Energy Policy

Arithmetic, Population and Energy, Part 3

Revision B, 2021

For the love of the human race.

Our Thesis

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 oppression.

The central piece of information to be gleaned in Part 3 is that we are running out of time.

Arithmetic, Population and Energy, Part 3

http://www.albartlett.org/presentations/arithmetic_population_energy_video1.html Better results were achieved by playing the video clip directly from this site, rather than by linking through YouTube. Click on the arrow in the middle of the picture, rather than on the black bar at the top. This is Part 3.

Dr. Bartlett asks the question, "How long can growth continue? Even with startling new discoveries?" What kind of growth control might be necessary? Then he quips about controlled growth: "Arithmetic doesn't hold in Boulder."

This study is about growth in a finite environment; the bacteria in the bottle. This model is the same as the chess board model, without considering any accumulation. At ***11:00 am*** there is one bacterium in the bottle. Every minute the bacteria grow steadily, doubling by division, so that the parent bacteria divide into the children and the parents disappear. At noon the bottle is full of bacteria. What is different about this perspective of the exponential equation is its emphasis on time, rather than size.

This must be fascinating for a biologist studying culture growth: for over 52 minutes nothing seems to be happening, the culture appears to be dead, unless it is observed under a microscope. Suddenly, it explodes in the last 8 minutes filling the container.

Similarly, the baker observes rising bread. After 59 minutes, he observes that the bowl is half full, and decides to come back in another hour or so. When he returns, the dough has run all over the floor, the starch in the dough is completely consumed, and the dough is ruined. After 59 minutes, the wise and experienced baker, begins to watch the dough every minute, perhaps even continuously, and pops it in the oven at the perfect moment.

1. “When was the bottle half full?
A. At 11:59, 1 minute before noon.

2. “When would you first realize that you were running out of space?
A. At 11:52 or later, when less than eight minutes remain.

3. “How long can growth continue as a result of multiplying the available resources by 4: that is by adding 3 times the resources ever known before?
A. At 12:02, after two additional minutes.”[1]

Dr. Bartlett observes that this kind of thinking, “… is the centerpiece of the national and global economies.” It should be clear by the end of this part of Dr. Bartlett’s talk that national and global economies need to be changed. Leaders everywhere need to put the growth mentality to death,

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[1] Dr. Bartlett’s critical questions: if these three questions are understood, all of Part 3 is understood.

before it puts us to death. Here is a mathematical reproduction of Dr. Bartlett's slide:

Clock Time (hr:mn)	Stop Watch (minutes)	Bacteria Count	Space Taken	Space Left	Time Left (minutes)
11:00	0	1	0.0%	100%	60
11:01	1	2	0.0%	100%	59
11:02	2	4	0.0%	100%	58
11:03	3	8	0.0%	100%	57
11:04	4	16	0.0%	100%	56
11:05	5	32	0.0%	100%	55
11:06	6	64	0.0%	100%	54
11:07	7	128	0.0%	100%	53
11:08	8	256	0.0%	100%	52
11:09	9	512	0.0%	100%	51
11:10	10	1,024	0.0%	100%	50
11:11	11	2,048	0.0%	100%	49
11:12	12	4,096	0.0%	100%	48
11:13	13	8,192	0.0%	100%	47
11:14	14	16,384	0.0%	100%	46
11:15	15	32,768	0.0%	100%	45
11:16	16	65,536	0.0%	100%	44
11:17	17	131,072	0.0%	100%	43
11:18	18	262,144	0.0%	100%	42
11:19	19	524,288	0.0%	100%	41

Clock Time (hr:mn)	Stop Watch (minutes)	Bacteria Count	Space Taken	Space Left	Time Left (minutes)
11:20	20	1,048,576	0.0%	100%	40
11:21	21	2,097,152	0.0%	100%	39
11:22	22	4,194,304	0.0%	100%	38
11:23	23	8,388,608	0.0%	100%	37
11:24	24	16,777,216	0.0%	100%	36
11:25	25	33,554,432	0.0%	100%	35
11:26	26	67,108,864	0.0%	100%	34
11:27	27	134,217,728	0.0%	100%	33
11:28	28	268,435,456	0.0%	100%	32
11:29	29	536,870,912	0.0%	100%	31
11:30	30	1.074E+09	0.0%	100%	30
11:31	31	2.147E+09	0.0%	100%	29
11:32	32	4.295E+09	0.0%	100%	28
11:33	33	8.590E+09	0.0%	100%	27
11:34	34	1.718E+10	0.0%	100%	26
11:35	35	3.436E+10	0.0%	100%	25
11:36	36	6.872E+10	0.0%	100%	24
11:37	37	1.374E+11	0.0%	100%	23
11:38	38	2.749E+11	0.0%	100%	22
11:39	39	5.498E+11	0.0%	100%	21
11:40	40	1.100E+12	0.000%	100%	20
11:41	41	2.199E+12	0.000%	100%	19
11:42	42	4.398E+12	0.000%	100%	18

Clock Time (hr:mn)	Stop Watch (minutes)	Bacteria Count	Space Taken	Space Left	Time Left (minutes)
11:43	43	8.796E+12	0.001%	100%	17
11:44	44	1.759E+13	0.002%	100%	16
11:45	45	3.518E+13	0.003%	100%	15
11:46	46	7.037E+13	0.006%	100%	14
11:47	47	1.407E+14	0.012%	100%	13
11:48	48	2.815E+14	0.024%	100%	12
11:49	49	5.629E+14	0.049%	100%	11
11:50	50	1.126E+15	0.098%	100%	10
11:51	51	2.252E+15	0.195%	100%	9
11:52	52	4.504E+15	0.391%	100%	8
11:53	53	9.007E+15	0.781%	99%	7
11:54	54	1.801E+16	1.563%	98%	6
11:55	55	3.603E+16	3.125%	97%	5
11:56	56	7.206E+16	6.25%	94%	4
11:57	57	1.441E+17	12.5%	88%	3
11:58	58	2.882E+17	25%	75%	2
11:59	59	5.765E+17	50%	50%	1
Noon	60	1.153E+18	100%	0%	0
12:01	61	2.306E+18	200%	-100%	-1
12:02	62	4.612E+18	400%	-300%	-2

What is important to observe from this table is that growth is now moving at express train speed. The problem is undetectable until there are less than ***8 minutes*** left on the clock. It may now be impossible to stop the train in time to avoid a catastrophe. The momentum is very great. By 1:00 pm the bacteria will have spilled out of all 4 bottles, consumed the laboratory, and taken over the entire building. This is the same mathematical model as that used for explosions.

In the energy crisis, "we have a classic case of exponential growth against a finite source."[2]

The average growth rate of world crude oil consumption, ***between the years 1880 and 1980*** is approximately ***7.04% per year***.[3] Without the discovery of massive new reserves the world's supply of crude oil would have been half consumed by 1991. Even with the discovery of massive new reserves, the rate of consumption is now so large that the available time left for total practical depletion, amounts to a few mere decades. At a continuing depletion rate of ***7.04%*** we are able to reproduce the following table of estimated values.[4] The computer produces slightly more precise numbers than the slide rule or logarithmic paper: this explains the minor differences between the talk slide and the table below.

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[2] James R. Schlesinger, U. S. Secretary of Energy, in *Time Magazine*, April 25, 1977, p. 27 http://en.wikipedia.org/wiki/James_R._Schlesinger

[3] Studies of Dr. M. King Hubbert: http://en.wikipedia.org/wiki/M._King_Hubbert, http://en.wikipedia.org/wiki/Hubbert_peak_theory, http://en.wikipedia.org/wiki/Peak_oil, http://www.princeton.edu/hubbert/the-peak.html, http://conspiracywiki.com/articles/peak-oil/hubbert-peak-oil-theory/

[4] Watt, Kenneth E. F., *The Titanic Effect* (e. P. Dutton, 1974: 268 pages): http://books.google.com/books/about/The_Titanic_Effect.html?id=5lw0AAAAMAAJ

Dr. Bartlett's slide is hard to read, so we reconstructed it. In any case, we need our own spreadsheet with which to examine various growth rates and fresh data. Here is how we did it.

Year	Crude Oil Production (G-bbls)	Accumulated Consumption (G-bbls)	Reserves Left (G-bbls)	Fraction Left	Time
1971				7/8	11:57
1972					
1973	20.4	334	1,765		
1974	21.8	356	1,743		

In the first row we entered whatever titles suited us. In keeping with modern international notation we used the letter G instead of billions.

In the 1971 row we reasoned backward that this was the 7/8 reserves left point or 11:57 on our bacteria bottle clock model, so we started there. From that point on we reserved one row for each year.

In the 1973 row we entered that data exactly as we found it on Dr. Bartlett's slide.

In the 1974 row we made the following calculations using 7.04% as our Depletion Growth Rate. This number was stored in its own block on the spreadsheet.

† In the second column: $y(t) = a * b^t$; ***a = 20.4***, ***b = 1.0704***, ***t = the current year – 1973***. It looks like this: =$C$88*(1+$D$84)^(B89-$B$88). Notice that the blocks for ***a***, ***b***, and the starting year are all frozen: the F4 key creates the $ that freeze the location.

† In the third column: we simply added the number above to the number on the left: =D88+C89.

† In the fourth column: we subtracted the number from column two on the left from the number above: =E88-C89. Then we refined it

with a conditional statement that prevented the calculation from going below zero: =IF(E88-C89<0,0,E88-C89).

† Finally, we added notations for the fractions remaining and the time on the bacteria bottle clock model. These latter are not essential, but they help dramatize the acceleration present in this chart.

Now we simply copy these calculations down for as many years into the future as we care to study. Scientists may want a ***100 year*** or longer plan. Business planners may be happy with a ***30 year*** plan. Nearly everyone needs to have access to some kind of a plan or other. As each year passes, the predictive calculations can be replaced with hard data. In this case the second column calculation will need to be corrected: for 1973 will no longer be the starting year. If many depletion growth rate changes are anticipated we can easily add a column for depletion growth rate, to account for shifts in growth. Hopefully, we would be able to stem this tide, and see zero growth, or even negative growth rates, as we learn to better conserve our natural resources.

Here is the full completed chart at ***7.04% growth***:

Year	Crude Oil Production (G-bbls)	Accumulated Consumption (G-bbls)	Reserves Left (G-bbls)	Fraction Left	Time
1971				7/8	11:57
1972					
1973	20.4	334	1,765		
1974	21.8	356	1,743		
1975	23.4	379	1,720		
1976	25.0	404	1,695		
1977	26.8	431	1,668		
1978	28.7	460	1,639		

Year	Crude Oil Production (G-bbls)	Accumulated Consumption (G-bbls)	Reserves Left (G-bbls)	Fraction Left	Time
1979	30.7	490	1,609		
1980	32.8	523	1,576		
1981	35.2	558	1,541	3/4	11:58
1982	37.6	596	1,503		
1983	40.3	636	1,463		
1984	43.1	679	1,420		
1985	46.2	726	1,373		
1986	49.4	775	1,324		
1987	52.9	828	1,271		
1988	56.6	884	1,215		
1989	60.6	945	1,154		
1990	64.9	1,010	1,089		
1991	69.4	1,079	1,020	1/2	11:59
1992	74.3	1,154	945		
1993	79.5	1,233	866		
1994	85.1	1,318	781		
1995	91.1	1,409	690		
1996	97.5	1,507	592		
1997	104.4	1,611	488		
1998	111.8	1,723	376		
1999	119.6	1,843	256		
2000	128.0	1,971	128		

Year	Crude Oil Production (G-bbls)	Accumulated Consumption (G-bbls)	Reserves Left (G-bbls)	Fraction Left	Time
2001	137.1	2,108	0		Noon
2002	146.7				12:01
2003	157.0				
2004	168.1				12:02

As Dr. Bartlett notes, "Fortunately, the growth rate slowed because OPEC raised their oil prices." But the terrible wars we've fought since 1990 have been, to a great extent, over this oil and who owns it. In the process of waging these extravagant wars, we have succeeded in squandering huge quantities of these precious oil reserves

These facts are demonstrated very forcefully in a doubling area plot.[5]

A ***2012*** report[6] rates the world oil reserves at ***1,324 G-bbl***. My calculations from the same report show ***1,602 G-bbl***, so the report seems to contain errors. Adding in the latest shale oil find at Coober Pedy, Australia, yields a maximum of ***1,825 G-bbl***. At the present estimated rate of world production of ***58.5 M-bbl per day***, or ***21.367 G-bbl per year***, we have roughly an ***85 year*** supply of oil at ***zero growth***. The problem is that oil production is not a zero growth industry. At a modest ***1.030% growth per year***, the world has less than ***62 years*** before it runs out of oil. In the same report, the United States claims ***26.8 G-bbl***, being produced at ***7 M-bbl per day***, or ***2.557 G-bbl per year***. At this pace we have a ***10 year*** supply, at which point we will be totally dependent on foreign oil. If we increase our production, we have even less than 10

[5] Courtesy of Prof. Mario Iona (1917-2004), University of Denver, Physics Department: http://www.rbs0.com/Iona.htm

[6] http://en.wikipedia.org/wiki/Oil_reserves

years. Russia, on the other hand, reports reserves for 22 years at zero growth and less than 19.8 years at 1.030% growth.

Here is our complete set of data as collected:

Rank	Country	Reserves (G-bbl)	Production (M-bbl/d)	Production (M-bbl/y)	Years at Zero Growth	Years at 1.030% Growth
1	Venezuela	296.5	2.1	767.0	387	156.3
2	Saudi Arabia	265.4	8.9	3,250.7	82	59.3
2.5	Australia (3.5-223 G-bbl)	223	0	0.0		0.0
3	Canada	175	2.7	986.2	177	101.1
4	Iran	151.2	4.1	1,497.5	101	69.3
5	Iraq	150.0	2.4	876.6	171	98.8
6	UAE	136.7	2.4	876.6	156	93.2
7	Kuwait	101.5	2.3	840.1	121	78.6
8	Russia	80	10	3,652.5	22	19.8
9	Kazakhstan	49	1.5	547.9	89	63.5
10	Libya	47	1.7	620.9	76	56.0
11	Nigeria	37	2.5	913.1	41	33.9
12	Qatar	25.41	1.1	401.8	63	48.8
13	China	20.35	4.1	1,497.5	14	12.7
14	United States	26.8	7	2,556.8	10	10.0
15	Angola	13.5	1.9	694.0	19	17.7
16	Algeria	13.42	1.7	620.9	22	19.5
17	Brazil	13.2	2.1	767.0	17	15.8

Rank	Country	Reserves (G-bbl)	Production (M-bbl/d)	Production (M-bbl/y)	Years at Zero Growth	Years at 1.030% Growth
	Calculated Sum without Australia	1,602	58.5	21,367	75	55.6
	Reported Sum	1,324	56.7	20,710	64	49.2
	Calculated Sum with Australia	1,825	58.5	21,367	85	61.4

Just look at Australia. With the find at Coober Pedy, Australia has the potential of being the third largest reserve in the world. Potential. Let's face some realities: it is shale oil,[7] not liquid pumped crude; it's not in production; its exact volume is unknown and could be as low as 3.5 G-bbl, which would make it the world's smallest reserve; not the overly optimistic 223 G-bbl that everyone grasps after. This is like claiming victory in war before the first shot of the first battle is fired.

Let's compare this with Dr. Bartlett's data.

Year	Crude Oil Production (G-bbls)	Accumulated Consumption (G-bbls)	Reserves Left (G-bbls)	Fraction Left	Time
1973	20.4	334	1,765		
2012	21.4		1,825		

$$\boldsymbol{y\ (t) = a * b^t}\textit{: dividing by } \boldsymbol{a}$$

$$\boldsymbol{b^t = y / a}\textit{: taking the root } \boldsymbol{1/t}$$

$$\boldsymbol{b = (y / a)^{(1/t)}}\textit{: substituting values}$$

$$\boldsymbol{b = (21.4 / 20.4)^{(1/(2012\text{-}1973)} = 100.1\%}\textit{: solving for } \boldsymbol{r}$$

$$\boldsymbol{r = b - 1 = 0.119\%}$$

[7] http://en.wikipedia.org/wiki/Shale_oil_extraction

Now we have some reasonably hard data to show that between 1880 and 1980 the growth rate of fuel production is approximately ***7.04% per year***. Somewhere around the end of that era the growth rate was broken, largely due to the efforts of the Carter administration. From 1973/1980 to the present, based on predictions the growth rate of fuel production was reduced to around ***0.119%***. Even though this calculation is a crude estimate, which we shall improve with new data, it is corroborated by the fact that very little money was invested in new refineries since this period.

We recently located annual world production data for the period between 1980 and 2012.[8] By analyzing this data with a regression analysis of its ln plot we get the best possible data. The end point analysis by the formula we just used yields ***0.715%***. Regression analysis shows an actual growth rate from 1980 to 2012 of ***1.030%***. This is actual data analysis, not a predictive approximation.

We can also calculate the peak production maximum value and latest date from these numbers. Factors that we have not yet considered will also influence this date: principal among them are changes in growth rate and new discoveries, which may be evaluated by including undiscovered oil. Based on 1.030% growth without including undiscovered oil world oil production cannot peak at greater than 40 G-bbl per year or later than 2073. United States oil production cannot peak at greater than 2.8 G-bbl per year or later than 2022. These peaks are based on the catastrophic failure assumption. Based on other considerations we have good reason to believe that these peaks have already occurred.

If we multiple the production rate of 21.4 by the 39 intervening years, we discover that 833 G-bbl of oil was produced in this period. Since we began with 1,765 G-bbl of oil, we saved about 932 G-bbl of oil

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http://www.indexmundi.com/energy.aspx?product=oil&graph=production

worldwide. This is very good news, because at 7.04% we were destined to consume every drop of this by 2001. This is truly a notable conservation effort: but it is not enough. Since that time we have found about 886 G-bbl of new reserves, a truly impressive find: but it is not enough. The figures are deceptive; it looks like a lot of oil; it looks like we are better off than in 1973; it looks like somebody "cried, Wolf!" The bad news is that all of this oil, our remaining reserve of 1,825 G-bbl of oil will last a mere 85 years if we don't increase world oil production at all, not even 1% per year. The chances that we will not double world oil production in a few years are very small. As China comes on line with a pent-up demand for motor vehicles, they will soon eclipse the United States as the world's largest oil consumer. We will do well if this reserve lasts 43 to 62 years worldwide.

In the meantime, the United States economy will tank, because our piddling, minuscule oil reserve of 10 years will be gone, and we will be at the total mercy of those few nations who are still willing to sell oil to us. At this point we will learn how many real friends we have: and I fear we will discover that we, like Smaug,[9] have made a lot of enemies.

We have slowed growth, we have nearly stopped it. Good for us. Oil still doesn't grow on trees. We need to do more. The sad facts are that our nation is nearly bankrupt in terms of oil reserves. The world is nearly bankrupt in terms of oil reserves. At the outside we have an 85 year supply, without more, much needed, discoveries we could have as little as a 43 year supply left worldwide. Against this rising tide of destruction, we continue to discuss growth plans, rather than conservation plans. China is becoming a major consumer of automobiles, and internal combustion fuels. This is a disaster waiting to happen. We need a solid plan to contain and manage this disaster. Sadly the industrialized nations will suffer most: for they are the ones

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[9] Smaug is the fictional dragon in J. R. R. Tolkien's, *The Hobbit*. He is an apt picture of American gluttony and greed. If Nazi Germany were the Smaug of Tolkien's lifetime, the United States is the Smaug of our world today. The curse of the ring still plagues us.

who have built their vast empires on fossil fuel dependency. When fossil fuels die, these nations will also die, because they haven't got the sense and foresight to develop alternative energy sources in a timely manner.[10]

Our Conclusion

Unfortunately, this data set is hopelessly out of date. New studies need to be completed. New oil fields may have been discovered. Fracking is now an active practice in many places. Consumption patterns have changed. The budding China economy has matured slightly. I am now too old and too tired to keep up with this work of finding current data: which, should be openly published by our own government and in plain sight for everyone.

Dr. Bartlett has correctly alerted us to the fact that we are out of time. There is nothing wrong with his understanding of the exponential curve with respect to its implications for time. The focus of Dr. Bartlett's analysis is moving away from overpopulation to overconsumption as his argument develops. As promised, we updated his data with the best data we could find at the moment. However, this is an ongoing quest, and we are very dependent on energy data experts for accurate data. We promise to provide similar updates for coal, natural gas, and any other resource of importance to us. This part of the study emphasizes the fact that on the scaled down bottle clock model, we have only minutes left to make a rational decision, before the raging forces of nature make all the decisions for us. On the real life clock, it would appear that, realistically, we have only a few decades to wake up and change. We have made changes since 1970, but these are scarcely sufficient. We may have delayed our own death sentence by thirty years or so.

10

http://www.eia.gov/pub/oil_gas/petroleum/feature_articles/2004/worldoilsupply/oilsupply04.html

1. “When was the bottle half full?
A. At 11:59, 1 minute before noon.

2. “When would you first realize that you were running out of space?
A. At 11:52 or later, when less than eight minutes remain.

3. “How long can growth continue as a result of multiplying the available resources by 4: that is by adding 3 times the resources ever known before?
A. At 12:02, after two additional minutes.”[1]

In the energy crisis, “we have a classic case of exponential growth against a finite source.”[2]