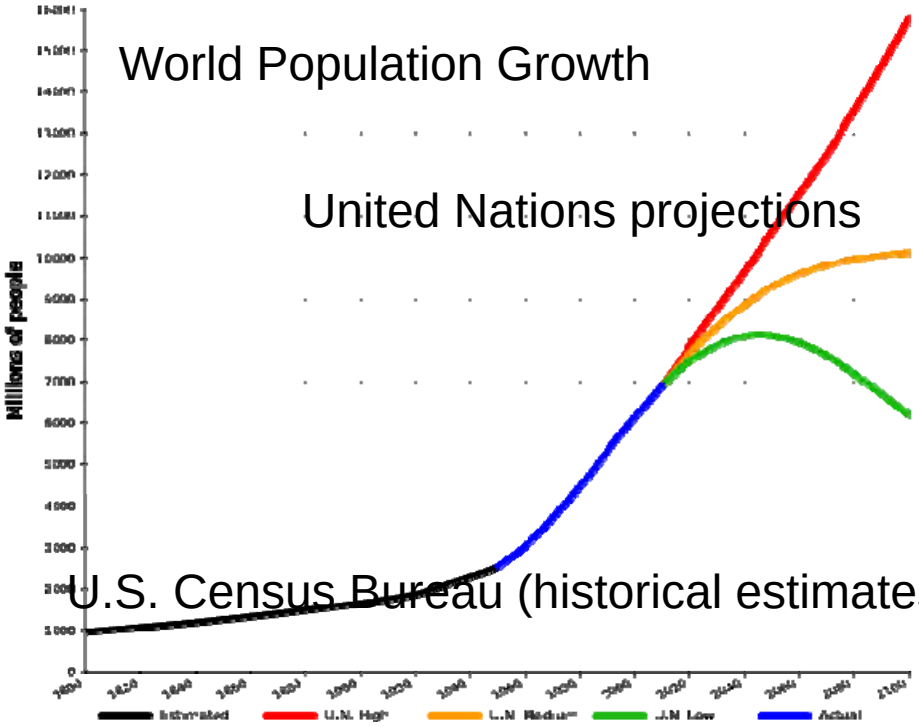
- Industry will produce by-products or waste
- Understand and model process: will help improve product and reduce waste
- Explore opportunities to re-cycle, and more importantly – re-use
- Deploy state of the art pollution control technologies (PPP critical in effective implementation)

Environmental Impact =P *A *T

Ehrlich, Holdren and Commoner, 1970s

Environmental Impact (I) = Population (P) × Affluence (A) × Technology (T)

- Affluence : GDP per capita
- Technology: Emissions per unit of GDP (consumption)



- Population: ↑
- Economic Growth (consumption): ↑