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Peak Oil and Gas

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Reply to the article of P. Burri 2008: World oil and gas resources: status and outlook – A rational attempt at an emotional issue. Bull. angew. Geologie, 13/1, 3-26.

Key Words: Oil Geology, Oil Technology, Peak Oil, Depletion, Oil Company, OPEC, Nationalism

Abstract
Oil and gas were formed under exceptional conditions in the geological past, meaning that they are subject to natural depletion, such that the past growth in production must give way to decline. Although depletion is a simple concept to grasp, public data on the resource base are extremely unreliable due to ambiguous definitions and lax reporting. The oil industry is reluctant to admit to an onset of decline carrying obvious adverse financial consequences.
There are several different categories of oil and gas, from tarsands to deepwater fields, each with specific characteristics that need to be evaluated. It is important to build a global model on a country by country basis in order that anomalous statistics may be identified and evaluated. Such a study suggests that the world faces the onset of decline, with far-reaching consequences given the central role of oil-based energy. It is accordingly an important subject deserving detailed consideration by policy makers.

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1. Introduction

It is well to remember that the Managers of companies, including oil companies, have a fiduciary duty to protect their shareholders' interest on a volatile Stock Market, much influenced by emotional and transitory factors. Public Relations are important in this connection. It is simply not their job to address wider issues affecting the future of mankind, of which energy supply is certainly one.
No doubt the surge in oil prices in the summer of 2008 caused embarrassment for the oil industry, which was accused of reaping excessive profits, and of having made inadequate investments to provide the needed supply. More serious yet was the implication that, if the peak of production had arrived, the companies might be seen as operating in a sunset industry, which could in turn adversely affect recruitment and their image on the Stock Market. In fact, the challenges of extracting the remaining oil will call for yet more expertise.

In short, the article of Burri (2008) suggests that there are no serious resource constraints. At the same time, it does admit that changes in demand will smooth the transition to a new world of better, cleaner and affordable energy, implying that the oily days are numbered. This echoes the slogan of BP, whose initials no longer stand for the venerable British Petroleum but for «Beyond

Petroleum». Despite the generalities and assertions, the careful reader can spot some of the underlying truths. Perhaps the most significant clue to reality is conveyed by Fig. 1 in the article, which admits that the peak of discovery was passed more than forty years ago, and that the World started using more than it found in new fields in the 1980s.

The author has not denied that oil and gas are finite resources, formed under special conditions in the geological past, which means that they are subject to natural depletion. Furthermore, it is clear that they have to be found before they can be produced, carrying the clear implication that the peak of discovery must in due time deliver a corresponding peak in production. One stratagem used to obscure this obvious relationship was to refer to so-called «Reach», based on reserves to production ratios (R/P), quoted in years. This leads the uninformed to conclude that reserves support current production for forty years, failing to see that production can not be held constant for a given period of time and then stop overnight, when all oilfields are observed to decline gradually to final exhaustion. Supply will last much longer than 40 years, but in ever decreasing amounts.

There is also a tendency to confuse the issue of the peak of production with finally running out, which are two very different things. The world may never produce the last barrel lying in some obscure location, but it certainly faces the peak of production. In this connection, it is important to stress that estimating world production relies on the sum of the profiles of individual basins and countries. The fact that more than fifty countries produce less to-day than at some date in the past, some having been in decline for many years, carries a clear global implication. But despite the obfuscation, the article under consideration does finally admit to there being an Oil Age, as depicted in Fig. 19.

It may be helpful to briefly review the essential elements to be addressed in a serious study of depletion. It is far from an easy task due to ambiguous definitions and lax reporting practices, almost calling for the skills of a detective to collect the evidence.

The data tables rely on information published by public sources including the Energy Information Agency, BP, Oil & Gas Journal, World Oil, US Geological Survey, and the interpretation furnished in the Atlas of Oil & Gas Depletion.

2. Definition

The terms «Conventional» and «Unconventional» oil and gas are in wide usage but lack a standard definition, opening the risk that analysts may find themselves speaking at cross purposes. It is important therefore to define clearly the different categories. Some are cheap, easy and, above all, fast to produce, whereas others are the precise opposite, in some cases having a low or even negative net energy yield. There is merit in identifying «Regular Conventional» oil and gas, which has delivered most to-date and will dominate all supply far into the future, and distinguish it from the following categories:

- Oil from coal and «shale» (technically *kukersite*)
- Extra-Heavy Oil and Bitumen
- Heavy Oil (10-17.50 API)
- Deepwater Oil and Gas (> 500 m water depth)
- Polar Oil and Gas
- Natural Gas Liquids from gas-plants
- Unconventional Gas (including «tight» gas, coalbed methane, hydrates, etc).

Whether or not this particular classification is adopted, it behoves the serious analyst to state clearly what he endeavours to measure and model.

3. Data Reporting

The issue of peak oil would be almost self-evident were valid information on production and reserves in the public domain. In earlier years, there were fairly reliable industry databases compiled with the informal help of the major international oil companies, but those days are long gone, with the critical information being regarded as a State secret in some key countries.

Production data are relatively reliable, although war-loss, for example, which is production in the sense that it reduces the reserves by like amount, has not been reported at all.

Reserve data by contrast are generally most unreliable, as illustrated, for example, by the fact that the Oil and Gas Journal assessment for 2008 reports unchanged year on year numbers for many countries, as if it were remotely plausible that annual discovery and/or upward reserve revision should exactly match production. The Oil and Gas Journal has done valiant work over many years trying to assemble valid data, but the task evidently has become much more difficult.

Determining the size of an oilfield early in its life poses no particular technical challenge, although naturally subject to a degree of uncertainty. The reporting of its size is another matter. The rules were set long ago by the Securities and Exchange Commission (SEC) in the United States, being designed to prevent fraudulent exaggeration while smiling on under-reporting as commercial prudence. In financial terms, emphasis was given to «Proved Reserves», which were divided into «Proved Producing» and «Proved Undeveloped» for the estimated future production from respectively current wells, and yet-to-be-drilled, low-risk, infill wells. «Probable and Possible Reserves» carried little financial weight but eventually delivered some additional oil and gas.

The system worked well enough for the particular circumstances of the US onshore, but was open to a certain manipulation on the international scene. It made sense for the major companies to report only as much as they needed to deliver a satisfactory financial result. In part, this practice was influenced by the SEC requirement to report only the committed stages of development. The larger fields, especially offshore, have normally been developed step by step as the required facilities were installed. The consequential progressive upward revision led to a comforting but misleading image of steady growth. It was attributed to technological progress, when in reality it was mainly due to cautious reporting. We may note in passing that if the early giant fields, offering most scope for upward revision, turn out to be larger than currently estimated, it simply means that the decline in discovery over the past forty years will have been that much steeper.

The OPEC countries, for their part, announced massive reserve increases in the 1980s although nothing particular had changed in the oilfields themselves. They were vying with each other for production quota based in part on what they reported as «Reserves». As much as 300 billion barrels are associated with this reporting anomaly, and it is significant that the Oil Minister of Kuwait has publicly admitted that its «Proved Reserves» stand far below the widely reported official number.

4. The Impact of Technology

Oil and gas have been known since antiquity, but the modern Oil Age opened in the 19th Century in Pennsylvania and on the shores of the Caspian, where drilling rigs, already used for tapping salt brines, were adapted to drill for oil. It did not take long for geologists to identify the basic controls in terms of source-rock, reservoir, trap and seal. The search for oil expanded progressively around the world, and led to the early identification of the prime onshore basins and the larger fields within them. Geological field work was supplemented by ever more sophisticated geophysical surveys to scan the depths. As the onshore potential dwindled, attention turned to the offshore, prompting the development of the necessary technology. A particularly important development was a geochemical breakthrough in the 1980s which made it possible to relate the oil in a field with the source-rock from which it was derived. Taking into account depth and temperature, it became possible to determine which areas were oil- and gas-bearing, and which were not.

As the article under discussion stresses, technological progress has indeed been most impressive ranging from high resolution seismic surveys to sophisticated new drilling and production techniques. It has become possible to determine the reservoir characteristics in great detail and exploit them with high efficiency. But the main impact has been to identify ever smaller traps and drain more difficult reservoirs quicker. There is in fact a certain irony about technological progress: namely, that it tends to accelerate depletion, being in part influenced by the economic principle of discounted cash flow, whereby profit to-day is deemed to be worth more than profit tomorrow. This is well illustrated by the United Kingdom where a change of Government in the 1980s led to a new open market environment, encouraging all the well-known attributes of initiative, enterprise, competition and enthusiasm that led to the growth of a highly successful new industry producing oil and gas at the maximum rate possible. It was a successful short-term policy, reducing the cost to the consumer, but was achieved at the price of accelerated depletion such that oil production is now in decline at about 6% a year. The country exported its precious surplus at low prices but now faces soaring imports at high prices. Ever smaller and more difficult discoveries continue to be made but do not compensate for the natural decline of the older fields. With hindsight, it might have been a better policy to deplete the resource more slowly, so that it lasted longer.

The same general pattern of depletion is represented in many countries. This raises the issue of so-called resource nationalism, which offends the principles of globalism whereby the resources of any country are deemed to belong to the highest bidder. But as depletion bites in earnest, countries will likely be prompted to conserve their remaining resources for their own benefit, which will in turn reduce world trade. Many already have national companies, which are criticised in the article under consideration for under-investment and for failing to apply the most modern technology. If so, it ironically means that they have more left in the ground for their future. The major oil companies, dubbed the «Seven Sisters», previously controlled world supply from the wellhead to the filling station, but are now reduced to four by mergers, symptomatic of contraction. As the article under review states, they welcome any chance to be associated with the national companies as contractors, or in other ways capable of accessing the remaining reserves of relatively easy oil, implying that their other options are limited.

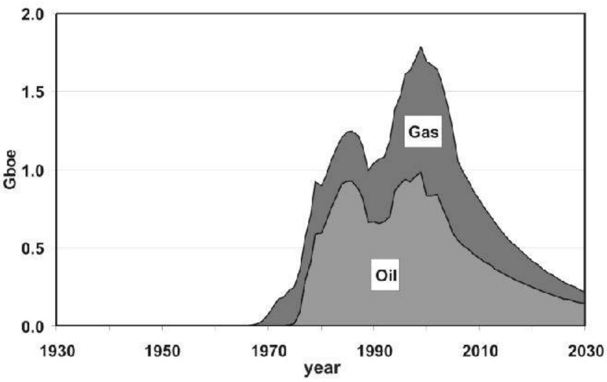

Fig. 1: United Kingdom oil and gas production 1930 to 2030.

5. New Discovery

The accessible world has now been so thoroughly explored that little chance remains for a major new play to be found in it. Hopes for deepwater and Polar regions are expressed, but will likely fall far short of offsetting the decline of conventional oil and gas.

Deepwater

While there is plenty of deep water, discovery depends on a very remarkable combination of geological factors. The prime tracts lie in divergent plate tectonic settings bordering the South Atlantic and Gulf of Mexico, where hydrocarbon source rocks were deposited in tropical lakes that formed during the Cretaceous period as the continents moved apart. The sea later broke into the rifts, and evaporation led to the deposition of salt, which sealed the underlying hydrocarbons. Later, during the Tertiary Period, bars at the mouths of rivers on the bordering continents occasionally ruptured and slumped down the continental slopes in the form of turbidites. They generally tend to have rather poor reservoir conditions, but in certain places long-shore currents took the sediment back into suspension winnowing out the fine grained material to leave highly porous sands. Relief on the sea-floor locally led to the ponding of such sand bodies with excellent characteristics, which is in some places overlaid the deeper oil sources. Attention now turns to the sub-salt plays, notably off Brasil, but they are likely to deliver only locally, and the technical and economic challenges are great. Elsewhere in convergent plate-tectonic settings, which lack the critical early rifts to provide a prime source, deltas have locally extended into deepwater, but such prospects rely on source-rocks within the delta front itself, which are likely to be lean and gas-prone.
A realistic estimate suggests that the deepwater areas, principally off Angola, Nigeria, Brasil and in the Gulf of Mexico, may yield about 90 Gb (billion barrels), of which about 12.3 Gb have already been produced. Current production of about 6 Mb/d is likely to rise to a plateau at about 8 Mb/d between 2015 and 2020, before declining steeply.

Polar Regions

Hopes have also been expressed for major new discovery in the Polar regions, facilitated in part by the loss of ice due to global warming. Countries are already in dispute over national boundaries. This interest has been in part sparked by the remarkable giant Prudhoe Bay find in Alaska holding some 12.5 - 15 Gb, but generally the geological conditions are less than favourable. Briefly, the prime source-rocks were deposited in tropical areas, meaning that the Polar regions have to rely on those transported there by plate-tectonic movements, which in turn means they are relatively old, and have therefore been subject to dissipation over time. Another adverse factor has been vertical movements of the crust under the weight of fluctuating ice caps, such that source-rocks have been depressed into the gas window, and seal integrity adversely affected. The results to-date in North America have been disappointing, apart from the Prudhoe Bay find, although a number modest finds, principally of gas, have been found. The Arctic areas of Greenland, Norway and Russia have also yielded some finds, principally of gas, including the Snovhit Field off Norway and the Stockman Field off Russia, but the overall record to-date has been less that encouraging. Antarctica, likewise, lacks geological promise, and is also closed to exploration by international agreement.
A reasonable estimate on to-day's evidence suggests that the Polar regions might hold about 50 Gb. Production stands at about 1.2 Mb/d and might double by 2030 before

declining. By all means, more exploration is called for to confirm the assessment, but it would be a mistake to assume new discovery, sufficient to have much global impact.

6. Enhanced Recovery

Much of the oil in a reservoir is held in place by capillary forces, and many reservoirs are far from homogenous, such that on average no more than about 35% of the oil-in-place is recoverable under normal methods. But the industry has long applied techniques to improve the recovery, ranging from the injection of steam, nitrogen and carbon dioxide and other sophisticated techniques to the application of highly deviated («horizontal») wells to better drain the reservoir. While such techniques have been widely used in areas such as the onshore USA and North Sea, there is scope for further application in remote areas and possibly the Middle East. The Oil & Gas Journal has reported production from Enhanced Recovery, and it is significant that its 1996 and 2004 surveys report little change in the amount, standing at 1.8 Mb/d, or 2% of the total. Only certain types of reservoir are susceptible, and at best various applications add about ten percent. Furthermore, there are economic constraints linked to the availability of cheap solvents, such as carbon dioxide.
It is well to remember in this connection that estimates of oil-in-place can be no more than approximate, so that claims for high recoveries should be treated with some caution.

The surge in oil and gas prices in recent years has also encouraged the development of a range of non-conventional gases, especially in the United States. They include coalbed methane, derived from coal measures, and production from so called «tight» reservoirs, tapping thin porous zones in shale sequences or relying on fractures. It is reported that coalbed methane production in the United States is close to peak, partly due to the environment problems in disposing of associated contaminated water. Efforts have also been applied to producing so-called shale-oil (technically *kukersite*) by retorting source-rocks which have been insufficiently heated in nature to give up their oil, but few such projects have proved to be economically viable.

7. Modelling Depletion

The article under consideration is generally dismissive of the work of Dr. M. King Hubbert, an eminent geoscientist in several fields, who was one of the first to address natural depletion. He plotted the production and discovery record of the onshore US-48 in the 1950s when it was already at a mature stage of development. Extrapolating the trends gave an indication of the resource base, leading to the conclusion that production would peak at approximately the midpoint of depletion, when half the indicated resource had been taken. He presented two alternative assessments, one of which proved correct when production did indeed peak in 1970. It was an unconstrained environment giving a simple natural depletion profile. Other cases are more complex reflecting for example late-stage moves offshore. The world profile was also affected by the anomalous fall in production due to OPEC constraints and other political factors. More detailed modelling techniques include the so-called creaming curve, whereby cumulative discovery is plotted against cumulative exploration drilling, or over time. The larger fields tend to be found first for obvious reasons, and the subsequent flattening trend can be readily extrapolated to asymptote, which equates with the total producible resource base. Field-size distributions can be modelled with the parabolic fractal, based on a law of nature that a complete segment of a distribution mimics the whole. Ideally, such models should be conducted on individual petroleum systems, but do give a good indication of national production profiles.

Many oilfields contain a gas-cap that tends to be produced late in its life, but there are also gasfields relying on gas-prone source rocks or gas derived from the breakdown of oil on deep burial. There are many complexities including the identification of associated liquids and non-combustible gases such as carbon dioxide which may be present. Gas, being a gas, not a liquid, depletes differently from oil. A higher percentage is recoverable, but production is normally constrained by infrastructure giving a plateau rather than a peak. The post-plateau terminal decline tends to be steep, and gas located far from market requires costly liquefaction facilities.

In practice, developing a realistic global model relies on studying the details of each country or basin, identifying and trying to resolve the great discrepancies in the public and such confidential data as are available. The full range of modelling techniques has to be used to try to come up with a plausible and realistic solution. Summing such assessments gives a world total as indicated in the

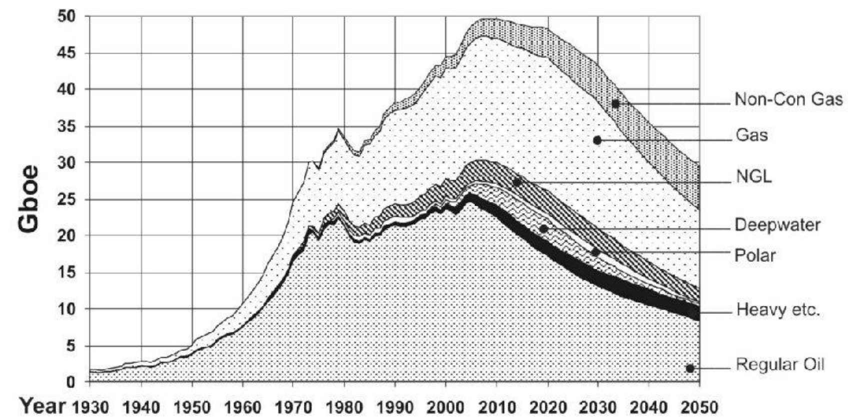

Fig. 2: Oil and gas production profiles (2008 base case).

ESTIMATED PRODUCTION TO 2100										Ref. Date End 2008	
Amount			**Gb**	**Annual Production Rate - Regular Oil**						**Gb**	**Peak**
Regular Oil				Mb/d	**2007**	**2010**	**2015**	**2020**	**2030**	**Total**	**Date**
Past	**Future**		**Total**	US-48	3.0	2.6	2.1	1.7	1.1	200	1970
Known Fields		New		Europe	4.3	3.5	2.5	1.8	0.9	75	1999
1053	734	114	1900	Russia	8.7	8.2	6.8	5.7	4.0	230	1987
	848			ME Gulf	20	20	20	19	16	673	1974
All Liquids				Other	29	27	23	19	14	722	2005
1154	1246		2425	**World**	**65**	**61**	**54**	**47**	**36**	**1900**	2005
2008 Base Scenario				**Non Conventional Oil and Gas Liquids**							
Middle East producing at capacity				Heavy etc.	4.0	5.0	6.5	7.2	7.7	226	2030
(anomalous reporting corrected)				Deepwater	5.2	6.6	8.1	8.1	4.7	89	2013
Regular Oil excludes Heavy Oils				Polar	1.4	1.5	1.7	2.0	2.3	52	2030
(inc. tarsands, oilshales); Polar &				Gas Liquid	5.1	5.5	5.6	5.9	5.6	156	2020
Deepwater Oil; & gasplant NGL				*Rounding*			-1		-1	2	
Revised	01/03/09			**ALL**	**81**	**80**	**75**	**70**	**55**	**2425**	2008

Tab 1: Estimated production to the year 2100 (NGL: Natural Gas Liquids, US-48: The US without Alaska and Hawai, ME: Middle East).

above illustration. The uncertainties and difficulties are great, and the conclusions are subject to revision. Bland global assessments lacking the detailed building bricks from individual country assessments (as for example provided by Campbell & Heaps 2008) may be readily pronounced, but in fact carry little weight or credibility.
A realistic assessment is provided in the following table. It is expedient to consider only production through the rest of this Century, to avoid having worry about the minor tail-end supplies which are unquantifiable and largely irrelevant.

8. Conclusions

The world has recently faced a serious financial and economic crisis, and it may be no coincidence that it was preceded by an extreme surge in oil prices in 2008. Oil-based energy fuels the modern world, so its price has a serious economic impact. The evidence suggests that the peak of Regular Conventional Oil was passed in 2005, but the small shortfall was made up by costly oil from tarsands and deepwater areas. The rising price trend may have attracted the attention of speculators, while the industry itself may have built its storage which appreciated in value. The high prices also delivered a massive flood of petrodollars to the governments and royal families of the Middle East, where production costs are still largely in the $ 10-15 per barrel range. The surplus may have been placed with financial institutions which were, as a result, encouraged to lend on ever less secure collateral. But the rising prices began to adversely affect the real economy, prompting shrewd traders to conclude that the surge was reaching its limit, which in turn prompted them to sell short on the futures market. The net result was a collapse in oil price back to 2005 levels. Governments now wrestle with the challenges of restoring financial confidence, and it is significant that the newly elected President of the United States proposes massive investments in renewable energies to lessen his country's dependence on imported oil.

Current annual production of all categories of oil stands at about 30 Gb (billion barrels), supporting a world population of 6.7 billion people, but production by 2050 will down to about 13 Gb, sufficient to support no more than about half the number of people in their present style of life. The role of oil in mechanised agriculture is critical. The challenges of finding ways to use less, and bring in alternative sources of energy are clearly colossal, as indeed the article under consideration confirms. It is by all means a serious subject deserving more than superficial treatment.

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