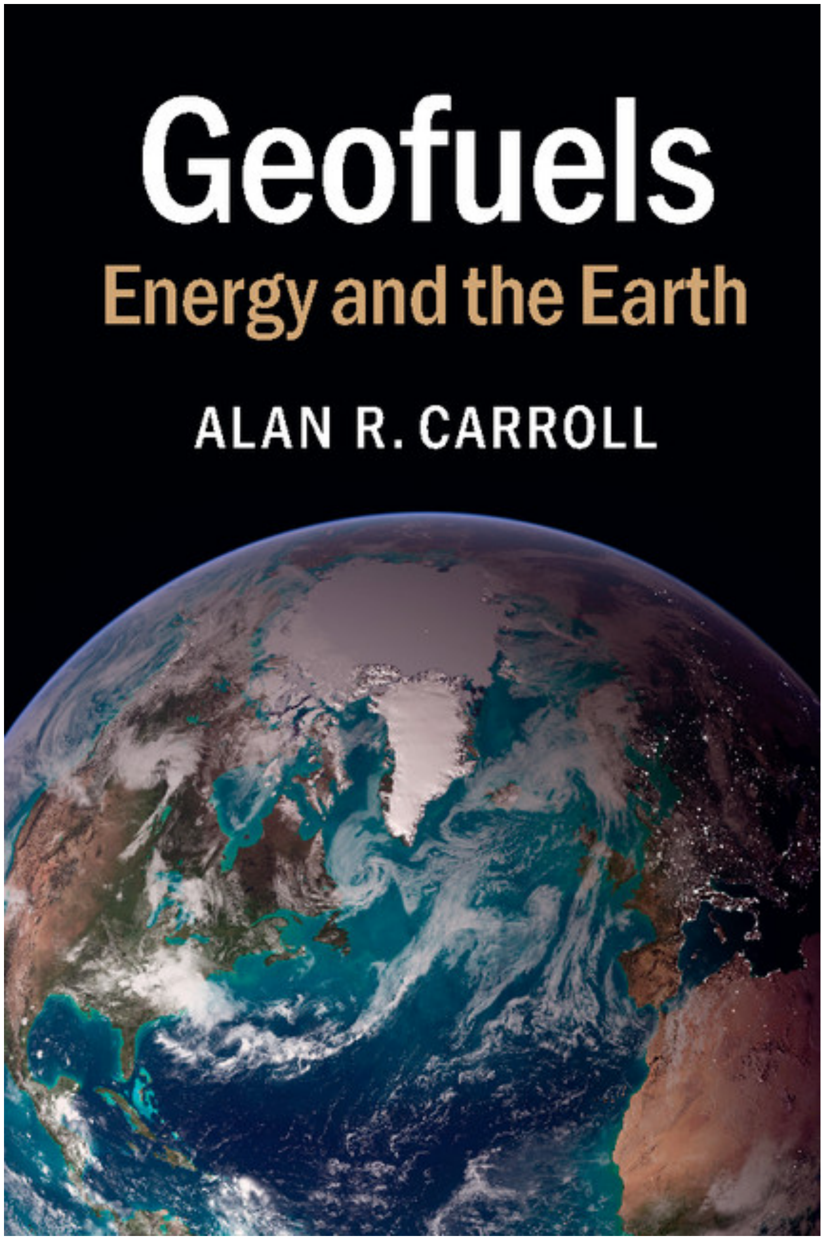
The Future of Fossil Fuels

Excerpts from “Geofuels: Energy and the Earth” by Alan Carroll



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The idea that we are about to run out of fossil fuels has been with us nearly as long as fossil fuels themselves. A continual procession of prognosticators have foretold their imminent decline, based on the seemingly common sense principle that reserves are finite, but future demand is not. For example, economist William Stanley Jevons predicted in 1865 that the British prosperity would soon be stifled due to the inability of coal supplies to keep up with exponentially rising demand. In 1921 the director of the U.S. Geological Survey, George Otis Smith, warned that "The estimated reserves are enough to satisfy the present requirements of the United States for only 20 years…".

M. King Hubbert predicted in 1956 that the United States would soon see its oil production reach a peak, and then begin to decline. The central tenet of his "peak oil" concept was that the decline of U.S. production would be a mirror image of its rise, eventually resulting in a nicely symmetrical bell-shaped curve. If you know the shape of the rising limb of such a curve, along with the total amount of available reserves, then the timing of peak production can be easily deduced. Hubbert predicted that a peak of U.S. production would arrive in either 1965 or 1970, on the basis of two different reserves estimates. The latter prediction ultimately proved correct.

Global *discoveries* of new oil and gas accumulations peaked in the 1960s to 1970s, leading many experienced and thoughtful experts to predict that a peak in world oil production would soon follow. To date, reality has stubbornly refused to cooperate with these predictions. Unlike oil production in the United States, world oil production has not peaked. Production in 2014 exceeded that of any previous year, and the International Energy Agency projected that increases would continue until at least 2040. Even Hubbert's apparent success in predicting U.S. peak oil production may not have been what it seemed; after decades of steady decline U.S. oil production actually reversed course and began to rise again in about 2008.

So why has world oil production thus far failed to peak as expected? Possibly the peak has only been delayed and is just around the corner. Only time will tell. Meanwhile the peak oil concept itself needs to be more closely scrutinized. As it turns out, real-world oil production histories often fail to conform to the idealized bell-shaped curve, a fact first noted by Hubbert himself. Conversely, bell-shaped production histories do not necessarily reflect resource depletion. For example, anthracite coal production in Pennsylvania traced out a beautifully symmetric curve during the late 19th and early 20th centuries, peaking around 1920. As the geologist Peter McCabe pointed out in 1998, however, nearly all of the known anthracite remains untouched! Rather than reflecting resource depletion, the decline in production resulted from the entry of cheaper energy sources into the market, including oil and lower-rank coal.

Although intuitively appealing, the peak oil concept entirely disregards the fact that the production of any natural resource is controlled as much by market factors and extraction technology as it is by natural abundance. Whereas the Earth's total oil endowment is clearly fixed, its economically extractable endowment of oil is not.

Held in Reserve

The word "reserves" is frequently used to indicate a quantity of crude oil or other resource remaining in the ground, usually with the implication that this quantity represents a finite limit. But what does the word really mean? Its actual definition is often left unspoken, and the common addition of modifying terms such as "proven" or "probable" only multiplies this confusion.

The word "reserves" derives from the Latin verb *reservare*, which means to keep back. If you reserve a hotel room your expectation is that a room will be held for your arrival; in military usage the noun "reserves" refers to troops who are held back from the main fighting force. The word "reservoir" shares a similar derivation; for example, an artificial lake can be thought of as part of a river that is being kept back by a dam. Note that in none of these cases do reserves imply an absolute quantitative limit. The hotel has other rooms in addition to the one you reserved, the military has many active duty soldiers in addition to reserves, and the whole volume of water that flows through a river is not contained in a single reservoir.

Extending this idea to crude oil, reserves would constitute oil that has been intentionally held back, as a buffer against future increases in demand or unexpected supply interruptions. If so, then there is really not much difference between oil and any other commodity. For example, Peter McCabe used an analogy to baked beans kept in a grocery store warehouse. The purpose of the warehouse is to ensure that grocery store shelves can be kept continuously stocked, regardless of short-term fluctuations in the public's appetite. Should the shelves become depleted, the store manager has only to call the warehouse and ask them to send over some additional cases.

The amount of baked beans stored in the grocery warehouse obviously has no bearing on the total amount of baked beans that exist in the world at a given moment or that may exist in the future. The warehouse is merely a tool used by grocery stores to guarantee a steady supply of beans to store shelves. With proper management the warehouse need never actually run out of beans; the cans that are removed to stock store shelves are continuously replenished with shipments from the baked bean supplier. Enough beans need to be kept on hand to meet normal fluctuations in demand, but no more. Increasing these reserves would only add cost, because of the need for a bigger warehouse.

Reserves on Demand

The vast majority of our available crude oil does not reside in tanks, pipelines, or strategic petroleum reserves. Instead it remains in its original state, trapped below the surface within porous rocks. Even so, these geologic reserves can still be viewed as analogous to baked beans in a grocery warehouse, provided you take a slightly longer-term view. Increases in the market demand for oil can be accommodated by increasing the rate at which it is pumped from the ground. Accomplishing such increases generally requires more than just opening a valve, however.

Returning for a moment to the grocery analogy, imagine a warehouse that was originally designed with a very small delivery chute, through which beans must be pushed out one can at a time. The chute limits the rate at which store shelves can be restocked. It may be large enough to keep stores supplied on most days, but should holiday picnics trigger unusually high bean demand the small chute could cause a temporary shortage. A carpenter could remedy the situation by building a larger chute, but that job could take days or maybe even weeks. By then the holiday would be only a distant memory.

The narrow well bores through which crude oil must pass are the functional equivalent of small warehouse chutes. Minor increases in oil demand may be accommodated by pumping it more quickly from existing wells, but larger increases require drilling more wells. Drilling those wells can easily require months or years to complete, provided that sufficient drill rigs are available and work starts immediately.

Meanwhile the failure of oil production to keep pace with consumer demand may result in rising oil prices, especially if the increased demand reflects a global trend. Eventually, though, the higher prices should provide an incentive for greater oil production, which in principle should push prices back down.

Proven reserves of crude oil definitely do not equal the total amount of potentially accessible oil contained in the Earth's crust. The history of reported reserves in the United States makes this point clear. For example, in 1921 the United States had approximately 8 billion barrels in proven reserves. By midcentury this figure had grown by a factor of nearly 20. In 1956 Hubbert estimated U.S. "ultimate potential oil reserves," the sum cumulative production, proven reserves, and future discoveries, to fall between 150 and 200 billion barrels. By 2010 cumulative oil production had eclipsed the latter amount, and by 2014 annual production in the U.S. had rebounded to approximately 90% of its 1970 peak.

The Resource Pyramid

How is it possible for reserves of crude oil to grow continuously when we know that the total amount of oil contained in the Earth is finite? The short answer is that reserves only constitute a small fraction of the Earth's natural endowment of crude oil. This relationship can be conveniently expressed through the "resource pyramid," a commonly used metaphor for crude oil and other geologic resources. The overall volume of the pyramid represents the Earth's total endowment of oil, whereas its uppermost tip represents oil reserves. Geologists define reserves as *the known amount of crude oil that can be profitably extracted, assuming present- day technology and economic conditions*. Note that under this definition, the price of oil matters as much as its physical abundance in the Earth. If the price of oil rises, it becomes profitable to dig deeper into the pyramid, converting more of the Earth's total oil endowment into reserves. The same thing can happen if a new technology, for example, rotary drilling or hydraulic fracturing, allows oil to be extracted at a lower cost.

In addition to being profitable to extract, reserves by definition must be *known*. The subdivisions proven, probable, and possible denote the certainty with which they are known to exist. For oil and gas this knowledge is gained primarily from drilling; more wells provide more certainty. Strange as it may seem, the vast majority of the Earth's crust has never been tested by drilling, and much of it has never even been imaged by seismic surveys. The reason for this knowledge gap is simple: drilling and seismic surveys are extremely expensive. Oil producers must therefore weigh new exploration against the anticipated future price of oil, and the competing value of other possible investments. Only the most promising areas have been drilled.

Our comprehension of oil reserves also changes continuously as geologists learn more about how these deposits are formed. In the mid-19th century such knowledge was extremely limited, and oil was found mostly by digging in places where it naturally seeps out onto the Earth's surface. The anticlinal theory of oil entrapment came along later in that century. It eventually resulted in an enormous increase in known commercial oil supplies, including most of the oil in the Middle East. Later still it was discovered that oil could be trapped between different rock layers that gently converge in the subsurface, even if those layers do not form an anticline. These more subtle "stratigraphic" traps further expanded known supplies. Over the past few decades we discovered that oil and gas can also be profitably extracted from rocks that lack any distinct trapping mechanism. These Cenothermic deposits are held in place by the low permeability of their host rocks, or by thickening of oil due to microbial scavenging of its solvent components.

Reserves figures also depend directly on the technology used to find, extract, and utilize crude oil. In 1800 the world's total reserves were near zero, because oil was not yet widely used as an energy source and extracting it from the ground was very difficult. Shovels and pickaxes were used to dig the earliest oil wells, eventually giving way to crude drilling tools lowered by cables, and later to modern rotary drilling. Each new advance has spurred increases in world oil reserves, which up until now have conveniently kept pace with world's increasing population and their demand for oil.

Can this pattern be sustained forever? Clearly not, unless "forever" stretches into the millions of years required for fossil fuel renewal. But how much oil is available over timescales that humans care about? The answer to this question depends on how much further down we can profitably dig into the resource pyramid.

Digging Deeper

The next level down in the pyramid contains "resources," which include that portion of Earth's total endowment of coal, oil, or natural gas that we think could potentially be converted into reserves at some time in the future. In 1972 the director of the U.S. Geological Survey, V. E. McKelvey, proposed that resources are of three basic types: those that have not yet been discovered, those that cannot be profitably extracted under present-day technology and economic conditions, and those that haven't been discovered *and* are not presently profitable. The future conversion of resources into reserves depends on new exploration efforts, advances in technology, increased commodity price, or some combination of these factors.

Because of this fundamental dependency on events that have not yet happened, the ultimate magnitude of fossil fuel resources is effectively impossible to know. You might as well ask what home mortgage rates will be in ten years, or which stocks will rise the most in value. The futility of the latter question was nicely demonstrated by a recent experiment in which a British house cat named Orlando picked stocks by throwing a toy mouse at a list of companies. Over the course of a year Orlando's picks outperformed those made by a team of market professionals by a large margin. Either Orlando possessed a level of innate financial acumen that eludes most humans, or else future stock prices are governed by information we do not yet possess. Foreknowledge of the impact of future fossil fuel technology and markets has proven to be similarly elusive.

Neither reserves nor resources represent fixed, finite quantities, but reserves are at least objectively measurable, whereas resources are by definition subjective. As described by the MIT economists M. A. Adelman and M. C. Lynch in 1997, reserves represent "inventory" that has been created and renewed by continuous investment in exploration and development. Resource estimates, on the other hand, represent "implicit forecasts of investment, therefore of future technology, which nobody knows." In the case of crude oil and natural gas these forecasts have generally grown progressively more optimistic through time, resulting in ever-larger resource estimates.

Conclusions

We will never truly exhaust the Earth's endowment of fossil fuels, but there may come a time when they become economically unattractive. Precisely when this time will arrive is difficult or impossible to know, because it depends on future economic and technological events that have not yet happened. Past predictions of imminent disaster have failed with remarkable consistency. Current predictions of the future availability of nonrenewable energy vary widely, depending on the energy source, how it is used, and who does the predicting. What is not in doubt is that the consequences of energy consumption will be with us for much longer periods, which could well exceed the lifetime of our species. The release of greenhouse gases may peak within the next century or two, but their long-term impact is expected to persist for tens of thousands of years beyond that.

Excerpts from *Geofuels: Energy and the Earth* (Cambridge University Press).