The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

A Primer on Reserve Growth - part 1 of 3

Posted by Rembrandt on December 23, 2006 - 7:05am in The Oil Drum: Europe
Topic: Supply/Production
Tags: iea, jean laherrère, peak oil, reserves growth, usgs [list all tags]

The difference in vision between so called "optimists" and pessimists" with respect to the peak in world oil production is often caused by a view of future technological development in the oil industry. This development influences both conventional and unconventional oil production. Only a part of the oil in an oil field can be produced. It is claimed by oil companies and various institutes that technological advancement will increase the recoverable amount, thereby postponing the peak in conventional oil for several decades. In essence this means that the amount of recoverable reserve increases over time due to changes in technology, economy, insights. But also expected recoverable reserves increase over time due to past underestimates. This is why the term is called "reserve growth".

The only institute that has done exensive studies with respect to the growth of recoverable reserves over time is the United States Geological Survey. In their World Petroleum Assessment 2000, the USGS claims that between 1996 and 2025 worldwide conventional oil reserves will increase by 730 billion barrels due to reserve growth.

A large amount of forecasting institutes such as the International Energy Agency and Energy Information Administration take the figure of 730 billion barrels from the USGS for granted. In addition to forecasting institutes, oil companies often claim that reserve growth is the key to postponing the worldwide peak of conventional oil production. The question is to what extent the USGS prediction can be relied upon.

Two weeks ago I posted a piece about the discovery forecast of the USGS. In this second post with respect to the USGS World Petroleum Assesment 2000 we take a first glance at what reserve growth really is and what we can learn from studying the worldwide recovery factor of conventional oil fields

Because the topic is so complex, I have decided to split this keypost into three parts:

1. General introduction to reserve growth, what can we learn from the worldwide recovery factor of conventional oil fields?

2. What do scientific studies say about reserve growth in the United States, the North Sea and Russia?

3. To what extent does the USGS study give a reliable figure for future reserve growth?

This is the first post of this three part series.

Lets start with a simple definition of reserve growth

Reserve growth is an increase in the estimated recoverable oil reserves from the moment that an oil field is discovered and/or starts producing until the end of the fields life.

In order to study reserve growth it is necessary to look at the change in estimates for recoverable reserves over time in the life of an oil field, from initial production until the time at which production seizes.

As an example of reserve growth the American oilfield Prudhoe Bay is shown below. Prudhoe bay is one of the largest fields in the world. Production started in 1975. In 1977 it was forecasted by reservoir engineers that ultimately, 9.4 billion barrels would be produced from the field. By 2005 this estimate had been increased to 13.5 billion barrels. Estimated reserves in Prudhoe Bay have so far "grown" with 4.1 billion barrels over time. Of course we won't know until Prudhoe Bay stops producing whether this will actually be the case.

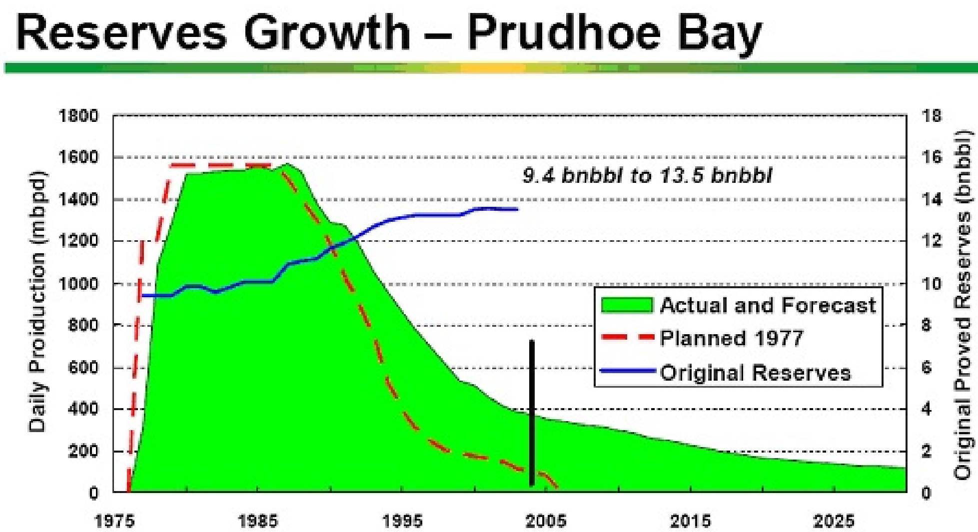


Chart 1 - source: presentation from Chris Skrebowski at ASPO-V

The causes for reserve growth can be classified into three main groups:

1) An Increase in the Oil initially in place (OIIP), for instance by the discovery of an extension to the field or the addition of a satellite (small oil field nearby). This addition is sometimes counted as a discovery and sometimes as reserve growth. The addition of Oil Initially In Place usually does not change the recovery factor.

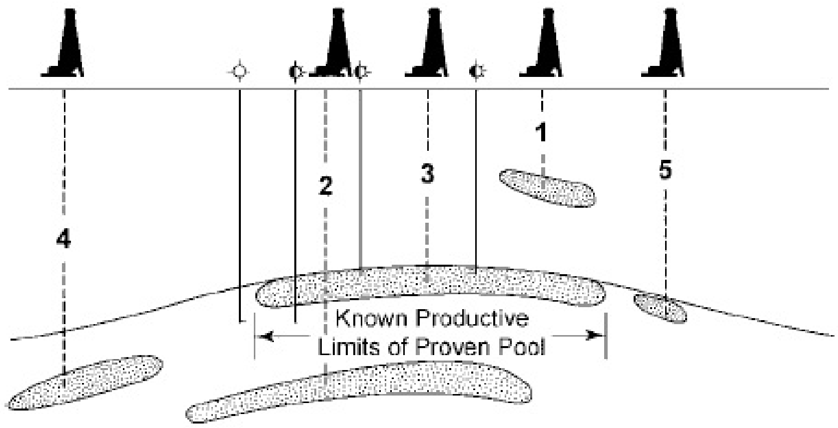


Figure 1. Schematic wells leading to additions to reserves in discovered fields; (1) shallower pool test, (2) deeper pool test, (3) infill well, (4) new pool test, (5) extension or outpost (modified from Drew, 1997). In practice, an operator or regulatory body may classify accumulations penetrated by wells 1 through 5 as a single field or as more than one field. Recognition of the relationship among accumulations also could be complicated further by the order in which wells were actually drilled.

Chart 2 - Reserve growth by increasing OIIP - Source: Attanasi & Coburn.

2) An increase in the reserves of the field due to bad and inconsistent reporting practices. For instance, due to financial reporting rules (conservative) instead of geological reporting rules (probable). The change of reserves from past underestimates falsely change the expected oil recovery factor.

3) Technological development that causes an increase in the amount of oil that can be recovered. These changes cause actual changes in the oil recovery factor.

The way in which overall reserve growth can be measured is by simply looking at past estimates for recoverable reserves and comparing those with present estimates for recoverable reserves in oil fields, countries and the world. By correcting for discoveries in a given timeframe, this comparison gives the amount of reserve growth. However there are a few restrictions that need to be taken in mind. In order to prevent comparing apples with oranges it is necessary to look at the best estimates for recoverable reserves over time (not too conservative or too optimistic). This means taking changes in proven + probable (2P) reserves over time, because this approach gives the best estimate for ultimate recovery of an oil field. **This implicates that publications and databases that base themselves on proven reserves such as the World Oil, the Oil & Gas Journal and the BP Statistical Review are automatically ruled out for purposes of making reserve growth estimates!**. The only sources that should be taken to study reserve growth are the IHS Energy and WoodMackenzie databases, because these are the best databases which contain proven + probable reserve estimates.

However simply looking at the changes in reserve growth over time do not tell enough for future forecasting. This is because this method does not make clear by which of the three causes reserve growth has occured. This is important to know, because as the amount and reliability of data on the world's oil fields increases it is not likely that reserve growth due to underestimates caused by bad reporting practices will be as large in the future as in the past. If reserve growth is however caused mainly by technological development, it is more likely that the trend in past reserve growth will continue. This is why it is necessary to find a way in which to measure the different types of reserve growth.

One of the better ways to do this is by looking at the change in the recovery factor over time. The recovery factor is the percentage of oil resource in an oil field that is estimated to be recoverable. As an example, if there is an oil field that contains 2 billion barrels of total resource (Oil initially in place), and over the lifetime of the field 26% is recovered (520 million barrels), the recovery factor will be 26%. Many claim that the recovery factor over time will keep increasing due to technological advancements (IEA, resources to reserves, 2005). Since type I (increase in the OIIP) does hardly influence the recovery factor, a seperation can be made between Type I and type II (bad reporting) + III (technological advancement) of reserve growth. Secondly, if the reporting practice is good enough, then reserve growth should not occur anymore due to type II since there is sufficient reliable data that can be tracked over time.

The problems with studying reserve growth

The main problem with reserve growth is that the data on oil field reserves is very bad. The best databases in the world are IHS Energy and WoodMackenzie, of which IHS Energy (formerly petroconsultants) is the largest. These databases have been gathering data for a long time, but it was not until the end of the '90s that the sum of data has become so large to be reliable with respect to looking at worldwide reserve growth. In addition there still is no reliable data for the largest oil producers with respect to recoverable reserves (the OPEC countries in the middle east and Russia). The most problematic example is the huge increase in reported oil reserves in the Middle East in the '80s. The OPEC countries claimed an increase in their recoverable reserves of approximately 300 billion barrels within the space of five years while no significant new discoveries were made. This increase is accepted for several Middle East countries even in the IHS Energy database, and to lesser extent in the WoodMackenzie database. We can count these increases as reserve growth, but to what extent are these increases reality? Is the oil really recoverable? If the claimed reserves from OPEC countries is too high, then reserve growth would also be overestimated.

The second problem is that big assumptions are made based on very little data. There are only three countries in the world for which reasonably consistent datasets are available in the public domain, Norway, the United Kingdom and the United States. The USGS study for reserve growth is based on extrapolation from the past in the United States onto the entire world. The authors claim that this is not a problem, which we will discuss in part 3.

What are the various claims with respect to reserve growth?

In essence there are two different visions with respect to expected reserve growth. The first sees technology as the main driver which will continue to cause a large increase in the recovery factor in the future and therefore a large increase in the amount of oil that will be produced. This group ignores the two other categories of reserve growth (underestimates of OIIP + bad reporting practices). Acting as if all reserve growth comes from technological development. One of the most important publications in this part is the World Petroleum Assessment 2000 from the United States Geological Survey. The USGS claims that there is potential for reserve growth potential between 1996 and 2025 for 730 billion barrels in the entire world. While the USGS in the World Petroleum Assesment 2000 did not promote the view that this was solely due to technology, in latter publications this has been mentioned (USGS,Vekma, 2000). Others who use the USGS figures also claim that there is no problem ahead with respect to peak oil because of technological development. Examples are the International Energy Agency, the Energy Information Administration and oil companies:

> "Currently available technologies enable 30 to 35% of the oil in place in reservoirs to be recovered. Increasing this percentage by 10% could represent an additional 200 billion to 300 billion barrels of global reserves, or nearly ten more years of production." (Total,

Corporate Social Responsibility Report 2004, page 74)

It is interesting to note that the figures cited in the TOTAL publication are flawed. Since the Oil Initially In Place is estimated to be 5500 to 7000 billion barrels for conventional oil, an increase in the recovery factor of 10% would mean an additional 550 to 700 billion barrels.

The second group thinks that reserve growth is mainly an anomaly due to bad reporting practices. Since the amount and reliability of data has increased over time, this means that reserve growth will decrease in the future. More importantly, if reliable estimates are taken for the recoverable amount of reserves and the Oil Initially In Place, one would not have to account for future reserve growth, since it would no longer occur. While technological advancement serves its purpose to produce reserves faster and more cost efficiently, the amount of recoverable reserves does not increase due to technology in the world view of the second group. One cannot simply change the geology of an oil field due to adding for example horizontal instead of vertical oil wells. The main argument used is that the largest amount of reserve growth occurs in the first six years after initial discovery/start of first production. In later years, when new technology is applied, little to no reserve growth occurs. In some very special cases reseve growth occurs seems to occur due to technology at the end of the life of several oil fields, however this is due to natural causes which change the structure of the reservoir (such as in the Ekofisk oil field in the North Sea). In nearly all cases technology only succesfully enhances early production at the detriment of production at a later stage, it does not increase the recoverable amount of reserves.

An example of this effect is shown in the chart below. We see a field at which two types of Enhanced Oil Recovery techniques were applied (phase I and II). Due to the introduction of these techniques production by conventional means dropped further then would normally have been the case (darker green). The amount of production shown in the light green part of the graph would have been produced by means of conventional recovery if EOR had not been applied. Now the same amount of oil is produced in phase I and II in red/pink. The light green slice has been added in the graph for comparison purposes. The oil wells of the applied techniques interfered with the normal production wells, causing a sharp drop in the normal production wells. On a net basis, conventional production techniques would have caused the same reserve level at the end of the fields life, but the oil would have been produced much more slowly.

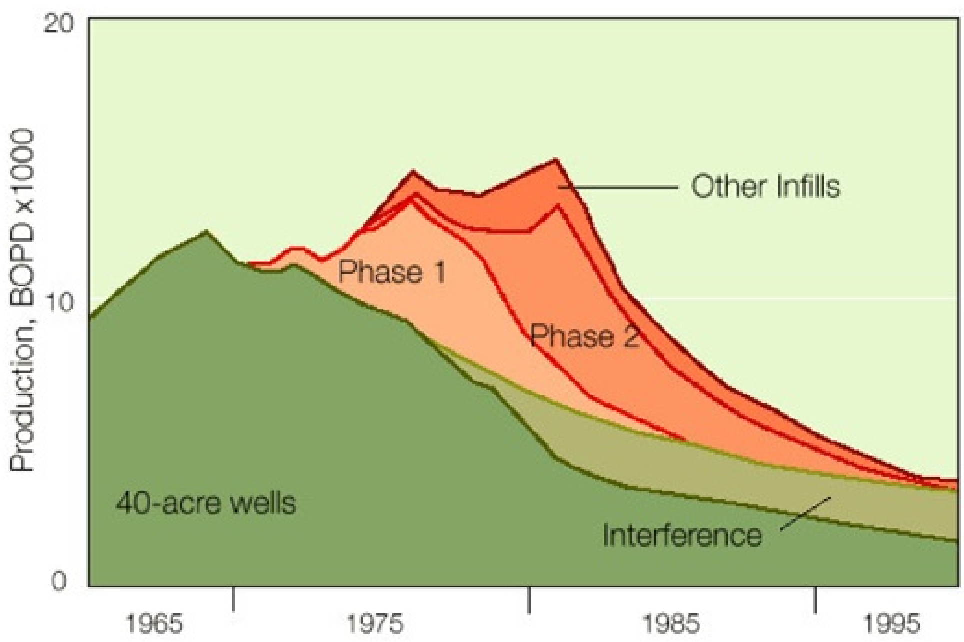


Chart 3 - Source: [Prof. dr. Stephan Luthi (Production geology - TUDelft)]

The best known proponents of the second group are investment banker Matthew Simmons (Simmons & Company) and geophysicist Jean Lahherrère (ASPO France).

What does the worldwide recovery factor tell us?

By looking at the change in the worldwide recovery factor in oil fields, we can obtain a rough estimate whether reserves are increasing due to technological advancement or not. The problem is that the change in recovery factor is largely influenced by bad reporting practices and past underestimates. However, over time the data has become better so it is possible to look at what the change in the worldwide recovery factor tells us in more recent years. In general, a figure of between 33% and 37% is often quoted for the worldwide recovery factor. The reliability of such precise figures is highly doubtful as also agreed upon by the International Energy Agency:

"Numbers of this order [recovery factor of 35%] are often quoted, but rarely supported by abundant data. In fact, it is in principle necessary to look at abandoned reservoirs, estimate original oil in place (which is always somewhat uncertain) and compare it with actual cumulative production up till abandonment. Also, because such analysis looks at the past, it does not necessarily take into account current, more advanced technology practices. The data available is mainly from the United States." (IEA, Resources to Reserves, 2005, pag. 51)

A recent chart from geophysicist Jean Laherrère from ASPO France shows that the worldwide recovery factor worldwide is more likely to be 27%. He bases this on an average of 11242 oil fields from the IHS Energy Database. IHS Energy, formerly Petroconsultants, has a considerable amount of data that is not available to the public. An earlier comparison from the IHS Energy database back in 2001 when the database was less complete showed an average recovery factor of 26%. This implies that the recovery factor has hardly changed over time. The slight difference is more likely to be explained by the increasing number of fields, then an increase in the recovery factor.

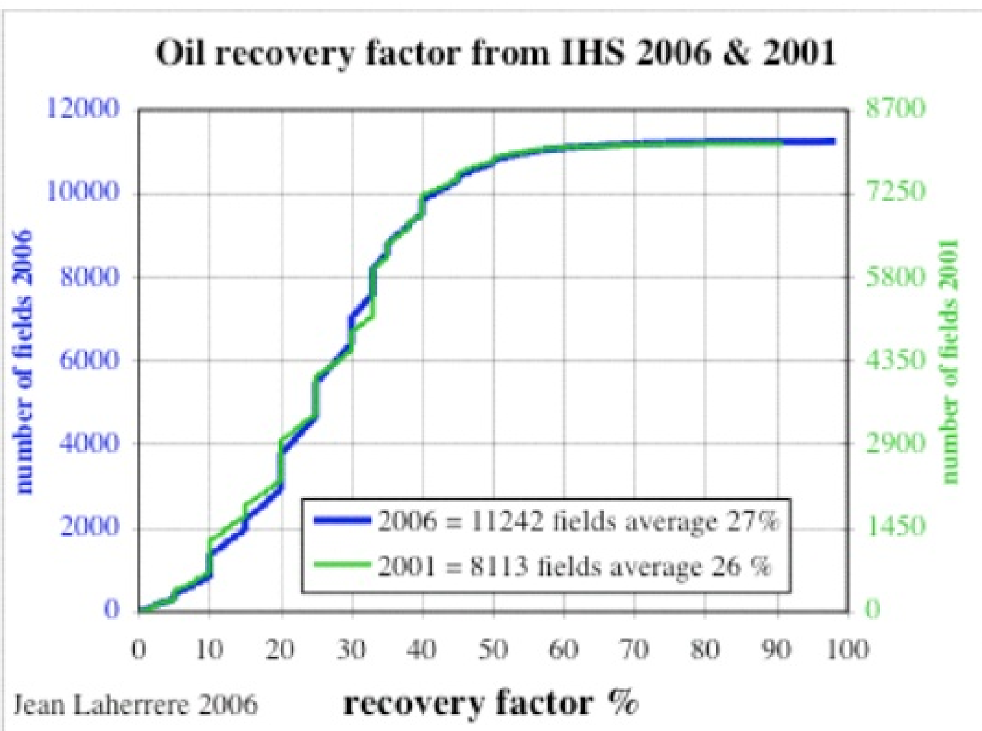


Chart 4 - Source: [J. Laherrère, oil and gas, what future?,](#) November 2006

An similar graph from Laherrère comparing IHS 1997 (897 fields) and IHS 2006 (11242 fields) actually shows a large decrease in the recovery factor. This can be explained by the sheer change in fields used for comparison.

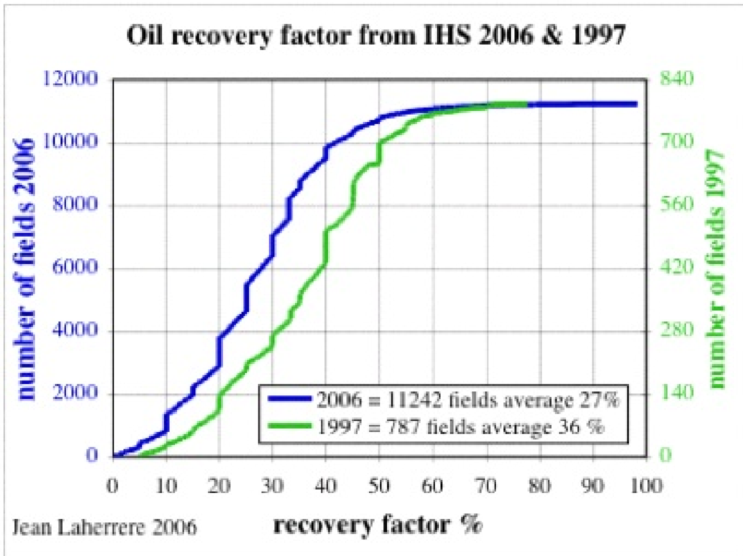
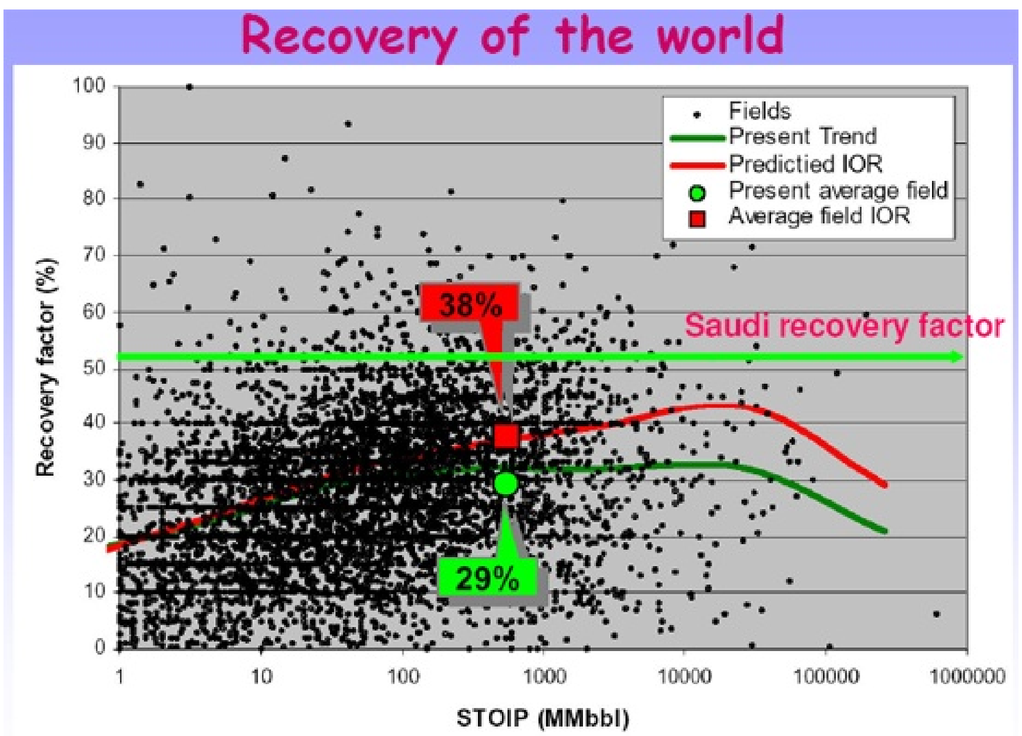


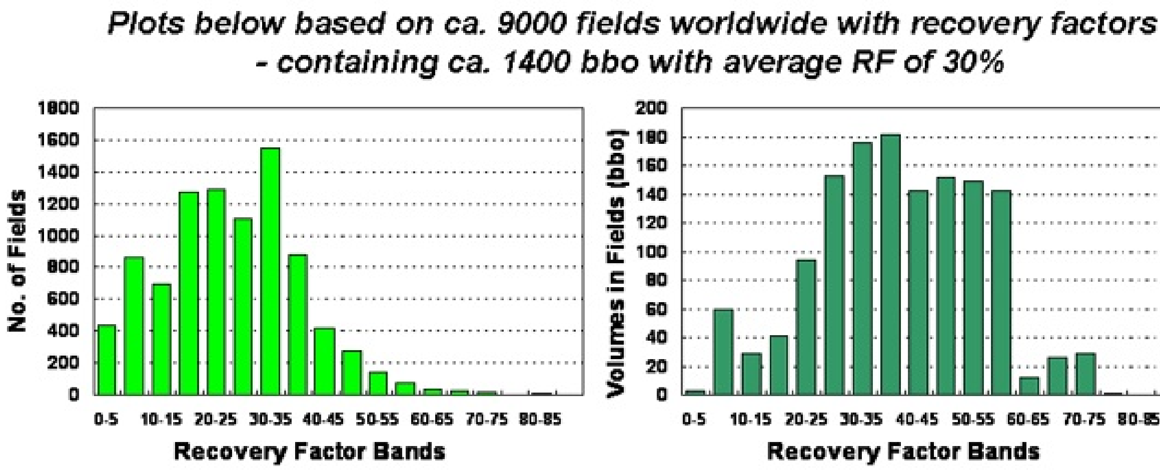
Chart 5 - Source: J. Laherrère

Kjell Aleklett, President of ASPO recently gave a presentation in my country in the city of Groningen. There he presented the following graph below on recovery factors which, if I remember correctly, was based on data from Statoil. It shows a current worldwide average recovery factor of 29%. A nice detail is the line which compares the claims from the Saudi's about the average recovery factor in Saudi Arabian oil fields with the average recovery factor of the world. The claimed recovery factor in Saudi Arabian oil fields appears to be unrealistically high at above 50%. There are several claims that Saudi Arabia will be able to increase their recovery factor by 10%/20% in the next decades by Saudi Arabia/oil companies and the IEA/EIA. These claims seem to be even further from reality when comparing recovery factors from Saudi Arabia to other countries such as Norway, which has an average recovery factor of 45 and hopes to get this to 50% in the coming decades.



Graph 6 - Source:[Kjell Aleklett, An unconvenienth truth for oil and gas,] November 2006

A similar value has been quoted by Francis Harper, a geologist from BP. Based on 9000 fields in the IHS Energy database he came up with an average recovery factor of 30%.



Graph 7 - Source: [Francis Harper, BP, 2004]

In all the time that I have studied the issue of peak oil I have only come accross one chart that compares the worldwide recovery factor in oil fields over time from the "optimists" perspective. This chart was published in the International Energy Agencies World Energy Outlook 1998, shown below. In this chart the IEA compares giant oil fields from two databases (200 giants Laherrere 1996) and (300 giants Roadifer 1987):

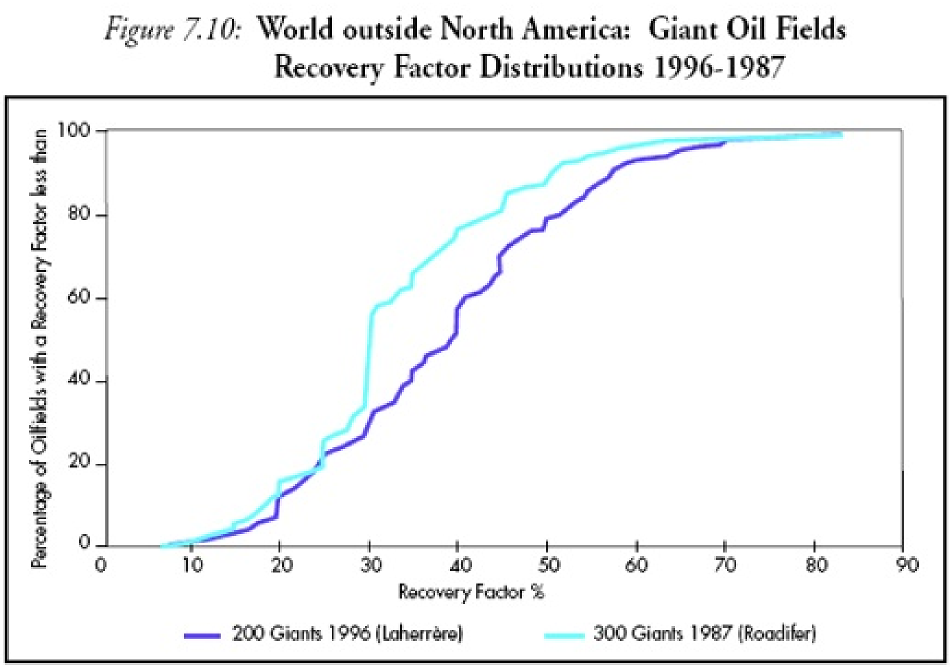


Chart 8 - Source: IEA - World Energy Outlook 1998, page 100

The IEA concludes from this chart that:

> "Using data from Figure 7.10, it has been calculated that the average recovery factor for Roadifer's 1987 sample of 300 giant oilfields was 33.3% compared to 38.6% for Lahherere's 1996 sample of 200 giant oil fields. This analysis suggests that the average giant oilfield's recovery factor increased by 5.3 percentage points in the space of nine years, or 0.6 percentage points per annum. In the unlikely event that giant oilfield's recovery factors were to continue to increase at 0.6 percentage points per annum, then by the year 2020 the average recovery factor would be some 14.2 percentage points

> higher than in 1996. The average giant oilfield in 2020 would therefore have an average recovery factor of 52.8%." (IEA, World Energy Outlook, page 100)

The IEA then goes on with discussing the validity of this comparison:

> "One criticism of this analysis is that it is based on two different sets of giant oil fields. In discussions with the IEA about this comparison Jean Laherrère has made the point that the comparison is between two different distributions of fields. Each distribution therefore contains different fields and one is not directly therefore comparing like with like. While this criticism undoubtedly has some validity, the sample sizes are sufficiently large for there to be considerable overlap between them. Put simply, Figure 7.10 shows evidence of giant oil fields' recovery factors improving during the period 1987 - 1996. It may no be possible to extrapolate this result to all fields."(IEA, World Energy Outlook, page 100 - 101)

The problem with this graph from the IEA is that it appears to compare apples and oranges. While looking through several of Jean Laherrère's papers I came accross an old graph which depicts his 200 giant fields set (1996) based on IHS Energy used in the IEA graph. The graph from Laherrère also shows another set of 800 large oil fields from Laherrère (1996), Roadifer's set of 300 giant fields from 1987 and a set of 3300 oil fields Laherrère (1996). The distribution in the 300 giant fields Roadifer set does not show the same difference with the set of 200 fields from Laherrère in the graph from Laherrère! When one looks in more detail, it seems as if the IEA has taken the Laherrère(1996) set of 800 large oil fields, and compared it with the Laherrère set of 200 giant fields (1996). The comparison is shown below (click for large version).

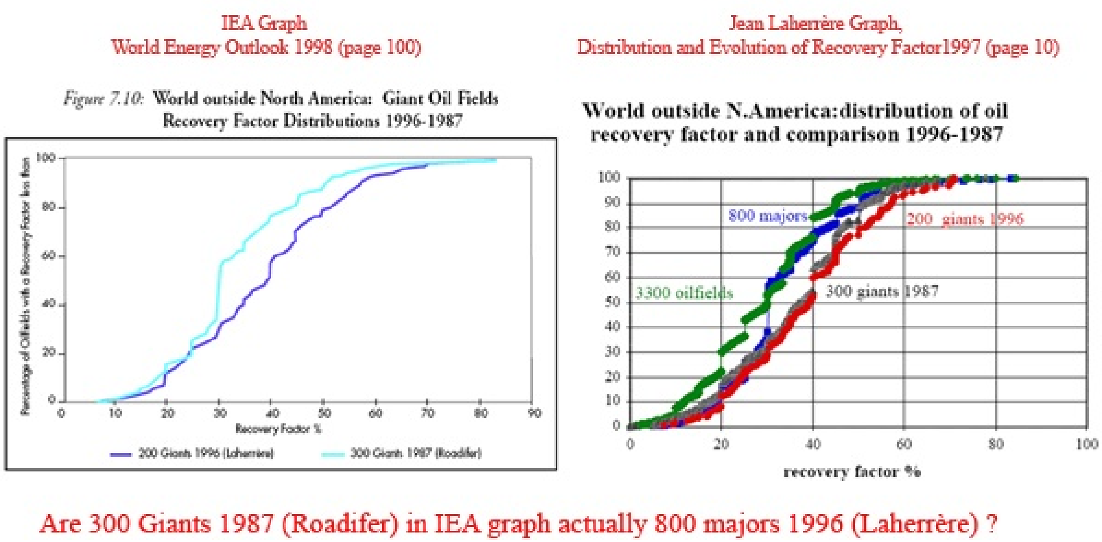


Chart 9 - Source: J. Laherrère, 1997 & IEA, 1998

In one of these charts there is a large error. The question is which one? I tried to find out which chart shows the error, however when contacting Jean Laherrère he told me that he has lost the original datasheet from 1997, and I can't find Roadifer's data. Before this case is solved, it is hard to discuss recovery factors based on this specific graph from the IEA. To me it looks like the IEA graph is flawed.

Summarizing and concluding remarks

1. The issue of reserve growth is a very complex one that needs to be studied in detail.

2. The data that is available to the public is not usable at all to compare reserve growth. One needs to compare data in large reliable databases that contain estimates for proven +

probable reserves over time, preferably per separate oil field.

3. Claims about reserve growth based on changes in the worldwide recovery factor before the end of the 90's should not be taken seriously. This is because it is only in the last decade that the amount of data in the IHS Energy database is large and reliable enough to make comparisons.

4. There are large differences in views with respect to reserve growth from technological advancement. One group sees technological advancement as the leading factor. Since technological development continues this means that reserve growth will continue in the future like in the past. The second group thinks that reserve growth is mainly an anomaly due to bad reporting practices. Since the amount and reliability of data has increased over time, this means that reserve growth will decrease in the future. More importantly, if reliable estimates are taken for the recoverable amount of reserves, one would not have to account for future reserve growth, since it no longer would occur. While technological advancement serves its purpose to produce reserves faster and more cost efficiently, the amount of recoverable reserves is not increased due to technology in the world view of the second group.

5. Based on the data in the IHS Energy database it seems that the worldwide recovery factor did not increase in the past five years. This could mean that large reserve growth due to technological advancement can be ruled out. However, the time period is so short that this conclusion could be preliminary.

Part 2 will be published next week