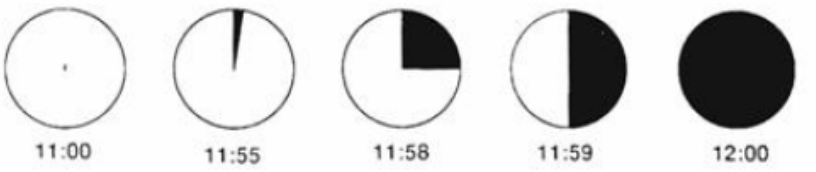
Exponential Icebergs

By Harry Braun

Very few people have an understanding of exponential growth, yet it is clearly the most significant event of the Exponential Age in which we live. The danger of exponential growth is that when it first starts to grow, the level of growth seems insignificant, which leads to complacency. But after a few doubling times, even small amounts can increase into staggering quantities. Indeed, one cannot understand the serious nature of the interrelated global energy and environmental problems without understanding exponential growth, and what is meant by the exponential time of 11:59. For example, if one bug is put into an empty bottle at 11:00 in the morning, and it is observed that the bottle is full of bugs at 12:00 noon, when will the bottle be half-full?

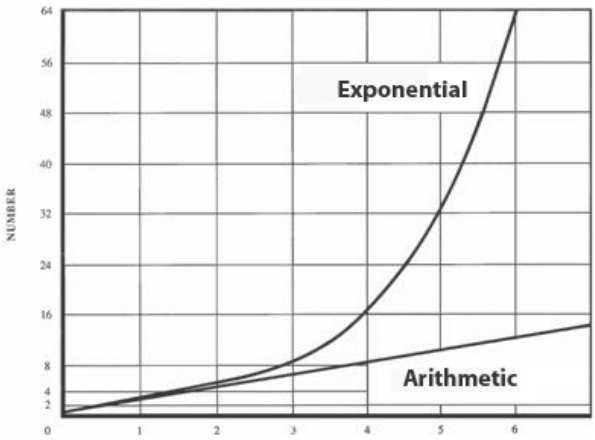
The Exponential Time of 11:59

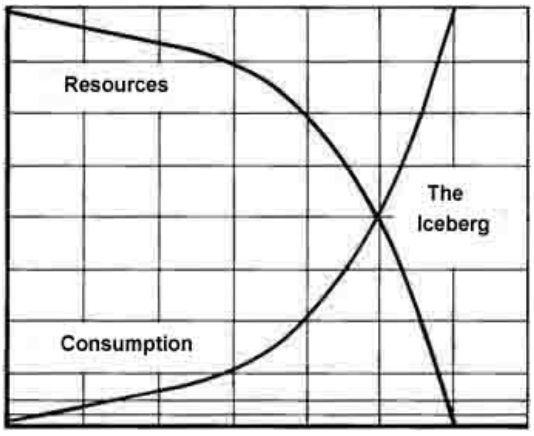


The Answer is 11:59. But the significance of this analogy is that if you were one of the bugs in the bottle, at what point would you begin to realize that you were running out of resources? Note that at 11:55, the bottle is only 3% filled, leaving 97% of the space for growth, but the exponential inertia of the last four minutes will totally consume what appeared to be a vast resource.

Arithmetic vs. Exponential Growth

Note that in the graph below that arithmetic growth increases at a constant rate. This is in contrast to the classic exponential growth curve that increases at an increasing rate. When the ascending exponential curve of consumption intersects the descending curve of resources (below right), one will find the iceberg.





Given the exponential nature of the global energy and environmental problems, it's like being in a car that is accelerating towards a cliff. After a certain point, it doesn't matter what the driver does, because the inertial momentum will propel the car over the cliff. Ships are much larger than cars, and therefore are much more difficult to turn because of their greater momentum, and global ecosystems are much larger than ships. It is why the passengers on *Spaceship Earth* are like the passengers aboard the *Titanic*, and there is very little time left to change course.

Professor Alpert Bartlett

One of the foremost experts on exponential growth is Albert Bartlett, professor of physics at the University of Colorado. Bartlett has published numerous papers and articles on exponential growth and its relationship to the consumption of energy and environmental resources. Bartlett has emphasized that one of the greatest shortcomings of most elected officials is their inability to understand the exponential function and, in particular, how it relates to the global energy and environmental problems. Bartlett describes exponentials as probably the most important mathematics students will ever come to understand. In his paper, "Forgotten Fundamentals of the Energy Crisis," published in the September 1978 issue of *The American Journal of Physics*, professor Bartlett explains that when a quantity, such as the rate of consumption of a resource, is growing at a given percent per year, the growth is said to be "exponential." It follows that a constant time will be required for the growing quantity to double its size (increase by 100%). This time is called the doubling time, T2, and it is related to P, the percent growth per unit time by a very simple equation:

$$T_2 = \frac{70}{P}$$

A growth rate of five percent per year will result in the doubling of the size of the growing quantity in a time T2 = 70/5 = 14 years. But in two doubling times (28 years), the growing quantity will double twice (quadruple) in size. In three doubling times, its size will increase eightfold, and in four doubling times it will increase sixteen fold, etc. An important characteristic of exponential growth and doubling times is that the increase in any doubling is approximately equal to the sum of all the preceding growth.

Consider that if on the first day of a 31-day month you explain this exponential concept to two other people, and by the end of the second day, each of the two people have in turn contacted two other people, 4 new people are now involved. Then on the third day, each of the 4 new people contact 2 other people, 8 new people are now involved. By the end of the forth day, the number is 16. By day five, the number is 32. On day six, the number is 64, and on day seven, the number is 128. Day eight: 256. Day nine: 512. Day ten: 1,024. Day eleven: 2,048. Day twelve: 4,096. Day thirteen: 8,192. Day fourteen: 16,384. Day fifteen: 32,768. Day sixteen: 65,536. Day seventeen: 131,072. Day eighteen: 262,144. Day nineteen: 524,288. Day twenty: 1,048,576. Day twenty one: 2,097,152. Day twenty two: 4,194,304. Day twenty three: 8,388,608. Day twenty four: 16,777,216. Day twenty five: 33,554,432. Day twenty six: 67,108,864. Day twenty seven: 134,217,728. Day twenty eight: 268,435,456. Day twenty nine: 536,870,912. Day thirty: 1,073,741,824. Day thirty one: 2,147,483,648.

In sum, starting with only one person who contacts two other people, over two billion people can be part of the solution in one month. With a doubling time of 24 hours, note how the exponential growth starts out very slow at first, but before long, the numbers get to be staggering. This is a graphic example of how powerful exponential forces are, and it is why humanity is as close to a utopia of prosperity without pollution, biochips and designer genes, as it is to an ecological oblivion of mass-starvation and death.

Utopia or Oblivion

It is important to realize that exponential growth does not have to be negative. It all depends on what is growing exponentially. An exponentially increasing savings account is obviously a highly desirable asset to own. Even a one or two percent increase in the annual rate of interest can make an enormous difference in a savings account over a period of ten or twenty years. Although the exponential growth in knowledge and information is much more difficult to quantify, there is no question that it is increasing at a staggering rate. This is particularly the case in the technical areas of engineering, computer science, molecular biology and medicine. It is only because of these explosive developments in information and technology that it seems reasonable to expect that molecular medicine will soon usher in an age where aging and disease will essentially be eliminated. With such fundamental changes in human life spans, a future of unlimited possibilities awaits those who will be able to take advantage of such biotechnologies.

The Exponential Age

Such options are based, however, on an assumption that the human community will be able to survive the many interrelated and deadly serious global environmental problems that continue to worsen exponentially. Never before has humanity been at the crossroads of such awesome opportunities -- or problems -- as the exponential forces of life and death are simultaneously evolving and racing toward some ominous conclusion. What needs to be understood by every thinking person is that the decisions that are made now could well make the critical difference in the ultimate outcome.

Climate change is being driven by our exponentially increasing use of carbon-based fossil fuels, and hydrogen made from water with electricity generated by wind and other solar technologies is the only zero carbon emission fuel that is inexhaustible and can permanently replace fossil and nuclear fuels worldwide. The fact that hydrogen is the only "universal fuel" is significant because it means that it can power virtually every existing vehicle, from the family automobile, to aircraft, ships, trains, or moon rockets, as well as power plants, or a Coleman stove operating on a mountain top.

Because of the Exponential Age in which we live, it is much later that most people think. Existing oil reserves were assumed to last for 40 or 50 years, but the primary oil fields in Saudi Arabia are already declining in their output, and globally only one new barrel of oil is produced to replace each two that are consumed. Production is these Saudi oil fields will soon begin to drop off dramatically, which will have a catastrophic impact on the global economy and food production systems, because it takes ten calories of fossil fuels to make one calorie of food. However, even if there were a 1000-year supply of oil, with 5% annual growth in consumption, the 1000-year supply would be exponentially consumed in only 79 years.

The U.S. now consumes about 100 quads (i.e., quadrillion Btus) of energy annually, and has approximately 5,600 quads of coal reserves, and presently consumes approximately 22.3 quads per year of coal to generate approximately 50 percent of the electricity. This means there is a 250-year supply of coal. However, if coal were to be used to make hydrogen for 100% of the current U.S. energy requirements (i.e., 100 quads annually), even assuming no energy growth in demand, the 250-year supply of coal would be consumed in approximately 56 years (i.e., 5,600 quads divided by 100 quads = 56). However, it actually takes four times as much coal to make a similar quantity of energy in the form of hydrogen than it does to make electricity directly, which means the 5,600 quads of coal would be consumed in only 14 years, and the environmental impact from the strip mining and mercury emissions would be devastating. And for those who ask why don't we just use coal to make electricity instead of hydrogen, the answer is that electricity cannot fuel the engines that power aircraft, ships, trains, trucks, automobiles, or the power plants that are now fueled by gasoline, oil and other fossil and nuclear fuels.

Even if the oil and coal reserves were inexhaustible, their profoundly negative environmental impacts would still dictate a transition to a solar hydrogen energy system. Given these exponential consumption realities, the focus needs to be on manufacturing hydrogen from water with renewable energy resources and technologies, which is what photosynthetic green plants on the earth have been successfully doing on a global scale for over 3.5 billion years. Unlike oil and natural gas, the renewable energy technologies can not only make the U.S. energy independent, but allow it to be transformed from the world's largest energy importer, to the world's largest energy exporter of a fuel that is pollution-free and inexhaustible. We have found our civilization addicted to an "Oil Economy" that is highly polluting and rapidly diminishing, and we have the opportunity to replace it with a "Solar Hydrogen Economy," which will provide "sustainable prosperity without pollution" for the global human community.

Phoenix Project Foundation
6128 North 28th Street, Suite 100, Phoenix, Arizona 85016, Telephone: 602-977-0888
Email: hb@PhoenixProjectFoundation.US