Searchlights in the Darkness

Books Reviewed by John Attarian

The Essential Exponential! For the Future of Our Planet
by Albert A. Bartlett
Lincoln, NE: University of Nebraska-Lincoln, Center for Science, Mathematics & Computer Education
294 pages, $25.00 paperback

The Truth About Oil & the Looming Energy Crisis
by C. J. Campbell
Ireland: Eagle Print
56 pages, $30.00 paperback
Can be ordered from info@eaglepress.net

If we are going to respond intelligently to oil extraction's peak and decline, and to the broader problem of population growth in a world of depleting nonrenewable resources, it is imperative that the public be educated about our predicament. Two recent books by prominent scientists are outstanding resources for this task.

In articles and oral presentations, University of Colorado physicist Albert A. Bartlett has worked for decades to explain the exponential function, exponential growth, its manifestations, and the momentous implications. He maintains that "The greatest shortcoming of the human race is its inability to understand the exponential function." *The Essential Exponential!* brings together his papers on this vitally important but obscure phenomenon.

An exponential function is one in which a variable increases at a fixed *rate* (percent) per time period, as opposed to a linear or arithmetic function, in which growth is by a fixed *amount* per period. An example of exponential growth is the doubling sequence 1, 2, 4, 8, 16, 32, …, whereas 1, 2, 3, 4, 5, 6, …, illustrates arithmetic growth. An exponential function may be expressed as

$$N_t = N_0 e^{kt}$$

where N_t is the value at time t, N_0 is the initial value, k is the growth per unit time, t is time, and e is the base of natural logarithms, 2.71828.

The time required for a variable growing exponentially to double is constant. It turns out that the doubling time (T_2) may be calculated by dividing 70 by P, the growth rate per unit time, or

$$T_2 = 70/P$$

That's really all there is to it. Although the mathematics may look unfamiliar, exponential growth, as Bartlett shows, is going on all around us. An important example is oil consumption, which he addresses in his classic 1978 article, "Forgotten Fundamentals of the Energy Crisis," which alone is worth the price of the book. After concisely explaining exponential growth and doubling times, Bartlett argues convincingly that protracted growth of both population and per-capita energy use are driving our energy problem. The steady growth of oil consumption is analogous to the reproduction of bacteria by fission in a bottle, with the bottle representing fixed oil supply, and the steady growth of oil consumption analogous to bacterial population growth. If more oil is discovered (more bottles are added) the reprieve is illusory; if resource use is growing exponentially, quadrupling the amount of the resource extends its lifetime by only two doubling times!

Bartlett draws the moral that: "The question of how long our resources will last is perhaps the most important question that can be asked in a modern industrial society." Resource lifetime depends on the

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resource endowment and how fast its consumption is growing. Consumption growth makes oil's lifetime much shorter than most people realize. After warning that "Modern agriculture is the use of land to convert petroleum into food," and adding that he is not trying to predict the future, just illustrate what steady growth in energy consumption implies, Bartlett advocates education in the "forgotten fundamental" of the arithmetic of growth; conserving; recycling; researching alternative energies, and shifting to a decentralized, humane-scale economy.

In articles on coal and fossil fuel lifetimes, Bartlett uses the exponential function to deflate widely publicized, large estimates of fossil fuels' lifetimes at current rates of consumption. He points out, correctly, that consumption is growing, and mathematically demonstrates the consequences. His more general treatment, "Expert Predictions of the Lifetimes of Non-renewable Resources," should be required reading for energy analysts. Citing a 1992 claim that world fossil fuel reserves will last 600 years at current rates of consumption, Bartlett shows that even modest steady growth in consumption causes startlingly large declines in resource lifetime. If consumption increases just one percent a year, the estimated lifetime for world fossil fuels drops from 600 years to 195; at two percent annual growth, it drops to 128 years; and if consumption grows three percent annually, fossil fuels will last just 98 years.

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Turning to oil peak and decline, Bartlett presents a mathematically rigorous analysis of production data available as of 1995 in "An Analysis of U.S. and World Oil Production Patterns Using Hubbert-Style Curves" (2000). A Gaussian error curve best fits the data, and implies that if the world's total estimated oil recovery is about two trillion barrels, about half had been extracted as of 1995, and annual production will peak in 2004. Different estimates generate different peak forecasts: with three trillion barrels of oil, peak occurs in 2019; with four trillion, extraction peaks in 2030. Put another way, every additional billion barrels of oil recovered delays peak about five and a half days. (It would have been interesting had this article been updated.) Bartlett concludes somberly that current rates of oil consumption are unsustainable, and that "a society cannot be sustainable as long as it remains vitally dependent on oil." Given his analysis, his conclusion is indisputable.

A main driver of energy use is population growth. Using simple arithmetic and elementary algebra, "Zero Growth of the Population of the United States" presents the combinations of births and immigration per year which would halt our population growth. This implies a tradeoff whereby more births require less immigration, and vice versa, to maintain a given growth rate. ZPG is desirable on resource preservation, environmental protection, and other grounds, Bartlett argues, and both lowering fertility and stopping or reducing immigration are essential to national survival.

"Democracy Cannot Survive Overpopulation" argues convincingly that overpopulation, by raising the number of constituents per elected official, makes it harder for individuals to gain access to representatives and have a voice in politics. Also, overpopulation breeds government regulation to cope with problems caused by population pressure.

Bartlett observes with dismay that evasion of Malthus's warnings about population growth is widespread. This evasion takes two forms: denial of the problem, and diversion of attention from the arithmetic of population growth to other things, by invoking other causes of environmental problems (e.g., high personal consumption), arguing that sustainable development is the answer, or asserting that overpopulation is a problem in developing countries, not in America. Bartlett rebuts these claims, pointing out that population growth is at the heart of environmental problems, that immigration contributes substantially to population growth, and that our high resource use makes America one of the world's most overpopulated countries.

Indeed, resource use receives much attention. "Sustained Availability: A Management Program for Nonrenewable Resources" is a rigorous mathematical derivation of the depletion rate which would allow a nonrenewable resource to last forever. It turns out to be negative: less is used each successive year. Since America is already descending the Hubbert curve, such a management plan doesn't make sense for oil, Bartlett argues, but it does for coal. Some "experts" recommend rapid depletion of nonrenewable resources on the assumption that we can always develop alternatives. He advocates the prudent course n the one which will leave us least badly off if it turns out to be wrong n which is conservation.

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In a long, thoughtful essay on sustainability and population growth, making many valid points, Bartlett notes that sustainable means able to persist for an indefinitely long time, therefore "sustainable growth is an oxymoron." He warns that population growth can devour resource savings from improved efficiency, and that if we do not stop the growth of population and resource consumption, nature will.

Some articles by other scientists are included, the best being M. King Hubbert's "Exponential Growth as a Transient Phenomenon in Human History" (1976). Surveying the exponential growth in population and in coal, oil, and iron extraction, Hubbert asks if this is sustainable n put another way, how many doublings of these phenomena are possible. He invokes grains of wheat placed on chessboard squares in geometric sequence, 1, 2, 4, 8, etc., to argue that Earth cannot tolerate many doublings. Rapid growth of population and industrial output, then, "must be a transient and ephemeral phenomenon of temporary duration."

The book presents the exponential function itself, doubling times, and real-world applications, etc., in two series of articles, "The Arithmetic of Growth" and "The Exponential Function." Population applications are sobering. Steady 1.9 percent annual growth (i.e., the 1976 world population growth rate) implies, Bartlett points out, that population doubles in just 36 years n and that food production must also double in 36 years just to hold constant the population *share* of people dying of hunger, whose *number* would *also* double. To have fewer hunger victims, food production must greatly outrun population growth. "Thus, before we have done any serious calculations we can see that the population explosion is the most serious problem facing mankind!" Using this growth rate, Bartlett also shows that if humanity began with a single couple, they must have lived in 849 A.D. Since they obviously didn't, population must have grown *faster* than exponentially. (The graph of population growth since 8000 B.C., resembling a hockey stick, bears this out.)

Bartlett's use of the exponential function to demolish one of Julian Simon's loopier bloviations is not to be missed. Simon claimed in 1995 that we had enough technology to adequately support "an ever-growing population for the next 7 billion years." Challenged, Simon said that "7 billion" should read "7 million." Starting from 1995's population of 5.7 billion and assuming an annual growth rate of one percent, Bartlett calculates that in 7 million years, the world's population would be 2.3×10^{30410} people. This number, he adds, is roughly 30,000 times larger than the estimated number of atoms in the known universe. Imagine what we'd have been spared if only Julian Simon had been required to study the exponential function under Al Bartlett!

Some general observations stand out in Bartlett's book. In just a few doubling times, exponential growth can yield huge quantities. Even modest growth rates can generate large numbers surprisingly quickly. Estimates of resource lifetimes at current consumption rates are worthless, given growing resource use. While non-physical things, such as compound interest, can grow for long periods, the finitude of matter makes growth of physical phenomena such as populations and resource extraction unsustainable.

Because understanding Bartlett's book depends on your grasp of the exponential function, how to approach it does, too. Readers familiar with the function can start with "Forgotten Fundamentals of the Energy Crisis." If you've forgotten it since high school or college, you should start with "The Arithmetic of Growth: Methods of Calculation," "The Exponential Function — Part I," or both (placed, perhaps mistakenly, toward the back of the book). If need be, consult an algebra or calculus textbook. The payoffs for your time investment will come throughout your study of the book; and prose pieces aside, Bartlett requires not reading, but study: following his mathematical derivations, working his examples, thinking things through. Make the effort, and you will be astonished at how the mathematics make the principles starkly clear, and pleased with yourself at your grasp of Bartlett's message.

Bartlett is renowned as a teacher, and in these clear, well-structured articles, we see why. His expositions are well supported with numerical examples, his prose crisp and readable. The articles make a nice blend of differing levels or rigor.

Working through *The Essential Exponential!* is like getting a solid, college-level tutorial on the exponential function by a first-rate teacher. It's a worthwhile challenge. If politicians, businessmen, and opinion leaders mastered this book, we'd all be a lot better off.

Our situation would also improve if everybody read petroleum geologist Colin Campbell's short book *The Truth About Oil & the Looming Energy Crisis*, written for general readers. Campbell argues that oil depletion is the "most critical but least understood of subjects," and that we all need to understand it, both to plan our lives, and "to give the politicians the mandate for the unpopular actions they will be obliged to take." Our enormous dependence on a steady, cheap oil supply means depletion will force radical restructuring of the way we live. While difficult, this "is not a hopeless cause. We have perhaps twenty years to adapt before oil production need fall below present levels, and even then we face no more than a gentle decline." Unfortunately, given our long conditioning to believe in markets and technology, oil peak will be a profoundly traumatic shock.

Written in the form of an imaginary public inquiry into depletion, Campbell's book presents previous oil discovery and production, forecasts future discovery and production, and explains depletion's consequences. Tables giving country-by-country production and reserves data, production forecasts, and so on, accompany. Campbell points out that oil is very unevenly distributed, present in large quantities in only a few locations. Moreover, the planet has been thoroughly explored.

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Muddles over data and definitions are serious, especially regarding "reserves." As an oil field is developed, estimates of reserves get revised upward, creating a misleading impression that reserves are growing. In fact, Campbell observes, all the oil was found when the field was discovered, so accuracy demands backdating reserve revisions to when the field was found. His chart of discovery and production trends since 1930 shows that world oil discovery peaked in the 1960s and that since the mid-1980s, annual production has exceeded discovery by a growing margin. Discovery is projected to decline to virtually nothing by 2050.

As Campbell sensibly points out, oil must be found before it can be extracted, therefore "falling discovery must in due time be reflected in falling production." So extrapolation from past discovery is a good way to forecast future production. Resource finitude implies extraction peak and decline, but Campbell acknowledges that economic and political factors, especially price, will affect production.

Campbell breaks down oil by physical characteristics and the nature of its location: "regular" (i.e., conventional), shale, heavy, deepwater, and polar oil, as well as liquids obtained from extracting and processing natural gas. Factoring in oil price shocks when ceilings on production capacity are hit, and resulting recessions and lowered demand for oil, he tentatively forecasts a peak for regular oil in 2005, with all liquids peaking before this decade's end, after which supply will start dropping by about 2.5 percent a year.

Oil's peak and decline will greatly disrupt economic activity, especially trade and food production. However, reduced carbon emissions may relieve climate-change concerns, and less energy-intensive fishing may enable fish stocks to recover. Campbell sees three possible responses to peak and decline: profiteering by the oil-producing countries, which could trigger devastating recessions; seizure of oil by consuming countries, who might accelerate extraction to reduce prices, bringing on an earlier peak and faster subsequent decline; and restrained consumption. Only the last makes sense, he argues, and could be managed by an international Depletion Protocol, whereby importers cut their oil imports at the same rate as global depletion, keeping price reasonably linked to production cost and eliminating profiteering with its destabilizing international shifts of liquidity.

Given the unreliability of publicly available data, the "most urgent need," he rightly maintains, is to get an accurate picture of the oil and gas situation, through well-funded research accessing industry data or collecting data firsthand. Once obtained, accurate data should be disseminated to the public, which needs to understand that depletion is a geological phenomenon and that shortages and rising prices "do not necessarily speak of fraud, conspiracy, gouging and profiteering," though these may occur.

We must also minimize oil waste, using fiscal incentives and penalties such as high prices for "gas-guzzler" vehicles and revising corporate taxation so transport costs may no longer be charged against taxable income. While free markets could operate within the depletion provisions, rationing may eventually be necessary to ensure everyone a minimum supply. Unpleasant? Maybe, but there is no blinking Campbell's point that when things get scarce, "the most obvious response is to use less of them."

Finally, we should shift to renewable energy. Renewables have made little headway, Campbell observes, because they are competing with "fossil fuels being dumped onto the market at far below replacement cost – that being, in fact, infinitely high." Shifting to renewables should be undertaken at the local level, which may, he concludes, also enhance our sense of solidarity and community.

Compact and informative, this book is a good education in oil depletion basics. It includes a CD-Rom containing ten PowerPoint presentations, for Windows and Macintosh, on discovery of oil to date, how much remains to be found, depletion modeling,

Geology Dictates World History

Regarding recent events in the Indian Ocean, a statement by historians Will and Ariel Durant in their final book, *The Lessons of History* is appropriate:

> *History is subject to geology. Every day the sea encroaches somewhere upon the land, or the land upon the sea; cities disappear under the water and sunken cathedrals ring their melancholy bells. Mountains rise and fall in the rhythm of emergence and erosion; rivers swell and flood, or dry up or change their course; valleys become deserts and isthmuses become straits. To the geologic eye all the surface of the earth is a fluid form, and man moves upon it as insecurely as Peter walking on the waves to Christ.*

Elsewhere they state it succinctly: "Civilization exists at the whim of geology – subject to change without notice."

In the final analysis the earth, with its movements and its mineral and energy resources, runs the show.

Walter Youngquist, Ph.D.

Eugene, Oregon

myths about oil, examples of depletion, and more, with numerous charts on, e.g., production and discovery trends and worldwide location of regular oil. Thanks to the CD-Rom, Campbell's book is suitable for lectures and slideshows, greatly enhancing its power as a teaching tool.

Exponential growth and oil depletion are two of the most powerful forces shaping the future of every reader of this page. They imply that our growth-based way of life is doomed. Our existence in ignorance of them is a night march toward a precipice.

Mastering these wise books turns on searchlights in the darkness.