We are NOT running out of Uranium (or any other mineral resources)

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Special Note
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Wrede 2020
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.


1 – generalities proven useless and wrong in forecasts
2 – trivialities associated with any human endeavor
3 – claims without numerical and statistical substantiation

Unbalanced Statements Contrary to Historical Evidence and Trends
“...the maintenance of such a position is impossible. We have to make the momentous choice between brief greatness and longer continued mediocrity.”


[http://books.google.com/books/about/The_coal_question.html?id=gAAKAAAAIAAJ](http://books.google.com/books/about/The_coal_question.html?id=gAAKAAAAIAAJ)
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)
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)
Landau on Cosmologists

Often in Error, Never in Doubt!
Partial Truth:
If It Can't be GROWN, It Must Be MINED

Full Truth:
everything must be mined by someone or something
Each of us is an extractive industrialist
2 sacred cows

Resources become more scarce and expensive

Geologists know more about resources than economists

It's high time to tip sacred cows
The only scarce resource is human ingenuity

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.

Julian L. Simon, 1932-1998

The Ultimate Resource, 1981
Scarcity or Abundance, 1994
The State of Humanity, 1995
The Ultimate Resource II, 1996

Erich Walter Zimmermann, 1888-1961
Born in Mainz, Germany
Emigrated 1911

Resources are not
They become

(In 1984, the University of Texas established the Erich W. Zimmermann Regents Professorship)
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
OIL PANIC AND THE GLOBAL CRISIS

Predictions and Myths

Steven M Gorelick
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.
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 steam-based enhanced oil recovery technology, the expected yield from this one field is another 2.5 billion barrels.

Gorelick, 2010, p. 166
**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)). (Data: production from EIA and curve from Hubbert (1956).)

**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)).

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)). (Data: oil production, EIA; endowment value since 1996 added based on DOE (2006)).

**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)) with the exception of early estimates by Weeks (1948) and Hubbert (1956). The value in 1969 is the average of two values made by Hubbert when working for the USGS. Cumulative production from Salvador (2005) through 1989 and EIA from 1990 on. (Figure after McCabe (1998)).
Resource Assessments Change Over Time

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

Changes result from improved geologic understanding, technological developments, other factors
The fascinating impressiveness of rigorous mathematical analysis, with its atmosphere of precision and elegance, should not blind us to the defects of the premises that condition the whole process (T.C. Chamberlin, 1899)
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
"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.
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)
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.

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

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


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

\(^a\)Billion barrels.
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.

(http://www.saimm.co.za/Journal/v103n10p601.pdf)
### Table 21.2
Resource Prices Indexed to Wages, 1950-90
(Relative to 1990 Baseline)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Food&lt;sup&gt;a&lt;/sup&gt;</td>
<td>386</td>
<td>210</td>
<td>145</td>
<td>161</td>
<td>100</td>
<td>-74</td>
</tr>
<tr>
<td>Lumber</td>
<td>170</td>
<td>114</td>
<td>95</td>
<td>126</td>
<td>100</td>
<td>-41</td>
</tr>
<tr>
<td>Paper</td>
<td>139</td>
<td>121</td>
<td>97</td>
<td>104</td>
<td>100</td>
<td>-28</td>
</tr>
<tr>
<td>Minerals&lt;sup&gt;b&lt;/sup&gt;</td>
<td>194</td>
<td>147</td>
<td>179</td>
<td>217</td>
<td>100</td>
<td>-48</td>
</tr>
<tr>
<td>Energy&lt;sup&gt;c&lt;/sup&gt;</td>
<td>184</td>
<td>126</td>
<td>74</td>
<td>138</td>
<td>100</td>
<td>-46</td>
</tr>
</tbody>
</table>

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

<sup>a</sup>Includes barley, broilers, carrots, cattle, corn, cotton, eggs, milk, oats, oranges, rice, sorghum, soybeans, wheat and wool.

<sup>b</sup>Includes aluminum, antimony, copper, lead, magnesium, manganese, mercury, nickel, platinum, silver, tin, tungsten and zinc.

<sup>c</sup>Includes coal, electricity, natural gas and oil.

http://www.cato.org/pubs/chapters/marlib21.html#table1
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
Measuring the gears is not the same as understanding the machine
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.
'... 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

"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."

Northern Cheyenne Indian Reservation, coal exploration, AMAX 1.5 billion tons (1975 congressional hearing)

Gold deposits in Bohemia, 50 km south of Prague, on the Vltava river
https://scholarsmine.mst.edu/cgi/viewcontent.cgi?article=2952&context=icchge

Rare Earth deposits in Trans-Pecos Texas

Keep It In The Ground
https://www.globalenergyinstitute.org/sites/default/files/GEI_KIITG_report_WEB.pdf

https://www.mdpi.com/2075-163X/8/10/423
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
31st century
26th century
11th millennium
• 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
Earth First!
we’ll mine the other planets (asteroids, etc.) later
Auxiliary slides
“But he hasn’t got anything on!” the whole town cried out at last.”

Does “majority opinion” agree with the “honest kid” these days?

LNT, ALARA, Hormesis anyone?
Overpopulation, Peak Oil, Socialism anyone?
“People would rather live with a problem they cannot solve than accept a solution they cannot understand.”

Woolsey Swanson Rule


“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 prevaricating, there is the teller of tales, and there is the geological consultant

J. W. Gregory

from: A Geological Miscellany, Orbital Press, 1982
Phosphates: A Case Study Of A Valuable, Depleting Mineral In America

This report discusses the many problems and long leadtimes involved in phosphate development in the United States, world’s largest producer of phosphates. Phosphate rock is the only known practical source of phosphorus, crucial to fertilizer used in agriculture.

Over the next two decades the richest U.S. phosphate deposits are likely to be depleted. There is cause for concern as to how new sources may be developed to meet the Nation’s growing agricultural needs.

GAO recommends that the highest levels of Government begin promptly an assessment of access impediments to phosphate minerals and review of the Nation’s long-range phosphate position regarding future availability, including legislative changes as may be needed to ensure supply.

World Phosphate Reserves Estimates
(billion metric tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>104</td>
</tr>
<tr>
<td>1973</td>
<td>61</td>
</tr>
<tr>
<td>1974</td>
<td>5</td>
</tr>
<tr>
<td>1975</td>
<td>13</td>
</tr>
<tr>
<td>1976</td>
<td>16</td>
</tr>
<tr>
<td>1977</td>
<td>18</td>
</tr>
<tr>
<td>1978</td>
<td>26</td>
</tr>
<tr>
<td>1979</td>
<td>27</td>
</tr>
</tbody>
</table>

Source: Bureau of Mines

2017: 68
“Global average production cost has fallen”
Indicative peak phosphorus curve, illustrating that, in a similar way to oil, global phosphorus reserves are also likely to peak after which production will be significantly reduced (Jasinski, 2006; European Fertilizer Manufacturers Association, 2000).

Source: Cordell, Dragert and White, 2009
Summary

- Phosphate rock is a finite, non-renewable resource
  - Maximum recovery, utilization and recycling of phosphate rock, fertilizers, byproducts and wastes should be emphasized

- Reserves and resources
  - Reserves are a dynamic quantity
  - Resources can become reserves
  - There is no evidence for a “peak phosphorus” event
Goal

"Nothing in life is to be feared, it is only to be understood. **Now is the time to understand more, so that we may fear less.**"  
--Nobel Prize winner Marie Curie

"Most of us were taught that the goal of science is power over nature, as if science and power were one thing and nature quite another. **Niels Bohr observed to the contrary that the more modest but relentless goal of science is, in his words, 'the gradual removal of prejudice.'** By 'prejudice,' Bohr meant belief unsupported by evidence."

--Pulitzer Prize-winner Richard Rhodes, in his introduction to Power to Save the World: The Truth About Nuclear Energy by Gwyneth Cravens
Modified from Bjorn Lomborg’s “Apocalypse No!” (english language edition)
Prediction is difficult
Especially about the future
(Danish proverb)

From Amazon reviews:
Magical tour;
Tools for enlightenment;
Aura and Tarot reading;
Ancient Stardust Directional cards;
Cards, runes, faerie cards, etc.
THIS IS THE LATEST MODEL FOR GEOCHEMISTS - IT GUESSES TO FIFTEEN DECIMAL PLACES!

(Courtesy of Australian Geologist)

from: A Geological Miscellany, Orbital Press, 1982

now a respectable academic subject

First published 1986
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
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.

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

U.S. dry gas trillion cubic feet per year

History 2009 Projections

- Net imports
- Shale gas
- Non-associated onshore
- Non-associated offshore
- Tight gas
- Coalbed methane
- Associated with oil
- Alaska


Source: EIA, Annual Energy Outlook 2011

Richard Newell, December 16, 2010
Resources: Two Schools of Thought

ONE: The World is a Bundle of Hay
- Resources are Finite
- Resources are Static
- Resources are Purely Economic
  - Utility
  - Scarcity
  - Demand & Competition

TWO: “Resources are NOT, they BECOME”—Erich Zimmerman
- The scope of potential resources is virtually infinite
- Resources are dynamic
  - What didn’t interest us before may prove extremely interesting at some point, and what was interesting may lose its appeal

http://www.strom.clemson.edu/becker/prtm320/notes/defining-resources.pdf
The long-term decline in food prices

World Bank Food Price Index 1960-2015

World Bank, various sources (personal communication with Betty Dow, Commodities Information Analyst, Development Prospects Group, World Bank, 7 September 2006). The price is weighted by the Manufactures Unit Values Index and is given in constant 1990 USD, thus reflecting real prices. For the trend to reflect real food availability all markets have to be open (in order to make the price mechanisms work properly). If this caveat holds, there seems to be a marked decline in global food prices up to the mid 1980s when it stabilizes. The peak in 1974 is due to increased production costs (and perhaps increased hoarding) due to the 1973 oil crisis. [1]

http://hei.unige.ch/sections/sp/courses/0607/gleditsch/Environmental-Security-Slides1.ppt#348,19,The long-term decline in food prices
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.
Figure 7—A comparison of the magnitude of some mean estimates of undiscovered recoverable crude oil resources of the United States that have been published over the last 50 yr. Estimates are arranged in chronological order from left to right. Other estimates that generally fall within the ranges of these estimates have been made, but they are less well documented in the public literature.
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.
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.

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:

<table>
<thead>
<tr>
<th>Year</th>
<th>Reserves (billion barrels)</th>
<th>Reserves/Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>86</td>
<td>22</td>
</tr>
<tr>
<td>1955</td>
<td>190</td>
<td>33</td>
</tr>
<tr>
<td>1960</td>
<td>298</td>
<td>37</td>
</tr>
<tr>
<td>1965</td>
<td>348</td>
<td>30</td>
</tr>
<tr>
<td>1972</td>
<td>667</td>
<td>35</td>
</tr>
<tr>
<td>1990</td>
<td>887</td>
<td>47</td>
</tr>
<tr>
<td>2000</td>
<td>~1000</td>
<td>~50</td>
</tr>
</tbody>
</table>