‘THE DEVIL IS IN THE DATA’

(actually, she’s in the LACK of data!)

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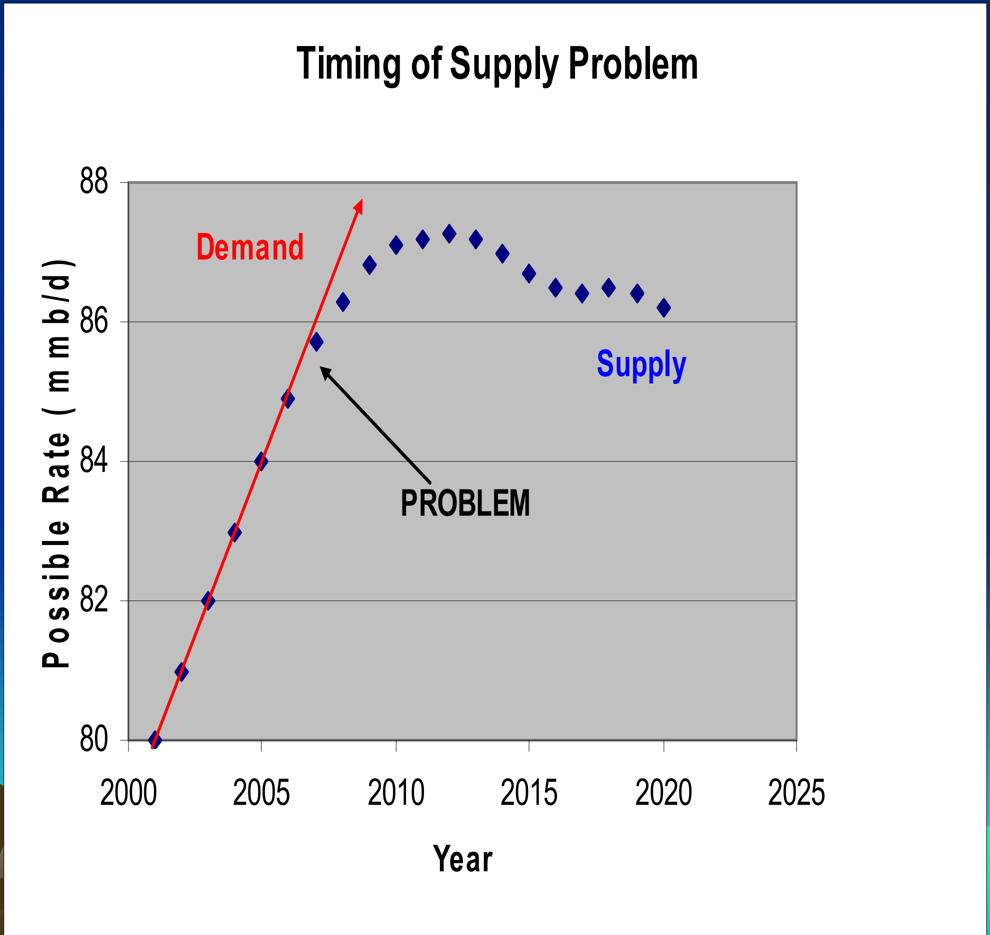
Status of the ‘Peak Oil’ message

- **Concept of a future gap between oil supply and demand is widely accepted**
- **Timing of the supply peak is still uncertain – but if within next 10-15 years it’s now probably too late to make smooth transition to adding alternative energy sources**
- **Further studies should concentrate on shape of supply curve after peak is reached**

Status of the 'Peak Oil' message

Not everyone seems aware that problems for consumers will begin BEFORE we reach a supply peak



Deriving the Supply curve

The shape of the supply v. time curve will be determined by:

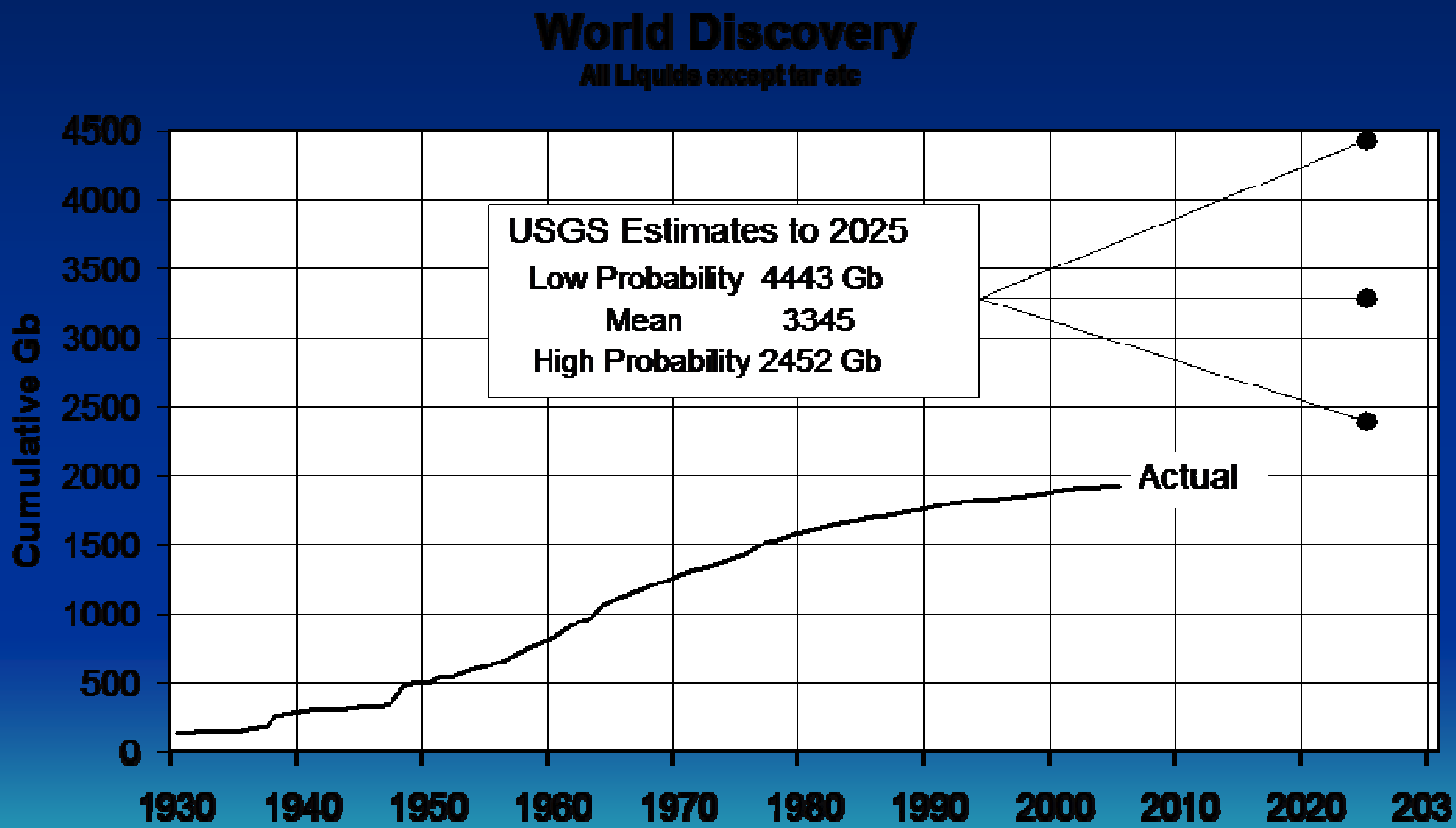
- **The performance of fields now on production as they mature and go into decline**
- **The pace of development of new fields, and their performance**

Supply Forecast Background

Acceptance that production from existing fields is declining at about 5%/year …. but a wide gap in views of how new discoveries and new technology might slow – or even reverse – this decline

Huge disparities in estimates of potential for additional discoveries of conventional oil. Range includes Campbell / ASPO level of 130 b bbls and USGS mean level of 724 b bbls

Supply Forecast Background



Supply Forecast Background

Even if higher end of yet-to-find range proves correct, time needed to discover and develop new fields will be long – remote, deepwater and complex reservoirs with reducing IOC project management input.

Most of any new production will only come after a supply peak.

Supply Forecast Background

Supply levels can only be maintained, and perhaps increased slightly, if 'reserves growth' is achieved very quickly and is very substantial

Potential for 'Reserves Growth'

Is there agreement on how much 'Reserves Growth' we may reasonably expect to achieve?

! NO !

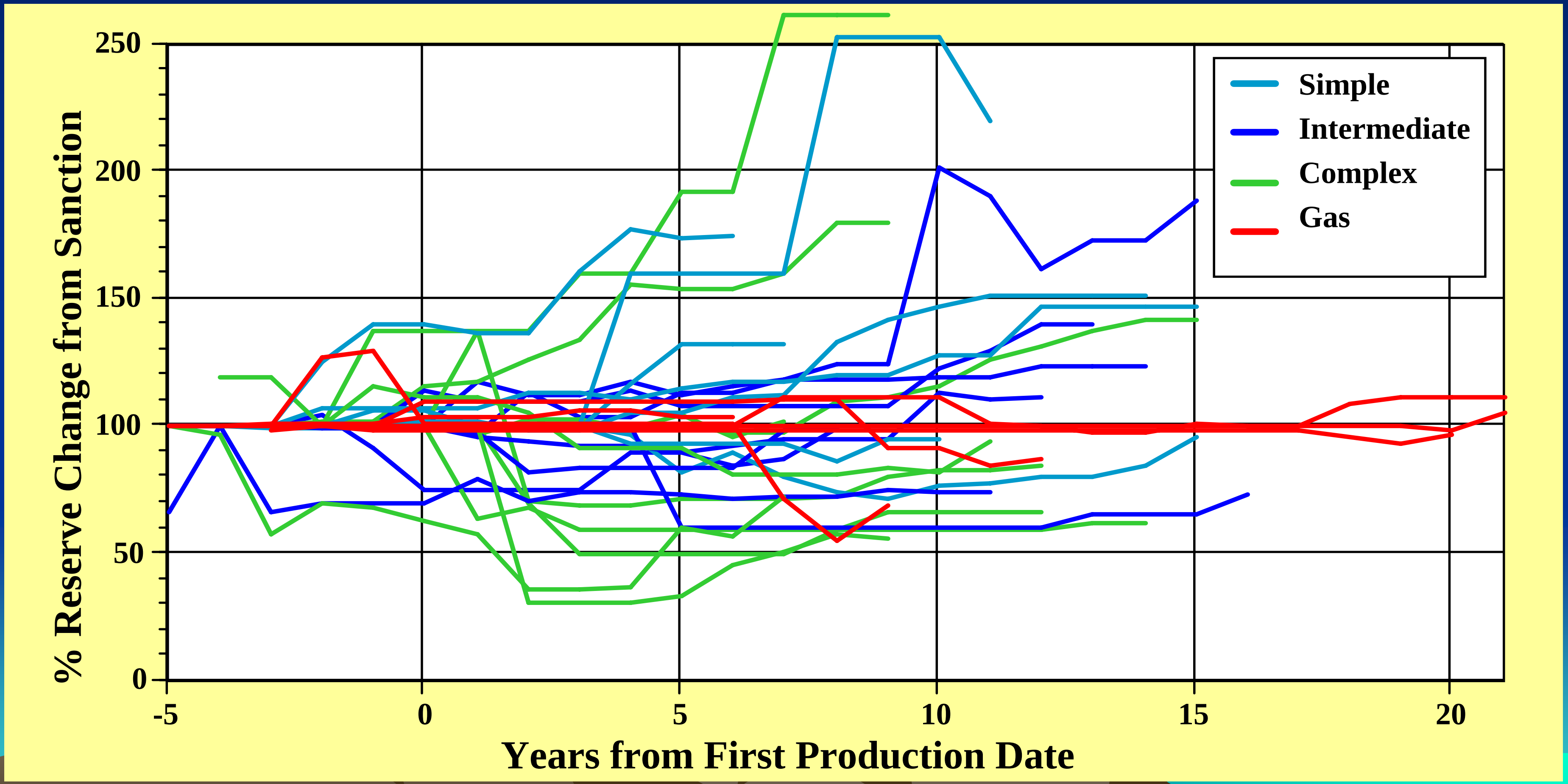
Estimates range from Campbell's zero to the USGS F50 level of 674 b stb

Differences in RG estimates

Let's consider why successive estimates of reserves should grow

– if indeed they really do!!

Reserves DON'T always grow !!



How Reserves are estimated

Let's recall this equation (from last year's conference!):

Reserve = Resource * (Recovery Factor)

'Resource' is the oil-in-place volume.

Recovery Factors vary from 5% to 70%

Procedures for estimating reserves may vary from company to company and from country to country

Why might RESOURCE estimates change?

There is considerable uncertainty in oil-in-place (resource) estimates made after the drilling of only a few wells on a structure

This arises from potential errors in estimates of

- reservoir gross volume
- rock quality (porosity and net-to-gross ratio)
- oil saturation
- fluid properties

Uncertainty in resource size could easily be ± 20%

Why might RESOURCE estimates change?

Revisions to existing reservoir data

… but these are as likely to cause a decrease as an increase!!

Additional reservoir data

In fields where US SEC reserves rules used:

New data will increase reported estimates … but these are <23% of world production!

In all other fields:

New data as likely to cause decrease as increase

Why might REC. FACTOR estimates change?

1. **Higher oil prices, which allow:**

Denser application of existing technology

- **infill drilling**
- **intelligent wells**
- **enhanced well productivity**
- **subsea processing**
- **4-D seismic**

Research / development / application of new technology

BUT

Associated increased operating costs may tend to shorten field life

Why might REC. FACTOR estimates change?

2. Technical Advances

Better 'Housekeeping'

- Cut water production (>25 b bbl/yr. in US alone; >$15 b/yr.)
- Stop gas flaring/venting (5 tcf/yr. worldwide, 25% of US demand!)

Improve current technologies

- Identify/contact unswept reservoir zones
- Optimize gas/water floods
- Optimize miscible gas/CO2 flooding

Develop and apply new techniques

- **Chemical** – for fluid mobility, rock wettability
- **Thermal** – for fluid viscosity
- **Microbial** – to improve on existing chemical applications

CO2 and EOR

Must distinguish carefully, in considering reserves growth, between CO2 injection projects intended to:

(a) dispose of surplus CO2, "sequestration"

(b) result in increased recovery from an oilfield, "EOR"

World CO2 production: 26 <u>billion</u> ton/year

World CO2 injection: 30 <u>million</u> ton/year

CO2 Injection as an EOR process

Objective: To mobilize viscous oil left behind by earlier recovery operations

Main application is in near-depleted fields, where recovery efficiency can be increased by 10-15%

Technique most efficient at limited range of pressures and temperatures

Candidate fields need easy access to CO2 resources

Facilities for removal of CO2 from produced fluids ultimately required

CO2 Sequestration

Hydrocarbon industry is well-placed to take the lead in developing disposal facilities

(i.e. projects without any EOR effect)

- geological database and skills
- well drilling and completion technology
- gas pipelining and compression experience
- saturation tracking technology

Scope for application of Reserves Growth techniques

(a) In existing developments

Field Maturity

Location

	In devpt.	On Plateau	Early decline	Late Decline
Onshore	High	Fair	Low	Very low
Offshore	Fair	Low	Very low	Very low

Scope for application of Reserves Growth techniques

(b) Fields under development

Effects of likely new techniques already included in initial reserve estimates.

Low possibility of significant increase in reserves

(c) Yet-to-Find fields

Majority of new fields likely to be in remote areas / ultra-deep water / of complex geometry.

Effects of new technology included in initial reserves estimates.

Low possibility of significant increases in reserves

Can Recovery Efficiency ever reach 100%?

Of the various possible types of drive in a reservoir, the most efficient is usually waterflooding. For this case:

Recovery Efficiency =

$$DE_{(area)} * DE_{(vertical)} * DE_{(pore)} * \Delta F$$

Although $DE_{(area)}$ and ΔF can be as high as 100%, physics ensures $DE_{(vertical)}$ and $DE_{(pore)}$ will always be <100%

Hence:

Recovery Efficiency will always be < 100%

Can Recovery Efficiency ever reach 100%?

DE (vertical) can never be 100% because water level in the reservoir can never reach right to the top

DE (pore) can never be 100% because

$$\mathbf{DE}_{(pore)} = 1 - \frac{\text{(final oil saturation)}}{\text{(initial oil saturation)}}$$

and final oil saturation is never as low as 0%

A better estimate of potential for Reserves Growth?

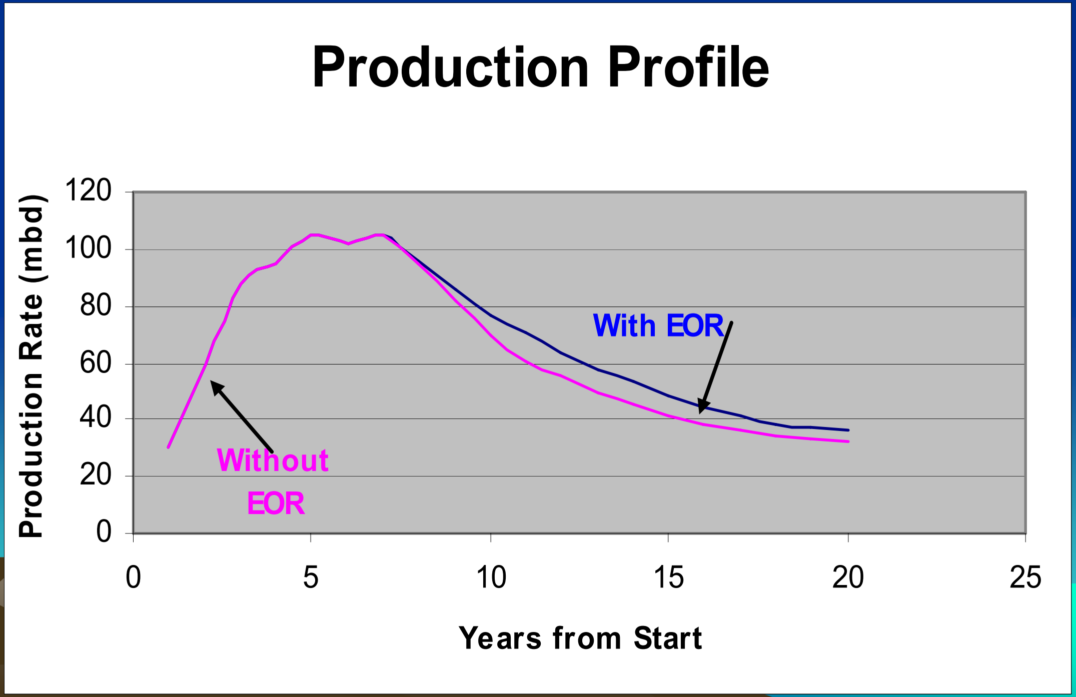
Field Category / Maturity		Original Reserves	Possible increase in Rec. Efficiency *	Possible increase in Reserves
		mmstb	%	mmstb
Not developed / not yet found		200	15	30
Developed	Primary depln.	240	12.5	30
	Secondary depln.	920	10	92
	Tertiary depln.	12	5	6
	Late life	400	5	20
Suspended/ Abandoned		20	10	2
TOTAL		**1900**		**180**

* Increase over estimates using current technology

Incremental Production due to Reserves Growth

Most reserves growth techniques will deliver production late in field life – target is to produce immobile oil not recovered by other techniques

Hence, incremental production will be expected post-plateau, late in field life



Reserves Growth: Impact of New Technology

Rather than adding to early estimates, much new technology goes into overcoming unanticipated problems:

- coping with unanticipated reservoir heterogeneity
- overcoming well damage
- modifying oil or water mobility
- avoiding / dealing with hydrates
- identifying / recovering from unswept areas

The new technology is needed to achieve the recovery factor we initially expected and included in reserves calculations

Reserves Growth: Impact of New Technology

Development / application of new technology will continue to add to recovery efficiency of field developments.

BUT

As physical limits for displacement efficiency are approached, effect on reserves will be much less than suggested by extrapolating from the past

Future Supply – even with Reserves Growth

Assume 180 b bbls is the potential Reserves Growth prize and that it can be 'booked' (NOT produced!) over 20 years; this represents reserve additions of 9 b bbls/year

Current average discovery rate is about 6 b bbls/year
- and declining

Replacing production requires 32 b stb/year to be found

… hence …

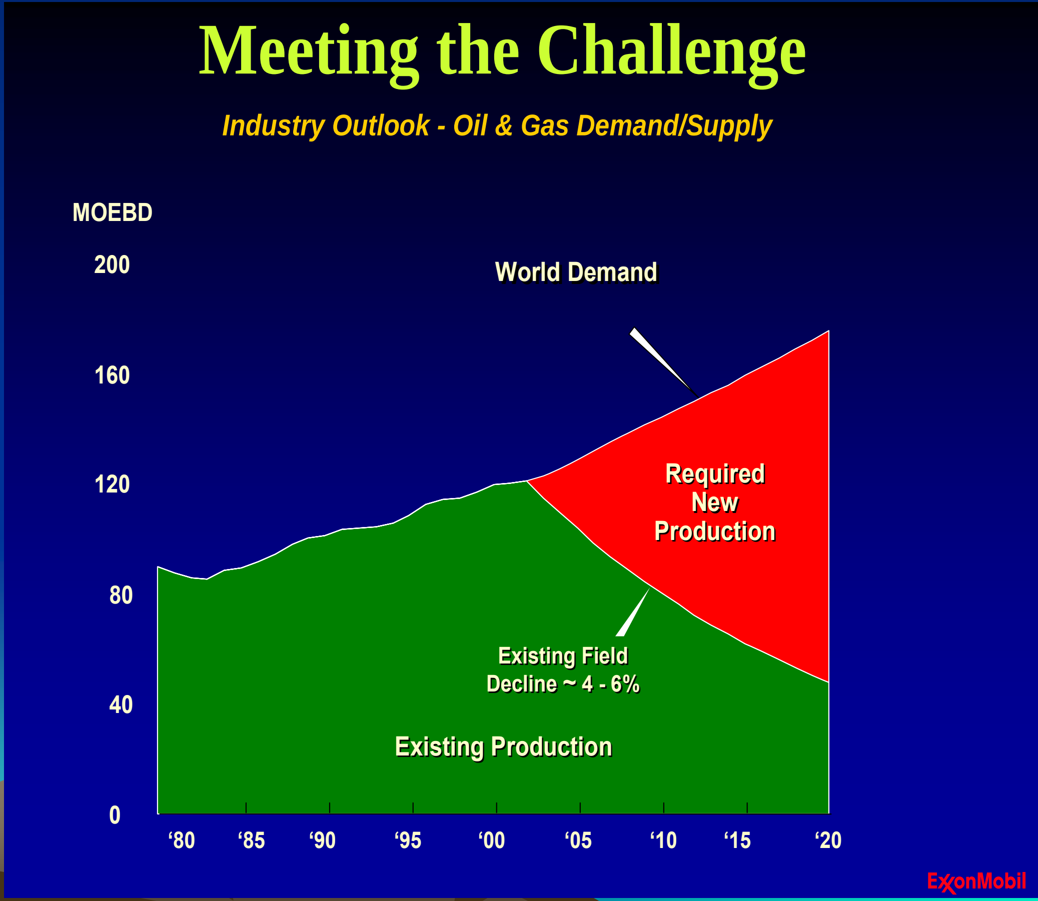
Future Supply – even with Reserves Growth

Realization of 9 b bbls reserves could result in added production of about 2 mmbd

…. but this is much less than the decline in productivity from existing fields

Future Supply – even with Reserves Growth

Even with an aggressive estimate of the impact of reserves growth we face declining post-peak production



Reserves Growth – the take-home message

Of course recovery efficiency is growing - and it will continue to do so

If we were evaluating Prudhoe now we wouldn't estimate reserves to be 9.5 b stb!

Most growth in published reserves estimates only occurs because of initial caution

NOCs and IOCs don't make investment decisions on basis of SEC numbers; the estimates they use include likely efficiency gains

Reserves Growth – the take-home message

The pace of reserves growth seen in the past is NOT a guide to the pace for the future

In 1972, 93% of world production was by IOCs from fields where SEC procedures were followed

Now only about 20% of production is by IOCs. Reserves estimates are made on a different basis, one which will reduce reserves growth

The End!

Thank you for listening!

We don't always get it right!

North Sea, 1970s and 1980s

Capital Cost Over-runs	Average 95%, max. 974%
O. and M. Costs	Average 140% over planned
First Oil	1-3 years later than planned
Plateau Rate	65% of planned

2007 Houston World Oil Conference

Proceedings

- Conference Program
- Conference DVD
- Video Highlights
- Peak Oil Review
- ASPO-USA