Resources, the Economy and the Ecosystem (and the Seneca Effect)

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Trantor





Selected non fuel world mineral production









The End of Cheap Oil

Global production of conventional oil will begin to decline sooner than most people think, probably within 10 years

by Colin J. Campbell and Jean H. Laherrère

Please note that the Invout of this document is slightly differ and than the original.

Tn 1973 and 1979 a pair of sudden price increases rudely awakened the industrial world to its dependence on cheap crude oil. Prices first tripled in response to an Arab embargo and then nearly doubled again when Iran dethroned its Shah, sending the major economies sputtering into recession. Many analysts warned that these crises proved that the world would soon run out of oil. Yet they were wrong.

Their dire predictions were emotional and political reactions; even at the time, oil experts knew that they had no scientific basis. Just a few years earlier oil explorers had discovered enormous new oil provinces on the north slope of Alaska and below the North Sea off the coast of Europe. By 1973 the world had consumed, according to many experts' best estimates, only about one eighth of its endowment of readily accessible crude oil (socalled conventional oil). The five Middle

Eastern members of the Organization of cause official charts show reserves grow-Petroleum Exporting Countries (OPEC) ing. were able to hike prices not because oil was growing scarce but because they had managed to corner 36 percent of the market. Later, when demand sagged, and the flow of fresh Alaskan and North Sea oil weakened OPEC's economic strangle- tant, conventional wisdom erroneously hold, prices collapsed.

The next oil crunch will not be so temporary. Our analysis of the discovery and as the barrels of oil gushing from wells production of oil fields around the world suggests that within the next decade, the supply of conventional oil will be unable to keep up with demand. This conclusion half the oil is gone, begins falling graducontradicts the picture one gets from oil industry reports, which boasted of 1,020 billion burrels of oil (Gbo) in "Proved" reserves at the start of 1998. Dividing that figure by the current production rate of about 23.6 Gbo a year might suggest that crude oil could remain plentiful and cheap declines commensurately. for 43 more years-probably longer, be-

Unfortunately, this appraisal makes three critical errors. First, it relies on distorted estimates of reserves. A second mistake is to pretend that production will remain constant. Third and most imporassumes that the last bucket of oil can be pumped from the ground just as quickly today. In fact, the rate at which any wellor any country-can produce oil always rises to a maximum and then, when about ally back to zero.

From an economic perspective, when the world runs completely out of oil is thus not directly relevant: what matters is when production begins to taper off. Beyond that point, prices will rise unless demand



78 Scientific American March 1998

HISTORY OF OIL PRODUCTION, from the first commercial American well in Titusville, Pa. (leff), to dericks bristling above the Los Angeles basin (below), began with steady growth in the U.S. (red line). But domestic production began to decline after 1970, and restrictions in the flow of Middle Eastern oil in 1973 and 1979 led to inflation and shortages (near and center fight). More recently, the Persian Gulf War, with its burning oil fields (far right), reminded the industrial world of its dependence on Middle Eastern oil production (gray line).



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AND, WITH THIS, PEAK OIL IS ABOLISHED!

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

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 💵

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



Tiffany's jewelry fallacy:



Mining requires energy





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

The Hagu Centre fo Strategiu Studie

Borrowed Time?

Assessing the Threat of **Mineral Depletion**

John E. Tilton

Scarcity of Minerals A strategic security issue

ic Studies Nº 02 | 01 | 1

QUEL FUTUR POUR LES MÉTAUX ?

Philippe Bihoutx lenoît de Guillebo

aréfaction des métaux un nouveau défi pour la société





Image from Fantazzini et al, 2011 http://energyskeptic.com/2015/global-oil-risks-in-the-early-21st-century-energy-policy-2011/financialsense.org"



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





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

Ore grades mined have declined over time

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



MinEx Consulting

Strategic advice on mineral economics & exploration



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











The Limits to Growth, 1972





A NEW OPEN-SOURCE ENERGY MODEL TO GUIDE THE TRANSITION TO A LOW CARBON EUROPEAN SOCIO-ECONOMY.

NEWS & EVENTS

MEDEAS General Assembly in Florence

TUE, 20 FEBRUARY

The second MEDEAS General Assembly was organized between 5 and 9 February in Florence, Italy by the National Interuniversity Consortium of ...

IN THE SPOTLIGHT

Publications

Transportation in a 100% renewable energy system

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

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

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

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

EROEI and NET ENERGY



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 Seneca Effect: Caviar production in the Caspian sea





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



Detailed Sustainable Energy Transition Path



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







Global Investment in Renewable Energy 2004-2017






Figure 6 – European Population at the time of the Great Plague (from Langer⁶)









Acknowledgement







The Club of Rome



The «Energy Transition» group

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."







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



Figure 1. Ecological Overshoot



SilverCorp Average Silver Ore Grades





The Limits to Growth was right







System Dynamics Stock and Flow models ("mind-sized" models)



Californian Sardine Fishery



Perissi, Lavacchi and Bardi, to be published



US 48 - OII Discoveries vs. Wildcats

U. Bardi and A. Lavacchi, Energies, 2009









China population trends according to a reconstruction published by Columbia University.



China population trends according to a reconstruction published by Columbia University.

Zheng He - 1402

The Bell Curve (the Hubbert Curve)



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

The Seneca Curve



Exploration of major mineral deposits and the "Law of diminishing returns"



Graph: Raw Materials Group, Sweden

Graph by A. Diederen



Number of Horses in the United States



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





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







'STEADY AS SHE GOES'



Www.cassandralegacy.blogspot.com





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

◆ €7 16,634 ★ 8,586

The giant mining and recycling machine

Rules for mining

Use what's abundant Use as little as possible Recycle ferociously

Prof. J. Gutberlet and a Brazilian Catador










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."



Figure 18.6 Total international landings of sandeels in the North Sea by country. From ICES (2007b).



Source: http://appinsys.com/globalwarming/ Puffins_UK.htm 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



US 48 - Oil Discoveries vs. Wildcats

U. Bardi and A. Lavacchi, Energies, 2009

THE NET ENERGY CLIFF



ENERGY RETURN ON ENERGY INVESTED (EROEI)

World Model – 6 stocks



World3 calculations 2004

State of the World





Myrtveit 2005

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



The Seneca Effect



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Lucius Annaeus Seneca 4 AD – 65 AD



The Bell Curve



In 1956 M.King Hubbert predicted that US oil production would peak around 1965-1970

It did ... at the end of 1970.

He went on to predict that world oil production would peak around 2000.



Pic: Energy Bulletin

The global coal peak



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



"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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World oil production



Dati ASPO (2008)



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Three Predictions:

- 1. World production of *conventional* oil to peak in 2004-2010
- 2. World Production to follow a "bell shaped" curve
- 3. Crude oil Prices to increase near the peak
- 1: Incorrect at best partly correct
- 2. Partially correct
- 3. Correct

The global oil peak



Non-equilibrium thermodynamics of the dissipation of finite resources



Non-equilibrium thermodynamics of the dissipation of antelopes by cheetahs



Non-equilibrium thermodynamcs of the dissipation Of whales by the 19th century whaling industry



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

Global Maritime Trade Routes. Ca 2% of world's energy suppy



THE NET ENERGY CLIFF



ENERGY RETURN ON ENERGY INVESTED (EROEI)

Abandoned Diamond mine, Mir, Russia



Mining requires energy!





Mining Requires Energy





Morency copper mine, Australia

10




The end of mining as we know it