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Future world oil production: Growth, plateau, or peak?[1]

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Abstract

With the exception of two oil shocks in the 1970s, world oil production experienced steady growth throughout the 20th century, from about 400,000 barrels a day in 1900 to over 74 million by 1999. Projections for 2030 suggest that production will increase to almost 104 million barrels a day. If this target is met, world oil production will have exceeded 1,900 gigabarrels (billion barrels) in the span of 130 years.

Almost all of the oil products humans consume come from sources which are non-renewable. With this in mind, this paper considers how long world oil production can continue to grow or if it will eventually plateau or peak and then decline. The paper concludes with the observation that whether peak oil has already occurred or won't occur for many years, societies should prepare for a world with less oil.

Keywords: Energy security, depletion, peak oil, non-conventional energy sources.

Introduction

Energy is central to the economic and social wellbeing of any society. Of all the primary energy sources available to mankind, three are dominant: oil (34% of world's total energy demand), coal (26.5%), and natural gas (20.9%) (1). Refined oil products, with their high energy density, ease of transport, and capacity to be used in any modern energy service (transportation, heating and cooling, and electrical generation), is the most versatile. The importance of oil to the world's economy cannot be overemphasized, not only does it meet almost all of the world's transportation energy needs (1), its byproducts can be used as a feedstock for the petrochemical industry (2).

As Figure 1 shows, the first seven decades of the 20th century witnessed the unprecedented and exponential growth in the production of oil, doubling roughly every ten years, from 435,000 barrels per day in 1900 to over 48 million barrels per day in 1970. The rise in production was interrupted twice, in 1975 and then in 1980; attributable to the two oil "shocks" that reduced oil supply and increased its price tenfold (3; 4; 5). Despite the shocks and commitments by western governments to reduce their energy intensity (6), the growth in oil production resumed in the mid-1980s, albeit in a more linear fashion. By the end of the century, world oil production had reached almost 74 million barrels a day.

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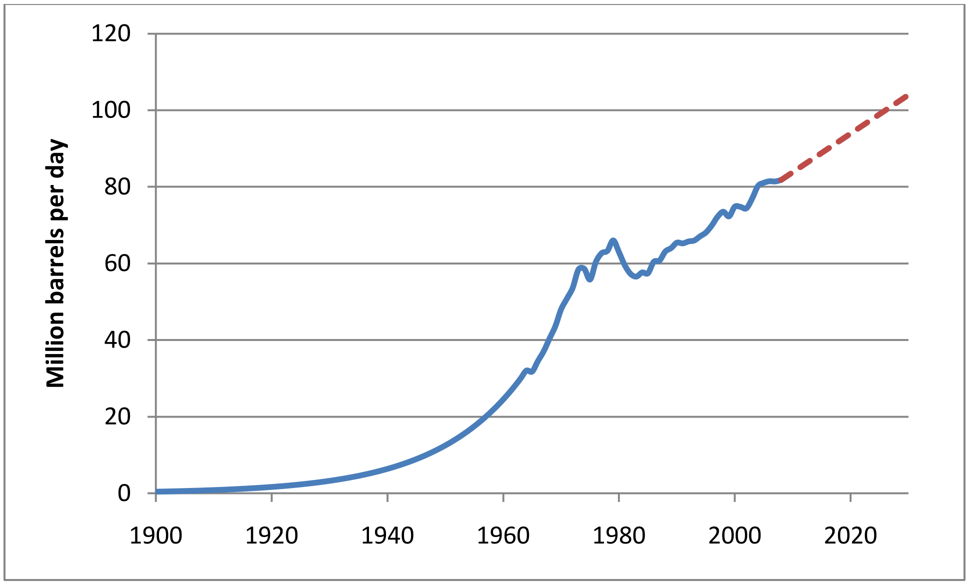

Figure 1: World oil production: Estimated (1900 to 1964) (7), actual (1965 to 2008) (4), and IEA projections (2009 to 2030) (8)

Increasing demand for oil from China and other emerging market economies pushed world oil demand higher in the early years of the 21st century; by 2008, the world was producing about 82 million barrels of oil a day (4). In the International Energy Agency's 2008 World Energy Outlook, production is projected to increase to 103.8 million barrels of oil a day by 2030 (8).[3] (Future production will be driven largely by growing demand from non-OECD countries; demand for OECD countries is expected to stabilize because of its ageing population (9).)

If world oil production reaches 104 million barrels a day by 2030, it will mean that in the 130 year span shown in Figure 1, the world will have produced over 1,900 gigabarrels (billion barrels) of oil. There are, not surprisingly, environmental consequences associated with producing this much oil: like all other hydrocarbon fuels, oil emits carbon dioxide when combusted; between 2006 and 2030, carbon dioxide emissions from oil combustion are expected to increase over 20% from 10,768 Mt to 13,670 Mt (8). One widely discussed approach to reducing CO_2 emissions is carbon capture and storage (10); how applicable this will be to oil is unclear, as principal use for oil will be for transportation as opposed to stationary combustion.

In addition to the environmental impacts of consuming this amount of oil, it is important to consider where the oil comes from and whether there are limits to the amount of it that can be produced.

Sources of oil

Broadly speaking, the world's refined oil products come from conventional sources or "crude oil" (usually defined as fields that produce light and medium crude oil), non-conventional

[3] This is in keeping with other projections to 2030 such as the Energy Information Administration 103.9 million barrels a day (62), Exxon-Mobil 104 million barrels a day (63), and OPEC's 105.9 million barrels a day (64).

sources (heavy oils, tar sands, and biological sources), and natural gas liquids (the liquid content of natural gas) (11).

Presently, more than 85% of the world's oil production is from conventional sources, while the remainder is predominantly from natural gas liquids (12; 8). In a conventional field, production is ramped up to a plateau and maintained at this level until primary (natural pressure), secondary (pumps to maintain flow), and tertiary/enhanced (chemicals or other techniques to encourage flow) recovery methods have been exhausted and production declines (13).

Any oil production can be affected by "below ground" (the geology of the field) factors as well as "above ground" (politics and corporate objectives) factors. As the volume of conventional oil from existing oil wells declines because of geology or politics, other sources must be found. For example, in the 1970s, production from the newly discovered oil fields of Prudhoe Bay in Alaska and the North Sea meant that western countries were no longer at the mercy of OPEC. More recently, declining onshore production has forced international oil companies such as BP, Exxon-Mobil, and Shell to drill offshore in deep (300 to 1,500 metres) and ultra-deep (more than 1,500 metres) locations in order to maintain their production levels because they are not welcome in a number of oil-producing countries due, in part, to the rise of resource nationalism (14; 15). The offshore has allowed some countries to maintain or even increase their domestic production of conventional oil (Angola, Brazil, Nigeria, and the United States are all reliant on the offshore to meet a growing percentage of their oil production (16)). Prior to April 2010, it is reasonable to assume that few people gave offshore oil production much thought; however, the blowout of BP's Macondo exploratory well in the Gulf of Mexico highlighted the human and environmental risks—and consequences—associated with deep-water drilling (17). One of the last regions available for exploration and potential production is the Arctic where the melting of the polar ice is resulting in many countries pursuing national strategies to explore and exploit whatever fossil energy sources may be found (18).

In addition to conventional sources of oil, there are also non-conventional (or unconventional) ones. These energy sources are feedstocks to a variety of conversion processes that produce a liquid fuel that can be used with or in place of conventional oil. For example, the technology to liquefy coal is well known, although it is energy intensive, meaning that using coal as the energy source of the process will produce more greenhouse gases (19; 20). Natural gas, a cleaner fuel, can be converted to methanol for use as a transportation fuel (21), although some sources of natural gas, such as shale gas or coal-bed methane in the United States, are not without their environmental impacts (22).

Canada's tar sands and Venezuela's heavy oils are other examples of non-conventional oil sources. The tar sands are being mined for their heavy crude and bitumen in an effort to replace Canada's dwindling supplies of conventional sources of crude oil. The water and energy required to produce a barrel of synthetic crude—and the associated greenhouse gas emissions—go well beyond those of conventional oil production (23).

Many governments are pushing for the use of biologically derived liquid fuels from feedstocks such as algae, woody and waste biomass, and agricultural biomass. There are challenges associated with each of these potential replacement fuels, including social (the use of agricultural land for food rather than fuel), economic (the costs of subsidies for biological fuels), environmental (the destruction of equatorial regions for sugar cane and palm oil and the removal of "waste" biomass from forests), and energetic (biological fuels such as ethanol do not have as high an energy density as petroleum) (24). Even when considering "second generation" cellulosic biofuels that offer the promise of not using food products for fuel, biological liquid fuels are expected to supply about four percent of the world's primary energy needs by 2050 (25).

Although the end product may be the same, there are two significant differences between the production of conventional and non-conventional oil sources. The first is the cost of production; because of the additional processing costs, non-conventional energy sources typically have a lower EROI or energy return on investment. Some of these differences are shown in Figure 2.

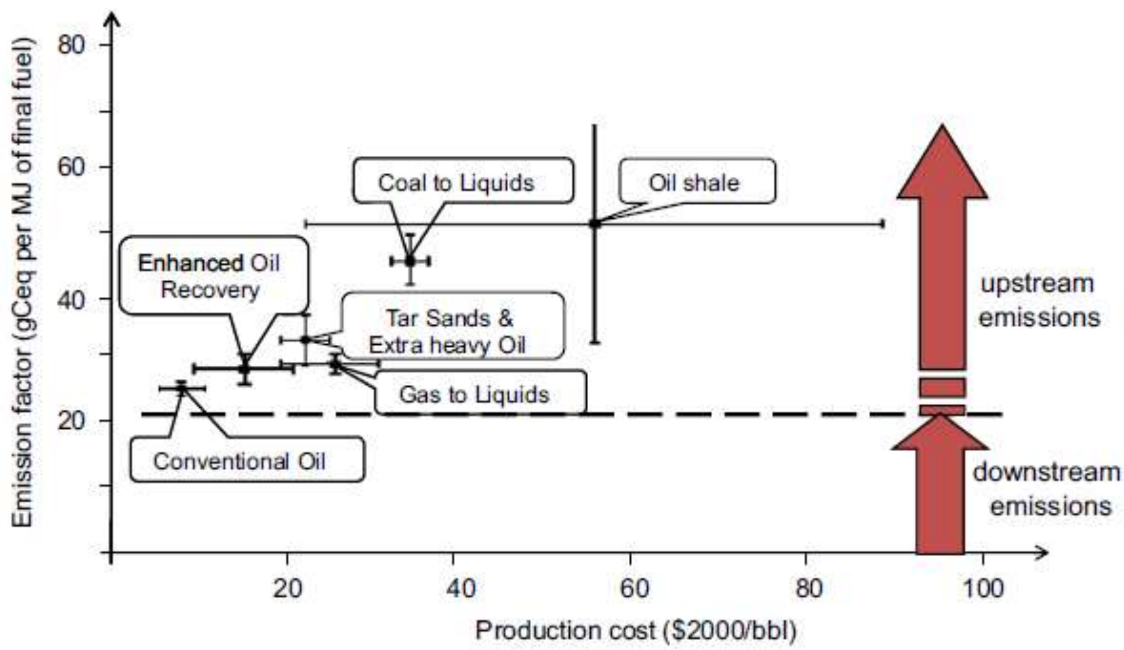

Figure 2: Production costs and emissions for various conventional and non-conventional sources (from (26))

Both conventional and non-conventional energy sources require some form of energy input in order to produce them; this can be referred to as energy return on energy investment or EROEI. In the 1930s, finding and producing conventional crude oil in the United States had an EROEI of more than 100; by 1970 it had declined to 30; recent estimates for production from new conventional crude oil wells put the EROEI value as low as 11 (27). For non-conventional sources of oil, the EROEI values for Canada's tar sands is about 6 (28), while for biofuels, it ranges from less than 1 (according to corn ethanol opponents) to as high as 3.2 (according to biodiesel proponents) (29). In all cases, the non-conventional EROEI is considerably less than that of conventional EROEI.[4]

[4] EROEI can be misinterpreted to mean that the energy input is oil, implying, for example, that one barrel of oil is required to produce 3.2 barrels of biodiesel. This need not be the case. However, energy still is needed; for

For more than a century, discoveries of new conventional oil fields and the development of new technologies for the production of both conventional and non-conventional oil have ensured ever increasing world oil production. The challenge facing the oil industry is how to increase production when existing fields are experiencing depletion rates of 5% or more while annual demand for oil is expected to increase at rates exceeding 1% (8). One can argue that what is being experienced today is no different from what has happened in the past—the oil is there to be discovered, given sufficient investment and technological advances. While there may be truth to this statement, the oil industry is being forced to look for conventional oil in locations that are both risky and more expensive, such as deep and ultra-deep water and the Arctic (30), while pursuing non-conventional sources, notably Canada's tar sands, that are expensive, energy intensive, and damaging to the environment (31).

Peak oil

Since all conventional and most non-conventional sources of oil are non-renewable, oil production cannot be sustained indefinitely. These distinctive characteristics have many people claiming that world oil production has reached or is about to reach the point at which the production from a particular oil producing region—in this case, the world—is at its maximum or peak and then begins to decline. This is often referred to as **peak oil**.

Claims that a particular jurisdiction has reached its peak production capacity have been made by many people over the past 150 years—most have been proven wrong (32). Probably the most significant exception was Marion King Hubbert's prediction in 1956. Hubbert, a geophysicist working for Shell in the United States, predicted that crude oil production in the United States would peak around 1970 (33). Hubbert based his prediction on the time of discovery and production from oil fields, the volume of crude oil extracted, and an estimate of the ultimate recoverable resource (URR); from this, he assumed that oil production would peak when half of the resource had been extracted, producing a bell curve (a symmetric logistic curve) now referred to as Hubbert's curve (34).

At the time, Hubbert was ridiculed; however, in 1970, oil production in the lower 48 states peaked at 10 million barrels a day (35). Although production from Prudhoe Bay in Alaska did raise U.S. production slightly, it has been in decline since 1972 (4). Hubbert's success in predicting the U.S. oil peak gained him a significant following and his prediction that world oil production would peak around 2000 focused many minds, including that of President Carter who spent much of his presidency warning Americans of the dangers of energy profligacy and oil dependency (for example, see (6; 36)).

Despite being proven wrong for his prediction of a global oil peak in 2000, many of Hubbert's supporters argue that he would have been right had the world not experienced the downturn in demand caused by the oil shocks of the 1970s (37). Hubbert's method is far from perfect and has numerous constraints, such as knowing discovery dates, backdating apparent "new"

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example, steam from natural gas is employed to liquefy and extract bitumen from Canada's tar sands; in order to use natural gas for other services an approach being given serious consideration is produce steam from a fleet of nuclear reactors (28).

discoveries to the discovery date of the original field, and requiring that production is free of political manipulation (37).

The shortcomings of Hubbert's method are one of a number of reasons why critics dismiss peak oil (38); however, there are other techniques being employed to examine the world's oil reserves in order to find when oil production will peak (39). For example, most of the world's oil is produced from a limited number of super-giant fields, many of which are more than 50 years old and are in decline; the cumulative effects of these declines, when coupled with information on new projects give an indication as to future production (40).

One of the most comprehensive studies on peak oil literature was completed in 2009 by the UK Energy Research Council; it suggests that a peak in conventional oil production by 2030 is likely and that there is a significant risk of the peak occurring before 2020 (41). A list of the individuals and organizations that project a peak before 2030 is shown in Table 1, while those that do not project a peak before 2030 are shown in Table 2.

The IEA's projection for world oil production is shown in Figure 3 and is divided into natural gas liquids, non-conventional oil, and crude oil. Crude oil is further divided into currently producing fields, fields yet to be developed, fields yet to be found, and additional enhanced oil recovery. Natural gas liquids and non-conventional oil show steady growth, whereas crude oil production essentially remains flat. Peak oil is averted by the fields yet to be found—if they are not found and there is insufficient production of natural gas liquids or non-conventional oil, a plateau or a peak will have occurred sometime between 2020 and 2030 (42).

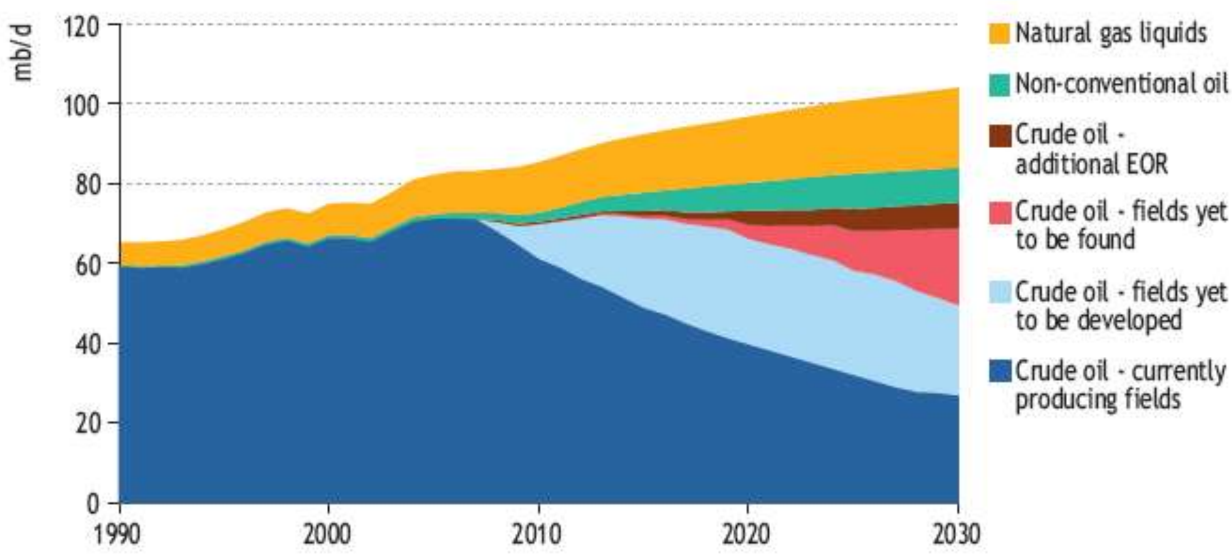

Figure 3: The IEA's world oil production by source (8)

There is limited publically accessible information on the current state of the world's oil resources. Much of the problem lies with the fact that many Middle Eastern oil producers keep their reserve data secret (12). Moreover, there are instances of misrepresentation of data (43). There have been attempts at making the data public; however, to date there has been little success (44). Understanding the state of the world's oil resources is important to any jurisdiction developing long-term energy policies.

A plateau or peak in world oil production could be driven by any number of factors, both above ground (lack of investment in oil exploration (8), environmental legislation banning or limiting drilling, conflicts in oil producing regions (45)) and below ground (depletion of giant and super-giant oilfields, the availability of energy and water for non-conventional oil production, the failure of natural gas to meet the production targets many are predicting (46)).

Accommodating future demand

Over the past century, much of the world has become dependent on oil. Infrastructure has been designed that supports long-term oil availability and short-term accessibility of widely acceptable and affordable oil products (47; 48). As more of the world's population becomes (or wants to become) dependent on oil, growth in oil production is necessary. However, should production reach a plateau or a peak, availability, accessibility, and affordability may quickly become a thing of the past as demand cannot be satisfied (49).

Preparing for a plateau or a peak in world oil production will be a long-term activity potentially requiring considerable changes in the way a jurisdiction uses energy (50). Ideally, this would be a worldwide activity, much like the IEA's Coordinated Emergency Response Measures (CERM) for major international oil disruptions which, amongst other things, allows sharing of available supplies between member countries (51). Alternatively, Campbell's oil depletion protocol that ensures fair and equitable access to oil products during a time of oil depletion could be employed (52). However, without international agreements the impact would not be felt uniformly across the world; for example, wealthy individuals and jurisdictions would be less affected by access and affordability issues, potentially protected by bilateral agreements between suppliers and consumers. The impact of the plateau or peak on a jurisdiction will depend in part on how reliant it was on oil (53).

Actions to address a plateau or peak fall into one of reduction (reducing energy use through conservation or gains in energy efficiency), replacement (replace existing sources of oil with other, secure sources of liquid fuel), and restriction (restrict new energy demand to energy sources other than oil) (54).

Of the three actions, restriction may be the most important as there will be a need for energy sources that enable the movement of goods and people. Restricting future energy consumption to non-liquid fuels will require a change in the energy sources and infrastructure now used to meet the demand currently satisfied by liquid fuels. Ignoring aviation, there are essentially two contenders at present: natural gas and electricity, while hydrogen is seen as something in the more distant future. Large-scale adoption of natural gas in gas-poor regions of the world (such as parts of the EU) will require more infrastructure in the form of pipelines or liquefied natural gas (LNG) liquefaction and regasification facilities to meet both existing and new demand. However, the lack of investment, domestic demand in the supplying country, and geopolitical tensions can all contribute to natural gas shortages in importing countries (55; 56).

Given sufficient supply and the proper storage facilities, future demand for energy in transportation and heating and cooling could be restricted to electricity. Whether enough environmentally sustainable supply can be found is an issue that must be addressed with countries such as China and the United States planning to maintain or expand their reliance on coal for electrical generation (57; 58). One method of increasing electrical supply without new capacity is to reduce grid losses while using spare capacity to meet the demand from interruptible loads (59). Although renewables such as wind are often maligned because of their intermittency, by making the load "follow" the supply (as opposed to today's approach of having the supply follow the load), renewable electricity can be used more effectively (60).

Concluding remarks

Oil has transformed the world. Plastics and aviation are but two of a myriad of goods and services that oil has permitted. This is not to say that humanity's use of oil has been faultless: spills, blowouts, and emissions are all the result of the widespread and virtually unrestricted use of oil. As the world's population has become more dependent on oil products, the possibility of shortages or price increases, or both are viewed with grave concern by politicians and the public alike.

Once, crude oil was simply something that was relatively easily extracted from the ground and refined. Over time this has changed, not only is crude oil becoming harder and more expensive to produce, with the rise of resource nationalism, it is no longer the exclusive domain of western international oil companies. This and the demand for greater environmental regulations in many developed countries has spawned the development of technologies to increase the production from abandoned oil fields as well as making fields that were once ignored due to their size suddenly much more attractive. Furthermore, exploration is moving into the oceans and Arctic to search for other sources of crude oil—at a greater expense.

There has also been a rise in the use of non-conventional oil sources, such as Canada's tar sands and Venezuela's heavy oil, to help offset the seemingly limitless growth in the demand for oil. Unlike conventional oil sources, non-conventional sources are both more expensive and more energy intensive—adding to the cost of the oil produced and to the environmental impact.

The earth is finite; thus the sources of conventional and non-conventional oil are finite as well. Which raises the question, is the energy source that transformed the world reaching a point where continued growth in production still possible?

Data from a variety of sources suggests that the world's production of conventional oil has reached a plateau, but the combined production of conventional (including natural gas liquids) and non-conventional oil is still rising. As production from conventional oil fields begins to decline, there is literally a race taking place to find new sources of conventional crude to offset these declines. If sufficient crude oil is not found, world oil production will plateau and eventually peak, leading to accessibility and affordability issues for many people.

Addressing the plateau and peak will require a reduction in the amount of oil (and energy in general) the world consumes. There will be a need for liquid fuels that can replace existing sources of oil and the development of new energy sources and technologies that restrict new demand to sources other than oil.

Whether future oil production leads to continued growth, a plateau, or a peak, accessibility and affordability issues will require jurisdictions to prepare for a world with less oil.

Table 1: Selected forecasts of global oil production, made between 1956 and 2005, which gave a date for the peak (61)
Pr – Probable; Cv – Conventional; Ncv – Non-conventional; xN – Excluding natural gas liquids

Date	Author/Group	Hydrocarbon	Ultimate (Gb)	Date of peak
1956	Hubbert	Cv oil	1250	"About the year 2000" (at 35 Mb/day)
1969	Hubbert	Cv oil	1350; 2100	1990 (at 65 Mb/day); 2000 (at 100 Mb/day)
1972	ESSO	Pr Cv oil	2100	"Increasingly scarce from ~2000"
1972	Report: UN Conference	Pr Cv oil	2500	"Likely peak by 2000"
1974	SPRU, UK	Pr Cv oil	1800 - 2480	No prediction
1976	UK DoE	Pr Cv oil	na	"About 2000"
1977	Hubbert	Cv oil	2000	1996 If unconstrained logistic; plateau to 2035 if production flat
1977	Ehrlich et al	Cv oil	1900	2000
1978	WEC/IFP	Pr Cv oil	1803	No prediction
1979	Shell	Pr Cv oil	na	"Plateau within the next 25 years"
1979	BP	Pr Cv oil	na	Peak (non-communist world): 1985
1981	World Bank	Pr Cv oil	1900	"Plateau - turn of the century"
1992	Meadows et al	Pr Cv oil	1800 - 2500	No prediction
1995	Petroconsultants	Cv Oil (xN)	1800	About 2005
1996	Ivanhoe	Cv oil	~2000	About 2010 (production mirrors discovery)
1997	Edwards	Pr Cv oil	2836	2020
1997	Laherrère	All liquids	2700	No prediction
1998	IEA	Cv oil	2300	ref. case 2014
1999	USGS	Pr Cv oil	~2000	Peak ~2010 (Magoon, 2000)b
2000	Bartlett	Pr Cv oil	2000 & 3000	2004 and 2019, respectively (Bartlett, 2000)
2002	BGR	Cv & Ncv oil	Cv: 2670	Combined peak in 2017
2003	Deffeyes	Cv oil		~2005 (Hubbert linearisation)
2003	Bauquis	All liquids	3000	Combined peak in 2020
2003	Campbell - Uppsala	All hydrocarbons		Combined peak ~2015 (includes gas infrastructure constraints)
2003	Laherrère	All liquids	3000	
2003	Energyfiles Ltd	All liquids	Cv: 2338	2016 (if 1% demand growth)
2003	Energyfiles Ltd	All hydrocarbons		Peak ~2020 (includes gas infrastructure constraints)
2003	Bahktiari	Pr Cv oil		2006 - 07
2004	Miller, BP: own model	Cv & Ncv oil		2025 all possible OPEC production used
2004	PFC Energy	Cv & Ncv oil		2018 (base case)
2005	Deffeyes	Cv oil		2005 (Hubbert linearisation)

Table 2: Selected forecasts of global oil production that forecast no peak before 2030 (61)
Cv – Conventional; Ncv – Non-conventional; +N – plus natural gas liquids

Date	Author /Group	Hydrocarbon	Ultimate (Gb)	Forecast date of peak (by study end-date)	World production	
					2020	2030
1998	WEC/IIASA-A2	Cv. oil		No peak	90	100
2000	IEA: *WEO 2000*	Cv. oil (+N)	3345	No peak	103	n/a
2001	US DoE EIA	Cv. oil	3303	2016 / 2037	Various	Various
2002	US DoE	Ditto		No peak	109	n/a
2002	Shell Scenario	Cv. & Ncv. oil	~4000	Plateau: 2025 - 2040	100	105
2003	"WETO" study	Cv. oil (+N)	4500	No peak	102	120
2004	Exxon-Mobil	Cv. & Ncv. oil		No peak	114	118
2005	IEA: *WEO 2005* Reference Sc. Deferred Invest.	 Ditto Ditto		 No peak No peak	 105 100	 115 105
2007	IEA: *WEO 2007* Reference Sc.	 Ditto		 No peak	 -	 116

Recommended readings from reference list

3. BP's *Statistical Review of World Energy* is widely cited and is a useful source of data. Its major shortcoming is that it relies on unverified government data. Data from the Energy Information Administration (for example, 9, 16, and 58) is always helpful, as is that from the International Energy Agency (for example, 1 and 8).

6. (Daniel Horowitz) and 26. (Kevin Mattson) give sobering accounts of President Jimmy Carter's attempts at informing the American public of the energy challenges they were facing in the late 1970s. Had they listened, things may have been very different now.

12. Matt Simmon's *Twilight in the Desert* is an interesting analysis of why Saudi Arabia may well have reached the peak of its production capacity. The description of the oil industry and the history of giant and super-giant oil fields is extremely well done.

24. Adams and Jeanrenaud's *Transition to Sustainability: Towards a Humane and Diverse World* is an all encompassing review of the major environmental challenges that we face today and how each challenge is interdependent. Although quite hopeful and wildly optimistic for the environmental movement, it still provides inspiring goals in "energizing the future".

37. Jean Laherrère's *The Hubbert Curve: Its strengths and weaknesses* is an excellent introduction to Hubbert's analysis techniques.

38. Maugeri's *Oil: never cry wolf—Why the petroleum age is far from over* was one of the few papers that attempted to show the flaws in the peak oil argument. The rebuttal from Meng and Bentley (39), although several years after Maugeri's original paper, was a well-written defense of peak oil.

41. *Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production* from the UKERC (Steve Sorrell, Jamie Speirs, Rodger Bentley, Ada Brandt, and Richard Miller) is probably the best summary of the peak oil debate that has been written to date.

50. Robert Hirsch's analysis of how oil shortages can be handled, *Mitigation of maximum world oil production: Shortage scenarios*, is a good overview of how the problem may have to handled should it arise.

References

1. **IEA.** *Key World Energy Statistics 2009.* Paris : International Energy Agency, 2009.

2. **Ren, Tao.** Petrochemicals from Oil, Natural Gas, Coal and Biomass: Energy Use, Economics and Innovation. *PhD Thesis.* s.l. : Utrecht University, Netherlands, 2009. http://igitur-archive.library.uu.nl/dissertations/2009 .

3. **Hirsch, Robert L, Bezdek, Roger and Wendling, Robert.** Peaking of world oil production and its mitigation. [book auth.] Daniel Sperling and James S. Cannon. *Driving Climate Change: Cutting Carbon from Transportation.* s.l. : Academic Press, 2007, pp. 9-27.

4. **BP.** *BP Statistical Review of World Energy.* London : BP plc, 2009.

5. **Economagic.** Series Title: Price of West Texas Intermediate Crude; Monthly NSA, Dollars Per Barrel . *Economagic.com: Economic Time Series Page .* [Online] n.d. [Cited: June 30, 2010.] http://www.economagic.com/em-cgi/data.exe/var/west-texas-crude-long.

6. **Horowitz, Daniel.** *Jimmy Carter and the Energy Crisis of the 1970s - The "Crisis of Confidence" speech of July 15, 1979.* s.l. : Bedford/St. Martin's, 2005. ISBN 0-312-40122-1.

7. **Caruso, Guy.** When Will World Oil Production Peak? [Online] June 13, 2005. [Cited: June 26, 2010.] http://www.blacksandspetroleum.com/reportusa.pdf.

8. **IEA.** *World Energy Outlook 2008.* Paris : International Energy Agency, 2008. ISBN: 978-92-64-04560-6.

9. **EIA.** *International Energy Outlook 2009.* Washington : Energy Information Administration, 2009.

10. **Johnsson, Filip, et al.** Stakeholder attitudes on Carbon Capture and Storage: An international comparison. *International Journal of Greenhouse Gas Control.* March 2010, Vol. 4, 2, pp. 410-418.

11. **Bentley, Roger, et al.** *UKERC Review of Evidence for Global Oil Depletion - Technical Report 7: Comparison of global oil supply forecasts.* s.l. : UK Energy Research Council, 2009. REF UKERC/WP/TPA/2009/022.

12. **Simmons, Matthew.** *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy .* s.l. : Wiley, 2005. 0-471-73876-X.

13. **Babadagli, Tayfun.** Development of mature oil fields: a review. *Journal of Petroleum Science and Engineering.* June 2007, Vols. 3-4, pp. 221-246.

14. **Gold, Russel and Davis, Ann.** Oil officials see limit looming on production. *Wall Street Journal.* [Online] November 19, 2007. [Cited: June 28, 2010.] http://online.wsj.com/article_print/SB119543677899797558.html.

15. **Knovel.** *Handbook of Offshore Engineering.* [ed.] Subrata K. Chakrabarti. Amsterdam : Elsevier, 2005. Vols. 1-2. ISBN 978-0-0805-2381-1.

16. **EIA.** Country Analysis Briefs. *Energy Information Administration.* [Online] n.d. [Cited: June 30, 2010.] http://www.eia.doe.gov/cabs/index.html.

17. **Williams, Nigel.** New focus on tar sands. *Current Biology.* June 8, 2010, Vol. 20, 11, pp. R461-R462.

18. **Kontorovich, A.E., et al.** Geology and hydrocarbon resources of the continental shelf in Russian Arctic seas and the prospects of their development. *Russian Geology and Geophysics,.* January 2010, Vol. 51, 1.

19. **Sudiro, Maria and Bertucco, Alberto.** Production of synthetic gasoline and diesel fuel by alternative processes using natural gas and coal: Process simulation and optimization . *Energy.* Deceber 2009, Vol. 34, 12, pp. 2206-2214.

20. **Van Vliet, Oscar P.R., Faaij, André P.C. and Turkenburg, Wim C.** Fischer–Tropsch diesel production in a well-to-wheel perspective: A carbon, energy flow and cost analysis. *Energy Conversion and Management.* April, April 2009, Vol. 50, 4, pp. 855-876.

21. **Hu, Xiaojun, et al.** Energy for sustainable road transportation in China: Challenges, initiatives and policy implications. *Energy.* 2010. Article in press.

22. **Elcock, Deborah, Gasper, John and Moses, David O.** *Environmental regulatory drivers for coal bed methane.* s.l. : Argonne National Laboratory, 2002. W-31-109-ENG-38.

23. **Kavanagh, Richard J., et al.** Detecting oil sands process-affected waters in the Alberta oil sands region using synchronous fluorescence spectroscopy. *Cheosphere.* June 2009, Vol. 76, 1, pp. 120-126.

24. **Adams, W.M. and Jeanrenaud, S.J.** *Transition to Sustainability: Towards a Humane and Diverse World.* Gland, Switzerland : International Union for Conservation and Nature, 2008. IUCN Future of Sustainability Initiative 2008. ISBN: 978-2-8317-1072-3.

25. **OECD/IEA.** *Energy Technology Perspectives 2008 -- Scenarios and Strategies to 2050.* s.l. : Organization for Economic Cooperation and Development - International Energy Agency, 2008. ISBN 978-92-64-04142-4.

26. **Verbruggen, Aviel and Al Marchohi, Mohamed.** Views on peak oil and its relation to climate change policy. *Energy Policy.* June 2010. Article in press.

27. **Hall, Charles A.S. and Day Jr., John W.** Revisiting the limits to growth after peak oil. *American Scientist.* May/June 2009, Vol. 97, 3, pp. 230-237.

28. **WNA.** Nuclear Power in Canada Appendix 2: Alberta . *World Nuclear Association.* [Online] February 2010. [Cited: June 24, 2010.] http://www.world-nuclear.org/info/inf49a_Alberta_Tar_Sands.html.

29. **Addison, Keith.** Is ethanol energy efficient? *Journey to forever.* [Online] n.d. [Cited: June 24, 2010.] http://journeytoforever.org/ethanol_energy.html.

30. **Webb, Simon.** Europe crisis, China fiscal policy risks for oil. *Reuters.* [Online] May 9, 2010. [Cited: June 29, 2010.] http://www.reuters.com/article/idUSTRE6482BU20100509.

31. **De Castro, Carlos, Miguel, Luis Javier and Mediavilla, Margarita.** The role of non conventional oil in the attenuation of peak oil. May 2009, Vol. 37, 5, pp. 1825-1833.

32. **Exxon-Mobil.** Crude Oil Supply . *Gasoline: A global market to meet your needs.* [Online] n.d. [Cited: June 28, 2010.] http://www.exxonmobil.com/corporate/newsroom/publications/c_gas_prices/c_crudeoil_ix.html.

33. **Hubbert, M. King.** Nuclear Energy and the Fossil Fuels. [Online] March 7-9, 1956. [Cited: June 29, 2010.] http://www.hubbertpeak.com/hubbert/1956/1956.pdf.

34. **Deffeyes, Ken.** *Beyond Oil - The view from Hubbert's Peak.* s.l. : Hill and Wang, 2005.

35. **Salameh, Mamdouh G.** Oil Crises, Historical Perspective. *Encyclopedia of Energy.* 2004, Vol. 4, pp. 633-648.

36. **Mattson, Kevin.** *"What the heck are you up to, Mr.President?" .* New York : Bloomsbury, 2009. ISBN 1-59691-521-8.

37. **Laherrère, J.H.** The Hubbert Curve: Its strengths and weaknesses. [Online] n.d. [Cited: June 28, 2010.] Version proposed to Oil and Gas Journal on Feb 18 2000. http://dieoff.org/page191.htm.

38. **Maugeri, L.** Oil: never cry wolf—Why the petroleum age is far from over. *Science.* 2004, Vol. 304, pp. 1114–1115.

39. **Meng, Q.Y. and Bentley, R.W.** Global oil peaking: Responding to the case for 'abundant supplies of oil'. *Energy.* August 2008, Vol. 33, 8, pp. 1179-1184.

40. **Höök, Mikael, Hirsch, Robert and Aleklett, Kjell.** Giant oil field decline rates and their influence on world oil production. *Energy Policy.* June 2009, Vol. 37, 6, pp. 2262-2272.

41. **Sorrell, Steve, et al.** *Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production.* s.l. : UK Energy Research Council, 2009. Available from http://www.ukerc.ac.uk/support/Global%20Oil%20Depletion. ISBN 1-903144-0-35.

42. **CERA.** Peak Oil Theory – "World Running Out of Oil Soon" – Is Faulty; Could Distort Policy & Energy Debate. *Cambridge Energy Research Associates.* [Online] November 12, 2006. [Cited: June 29, 2010.] http://www.cera.com/aspx/cda/public1/news/pressReleases/pressReleaseDetails.aspx?CID=8444.

43. **Kontorovich, A.E.** Estimate of global oil resource and the forecast for global oil production in the 21st century. *Russian Geology and Geophysics.* 2009, Vol. 50, 4.

44. **UN.** Joint Oil Data Initiave (JODI): Project on Monthly Oil Statistics. *United Nations Statistics Division.* [Online] 2010. [Cited: June 26, 2010.] http://unstats.un.org/unsd/energy/jodi.htm.

45. **Klare, Michael T.** *Rising Powers, Shrinking Planet: The New Geopolitics of Energy.* s.l. : Holt Paperbacks, 2009. ISBN 0-805-08921-7 .

46. **Knight, Helen.** Wonderfuel gas. *New Scientist.* June 12, 2010, Vol. 206, 2764, pp. 44-47.

47. **APERC.** *A Quest for Energy Security in the 21st Century.* Institute of Energy Economics. Tokyo : Asia Pacific Energy Research Centre, 2007. www.ieej.or.jp/aperc. ISBN 978-4-931482-35-7.

48. **Hughes, Larry and Shupe, Darren.** Applying the four 'A's of energy security as criteria in an energy security ranking method. [book auth.] Benjamin Sovacool (editor). *Routledge Handbook of Energy Security.* s.l. : Routledge, 2010.

49. **Hofmeister, John.** *Why We Hate the Oil Companies: Straight Talk from an Energy Insider.* s.l. : Palgrave Macmillan, 2010. ISBN 0-230-10208-5.

50. **Hirsch, Robert.** Mitigation of maximum world oil production: Shortage scenarios. *Energy Policy.* February 2008, Vol. 36, 2, pp. 881-889.

51. **IEA.** Oil Markets and Emergency Preparedness . *International Energy Agency.* [Online] n.d. [Cited: June 28, 2010.] http://www.iea.org/about/ome.htm.

52. **Campbell, Colin.** The Oil Depletion Protocol. [Online] n.d. [Cited: June 29, 2010.] http://www.oildepletionprotocol.org/.

53. **Maconachie, Roy, Tanko, Adamu and Zakariy, Mustapha.** Descending the energy ladder? Oil price shocks and domestic fuel choices in Kano, Nigeria. *Land use policy.* October 2009, Vol. 26, 4, pp. 1090-1099.

54. **Hughes, Larry.** The four 'R's of energy security. *Energy Policy.* June 2009, Vol. 37, 6, pp. 2459-2461.

55. **Bilgin, Mert.** Geopolitics of European natural gas demand: Supplies from Russia, Caspian and the Middle East. *Energy Policy.* November 2009, Vol. 37, 11, pp. 4482-4492.

56. **Goldthau, Andreas.** Rhetoric versus reality: Russian threats to European energy supply. *Energy Policy.* 2008, Vol. 36, 2, pp. 686-692.

57. **Shealy, Malcolm and Dorian, James P.** Growing Chinese coal use: Dramatic resource and environmental implications. *Energy Policy.* May 2010, Vol. 38, 5, pp. 2116-2122.

58. **EIA.** *Annual Energy Outlook.* Washington : Energy Information Administration, 2010. DOE/EIA-0383(2010).

59. **Biello, David.** Waste Not, Want Not: Energy via the Smart Grid. *ScientificAmerican.com.* [Online] February 9, 2009. [Cited: June 22, 2010.] http://www.scientificamerican.com/podcast/episode.cfm?id=6BCDB36C-A91E-8688-8CCA29A380672B65.

60. **Hughes, Larry.** Meeting residential space heating demand with wind-generated electricity. *Renewable Energy.* November 2009b, p. Article in press.

61. **Bentley, Roger and Boyle, Godfrey.** Global oil production: forecasts and methodologies. *Environment and Planning B: Planning and Design.* 2008, Vol. 4, pp. 609-626.

62. **EIA.** *International Energy Outlook - 2010.* Washington : Energy Information Adinistration, 2010. DOE/EIA-0484(2010).

63. **Exxon-Mobil.** Global liquids supply grows. *Exxon-Mobil.* [Online] n.d. [Cited: June 30, 2010.] http://www.exxonmobil.com/Corporate/energy_o_sup_liquid.aspx.

64. **OPEC.** *Oil outlook to 2030 - OPEC Secretariat background paper.* s.l. : Organization of Petroleum Exporting Countries, 2010. 12th International Energy Forum.