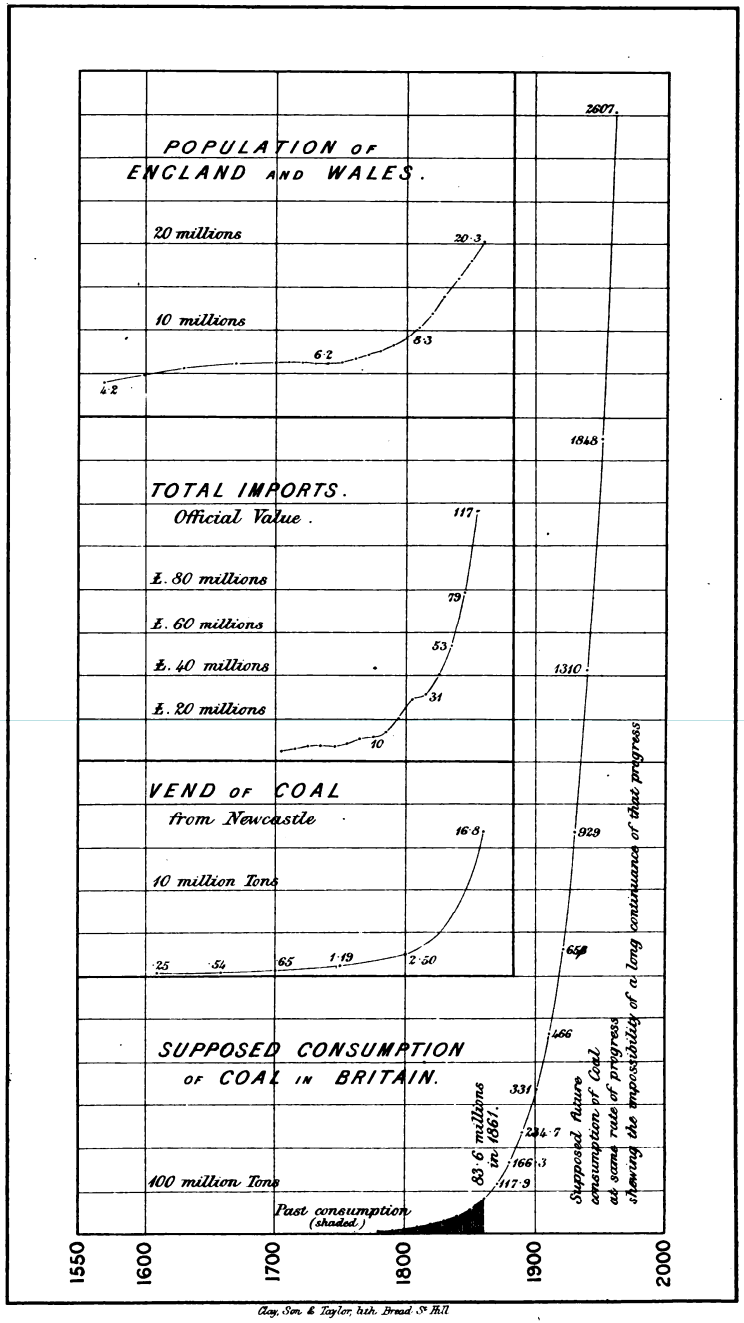
Perception v. Reality in Mineral Resource Assessment and Geoscience Education

Norbert T. Rempe

ng(o)$_3$

rempent@yahoo.com

W. Stanley Jevons, 1865: *The coal question: an inquiry into the progress of the nation, and the probable exhaustion of our coal mines,* MacMillan & Co., London and Cambridge



"…*the maintenance of such a position is impossible. We have to make the momentous choice between brief greatness and longer continued mediocrity.*"

(italics in original)

http://books.google.com/books/about/The_coal_question.html?id=gAAKAAAAIAAJ

Scarcity: Neomalthusian predictions

The Limits to Growth (1972): Oil will run out before 1992

Paul Ehrlich (1987): The oil crisis will return in 1992

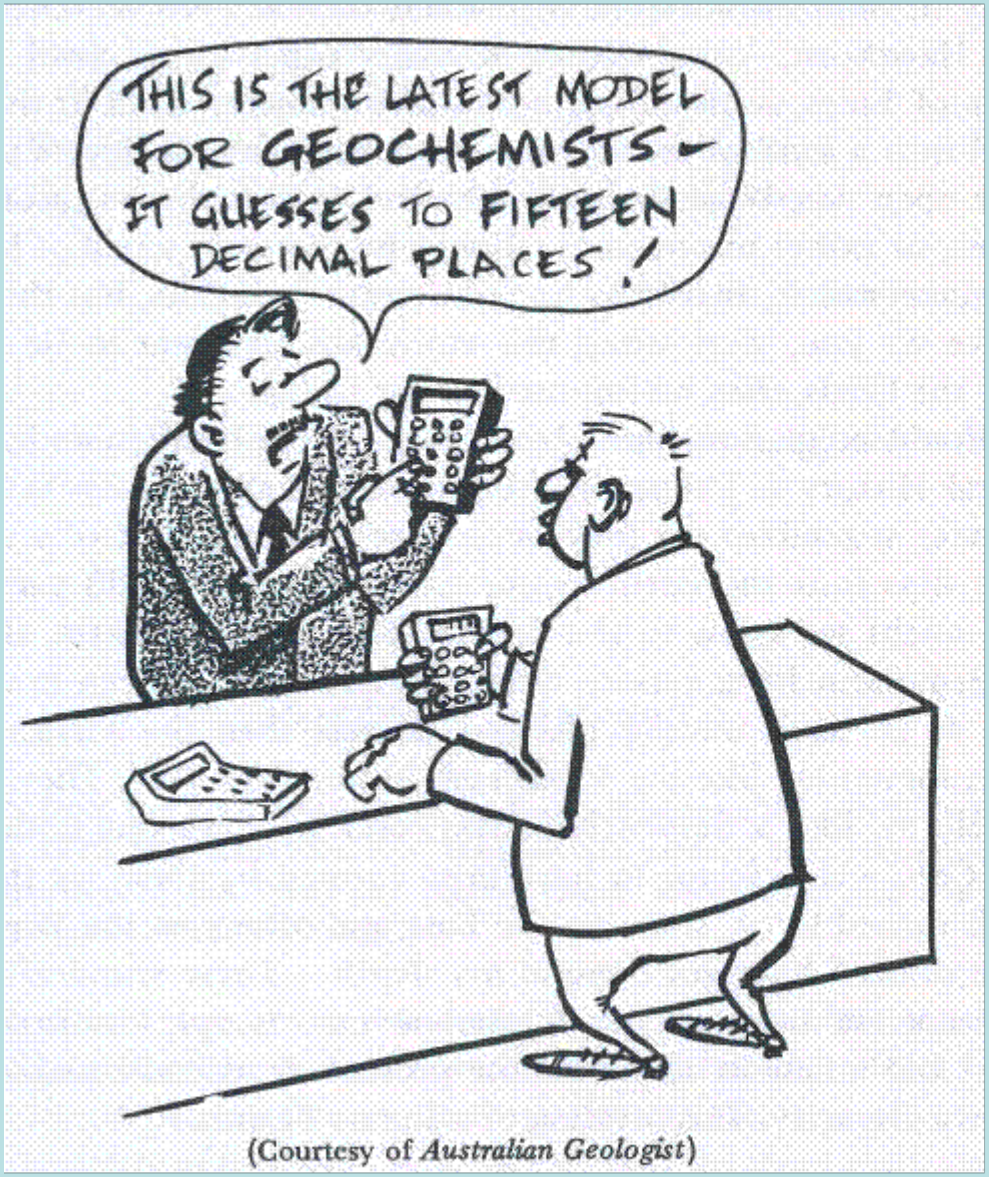
Beyond the Limits (1992): Oil will run out by 2031

(Frank Notestein (1902-1983), Princeton:
We've been running out of oil
ever since I was a boy

Humanity was predicted to exhaust critical resources in the following order . . .

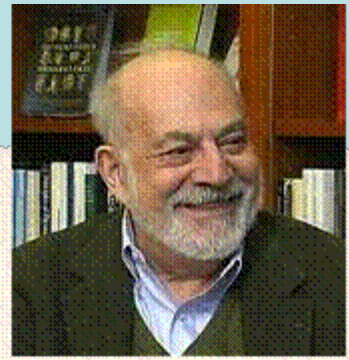
gold	1981
mercury	1985
tin	1987
zinc	1990
petroleum	1992
copper	1993
lead	1993
natural gas	1993

Club of Rome, *Limits to Growth* (1972)



(Courtesy of *Australian Geologist*)

from: A Geological Miscellany, Orbital Press, 1982



ON BULLSHIT

Harry G. Frankfurt

PRINCETON UNIVERSITY PRESS

PRINCETON AND OXFORD

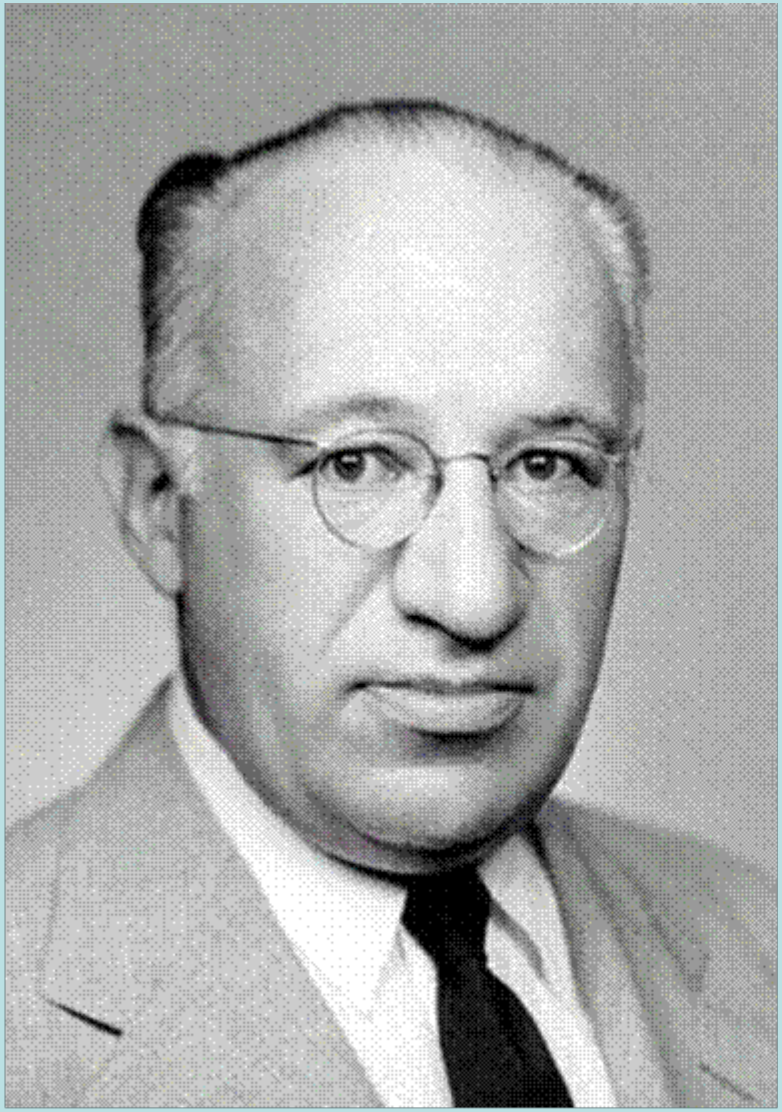
First published 1986

2 sacred cows

Resources become more scarce and expensive

Geologists know more about resources than economists

it’s high time to tip sacred cows

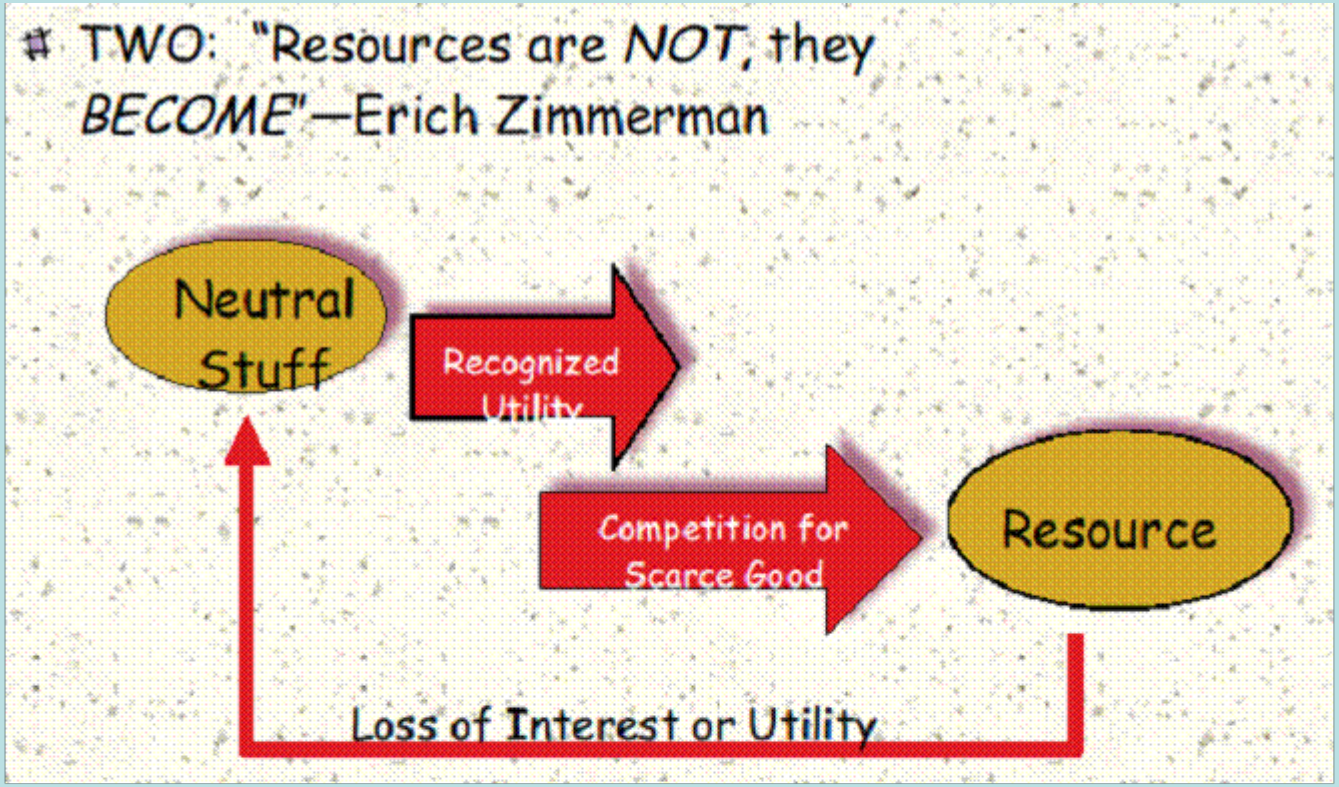


Erich Walter Zimmermann, 1888-1961

Resources are not
They become

(In 1984, the University of Texas established the Erich W. Zimmermann Regents Professorship)

TWO: "Resources are *NOT*, they *BECOME*"—Erich Zimmerman



Example of **BECOMING** a resource:

Uranium: from almost useless byproduct to dense energy source

Example of reverting to **NEUTRAL STUFF**:

Mules: from essential for pulling fire-fighting equipment, artillery and wounded soldiers and borax from Death Valley mines to obsolete

http://www.strom.clemson.edu/becker/prtm320/notes/defining-resources.pdf

- Typically, one looks at figures on reserves, or the ratio of reserves to annual production, which gives the number of years to exhaustion.

- For example, for world oil:

What's happening?

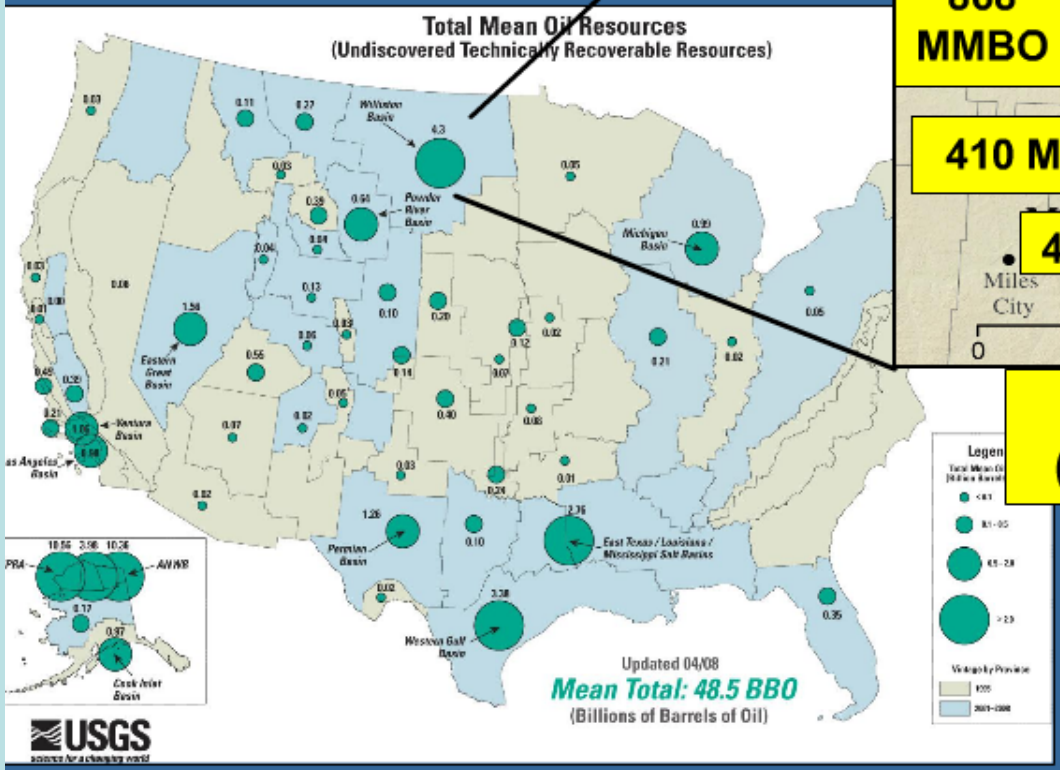
Year	Reserves (billion barrels)	Reserves/ Production
1950	86	22
1955	190	33
1960	298	37
1965	348	30
1972	667	35
1990	887	47
2000	~1000	~50

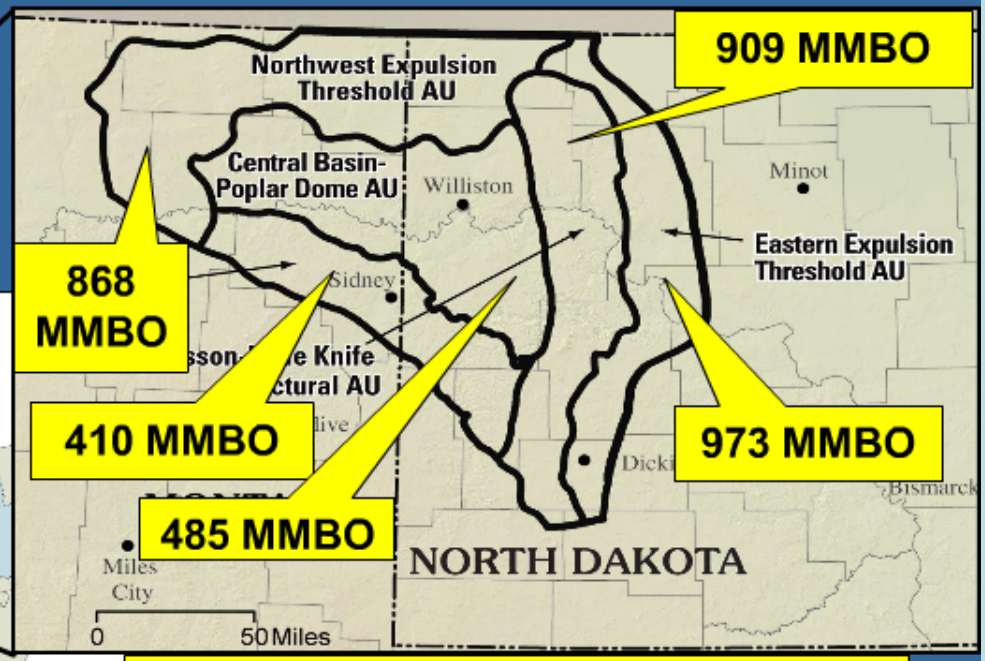
http://are.berkeley.edu/courses/EEP161/fall2008/Resources,_Growth_and_Sustainability2.ppt

Resource Assessments Change Over Time

http://pubs.usgs.gov/fs/2008/3021/

Example: Bakken Formation (2008)





Mean total = 3.65 BBO
(F95=3.0 BBO; F5=4.3 BBO)

USGS 1995 Bakken Assessment:
Mean total = 151 MMBO

USGS

Changes result from improved geologic understanding, technological developments, other factors

The only scarce resource is human ingenuity

Julian L. Simon, 1932-1998

The Ultimate Resource, 1981

Scarcity or Abundance, 1994

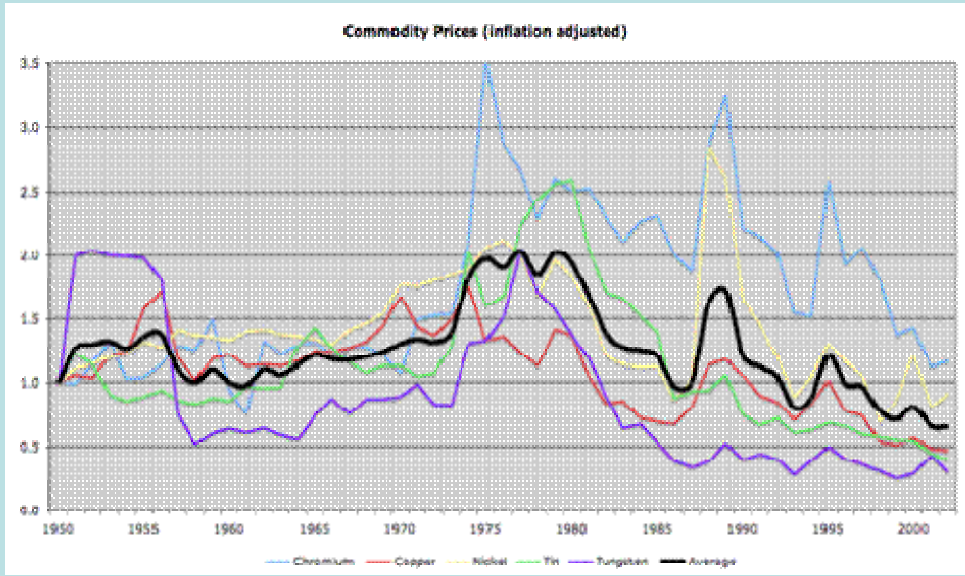
The State of Humanity, 1995

The Ultimate Resource II, 1996

Falling long-term prices are prima facie evidence of greater abundance, not increasing scarcity.

Natural resources are not finite in any serious way; they are created by the intellect of man, an always renewable resource.

Paul Ehrlich bet Simon $1,000 in 1980 that five resources of Ehrlich's choosing (copper, chrome, nickel, tin, and tungsten) would be more expensive in 10 years. Ehrlich lost: 10 years later every one of the resources had declined in price by an average of 40 percent.



http://en.wikipedia.org/wiki/Simon-Ehrlich_wager

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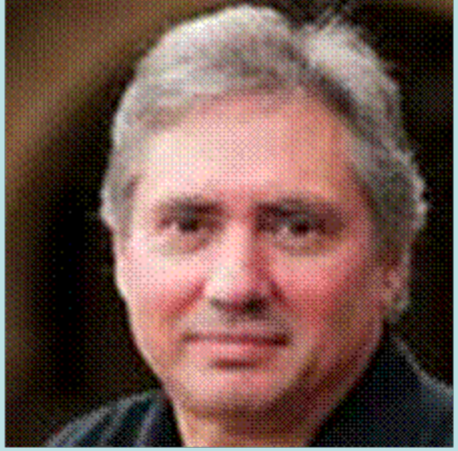
OIL PANIC AND THE GLOBAL CRISIS

Predictions and Myths

Steven M Gorelick

WILEY-BLACKWELL



Steven M. Gorelick

Hydrology Professor, Stanford University
Fellow, AGU and GSA
Author: Oil Panic and the Global Crisis – Predictions and Myths, 2010

In past estimates, we usually had 30-40 years of oil remaining.

Regardless of huge increases in demand and considerable leaps in technology, we always have in reserve what is economical to discover.

The fundamental peak oil assumption that the rate of oil production growth will be mirrored in the decline of production is flawed. Past oil production rates are principally a record of consumer demand, rather than of resource availability.

The ultimate size of resources is unknown, but much larger than the conservative estimates. We consistently underestimate true resource size and future development of new extraction technologies.

Perceptions of reality based on current technological or scientific assessment drive policy, and the strong tendency is to build upon these assessments without ever looking back. Thus are errors compounded.

Figure 4.30 Location of continental shelf regions of the US believed to contain rich oil and gas resources. (Based on US Minerals Management Service map)

from Gorelick, 2010

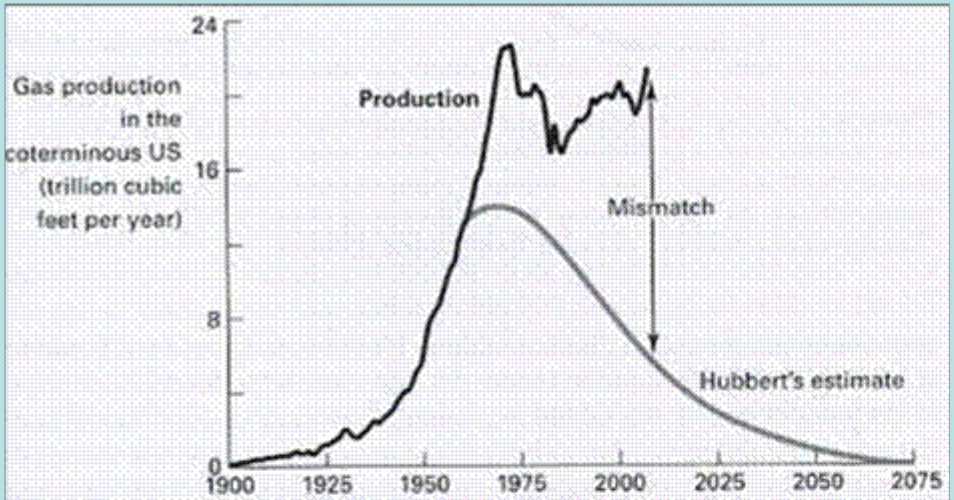


Figure 4.6 Comparison of 1956 Hubbert's prediction of US natural gas production with actual natural gas production data showing a significant mismatch. Hubbert's original curve in 1956 was drawn by hand (after Deming (2000)[18]). (Data: production from EIA and curve from Hubbert (1956)[19])

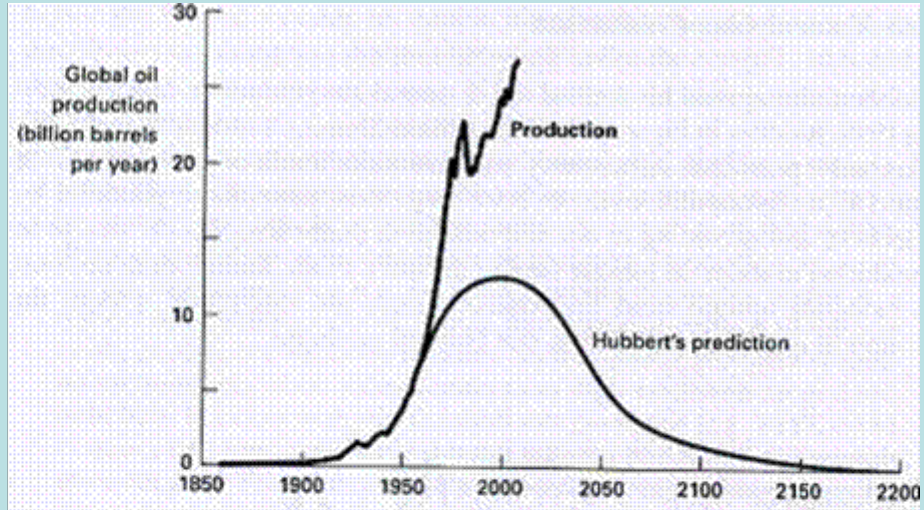


Figure 4.7 Hubbert's prediction of global oil production made in 1956 drastically underestimated modern production of about 27 billion barrels per year, with no peak in production yet occurring. Hubbert assumed a global oil endowment of 1.25 trillion barrels, which is far less than the current USGS estimate of over 3 trillion barrels. (Data: production from EIA and curve from Hubbert (1956)[21])

from Gorelick 2010

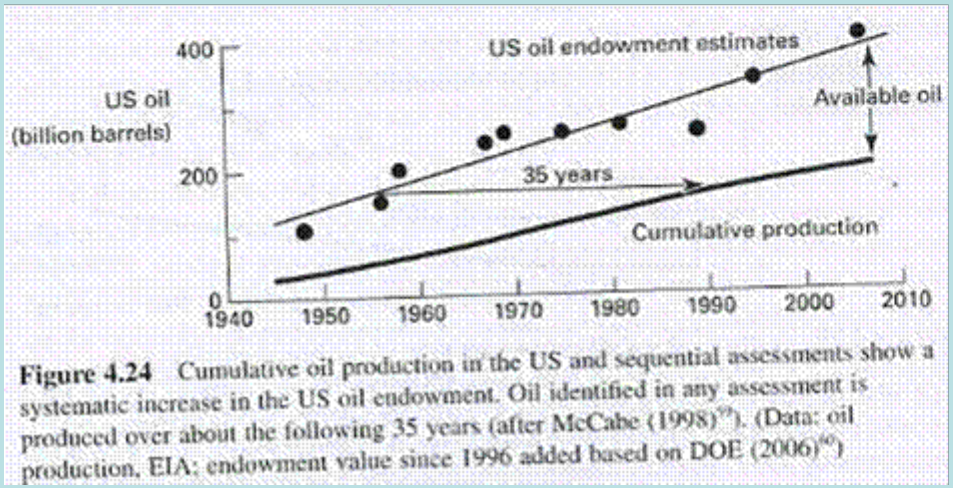


Figure 4.24 Cumulative oil production in the US and sequential assessments show a systematic increase in the US oil endowment. Oil identified in any assessment is produced over about the following 35 years (after McCabe (1998)[57]). (Data: oil production, EIA; endowment value since 1996 added based on DOE (2006)[60])

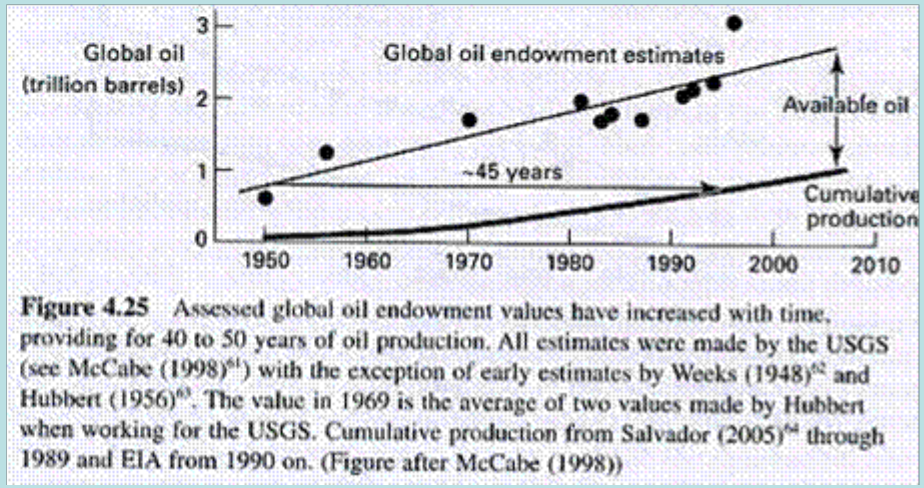
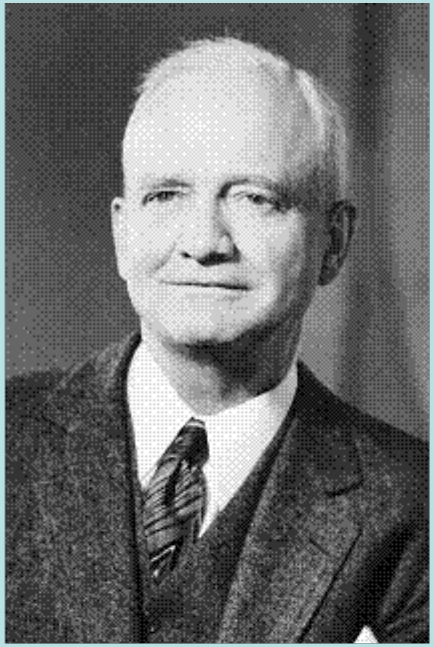


Figure 4.25 Assessed global oil endowment values have increased with time, providing for 40 to 50 years of oil production. All estimates were made by the USGS (see McCabe (1998)[61]) with the exception of early estimates by Weeks (1948)[62] and Hubbert (1956)[63]. The value in 1969 is the average of two values made by Hubbert when working for the USGS. Cumulative production from Salvador (2005)[64] through 1989 and EIA from 1990 on. (Figure after McCabe (1998))



WALLACE E. PRATT

1885-1981

"**Toward a philosophy of oil-finding**" (*AAPG Bulletin*, v. 36, no. 12, p. 2231-2236) :

Where oil is first found, in the final analysis, **is in the minds of men.**

The undiscovered oil field exists only as an idea in the mind of some oil-finder.

When no man any longer believes more oil is left to be found,
no more oil fields will be discovered,

but so long as a single oil-finder remains with a mental vision of a new oil field to cherish,
along with freedom and incentive to explore,
just so long new oil fields may continue to be discovered.

Robert L. Bradley, Jr.

Founder, Institute for Energy Research (IER)

Visiting Fellow, Institute of Economic Affairs in London

Adjunct Scholar, Cato Institute and Competitive Enterprise Institute

Honorary Senior Fellow, University of Texas at Austin

Scientists are largely ignorant of economics. This ignorance constantly leads them astray because they tend to think that human beings are merely more clever herds of deer.

When deer run out of their sustenance, they die. When human beings begin to run out, they turn their brains and their social institutions to producing more.

Science can tell us what may be problems, but solutions depend on human values, politics, and economics. Scientists are no more qualified to pronounce on those topics than their non-scientific fellow citizens.

http://reason.com/archives/2004/02/04/science-and-public-policy/1

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1. Presentations are open to misinterpretation without (or likely even with) the presenter's interaction with his audience.
2. Data, ideas, and conclusions that are extracted may be in error outside the original context or intent.
3. The presenter or provider of this material is not liable for inappropriate or erroneous use of the material or its consequences.
4. None of the material should be assumed to be be original.

Special Note

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Auxiliary slides

PERCEPTION VERSUS REALITY IN MINERAL RESOURCE ASSESSMENT AND GEOSCIENCE EDUCATION

REMPE, Norbert T., 1403 N Country Club Cir, Carlsbad, NM 88220-4115, rempent@yahoo.com

Prognoses of the future availability of resources have sounded alarms over impending shortages since before the 19th century. Increasingly sophisticated updates still underestimate the inventory of most mineral commodities as approximately sufficient for only the next generation. One among several reasons for even local and regional forecasts being serially flawed is that enterprises lack economic incentives to identify reserves for production in the more distant future. National and global estimates are for the most part constrained by the availability of original industry data and therefore also err consistently on the low side.

Despite their dismal record, pessimistic predictions of unprecedented scarcity just a few years or decades hence continue to enjoy respectability not only in the general media, but also in academic journals, science textbooks, and classroom instruction. Incontrovertible historical and recent evidence that is incompatible with this negative paradigm and instead justifies optimism is ignored or at least belittled.

Economic and applied geology are well suited to address this paradox. Earth science education can and must employ and advance true scientific skepticism to reduce and eventually eliminate the discrepancy between perception and reality in mineral resource assessments. Concerning the future availability of any geologic commodity we must heed Wallace E. Pratt’s dictum: where oil is first found, in the final analysis, is in the minds of men.

Very mixed bag of assertions generally assumed to be correct

Mineral resources are limited. Many are nonrenewable on human time scales and, at the present rates of usage, many will run critically low in the near future.

All forms of energy production, and other resource extraction, have associated economic, human, environmental and geo-political costs and risks, as well as benefits. New technology and regulation can change the balance of these factors.

Human activities have significantly altered the biosphere, destroying many natural habitats and causing a huge decline in biodiversity.

http://www7.nationalacademies.org/bose/Standards_Framework_Preliminary_Public_Draft.pdf

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—Bob Olson, editor of OfSpirit.com Magazine

Divining the Future

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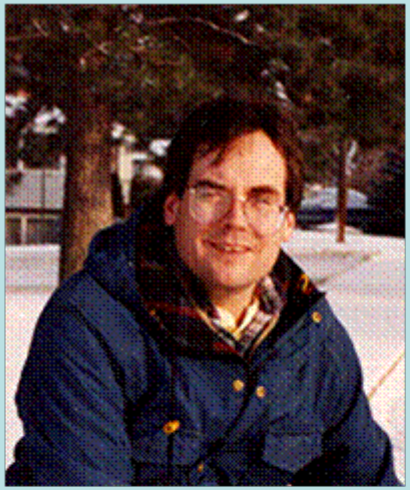
- **Intuitive exercises** to ground, center, and raise your psychic senses
- **Divination insights** from the Universe's Big Bang to our Age of Aquarius—and beyond!

Laura Scott
and **Mary Kay Linge**

In 1942, it was estimated that 54 million barrels of heavy oil remained after primary extraction methods had been exhausted in the Kern River oil field in California.

By 1986, more than 13 times that amount, 736 million barrels, had been produced. With stem-based enhanced oil recovery technology, the expected yield from this one field is another 2.5 billion barrels.

Gorelick, 2010, p. 166



Jeffrey A. Krautkraemer (1954-2004)

Economics Professor, Washington State University

Fellow, Resources for the Future

Since costly investment is required to "prove" reserves, there is a limited incentive to prove reserves beyond a certain point

The reserve to consumption ratio for petroleum increased from 35 in 1972 to 45 in 1990, even though commercial energy consumption increased by more than 50% between 1971 and 1991

Physical measures of reserves are rather indicators of inventory on hand than of resource cost

2003 (http://ageconsearch.umn.edu/bitstream/10842/1/dp030001.pdf)

Empirical evidence does not indicate a significant increase in the scarcity of natural resource commodities.

Fossil fuel reserves are as abundant relative to the rate of consumption as they have been over the last century, and the technologies for discovering and recovering these resources have developed substantially over the past decades.

The same can be said of most mineral resources.

One can be optimistic or pessimistic about future possibilities, but there doesn't appear to be a significant shortage on the near horizon.

Krautkraemer 2005: Economics of Natural Resource Scarcity: The State of the Debate, Resources for the Future, Discussion Paper 05-14 (http://www.rff.org/Documents/RFF-DP-05-14.pdf)

John E. Tilton
Colorado School Mines

Depletion is no longer inevitable.

New technology… has kept the adverse effects of depletion at bay despite an unprecedented surge in both population and the consumption of mineral commodities. Real production costs and prices… have actually fallen, implying their availability has increased.

Shortages have occurred… for a number of reasons …but depletion is not among them.

Reserves are often not more than 20-30 years worth of usage, for lack of economic incentive to certify more.

"On Borrowed Time? – Assessing the Threat of Mineral Depletion", Resources for the Future, Washington, DC, 2003

Wallace E. Pratt, "Our Petroleum Resources",
Mining and Metallurgical Society of America, New York City,
*November 17, **1943**:*

The following quotation is typical of recent press comments on the subject of our petroleum reserves in the United States:

> This nation's proved reserves of petroleum now bulk some twenty billion barrels, a quantity equal to our present peace-time requirements for a period of about 15 years. Over the last three years our discoveries of new reserves have consistently failed to balance our annual consumption.

These over-simplified figures, though entirely accurate, lend themselves readily to misinterpretation. Many people conclude from them that fifteen years hence we will have no gasoline for our automobiles…The statement quoted leads to the assumption that our 20 billion barrels of proved reserves in the United States constitute our total remaining resources in petroleum.

Proven Reserves of Various Resources, 1950-90
(Million Metric Tons)

Resource	1950	1990	Change (%)
Bauxite	1,400	21,500	1,436
Chromium	70	420	500
Copper	100	350	250
Iron Ore	19,000	145,000	663
Lead	40	70	75
Manganese	500	980	96
Nickel	17	59	247
Oil[a]	104	1,002	863
Tin	6.0	4.2	-30
Zinc	70	145	107

SOURCE: Kahn, Brown, and Martel, p. 92; U.S. Bureau of Mines, *Mineral Commodities Summary*, January 1990; *Resources for Freedom*, Report of the President's Materials Policy Commission, 1952, vol. 2, p. 27; and *Energy Statistics Resource Book* (New York: PennWell, 1991), pp. 143, 151.

NOTE: Information on proven reserves of coal, magnesium, natural gas, and titanium in 1950 is unavailable.

[a]Billion barrels.

http://www.cato.org/pubs/chapters/marlib21.html#table1

Table 21.2
Resource Prices Indexed to Wages, 1950-90
(Relative to 1990 Baseline)

Resource	1950	1960	1970	1800	1990	Change (%) 1950-90
Food[a]	386	210	145	161	100	-74
Lumber	170	114	95	126	100	-41
Paper	139	121	97	104	100	-28
Minerals[b]	194	147	179	217	100	-48
Energy[c]	184	126	74	138	100	-46

SOURCE: Moore, pp. 18-19, 23, 30-31, 40.

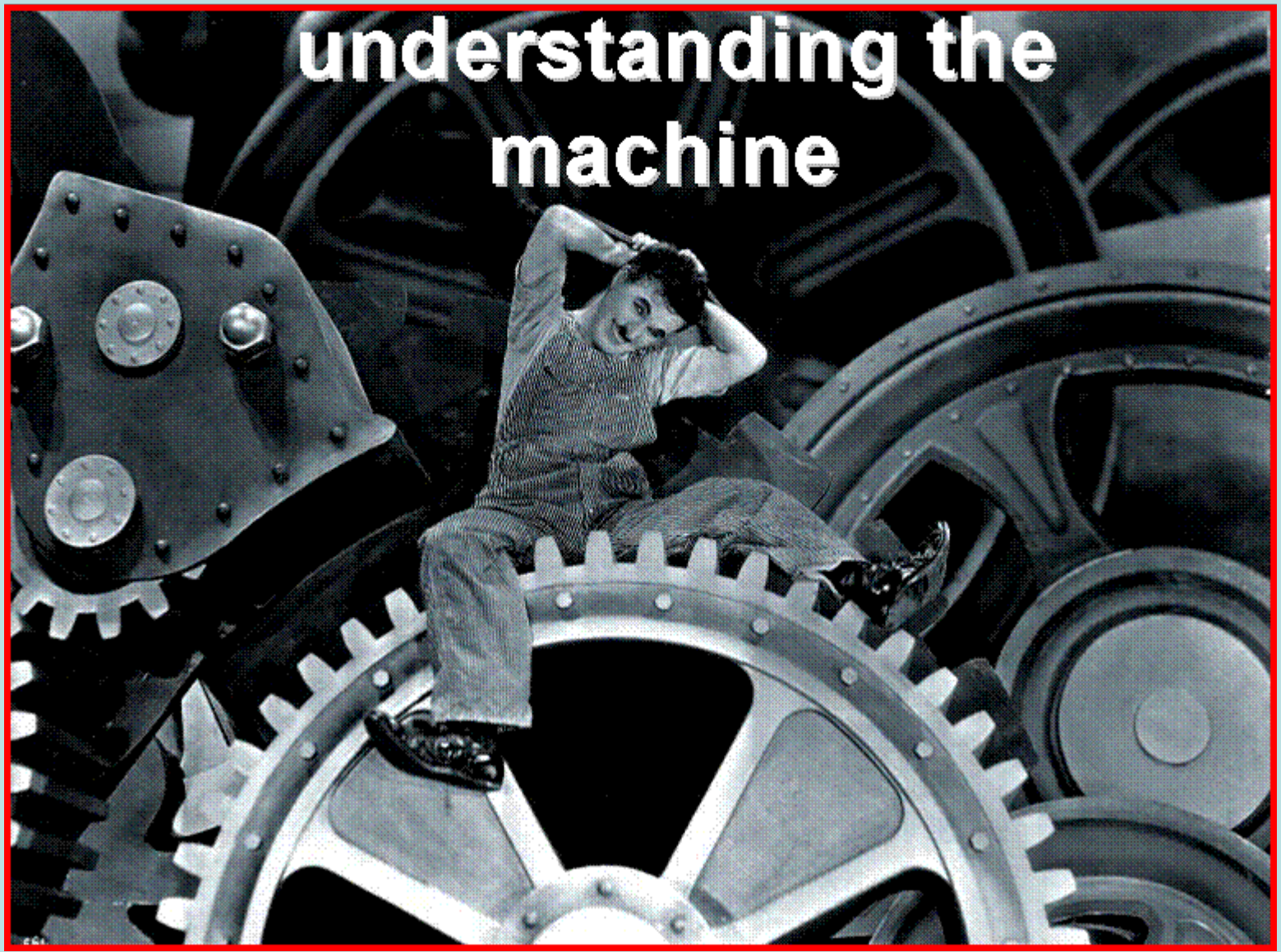
[a]Includes barley, broilers, carrots, cattle, corn, cotton, eggs, milk, oats, oranges, rice, sorghum, soybeans, wheat and wool.

[b]Includes aluminum, antimony, copper, lead, magnesium, manganese, mercury, nickel, platinum, silver, tin, tungsten and zinc.

[c]Includes coal, electricity, natural gas and oil.

http://www.cato.org/pubs/chapters/marlib21.html#table1

Measuring the gears is not the same as



"Industrial development would have been greatly retarded if sixty or eighty years ago the warning of the conservationists about the threatened exhaustion of the supply of coal had been heeded; and the internal combustion engine would never have revolutionized transport if its use had been limited to the known supplies of oil ... though it is important that on all these matters the opinion of the experts about the physical facts should be heard, the result in most instances would have been very detrimental if they had had the power to enforce their views on policy."

Friedrich A. von Hayek (1974 Nobel Prize in Economics Lecture on "The Pretence of Knowledge"), *The Constitution of Liberty* (Chicago: University of Chicago Press, 1960), pp. 369-70

Why predictions routinely fail

- ‘Known resources' keep growing
- Existing resources are exploited more fully
- Resources are being used more efficiently
- Technology makes “unconventional” resources economical

Stanford University ecologist Paul Ehrlich predicted in his 1968 book, "The Population Bomb," that one-fifth of humanity would starve to death by 1985.

In 1980, Ehrlich and two colleagues from the University of California at Berkeley were piqued by an article Julian Simon wrote for Science magazine titled "Resources, Population, Environment: An Oversupply of False Bad News." They responded to a challenge by Simon to Malthusians that the price of any natural resource would be lower by a mutually agreed-upon date, not higher.

Ehrlich and his colleagues took the bet on the belief that rising demand for raw materials by an exploding global populace would pare supplies of nonrenewable resources, driving up prices. Ehrlich said he had accepted Mr. Simon's "astonishing offer before other greedy people jump in."

The Ehrlich group bet $1,000 on five metals — chrome, copper, nickel, tin and tungsten — in quantities that each cost $200 in October 1980, when the bet was made. Simon agreed that he would sell the agreed-upon quantities of the metals to the Ehrlich group 10 years later at 1980 prices. If the combined prices of acquiring the metals in 1990 turned out to be higher than $1,000, Simon would pay the difference in cash. If prices fell, the Ehrlich group would pay him.

During the decade, the world's population grew by more than 800 million, the greatest increase in history, and the store of metals did not get any larger. Yet in the fall of 1990, with the prices of the metals down sharply, Ehrlich mailed Simon a check for $576.07. Simon wrote back a thank you note, along with a challenge to raise the wager to as much as $20,000, tied to any other resources and to any other year in the future. Ehrlich declined to take him up on the new offer.

'… the stone age came to an end not for a lack of stones, and the oil age will end, but not for the lack of oil.‘

Sheik Yamani, former oil minister of Saudi Arabia and a founding father of OPEC

- The world has never run out of any significant globally traded non-renewable Earth resource
- Changes in demand caused peak production and decline for various renewable and non-renewable resources
- U.S. government estimates of the global oil endowment have grown over time such that global oil consistently could be produced for the next ~45 years
- Global oil reserves increased 30 percent since 2000
- The Middle East, Eastern Europe, and Africa contain 3/4 of world oil reserves, yet account for only 1/7 of exploratory drilling. Exploration remains overly focused on North America.
- The success rate of U.S. wells drilled for oil and gas increased from 20% in 1950 to >50% in 2007

Gorelick 2010

A remarkable feature of nearly all primary metals is the extent to which their prices—

while fluctuating strongly from year to year—

have shown a clear declining trend over time, even as production has risen strongly.

P. C. Pistorius, *The Journal of The South African Institute of Mining and Metallurgy*, December 2003
(http://www.saimm.co.za/Journal/v103n10p601.pdf)

In 1921 a joint committee composed of representatives from the United States Geological Survey and the American Association of Petroleum Geologists claimed that the United States petroleum reserves would last for only eighteen to twenty years. Four years later the oil industry trade association, the American Petroleum Institute, announced that America possessed a nearly infinite supply of oil.

From the abstract of "Drilling for Dollars: The Making of US Petroleum reserve Estimates, 1921-1925" by Michael A. Dennis, Social Studies of Science (SAGE, London, Beverly Hills and New Delhi), Vol. 15 (1985), 241-65

- Cornucopians are justified in questioning the apocalyptic visions of global man-made collapse

- Neo-Malthusians rightly point to local scarcity conflicts over land, water, etc.
  - but low-level conflicts are tied to the quality of government and the level of development

- 'Resource cursers' argue correctly that some conflicts are fueled by natural resource wealth
  - but their generalizations are as mistaken as those of the neo-Malthusians (cf. Norway, Australia)

- Liberal capitalist (cornucopian)policies provide the best answer to threats against human security and the environment
  - they promote development by peaceful means

Modified from: http://hei.unige.ch/sections/sp/courses/0607/gleditsch/Environmental-Security-Slides1.ppt#325,31,Some tentative conclusions

Assessment of WIPP performance during the regulatory time frame of 10 000 years must consider inadvertent human intrusion (IHI) resulting from future drilling and mining; therefore:

Please forecast your three best estimates of each:

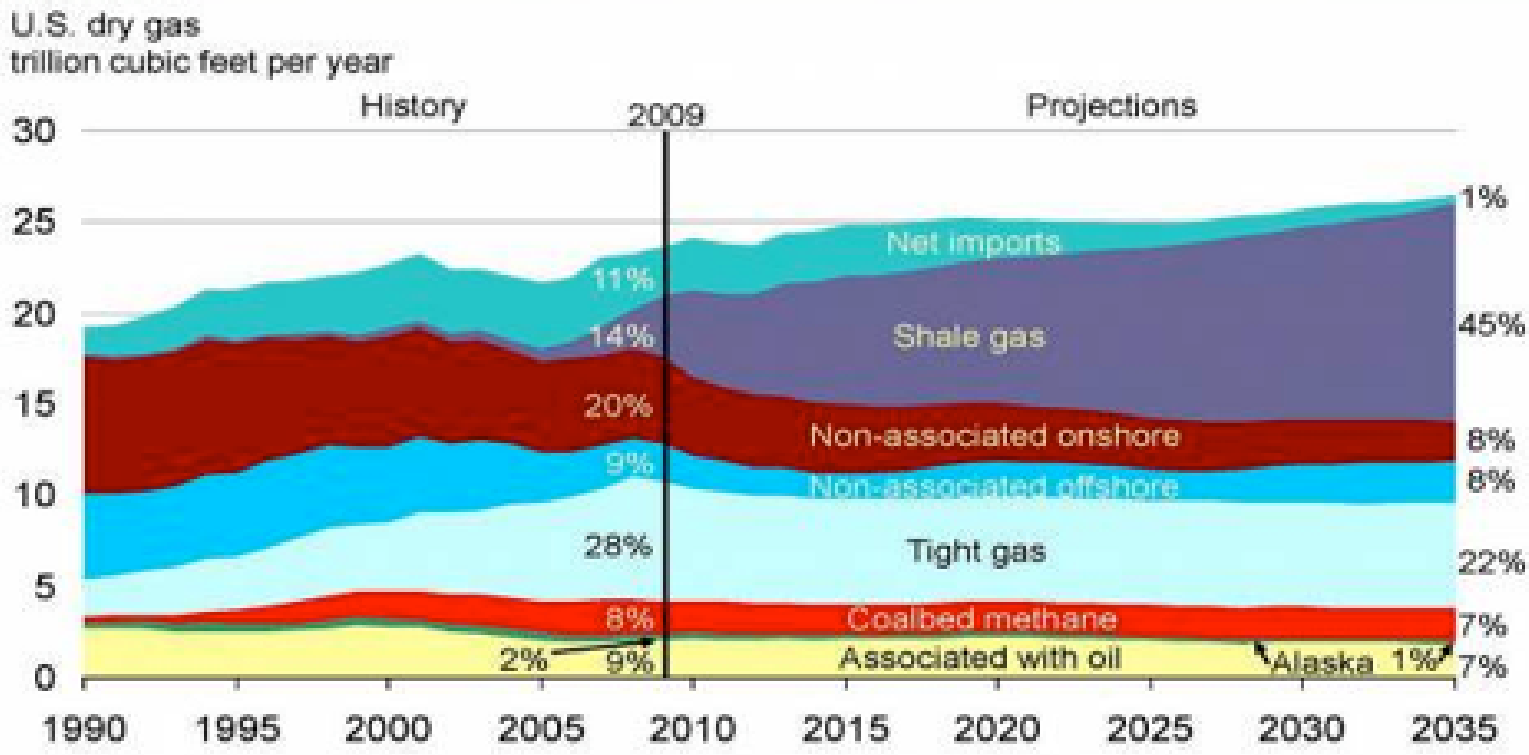
- **exploration methods, and**
- **mineral resources (fuel and non-fuel),**
- **extraction methods**

in the

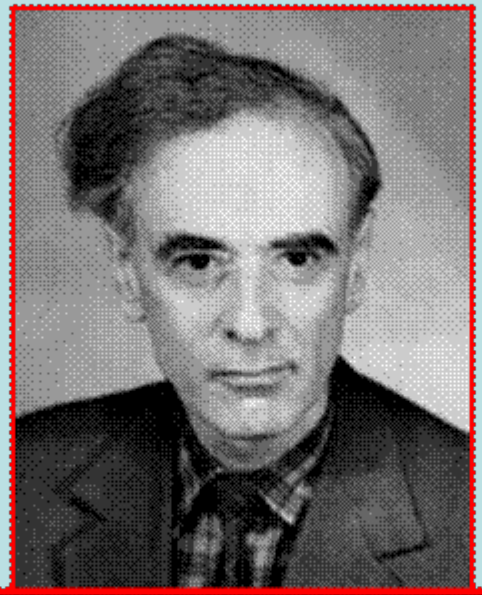
22nd century **26th century**
31st century **11th millennium**

ng(o)$_3$

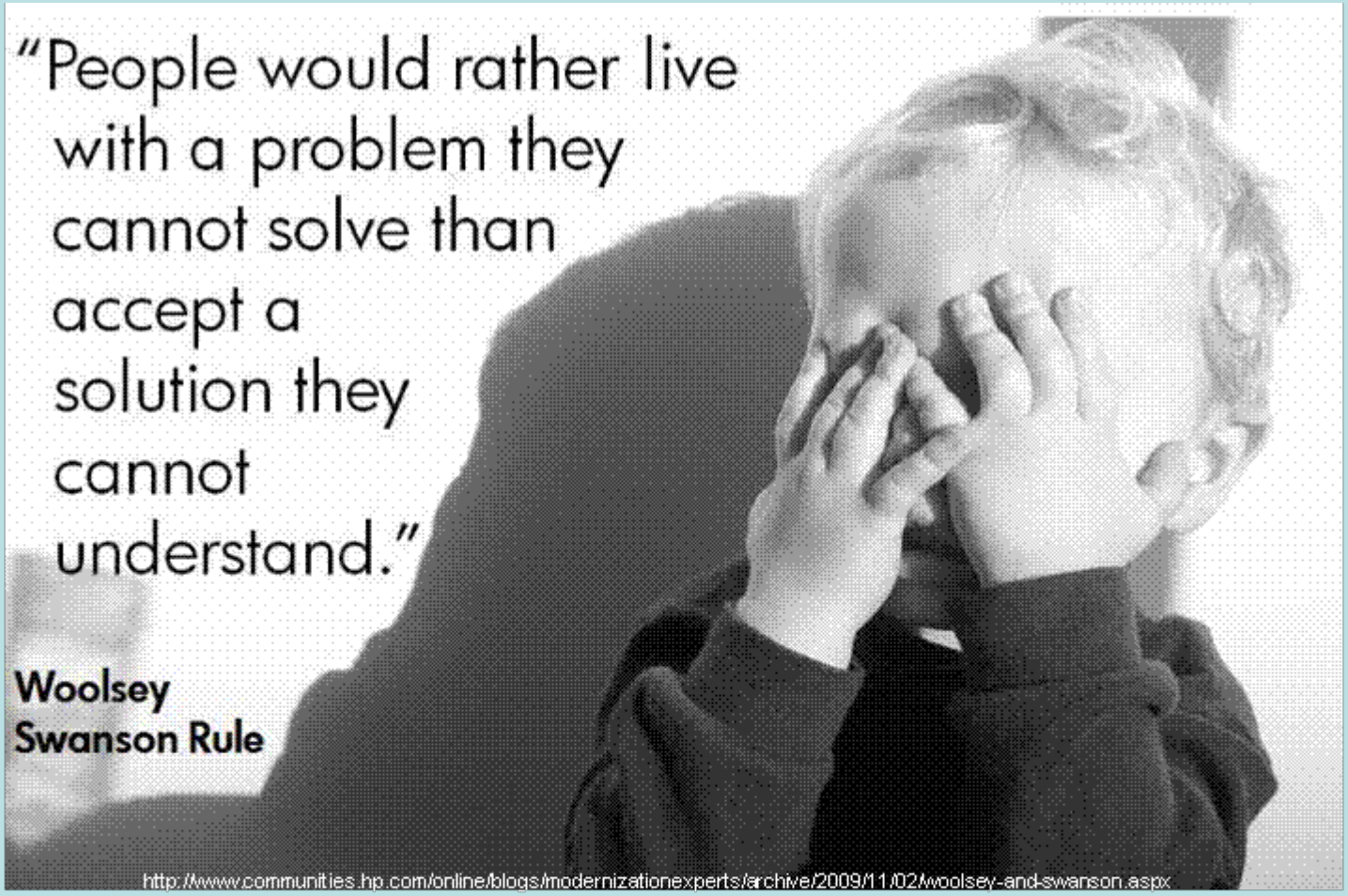
Shale gas offsets declines in other U.S. supply to meet consumption growth and lower import needs



Landau on Cosmologists



Often in Error, Never in Doubt!



"The great enemy of the truth is very often not the lie -- deliberate, contrived and dishonest, but the myth, persistent, persuasive, and unrealistic. Belief in myths allows the comfort of opinion without the discomfort of thought." - John F. Kennedy

"Example is always more efficacious than precept." - Samuel Johnson

Expert advice

There is the prevaricator,
there is the teller of tales,
and there is the geological consultant

J. W. Gregory

from: A Geological Miscellany, Orbital Press, 1982