Sustainability for Engineers

National Risk Management Research Laboratory

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ABNT-INMETRO-sponsored Rio Short Course, August 14-15, 2012

Workshop Outline (1)

Day 1 morning 10:30 am 1:00 pm (Subhas Sikdar)

Introduction: Meaning of sustainability in engineering sciences

Background: Brundtland Commission or WCED, global summits, and history. Business involvement, reporting requirements

Day 1 afternoon 2:30 pm to 3: 30 and 4:30 to 6pm

Engineering Approaches Progress of engineering analysis of sustainability from industry and academia, systems approach, interdisciplinary

Industrial, community, ecological, agricultural, and technology systems

Analysis Systems classification, metrics and indicators, methods of sustainability analyses for various types of systems, data Issues, decision Making

Workshop Outline (2)

Day 2 morning 9:30 am to 1 pm (Farhang Shadman)

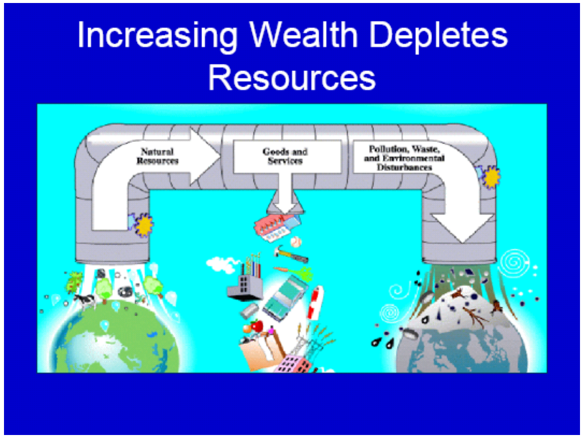
Sustainability in high-technology industry: semiconductor industry as an example of nano manufacturing, complexity due to new materials, use of nanoparticles, challenges of nano manufacturing, new sensors and metrology, water and energy use, subtractive technology, and the paradigm of additive technology in nano manufacturing

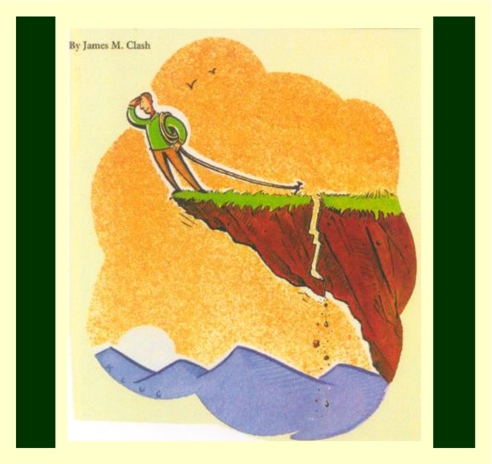
Day 2 afternoon 2:00 pm to 6 pm (Subhas Sikdar)

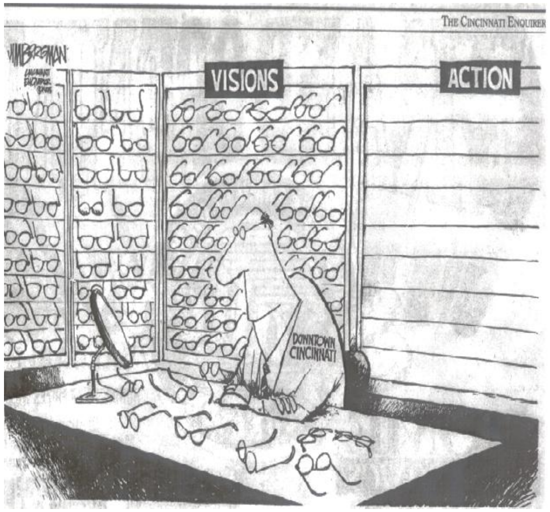
Analyses and Case Studies case studies of sustainability analyses of industrial processes and products

Outline

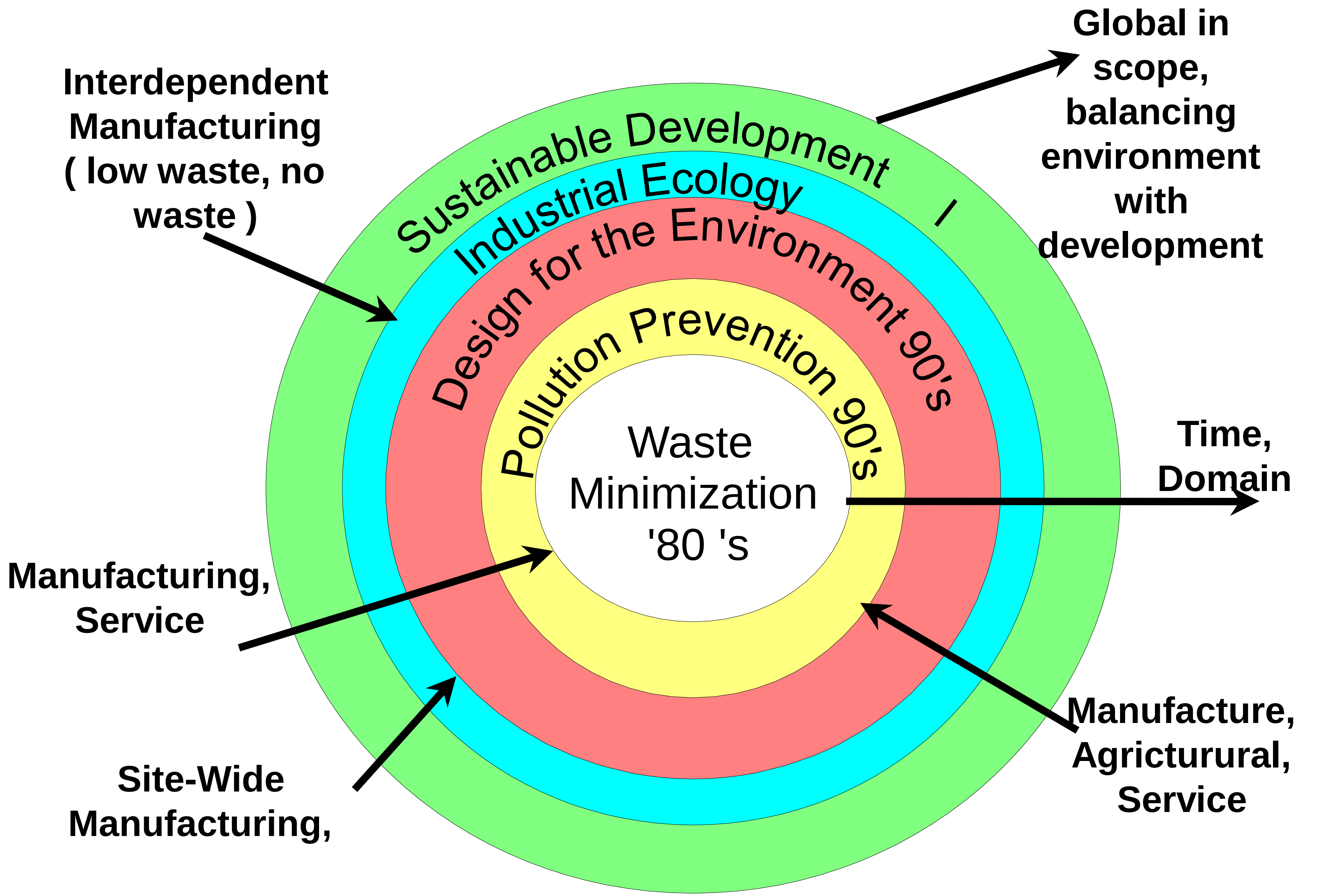
- Meaning and background
- Engineering approaches
- Sustainability Analyses
- Sustainability in high-tech industry
- Case studies of analyses



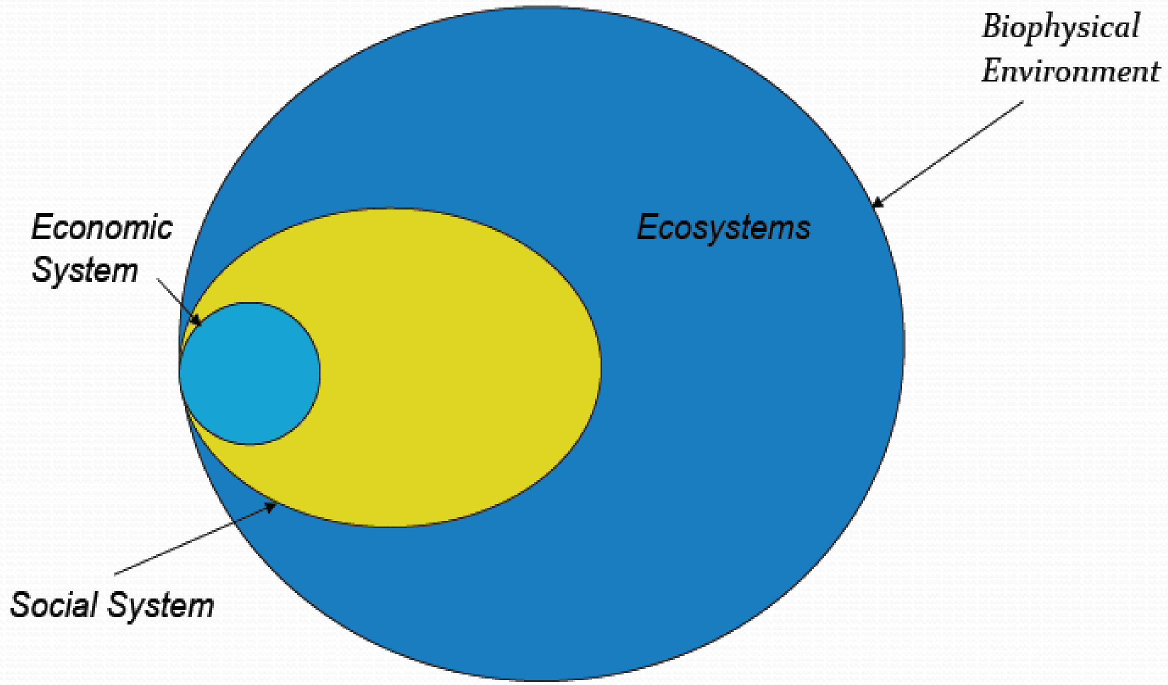




Continuum of Sustainable Technologies



Essential Relationships of Sustainability



Why the concerns: U.S. as an Example

Taking the USA as a case study:

- **US Annual waste**
  - **19 billion lbs of polystyrene peanuts**
  - **40 billion plastic knives, forks, and spoons**
  - **28 billion lbs of food**
  - **Enough steel to level and restore Manhattan**
  - **Enough plastic film to shrink-wrap Texas**
    - **(Source: Garbology and Wall Street Journal, April 14, 2012**
- **Trash is America's leading export: waste paper, solid cardboard, crushed beer cans, junked electronics**
  - **(China's #1 export to the US is computers, US's #1 to China is scrap.**
- **America's communities spend more on waste management than on fire protection, parks and recreation, libraries, or school books**
  - **(NY City spent in 2011 $2.2 billion on sanitation, $300 million of that for transporting 12,000 tons/d to out of state landfills. 12,000 tons are equivalent to 62 Boeing 747 or 8,730 Honda Civics**

More on the Concerns

- Largest landfill in the nation is Los Angeles's Puente Hills landfill, a 500 ft high garbage mountain
- Waste Management Company estimated that the nation's landfills have <u>$20 billion in valuable resources/year</u>
- Personal wastes:
  - An American: 7.1 lbs/day
  - A Dane: 4 lb/day
  - A Japanese: 2.5 lb/day
  - Each American is on track to produce 102 tons of waste in an average lifetime
- Belgium and Denmark send less than 4% waste to landfills

Background- Global concerns

- **Population: to increase by 2.6 billion by 2050**
- **That increase is more than the population in 1050 (2.5 billion), most of the increase in developing countries**
- **Tropical soils and food security (Stocking, M.A., Science, vol 302, issue 5649, 1156-1359, 21 Nov 2003)**

  soil loss resulting in loss in productivity. Poorer countries affected. UN Millennium Development Goals (2000) to cut number of people suffering insecurity by half by 2015

- **The future for fisheries (D.Paulty, J. Alder, E. Bennett, V. Christensen, P. Tyedmers, R. Watson, Science, 302, 5649, 1359-1361, 21 Nov 2003)**

  Decline of fish stocks due to overfishing: international agreements on ocean fishing

  Otherwise seen as local issue

  Farm fishing

  Environmental sustainability (enforcing international agreements)

Background- Global concerns (2)

- **Global air quality and pollution (H. Akimoto, Science, 302, 5651, 1716-1719, 5 Dec 2003)**

  -intercontinental transport and hemispheric air pollution by ozone impact natural ecosystems worldwide, and affect climate

  - aerosols affect climate through radiative forcing

  - Measurement of air pollution from satellite (MAPS) of CO made it an international issue

  - Total ozone mapping spectrometer (TPMS) also made it international

  -other gases tropospheric NO2, SO2 and HCHO

  - recently NOx has seen rapid increase from Asia

Background- Global Concerns (3)

- **Modern global climate change (T.R. Karl, K.E. Trenberth, Science, 302, 5651, 1719-1723, 5 Dec 2003)**

  Pre-inductrial CO2: 280 ppm, current close to 390 ppm

  global warming due to CO2, other gases, cloud, ice albedo

  We are entering the unknown with our climate

- **Sustainability and the commons (D. Kennedy, Science, 302, 5652, 12 Dec 2003)**

  -Garret Harden: “Tragedy of the commons” article in Science discussed population growth and the environment

Background- Global Concerns (4)

- The struggle to govern the commons (T. Dietz, E. Ostrom, P. Stern, Science, 302, 5652, 1907-1912, 12 Dec 2003)

  -Hardin: either state ownership or private ownership

  - others disagreed: such as self-governing institutions, which have not succeeded; neither has Hardin's alternatives

  -examples: Maine lobster fishery: high level of compliance

  - Montreal Protocol on stratospheric ozone; International Commission for the Protection of the Rhine Agreements

  - by simple set of rules that all can comply with to protect resources

  - Adaptive governance: good trustworthy information about stocks, flows and processes within resource systems

Background- Global Concerns (5)

- The challenge of long-term climate change (K. Hasselmann, M. Latif, G. Hooos, C. Azar, O. Edenhofer, C.C. Jaeger, O.M. Johannessen, C. Kemfert, M. Welp, A.Wokaun, Science 302(5652)1923-25, 12 Dec 2003

  - advocates both market-based short-term and policy-based long-term mesaures

  - 100 years is long-term

  - because of inertia of GHG, large heat capacity of oceans, biosphere, ice-sheet, etc. human influence will persist for a long time - -hence long-term policy

  - Kyoto protocol called for 5-10% reduction from 1990 by between 2008 and 12.

  - If all estimated fossil fuels are burnt, CO_2 will be between 1200 and 4000 ppm, corresponding to 4^0 to 9^0 C by the second half of this millenia (2500), sea level rise of 3-8 m

Background- Global Concerns (6)

- **Climate Change: The Political Situation (**Watson, Science, 302 (5652)1925-1926, 12 Dec 2003)

  - United Nations Framework Convention on Climate Change (UNFCCC) called for CO_2 emission reduction to 5-10% of current emissions for long term sustainable development

  - Practical approach seen as limiting to 450-550 ppm level, less than 2-3^{0}C (less than 0.2^{0}C per decade)

Background- Global Concerns (7)

- Social capital and the collective management of resources (J. Pretty, science, 302(5652)1912-1914, 12 Dec 2003):

  Some thoughts:

  - social capital is when groups of people get together and act to preserve resources

  - policy-makers believe that natural resources must be protected from destructive yet rational people

  - since the first national park in Yellowstone was set up in 1872, some 1 2,750 protected areas greater than 1000 hectares have been set up worldwide

  - instead of enclosure and strict regulation, a “third way” is the governance of the commons by social groups

  - do they work? Research shows that groups with economic and social well-being are better at it.

  - (so the question is: the poor who are dependent on natural resources for survival are not likely to succeed. That is where the need is most critical)

Background- Global Concerns (8)

- **Managing tragedies: understanding conflict over common pool resources** (W.M. Adams, D. Brockington, J. Dyson, B. Vira, Science, 302(5652)1915-16, 12 Dec 2003)

  - talks about cognitive conflict in common pool resource management

  - perception of the problem by individuals will be different, actions ending up in unintended consequences

- **Tales from a troubled marriage: science and law in environmental policy** (O. Houck, Science, 302(5652)1926-29, 12 Dec 2003)

  - lawyer's tirade against application of science to environmental protection

  - first he says science was king: NEPA, CERCLA, etc.

  - then Superfund created how clean is clean

  - litigation and delay

  - then BAT: just do it

  - copycats

  - now, he thinks science is on the defensive but still an actor

  - does not like NRDC or EDF working on scientific issues

Many Men, Many Minds
Sustainability through disciplinary lenses

- **For an economist, sustainability is at first related to new economic models of growth and regulation, taking into account not only the traditional quantifiable components of welfare, but also a lot of environmental "externalities" and qualitative assets.**

- **For an ecologist, sustainability means the use of natural resources to the extent that the carrying and regenerative capacities of the ecosystems are not jeopardized.**

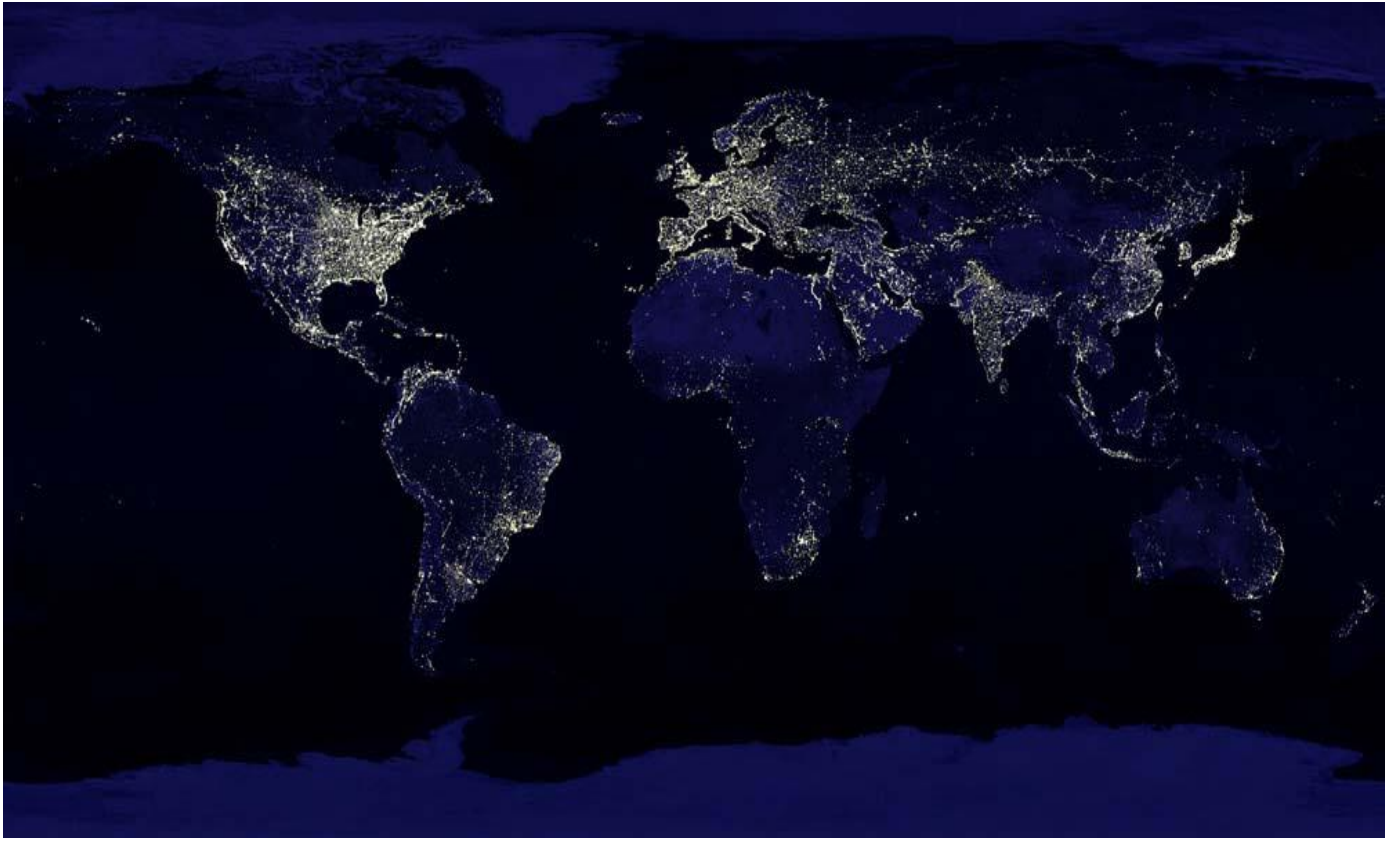
- **For a physicist, sustainability means the ability of biological systems to fight against degradation of energy and resources (entropy) by creating new forms of order (negentropy) using the various inputs of solar energy.**

- **For a chemist or an engineer, the challenge of sustainability is to complete material and energy life cycles created by human activities, through new techniques for material design, re-use, recycling and waste management.**

- **For a social scientist, sustainability implies the social and cultural compatibility of human intervention in the environment with its images constructed by different groups within society.**

J. Pop-Jordanov, in Technological Choices for Sustainability, Ed. Sikdar, Glavic and Jain, Springer 2004, p. 305

Uneven Human Growth



http://veimages.gsfc.nasa.gov/1438/earth_lights_lrg.jpg

Sustainability issues associated with modern products and processes

Ten Years after the Bruntland Report

“---The political impetus that carried the idea of sustainable development so far and so quickly in public forums has also increasingly distanced it from its scientific and technological base. As a result, even when the political will necessary for sustainable development has been present, the knowledge and know-how to make some headway often has not.”

-Our Common Journey, National Academy Press, Washington, D.C. 1999.

Sustainability: Politics, Policy, and Science

- **Sustainable development is a political philosophy, a global wealth redistribution to remove the scourge of poverty (according to Bruntland)**
- **Disciplines central to the understanding of sustainability: <u>demography, economics, ecology, and epidemiology</u> (McMichael, Butler, and Folke, Science, 302(5652), 2003)**

    but none, they think, appropriately incorporate environmental criticality into thinking (7th of the 8 UN Millenium Goals)

    sustainability, according to these authors means transforming our ways of living to maximize the chances that environmental and social conditions will indefinitely support human security, well-being, and health (flow of non-substitutable goods and services from ecosystems must ne maintained)

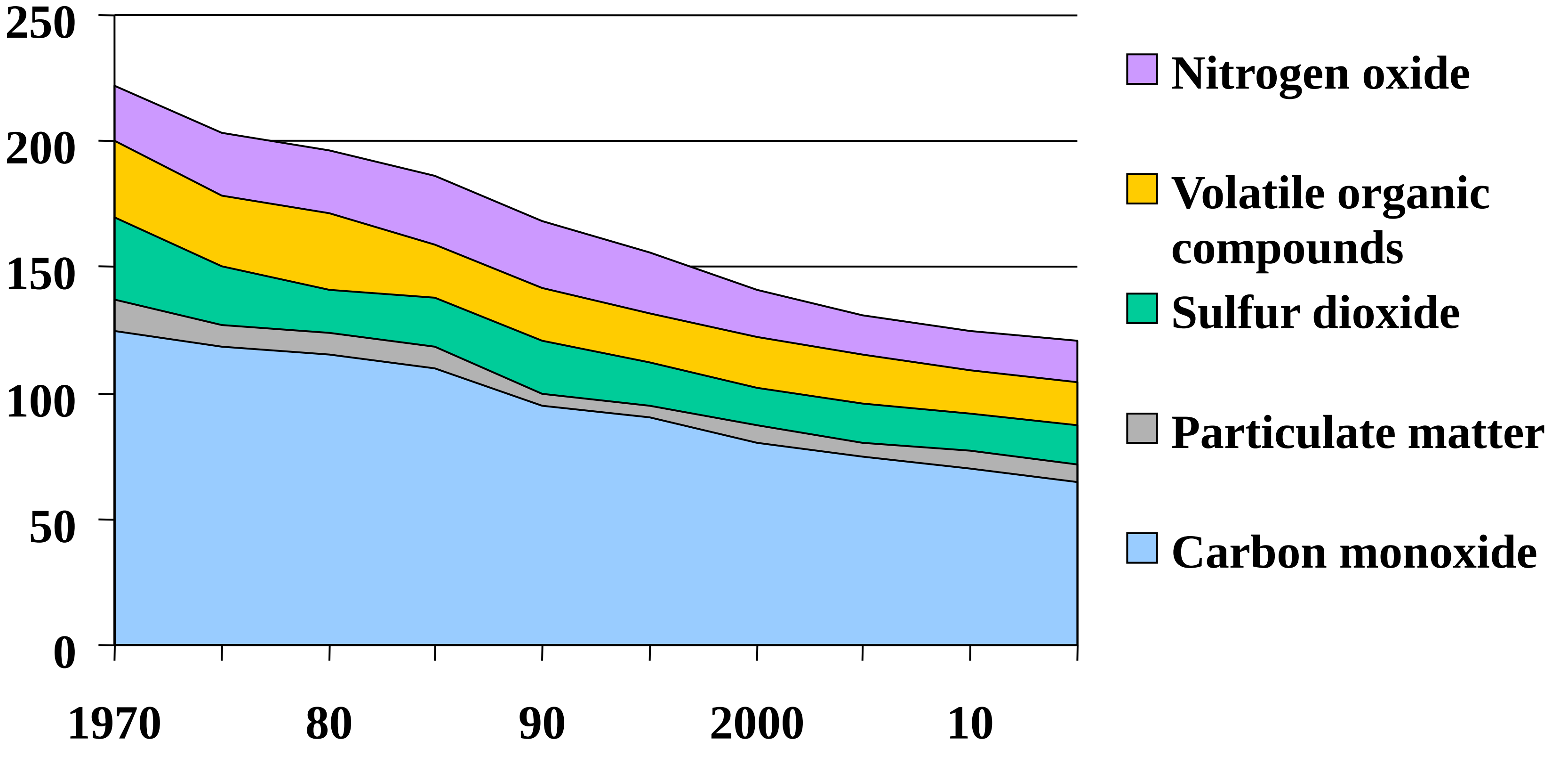
Sustainability: Politics, Policy, and Science (2)

  - Social change has to be made. Identify forces that oppose: indifference, incomprehension, self interest (according to these authors)
- Sustainability Science (Kates et al., science, 292(5517), 2001):
  - "science must be connected to the political agenda for SD"
- Sustainability science and engineering as a meta discipline (Mihelcic et a., EST, 37, 2003):
  - integrates industrial, social, and environmental processes in a global context

But SD awareness has had some effects

- For instance US has made partial progress towards national sustainability:
  - Energy use
  - Water use
  - Material use
  - Recycle reuse
  - Control of toxic substances
  - Emission and discharge controls

Air emissions expected to continue downward



Note: Projections made using EPA methodology.
Particulate matter excludes fugitive dust.
Source: Tech Environmental

New York City circa 1950

New York City December 2001

Conditions have improved over time
BUT

Why is sustainability important?

- Rapid growth in developing nations (depletion of natural resources)
- Uneven wealth creation around the globe
- Localization of extreme pollution
- Population growth and relative poverty
- Lax environmental regulation in parts of the world
- Very rapid advances in analytical chemistry
- Emerging pollutants (EDCs, pharmaceuticals, nutraceuticals)
- Political strength of the environmental groups
- Industry adoption of the idea
- Growing government support throughout the world

Strong Sustainability:

--Per capita biophysical assets (ecological wealth) must remain constant, Even in the face of population increase.

Weak Sustainability:

--Allows the substitution of depleted natural resources or capital with man-made capital (e.g. factories). Constant biophysical plus man-made Capitals must remain constant, even if population increases.

Two views of sustainability:

1. **Critical limits view: ecosystems' carrying capacity**
2. **Competitive objectives view: balance of the components of sustainability. This view totally ignores carrying capacity or resource limitation.**

Sustainability: means different things to different people

Dictionary definition: to keep up or keep going, as an action or process

Other definitions:

-- living within the resources of the planet without damaging the environment now or in the future

-- renewing resources at a rate equal to or greater than the rate at which they are consumed

Not Helpful, because:

- **keep up or keep going itself can be unsustainable**
- **the planet being huge compared to systems we design, operate and control, we may not know how to relate to resources at the planet scale**
- **Manufacturers won't in general know the renewal process or be accountable for it.**

CORPORATE Sustainability Reporting Example: Dow Chemical

- **Global Reporting Initiative**

  Topics under Sustainability Goals:

  Sustainable Chemistry

  Breakthroughs to World Challenges

  Product Safety Leadership

  Energy Efficiency and Conservation

  Addressing Climate Change

  Contributing to Community Success

  Local Protection to Human health and the Environment

- **Corresponding Sustainability Goals:**
  - **Sustainable Chemistry Goal**
  - **Breakthroughs to World Challenges**
  - **Product Safety**
  - **Energy Efficiency and Conservation**
  - **Climate Change**
  - **Community Success**
  - **Local Protection of Human health and the Environment**

Corporate Sustainability Reporting Example; Dupont

- **Global Reporting Initiative:** Goals under three categories

Market Facing Goals	Footprint	Energy
Invest in R&D for reducing environmental impacts	Reduce GHG emission	Reduce total energy consumption
Invest in services that make people safer	Reduced over all water consumption	Increase use of renewable energy
Increase revenue from products That reduce GHG emission	Greater reduction of water in stressed areas	
Increase revenue from products That use non-depletable Resources	Increase fleet vehicle with leading technology	
	Reduce carcinogen emission	
	Increase ISO 14001 certification	

UN Global Compact for corporations:

Human Rights:

Principle 1: **Businesses should support and respect the protection of internationally proclaimed human rights; and**

Principle 2: make sure that they are not complicit in human rights abuses.

Labour

Principle 3: **Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining;**

Principle 4: **the elimination of all forms of forced and compulsory labour;**

Principle 5: **the effective abolition of child labour; and**

Principle 6: **the elimination of discrimination in respect of employment and occupation.**

Environment

Principle 7: **Businesses should support a precautionary approach to environmental challenges;**

Principle 8: **undertake initiatives to promote greater environmental responsibility; and**

Principle 9: **encourage the development and diffusion of environmentally friendly technologies.**

Anti-Corruption

Principle 10: **Businesses should work against corruption in all its forms, including extortion and bribery.**

These are the 10 criteria DuPont uses for sustainability of their R&D programs

- Climate Change
- Energy Use
- Pollution
- Material Use
- Waste
- Disposal
- Ecosystems and Biodiversity
- Water
- Toxicological Risk
- Use of Non-Depletable Resources