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Energy 34 (2009) 323–326

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Peak oil: The four stages of a new idea

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ARTICLE INFO

Article history:
Received 15 January 2008
Available online 14 October 2008

Keywords:
Peak oil
Hubbert's peak
Crude oil
Resource depletion

ABSTRACT

The present paper reviews the reactions and the path of acceptance of the theory known as "peak oil". The theory was proposed for the first time by M.K. Hubbert in the 1950s as a way to describe the production pattern of crude oil. According to Hubbert, the production curve is "bell shaped" and approximately symmetric. Hubbert's theory was verified with good approximation for the case of oil production in the United States that peaked in 1971, and is now being applied to the worldwide oil production. It is generally believed that the global peak of oil production ("peak oil") will take place during the first decade of the 21st century, and some analysts believe that it has already occurred in 2005 or 2006. The theory and its consequences have unpleasant social and economical implications. The present paper is not aimed at assessing the peak date but offers a discussion on the factors that affect the acceptance and the diffusion of the concept of "peak oil" with experts and with the general public. The discussion is based on a subdivision of "four stages of acceptance", loosely patterned after a sentence by Thomas Huxley.

1. Introduction

"Peak oil" is a term that summarizes the concept that the production of crude oil—as well as that of most finite resources in a market economy—grows, reaches a maximum (peak), and then gradually declines to zero. This concept was expressed for the first time by Marion King Hubbert in 1956 [1] and today the maximum production is often termed "Hubbert's peak". Hubbert had proposed that the production curve is "bell shaped", that is symmetric. In this case, the peak occurs when about half of a non-renewable resource is extracted.

The mechanisms that lead to bell-shaped production curves are by now well understood [2–4]. Initially, the extraction of an abundant and cheap resource leads to economic growth and to increasing investments in further extraction. Gradually, however, the cheap resources are depleted and extraction costs become higher because of the need of extracting lower quality deposits. In time, investments cannot keep pace with these rising costs; the growth slows down and, eventually, production starts declining. Here, "costs" are to be understood in monetary terms but, at the same time as *energy* costs which grow for physical reasons related to the lower concentration and or lower quality of the resource. In other words, what creates the bell curve for an energy resource as oil is the variation with time of the net energy of extraction, also known as "Energy Return on Energy Investment" (EROEI). [5] In the case of oil, the EROEI effect is enhanced by physical factors related to the fall in reservoir pressure and also with the fact that less and less oil-bearing reservoir is in touch with the wells as the oil is progressively extracted.

The worldwide Hubbert's peak for crude oil ("peak oil") is expected to occur during the early decades of the 21st century [6]. It is often stated that peak oil is a turning point for humankind, a "rollover" that will cause dramatic changes in the world's economic and social system. The concept of peak oil is more and more often mentioned in the media and it has caught the imagination of the public. In general, the reaction to peak oil is not different than that to any new idea, and we may say that it follows a series of four phases, loosely patterned after a well known sentence by Thomas Huxley "*History warns us that it is the customary fate of new truths to begin as heresies and to end as superstitions.*"

Phase 1: Never heard of it.
Phase 2: It is wrong.
Phase 3: It is right, but irrelevant.
Phase 4: It is what I had been saying all along.

At present, the attitude of the public and of the specialists is spread over these four attitudes. The situation is dynamically changing with perceptions moving from one stage to another. Human perception does not change the reality of oil depletion, but

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doi:10.1016/j.energy.2008.08.015

it does change the way society reacts to it. Most people of the "peak oil movement" will say that it is important to diffuse the concept of the impending worldwide peak in order to accelerate the work on measures able to prevent its negative consequences. The question is whether the public will actually react to an event that will likely spread over several years and that will not be, in itself, spectacular. If history is a guide, it is likely that the global peak oil will be forgotten in the turmoil of political events accompanying it. [7,8].

In the following, I will briefly discuss the present situation with peak oil, how the concept is spreading, the criticism it generates, and its likely perspectives in the near future. It may well be that the peak has already taken place for the so called "conventional oil"; but here I am not going to enter into a specific discussion of the peak date.

2. Stage one: never heard of it

At present, it seems that almost all operators in the field of oil and fossil fuels have at least heard something about the concept of peak oil. The idea is also spreading with non specialists and the general public. A search of the web shows that the term "peak oil" has had a certain success, but that it is still overshadowed by news about politics, entertainment, and other scientific concepts. In October 2006, a Google search returns the following results

Google hits

Hollywood 197,000,000
Terrorism 111,000,000
Nanotechnology 26,600,000
Global warming 26,500,000
Peak Oil 4,320,000
Hydrogen economy 1,120,000

Howard [9] has examined the diffusion of the peak oil idea in the media, finding a hierarchy similar to the one above. The term "peak oil" and similar ones are mentioned in the media orders of magnitude less frequently than such terms as "war to terrorism" and "Hollywood". Reading the newspaper and watching TV, the general public has a much different view than that of the people studying resource depletion. Nevertheless, the concept of peak oil is fast growing in people's consciousness. According to Howard [9], the growth rate of mentions in the media for terms related to the peak oil concept is of the order of 500–2000% per year and even more.

The problem is that the diffusion of the idea is accompanied by a loss of focus on what the idea exactly means. As it spreads, "peak oil" becomes a poorly defined concept. It becomes the focus of highly pessimistic visions and it risks becoming a cult. This is clearly counterproductive as it causes strong counter-reactions based on arguments just as emotional as those of expect the end of the world from the peak. Still, it is evident that the public awareness of the concept is destined to increase in the near term.

3. Stage two: it is wrong

Facing for the first time the concept that oil production is going to peak and to decline, the reaction of the public and of experts alike is one of complete disbelief. Assuming that the concept is understood, and not trivialized as meaning something like "the end of oil is coming", a more articulated reaction can take two main forms; one that Hubbert's theory itself is wrong, the other that the data in input are overly pessimistic.

Sometimes, the criticism can be simply stated as "if there is still oil to be extracted, why should production decline?" Apparently, some people cannot understand that extracting oil from the ground is not like extracting beer from a refrigerator. Barrels are not all the same and extracting low EROEI oil is not the same as extracting high EROEI oil. Sometimes, it is pointed out that not all historical cases of oil production show a bell shaped curve (e.g. Saudi Arabia) or show double peaks (e.g. Iran or Russia). Indeed, the assumptions that stand behind the Hubbert model are based on a free market economy. That is not always the case, of course, depending on the political situation and the actual production may stray away from the Hubbert curve [10]. The multiple peaks observed historically can be often correlated with abrupt political changes, wars and revolutions. The Hubbert based models of the world production do not, and cannot, take into account such events which, however, will often worsen the situation.

A different kind of criticism is that the price mechanism of a free market will prevent the peak from occurring. If peak oil gets close, it is argued, prices will increase. High prices will generate more investments in exploration and extraction technologies and this will also increase the amount of oil that will be found and put on the market. Hence, there will be no peak. This model is often termed the "Resource Pyramid" and it goes back to Zimmermann [11]. On this point, it should be noted that there are obvious differences from a geological point of view in the fact that some resources are "graded", that is exist in a range of declining concentrations (such as most metals) and some resources being "either–or" such as oil, which either is present in liquid form, or not present at all. However, from an *economic* point of view, all mineral resources are graded. That is, even for crude oil the cost of extraction varies smoothly with such factors as depth, size, quality, location, etc. In principle, therefore, the Resource Pyramid model should be valid for crude oil, as well. It is a seductive model since it implies that no mineral resource will ever run out. However, it does not take into account that in an economy there is more than just the extraction of mineral resources. If all the elements of the economy are dynamically considered [12,13], the result is that the amount of capital that can be transferred to the extraction of minerals from other sectors of the economy is limited. At some point, the costs of extraction become too high to be sustained and the decline must start even though a fraction of the resources may be left in the ground.

But, by far, the most common criticism made at the peak oil concept is that the reserves available are so huge that there is no reason to worry; the peak will come, maybe, but we still have several decades, or even more, to go [14]. Indeed, the estimation of the global peak date is often based on a geological assessment of the available reserves. This assessment is, of course, uncertain both because of geological uncertainties and because of economic uncertainties. The latter kind of uncertainty is perhaps more important since it depends on market prices, something notoriously difficult to forecast. Another cause of misunderstanding is the wide use of reserve/production (R/P) ratio. It claims that reserves support current production for say 40 years. But it is absurd to suggest that production can stay flat for so many years and then stop overnight.

As long as we consider estimates made by professional geologists, modelling based on the Hubbert curve is robust, in the sense that the uncertainty in the estimates does not strongly affect the year predicted for the peak. Unfortunately, nothing prevents people with no other qualification than that of being able to put together strings of (more or less) intelligible sentences on a keyboard from stating that oil is actually "infinite" as it is created by mysterious abiotic processes in the earth's mantle. At the same time, nothing prevents people with no qualifications in geology

(typically CEOs of major oil companies) from passing to the press estimates of barrels which have no relation whatsoever with the real world. Obviously, if the reserves are doubled or tripled (on paper) the peak may move decades forward.

Geological estimates are often seen as crucial to the peak oil concept but they are not the only element of the question. Surely the shape of the production curve depends on the amount of extractable resources but, in a certain way, the curve "knows" what the extractable amount is and moves on accordingly. In principle, therefore it should be possible to determine that amount from the curve without resorting to geological estimates. For the global oil production, this approach needs a sophisticated mathematical approach, but it can be done [15]. The result is an estimate of the amount of extractable oil which matches reasonably well with the geological estimates and is therefore a strong argument for the correctness of these estimates. As a further point, history has shown that even serious geologists tend to *overestimate* oil resources when getting close to the production peak [16]. This factor may be at work nowadays as well and may explain some high estimates by institutions which should be—in principle—reliable (e.g. [17]).

In any case, the strongest argument in favor of the idea that peaking is going to occur in the near future is to note that peak oil has already taken place more than 30 years ago. What has taken place, actually, is not "peak-production", but "peak-discovery". Oil has to be found before it is produced; it is obvious that the peak of discovery in the 1960s (a matter of undisputed historical fact) must deliver a corresponding peak of production, as indeed it already has in some 50 countries, whose production is falling.

The discovery curve in the figure is obtained by removing the spurious "reserve growth" effect that derives from the standard accounting procedures of the oil industry. If the total amount of oil in a well is plotted as a function of the actual year of discovery, the result is a peak in discoveries that took place in the 1960s. It is obvious that before you can extract (produce) oil, you have to discover it and we know that production of oil may last years or decades before a well is considered exhausted. So, we are now extracting oil that was discovered decades ago and the production curve mirrors the discovery curve [18]. Therefore, a production peak is unavoidable in the near future (Fig. 1).

The figure does not prove that the discovery curve cannot invert its decline in the near future, but that can be at most a temporary phenomenon as shown by the historical data. The strong rise in oil prices that started in 1973 gave rise, later, to increased discoveries. Indeed, the effort in exploration for oil was stepped up in the 1970s [26]. Nevertheless, the rising discovery trend soon peaked and abated. The new discoveries peaked approximately in 1977, much before the peak in oil prices in 1979. High prices do, apparently, stimulate more discoveries but the trend cannot be sustained. The problem is that prospecting for oil requires energy and the EROEI of prospection goes down with progressive depletion, also because the larger fields are found first, being too big to miss [19]. Note also how the highest discovery rates in history were obtained for the lowest historical prices of oil. High prices, clearly, cannot invert the declining discovery trend.

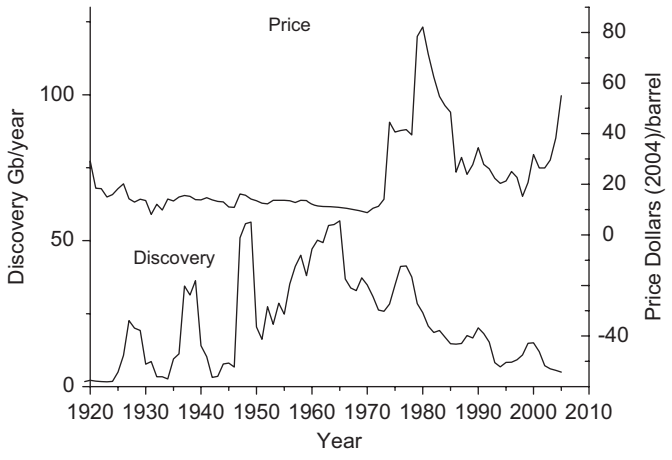

Fig. 1. Historical trends of world prices and discoveries of crude oil. Data courtesy of the Association for the study of peak oil and gas (ASPO). Oil prices (corrected for inflation) and discovery rates.

4. Phase 3: it is true, but irrelevant

Some critics of the concept of peak oil do not question that oil production will peak and decline in the near future. They maintain, however, that it will have no effects on the world economy since the price mechanisms will cause a smooth transition to alternative energy resources. These alternative resources may be of three kinds, (1) coal, natural gas or other fossil fuels, (2) nuclear energy and (3) renewables. Sometimes, energy saving is classed as an energy "source" and it is maintained that it will be energy efficiency that will eliminate the effects of the peak. Discussing these concepts in depth would be, obviously, too much for the present paper. However, it appears unlikely that the transition from oil to different resources will be smooth.

Hirsch et al. [20] has examined in detail the possibility of mitigating the effects of peak oil by using alternative fossil fuels and various energy saving measures. Hirsch's analysis is very conservative in the sense that it totally neglects the effects on the environment of switching from oil and gas to dirtier fuels such as those derived from coal or tar sands. Even assuming that we would be able to pay the high price of pollution and global warming, Hirsch finds that, if the peak is coming in the near future, the measures considered would come too late. Likely, switching to such fuels would not help in the long term, either, since these are finite resources anyway and subjected to EROEI-related peaking.

About nuclear energy, the possibility to play a significant role in the transition will depend on focussing sufficient capital resources to build a large number of new plants. This depends, in the end, in the return that these plants can provide and this, in turn, depends on the EROEI of the technology. The value of the EROEI of the present nuclear technology is hotly debated, with reported values that go from less than 1 to more than 50, although it seems that most estimates tend to place it in the range of 5–10 [21,22]. This EROEI is relatively low and with the high investments costs involved it appears unlikely that nuclear fission as it is now, will be able to provide a smooth transition away from crude oil. However, nuclear technology may somewhat cushion the shock of peak oil. Of course, fission technology improves with time, but at the same time the resources of fissionable uranium are being depleted so that in the long run the prospects of nuclear fission are poor. Other nuclear technologies such as fusion are at present under study, but their development as commercial technologies seems to be far away in time. In addition, the fusion technology being developed at present uses as fuel a relatively rare isothope of lithium (^{6}Li). The mineral resources of lithium in the world may not be abundant enough for a replacement of fossil fuels at the level of the present level of energy production [23].

The prospects of renewable energies are better under several respects: technologies such as photovoltaics and wind energy are available on the market and have acceptable EROEIs: around 20 for wind power [21] and around 10 for PV (see e.g. [24]). Considering that renewable energy is not subject to depletion,

its EROEI can only increase with time, owing to technological progress. Therefore, renewables are very promising and their growth is very fast [25]. Nevertheless renewables are still far away from producing amounts of energy comparable to the world needs. Furthermore, an energy system based on renewables needs to tackle the problem of energy storage, both daily and seasonal. Storage technologies are available, but they add further costs. The resources needed for the transition from fossil fuels to renewables are immense and it is unlikely that the transition will be smooth.

5. Phase four: it is what we had been saying all along

Will we ever arrive at Phase Four in respect to the general attitude of experts and public alike? Most of the members of the so called "peak oil movement" are of the opinion that, if the concept of peak oil was to be generally known and understood, effective strategies could be developed to counter its negative effects.

We are clearly moving in that direction but, if the past is a guide for the present, we may never arrive there. The present situation repeats under many respects the situation of the United States in the late 1960s. At that time, the date of Hubbert's prediction for the US peak was getting closer and a considerable debate was taking place among the experts. That debate did not generate a "peak oil movement" similar to the one existing today, but it probably affected the general opinion, as shown from the publication of such books as "The Limits to Growth" [12]. However, the events that followed pushed resource depletion away from public perception.

When it peaked, in 1971, the US production was around 3.5 billion barrels per year, about 20% of the total world production of the time. The US peak was a major event of 20th century: a critical mineral resource going through the production peak in a major production region. Yet, the wars and the political events that followed made the US oil peak a non-event; something that was not mentioned in the media and remained invisible with the public. The Yom Kippur war of 1973 and the subsequent, short lived Arab oil embargo were taken as the cause and not as the consequence of the US oil shortage. With the mid 1980s, the oil crisis was over, or at least it was perceived to be over as the result of new fields being brought into production. At that point, the peaking of the US production slipped away from the world consciousness. The concept of peak oil was not revived until the late 1990s, when a group of oil geologists founded the Association for the Study of Peak Oil (ASPO).

6. Conclusion

At present, we are facing an uncertain world political situation. If a major war were to erupt in the Middle East region that would surely have effects on the already strained world oil market that could be much worse than those of the Yom Kippur war of 1973. A war would not cause peak oil, but it would enhance the high prices and shortages associated with it. It may well happen that these high prices and shortages would be attributed by the public to political events and not to geological ones. The evolution of these tendencies might even lead to a general rejection of the peak oil concept, as it happened with the discussion of the first edition of "The Limits of Growth" [12] in a debate that took place several years ago. That could be a disaster if it would lead to misunderstanding the causes of the catastrophe and concentrate the remaining resources for further wars instead of using them for developing technologies useful to counter the effects of peak oil. In the present confused situation, it may well happen that the global peaking of oil production will become an epochal non-event for the public. However, that will not be the case for its consequences.

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