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Hubbert's Peak: The Great Debate over the End of Oil

ABSTRACT

This paper analyzes the major debates over future petroleum supply in the United States, in particular the long-running feud between the world-famous geologist, M. King Hubbert, and the director of the U.S. Geological Survey, Vincent E. McKelvey. The intellectual history of resource evaluation reveals that, by the mid-twentieth century, economists had come to control the discourse of defining a "natural resource." Their assurances of abundance overturned earlier conceptions of petroleum supplies as fixed and finite in favor of a more flexible understanding of resource potential in a capitalist society and acceptance of the price elasticity of natural resources. In 1956, King Hubbert questioned these assurances by predicting that U.S. domestic oil production would peak around 1970, which drew him into a long-running debate with McKelvey and the so-called "Cornucopians." When Hubbert's Peak was validated in the mid-1970s, he became a prophet. The acceptance of Hubbert's theory ensured the centrality of oil in almost all discourses about the future, and it even created a cultural movement of prophecy believers fixated on preparing for the oil end times. Although notions of resource cornucopia seem to be once again in ascendance in the United States, Hubbert's Peak still haunts any consideration of humanity's environmental future.

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The following abbreviations are used: AAAS, American Academy of Arts and Sciences; AAPG, American Association of Petroleum Geologists; AHC MKH, M. King Hubbert Papers, American Heritage Center, University of Wyoming, Laramie, WY; AHC VEM, Vincent E. McKelvey Papers, American Heritage Center, University of Wyoming, Laramie, WY; API, American Petroleum Institute; ASPO, Association for the Study of Peak Oil & Gas; *BAAPG*, *Bulletin of the American Association of Petroleum Geologists*; *COMRATE*, Committee on Mineral Resources and the Environment (NAS-NRC); MKH INT, M. King Hubbert, transcript of recorded interviews by Ronald E. Doel, January 4, 10, 13, 17, 20, 27, and February 3, 6, 1989, Niels Bohr Library, American Institute of Physics, Center for History of Physics, College Park, MD; NAS, National Academy of Sciences; NRC, National Research Council; USGS, U.S. Geological Survey.

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INTRODUCTION

Are we nearing the end of oil? Some prognosticators have warned that the world production of oil, the lifeblood of modern civilization, is reaching or has reached a peak, to be followed by inexorable decline. Prophecies of fossil fuel scarcity have led to predictions that we are approaching a peak in overall material consumption. Food and fresh water shortages, climate instability, and unsustainable patterns of extraction and urbanization combine to offer a grim future of converging and intensifying global crises. According to several self-styled collapsitarians, the world now faces a century of declines, the long emergency, environmental collapse, or peak everything.[1]

Peak oil, the concept that underpins most other notions of peak and collapse, is often referred to as Hubbert's Peak, after the Shell Oil geophysicist, M. King Hubbert, who in 1956 famously forecast the peak in U.S. oil production. Critics in both industry and government attacked Hubbert's Peak for the next fifteen years, citing the erroneous warnings of oil shortages by earlier forecasters. As the United States grew increasingly dependent on oil, estimating the future domestic supply of this precious resource became a more serious and contested endeavor, with major implications for policymaking. When U.S. crude oil production in the lower forty-eight states did in fact peak in late 1970 and start to decline steadily, year after year, Hubbert became known as "the oil prophet."[2]

The apparent confirmation of Hubbert's Peak during the middle of the 1970s energy crisis helped reframe the national dialogue on petroleum issues. It convincingly questioned the long-standing ideology of American abundance. Hubbert's thesis suggested that Americans were no longer the people of plenty, no longer the masters of nature. The peaking of oil production even foretold

1. Paul Roberts, *The End of Oil: On the Edge of a Perilous New World* (New York: Houghton Mifflin, 2004); Jared Diamond, *Collapse: How Societies Choose to Fail or Succeed* (New York: Penguin, 2005); James Howard Kuntsler, *The Long Emergency: Surviving the End of Oil, Climate Change, and Other Converging Catastrophes of the Twenty-First Century* (New York: Grove Press, 2006); and Richard Heinberg, *Peak Everything: Waking Up to the Century of Declines* (Gabriola Island, BC: New Society, 2007). The term "collapsitarian" was coined in a quote by Kuntsler in Ben McGrath, "The Dystopians," *New Yorker*, 26 Jan 2009, 40.

2. "Oil Prophet Cited: Geologist Saw Crisis in 1948," *Washington Post*, 15 Nov 1977, 1.

the end of economic growth. Following his death in 1989, Hubbert's followers used the same methodology to forecast an impending peak in world oil production.[3] Kenneth Deffeyes, an emeritus professor at Princeton and former colleague of Hubbert's at Shell's research lab in Houston, asserted in 2005 that the world peak had arrived, declaring that "we are all historians now."[4]

Hubbert's detractors, sometimes labeled Cornucopians, did not concede defeat. They dismissed Peak Oilers as neo-Malthusians, after Thomas Malthus, the eighteenth-century British economist who predicted subsistence crises due to population growth, or Cassandras, after the Greek goddess endowed with the gift of prophecy. "This is the fifth time that the world is said to be running out of oil," commented oil industry historian and consultant, Daniel Yergin, in 2006. "Each time—whether it was the 'gasoline famine' at the end of WWI or the 'permanent shortage' of the 1970s—technology and the opening of new frontier areas has banished the specter of decline. There's no reason to think that technology is finished this time."[5]

3. For the most widely cited studies, see Colin Campbell, *The Coming Oil Crisis* (Essex, UK: Multi-Science, 1997); Kenneth S. Deffeyes, *Hubbert's Peak: The Impending World Oil Shortage* (Princeton, NJ: Princeton University Press, 2001); Richard Heinberg, *The Party's Over: Oil, War and the Fate of Industrial Societies* (Gabriola Island, BC: New Society, 2003); Colin Campbell, *Oil Crisis* (Essex, UK: Multi-Science, 2005); Kenneth S. Deffeyes, *Beyond Oil: The View from Hubbert's Peak* (New York: Hill and Wang, 2005); Matthew R. Simmons, *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy* (Hoboken, NJ: John Wiley & Sons, 2005); David Strahan, *The Last Oil Shock: A Survival Guide to the Imminent Extinction of Petroleum Man* (London: John Murray, 2007); and Kjell Aleklett, with Michael Lardelli, *Peeking at Peak Oil* (New York: Springer, 2012). A list of peak oil publications can be found at the Association for the Study of Peak Oil & Gas (ASPO) website: http://www.peakoil.net/publications (accessed 1 Aug 2013).

4. *The End of Suburbia: Oil Depletion and the Collapse of the American Dream*, directed by Gregory Greene (DVD, Electric Wallpaper, 2005).

5. CERA (Cambridge Energy Research Associates), "Peak Oil Theory—World Running Out of Oil Soon—Is Faulty: Could Distort Policy and Energy Debate," Press release, 14 Nov 2006, http://www.cera.com/aspx/cda/public1/news/pressReleases/pressReleaseDetails.aspx?CID=8444 (accessed 10 Mar 2007). An API researcher found seven shortage scares before 1950. See Edward D. Porter, "Are We Running Out of Oil?" API, Policy Analysis and Strategic Planning Department, Discussion Paper #081 (1995). For other examples of Cornucopian writings, see Vaclav Smil, *Energy at the Crossroads: Global Perspectives and Uncertainties* (Cambridge, MA: MIT Press, 2003); Peter Huber and Mark P. Mills, *The Bottomless Well: The Twilight of Fuel, the Virtue of Waste, and Why We Will Never Run Out of Energy* (New York: Basic Books, 2006); Duncan Clarke, *The Battle for Barrels: Peak Oil Myths and World Oil Futures* (London: Profile Books, 2007); Michael C. Lynch, "The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers)," SEER (Strategic Energy & Economic Research Inc.), http://www.energyseer.com/NewPessimism.pdf (accessed 1 Aug 2013); and Steven M. Gorelick,

Both sides in recent debates over peak oil make appeals to history, but rarely does anyone bother to revisit the original controversy over Hubbert's Peak. For those who follow oil and energy, Hubbert is a household name. Few people, however, have ever heard of his chief adversary, Vincent McKelvey, a longtime research geologist at the U.S. Geological Survey (USGS) who in 1971 rose to become the director of that agency. McKelvey embraced an expansive interpretation of U.S. petroleum resources, and he repeatedly suppressed the peak oil forecasts of King Hubbert, who moved to the USGS in 1964 after retiring from Shell. For the next ten years, McKelvey and Hubbert argued bitterly with each other over the extent of American petroleum reserves. By the mid-1970s, Hubbert's theory appeared to be confirmed, paving the way for later predictions about global peak oil. McKelvey was fired as USGS director for his reckless optimism about U.S. oil potential, and his name faded into obscurity. But the recent and spectacular reversal of the decline in U.S. oil production along with major new discoveries around the world has challenged many peak oil prophecies, including Hubbert's most famous one. Vincent McKelvey may yet have the last laugh.

The great debate over peak oil reveals the dilemmas faced by policymakers in managing the boundaries between science and politics as the subject of energy moved to the forefront of national policymaking. Both Hubbert and McKelvey possessed strong personalities characterized by arrogance and insecurity. Their disagreement was ostensibly a scientific one, but it was also ideological and personal. In estimating the extent of undiscovered oil reserves, an inexact and speculative practice, they hardened their positions over time. Hubbert's emphasis on geological depletion as a mechanism for creating scarcity clashed irreconcilably with McKelvey's focus on price and technology as the keys to manufacturing plenty.

Prefiguring other polarizing environmental debates that emerged in the 1970s, Hubbert and McKelvey offered opposing narratives about the sources and sustainability of American material abundance.[6] Their confrontation demonstrated the tension in postwar futurology between a conception of the future

Oil Panic and the Global Crisis: Predictions and Myths (Oxford: Wiley-Blackwell, 2010). The terms Cornucopians and Cassandras were introduced in a 1975 study by the Committee on Mineral Resources and the Environment, National Research Council, *Mineral Resources and the Environment* (Washington, DC: National Academy of Sciences, 1975), 9–10.

6. See, for example, the debate between Paul Ehrlich and Julian Simon over population growth as discussed in Paul Sabin, *The Bet: Paul Ehrlich, Julian Simon, and the Gamble over the Earth's Future* (New Haven, CT: Yale University Press, 2013).

as "an object of science in which certain traces could be found" (Hubbert) and one that was "an object of the human imagination, creativity, and will" (McKelvey).[7] Hubbert's discovery of a predictable trend in oil production and consumption increasingly influenced discourses about the fate of society, and it even created a cultural movement of prophecy believers who anxiously anticipated the end of oil. [8] Although Hubbert's influence in the profession of resource estimation has waned, and notions of resource cornucopia are once again in ascendance in the United States, Hubbert's Peak still haunts any consideration of humanity's environmental future.

EARLY PROPHECIES

During the twentieth century, scientists were increasingly called on to make predictions—about weather, earthquakes, floods, resource availability, and climate change—in order to assist forward-looking decision making. The job of estimating and forecasting American petroleum resources fell upon the USGS. Established in 1879 during the era of westward expansion, the USGS assumed responsibility for the "classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain."[9] By the turn of the century, this mandate included evaluating water and coal resources and estimating the nation's petroleum resources and reserves.[10]

7. Jenny Andersson, "The Great Future Debate and the Struggle for the World," *American Historical Review* 117 (2012): 1411–30.

8. See Imre Szeman, "System Failure: Oil, Futurity, and the Anticipation of Disaster," *South Atlantic Quarterly* 106 (2007): 805–23.

9. Cited in Mary C. Rabbitt, *The United States Geological Survey, 1879–1989*, U.S. Geological Survey Circular 1050, http://pubs.usgs.gov/circ/c1050/index.htm (accessed 1 Aug 2013). Also see Mary C. Rabbitt, *Minerals, Lands, and Geology for the Common Defence and General Welfare: A History of Public Lands, Federal Science and Mapping Policy, and Development of Mineral Resources in the United States*, *Volumes I–III* (Washington, DC: U.S. Government Printing Office, 1979, 1980, and 1986).

10. The distinction between resources and reserves has become critical to petroleum appraisal. The term resource encompasses all naturally occurring concentrations of hydrocarbons in the earth's crust, whereas reserves refer to that part of the resource base that has been demonstrated to be recoverable under normal economic conditions and existing technology. In the reserves category, distinctions are made between possible, probable, and proved. Distinctions also are made between conventional petroleum (crude oil, natural gas, and natural gas liquids from commonly exploited reservoirs) and unconventional petroleum (continuous-type formations such as shale,

Early USGS petroleum resource assessments, as well as those made by other geologists, were based on an evolving but quite underdeveloped understanding of petroleum geology. Predictions consistently underestimated the extent of proven and undiscovered oil resources. In 1884, the USGS noted in its annual report that "it is possible that the wells in some districts (in Pennsylvania) may so completely give out that the whole district may be abandoned."[11] As production fell in Pennsylvania, but not nearly as quickly as the USGS had projected, Standard Oil executive John D. Archbold confronted the possibility of oil finds in Oklahoma with the remark: "Are you crazy? Why I'll drink every gallon west of the Mississippi."[12]

As Naomi Oreskes explains, earth science was not historically a predictive science, like astronomy, physics, or chemistry. Geology had advanced through inductive generalizations about observational evidence. During the nineteenth century, intensive mapping had led to significant theoretical insights. Still, geologists were concerned with explaining the unknown and the earth's past as it unfolded over millions of years, not predicting a future that was unknowable, especially in geologic time. For decades, resource assessment was the work of consulting geologists who did not benefit from substantial institutional backing or sophisticated methodology.[13]

That is not to say their forecasts went unheeded or that their geological expertise was discounted. In 1909, Dr. David Day of the USGS published the first major assessment of U.S. petroleum reserves. Using a rudimentary "volumetric" method, Day examined past production of known fields and reduced their numbers to barrels per acre. Making assumptions about average geological characteristics (porosity, yield per cubic foot, reservoir thickness, rate of

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heavy oil deposits, and oil sands). Almost all petroleum resource appraisals until the 1980s focused exclusively on estimating conventional reserves.

11. Department of the Interior, *Mineral Resources of the United States* (Washington, DC: GPO, 1884), 196.

12. Quoted in Ralph W. Hidy and Muriel E. Hidy, *Pioneering in Big Business, 1882–1911: History of Standard Oil Company (New Jersey)* (New York: Harper and Brothers, 1955), 177–78.

13. Naomi Oreskes, "Why Predict? Historical Perspectives on Prediction in Earth Science," in *Prediction: Science, Decision Making, and the Future of Nature*, ed. Daniel Sarewtiz, Roger A. Pielke, Jr., and Radford Byerly, Jr. (Washington, DC: Island Press, 2000), 23–40. On early petroleum geology, see Paul Lucier, *Scientists and Swindlers: Consulting on Coal and Oil in America, 1820–1890* (Baltimore, MD: Johns Hopkins University Press, 2008); and Brian Frehner, *Finding Oil: The Nature of Petroleum Geology, 1859–1920* (Lincoln: University of Nebraska Press, 2011). On the early history of geology in general, see Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World* (Ithaca, NY: Cornell University Press, 1983).

recovery) and average barrel per acre yield, Day estimated a total proved reserve of between 10 billion and 24.5 billion barrels, pointing to the middle range of 15 billion barrels as the most probable figure. Assuming constantly increasing production, the oil industry would exhaust national reserves by 1935.[14]

World War I increased the importance of estimating U.S. petroleum reserves. In 1916, the USGS created an Oil and Gas Section. During the war, the section's geologists developed standard methods, such as depletion curves, for assessing the amount of oil available in established fields. This helped both in planning the war effort and in determining oil company taxes on production. However, estimating the size of undiscovered oil deposits, especially before the introduction of seismic methods in the mid-1920s, was mostly a crapshoot. Estimates were later confirmed as exceedingly low. In 1919, David White, USGS chief geologist and head of the Oil and Gas Section, warned that American petroleum reserves of 6.74 billion would only be enough to last another seventeen or eighteen years at current rates of consumption. He also predicted that U.S. oil production would peak in three to five years. USGS director, George Otis Smith, used this forecast to lobby U.S. foreign policymakers to secure petroleum overseas so that it could be conserved at home. In 1921, the USGS joined forces with the newly founded American Association of Petroleum Geologists (AAPG) to place the nation's petroleum resources at 9.15 billion barrels. That was larger than the Survey's 1919 estimate because it included new production from California fields, but it was still pessimistic about future supply.[15]

14. United States Congress, *Report of the National Conservation Commission,* Vol. 3: *Accompanying Papers: Land, Minerals, and National Vitality*: "The Petroleum Resources of the United States," by David T. Day, Senate Document no. 676, 60th Cong., 2d sess. (Washington, DC: GPO, 1909). To demonstrate how conservative these estimates turned out to be, by 2010 the United States had produced cumulatively, since the beginning of the oil industry, 202 billion barrels.

15. David White, "The Petroleum Resources of the World," *Academy of Political and Social Science Annals* 89 (1920): 111–34; George Otis Smith, ed., *The Strategy of Minerals: A Study of the Mineral Factor in the World Position of America in War and in Peace* (New York: D. Appleton, 1919); George Otis Smith, "Where the World Gets Its Oil, But Where Will Our Children Get It When American Wells Cease to Flow?" *National Geographic* 37 (1920): 181–202. Smith was the director of the USGS between 1907 and 1930. On the USGS-AAPG Joint Committee, see Michael Aaron Dennis, "Drilling for Dollars: The Making of U.S. Petroleum Reserve Estimates, 1921–25," *Social Studies of Science* 15 (1985): 241–65. Dennis and others contend that geologists used the threat of scarcity to enhance their own professional authority in the federal control and regulation of the oil industry. See Dennis, "Drilling for Dollars"; Diana Davids Olien and Roger M. Olien, "Running Out of Oil: Discourse and Public Policy, 1909–1929," *Business and Economic History* 22 (1993): 62, 42; and August W. Giebelhaus, "Petroleum's Age of Energy and the Thesis of American Abundance," *Materials and Society* 7, nos. 3/4 (1983): 279–93.

A multitude of oil discoveries along the Gulf Coast, in the Mid-Continent, and in California during the 1920s led to a supply glut by the early 1930s that erased worries about impending shortages. Fears of oil famine had led the federal government to offer multiple incentives for oil exploration and production, with dramatic results.[16] At the same time, the American Petroleum Institute (API), the industry trade organization created in 1919, employed modern public relations and lobbying to counter conservationist proposals. The API used similar data as the USGS-AAPG, but disseminated it in a way to support highly optimistic claims for U.S. oil potential. For the next several decades, abundance, not scarcity, would dominate discourse and policymaking on natural resources in the United States.[17]

ASSURANCES OF ABUNDANCE

In the 1930s, scholars began to offer new conceptions of an inexhaustible resource, providing the foundational arguments for assertions of resource abundance. In response to proposals for restricting the depletion of finite resources, economists began to theorize and calculate the optimal rate of depletion. In 1931, Harold Hotelling, a Columbia University statistician and economic theorist, published a landmark paper, "The Economics of Exhaustible Resources," which argues, in effect, that market forces will conserve resources by raising prices, reducing demand, and thus slowing depletion. Although Hotelling's Rule did not become a staple of neoclassical economics until the 1960s, it pioneered a market-based, economic interpretation of nonrenewable resources, which argued that they would not necessarily be produced and consumed wastefully.[18]

16. In 1913, Congress passed tax breaks for wildcat drilling that by the mid-1920s evolved into a depletion allowance giving a 27.5% tax deduction on production and provisions that allowed for the expensing of intangible drilling costs against current income. In 1920, Congress also passed the Mineral Leasing Act, which reopened federal lands to private petroleum producers.

17. Joseph A. Pratt, "Creating Coordination in the Modern Petroleum Industry: The American Petroleum Institute and the Emergence of Secondary Organizations in Oil," *Research in Economic History* 8 (Greenwich, CT: JAI Press, 1982), 179–215; Dennis, "Drilling for Dollars" (ref. 15), 255–58; and "A Report to the Board of Directors of the American Petroleum Institute by a Committee of Eleven Members of the Board," *American Petroleum Supply and Demand* (New York: McGraw-Hill, 1925).

18. Harold Hotelling, "The Economics of Exhaustible Resources," *Journal of Political Economy* 39 (1931): 137–75. Hotelling's Rule formally states that the price of an exhaustible resource must grow at a rate equal to the rate of interest, both along an efficient extraction path and in

A lesser-known contemporary of Hotelling's, Erich Zimmermann from the University of Texas, became the first modern economist to challenge the idea of natural resources as something fixed in nature. Zimmermann insisted that human society created, altered, and depleted natural resources. Their supply changed with evolving technologies, markets, and political institutions. "Resources *are* not, they *become*," wrote Zimmermann in his 1933 study, *World Resources and Industries* (emphasis in original). "They evolve out of the triune interaction of nature, man, and culture, in which nature sets outer limits, but man and culture are largely responsible for the portion of physical totality that is made available for human use."[19]

A new generation of economists and economic geologists would take the implications of Zimmerman's analysis further and declare that no resource was depletable.[20] By the 1950s, the dominant discourse asserted that Americans, for better or worse, produced plenty. They did not deplete the nation's resources. The book that captured the spirit of the age was historian David Potter's *People of Plenty* (1954). Potter argued that American abundance resulted not from natural endowment or luck, but from "human resourcefulness." Physical abundance had initially produced a high degree of social, economic, and political dynamism in the United States, giving Americans an exceptional capacity to exploit natural resources and regenerate abundance.[21]

For U.S. social scientists in the postwar period, the dilemma for American society was not alleviating scarcity, but, as Martin Melosi describes it, "coping with abundance." With such a wide set of energy choices, argues Melosi, Americans, prior to the 1970s, had never been able to develop a workable national energy strategy.[22] Some contemporary economists identified other

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competitive industry equilibrium. For an analysis of how Hotelling's Rule spawned a new branch of economics, see Shantayanan Devarajan and Anthony C. Fisher, "Hotelling's 'Economics of Exhaustible Resources': Fifty Years Later," *Journal of Economic Literature* 19 (1981): 65–73.

19. Erich W. Zimmermann, *World Resources and Industries*, 2nd edn. (New York: Harper & Brothers, 1951), 15. For an insightful discussion of Zimmermann and his contribution to the economics of natural resources, see Robert L. Bradley, Jr., *Capitalism at Work: Business, Government, and Energy* (Salem, MA: M&M Scrivner Press, 2009), 208–15.

20. See, for example, Kirtley F. Mather, *Enough and To Spare: Mother Earth Can Nourish Every Man in Freedom* (New York: Harper & Brothers, 1944). For a discussion, see Jack D. Salmon, "Politics of Scarcity versus Technological Optimism: A Possible Reconciliation?" *International Studies Quarterly* 21 (1977): 701–20.

21. David M. Potter, *People of Plenty: Economic Abundance and the American Character* (Chicago: University of Chicago Press, 1954), 86.

22. Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (Philadelphia: Temple University Press, 1985).

problems arising from bountiful resources and production. John Kenneth Galbraith criticized the "affluent society" for failing to achieve an adequate distribution of its abundance, and Robert Theobald, in *The Challenge of Abundance* (1962), feared the enervating effects of that abundance on American social and economic values.[23] But, for David Potter and others, abundance was cause for celebrating American innovation, technology supremacy, and market-driven growth, which rendered obsolete the paradigm of scarcity.[24]

Faith in abundance colored domestic oil supply assessments as well as larger notions of American exceptionalism and national superiority. As early as 1952, the Independent Petroleum Association of America (IPAA) declared a new age of abundant oil wealth. Seeking to ensure that public policy did not encourage the development of Middle Eastern oil resources at the expense of the domestic industry, the IPAA nevertheless was sincere in its optimistic assessment. Previous reserve estimates had been surpassed easily, technologies were improving, the rate of discovery exceeded the rate of depletion, and production capacity was greater than actual production.[25] Likewise, the National Petroleum Council (NPC), the oil and gas industry advisory body established in 1945 by President Harry Truman, consistently pinned its advice on the assumption that appropriate price signals would always call forth new resources and ensure adequate supplies, and it refused even to project supply trends into the distant future.[26]

Postwar resource optimism reached a climax in 1963 with Howard J. Barnett and Chandler Morse's *Scarcity and Growth: The Economics of Natural Resource Availability*. Examining data for 1870–1957, Barnett and Morse found that extractive industries did not experience diminishing returns, as often argued by conventional economic theory, but rather produced increasing returns in

23. John Kenneth Galbraith, *The Affluent Society* (New York: Houghton Mifflin, 1958); Robert Theobald, *The Challenge of Abundance* (New York: Mentor Books, 1962). Also see Robert M. Collins, *More: The Politics of Economic Growth in Postwar America* (Oxford: Oxford University Press, 2000). Although he does not directly address the issue of petroleum supply, Collins analyzes the "movement away from scarcity economics toward a new economics of abundance" and the "ascendency of growth liberalism" and general "growthmanship" (14).

24. Robert M. Collins, "In Retrospect: David Potter's *People of Plenty* and the Recycling of Consensus History," *Reviews in American History* 16 (1988): 321–35.

25. Independent Petroleum Association of America, *Petroleum in the Western Hemisphere* (Washington, DC: IPAA, 1952).

26. On the NPC, see Joseph A. Pratt, William H. Becker, and William M. McClenahan, *Voice of the Marketplace: A History of the National Petroleum Council* (College Station: Texas A&M Press, 2002).

the form of a steady reduction in labor-capital costs per unit of output.[27] *Scarcity and Growth* inspired a new generation of Cornucopian resource economists such as M. A. Adelman of MIT and Julian Simon of the University of Illinois, who were convinced "that resource scarcity did not yet, probably would not soon, and conceivably might not ever, halt economic growth."[28]

HUBBERT'S PREDICTION

This was the climate of opinion that the talented and headstrong geophysicist, Marion King Hubbert (Fig. 1), first waded into in 1956 and battled for years thereafter. A native of San Saba, Texas, he received BS and MS degrees from the University of Chicago in the 1920s and his PhD in geology and geophysics from the same university in 1937. In the late 1930s, while teaching at Columbia University, Hubbert helped found an organization called Technocracy, Incorporated. Evolving out of a Progressive Era emphasis on efficiency and expertise, and influenced by the iconoclastic ideas of Thorstein Veblen, Technocracy spearheaded a social movement to bring about a new kind of industrial society governed by scientists and engineers who would use their technical expertise to manage the economy. The ill-fated and controversial mission of Technocracy, Inc. was to seek, in Hubbert's words, a "social structure whose fundamentals were energy and mineral resources, and whose accounting system was based on physical relations, thermodynamics and so on, rather than a monetary system."[29] Although technocracy faded rather quickly as a social movement, Hubbert remained a technocrat all his life, believing that most of society's problems were not understood or effectively addressed by the vast majority of people, whether they be businessmen, politicians, or, especially, economists.

Hubbert had no tolerance for the modern economist's subjective definition of natural resources and obsession with growth. The quest for perpetual growth—"the sacred cow in the economists' language"—and unchecked

27. Howard Barnett and Chandler Morse, *Scarcity and Growth: The Economics of Natural Resource Availability* (Baltimore, MD: Johns Hopkins University Press, 1963).

28. R. David Simpson, Michael A. Toman, and Robert U. Ayres, eds., "Introduction: The 'New Scarcity,'" in *Scarcity and Growth Revisited: Natural Resources and the Environment in the New Millennium* (Washington, DC: Resources for the Future, 2005), 1.

29. MKH INT, 119. Copy available for review in AHC MKH, Box 83A. The master transcript covers approximately thirty-six hours of recorded interview with Hubbert over eight nonconsecutive days. On the technocracy movement, see William E. Akin, *Technocracy and the American Dream* (Berkeley: University of California Press, 1977).

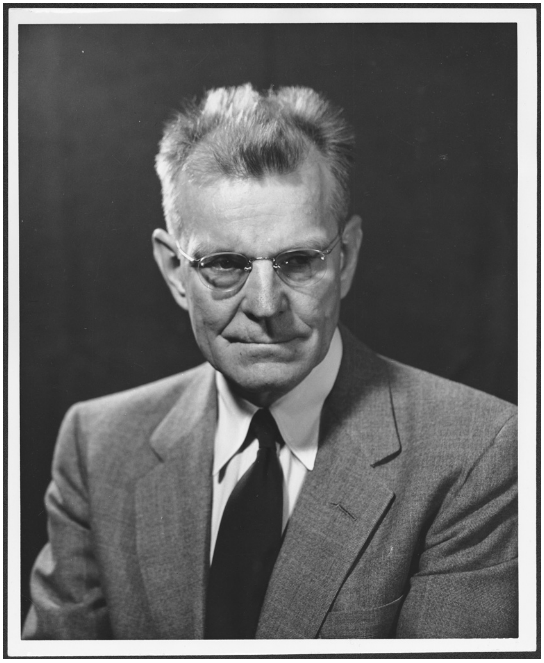

FIG. 1. Marion King Hubbert. Photo courtesy of Digital Collections, American Heritage Center, University of Wyoming, Laramie, WY. Printed without restriction by the American Heritage Center, University of Wyoming and M. King Hubbert; photographer unknown.

consumption both disguised and endangered the link between the human species and the "basic properties of matter and energy."[30] The earth, in Hubbert's view, was a material system with a finite amount of energy. He insisted that there were hard physical limits to human population growth and per capita energy consumption.[31]

30. MKH INT, 373. M. King Hubbert, "Energy from Fossil Fuels," *Annual Report Smithsonian Institution, 1950*, Publication 4032, 271.

31. A story related by Martha Lou Broussard, Hubbert's former technical assistant at Shell Oil, illuminates his conviction. In her job interview, Hubbert asked Broussard if she had children or if she intended on having children. He believed the world was overpopulated; he and his wife had elected not to have children. He then had her stand at a blackboard and write out math problems, one of which was to calculate, given the current rate of population increase, when the earth's population density would reach one person per square meter. Martha Lou Broussard interview by author, Houston, TX, 17 Apr 2009.

By almost every account of anyone who knew or worked with him, Hubbert was rude, boastful, and belligerent.[32] But he was a brilliant scientist. Famous for his later studies of petroleum reserves, Hubbert's earlier scientific achievements actually were more substantial. By the early 1950s, he already had become a giant in the world of petroleum geology and geophysics. He had resolved a long-standing paradox regarding the plastic flow of hard rocks in the earth's crust, revised theories about the movement of underground fluids, and revolutionized thinking about petroleum entrapment.[33] The weight of his work came from demonstrating new mathematical approaches to problems. His talent and achievements had earned him a mandate to do open-ended geophysical research at Shell Oil, and his reputation made people listen to him.[34]

After the war, during a brief period of concern about resource supplies in the corridors of Washington, Hubbert brought his mathematical prowess to bear on oil and gas reserve estimates. He began researching this subject in 1948, the year the United States became a net importer of oil for the first time in the nation's history. In a presentation at the American Association for the Advancement of Science's centennial celebration, Hubbert emphasized the unsustainable rate of increase in the consumption of fossil fuels and pointed out "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."[35]

32. Peter Rose, phone interview by author, Houston, TX, 18 Mar 2009; Broussard interview (ref. 31).

33. M. King Hubbert, "The Theory of Ground-Water Motion," *Journal of Geology* 48, no. 8, pt 1 (1940): 785–944; M. King Hubbert, "Strength of the Earth," *BAAPG* 29, no. 11 (1945): 1630–53; and M. King Hubbert, "Entrapment of Petroleum under Hydrodynamic Conditions," *BAAPG* 37, no. 8 (1953): 1954-2026.

34. Hubbert taught at Columbia until 1940, then worked brief stints for Amerada Petroleum in Oklahoma, the Illinois State Geological Survey, the U.S. Geological Survey, and the U.S. Board of Economic Warfare in Washington before joining Shell Oil's Houston geophysical laboratory in 1943. For more biographical background on Hubbert, see Gary Bowden, "The Social Construction of Validity in Estimates of U.S. Crude Oil Reserves," *Social Studies of Science* 15 (1985): 235 n.19; Ronald Doel, "Marian King Hubbert," *New Dictionary of Scientific Biography* (New York: Scribners, 2007); and Ronald Doel, "Marion King Hubbert," *The Handbook of Texas Online*, http://www.tshaonline.org/handbook/online/articles/HH/fhu85.html (accessed 1 Aug 2013). Doel is working on a biography of Hubbert. Another reliable but unconventional source is George Pazik, "Our Petroleum Predicament," *Fishing Facts* (Nov 1976): 1–20. Pazik, the editor and publisher of *Fishing Facts*, based in Menomenee Falls, Wisconsin, took a special interest in Hubbert's prophetic prediction after the Arab oil embargo, and devoted a whole issue of his monthly fishing magazine to the subject, based on interviews with Hubbert.

35. M. King Hubbert, "Energy from Fossil Fuels," *Science* 109 (1949): 105.

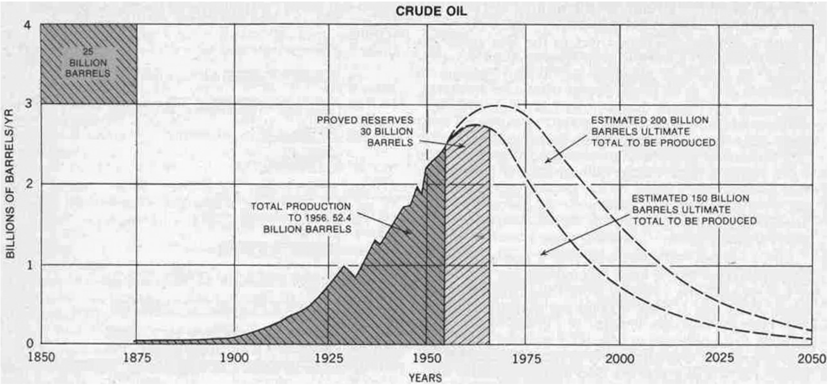

FIG. 2. Hubbert's 1956 peak oil graph. *Source*: M. King Hubbert, "Nuclear Energy and Fossil Fuels," Shell Development Company, Publication No. 95, reprinted from *Drilling and Production Practice* (1956).

Having identified the tensions between fossil fuel consumption and supply, he set about finding a quantitative way to express this relationship.

Hubbert presented his initial finding at a 1956 API meeting in San Antonio. Invited to present a "broad brush picture of the overall world energy situation," he began his paper, "Nuclear Energy and Fossil Fuels," by plotting logistic curves of oil and gas production for Texas, the United States, and the world. Drawing on the work of economic geologist D. F. Hewett on the life cycles of mining districts, he wrote a paper that treated the issue of oil and gas depletion quantitatively as a function of cumulative production. His calculations actually were quite simple. He plotted the rate production on the y-axis and time on the x-axis (Fig. 2). Annual production rose from zero at the beginning of the oil age, curved into a peak, and then trended toward zero as ultimate reserves were exhausted.[36] Hubbert drew the bell-curve graph so sharply on both sides, depicting the rise and fall of the oil age as merely a blip in time, that for many years it was called Hubbert's Pimple rather than Hubbert's Peak.[37]

36. D. F. Hewett, "Cycles in Metal Production," *Transactions of the American Institute of Mining and Metallurgical Engineers*, Petroleum Division, 82 (1929): 65–98; M. King Hubbert, "Nuclear Energy and Fossil Fuels," Shell Development Company, Publication No. 95, reprinted from *Drilling and Production Practice* (1956), copy in AHC MKH, Box 133, Folder Energy Resources—Writings, Correspondence, 1950–1979.

37. See, for example, "He Predicted the Oil Shortage 19 Years Ago," *National Observer*, 10 May 1975, 1E.

Hubbert did not venture an independent estimate of ultimate volumes (discovered plus to-be-discovered) in his graph. Rather, he borrowed estimates from industry experts, who approached reserves during this period with restrained optimism, in contrast to the exuberant optimism of academic economists.[38] To calculate ultimate reserves, these industry officials, as well as the USGS, used variations on volumetric yield analysis, which extrapolated average per unit oil-production yields from explored basins to less-explored but geologically similar areas. This method involved a high degree of subjectivity in determining volumes and geological similarity. It assumed similar recovery of oil per unit volume of sediment, but without empirical evidence to support such an assumption. Still, in the mid-1950s, it was as reliable as any other method.[39] At the time, it was reliable enough for Hubbert. Based on the industry estimates, Hubbert drew two curves, one assuming an ultimate reserve of 150 billion barrels, and one assuming 200 billion barrels, the difference covering the realm of uncertainty.[40]

Hubbert was chiefly interested in determining the moment of peak production, a concept not previously addressed in petroleum resource assessment. He argued that the peak occurs when half of the oil has been produced, or about 75–100 billion barrels if 150–200 billion barrels are used as the ultimate reserve. Assuming increasing consumption, Hubbert regarded peak production as the critical event in the life cycle of an extracted resource; the peak would inevitably force a fundamental readjustment in production and consumption trends. In the 1956 paper, Hubbert's graph projected the U.S. crude oil peak to occur sometime between 1965 and 1970 (see Fig. 2). Given the limits on future oil supply, the second half of the paper dwelt on how nuclear energy offered the best hope "for our needs for at least the next few centuries of 'the foreseeable future.'"[41]

38. L. G. Weeks, "Highlights on 1947 Developments in Foreign Petroleum Fields," *BAAPG* 32, no. 6 (1948): 1094; L. G. Weeks, "Discussion of 'Estimates of Undiscovered Petroleum Reserves by A. I. Levorsen,'" *Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources* 1, no. 107 (1950); Wallace E. Pratt, "The Earth's Petroleum Resources," in *Our Oil Resources*, ed. L. M. Fanning (New York: McGraw-Hill, 1950); Wallace E. Pratt, "The Impact of the Peaceful Uses of Atomic Energy on the Petroleum Industry," *Report of the Panel on the Impact of the Peaceful Uses of Atomic Energy* 2, no. 89 (1956): 89–105.

39. Bowden, "Social Construction of Validity" (ref. 34), 212; Hollis D. Hedberg, "The Volume of Sediment Fallacy in Estimating Petroleum Resources," in *Methods of Estimating the Volume of Undiscovered Oil and Gas Resources*, ed. John D. Haun (Tulsa, OK: AAPG, 1975), 160.

40. Hubbert, "Nuclear Energy and Fossil Fuels" (ref. 36).

41. Ibid., 24.

What was so shocking about Hubbert's projection was that it offered a unique and intuitive interpretation of widely published data that overturned conventional wisdom. That wisdom held that petroleum resources were plentiful, not poised for decline. Hubbert often told the story of being called off the platform a few minutes before giving his address by a Shell Oil public relations executive in New York. He remembered the executive pleading: "Couldn't you tone it down a bit? Couldn't you take the sensational parts out?"[42]

Hubbert's Peak threatened the U.S. oil industry in several ways. First, by suggesting that the United States did not have as much oil as assumed, it could make investors and creditors question the future viability of domestic oil and consequently raise the cost of capital. Second, a pessimistic outlook for domestic oil would also undercut the campaign by the domestic-based, independent oil companies for protection from Middle Eastern imports. Other government benefits, such as oil tax breaks, subsidies, and access to public lands, might also be jeopardized if long-term prospects for the industry appeared uncertain. Finally, Hubbert questioned the deeply imbued psychology of abundance that permeated the industry and American society.

The aftershock of his prediction reverberated through the industry for years. Although some oilmen privately respected the new insight Hubbert brought to the subject, public reaction by many in the industry denounced Hubbert's thesis and rejected any restraint on optimism.[43] Morgan Davis, who would become president and chairman of Humble Oil in 1957, together with his chief economic advisor, Richard Gonzalez, who shaped oil policy recommendations at the National Petroleum Council, led the charge against Hubbert. Their initial tactic was to assert that the ultimate reserve estimates he cited were far too conservative. Improved production techniques and additional discoveries would move ultimate reserves higher.[44] They then disputed the idea that the declining rate of discoveries inevitably would be followed by a declining rate of production. There was no necessary correlation; the magnitude of discoveries was bound to increase, justifying larger estimates of ultimate production and pushing the production peak beyond worry far into the future.[45]

42. MKH INT, 271.

43. See, for example, Wallace Pratt to Ray P. Walters, 6 Sep 1977, AHC MKH, Box 133, Folder Energy Resources—Writings and Correspondence 1950–1979.

44. Richard Gonzalez, "Petroleum for Future Progress," *Journal of Petroleum Technology* 9 (1957): 44–51; and Richard Gonzalez, "U.S. Not Running Out of Oil," *World Oil* 144 (1957): 66.

45. Morgan Davis, "The Dynamics of Domestic Petroleum Resources," *Proceedings of the American Petroleum Institute* 38 (1958): 22–27.

Hubbert warmed to the attention he received as an oil company researcher in a public debate with the president of a major American oil company. During the next several years, he further developed his thesis. As he himself recognized, the weakness of his 1956 curve was that it relied on an exogenous estimate of unknown quality for the ultimate amount of oil to be produced. Setting out to develop his own estimate, he began analyzing the statistics on annual oil production and proven reserves. In papers given at the University of Texas in 1958 and at the AAPG annual meeting in Dallas in 1959, he theorized that the curve indicating a peak in crude oil production would be an asymptote of the curve describing the peak in the growth of crude oil reserves. In other words, as Hubbert described it, "I pointed out that when the reserves peaked, that was a clue of how close you were to the peak of production."[46]

In the late 1950s, Hubbert's views had no effect on official oil supply forecasts. Those years witnessed a giant leap in U.S. crude oil reserve estimates, although not because of any immediate new finds or improvements in technology. They were theoretical increases, unsupported by any new data. In 1956, the Department of the Interior issued a new estimate of 300 billion barrels, without attribution or revelation of the methods used to arrive at the estimate.[47] A 1958 study by the Washington think-tank, Resources for the Future, surveyed the new estimates and concluded, "the total crude oil awaiting (potentially available for) future recovery in the United States can be inferred from expert opinion to be on the order of 500 billion barrels."[48]

HUBBERT VS. MCKELVEY

Hubbert's next, and perhaps most famous, peak oil prophecy came in a 1962 report he submitted to the Committee on Natural Resources under the joint auspices of the National Academy of Sciences (NAS) and National Research Council (NRC). Renowned biophysicist Detlev Bronk, president of the NAS, invited Hubbert, one of the academy's distinguished members, to chair the

46. MKH INT, 286.

47. Hubbert believed that Samuel Lasky, a former mining industry and USGS geologist, consultant to the President's Raw Materials Commission (Paley Commission), and high-level Department of the Interior appointee, was the author of the report. MKH INT, 343.

48. Bruce Netschert, *The Future Supply of Oil and Gas: A Study of the Availability of Crude Oil, Natural Gas, and Natural Gas Liquids in the United States in the Period Through 1975* (Baltimore, MD: Johns Hopkins University Press, 1958), 24. Hubbert savaged the book in a review for *Science* 128 (1958): 196.

subcommittee on energy.[49] Bronk ordered the USGS to work with Hubbert's committee on producing the final report. Vincent McKelvey, a career USGS geologist who had just risen to the position of assistant chief geologist, took responsibility for compiling and coordinating the Survey's data for the subcommittee. Hubbert and McKelvey were two headstrong men who came at the problem of estimating U.S. petroleum reserves from completely different directions. Their disagreement over the future of domestic production, beginning with this study, would shape petroleum assessment at the USGS and in wider circles for the next fifteen years.

In January 1962, McKelvey hand-delivered to Hubbert a thick report that included a preprint of a new official USGS estimate of ultimate U.S. crude oil resources, based on research by a USGS staff geologist, Alfred D. Zapp. Reportedly frustrated by earlier USGS estimates that were too conservative, Zapp looked for a way to improve the volumetric yield method of extrapolating from proved reserves. By 1961, the industry had drilled a cumulative 1.1 billion feet and discovered 130 billion barrels of crude oil in 20 percent of the nation's sedimentary rock. Thus, an average of 118 barrels were discovered per foot of exploratory drilling. Assuming a similar rate of discovery in the nation's other 80 percent of sedimentary rock, Zapp's preprint estimated that at least an additional 170 billion barrels, under static economic and technological conditions, could be discovered with an additional 2 billion feet of exploratory drilling.[50]

Hubbert objected to what he considered an inflated ultimate estimate of 300 billion barrels of ultimate reserves (130 billion discovered plus 170 billion to be discovered). When he voiced this complaint to McKelvey, the response he received was that the ultimate should be 590 billion barrels, not 300 billion. An additional 290 billion would be added under the classification, submarginal resources. This was based on an optimistic discovery rate estimate of 145 barrels per foot through an additional 2 billion feet of drilling. Even 590 billion barrels,

49. The NAS-NRC study was organized into seven separate subcommittees: renewable resources, water resources, mineral resources, energy resources, marine resources, environmental resources, and social and economic aspects of natural resources.

50. Robert Gillette, "Oil and Gas Resources: Did USGS Gush Too High?" *Science*, new series 185 (1974): 128; M. King Hubbert, "Degree of Advancement of Petroleum Exploration in the United States," *American Association of Petroleum Geologists Bulletin* 51 (1967): 2216–18; MKH INT, 308–10. (Note: *American Association of Petroleum Geologists Bulletin* changed names in 1967 from *Bulletin of the American Association of Petroleum Geologists* (*BAAPG*) to *American Association of Petroleum Geologists Bulletin*, so it appears two ways in these notes).

McKelvey told a dumbfounded Hubbert, was conservative. The so-called Zapp hypothesis assumed an average rate of return per well for known discoveries and then applied this rate to deeper wells in existing and potential petroleum-bearing basins, arriving at the figure of 590 billion barrels from a total 5 billion feet of exploratory drilling.[51] *Science* magazine later described the technique as "requiring nothing more sophisticated than a geologic map of the country and an adding machine."[52]

"The magnitude of 590 billion barrels was just jolting!" Hubbert recalled.[53] In response, he informed McKelvey, USGS Director Tom Nolan, and everyone else associated with the NAS-NRC study that he could not accept that estimate in his subcommittee report. He was going to produce his own estimate, and if the other members of the committee did not like it, he would resign from the committee and publish it somewhere else. Hubbert was convinced that discoveries were not made at a constant rate per foot of drilling, but he did not yet have the time or the data to disprove this assumption [he would later, see below]. The committee grudgingly went along with him.[54]

In his report, Hubbert offered a new method for estimating ultimate U.S. crude-oil production that used the most reliable series of statistics on cumulative production, proved reserves, and cumulative proved discoveries (the sum of the first two). He then fitted those statistics to the theoretical curve he described in 1956. From his curves, he concluded that cumulative proved discoveries peaked in 1957, proved reserves would peak about 1962, and that the production peak would occur in the late 1960s. Given this information, applying his theory about the asymptotic relationship between production and reserves, and assuming that cumulative production before the point of inflection on the theoretical curve would equal one-half the ultimate production, Hubbert calculated ultimate production in the continental United States and near-adjacent offshore areas to be 175 billion barrels.[55]

51. Alfred Zapp died in October 1962, and there is no evidence linking him directly to the 590 billion barrel figure. Hubbert asserted that this high value should not be attributed to Zapp, a well-respected scientist, because he had no chance to refine his analysis. The implication is that McKelvey commandeered Zapp's research and tacked on the extra 290 billion barrels. MKH INT, 308–09, 352–53; Charles A. S. Hall, Cutler J. Cleveland, and Robert Kaufman, *Energy and Resource Quality* (Boulder: University Press of Colorado, 1992), 342–49.

52. Gilette, "Oil and Gas Resources" (ref. 50), 128.

53. MKH INT, 311–12.

54. Ibid.

55. M. King Hubbert, *Energy Resources* (Washington, DC: National Academy of Sciences/National Research Council, 1962), 50.

Before Hubbert's report went to publication, Roger Revelle, science advisor to the secretary of interior, passed on a draft to McKelvey for comment, which led to a sharp exchange of letters between McKelvey and Hubbert during the summer of 1962. This exchange reveals their uncompromising ways of thinking about natural resource supply. "In essence," objected McKelvey to Hubbert, "you are using the record of human activity to indicate the earth's content of oil. To me this is unsound, for the results obtained in our search for a given substance depend not only on how much exists but also on the efficacy of the knowledge and tools used in the search and the amount of effort devoted to the search." Replied Hubbert: "if estimates of the earth's content of oil are to be made independently of 'the record of human activity' I am at a loss to see how any limits can be set to the size of estimates that may be dreamed up (I used the word 'dream' advisedly), or what criteria of plausibility may be employed in evaluating such estimates." Hubbert based his estimate on a quantitative technique that could not shake McKelvey's faith in human ability to manufacture natural resources from the earth, while McKelvey's and Zapp's method struck Hubbert as not only woefully unscientific, not based on measurable observations of the physical environment, but, if "accepted as a basis for present policy," would be detrimental "in terms of national welfare." [56]

After Hubbert's NAS-NRC report was published, McKelvey engineered a more public challenge to Hubbert's model as well as a defense of Zapp, who died of cancer in October 1962. Using Zapp's method of geological analogy, McKelvey prepared an internal working document for an Interdepartmental Energy Study and then leaked the document to the *Oil and Gas Journal*, resulting in an article with unattributed authorship under the banner headline "U.S. Reserves Put at 600 Billion BBL."[57] Hubbert was furious at what he considered a bureaucratic maneuver to undermine the NAS-NRC report.[58]

56. Vincent McKelvey to M. King Hubbert, 29 Jul 1962, and Hubbert to McKelvey, 17 Aug 1962, both in AHC MKH, Energy Resources—Writings, Box 133, Correspondence, 1950–1979 File.

57. "U.S. Reserves Put at 600 Billion BBL," *Oil and Gas Journal* (1963): 78–79. A second article ran two weeks later, reporting a USGS estimate of world petroleum reserves at 4 trillion barrels, much higher than even the most optimistic forecasts today. This contrasted with Hubbert's much lower estimate of 1.25 trillion bbl in his NAS-NRC study. "USGS Estimates 4-Trillion-BBL Reserve," *Oil and Gas Journal* (1963): 63.

58. Hubbert to Tom Nolan, Director, USGS, 17 Oct 1962, AHC MKH, Box 153, NAS Committee on Natural Resources, General Correspondence; Robert Barlow, Executive Office of the President, Office of Science and Technology, to Hubbert, 25 Sep 1963, Subject Files, Energy from Fossil Fuels, AHC MKH, Box 132, Folder 1. Hubbert claims that Tom Nolan later told him

The USGS director, Tom Nolan, feebly explained that the estimates cited in the *Oil and Gas Journal* did not come from an official Geological Survey report, and that a range of figures was warranted. But Nolan's statements only obfuscated matters, since the positions of Hubbert and McKelvey were simply incompatible.[59]

HUBBERT'S TRIUMPH

Once the voice of resource pessimism and conservation, the USGS became the leading disseminator of what could be called the discourse of market-driven abundance. It is tempting to argue that the USGS in the 1930s and 1940s had become captive to the interests of mineral industries and oil-state representatives in Congress, and thus prone to making favorable assessments of the ability of markets and technology to extend domestic mineral resources. But on closer inspection, it appears that the USGS actually had become more removed from the influence of the oil business.

The USGS's optimism did not differ superficially from that expressed by many oilmen. The Survey was insulated, however, from changing views on resource appraisal that spread through the industry in the 1960s. Leadership in the USGS always came from the Geologic Division, an elite unit of academic geologists with expertise in hard-rock geology and little experience with modern petroleum.[60] As many in the industry began to arrive at more sober assessments of supply increasingly in line with Hubbert's, the USGS continued to "gush higher."[61]

This was due almost entirely to the influence of Vincent McKelvey (Fig. 3). An expert in phosphates with advanced degrees from the University of Wisconsin, McKelvey had gone to work for the USGS Geologic Division in 1941. He established his reputation doing field investigations for strategic minerals during World War II. After the war, he conducted research on

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that the initiative for this article came from Roger Revelle and Jerome Wiesner. Hubbert Oral History, 322; Hubbert, Memorandum: Confidential, For: Thomas B. Nolan File, 31 Mar 1975, AHC MKH, Box 135, Energy–Natural Resources Thomas B. Nolan, 1963–1976.

59. Tom Nolan to Editor, *Oil and Gas Journal* (4 Oct 1963), Subject Files, Energy from Fossil Fuels, AHC MKH, Box 132, Folder 1.

60. The other divisions of the USGS were the Mapping Division, the Water Resources Division, and the Conservation Division.

61. Gillette, "USGS Gush Too High?" (ref. 50), 128.

FIG. 3. Vincent E. McKelvey. Photo courtesy of U.S. Geological Survey Photographic Library, Denver, CO, in public domain, http://libraryphoto.cr.usgs.gov/terms_of_use.htm.

phosphates and led the USGS's uranium geology program for the Atomic Energy Commission. He had no background in oil and gas geology, but that did not stop him from launching an assault on Hubbert's oil supply projections. One associate described him as "so bright, he always knew so much—a hard driver, sometimes arrogant."[62] In 1963, while he was battling Hubbert, McKelvey received the Distinguished Service Award, the Department of the Interior's highest. In 1965, he became a senior research geologist, advancing to chief geologist briefly before becoming the Survey's director in 1971.

McKelvey aspired to be more than a research geologist. He wanted to be known as a man of vast knowledge, pursuits, and authority. During the USGS's new age (1956–65), Director Tom Nolan encouraged his geologists to "expand their fields of interest from individual problems and 'participate

62. Quoted in Bernardo F. Grossling, "The Return of Vincent E. McKelvey," *Geophysics: The Leading Edge of Exploration* 7 (1988): 18.

actively and authoritatively in the matters affecting the whole country.'"[63] As he ascended the administrative ranks of the Survey, McKelvey took growing interest in the broader aspects of mineral resources first aroused by his Wisconsin mentor, Charles (C. K.) Leith, a world-famous geologist and advisor to several U.S. presidents on strategic minerals issues.[64] Often sporting a bowtie, McKelvey fashioned himself as a public intellectual who could offer incisive commentary on the big questions of the day, the most important of which, for him, had to do with the foundations of material prosperity in human society. He was an unabashed Cornucopian. He made it his mission to place an optimistic spin on the Survey's resource estimates, and he made sure to surround himself with loyal lieutenants who would tow the line.[65]

He first joined the public conversation on resource supply in the late 1950s, when American assurances of abundance were becoming bolder. In an article for *Science* magazine in 1959, McKelvey attempted to dispel concerns about the explosion in world population by pointing to the almost unlimited human potential to alleviate food and resource constraints. Venturing far from his expertise as a phosphate geologist, McKelvey tried to develop a grand theory about how and why humans had been able to overcome subsistence crises. The result combined culturally chauvinistic views on population control with facile observations on history and anthropology. The increasing consumption of raw materials and energy should not be cause for alarm, he argued, because such increases were associated historically with the growing ability of Western societies to extend their control over the physical environment and thus increase their means of subsistence. "Resources of usable raw materials and energy may be increased to an unpredictable extent by the development and application of ingenuity," wrote McKelvey.[66]

63. Rabbitt, *Geological Survey: 1879–1989* (ref. 9).

64. Vincent McKelvey, Preface to draft manuscript, "Cornerstones of Affluence," AHC VEM, Box 3, Professional File: 1968, Energy and Natural Resources, Minerals—Development and Policy, 5 of 8, 5058-88-01-11.

65. These men included Dick Sheldon, another phosphates expert and longtime McKelvey underling who became chief geologist when McKelvey made director; Bernardo Grossling, a USGS research who worked closely with McKelvey to resist downward revisions in the Survey's reserve estimates, who for years afterward issued extremely high estimates of Latin America's petroleum potential, and who became McKelvey's most devoted hagiographer (see ref. 62); Tom Hendricks and Donald Duncan, who contributed to the Survey's optimistic 1960s estimates; and Chuck Masters, whose hiring as Chief of the Office of Energy Resources in 1973 raised eyebrows in the Survey because Masters was a close friend and former classmate of Dick Sheldon.

66. Vincent E. McKelvey, "Resources, Population Growth, and Level of Living," *Science* (1959): 875–81, on 880.

Rather than fretting about abundance, like Galbraith or Theobald, McKelvey celebrated it as the product and handmaiden of innovation. In an unpublished manuscript entitled "Cornerstones of Affluence," he argued that mineral fuels, metals, nonmetals, and water formed "the basis of the affluent industrial society." If these resources were the cornerstones, then the structure and pillars of affluence were "human purpose, effort, and advanced technological, socioeconomic, and political ingenuity that converts worthless sand and clay into useful products." Citing Erich Zimmermann, he asserted that the usability of resources, rather than their mere existence, is what makes them valuable.[67] For McKelvey and other apostles of abundance, resources were more important as ideas rather than as concrete objects of nature. "The process by which we create resources," wrote McKelvey in an article adapted from his "Cornerstones" manuscript, "have dimensions beyond our knowledge and even beyond our imagination at any given time."[68]

This imagination colored McKelvey's, and thus the USGS's, petroleum supply estimates from the early 1960s into the mid-1970s. Resource appraisal needed to incorporate economic and technological factors, which Hubbert often resisted. But the way the government scientists blended these factors into their estimations, as Hubbert pointed out, imposed almost no limit on the size of reserves that could be imagined.

The chapter at the heart of McKelvey's manuscript is called "Meaning and Preparation of Reserve and Resource Estimates," which was eventually published in the 1972 issue of *American Scientist*. In this piece, McKelvey offers a simplistic mathematical equation to illustrate the "essential role of mineral and mineral fuels in human life": L = R x E x I / P, where "L" is a society's average "level of living," "R" is raw materials, "E" is energy, "I" is all forms of ingenuity, and "P" is the population that shares in the product. Hubbert blasted this formula as lacking "any understanding of the incompatibility of the quantities dealt with," and having only "the appearance of conveying meaning without actually doing so." McKelvey had presented it as merely a conceptual equation, acknowledging that numerical values could not be assigned to some of its components." If so, chided Hubbert, "what is the

67. The manuscript begins with an expanded version of McKelvey's 1959 *Science* article, surveys the role of minerals in regional economic development, examines national mineral policies, including reserve and resource estimation, and discusses the role of minerals in international affairs. McKelvey, "Cornerstones of Affluence" (ref. 64).

68. V. E. McKelvey, "Mineral Resource Estimates and National Policy," *American Scientist* 60 (1972): 32.

purpose of introducing it if not to create an impression that the analysis can be intoned by being expressed mathematically?"[69]

During the 1960s, McKelvey and Zapp's volumetric, geological analogy approach to petroleum estimates held sway over Hubbert's curve-fitting technique. Although some industry representatives were persuaded by Hubbert's method,[70] most were still uncomfortable with the way he extrapolated past trends into the future. "Exercises . . . based on statistics without regard for the controlling fundamentals," grumbled Lewis Weeks, one of the more respected appraisers of petroleum resources, "should not be dignified as estimates of resources." John Ryan, an economist for Standard Oil of New Jersey (Exxon), added that Hubbert's analysis ignored the role of economics in determining the size of reserves, and he pointed out that no fundamental law of physics would dictate that cumulative discoveries or production would follow a logistic curve in the future.[71]

Unspoken but palpable were the political implications of the different positions of Hubbert and McKelvey. Although both were longtime registered Democrats, McKelvey's views reinforced a *laissez-faire* approach to business and a belief in a self-correcting market, while Hubbert envisioned an active, technocratic role for government in devising policies to conserve fossil fuels, which made it difficult for oilmen to embrace his ideas. McKelvey conformed to the post–New Deal retreat from regulation and became a consummate Washington insider. Hubbert, by contrast, remained a dissenting outsider whose environmental awareness was ahead of its time.[72]

69. M. King Hubbert, "Commentary on 1972 Paper of V. E. McKelvey, 'Mineral Resource Estimates and National Policy,'" *American Scientist* 60 (1972): 32–40, AHC MKH, Box 158, Oil & Gas Reserves Evaluation/Denver Workshop.

70. In addition to Wallace Pratt of Humble Oil, there was H. K. Hudson of Phillips Petroleum, who called the Zapp-McKelvey estimates "pure extrapolations" that "induce a dangerous and false feeling of assurance" in the face of "a vast amount of geological evidence conflicting with these estimates." H. K. Hudson to Jerome Wiesner, Director of the Office of Science and Technology, "Re: Future Supplies of 'Conventional' Crude Oil and Natural Gas," 3 Oct 1963, AHC MKH, Box 132, Energy from Fossil Fuels.

71. Lewis G. Weeks, "Estimation of Petroleum Resources: A Commentary," *BAAPG* 50 (1966): 2009; John M. Ryan, "National Academy of Sciences Report on Energy Resources: Discussion of Limitations of Logistic Projections," *BAAPG* 49 (1965): 1713–20; and Hubbert's reply, M. King Hubbert, "National Academy of Sciences Report on Energy Resources: A Reply," *BAAPG* 49 (1965): 1720.

72. For Hubbert's general views on environmental issues, see W. von Englehardt, Jean Goguel, M. King Hubbert, R. A. Price, and R. Trümp, "Earth Resources, Time, and Man: A Geoscience Perspective," *Environmental Geology* 1, no. 4 (1976): 193–206; Hubbert's environmental views are

Ironically, in 1964, just after his first big showdown with McKelvey, Hubbert retired from Shell Oil and went to work as a research geophysicist for the USGS. For the next thirteen years, he worked nominally under his chief antagonist. A strange career choice on the face of it, Hubbert had his reasons. He had reached the age of mandatory retirement at Shell (60 years). Despite McKelvey's presence, he still respected the USGS as an earth science research organization and, in the late 1950s, had received a standing offer to work there. Plus, he believed the USGS would allow him to continue working on open-ended problems. Employment at the USGS also allowed him reside in Washington, DC, near two organizations of which Hubbert took great pride in being a member: the National Academy of Sciences and the Cosmos Club, the private social club founded in 1878 by the famous geologist and explorer, John Wesley Powell, which was open only to people of distinction in science, literature, and the arts. Although always the iconoclast, Hubbert felt a strong need to belong and to be recognized by his peers.[73]

After joining the USGS, Hubbert continued to make predictions about oil and gas production and reserves, but the Survey published not a single one. In a now-famous 1967 paper for the AAPG, "Degree of Advancement of Petroleum Exploration in the United States," he issued his most penetrating critique of the Zapp/McKelvey methodology, empirically demonstrating that oil historically was not discovered at a constant rate per unit drilling. Rather, oil production in the United States displayed decreasing returns per drilling effort over time. Hubbert showed that finding rates had declined sharply since the 1930s, as oil companies went after the easiest oil first, skimming the cream off the biggest and most productive fields in Texas, Oklahoma, and California.[74]

McKelvey and the USGS greeted Hubbert's study with silence. The simmering disagreement became increasingly personal as McKelvey ascended the ranks of the USGS. On a Friday in December 1971, President Richard Nixon confirmed McKelvey as director of the Survey. On the following Monday, Hubbert was told that the Survey was taking away his secretary. "For two years I wrote official letters longhand and my wife typed every word of my Senate report [see below] at home," he lamented.[75] Hubbert soon exacted his revenge.

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also noted in Ronald E. Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945," *Social Studies of Science* 33 (2003): 635–66.

73. Broussard interview (ref. 31).

74. Hubbert, "Degree of Advancement" (ref. 50), 2207–27.

75. M. King Hubbert, File Memo: USGS-McKelvey-Pecora, 18 Dec 1976, AHC MKH, Box 135, Energy–Natural Resources, Thomas B. Nolan, 1963–1976; MKH INT, 360–62; Department

In 1972, as a member of the National Academy of Sciences and the American Academy of Arts and Sciences (AAAS), he helped kill McKelvey's nomination to both organizations by challenging the USGS director's "scientific competence" and "intellectual integrity."[76] As domestic supply constraints tightened and the Arab oil embargo of 1973 magnified this predicament into a full-blown energy crisis, Hubbert followed his own star, granting interviews with the press and giving lectures that were interpreted by the USGS leadership as contradicting official policy or running down the Survey.[77]

In his confrontations with McKelvey and the USGS, Hubbert resorted to boundary work to establish his authority.[78] He presented his views as scientific and objective, in contrast to those of his adversaries, which he depicted as nonscientific and ideological. He regarded himself as a technocrat whose unbiased, scientific expertise gave him privileged insight into energy policy. However, his science rested on firmly held, some might say ideological, convictions about the material limits to economic growth. Although the McKelvey/Zapp assessment method may not have been as rigorously quantitative as Hubbert's, it was still based on scientific inquiry and remains part of the resource appraiser's toolkit. For all his concern about nontechnocratic influences over policymaking, Hubbert himself was not above playing politics. He policed the social and professional boundaries of science in Washington through the Cosmos Club, the NAS, and AAAS to solidify his position and marginalize McKelvey. Hubbert also was not shy about mentioning that he had the ear of Senator Henry M. "Scoop" Jackson, the powerful chairman of the Senate Committee on Interior and Insular Affairs and leading presidential contender, as a veiled threat to anyone who might think of crossing him.[79]

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of the Interior, News Release, 6 Dec 1971, "Vincent E. McKelvey to Be Sworn in as New Director of the United States Geological Survey," Correspondence-Professional 1971, AHC VEM, Box 3, VEM Letters of Congratulations, 5058-85-10-03. McKelvey never denied this accusation, which Hubbert aired publicly.

76. M. King Hubbert to Dr. Harvey Brooks, Feb 1972, and Hubbert, "Comments Regarding Nominee for Membership in National Academy of Sciences, Vincent Ellis McKelvey," Aug 1972, both in AHC MKH, Box 134, File McKelvey II 1972–1977.

77. M. King Hubbert, Confidential Memorandum, Visit from Richard P. Sheldon, Chief Geologist, U.S.G.S., 25 Sep 1975, AHC MKH, Box 134, Energy–Natural Resources, U.S.G.S. Censorship, 1975; MKH INT, 365–70.

78. Thomas F. Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Science," *American Sociological Review* 48 (1973): 781–95. Also see Sheila Jasanoff, *The Fifth Branch: Science Advisers as Policymakers* (Cambridge, MA: Harvard University Press, 1990).

79. Rose interview (ref. 32).

By the time McKelvey took the director's position, pressure had begun to build on the Survey for better justification of the vast gulf between its supply projections and Hubbert's. In 1969–70, for the first time in U.S. history, the reported amount of proved natural gas reserves plummeted. East Coast purchases of foreign fuel oil, now exempted from import quotas, soared. That winter, the coldest in thirty years, witnessed alarming fuel shortages. The following summer, capacity constraints on utilities caused brownouts in cities all along the Atlantic Coast. As the cost of foreign oil delivered to the United States caught up with the domestic wellhead price, imports began to surge, aided by loopholes in the oil quota system.[80]

Dysfunctional regulations were one reason for the shortfalls, but many people began to think the crisis might also be caused by depleted reserves and a peak in production. In March 1972, the Texas Railroad Commission (TRC), the lead regulator of the oil industry, removed production limits, which encouraged oil producers to open the taps on their wells and produce at full capacity. The TRC's action was a sure sign that U.S. oil production was not keeping up with demand. Oil companies saw a day of reckoning not far on the horizon, and they began privately circulating statements that their own reserve numbers were far below those of the USGS.[81] Many industry geologists found they could not quarrel with Hubbert's method. Those who had in the past, such as Morgan Davis and Richard Gonzalez from Humble Oil, had retired.[82]

The final act in the Hubbert-McKelvey drama began a year earlier, when, on a request from Senator Jackson, Hubbert worked up a new report, "U.S. Energy Resources: A Review as of 1972." Finished in the fall of 1973 and released by Jackson's Senate Committee in June 1974, the study offered a new estimate of the total amount of crude oil, natural gas liquids, and natural gas to be produced in the entire United States (including Alaska) and bordering

80. Neil De Marchi, "Energy Policy Under Nixon: Mainly Putting Out Fires," in *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions*, ed. Craufurd D. Goodwin (Washington, DC: Brookings Institution, 1981), 395–473.

81. In 1965, Shell Oil, Hubbert's former employer, formulated an internal, long-term crude oil forecast that predicted the U.S production peak in the mid-1970s. The study also revealed that spare shut-in capacity in U.S. oilfields was much less than what was being reported. See Tyler Priest, *The Offshore Imperative: Shell Oil's Search for Petroleum in Postwar America* (College Station: Texas A&M Press, 2007), 157–58.

82. Hubbert claims that many of his colleagues within Humble Oil privately expressed their support for his studies and irritation with the obsessive attacks on him by Davis, Gonzales, and Ryan. MKH INT, 283, 348.

continental shelves. It estimated ultimate crude oil to be 170 billion barrels (240 billion including natural gas liquids) for the lower 48 states and 43 billion barrels for Alaska, totaling 213 billion barrels (252 billion including natural gas liquids).[83]

During the spring and summer of 1974, the reckoning arrived for the USGS. Annual crude oil production had declined each year since 1970. The inability of U.S. supply to respond to the crude oil price spike that followed the Arab oil embargo convinced many inside and outside the oil industry that the peak had past, just as Hubbert had predicted, and that the USGS figures for undiscovered crude oil were wildly inflated. For the first time, McKelvey hedged his bets. In testimony before Jackson's committee, he indicated a low range of 388 billion barrels and a high range of 608 billion barrels (including natural gas liquids), though the entire range was still significantly higher than Hubbert's. When the USGS published these numbers in a news release later that month, it met a tide of criticism. The most damaging rebuke came from John Moody, senior vice president for exploration and production at Mobil Oil, who called USGS estimates for the continental United States inconceivable, well above any figure his company could justify.[84]

This criticism forced the Survey to accelerate a thorough reevaluation of its method of estimating petroleum reserves and resources. In 1973, the Survey's Office of Energy Resources, under Thane McCullough, had reorganized its Oil and Gas Branch, installing Peter Rose, a former geologist with Shell Oil, as head. Rose began hiring geologists and researchers from various oil companies to bring the branch up to speed with methods being used by industry to assess oil and gas potential. These people were highly experienced in basin analysis, or play analysis. This involved looking at a prospective region from a petroleum geology perspective, examining the geothermal heat regime, the existence of organic-rich source rocks, the age of structural deformation, reservoir formations and seals, and other data. Using all this information, basin analysis then expressed the likelihood of a large oil and gas presence in a given play and what

83. M. King Hubbert, "U.S. Energy Resources, A Review as of 1972, Pt. 1," in *A National Fuels and Energy Policy Study*, Senate Committee on Interior and Insular Affairs, 93rd Cong., 2d sess., Serial no. 39-40 (92-75).

84. Furthermore, Mobil's estimates included offshore oil out to a depth of 6,000 feet, whereas the USGS stopped at 660 feet, which made the USGS estimates appear even more fantastic. J. D. Moody to V. E. McKelvey, 8 Apr 1974, Energy–Natural Resources, AHC MKH, Box 134, Energy Resources—Writings, Correspondence, USGS Estimates, #3.

the range of reserves might be. USGS geologists did not have the data or knowledge of how to do this.[85]

Just prior to the March 1974 Senate hearings, Rose and McCullough set up a special Resources Appraisal Group (RAG) to develop this kind of analysis and publish a new set of reserve estimates by June 1975. RAG involved more than seventy regional specialists and analyzed more than a hundred possible petroleum provinces. Using methods of province-by-province geologic evaluation, RAG produced a range of estimates with assigned probabilities. Published as USGS Circular 725, the RAG numbers ranged between 218 and 295 billion barrels of ultimate reserves.[86] These were still higher than Hubbert's and arrived at using a different methodology, but they were much closer to his than to those of the USGS, and more in line with other estimates being made at the time. Circular 725 was significant in that it marked the end of a fourteen-year period during which the USGS estimates had been at least two or three times higher than this.

Although McKelvey still tried to subvert the acceptance of Circular 725 as the agency's official position, the walls began to close in around him.[87] In 1974, the former Interior Secretary (1961–69) Stewart Udall co-authored a book called *The Energy Balloon*, which employed an apt metaphor for the Survey's inflated petroleum estimates. "I had been assured again and again by Interior's experts that there was plenty of domestic oil to take care of our needs at least until the year 2000," Udall wrote in the book's foreword. After he left office, it became clear to him "that an enormous energy balloon of inflated promises and boundless optimism had long since lost touch with any mainland reality."[88] The next year, Udall said that if he were interior secretary, "the first thing I would do would be to kick McKelvey out."[89]

85. Nor was the Survey making any efforts in this direction. Rose reveals that Dick Sheldon, McKelvey's chief geologist, was even diverting funds appropriated for resource evaluation, perhaps illegally, to other purposes within the Survey. Rose interview (ref. 32).

86. B. M. Miller, H. L. Thomsen, G. L. Dolten, et. al., *Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States* (Washington, DC: U.S. Geological Survey, Circular 725, 1975); Department of the Interior, News Release, 7 May 1975, "New Estimates of Nation's Oil and Gas Resources," 5058-88-01-11, Professional File: 1975–1980, Energy and Natural Resources, AHC VEM, Box 3, Estimation and Classification Methods, 3 of 3.

87. On McKelvey's efforts at subversion, see "Report Tampering Charged," *National Journal*, 27 Sep 1975, 1349; M. King Hubbert, Confidental Memorandum, 25 Sep 1975, Energy–Natural Resources, AHC MKH, Box 134, USGS Censorship, 1975; MKH INT, 420–21.

88. Stewart Udall, Charles Conconi, and David Osterhout, *The Energy Balloon* (New York: McGraw-Hill, 1974), 8–9.

89. Arthur J. Magida, "Energy Report/USGS Plays a Numbers Game on Remaining Oil, Gas Resources," *National Journal*, 27 Sep 1975, 1349.

In 1975, the NAS-NRC's Committee on Mineral Resources and the Environment (COMRATE) published a study that was milder than Udall in its criticism of USGS's petroleum assessment, but which rebuked the Survey for relying on little more than guesses. Chaired by Yale University geophysicist, Brian Skinner, COMRATE was the first to characterize the debate as one between the Cassandras, who "pay too little attention to the adjustment potential of the market mechanism and generally fail to understand the distinction between 'reserves' and 'resources,'" and the Cornucopians, who "rely too heavily on the market mechanism for inducing the transformation of 'infinite' resources into almost infinite reserves, and on the technological miracle for providing the physical wherewithal." The study bemoaned the data deficiencies, divergent methodologies, and "definitional vagueness" that plagued petroleum resource assessment. Yet it concluded unequivocally that the "undiscovered recoverable resources of oil and natural gas, onshore and offshore, in the United States, including Alaska, are considerably smaller than indicated by figures currently accepted in government circles."[90]

The COMRATE report marked the end of a long period of boundless optimism about U.S. petroleum supplies. In the summer of 1977, newly elected president Jimmy Carter and his Interior Secretary, Cecil Andrus, forced Vincent McKelvey, the symbol of this optimism, to resign as USGS director, the first time this had happened in the Survey's ninety-eight-year history. On his way out of the director's office, McKelvey received one last bit of recognition for his service: in 1978, the U.S. Board on Geographic Names named a peak in the Thiel Mountains of Antarctica after him. Mount McKelvey, however, stood in the long shadow cast by Hubbert's Peak.[91]

90. Committee on Mineral Resources and the Environment, *Mineral Resources and the Environment* (ref. 5), 16–18. The study proposed that out of an original stock of crude oil and natural gas liquids (249 billion barrels), only 113 billion remained to be discovered. For natural gas, 530 trillion cubic feet out of an original 1,227 trillion remained.

91. "Interior Secretary Will Replace Head of U.S. Geological Survey," *New York Times*, 7 Sep 1977, 1A; Thomas O'Toole, "Chief Geologist's Downfall," *Washington Post*, 13 Nov 1977, A6; Richard Pearson, "Noted Research Geologist Vincent E. McKelvey Dies," *Washington Post*, 25 Jan 1987, C12. In 1996, Congress also named the federal Earth Sciences and Library Building in Menlo Park, California after McKelvey.

"ALL HAIL KING HUBBERT"

There are several interrelated ways to analyze the legacy of Hubbert's Peak. One is to evaluate its impact on the field of petroleum resource assessment and what it reveals about the role of science advisors in policymaking. This requires placing the issue in the context of the energy crises and environmentalism of the 1970s. We can also consider the confirmation of Hubbert's Peak as part of the fracturing of the postwar growth consensus and the simmering apprehension about the future.[92] This may help explain the cultural endurance and popularity of Hubbert, even in the face of mounting evidence against the peak oil thesis.

Estimates of petroleum supply inform official thinking about energy policy. Although some Washington insiders denied the importance of USGS's petroleum estimates to policymaking, the Survey's optimistic estimates under McKelvey at the very least obscured the need for rethinking assumptions about domestic oil abundance that shaped policy choices.[93] Better planning and conservation measures would not have prevented growing dependence on foreign oil, but, as the COMRATE report pointed out, the lack of such measures resulting from overconfident assurances of abundance helped speed the depletion of domestic U.S. petroleum resources.[94]

The debate over Peak Oil never moved far beyond policymaking into academic earth sciences,[95] but it did resonate in the wider official and public

92. On the fracturing and fragmenting of ideas in American intellectual debate in the late twentieth century, see Daniel T. Rodgers, *The Age of Fracture* (Cambridge, MA: Harvard University Press, 2011). Although Rodgers skillfully analyzes and synthesizes numerous topics and debates in the realms of politics, economics, race, gender, class, culture, and religion, he neglects the subject of the natural environment.

93. Gillette, "USGS Gush Too High?" (ref. 5), 129.

94. Committee on Mineral Resources and the Environment, *Mineral Resources* (ref. 5), 17.

95. Resource estimation was an aspect of exploration geology and geophysics. These were applied fields in the oil and gas industry, where proprietary data was generated. Advances in theoretical and applied geophysics tended to come out of the geophysical laboratories of the major oil companies. With the acceptance of theory of plate tectonics in the 1960s, geophysics achieved greater penetration into academic geosciences. At the same time, contact between the oil industry and academia increased, largely through the patronage of oil industry contractors in funding geophysical laboratories at places like the Colorado School of Mines and Stanford University. In 1954, Henri Salvatori, the founder of Western Geophysical, an industry seismic contractor, donated funds to build a geophysical laboratory at Stanford. In 1961, Cecil Green, founder of Geophysical Services, Inc., the other leading seismic contractor, subsidized a new geophysical lab at the Colorado School of Mines. Hubbert himself helped create an environmental studies program at Stanford in the early 1960s, but natural resource evaluation was not part of the curriculum. Not until the late 1970s did curricula addressing subjects such as basin

realms from the 1970s forward. Hubbert helped to restore credibility to arguments that asserted the finitude of oil resources and called for greater conservation, efficiency, and planning in the use of energy. By the mid-1970s, his was no longer a lone voice warning about petroleum exhaustion. From the Club of Rome's *Limits to Growth* (1972), to Udall's *Energy Balloon* (1974), to the Ford Foundation's *A Time to Choose: America's Energy Future* (1974), the chorus grew louder in support of government promotion of conservation or moderation in energy consumption as a pathway out of the crisis. Such proposals also underpinned President Jimmy Carter's national energy plans of 1977 and 1979.[96]

Hubbert contributed to an even larger social and political awakening over what Seymour Martin Lipset once called the "implications for the American tradition" of moving "from abundance to scarcity."[97] He joined other celebrity scientists of his era, such as Rachel Carson and Paul Ehrlich, in warning about the limits on humans' ability to manipulate and control the natural environment.[98] Beginning in the 1970s, growing evidence revealed that excessive optimism had steered policies governing sustainable yields in other resources, similar to estimates of U.S. oil reserves in the 1950s and 1960s. As Paul Hirt demonstrates in the case of U.S. forest policy, a "conspiracy of optimism" in

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analysis, petroleum systems modeling, and resource evaluation emerge in geoscience departments at places such as the University of Texas, Stanford, the Colorado School of Mines, and the University of Kansas. Still, resource evaluation remained a field associated largely with state government agencies attached to those particular academic programs (e.g., the Texas Bureau of Economic Geology and the Kansas Geological Survey), with the federal agencies in the Department of the Interior, or with industry consultants and professional organizations linked to them. For background on the history of exploration geophysics, see L. C. Lawyer, Charles C. Bates, and Robert B. Rice, *Geophysics in the Affairs of Mankind: A Personalized History of Exploration Geophysics* (Tulsa, OK: Society of Exploration Geophysicists, 2001). For insight into the world of resource estimation, see Lawrence J. Drew, *Oil and Gas Forecasting: Reflections of a Petroleum Geologist* (New York: Oxford University Press, 1990).

96. Donella H. Meadows, Dennis Meadows, Jorgen Randers, and William H. Behrens III, *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (New York: Signet, 1972); Udall et al., *Energy Balloon* (ref. 88); Final Report by the Energy Project of the Ford Foundation, *A Time to Choose: America's Energy Future* (Cambridge, MA: Ballinger, 1974); Jay Hakes, *A Declaration of Energy Independence: How Freedom from Foreign Oil Can Improve National Security, Our Economy, and the Environment* (Hoboken, NJ: John Wiley and Sons, 2008), 45–67.

97. See Kenneth E. Boulding, Michael Kammen, and Seymour Martin Lipset, eds., *From Abundance to Scarcity: Implications for the American Tradition*, The Hammond Lectures, no. 1 (Columbus: University of Ohio Press, 1978).

98. Rachel Carson, *Silent Spring* (New York: Houghton Mifflin, 1962); and Paul R. Ehrlich, *The Population Bomb* (New York: Ballantine Books, 1968). See Sabin, *The Bet* (ref. 6), on the debate between Ehrlich and Julian Simon over the issue of global population growth.

the U.S. Forest Service led to the use of flawed data to conjure the illusion of timber cornucopia, allowing rapid depletion of timber reserves and damage to forest ecosystems. In the case of U.S. and international fisheries management, as Carmel Finley argues, the highly permissive policy of "maximum sustainable yield" gave rise to an industrial fishing system with the capacity for exploitation that far exceeded the ability of fish stocks to reproduce.[99]

The sudden realization of peak oil production in the United States seemed to confirm the notion of "future shock," the title of futurologist Alan Toffler's 1970 bestseller, which sensationally described "the shattering stress and disorientation that we induce in individuals by subjecting them to too much change in too short a time."[100] According to one new history of the future, Toffler's brand of futurology was a radical break with previous imaginings of future modernity and progress, reflecting the "growing unease and fear in a period in which the future became laden with connotations of looming disasters such as ecocide, atomic war, and the population bomb."[101]

The apprehension about the future in the 1970s gave rise to the phenomenon of futurology. From scenario planning and forecasting, to the growth in futures markets (in oil, incidentally, for the first time), to the new popularity of astrology, to religious predictions of the apocalypse, such as Hal Lindsey's *The Late, Great Planet Earth*, "people became extraordinarily focused on the future."[102] Secular prophecies like Paul Ehrlich's *The Population Bomb* (1968) and the Club of Rome's *Limits to Growth* contributed to the obsession with the future by warning of impending food and resource shortages. Although these warnings turned out to be overly alarmist, the one secular prophecy that actually did come true was Hubbert's prediction of peak oil in the United States, which made him a folk hero among conservationists who feared the impending exhaustion of resources in a high-growth society.[103]

99. Paul W. Hirt, *A Conspiracy of Optimism: Management of the National Forests since World War II* (Lincoln: University of Nebraska Press, 1996); Carmel Finley, *All the Fish in the Sea: Maximum Sustainable Yield and the Failure of Fisheries Management* (Chicago: University of Chicago Press, 2011).

100. Alvin Toffler, *Future Shock* (New York: Bantam, 1984), 2.

101. Andersson, "Great Future Debate" (ref. 7), 1415.

102. Matthew Connelly, "Future Shock: The End of the World as They Knew It," in *The Shock of the Global: The 1970s in Perspective*, ed. Niall Ferguson, Charles S. Maier, Erez Manela, and Daniel J. Sargent (Cambridge, MA: Harvard University Press, 2011), 338.

103. For testimony about Hubbert's status as folk hero, see "M. King Hubbert Successors," Global Public Media, Public Service Broadcasting for a Post-Carbon World,

Hubbert's prophecy created a unique and lasting legacy. In the 1990s, his followers, led by former oil industry geologist Colin Campbell, began issuing predictions about an impending peak in world oil production. In 2000, Campbell organized the Association for the Study of Peak Oil (ASPO), which drew together a diverse assortment of people, ranging from geologists and hobbyists who specialized in reserve estimations, to industry partisans looking for tax and regulatory breaks, to anti-oil environmentalists, to advocates for population control, to miscellaneous doomsayers and futurologists who fantasized about the decay and obliteration of the petroleum-dependent aspects of modern life. ASPO found a larger audience when skyrocketing oil prices during the first decade of the twenty-first century convinced many people that the peak was near or had even past.[104]

The peak oil movement reached critical mass in 2005, when Hubbert's former colleague at the Shell Bellaire lab, Kennneth Deffeyes, popularized a linear regression technique, sometimes called Hubbert Linearization, that graphed the ratio of annual global oil production to cumulative production in order to estimate ultimate reserves and the moment of peak production (Fig. 4). Deffeyes mischievously predicted this moment to arrive on Thanksgiving Day of that year.[105] At the same time, global peak oil prophecies gained official credibility with the publication of a report commissioned by the U.S. Department of Energy called *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management* (also know as the Hirsch Report after its lead author, Robert L. Hirsch).[106]

Peak oil spawned a subculture of true believers. Matthew Schneider-Mayerson calculates that during the 2000s "over one hundred thousand Americans came to believe that oil scarcity would lead to the imminent collapse of industrial society and the demise of the United States of America." Most of them were upper middle-class, middle-aged white men with a profound "sense of political alienation and a bleak evaluation of contemporary environmental

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http://old.globalpublicmedia.com/transcripts/671 (accessed 1 Aug 2013). Also see the website, The Hubbert Tribute, http://www.mkinghubbert.com/ (accessed 1 Aug 2013).

104. See ref. 1.

105. Deffeyes, *Beyond Oil* (ref. 3), 35–51. Hubbert introduced this straightforward technique in "Techniques of Prediction as Applied to Production of Oil and Gas," in *Oil and Gas Supply Modeling*, special publication 631, ed. S. I. Gass (Washington, DC: National Bureau of Standards, 1982), 16–141.

106. Robert L. Hirsch, Roger Bezedek, and Robert Wendling, *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management* (Washington, DC: U.S. Department of Energy, 2005).

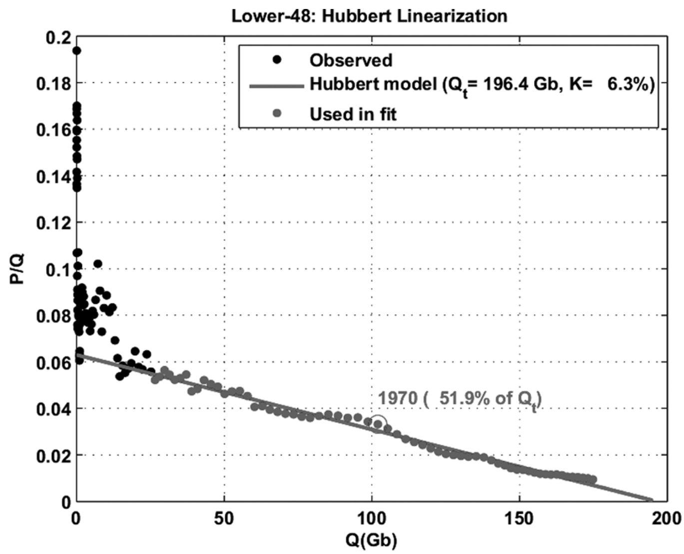

FIG. 4. Hubbert Linearization graph. *Source*: Sam Foucher, "A Different Way to Perform the Hubbert Linearization," 18 Aug 2006, The Oil Drum website, http://www.theoildrum.com/story/2006/8/16/102942/337 (accessed 1 Aug 2013).

politics."[107] They churned out books, websites, blogs, podcasts, YouTube channels, novels, poems, cartoons, video games, and documentary films warning of the unhappy fate that awaited the world. All paid homage to the peak oil prophet, King Hubbert. One could even find bumper stickers and T-shirts emblazoned with the slogan "All Hail King Hubbert" (Fig. 5). Despairing of the futility of political action, many Peak Oilers retreated to bunkering food and supplies in preparation for the impending energy famine. Peak oil became yet another strain in the long American tradition of prophecy belief, which after 1970, according to cultural historian Paul Boyer, "unquestionably intensified" and "filtered into secular mass culture."[108] In recent years the more radical Hubbertians have earned a reputation as the liberal equivalent of the born-again Christian fans of the "Left Behind" novels.[109]

107. Matthew Schneider-Mayerson, "From Politics to Prophecy: Environmental Quiescence and the 'Peak Oil' Movement," *Environmental Politics* 22, no. 5 (2013): 866–882, on 867 and 871.

108. Paul Boyer, *When Time Shall Be No More: Prophecy Belief in Modern American Culture* (Cambridge, MA: Belknap Press, 1992), 11, 8.

109. Bryant Urstadt, "Imagine There's No Oil: Scenes Form a Liberal Apocalypse," *Harper's Magazine*, 1 Aug 2006, 31–40. "Left Behind" is the title of a series of novels by Tim LaHaye and

FIG. 5. "All Hail King Hubbert" bumper sticker. *Source*: Created by Four Winds Alternative Farming Emporium, for sale at Zazzle, http://www.zazzle.com/fourwindsfarm (accessed 1 Aug 2013).

THE CORNUCOPIAN COMEBACK

Although Hubbert deserves credit for helping to professionalize the field of petroleum resource estimation, the methods he pioneered have remained controversial and not widely accepted by other practitioners. The 1970s reforms in the USGS Oil and Gas Branch moved federal resource assessment in a different direction. Government scientists came to rely on multiple techniques for assessing undiscovered conventional oil and gas reserves, using probabilistic methods rather than deterministic, single-value ones, like those favored by Hubbert and McKelvey. They deployed analytical innovations such as discovery process models, which empirically characterize the relationship between drilling and discoveries. Geological research on regions, provinces, and petroleum systems also informed assessments, which introduced separate categories for conventional oil and gas, reserve growth in existing fields, and unconventional (mainly shale and oil sands) resources.[110]

One obvious weakness of the Hubbert model was that it did not account for the influence of oil imports in the early 1970s. The fact that oil imported from abroad was available at the same or lower cost than domestic oil caused

Jerry B. Jenkins. These novels lay out a right-wing Christian fantasy about the coming end times, as foretold by the Book of Revelations, in which many people have been "raptured," leaving behind a group of born-again Christians who embark on a mission to save lost souls and struggle against the Antichrist, who has become secretary-general of the United Nations.

110. On discovery process modeling, see Drew, *Oil and Gas Forecasting* (ref. 95), 86–146, and Lawrence J. Drew, *Undiscovered Petroleum and Mineral Resources: Assessment and Controversy* (New York: Plenum Press, 1997). On the evolution of USGS methodology, see Ronald R. Charpentier and T. R. Klett, "Guiding Principles of USGS Methodology for Assessment of Undiscovered Conventional Oil and Gas Resources," *Natural Resources Research* 14 (2005): 175–86.

domestic production to peak and decline faster than it would have without the replacement. Barring imports, the production curve probably would have looked more like a long plateau instead of a sharp peak.[111] As Edward Porter of the API later noted, the accuracy of Hubbert's prediction for U.S. oil could be seen "as a lucky coincidence, similar to that of a broken clock that tells the right time twice a day."[112]

A growing body of literature has shown that Hubbert's curve-fitting and extrapolation techniques suffer from many statistical and conceptual problems. Different functional models often fit the same data but give widely varying estimates of ultimate reserves. The techniques cannot predict future cycles of discovery and production and do not account well for oilfield growth over time—that is, the tendency of oil discoveries to grow in size with delineation drilling. Results are highly sensitive to the length of the data series. Over time, Hubbert linearization has tended to underestimate ultimate production for many fields and regions. Hubbert's techniques, which rely on aggregate data, work well only under special conditions— in geologically homogenous regions with few restrictions on exploration and a long history of production. This does not describe most places around the world. For less-explored regions, volumetric yield analysis is still used in combination with other methods for estimating ultimate reserves. Finally, many studies have shown that Hubbert's methods neglect future changes in prices and technology, just as McKelvey and others had long asserted. All these weaknesses combine to produce overly pessimistic oil supply forecasts.[113]

Oil and gas production trends have increasingly validated these criticisms. Hubbert's 1962 prediction about the U.S. natural gas production peak (circa 1975) and his most optimistic 1974 prediction about the world oil production peak (circa 2000) are increasingly distant from the actual peaks, whenever they come. Neither has peaked yet. Moreover, deepwater discoveries and recent breakthroughs in exploiting unconventional sources of oil and gas have recently increased production of both. Since 2005—the year of Deffeyes's peak oil prediction—hydrofractured drilling has unlocked oil from

111. Rose interview (ref. 32).

112. Porter, "Running Out of Oil?" (ref. 5), 15.

113. For a comprehensive survey of the literature, see Steve Sorrell and Jamie Speirs, "Hubbert's Legacy: A Review of Curve-Fitting Methods to Estimate Ultimately Recoverable Resources," *Natural Resources Research* 19 (2010): 209–30.

tight sandstone formations, reversing the historical decline of domestic U.S. oil production.[114] Hubbert's reputation for clairvoyance is fading.

Recent estimates of conventional oil reserves are neither as optimistic as those of the USGS under McKelvey nor as pessimistic as the Peak Oilers'. In 2000, the USGS boosted its estimates of ultimate conventional reserves to a mean 3.01 trillion barrels worldwide—the United States portion accounting for a mean 362 billion barrels—enough to continue with current rates of production for fifty to a hundred years. These estimates were far higher than the 230 billion barrels for the United States and 2 trillion barrels predicted by ASPO. By the end of the decade, the U.S. numbers were well above Hubbert's prediction. Cumulative U.S. production of crude oil and lease condensate had reached 202 billion barrels, close to Hubbert's estimate of ultimate reserves, while the Energy Information Administration (EIA) and USGS predicted in 2012 that the nation still has another mean 220 billion barrels of technically recoverable proven and unproven reserves.[115]

As convincing as Hubbert's Peak appeared to be during the twin energy and environmental crises in the 1970s, it still did not quash American faith in resource abundance. In 1980, at the height of the second oil price shock, University of Illinois economist Julian Simon made a famous thousand-dollar bet with Paul Ehrlich over whether the prices of chromium, copper, nickel, tin, and tungsten would rise or fall during the decade of the 1980s. Ehrlich, famous for his warnings about population pressures on natural resources, believed that rising metals prices would confirm his pessimism. Simon, an outspoken critic of Malthusian warnings about overpopulation, wagered that markets and technology would reverse the steep rise in raw

114. After a decline from the early 1970s to the mid-1980s, U.S. natural gas production has steadily risen past its 1973 mark and exploded recently with the hydrofracturing of shale gas. For oil and gas production trends, see the U.S. Energy Information Administration (EIA) website, http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html (accessed 1 Aug 2013).

115. USGS, *USGS World Petroleum Assessment 2000*, http://pubs.usgs.gov/dds/dds-060/ESpt2.html (accessed 1 Aug 2013). After 1983, the USGS handled resource assessment for the onshore and state waters offshore, while the Minerals Management Service (MMS) of the Department of the Interior assessed the federal outer-continental shelf. The estimate for the United States comes from the 1995 USGS Assessment and 1996 MMS Assessment. They include both Alaska and the Federal outer-continental shelf. The 362 billion barrel estimate is higher than Hubbert's 1974 projection of 213 billion barrels of ultimate reserves, but lower even than McKelvey's "low range" of 388 billion. For the 2010 estimates, see Energy Information Administration, *Annual Energy Review 2012*, DOE/EIA-0384 (2012), tables 4.1 and 4.2.

materials prices. Following the oil and commodities price collapse of the 1980s, Simon won the bet easily.[116]

Simon the "Doomslayer" became a Cornucopian hero. In 1998, just before his death, he published a revised version of his 1981 treatise, *The Ultimate Resource*. In the new edition, Simon expounded on the nonfiniteness of oil and the unwarranted pessimism of official supply forecasts. He even lamented what he considered the unfair treatment Vincent McKelvey had received by the Carter White House. In Simon's view, if society would only allow the "ultimate resource," human ingenuity, to perform its magic on the "master resource," which was energy, the world would never have to worry about an energy shortage. Around the same time, organizations such as the API and Daniel Yergin's think-tank, Cambridge Energy Research Associates (CERA), turned to debunking the new wave of peak oil theories.[117]

The new Peak Oil craze of the early 2000s prompted a reprise of the famous Simon-Ehrlich bet. This time it was over the future price of oil. In 2005, *New York Times* columnist John Tierney, a friend and protégé of Simon, challenged Matthew Simmons, a Houston investment banker and Peak Oil celebrity, to a five-thousand-dollar wager that the price of crude oil would not surpass $200/barrel (in 2005 dollars) by the end of 2010. Simmons, who expected the peaking of global oil production to more than triple the price of oil, gladly accepted. When the annual average price of crude oil closed at $90/barrel at the end of 2010, another prophecy of doom fell.[118] In the years since, booming hydrocarbon production from deepwater, shale, and tight sandstone formations appears to have further vindicated the Peak Oil skeptics, spurring celebration for a new age of petroleum cornucopia.[119]

116. See Sabin, *The Bet* (ref. 6). On the factors behind the oil price collapse, see Tyler Priest, "The Dilemmas of Oil Empire," *Journal of American History* 99 (2012): 244–45.

117. See Julian Simon, *The Ultimate Resource 2* (Princeton, NJ: Princeton University Press, 1998), chap. 11, "When Will We Run Out of Oil? Never!"; Bradley, *Capitalism at Work* (ref. 19), 262–70.

118. John Tierney, "Economic Optimism? Yes, I'll Take That Bet," *New York Times*, 27 Dec 2010, http://www.nytimes.com/2010/12/28/science/28tierney.html?_r=1 (accessed 1 Aug 2013).

119. See, for example, Michael Lind, "Everything You've Heard about Fossil Fuels May Be Wrong: The Future of Energy Is Not What You Think It Is," Salon.com, 31 May 2011, http://www.salon.com/2011/05/31/linbd_fossil_fuels/ (accessed 1 Aug 2013); Peter H. Diamandis and Steven Kotler, *Abundance: The Future Is Better Than You Think* (New York: Free Press, 2012); Leonardo Maugeri, "Oil—The Next Revolution: The Unprecedented Upsurge of Oil Production Capacity and What It Means for the World," Discussion Paper #2012-10, Geopolitics of Energy Project (Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, 2012), http://belfercenter.hks.harvard.edu/files/

Peak Oilers responded to mounting evidence against their theories with qualifications and denials. They moved their day of reckoning further into the future. They insisted that oil from shale and deepwater oil were not part of Hubbert's original analysis of U.S. domestic production. They distinguished between the peak in conventional versus unconventional fossil fuels, the peak in "easy" versus "hard" oil, and the peak in OPEC versus non-OPEC oil.[120] Some shifted the focus to declining "energy return on investment" (EROI) as a harbinger of dwindling conventional oil supply.[121] Others even ridiculed the oil and gas fracking boom as a Ponzi scheme that at best would provide "a temporary reprieve from having to deal with real problems."[122] In general, Peak Oilers refused to accept the central insight passed on from Zimmerman to McKelvey to Simon to Yergin, which is that changes in price and technology push oil exploration into new geological frontiers, convert probable reserves into proven reserves, and turn unconventional oil into conventional oil.

No matter how innovative the model, robust the forecasting tool, or scientific the analysis, predictions about trends or events in the future are often inaccurate, and usually by a large margin of error.[123] In the original debate about the end of oil, King Hubbert and Vincent McKelvey allowed their personal animosity and doctrinaire positions to keep them from acknowledging uncertainty in their claims about the future. Hubbert insisted that oil resources could be defined entirely in physical terms, and that their supply could be expressed with accuracy in a neat mathematical formula, while McKelvey denied that resources could be constrained by physical factors. Neither man's expertise was sufficient to handle the complex problems of resource estimation with the kind of confidence they expressed.[124] Their

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Oil%20-%20The%20Next%20Revolution.pdf (accessed 1 Aug 2013); and Ramez Naam, *The Infinite Resource: The Power of Ideas on a Finite Planet* (Lebanon, NH: University Press of New England, 2013).

120. See, for example, extensive archived discussions on *The Oil Drum* blog, http://www.theoildrum.com/ (accessed 1 Aug 2013) and at the website for the Association for the Study of Peak Oil & Gas, http://www.peakoil.net/ (accessed 1 Aug 2013).

121. David J. Murphy and Charles A. S. Hall, "Energy Return on Investment, Peak Oil, and the End of Economic Growth," *Annals of the New York Academy of Sciences* 1219 (2011): 52–72.

122. Jean Laherrère and Post Carbon Institute study quoted in Charles C. Mann, "What If We Never Run Out of Oil?" *Atlantic,* May 2013, http://www.theatlantic.com/magazine/archive/2013/05/what-if-we-never-run-out-of-oil/309294/ (accessed 1 Aug 2013).

123. See Smil's chapter, "Against Forecasting," in *Energy at the Crossroads* (ref. 5), 121–80.

124. For an insightful analysis of science in environmental policymaking, see Stephen Bocking, *Nature's Experts: Science, Politics, and the Environment* (New Brunswick, NJ: Rutgers University Press, 2004), and for government science in general, see Roger A. Pielke, Jr.,

successors continue to assert confidently that they have divined the future of oil, which only ensures that energy policy debates remain hopelessly polarized. Publicity stunts such as bets on short-term movements in resource prices further contribute to such polarization. Resource estimation may be more sophisticated than ever before, but there is still massive uncertainty about future petroleum supply—not to mention, demand—and how difficult and costly it will be to develop.

Scarcity and abundance have always existed in a dynamic relationship, shaped by many physical and social variables. For now, the pendulum seems to have swung back toward accepting abundance, but with new implications. For years, the concept of peak oil was important to many environmentalists' vision of the future. Some environmental leaders, however, are now beginning to reframe the problem, accepting the world's large endowment of fossil fuels, but warning of the disastrous implications of the increased burning of the earth's carbon budget for the global climate.[125] Just as Cornucopians insist on a flexible definition of what a resource is, environmentalists have redefined the meaning of scarcity and abundance to include the degradation of ecosystem resources—water quality, biodiversity, climate stability—resulting from the intensive production and consumption of fossil fuels.[126]

King Hubbert never envisioned the oil age ending as a result of too much oil. Were he alive today, he may defend his method and reject the new assurances of petroleum abundance, just as his followers do. But as a public intellectual concerned with how to value natural resources across generations, and as an environmentalist who believed that relentless economic growth could as easily impoverish as enrich society, today's Hubbert may be willing to rethink the problem of oil. From our current vantage point, the future could easily bear out the famous words of former Saudi Arabian oil minister, Shiekh Zaki Yamani: "The Stone Age came to an end, not because we had a lack of stones, and the oil age will end not because we have a lack of oil."[127]

The Honest Broker: Making Sense of Science in Policy and Politics (Cambridge: Cambridge University Press, 2007).

125. See, for example, Bill McKibben, "Global Warming's Terrifying New Math," *Rolling Stone*, 19 Jul 2012, http://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719 (accessed 1 Aug 2013).

126. See, for example, Gretchen Daily, *Nature's Services: Societal Dependence on Natural Ecosystems* (Washington, DC: Island Press, 1997).

127. "Sheikh Yamani Predicts Price Crash as Age of Oil Ends," *Telegraph*, 25 Jun 2000, http://www.telegraph.co.uk/news/uknews/1344832/Sheikh-Yamani-predicts-price-crash-as-age-of-oil-ends.html (accessed 1 Aug 2013).

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