Resource Based Economy

Ugo Bardi

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The Club of Rome
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)

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.
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
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 fluor spar, 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

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

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

MinEx Consulting
Strategic advice on mineral economics & exploration
SilverCorp Average Silver Ore Grades

info from SilverCorp's Quarterly & Annual Reports
Exploration of major mineral deposits and the “Law of diminishing returns”

low expectations of yet to be discovered major deposits

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.S. Crude Oil Production versus Hubbert Curve

Data source: US Energy Information Administration
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)

Year

Consumption (Billions of Tons of Oil Equivalent)

World
Wind
Solar

(BP, 2017)
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
Detailed Sustainable Energy Transition Path

Fossil phase-out: 2020 - 2075  |  Emissions cap: 990 GtCO₂
EROEI = 20 in year 2014  |  Demand = 2000 W / person in year 2100

Sgouridis, Csala, Bardi, 2016

26.7% Annual Growth

0.7% Annual Growth

Billions of US Dollars

Year

Inequality: Who Eats the Cake?
Wealth Inequality Defined by the Gini Coefficient

Fraction of private wealth in the nation.

Fraction of the population

- All people have the same wealth
- US including home equity
- US Stocks, Bonds, Real Estate only
- One person has all the wealth
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.

Source: World Bank

OurWorldInData.org/income-inequality/ • CC BY-SA
Gini Index in the US
Data from the US Census Bureau

By Ugo Bardi - 2018
www.cassandralegacy.blogspot.com
“Something” happened in the mid-70s.
Figure 1: MLT 2020 and MLT 2030 GHG emission are extrapolated from the BAU scenario considering that the global carbon budget is 485 GtCO₂ until 2050. The data source for BAU and OT is from Climate Action Tracker (CAT).
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...
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

\[ R' = -k_1 CR \]
\[ C' = k_2 CR - K_3 C \]

\( R' \) = Production
\( C' \) = Economic growth
\( C \) = Capital
\( R \) = Resources

\[
\text{EROEI} = \frac{(k_1 \times \text{Oil Reserves} \times \text{The Economy})}{((k_1 \times k_2) \times \text{The Economy})}
\]

\[
\text{EROEI} = \frac{\text{Oil Reserves}}{k_3}
\]

\[
\text{Net energy} = (k_1 \times \text{Oil Reserves} \times \text{The Economy}) - ((k_1 \times k_2) \times \text{The Economy})
\]

\[
\text{Net energy} = (k_1 \times \text{The Economy}) \times (\text{Oil Reserves} - k_2)
\]
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 CO₂ 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].
Total predicted emissions: $5 \times 10^{12}$ t CO2.
Maximum allowable for $+2^\circ$ C: $2.3 \times 10^{12}$ t CO2
The Bell Curve (the Hubbert Curve)
Number of Horses in the United States

by Ugo Bardi · 2017
www.humanesociety.org/assets/pdfs/hsp/soaiv_07_ch10.pdf

http://www.humanesociety.org/assets/pdfs/hsp/soaiv_07_ch10.pdf
Figure 6 – European Population at the time of the Great Plague (from Langer⁶)
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

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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

From the Maddison database
http://www.ggdc.net/maddison/Historical_Statistics/horizontal-file_02-2010.xls
The Seneca Curve
DO SOMETHING, YOUNG LADY...
WELL! IT'S EASY TO JUST CRITICIZE. YOU'VE GOT AN ALTERNATIVE ALL WORKED OUT, HAVE YOU?
...AND I SUPPOSE HYSTERICAL ECO-FANATICS! ALWAYS TELLING PEOPLE HOW TO LIVE...
GET YOURSELF A PROPER JOB!

'HOLD YOUR NÝTS, YOU BUNCH OF MANIACS!'
LAND AND SEA GLOBAL YEARLY MEAN TEMPERATURE

Data from the NASA-GISS 'GLB.Ts+dSST.txt' file from 1880 to 2017.

Global mean near surface temperature rose at 0.72 ± 0.04 K/century.
It grew exponentially at 13.673 + 0.04583 * exp(0.0238 * (YEAR - 1880)) C.

The 20 warmest years since 1880.

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By Roger Coppock
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.
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
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 retweets
8,586 likes
The giant mining and recycling machine

Rules for mining
Use what's abundant
Use as little as possible
Recycle ferociously
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
US North Atlantic Cod Landings

By Ugo Bardi
www.cassandralegacy.blogspot.com
Data from Faostat
From Global Carbon Report

- RCP8.5: 3.2–5.4°C relative to 1850–1900
- RCP6: 2.0–3.7°C
- RCP4.5: 1.7–3.2°C
- RCP2.6: 0.9–2.3°C

- 2014 Estimate
- Historical emissions

below this line represents net-negative global emissions
Global breakeven prices (considering only technical extraction costs) versus production. Source: Alliance Bernstein, October 2014.
Industrial Production Volume in EU Countries
Published EROI Values for Oil and Production in the US

- US Oil and Gas (Cleveland et al. 1984)
- US Oil and Gas (Hall et al. 1986)
- US Oil and Gas (Guilford et al. 2011)

Key Events:
- Eisenhower imposes Oil Import Quota
- North Slope Oil Production Peak
- US Oil Market Control Ends
- US Oil Import Quota Eases
- Gulf War
- Iraq War
- Low Drilling US
- Record Drilling US
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
"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].
World Model – 6 stocks
World3 calculations 2004
The Brutal Logic of Climate Change

Figure 1. Global, Annex 1 and non-Annex 1 emission pathways of CO₂ 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].

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”

- 20 years average development time

[Graph showing gold production and discovery trends over time]
"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
The Bell Curve
The global coal peak

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.”

— ,