Peak Oil and the Fate of Humanity

“The energy crisis has not yet overwhelmed us, but it will if we do not act quickly.”

(US President Jimmy Carter’s *Address to the Nation on Energy*, 18 April 1977)

Hans Zandvliet[1]

New York, January 2011

Table of Contents

---

[1] Hans Zandvliet graduated as a Dutch civil engineer in 1987. From 2002 until 2008, he worked on sanitation projects in Bolivia. Currently he lives in New York, studying - as an autodidact - the interactions between climate change, depletion of fossil energy and other natural resources, human population growth, the economic crisis and proposed solutions. Contact: **hans.ut.fryslan@gmail.com**

Introduction

Peak oil does not mean that oil production ends. It refers to the maximum oil production capacity, after which oil production goes into a terminal decline until nearly ending by the end of the century. There is conclusive evidence that we are very near, or maybe even past the moment of peak oil.

The 1970s saw the first signs of peak oil and its consequences in the decades ahead. It became clear that U.S. oil production had peaked in 1970, just like the oil geologist Marion King Hubbert had forecast 14 years before, and that world oil production would peak around the turn of the century. The Club of Rome warned in 1972 in its report “The Limits to Growth”, that we could not continue depleting the world’s natural resources. The two oil crises of 1973 and 1979 showed us what the consequences were of just a slight and temporary oil shortage. President Jimmy Carter was fully aware and wanted to act boldly. His “Address to the Nation on Energy”[2] in 1977 was a courageous wakeup call, but as we know by now, his warnings were rejected. Alternative technologies of renewable energy production, which should have been developed vigorously to make a timely energy transition, continued their underdeveloped and semi-dormant existence.

Currently, world energy supply is still composed of more than 80% fossil fuels (coal, oil and natural gas) of which 40% consists of oil. Sources of renewable energy (hydropower, solar panels, wind turbines, etc.) are not ready yet to take over: to date they do not even make up 3% of the world’s energy supply. These data, 34 years after President Jimmy Carter offered us the one chance we dismissed, now indicate an inevitable global energy crisis, which will occur in the course of this very decade and which could eventually overwhelm humanity as we know it today.

Mechanized agriculture and the transport of products and people depend almost entirely on oil: diesel-driven tractors and combines to plough, sow and harvest; pesticides and chemical fertilizers made from oil and natural gas to boost crop yields; diesel-driven trucks to transport the harvests to food processing factories and cities. Without oil, our very food supply will be in jeopardy. Buses run on diesel and cars on gasoline for urban transport; airplanes on kerosene and ships on fuel-oil to transport people and cargo around the world. The global economy totally depends on the worldwide transport of people and cargo, while the alternatives are still immature or even nonexistent.

The fundamental problem with our current economic model is that it has to grow perpetually, or it enters a crisis. This economic model is not compatible anymore with a finite world of dwindling natural resources. When oil production and other base materials start to diminish progressively in the course of this century, the physical means of economic growth will vanish, so we will enter an age of permanent economic decline. It is quite unlikely that our present globalized capitalist economic model, designed for growth, is able to adapt to such an age of economic decline. If we keep clinging to this now inapt economic model, as our leading politicians, bankers, CEOs and economists (the haves) would have us (have-nots) do, it will ultimately cause a socio-economic collapse in those countries most dependent on fossil fuels.

Meanwhile, the oil sector does not want to inform the public about the reality of peak oil, to protect their own short-term economic interests, and world leaders and politicians do not dare to for fear of not being re-elected, as President Jimmy Carter found out. Thus, while the “haves” keep themselves busy with the equivalent of “rearranging the deckchairs of the Titanic” (or maybe even worse, arranging their privileged seats in the lifeboats), human society remains unaware of, and unprepared for the calamitous consequences of the imminent decline of world oil production. Therefore, the objective of this article is to raise public awareness and to broaden public knowledge of the coming energy crisis and its consequences.

---

[2] President Jimmy Carter’s address to the Nation: **http://millercenter.org/scripps/archive/speeches/detail/3398**

Peak Oil

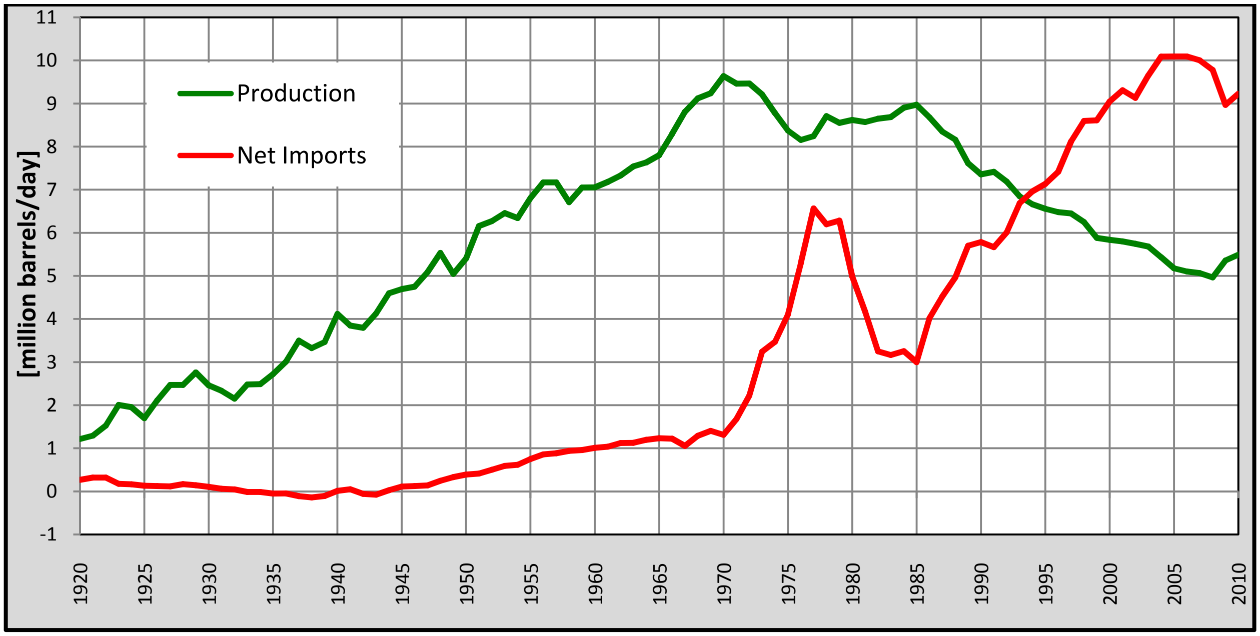
History

The history of petroleum started in the 1850s when the first petroleum wells were drilled to extract petroleum from the rocks (the Latin word for rock is petra and for oil oleum, hence the name "oil from the rocks"). Since the start of the 20th century various people have warned that oil is a finite resource and that it had to run out one day, but predictions were always wrong and with all the new oilfields that were still being found, petroleum companies got used to dismissing and ridiculing them.

Marion King Hubbert (1903–1989) was a petroleum geologist working at Shell's research laboratory in Houston, Texas. In 1956 he presented a paper at the American Petroleum Institute in San Antonio, Texas, forecasting that U.S. oil production would peak around 1970 (Hubbert, 1956). As usual he was criticized and even ridiculed by his contemporaries, but when 1970 came around, his forecast turned out to be spot-on. Ever since, in spite of frantic attempts, U.S. oil production has been in terminal decline. In 1993 U.S. net oil imports overtook domestic production and by 2005 net imports were higher than domestic oil production had ever been (in 1970), as graph 1 shows. Now, the big questions are:

- How could Hubbert forecast peak oil in the U.S. as much as 14 years in advance?
- What does this imply with respect to the peaking of global oil production?

Graph 1: U.S. oil production and net imports (1920–2010)



Source: EIA (U.S. Energy Information Administration): **http://www.eia.gov/dnav/pet/pet_move_top.asp**

Principle of Hubbert's Peak

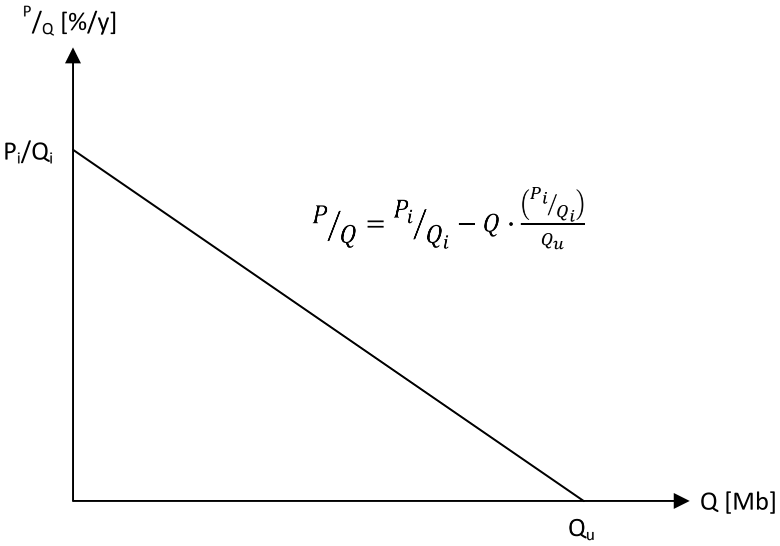
The principle of Hubbert's reasoning can be visualized with the analogy of a pond full of fish. Initially fishing is exciting and more friends come over to join in the bonanza of catching big fish. However, the more fish are caught, the less are left and fishing gets harder and slower, until it takes ages to catch the last small fish. Of course, the fish are analogous to oil fields and the fishermen to oil companies.

The mathematical part of this paragraph is added to complete the explanation of Hubbert's curve, but it is not essential for understanding the rest of this article. So if you feel incapable of dusting off your secondary school mathematics of so many years ago, feel free to skip it.

Graph 2 shows a straight declining line, which represents the theoretical decline of oil production. As Kenneth Deffeyes said about Hubbert's method: "Since we want to estimate likely future trends, nothing beats a straight line on a graph" (Deffeyes, 2005: 36). The horizontal axis (Q) gives the accumulated oil production from the beginning of the exploitation, so it represents the sum of all annual amounts of oil produced until a certain year.

The vertical axis ($^{P}/_{Q}$) means the quotient of the oil production of a certain year and the accumulated oil production until that year. Hubbert discovered that, after an erratic start, a linear trend emerges between $^{P}/_{Q}$ and Q. Once this linear trend emerges, the line can be extended until it crosses the horizontal axis. This is the point where annual production has decreased to zero, which means that the limit of the ultimately recoverable amount of oil is reached and no more oil can be produced. This is how, within certain limits of accuracy, the ultimately recoverable amount of oil can be estimated, although not all of it may yet be discovered.

Graph 2: Hubbert's P/Q graph



The mathematical formula of a linear equation is as follows (1):

$$y = a \cdot x + b \tag{1}$$

Or rearranged to let the order and sign coincide with the upcoming formula (2):

$$y = b - x \cdot a$$

Where:

- a = $^{\Delta y}/_{\Delta x}$ = the incline of the line (a negative value indicates a declining line)
- b = value where the line crosses the vertical axis.

Translating the mathematical parameters into petroleum parameters gives formula (2):

$$P/_{Q} = P_i/_{Q_i} - Q \cdot \frac{\left(P_i/_{Q_i}\right)}{Q_u} \tag{2}$$

Or transposed, to make an easier link with the upcoming formula (3):

$$P/_{Q} = P_i/_{Q_i} \cdot \left(1 - Q/_{Q_u}\right)$$

Where:

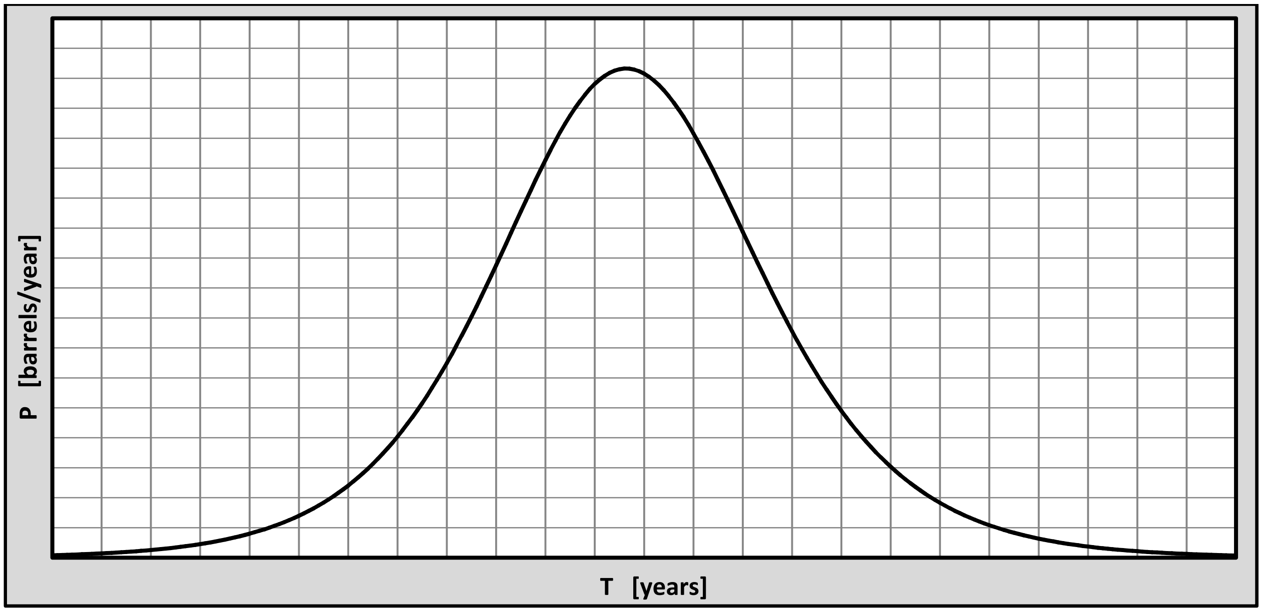
- P = oil production of a certain year $[^{\text{barrel}}/_{\text{year}}]$
- P_i = initial oil production in the first year $[^{\text{barrel}}/_{\text{year}}]$
- Q = x = cumulative oil production until a certain year [barrel]
- Q_i = initial cumulative oil production in the first year [barrel]
- Q_u = accumulation of ultimately recoverable oil [barrel]
- $P/_{Q}$ = y = quotient of annual production and cumulative production of a certain year $[^{\%}/_{\text{year}}]$
- $P_i/_{Q_i}$ = b = the value where the line crosses the vertical axis of the graph $[^{\%}/_{\text{year}}]$
- $\frac{\left(P_i/_{Q_i}\right)}{Q_u}$ = a = the decline of the line $[^{\%}/_{(\text{year} \cdot \text{barrel})}]$

Although graph 2 determines how much oil can be expected to be ultimately recovered, it does not indicate annual oil production. To show that, formula (2) has to be converted to formula (3) by multiplying both sides of the equation with ‘Q’:

$$P = Q \cdot {}^{P_i}\!/_{Q_i} \cdot \left(1 - {}^{Q}\!/_{Q_u}\right) \tag{3}$$

Now the annual production can be calculated, starting with the first year of production. Smart readers may notice that in order to calculate Q one needs to know P, while in order to calculate P one needs to know Q, but this can be solved iteratively (nowadays an Excel sheet solves this tiresome work in a second). The results show the theoretical course of oil production; a bell shaped curve named the Hubbert’s curve, as shown in graph 3:

Graph 3: Hubbert's Curve



One last step is missing. This theoretical curve starts with production year one, but that is not yet related to calendar years. Basically, what needs to be done is to move Hubbert’s curve horizontally until it fits best with the historical production data. The best fit is to let the year of theoretical cumulative production coincide with the calendar year of historical cumulative production. The outcome will indicate when peak oil is scheduled to happen.

Peak Oil in the USA

This is how Hubbert was able to forecast peak oil in the U.S. 14 years before it happened, and he proved to be exactly right (Hubbert, 1956). Before examining world oil production, let’s cross-examine this method with the oil production data of the U.S. The U.S. oil fields are most suitable for this purpose, because they are the oldest and most mature oil fields in the world:[3]

- Production already started back in the 1850s
- Peak oil production was reached in 1970 (120 years after production started)
- By 2009 production had declined to 55% of peak production (40 years after it peaked)
- By 2009 85% of the estimated ultimately recoverable oil had already been produced, which means there is only 15% of future oil production left to make forecast mistakes, so they cannot be very big anymore.

Graph 4 shows the relation between $^{P}/_{Q}$ and Q of U.S. oil production from 1860 to 2009. As of 1958 a linear trend starts to emerge. Extending this linear trend, it crosses the x-axis at 232.32 billion barrels[4] of ultimately recoverable oil, as mentioned in the formula in graph 4. This reveals an interesting question still: “How was Hubbert

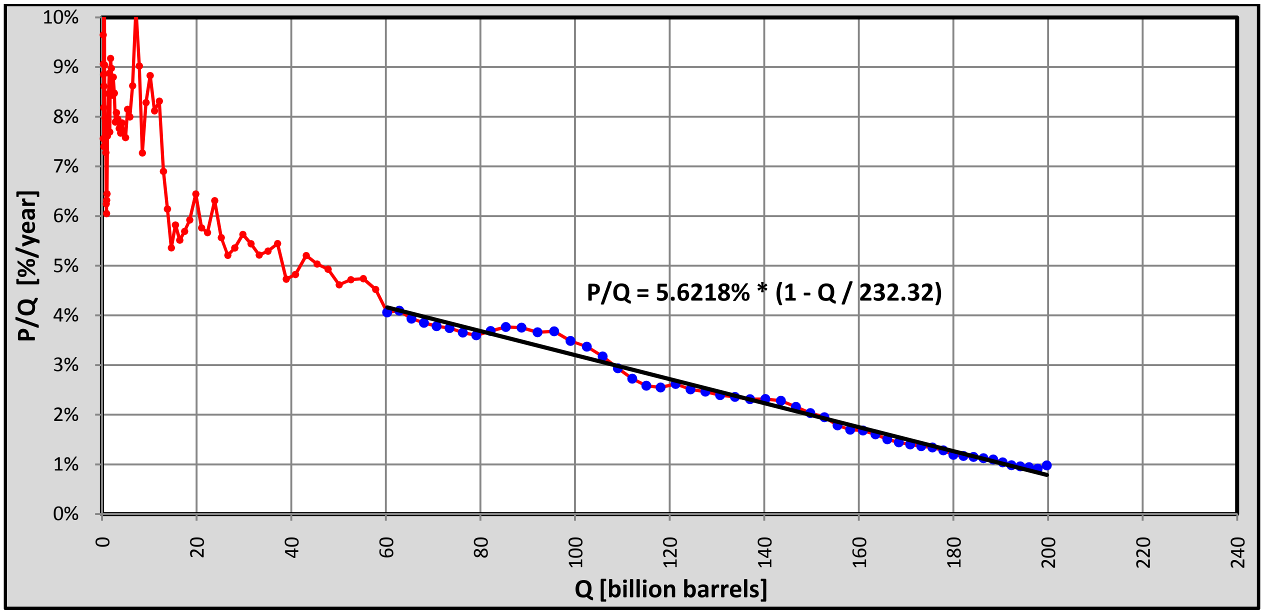
---

[3] EIA: **http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS1&f=A**

[4] Kenneth Deffeyes arrived at 228 billion barrels. His trend line was based on a data range of 1958–2003, so the updated data range of 1958–2009 that I used has altered this figure slightly (Deffeyes, 2005: 36).

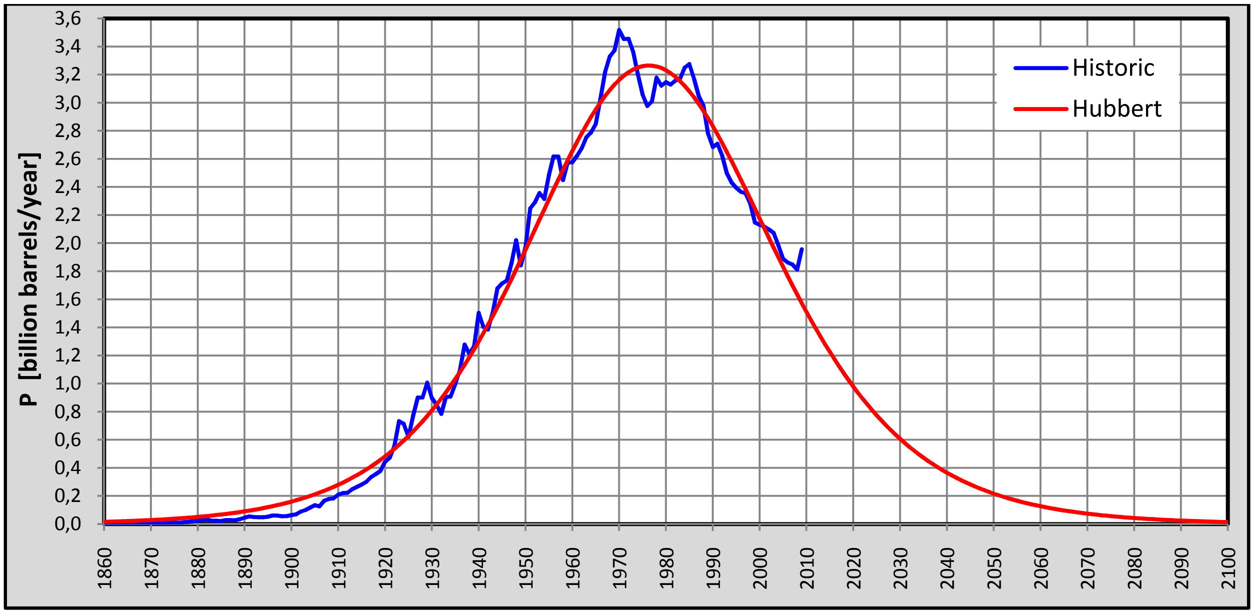
able to forecast U.S. peak oil production in 1956 already, two years before this linear trend started to appear?" The secret is that Hubbert studied the oil discovery data, and since the production data lagged behind the discovery data by 11 years, he was able to, as it were, look 11 years into the future (Deffeyes, 2001: 145).

Graph 4: P/Q graph of U.S. oil production



Based on the formula in graph 4, the Hubbert's curve of graph 5 can be calculated. It shows U.S. annual oil production from 1860 to 2009 and Hubbert's curve until 2100. It clearly shows the strong correlation between theory and history, so it proves that Hubbert's method is reliable.

Graph 5: Hubbert's curve of U.S. annual oil production (1860–2100)



Peak Oil in the World

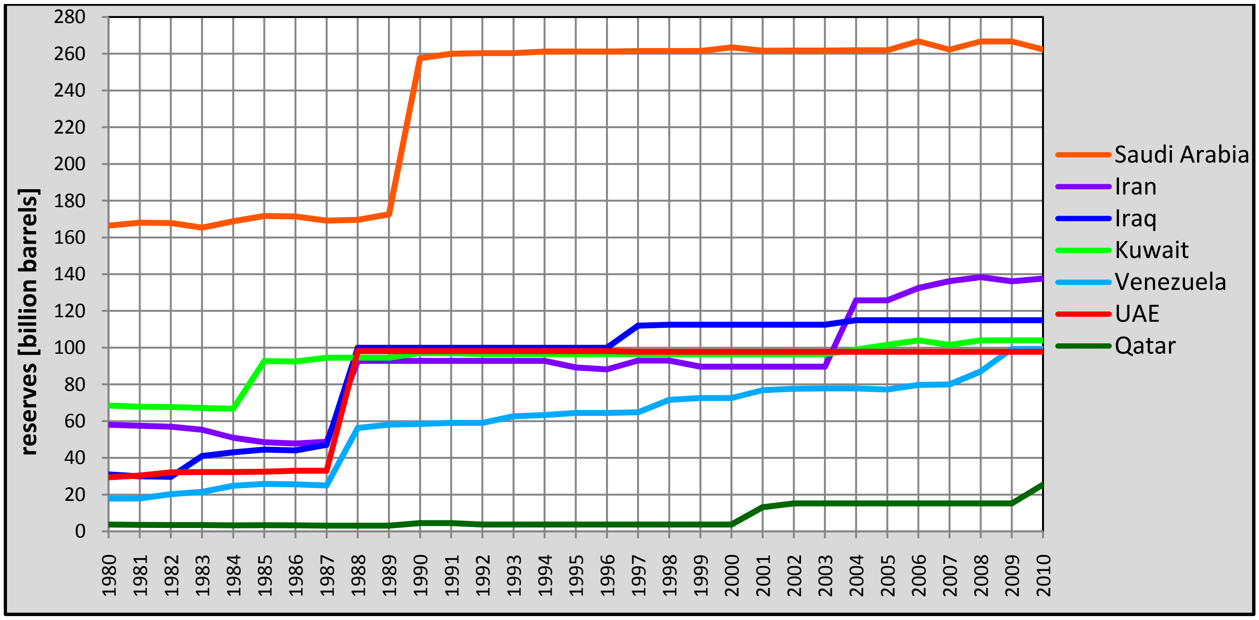
Hubbert calculated the world's peak oil production as well and continued to improve his calculations over the years, like several other oil geologists and experts mentioned in table 1. However, it is far from easy to get those data together from all over the world. The main problem is that since the 1980s production data have been shrouded in secrecy by the oil producing countries and oil companies, for economic and political reasons. At the same time, the oil reserves declared by the OPEC countries made suspiciously large jumps without being backed by new oil field discoveries. Just before those suspicious jumps, OPEC decided to determine the oil production quota of its members by their reserves, so for individual members it became quite attractive to declare bigger reserves in order to be allowed to produce more oil.

Table 1: Global peak of oil production according to various oil geologists and experts (Hirsch, 2005: 19)

Name	Nationality	Profession	Estimation
Marion King Hubbert	USA	oil geologist	2001–2004
A.M.S. Bakhitari	Iran	Iranian oil executive	2006–2007
C. Skrebowski	UK	oil analyst and journalist	after 2007
Matthew R. Simmons	USA	investment banker	2007–2009
Kenneth S. Deffeyes	USA	oil geologist	before 2009
David Goodstein	USA	vice provost Cal. Tech.	before 2010
Colin J. Campbell	UK	oil geologist	2010

Graph 6 shows these unaccountable jumps in the figures of seven major OPEC countries. Since then the official data were no longer reliable, while the real data became state and company secrets. To overcome this lack of public and reliable data, oil geologists studied the data from before the 1980s, estimated the artificial exaggerations and subtracted them from the official data to arrive at credible estimates. Other sources of data were included from oil shipments, imports and refineries from around the world (Campbell and Laherrère, 1998; Deffeyes, 2001; Deffeyes, 2005; Simmons, 2005).

Graph 6: Unaccountable jumps in declared oil reserves of seven OPEC countries (1980–2010)



Source: EIA International Energy Statistics[5]

Personal Calculations

Kenneth Deffeyes was a direct colleague of King Hubbert and he explained in great detail how to calculate Hubbert's peak (Deffeyes, 2005). As an engineer with a fondness for cracking arithmetic puzzles, I felt really tempted to do the math myself, but from where would I get reliable oil production data? From earlier calculations of fossil carbon emissions, I knew the database of CDIAC[6] very well: it offers annual emission data of all countries in

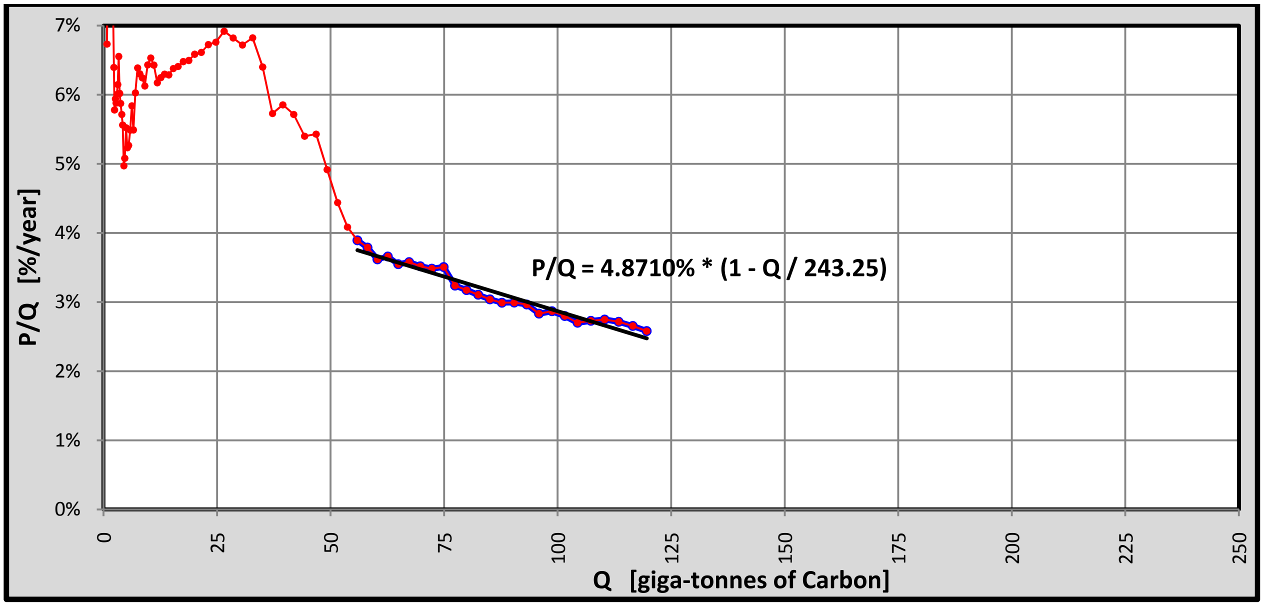
---

[5] The 'proven' oil reserves of the OPEC countries can be freely downloaded from EIA's website at: **http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=57&aid=6&cid=CG9,&syid=1980&eyid=2010&unit=BB**

[6] CDIAC = Carbon Dioxide Information and Analysis Center of the U.S. Department of Energy (DoE): **http://cdiac.ornl.gov/trends/emis/meth_reg.html**

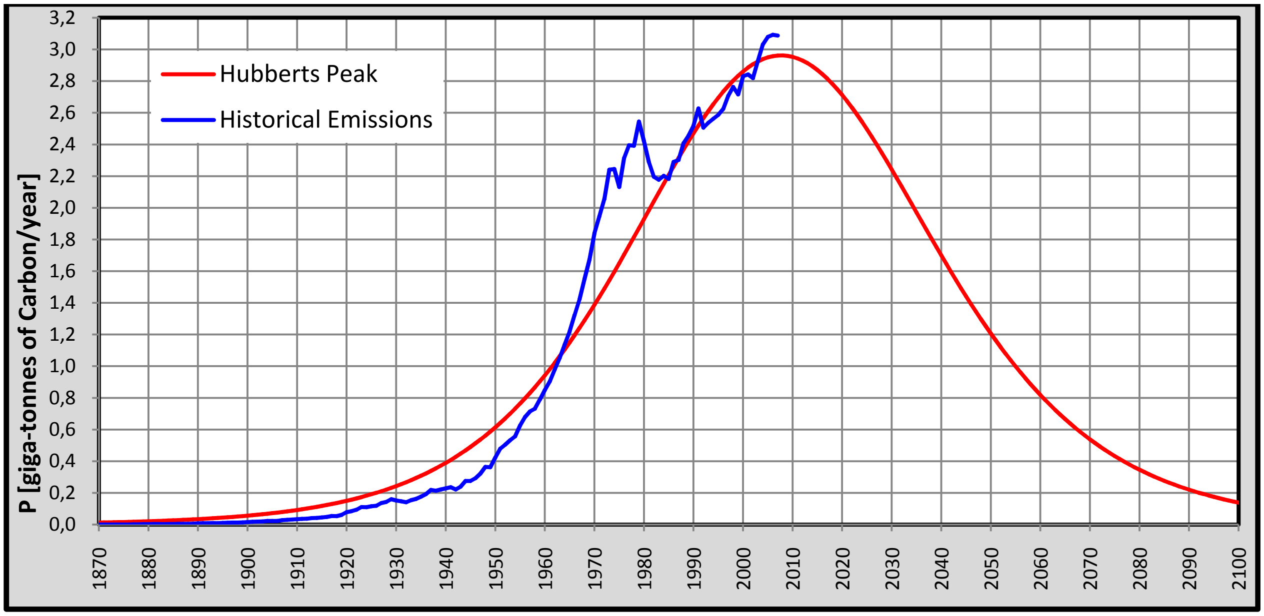
the world as far back as 1750 and it distinguishes between solid (coal), liquid (oil) and gaseous (natural gas) fossil carbon emissions. I realized it made an excellent proxy for the world's oil production data, because the same amount of oil will always release the same amount of CO_2 and H_2O when burnt. The unit in the graphs 7 and 8 changes from barrels of oil to tonnes of carbon, but the Hubbert's curve maintains the same shape. That is how I started my own peak oil calculations based on the CDIAC data of fossil carbon emissions from liquid fossil fuels. Graph 7 shows the relation between $^P/_Q$ and Q: as of 1983, perfectly in line with Deffeyes' calculations (Deffeyes, 2005: 43), the anticipated linear trend started to emerge again.

Graph 7: P/Q graph of global fossil carbon emissions from liquid fossil fuels



Based on the equation in graph 7 Hubbert's curve can be calculated again as shown in graph 8. The blue line shows the historic annual carbon emissions and the red line represents the forecasted emissions according to Hubbert. Essentially my calculations turn out to be smack in the middle of the range of forecasted peak oil years as mentioned in table 1: 2008. It also happens to coincide with the record oil price of $147/barrel on 12 July 2008. If Hubbert's curve holds, we can expect annual declines in world oil production of 0.8% in 2015, 1.3% in 2020, 2.3% by 2030, 3.1% by 2040 and up to 4.5% after 2050.

Graph 8: Hubbert's curve of global fossil carbon emissions from liquid fossil fuels (1870–2100)

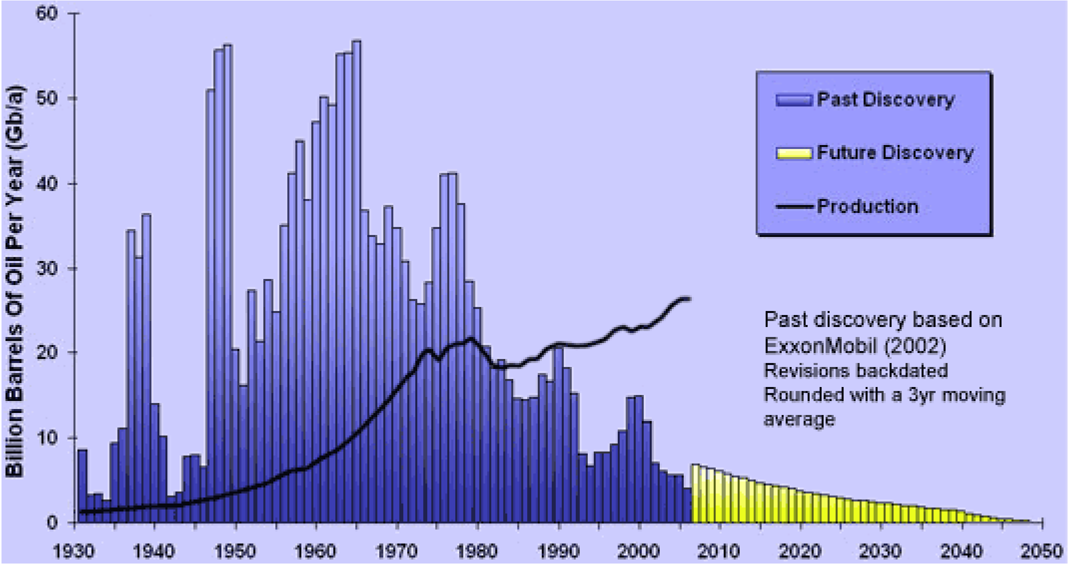


To put these production declines in perspective, during the economic recession of 1980–1983 (after the second oil crisis of 1979), oil consumption fell by 3.8% per year. This shows that just a few percentage points of annual decline results in serious economic hardship. Moreover, there are some essential aggravating differences in the imminent decline of global oil production. This time it will not be a temporary decline, from which we can hope to recover soon, but a terminal decline until the oil runs out completely. This time the decline of oil consumption will not be the result of an economic recession, but the driving force behind it.

Oil Discoveries

Another persuasive indicator that we are approaching (or even past) peak oil and that there is little hope of postponing it with new oil discoveries, is the history of discovered oil fields. The blue bars in graph 9 show this history. In spite of the erratic ups and downs of fortune, a bell-shaped Hubbert's curve can be imagined with its peak in the 1960s. The yellow bars represent the oil discovery forecasts. The black line is the same[7] as the blue line in graph 8: global oil production.

Graph 9: Global oil discoveries compared with global oil production (1930–2050)



Source: Energy Bulletin (**http://www.energybulletin.net/primer.php**)

So oil discoveries peaked back in the 1960s and what is found nowadays, apart from the incidental thrills of fortune, is only a fifth or a sixth of what used to be found in the good ol' sixties. Nowadays we are consuming 4–6 barrels of oil for every new barrel found, so we are rapidly depleting the existing reserves (Deffeyes, 2001; Deffeyes, 2005, Simmons, 2005).

In 2007 Brazil announced they had discovered 10 billion barrels of oil on their Atlantic shores. In 2008 those estimates went up to 33 billion barrels and by 2009 there were even rumours of 150 billion barrels. However, apparently those estimates were way too euphoric, because according to the press information on their own website, in April 2010 PetroBras estimated the ultimately recoverable oil reserves of their offshore Santos Basin and Campos Basin at 10.6–16.0 billion barrels.[8] It may still sound impressive, but since actual global oil consumption is as much as 31 billion barrels a year, it only means 4–6 months of global oil supply.

Moreover, those oil fields are not easily accessible: those basins are some 200 km offshore from Rio de Janeiro where the Atlantic Ocean is more than 2 km deep, and where boreholes have to be drilled through 3 km of sedimentary rock and another 2 km of salt. Such conditions are even more challenging than those which resulted in the Deepwater Horizon disaster in the Gulf of Mexico in April 2010. Development of those basins will take 5–10 years and will be laborious and slow, so it will not detain the imminent decline of global oil production.

---

[7] They only appear different because the scales and units (oil versus carbon) are different. It also shows that the CDIAC data of global fossil carbon emissions from liquid fuels are indeed a good proxy for global oil production.

[8] PetroBras, News Agency: **http://www.agenciapetrobrasdenoticias.com.br/default_en.asp**

Meanwhile other disappointing news gets out: CNN[9] announced in October 2010 that the USGS (U.S. Geological Survey) lowered its 2002 estimates of conventional, undiscovered oil in the National Petroleum Reserve in Alaska by 92% (from 10,600 million down to 896 million barrels). So much for the great Alaskan oil reserves.

Energy Return on Energy Invested

There are still enormous amounts of oil to be extracted, but it is not always worth the effort. If it takes more energy than the energy you get back from it, it is no longer profitable to do it. If it takes a fox more energy to catch a hare, then he would get back from eating it, he is clever enough to quit. That is why the concept of Energy Return on Energy Invested (ERoEI) is so important to understand the limits of oil production (Heinberg, 2007; Martenson, n.d.; Ruppert, 2009).

Illustration 1: A 19th century wooden drilling rig and a modern one for deep-sea drilling

At the start of the oil age, drilling was done with small wooden drilling rigs (see left picture of illustration 1), drilling depths were just a few hundred meters and light sweet crude came rushing out. ERoEI was over 100:1, so energy-wise (as well as economically) the oil business was highly profitable in spite of oil prices as low as $2–$3/barrel.

The days of such profitable oil fields are long gone, so the oil companies turn to ever more remote, deep and difficult places, like the depths of the Gulf of Mexico and the Brazilian Atlantic, and the tar sands of Canada and Venezuela (which have to be heated with steam to wash the tar from the sand, which uses enormous amounts of water and energy). They are even planning to drill in the Arctic Ocean, off the coast of Greenland and around Antarctica, with all the technical and logistical problems (freezing equipment, drifting sea ice and icebergs) and environmental risks that implies. To meet all those challenges, equipment needs to be ever bigger, more powerful and more expensive to make (energy-wise as well as economically). The picture on the right in illustration 1 shows a deep-ocean drilling ship: it even has a helicopter deck. Moreover, because it is much easier to find a giant oil field, most of those giants have been found by now and the new ones tend to be ever smaller. So while it takes ever more energy to drill new oil fields, the energy return gets ever less. Nowadays an oil price below $75/barrel would make large numbers of oil fields uneconomic, which would cause oil production to slump. The ERoEI of many oil fields is currently down to 10:1 or even 5:1. So 1:1 is getting close, after which it is pointless to continue.

Latest Report of the IEA

The IEA (International Energy Agency) of the OECD[10] countries publishes its annual WEO (World Energy Outlook). The IEA has always been among the notorious optimists who did not even recognize the urgency of peak

---

[9] CNN: “Alaska’s untapped oil reserves estimate lowered by about 90 percent”, at **http://edition.cnn.com/2010/US/10/27/alaska.oil.reserves/index.html**

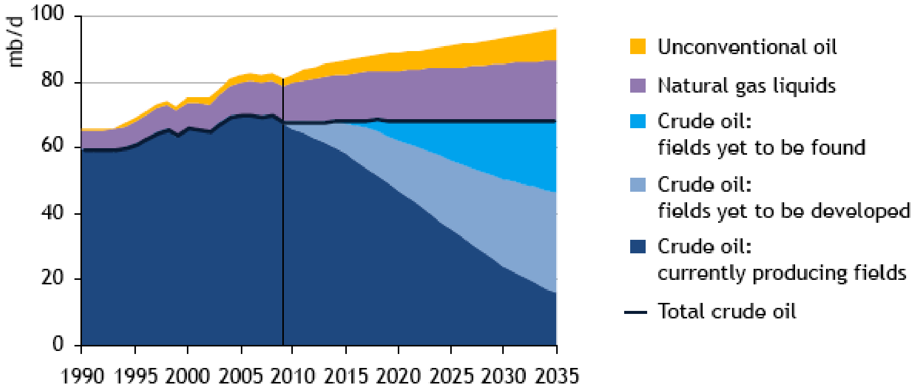
[10] Organisation for Economic Cooperation and Development has 34 member countries: all Western European and some Central European countries, USA, Canada, Australia, New Zealand, Japan, South Korea, Mexico and Chile.

oil in its WEOs. This position started to change in its WEO-2004 and the Executive Summary of its WEO-2010[11] states the following:

> "Crude oil output reaches an undulating plateau of around 68–69 mb/d by 2020, *but never regains its all-time peak of 70 mb/d reached in 2006*, while production of natural gas liquids (NGLs) and unconventional oil grows strongly." (emphasis added)

It is still quite optimistic ("Crude oil output reaches an undulating plateau of around 68–69 mb/d by 2020, [...]" and "[...] while production of natural gas liquids (NGLs) and unconventional oil grows strongly"), but they state loud and clear that conventional oil production has peaked back in 2006!

Graph 10: Global oil production according to IEA's 'New Policies Scenario'[12] (1990–2035)



Source: IEA, WEO-2010

A year ago, after years of rebuffing external criticism, the presentation of the WEO-2009 came under attack from two whistleblowers from within the IEA. Two IEA senior officials claimed, the IEA –in order "not to anger the Americans"– was underplaying the rate of decline of oil production and overplaying the chances of finding new reserves.[13] It indicates that the IEA has a double agenda, instead of publishing reliable World Energy Outlooks.

Table 2: Global oil production data of 2009

Countries (Top-10)	Production	
	Mt/year (Mb/day)[14]	%
Russia	494 (9.88)	12.9%
Saudi Arabia	452 (9.04)	11.8%
USA	320 (6.40)	8.3%
Iran	206 (4.12)	5.4%
China	194 (3.88)	5.0%
Canada	152 (3.04)	4.0%
México	146 (2.92)	3.8%
Venezuela	126 (2.52)	3.3%
Kuwait	124 (2.48)	3.2%
UAE	120 (2.40)	3.1%
Rest of the World	1.509 (30.18)	39.2%
Total	**3.843 (76.86)**	**100.0%**
Source: IEA, Key World Energy Statistics 2010[15]		

---

[11] IEA, WEO-2010, Executive Summary: **http://www.iea.org/Textbase/npsum/weo2010sum.pdf**

[12] IEA, WEO-2010, Key Graphs: **http://www.worldenergyoutlook.org/docs/weo2010/key_graphs.pdf**

[13] The Guardian: **http://www.guardian.co.uk/environment/2009/nov/09/peak-oil-international-energy-agency**

[14] Conversion: 1 metric ton ≈ 7.3 barrels; 1 year ≈ 365 days; M = mega = million.

[15] IEA, Key World Energy Statistics 2010: **http://www.iea.org/textbase/nppdf/free/2010/key_stats_2010.pdf**

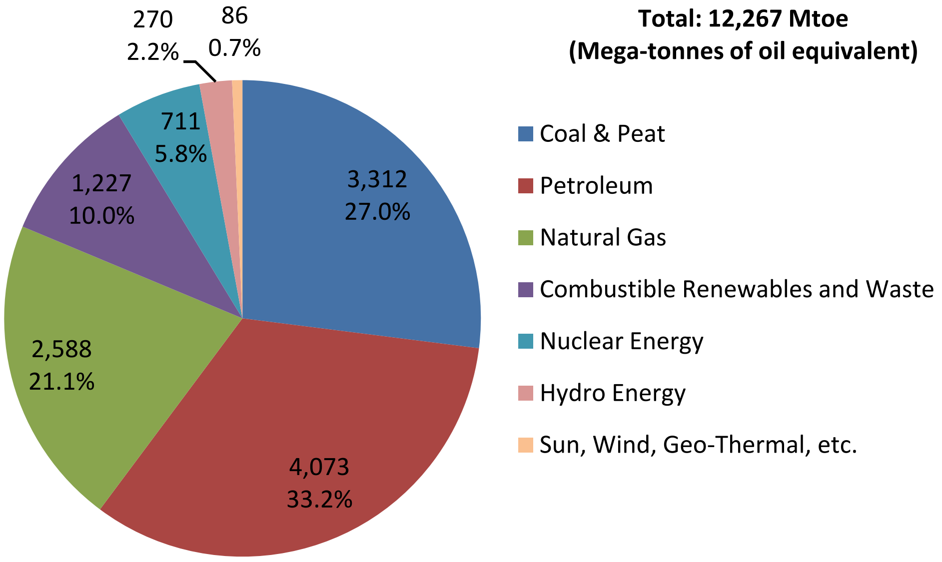
Graph 10 shows that "currently producing fields" are already in decline and the already discovered but "yet to be developed" fields are expected to be able to offset the decline of the "currently producing fields" until 2015. After 2015 "fields yet to be found" are supposed to offset the decline of conventional oil production and those offsets are supposed to deliver around 22 Mb/day by 2035. As table 2 shows, 22 Mb/day (or 1,100 Mt/year) equals the current oil production of the number 1, 2 and 4 biggest oil producing countries in the world together (namely: Russia, Saudi Arabia and Iran). This equals 29% of current world oil production.

In view of the above calculations of Hubbert's peak in a thoroughly explored and exploited world, it does not seem very likely that such huge oil fields are still to be found. It is comprehensible that the IEA hesitates to announce the bad news that world oil production is about to decline terminally, for fear of the political and economical upheaval it would spark, but it is not of great help to fail to forewarn us of the imminent energy crisis we are sleepwalking into so utterly unprepared.

Limits to a Global Energy Transition

Our dependence on fossil fuels is staggering. As graph 11 shows, fossil energy sources account for (27.0% + 33.2% + 21.1% =) 81.3% of our global energy consumption.

Graph 11: Global primary energy supply by type of fuel



Source: IEA WEO-2010 Key World Energy Statistics

"Combustible renewables and waste" account for 10.0% and consist mainly of firewood, charcoal and dried manure, which are extensively used for cooking in poor countries (causing deforestation and desertification), and to a lesser extent of agro-fuels[16] (which cause worldwide food shortages). The 436 nuclear power plants in the world only contribute 5.8% to the total energy supply. At 2.2% hydropower is the biggest non-carbon renewable energy source (causing floods, ecological damage and displacements of people). All the other renewable energy sources (wind, solar, geo-thermal, etc.) still do not account for more than 0.7% of total world energy supply.

Even if someone is already aware of the coming oil shortages, (s)he usually believes we are ready to solve this problem with the new technologies to capture the renewable sources of energy. However, (s)he is unaware that we still have a long long way to go (starting at 2.2% + 0.7% = 2.9%) and many obstacles and limitations to overcome.

Technical Limits

Most sources of renewable energy produce electricity, like wind, solar and geo-thermal energy. Meanwhile in many economic sectors the combustible energy sources cannot be so easily replaced by renewable sources of

---

[16] I do not use the term bio-fuels, because "bio" has a connotation of being an ecological and sustainable solution, which is not at all the case. "Agro" of agro-business, agro-chemicals and agro-industry is more appropriate.

electricity. These incompatibilities are causing serious obstacles to actually get the nuts and bolts together and make the necessary energy transition away from fossil fuels.

The transport sector (land, water and air) depends almost entirely on petroleum-based fuels, while the technology for renewable alternatives is still in its infancy (Hirsch, 2005: 25). There are still no commercially feasible alternatives for ships on fuel-oil, trucks on diesel and airplanes on kerosene. Electric cars need small, light, powerful and quickly rechargeable batteries. However, in spite of the big advances of lithium batteries, this list of technical demands still seems to be a contradiction in terms: car batteries are still big, heavy, of modest capacity and slow to recharge. That is why it is taking so long for the first electric cars to arrive on the market. There has been talk of them for so long now, but it is still rare to encounter them in the street. Meanwhile electric trucks, ships and airplanes are still a long way over the technical horizon (if possible at all). Other sectors with serious compatibility problems are the heavy industries, like the blast-furnaces to produce iron and steel (which run on coke made from coal), the ovens that make cement, brick and glass (which constitute the base materials of all industrial and construction activity) and agro-industry (tractors, combines, pesticides, chemical fertilizers etc.). Needless to say, the petrochemical industry cannot do without petroleum and natural gas to supply us with thousands of plastics, synthetic fibres, paints, glues, pharmaceutics, cosmetics, pesticides, chemical fertilizers, etc.

Photovoltaic panels and wind turbines depend on the weather: on a windless night, one would not have electricity. Meanwhile, large-scale storage of electricity (think about a battery to store a week's electricity demand of a large city) is still next to impossible, so power plants that can guarantee the supply of a base-load of electricity (power plants that can be switched on and off, as deemed necessary) are still indispensable. To date the only power plants theoretically able to supply a base-load, run on fossil, agro and nuclear fuels, hydro and geothermal power:

- Fossil fuels are running out and their CO_2 emissions cause the world's climate to change, so there are two urgent reasons to get rid of those sources.
- Agro-fuels supplant food production, which is already under pressure from an explosive human population growth. Nor is it possible to expand our arable land by cutting down more natural forests, due to the already alarming rate of biodiversity loss.[17] That is why agro-fuels are a lethal blind alley.
- Hydropower plants are a long-established renewable energy technology. However, they represent an insurmountable barrier for migrating fish, disrupting the aquatic ecosystem and triggering far-reaching environmental chain reactions (in areas like the Amazon Watershed). The artificial lakes are basically huge flooded areas, sometimes dislocating indigenous tribes from their ancestral lands. From a renewable energy point of view, hydropower is a very attractive alternative, but the adverse effects should be dealt with a lot more seriously than today's practice demonstrates.
- Geo-thermal power plants circulate thermal water from depths of 2–3 km with temperatures of 150°–200° C to produce steam to drive generators. Although it is an excellent source of renewable energy in areas of tectonic or volcanic activity, outside those areas thermal aquifers are so deep that construction becomes too expensive and the ERoEI for circulating the thermal water (by pumping) becomes unrewarding, so its applicability is practically limited to tectonic and volcanic areas.
- An important advantage of nuclear power plants is that they do not emit carbon dioxide. However, they run on a mineral of finite availability. A uranium shortage may already occur between 2020 and 2050,[18] while the radioactive waste remains dangerous for several millennia. It is justified to wonder if it is still worthwhile to build so many new nuclear power plants for only 20–30 years of use and leave our descendants with the radioactive waste. The high-tech installations are not accessible to poor countries and due to the risks of proliferation of the technology for manufacturing nuclear weapons, rich countries oppose this vehemently, as can be observed by the international response to Iran's current nuclear energy program. On the other hand, the fourth generation nuclear power plants currently on the drawing boards aim at designs that are inherently safe, more efficient, cheaper and able to run on nuclear waste from older power plants and from nuclear weapons. In other words, this next generation of power plants would solve a nuclear waste problem, while generating electricity. In short, nuclear energy generation

---

[17] United Nations, UNEP, CBD (Convention on Biological Diversity) "Global Biodiversity Outlook 3" (2010): **http://www.cbd.int/gbo/gbo3/doc/GBO3-final-en.pdf**

[18] Energy Watch Group: "Uranium Resources and Nuclear Energy" (EWG-Series No 1/2006) **http://www.energywatchgroup.org/Homepage.14+M5d637b1e38d.0.html**

has a lot of disadvantages as well as advantages, so its fate is still undecided (and heavily debated once again).

Hydrogen is often mentioned as the future alternative to fossil fuels. However, pure hydrogen cannot be found in nature. It has to be produced, which should be done by electrolysis of water (from renewable sources of electricity), which uses energy, so essentially it is not a source of energy but a storage method. The advantage is that hydrogen could be generated with the surplus electricity from solar panels and wind turbines to solve the electricity storage problem: Eureka, a battery for our city! But we are not there yet:

- Consider for example the consequences of hydrogen being the lightest element. Although a kilogram of hydrogen contains about 2¾ times as much energy as a kilogram of petrol, even under a pressure of 700 atmospheres (which equals 7 km below sea level) its volume is still 12 times as large. So to be able to drive the same distance as a car on petrol, a hydrogen cylinder has to be (12 / 2¾ =) 4⅓ times as big as a petrol tank. For a passenger car a hydrogen cylinder of 200 litres (1.30 m long by 0.50 m diameter) instead of a 45-litre petrol tank (like a suitcase of 60 by 50 by 15 cm) is a real problem: where shall we put it?
- Hydrogen consists of just one proton and one electron. The electron can travel through metals as an electrical current and the leftover hydrogen ion (just a loose proton) is soluble in metals, making them brittle (so easily shattered). In other words, hydrogen can escape from steel cylinders, and the pipelines for transporting and distributing natural gas are wholly unsuitable for hydrogen gas. Ouch, that problem hurts! Therefore, hydrogen has enormous potential as a substitute for gaseous and liquid fossil fuels, but there are still many technical obstacles to overcome, so it will take several more decades before it can be globally introduced and popularized (Ewing, 2004).

In the long run solar energy (being the mother source of all energies) is the biggest and most promising source of renewable energy. Although the photovoltaic property was already discovered in 1839, the first photovoltaic cells (silicon cells that generate electricity directly from sunlight) were made in 1954. Unfortunately, the development of photovoltaic technology was not given much priority, because it seemed too inefficient as compared to the price of crude oil in those days (as cheap as $2/barrel), so it remained a semi-dormant technology and was only used in special situations such as in space or in remote unmanned places like lighthouses. The immaturity of this technology is still noticeable from the big differences between commercial practice and R&D (Research & Development) achievements: the average efficiency of commercially installed solar panels is around 12%–18%, the best commercially-available solar panels achieve some 24% efficiency, while recent R&D laboratory records claim efficiencies of 35%–40%. These percentages show how fast this technology is still developing (which is the opposite characteristic of a mature technology), and also that it is not yet known how far the efficiency can still be improved. In any case, it will take another couple of decades to get there and to introduce and popularize those new technologies on a global scale.

Material Limits

Fossil energy is not the only natural resource that we are depleting. Let us look at copper mining for example.[19] Illustration 2 shows a copper nugget of nearly three metric tons, found in the riverbed of Copper River, Alaska, in 1903. Nowadays you will not find copper nuggets that size anymore. Worse, a metric ton of copper ore nowadays contains only a few kilograms of copper. They are not exploiting such poor quality copper ore just for the fun of the challenge; they do so because there is no better quality ore left. Illustration 3 shows the Chuquicamata copper mine, 210 km northeast of Antofagasta, Chile. The main pit measures 4.4 km by 2.8 km and is 900 m deep. The dumper trucks are assembled on the mine's premises because they are too big (8½ m wide, by 7½ m high) to get there by road. They can carry

Illustration 2: Copper River, Alaska, 1903

---

[19] The example comes from Chris Martenson's *Crash Course*, which will be discussed in more detail below.

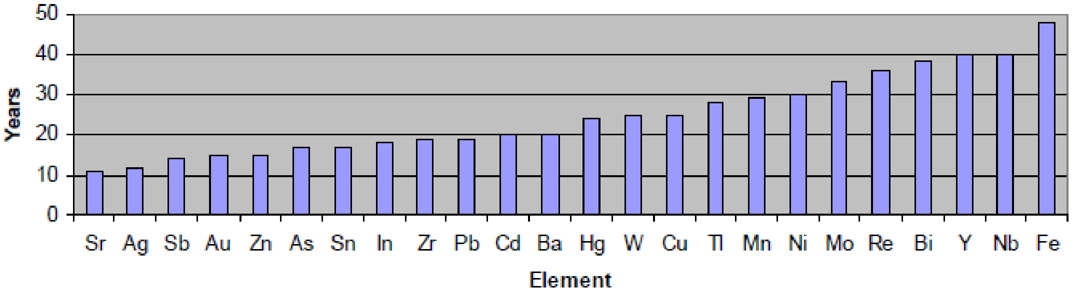
a payload of 360 metric tons and have an engine of 3500 HP (which equals roughly eight heavy trucks, as we know them from daily life). I mention all these impressive figures to underscore the enormous amount of energy it takes to mine those poor leftover copper ores; with mules it would be an impossible job. Therefore, when we run out of oil to drive those dumper trucks, it will soon be over with copper mining as well.

Illustration 3: Chuquicamata copper mine, Chile

The situation of copper is just one example out of many. Graph 12 shows that shortages of the following elements are expected to occur in 10–20 years: strontium (Sr), **silver** (Ag), antimony (Sb), **gold** (Au), **zinc** (Zn), arsenic (As), **tin** (Sn), indium (In), zirconium (Zr), **lead** (Pb), cadmium (Cd) and barium (Ba). And another string of rare earth metals faces shortages in 20–50 years from now: **mercury** (Hg), wolfram (W), **copper** (Cu), thallium (Tl), **manganese** (Mn), **nickel** (Ni), molybdenum (Mo), rhenium (Re), bismuth (Bi), yttrium (Y), niobium (Nb) and even **iron** (Fe).

Those metals play key roles in the production of ICT hardware and renewable energy equipment: from cell phones and laptops to communication satellites, photovoltaic panels and hydrogen fuel cells. This raises a serious question: How are we to make the necessary energy transition, without copper and all those key minerals?

Graph 12: Years left at sustained 2% annual primary production growth, based on reserves



Source: TNO/HCSS[20]

Time Limits

As history shows, an energy transition takes at least 30–40 years to complete: invent, improve, introduce and popularize globally in daily life. The first precursors of the steam engine were already described by Taqi al-Din of the Ottoman Empire in 1551 and by Giovanni Branca of Italy in 1629. Still it took until James Watt improved the steam engine enough in 1775 for it to be commercially introduced: a technical evolution of 225 years. The Frenchman Alphonse Eugène Beau invented the first four-stroke internal combustion engine in 1861, but automobiles remained a curiosity until the American Henry Ford revolutionized transport by mass production of his famous T-Ford: a period of 47 years. The Wright brothers flew their first motorized airplane in 1903. During WW-I military airplanes

---

[20] TNO/HCSS, the Netherlands: “Metal Minerals Scarcity: A Call for Managed Austerity and the Elements of Hope” (Dr. A.M. Diederen, 2009) **http://www.hcss.nl/en/publication/1051/**

were still curiosities with legendary pilots like the Red Baron and his little triplane. In 1935 the Douglas DC-3 made its maiden flight on the 32nd anniversary of the first motorized flight of the Wright brothers. Just like the T-Ford did for car transport, the DC-3 transformed and matured aviation.

Humanity should have been aware of the coming fossil energy shortages already since the 1970s, when Hubbert's U.S. peak oil forecast came true in 1970, when the Club of Rome presented their report about "The Limits to Growth" in 1972 and after the two oil crises of 1973 and 1979. President Jimmy Carter was fully aware and wanted to act boldly. His "Address to the Nation on Energy"[21] in 1977, just 3 months after taking office, was a courageous wakeup call. There was still enough time to develop a global energy transition away from fossil fuels. Unfortunately, as we know by now, the rich countries preferred just to enjoy the abundance of those golden decades and not to spoil the party by demanding austerity and enforcing heavy investments in renewable energy technology. In retrospect, by ignoring President Jimmy Carter's warnings, we have missed the one chance we got to make a timely energy transition. Alternative technologies, which should have been developed vigorously, continued their underdeveloped and semi-dormant existence for three more decades. Now the world finds itself utterly unprepared to face the imminent oil shortages.

So, although solar panels and wind turbines do exist, it will take another couple of decades to perfect and introduce them on a global scale. Meanwhile, by the end of December 2010 the price of crude oil had surpassed $90/barrel again, which means we are already suffering oil shortages, and these will worsen rapidly over the next couple of years. It is already inevitable that the world will face a serious energy deficit decades before it is able to equip itself with renewable alternatives.

Exponential Growth

It appears that, by some unfortunate coincidence, an array of crises is awaiting us at the same time like a perfect storm: depletion of fossil fuels and all sorts of minerals, climate change, biodiversity loss, erosion of arable land, water shortages, soil, water and air pollution, poverty and hunger, and to top it off the current economic crisis. What a coincidence! Or, could it be that it is not such a coincidence? The next paragraphs will explain why it is no coincidence (Heinberg, 2007; Martenson, n.d.)

Principles

To understand this confluence of crises, it is necessary to understand the implications of exponential growth. Every growth with a certain annual percentage is an exponential growth: initially growth goes slowly, but it gathers ever more pace until it reaches an explosive speed.

Illustration 4: Aztec football stadium in Mexico City

Let us visualize exponential growth by means of a (sadistic) experiment.[22] The Aztec football stadium in Mexico City is one of the biggest football stadiums in the world with 105,000 seats. The stadium has been made waterproof for the experiment and I brought a piece of rope and an eyedropper with magic drops. These magic

---

[21] President Jimmy Carter's address to the Nation: **http://millercenter.org/scripps/archive/speeches/detail/3398**

[22] Chris Martenson's *Crash Course*, which will be discussed further down, deserves the credit again.

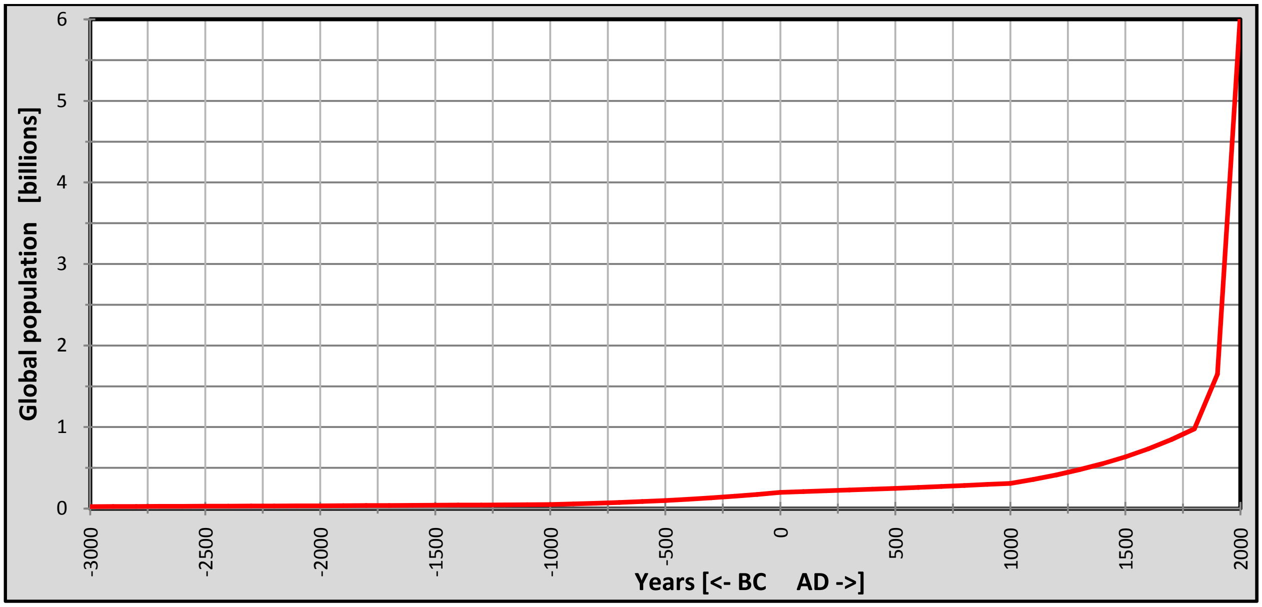
drops multiply every minute once they leave the eyedropper: 1, 2, 4, 8, etc. I tie you to the highest row of seats in the stadium, then I walk down to the pitch, I drop one magic drop on the centre spot and (sadistically) leave you tied to the top row. Question: how much time do you think you have to liberate yourself before you will drown? For the sake of the experiment, make your own estimate first, before reading the answer here.[23] Now a second question: how much time do you think will elapse before the bottom row will be inundated and you start to get really worried? Again, first make your own estimate, before reading the answer here.[24] Surprised, startled maybe? It seems like not much is happening during the first thirty-eight minutes and then the entire stadium will be inundated within the last seven minutes. That is how treacherous exponential growth is.

Any mathematician (or economist) may protest that any exponential graph can be shown as growing explosively by manipulating the scales and ranges of the axes and (s)he is right, in principle. However, if the vertical range has a physically defined upper limit, exponential growth will hit the ceiling some day, as will be shown in the next paragraphs.

Exponential Growth of Humanity

Graph 13 shows the exponential growth of the human population from the start of written human history (some 3000 years B.C.) until the end of the 20th century. Jesus Christ lived among only an archeologically estimated 200 million contemporaries and by the end of the Middle Ages (1500) the world population had grown to only some 500 million people. Then, as table 3 shows as well, the world population started to grow explosively. Just like the Aztec stadium, the world seems so huge and we humans as insignificant as a drop in the ocean, but our population growth has been as treacherous as a magic drop.

Graph 13: Global human population growth (3000 BC – 2000 AD)



Source: **http://en.wikipedia.org/wiki/World_population_estimates**

Table 3: Global human population growth (1800 –2050)

Year	1804	1927	1960	1974	1987	1999	2011	*2025*	*2050*
Population [billions]	1	2	3	4	5	6	7	*8*	*9*

Source: **http://en.wikipedia.org/wiki/World_population**

---

[23] About forty-five minutes.

[24] If you like, you can check the calculation: the volume of a metric drop is $^{1}/_{20}$ ml and the Aztec stadium has a volume of about 1.6 million m^3 (1 m^3 = 1000 li). The bottom row will be inundated after thirty-eight minutes.

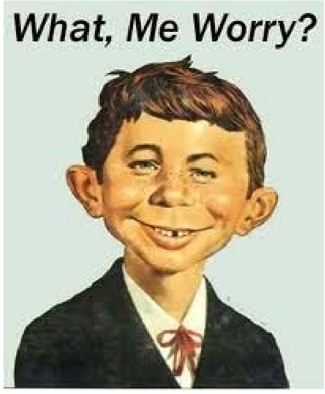
Nobody knows exactly how many our human population can and will grow to, but the carrying capacity of our planet is usually estimated at a human population of around 10 billion people, a number we are approaching very rapidly, just like the water in the Aztec stadium.

Exponential Growth of the Use of Natural Resources and Emissions of Waste

Human population growth drives all other growth rates of consumption (energy, minerals, deforestation, land erosion, water shortages, overfishing, food shortages, etc.) and waste production (garbage, industrial waste, soil, water and air pollution, greenhouse gases, climate change, etc.). Like any population, an ever-increasing human population consumes an ever-increasing amount of natural resources and produces an ever-increasing amount of waste. If our planet were infinitely big, there would not be a problem. But our earth does have finite limits and now we can see we are pushing these limits everywhere around us, but we cannot make our planet one inch bigger than it is.

This is why it is not at all surprising that all these crises seem to be gathering at the same time, like a perfect storm. It is not a coincidence; we ourselves are the driving force behind it. The crises we are facing are not increasing according to a gently linear trend; they are all converging and speeding up at an exponential rate. We have enjoyed such abundant lives, allowing ourselves a capitalist economic system based on perpetual growth and imposing it on all other nations on earth. Now it is spiralling out of control, as this 70-second video of the Impossible Hamster[25] visualizes in a way that is both funny and sobering.

Consequences of Energy Shortages



The imminent shortages of oil and other natural resources will have many kinds of profound impacts. Although it is difficult to foresee all of them, what follows is an attempt to survey some principal risks and consequences. To interpret these consequences may be more speculative than calculating the peak of oil production, which by now should be accepted as a fact –give or take a few years–, but it is imprudent not to consider the risks. Indeed, it is reckless to pretend there is nothing to worry about.

An Energy Crisis means an Economic Crisis

Graph 14 shows the production and price of petroleum between 1994 and 2010. The left vertical axis indicates Mb/d (million barrels of oil per day) and the right axis the monthly average price of petroleum in dollars per barrel.

The graph shows that world oil production grew to 85 Mb/d in 2005 and remained at this undulating level until the economic crisis of 2008. In the same period, the price of petroleum spiked from $50 to $135/barrel (with a daily record high of $147/barrel on 12 July 2008). The most logical answer to this price spike is not oil price speculation, as so often suggested. At such price levels, oil producers had every incentive to open up their valves and cash in, flooding speculators with oil in the process. The price spike can be simply explained by the economic law of supply and demand: they did not open up their valves because they could not be opened any further. Oil demand was surpassing supply, which was at its peak.

Due to the ensuing economic crisis, oil demand slumped to below production capacity and oil prices tumbled back down to $40/barrel. However, when the world economy started to recover in 2009, oil demand encroached upon production capacity again, prices quickly returned to a $75–$85/barrel range and by December 2010 the oil price was back at $90/barrel.

Prices in the industrial production and transport sectors, as well as mechanized agriculture, are closely linked to the price of petroleum. When the oil price goes up, prices of industrial products, food crops and their transportation go up as well, and with so many rising prices inflation goes up.

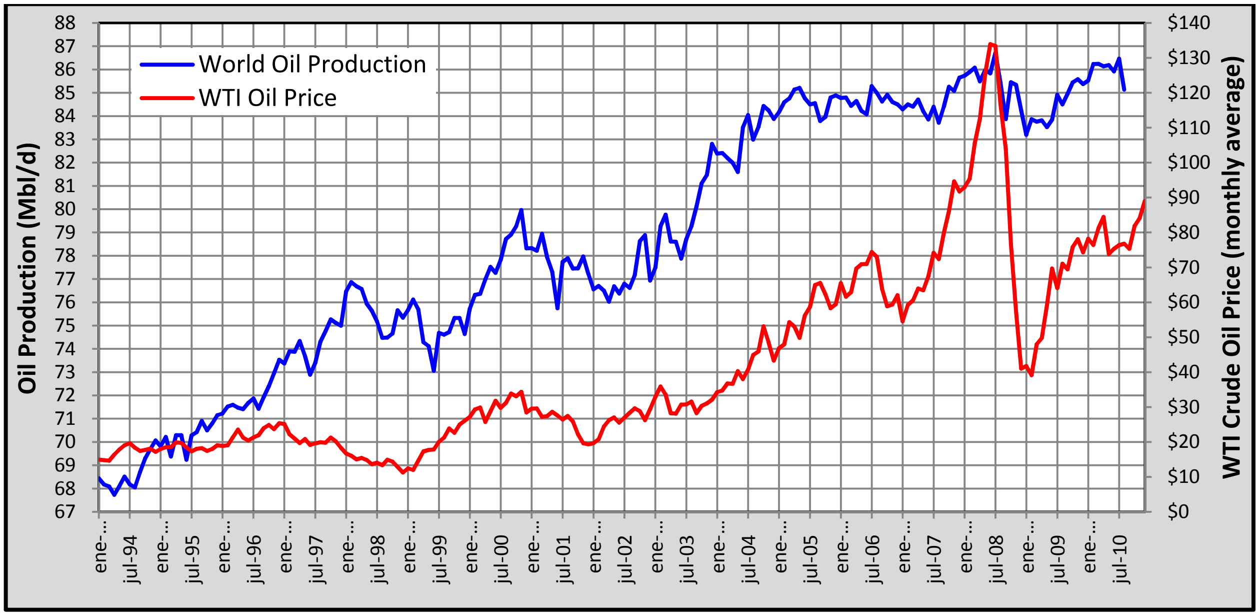
The economic crisis, which started in September 2008 in the U.S. as a mortgage crisis, originated from the rapidly rising oil prices during the previous 1½ years. Since the start of 2007 Americans had to pay ever higher prices for their food and energy bills, which reduced their capacity to pay off their mortgages ever more. That is why many

---

[25] The Impossible Hamster: **http://www.impossiblehamster.org/**

families went broke and had to leave their foreclosed homes, while so many houses for sale caused the housing bubble to burst. The rest of the recent crisis is common knowledge. What remains underexposed is that the oil price spike from $50 to $135/barrel instigated this economic crisis, just as it did in the oil crises of 1973 (oil price spike from $3 to $12/barrel) and 1979 (from $18 to $40/barrel), so in reality the economic crisis of 2008 should be coined the third oil crisis.

Graph 14: Global production and monthly average price of petroleum (1994–2010)



Source: EIA (**http://www.eia.doe.gov/emeu/international/contents.html**)

Currently the economic situation of the rich countries is in grave shape. Due to the efforts to rescue the banks in 2008 and 2009, their national debts and deficits have soared to unbearable levels. In November 2010 the U.S. Fed announced its QE-II plan (Quantitative Easing II) to buy up bonds worth $600 billion, which in essence means monetizing debt. It is common knowledge that this reeks of hyperinflation and it was one of the reasons why the atmosphere at the G20 summit in Seoul a week later was tense with rumours about currency wars and a second recession. The European Union has its own worries. Member states had to set up a rescue fund of €750 billion to bail out Greece in April and Ireland in November, while Portugal and Spain are next in line and rumours circle around Italy and Belgium, so maybe even this rescue fund will turn out to be insufficient. Meanwhile, in spite of the tremendous efforts, recovery is still anaemic.

The fundamental problem with a capitalist economic system is that it has to keep growing perpetually. Even its vocabulary is clear about this: there is not even a proper word for negative growth, which means crisis, recession, depression. Growth is necessary to pay off debts from the past with anticipated profits from future growth. Money is lent into existence through the practice of *fractional-reserve banking*. The sum of all debts is always bigger than the sum of all the money in circulation, which means that a run on the banks would always result in the collapse of the entire monetary system. When physical production growth is no longer possible because of oil scarcity and the depletion of other natural resources, the economy will no longer be able to grow and the entire monetary system will collapse like a house of cards.

Chris Martenson's *Crash Course*[26] explains all this in much more detail than is possible within this article. It explains, through a presentation of graphs and tables with a voice-over commentary, the workings of the monetary and banking systems, debts and deficits, savings and inflation, real-estate and mortgages. Eventually it demonstrates that this economic and monetary Ponzi scheme (pyramid scheme) is headed for a clash with the real world of dwindling oil and other natural resources. Although the *Crash Course* tells the story through the U.S. economy, it equally applies to all capitalist economies in the world.

---

[26] Chris Martenson's *Crash Course*: **http://www.chrismartenson.com/**. It takes 3½ hours and is highly worthwhile.

Transport

The neoliberal economy and the global market depend completely on the international transport of goods and people. For all this transport the world numbers some 800 million cars, 300 million trucks, 3½ million fishing boats, 50,000 seagoing cargo ships, 45,000 airliners and an unknown number of trains, buses and cargo ships for inland waters.[27] Virtually all these vehicles run on petrol, diesel, kerosene and fuel-oil.

It is very unlikely that all these vehicles can be replaced by, or converted to, renewable energy alternatives, due to a lack of mature technologies, insufficient base materials and a lack of time (production capacity) to do so. Moreover, due to the economic crisis this would require a seemingly impossible level of investment.

Without petroleum, the global economy is incapable of maintaining itself. Without fuel-oil, products cannot be shipped from China to the U.S. Without kerosene, global tourism by airplane to exotic places will grind to a halt. Without diesel, one cannot even travel from Amsterdam to Barcelona. Without oil the global economy will have to contract and, assuming that an adequate energy transition of the transport sector cannot be realized effectively and in time, transport will have to return to horse and carriage, oxen and carts, sailing ships and towing barges. And forget about air travel.

On the other hand, if you want to look at it from the bright side, it would mean the end of the globalized neoliberal system that makes so many countries and people suffer perpetual misery, and the end of greenhouse gas emissions that are causing disastrous climate change. As the legendary Dutch football player and coach Johan Cruijf once said: “Every disadvantage has its advantage.”

Agriculture

Since the Green Revolution (the mechanization of agriculture in the 1950s, 60s and 70s), agriculture has become heavily dependent on petroleum. Tractors and combines need diesel to plough, sow and harvest. Pesticides (made from petroleum) and chemical fertilizers (made from natural gas) have become indispensable to boost crop yields. Crops are irrigated by pumping water from (declining) aquifers with petrol or diesel pumps. For every calorie of food we eat, ten calories of fossil fuels are expended to produce, transport, process and distribute them, which is highly inefficient and unsustainable. The current levels of food production are impossible to maintain without petroleum (Heinberg, 2004; Heinberg, 2007; Pfeiffer, 2006; Ruppert, 2009).

Currently the major food exporters are the USA, Canada, France, Germany, Russia, the Ukraine, Australia and Argentina.[28] After the poor countries were prohibited by WTO rules from protecting their local food production with import duties, the USA and European food exporting countries in particular have destroyed their local food production by food dumping, to the extent that many poor countries are now dependent on the food exports of the rich countries. Haiti, among many, is a harrowing example of total food dependence after its domestic rice production was wiped out by (heavily subsidized) American rice dumping.

Meanwhile rising oil prices incite the production of agro-fuels from food crops in these food-exporting countries, which drives up food prices worldwide. Mexico, the cradle of the indigenous maize plant, used to have a self-sufficient domestic maize production, until the North American Free Trade Agreement (NAFTA) was signed. Now Mexico needs to import the bulk of its maize consumption from the USA, while the USA is turning ever more of its corn production into agro-ethanol, leaving the Mexican poor to starve.

As graph 15 shows, the FAO-FPI (Food Price Index) broke the June 2008 record (214) again in December 2010 (215).[29] In 2008 the world saw food riots in many (mostly poor) countries and in view of the recent FAO-FPI developments, it is no surprise that we see them appearing again recently in countries like Algeria and Tunisia. In the face of the imminent oil scarcity, the pending agrarian crisis and the increasing pressure of agro-fuels on food production, (mostly poor) food-importing countries are caught in an ever more vulnerable position. Although import duties against food dumping are not allowed under the present WTO rules, it is of pivotal importance and urgency for these (mostly poor) food-dependent countries to re-establish their food import duties and revive their domestic food production, because it is becoming a life and death struggle.

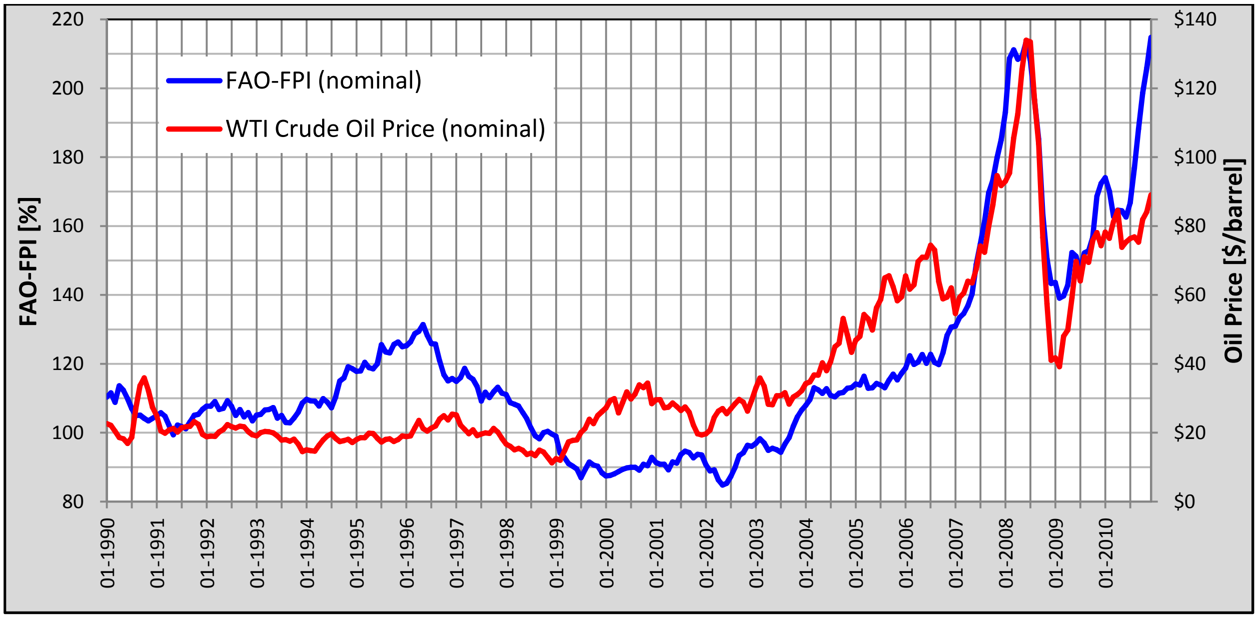
---

[27] Estimates pieced together from an array of websites, but they serve as a rough indication.

[28] FAO statistics on imports and exports of food commodities: **http://faostat.fao.org/site/342/default.aspx**

[29] FAO-FPI data: **http://www.fao.org/worldfoodsituation/FoodPricesIndex/en/**

Graph 15: Correlation between monthly FAO-FPI and monthly average WTI oil price (1990–2010)



Rich countries might have to face a different food security risk: less than 5% of their citizens still know how to grow their own food crops. Very few and rapidly aging farmers are left who could still teach millions of young urban professionals how to grow their own food without the use of diesel, pesticides and chemical fertilizers. Much of this traditional knowledge has been lost already.

Resource Wars

The ultimate resource wars have already begun. The countries around the Persian Gulf possess about 55% of all known oil reserves in the world.[30] Iran is the only country among them that is not (in some shape or form) controlled by the USA. As a result of the many past and present wars in the region, the USA already has military bases in many countries, which effectively surround Iran: Afghanistan, Saudi Arabia, the UAE, Iraq, Israel, Kuwait, Oman, Qatar and Turkey. In 2009 the U.S. opened its new bunker-like embassy in Bagdad, which cost $736 million to build, and measures 42 hectares, which is even bigger than the Vatican in Rome. It is the biggest and most expensive embassy ever built in human history. They are also constructing a couple of huge military bases in Iraq, which cost hundreds of millions of dollars, like the “Joint Base Balad”, a 26 km^2 military airport with all the facilities to accommodate 28,000 troops and 8000 civilian personnel, complete with supermarkets, bars, restaurants, cinemas and even their own newspaper. In spite of the so-called withdrawal from Iraq, after having freshly invested so many hundreds of millions of dollars in key infrastructure designed to dominate, one has no real intentions to withdraw. They are ready to be manned again and there is a logic to it: the Iraqi and neighbouring countries’ oil reserves.

As for Iran, of course they feel threatened, and looking at the USA’s record of recent decades they have every reason to. So what would be the best guarantee to keep USA troops outside its borders? Well, a nuclear bomb is not a guarantee (see Pakistan), but it is your best option. Iran would be the second country in the Middle East to have nuclear arms, after Israel. Contrary to the dominant western opinion, “a [57%] majority of the Arab public now see a nuclear-armed Iran as being better for the Middle East.”[31] Such an opinion says a great deal about how the Arab world views the Western world, and it should not come as a surprise.

On the other hand, China needs large quantities of oil as well: it is the fifth largest oil producer and at the same time the third largest oil importer in the world, while its appetite for oil is growing fast. In March 2004 China signed a mega-deal with Iran worth $100 billion (with expansion possibilities that would double it) for the export of

---

[30] EIA, IEO-2010 (International Energy Outlook), Table 5: **http://www.eia.doe.gov/oiaf/ieo/**

[31] Brookings Institution, Washington, DC: **http://www.brookings.edu/reports/2010/0805_arab_opinion_poll_telhami.aspx**

LNG and for the CNPC (Chinese National Petroleum Corporation) to participate in oil and gas exploration and exploitation in Iran. India joined the deal with another $40 billion in January 2005.[32] China cleverly negotiated in the UN Security Council that the sanctions against Iran would not include their appetite for oil and gas. New geopolitical players are coming on the scene and it seems like they drew a line in the sand: “Do not cut off our energy supply by waging war against Iran.”

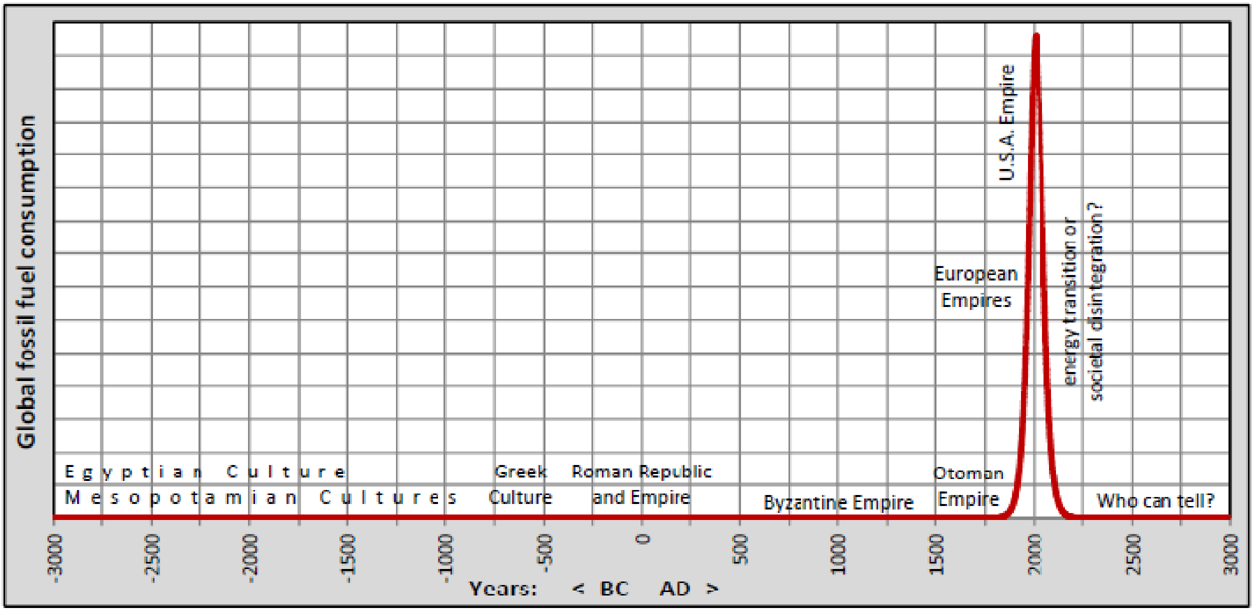
Tensions around the world are rising rapidly. In nearly all major oil producing countries tensions, skirmishes and wars are already occurring: Russia (the largest world oil producer, partly through its Caucasian republics: Azerbaijan, Chechnya, Dagestan, Ingushetia, Ossetia and Georgia), Saudi Arabia (2nd), Iran (4th), Nigeria (5th), Angola (6th), Venezuela (7th), Iraq, South-Sudan (Darfur), etc. This trail of conflict areas is not coincidental; they mark the battlefields over the last oil reserves in the world and the U.S. seems less willing than ever to solve global crises in a peaceful, lawful, civilized and humane way. On the contrary, by spending as much as 43% of the world’s total[33] on their military forces, they seem to have prepared themselves well for these last resource wars. Forget about the so-called ‘war on terrorism’: that is just a red herring, a cover-up to claim the oil.[34] (Ruppert, 2004).

I only have a gleaming hope that the U.S. economy, weakened as it is, will not be able to bear such an extreme and perpetual multiple war effort against the rest of the world to maintain its imperial aspirations.

Die Off of Humanity

Putting global fossil fuel consumption (coal, oil and natural gas) in a perspective of human history, as graph 16 does, makes it clear how exceptional the current Western lifestyle really is. During all those millennia humanity developed without the energy abundance we have become so used to nowadays. The way we take it for granted and waste it like water, will be judged by our great-grandchildren as a collective insanity.

Graph 16: Global fossil fuel consumption (3000 BC – 3000 AD)



Before the use of fossil fuels (around 1800) global human population was still less than one billion people. Thanks to fossil fuels, labour and agriculture were mechanized and our numbers were able to grow, as shown in

---

[32] Asia Times Online, Hong Kong: **http://www.atimes.com/atimes/Middle_East/FK06Ak01.html** and **http://www.atimes.com/atimes/South_Asia/GA11Df07.html**

[33] Wikipedia data, based on data from the *SIPRI Yearbook 2010* (Stockholm International Peace Research Institute): **http://en.wikipedia.org/wiki/List_of_countries_by_military_expenditures**

[34] Of course some people from pillaged countries seek revenge and take up arms: aggression provokes aggression. If the U.S. and other NATO countries had behaved in a lawful, civilized and peaceful way in the world during the last few decades, they would not have attracted so many revenge-seeking ‘terrorists’ now.

graph 13 and table 3. Not only did our numbers grow, our annual growth rate increased from less than 0.5% before 1800 to more than 2% during the 1960s. Thanks to fossil fuels we were able to increase our planet's carrying capacity to support nearly seven billion people. However, without oil to drive our mechanized agriculture, it will not be possible to maintain current food production, which would signify, willingly or unwillingly, a human population decline.

Our planet's human carrying capacity, without the help of fossil fuels, is generally estimated at somewhere between one and two billion people: equal to the pre-industrial population and perhaps twice that. This means there are already five billion people more on our planet than may be possible to sustain without fossil fuels and other depleted natural resources. If, in the course of this century, our human civilization is not able to implement (willingly) an organized and coordinated population reduction, nature will take care of it (unwillingly) through famines, disease, migrations and wars (Heinberg, 2004; Heinberg, 2007; Pfeiffer, 2006; Huppert, 2009).

Simplified Civil Society

There is a correlation between the available amount of energy (be it food, draught animals, slaves or whatever kinds of fuels and machines) and the level of complexity a society is able to establish. Today's rich countries have been able to develop extremely complex societies: with cars, trains, electricity, telephone, radio, television, airplanes, nuclear energy, computers, internet, wireless telecommunication, satellites, manned voyages to the moon and unmanned ones to many parts of our solar system, highly developed universities, heart and brain surgery, genetic manipulation, etc. The achievements are totally impressive, but none of this would have been possible without coal, oil and natural gas.

When the necessary energy transition (sufficiently and timely) turns out to be impossible, human civilization is bound to recede to more simple forms, as happened to all empires before. A surgeon may have to downgrade to being a shaman (and a herbalist might be a useful assistant). A petrol station owner may turn to selling firewood and charcoal (if there are still enough trees around). A car mechanic may find it useful to return to be a blacksmith again. Airplane pilots, radiologists and ICT specialists may have to find another job altogether. But a farmer will remain a farmer and many other traditional forms of craftsmanship will continue to exist or reappear.

Nobody likes to climb down the ladder of prosperity to a simpler way of life, although it does not at all spell the end of the world. In a simpler society, "time is money" may soon become a legend of the past. Not knowing your neighbours will become unthinkable again. Out of mutual necessity, a spirit of solidarity-based community building may reappear again. There may be a revival of a mentality of reciprocity: "I will help you out now, because you are my neighbour and because I am aware that I might need your help tomorrow." In spite of its simpler way of life, this could create an entirely new society, based on strong social contacts and solidarity, which is not necessarily worse to bear than our present urbanized madness: pride and joy from honest craftsmanship, more time to spend, more personal contact, family and neighbours to count on instead of a "JP Morgan Chase" life-insurance. It all depends on how local communities take it upon themselves to realize the inevitable downscaling process. In solidarity, a simple but decent and humane community can be established. (Hartmann, 1998; Heinberg, 2004; Kunstler, 2005)

However, if everybody tries to fight to be the last man standing (on a local as well as on an international scale), the collapse will be so much more disastrous. In this respect, the current powers that be are not at all setting the right example. It is high time to face reality. It is essential not to panic and not to allow governments to wage resource wars, when oil shortages start to hit home. Resource wars essentially boil down to pillaging other countries like barbarians. It is also essential to prepare for the worst now in a civilized and humane way, before hoping for the best. (Ruppert, 2004)

Bibliography and Further Reading

Books

Abramsky, Kolya (Editor), 2010, *Sparking a Worldwide Energy Revolution: social struggles in the transition to a post-petrol world* (Oakland, CA, USA: AK Press)

Deffeyes, Kenneth S., 2001, *Hubbert's Peak: the impending world oil shortage* (Woodstock, Oxfordshire, UK: Princeton University Press)

Deffeyes, Kenneth S., 2005, *Beyond Oil: the view from Hubbert's peak* (New York, NY, USA: Hill and Wang)

Ewing, Rex A., 2004, *Hydrogen: hot stuff, cool science* (Masonville, CO, USA: PixyJack Press)

Hartmann, Thom, 1998, *The Last Hours of Ancient Sunlight: the fate of the world and what we can do before it's too late* (New York, NY, USA: Three Rivers Press)

Heinberg, Richard, 2003, *The Party's Over: oil, war and the fate of industrial societies* (Gabriola, BC, Canada: New Society Publishers)

Heinberg, Richard, 2004, *Power Down: options and actions for a post-carbon world* (Gabriola, BC, Canada: New Society Publishers)

Heinberg, Richard, 2007, *Peak Everything: waking up to the century of declines* (Gabriola, BC, Canada: New Society Publishers)

Heinberg, Richard, 2009, *Blackout: coal, climate and the last energy crisis* (Gabriola, BC, Canada: New Society Publishers)

Kunstler, James Howard, 2005, *The Long Emergency: surviving the converging catastrophes of the twenty-first century* (New York, NY, USA: Atlantic Monthly Press)

Pfeiffer, Dale Allan, 2006, *Eating Fossil Fuels: oil, food and the coming crisis in agriculture* (Gabriola, BC, Canada: New Society Publishers)

Ruppert, Michael C., 2004, *Crossing the Rubicon: the decline of the American empire at the end of the age of oil* (Gabriola, BC, Canada: New Society Publishers)

Ruppert, Michael C., 2009, *Confronting Collapse: the crisis of energy and money in a post peak oil world; a 25-point program of action* (White River Junction, VT, USA: Chelsea Green Publishing Company)

Simmons, Matthew R., 2005, *Twilight in the Dessert: the coming Saudi oil shock and the world economy* (Hoboken, NJ, USA: John Wiley & Sons Inc.)

Reports from Governmental Institutions

Australia: The Australia Institute, 2010, *Running on empty? The peak oil debate*, at **https://www.tai.org.au/index.php?q=node%2F19&pubid=788&act=display**

Germany: Zentrum für Transformation der Bundeswehr, 2010, *Peak Oil:Sicherheitspolitische Implikationen knapper Ressourcen*, at **http://data6.blog.de/media/069/4935069_f5a3ae07a3_d.pdf**

Netherlands: Institute of International Relations 'Clingendael', 2008, *Oil Turbulence in the Next Decade: an essay on high oil prices in a supply-constrained world*, at **http://www.clingendael.nl/publications/2008/20080700_ciep_energy_jesse.pdf**

New Zealand: Parliamentary Library, 2010, *The Next Oil Shock?* at **http://www.parliament.nz/NR/rdonlyres/7BEC9297-DEBE-47B5-9A04-77617E2653B2/163251/Thenextoilshock3.pdf**

USA: Joint Forces Command, 2010, *The JOE 2010: Joint Operating Environment*, at **http://www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf**

USA: National Intelligence Council, 2008, *Global Trends 2025: a transformed world*, at **www.dni.gov/nic/NIC_2025_project.html**

Prominent Reports and Articles

Aleklett, Kjell et Al., 2010, *The Peak of the Oil Age: analyzing the world oil production Reference Scenario in World Energy Outlook 2008*, in "Energy Policy" (Volume 38, Issue 3, March 2010, Pages 1398-1414), at **http://www.tsl.uu.se/uhdsg/Publications/PeakOilAge.pdf**

Campbell, Collin J. y Laherrère, Jean H., 1998, *The End of Cheap Oil*, in "Scientific American" (March 1998, 78–83), at **http://www.hubbertpeak.com/campbell/EndOfCheapOil.pdf**

Heinberg, Richard, 2009, *Searching for a Miracle: "Net Energy" Limits & the Fate of Industrial Society*, at **http://www.postcarbon.org/new-site-files/Reports/Searching_for_a_Miracle_web10nov09.pdf**

Hirsch, Robert L., 2005, *Peaking of World Oil Production: impacts, mitigation, & risk management*, at **http://www.netl.doe.gov/publications/others/pdf/oil_peaking_netl.pdf** (the renowned "Hirsch Report")

Hubbert, Marion King, 1956, *Nuclear Energy and the Fossil Fuels*, in "American Petroleum Institute", at **http://www.hubbertpeak.com/hubbert/1956/1956.pdf**

ITPOES (UK Industry Taskforce on Peak Oil & Energy Security) 2010 *The Oil Crunch: A wake-up call for the UK economy*, at **http://peakoiltaskforce.net/wp-content/uploads/2010/02/final-report-uk-itpoes_report_the-oil-crunch_feb20101.pdf**

LLOYD'S & Chatham House, 2010, *Lloyd's 360° Risk Insight: Sustainable Energy Security; strategic risks and opportunities for business*, at **http://www.lloyds.com/~/media/Lloyds/Reports/360%20Energy%20Security/7238_Lloyds_360_Energy_Pages.pdf**

Websites with News and Information

ASPO International: "Association for the Study of Peak Oil & Gas", at **http://www.peakoil.net**

ASPO Ireland: "Association for the Study of Peak Oil & Gas – Irish Chapter", at **http://aspoireland.org/**

ASPO USA: "Association for the Study of Peak Oil & Gas – USA", at **http://www.aspousa.org/**

Deffeyes, Kenneth S.: "When Oil Peaked", at **http://www.princeton.edu/hubbert/index.html**

ITPOES: "Industry Taskforce on Peak Oil & Energy Security", at **http://peakoiltaskforce.net./**

Martenson, Chris: "Economy, Energy, Environment", at **http://www.chrismartenson.com/**

ODAC: "Oil Depletion Analysis Centre", at **http://www.odac-info.org**

Peak Oil: "Exploring Hydrocarbon Depletion", at **http://peakoil.com/**

Post Carbon Institute: "Energy Bulletin", at **http://www.postcarbon.org/** and **http://www.energybulletin.net/**

Renewable Energy World, at **http://www.renewableenergyworld.com/rea/home**

The Oil Drum: "Discussions about Energy and Our Future", at **http://www.theoildrum.com/**