

several books, Eric Greenleaf is a practicing psychologist in California, and Alice is a columnist, author and teacher.

More on coal reserves

I read with great interest and some dismay the letter by Albert Bartlett (December, page 10) discussing the life expectancy of US coal reserves. Two aspects of his model appear to be oversimplified. Bartlett assumes an exponential growth of coal consumption, $C = C_0 \exp(kt)$, up to the time T at which the total coal reserve R is depleted. It is more realistic to assume that at some time in the future the consumption rate will begin to decrease, either due to a deliberate policy decision or (more likely) because of the increasing difficulty and expense of mining the remaining coal.

An eventual declining consumption rate is most simply incorporated into Bartlett's model by assuming exponential consumption up to a time aT (where a is some number less than one) and a linear decrease in consumption until depletion at time T . The result of this model is

$$\frac{kR}{C_0} + 1 = \left[1 + \frac{1}{2} kT(1-a) \right] e^{akT}$$

The times T corresponding to an assumed value of $a = 0.5$ for various values of k are shown in the table along with Bartlett's results. The values used for R and C_0 are those quoted by Bartlett:

$$R = 1.49 \times 10^{12} \text{ metric tons}$$

$$C_0 = 5 \times 10^8 \text{ metric tons per year}$$

It could be argued that an exponential consumption rate is too drastic, especially in view of the recent history of coal consumption. In this case, a linearly in-

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These results show that allowing for a declining consumption rate in the future increases the predicted lifetime of our coal reserves by about 50%. If, however, the consumption rate is more nearly linear, the lifetime of US coal reserves would be considerably extended, perhaps to the point where alternative energy sources could be successfully found. Bartlett's basic argument, that our coal reserves are finite, remains unaltered.

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THE AUTHOR COMMENTS: Daniel Winicur gives my calculations more dignity than they deserve. They are not a model. They are not offered as predictions even though I glibly spoke of "the day after the reserves run out." They are only calculations offered in the hope that they can be used by the physics community to add a sobering touch of realism to the glowing predictions of those who say that we can vastly increase our annual production of coal and have the coal last a very long time.

Life expectancy of US coal reserve

Annual growth in consumption (percent)	Simple exponential growth	Years R will last:			
		Exponential growth/linear decay $a = 0.5$	Linear growth and decay		
			$a = 0.5$	$a = 0.75$	
20	32.0	51.2	237	194	
15	—	64.9	272	223	
10	57.0	90.4	331	270	
6.69	79.2	125	400	328	
5	100	157	459	376	
3	149	233	582	477	
2	205	316	701	575	
1	342	519	952	782	
0	2980	3973	3973	3406	

creasing consumption rate followed by a linear decreasing rate provides the following solution for the depletion time

$$T = \left(\frac{a+1}{2ak} \right) \left[\sqrt{1 + \frac{8akR}{(a+1)^2 C_0}} - 1 \right]$$

"... the real aim, to increase coal's share of the (growing) energy market will require a staggering growth rate."

"Our coal reserves are so huge that they could last a minimum of 300

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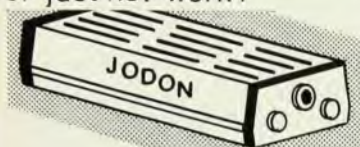
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years and probably a maximum of 1000 years."²

Should members of the physics community sit back and say nothing when energy industries advertise,

"There is an increasing scarcity of certain fuels. But there is no scarcity of energy. There never has been; there never could be. Energy is inexhaustible."³ [Emphasis is in the original.]

How do we react when we read,

"Energy industries agree that to achieve some form of self-sufficiency the US must mine all the coal that it can."⁴

People may wish that we could greatly increase our rate of coal production and have the resource last for a very long time, but we as scientific educators cannot let our people continue to place their faith in Walt Disney's First Law:

Wishing will make it so.

What I offered was not a model but rather was the simplest possible calculation that could be used to demonstrate the effects of continued growth in rates of consumption of fossil fuels. Because the exponential calculations are simple⁵ and because so few people seem to have calculated the effect of growth on the life expectancy of non-renewable resources, I have characterized my equation 1 as "The best kept scientific secret of the century."⁶

In reality, coal production will not rise exponentially until the day the resource expires. Rates of consumption will decline, as Winicur suggests. M. King Hubbert worked out detailed models years ago. His curves (see the figure in my letter) have the appearance of a Gaussian error curve and they are based on actual data from resources that are now nearly exhausted. Hubbert's models are set forth beautifully in many of his publications.^{7,8,9} The models and an account of the difficulties that Hubbert has encountered in many years of trying to convey their meaning and import to the scientific and political communities are eloquently summarized in considerable detail by G. Pazik.¹⁰

Our economy is totally committed to continued steady growth of the rates of consumption of energy resources. In this context I am distressed to read the opening words of the AIP publication on energy:¹¹

"The United States has an abundance of energy resources; fossil fuels (mostly coal and oil shale) adequate for centuries, fissionable nuclear fuels adequate for millenia, and solar energy that will last indefinitely."

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6. "The Forgotten Fundamentals of the Energy Crisis," paper presented at the UMR-MEC Conference on Energy, Univ. of Missouri at Rolla, 12 October 1976. Copies are available from the author.
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8. M. King Hubbert, chapter 3 in the book "Energy and Power," W. H. Freeman, San Francisco, 1971 and *Scientific American*, September 1971.
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10. G. Pazik, *Fishing Facts*, November 1976, pages 4-33 (available from Northwoods Publishing Co., P.O. Box 609, Menomonee Falls, Wis. 53051).
11. "Physics and the Energy Problem," American Institute of Physics, New York (1974); page 1.

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Refereeing rectitude

E. R. Harrison (January, page 85) is entirely right in his misgivings about the refereeing system. The original notion was that a man's work would be assessed by unbiased (because disinterested) peers, and there is no reason to doubt that this is what actually happened during the romantic period of science's growth. Publication media were few and far between, and editors saw it as their principal task to protect their pages from humdrum contributions.

Nobody would want to deny that this is still an editorial task, but it is only one of many. No less important is the editorial obligation to ensure that matters of conceptual novelty pass into print, if necessary even in the face of Establishment misgivings. An occasional piece of nonsense might filter through, but this danger must always be weighed against that other danger: the suppression of originality. No schematic rule can serve both tasks, and it would be unrealistic to look for a formula that would free editors from the responsibility for editing.

However, it is useful to point out that refereeing practices have in fact been reformed (here and there). The *Materials Research Bulletin*, for instance, has been operating since its inception in 1966 along