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.*

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- 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.

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