Background & Objectives

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

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

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

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

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

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

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Editorial

Welcome to the Autumn 2016 issue of this journal. This time we carry only two papers, as follows:

The first is a review paper on the perceptions and realities of peak oil in China. This is an excellent paper, and exactly the type of review of the 'peak oil' topic within a country of which it is the intention to carry more in future.

Incidentally, in this paper readers' attention is drawn to its Figure 2, which I will term a 'CUP-B' plot, from its originating university. This gives, for different categories of oil, the size of estimated ultimately recoverable resource (URR), development cost, and upstream CO_2-equiv. emissions. (The authors of this plot note that it is derived by adding URR data to a plot of the type given by Figure 1 of Verbruggen and Al Marchohi, 2010; which in turn was based on Figure 3 of Brandt & Farrell, 2007). The significance of a 'CUP-B' plot is that - like Brandt and Farrell's Figure 3 - it shows on a single chart three key characteristics of any fossil energy resource (URR, cost and CO_2 emissions) which will be of increasing importance in modelling energy options in the future.

The second paper in this issue is quite long. It is the first part of a two-part paper that discusses data sources used in oil forecasting, and presents some of the problems with the data. This also is an important topic, as it can be argued that much of the confusion over past oil forecasts has resulted from the use of poor quality data; in particular on oil reserves, on apparent changes of these reserves over time, and on URR estimates by category of oil.

As the paper mentions, we intend to send copies to the organisations listed in the paper, to solicit corrections and criticisms. If useful feedback is obtained, then we intend to publish a corrected version in a future issue.

Note also that quite a number of the charts in this paper are complex, and may be difficult to read in black and white. It will be

possible for subscribers of the printed edition to access a PDF version of the paper, giving the charts in colour, by contacting Noreen Dalton at: theoilage@gmail.com

I trust you find these papers of interest.

- R.W. Bentley, October 6th, 2016.

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The Debate and Reality of Peak Oil in China

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Abstract

China's oil consumption has been increasing significantly during the past decades while its oil production has been growing more slowly, making the gap between domestic oil supply and demand ever larger. Peak oil, now acknowledged by a number of nations, will become inextricably an issue for China, and is likely to impact China's national energy policy in the future. Currently debates on the peak oil issue are rare in China, and most senior Chinese officials, researchers and the general public do not recognise "peak oil" and its potential implications. This paper examines the current debate regarding peak oil among Chinese government members, industrial officials, and scholars as reported in various aspects of the media, official publications, and academic papers. Additionally, here we analyse what we see as the facts about China's peak oil, and we show that China is already facing its peak oil problem. Several unfortunate situations caused by the public denial of peak oil are discussed and three potential reasons of the public denial and lack of knowledge are analysed. Lastly, we discuss some actions China should take to deal with its peak oil issue.

1. Introduction

Peak oil refers to a point in time at which oil production ceases to grow. Typically the period around the oil peak is characterized by an undulating plateau punctuated by short periods of increased production followed by periods of decline. This phenomenon may occur at the regional, national, or global level. Hubbert's prediction [1] of a 'peak' in US oil production has spurred a long-lasting and divisive debate on the exhaustion of petroleum resources. In 2003, the Executive editor of the established US-based trade magazine *The Oil & Gas Journal,* noted this debate, and commented that this global issue had become increasingly "polarized and more rancorous – and, especially noteworthy, more politicized" (referenced in [2]).

Though nowadays the emerging US shale industry and low oil price are leading to more scepticism and less interest in peak oil, Chapman argues that the topic of peak oil is still with on-going relevance [3]. In addition, Tverberg has predicted, early in 2012, the fact that oil limits may manifest themselves as low oil prices and a "glut" of oil supply [4].

While this international debate on peak oil is going on in the world, China's academic, government, and industrial media remain largely silent on this issue. On the other hand, since China is the largest oil consumer in the world and its oil consumption is increasing rapidly, while at the same time her domestic production is growing much slower than oil consumption [5], it would seem that peak oil may become an inextricable problem that she has to face.

This paper discusses the status of the debate on peak oil in China, and presents objective analysis of the realities of peak oil in the country. Furthermore, this paper discusses the potential reasons for the public lack of knowledge of peak oil, and suggests some possible actions China should take to deal with its peak oil problem.

2. A Review of Development of the Peak Oil concept in China

China's contributions to the acknowledgment of the issue of peak oil were limited until 1984 when Weng [6] published his "Fundamentals of Forecasting Theory." As a geophysicist and petroleum geologist from the Chinese Academy of Science, Weng designed a model for forecasting long-term oil and gas reserves and production levels. Weng called this model a "Poisson Cycle", because Weng's formula

was similar to the probability function of Poisson distribution. This "Poisson Cycle" model was designed to predict the world oil and gas production based on the production levels from the year 1918.

Chen [7], a researcher from the Petro China Exploration & Development Research Institute, expanded this model using trial and error to derive a new non-linear model, entitled the General Weng Model. Until 2005, many Chinese researchers, including Chen and Hu [8], used these models for predicting future world oil and gas production but not specifically referencing it as "peak oil" production and its potential implications.

In 2005 Association for the Study of Peak Oil (ASPO)-China was founded, and this led to the establishment of the Group for the Global Energy System-China, which introduced the concept of "Peak Oil" to Chinese society. Later that year the first paper on peak oil by Zhao et al. [9] was published marking the inception of Peak Oil dialogue within Chinese academia.

Qian [10] published a series of papers to refine the theory and discourse of peak oil in China. His papers, "China will Face Peak Oil in 2015" [11] and "The Current Situation of Oil and Gas Production Peak in China" [12], are aggregations of existing scientific works focused on oil production. While he has remained neutral with regard to the concepts and findings included in his papers, Qian is perhaps the first Chinese researcher to acknowledge the concept of peak oil.

Later on, the issue of peak oil in China has been further researched by several scholars, most of them are ASPO-China members [13-19].

3. The Current Debate about Peak Oil in China

Participants of the debate over peak oil in China can be divided into those that support the concept, those that do not support the concept, and those that remain neutral.

Questions and discussion surrounding this debate have included the following topics: the amount of remaining and recoverable oil and gas reserves; when and if peak oil has/will occur; the role of technology in current and future oil and gas exploration, production, and recovery; and the ability of non-conventional and renewable energy to substitute or compensate for potential reductions in conventional oil and gas production. This paper will conduct a review of this debate within Chinese literature.

3.1 Arguments of different parties regarding Peak Oil issue in China

Chinese energy theorists who argue against the idea of global peak oil believe that international oil prices will regulate oil production and consumption. Some even suggest that limitations on world oil availability are a result of a monopolistic oil trade. For the purposes of this paper these researchers are referred to as "non-supportive" of the peak oil concept.

Zhou, a former leader of the Energy Bureau of the National Development and Reform Commission of China, espouses the view that we are not facing the 'end of the age of oil' but that we are experiencing high oil prices [20]. Zhou believes that it will take a long time to change the situation of oil and gas production and that oil and gas will continue to meet demand for decades to come. He also infers that the perception of oil scarcity is a result of oligopolistic actions on that part of oil producers and oil producing nations.

Wu [21] of the Ministry of Commerce of the China believes that the demand for oil will peak as a product of peak consumption. He concludes that decreases in the oil price will result from a decline in consumption after peak consumption has been reached, rather than as a result of a peak in production. This scenario, she suggests, will effectively render the theory of peak oil moot.

Zhang [22-24] of the Sinopec Research Institute of Petroleum Exploration and Development strongly opposes the peak oil theory. He suggests that while Hubbert's model forecasting peak oil production within the continental United States is relatively accurate, the latter's predictions for world oil production are flawed. Zhang asserts that peak oil models are suitable for simple, static and closed systems such as countries, rather than complex, dynamic and open systems such as world oil production. He claims that world oil production cannot be predicted based on our understanding of current production trends, and/or life cycle assessments of a single well or a small geographic area.

Hu [25], a leader in research policy for the China National Offshore Oil Corporation (CNOOC), argues that peak oil projections are theoretical in practice, having little or no physical evidence to support peak oil projections. According to Hu, Hubbert's global peak oil predictions and other peak oil studies that followed do not adequately take into consideration the accuracy of oil reserves and production data,

nor do these predictions take into account technological developments, the impact of price fluctuations, the influence of investment, changes in demand, and the introduction of substitute energies. Hu indicates that peak oil theory is based on studies that do not employ a rigorous scientific approach when dealing with a highly varied and complex world.

There is also another group of researchers that weigh in on the theory of peak oil. These are those who agree with and advocate peak oil theory and its implications. This group includes researchers who are members of ASPO-China, particularly Feng [26], who has published more than 20 peer-reviewed papers about peak oil issues. In addition, Chen [27, 28], Chen and Guo [29], Chen and Zhao [30] and some other researchers [31, 32] do not directly reference peak oil within their writing, but draw similar conclusions. Chen's research, for example, analysing China's oil reserves, indicates that Chinese oil production has likely peaked. In addition, Li, and also Tao, have published papers expressing their support of peak oil theory. Unfortunately, these researchers have not continued to publish in the field of peak oil. Examples of recent papers about China's peak oil issue are those by Wang et al. [17], Wang et al. [18] and Wang et al. [19].

Besides the two groups above, there is also a group of researchers who keep neutral opinions regarding peak oil. These analysts include Xu [33, 34], Guan [35], and Lin [36], and Lin and Liu [37].

3.2 Summary of the Debate

Even though the forecast of oil production commenced in China as early as 1984, our previous discussion of varying points of view in the debate is confined to research in the field of "peak oil" theory occurring within the past 15 years. While this and similar issues have been debated using different terms we restrict our discussion to research that directly mentions the concept of peak oil and its implications. The following (Table 1) is a summary of the aforementioned researchers' published opinions on peak oil.

Table 1 Published Opinions on Peak Oil from Influential Research and Policy Makers in the People's Republic of China.

Peak Oil Position Researcher	Affiliation	Published Statements [a]	Reference(s)
Non-Supportive			
D.D. Zhou	Energy Bureau of the National Development and Reform Commission	We will not enter a post oil age.	[20]
D.H. Wu, 2010	Ministry of Commerce, the People's Republic of China	Peak oil theory will collapse without evidence to support it.	[21]
K. Zhang, 2008, 2009	Sinopec Research Institute of Petroleum Exploration and Development	Peak oil is like a popular song which is made by the media and has an impact on the public.	[22-24]
S.L. Hu, 2010	China National Offshore Oil Corporation	Peak oil theory is just a scare tactic.	[25]
Neutral			
D.M. Xu, 2009	Energy Bureau of National Development and Reform Commission	Technology will decide our energy future and influence future energy production.	[33,34]
Q.Y. Guan, 2010	The Global Macroeconomic Policy of Change Think-tank	We should focus on peak consumption and peak CO_2 emissions.	[35]
B.Q. Lin, 2007; Lin, et al., 2010	China Energy Economic Research Centre at Xiamen University	Peak oil is the basis of China's national oil security strategy and a motivation for conservation.	[36, 37]

Supportive			
L.Y. Feng et al. 2008	China University of Petroleum (Beijing)	Peak oil will occur; We have entered the post-oil age; China's oil production might peak in 2026, with peak production of 196 million tons/yr.	[16, 26]
Y.Q. Chen, 2003; 2005; Chen, et al. 2008, 2009	Research Institute of Petroleum Exploration &Development, China National Petroleum Corp.	Oil production has likely peaked.	[27-30]
Y Li, 2007	Shanghai Alliance Investment Ltd	China's oil production would peak in 2020-2030, with peak production of 216-219 million tons/yr.	[13]
Z.P. Tao et al. 2007	NorthEastern University, China	China's oil production would peak in 2019 and the peak production would be 199.5 million tons/yr.	[14]
J.L Wang, et al. 2015	China University of Petroleum (Beijing)	China's unconventional oil production will peak in 2068 at 0.35 Gt/yr. in the TRR scenario, whereas the peak production in the PR + CP scenario will appear in 2023 and is 0.05 Gt/yr.	[17]
T.T. Wang, et al. 2015	Southwest Petroleum University, China	China's oil production would peak during 2024-2025, with peak production of 209 million tons/yr.	[18]
K Wang, et al. 2016	China University of Petroleum (Beijing)	China's conventional oil has already peaked in the year 2010 and the peak production was 167.5 million tons/yr.	[19]

[a] Statements included within the "Published statements" column of this table have been translated from Chinese and also in some cases edited slightly for clarity.

As is shown in Table 1, the strongest voices against peak oil in China are typically government officials or leaders within the oil industry. Their opinions opposing peak oil are usually published through informal, non-academic information sources, such as industrial newspapers, media interviews, etc.

Those who clearly support peak oil and advocate public policy changes, guided by an understanding and acknowledgement of peak oil theory, are often academics and researchers with little public influence. Their opinions and arguments are generally published in formal academic journals.

Therefore, objective and calm debate regarding the problem of peak oil in China is unfortunately not enough to achieve widespread agreement on this important but still-contentious issue.

4 The Reality of Peak Oil in China

In this section we look at the facts concerning oil production in China.

4.1 Conventional oil production of China has peaked

As shown in Figure 1, Wang et al. indicate that China's *conventional* oil production had already peaked in 2010, with the peak production being 167.5million tons/year; while the continued increase of oil production in China after the year 2010 has been caused by increased production of unconventional oil [19].

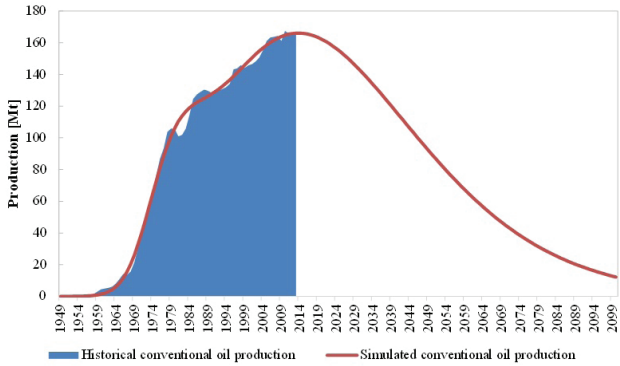

Figure 1. Forecast of China's conventional oil production [19]

Wang et al. (2016) also show that China's unconventional oil can only postpone China's peak year of oil production by about 11 years. Actually, if the likelihood of high development costs, large environmental impacts, and continued low oil prices are considered, the prospect of China's unconventional oil development would probably be even less favourable.

As is illustrated in Figure 2, compared with conventional oil, the equivalent amount of unconventional oil tends to be both more expensive to develop and also tends to produce a larger quantity of greenhouse gases (GHG) in the process of extraction. Thus, there are many uncertainties when considering the substitution of unconventional oil for conventional oil [19]. According to a recent report, in fact China's total oil production (conventional + unconventional) has already peaked in 2015 [38].

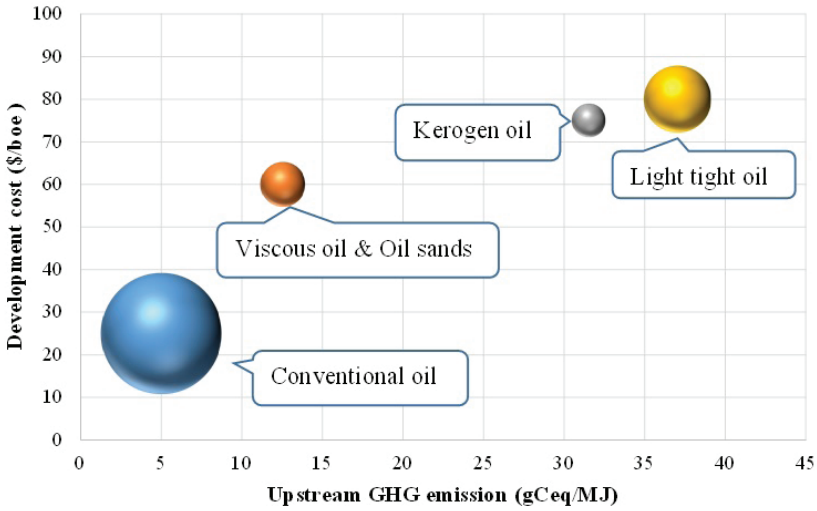

Figure 2. Upstream GHG emission and development cost of different kinds of oil

Note: The size of 'bubbles' in the figure represents URR of certain kinds of oil in China;

Data sources: URR data are from Wang et al. [19]. Development cost data are from IEA [39]; Upstream GHG emission data is from Brandt and Farrell [40].

4.2 Energy Return on Investment (EROI) of China's fossil fuel are declining

Most energy policies calculate energy supply from gross domestic energy production plus energy imports. However, what is important to society is the *net energy* available from these resources [41]. EROI, like net energy, describes numerically how much energy is left to power the modern industrial society after extraction, processing and delivery.

As is mentioned by Hu et al. (2013), the EROI for China's conventional oil and natural gas extraction decreased from a maximum value of 14:1 in 1996 to 10:1 in 2010, with an annual rate of decline of 2.6% , and is estimated to decrease to 9:1 by 2020 [42].

The declining EROI of China's oil and gas extraction indicates that despite the development of technology, the Chinese society is consuming an increasing amount of energy to find and produce its energy due to the declining quality of energy. This, in turn, may be a reflection of the issue of peak oil in China.

4.3 Peak oil may manifest itself in a low oil price

Most people naturally believe that if we encounter oil limits, the impact will be high oil prices and shortage of supply. As is noted by Tverberg (2012), this view may be completely backwards, however, because the world economy is a networked system, and the way feedbacks work is not always obvious. Tverberg has argued that the fact oil limits may manifest themselves as low oil prices and a "glut" of oil supply [4]. Her reasoning concerns the productivity of workers, and for that matter, the productivity of investments in general, when the cost of oil production is rising.

When oil costs are rising, it is taking more workers, and more resources in general, to produce a given amount of oil, say one ton of oil. This is precisely the opposite of a gain in productivity; it is a loss of productivity, because the process is now more complex, and thus more expensive. More workers, more capital goods, and more resources of many kinds are required because deeper or more complex wells are needed, and more advanced technology is required. Therefore, Energy Returned on Energy Investment is falling [43].

Economists often talk about the importance of growing productivity in producing higher wages for workers [44]. Here we are encountering

the opposite effect: falling productivity of workers. This type of falling productivity is not generally measured in usual economic analyses, because these typically look at the efficiency of particular step in the process, say, the cost of drilling one foot of oil well. The problem here is that the nature of the process is changing, so that many more feet of oil well are needed to obtain a ton of oil, and many other steps are also needed to be added to the oil extraction process. Viewed in terms of how many tons of oil a typical worker (or a ton of steel) can be expected to produce, productivity falls.

As the cost of producing many types of commodities is rising, due to, in some cases, the diminishing returns (similar to the problem for oil), the world economy is reaching a situation where the cost of producing many commodities is rising, in a way that represents the need for more workers and other resources. This situation might be described as falling productivity of workers and resources. In such an environment, wages are likely to remain stagnant or even decline, even as the cost of many commodities rises. This combination of rising costs and stagnant wages is likely to lead to a slowing economic growth and even recession [4].

One particular problem for workers with wages that are lagging behind is the difficulty of purchasing "big-ticket" items such as new homes, furnishings, or cars. As these items become less affordable for many workers, demand for commodities (such as oil) is reduced for two reasons: (1) Oil is required to make these big-ticket items. (2) These big-ticket items also use oil and other energy products in their operation. It is this lack of demand (really affordability), brought about by falling productivity that can be expected to lead to low commodity prices, such as we are seeing today. These low prices are likely to eventually lead to the end of oil production.

5. Discussion

5.1 Unfortunate situations caused by lack of knowledge (or rejection) of the concept of peak oil in China

As indicated above, it seems very likely that China's production of conventional oil has already peaked. Furthermore, production of its unconventional oil has an uncertain future. However, the mainstream attitude of China's future oil production is almost always quite optimistic.

Looking back over history, several unfortunate situations have been caused by the public denial of peak oil, and over-optimistic estimates of China's future oil production.

The most typical one is was the controversy over the stated 1 billion tons of reserves of the Nanpu Oilfield, which is part of the Jidong Oilfield of CNPC. In May of 2007, Jidong Oilfield published the news through Xinhua News Agency (China's core media) saying that they had found a new oilfield, named "Nanpu", with oil reserves of 1 billion tons, and that the oil production of this Nanpu Oilfield would grow to 10 million tons/yr. by the year 2012 [45]. China's high level media "People's Daily" had also actively reported and advertised the great discovery [46]. According to CNPC, this discovery stemmed from a break-through in petroleum geology theory and in exploration techniques. These advances would greatly improve China's security of oil supply, and became a milestone in the history of China's petroleum industry. Some people even regarded it as the start of another 'golden age' of China's oil discovery. However, in fact, the reserves of the Nanpu Oilfield were seriously overestimated. According to the real data, the oil production of the whole Jidong Oilfield (including Nanpu Oilfield and another affiliated oilfield) in 2013 was just 1.7 million tons/yr., and the recoverable reserves were corrected to 85.7 million tons [47].

Another unfortunate situation was the "Ten Daqing oilfields", which happened in the 1980s. With the discovery of Renqiu Oilfield, China's oil production had finally broken through 100 million tons/yr. level. The government was enthusiastic about China's oil industry, and soon set the target of reaching oil production of 400 million tons/yr. in 2000, and of finding ten Daqing-scale oilfields in 20 years. China's core media all reported this actively, and posts and songs were created in order to broaden this target slogan. However, the reality proved that in the target year 2000, the production of China's conventional oil was only 146 million tons, and the total production of both conventional and unconventional oil was only 163 million tons.

The lesson from these situations is that an attitude of objectivity and calm is important in all oil resource and production forecasts, and that as a nation we should change from over-optimistic attitudes as soon as possible, and instead bravely face reality, and deal intelligently with the approaching problem of peak oil.

5.2 Possible Reasons for the "Invisibility" of Peak Oil in China

It is an interesting question to ask: Why have scientific warnings of peak oil and declining oil availability been generally disregarded by those in power in China? Here we suggest three potential reasons.

The first reason could be the large variations in the estimated/projected ultimate recoverable resource (URR) values for oil resources in China. Several estimates of China's ultimately recoverable oil resources (URR, the total amount of "recoverable oil" that is in the ground prior to extraction) have been generated in the past few decades. The studies involved have produced highly variable URR results, and hence corresponding implications for China's future as a producer of oil. A review of the academic literature during the past 15 years regarding the URR of China's total oil resource (including both conventional and unconventional) shows an average value of 12.2 Gt [19]. At the same time, China's official agency has published quite optimistic URR estimates for China's conventional oil. According to the *New round of oil and gas resources assessment report*, published by China's Ministry of Land and Resources in 2006, China's conventional oil URR is 21.2 Gt [48]; the number was raised to 23.3 Gt in the *Dynamic evaluation of oil and gas resources in China* report published in 2010 [49]; and was again raised to 26.8 Gt in the equivalent report published in 2015 [50]. Because of the optimistic attitude of Chinese official agencies toward oil resources, mainstream opinions tend to ignore the peak oil issue.

The second reason that peak oil has been 'invisible' could be a natural reluctance to acknowledge a theory built on the premise that technological advancement in the field of oil production and efficiency will be insufficient to compensate for diminishing oil availability.

Lambert and Lambert [51] suggest that a society's inability to perceive the danger associated with the depletion of finite resources (with oil being just one example) may be due, in part, to a predisposition to assess future dangers within the construct of the known and familiar. To-date there are few, if any, scenarios in which technological advancements fail to eventually provide society with a satisfactory solution. This suggests that the present-day society may not be able to adequately recognize and define the "danger" associated with peak oil and is, therefore, unable to extrapolate how to act in the presence of this "danger".

Also, Hubbert (1956), when discussing the relation between energy consumption and population growth, stressed that technological

advancement could not be looked upon as the ultimate solution. Similarly, Weng's model (1984) limits the discussion of technological advancement and chooses, instead, to focus on resource availability and lifecycle assessments as generally applied to the production of finite resources [6]. Hubbert's and Weng's less-than-optimistic forecasts are difficult to accept in the face of growing production rates and technological advancements that have assisted in this development.

In addition, as mentioned earlier, several studies have been released that call into question Hubbert's ability to accurately predict global peak oil [52; and see 53]. These studies and /or resulting discussions choose to focus on the minutia, limitations, influence of unknown variables, and precision of Hubbert's and Weng's models and findings, rather than on the long-term accuracy of peak oil theory and general consequences associated with diminishing resource availability and uncontrolled population growth. It seems probable that these arguments against models lack sufficient perspective. They, in our opinion, appear encumbered by academic pedantry and, as a result miss the all-encompassing societal issues resulting from oil depletion.

The third potential reason that peak oil has received relatively little attention could be an understandable desire for those in power to minimize the impact that knowledge of this issue might have on China's economic stability and short-term well-being. According to Nevis [54], a crucial cultural concept, central to Chinese management practices is that "being a good member of society and putting group goals before individual needs should govern all practices." This possible collective orientation [55] may reveal a fundamental difference between the Chinese approach to deal with peak oil theory and the more open dialogue more normal in some western nations. If the flexibility and malleability of China's economy has been over-estimated, then this could cause Chinese officials to minimize the potential impact of peak oil [56, 57], in an attempt to protect and shield the Chinese people and economy. It is possible that China's government officials are, in fact, aware of the possibility of peak oil, are concerned about imminent economic and societal repercussions, and hence have a desire to minimize public concern while solutions are sought and policy decisions are hammered out.

We posit that each of these possible reasons for the obvious "invisibility" of peak oil in China does not exist within a vacuum. What

is much more likely is that there is a synergistic interplay between these psychological, sociological and political influences. We submit that this interactive effect indeed magnifies their influence on current policy decisions and China's economic market.

5.3 What should China do in face of Peak Oil?

There are a number of actions that China can take in the face of peak oil.

Firstly, developing renewable energy is necessary. Since fossil fuels are nonrenewable energy resources, they will all run out some day. Therefore, exploring for more fossil fuel resources cannot entirely solve the energy supply problem, and is thus not a reasonable avenue to take. China has to seek solutions from increasing use of renewable energy. In practice, the renewable energy industry is now being developed quite fast in China. In 2016, China has already become the world's largest producer of photovoltaic power, at 43 GW installed capacity [58]. In addition, China is now leading the world in the production and use of wind power and smart grid technologies [59]. Despite the optimistic development of China's renewable energy industry, energy consumption in China is still dominated by fossil fuels. By the end of 2012 renewable energy only accounted for 9% of China's total energy consumption. In addition, the EROI of the current renewable energy production is still quite low [43]. There will still be a long way for China to go to sufficiently develop its renewable energy industry.

Secondly, improving energy efficiency is another important action China should take to deal with the problem of energy supply. This includes improving efficiency of both energy production and of energy consumption. Since the EROI of the oil and gas extraction industry in China is declining [42], the energy *efficiency* of oil and gas extraction is also declining, due to the depletion of oil and gas resources, and the decrease of oil and gas resource quality. Nevertheless, there are still many things we can do improve the efficiency of energy consumption, e.g. improve fuel consumption efficiency of vehicles through technology innovation, and use energy more efficiently at home. With improved technology, the same amount of energy resources can be used to support the societal development for a longer time.

And last but not the least, China's public have to change their concepts regarding lifestyle. The idea of expanding expenditure

and consumption while being richer is not an ideal goal of life. The expectation of more and more fossil energy resource exploration and exploitation, requiring large and ever-increasing investment, is not reasonable, since this cannot solve the problem fundamentally. The public should change their lifestyle to a more environmentally and energetically sustainable way.

6. Conclusions

We suggest that opponents to the concept of peak oil are mostly top-level government officials and leaders within the oil industry. Their opinions of opposing peak oil are nearly always published through informal, non-academic information sources, such as industrial newspapers and media interviews. Those who support peak oil and advocate public policy changes, guided by an understanding and acknowledgement of peak oil theory, are often academicians and researchers but with little public influence. Their opinions and arguments are generally published in formal academic journals. Calm and objective debate in China regarding the question of peak oil is present, but is not yet enough to get opinions to change widely.

Recent analysis indicates that China's *conventional oil* production has already peaked in 2010, and that probably China's total oil production may also have peaked in 2015. In addition, the important EROI of oil and gas extraction in China has been decreasing during the past two decades. The arrival of peak oil seems pretty much certain in China.

Rejections to the concept of peak oil have in the past caused several unfortunate situations, while the mainstream idea in China now is still against peak oil. The potential reasons of the "invisibility" of peak oil in China have been discussed in section 5.2, and include: the large variations in estimated/projected size of the ultimate recoverable resource (URR) of oil resources; a natural reluctance to acknowledge peak oil theory; and perhaps a desire for those in power to minimize the impact that knowledge of peak oil issue might have on China's economic stability and short-term well-being.

In our view, China should change its over-optimistic attitude and objectively recognize the issue of peak oil as soon as possible, bravely face the reality, and deal with the peak oil problem actively. Potential

ways to deal with peak oil include: further developing renewable energy, improving energy efficiency, and changing the public's expectations regarding lifestyle.

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