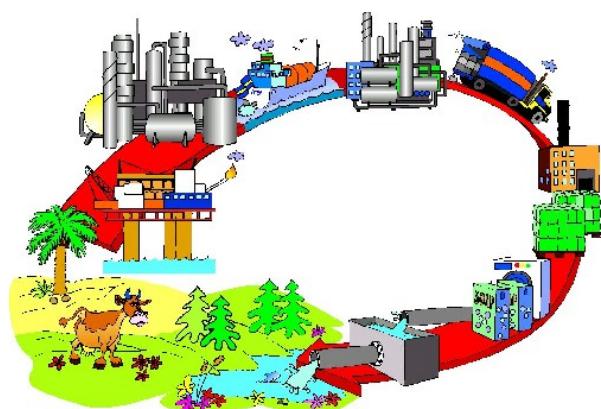


# **Environmental Life Cycle Assessment**

## **PSE 476/FB 576**

### **Lecture 1: Why LCA?**



Fall 2016

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# Tragedy of the Commons

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

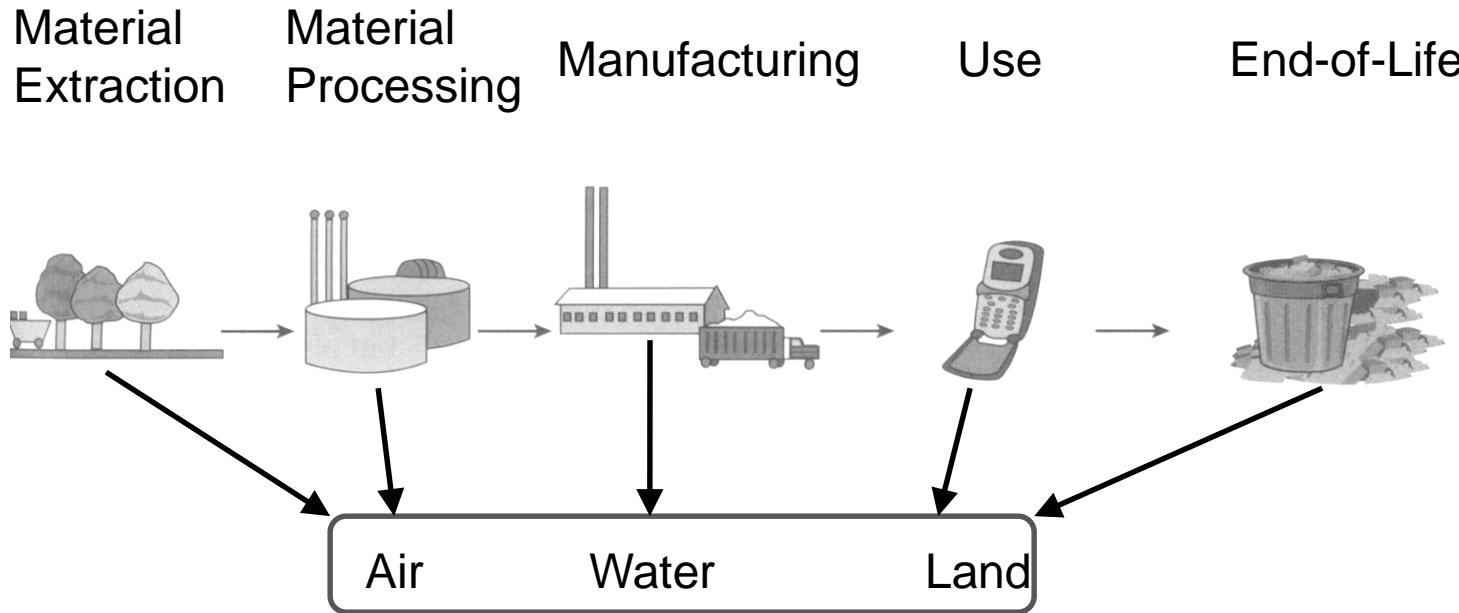


"Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

<http://nocamels.com/2016/05/air-pollution-raises-heart-disease-risk/>



# Unfortunately: A common approach

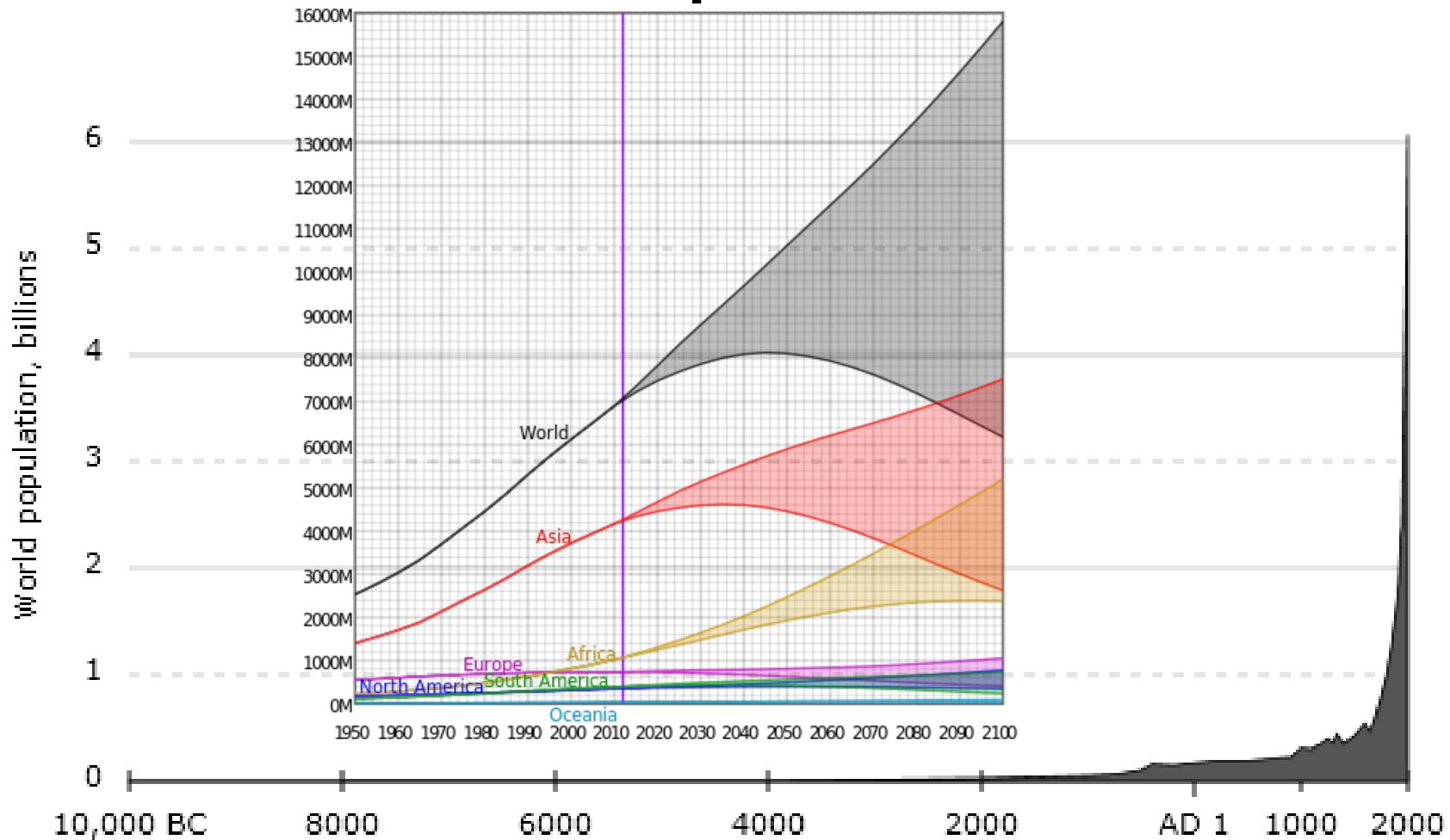


## Objectives

- Minimize cost
- Maximize appeal

Environment  
treated as  
commons

# World Population



Wikipedia, World Population

## U.S. and World Population Clock

Note: The Population Clock is consistent with 2010 Census data and the most recent national population estimates.

Aug 22, 2013 12:34 UTC (-4)

Learn More | Download and Share



U.S. Population

3 1 6 , 5 1 1 , 9 0 5



World Population

7 , 1 0 6 , 3 8 2 , 1 7 7

### COMPONENTS OF POPULATION CHANGE

12:34:42 UTC

One birth every 8 seconds



One death every 12 seconds



One international migrant (net) every 44 seconds



Net gain of one person every 13 seconds



### TOP 10 MOST POPULOUS COUNTRIES

1. China	1,349,585,838	6. Pakistan	193,238,868
2. India	1,220,800,359	7. Nigeria	174,507,539
3. United States	316,668,567	8. Bangladesh	163,654,860
4. Indonesia	251,160,124	9. Russia	142,500,482
5. Brazil	201,009,622	10. Japan	127,253,075

## U.S. and World Population Clock

Tell us what you think &gt;



The United States



The World

New!

May 26, 2016 17:23 UTC (+4)

Learn More | Download and Share



U.S. Population

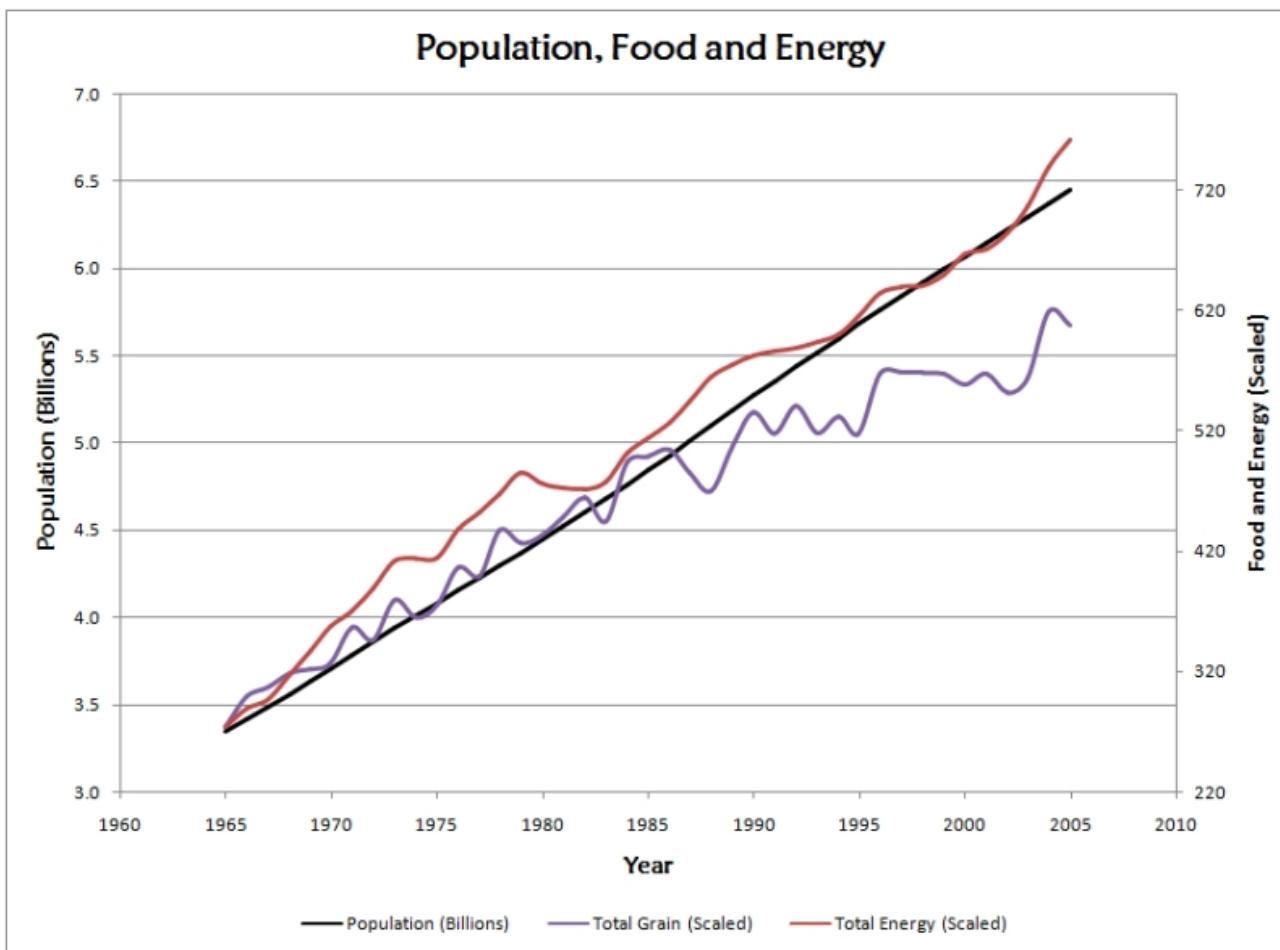
3 2 3 , 6 3 7 , 7 4 6



World Population

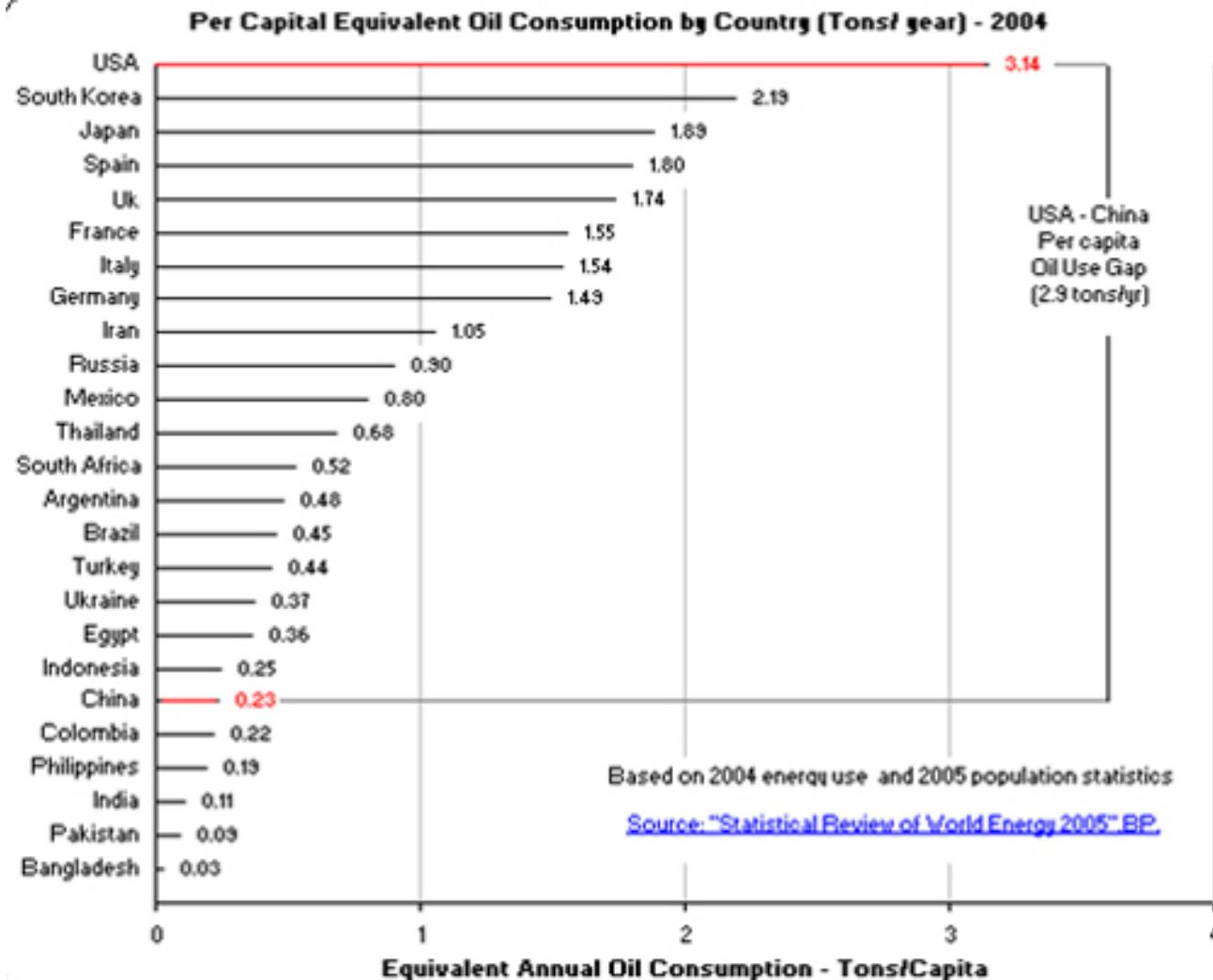
7 , 3 2 7 , 2 2 6 , 7 8 9

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



<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/](http://www.wired.com/thisdayintech/tag/smog/)

# Acid rain



Jizera Mountains, Czech Republic  
(Source: Wikipedia)



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



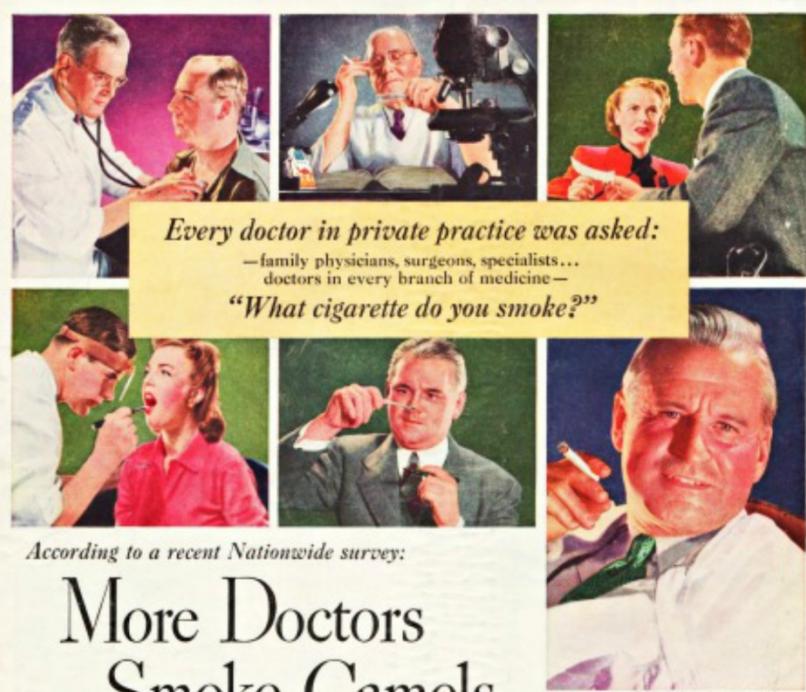
# What don't we know?



Born gentle

PROUD mothers, please forgive us if we too feel something of the pride of a new parent. For new Philip Morris, today's Philip Morris, is delighting smokers everywhere. Enjoy the gentle pleasure, the *fresh unfiltered flavor*, of this new cigarette, born gentle, then refined to special gentleness in the making. Ask for new Philip Morris in the smart new package.

**New Philip Morris**...gentle for modern taste  
[envisioningtheamericanadream.com](http://envisioningtheamericanadream.com)



*Every doctor in private practice was asked:  
—family physicians, surgeons, specialists...  
doctors in every branch of medicine—  
“What cigarette do you smoke?”*

*According to a recent Nationwide survey:*  
**More Doctors  
Smoke Camels  
than any other cigarette!**



The "E-Zone"—T for taste and E for throat—is your own laboratory, your proving ground, for any cigarette. Ask only two men and your throat can decide which cigarette has the "E-Zone" and it defines your choice. On the basis of the experience of over 20 million smokers, we believe Camel will set your "E-Zone" to a "T."

Not a guess, not just a trend—but an actual fact based on the statements of doctors themselves to 3 nationally known independent research organizations.

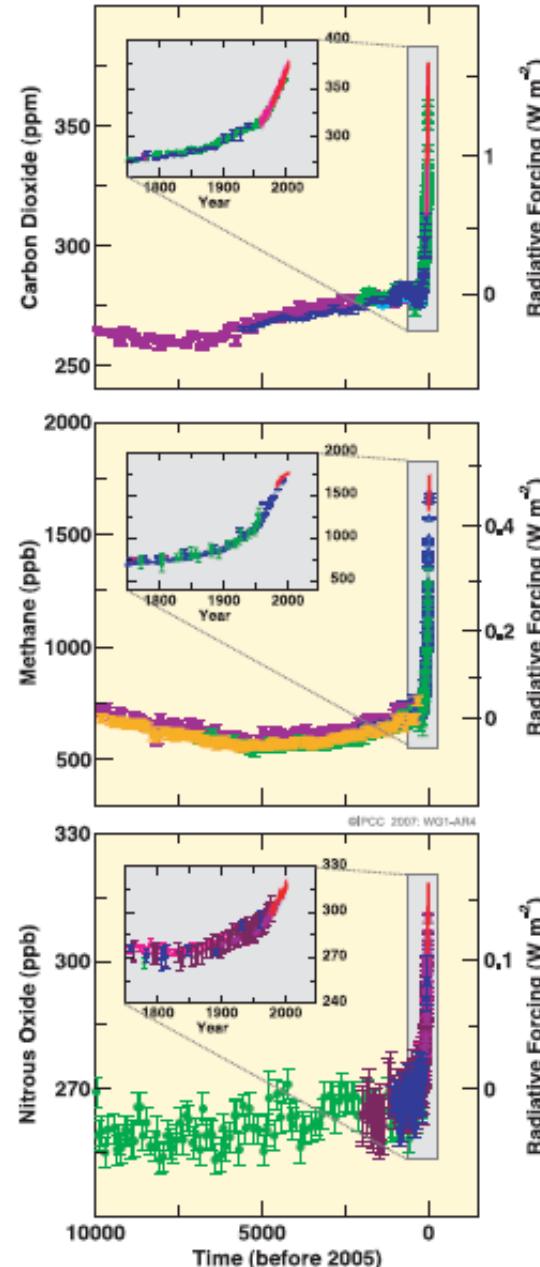
YES, your doctor was asked...along with thousands and thousands of other doctors from Maine to California. And they've named their choice—the brand that more doctors named as their smoke is *Camel*! Three nationally known independent research organizations found this to be a fact. Nothing unusual about it. Doctors smoke for pleasure just like the rest of us. They appreciate, just as you, a mildness that's cool and easy on the throat. They too enjoy the full, rich flavor of expertly blended costly tobaccos. And they named *Camel*...more of them named *Camel* than any other brand. Next time you buy cigarettes, try *Camel*.

[envisioningtheamericanadream.com](http://envisioningtheamericanadream.com)

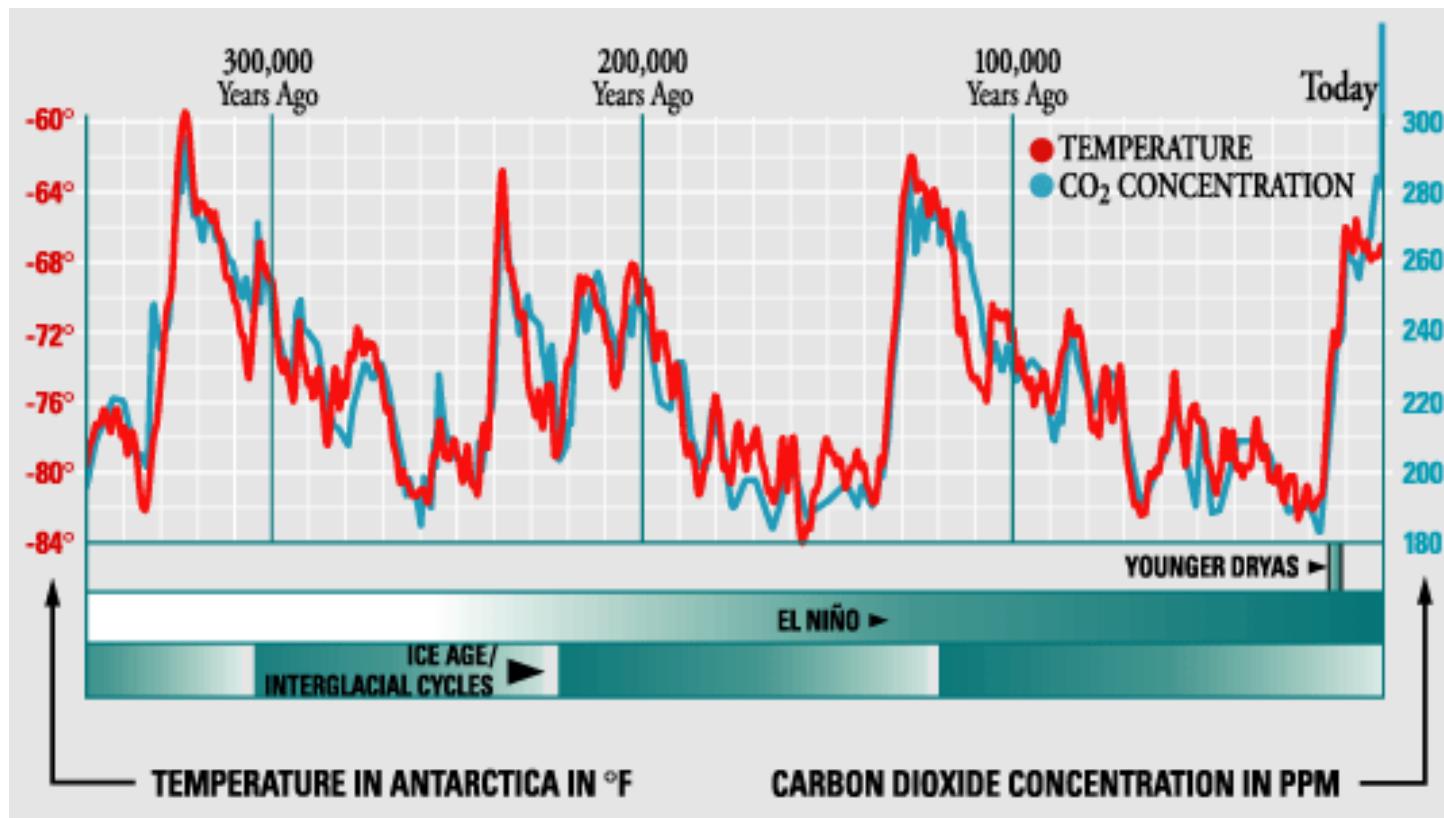
# Changes in GHGs

- 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)

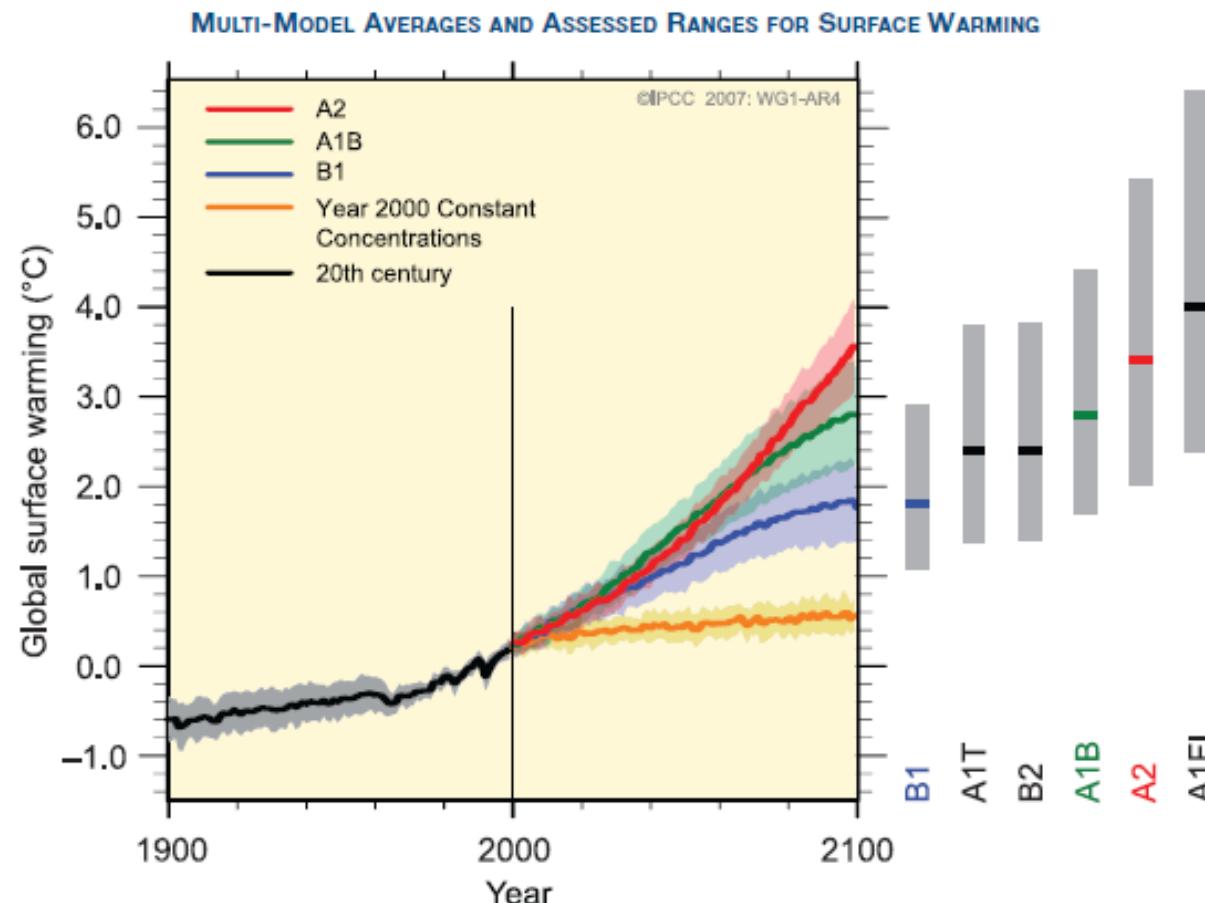


# Global Warming



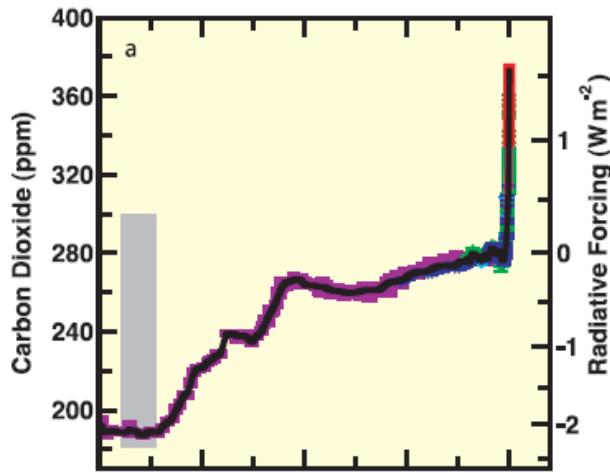
**Figure 2.** Ice core record from Vostok, Antarctica, showing the near-simultaneous rise and fall of Antarctic temperature and CO<sub>2</sub> levels through the last 350,00 years, spanning three ice age cycles. However, there is a lag of several centuries between the time the temperature increases and when the CO<sub>2</sub> starts to increase. Image credit: [Siegenthaler et al., 2005, Science](#)

# Global Warming Predictions

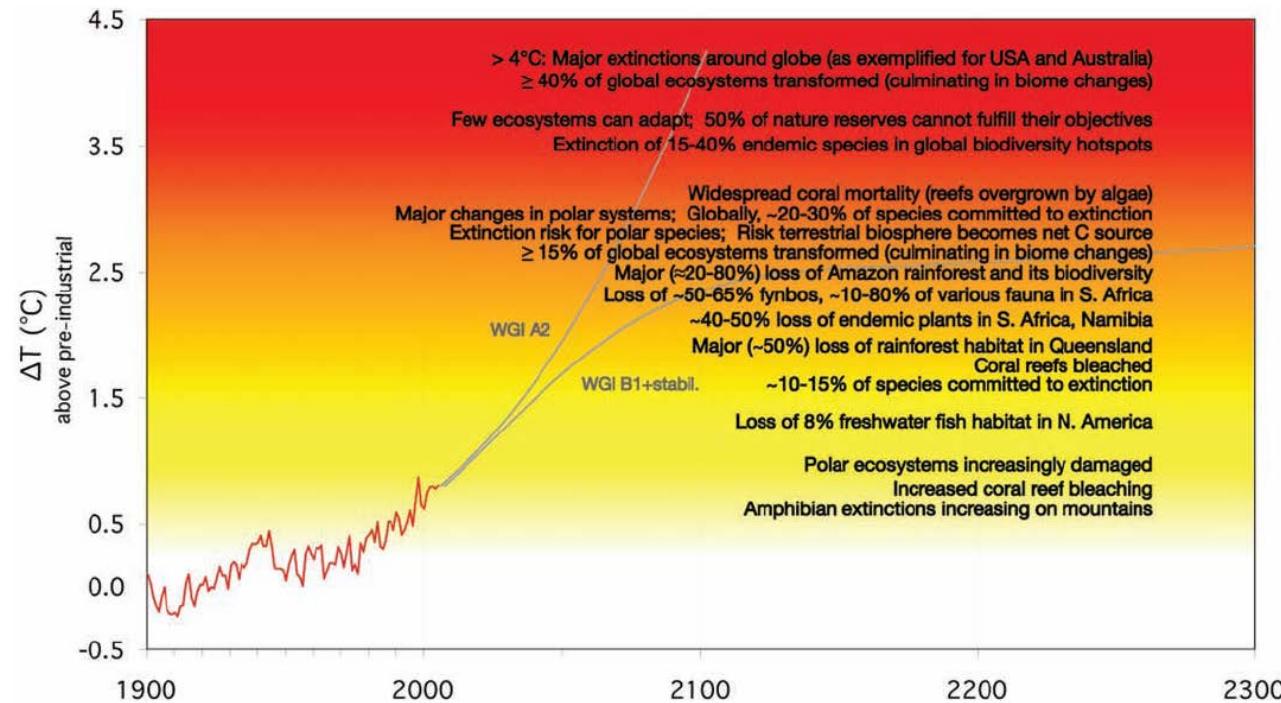


**Figure SPM.5.** Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the  $\pm 1$  standard deviation range of individual model annual averages. The orange line 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

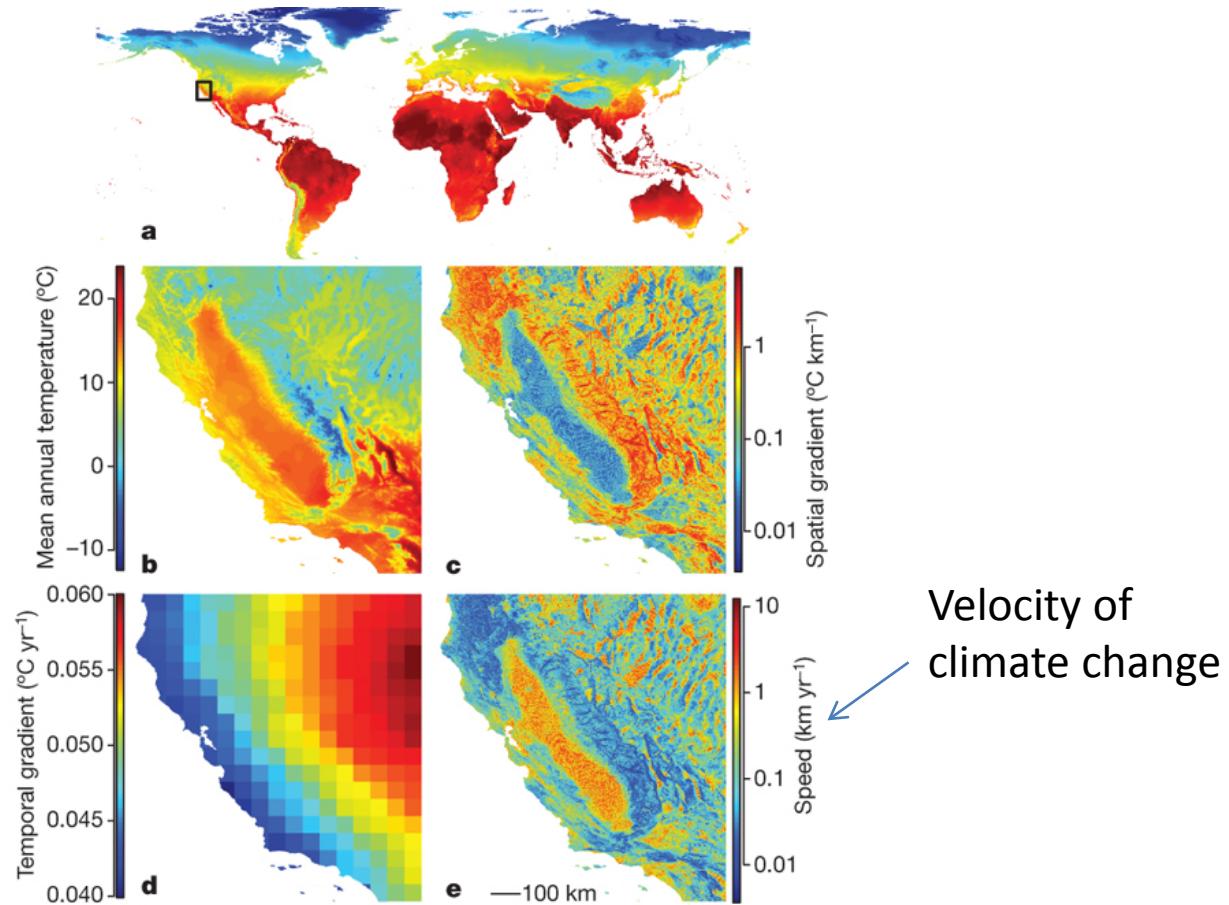


Source:  
Intergovernmental  
Panel on Climate  
Change (2007), FAR,  
WGI, *The Physical  
Scientific Basis*, TS,  
p. 25



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

## Changing temperature in California.



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

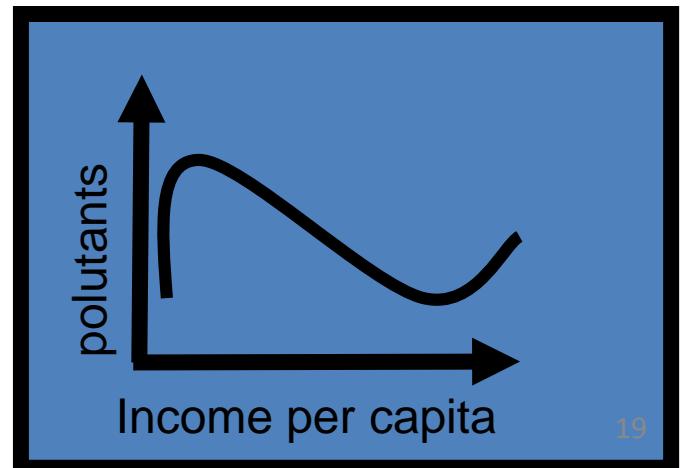
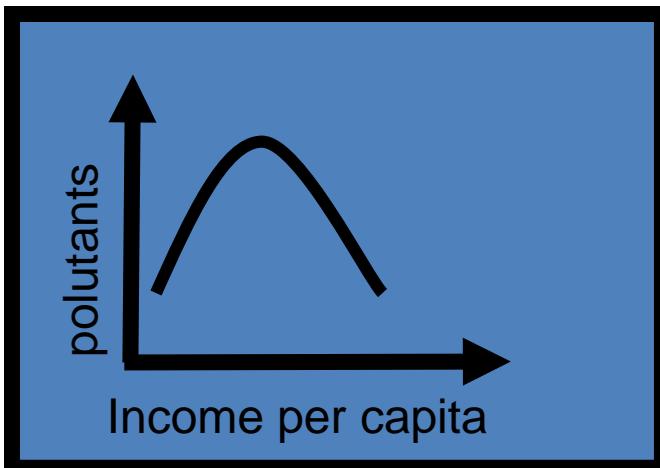
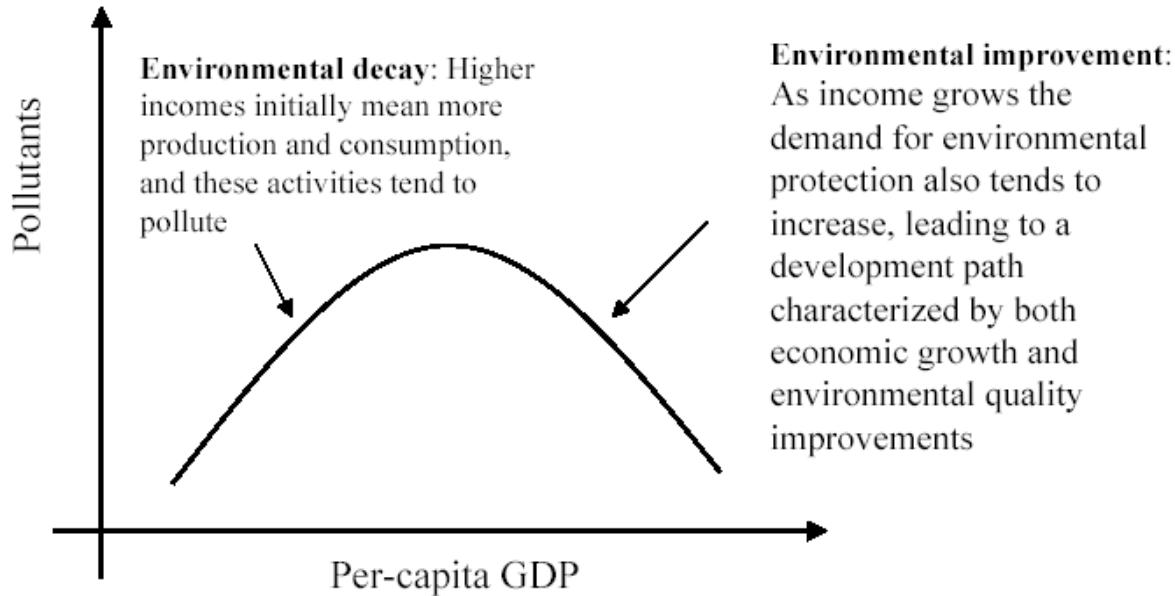
nature

# Green Products

- It is impossible for humans to live without obtaining resources from the environment
- There is no such thing as a GREEN PRODUCT, every product or service we use taxes the environment
- What is important is to be able to rationally choose between options
- Life cycle analysis – system thinking is required

# Environmental Kuznet's curve

“Inverse-U” relationship between pollution and national income



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

**Environmental impact =**

$$\text{population} \times [\text{GDP/person}]$$
$$\times [(\text{environmental impact})/(\text{unit of GDP})]$$

## **Over the next half century**

Population ... 50% increase

Affluence [GDP/capita] ... 300-500% increase

Efficiency [impact/GDP] ... ?

# 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.”*

# 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)
  - PPP = social, environmental, and economic
- We have many options to meet our demands.
- How to choose the “best” option?
- Life cycle assessment helps to inform our choices.  
22

# **The Grand Objectives (Graedel 1998)**

How do we downscale the sustainability concept (for the environment) to create metrics?

## **The $\Omega_1$ Objective**

Maintaining the existence of the human species

## **The $\Omega_2$ Objective**

Maintaining the capacity for sustainable development

## **The $\Omega_3$ Objective**

Maintaining the diversity of living things

## **The $\Omega_4$ 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
$\Omega_1$ : Human species extinction	1. Global climate change 4. Human organism damage 5. Water availability and quality 6. Resource depletion: fossil fuels
$\Omega_2$ : 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
$\Omega_3$ : Biodiversity	1. Global climate change 2. Loss of biodiversity 3. Stratospheric ozone depletion 5. Water availability and quality 7. Acid deposition 16. Thermal pollution
$\Omega_4$ : 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.

# 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

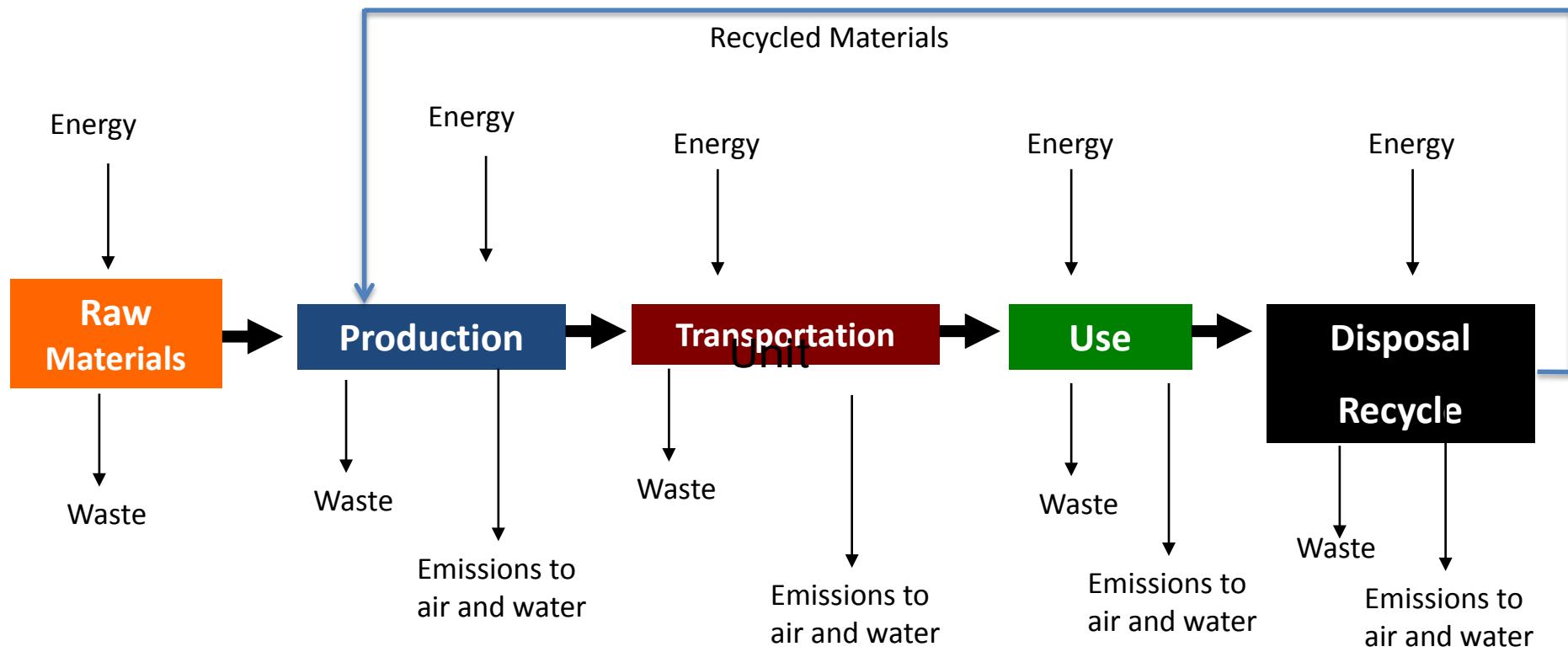
# What is a Life Cycle Assessment ?

**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].

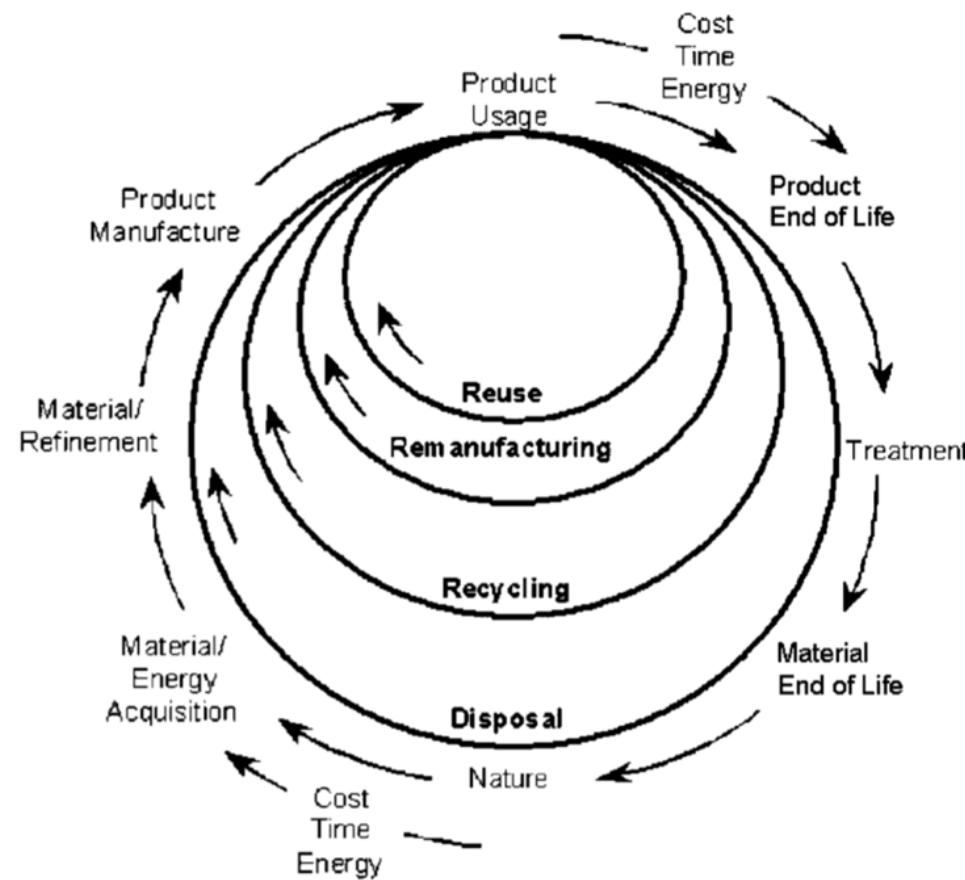
## Objectives

- Identify “hot spots” that have critical environmental impact
- To compare two different solutions to a need

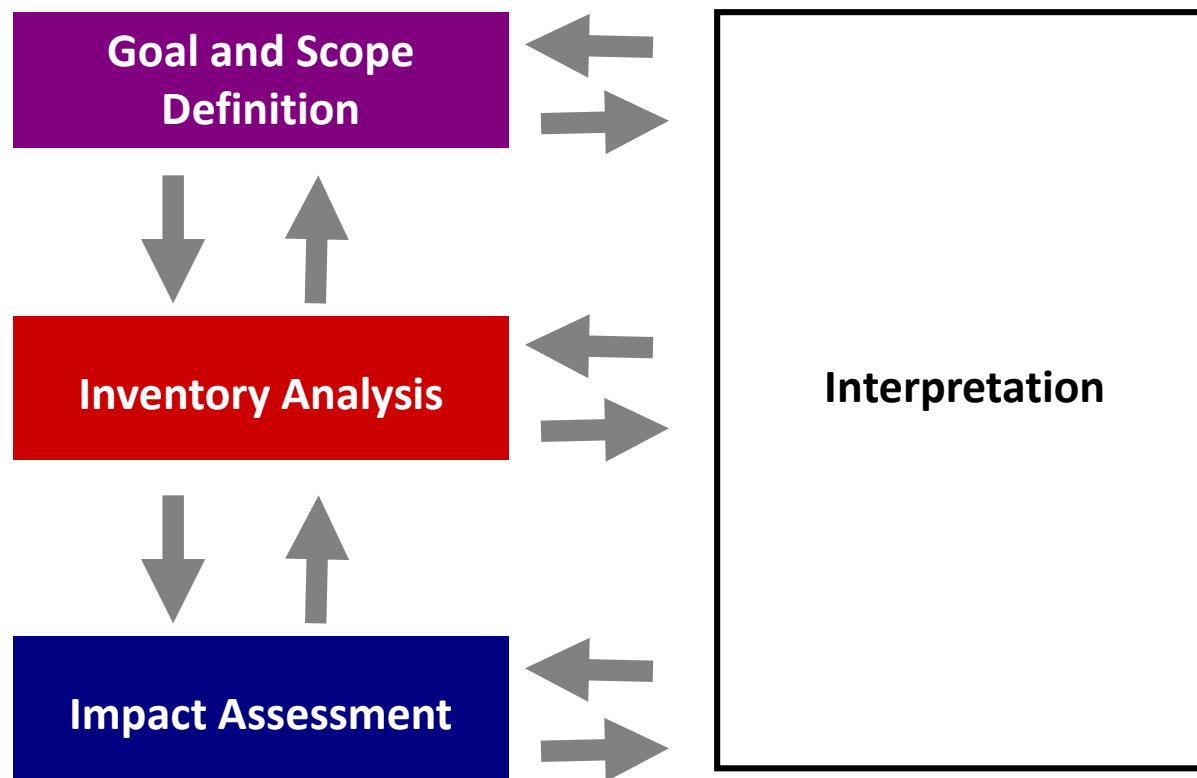
# Life Cycle Stages



# Alternate view of life cycles as concentric circles: Mihelcic et al 2003.



# Important Aspects of Life Cycle Assessment



# Other Definitions of Life-Cycle Assessment

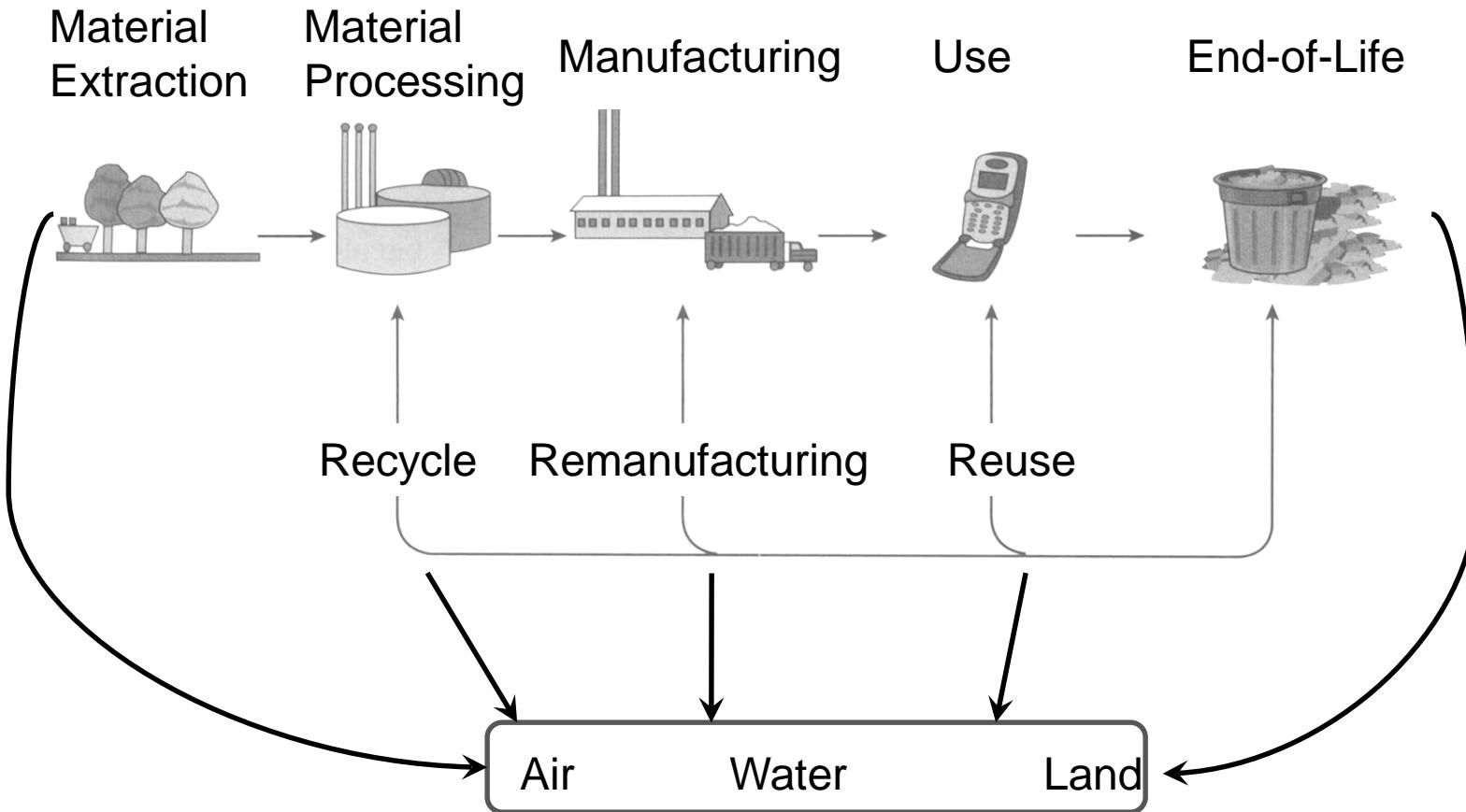
Graedel and Allenby (1995):

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

Global Warming

The Master Equation

Grand Objectives (4)

Sustainability

PPP

Life Cycle Analysis

Life Cycle Stages

Clean Growth