

Chemistry 321
The Sustainable World

UNIT 1: What is sustainability?

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A. An Introduction to Sustainability

The old view: A world without limits

- The traditional view is that the world is so vast that it is in effect infinite.
- Pollution can be dumped in rivers & oceans- it will disperse.
- Resources (ores, coal, oil) will never run out.

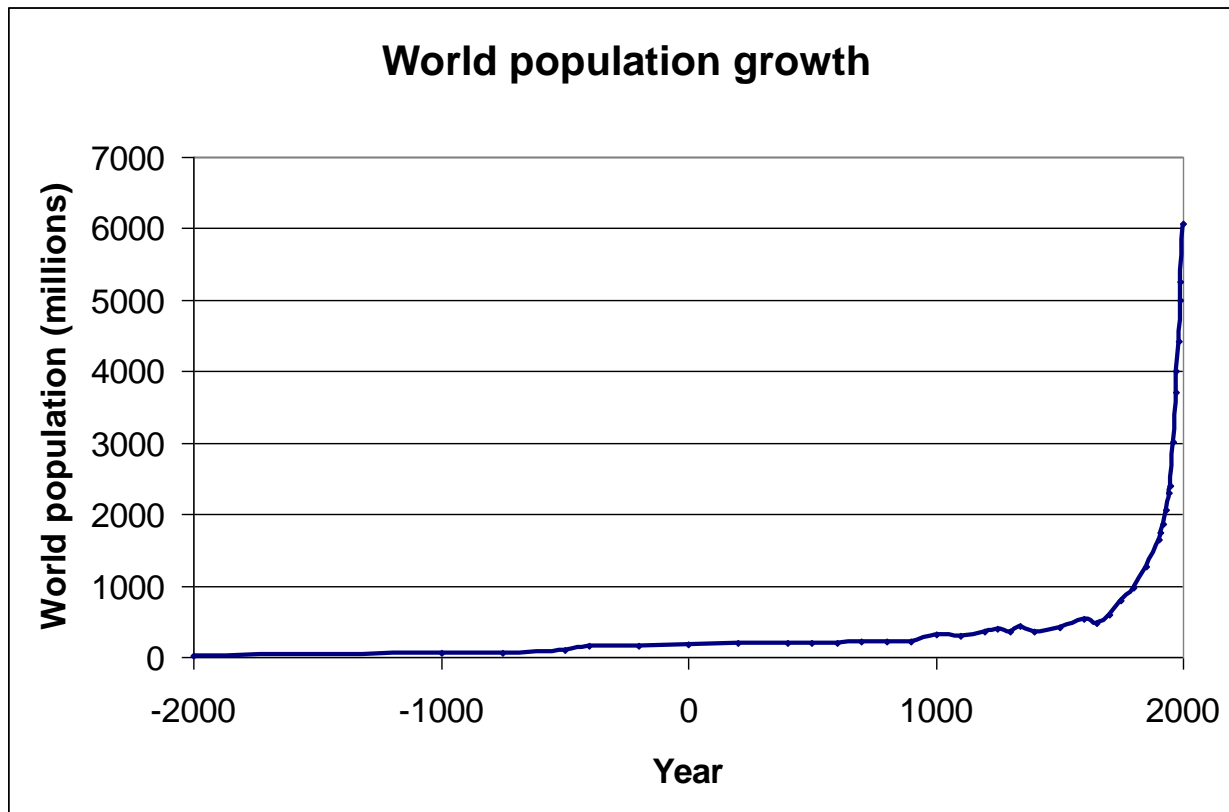


The old view: “Dilution is the solution to pollution”

- In an “infinite world,” all we need to do is to get our waste to the oceans or into the air, and it will be dispersed completely....



The old view: limitless resources



When the world population was very low, it seemed that resources, other than food, were limitless. If you ran out of wood in one forest, you could just go to the next!

The old view: Industrial power =
political strength



- *“The smoke of chimneys is the breath of Soviet Russia”*

But after World War II, a new world view began to emerge.

Silent Spring by Rachel Carson

Minamata Disease

Flower power!

The environmental movement

ppm ppb

Love Canal

Toxicology

Spectroscopy

US EPA

What tells us we live in a finite world?

- Global warming
- Depletion of the ozone layer
- Acid rain
- Toxic materials in the environment
- And pictures like this...!



The new world view

- **Sustainability**

We must try not to consume more than the Earth can produce and replace.

- **Responsibility**

We need to ensure that the environment is safe and healthy – now and in the future.

We must work to prevent global warming, acid rain, etc.

- **The solution is global, not national**

We need global solutions to global problems, we can't just export our pollution!

Sustainability



- Implies a balance (or near balance) between consumption of resources and growth of new resources.
- “Sustainable is not the same as “renewable.”

RESOURCES

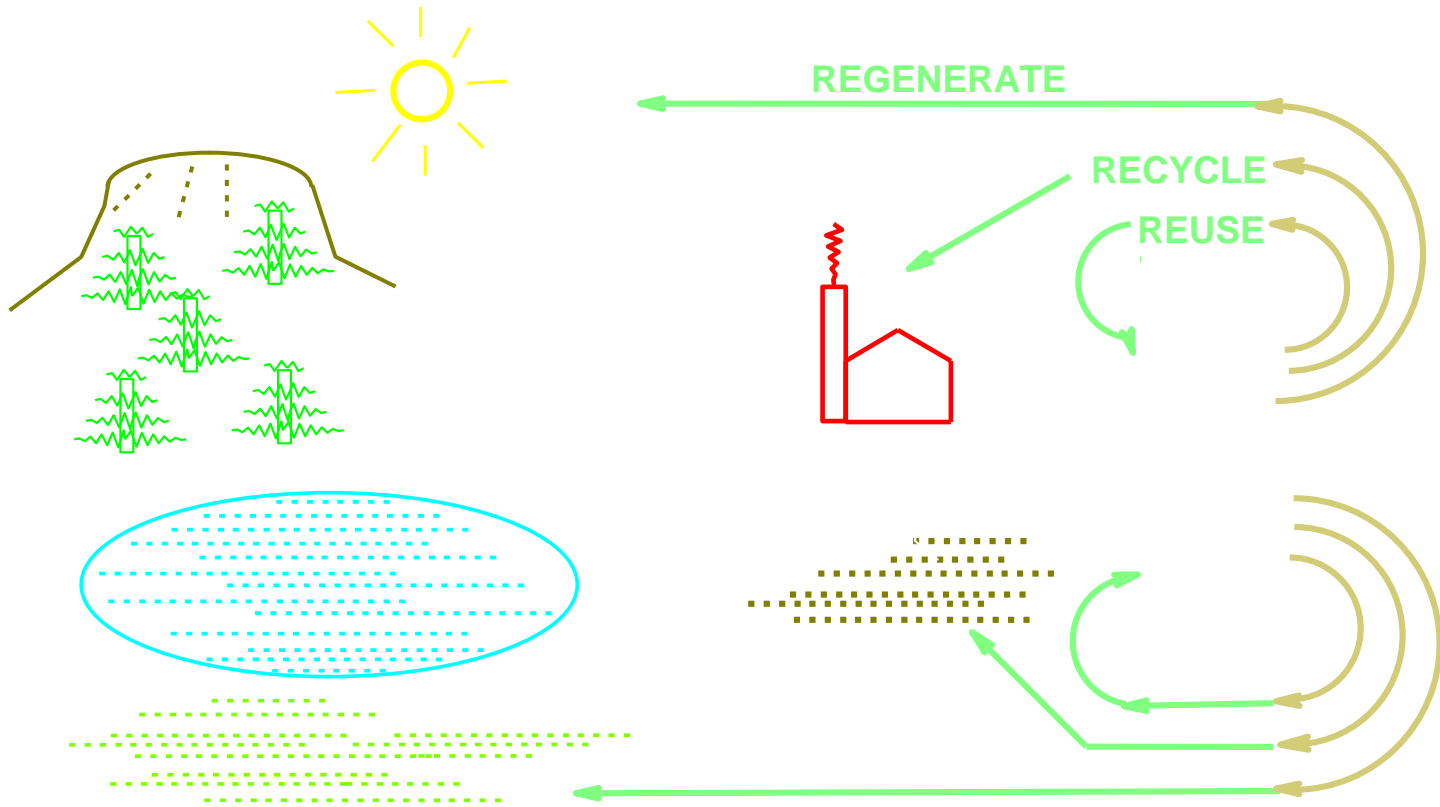
Oil & coal
Other minerals
Air & water
Food

CONSUMPTION

Energy, plastics
Other materials
Healthy life
Healthy life

If we consume more than we can produce, the future looks bleak!

Renewable resources



Resources that can be replenished as rapidly as they are consumed. Often this involves natural processes, for example wood as an energy source.

Renewable resources

*World energy consumption is now seven times what it was when I was born (in 1960).**

QUESTION: Do you think we could we switch to wood & biomass for *all* our present energy needs?

(Answer on next slide)

* *M. Wackernagel, Ecological Footprint Accounting, Springer 2006*



Renewable resources

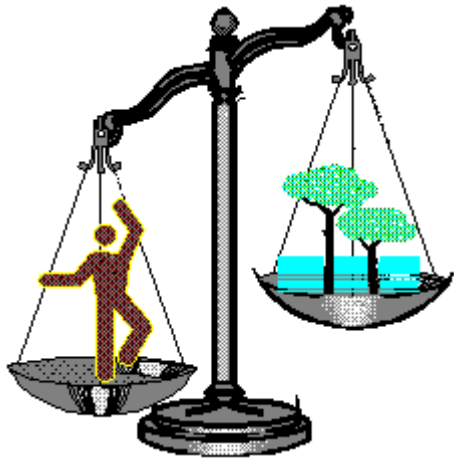
QUESTION: Could we switch to wood & biomass for *all* our present energy needs?

ANSWER: **No**. The rate of world energy consumption is currently roughly 20 TW. The total conversion of solar energy via photosynthesis is around 130 W. Thus we would have to be burning all of the world's plant life over about 7 years to meet our fuel energy needs, with nothing left for other wildlife or for food. Biomass is renewable, but biomass alone is *not* a sustainable energy supply.



Photo by John
McColgan,
USDA.
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The earth's carrying capacity



- May refer to the population that a given ecology can support over the long term.
- Alternatively defined as the earth's ability to provide required inputs and outputs as well as assimilate the waste outputs for a given population.

Natural capital

- Those features of nature, such as minerals, fuels, energy, biological yield, or pollution absorption capacity, that are utilized or potentially utilizable in human social and economic systems.



A scene from Sierra Leone.
Picture by Lindsay Stark,
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Paul Ehrlich's view



Picture credited to
Paul Ehrlich,
[from WM Commons](#)
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- *To put this in context, you must remember that estimates of the long-term **carrying capacity** of Earth with relatively optimistic assumptions about consumption, technologies, and equity ($A \times T$), are in the vicinity of two billion people.*
- -- [Paul Ehrlich \(Sept. 25, 1998\)](#)

Paul Ehrlich's view (contd.)

- *Today's population cannot be sustained on the 'interest' generated by natural ecosystems, but is consuming its vast supply of **natural capital** -- especially deep, rich agricultural soils, 'fossil' groundwater, and biodiversity -- accumulated over centuries to eons. In some places soils, which are generated on a time scale of centimeters per century are disappearing at rates of centimeters per year. Some aquifers are being depleted at dozens of times their recharge rates, and we have embarked on the greatest extinction episode in 65 million years. -- [Paul Ehrlich \(Sept. 25, 1998\)](#)*



Deforestation in Tanzania
Picture [from WM Commons](#)
by Mohsin S. Karmali
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Mathis Wackernagel's view

“In 2002, humanity operated in a state of overshoot, demanding over 20% more biological capacity than the Earth's ecosystems could regenerate in that year. Using the Ecological Footprint as an accounting tool, we propose and discuss three possible global scenarios for the future of human demand and ecosystem supply. Bringing humanity out of overshoot and onto a potentially sustainable path will require managing the consumption of food, fibre and energy, and maintaining or increasing the productivity of natural and agricultural ecosystems.”

Justin Kitzes, Mathis Wackernagel, et al., in “Shrink and share: humanity's present and future Ecological Footprint,”
Phil. Trans. R. Soc. B 12 2008 v363 pp467-475



Mathis Wackernagel,
President of the Global
Footprint Network.
Photo by [Friends of Europe](#)
Flickr, [CC license](#)

Is it the end of civilization?

- Solution #1- go back to the Stone Age or become ascetics:
 - not politically realistic for society as a whole.
- Solution #2- raise environmental awareness, improve efficiency and equitability in use of energy & materials, reduce consumption, move towards sustainability:
 - the only solution in the long term that avoids destruction
 - but what do we do in the short term?

This course will focus on solution #2 - what needs to be done, why and how, to the best of our current knowledge.



Picture [by Margaret A. McIntyre](#)
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Sustainable development

- “Meeting the needs of the present without compromising the ability of future generations to meet their needs.”
 - *The [Brundtland Report](#), 1987.*
- Adopted by the UN after the Rio summit (1992)



Children in Mali. [Picture by Guaka](#),
Wikimedia Commons, CC by SL license.



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DISCUSSION point:
Is Sustainable development realistic?

Key dates

- 1987: “[Our Common Future](#)” (the Brundtland Report) advocates sustainable development
- 1992: Rio “[Earth Summit](#)”- UN conference. By 1994, govts. around the world sign on to support sustainable development.
- 1997: [Kyoto protocol](#)
- 2002: [World Summit for Sustainable Development](#) in Johannesburg.
- 2007: [Bali Summit on Climate Change](#)
- 2009: Copenhagen Summit on Climate Change

United Nations response



- “[Agenda 21](#)” is a 1992 UN policy statement adopted as a result of the Rio summit.
- The UN “[Commission on Sustainable Development](#)” was established in 1992. It monitors progress and organizes conferences.

Rio Summit 2012



- See www.uncsd2012.org/
- Widely considered to be a failure – poor leadership, and too much focus on development, but little support for the environment.
- UN Chief Ban Ki-Moon had submitted a proposal titled “Sustainable Energy for All”, but this was merely “noted” rather than embraced as policy.

Sino-American agreement



- As the world's two largest carbon producers, the 2014 agreement between the US and China is a real step forward. Instead of asking “the other guy to go first”, the two countries have both committed to reduce CO2 emissions. Read the details [here](#).
- In China, domestic pollution in cities is making coal very unpopular – and this has helped drive China towards renewable energy.

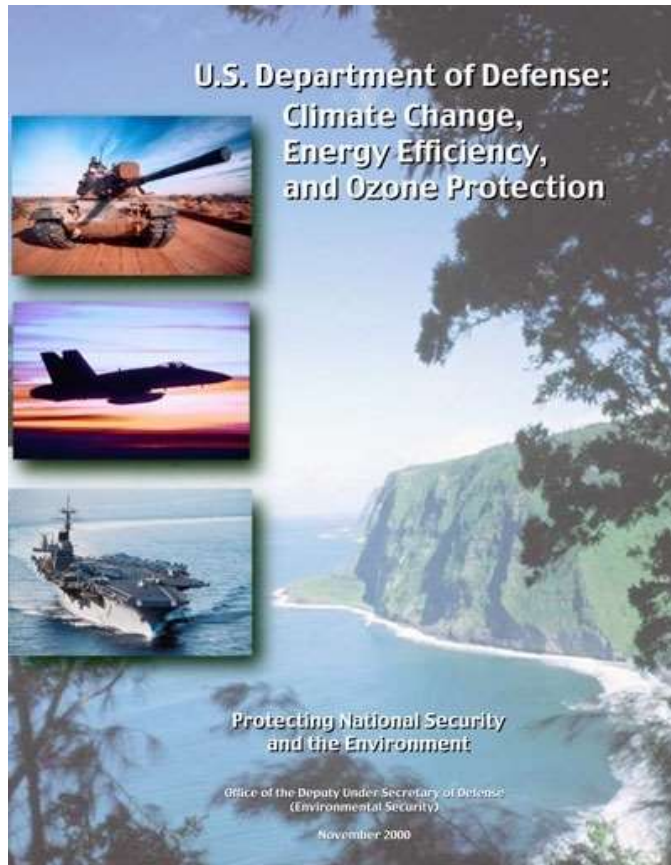
Government response (US)



Picture by Pete Souza / [Notwist](#) ,
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- *“I refuse to condemn your generation and future generations to a planet that’s beyond fixing.”*
[President Obama, June 25, 2013](#)
- “Since 2005, the United States has reduced its total carbon pollution more than any other nation on Earth. Wind power has tripled, and energy from the sun has increased tenfold.”
[White House website, accessed July 2015](#)
- Federal agencies are [now committed](#) to reducing greenhouse gas emissions by 2020.

Government response (US)



- The US Department of Defense is not taking chances in their [2014 report](#). They say that climate change poses an “immediate threat to national security, with increased risks from terrorism, infectious disease, global poverty and food shortages.” And in the past, they have even looked at [hybrid Humvees!](#)

Government response (Japan)



Japanese PM

[Shinzō Abe](#)

[Pic](#) by Ash Carter, CC

- "Global environmental problems could threaten the very foundation of human existence and must be dealt with immediately through the mutual cooperation of countries around the world. Developed countries should take the initiative in addressing the

From Japan's "[National Action Plan for Agenda 21](#)"



Tokyo Governor
Shintarō Ishihara

- "Tokyo has stolen a march on the national Japanese government by introducing the country's first mandatory carbon trading scheme as part of new environmental regulations that will force thousands of businesses to cut their greenhouse gas emissions..... the capital's most energy-hungry office buildings, factories and universities must cut emissions by between 6 and 8% over the next five years. Those that fail to do so will have to buy pollution credits..."
- [Financial Times, April 7 2010](#)

Government response (Japan)

Under the Kyoto protocol, Japan is committed to reducing its greenhouse gas emissions to 6% below 1990 emissions. As of 2011, they have in fact [increased by 3.7%](#) since 1990, though this does not include any offset for reforestation (estimated to equate to a -4.0% effect).

PM Shinzō Abe spoke to CNN about climate change as one of the [“three big challenges facing the world”](#):

“Japan's energy consumption per unit of GDP is already some 30% less than the average of other G7 nations, making it a top performer in the world. And we want to do even better -- we will aim for a 35% improvement in energy efficiency by 2030. We believe this will be possible through the greater use of renewable energy -- including a seven-fold increase on our current solar energy capacity, and a four-fold increase in our wind and geothermal capacity.”



Japanese PM
Shinzō Abe
[Picture](#) in
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Government response (China)

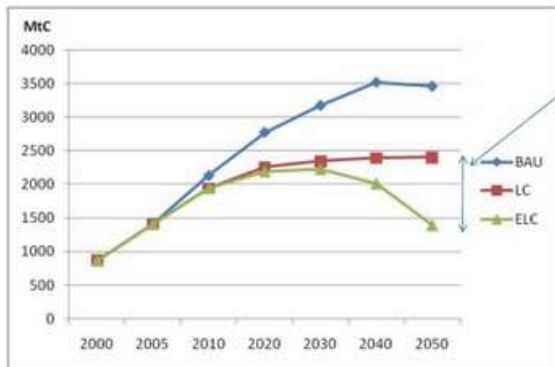


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12th Five-year Plan on Greenhouse Emission Control (2012):

- "By 2015, carbon dioxide emission per-unit GDP would be reduced by 17 percent and energy consumption per-unit GDP by 16 percent as compared with that in 2010; the proportion of consumption of non-fossil energy to the consumption of primary energy would be increased to 11.4 percent; and the acreage of new forests would increase by 12.5 million ha, with the forest coverage rate raised to 21.66 percent and the forest growing stock increased by 600 million cu m.

Low carbon scenarios:
Carbon emission



Graph from [nextbigfuture.com](#)

- The agreement with the US committed China to 20% renewable energy by 2030, aiming to have carbon emissions peak by that time.

Government response (Germany)



Angela Merkel,
German Chancellor.
Credit: "Photo
European Parliament"
Read her [1998 essay
on sustainability](#). Merkel
has a chemistry PhD.

- In 1994 the German Bundestag amended the Basic Law, the *de facto* constitution of Germany. It states that being aware of the Federal State's "*responsibility toward future generations, it shall protect the natural basis of life*" whenever a state organ takes up action. .
- In 2000, the German government formed the National Council on Sustainability (the [Nachhaltigkeitsrat](#)), to create a national sustainability strategy.
- On 17 April 2002 the Federal cabinet passed the German [Strategy for Sustainable Development](#). This is based on the idea that "The model of sustainable development is the leitmotif which will guide us into the 21st century." The strategy is "for devising a form of development which is economically, ecologically and socially sustainable."

Government response (UK)



David Cameron
British PM



Amber Rudd
Minister for
Climate Change

- On February 28th, 2011, the UK government published its environmental proposals in “[Mainstreaming Sustainable Development](#)”: “Our long term economic growth relies on protecting and enhancing the environmental resources that underpin it, and paying due regard to social needs. As part of our commitment to enhance wellbeing, we will start measuring our progress as a country, not just by how our economy is growing, but by how our lives are improving; not just by our standard of living, but by our quality of life..” [See more...](#)
- The UK is committed to reducing its greenhouse gas emissions by at least 80% by 2050, relative to 1990 levels. We need a transformation of the UK economy while ensuring secure, low carbon energy supplies to 2050.
<http://www.decc.gov.uk/>
- The [London Array](#), the world’s largest offshore windfarm, was [opened on July 4th, 2013, by Cameron](#). It will provide enough energy to power almost half a million homes.



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by Ton Ziltra, [CC lic.](#)

DISCUSSION point:

What should *our* Government be doing?

What Sustainable Development
means
in practice

Sustainable development

- We don't need to return to the Stone Age, and maybe we even keep our cars, though they may be smaller and use fuel cells.
- We must consider the environmental impact of all technology and new development, and aim for minimal impact.
- Use science & technology as a solution to current problems.
- Must also be viable in economic terms.

A sustainable economy

- “Rates of use of renewable resources do not exceed regeneration rates.
- Rates of use of non-renewable resources do not exceed rates of development of renewable substitutes.
- Rates of pollution emission do not exceed assimilative capacities of the environment.”
 - Daly, H. *Beyond Growth*, Beacon Press, Boston, 1996.



A biodiesel refinery
In Germany

*Image under GNU,
by Wolfgang Priwo,
[Wikimedia Commons](#)*

A sustainable society

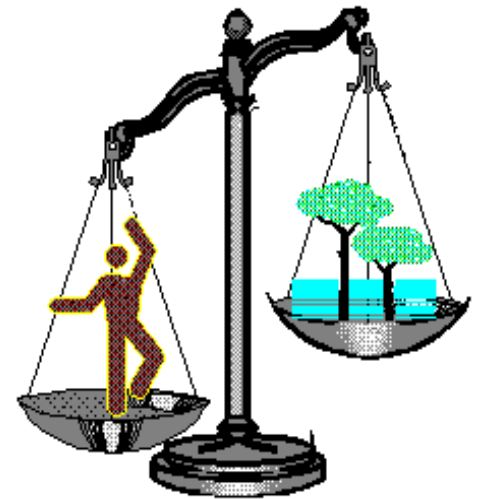
- We need to set realistic yet desirable goals for society:
 - Permanent prosperity, with constraints of the real world
 - This prosperity distributed fairly and equitably to all of humanity, to other species, and to future generations.

Principles of ecosystem sustainability

- The necessary conditions for processes in an ecosystem must be maintained.
- Operation must be within the carrying capacity of the ecosystem.
- Harvesting rates should not exceed the regeneration rate.
- Waste emissions should not exceed the assimilative capacity.
- The rate of exploitation of non-renewable resources should be equal to or less than the rate of development of renewable substitutes.

Factors affecting the sustainability balance

- Population
- Consumption of resources per capita, based on
 - Wealth
 - Efficiency of resource utilization
- Intellectual capital
- Natural capital
- Food/water production and land use
- Human organization
- Waste



Population

- By 1999, world population exceeded 6 billion. By 2014 it had reached [7.2 billion](#).
- Improving sanitation & medicine have led to falling death rates
- However, increasing urbanization and affluence tends to cause lower birth rates.
- Improvements in agricultural productivity have allowed the world to support a much higher population than hitherto possible.
- A [major study](#) in 2012 concluded that we must restrain population and consumption if we are to avoid disaster.



Dhaka street crowds

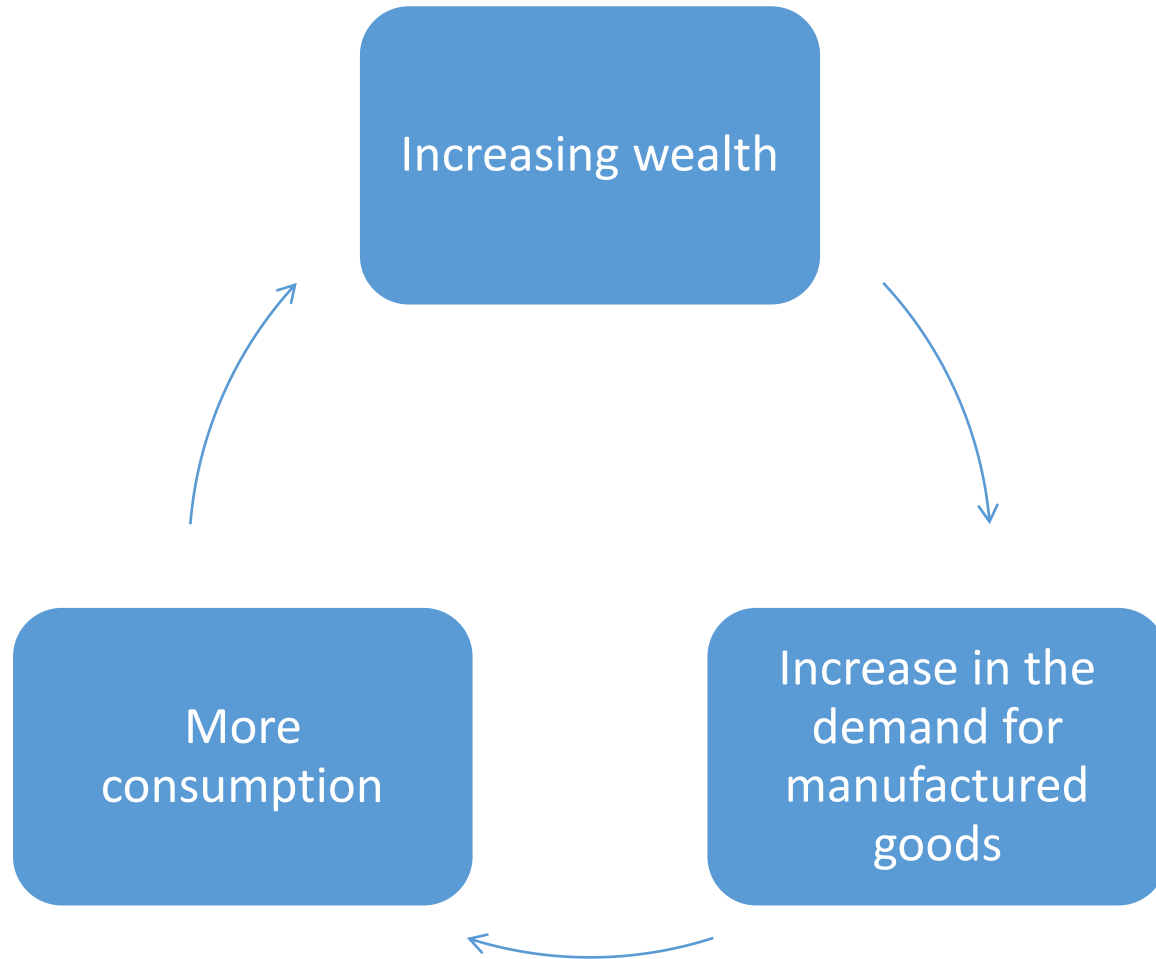
*Image under CC,
by Ahron de Leeuw
From [Flickr](#)*

Per capita consumption

- Two main categories- materials and energy.
- Materials in a sustainable economy must either be renewable (e.g., wood) or extremely plentiful (e.g, magnesium chloride in seawater).
- Energy sources may be based on material fuels (oil, gas, uranium, etc.) or on natural phenomena (solar radiation, wind power, tidal power, etc.)

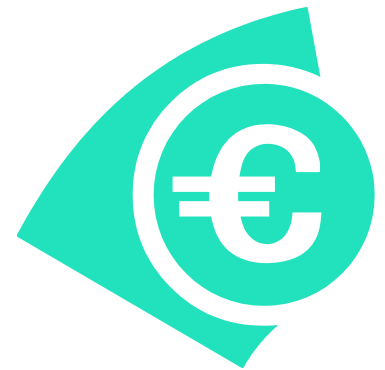


Wealth



Wealth

- Fortunately science & technology have allowed goods to be manufactured more efficiently, using fewer resources.
- On balance, per capita consumption of resources has risen as wealth has increased.



Intellectual capital

Two sources of intellectual capital in an organization- *human capital* and *organizational capital*.

- *Human capital* = knowledge & ability.
- *Organizational capital* = hardware, software, technology, management methods.
- An increase in intellectual capital leads to a more efficient use of resources and reduces waste.



Figure 1.1 Lateral surface of the cerebral hemisphere, brain stem, cerebellum, and rostral spinal cord.

Natural capital

- Those features of nature, such as minerals, fuels, energy, biological yield, or pollution absorption capacity, that are utilized or potentially utilizable in human social and economic systems.
- This **must be maintained** in a sustainable economy.



Coral reef. [Picture](#) by USFWS, CC license



Picture by my wife Amy at Lochinch Castle Estates, on our vacation! Scotland, June 2012 CC-license

Climate Change

- At the Copenhagen summit in 2009, countries agreed that we should aim to keep global temperature rise to 2 °C or below, since scientist claim that more than +2 °C could lead to global catastrophe. It is not a binding accord.



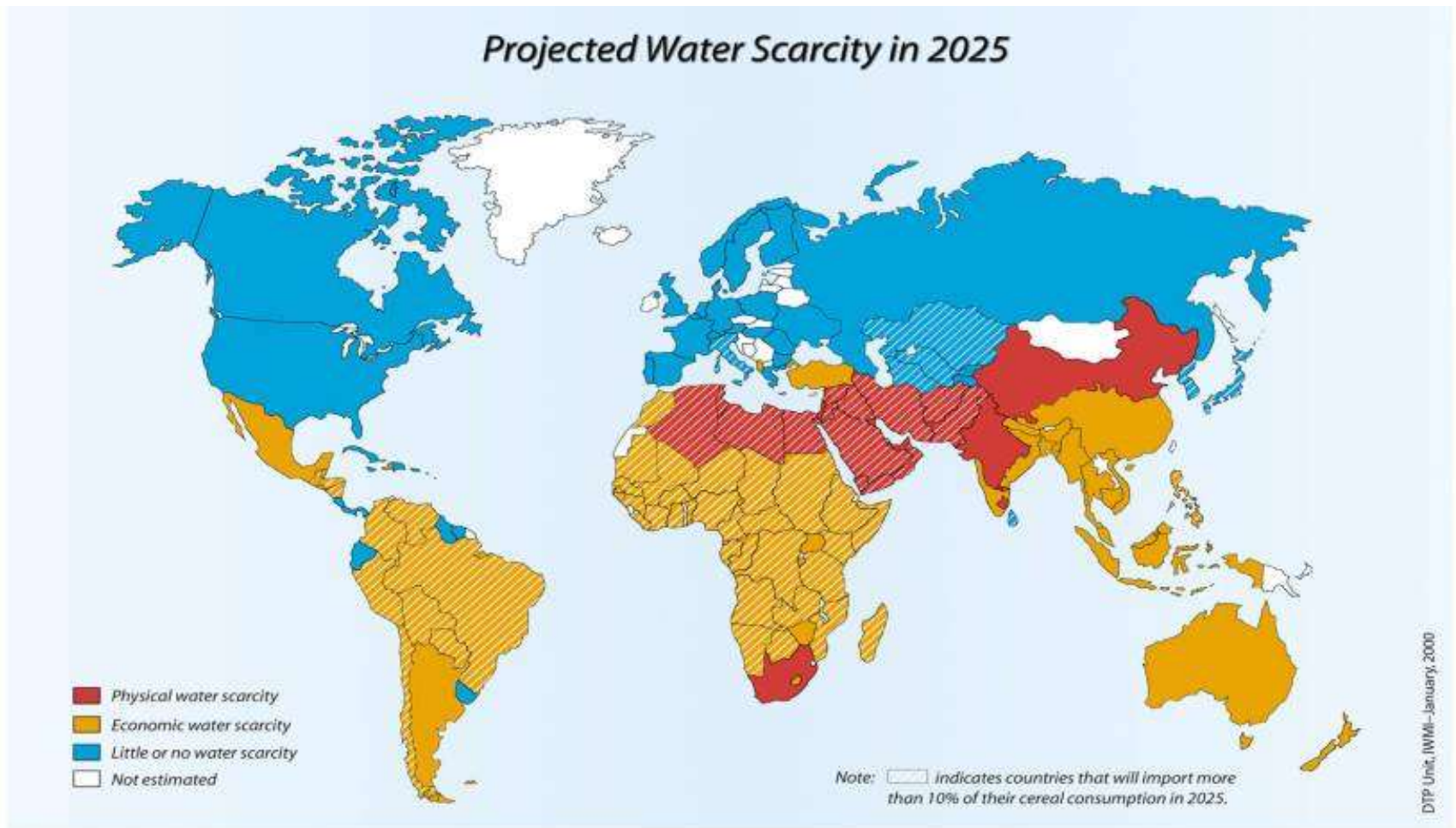
Dried-up river near Lone Pine, CA in 2014 Picture by Martin Walker, CC licence

Food/water & land use

- Increasing population & wealth lead to increasing demand for food and water, and also land.
- The amount of land used for agriculture depends on climate, fertility, human occupation and type of agriculture.
- Fertile soil is being lost due to overuse & erosion (30% since 1960).
- Water is needed both for human consumption and by agriculture.
- Some predict severe land/water shortages.

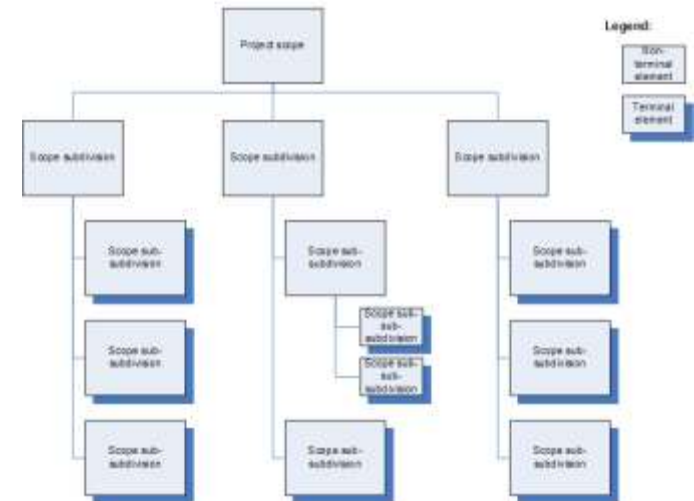


Water is running out...



Human organization

- Different political & economic systems will affect the balance in different ways.
- Within a business, a company that considers sustainability a priority is likely to have a much lower impact on ecosystem.
- If science & technology are focused on the environment, great improvements may be made.



GNU license, [diagram by Mkoval](#)

Waste



- When waste is large-scale or highly toxic, it may exceed the assimilative capacity of the ecosystem (global and/or local).
- “Waste Reduction at Source” (WRAS) or Pollution Prevention (P2) can have a huge impact on reducing waste, *and* make the process more efficient.



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DISCUSSION point:
Which is the most important issue? What are we missing?

End

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