Survey of Modern Concerns Related to Chemicals and Materials.

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https://iscamapweb.chem.polimi.it/citterio/it/education/course-topics/
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Economy and Environment: Key Connections.

The economic activity depend on:
- Energy Sources and Raw Materials
- Transformation Efficiency/effectiveness
- Waste elimination/reuse
- Available services
- Space for economical activity and goods trade

But also from global factors
Environmental Issues.

POLITICAL DEVELOPMENT

- During the 1970's the environmental movement emerged, led by Greenpeace and Friends of the Earth and other organizations.

- At early 1980's, the environment moved towards the political mainstream:
  - "Green parties"
  - Environmental protection and management became major issue.

- Nowadays, environmental policies:
  - Are like all other policies
  - Are created through the political process in one form or another
  - Had been mapped
  - The theoretical basis for many of the possible strategies defined
  - Agreement for some limitations (i.e. 1.5 degree in temperature increase) was established in 2015.

Energy/Atmosphere
- Fossil fuel use grows 1.5%
  - Oil - .5%. Coal – 1.9%, Gas, Natural gas 2%
- Nuclear power capacity grows 1.5%
- Wind energy capacity grows 27%
- Atmospheric CO$_2$ level up 18% since 1960
  - Most likely highest level in 20M yrs.
- Severe weather events on the rise
  - 31% since 1750
  - Weather disaster economic losses grow 93% over 2001 to $53B
  - Cyclone intensity increases 10-20% with increasing temperature

Economic
- Humanity withdrawing earth resources 20% faster then renewal rate (45% in the US)

Nature
- 12% of 9800 bird species threatened with extinction in this century
  - Causes are habitat loss, exotic species, poorly regulated hunting, long line fishing
  - Birds disperse seeds, pollinate flowers, control insect & rodent populations

Transportation/Communication
- Vehicle production grows 2%
- Number of mobile & cell phone subscribers increases 21% to 1.15B
- Ratio of internet users between industrial & developing countries is 17:1 (40:1 in 1995)

Health & Social
- World births exceeded deaths by 74M leading to population of 6.23B
- Population of the 49 poorest countries grows 2.4%, 10 times the rate of industrial countries
- Number of people with HIV/AIDS rose to 42M
  - 5M became infected and 3.1M died
  - 70% in sub-Saharan Africa
- Cigarette production down .5% to 5.6T
  - 82% of 1.1B smokers in low/middle income countries; expected hi growth due to marketing focus
  - Smoking killed 4.9M (more than HIV/AIDS)
- Consumption patterns contribute to mortality,
  - Heart condition and stroke kill 16.7M
  - Infectious & parasitic disease kill 14.4M
  - Cancer kills 6.9M

Military
- Resource wars plague developing nations (funds from resource extraction fund armed conflict)

*Data from State of the World 2003 published by the Worldwatch Institute, Washington, D.C.
Some Facts About The State of the World (2013)*

**Energy/Atmosphere**
- Fossil fuel use grows 1.9%
  - Oil -1.2%, Coal -2.2%, Gas, Natural gas 1.2%, Electricity 2.2%
- Nuclear power capacity stop in 2010
- Wind energy capacity grows 27%
- Atmospheric CO$_2$ level rise up to a 400 ppm since 1960
  - Most likely highest level in 20M yrs.
- Severe weather events on the rise
  - 15% since 1750
  - Weather disaster economic losses grow 103% over 2001
  - Cyclone intensity increases 10-20% with increasing temperature

**Transportation/Communication**
- Vehicle production grows 0.3%
- Number of mobile & cell phone subscribers increases 50% to 200 B.
- Ratio of internet users between industrial & developing countries is 2.5:1 (40:1 in 2003)

**Health & Social**
- Increase of population (7.1B):
  - More developed country 1.2 %
  - Less developed country: 5.9 %
- Africa’s population is estimated to increase to 2.4 billion, from 1.1 billion in 2013.
- The average life expectancy at birth for women in Japan is 86, one of the highest in the world
- In 1950, 117 million people lived in the top 30 metros but that number rose to 426 million by 2013.
  - Heart condition and stroke kill 16.7M

**Military**
- Resource wars plague developing nations (funds from resource extraction fund armed conflict)

**Economic**
- Humanity withdrawing earth resources 20% faster than renewal rate (35% in the US)

**Nature**
- 12% of 9800 bird species threatened with extinction in this century
  - Causes are habitat loss, exotic species, poorly regulated hunting, long line fishing
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*Data from State of the World 2013 published by the Worldwatch Institute, Washington, D.C.*
Global Threats to Ecosystem Viability.

- loss of crop & grazing land
- depletion of world’s tropical forests
- extinction of species
- rapid population growth
- shortage of fresh water resources
- over-fishing, habitat destruction

- pollution in the fresh water and marine environment
- threats to human health
- climate change, GW
- acid rain
- ozone layer depletion
- pressures on energy resources
- solid waste pollution
- ............

Bird population decline
State of the World Environment Warrants Attention.

<table>
<thead>
<tr>
<th></th>
<th>1950</th>
<th>1972</th>
<th>1997</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Population (x billion people)</td>
<td>2.5</td>
<td>3.8</td>
<td>5.8</td>
<td>10.7</td>
</tr>
<tr>
<td>2. Megacities (&gt;8 million)</td>
<td>2</td>
<td>9</td>
<td>25</td>
<td>200</td>
</tr>
<tr>
<td>3. Food (calories/capita)</td>
<td>1980</td>
<td>2450</td>
<td>2770</td>
<td>2200</td>
</tr>
<tr>
<td>4. Fisheries (Million ton·yr⁻¹)</td>
<td>19</td>
<td>58</td>
<td>91</td>
<td>35</td>
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<tr>
<td>5. Water use (km³·yr⁻¹)</td>
<td>1300</td>
<td>2600</td>
<td>4200</td>
<td>7500</td>
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<tr>
<td>6. Rainforest (1950=100)</td>
<td>100</td>
<td>85</td>
<td>70</td>
<td>45</td>
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<tr>
<td>7. CO₂ Emissions (billion ton·yr⁻¹)</td>
<td>1.6</td>
<td>4.9</td>
<td>7.0</td>
<td>14.0</td>
</tr>
<tr>
<td>8. Ozone Layer (CFC in ppb)</td>
<td>–</td>
<td>1.4</td>
<td>3.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Source: World Resource Institute, 1996
Unsustainable Place.
## Major Trends Affecting the Bio-economy.

1. **Changing trade patterns:**
   - globalisation
   - Common Agricultural Policy (CAP) reform
   - consumer-led production

2. **Climate change:**
   - spread of plant diseases (e.g. fungi affecting banana, olive and rubber farms)
   - new varieties/crops
   - water and temperature issues
   - soil degradation

3. **World population trends:**
   - 6.5 bn in 2005 - 8.3 bn in 2030
   - increasing calorie consumption per capital
   - rising meat demand – up 70% by 2030

4. **Environmental considerations:**
   - land use and reduction of inputs
   - habitat protection
   - maintaining biodiversity

5. **Shifts in energy supply:**
   - higher costs of fossil fuels/scarcity
   - security of supply
   - reduction of GHG emissions
Concerns Related to Human Activity.

- **Global issues**
  - Greenhouse gas emission and global warming
  - Ozone depletion in the stratosphere
  - Global population growth
  - Resource depletion

- **Environmental issues**
  - Air and water pollution
  - Acid and base deposition
  - VOC and photochemical smog

- **Health and Safety issues**
  - Particulate matter
  - Freshwater contamination by hazardous wastes
  - At work accidents and disasters
## The 21 Emerging issues. (UNEP 2012)

<table>
<thead>
<tr>
<th>Issue ID</th>
<th>Issue Title</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Cross-cutting issues</strong></td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>Aligning Governance to the Challenges of Global Sustainability</td>
<td>1</td>
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<tr>
<td>002</td>
<td>Transforming Human Capabilities for the 21st Century: Meeting Global Environmental Challenges and Moving Towards a Green Economy</td>
<td>2</td>
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<td>003</td>
<td>Broken Bridges: Reconnecting Science and Policy</td>
<td>4</td>
</tr>
<tr>
<td>004</td>
<td>Social Tipping Points? Catalyzing Rapid and Transformative Changes in Human Behavior towards the Environment</td>
<td>5</td>
</tr>
<tr>
<td>005</td>
<td>New Concepts for Coping with Creeping Changes and Imminent Thresholds</td>
<td>18</td>
</tr>
<tr>
<td>006</td>
<td>Coping with Migration Caused by New Aspects of Environmental Change</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td><strong>Food, biodiversity and land issues</strong></td>
<td></td>
</tr>
<tr>
<td>007</td>
<td>New Challenges for Ensuring Food Safety and Food Security for 9 Billion People</td>
<td>3</td>
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<tr>
<td>008</td>
<td>Beyond Conservation: Integrating Biodiversity Across Environmental and Economic Agendas</td>
<td>7</td>
</tr>
<tr>
<td>009</td>
<td>Boosting Urban Sustainability and Resilience</td>
<td>11</td>
</tr>
<tr>
<td>010</td>
<td>The New Rush for Land: Responding to New National and International Pressures</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td><strong>Freshwater and marine issues</strong></td>
<td></td>
</tr>
<tr>
<td>012</td>
<td>Shortcutting the Degradation of Inland Waters in Developing Countries</td>
<td>15</td>
</tr>
<tr>
<td>013</td>
<td>Potential Collapse of Oceanic Systems Requires Integrated Ocean Governance</td>
<td>13</td>
</tr>
<tr>
<td>014</td>
<td>Coastal Ecosystems: Addressing Increasing Pressures with Adaptive Governance</td>
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</tr>
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The 21 Emerging issues (UNEP 2012) - cont.

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<td><strong>Climate change issues</strong></td>
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<tr>
<td>015</td>
<td>New Challenges for Climate Change Mitigation and Adaptation: Managing the Unintended Consequences</td>
<td>7</td>
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<tr>
<td>016</td>
<td>Acting on the Signal of Climate Change in the Changing Frequency of Extreme Events</td>
<td>16</td>
</tr>
<tr>
<td>017</td>
<td>Managing the Impacts of Glacier Retreat</td>
<td>21</td>
</tr>
<tr>
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<td><strong>Energy, technology, and waste issues</strong></td>
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<tr>
<td>018</td>
<td>Accelerating the Implementation of Environmentally-Friendly Renewable Energy Systems</td>
<td>7</td>
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<tr>
<td>019</td>
<td>Greater Risk than Necessary? The Need for a New Approach for Minimizing Risks of Novel Technologies and Chemicals</td>
<td>10</td>
</tr>
<tr>
<td>020</td>
<td>Changing the Face of Waste: Solving the Impending Scarcity of Strategic Minerals and Avoiding Electronic Waste</td>
<td>14</td>
</tr>
<tr>
<td>021</td>
<td>The Environmental Consequences of Decommissioning Nuclear Reactors</td>
<td>17</td>
</tr>
</tbody>
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* Ranking based on scoring by the UNEP Foresight Panel and after considering the polling results of more than 400 scientists worldwide.
The world will need to support 5 billion more people.
World population passed 6 billion in 2000, up from 2.5 in 1850 and 4.4 in 1950 and it is projected to grow to about 8 billion in 2025 and 11 billion in 2050.
<table>
<thead>
<tr>
<th>Societal Regime</th>
<th>Energy Use (GJ)</th>
<th>Material Use (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic human metabolism</td>
<td>3,5</td>
<td>1</td>
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<tr>
<td>(biomass intake by nutrition)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hunter-gatherers</td>
<td>10-20</td>
<td>2-3</td>
</tr>
<tr>
<td>(uncontrolled solar energy use)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrarian societies</td>
<td>60-80</td>
<td>4-5</td>
</tr>
<tr>
<td>(controlled solar energy use)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial/Technological societies</td>
<td>250</td>
<td>20-22</td>
</tr>
<tr>
<td>(fossil energy use)</td>
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</tbody>
</table>
Agricultural expansion is the main cause of deforestation. Permanent cultivation and shifting agricultural and pastures are the main contributes to deforestation. In tropical areas, the major change has been a decline in closed forest, in case with urban expansion. In developing regions, continuing population growth and increased demand for food, combined with declining in agricultural productivity, increase pressure for deforestation.

The capacity of forest to provide goods and services is decreasing (U.N. - The Millennium Development Goals Report 2011)
Species Extinctions Since 1800.

http://www.whole-systems.org/extinctions.html
The Element Shortage – Some Elements are Rare on the Earth.

Relative abundance of the chemical elements in Earth’s upper continental crust.

- **Rock-forming elements**
- **Rare earth elements**
- **Major industrial metals in Bold**
- **Precious metals in Italic**
- **Rarest “metals”**

Abundance, atoms of element per $10^6$ atoms of Si

$10^9$ - $10^6$ - $10^3$ - $1$ - $10^{-3}$ - $10^{-6}$

Atomic number, Z

U.S. Geological Survey Fact Sheet 087-02
Also the most Abundant Compounds need Attention, i.e. Water.

Access to fresh water was widen in several country in the last 20 years, but pollution has also remarkably increased.

*Science* 313, 1088-1090, 2006
Increasing Water Use.

Industrial water use increases with development.

Water use generally increases with economic development, particularly for industrial and municipal use. Industry requires water for cooling, washing and processing with major uses including power generation, steel, chemicals, paper and petroleum refining. People require water also for drinking, food preparation, sanitation, etc. Industrial and municipal uses generally have much higher economic value than agricultural use.

Services provided by freshwater ecosystems are threatened.

Freshwater ecosystems (lakes, rivers, etc.) provide a variety of critical services, including water supply, water purification, flood control, recycling and transport of nutrients, fish production and protection of biodiversity. But many freshwater systems are being degraded through excessive water withdrawals, pollution and introduction of invasive species. Worldwide, about half of all wetlands have been lost and more than 20% of the 10,000 known freshwater species are extinct.
Nearly half of the world’s people will experience water shortages by 2030. On a global basis, water withdrawal amounts to only 10-20% of total renewable water resources. However, water supply is very unequally distributed and conveniently cannot be moved over long distances. About 40% of the world population already live in river basins with less than 2000 m$^3$ of water per person per year for all purposes. By 2030, about half of the world population will live in areas facing such water shortages.
In developed country houses need:

- 65.2% of total electricity consumption
- > 36% of total primary energy use
- 30% of total greenhouse gas emissions
- 136 million tons of construction and demolition waste (approx. 1.26 kg·person⁻¹·day⁻¹)
- 12% of potable water
- 40% (3 billion tons·yr⁻¹) of raw materials use globally
Indoor Air Pollution.

- Bacteria
- Molds and mildews
- Viruses
- Animal dander and cat saliva
- Plants
- House dust
- Mites
- Cockroaches
- Pollen

More than 3 million deaths each year are caused by air pollution, mostly due to particulate pollution. Acute respiratory infections due to indoor pollution are mainly responsible for these deaths.
Increasing Energy Consumption.

Global population and consumption of energy has increased steadily in the last 100 years. This has occurred mainly from nonrenewable fossil sources!

“It is cheaper to save fuel than to buy it, no matter what kind it is”

Natural Capital by A. Lovins 2000
Fossil Fuel Processing has Environmental Consequences...
Effects of Fossil Fuel Combustion.

- Fossil fuels are hydrocarbons containing traces of nitrogen, sulfur and other elements.
- Typical combustion reaction:
  \[ C_w H_x O_z N_a S_b + O_2 + cN_2 \rightarrow w(CO_2+CO) + x/2 H_2O + (a+c/2)NO_x + bSO_2 + \ldots \]
- Only \( H_2O \) is essentially benign ...
- CO and many HC's are toxic to humans.
- \( NO_x \) and \( SO_2 \) combine with rainwater to form nitric and sulfuric acids, i.e., "acid rain".
- \( CO_2 \) is the primary culprit in global warming, but other GHG gases are also important.
- Stratospheric Ozone Depletion (if halogen are present).
- Transition metal pollution from ashes.
Atmospheric carbon dioxide concentrations (from 1750 to 2000 ac). N.B. In 2013 the CO₂ level growths to 400 ppm!!!

Source: C.D. Keeling and T.P. Whorf, Atmospheric CO₂ Concentrations (ppmv) derived from in situ air samples collected at Mauna Loa Observatory, Hawaii, Scripps Institute of Oceanography, 1998. A. Neftel et al, Historical CO₂ Record from the Siple Station Ice Core, Physics Institute, University of Bern, Switzerland, 1994.
The Effect of Industrial Revolution on Atmospheric CO$_2$ Concentration.

Figure. Carbon dioxide (CO$_2$) concentrations (in parts per million) for the last 1100 years, measured from air trapped in ice cores (up to 1977) and directly in Hawaii (from 1958 onwards).


Something new may have happened between 1800 AD and 2000 AD. The year 1769 is marked because in that year James Watt patented his steam engine. (The first practical steam engine was invented 70 years earlier in 1698, but Watt’s was much more efficient)
Note: Human perturbation, occurred in the last 200 years, is now close to CO$_2$ changes of glacial-interglacial cycles, occurred in ten of Townshend years. In the insert the time trend of CO$_2$ vs. time in the last 400,000 years is reported as estimated from glass carrots (Petit et al., 1999, Indermuehle et al., 1999) and direct atmospheric observations (Keeling et al., 1995, Tans et al., 1999).

Each rectangle’s area represents the greenhouse gas emissions of one region. The width of the rectangle is the population of the region, and the height is the average per-capita emissions in that region.

Climate Change.

There are many signs of climate change

- Global average surface temperature have increased by about 0.6 °C since 1900
- Sea levels are rising by about 1 cm per decade.
- Arctic sea ice thickness has declined 40 cm in the past 40 years
- Major glaciers throughout the world are retreating.
- Nordic lake ice is forming late in the autumn and melts early in the spring.
- Precipitations in the Northern Hemisphere are increased, particularly strong rainfall.
- El Nino events have become more common and more intense
- In part of Asia and Africa, droughts have increased in frequency and intensity.
- Insurance payments for damage from floods and storms from about $2 billion annually in the 1980s to $30 billion in the early 1990s and to $120 billion in 2015.
A Greenhouse...

- Sunlight at $\lambda = 0.5 \, \mu m$ mostly passes through the glass.
- Re-emitted radiant energy from the $\sim 300 \, K$ interior is at $\lambda \approx 10 \, \mu m$.
- The glass is opaque to this infrared wavelength, so re-emitted energy cannot radiate away.
- The greenhouse warms up.

### Glass Absorption

- **Overall spectral transmittance $T_{\lambda}$**
  - **Borosilicate glass, 0.478 cm thick**
  - **Fused silica glass, 1.27 cm thick**

### The Greenhouse Effect

- **$T_{\text{sun}} = 5760 \, K$**
- **$\lambda_{\text{sun}} = 0.5 \, \mu m$**
- **$T_{e} = 300 \, K$**
- **$\lambda_{e} = 10 \, \mu m$**
- **“earth”**
Leading Facts about CO$_2$ Science.

- **The earth absorbs anthropogenic CO$_2$ at a limited rate**
  - Emissions would have to drop to about half of their current value to stabilize atmospheric concentration at 550 ppm
  - This in the face of a doubling of energy demand in the next 50 years (1.5% per year emissions growth)

- **The lifetime of CO$_2$ in the atmosphere is 200-300 years**
  - The atmosphere will accumulate emissions during the 21$^{st}$ Century
  - Near-term emissions growth can be offset by greater long-term reductions
  - Limited emissions reductions only delay the concentration growth (20% emissions reduction buys 15 years)
Effects of Mean World Temperature Increase.

What can occur if surface hearth temperature will increase 1-2 degree, in mean.

- Relevant Polar Ice Reduction
- Strong decrease of corn production
- Collapse of anchovy fishing
- Increase of crops crowing
- Short rainy winter, long dry summer
- Strong decrease of corn production
- Increase of sea level
- More humid than before
- Less humid than before
- Flooding generated by sea level increase
- Poor rice harvest
Actual Primary Production and Nutrients.

Annual carbon production in modern ocean: coastal, equator, southern ocean

* Tropical pump, enough light, so nutrient (N, P) limited
* Southern ocean pump, Not enough light, excess nutrients, but. iron limited.
Minimum of Summer Arctic Ice 2007 vs. 2005.

- Current Ice Extent 09/16/2007
  - Total extent = 4.1 million sq km
  - median ice edge

- Current Ice Extent 09/21/2005
  - Total extent = 5.3 million sq km
  - median ice edge
Stratospheric Ozone Depletion.

- Ozone is a good absorber of solar ultraviolet radiation, and depletion of upper atmosphere ozone results in increased surface levels of UV radiation.
- Increased levels of UV can result to increased human skin cancer and plant damage.
- CFC compounds decompose ozone by generation of chlorine atoms in the stratosphere

\[
\begin{align*}
\text{cycle } \text{Cl}^\cdot/\text{ClO}^\cdot & \\
\text{Cl}^\cdot + \text{O}_3 & \rightarrow \text{ClO}^\cdot + \text{O}_2 \\
\text{ClO}^\cdot + \text{O} & \rightarrow \text{Cl}^\cdot + \text{O}_2 \\
\text{O} + \text{O}_3 & \rightarrow 2 \text{O}_2
\end{align*}
\]

\[k_1 = 2.9\times10^{-11} \ e^{-260/T} \ \text{cm}^3\cdot\text{molec}^{-1}\cdot\text{s}^{-1}\]
\[k_2 = 7.7\times10^{-11} \ e^{-130/T} \ \text{cm}^3\cdot\text{molec}^{-1}\cdot\text{s}^{-1}\]

The ozone hole at its peak in 2003 over Antarctica
CFC from HVAC Equipment and Ozone.

- Refrigerators, air conditioners and heat pumps have used chlorofluorocarbons (CFC's) as their working fluids (refrigerants).
- CFC's at normal conditions are extremely inert, stable and non-toxic. Their use leads to good equipment efficiency and safety.
- Because they are so inert, CFC's are not destroyed in the lower atmosphere and eventually rise to upper atmosphere (stratosphere).
- UV light in the stratosphere breaks down the CFC molecule, releasing chlorine atoms, which attacks ozone (O$_3$) converting to O$_2$ and O.
- The Cl atoms are released after breaking down an O$_3$ molecule, and both the O and the Cl are free to attack other O$_3$ molecules.
- Release of CFCs has already caused significant stratospheric ozone depletion, particularly in the South and North Polar regions.

**CFC-12**
\[ CF_2Cl_2 \]
Refrigerant

**CFC-11**
\[ CFCl_3 \]
Blowing agent

**CFC-113**
\[ CF_2CICFCl_2 \]
Cleaning agent
Outdoor Air Quality Issues: Smog Formation.

“A smog inversion layer blanketing downtown Los Angeles in 1956.” Source: www.epa.gov
Acid Rain: Defoliation – Corrosion.

Atmospheric intake of sulfur produce acid oxides $\text{SO}_2$ and $\text{SO}_3$ and then sulfuric acid ($\text{H}_2\text{SO}_4$) starting a process known as acid rain.
The Waste Concern.

• “E” is for “End Line” Technologies
• Containing systems for stocks and landfills
  - Costly
  - Constant Monitoring
  - Potentially fail
Hazardous Waste Landfill.
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Relevant Industrial Accidents!

BASF, Oppau/Ludwigshafen, September 21, 1921
Crater: 80 m diameter, 16 m deep
450 dead

NH$_4$NO$_3$ $\rightarrow$ N$_2$ + $\frac{1}{2}$O$_2$ + 2H$_2$O
{300$^\circ$, $\Delta$G<0}

AZF, Toulouse, September 21, 2001
Crater: 50 m diameter, 10 m deep
29 dead

80 years
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Level of Safety at Work.

7,628,184 ➢ number of reported accidents EU-15 2000

4.2 ➢ million accidents at work with more than 3 days absence 2003

4,664 ➢ fatal accidents at work EU-15 2003 (3,876 in the EU-28 during 2015, 102 deaths more than 2014)

54,250 ➢ occupational diseases in 11 Member States 2003 (68,800 in EU-28 in 2015).

one accident at work in Europe every 5 seconds

4% of all workers are victims of an accident at work during the year

Relevant Accidents in Chemical Plants and Transport of Chemical Substances.

- Bhopal UC plant, 1984
- Viareggio Explosion
- Buncefield accident, 2006
- Exxon Valdez

Chemicals: $\text{CH}_3\text{NCO}$, GPL

Accidents:
- HC tank explosion
- Oil spill
Methyl isocyanate (“MIC”, CH$_3$NCO) used to manufacture carbaryl (Sevin®) at a Union Carbide plant in Bhopal, India.

Water (somehow) got into a storage tank containing 15 Tons of MIC

\[
\text{CH}_3\text{NCO} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{OH} + \text{HNCO}
\]

(b.p. 40°C) (b.p. 100°C) (b.p. 65°C) (b.p. ca. 25°C)

$\Delta H_{\text{rxn}} \approx -250 \text{ kJ mol}^{-1}$

$T \uparrow$, rate $\uparrow \{\text{Arrhenius Law, } k = \exp(-E_{\text{act}}/RT)\}$

$\Delta P = (nR\ \Delta T)/V$ plus vaporization:

pressure valve burst open, backup scrubber did not work, flare tower did not work

4 Tons of MIC vaporized, wind carried vapor across the city. At least 3,800 people died, 1,000 more injured and blinded. Legal claims arose.
Unintended Consequences on Health.

• The Surprises (see REACh – EU regulation)
  ▪ Persistent Organic Pollutants (POP e.g. DDT, PCB, Polyacrylates..)
  ▪ Bioaccumulation
    ▪ PCB at 1 ppb conc. in H₂O, accumulate to 6,400 in plankton, 240,000 in squid, 13,000,000 in dolphin and tuna
  ▪ Atmospheric Distillation (especially in northern latitudes)
  ▪ Endocrine disruption

• The Messes Left Behind
  ▪ Thousands of tons of abandoned pesticides
  ▪ Nuclear legacy with $300 billion price tag
  ▪ Industrial contaminated sites
  ▪ Spread of POP in environment and humans

Some things are tough to throw away
## Materials of Concern (Pratt & Whitney)

<table>
<thead>
<tr>
<th>Prohibited - Higher Risk Substitutes In Hand</th>
<th>Restricted - Higher Risk Substitutes Being Developed</th>
<th>To Be Reduced - Lower Risk Being Monitored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic &amp; compounds</td>
<td>Beryllium (&lt;2%)</td>
<td>Acetone</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Chromium, hexavalent</td>
<td>Ammonia</td>
</tr>
<tr>
<td>Benzene</td>
<td>Class II ODS</td>
<td>Butyl alcohol</td>
</tr>
<tr>
<td>Beryllium (&gt;2%)</td>
<td>Cyanides</td>
<td>Ethyl benzene</td>
</tr>
<tr>
<td>Cadmium &amp; compounds</td>
<td>Dimethylformamide</td>
<td>n-Hexane</td>
</tr>
<tr>
<td>Chlorinated solvents</td>
<td>HCFC-14 lb &amp; HCFC-22</td>
<td>Hydrofluoric acid - cleaning</td>
</tr>
<tr>
<td>Ethyl alcohol (ash and wipe)</td>
<td>Hydrazine</td>
<td>Isocyanates</td>
</tr>
<tr>
<td>Ethylene glycol ether compounds</td>
<td>Hydrofluoric acid - braze fluxes</td>
<td>n-methyl-2-pyrrolidone</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Hydrogen fluoride gas</td>
<td>Isopropyl alcohol</td>
</tr>
<tr>
<td>Mercury &amp; compounds</td>
<td>Lead &amp; compounds</td>
<td>Nickel plate</td>
</tr>
<tr>
<td>Methanol (as handwipe)</td>
<td>Manmade fibers, e.g., cristobalite, fiberfrax</td>
<td>Nitric acid</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>MDA (4’, 4’-Methylenedianiline)</td>
<td>Petroleum distillates (e.g.,</td>
</tr>
<tr>
<td>Class I ozone depleting substances</td>
<td>Methyl alcohol (methyl alcohol)</td>
<td>naphtha, mineral spirits,</td>
</tr>
<tr>
<td>Radioactive materials, including</td>
<td>Methyl ethyl ketone (MEK, 2-butanone)</td>
<td>Stoddard solvent,</td>
</tr>
<tr>
<td>Thoriated (TD) nickel</td>
<td>Methyl iso-butyl ketone (MIBK, 4-methyl-2-pentanone)</td>
<td>varsol,</td>
</tr>
<tr>
<td>Toluene diisocyanate</td>
<td>Phenol</td>
<td>evaporative lubricants)</td>
</tr>
<tr>
<td></td>
<td>Styrene</td>
<td>Phosphoric acid</td>
</tr>
<tr>
<td></td>
<td>Toluene</td>
<td>Sec-butyl alcohol</td>
</tr>
<tr>
<td></td>
<td>Xylene</td>
<td>Sulfuric acid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1, 2, 4-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trimethylbenzene</td>
</tr>
</tbody>
</table>

ODS = Ozone-depleting Substances
Banned Chemicals.

- **Atrazine**: banned in EU in 2003 because of unavoidable water contamination
- **Tributyltin (TBT)**: Most antifoulant uses phased out by 2003, remaining uses by 2008
- **Alkyl phenols and their ethoxylates**: EU Directive prevents use as co-formulants in new products from 2005; voluntary UK agreement to replace AP(E)s in existing pesticide formulations
- **Lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated biphenyl ether**s are banned from 2006 in electronic equipment (EU RoHS directory)
- Some fluorocarbons (i.e. HCFC-141b, CFC-11) are banned from 2004
- **Vinclozolin, Procymidone, Fenarimol**: EU discussing phasing out all uses.
- In Europe the REACh encourage new bans. (see https://echa.europa.eu/regulations/reach/understanding-reach)
Beyond the Environment: the Triple Bottom Line.

Living within environmental limits:
Ensure natural resources to support life remain unimpaired

Ensuring a strong, healthy & just society:
Meet diverse needs of all; promote wellbeing inclusion/opportunity

Achieving a sustainable economy:
Strong, stable, efficient & fair