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End of the Oil Era

Cause for Concern

The year 1859 was a double milestone in world history. Charles Darwin published his *Origin of Species*, and across the Atlantic, in a 33-state America, Edwin Drake sank the first US oil well in Titusville, Pennsylvania. Darwin offered the concept of the extinction of entire species as the backdrop for a potentially finite "Human Era," while Drake's discovery ushered in the "Oil Era," whose end, some speculate, is not very far off.[1,2] Since that year, oil has become the foundation of individual empires and a source of wealth for nations endowed with abundant reserves. Measured in antiquated units of 42-gallon barrels, oil is both a practical commodity and a tradable international currency. Oil is used to produce a wide diversity of products, such as fuel, plastics, paint, nylon, cosmetics, toothbrushes, and toothpaste. Our freedom of movement depends on oil for gasoline, a liquid that propels, pollutes, and has typically cost less than most bottled water. Oil's global abundance is ultimately unknown, yet the competition for control of this resource in the Middle East and fear about its future have been an impetus for war.[3]

That the world must run out of oil, perhaps some day soon, seems so obvious to most people that it is difficult to believe the topic is debated among scholars ranging from scientists to economists. After all, there is a finite amount of oil in Earth. That cannot be debated. Intuition tells us that scarcity is inevitable, given our societal history of consumption, our huge and continuing appetite for oil, and the fact that every developing nation relies on oil as a major stepping-stone to modernization. It stands to reason that

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global energy consumption must be increasing with our ever-growing population, particularly in the emerging mega-industrial regions of China and India.

Common wisdom holds that since oil is a finite resource, its supply must be rapidly diminishing in the presence of clearly increasing demand, and the end of our days of oil must be on the horizon. Yet there have been predictions of the end of oil since it first became a common commodity. As early as 1916, the US Bureau of Mines stated, "… with no assured source of domestic supply in sight, the United States is confronted with a national crisis of the first magnitude."[4] A report commissioned by the US Department of Energy, called the Hirsch Report (2005), begins with the ominous warning, "The peaking of world oil production presents the U.S. and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented."[5] A piece published in the journal *Science* in 2007 states, "The world's production of oil will peak, everyone agrees. Sometime in the coming decades, the amazing machinery of oil production that doubled world oil output every decade for a century will sputter. Output will stop rising, even as demand continues to grow. The question is when."[6] Similarly, a 2007 assessment by the US Government Accountability Office reported on the uncertainty of future global oil supply based on the premise that global oil production will peak and begin to decline "sometime between now and 2040," with the majority of cited studies suggesting that the production peak will likely occur by 2020.[7] Is this fear and doom-saying just another in a succession of false alarms?

Some experts say that there is plenty of oil. The essence of the idea that we will not run out any time soon was expressed in June of 2000 by former Saudi Oil Minister (1962–86) Sheikh Zaki Yamani. He claimed, "Thirty years from now there will be a huge amount of oil – and no buyers. Oil will be left in the ground. The Stone Age came to an end, not because we had a lack of stones, and the oil age will come to an end not because we have a lack of oil."[8] The Energy Information Administration (EIA), which is part of the US Department of Energy, says that only 4–7 percent of the world's original in-place liquid petroleum has been recovered.[9] Individuals ranging from oil company executives to energy consultants to academic economists firmly believe that any concerns about global depletion in the foreseeable future are premature for several reasons – oil is abundant, we have only consumed a fraction of the global oil endowment, technology to discover and extract new oil has consistently proven out, and the profit motive combined with the law of supply and demand will prevail.[10–13]

Why is our oil future so uncertain? What are the underlying data, analyses, and philosophies that lead to predictions of global oil depletion by some versus the conviction by others that the current state of alarm is unjustified and just crying wolf? Why is there any controversy at all? We can begin to answer these questions by considering the arguments supporting our intuition that the end of the Oil Era is near.

The Oil Era is a period of hundreds of years, contained in a longer period, during which global fossil fuel resources[14] are being consumed (Figure 1.1). Fossil fuels are the remains of ancient plants and animals. They represent a history of stored energy from the sun, which directly or indirectly gave them life and substance. Although fossil fuels took millions of years to form, humans are consuming them, and oil in particular, over a very brief span of Earth history. On the scale of thousands of years, looking back and to the future, "The consumption of energy from fossil fuels is thus seen to be but a 'pip,' rising sharply from zero to a maximum, and almost as sharply declining, and thus representing but a moment in the total of human history."[15]

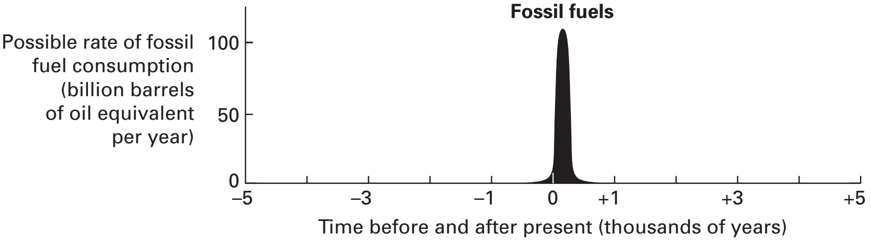

Figure 1.1 The consumption of fossil fuels considered over a 10,000-year horizon. The resource will likely be used during a relative instant of Earth history (after Hubbert, 1956 and 1981).[16]

Based on the presumption that the depletion of the world's oil resources is unavoidable, oil resource analysts have focused on four simple questions: How much oil exists to be exploited? What is the likely trend of new discoveries? What is the projected rate of global consumption? And, when will the end of the Oil Era arrive? Answering these questions is a subject of intense discussion in both the scientific literature and popular press. Many oil analysts have made estimates and projections. Cutting to the chase, most of these analysts have focused on the final question about when the end of oil will come, but they have framed the question in a slightly different way. The oil analysts focus not on when the last drop of oil will be pumped from the ground but rather the time when oil production will reach its peak ("peak oil"). It is their belief that the occurrence of peak oil production marks the beginning of the end, that is, the point when production can no longer keep up with demand. The argument goes that at the peak of oil production, the end is in sight, and it is urgent that a fundamental restructuring of our oil-based society begin.

So, when do analysts say that "peak oil" will occur? Surprisingly, the projections do not differ by much. The average collective estimate is that global peak oil production will occur before 2025, with the more pessimistic analysts suggesting that the peak has already occurred and we just do not know it, and the optimists pushing the date out to almost 2050. Remarkably, a great deal is made of the differences among the estimated times to peak oil production, and the debate among analysts is vigorous. But why is the exact year so important? The big message is that if they are correct, a key turning point in the nature of global industrial societies will occur within our likely lifetimes.

Hubbert's Curve

The general agreement among so many oil analysts regarding the time to peak oil production is not a tremendous surprise, because most use the same basic method for prediction. Although there are different flavors of the approach, they are based on the original method proposed by M. King Hubbert (1903–89), who initiated the modern-day scientific debate about oil depletion. Hubbert was a Texas-born geologist, oil company research scientist, and energy resource analyst. A respected scientist with a PhD in geology from the University of Chicago, he made durable contributions to the fields of both petroleum exploration and the study of natural subsurface water flow. After a 20-year career at Shell Oil and Shell Development companies, Hubbert joined the US Geological Survey (USGS) in 1963 and began a five-year teaching position at Stanford University. In 1973 he was appointed California Regent's professor at the University of California at Berkeley. Hubbert retired from academia in 1976, although he remained affiliated with the USGS.[17] He published more than 70 articles, and his work is still highly regarded and commonly referenced. Hubbert was famous during his lifetime, being elected to the National Academy of Sciences in 1955 and the American Academy of Arts and Sciences in 1957. He was the president of the Geological Society of America in 1962 and was awarded the Rockefeller Public Service Award in 1977. Hubbert was not only appreciated in scientific circles for his scholarly publications but also enjoyed attention in the press when it came to energy resources. After making predictions of the likely near-term depletion of US oil and natural gas as well as global oil resources, and suggesting that the development of nuclear energy was the best course of action, he testified before Congress on the bleak future of fossil-fuel energy resources.

The main theme in many of Hubbert's articles and monographs on energy resources was the fragility of our industrial global society that is so dependent on energy. He was fixated on the seemingly inevitable collision of finite Earth resources and the exploitation of those resources under the pressures of explosive global population growth. In a compelling 1949 article in the journal *Science*, Hubbert tied the consequences of exponential population growth to the general problem of fossil fuel depletion, considering oil, gas, and coal. Hubbert argued persuasively that even the habitable land required by society as we know it could not be sustained given a doubling of global population every hundred years, a 0.7 percent annual rate of increase that characterized population growth in the first half of the twentieth century. In his words,

> Such a rate is not "normal" as can be seen by backward extrapolation. If it had prevailed throughout human history, beginning with the mythical Adam and Eve, only 3,300 years would have been required to reach the present population. … In fact, at such a rate, only 1,600 years would be required to reach a population density of one person for each square meter of the land surface of the Earth.[18]

Throughout his career, Hubbert offered various forecasts of the decline in global oil supply, with published time-to-peak-oil predictions ranging from 1990 to 2000. His forecast peak dates were premature, but in the overall scheme of things, they do not differ dramatically from those made by modern-day energy analysts. Toward the end of his active career, Hubbert repeated the same somber message that he had put forth during prior decades,

> It is difficult for people living now who have become accustomed to the steady exponential growth in the consumption of energy from fossil fuels, to realize how transitory the fossil-fuel epoch will eventually prove to be when it is viewed over a longer span of human history.[19]

With his steadfast belief in exponentially increasing demand overtaking limited supply, Hubbert presented a quantitative method to represent the amount of any natural resource and its estimated rate of depletion. Hubbert's curve, as it is known, is a graph that shows the extraction of petroleum, or any non-renewable Earth resource, versus time. It is a bell-shaped curve, called a logistic curve,[20] similar in appearance to the bell-curve normal distribution commonly used in statistical analysis.

Hubbert used a straightforward formula that yields the curve as illustrated in Figure 1.2. The logistic-curve formula is a simple expression with three adjustable parameters (mathematical knobs) that control the slope, peak

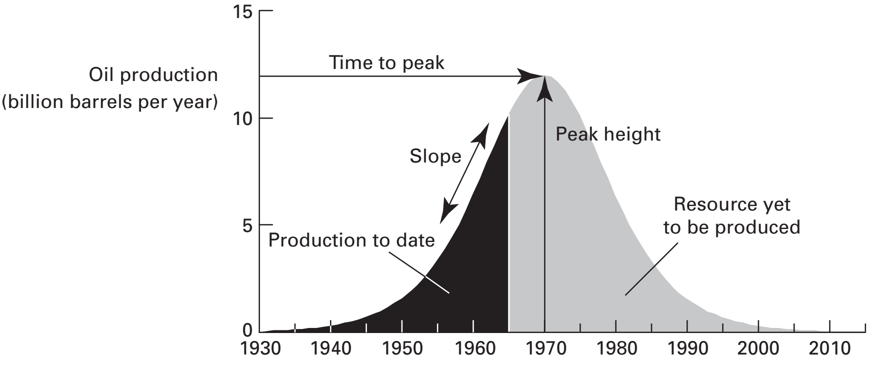

Figure 1.2 Generalized illustration of a logistic curve, showing its symmetric bell shape that Hubbert used to describe the rise, peak, and fall in production of a fossil fuel over time.

height, and time of the peak. The values of the parameters are adjusted to fit the historical production rates (data), which are matched by the curve since production began until production data are no longer available. With the constraint that the area under the curve represents the **resource endowment**, or total amount that can ultimately be produced plus the amount already produced, the formula is used to predict the future rate of resource production and depletion. The declining limb of the curve mirrors the rising limb. As Hubbert saw it, the use of any finite resource has a beginning, middle, and end. Indeed, it seems obvious that every finite commodity that is regularly consumed – from our life savings to our material supplies – must come to an end. Hubbert's curve reflects that commonly held belief.

Hubbert's approach was to take historical data of oil production over time and fit the logistic formula (his bell-shaped curve) to those data. The approach is attractive because anyone can reproduce it by fitting this or a similar bell curve to pre-peak production data. Hubbert observed that after oil was first extracted by wells in the 1860s, there was a rapid increase and then a marked decline in the discovery of new oil fields in the coterminous US, with the discovery peak occurring in the mid-1930s. He predicted that production would follow a similar decline. Figure 1.3 shows a logistic curve fit to historical oil production data through 2008 for US oil production in the lower 48 (coterminous) states, for which Hubbert estimated an oil endowment of 200 billion barrels.

The historical leg of the curve through 1956, when Hubbert made his original prediction, matches the oil production data. The early period of oil

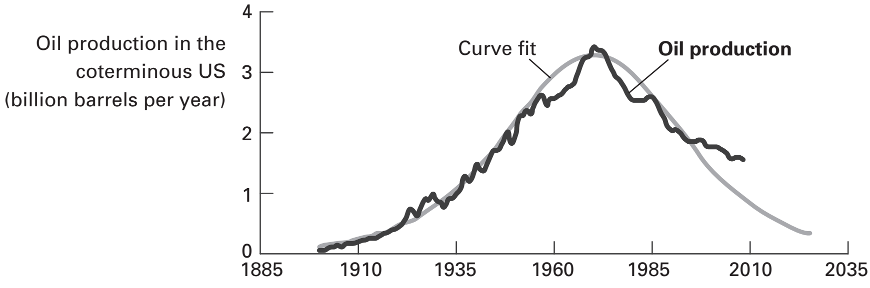

Figure 1.3 US lower 48 state oil production data and a curve fit using Hubbert's approach based on an estimated oil endowment of 200 billion barrels. (Data: EIA)

production and other resource utilization tends to display a rapid exponential increase. As time continued, oil production increased, but the rate of increase slowed until peak production (about 3.5 billion barrels per year for the lower 48 states) was reached. The date corresponding to this peak (actually occurring in 1970) is the time of maximum oil production, or "peak oil" production. Beyond peak oil, supplies presumably become depleted more rapidly than production from new discoveries can be brought on line. The curve after the peak falls back toward a level of nominal production. Eventually, the resource is exhausted when cumulative production nears the value of the oil endowment.

One might wonder how robust the curve-fitting procedure might be. That is, perhaps it is possible to fit the historical data with a variety of curves, each showing a different time to peak oil. It turns out that, even though the shapes of various curves that fit these data might be a bit different, the time of peak oil estimated using the approach does not vary by much. This is because there are two primary constraints controlling the curve-fitting process. The first constraint is that the historical data, typically representing the period before the peak, must be fit by the rising production limb of the curve. Only a limited subset of curves can match those historical data because they show a particular trajectory of increasing oil production. The second constraint is that the sum total of all production over time must equal the oil endowment. That total volume is a quantity that one must estimate independently of the curve-fitting procedure. It is this figure, the oil endowment, that is a subject of disagreement among oil analysts and one of the main sources of differing estimates of the time to peak oil. In essence, the trend of oil production largely dictates the uphill slope of the curve, while the total oil endowment controls the height and timing of the peak. As Hubbert himself stated in 1949,

> Thus we may announce with certainty that the production curve of any given species of fossil fuel will rise, pass through one or several maxima, and then decline asymptotically to zero. Hence, while there is an infinity of different shapes that such a curve may have, they all have this in common: that the area under each must be equal to or less than the amount initially present.[21]

The time of peak oil based on fitting a logistic curve to the historical production data is not very sensitive to the independently estimated value used for the oil endowment. Figure 1.4 shows logistic curves fit to the US oil production data through 1956 but with three very different assumed oil endowments: 200, 300, and 450 billion barrels (only the first of these values was used by Hubbert). Although the peak value is very different in the three predictions, the time of the peak is not, in this case, 1971, 1981, and 1990. If Hubbert's estimate of the oil endowment is more than doubled, peak production is only delayed by 20 years. The various predictions based on different estimated oil endowment values all give similar times to peak oil. This is the main reason why oil analysts' predictions of the time of global peak oil typically vary by only about 20 to 30 years, even though they assume different oil endowment figures. This is also why the predictions do not differ significantly from Hubbert's predictions, first presented half a century ago.

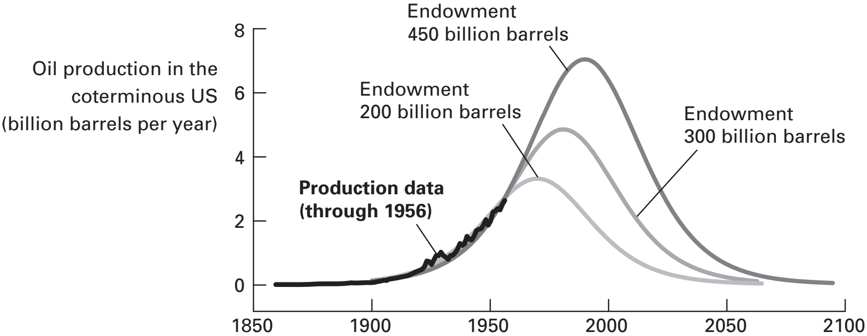

Figure 1.4 Curves based on Hubbert's approach that match US lower 48 state production data through 1956, when Hubbert first made his predictions, but assuming oil endowments of 200, 300, and 450 billion barrels: estimated peak oil production occurred in 1971, 1981, and 1990, respectively. (Data: EIA)

Between 1972 and 1976, Hubbert extended his analysis to global oil depletion. He made three estimates of the time of global oil depletion, with peak oil occurring in 1995, 1996, and 2000. Hubbert applied his approach using total global oil endowment figures ranging from 1.35 to 2.1 trillion barrels.

As displayed in Figure 1.5, a curve fit to the pre-1976 production data using the endowment value of 2.1 trillion barrels peaks at 35 billion barrels in the year 2000. Had Hubbert used the most recent worldwide oil endowment estimate by the US Geological Survey[22] of approximately 3 trillion barrels, the projected peak would occur in 2005. Using the two different global oil endowment estimates, the peak production values differ but the date of the peak is similar. With Hubbert's approach, the projected date of global peak oil production is rather immune to significant increases in the assumed oil endowment figure. From these analyses, it would appear that peak oil production is at hand.

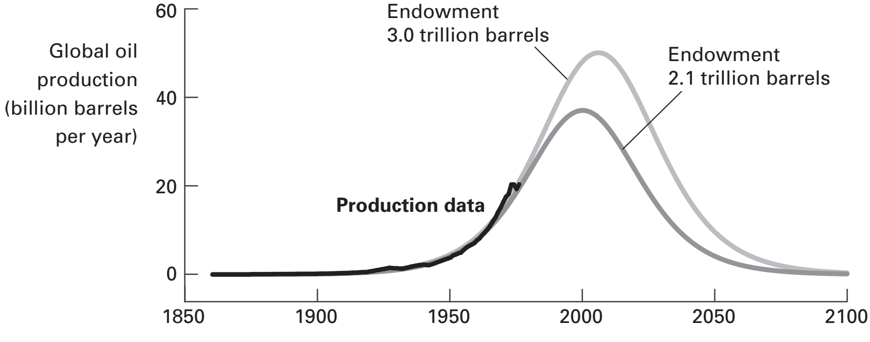

Figure 1.5 Global oil production data through 1976 when Hubbert made his final prediction of global oil depletion based on the highest endowment estimate he used of 2.1 trillion barrels. Also shown is a fit to production data using Hubbert's approach but assuming an oil endowment value of 3 trillion barrels. The time of peak oil does not change substantially under these scenarios. (Data: EIA and Hubbert (1969)[23])

Many analysts have followed in Hubbert's footsteps and made predictions of their own. There are various studies of the timing of peak oil production that show how different assumed oil endowment values and other factors, such as the growth of demand, affect the timing of global oil depletion. A 2004 study of global oil depletion in the journal *Energy* by Hallock and others looked at peak oil timing under a range of assumptions of oil endowment and future demand. Their model of oil depletion is more complicated than that of Hubbert, but the central idea is the same. They conclude that "global production of conventional oil will almost certainly begin an irreversible decline somewhere between 2004 and 2037."[24] Of equal concern, their study finds that demand will convert net-exporting countries into net consumers and that the number of exporting countries will fall from 35 in the present decade to between 12 and 28 by 2030.

The Appeal of Hubbert's Curve

For scientists and engineers, there is great appeal to Hubbert's method. For one thing, scientists like to bring order to data in a quantitative fashion. Given a set of data over time, many, if not most, scientists would study those data by seeing if a formula can be used to characterize them and perhaps explain trends, interpolate between values, and make projections. Often, curves are fit to data to allow a better understanding of the underlying process or processes that give rise to the data, such as trends suggesting exponential growth or decay. In engineering, physics, chemistry, and biology, formulas often describe governing forces and effects. Mathematics is the language used to quantitatively describe governing processes, even if a graphical presentation of a mathematical model, such as Hubbert's curve, is employed.

Engineers and scientists like to have a mathematical basis for making predictions beyond their current data, and predicting the trajectory of resource depletion is the main benefit of Hubbert's approach. The predicted rise, peak, and fall of Hubbert's curve follows naturally from the way he thought about the consequence of exponential growth in resource use. The logistic bell-shaped curve has a form that is familiar to scientists, engineers, and, indeed, much of the general public. Many are intuitively comfortable with such a curve being used to fit and "explain" a pattern of consumption.

Perhaps the main scientific appeal of Hubbert's approach is the fact that it represents a type of mass balance. One of the fundamental laws of science is conservation of mass, or in the case of oil measured in barrels, conservation of volume. There is only so much oil that can be extracted from Earth. Given that fixed volume of oil, how long it will last depends on its rate of extraction and consequent consumption. If the volume of new discoveries has already been incorporated into the oil endowment figure, then the oil in the ground is a "known," fixed volume that is simply waiting to be extracted. A fixed oil endowment subject to that oil being extracted over time is an expression of conservation of mass. Furthermore, the driving force behind oil consumption is assumed to be demand accompanying exponential growth of population and industry. This growth is the reason for the steep leading edge of the logistic curve. As long as global oil is plentiful, the effects of exponentially increasing production are not detrimental because there is ample supply to meet demand. However, as peak oil is approached, Hubbert and those using his method believe that demand will overtake the ability to extract oil. Both intuitively and mathematically, the future decline shown by Hubbert's curve appears to be the natural, inevitable result of the conflict between demand and a fixed, finite endowment. The result that there is a rapid increase in production followed by a symmetric, mirror-image decline is satisfying in the familiar sense that what goes up must come down.

Many scientists are comfortable with the Hubbert-curve approach because it describes a rate of depletion that is (1) consistent with conservation of mass, (2) based on a familiar mathematical and graphical form, (3) shows a trend with a leading limb that has a plausible behavioral underpinning tied to exponential growth in demand, and (4) is consistent with the expected declining production of a diminishing resource. Finally, scientists appreciate predictive models that are "robust," which means that uncertainty in the underlying data and parameters used in the predictive model do not greatly affect the results. As described above, even if the estimates of global oil endowment differ by a factor of two, the predicted oil production peak shifts by only two to three decades. This shift in timing is rather insignificant considering the anticipated consequences of global oil depletion.

Hubbert's Success

The successful demonstration of an approach goes a long way to convincing skeptics of its validity, particularly those in the scientific community. Hubbert did remarkably well with his early predictions. In 1956, Hubbert applied a precursor of his curve-fitting approach to oil production data in the coterminous US by fitting the historical production data by hand.[25] The data he used and his predictions are shown in Figure 1.6.

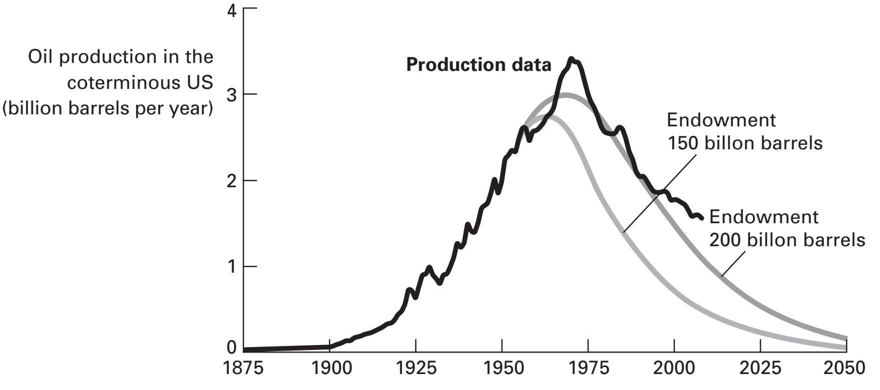

Figure 1.6 Hubbert's 1956 predictions of peak oil in the coterminous US modified to show production data through 2008 (after Hubbert (1956)[26] with production data from EIA).

Based on data through 1956, Hubbert attempted to predict the pattern of future oil production. His best estimate of the US oil endowment showed "peak oil" in the coterminous US occurring in 1965[27], and with his higher estimate of the endowment, the projected peak occurred in 1971. Compared with the actual long-term data collected after Hubbert made his predictions, which show a peak around 1970, Hubbert's estimates were surprisingly good. He successfully predicted the declining trend of oil production in the coterminous US, attributing that decline to the depletion of the available domestic resource. Given the right estimate of the oil endowment, the logistic curve can be used fairly well to describe both historical and post-peak production in the coterminous US. The success of Hubbert's approach in estimating the shape of the US oil production curve has been hailed as a remarkable achievement and has been used to support the applicability of his approach to global oil, coal, and natural gas resource analyses. Hubbert's prediction served as a wake-up call that oil is a finite resource and that its steadily increasing use would not be sustainable. Additional data gathered since Hubbert's time have provided the bases for numerous analyses supporting the conclusion that the end of the Oil Era is near.

US Oil Dependence Since Peak Production

Judging by the US experience, will a peak in global oil production matter? After the peak in US oil production in 1970, the US began to rely heavily on oil imports, and oil dependence has been a major focus of US foreign policy. The US maintains troops to defend the Middle East to insure against a global oil supply disruption. One cannot quantify the cost of potential loss of life that this service represents, but efforts have been made to determine the economic cost to the US government. Apart from the cost of war, there is a cost of having the military stand ready to defend the Middle Eastern supply.[28] Such annual costs are not reported by the US military; however, the US General Accounting Office[29] estimated the cost in 1990 of defending oil supply from the Middle East at $33 billion, which, adjusted for inflation, is $52 billion (in equivalent 2007 US dollars, 2007$). This cost corresponds well to a 2003 estimate made by the National Defense Council Foundation[30] of $49 billion, which, adjusted for inflation, is equivalent to about $55 billion (2007$).

Given that the US imports about 775 million barrels of oil per year from the Middle East and annually spends $50 billion per year to maintain a military force to defend that region, the standing armed force cost alone amounts to $65 per barrel. That "hidden cost" is equal to more than half of the average annual per-barrel oil price (adjusted for inflation – in 2007$) in any year through 2008. It is also more than double the $28 average annual price of oil since 1861.[31] The true cost of oil dependence encompasses far more than the price paid for gasoline. Should a peak in global oil production occur as it did in the US, oil-rich regions may well influence the global economy and the security concerns of all nations in ways that we have yet to experience.

Chapters Ahead

The concern about global oil depletion is not new, but the issue seems to draw attention primarily when oil and fuel prices climb. An appreciation of oil availability, supply, and demand issues in the US and the world is needed to evaluate opposing positions taken in the oil-depletion debate. Chapter 2 provides some key definitions and an overview of oil availability, production, and consumption. Alarm about the depletion of resources essential to society goes back at least 200 years. The resource-depletion debate and historical predictions of the exhaustion of natural resources, including oil, are discussed in Chapter 3. Given this historical context, additional arguments are presented that support the case for the world's running out of oil. Although there is compelling information that supports the case for global oil depletion, there are also counter-arguments that advocate the position that plenty of oil remains. These counter-arguments are made in Chapter 4. They focus on fallacies in the oil-depletion case and critique key assumptions underlying forecasts of global availability and demand. Finally, Chapter 5 applies some of the lessons learned from the examination of non-energy Earth resources to the analysis of global oil resources and explores important issues affecting our future reliance on oil.

Notes and References

1. Yergin, D. (1991). *The Prize: The Epic Quest for Oil, Money, and Power*. New York: Free Press, Simon and Schuster.
2. Darwin, C. (1859). *The Origin of Species*, reprinted in 1979 by Gramercy Books, Random House, New York: 461 pp.
3. Greene, D. L. (2009). "Measuring Energy Security: Can the United States Achieve Oil Independence?" *Energy Policy*. ISSN 0301-4215, DOI: 10.1016/j.enpol.2009.01.041 (in press).
4. Porter, E. D. (1995). "Are We Running Out of Oil?" American Petroleum Institute Policy Analysis and Strategic Planning Department, American Petroleum Institute, Discussion Paper #081.

5. Hirsch, R. L., R. Bezdek, and R. Wendling (2005). *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management*, Department of Energy National Energy Technology Laboratory, February 2005.
6. Kerr, R. A. (2007). "The Looming Oil Crisis Could Arrive Uncomfortably Soon," *Science*, **316**, April 20, 2007: 351.
7. Government Accountability Office (2007). *Crude oil: Uncertainty about future oil supply makes it important to develop a strategy for addressing a peak and decline in oil production*, United States Government Accountability Office, GAO-07-283.
8. Fagan, M. (2000). "Sheikh Yamani predicts price crash as age of oil ends," *Daily Telegraph* (London, UK), June 25, 2000.
9. Sweetnam, G. (2008). "Long-term Global Oil Scenarios: Looking Beyond 2030," EIA 2008 Energy Conference, Washington, DC, April 7, 2008, Energy Information Administration.
10. Economides, M. J. (2007). "The Future of Peak Oil," *The Way Ahead* (produced by the Society of Petroleum Engineers), **3**(2).
11. Jackson, P. M. (2007). "Peak Oil Theory Could Distort Energy Policy and Debate," *Journal of Petroleum Technology* (produced by the Society of Petroleum Engineers), **59**(2).
12. Howden, D. (2007). "A world without oil," *The Independent* (London, UK), June 14, 2007: 1–2. "This scenario *of imminent global oil depletion* is flatly denied by BP, whose Chief Economist, Peter Davies, has dismissed the arguments of 'peak oil' theorists" (italics added).
13. Bahorich, M. (2006). "End of oil? No, it's a new day dawning," *Oil and Gas Journal*, **104**(31), August 21, 2006.
14. Fossil fuels are natural carbon-rich substances formed from the remains of plants and animals living millions of years ago. Found in Earth, these substances can be burned. They include coal, oil, natural gas, and peat.
15. Hubbert, M. K. (1949). "Energy from Fossil Fuels," *Science*, **109**(2823), February 4, 1949: 103–9 (p. 108).
16. Hubbert, M. K. (1956). "Nuclear energy and the fossil fuels," presented at the Spring Meeting of the Southern District Division of Production, American Petroleum Institute, San Antonio, TX, March 1956: Shell Development Company Publication No. 95; Hubbert, M. K. (1981). "The world's evolving energy system," *American Journal of Physics*, **49**(11): 1007–29.
17. "Tribute to M. King Hubbert," Letter to Members, National Academy of Sciences, 19(4), April 1990.
18. Hubbert, M. K. (1949). "Energy from Fossil Fuels," *Science*, **109**(2823) February 4, 1949: 105.
19. Hubbert, M. K. (1971). "The Energy Resources of the Earth," *Scientific American*, **225**, September 1971: 31–41 (p. 31).
20. Mathematically, the logistic curve is based on a simple, three-parameter formula in which, in our case, P is resource production, t is time, a is the peak height, b is the center or peak of the symmetric curve, and c controls the changing

slope, whose absolute magnitude is the same on both the rising and declining limbs. The area under the curve represents the total amount of the resource and is calculated as simply the product *4ac*.

$$\text{Production rate, } P = 4a\frac{\exp\left[-\left(\frac{t-b}{c}\right)\right]}{\left\{1+\exp\left[-\left(\frac{t-b}{c}\right)\right]\right\}^2}$$

21. Hubbert, M. K. (1949). "Energy from Fossil Fuels," *Science*, **109**(2823) February 4, 1949: 105.
22. US Geological Survey World Petroleum Assessment Team, (2000). *U.S. Geological Survey World Petroleum Assessment 2000—Description and Results*. US Geological Survey Digital Data Series DDS-60, 4 CD-ROMs; Ahlbrandt, T. S., R. R. Charpentier, T. R. Klett, J. W. Schmoker, C. J. Schenk, and G. F. Ulmishek (2005). "Global Resource Estimates from Total Petroleum Systems," AAPG Memoir 86, American Association of Petroleum Geologists, Tulsa, OK.
23. Hubbert, M. K. (1969). "Energy Resources," in *Resources and Man*, W.H. Freeman and Co. Chapter 8: 157–242.
24. Hallock, J. L. Jr., P. J. Tharakan, C. A. S. Hall, M. Jefferson, and W. Wu (2004). "Forecasting the limits to the availability and diversity of global conventional oil supply," *Energy*, **29**: 1673–96.
25. Hubbert, M. K. (1956). "Nuclear energy and the fossil fuels," presented at the Spring Meeting of the Southern District Division of Production, American Petroleum Institute, March 1956.
26. Ibid.
27. Ibid.
28. Davis, S. C. et al. (2008). *Transportation Energy Data Book*, Oak Ridge National Laboratory, ORNL-6981.
29. General Accounting Office (1991). *Southwest Asia: Cost of Protecting U.S. Interests*. Washington DC: US GAO/NSIAD-91-250, August 1991.
30. Copulas, M. R. (2003). *America's Achilles Heel – The Hidden Costs of Imported Oil*. Washington DC: National Defense Council Foundation, October 2003.
31. *BP Statistical Review of World Energy*, June 2008, http://www.bp.com/statisticalreview