

“The energy fulcrum” is an introduction to the theory of “peak oil”. Peak oil describes the facts of the decline of an oil field’s production yield, and provides a methodology for predicting the timeframe of the yield demise. The purposes of the document are to provide a framework for understanding and describing future trends; and to serve as an anchor for future discussion and action.

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The energy fulcrum

An introduction to peak oil theory

A strategic viewpoint

It has taken nearly 50 years for Hubbert's initial work on peak oil theory to become accepted as anything more than alarmist grumbling. With oil prices heading higher on a monthly basis however the impending decline of cheap and plentiful liquid fuels has become front-page news. While OPEC, and in particular the world's largest oil producer Saudi Arabia, continue to play up the numbers we are left with only one probability: Hubbert is looking like a winner, as do the balance sheets of the oil companies, while the rest of us look like the losers. Meanwhile we await the recently announced International Energy Agency's (IEA) report for a level of independent oversight and analysis.

Hubbert's model gave the world a way to predict the halfway point in an oil field's productive life. After which oil would be increasingly difficult and expensive to extract; with the field eventually collapsing into non production. This halfway point became known "Hubbert's Peak". He famously predicted the peak of US production to be in the early 1970's; he was accurate to within a couple of years.

Applying the same formula to global supplies predicts us reaching peak in the first decade of the 21st century. Only history will silence the critics and deniers of peak oil theory. Strategic planning and risk management deals with the future however. The last 100 years of economic development has surfed along on three major economic waves i, each the result of technology innovation. Underlying each of these innovations; from transportation to plastics, from aviation to computing; is abundant liquid based energy production. Together with coal, we rely on oil for almost every aspect of human activity in the developed world.

The current economic wave, which is in its last few years, is powered by Information and Communications Technology innovations. The analytical capabilities of IT; together with anywhere, anyone, anytime communications capabilities have transformed the way society banks, sells, trades equities, farms, heals, and kills. Without cheap energy, the economic waves threaten to break us on an unyielding shore.

The continued profligate use of either coal or oil is of course an urgent problem itself due to anthropomorphic climate change. Peak oil is "the other elephant" in the boardroom. Strategic planning demands that we examine now how to manage a soft landing for humanity. Given the degree to which the waters of our economic waves are mixed with the oil of the energy fires we must recognize that a soft landing will require decades, planning, and coordinated effort.

This strategic insight paper examines oil supply theory in light of the recent data points. It positions the start point for the journey we must undertake to land softly on the other side of the energy fulcrum.

An Introduction to Peak Oil Theory

M. K. Hubbert (5/10/1903 – 11/10/1989) was a lead Shell exploration scientist, with specific expertise in the properties of the various geographic formations and rock characteristics associated with oil fields. Hubbert contributed enormously to our current understanding of the specific geological structures required for oilfields to form. His breakthrough contribution in insight was to combine that knowledge with an analytical approach to reported oil reserves.



This led to a model that pointed to the existence of a halfway point in any oil field's life, allowing us to predict with a degree of certainty when half the oil had been extracted from a field. Once half the oil has been extracted from a field the yield rapidly declines, and the cost of extracting each additional barrel continues to increase. Hubbert's theory has continued to be refined and tested. It is now accepted as a workable model in understanding the timeframes of an oilfield's finite life, especially when applied together with modern geospatial mapping and exploration technologies

In understanding peak oil theory to even a basic level, it is important to understand the answers to two questions;

- What would prevent there being an infinite supply of oil, even if we haven't found it all yet?
- How can we measure the size of something that we can't see?

Answering these questions requires a cursory brush with the geography of oil bearing rock formations, as well as a quick overview of the technology of oil recovery methods. Of course by definition a non-renewable resource has a finite lifespan of availability. Examining the answers to these two questions allows us to understand the limits of this most important and dangerous finite resource.

Black Goldilocks

Oil has been called "black gold", but given how fussy oil is it might better be called "Black Goldilocks". Like gold, hydrocarbons (the basis of coal, natural gas, and crude oil) need a specific range of conditions to form in the first place. A certain confluence of feed materials from which oil forms needs to be present, and placed under a specific combination of temperatures and pressures for the right length of time. Unlike gold and the metals and minerals, which are the building blocks of modern technology, hydrocarbons are particularly hard to please. Hydrocarbons do not just require the right combination of "inputs" in order to form (complex as that may be); they also require the right conditions for significant oil fields to form, and then for those fields to continue to hold oil. From the time they formed, certain conditions must continue to be present all throughout time, in a planetary crust active with tectonic movement.

Oil and coal, as anyone who stayed awake in high school science lessons will know, require massive amounts of organic materials as feedstock. The energy content of oil is simply the sequestered energy of the sun transformed through photosynthesis and digestion and locked in the living cellular structure of countless animals and plants. The golden warmth of a long ago day, captured through biological processes, and transformed again by the planetary alchemist's oven into energy stored as carbon in oil, gas and coal. It is of course the release of history's carbon stores through burning oil, gas and coal that is today causing potentially catastrophic climate change.

Unlike a good garden compost heap, these ancient feedstocks only turn into hydrocarbons through an anaerobic decay process. Due to this requirement the first steps to oil field formation took place in the oxygen-starved environment of the deep oceans. Most oil formed at the bottom of what initially was a large area of water such as deep ocean. Without the right conditions of decay the organic feedstocks will break down very differently. They may literally decay via aerobic means into a massive pile of compost. This is in fact exactly what has given us soil today so relatively rich in organic material.

It is easy to imagine an oil field as a humungous cave, buried deep underground. Just waiting for a time when Jed Clampett's bullet penetrates the top of the cavern. Reality is unsurprisingly a little more complex than that. Crude oil is held in saturated rock structures known as oil bearing rocks. Oil bearing rock formations have specific characteristics in terms of chemical structure as well as permeability levels. Oil bearing rock is permeable and porous, and is generally sedimentary structures and/or dolomite. The permeability properties of a rock structure is a key factor in both the rock's ability to hold oil, and to give it up during oil field extraction.

Once they formed, the world's oil fields would long since have simply evaporated if they were exposed to either high temperatures, or if they were exposed directly to the atmosphere for any great period of time after they formed. Temperatures higher than a few hundred degrees Celsius will result in natural "cracking" of the crude oil. As the temperature of the Earth's crust increases with depth, no oil fields will be located below several thousand metres in depth, therefore unlike solid minerals and precious metals it is not possible to simply dig deeper in order to find more oil.

While oil fields cannot be too deep, nor can they be too shallow. Oil bearing rocks must be buried and protected from the Earth's atmosphere by a non-permeable geological formation, referred to as cap rock. Cap rock, is generally comprised of some material like granite. To state an obvious point, cap rocks must surround (and sit on top of) oil bearing rock. Cap rock must be laid down on top (or in geological terms after the formation of) the oil bearing rock.

So it is not only the existence of both types of rocks that is important, it is both the order that each rock structure formed, as well as the time gap between permeable and cap rock forming that is also critical. If the cap rock forms too long after the oil has become stored in the matrix of the permeable oil bearing rock, the oil will "boil off" to the atmosphere before the cap rock can contain it. The process of boiling doesn't happen overnight, but remember we're measuring time frames in millions of years.

The amount of the oil field organic feedstock defines the size of an oil field, while the combination of the permeability characteristics of the oil bearing rock structures, the pressure the oil is held under, and the effectiveness of the cap rock define the extractability of an oil field. Other major factors are at play as well, all affecting the economic viability of a field. These include field (or well-head) pressure, water levels (all oil fields also contain water which must dealt with), gas, salt and minerals, and infrastructure limitations.

The characteristics of the organic feedstock together with the chemical constituents of the oil bearing rock also determine the "sweetness" and "lightness" of the resulting crude oil. "Sweet" oil has no or little hydrogen sulfide content, while "light" oil has a lower viscosity. While sour, heavy crude has its uses, not all oils are created equal and it is sweet, light crude that is best suited to the cracking techniques that provide us with the liquid fuel supplies upon which we rely. Unsurprisingly light, sweet crude is therefore the most valuable commercially. Hydrogen sulfide creates exploitation and safety problems, being both extremely toxic. The safe level for breathing hydrogen sulfide is one part per million, being the same as for cyanide, and therefore exploitation of highly sour fields represents a very real and immediate risk to human and animal populations.

The otherwise promising (Saudi) Qatif field (claimed to hold 8.4 billion barrels of sour crude) extends underneath densely populated as well as agricultural areas and well-head locations have been rejected as a result of the dangers of hydrogen sulfide.

In summary, unlike any other resource mined by mankind, crude oil requires an incredible set of circumstances to happen in order for it to collect in oil fields. It is not just the initial existence of the chemical feedstocks, together with the provision of the right conditions to transform the feedstocks that is required. It also needs the presence of both a suitable bearing rock and the existence of an impermeable cap rock. All of that had to happen in the right order; and then it had to remain relatively static as the Earth's crust changed over the epochs.

With all those balls in the air, the fact that we have any oil at all is a testimony to the prodigious fecundity of the Earth over the history of the planet. Enough organic feedstocks existed in the first place to overcome the unlikely odds of their ever brewing into oil. Not too hot. Not too deep. Not too shallow. Black Goldilocks indeed.

Many eggs in few baskets

Meanwhile, we are highly reliant on a small number of extremely large oil fields. The largest being Ghawar in Saudi Arabia. The state of the Ghawar field would be a long topic in itself to do justice to. In short, there are significant concerns over the continued ability of the Ghawar field to continue to pump at historical rates (some 5+million barrels per day). The land surfaces available for exploration have been explored, including the planet's oceans (it is in fact easier to explore using seismic and sound wave methods over water than it is over land).

It is highly unlikely that we will find new, significant supplies of oil. The specific geography associated with oil fields is a much-studied field of science that has enjoyed multi billion dollar funding. Similarly, exploration techniques are highly developed and now employ incredibly sophisticated remote examination methods that allow for exploration from sea, air, land and space. Anywhere on the Earth's crust that is likely to hold oil has already been surveyed. We're not going to find more by digging deeper, or by digging in a different type of rock formation. It is extremely unlikely that any significant oil fields remain undiscovered

That is not to say that no more oil fields will be found. However, it is extremely unlikely that any significant oil fields remain undiscovered. We may likely find more small fields, however they will supply so little additional crude oil that at best their exploitation may extend the overall lifespan of global oil supplies by a year or two.

Finding the Unseen Edges

Accepting the logic of a finite supply, we can then turn to the questions of how much oil is there and how much is left?

Unlike the task of measuring the amount of air contained in an inflated balloon, we can't easily examine the size and shape of an oilfield. With a balloon, or any other container we can measure the shape and dimensions of the container as well as the pressure that the contents are held under. Thus allowing us to measure the volume of the contents through examination of the container. Of course we can't "see" an oil field in any normal sense. We can poke, probe and scan the earth and guess at a field's edges, and a multi-billion dollar exploration industry has developed to create more accurate techniques to do so. However the only truly accurate measure of how much oil may be recovered from an oilfield is to pump the field to a 'dead' state. ii When the last litre has been sucked from it we can tally the barrels and accurately declare how much that field contained.

So how can we possibly predict how much remains in the ground until we remove it all? Like oil exploration, oil extraction is a well studied and well practiced industry. Various techniques have been developed over time to deal with a range of oil viscosity and extraction challenges. This includes pumping water and gas into a well in order to force the oil out. In fact, water extraction has been used for decades in the Saudi super-fields including Ghawar . The proposal to remove CO₂ from the atmosphere and sequester it underground is in fact simply an excuse to use an unwanted and dangerous gas (that results from the burning of oil) into a well in order to force more oil out.

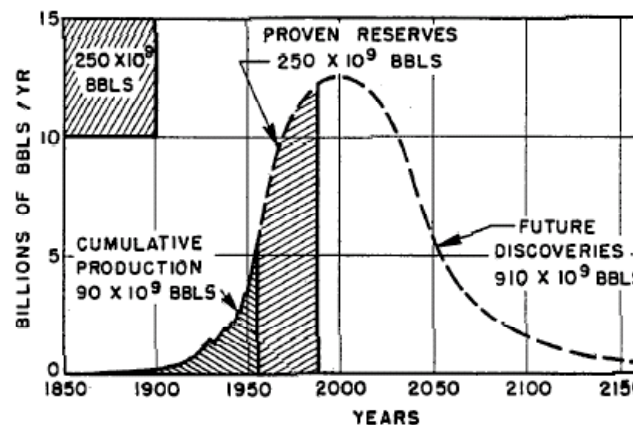
Oil does not flow at the same rate from the well-head over the life span of a field. As the level of oil falls in the field the inherent pressure changes. For example the Khaffi field, the largest in the Neutral Zone shared by Saudi Arabia and Kuwait, suffered a pressure drop of 1000 psi after almost ten years of exploitation iii

As a field ages the oil is harder to extract effectively. As pressure drops the field approaches "bubble point". "Bubble point" is the term given to the pressure at which gas dissolved

(under pressure) in the oil returns to a gaseous state – a phenomenon familiar to scuba divers. Effectively an oil field gets the bends as pressure drops below a certain point. The resultant gas forms a cap on top of the oil deposit, once bubble point is reached field pressure continues to drop and further expense is incurred, as well-heads require re-drilling and relocation.

Secondly, as a field ages, the percentage of water that flows from the well-head together with the oil, called the "water-cut" increases. This is both "natural water" from aquifers as well as water that is pumped into the field in an attempt to maintain field pressures. Aging fields begin to have a water-cut of 30-50% or higher. Eventually there is so much water flowing from a well-head that the percentage of oil that can be extracted becomes uneconomical. Both water and gas must be separated from the oil stream and treated in a Gas Oil Separation Plant (GOSP), which must be co-sited. Increasing water cut also requires the relocation of wells above the water point.

Measured over time, the productivity of a single oil field or that of the world many fields may be plotted as a classic bell curve. Once roughly half the oil has been removed from a field the productivity of a field will reduce (eventually to zero) in a mirror image of its behaviour prior to that point being reached. Simplistically, if the flow rate (taking into account the various techniques being used to force the oil to the well-head) is the same today as yesterday, you know you're not on the downward slope of the curve. As long as extraction rate can be increased you're on the upward side of the bell curve's slope. Beyond the



fulcrum however tomorrow's extraction flow rate will continue to decline. A field is never left empty; there will always be oil that is left un-extractable, trapped in geological formations and left behind the oil / water contact point.

One last important factor is a field's "rate sensitivity". In all fields, there is a relationship between how, and how fast oil is extracted, and the eventual total yield. While there are many factors to this it suffices for now to say "the faster and harder a field is exploited, the more rapidly it will decline and with a lower total yield".

Hubbert's Peak

Hubbert's simple brilliance was to correlate three data sources in order to measure the unseen;

- Known oil being that which has already been extracted and thus can be measured with complete certainty. Extracted oil also provides data useful to monitoring the rate sensitivity, and water cut levels of a field.
- So called Proven Reserves estimates: being that which remains in the ground and being verifiable to a degree through geological survey.
- Yearly discovery rates of new fields which gives an estimate of future oil sources.

Furthermore, Hubbert built into his formula measurement of the ongoing accuracy of reserve forecasts by comparing (future looking) annual capacity estimates against actual (historical) extraction results. This is the "reality check" for any field's predicted reserves. Combined then with the level of demand it is possible to estimate the life span of a given field.

In the last century enough oil fields have been "mined to death" for us to map accurately their behaviour. While every oil field is unique, they share enough behavioural characteristics for us to have learned through direct observation as oil fields are exploited to exhaustion, to have proven the basic truth of Hubbert's bell curve model. Oil fields in US territories, the North Sea fields, as well as other fields in the Middle East have all tracked the bell.

Ring the bell on the world's great fields.

Peak oil theory stands up well, but like any analytical model it is only as good as the accuracy of the data being inputted into the equation. In the case of those fields upon which the world primarily relies we are unfortunately kept in the dark. The Saudi kingdom allows no external oversight or independent review of its claimed reserves. Hardly a model of accounting transparency and one that in any other business management and governance scenario would be considered unacceptable at best. At worst regulators would demand reporting and performance clarity – witness SOX.

A thorough review of the history of the Saudi kingdom and its oil industry would give a rich understanding of exactly what we know about Saudi fields, and how we know what we do. In the interest of brevity suffice to say that we have a reasonably good idea of the state of the Saudi reserves up to the 1980s. Prior to that date US and European oil companies (including BP, Chevron, Exxon, Gulf, Mobil and Texaco – or their forebears) played a critical and central role in exploration of the country's fields. As the original international company's concessions expired the Kingdom took over Aramco and nationalized oil exploration. Eventually they created the company we know today as "Saudi Aramco", and in the process cut off independent and international oversight of reserve estimates, individual field performance and other important metrics.

Since that time the Saudi Kingdom has reported reserves far in excess of early estimates and with suspicious disregard for historical field performance. Numerous fields including Khursaniyah, Abu Hadriyah, Fadhili and the fields of the Hawtah Trend have all been reported as being able to "steadily produce 500,000 barrels of oil per day for decades". In fact it is impossible for the Aramco engineers to accurately predict how a field will continue to perform for 20 or 30 years or more. The history of field production is rife with unexpected challenges and field behaviour.

What is indisputable is that Saudi's major fields have been under heavy, and sustained extraction for a long time. Saudi's five super- fields have in some cases been operating for more than fifty years, a long time in industry terms. At numerous times the fields have been pushed beyond their sustainable rate sensitivity points – for example during the first Gulf War. Doing so ultimately damages a field and reduces its eventual total productivity. It is also a matter of recent history that Saudi refuses to increase supply to balance increasing demand. The regime hints that they could, but they see no reason to do so. It is of course in their interests to constrain supply in order to maintain a high price per barrel.

Oil industry experts are rightly beginning to question whether it is not that Saudi chooses to constrain supply, but rather that supply cannot physically be increased. That the fields have reached a point where there remains no additional supply capacity. Of course Saudi Aramco may have unexpected reserves up their sleeves. The question is; do we bet the world's economy on that chance? Remembering the degree of confidence we would have in any other company in any other industry that displayed a similar degree of opacity in their financial reporting and performance measurements.

The simplistic answer is that as the price per barrel of oil escalates it will become more economically attractive to exploit fields that have proven to be difficult and expensive to bring online in the past. Therefore it might seem that price will balance supply and demand. This is true to an extent, however exploring for, and exploiting petroleum based energy is not simply a matter of money, it also requires energy in the form of electricity to run plants, GOSPs, and pumps, and liquid fuels and lubricants for equipment. Eventually a field requires more energy to exploit than the energy delivered from the exploitation – this is known as the Energy Return On Energy Invested (EROEI) ratio.

Given the degree to which oil supplies are inextricably bound with the technologies that underpin our economic engines there is a more vital question we should ask ourselves. How long do we think it might take to engineer ourselves out of dependency from cheap oil supply?

No sensible person could give an answer to that question that is measured in less than decades. The Hirsch Report of 2005 stated "we will require twenty or more years to engineer alternatives to traditional oil based energy supplies".

If we accept that we are extremely unlikely to find another super-massive field anywhere in the world, then we accept that any additional find will only add a few years onto the existing time frame of economically viable oil availability.

Meanwhile, the use of any more oil whatsoever is unwise given its catastrophic contribution to environmental damage through climate change. Alternative energy supplies which have been mooted to date; namely biofuels and synthesized oil (mainly from coal) are environmental disasters. Both biofuels and coal-oil would hasten the environmental disaster of anthropomorphic climate change.

Beyond the Energy Fulcrum

It is vital that we rapidly develop, and implement, a plan for surviving the removal of hydrocarbon based energy supplies from our economic models. Both of the elephants that are jostling for attention in the boardrooms and presidential offices of the world; Peak Oil, and Climate Change; require urgent and coordinated effort. The answer to both is to rapidly engineer out our reliance on hydrocarbon based fuel supplies.

This is not a message that many want to hear. Beyond ignorance, bravado and the lies of self-interest are the simple truths of finite oil supplies, and the observable reality of climate change. What is lacking is a clear way forward. Strategic planning demands that we recognize these two interrelated problems and coordinate all our efforts towards their resolution.

Half hearted efforts will not go down in history praised as us having “tried hard, done good”. It is likely that there will be neither the social structures nor the people to record that history. Every industry must understand their current and future role and work together for a common and positive outcome.

We require a methodology for analyzing the scope, contribution (to solving the problems), and effort inherent in each of the changes we must undertake. Such a methodology is suggested in “The Survival Curve: Planning for powerdown”.

Hubbert’s brilliance was to not only develop Peak Oil Theory, it was also to stick to its inherent truth despite decades of nay-saying pressure. Our brilliance will be to find within ourselves the courage and collective social intelligence to take the appropriate actions to ensure a soft landing beyond the energy supply fulcrum.

References

i

See “Energy Waves: Information Technology and Economic Growth”

ii

While the perception might be that an empty field is ‘dry’ of oil, it is important to note that an oil field will always have some oil left in it. A dead field is one where the problems with field extraction outweigh the economic benefits of the yield, or where the Energy Return On Energy Invested (EROEI) ratio exceeds 1:1.

iii

Simmons: “Twilight in the desert”

iv

Hirsh Report

Further reading

The purpose of this opinion paper is to be a catalyst for further research, discussion and action toward effective climate change response strategies. Further work may be found www.thinkingstring.com and active discussion is encouraged.

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