Comments on Maugeri's Oil Revolution - Part I

Posted by Luis de Sousa on September 27, 2012 - 12:15am

This is part I of a guest post by Jean Laherrère, long term contributor to The Oil Drum. Jean worked 37 years for TOTAL on exploration and production of oil and gas, and since his retirement has worked tirelessly to analyse the world's oil & gas data and developments.

Leonardo Maugeri is an economist who worked for ENI since 1994, where he is currently on a sabbatical leave. He is also a senior fellow at Harvard University. In October 2009 he wrote an article in Scientific American entitled "Squeezing More Oil From the Ground: Amid warnings of a possible "peak oil," advanced technologies offer ways to extract every last possible drop", which is now found with another title: "Another Century of Oil? Getting More from Current Reserves". At the time, I wrote some comments on The Oil Drum in response: "Comments on Squeezing more oil from the ground by L. Maugeri Scientific American October 2009"

Recently, Maugeri published a new working paper, "Oil the Next Revolution: The uprecedented usurge of oil production capacity and what it means for the world". I again disagree with L. Maugeri's stance that oil production capacity is surging, because production capacity data is completely unreliable, based on guesses and not on real measurements. Only oil production data should be used for forecasting purposes; his forecast on non conventional oil is also flawed. L. Maugeri has a poor understanding of the accuracy of oil data and his statements are in my view political and not scientific. His paper does not deserve to be on the website of Harvard University, a centre for science.

Below the fold are my comments on Maugeri's Oil Revolution discussion paper.

Summary

My analysis highlights a number of errors of fact and analysis in Maugeri's work. These include:

- Carrying out analysis on productive capacity, where such data are very poorly known; and only very weak conclusions can be drawn.**(Section 2)**
- In his data of possible future oil production by an "original, bottom-up, field-by-field analysis of most exploration and development projects in the world", a significant proportion of the amount accounted for derives from proposed projects in Iraq, where the likelihood of early, and full, implementation is doubtful, as Maugeri should have pointed out.**(Section 2)**
- Maugeri uses OPEC data without indicating the serious flaws in these data. **(Section 2)**
- His projection of Canadian tar sand production is significantly higher than the projections of the Canadian Association of Petroleum Producer's (CAPP). **(Section 2)**
- Likewise, his US projections are higher than those from the Energy Information Administration (EIA) **(Section 3)**; and in case of the Bakken production he has used data from an early optimistic report instead of subsequent more reliable studies. **(Section 5)**
- Maugeri is wrong to assert that conventional oil production recently surged, it has been in a plateau since 2005.**(Section 4)**
- If the oil price stays high, it is true that considerable work will be done to increase recovery from existing fields. But Maugeri's data on reserves growth, which underpins much of his thinking and analysis, is based partly on a USGS study where the apparent reserves growth was almost entirely in a few OPEC countries, with the data being questionable. Also, on

reserves growth, Maugeri - like many other economists - quotes Kern River, without pointing out the simple reasons why estimates of recoverable reserves increase in a century-old, heavy oil field; reasons which are quite inapplicable to the majority of oil fields. **(Section 5 & To follow in part 2)**

- Finally, Maugeri makes the usual error in not understanding the evolution of proved reserves data over time; not understanding the statistical under-estimation that results from aggregation; nor the fact that, under Security Exchange Commission (SEC) reporting rules, these reserves have been significantly less in the past than the "proved and probable" reserves; and so can be expected to grow.**(To follow in part 2)**

Overall, these findings make Maugeri's conclusions too erroneous to be sustainable.

1. The problem of using proper units

In page 1 of Maugeri's discussion paper we can read:

> Based on original, bottom-up, field-by-field analysis of most oil exploration and development projects in the world, this paper suggests that an unrestricted, additional production (the level of production targeted by each single project, according to its schedule, unadjusted for risk) of more than 49 million barrels per day of oil (crude oil and natural gas liquids, or NGLs) is targeted for 2020, the equivalent of more than half the current world production capacity of 93 mbd.

In his list of abbreviations, “million barrels per day” is reported as Mbd, so why use mbd in the text? In fact it should be Mb/d. ENI must follow the SI (International System of units), which is the rule in every country outside the US, Liberia and Myanmar. By the SI, million is mega or M, m is metre or milli, d is day (dies) or deci, so mbd is millibarrel multiplied by days!

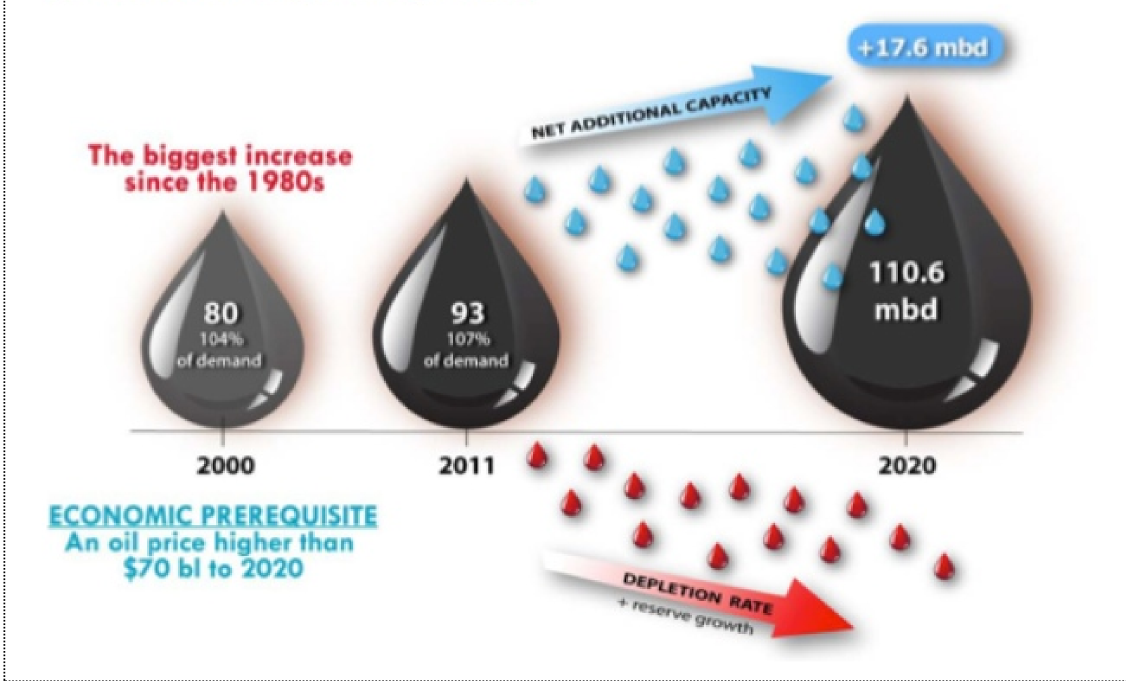
2. The inaccuracy of Production Capacity estimation

The field by field study presented by Maugeri is mainly based on Iraq contracts, which are unlikely to be realised due to political constraints. He continues:

> the net additional production capacity by 2020 could be 17.6 mbd, yielding a world oil production capacity of 110.6 mbd by that date – as shown in Figure 1.

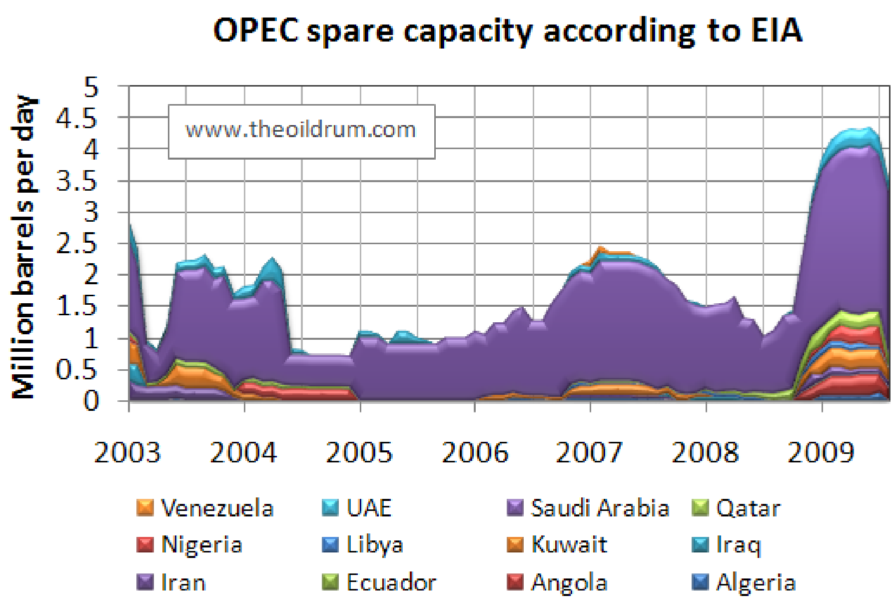
Figure 1: World oil production capacity to 2020

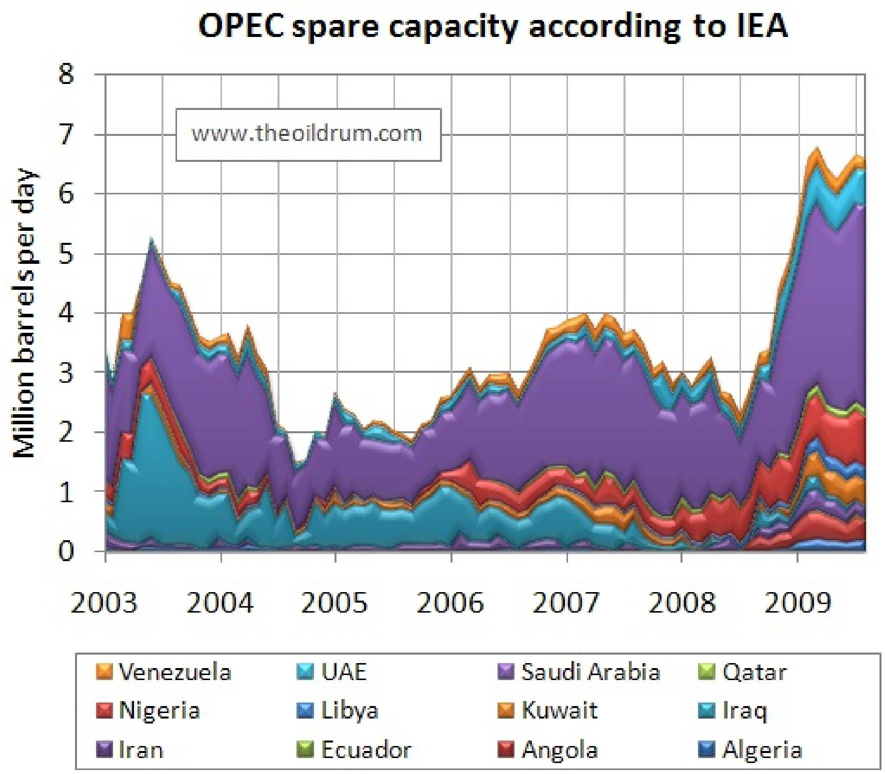
(Crude oil and NGLs, excluding biofuels)



Oil production capacity is a very badly defined value and the data for OPEC spare capacity from the EIA and IEA differs widely, as shown [by Rembrandt Koppelaar in these two graphs](#) from 2003 to 2009. In the EIA reports the spare capacity in 2003 for the UAE varies little, while the IEA reports more than 2 Mb/d.

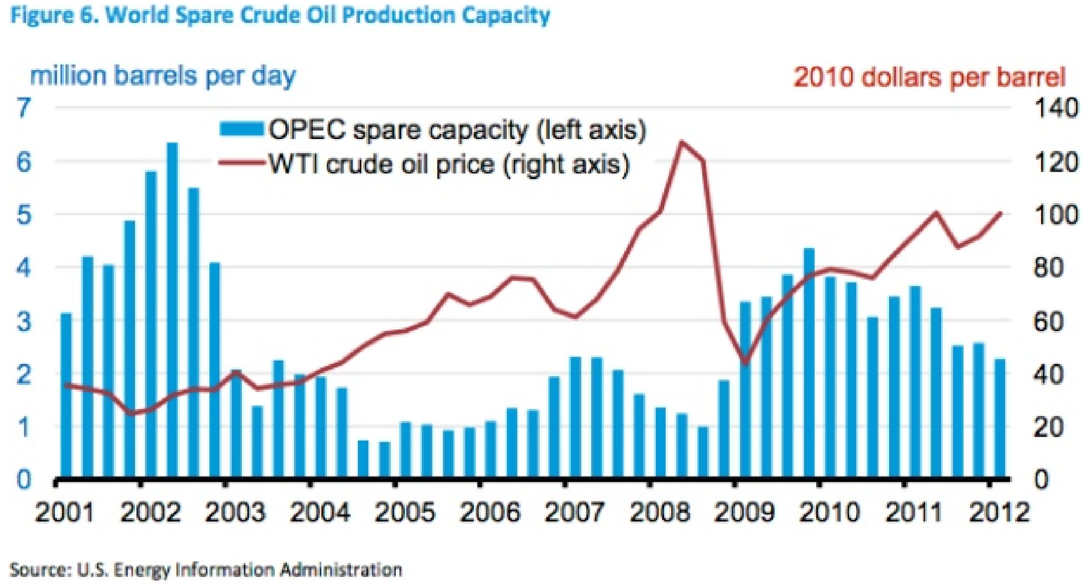
Figure 1: OPEC spare capacity by EIA & IEA from Koppelaar 2003-2009





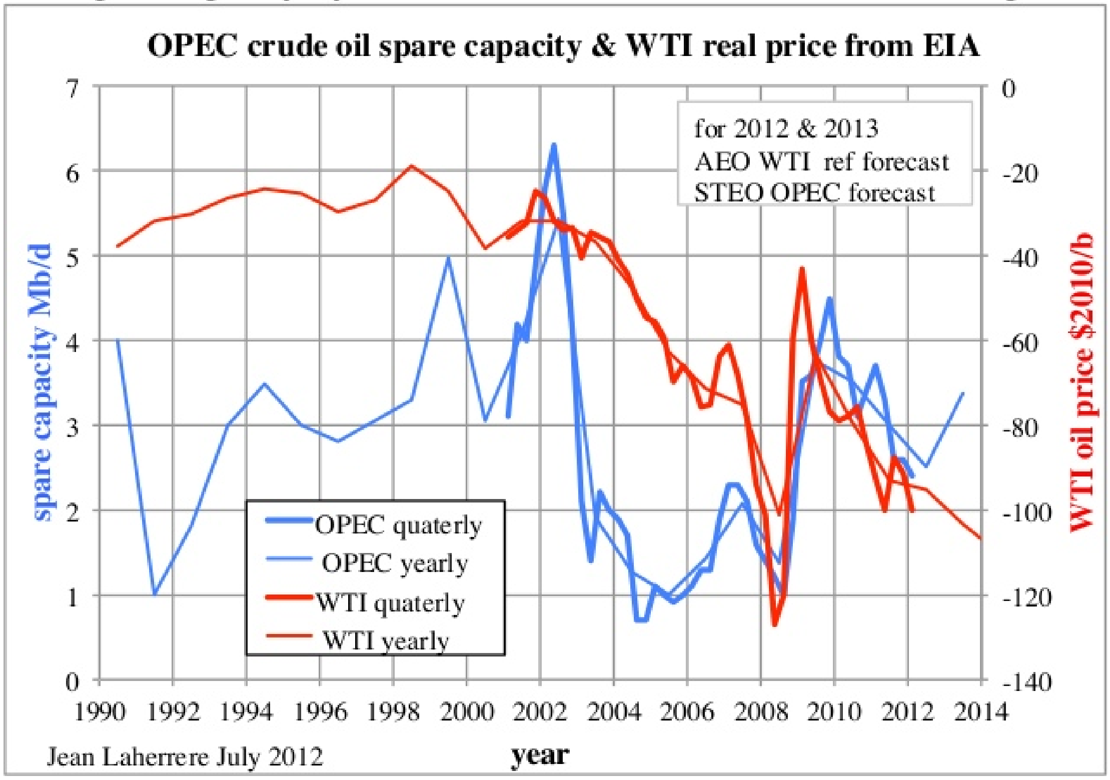
OPEC spare capacity is reported by the EIA with the following graph, showing an inverse correlation with the inflation corrected WTI oil price index (2010 $/b). And if OPEC capacity is shown, the title is for world spare oil production capacity! The EIA assumes that the non-OPEC production has no spare capacity.

Figure 2: OPEC spare capacity by EIA 2001-2012 and WTI crude oil price



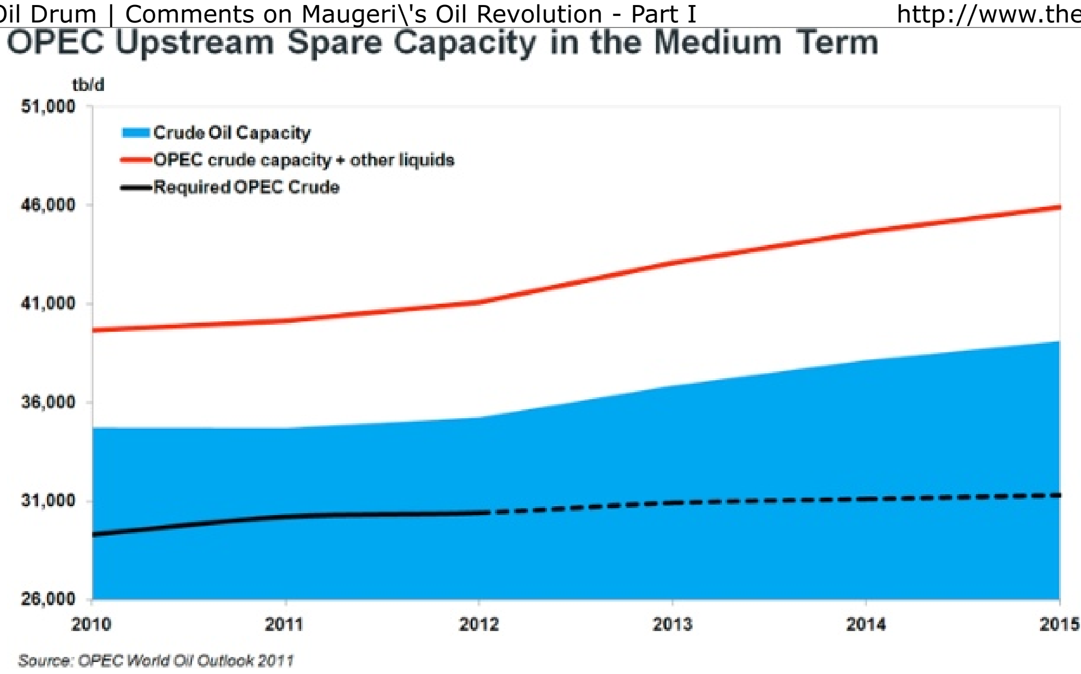
The EIA provides data since 1990 and a better presentation can be plotted for the WTI, shown here as a negative value. The relationship between OPEC spare capacity and the WTI may seem good on a periodic basis, but it is not very reliable. It is obvious that the "*unprecedented upsurge of oil production capacity*" claimed by Maugeri is the OPEC increase in 2009 (from 1 to 5 Mb/d), correlating well with the decrease in WTI from 120 $/b to 50 $/b. The meaning is clear for 2009: low oil prices correlate with high spare oil capacity. But, like the chicken egg and the egg, which came first? Spare capacity being a guess, it is difficult to time exactly the increase, depending on the brains of the author! OPEC annual spare capacity, as reported by the EIA, was 3.05 Mb/d in 2000 and 2.99 Mb/d in 2011: it means the same value over a long period. For the period 1990-2012 the EIA average is around 3 Mb/d, with up to 6 Mb/d and down to 1 Mb/d: usually a surge follows a fall! For a long term forecast, extrapolation from the past has to be made on the long term and not on the short term!

Figure 3: OPEC spare capacity by EIA/AEO & STEO 1990-2013 and WTI price in negative scale



OPEC, in its monthly oil market report, does not mention OPEC spare capacity and in its annual report there is only the sentence: "*OPEC crude oil spare capacity is also expected to remain at comfortable levels*", but no figure is presented! In the (last) OPEC 2010-2011 Annual Statistical bulletin edition, spare capacity is only mentioned in a note on page 10, quoting the 2005 OPEC Conference. It is only in the OPEC World Oil Outlook that a graph on spare capacity is given, since 2009 , stating that OPEC spare capacity was around 4 Mb/d in 2011 (against 2 Mb/d for the EIA) and should be 8 Mb/d in the medium term.

Figure 4: OPEC spare capacity by OPEC WOO 2011



To estimate spare capacity, it is necessary to know exactly what the production is. But it appears that OPEC does not agree on what their production is. This graph uses secondary data sources, but it should be quite different, using data directly communicated by members! There are also discrepancies on capacity and production between OPEC presentations:

- Ch.Khelil "Oil production capacity", OPEC seminar, September 2006.
- Dr Nimat B. Abu Al-Soof "Upstream Oil Industry Analyst OPEC", May 2007 .

For 2003, Khelil reports OPEC capacity at 29 Mb/d, while al-Soof puts it at 31 Mb/d. The inaccuracy on OPEC capacity is more than 2 Mb/d.

Figure 5: OPEC spare capacity by Khelil 2007

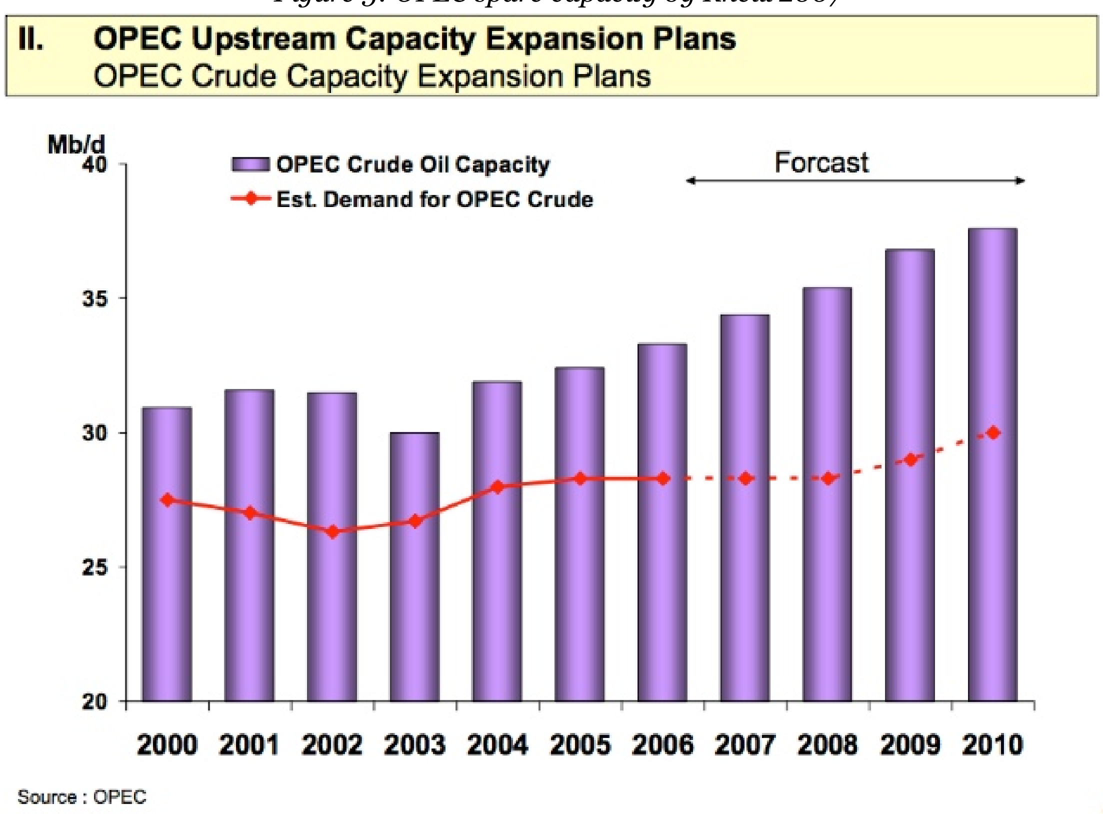
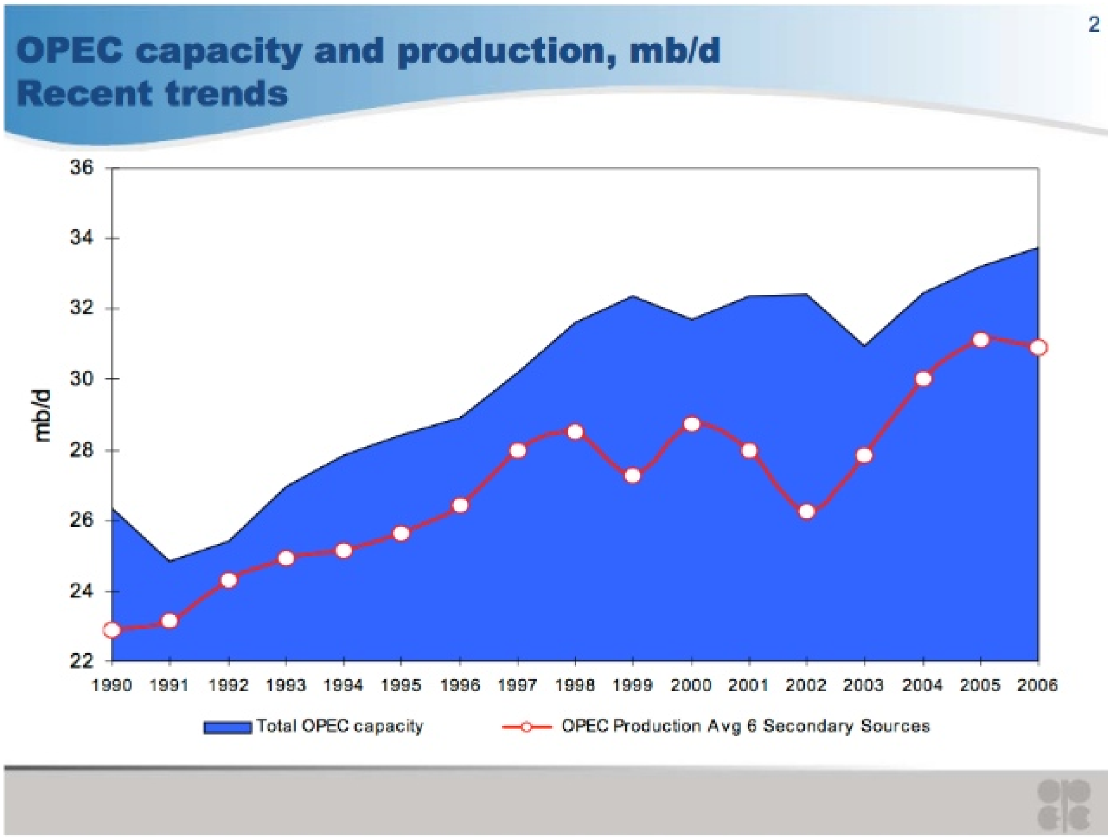


Figure 6: OPEC spare capacity by al-Soof 2006



In fact, the reliability of OPEC oil production is very poor (because they cheat on quotas, and they cheat on production data or on its definition). OPEC reports mainly its production from secondary sources, meaning that the value reported by its members (called direct communication) is less reliable. The difference between secondary sources and direct communication varies (from -7 % for 1997 to 4 % in July 2012), in particular for Venezuela (from -25 % in 1997 to 19 % in July 2012). Direct data is often higher than secondary sources, but not always because of quotas.

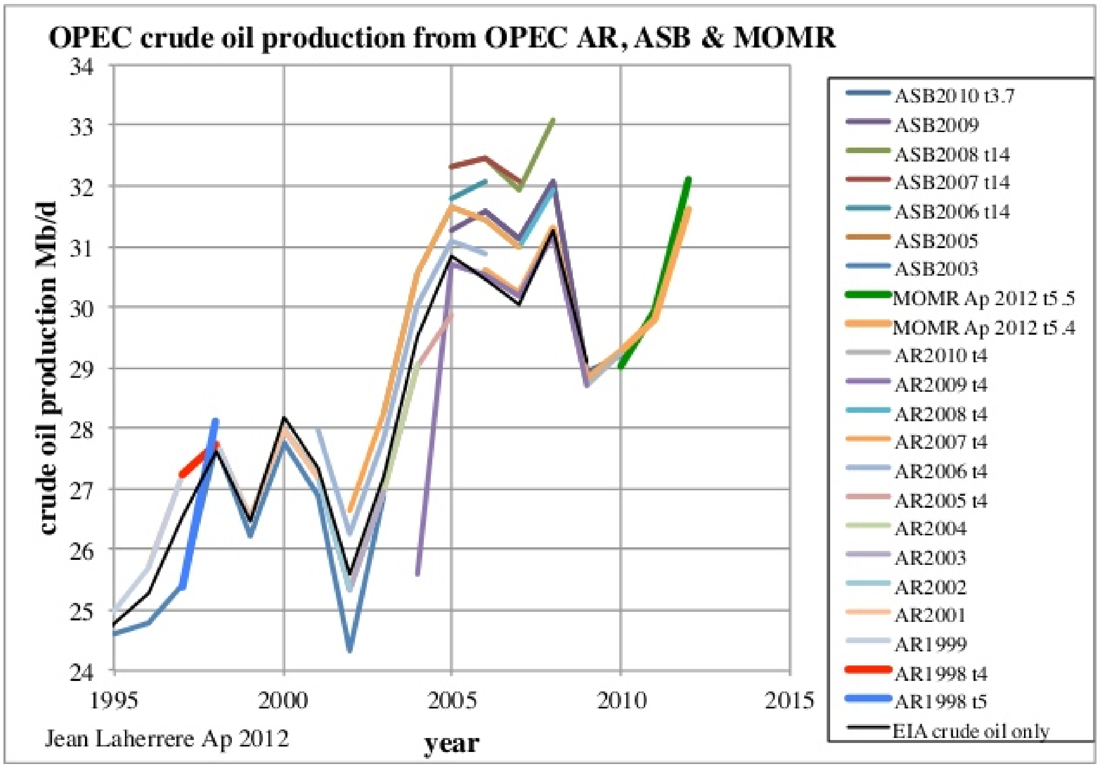
Table: crude oil production sources: AR 1998 & MOMR Ap 2012

Mb/d	secondary source	direct communication by member countries	difference %
OPEC			
1997	27.228	25.384	-7
1998	27.726	28.100	1
2010	29.254	29.020	-1
2011	29.776	29.942	1
Feb 2012	31.176	32.107	3
July 2012	31.619	32.964	4
Venezuela			
1997	3.228	2.411	-25
1998	3.137	3.409	9
2012	2.338	2.779	19
2011	2.380	2.795	17
Feb 2012	2.379	2.785	17
July 2012	2.370	2.831	19

The data for OPEC crude oil production also varies with time between different OPEC Annual Reports (AR) and Annual Statistical Bulletins (ASB). For the year 2005, OPEC data varies from

29.9 Mb/d (AR 2005) to 32.3 Mb/d (ASB 2007 & 2008), while the figure reported by the EIA is 30.8 Mb/d . For the period from 2006 to 2008, there is a difference of about 1 Mb/d between the values from AR 2009 and ASB 2009. OPEC data is next compared to EIA crude oil production up to 2009 (EIA ceased to publish such data in January 2011 due to budgets cuts).

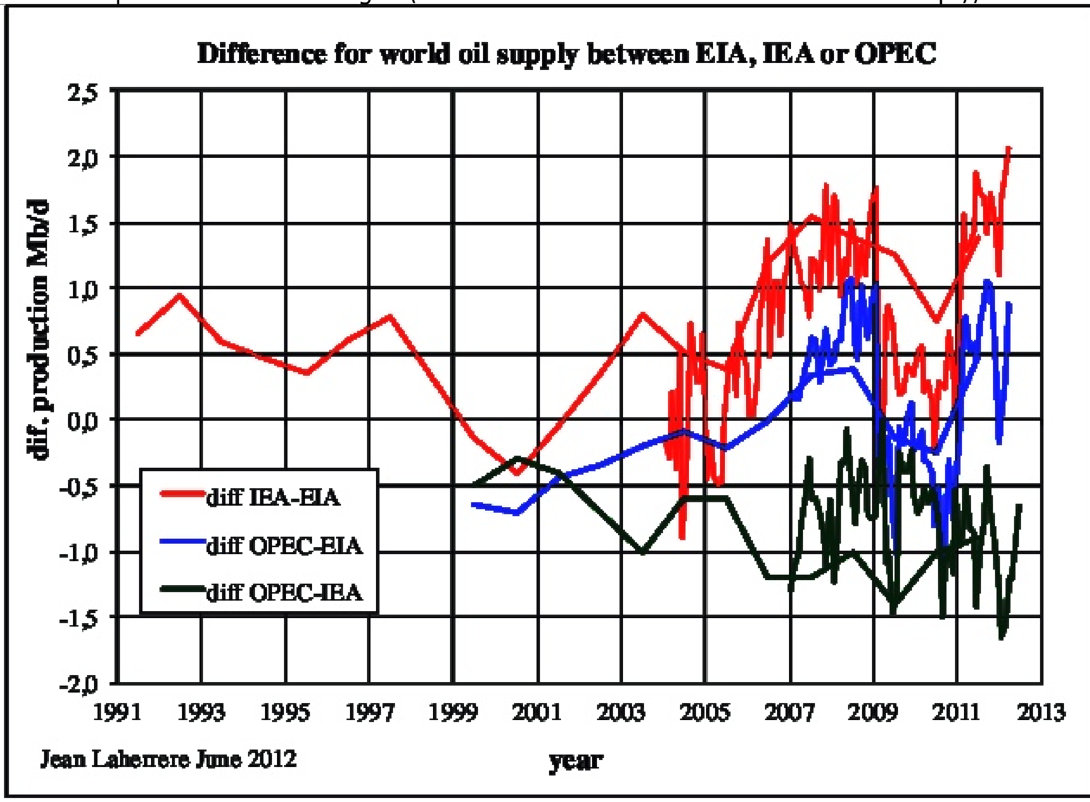
Figure 7: OPEC crude oil production from AR & ASB OPEC reports compared to EIA crude oil (1980-2009)



It appears that the accuracy of OPEC oil production is about 2 Mb/d!

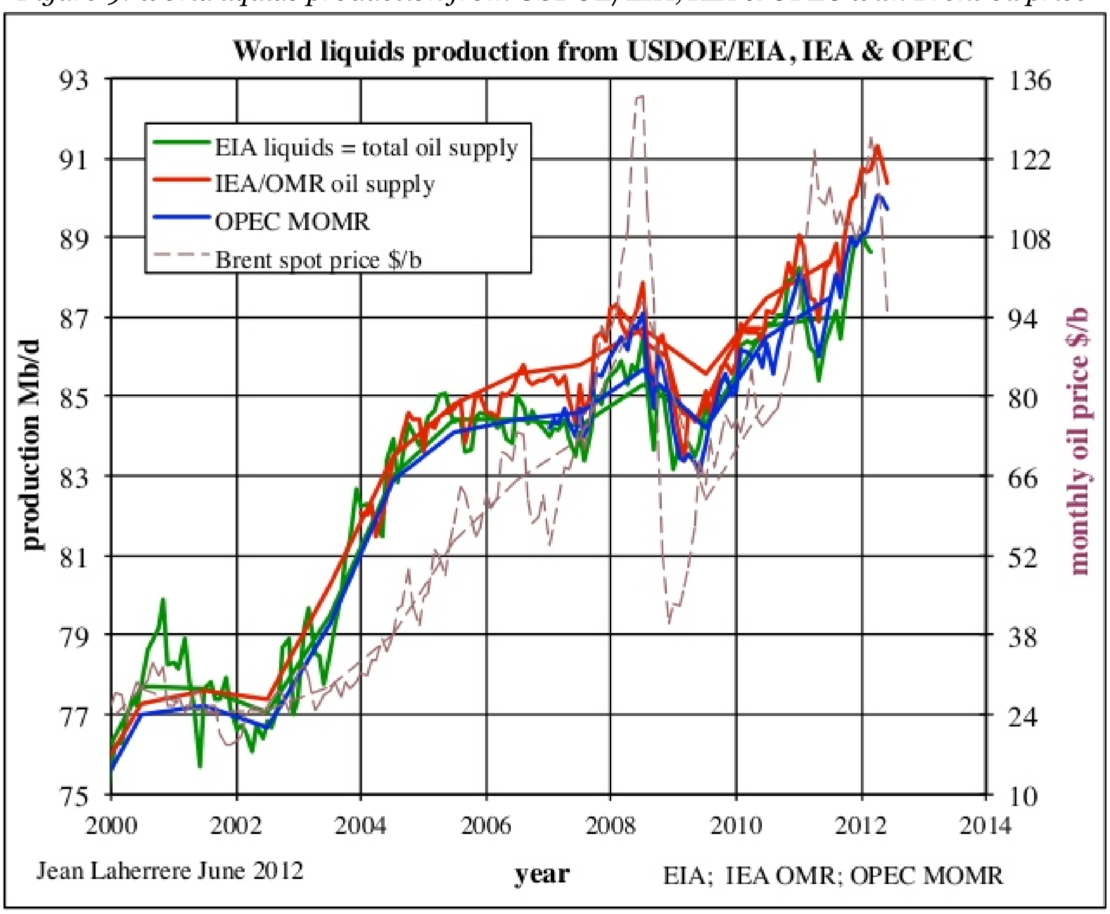
World oil production capacity is badly known and completely unreliable,and its use should be avoided. Only CERA is forecasting production capacity, while reliable agencies forecast only oil production. Already the world oil supply data differs widely between sources (EIA, IEA, OPEC), mainly due to different definitions. For the period 1991-2012 the discrepancy could be plus or minus 2 Mb/d, and the most striking is the sharp change at the beginning of the year, due to a change in definition. The monthly data does not agree with the annual data, showing the uncertainty involved, varying with time and authors!

Figure 8: difference for world oil supply (monthly & yearly) between USDOE/EIA, IEA & OPEC



The EIA data is reported late and isn't subject to much revision. This agency has warned that it may stop reporting international data because of budget cuts!

Figure 9: world liquids production from USDOE/EIA, IEA & OPEC with Brent oil price

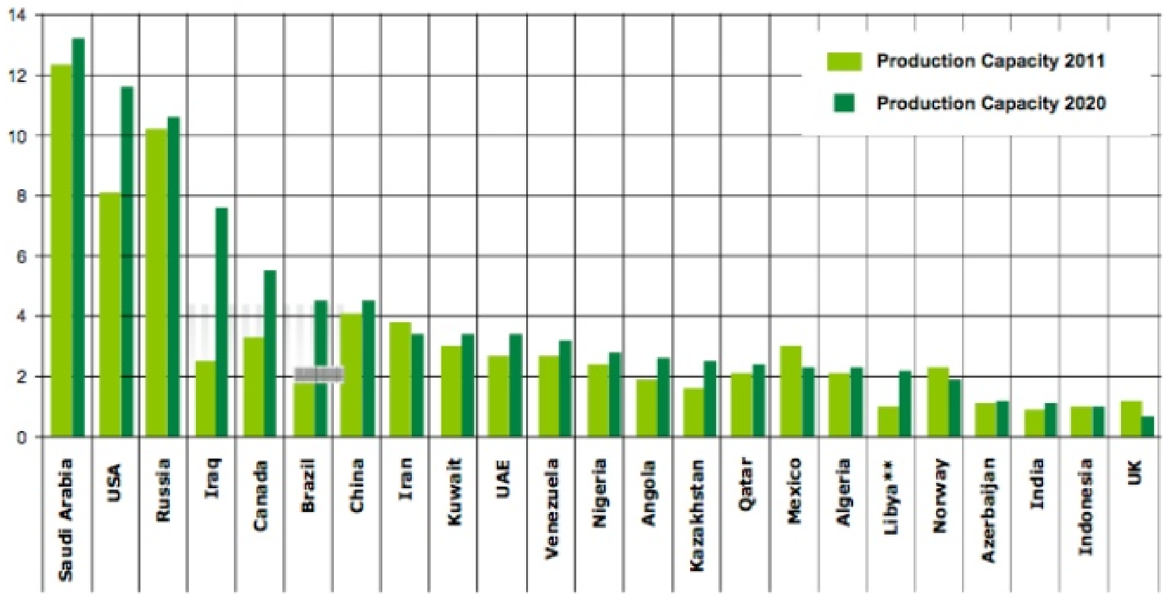


Using oil production capacity is adding more uncertainty, but it is a trick to claim in the future that the forecast was right by manipulating the data. In fact, past world crude oil plus NGL production data from the EIA gives an increase of 7.7 Mb/d from 2000 to 2011, against 13 Mb/d for production capacity in Maugeri's Figure 1. As OPEC spare capacity from the EIA was about the same and Non-OPEC production is at or close full capacity (EIA Newell 23 Feb 2011), this 13 Mb/d looks wrong! There is no increase in US crude oil and NGL production from 2000 to 2011.

EIA Mb/d	2000	2011	increase 2000-2011
World			
crude oil (& condensate)	68.522	74.030	
NGPL	6.376	8.571	
crude oil & NGL	74.898	82.601	7.7
US			
crude oil	5.881	5.659	
NGPL	1.911	2.183	
crude oil & NGL	7.792	7.832	0

On page 3 of his discussion paper, Maugeri produces the following graph comparing production capacity between 2011 and 2020.

Figure 2: Country-by-country evolution of oil production capacity to 2020
(First 23 countries)



Let's now compare Maugeri's increase from 2011 to 2020 to official production forecasts in Mb/d. We can see the difference between his forecasts and that of the Canadian Association of Petroleum Producers (CAPP) being 1.2 mb/d higher for 2020. Similarly, his forecast is forecast for the United States is also 1.2 mb/d higher than the forecast of the Energy Information Administration.

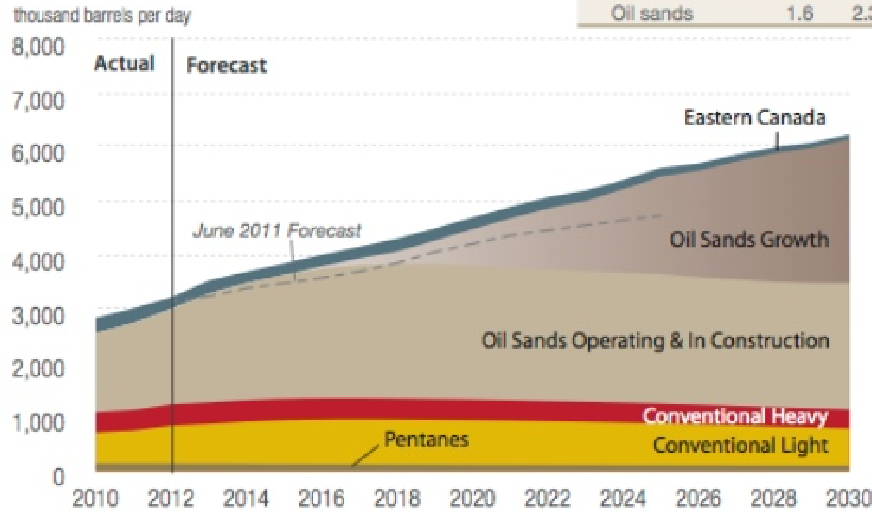
Canada Mb/d	Maugeri	CAPP June 2012	Maugeri/CAPP
2011	3.2	3	1.07
2020	5.6	4.7	1.19
increase	2.4	1.7	1.41

Figure 10: CAPP June 2012 forecast on Canada production 2010-2030

Canada grew for the first time in many years, surpassing previous expectations and is expected to grow until at least 2017.

million b/d	2011	2015	2020	2025	2030
Total Canadian (including oil sands)	3.0	3.8	4.7	5.6	6.2
Eastern Canada	0.3	0.2	0.2	0.2	0.1
Western Canada					
Conventional	1.1	1.3	1.3	1.2	1.1
Oil sands	1.6	2.3	3.2	4.2	5.0

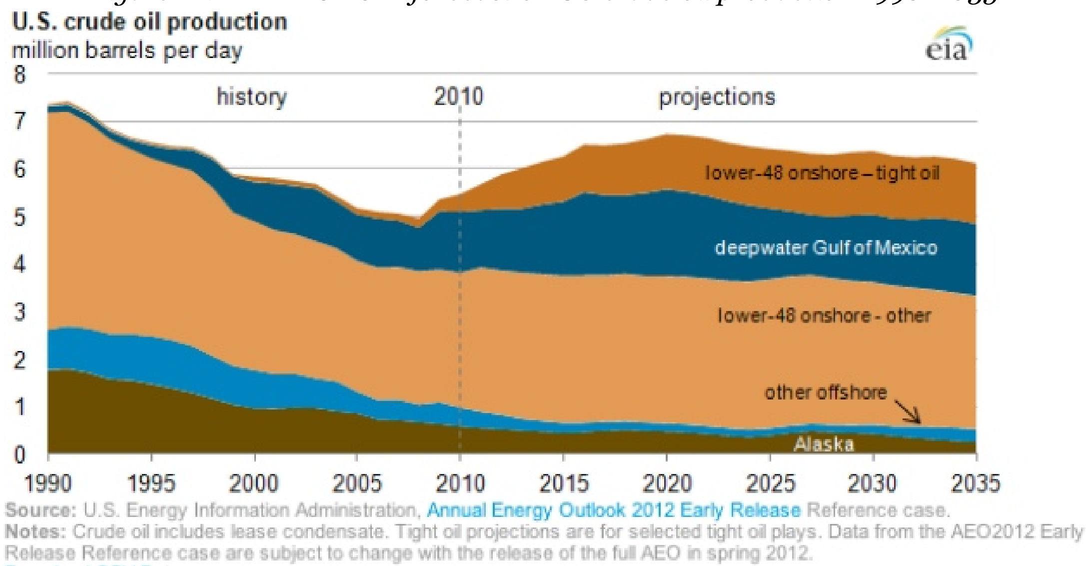
Canadian Oil Sands & Conventional Production



Crude Oil Forecast, Markets & Pipelines

USA Mb/d	Maugeri	EIA/AEO2012 production			Maugeri/EIA
		crude	NGL	crude + NGL	
2011	8	5.68	2.16	7.34	1.09
2020	11.6	6.73	2.79	9.52	1.21
increase	3.6			2.2	1.64

Figure 11: EIA AEO 2012 forecast on US crude oil production 1990-2035



It is important to repeat, Maugeri can always claim afterward that he is right because his forecast is on capacity, which is a mere guess, as no one can state what capacity has been even in retrospect!. See the numbers for OPEC above. Every reliable forecast is on production.

3. Oil production in the USA

On page 4 of Maugeri's discussion paper we read:

> Thus, the U.S. could produce 11.6 mbd of crude oil and NGLs by 2020, making the country the second largest oil producer in the world after Saudi Arabia. Adding biofuels to this figure, the overall U.S. liquid capacity could exceed 13 mbd, representing about 65 percent of its current consumption.

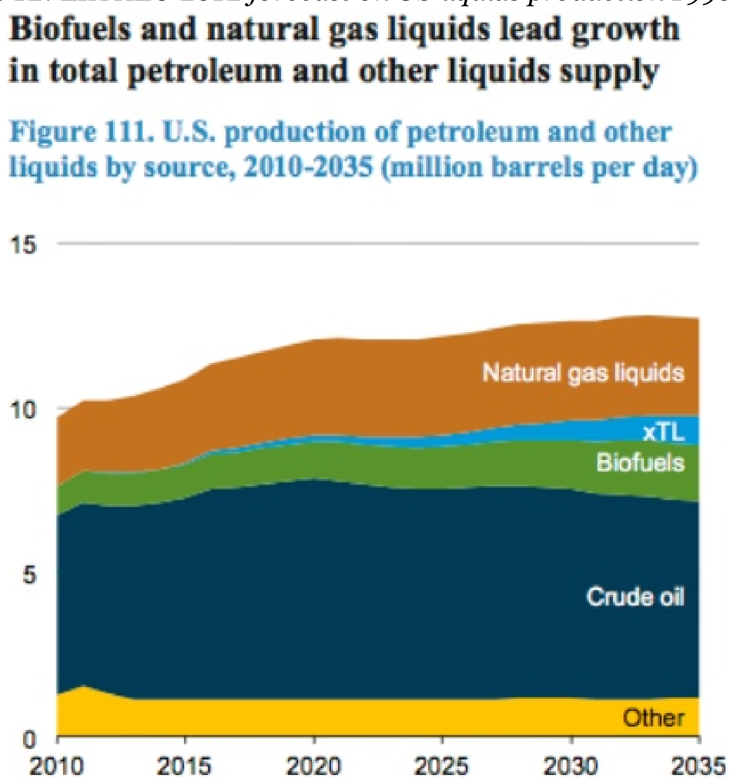
In Figure 2 on page 3, shown above, Maugeri points to a figure of 11.6 Mb/d for production capacity in the US by 2020, but on page 4 it is indicated as **production**. He forecasts US liquids capacity for 2020 at 13 Mb/d, adding biofuels, but misses refinery gains, which for the US was 1 Mb/d in 2010. This a non negligible part of the US liquids production, which could come from imported oil but also from domestic natural gas used to make lighter products, being a kind of Gas to Liquids (GTL.

AEO 2012 table A11 forecasts in Mb/d

Domestic production Mb/d	**2010**	**2020**	**2035**
crude oil	5.47	6.70	5.99
NGL	2.07	2.91	3.01
refinery processing gain	1.07	0.94	0.85
ethanol	0.85	1.04	1.65
biodiesel	0.01	0.12	0.13
CTL	0	0	0.28
total	9.34	11.62	11.06

In its AEO 2012 forecast, the EIA includes an “other” category that is mainly refinery gains.

Figure 12: EIA AEO 2012 forecast on US liquids production 1990-2035



Maugeri’s forecast of US production capacity of 13 Mb/d by 2020 seems significantly higher than the lastest EIA forecast!

Maugeri also claims that “in the first quarter 2012, average world oil production consistently reached or surpassed 91 mbd”. However, the data available publicly shows otherwise with EIA published 88.8 million b/d, IEA 90.7 million b/d and OPEC 89.2 million b/d, for world oil production in first quarter 2012.

4. Non-Conventional Oil flow rate expectations

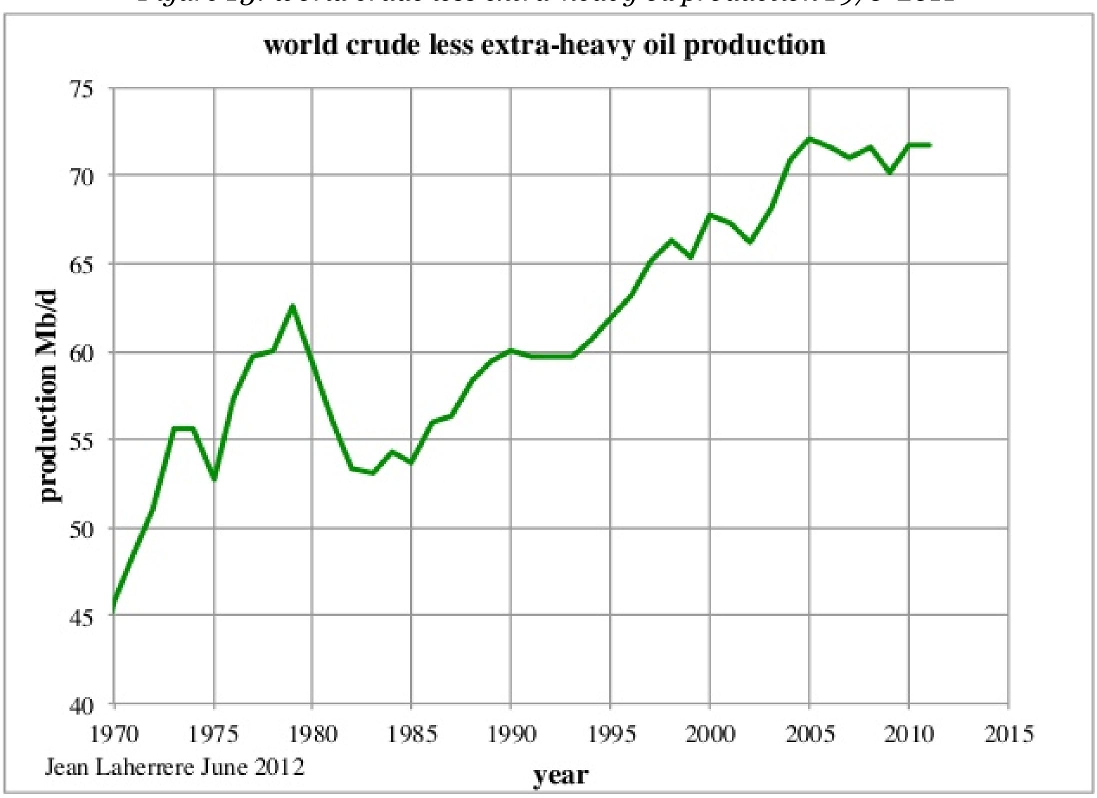
On page 6 of Maugeri's discussion paper he states:

> In the aggregate, conventional oil production is also growing throughout the world at an unexpected rate, although some areas of the world (Canada, the United States, the North Sea) are witnessing an apparently irreversible decline of the conventional production. Technology may turn today’s expensive oil into tomorrow’s cheap oil.

There is no consensus on the definition of conventional oil; for some it is the easy flowing oil, for others it is the oil from continuous-type accumulations. Maugeri states in page 14 the EIA definition for conventional oil: “produced by a well drilled into a geologic formation in which the reservoir and fluid characteristics permit the oil and natural gas to readily flow to the wellbore”. But the EIA does not provide the production data of so-called conventional oil and neither does Maugeri, he simply claims an unexpected growth for world production at present.

Extra-heavy oil (Athabasca & Orinoco) are obviously not conventional and the world crude less extra-heavy oil production from the EIA displays an increase from 1982 to 2005, but **since 2005 it is plateauing at 72 Mb/d, contrary to Maugeri’s claim that conventional oil production is growing**.

Figure 13: world crude less extra-heavy oil production 1970-2011



Scrolling forward on page 8 of the report we read:

> The unexpected and rapid increase of oil production from the forerunner of shale/tight oil (the Bakken Shale formation in North Dakota) is astonishing: production has grown from a few barrels in 2006 to more than 530,000 barrels in December 2011. This

> development seems consistent with the **best study ever conducted** on the geological features and potential productivity **of Bakken (Price, 1999), which estimated the maximum Original Oil in Place of the whole formation at more than 500 billion barrels, with a probable recovery rate of about 50 percent.**

The production data for Bakken (North Dakota) to date yields:

- 2006 – total production of 2.3 million barrels in the entire year;
- December 2006 – 10 kb/d average flow rate;
- December 2011 - 14.6 million barrels for the entire month;
- December 2011 - 510 kb/d average flow rate.

L. Maugeri, who is called by some a world oil expert, should know the difference between b and b/d, in other words stocks and flow rates. He should have made himself consistent with page 47 of his report where he writes, notwithstanding again confusing bd, b/d and b:

> Thanks to the Bakken Shale, oil production in North Dakota skyrocketed from around 110,000 **bd** in 2006 (of which 7,600 **boe/d** in the Bakken Shale) to nearly 264,000 **boe/d** in 2010 and more than 530,000 **barrel**s in December 2011.

The confusion can be found in the Bakken formation which is presently being produced not being the shale section, but the sandy limestone (or dolomite for Elm Coulee) in its middle: calling Bakken a shale play is wrong. It is a structural/stratigraphic play depending of the quality of the reservoir and it is called now light tight oil.

5. Non-Conventional Oil reserves and resources

When reading on at page 8 we find:

> In April 2008, a report by the North Dakota Department of Mineral Resources (NDDMR) estimated that the North Dakota portion of the Bakken contained up to 167 billion barrels, and that approximately 2.1 billion barrels of that oil (the estimated ultimate recovery), less than 2 percent, could be recovered using 2008 technology. In any case, the report also recognized that technological evolution could dramatically increase the recovery factor.

In page 8 Maugeri quotes the Bakken oil in place to be 500 Gb (a maximum) **with a recovery factor of 50%**. But why chose an obsolete (1999) and controversial paper when many more recent estimates exist from the USGS, and in particular from the North Dakota Department of Mineral Resources, and mention them only in page 48? In the book written by the USGS geochemist Leigh C. Price "Origins and characteristics of the basin-centered continuous-reservoir unconventional oil-resource base of the Bakken Source System, Williston Basin" (1999/2000) it can be read:

> In section 10.0, we present preliminary mass-balance calculations regarding the amount of oil generated by the Bakken shales in the Bakken HC kitchen of the Williston Basin (North Dakota and Montana). **Our calculations suggest that 413 billion barrels of oil have been generated, with a potential upside of 503 billion barrels and a minimum of 271 billion barrels**. These numbers are larger than three previously-published estimates of 92, 132, and 150 billion barrels"

The assumption of a recovery factor of 50% is well above the recovery in a conventional field and seems unrealistic. Price's 1999 paper is described as controversial by Julie LeFever and Lynn

Helms in "Bakken Formation Reserve Estimates Julie LeFever" (ND DMR 2006):

> Nature of the Controversy
>
> The methods used by Price to determine the amount of hydrocarbons generated by the Bakken and the idea that the oil has not migrated out of the Bakken are under dispute. Price (unpublished) used a more complete database and estimated that the Bakken was capable of generating between 271 and 503 BBbls of oil with an average of 413 BBbls. New estimates of the amount of hydrocarbons generated by the Bakken were presented by Meissner and Banks (2000) and by Flannery and Kraus (2006). The first of these papers tested a newly developed computer model with existing Bakken data to estimate generated oil of 32 BBbls. The second paper used a more sophisticated computer program with extensive data input supplied by the ND Geological Survey and Oil and Gas Division. Early numbers generated from this information placed the value at 200 BBbls later revised to 300 BBbls when the paper was presented in 2006. How much of the generated oil is recoverable remains to be determined. Estimates of 50%, 18%, and 3 to 10% have been published.
>
> How much of the oil that has been generated is technically recoverable is still to be determined. Price places the value as high as 50% recoverable reserves. A primary recovery factor of 18% was recently presented by Headington Oil Company for their Richland County, Montana wells. Values presented in ND Industrial Commission Oil and Gas Hearings **have ranged from 3 to 10%**. The Bakken play in the North Dakota side of the basin is still in the learning curve. North Dakota wells are still undergoing adjustments and modifications to the drilling and completion practices used for this formation. It is apparent that technology and the price of oil will dictate what is potentially recoverable from this formation.

A Wikipedia article entitled History of Bakken oil resource estimates contains further details:

> A landmark paper by Dow and a companion paper by Williams (1974) recognized the Bakken formation as a major source for the oil produced in the Williston Basin. These papers suggested that the Bakken was capable of generating 10 billion barrels (1.6×109 m3) of oil (BBbls). Webster (1982, 1984) as part of a Master's thesis at the University of North Dakota, further sampled and analyzed the Bakken and calculated the hydrocarbon potential to be about 92 BBbls. These data were updated by Schmoker and Hester (1983) who estimated that the Bakken might contain a resource of 132 BBbls of oil in North Dakota and Montana. A research paper by USGS geochemist Leigh Price in 1999 estimated the total amount of oil contained in the Bakken shale ranged from 271 billion to 503 billion barrels (8.00×1010 m3), with a mean of 413 billion barrels (6.57×1010 m3).[14] While others before him had begun to realize that the oil generated by the Bakken shales had remained within the Bakken, it was Price, who had spent much of his career studying the Bakken, who particularly stressed this point. If he was right, the large amounts of oil remaining in this formation would make it a prime oil exploration target. **However, Price died in 2000 before his research could be peer-reviewed and published**. Nevertheless, the drilling and production successes in much of the Bakken beginning with the Elm Coulee Oil Field discovery in 2000 have proven correct his claim that the oil generated by the Bakken shale was still there. New estimates of the amount of hydrocarbons generated by the Bakken were presented by Meissner and Banks (2000) and by Flannery and Kraus (2006). The first of these papers tested a newly developed computer model with existing Bakken data to estimate generated oil of 32 BBbls. The second paper used a more sophisticated computer program with extensive data input supplied by the ND Geological Survey and Oil and Gas Division. Early numbers generated from this information placed the value at 200 BBbls later revised to 300 BBbls when the paper was presented in 2006.".[15] In April 2008, a report issued by the state of North Dakota Department of Mineral Resources estimated that the North Dakota portion of the Bakken contained 167 billion barrels (2.66×1010 m3) of oil.[6]

While these numbers would appear to indicate a very large oil resource, the percentage of this oil which might be extracted using current technology is another matter. **Estimates of the Bakken's technically recoverable oil have ranged from as low as 1%** — because the Bakken shale has generally low porosity and low permeability, making the oil difficult to extract — to Leigh Price's estimate of 50% recoverable.[16] Reports issued by both the USGS and the state of North Dakota in April 2008 seem to indicate the lower range of recoverable estimates are more realistic with current technology.

The flurry of drilling activity in the Bakken, coupled with the wide range of estimates of in-place and recoverable oil, led North Dakota senator Byron Dorgan to ask the USGS to conduct a study of the Bakken's potentially recoverable oil. In April 2008 the USGS released this report, which estimated the amount of technically recoverable, undiscovered oil in the Bakken formation at 3.0 to 4.3 billion barrels (680,000,000 m3), with a mean of 3.65 billion.[5] **Later that month, the state of North Dakota's report [6] estimated that of the 167 billion barrels (2.66×1010 m3) of oil in-place in the North Dakota portion of the Bakken, 2.1 billion barrels (330,000,000 m3) were technically recoverable with current technology**.

In 2011, a senior manager at Continental Resources Inc. (CRI) declared that the "Bakken play in the Williston basin could become the world's largest discovery in the last 30-40 years", as ultimate recovery from the overall play is now estimated at 24 billion bbls. This considerable increase has been made possible by the combined use of horizontal drilling, fracking, and a large number of wells drilled. While these technologies have been consistently in use since the 1980s, Bakken is the place where they are being most heavily used: 150 active rigs in the play and a rate of 1,800 added wells per year. CRI developed a technology allowing its rigs to move a few hundred yards on hydraulic "feet", increasing the rate of well completion.

To add to the confusion, the USGS 2012-1118 report "Variability of Distributions of Well-Scale Estimated Ultimate Recovery for Continuous (Unconventional) Oil and Gas Resources in the United States" reports EUR (estimated ultimate recovery) in Mb when it should be in Gb. Shale oil is not called tight oil, but continuous oil. They speak about continuous oil but are obviously referring to discrete fields.

Figure 14: USGS 2012-1118 table 4: estimated ultimate recovery in Mb

Table 4. Input data for estimated ultimate recovery distributions for United States continuous-oil assessment units, values in millions of barrels of oil. [AU, assessment unit; and EUR, estimated ultimate recovery]

AU number	AU name	Province	Year assessed	Minimum EUR	Median EUR	Maximum EUR	Mean EUR
50310164	Eastern Expulsion Threshold	Williston Basin	2008	0.002	0.12	5	0.241
50310163	Nesson-Little Knife Structural	Williston Basin	2008	0.002	0.09	4	0.185
50210361	Cane Creek Shale Oil	Paradox Basin	2011	0.002	0.08	3	0.154
50310165	Northwest Expulsion Threshold	Williston Basin	2008	0.002	0.065	4	0.151
50310161	Elm Coulee-Billings Nose	Williston Basin	2008	0.002	0.08	2	0.135
50270561	Marias River Shale Continuous Oil	Montana Thrust Belt	2002	0.001	0.08	1.6	0.126
50370361	Niobrara Continuous Oil	Southwestern Wyoming	2002	0.001	0.08	1.6	0.126
50300361	Niobrara Continuous Oil	Hanna, Laramie, Shirley Basins	2005	0.001	0.04	1.6	0.079
50310162	Central Basin-Poplar Dome	Williston Basin	2008	0.002	0.025	2	0.064
50210363	Gothic, Chimney Rock, Hovenweep Shale Oil	Paradox Basin	2011	0.002	0.03	1.5	0.064
50580162	Woodford Shale Oil	Anadarko Basin	2010	0.003	0.03	1.5	0.064
50200561	Deep Uinta Overpressured Continuous Oil	Uinta-Piceance	2000	0.003	0.045	0.45	0.059
50440165	Spraberry Continuous Oil	Permian Basin	2007	0.001	0.045	0.4	0.057
50490170	Eagle Ford Shale Oil	Gulf Coast Mesozoic	2010	0.002	0.03	1	0.055
50490168	Austin Pearsall-Giddings Area Oil	Gulf Coast Mesozoic	2010	0.002	0.04	0.5	0.055
50330361	Niobrara Continuous Oil	Powder River Basin	2002	0.002	0.028	0.5	0.042
50330261	Mowry Continuous Oil	Powder River Basin	2002	0.002	0.025	0.35	0.035
50340262	Mowry Fractured Shale Continuous Oil	Big Horn Basin	2008	0.002	0.025	0.35	0.035
50390261	Fractured Niobrara Limestone (Silo Field Area)	Denver Basin	2001	0.002	0.022	0.4	0.033
50390661	Niobrara-Codell (Wattenberg Area)	Denver Basin	2001	0.003	0.008	0.1	0.011

The mean EUR for continuous oil assessment units in Williston Basin are:

- Eastern expulsion threshold - 0.241 Mb or 241 Mb?
- Nesson-Little Knife structural - 0.185 Mb or 185 Mb?
- Northwest expulsion threshold - 0.151 Mb or 151 Mb?
- Elm-Coulee-Billings Nose - 0.135 Mb or 135 Mb?
- Central Basin-Poplar Dome - 0.064 Mb or 64 Mb?

An earlier USGS report by the Williston Basin Province Assessment Team: “Assessment of undiscovered oil and gas resources of the Williston Basin Province of North Dakota, Montana, and South Dakota, 2010”, U.S. Geological Survey Digital Data Series 69–W, 7, 2011, displays a map indicating the main structural features.

Figure 15: USGS 2011 DGS 69-W: map of Williston basin features

2 **Executive Summary—Assessment of Undiscovered Oil and Gas Resources, Williston Basin Province**

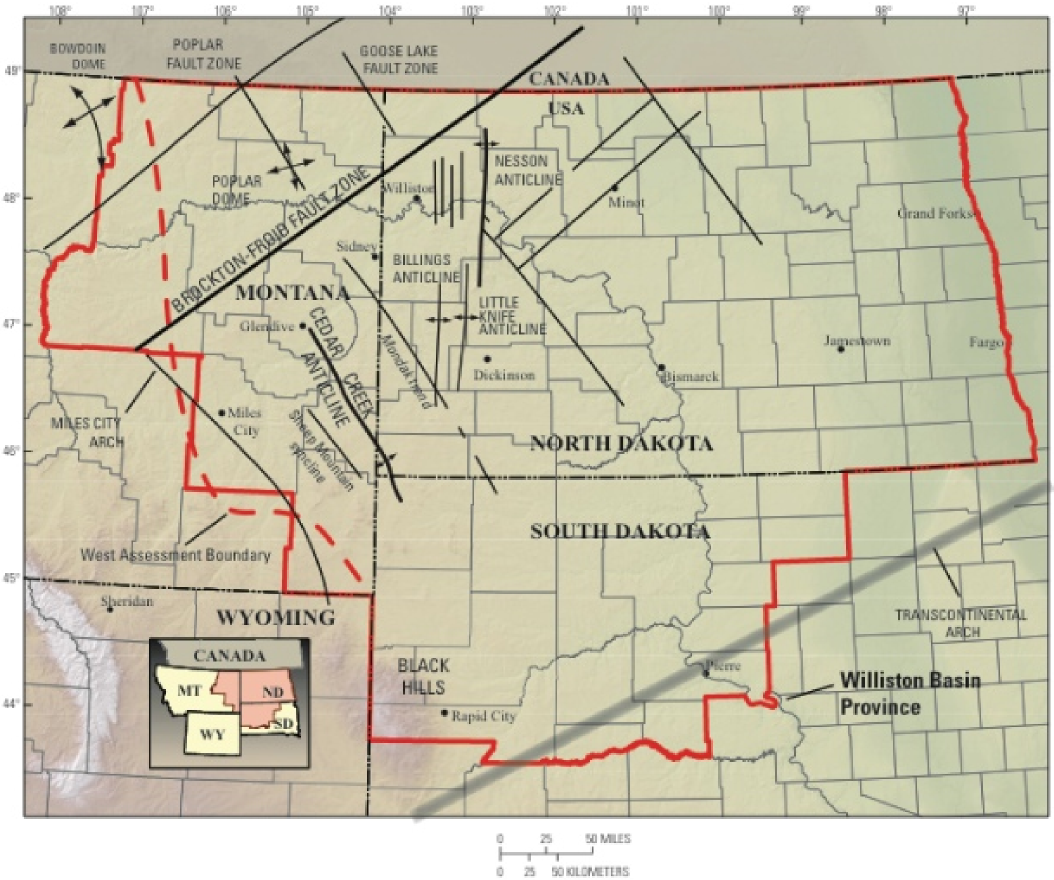


Figure 1. Location and physiographic features of the Williston Basin Province. Black lines not labeled are major lineaments or faults. Solid red line is province boundary; dashed red line represents the western boundary for assessment units. Lineaments and structure locations are from Gerhard and others (1982) and Anna (1986).

This report estimates undiscovered resources for the main assessments units, being structural features (nose, dome) under the item of continuous oil & gas resources.

Figure 16: USGS 2011 DGS 69-W: undiscovered resources in Mb & Gcf

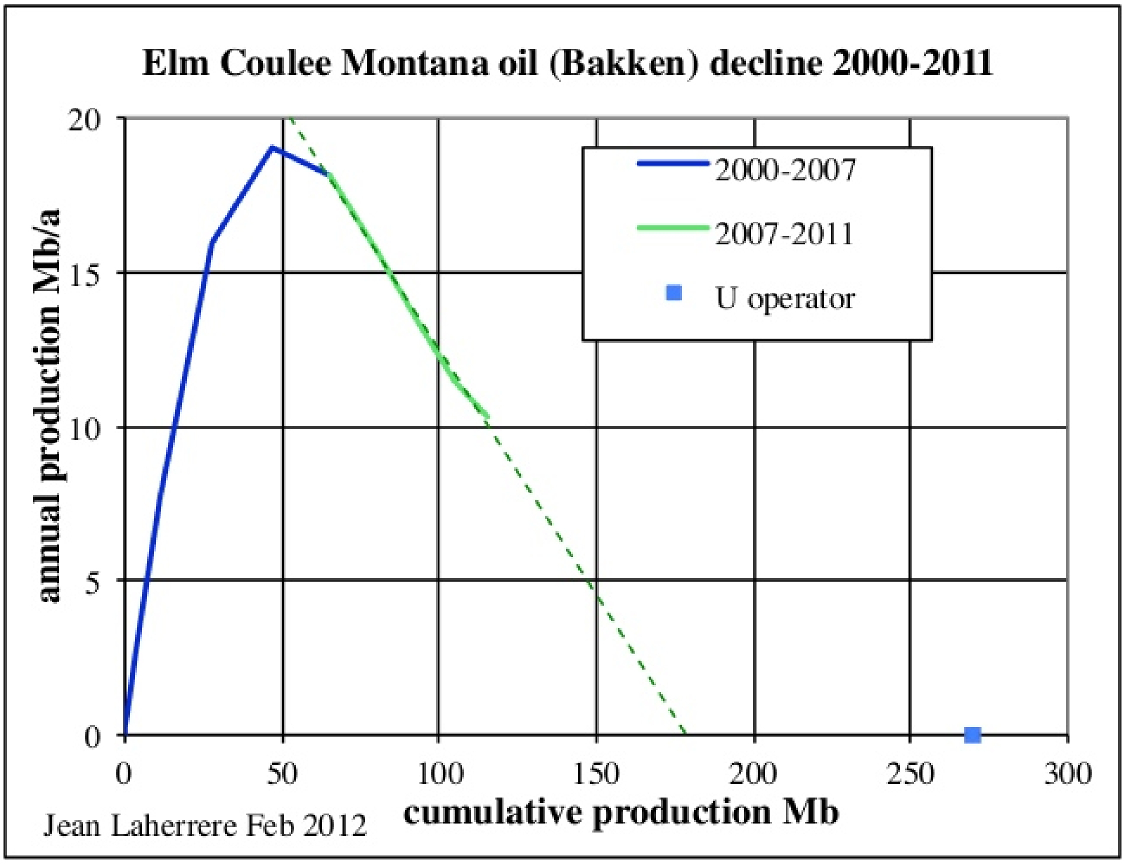
Table 1. Williston Basin Province assessment results.

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included as NGL (natural gas liquids). F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. TPS, total petroleum system; AU, assessment unit. Gray shading indicates not applicable]

	Total Petroleum System and Assessment Unit	Field Type	Total Undiscovered Resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Continuous Oil and Gas Resources	**Bakken–Lodgepole TPS**													
	Elm Coulee–Billings Nose AU	Oil	374	410	450	410	118	198	332	208	8	16	29	17
	Central Basin–Poplar Dome AU	Oil	394	482	589	485	134	233	403	246	10	18	35	20
	Nesson–Little Knife Structural AU	Oil	818	908	1,007	909	260	438	738	461	19	34	64	37
	Eastern Expulsion Threshold AU	Oil	864	971	1,091	973	278	469	791	493	20	37	68	39
	Northwest Expulsion Threshold AU	Oil	613	851	1,182	868	224	411	754	440	16	32	64	35
	Coalbed Gas TPS													
	Fort Union Coalbed Gas AU	Gas					368	791	1,701	882	0	0	0	0
	Total Continuous Resources					3,645				2,730				148

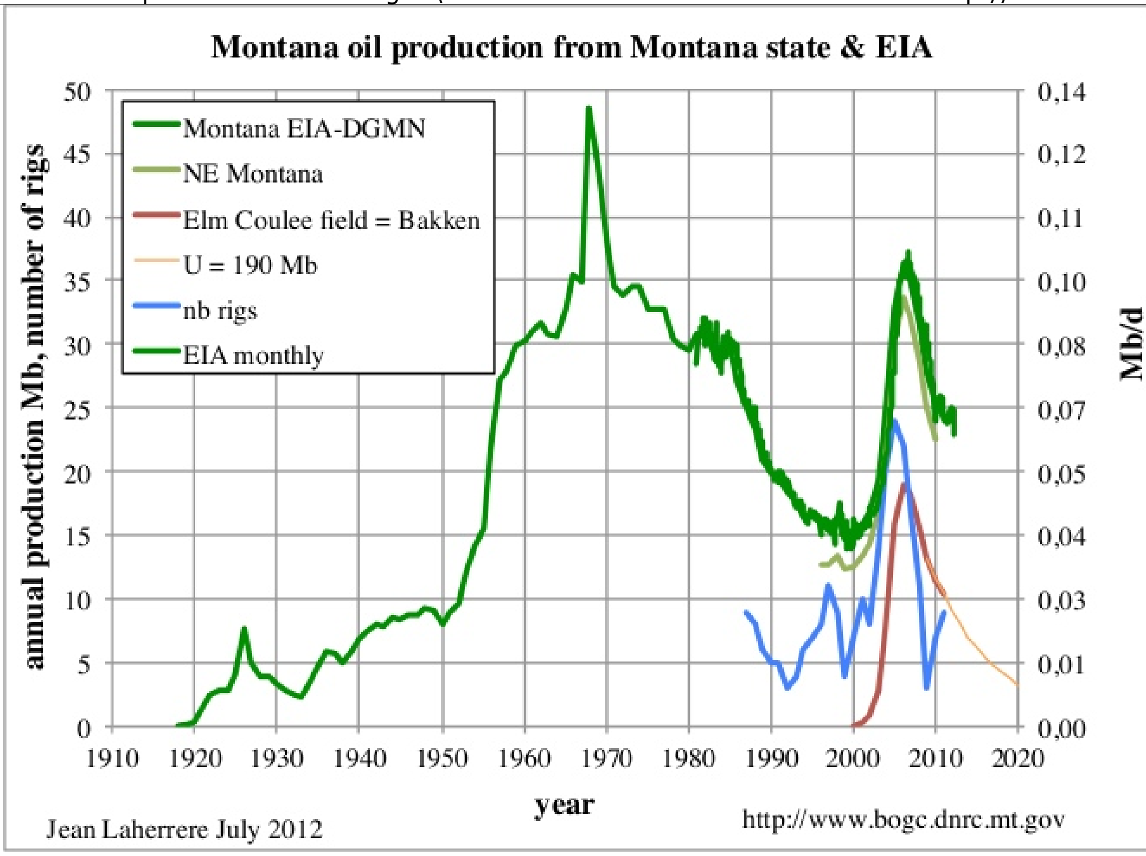
It is surprising to see that the undiscovered mean for the Elm Coulee - Billings nose is assessed at 410 Mb, while in the USGS 2012-1118 report the estimated ultimate recovery (EUR) is reported by at 135 Mb. It seems that this ultimate is not for the area but for the present discovered fields (in fact Elm Coulee). But the plot of the oil decline for Elm Coulee (in Montana) shows a 12 %/a decline from 2007 to 2011, pointing towards 190 Mb (and not 135 Mb) whereas the operator reports 270 Mb.

Figure 17: Elm Coulee (Montana & Bakken) oil decline 2000-2011



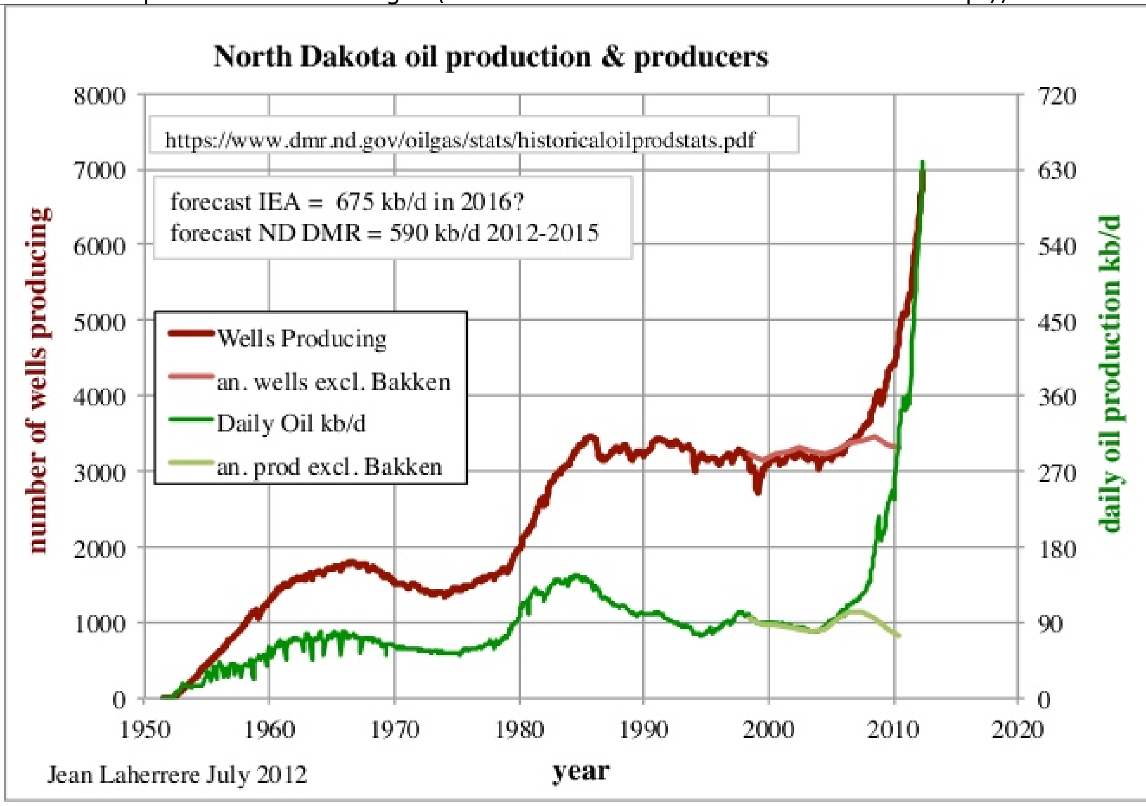
Oil production in Montana displays an interesting sharp peak in 1968 at 130 000 b/d and a second peak, also sharp, in 2006 at 100 000 b/d.

Figure 18: Montana oil production from Montana State & EIA



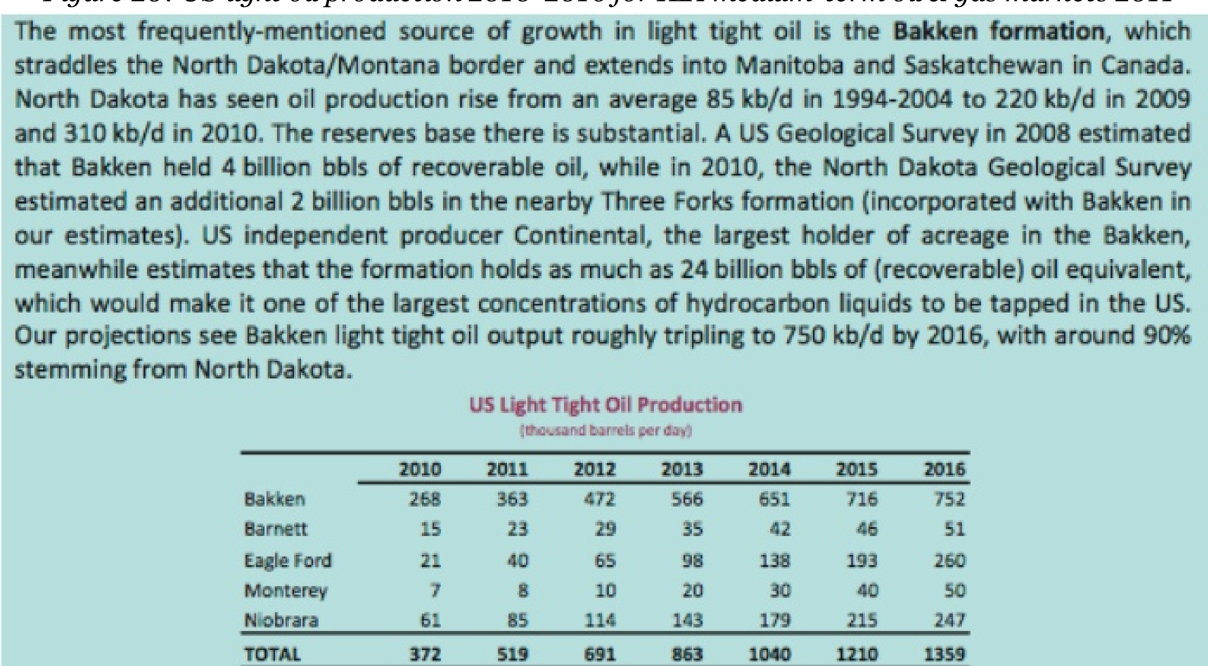
It is likely that North Dakota will follow the same pattern as Montana, with a sharp increase and a sharp decline. But it is hard to guess the level of the peak, which depends upon the number of wells drilled: it could be this year or the next, though I doubt that they can keep adding producer wells at such rate, doubling the number since 2005. Contrary to what is said, it is not a continuous-type accumulation, but the sweet spots of fields. The best way to see that is to to look at the EIA video on Bakken drilling activity from 1985 to 2010.

Figure 19: North Dakota oil production & producers



In "[Medium-term oil & gas markets 2011]" the IEA forecasts oil production in Bakken (called light tight oil) at 472 kb/d in 2012 (when it is already at 575 kb/d just for North Dakota alone in May 2012) and at 752 kb/d in 2016.

Figure 20: US light oil production 2010-2016 for IEA medium-term oil & gas markets 2011

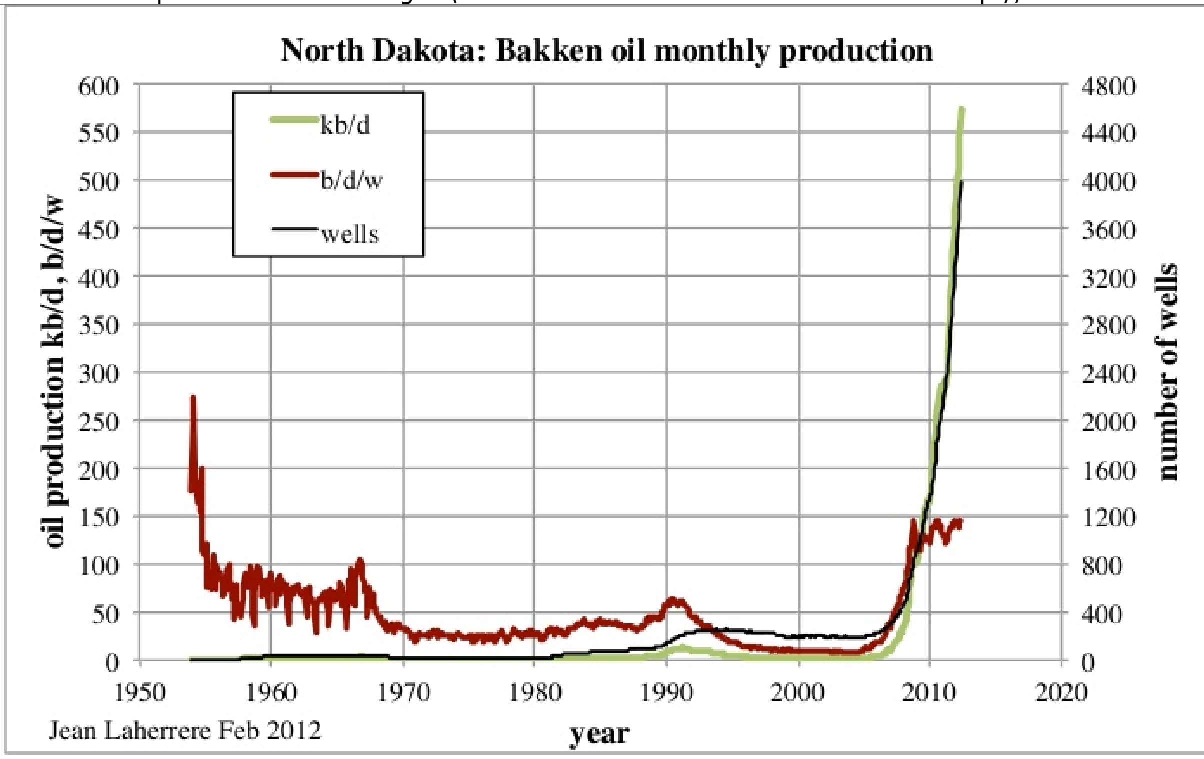

The most frequently-mentioned source of growth in light tight oil is the **Bakken formation**, which straddles the North Dakota/Montana border and extends into Manitoba and Saskatchewan in Canada. North Dakota has seen oil production rise from an average 85 kb/d in 1994-2004 to 220 kb/d in 2009 and 310 kb/d in 2010. The reserves base there is substantial. A US Geological Survey in 2008 estimated that Bakken held 4 billion bbls of recoverable oil, while in 2010, the North Dakota Geological Survey estimated an additional 2 billion bbls in the nearby Three Forks formation (incorporated with Bakken in our estimates). US independent producer Continental, the largest holder of acreage in the Bakken, meanwhile estimates that the formation holds as much as 24 billion bbls of (recoverable) oil equivalent, which would make it one of the largest concentrations of hydrocarbon liquids to be tapped in the US. Our projections see Bakken light tight oil output roughly tripling to 750 kb/d by 2016, with around 90% stemming from North Dakota.

US Light Tight Oil Production
(thousand barrels per day)

	2010	2011	2012	2013	2014	2015	2016
Bakken	268	363	472	566	651	716	752
Barnett	15	23	29	35	42	46	51
Eagle Ford	21	40	65	98	138	193	260
Monterey	7	8	10	20	30	40	50
Niobrara	61	85	114	143	179	215	247
TOTAL	**372**	**519**	**691**	**863**	**1040**	**1210**	**1359**

Present oil production in Bakken is increasing so sharply that it couldn't be forecast properly and is likely unsustainable. The production per well stays around 140 b/d/w; but it will fall as soon as the drilling slows down. The number of wells in Bakken went from 200 in 2005 to 4000 today.

Figure 21: North Dakota: Bakken oil monthly production & number of wells



The North Dakota Department of Mineral Resources (ND DMR) described in 2008 the Bakken with a recovery of 1.4% of oil in place (149 Gb). In a reported entitled “State of North Dakota Bakken Formation Resource Study Project”, authors M. Bohrer, S. Fried, L. Helms, B. Hicks, B. Juenker, D. McCusker F. Anderson, J. LeFever, E. Murphy and S. Nordeng write:

> The original oil in place in the Bakken Formation within the thermally mature portion of the State of North Dakota is estimated to be 149.2 billion barrels. The estimates are presented by County and separated into the total Bakken Formation, upper Bakken shale member, middle Bakken member, and lower Bakken shale member to make them more useful for resource evaluation and planning (Tables 1-4) and (Figures 3-6).
> The Bakken Formation EUR using current drilling and completion practices within the thermally mature portion of the state of North Dakota has also been estimated. **The estimated ultimate recovery is approximately 1.4% of original oil in place, which is equal to 2.1 billion barrels**.

The structural features are shown for the Bakken/Three Forks production. The Three Forks formation is just a reservoir below the Bakken lower shale. It is the Bakken middle formation that produces, because it is not shale but a sandy limestone.

Figure 22: Williston Basin Bakken features from ND DMR 2008

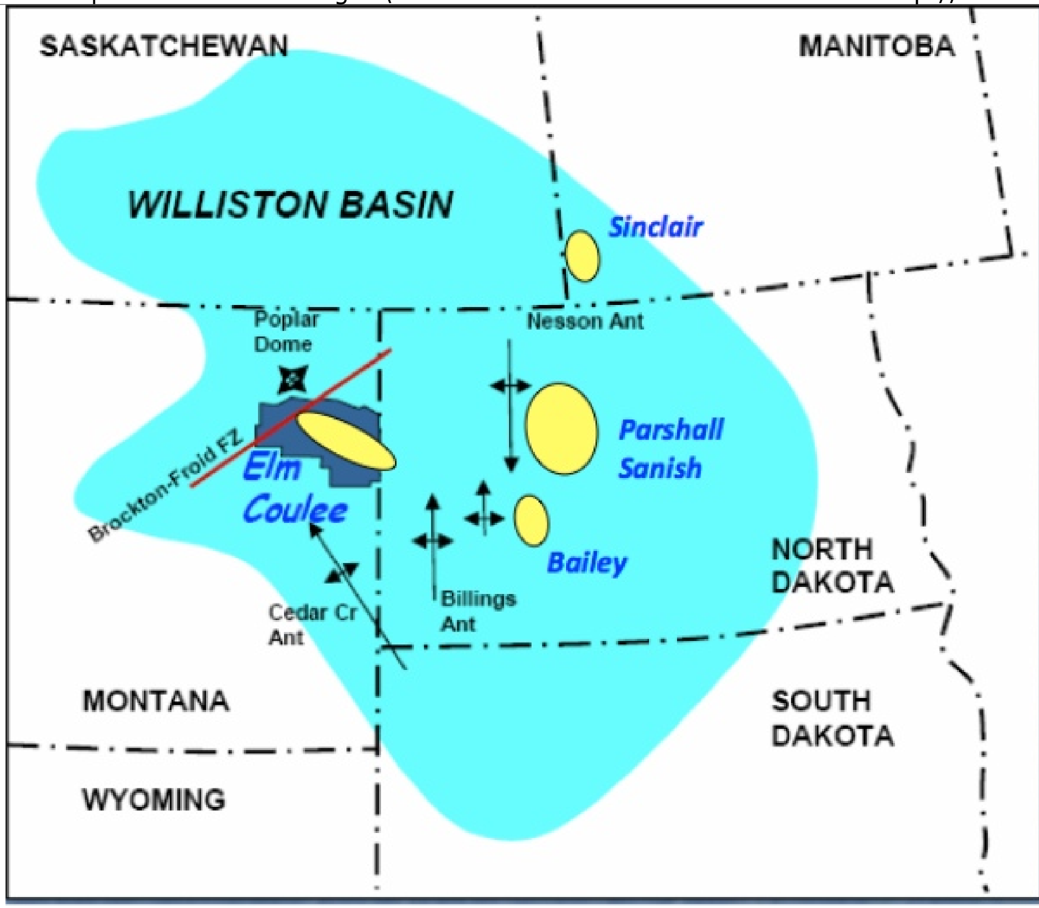


Figure 3 – Williston Basin with major structural features and modern Bakken / Three Forks production areas.

This report presents the oil in place in the Bakken formation disaggregated by county, summing up to 149 Gb with 2.1 Gb recoverable.

Figure 23: North Dakota Bakken oil in place & reserves from ND DMR 2008

Table 1
Bakken Formation Oil In Place and Recoverable Reserves (barrels)
April 7, 2008

	Mean Values				
County	OOIP per County	OOIP per 640	EUR per County	EUR per 640	Rec Factor
McKenzie	32,438,937,580	11,698,740	382,654,320	138,000	1.18
Mountrail	27,242,795,837	14,043,773	424,826,873	219,000	1.56
Williams	26,263,485,095	12,235,090	474,392,108	221,000	1.81
Dunn	18,059,716,691	9,392,995	294,169,921	153,000	1.63
Divide	16,836,857,774	13,380,393	123,315,660	98,000	0.73
Burke	14,891,719,317	16,715,777	187,975,278	211,000	1.26
Ward	4,540,670,907	7,903,591			
McLean	3,253,719,118	10,742,320			
Billings	3,141,271,156	4,636,325	115,858,434	171,000	3.69
Stark	2,349,351,546	2,856,068	86,371,150	105,000	3.68
Golden Valley	66,147,411	1,209,544			
Grant	62,508,094	509,248			
Slope	10,586,089	238,919			
Total	149,157,766,614		2,089,563,745		

In a subsequent report, “Three Forks Assessment”, published in 2012, the DMR shows that the geographic distribution of the Three Forks oil is very unequal, with few sweet spots.

Figure 24: North Dakota Three Forks oil in place in acre-foot oil from ND DMR 2010

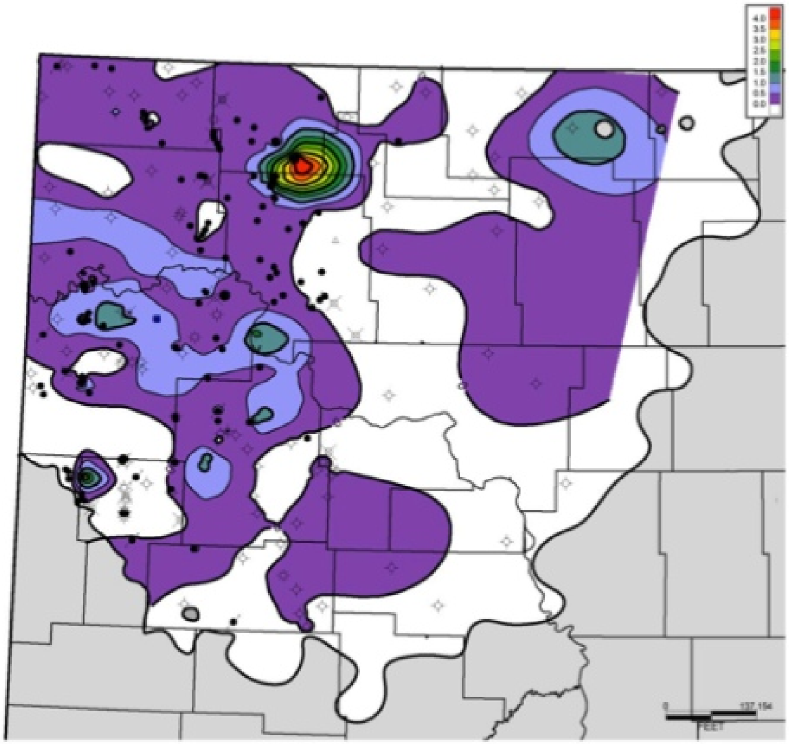


Figure 4) Total original oil in place (OOIP) for the Three Formation contoured as acre-feet oil. Only those intervals containing at least 50% oil-filled porosity contribute to the net pay that is contoured as acre-feet oil. The well locations illustrated correspond to the wells used in this study.

The total EUR is 2.1 Gb for Bakken and 1.9 Gb for the Three Forks, with a total of 3.9 Gb.

Figure 25: North Dakota oil in place & EUR for Bakken & Three forks from DMR 2010

Most Likely						
	Bakken		Three Forks		Total	
County	OOIP per County	EUR per County	OOIP per County	EUR per County	OOIP per County	EUR per County
Billings	3,141,271,156	115,858,434	1,717,909,400	154,611,846	4,859,180,556	270,470,280
Bottineau			1,642,257,140	147,803,143	1,642,257,140	147,803,143
Burke	14,891,719,317	187,975,278	2,084,609,970	187,614,897	16,976,329,287	375,590,175
Divide	16,836,857,774	123,315,660	855,513,980	76,996,258	17,692,371,754	200,311,919
Dunn	18,059,716,691	294,169,921	2,008,459,540	180,761,359	20,068,176,231	474,931,279
Golden Valley	66,147,411		25,519,700	2,296,773	91,667,111	2,296,773
Grant	62,508,094				62,508,094	
McHenry			539,104,280	48,519,385	539,104,280	48,519,385
McKenzie	32,438,937,580	382,654,320	3,941,684,770	354,751,629	36,380,622,350	737,405,950
McLean	3,253,719,118		351,841,190	31,665,707	3,605,560,308	31,665,707
Mercer			118,427,220	10,658,450	118,427,220	10,658,450
Morton			84,144,950	84,144,950	84,144,950	84,144,950
Mountrail	27,242,795,837	424,826,873	1,676,048,980	150,844,408	28,918,844,817	575,671,281
Oliver			9,002,880	810,259	9,002,880	810,259
Renville			183,377,880	16,504,009	183,377,880	16,504,009
Slope	10,586,089				10,586,089	
Stark	2,349,351,546	86,371,150	1,604,239,450	144,381,551	3,953,590,996	230,752,701
Ward	4,540,670,907		446,420,030	40,177,803	4,987,090,937	40,177,803
Williams	26,263,485,095	474,392,108	2,666,823,630	240,014,127	28,930,308,725	714,406,235
Total	**149,157,766,614**	**2,089,563,745**	**19,955,384,990**	**1,872,556,554**	**169,113,151,604**	**3,962,120,299**

Maugeri is quoting unrealistic and obsolete reserve assessments for Bakken, by reporting 500 Gb of oil in place with a recovery factor of 50% (or 250 Gb of reserves). He neglects more recent studies, in particular by the agency knowing the most, the North Dakota Department of Mineral Resources.

In the second part of this article Jean tackles Maugeri's reserve growth predictions, looking into several giant oil fields and some of the largest oil exporting countries.

Acknowlegdement

Thanks to Roger Bentley for review the article and helping with the Summary.