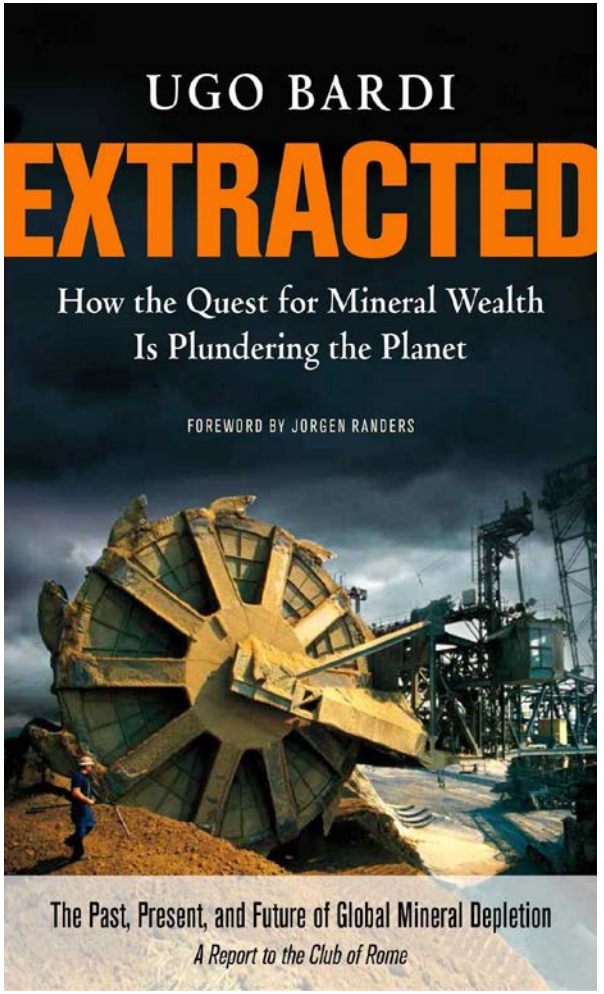
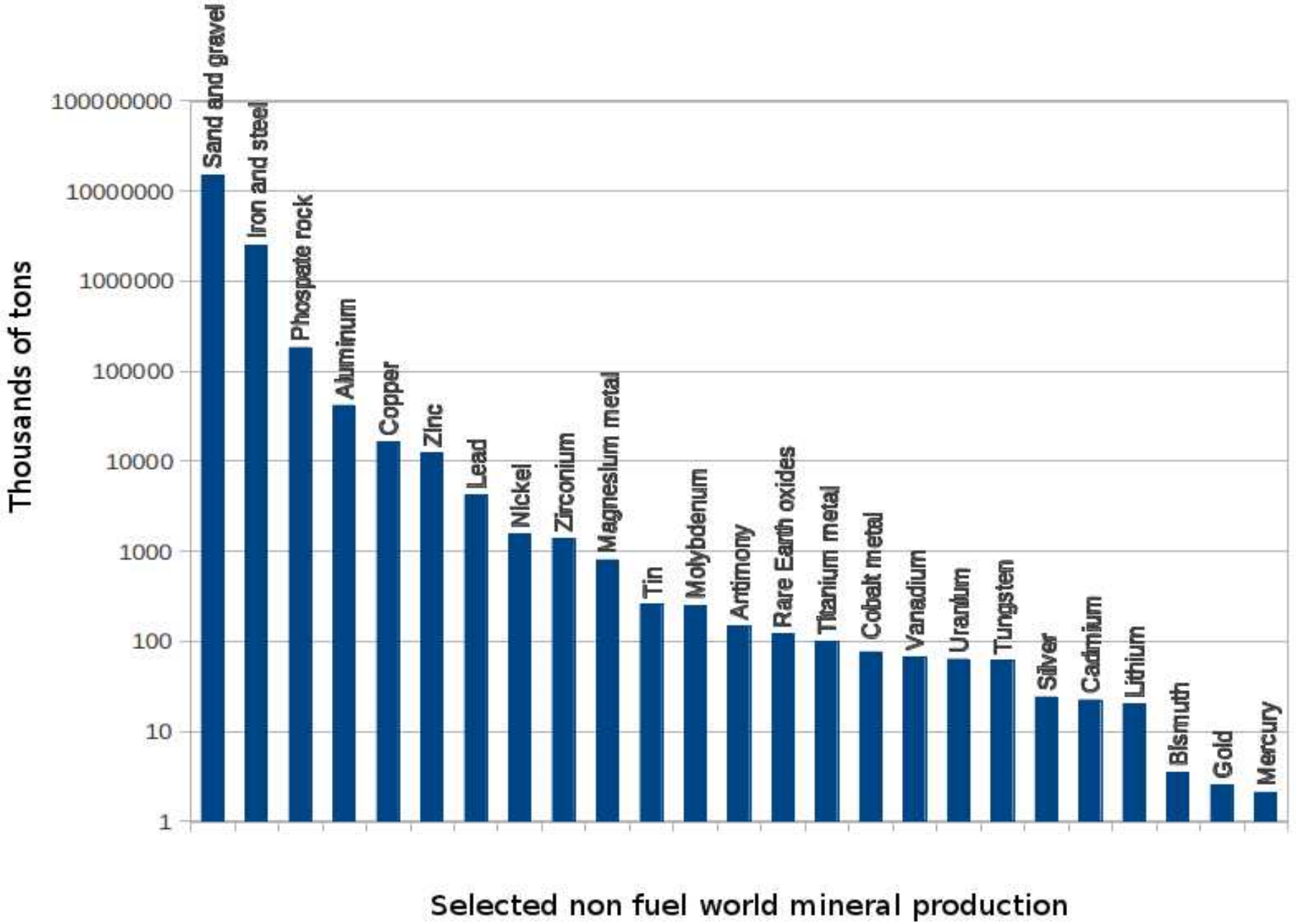
Resource Based Economy

Ugo Bardi

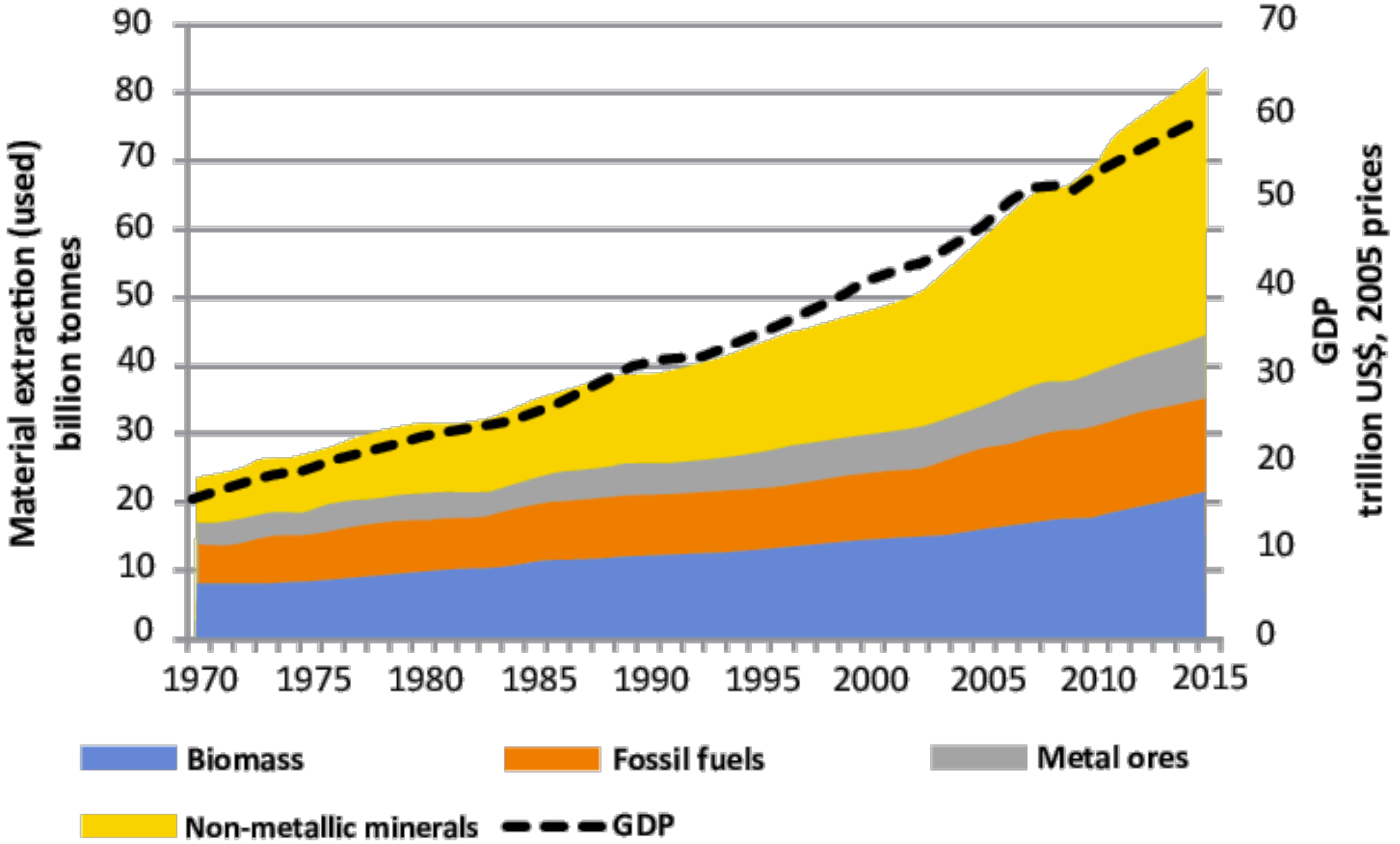
University of Florence, Department of Chemistry
The Club of Rome



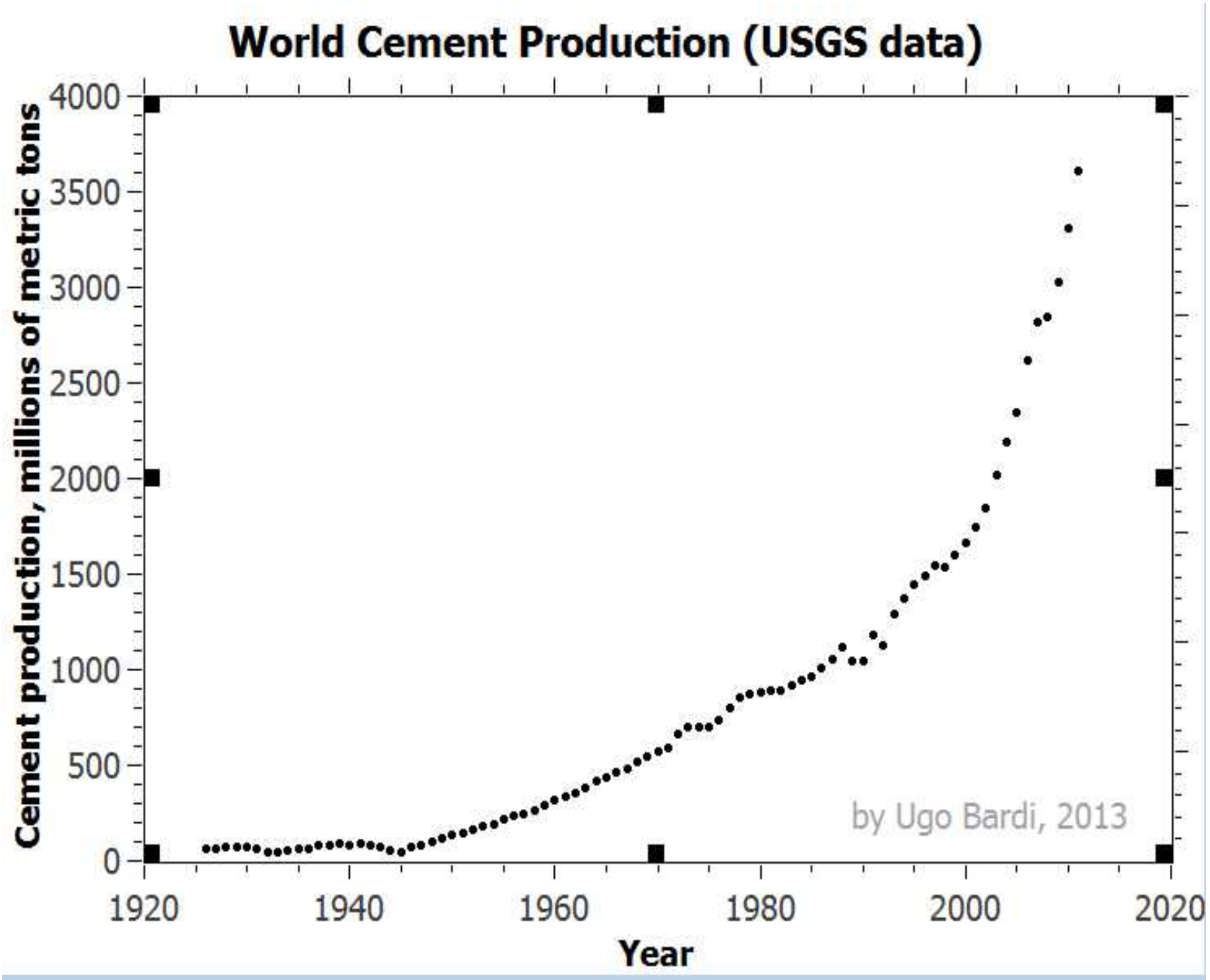
Natural Resources?



USGS data 2008



Ekins et al. UNEP report (2016). Resource Efficiency: Potential and Economic Implications Summary for Policymakers.

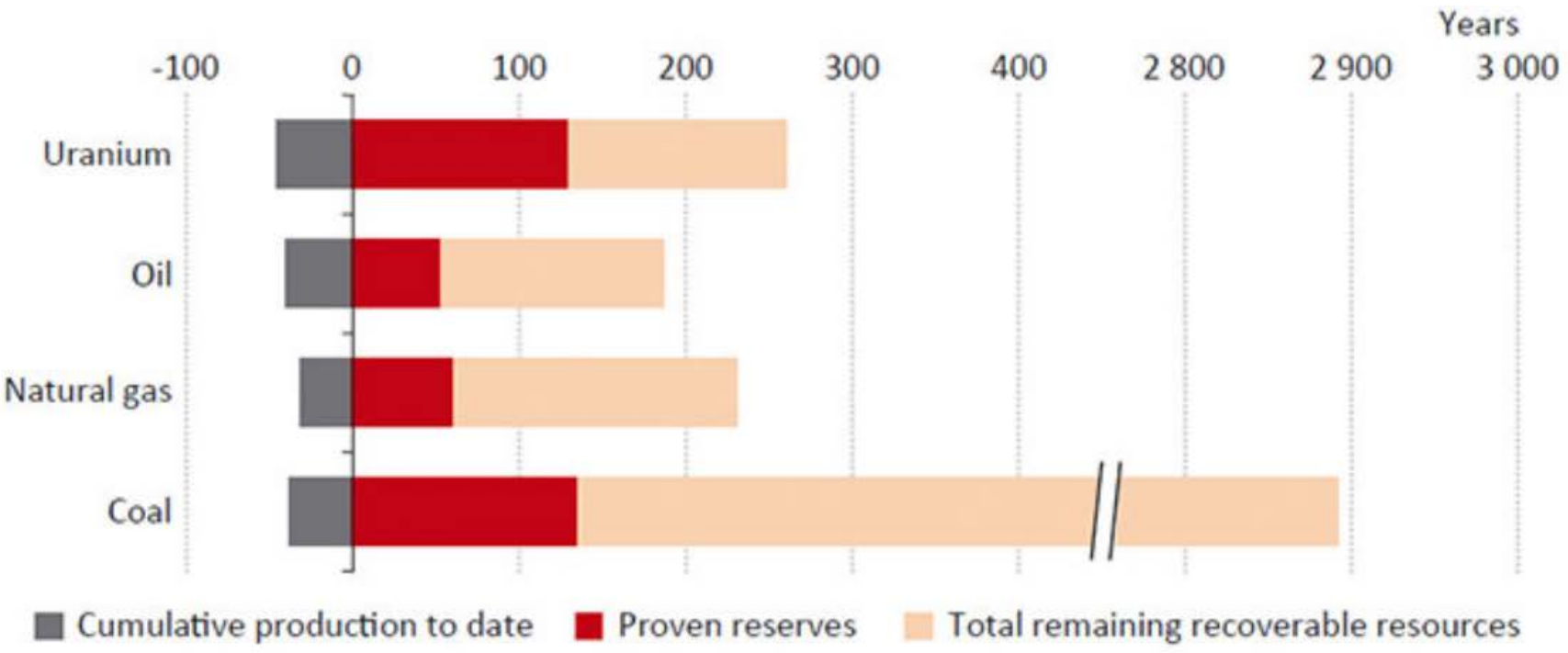

World Cement Production (USGS data)
Cement production, millions of metric tons
4000
3500
3000
2500
2000
1500
1000
500
0
1920
1940
1960
1980
2000
2020
Year
by Ugo Bardi, 2013

Trantor

STUFF
THEY DON'T
WANT YOU
TO KNOW
81
D

Depletion: once you eat the cake, you don't have it any more

What Fossil Resources do we still have?



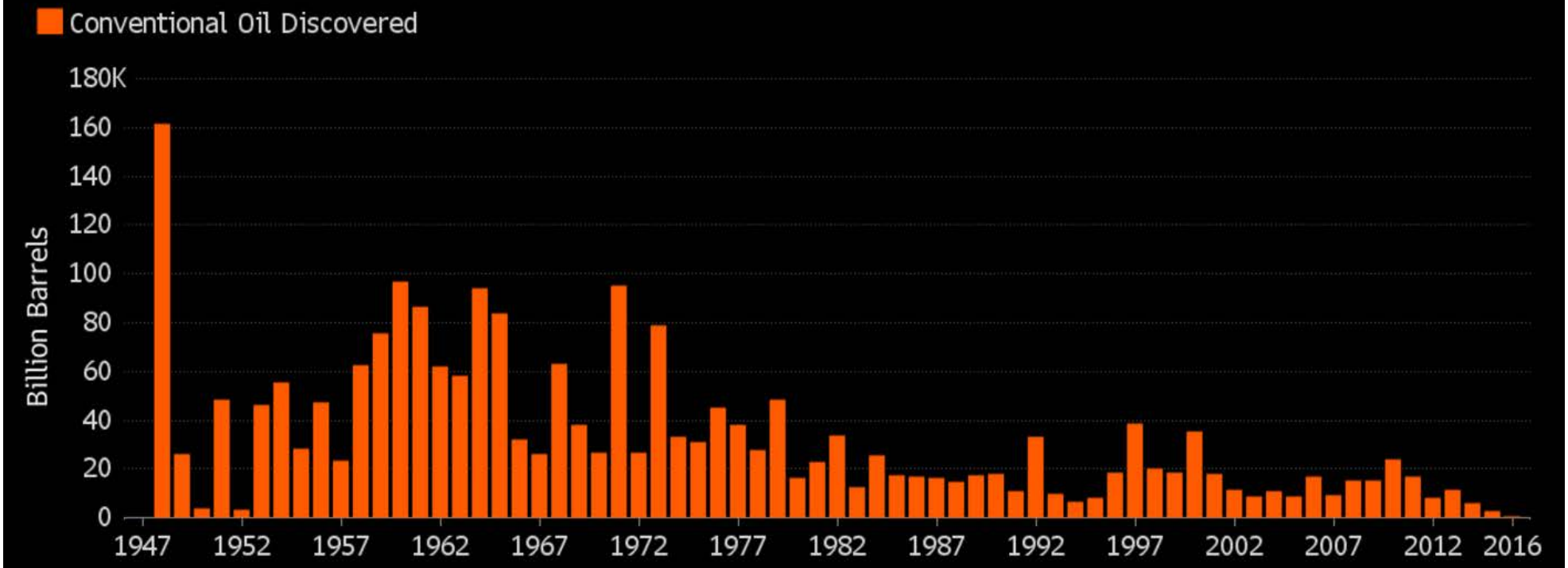
Lifetimes of fossil-fuel resources (expressed as # of years produced and remaining resources based on production rates in 2013)

Source: BGR, 2013; O&GJ, 2013; USGS, 2012; USGS, 2012; BP, 2014; NEA/IAEA, 2014; IEA World Energy Outlook 2014

AND, WITH THIS, PEAK OIL IS ABOLISHED!

Oil Discoveries Lowest Since 1947

Explorers slash spending after price collapse



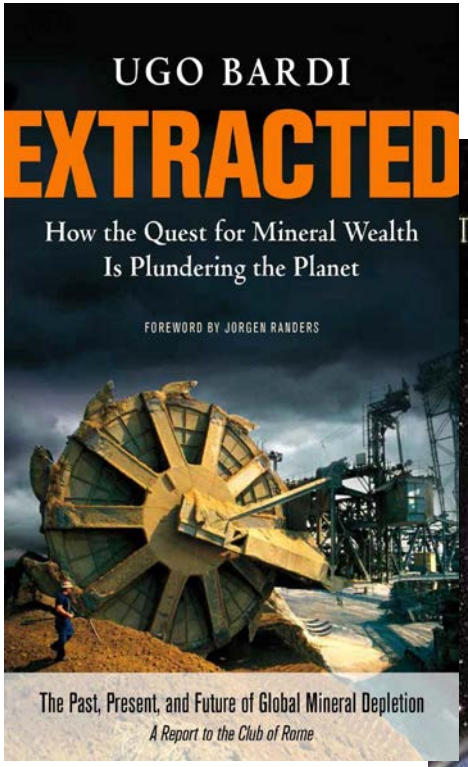
Source: Wood Mackenzie
Note: 2016 figure covers exploration results to August. Discoveries amounted to just 230 million barrels in 1947 but ballooned the following year with the Ghawar find in Saudi Arabia, still the world's biggest field.

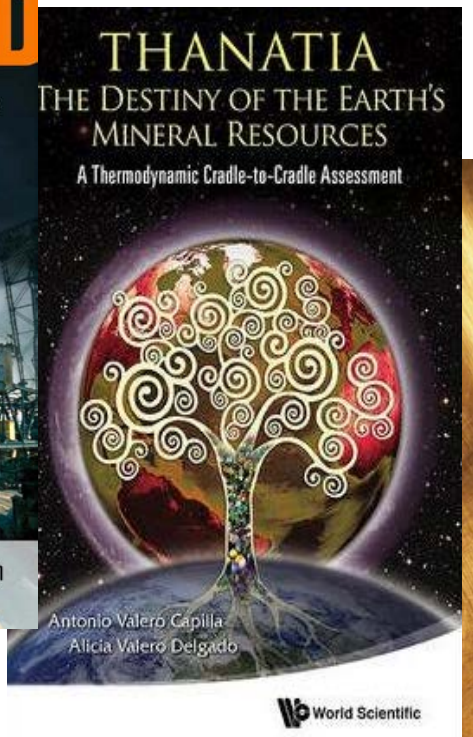
Bloomberg

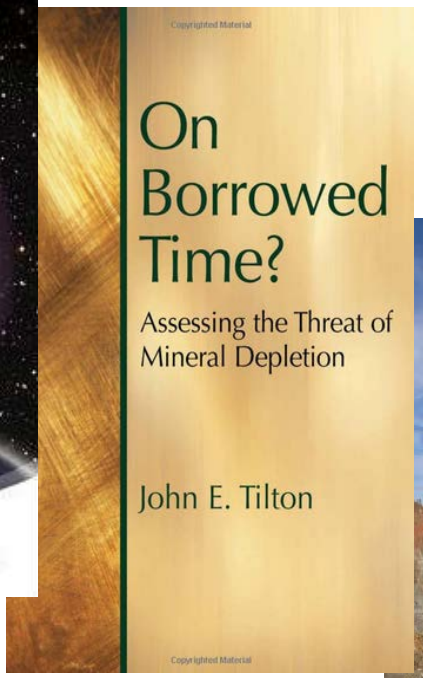
2018
Prices

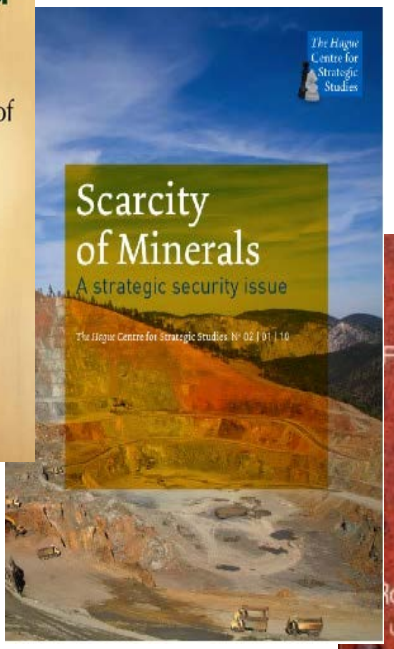
Tiffany's jewelry fallacy:

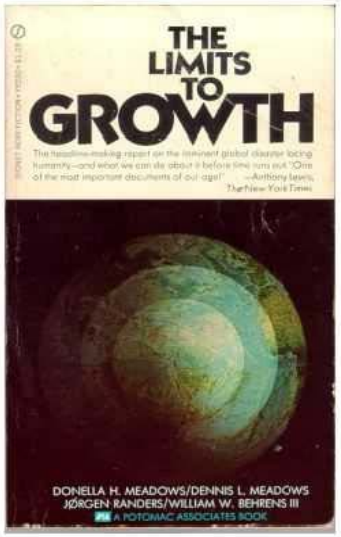
The new paradigm in mineral depletion studies: *Dynamic depletion effects*











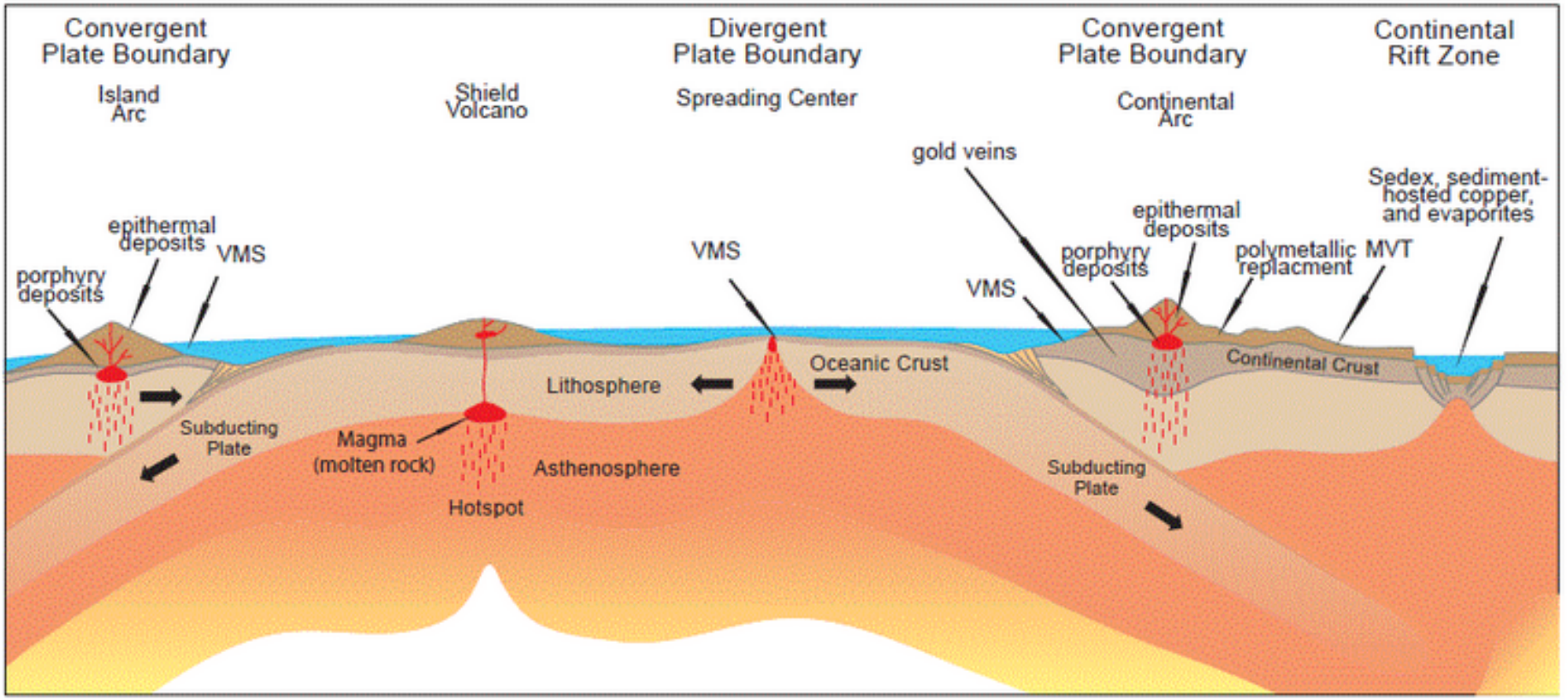
Depletion: as you eat the cake, it becomes less and less tasty

https://en.wikipedia.org/wiki/File:Native_gold_nuggets.jpg

What is a Mineral Deposit by Definition

An ore is defined as a mineral or rock from which some valuable constituent, usually a metal, can be profitably extracted. Thus hematite and magnetite are ores of iron; galena is an ore of lead; zinc blende is an ore of zinc. With the ore-mineral is more or less material of no value, called gangue; and whether the ore as a whole can be profitably mined or not depends partly on the proportion of ore to gangue. The expression mineral deposits is conveniently used to cover both metal ores and other valuable minerals.

In the discussion of mineral deposits it is usual to include certain minerals of commercial value, such as talc, barite, apatite, feldspar, and fluorspar, which are not used as sources of metals.

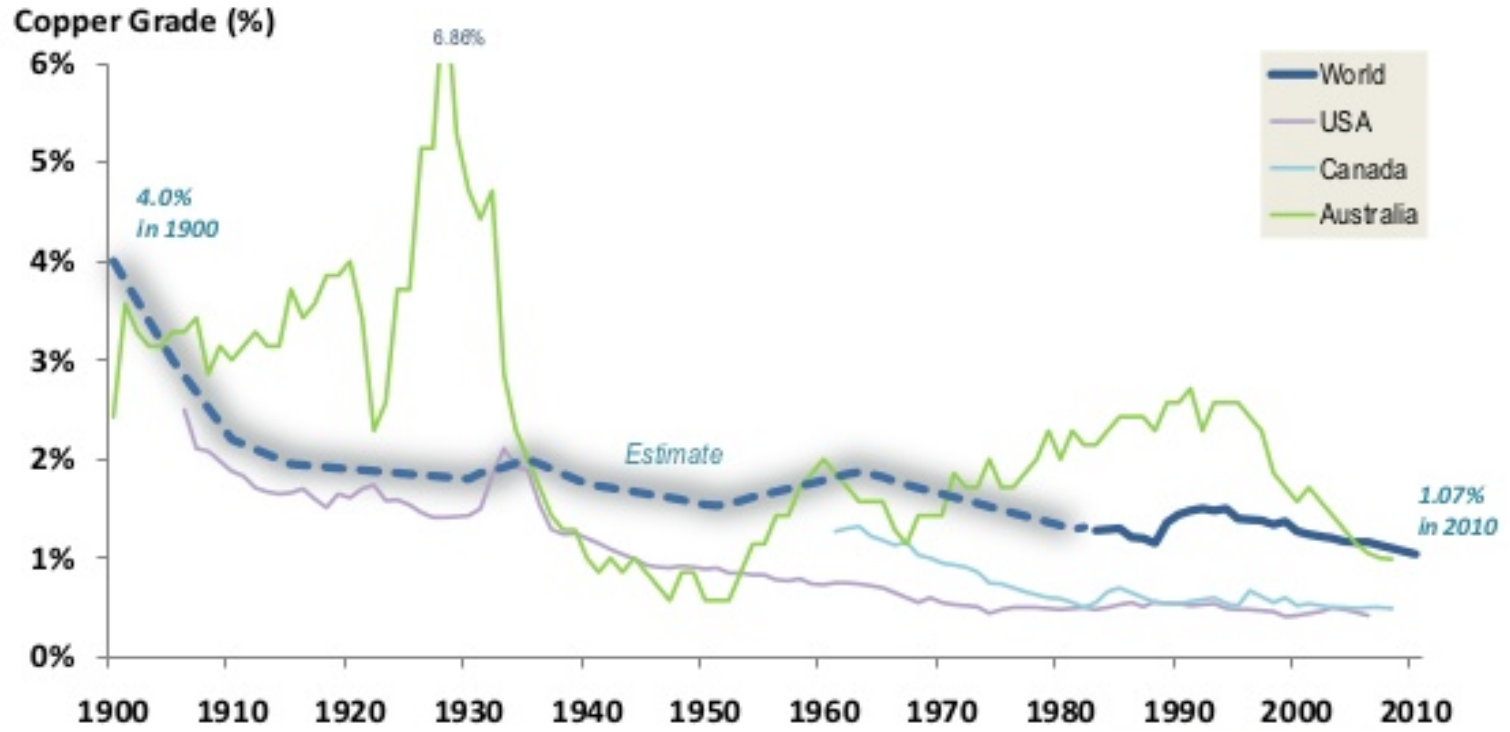


There are no gold ores in space!

Want to mine gold
In the Solar System?
Look for it on the Earth!

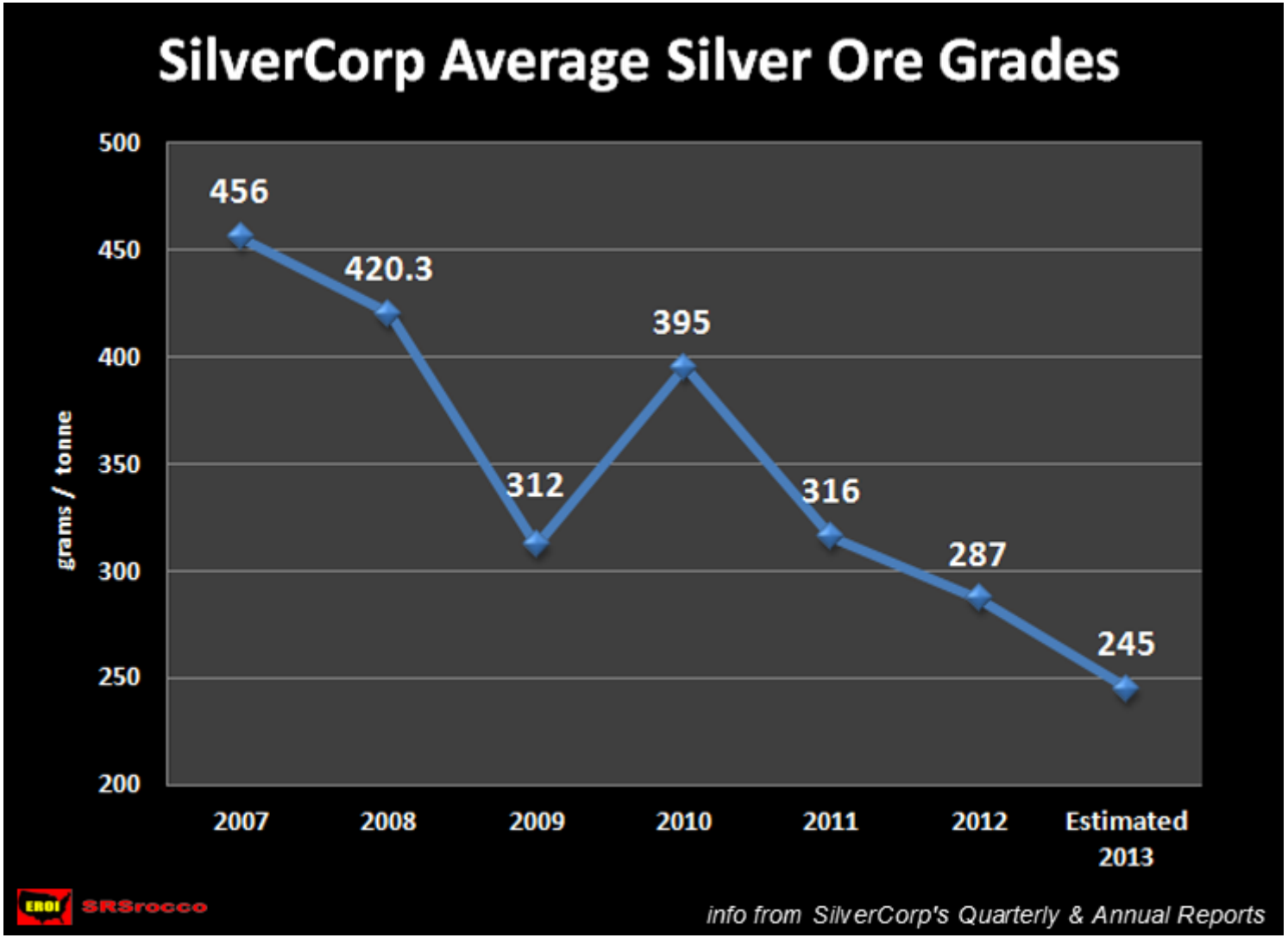
Ore grades mined have declined over time

Copper ore grade for World and selected countries: 1900-2008

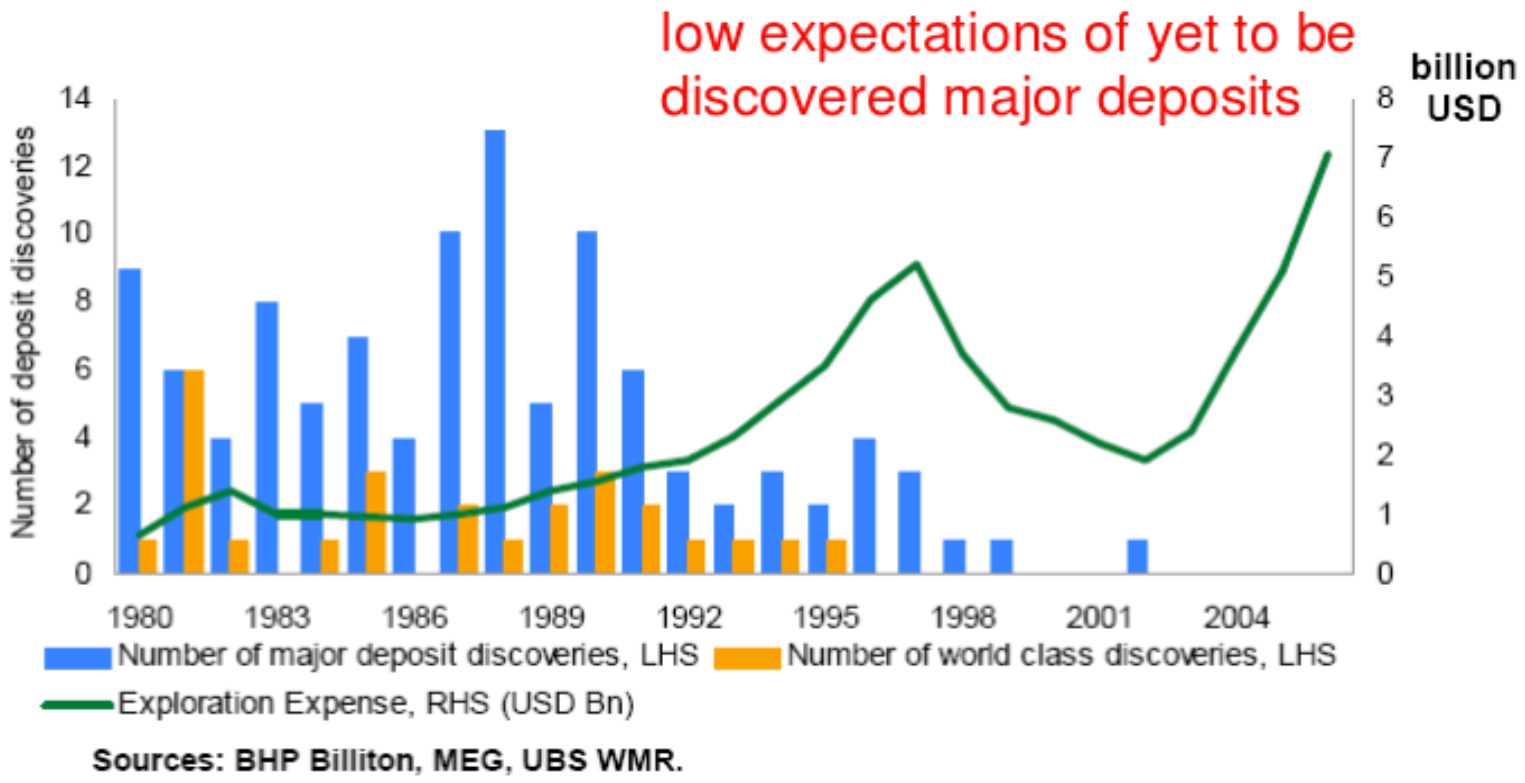


Sources: USGS, Mudd (2009)
Brook Hunt, UBS

Note: Rise in ore grade in Australia from 1972 onwards is due to startup of the high-grade Olympic Dam mine


SilverCorp Average Silver Ore Grades
500
450
400
350
300
250
200
grams / tonne
456
420.3
312
395
316
287
245
2007
2008
2009
2010
2011
2012
Estimated 2013
SRSrocco
info from SilverCorp's Quarterly & Annual Reports

Exploration of major mineral deposits and the “Law of diminishing returns”



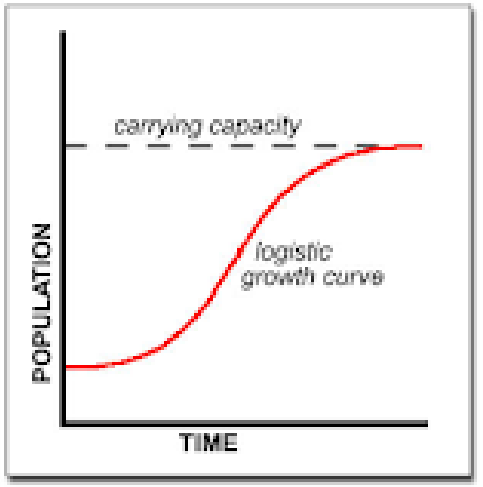
Graph: Raw Materials Group, Sweden

Graph by A. Diederen

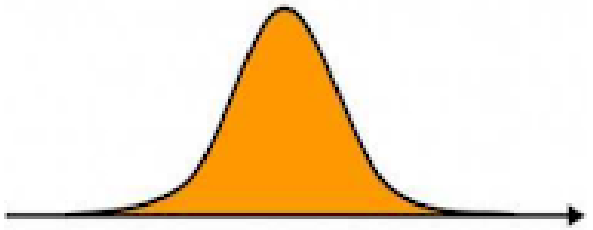
Mining requires energy!

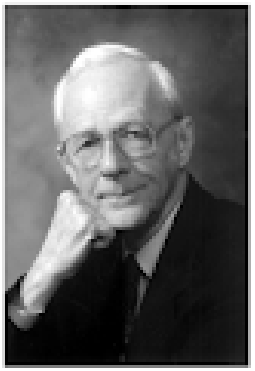
Mining Requires Energy

Thomas Malthus,
An essay on the principle of Population
1798

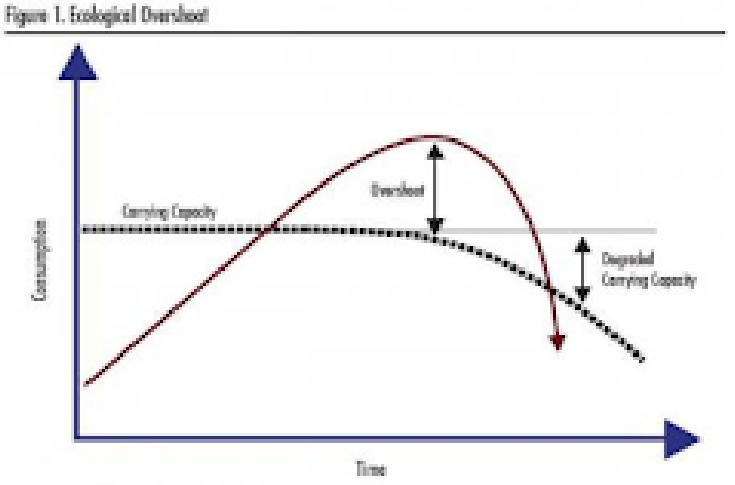


Marion King Hubbert
Peak Oil - 1956

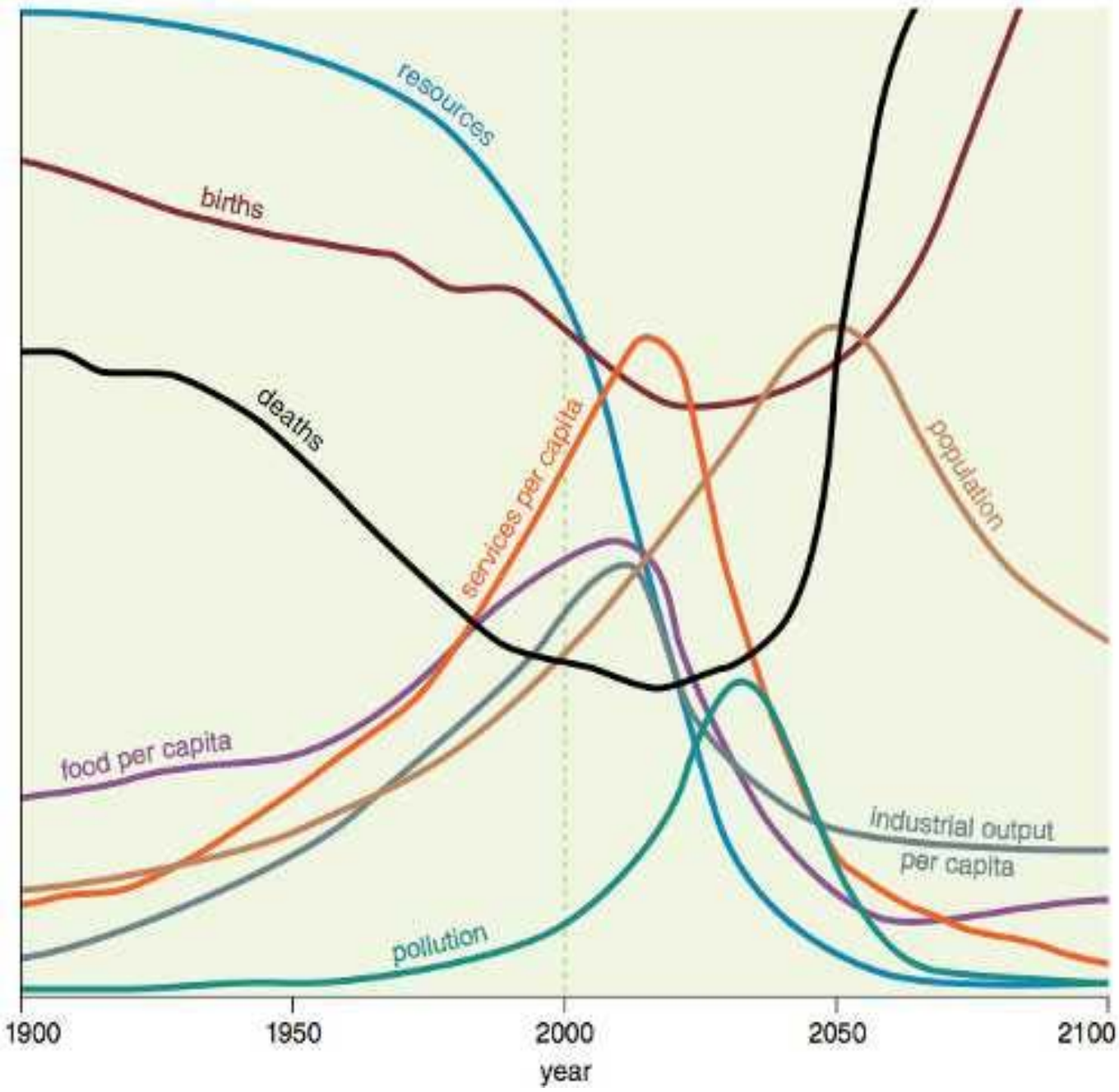




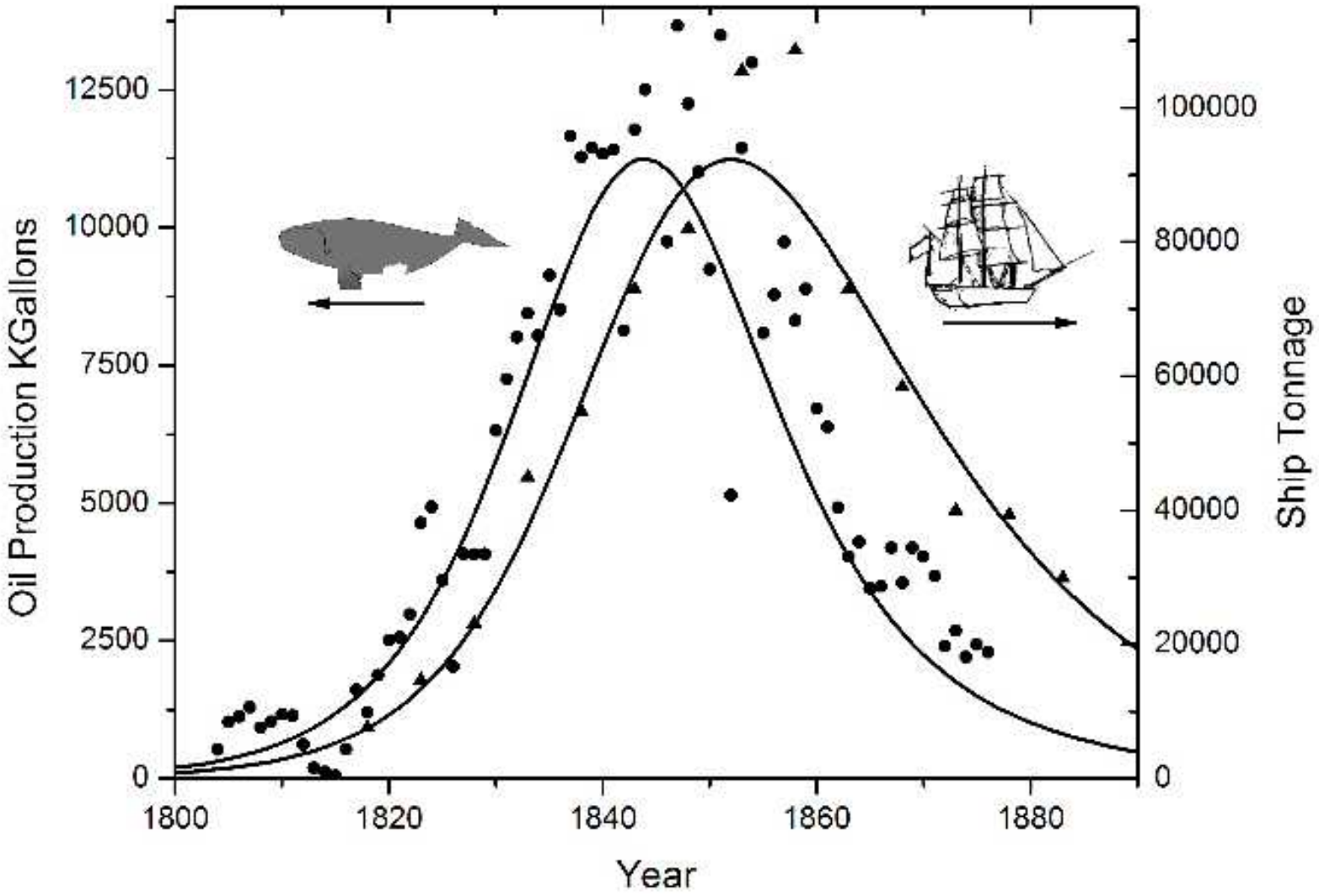
Jay Forrester: the concept of
«overshoot» in
Socioeconomic systems.
1971



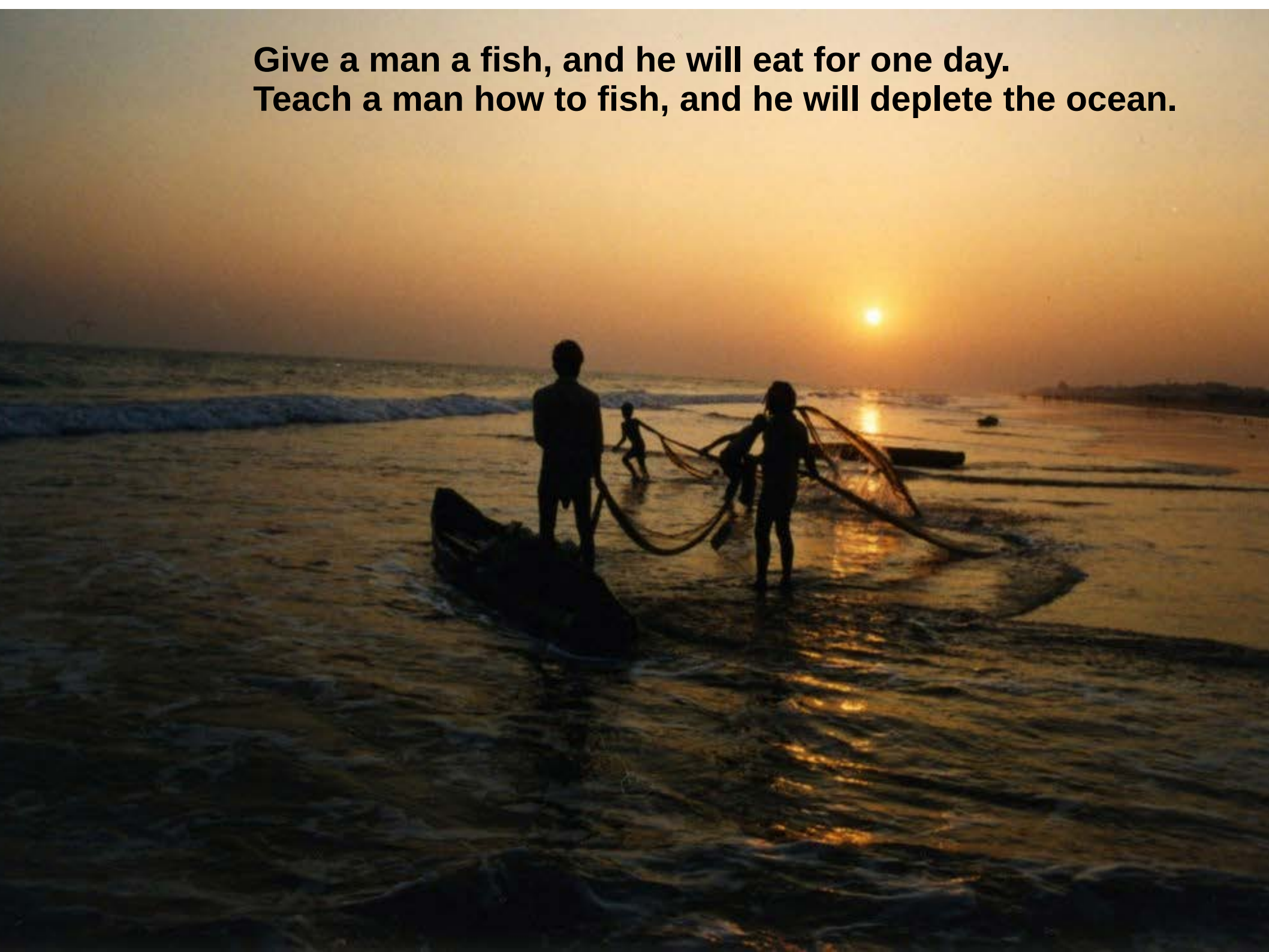
The Limits to Growth, 1972



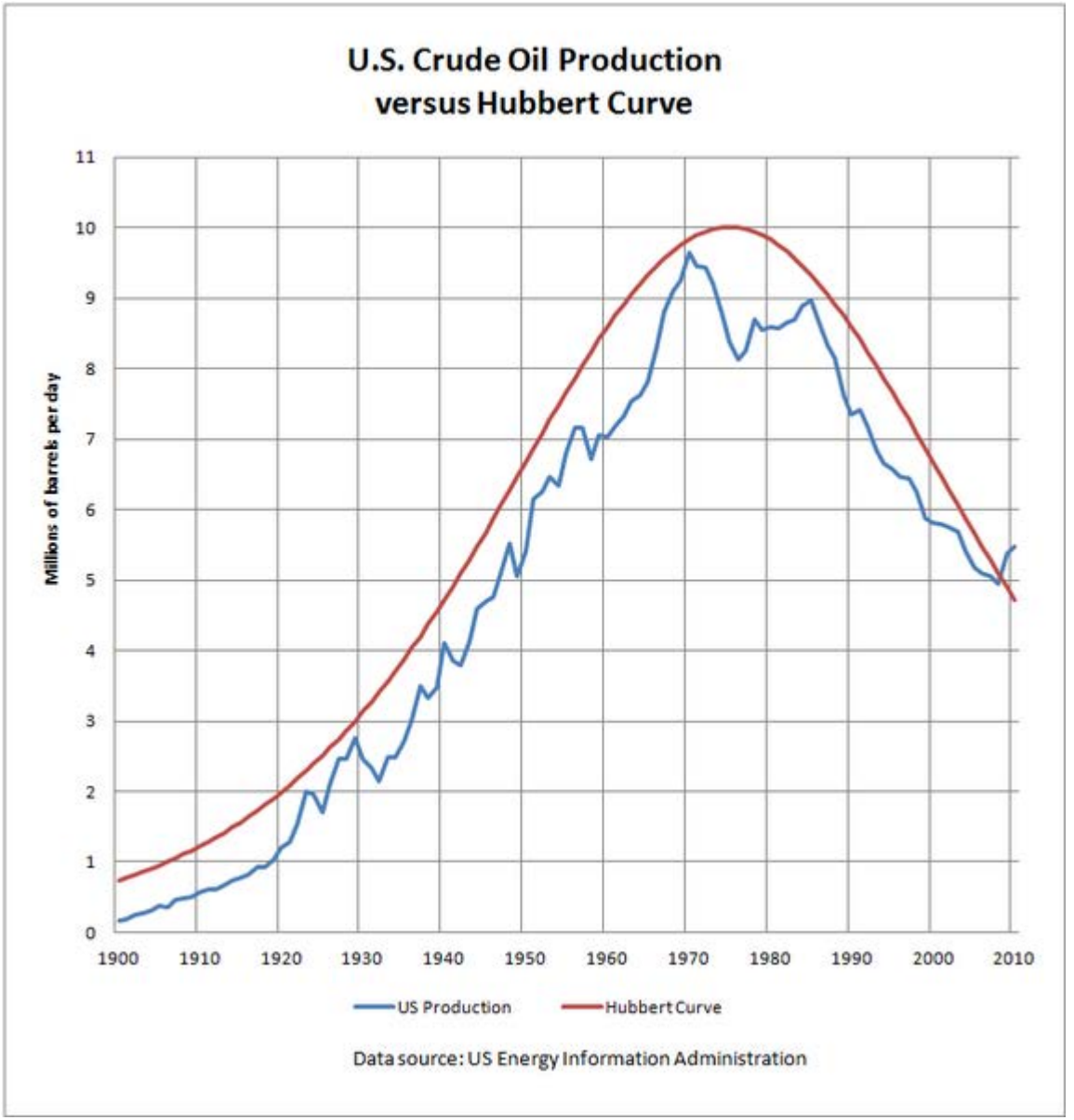
Whaling in 19th century

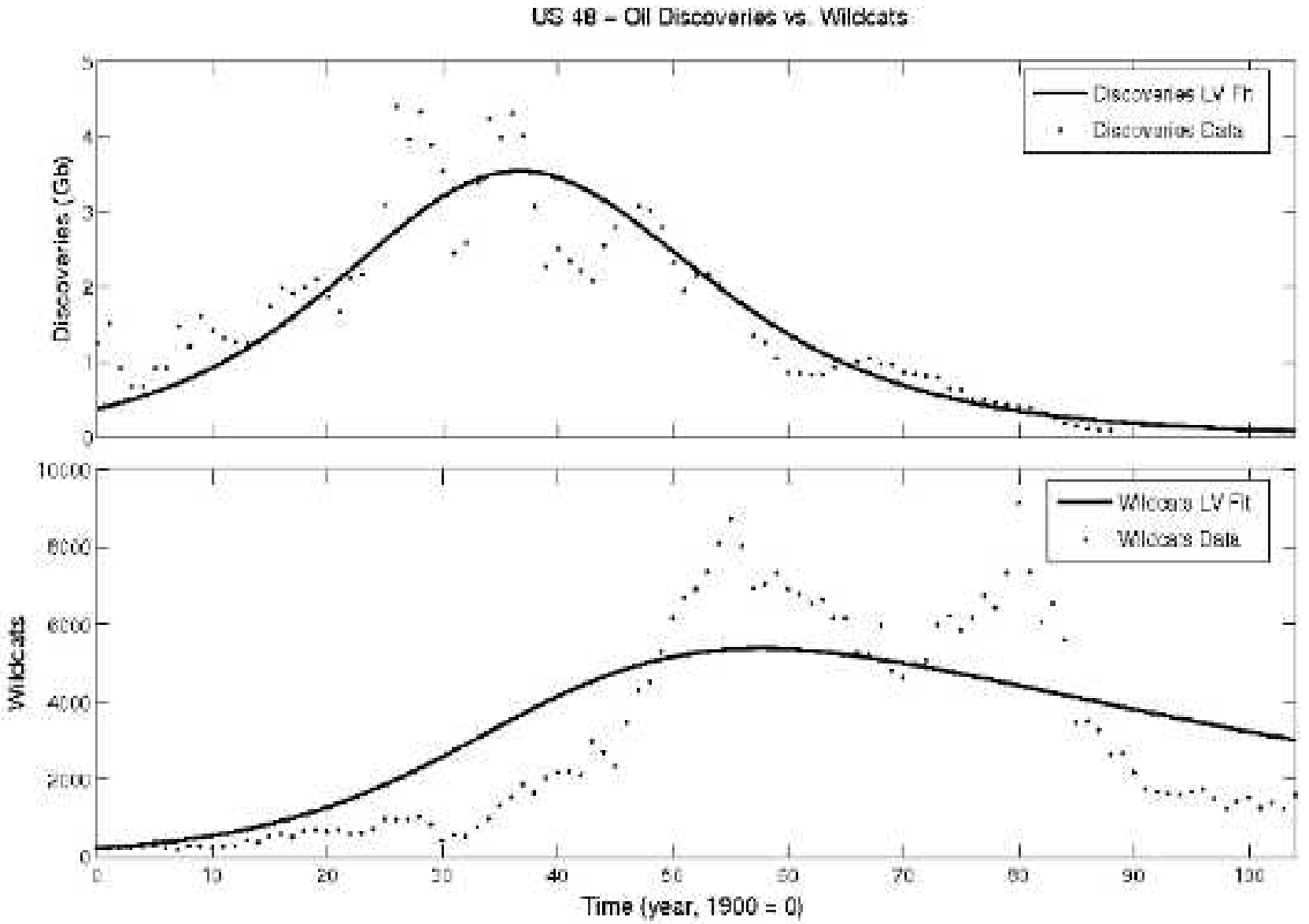


U. Bardi and A. Lavacchi, Energies, 2009


Give a man a fish, and he will eat for one day.
Teach a man how to fish, and he will deplete the ocean.

An example of the Hubbert curve, oil production in the US





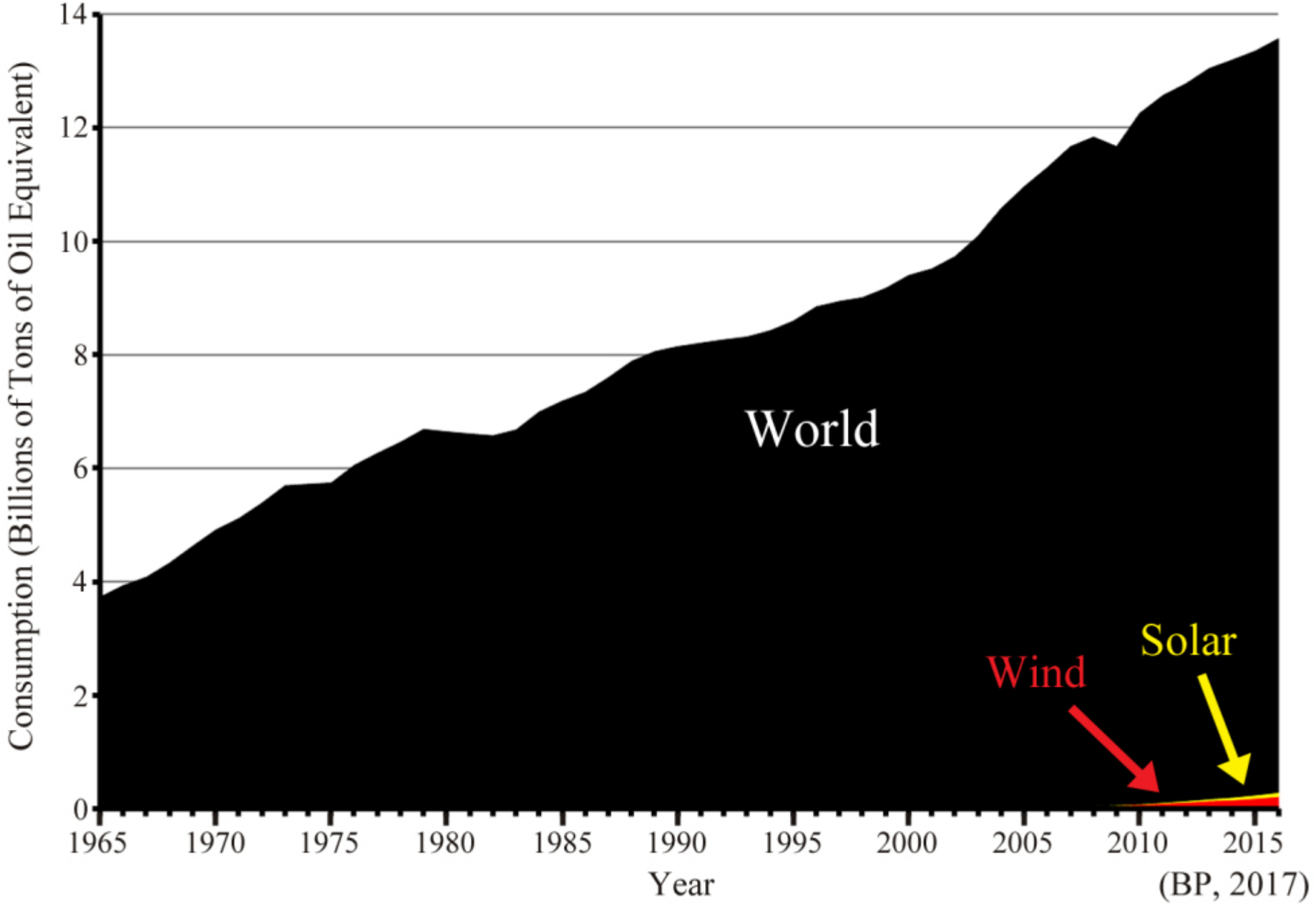
U. Bardi and A. Lavacchi, Energies, 2009

Energiewende

Energy **in truth stands not beside but entirely above all other commodities.... With *energy* almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times.**

William Stanley Jevons, 1866

Total World, Wind, and Solar Energy Consumption (1965-2016)



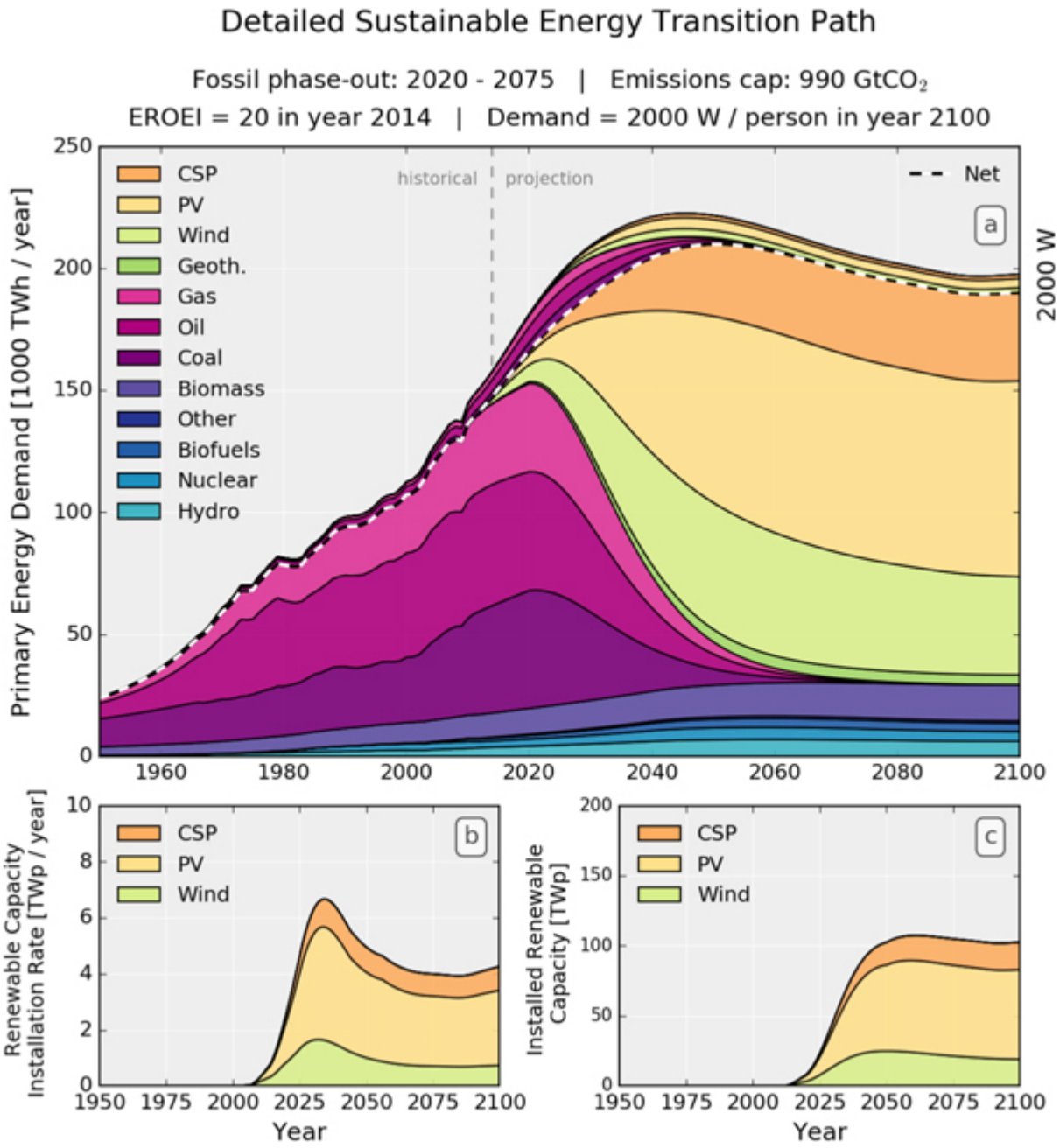
The Sower's Strategy:
Sowing today's Energy for the energy of tomorrow

As a man himself sows, so he himself reaps... The fruit is of the same quality as the action.

—Mahabharata, xii.291.22

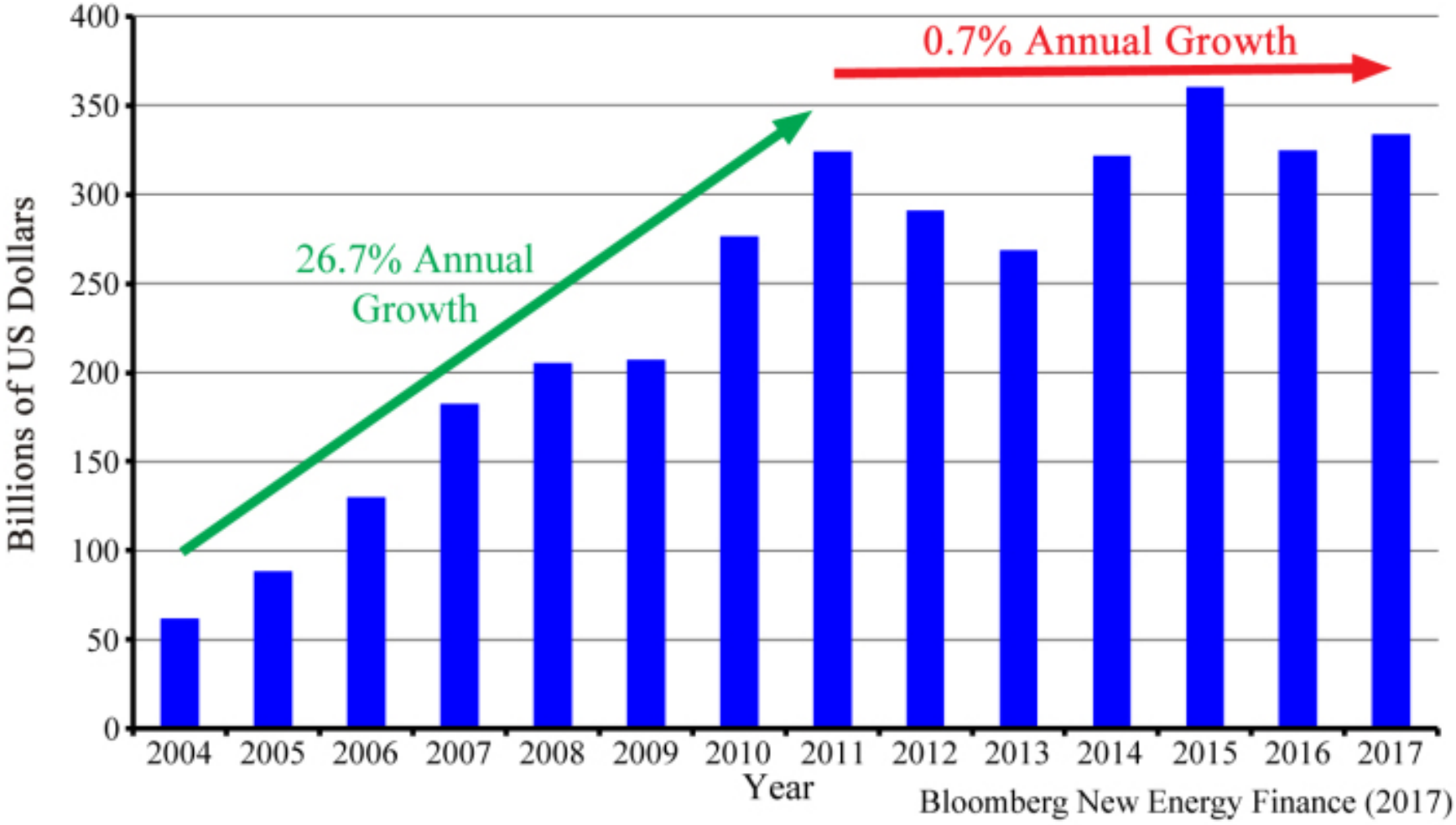
Whoever sows sparingly will also reap sparingly, and whoever sows bountifully will also reap bountifully.

Corinthians 9:6



Sgouridis, Csala, Bardi, 2016

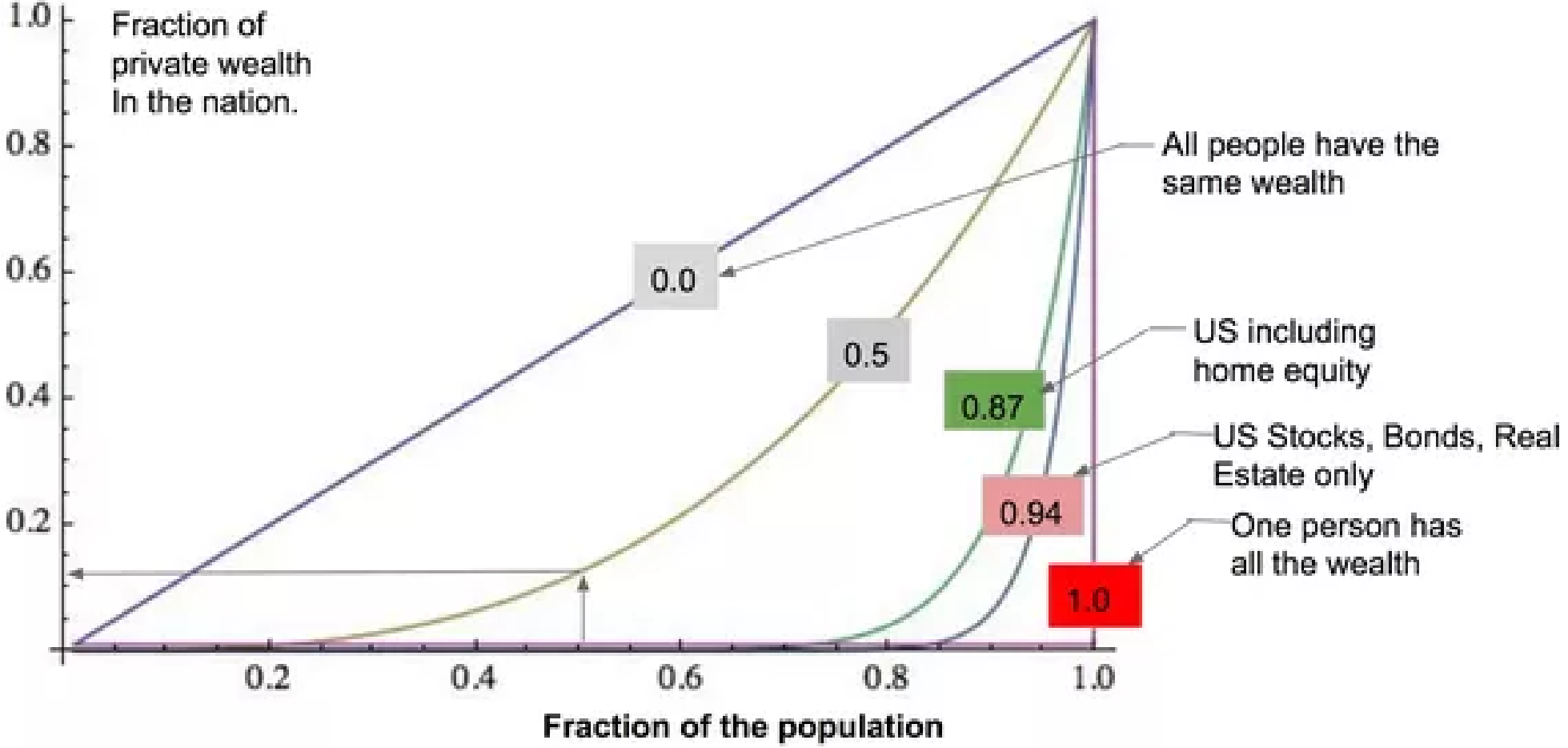
Global Investment in Renewable Energy 2004-2017



1 NO POVERTY
2 NO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 RENEWABLE ENERGY
8 GOOD JOBS AND ECONOMIC GROWTH
9 INNOVATION AND INFRASTRUCTURE
010 011
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS
For Sustainable Development

Inequality: Who Eats the Cake?

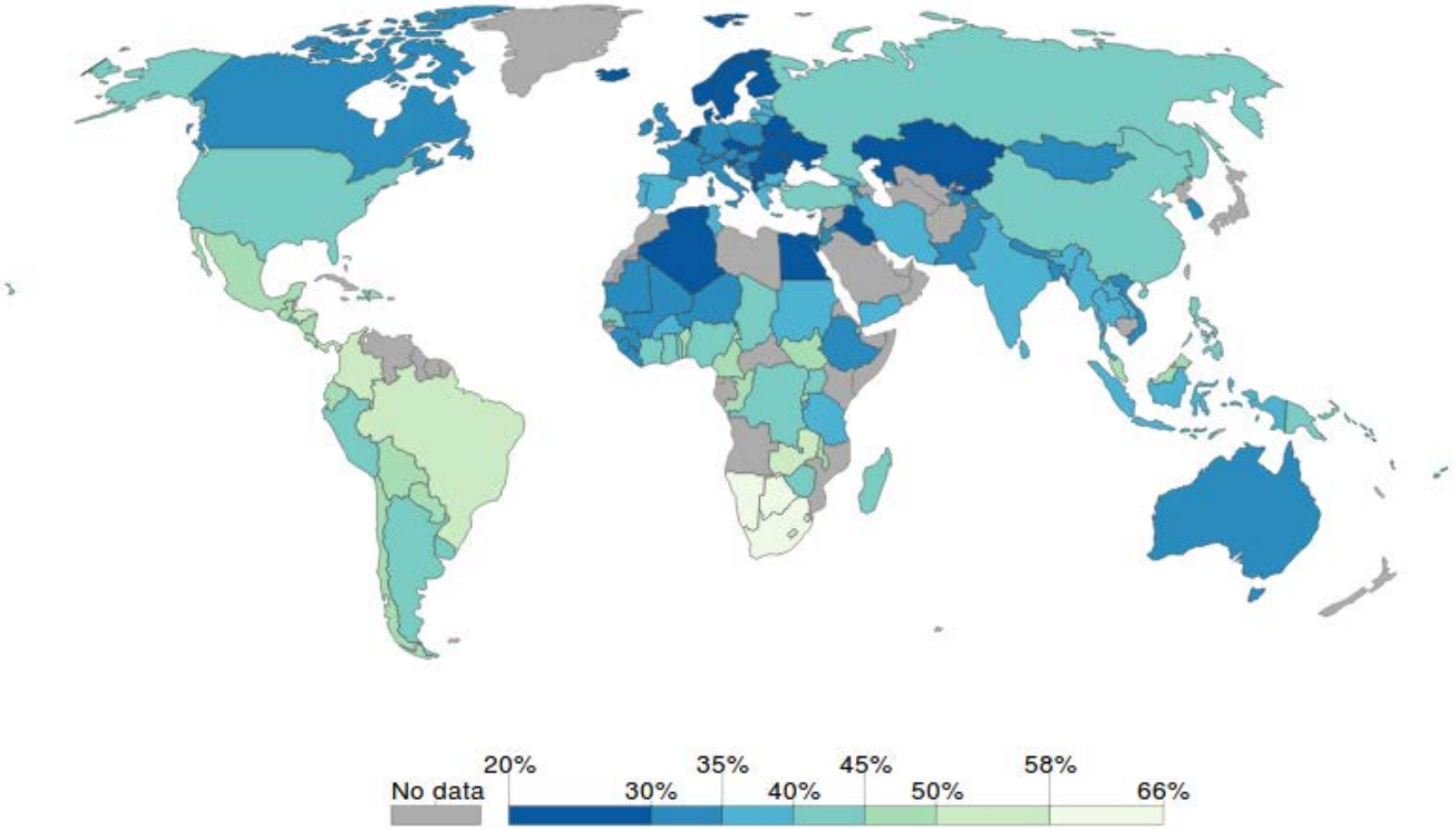
Wealth Inequality Defined by the Gini Coefficient



Economic inequality – Gini Index, 2013

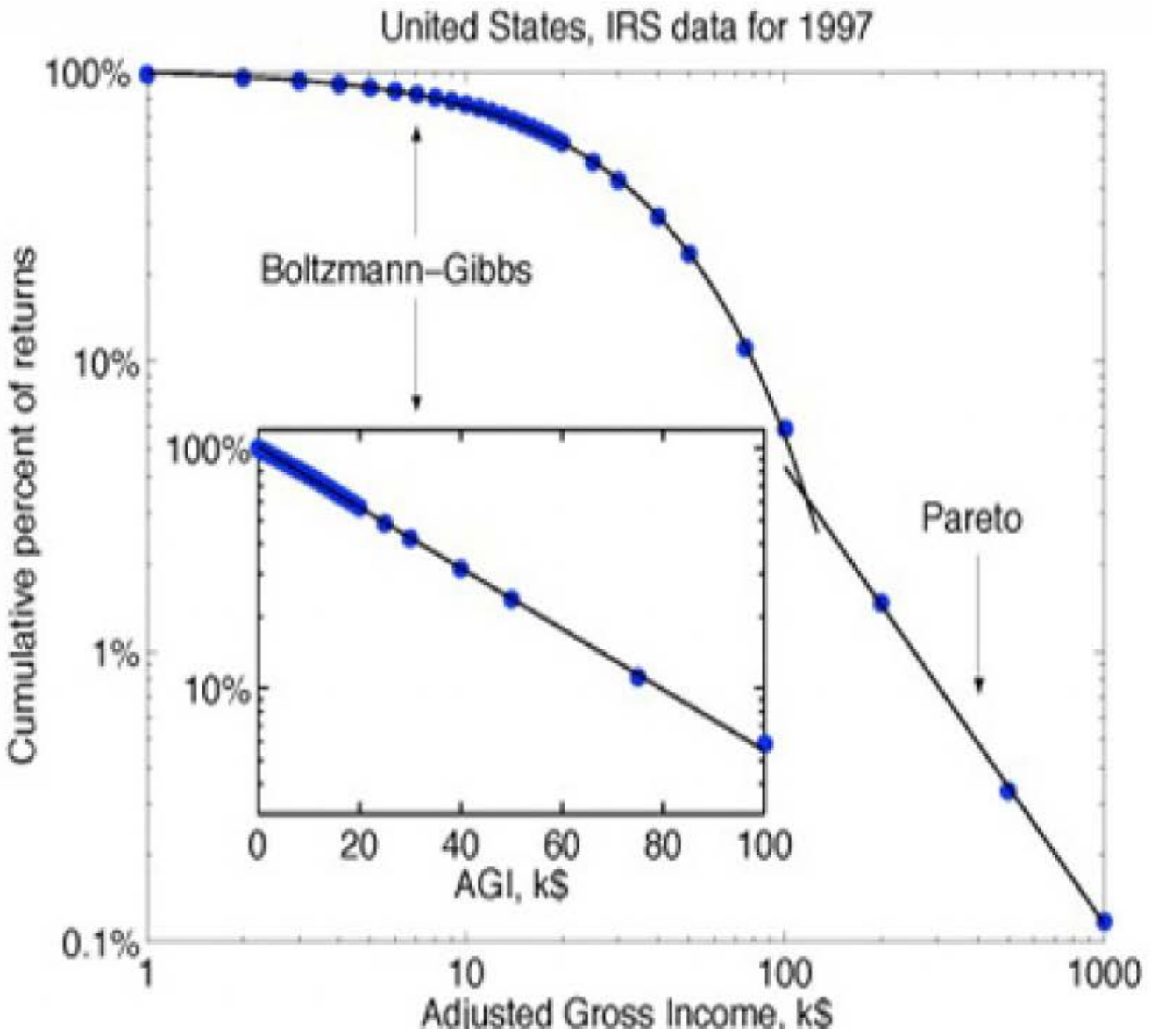
Shown is the World Bank (PovcalNet) inequality data. This data includes both income and consumption measures and comparability across countries is therefore limited. A higher Gini index indicates higher inequality.

Our World in Data

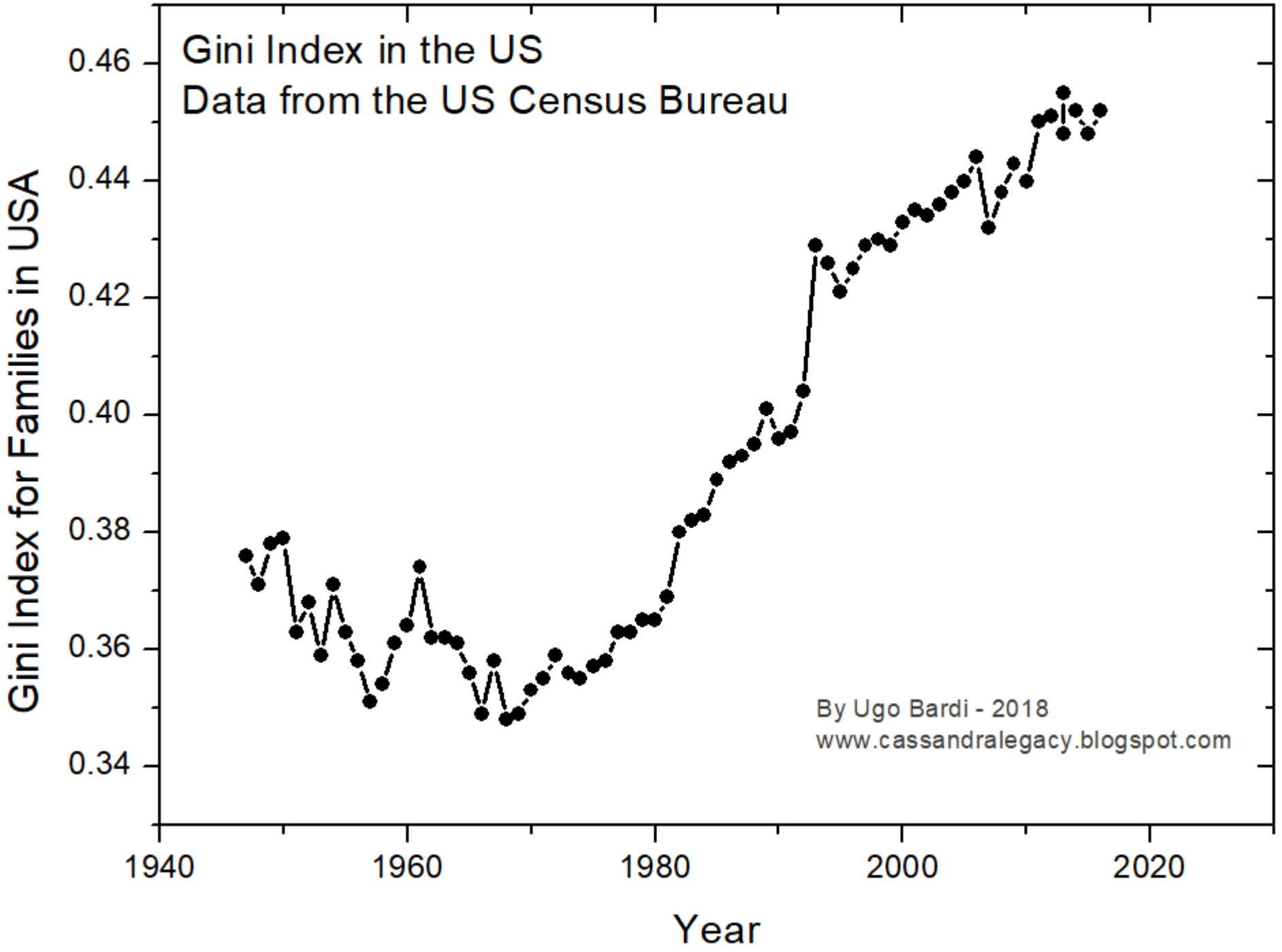


Source: World Bank

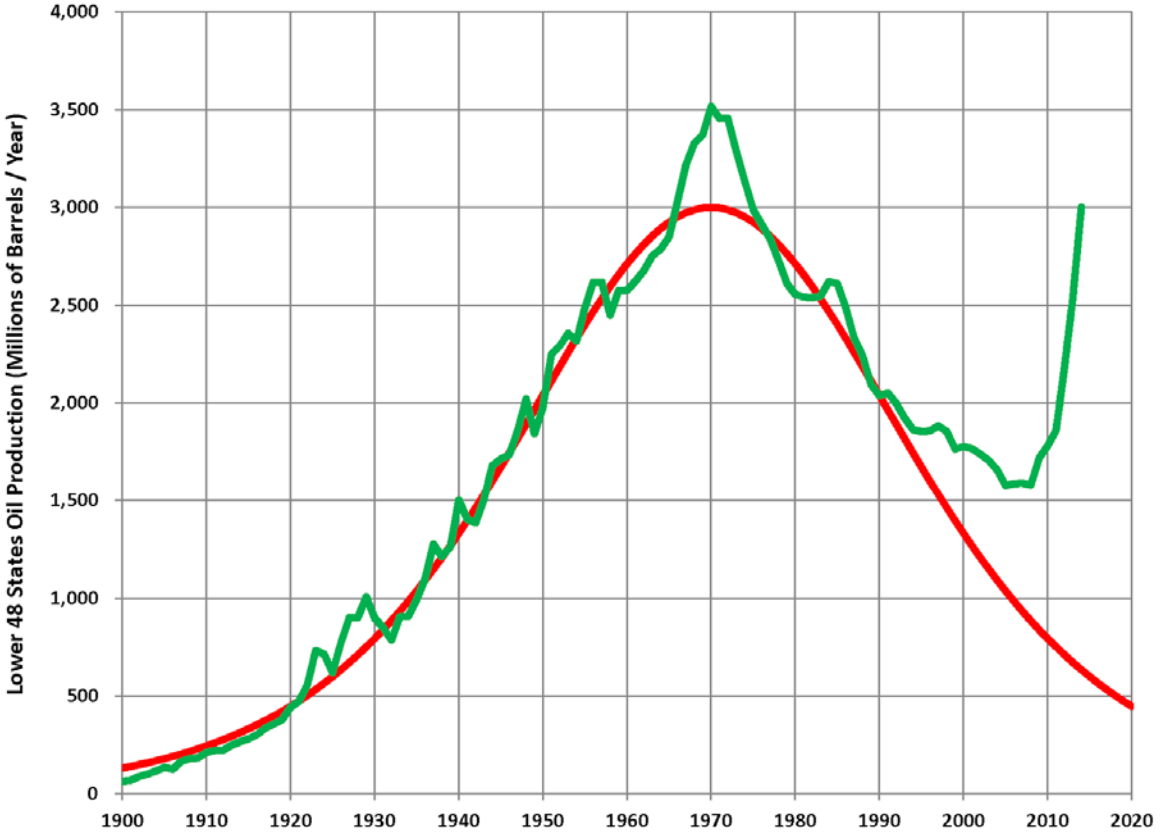
OurWorldInData.org/income-inequality/ • CC BY-SA



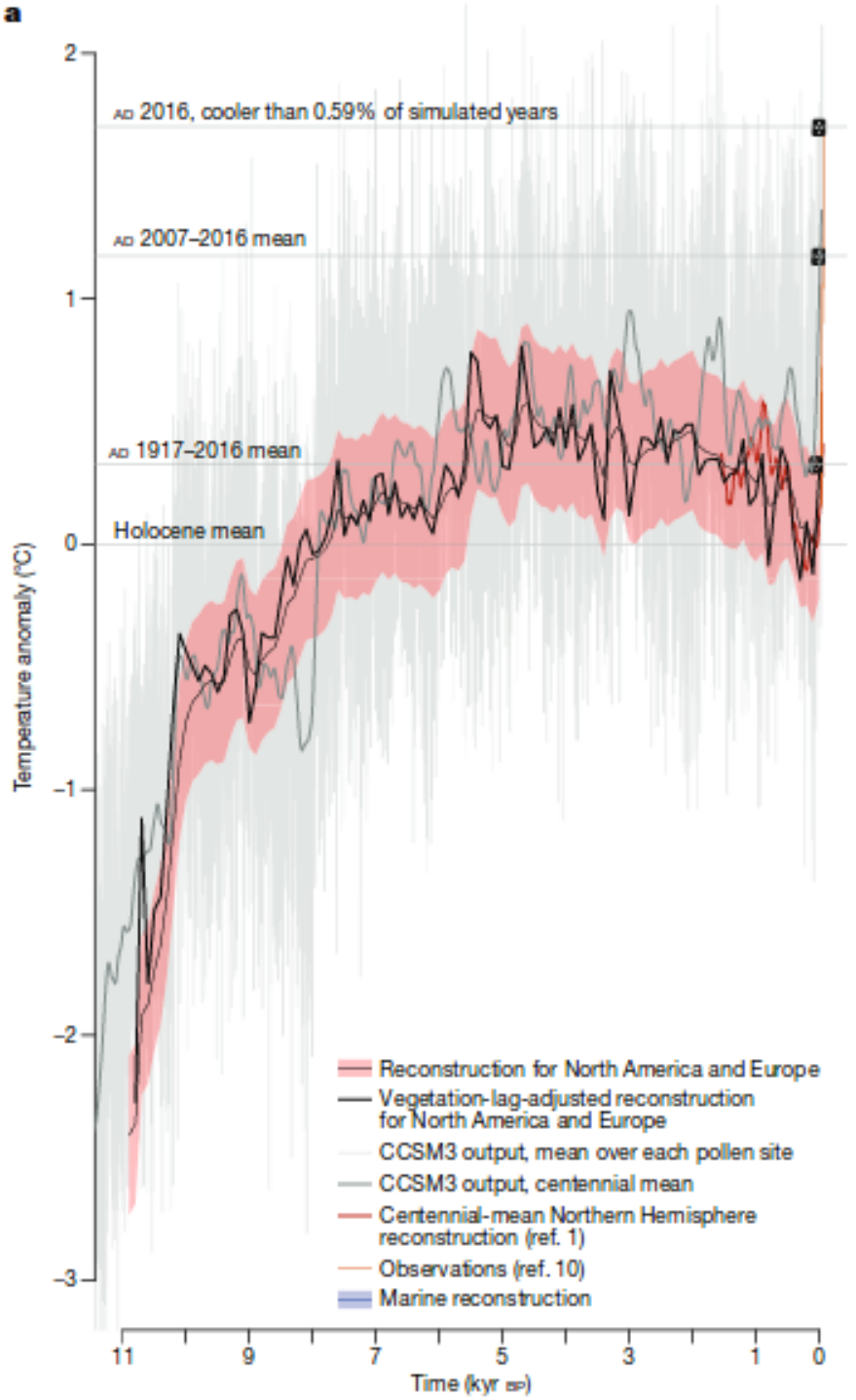
Yakovenko et al.


Gini Index in the US
Data from the US Census Bureau
Gini Index for Families in USA
0.46
0.44
0.42
0.40
0.38
0.36
0.34
1940
1960
1980
2000
2020
Year
By Ugo Bardi - 2018
www.cassandralegacy.blogspot.com

"Something" happened
In the mid-70s



Pollen Temperature reconstruction



Marsicek et Al. Nature 2018

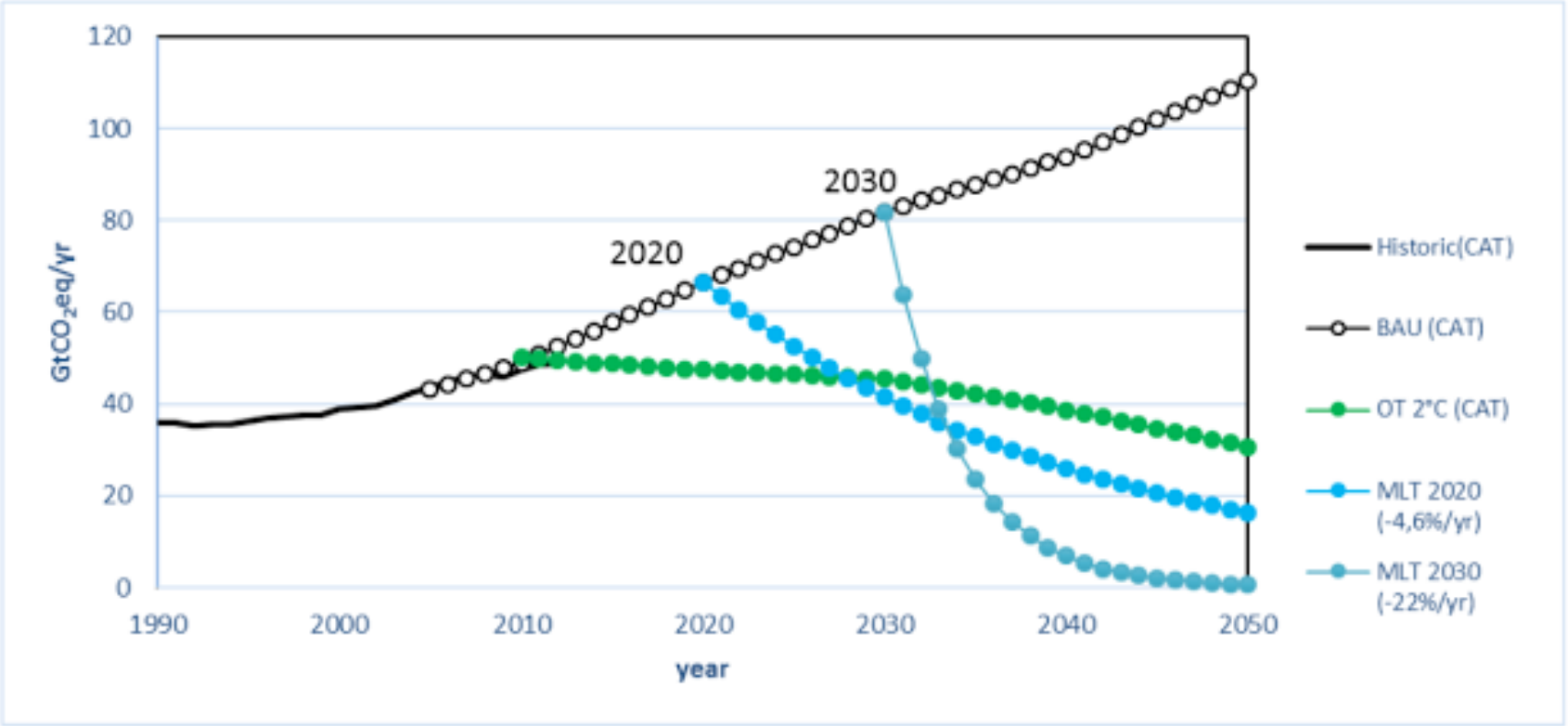


Figure 1: MLT 2020 and MLT 2030 GHG emission are extrapolated from the BAU scenario considering that the global carbon budget is 485 $GtCO_2$ until 2050.The data source for BAU and OT is from Climate Action Tracker (CAT).

Bardi, Falsini, Perissi, 1018

Wednesday, June 13, 2018

Climate Change as a Game of Russian Roulette

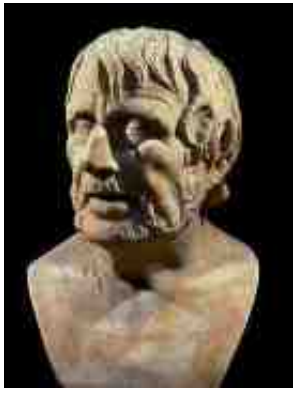
Ugo Bardi speaks at an event on climate change in Florence, on May 25th, 2018. Obviously, what I am holding is a toy, not a real gun. I was discussing guns as a metaphor for our penchant for doing dangerous things without exactly knowing what we are doing - for instance

Www.cassandralegacy.blogspot.com

The Seneca Effect

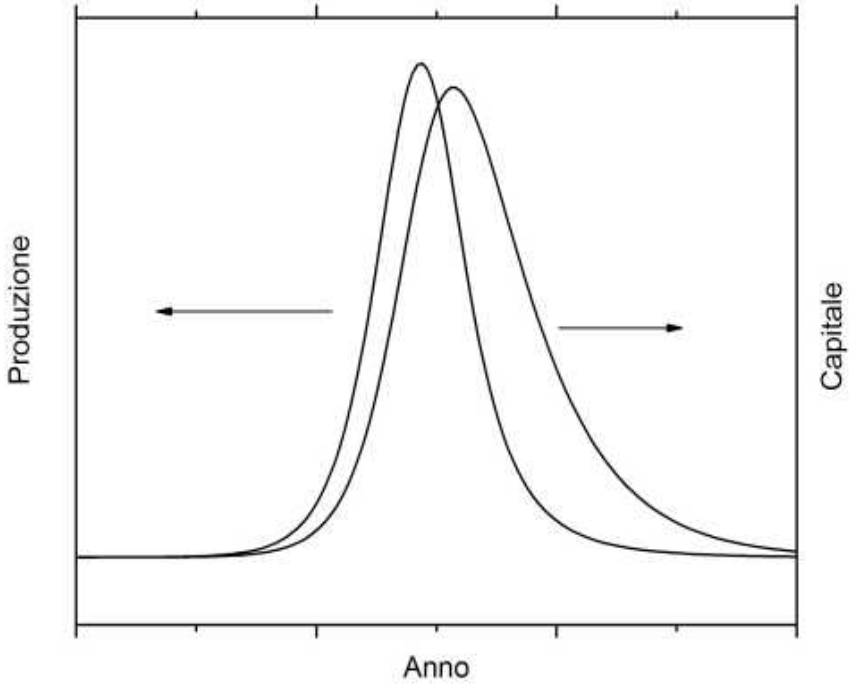
"It would be some consolation for the feebleness of our selves and our works if all things should perish as slowly as they come into being; but as it is, increases are of sluggish growth, but the way to ruin is rapid."

Lucius Annaeus Seneca 4 AD – 65 AD



Simplified model of resource depletion

$$R' = -k_1CR$$
$$C' = k_2CR - K_3C$$



***R'* = Production**
***C'* = Economic growth**

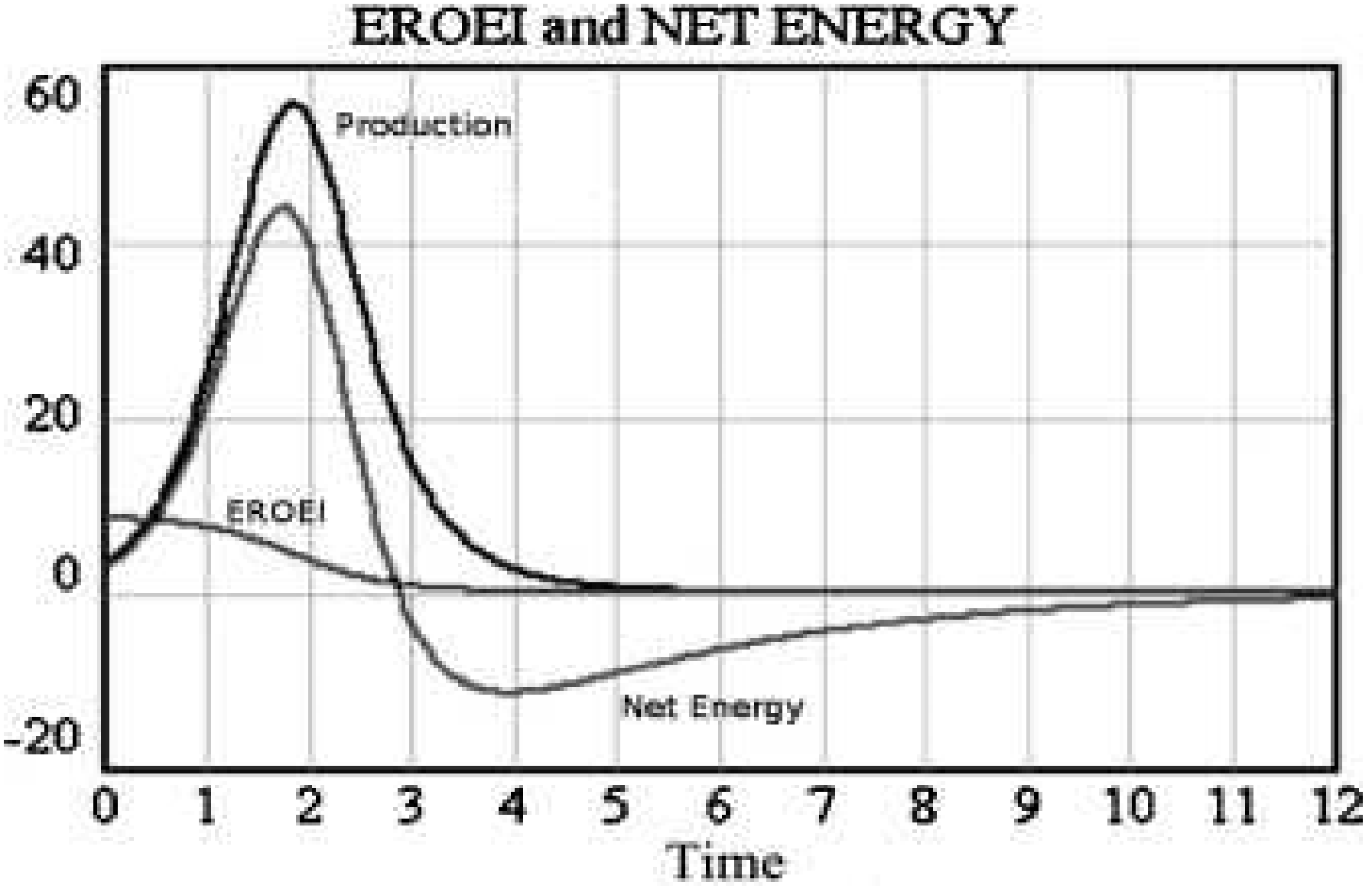
***C* = Capital**
***R* = Resources**

EROEI = (k1 * Oil Reserves * The Economy)/((k1*k2) * The Economy)

$$\text{EROEI} = \frac{Oil\ Reserves}{k_2}$$

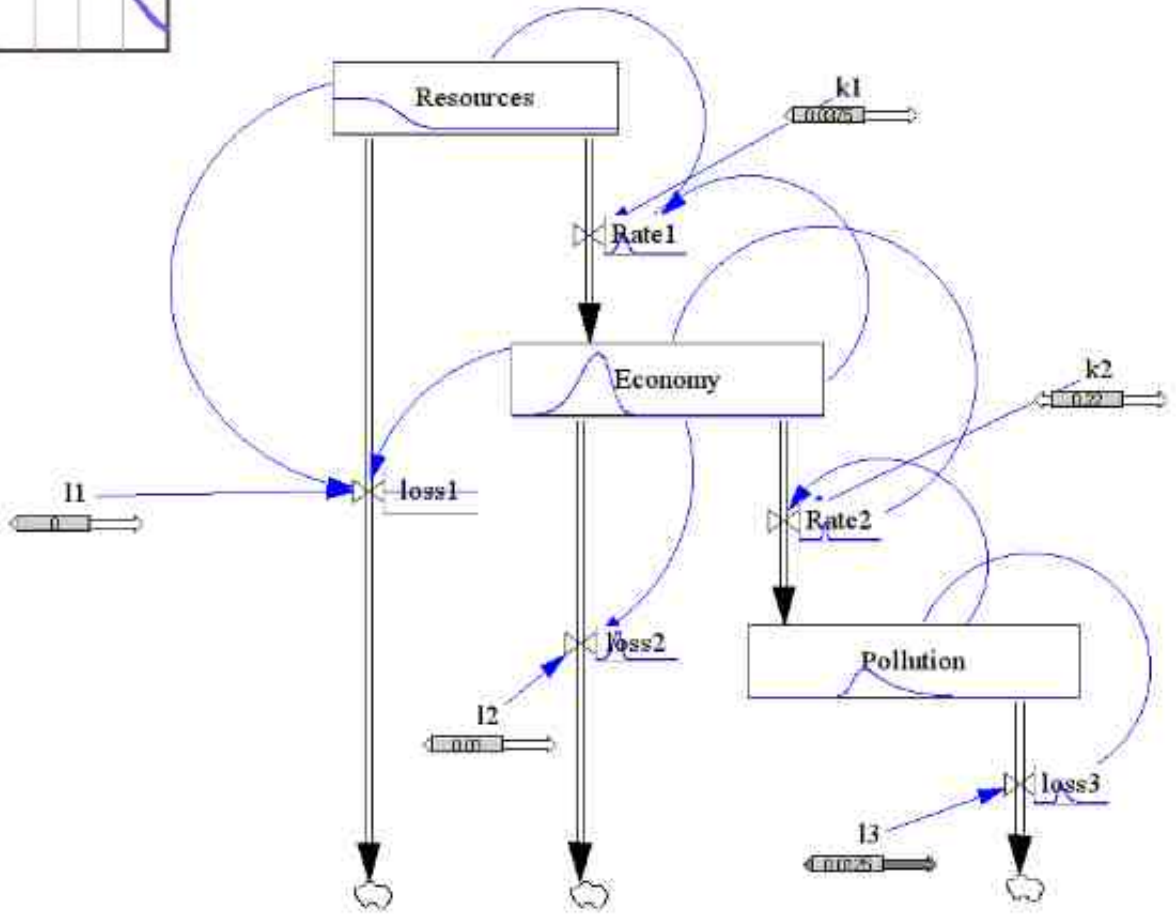
Net energy = (k1 * Oil Reserves * The Economy) - ((k1*k2) * The Economy)

Net energy = (k1 * The Economy) * (Oil Reserves – k2)

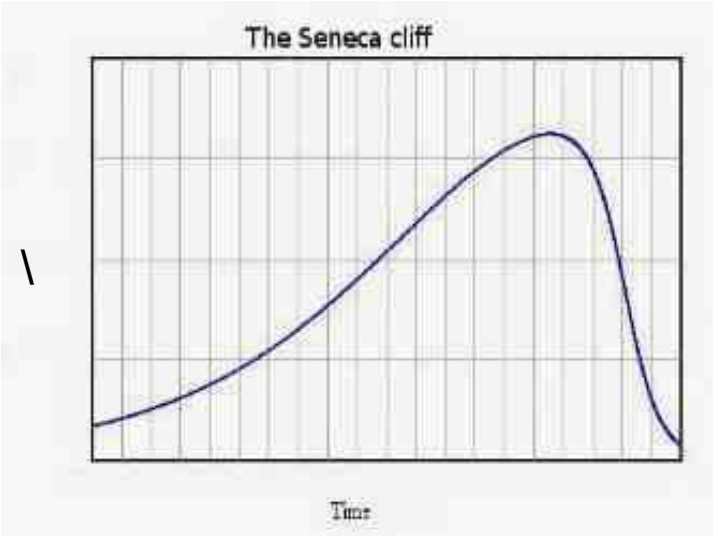


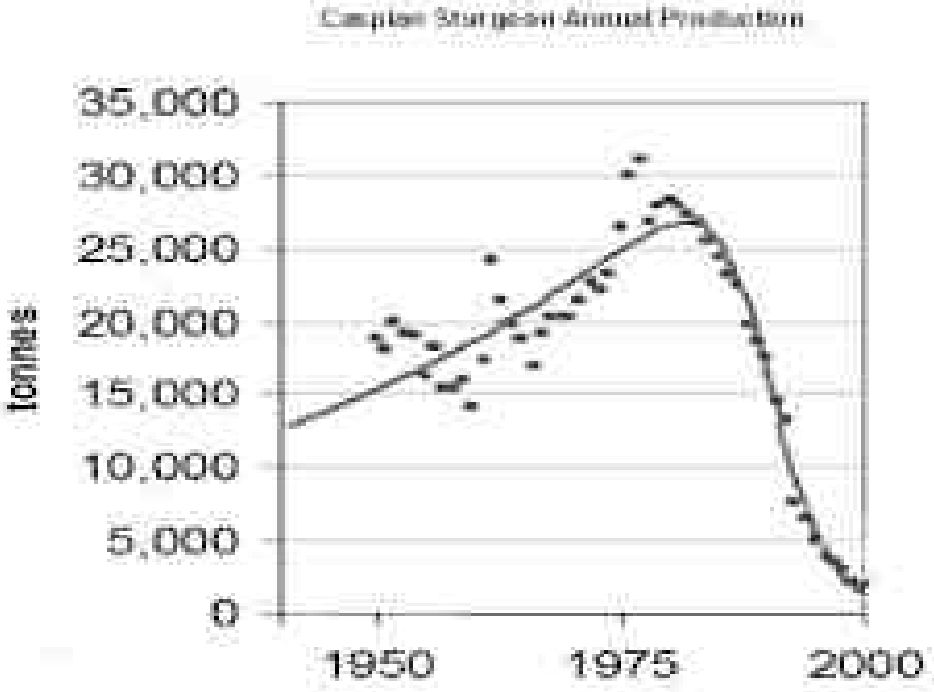
Bardi, Lavacchi, and Yaxley - 2011

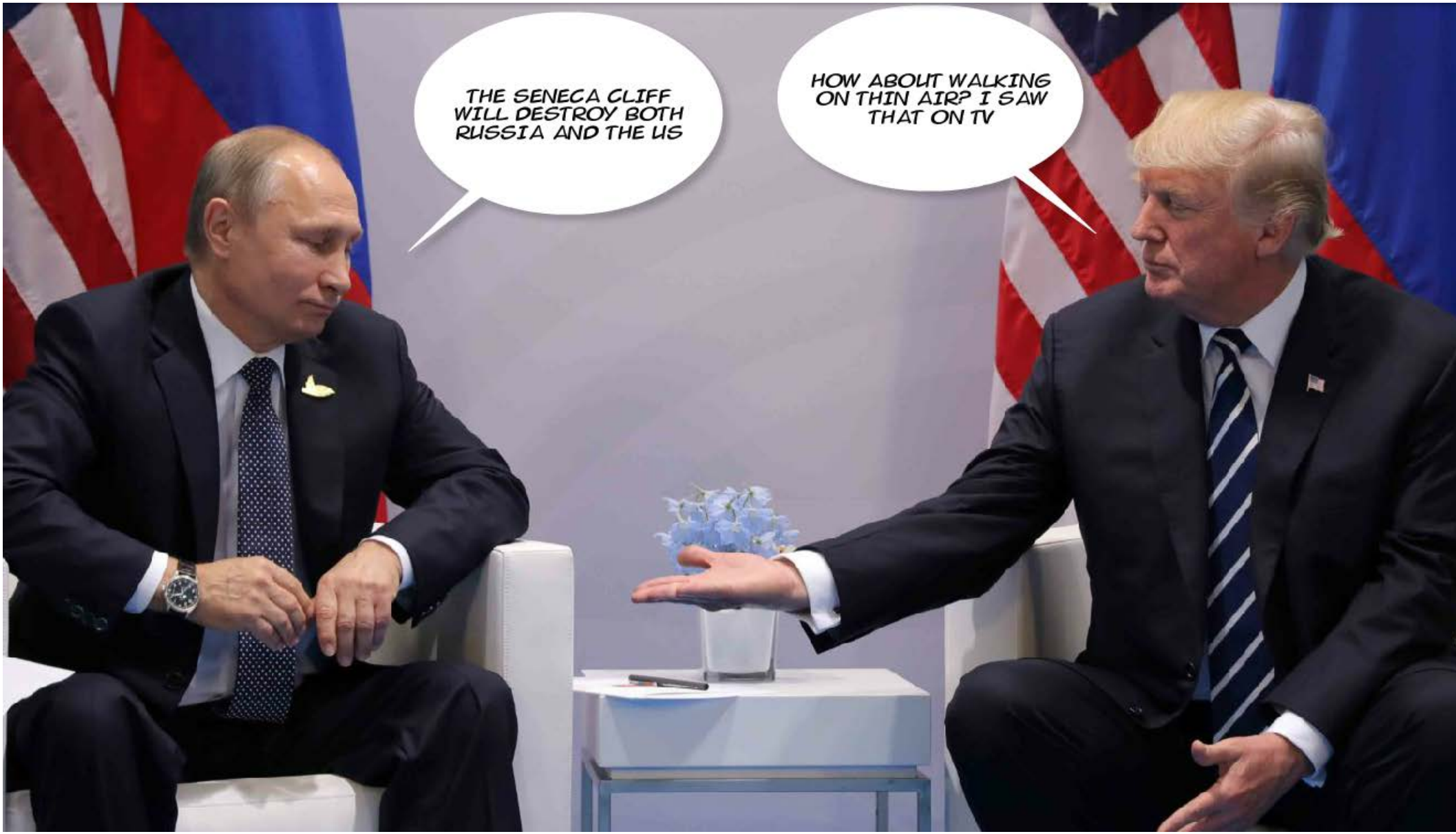
The Seneca Effect



An example of the Seneca Effect: Caviar production in the Caspian sea






THE SENECA CLIFF WILL DESTROY BOTH RUSSIA AND THE US
HOW ABOUT WALKING ON THIN AIR? I SAW THAT ON TV

Acknowledgement

The MEDEAS EU project

The Club of Rome

The «Energy Transition» group

The Brutal Logic of Climate Change

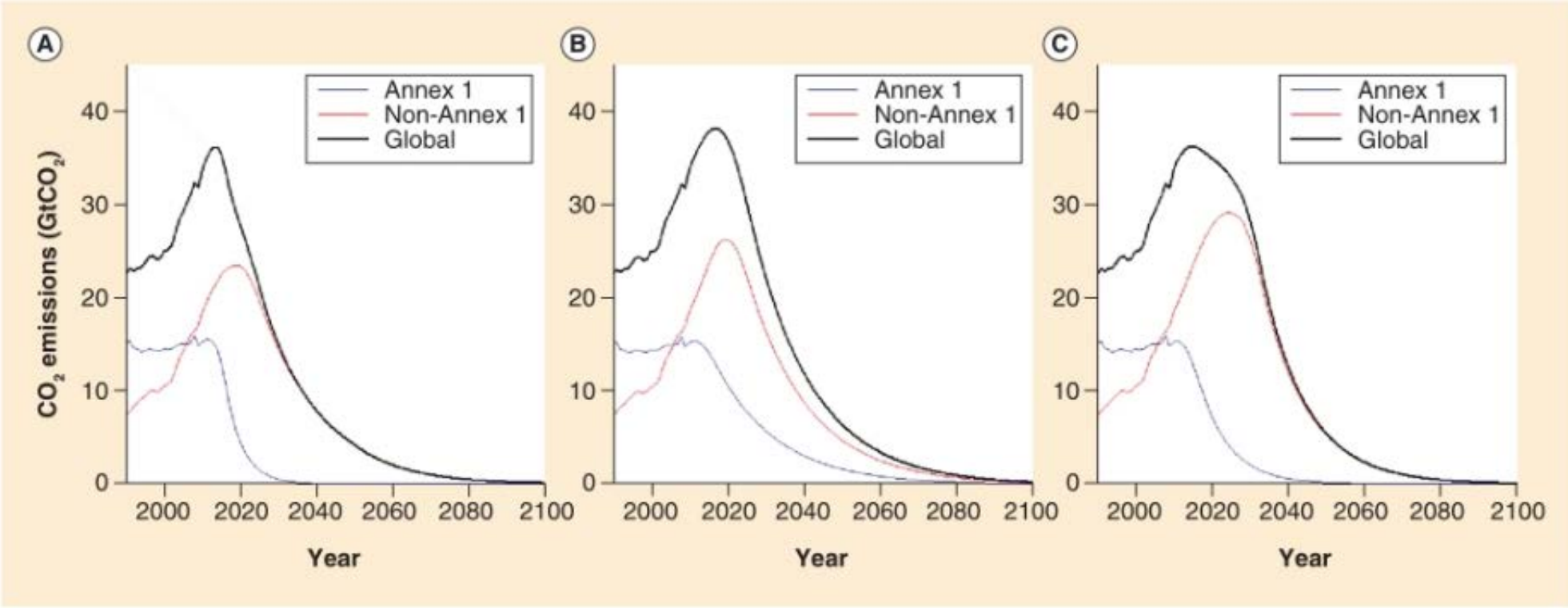
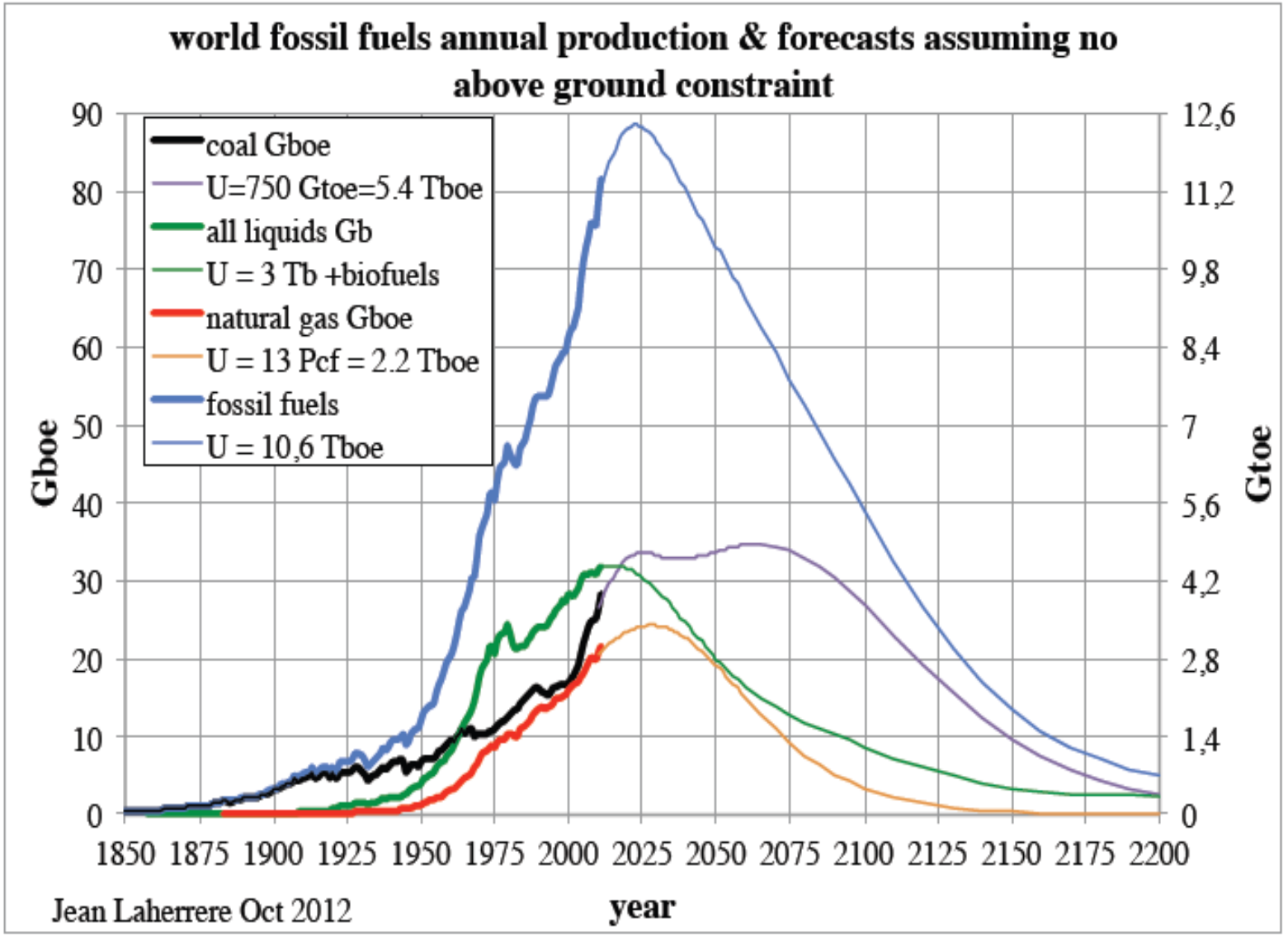


Figure 1. Global, Annex 1 and non-Annex 1 emission pathways of CO_2 only from energy with different probabilities of not exceeding 2°C. (A) Has an approximately 60% chance; **(B)** an approximately 50% chance with a later peak; **(C)** an approximately 50% chance with an earlier global (and later non-Annex 1) peak. All pathways are updated versions of those within Anderson and Bows [10].

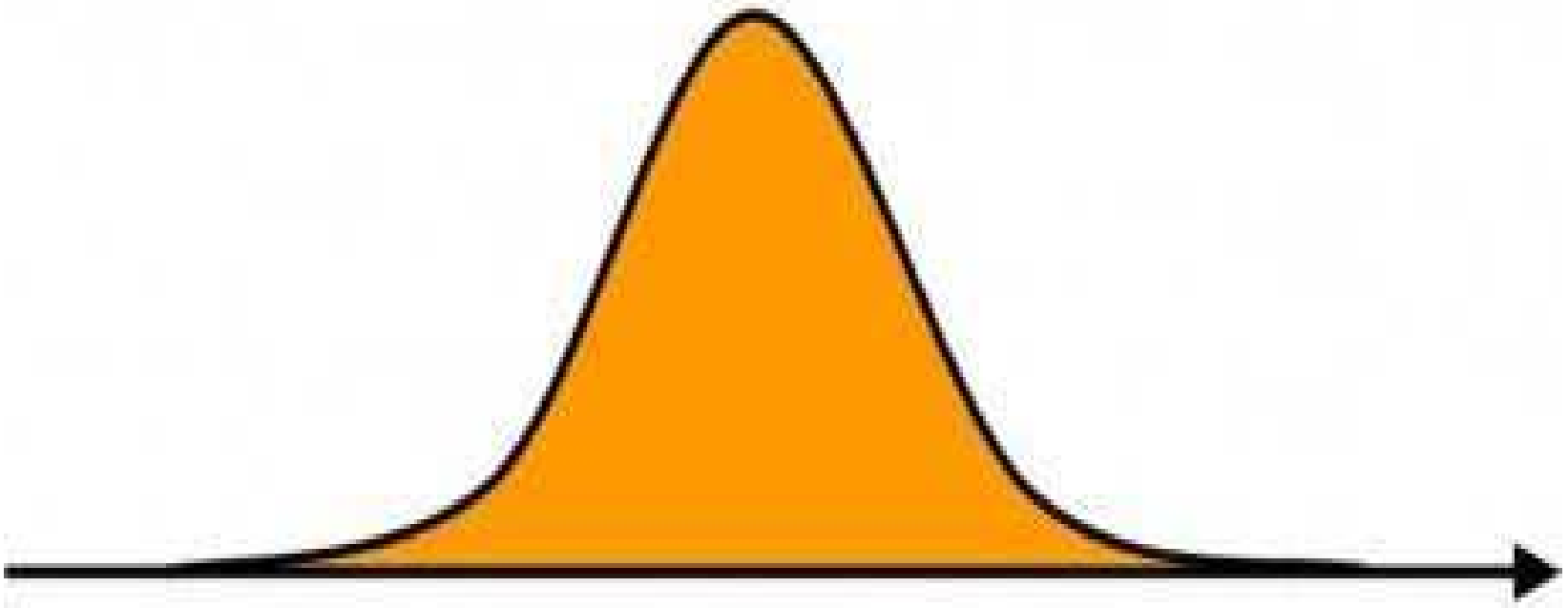
http://grist.org/climate-energy/the-brutal-logic-of-climate-change-international-shipping-edition/

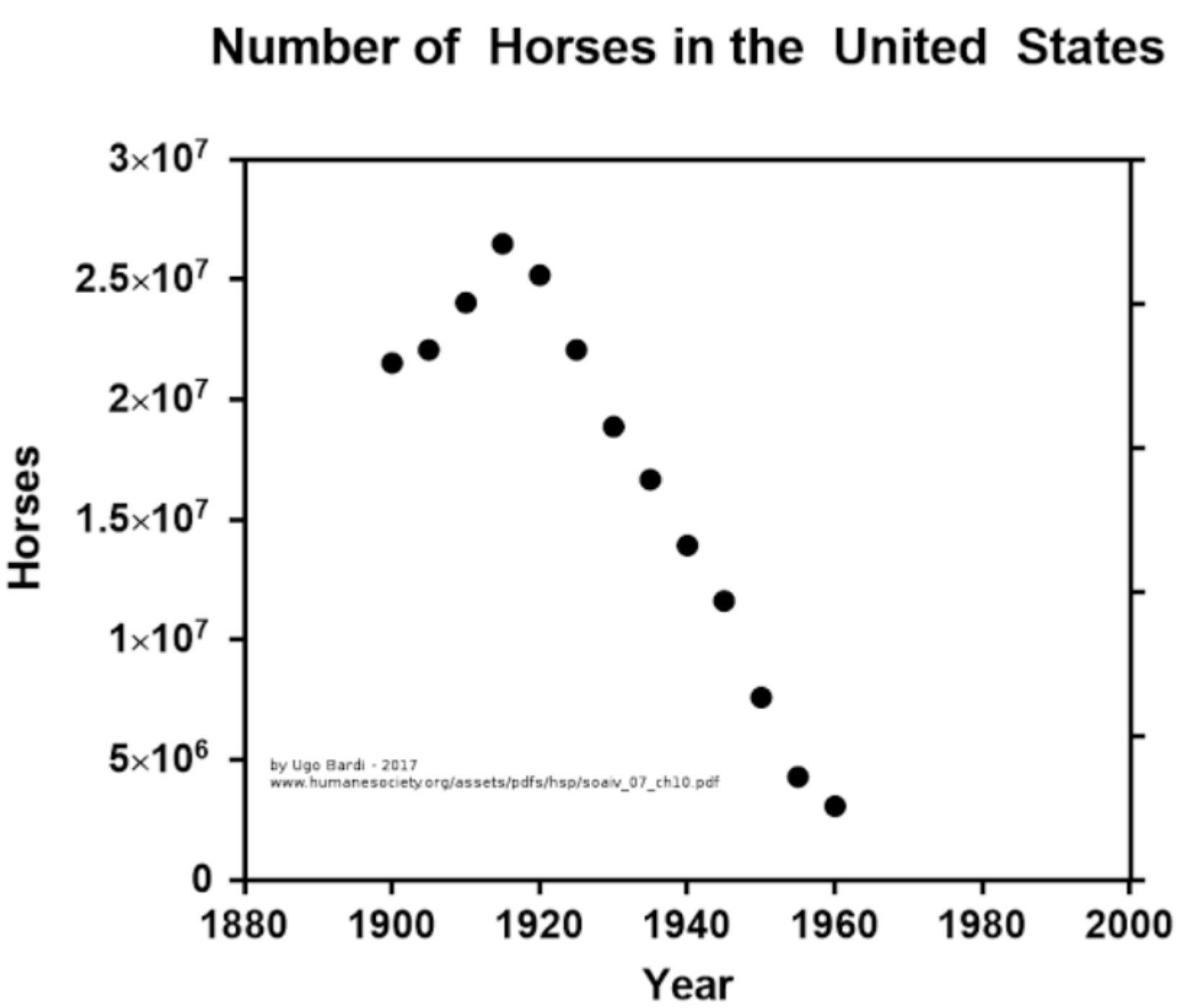


Total predicted emissions: 5x10+12 t CO2.
Maximum allowable for +2° C : 2.3x10+12 t CO2

http://www.theoildrum.com/node/9583

The Bell Curve (the Hubbert Curve)





http://www.humanesociety.org/assets/pdfs/hsp/soaiv_07_ch10.pdf).

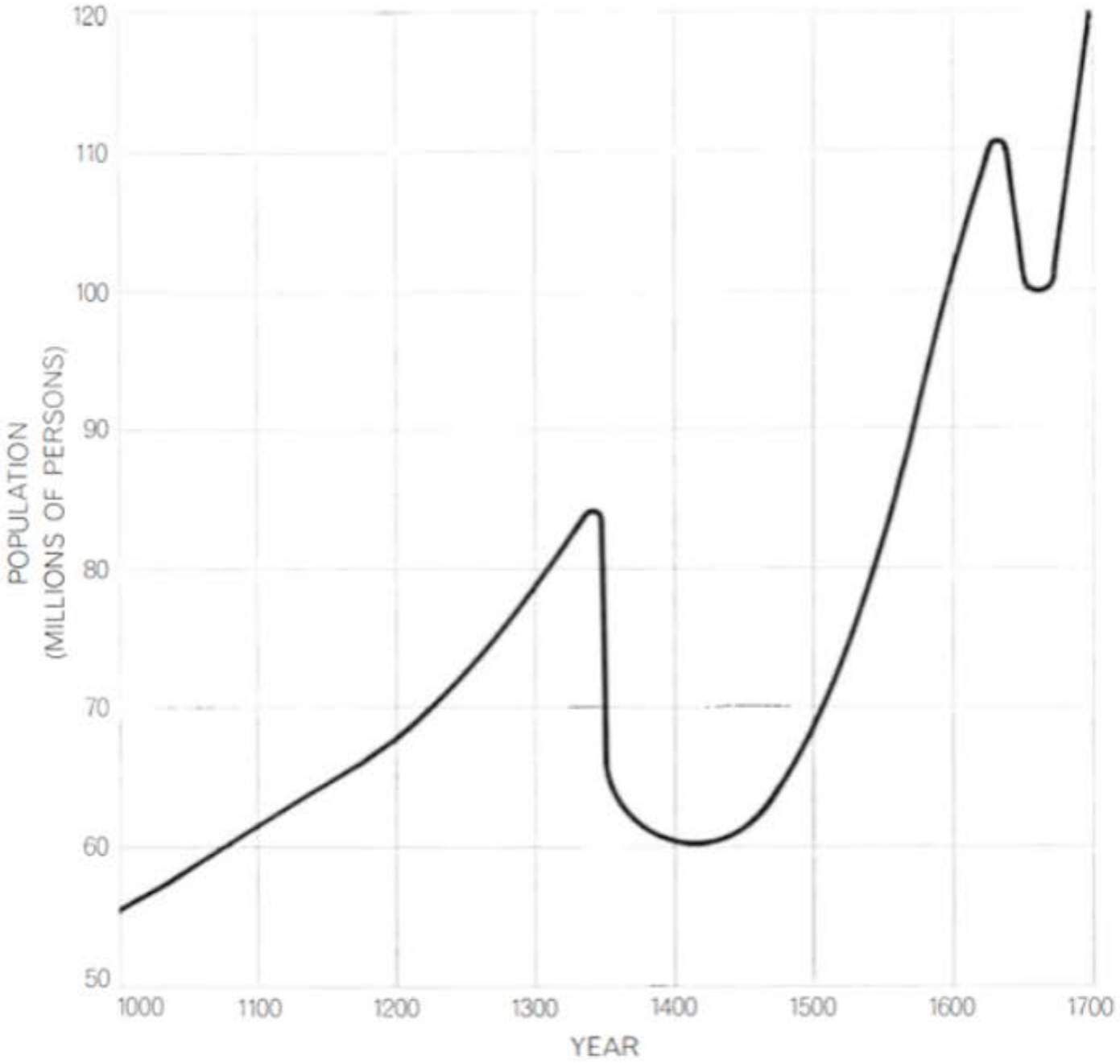


Figure 6 – European Population at the time of the Great Plague (from Langer[6])

Money, it's a gas
Grab that cash with both hands
And make a stash
(Pink Floyd)

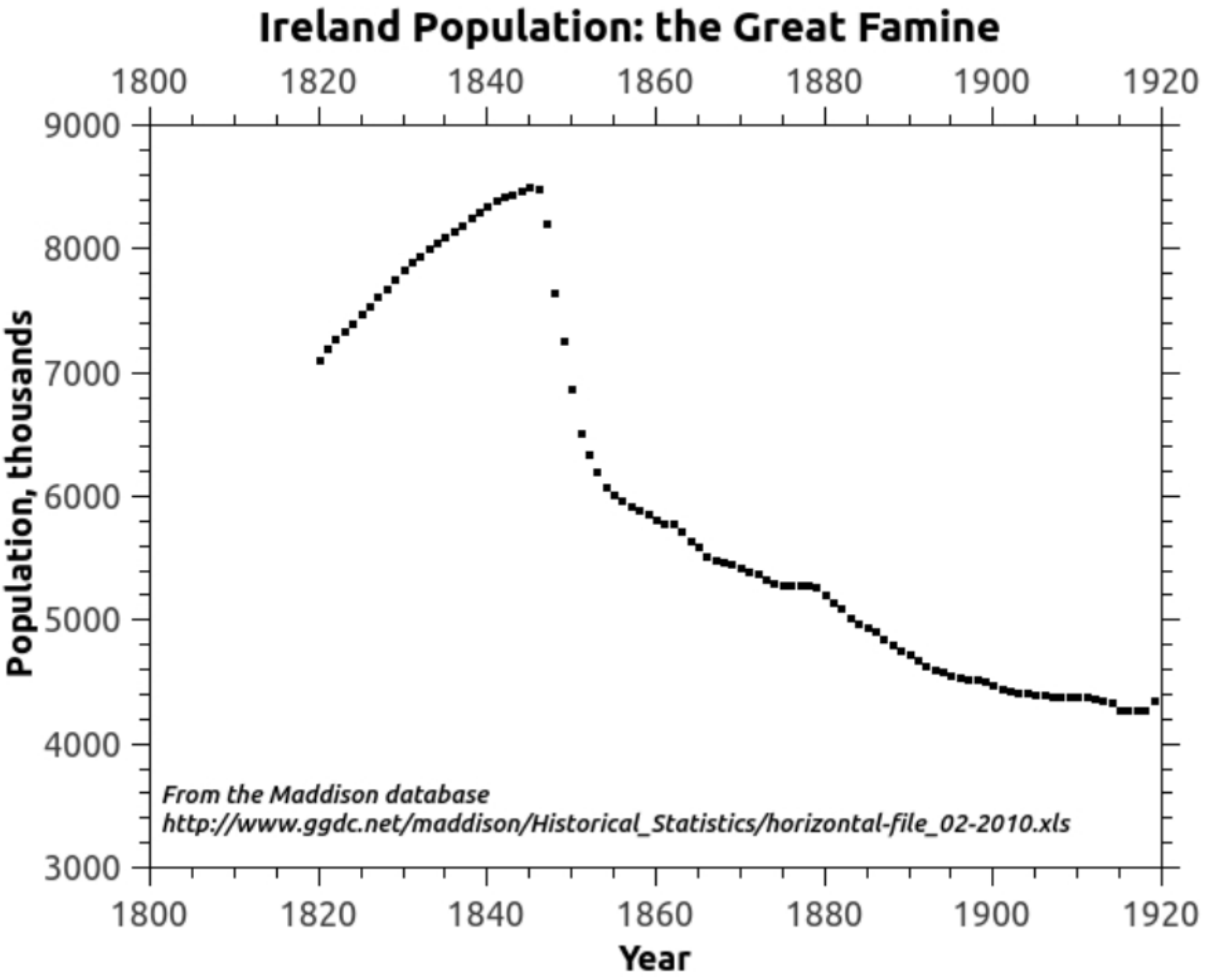
Give Them Money: The Boltzmann Game, a Classroom or Laboratory Activity Modeling Entropy Changes and the Distribution of Energy in Chemical Systems

Robert M. Hanson*
Department of Chemistry, St. Olaf College, Northfield, MN 55057; **hansonr@stolaf.edu*

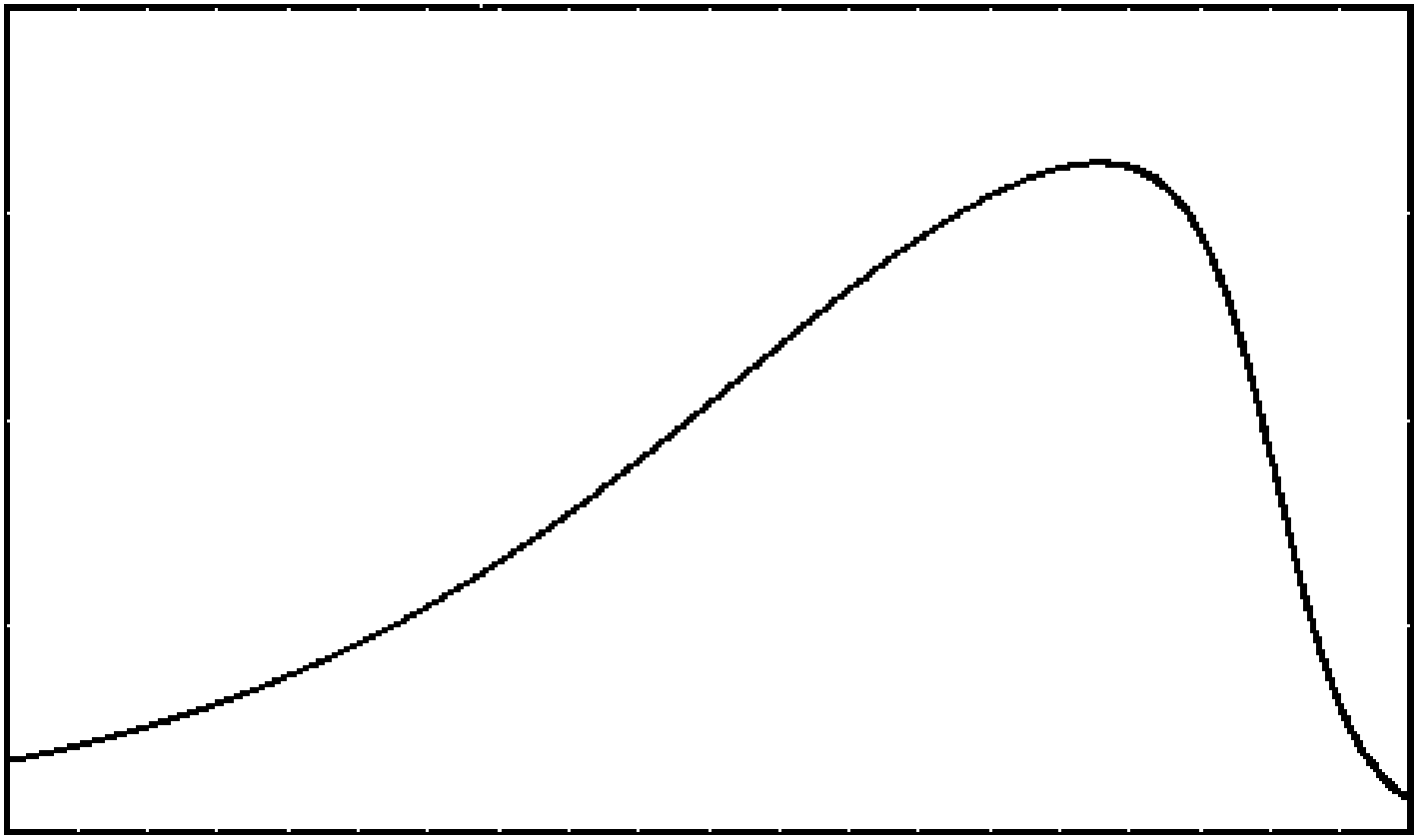
Bridget Michalek†
Eastview High School, Apple Valley, MN 55124

Recently in this *Journal (1–10)* and on the CHEMED-L listserv *(11)* there has been a lively discussion of the meaning of "entropy" and, in particular, how characterizing it as "disorder" is not helpful. Attempts have been made to characterize entropy qualitatively as the "spreading and sharing of energy" *(12)* or the "dispersal of energy" *(5)*. However, one of the essential characteristics of entropy often missing in these discussions is its simple relationship to probability. While there are many classroom activities that have been described that model equilibrium and Le Châtelier's principle *(13–17)*, and these, too, can all be conceptualized in terms of probability *(18)*, what seems to be lacking are simple *quantitative* activities that students can participate in that effectively convey the essential probabilistic nature of entropy. We describe just such an activity, then discuss why it works and suggest variations that might be used to illustrate additional points.

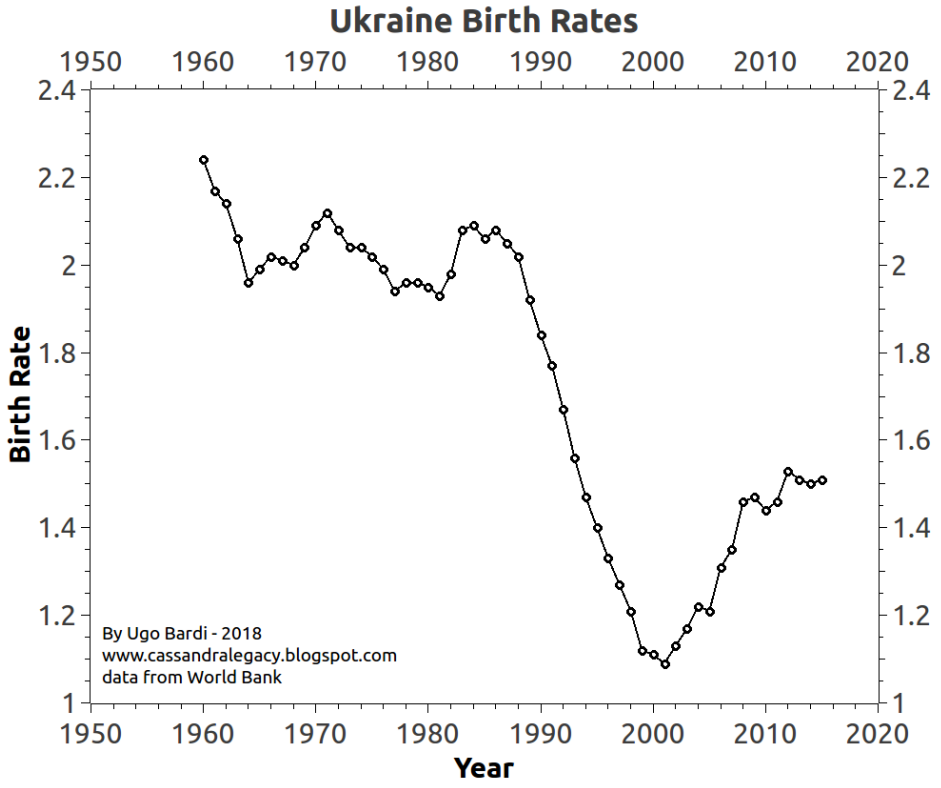
Figure 1. A group of 36 students playing the Boltzmann game.

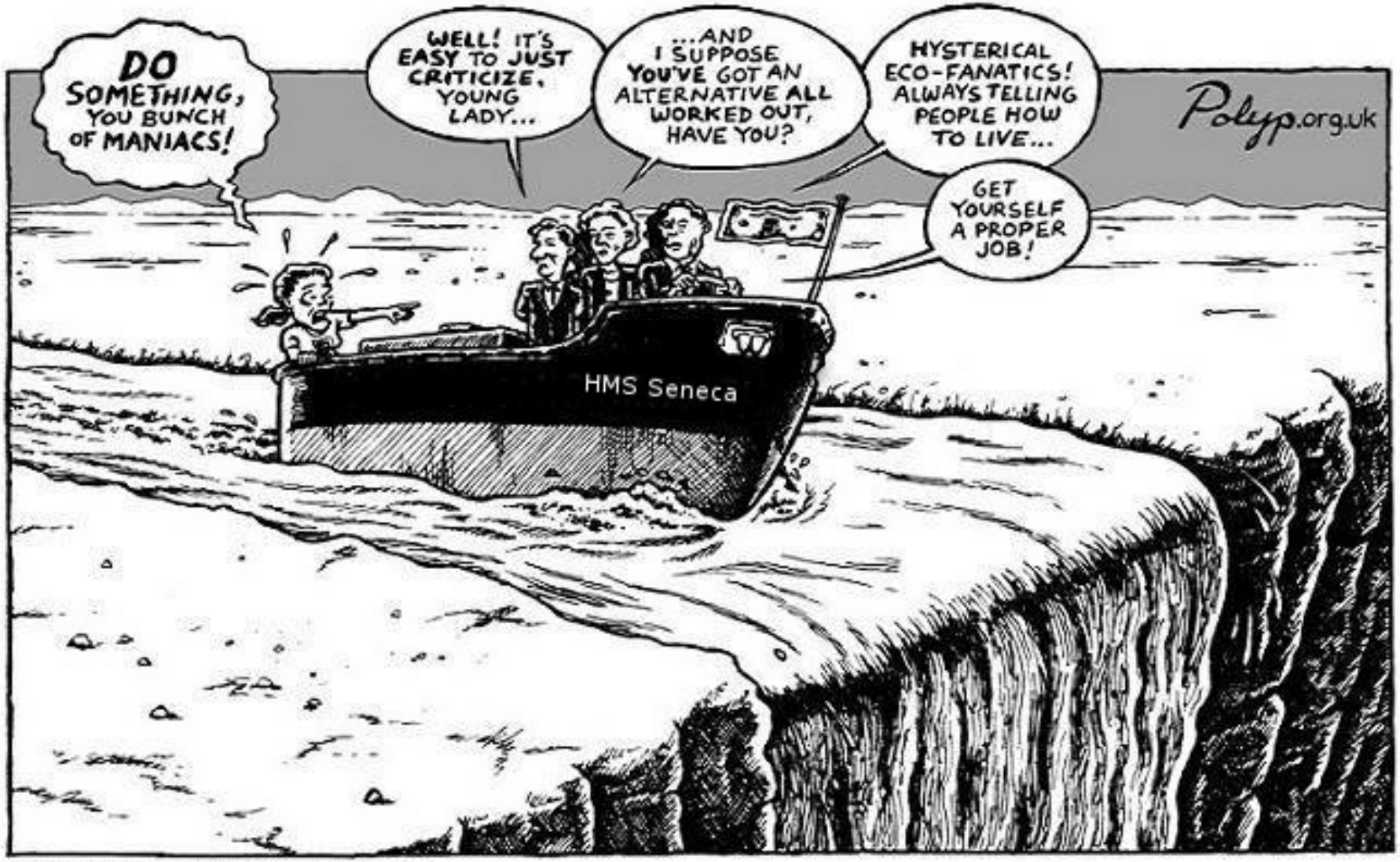

Ireland Population: the Great Famine
1800
1820
1840
1860
1880
1900
1920
9000
8000
7000
6000
5000
4000
3000
Population, thousands
Year
From the Maddison database
http://www.ggdc.net/maddison/Historical_Statistics/horizontal-file_02-2010.xls

The Seneca Curve

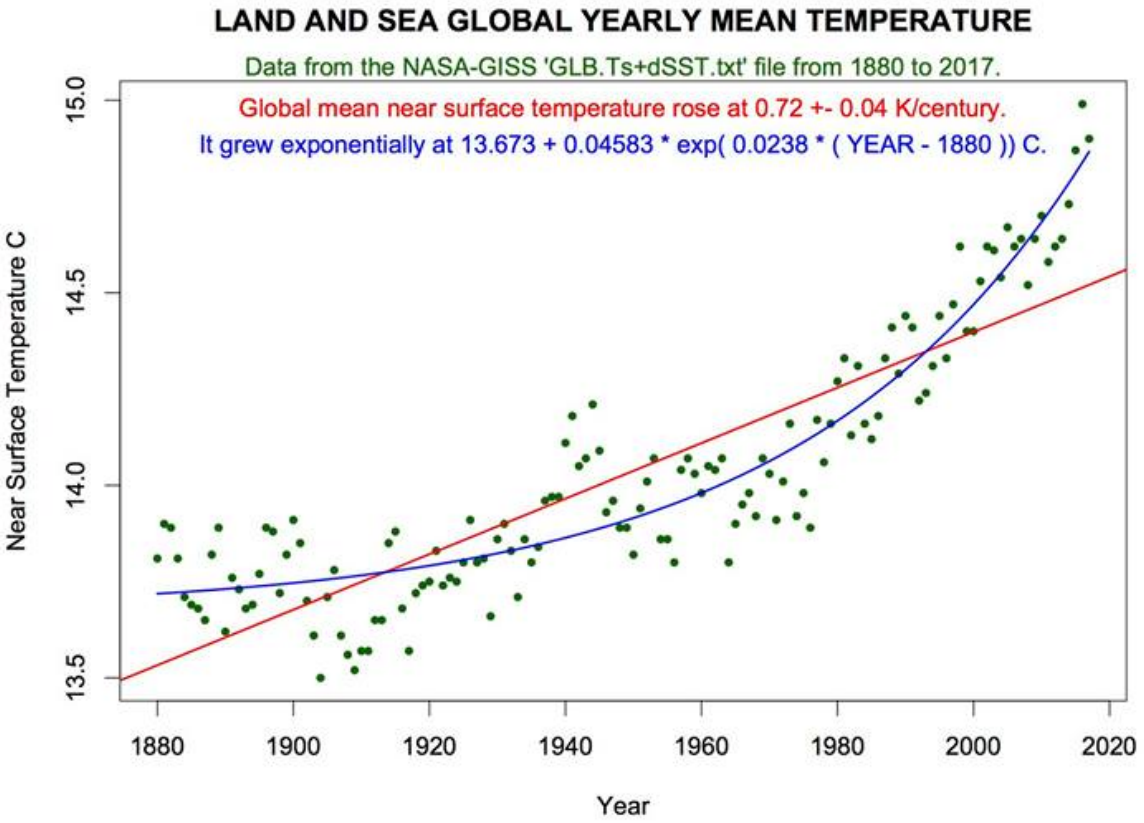


Ukrainian Population
By Ugo Bardi -2018
data from World Bank
www.cassandralegacy.blogspot.com
Ukrainian Population
Year
1950
1960
1970
1980
1990
2000
2010
2020
54M
52M
50M
48M
46M
44M
42M
40M


Ukraine Birth Rates
By Ugo Bardi - 2018
www.cassandralegacy.blogspot.com
data from World Bank
Birth Rate
Year
1950
1960
1970
1980
1990
2000
2010
2020
2.4
2.2
2
1.8
1.6
1.4
1.2
1



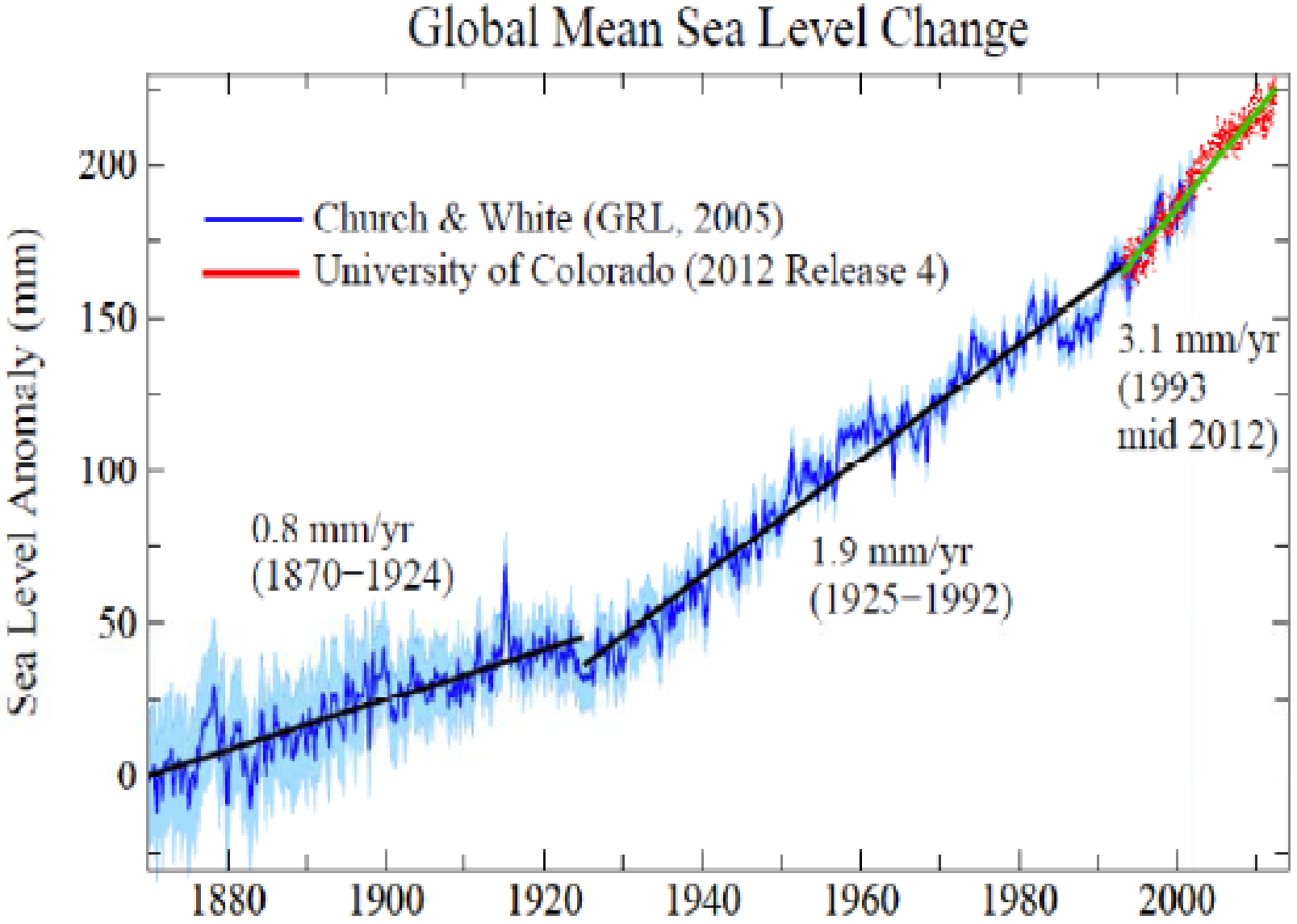
'STEADY AS SHE GOES'

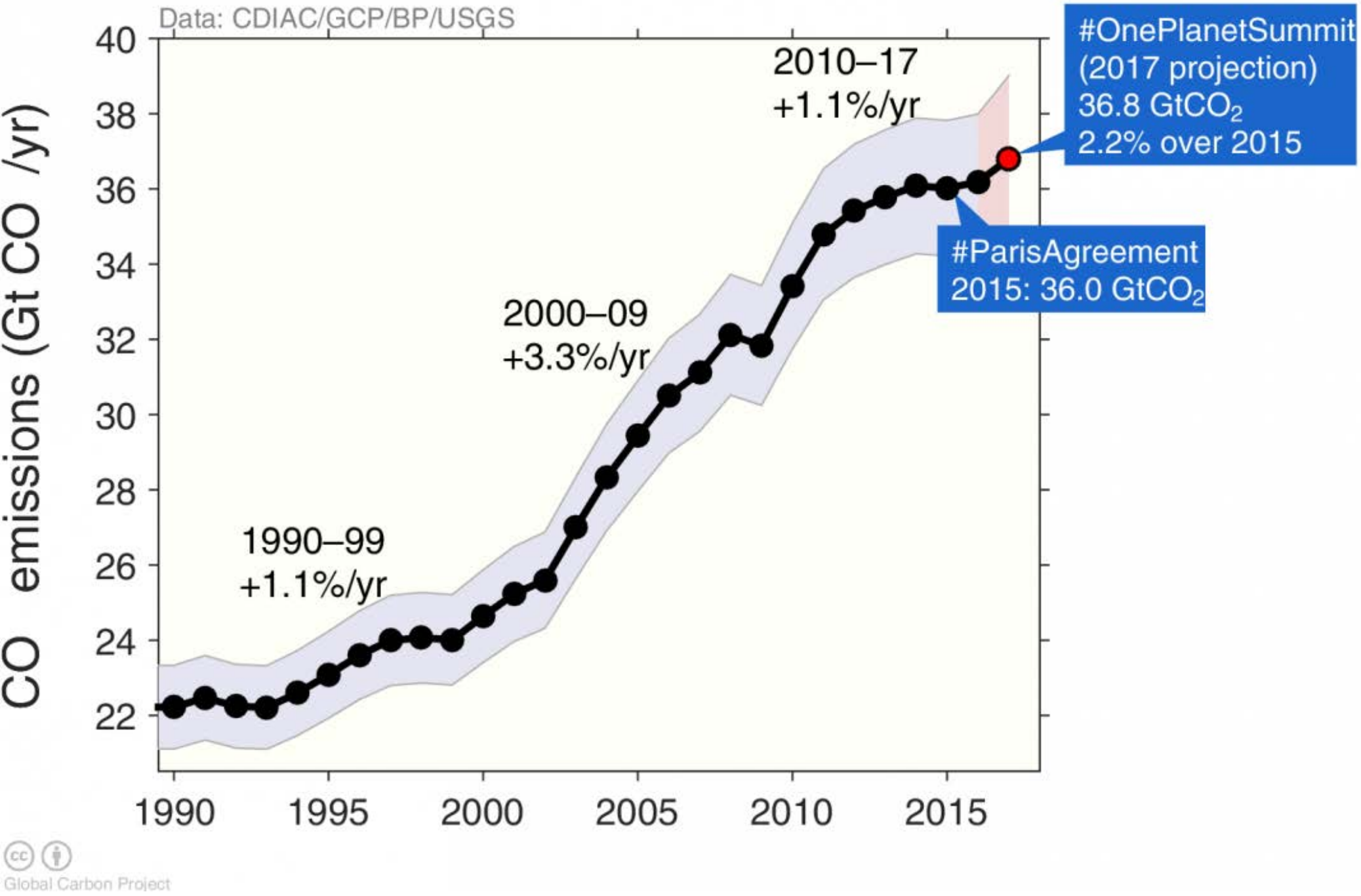


The 20 warmest years since 1880.

	Year	Temp C
1	2016	14.99
2	2017	14.90
3	2015	14.87
4	2014	14.73
5	2010	14.70
6	2005	14.67
7	2007	14.64
8	2009	14.64
9	2013	14.64
10	1998	14.62
11	2002	14.62
12	2006	14.62
13	2012	14.62
14	2003	14.61
15	2011	14.58
16	2004	14.54
17	2001	14.53
18	2008	14.52
19	1997	14.47
20	1990	14.44

By Roger Coppock

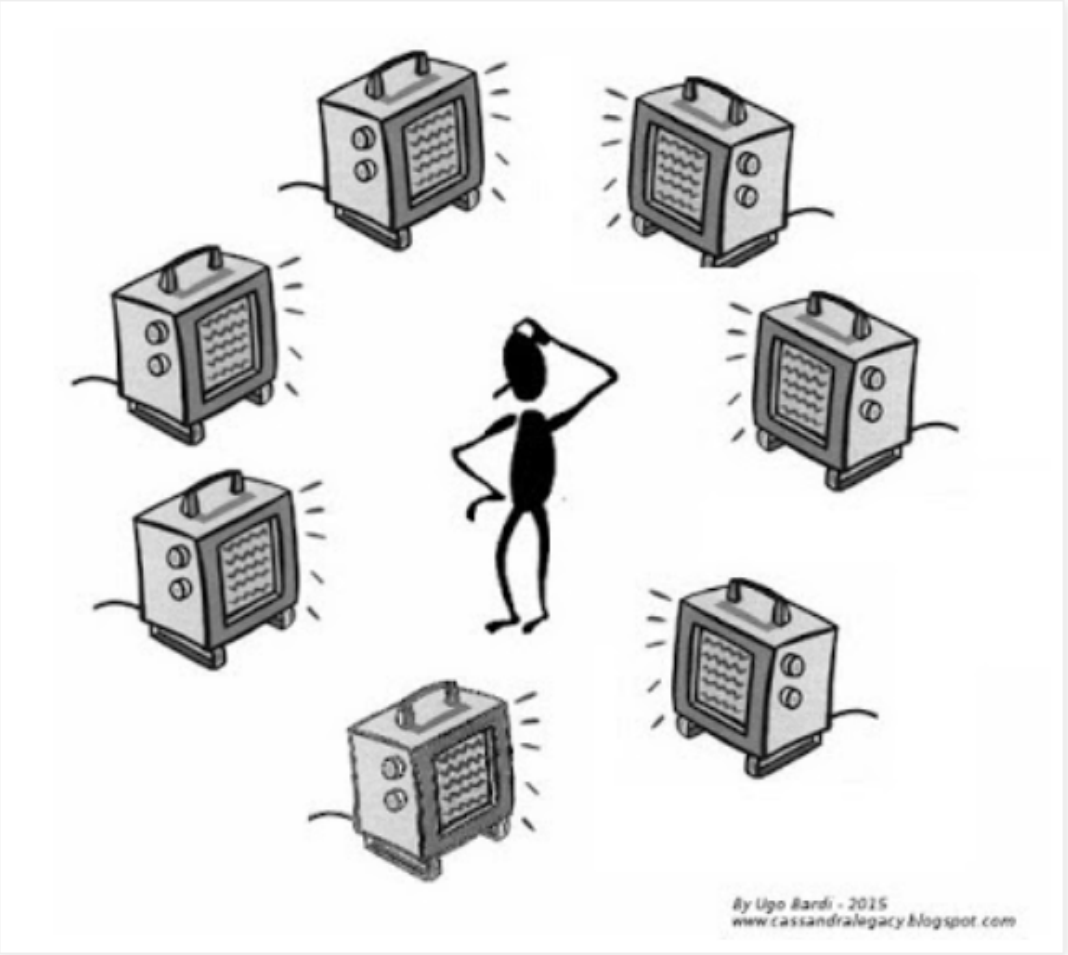

Global Mean Sea Level Change
Sea Level Anomaly (mm)
200
150
100
50
0
1880
1900
1920
1940
1960
1980
2000
Church & White (GRL, 2005)
University of Colorado (2012 Release 4)
0.8 mm/yr
(1870−1924)
1.9 mm/yr
(1925−1992)
3.1 mm/yr
(1993
mid 2012)

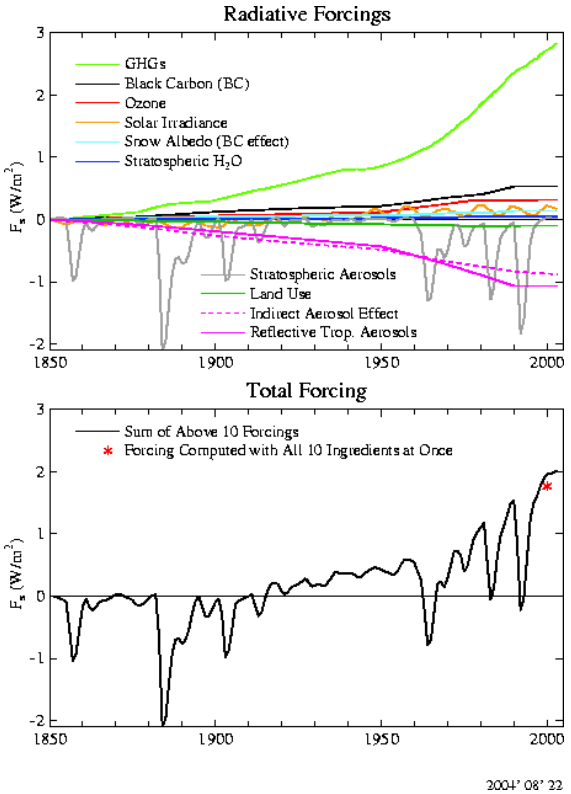


Global Carbon Project

Monday, September 7, 2015

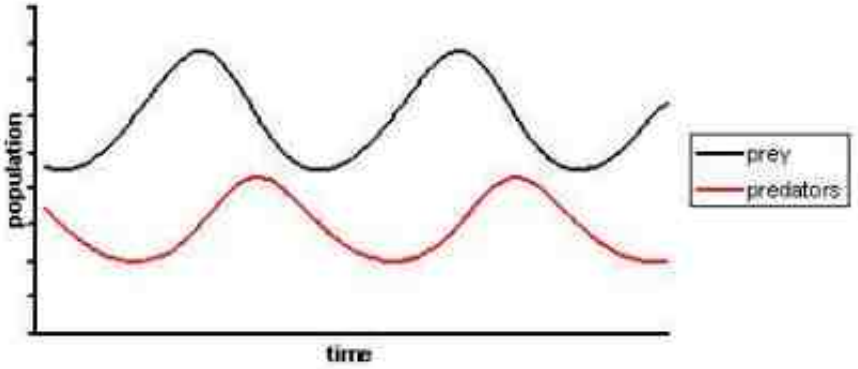
Global warming: how much heat, exactly?





It is often difficult to visualize what we are doing to our planet. But a simple calculation shows that the greenhouse effect generated by fossil fuels can be seen as the equivalent of turning on more than a hundred 1 kW electric heaters for each human being on the earth.

$$\frac{dx}{dt} = x(\alpha - \beta y)$$
$$\frac{dy}{dt} = -y(\gamma - \delta x)$$



For 4°C global mean surface temperature

5°C - 6°C global *land* mean

… & increase °C on the hottest days of:

6°C - 8°C in China

8°C - 10°C in Central Europe

10°C -12°C in New York

In low latitudes 4°C gives

up to 40% reduction in maize & rice

as population heads towards 9 billion by 2050

http://www.slideshare.net/DFID/professor-kevin-anderson-climate-change-going-beyond-dangerous

Donald J. Trump
@realDonaldTrump

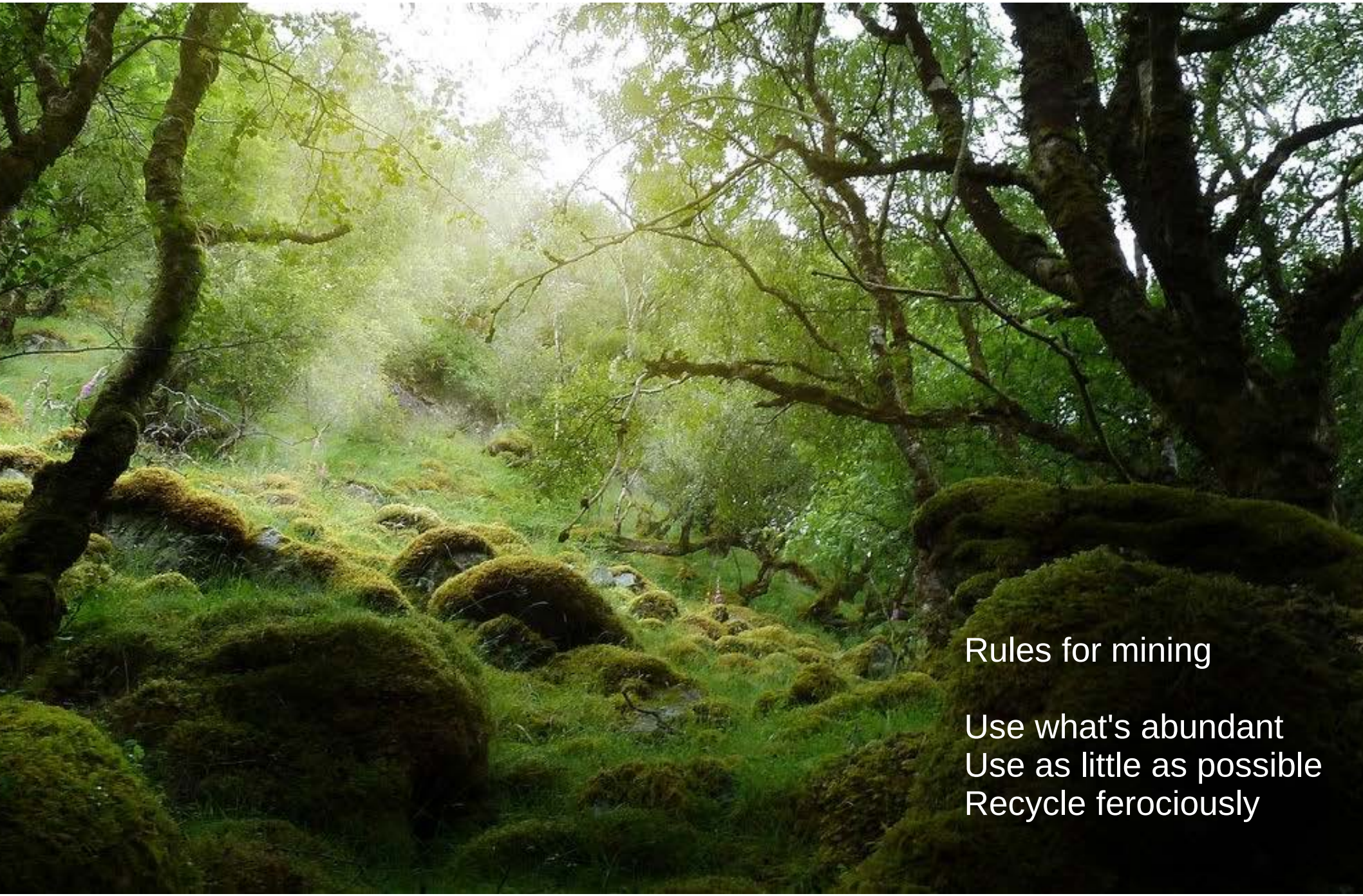
Follow

The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive.

2:15 PM - 6 Nov 2012

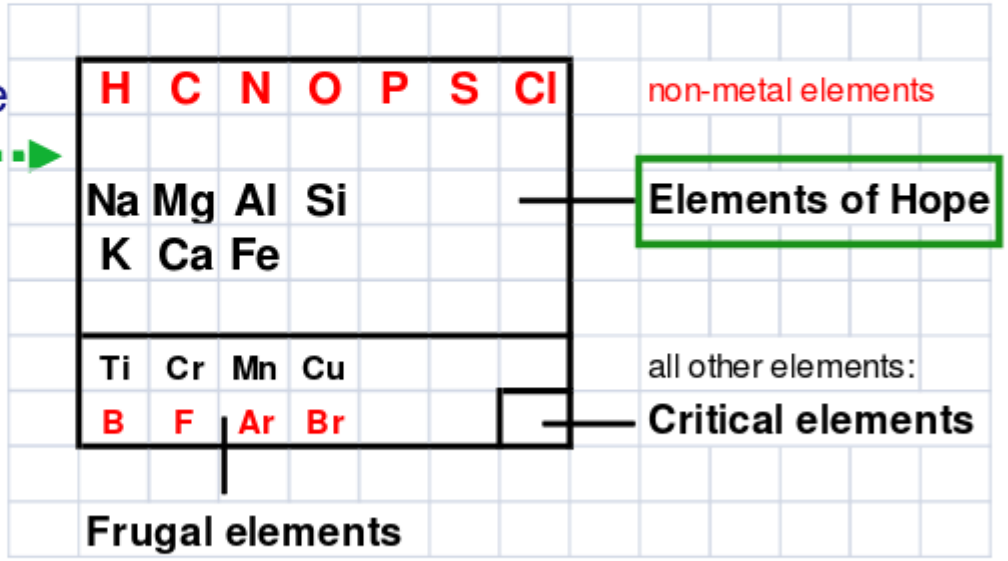
16,634 8,586

The giant mining and recycling machine



Adaptation framework with intrinsic benefits, applicable to energy as well as metals

1. Use less (*involves human behaviour and "**managed austerity**"*)
2. Longer life
3. Re-use and recycle
4. Substitute
5. Product and process (re)design
6. Buffers



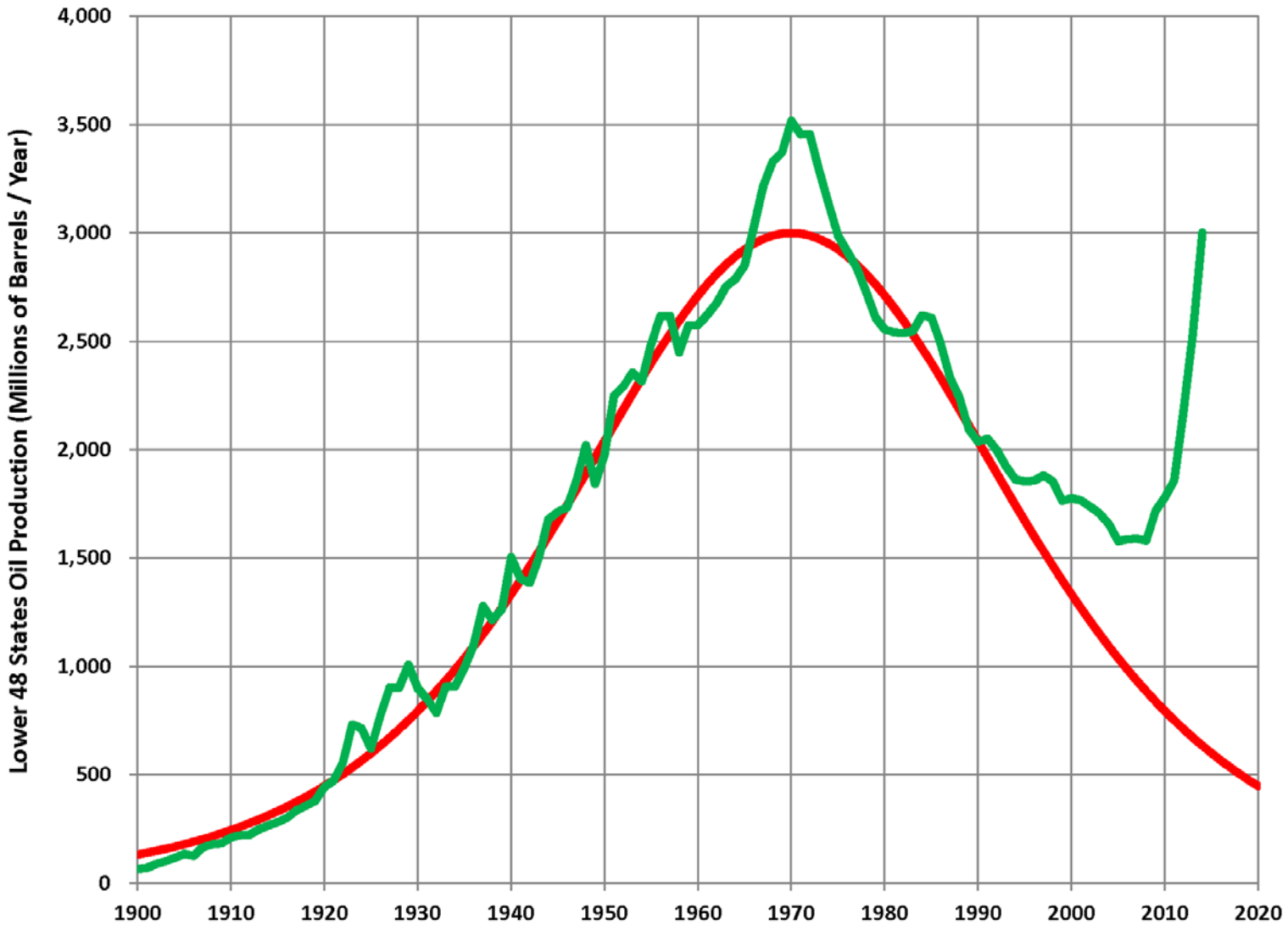
Source: Global Resource Depletion, Managed Austerity and the Elements of Hope (2010), ISBN 9789059724259

Graph by A. Diederen

Good ideas?

Prof. J. Gutberlet and a Brazilian Catador

US «all liquids» production



Data from wikipedia

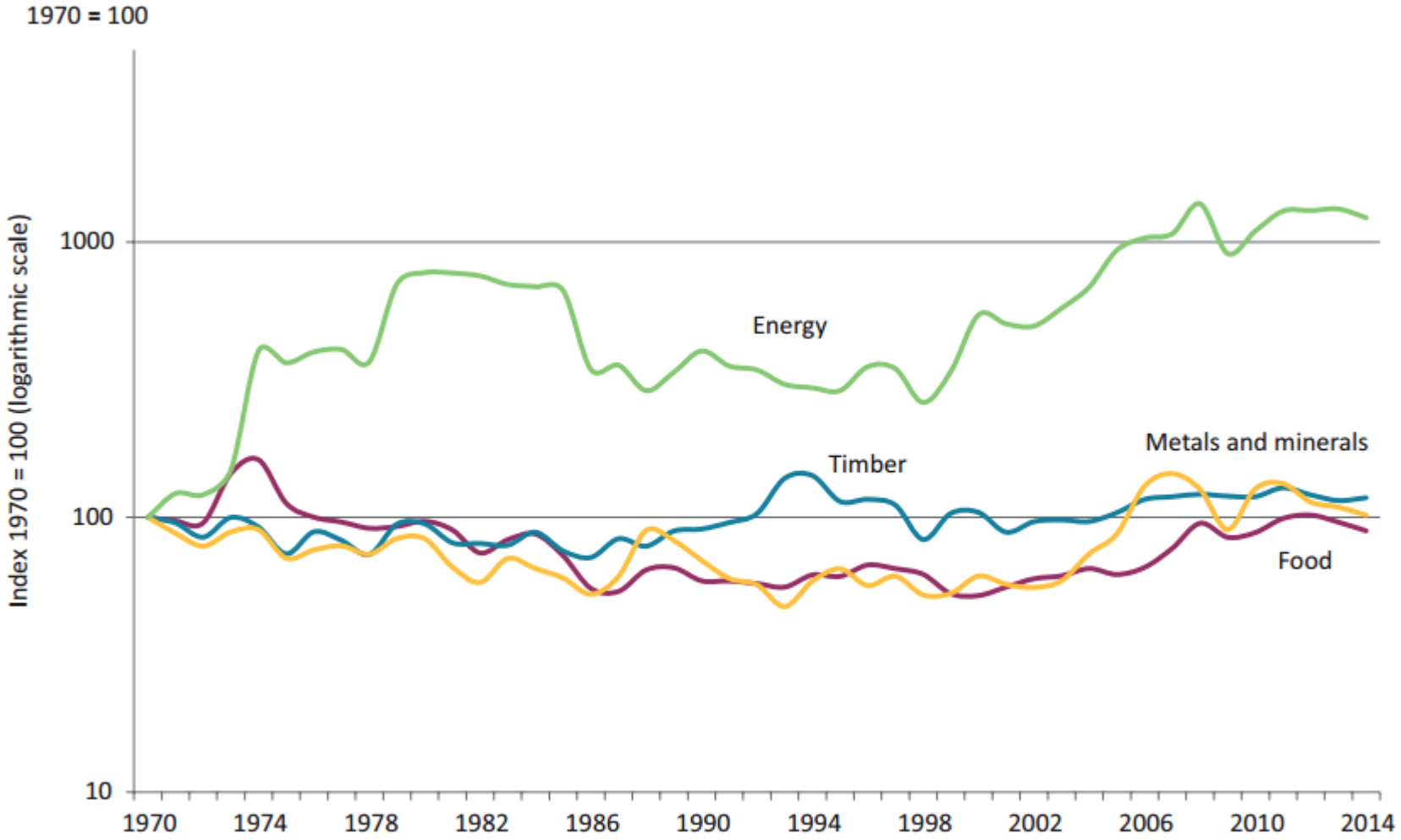
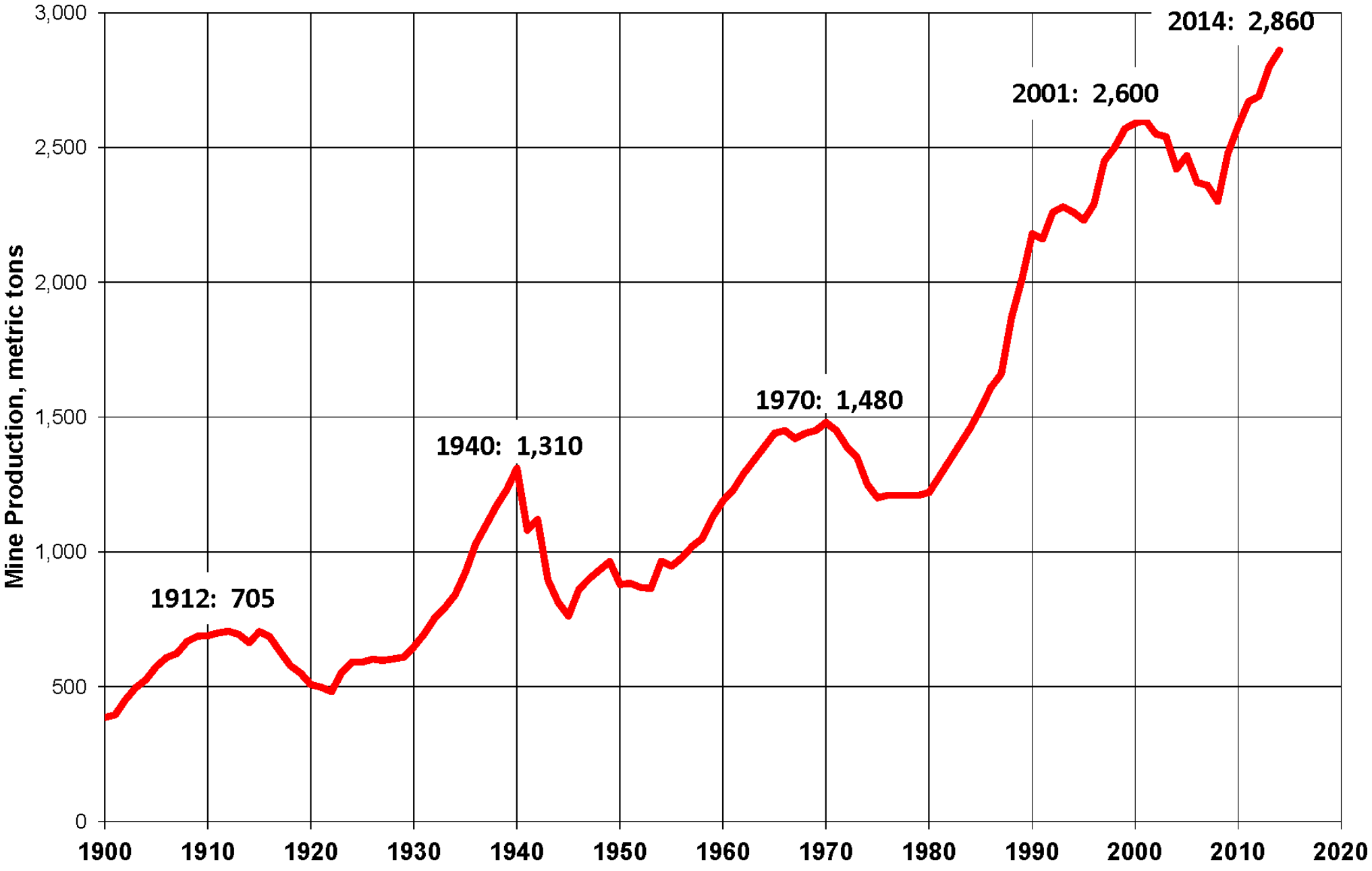


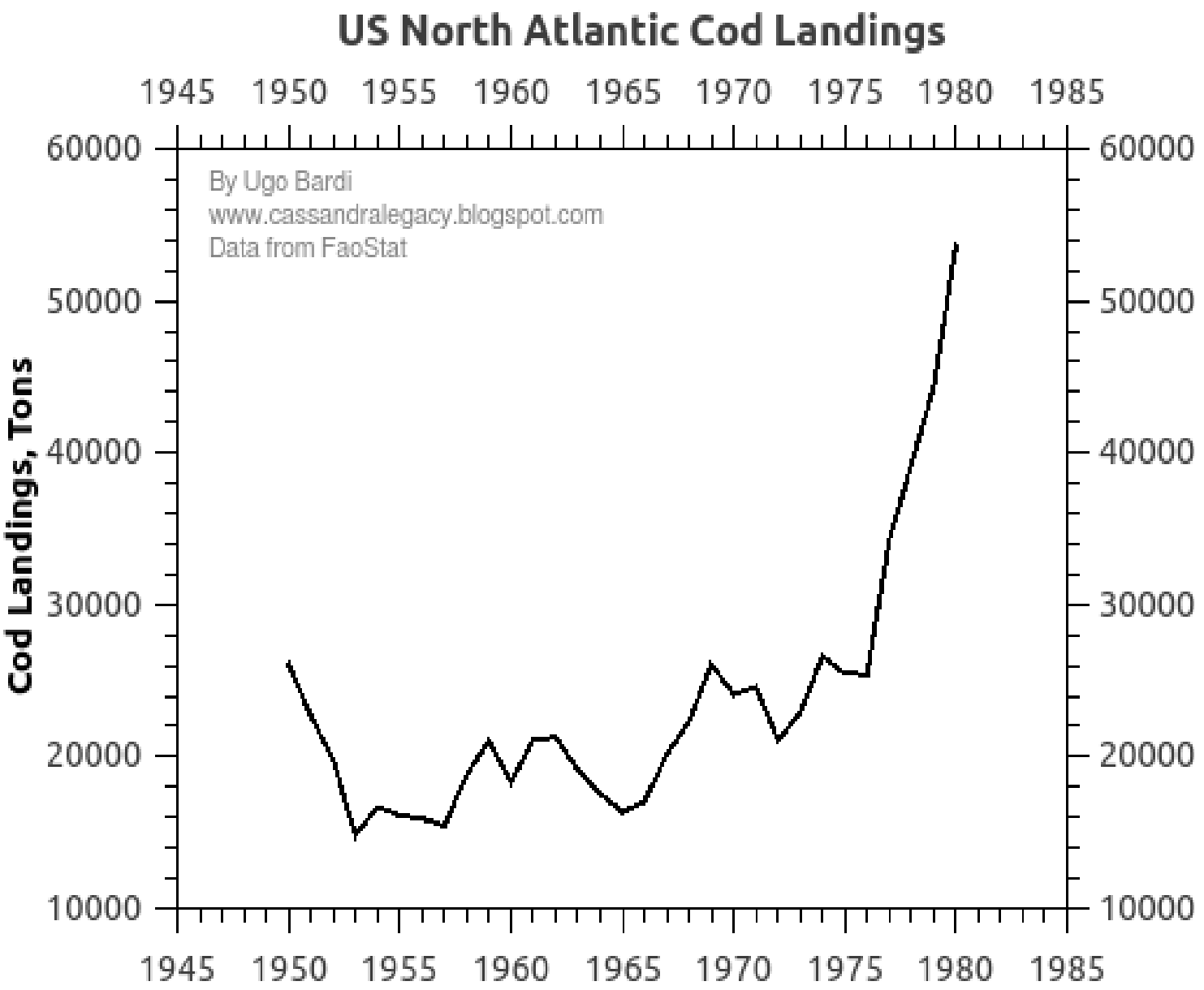
Figure 4. Trends in global resource prices, 1970–2010, indexed

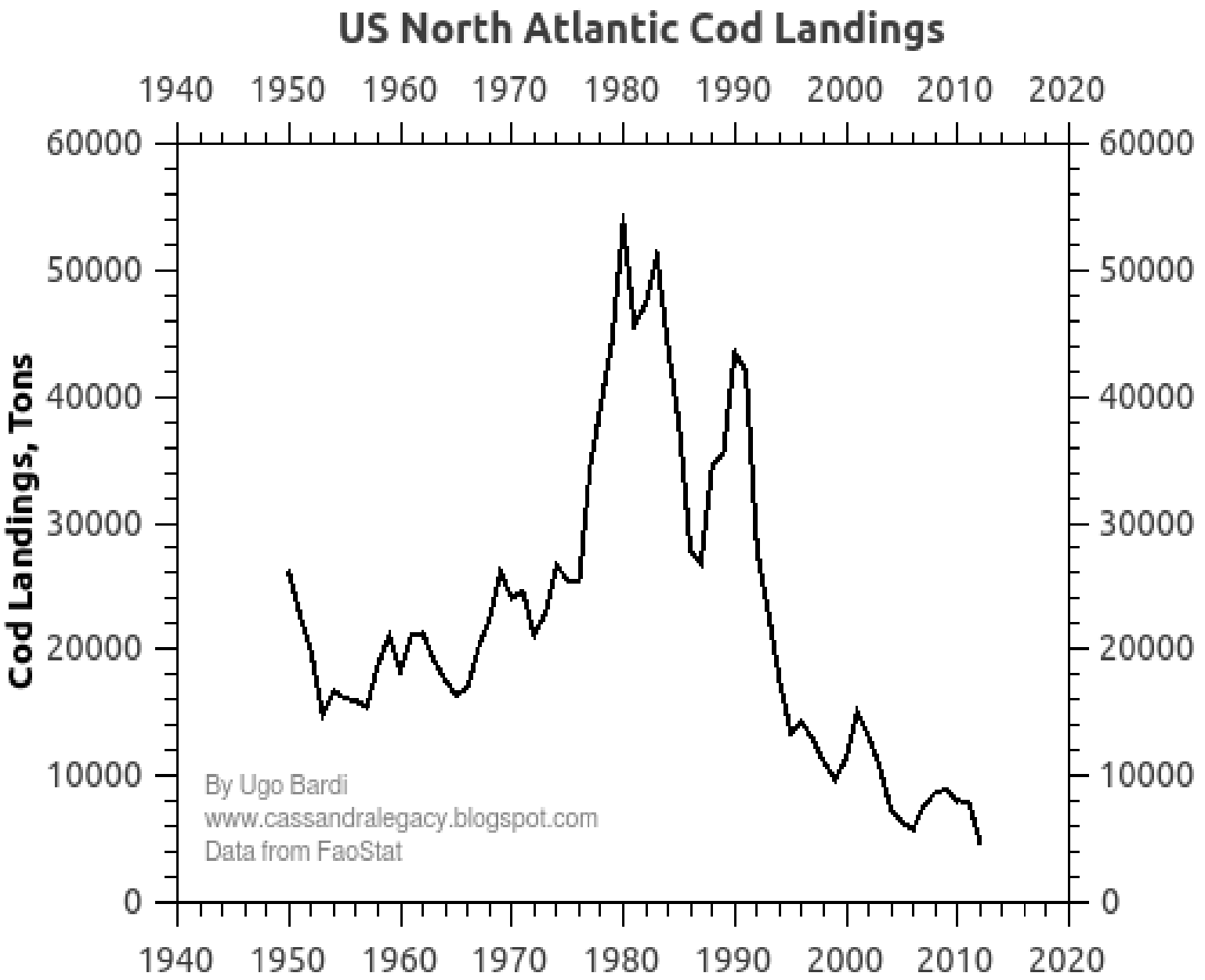
Unep-2016

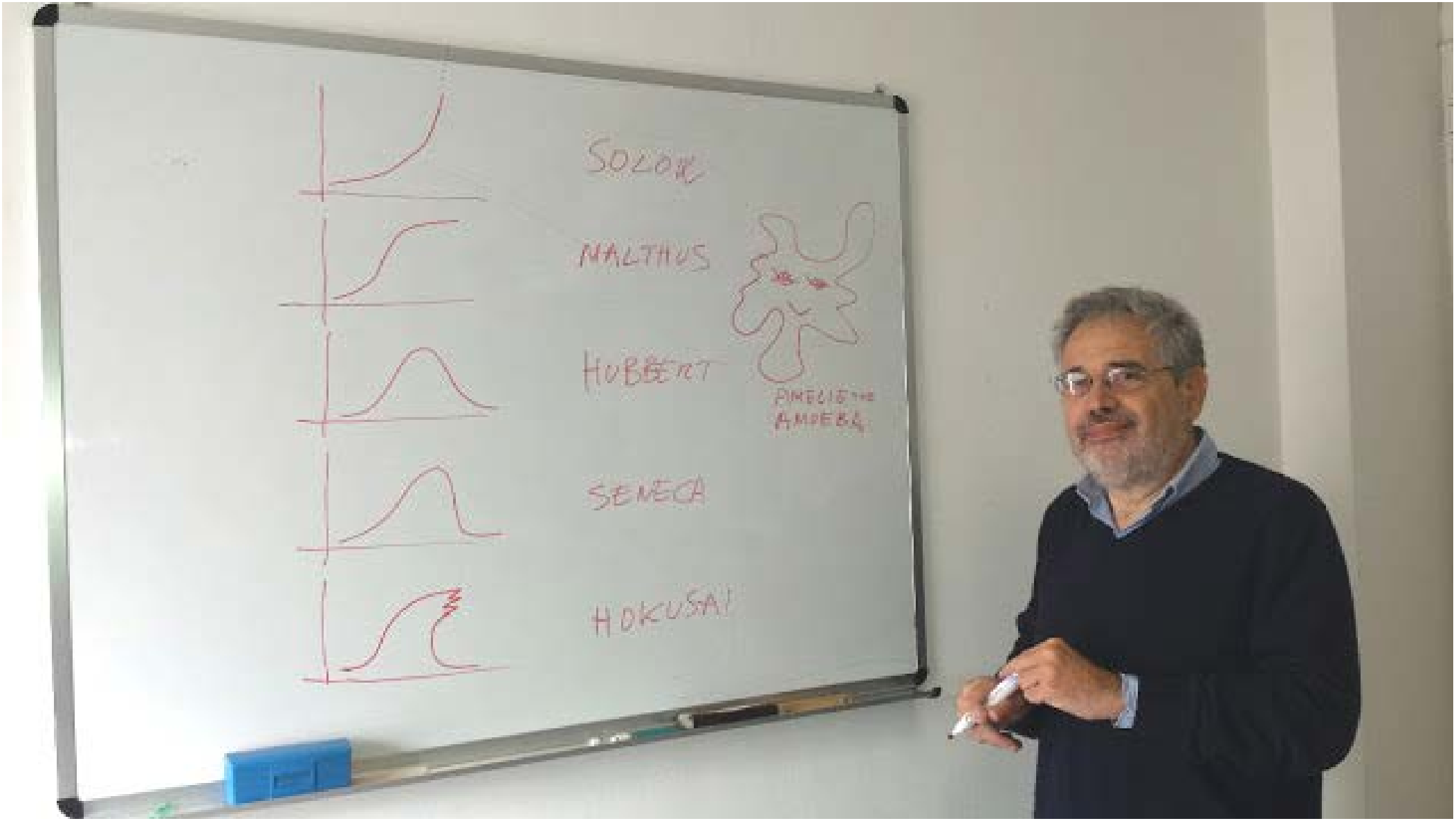
World gold production

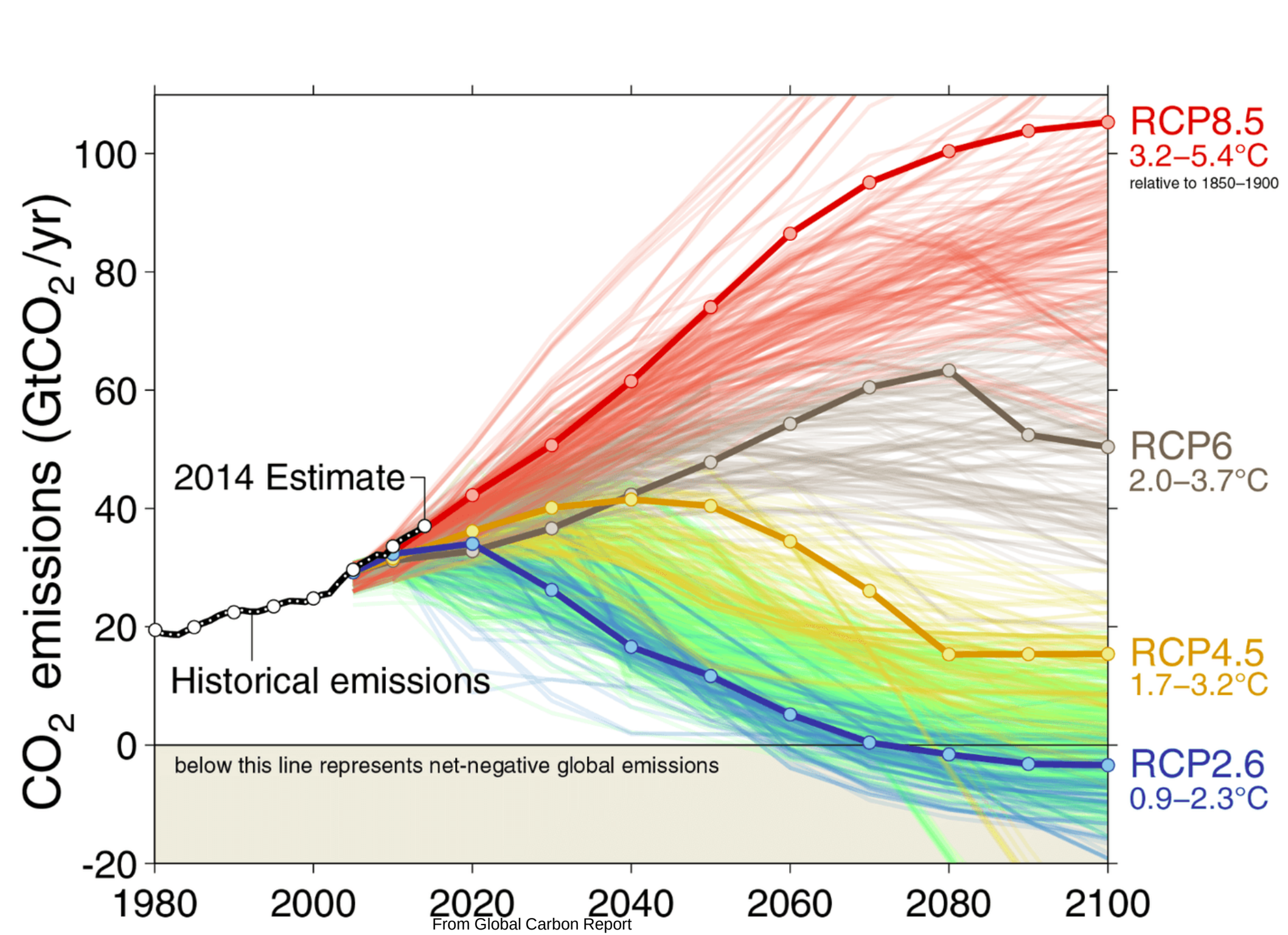


Data from Wikipedia

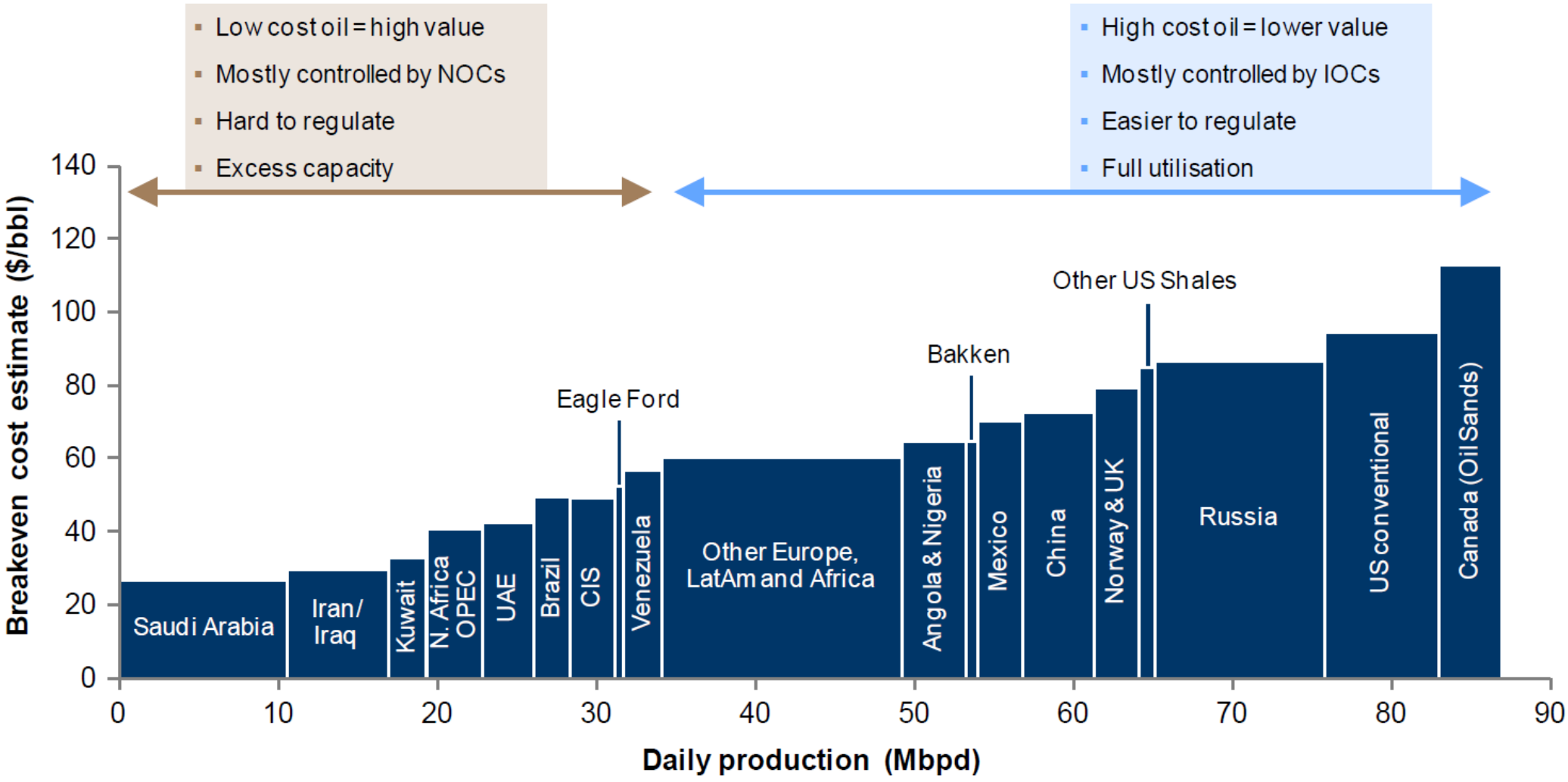

US North Atlantic Cod Landings
By Ugo Bardi
www.cassandralegacy.blogspot.com
Data from FaoStat
Cod Landings, Tons
1945
1950
1955
1960
1965
1970
1975
1980
1985
10000
20000
30000
40000
50000
60000


US North Atlantic Cod Landings
1940
1950
1960
1970
1980
1990
2000
2010
2020
60000
50000
40000
30000
20000
10000
0
Cod Landings, Tons
By Ugo Bardi
www.cassandralegacy.blogspot.com
Data from FaoStat


SOLON
MALTHUS
HUBBERT
SENECA
HOKUŠAI



From Global Carbon Report

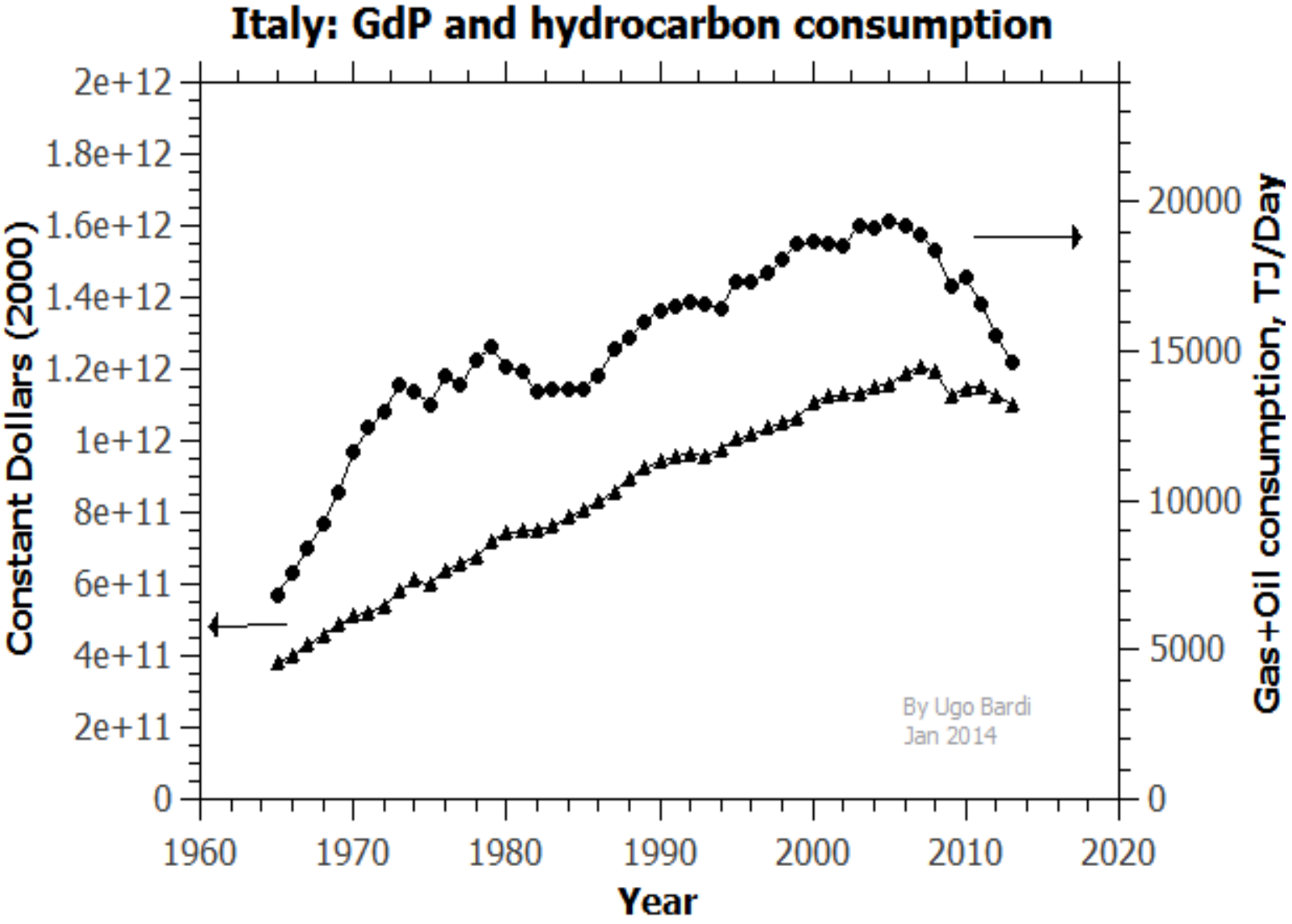


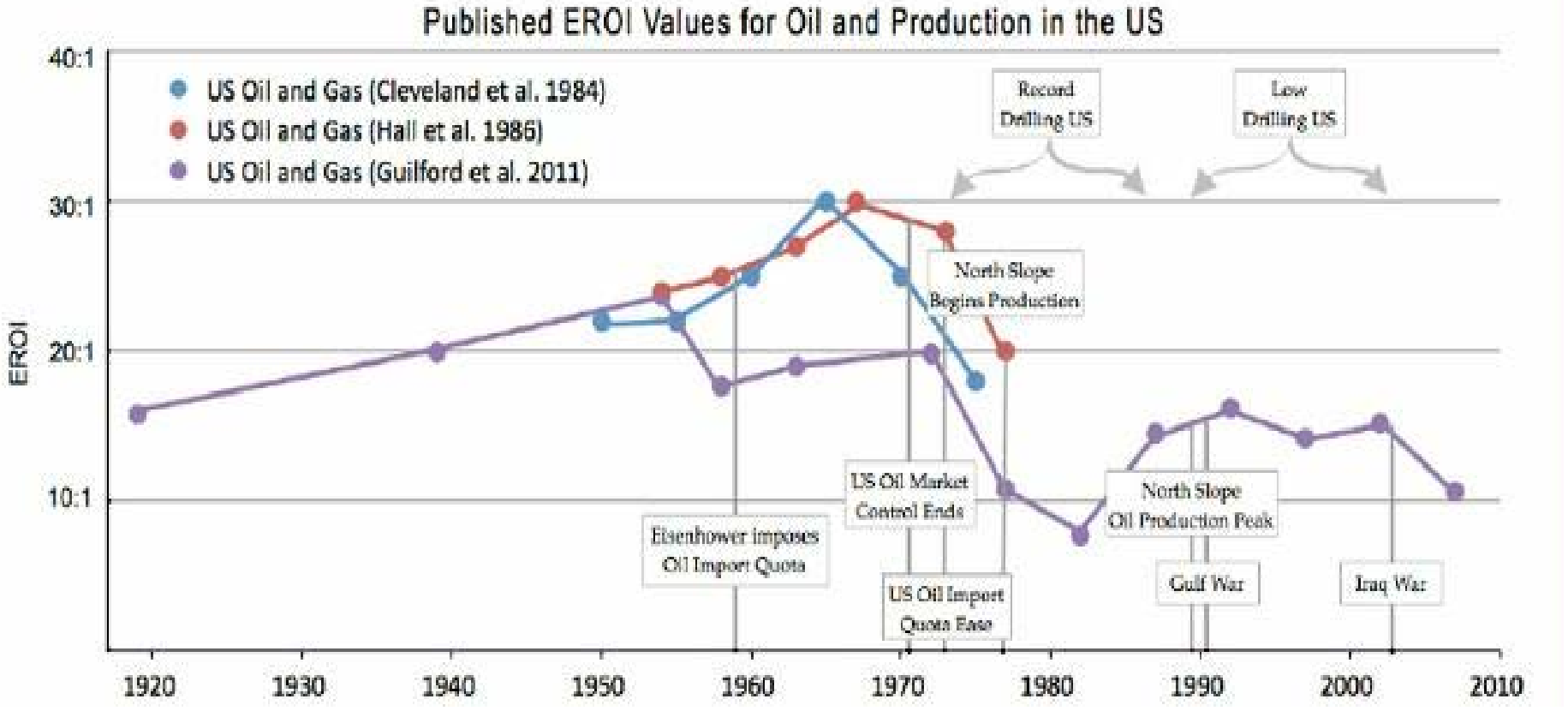
Global breakeven prices (considering only technical extraction costs) versus production. Source: Alliance Bernstein, October 2014

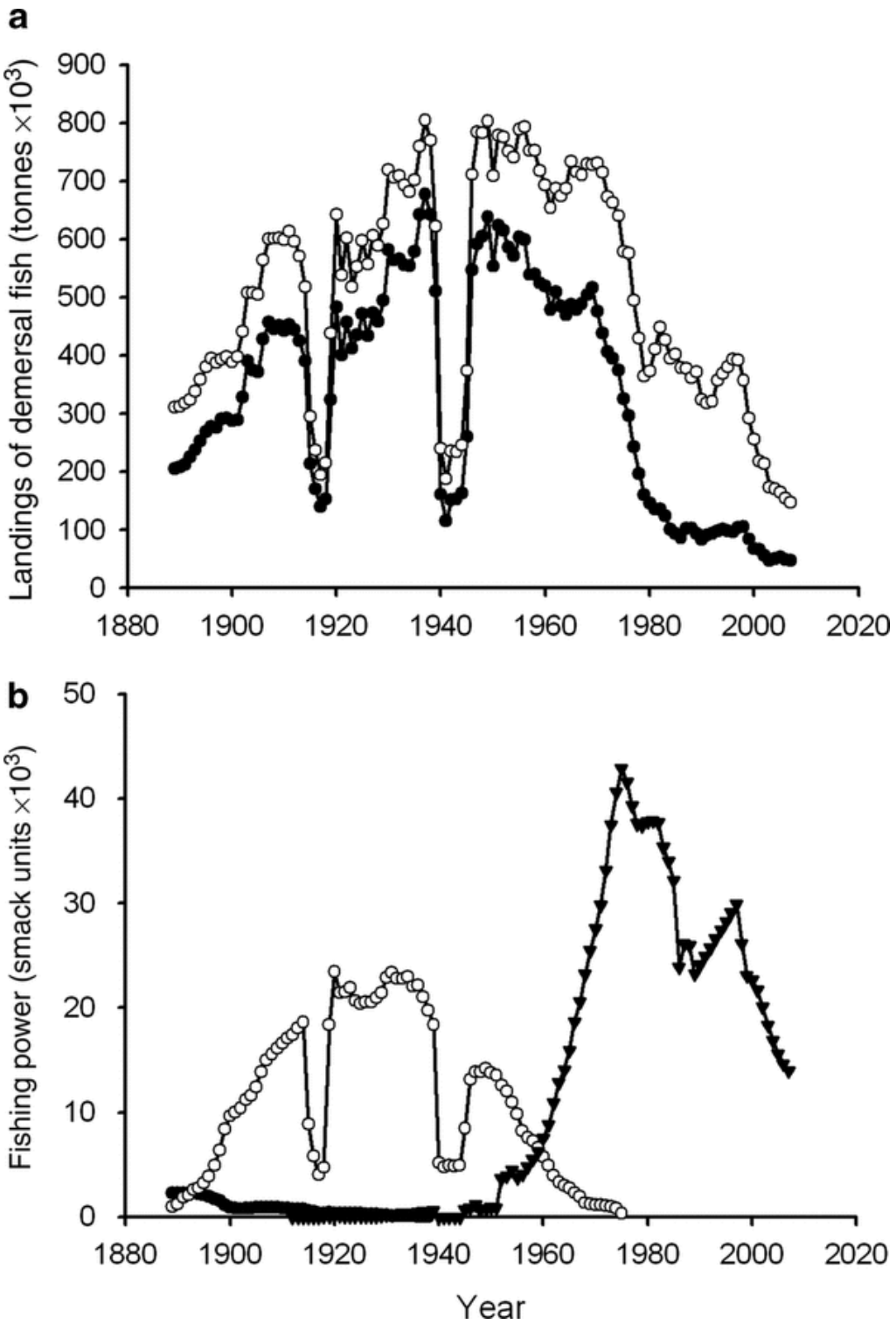
Industrial Production Volume in EU Countries

Source: Macrobond

Technology Industries


Italy: GdP and hydrocarbon consumption
Constant Dollars (2000)
Gas+Oil consumption, TJ/Day
Year
2e+12
1.8e+12
1.6e+12
1.4e+12
1.2e+12
1e+12
8e+11
6e+11
4e+11
2e+11
0
20000
15000
10000
5000
0
1960
1970
1980
1990
2000
2010
2020
By Ugo Bardi
Jan 2014

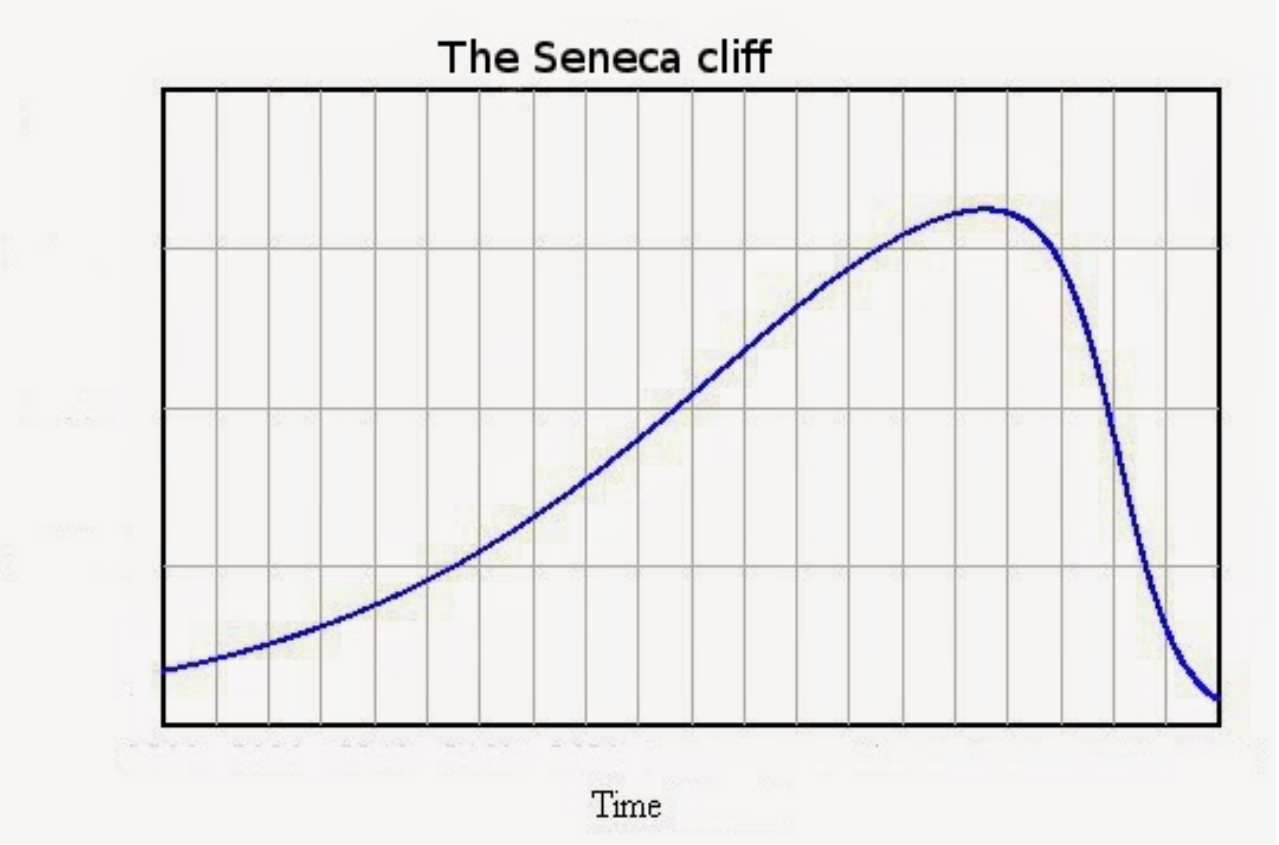

Published EROI Values for Oil and Production in the US
EROI
40:1
30:1
20:1
10:1
US Oil and Gas (Cleveland et al. 1984)
US Oil and Gas (Hall et al. 1986)
US Oil and Gas (Guilford et al. 2011)
Record Drilling US
Low Drilling US
North Slope Begins Production
US Oil Market Control Ends
Eisenhower imposes Oil Import Quota
US Oil Import Quota Ease
North Slope Oil Production Peak
Gulf War
Iraq War
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010



The Collapse of the UK Fishery

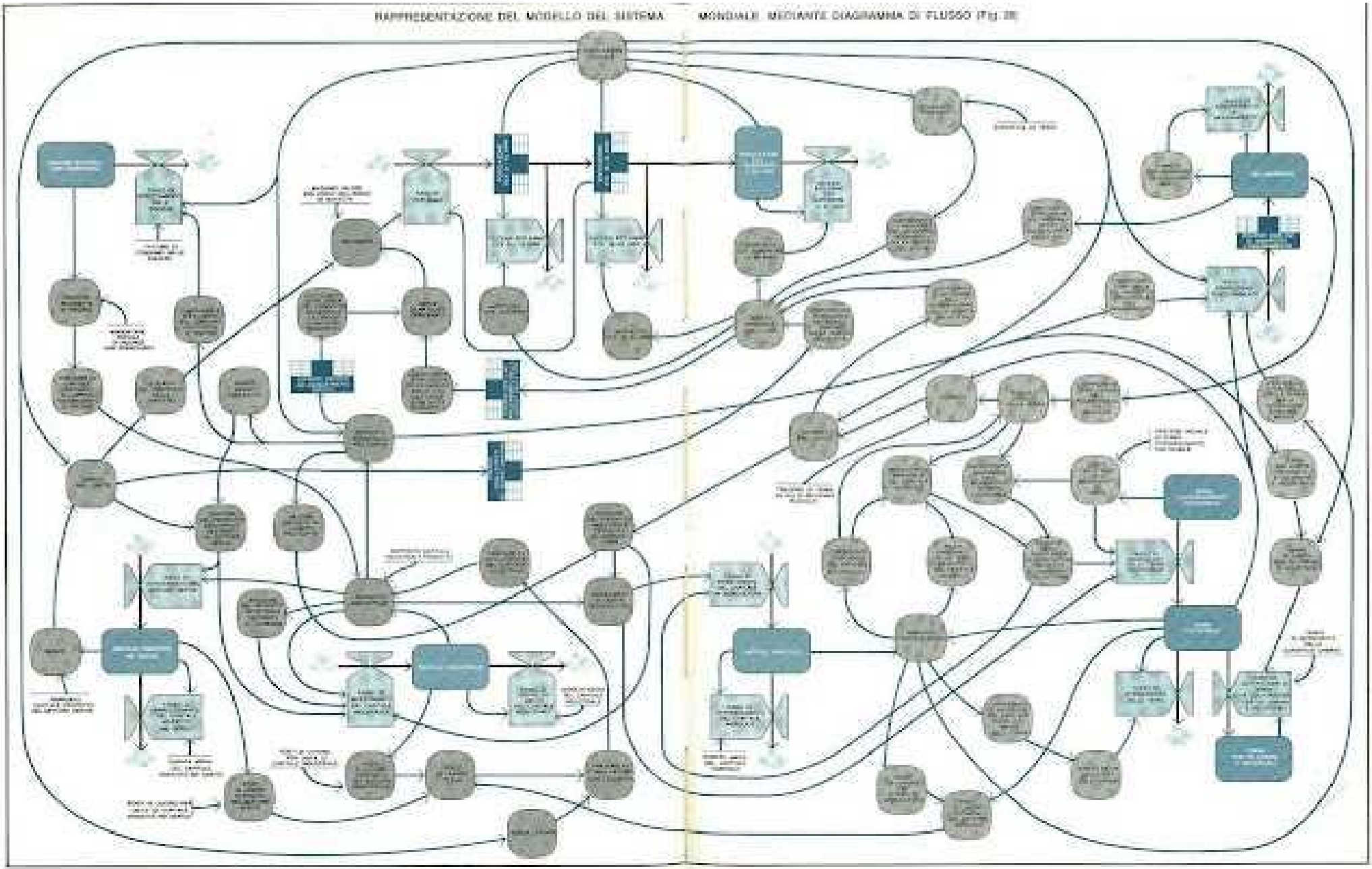
The effects of 118 years of industrial fishing on UK bottom trawl fisheries, Ruth H. Thurstan, Simon Brockington, Callum M. Roberts, Nature Communications, 1, 15, 1013

The Seneca Effect



"It would be some consolation for the feebleness of our selves and our works if all things should perish as slowly as they come into being; but as it is, increases are of sluggish growth, but the way to ruin is rapid."

The World3 model



Global marine yield halved as fishing intensity redoubles
A Watson et. Al
DOI: 10.1111/j.1467-2979.2012.00483.x
© 2012 John Wiley & Sons Ltd

DIMINISHING RETURNS ON FISHING

For each unit of fishing power expended by fleets, fish catches are half what they were fifty years ago.

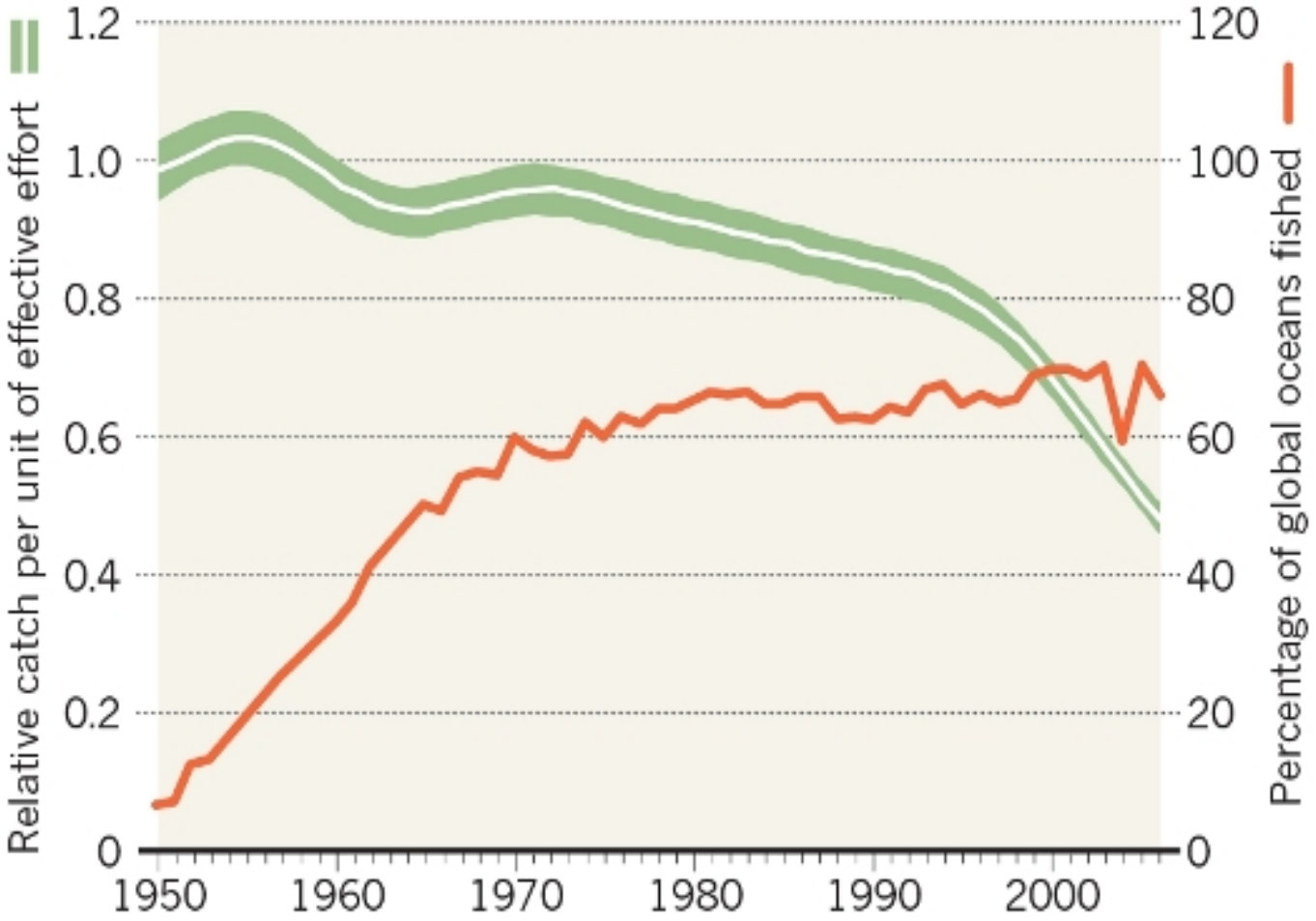
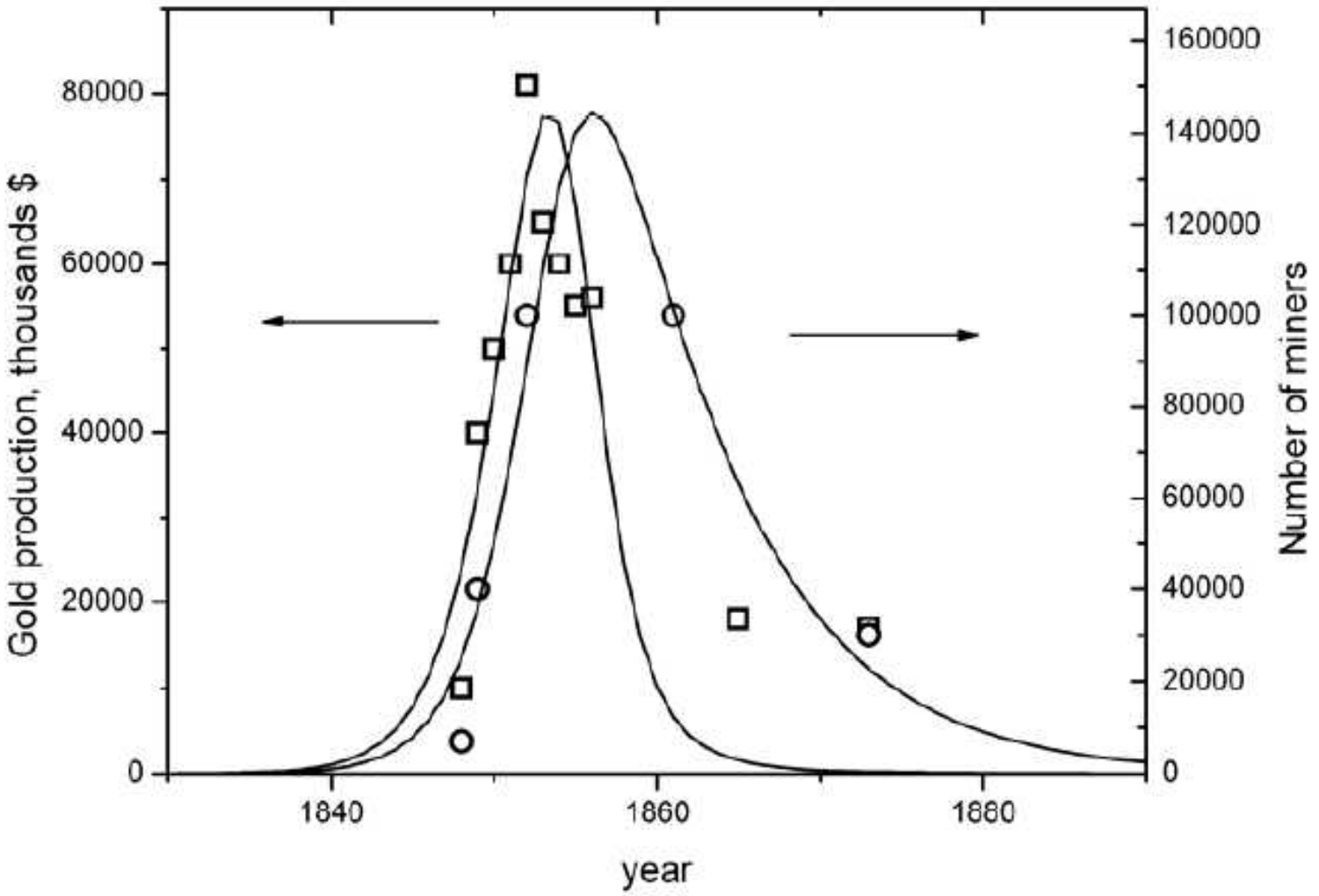
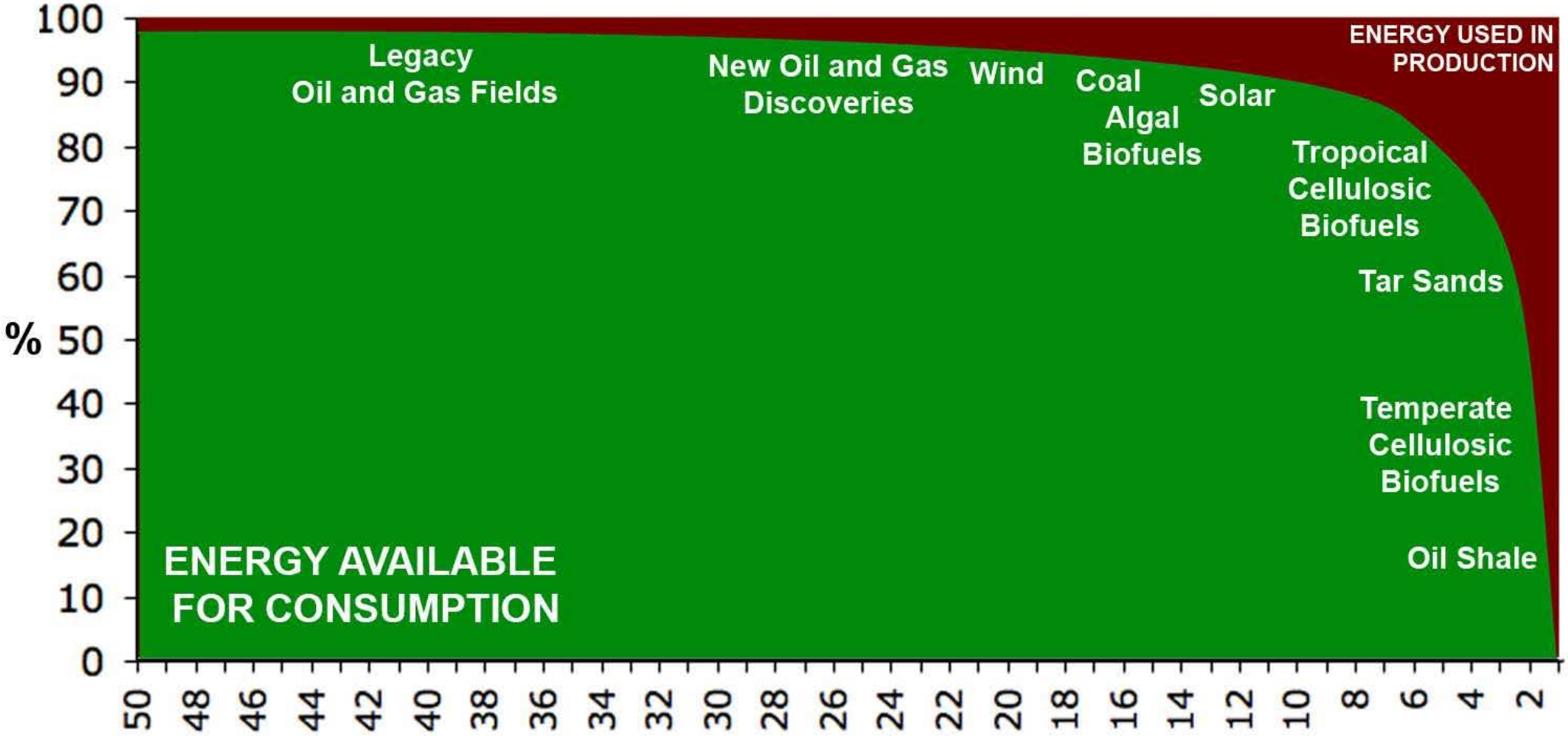


Figure 3. Gold production and number of miners during the "Gold Rush" in California fitted using the LV model developed here. The data are from [22].

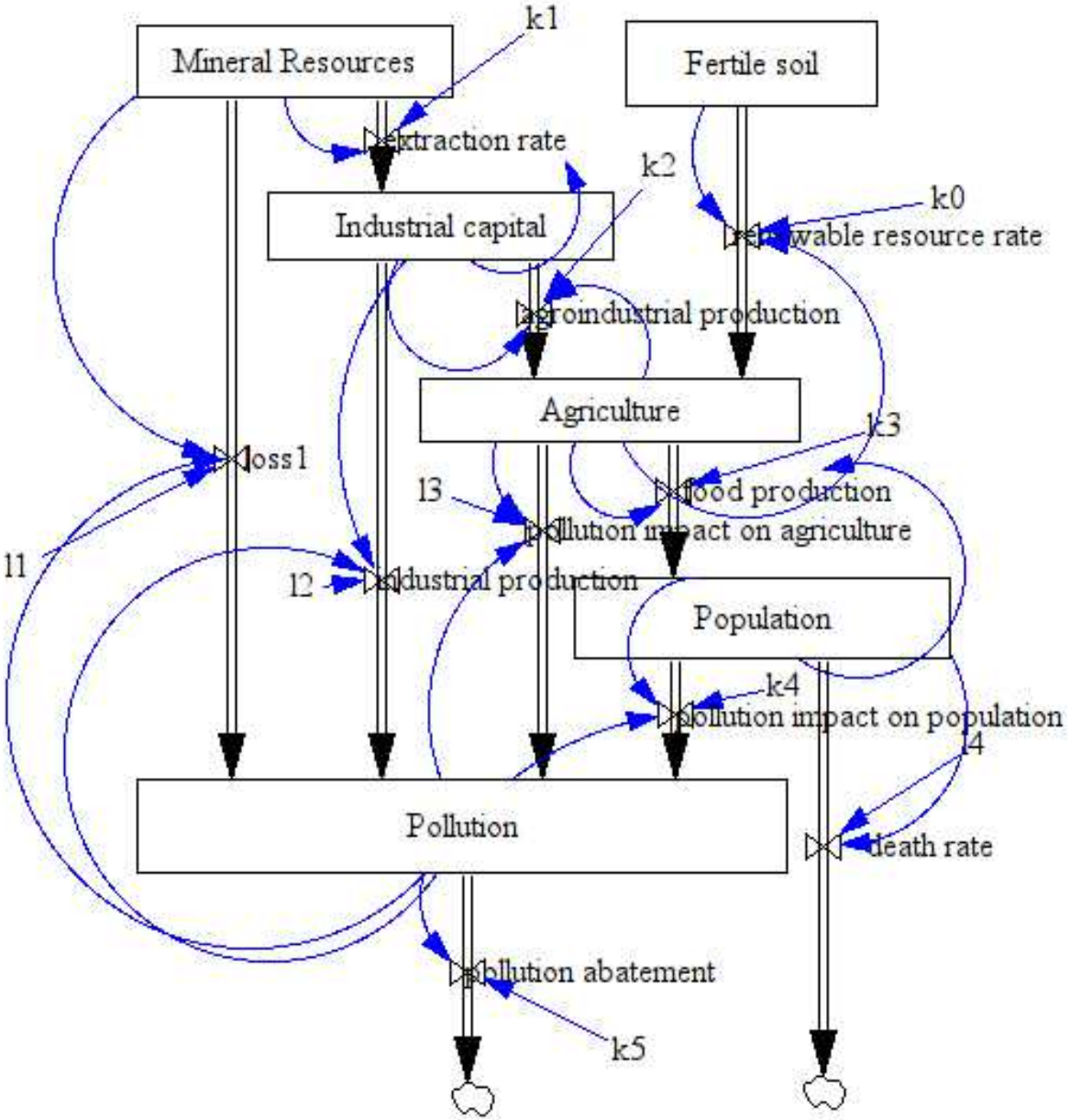


Bardi and Lavacchi, "Energies" 2009

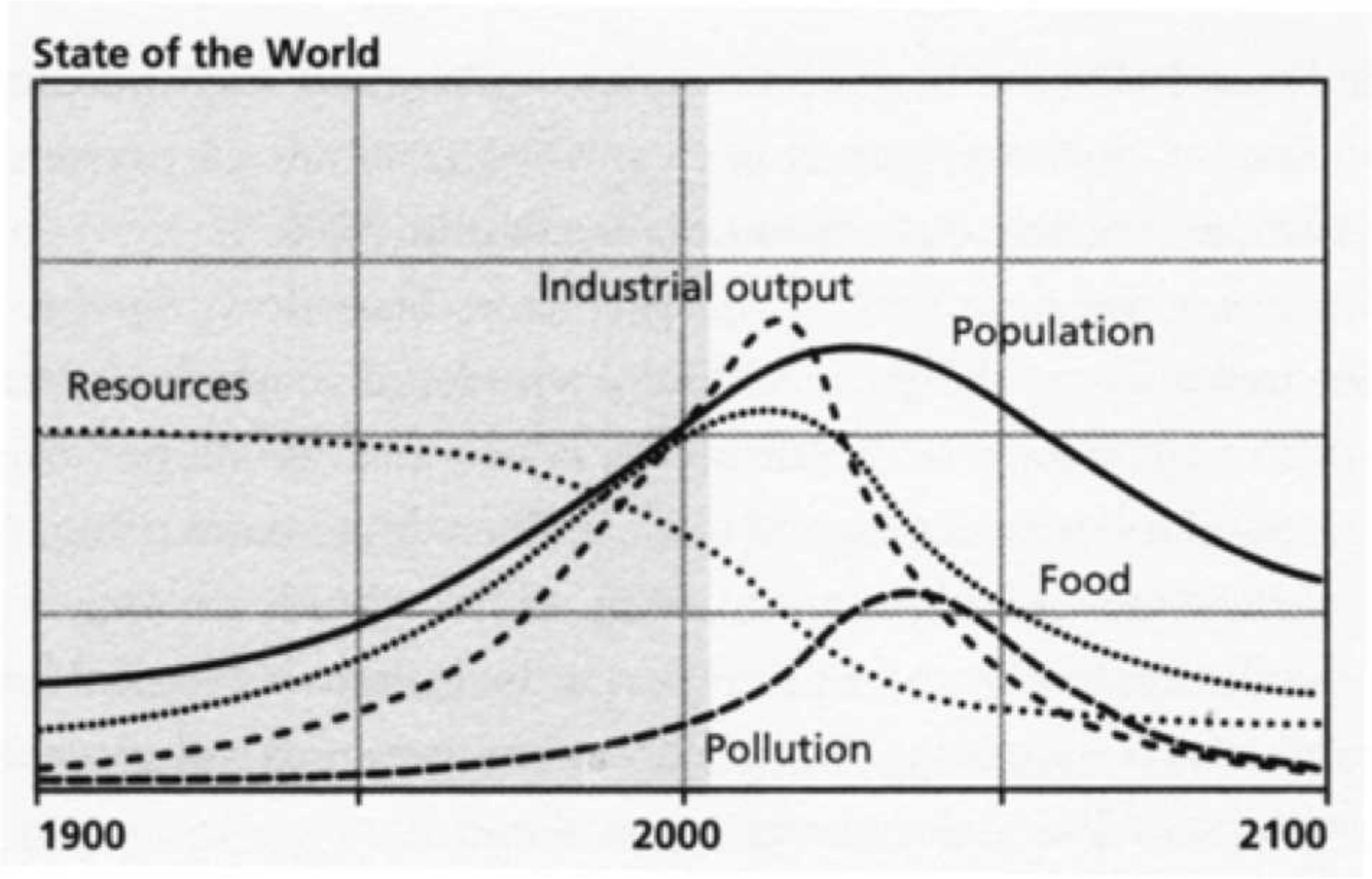
THE NET ENERGY CLIFF

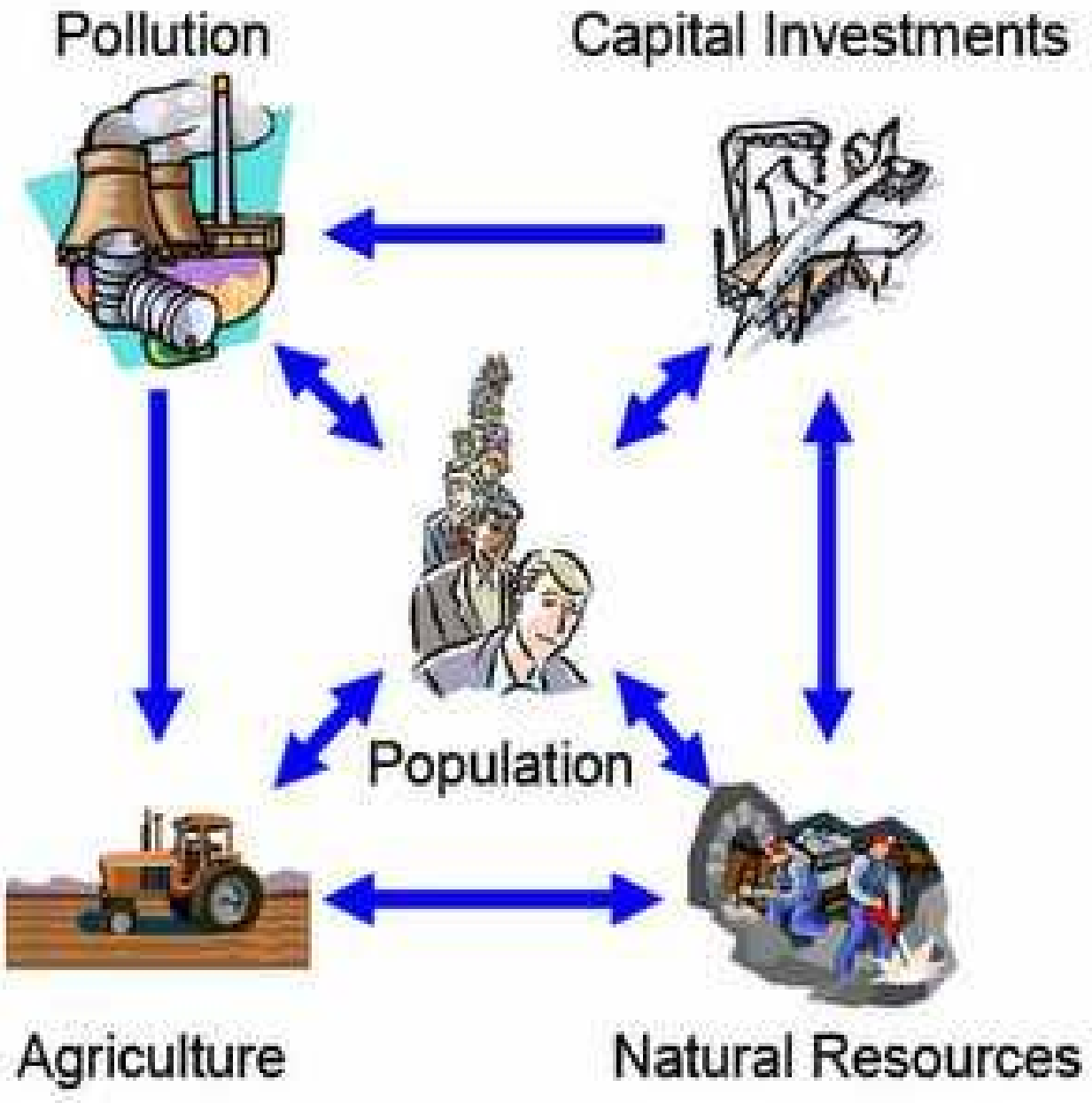


World Model – 6 stocks



World3 calculations 2004





Myrtveit 2005

The Brutal Logic of Climate Change

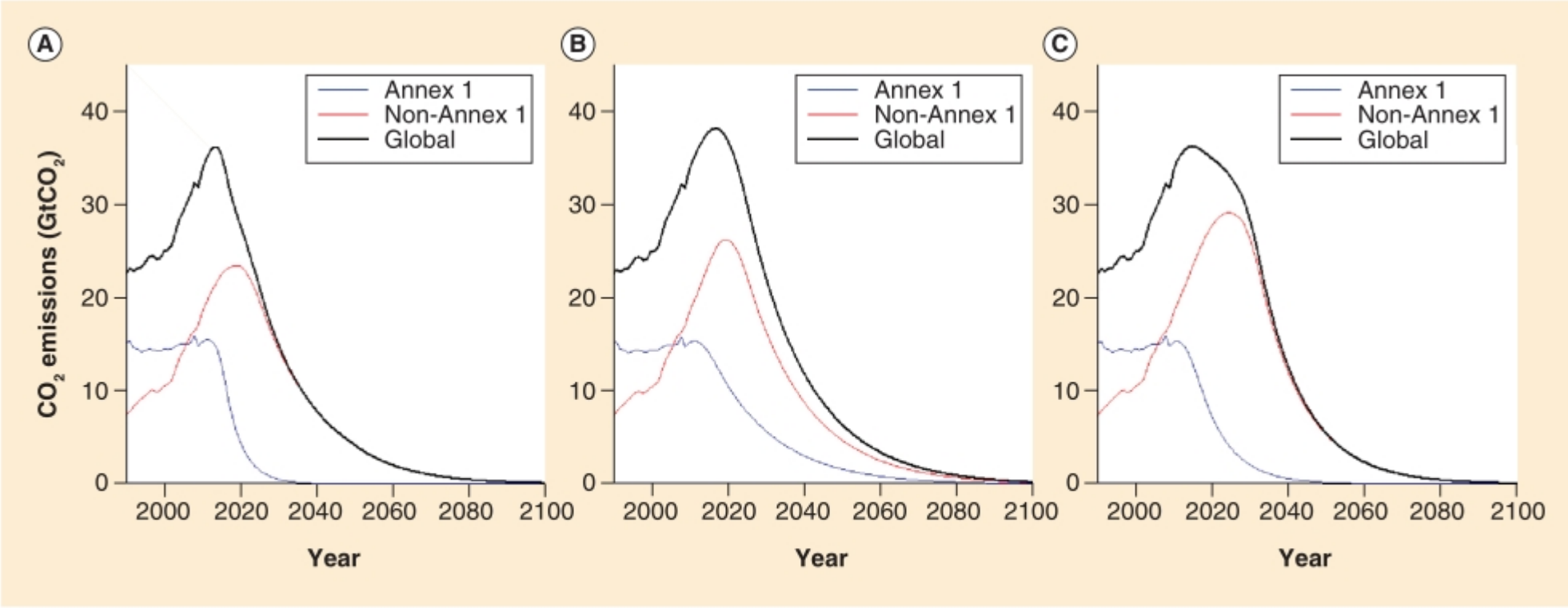


Figure 1. Global, Annex 1 and non-Annex 1 emission pathways of CO_2 only from energy with different probabilities of not exceeding 2°C. (A) Has an approximately 60% chance; **(B)** an approximately 50% chance with a later peak; **(C)** an approximately 50% chance with an earlier global (and later non-Annex 1) peak. All pathways are updated versions of those within Anderson and Bows [10].

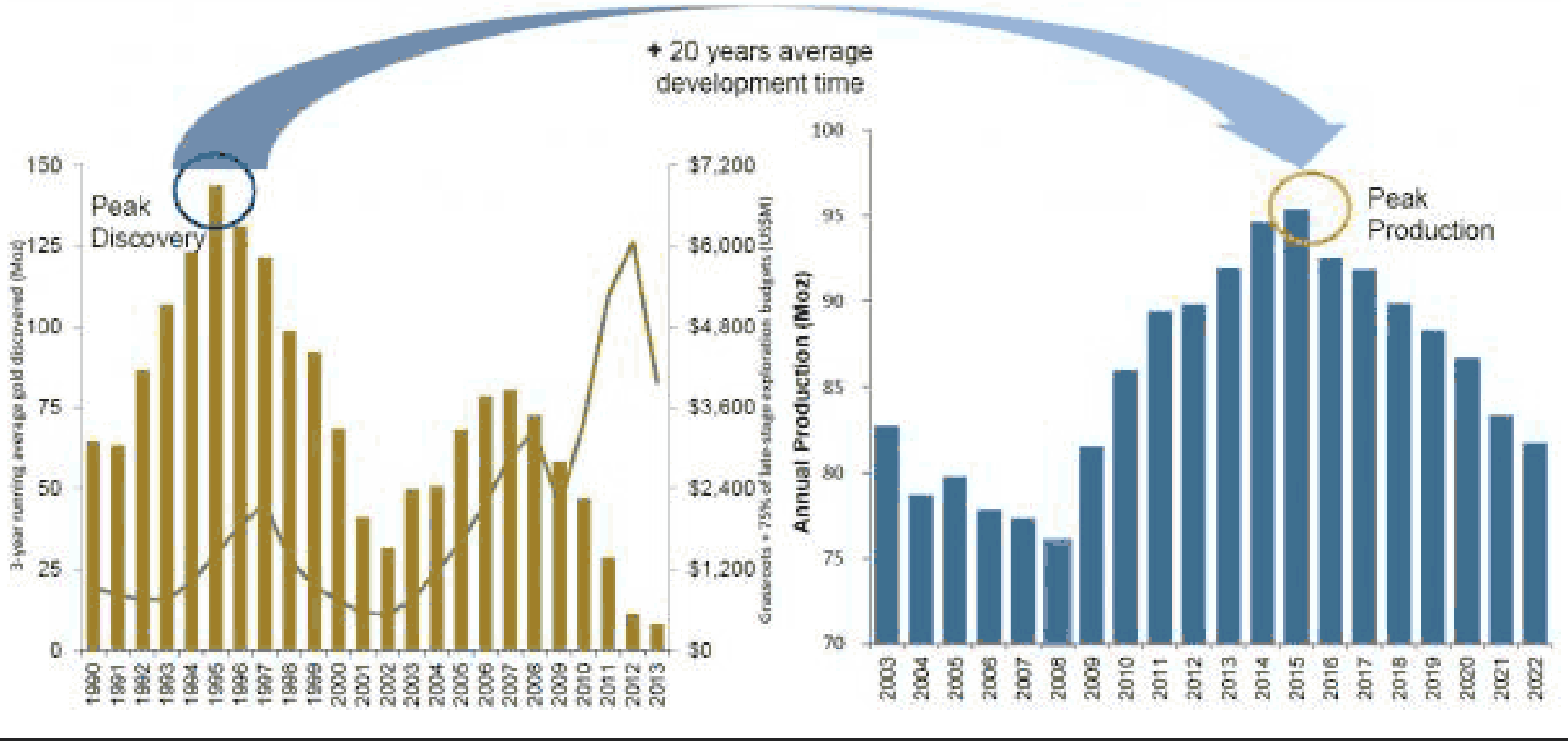
http://grist.org/climate-energy/the-brutal-logic-of-climate-change-international-shipping-edition/

Peak Gold

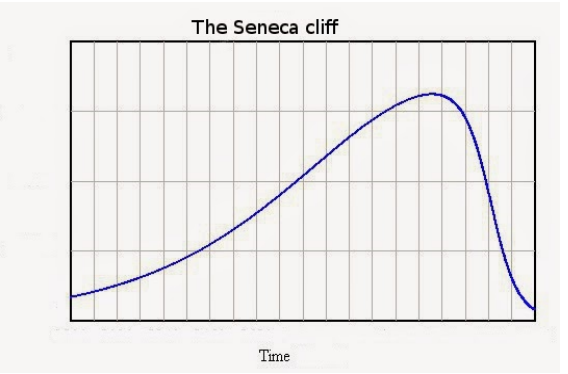
PEAK PRODUCTION IS EXPECTED ~2015

- Gold market forecasters are expecting peak production in ~2015
- This coincides with a ~20 year development cycle from peak discovery

"PEAK GOLD"

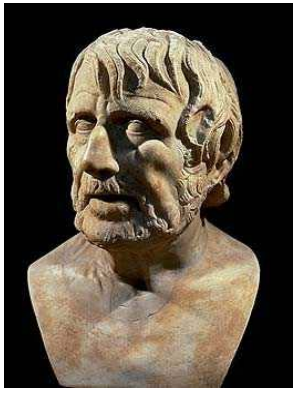


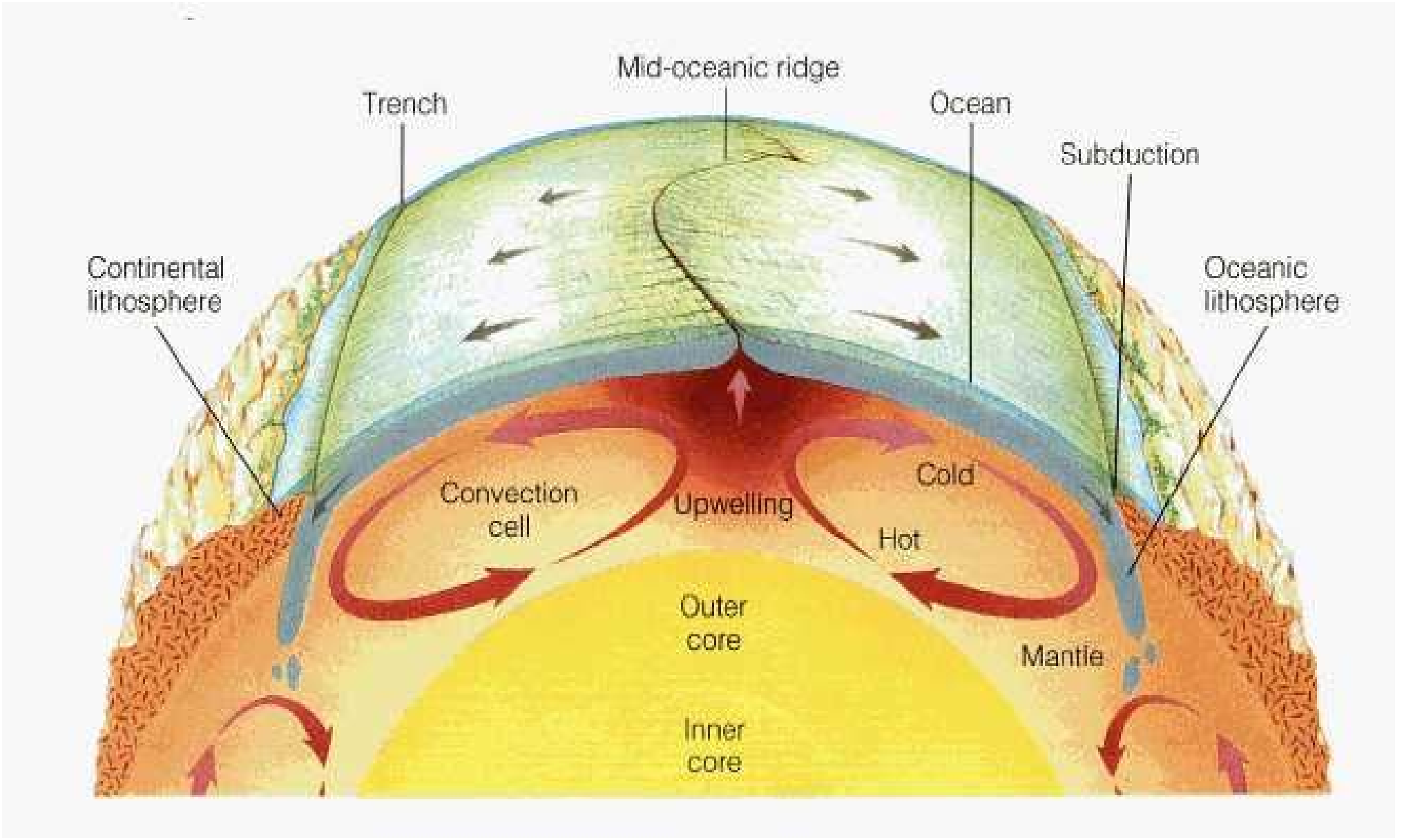
The Seneca Effect

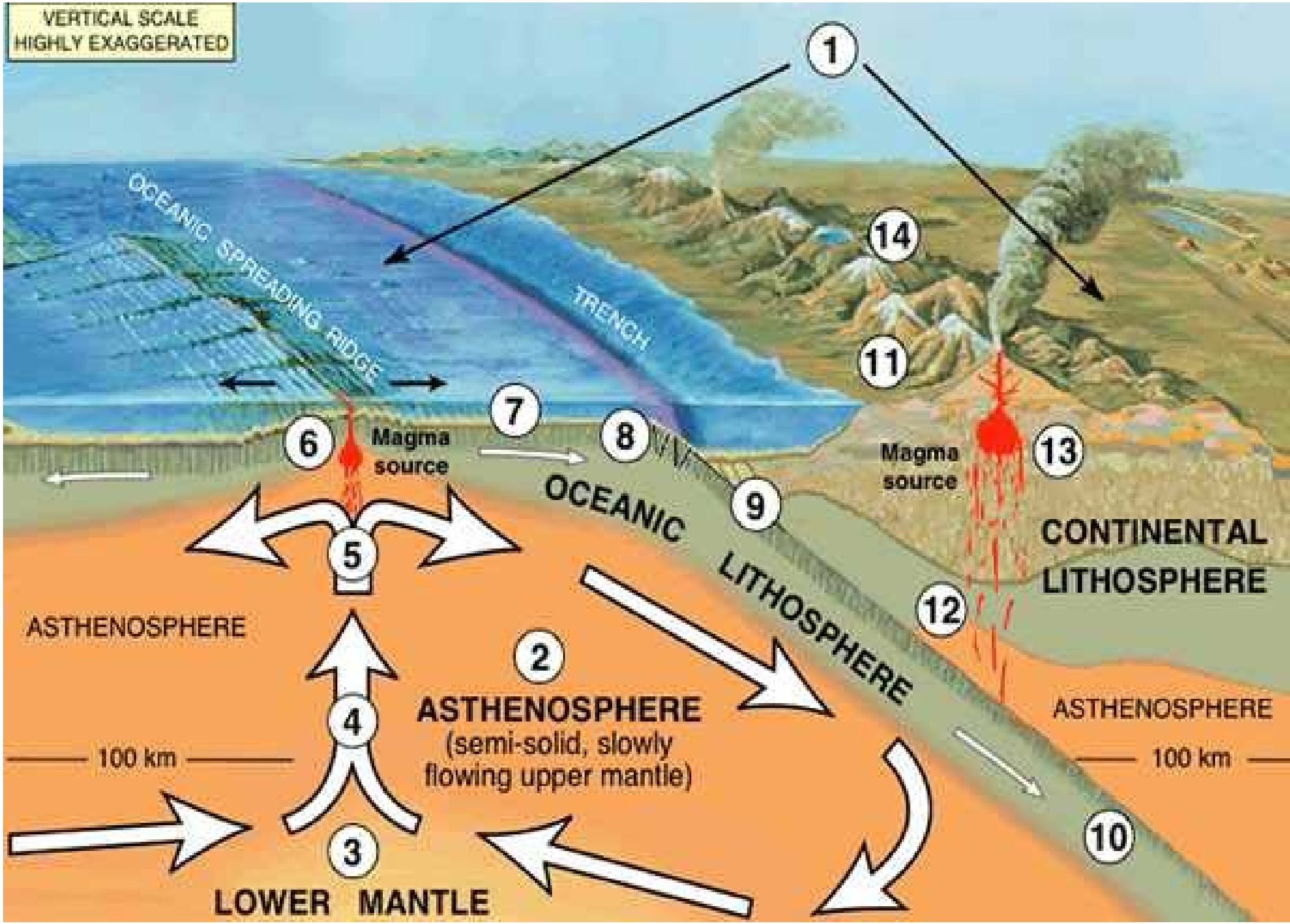


"It would be some consolation for the feebleness of our selves and our works if all things should perish as slowly as they come into being; but as it is, increases are of sluggish growth, but the way to ruin is rapid."

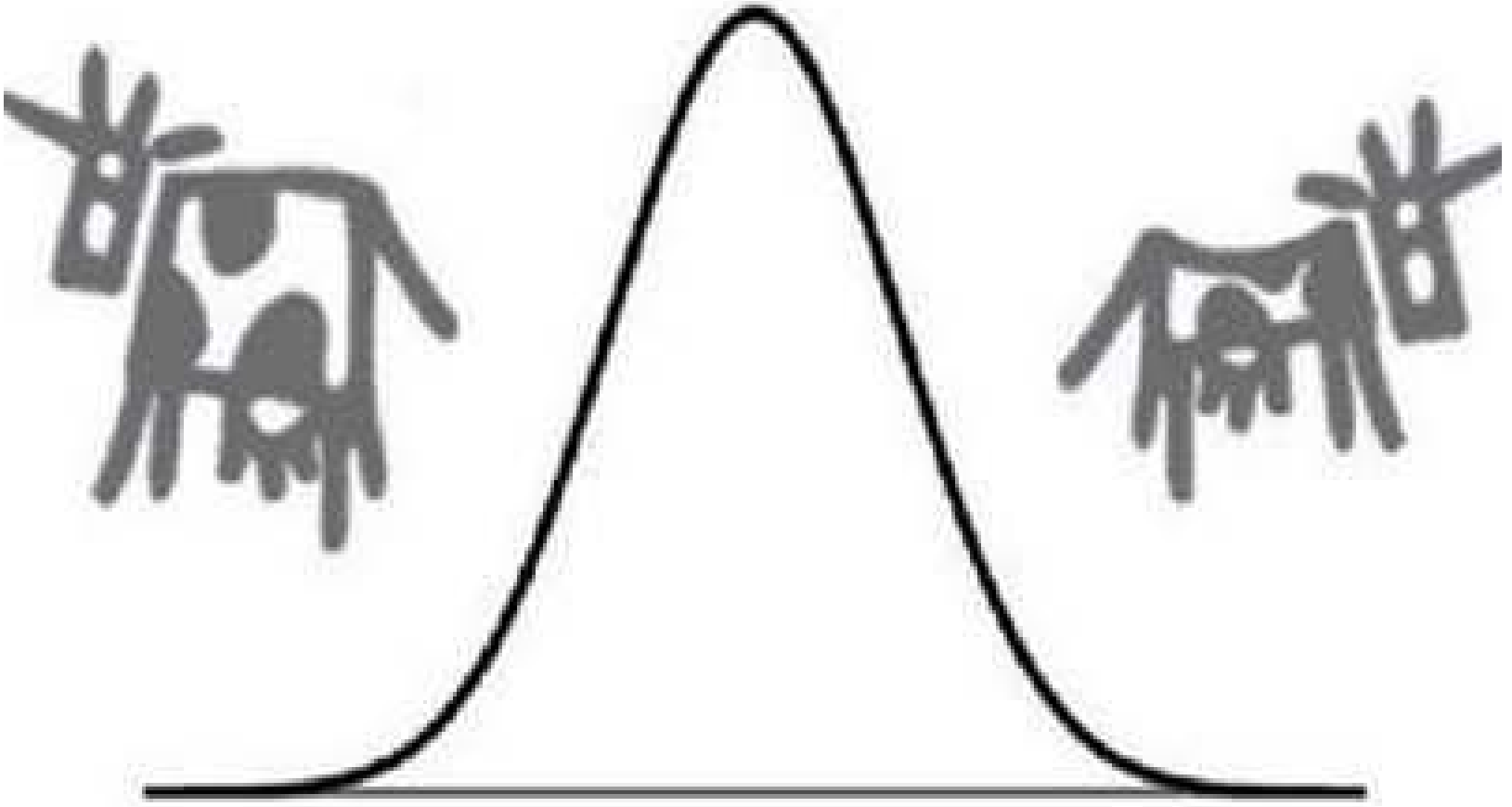
Lucius Annaeus Seneca 4 AD – 65 AD



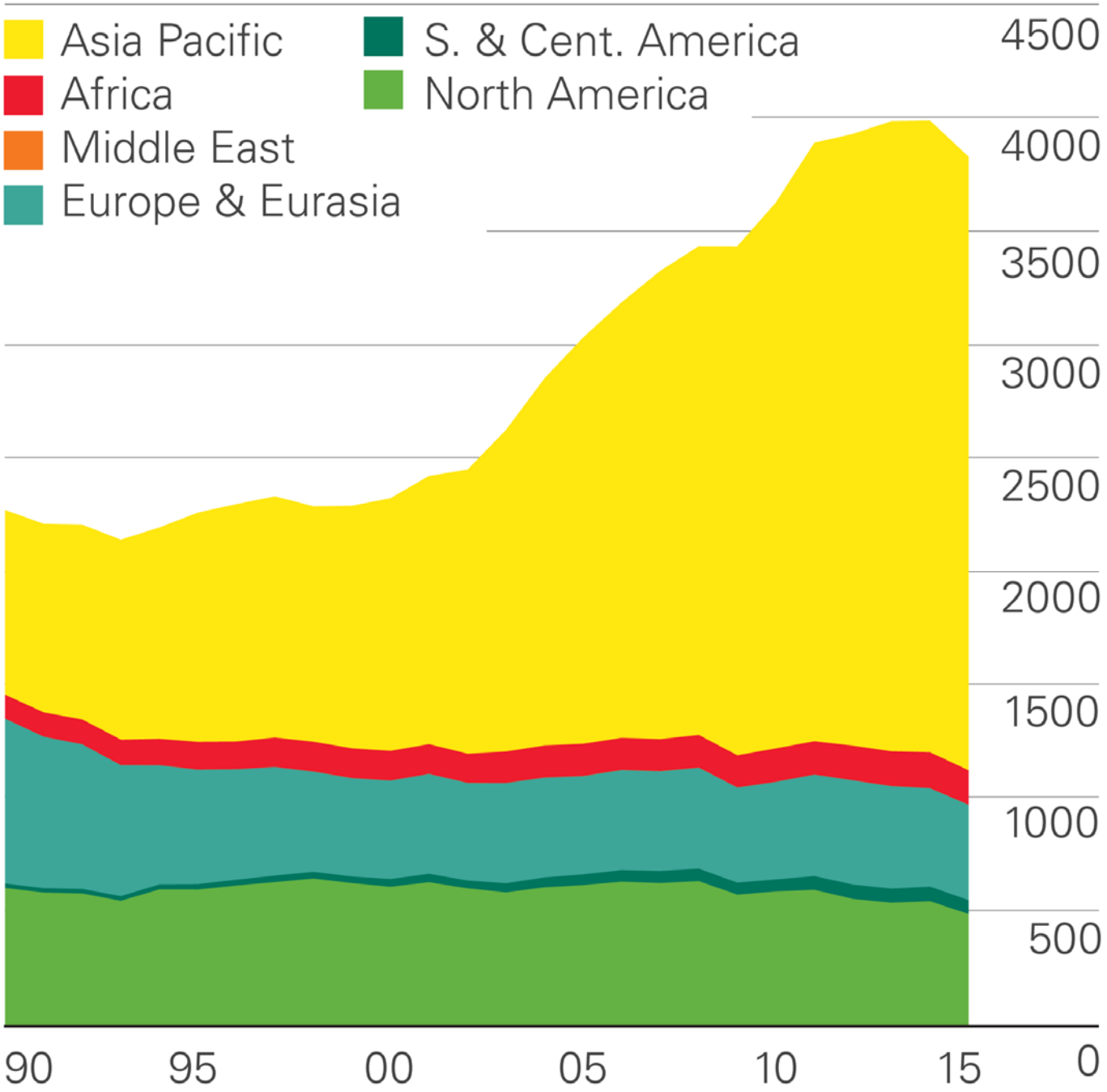

Mid-oceanic ridge
Trench
Ocean
Subduction
Continental lithosphere
Oceanic lithosphere
Convection cell
Upwelling
Cold
Hot
Outer core
Mantle
Inner core


VERTICAL SCALE
HIGHLY EXAGGERATED
1
OCEANIC SPREADING RIDGE
TRENCH
14
11
7
8
6
Magma source
Magma source
13
OCEANIC
9
CONTINENTAL
LITHOSPHERE
5
LITHOSPHERE
12
ASTHENOSPHERE
2
ASTHENOSPHERE
(semi-solid, slowly
flowing upper mantle)
ASTHENOSPHERE
4
100 km
100 km
10
3
LOWER MANTLE

The Bell Curve



The global coal peak



http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/coal/coal-production.html

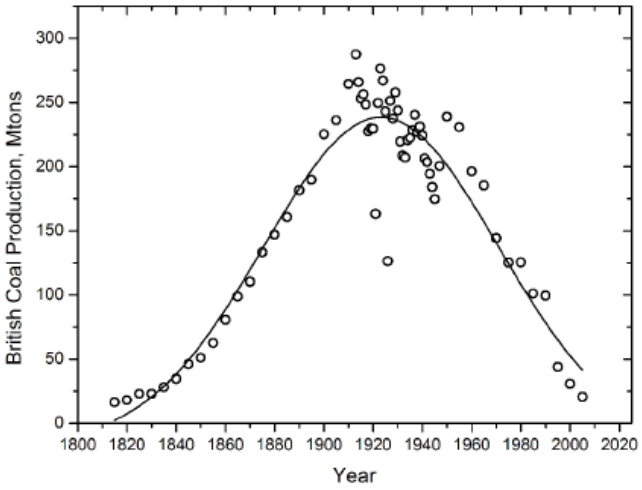
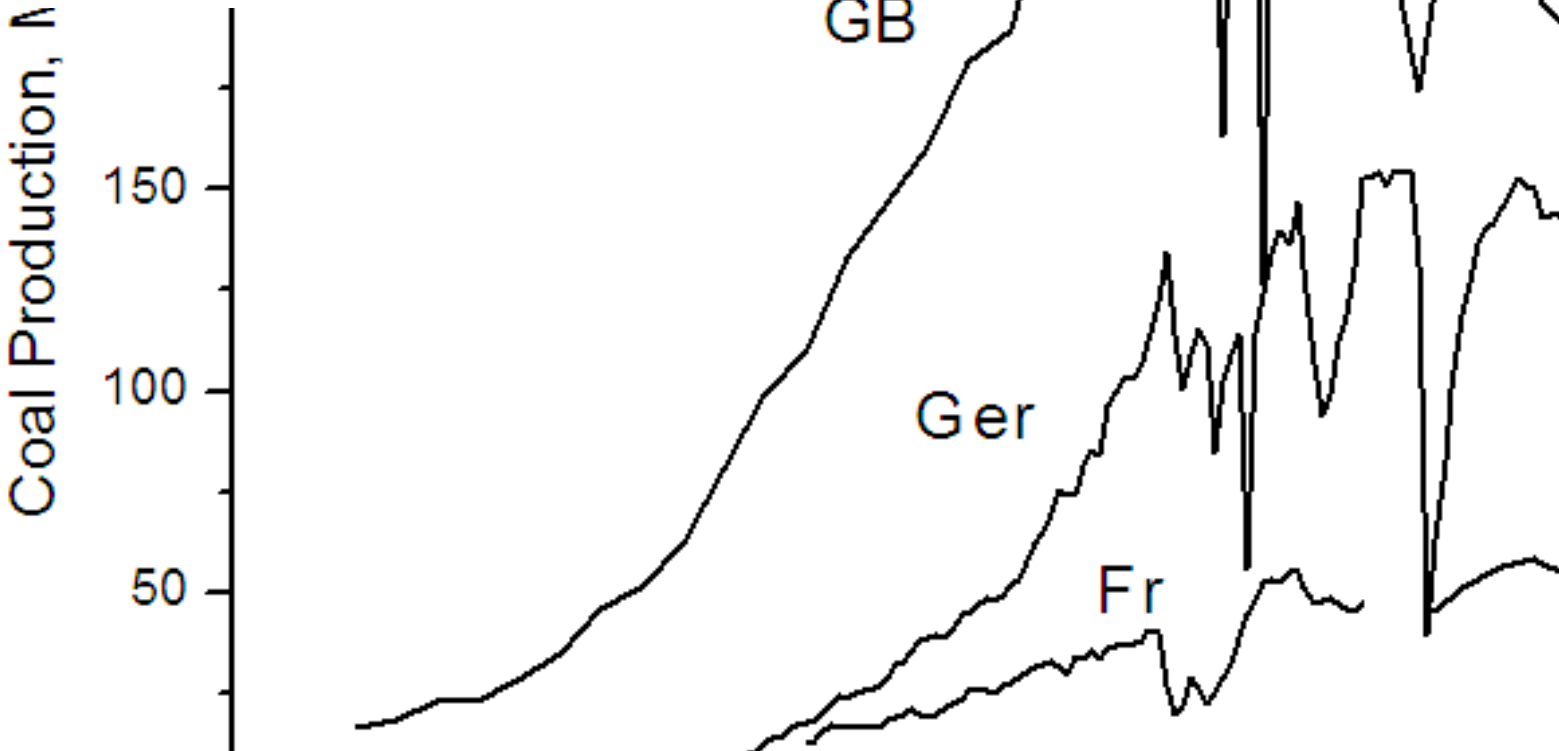


Figure 1. British coal production from 1815 to 2004. The data from 1815 to 1860 are from Cook and Stevenson, 1996. The data from 1860 to 1946 are from Kirby 1977; the data from 1947 up to present are from the British Coal Authority (accessed 2006). The production data are fitted with a Gaussian function which approximates the Hubbert curve. The maximum historical production is in 1913 with 287 M tons, the maximum of the fitting curve is in 1923.



“If you realize that all things change, there is nothing you will try to hold on to. If you are not afraid of dying, there is nothing you cannot achieve.”

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