JOINT TRANSPORT RESEARCH CENTRE

Discussion Paper No. 2007-17
December 2007

Peak Oil and the Evolving Strategies of Oil Importing and Exporting Countries

Facing the hard truth about an import decline for the OECD countries

Kjell ALEKLETT
Uppsala University
Uppsala, Sweden

SUMMARY

Uppsala, September 2007

ABSTRACT

Statistical trends of oil intensity from individual countries and groups of countries show that an average increase of GDP of 3% per annum equates to a projected demand for liquids of 101 Million barrels per day (Mbpd) by the year 2030. This analysis shows that this demand cannot be fulfilled by production from current reserves and expected new discoveries.

Two models to assess peaks in production of oil are considered: the depletion model (DM), and the giant field model (GFM). The DM model shows Peak Oil (the maximum rate of production) date in the year 2011 with 90 Mbpd. Adding GFM we develop a "Worst Case" scenario of a plateau in production for the next 5 to 7 years at a rate of 84 Mbpd. A more optimistic case in the "Giant High Case" scenario is a peak in 2012 at 94 Mbpd. A less steep increase demand can move the peak to 2018. Both models show an oil production rate of the order of 50 to 60 Mbpd by 2030.

The demand for oil from countries that are importers is forecast to increase from current import levels of 50 Mbpd to 80 Mbpd. Saudi Arabia, Russia and Norway, today's largest oil exporters, will experience a decline in their export volumes of the order of 4 to 6 Mbpd by 2030 because of (what?). The projected shortfall cannot be offset by exports from other regions.

In a business-as-usual case, the shortage of fossil fuel liquids for transportation will be substantial by the year 2030. The necessary decisions for the economic transformation required to mitigate this decline in available oil supply should already have been made and efforts to deploy solutions under way.

We have climbed high on the "Oil Ladder" and yet we must descend one way or another. It may be too late for a gentle descent, but there may still be time to build a thick crash mat to cushion the fall.

1. INTRODUCTION

1.1. Mission

Modern civilization has become increasingly dependent upon oil over the previous century with oil now recognized as the most important global commodity. Currently the oil and gas industry has even surpassed agriculture as the single biggest industry in the world. At $70 per barrel, the value of just the world's crude oil business is over $2 trillion/year. However, crude oil is far from uniformly distributed around the world, and only a limited number of countries are significant producers. This fact divides the world into oil exporting and oil importing countries. The majority of the OECD countries import oil and these economies will not function without global security in the oil export market. Unfortunately Peak Oil will create a progressively more insecure export market.

This study contained within this paper will address Peak Oil and the evolving strategies of oil importing and oil exporting countries. The Organisation for Economic and Co-operation and Development (OECD) and the International Transport Forum (ITF), have specified the topics to be discussed and this study will focus on those topics where Peak Oil is most relevant. The specified topics are:

Price instability: the determinants of price in the short term

- Politics -- tension in the Middle East, nationalisations (South America, Russia);
- OPEC production quotas;
- Refining investment lags;
- Weather, accidents, natural disasters, terrorism;
- Financial instruments and trading.

Peak-oil and the evolving strategies of national oil producers and major oil companies

- Resources, reserves and production;
- Demand;
- Geopolitics:
    - Access of the oil majors to low cost reserves;
    - Refocusing of oil company investment;
    - Nationalised company policies.

The determinants of oil prices and supply in the long term

- The price and availability of substitutes:
  - Very deep sea oil;
  - Very heavy high sulphur oil;
  - Tar sands and oil shale;
  - *Natural gas;*
  - Coal.

- Greenhouse gas emissions:
  - Constraints on production of non-conventional oil, coal, and gas to liquids;
  - Prospects for and cost of carbon sequestration.

Long term trends in demand:

- For transport services and for oil products in the transport sector (liquid fuels);
- The impact of oil prices on demand – fuel price elasticity;
- Changing structure and resilience of the economy and the transport sector;
- The impact of fuel excise duties and carbon taxes on demand;
- Transport policy responses to the oil supply and price outlook.

1.2 Major articles by Uppsala Hydrocarbon Depletion Study Group

The findings in this report are mainly based on research done by Uppsala Hydrocarbon Depletion Study Group, Uppsala University, Sweden, and the following works will be used as main references:

[1.1] K. Aleklett and C.J. Campbell; The Peak and Decline of World Oil and Gas Production, Minerals & Energy 18 (2003) 5-20 (the article is available at http://www.tsl.uu.se/uhdsg/Publications/Minerals&Energy_2003.doc)

[1.2] K. Aleklett; TESTIMONY ON PEAK OIL before the House Subcommittee on Energy and Air Quality, Washington DC, USA, December 7, 2005, http://energycommerce.house.gov/reparchives/108/Hearings/12072005hearing1733/Aleklett2770.htm

[1.3] K. Aleklett; Oil: A Bumpy Road Ahead, World Watch 19-1 (2006) p.10, (the article is available at http://www.peakoil.net/uhdsg/WorldWatch_2006_Jan.doc)

[1.4] K. Aleklett; Oil production limits mean opportunities, conservation, Oil & Gas Journal 104-31 (2006) p, (the article is available at http://www.tsl.uu.se/uhdsg/Publications/OGJ_Aug_21_2006.doc)

[1.5] Bengt Söderbergh, Fredrik Robelius and Kjell Aleklett;, A crash programme scenario for the Canadian oil sands industry, Energy Policy, 35-3 (2007) p.1931-1947

[1.6] Fredrik Robelius, Giant Oil Fields - The Highway to Oil: Giant Oil Fields and their Importance for Future Oil Production. Acta Universitatis Upsaliensis 69 (2007) http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-7625, (R. Robelius and K. Aleklett, in preparation for Energy Policy)

[1.7] Kristofer Jakobsson, Fredrik Robelius and Kjell Aleklett; Oil use and economic growth in sub-Saharan Africa: current patterns and scenarios, submitted to Energy Policy (2007), http://www.tsl.uu.se/uhdsg/Publications.html and Kristofer Jakobsson, Oil Use and Economic Development in Sub-Saharan Africa, Diploma thesis, Uppsala University UPTEC F05 000 (2007), http://www.tsl.uu.se/uhdsg/Publications/Jakobsson_Thesis.pdf

[1.8] Kjell Aleklett, Discussion - Peak Oil - a fact of reality, Journal of Petroleum Technology 59-6 (2007) http://www.spe.org/spe-app/spe/jpt/2007/06/DissReply.htm

[1.9] Aram Mäkivierikko, Russian Oil, an estimate of the future oil production and oil export potential of Russia using the Depletion rate model, Diploma thesis Uppsala University, UPTEC ES07 018 (2007), http://www.tsl.uu.se/uhdsg/Publications.html (Aram Mäkivierikko, B. Söderbergh, R. Robelius and K. Aleklett, in preparation for Energy Policy).

[1.10] Mikael Höök, Werner Zittel, Jörg Schindler and Kjell Aleklett, A resource-driven forecast for the future global coal production, Submitted to Energy Policy (2007); http://www.tsl.uu.se/uhdsg/Publications.html

1.3 Peak oil and today's society

The Association for the Study of Peak Oil and Gas (ASPO) introduced the term "Peak Oil" in 2001 with Colin Campbell (founder of ASPO) defining Peak Oil thus:

"The term Peak Oil refers to the maximum rate of the production of oil in any area under consideration, recognising that it is a finite natural resource, subject to depletion."

When the International Energy Agency (IEA), an autonomous agency linked with the OECD, presented the World Energy Outlook 2004 (WEO 2004) the term Peak Oil was discussed as a possible future scenario. In the summary the IEA stated: "Production of conventional oil will not peak before 2030 if the necessary investments are made". However, when we look further we find that in Chapter 3 a peak in 2030 is premised on a USGS (United States Geological Survey) "Mean estimate" of 2626 billion barrels of remaining conventional oil. In WEO 2004 the IEA adds the caveat that if this estimate should prove too high, then "**the peak of production would come by 2015 or before"**. The Uppsala Hydrocarbon Depletion Study Group (UHDSG based at Uppsala University in Sweden) has shown, in an article discussing WEO 2004, that an oil production of 120.3 million barrels per day in 2030 is improbable [1.11]. Subsequent events and reports have demonstrated the importance of Peak Oil as a central theme around which economic development must be discussed.

From July 2005 till December 2006 The United States Government Accountability Office (GAO) investigated issues related to Peak Oil and in February 2007 released a report to Congressional Requesters entitled "CRUDE OIL – Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production" [1.12]. The fact that this GAO study took nearly two years to be completed shows the seriousness with which US policy makers treat Peak Oil.

Furthermore, on October 5, 2005 the USA Secretary of Energy, Samuel W. Bodman, requested that the National Petroleum Council (NPC) undertake a study on the availability of global oil and natural gas [1.12]. This letter helps demonstrate the political levels that Peak Oil has now reached:

"Dear Mr. Raymond,

Perspectives vary widely on the ability of supply to keep pace with growing world demand for oil and natural gas, the point in time at which global oil production will plateau and then begin to decline ("peak oil"), the implications these may have for the U.S. and world economy, and what steps should be taken to achieve more positive outcomes.

Accordingly, I request the National Petroleum Council, NPC, conduct a study on global oil and natural gas supply. Key questions to be addressed in the study may include:

- *What does the future hold for global oil and natural gas supply?*
- *Can incremental oil and natural gas supply be brought on-line, on-time, and at a reasonable price to meet future demand without jeopardizing economical growth?*
- *What oil and gas supply strategies and/or demand side strategies does the Council recommend the U.S. pursue to ensure greater economical stability and prosperity?*

……..I look forward to reviewing the Council's proposed study committee and detailed study plan.

Sincerely,
Samuel W. Bodman"

On July 18, 2007, the NPC accepted the report "Facing the Hard Truths about Energy" and presented this to the Secretary of Energy.

December 2005 saw the Swedish Prime Minister, Göran Persson, set up the Commission on Oil Independence. He asked the Commission to present concrete proposals for reducing Sweden's dependence on oil by 2020 and therefore, in this context, significantly reduce the actual consumption of oil in Sweden. The report from June 21, 2006, "Making Sweden an *Oil-Free* Society" [1.14], points out that the Peak Oil debate in Sweden was the main cause for the appointment of such a commission.

In December 2005 the Peak Oil discussion had also reached the U.S. House of Representatives and the subcommittee for energy and air quality. On December 5, as the only non-American citizen, I was called to deliver a written testimony and invited to Capital Hill for an oral presentation [1.2].

For obvious reasons GAO and NPC have concentrated their effort on the situation in the USA and before turning to some of the key points in the report it is necessary to place the report in a more OECD context. In the USA oil production peaked in 1970 and since then production has seen a steady decline. At the same time consumption in the USA has been increasing, making the USA more and more dependent upon imported oil. Within Europe we witnessed an increase in the production of oil until the end of the 20th century, but the new millennia has seen this rate of production start to decline. Year on year Europe is steadily growing more dependent on imported oil just as we have seen previously in the USA. Europe is therefore facing the same problems as the USA outlined in the GAO and NPC reports.

During the time frame 2008 - 2030 it is expected that all oil producing countries within the OECD will face the same problems as those the USA and Europe face today. The hard fact is that OECD countries in general will be more dependent on oil imports in 2030 then they are today.

The outline of this report will concentrate on oil and will have the following structure:

- The future demand for oil.
- How much oil have we found and when did we find it?
- Historical consumption and limits for future consumption.
- Import and export scenarios.
- Production of transport liquids with ctl and gtl.
- Possible strategies of oil importing and oil exporting countries.
- Awareness of peak oil.

1.4 References 1

[1.1] K. Aleklett and C.J. Campbell; The Peak and Decline of World Oil and Gas Production, Minerals & Energy 18 (2003), pp. 5-20 (the article is available at http://www.tsl.uu.se/uhdsg/Publications/Minerals&Energy_2003.doc)

[1.2] K. Aleklett; Testimony on Peak Oil, before the House Subcommittee on Energy and Air Quality, Washington DC, USA, December 7, 2005, http://energycommerce.house.gov/reparchives/108/Hearings/12072005hearing1733/Aleklett2770.htm

[1.3] K. Aleklett; Oil: A Bumpy Road Ahead, World Watch 19-1 (2006) p. 10, (the article is available at http://www.peakoil.net/uhdsg/WorldWatch_2006_Jan.doc)

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[1.5] Bengt Söderbergh, Fredrik Robelius and Kjell Aleklett;, A crash programme scenario for the Canadian oil sands industry, Energy Policy, 35-3 (2007), pp. 1931-1947.

[1.6] Fredrik Robelius, Giant Oil Fields - The Highway to Oil: Giant Oil Fields and their Importance for Future Oil Production. Acta Universitatis Upsaliensis 69 (2007) http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-7625, (R. Robelius and K. Aleklett, in preparation for Energy Policy)

[1.7] Kristofer Jakobsson, Fredrik Robelius and Kjell Aleklett; Oil use and economic growth in sub-Saharan Africa: current patterns and scenarios, submitted to Energy Policy (2007), http://www.tsl.uu.se/uhdsg/Publications.html and Kristofer Jakobsson, Oil Use and Economic Development in Sub-Saharan Africa, Diploma thesis, Uppsala University UPTEC F05 000 (2007), http://www.tsl.uu.se/uhdsg/Publications/Jakobsson_Thesis.pdf

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[1.9] Aram Mäkivierikko, Russian Oil, an estimate of the future oil production and oil export potential of Russia using the Depletion rate model, Diploma thesis Uppsala University, UPTEC ES07 018 (2007), http://www.tsl.uu.se/uhdsg/Publications.html (Aram Mäkivierikko, B. Söderbergh, R. Robelius and K. Aleklett, in preparation for Energy Policy).

[1.10] Mikael Höök, Werner Zittel, Jörg Schindler and Kjell Aleklett, A resource-driven forecast for the future global coal production, Submitted to Energy Policy (2007); http://www.tsl.uu.se/uhdsg/Publications.html

[1.11] Kjell Aleklett, 20040906, International Energy Agency accepts Peak Oil. An analysis of Chapter 3 of the *World Energy Outlook* 2004 http://www.peakoil.net/uhdsg/weo2004/TheUppsalaCode.html

[1.12] The United States Government Accountability Office (GAO), February 2007, "Crude Oil – Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production", www.gao.gov/new.items/d07283.pdf

[1.13] National Petroleum Council, NPC, "Facing the Hard Truths about Energy", presented to the Secretary of Energy, http://www.npc.org/

[1.14] The Swedish Oil Commission, report from June 21, 2006, "Making Sweden an Oil-Free Society" (http://www.sweden.gov.se/sb/d/574/a/67096).

2. FUTURE DEMAND FOR OIL

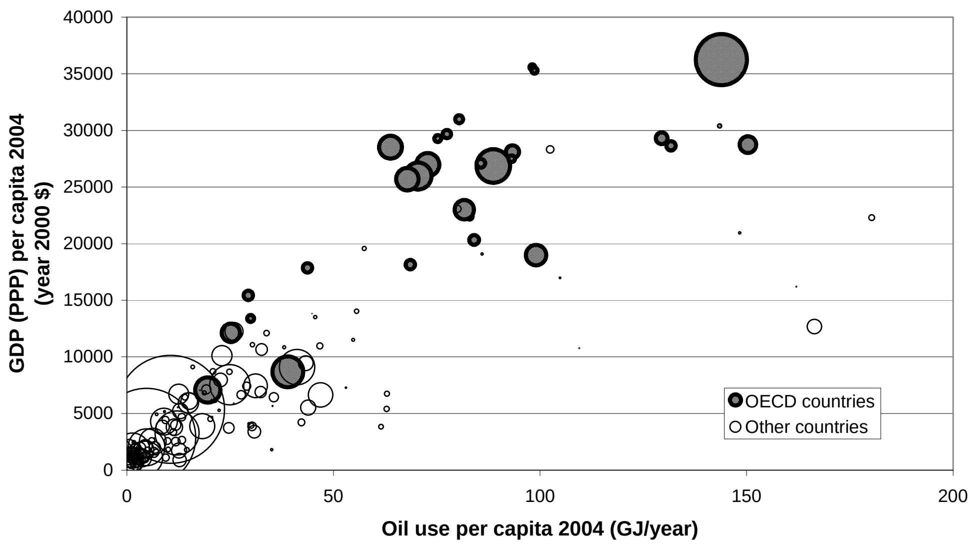
2.1. Future oil demand forecasts by IEA and EIA

In the World Energy Outlook 2004 (WEO 2004), published by the International Energy Agency (IEA [2.1]), the correlation between GDP growth and increases in oil consumption was discussed. The conclusion was that over a 20-year average an increase of 3% in GDP was correlated with a global increase in oil consumption of 1.6% per year. Starting with a consumption of 77.0 million barrels per day (Mbpd) for the year 2002, the demand predicted for 2030 is set to be 121.3 Mbpd, an exponential growth over 28 years. Previously in WEO 2001 the final year for the forecast period was 2020 [2.2] and in WEO 2002 the IEA added a further 10 years of exponentially increasing demand [2.3] without considering the implications of Peak Oil. The next WEO was for 2004 with exponential growth still being utilised for forecasting purposes. We made an analysis showing that this prediction of exponential growth was unrealistic [2.4], an analysis which consequently so disturbed the IEA that they contacted us and requested that the analysis be removed from the web. However, the analysis remained on the web and in WEO 2005 the increase in demand was reduced to 1.4% with demand for 2030 being reduced to 115 Mbpd [2.5]. This number has since remained the official demand figure for the IEA [2.6]. The US Energy Information Administration (EIA [2.7]) has calculated a 118 Mbpd of demand for 2030 with OPEC and Non-OPEC production divided 57 Mbpd and 61 Mbpd respectively.

2.2. Oil intensity driven demand

The fact that a scaling of GDP is used as driving force for growth in oil demand has lead us to making a detailed study of the correlation between GDP and oil consumption [1.7]. The standard GDP measure is calculated from currency exchange rates, a misleading figure in comparisons between countries since differences in price levels are not taken into account. The GDP adjusted to Purchasing Power Parity (PPP) addresses this problem and gives a somewhat more accurate picture of relative income levels and standards of living. Throughout this study, real GDP (PPP) at constant year 2000 prices has thus been used instead of unadjusted GDP.

Figure 2.1. **Oil use versus GDP (PPP) per capita in 2004 for all countries with available data**



The size of a circle represents population size. A number of small countries, among those Luxembourg, Singapore, Kuwait and Qatar, have too large an oil use to be shown in the graph. The OECD countries are hatched circles and Turkey has the lowest number.

To understand how important oil is for GDP we show in Figure 2.1 the correlation between GDP per person and oil consumption by person. The size of the circle is related to the population in the country. There is no doubt that GDP and oil consumption is strongly correlated. No country has attained a GDP similar to OECD Europe without a significant increase in oil consumption. Presumably, this also applies to Turkey and other countries striving for higher GDP. Historically countries at the top of the list, like the USA, have used more than a one to one correlation for economic growth. For today's expanding economies, like China and India, we have a one to one correlation [1.7].

Based on the supposition that GDP is the primary driver of oil demand, a simple model of oil demand can be formulated:

$$E_{oil} = (E_{oil}/GDP) * GDP \quad (1)$$

where E_{oil} is the total demand of energy from oil, and (E_{oil}/GDP) is a factor henceforth labelled "*oil intensity" (OI)*. *OI* is in itself a function of a number of factors such as technical efficiency, the structure of GDP, and the relative importance of oil as a primary energy source. Thus, treating *OI* as a straightforward measure of 'efficiency' in oil use, as is done occasionally, is misleading. *OI* is affected by several factors unrelated to efficiency. Constructing a scenario of oil demand using equation (1) only requires scenarios of *GDP* and *OI* respectively.

Figure 2.2. **Development of OI in selected countries, 1980-2005** [1.7]

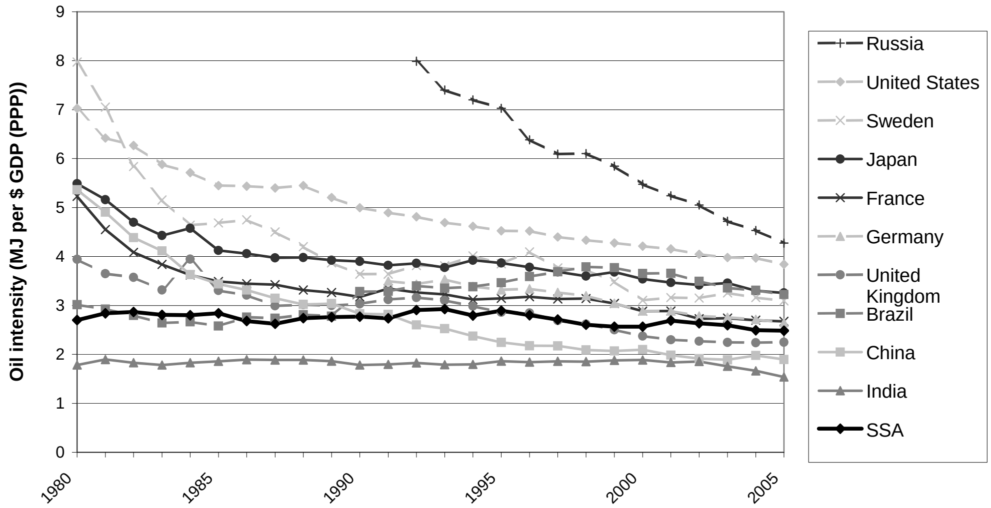


Figure 2.2 shows the development of *OI* in selected countries 1980-2005: Sub-Saharan Africa, SSA, representing a region without any growth per capita in GDP; China and India with strong growth in GDP; Russia, as a transition economy; and some OECD countries.

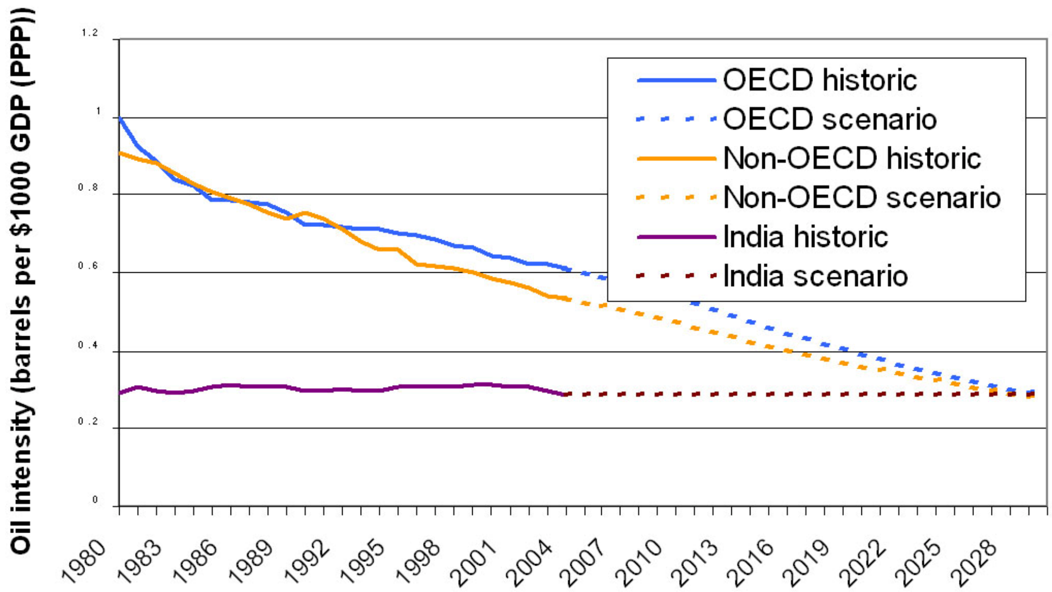
Four observations can be made:

- *OI* has tended to converge towards a common level over time.
- Countries with initially high *OI*, e.g. United States, Russia, Japan, France, China and Sweden, have declined dramatically.
- Most of the decline in *OI* took place during the first decade of the period, 1980-90, while subsequent decline has been much less dramatic (except in the case of Russia).
- Despite declining *OI* in OECD countries, they are still more oil intense than India has been throughout the period. SSA also appears to maintain a rather low *OI* by international standards.

The last observation is perhaps counterintuitive. The OECD countries, despite their shift towards service economies, access to various alternative energy sources, technological capabilities, and occasionally explicit policies of reduced oil dependence, have not managed to become less oil intense than the developing economy of India. The radical decline in *OI* that occurred in several countries after 1980 may be interpreted as a response to the record high oil prices of the second oil shock. Conspicuous, though, is that no such price response is visible in SSA, India and Brazil, countries at an already low level of *OI*. More recently, India has been suspected of underreporting its oil products imports [2.7], which make it difficult to determine whether the decline in *OI* observed since 2002 is actually genuine.

The bottom line conclusion is that no OECD country has developed an economy that functions at lower oil intensity than that of India. Regarding the oil intensity of India as the lower limit for the foreseeable future, it is possible to make a scenario of world oil demand based on future development of oil intensity.

Figure 2.3. **Oil intensity for OECD countries and non-OECD countries compared with the oil intensity of India**



In our forecast we assume that the whole world will have the same oil intensity as India in year 2030. Starting in 2010 the oil intensity for OECD has to decrease with 3.2%t per year and for the non-OECD countries with 2.7% per year.

If we look at the oil intensity in the OECD countries and the non-OECD countries and compare with India it is obvious that the world economy has to be less oil intense. The annual decrease for OECD has to be 3.2% and for non-OECD 2.7%. New technologies, savings, changes of life style, etc., are needed, but let us assume that these are all possible.

In our scenario we assume that the future global increase in GDP of 3% is divided in such a way that OECD takes 2% and non-OECD 5%. With these numbers equation 1 will give a demand of 101 Mbpd. This value is 14 Mbpd lower than the IEA forecast and 17 Mbpd lower then the EAI forecast, but we should remember that the cut in oil intensity for most of the countries in the world is a very tough mission.

2.4 References 2

[2.1] International Energy Agency, IEA; World Energy Outlook 2004; http://www.iea.org/textbase/nppdf/free/2004/weo2004.pdf

[2.2] International Energy Agency, IEA; World Energy Outlook 201; http://www.iea.org/textbase/nppdf/free/2000/weo2001.pdf

[2.3] International Energy Agency, IEA; World Energy Outlook 2002; http://www.iea.org/textbase/nppdf/free/2000/weo2002.pdf

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[2.6] International Energy Agency, IEA; World Energy Outlook 2006; http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1929

[2.7] Energy Administration Information, EAI, International Energy Outlook 2007, May 2007; http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2007).pdf

3. HOW MUCH OIL HAVE WE FOUND AND WHEN DID WE FIND IT?

The production process of oil is based upon the development of oilfields that were originally located by the exploration of potential geological structures. The United States Geological Survey (USGS) has made detailed studies of where conventional oil resources can be found around the world [3.1], and, with exception of regions around the North Pole, we can conclude that oil companies have been, and are, looking for oil in all of these regions. When discussing future oil production it should be further noted that the oil industry is a mature industry lacking in the naiveté of less mature industries.

3.1 Resources and Reserves

To better understand how much oil has been found and when it was found a short review of the various classifications of oil resources and reserves is required. Original resources are the total amount of oil that originally existed in the Earth's crust. From that part of the original resources that have been discovered, some are recoverable and some are unrecoverable. Every oilfield has a specific recover factory that is dependent upon the geological condition of the reservoir, but is also affected by technical solutions used in the production of each oilfield.

The discovered recoverable resources are referred to as the ultimate recoverable reserves, URR, the sum of cumulative production and production from reserves. The discovered unrecoverable resources are divided into technically recoverable but not economic, and unrecoverable resources that are neither technically recoverable nor economic. Future production of oil is therefore dependent on today's reserves, future economical reserves, and undiscovered oil that can be converted into economic reserves.

However, there is always uncertainty about how much oil in an oilfield can actually be recovered. This uncertainty has lead to the calculation of reserve figures based upon a probability of extraction, the confidence of recovering a given amount of oil from a given oilfield. A reserve estimate followed with, for instance, 'P90' means that there is a 90% chance that there is at least as much recoverable oil as the reserve estimate claims.

In addition industry makes the following division of reserves:

a. Proved Reserves: Proved reserves are those reserves that can be estimated with a high degree of certainty to be recoverable. It is likely that the actual remaining quantities recovered will exceed the estimated proved reserves. Proved reserves are labelled 1P.
b. Probable Reserves: Probable reserves are those additional reserves that could be recovered but with less certainty than Proved Reserves. It is equally likely that the actual quantities recovered will be greater or less than the sum of the estimated proved + probable reserves. This sum is labelled 2P.
c. Possible Reserves; Possible reserves are those additional reserves that are less certain to be recovered than Probable Reserves. It is unlikely that the actual remaining quantities recovered will exceed the sum of the estimated proved + probable + possible reserves. This sum is labelled 3P.

Understanding published statistics of reported reserves is difficult because some publications report only 1P reserves, others report 2P reserves, and yet others report a mixture of 1P, 2P or even 3P reserves. [3.2]

As an example let us take the reserves in Saudi Arabia and for the purposes of this discussion we will use the data presented by Mahmoud M. Abdul Baqi and Nansen G. Saleri from Saudi Aramco at a presentation in Washington D.C., February 24 [3.3].

Oil-in-place (OIP) is the estimated total amount of oil that is in the ground before production has started, and OIP for Saudi Arabia is reported to be 700 billion barrels (Gb) (the number 720 Gb has been recently reported in some newspapers). The total production so far is 105 Gb or 15% of the 700 Gb of OIP. The 2P reserves were claimed to be 260 Gb, or 37% of OIP. If we add the fraction produced and the fraction in reserve we get that a recovery factor of 52% on average for all of the one hundred oilfields in Saudi Arabia.

Leif Magne Merling from Statoil has made a study of recovery factors for thousands of oilfields and in 2004 he reported the average global recovery factor as 29% (and technology may increase this figure to 38% in the future) [3.4]. The P1 number for Saudi Arabia has been reported as 131 Gb, or 19% of OIP [3.3]. This number combined with the produced figure gives a recovery factor of 34%, which is already over the average reported currently.

In the 1980’s the reserves in OPEC countries were reported to have increased by 300 Gb [1.1], even though new discoveries had not been made. We can then treat theses increase as new estimates of recovery factors, but the question remains ‘can these new high recovery factors be sustained?’ When it comes to planning future liquid production for transportation we better not simply accept this as fact.

3.2 Oilfields

Oilfields come in many different sizes and of the total number of oil fields in the world, estimated at 47 500, only 507 are considered to be giant oilfields. The definition of a giant oilfield is one that will ultimately produce more than 500 million barrels (Mb) of oil. Uppsala Hydrocarbon Depletion Study Group has made an extensive study of Giant oilfields presented in the thesis of Fredrik Robelius [1.6]. Data and information on giant fields has been collected in a database named “Giant Field Data”. This database includes information on discovery year, year of first production, cumulative production up to 2005 and different URR estimates.

In this study by the UHDSG the measure of the size of an oilfield (from which the designation giant is derived) proved to be important and the measure chosen was the Ultimate Recoverable Reserves (URR). Previously, URR was defined as the cumulative production plus the Recoverable Reserves. Yet the phrase Recoverable Reserves represents a highly dynamic value that consequently affects the URR. In order to minimize the impact of this dynamic aspect of URR, proven plus probable (2P) reserves were used in the study.

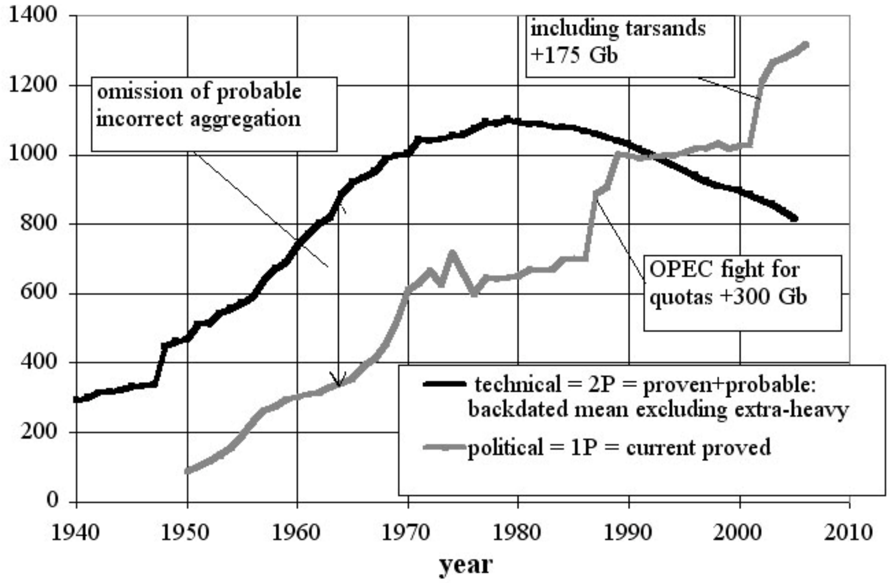
The many different estimates for URR over the last ten years lie in the range of 1750 to 2850 GB. One reason for this wide variation is the diverse types of oil included in the various estimates where, for example, some will include oil sands but other estimates are confined to conventional oil. Moreover, the estimates include oilfields ‘yet to find in the near future’ and obviously this ‘yet to find’ part of the estimate is uncertain with much controversy revolving around this figure.

An average of the estimates from the last ten years gives a URR value of 2250 GB and a similar value is obtained by adding the approximate 1000 Gb produced to date to the HIS inc. energy estimate of remaining 2P reserve of 1200Gb [3.10]. According to our database, the URR of the 507 giant oil fields is estimated at between 1150 and 1550 Gb, thus, if using 2250Gb as a global value of URR, giant fields represent about 55 per cent of the global URR. Giant fields have obviously dominated past production and future production will continue to be dependent upon these giant oilfields.

3.3 Discovery of crude oil

To estimate how much oil can be produced in the future we need to know how much has been found, when in time it was found, and how much we can expect to find. Every year the publications Oil & Gas Journal [3.5], BP Statistical Review of World Energy [3.6] and World Oil [3.7] report the figures for production of oil, consumption of oil, and oil reserves. The year-by-year calculated reserve from these open databases is a sum of P1 reserves, politically motivated reserves and the Canadian tar sand reserves. Jean Laherrere, former exploration manager for the French oil company Total, has for many years collected reserve data and presented them in different articles [3.8], [3.9]. Figure 3.1 shows a time series of these reserves (labelled 'political') against 'technical' reserves. An examination of these 'political' reserve numbers would appear to show that reserves are increasing over time.

Figure 3.1. **Global oil reserves in billion barrels (Giga barrels, Gb)** reported as proven (P1) and proven + probable (2P) [3.9]

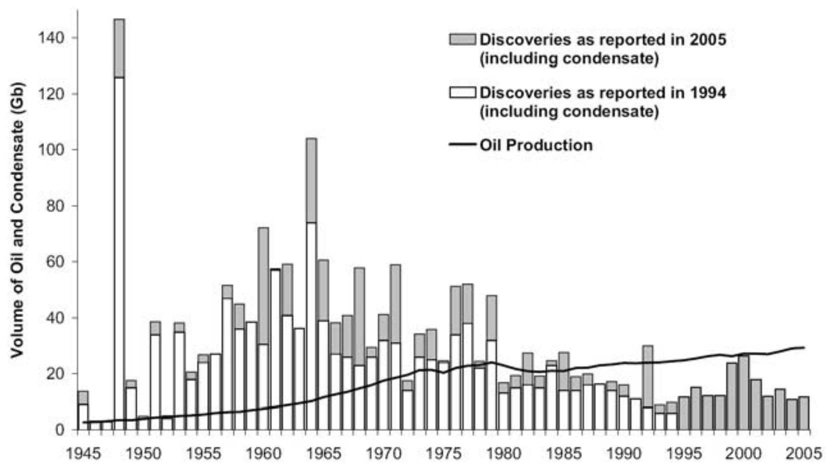


Conversely, examination of those reserves labelled "technical" (backdated 2P reserves excluding extra-heavy oil) provides a completely different picture. Reserves reach a maximum in or around 1980, and from that point in time a clear decline in reserves is observable. Future oil production looks a lot less positive.

The reserve classifications 1P, 2P and 3P were discussed in section 3.1 and when a new oilfield is discovered estimates are made according to these classifications. These first estimates are defined in the discovery year of that oilfield. During the production phase of the field, typically several years later, more accurate estimates can be made. In a few cases this will reduce the reported size of a field, but normally we will observe a reserve growth. This reserve growth can be due to field extensions, revision of earlier estimates and the availability of new technologies that improve oil recovery. The question is when in time this growth should be reported. Industry databases such as that of IHS [3.10] locate these changes in field size at the year of discovery. This is known as backdating. In figure 3.1 the 'technical' data points are backdated. This means that all the oil in the field was found the year the field was discovered with the consequence that the 2P reserves reached a discernible ceiling around the year 1980 and they are now in decline.

Figure 3.2 presents the global annual 2P discoveries of both oil and condensate as reported in 1994 and 2005. The difference in the discoveries for a single year between the two reporting periods is the backdated growth of existing oilfields. The fields discovered in the 1960s and 70s were found with less advanced methods than the fields found in the last 10 years and there is no surprise that we get a more substantial growth in the size of fields for this period. Another important detail exposed by this data is that we will never find so numerous and such large oilfields as we did in the middle of the last century.

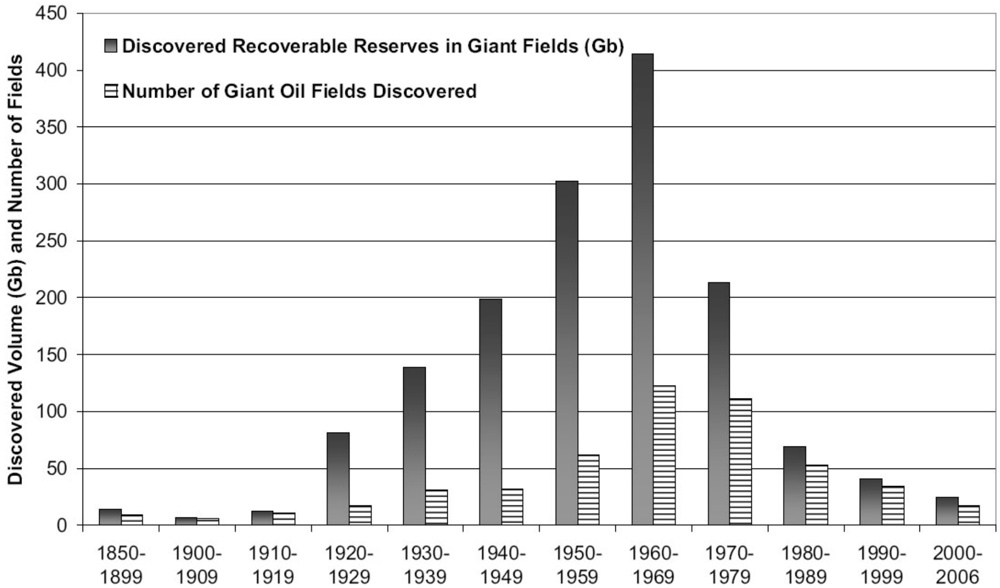
Figure 3.2. **Global annual discoveries of both oil and condensate, as reported in 1994 and 2005, together with oil production in billions of barrels (Gb)**



The difference in reported reserves between 2004 and 2010 is the reserve growth.
Source: Based on data from IHS Energy, ASPO and *Oil & Gas Journal* [1.6]

A separate study of giant oilfield discovery (Figure 3.3), the fields that today produce more than 50% of the world's crude oil, generates a clearer the picture. Although a similar number of giant oilfields were found in the 1990's as in the 1940's, those in the 1940's were on average four times larger than the fields discovered in the 1990's. It is clear that the golden age of the oil industry was the 1960's. It is unlikely that these golden times will ever return.

Figure 3.3: **Discovery of giant oil fields per decade, with respect to number and URR**

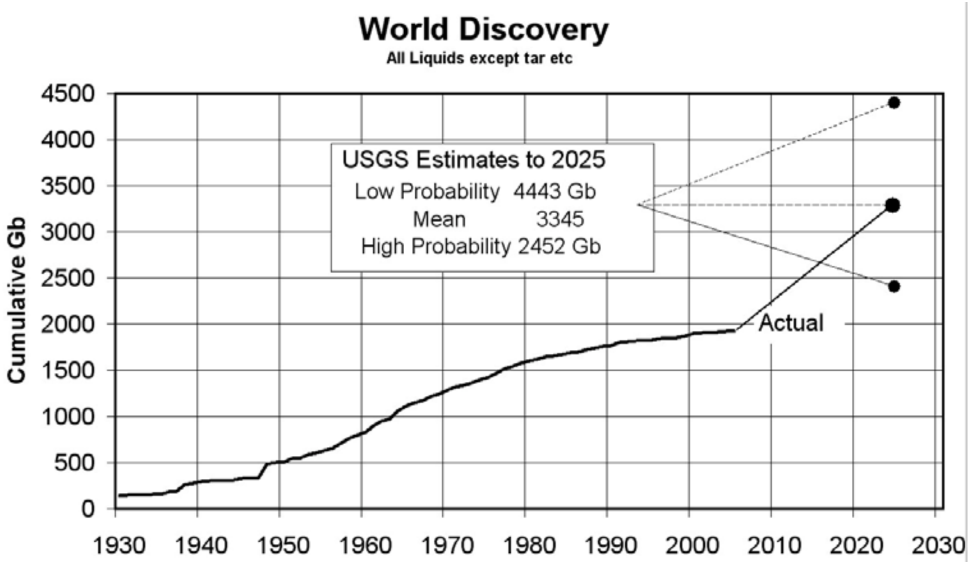


The most optimistic URR estimates have been used [1.6].

By adding the discoveries given in Figure 3.2 and discoveries from the beginning of the 20th Century we get total cumulative discoveries to date of close to 1800 Gb. The cumulative consumption of crude oil has reached 1000 Gb, and from this we get 800 Gb of reserves, the same number as figure 3.1. Yet in a report dated 2000 the US Geological Survey estimated that by 2025 we should have found 3345 Gb [3.1]. This number is subsequently used by the IEA for their base case scenario for future oil production. Following the statistical trends evident in Figure 3.4 it is unlikely that the cumulative discovery rate will have reached the predicted 3345 Gb by 2025.

The discovery trend presented in Figure 3.2 shows a declining rate of discovery and the decade discovery rate displays a logarithmic decline. Extrapolation of this trend for the next 30 years provides an expected 150 Gb of discoveries in new oilfields. If we assume that the growth in existing oilfields will also be in the order of 150 Gb we get the total cumulative value of discovered crude oil by the year 2030 of 2100 Gb. This is far from the number provided by the USGS and used by the IEA for their scenario analysis.

Figure 3.4: **The global cumulative crude oil discoveries [1.1] and the USGS estimate of crude oil discovery in year 2025**



At the ASPO-6 conference in Cork, 16-17 September 2007, Ray Leonard presented data from the 2006 Hedberg Conference [3.12]. This was a gathering of experts from private industry, state companies, academia and consultants to discuss world oil reserves and the potential for future growth. Attendees included representatives of the six largest private companies, major independents, OPEC, major state companies (Aramco, Petrobras, Petronas, Pemex), state organizations and 'think-tanks'. All attendees were specifically invited and had to make presentation on their area of expertise. The press was not allowed access and presentations were only shared among participants so as to permit more open discussion.

For 7 regions, West Siberia, Niger Delta, SW Africa, North Caspian, Offshore Brazil and Saudi Arabia, estimates of growth from exploration from industry experts were compared with estimates from the USGS. Ray Leonard pointed out that he personally had made the estimate for West Siberia for which USGS have reported 55 Gb, but he could perceive only 15% of the figure provided by the USGS as being realistic. For the 7 regions explored the USGS has a combined figure of 368 Gb but experts from within the industry could only see 36% of that as a realistic calculation. **If this holds for the rest of the world the conclusion is that the IEA must stop using data from the USGS in scenarios for future oil production.**

3.4 Discovery of heavy oil

The oil resource bases in Alberta in Canada and the Orinoco belt in Venezuela are usually referred to as unconventional oils. In historical context conventional drilling and production methods could not be used to produce the oil and hence the term unconventional. The main reasons for this are the density and high viscosity of the oil.

Heavy oil is not limited to these two areas and heavy oilfields occur all over the world such as the Kern River, California, Captain in the U.K section of the North Sea, and Duri, Indonesia. However, the two largest accumulations of heavy oil by far are in the Orinoco Belt and Alberta. Oil from Orinoco is usually called heavy oil while the extracted fluid from the oil sands in Alberta is referred to as bitumen.

Established reserves in the Orinoco belt equals 37 Gb, but actual oil in place is much larger and there is therefore potential for reserve growth in the future. The reserves in Alberta can be divided into two fractions. A smaller part with 32 Gb that can be mined, and a larger part, 142 Gb, that can be extracted by the "In Situ method"[1.7].

3.5 References 3

[3.1] USGS World Energy Assessment Team, U. S. Geological Survey World Petroleum Assessment 2000, http://pubs.usgs.gov/dds/dds-060/

[3.2] A detailed description of resources and reserves is given in Section 5, Definitions of Resources and reserves, of the Canadian Oil and Gas Evaluation Handbook; www.ccpg.ca/guidelines/cogeh_section5_definitions_51-101-2667.pdf

[3.3] Mahmoud M. Abdul Baqi and Nansen G. Saleri, Fifty-Year Crude Oil Supply Scenarios: Saudi Aramco's Perspective, February 24, 2004, CSIS, Washington D.C., http://www.csis.org/media/csis/events/040224_baqiandsaleri.pdf

[3.4] Meling, Leif Magne: How and for how long it is possible to secure a sustainable growth of oil supply (PowerPoint presentation), 2004-02-27 http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=en&name=en_830170164.pdf

[3.5] Oil&Gas Journal, http://www.ogj.com/index.cfm

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[3.9] Jean H. Laherrère, Uncertainty of data and forecasts for fossil fuels, Universidad de Castilla-La Mancha, Ciudad Real, 24 April 2007 www.hubbertpeak.com/laherrere/Castilla200704.pdf

[3.10] Homepage for HIS incorporation, http://energy.ihs.com/index.htm

[3.11] Reference [3.2] page 68.

[3.12] Ray Leonard, World Oil Reserves and Production: Industry view, ASPO-6 2007-09-16.

4. HISTORICAL CONSUMPTION AND LIMITS FOR FUTURE CONSUMPTION

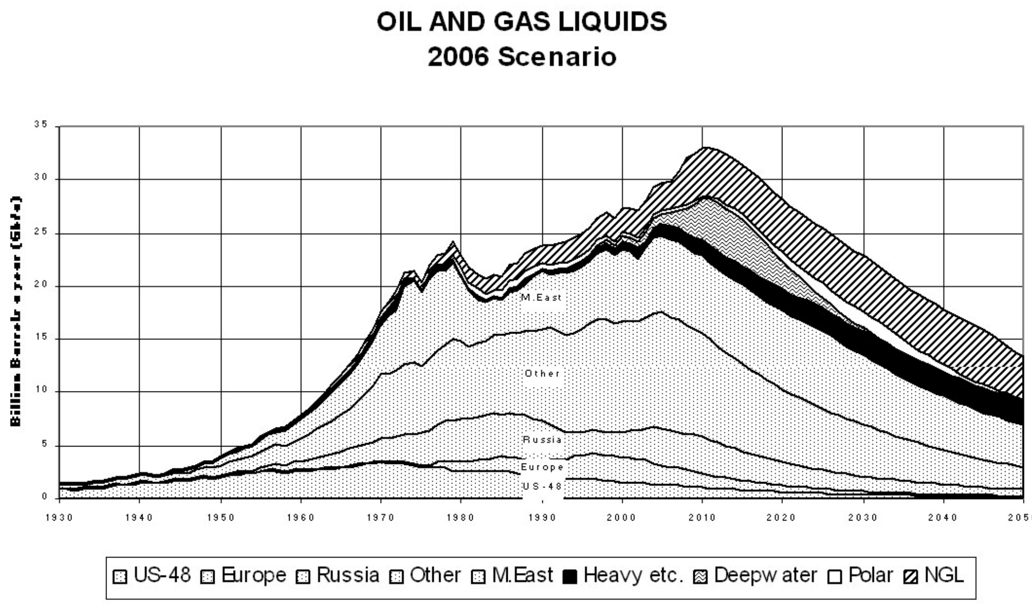
The BP Statistical Review of World Energy [4.1] is probably the most cited reference when it comes to detailed description of oil consumption (it can be accessed via Internet free of charge). This document includes detailed figures for consumption of crude oil, shale oil, oil sands and NGLs (natural gas liquids - the liquid content of natural gas where this is recovered separately). For 2005 the total consumption of these products was reported to be 81.1 million barrels per day (Mbpd).

The IEA has another reporting praxis that includes as part of the non-conventional fraction coal to liquids (CTL) etc. They also include “processing gains” which is the increase in the volume of end products compared with the volume entering the refineries, etc. The IEA reports a global consumption of 84.5 Mbpd for the year 2005.

4.1 Production forecasts based on the depletion model

In the publication “The Peak and Decline of World Oil and Gas Production” we divide the production of oil reported by BP into Regular oil, Heavy oil, Deepwater, Polar oil and NGL [1.1]. Figure 4.1 presents an updated version [4.2] of the one detailed in that article.

Figure 4.1. **Production of oil and gas liquids to year 2006** [4.2] **and production scenarios** as described in [1.1]



The regular oil is divided into the fractions US-48, Europe, Russia, Middle East, and Other is the rest of the world.

Figure 4.1 divides regular oil into the fractions US-48, Europe, Russia, Middle East and the rest of the world. Future production of regular oil is considered country by country and then these results are combined to produce the graph. Separate studies are then made for each of the other fractions and combined with the data for regular oil. Future regular oil production is based on the fact that the reserves in a country can only be depleted within a certain%age, the depletion rate.

With just the information for yearly production the change in production for a country can be expressed in terms of a decline rate, defined as the negative relative change of production over the year.

(Decline rate) = (Last year's production – This year's production)/(Last year's production)

As oil reserves are not included in the decline rate, it is not suitable for scenarios of future production.

The depletion rate differs in that it takes into account the amount of oil that is left. It is defined as *this year's production* divided by *the amount of oil that is left*.

(Depletion rate) = (This year's production)/(Oil left at start of this year)

Clearly, as more oil is produced, less oil is left. At a constant rate of production the depletion rate grows while the decline rate is zero. The depletion rate can never become negative.

Production for previous years gives the statistical trend for depletion and new reserves are added based on previous updates and estimations of oil to be found in the country. The highest depletion rates are found in the North Sea and the smallest in the Middle East. The strength of this model is that it is based on the obvious fact that oil has to be found before it can be produced.

The updated forecasts presented in Figure 4.1 are given as updated numbers in Table 4.1 for regular conventional oil and polar oil. Excluded from this data is production from bitumen, heavy oil, deepwater, and Natural Gas Liquids.

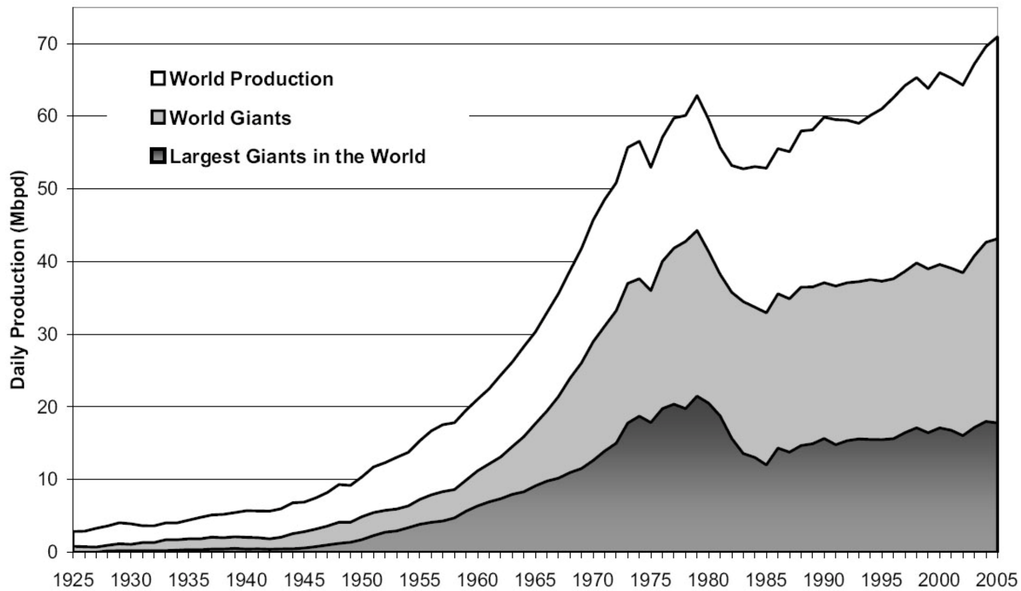
Table 4.1. **Production of regular conventional oil for 2000 and 2005, as well as resource-based production forecasts for 2010, 2020 and 2030**
Production from bitumen, heavy oil, deepwater and Natural Gas Liquids are excluded

Region	**2000 MB/d**	**2005 MB/d**	**2010 MB/d**	**2020 MB/d**	**2030 MB/d**
Middle East gulf region	*18.54*	*19.77*	19.86	20.23	17.80
Eurasia, including Russia	*11.27*	*15.32*	16.07	11.54	7.99
North America	*5.29*	*4.67*	3.72	2.11	1.21
Latin America	*8.43*	*7.97*	5.99	3.69	2.31
Africa	*6.77*	*7.87*	7.33	5.22	3.67
Europe	*6.53*	*5.26*	3.56	1.71	0.83
Asia-Pacific	*4.02*	*3.67*	3.19	2.11	1.38
Middle East minor	*2.91*	*2.85*	2.28	1.37	0.85
Other minor producer	*0.47*	*0.61*	0.53	0.38	0.28
Polar oil, Alaska	*1.0*	*0.8*	0.6	0.4	0.3
World total regular oil	***65***	***69***	**63**	**49**	**37**
Middle East Gulf Share	*28%*	*29%*	31%	41%	49%

4.2 Production from Giant oilfields

Section 3.3, “Discovery of crude oil”, discussed giant oilfields, those fields that will ultimately produce more then 500 million barrels (Mb) of oil, separately. In the UHDSG-Giant Oilfield Database (UHDSG-GOD [1.6]) we have collected all data on the production from giant fields, and Figure 4.2 illustrates their share of production.

Figure 4.2. **World oil production, excluding condensate and NGLs,** in million barrels per day (Mbpd), and the contribution from 312 giant fields and 21 fields with production exceeding 0.1 Mbpd for at least one year. In addition, the contribution from the largest fields is included [1.6].



The disadvantage with the country-by-country depletion model is that the summing of country predictions also incorporates the uncertainty of individual forecasts. If the primary interest is to construct a global forecast, it is much better to divide the production into the following fractions:

- Giant oilfields;
- Small oilfields;
- Deep water oilfields;
- New field developments;
- Oil sand production;
- Heavy oil – Orinoco Belt;
- Natural gas liquids.

The open data for giant oilfields gives conflicting values for their URR, and subsequently the best way to use these numbers is to treat them as upper and lower limits. Table 4.2 presents the data for the 20 largest oil fields in the world.

Table 4.2. **The 20 largest oil fields in the World with respect to URR [1.6]**

Field name	Country	Discovery year	Production start	Range of URR (Gb)
Ghawar	Saudi Arabia	1948	1951	66–150
Greater Burgan	Kuwait	1938	1945	32–75
Safaniya	Saudi Arabia	1951	1957	21–55
Rumaila	N. & S. Iraq	1953	1955	19–30
Bolivar Coastal	Venezuela	1917	1917	14–30
Samotlor	Russia	1961	1964	28
Kirkuk	Iraq	1927	1934	15–25
Berri	Saudi Arabia	1964	1967	10–25
Manifa	Saudi Arabia	1957	1964	11–23
Shaybah	Saudi Arabia	1968	1998	7–22
Zakum	Abu Dhabi	1964	1967	17–21
Cantarell	Mexico	1976	1979	11–20
Zuluf	Saudi Arabia	1965	1973	11–20
Abqaiq	Saudi Arabia	1941	1946	13–19
East Baghdad	Iraq	1979	1989	11–19
Daqing	China	1959	1962	13–18
Romashkino	Russia	1948	1949	17
Khurais	Saudi Arabia	1957	1963	13–19
Ahwaz	Iran	1958	1959	13–15
Gashsaran	Iran	1928	1939	12–14

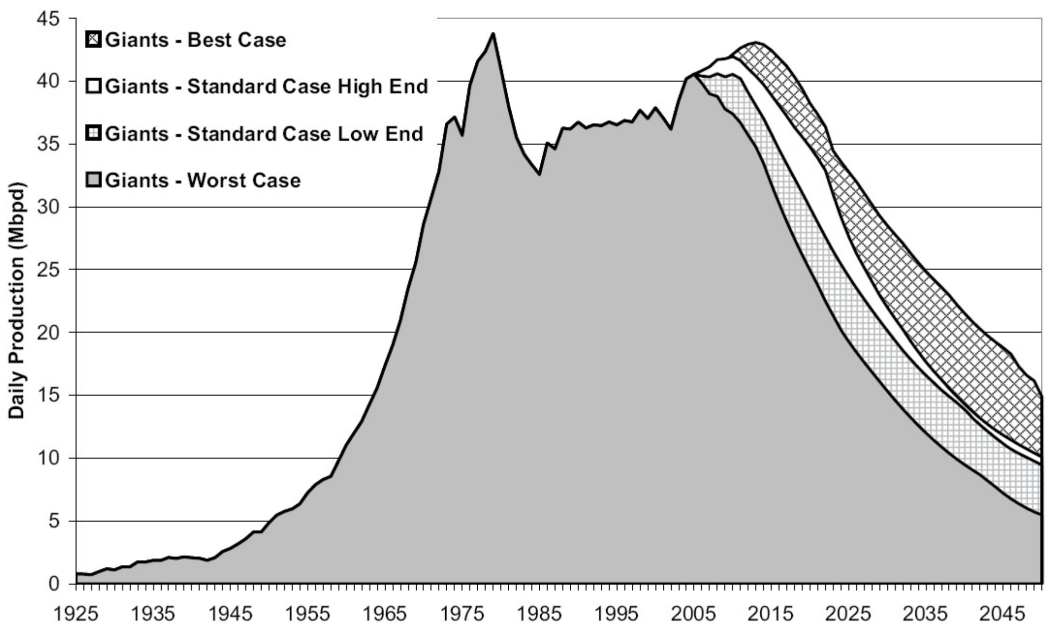
An oil company with detailed field information can make sophisticated predictions about future oil production. In late 2005 the state-owned Mexican oil company, Pemex, made an internal forecast for the giant oilfield Cantarell. They presented a "best case" and a "worst case" scenario. Cantarell, the second largest oilfield in the world when it comes to production, produced 2 Mbpd in December 2005. According to the "best case" scenario production was predicted to be 1.9 Mbpd over the next year, with the "worst case" scenario predicting 1.6 Mbpd. The two different scenarios were based on varying estimates of URR. The actual production turned out to be 1.5 Mbpd [4.3].

Uppsala Hydrocarbon Depletion Study Group has developed a model to predict future production from giant oil fields [1.6]. A general model is applied along with a number of outcomes dependent upon the stated upper and lower limits for the URR (another important parameter is the decline parameter for giant oilfields). Data from the Cantarell scenarios supports such an approach. Different future production conditions will be simulated and the range between the various outcomes can serve as an error estimate.

Production from a giant oilfield follows a very specific pattern. Past production includes a start up period and an early plateau in production based upon installed production facilities. There is then a late production plateau followed by declining production. Summing the three phases should yield the applied URR. Analyses of 20 giant fields' gives decline rates of between 6 and 16% and three different rates (6, 10 and 16%) are used for different scenarios.

The results of this analysis produced four different possible scenarios. “Worst Case” and “Best Case” as the limits, but the more realistic scenarios are designated the “Standard Case Low End” and “Standard Case High End”. The four scenarios for production from giant oilfields are presented in Figure 4.3.

Figure 4.3. **Future oil production from giant oilfields**
million barrels per day, Mbpd [1.6].



The fact that most of the oil in giant oilfields was found between the years 1940 and 1980 (a forty year period) means that the bulk of their production will go into decline during a rather short time frame and the high decline rates for giant oilfields will mark the beginning of the end of production.

4.3. Production from small oilfields

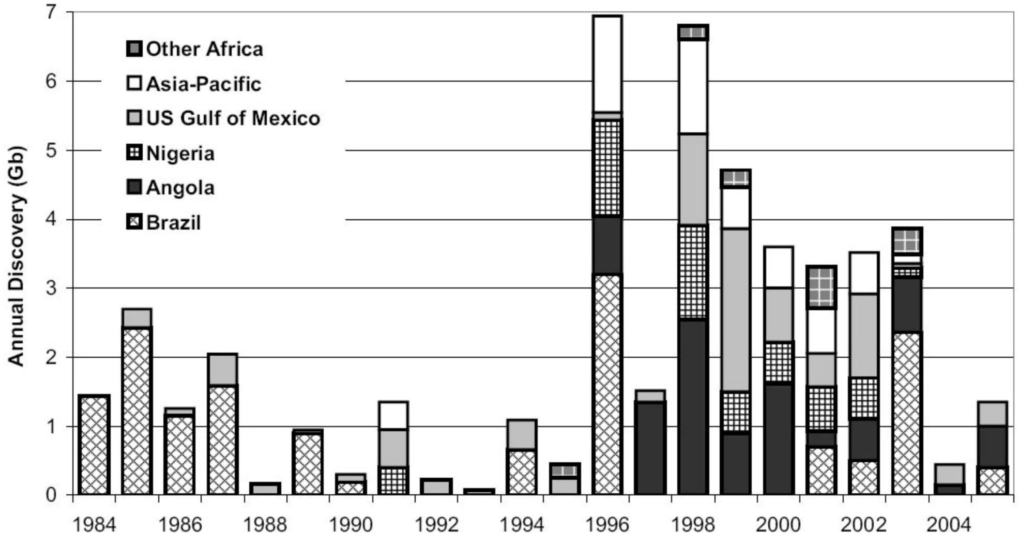
The total production from existing oilfields is declining. As an example ExxonMobile provides a range of 4 to 6% in their publication “A report on energy trends, greenhouse gas emission and alternative Energy” [4.4]. As the giant oilfields tend to have high decline rates we apply only a 3% decline in the production from existing small oilfields.

4.4. Production from deep-water oilfields

The development of offshore technology for exploration and production of petroleum is a true landmark in technological development. The first 94 offshore drilling projects took place in waters of a depth of 11 meters in Summerland, California in 1897 and currently typical water depth is around 1000 meters.

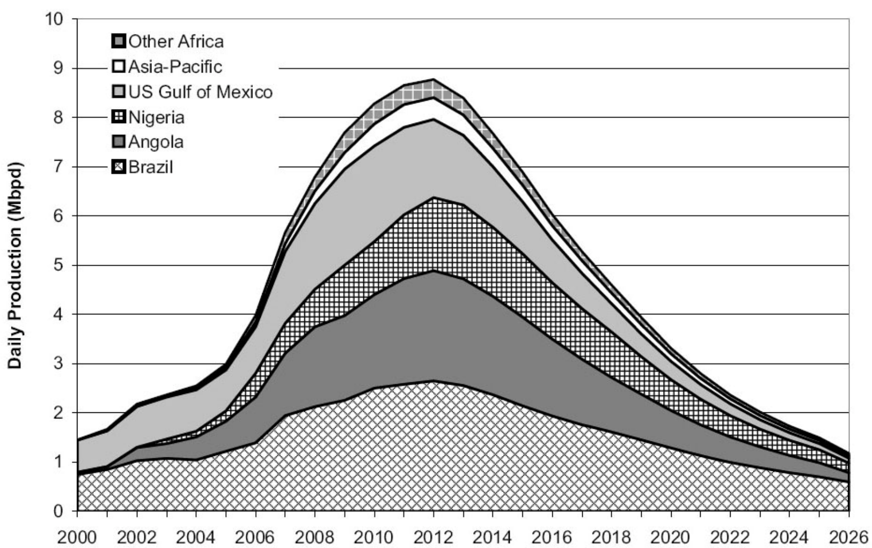
Exploration in deepwater (waters exceeding 500m deep) has so far been conducted primarily in three regions that hold the most discovered resources: the US Gulf of Mexico, Brazil and West Africa. Figure 4.4 shows the annual deepwater discoveries and further illustrates that exploration really took off in the mid 1980s mainly due to advances in seismic reflection imaging that led to a reduction in the geological risk involved in deepwater exploration. Data for deepwater oilfields has been collected in a database [1.6] and this database has been used to determine production forecasts from these deep water oilfields (see Figure 4.5).

Figure 4.4. **Annual deep water discoveries**
billion barrels per year [1.6]



The peak in discoveries at the end of the 1990s is reflected as a peak in production with 8.8 Mbpd around 2012. Even though new discoveries can make the decrease in production less steep we can not expect this production to offset the decline in production of existing oilfields.

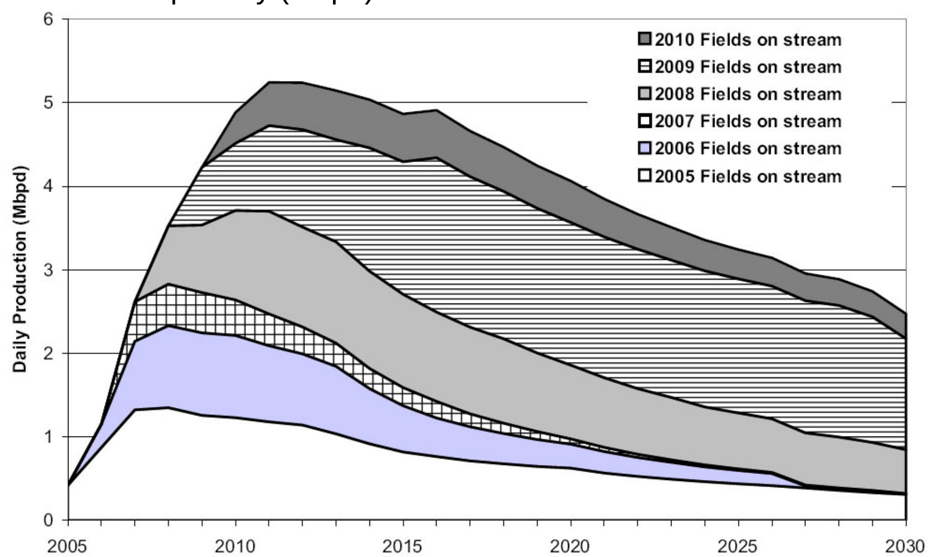
Figure 4.5. **Deepwater production forecast**
million barrels per day [1.6]



4.5. Production from developments of new oilfields

The future development of oil fields is an essential part of future oil production. Those fields will help to fill the gap between old declining fields and rising demand. The forecast for future production from new field developments includes all major developments but excludes deepwater projects (figure [1.6]). Our database covers over 80 fields that came on stream during 2005 or will come on stream as late as 2013. In addition, some field extensions in non-giant fields that came on stream prior to 2005 are included (for details se Appendix B in reference 1.6).

Figure 4.6. **Production forecast for new field developments**
million barrels per day (Mbpd)

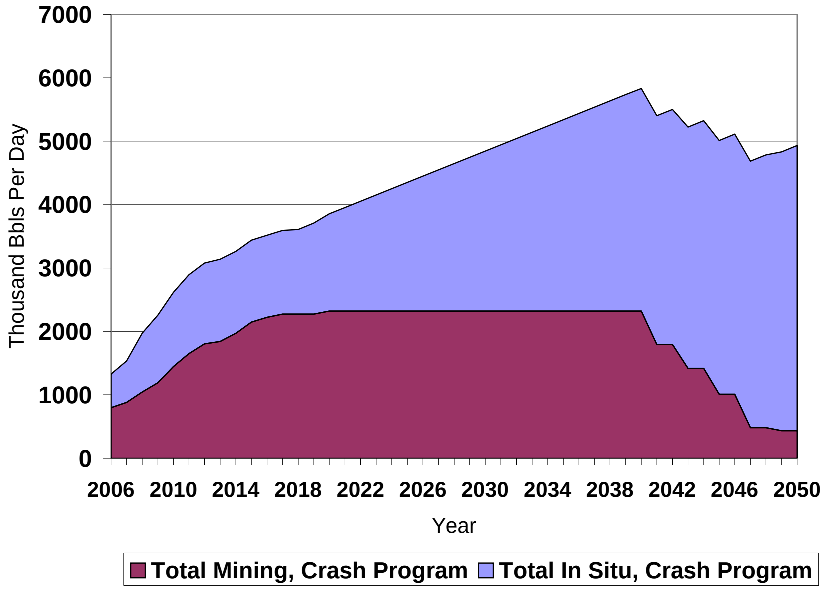


4.6. Production from oil sand in Canada

The province of Alberta in the south-western part of Canada holds the entire resource base of Canadian oil sands, and UHDSG has made a “Crash Program Scenario for the Canadian Oil Sand Industry” [1.5]. Typically oil sand is assembled in porous rocks and consists of up to 80% sand, silt and clay. The actual resource extracted from oil sands is bitumen, which in turn goes through further processing to produce a synthetic crude oil (SCO) suitable for conventional refineries.

There are two main technologies for extracting bitumen from oil sands: open mining and in-situ thermal production. Open mining requires the removal of an overburden in order to reach the oil sands. Some 20 per cent of the reserves, 35.2 Gb, are deposited shallow enough to be mined.

Figure 4.7. **Oil production from Canadian oil sand**
million barrels per day from mining and *in situ* production [1.5]

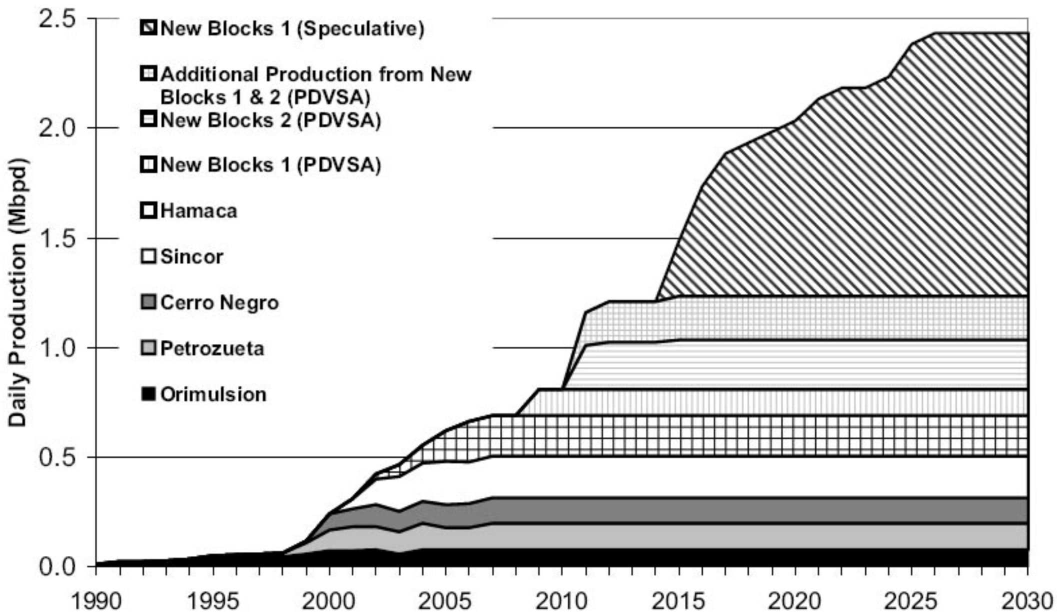


When the overburden is too thick for strip mining in-situ extraction methods have to be applied, and the different thermal methods applied have been described in our existing work. One big hurdle in the expansion of in-situ production is the need for natural gas. As an industry rule of thumb it takes 1000 cubic feet of natural gas to produce one barrel of bitumen. In addition some 400 cubic feet of gas is needed to upgrade one barrel of bitumen to one barrel of SCO [1.5]. Thus, 1 400 cubic feet of natural gas is required to convert bitumen to one barrel of SCO. The remaining established in situ reserves are 142.2Gb. Production for the two scenarios is presented in figure 4.7, and for the year 2030 we have a maximum production of 5 Mbpd, but this high production needs nuclear power to produce steam.

4.7. Production of heavy oil from the Orinoco belt in Venezuela

The estimated oil in place in the Orinoco heavy oil belt is 1 360Gb and the latest recovery estimate approaches 20 per cent which gives a reserve of 236Gb. The development of horizontal drilling techniques and increased cost effectiveness of both drilling and pumps has made it possible to recover the heavy oil without using costly thermal methods. However, even with these advances in technology thermal methods are still used to a certain extent.

Figure 4.8. **Production from the Orinoco Belt, both historic and a forecast up to 2030** million barrels per day (Mbpd)



Note: Only Hamaca, Cerro Negro, Petrozueta and Sincor are actually in production [1.6].

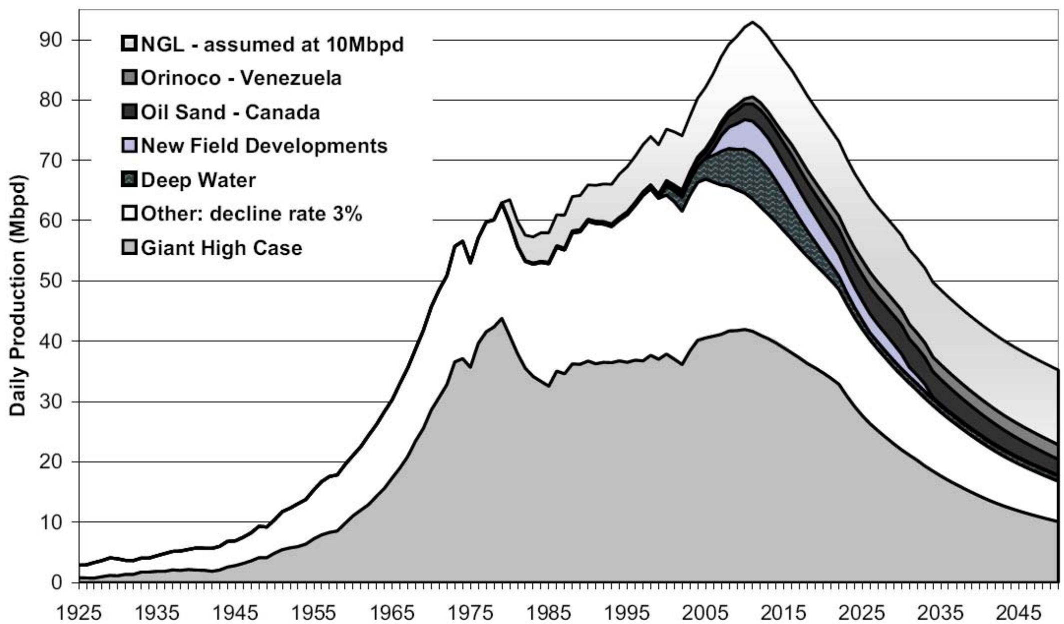
The production profile for the Orinoco fields is to ramp up to a plateau and then maintain this production plateau for a long period of time. The aim for the four main projects in Orinoco is to keep the level at 0.6Mbpd for 35 years. This level is used as the base for the forecast of future Orinoco production (figure 4.8). From 2009, a new block will add a production of 0.12Mbpd and in 2010 a further new block plus additional production from the first new block will add 0.35Mbpd extra. This leaves a total production, including an assumed Orimulsion production of 0.10Mbpd, of 1.2Mbpd in 2012 [1.6].

However, since the resource base is large it is assumed an extra expansion starting in 2015 will eventually reach 1Mbpd by 2020. As this expansion continues total production will reach 2.4Mbpd by 2025.

4.8 Final production profile and conclusions

The aim of the giant oilfield study was to examine the dominant influence on production from giant oilfields so we have not tried to make a detailed analysis of the Natural Gas Liquid fraction, we have simply assumed that today's production will remain constant. In figure 4.9 we have added all the different liquid streams for the Giant High Case scenario.

Figure 4.9. **Global liquids production per liquid stream for the Giant High Case** million barrels per day (Mbpd) [1.6]



This scenario allows for an increase in production over successive years at a rate greater than the 1.4% that the IEA use in their demand forecast, but there is no way that we can see a production of 115 Mbpd by 2030. Peak Oil for this scenario will occur around the year 2012.

If we now adjust the forecast scenarios to an increase in demand of 1.4%, the peak in oil production will be delayed and the upper limit for Peak Oil will be 2018, and this is for the best case scenario (see Figure 4.10).

However, we believe that the high case scenario is unlikely to happen, as it requires the 10 giant oilfields described in Table 4.3 to come in to production shortly. Seven of these fields can be found in Iraq and investments in these oilfields require political/economic stability in that country.

Figure 4.10. **Global liquids production for all scenarios**,
with the best case scenario adjusted to fit an annual demand growth of 1.4%,
million barrels per day (Mbpd)

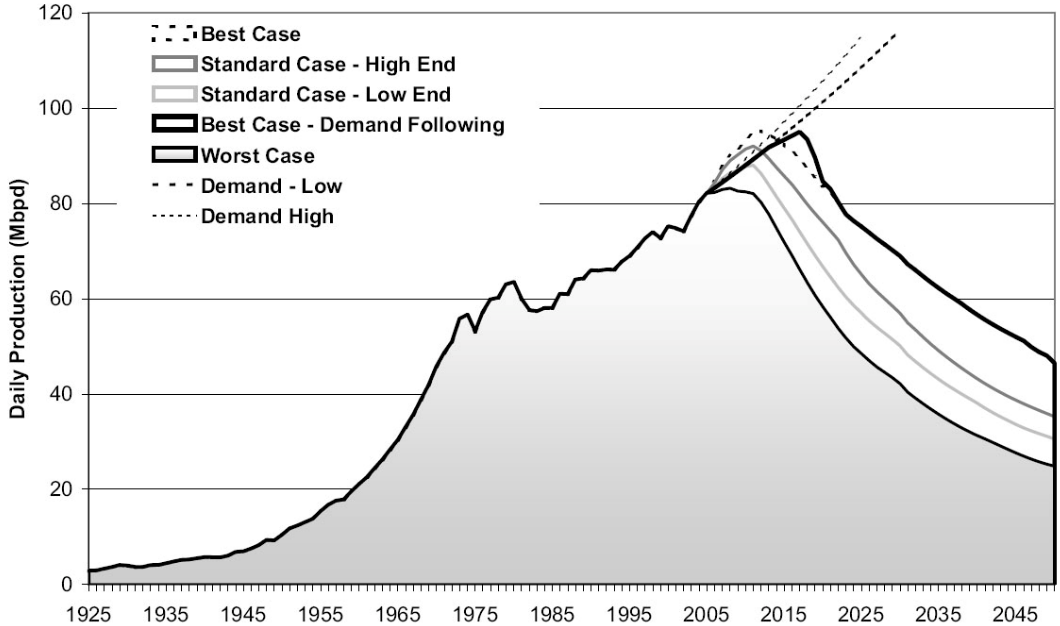


Table 9.3. **Major field expansions included in the best case scenario,** [thousand barrels per day (kbpd)]
Field production is assumed to increase gradually.

Field	Country	Peak level	Year of peak (kbpd)	Comments
Tengiz	Kazakhstan	825	2012	
Northern fields	Kuwait	900	2013	Much delayed project
Majnoon	Iraq	1000	2018	Gradual expansion
West Qurnah	Iraq	550	2015	
Halfayah	Iraq	250	2014	Re-development of old field
Nahr-Umr	Iraq	500	2017	Re-development of old field
Nasiryah	Iraq	300	2016	Re-development of old field
Zakum Upper	Abu Dhabi	700	2013	Low pressure, poor porosity
Ratawi	Iraq	200	2013	Re-development of old field
Tuba	Iraq	180	2015	Re-development of old field

4.9 Conclusions for production

Production of future oil has been studied with the “depletion model” and with the “giant field model”. Both models give us a peak in the production of oil in the vicinity of the year 2012. The giant low case scenario indicates that we have now just reached a plateau in production that will remain constant for 5 to 7 years and that we will then witness a steady decline.

Another interesting observation is that both models predict a production between 50 and 60 Mbpd for the year 2030. The giant field study can explain this by observing that giant oilfields are already declining rapidly and that more than 50% of current oil production is in the giant fields. Therefore our demand forecast of 101 Mbpd in 2030 (see section 2.2) cannot be fulfilled.

4.10 References 4

[4.1] *The BP Statistical Review of World Energy*, www.bp.com

[4.2] Colin Campbell, ASPO Newsletter 81, http://www.aspo-ireland.org/contentFiles/newsletterPDFs/newsletter81_200709.pdf

[4.3] David Luhnow, Dying Giant - Mexico Tries to Save A Big, Fading Oil Field, *Wall Street Journal*, April 5 (2007) Page A1.

[4.4] ExxonMobil, A report on energy trends, greenhouse gas emission and alternative energy, February 2004.

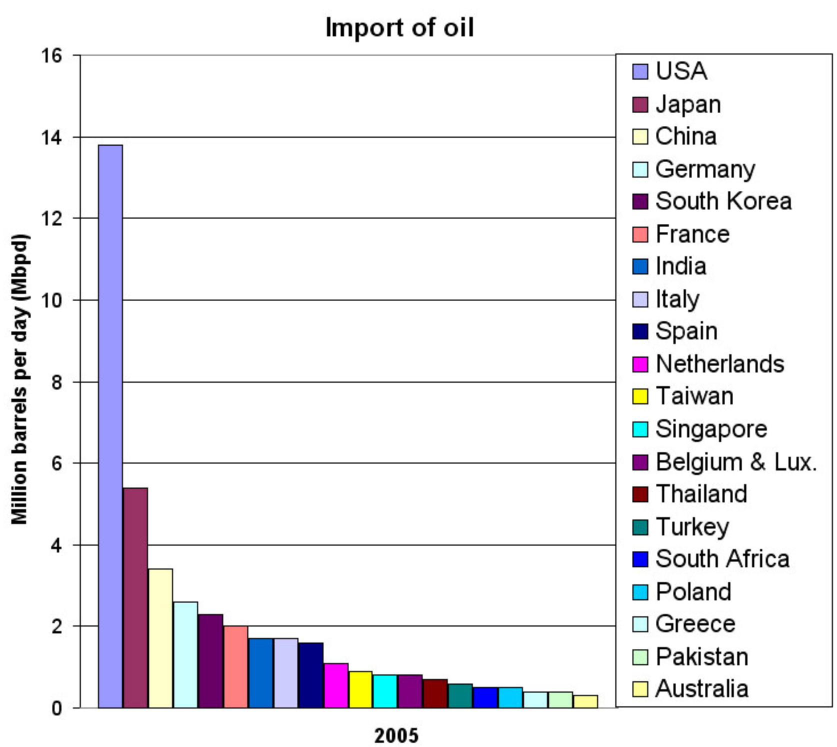
5. IMPORT AND EXPORT SCENARIOS

Over the years it has been hard to convince politicians, economists, etc, that Peak Oil is a fact of life and not just a theory. When it comes to describing Peak Oil theoretical methods are used and in this work we have discussed the 'depletion model' and the 'giant field model'. A break through in convincing the individual of Peak Oil occurs as we begin to discuss the import and export of oil. So far there has been no other opinion than **"the import of oil requires that someone else is willing to export oil".** The "Peak Oil Moment" arrives and Peak Oil becomes reality.

5.1 Importing and exporting countries

From the annual figures for oil production/consumption published in the BP Statistical Review of World Energy [5.1] we can determine which countries are net importers and which are net exporters. In 2005 export trade of oil was 48 million barrels per day with 29% of global crude oil exports going to the US with Japan and China at number two and three (11% and 7% of global exports respectively).

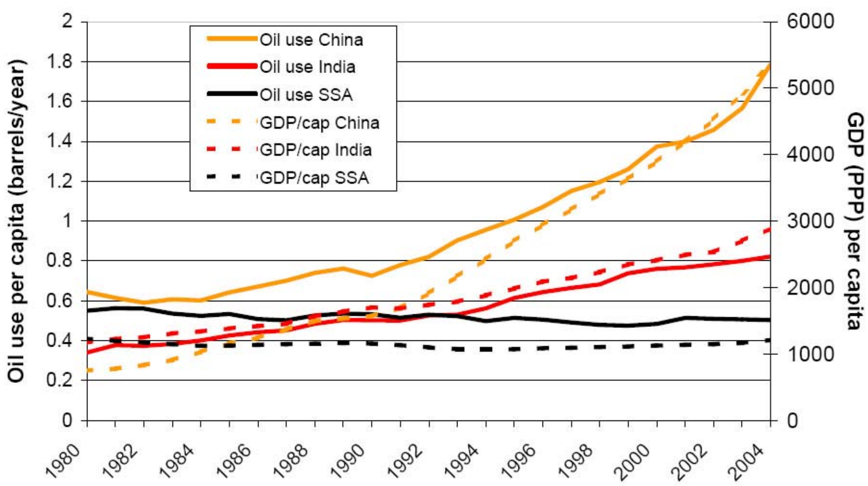
Figure 5.1. Net import of crude oil for the twenty largest importers [1.4]



Clearly, those nations that require imported oil must find countries that are prepared to export oil and to date this has been possible, with the exception of the 1970s and 1980s when the flow of oil was constricted in the Middle East. Normally the transfer of oil into one country will come from several different sources. Examining all exports, we find that Saudi Arabia is the number one exporter, with a volume of just over 9 Mbpd, Russia is number two with 6.8 Mbpd and Norway comes third with 2.8 Mbpd. Exports from Norway, a member of the OECD, are now in decline.

During the last 30 years, the annual increase in average gross domestic product (GDP) globally has been 3% per year compared with an average increase in oil consumption of 1.6% per year [5.2]. In developing countries, the correlation between GDP and oil consumption is stronger than average. The correlation for China, India and SSA (sub-Sahara Africa) for the time period 1980 to 2004 is given in figure 5.2. The Sub-Sahara Africa region shows no increase in oil consumption per capita and this correlates with a zero increase in GDP per capita for the region [1.7].

Figure 5.2. **Development of GDP (PPP) and oil use per capita in China, India and SSA 1980-2004**



In WEO 2006, the IEA forecast that the increase in oil consumption would be 1.4% per year for the next 25 years, requiring that oil production reach 115 Mbpd by 2030 [2.6]. The US EIA forecasts a production of 118 Mbpd for the same year [2.7]. Compared with today's production of 85 Mbpd, an increase of 30 Mbpd in global production will be required to reach the forecasts of the IEA and the EIA [1.4].

According to the EIA US consumption will increase by 6.2 Mbpd (30%) by 2030. As production is projected to stay constant all of this increase must come from new imports of oil meaning imports will increase from 13.8 Mbpd (2005 numbers) to 20.0 Mbpd, an increase of 45%.

China is consuming 7.4 Mbpd and imports reached 3.8 Mbpd in 2006. Over the last 5 years consumption has increased by an average of 9% per year. Production within China is 3.7 Mbpd today and is expected to decline through to 2030. What future increase in oil demand will we see in China? A 9% increase would give an unrealistic 54 Mbpd, twice as much as the USA. But a 5% increase will put China and the USA on the same level, and a required import of the order of 20 Mbpd.

The rest of the importing countries import 31 Mbpd and a modest increase of 1% per year will give an additional 10 Mbpd in import demand producing a combined import requirement of the order of 80 Mbpd or an increase of the order of 30 Mbpd. Can those countries exporting oil deliver?

Saudi Arabia is the largest oil exporter in the world and no one denies that this primacy will be assailed. When there is any discussion of future Saudi oil production it is normally the business of the oil minister. An exception to this was in February 2004, when Mahmoud M. Abdul Baqi and Nansen G. Saleri reported data from the state oil company Saudi Aramco [5.3]. The production scenarios presented were labelled Maximum Sustainable Capacity (MSC). Today the MSC is 10 Mbpd and it is proposed this could be maintained until 2042. Another scenario increases production to 12 Mbpd maintaining the MSC until 2033. The base for these scenarios is that the Saudi reserves are 260 Gb, and as pointed out in 2.2 this is a highly questionable figure.

Figure 5.3. **Net export of crude oil for the twenty largest exporters** [1.4]

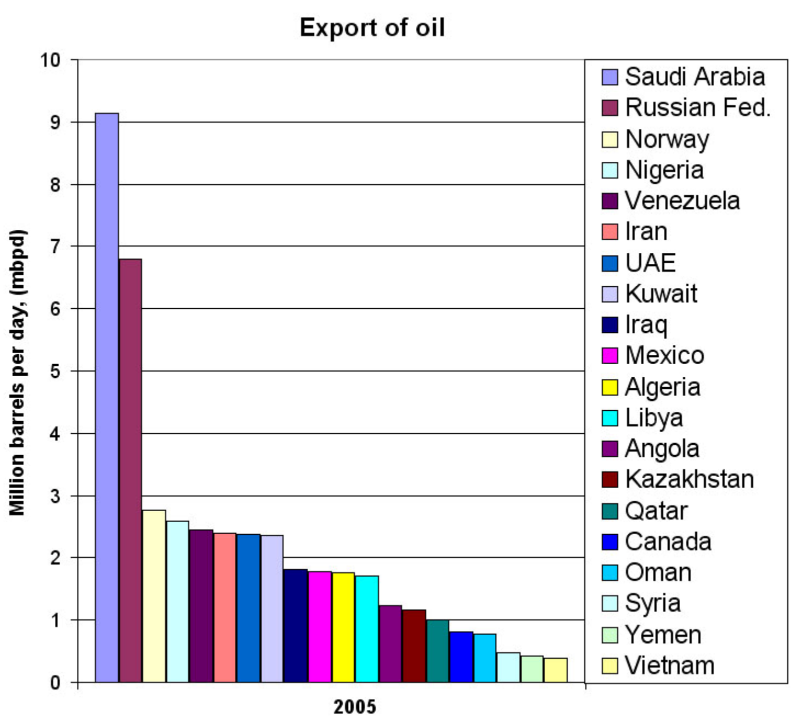
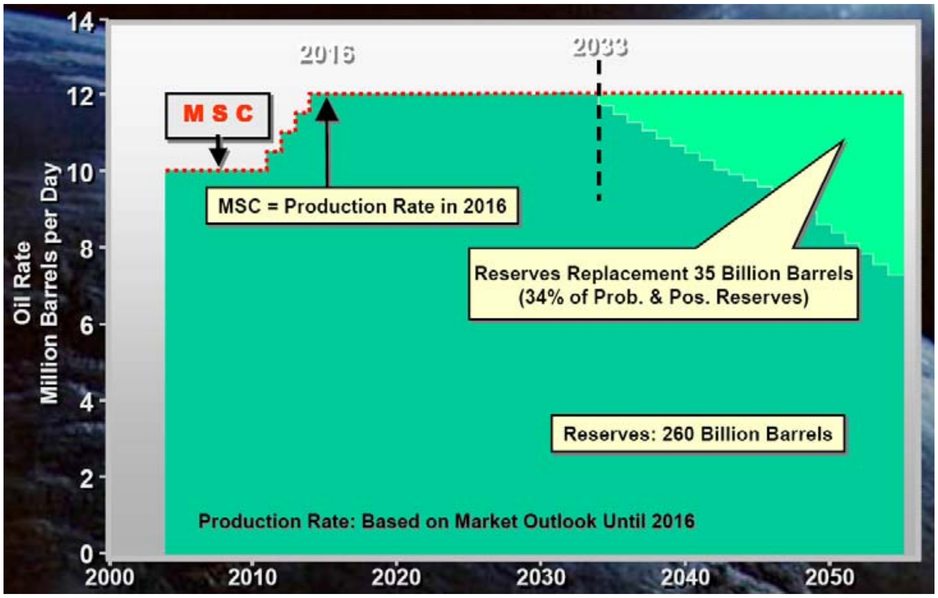


Figure 5.4. **The Saudi Aramco Maximum Sustainable Capacity Production Scenario [7.4]**

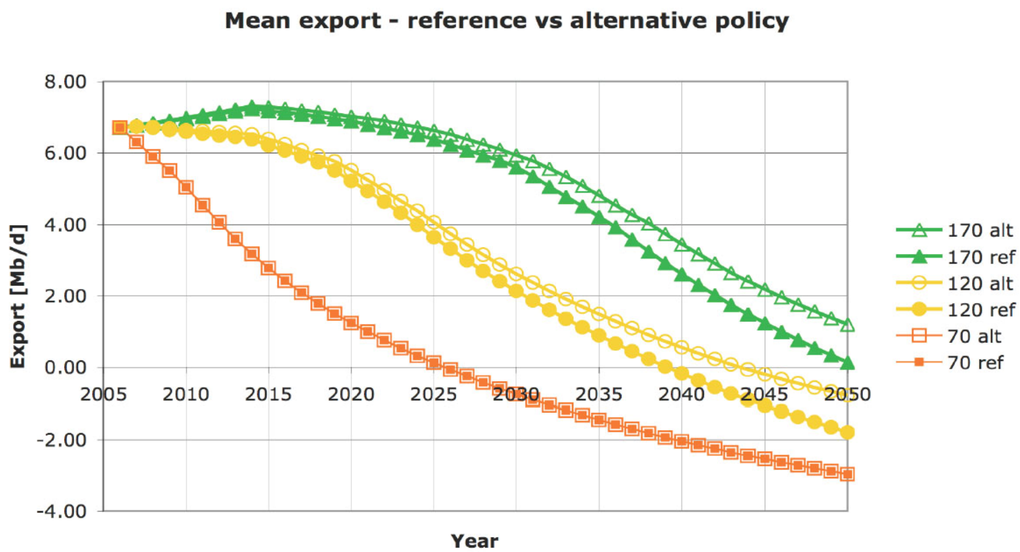


When trying to determine possible future exports the growing Saudi population must be taken into account, as more of Saudi's oil will be needed for domestic use. Consumption now stands at 2.0 Mbpd with an average increase over the last 25 years of 5% per year. It will be very hard for Saudi Arabia to put any restrictions on this domestic consumption and an increase of 5% per year in the coming years will increase consumption to 4 Mbpd. The planned production increases reported will be needed within the country, and therefore we cannot expect ever increasing exports from Saudi Arabia.

In early June 2006, the Russian Ministry of Economics announced that Russia would reach a maximum production of 9.85 million b/d in 2009. By accepting this number as a plateau number it is possible to predict future production from the oilfields in Russia, if URR is known. An alternative method could be to assume that Russia can increase its production by 2 Mbpd, the same amount that Saudi Arabia claims to be possible.

There are different opinions about possible future Russian URR grouped around the figures 70, 120 and 170 Gb. Today BP lists the number 79 Gb. With a modest increase in domestic use and depletion rates within acceptable values we have made predictions on future export capacity for Russia (see figure 5.5). The 70 Gb scenario appears pessimistic, the 170 Gb over optimistic leaving the 120 Gb scenario as the probable best case. The best case gives an export between 2 and 3 Mbpd for 2030 depending upon consumption within Russia [1.9].

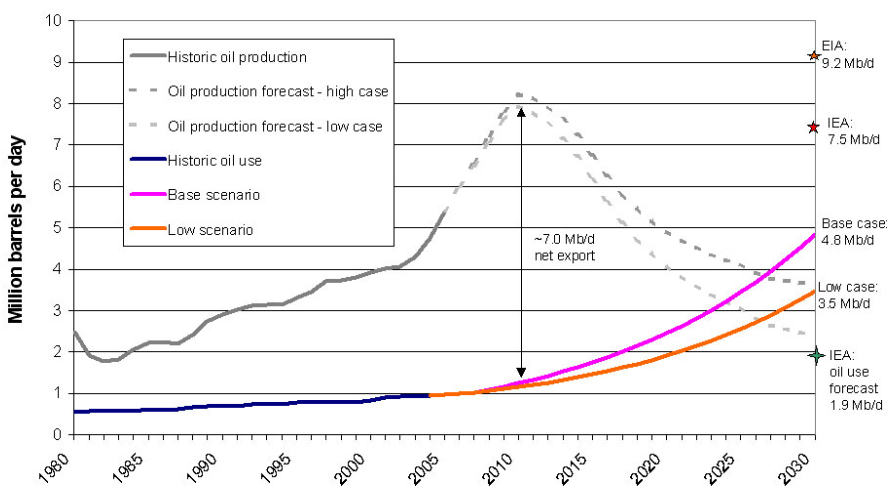
Figure 5.5. **Mean export comparison between the reference policy and the alternative policy for Russia with respectively 70, 120 and 170 Gb left to produce** [1.7]



Norway, the number three exporter today, states that in 2030 its maximum production will be 500,000 b/d, with a possible minimum of 200,000 b/d. Exports for 2005 of 2.8 million b/d will therefore decline by more than 2 million b/d by 2030.

Mexico is yet another exporter that will lose a big fraction of its export capacity if new fields are not discovered and massive additional production developed. We know that production from Cantarell is falling like a rock.

Figure X. **Scenarios of total oil use versus projected oil production in SSA**



The SSA region has been studied in detail [1.7] and it is obvious that an increase in GDP requires a proportional increase in the consumption of oil. The necessary oil is produced within the region, but OECD countries and China are taking the oil away from where it is needed. Over the next 5 years, Angola and Nigeria will increase production by 3 million b/d, but by 2030, production in these two countries will have declined back to current levels [1.7]. The IEA expects an increase in exports from the region by 2030 of 1 Mbpd, but in reality we can expect a decline. If the IEA oil use forecast for the region is accepted the decline will be 2 Mbpd.

To avoid any more clouds on the stark horizon, just assume that other Middle East countries can keep their export volumes constant, which is a very optimistic assumption, and allow the Caspian region an export increase of 2 Mbpd, we conclude that there will be a decline in export volumes by 2030. Anyone that claims something different must explain in detail what is wrong with this analysis.

5.2. References

[5.1] BP Statistical Review of World Energy (www.bp.com).

[5.2] International Energy Agency, World Energy Outlook 2004; http://www.iea.org/textbase/nppdf/free/2004/weo2004.pdf

[5.3] Mahmoud M. Abdul Baqi and Nansen G. Saleri, Fifty-Year Crude Oil Supply Scenarios: Saudi Aramco's Perspective, February 24, 2004, C, Washington, DC, http://www.csis.org/media/csis/events/040224_baqiandsaleri.pdf

6. PRODUCTION OF TRANSPORT LIQUIDS WITH CTL AND GTL

Coal-to-Liquids (CTL) and Gas-to-Liquids (GTL) are fuels that can be produced from coal, natural gas and biomass using the Fischer-Tropsch process. The liquids produced include naphtha, diesel, and a variety of chemical feedstock. The resulting diesel can be used neat or blended with today's diesel fuel and used in existing diesel engines and infrastructure. In mitigation studies [6.1] these fuels are discussed as an opportunity to reduce dependence on petroleum-based fuels, but can they perform this function in reality?

6.1 CTL production

The USA and China are now importing more then 50% of their oil requirements and this reality has opened a debate about the use of coal reserves for the production of liquid fuels. The Fischer-Tropsch method was developed in Germany during the Second World War and used by South Africa during the period of Apartheid & international sanctions when they were cut off from imports of oil. Economically it has been much more expensive then pumping oil from the ground and the fact remains that this technique has only been used to secure liquid fuels when a country is in a state of emergency. The fact that this method is now discussed might indicate that the world is entering just such a state of emergency.

The Coal-to-Liquids Coalition (CTLC) in the USA is using energy security as motivation for further development of CTL production [6.2]: “Establishing a goal of producing at least 300 000 barrels of high-grade fuel per day by 2015 using CTL technology is a feasible target. This is equivalent to the amount of transportation fuel consumed daily by the U.S. military for domestic operations.”

In China oil security is also on the agenda and at the ASPO-6 conference Professor Pang (vice-chancellor of China Petroleum University in Beijing) pointed out that the security goal for China was to have a self-sufficiency ratio, self-produced-oil/oil-consumption, of more then 50% [6.3]. CTL is part of this equation.

Figure 6.1. **Coal Production Forecast for China**
The peak is even more imminent if the reserves are backdated to 1992 when the last actual updates took place [1.10].

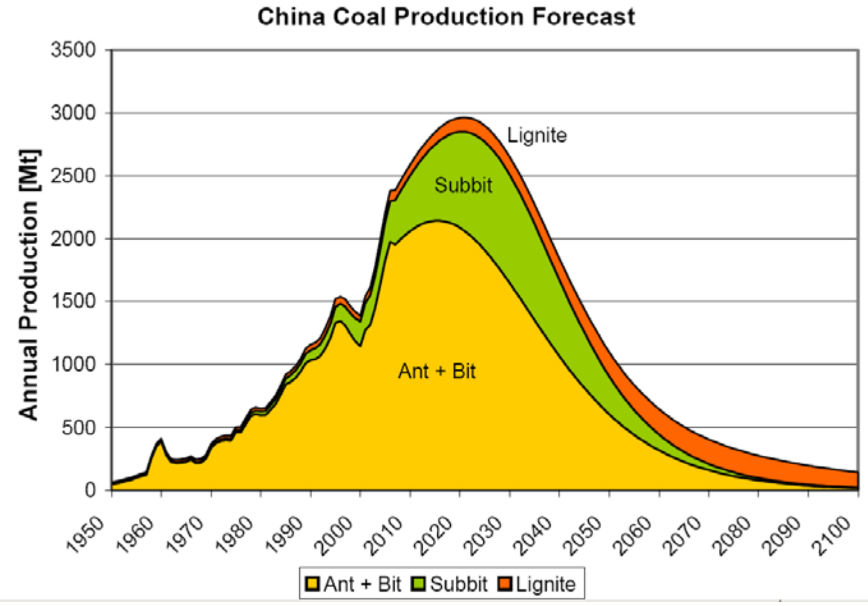
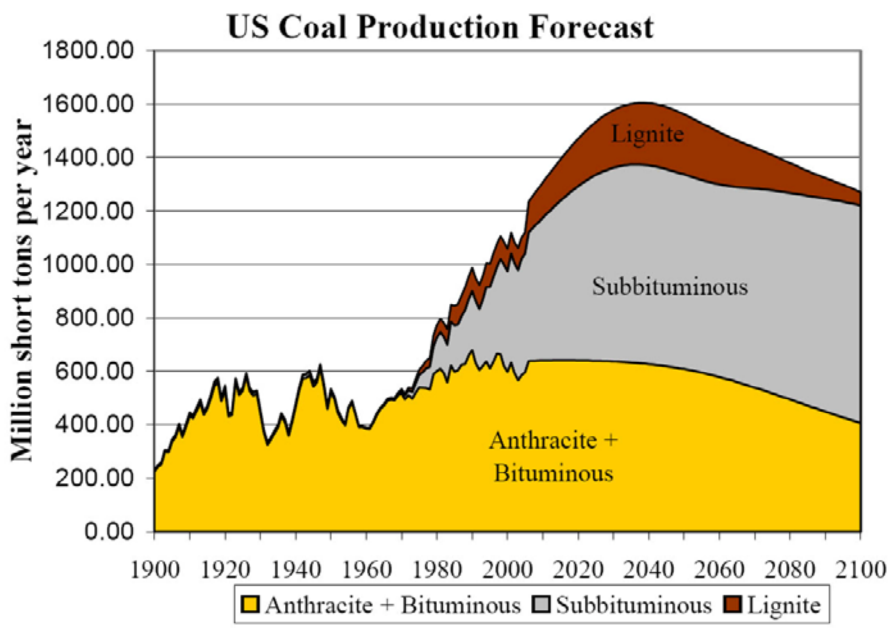


Figure 6.2. **Forecasted coal production based on EIA-data on the recoverable reserves and adapted to historical production**



The continued rapid expansion of coal production from Wyoming peaks in 2030 and is followed by a decline, dampened by subbituminous coal from Montana. No major *increase in bituminous coal production is possible due to a lack of available reserves. It will also be impossible to reach the EIA forecast for 2030 [1.10].*

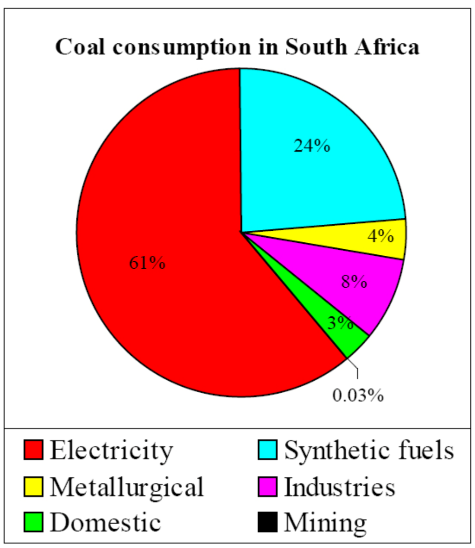
The Uppsala University Hydrocarbon Depletion Study Group has, in collaboration with other researchers, made "A resource-driven forecast for future global coal production" [1.10], and we have found that both China and the USA will face a 'Coal Peak' before 2050 (Figures 6.1 and 6.2), and furthermore there will be increased competition between coal for electricity and CTL production.

Table 6.1. Top Five Coal Producers 2006 [1.10]

Country	Production (Mt)	Share of world
China	2380	38.4%
USA	1054	17.0%
India	447	7.2%
Australia	374	6.0%
Russia	309	4.9%
South Africa	240	3.8%

South Africa has a large CTL-industry producing approximately 30% of its fuel needs by Fischer-Tropsch synthesis. This takes place at the Sasol CTL-complex at Secunda, which has a production capacity of 150 000 barrels per day. As seen in Figure 6.3, this utilizes a significant share of the country's coal production, and from Table 6.1 we can conclude that this represents 0.9% of global coal production.

Figure 6.3. **South African coal consumption divided into groups** [1.10]



The decline in production from existing oilfields is said to be between 4 and 6%. In absolute terms this means that one year from now new production in the order of 4 Mbpd must come on stream to compensate for the decline. A modern CTL-factory might yield 0.2 Mbpd and therefore 20 factories could produce the annual decline of 4 Mbpd. With the numbers taken from South Africa it can be seen that this development of CTL production represents a total requirement of coal that is 60% of Chinese production, or 60% more than current production within the USA. Compared with the global production we get that 4 Mbpd synthetic diesel need 25% of the production. New facilities might be more efficient but even a 50% increase in production efficiency will still draw a substantial fraction of global coal production.

A massive investment in CTL cannot solve the problem in global oil decline. The 300 000 barrels per day that the American military needs in the future may be attained.

6.2. GTL production

The gas-to-liquid, GTL, process requires large volumes of low cost natural gas to compete with diesel fuel in the open market. GTL produced from pipeline-supplied natural gas would not be competitive due to the higher alternative value of pipeline natural gas in the EU and the USA.

Natural gas is more expensive to transport on ships than oil and converting remote natural gas into a liquid before transportation is discussed as a more cost-effective method. Since the late 1990s, major oil companies including: ARCO, BP, Conoco Phillips, ExxonMobil, Statoil, Sasol, Sasol Chevron, Shell, and Texaco have announced plans to build GTL plants to produce liquid fuels, but today we can see that only a few of these projects may actually reach production. Millions and millions of barrels will never be produced in the time frame 2008 to 2030.

6.3 References 6

[6.1] Hirsch, R.L., Bezdek, R., Wendling, R. Peaking of World Oil Production: Impacts, Mitigation, & Risk Management. DOE NETL. February 2005. http://www.pppl.gov/polImage.cfm?doc_Id=44&size_code=Doc

[6.2] Home page for the Coal-to-Liquids Coalition (CTLC) in USA; http://www.futurecoalfuels.org/security.asp

[6.3] Pang Xiongqi, Feng Lianyong, Zhao Lin, Tang Xu, Li Junchen, Meng Qingyang, China University of Petroleum, Beijing, ASPO-6, http://www.aspo-ireland.org/index.cfm?page=aspo6

7. POSSIBLE STRATEGIES OF OIL IMPORTING AND EXPORTING COUNTRIES

At the time of writing, the price of oil has passed $80 per barrel and has remained above this landmark price for some time. When the Association for the Study of Peak Oil & Gas (ASPO) was founded in 2001 most authorities on oil held the belief that the future price of oil would not pass $30 per barrel, Table 6.1. When I wrote at that time about Peak Oil in a number of Swedish newspapers my ideas were considered to be crazy, as "Actual forecasts from repayable official and private actors showed no sign of increase [6.1]." At that time it was forecast that a price of $80 per barrel in 2010 would be an indicator of Peak Oil. Today major players still deny Peak Oil even though we have now seen sustained high oil prices.

Table 7.1. **Oil price predictions by agencies and market analysts at the beginning of 2001, in $ per barrel**

	2010	2020
International Energy Agency,	20	27
IEA	21	22
US Department of Energy,	20	24
EIA	21	21
European Commission	17	20
Canada Department of	18	18
Energy		
Standard & Poor		
Deutsche Bank		

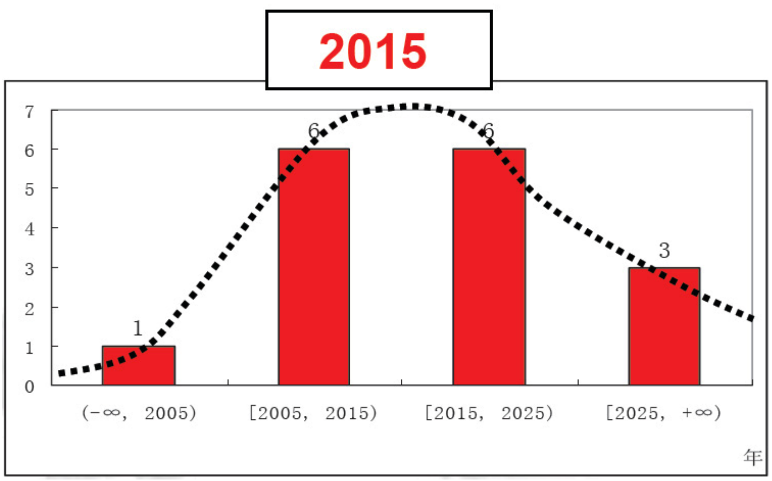
When it comes to considering import strategies we must start by examining the USA. Of the 20.6 Mbpd the USA consumes they have a self-sufficiency ratio of 33%. The reality of this is that at least one supertanker must arrive at a US port every four hours. Any interruption in this pattern is a threat to the American economy. The fact that imports from the Middle East are crucial has inexorably lead to a policy requiring a prolonged military presence in the region. The statement "I am saddened that it is politically inconvenient to acknowledge what everyone knows: the Iraq war is largely about oil" from the memoirs of the former Federal Reserve chairman Alan Greenspan lends supports to this position. It should also be noted that President Bush has told the American people that military bases in Iraq will be needed for the foreseeable future. Furthermore, UHDSG has concluded that an even best-case scenario requires that seven giant oilfields in Iraq must be brought on-stream soon [1.7].

When it comes to Japan and South-Korea we can conclude that their security of supply is non existent and they have to rely on an American presence in the Middle East.

Oil production in Europe has passed Peak Oil, with the United Kingdom passing peak in 1999 and Norway in 2001. The European decline rate as of 2006 was 7.6%. Europe will become increasingly dependent upon import from the Middle East and North Africa (MENA).

The growing economy of China clearly demands more oil and with today's correlation between growth in GDP and use of oil we can expect an increase of the order of 10% per year in the coming years. Since 2000 production within China has increased by 0.4 Mbpd compared with an increase in consumption of 2.7 Mbpd. Today China has a self-sufficiency ratio of 50%. A 10% increase in consumption equates to 0.7 Mbpd, and with Peak Oil on the horizon they must obtain this oil by increasing their imports by the same amount. This is equal to a 20% increase in imported oil.

Figure 7.1. **Projected production of oil in China [7.3]**

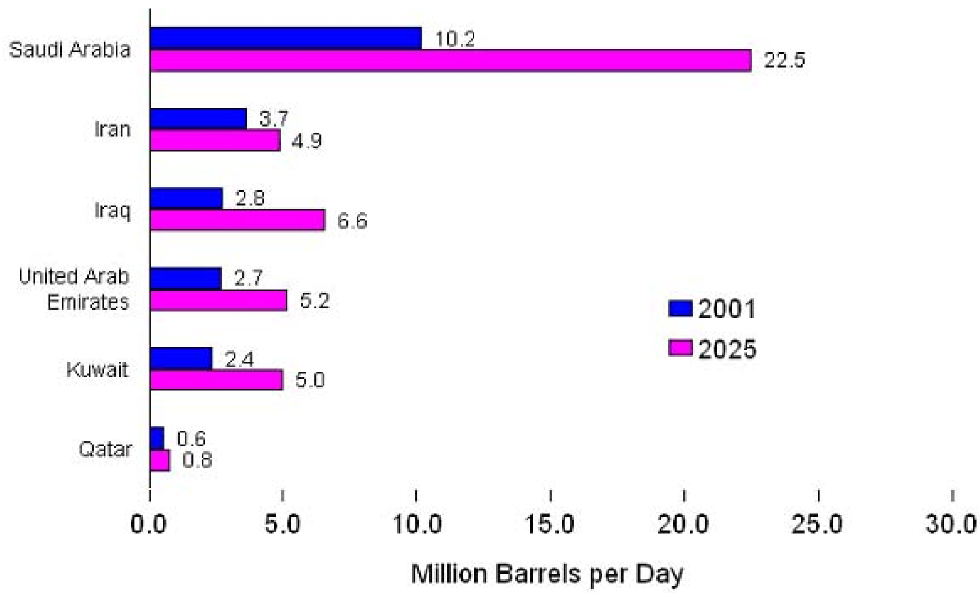


In mitigation strategies for the Peak Oil problem, China has indicated that they would like to maintain a self-sufficiency ratio of 50%. To increase quantities of self-produced oil they intend to; a) improve provable ratio, b) enhance oil recovery and c) develop resources abroad.

Today the China National Petroleum Corporation (CNPC) operates 65 projects in 25 countries around the world [7.3] where official policy will be to ring fence production from these projects for consumption in China.

On 28 September 2004 the price of oil passed $50 per barrel and on that day I happened to be visiting the giant oilfield Bab in Abu Dhabi. Two days prior to this visit, I had attended the conference on “The Gulf Oil and Gas Sector: Potential and Constraints”, at which we had discussed calls on the Middle East made by Guy Caruso and the US EIA earlier that year [7.4]. In a reference scenario, an estimated increase in production was required such that a production of 28.2 Mb/d increased to 64.8 Mb/d, a 130% change (see Figure 7.2).

Figure 7.2: **Production capacity year 2001 and demanded production from US Energy Information Administration**
in units of million barrels per day



In the discussion, experienced oil experts stood up one by one and claimed that production should not be increased, they felt that it was time to think about future generations. The Middle East needed a maximum sustainable production; the words from Saudi Aramco were repeated.

When I discussed a potential increase in production from the Bab field, the Field Manager, Abdulla M. Al-Malood, pointed out that he would prefer to maintain a “sustainable production” level from the region and the fields currently under production. Any increase in production will stress the oilfield and increase the water cut, the percentage of water produced together with the oil. Furthermore he also highlighted the fact that there were new regions that should be coming on stream as well as some smaller fields tied to the production of the current field. There is the possibility that several other oilfields can be put in to production, but surely these fields should be reserved for future generations.

The fact that Saudi Arabia requires more end products for domestic consumption means we can expect that new capacity will be built up in the country. In the future we can anticipate exporting countries in the Middle East to change from the export of crude oil to increasing export of oil products. As the region cannot grow enough food for the population other types of employment are required to generate the necessary income.

We will also probably see Russia compensate for the decline in possible future crude oil exports by developing exports of oil products with higher revenue potential.

Venezuela is a small exporter, but an exporter with a strong political message; export is needed for South America. Countries in sub-Sahara Africa have a similar serious need for oil, but we do not expect to hear the same message from the exporting countries of West Africa as we hear from Venezuela.

A general conclusion is that with Peak Oil on the horizon exporting countries will reconsider the way they export oil in the future. Their actual reserves may be saved for future generations, and the pattern of export products may very well change.

7.1 References

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[7.2] Graham Paterson, Alan Greenspan claims Iraq war was really for oil, *The Sunday Times*, September 16, 2007, http://www.timesonline.co.uk/tol/news/world/article2461214.ece

[7.3 XiongqiPang, China Syndrome, http://www.aspo-ireland.org/index.cfm/page/aspo6

[7.4] Mahmoud M. Abdul Baqi and Nansen G. Saleri, Fifty-Year Crude Oil Supply Scenarios: Saudi Aramco's Perspective, February 24, 2004, CSIS, Washington, DC, http://www.csis.org/media/csis/events/040224_baqiandsaleri.pdf

8. AWARENESS OF PEAK OIL

Dr. M. King Hubbert was the first person to become aware of the fact that oil production for a specific region could peak. In March 1956 he presented the famous paper “Nuclear Energy and Fossil Fuels” for the American Petroleum Institute [8.1]. Hubbert used two different URR numbers for USA (now US-48) in his forecasts, 150 Gb and 200 Gb. Today we know that the 200 Gb figure is closer to current statistical trends that provide a figure for URR of 220 Gb. The high case scenario gave a peak in 1973. The most remarkable part of Hubbert’s forecast is that 44 years before the millennium he predicted production to be at 4.1 Mbpd utilising the high case, and in fact actual production turned out to be 4.2 Mbpd.

The predicted scenarios for US-48 showed that the figure for URR is a crucial number in the calculation of future oil production. Because discoveries of oil peaked in the 1960’s and the industry hid this reality by not backdating this data, all estimates of future oil production before 1990 are clearly unreliable. Therefore, statements such as “the forecasts were wrong in the beginning of the 20th century and therefore they must be wrong in the beginning of the 21st century” have no scientific validity.

The first ever oil depletion conference took place in Uppsala in 2002 and in its wake the expression “Peak Oil” spread around the world. The discussion about Peak Oil in Sweden commenced and in 2004 the Royal Swedish Academy of Sciences (the organization handing out the Nobel Prize in Physics and Chemistry) decided to appoint an energy committee with its first mission being an examination of future oil production. In October 2005 a statement was drafted (see Appendix 1), and this statement together with activities by ASPO in Sweden lead to the appointment of an Oil commission by Swedish Prime Minister Göran Persson [8.2].

Lines from the report from the Commission include:

“Declining access to conventional oil, in combination with our joint responsibility to stop global warming, will be a test of the world community’s readiness to switch to energy systems that are more sustainable in the long term. Basically, it is a question of the will to show solidarity with present and future generations.

Sweden accepts this challenge.

In this document, we propose a number of far-reaching, concrete measures that can end our dependence on oil by the year 2020 and tangibly reduce our use of oil products. Our ambitious objectives are as follows:

- *Through more efficient use of fuel and new fuels, consumption of oil in road transport shall be reduced by 40-50 per cent.*
- *In principle no oil shall be used for heating residential and commercial buildings.*
- *Industry shall reduce its consumption of oil by 25-40 per cent"*

Industry and various agencies have frequently based decisions about future oil production on predictions by the Cambridge Energy Research Associates (CERA). In June 2006 CERA released a forecast that we criticized in an interview in the Oil & Gas Journal [8.3]. A reply to this critique came in the form of an article published in the February 2007 issue of Journal of Petroleum Technology (JPT) by Peter M. Jackson from CERA. In the article Jackson reviewed "Peak Oil Theory" and concluded that the "… peak oil lobby" – a group of professionals that forecasts world conventional oil peaking within a decade -- "allows fear to replace careful analysis".

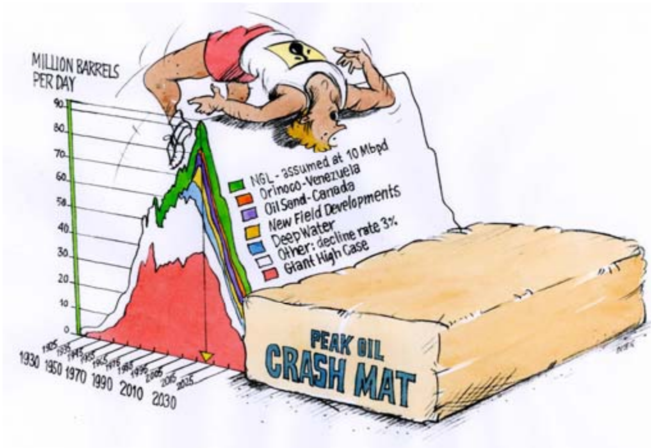
My reply [1.8] concluded: "*Figure 1 in the Jackson JPT article shows conventional oil production for 2006 at around 74 Mbpd, million barrels per day, and is forecast to increase to a maximum of 96 Mbpd in 2030, a plateau production until 2045 and a decline to 68 Mbpd in 2070. Integration under the CERA forecast plot gives a total conventional oil production of 2050 million barrels. This is almost twice as much as we today have as conventional oil reserves according to CERA. I hope that CERA now accept to publish detailed analysis of the prediction, as we are doing*."

It is very encouraging that US Secretary of Energy, Samuel W. Bodman, requested that the National Petroleum Council (NPC) should undertake a study on the availability of global oil and natural gas [1.12], and that he specifically mentioned Peak Oil (see section 1.3). The reply to Mr Bodman's request was a huge disappointment. It is unbelievable that the Council "involved more than 1000 people actively involved in energy" and could not give an answer to Mr Bodman's question about Peak Oil. The 422 page report is simply a description of how to circumnavigate the reality of Peak Oil.

At the ASPO-6 Conference in Cork, Ireland, 16-17 September 2007, Dr. James Schlesinger, the United State's First Secretary of Energy, was invited as a keynote speaker. For him, Peak Oil is no longer a question, simply a stark reality. His statement, "*And therefore to the peakists I say, you can declare victory. You are no longer the beleagured small minority of voices crying in the wilderness. You are now main streams. You must learn to take yes for an answer and be gracious in victory*" was a great moment. But I am also willing to accept his request that we should be "gracious in victory". Peak Oil must be addressed at all levels in today's society and we need to work together.

We have climbed high on the "Oil Ladder" and yet we must descend one way or another. It may be too late for a gentle descent, but there may still be time to build a thick crash mat to cushion the fall.

Figure 8.1: **Passing Peak Oil we must land on a “Crash Mat”**



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9. ACKNOWLEDGMENTS

This paper was written at the request of the OECD and the International Transport Forum, for presentation at a Round Table on "**Oil Dependence: Is Transport Running Out of Affordable Fuel?"**, to be held in Paris, 15-16 November 2007. I would like to express my thanks to the organizers for allowing Peak Oil to be a part of the discussion.

It would not have been possible to present some of the data in this report without the outstanding work of my students, Mikael Höök, Kristofer Jakobsson, Aram Mäkivierikko, Fredrik Robelius and Bengt Söderbergh. Thank you for all of your work.

Finally, I would like to thank Simon Snowden (University of Liverpool Management School, UK) for proofreading the paper and the provision of feedback.

ANNEX:
STATEMENTS 14 OCT 2005

Statements on Oil
by the Energy Committee at the Royal Swedish Academy of Sciences

Introduction

The Royal Swedish Academy of Sciences is an independent non-governmental organization, with expertise in most of the sciences as well as economical, social and humanistic fields. The Academy has recently established a committee to consider today's important energy issues that need our full, unbiased attention. The Energy Committee has a national as well as a global perspective and will summarize scientific knowledge on the supply and use of energy as well as the predicted impacts on society over the coming 50 years. Sustainability and environmental considerations are essential for any future energy system. Readily available, inexpensive and environment-friendly energy provides the foundation for economic growth and prosperity.

The Energy Committee has selected a number of subjects to be studied in some depth. One of these deals with oil and related carbon-based fuels. Therefore, the Committee, organized, together with the Committee of Energy and Environment of the Royal Academy of Engineering Sciences, a seminar with the title "Running out of oil – scientific perspectives on fossil fuels" held at the Academy on 26 May 2005. Prior to the Seminar, the Energy Committee conducted a hearing with the seminar participants. More information about this seminar can be found on the Academy's web page at www.kva.se. The Committee also arranged a hearing with speakers in an Uppsala seminar on "Global oil reserves" on 23 May 23 2005 together with the Graduate School of Instrumentation and Measurements (AIM). Members of the Committee participated in the Uppsala Seminar. Some essential points brought up at the hearings and seminars are highlighted below. It should be pointed out that the perspective given here is not purely scientific, since there are important social, political and technical factors that need consideration.

General Remarks

It is very likely that the world is now entering a challenging period for energy supply, due to the limited resources and production problems now facing conventional (easily accessible) oil. Nearly 40% of the world's energy is provided by oil, and over 50% of the latter is used in the transport sector. An increasing demand for oil from emerging economies, such as China and India, is likely to further accentuate the need for new solutions. In addition, it is important that the poorer countries have access to oil at reasonable prices to meet their development goals. This places an additional burden on responsible, matured economies. Compared to many developing countries, the same%age increase in the crude oil price will be less problematic for Sweden and other European countries because of our tax system (the crude oil's share, c. 25%, in the gasoline price is quite small, compared to the taxes). The poor countries will suffer most from an increased price.

China and India and several nations in South-East Asia and Latin America are now experiencing rapid economic development. Continued high oil prices will jeopardize their chances of economic growth. Many countries, for example in Africa, may not even be able to develop economically in the absence of cheap oil. With China and India emerging as engines of the global economy, the sharp increase in the oil prices which we are witnessing today could lead to a serious international economic recession, similar to those that followed the oil price increases in 1973-74 and 1981. The European economies may be severely affected.

There is at present an extreme dependence on supply from the Middle East holding more than 60% of the global oil reserves. A key country is Saudi Arabia, which is supposed to hold about 20% of the global reserves of conventional oil and much of the world's spare capacity. Some analysts maintain that there are inherent technical problems in the Saudi oilfields, but this is not an uncontested viewpoint. It is uncertain how much the oil production in the Middle East can be increased in the next few years and to what extent it would be in the interest of these countries to greatly increase production. It is clear that, even in these countries, conventional oil is a limited resource that they are almost totally dependent on. It is, however, also clear that the countries of the Middle East are undergoing massive internal and regional changes which may have negative consequences for the global oil supply system. Mitigation measures must be initiated in the next few years in order to secure a continued adequate supply of liquid fuels, especially for the transport sector. Over the longer term, completely new solutions are required. Therefore, increased R&D (Research and Development) in the energy sector is urgently needed.

Key Points

1. Shortage of oil

The global demand for oil is presently growing by nearly 2% per year and the current consumption is 84 million barrels per day (1 barrel=159 litres) or 30 billion barrels per year. Finding additional supplies to increase the production rate is becoming problematical, since most major oilfields are well matured. Already 54 of the 65 most important oil-producing countries have declining production and the rate of discoveries of new reserves is less than a third of the present rate of consumption.

2. Reserves of conventional oil

In the last 10-15 years, two-thirds of the increases in reserves of conventional oil have been based on increased estimates of recovery from existing fields and only one-third on discovery of new fields. In this way, a balance has been achieved between growth in reserves and production. This can't continue. 50% of the present oil production comes from giant fields and very few such fields have been found in recent years. Oil geologists have a wide range of opinions on how much conventional oil there is yet to be discovered, but new reservoirs are expected to be mainly found in the deeper water, outer margins of the continental shelves, and in the physically hostile and sensitive environments of the Arctic, where the production costs will be much higher and lead times much longer than they are today. A conservative estimate of discovered oil reserves and undiscovered recoverable oil resources is about 1200 billion barrels, according to the US Geological Survey; this includes 300 billion barrels in the world's, as yet unexplored, sedimentary basins.

3. The Middle East's key role

Only in the Middle East and possibly the countries of the former Soviet Union is there a potential to significantly increase production rates to compensate for decreasing rates in other countries. Saudi Arabia is a key country in this context, providing 9.5 million barrels per day (11% of the current global production rate). Their proven reserves are 130 billion barrels and their reserve base is said to include an additional 130 billion barrels. Iraq also has considerable untapped oil reserves.

4. Unconventional oil resources

In addition to conventional oil, there are very large hydrocarbon resources, so-called unconventional oil, including gas (c. 1000 billion barrels of oil equivalent, much of which could be converted to liquid fuels), heavy oil and tar sands (c. 800 billion barrels) and oil shale's (c. 2700 billion barrels); coal, from which liquid fuels can be produced and methane hydrates provide a vast additional potential. During a transition period, gas often available adjacent to the oil fields, will help to bridge future deficits of conventional oil. With the exception of gas, all unconventional oil is expensive to produce (c. $ 20-40/barrel) and exploitation involves significant environmental problems. At $ 40 oil, which is now commonly accepted as the long term equilibrium price, the cost of developing unconventional oil is less problematic. (see pt. 7 below). At present, 1 million barrels of oil per day comes from Canadian tar sand and 0.6 million barrels from Venezuelan heavy oil. The Canadian government estimates that by 2025 the daily production rate will have increased to 3 million barrels per day. Thus, the problem with these unconventional oils is not so much price, but lead times and non-price related aspects, such as the effects on the environment and availability of water and natural gas for the production process.

5. *Immediate action on supplies*

Forceful measures to improve the search for and recovery of conventional oil as well as improving the production rate of unconventional oil are required to avoid price spikes, leading to instability of the world economy in the next few decades. Improved recovery of oil in existing fields can be expected. The estimated reserves of conventional oil are, however, located primarily in unexplored sedimentary basins, in environments difficult to access. A substantial part has yet to be found! Sizeable contributions from unconventional oil need time (some decades) to become really effective. It is necessary to have public funding for long term petroleum-related research, since this must not be an exclusive task for the oil companies.

6. *Liquid fuels and a new transport system*

Oil supply is a severe liquid fuels problem and less of a general energy supply problem; 57% of the world's oil is consumed in the transport sector. Unless government's ration oil, there will never be a shortage of oil; just increasing prices. Major programs need, therefore, to be implemented to develop alternatives to oil in the transport sector. Until these measures have been introduced, (which may take one to two decades) demand for oil for the needs of a globally expanding transport sector will continue to rise; other users of oil will suffer, including those concerned with power generation.

7. *Economic considerations*

At present the high oil prices are due to the limitations of worldwide production, refining and transportation capacities. Furthermore, the price is influenced by the threat of terrorist attacks on the world's oil supply, transport system and infrastructure. In the long run, the price of crude oil will be determined by the price of substitutes. Some estimates indicate that oil may be produced from tar sand at a price of 20-25 USD a barrel, compared to the present cost of about USD 5 for Saudi Arabian oil. Liquid fuels from coal could be produced for many decades; cost estimates vary greatly and generally exceed USD 30. Factors that are hard to estimate are environmental requirements, taxation levels and profit margins. However, we can anticipate continued high oil prices, as long as the pressure from the expanding Asian economics is maintained.

8. *Environmental concerns*

Unconventional oil will significantly extend the length of the hydrocarbon era, assuming that the negative impacts on the environment can be avoided. Constraints similar to those imposed on other fossil fuels (for example emission controls and CO2 sequestration) will be necessary and provide major challenges for industry. The impact on the environment, in general, and on the atmosphere and climate in particular, produced by combustion of fossil fuels, is not considered here. However, it is worth noting that such considerations provide further support for the conclusions presented below.

9. Increased R&D and international efforts

To avoid acute economical, social and environmental problems worldwide, we need a global approach, with the widest possible international cooperation. Activities in this direction have started and they should be strongly encouraged and intensified; the technically advanced countries have a particular responsibility. Considerably increased resources for R & D on alternative non-fossil energy sources, as well as on efficient and sustainable use of energy, particularly electricity, are necessary. In order to develop a sustainable energy system beyond the fossil fuel era, we need a full system analysis of the energy sector based on realistic time scales. The Energy Committee intends, in the next couple of years, to study other sources of energy and evaluate their relative merits and impact on environment and climate.

Members of the Energy Committee at the Royal Swedish Academy of Science:

Sven Kullander, Professor em., Uppsala University
Gia Destouni, Professor, Stockholm University
Harry Frank, Professor, Mälardalens University
Karl Fredga, Professor em., Uppsala University
Bertil Fredholm, Professor, Karolinska Institutet
David Gee, Professor em., Uppsala University
Karl Grandin, Ph.D., Centre for History of Science
Peter Jagers, Professor, Chalmers Institute of Technology
Bengt Kasemo, Professor, Chalmers Institute of Technology
Rickard Lundin, Professor, Swedish Institute of Space Physics
Karl-Göran Mäler, Professor em., The Beijer International Institute of Ecological Economics
Kerstin Niblaeus, Director General, Council of the European Union
Bengt Nordén, Professor, Chalmers Institute of Technology
Contact persons:
Malin Lindgren, Information Of. cer, +46 8 673 95 22, +46 709 88 60 04, malin@kva.se
Eva Krutmeijer, Executive Director, +46 8 673 95 95, + 46 709 84 66 38, evak@kva.se

The Royal Swedish Academy of Science
Box 50005, SE-104 05 Stockholm, Sweden
Phone: +46 8 673 95 00, Fax: +46 8 15 56 70
E-mail: info@kva.se, Website: www.kva.se