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British Institute of Energy Economics
Energy, Economics and Climate Change: An Actuarial View

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Chair, Research Committee for the IFoA's Resource and Environment Board

7 October 2015

My background

- >25 years working in non-life insurance
- Senior pricing actuary for the London direct insurance arm of a global reinsurance company
- Interest in climate change came from pricing insurance business affected by changes in weather related risk
- Chair of the research committee for the IFoA's Resource and Environment Board

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My background

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Energy, Economics and Climate Change: An Actuarial View

1. **The actuarial profession; a short introduction**
2. Energy and the industrial revolution
3. “The greatest shortcoming of the human race”
4. Climate change risk
5. Thermodynamics and economics
6. Thermodynamic limits?

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History of the Actuarial Profession

- 1762 First life insurance company with scientifically calculated premium rates.
- The actuarial profession began at the same time and place as the industrial revolution.
- 19th-20th centuries – massive growth in life assurance and pensions, where most actuaries still work today
- 1960s onwards - Actuaries start to work in general insurance, finance and risk management

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Thanks to David Raymont, IFoA librarian, for information on actuarial history

My role – pricing insurance risk

World Trade Center 9th Sept 2001

Two of the largest ever insurance losses:

Hurricane Katrina, August 2005

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What actuaries do:

- Forecasting the future – sometimes long term
- Model building
- Risk management
- Always try to eliminate bias (“Making actuaries less human”)

- In 2013 Resource & Environment Board was founded, to investigate climate change and other “finite Earth” issues

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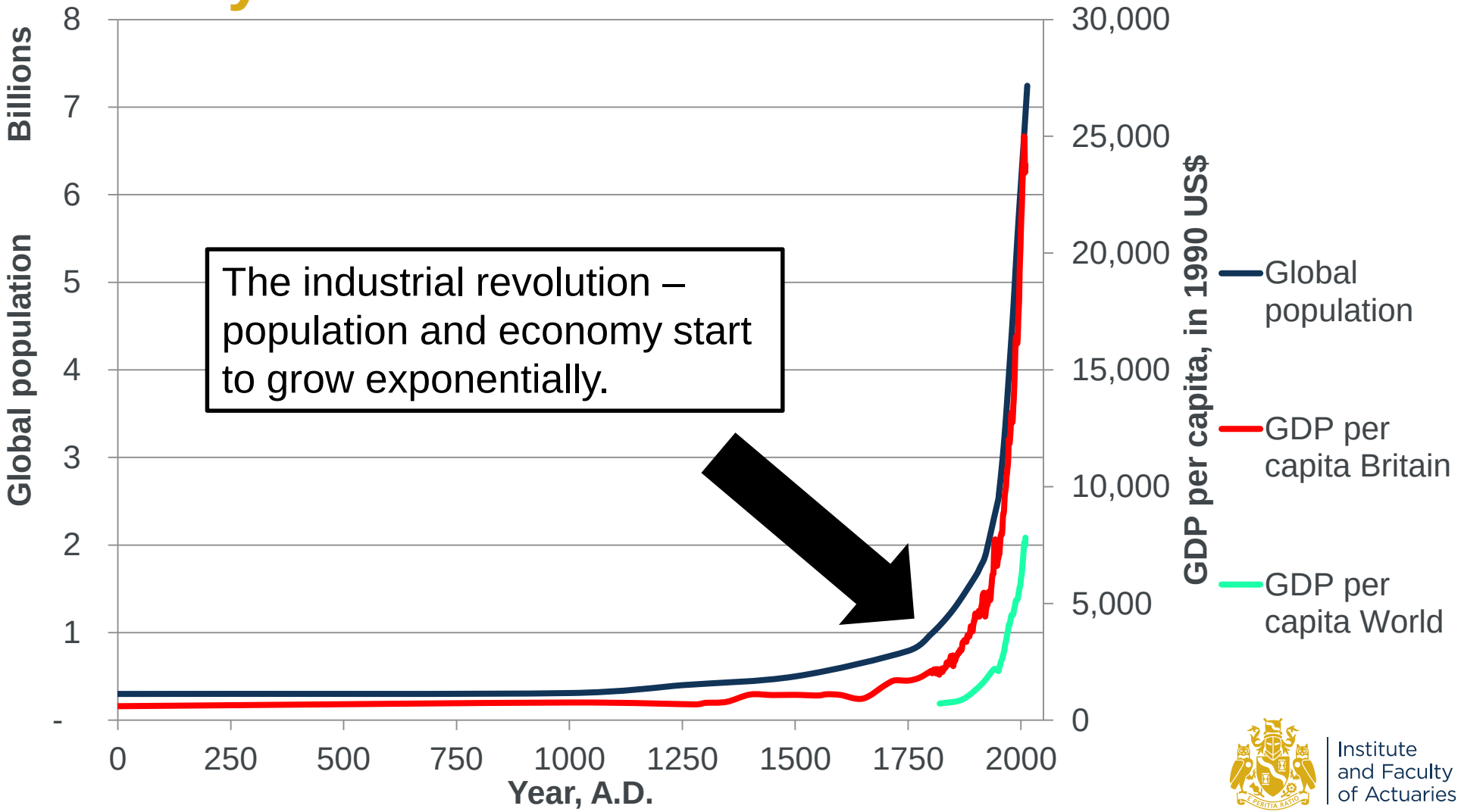
History of the Industrial Revolution



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GDP data from Maddison, Population data from United Nations

Why did the industrial revolution start in 18th century England?

- Late 18th century economists e.g. Adam Smith would have considered as absurd the notion that economy could grow by fixed % per year.
- Why didn't economic growth stop, as in all previous societies?

Refer: Wrigley, E. A. (2010), *Energy and the English Industrial Revolution*, Cambridge University Press, Cambridge, UK By Wrigley, E. A. (2010), Professor of Economic History at Cambridge University and President of the British Academy 1997-2001.

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Fossil fuels allowed humanity to escape the photosynthetic limits of the land

The key was fossil fuel energy – 18th century England had easily accessible coal deposits, used since Tudor times.

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Energy is the “master resource”

Road transport

Aviation

Heating and lighting

Construction

Mining

Agriculture

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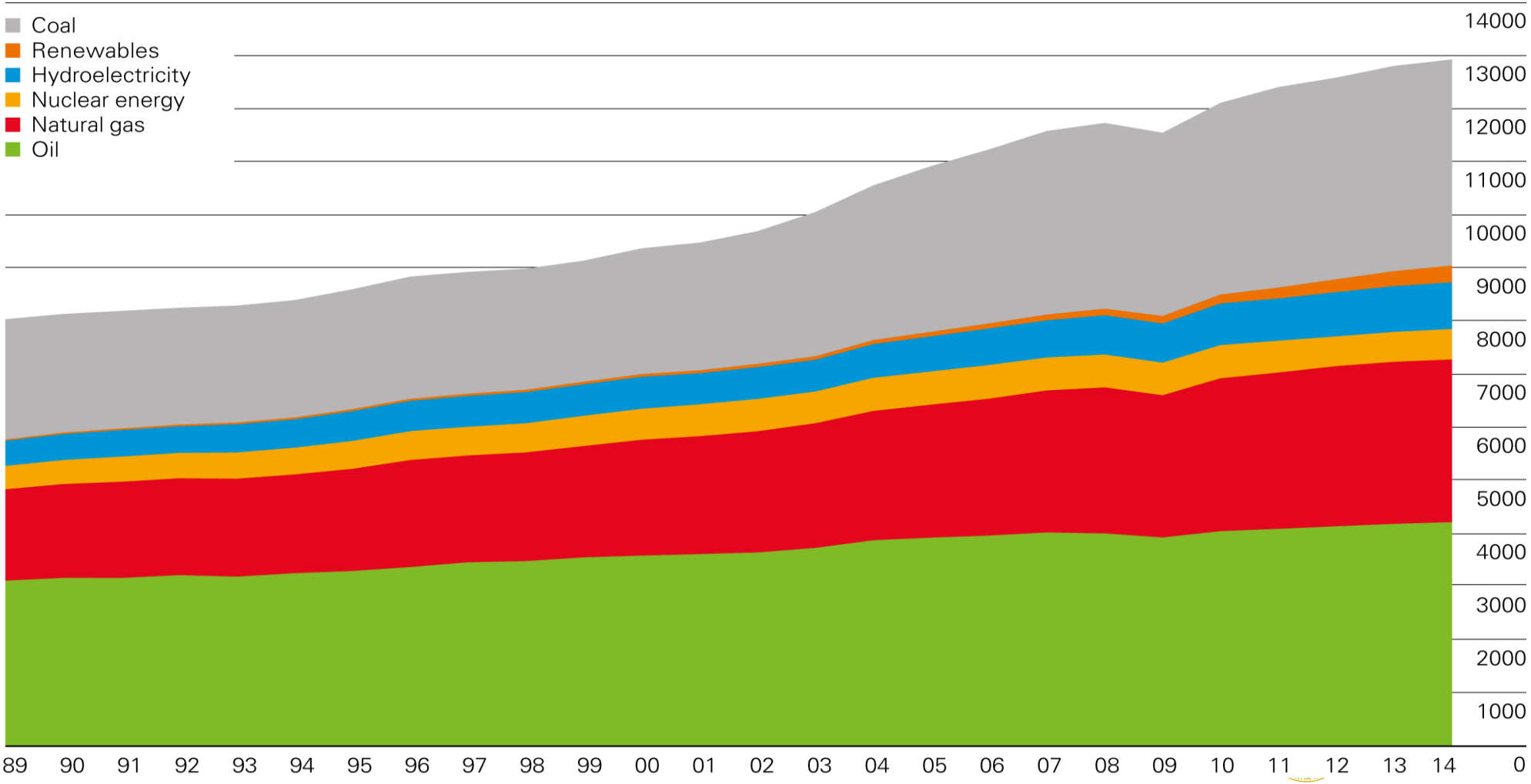
Most of the world's energy still comes from fossil fuels

Primary energy world consumption, Million tonnes oil equivalent



BP Statistical Review of World Energy 2015, © BP p.l.c. 2015

Why are Fossil Fuels so Useful?

- Fossil fuel is very energy dense
- Oil is particularly useful as it is liquid – easy to transport
- Energy content of 1 barrel of oil = manual labour of 30 people for 1 month.

“Energy Slaves”

- UK citizens use energy for the equivalent of c.70 “energy slaves”
- Energy allows our economy to grow exponentially

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* Refer: www.withouthotair.com - David MacKay, ‘Sustainable Energy Without Hot Air’

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The greatest shortcoming of the human race

"The greatest shortcoming of the human race is our inability to understand the exponential function"

– Professor Albert Bartlett, Colorado University

Rule of thumb for doubling time

- Approx. doubling time = 70/(Growth Rate in %) [Because 70 ≈ 100*ln(2)]
- 3% p.a. growth ⇒ doubling time of 70/3 = 23 years
- 7% p.a. growth ⇒ doubling time of 70/7 = 10 years

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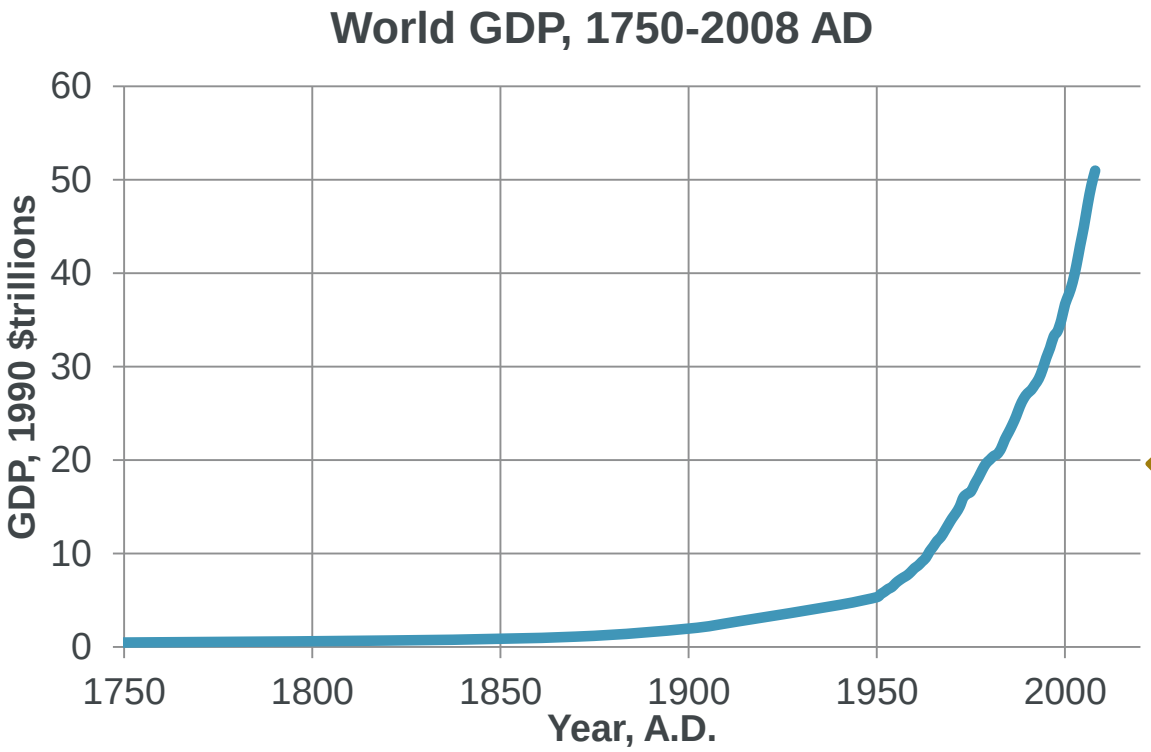
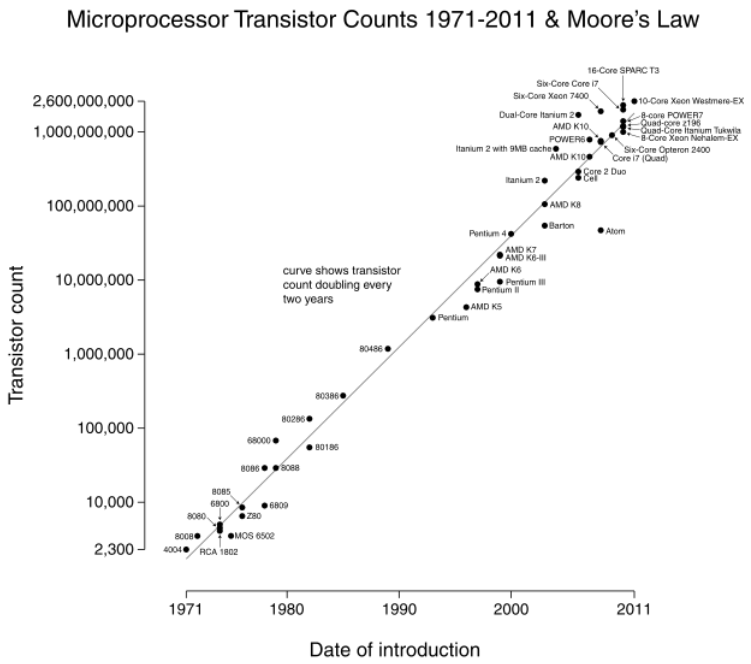
Source: http://www.albartlett.org

Exponential Growth



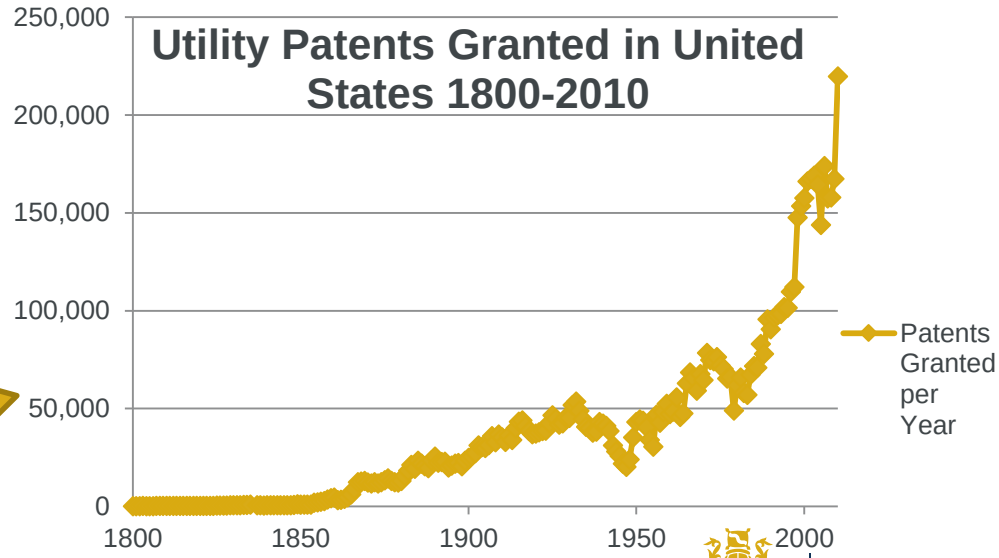
- In real terms world GDP has grown at average rate of c.3% per year in recent decades = doubling time 23 years.
- 2015 to 2100 is almost 4 doubling periods.
- If 3% growth continues, world economy would grow 14 times as large in 2100 as it is now.

Exponential Growth in Knowledge



Moore's Law

The number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years.



Intellectual Property

No. of patents granted illustrates the explosive growth in human knowledge.

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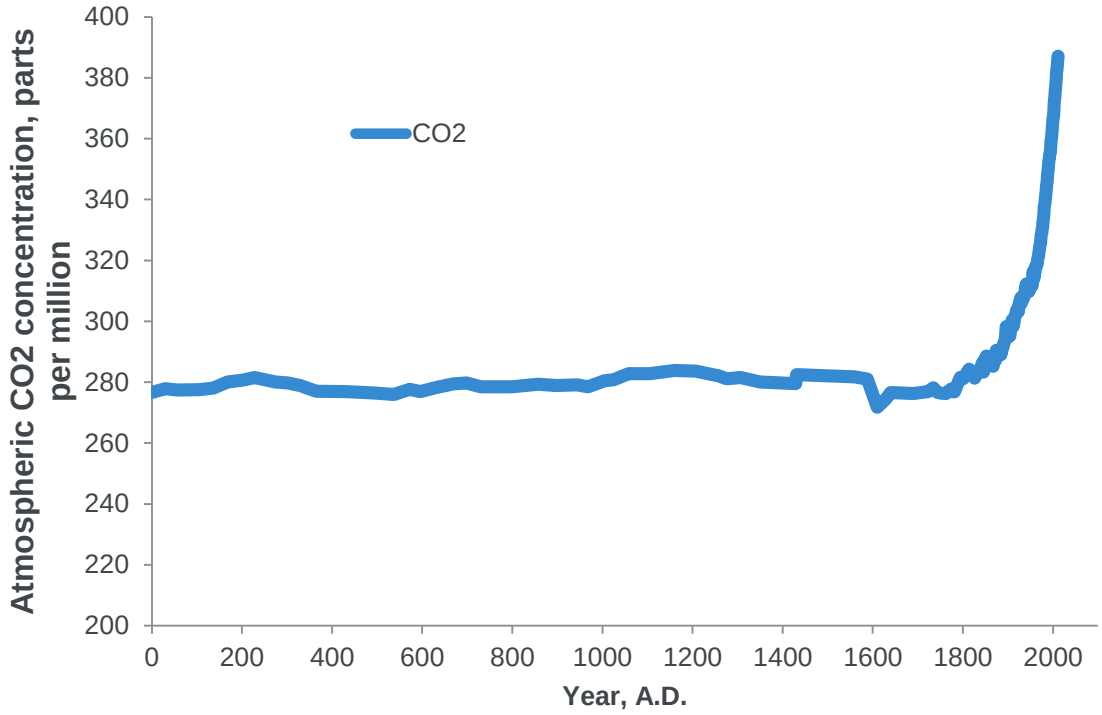
“Goods” and “Bads” are both growing exponentially

Carbon Dioxide

Exponential growth of the economy has driven exponential growth of carbon emissions



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Source: Scripps Institution of Oceanography (SIO) CO2 Program http://scrippsco2.ucsd.edu R. F. Keeling, S. C. Piper, A. F. Bollenbacher and S. J. Walker

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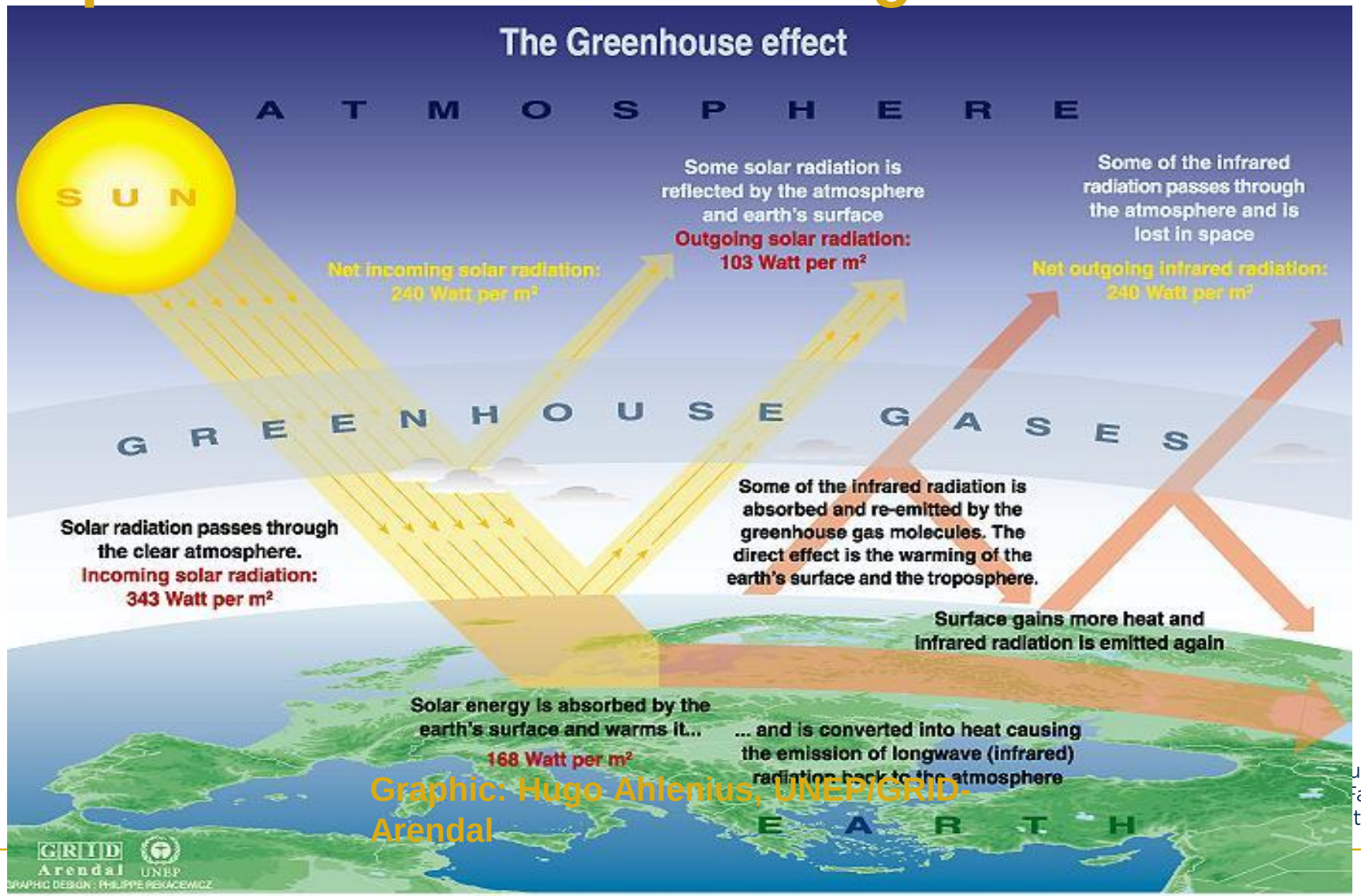
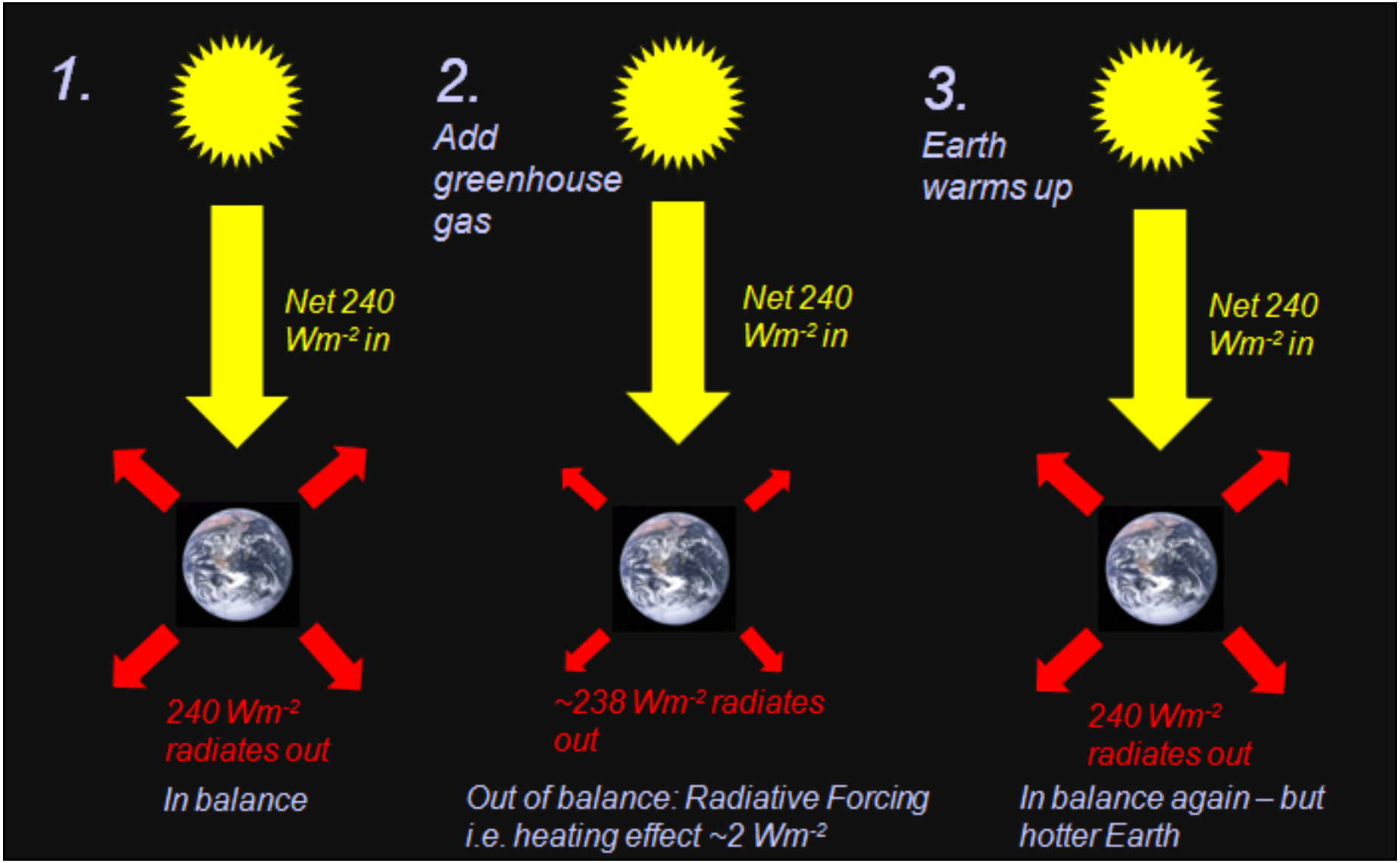
The natural greenhouse effect
Keeps the Earth from freezing



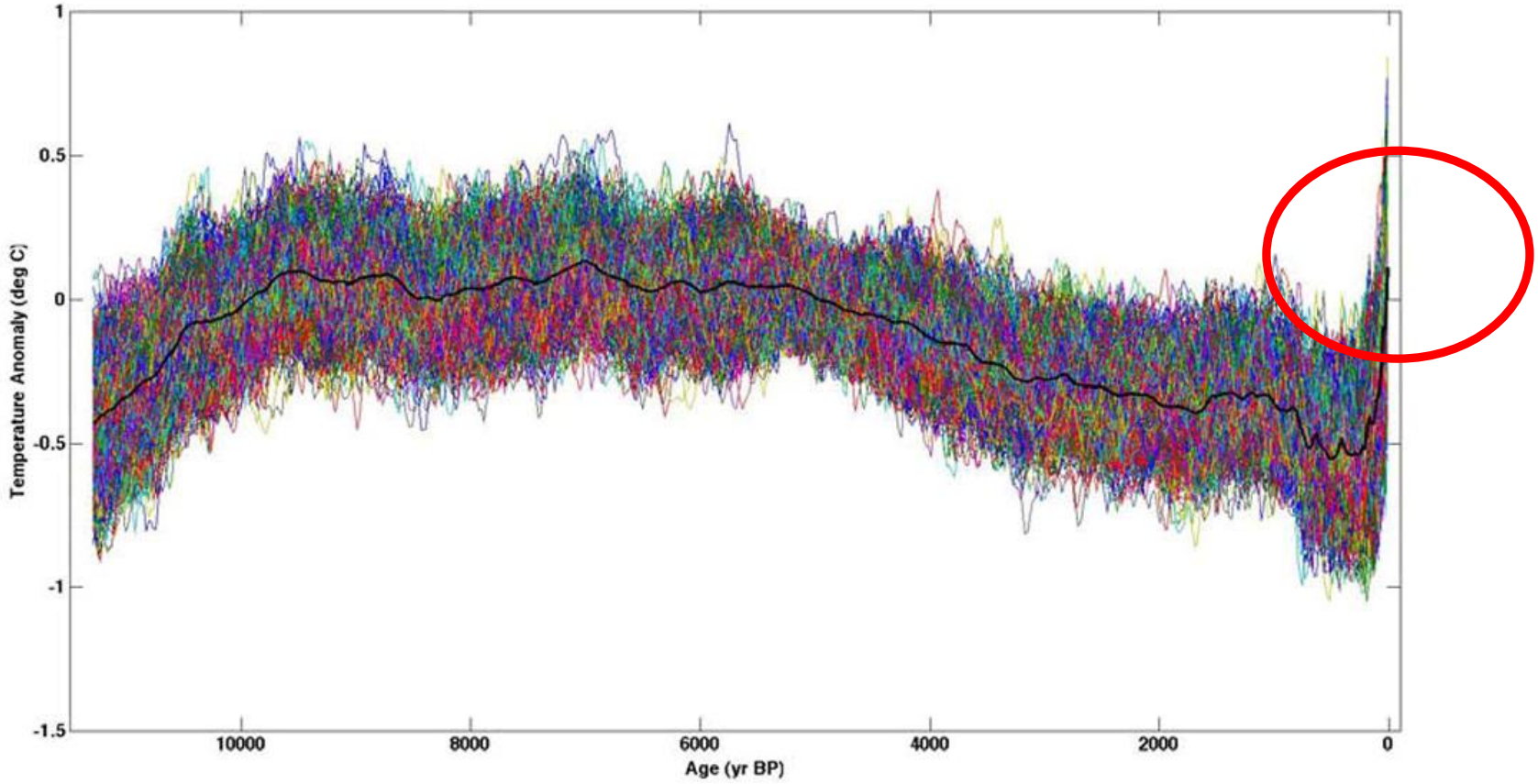
Graphic: Hugo Ahlenius, UNEP/GRID-Arendal

Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Simplified man-made climate change



Climate change
Global temperature for last 11,000 years



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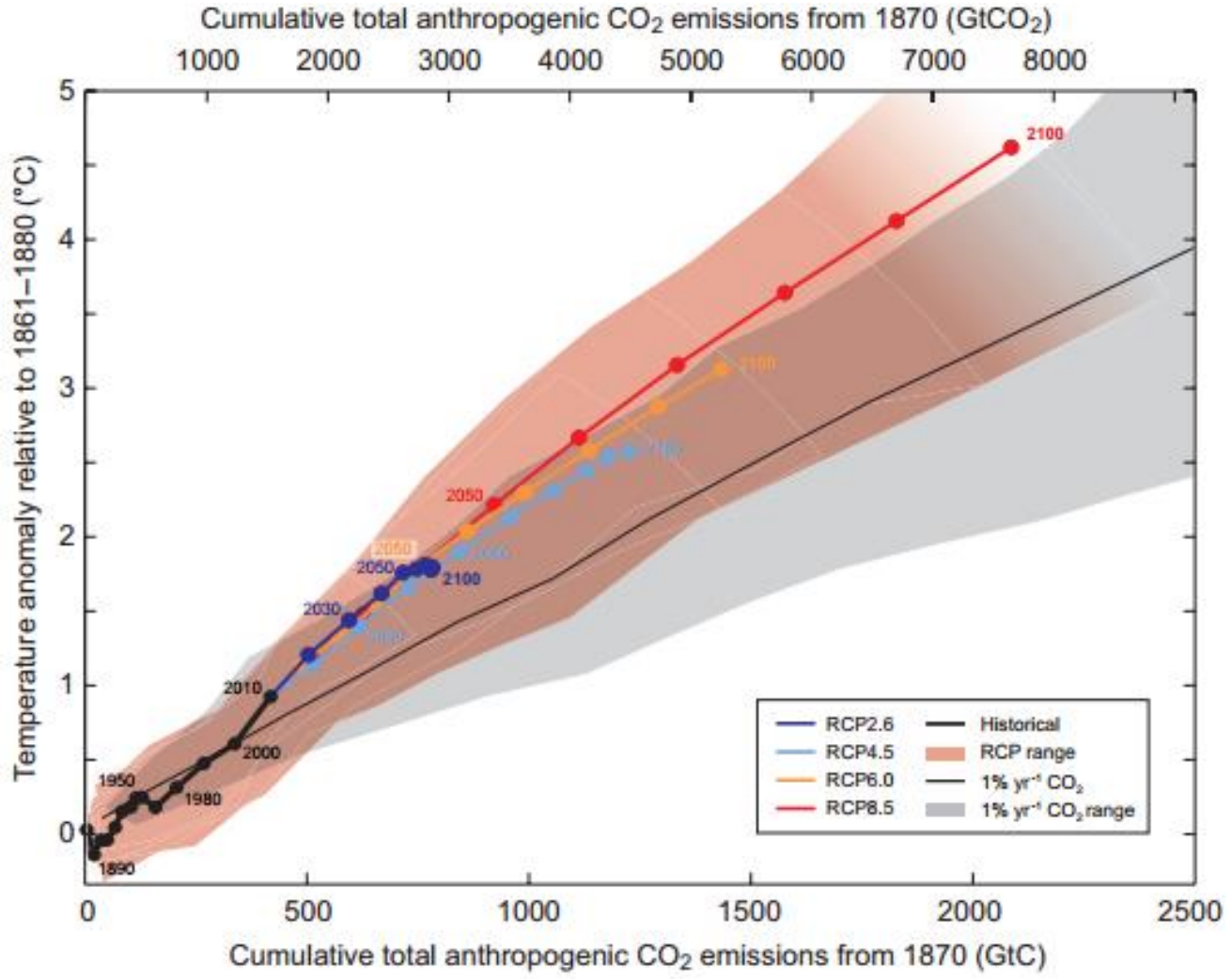
http://www.sciencemag.org/content/339/6124/1198

DOI: 10.1126/science.1228026 A Reconstruction of Regional and Global Temperature for the Past 11,300 Years, Shaun A. Marcott, Jeremy D. Shakun, Peter U. Clark, Alan C. Mix

IPCC 5th Assessment Report – Climate change forecasts to 2100



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Scientists are sounding a warning

Planet Under Pressure 2012 was the largest scientific conference leading up to the United Nations Conference on Sustainable Development (Rio+20), with over 3000 delegates.

State of the Planet Declaration:

- "1. Research now demonstrates that the continued functioning of the Earth system as it has supported the well-being of human civilization in recent centuries is at risk…"

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See: http://www.planetunderpressure2012.net/

The Economist on the Anthropocene Age

"Welcome to the Anthropocene",

- Humans are reshaping the planet on a geological scale
- Moment of realisation, like Copernicus grasping that the Earth revolves around the sun.
- "It would be odd not to be worried."

The Economist, May 2011

"You maniacs! You blew it up!"

Source: The Economist – 26 May 2011 http://www.economist.com/node/18744401

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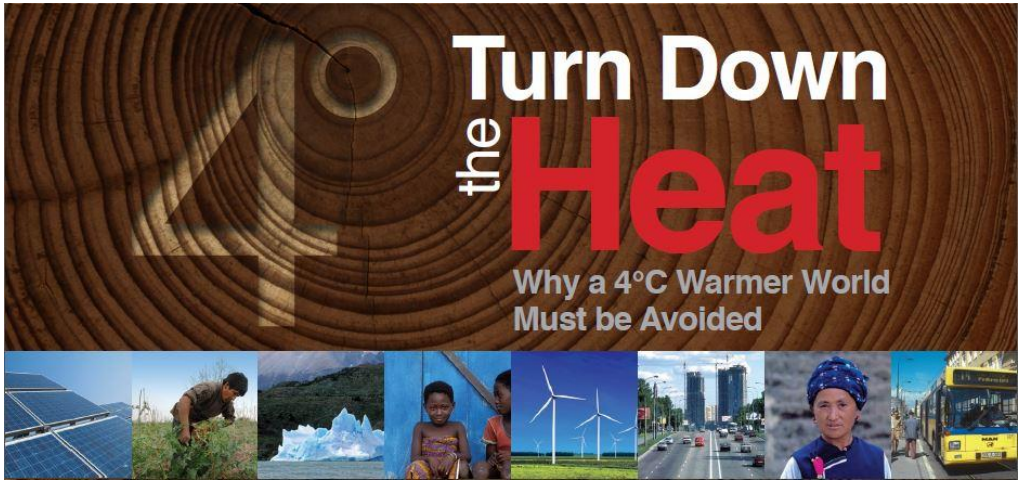
Report for the World Bank (2012)
Effect of 4°C global average temperature rise



- Possible large-scale displacement of populations.
- Risk of nonlinear tipping elements in the Earth system e.g. disintegration of West Antarctic ice sheet.
- “there is no certainty that adaptation to a 4°C world is possible.”

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Source:http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

What is the risk from climate change?

- Carrying on “Business as usual” is not a risk, by any normal meaning of the word.
- BAU gives probability of catastrophe >50%

There is a risk that climate change is a more serious problem than the IPCC best estimates

- Risk that sensitivity of the climate to greenhouse gas is high
- Risk that the global carbon budget is already negative
- Risk that every kg of CO_2 emitted from now on will have to be removed from the air

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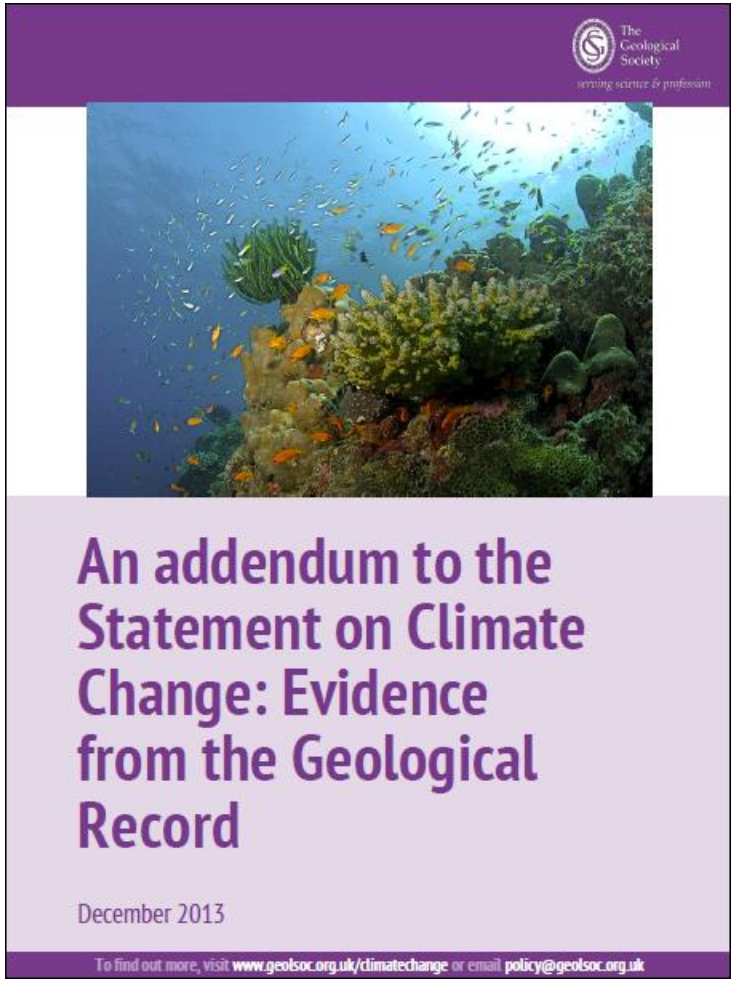
Risk of higher sensitivity to greenhouse gas



Summary

Since our original 2010 statement, new climate data from the geological record have arisen which strengthen the statement's original conclusion that CO_2 is a major modifier of the climate system, and that human activities are responsible for recent warming.

Palaeoclimate records are now being used widely to test the validity of computer climate models used to predict climate change. Palaeoclimate models can simulate the large-scale gradients of past change, but tend not to accurately reproduce fine-scale spatial patterns. They also have a tendency to underestimate the magnitude of past changes. Nevertheless they are proving to be increasingly useful tools to aid thinking about the nature and extent of past change, by providing a global picture where palaeoclimate data are geographically limited.

Geologists have recently contributed to improved estimates of climate sensitivity (defined as the increase in global mean temperature resulting from a doubling in atmospheric CO_2 levels). Studies of the Last Glacial Maximum (about 20,000 years ago) suggest that the climate sensitivity, based on rapidly acting factors like snow melt, ice melt and the behaviour of clouds and water vapour, lies in the range 1.5°C to 6.4°C. Recent research has given rise to the concept of 'Earth System sensitivity', which also takes account of slow acting factors like the decay of large ice sheets and the operation of the full carbon cycle, to estimate the full sensitivity of the Earth System to a doubling of CO_2. It is estimated that this could be double the climate sensitivity.

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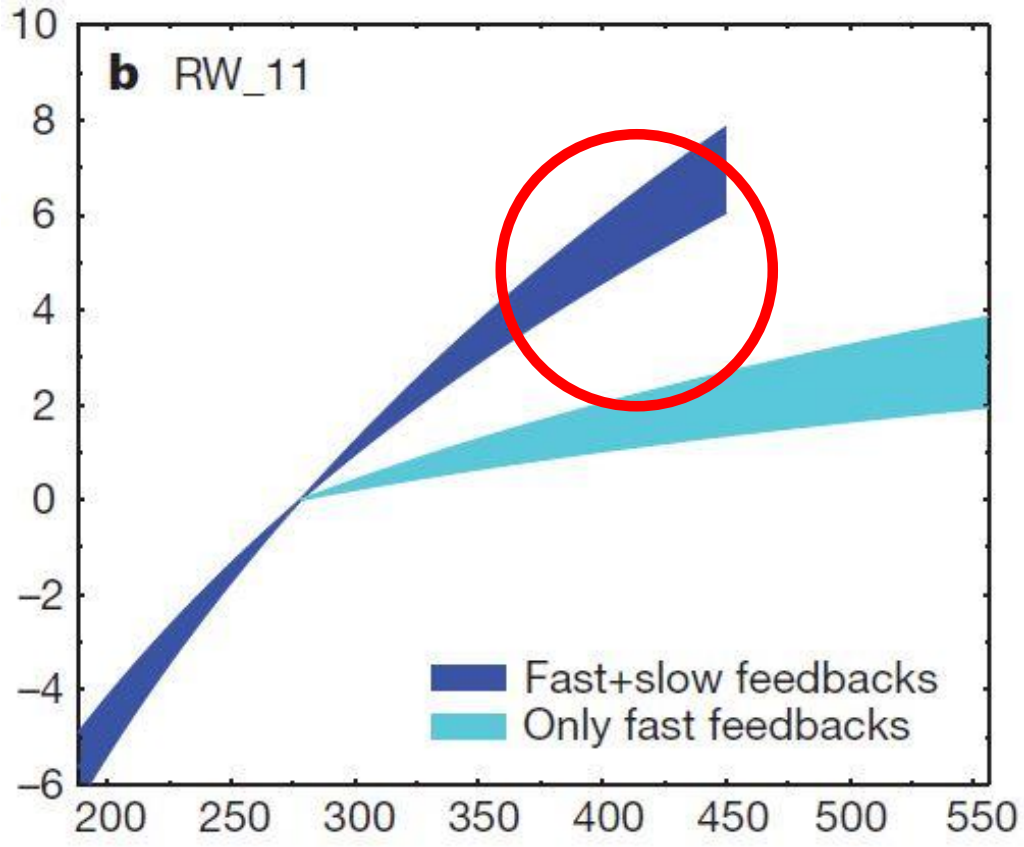
Slow climate feedbacks may lead to higher warming, in the long term



- There is evidence that long term changes e.g. to ice sheets and vegetation, leads to higher climate sensitivity in the long term

"Earth System Sensitivity" > "Climate Sensitivity"

Source: Nature 2012 doi:10.1038/nature11574 PALEOSENS project members

Also see http://www.climatenewsnetwork.net/2013/12/earth-may-be-doubly-sensitive-to-co2/

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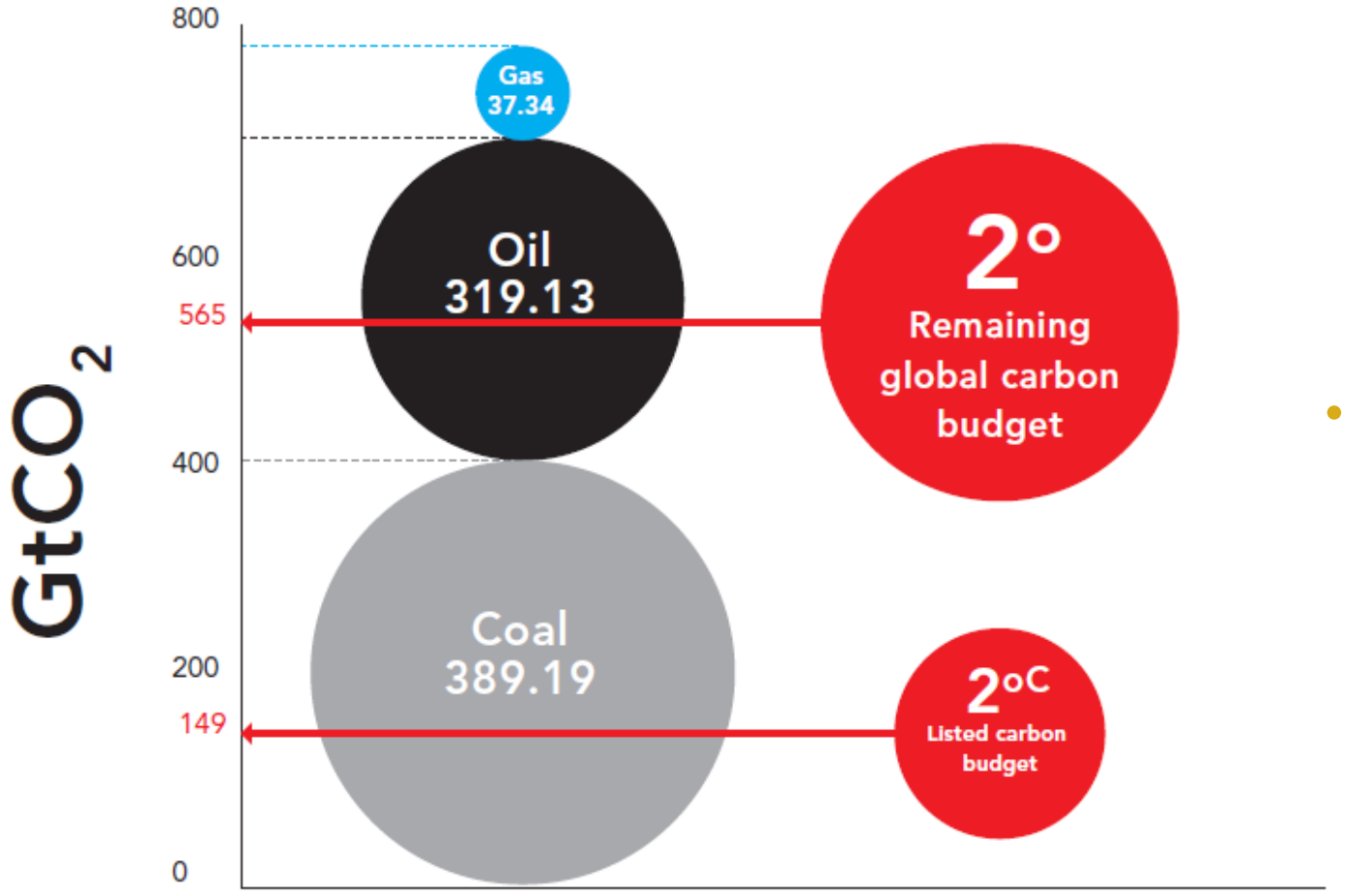
Risk of Stranded Carbon Assets/ “Carbon Bubble”



- Many fossil fuel companies are valued assuming all resources will be extracted and consumed
- Consumption of proven fossil fuel reserves in top 100 quoted companies gives more than safe emissions.

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Source: http://www.carbontracker.org/carbonbubble

Can we learn from other risks?

Sometimes society is slow to fully recognise risks. E.g.:

1. Tobacco

- Link to lung cancer was proved in the 1950s.
- Societal attitudes changed, but slowly.
- More than half a century later, laws are still changing.

2. Asbestos

- Health hazard was proved from the mid-1960s at latest.
- Asbestos continued to be used.
- “Wilful Blindness” by Margaret Heffernan.

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John Maynard Keynes on Economics

"The ideas of economists and political philosophers, both when they are right and when they are wrong are more powerful than is commonly understood. Indeed, the world is ruled by little else."

JM Keynes

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Climate Change, Energy and Economics

- Fossil fuel energy drives exponential growth of the economy
- The same exponential growth drives climate change
- So far, technology is not fixing climate change
- We need economics to tell us how to get sustainable economies
- Therefore, understanding energy and economics must be necessary conditions for solutions to climate change
- But, the history of traditional economics suggests that thermodynamics was not fully included in its development

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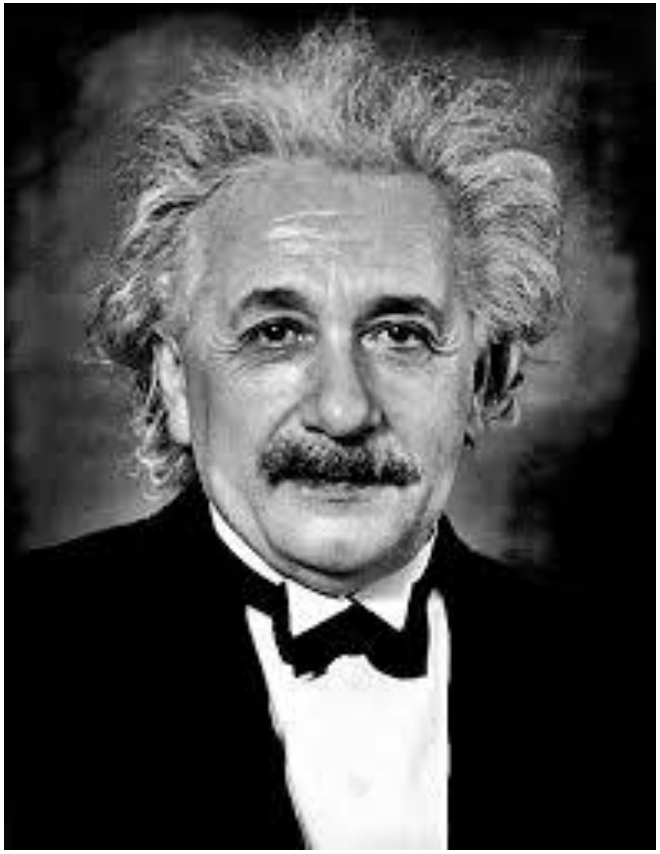
Thermodynamics

Albert Einstein on thermodynamics

- “It is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts.”



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The Laws of Thermodynamics

- Thermodynamics is so named because it relates motion, dynamics, to heat

1st Law of Thermodynamics

Conservation of energy

Energy cannot be created or destroyed.

"You cannot win"

Perpetual motion machines are impossible

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The Laws of Thermodynamics

2nd Law of Thermodynamics

The entropy [disorder] of the universe increases in the course of any spontaneous change

Heat will not pass spontaneously from a body at low temperature to one at high temperature

"You cannot break even"

"Heat won't pass from a cooler to a hotter

You can try it if you like but you far better notter",

Flanders and Swann ("First and Second Law", see on YouTube)

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2nd Law of Thermodynamics = The Arrow of Time

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Thermodynamics - Useful work comes only with temperature gradient

Energy is needed to prevent order going to disorder

Entropy in chemistry, G = H -TS

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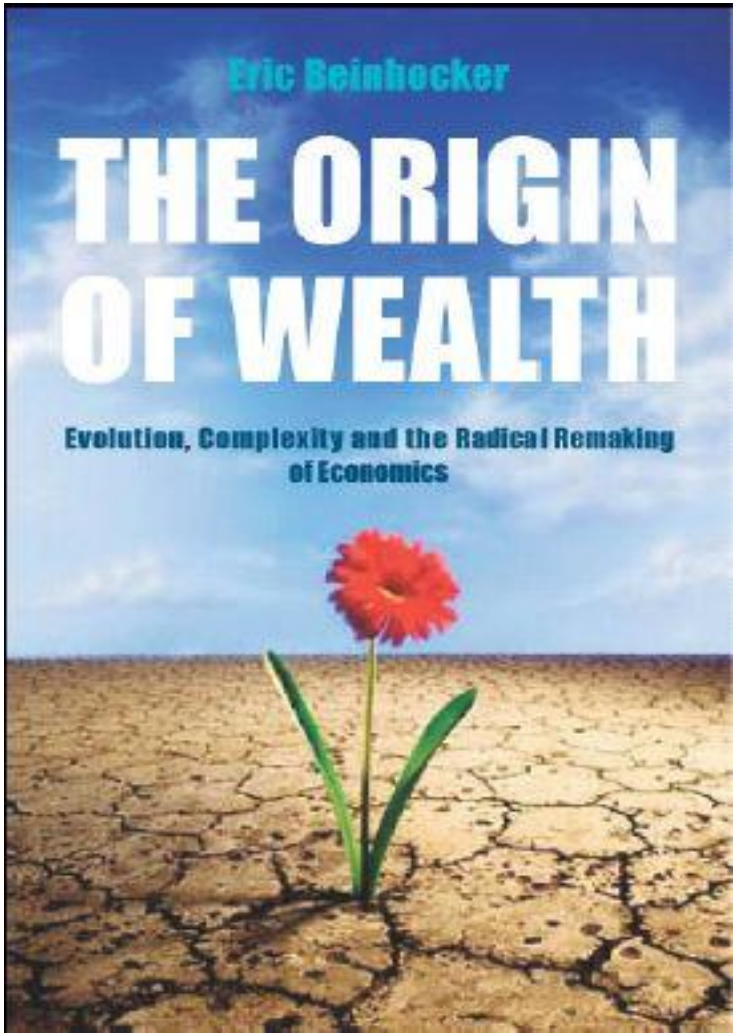
Development of Traditional (neo-classical) economics



- 19th century economists wanted to make economics more scientific
- They borrowed from the physics of the time to mathematise economics
- Assumed the economy is an equilibrium system
- Used the 1st law of thermodynamics, but the 2nd law had not yet been discovered

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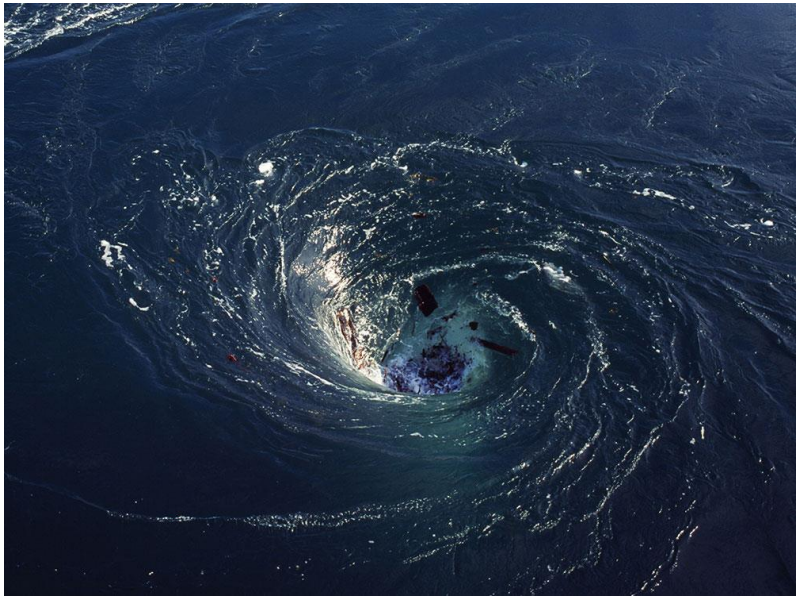
"The Origin of Wealth", by Eric Beinhocker, Random House Business, 5 April 2007

The economy is a complex adaptive system

- The economy is an open system of a special kind – a complex adaptive system.
- Contrary to assumptions often made, the economy is never in equilibrium, it is not an equilibrium system.



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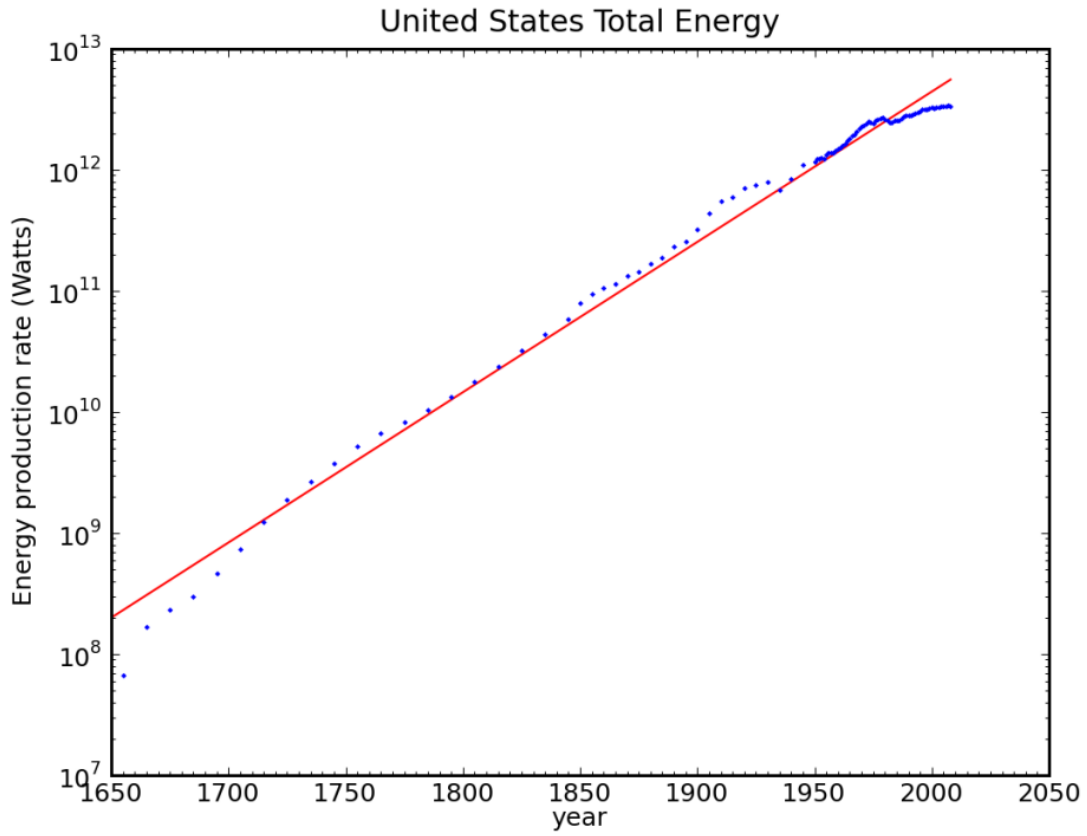
Exponential Growth meets thermodynamic limits - “Galactic Scale Energy”



Observed Growth:
Best fit 2.9% annual growth in energy used since 1650.

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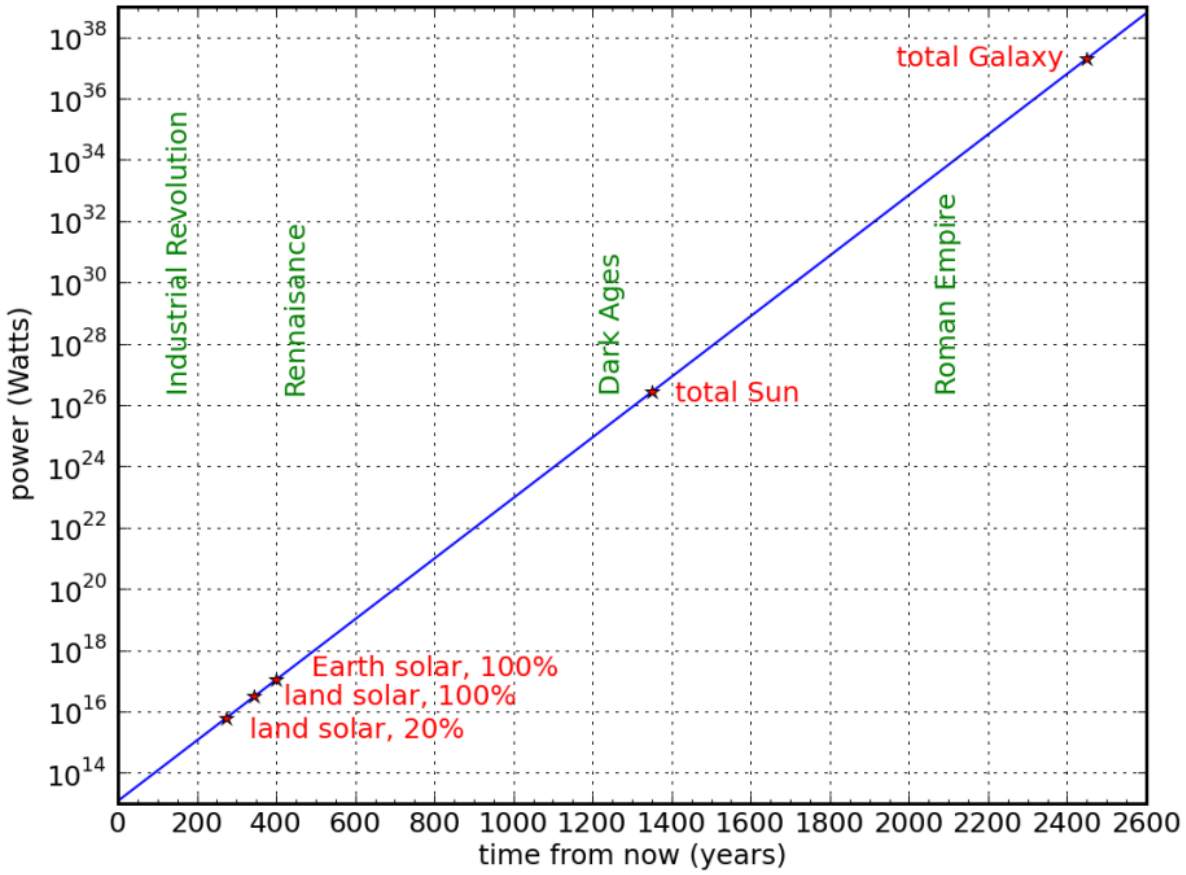
By Tom Murphy http://physics.ucsd.edu/do-the-math/2011/07/galactic-scale-energy/

“Galactic Scale Energy”
Global Energy growth – projections



Assumption:
2.3% annual growth in global energy.
Leads to 10x growth every 100 years.

Outcome:
Clearly absurd outcomes after just a few hundred years

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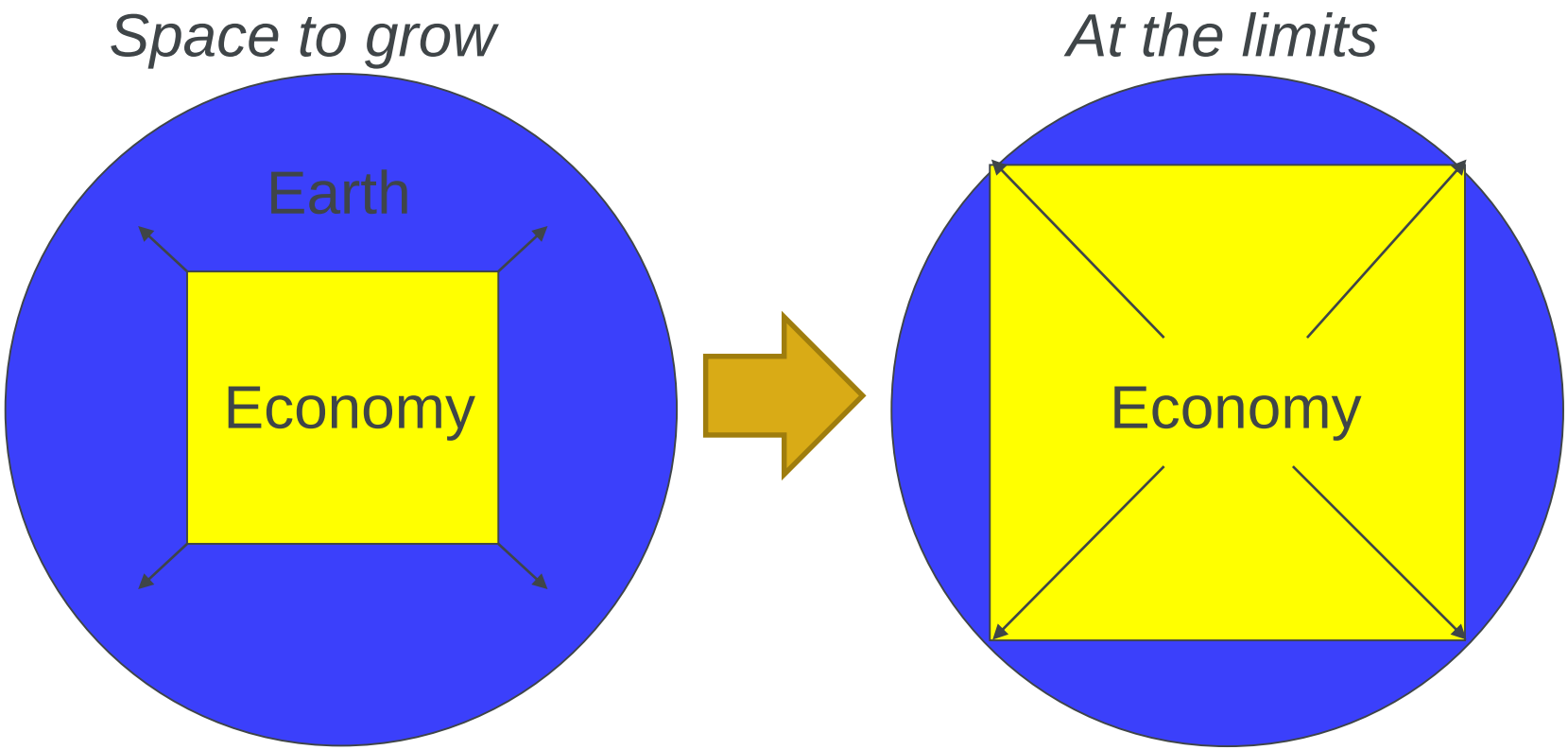
Could we reach physical limits to growth in the 21st century?



(adapted from Clapp and Dauvergne 2005: p.101)

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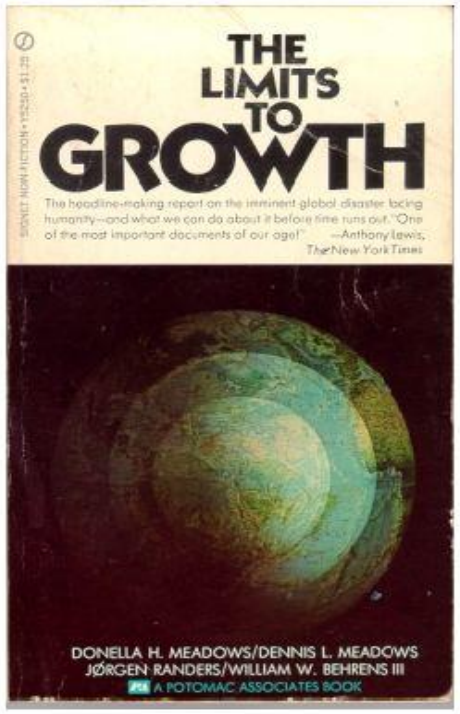
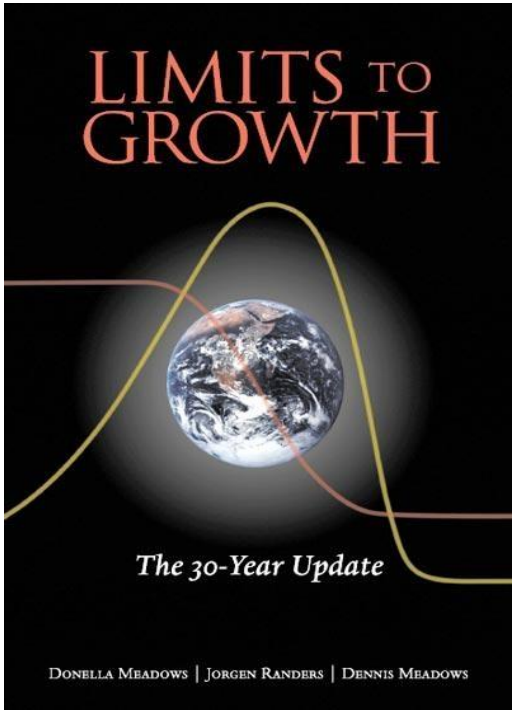
Time to revisit the “limits to growth”?



The original 1972 study was updated in 2004 Investigation of the global economy as a complex system



Ecological economists investigate the economy as a complex system, incorporating thermodynamics.
E.g. Nicholas Georgescu-Roegen, Herman Daly

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Energy Return on Energy Invested (EROEI)

- Energy is a more fundamental unit than money
- It takes energy to extract fossil fuels
- The more energy to extract the fuel, the less is available for consumption
- Easily available sources have already been used up. EROEI is declining.
- If EROEI falls too low, this would be problematic

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Final Thoughts

- The true risk of climate change might not yet be fully appreciated by society
- Exponential growth accelerates change, (but people aren't good at thinking through the implications)
- More focus on thermodynamics might make solutions to environmental problems easier

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Questions

Comments

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.

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