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THE OIL AGE

Understanding the Past, Exploring the Future

Special Issue: M.K. Hubbert

Editorial

Articles:

Background & Objectives

This journal addresses all aspects of the evolving Oil Age, including its physical, economic, social, political, financial and environmental characteristics.

Oil and gas are natural resources formed in the geological past and are subject to depletion. Increasing production during the First Half of the Oil Age fuelled rapid economic expansion, with human population rising seven-fold in parallel, with far-reaching economic and social consequences. The Second Half of the Oil Age now dawns.

This is seeing significant change in the type of hydrocarbon sources tapped, and will be marked at some point by declining overall supply. A debate rages as to the precise dates of peak oil and gas production by type of source, but what is more significant is the decline of these various hydrocarbons as their production peaks are passed.

In addition, demand for these fuels will be impacted by their price, by consumption trends, by technologies and societal adaptations that reduce or avoid their use, and by government-imposed taxes and other constraints directed at avoiding significant near-term climate change. The transition to the second half of the Oil Age thus threatens to be a time of significant tension, as societies adjust to the changing circumstances.

This journal presents the work of analysts, scientists and institutions addressing these topics. Content includes opinion pieces, peer-reviewed articles, summaries of data and data sources, relevant graphs and charts, book reviews, letters to the Editor, and corrigenda and errata.

If you wish to submit a manuscript, charts or a book review, in the first instance please send a short e-mail outlining the content to the Editor. Letters to the Editor, comments on articles, and corrections are welcome at any time.

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Editorial

Welcome to this special issue of the journal covering aspects of the life and work of M.K. Hubbert.

This issue arose by a coincidence of events: Steve Andrews had mentioned his interview of Hubbert, and at about the same time it became known that Mason Inman's biography of Hubbert was soon to be published. It seemed sensible therefore to consider an issue focussed on Hubbert's work. In my view there are many important lessons still current from the latter's work, as set out in my review of Inman's book. Not least of these is that we currently face peak in the global production of conventional oil, in line with the resource-based forecasts from Hubbert, and a wide range of others from the 1970s onwards, that this peak would occur around the year 2000; or indeed a bit after, given the fall in global demand that occurred post the price shocks of the 1970s.

I am very grateful to the publishers of Inman's book for permitting an extract; to Inman himself for writing an interesting account of why and how the book came to be written; and to Andrews for originally making, and then keeping, the interview with Hubbert; and more recently for his considerable work in carefully transcribing and editing this, and writing an informative lead-in and postscript.

I hope these papers together help explain some of Hubbert's thinking, and that they also lay to rest a number of the misunderstandings about his work that persist to this day.

On a separate topic, I apologise that I rather 'jumped the gun' in announcing a website for this journal. It has taken longer than expected to produce, but we now expect it to be ready soon after publication of this issue of the journal. As before, should you have comments on this website, we would be pleased to hear.

- R.W. Bentley, May 25th, 2016.

Excerpt from the book:

The Oracle of Oil: A Maverick Geologist's Quest for a Sustainable Future

By Mason Inman, published by W.W. Norton, April 2016.

The following is an extract, reprinted with the publisher's permission, from the recent book by Mason Inman about the life of M. K. Hubbert. A review of this book, a short article by its author, and a transcription of an extensive interview by Steve Andrews with Hubbert late in the latter's life, are given elsewhere in this issue. This extract concerns mainly events surrounding the 1973 oil price shock, but also has a very telling section on why Hubbert changed his view on both nuclear and solar energy.

As the energy crisis in the United States deepened in the fall of 1973, M. King Hubbert continued with his many talks. In a public lecture at Stanford, he argued the nation's problems were just symptoms of longer trends: "Our institutions, our system of accounting, our monetary system, our legal system, our government-the whole works-are premised on a continuing exponential growth." However, this growth phase, at least for countries like the United States, was "just about over," he said. "Now we're running into a situation where we cannot keep up exponential growth."

Hubbert explained he didn't want to create a sense of alarm or doom. He still was hopeful about humanity's ability to cope with the situation. The problem wasn't so much about resources or technology but about ways of thinking. "We're going into a cultural shock or crisis far more than we are going into an energy crisis," he concluded.

Very soon, though, the situation would grow far worse.

"The Saudis are getting heady over the power of oil," Secretary of Defense James Schlesinger told other top officials, including Secretary of State Henry Kissinger and the head of the Central Intelligence Agency. They met over breakfast in the White House's Map Room on November 3, 1973, just weeks after war had broken out again in the Middle East, and Saudi Arabia and other members of OPEC had slashed their production and instituted an embargo against the United States.

These top US officials were in the midst of developing a plan for the Marines to invade the small, oil-rich kingdom of Abu Dhabi on the Arabian Peninsula and seize control of its oil fields-and to send a warning to other OPEC members. Even before the embargo, Marines had been training in the Mojave Desert for such an invasion. Soon the US military would have two navy destroyers at the entrance to the Persian Gulf, and an aircraft carrier, the USS John Hancock, was moving into the area.

"We need a public line on the Hancock when it arrives," Schlesinger said.

"Routine," Kissinger said. "An exercise we have been planning a long time."

After discussing strategies for the conflict between Egypt and Israel, and how to keep the Soviets from getting too involved, Kissinger concluded, "Let's work out a plan for grabbing some Middle East oil if we want."

"Abu Dhabi would give us what we want," Schlesinger replied.

During the 1956 Suez Canal crisis, Saudi Arabia had instituted an embargo, to little effect. In 1967, OPEC had tried to use an oil embargo as a weapon, and that likewise fizzled. Throughout 1973, OPEC members-including Saudi Arabia, Libya, Iraq, and Kuwait-had been again warning that if the United States didn't change its policies toward Israel, they would cut off oil exports to America. Most US officials did not take the warnings seriously.

The situation in 1973, however, was much different. The United States was still the world's largest oil producer-but it was also the world's largest oil consumer. The nation had eaten through its spare capacity. Its production was falling while its consumption continued rising. As James Akins, the White House energy adviser, had predicted several months earlier, "This time the wolf is here."

Egypt's leader Anwar Sadat had wanted to break a stalemate following Egypt's 1967 war with Israel, and to push the United States to be more even-handed in its policies toward the region. After tensions in the region mounted for months, in early October 1973 Egypt launched a surprise attack on Israel.

In response, United States tried to placate Arab nations, while also quietly aiding its longtime ally Israel. But when Arab nations discovered this aid to Israel, they followed through on their threats, slashing oil production by 10 percent and vowing further cuts until the war was resolved, and hiked prices by nearly double. They also instituted an embargo, barring tankers from carrying their oil to the United States. International oil companies followed the embargo to the letter but undercut the spirit of it by reshuffling global oil shipments-just as they had during earlier embargoes. But this time, OPEC had more power over world markets. They were able to restrict the total amount of oil for sale, so consumers had to swallow higher prices.

Up to then, the Nixon administration had done almost nothing to prepare for such a situation. Nixon's top foreign policy adviser, Henry Kissinger-by then promoted to secretary of state-had been busy trying to negotiate a cease-fire in Vietnam, for which he won a Nobel Peace Prize earlier in 1973. Others in the administration had been consumed with reelection, continuing stagflation, and the deepening Watergate scandal.

Once OPEC instituted the embargo, the Nixon administration's outlook suddenly flipped. Kissinger considered it "blackmail" and pressured the major oil-consuming nations to respond by forming a united front. Meanwhile Kissinger and Schlesinger continued discussing plans to invade Abu Dhabi.

On November 11, Nixon took to television and gave the American people a stark warning: "We are heading toward the most acute shortages of energy since World War II." Nonetheless he remained positive and reassuring. "This does not mean that we are going to run out of gasoline or that we will freeze in our homes," he said. "The fuel crisis need not mean genuine suffering for any American. But it will require some sacrifice by all Americans."

For the longer term, Nixon had a vision. Invoking the Apollo Project to put a man on the moon, and the Manhattan Project to develop the atomic bomb, he called for a new national goal of freeing America from "foreign energy sources"-which meant oil, the only energy source the

United States imported in any significant quantity. "Let us pledge," he said, "that by 1980, under Project Independence, we shall be able to meet America's energy needs from America's own energy resources."

The day after Nixon's speech, Hubbert began a long lecture tour-a "man killer," he called it, nine weeks of travel across the United States and Canada. The tour was sponsored by the American Association of Petroleum Geologists, which had invited him to make the tour months before the OPEC embargo. Hubbert's talk, "The World's Energy Economy," covered his overall outlook-in particular, the peaks of US and world oil and the coming end of growth. He typically drew 150 or 200 people at a time, over the whole tour reaching some ten thousand people.

"Audiences are no longer disposed to argue," Hubbert told Stewart Udall, the former interior secretary, when they spoke in the midst of his tour. "There is a very sober, thoughtful attitude with regard to the situation."

Just as audiences had changed their attitude, Hubbert told them he'd changed his mind about a crucial issue: the world's ideal energy source for the long term.

Throughout his time advising the Atomic Energy Commission, Hubbert had been critical of its handling of nuclear wastes. All along, he had thought these problems could be fixed-and must be fixed-because he had considered atomic energy essential for maintaining industrial civilization for centuries or millennia. He'd followed the technology as it emerged from military applications-for building bombs and powering submarines-and became a commercial reality. He'd seen nuclear power generation rise quickly through the 1960s and early 1970s, so that by 1974 nuclear supplied 6 percent of US electricity-a significant portion, but still less than the share of electricity derived from hydroelectric dams or natural gas, or even from oil.

After advising on nuclear power for more than fifteen years, Hubbert was frustrated. He felt the AEC showed little interest in handling nuclear waste carefully. Breeder reactors, which he thought essential, had been treated as a side-project. Nonetheless, as recently as 1972 he'd stated, in an interview with Newsweek, that nuclear was "the only source to meet the world's power requirements in the future."

By the time of his AAPG lecture tour in 1973, he told audiences, his view had turned around "180 degrees."

"Fifteen years ago I was like everyone else in thinking nuclear power would help meet our energy needs," Hubbert said in one talk. "But I've gradually come around to look at the hazardous aspects and it scares the hell out of me." The same technologies for creating nuclear power plants could be used to assemble the material for more warheads, he pointed out-and in "this unsteady world, with a propensity for throwing bombs at each other, the chances of a nuclear disaster have become increasingly frightening." It wasn't simply the Cold War faceoff between the Americans and Soviets. Terrorists might attempt to "hold up New York or London or Paris," he argued. He concluded that nuclear was a "perpetual hazard," creating wastes requiring "perpetual care."

In the early 1960s, Hubbert had thought solar power might be feasible only for developing countries or for special applications such as satellites. By the early 1970s, he'd come to see more promise in this approach, arguing in favor of government-funded research on large-scale solar power plants. He thought people had the basic knowledge to build them but warned that "the technological difficulties of doing so should not be minimized." Meanwhile he'd continued following solar research and development-attending international conferences and visiting with scientists to learn of their progress.

With Hubbert's 180-degree turn, he touted the power of the sun. "Solar energy dwarfs everything else in sight," he argued. "It turns out the big source of energy on this earth is sunshine. It's inexhaustible. It's been pouring in for billions of years and will continue for billions of years when the human species isn't here."

Though he'd downplayed solar power before, he admitted, "I'm happy to say that I was proven wrong."

As Hubbert traveled on his lecture tour, the Nixon administration continued with efforts to resolve the Middle East conflict. Kissinger and Schlesinger discussed how to get Congress to approve a $2 billion package for military aid to Israel, and how to break OPEC's embargo.

In a meeting in the White House's Map Room on November 29, six weeks after the start of the embargo, Kissinger said, "The Saudis are blinking."

"They think we knocked off Idris," Schlesinger said, referring to the king of Libya, who'd been deposed by Muammar Gaddafi a few years earlier.

"They have never played in this league before. They are scared," Kissinger said.

"We need to build a presence in the Middle East," Schlesinger said.

"It is essential," Kissinger replied, adding, "Can't we overthrow one of the sheikhs just to show that we can do it?"

Meanwhile consumers around the world felt the bite of OPEC's oil cutbacks. In the eastern United States, there were local fuel shortages. Hit first and hardest were independent truckers, whose earnings were slashed once oil prices shot up. They began blockading freeways and turnpikes from New Jersey to Ohio and planned nationwide protests. One trucker told a reporter, "We want Nixon and his people, when they turn on the television, to hear us."

In some areas, gas stations ran out of fuel after being open only a few hours each day. Several states instituted "odd-even" rules, by which people had to take turns, able to fuel up only every other day, depending on whether their license plate ended in an odd or an even number. One Pennsylvania gas station attendant recalled that when tankers drove through town on their way to deliver more fuel, "motorists would follow the trucks right up to the pumps."

To try to manage the situation, Nixon created a Federal Energy Office and put his treasury secretary, William Simon, in charge. When asked when the United States would consider national fuel rationing, Simon replied, "I would say a critical factor would be if people begin queuing up at gas stations for three or four hours at a time." The Boston Globe commented, "A government policy based solely on visible chaos is something to ponder."

In the face of shortages, many called for the United States to boost its oil production. The development of Alaska's Prudhoe Bay oil field-estimated to be the nation's largest discovery to date-had been stuck in legal limbo for four years. Within a month of the OPEC embargo, however, Congress overrode the legal challenges to the pipeline across Alaska, finally pushing through its approval. However, it was a "triumph of scare propaganda and economic pressure over reasoned public policy," argued a New York Times editorial, since the pipeline would take years to build, providing no help in the short run.

Before the embargo, the United States had already been suffering from stagflation. With the oil price hike, inflation grew worse, eroding consumers' purchasing power, and the economy sank into a recession. The price hike had an even larger effect on other nations entirely dependent on oil imports-all of Western Europe, and fast-growing Asian countries such as Japan and Korea.

In the face of higher prices for gasoline, job losses, and a worsening economy, Americans cut back their consumption. When they did buy cars, they opted for more efficient ones, leading Time magazine to declare on its cover, "The Big Car: The End of the Affair." Speed limits in many locales were lowered to fifty miles per hour, and some states gave incentives to employees to carpool to work. Businesses and homes lowered their thermostats and turned off unnecessary lighting, including advertisements and streetlights. The floodlights that had lit Chicago's Wrigley Building almost continuously for half a century were switched off.

By early 1974, OPEC members talked openly of lifting the embargo and raising production. Anticipating an end to fuel shortages, a top energy official announced that the federal government would sell off oil in emergency stockpiles, "so that we can release the energy supplies needed to support sustained economic growth." The government was eager to get back to normal-that is, to times of growth.

In mid-March 1974, most OPEC members-including the biggest producer, Saudi Arabia-did end their embargoes. However, oil prices remained as high as ever, which took a heavy toll on the US economy. With Americans questioning their addiction to cars and their assumption that resources were essentially limitless, the oil shock turned out to be, as Hubbert had put it, a "cultural shock."

How I came to write *The Oracle of Oil*

Mason Inman

In 2008, I attended a meeting of the American Geophysical Union (AGU), where two prominent climate scientists, James Hansen of NASA and Ken Caldeira of the Carnegie Institution for Science, spoke in a press conference about the idea of peak oil. Their argument was basically this: there may be limits on oil resources, but if we want to avoid severe climate change, there was still a lot more fossil fuels than the world could burn, and still keep temperatures tolerable.[1]

If oil ran short, the world could make oil out of coal. "Coal's abundance, and its carbon intensity, is far more than enough to keep carbon dioxide levels above what we consider dangerous well into the next century," said climatologist Pushker Kharecha at that AGU meeting.

The message I took away from it was: Peak oil won't spare the climate.

At that point I'd been reporting on climate science for a couple of years, and was on a fellowship to report on climate change impacts and adaptation in Bangladesh. I thought I had a fairly strong grasp of the overall energy picture. However, I hadn't heard of this idea of peak oil, and I found it intriguing. Nonetheless I found the arguments at the AGU conference convincing, and I continued to think that the main issue facing the world was simply that there was too much carbon that we could burn, and somehow we had to get people to stop burning it.

At the time I first learned of peak oil, I was living in Karachi, Pakistan. (That's a whole other story.) The main English-language bookstore there, Liberty Books, was small but it had a wide-ranging and somewhat idiosyncratic selection, which made browsing interesting. There I ran across a book called *The Last Oil Shock* by David Strahan and that was my first real introduction to a more nuanced look at peak oil. I got hooked.

Before going into writing, I had received my bachelor's degree in physics, so the notion of peak oil made perfect sense-that is, it was natural that oil would get harder and harder to find and extract, and that the rate of oil production would at some point hit a peak, and then eventually decline to zero. I started digging around for more information and came across various papers on the issue, as well as website The Oil Drum.

In reading Strahan's book and other work on peak oil, I often came across mentions of M. King Hubbert, a geologist who worked for Shell and became famous for his prescient oil predictions. At first I got the impression that Hubbert was a narrowly focused researcher who specialized in forecasting the future of oil-which, I presumed, was his task at Shell.

But as I read more I learned that Hubbert was actually one of the top geologists of the twentieth century, and that he had made wide-ranging contributions to science. I learned that he didn't have the job of forecasting the future of oil for Shell. Instead he made his forecasts despite his company's opposition, and despite strong backlash from the wider oil industry as well as government researchers. Yet Hubbert was stubborn and kept improving his forecasts and reiterating his warnings about a coming peak for oil production in the US and, later, the world. He turned out to be right about the US, and I believe he'll be proved to be largely right about the world as well.

As I read more about Hubbert, I realized he was also a big-picture thinker who tried to put modern industrial civilization in a long-term perspective-and for him, "long term" mean thousands of years. I came across a post on The Oil Drum titled "Hubbert: King of the Technocrats," which told of Hubbert's role in co-founding a movement called Technocracy in the early 1930s.

The Technocrats aimed to revamp the U.S. economy-and the whole of society-to try to pull the nation out of the Great Depression. I began reading more about Technocracy and learned of how they argued that machines were putting people out of work-and that was a good thing. The promise of machines, fueled by fossil fuels, was that they could free people from toil and give us leisure time. But they would only fulfill that promise if the fruits of the machines-all the products they could make-were shared equally among people. If, instead, everyone had to compete for the dwindling number of jobs available, that was a recipe for economic collapse and civil unrest-which was exactly the situation in the United States at the time Technocracy was founded. The movement started as just a handful of scientists and engineers in New York City, but quickly became a media sensation and branches of the movement sprang up spontaneously across the country.

Many of the Technocrats' ideas were naïve. (Keep in mind that when Hubbert co-founded the group, he was only 28.) Nonetheless, I found it incredibly intriguing. This episode of Hubbert's life showed me he was a big picture thinker and an activist. Many knew him for his oil forecasts, which had earned Hubbert a reputation as a pessimist. But actually he was trying to get society to plan ahead and make a transition off of oil, and eventually off of fossil fuels. That is, he was talking about sustainability long before most anyone else. And he was optimistic that, eventually, people would take action.

I looked around for a biography of Hubbert, and but no one seemed to have written one. Through the wonders of the internet, even while I was in Pakistan, I found that there was be a lot of material to draw on: Hubbert's letters and other papers were collected at the University of Wyoming, and he gave a long oral history just before his death in 1989 in which he told many stories of his intellectual battles. Since no one else had published a biography of Hubbert, I decided to try do it myself.

Actually writing that book was in some ways much easier than I expected, but in other ways much harder. I was able to quickly get the interest of an agent who agreed to help sell the book idea to a publisher, and that encouraged me that there was actually interest in a biography of Hubbert.

However, writing the story of Hubbert's life was harder than I imagined. First, I had to learn how to write a long narrative, something I had never done before. I thought that Hubbert's life was so fascinating that his story would, in effect, write itself. But, sadly, things were not that simple. (For anyone thinking of writing narrative, I highly recommend the book *Storycraft* by Jack Hart, which incidentally came out just as I was struggling with learning how to write narrative.)

Also, Hubbert's story was complex, spanning decades, and as I did more research, I found there was almost too much material to draw on. Hubbert saved essentially all of his letters, he wrote many academic papers and long reports, gave testimony in Congress, and was covered in the media. And then I had to grapple with all the arguments, from all sides, about the notion of peak oil, and more broadly any limits to resources or limits to growth (of economies, of consumption, of populations).

Fortunately my agent was able to get the interest of a top publisher, W.W. Norton, and with time and the guidance of my editor there, I was able to winnow down the material into a coherent story. It took five years, but I'm happy to see the book finally published, and the positive responses from many readers have been very gratifying. Many of the early readers were those who had long known of Hubbert's work. Some said that reading my book, they learned a lot about him that they didn't know, and felt like, finally, they knew him as a person.

My hope all along was that by telling the story of Hubbert's life, it would also engage readers who might not normally read about topics such as the history of oil or the potential fate of industrial civilization. Time will tell whether that is actually the case.

Endnote

1. The ideas presented at the AGU conference were summed up well by the journalist Kurt Kleiner in "Peak energy: promise or peril?," Nature Reports Climate Change, 19 February 2009, doi:10.1038/climate.2009.19

The World of Oil According to Hubbert, in 1988

An interview with M. King Hubbert,
by Steve Andrews, March 5, 1988.

Abstract

This article is a lightly-edited version of an interview the author carried out with M. K. Hubbert at the latter's home on March 5, 1988. It centers on Hubbert's views and experiences in evaluating oil and gas resources of the US and in forecasting their production, and also to a lesser extent, that of oil globally. It covers, from Hubbert's perspective, some personal and institutional obstructions and controversies surrounding his and others' estimates. The interview also touches on a number of wider topics, including Hubbert's views on how humankind should deal rationally with its energy supply options into the future, including nuclear and solar energy. The article includes an introduction by the author to the interview, plus some present-day reflections of its significance.

Background

Some sixty years ago, in 1956, M. King Hubbert stepped to the microphone in the ballroom of San Antonio's Plaza Hotel to speak to a regional meeting of the American Petroleum Institute about his projections for long-term U.S. oil production trends. What followed was a presentation that broke new ground. The interview below explores his observations on times before - and decades after - which pivot around that presentation.

Hubbert certainly wasn't the first to forecast future U.S. and world oil production. But he was the first to both graph the consequences-forecasting the timing of U.S. peak production between 1965 and 1970-and then present his findings in a high-profile location to the U.S. oil industry.

At the very last moment before Hubbert's presentation, an urgent phone call from his employer Shell included a request for him to tone down the key message in his findings. As he recalled during the interview, "they tried to steer me, but I didn't steer very well."

Not surprisingly, after Hubbert's presentation on March 8, 1956, a number of players in the petroleum industry-including the leadership at Shell-closely scrutinized his message. Then they came out with two generic types of responses: denial ("it won't happen during our lifetimes") or reluctant acceptance. Shell carefully and probably skeptically reviewed his supporting data, then joined the relatively quiet group of reluctant supporters; yet they became more supportive as they also invited him to present his views to training retreats for promising Shell executives. But several other notable voices in the industry either spoke out in opposition or went to work generating theories and gathering data that told a much more optimistic story.

At the time of my interview with him, some thirty-two years after Hubbert's most famous presentation, that split response between reluctant supporters and emphatic deniers lived on. Though the skeptics were somewhat subdued during the long decline in US oil production that Hubbert had bravely forecast, they certainly retained their skepticism and voiced it from time to time.

Nearly a decade after Hubbert died in October 1989, the argument over long-term U.S. and world oil resources regained prominence, especially after the March 1998 publication in Scientific American *magazine of "The End of Cheap Oil" by Colin Campbell and Jean Laherrère, as well as during the subsequent 2004 – 2008 historic spike in oil prices. To this day, Hubbert's name is often linked to the phrase "peak oil." And since 2011, there has been a string of high-profile critiques, usually hammered home with the notion that "peak oil theory is dead."*

What follows is an opportunity to review, in Hubbert's own words, some of the debate from the early days through the 1980s in order to help understand where he came from, what his key positions were, how *he viewed some of his staunchest critics, and what some of his key observations were about our energy future.*

Anyone interested in more information about Hubbert is strongly advised to purchase a copy of Mason Inman's recent publication The Oracle of Oil: a Maverick Geologist's Quest for a Sustainable Future, *W.W. Norton & Co., 2016.*

A personal note

Why did I ask for this interview? Fifteen years before I called Hubbert, I became curious about energy resources, especially the oil sub-story within our larger energy picture.

During my 20s, I read The Limits to Growth - an exploration *of how exponential growth interacts with finite resources - soon after its publication in 1972. While I was reading it, the 1973 oil embargo triggered the first U.S. gasoline price spike, the first serious gasoline lines, and the first push for improved vehicle efficiency. Although I didn't start working in the energy efficiency and renewable energy sectors until 1980, the 1973 oil embargo and accompanying events triggered strong personal interest. I've never lost that interest.*

Later on I read Beyond Oil *by John Gever et al. right after its 1986 publication. The book explored the close relationship between US agricultural outputs, energy resource inputs, and the long-term limits to both. It featured Hubbert's data and forecasts on U.S. oil production. Curiously, the authors never contacted Hubbert directly, though the latter noted that they did a reasonable job of summarizing key elements of his work. (In retrospect, their book included an overly pessimistic assessment of U.S. production going forward: "…by the year 2020 domestic [US] oil supplies will be effectively depleted…")*

Later in the decade, I dug deeper into the range of perspectives on world oil resources held by well-positioned industry geologists and analysts. As a part-time freelance writer, it struck me that there was likely an important story to be shared regarding that range of related viewpoints. In a file entitled "Oil Prophets," I starting lining up potential interviewees. Without question, Hubbert was first on the list. Over the following several years, I talked with roughly a dozen experts who had been involved in one way or another in world oil studies. Those interviews have largely gathered dust, although a few extracts are included in an article I co-authored with Randy Udall: 'Oil Prophets', *in* The Oil Age *vol. 1 no. 3. Of all those contacts, the Hubbert interview is the only one to be published at length….right here.*

Backdrop for the interview

When I visited Hubbert, at age 85, he lived with his wife in a solid, unpretentious two-story brick home in the Chevy Chase (MD) area. On a raw day in late winter, he greeted me at the door, we said hello to his wife, and he took me down into his basement for our discussion.

On that day his finished basement seemed dark if not gloomy. Dominating the room were stacks of papers as tall as two or three feet on many horizontal surfaces: countertops, desk, tables, even here and there on the floor. We sat on an old beater of a sofa beside his coffee table. The conversation was taped; it follows below, interrupted by a periodic gap to change the tape.

During my phone call several weeks earlier, I had asked for an hour of his time. Four hours passed before my exit. I started with some simple question; my aim didn't matter-I could asked about Mars-since it quickly became clear that Hubbert had a detailed perspective that he wanted to define and share, as he responded:

"Let's go back to the 1950s and 60s…"

While physically frail, mentally Hubbert was still quite sharp, thoughtful and more articulate than someone younger who spoke more quickly. He retained a substantial portion of his reputation for brooking no fools. Yes, he repeated himself from time to time, though not to a distracting degree. In retrospect, he intended to share some personal background plus detailed perspective about two major themes on his mind:

1. *The determined efforts of key players at the US Geological Survey, from the late 1950s through the mid-1970s, to assure policy makers and others that the US held substantially more producible oil than Hubbert's analysis showed; and*
2. *The ongoing work of individuals like William Fischer, advising that there was still plenty of oil to be extracted in the US; he felt this was a deeply flawed perspective often motivated by self-interest.*

On several occasions, Hubbert launched into visually-based discussions that don't read well ("the curve goes up like that"). On other *occasions, he rambled about things of marginal interest to the average reader. In the version below, nearly all of the words that follow are Hubbert's, though they have been trimmed modestly in places to reduce redundancy, and edited lightly to add clarity.*

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The Interview (Hubbert speaking):

Let's go back to the 1950s and 60s…

In 1956, there was a regional meeting of about 500 petroleum engineers in San Antonio, Texas. It was a two-day meeting of the Southwest Production Division of the American Petroleum Institute. I was invited to attend as one of their speakers, to give kind of a broad-brush picture of the world energy situation. So I gave a paper at the meeting and we printed about 500 copies for distribution. It was a pre-print subject to revision.

For background, you might say I'm an oil man. My first job was in 1926 when I surveyed 500 oil wells in what was then the biggest and wildest developing oil field in the country. In the Amarillo Field, subsequently called the Panhandle Field. So in the summer of 1926 I ran well elevations for 500 wells, within 10 or 12 miles of that field. It was just a summer job. I was a university student in Chicago. During the following summer, I took a job again with the Amarillo Petroleum Corporation, that time for 15 months, starting in the summer of 1927 into October 1928. That was pioneer exploration work, principally with the newly developing seismic methods.

Then I went back to the university and taught for 10 years at Columbia University during the 1930s. I spent part of the war in Washington on the Board of Economic Warfare considering mineral resources. In the midst of that I was offered a job by Shell as a research geophysicist.

So I joined Shell in October 1943 and I spent 20 years with them in Houston. My first job was as research geophysicist. A year and a half later, they decided to build a new research laboratory dedicated to the exploration and production of oil. I was brought up to the head office and told I was the associate director of this enterprise. So I helped design, build, staff and plan the research program for this new research enterprise.

I retired from Shell at the statutory age of 60 in 1964. I went back in October 1987 for the centennial celebration, and the lab had grown so big since I left it that I hardly knew the place. It's unquestionably one of the biggest and best research laboratories, devoted to the exploration and production of oil, in the world. It's comparable to when I left but with a lot more sophisticated stuff. Other major oil companies also have comparable research facilities. Generally, the oil industry has some of the finest industrial research laboratories in the world.

That's kind of essential background for William Fischer's claims a whole lot later.

Anyhow, I had been studying broad resource supply issues, as a more or less continuing side issue if you like, since I was a student in the 1920s. At Columbia I worked out certain techniques of analysis, and techniques of prediction in particular. I first became aware of the significance of supply issues when I was a student in my senior year, in an undergraduate course taught by the chairman of the department who was an economic geologist and who had formerly been the head of the mineral division of the Geological Survey. He had gone through World War I and had been concerned with the problem of mineral supplies for the war effort; he was intimately familiar with the geological occurrence of these minerals, their industrial uses and their production data.

I remember that professor had a wall chart showing the production of coal in the United States and the chart went up exponentially, and I remember looking at that with complete amazement. Coal mining… one of the fundamental industries of the country at that time. All that information I got from that course came from original sources such as statistical abstracts in mineral resource volumes published annually by the US Geological Survey. The data were laid out with curves on a semi-logarithmic scale. A semi-logarithmic scale that got you a straight line means the growth is exponential at a high compound rate. And I found that up until around World War I, coal and iron had a growth rate of about 6% per year, doubling about every 10 or 12 years. Then the curve broke, and I attributed it at the time to the disturbance of the war. Later examination of the same curve showed that the break didn't occur at the beginning of WWI but in the depression of 1907. I used that curve many times thereafter. That 1907 coal production peak was a major event in U.S. history, and nobody even knew it happened.

[Short gap in tape.] The obvious conclusion, using a little bit of arithmetic, is that you can't possibly keep that exponential growth up very long, because it will soon exceed-even if we don't know how much coal and oil there is in the world, and we're not totally ignorant…we have approximate ideas, certainly on coal-it will exceed all the coal in the world in a reasonably short time. You can't keep it up. At the time, that was about as far as I could go.

Then in 1931 there was a small volume published by the American Institute of Mining and Metallurgical Engineers. I think it was called *Mineral Economics,* written by a small group of outstanding people at the Bureau of Mines. In it they reproduced and abbreviated a paper by D.F. Hewitt of the Geological Survey, called "Cycles in Metal Production." The original paper had been published by the AIMI *Transactions* in 1929. In the mid-20s, Hewitt came up with the idea that if we could go over all the mining districts of the world and review their history, it would be kind of a preview for our oil history which was much younger. So he got permission from his boss in the Survey to make that study.

Hewitt went over to Europe, visited most of the old classical mining districts and collected history, statistical data and production numbers that were available and incorporated them into his great paper. He informed me when it came out. The key finding of his work was that the production in any district of any non-replaceable mineral, whether it be coal or oil or gas, starts at zero, then production usually grows exponentially, and then eventually it has to go over the production hump and descent towards zero.

Now in a small area, that production curve might have multiple peaks. In other words, you might develop one area and then go up and over that hump, start down, and then another one comes in, so that there may be more than one maximum. Just like an individual arc has its own maximum. And then as you combine small production curves within a larger area, the whole curve tends be a curve with a single principle maximum. It jigs and jags and has saw teeth on the curve, but the full curve in a large area like the United States or the state of Texas gives out just one principle maximum-it goes up to a peak and goes back down. So that instead of looking at these curves and extrapolating on up to heaven, the summed-up curve declines back towards zero. That's what I hadn't realized before.

Q: You're talking about the back side of the production curve.

I'm talking about future production. You look at these curves and they go up exponentially. So if you didn't know better, you would extrapolate that on up to heaven. But we do know better. We know the quantity of this material in the ground is finite. And we know that it took millions of years of geologic time to accumulate these minerals. We know that they are not further accumulating at a rate that'll change during our lifetimes. So that instead of this curve going up to heaven, we know at some point it *has* to go over a hump and it *has* to come back to zero.

Q: The question is when you will hit zero.

All right. But that's quite different from having no guidance whatever. We don't know the date, but we know that curve is going to go back to zero. We also know that when you plot that curve arithmetically, not geometrically, not on log paper but just straight arithmetically-and that's what I'm talking about when I say it goes over the hump and back to zero; it's the annual production applied arithmetically.

So suppose we're plotting US oil production. Right here on the x-axis is zero, then it moves up to one billion barrels per year, two billion per year, three billion, and on up to four. And we put some time frame on the y axis-say, 1850, 1900, 1950, 2000 and 2050. And we plot that curve, going from zero in 1859…and in 1930 it hit a billion barrels per year as the depression came on…and by 1956 it was up to about 2.4 billion. We know that curve is going to go over the hump and go back to zero. After the hump, it can't drop sharply; it's got to decline gradually because that's how you find oil. You don't find it all at once and you don't produce it all at once. It peters out gradually.

Now, let's look more closely at the U.S. oil production curve. Within a single year's time we've got a little sliver here, and that in time is one year. The height of this curve is defined by the oil produced in that year. Suppose it's ¾ of a billion barrels per year. So let's take all the other one-year slivers and add them up-say 10 years-so it turns out that the area beneath this curve is the oil we produced during those ten years. We just count the squares under this curve and it tells you how much oil it represents.

To the right of the production history is a shaded area that we call proved reserves-the oil that's been discovered but not yet produced.

Now, the point is we know these curves are going to go over the hump and back to zero. If we had some reasonable estimate of how much oil was going to be produced ultimately, then we know how many squares are going to be under this curve-and the minute we make an estimate we automatically define how much oil is going to be under this curve. This curve has to be drawn such that that area cannot be exceeded.

We had enough knowledge about oil in the Lower 48 to estimate the amount under the curve. My figure was about 150 billion, but the week before I presented my paper, a paper was released on peaceful use of atomic energy. Part of it included Pratt's oil data. He was one of the best informed men on the subject. He asked the best 25 qualified men to estimate oil reserves and to limit the focus on the US. A Dallas firm held out for 200 billion barrels. My figure was about 150. These are estimates for crude oil only. Pratt's own estimate was 170 billion, including 15% natural gas liquids; excluding NGLs, his figure was 145. My conclusion: the best estimate was between 150 and 200 billion barrels for the Lower 48.

Using commonly accepted oil data, the best data available, pointed to a production peak between 1966 and 1971.

In a typical bull session in the industry, the question would often come up: how long will it be before we hit the peak of a U.S. production? The intuitive judgment: here we've been in the oil business 100 years and produced a whisker over 50 billion barrels. For the estimates between 150 and 200 billion barrels, the intuitive answer was 'not in our lifetimes. Our grandchildren may have to worry about it."

After my talk, there were two camps of thought. The first reaction was 'the guy must be crazy.' It violated their intuitive judgment. Everyone went back to take their best look at this quantity. Some found it fell within their range of estimates and they couldn't avoid the conclusion. Others found the conclusion so abhorrent that they couldn't accept it.

You don't change the implications of that 1970 peak production curve by small figures; it takes big ones. Within a year the figures began to escalate. At the end of five years, they had more than tripled.

That presentation in San Antonio made the petroleum press. And though I never saw it, I was told it was in the *New York Times* and in the *Wall Street Journal*, but I don't have the clippings. There was a national petroleum journal called *Petroleum Week*, put out by McGraw Hill, that had a major article including this paper and analysis. It created quite a stir in the petroleum industry, including in my own company Shell. This thing hit the *New York Times* and some officers at Shell nearly went through the roof-the principal involved was the vice president of public relations. They just about had cat-fits. Things were pretty intense for a few weeks around Shell. By the time they had time to study the paper, they found they couldn't refute it.

That San Antonio meeting was in March. In July of the same year, Shell instituted a new series of high-level executive trainings for their own employees, and they held this series in Arden House at the Harriman Mansion, which was about 7 miles west of West Point. It was a former mansion built by Averill Harriman's father and subsequently owned by Averell Harriman. Shell held two or three trainings a year there for the next five years. That Arden House had a hotel-like kitchen and facilities and plenty of space to accommodate 50 people.

Shell hand-picked from their own staff the up-and-coming people who seemed to have executive possibilities, and would send them to this school for a month. The lecturers of that school were principally Shell officials, the presidents and vice presidents and division managers, production managers and so on - financial people - and also several outside people including Harvard Business School and others...and me. I lectured in that training school for five years.

I have a letter I received a few years ago, written by a Shell vice president who wanted some information because of a talk he had to give to some prestigious group, and could I supply him with some information. He had been in one of these Arden House groups and he said he thought I was the most pessimistic geologist he ever heard…. and how right I was. *[Hubbert laughed here…something he did rarely during the interview.]*

Q: Did it hurt to be called the most pessimistic? It sounds as if that was plaguing you, that people were not willing to accept your figures. But Shell, by selecting you to be a key lecturer there, obviously felt highly about the information.

They didn't have to accept them.

Between 1956 and 1962, the published figures for ultimately recoverable oil in the US were escalating. My high figure was 200 billion barrels. All the rest of these figures *[he showed a list]* were published. There was one for 300 billion barrels that I didn't know about at the time. Here are four figures all running about 400 billion barrels. And out here in right field is the US Geological Survey with 590.

So the next development in this unfolding drama occurred in 1961. At that time there was a negotiation between the National Academy of Sciences and President Kennedy over the Academy settling up a Committee to advise the president on policy with regard to natural resources. The letter authorizing or requesting that work was written by Kennedy-a one-page letter on I think March 2, 1961. He directed all government bureaus having anything to do with natural resources to collaborate fully with the Committee, including the Geological Survey.

Now in the government there already existed a loose coordinating body called the Federal Council, I believe. It was a kind of inter-departmental clearing house. So the input to the Committee was funneled through this Federal Council.

Well when this Committee held its first meeting - I think in June, 1961 - I was a member of the Committee. Here are the reports that were put out and these were the members of the Committee. *[Examples: Phil Morse of MIT, Gilbert White of the University of Chicago were noted.]* I don't know whether a chairman is mentioned there - I think not. But the *defacto* chairman of the Committee was the president of the AcademyDetlev Bronk. He wouldn't dare let anyone else run such an important committee, he did it himself. But he never called himself the chairman and I'm not sure his name even appears there.

They held their first organizational meeting. They decided in the first place that, collectively, individual members of the Committee knew a great deal about some facet but none of us knew enough about the entire field. So if we were going to advise the president we first had to educate ourselves. It was agreed, over the next two years, to hold a series of two-day conferences on different subjects. Different members of the Committee were assigned to organize, run or chair these different conferences. I was given the assignment of energy resources.

So I went to the Geological Survey for coal, because they've been the principal measurers of coal during this century and certain other things like uranium and things of that sort. But for oil and gas I asked one of my friends, a vice president of Gulf, whom I should get, and he said you better do it yourself, you know as much as anybody. So I handled oil and gas, and I handed out the other subjects to other invited people, including a professor from Yale for biological energy, engineers from MIT to handle magneto hydrodynamics...that kind of business. But the oil and gas I handled myself.

So the Geological Survey, in response to this directive, appointed an assistant chief geologist by the name of Vincent McKelvey-I think they brought him in from California or Washington just for this purpose…in July. And his assignment was to pull together the input of the geological survey for this Committee. So he organized people within the Survey-coal, oil, uranium, and so on-and assembled this together in a photo-offset, type-written report that had a printed cover saying something like "The Preliminary Estimates by Members of the Geological Survey on Energy Resources." In that report the first 10 or 15 pages were written by McKelvey himself, and there were brief two- or three-page papers of text written by the various individuals on the various subjects. The one on oil and gas was written by Al Zapp, from the little oil and gas division in Denver. And in addition to these brief texts there were full-page tables assembling several things together, like coal and oil and gas-fossil fuels-on one table.

In the oil and gas paper by Zapp, what he said was that the way we find oil and gas is by exploratory drilling and that up to this date in 1961 we had found about 130 billion barrels of oil-that's the amount produced plus the additional oil in fields already discovered. And we had done this with 1.1 billion feet of exploratory drilling. Then he estimated that with slightly less than 2 billion feet more exploratory drilling we would probably find another 170 billion barrels of oil. And that's where he signed off-his text.

In parallel with this, I was given a pre-print copy of a paper by Zapp that hadn't yet been released that was eventually published in 1962. It had the title of "Petroleum Production Capacity of the United States." Now essentially what that means is, "how much could we produce if we opened all the valves and produced as much as we could," say like in a war situation? So that paper was his assignment, and he only edged peripherally into this problem we're dealing with now-the size of energy resources. And rather that giving specific data, he more or less hinted at what could be done.

In his capacity report Zapp estimated the area of all of the potential oil-bearing regions of the lower-48 states and the adjacent continental shelf, in square miles. These are basins that are now producing or potentially producing oil and gas. He estimated that since the size of most of the fields was small, to find nearly all producible oil would require a density of drilling of about one well to every two square miles in all of this area. So now he had both the area and the number of wells.

The next question was, what would be the average depth of these wells? These wells would be drilled through the sediments, either to the bottom of the sediments, to the so-called basement rock, or to 20,000 feet in case the sedimentary basement was thicker than that. The reason to drill to 20,000 feet is that we find very little oil below that depth; we find gas but very little oil. So he poses that we would need to drill one well every two miles, either to the basement or to 20,000 feet, in order to more or less complete exploration to find the oil in the United States. He estimated that the average depth of hole would be about 7000 or 8000 feet-that's the approximate figure. So here he has the number of wells, the average depth, and that totaled a little over 5 billion feet. So that's the amount of exploratory drilling we would have to do in order to find most of the oil.

This capacity report that I'm describing was written as of 1959. By that time he had estimated that we had drilled 980 million feet of exploratory drilling-just a shade under a billion feet. And as he put it we had already found over 100 billion barrels of oil. So then he added with kind of a broad sweep two statements on the same page; one of them says, *"But this much is certain. It cannot be safely assumed that even the 20% mark has been reached in exploration for petroleum in the United States excluding Alaska and excluding rocks deeper than 20,000 feet."*

How do you get that figure? Well, we've drilled just about a billion feet of oil wells; figure we're going to have to drill 5 billion feet of oil wells. So therefore we're less than 20% oil. The next statement, which is not adjacent but later on the same page, deals with the current yardstick of at least 100 billion barrels of oil found so far. *"In a rough appraisal of the exploration so far, an objective estimate of* *the approximate minimum ultimate 'reserves' appears to be in sight."* So the implication was that the ultimate amount would be over 500 billion barrels.

Concerning this report by Zapp, here's McKelvey's statement: *"Those who have studied Zapp's method are much impressed with it, and we in the Geological Survey have much confidence in his estimates."* Well, in the table of this report, he said we've already discovered over 100 billion barrels with just under 1 billion feet of drilling. By simple arithmetic, we're going to drill another 5 billion feet of well and will ultimately produce 590 billion barrels of oil.

Zapp's report was the numeric basis for the Geologic Survey estimates for the next 15 years.

In the meantime I had periodically done a good deal of work to find a way to deal with these numbers after the first paper in 1956. Overall, I had been working on this for almost 35 years. And the evidence was very clear to me.

I discuss in this paper the possibility of there being more than one peak with the United State, going like this. So here would be another hypothetical production curve and here's a single peak. For the United States as a whole there is no evidence that there will be anything but a single peak, up and down.

So if we deal with cumulative production, the theoretical curve begins at zero then it will ultimately level off asymptotic to the ultimate amount. Well, we have another statistic; we have the start date of 1859 for this curve. We have another statistic; since we have pretty good data since 1900, and more detail since the middle 30's, that's this so-called proved reserves, which was an annual estimate by a committee of the Petroleum Institute that represents the entire petroleum industry. Proved reserves is essentially the amount of oil that exists and is producible in fields already discovered using present methods of production technology and so on. That was an annual figure that was watched with great interest and came out every year in March or April. And every year it included the proven reserves at the beginning, the amount produced during the year, and the proved reserves at the end of the year. So we have the shape on this theoretical production curve, and that actual production curve would begin at zero, would reach a peak somewhere in mid-range, and would be zero again when we're through.

There's a third curve here - proved discoveries. That would be the amount we've already produced plus proved reserves. Add them together and we've discovered that much. The discoveries curve precedes the production curve by a certain number of years. Which turned out to be, when I plot the data, about 10 or 12 years. And then there's the rate of these things-the rate of production per year, the rate of discoveries per year, and the rate of increase of proved reserves. So that if we're back here in the 1940s, those curves are perking up and the fishing is good. As we advance and those various peak begin to occur, this is very significant information about our production history.

Here are the raw data on those curves, as of the 1961. Here's the cumulative production, here are approximate proved reserves from 1900. By eye you can see discoveries beginning to slow down in the mid-1950s. The time delay between these curves is obtained by tracing these two curves and shifting one over until it matches the other, and that shift was about 10.5 years, with an uncertainty of not more than about a year or two.

So in this report of mine, the actual data are a reasonable fit. The ultimate for lower-48 oil figures out to be about 170 billion barrels, as compared with Zapp's 590 billion.

The McKelvey report was never published; unfortunately it was disassembled in my office to take out the nuclear materials which I reproduced in here, and was never put back together again. So I only have a fragment of that report-these tables plus the cover for it. But his final comes out to be 590 billion barrels. And here is the text of the Zapp paper. So the McKelvey paper is not available.

Finally, in June of 1962, we had a review meeting of everybody's reports. All the reports had been written and there was a general committee review, including by certain outsiders who were invited. My report was photo-offset, type-written copy; I brought along about 20 copies. In fact it wasn't quite complete; I hadn't completed the nuclear energy section at the time. So, I came up with this figure of about 170 billion barrels for oil and roughly 1000 trillion cubic feet for gas. The Geological Survey gave us 590 billion barrels for oil and 2630 trillion cubic feet for gas. Those reports were delivered to the President in November 1962. In January he wrote a letter releasing the reports for the public and recommended that they be given wide dissemination.

Then everything was quiet until about October 1962 when there appeared in the *Oil & Gas Journal* two successive feature articles. In them the US Geological Survey estimates were cited; one was on domestic and the other on foreign. For the foreign production ultimate, the Geological Survey had estimated at around 6 trillion barrels. Today they are down from that to about 1,700 billion barrels. Today there's a consensus among oil people, including the Geological Survey, that the total is closer to 1,700 billion. The USGS report had a range including the higher figure, but they warned that the lower figure better be taken seriously. And other independent estimates, including L.F. Ivanhoe's who has been working on this world problem-I haven't-he's been coming out with around 1,700 billion.

There was a big blow-up over the *Journal's* articles. That first article was principally put in the context of the USGS vs. Hubbert. I should note that I retired from Shell at the end of 1963 at the statutory age of retirement. I was a part-time visiting professor at Stanford University for two years before that, and I continued as a full professor at Stanford part-time until 1968 when I headquartered here at the Geological Survey in Washington. But they had tried to steer me away from oil and gas and leaving that to McKelvey, but I didn't steer very well *[he chuckles]*.

At the same time I was chairman of the US Science Division of the National Research Council, which is a subsidiary of the National Academy of Sciences. There came before our committee a proposal to do an updated study on resources and their human implications. That eventually was published commercially by a company in San Francisco-Freeman-though originally as a report of this committee-a National Research Council report. Freeman gave it very wide distribution. I wrote about a third of that on fossil fuels.

Q: Looks like it was published in 1969...

So the oil curves-world and US-were updated to that time. Much of this was repetitive, because what I was doing was updating. But here was something new: oil found per foot. In here I think I gave ultimate oil recovery for Lower 48 States as about 168 billion. That was in substantial agreement with a number of other estimates. But in that paper by Zapp, here's a little graph of the oil found per foot vs cumulative footage that leads you to that 590 billion barrels…what I call the Zapp hypothesis. And here's the contrast: there was my approximate estimate of this decline around the corner, and here's that 118 barrels per foot of his. The large blank area between the two curves is the magnitude of the difference between his estimate and mine.

Q: It's sort of a tooth fairy theory?

Yeah. The Zapp hypothesis. It gives you 590 billion barrels.

And during that time in the 1960s McKelvey was the fair-haired boy of the Geological Survey and the official spokesman of the USGS on oil and gas.

Q: Would it be fair to say that that's the reason why the Johnson administration didn't appear to do anything or even take notice about long-term U.S. oil production?

Johnson wasn't interested. Johnson after all is from Texas and he thought he knew all about oil. He knew oil people and they could tell him. So Johnson, I would say, wasn't interested.

So we go on during the 1960s. The USGS published repeatedly-particularly by McKelvey with a co-author or two-updates of these estimates, but always coming out with substantially the same figures…around 600 billion barrels for the Lower 48 states, for crude oil, and natural gas in a general bracket around 2,500 trillion cubic feet. And the trust in the USGS, which is one of the greatest scientific bodies of the U.S. government, was such that whatever their official figures were, they were taken seriously in Congress.

Q: How about in the industry?

Industry wasn't quite so taken in, but the government was. Until, approaching the end of the 1960s, evidence that didn't match the 600 billion barrels began to appear. Certain published papers by industry people were pointing out the imminent shortage of gas, and others were doing something similar with respect to oil.

So when an annual report from the American Petroleum Institute-in conjunction with the American Gas Association and the Canadians, which is published annually-came out on proved reserves in April or May 1968, proved reserves of natural gas, which had been climbing steadily at least since World War II, dropped by a trillion cubic feet between 1967 and 1968. That jolted the complacency. The next year they dropped 10 or 12 trillion cubic feet. The year after that they dropped another 10 or 12 trillion cubic feet. That began to convince the Congress and other people in the government that something was seriously wrong in what they had been told about oil and gas.

What I had pointed out in my report was that *if* this McKelvey estimate were true, the peak in production for oil would not occur until near the end of the century. Whereas according to my figures it was due to occur around the end of the 1960s decade.

So if you back up to 1962, if a rational analysis of the data-as I presented it for the National Academy of Sciences study-proves ineffective, what can you do? Well, the only legitimate test is time. We're both predicting the future. I'm predicting that this peak will occur shortly, within less than 10 years, and the Geological Survey is predicting that it will occur in closer to 40 years. So, okay, I said "well, let's wait and see what happens." And it began to happen as we approached the end of the 1960s decade.

During 1970, I was out of my office when my secretary said there had been a visit by someone from the Library of Congress Research Service, which does research for Congressional committees. One of their people had come over and had picked up a bunch of my publications. He gave no explanation, just wanted copies. A few weeks later, without consulting me, I learned that the chairman of the Senate Committee on Interior and Insular Affairs, Senator [Henry "Scoop"] Jackson-

Q: Is that now the Senate Committee on Energy and Natural Resources?

Yah. What I learned was, when I got a copy of the letter from the Committee, that Senator Jackson had addressed a letter to the Secretary of the Interior saying that by a Joint Resolution of Congress his Committee had been authorized to make a new study of oil and gas resources.

Backing up, two or three personal events took place during the late 1960s. The Survey's chief geologist, who was pre-eminently a politician, by the name of William T. Pecora, was appointed Director of the USGS in 1965 and he appointed McKelvey Chief Geologist. In

1971, Pecora moved up to Undersecretary of the Interior and McKelvey was appointed the Director of the USGS. Pecora had collaborated with McKelvey on those overestimates.

Back to 1970, the letter from Senator Jackson to the Secretary of the Interior requested that one of the Assistants of his Department help the Committee in their studies of energy resources, and that I participate as well. Well, that letter went from the Secretary's office over to the USGS and there was apparently some consternation and a considerable delay of several weeks. I couldn't speak to the Committee until that letter was replied to one way or the other. Finally a *reluctant* reply was sent saying yes. I say it was reluctant because the man who wrote the letter told me so. He was Assistant Secretary of the Interior, overseeing the Minerals Division and Bureau of Mines in the Geological Survey. And he told me emphatically, "I wrote that letter *very* reluctantly." Nonetheless he did say yes. I afterwards learned from persons who were present that there were internal conferences over whether to reject that request. And a wiser older head told them that if they really wanted to get themselves in trouble that was the quickest way to do it. So they said yes and I was to participate.

Once that was done, I went down to talk to the chief of staff of the Committee to find out what they wanted me to do. They wanted me to update previous studies, such as my work for the Academy report, and bring it to the Committee. McKelvey wasn't yet the [USGS] Director-he was Chief Geologist. I told the chief of staff, "Look, I have no technical help and there's a hell of a lot of man-hours that has to go into this effort, including plotting and so on. I've got to have a technical assistant." "Well," he said "I'll speak to McKelvey about this and there shouldn't be any problem on that," but nothing happened.

One day, I think it was early in November 1970, I got called by my branch chief saying "Sorry, we're taking your secretary away from you; somebody else needs her worse than you do." I said, "Look, you know I have this request to do this job for the Committee and I've got to have help. I need a secretary and technical help." Well, in effect he shrugged his shoulders over the phone and said he couldn't do anything about it, that I would have to go higher up. Higher up was McKelvey. And I got the call taking away my secretary one day after McKelvey was confirmed as Director of the USGS. So here I was with no secretary, no technical help and this assignment. And I told him, "Well, all I can do is report this to the Committee." I did and the chief of staff said, "Okay I'll talk to McKelvey and tell him."

So, okay, I got a sharp-toned call from a secretary that day saying that the Director wanted to see me at 11 o'clock. I went in and he was sitting at his desk, fumbling some papers. Then he turned on me and accused me of going over his head to this committee. I told him, I said, "Look, I've got to do this job. You know I've got to do it, and I've got to have help. You've taken my secretary away from me and I have to have technical help."

There had been an executive order in force for two or three years against extra employment, except on a part-time basis. So I said, "Okay I would like to go to the local universities where there were engineering or mathematics departments and hire a graduate student as an assistant, part-time, to help me with this work." I did, and I got the top mathematics student at American University. He was hired on a part-time basis, but still no secretary.

Q: Who was the student?

His name was Jerome Karaganis, a Greek name. He's now with the Coal Institute, headquartered here.

We went ahead and embarked on this. Still no secretary. This report was finally finished in 1973-74…. This was a book-sized report in fairly fine print but the USGS added an appendix, including some of these Survey reports that had these wild figures in them. But the main report was my report; it was published in 1974 by the Committee. The title was "U.S. Energy Resources as of 1972" and it was labeled Part I. Unfortunately Part II, which would have included nuclear energy, never got written-I ran out of time.

My wife typed that report at home-every word of it. It was just as well to have it that way because I didn't want anybody seeing that report until it was published. The drafting work was done by the USGS, but the writing and typing was done by me and my wife.

When the report came out in print, the USGS sent copies to something like a dozen reviewers, saying "Tell us what's wrong with this!" I know about the letter because I knew several of the people who got it. Well, that report was the end of this particular episode.

In 1974, the same time that report came out, the Geological Survey had a contract with a branch of an energy office that doesn't exist anymore. The chairman's name was Sawhill. And they had a contract to make a new estimate of US oil and gas resources. So in that connection they hired some outside petroleum geologists and enlarged their little group in Denver that had been their oil and gas branch. They considerably enlarged and reorganized the internal structure. This particular study was put under the joint direction of two people: a woman named Betty Miller who had been in this kind of work with Sun Oil Company, and Harry Thompson who had recently retired from Shell and who had spent the last 10 or 15 years in Shell's head office in New York, with and overall review of the whole oil situation with the US and Canada. These two were in charge of this study.

They finally came out with their report in June of 1975. It couched everything in probability units-a system I don't personally care for. There's a 5% probability that the ultimate amount is this big, there's a 95% probability that it is this big, and a mid-range. So they had these ranges that were very considerable. Well, their lower ranges were pretty close to my figures. The higher ones were higher, but the lower ones were very close to the figures that I had arrived at. The chief of that group gave the paper at a conference over in Austria-a group called IIASA I believe. It's an international group that was organized by Lyndon Johnson. The Austrian Government gave them a headquarters by refurbishing the old run-down country palace of Maria Teresa.

So I attended their meeting in 1975. Peter Rose, who was the head of the oil and gas people for the Survey, gave a synopsis of that paper by Miller and Thompson at that meeting. I hadn't seen their report before; they had a meeting just before I was leaving for Europe and I was invited to attend but I couldn't because I was catching a plane. Okay. Their report was a *drastic* comedown from the USGS's earlier figures.

In October I had to go to Denver for a meeting that had nothing to do with the USGS. While I was there I planned to spend a couple of days and go and visit my colleagues at the Survey offices. When I arrived, I hadn't taken the precaution of reserving a rental car, so I called up the Survey and called Betty Miller, told her I was stuck at the airport without a rental car and was there a possibility of someone from the Survey coming and picking me up. Betty Miller and Harry Thompson both came to pick me up. On the way out, I complimented them on the quality of their report but I speculated that they may have had a little administrative opposition. Harry Thompson said, "That's the understatement of the year." They had a bloody battle with McKelvey over this report. And he and an assistant secretary had rewritten parts of the report over the objections of the authors. I have an annotated copy by Betty Miller which includes passages that were written into this by McKelvey and the Assistant Secretary of the Interior, over the objections of the authors. Harry Thompson said, "If you change this report I'll resign." They did change it, and he did resign. Betty Miller was subsequently transferred to something else.

Now in about 1978, I got a telephone call from Houston saying, "You wrote this report for the API back in 1956 and a lot of things have been happening during the subsequent 20+ years. How about writing an update report for our forthcoming Denver meeting, telling us what's happened since? I said, well, "I haven't got time to write a report before the meeting. If you'll allow me to make an oral presentation at the meeting and write the report later, I'll do it." They agreed to that, and so I wrote a report that by that time had seven or eight more years of information. And I reviewed historically the things that we've been talking about here today, and made an updated estimate.

Well, something went wrong and I don't know what, but my data this time gave me a figure of about 163 billion barrels. I thought that was too low, but the data would allow no exception, and whether I had wrong data or did something wrong I don't know which. But I think this figure was too low, but that was the best one I could do at that time-163 billion barrels.

Now I'm working to update the oil data now, with the best information we've got… come out with a new review of the whole situation. And I haven't yet got final figures. But there's something else that has been going on in the meantime that needs to be mentioned.

In the late 1950s, the same time this Zapp business was building up, there was a very vigorous movement within the USGS and the Dept of the Interior promoting the thesis that you couldn't trust the petroleum industry figures, especially for proved reserves. They were biased and too low. So an agitation was begun to try to force the API and Gas Association to raise their figures. I have a copy somewhere of a preliminary draft they sent out proposing these changes, and one of them was to tell us how much oil there is. It was sent out to various people in the petroleum industry; the criticism that came back was, "Hell that isn't statistics, that's guesswork. We deal with statistics, facts."

One of the principals in this effort was McKelvey and the other was Sam Lasky who had been with the USGS and was later transferred to the Secretary's office in the Energy Department. In 1962, in parallel with our Academy Committee, the Senate Interior and Insular Committee under a previous Chairman-Anderson, if I remember-was holding hearings on fuel and energy policy and they brought in Sam Lasky as their chief of staff for the study. And they put out two or three draft reports and circulated them before they printed the final one. But in this final report, you have to piece together the scraps, but they came out with somewhere around a 500 billion barrel estimate for oil. And Sam Lasky devoted about three pages to *ridiculing* the Proved Reserve Committee's estimates on proved reserves, attempting to completely discredit them.

Now, what's the basis for all this? Very simple; those proved reserve figures were standing between Lasky and McKelvey and the conclusions they were trying to draw. A 500 or so billion barrel figure was utterly incompatible with petroleum industry data. So what then? Petroleum industry data were wrong and the government should take it over and make their own data. And eventually that's what happened. The API finally said "Go to hell, and we'll pull out of it. You handle it." And subsequently we've had no reliable figures on proved reserves which we'd had for years before that, a consistent series run by a standing committee of a cross-section of the petroleum industry, using a consistent set of rules.

Q: When did the industry pull out?

The transition was made around 1978-79.

Q: So we haven't had reliable reserves figures since then?

No. Publication of "20th Century Petroleum Statistics" was started during the War, as a public service by the industry, to get a consistent set of statistics. They continued it annually thereafter. The figures were put together from the best and most authoritative sources available. But here, with the new proved reserves situation when the Department of Energy took over.... the old and new sources are just utterly incompatible.

That leads up to the present situation. In these earlier studies of mine, we hadn't yet reached the peak of production, so I was estimating when the peak would occur. Secondarily, I was estimating what the size of the Ultimate Recoverable Resource would be, but that was less secure than the date of when US oil production ought to peak. So I had to make use of two sets of data, namely the production data with a high degree of accuracy, and the Proved Reserves data which had a lesser degree of accuracy but still pretty good. And so the combination of those gave me the cumulative discoveries, which I could use for making these estimates. But I had to use proved reserves. In this report of 1979 is where I got that figure of 163 billion barrels. I'm still using proved reserves, but the government has been messing with the Proved Reserves Committee's figures, so the proved reserves have become less reliable during the 1970s, when the Committee finally threw up their hands and said "you run it."

So I don't know now the original source for my error. I'm assuming now that the figure of 163 billion was too low, but I don't know why. It may have been that I was still using the proved reserves, and that fouled me up because they have become less reliable.

Q: Do you think the figure is closer still to 170 or…?

I'm working on that now. I think it's going to be more than 170 billion barrels for the Lower 48, but not a hell of a lot more. It could be as much as 180. So I'm going to go back and reexamine the data of 1979 and see if I can find out what went wrong with that apparently erroneous figure of 163.

Now, in this report of 1983…well, go back to the Senate report. In the Senate report, the gas data was so fouled up…in this case it was a combination of proved reserves, very irregular production-a large part of the gas was flared up until the 1950s-so the gas statistics, even if accurate as far as they went, were still a mess. So consequently, I did the best I could with them and….they just didn't fit anything. So I made a crude estimate, in which I didn't believe, of about 1050 trillion cubic feet. In the 1983 report, I used about three different methods of estimating, and I got a range of around 950 to a low of around 700 and something, and the average is somewhere close to 900.

Where we are now, which we didn't have before, is that the production figures are far enough along that you don't have to depend on proved reserves.

Q: For both oil and gas?

Yes. So you can deal with the production figures alone. We couldn't do that before, at least before the peak in 1970. So what I'm doing now is I'm staying away, as far as possible, from proved reserves and relying entirely on accurate production figures. And I'm getting, by different methods of analysis, figures on gas-which is where I've done the most work so far-agreements within a few percent.

Q. And the numbers are showing...?

Somewhere close to the upper 800's [Tcf].

Q. Below 900? Still showing that?

Yeah. Using *only* production figures. I'm working on the same thing on oil but I haven't finished the job; I'm not far enough along to give that figure. The gas data so far is in the order of 880 or thereabouts, but maybe as much as 900.

Q. And the oil may be as much as 180 but...?

As of now it looks like it may be somewhat more than that, because one figure I got was 175 billion.

Q: Still, that's within these two lines that you drew back in 1956.

That's right. But I'm trying to precise it with this new and better data.

Now, this brings us up to Mr. Fischer. His key production estimates are in his figure 1 in *Science*, which contains all of his data and which is modeled after my figures of 1967 and 1972-the oil found per foot. Except in his work, he has combined oil and gas and called it barrels of oil equivalent, but it's still the Lower 48 states. So he's taken the unit of drilling, which I used in the first place, of 100 million feet drilled, which is a convenient block to work with, and by now he's estimated that we have drilled 2.5 billion feet of exploratory hole. That would make 25 units of 100 million feet each. So each one of those blocks, on his ordinate there-he says that's feet, it isn't feet, it should be barrels per foot. So the height of each of those columns on his scale gives you the average number of barrels per foot found during drilling. And his high point is 500 million. He notes that the first five blocks-and he's right about this-include the discovery of most the big oil and gas fields whereas the rest is mostly little fields.

So what he does then is separate the total into three stair steps. The first one is those first five blocks which he says delivered an average of 345 barrels per foot. Then he drops down to a second step that averages 82 barrels per foot. Then 40 barrels per foot for the last step. In his text he writes that production, instead of going into a negative exponential decline, it extends out in stair steps. And each of those stair steps is nearly level. He goes into a long argument that you can continue to drill and find all these little pockets of oil that will produce what my friend Ivanhoe calls scavenger production, and that you can carry out that figure of 40 barrels per foot drilled for another 3 or 4 billion feet of drilling. Now, you may recognize that that's nothing other than the Zapp hypothesis applied, beginning with the 40 barrels per foot. You're going to hold that constant for another 3 or 4 billion feet of hole.

Q: He says that that could last another 30 years?

No, 50 years. Well he says here, "The remaining yet-to-be-discovered U.S. oil resources could thus support levels of drilling with finds achieved during the 1970s and early 1980s for a thirty-year period."… But then he contradicts himself in the next paragraph. He says, "As critical as the discovery of new fields is, it has not been a volumetrically major factor in reserve additions in the Lower 48 States in recent years, nor is it likely to be in the future." So he says the resources could maintain at 40 barrels per foot…

What he's saying there is that it doesn't depend on new discoveries, which means that most of their drilling recently has not been exploratory drilling but infill drilling in the oil fields. Well you see, there's another aspect to that. *[He pulls out another paper.]*

Q: Winter 1988, so this is new?

I don't know whether this has been printed yet. This is a preprint copy from the magazine. *[Issues in* Science and Technology*, Winter 1988: "Rediscovering Oil and Gas."]*

[Tape-change gap.] Texas produces approximately a third of the oil and gas in the Lower 48 States. The economy of the state of Texas is

approximately 50% dependent on oil and gas. The city of Houston, which is the oil capital of the country if not the world, now has hundreds of vacant residences; they can't be sold or rented because the people have left.

I have a couple of clippings here if I can get my hands on them. *[He pulls out* Washington Post, *May 3, 1986, "Oil Crunch Hits Geology, Engineering Students." And* Washington Post, *November 28, 1986, "Jobs Are Foremost of Petroleum Economy Cares."]*

Q. [Reading:]"...employment opportunities not about what's going on now but what will be going on in four to five years." So the university is trying to keep their good ship afloat. That's essentially the motivation here?

Right.

Now let's come back to Fischer's paper. His entire analysis is fallacious on two counts. First, it's an optical illusion. Those steps look nearly flat when plotted on that scale; on any curve, when you reduce the scale enough it goes flat. What happens if you blow that up ten-fold? It looks vertical. So take the 12th of the last unit there, which is 1.3 billion feet of hole; that drops from 8 to 3 barrels per foot. It's an optical illusion.

The second fallacy is that he does not do any legitimate analysis of his data. If you take the data-I've not done this with his data-but if you took those columns and added them up, stacked the columns…that is, if you had a hundred barrels per foot per billion feet, you'd have 100 billion barrels-1/10 of a billion feet you'd have 10 billion barrels.

So when you plot these data and draw a straight line to zero barrels per foot, that's your ultimate figure for ultimately recoverable oil. These are his data. It turns out to be a very good straight line that intersects this bottom axis at 335.8 billion barrels. That's what his *own data* say. There are some stair-steps in there. There's the best least-squares fit.

Q: So he didn't analyze the implications of his own data?

Nope. And he doesn't know how. He says if this carries on at the rate of 40 barrels/foot for another 3 billion feet, it'll be another 120 billion barrels, or for 4 billion feet it'll be 160 billion barrels. But with his data, where we are *now* is approximately 300 billion barrels. That curve would have to come out such that we would add to this 120 to 160 billion barrels. So I would have to intersect between 420 and 460 billion barrels of cumulative oil. You can do it with a pencil and paper, but you can't do it with a drill. In other words, the data will not support his conclusions.

Q: Are you going to be publishing information to that affect?

They invited me to write a discussion in the letter column, limited to 600 words. I wrote without consideration of the words what it took to show what was wrong with his thesis. It was a more than 600 words, maybe 1200, and so I'm quite sure they're not going to publish it. They put you in a negative position to begin with, they've got this guy up on a pedestal and you're down here without equal space and equal time. Give me equal time and I can obliterate it. So I did submit a manuscript. I got word yesterday that, oh, that's too long. So I said in effect "to hell with you."

What is Fischer going to do about the production problem? He proposes an R&D agenda. He says we don't have enough research and development, but he's prepared to provide it for the oil industry. There's the crux of it right here.

Q: [Reading from an article:] "We need a government-funded R&D effort, tax incentives to encourage energy companies to do more R&D with their own money, and greater public/private R&D cooperation."

All right but look, read the rest of that. It cites with approval a committee report which recommends the establishment of centers of excellence at six or seven major universities in oil producing regions, which obviously the University of Texas would be one. So it's a pitch for a big block of federal money to bail him out. That's all it is.

The drilling program he proposed won't produce the oil he's talking about, but it will deplete what we've got left in a hurry. The man who was head of the Ford Foundation in about 1978 made a very quotable remark which I've used with respect to this Fischer argument. What it amounts to is a "deplete America first policy." He goes in with a phony argument of how it's important to be free of imports. Well, our imports right now, this year, are approximately equal to our production.

Q: Really? I thought we were at 38% last year.

Well, let's get the figures. For the Lower 48 States ...

Q: [While he was looking for data:] You have a hopeful scenario somewhere, and I'm wondering what it is and how we get there.

Well, you have to look at the resources we've got. Coal, oil and gas will last a little longer but not a hell of a lot longer. So you've got the fossil fuels which are short-lived, then you have nuclear-fission or fusion ...

We went into nuclear quite optimistically, including myself, but it turned out to be a very very hazardous business. We're in the midst of a hell of a lot of trouble with nuclear power plants. We've got the waste disposal problem. We've got the associated atom bomb problem. We've got the problem of what are we going to do with these plants when they wear out, which is about 30 years; we haven't faced up to that problem yet. So, my conclusion right now is if we had breeder reactors, that would prolong the life of our fuel supply compared to fission, but all the other problems are still with us.

So then we go to fusion. Every year about the budget time, we get these great glowing stories about how close we are to producing fusion. We never quite get there; seems to be close to the horizon-a mirage. If we had fusion, that would certainly be a big supply-the deuterium in the ocean for example is very very large, even though a small percentage, and it is extractable at an energy cost that is positive compared to the energy you can get out of it. But we haven't got fusion, except for atom bombs. So let's just ditch nuclear energy for the time being and see what else we've got.

The biggest source of energy on this earth, now or ever, is solar. It's time span is astronomical; instead of decades of supply, there are centuries. My original thought on solar was it's so diffuse that it's impractical. But I've changed my mind. It's not impractical. So let's just do a little bit of elementary arithmetic.

The desert research institute a few years ago made a series of measurements around the state of Nevada, and I had one of the reports of their measurements over a period of a couple of years or so. Solar energy incident around Las Vegas, per square meter of the surface of the ground, averaged day and night summer and winter was 250 watts per square meter. Solar cell technology at the present has an efficiency of 10% or 12%, and it can probably be doubled. The principle constituents are silicon, which is the earth's second most abundant chemical element.

So in the Las Vegas area, if we had a square kilometer of collection area covered with solar cells-assume 10% efficiency-we would be collecting 25 watts per square meter, averaged per 24-hour period, year in and year. For a square kilometer, that would be 25 megawatts. So all right, a 1000 megawatt plant which is the size of the big nuclear plants at the present time-how much collection area would it take for a 1,000 megawatt plant? So 40 square kilometers would be a 1000 megawatt power plant. That would be an area about 6 kilometers square; allow access area and auxiliary area, we could easily say an area say 7 or 8 miles wide would accommodate a 1000 megawatt solar power plant. Now if you take a look at the solar maps of Russia and the U.S.-there are such maps published-the average from the Pecos River to the Mojave Desert is close to 200 watts per square meter.

Q: Peak daytime?

No. Average day and night, summer and winter-around the clock. In daytime it would be over 1000, close to noon. So that would be 20 watts per square meter. So almost any 15 kilometer-square area in this region could power a 1000 megawatt power plant, allowing for access and auxiliary space. Once you've built it, it just sits there and runs; all it requires is maintenance.

Now, utilizing the existing technology-in the electrical industry, the chemical industry and the petroleum industry-that energy could be delivered by power lines, plus in pipelines in gaseous forms and liquid forms, anywhere you wanted deliver it to.

Q: Hydrogen gas?

Oh, methane if you want, methanol. The most obvious would be hydrogen. It's chemically the simplest, though it has technical problems. In that case the combustion product is drinking water-no carbon dioxide, no fouling the atmosphere.

This technology exists right now. If we just convert the technology and research and facilities of the oil and gas industries, the chemical industry and the electrical power industry-we're not dealing with some hypothetical future, we're dealing with things we could do tomorrow. All we have to do is throw our weight into it.

In this article which apparently will not be published, I use the sentence, “Were we a rational society, a virtue of which we have rarely been accused, we would do so and so…” In other words, we would husband our dwindling supplies of oil and gas-supplemented by imports as long as they are available-and institute a program comparable to that in the nuclear industry of the 1940s, 50s and 60s, for the conversion over to solar energy. These things we could do *tomorrow*. We could improve the technology, but we have the technology already.

I don’t know whether you’ve ever heard of the process the Germans have developed, a very simple one they call the Adam and Eve System. I encountered it in the Saar Valley when I was in Germany about 10 years ago. One of the German scientists took me out for a visit to the Saar Valley, one of enormous mining operations of lignite. And within this area there’s an old castle, and that’s a national monument so the mining’s all around it. But this old castle is a kind of public museum and information center. I was being shown around, and there on the wall was this diagram of this Adam and Eve System. It was a means of transmitting energy in a closed loop, chemically. What they have is this closed pipeline loop, and on the input end they put thermal energy into it. And on the other end they take the thermal energy out by a power plant. So it’s a closed loop chemical system. So the chemicals that are coming back are methane and water-returning chemicals from the power plant. Then you put into that along the way catalysts, and you convert that to carbon monoxide and hydrogen. And so you deliver energy, in the form of carbon monoxide and hydrogen, to the power plant. When it gets there, you put it through another catalytic reactor and it reacts back to water and methane. And you take the heat out and run the power plant. You could deliver energy by this means, by pipeline, and you’re not adding anything to the environment, although you could dump the water at the other end if you have a water supply, bring the methane back and pick up water at the beginning instead of using the pipeline for the water. But all the rest of it is a closed-loop pipeline. It’s a simple and fascinating system.

Q: Maybe I’m wrong in drawing a conclusion as a listener from what you’ve said so far, but one of the questions I was going to ask you was why haven’t policy makers responded more effectively to some, if not obvious energy problems, certainly

growing problems.

Look, you've got the USGS which mislead the government for 15 years. In fact, that lasted until they fired McKelvey in 1977. He wouldn't let go. And he was still hanging on to his viewpoint. And the Geological Survey has traditionally been one of the great scientific institutions in the country until they went into this screwball situation in about the late 1950s. And went haywire, God only knows why.

Q: The reality is that present day politicians aren't even talking about energy in the presidential campaign-

They're *ignorant*, they don't know anything about energy. The entire crop, with the exception of Bruce Babbitt, is a bunch of ignorant asses. They haven't any idea of the state the country's in or headed into, with respect to energy resources.

Q: I'll read you something from an article written about you and ask you a question about it. It was the article "King Hubbert," by Robert Dean Clark, in Geophysics, February 1983. In it you're quoted as saying:

> *"'We are in a crisis in the evolution of human society. It's unique to both human and geologic history. It has never happened before and it can't possibly happen again. You can only use oil once. You can only use metals once. Soon all the oil is going to be burned and all the metals mined and scattered.'"*
>
> *"That is obviously a scenario of catastrophe, a possibility Hubbert concedes. But it is not one he forecasts. The man known to many as a pessimist is, in this case, quite hopeful."*
>
> *"'We are not starting from zero. We have an enormous amount of existing technical knowledge. It's just a matter of putting it all together. We still have great flexibility but our maneuverability will diminish with time.'"*

From where we are now, where do you see us going, and do we have less maneuverability than we had five years ago?

Our maneuverability is diminishing damned rapidly right now.

Q: So, a scenario of catastrophe, which you weren't forecasting-according to the article-is starting to look a little more ominous.

I'm saying that this perspective of Fischer's is a prescription for catastrophe.

Q: Is this focusing of our energies on drilling in the ANWR and offshore California, is that similar to the scenario you mentioned earlier where we're focusing our remaining efforts on drilling and depleting America first or fastest-

We should husband our dwindling supplies of oil until we can get out of this mine we're in, use it economically, import as much as possible as long as it's available. But merely do that is a time-saving device until we can make a transition over to an independent source of energy.

Q: I appreciate your perspective on renewable energy, and yet the simplest things which we could do first, the conservation, we're rolling back...the fleet mileage requirements-

We're dealing with a cultural problem. We've had nothing but exponential growth for 200 years. Most of us, the history we carry in our head is limited to about the American Revolution, or when our ancestors came over from wherever they came from. And during that period we've had nothing but exponential growth, and so we've in effect developed an exponential growth culture. That's the reason that one of the most ubiquitous expressions in the language right now is growth-how to maintain our growth. If we could maintain it, it would destroy us.

Q: We don't have a national energy policy.

Of course not.

Q: If we did, we could evaluate rationally, as you say, the ideas that-

Were we a rational society, a virtue of which we have rarely been accused …

Q: I'll remember those words, will use them, and will credit you.

Very good.

[He shares a copy his article "Exponential Growth as a Transient Phenomenon in Human History," printed in Societal Issues: Scientific Viewpoints, edited by Margaret A. Strom, American Institute

for Physics]

There's an interesting little story attached to this paper. The editor is a remarkable woman. She was teaching a little English course part-time at George Washington University, until she began to get into readings of this nature, written by prominent scientists and others, as both an example of the problems that we're facing and also of competent writing by the leaders in physics. She was having very good success with her students reading these papers and got very excited about it. And so she decided to collect a bunch of these things and put them together in a volume for the use of her students. With that connection, she wrote letters to potential authors to invite them to give her copies of things they had written that she could use.

I got such a letter from her addressed to me in California-I was here in Washington but she had an address at UCLA. I called her on the phone about her excellent letter. And I submitted to her half a dozen papers I had written that might fit into her format, and she selected this one ["Exponential Growth"]. It's a paper I gave to a World Wildlife Conference in San Francisco in 1976 or 77. It's the only time I addressed royalty; I had the King of Sweden in the audience. But the paper was not published; none of the proceedings at that conference were published. So she picked this paper for inclusion.

The newspapers in San Francisco mentioned this paper, and there it is in the *New York Times.*

[Gap while changing the tape; he mentioned the need for a comprehensive energy education process.]

To achieve major change probably requires a spiral of adversity. In other words, things have to get worse before they can get better. But the most important thing is to get a picture of the situation we're in now, and the outlook for the future-exhaustion of the oil and gas, that kind of thing, an appraisal of where we are and the time scale. And the time scale is not centuries, it's decades.

It's like this whole question of we're running out of oil. The answer is yes. When did that start? It started in 1859. Every barrel of oil we've taken out of the ground since the first oil field was discovered is one less barrel of oil to go. So it's like a leaky tank, and every drop that comes out of it is one less remaining.

Q: In the Lower 48 states, how much is remaining

I would say close to a quarter. Roundly we've probably already consumed about three-quarters of our oil and gas in the Lower 48.

Q: And yet I hear the president of the American Gas Association that we have about a 50-year supply at current rates of usage-

The Gas Association has been notorious for misinformation for at least 20 or 30 years. I don't trust any official from any gas company. The oil industry has done better, but nonetheless you've had certain people in the oil industry who have been just as misleading.

Q: But utilities are mouthing that 50-year-supply notion, customers hear that, policymakers-

Of course. And then you've got this guy Fischer who's a propagandist of the same type.

Q: But an education effort that has to combat entrenched sources of information that are considerable-

You've got to go right back to basics. If you start quoting authorities, anybody can quote his own authority, and that's the old trick of expert witnesses in lawsuits. We've got our expert witness, they've got theirs, and they contradict each other-you be the judge. Standard technique. And the law firm that hires the cleverest expert witness tends to win the case.

Q: In that case, you're the best expert witness because in 1948 you stated-

I'm a reasonably well-known public figure.

Q: And yet your perspective is marginalized. I don't understand why it isn't impacting policy.

Yeah, this has been a kind of an uphill grind of sorts, but not totally. For example, I was lecturing on this subject in the so-called Distinguished Lecture Circuit for the American Association of Petroleum Geologists during the 1970s. We traveled all over the US and Canada for nine weeks, talking to local petroleum groups, universities, government groups, financial people-Ottawa, New York City-so I'm not a pariah by any means.

Here's a little story about that period. During that lecture tour, I talked to a very elite group-representatives of all the oil companies headquartered in New York, plus their financial associates with New York banks. Not very long after that, I was invited to address a meeting of the Society of Petroleum Analysts-people who analyze the oil situation for financial institutions. And I was invited to come to their annual meeting in Fort Lauderdale, Florida and address this group, during 1973, shortly after this meeting in New York where I talked with the elite group. Now, the person who invited me was the president of that society who apparently was at that meeting in New York. He was one of the top petroleum analysts in the business and he was so impressed with my presentation and analysis that I was invited down to talk to this organization in their annual meeting. At the time he was VP of E.F. Hutton.

Not long after that talk in Fort Lauderdale, I got a call from a Hutton manager in Milwaukee, wanting me to come up and talk to their financial group. Well, my friend Robert Devine said, before the evening Milwaukee meeting, "what the hell, why don't we have a luncheon meeting in Chicago on the way." So we did, for a specially invited group as guests of the E.F. Hutton Company. And they did something very clever. Ordinarily at meeting like that, they have two or three martinis and then stuff themselves, and then you talk to a stupefied audience. That time they had the speech first, then cocktails and lunch. Then they did the same thing in Milwaukee at a private club in the evening; they did it the same way, having the speech before dinner. We did the same thing in Boston. And then on to New York, they did one of the same talks in one of the skyscrapers along Wall Street-a luncheon with people coming from as far as the Mellon Bank in Pittsburg to this lecture. Later we did the same thing in San Francisco, then Dallas, then Houston, then London.

Q: Did they not understand or did they forget?

The man who arranged this damned well understood, but he's not running the country. He did his part and organized all these meetings at Hutton expense. You can't change the world but none the less I'm just giving you an example of one thing that has gone on.

Q: Sadly, policy has not shown up which reflects the rationale

which you so clearly present. It hasn't come forward yet.

Okay, again I have to admit that time's running out on me too. In 1968-69, I had the Hong Kong flu. Well, that damaged me permanently. For about three months after that I couldn't write a letter or read a newspaper; I could read the words but it made no sense. And in this report I wasn't quite through with the atomic waste problem, so I had to call in one of my friends to write that section.

I developed out of that a case of incurable chronic asthma. I've been a guinea pig of the National Research Institution for the last 10 years. In addition I developed an embolism about five years ago and it's a life-threatening situation. If that could get into the heart it could block the heart or get into the brain-either one…a very dangerous situation.

During that time I had just committed myself to write a new paper. It's the lead article in this book [*History of Geophysics*]. I was writing that paper during my health problems. When they published it, they ran it as the feature article of the volume-keynote papers, they called it.

Q: The Vetlessen Award-

That was before this.

Q: That award made clear that you would have won the acclaim of your peers without all the controversy had you not ever entered into the business of long-term energy resource analysis.

Well, the Vetlessen Award was secondary to all this. It was for other work. It was for cumulative work. But the part in which you are more interested was this. *[He handed over another article.]*

Q: A copy of that was sent to me by L.F. Ivanhoe.

Something directly related to what you're interested in was in 1977 and that was the Rockefeller Public Service Award from Princeton University for, explicitly, this oil and gas work-$10,000 award.

Q: Have you by any chance seen this book? [Beyond Oil]

I have a copy right over there. It's based largely on my own work.

Q: I know. I contacted them and discovered that they never

contacted you directly, and I didn't understand that. They credited you at length. Do you have any thoughts about the book?

Well, it's been a long time since I've looked at it. I really can't say. At least they're moving in the right direction. How well they did it I don't know.

Q: Just looking at my watch, I've been here and awfully long time and made it a long day for you.

Well, we pretty much covered the ground that we should have covered, and I've enjoyed your visit.

[Hubbert brought over copies of more papers that he gave me, mentioned a few points here and there, then launched into more discussion:]

This is a more philosophical paper, given at the German Geological Society in 1977.

Q: In one of the articles I read, you were quoted as saying there is an incompatibility between the science of energy matter and the financial system. Is that covered in any of the papers you've given me?

Not explicitly. I've got a little one-sheet paper on it here which I'll get for you.

Q: Besides L.F. Ivanhoe, who are the people who have picked up your work and are carrying it forward? He calls himself a disciple.

Not very many actively. He's the most active person, much more so that I.... He can write faster than I can read.

[Hubbert found and then discussed the one-pager which he had finally located: "Two Intellectual Systems-Matter-Energy and the Monetary Culture," presented and discussed at the seminar of MIT's Energy Laboratory, Center for Energy Research, September 30, 1981 and other locations: he read from it briefly, then waxed philosophically:]

Our real problem is a cultural problem. Our monetary system is a culture prehistoric in origin. It works fine in a simple culture, but not as well in a complex industrial system.

The rules of the monetary system are different from the science-energy system. There is the matter of earning compound interest dollars, which is fundamental to the system. "Interest can go to heaven." Oil and gas supplies can't do that.

A curve of a biologic population looks relatively steady-state. Rapid growth is only a transient or temporary phenomenon. Yes, there can be fluctuations. But a sustained disturbance like rapid growth can change the entire system. The current disturbance is based largely on the fossil fuels; we've got to stabilize that. With these high-level inputs, we could overshoot and drop back down. It could be a real catastrophe; worst case, we could become extinct.

We've got to stabilize the human population. If it could achieve non-growth at a level compatible with the physical system, then it would be possible to have a leisurely, well-fed society. Such a flowering society is entirely possible.

Oil represents energy. Money is paper. The common denominator of money is the IOU. Money is a system of paper booking inherited from a prehistoric past. Those rules are incompatible with the rules of modern energy.

We emerged from the basement and paused at the top of the steps beneath Hubbert's famous huge painting of Don Quixote. At that point his wife joined him and they bade me a pleasant goodbye.

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Reflections on this interview:

In the 60 years since Hubbert's seminal paper was presented in San Antonio, his initial position-that U.S. production would peak by 1970 and that world oil production was likely to peak by around 2000-has drawn critics like a magnet to metal. In his trail lies a complex tale interweaving vilification and vindication, then yet more vilification.

Back in the 1960s, when Hubbert and the USGS were at loggerheads, he eventually posited that time would tell who was right-his harsh realism or the optimism of the Zapp-McKelvey perspective. By the time of the interview, the peak in US crude oil (and lease condensate) production-9.64 mb/d in 1970-was already 18 years in the rear view mirror. In fact, for over five decades after his talk, the score with respect to his initial views of U.S. oil production held up: Hubbert 1, Critics 0.

Then came the U.S. shale gas and shale oil boom. From 2011 through *early 2015, the shale oil or tight-oil boom was the fastest period of oil production growth in U.S. history, possibly in world oil production history. Annual U.S. crude oil production rose from around 5 mb/d in 2008 to 9.4 in 2015. At that time, U.S. crude production re-peaked at almost the same level it had in 1970. Score tied: Hubbert 1, Critics 1.*

The shale oil boom surprised peak oil and Hubbert supporters far and wide. Even industry analysts and the U.S. EIA missed the scale and speed of the boom. Starting in the fall of 2011 and running through 2015, well-known industry analysts such as Daniel Yergin (IHS-CERA) and Ed Morse (Citi-Group) vilified Hubbert's perspective of peak oil, declaring his perspective so flawed that it was dead and buried, thanks to the shale oil boom. Combining recent shale oil production with cumulative production from the Lower-48, all off-shore and Alaska, Jean Laherrère recently reported that US oil production in the US through 2015 reached 215 billion barrels-considerably higher than Hubbert forecast (though his forecast excluded Alaska).

Additionally, Hubbert's estimates for ultimately recoverable natural gas from the Lower 48 badly missed the mark. Production has already exceeded his estimates. In fairness, he acknowledged several times during the interview that his estimates for natural gas were flawed. Hubbert 1, Critics 2.

Finally, Hubbert's estimates for ultimately recoverable world oil-1700 billion was the number he used during the 1970s-will most likely end up being low. To date, the figures Jean Laherrere uses show that the worldwide industry has produced roughly 1250 billion barrels of oil to date (excluding extra-heavy oil and NGLs). Hubbert 1, Critics 3.

But don't bury Hubbert's contribution just yet.

For starters, the recent shale oil boom was not sustainable, in part due to geological limits, in part due to the higher dollar and energy costs of extraction, and-at the world level-in part due to differences in mineral and surface rights in the U.S. vs. nearly the rest of the world. In fact, the boom has been cut short due to the oil price crash that started in 2014. U.S. tight oil production has been in moderate decline since the April 2015 peak. Given the enormous decline in U.S. rigs drilling for oil, plus the financial cutbacks in oil production investments worldwide, U.S. production-the largest gainer in world oil production over the last four years-appears to be slipping into *accelerating decline. Only a sustained recovery in oil prices might avert the growing number of bankruptcies plaguing the oil industry, with a best-case revival perhaps eliminating further decline within a year or two … for a few years.*

The broader value of M. King Hubbert's controversial contribution to the long-term analysis of how world oil production will proceed over its two- or three-century span can't be captured in a simple score sheet. He asked us to do something no one before him had done: consider the timing and consequences of a peak in oil production that was nearer than virtually everyone thought. His dogged efforts to share his ground-breaking vision of an eventual peaking in U.S. oil production were met with not only denial but also some outright obstruction, almost from the day they were introduced through the present day.

Sometime within the next 10 years, possibly even this year, world oil production is very likely to peak. When it does, we will most certainly wish we had done two things that Hubbert urged. First, that we should have turned earlier to what he called our window of opportunity to shift away from depleting fossil fuels sooner rather than later. Second, we should have internalized one of his favorite rhetorical points: "were we a rational society, a virtue of which we have rarely been accused, we would husband our resources."

Eventually, history will almost certainly vindicate Hubbert's broader views. Until it does, his critics will continue to heap abuse on the concept of peak oil, harping on his errors, missing the forest for the trees. As he advised, time will tell.

Book Review:

The Oracle of Oil: A Maverick Geologist's Quest for a Sustainable Future

By Mason Inman, published by W.W. Norton, April 2016.

Note: An extract from this book is given elsewhere in this issue of the journal.

I thoroughly recommend this book: it is well written, extraordinarily informative, and highlights a number problems which today are still of considerable importance, and which society will need to face.

The subject of the book is the life of M. K. Hubbert, with the primary focus being his geological background and research. A key area within this was the estimates he made over the course of his life of the likely recoverable resources of US oil and gas, and hence their probable production profiles; and likewise for global oil supply. Well described in the book are the deep - and still resonant - controversies surrounding these estimates.

Hubbert had been concerned with the issue of resource depletion since his days at college; and near the end of his life was still seeking to refine his estimates (see Andrews' interview of Hubbert in this issue). One of his main concerns, as Inman's book clearly brings out, was that humankind should know the limits to the natural resources available, and, as a consequence, act to use them wisely.

While Hubbert's resource analyses during his life were primarily of conventional oil and gas, he also examined in depth many wider aspects of the general 'global resources problem'. These included the energy available from other energy sources, including non-conventional oil and gas, hydroelectricity, nuclear fuels (conventional fission, breeder fission, and fusion), and solar energy; as well as the availability of minerals and water resources (modelling the future scope for water extraction from the Ogallala aquifer, for example). He also studied the deeper problems underpinning the use of resources, including population growth, society's expectation of exponential economic growth, and of the best way to govern society given the resource constraints.

Though triggered while at college, Hubbert's lifetime interest in asking these questions was almost certainly reinforced by his exposure to the Great Depression. As Hubbert said, in an interview published in 1983 in the Society of Exploration Geophysicists' magazine *Leading Edge* (Annex 3):

> *"I was in New York in the 30s. I had a box seat at the depression. … I can assure you it was a very educational experience. We shut the country down because of monetary reasons. We had manpower and abundant raw materials. Yet we shut the country down."*

This experience was also almost certainly part of what led to Hubbert's collaboration from 1931 with Howard Scott and the Technocracy movement.

Scott had been a member of the Technical Alliance, a consulting firm (and intellectual group) that since about 1920 had been considering better ways to manage the economy, in turn in part based on the American government's apparent success in running a fiat economy during World War 1. The ideas of the Technical Alliance followed those espoused by William H. Smyth, a Californian engineer, who had invented the word "technocracy" in 1919 to describe "the rule of the people made effective through the agency of their servants, the scientists and engineers" (Wikipedia). Over the years Scott had spent effort developing his 'Theory of Energy Determinants', which led to the notion that society should be run not on money, but instead on 'energy certificates', where these could buy products based on the amount of energy they took to make. Early chapters in Inman's book covers these intellectual developments well, and sets them against the background of the times.

Needless to say, today the ideas of the Technocracy movement are seen as part of discredited 'statism', the antithesis of the free market. As an example of this, perhaps a decade back I was at an oil meeting where a fairly senior US official dismissed the validity of Hubbert's forecasts, in part because the latter's membership of the Technocracy movement (and here the official put up slides of the group's philosophy) which showed that Hubbert had to be a crank. Section (c), below, looks briefly at this question of how best to run society given the resource constraints we face.

Inman then covers Hubbert's many important contributions to geology: on scaling (and hence understanding how rocks could be bent and squeezed); on groundwater motion and on hydrodynamic oil traps; with David Willis on fracture orientation following hydraulic fracturing; and his work with William Rubey on the mechanism by which naturally-occurring extremely high pressure water within rock beds allows overthrust faults to occur.

But the main part of the book deals with a detailed look at the estimations by Hubbert and others of the quantities of oil and gas that might be producible in the US, as well as globally. The book covers the evolution of the ideas on both sides of the debates, and in sufficient detail to allow the reader to understand the thinking that was involved. Of particular value here are the very clear diagrams that Inman incorporates; these illustrate the points being made very well, and allow a number of criticisms of Hubbert's work to be refuted.

Another of the book's great strengths is Inman's broad coverage of the changing attitudes within US governments towards energy issues, varying as the presidents changed, and hence as also the advisory teams they selected changed. Perhaps the most dramatic of these was the switch from the Carter administration's concerns over energy supply, exemplified by his 'Moral equivalent of war' speech, to the Reagan administration's free-market view.

As Inman explains, Carter's view in his 1977 speech (*"Unless profound changes are made to oil consumption, we now believe that early in the 1980s the world will be demanding more oil than it can produce."*) was considerably more pessimistic than the by-then fairly mainstream view held by Hubbert, most oil company forecasters, and also by Schlesinger, that the global production of conventional oil would not peak until around the year 2000. Carter seems to have been influenced in part by a CIA report that he got declassified. By contrast, the subsequent free-market view of the Reagan administration was influenced on the energy side by the Head of his energy transition team, Michael Halbouty, a Houston oilman with a far more optimistic take on US oil supply.

Finally, Inman's book includes an excellent epilogue that brings up to date the controversies over Hubbert's views, and covers the more recent changes in US government policy towards oil supply and wider energy issues, including discussion of the dramatic change of view in many quarters on oil limits (and, implicitly, on other energy limits also) that has accompanied the rise of shale oil production in the US.

Overall, Inman's book is just excellent, giving detailed coverage of Hubbert's life, of the intellectual battles he fought, and vividly painting the background of competing political, industrial, and economic forces which characterised the times, and which strongly influenced these debates.

Below I briefly discuss some of the important issues raised in the book which seem to me as still relevant – indeed, probably more so now than then.

(a). Being misled by proved reserves

The first still-relevant issue is that of proved oil reserves. Confusion over these has long been the cause of much of the disagreement about 'peak oil', and this is still the case today. (For example, see the recent very misleading statement by BP's Chief Economist, based on proved oil reserves, that: *"over the past 35 years … for every barrel of oil consumed, another two have been added"*, Dale, 2015).

How Hubbert learned to handle the problems posed by US proved reserves has important current implications, but because it is rather technical it is covered in Annex 1.

The wider issue is the atrocious lack of reliable data in the public domain on all aspects of oil supply: discovery, reserves, and even for many key fields, production. As Campbell has written: *"The whole question we're discussing* [of peak oil] *would be obvious and easy to understand if there was valid information in the public domain."* Until this issue is resolved, we must expect continuing confusion within society about expectations of future oil supply.

(b). How knowledge of a technical subject gets into government thinking

A second issue that still has great relevance is the question of how knowledge of a technical subject gets into government thinking.

In both Inman's book and in Andrews' interview above one can see Hubbert wrestling with this question. Hubbert points out that the government institutions that were supposed to do this job often seemed to fail; his long battle with the USGS over the size of the US *conventional oil* recoverable resource - as it would influence the date of the US production peak - being a case in point.

This is a big topic, and here I will only sketch a few rather random thoughts.

As Hubbert pointed out, the mainstream government or quasi-government institutions set to examine such problems all too often seem to miss crucial information, or make poor assumptions and hence poor judgements. The history of oil forecasts a decade or so back, by the IEA, US EIA, OPEC and some of the oil majors', of not anticipating the current constraints on the global production of *conventional* oil, and hence the steep rise in oil price after 2004, is a case in point; see Bentley (2016a).

Plenty of people have worried about how best to get correct (often, scientific) information into a government's vision, and it was for this reason that organisations such the US Office of Technology Assessment (OTA) - now disbanded - was set up. On the OTA, Wikipedia writes:

> "[It] *was an office of the United States Congress from 1972 to 1995.* [Its] *purpose was to provide Congressional members and committees with objective and authoritative analysis of the complex scientific and technical issues of the late 20th century. … Its model was widely copied around the world. … During its twenty-four-year life it produced about 750 studies on a wide range of topics, including acid rain, health care, global climate change, and polygraphs.*
>
> *Criticism of the agency was fuelled by* Fat City, *a 1980 book by Donald Lambro that was regarded favourably by the Reagan administration; it called OTA an "unnecessary agency" that duplicated government work done elsewhere. OTA was abolished … in the "Contract with America" period of Newt Gingrich's Republican*

ascendancy in Congress. … The move was criticized at the time, including by Republican representative Amo Houghton, who commented … "we are cutting off one of the most important arms of Congress when we cut off unbiased knowledge about science and technology". [However] *the idea of technology assessment survived, in particular in Europe. The European Parliamentary Technology Assessment (EPTA) network coordinates members of technology assessment units working for various European governments. The US Government Accountability Office* [GAO] *has meanwhile established a TA unit, taking on former duties of the OTA."*

On oil supply specifically, the efforts of the University of Reading's *ad hoc* 'Oil Group' to inform the UK government of the then-coming (post-2004) oil price supply shock are detailed briefly in Chapter 4 of Campbell (2011), as are the reasons these efforts largely failed.

There is also much to be learned from the ineffectiveness of apparently well-conceived meetings. Jeremy Gilbert, former Chief Petroleum Engineer for BP in the US, put it succinctly: When asked about the significance of the US National Research Council 2-day workshop on Oil Supply held in October 2005 (at which – *inter alia* – he, David Greene of ORNL, Tom Ahlbrandt USGS, Peter Jackson IHS CERA, Matt Simmons, Simmons & Co., Michael Rodgers PFC Energy, Bob Hirsch MISI, and Kjell Aleklett of Uppsala University attended), he responded: "*The Washington meeting was good, a small group of people who participated energetically in discussion - but I don't know that we gathered in any converts, another case of* [each side] *'singing to the choir'?*" (For a summary report of this workshop see NRC, 2006.)

We found a similar experience from the succession of annual one-day conferences held in London by the Institute of Energy, and later by its successor, the Energy Institute. Information was put across by both sides of the 'peak oil' debate, but no-one's mind was changed. The trouble with such an outcome is that when government then asks these experts what is the truth, they get conflicting answers and conclude (incorrectly) that the truth is not known.

What may be needed to help minds change, and hence a consensus develop on these society-critical problems, could well be longer-duration less formal events, such as the many annual 'summer schools' that over the years have contributed significantly to helping scientists unravel the workings of the universe. As another approach, in 1967

Arthur Kantrowitz, the American scientist and engineer, proposed an 'Institution for Scientific Judgment,' to draw conclusions on just these sorts of matters.

And given the potential (some would judge, near-certainty) for conflict engendered by the resource constraints that likely lie ahead, there would seem to be a strong case for convening UN meetings on these issues, like the UN Conference on Resources that Hubbert attended in 1949, and making international agreements on resources, such as those already the case for boundary disputes, laws of the sea, disease monitoring and prevention, cross-border water issues, and - most recently - climate change.

On specifically peak oil, in addition to the NRC workshop mentioned above, recent significant studies of the problem have included the US GAO (2007) report to Congress: *Crude Oil*; in the same year an NPC report (2007): *Facing the Hard Truths about Energy*; and the UKERC report: *Global Oil Depletion* (Sorrell *et al.*, 2009). But despite these studies, there still remains widespread confusion about the topic: it is not enough to make a study, it needs publicity, widespread discussion and critique, and significant outreach activity if significant sectors of society are to understand a problem.

Overall, it seems clear that we need to find better mechanisms for reaching agreement on the difficult technical issues on which politicians need to act.

(c). Free market or technocratic control?

As mentioned above, an important topic raised in Inman's book is that of how we will need to govern society, given the energy, mineral and other resource constraints that we face.

We currently have one main solution: the free market economy, coupled with politically-derived incentives and directives. Hubbert and many others, then and since, have raised the question of whether we will need a different approach, given the severity and intractability of the problems that lie ahead.

On the energy side we now know that these include:

- peak global conventional oil about now, and peak global conventional gas in about 10 to 15 years (Bentley, 2016a);

- probably peak global high-quality low-cost coal (Mohr *et al.*, 2015);
- lower EROI ratios for nearly all the non-conventional fossil fuels, and for most of the renewables (Hall, 2016);
- EROI *rate-limits* that prevent an energy-useful rapid uptake of these various alternatives, with the 'poster-child' for this being the zero net energy to-date from PV installations, due to their relatively modest EROI ratios and rapid global expansion (Dale & Benson, 2013);
- the increasing amounts of energy likely to be required:
    - for extracting minerals, due to falling ore concentrations (Bardi, 2014; Ragnarsdóttir and Sverdrup, 2015);
    - for agriculture, to pump irrigation water from falling aquifers, and raise total production to feed a hungry world;
    - to meet the growing energy expectations of the world's population;
    - and to match population growth;
- and climate change constraints on fossil energy use, where a practical path to meet 2°C requires global fossil fuel use to start to decline only five years from now.

Sadly, quite a list. Is the free market up to the job?

Firstly we must explain what is meant by 'free market'. Today no major economy is a free market, and it is doubtful if one ever was. Leaders or governments have always found it necessary to spend money on a judicial system, tax collection, defence (or military conquest) and infrastructure; and today this list is lengthened to include education, health provision, welfare, pensions, basic science, the arts, national parks and heritage and so on; as well as the cost of regulation and monitoring found necessary to control the free market (including labour laws, environmental controls, consumer protection, and rules on company reporting, anti-competitive behaviour and tax avoidance). In addition, governments have a very long history of intervening in free markets by way of incentives and constraints to encourage business to certain ends.

With this definition in mind, the concept of using the free market to solve energy problems has strong supporters (see, e.g., Gordon, 2009), and certainly the case can be made that governments often do a bad job when intervening in energy issues.

But let's take the example of the 2008 recession. Gordon (2009, p 8) may be right to state that "*The financial turmoil prevailing in September 2008 is rooted in Congressional policies to promote risk mortgage lending*." rather than in the financial world's willingness to invent and sell dubious mortgage-backed securities, or in the high oil price (which certainly played a role). But if the consistent 30 years' of warnings from 'resource-based' forecasts, that constraints on the global production of conventional oil production would occur shortly after the year 2000, had been acted on by governments to restrain risky financial lending, it would seem very possible that the impact of the recession would have been far less. (Note that such a cautionary lending policy would have had to be enacted at least EU, perhaps OECD, wide, otherwise constraints on lending in London would have resulted in the lending moving to Frankfurt, or New York.)

Going forward, as the energy problems listed above bite ever more deeply, will the free market with its mantra of growth be our best salvation? Hubbert didn't think so, nor probably the authors of the 'Limits to Growth' studies (Meadows *et al*., 1972, 1992 and 2004; and see also Bardi, 2011), nor many more recent thinkers (e.g., Fleming, 2016). Selecting the correct approach to meet these increasing problems will need to thought about carefully if the paths to societal collapse that modelling suggests are possible are to be avoided.

(d). The 'Hubbert controversy' today

Finally in this list of 'still-relevant' issues, I mention briefly the state of the 'Hubbert controversy' today. Perhaps surprisingly, this controversy is still with us, with views existing that Hubbert 'got lucky' with his US forecast, or that the advent of shale oil via fracking has made the concept of peak oil irrelevant. A recent example of the latter was a review of Inman's book in the *Wall Street Journal* (April 25, 2016) written by the historian R. Tyler Priest. The latter makes a number of points, but a key one is:

"The technologies of the shale revolution have blurred the distinction between conventional and unconventional hydrocarbons and reversed

the decline in U.S. oil and gas production that Hubbert insisted was terminal. Current U.S. oil production, at nearly nine million barrels per day, is nine times what Hubbert believed it would be in the 21st century."

This statement is simply not correct. Hubbert's forecast was *explicitly for conventional oil production in the US Lower-48*, and was never intended to be a forecast of US total oil production in the 21st century. Though just about everyone has been surprised by the rate of production of shale (light-tight) oil, Hubbert knew about the potential scope of oil from Alaska and US deep offshore, and also had assessed the amounts of oil potentially available from NGLs, tar sands, and oil shale (by retorting the kerogen within); see Bentley (2016b). Hubbert also knew of the ability to turn coal to oil, the potential for biofuels, and so on. But as Hubbert noted (Inman, p 294):

"However, there is a different and more fundamental cost [to oil production] *that is independent of monetary price. That is the energy cost of exploration and production. So long as oil is used as a source of energy, when the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil, production will cease no matter what the monetary price may be."*

As Bentley (2016a) shows, the difference between conventional and non-conventional oil is important, and is the still little recognised explanation for the dramatic rise in oil price post-2004, see Bentley and Bentley (2015).

Finally, in tying together some of the issues raised above, I cannot help mentioning two facts in connection with George Mitchell, the Texas businessman credited with pioneering the economic extraction of shale gas in the US, that in turn led to the shale oil boom. The first is that, although it is true that much of the credit for this development goes to Mitchell's foresight and determination (the free market), credit must also go to the related government-sponsored research (statism). Secondly, on the wider energy problems we face, Mitchell was clearly a man with vision who thought about the risks. As Wikipedia reports, Mitchell helped fund many projects concerning sustainability, including the original 'Limits to Growth' study.

Conclusions

I do not think I can conclude this article better than by offering the conclusion at the end of the 1983 article on Hubbert in the Society of Exploration Geophysicists' magazine *Leading Edge*:

> "[Hubbert] *makes people, intelligent people who both admire and deplore his opinions, think hard about unpleasant things. If Hubbert is right about man being on the brink of an unparalleled crisis, then men are going to have to make fantastic decisions - species-wide decisions - imminently. This ability to make people, particularly the right people, think, will be of inestimable worth. It may be Hubbert's greatest legacy."*

-Book review by R.W. Bentley, Editor *The Oil Age*, 19th May 2016.

Annexes:

This paper includes three annexes, as follows:

Annex 1. Being Misled by Proved Reserves.

Annex 2. *Two Intellectual Systems: Matter-energy and the Monetary Culture* - Summary by M. King Hubbert.

Annex 3: Extracts from the article: *King Hubbert: Science's Don Quixote*, published in the February 1983 issue of *Leading Edge*, the magazine of the Society of Exploration Geophysicists.

Annex 1: Being Misled by Proved Reserves

Much of the controversy over 'peak oil' has been due to not understanding the difference between proved ('1P') oil reserves and proved-plus-probable ('2P') reserves; see for example Bentley *et al*. (2007), or Bentley (2016a). The discussion of Hubbert's views in Inman's book relates to four important aspects of this topic:

i). Being initially misled by US proved reserves

Like many others over the years, Hubbert also originally fell into the trap of thinking proved reserves to be a good measure of how much discovered oil at a given time remains to be exploited. As Bentley

(2016a) notes:

"In 1938, Hubbert made a forecast for the US peak that predicted peak too early by 20 years, writing that "it seems doubtful that [the beginning of the US oil decline] can be postponed any later than 1950, and possibly not that long" (Hubbert, 1938).

He based this on the fact that "the easy discoveries have already been made" (which was correct, as US 2P discovery peaked in the mid-1930s), and on the then-size of proved US reserves, at "11 or 12 billions of barrels". It was here his error lay, as he wrote that proved reserves represented "the oil already discovered".

Like many to come after him, he had been led astray by thinking that proved (i.e., 1P) reserves were a useful measure of the amount of oil discovered but not yet produced. The actual US proved-plus-probable (2P) reserves at that date were certainly much greater; East Texas alone contained over 5 Gb. To-day's backdated value for the size of US 2P reserves in 1938 is 95 Gb … i.e. about eight times the '11 or 12 Gb' that Hubbert quoted for the then-proved reserves!"

(Note: This use of the US proved reserves, at *"11 or 12 billions of barrels"* probably relates to Inman's comment on p73 *"- but Hubbert didn't provide any more detail"*.)

ii). 'Growing' US proved reserves, to provide data closer to proved-plus-probable

Hubbert fairly quickly picked up on his error, and developed a procedure to 'grow' US proved reserves at any given date, by examining the growth in such reserves that had happened in the past (Inman, p 209). This gave much more realistic estimates of the true size of these reserves.

iii). Use of 'non-grown' proved reserves plus cumulative production to generate 'proved discovery'; and hence predict production by time delay

However, despite having developed this procedure, Hubbert perhaps seems to have shown some ambiguity in how he regarded US proved oil reserves data. For example, at that time the current oil industry databases that record 2P reserves did not exist, and Hubbert made use of the fact that if 'non-grown' US oil reserves are combined with cumulative production they generate 'proved-only' discovery data. The latter, when plotted cumulatively against date, show an 'S-shaped' logistic curve profile, and this can be plotted on the same graph as cumulative production, to predict both the peak in proved reserves, and the subsequent peak in production. (Note that the 'S-shape' of 'proved-only' cumulative discovery data contrasts sharply with 'quasi-parabolic' shaped curve that typically results when 2P discovery data are plotted cumulatively against date; this shape resulting from the fact that in a given region typically the big fields are found first.)

iv). Whose data to use to get reserves?

Another example of Hubbert's possible ambiguity on US proved reserves is reported in the interview with Andrews, as follows:

"In the late 1950s … there was a very vigorous movement within the USGS and the Dept. of the Interior promoting the thesis that you couldn't trust the petroleum industry figures, especially for proved reserves. They were biased and too low. So an agitation was begun to try to force the API and Gas Association to raise their figures. I have a copy somewhere of a preliminary draft they sent out proposing these changes, and one of them was to tell us how much oil there is. It was sent out to various people in the petroleum industry; the criticism that came back was, "Hell that isn't statistics, that's guesswork. We deal with statistics, facts."

One of the principals in this effort was McKelvey and the other was Sam Lasky … Lasky devoted about three pages to ridiculing the Proved Reserve Committee's estimates on proved reserves, attempting to completely discredit them.

Now, what's the basis for all this? Very simple; those proved reserve figures were standing between Lasky and McKelvey and the conclusions they were trying to draw. A 500 or so billion barrel figure was utterly incompatible with petroleum industry data. So what then? Petroleum industry data were wrong and the government should take it over and make their own data. And eventually that's what happened. The API finally said "Go to hell, and we'll pull out of it. You handle it." And subsequently we've had no reliable figures on proved reserves which we'd had for years before that, a consistent series run by a standing committee of a cross-section of the petroleum industry, using a consistent set of rules."

Annex 2: Two Intellectual Systems: Matter-energy and the Monetary Culture - Summary by M. King Hubbert.

The website: http://www.hubbertpeak.com/hubbert/monetary. htm reports as follows: *'During a 4-hour interview with Stephen B Andrews, on March 8, 1988* [i.e., the interview included in this issue], *Dr. Hubbert handed over a copy of the following, which was the subject of a seminar he taught, or participated in, at MIT Energy Laboratory on Sept 30, 1981':*

"The world's present industrial civilization is handicapped by the coexistence of two universal, overlapping, and incompatible intellectual systems: the accumulated knowledge of the last four centuries of the properties and interrelationships of matter and energy; and the associated monetary culture which has evolved from folkways of prehistoric origin.

The first of these two systems has been responsible for the spectacular rise, principally during the last two centuries, of the present industrial system and is essential for its continuance. The second, an inheritance from the prescientific past, operates by rules of its own having little in common with those of the matter-energy system. Nevertheless, the monetary system, by means of a loose coupling, exercises a general control over the matter-energy system upon which it is superposed.

Despite their inherent incompatibilities, these two systems during the last two centuries have had one fundamental characteristic in common, namely, exponential growth, which has made a reasonably stable coexistence possible. But, for various reasons, it is impossible for the matter-energy system to sustain exponential growth for more than a few tens of doublings, and this phase is by now almost over. The monetary system has no such constraints, and, according to one of its most fundamental rules, it must continue to grow by compound interest. This disparity between a monetary system which continues to grow exponentially and a physical system which is unable to do so leads to an increase with time in the ratio of money to the output of the physical system. This manifests itself as price inflation. A monetary alternative corresponding to a zero physical growth rate would be a zero interest rate. The result in either case would be large-scale financial instability.

With such relationships in mind, a review will be made of the evolution of the world's matter-energy system culminating in the *present industrial society. Questions will then be considered regarding the future:*

- *What are the constraints and possibilities imposed by the matter-energy system?* [Can] *human society* [be] *sustained at near optimum conditions?*
- *Will it be possible to so reform the monetary system that it can serve as a control system to achieve these results?*
- *If not, can an accounting and control system of a non-monetary nature be devised that would be appropriate for the management of an advanced industrial system?*

It appears that the stage is now set for a critical examination of this problem, and that out of such inquires, if a catastrophic solution can be avoided, there can hardly fail to emerge what the historian of science, Thomas S. Kuhn, has called a major scientific and intellectual revolution." '

Annex 3: Extracts from the article: "King Hubbert: Science's Don Quixote", published in the February 1983 issue of Leading Edge, the magazine of the Society of Exploration Geophysicists.

The following two extracts are from an interview of Hubbert by Robert Dean Clark, Assistant Editor of *Leading Edge*:

(i). On the 'Hubbert curve'

D.F. Hewett's 1929 paper, Cycles in Metal Production, influenced Hubbert enormously. Hubbert has often called this "a truly great paper, one of the more important papers ever written by a member of the US Geological Survey." Hewett's basic conclusions on the evolution of a mineral-producing area are still cited today, indicating they have risen to the level of accepted dogma.

Hewett's work was also the immediate ancestor of "Hubbert's pimple" and related graphs. "The important thing I got from it was the answer to the question of how long can you keep going up? The answer is, the curves don't keep going up. They go over the hump and back to zero. This is the one future point on the curve that you definitely know *and it greatly facilitates the mathematics. The area beneath the curve is graphically proportional to the amount of development. The area beneath the curve can't exceed your estimate. It's a very simple but very powerful method of analysis."*

(b). Hubbert's views on the energy and money systems; on society's need for labour; and on the ability of earth scientists to advise on these problems.

In recent years [Hubbert] *has assaulted a target - which he labels the culture of money - that is gigantic even by Hubbert standards. His thesis is that society is seriously handicapped because its two most important intellectual underpinnings, the science of matter-energy and the historic system of finance, are incompatible. A reasonable co-existence is possible when both are growing at approximately the same rate. That, Hubbert says, has been happening since the start of the industrial revolution but it is soon going to end because the amount the matter-energy system can grow is limited while money's growth is not.*

"I was in New York in the 30s. I had a box seat at the depression," Hubbert says. "I can assure you it was a very educational experience. We shut the country down because of monetary reasons. We had manpower and abundant raw materials. Yet we shut the country down. We're doing the same kind of thing now but with a different material outlook. We are not in the position we were in 1929-30 with regard to the future. Then the physical system was ready to roll. This time it's not. We are in a crisis in the evolution of human society. It's unique to both human and geologic history. It has never happened before and it can't possibly happen again. You can only use oil once. You can only use metals once. Soon all the oil is going to be burned and all the metals mined and scattered."

That is obviously a scenario of catastrophe, a possibility Hubbert concedes. But it is not one he forecasts. The man known to many as a pessimist is, in this case, quite hopeful. In fact, he could be the ultimate utopian. We have, he says, the necessary technology. All we have to do is completely overhaul our culture and find an alternative to money.

"We are not starting from zero," he emphasizes. "We have an enormous amount of existing technical knowledge. It's just a matter of putting it all together. We still have great flexibility but our manoeuvrability will diminish with time."

A non-catastrophic solution is impossible, Hubbert feels, unless society is made stable. This means abandoning two axioms of our culture: the work ethic and the idea that growth is the normal state of affairs. Hubbert challenges the latter mathematically and concludes the exponential growth of the last two centuries is the opposite of the normal situation.

"It is an aberration. For most of human history, the population doubled only once every 32,000 years. Now it's down to 35 years. That is dangerous. No biologic population can double more than a few times without getting seriously out of bounds. I think the world is seriously overpopulated right now. There can be no possible solutions to the world's problems that do not involve stabilization of the world's population."

Hubbert's ideas about work are even more heretical. Work is becoming, he says, increasingly unimportant. He thinks it is conceivable that the future work week might be on the order of 10 hours. Indeed, because production will have to be limited by increasingly limited mineral resources, that might be inevitable. And that, Hubbert stresses, could be the foundation of an earthly paradise.

"Most employment now is merely pushing paper around," he says. "The actual work needed to keep a stable society running is a very small fraction of available manpower."

The key to making this cultural alteration is to come up with a limitless supply of cheap energy. Hubbert feels the answer is obvious - solar power - and he does not feel more technological breakthroughs are needed before it can be made universally available. His faith is not that of a kneejerk trendy but that of a doubter who did much studying before his conversion.

"Fifteen years ago I thought solar power was impractical because I thought nuclear power was the answer. But I spent some time on an advisory committee on waste disposal to the Atomic Energy Commission. After that, I began to be very, very skeptical because of the hazards. That's when I began to study solar power. I'm convinced we have the technology to handle it right now. We could make the transition in a matter of decades if we begin now.

"Solar power is limited by astronomic time but not in a human time frame. It's been there for billions of years and it will be going on for billions of years after we're gone. It also has another great advantage

over conventional sources - once the system is in place it is permanent. All that's required to keep it going is routine maintenance."

Harnessing an infinite supply of cheap energy is the key to Hubbert's utopia because of the leisure time it would generate. "Look at the people who did remarkable things in the past. The Greeks. The English of a century ago. What did they have in common? They were highly educated and had a lot of leisure time. Of course, not everyone with that combination did remarkable things, but the people who did do remarkable things generally had that combination." In both those cases, though, the opportunities for intellectual greatness were limited to very few. The intellectual life of Greece was made possible because it was a slave society. England's was supported by great masses who lived in terrible poverty. But if the sun is conquered, education and leisure could be universal. "It could result in the greatest intellectual renaissance of all time," Hubbert says.

And his nominees for the leadership role in making this cultural change? His earth science peers. Intellectual leadership is, he says, their natural function.

"I think earth sciences are about to enter a third phase. The first was about 1780-1880 when a handful of men like Hutton, Lyell, and Darwin changed the world. They gave us a geologic view of history instead of a Biblical view. In the second stage, from 1880 until now, earth scientists became utilitarian and concentrated mostly on the search for ores, metals and fossil fuels. They did very little thinking about the broader subjects. Now is the start of a third phase when the world is heading into intellectual turmoil. It needs guidance. The knowledge essential to competent intellectual leadership in this situation is pre-eminently geological - a knowledge of the earth's mineral and energy resources. The importance of any science, socially, is its effect on what people think and what they do. It is time earth scientists again become a major force in how people think rather than in how they live."

Although he is nearing 80, it is obvious Hubbert has not lost what is probably the most remarkable of his many gifts. He makes people, intelligent people who both admire and deplore his opinions, think hard about unpleasant things. If Hubbert is right about man being on the brink of an unparalleled crisis, then men are going to have to make fantastic decisions - species-wide decisions - imminently. This ability to make people, particularly the right people, think, will be of *inestimable worth. It may be Hubbert's greatest legacy.*

References

Note: There are many excellent sources concerning Hubbert's life, many of which I did know about before writing this review. These include:

- Hubbert on camera: YouTube videos; and a programme made for the UK Open University with an introduction by L. Ivanhoe, titled: *Oil: Finds for the Future*; produced for the course 'The Earth's Physical Resources', S238; 1984.

- Interviews of Hubbert by Ronald Doel in 1989: Reference: Niels Bohr Library & Archives, American Institute of Physics, College Park, MD USA, www.aip.org/history-programs/niels-bohr-library/oral-histories/5031-1.

- An excellent informative website, marking the 50th anniversary of Hubbert's 1956 speech, at: http://www.mkinghubbert.com/about/tribute. This site includes much key information, including (under the 'Tribute' tab) an interview with Doel about his making of the Hubbert interviews.

Bardi, U. (2011). *The Limits to Growth Revisited*. Springer, New York.

Bardi, U. (2014). *Extracted – How the Quest for Mineral Wealth is Plundering Our Planet. A Report to the Club of Rome*. Chelsea Green Publishing, Vermont.

Bentley, R.W., Mannan, S.A., and Wheeler, S.J. (2007). *Assessing the date of the global oil peak: The need to use 2P reserves*. Energy Policy, vol. 35, pp 6364–6382, Elsevier.

Bentley, R.W. (2016a). *Introduction to Peak Oil*. Lecture Notes in Energy, Vol. 34. Springer.

Bentley, R.W. (2016b). *A Review of some Estimates for the Global Ultimately Recoverable Resources ('URR') of Conventional Oil, as an Explanation for the Differences between Oil Forecasts (Part 3)*. The Oil Age, vol. 2, no. 1 pp 57-81.

Bentley, R.W. and Bentley Y. (2015). *Explaining the Price of Oil, 1971 to 2014: The need to use reliable data on oil discovery and to account for 'mid-point' peak.* Energy Policy Special issue on '*The Enigma of*

Economic Growth'; vol. 86, pp 880–890.

Campbell, C.J. (Ed.) (2011). *Peak Oil Personalities*. Inspire Books, Skibbereen, Ireland.

Dale, M. and Benson, S.M. (2013). *Energy Balance of the Global Photovoltaic (PV) Industry - Is the PV Industry a Net Electricity Producer?* Environ. Sci. Technol., 2013, 47 (7), pp 3482–3489.

Dale, S. (2015). *New Economics of Oil*. Presentation at the Society of Business Economists' Annual Conference, London, 13 October 2015.

Fleming, D. (2016). *Lean Logic – A Dictionary for the Future and How to Survive It*. Chelsea Green Publishing. (And see also extracts from this in: Fleming, D. *Surviving the Future – Culture, Carnival and Capital in the Aftermath of the Market Economy*.) Publishing date for both books: Sept 8th, 2016.

GAO: US Government Accountability Office (2007). Report to Congressional Requesters: *Crude Oil – Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production*; GAO-07-283, Feb. 2007.

Gordon, R. L. (2009). *Hicks, Hayek, Hotelling, Hubbert and Hysteria or Energy, Exhaustion, Environmentalism, and Etatism in the 21st Century*. The Energy Journal, IAEE vol. 30 no. 2, pp 1–16.

Hall, C.A.S. (2016). *EROI Ratios of Energy Sources as Inputs to Energy Forecasting: Implications for Long-Term Prosperity*. The Oil Age, vol. 2, no. 1 pp 29-55.

Hubbert, M. K. (1938). Technocracy Research Library: from http://www.technocracy.org/technical-alliancetn/17-m-king-hubbert/205-hubbert; accessed 28 March 2014.

Meadows D.H., Meadows D.L., Randers J., Behrens W.W.III. (1972). *The Limits to Growth*. Universe Books, Potomac Associates, New York.

Meadows D.H., Meadows D.L., Randers J. (1992). *Beyond the Limits*. Chelsea Green, VT.

Meadows D.H., Randers J., Meadows D.L. (2004). *Limits to Growth: The 30-Year Update*. Chelsea Green, VT.

Mohr, S. *et. al.* (2015). *Projection of World Fossil Fuels by Country*.

Fuel, Elsevier, vol. 141, pp 120-135.

NPC: National Petroleum Council (2007). *Facing the Hard Truths about Energy - A comprehensive view to 2030 of global oil and natural gas*.

NRC: National Research Council (2006). *Trends in Oil Supply and Demand, Potential for Peaking of Conventional Oil Production, and Possible Mitigation Options: A Summary Report of the Workshop. Washington, DC:* James Zucchetto. The National Academies Press, 2006. doi:10.17226/11585. See: http://www.nap.edu/read/11585/chapter/1

Ragnarsdóttir, K.V. and Sverdrup, H.U. (2015). *Limits to Growth Revisited*. Geoscientist vol. 25 no. 9 (October), pp 10-15. Geological Society of London.

Sorrell, S., Speirs, J., Bentley, R., Brandt, A., Miller, R. (2009). *Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production*. Technology and Policy Assessment report: UK Energy Research Centre, August 2009. ISBN 1-903144-0-35 (Go to: www.ukerc.ac.uk & search 'TPA reports').

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