

Actuarial Teachers and Researchers Conference 2011
Oliver Bettis

**Risks to the economy arising from
constrained global energy supply**

14 July 2011

Risks to the economy arising from constrained global energy supply

Exponential Growth

- “The greatest shortcoming of the human race...”

Energy

- The importance of energy to the economy
- History of oil production
- Future prospects for oil

The Economy

- The IMF World Economic Outlook
- The level of indebtedness in Western economies
- We live in interesting times...

Risks and Opportunities for the Actuarial Profession

Exponential Growth

“The greatest shortcoming of the human race is our inability to understand the exponential function” – Professor Albert Bartlett

$$x(t) = x_0 e^{ti}$$

- The exponential function arises whenever a quantity grows or decays at a rate proportional to its current value.
- For example; compound interest.

Refer: <http://www.albartlett.org>

Exponential Growth - Doubling Time

- Doubling time
Approx. doubling time = $70 / (\text{Growth Rate in } \%)$
Reason: $70 \approx 100 * \ln(2)$
- Every time you hear a growth rate, think doubling time:
 - “Crime Doubled in a Decade!”
 - “Growth in GDP”

Exponential Growth – Resource Use

For a resource which is used up at a constantly increasing rate:

- In the time it takes to double the rate of use, the amount of resource used will be the same as the resource used in all prior doubling periods combined.
- This is not an intuitive result!

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Why did the industrial revolution start in England?

“Energy and the English Industrial Revolution”

By Sir Edward Anthony Wrigley:

- Professor of Economic History at Cambridge University
- President of the British Academy from 1997-2001.
- Answers question, “Why didn’t growth stop?”
- Fossil fuel allowed us to escape the limits of land.
- England had easily accessible coal deposits
- Adam Smith and David Ricardo would have considered as absurd the notion that economy could grow by fixed % per year.

The importance of energy to our economy



Road transport



Aviation



Heating and lighting



Construction



Mining

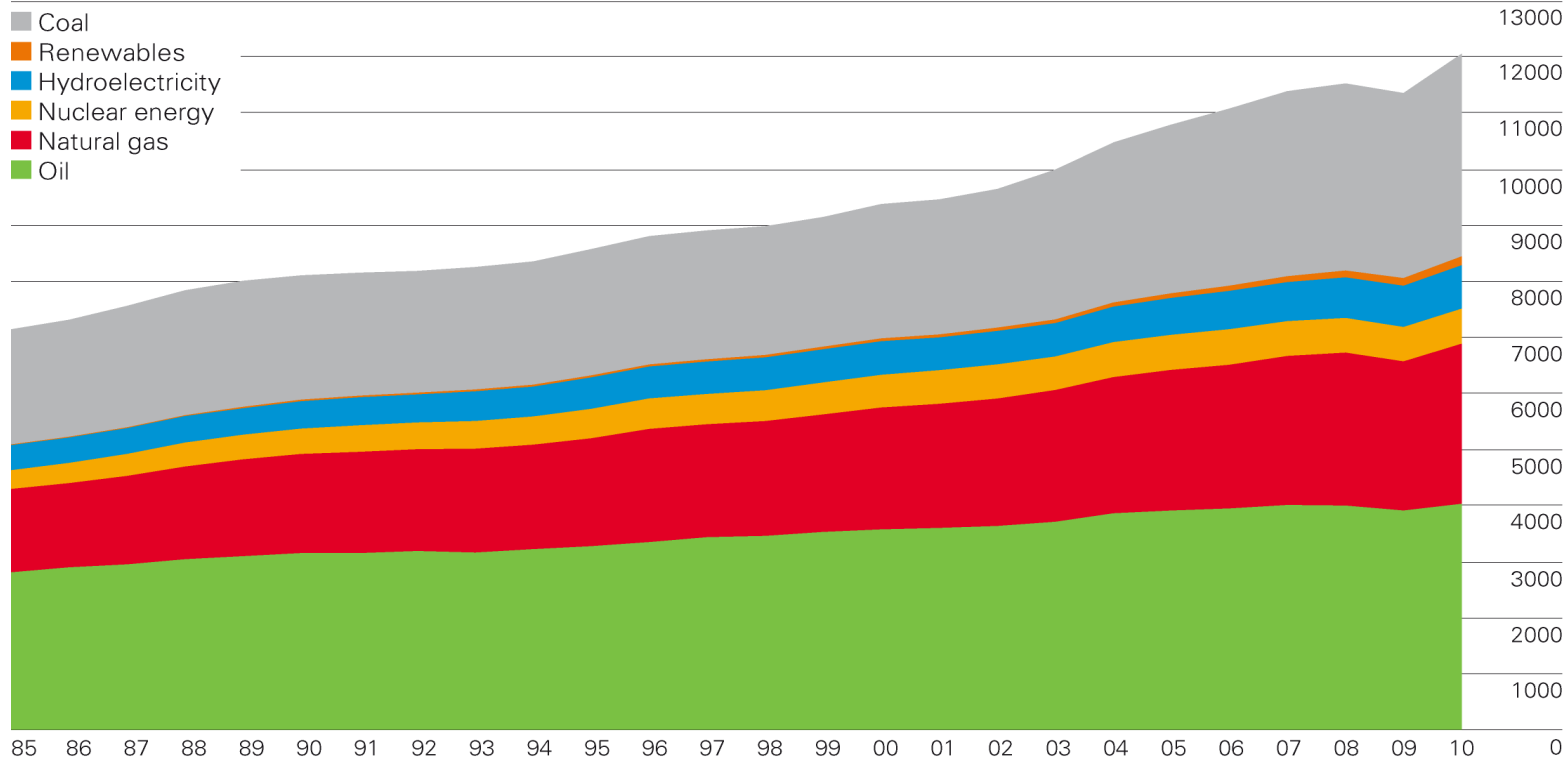


Food production

World primary energy consumption

World consumption

Million tonnes oil equivalent



World primary energy consumption grew by 5.6% in 2010, the strongest growth since 1973. Growth was above average for oil, natural gas, coal, nuclear, hydroelectricity, as well as for renewables in power generation. Oil remains the dominant fuel (33.6% of the global total) but has lost share for 11 consecutive years. The share of coal in total energy consumption continues to rise, and the share of natural gas was the highest on record.

- Our industrial civilization uses about 13 Tera Watts for machinery.

- Estimated net primary productivity of Earth's ecosystems $\approx 70\text{TW}$ on land*2.

Source: BP Statistical Review of World Energy 2011

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 energy consumption per person = 125kWh per day*¹ (= 5.2kW per person)
- 1 person produces ~ 75 Watts sustained power
- UK citizens have ~ 70 “energy slaves”

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

The Deepwater Horizon Oil Spill



Questions Raised by Deepwater Horizon

- Proximate cause of the oil spill was a blowout, with lax safety standards possibly a contributory factor.
- Why was the blowout so hard to plug?
- Deepwater Horizon rig was drilling through 1 mile of sea and 2 miles of rock.

Question:

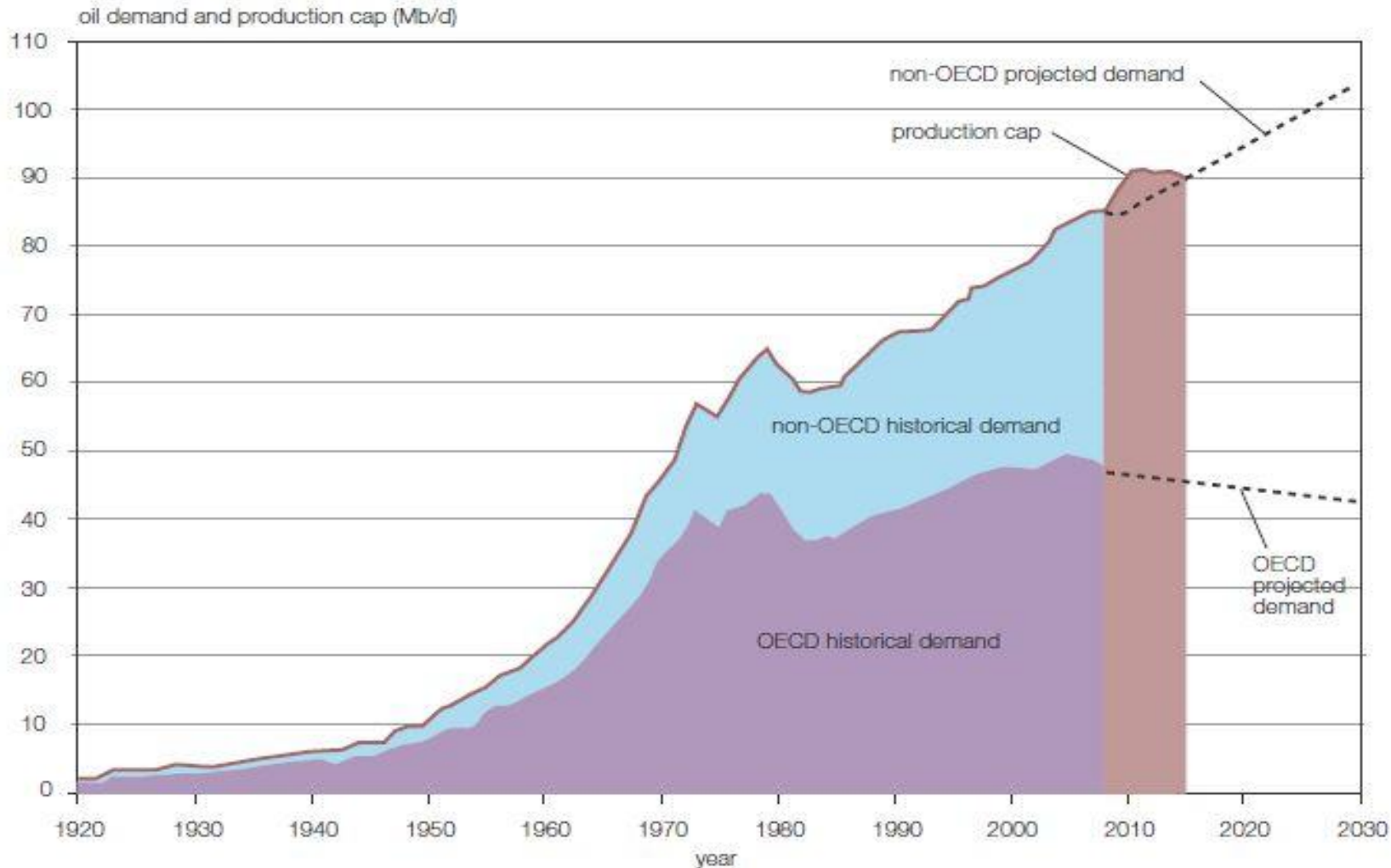
- Why drill in such extreme conditions?

Oil Discoveries versus Oil Production



“Discoveries of new deposits peaked as far back as the 1960s and 1970s. Now a number of countries in addition to the UK and the USA, for instance, have reached their production limits. The quantity of oil being pumped out of the earth exceeds new discoveries.”

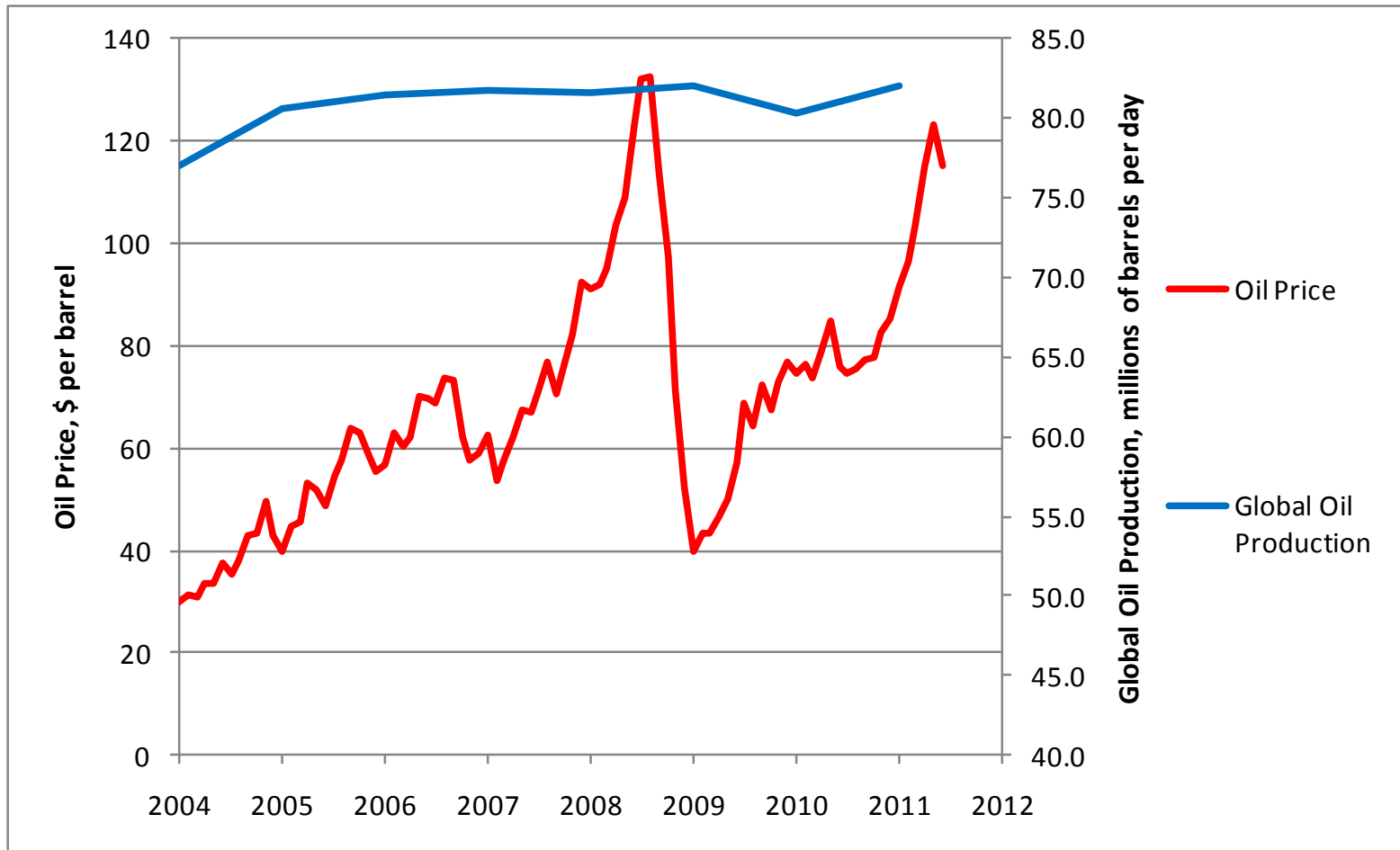
Global Oil Production Since 1920



From "The Oil Crunch"; Second report of the UK Industry Taskforce on Peak Oil & Energy Security (ITPOES) , February 2010 <http://peakoiltaskforce.net/>

Oil Price and Global Oil Production 2004-2012

Supply has not yet responded to price signal



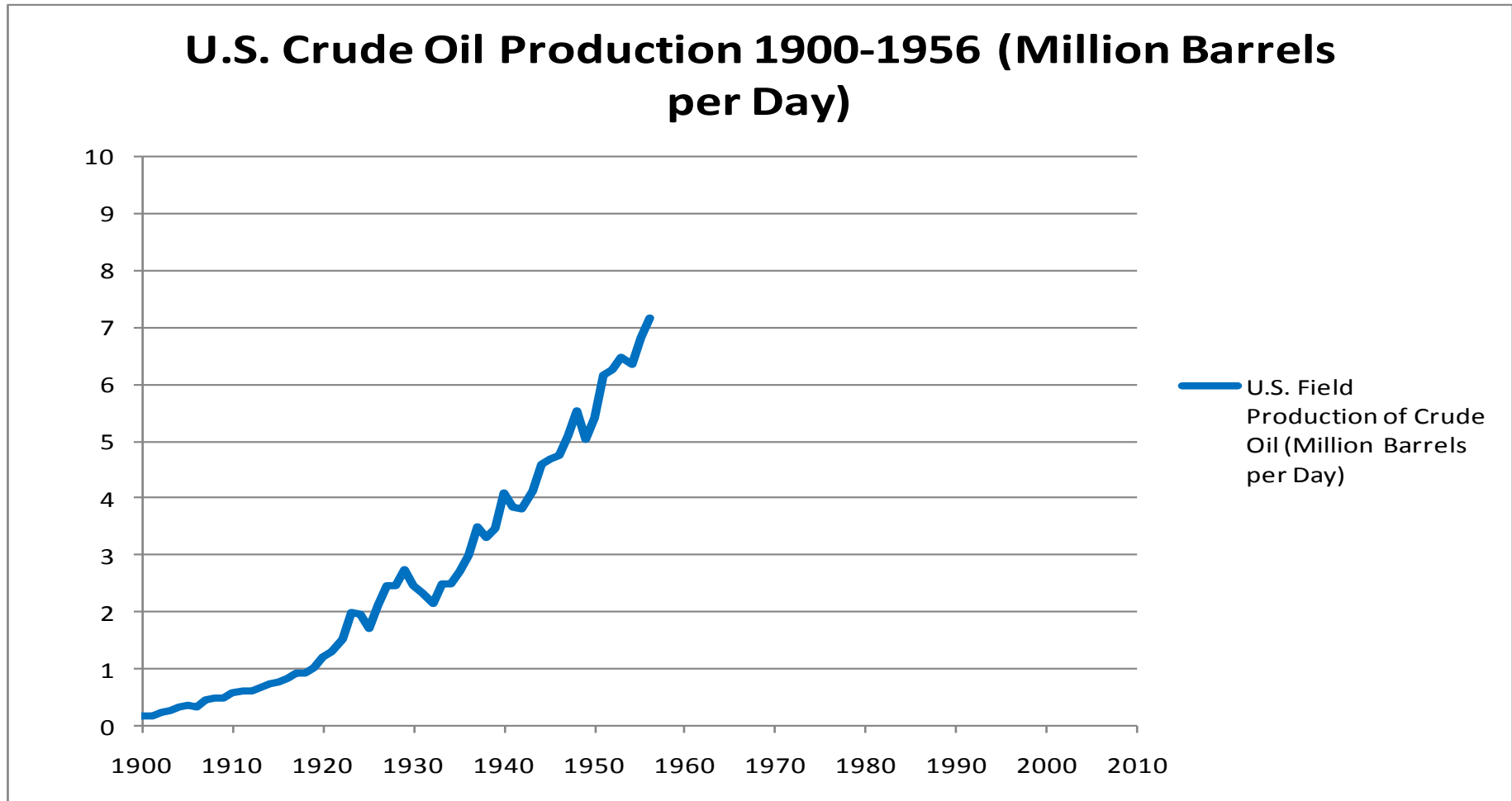
Sources: Oil Price – United States EIA <http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=m>

Oil Production: BP Statistical Review of World Energy 2011

<http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>

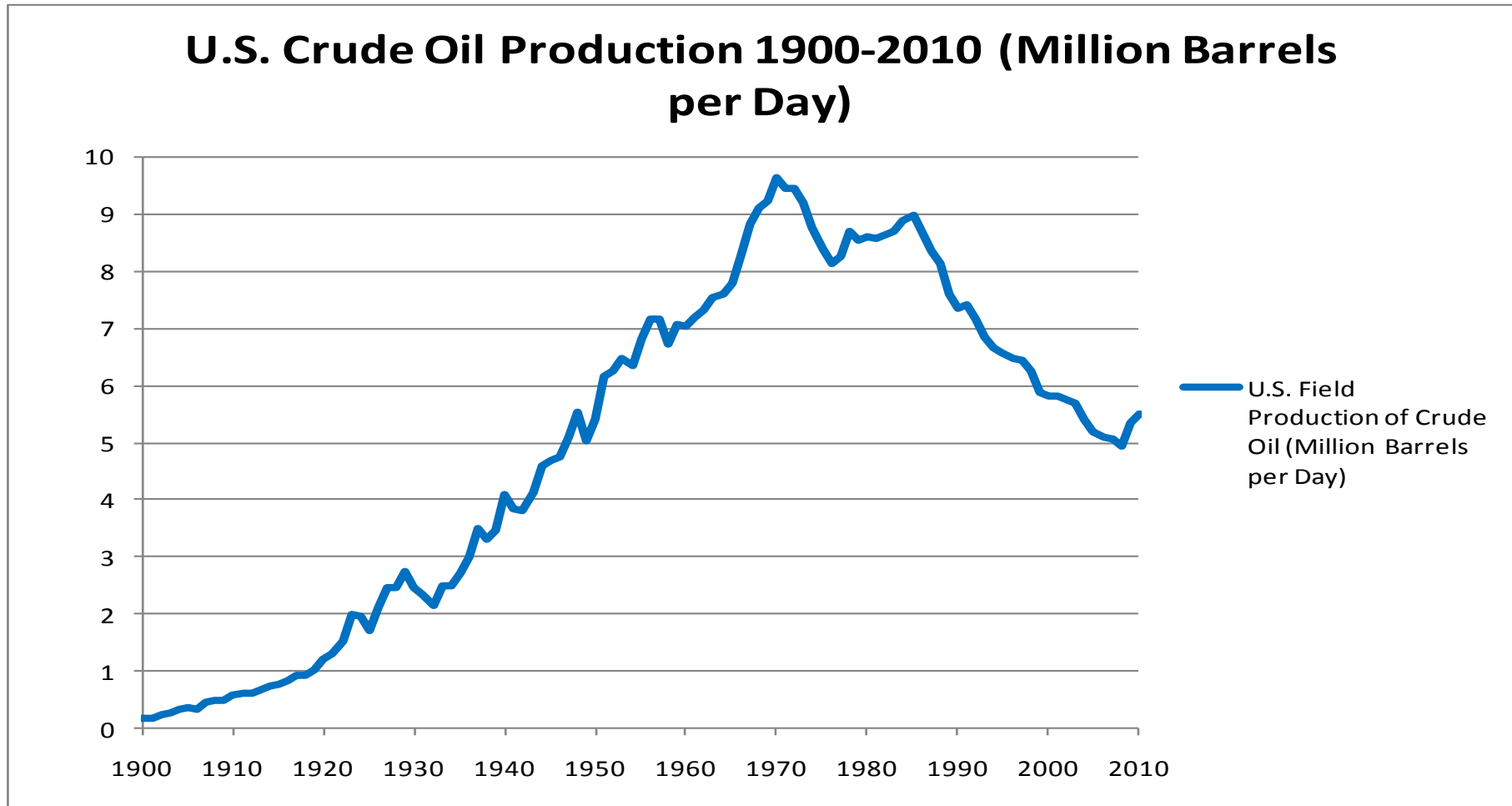
The history of one oil producing region

United States Oil Production 1900-1956



Source: United States Energy Information Agency

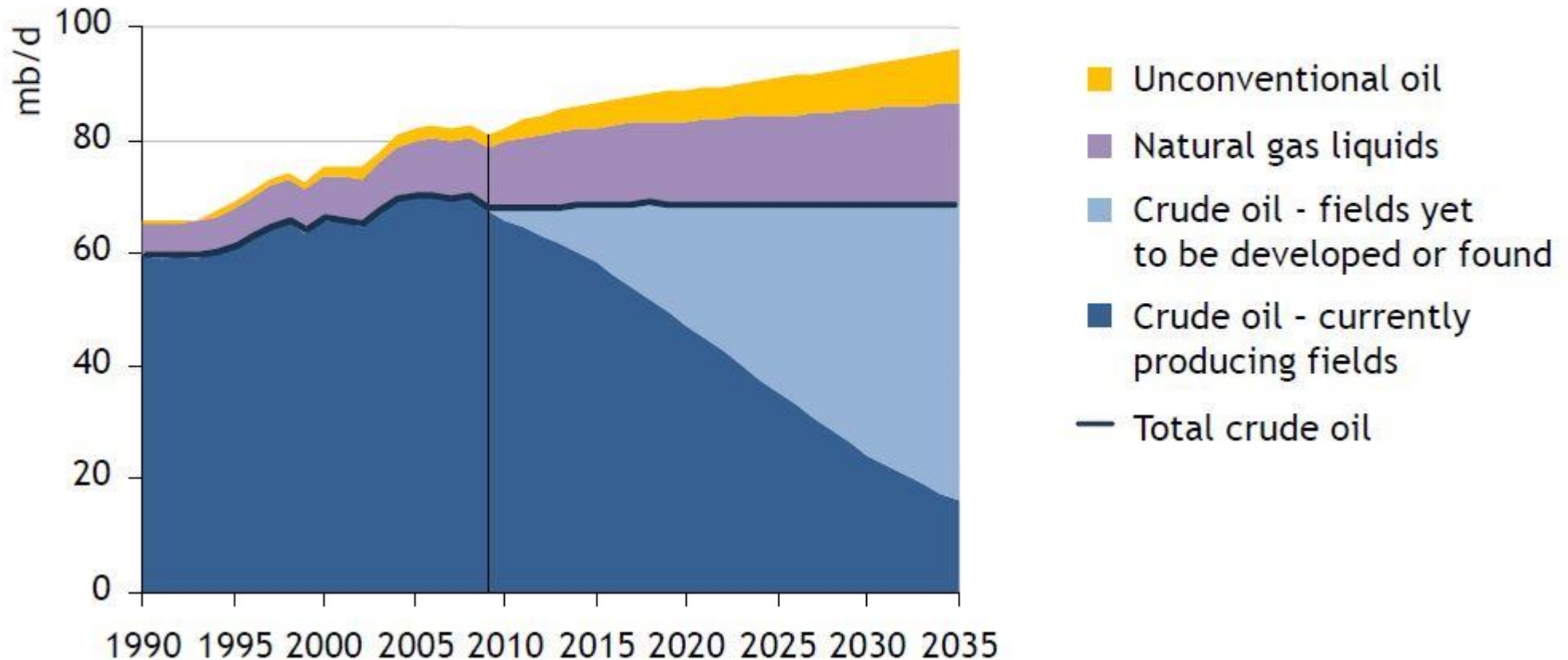
United States Oil Production 1990-2010



Source: United States Energy Information Agency

International Energy Agency World Energy Outlook (WEO) 2010

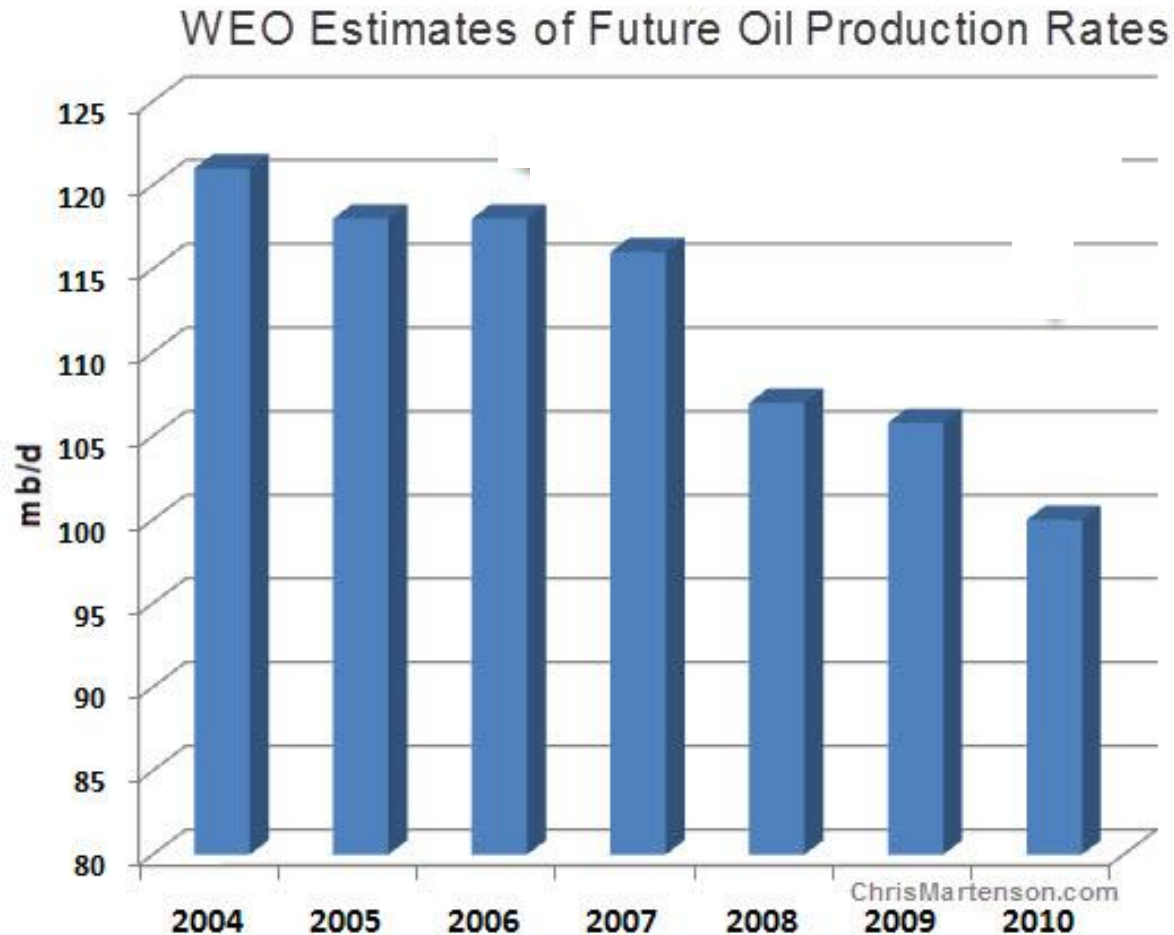
World oil production by type in the New Policies Scenario



Source: Lecture Fatih Birol, Chief Economist of the IEA, at Imperial College, 18 January 2011

http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/naturalsciences/climatechange/newssummary/news_20-1-2011-13-4-51

IEA: Estimates of the level of oil production 25 years in the future, in the WEO 2004-2010



In the 2004 WEO, forecast oil price until 2030:

- Baseline forecast was \$25 a barrel.
- “High” scenario was \$35 a barrel

Source: Chris Martenson summary of IEA WEO's <http://www.chrismartenson.com/>

Peak net energy is more important than peak oil

Energy Return On Energy Invested (EROEI)

Energy Return On Energy Investment for an activity:

$$\text{EROEI} = \frac{\text{Energy delivered to society}}{\text{Energy put into that activity}}$$

Usually consider energy invested *from society*

The oil business uses it's own product e.g. drilling, exploration – but what matters is the net oil available to society.

What about alternative energy sources?

There are plenty of alternative hydrocarbons:

- Tar sands
- Oil shale
- Shale gas
- Coal (can convert to synthetic oil – “coal to liquid”)

However:

- Transport needs liquid fuel. There are no easy substitutes*
- The alternatives emit more carbon – this is highly dangerous

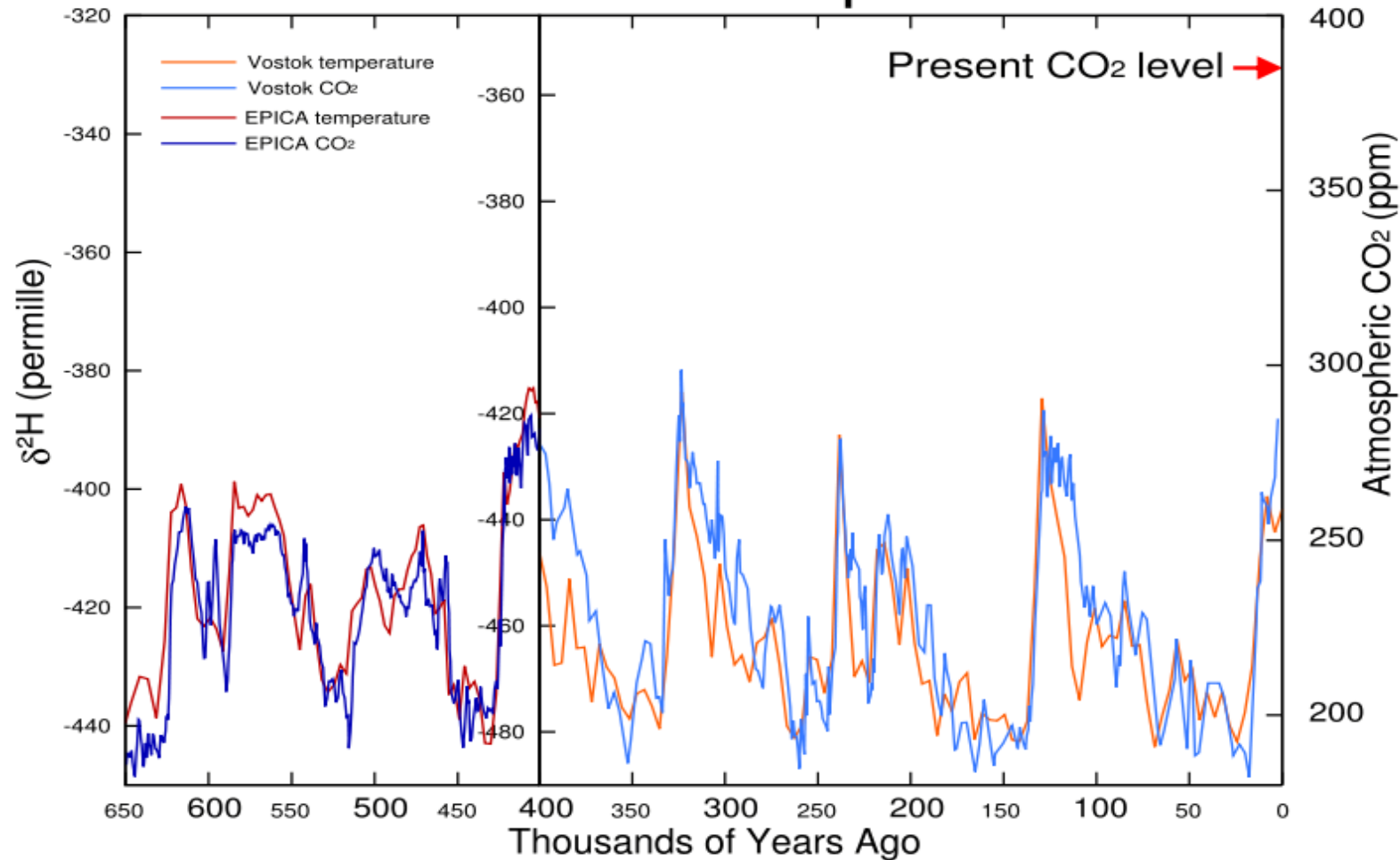
*Refer: Hirsch Report, 2005 for the US Department of Energy

http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf

Why we can't burn all the unconventional hydrocarbons

Climate Change

Carbon Dioxide and Temperature Records



Renewable Energy Sources

- There is a huge amount of renewable energy available: wind, wave, tidal and solar
- However, these energy sources are diffuse
- Problem is in capturing, concentrating and storing the energy
- This requires huge investment
- Can the investment be ramped up quickly enough to avoid “energy descent”? (i.e. decrease in per capita energy availability)

Refer: David Mackay “Renewable Energy Without the Hot Air”

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Risks and Opportunities for the Actuarial Profession

IMF World Economic Outlook, April 2011

Chapter 3: Oil Scarcity, Growth and Global Imbalances

Modelling

- IMF estimated energy and oil elasticities in OECD and non-OECD regions (regression on c.50 nations).
- With global growth at 4.6% in 2011-15, oil price rises 75% assuming no supply response.
- China's energy demand doubles by 2017 vs 2008

Baseline scenario – oil growth reduces from 1.8% to 0.8% p.a.

- 0.8% growth is broadly consistent with the 2010 IEA WEO
- Reduction in global economic growth rate of <0.25%
- Oil price increase of 200% over 20 years

IMF World Economic Outlook, April 2011

Chapter 3: Oil Scarcity, Growth and Global Imbalances

Scenario 2: Faster oil decline (-2% per year)

- 3 to 4x reduction in GDP growth vs baseline scenario
- Oil price increase of 800% over 20 years
- Likely non-linear outcomes of such an increase

Scenario 3: Greater economic role for oil

- Contribution of oil to output 20-25% instead of the 2-5% cost share in the benchmark scenario
- Deterioration in GDP is about 2x larger than in the baseline

IMF World Economic Outlook, April 2011

Chapter 3: Oil Scarcity, Growth and Global Imbalances

Additional Considerations

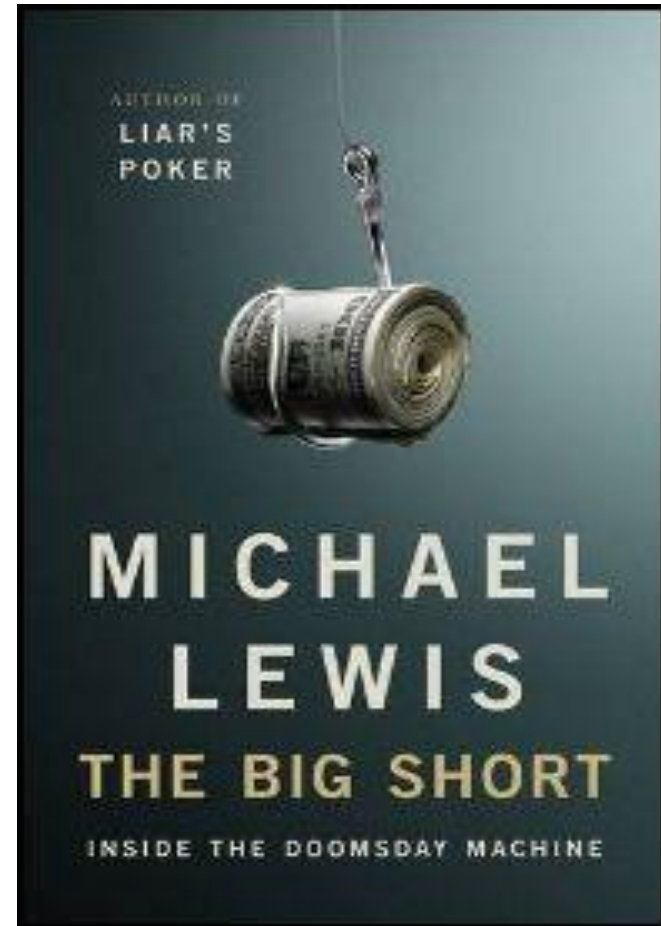
- Model used by the IMF assumes smooth transitions
- Real economies have highly interdependent industries. Adverse effects could spread to rest of the economy
- Modelling does not consider the possibility that oil exporters may reserve an increasing share of oil output for themselves

Not modelled in the IMF chapter

- What if premises of both scenarios 2 and 3 are true?

The Energy Crunch: A Parallel with the Credit Crunch?

- Not many people predicted the severity of the credit crunch before it happened.
- But some people did predict it - it was predictable.
- Why did so few people predict the credit crunch?
- What can we predict today?



Some recent reports

- Feb 2010 – UK Industry Task Force on Peak Oil, 2nd Report
“The next five years will see us face another crunch - the oil crunch. ... the era of cheap oil is behind us.”
- June 2010 – Lloyd’s 360 Report, Sustainable Energy Security
“We are in a period akin to a phoney war”, Lloyd’s CEO Richard Ward
- June 2010 – Tullett Prebon research “Dangerous Exponentials”
“there is an impending collision between economic system that must grow and finite resources which cannot grow.”
- April 2011 - GMO letter to investors *“Time to wake up: Days of abundant resources and falling prices are over”*

GMO Asset Managers

Letter to investors April 2011 “Time to Wake Up”

GMO are an asset management firm controlling >\$100 billion of assets.

GMO

QUARTERLY LETTER

April 2011



Time to Wake Up: Days of Abundant Resources and Falling Prices Are Over Forever

Jeremy Grantham



Summary of the Summary

The world is using up its natural resources at an alarming rate, and this has caused a permanent shift in their value. We all need to adjust our behavior to this new environment. It would help if we did it quickly.

Iron Ore Price

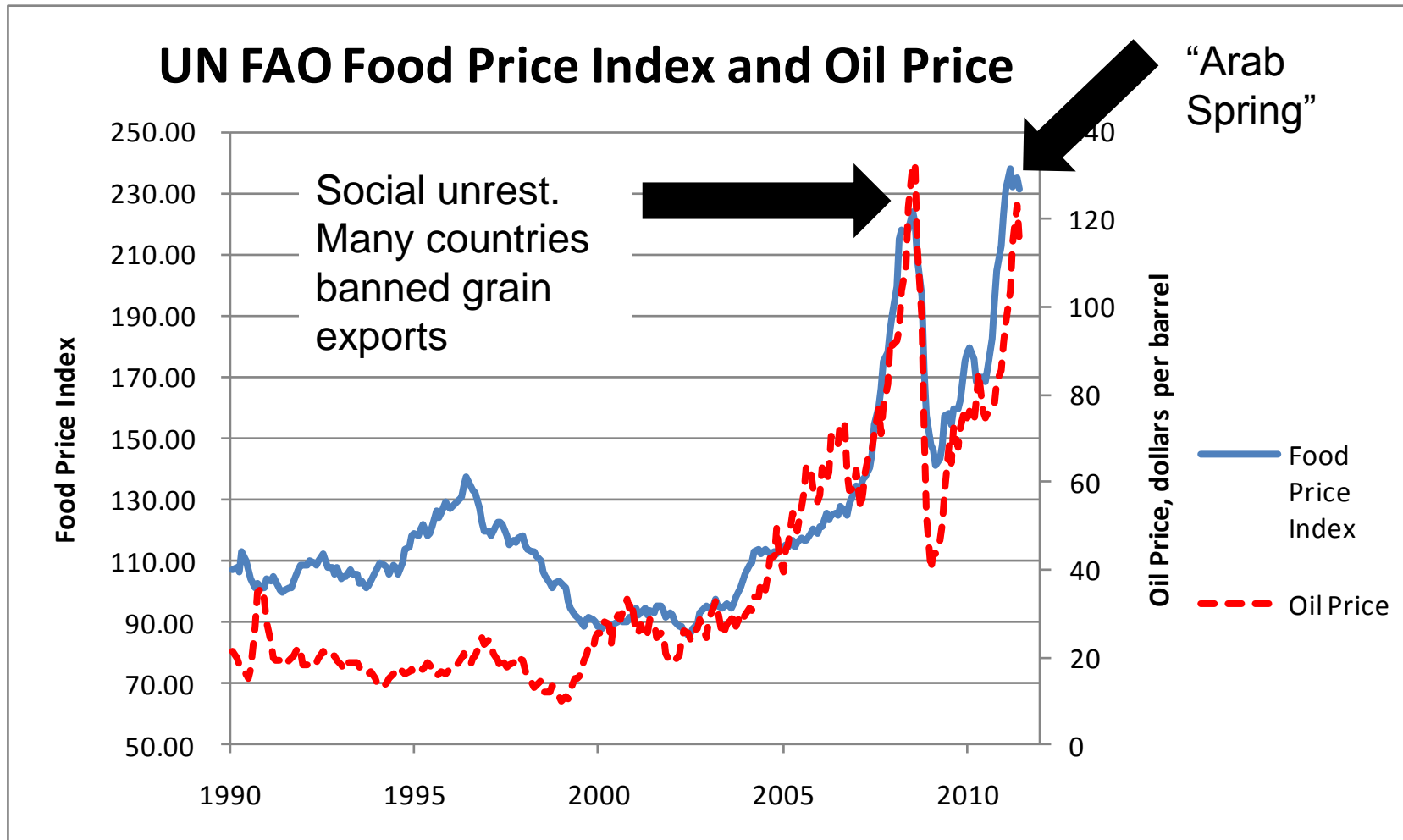
100 year low – then 110 year high within 8 years

Iron Ore Prices (2011 \$/dry metric ton)



Source: GMO Quarterly Letter, April 2011

Oil and Food Prices



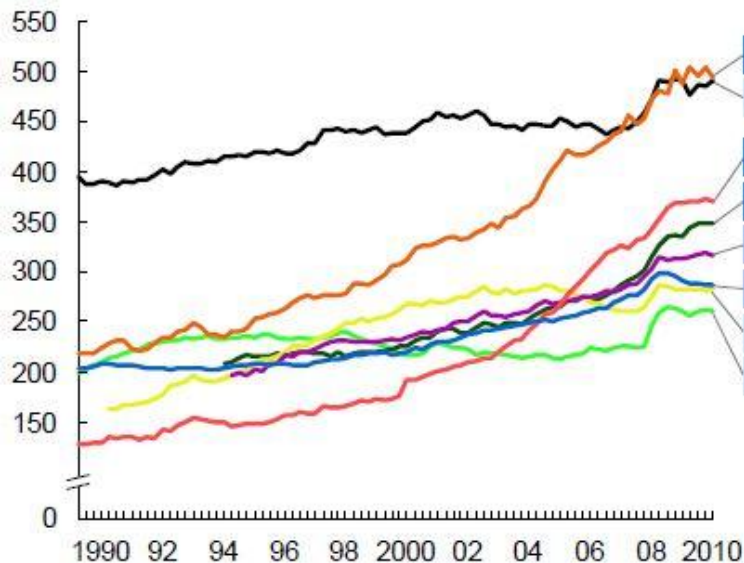
Sources: <http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/>
<http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=p&s=rbrte&f=m>

McKinsey Global Institute

Debt to GDP Ratios in Western economies

Debt remains high in the world's largest mature economies

Domestic private and public sector debt¹
by country, 1990–2010
% of GDP, quarterly data



■ Rapid growth
■ Moderate growth
■ Slow/negative growth

| | Compound annual growth rate (%) | | Change, 2000–10 Percentage points |
|--|---------------------------------|---------|--------------------------------------|
| | 1990–2000 ² | 2000–10 | |

| | | | |
|----------------|-----|-----|-----|
| United Kingdom | 3.4 | 4.7 | 182 |
| Japan | 1.2 | 1.1 | 52 |
| Spain | 4.1 | 6.7 | 177 |
| France | 1.3 | 4.5 | 123 |
| Italy | 3.0 | 3.0 | 82 |
| United States | 0.6 | 2.7 | 67 |
| Germany | 5.6 | 0.5 | 15 |
| Canada | 0.3 | 1.9 | 44 |

1 "Debt" defined as all credit market borrowing, including loans and fixed-income securities.


2 Or longest time period available.

SOURCE: McKinsey Global Institute analysis

Source: McKinsey Global Institute 2010 "Debt and Deleveraging: The Global Credit Bubble and its Economic Consequences"

“... deleveraging has followed nearly every major financial crisis in the post-World War II period.”

The four archetypes of deleveraging:

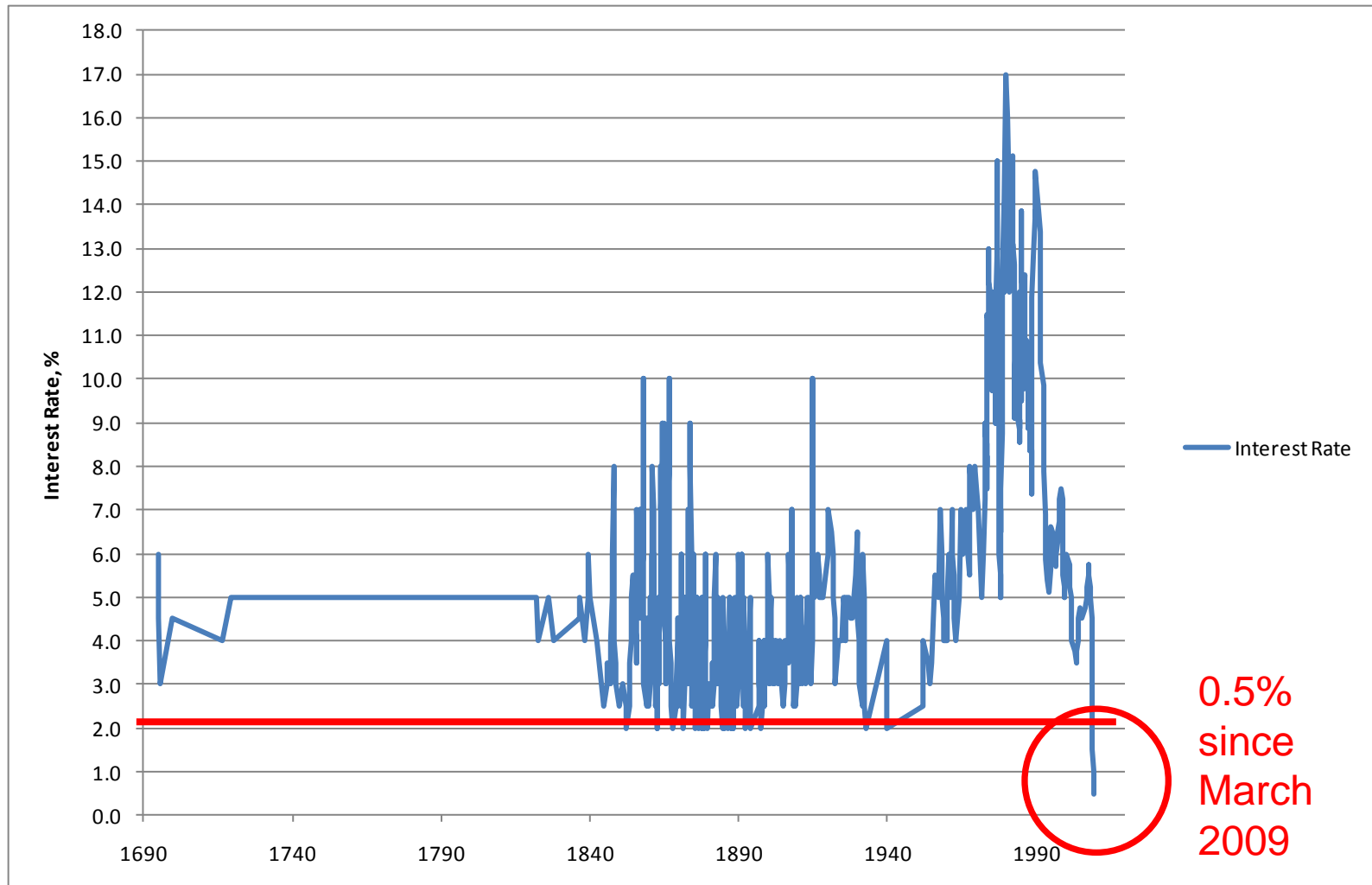
- 1) Austerity (or “belt-tightening) in which credit growth lags behind GDP growth for many years
- 2) Massive defaults
- 3) High inflation
- 4) Growing out of debt through very rapid GDP growth 

My guess: High inflation is most likely. Inflation will be >10% within the next few years – although deflation is also possible.

Source for the four archetypes of deleveraging: McKinsey Global Institute 2010 “Debt and Deleveraging: The Global Credit Bubble and its Economic Consequences”

We live in interesting times...

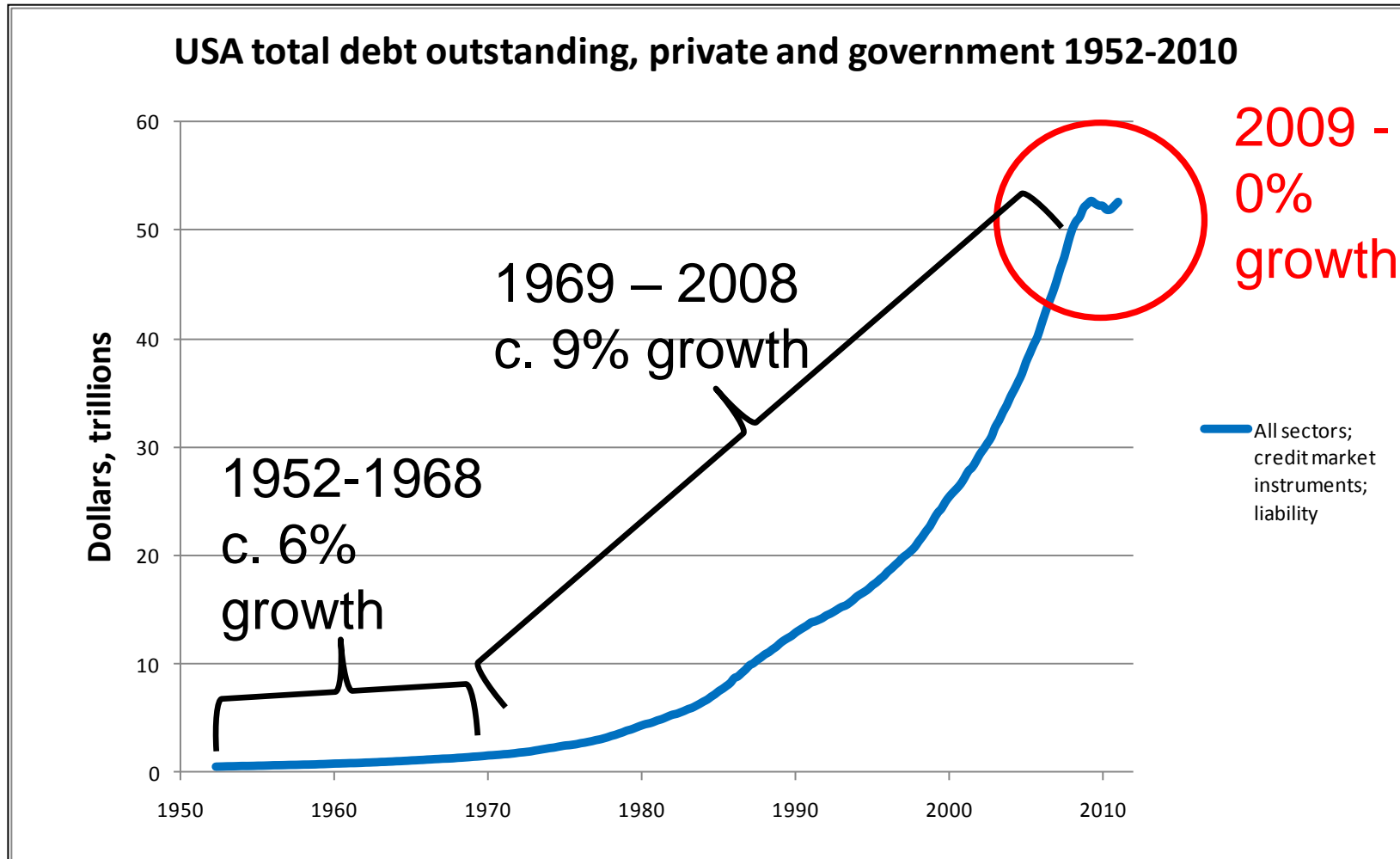
Bank of England Base Rates since 1694



Source: Bank of England <http://www.bankofengland.co.uk/monetarypolicy/decisions/decisions11.htm>

We live in interesting times...

United States total debt – fundamental shift

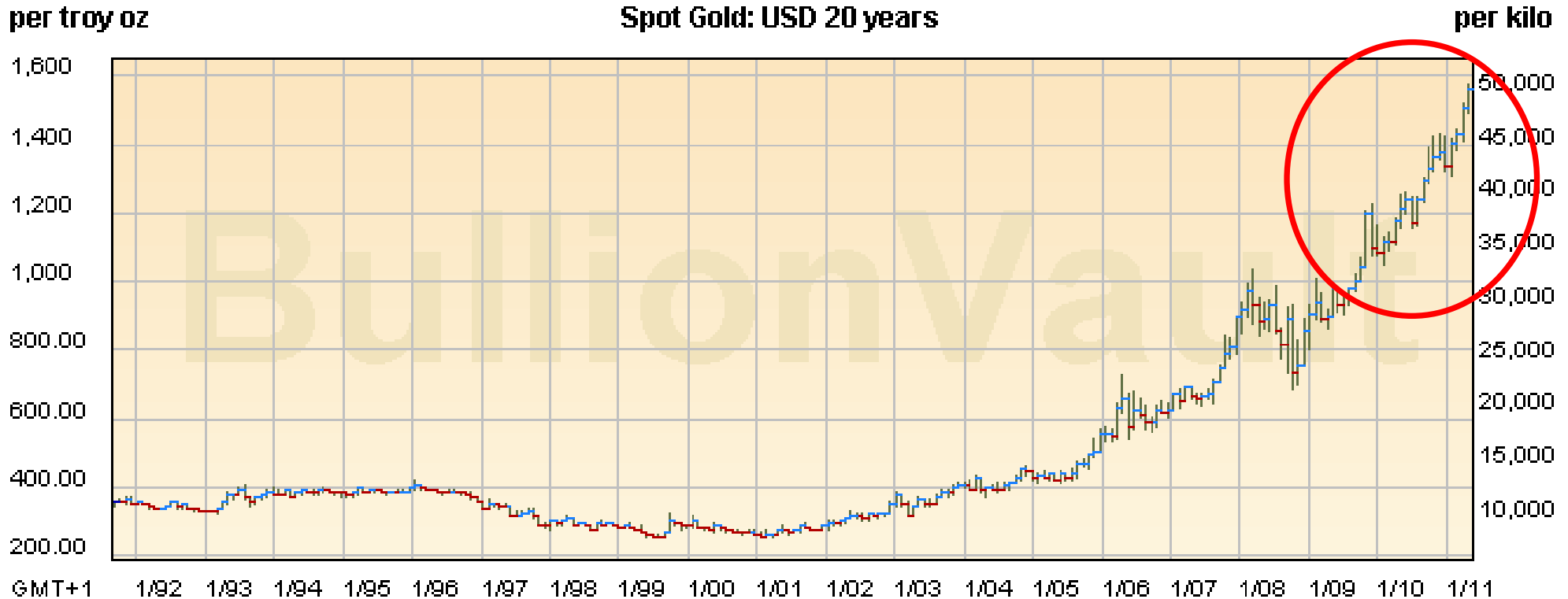


Source: United States Federal Reserve data download program

<http://www.federalreserve.gov/datadownload/>

We live in interesting times...

The price of gold has nearly doubled since 2009



Source: www.bullionvault.com

Summary of the Argument:

1. Economy relies on fossil energy – oil is the most important part.
2. Oil supply constraints will constrain global GDP growth
3. Western economies are likely to deleverage, this has hardly started yet
4. Deleveraging is unlikely to occur through rapid GDP growth
5. Therefore austerity, default or inflation are most likely

Resource and Environmental Issues

Risks and Opportunities for the Actuarial Profession

Risks:

- Actuaries seek to “make financial sense of the future”
- What if we miss the big trends?
- What if our economic assumptions are inaccurate?

Resource and Environmental Issues

Risks and Opportunities for the Actuarial Profession

Opportunities:

- Research on the limits to growth, closing date 31st July 2011.
- New governance structure for the Profession: Resource and environmental issues to be addressed with urgency.
- IAA have organised an environmental committee, we will contribute. IAA meeting in Zagreb, 29th September 2011.
- Networking event on 13th September for actuaries working in this field
- The Resource & Environment Member Interest Group are producing the 2nd Edition Literature Review on Resource & Environment, launch date 17th October 2011

Resource and Environmental Issues

Risks and Opportunities for the Actuarial Profession

- The world needs unbiased forecasting – not optimistic or pessimistic. Actuaries are ideally suited for this role:*
 - Long term thinking
 - Base decisions on data; scientific approach
 - Experts in risk and modelling
 - Exponential growth is bread and butter
 - Used to giving bad news!
- We are coming to this field relatively late. In many ways this is an advantage.
- This is potentially a huge area of work for actuaries; we can be leaders in this field.

*We care about removing bias “Making actuaries less human: Lessons from behavioural finance” by Nigel Taylor http://www.sias.org.uk/siaspapers/listofpapers/view_paper?id=BehaviouralFinance

Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

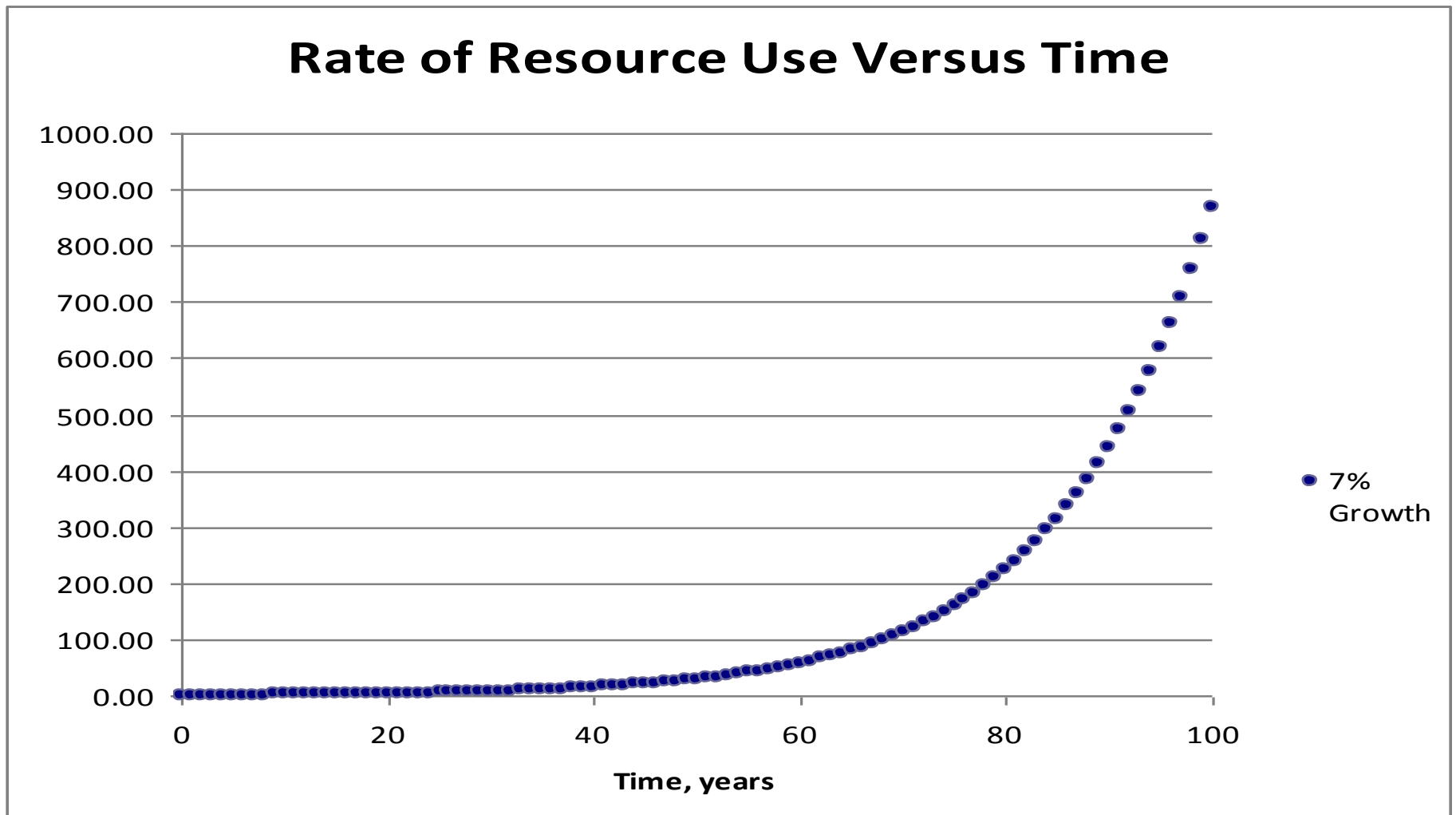
The views expressed in this presentation are those of the presenter.



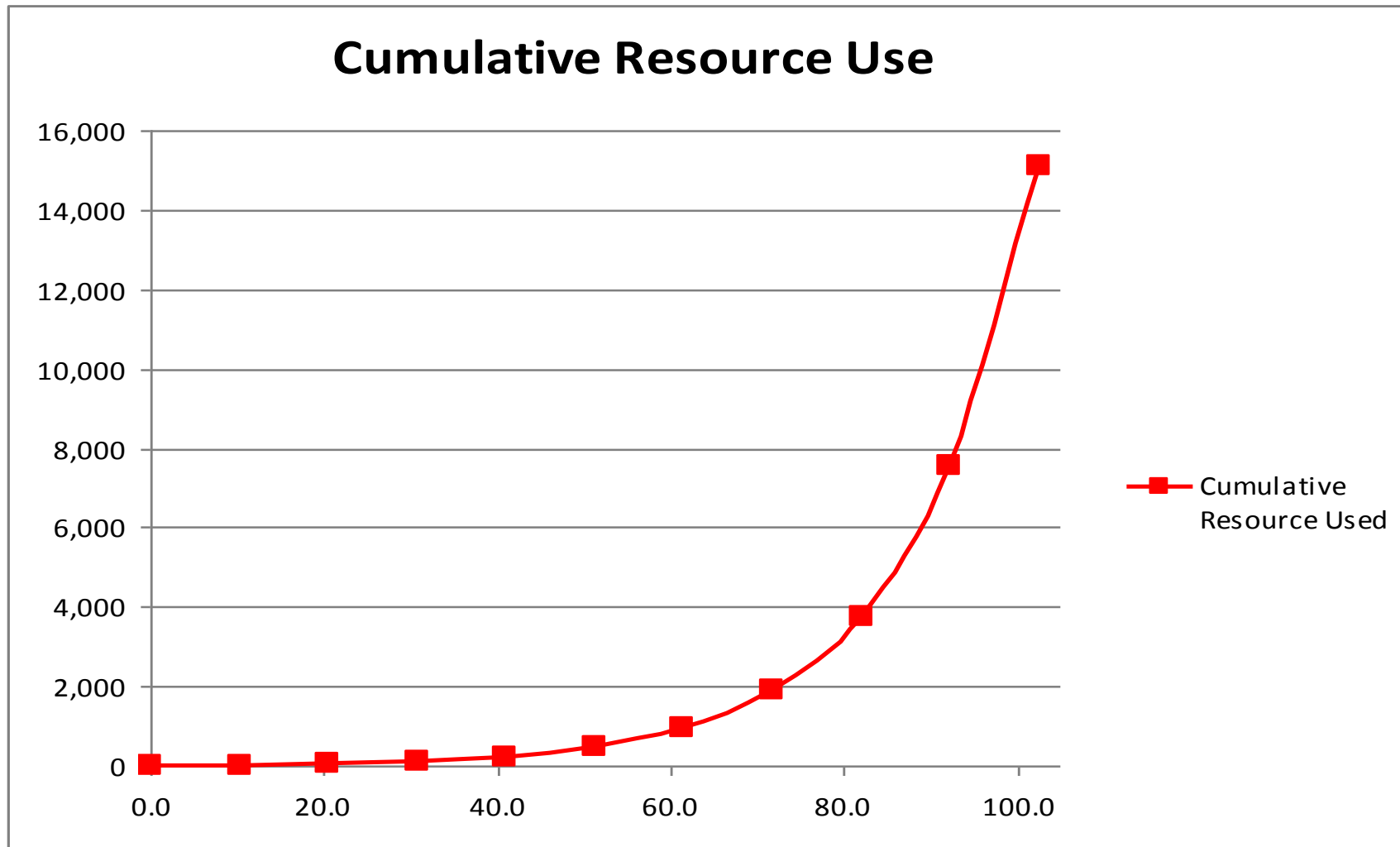
Additional slides after here

Exponential Growth – Resource Use

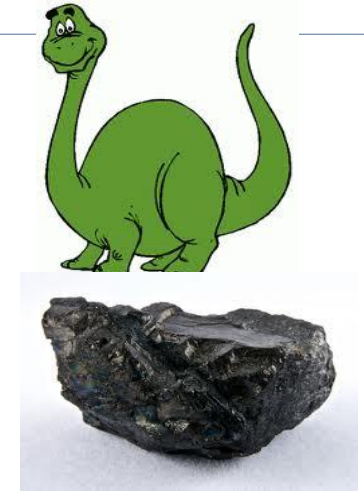
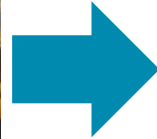
Example: 7% p.a. growth



Exponential Growth – Resource Use



Where does our energy come from? How much do we use?



The Sun

Photosynthesis captures the sun's energy

Energy is trapped in fossil carbon over millions of years

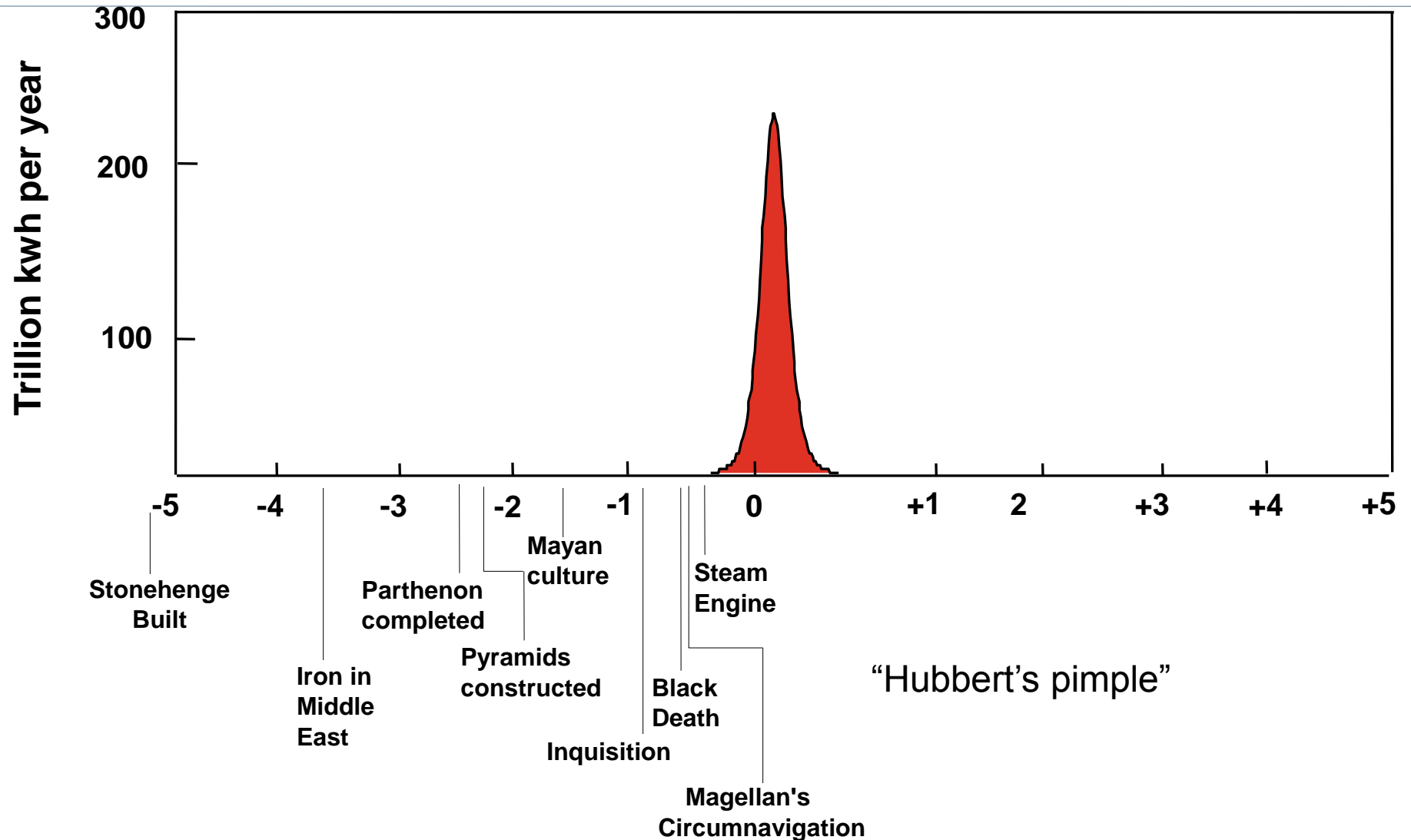
Whether directly, or from energy trapped in fossil fuel, the great majority of our energy comes from the sun.

Our industrial civilization uses about 13 Tera Watts (=13 million million Watts) for machinery. In comparison, heat flow from centre of Earth powering all earthquakes $\approx 40\text{TW}$. Estimated net primary productivity of Earth's ecosystems $\approx 70\text{TW}$ on land.

Source: "Eating the Sun", by Oliver Morton

Global Fossil Fuel Use – A Long Term View

(after Hubbert, 1969)



Source: Professor Charles A.S. Hall, State University of New York <http://www.esf.edu/efb/hall/>

Energy Return On Energy Invested (EROEI)

- “An assessment of the future outlook for energy inputs needs to be calibrated in terms of an energy rather than a monetary equation.”

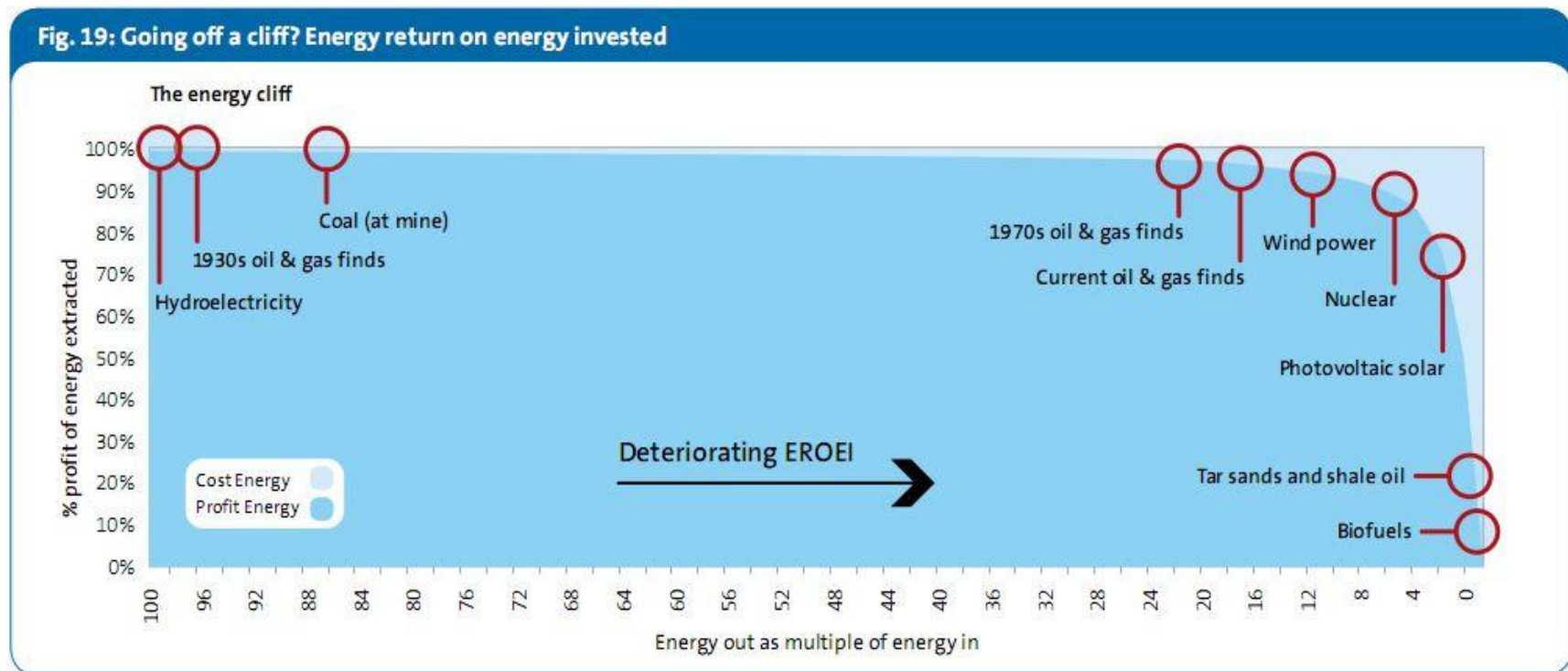
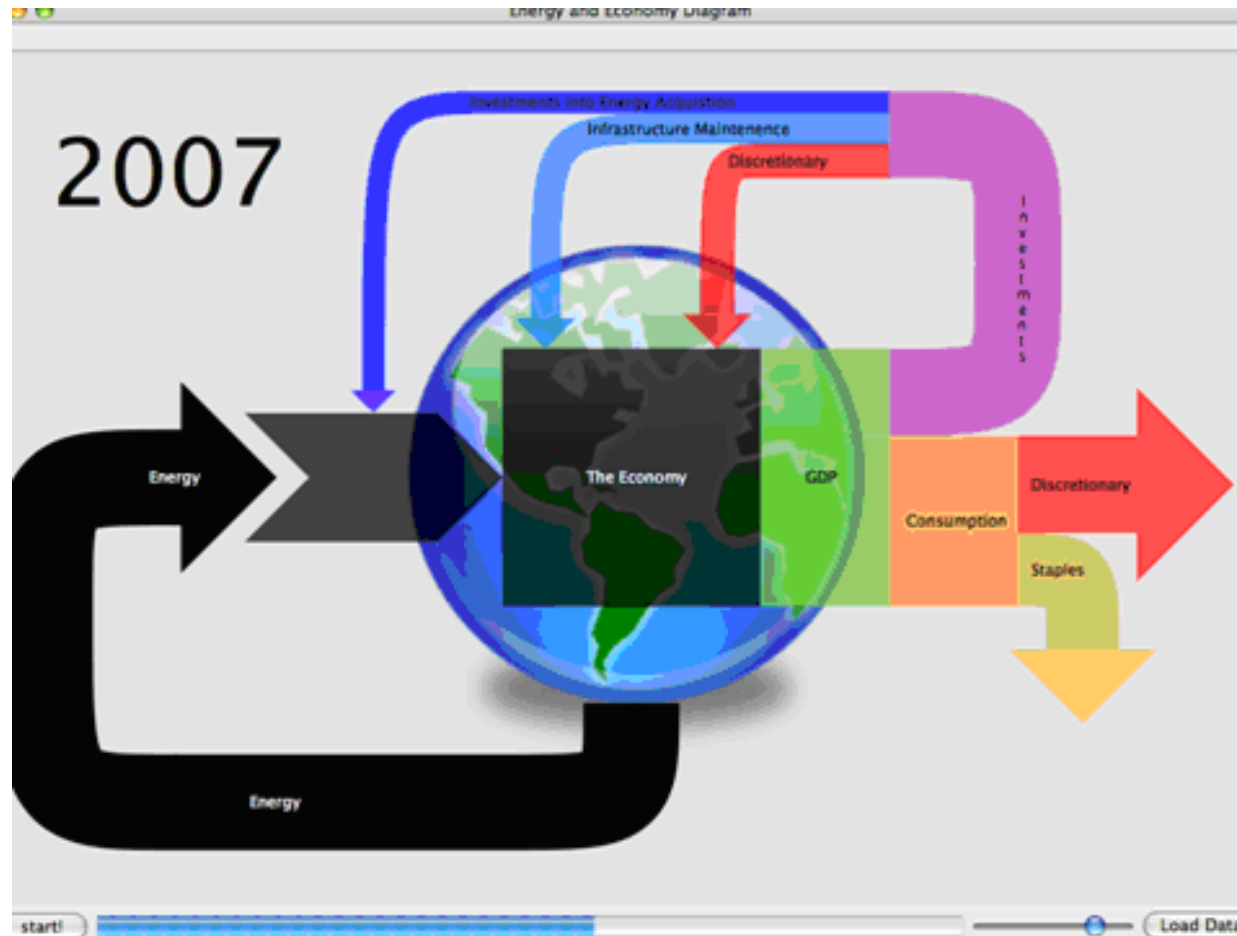
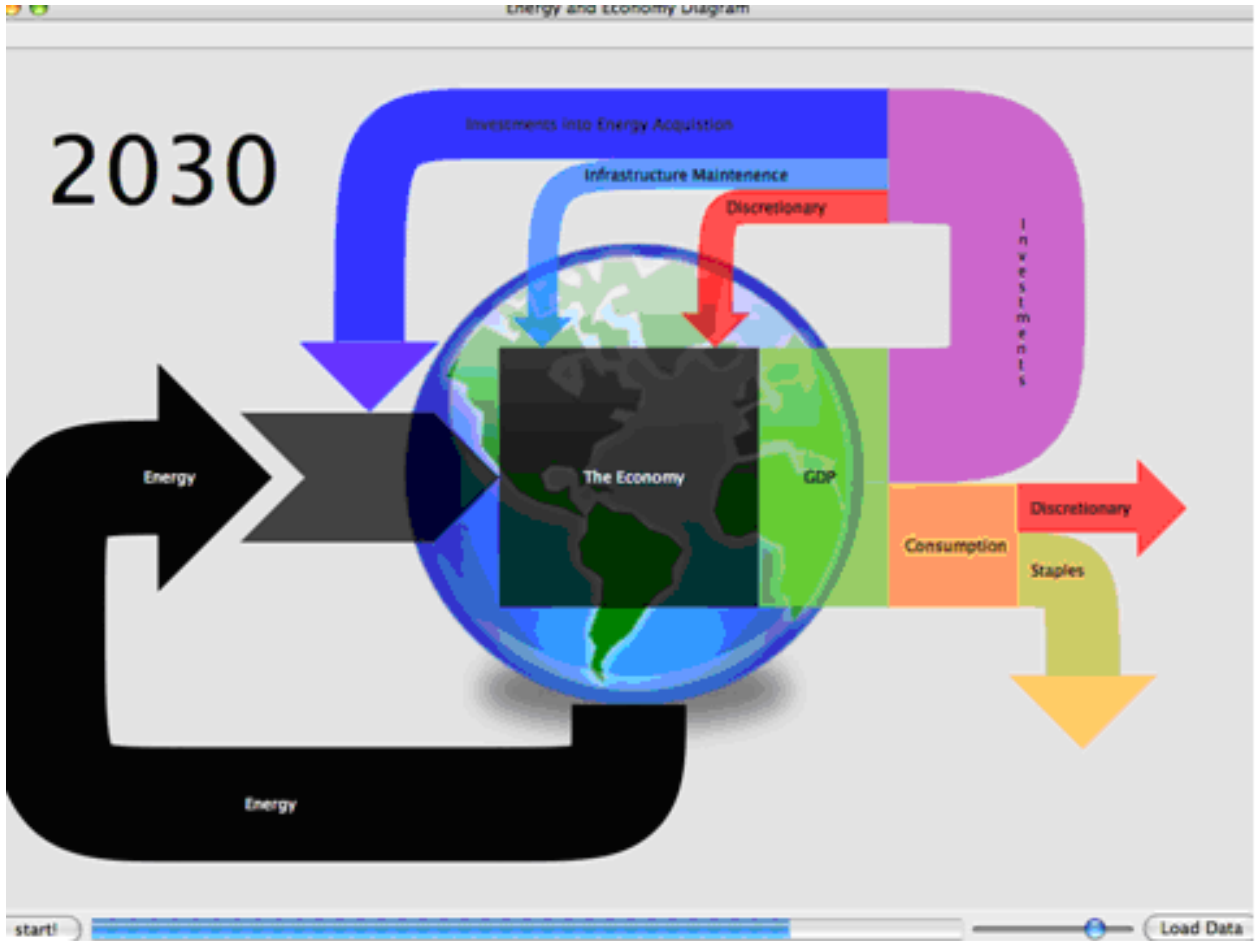


Chart from: Morgan T. “Dangerous exponentials: A radical take on the future”
Tullett Prebon Strategy Insights issue 5, June 2010

The argument for increased importance of energy to the economy



The argument for increased importance of energy to the economy



What if we can't grow the economy?

Economist and Nobel Laureate Robert Solow From Harper's Magazine, March 2008

“It is possible,” says Solow, “that the United States and Europe will find that, as the decades go by, either continued growth will be too destructive to the environment and they are too dependent on scarce natural resources, or that they would rather use increasing productivity in the form of leisure. . . . There is nothing intrinsic in the system that says it cannot exist happily in a stationary state.”

Fractional Reserve Banking

“... of all the many ways of organising banking, the worst is the one we have today.” Possible remedies included not just breaking up banks, but also “eliminating fractional reserve banking”

Mervyn King, reported in the Economist, 28th October 2010

