1.964: Design for Sustainability

Lecture 1: Global Challenges

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Life Cycle Impact of Electronics

- 30 million computers are thrown away each year in US (~14% are recycled now)
- Heavy metals pollute water
- Estimated 600 million computers to be thrown away
- Tackling waste flows can reduce environmental impact and save money

What happens to discarded computers?

- 2002 Report by the *Clean Computer Campaign:* <u>Exporting Harm: The High-Tech Trashing of Asia</u>
- Giuyu, China: 100,000 migrant workers disassemble electronics for precious metals
- Lead, mercury, and other heavy metals are a hazard to local environment and workers

Problems with Electronics

- **Designers are not responsible for end of life design**
- **Product manufacturing does not consider the entire lifetime of the product**
- **Result is *waste***
  - **Economically inefficient**
  - **Environmentally harmful**
  - **Socially irresponsible**
- **→ UNSUSTAINABLE**

Life Cycle Impact of Design

- This class is about considering the whole life of an engineering design
- Quantify the impacts of different alternatives using life cycle assessment (LCA)
- We will investigate materials, water, energy, etc in the context of whole life design
- Focus on the built environment

Start with a story - about a can of Cola….

- Materials Transport Country Energy/processing

Mine
Baux
1/2 =

Sme
Al-O
= Al

Water/flavore
phosphorus/c

sugar beet
phosphorus

throwing the can away takes a second

Drinking the cola takes a few minutes

purchased within three days

supermarket

Palletized

mical manufacturer

Reducing - electricity for 100,000 people

Mined

Smelted

Heated/rolled

cold rolled

Punched/formed into cans

washed, dried, painted x 2

flanged

nside with

ve coating

tised/forklifted

warehoused

/cleaned/filled

ining

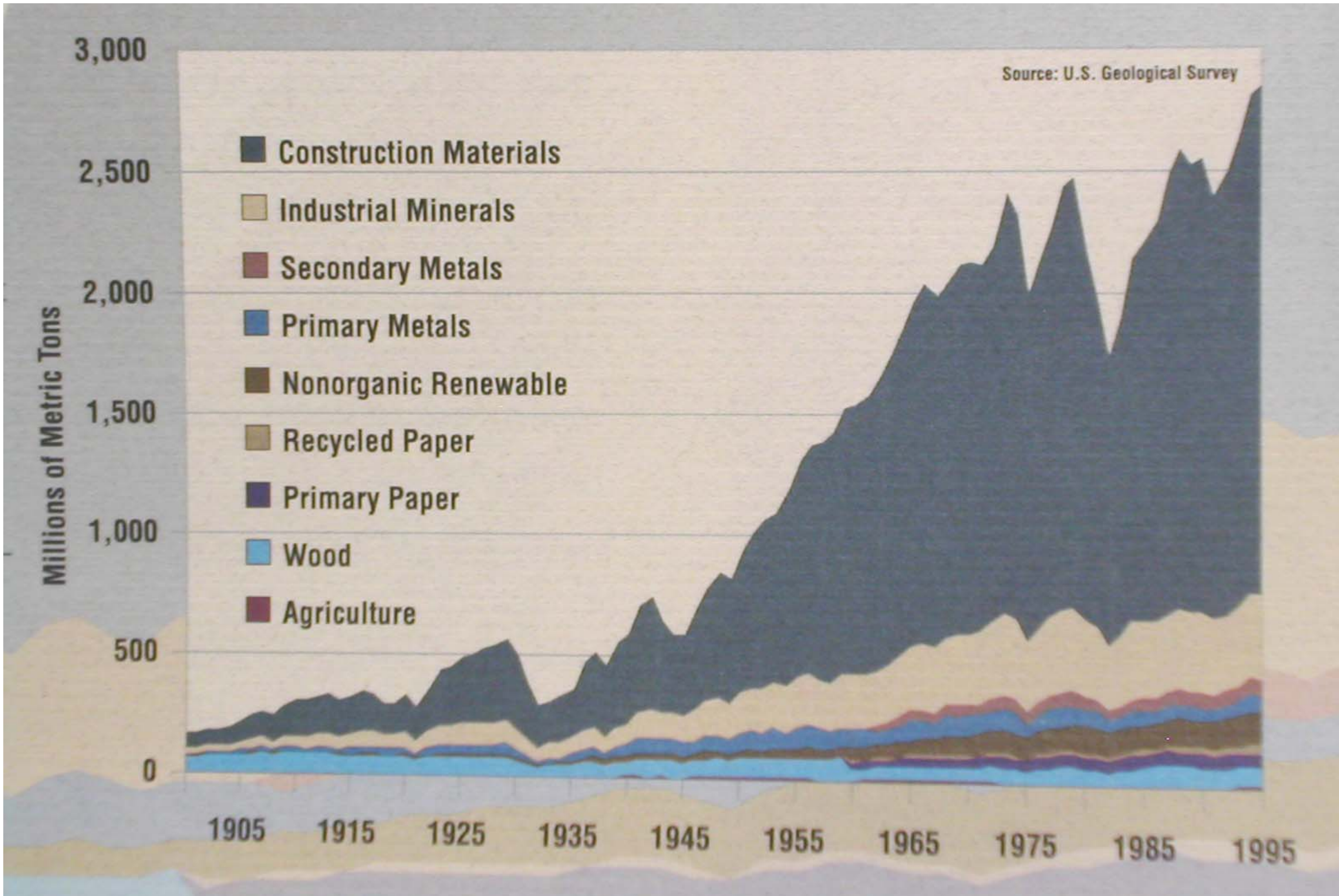
excavated from mines

Why does this seem ‘cost-efficient’?

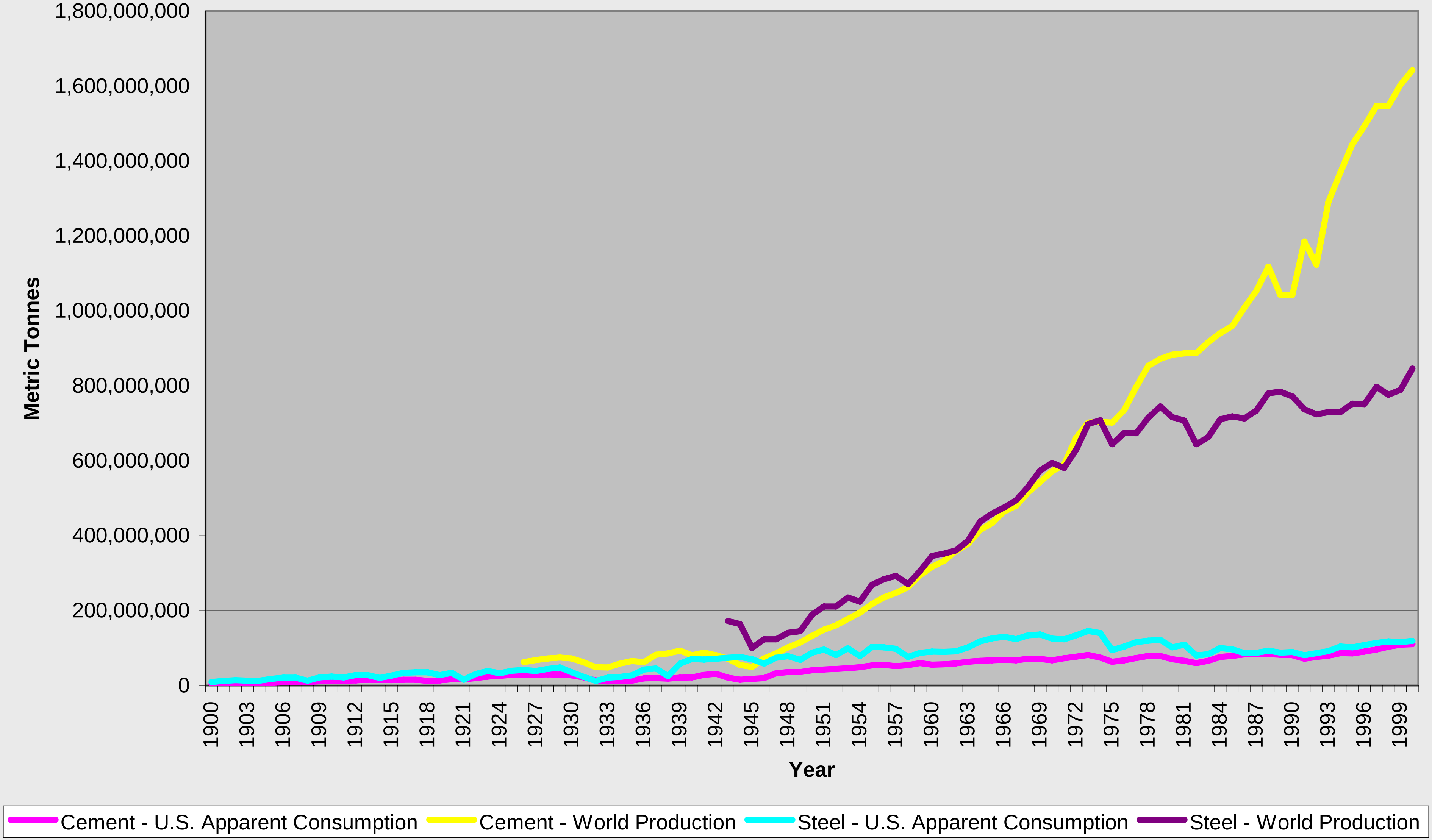
- We (as consumers) pay (directly) only for the end product:
- the ‘price’ does not include the cost of ‘externalities’….
- social, environmental, resource use and health costs:

- so the ‘cost’ signals to manufacturers’ are incomplete
- we have a ‘linear thinking’ mind-set:
- each part of the process is separately ‘optimized’
- *But we don’t look at the process as a whole...*

Use of Raw Materials in the US



Trends in Steel and Cement Production



Source: Chaturvedi, MIT thesis, 2004

Projections for Steel and Concrete

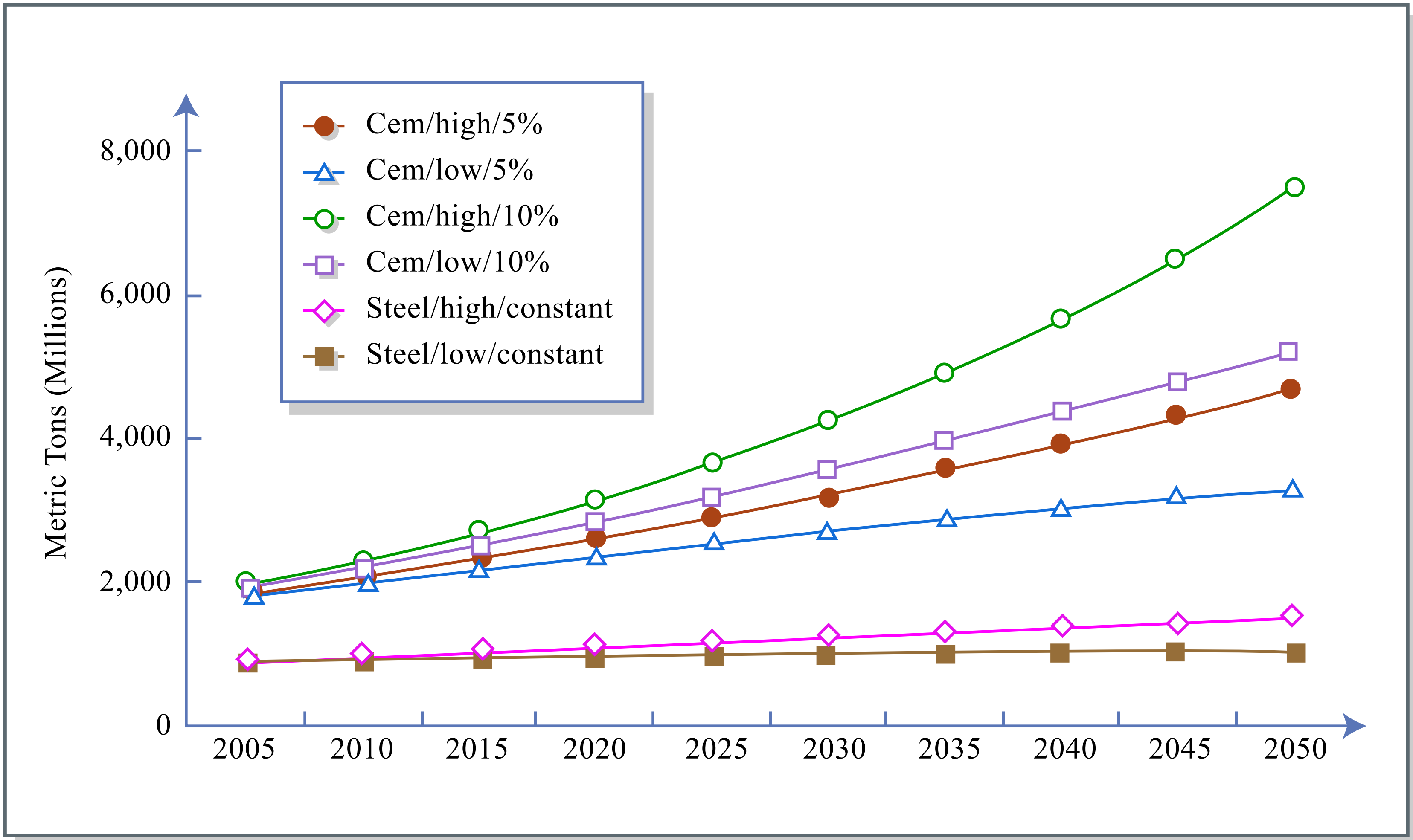


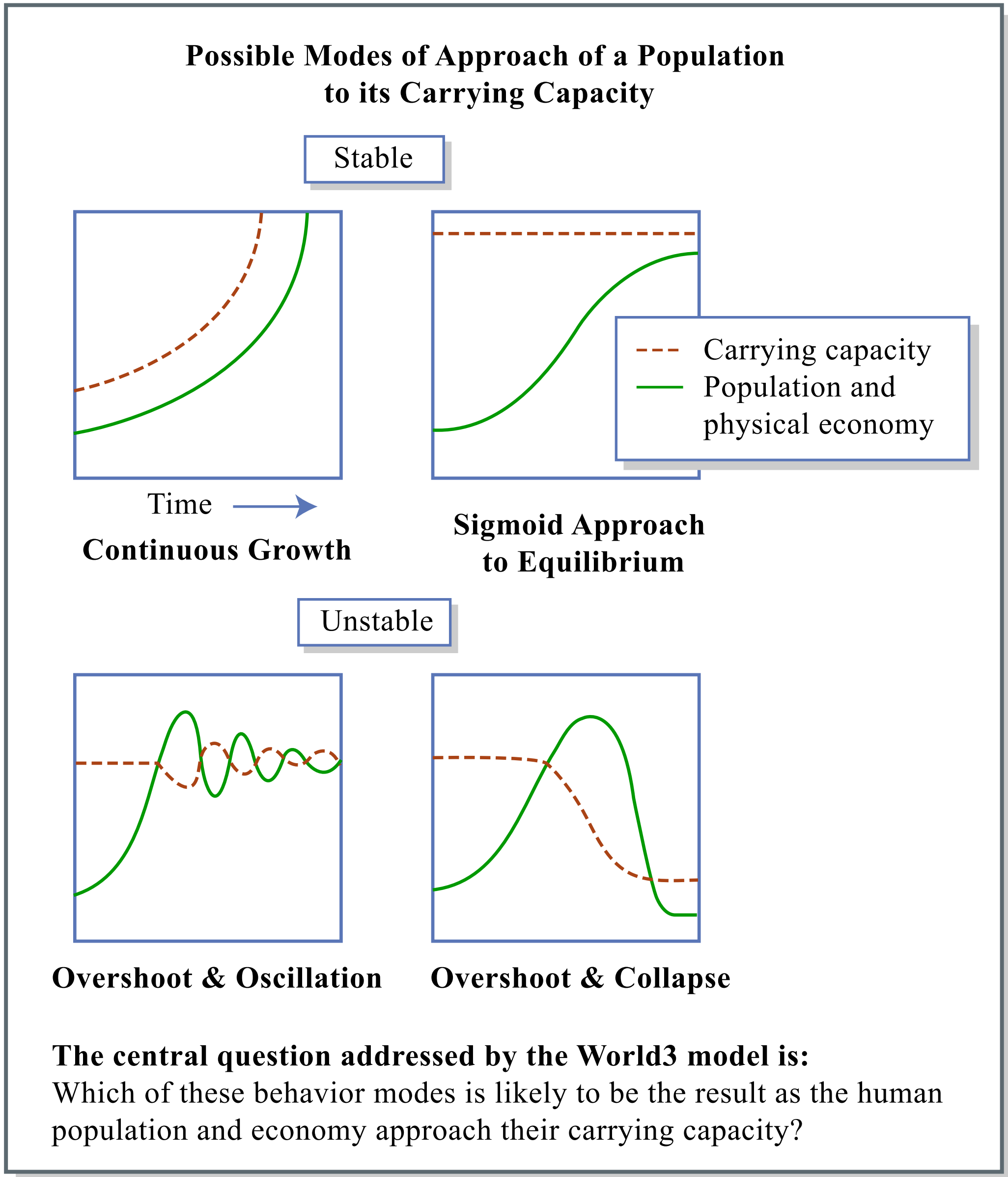
Figure by MIT OCW.

Source: Chaturvedi, MIT thesis, 2004

The earth is finite…

….natural resources have a limit

Our environmental and economic system: where does it lead?



Continuous growth: *impossible, in a finite world*

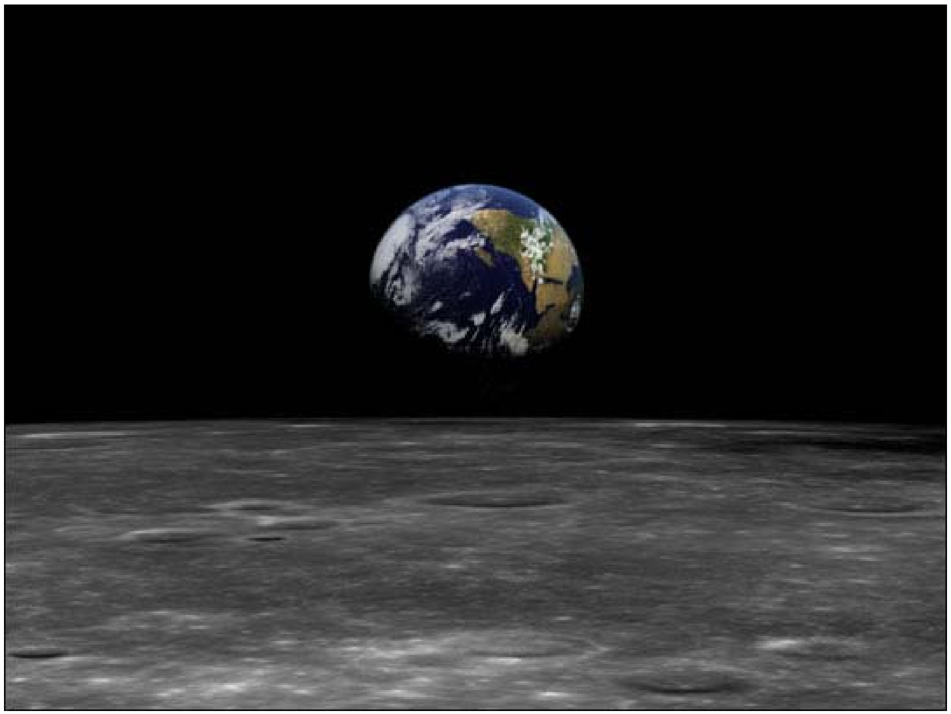
Controlled approach to equilibrium: *the ideal - sustainability - but can we manage it?*

Overshoot and oscillation: *still sustainability eventually, but a much rougher journey*

Overshoot and collapse: *to be avoided!*

Figure by MIT OCW.
(From 'Beyond the Limits'', 1998)

This class...



It's about us and our planet Earth - our people, environment and quality of life…

…and how sustainable (or not) we can be: the key issue of the 21st century.

...and what engineers have to do with it

Demand for sustainable design…

Now and in the future…

There is tremendous demand for engineers and architects who can lead sustainable design efforts in the 21st century

You will tackle these problems

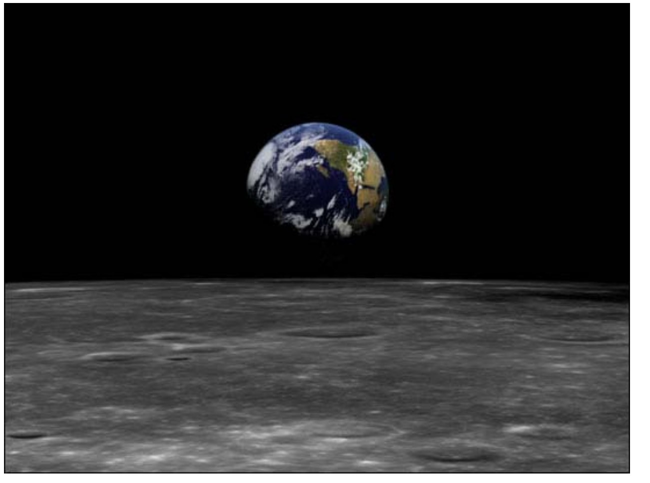
First two lectures by JAO

1) Global challenges

2) Construction industry

Lecture 1: Global Challenges

- Introduction
- Trends
- Defining Sustainability
- Ecological Footprint
- Limits to Growth
- Discussion



Where we stand now: social inequality
If the world had only 100 people

- You would find 60 Asians, 12 Europeans, 15 North and South Americans, and 13 Africans
- 80 would live in sub-standard housing
- 20 would not have safe drinking water
- 42 would not have adequate sanitation
- 33 would suffer from malnutrition
- Ten would own a computer
- Five would have a college education

Is this socially sustainable? We need 'development'

But, if 'Development' gave global equality of quality of life and resource use:

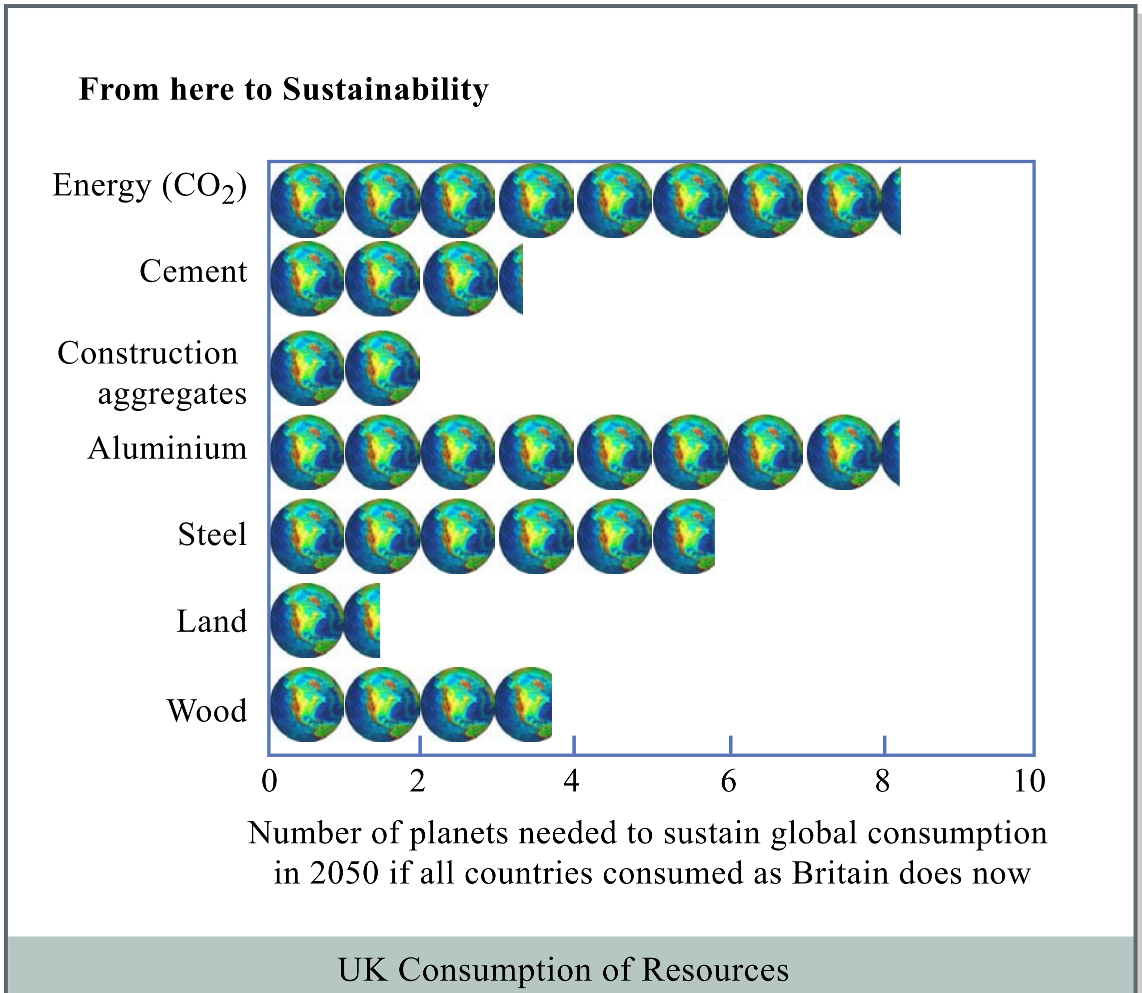


Figure by MIT OCW.

- If we accepted that all people on Earth are entitled to use as much resource per capita as us now...
- By 2050 we would need more than eight 'Earths' to sustain us all, using current technologies.....

To allow that 'development', our technologies need to become environmentally sustainable.

A vital debate about the future…

On technology and ecology:

- ‘Technology magicians’ - *there are no limits; science & technology will save us*
- ‘Deep Green Doomsayers’ - *the earth is in deep trouble; we’re going downhill fast”*

And on the economic system:

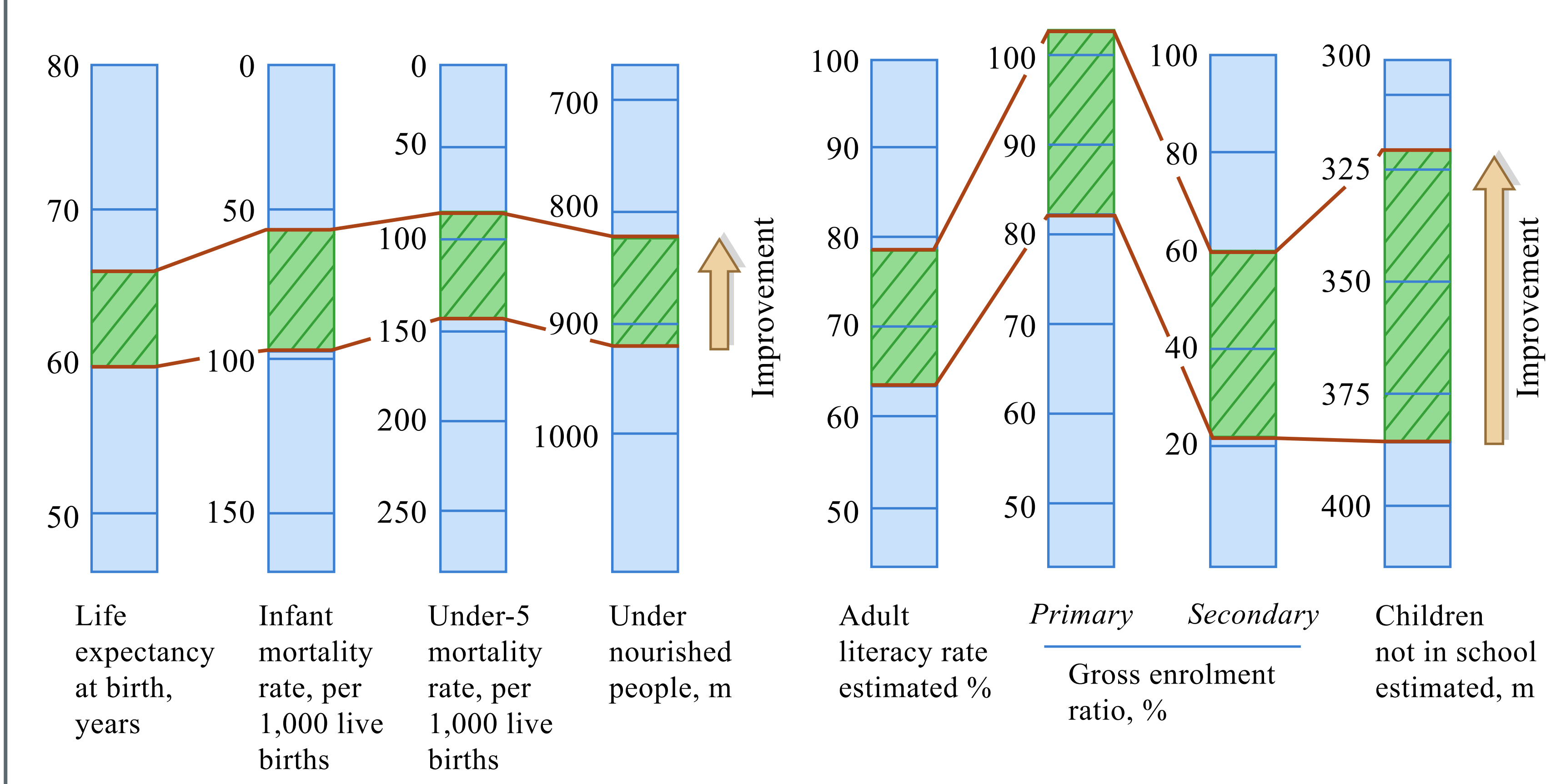
- The ‘Economist’ view - *capitalism and globalisation are the only deliverers of growth and development*
- The IMF protesters’ view – *They are (part of) the problem, not the (only) solution; we must give people back control over their own lives*

The global picture…

- ***"We are modifying physical, chemical and biological systems in new ways, at faster rates, and over larger spatial scales than ever recorded on Earth. Humans have unwittingly embarked upon a grand experiment with our planet. The outcome is unknown, but has profound implications for all of life."***
  (President, American Academy for the Advancement of Science, 1999)

- **In the developed North, we are each typically using 3-5 times as much of the Earth's resources as our 'fair share'.**

On *social need*, there is some good news on health, literacy and education...



Better Lives: Worldwide Improvements over past 30 years

Figure by MIT OCW.

(Source: Economist, 2002)

Poverty remains a major problem

Between 1987 and 1998, in ‘developing’ and ‘transition’ economies:

- **The number of people living on < $1/day fell from 28% to 24%, *but* the absolute number of poor people hardly changed….**
- **In India, over 80% live on < $2,day, and over 40% on < $1/day**

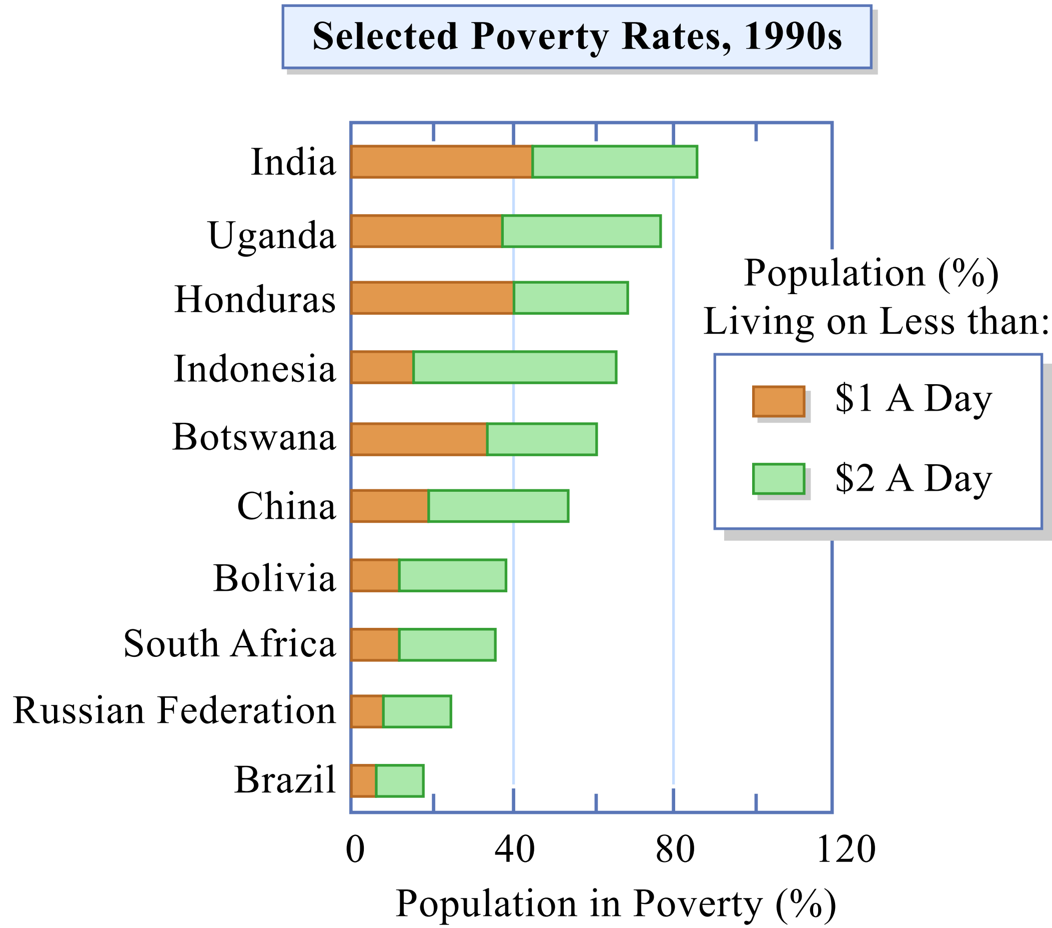


Figure by MIT OCW.

Our ‘Ecological Footprint’ is already *unsustainable*

Ecological Footprint = “An estimate of human pressure on global ecosystems, expressed in ‘area units’” - food, wood, infrastructure, CO_2 absorption

1. **World average footprint/capita was ~constant between 1985 - 1996 = 2.85ha/capita**

2. **US average is ~ 10 ha/capita**

3. **My own is ~ 15ha/capita**

4. ***The world’s footprint (1999) is about 1.25 x the 11.2 Bn Ha available***

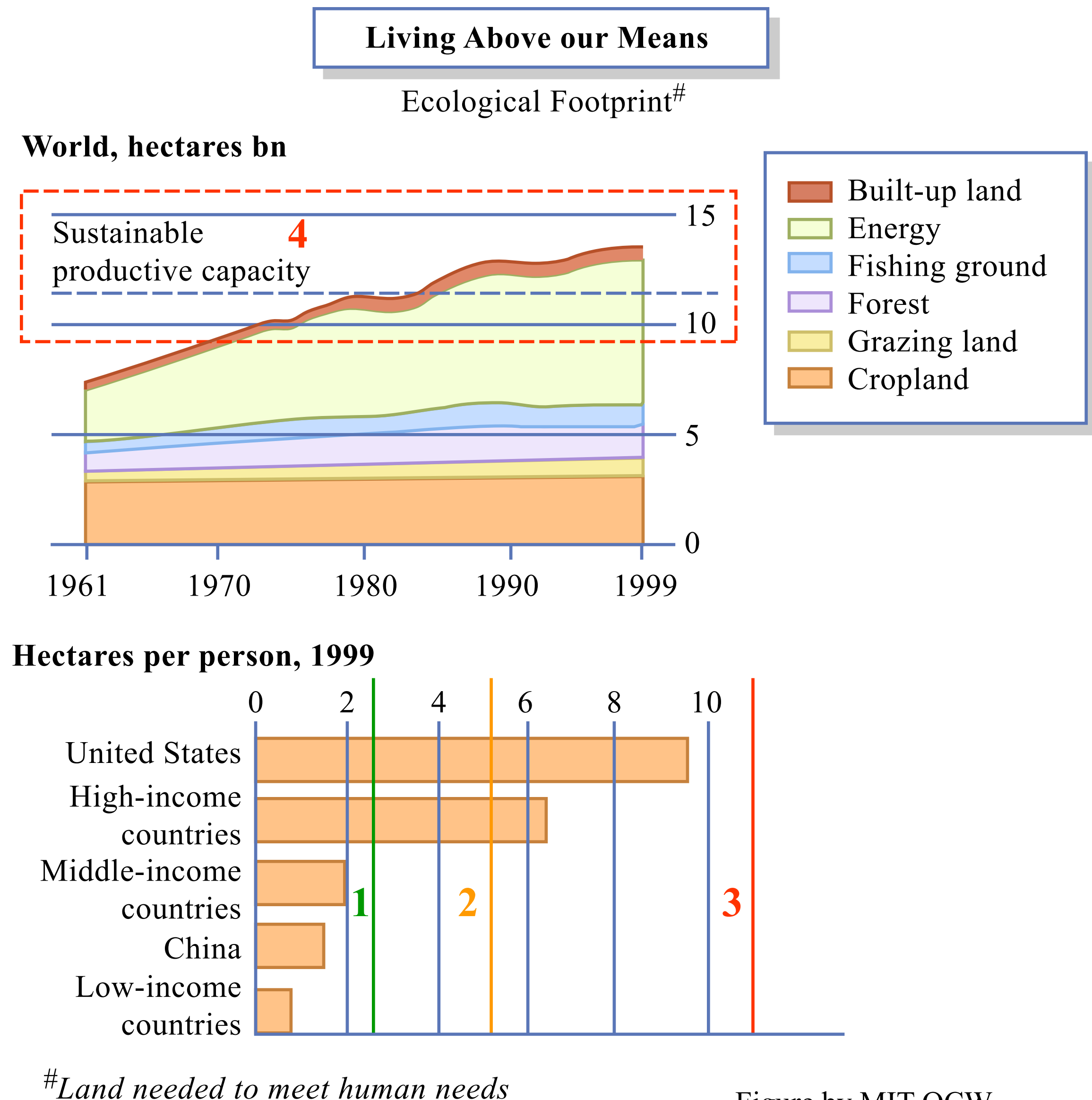


Figure by MIT OCW.

(Source: Geo3 and Economist 6/7/02)

Some complex regional or global systems show signs of failing

- Traffic congestion
- Worldwide fish resources → stocks collapse
- Global warming/climate change → floods

Where do these trends lead?

- **Over the last 50 years, ‘development’ - comprising engineering projects, and products - has benefited large numbers of people, world wide……………*but:***
- **The way we have been doing our development is often ‘unsustainable’ - in social and environmental terms**
- **This leads to real fears about the security and quality of life that our children and grandchildren - and the world’s - can expect**

“We do not inherit the earth from our ancestors - we borrow it from our children” (Anon)

‘Sustainability’ definitions - start with the Dictionary *(Collins, 2nd Ed 1986)*

***Sustain*:**

- **to maintain or prolong**
- **to support physically**
- **to provide or give support to - esp. by providing necessities**

***Sustenance*:**

- **means of sustaining health or life: nourishment**
- **means of maintenance; livelihood**

This is beginning to give us the idea...

Defining Sustainable Development

- *Original definition:*

  "Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs" **(Brundtland Commission 1987)**

- **The concept goes back 20 years; and by now 'sustainability' has become almost a mainstream - even overused - word.**

- *More recently:*

  "A dynamic process which enables all people to realize their potential and to improve their quality of life in ways which simultaneously protect and enhance the earth's life support systems" **(Forum for the Future)**

Engineers and Sustainability

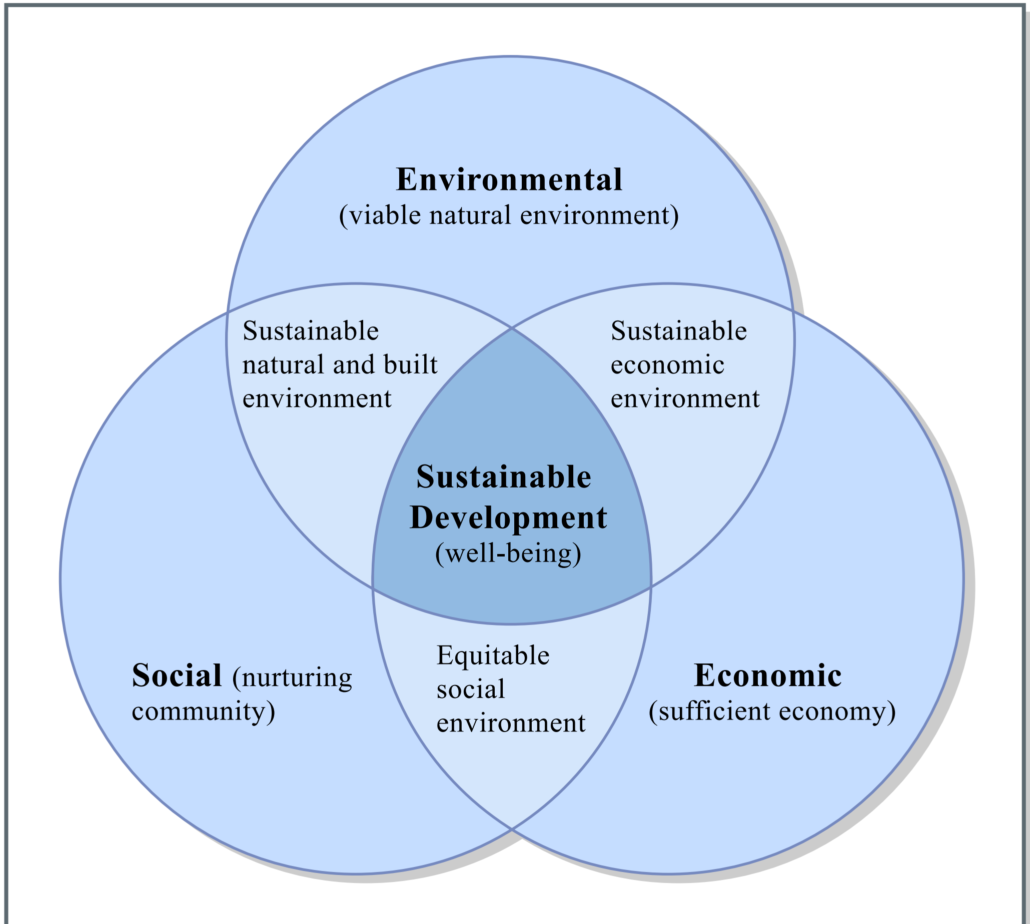
- 'Development' = the sum of our products and projects, ie *our application of technology*

- In these applications, engineers carry out, influence or decide:
  - *the options evaluated*
  - *the decision-making criteria, and the decision*
  - *the detailed design and implementation/production*

- *For development to become 'sustainable', engineers must incorporate 'sustainability' into all our planning and engineering of products and projects*

- This course asks: "How do we start to do this?"

Sustainable development aims to balance three elements:



The Concept of Sustainable Development

- Economic: **what things cost - and how to make a business out of providing infrastructure, goods or services**
- Environmental: **what impact those things have on nature and the earth's support systems - which are finite**
- Social: **how those things serve the needs and quality of life of people and their communities**

Figure by MIT OCW.

Technology is neither good nor bad in itself - how we choose to apply it determines whether a good balance is achieved.

Where are *you* starting from?

- 1. How much do you know already about the sustainable development debate - and your own contribution?
- 2. Discuss ecological footprint results from www.myfootprint.org.

The Environmental Dimension within Sustainable Development

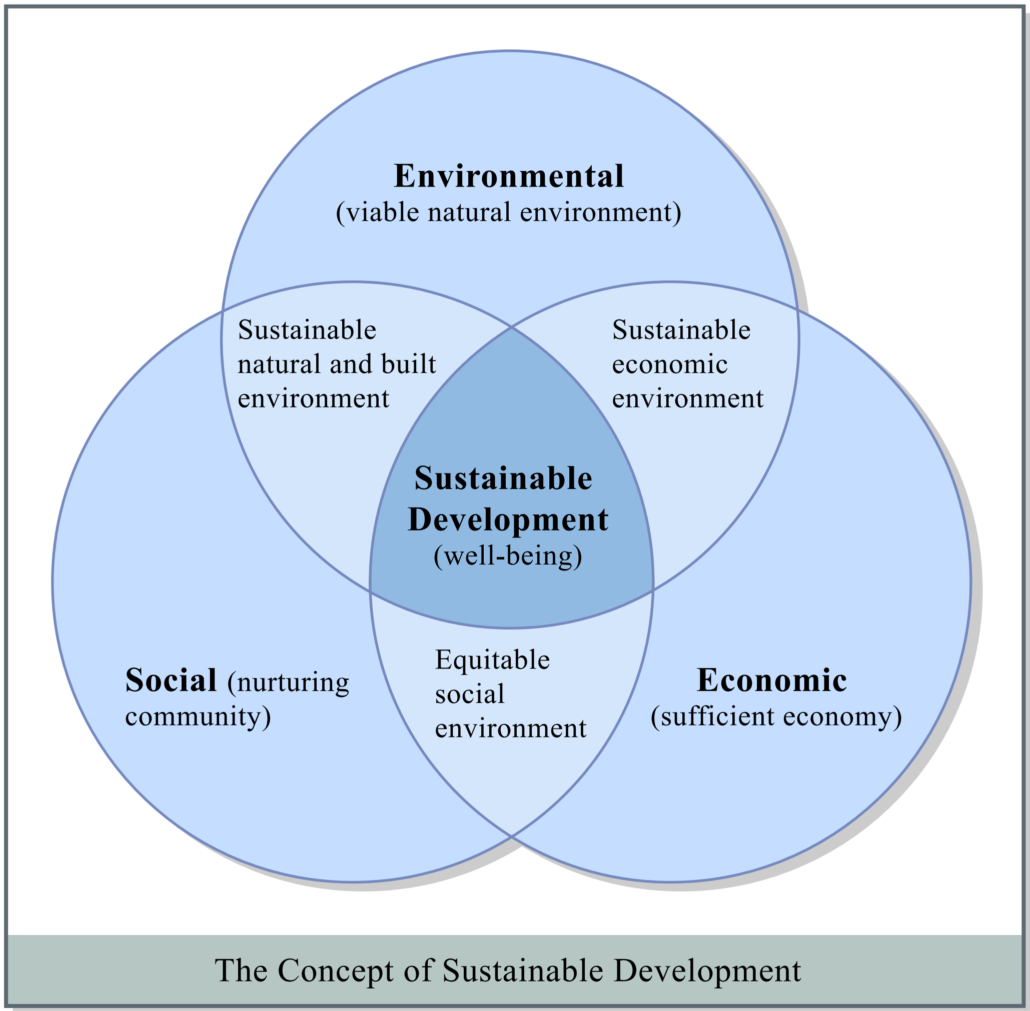


Figure by MIT OCW.

- Environmental: **what impact projects and products have on nature and the earth's support systems - which are finite**
- **The need to protect the environment has become accepted - almost 'the establishment view'**

But the hard part is an addiction to 'growth' on a finite planet….

Our environmental and economic system: where does it lead?

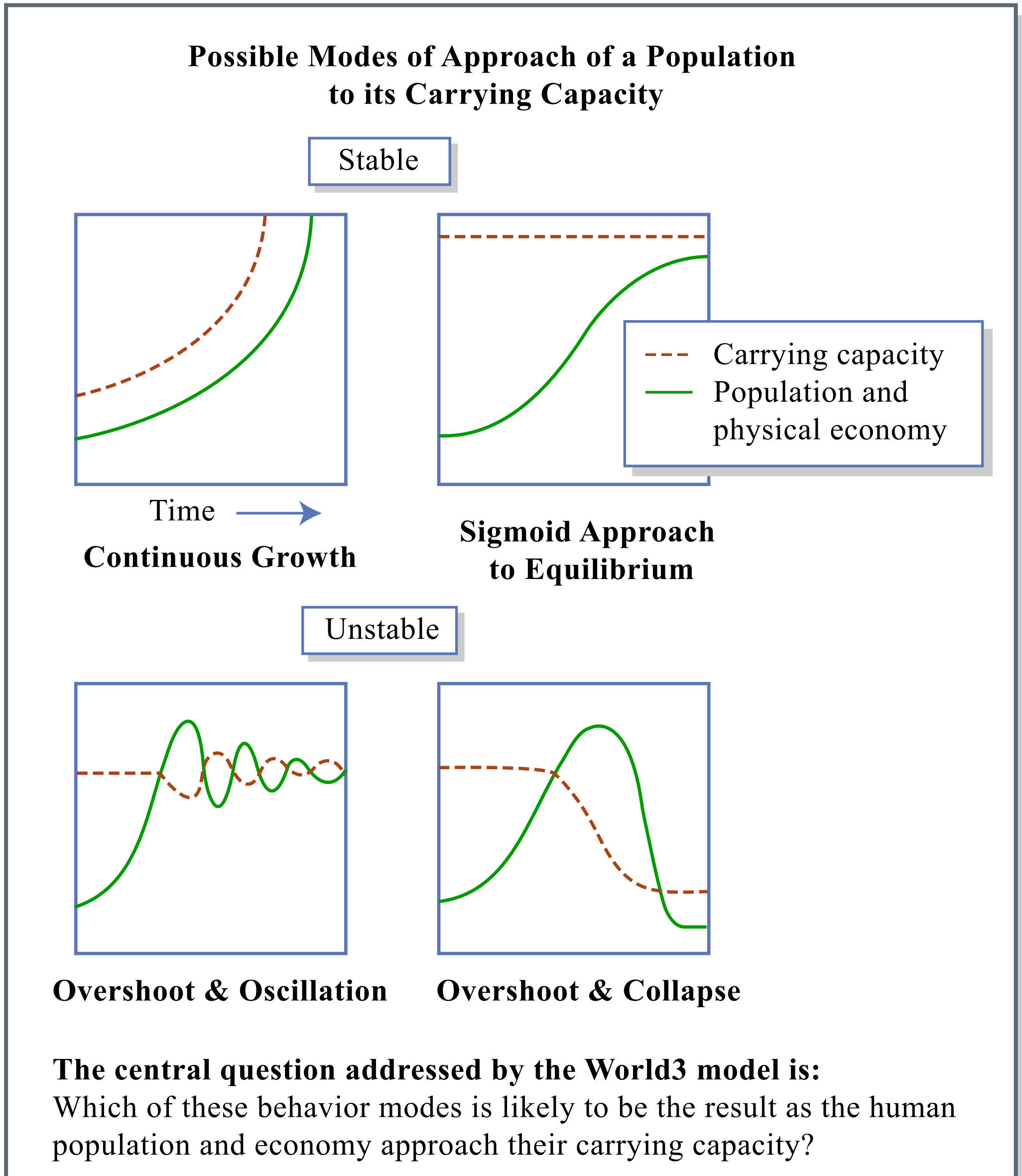


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Figure by MIT OCW.
(From 'Beyond the Limits'', 1998)

Predicting global impact - systems modeling with 'World3'

Global 'systems modeling' by MIT in 1970; updated, U of New Hampshire
in 1991; re-calibrated over 1970-1990 events
('Beyond the Limits'', 1998)

- Used 9 interconnected systems: +ve and -ve feedback loops
  - -persistent pollution
  - -non-renewable resources
  - -population
  - -food production
  - -land fertility
  - -land development & loss
  - -industrial output
  - -services input
  - -jobs

- Ran 13 scenarios, 1900 to 2100

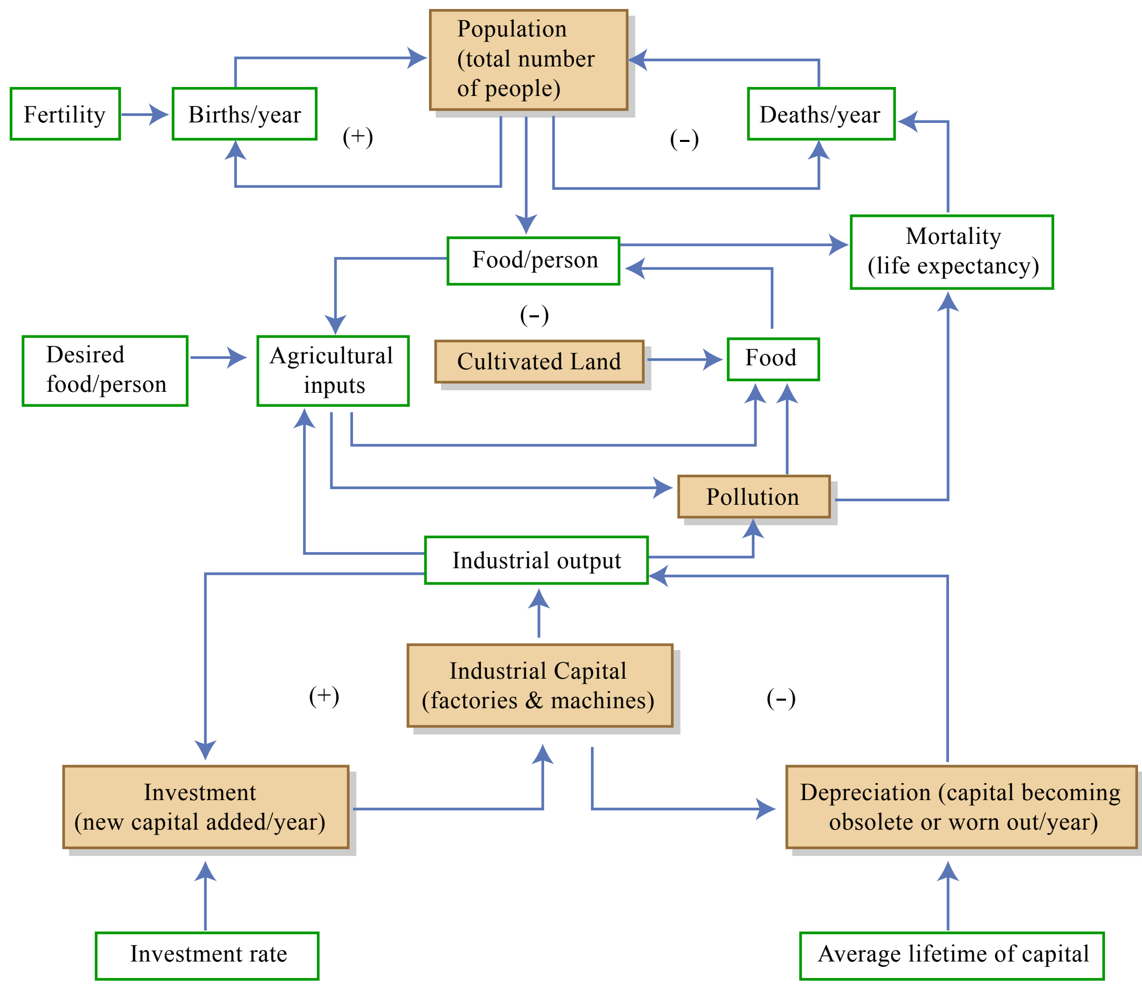


Figure by MIT OCW.

Some of the interconnections between population and industrial capital operate through agricultural capital, cultivated land, and pollution. Each arrow indicates a causal relationship, which may be immediate or delayed, large or small, positive or negative, depending on the assumptions included in each model run.

Scenario 1: the 'Standard Run'

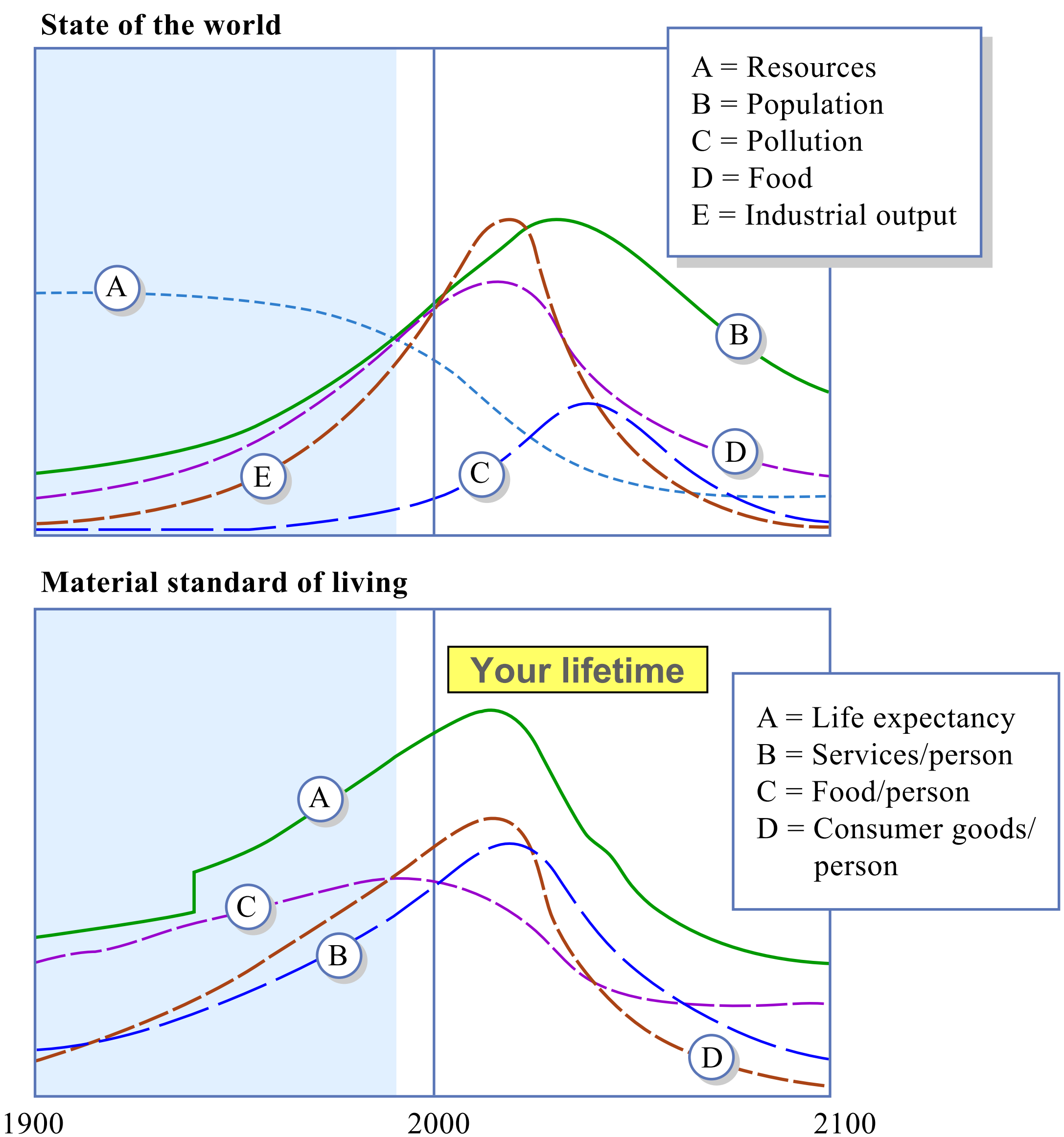


Figure by MIT OCW.

Assumptions:

- 'continue historical path as long as possible - no major change'
- growth continues until environmental and resource constraints finally limit it

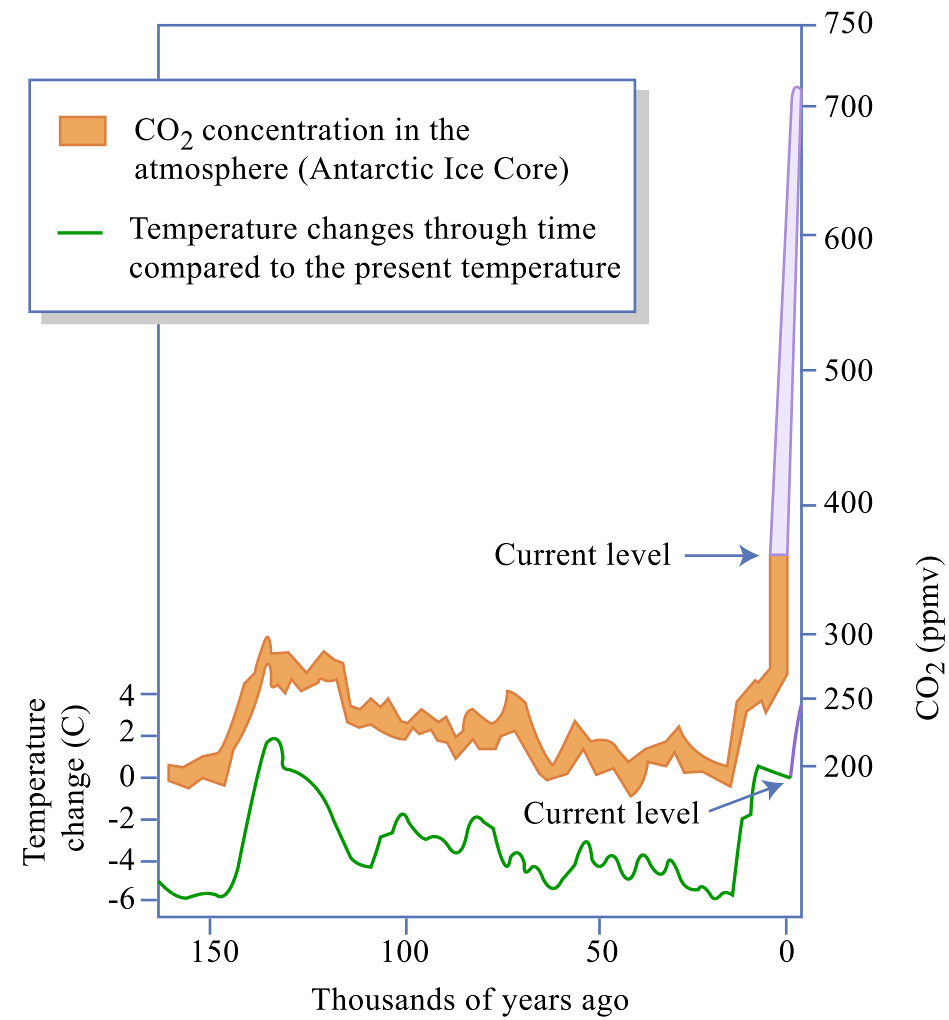
Results:

- irreversible environmental changes occur
- investment capital depreciates faster than it can be re-built
- as it falls, food and health services fall too
- death rates increase and life expectancy reduces

(From 'Beyond the Limits'', 1998)

Example: irreversible environmental change

- The Greenhouse effect and global warming is ‘irreversible’ in a human lifetime at least
- Rising CO2 Concentrations & Temperatures
- We are just beginning to think about slowing temperature rise and climate change by CO2 release reduction
- But inevitable consequences are already becoming apparent



Atmospheric CO_2 Concentration and Temperature Change

Figure by MIT OCW.

Can we improve 'Technology' by a 'Factor 4' or even 10?

- Energy efficiency:

"The whole economy is less than 10% as energy-efficient as the laws of physics permit"

- Materials efficiency:

It has been estimated that only 6% of its vast flows of materials end up in products" **(From *Natural Capitalism*, 1999)**

- *And - using renewable resources…so engineers have plenty of scope for improvement*

Scenario 6: all technical solutions

Assumptions: (from 1995)
- doubled resources at start
- pollution control eff. + 3% pa
- land productivity + 2% pa
- reduce land erosion by 3x
- industrial resources eff. + 3% pa

Results:
- population growth continues with food supplies just maintained
- growth in quality of life still stops and declines from 2020, but more slowly; because….
- in the end, we cannot afford the combined cost of the technologies needed to provide it

Not good enough, yet?

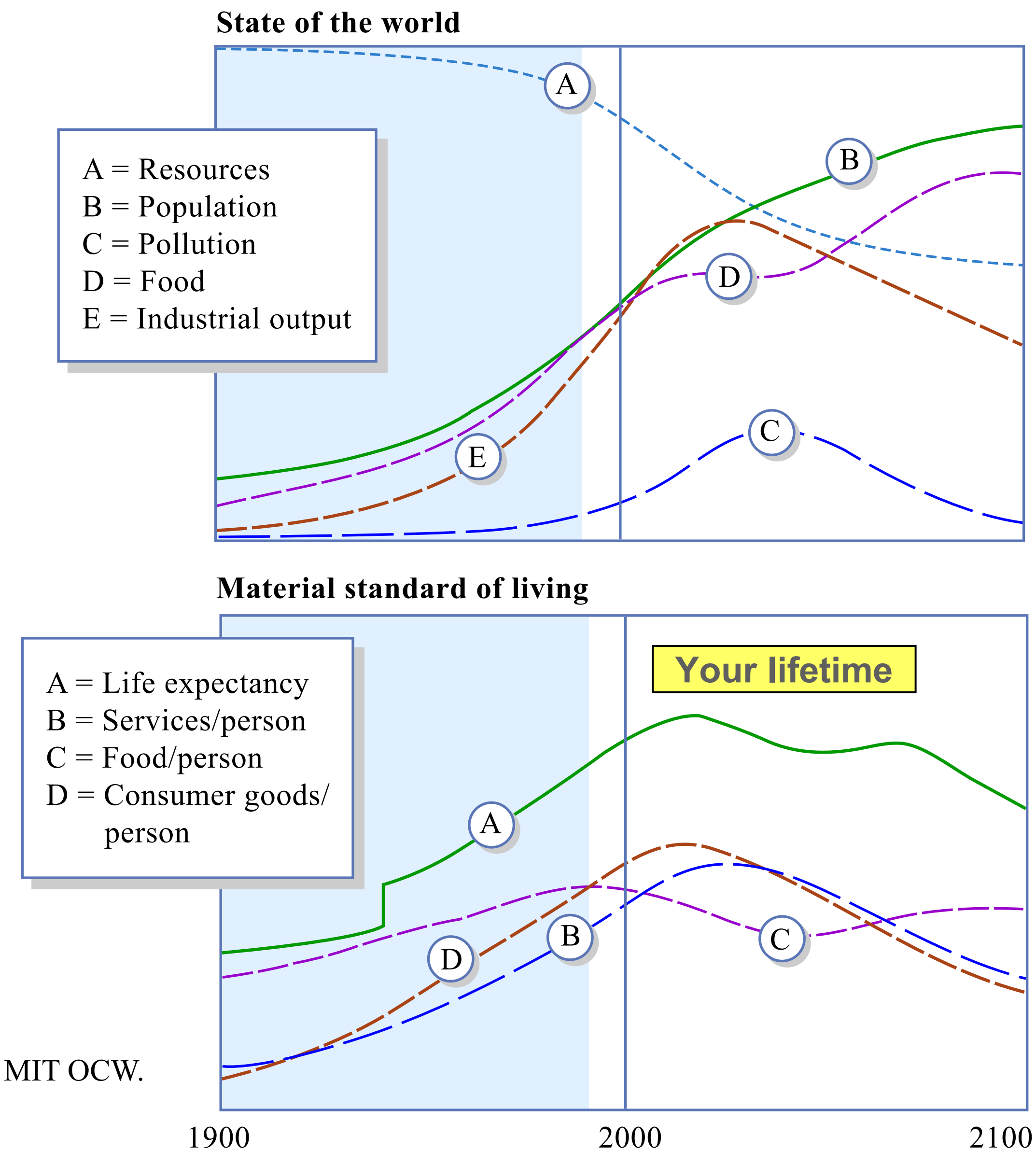


Figure by MIT OCW.

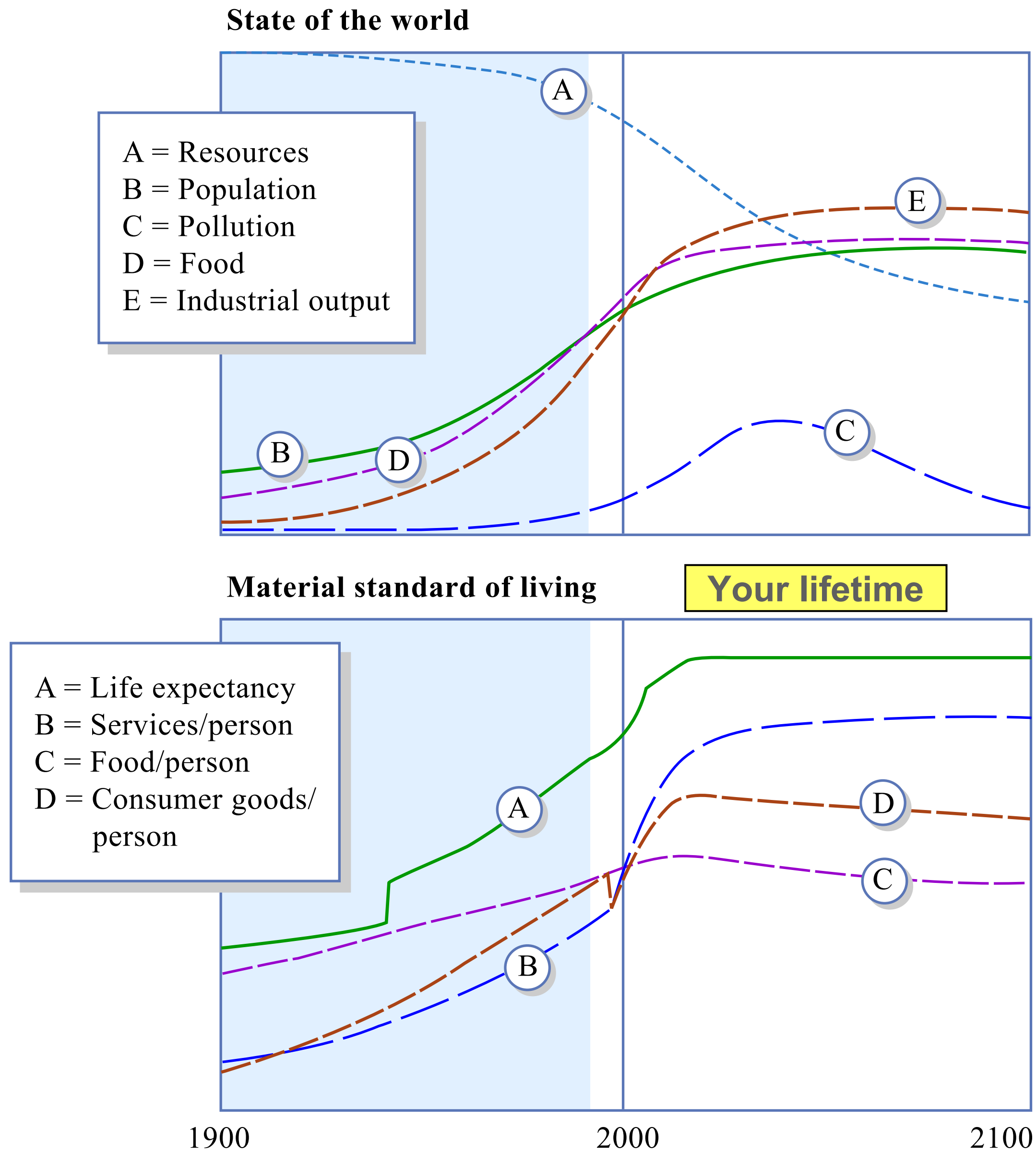
(From 'Beyond the Limits'', 1998)

Scenario 10: accept having 'enough'?

Assumptions: (from 1995)
P - population: 2 children per family
A -'affluence': 'enough' is $350 per cap industrial output (= S. Korea, or 2 x Brazil, in 1990)
T - technology: as Scenario 6: 2 x resources; same improvements in technologies - started when needed

Results: until at least 2100
Population stabilises at 7.7B, with;
- comfortable standard of living,
- high life expectancy and
- declining pollution

So - we know where we need to aim for - but what are the challenges?



(From 'Beyond the Limits'', 1998)

Figure by MIT OCW.

Challenges to make development sustainable

- 1. Defining ‘progress’ to sustainability: **better indicators and sustainability measurements to drive better choices**

- 2. Dealing with economic market-technology ‘failure’: **learning why market economics and technology do not interact fast enough to produce sustainability - and changing the signals**

- 3. Addressing the harder ‘social dimension’: **including ‘social’ components in projects; social objectives for products and projects; consulting properly with local communities**

- 4. Understanding and engaging with real world complex systems: **changing our ‘world view’ to understand complex interactions and feedback loops, and changing to adopt the ‘precautionary principle’**

- 5. Differences in timescales: **bridging the gap between typical political and commercial timescales and the long view of sustainability**

2. Dealing with economic-technology market 'failure':

'Negative feedback loops' ought to send the right controlling signals?

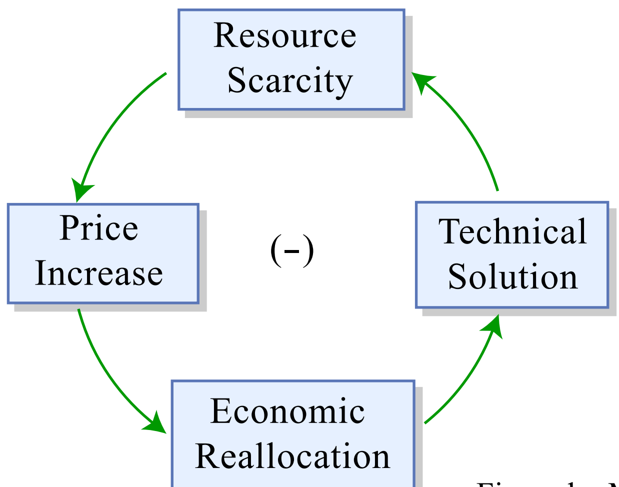


Figure by MIT OCW.

They don't work - or not fast enough - because:

- commercial objectives are to control the market, not to free it up
- 'financial return' time-scales are far too short

- technology's first response is to dig deeper into marginal resources
- exponential growth goes on shortening the time for effective action
- so environmental signs of 'collapse' come too late to avoid it
- successfully delaying limits, in a global 'free trade' economy, means you hit many at once - you run out of *the ability to cope*

So - political and regulatory intervention is needed, as well

2. Sustainable local solutions may not meet commercial objectives:

- Our roofs are a large under-used resource:

Fit solar PV roof tiles, and generate 100% of my electricity needs… ~$20k per house

Rainwater collection and treatment to 25% - 75%(?) of water needs... ~$2k per house

- *But*: current large, privatised utility commercial structures hinder it:
- **- power companies have to buy your excess power - and accept loss of income**
- **- water companies have to accept less income from customers**

3. Why including the social dimension is hard...

- **It requires defining and measuring *'soft'* qualities that we have not defined and measured in the past**

- **It will often demand *decentralization* - challenging the economic trends of globalization - issues of inequality, power, ownership, scale - and even growth...**

- **It challenges our engineers' training and preference for *large, complex, interesting, new,* engineering… which is hard to change**

5. Differences in timescales:

- Typical political interest and commercial decision timescales are 3 - 10 years maximum
- Infrastructure working lives, lifetimes, and timescales for environmental damage are factors of 10 larger
- Sustainability requires decision-makers to take the longer view
- Engineers are well placed to understand, and bridge, the gap

Time Horizon of the World3 Model

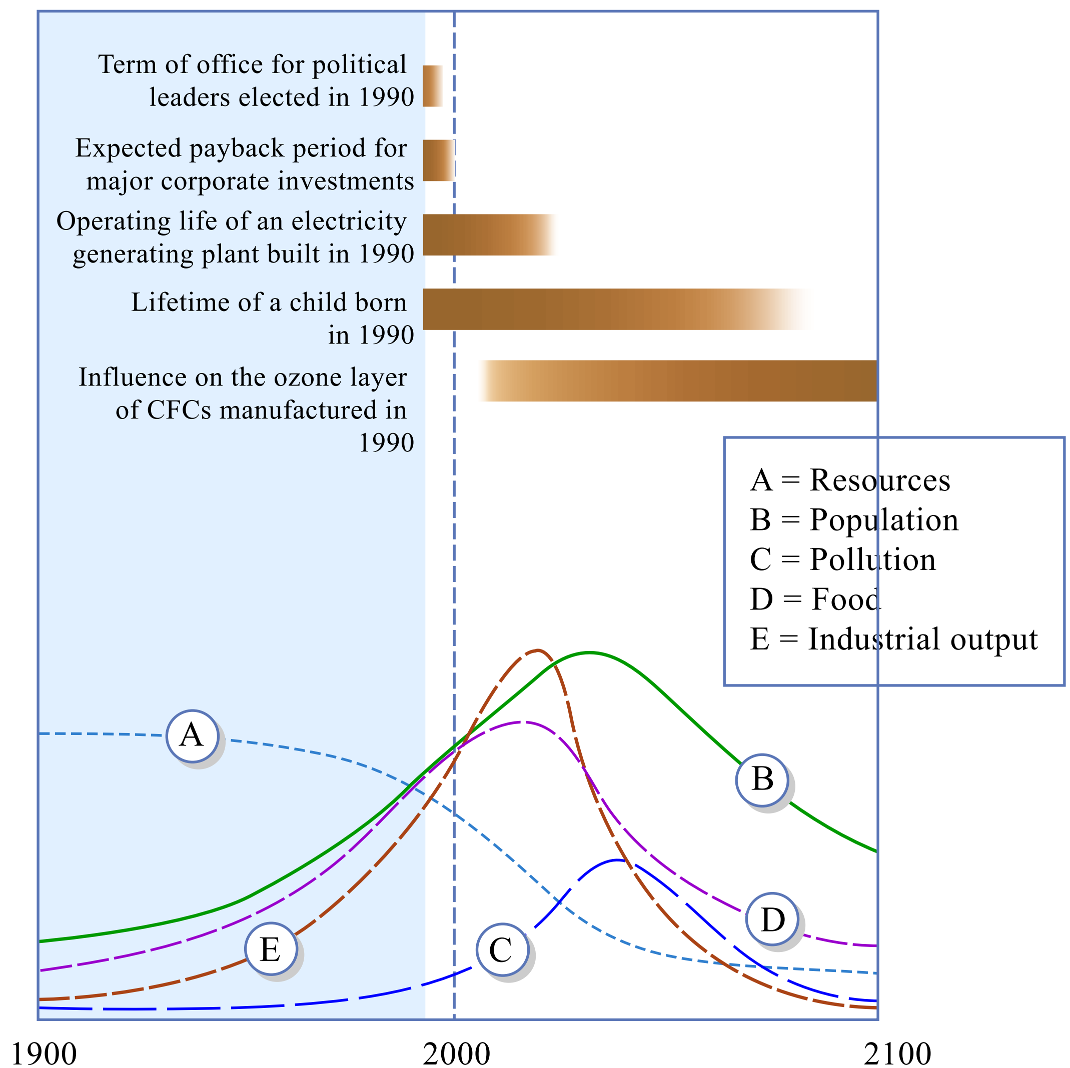


Figure by MIT OCW.

Summary

- Three elements of sustainable development: environment, which nurtures society, which invented the economy

- The social and environmental dimensions must be balanced with economics – we will focus on environmental dimensions in this class

- The World3 model, and 'what is 'enough'? Do we need less material consumption to avoid collapse?

- Challenges to change - and what is the engineers' role in this - leader, or follower?

Goals of the Course

- Explore how sustainability challenges engineering, and what can be done to improve our future prospects
- Provide a high level overview, in a way that is relevant to engineers, and then focus on specific problems
- Use life cycle assessment (LCA) to look at how engineering serves needs, and causes impacts, in key areas, including energy, water and waste.

Engineer and the Environment

The art of directing the great sources of power and Nature to the use and benefit of Man.

-Thomas Tredgold, 1818

Inst. of Civil Engineers

Engineer and the Environment

The art of directing the great sources of power and Nature to the use and benefit of Man.

-Thomas Telford, 1818
Inst. of Civil Engineers

Man and Nature as *separate*

Engineer and the Environment

Civil engineers are the custodians of the built and natural environment.

-Institution of Civil Engineers

<u>Agenda for the Future</u>, 2003


Want to save the earth?
Become an engineer!

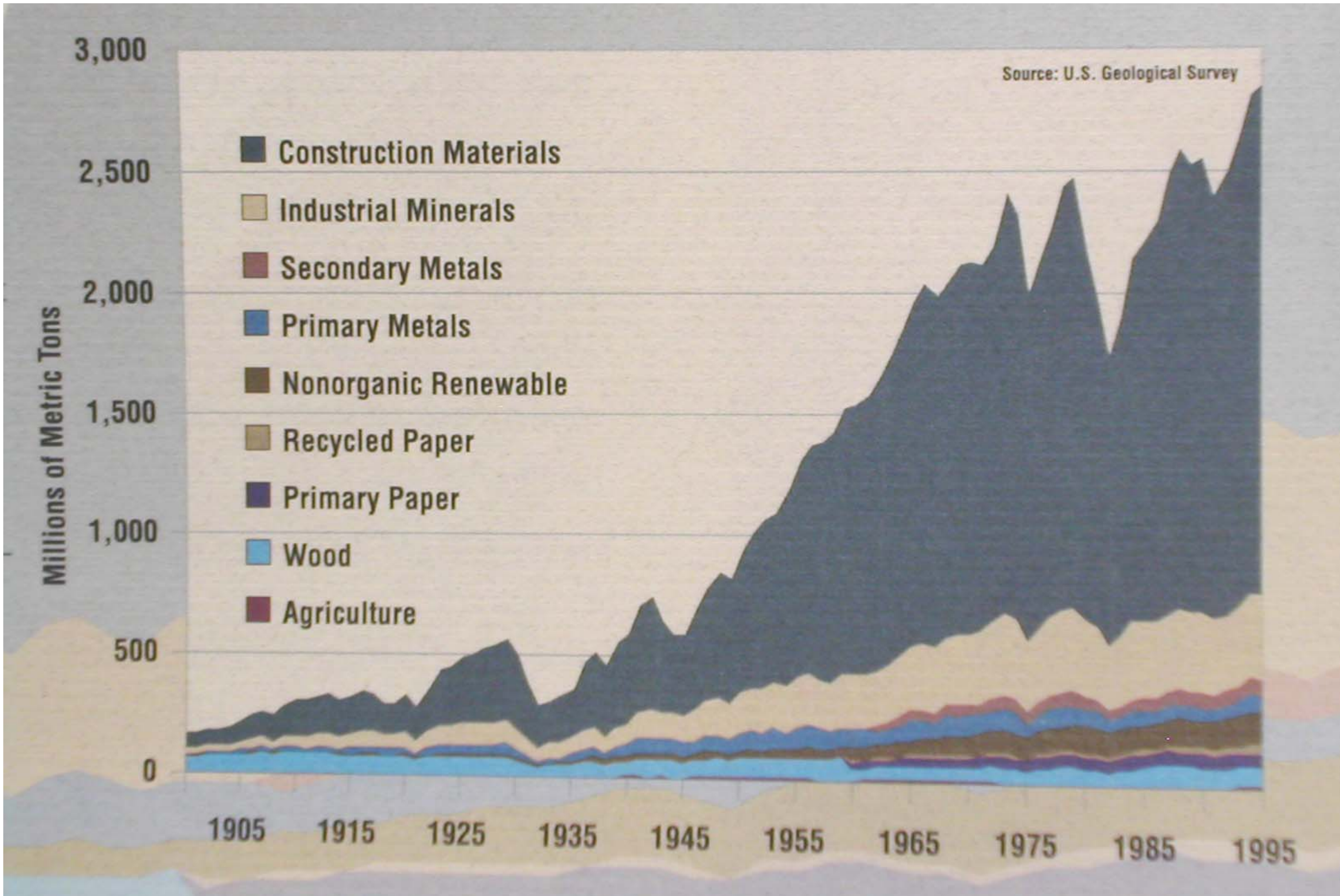
Construction and the Environment

US Primary Energy Consumption:

Buildings	**37%**
Industry	**36%**
Transportation	**28%**

Source: US Dept. of Energy (2002)

Use of Raw Materials in the US



‘Architects and engineers are the ones who *deliver things to people*’

- *“We can only get there...if the key professionals who deliver things to people are fully engaged... [architects and engineers], not the politicians, are the ones who can ensure that sustainable development:*
- *is operational*
- *is made to work for people*
- *delivers new ways of investing in our infrastructure, new ways of generating energy and providing a built environment*
- *delivers new ways of using consumer durables.*
- *There is no point along the sustainable development journey at which an engineer will not be involved.*
  - *(address to RAE, June 2001)*

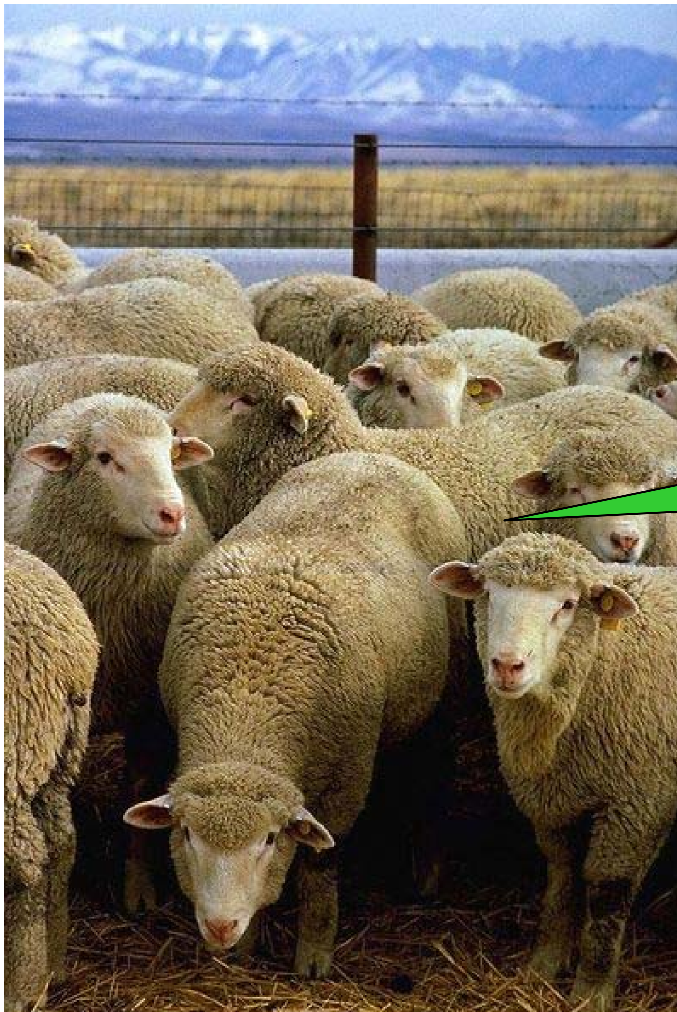
Demand for sustainable design…

Now and in the future…

- **There is tremendous demand for engineers and architects who can lead sustainable design efforts in the 21st century**

- **You will tackle these problems**

What role can engineers play in sustainable development?



Are we followers?

Photograph courtesy of Nevit Dilmen.

Readings

• If you are interested in the various scenarios, then buy Limits to Growth: The 30-Year Update by Meadows et al (2004)

•I also recommend the book Natural Capitalism

•Readings will be distributed weekly – get from TA
•Check out www.terrapass.com

Acknowledgments

Some slides courtesy of Centre for Sustainable Development, Department of Engineering, University of Cambridge