Environmental Physics

Dr Jenny Nelson, Dr Arnaud Czaja, Dr John Hassard, (Prof Keith Barnham)

Foreword

Energy is vital to a modern economy. We need energy to heat and light our homes, to help us travel and to power our businesses. Our economy has also benefited hugely from our country's resources of fossil fuels - coal, oil and gas.

However, our energy system faces new challenges. Energy can no longer be thought of as a short-term domestic issue. Climate change - largely caused by burning fossil fuels - threatens major consequences in the UK and worldwide, most seriously for the poorest countries who are least able to cope. Our energy supplies will increasingly depend on imported gas and oil from Europe and beyond. At the same time, we need competitive markets to keep down costs and keep energy affordable for our businesses, industries, and households.

This white paper addresses those challenges. It gives a new direction for energy policy. We need urgent global action to tackle climate change. We are showing leadership by putting the UK on a path to a 60% reduction in its carbon dioxide emissions by 2050. And, because this country cannot solve this problem alone, we will work internationally to secure the major cuts in emissions that will be needed worldwide.

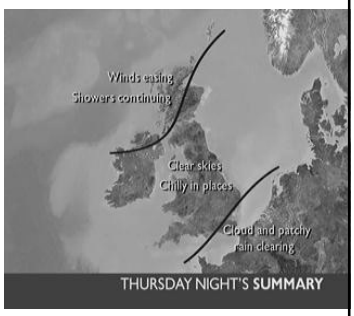
Our analysis suggests that, by working with others, the costs of action will be acceptable - and the costs of inaction are potentially much greater. And as we move to a new, low carbon economy, there are major opportunities for our businesses to become world leaders in the technologies we will need for the future - such as fuel cells, offshore wind and tidal power. Science and technology are vital, and we will be supporting further research and development in these areas.

In parallel, we need access to a wide range of energy sources and technologies and a robust infrastructure to bring the energy to where we want to use it. We will maintain competitive markets in the UK and press for further liberalisation in Europe. And we renew our commitment that no household in Britain should be living in fuel poverty by 2016-18.

The white paper is a milestone in energy policy. It is based on the four pillars of this environment, energy reliability, affordable energy for the poorest, and competitive markets for our businesses, industries and households.

This white paper sets out a strategy for the long term, to give industry the confidence to invest to help us deliver our goals - a truly sustainable energy policy.

The Perfect Approach



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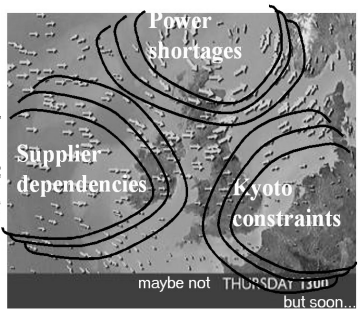


The Perfect Storm

Aims and Objectives

Aims:

- To introduce students to the application of core physics concepts to issues related to energy and the environment, with special focus on: energy production use and conversion; factors influencing the Earth's temperature; environmental monitoring techniques. The course should develop students' problem solving abilities, provide practice in the applications of physics and help to develop a critical awareness of the wider context of aspects of science and technology.

Objectives:

- To understand the physical basis of the main sources of energy for human use.
- To be familiar with the factors influencing energy consumption and its true costs in the past and the issues determining future trends.
- To understand how spectroscopy and detection technology may be used for monitoring environmental processes and pollutants.
- To be able to discuss the main factors influencing Earth's temperature
- To understand the origin and action of the "greenhouse effect"
- To understand the influences of CO_2 and water vapour feedback on radiative forcing and Earth temperature
- To understand the origin of winds and ocean currents
- To understand how solar energy can be converted into thermal, kinetic, electrical or chemical energy, and the function of a photovoltaic cell
- To calculate the efficiency of solar thermal and solar photovoltaic energy converters using heat engine models
- To understand the production of electricity from wind, wave, tidal and hydroelectric resources.

Why this course for physicists?

Physicists are meant to have a better than average chance of being able to identify problems, apply rigorous analysis to quantifying, and identifying interdependencies within that problem, establishing a set of solutions and the consequences of those solutions.

All three components of that 'perfect storm' of problems have the potential to **massively disrupt our society**. All three have their roots in science and technology. All three have the roots of solutions in science and technology – and how these can be applied.

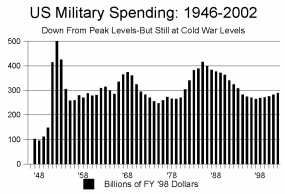
Our goal is to understand what is known, and what is not known about the environment now, and projecting into the future.

- To anticipate risks and opportunities by examining the underlying physical principles
- To see how physics reality, and its inherent uncertainties, guide, limit and constrain political and social response
- To apply our alleged relative sophistication in unbiased analysis to what might be the most serious threats to society presently around

Risk and Risk Perception

- "perfect storm' of problems have the potential to massively disrupt our society'

This would normally result in society trying to find ways to mitigate. However, 'risk perception' is not the same as 'risk' and it is a physicist's job – with other disciplines – to try to make the two converge to allow rational and cost effective measures to be formulated and executed.



Clinton approved an increase for the Pentagon of $112 billion over 6 years . . .
. . .
and $6.6 billion for Star Wars deployment over 6 years to the Pentagon budget

and 1-year Pentagon budget boost is $12.6 billion in fiscal year 2000 alone . . .

and that the combined annual military budgets of the Pentagon's rogue states – North Korea, Iraq and Iran -- totals less than $9 billion

Let's look at the perceived threat has been addressed over the last 50 years.

Risk Perception

Personal risks: Ralph Hertwig, PhD, of the University of Basel "People can arrive at relatively accurate estimates as long as they rely on their personal experiences of the frequencies of such events ....However, when they start sampling from the virtual world as created by the mass media, they are more likely to arrive at distorted estimates of likelihood."

The findings suggest that people aren't horribly off the mark as long as they do not rely on media reports and stick to what's happened to people they know. *Journal of Experimental Psychology: Learning, Memory and Cognition* (APA).

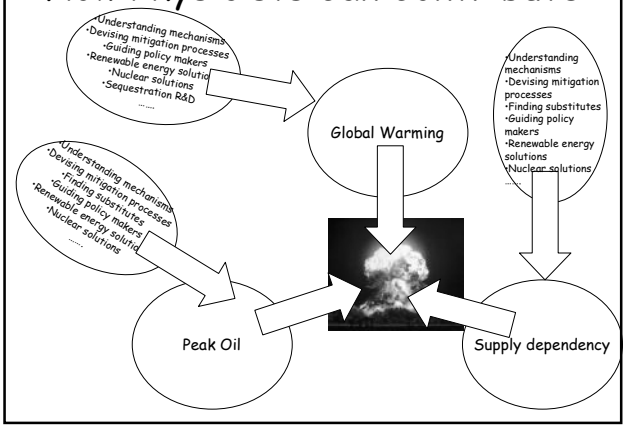
"Regressed-frequency mechanism" assumes that people base their health risks on automatically encoded frequency information arising from a goulash of various exposures –Because it's hard to reliably process all that information, however, people's estimates shift toward the average value in a category, a statistical phenomenon called "regression toward the mean."

As a result, small frequencies (such as dying from vitamin overdose) are overestimated and large frequencies (such as dying from rectal cancer) are underestimated.

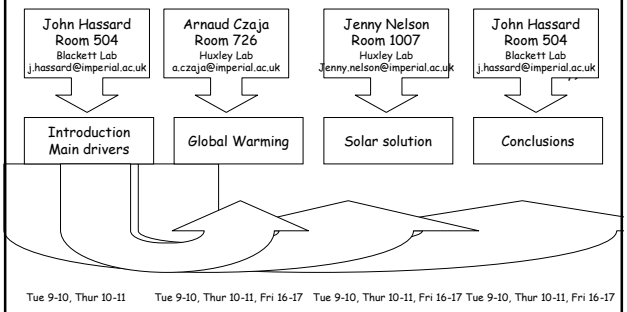
The implications for our response to potentially catastrophic events is profound

http://www.apa.org/releases/healthrisks.html see also *Journal of Experimental Psychology: Learning, Memory and Cognition* published by the American Psychological Association (APA).

How Physicists Can Contribute

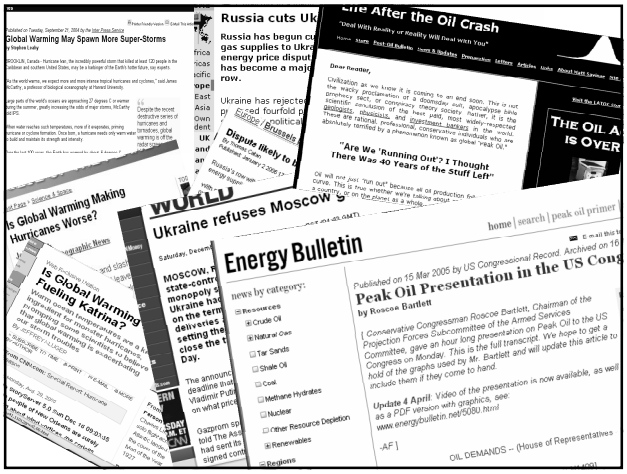


Course Structure



Course synopsis

A. Energy consumption, resources, trends Introduction World population and energy usage Energy consumption details Future trends in resources, population and energy usage Environmental Spectroscopy, methods in the atmosphere and water; Measuring Greenhouse Gas Emissions: Ground based techniques; Satellite observations.	JH 1-7
B. What controls the Earth surface temperature? The "greenhouse effect": pristine form The "greenhouse effect" modified: role of convection and surface evaporation Surface temperature response to CO_2 increase Water vapour feedback Role of atmospheric circulation: the tropics Role of ocean circulation: the Gulf Stream and the sea-ice albedo feedback **C. Production of winds and currents** The atmospheric heat engine The ocean is not a heat engine!	AC 8-14
D. Conversion of solar energy The solar resource. Absorption of sunlight in matter and Solar Conversion routes. Solar Thermal energy conversion. Semiconductor background. Solar photovoltaic energy conversion. Implementation of photovoltaic energy conversion. Solar chemical energy conversion. Photosynthesis Biomass.	JN 15-22
E. Wind, Wave, Tidal and Hydroelectric power. **G. Conclusions**	JH 23-26



Helpful hints

- Any slide with this on is not examinable
- Exam questions will NOT be essays
- They will be numerical, and explore concepts.
- First problem sheet will follow exam format (out on Monday)

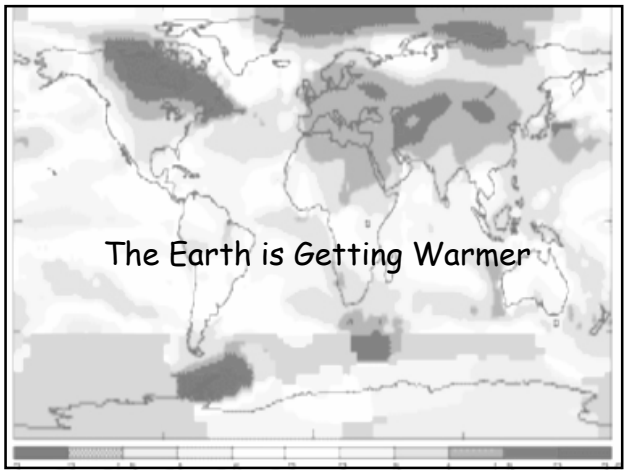
Exam

The exam in the summer (and the retake) will have the following format :

ENVIRONMENTAL PHYSICS
Half Unit - Two hours.
The paper consists of *two* sections: A & B.

Section A contains *one* question, comprising of small parts. (20 marks total)
Section B will contain four *smaller* questions on selected parts of the course. (20 marks each)

Candidates are required to:
Answer ALL parts of Section A and two of Section B

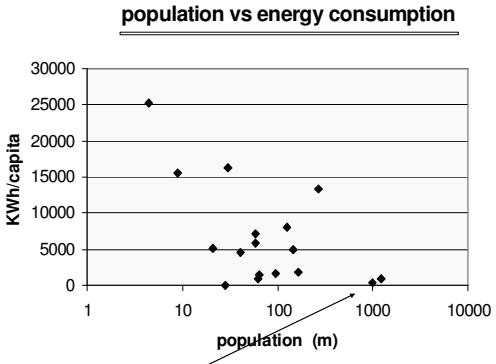


How big is the problem ?

International energy consumption in 1998:

	population(m)	KWh/ year/ capita
Norway	4.42	25304
Canada	30.30	16349
Sweden	8.85	15492
USA	269.09	13388
Japan	126.49	8008
France	58.85	7175
UK	59.24	5800
Saudi Arabia	20.74	5153
Russia	146.91	4873
S. Africa	41.40	4509
Brazil	165.87	1850
Mexico	95.68	1644
Turkey	64.75	1439
Egypt	61.67	900
China	1238.60	871
India	979.67	415
Sudan	28.35	47

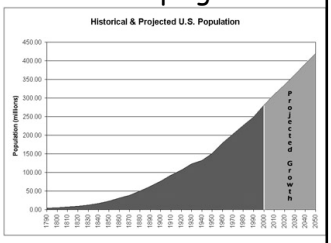
http://earthtrends.wri.org/searchable_db/index.cfm?theme=6&variable_ID=351&action=select_countries



Countries will aspire to Western standards by raising their energy consumption

The problem is not the developing world

A very large proportion of historical GHGs came from the developed world



Some countries are still growing fast, and per capita use is also increasing

But the solution must encompass the developing world

GHGs= Green House Gases

Total Energy Use

- **In 1996 the total energy used in the world was 8380 mtoe (million tons of oil equivalent) which is about 400 million terajoules.**
- **The growth of the amount of energy used has been very rapid. It can been expressed as the product of two factors, the growth in the population and the growth in the energy used per person. It can be seen that it is the growth in energy use per person which has been and will be the driving force more than the population increase.**

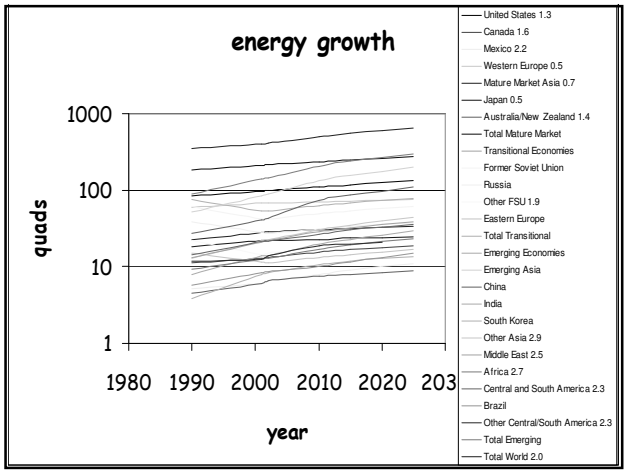
http://www.dti.gov.uk/energy/inform/energy_stats/total_energy/index.shtml

…onal Energy Outlook 2005 Report #: DOE/EIA-0484(2005) Released Date: July 2005

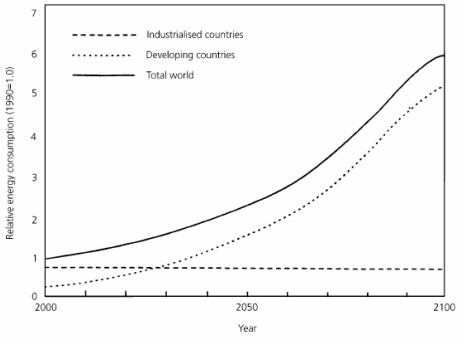
International Energy Annual 2002, DOE/EIA-0219(2002)

World Total Primary Energy Consumption by Region, Reference Case, 1990-2025 (Quadrillion Btu)

		1990	2001	2002	2010	2015	2020	2025
Mature Market Economies								
North America 1.4		100.9	115.2	117.7	134.2	143.6	152.9	162.1
United States 1.3		84.6	96.3	98.0	110.6	117.6	125.1	132.4
Canada 1.6		11.1	12.8	13.1	15.6	16.9	17.8	18.8
Mexico 2.2		5.1	6.1	6.6	8.0	9.1	10.0	10.9
Western Europe 0.5		59.9	68.0	67.4	70.2	72.2	73.4	76.1
Mature Market Asia 0.7		22.7	28.0	28.4	30.4	31.5	32.5	33.6
Japan 0.5		18.3	21.9	22.0	22.9	23.6	24.1	24.7
Australia/New Zealand 1.4		4.5	6.1	6.5	7.5	7.9	8.4	8.8
Total Mature Market	**1.1**	**183.6**	**211.2**	**213.5**	**234.7**	**247.3**	**258.7**	**271.8**
Transitional Economies								
Former Soviet Union	1.6	60.9	42.0	42.4	49.7	53.9	57.2	61.0
Russia 1.4		39.1	27.7	27.5	31.3	33.5	35.7	37.9
Other FSU 1.9		21.8	14.3	14.9	18.4	20.4	21.5	23.1
Eastern Europe	1.7	15.3	11.4	11.2	13.3	14.5	15.6	16.7
Total Transitional	**1.6**	**76.2**	**53.4**	**53.6**	**63.0**	**68.4**	**72.8**	**77.7**
Emerging Economies								
Emerging Asia	3.5	51.5	84.7	88.4	133.6	155.8	176.3	196.7
China 4.1		27.0	40.9	43.2	73.1	86.1	97.7	109.2
India 3.3		8.0	13.8	14.0	19.6	22.7	26.0	29.3
South Korea 2.1		3.8	8.0	8.4	10.6	11.8	12.7	13.5
Other Asia 2.9		12.7	21.9	22.9	30.3	35.1	39.9	44.6
Middle East 2.5		13.1	20.9	22.0	28.7	32.4	35.6	38.9
Africa 2.7		9.3	12.5	12.7	16.7	19.3	21.4	23.4
Central and South America 2.3		14.5	21.2	21.2	26.8	30.4	33.2	36.1
Brazil	2.5	5.8	8.4	8.6	10.2	11.6	13.2	15.1
Other Central/South America 2.3		8.8	12.7	12.6	16.6	18.8	20.0	21.1
Total Emerging	3.2	88.4	139.2	144.3	205.8	237.8	266.6	295.1
Total World 2.0		348.2	403.9	411.5	503.5	553.5	598.1	644.6



Relative energy consumption 2000-2100



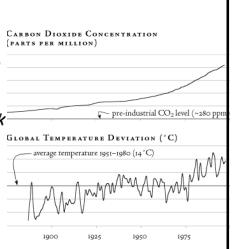
Global Warming

- This section introduces the concepts of global warming.
- It will be explored fully by Dr Czaja later in the course.
- The Solar Solution to renewable energy production will be detailed by Dr Nelson in the third part of the course

In 1896, Svante Arrhenius, a Swedish chemist, was the first to advance the theory that emissions of carbon dioxide (CO_2) would intensify the Earth's natural greenhouse effect and thus warm the planet.

> "*One may now ask, How much must the carbonic acid vary according to our figures, in order that the temperature should attain the same values as in the Tertiary and Ice ages respectively?*

"A simple calculation shows that the temperature of the Arctic regions would rise about 8 degrees or 9 degrees Celsius, if the carbonic acid increased 2.5 to 3 times its present value. In order to get the temperature of the ice age between the 40th and 50th parallels, the carbonic acid in the air should sink to 0.62 to 0.55 of present value (lowering the temperature 4 degrees to 5 degrees Celsius)."



http://earthobservatory.nasa.gov/Library/Giants/Arrhenius/arrhenius_2.html
http://www.longman.co.uk/tt_secsci/resources/scimon/arrhenius/arrh_main.htm

Since then, carbon dioxide and other so-called greenhouse gases have been building up rapidly in our atmosphere, primarily due to deforestation and the burning of coal, oil and gasoline in power plants, automobiles and factories.

These polluting activities release more than 25 billion tons of carbon dioxide into our atmosphere annually, and natural processes are unable to absorb all of what we emit, hence the 30 percent rise in atmospheric carbon dioxide since pre-industrial times, and the 145 percent rise in the second most important greenhouse gas, methane.

Dr Czaja will give us the facts.

http://www.bp.com/genericsection.do?categoryId=92&contentId=7005893
http://earthguide.ucsd.edu/globalchange/global_warming/03.html
http://www.eia.doe.gov/

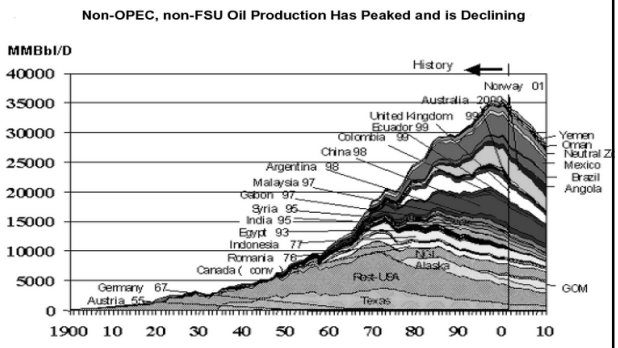
What we learnt last lecture

1) Convergence almost unique in human history of three forces which get to the heart of our society. According to the consensual view:
   - Primary energy resource depletion has begun
   - Remaining energy sources potentially unstable
   - The consequences of using those resources is altering the climate perhaps irrevocably, certainly to the detriment of the environment

2) Science has crucial role to play in establishing a solution, if there is one.

First job is to understand the problem (Dr Czaja) and then to provide a solution (Dr Nelson)

Oil Has Peaked in Most Places

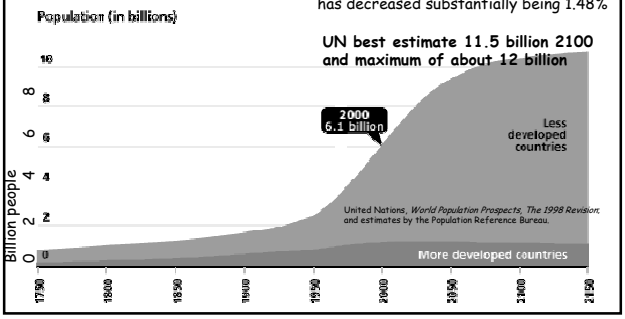


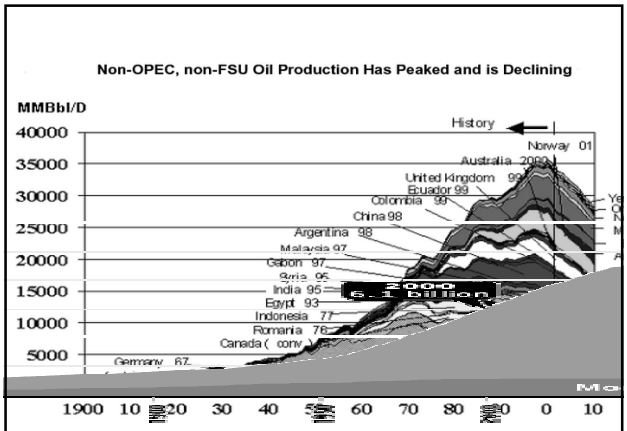
Population Pressure

In the 2400 years between 1600 BC and 800 AD, the population tripled from 0.06 billion to 0.2 billion, but in the last hundred years the population has more than tripled from 1.5 billion in 1890 to 5.3 billion in 1990. In mid-1998 the total world population was estimated to be 5.93 billion people.

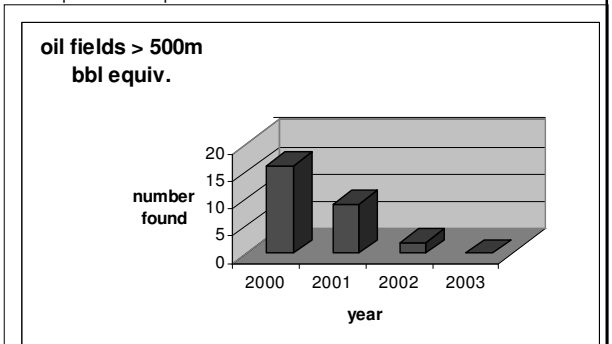
The population growth rate was about 0.04% per year over the first period but was 0.7% in 1890, and between 1975 and 1990 was 1.72% per year.

For 1990 - 1995, the annual growth rate has decreased substantially being 1.48%

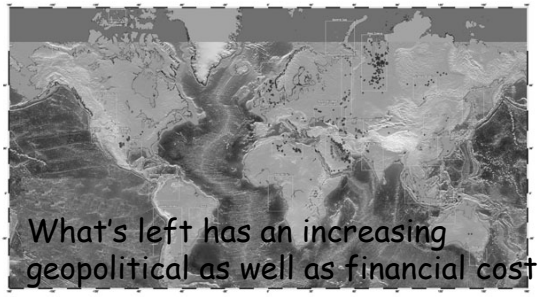




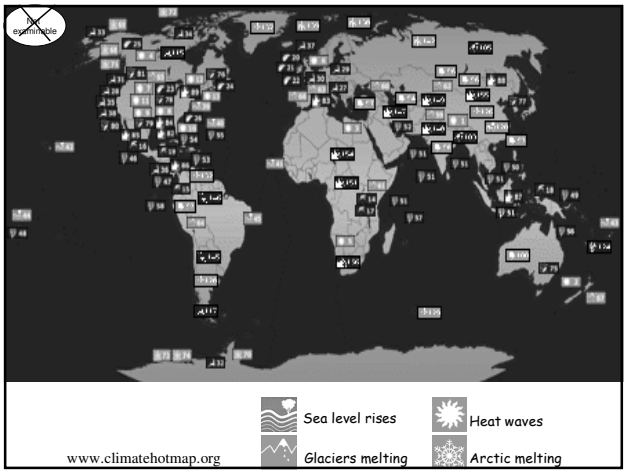
- http://news.independent.co.uk/environment/article339928.ece

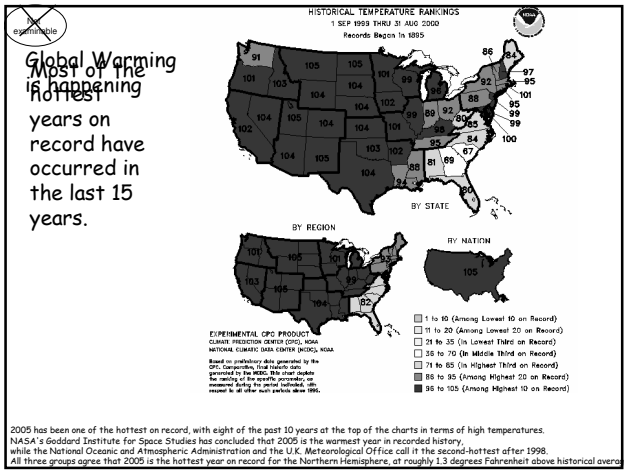


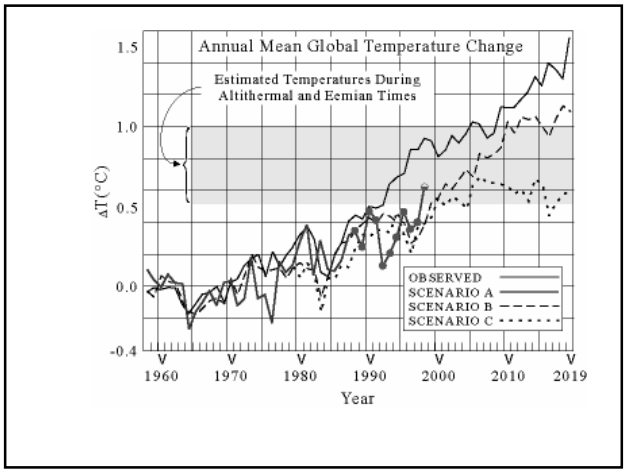
The peak of oil discovery was as long ago as 1965.

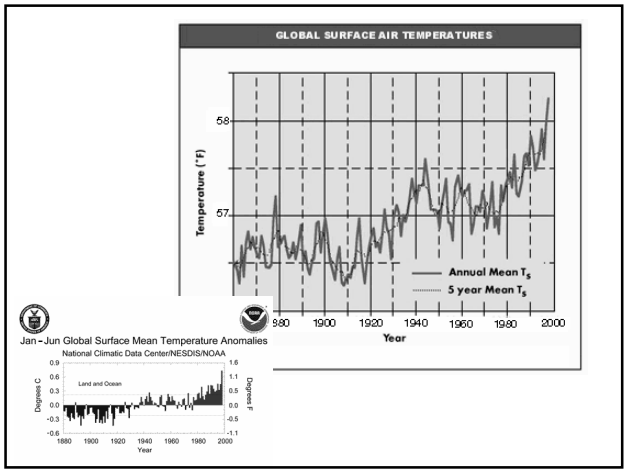


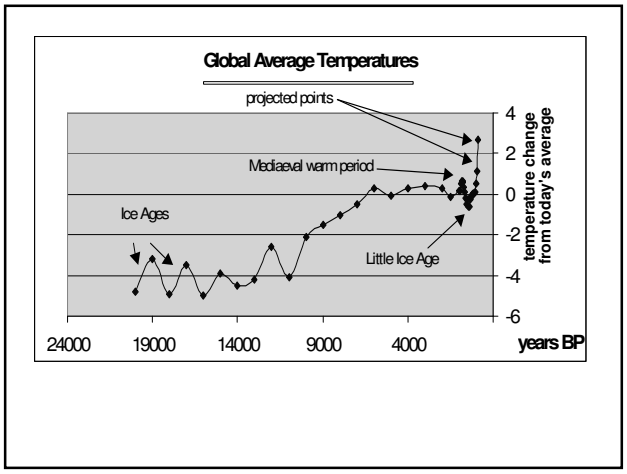
- The world's 877 giant oil and gas fields are those with 500 million bbl of ultimately recoverable oil or gas equivalent. Remarkably, almost all of these 877 giant fields, which by some estimates account for 67% of the world's petroleum reserves, cluster in 27 regions, or about 30%, of the earth's land surface

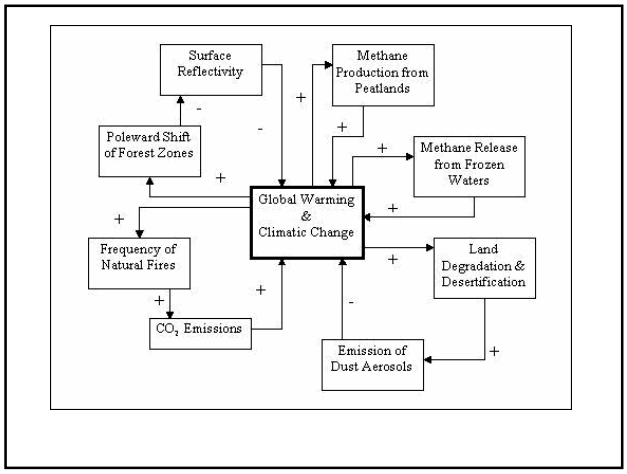

Sea level rises
Heat waves
Glaciers melting
Arctic melting
www.climatehotmap.org

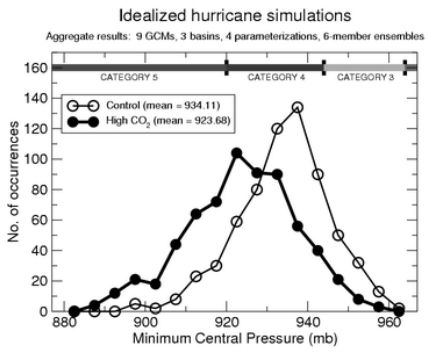

Global Warming is happening
Most of the hottest years on record have occurred in the last 15 years.
HISTORICAL TEMPERATURE RANKINGS
1 SEP 1999 THRU 31 AUG 2000
Records Begun In 1895
BY STATE
BY REGION
BY NATION
2005 has been one of the hottest on record, with eight of the past 10 years at the top of the charts in terms of high temperatures.
NASA's Goddard Institute for Space Studies has concluded that 2005 is the warmest year in recorded history,
while the National Oceanic and Atmospheric Administration and the U.K. Meteorological Office call it the second-hottest after 1998.
All three groups agree that 2005 is the hottest year on record for the Northern Hemisphere, at roughly 1.3 degrees Fahrenheit above historical averag


Annual Mean Global Temperature Change
Estimated Temperatures During Altithermal and Eemian Times
ΔT (°C)
Year
OBSERVED
SCENARIO A
SCENARIO B
SCENARIO C


GLOBAL SURFACE AIR TEMPERATURES
Temperature (°F)
Annual Mean T_s
5 year Mean T_s
Year
Jan - Jun Global Surface Mean Temperature Anomalies
National Climatic Data Center/NESDIS/NOAA
Land and Ocean
Degrees C
Degrees F

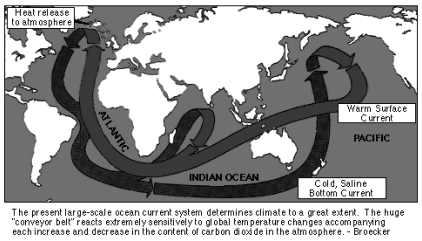

Global Average Temperatures
projected points
Mediaeval warm period
Ice Ages
Little Ice Age
temperature change from today's average
years BP


Surface Reflectivity
Methane Production from Peatlands
Poleward Shift of Forest Zones
Methane Release from Frozen Waters
Global Warming & Climatic Change
Frequency of Natural Fires
Land Degradation & Desertification
CO_2 Emissions
Emission of Dust Aerosols



It is certain that uncertainties remain - these are reflected in the range or results in the many scenarios.

These are due to the complexity of the science, and the uncertainties about other possible contributors.



The present large-scale ocean current system determines climate to a great extent. The huge "conveyor belt" reacts extremely sensitively to global temperature changes accompanying each increase and decrease in the content of carbon dioxide in the atmosphere. - Broecker

http://www.ldeo.columbia.edu/edu/dees/ees/climate/slides/ocean_index.html

One example of unproven hypotheses

Global surface temperature has increased about 0.5C since 1975, and it is commonly assumed that this warming will continue or accelerate.

Scientists at the Goddard Institute for Space Studies argue that observed warming has been driven mainly by non-CO_2 greenhouse gases. It would be practical to halt the growth of these gases.

They suggest a scenario in which an international focus on reducing air pollution, especially tropospheric ozone and black carbon aerosols, which would help unite the interests of developed and developing countries and slow global warming.

Gas	sources	annual increase	contribn
CO_2	Fossil fuels (77%) Deforestation (23%)	0.5% (353 ppmv)	55%
CFCs	solvents refrigerants	4% (764 pptv)	24%
CH_4	gas leakage Rice paddies enteric fermentation	0.9% (1.72 ppmv)	15%
N_2O	biomass burning fertilisers fossil fuels	0.58% (310 ppbv)	6%

(IPCC WG1)

not examinable

Another claimed effect:
Solar variability

It has been suggested that there are natural cycles in the sun which can explain present day global warming.

It is clear there are short term variations and a 11.3 year sunspot cycle.

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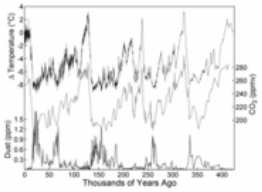


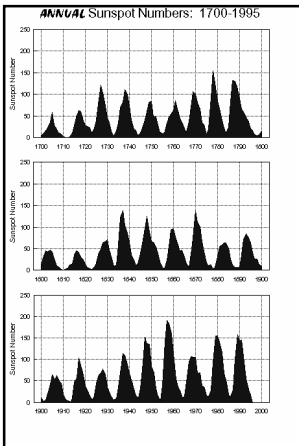
There are also long term cycles.

Understanding the correlations is difficult

Unfortunately for the solar cycle theorists,
150 years x 2 degrees/50,000 years = 0.006 degrees.

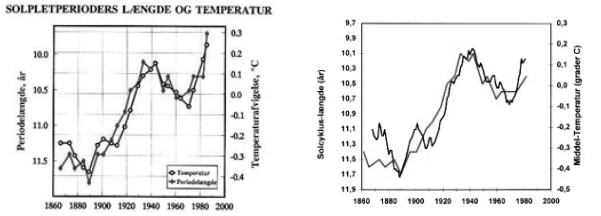
Space weather may also in the long term affect the Earth's climate. Solar ultra-violet, visible and heat radiation are the primary factors for the Earth's climate, including global average temperatures, and these energy sources appear to be quite constant.

However, some scientists have claimed correlations between the solar magnetic activity, which is reflected in the sunspot frequency, and climate parameters at the Earth. Sunspot activity has been recorded through several hundreds of years which makes it possible to compare their variable frequency to climate variations to the extent that reliable climatological records exists.



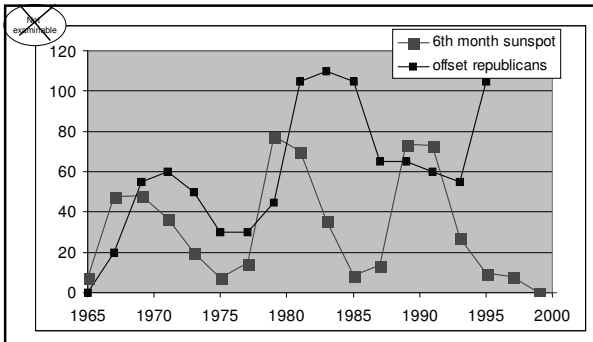
Reduced Sunspot Activity Predicted for Next Decade
YALE News Release
For Release: Jan. 14, 1997
Yale and NASA Astronomers Predict Decline in Sunspots, Which Could Bring Cooler Weather, Fewer Electronic Disruptions

The optimistic prediction, which contradicts that of many other scientists, will be reported Jan. 14 1997 at a meeting of the American Astronomical Society in Toronto, Canada, by Kenneth Schatten of Goddard Space Flight Center/NASA in Greenbelt, Maryland. He and Sabatino Sofia, chairman of the Yale astronomy department, inferred the magnitude of magnetic fields just below the sun's surface from observations with solar telescopes in Stanford and Big Bear, CA



The red curve illustrates the solar activity, which is generally increasing through an interval of 100 years, since the cycle length has decreased from around 11.5 years to less than 10 years. Within the same interval the Earth's average temperature as indicated by the blue curve has increased by approximately 0.7 degree C. It is even claimed that the finer structures in the two curves have similar appearances.

(Reference: Friis-Christensen, E., and K. Lassen, Length of the solar cycle: An indicator of solar activity closely associated with climate, Science, 254, 698-700, 1991).



Unfortunately, it's very easy to find correlations, not all of which make sense

More Variabilities….

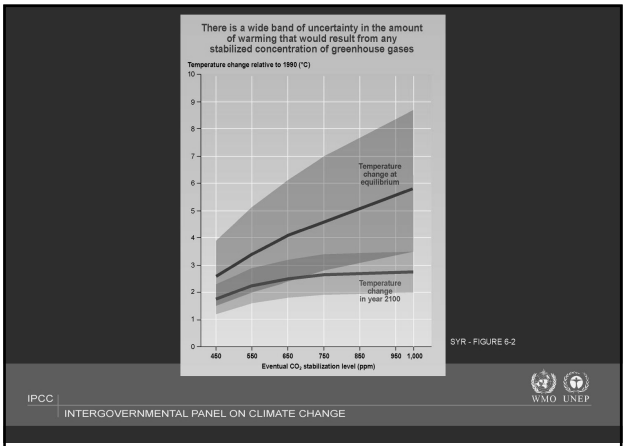
There are clearly also long term solar variations. One such is the Milankovitch orbital and the North Atlantic Oscillation periodicities. Some long term catastrophic changes in Global climate are unassociated with these.

For example, 'Heinrich' events occurred between 14000 and 70000 years ago. These are characterised by specific layers of rich carbonate deposits and clear evidence of low salinity, very cold water, and planktonic foraminifer, associated with brief and intense periods of glacial calving.

The N. Atlantic thermohaline circulation would have been stopped by these effects.

Global Warming: what's the truth?

- The rational way to see through this morass of claim, counterclaim, politics, ignorance, prejudice, commercial interests…
  - Go Back to Basics: look at the physics
  - Try to consider as many issues as possible without being blinded by the extraneous detail
  - Think for yourselves
  - Attend Czaja's lectures



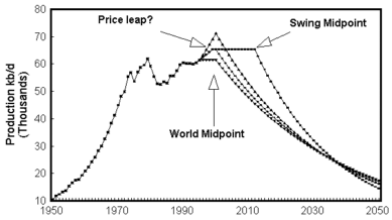
Things you should know

1) There are clear signs of global warming.
The near-consensus is that it is mostly anthropogenic

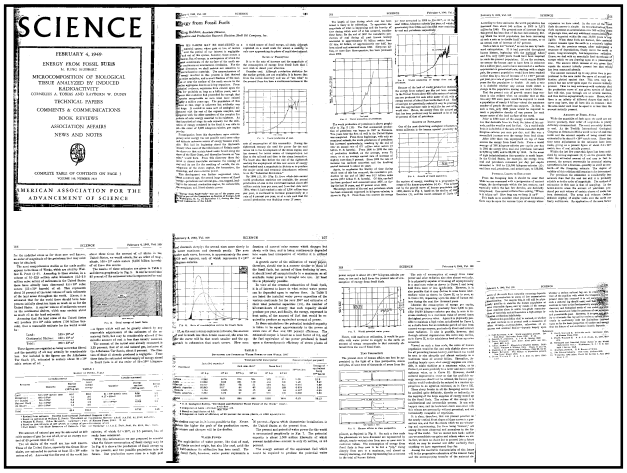
2) There are very large uncertainties

Oil Peak

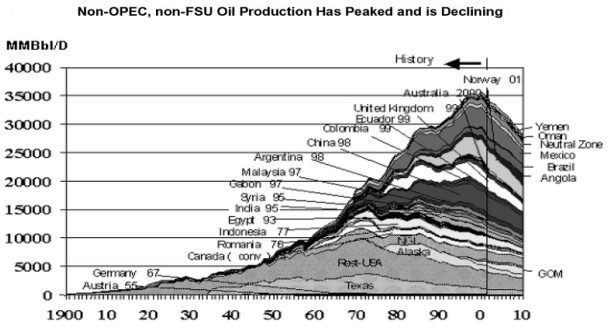
- This section introduces the concepts of peak oil
- The underlying science will be not be covered extensively in this physics course.
- But the consequences of it being true will be.



Dr. C.J. Campbell/Petroconsultants
http://www.oildepletion.org/
http://www.energiekrise.de/
http://www.peakoil.net

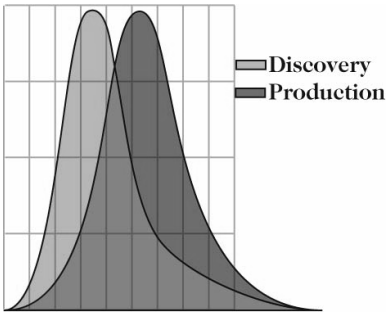


According to conventional geological theory, Oil Has Peaked in Most Places



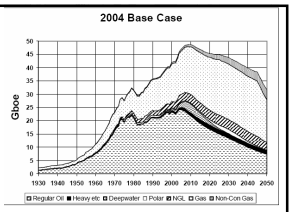
http://www.lifeafterthepeakoil.net/

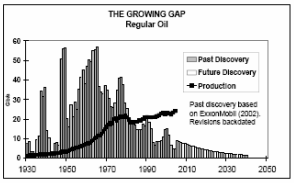
Discovery must predate production

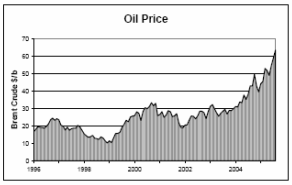


For Central Limit Theorem: http://www.stat.sc.edu/~west/javahtml/CLT.ht
See also http://mathworld.wolfram.com/CentralLimitTheorem.html
http://www.statisticalengineering.com/central_limit_theorem.htm

Oil and Gas Depletion
According to source







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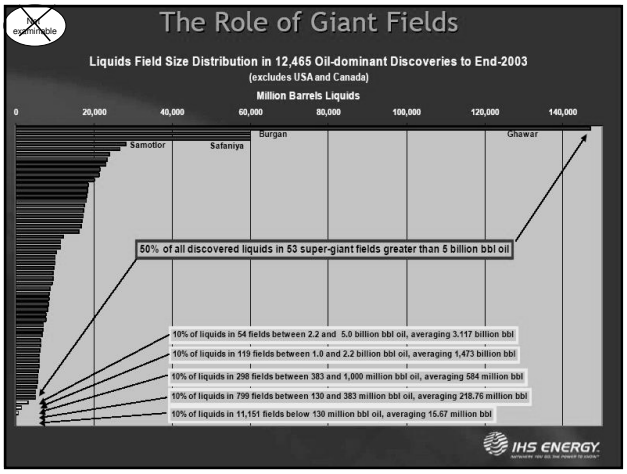
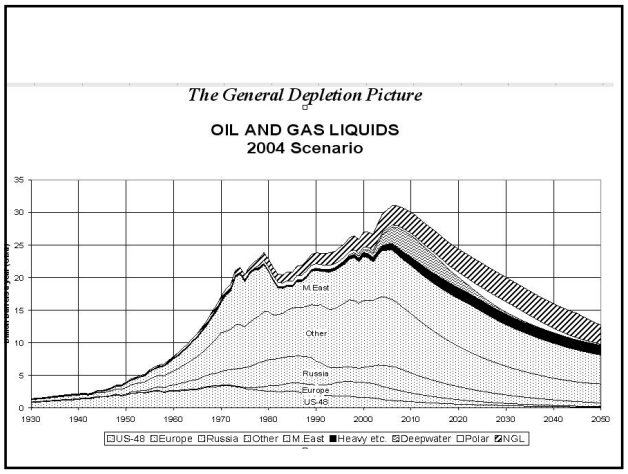
Oil Discovery vs production

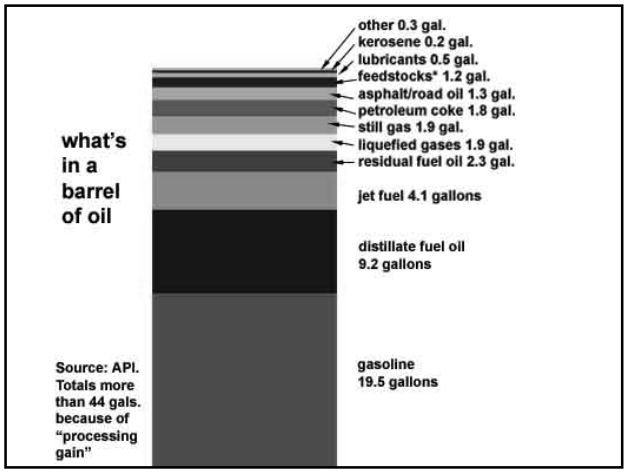
Oil Price





Exercise

- Hypothesise the discovery of a new North Sea Oil field
- Calculate how far back (in years) the peak of global oil would be set.
- Assume Gaussian production curve



How much Oil in a bottle of tomato ketchup?

…h tomato ketchup. Researchers at the Swedish Institute for Food and Biotechnology analysed the production of tomato ketchup.

The study considered the production of inputs to agriculture, tomato cultivation and conversion to tomato paste (in Italy), the processing and packaging of the paste and other ingredients into tomato ketchup in Sweden and the retail and storage of the final product. All this involved more than 52 transport and process stages.

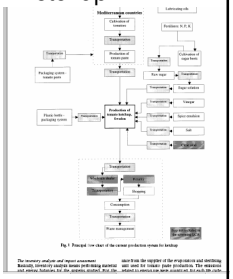
The aseptic bags used to package the tomato paste produced in the Netherlands and transported to Italy to be filled, placed in steel barrels, and then moved to Sweden.

The five layered, red bottles were either produced in the UK or Sweden with materials form Japan, Italy, Belgium, the USA and Denmark.

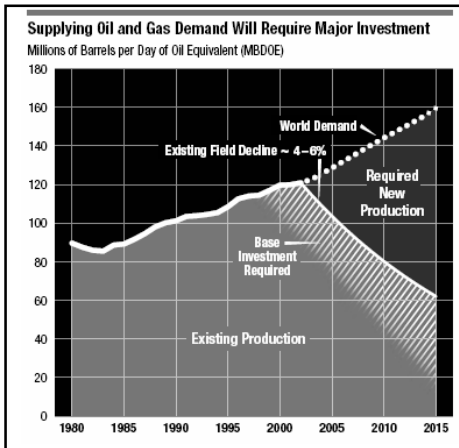
The polypropylene (PP) screw-cap of the bottle and plug, made from low density polyethylene (LDPE), was produced in Denmark and transported to Sweden.

LDPE shrink-film and corrugated cardboard were used to distribute the final product. Labels, glue and ink were not included in the analysis.

- http://www.ciclodevida.ufsc.br/artigos/ciclodevida40



http://www.321energy.com/editorials/church/church040205.html



Optimism rom an Oil Major

The Exxon view