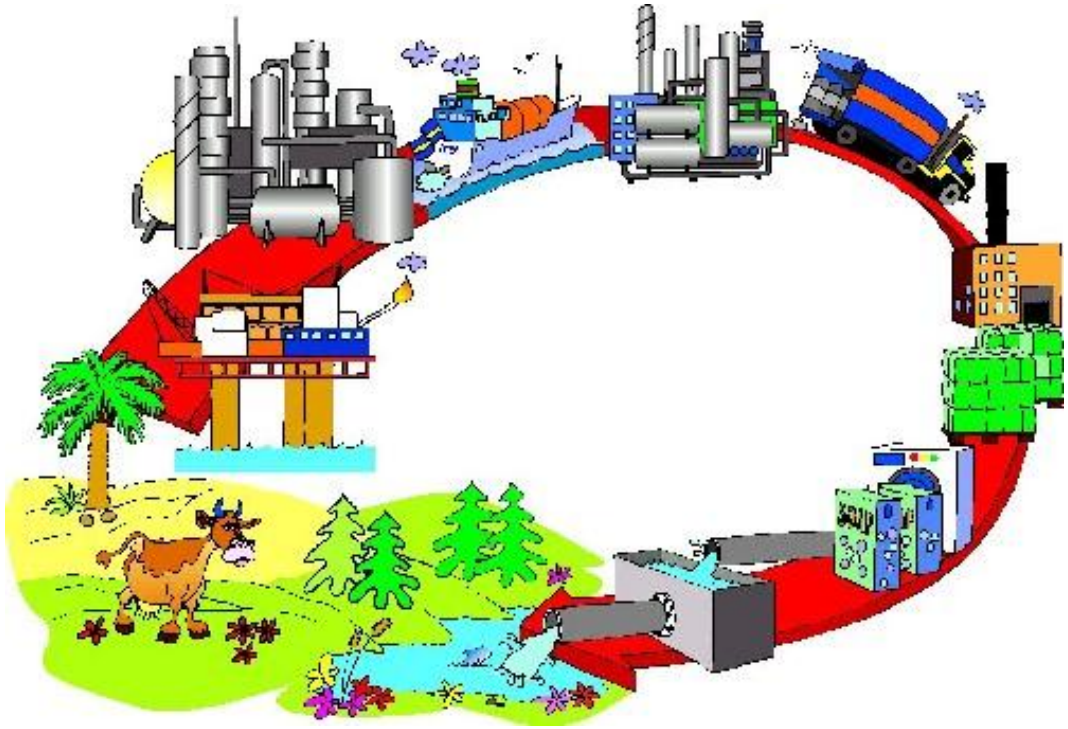
Environmental Life Cycle Assessment

PSE 476/WPS 576/WPS 595-005



Fall 2012

Richard A. Venditti
Forest Biomaterials
North Carolina State University
Raleigh, NC 27695-8005

Richard_Venditti@ncsu.edu
Go.ncsu.edu/venditti

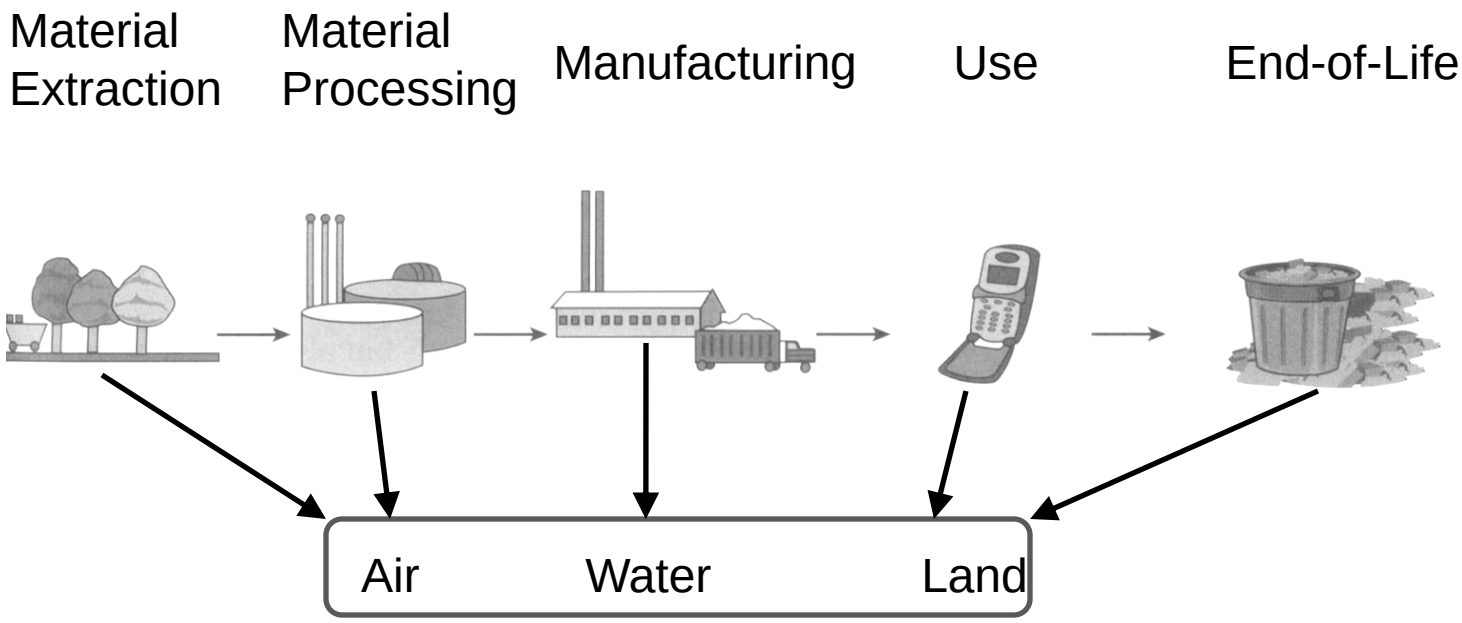
Lecture 1: Why LCA?

Tragedy of the Commons

Hardin, G. (1968). “The Tragedy of the Commons”. *Science, 12(3859): 1243-1248.*

“Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.”

A common approach

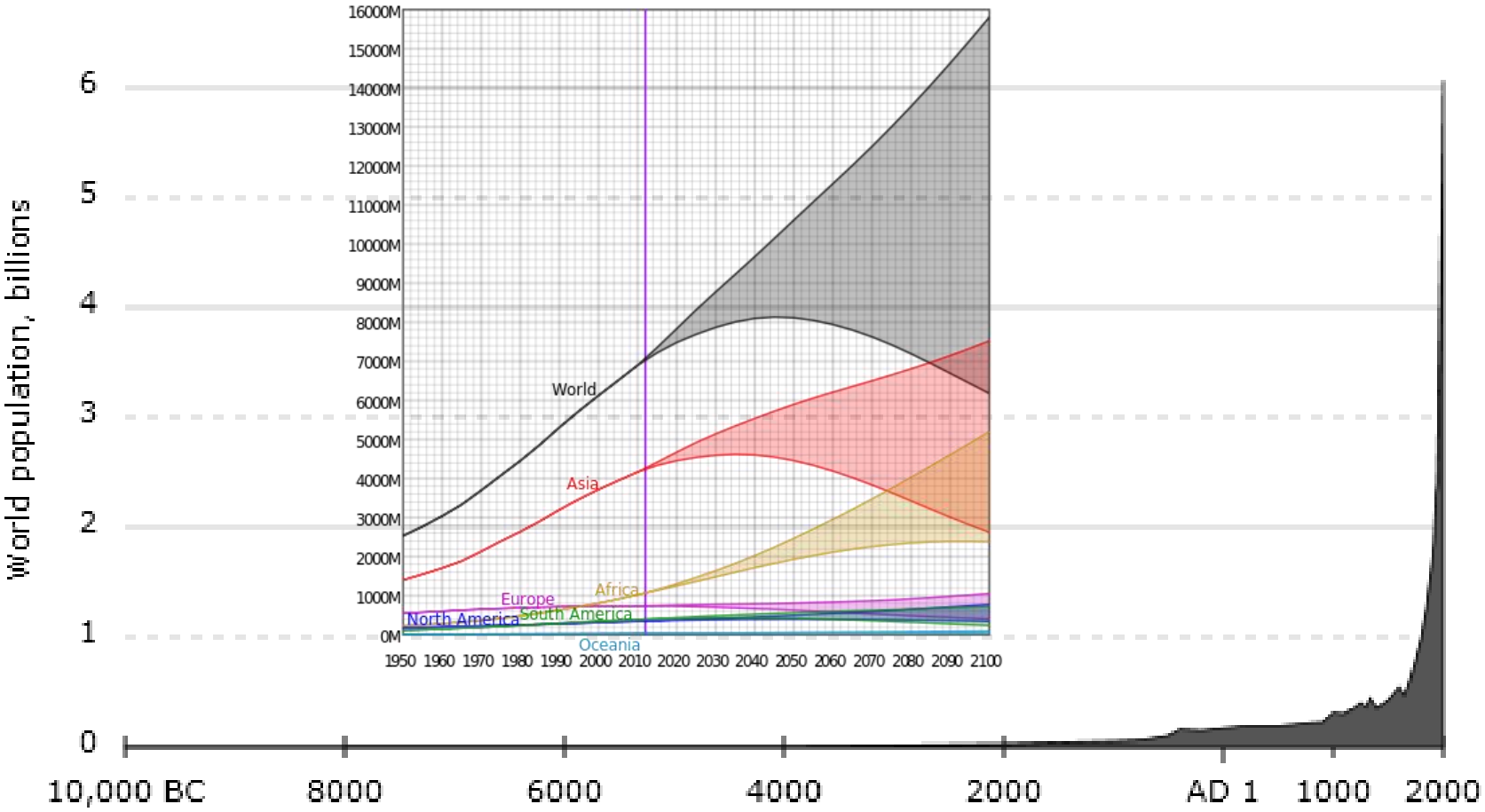


Environment treated as commons

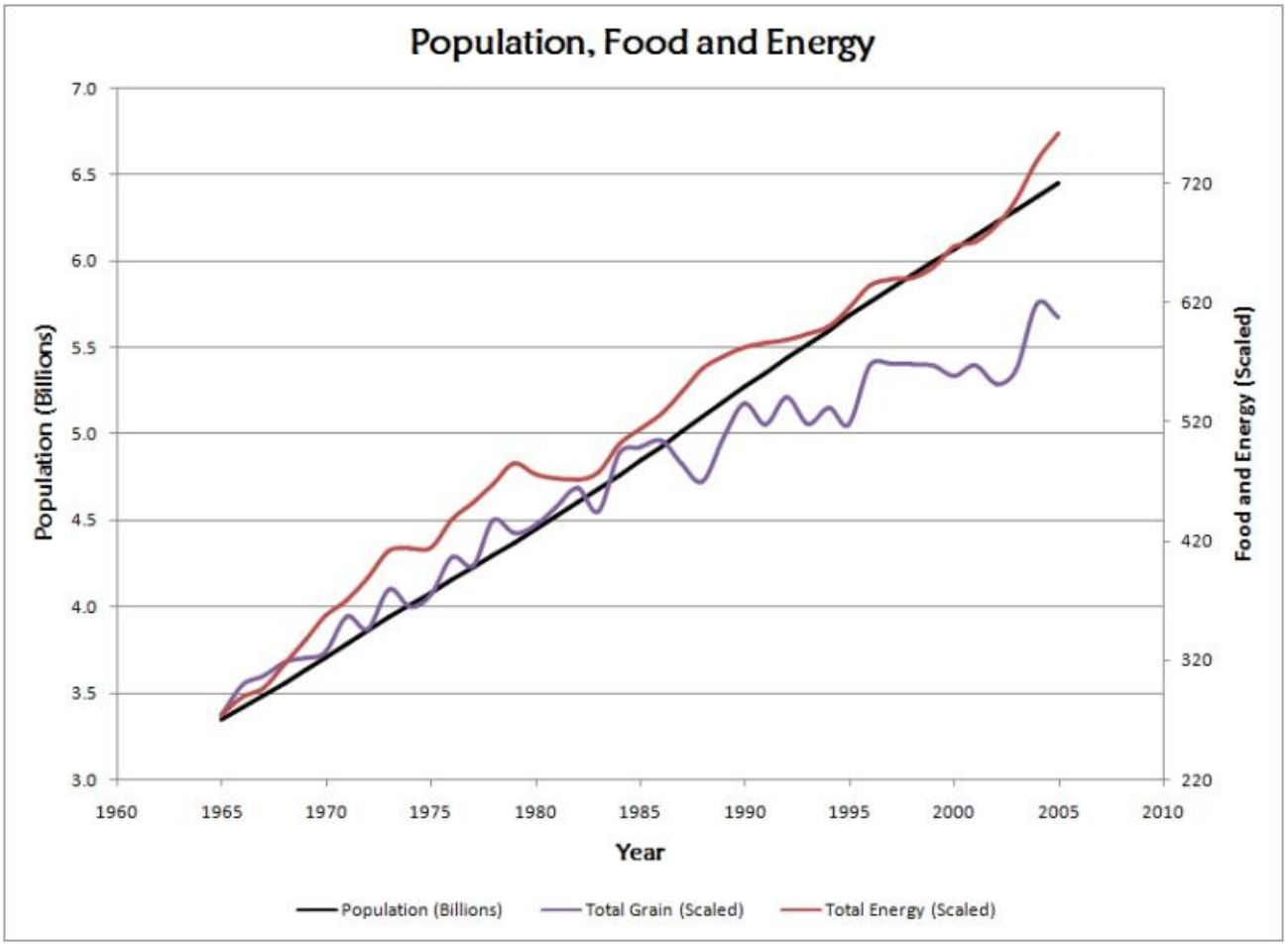
Objectives

- Minimize cost
- Maximize appeal

World Population

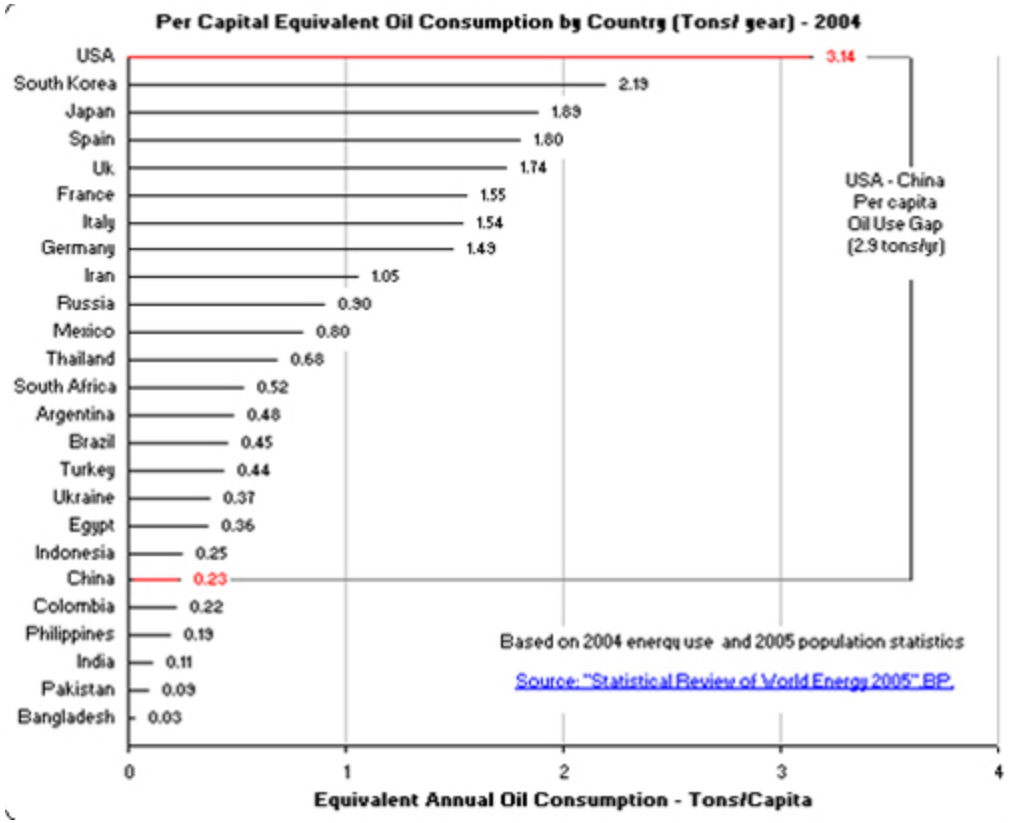


Wikipedia, World Population



http://www.paulchefurka.ca/PopulationFoodEnergy.html

Per capita energy use



http://makewealthhistory.org/2009/10/23/per-capita-energy-use-and-us-responsibility/

Cuyahoga river fires

Cuyahoga river in Ohio (runs through Cleveland) caught on fire several times between 1868 and 1969. A catalyst for Clean Water Act of 1972.

November 3, 1952 (Source: U.S. EPA)

Sometime in the 1960s (Source: cleveland.com)

Donora smog

Air pollution from U.S. Steel's Donora Zinc Works combined with an atmospheric inversion resulted in heavy smog that killed 20 people and sickened 7,000 in Donora, PA, near Pittsburgh. October 26-31, 1948.

Donora Smog,
(Source: The Allegheny Front)

Source:
http://www.wired.com/thisdayintech/tag/smog/

Acid rain

Jizera Mountains, Czech Republic
(Source: Wikipedia)

Source:
http://www.elmhurst.edu/~chm/vchembook/196buildings.html

Changes in GHGs

- **Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750**
- **Now far exceed pre-industrial values determined from ice cores spanning many thousands of years**
- **The global increases in**
  - **carbon dioxide concentration are due primarily to fossil fuel use and land use change,**
  - **Methane and nitrous oxide are primarily due to agriculture.**

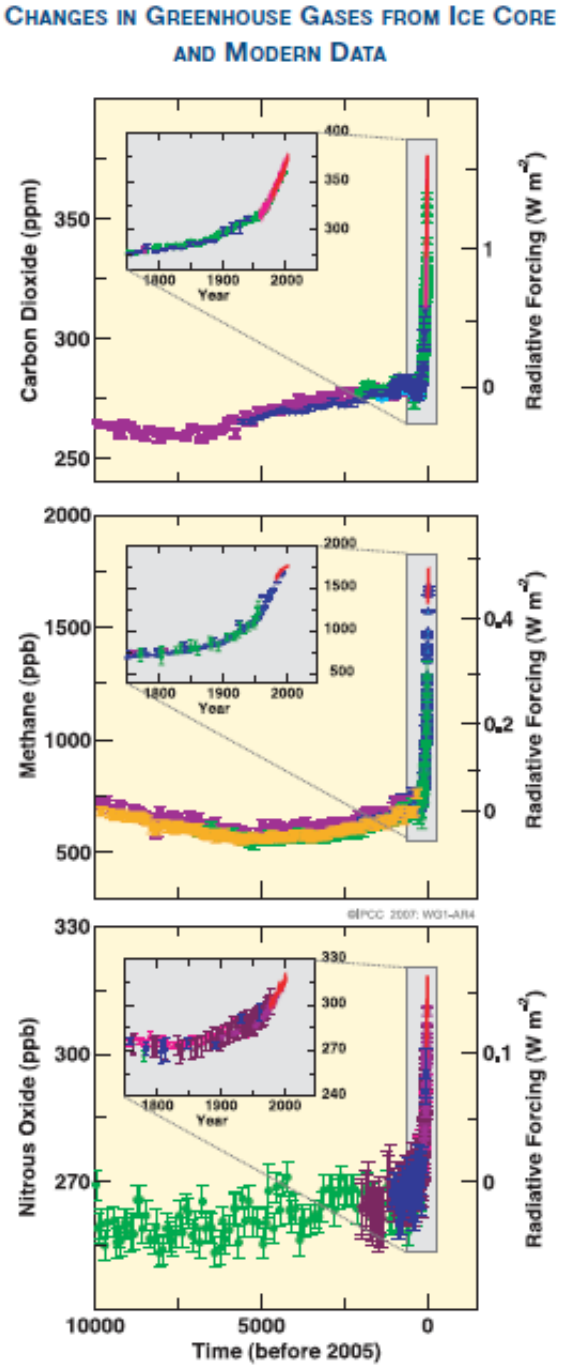


Figure SPM.1. *Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. (Figure 6.4)*

Global Warming

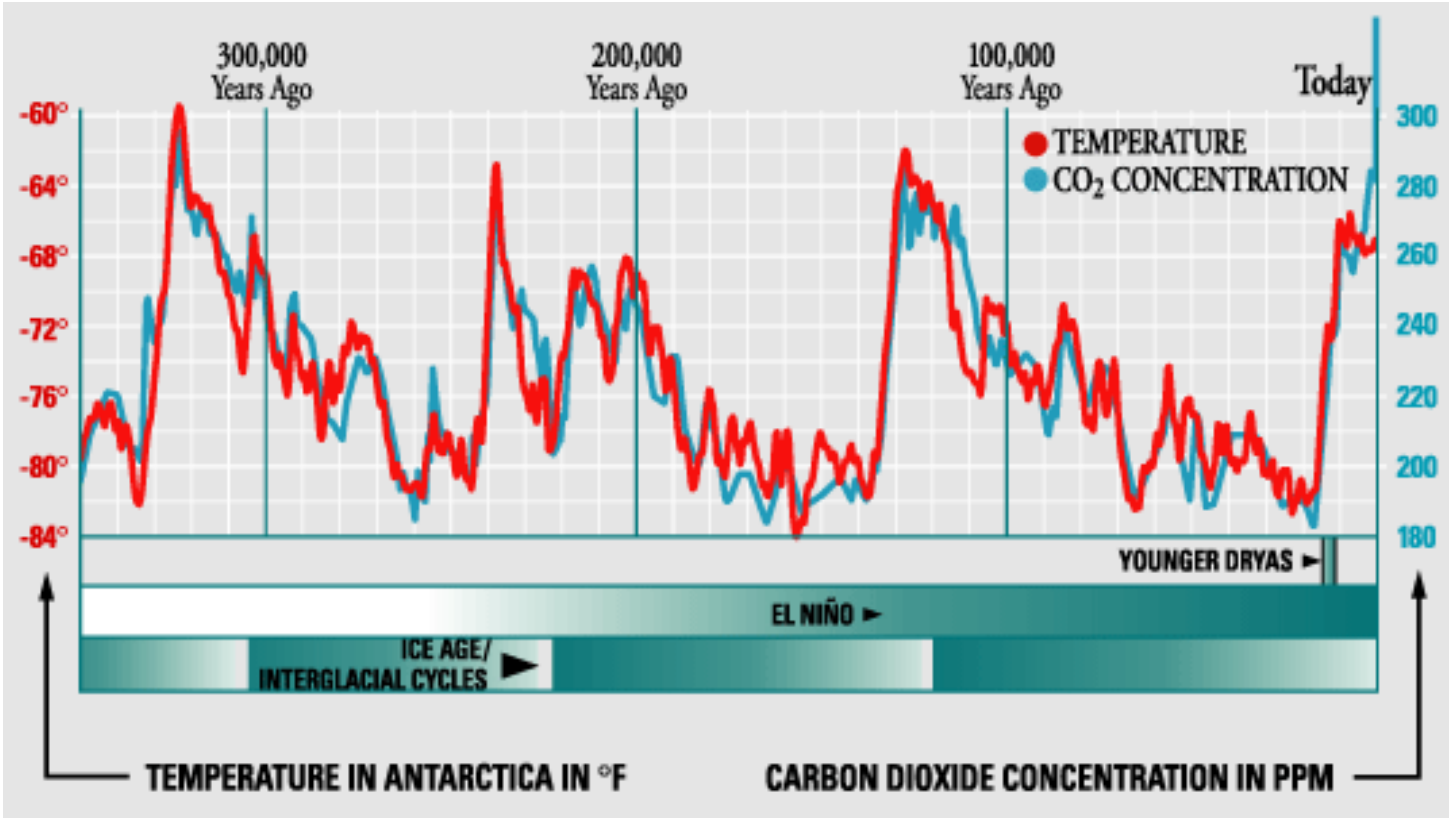


Figure 2. Ice core record from Vostok, Antarctica, showing the near-simultaneous rise and fall of Antarctic temperature and CO2 levels through the last 350,00 years, spanning three ice age cycles. However, there is a lag of several centuries between the time the temperature increases and when the CO2 starts to increase. Image credit: Siegenthalter et al., 2005, Science

Global Warming Predictions

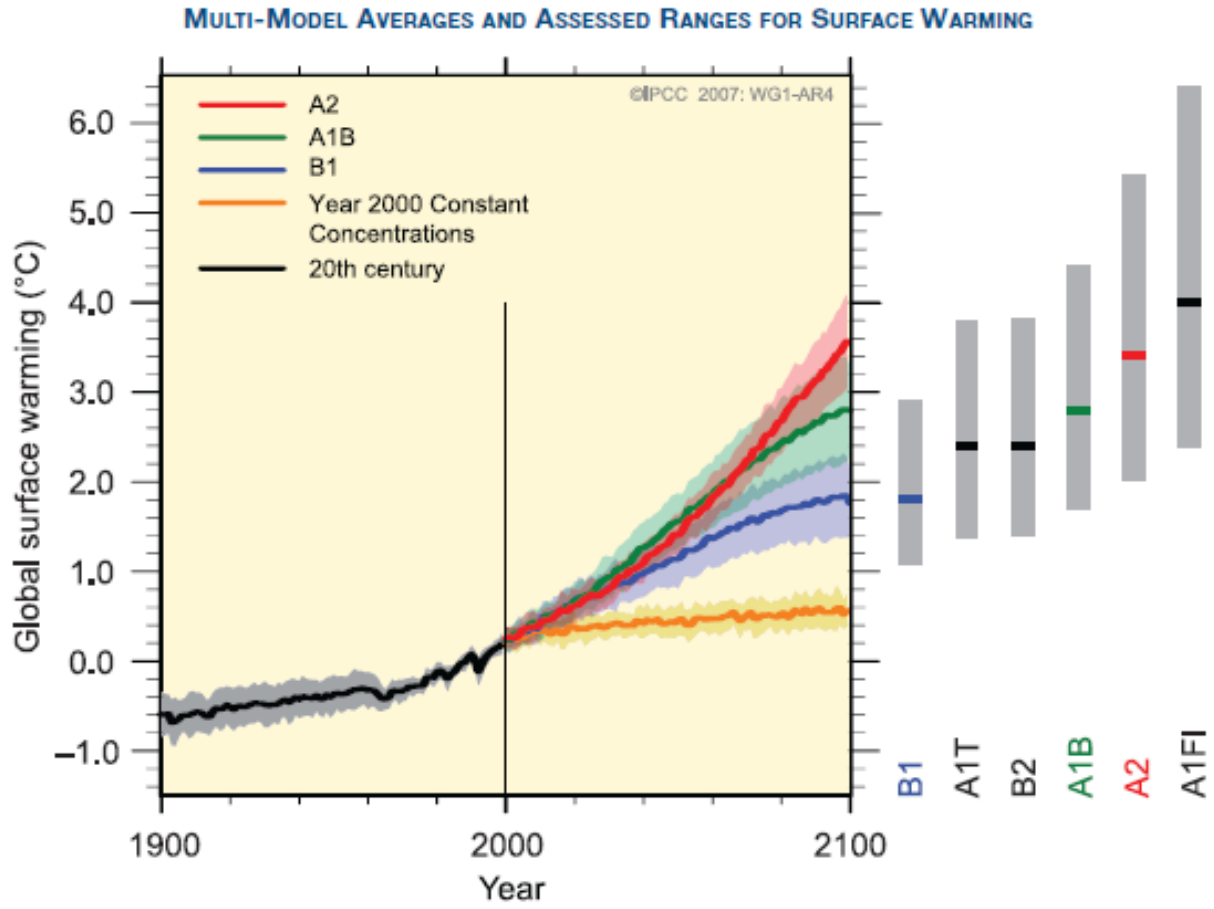
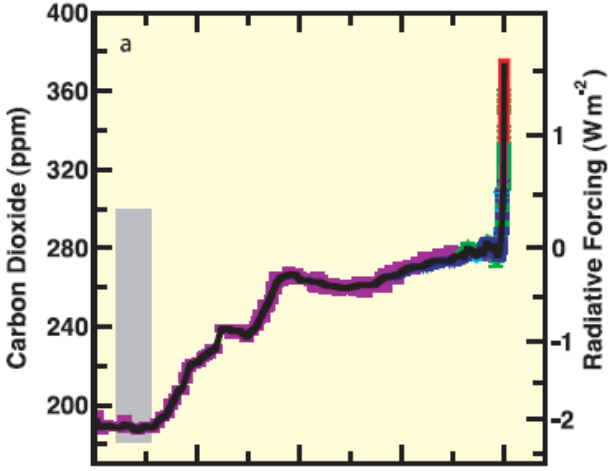
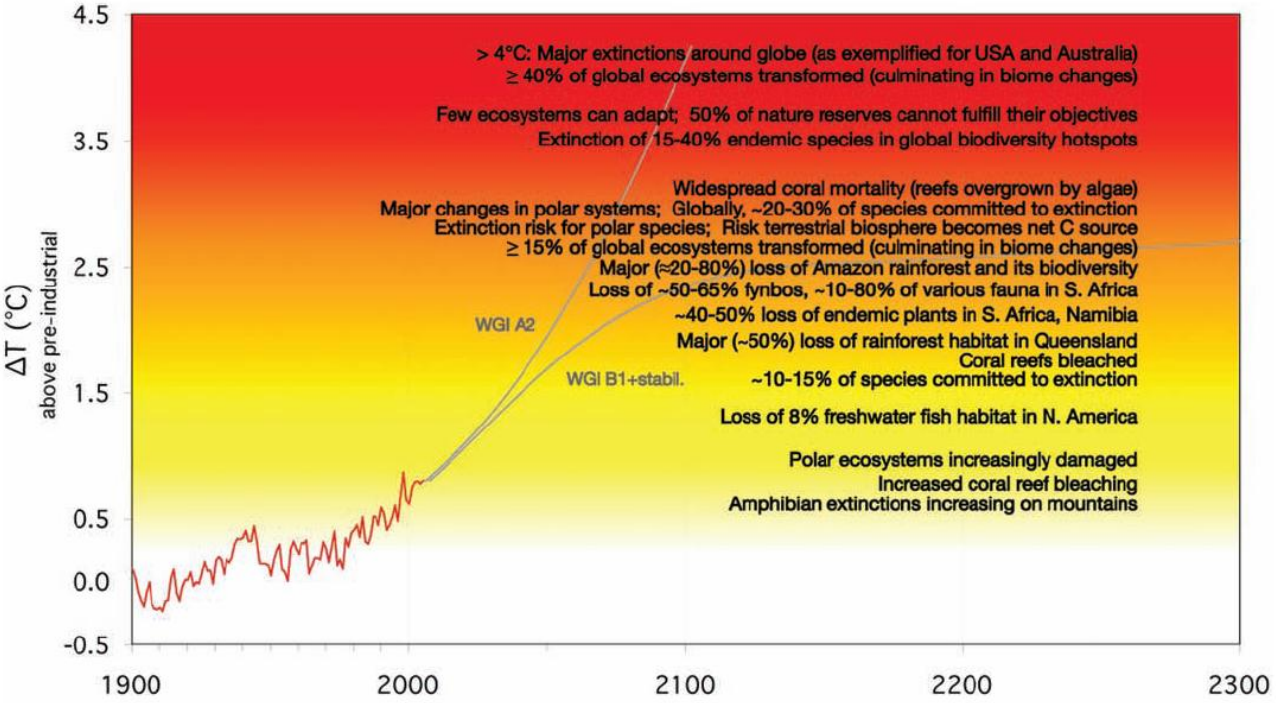


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

Climate change

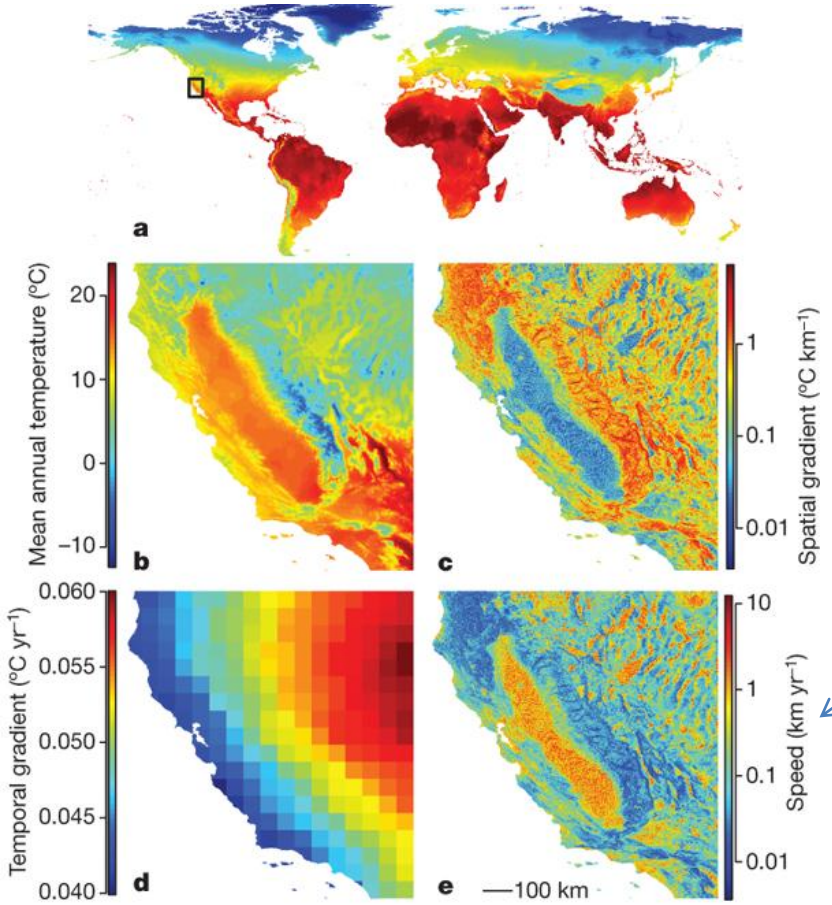


Source: Intergovernmental Panel on Climate Change (2007), FAR, WGI, *The Physical Scientific Basis*, TS, p. 25



Source: IPCC (2007), WGII, *Technical Summary*, p. 37.

Changing temperature in California.



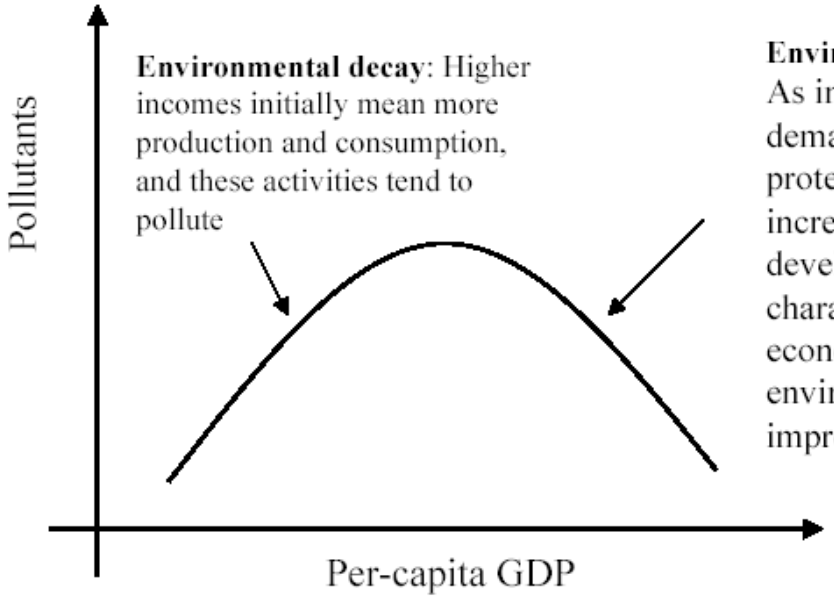
Velocity of climate change

SR Loarie *et al. Nature* **462**, 1052-1055 (2009) doi:10.1038/nature08649

nature

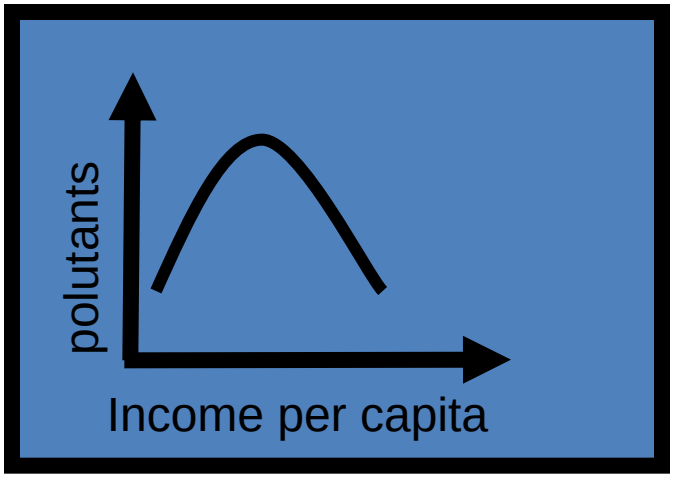
Environmental Kuznet's curve

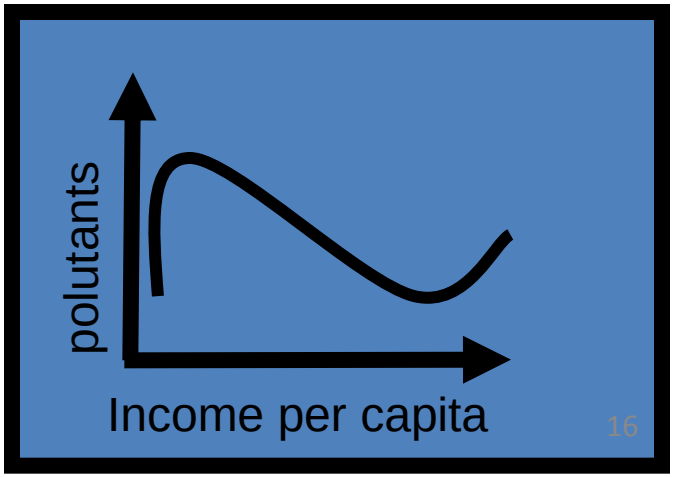
"Inverse-U" relationship between pollution and national income



Environmental decay: Higher incomes initially mean more production and consumption, and these activities tend to pollute

Environmental improvement: As income grows the demand for environmental protection also tends to increase, leading to a development path characterized by both economic growth and environmental quality improvements





“The Master Equation” (Graedel and Allenby, 1995)

Environmental impact =

population × [GDP/person]

× [(environmental impact)/(unit of GDP)]

Over the next half century

Population	… 50% increase
Affluence [GDP/capita]	… 300-500% increase
Efficiency [impact/GDP]	… ?

Sustainability?

- **The ability to supply societies needs without harming the environment or future generations' ability to meet their needs?**
- Often stated in terms of People Planet Profit (PPP)
- We have many options to meet our demands.
- How to choose the "best" option?
- Life cycle assessment helps to inform our choices.

The Brundtland Report, 1987

The term “sustainable development” popularized by the Report of the World Commission on Environment and Development: *Our Common Future* (1983). Definition put forth:

> *“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”*

> *“Living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability. Yet many of us live beyond the world's ecological means, for instance in our patterns of energy use. Perceived needs are socially and culturally determined, and sustainable development requires the promotion of values that encourage consumption standards that are within the bounds of the ecological possible and to which all can reasonably aspire.”*

Available online at: http://www.un-documents.net/ocf-02.htm

The Grand Objectives (Graedel 1998)

How do we downscale the sustainability concept to create metrics?

The Ω_1 Objective
Maintaining the existence of the human species

The Ω_2 Objective
Maintaining the capacity for sustainable development

The Ω_3 Objective
Maintaining the diversity of living things

The Ω_4 Objective
Maintaining the aesthetic richness of the planet

Relating environmental concerns to the Grand Objectives

TABLE 1.2 Relating Environmental Concerns to the Grand Objectives

Grand Objective	Environmental Concern
Ω_1: Human species extinction	1. Global climate change
	4. Human organism damage
	5. Water availability and quality
	6. Resource depletion: fossil fuels
Ω_2: Sustainable development	5. Water availability and quality
	6. Resource depletion: fossil fuels
	7. Soil depletion
	8. Optimal land use
	12. Resource depletion: other than fossil fuels or soils
Ω_3: Biodiversity	1. Global climate change
	2. Loss of biodiversity
	3. Stratospheric ozone depletion
	5. Water availability and quality
	7. Acid deposition
	16. Thermal pollution
Ω_4: Aesthetic richness	10. Smog
	11. Aesthetic degradation
	13. Oil spills
	15. Odor

The order of the numbers in the right column is that of Table 1.3.

Graedel, TE (1998) Streamlined Life-Cycle Assessment. Prentice Hall, NJ

Environmental concerns by significance

TABLE 1.3 Significant Environmental Concerns

Crucial Environmental Concerns
1. Global climate change
2. Loss of biodiversity
3. Stratospheric ozone depletion
4. Human organism damage
5. Water availability and quality
6. Depletion of fossil fuel resources
Highly Important Environmental Concerns
7. Soil depletion
8. Suboptimal land use
9. Acid deposition
10. Smog
11. Aesthetic degradation
12. Depletion of resources other than fossil fuels
Less Important Environmental Concerns
13. Oil spills
14. Radionuclides
15. Odor
16. Thermal pollution
17. Landfill exhaustion

The numbers within the groupings are for reference purposes, and do not indicate order of importance.

Graedel, TE (1998) Streamlined Life-Cycle Assessment. Prentice Hall, NJ

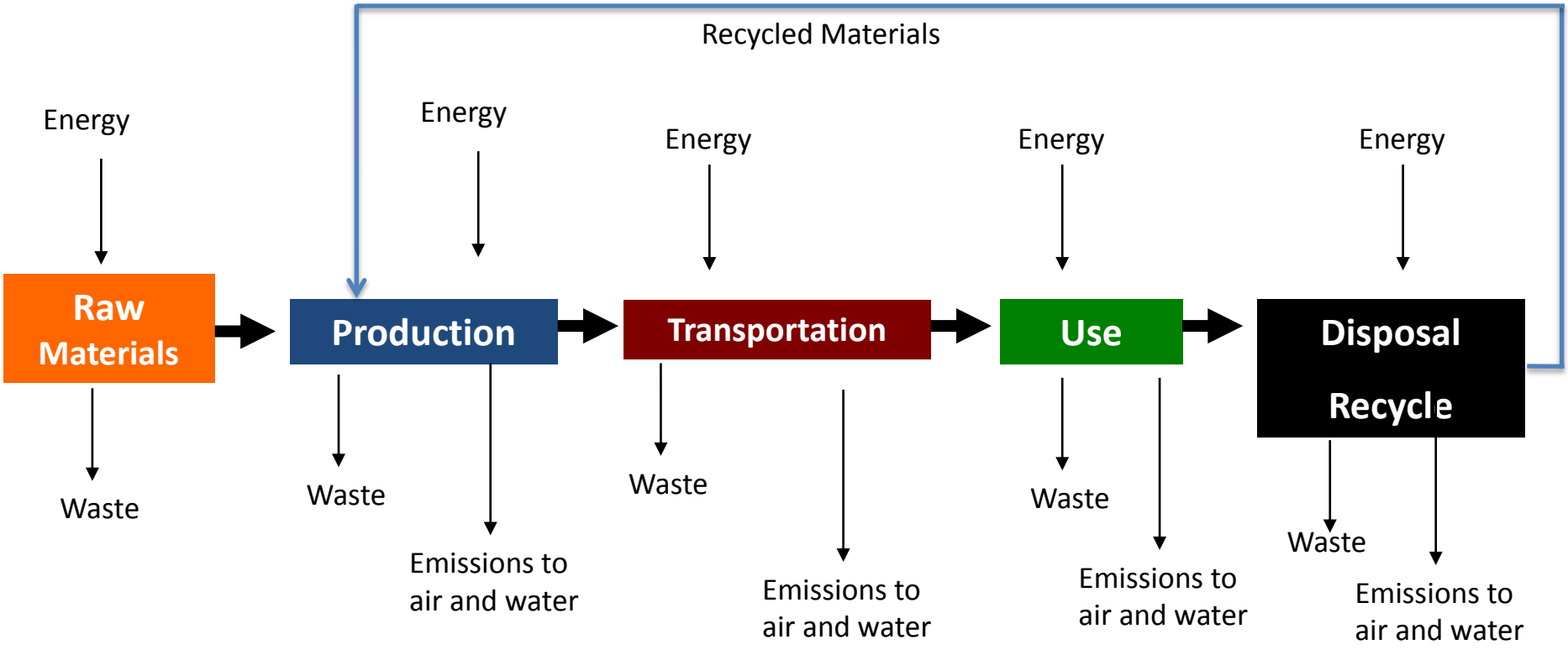
What is a Life Cycle Assessment ?

Life Cycle Assessment (LCA) is a tool to assess the potential environmental impacts of products, systems, or services at all stages in their life cycle [ISO 14001:2004].

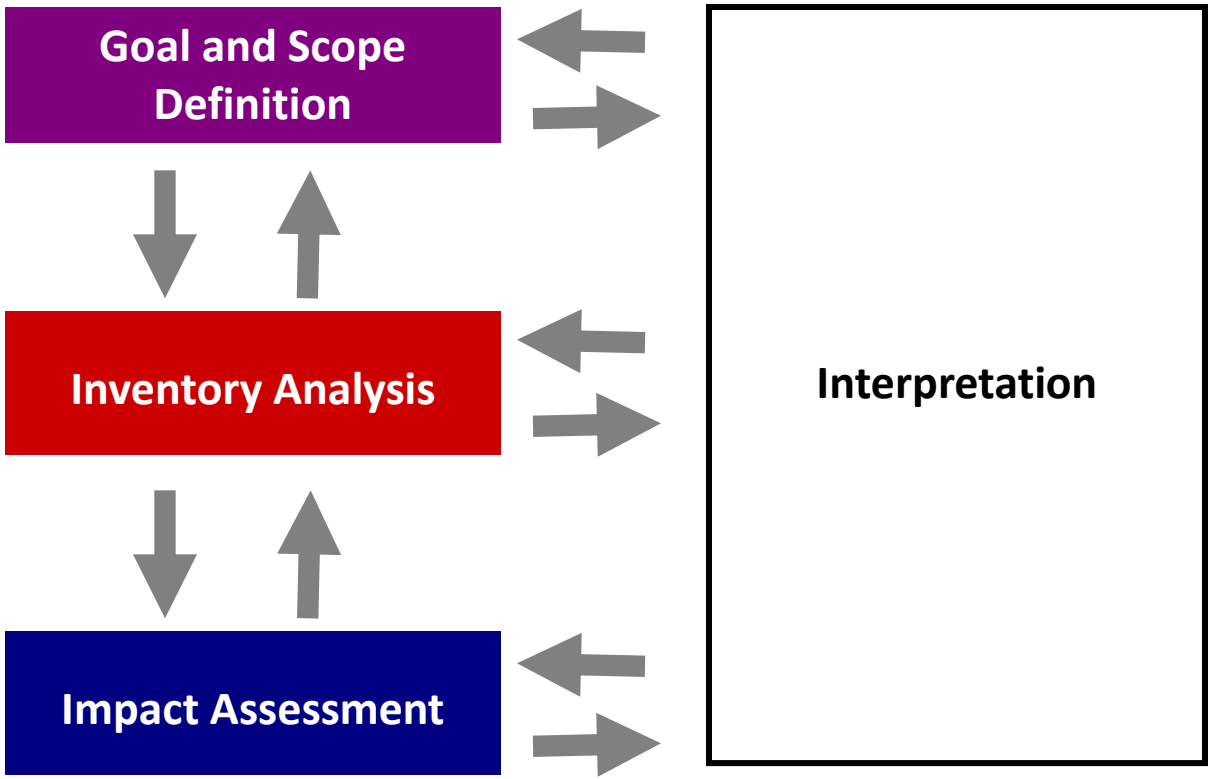
Types of LCA

- **Cradle to Gate**: raw materials to finished good (no use or end life considerations)
- **Cradle to Grave**: Considers everything from harvesting materials to the disposal of the finished goods

Life Cycle Stages



Important Aspects of Life Cycle Assessment



Other Definitions of Life-Cycle Assessment

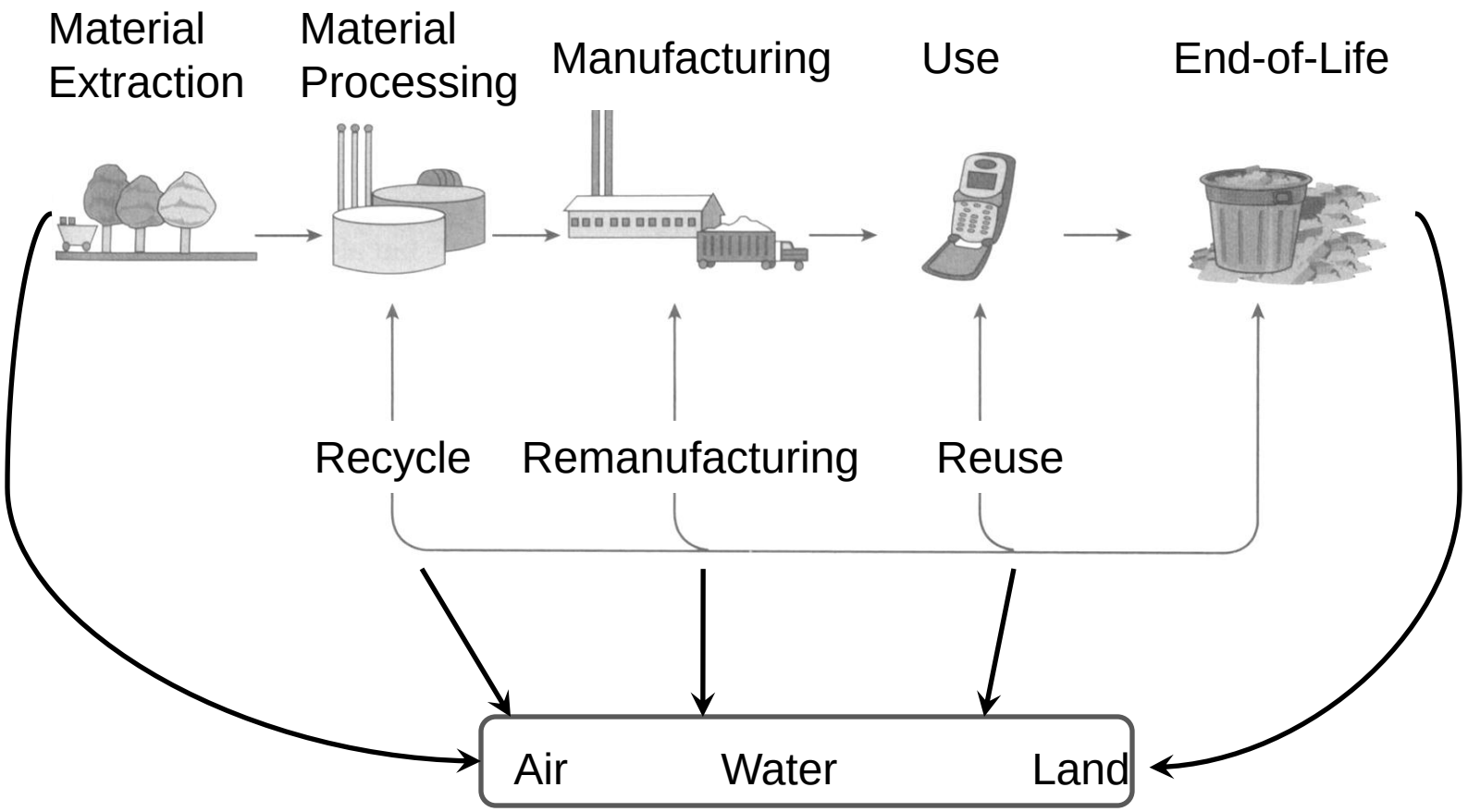
Graedel and Allenby (1995):

The life-cycle assessment is an **objective** process to **evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and material usage and environmental releases**, to assess the **impact** of those energy and material uses and releases on the environment, and to evaluate and implement opportunities to **effect environmental improvements**. The assessment includes the **entire life cycle** of the product, process, or activity, encompassing extracting and processing raw materials; manufacturing, transportation, and distribution; use/reuse/maintenance; recycling; and final disposal.

Wenzel et al. (1997):

To assess a product environmentally is: to define and quantify the service provided by the product, to identify and to quantify the environmental exchanges caused by the way in which the service is provided, and to ascribe these exchanges and their potential impacts to the service.

Improved product design



Objectives

- Minimize cost
- Maximize appeal
- Minimize environmental impact

- Our first goal is to find the way to achieve "clean" growth and I want to defend this idea here today. We haven't got to choose between saving the planet and growth. We need to have growth and save the planet. So we need a growth that consumes less energy and fewer raw materials. A new economy must be invented.[Nicolas Sarkozy Speech to UN Assembly, September 2007]

Summary:

Tragedy of the Commons

Velocity of Climate Change

Grand Objectives (4)

Sustainability

PPP

Life Cycle Analysis