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Strategies for Sustainable Energy

Lecture 2. Motivation and Balance Sheet

ENG2110-01
College of Engineering
Yonsei University
Fall, 2010

Prof. David Keffer

1. Motivations

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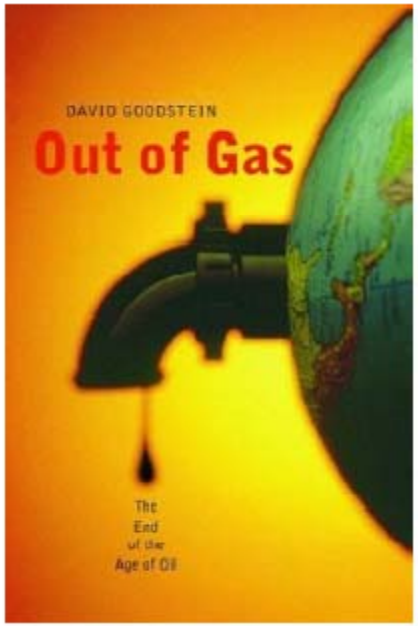
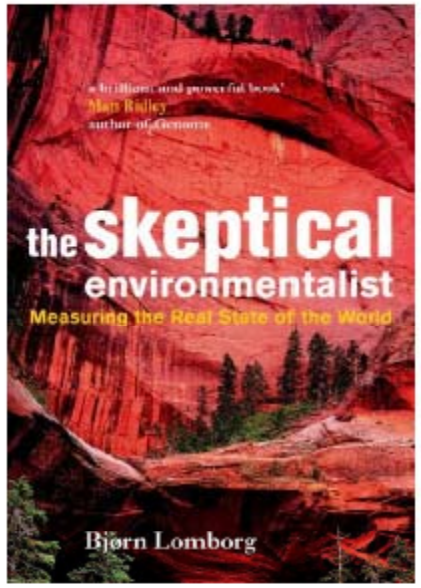


David Goodstein's *Out of Gas* (2004).

In *Out of Gas,* Caltech physicist David Goodstein describes an impending energy crisis brought on by The End of the Age of Oil. This crisis is coming soon, he predicts: the crisis will bite, not when the last drop of oil is extracted, but when oil extraction can't meet demand – perhaps as soon as 2015 or 2025. Moreover, even if we magically switched all our energy guzzling to nuclear power right away, Goodstein says, the oil crisis would simply be replaced by a *nuclear crisis in just twenty years or so, as uranium* reserves also became depleted.

In The Skeptical Environmentalist, Bjørn Lomborg paints a completely different picture. "Everything is fine." Indeed, "everything is getting better." Furthermore, "we are not headed for a major energy crisis," and "there is plenty of energy."



Bjørn Lomborg's *The Skeptical Environmentalist* (2001).

How could two smart people come to such different conclusions?

1. Motivations

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The discussion of an energy crisis requires numbers, not adjectives.

The numbers will be big because the problem is global.

If everyone does a little, we will achieve only a little.

What is required are country-sized changes in energy usage.

Motivations

- fossil fuels are a finite resource
- energy security (many fossil fuels are located in politically unstable regions of the world, like the Middle East)
- fossil fuels probably cause climate change

1. Motivations

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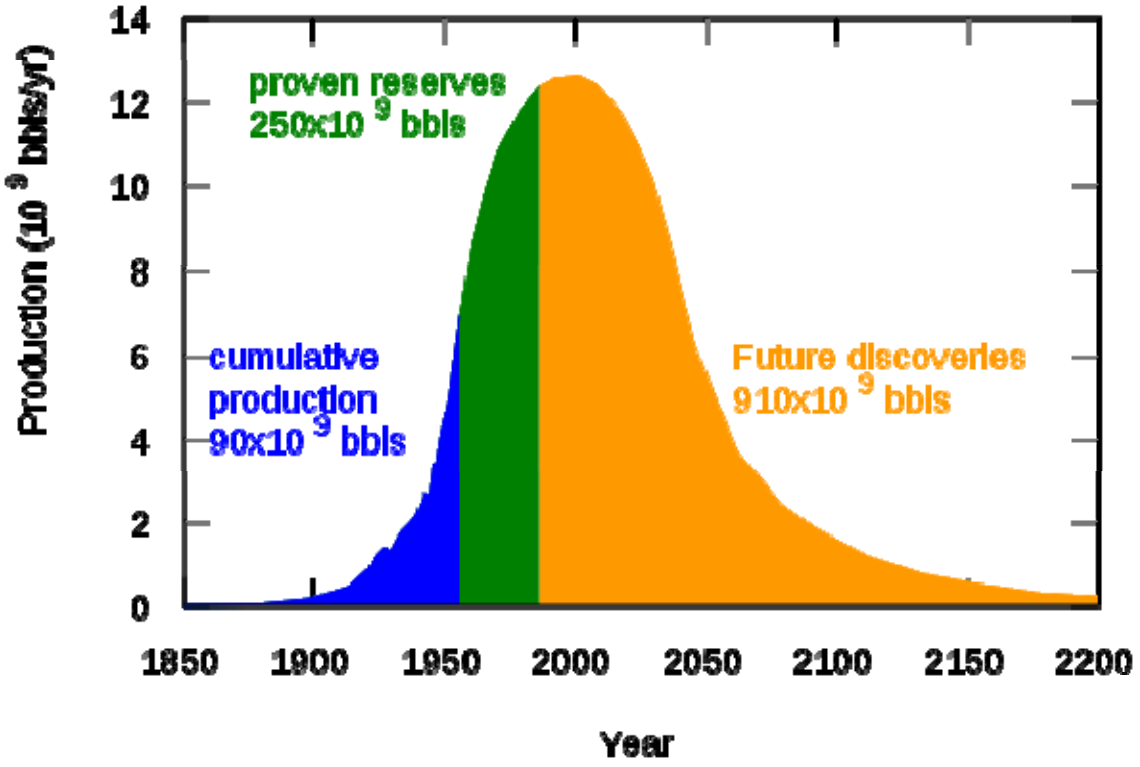

1. Fossil fuels are a finite resource: Peak Oil
http://en.wikipedia.org/wiki/Peak_oil

- Some experts argue that we will find more oil and the peak will be later.

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Not everyone believes in the idea of peak oil.

I first began writing on peak oil 6 years ago, in the summer of 2004. Matt Savinar was predicting imminent TEOTWAWKI, and telling folks to run for the hills. Now, 6 years later, I can go out on the street, and nothing whatsoever has changed since 2004. The streets are still clogged with cars going on mindless journeys. People are sleeping in their cars with the engine running to power the air-conditioning. Oil is at $75 and it's not going anywhere. Food prices and availability are completely normal. Plastic Hello Kitty paraphernalia is as plentiful and cheap as ever. Peak oil continues to be a ridiculously over-hyped non-event, just like I always predicted. I thumb my nose at it with impunity. LOL.

http://peakoildebunked.blogspot.com/
Posted June 25, 2010
Retrieved April 13, 2011

1. Motivations

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There is some truth in the uncertainty of peak oil predictions.

Over the past 33 years mankind has consumed more than three times the world's known oil reserves in 1976 – and today proven oil reserves are nearly double what they were before we started.

I think the key to the argument of Peak Oil, is that it not only ignores the huge amounts of oil yet to be found, but other hydrocarbon fuels as well.

America has developed new technologies to develop oil production from the many known shale oil fields containing a trillion barrels of oil, that has never been tapped until two years ago, because it was too expensive to extract, and the technology has not yet been improved enough to tackle it before then. But money solves a lot of problems, and $100/bbl oil would certainly do it

What I'm really arguing is not only is there enough oil, but really an excess, but that the new discoveries and technologies and alternatives will buy us enough time for the whole Peak Oil thing to be prolonged into the next century, which means there is no crisis.

http://oilprice.com/Energy/Crude-Oil/Debunking-the-Myth-of-Peak-Oil-Why-the-Age-of-Cheap-Oil-is-Far-From-Over-Part-1.html
Posted March 17, 2010
Retrieved April 13, 2011

1. Motivations

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What is Energy Security?

Energy security is a term for an association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities. Threats to **energy security** include the political instability of several energy producing countries, the manipulation of energy supplies, the competition over energy sources, attacks on supply infrastructure, as well as accidents,natural disasters, the funding to foreign dictators, rising terrorism, and dominant countries reliance to the foreign oil supply.[1]

With new advancements in renewable resources less pressure has been put on companies that produce the worlds oil, these resources are, geothermal, solar power, wind power and hydro-electric.

2. Energy Security

http://en.wikipedia.org/wiki/Energy_security
Accessed April 13, 2011

1. Motivations

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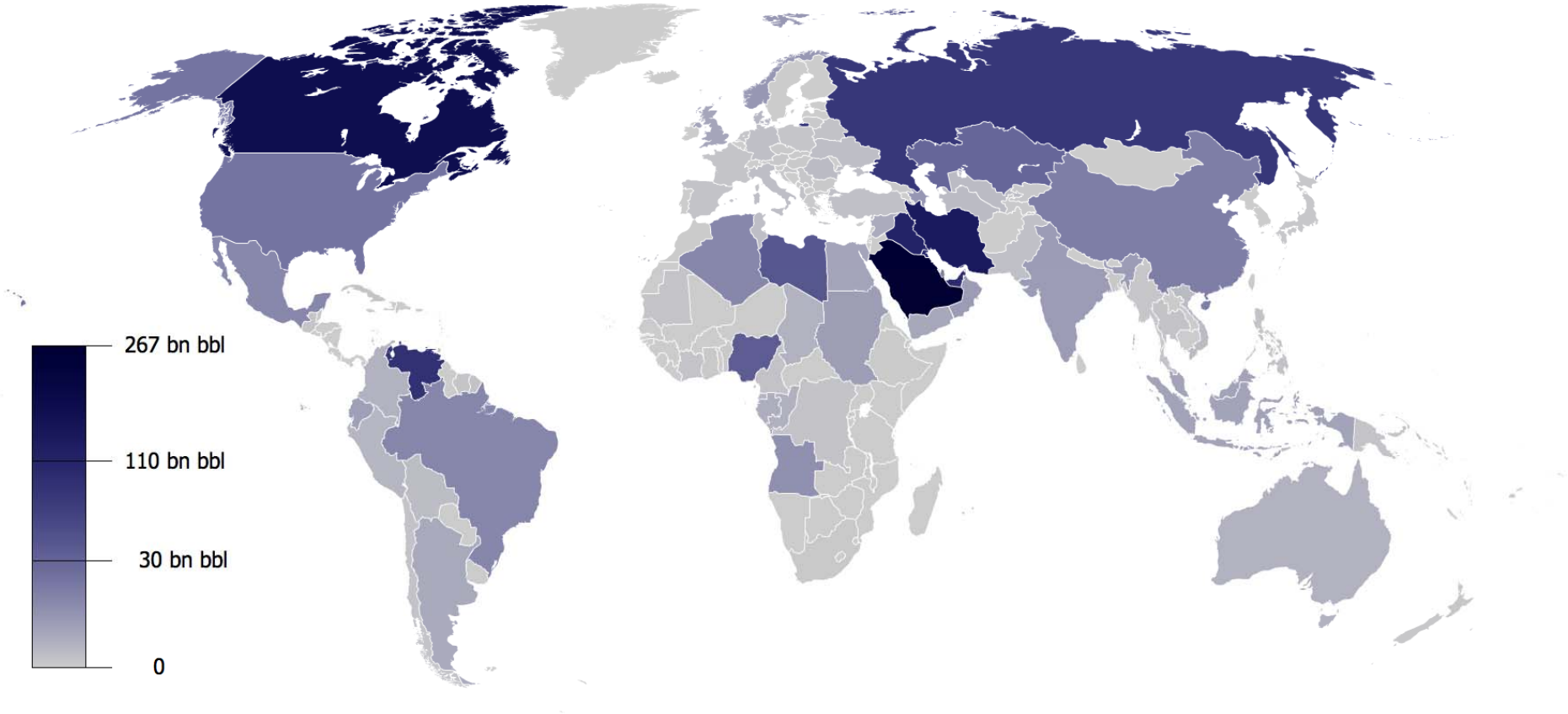
Geographical sources of petroleum.



2. Energy Security

http://en.wikipedia.org/wiki/Peak_oil

1. Motivations

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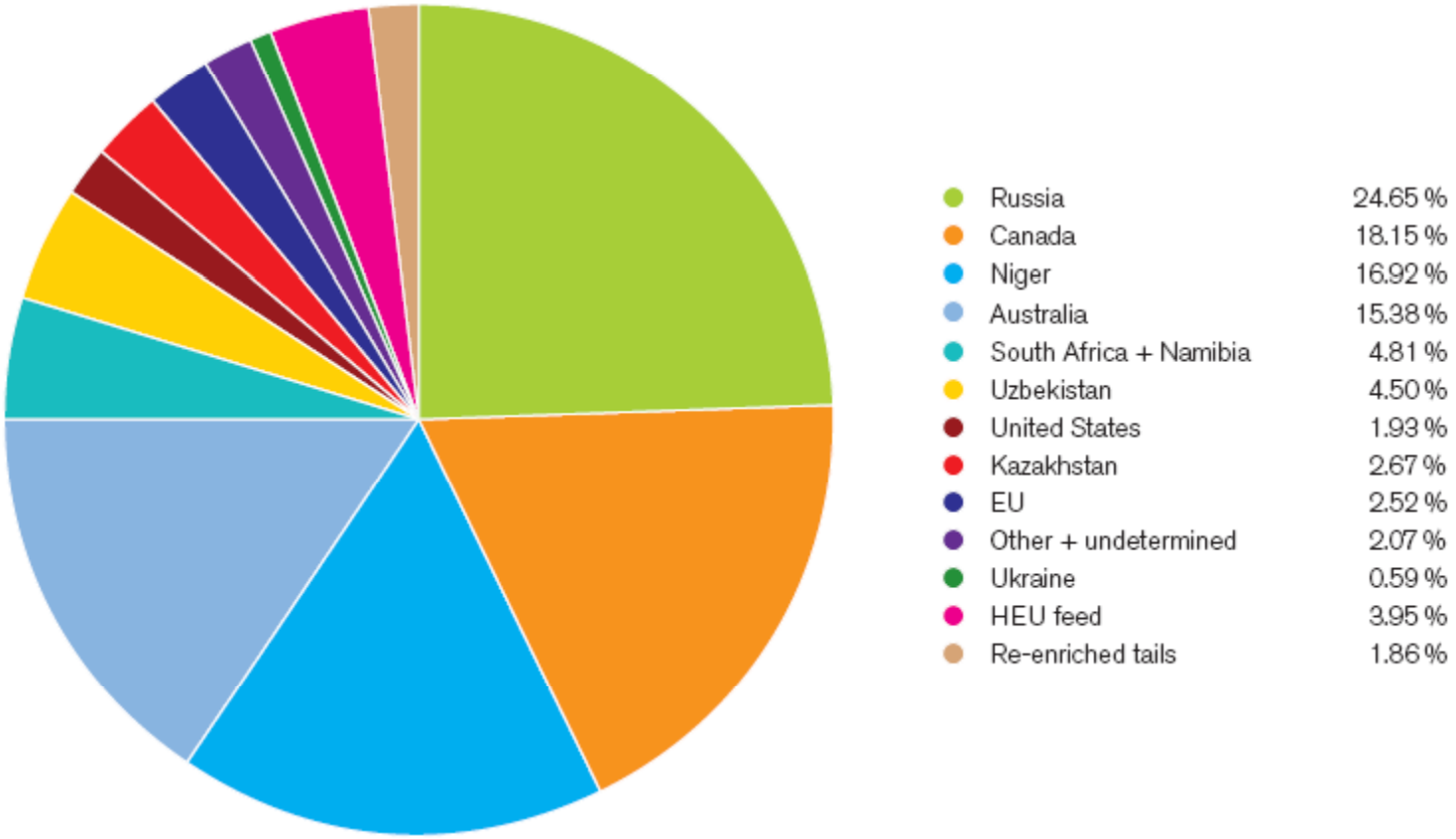
Energy security is not just limited to petroleum.
Geographical sources of uranium used in EU (2007).



http://en.wikipedia.org/wiki/Energy_security
Accessed April 13, 2011

1. Motivations

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Not everyone believes that "green energy" will solve energy security problems.

Remember how one advantage of green technology would be to make America less dependent on foreign sources of energy? Oops. A Department of Energy report released last month to little fanfare inadvertently blows this idea away.

The "Critical Materials Strategy 2010" represents DOE's effort to understand how green energy technologies depend on rare earths. Those are the minerals at the bottom of the periodic table whose unique properties make them indispensable in many high technologies, including wind turbines and solar panels.

As the world recently realized, more than 95% of these minerals are sourced from China. Because of the environmental problems associated with extracting them, most countries where deposits exist have discouraged mining.

2. Energy Security

http://en.wikipedia.org/wiki/Peak_oil

1. Motivations

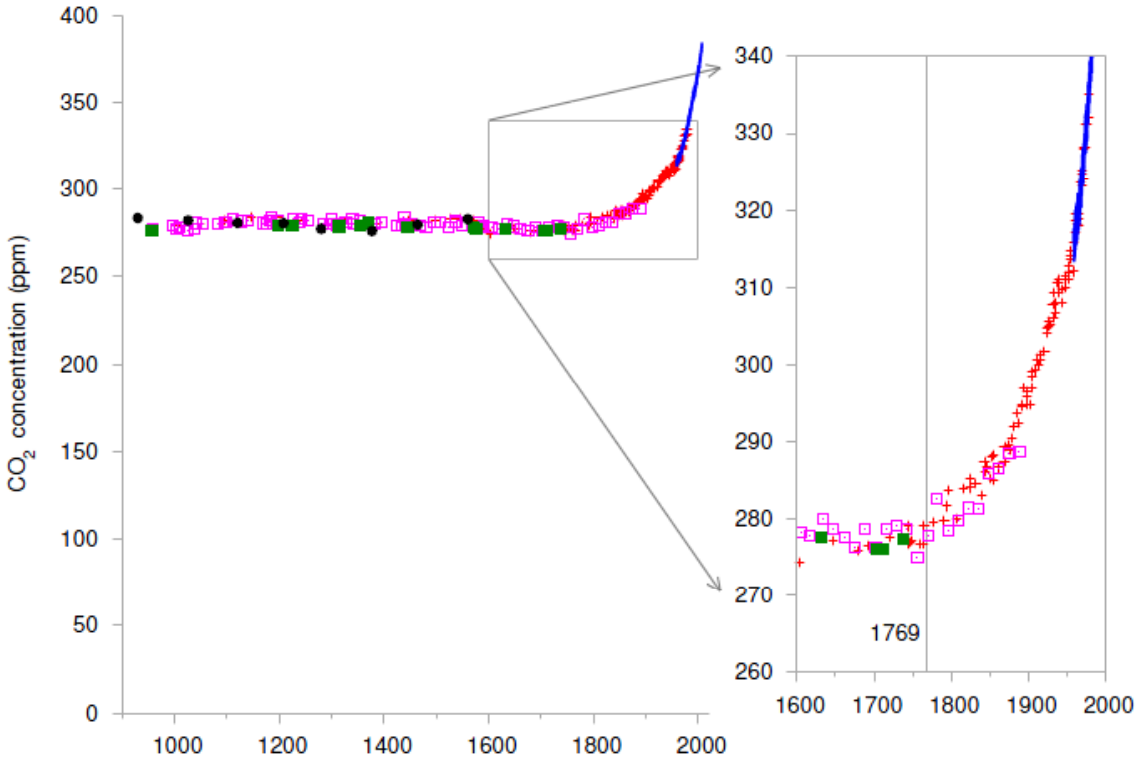

Figure 1.4. Carbon dioxide (CO_2) concentrations (in parts per million) for the last 1100 years, measured from air trapped in ice cores (up to 1977) and directly in Hawaii (from 1958 onwards).

I think something new may have happened between 1800 AD and 2000 AD. I've marked the year 1769, in which James Watt patented his steam engine. (The first practical steam engine was invented 70 years earlier in 1698, but Watt's was much more efficient.)

3. Climate Change

Atmospheric carbon dioxide concentrations over the past 1100 years.

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Scientific consensus on global warming?

Scientific opinion on climate change is given by synthesis reports, scientific bodies of national or international standing, and surveys of opinion among climate scientists. Individual scientists, universities, and laboratories contribute to the overall scientific opinion via their peer reviewed publications, and the areas of collective agreement and relative certainty are summarised in these high level reports and surveys.

National and international science academies and scientific societies have assessed the current scientific opinion, in particular on recent global warming. These assessments have largely followed or endorsed the Intergovernmental Panel on Climate Change (IPCC) position of January 2001 which states:

An increasing body of observations gives a collective picture of a warming world and other changes in the climate system... There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.[1]

No scientific body of national or international standing has maintained a dissenting opinion; the last was the American Association of Petroleum Geologists, which in 2007 updated its 1999 statement rejecting the likelihood of human influence on recent climate with its current non-committal position.[2][3] Some other organizations, primarily those focusing on geology, also hold non-committal positions.

http://en.wikipedia.org/wiki/Scientific_consensus_on_climate_change, retrieved April 13, 2011

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Scientific consensus on global warming?

The American Chemical Society stated:

Careful and comprehensive scientific assessments have clearly demonstrated that the Earth's climate system is changing rapidly in response to growing atmospheric burdens of greenhouse gases and absorbing aerosol particles (IPCC, 2007). There is very little room for doubt that observed climate trends are due to human activities. The threats are serious and action is urgently needed to mitigate the risks of climate change. The reality of global warming, its current serious and potentially disastrous impacts on Earth system properties, and the key role emissions from human activities play in driving these phenomena have been recognized by earlier versions of this ACS policy statement (ACS, 2004), by other major scientific societies, including the American Geophysical Union (AGU, 2003), the American Meteorological Society (AMS, 2007) and the American Association for the Advancement of Science (AAAS, 2007), and by the U. S. National Academies and ten other leading national academies of science (NA, 2005).[33]

http://en.wikipedia.org/wiki/Scientific_consensus_on_climate_change, retrieved April 13, 2011

1. Motivations

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Scientific consensus on global warming?

American Physical Society

In November 2007, the American Physical Society (APS) adopted an official statement on climate change:

Emissions of greenhouse gases from human activities are changing the atmosphere in ways that affect the Earth's climate. Greenhouse gases include carbon dioxide as well as methane, nitrous oxide and other gases. They are emitted from fossil fuel combustion and a range of industrial and agricultural processes. The evidence is incontrovertible: Global warming is occurring. If no mitigating actions are taken, significant disruptions in the Earth's physical and ecological systems, social systems, security and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now.
Because the complexity of the climate makes accurate prediction difficult, the APS urges an enhanced effort to understand the effects of human activity on the Earth's climate, and to provide the technological options for meeting the climate challenge in the near and longer terms. The APS also urges governments, universities, national laboratories and its membership to support policies and actions that will reduce the emission of greenhouse gases.[35]

http://en.wikipedia.org/wiki/Scientific_consensus_on_climate_change, retrieved April 13, 2011

1. Motivations

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Not everyone believes that “climate change” is real, or caused by man or even bad.

1. Climate has always changed, and it always will. The assumption that prior to the industrial revolution the Earth had a "stable" climate is simply wrong. The only sensible thing to do about climate change is to prepare for it.

2. Accurate temperature measurements made from weather balloons and satellites since the late 1950s show no atmospheric warmingsince 1958. In contrast, averaged ground-based thermometers record a warming of about 0.40 C over the same time period. Many scientists believe that the thermometer record is biased by the Urban Heat Island effect and other artefacts.

3. Despite the expenditure of more than US$50 billion dollars looking for it since 1990, no unambiguous anthropogenic (human) signal has been identified in the global temperature pattern.

4. Without the greenhouse effect, the average surface temperature on Earth would be -180 C rather than the equable +15 C that has nurtured the development of life.

Carbon dioxide is a minor greenhouse gas, responsible for ~26% (80 C) of the total greenhouse effect (330C), of which in turn at most 25% (~20C) can be attributed to carbon dioxide contributed by human activity. Water vapour, contributing at least 70% of the effect, is by far the most important atmospheric greenhouse gas.

5. On both annual (1 year) and geological (up to 100,000 year) time scales, changes in atmospheric temperature PRECEDE changes in CO2. Carbon dioxide therefore cannot be the primary forcing agent for temperature increase (though increasing CO2 does cause a diminishingly mild positive temperature feedback).

http://www.abovetopsecret.com/forum/thread525791/pg1, retrieved April 13, 2011

1. Motivations

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Not everyone believes that “climate change” is real, or caused by man or even bad.

6. The UN Intergovernmental Panel on Climate Change (IPCC) has acted as the main scaremonger for the global warming lobby that led to the Kyoto Protocol. Fatally, the IPCC is a political, not scientific, body.

7. The Kyoto Protocol will cost many trillions of dollars and exercises a significant impost those countries that signed it, but will deliver no significant cooling (less than .020 C by 2050, assuming that all commitments are met).

8. Climate change is a non-linear (chaotic) process, some parts of which are only dimly or not at all understood. No deterministic computer model will ever be able to make an accurate prediction of climate 100 years into the future.

9. Not surprisingly, therefore, experts in computer modelling agree also that no current (or likely near-future) climate model is able to make accurate predictions of regional climate change.

10. The biggest untruth about human global warming is the assertion that nearly all scientists agree that it is occurring, and at a dangerous rate.

The reality is that almost every aspect of climate science is the subject of vigorous debate. Further, thousands of qualified scientists worldwide have signed declarations which (i) query the evidence for hypothetical human-caused warming and (ii) support a rational scientific (not emotional) approach to its study within the context of known natural climate change.

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1. Motivations

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Not everyone believes that “climate change” is real, or caused by man or even bad.

- Myth 1 Average global temperature (AGT) has increased over the last few years.
  - Fact 1 Within error bounds, AGT has not increased since 1995 and has declined since 2002, despite an increase in atmospheric CO2 of 8% since 1995.
- Myth 2 During the late 20th Century, AGT increased at a dangerously fast rate and reached an unprecedented magnitude.
  - Facts 2 The late 20th Century AGT rise was at a rate of 1-20 C/century, which lies well within natural rates of climate change for the last 10,000 yr. AGT has been several degrees warmer than today many times in the recent geological past.
- Myth 3 AGT was relatively unchanging in pre-industrial times, has sky-rocketed since 1900, and will increase by several degrees more over the next 100 years (the Mann, Bradley & Hughes "hockey stick" curve and its computer extrapolation).
  - Facts 3 The Mann et al. curve has been exposed as a statistical contrivance. There is no convincing evidence that past climate was unchanging, nor that 20th century changes in AGT were unusual, nor that dangerous human warming is underway.
- Myth 4 Computer models predict that AGT will increase by up to 60 C over the next 100 years.
  - Facts 4 Deterministic computer models do. Other equally valid (empirical) computer models predict cooling.
- Myth 5 Warming of more than 20 C will have catastrophic effects on ecosystems and mankind alike.
  - Facts 5 A 20 C change would be well within previous natural bounds. Ecosystems have been adapting to such changes since time immemorial. The result is the process that we call evolution. Mankind can and does adapt to all climate extremes.

http://www.abovetopsecret.com/forum/thread525791/pg1, retrieved April 13, 2011

1. Motivations

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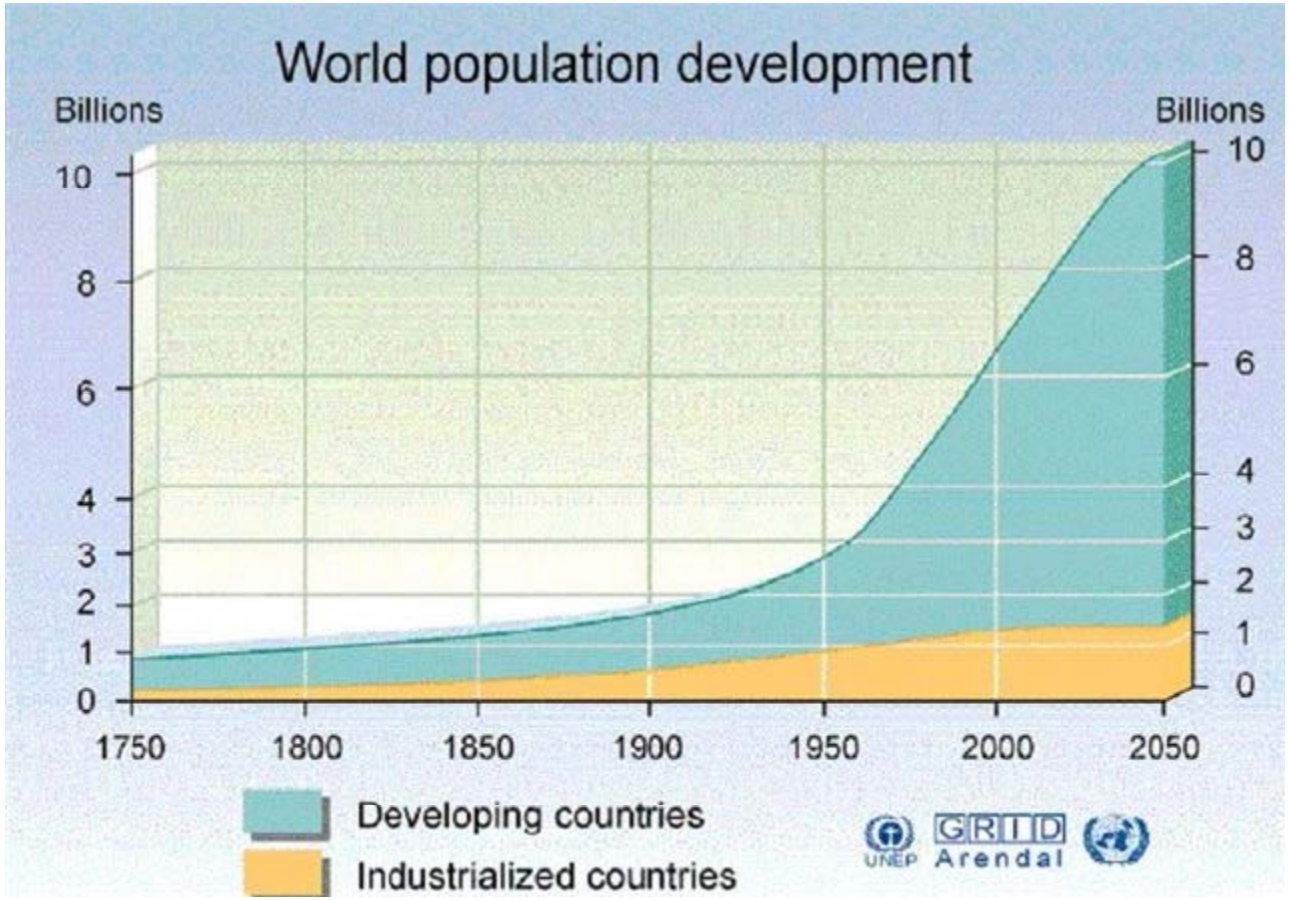
Not everyone believes that “climate change” is real, or caused by man or even bad.

- Myth 6 Further human addition of CO2 to the atmosphere will cause dangerous warming, and is generally harmful.
  - Facts 6 No human-caused warming can yet be detected that is distinct from natural system variation and noise. Any additional human-caused warming which occurs will probably amount to less than 10 C. Atmospheric CO2 is a beneficial fertilizer for plants, including especially cereal crops, and also aids efficient evapo-transpiration.
- Myth 7 Changes in solar activity cannot explain recent changes in AGT.
  - Facts 7 The sun's output varies in several ways on many time scales (including the 11-, 22 and 80-year solar cycles), with concomitant effects on Earth's climate. While changes in visible radiation are small, changes in particle flux and magnetic field are known to exercise a strong climatic effect. More than 50% of the 0.80 C rise in AGT observed during the 20th century can be attributed to solar change.
- Myth 8 Unprecedented melting of ice is taking place in both the north and south polar regions.
  - Facts 8 Both the Greenland and Antarctic ice sheets are growing in thickness and cooling at their summit. Sea ice around Antarctica attained a record area in 2007. Temperatures in the Arctic region are just now achieving the levels of natural warmth experienced during the early 1940s, and the region was warmer still (sea-ice free) during earlier times.
- Myth 9 Human-caused global warming is causing dangerous global sea-level (SL) rise.
  - Facts 9 SL change differs from time to time and place to place; between 1955 and 1996, for example, SL at Tuvalu fell by 105 mm (2.5 mm/yr). Global average SL is a statistical measure of no value for environmental planning purposes. A global average SL rise of 1-2 mm/yr occurred naturally over the last 150 years, and shows no sign of human-influenced increase.
- Myth 10 The late 20th Century increase in AGT caused an increase in the number of severe storms (cyclones), or in storm intensity.
  - Facts 10 Meteorological experts are agreed that no increase in storms has occurred beyond that associated with natural variation of the climate system.

http://www.abovetopsecret.com/forum/thread525791/pg1, retrieved April 13, 2011

1. Motivations



Primary Cause: World population from 1750 to 2050.

1. Motivations

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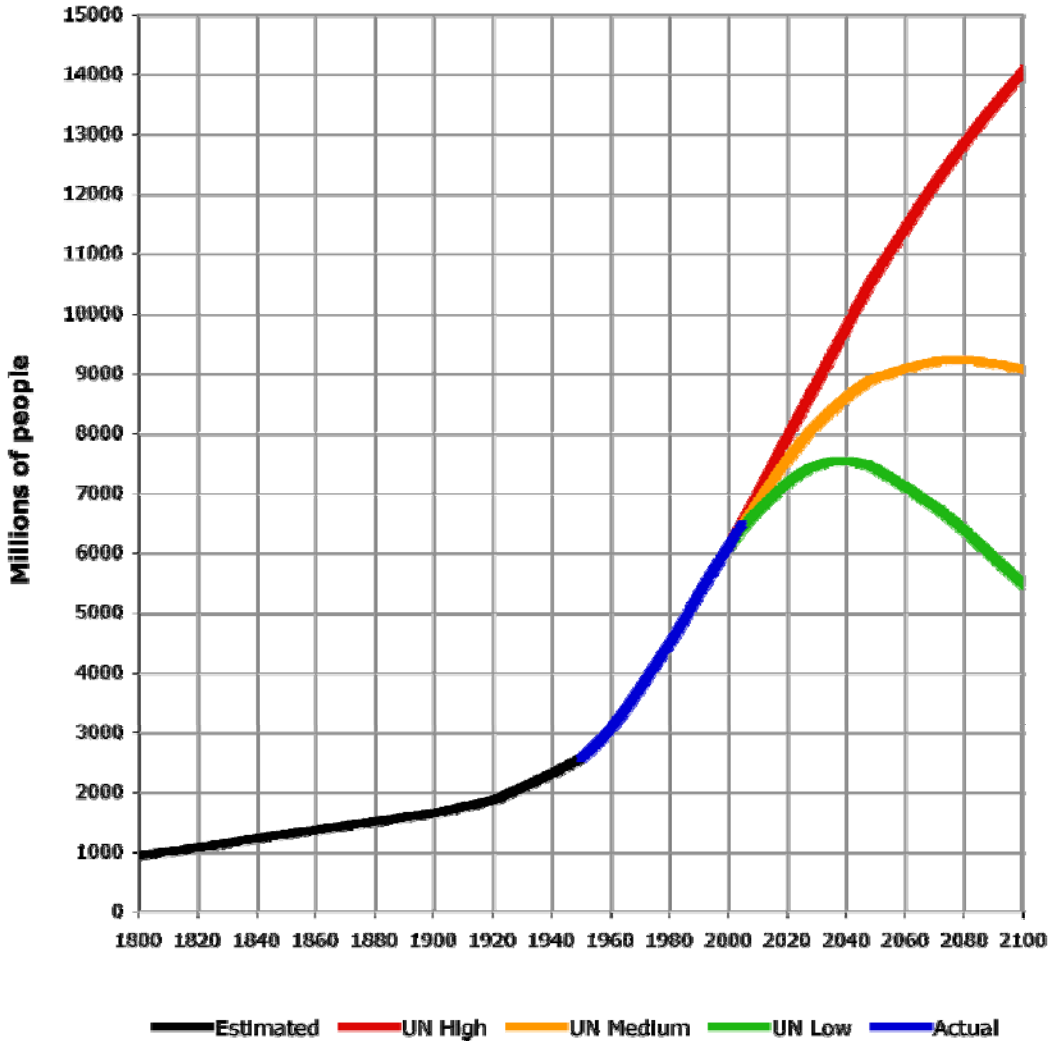
How valid are population projections?



The world population has experienced continuous growth since the end of the Bubonic Plague around the years 1348-1350.[2] The highest rates of growth—increases above 1.8% per year—were seen briefly during the 1950s, for a longer period during the 1960s and 1970s; the growth rate peaked at 2.2% in 1963, and declined to 1.1% by 2009. Annual births have reduced to 140 million since their peak at 173 million in the late 1990s, and are expected to remain constant, while deaths number 57 million per year and are expected to increase to 80 million per year by 2040. Current projections show a continued increase of population (but a steady decline in the population growth rate) with the population expected to reach between 7.5 and 10.5 billion in the year 2050.

http://en.wikipedia.org/wiki/World_population, retrieved April 13, 2011

1. Motivations

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What is CO_2 equivalency?

Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years).

Carbon dioxide equivalency thus reflects the time-integrated radiative forcing of a quantity of *emissions* or rate of greenhouse gas emission - a *flow* into the atmosphere - rather than the instantaneous value of the radiative forcing of the *stock* (concentration) of greenhouse gases *in the atmosphere* described by CO_2e.

For example, the GWP for methane over 100 years is 25 and for nitrous oxide 298. This means that emissions of 1 million metric tonnes of methane and nitrous oxide respectively is equivalent to emissions of 25 and 298 million metric tonnes of carbon dioxide.[1]

http://en.wikipedia.org/wiki/Carbon_dioxide_equivalent, retrieved April 13, 2011

Carbon dioxide has a GWP of exactly 1 (since it is the baseline unit to which all other greenhouse gases are compared).

1. Motivations

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What is CO_2 equivalency?

GWP values and lifetimes from 2007 IPCC AR4 p212 [2] (2001 IPCC TAR [3] in parentheses)	Lifetime (years)		GWP time horizon 20 years		100 years		500 years	
Methane	12	(12)	72	(62)	25	(23)	7.6	(7)
Nitrous oxide	114	(114)	289	(275)	298	(296)	153	(156)
HFC-23 (hydrofluorocarbon)	270	(260)	12,000	(9400)	14,800	(12,000)	12,200	(10,000)
HFC-134a (hydrofluorocarbon)	14	(13.8)	3,830	(3,300)	1,430	(1,300)	435	(400)
sulfur hexafluoride	3200	(3,200)	16,300	(15,100)	22,800	(22,200)	32,600	(32,400)

http://en.wikipedia.org/wiki/Global_warming_potential, retrieved April 13, 2011

1. Motivations

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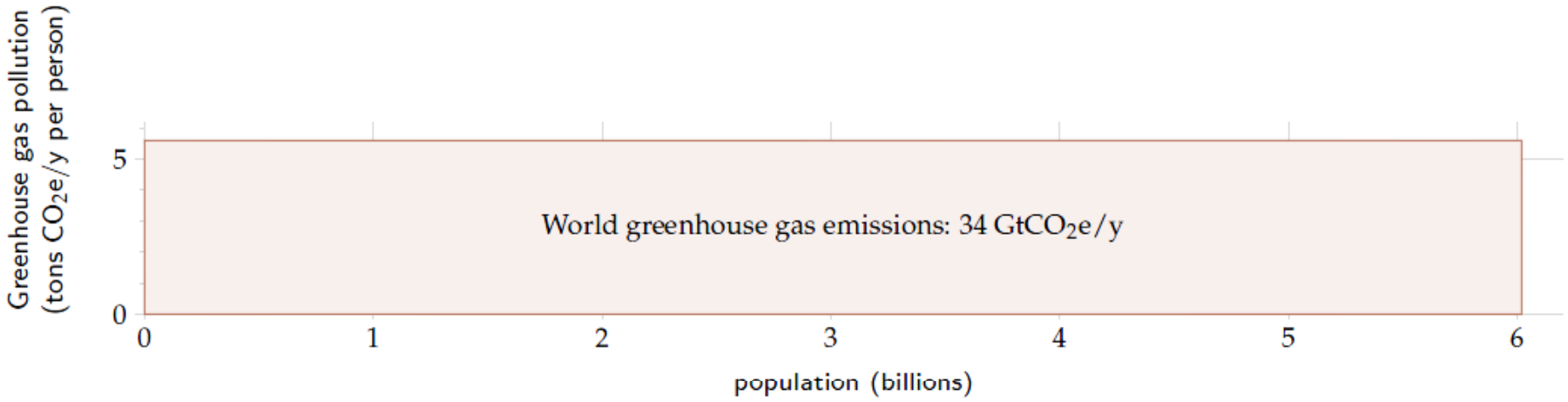
Where does CO_2 come from?



Global Greenhouse gas pollution

34 Gigatons of CO_2 equivalent per year

Hypothetically spread uniformly over the global population.

1. Motivations

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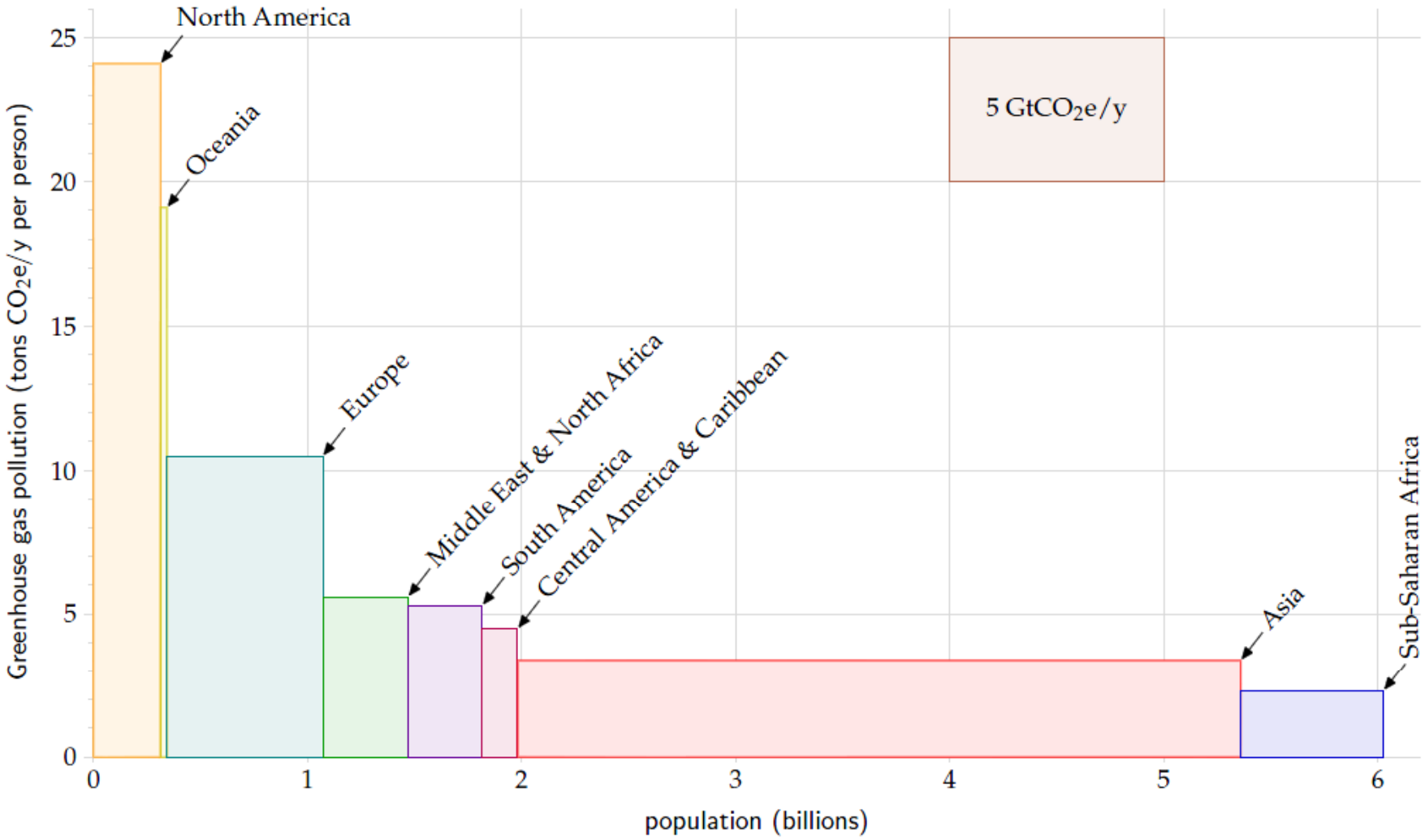
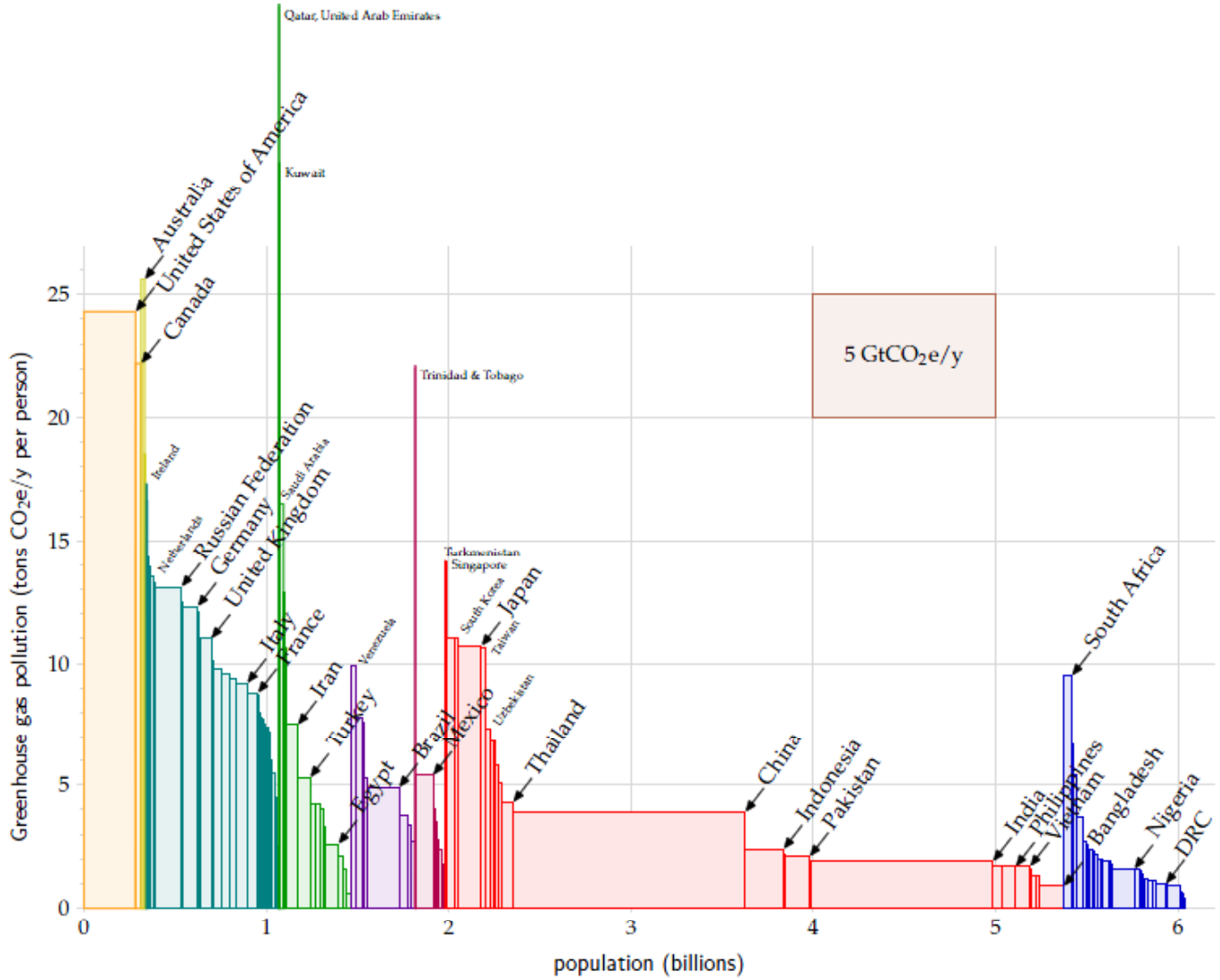


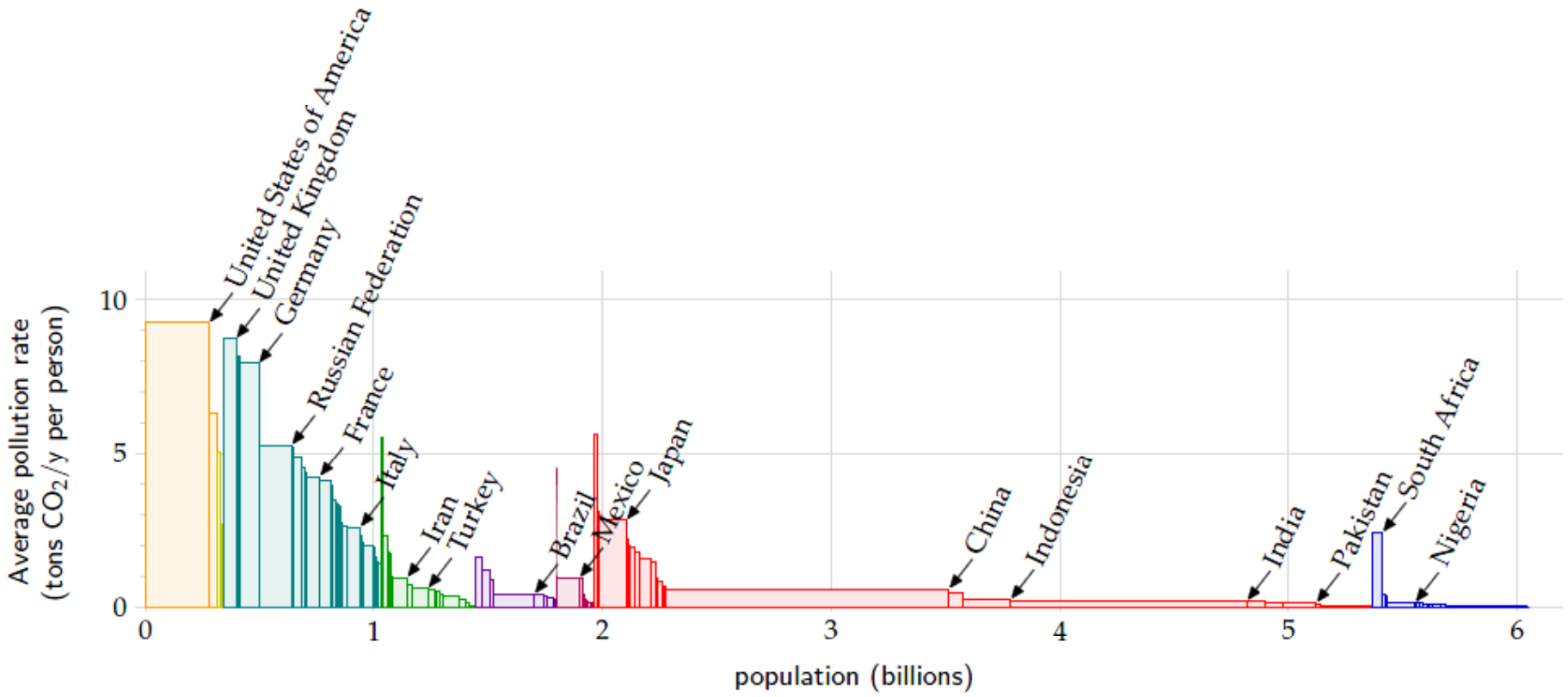
Greenhouse gas pollution by region.

1. Motivations



Greenhouse gas pollution by country.

1. Motivations



Cumulative Greenhouse gas pollution by country from 1880-2004.

1. Motivations

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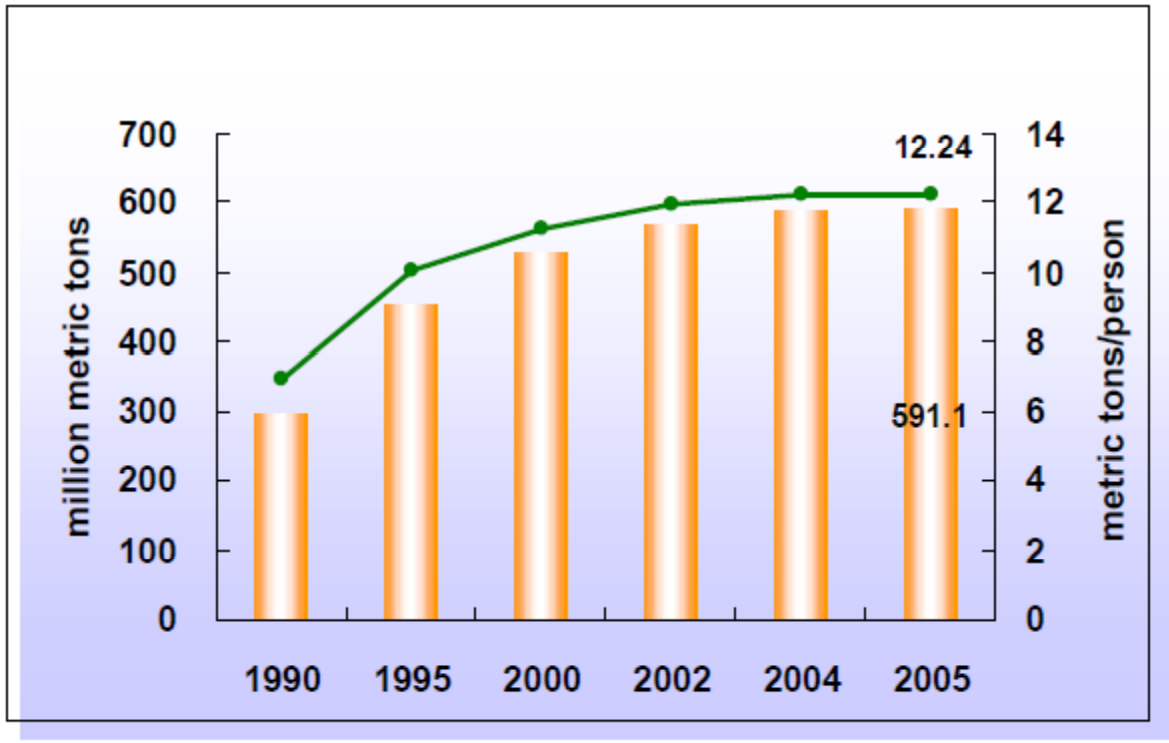
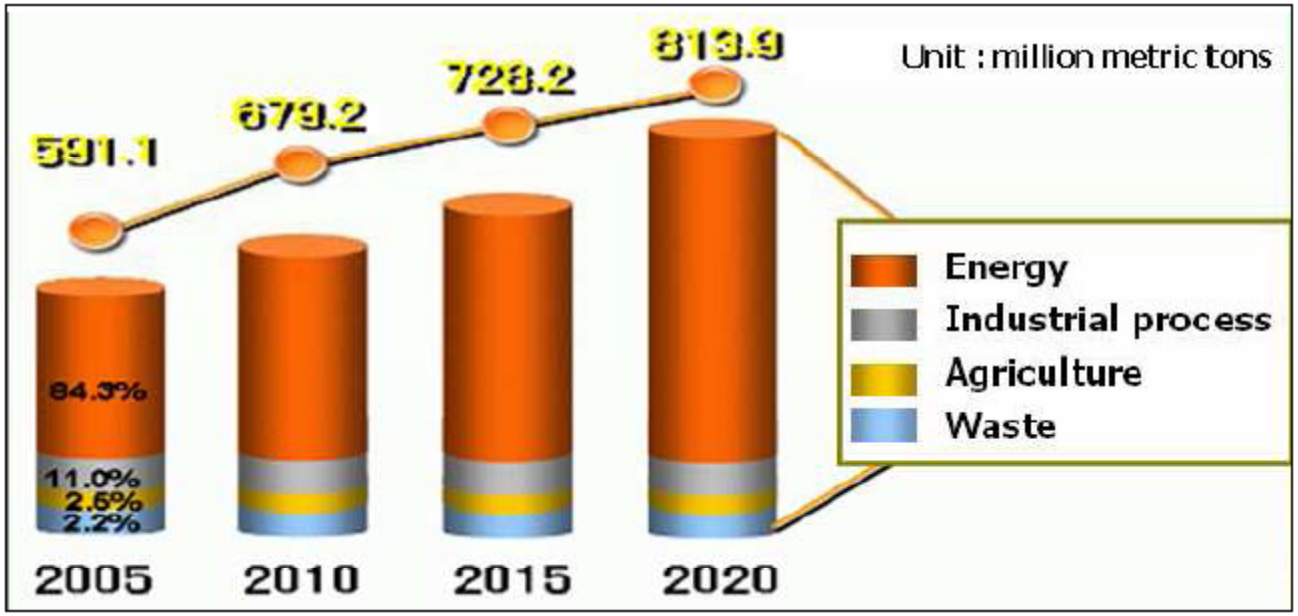


Source: Korea Energy Economics Institute, 2007

Greenhouse gas in Korea from 1990-2005
Above the global average of 5 but half that of the US or UK.
http://www.wpro.who.int/NR/rdonlyres/D10AF055-233A-4D4B-B2C2-688D9656510A/0/KOR2.pdf

1. Motivations



Source: Korea Energy Economics Institute, 2007

Projections of Greenhouse gas emissions in Korea from 2005-2020
Continuing to increase due to population increase.

http://www.wpro.who.int/NR/rdonlyres/D10AF055-233A-4D4B-B2C2-688D9656510A/0/KOR2.pdf

1. Motivations

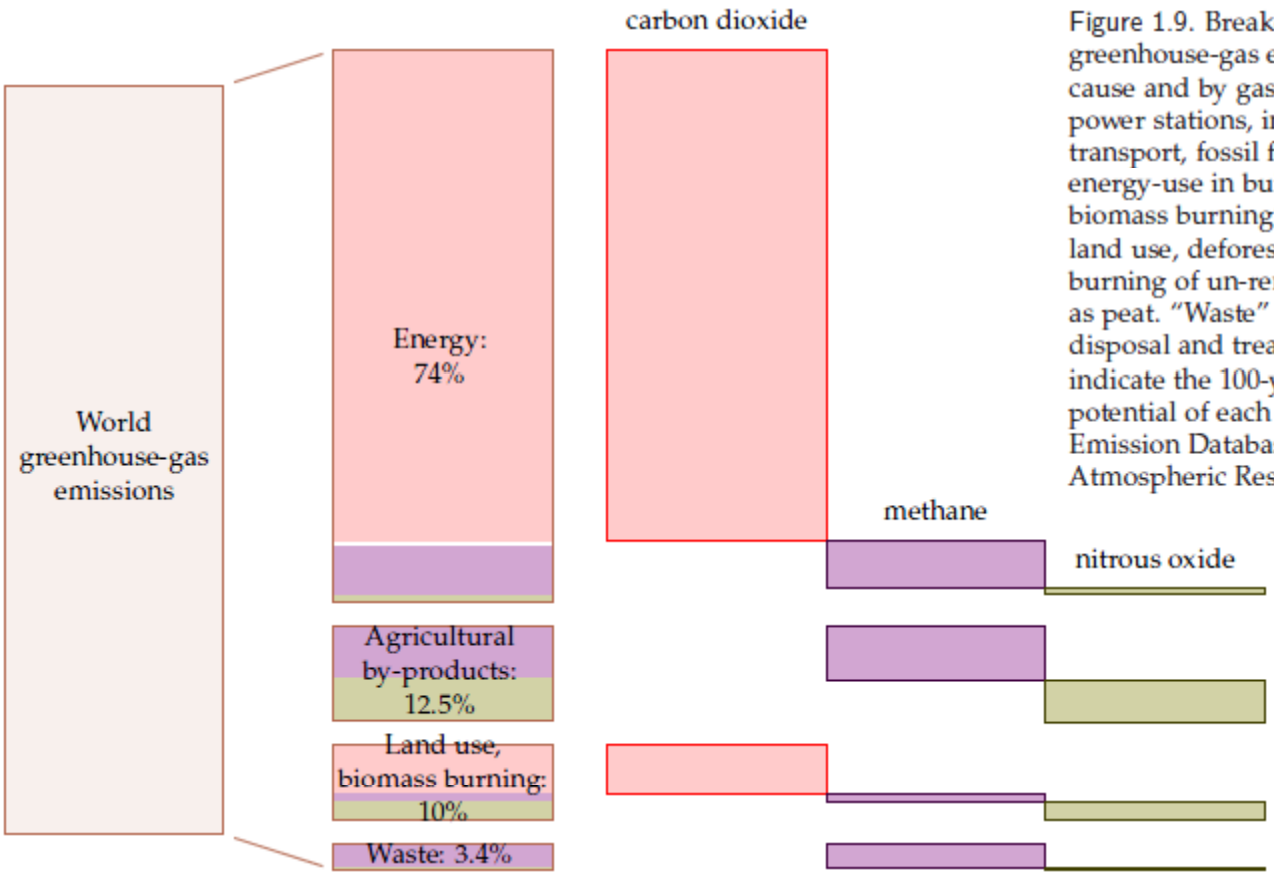


Figure 1.9. Breakdown of world greenhouse-gas emissions (2000) by cause and by gas. "Energy" includes power stations, industrial processes, transport, fossil fuel processing, and energy-use in buildings. "Land use, biomass burning" means changes in land use, deforestation, and the burning of un-renewed biomass such as peat. "Waste" includes waste disposal and treatment. The sizes indicate the 100-year global warming potential of each source. Source: Emission Database for Global Atmospheric Research.

Breakdown of Greenhouse gas pollution by cause and species.

1. Motivations

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Discussion questions

Which of the three motivations for sustainable energy presented here

- **the finite resources of petroleum**
- **energy security**
- **climate change**

are the most compelling?

Who should be held responsible for reducing the GHG emissions, the developed nations who benefited in the past or all nations now emitting GHG gases?

Currently there is little progress on reduction of GHG emissions. There is a negative economic impact (and thus a negative political impact). The threat of massive climate change in the future seems to be insufficient motivation. Do you think there ever will be sufficient motivation for GHG emission control? What do you think will provide sufficient motivation?

2. The Balance Sheet

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consumption

Some key forms of consumption for the left-hand stack will be:

- transport
  - cars, planes, freight
- heating and cooling
- lighting
- information systems and other gadgets
- food
- manufacturing

production

In the right-hand sustainable-production stack, our main categories will be:

- wind
- solar
  - photovoltaics, thermal, biomass
- hydroelectric
- wave
- tide
- geothermal
- nuclear? (with a question-mark, because it's not clear whether nuclear power counts as "sustainable")

Assemble two lists: one of energy consumption, one of conceivable production to answer the question:

Can we conceivably live on sustainable energy?

2. The Balance Sheet

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Units of Energy and Power

This book uses the unit of energy
kilowatt-hour (kWh)
1 Watt = Joule/second (J/s)
1 kWh = 1000 W/kW * 1 J/s/W * 3600 s/h = 3.6×10^6 J = 3.6 MJ

Power
power is the rate of energy usage
energy = power * time

This book uses the unit of power
kilowatt-hour per day (kWh/d)
1 kWh/d = 3.6×10^6 J/d = 3.6×10^6 J/d * 1/24 d/h * 1/3600 h/s
= 41.67 J/s = 41.67 Watts

A 40 Watt light-bulb uses energy at about a rate of 1 kWh/d.

2. The Balance Sheet

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This book frequently reports power per person
Why?

In the UK, waste incineration (burning garbage) generates 7 TWh per year.
In Denmark, waste incineration (burning garbage) generates 10 TWh per year.

However on a per person basis
In the UK, waste incineration (burning garbage) generates 0.3 TWh per day per person.
In Denmark, waste incineration (burning garbage) generates 5 TWh per day per person.
Danes burn 13 times as much garbage per person as the English.

2. The Balance Sheet

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Types of Energy

1. **Electrical Energy**
   - electricity
2. **Thermal Energy**
   - steam
3. **Chemical Energy**
   - gasoline
   - natural gas

Other types

4. **Gravitational Energy**
   - water falls

Types of energy vary in terms of entropy (disorder).

Energy can be converted from one type to another

Coal-fired power plants convert fossil fuels to electricity (efficiency about 40%)

Aluminum plants convert electrical energy to chemical energy (aluminum) (efficiency about 30%)

Hydroelectric plants in dams convert gravitational energy to electrical energy (efficiency about 90%)

2. The Balance Sheet

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Some people argue

● 1 kWh of electricity is equivalent to 2.5 kWh of oil, because if we put that much oil into a standard power station it would deliver 40% of 2.5 kWh, which is 1 kWh of electricity."

Hoewever in this class, we use a one-to-one conversion rate when comparing different forms of energy.

● It is *not the case that 2.5 kWh of oil is inescapably equivalent to 1 kWh of* electricity; that just happens to be the perceived exchange rate in a worldview where oil is used to make electricity.

● In an alternative world (perhaps not far-off) with relatively plentiful electricity and little oil, we might use electricity to make liquid fuels; in that world we would surely not use the same exchange rate – each kWh of gasoline would then cost us something like 3 kWh of electricity!

What is sustainability?

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Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

from The U.N. Report of the Brundtland Commission, *Our Common Future, 1987.*

Full text of the Brundtland Report available at
http://worldinbalance.net/agreements/1987-brundtland.php

What is sustainability?

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"Sustainability is the art of living well within ecological limits."

- Tim Jackson, Prof. of Sustainable Development, University of Surrey

"Sustainability is a 21st century business imperative."

- Edward G. Madzy, Director of Product Regulations and Product Stewardship, BASF Corporation

"Sustainability should be viewed as both a responsibility and an opportunity."

- Len Sauers, Vice President for Global Sustainability, Procter & Gamble

What is sustainability?

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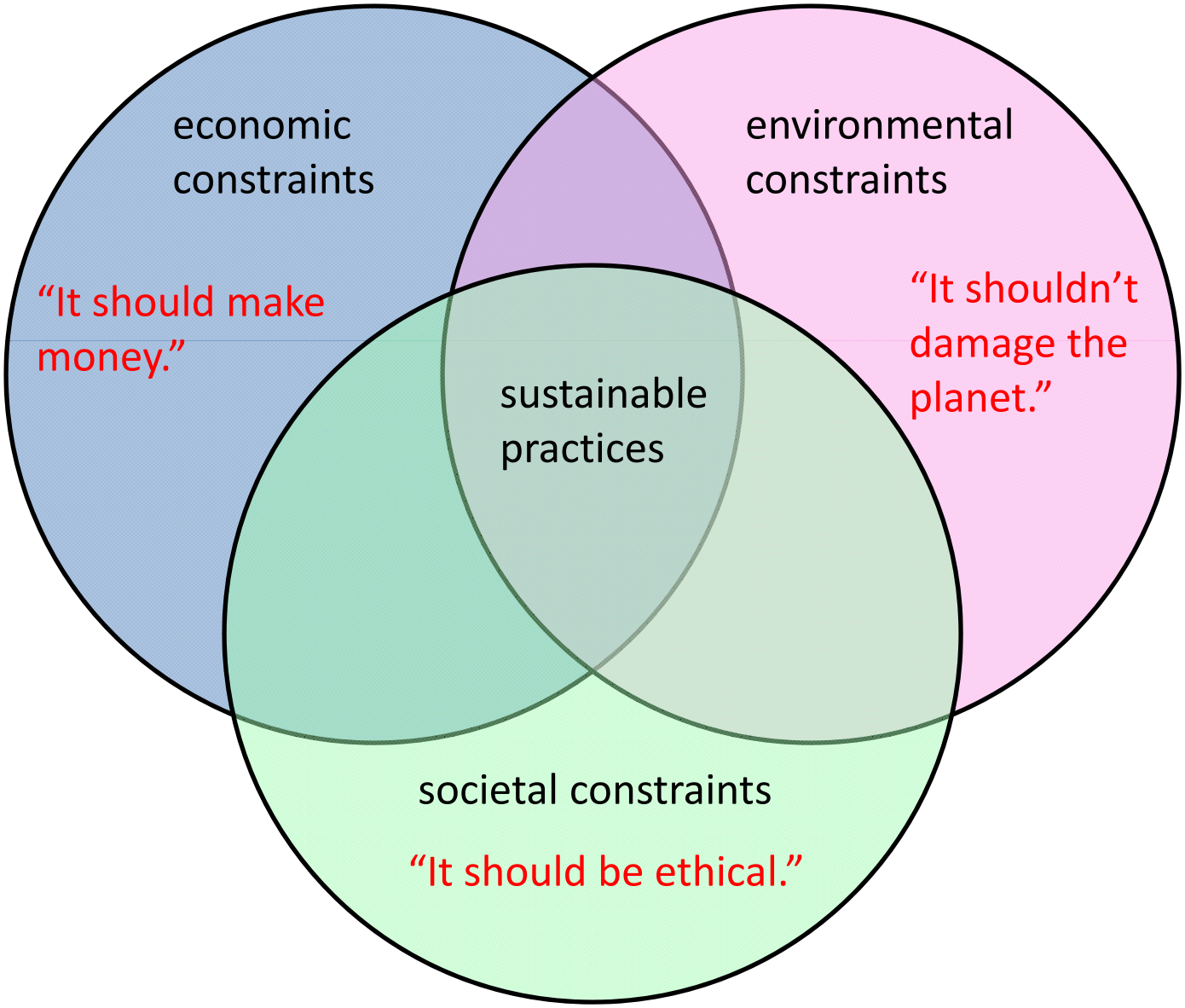

2. The Balance Sheet

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Discussion questions

The U.N. Brundtland Report suggests that given their definition of sustainable development, priority should be given to meeting the needs of the world's poor. While this is an admirable sentiment based on the morality of equality, are there more practical reasons why sustainable development cannot exist amidst a background of significant economic disparity?