The end of Peak Oil? Why this topic is still relevant despite recent denials

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Abstract

Up until recently Peak Oil was a major discussion point crossing from academic research into mainstream journalism, yet it now attracts far less interest. This paper evaluates the reasons for this and on-going relevance of Peak Oil, considering variations in predictive dates for the phenomenon supported by technological, economic and political issues. Using data from agencies, the validity of each position is assessed looking at reserves, industrial developments and alternative fuels. The complicating issue of demand is also considered.

The conclusions are that, supported by commercial interests, an unsubstantiated belief in market and technical solutions, and a narrow paradigmatic focus, critics of Peak Oil theory have used unreliable reserve data, optimistic assumptions about utilisation of unconventional supplies and unrealistic predictions for alternative energy production to discredit the evidence that the resource-limited peak in the world's production of conventional oil has arrived, diverting discussion from what should be a serious topic for energy policy: how we respond to decreasing supplies of one of our most important energy sources.

Key words: Peak Oil; Oil Reserves

1. Introduction

Peak oil is the point at which the global output of conventional oil reaches its maximum level and subsequently flow rates decrease (Bowden, 1985). This is when roughly half the world supply of oil has been produced and subsequent output falls. It is an important topic since oil is critical to the global economy, providing the ingredients for a range of manufactured goods and essential chemicals as well as supplying most of the energy for transportation, ensuring the operation of modern extended supply chains vital for international trade (Atkinson, 2010).

Evidence for the concept of Peak Oil comes in part from the work of Shell Oil geologist M.K. Hubbert who predicted that US production would peak in 1970, closely matching actual peak production in 1971 (Bowden, 1985). In 1974 he also suggested that global oil production would peak in 1995 which proved to be inaccurate (Demming, 2003). This approach was also developed separately through Shell scenarios in the seventies to examine the 'Oil Mountain', the point at which global supplies hit maximum output (Dumoulin and Eyre (1979). Now named Peak Oil, this is the time when all the cheapest oil has been extracted and costs rise, with serious ramifications for our oil-dependent industrialized societies built upon low energy costs.

The intention of this paper is to collate opinions and the varying views on the date of Peak Oil and consider reasons for variations and the subsequent denial of the phenomenon by the many commentators, taking positions that have serious implications for policy.

2. Prediction of the date for Peak Oil

There are a range of predictions as to when oil will peak and the groups can be largely split into those who believe in a late (or no) peak – the late-peak advocates[1] – and those who suggest we have, or soon will peak – the early peak advocates. Though this categorisation does not include every commentator on the oil industry, it does encompass those who have voiced strong views on the topic and gives an overview of opinions.

3. Late Peak advocates

The late-peak advocates examined include the Cambridge Energy Research Associates (CERA), the International Energy Agency (IEA), BP, Shell, the Energy Information Administration (EIA), the Energy Watch Group (EWG), Ged Davis, formerly of Shell, and Leonardo Maugeri, director of Strategies and Development at Eni SpA (table 1). Within this group there are wide variations with some dates close to those suggested by the early peak advocates.

CERA (2008) believed there was no evidence of a sudden increase in oilfield decline rates before 2017, following on from more optimistic earlier work by CERA's director Peter Jackson (2006) and Jackson and Esser (2004). Similarly BP's Tony Hayward did not believe there would be Peak Oil because of supply, though he suggested there may Peak Oil caused by demand (Macalister, 2010).

[1] For simplicity, the title of the group has been set as late-peak rather than late-and-no-peak

IEA (2010) was not explicit on Peak Oil, but implicitly considered it, looking at alternatives energy policies for the future. Shell (2011) saw supply struggling to keep pace with demand by the end of the decade, developing the observations made by Shell senior manager Ged Davis (2003) where he expounded Shell's *Energy Needs, Choices and Possibilities—Scenarios to 2050* (2001). Shell's *New Lens Scenarios* (2013) envisioned no peak under 'Mountains' scenario but saw oil demand 'reaching a long plateau in the 2040s' under the 'Oceans' scenario (Shell, 2013, p33).

Table 1: Summary of Dates for Late Peak

Peak Oil date	**Source and Date of forecast**
Not before 2017	CERA (2008)
After 2020	Hayward, T., BP (Macalister, 2010)
After 2020	CERA (Jackson and Esser, 2004)
2020 or beyond 2035	IEA (2010)
2020 (for oil and gas)	Shell (2011)
2025 or later	Davis (2003)
2035	CERA (Jackson, 2006)
Not before 2035	EIA (2010)
No visible peak	Maugeri (2012)
No peak but 54.2 years of global production	BP (2012)
'Peak oil theories have been abandoned' 'Oil demand …reaching a long plateau in the 2040s'	Mountains Scenario Oceans Scenario Shell (2013)

Sources: varied given in references

EIA (2010) was more specific than others, proposing that there would be no peak before 2035 with production increases up until that date. This included both conventional and unconventional supplies.

Maugeri (2012) considered the whole concept of Peak Oil as erroneous declaring that it ignored technological advances and the role of prices to spur innovation. Although BP also foresaw no evidence of a peak in supplies, the firm did point out that 'oil reserves in 2011 were sufficient to meet 54.2 years of global production' (BP, 2012, p7).

4. Early peak advocates

A more pessimistic view is provided by a number of proponents, many renowned for their staunch defence of Peak Oil predictions. Although there is some corroboration between dates there is no clear consensus (table 2).

Professor Ken Deffeyes (2010), having written extensively on the topic, used calculations to show that the 2005 peak in world oil production would never be surpassed, now supported by Hallock's recent review of his 2002 model (2013). Bakhtiari (2004) used simulations of the World Oil Production Capacity (Wocap) to propose global oil production peaking from 2006 to 2007. This was reinforced by energy investment specialist Matthew Simmons (2006) who argued that the oil and gas system lacked spare capacity and any minor incident in the industry was likely to cause a major crisis. Also supporting this was The World Energy Council (WEC, 2007), which suggested that we were in the *Second Half of the Age of Oil,* characterised by the decline of supply.

Using research into new discoveries Chris Skrebowski's Mega Projects (2004) observed a decline in large new discoveries of oil putting 2007-2008 as the peak point. With updated research he amended this to after 2010 (Skrebowski, 2005).

Table 2: Summary of Dates for Early Peak

Peak Oil date	Source and Date of forecast
2005	Deffeyes (2010) Hallock (2013)
2006–2007	Bakhtiari (2004)
2006 on	Simmons (2006)
After 2007	Skrebowski (2004)
Soon after 2007	World Energy Council (2007)
2009-2031	Sorrell et al (2009)
Before 2010	Goodstein (2004)
Around 2010	Campbell (2005)
Possibly 2010	Klare (2004)
2010	Aleklett et al (2010)
After 2010	Skrebowski (2005)
2006-2017	Hiro (2007)
Soon after 2010	De Margerie, C., Total S.A. (Walt, 2010)
2008-2012	De Almeida and Silva (2009)
2012-2017	Koppelaar (2005 and 2006)
2008–2018	Robelius (2007)
2014	Sami Nashawi, I., Malallah, A. and Al-Bisharah M. (2010)
2015	Shell (2008)

Sources: varied given in references

This matched the findings of a number of observers such as Klare (2004), who considered total historical global reserves half gone at 2010, and Hiro (2007), using data from the *BP Statistical Review of World Energy* (BP, 2006) to argue for a twin-crested peak from 2006 to 2017. Goodstein (2004) perceived a situation similar to the 1973 oil crises causing him to propose 2010 as the peak date. These researchers tended to concur with one of the key advocates of early peak, Dr. Colin Campbell of the Association for the Study of Peak Oil and gas (ASPO). Writing since the 1990s on the topic he used data from the Gulf War, and Shell's restating of its reserves, to support 2010 as peak date in his book *Oil Crisis* (2005). His more recent research put the global economy now at 'peak demand' (Lewis, 2010).

Further supporting this Christophe De Margerie, CEO of the oil firm Total, suggested that oil supplies could not easily cover demand after 2010, costing increasing amounts to recover (Walt, 2010). This also matched the research of Aleklett et al (2010), who looked at IEA's data and agreed with 2010. De Almeida and Silva (2009) concluded that market participants (including oil firms) expected a peak from 2008 to 2012 based on a study of oil futures.

The analysis of 47 major oil producing countries by Sami Nashawi et al (2010) estimated the world's crude oil reserves and remaining recoverable oil, giving (an estimated) peak in 2014. Koppelaar (2005 and 2006) concluded that world liquids would peak around 2012 then plateau from 2010 to 2016, possibly peaking again later at 2017 if recovery rates improved. Robelius (2007) put the range from 2008 to 2018 using four different predictive models.

In *Shell's energy scenarios to 2050* (2008) the firm mentioned oil supply 'struggling to keep pace' and gave a date of 2015, a specific figure absent in later publications. Covering many of these dates was the UKERC's *Global Oil Depletion* assessment cautiously stating 2009-2031 (Sorrell et al, 2009).

This gives a range of dates from 2005 from the earliest early-peak advocate to 'never' from the most optimistic late-peak advocate.

5. Reserve variations

One aspect of the debates about the peak of conventional supplies revolves around the size and quality of reserves available. There are different ways to categorise these, usually using the proved, probable and possible classifications.

EIA defines proved reserves as 'the estimated quantities that geological and engineering data indicate can be recovered in future years from known reservoirs, assuming existing technology and current economic and operating conditions' (2010, p37). These proved reserves (1P) are often used for financial purposes with a 'reasonably likely' chance of being produced, often 90% probability, though this can vary and is not usually mentioned. Additionally most of the proven oil is in countries where information is provided by state monopolies, which need not necessarily comply with industry procedures (Mitchell, 2004).

Probable reserves are those that are likely to be produced using current or imminent technology, assuming favourable economic and political factors. These are not yet proven but have over 50% chance of being developable, sometimes being called P50 reserves (UK DECC, 2010). When combined with proved they are known as proved plus probable or 2P.

Possible reserves are generally those with a 10 percent certainty of being developed (P10) under favourable circumstances[2]. These are often used for 3P measures, indicating proved plus probable plus possible reserves (Graefe, 2009).

Obviously the assumptions on current technology and market conditions and the different bases of these measures give variations in results and may cause confusion. Observers can look at the same fields using different definitions and come up with dissimilar figures (Owen et al, 2010). Therefore there are concerns that firms and countries may inadvertently, or intentionally, over-report, under-report or leave estimates unchanged for years (Campbell, 2003). Sometimes reserve statistics may be adjusted from 1P to 2P giving an apparent increase in the field size with no real change in the oil available. Consequently it could be argued that proved and probable reserves may give better estimates of reserves, though these are infrequently used (Bentley et al, 2007). Even if firms and countries adhere to the same classifications the figures are only probability-based estimates with inherent assumptions about technology, operating conditions and the economic situation. If any of these factors should change, the results can be significantly revised with the real reserve quantity unaffected (Höök, 2010). Changes of this nature can be seen with BP (2012) and WEC (2010) figures growing over time.

[2] Possible reserves are those which cannot be presently regarded as probable and are estimated to have less than 50% chance of being technically and commercially producible (UK DECC, 2010)

CERA states that flow rates are more important than reserve sizes but their research still gives a global reserve figure of 3740bn barrels (CERA, 2006). In their database of new field developments they consider the location of these, looking at 350 projects with contributions of 7.5mbd to future supplies (CERA, 2008). Similarly EIA (2010) is optimistic that oil discoveries off the West African coast will bolster non-OPEC reserves, based on the assessment by the U.S. Geological Survey (USGS, 2010), estimating mean-undiscovered resources of over 71 billion barrels of oil, though they state this is a P3 figure (less than 50% chance), with 21 billion barrels being P1 (95% likely).

Cohen (2006) criticises CERA's use of assumptions on undiscovered resources and notes that conventional oil discoveries have declined since the 1960s, echoing Deffeyes (2010) who disputes the importance of such finds, proposing that 95 percent of global oil reserves have already been found. Höök et al (2009) argue that even if such figures are realistic they do not balance the collapse in large fields. Bentley (2007) and Höök (2010) observe that many of these supposed discoveries are often due to moving from 1P to 2P measures.

In addition to variations in the methodology, with inadvertent discrepancies, there are political and financial pressures to misreport figures. This has led to contradictory estimates (University of Oxford, 2010). For example, OPEC quotas are set at a percentage of reserves so there is motivation to exaggerate figures to benefit flow rates and therefore income. As can be seen in Table 3 the claimed proved conventional oil reserves figures of Middle East OPEC Member countries increased by around 360 billion barrels between 1984 and 2011 (nearly 85%) despite constant production.

Table 3: Middle East Oil Reserves (billion barrels)

	1984	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Change 11/84 (%)**
IR Iran	58.9	138. 4	136. 2	137.6	137.0	151.2	154.6	162.5
Iraq	65.0	115.0	115.0	115.0	115.0	143.1	141.4	117.5
Kuwait	92.7	101.5	101.5	101.5	101.5	101.5	101.5	9.5
Qatar	4.5	26.2	25.1	25.4	25.4	25.4	25.4	464.4
Saudi Arabia	171.7	264. 3	264.2	264.1	264.5	264.5	265.4	54.6
UAE	32.5	97.8	97.8	97.8	97.8	97.8	97.8	200.9
Total	**425.3**	**478.9**	**739.8**	**741.4**	**741.2**	**783.5**	**786.1**	84.8

Source: BP (2005) and OPEC (2012)

Highlighting problems with OPEC data, internal Kuwaiti documents state that actual proven reserves are nearer 24 billion barrels that the 100 suggested (PIW, 2006). Simmons (2005), Graefe (2009) and Micu (2010) also challenge Saudi Arabia's figures, arguing they may be overestimated and could peak soon. This is supported by the surprising increases in reserves from 165 billion barrels in 1982 to 260 in 1989, a rise of 57%, and the region's total reserves rising from 388 billion barrels to 663 in the same period, an increase of 70.7% (OPEC, 2006). Hans Jud of Emeuerbare Energien suggests Saudi reserves are around 170 billion barrels (with 40-50 billion remaining) and ex-ARAMCO staff such as Obaid Nawaf and Sadad Al-Husseini believe Saudi Arabia has been near maximum output since 2006 (Barbir, 2008).

Although some small part of this can be attributed to discoveries and changes in methods of estimating reservoirs, there are fears that Saudi oil reserves (and others) may have been overestimated by at least 40%. This, admits Sadad Al-Husseini, may have added 300bn barrels to reserve size (Vidal, 2011), a figure that almost matches the increases in OPEC members' reserves in the 1980s, representing around a quarter of all reported reserves in 2007 (Bentley et al, 2007). These OPEC figures feed into to those of BP (2012) suggesting any errors will impact on global estimates.

Table 4: OPEC members and reserves (1984 and 2011)

OPEC member	**1984 Proven crude oil reserves (billion barrels)**	**2011 Proven crude oil reserves (billion barrels)**	**% of OPEC reserves (billion barrels)**
Algeria	9.0	12.20	1.0
Angola	2.1	9.50	0.8
Ecuador	1.1	7.21	0.6
Iran	58.9	151.17	12.7
Iraq	65	143.10	12.0
Kuwait	92.7	101.50	8.5
Libya	21.4	47.10	3.9
Nigeria	16.7	37.20	3.1
Qatar	4.5	25.38	2.1
Saudi Arabia	171.7	264.52	22.2
UAE	32.5	97.80	8.2
Venezuela*	28	(296.50)	(24.8)
**of which Orinoco belt extra-heavy oil*	-	*220*	*18.4*
Total	**503.6**	**1 193.17**	**100**

Sources: BP (2005) and OPEC (2011)

At best Saudi reserves are seen as near maturity (Hiro, 2007). Evidence of this is that 7 million barrels of sea water are being injected daily into the main field, Ghawar.

This is a technique for maintaining pressure and providing oil faster but it can limit ultimate recovery and cause rapid depletion, especially with older fields (Morton, 2006).

Saudi Arabia is critical to OPEC production, having the second largest resources after Venezuela (table 4). However Venezuela's figure has also increased adding nearly 270 billion barrels since 1984, including 'proven reserves of the Magna Reserve Project in the Orinoco Belt, which amounted to 94.1 billion barrels in 2008' (OPEC, 2008, p17), all of this being extra-heavy oil (Graefe, 2009) the remaining 126 billion barrels in BP's data being 'based on OPEC Secretariat and government announcements,' (BP, 2012, p6).

OPEC reserves are vital to global oil, contributing 72.4%: therefore non-OPEC countries only making up 27.6% (BP, 2012). Of these Canada is the biggest non-OPEC producer due to figures recently revised to account for oil-tar sands (table 5), pushing up the global figure from 2001 by nearly 175 billion barrels (and the Canadian figure has been backdated -1991 now showing over 40 billion barrels, not less than 8 billion).

The Russian federation is still the biggest conventional-oil producer, making up almost half of the non-tar-sands reserves according to BP's data. However, Russia declared all oil data a state secret in 2004 (WEC, 2007) making it difficult to accurately predict what remains, with estimates varying. *Oil & Gas Journal* estimates 60 billion barrels for both end-2008 and end-2009 (Radler, 2010) whereas

WEC adopted the BP estimated figure of 77.4bn barrels for 2010 (BP, 2011)[3]. This is critical as EIA expects Russian output to increase from 9.4 million barrels per day in 2016 to 12.8 million barrels per day in 2035, with future potential for 15.7 million barrels per day (EIA, 2010). Meng and Bentley (2008) stated that Russia oil reserves were past their peak with output rising only slightly to 10.38 million barrels a day in 2012 despite high prices (Rudnitsky, 2013).

Table 5: Significant non-OPEC Reserves

Country	**1991 billion barrels**	**2001 billion barrels**	**2010 billion barrels**	**2011 billion barrels**	**Share of global Total**	**Reserve/ Production ratio**
US	32.1	30.4	30.9	30.9	1.9%	10.8
Canada*	(40.1)	(180.9)	(175.2)	(175.2)	(10.6%)	(Over 100)
**Of which oil-tar sands*	*32.4*	*174.7*	*169.2*	*169.2*		
Mexico	50.9	18.8	11.7	11.4	0.7%	10.6
Brazil	4.8	8.5	14.2	15.1	0.9%	18.8
Azerbaijan	n/a	1.2	7.0	7.0	0.4%	18.5
Kazakhstan	n/a	5.4	30.0	30.0	1.8%	44.7
Norway	8.8	11.6	6.8	6.9	0.4%	9.2
Russian Federation	n/a	73.0	86.6	88.2	5.3%	23.5
Oman	4.3	5.9	5.5	5.5	0.3%	16.9
Sudan	0.3	0.7	6.7	6.7	0.4%	40.5
China	15.5	15.4	14.8	14.7	0.9%	9.9
India	6.1	5.5	5.8	0.8	0.3%	18.2
Total non-OPEC	**204.7**	**330.4**	**329.4**	**329.4**	**19.9%**	**26.3**

Source: BP (2012)

[3] Rising to 88.2 billion barrels in 2011(BP, 2012)

If Russian data is inaccurate this will support OPEC's position as the key provider of oil, putting further pressure on Saudi Arabian and Venezuelan reserves.

Consequently reserve data is hampered by different measures, the interpretation of figures and political pressures to adjust or construe statistics to favour a particular standpoint. Interestingly, if global reserves are over-estimated, as proposed by some early-peak advocates, this suggests that oil prices are artificially lower than should be and markets and politicians are being denied information vital for energy policy decisions.

6. More complex fossil fuels

Another part of the argument put forward by the late-peak advocates is that even if reserve sizes are optimistic, improved technology will provide better extraction of present fields and allow new hydrocarbon fuel sources to be efficiently accessed, counterbalancing declining stocks. EIA (2010, p23) argues that high oil prices will encourage 'the use of enhanced oil recovery technologies to increase production of conventional resources'. They maintain that increases in market prices may promote the economical development of these and unconventional resources which are seen as a likely source of future fuel by BP (Macalister, 2010).

Leonardo Maugeri (2012), building on his earlier work (Maugeri, 2010 and 2004), proposes that the concept of Peak Oil is flawed because it ignores such technological advances. This reinforces comments by Peter Jackson of CERA (2006) arguing that the main flaw in Peak Oil theory is its failure to consider increasing reserves due to exploration and technology, suggesting that the harder to extract sources are part of the solution, cushioning supply shortages. These maybe be tight oil, ultra-deep-water or near-oils such as oil shale (as opposed to tight oil from shale), oil-tar sands and extra heavy oil. Indeed these predictions have been seen to have bearing on North American production with hydraulic fracturing (fracking) and Canadian oil-tar sands pushing reserve figures and production levels to the highest for many years (EIA, 2013).

However important these developments are, they do not change the central argument of Peak Oil and Maugeri's earlier research has been criticised for making some incorrect assumptions about technology and unconventional oil and not setting it in the broader context of oil-peaking calculations (Meng and Bentley, 2008). His later work has also been extensively discredited by Jean Laherrere (2012) in two comprehensive analyses of 'errors in facts and analysis' supported by a range of observers, many in the industry. Deffeyes (2010) observed that exploring existing fields may yield deposits but this will not offset the global peak that he believes occurred in 2005. Even Maugeri acknowledges that 'our planet most likely does not hide many more gigantic basins of conventional oil, for which discovery peaked in the 1960s' (Maugeri, 2012, p14).

The Deepwater Horizon disaster in the Gulf of Mexico has also shown the risks with extraction in difficult conditions. Canadian oil-tar sands pose their own political and procedural problems and there are concerns as to how recoverable this resource is, with only around 15% of available deposits being developed (BP, 2012).

Additionally, both these and Venezuelan heavy oils have cost complications due to the low Energy Returns On Investment (EROI), typically 5:1 as opposed to conventional oil's 40:1 (Cobb, 2012), and have significant environmental externalities when exploited.

Furthermore, data on reserves of many unconventional sources are now regarded as optimistic (Kling, 2013), compounded by thermodynamic inefficiencies in the processes, often relying on high energy inputs, will ultimately limit the net gain to provide fuel quantities well below predicted figures (Cohen, 2006). Generally, the slow refinement rate for many unconventional sources prevents them being rapidly deployed to make up shortfalls in conventional oil and limits usefulness (De Almedia and Silva, 2009). As noted by the World Energy Council 'time is running out to prove that newly discovered fields and new technology can more than compensate for flagging production from the rapidly aging fields beyond OPEC' (WEC, 2011, p18).

As well as exploiting oil from such locations, there are methods to produce liquid fuel from other sources. Gas-to-liquids (GTL) or coal-to-liquids (CTL) technologies offer means to manufacture synthetic oil from alternative hydrocarbon reserves. CTL is seen as a method that will allow countries with extensive coal deposits to prolong oil resources and also secure domestic supplies. It has been piloted at a number of US plants and there is interest in the technology from China, South Africa and a number of countries in the Far East (Smith et al, 2008).

However the contribution to liquid fuel supply is limited due to the processing methods which cannot compare with the flexibility of conventional oil refining, therefore preventing CTL becoming a viable alternative to oil (Hook and Aleklett, 2010). CTL has previously only been used in situation of abundant coal reserves and oil shortages[4], due to energy loses in production. Also the process considerably increase global CO2 emissions, causing political difficulties with countries attempting to comply with greenhouse gas agreements, and will put pressure on solid fuel reserves which are increasingly being used for electricity generation (Bharadwaj et al, 2007). Indeed, although world reserves of coal in 2011 were sufficient to meet 112 years of global production they had fallen from the 2000 figure of 210 years suggesting consumption is already increasing excessively without further requirements on stocks using an inefficient fuel production method (BP, 2012).

GTL is an existing technology with potential to produce usable fuel, also reducing waste by converting gas that is currently flared in oil production into usable fuel. But this process is costly and difficult, with the potential of over a third of the energy content being wasted in the process (Maggio and Cacciola, 2009). There are also wider issues with natural gas supply which will face greater usage for electricity generation and heating as oil reserves reduce. Even without GTL or increased consumption for other uses, there is a suggestion that gas supply will peak around 2040 (EIA, 2010) possibly running out in 2069 at present consumption (eni, 2011).

[4] Noteworthy being South Africa and Nazi Germany

Consequently these methods are of minimal benefit, requiring high levels of investment, high energy inputs and performing poorly on environmental measures (Graefe, 2009).

A less contentious source is NGL which is proposed as making make up much of the shortfall in conventional supplies. NGL is the liquid portion of natural gas, recovered in processing and often blended with crude oil. Shell (2011), IEA (2011), BP (Macalister, 2010) and Ged Davis (2003) believe NGL and near-oils will possibly preventing peaking until after 2050.

Even NGL is not without its own shortcomings, the foremost ones being that many producers include it in reserve figures at present so it is not an additional resource, suggesting unsupported optimism about recovery and efficient conversion into useable liquid fuel (Graefe, 2009). It would also appear to be likely to peak in production at a similar time to oil, therefore providing little support to liquid fuel reserves (Maggio and Cacciola, 2009).

7. Non-fossil alternatives to oil

Those who argue against the theory of Peak Oil point out that renewables and other alternative sources will phase in as oil prices increase, ensuring oil output does not peak. IEA (2008) assumes a high level of adoption of low carbon technologies for their *450 Scenario* with oil peaking just before 2020. Adherence to efficiency measures for the *New Policies Scenario,* where oil is predicted not to peak before 2035, sees nuclear power grow from 6% in 2008 to 8% of global energy in 2035

(IEA, 2010). The suggestion is the 2020 peak would come from reduced demand not supply with the *450 Scenario*.

Shell (2008, 2011) offers its own scenarios titled *Blueprint* and *Scramble.* The former sees an increasing rate of renewable adoption whereas the latter envisions an attempt to continue with present production and consumption patterns. Within their research they identify supply shortages for both conventional oil and gas by 2020, though they make no specific mention of Peak Oil. Ged Davis' date for Peak Oil 'after 2025' is based on earlier Shell scenarios with comparable assumptions (Shell, 2001). In the later In the *New Lens Scenarios* (Shell, 2013), renewables reach a 30–nearly 40% of total energy by 2060 in both their *Mountains* and *Oceans* scenarios, with a suggestion of 60–70% provision later in the century.

Also there has been much publicity given to the International Panel on Climate Change prediction of up to 77% of global energy being supplied by renewable sources by 2050 (IPCC, 2011)

7.1 Biofuels

A significant part of the renewable energy mix is biofuel which has emerged as direct alternative to liquid fossil fuels. There are a range of different types of this fuel ranging from bioalcohols, biodiesel, green diesel and vegetable oil to bioethers, biogas and syngas as well as traditional biomass (Demirbas, 2009). Most research is into the liquids and gases that can be utilised as replacements to conventional oil, consequently there has been considerable interest in production of bioalcohols and biodiesel/green diesel with crops being grown specifically for these products. CERA (Jackson, 2006) sees biofuels as an important part of the future liquid-energy mix with BP suggesting ‘second generation’ crops could provide 10% of global petrol by 2020 (Macalister, 2010).

Despite technological improvements, there has been little adoption of biofuels, only accounting for 16% of global energy final consumption with over 60% of this being traditional biomass used for heating and cooking (REN, 2011). Similarly Hirsch et al (2005) observe the small volumes supplied, with roughly half of one percent of global energy produced from this source (table 6). Even Maugeri (2010) accepts that if the whole crop of U.S. maize were turned into biofuels, it would only supply about 5 percent of U.S. oil demand. This further reflects concerns about the cultivation of these fuels impacting on land use and food production (Penuelas and Carnicer, 2010). Also, since all palm-oil production is based in tropical regions of the developing world, there are worries about loss of endangered species, increased greenhouse gas emissions and deforestation (Carvalho, 2011). This has resulted in biofuels coming under attack from environmental and conservation groups with a decline in political support for subsidies and plateauing of output (BP, 2012).

7.2. Hydro, wind and others

Hydro-electric is the most successful of the renewable energy sources, contributing 2.3% of global power (IPCC, 2011). There was a rise in consumption of this power source by 32.7 million tonnes oil-equivalent between 2009 and 2010, with a production increase of 6.5% (table 6). Unlike some other renewable energies it tends to be economically viable and the construction costs are often offset against low long-term costs and spin-off uses for the reservoirs such as for domestic and industrial water supplies, irrigation, recreation and flood prevention.

Table 6: Global Energy Consumption, 2009, 2010 and 2011

	2009 Million Tonnes Oil Equivalent	%	2010 Million Tonnes Oil Equivalent	%	2011 Million Tonnes Oil Equivalent	%
Oil	3908.7	34.4	4028.1	33.6	4059.1	33.1
NG	2661.4	23.4	2858.1	23.8	2905.6	23.7
Coal	3305.6	29.1	3555.8	29.6	3724.3	30.3
Nuclear	614	5.4	626.2	5.2	599.3	4.9
Hydroelectric	736.3	6.5	775.6	6.5	791.5	6.4
Renewables	137.4	1.2	158.6	1.3	194.8	1.6
Biofuel$_{12}$	51.8	(0.5)	58.4	(0.5)	58.9	(0.5)
Total	11363.2		12002.4		12274.6	

Source: BP 2012
$_1$Production data. $_2$Also in Renewables.

However, there are limited sites that such facilities can be located and concerns have been raised about the impact on eco-systems from flooding land and the siltation of feed rivers. There has also been evidence of high greenhouse gas emissions[5] from tropical reservoirs, sometimes matching fossil-fuelled power stations (Graham-Rowe, 2005). The effects on communities and fear of catastrophic failure can also cause political resistance so that even when there are geographically suitable locations, dams may not be constructed (Bosshard, 2008). Therefore hydro-electric schemes cannot be seen as a solution capable of unbounded growth and it may be that the limits of this energy source may soon be approached.

[5] From methane, a significant greenhouse gas with greater potent than carbon dioxide

A technology nearer its early stages of development is wind power. This saw increased uptake of over 22% in 2010, notably in China and the US where there was 70% of global growth (BP, 2011). A number of countries have already achieved relatively high levels of wind power, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain and 9% in Germany (WWEA, 2010). Offshore wind power is seen as the focus for future development, accessing higher wind speeds compared to land-based facilities and reducing visual impact. Generally there are fewer effects on the environment from this power source from any other method (GWEC, 2011).

However wind power accounts for a tiny part of power production, being only 2.5% of world electricity output (WWEA, 2010). Indeed total non-hydro renewable energy only accounted for 1.6% of total global-energy consumption in 2011 (BP, 2012). Wind power is also unreliable (being weather dependent), being highly susceptible to geography and climate with much lower capacity than claimed (Jefferson, 2012a). Even Denmark's healthy figure corresponds to output but not consumption with much having to be exported, sometimes sold for zero return when there is little demand (Techconsult, 2007). Additionally, land-based systems often face local resistance and rely on conventional generation to back up supply (Le Pair, 2011).

7.3. Nuclear

Another existing element of alternative energy is nuclear power, claimed by some to experience a 'renaissance', with growth of 2% between 2009 and 2010, much of this being in Europe, particularly France (BP, 2011). Rising fossil fuel prices and greenhouse gas emission limits drove some of this, as did the promise of uninterrupted domestic electricity and national energy security at times of global unrest (World Nuclear Association, 2011). With the development of cleaner and safer thorium reactors the opportunities would seem to be greater than ever (Greaves et al, 2012)

But usage has not increased as predicted. This has been due to reluctance to commit to major projects because of the poor economic performance against coal or natural gas, on-going concerns about the disposal of waste and worries about weapon development (Bezdek, 2009). The 2011 earthquake in Japan highlighted the implications of incidents, raising the long-running question of safety and causing the cancellation of many programmes, with some countries abandoning this form of energy all together (Breidthardt, 2011). At best, concerns about nuclear accidents have reduced long–term investment in this technology, delayed projects or diverted investment into other energy systems (O'Donnell, 2011). Adding to this is the unease about declining global stocks of uranium, especially if a number of nations are to adopt fission as a major energy source (Bardi, 2009). Even thorium fuelling has technical and safety concerns, still requiring significant investment and the support of conventional reactors for fuel (Mathieu et al, 2006).

Consequently nuclear and alternative fuels show no signs of being developed in sufficient quantities or with the vigour required to rapidly replace conventional oil supplies.

The predictions for renewables in particular have to be viewed with caution. The IPCC's 77% statistic for 2050 has to be read as one of a range of scenarios with that particular figure requiring major policy changes and high levels of innovation (IPCC, 2011). Aleklett et al (2010) see IEA's production projections as being significantly overstated with the IEA accepting that government support and measures to improve cost-effectiveness are needed for the anticipated growth in renewables (IEA, 2010). Even Shell's detailed analysis, the result of complex scenarios built on earlier pioneering work (Jefferson, 2012b), has a positive bias towards the renewables uptake. Therefore the evidence is that none of these technologies are being developed or invested in with sufficient enthusiasm to quickly replace even a reasonable portion of the energy supplied by oil.

8. Complicating issue: the rising demand for oil

As well as considerations of supply and alternatives to conventional oil there is increasing demand putting pressure on reserves (table 7). Much of this has been driven by the growth of the global economy in the last 40 years (EIA, 2009). This has partially been due to the continued consumption in the developed world but exasperated by increased demand from China and India.

2011 global demand was 88 million barrels per day (32 132 million barrels per year) which was an increase of nearly 15% over the 2000 figure (BP, 2012). Indeed since the mid 1980s consumption has grown at an average rate of over 1% a year, despite the impact of recessions in 1990 and 2001 (EIA, 2009). At this rate of growth, it is suggested that by 2030 the world may consume 42 500 million barrels per year (Owen et al, 2010).

Table 7: growth in oil consumption for China and India 2001 -2011

Million barrels daily	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	% of global total
China	4.86	5.26	5.77	6.74	6.94	7.44	7.82	7.94	8.20	9.05	9.75	11.4
India	2.29	2.38	2.42	2.57	2.57	2.57	2.84	3.07	3.21	3.32	3.47	4.0
World	77.3	78.3	79.8	82.8	84.1	85	86.4	86	84.7	87.4	88.03	100

Source: BP 2012

However if global reserves soon peak in output and the world economy faces a situation of insufficient supply to meet present needs then the only response to such an increase in consumption will be through rising prices. Considering the impact of a 3% fall in output on prices in 1970s with the oil crises, it can be seen that a potential shortfall of 10 000 million barrels will have catastrophic consequences, with suggestions of a ‘near doubling, permanently, of real oil prices over the coming decade’ (Benes et al, 2012, p17). This huge hike in costs would undoubtedly result in a major global recession (Barsky and Kilian, 2004).

However late-peak advocates, such as Maugeri and to some extent CERA, suggest the price mechanism will act to stimulate supply causing greater exploration and exploitation of expensive resources to match demand. This would maintain output, but at an increased market price thereby making alternative sources economically viable and experiencing a growth in investment.

Unfortunately this takes no account of the impact of prices on the wider economy, as oil is not an easily substituted commodity. Being the main transport fuel and a critical source of energy and chemical constituents, any large price rise would have dire consequences, choking economic growth without any encouragement for investment in new technologies and risk taking (Tyerberg, 2012).

Indeed this has been a critical factor in recent years as the financial crisis and slowdown, combined with euphoria over oil shale, has seen a fall in oil prices. Without significant real changes in oil supplies or fuel sources the global price has reduced, leading to little discussion of Peak Oil, especially when many countries have been occupied with what are seen as more pressing problems related to debt and poor growth. Dealing with long-term energy questions has been secondary to such concerns, with politicians ignoring the link between financial and energy markets with the potential to trigger major geopolitical incidents (El Gamal and Jaffe, 2009)

9. Conclusion

Opinions on Peak Oil vary greatly but the key question is whether it is a critical issue or not. Many of the variations in perspective can be blamed on interpretation of figures and incentives for under or overestimating data. Balaban and Tsatskin (2010) point out the importance of Peak Oil predictors' values which may encourage commentators to over or underreport reserve sizes to justify a certain argument. Therefore those who believe it has already occurred or is imminent give data to suggest this, often providing a definite date. They have motivation to push for debate on the issue of Peak Oil, often being critics of the oil industry or doubtful as to the ability of governments to think strategically about energy.

Similarly the Peak Oil doubters supply figures and counter arguments for their own positions, tending to criticise the theory from three perspectives. Firstly, that reserve estimates show sufficient oil for decades of high output production, irrespective of inconsistencies in the data. Secondly, that technological solutions will ensure that conventional fields yield a higher percentage of oil than was previously possible whilst non-conventional sources will be developed economically. And thirdly, alternative energy will be increasingly adopted and gradually replace oil, eased by the use of gas as a lower-carbon intermediary.

All three positions are supported by market forces, incentivising the development of unconventional oil and alternative energy when conventional reserves do prove inadequate. Some dispute the approach to Peak Oil whilst others see it as irrelevant, discrediting the Peak Oil theorists to such an extent that the discussion becomes polarised and simplified.

But the evidence is that conventional oil production has peaked and prices will rise, though this is unlikely to benignly encourage a shift to new fuels. The modern global economy has been built on cheap energy and history shows that high oil prices will have a serious negative affect on already weak growth and trade. Although alternative energy sources are being developed there is little evidence that renewables will be able to replace even a small percentage of oil's provision, while nuclear is hampered by safety fears and low investment.

Rather than continuing to argue for or against the topic, Peak Oil should be acknowledged as part of a complex energy situation with the realisation that cheap fuel is no longer available and we now face circumstances where prices will increase and high energy-based growth will be limited.

With this acceptance, and while there still is sufficient oil, there should be investment in new energy sources. The role of nuclear power needs to be properly evaluated and the effectiveness of different forms of renewables assessed. Serious discussion is required on ways to reduce energy usage at production, distribution and consumption phases of the economy, using more than short-term tax inducements.

Moreover, this should not be about ad-hoc market based solution. Like the oil crisis of the 1970s, this is a situation of great importance that requires leadership, discussion and analysis on a global level. Many aspects of modern life will be impacted by conventional oil output falling and co-ordinated action between diverse agents will be required.

As noted in Shell's *New Lens Scenarios*, quoting an old African proverb, 'to go fast, go alone – but to go far, go together' (Shell, 2013, p7).

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