The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The Hubbert Linearization Applied on Ghawar

Posted by Sam Foucher on October 10, 2007 - 10:00am
Topic: Supply/Production
Tags: exports, ghawar, m. king hubbert, original, saudi arabia [list all tags]

The following analysis is based on a chart from Frederik Robelius (see Figure 2 below) from which I retrieved the production profile for Ghawar from 1950 to 2003 (xls file). Using the Hubbert Linearization method to fit a logistic curve, we get a size estimate for Ghawar close to what other TOD contributors (Stuart and Euan) derived using advanced analysis. A possible decline of Ghawar is happening in a context of record oil rig counts, record domestic consumption and record oil prices.

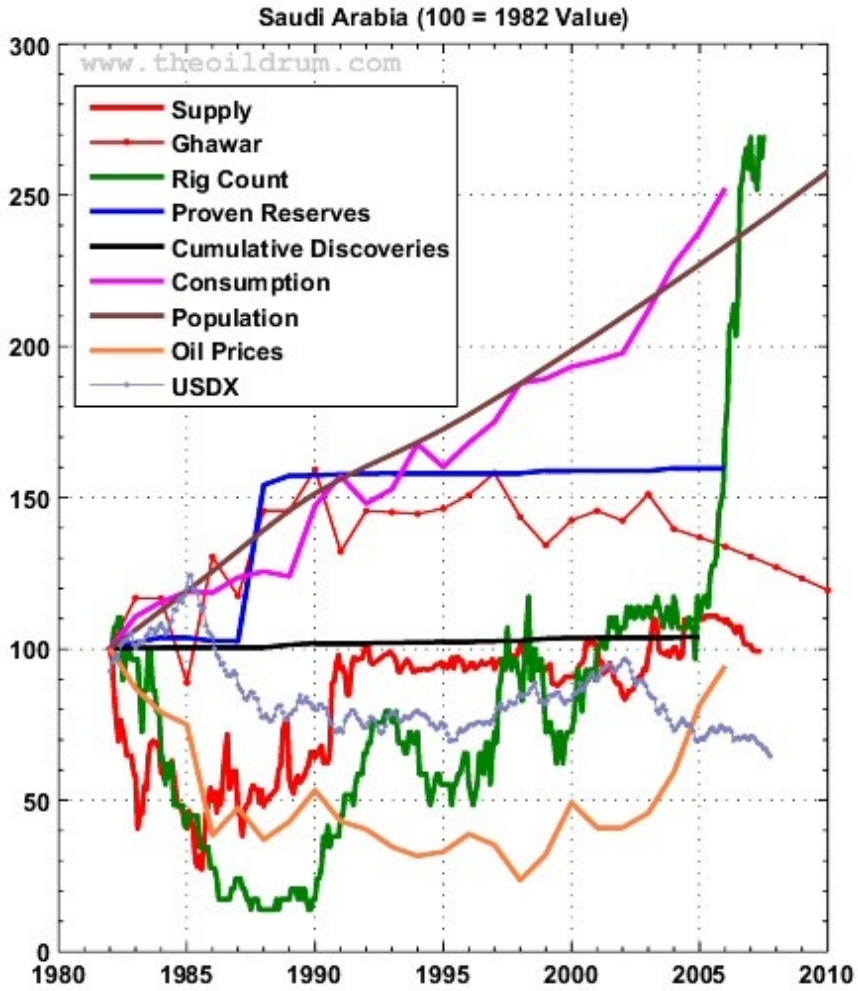


Fig. 1 Sources: oil supply from the EIA (crude oil + condensate); proven reserves, oil prices and domestic consumption from BP statistical review (2007); population from the UN; oil discoveries from IHS; the major currencies index from the Federal Reserve; Ghawar decline based on a logistic fit. Click To Enlarge.

Executive Summary:

- The fitting of a logistic curve (Hubbert Linearization) on Ghawar production produces an URR around 100.59 ± 8.59 Gb with a possible decline rate around 2.6%/year (asymptotic decline at 7.41%/year).
- The fitting of a logistic curve on non Ghawar production (crude oil + condensate) produces an URR around 60.13 ± 12.78 Gb.
- The Hubbert Linearization on total crude oil + condensate production gives an URR at 200 ± 24 Gb which is 20-40 Gb higher than the sum of the two above components.
- If Ghawar is in terminal decline, supply growth from other fields has to be at least 2% a year in order to maintain a flat production and 4% a year in order to maintain flat exports.

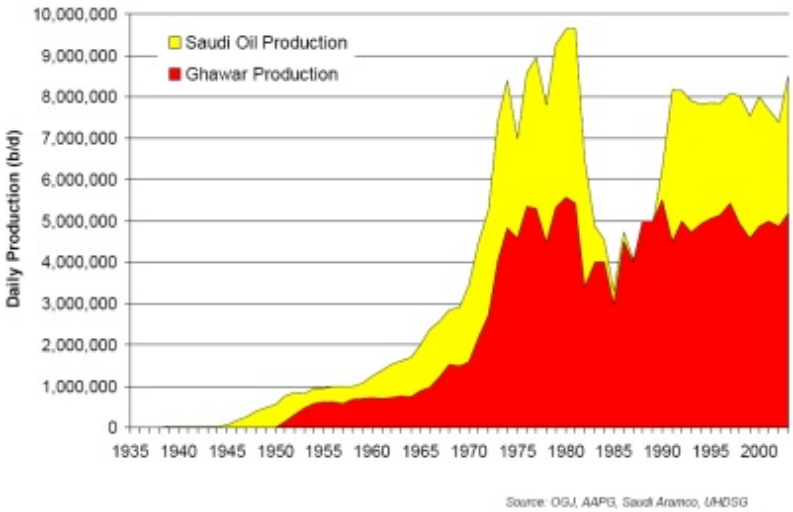


Fig. 2 Saudi Arabia and Ghawar production from a presentation given by Frederik Robelius (pdf here). Click To Enlarge.

Hubbert Linearization Applied on Ghawar Only

The Hubbert Linearization technique is applied on the curve profile above and we get the following result:

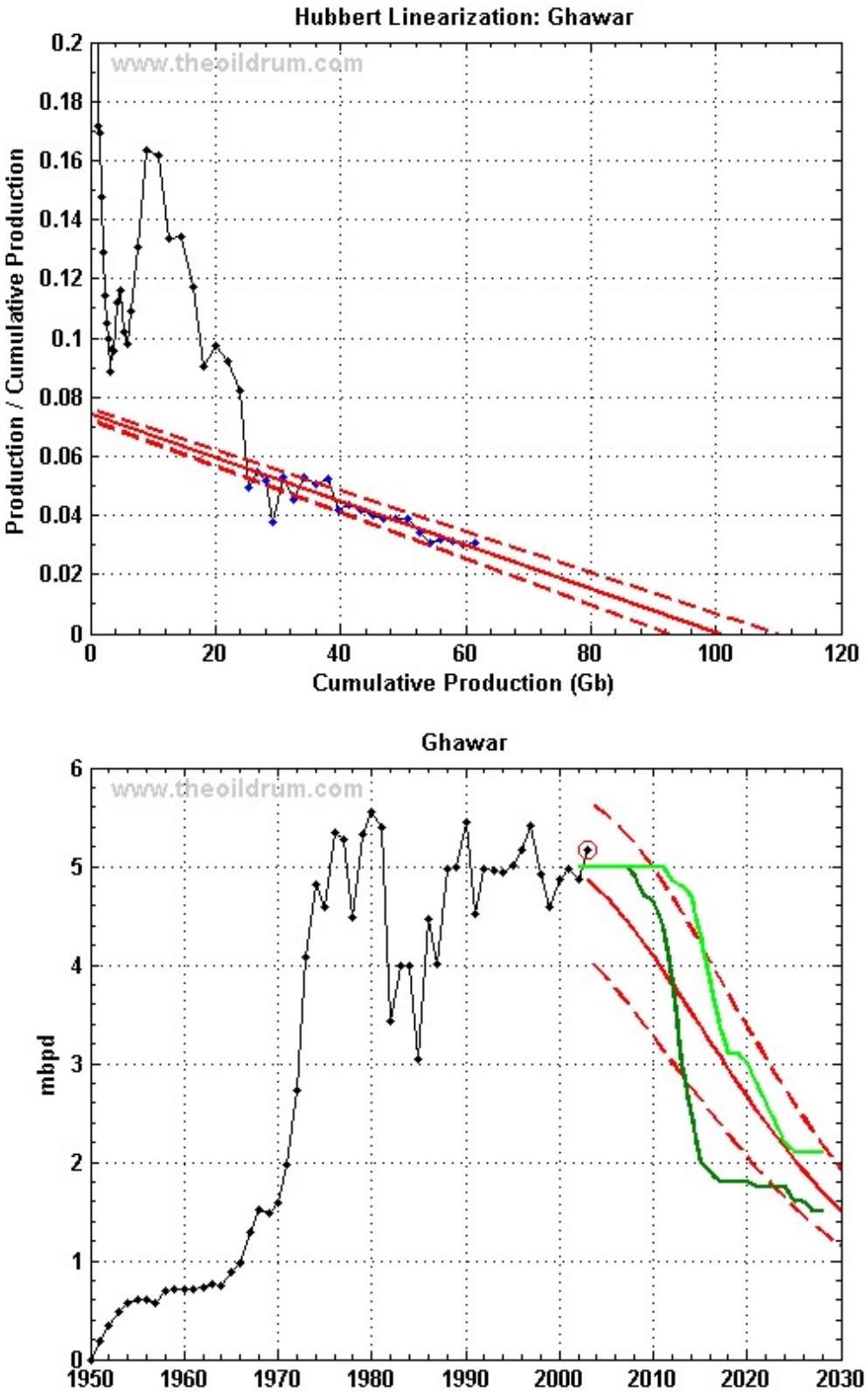


Fig. 3 Left or top Chart: Hubbert Linearization of Ghawar with the 95% confidence interval (red dashed lines). Only blue points are used in the fit.
Right or bottom chart: resulting logistic curve with the 95% confidence interval (red dashed lines). The green lines are Euan Mearns's base and high forecast for Ghawar (details here). The red circle indicates the year 2003.

Parameters of the logistic curve are given in Table I. We can see that the resulting URR as well as

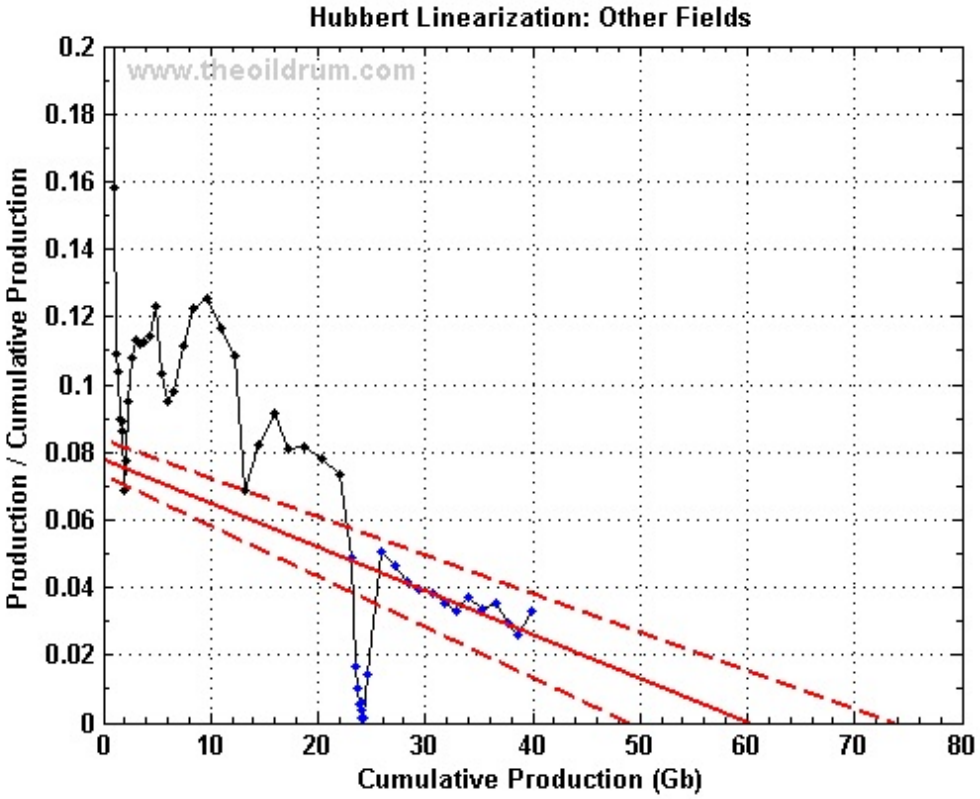
the future decline are close to Euan Mearns and Stuart Staniford estimates. Note also that the logistic growth rate (K) is relatively high suggesting that current yearly decline rate for Ghawar is 2.62 ± 1.30 %/year and could reach 3.65 ± 0.56% in 2010.

URR	Q(2003)	K(%)	t_{half}
100.59 ± 8.59 Gb	61.49 Gb	7.41 ± 3.65	1997.00 ± 3.25

Table I. Logistic curve parameters for Ghawar.

What About the Rest of Saudi Arabia Oilfields?

Using EIA's numbers for Saudi Arabia (crude oil + condensate) minus the above logistic model for Ghawar we can estimate the oil production from other fields. The resulting production profile is much more tortuous with a big drop in production from 1982 to 1990. The resulting fit gives an URR around 60 Gb and has a wider confidence interval (almost 25 Gb). We can see a big rise in production in 2003 which probably has continued in 2004-2006



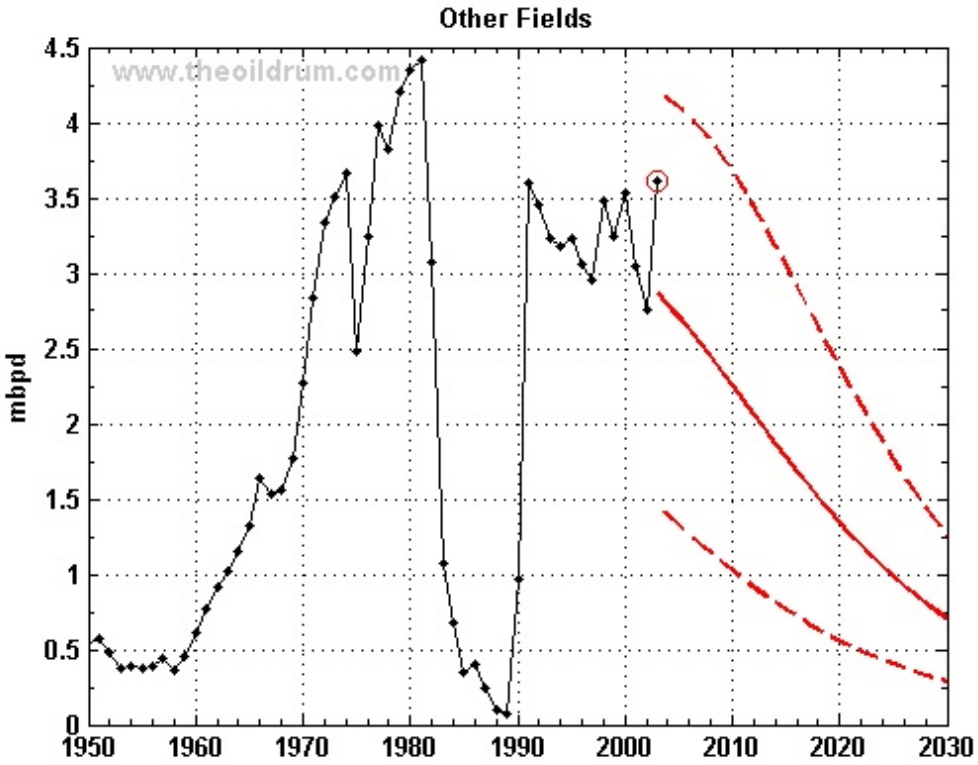


Fig. 4 Left or top Chart: Hubbert Linearization of Saudi Arabia crude oil + condensate (EIA) minus Ghawar production with the 95% confidence interval (red dashed lines). Only blue points are used in the fit. Right or bottom chart: resulting logistic curve with the 95% confidence interval (red dashed lines). The red circle indicates the year 2003.

URR	Q(2003)	K (%)	t_{half}
60.13 ± 12.78 Gb	39.99 Gb	7.79 ± 3.7	1994.25 ± 9.25

Table II. Logistic curve parameters for the Other Fields.

Hubbert Linearization on Saudi Arabia

Now, let's compare or previous two-stages result with the HL performed on the total C+C production.

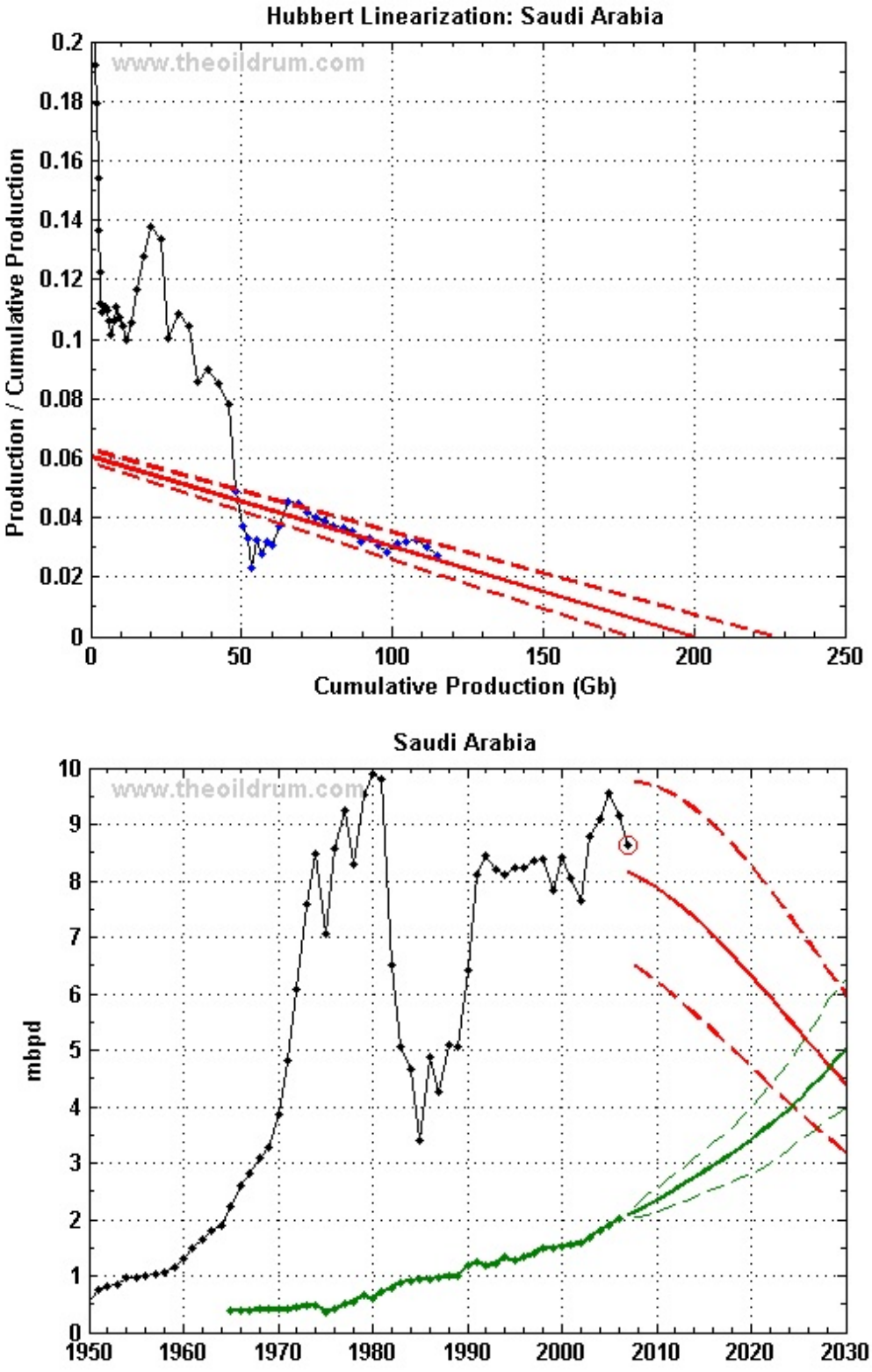


Fig. 5 Left or top Chart: Hubbert Linearization of Saudi Arabia crude oil + condensate (EIA) with the 95% confidence interval (red dashed lines). Only blue points are used in the fit. Right or bottom chart: resulting logistic curve with the 95% confidence interval (red dashed lines). In green, the domestic consumption (all liquids). The red circle indicates the year 2007.

URR	Q(2007)	K(%)	t_{half}

200.21 ± 24.12 Gb	114.78 Gb	6.06 ± 2.90	2002.25 ± 4.9

Table III. Logistic curve parameters for Saudi Arabia.

Summary

The URR resulting from the Hubbert Linearization applied on Ghawar is consistent with previous estimates.

	URR (Gb)	Produced (Gb)	Reserves (Gb)
Stuart Staniford (2007)	90-102	42-62	28-60
Euan Mearns (2007)	96.8 - 115	69.8-79.2	27.0-35.5
Logistic	100.6 ± 8.6	61.5*	39 ± 9

*Table IV. URR estimates for Ghawar. *2003.*

Different forecasts are summarized in Fig. 6 and Table V below. The two stages forecast is close to Ace forecast whereas the HL-SA forecast is closed to Euan.

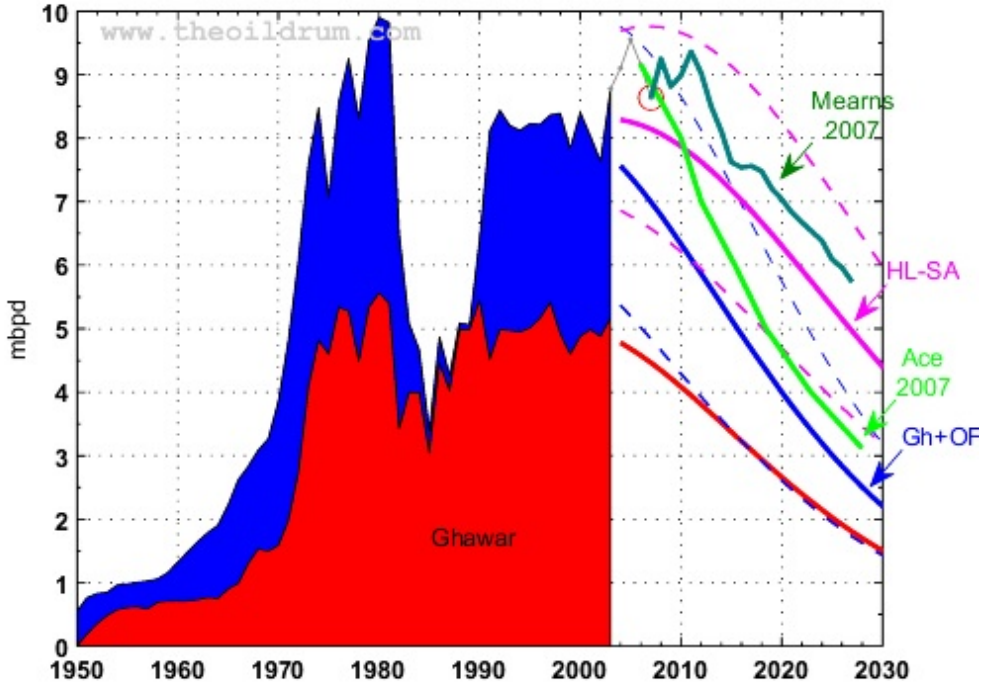


Fig. 6 The red circle indicates 2007 estimate. Click To Enlarge.

	2003	2007	2008	2010	2012
Ghawar Only	5.17	4.46 *[3.64 - 5.34]*	4.34 *[3.51 - 5.18]*	4.08 [3.26 - 4.92]	3.80 [3.01 - 4.63]
Other Fields	3.61	2.53 *[1.20 - 3.97]*	2.44 *[1.06 - 3.89]*	2.25 [0.95 - 3.68]	2.06 [0.84 - 3.45]
Total (Gh+OF)	8.78	7.99 *[4.84 - 9.31]*	6.78 *[4.57 - 9.07]*	6.33 [4.21 - 8.66]	5.86 [3.85 - 8.08]

HL on Saudi Arabia (HL-SA)	8.78	8.63	8.06 *[6.40 - 9.70]*	7.87 [6.15 - 9.61]	7.63 [5.87 - 9.44]

Table V. Production forecasts in mbpd. Bracketed values in italic are 95% confidence intervals Total is the sum of Ghawar and the Other Fields.

Below is a brief summary of available URR estimates for Saudi Arabia initially compiled by Euan here.

	URR Gb	Remaining Gb	Recovery %[2]	Notes
Parabolic Fractal Law[1]	200	85	29	C+C only
Ace	175	63	25	C+C only
Pre-nationalisation	211	91	30	minimum
Mearns	240	120	34	minimum, C+NGL
Mearns	200	86	29	minimum, C+C
Logistic	200 ± 24	85 ± 24	25-32	C+C only
Ghawar+Other Fields	161 ± 21	46 ± 21	20-26	C+C only
Campbell	275	155	39	C+C only
Saudi official	384	264	55	BP+produced

Table VI. Summary of available URR estimates for Saudi Arabia. [1]assuming a total of 400 fields discovered. [2]Note from Euan: The recovery factors are based on an ussumed 700 Gbs of original oil in place. This is the figure reported by Baqi and Saleri and by Colin Campbell.

Assuming that Ghawar will follow a terminal logistic decline as shown on Fig. 3, new supply growth from Yet-to-be-find or Yet-to-be-developed oilfields is unprecedented:

1. Maintaining production flat at the 2004 level and compensating for Ghawar decline will require a new supply growth of 2-3 % per year.
2. Maintaining exports flat at the 2004 level and compensating for Ghawar decline will require a new supply growth of 4-5 % per year.

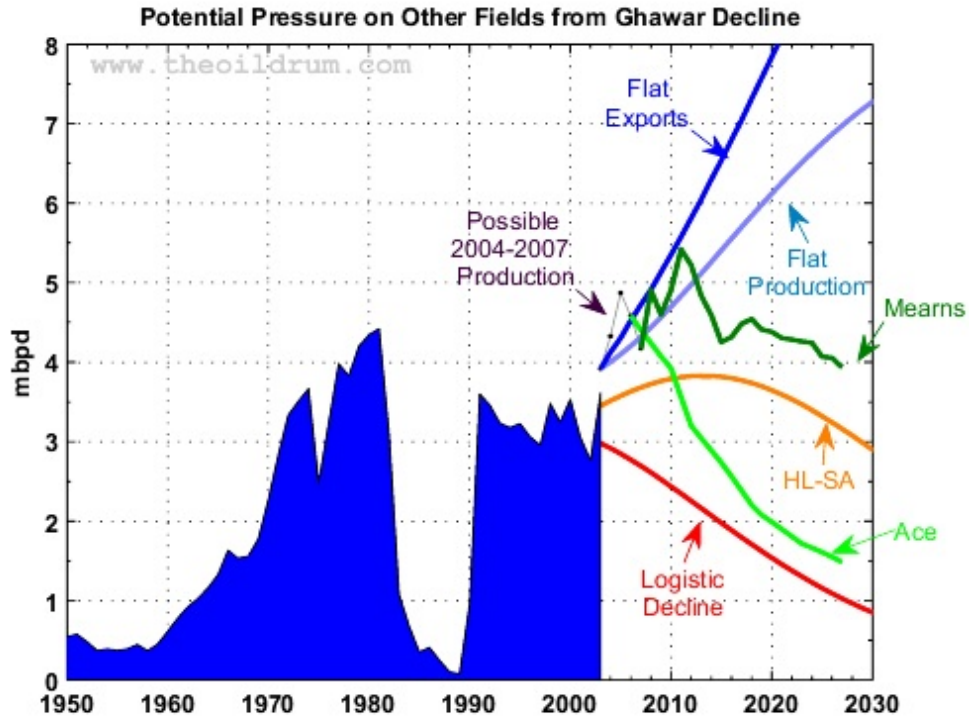


Fig. 7 The red circle indicates 2007 estimate. Click To Enlarge.

is the honeymoon over?

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- Depletion Levels in Ghawar
- The Status of North Ghawar
- Further Saudi Arabia Discussions
- Water in the Gas Tank
- A Nosedive Toward the Desert
- Saudi Arabian oil declines 8% in 2006

by Euan Mearns

- Saudi Arabia - production forecasts and reserves estimates
- Ghawar reserves update and revisions (1)
- GHAWAR: an estimate of remaining oil reserves and production decline (Part 2 - results)
- GHAWAR: an estimate of remaining oil reserves and production decline (Part 1 - background and methodology)
- Saudi production laid bare
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- Simple mathematics - The Saudi reserves, GOSPs and water injection
- Of Oil Supply trains and a thought on Ain Dar

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- Saudi Arabia's Reserve "Depletion Rates" provide Strong Evidence to Support Total Reserves of 175 Gb with only 65 Gb Remaining
- Further Evidence of Saudi Arabia's Oil Production Decline

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