Energy Policy

### Arithmetic, Population and Energy, Summary

Revision B, 2021

**For the love of the human race.**

### The Source of the Question

This study report is prompted by the labors of the late Dr. Albert Allen Bartlett (1923-2013), who labored as a Professor of Physics at the University of Colorado, Boulder. Even though he was fully qualified as a subject matter expert in physics, it is evident that his favorite topic was what might be termed the arithmetic of energy and population, an intense application of the exponential curve. So we are indebted to Dr. Bartlett, and write this in his honor, with a view to continuing his mission.

In his lectures Dr. Bartlett challenges his listeners to check his math. This is exactly what we did. The data with which he works is a moving target, so we will update the data, add some new data, and make suggestions, so that concerned listeners can update and check these principles regularly.

http://www.albartlett.org/

http://www.albartlett.org/presentations/arithmetic\_population\_energy.html

http://en.wikipedia.org/wiki/Albert\_Allen\_Bartlett

http://www.youtube.com/watch?v=umFnrvcS6AQ

### Our Thesis

We believe that Dr. Bartlett’s work is unfinished: it must be continued; newer, creative solutions, which may not have been apparent a few years ago, when Dr. Bartlett did his primary investigations, need to be uncovered. The single human mind is always limited in its abilities: this work needs the contribution of every mind. New solutions must be found.

We agree with Dr. Bartlett that any solution requires the education and participation of every single one of the earth’s seven billion plus residents. The problem is of such complexity and magnitude that no one person can possibly see lasting solutions. Moreover, the problem impinges on human freedom, so it is unreasonable to expect that lasting solutions can be achieved by human coercion of humans.

We have investigated Dr. Bartlett’s mathematics with rigor and found that his use of mathematics is both correct and precise. It is the task of the mathematician and the scientist to observe reality and explain exactly how and why it works. This field is known as mapping; Dr. Bartlett’s mapping speaks with deadly accuracy: he has been faithful in this task.

We also investigated Dr. Bartlett’s data, and observed that his data need updating. We attempted a partial update of the data, but this is an ongoing task that requires incessant continued surveillance. Maintaining a good, up-to-date data set is the most difficult part of the mathematical problem.

However, new and shifting data may require new mappings. When situations are altered, new maps must be used. There is nothing wrong with the old maps, they may simply be inapplicable to the new situation. Failing to understand this is like trying to find a place in Denver from a map of Cleveland.

Nevertheless, opponents of truth persist in discrediting and marginalizing legitimate practices of mathematics and science, by conveniently ignoring the need for appropriate mapping. This abuse is then made into the political or popular lever for claiming that the mathematics and science are incorrect, the mathematicians and scientists are to blame: they put forth a false theory, cried wolf, and lied to the populace. However, it is not usually the mathematician or scientist who lied, but rather the individuals who found it powerful or profitable to spin the truth to their individual advantage.

That being said, Dr. Bartlett did not determine that constant controlled growth should be the model under which we now live; society determined this model through business, government, and individuals. Dr. Bartlett simply studied and reported it. It is not the task of the mathematician or the scientist to determine these objectives. On the other hand, since objectives are set by business, government, and individuals; objectives can be changed by business, government, and individuals. Changes will always introduce the need for new data, mapping, and solutions.

These obstacles can defeat us: 1. Unwillingness to change in the face of the facts. 2. Inadvertently or deliberately ignoring the facts. 3. Failure to collect accurate, up-to-date data. 4. Inability to find sufficient meaningful solutions.

This is not a game of blind chance. This is not a game of fear mongering. This is a zero-sum game of war: if rationality does not prevail in this war; we, our children, grandchildren, and great- grandchildren will lose. Deciding not to play is a decision to lose. If rationality does not prevail, the forces we call nature will make the necessary decisions for us: we will lose and be stranded without the necessary survival map and plan. Nobody will like the solution.

### Arithmetic, Population and Energy, Summary[[1]](#footnote-1)

Dr. Bartlett’s talks end with part 8. The primary function of Part 9 is to review parts 1 through 8 and make some data additions as a means of continuing Dr. Bartlett’s life work. These data additions are a continuing source of trouble.

Data are always out of date. Therefore, we must form teams of committed advocates, who will work diligently to keep them up to date, as current as is humanly possible. This lag in knowledge, and the fact that knowledge is always growing, due to new discoveries, leads the uninitiated to believe that the former studies were wrong, not worth the time or effort; therefore, new studies are also a waste of time and effort.

We must persist and prevail at educating the public about the true nature of data as a moving target. We must show that new science is built on the foundation laid by old science; and we throw out the old science at our own peril. We must inculcate commitment to the idea, that new efforts are made better from what was learned in the old efforts. Even mistakes made in the old efforts are fertile ground for fresh ideas. The public must know that today’s predictions are not good enough for tomorrow. Every day requires a fresh, new map. Yesterday’s predictions are no more valuable than last week’s lettuce. The real science stands, and is adjusted; but, it is adjusted by rethinking it fresh every day.

The nature of this changing data environment makes the scientific community constantly vulnerable to adversaries who attack science to serve their own agendas. Such agendas are almost always motivated by the quest for power, for wealth, or out of bitter animosity. Our cause is not helped by the frauds and false science arising from within the scientific community itself. The specific vulnerability caused by ever changing data and predictions, is the accusation of “crying wolf” when there appears to be no wolf. Science must report its unbiased findings to the best of its ability at the time. The wolf, however, is a cleverly disguised moving target: he has the annoying capability of making us seem incompetent. We must firmly refute our adversaries, especially by our unrelenting quest for truth. Equally, we must screen out and eliminate frauds arising from within the scientific community itself.

Science is not the pristine objective environment it appears and even claims to be. Most science is funded by the powerful and wealthy, who are often science’s worst adversaries. When someone is holding your next meal, or your wife and children hostage, by controlling and limiting food, clothing, and shelter: it is difficult to deny their requests. Consequently, the underlying science may be perfectly correct and legitimate. On the other hand, the spokesperson chosen to report the science may have cleverly spun the report to mean something entirely different, something false. Meanwhile, the working scientists are “educated” so that they do not publicly disclose the fraud. Scientists who refuse “education” are quickly eliminated or marginalized so that they have no credibility left, with which to expose the fraud. The scientific community is not a place for the exercise of free speech.

This adds up to the necessity for commitment to incessant vigilance among us.

### Part 1

Part 1 of Dr. Bartlett’s talk emphasizes the fact that steady growth is in fact an aggressive, uncontrollable, vicious monstrosity that eventually destroys the culture in which it is allowed to exist. The exponential curve inevitably blows a hole in the ceiling/roof and keeps on going. Dr. Bartlett introduces the concept of doubling time, and produces, a very useful rule-of-thumb, the rule of seventy: for its handy and accurate approximation, ***DT = 70 / % rate of growth***, is reasonably accurate to ***10%***, and can be calculated in the head. We verified this rule by deriving it from the basic exponential equation. Dr. Bartlett introduces the energy crisis of the 1970’s from the viewpoint of doubling.

### Part 2

Part 2 of Dr. Bartlett’s talk applies the conclusions of the exponential curve and doubling to problems of inflation and population. We expanded on these ideas, and introduced one objection coming from the Christian community. We also added a few observations about population from our own study of the subject. Then we included the problem of consumption, which Dr. Bartlett hinted at in the energy crisis. Finally, we compared the three problems in an attempt to evaluate their relative merits. We voiced the hope for the development of a mathematics of sustainability.

### Part 3

Part 3 of Dr. Bartlett’s talk examines the exponential curve from the perspective of time, rather than size. This emphasizes the fact that time is running out in which we may make a rational decision about whatever problems may be increasing exponentially. Not only is time running out, but the problem is not even identifiable or recognizable until the last half of the fourth quarter, when the ballgame is almost over, and most of the fans have gone home in defeat. Dr. Bartlett observes that this kind of thinking, “… is the centerpiece of the national and global economies.” Now Dr. Bartlett moves from a population model (cell division) to a crude oil model. We reconstructed Dr. Bartlett’s hard-to-read slide in a spreadsheet, and provided detailed directions for recreating it. Then we introduced new data from a 2012 report, which was contrasted with Dr. Bartlett’s data. This revealed the 1980, break in the curve from around 7% to nearly 0% due to the 1970’s energy crisis. Using other new data and regression analysis we were able to calculate the new growth rate at 1.030%. We also were able to establish that the 1980 break saved a lot of oil and most likely averted a national disaster. Finally, we emphasized that much, much more needs to be done.

### Part 4

Part 4 of Dr. Bartlett’s talk resumes with a brief review of the remaining time for the disastrous culmination of the oil crisis; then he turns the discussion to coal. This produces the need to calculate the remaining time on the exponential curve from knowledge of existing or anticipated reserves. As suggested, we developed Dr. Bartlett’s equation using calculus, finding again the exact equation, and its rule-of-thumb approximation, ***TE = 1/r \* ln(r \* R / y0 + 1)***. We evaluated Dr. Bartlett’s coal data and compared it to a 2008 report we found on the internet. We discovered in agreement with Dr. Bartlett that our coal reserve is in alarming jeopardy, in some instances as brief as 30 to 50 years or less. The problem with predicting coal consumption is that it is a less desirable fuel than either natural gas or oil and will not likely be hard pressed for maximum production until natural gas and oil are gone.

A variety of authorities in the 1980’s said, “There is no reason to be concerned.”

**“Don’t believe any prediction of the life expectancy of a non-renewable resource until you have confirmed the prediction by repeating the calculation.”**[[2]](#footnote-2)

**“The more optimistic the prediction the greater is the probability that it is based on faulty arithmetic or on no arithmetic at all.”**2

### Part 5

Part 5 of Dr. Bartlett’s talk investigates the theory of “strength through exhaustion,” which we compare to a high-speed automobile collision. Then Dr. Bartlett introduces Dr. Hubbert’s theory of Peak Growth, or Peak Theory, possibly better known as Peak Oil. We explored this theory at some length and do not see how it could possibly be wrong. The very logical physical application of the exponential curve requires that it cannot continue indefinitely: indefinite continuation requires an infinite power source, which does not humanly exist. The only discussion can be over the size and timing of the peak and the nature of the descending curve: these three things are somewhat subject to human manipulation, but they cannot be prevented. There is no good reason to doubt that with considerations for kurtosis and skewness, the bell curve will prove to be the best fit. Human manipulation can also produce bimodal distributions. We also discuss some of the factors that necessitate some slope on the downward curve. Leaders may attempt to live in defiance of Peak Growth, but they will ultimately fail, simply because they do not possess infinite power.

“Instead of a crash, this is more like that sickening feeling you get when you run out of gas in the middle of nowhere. You are hopelessly out of control as your engine sputters, and you coast to a stop.

“Our leaders are not taking the sensible steps to put on the brakes and manage this crisis. We should be operating on reduced growth conservation plans, negative percentages. Our federal budget should be considering a -5% budget, instead of a +5% budget. Our president should be pushing for cuts.”[[3]](#footnote-3)

### Part 6

Part 6 of Dr. Bartlett’s talk reinforces the idea that every new energy discovery must be carefully examined against its related consumption: even enormous finds prove to be minuscule in the face of our increased consumption. Ethanol fuels appear to be counterproductive for a variety of reasons. America’s consumption of oil is out of touch with the rest of the world. Within the greater scheme of things, the era of fossil fuels is but a pimple within the eons of human history. Someday we will be out of fossil fuels. It is in our best interests to attempt to evaluate and manage this ultimate reality.

“We cannot let other people do our thinking for us.”

Unfortunately, “We worship growth.”

Dr. Bartlett outlines some his essential points for successful national and worldwide programs.

1. “we ought to have a big increase in the funding for research in the development and dispersion of renewable energy.”
2. “We must educate all of our people to an understanding of the arithmetic and consequences of growth, especially in terms of the earth’s finite resources.”
3. “We must educate people to recognize the fact that growth of populations and growth of rates of consumption of resources cannot be sustained.”

Finally, Dr. Bartlett introduces his First Law of Sustainability. We responded by proposing The Law of Carrying Capacity:

***0 ≤ CC ≡ P \* Cpc ≤ 1***

### Part 7

Part 7 of Dr. Bartlett’s talk exposes the fallacy of technical optimism.

**“We must educate people to see the need to examine carefully the allegations of the technological optimists who assure us that science and technology will always solve all of our problems of population growth, food, energy and resources.”**2

Chief among these optimists was Dr. Julian Simon (1932-1998) who held powerful influence in the “beltway.” We took pains to refute his ideas about biomass.

We also examined Dr. Asimov’s bathroom parable, but replaced it with an empty plate parable of our own. We rejected Dr. Bartlett’s analysis of decreasing government. We also rejected the idea that Global Warming is a significant problem; because, Global Warming will most likely stop with the depletion of fossil fuels. Dr. Bartlett maintains that he is merely reporting facts; he denies that he is predicting the future. In spite of the denial, predicting the future is exactly what this arithmetic is about. The question is not whether the future will be predicted; but rather, how can it be predicted more accurately, in an up-to-date, and timely manner. Dr. Bartlett’s arithmetic will remain the arithmetic of choice for exponential growth predictions. Dr. Hubbert’s modified bell curves will most likely remain the map of choice for Peak Growth predictions.

### Part 8

Part 8 of Dr. Bartlett’s talk concludes the series with several terse quotes and some observations about the Aswan Dam, as an illustration of man’s fixing things, only to make matters worse. However, his main point is this:

“So here’s a challenge. Can you think of any problem, on any scale, from microscopic to global, whose long term solution is in any demonstratable way, aided, assisted, or advanced by having larger populations in our local levels, state levels, national level, or global level? Can you think of anything that can get better if we crowd more people into our cities, our towns, into our state, our nation, or on this earth?”2

Our answer is, “Yes, we can think of at least one problem that might be resolved by an increase of population.” 3 The depletion of fossil fuels will result, temporarily in steam power, but ultimately in horse, man, and other animal power to replace the work done by internal combustion engines: it takes hundreds of horses, and possibly thousands of men to do the work of one internal combustion engine. This introduces the possibility that survival without fossil fuels may require more, not less men: but these will necessarily be more widely distributed, and not crowded together. In essence, we have been left with a modernized version of the Malthusian Catastrophe.[[4]](#footnote-4) The thinking of Kenneth Arrow,[[5]](#footnote-5) Paul Ehrlich,[[6]](#footnote-6) and the like needs to be brought into consideration. The questions raised, need to be answered now, not ten years from now.

### Part 9, Additions

### Oil Updates

The following chart adds a column for USGS publicly reported undiscovered oil statistics. This addition completes the total volume of oil in the opinion of top experts. Since all countries are not included in this evaluation, the world total will be at least this big. The total calculated directly in the USGS spreadsheet is only 1,666 G-bbl. Every country contributing 5 G-bbl or more was included. Anyone wishing to complete a more thorough study should consult: http://pubs.usgs.gov/dds/dds-069/dds-069-ff/downloads/Excel%20tables/ or other sources. Open the Country Summary.xlsx file.

The mathematics used in these tables is absolutely correct. The only disputable factor is the data, which requires incessant scrutiny.

There is no excuse for the United States not to have a firm Federal Energy Policy, which provides for reporting this information to the public every year, while updating and reporting this information with special reports immediately after any significant verified discovery.

The public should not be forced to drill down in endless complicated and highly technical data sources to find out the truth. This should make front page headlines.

None of the following data have been updated since this original, now hopelessly outdated, report. Please, do them all over.

| Rank | Country | Reserves (G-bbl) | Undiscovered F95, F50, & F5 (G-bbl) | Production (M-bbl/y) | Years at Zero Growth | Years at 1.03% Growth |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | Venezuela | 296.5 | 5.984 | 767.0 | 394 | 157.9 |
| 2 | Saudi Arabia | 265.4 | 20.241 | 3,250.7 | 88 | 62.7 |
| 2.5 | Australia (3.5-223  G-bbl) | 223 | 1.389 |  |  |  |
| 3 | Canada | 175 | 11.208 | 986.2 | 189 | 105.1 |
| 4 | Iran | 151.2 | 35.707 | 1,497.5 | 125 | 80.4 |
| 5 | Iraq | 150.0 | 68.197 | 876.6 | 249 | 123.7 |
| 6 | UAE | 136.7 | 2.105 | 876.6 | 158 | 94.1 |
| 7 | Kuwait | 101.5 | 2.458 | 840.1 | 124 | 79.9 |
| 8 | Russia | 80 | 68.272 | 3,652.5 | 41 | 33.9 |
| 9 | Kazakhstan | 49 | 8.542 | 547.9 | 105 | 71.3 |
| 10 | Libya | 47 | 4.944 | 620.9 | 84 | 60.4 |
| 11 | Nigeria | 37 | 8.225 | 913.1 | 50 | 40.1 |
| 12 | Qatar | 25.41 | 0.030 | 401.8 | 63 | 48.8 |
| 13 | China | 20.35 | 28.339 | 1,497.5 | 33 | 28.1 |
| 14 | United States | 29.0 | 27.723 | 2,070.0 | 27 | 24.2 |
| 15 | Angola | 13.5 | 3.174 | 694.0 | 24 | 21.5 |
| 16 | Algeria | 13.42 | 11.773 | 620.9 | 41 | 33.9 |
| 17 | Brazil | 13.2 | 21.061 | 767.0 | 45 | 36.8 |
|  | Offshore |  | 1,181.225 |  |  |  |
|  | Calculated World Total without Australia | 1,604 | 1,613 | 21,367 | 151 | 91.1 |
|  | Reported World Total | 1,324 | 1,666 | 20,710 | 144 | 88.6 |
|  | Calculated World Total with Australia | 1,827 | 1,614 | 21,367 | 161 | 95.1 |

Dr. Bartlett and Dr. Hubbert have come under considerable controversy over the Peak Oil theory. The gainsayers generally follow along some line of declaration over how much undiscovered oil remains in the ground. These charts report the data taken from the United States Geological Survey as of its 2011 study.[[7]](#footnote-7) Other information was drawn from a United States Department of Interior report.[[8]](#footnote-8) One must be very careful when handling this data. The units can be very confusing. When production is reported in units per day, we must insist that someone is deliberately distorting the data to make production seem smaller than it really is. The USGS report gives several figures, the most representative of which appears to be around 1,614 to 1,666 billion barrels worldwide. We will show more data in the United States specific chart, for you to get the idea. This number is actually smaller than Dr. Bartlett’s estimate of 2,000 billion barrels. There is no significant reason to doubt Dr. Bartlett’s estimate that the world oil peak came at 2004, and the world will run out of oil around the year 2100. Dr. Bartlett’s 3,000 billion barrel and 4,000 billion barrel curves are wildly generous in the light of the current data.

Gainsayers should be pushed hard to put-up or shut-up. If they have new information about other sources of undiscovered oil, let them deliver their data to USDI and USGS for verification and detailed reporting. Our predictions are no better than our data. Let them speak now, or forever after hold their peace. Gainsayers need to be forced to improve the data if they are able.

| Rank | Source | Country | Reserves  (G-bbl) | Undiscovered F95, F50, & F5 (G-bbl) | Production (M-bbl/y) | Years at Zero Growth | Years at 1.03% Growth |
| --- | --- | --- | --- | --- | --- | --- | --- |
| United States Oil Reserves (Wiki)[[9]](#footnote-9) | | | | | | | |
| 14 | 2011 | United States | 29.0 | 0 | 2,070.0 | 14 | 13.1 |
|  | USGS | F95 | 29.0 | 5.4 |  | 17 | 15.3 |
|  | USGS | F95, & F50 | 29.0 | 10.7 |  | 19 | 17.5 |
|  | USGS | F95, F50, & F5 | 29.0 | 11.7 |  | 20 | 17.9 |
|  | USGS | average | 29.0 | 27.7 |  | 27 | 24.2 |
|  | USGS | maximum | 29.0 | 36.1 |  | 31 | 27.3 |
|  | USDI[[10]](#footnote-10) |  | 29.0 | 134.0 |  | 79 | 57.7 |
| World Oil Reserves (Wiki)8 | | | | | | | |
| 14 | 2012 | United States | 26.8 | 0 | 2,556.8 | 10 | 10.0 |
|  | USGS | F95 | 26.8 | 5.4 |  | 13 | 11.8 |
|  | USGS | F95, & F50 | 26.8 | 10.7 |  | 15 | 13.7 |
|  | USGS | F95, F50, & F5 | 26.8 | 11.7 |  | 15 | 14.0 |
|  | USGS | average | 26.8 | 27.7 |  | 21 | 19.3 |
|  | USGS | maximum | 26.8 | 48.5 |  | 29 | 25.7 |
|  | USDI10 | min | 26.8 | 134.0 |  | 63 | 48.5 |

The 2011 “updated” information is slightly larger in its reported reserves, because the original report has another year of production. There may be other inconsistencies. We wanted to show how the USGS report details its reporting. The F95 USGS number reports a volume with a 95% probability of success: 5.4 G-bbl is the USGS F95 number times 95%. 10.7 G-bbl is the USGS F50 number times 50% added to 5.4. 11.7 G-bbl is the USGS F5 number times 5% added to 10.7. 27.7 G-bbl is the USGS weighted (average) total which was reported with the worldwide figures: because F95, F50, and F5 define three points on a curve, this USGS weighted (average) total evaluates the entire curve, and thus is the best statistical value available. 48.5 G-bbl is the raw total of the F95, F50, and F5 USGS figures. 134 G-bbl is the figure reported in the Wiki, United States Oil Reserves report which drew upon the USDI source.

These USGS and USDI figures clearly show that in 2012 we had about 10 years-worth of oil left in the United States. If undiscovered oil is actually discovered and produced we might have another 3 to 53 years of oil left for our wildest dreams. As anyone can plainly see, undiscovered oil is exactly that: undiscovered. And it is a probabilistic dice throw, whether we will find that oil or not find it. At a span of less than 63 years, we are once again spending our children’s and grandchildren’s future.

There is absolutely no reason whatsoever not to conclude that we remain in a serious energy crisis, in which we have very little time to find remedies. There is more than adequate cause for us to demand a simple accurate Federal Energy Policy that explains the problem clearly, and in no uncertain terms. It is time for us to act together as a unified nation. At the very least we need to reduce our annual consumption to match the pace of undiscovered oil as it is actually discovered, and brought into production. Moreover, we have no business selling oil to anybody else. Out of respect for the rest of mankind, our Federal Energy Policy needs to provide relief for the world’s dwindling 95 year supply of oil, as well. We have an obligation to deal with this crisis so as to minimize the risk of death from famine and exposure.

### Natural Gas

There is a massive public advertising campaign to draw attention away from oil and gasoline shortages, and direct that attention to natural gas and natural gas liquids. Natural gas liquids are the heavier compounds removed from a natural gas cut: these compounds include propane and butane. Liquid natural gas (LNG) is a different beast: LNG is ordinary natural gas made liquid by compression; natural gas and LNG are chemically identical. The topic of natural gas liquids is too complex to report here, but we can look at natural gas. Dr. Bartlett did not investigate natural gas or natural gas liquids: so, this represents a considerable hole in our understanding of energy.

| Rank | Country | Reserves  (T-m3) | Undiscovered F95, F50, & F5  (T-m3) | Production (T-m3/yr) | Years | Years at 5% Growth |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | Iran | 33.60 | 3.21 | 0.1461 | 252 | 53 |
| 2 | Russia | 32.90 | 6.74 | 0.6696 | 59 | 28 |
| 3 | Qatar | 21.00 | 0.00 | 0.1167 | 180 | 47 |
| 4 | Turkmenistan | 17.50 | 1.55 | 0.05950 | 320 | 58 |
| 5 | United States | 9.460 | 2.38 | 0.6513 | 18 | 13 |
| 6 | Saudi Arabia | 8.200 | 1.19 | 0.09923 | 95 | 35 |
| 7 | Venezuela | 5.525 | 0.47 | 0.03120 | 192 | 48 |
| 8 | Nigeria | 5.246 | 0.50 | 0.09200 | 62 | 29 |
| 9 | Algeria | 4.502 | 1.17 | 0.08461 | 67 | 30 |
|  | Offshore |  | 117.60 |  |  |  |
|  | Other | 2.915 |  |  |  |  |
|  | Calculated World Total | 187.3 | 156.6 | 3.605 | 95 | 36 |

Worldwide natural gas reserves and undiscovered deposits are in worse shape than for oil. Oil is reporting 161 years of reserves, compared to natural gas at 95 years of reserves. These numbers look enormous until we consider two vital facts: One. This is all the oil and natural gas that there is and ever will be. Two. Man’s destructive and gluttonous penchant for growth militates that these numbers will drop like rocks to 95 and 36 years respectively, or even less.

### World Gas Reserves (Wiki)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rank | Source | Country | Reserves  (T-m3) | Undiscovered F95, F50, & F5  (T-m3) | Production (T-m3/yr) | Years | Years at 5% Growth |
| 5 | 2012 | United States | 9.460 | 0 | 0.6513 | 15 | 11.0 |
|  | USGS | F95 | 9.460 | 0.776 |  | 16 | 11.7 |
|  | USGS | F95, & F50 | 9.460 | 1.651 |  | 17 | 12.4 |
|  | USGS | F95, F50, & F5 | 9.460 | 1.837 |  | 17 | 12.6 |
|  | USGS | average | 9.460 | 2.382 |  | 18 | 13.0 |
|  | USGS | maximum | 9.460 | 6.290 |  | 24 | 16.0 |
|  | USDI |  |  | no report |  |  | 0 |

In our natural gas analysis we used 5% as a realistic growth factor, because that is a number being bandied about in Federal Budget debates. God knows what a more realistic number might be. The way natural gas power interests are pushing for expansion, it should be obvious that the sky is the limit. It should be equally obvious that fracking[[11]](#footnote-11) is with us, whether we like it or not. As long as the money and the demand is on the table our leaders will continue to ride roughshod over public interests: common man has no real voice in this matter, other than to stop using the products.

The United States supply of natural gas is not eternal as the ubiquitous advertisements boldly claim: far from it; at best, we have a 10 to 30 year supply. This compares to oil which has a 10 to 63 year supply. This is about money, and is directly opposed to the public interest. This is a plan to crash the country. The movers and shakers don’t give a damn that millions of people will freeze or starve to death, while many others undergo extreme hardship.

### Coal Updates

Natural gas will most likely be depleted first: it is commonly advertised as the more desirable, clean fuel. It is also more easily produced: water removal, scrubbing to remove dirt, and extraction of propane, butane, etc. may be all that is required. Oil must be pumped, distillation is more complex, and cat cracking may be involved. After natural gas and oil are depleted the energy load will fall upon coal. There is very little hope that the world will awake in time to deal seriously with nuclear, wind, solar or other, more sustainable, energy technologies: man is more like a lemming, than like a wizard. When the coal is gone we will commence to burn our forests to the ground.

Interestingly, we could find no data for undiscovered coal. Such deposits must exist: but, they are most likely under our forests, which will be destroyed when we mine the coal. We did find a crude area plot from USGS, Bulletin 1450-B that paints a rough picture of undiscovered coal deposits.[[12]](#footnote-12)

| Rank | Country | Reserves  (M-tons) | Undiscovered (M-tons) | 2008 Production (M-tons/yr) | Years at Zero Growth | Years at 2.69% Growth |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | United States | 237,295 |  | 1,063 | 223 | 73 |
| 2 | Russia | 157,010 |  | 328.6 | 478 | 99 |
| 3 | China | 114,500 |  | 2,802 | 41 | 28 |
| 4 | Australia | 76,400 |  | 399.2 | 191 | 68 |
| 5 | India | 60,600 |  | 515.9 | 117 | 53 |
| 6 | Germany | 40,699 |  | 192.4 | 212 | 71 |
| 7 | Ukraine | 33,873 |  |  |  |  |
| 8 | Kazakhstan | 33,600 |  | 111.1 | 302 | 83 |
| 9 | South Africa | 30,156 |  | 252.6 | 119 | 54 |
| 10 | Serbia | 13,770 |  |  |  |  |
| 11 | Columbia | 6,746 |  | 74.0 |  |  |
| 12 | Canada | 6,528 |  |  |  |  |
| 13 | Poland | 5,709 |  | 144.0 | 40 | 27 |
| 14 | Indonesia | 5,529 |  | 240.2 | 23 | 18 |
| 15 | Brazil | 4,559 |  |  |  |  |
| 16 | Greece | 3,020 |  |  |  |  |
| 17 | Boznia Herzegovina | 2,853 |  |  |  |  |
| 36 | All Others | 5,613 |  | 182 |  |  |
|  | Calculated World Total | 860,884 |  | 6,869 | 125 | 55 |
|  | 2011 Report | 860,884 |  | 7,695 | 112 | 52 |

The USGS area plot suggests that there is another 1,721,000 M-tons of undiscovered coal that is recoverable; and 2,583,000 M-tons of undiscovered coal that is not recoverable without significant technological advancements, and financial inducements. Here are the worldwide approximations:

| Status | Reserves  (M-tons) | Undiscovered  (M-tons) | 2011 Production (M-tons/yr)[[13]](#footnote-13) | Years at Zero Growth | Years at 2.69% Growth |
| --- | --- | --- | --- | --- | --- |
| Reserve | 860,884 |  | 7,695 | 112 | 52 |
| + Recoverable | 860,884 | 1,721,768 | 7,695 | 336 | 86 |
| + Not-Recoverable | 860,884 | 4,304,420 | 7,695 | 671 | 111 |

Here are the United States approximations:

| Status | Reserves (M-tons) | Undiscovered (M-tons) | 2008 Production (M-tons/yr) | Years at Zero Growth | Years at 2.69% Growth |
| --- | --- | --- | --- | --- | --- |
| Reserve | 237,295 |  | 1,063 | 223 | 73 |
| + Recoverable | 237,295 | 474,590 | 1,063 | 670 | 110 |
| + Not-Recoverable | 237,295 | 1,186,475 | 1,063 | 1,786 | 146 |

Before we start crowing about a 1,786 year supply of coal, and coal running out of our ears, we should consider a few sobering facts: One. More than 1,000 years-worth of that coal is presently not-recoverable. Two. At a minuscule 2.69% growth, even these gigantic time spans are whittled down to less than 146 years of coal left. More realistically, we might have between 73 and 110 years of coal left. Once natural gas, natural gas liquids, and oil are gone, no one will be able to restrain massive and sudden coal production increases. Here is the same chart based on modest 8% growth.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Status | Reserves (M-tons) | Undiscovered (M-tons) | 2008 Production (M-tons/yr) | Years at Zero Growth | Years at 8% Growth |
| Reserve | 237,295 |  | 1,063 | 223 | 38 |
| + Recoverable | 237,295 | 474,590 | 1,063 | 670 | 51 |
| + Not-Recoverable | 237,295 | 1,186,475 | 1,063 | 1,786 | 64 |

Now we are able to project a 38 to 51 year supply of coal remaining: up to 64 years if our technology improves greatly.

The human ability to destroy and devour is without bounds.

### Population

Our population data showed a current world population of 7 billion, 162 million people, and a United States population of 317 million people. Of course these numbers change every day, so we arbitrarily froze the numbers at what we hope are reasonable values: but in a year or so, they will be hopelessly out of date.

The world has over 4 billion acres under cultivation, and another 10 billion acres in fixed crops, such as forests, fruit trees, bushes, etc.: an aggregate in excess of 14 billion acres of useable land worldwide. The United States has over 1 billion acres of useable land.

Dividing the usable acres by the population yields the number of acres per person: the world average is 2.01 acres per person; the United States, 3.67; India, 0.45; China, 0.66; Russia, 16.04; Brazil, 7.49. We collected data for nearly every country imaginable.

With the total depletion of fossil fuels, the ability to do work will be greatly diminished. Replacement of internal combustion engines with animal and human power sources will be accomplished at magnitudes of hundreds and thousands. We do not know what the population saturation point for earth is. It may well be that the population will need to increase, but be better distributed.

### Electricity[[14]](#footnote-14)

According to the Wiki report world electricity production looks like this:

* Coal 41%
* Oil 5%
* Gas 21%
* Sum of Fossil Fuels 67%
* Nuclear 13%
* Hydroelectric 16%
* Wind 1%
* Sum of Renewable 18%
* Bio other 1%

United States (the world’s largest user) production looks like this:

* Coal 49%
* Oil 1%
* Gas 21%
* Sum of Fossil Fuels 71%
* Nuclear 19%
* Hydroelectric 6%
* Wind 1%
* Sum of Renewable 8%
* Bio other 2%

Top Users

1. United States 22%
2. China 17%
3. Japan 5%
4. Russia 5%
5. India 4%
6. Canada 3%
7. Germany 3%
8. France 3%
9. Brazil 2%
10. South Korea 2%
11. UK 2%
12. Italy 2%

### Other

We have put no real effort into forest, oxygen, soil, or other vital necessity depletions. We desperately need the contributions of more and better minds to deal with these weighty and complex issues.

We are also caught in a dilemma over Global Warming. If fossil fuels are depleted, even if only gas and oil are gone in a few years, man’s ability to produce waste heat will be greatly diminished, and Global Warming will probably stop all by itself. We will be more concerned with freezing and starvation. On the other hand, if massive new discoveries of gas and oil become a reality, Global Warming could prove to be a considerable danger; because man, given the opportunity, will only increase consumption, with its attendant escalation of waste heat.

### Equations

The basic exponential equation:

***y (t) = a \* bt***

Where ***a***, is the value of ***y0***, the intercept where ***y (t)*** crosses the ***y*** axis, the initial value when the horizontal, or ***x*** value is ***zero***; ***b*** is the exponential constant; and ***t*** is the time, distance, or other factor plotted on the horizontal, or ***x*** axis. If ***r*** is the rate of growth:

***b = 1 + r***

Doubling time, or 100% ordinary steady growth:

If we begin with an initial value of a, and a final value of 2a, we find the doubling time:

***y (t) = a \* bt***

***2a = a \* bt****: dividing both sides by* ***a***

***2 = bt***

***ln (2) = ln (bt) = t \* ln (b)***

***t (doubling time) = ln (2) / ln (b)***

***≅ 0.693 / (r / t) or (69.3%) / (r% / t) or (70%) / (r% / t)***

In developing the rule-of-thumb approximation, we make note of the fact that for ***r*** values of ***10% or less***, the ***ln (1 + r) ≈ r***, and ***69.3% ≈ 70%***. The following chart compares exact and rule-of-thumb calculations. These estimates are very good and usually err on the safe side.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Growth % per year / Growth time (years) | | | | |
| % / t | 1 | 2 | 3 | 4 | 5 |
| Exact | 69.66 | 35.00 | 23.45 | 17.67 | 14.21 |
| Estimate | 70 | 35 | 23.3 | 17.5 | 14 |
| % put | 6 | 7 | 8 | 9 | 10 |
| Exact | 11.90 | 10.24 | 9.01 | 8.04 | 7.27 |
| Estimate | 11.7 | 10 | 8.8 | 7.8 | 7 |

In the chess board problem: we may number the squares from 1 to 64, or from 0 to 63. Since the Exponential Function always starts at ***t = 0***, we prefer including the idea of zero. Here are the equations for calculating the number of grains on any square, where ***b = 200% per square*** and moving from square to square takes the place of time, and the doubling time is ***1 square***:

***y (t) = 1 \* 2t = 2t***

***y (n) = 2n****: numbering from zero; or* ***2(n-1)****: numbering from one*

Geometric accumulation:

The chess board problem also considers accumulating the numbers as we go along. This sum is known as a geometric series and solving it involves a mathematical trick. Here it is:

***∑1 = a + ab + ab2 + ab3 + … + abt****: multiplying by b*

***b \* ∑1 = ab + ab2 + ab3 + … + abt + ab (t+1)***

We notice that both equations are identical except for the first and the last terms: so, subtracting the first equation from the second equation we arrive at something we can always calculate quite easily.

***b \* ∑1 – ∑1 = a \* b (t+1) – a****: factoring*

***∑1 \* (b – 1) = a \* (b (t+1) – 1)****: dividing*

***∑1 = a \* (b (t+1) – 1) / (b – 1)***

Dr. Bartlett’s remaining time equation:

***TE ≅ 1 / k \* ln (k \* R / r0 + 1)***

We begin by observing that: if exponential growth is in actual practice, that the reserve is equal to the area under the exponential curve.

***y (t) = a \* bt****: the exponential curve*

***A (t) ≡ ∫ y (t) dt = ∫ a \* bt dt + C***

The initial value, ***a***, or ***y0***, is a constant. Let ***z = bt***. We employ logarithmic differentiation:

***z = bt****: taking the natural logarithm and applying its properties*

***ln (z) = ln (bt) = t \* ln (b)***

***dz / z = ln (b) dt***

***dz = ln (b) \* z dt = ln (b) \* bt dt****: integrating*

***∫ a\*bt dt =a / ln (b) ∫ ln (b) \* bt dt = a / ln (b) \* bt + C***

At ***t = 0***, ***A = 0***, and always ***a = y0***

***A = 0 = y0 / ln (b) \* b0 + C****: solving for* ***C***

***C = – y0 / ln (b)****: substituting and factoring*

***R = A = y0 / ln (b) \* bt – y0 / ln (b) = y0 / ln (b) \* (bt – 1)****: multiplying*

***(bt – 1) = R \* ln (b) / y0 = ln (b) \* R / y0****: adding*

***bt = ln (b) \* R / y0 + 1****: taking the natural logarithm*

***t \* ln (b) = ln [ln (b) \* R / y0 + 1]****: dividing*

***T = 1 / ln (b) \* ln [ln (b) \* R / y0 + 1]***

We remember from before that ***b = 1 + r***, and that for small ***r*** (less than ***0.10***), ***ln (1 + r) ≈ r***: substituting….

***T ≈ 1 / r \* ln[r \* R / y0 + 1]****: QED*

So, now we have both an exact formula that even applies to enormous values of r, and an approximation similar to the Rule of 70, which can be worked with a slide rule and a pencil. The natural logarithm is no longer a problem, since modern spreadsheets and scientific calculators tackle it quite easily.

### Our Conclusion

In the not far distant future, the world will return to an agriculturally based economy. There will be no job shortage: for, farm and forest hands will be in great demand. If there are automobiles, they will be steam, muscle, solar, or battery powered. Automobile manufacturing, sales, or maintenance will probably not survive. Media businesses will diminish or disappear. Boats will be wind powered. Much of our present social structure will be gone. Central national governments, if they survive at all, will be replaced in power by smaller, more efficient local governments. Public services will vanish. Medicine and most education will be taken away. Human beings will be forced to find a different way, just to live. This is not all bad: life will be simpler.

1. Formerly, part 9 [↑](#footnote-ref-1)
2. Dr. Bartlett [↑](#footnote-ref-2)
3. Swanson [↑](#footnote-ref-3)
4. See http://en.wikipedia.org/wiki/The\_Population\_Bomb and http://en.wikipedia.org/wiki/Malthusian\_catastrophe. [↑](#footnote-ref-4)
5. http://en.wikipedia.org/wiki/Kenneth\_Arrow [↑](#footnote-ref-5)
6. http://en.wikipedia.org/wiki/Paul\_R.\_Ehrlich [↑](#footnote-ref-6)
7. http://pubs.usgs.gov/dds/dds-069/dds-069-ff/downloads/Excel%20tables/ [↑](#footnote-ref-7)
8. http://en.wikipedia.org/wiki/Oil\_reserves [↑](#footnote-ref-8)
9. http://en.wikipedia.org/wiki/Oil\_reserves\_in\_the\_United\_States [↑](#footnote-ref-9)
10. http://pubs.usgs.gov/dds/dds-069/dds-069-ff/ [↑](#footnote-ref-10)
11. http://en.wikipedia.org/wiki/Hydraulic\_fracturing [↑](#footnote-ref-11)
12. http://pubs.usgs.gov/bul/b1450b/b1450.htm [↑](#footnote-ref-12)
13. Updated production figures were applied to the 2008 data. [↑](#footnote-ref-13)
14. http://en.wikipedia.org/wiki/Electricity\_generation [↑](#footnote-ref-14)