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Limits to Global Energy Supply

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Limits to Global Energy Supply

- The planet has immense energy resources.
- We can use much less energy for the same outputs: heating/cooling; distance travelled; things produced.

But we face some very tough limits –

(a). Conventional fossil fuels:

1. The global maximum in the production of conventional oil at current prices is probably about now.
2. The global maximum in the production of conventional gas is probably in 10 to 15 years.
3. We may be close to the global maximum in the production of conventional hard coal.

Limits to Global Energy Supply *contd.*

(b). Alternative fuels:

4. Most of the alternative fuels - fossil as well as renewable - have lower energy returns.
5. We face rate-limits in moving to these alternatives.

(c). Other limits:

6. High energy cost destroys economies.
7. GHG emissions.

- We have known about many of these limits for a long time, but they largely got forgotten.
- Most are not in current models (let alone in the thinking of industry or government).
- As a result, we do not understand the energy future.

General Remark:

These are a lot of topics – and some strong claims.

We clearly cannot cover in enough detail here.

So we:

- Skim over detail - apologies to those who do not like this approach in a presentation.
- Provide backup slides for information provided: e.g.: world ‘immense’ energy resources given in ZJ.
- Slides will be up on website.

Limit 1: The probable maximum in the global production of *conventional* oil.

To understand this limit you need to know:

i). Never use proved ('1P') reserves.

ii). Use oil industry proved+probable ('2P') data for oil discovered, and likely to be discovered.

iii). 'Mid-point' peaking.

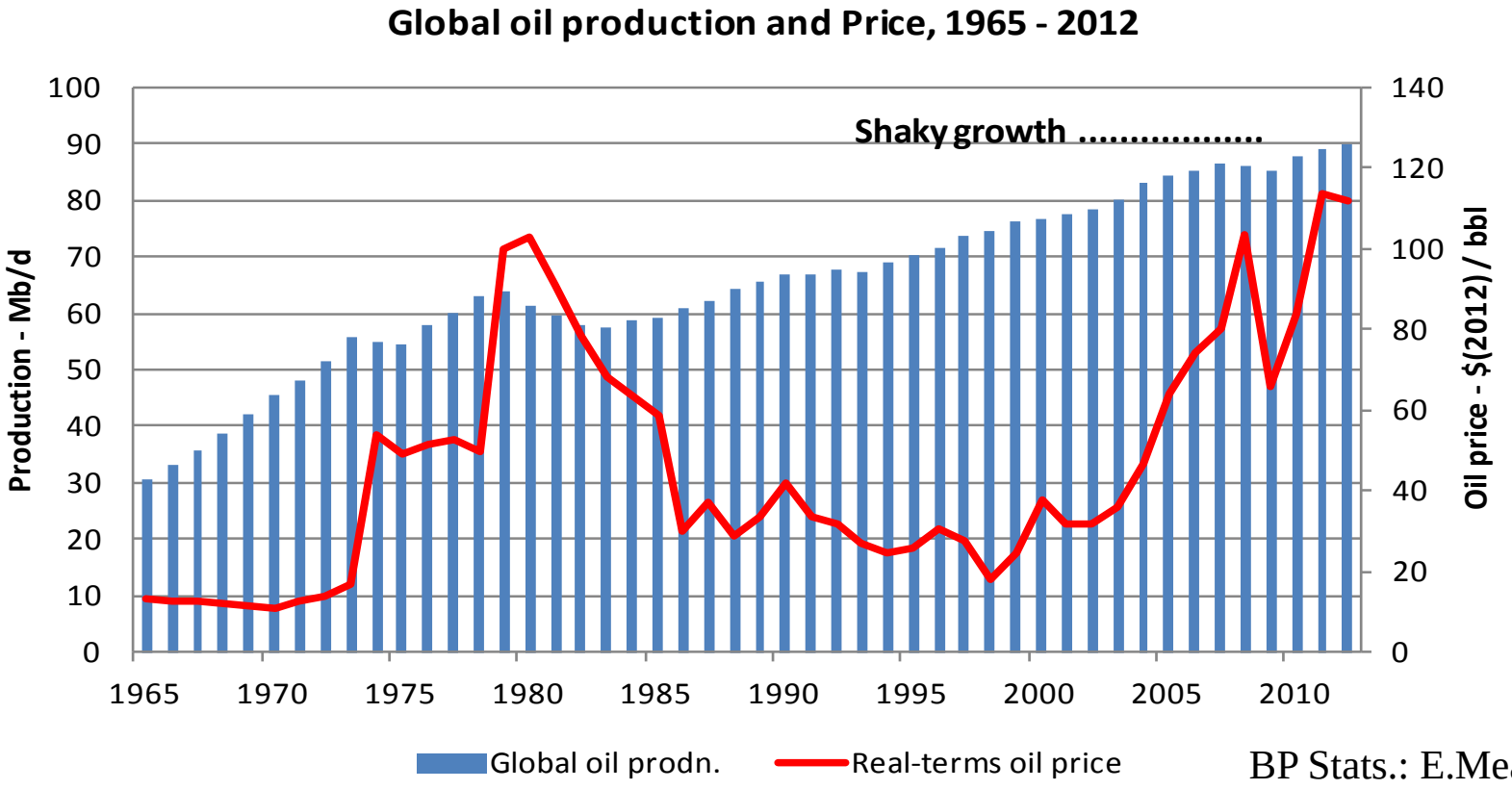
iv). 'Capacity' vs. 'likely' forecasts.

v). Why 'mainstream' forecasts were so wrong.

We start by looking at oil production and price.

Global oil production and price, 1965-2012.

- *Global all-oil production: weak growth since 2007.*
- *Real-terms price back to that of the 1978 oil shock.*



BP Stats.: E.Mearns

The current high oil price cannot be driven *fundamentally* only by demand: from 1861 to 1970 demand grew rapidly but the price fell.

i). Never use proved reserves ('1P') data

These data are:

- Understated, particularly early in a field's development.
- Overstated in some Middle East countries.
- Not stated: often static for countries for long periods.

ii). For forecasting must use oil industry proved + probable ('2P') backdated data.

The evolution of 1P ('political/financial') global oil reserves is very different from that of backdated 2P ('technical') reserves:

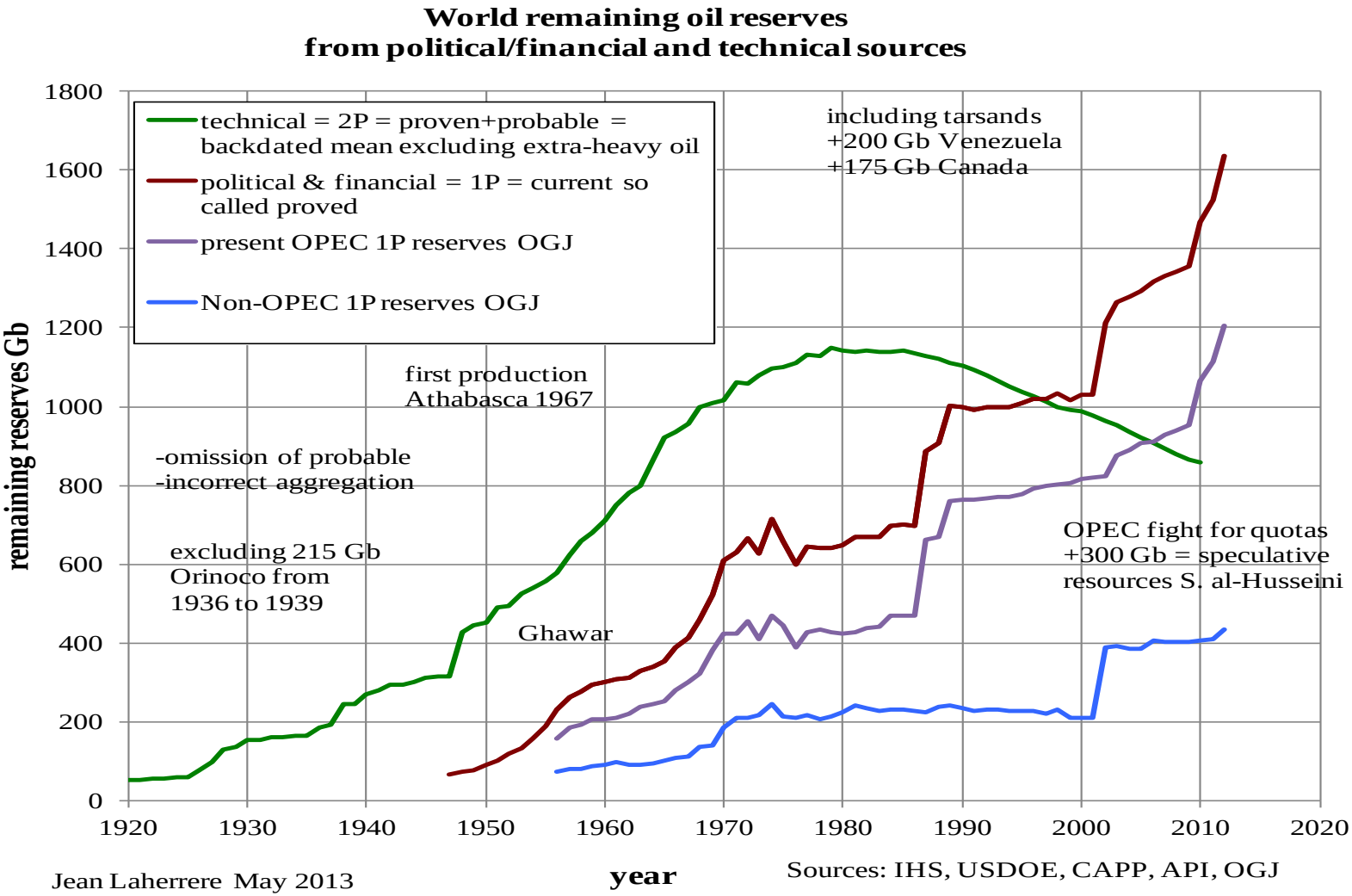
- 1P data show reserves always increasing;
- 2P data show that reserves peaked in 1980 (*next slide*).

By 2000 1P reserves *exceeded* 2P due to 'quota wars'!

(Note: Since 2000, 1P data include non-conventional oil.)

Comparing 1P vs. 2P data: Global oil reserves

1P (brown line): Ever-increasing. 2P backdated (green): Peak in 1980.



N.B. Since 2001, 1P include extra-heavy; 2P as shown here do not.

iii). 'Mid-point' peaking: When to expect the *resource-limited* peak of global *conventional* oil production

This needs industry 2P cumulative discovery data
i.e., (produced to-date) + (remaining reserves).

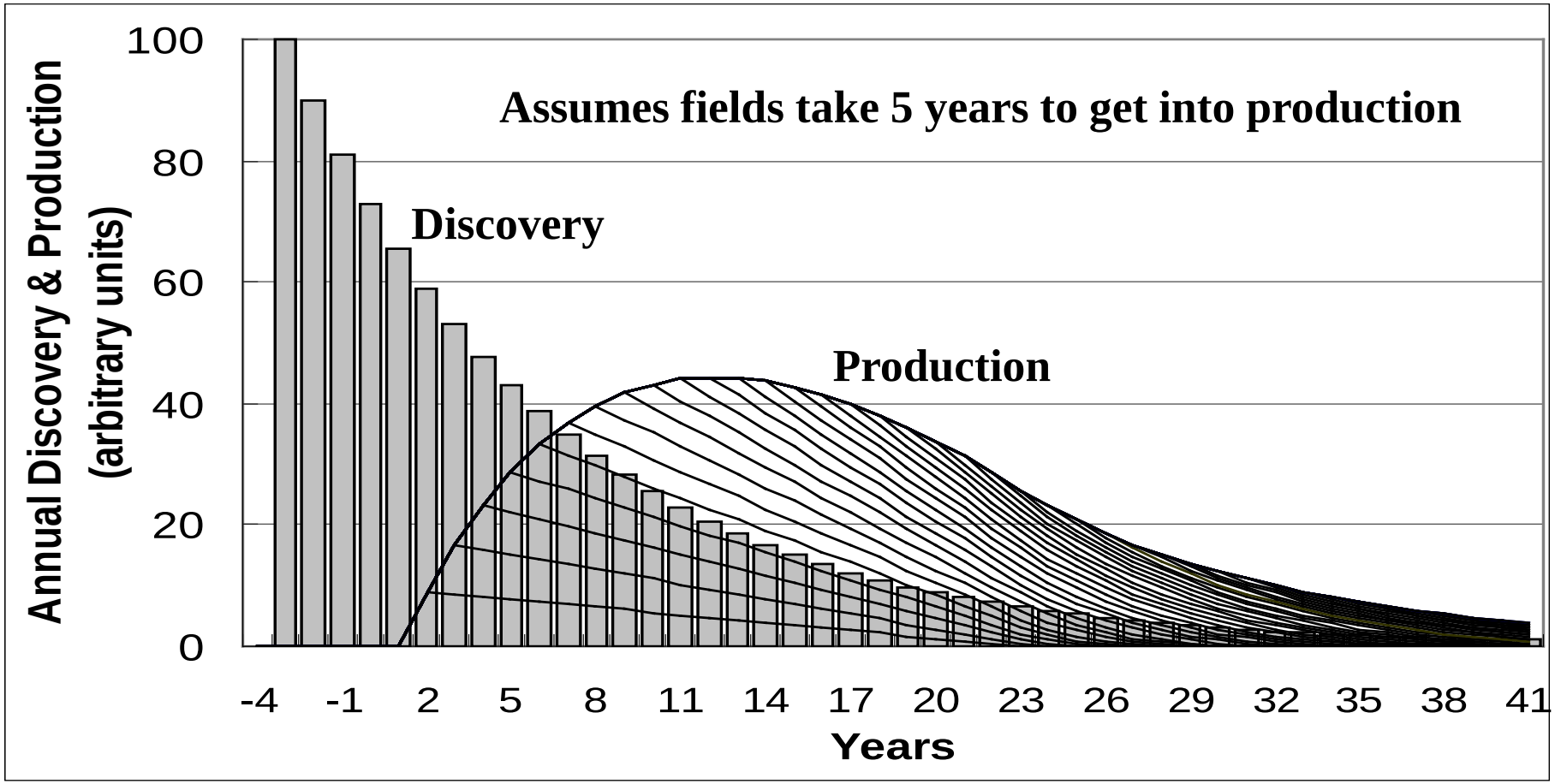
Most analysts:

- Did not know they needed these data - were happy to work with 1P.
- Did not have access - are expensive to license, or much work to assemble.
- Did not know how to use the data - did not understand 'mid-point' peaking.

N.B. 'Mid-point' peaking is short-hand for the complex interplay of geology (field-size distribution), physics (pressure decline and/or increasing water-cut in fields), and economics (marginal vs. avg. cost) that drives a region's production to peak well before all the recoverable resource has been produced.

‘Mid-point’ peaking in a region:

Peak is driven by discovery (big fields first) and by field decline.



Peak is counter-intuitive: It occurs when production has been rising; reserves are large; new fields are being discovered; & technology is raising recovery factors..

Date of peak of global conventional oil by comparing back-dated cumulative 2P discovery with cumulative production.

Use either extrapolated discovery and ‘mid-point’ to estimate date of peak, or PFC ‘60%’ rule. Discvy: green; Prodn: brown.

Data indicate that the conv. oil peak is ~now.

iv). ‘Capacity’ vs. ‘Likely’ forecasts

‘Capacity’: Projections on reasonable assumptions of: oil available in most / all fields; significant reserves growth; no major investment limit; economies pick up; no major political events; all-liquids (‘the fuel tank does not care where oil comes from’).

(E.g. IHS CERA, all-liquids; Miller, conv., all-fallow)

‘Likely’:

- different oils have different prodn. profiles: conv., deep offshore, Arctic, light-tight, non-convs. (tar sands, etc.)
- caution on Middle East reserves (… ‘don’t lose sleep’)
- caution on fallow fields (Miller: 138 Gb in doubt)
- multinational outputs in decline (Skrebowski).

(E.g. Smith; Campbell; Energy Watch; Uppsala)

Dates of oil peak / plateau from 'bottom-up' models

In addition to the simple, robust, approach of 'mid-point' peak, and the PFC Energy rule of 'peak at 60% of 2P discovery', we can use 'bottom-up' models.

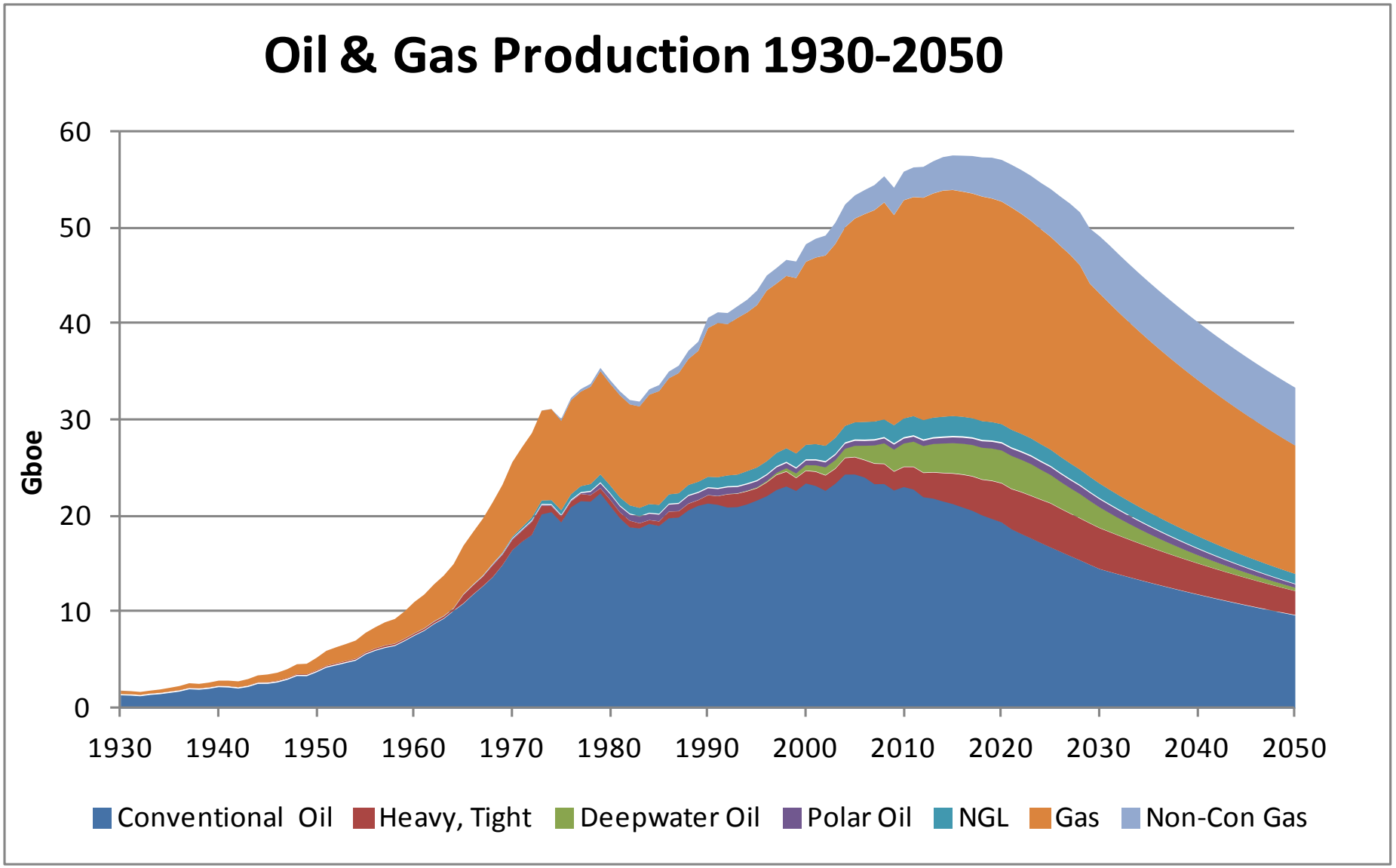
E.g:

- IHS CERA: By field, all-liquids.
  Capacity: 'Undulating plateau' starts ~2030 - 2040.
- Miller. By field, conventional oil only (& excl. NGLs).
  Capacity (moderate growth, all-fallow): Peak by ~2040.
  Likely: Peak now (at current prices).
- Smith (Globalshift). By field, all-oil, incl. NGLs & 'other' oils.
  Likely: Peak by ~ 2028.
- Campbell: By country, 'regular oil'. Likely: Peak 2005.
  " All-oil incl. NGLs: Likely: Undulating plateau 2005 - 2020.

Details of some models: UKERC 2009 report: *Global Oil Depletion*

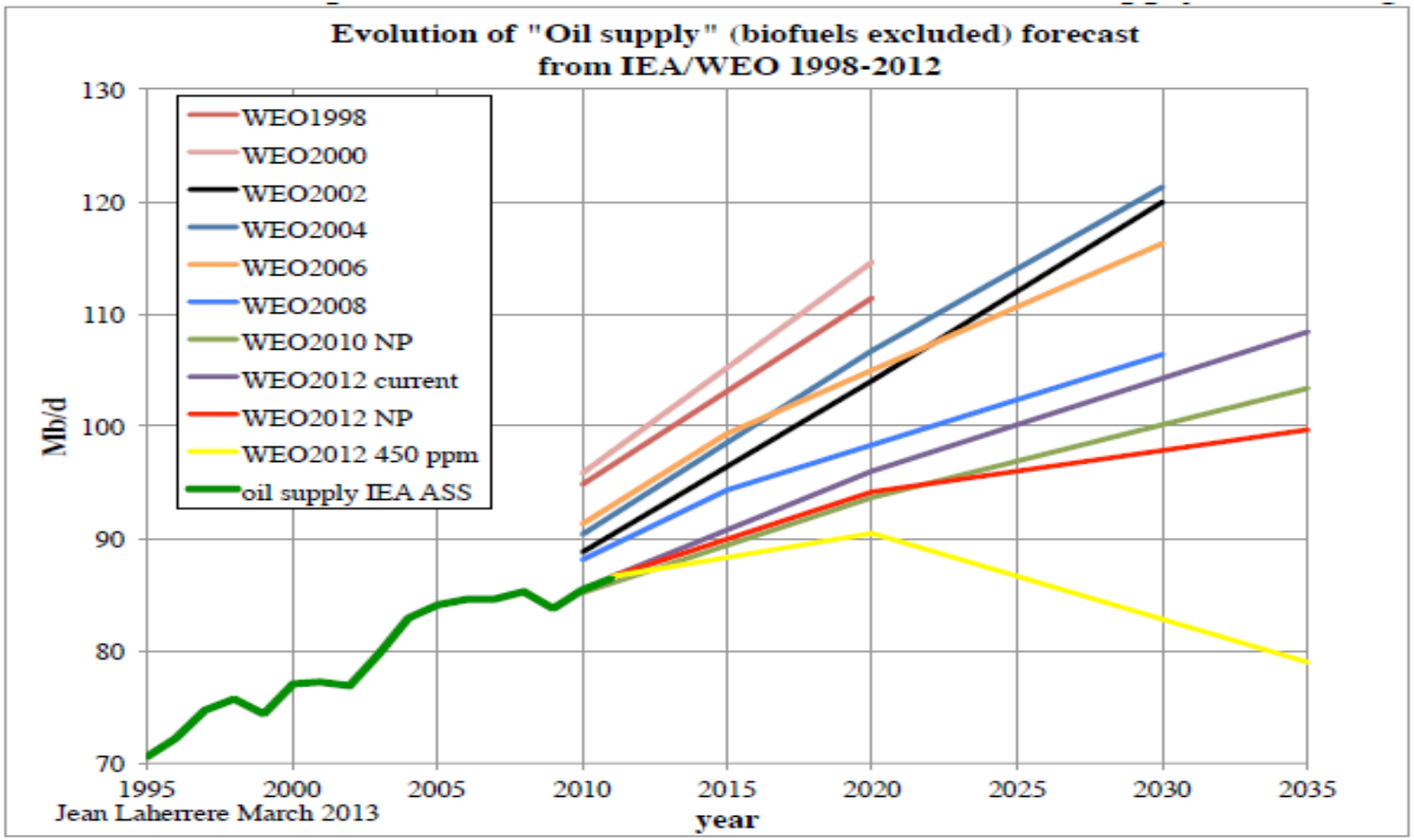
Campbell: All-oil, all-gas forecast to 2050 (Gboe/yr.)

(*Excludes*: CTLs, GTLs, biofuels; gas hydrates. 'Conv.' = 'regular')

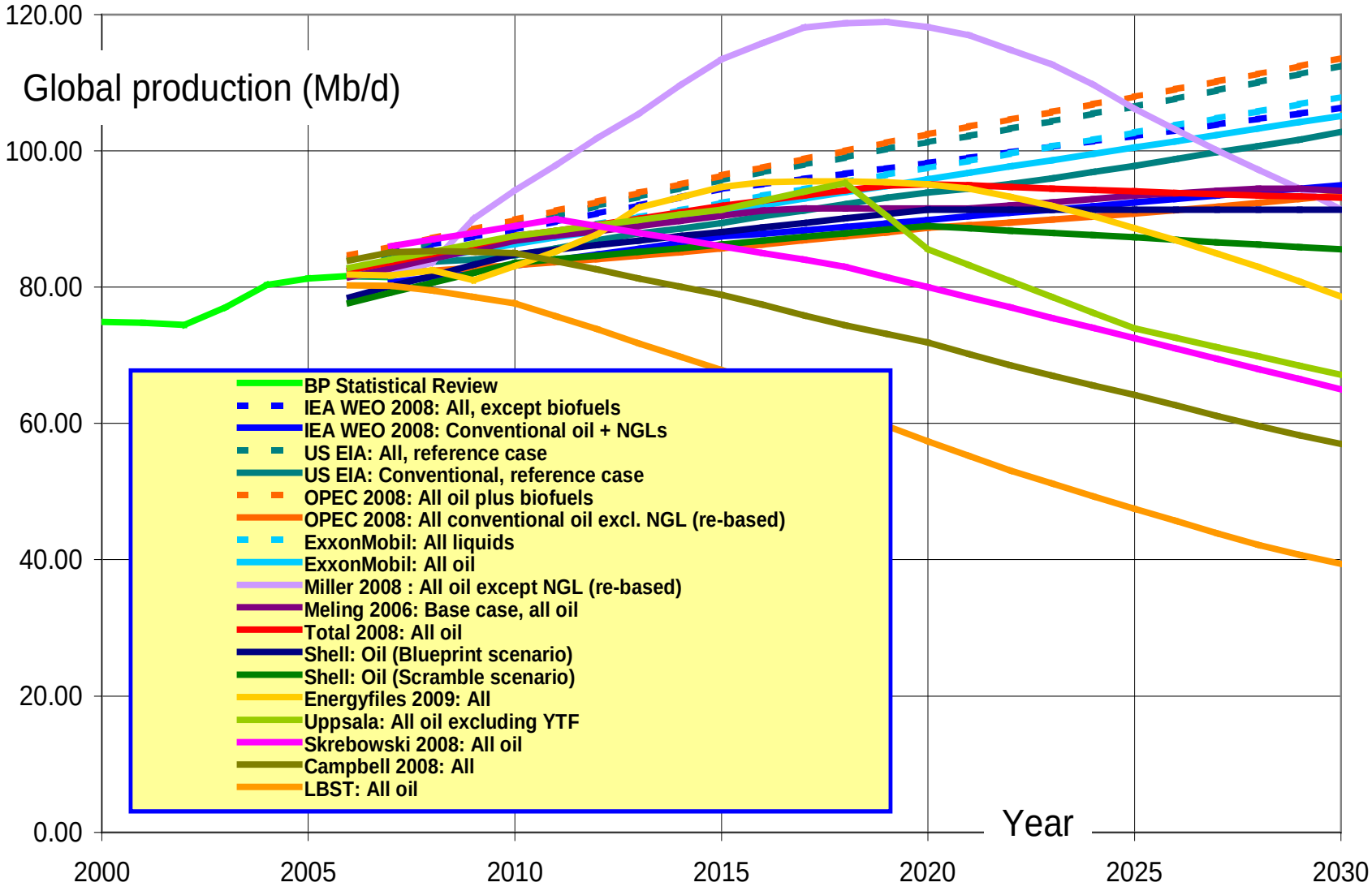


v) . Last piece of the puzzle: Why mainstream forecasts (IEA, EIA, OPEC, BP, ...) were so wrong.

E.g.: IEA forecasts 1998 - 2012: Forgot field decline (until 2008), hence no mechanism to generate peaking!

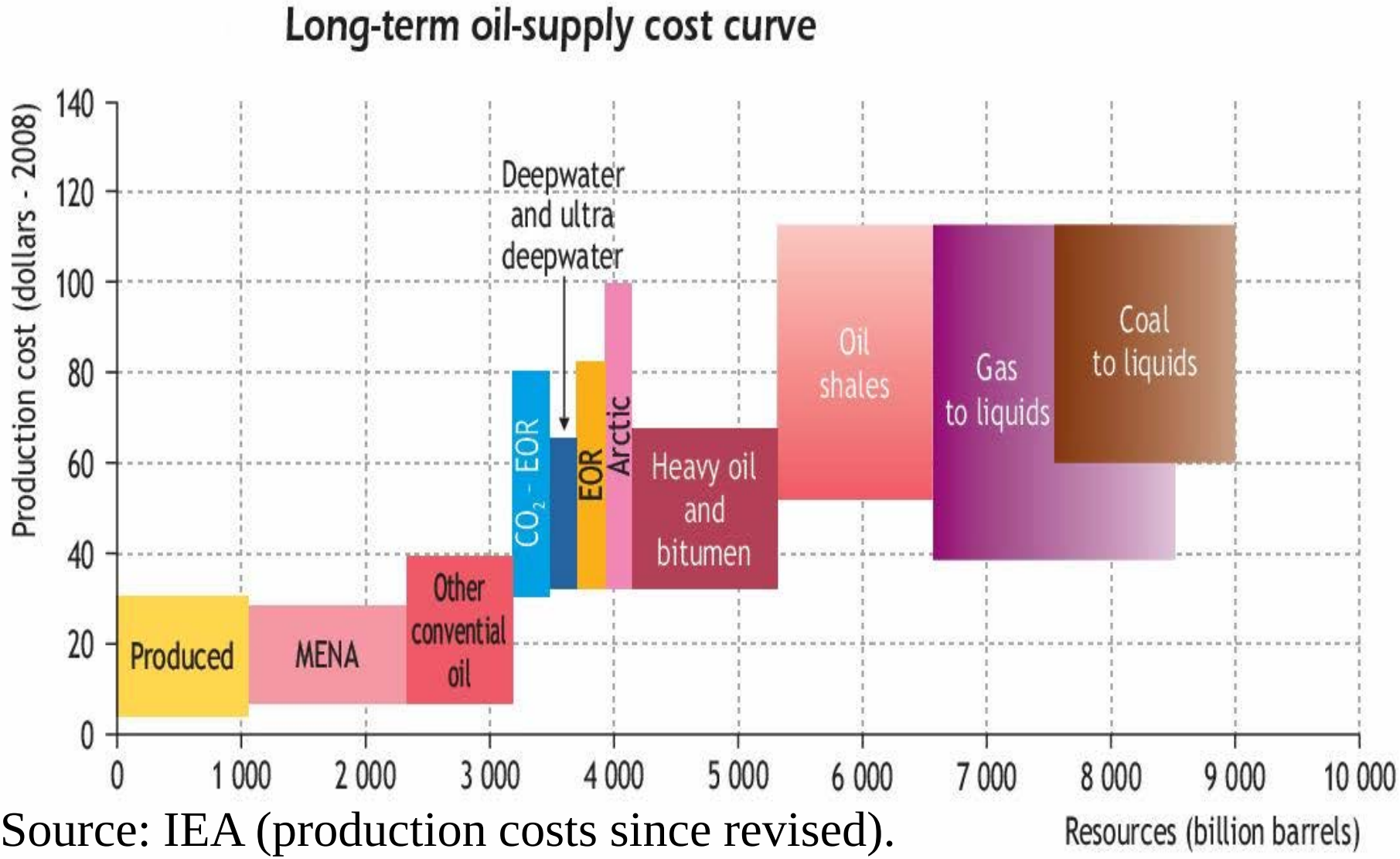


Mainstream ‘Quasi-linear’ forecasts, vs. Peak forecasts.



UKERC *Global Oil Depletion* report, 2009.

As we have long known - There is a lot of oil: conv. & non-conv. Total recoverable (incl . shale) prob. >10 Tb.



Source: IEA (production costs since revised).

But: Conclusions on Conventional oil

- Current constraints on global conventional oil production due to:
  - Below-ground: Discovery of oil in new fields in decline for ~50 years; production decline in fields, especially large-old.
  - Above-ground: Access by multinationals to some countries; Iran production; Saudi Arabia reluctant to pump all possible, etc.
- But there have always been above-ground factors.
- To-day's high oil price is *primarily* due to resource limits on the production of global conventional oil.
- We do not really know how fast non-conventional oil supply can grow: mainstream forecasts say 'sufficiently'; peak say 'not'.
- **Today's high price *is* 'The End of Cheap Oil'.**

Caution: Price reflects small differences in supply & demand, so is hard to predict and likely to be volatile. Oil costs go up due to depletion, more difficult fields, EOREI, etc.; but price destroys demand and brings on new projects. **In short-term prices can fall.**

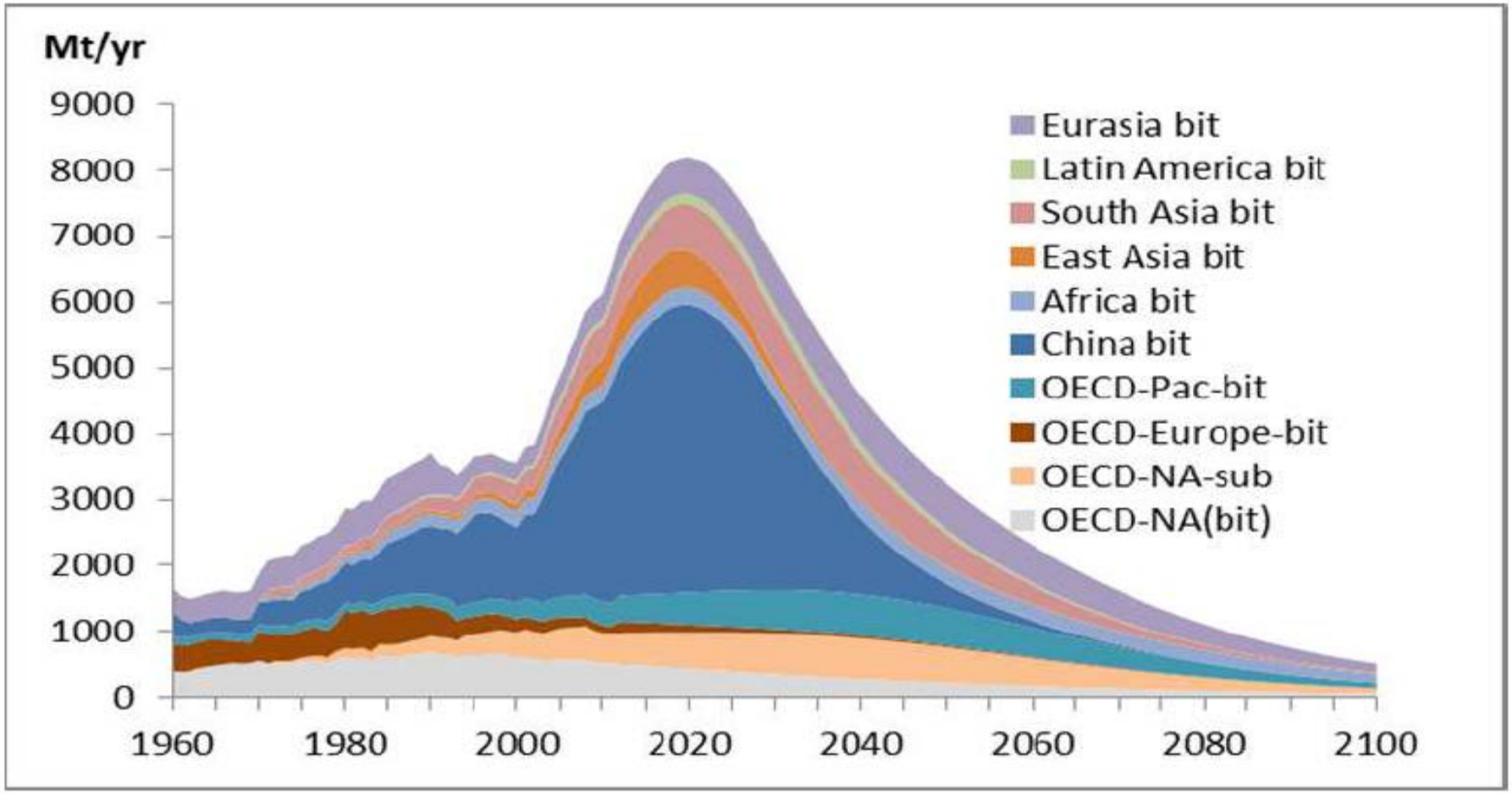
Limit 2: *Resource-limited* peak of *conv.* gas production
- Compare back-dated cum. 2P discovery with cum. prod'n.

Use either extrapolated discovery and 'mid-point' to estimate date of peak, or PFC '60%' rule. Discov'y: red; Prod'n: orange.

Data indicate the conv. gas peak is ~2025.

Limit 3: Maybe max. of conventional hard coal

Plot from *Energy Watch 2013 report*. Zittel cautions that global coal data are too poor for other than educated guess.



World coal production according to the updated scenario

Limit 4: Alternatives mostly have lower energy returns

Hall *et al*. suggest that modern society needs a minimum energy return on energy invested (EROEI) of ~10 -15x.

Even where ratios are higher than this, falling EROEI ratios reduce society's overall wealth.

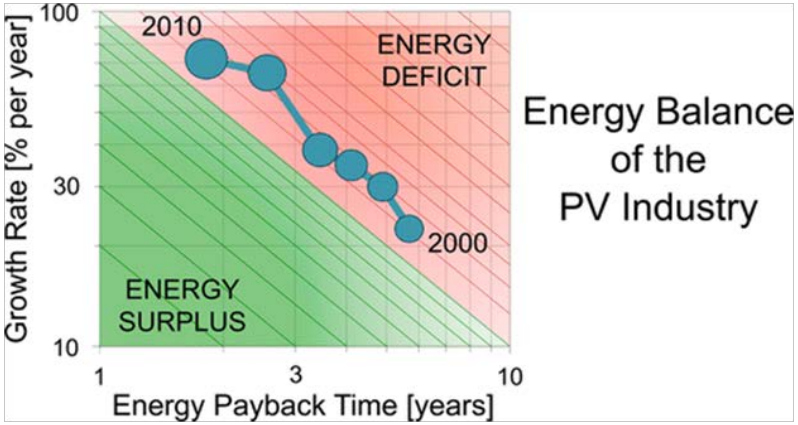
	Approx. EROEI range
Conv. oil: 1930 / 1970 / today	100 / 40 / 14
Tar sands	1.5 - 8
Coal	40 - 80
Nuclear fission	4 - 16
Wind	10 - 28
PV	2.5 - 8
Biodiesel, gasohol	~3

Most data: C. Hall & J. Day, *American Scientist*, 97, 230-237, 2009. (Gives EROEI of PV as ~8; value of 2.5 is from Prieto & Hall, Springer Briefs in Energy, 2013.)

Limit 5: Rate-limits in moving to these other fuels

- Changing to a new energy-saving measure, or new energy source, faces rate-limits that are sometimes overlooked.
- These include: technological & society readiness, availability of investment, limits to inputs such as water or gas, and net-energy rate-limits.
- The latter are often forgotten, and may be critical.

E.g. Because of rapid growth, the total PV installed to-date (~ 100 GWp) has not yet returned any net-energy to Mankind. The date for positive net-energy return is unclear.



See: Dale & Benson. Energy Balance of the Global Photovoltaic (PV) Industry - Is the PV Industry a Net Electricity Producer? Environ. Sci. Technol., 2013, 47 (7), pp 3482–3489. Also: Prieto & Hall: *Spain's Photovoltaic Revolution - Energy Return on Investment* ISBN: 978-1-4419-9436-3

Limit 6: High energy cost destroys economies

OPEC exports now cost importers $1 tn./yr., real-terms, as in 1979.

[Note the rapidly rising internal demand within OPEC.]

- There is a very poor understanding of the impacts of high energy cost on economic activity. Authors such as Slessor, Odum, Hawker, Lovins & Lovins, Kümmel, Ayers, and Hall and Klitgaard suggest new paradigms, but we guess (we are not experts) that none has been adequately tested.
- To understand the future, the links between availability of energy and economic activity need to be properly understood.

Limit 7: Greenhouse gas limits

(450 ppm, Hansen 350 ppm? 250 ppm?)

- Discussed elsewhere in this conference.

We have long known about many of these limits, e.g.:

- **Conventional oil:** Estimates made from 1956 to 1981 by Hubbert, Esso, a report to the UN, UK Dept. of Energy, Shell, BP and others, based on estimated global conventional oil 'ultimates' of 1,250 - 2,500 Gb, predicted the global resource-limited peak or plateau of conventional oil production at about the year 2000.
- **Non-conventional oil EROEI limit:** Hubbert,1981.
- **All resources:** *The Global 2000 Report to the President*, 1982.
- **Net-energy rate limit:** Chapman, *Fuels paradise* (nuclear), 1975.
- **Systems limits -** Resource use grows to extract resources, and deal with pollution: *Limits to Growth*, 1972, 1993, 2004; Bardi, 2011.
- **Temperature effect of CO_2 in the atmosphere:** Arrhenius, 1896.

Conclusions

- The planet has immense energy resources.
- We can use much less energy than now.
- But we face some tough energy limits:
  - Peak conventional oil: probably about now.
  - Peak conventional gas: ~10 to 15 years from now.
  - Peak conventional hard coal: possibly fairly near.
  - Lower EROEI of non-convs. & renewable energies.
  - Limits to rate-of-change; incl. net-energy.
  - Impact of energy cost on global economic activity.
  - Greenhouse gases.
- We long knew about many of these limits, but were forgotten. **They must be taken into account.**

Thank you for listening