Beyond Oil-
Future fuel for Combustion Engines

The Collin Trust Lecture

CIMAC Congress, International Council on Combustion Engines
Bergen, Norway, 2010 June 14-17

The Ångström laboratory

Kjell Aleklett

Global Energy Systems
Uppsala University, Sweden
Kjell.aleklett@fysast.uu.se
www.fysast.uu.se/ges
Blog: aleklett.wordpress.com

UPPSALA UNIVERSITET

Kjell

UPPSALA
UNIVERSITET

Kjell []

UPPSALA
UNIVERSITET

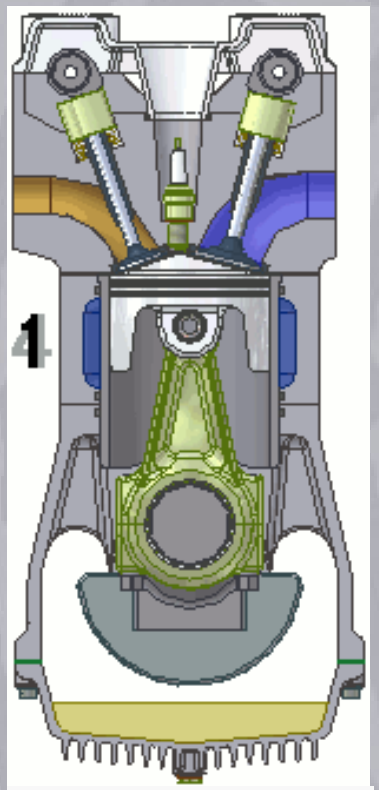
Combustion Engines

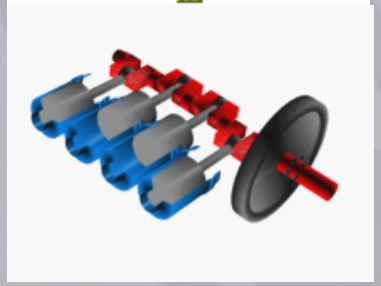
Internal combustion engines:
Four-stroke and two-stroke piston

Continuous combustion:
Gas turbines, jet engines and most rocket engines

External combustion engines:
Steam engines, Stirling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products.

Peak Fossil, the combustion engines and the Human Well-Being Equation





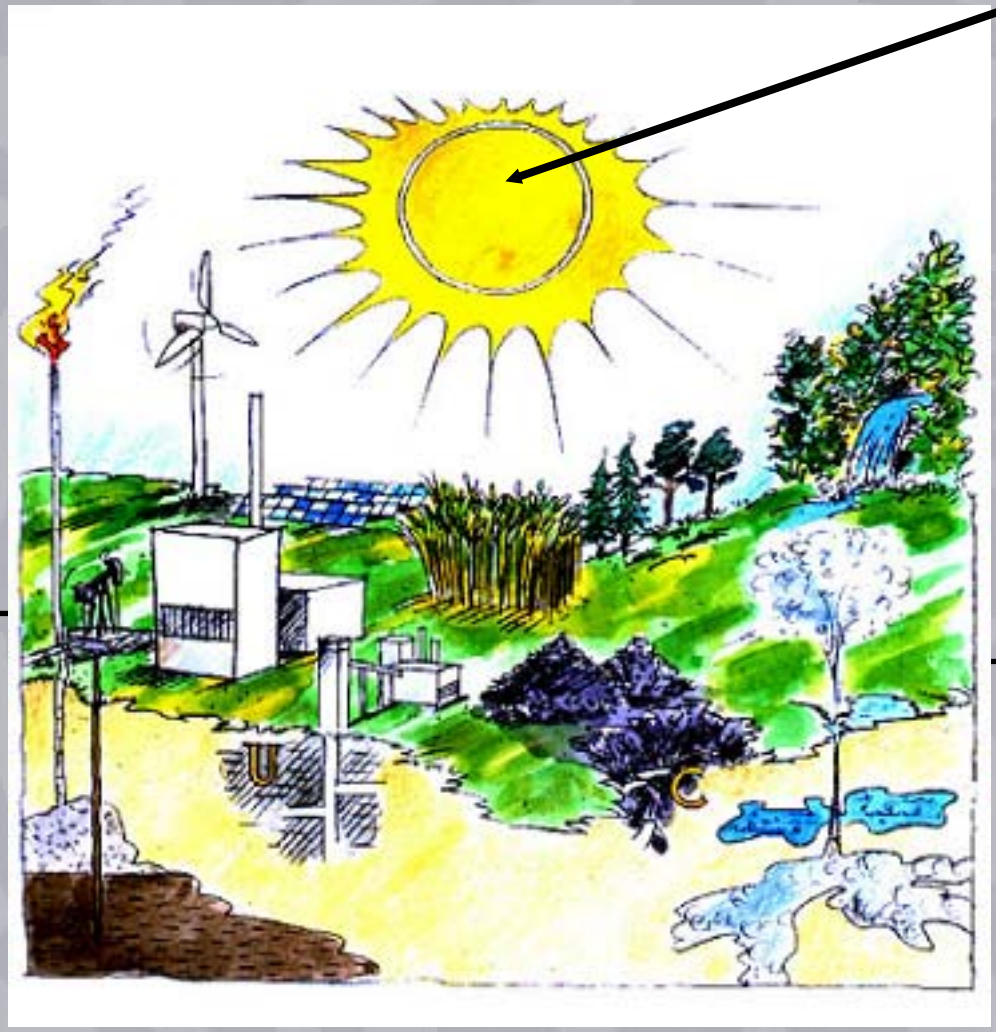
- Peak Oil, Peak Gas and Peak Coal
- The Human Well-Being Equation
- Food and Water
- Economy and Energy
- Peace and resources
- Climate

UPPSALA UNIVERSITET

Kjell Aleklett

Global Energy Resources

$E = m c^2$



Renewable Energy

Politically Correct

Bio energy and Sun, Wind and Water (Geothermic)

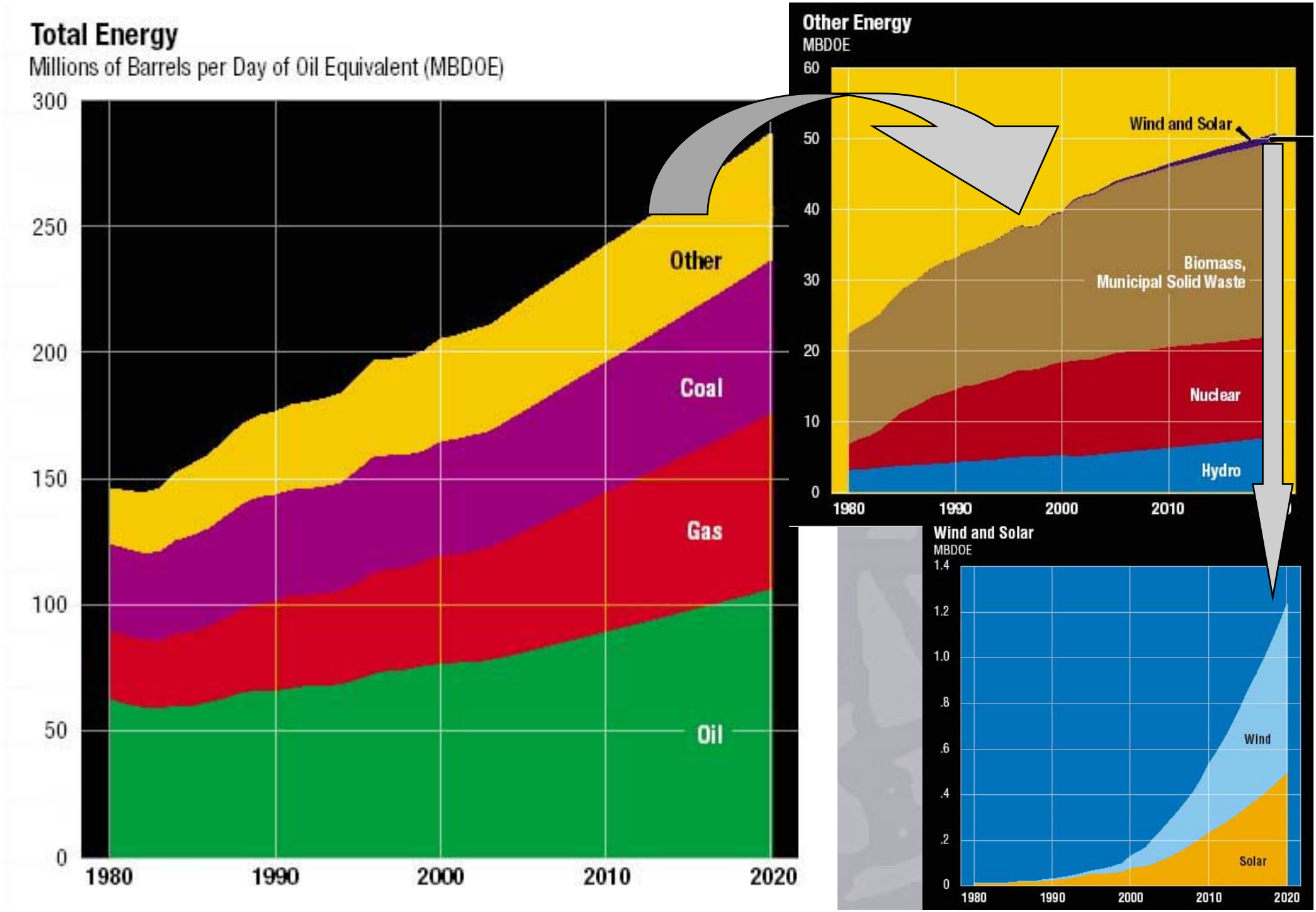
The Global Fraction ~15% ?

Fossil fuel and Super Nova "Ashes"

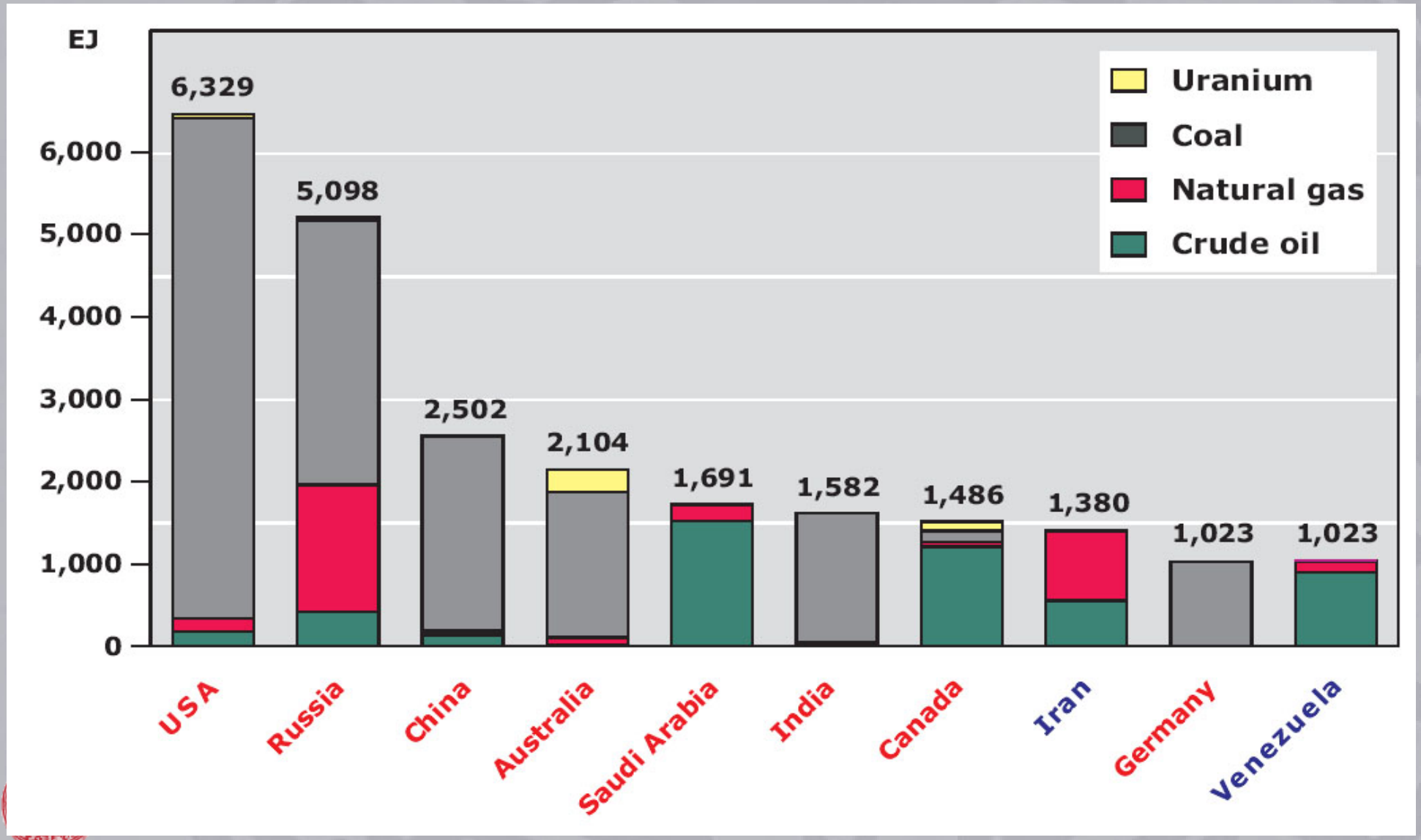
Politically NOT Correct

Coal, Oil and Natural Gas Uranium-235

Global ~ 85%


Total Energy
Millions of Barrels per Day of Oil Equivalent (MBDOE)
300
250
200
150
100
50
0
1980
1990
2000
2010
2020
Other
Coal
Gas
Oil
Other Energy
MBDOE
60
50
40
30
20
10
0
Wind and Solar
Biomass,
Municipal Solid Waste
Nuclear
Hydro
1980
1990
2000
2010
Wind and Solar
MBDOE
1.4
1.2
1.0
.8
.6
.4
.2
0
Wind
Solar
1980
1990
2000
2010
2020

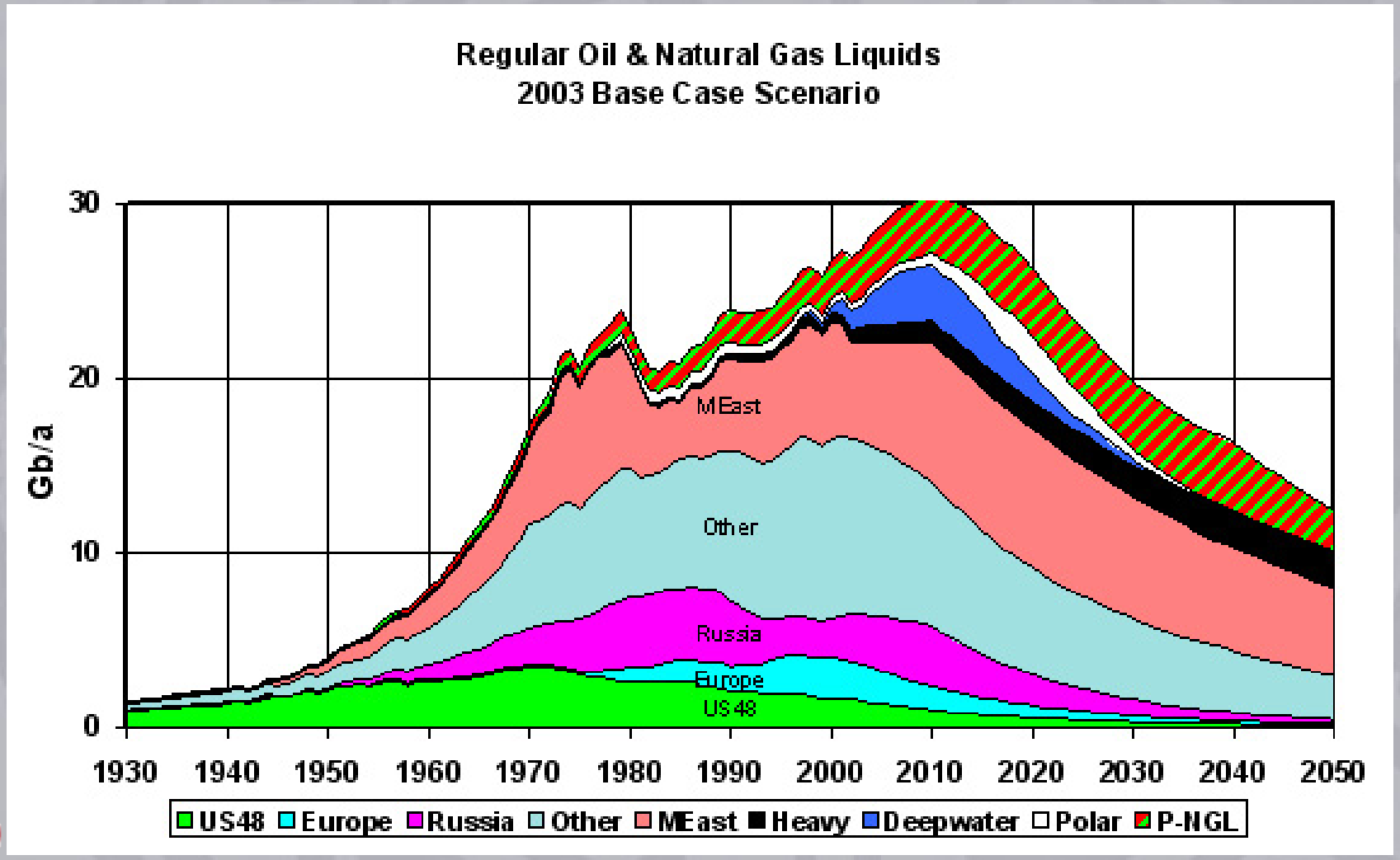
Where to find fossil fuel



UPPSALA UNIVERSITET

Kjell Aleklett

The Uppsala model – Peak Oil

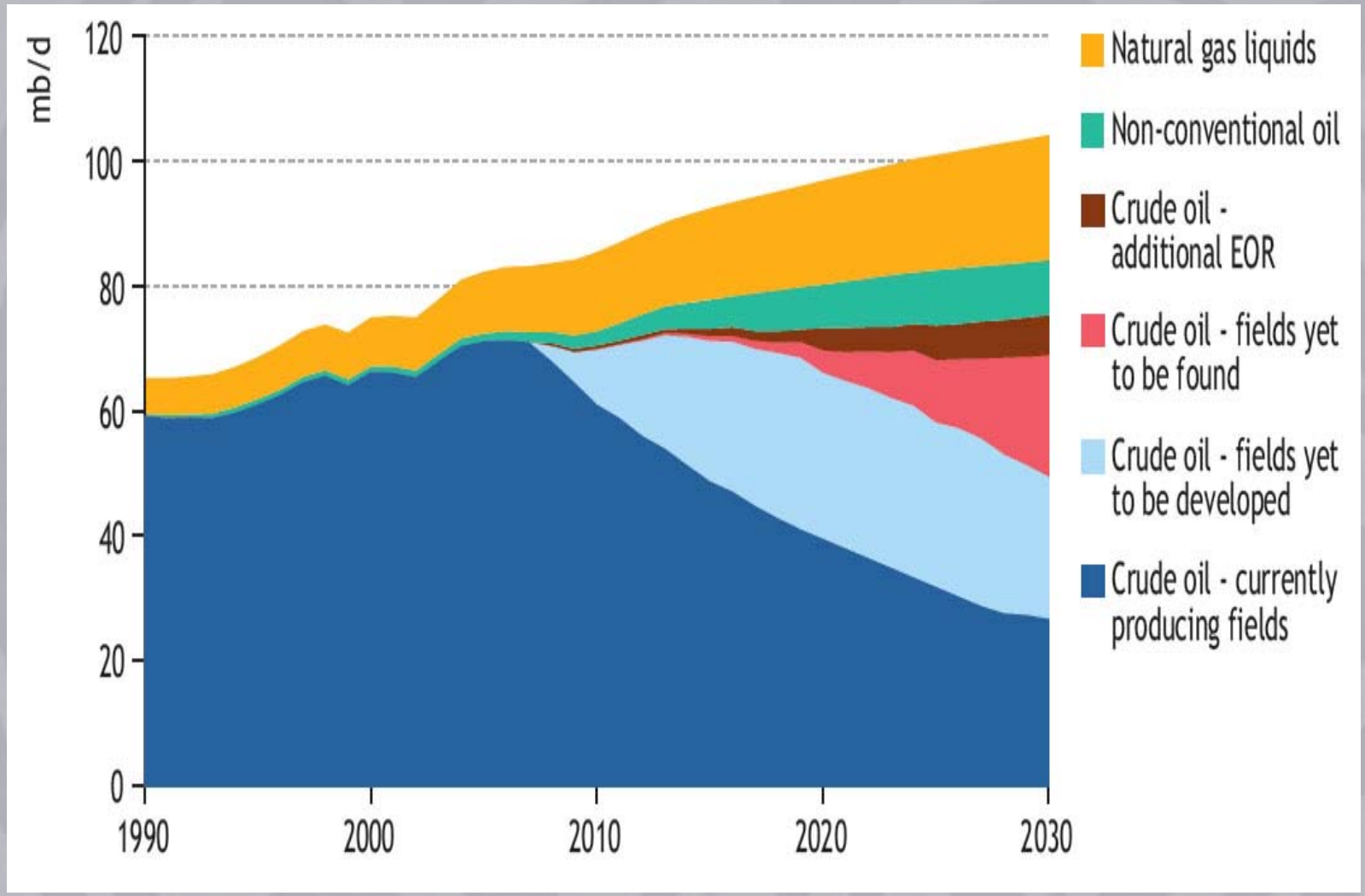


UPPSALA UNIVERSITET

STENA 040112

Kjell Aleklett

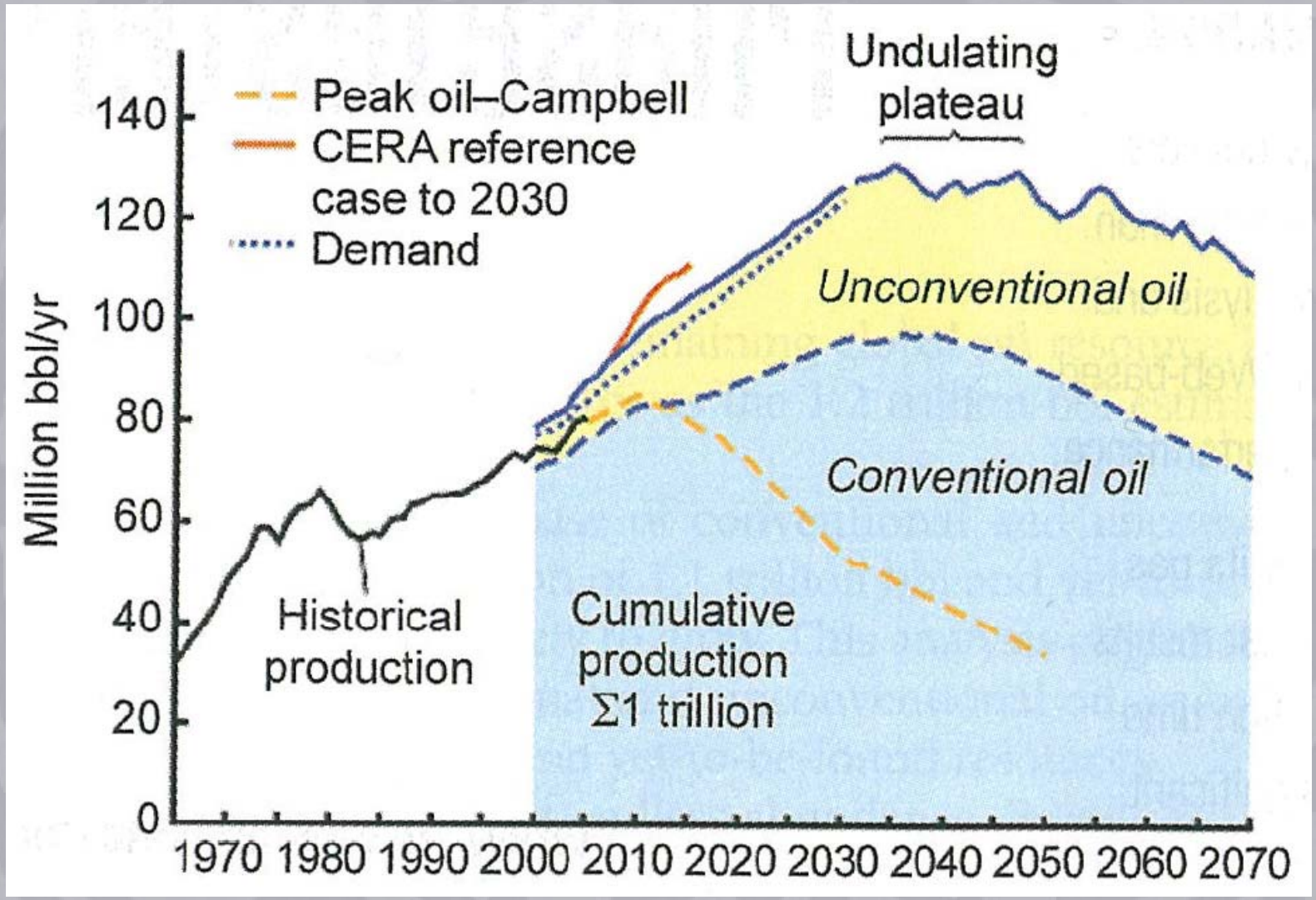
IEA - World Energy Outlook 2008



UPPSALA UNIVERSITET

Kjell Aleklett

Future Oil Production According to CERA



The February 2007 issue of *JPT* included a Guest Editorial by Peter M. Jackson of CERA.

The unrealistic numbers

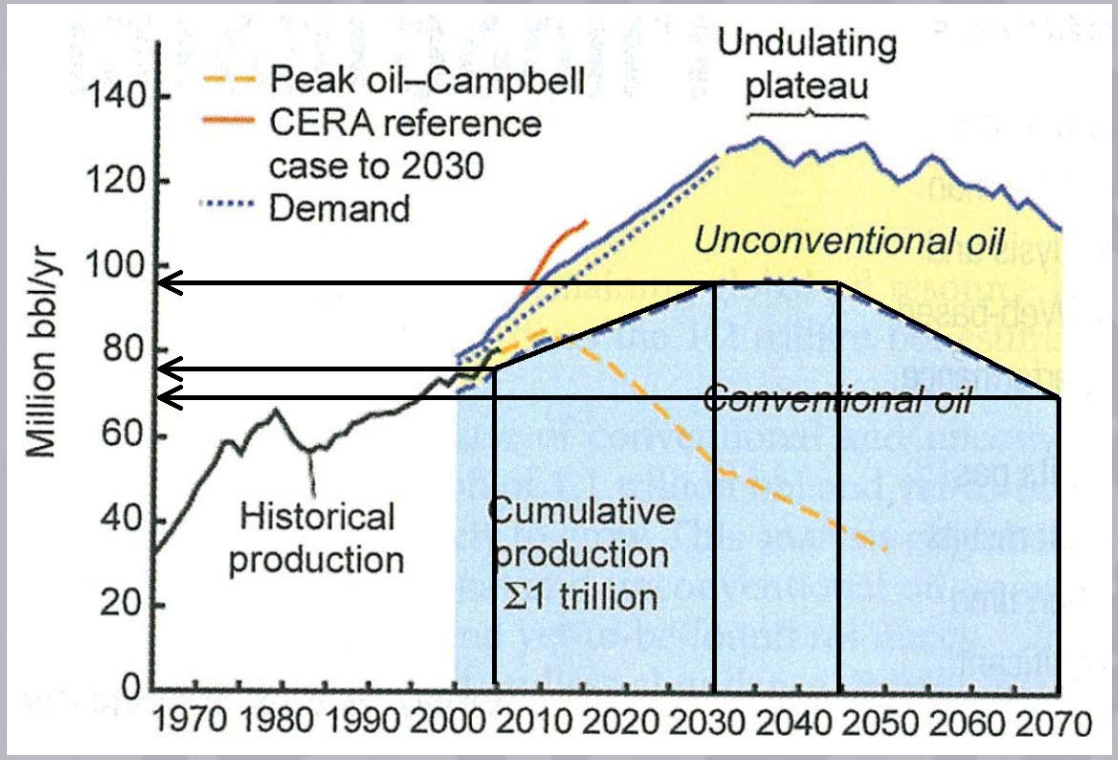
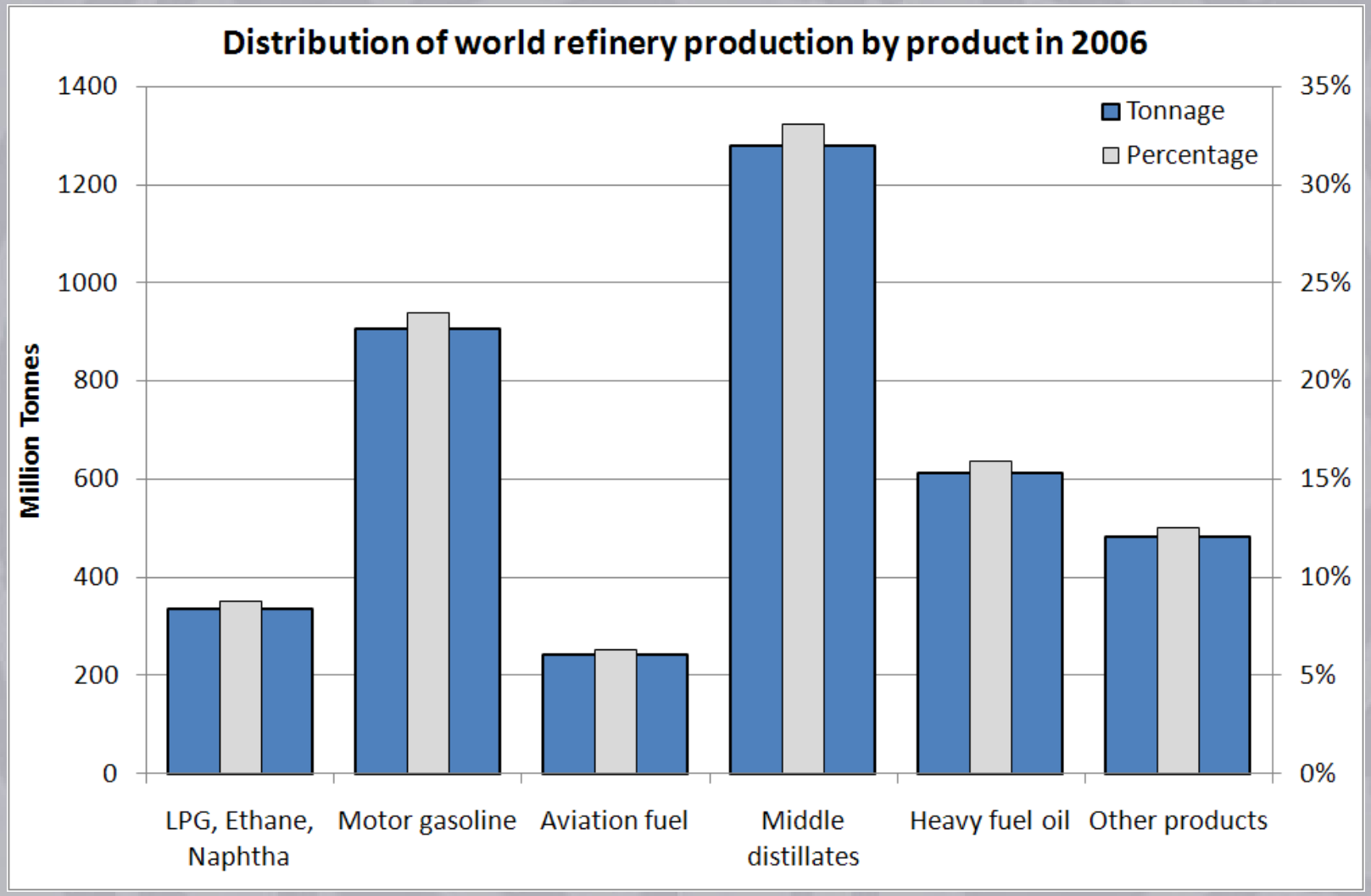


Fig. 1 in the Jackson article shows conventional oil production for 2006 at approximately 74 million BOPD, with a forecast increase to a maximum of 96 million BOPD in 2030, plateau production until 2045, and a decline to 68 million BOPD in 2070. Integration under the CERA forecast plot gives total conventional oil production of 2050 billion bbl. This is almost twice as much conventional oil reserves as we have today, according to CERA. I hope that CERA will publish a detailed analysis of its prediction, as we are doing.

UPPSALA UNIVERSITET

Transport Fuels in the Future



UPPSALA UNIVERSITET

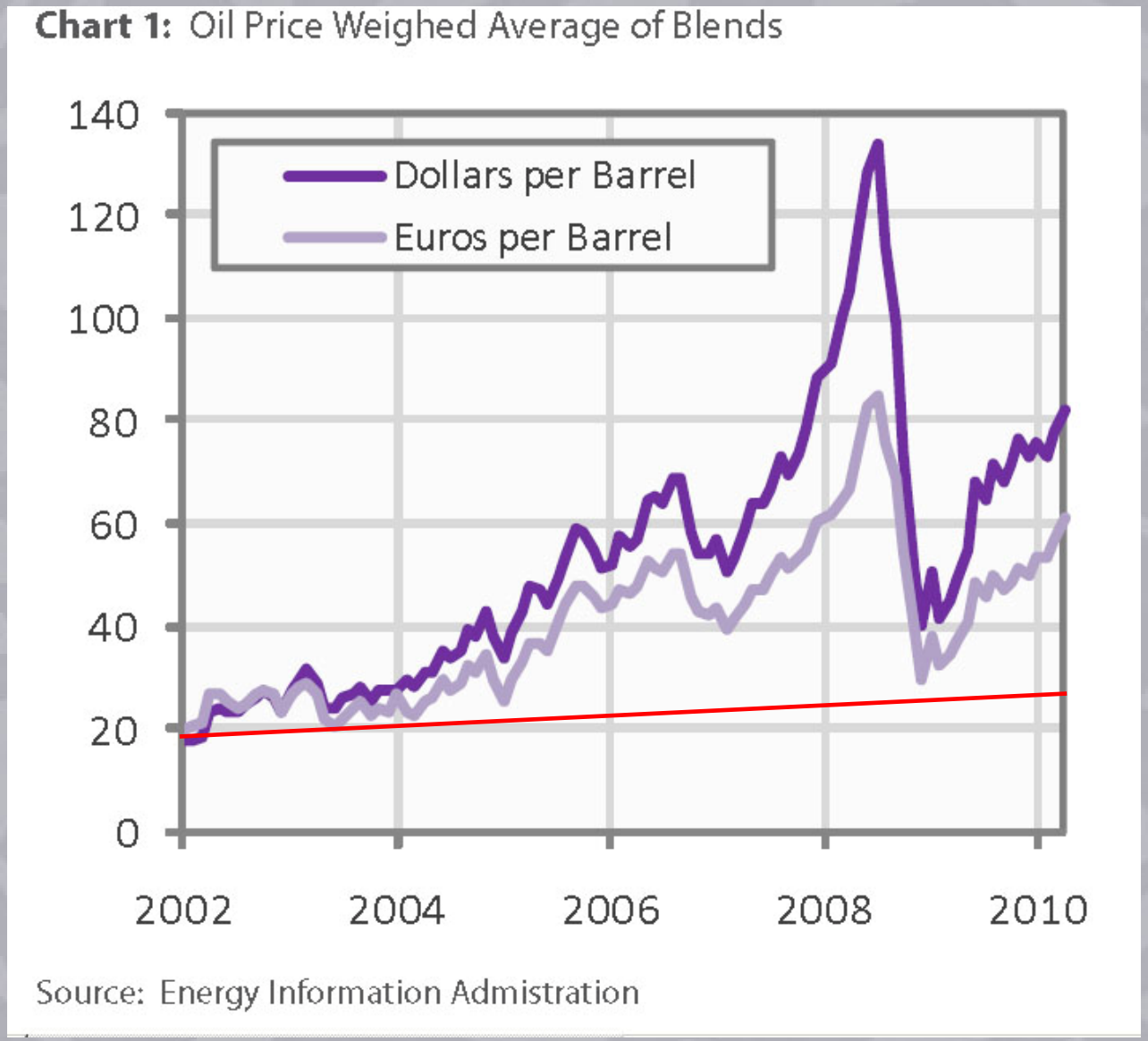
Kjell Aleklett

Oil Price Forecast in 2001 (without compensation for inflation)

Organization	2010 (US$/b)	2020 (US$/b)
US Department of Energy	21	22
International Energy Agency	20	27
European Commission	20	24
Canada Department of Energy	21	22
Standard & Poor	17	20
Wharton Econometrics	19	20
Deutsche Bank	18	18

UPPSALA UNIVERSITET

Oil prices 2002 - 2010



UPPSALA UNIVERSITET

Kjell Aleklett

What are important for today's students?

Students in Energy Systems at Uppsala University, Sweden

Food three times per day
Shelter
To make money
Social relations
Climate
Security

UPPSALA UNIVERSITET

Kjell Aleklett

The Human Well Being (HWB) equation

HWB = Food&Water + Economy + Climate + Security

UPPSALA UNIVERSITET

The Human Well Being (HWB) equation

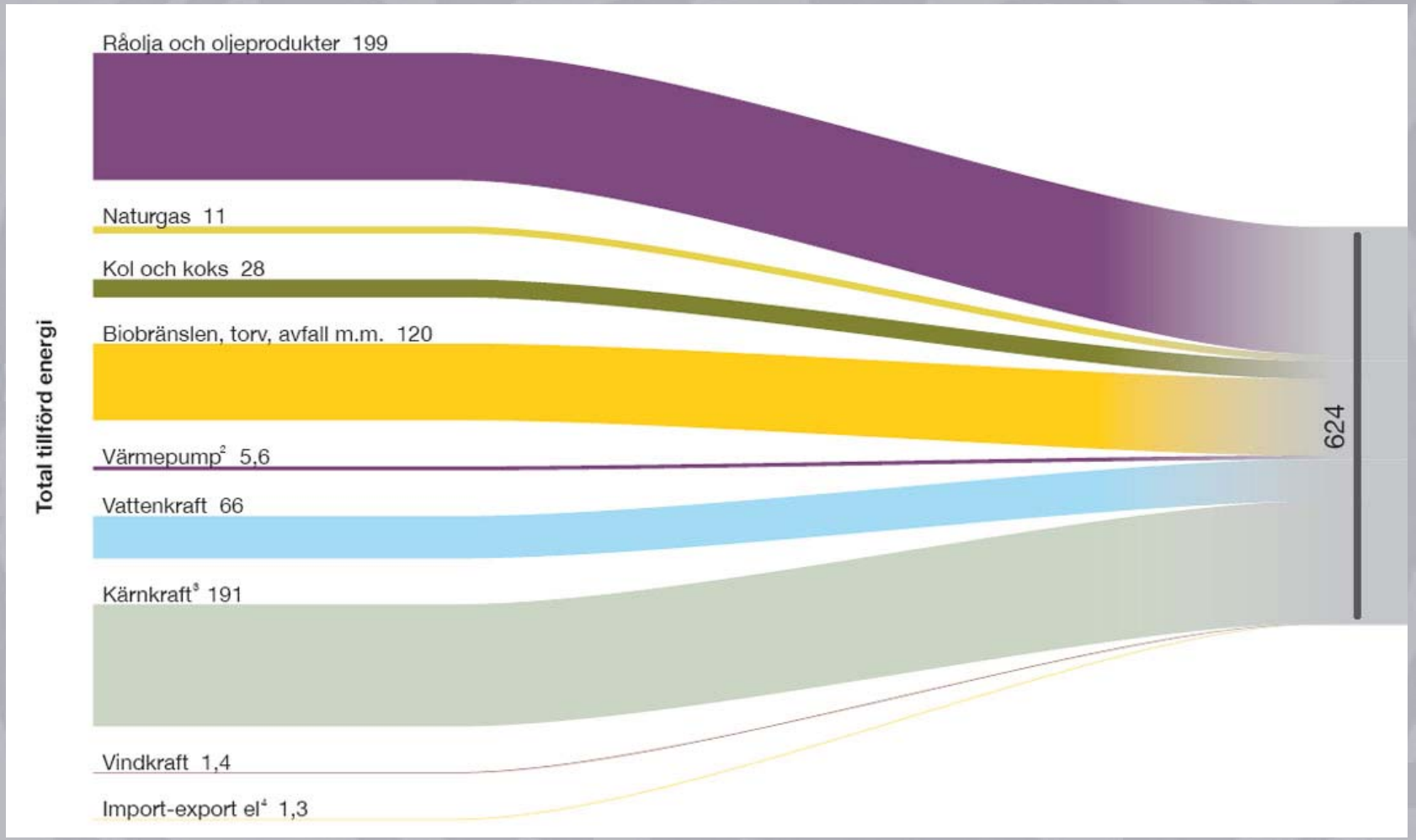
HWB(E) =

Food&Water(E) + Economy(E) + Climate(E) + Security(E)

E = Energy

UPPSALA UNIVERSITET

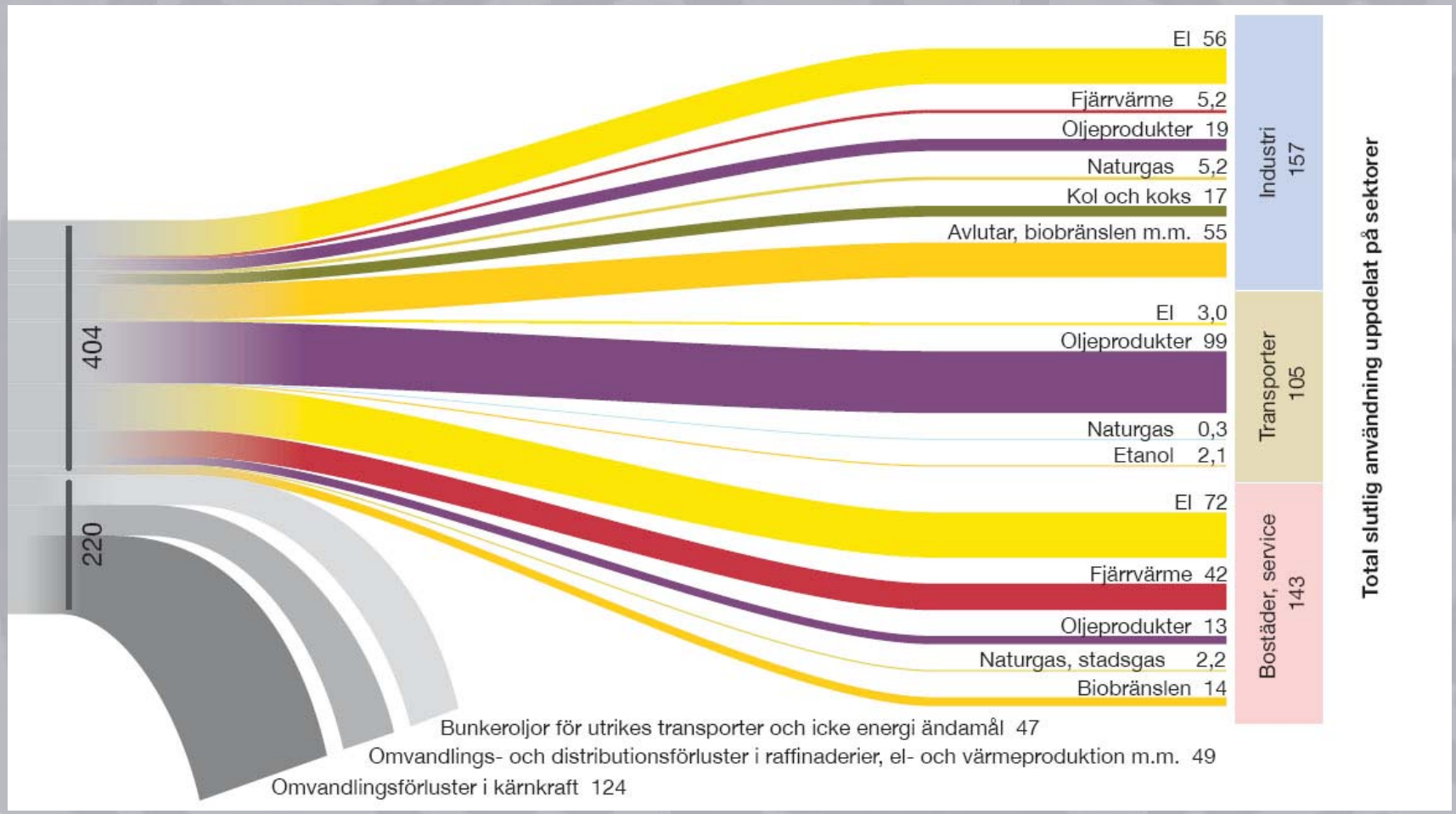
Energy supply in Sweden



UPPSALA UNIVERSITET

Kjell Aleklett

Energy use in Sweden



UPPSALA UNIVERSITET

Kjell Aleklett

Peak Oil

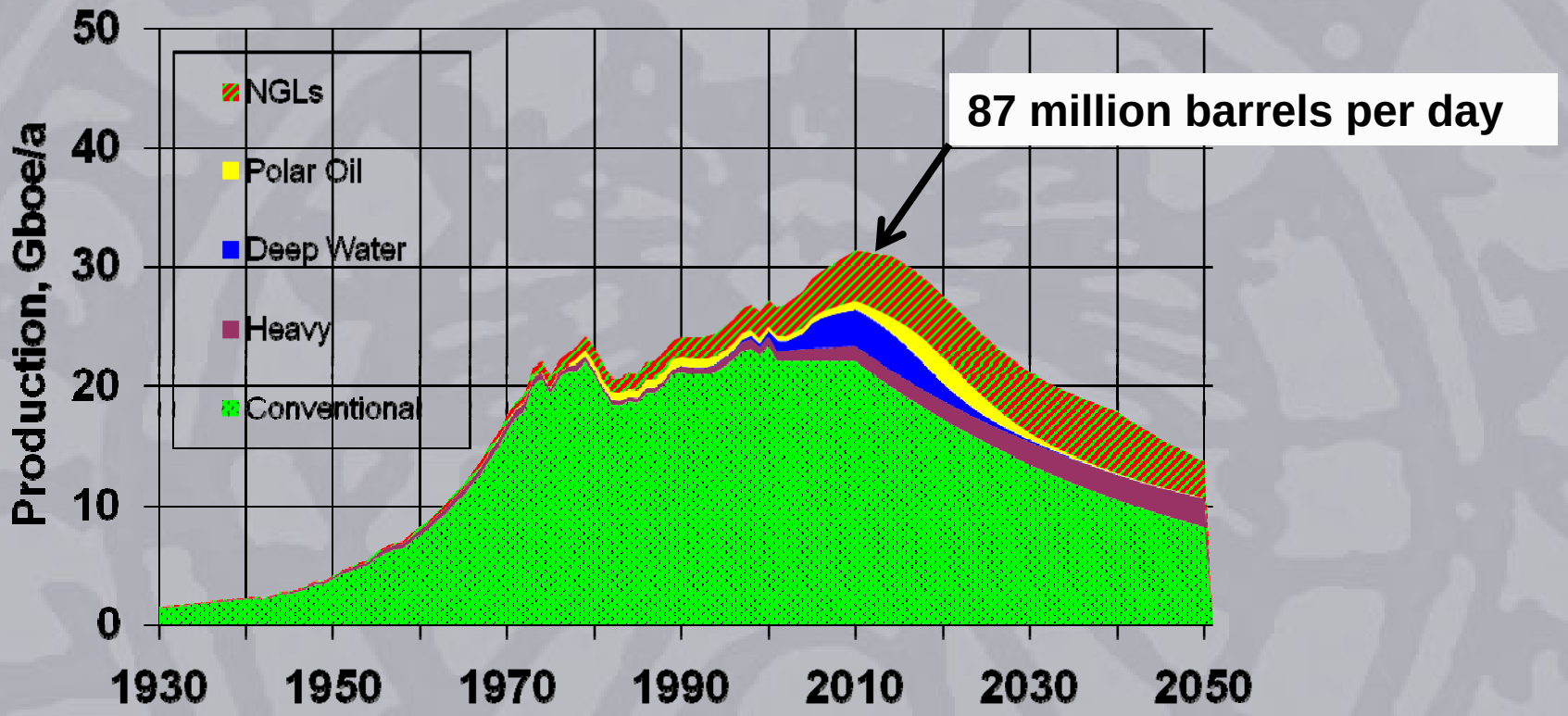
ASPO – The Association for the Study of Peak Oil&Gas

"The term Peak Oil refers the maximum rate of the production of oil in any area under consideration, recognizing that it is a finite natural resource, subject to depletion."

UPPSALA UNIVERSITET

Kjell Aleklett

First Press Release from ASPO 2002

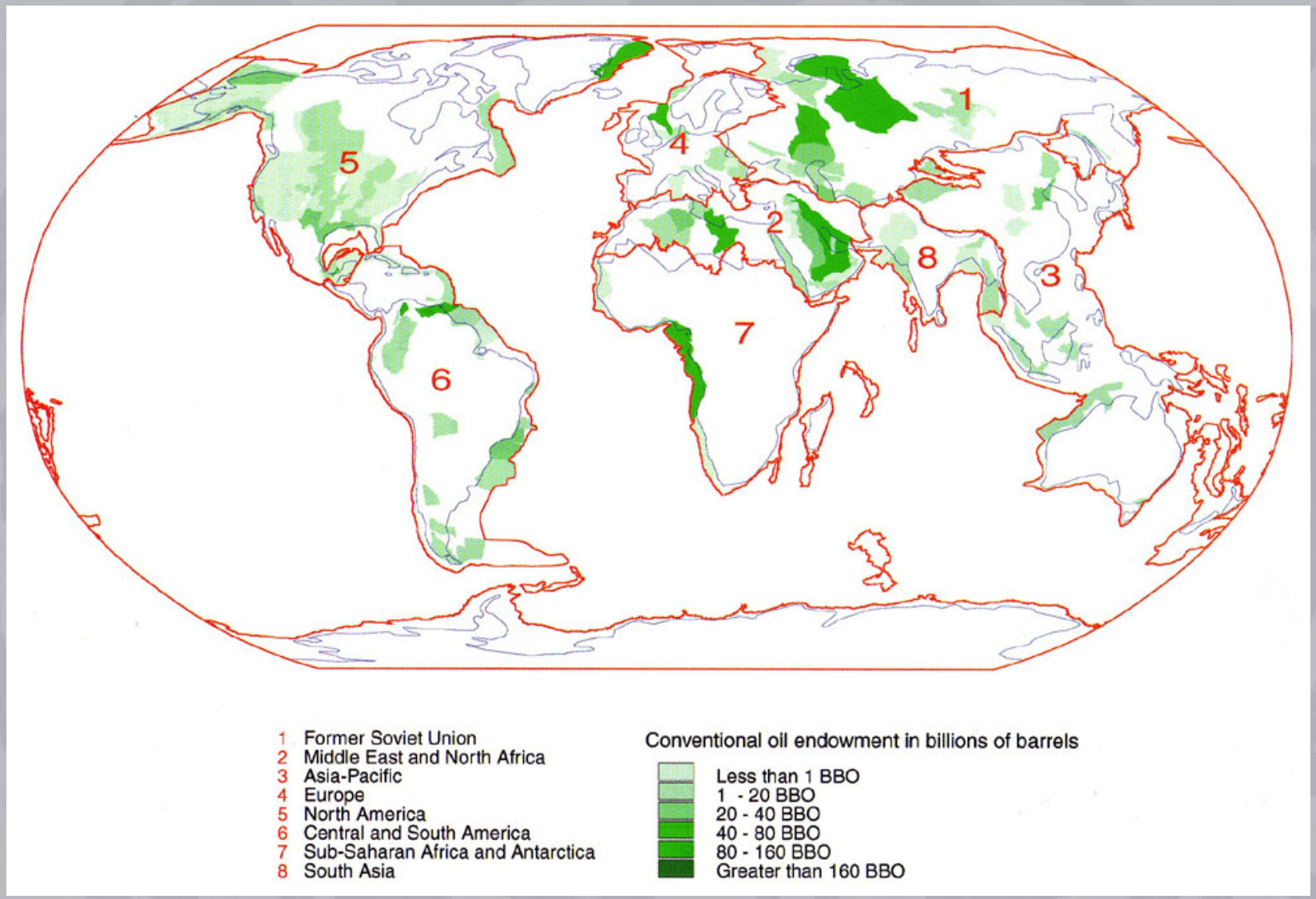


"The world oil depletion curve, above, is based on all available information on oil reserves and estimates of the amounts yet-to-find, and indicates that world oil production will reach a peak (87 million barrels per day) around 2010 and decline thereafter."

UPPSALA UNIVERSITET

Kjell Aleklett

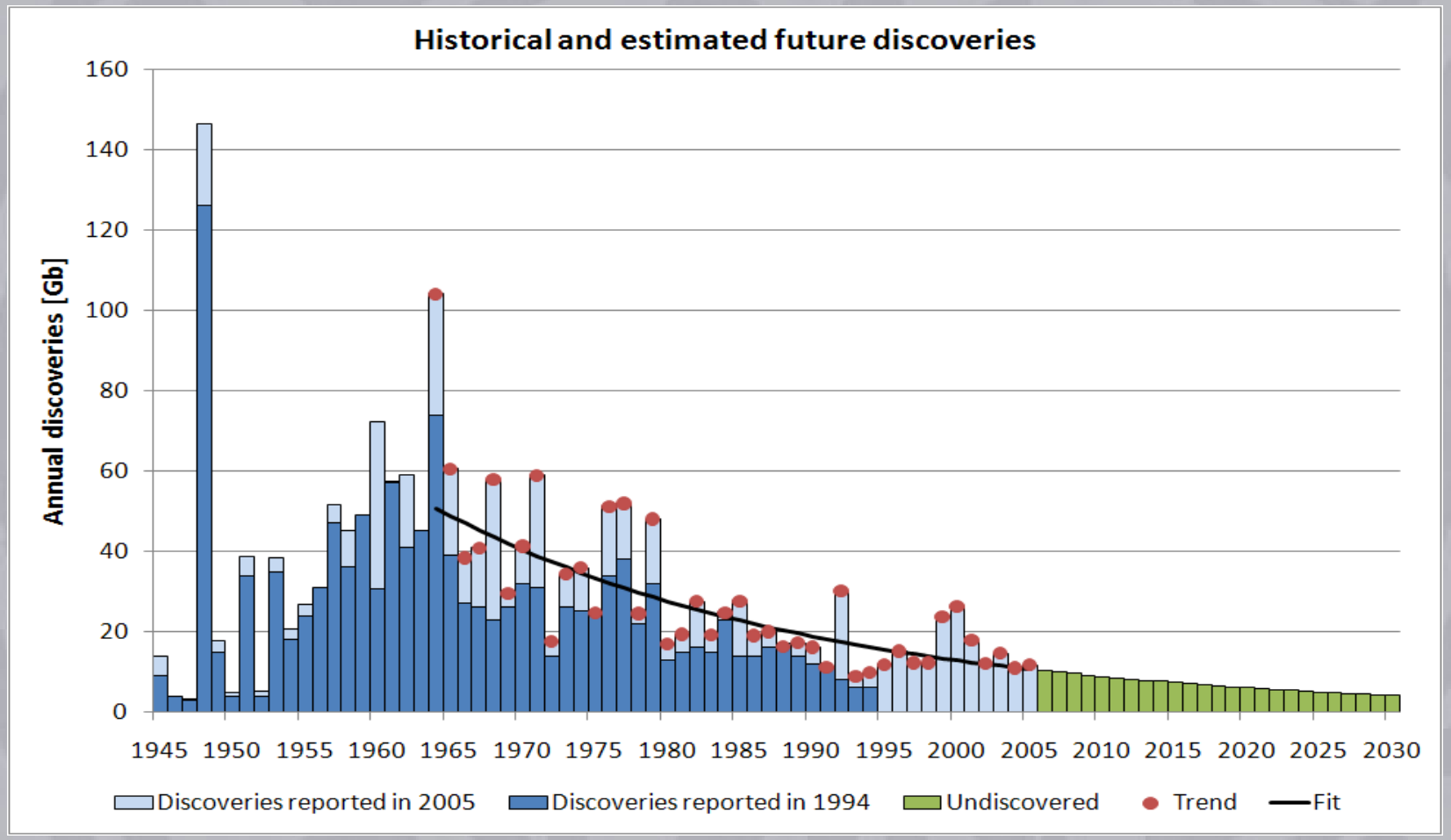
There must be places there we can find more oil
Oil endowment - USGS



UPPSALA UNIVERSITET

Kjell Aleklett

Discovery of oil

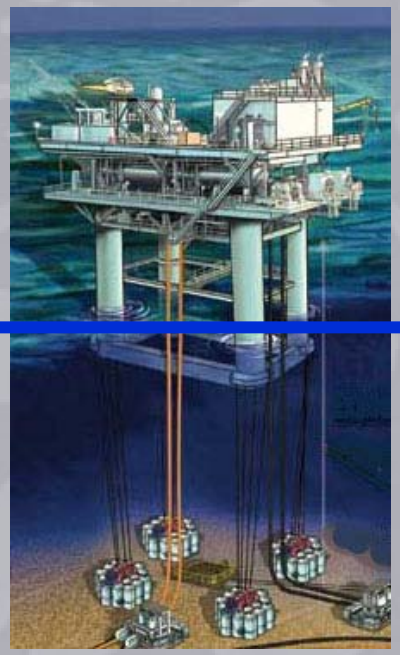


UPPSALA UNIVERSITET

Kjell Aleklett

Jack 2 – Kebnekaise and Mount Everest

8.848 meter



2.100 meter

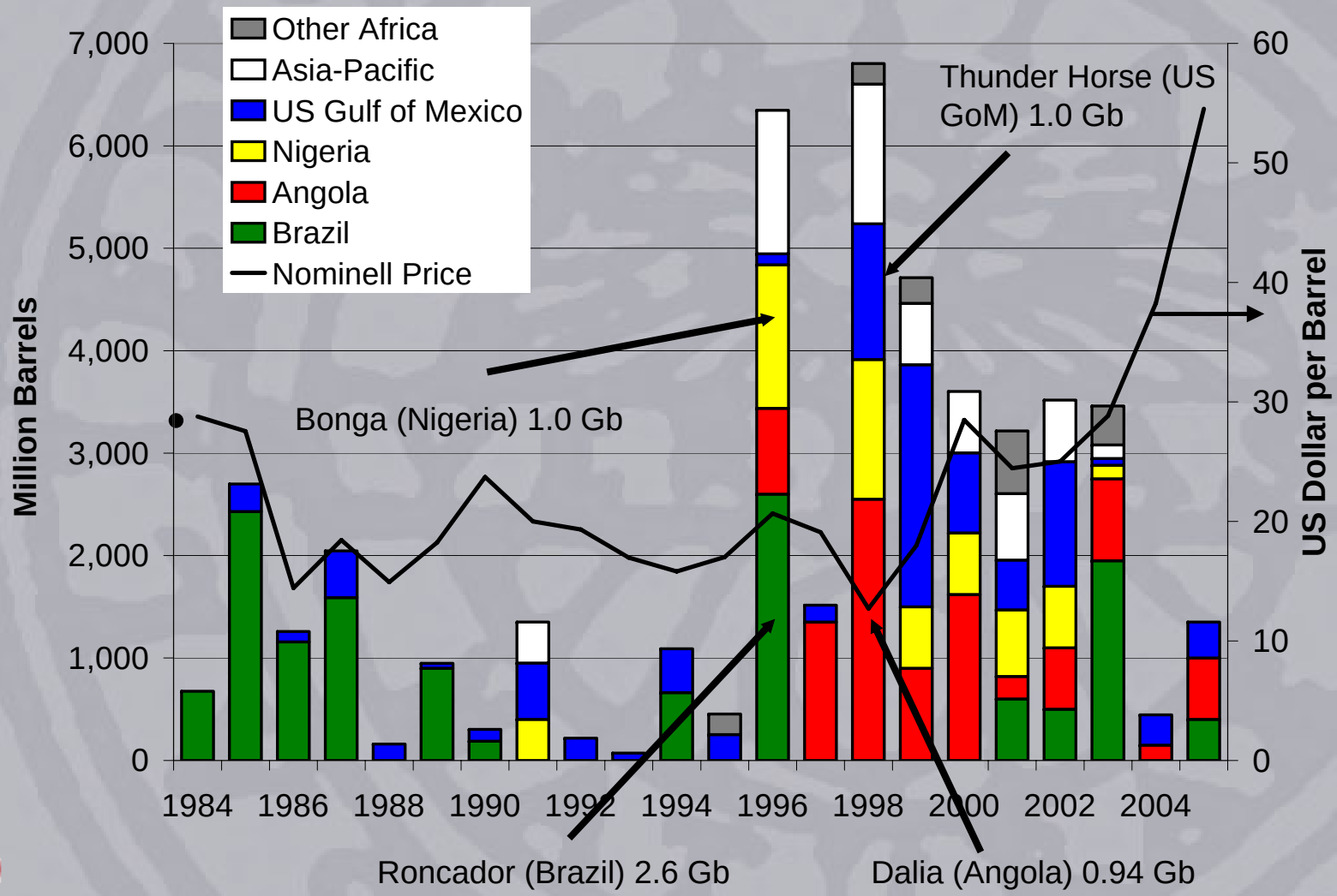
8.588 meter

Jack 2

UPPSALA UNIVERSITET

Kjell Aleklett

Deepwater Discoveries and the Largest Field per Region

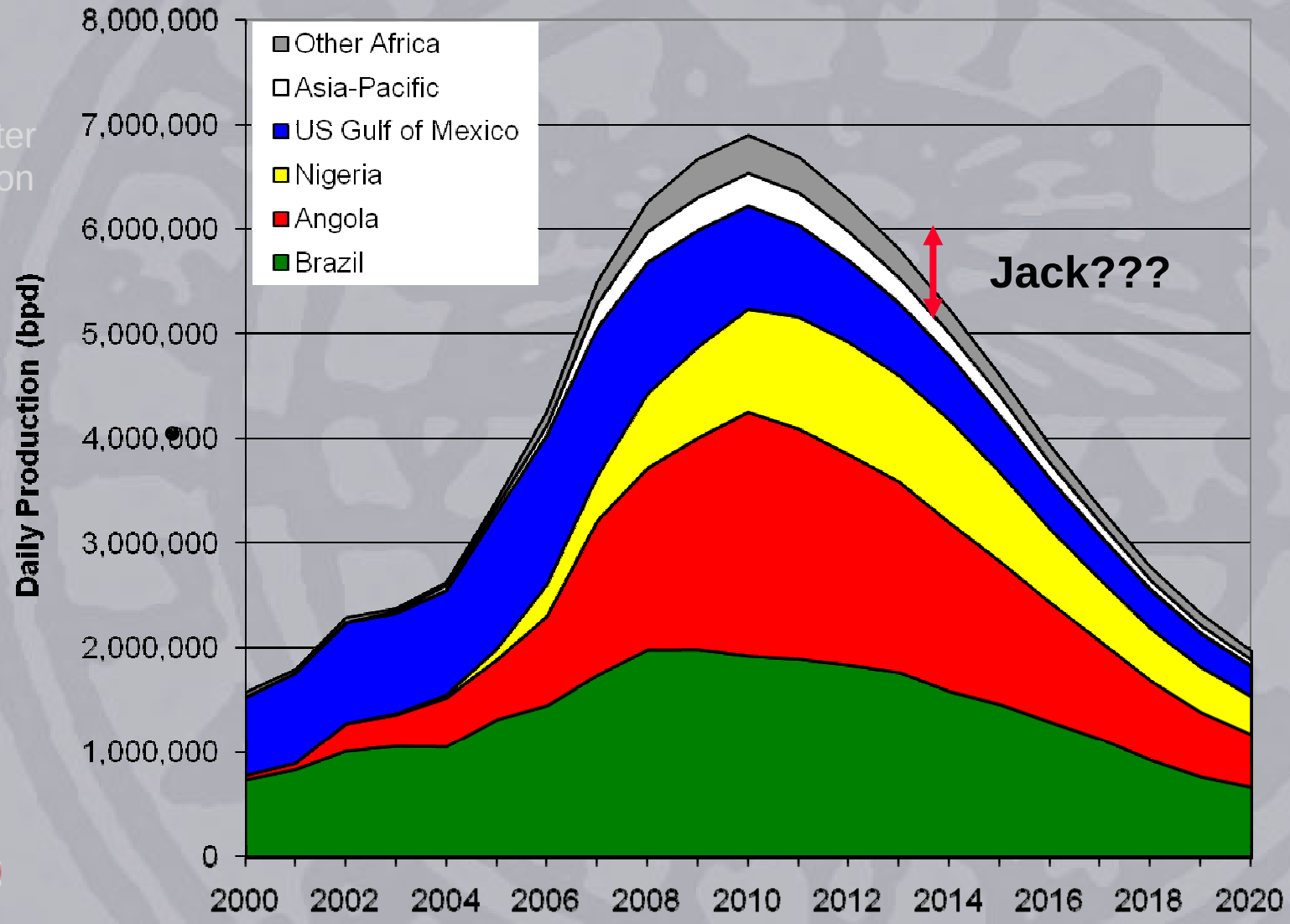


UPPSALA UNIVERSITET

Kjell Aleklett

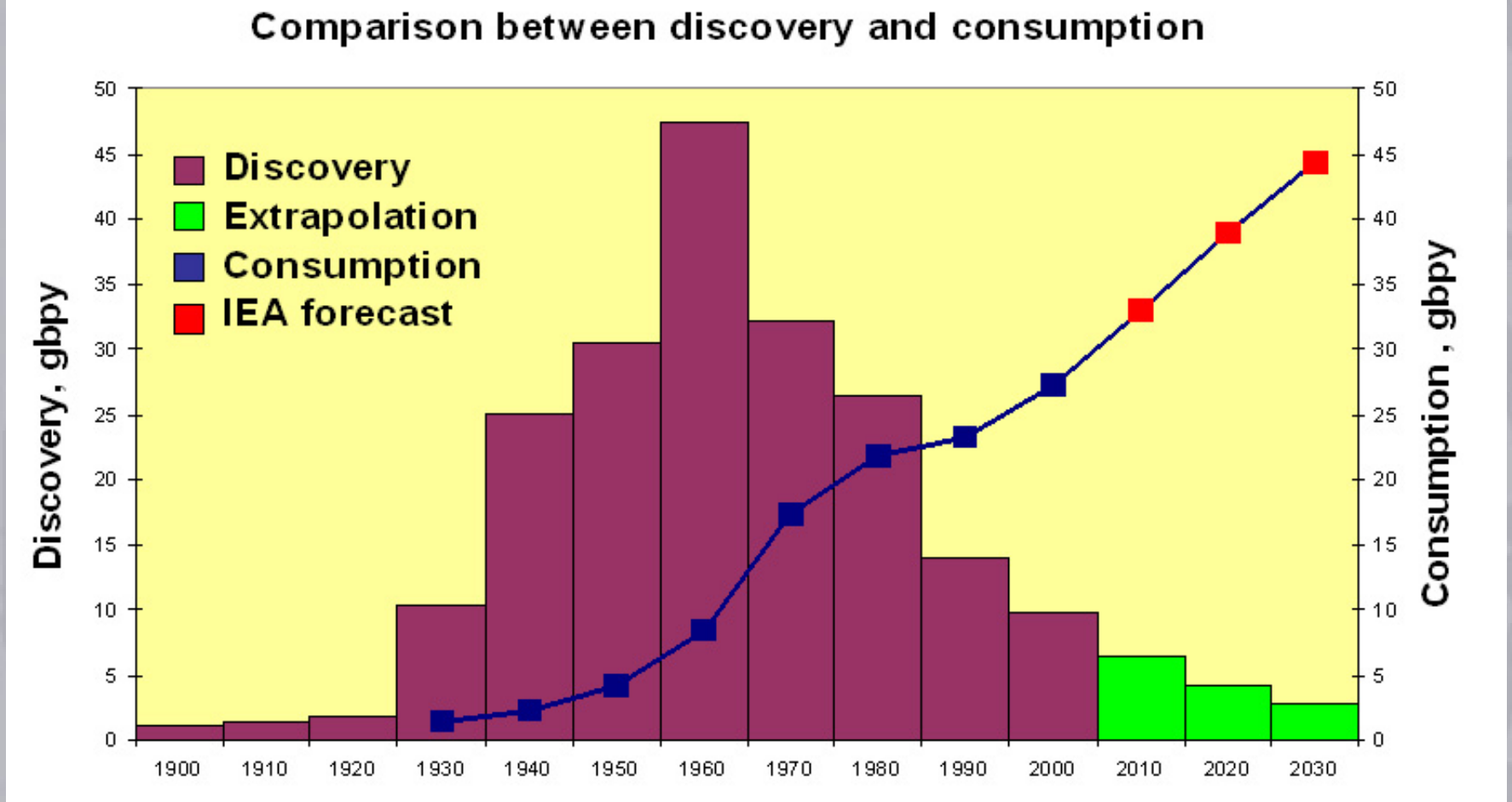
Deepwater Production Forecast

Deepwater Production



UPPSALA UNIVERSITET

Kjell Aleklett

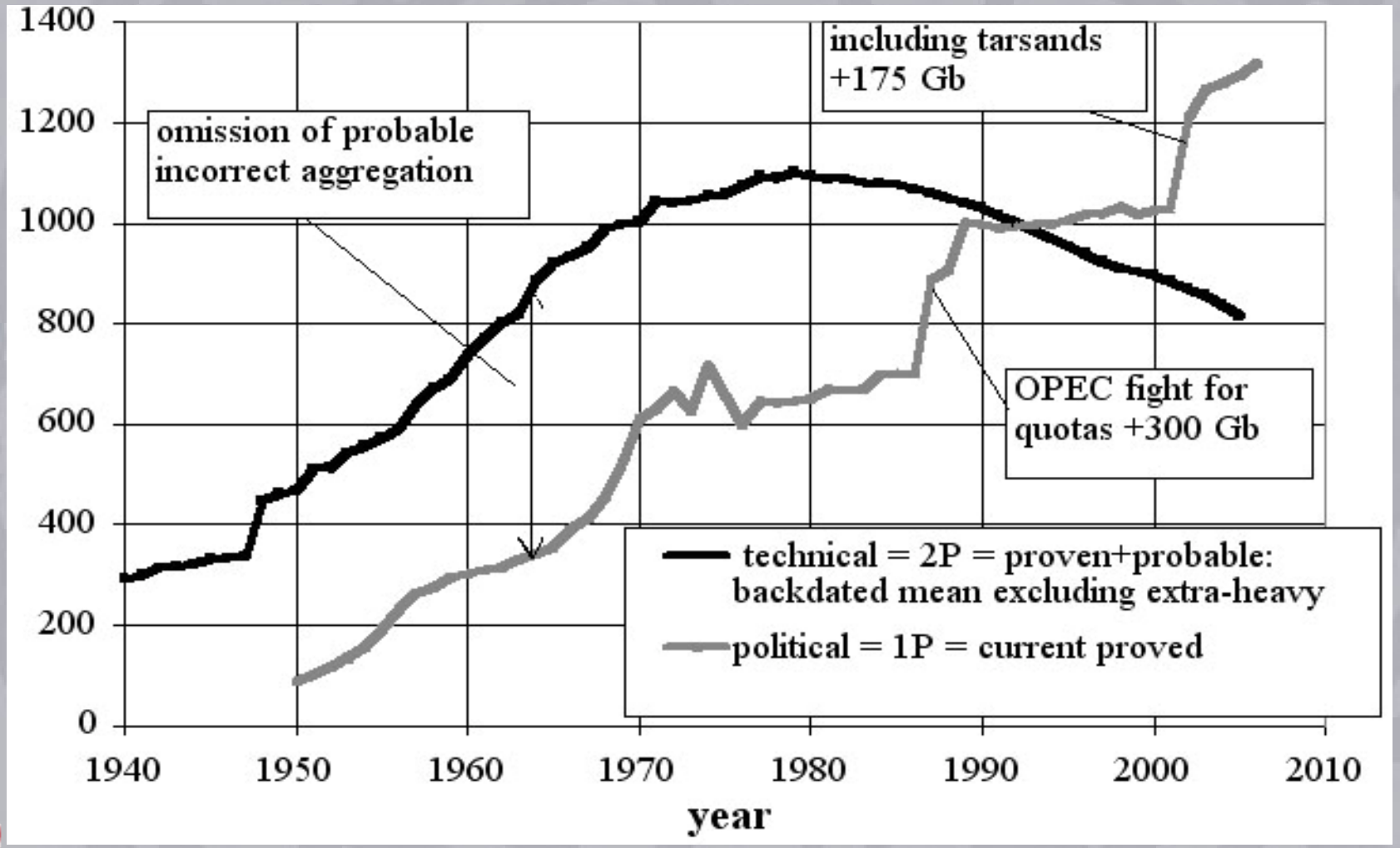


New discoveries from 1995 till 2025 is 100 billion barrels found and 100 billion barrels expected to be found. USGS mean prediction for the same time period is 649 billion barrels.

UPPSALA UNIVERSITET

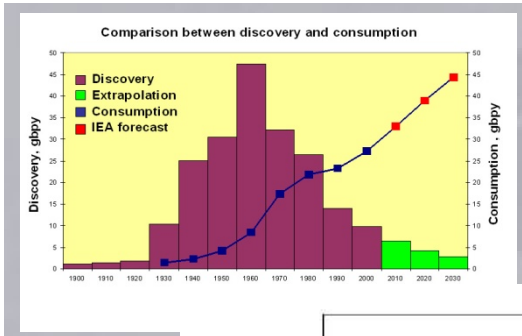
Kjell Aleklett

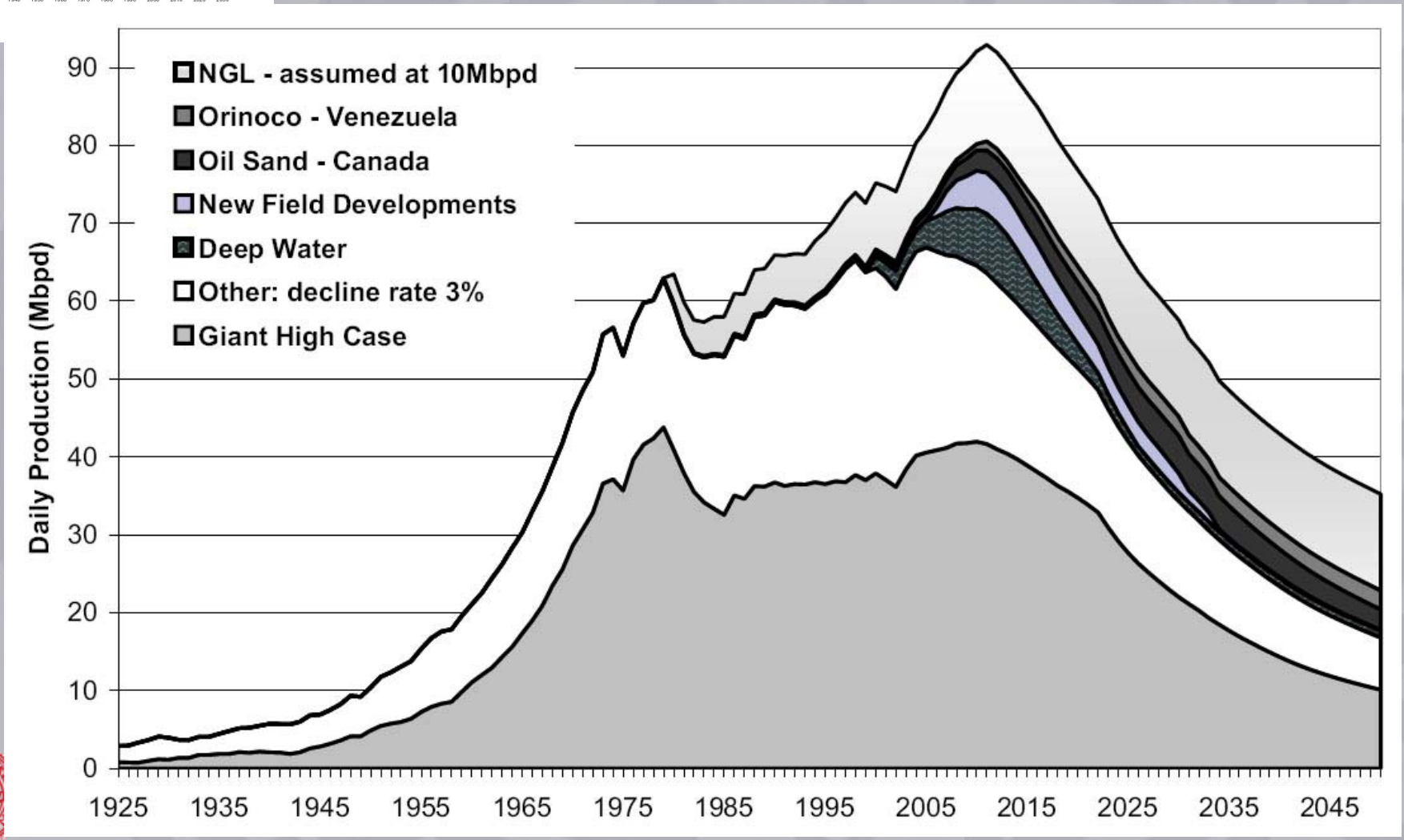
Global crude oil reserves



UPPSALA
UNIVERSITET

Kjell Aleklett





UPPSALA UNIVERSITET

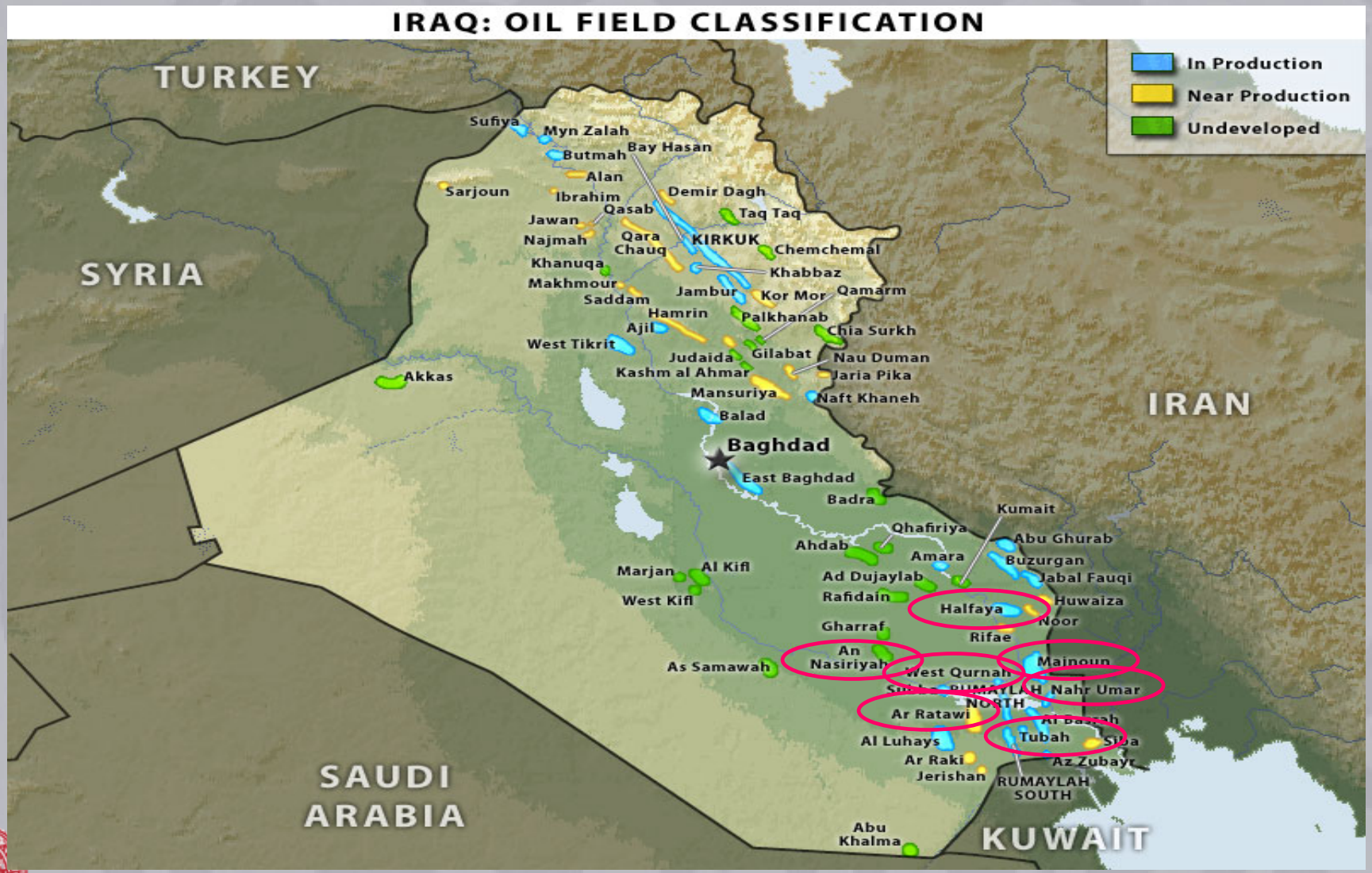
Kjell Aleklett

Fields needed for the best case oil end game

Table 9.3: *Major field expansions, given in thousand barrels per day (kbpd) included in the best case scenario. Field production is assumed to be increased gradually.*

Field	Country	Peak Level [kbpd]	Year of Peak	Comments
Tengiz	Kazakhstan	825	2012	
Northern fields	Kuwait	900	2013	Much delayed project finally in progress
Majnoon	Iraq	1000	2018	Gradual expansion, reaching 600 kbpd 2012
West Qurnah	Iraq	550	2015	
Halfayah	Iraq	250	2014	Re-development of old field
Nahr-Umr	Iraq	500	2017	Re-development of old field
Nasiryah	Iraq	300	2016	Re-development of old field
Zakum Upper	Abu Dhabi	700	2013	Low pressure and poor porosity reservoir
Ratawi	Iraq	200	2013	Re-development of old field
Tuba	Iraq	180	2015	Re-development of old field

Best case Oil fields in Iraq

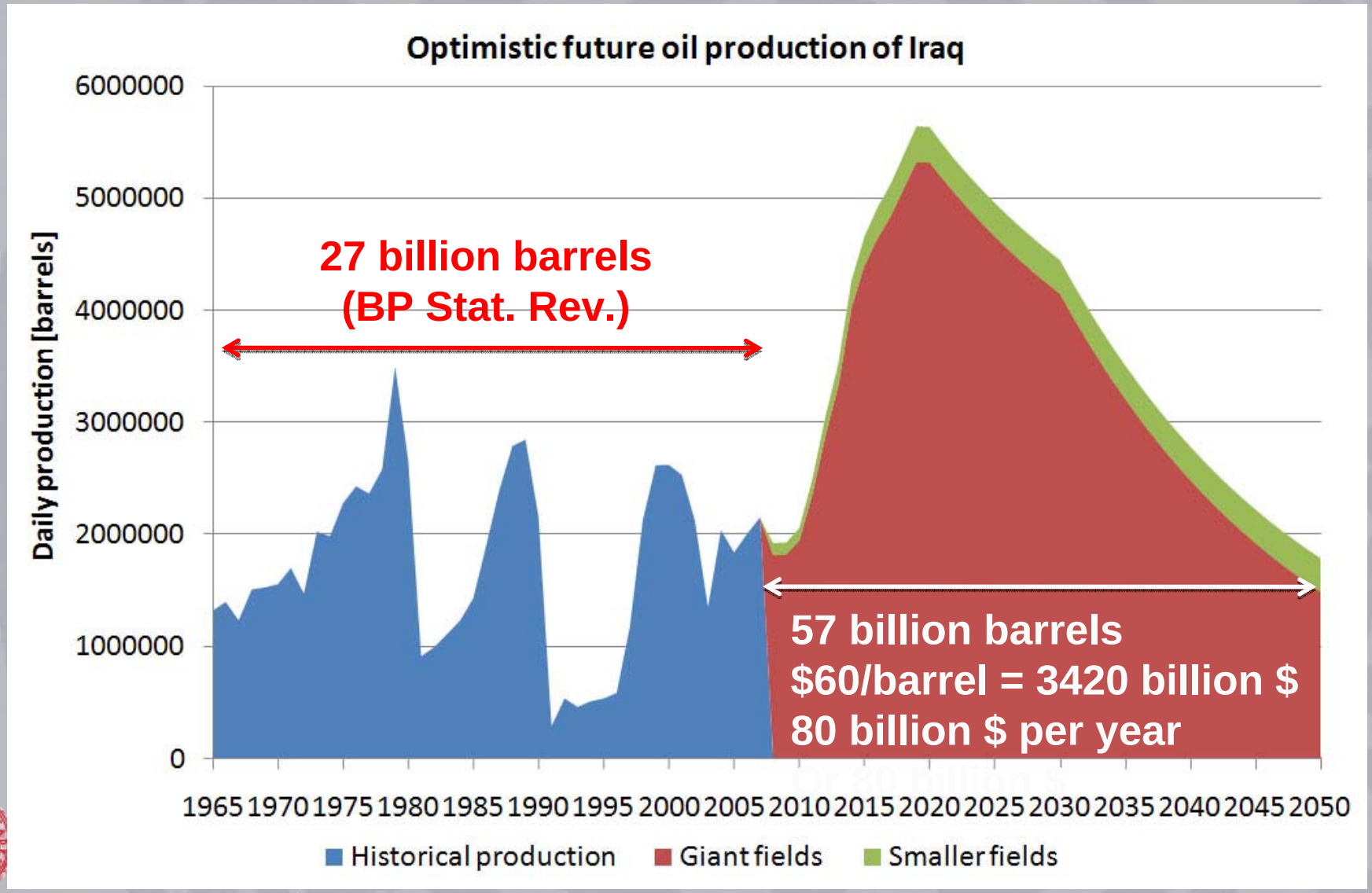


UPPSALA UNIVERSITET

Source: Strategic Forecasting, Inc

Kjell Aleklett

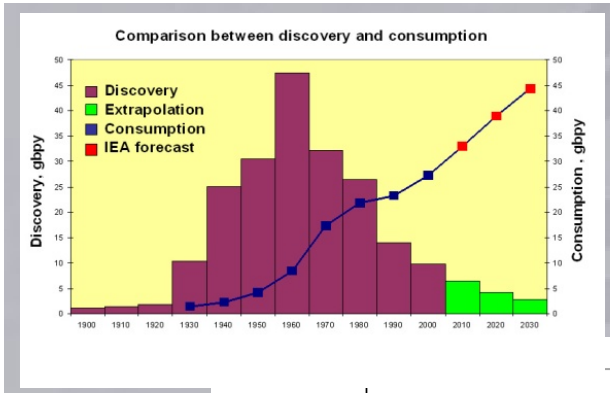
Future Oil Production of Iraq



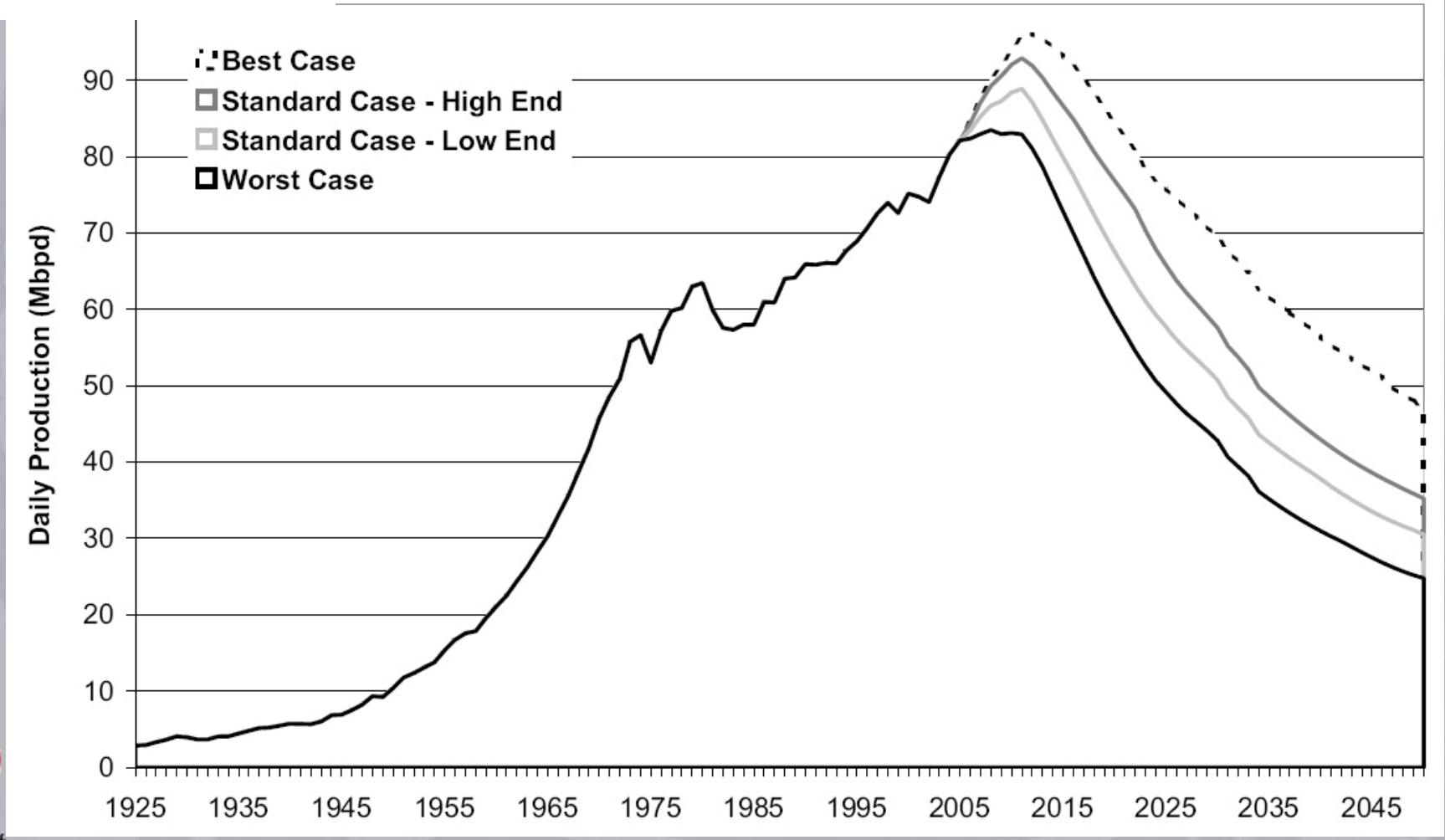
UPPSALA UNIVERSITET

Future oil production in Iraq (Uppsala GES)

Kjell Aleklett



Uppsala Giant Oilfield Model

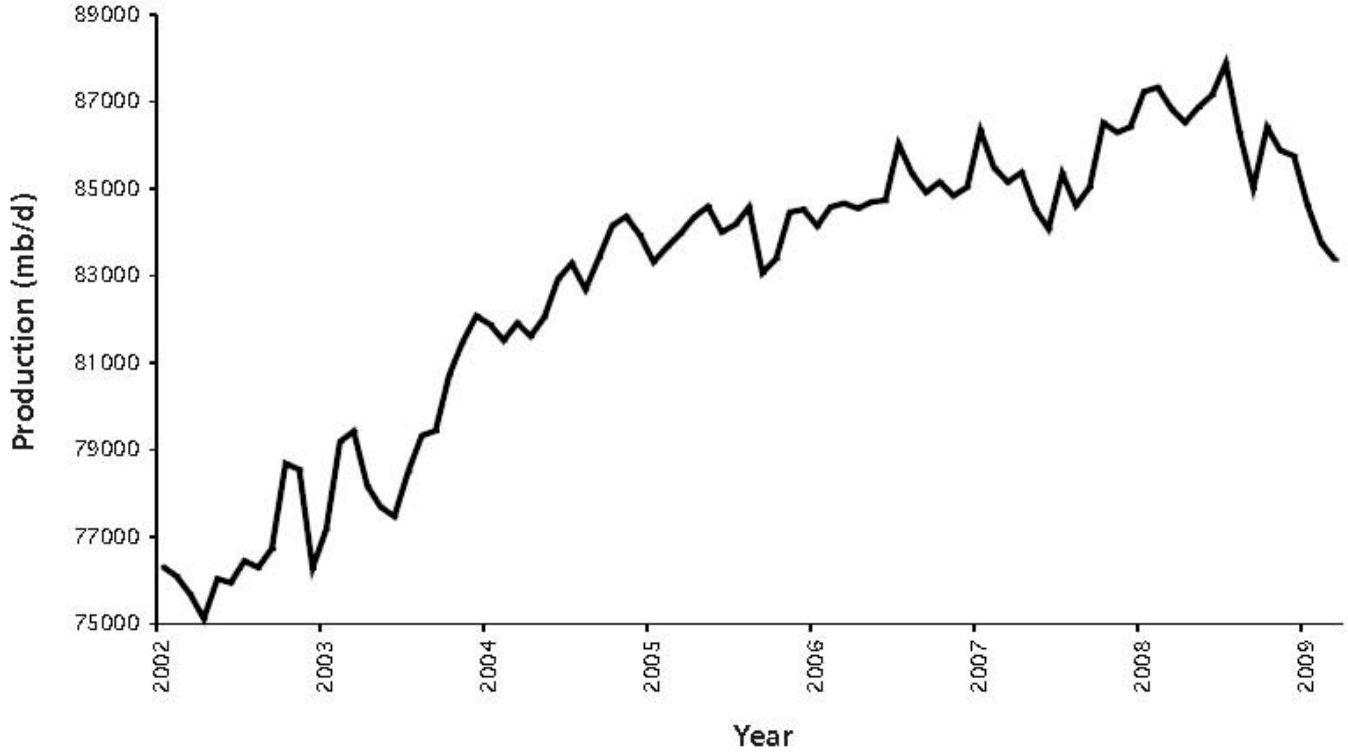


UPPSALA UNIVERSITET

Kjell Aleklett

Global oil production

Figure 1.1 World total liquids production - January 2002 to March 2009



Source: IEA

Note: Includes crude oil, condensate, natual gas liquids, refinery gains, oil sands, heavy oil, oil shales, coal-based and natural gas-based oil substitutes and methane-based blending components.

UPPSALA UNIVERSITET

UPPSALA UNIVERSITET

Kjell Aleklett

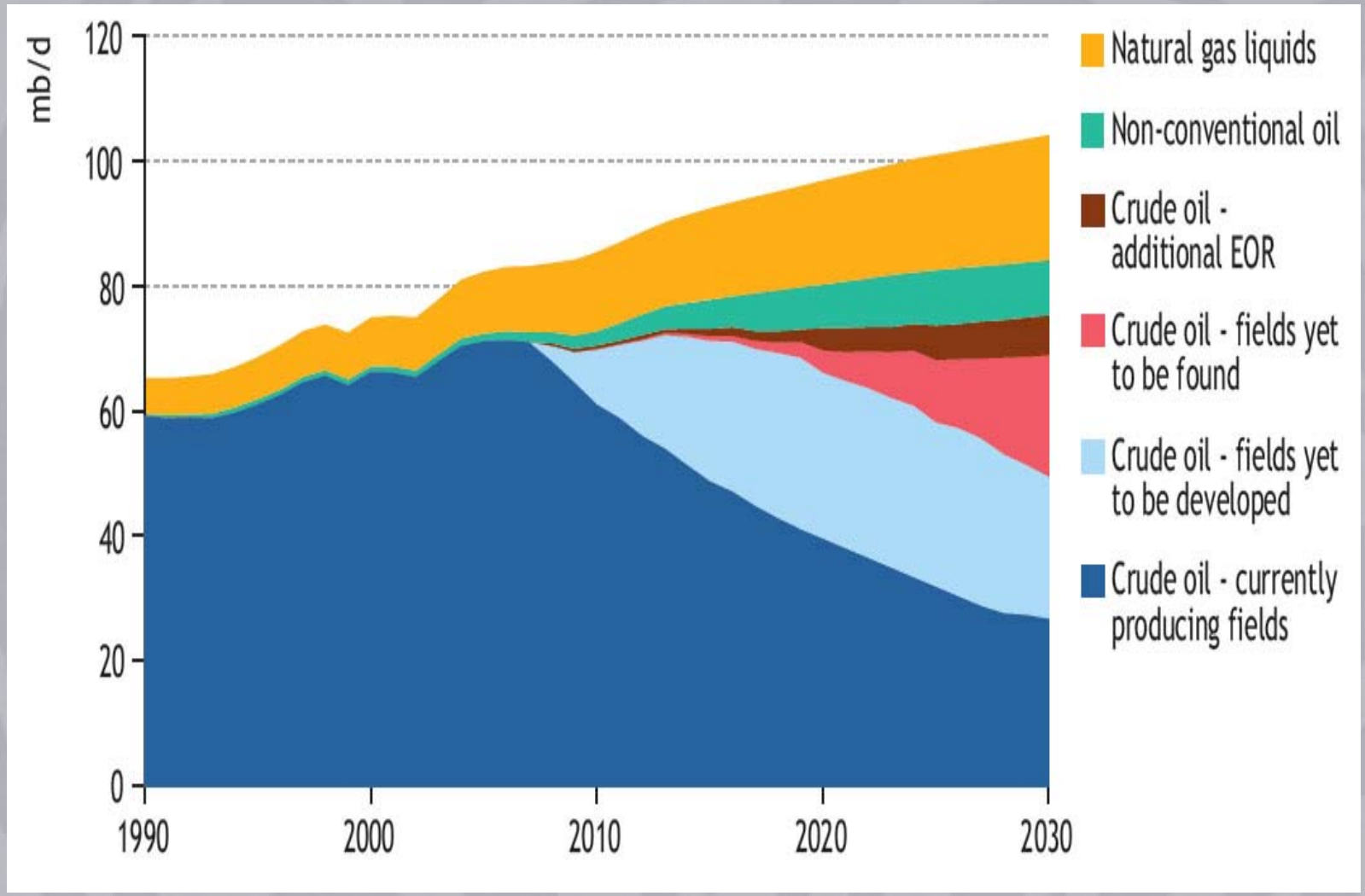
IEA, World Energy Outlook 2008, WEO 2008

WEO 2008 was released on November 12th.
On page 51 the IEA states that

"the results of these analyses [prospects for oil and gas production] are intended to provide policy makers, investors and end users with a rigorous quantitative framework for assessing likely future trends in energy markets".

UPPSALA UNIVERSITET

IEA - World Energy Outlook 2008

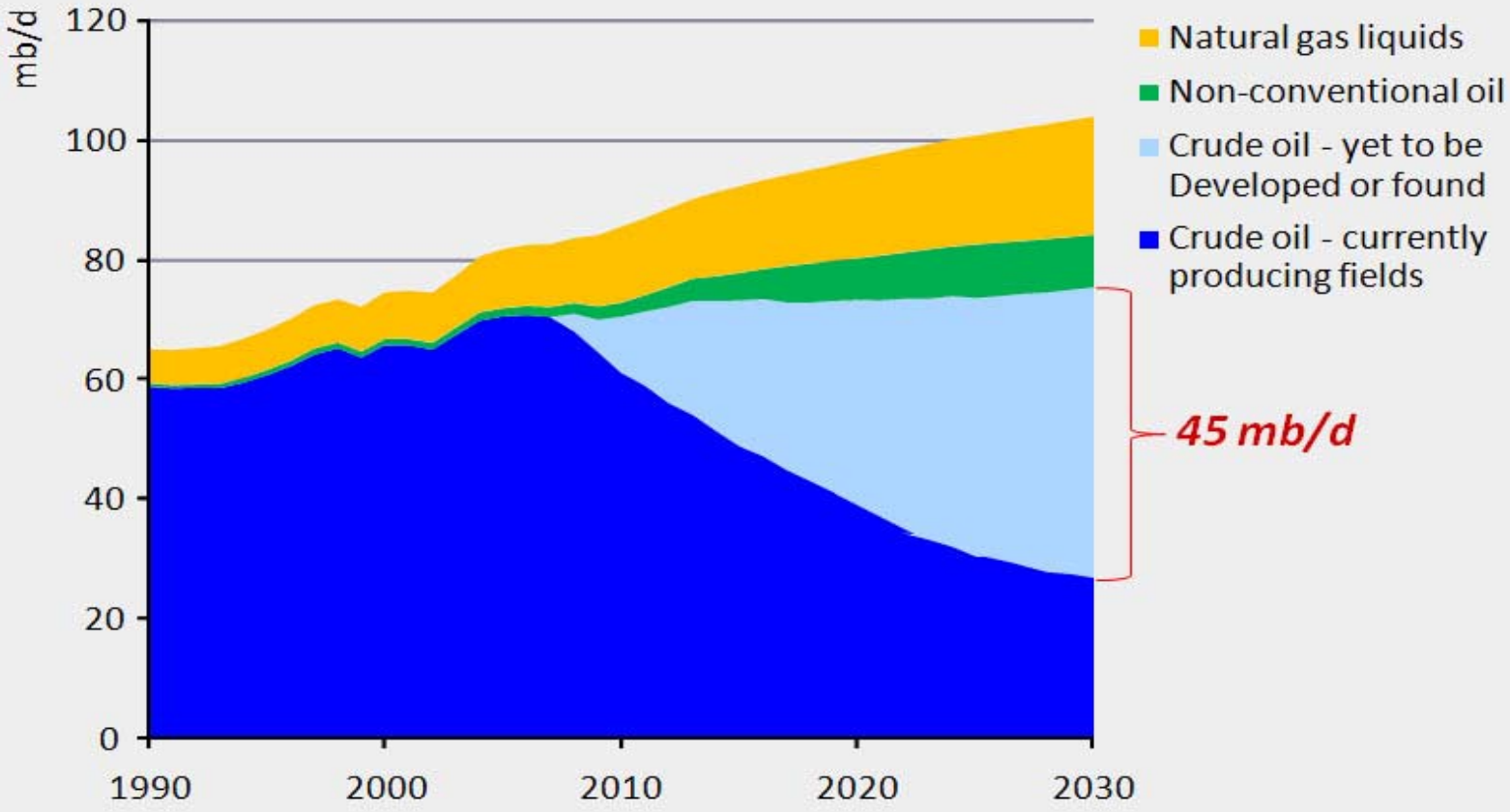


UPPSALA UNIVERSITET

Kjell Aleklett

World oil production by source in the Reference Scenario

World Energy Outlook 2008



Even if oil demand was to remain flat to 2030, 45 mb/d of gross capacity – roughly four times the capacity of Saudi Arabia – would ne needed just to offset decline from existing fields.

Energy Policy 37 (2009) 2262–2272

Contents lists available at ScienceDirect

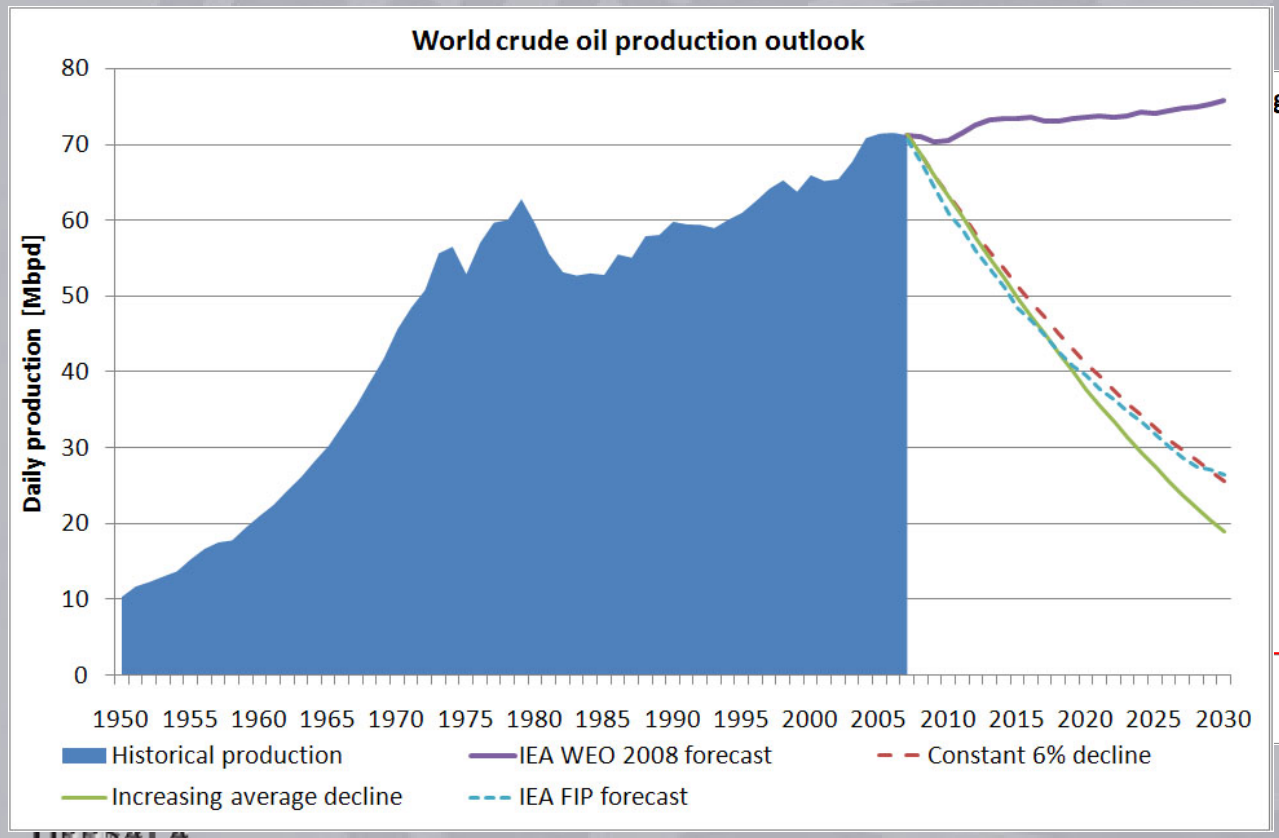
Energy Policy

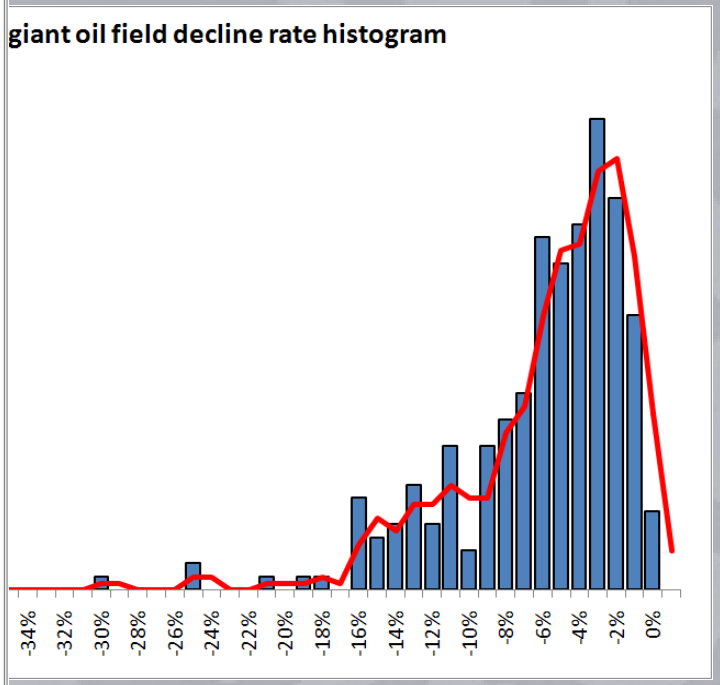
journal homepage: www.elsevier.com/locate/enpol

Giant oil & gas field research at Uppsala University, Sweden

Giant oil field decline rates and their influence on world oil production

Mikael Höök [a,*], Robert Hirsch [b], Kjell Aleklett [a]





UPPSALA UNIVERSITET

Kjell Aleklett

Energy Policy 37 (2009) 2262–2272

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Giant oil & gas field research at Uppsala University, Sweden

Giant oil field decline rates and their influence on world oil production

Mikael Höök [a,*], Robert Hirsch [b], Kjell Aleklett [a]

Depletion: An assessment of the evidence for a near-term peak in global oil production

Table 3.4 Comparison of global decline rate studies

	IEA	Hook *et al.*	CERA
No. of fields in sample	651 (54 supergiant, 263 giant, 334 large)	331 (all giant)	811 (400 large and above)
No. post-peak fields	580[1, 2]	261[3]	-
% of total production of crude oil in sample	~58%	~50%	~66%
Cumulative discoveries of crude oil in sample	1241 Gb	1130 Gb	1155 Gb
Definition of plateau	Production >85% of peak	Production >96% of peak	Production >80% of peak
Definition of onset of decline	After year of peak production	After last year of plateau	After last year of plateau
Production weighting	Cumulative production[4]	Annual production	Annual production

Source: IEA(2008), CERA (2008) and Höök, *et al.*(2009; 2008; 2009a; 2009b).

Notes:

1 101 fields in plateau (production >85% of peak), 117 fields in 'phase 1 decline' (production >50% of peak), 362 fields in 'phase 3' decline (production <50% of peak)

2 387 onshore, 264 offshore, 185 OPEC and 466 non-OPEC.

3 261 onshore, 214 offshore, 143 OPEC and 188 non-OPEC.

4 IEA weights by annual production when estimating historical trends in decline rates.

UPPSALA UNIVERSITET

Kjell Aleklett

Depletion rate of remaining reserves

$$d_{\delta t} = q_t / (R_0 - Q_t)$$

where

$d_{\delta t}$ = **depletion rate of remaining reserves**

q_t = **production at time t**

R_0 = **Initially present reserves or ultimate recoverable resources**

Q_t = **Cumulative up to time t**

Kjell Aleklett, Mikael Höök, Kristofer Jakobsson, Bengt Söderbergh,
The Peak of the Oil Age –
***reviewing the Reference Scenario World Oil Outlook in IEA World Energy Outlook 2008*,**
Energy Policy, submitted to Energy Policy

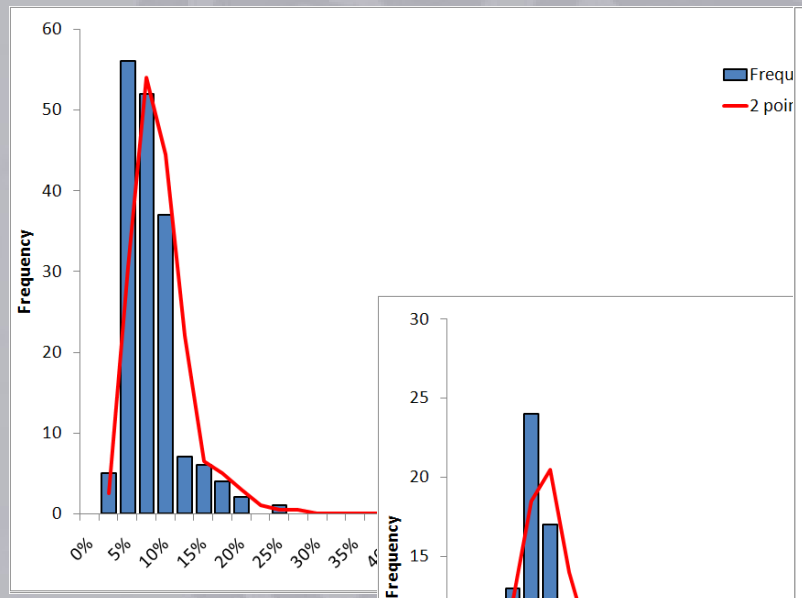
UPPSALA UNIVERSITET

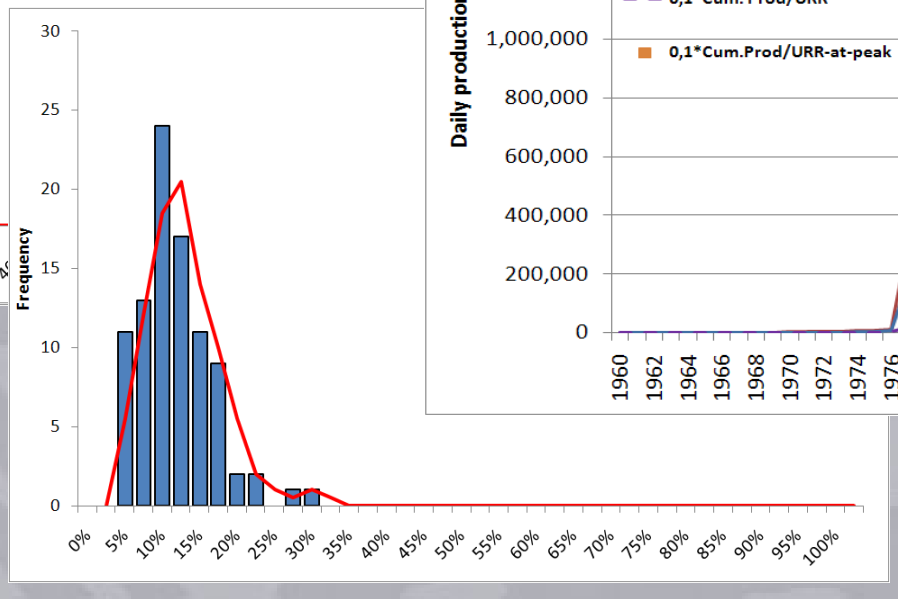
Giant oil & gas field research at Uppsala University, Sweden

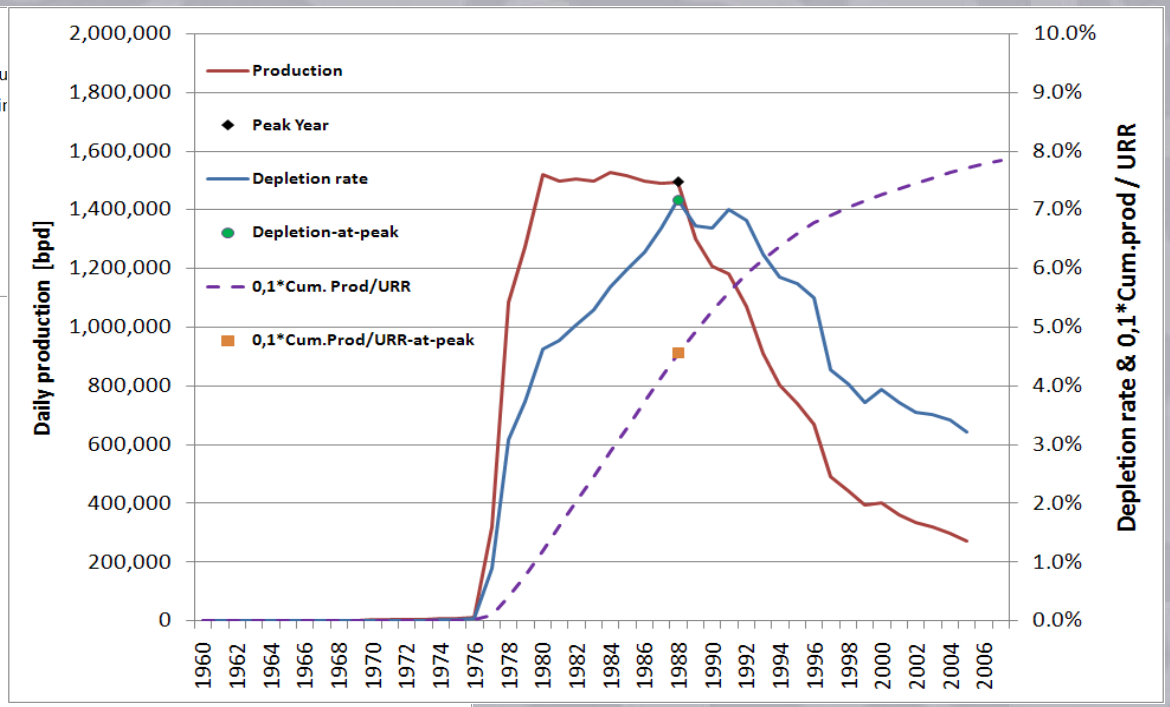
Accepted by Natural Resources Research
http://www.springer.com/journal/11053

The evolution of giant oil field production behaviour

Mikael Höök*, Bengt Söderbergh*, Kristofer Jakobsson*, Kjell Aleklett*



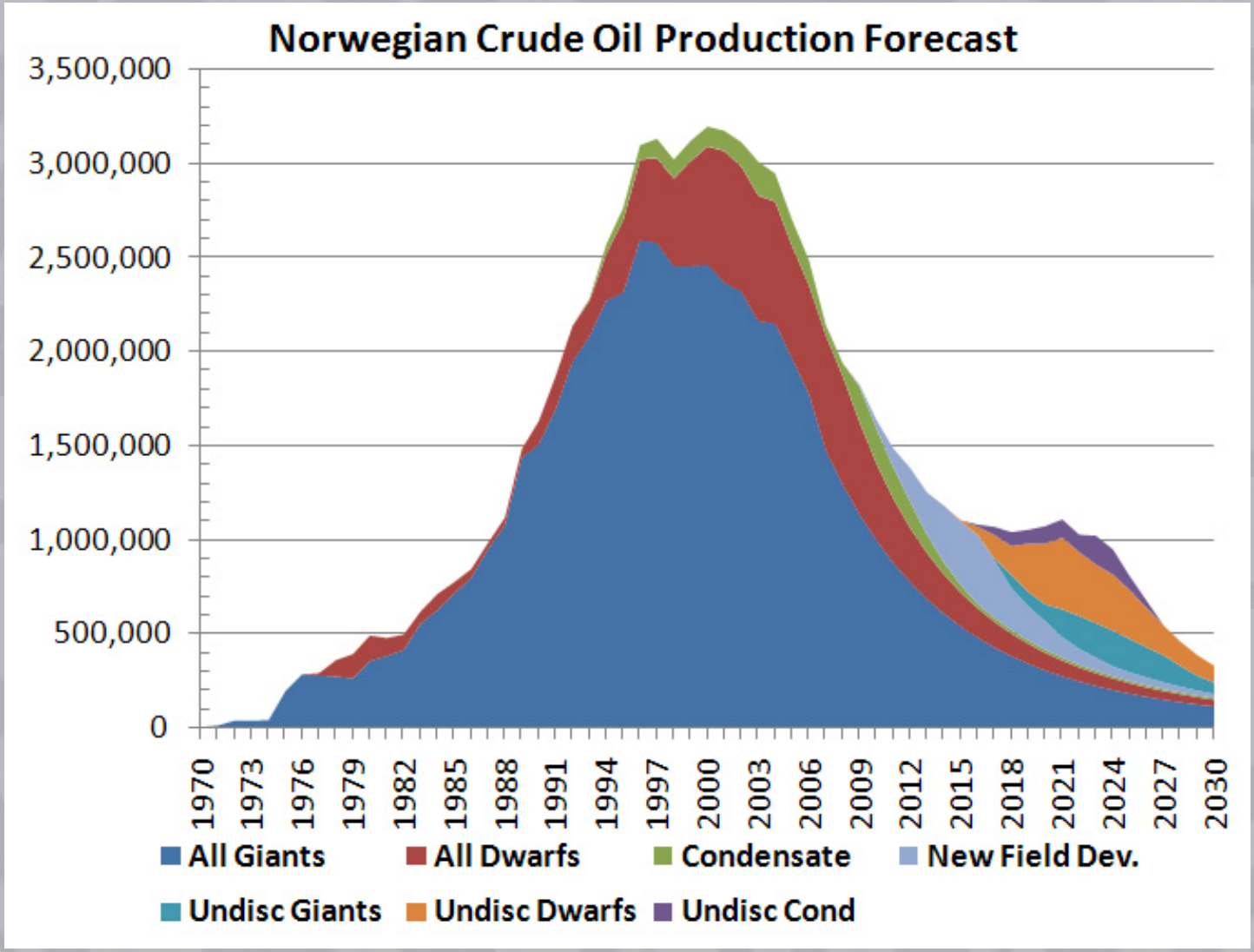




UPPSALA UNIVERSITET

Kjell Aleklett

The Norwegian Oil End Game

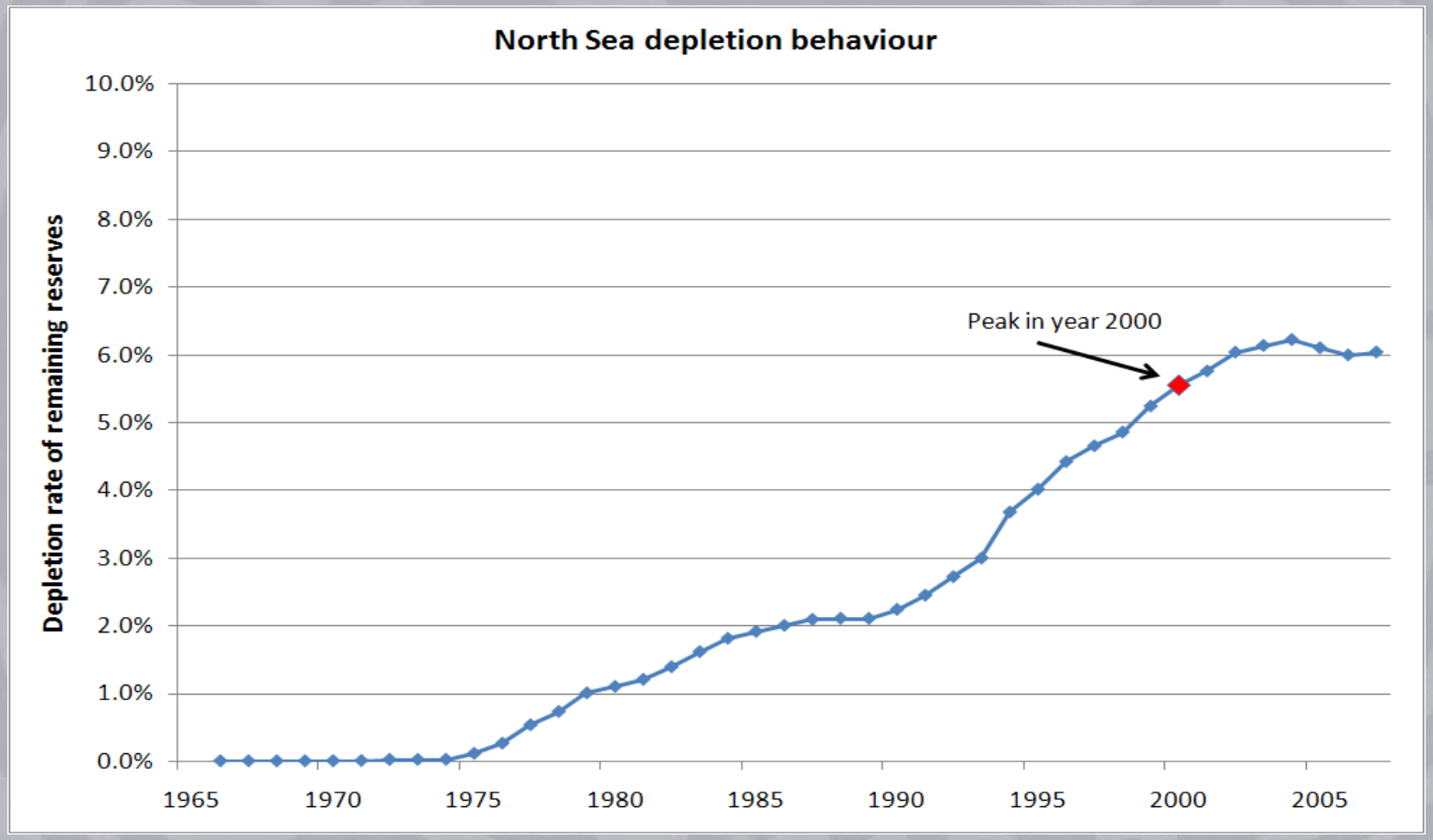


A field by field analysis with maximum discovery potential. As Norway uses 0.2 Mbpd the export in 2030 will be around 0.2 Mbpd

UPPSALA UNIVERSITET

Kjell Aleklett

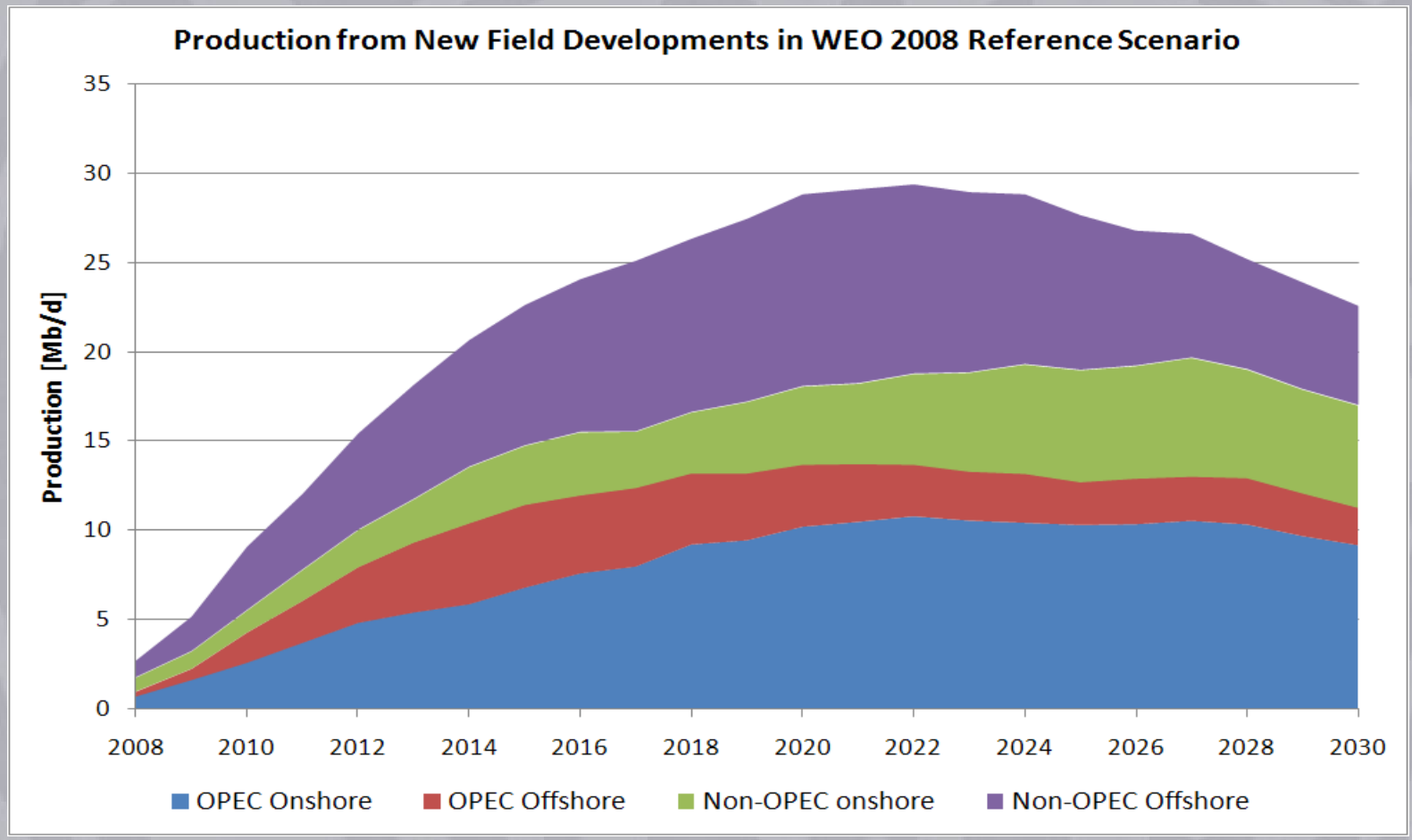
Depletion RR (d_δ) - North Sea



UPPSALA UNIVERSITET

Kjell Aleklett

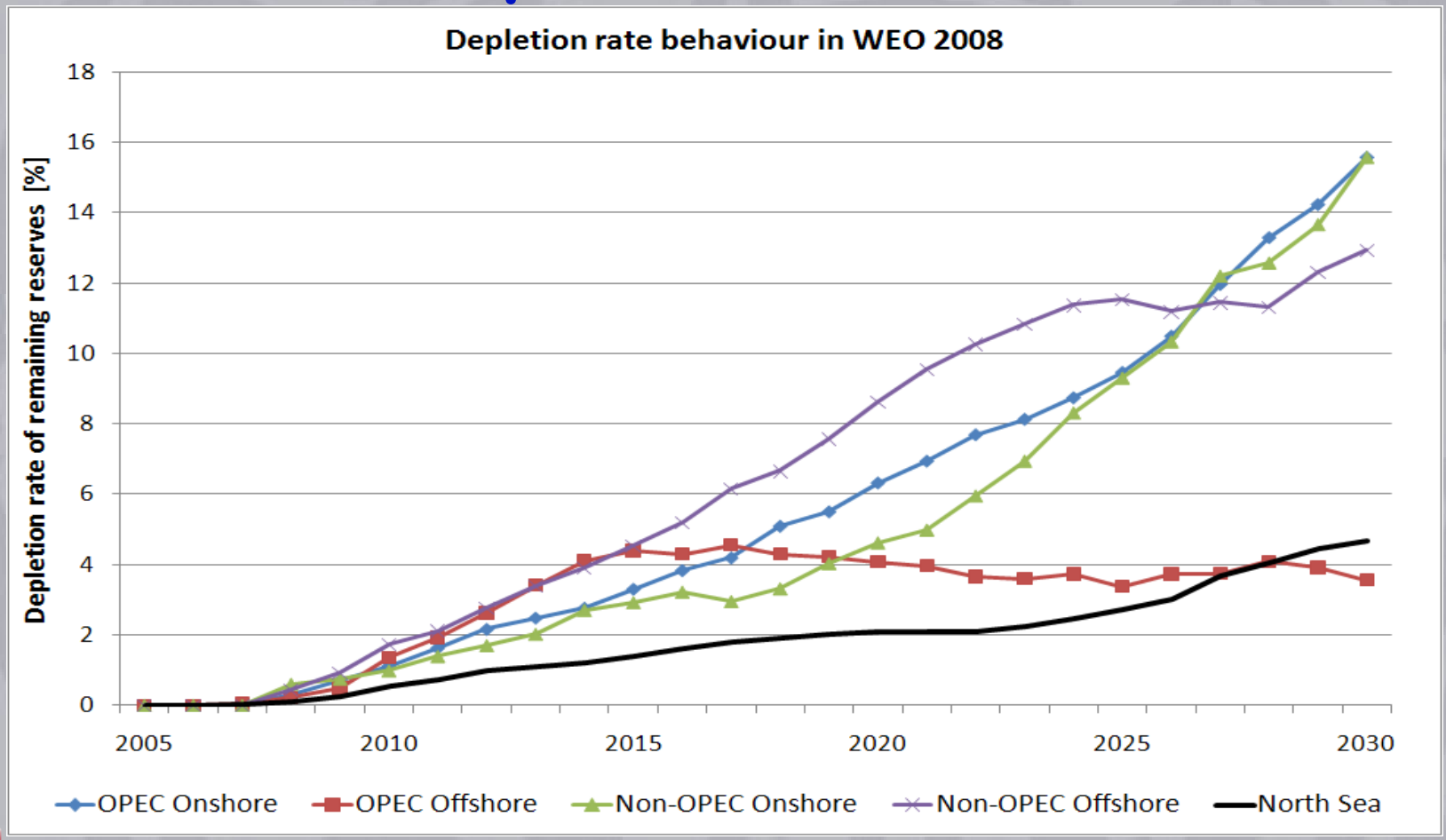
New field developments in WEO 2008 IEA, Economical limits



UPPSALA UNIVERSITET

Kjell Aleklett

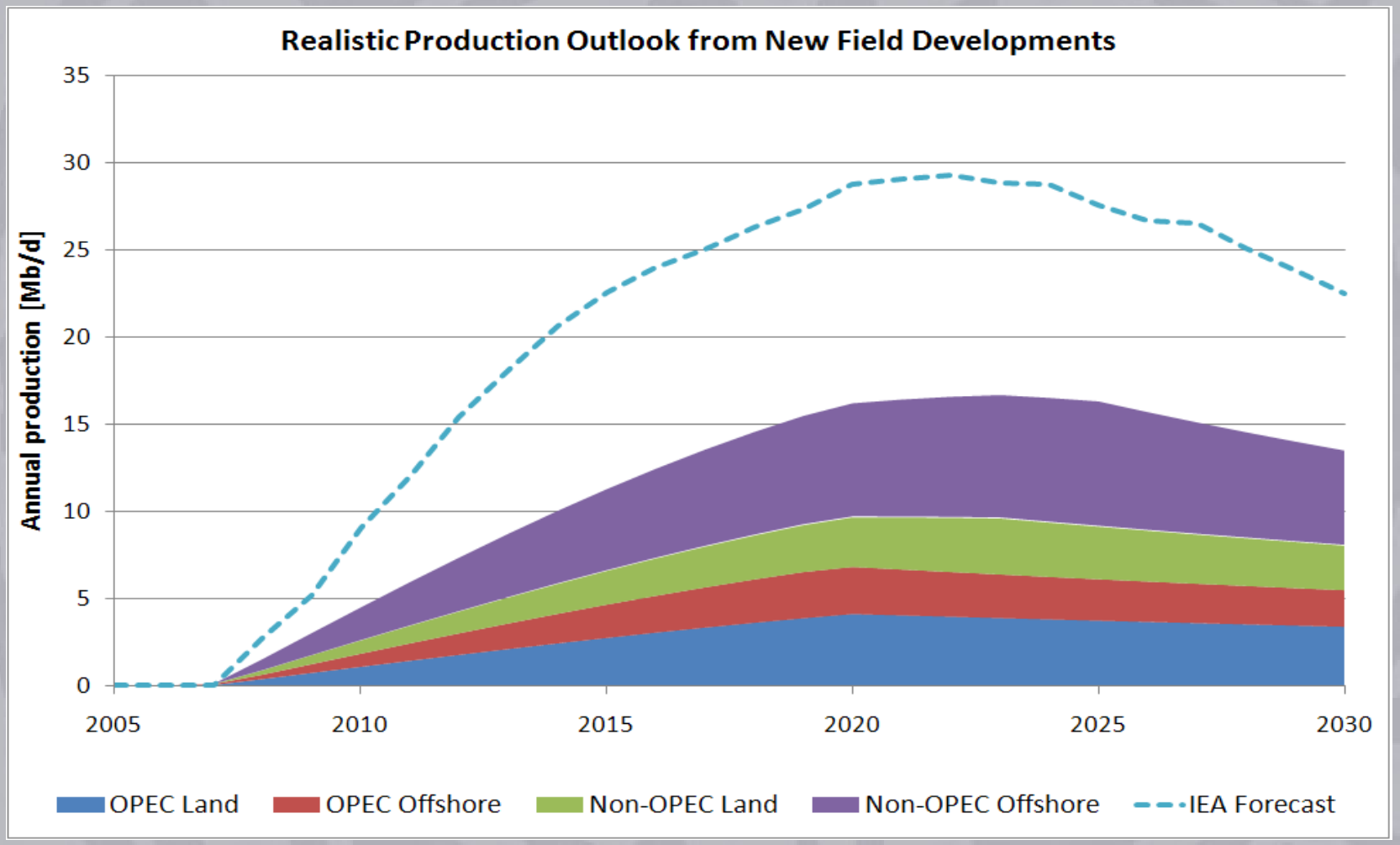
Depletion (d_δ) for fields to be developed in WEO 2008



UPPSALA UNIVERSITET

Kjell Aleklett

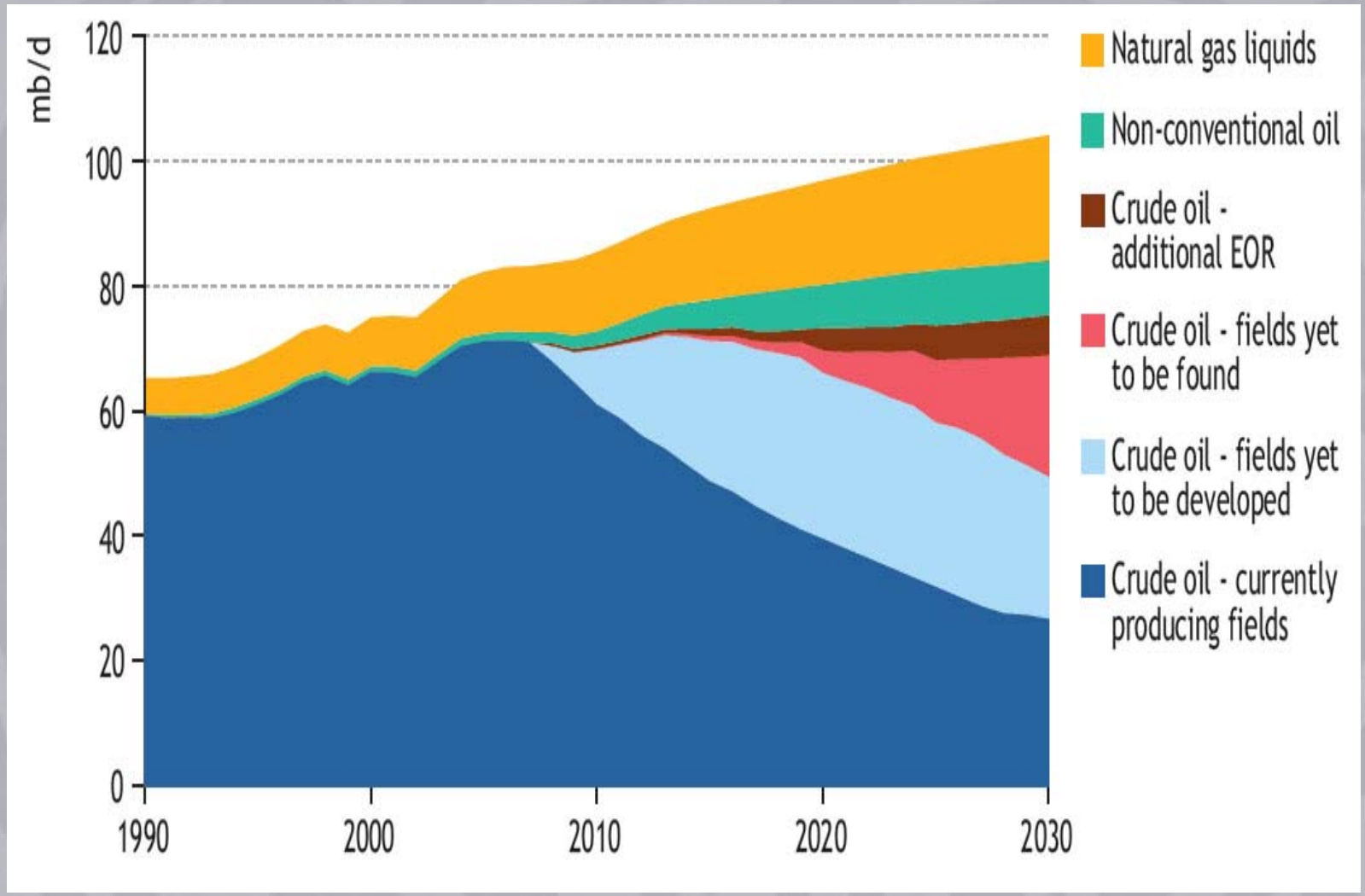
Production for fields to be developed with physical depletion rr (d_δ) limits



UPPSALA UNIVERSITET

Kjell Aleklett

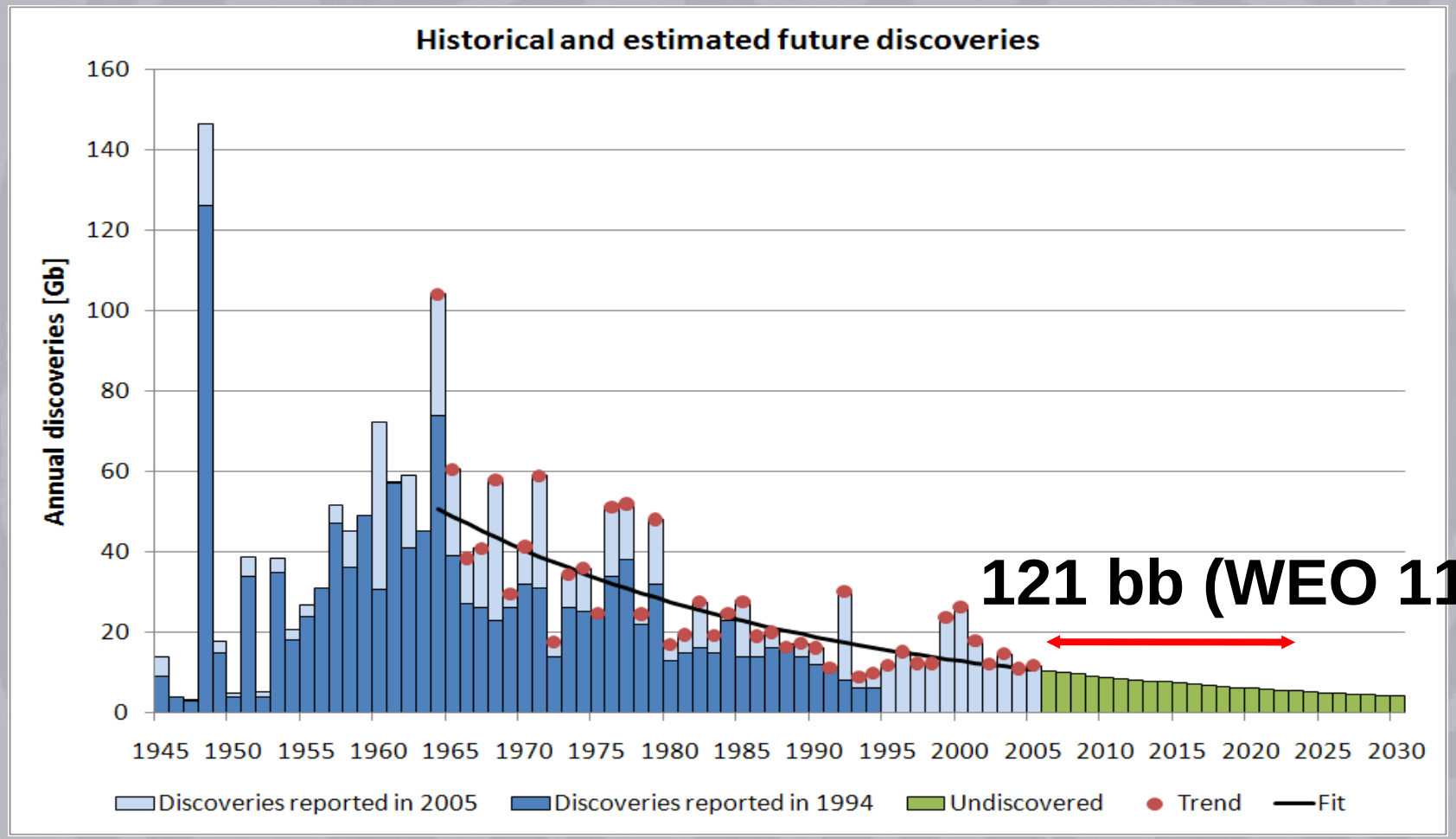
IEA - World Energy Outlook 2008



UPPSALA UNIVERSITET

Kjell Aleklett

Historical crude oil discovery
114 billion barrels is OK

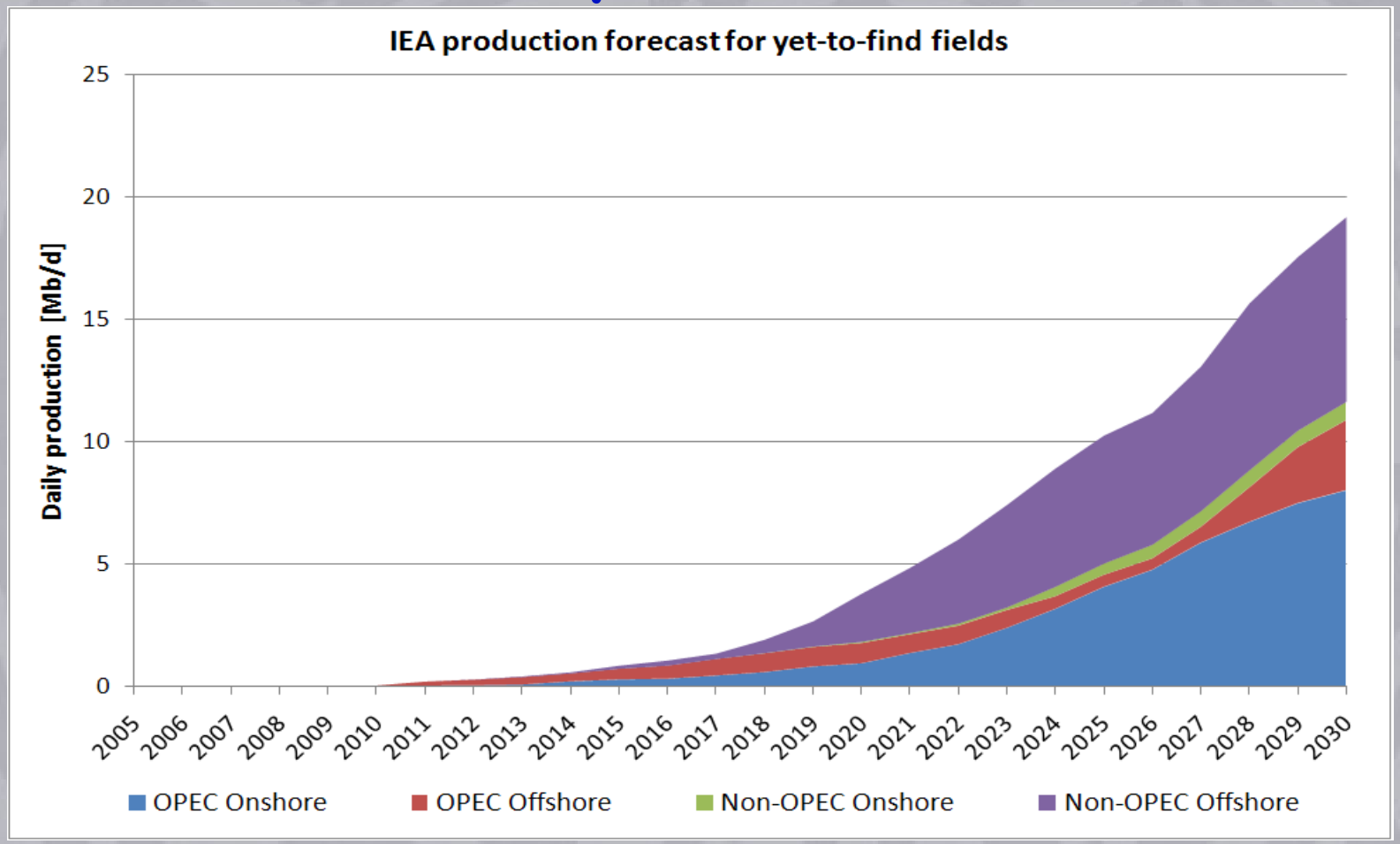


121 bb (WEO 114 bb)

UPPSALA UNIVERSITET

Kjell Aleklett

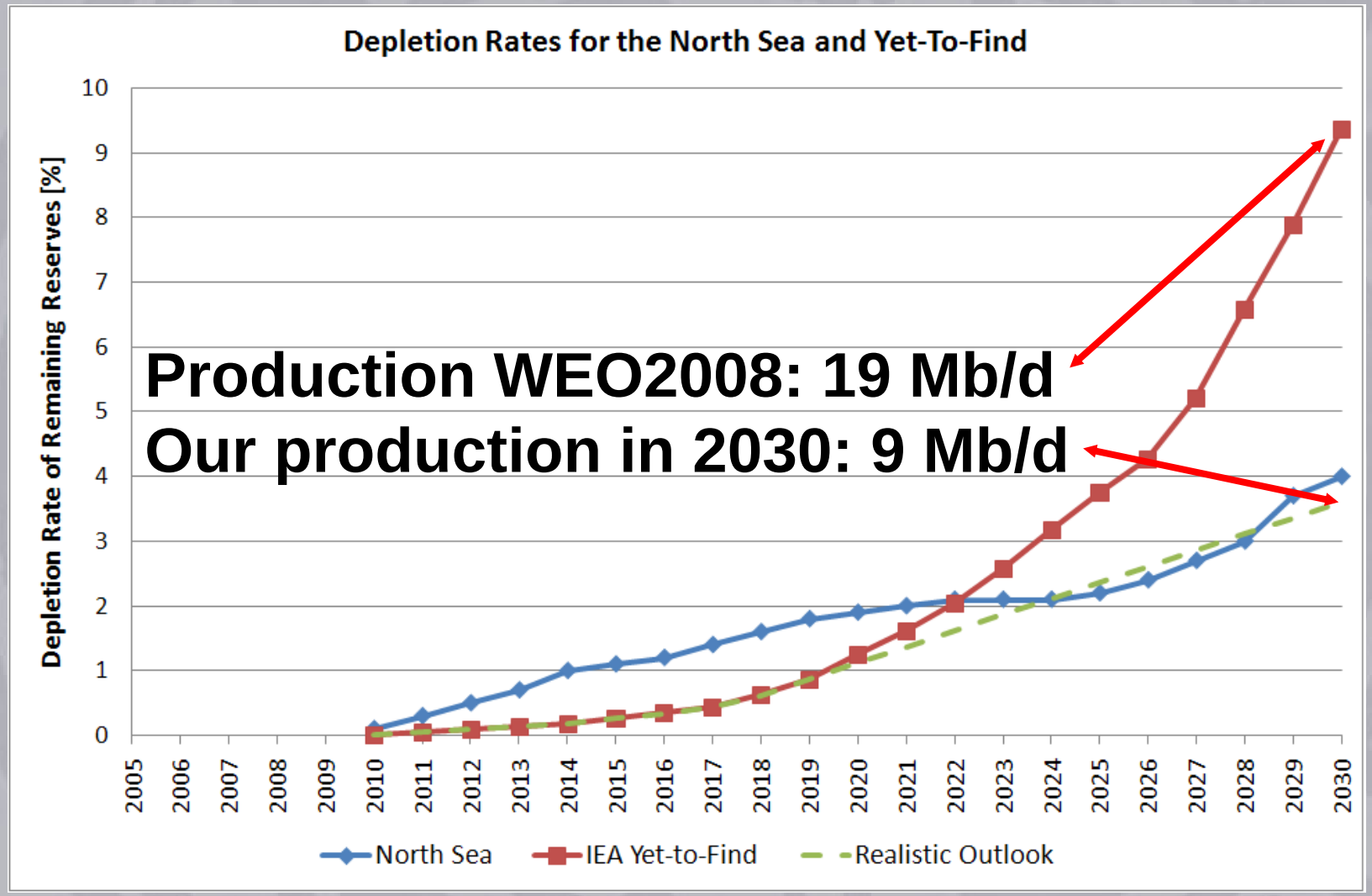
Production from Yet-to-find fields in WEO 2008, economical limits



UPPSALA UNIVERSITET

Kjell Aleklett

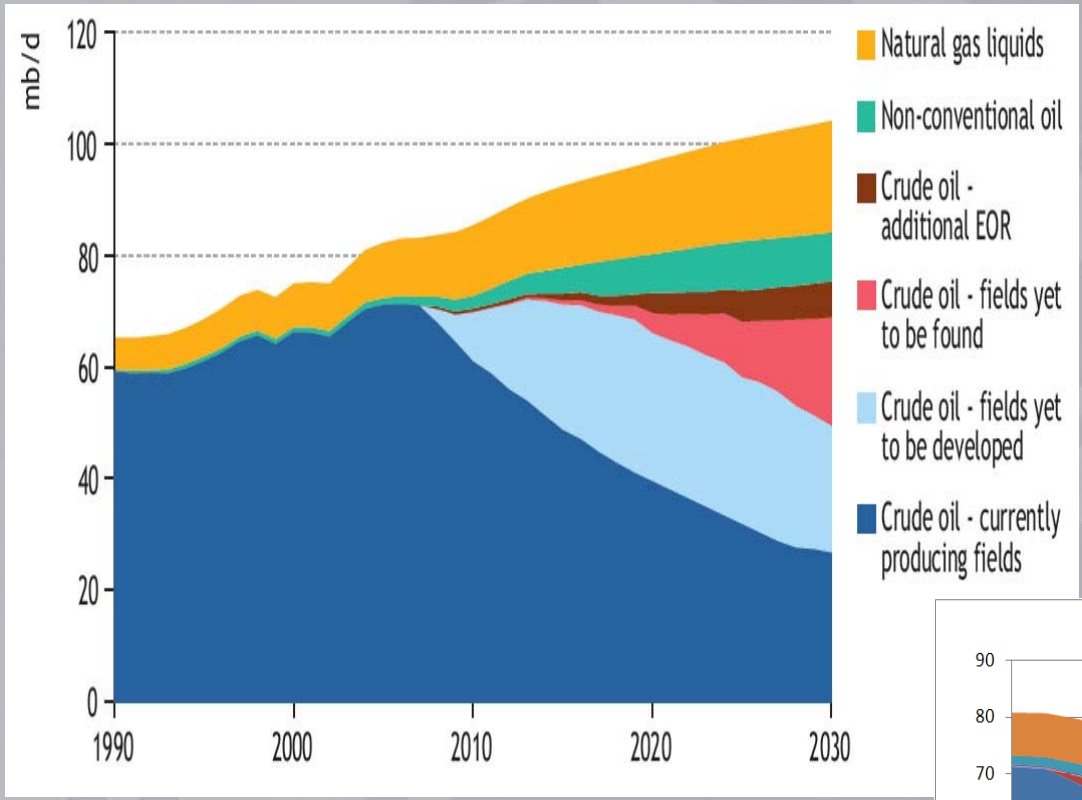
Depletion (d_δ) for fields Yet-To-Find in WEO 2008

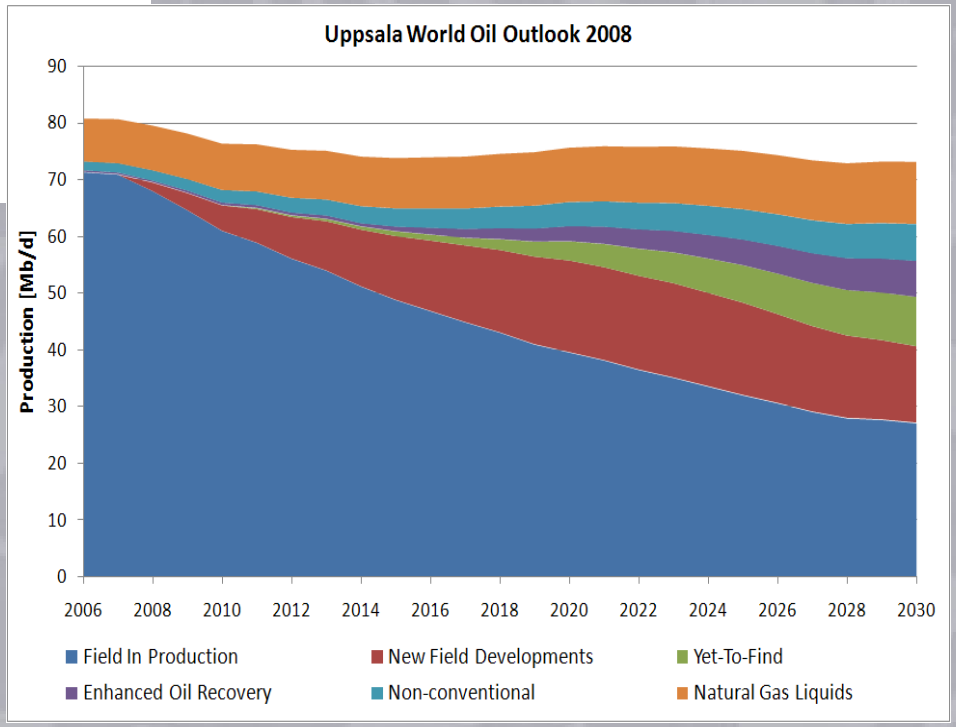


UPPSALA UNIVERSITET

Kjell Aleklett

WEO 2008 and Uppsala Oil Outlook 2008





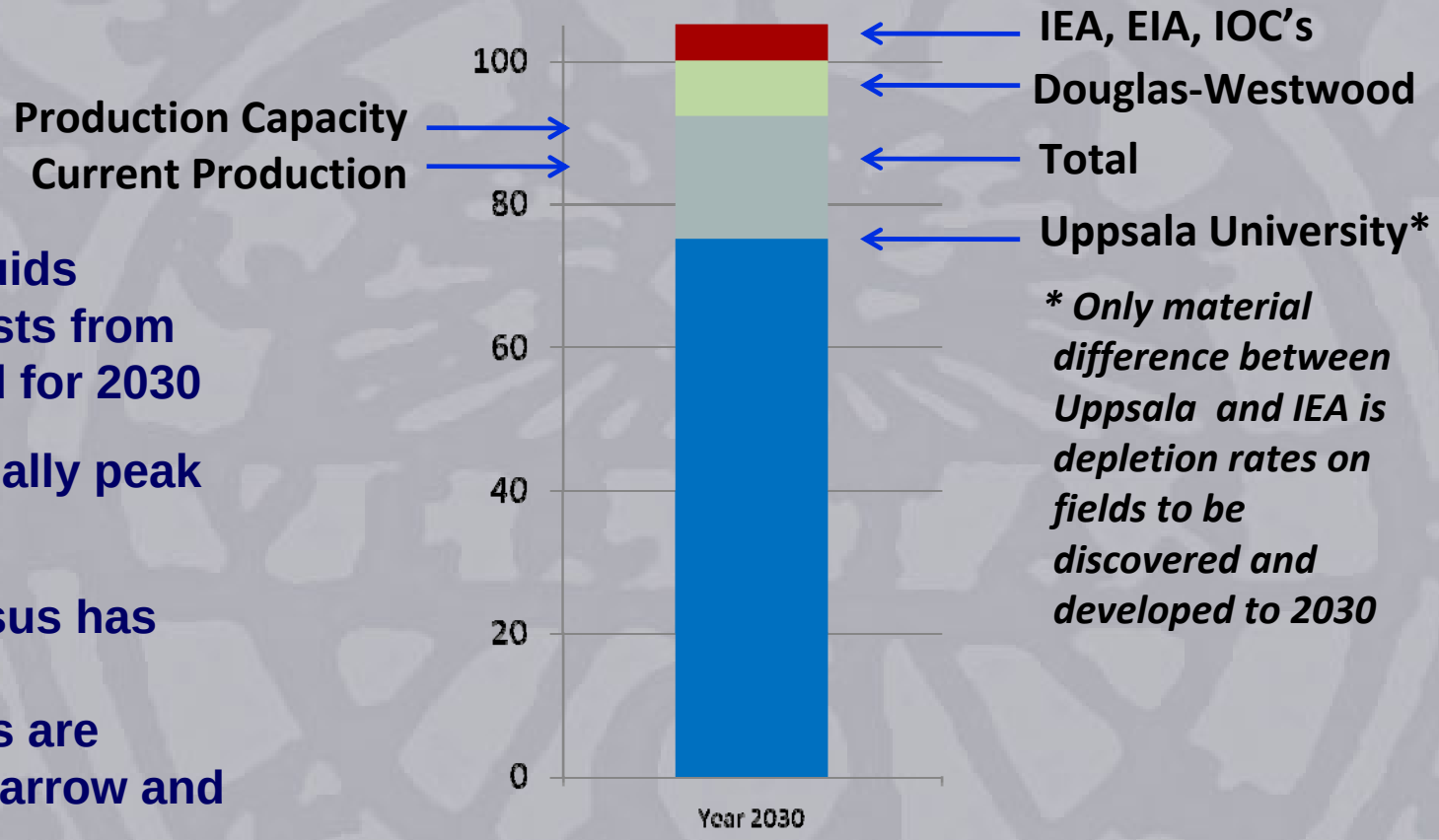
Kjell Aleklett, Mikael Höök, Kristofer Jakobsson, Bengt Söderbergh,
***The Peak of the Oil Age – reviewing the Reference Scenario World Oil Outlook in IEA World Energy Outlook 2008*,**
Energy Policy, submitted to Energy Policy

UPPSALA UNIVERSITET

Kjell Aleklett

WEO 2008 and Uppsala Oil Outlook 2008

- Petroleum liquids supply forecasts from 75 – 105 mbpd for 2030
- All are essentially peak oil forecasts
- Quiet consensus has emerged— disagreements are increasingly narrow and specific



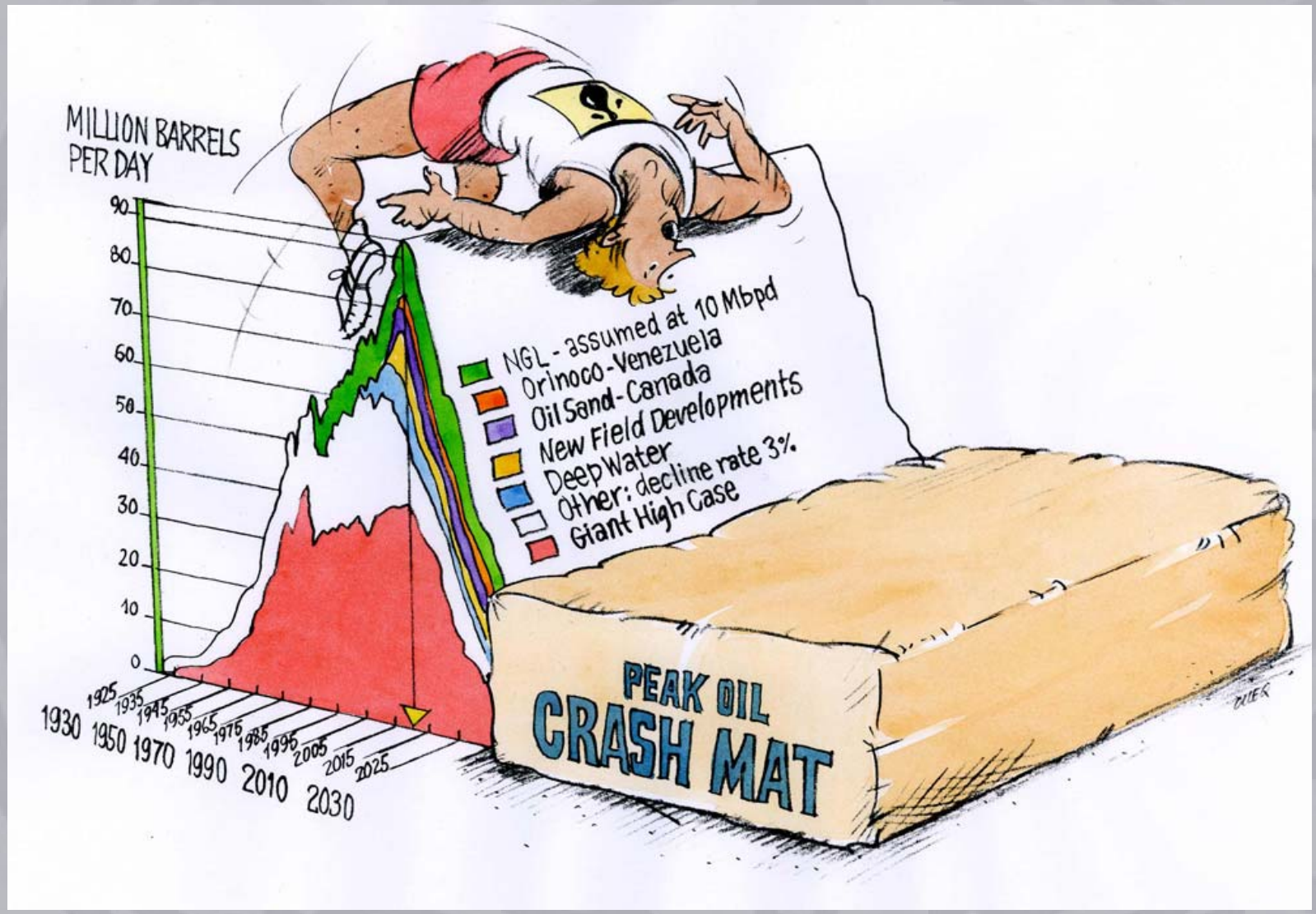
Range of Global Oil Supply Forecasts – 2030 – All Liquids
Source: various

- Oil supply looks unlikely to keep up with demand over time

UPPSALA UNIVERSITET

Kjell Aleklett

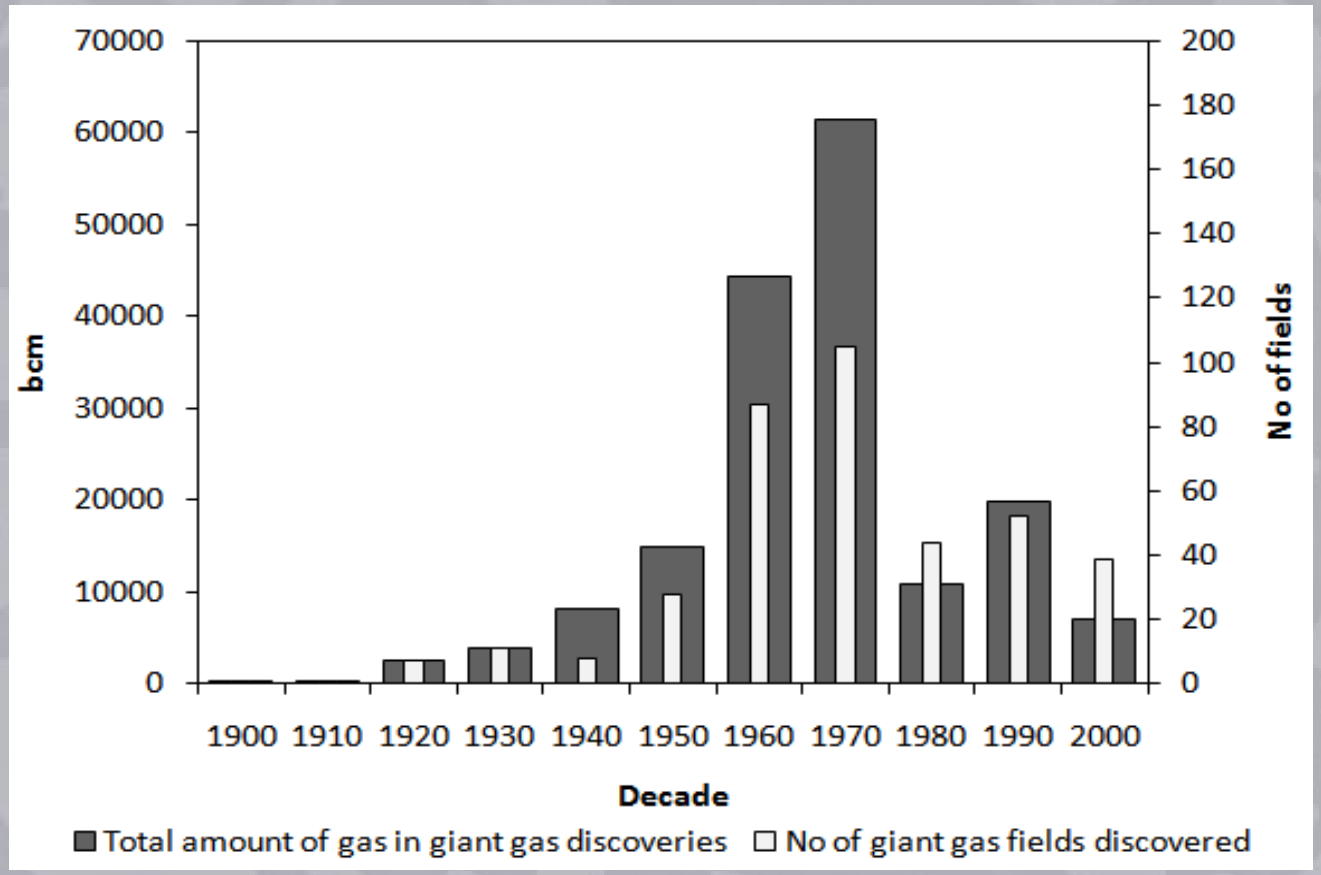
We have to build a "Crash Mat"



UPPSALA UNIVERSITET

Kjell Aleklett

Peak Gas

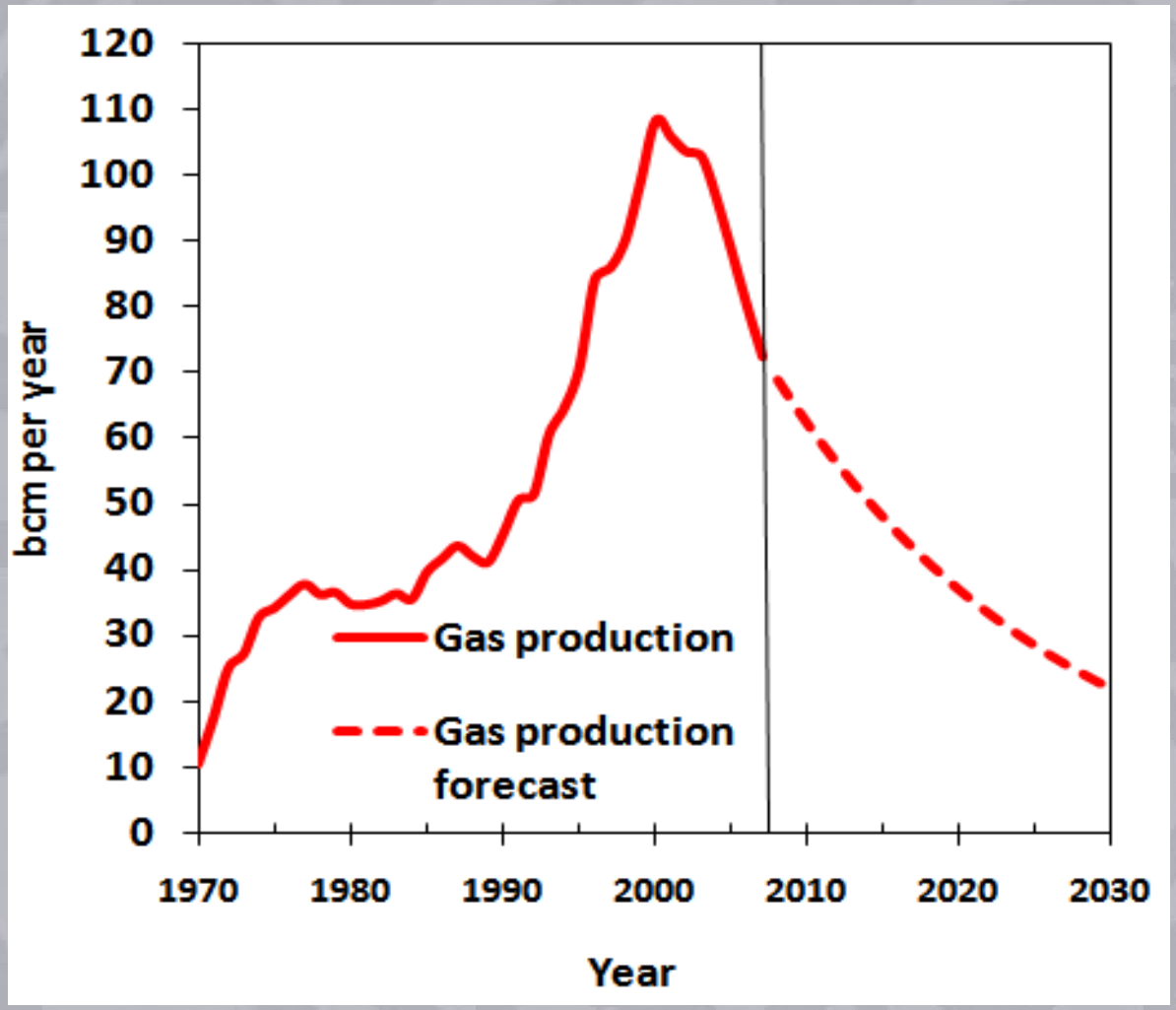


A peak in discoveries must give a peak in production!

UPPSALA UNIVERSITET

Kjell Aleklett

UK Gas Production Peaked in 2000



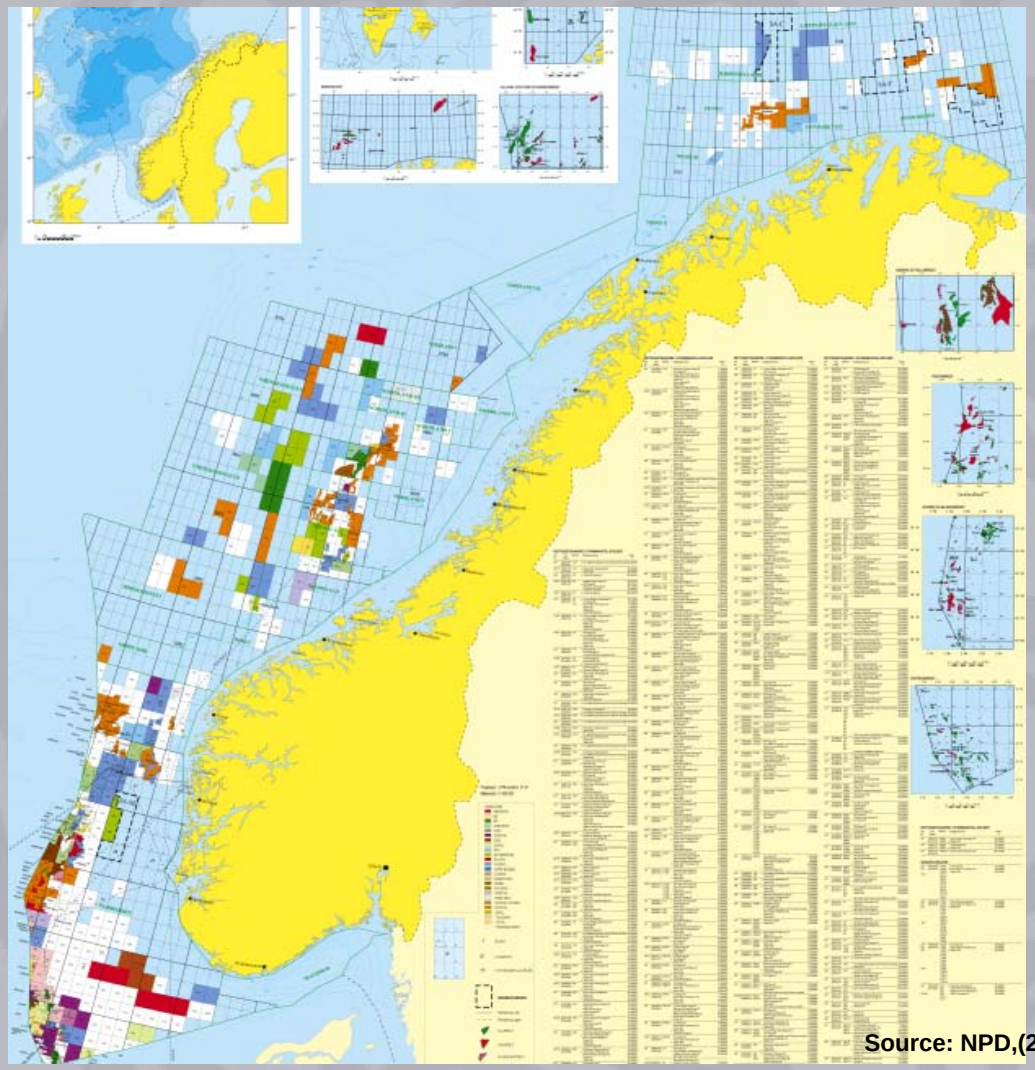
- The biggest gas producer of the EU.
- Became net importer of gas In 2004.
- The UK and the Netherlands produce 70% of EU gas output

Sources: BP Statistical Review 2009, Söderbergh (2010)

UPPSALA UNIVERSITET

Bengt Söderbergh
Kjell Aleklett

The Petroleum Producing Regions of Norway



Source: NPD,(2008)

- The Norwegian shelf is divided in three separate petroleum systems.
- 66% of production in the North Sea (2008).
- 31% of production in the Norwegian Sea (2008).
- 2.4% of production in the Barents Sea Sea (2008).

Source: Söderbergh, B., et al., European energy security: The future of Norwegian natural gas…. Energy Policy (2009)

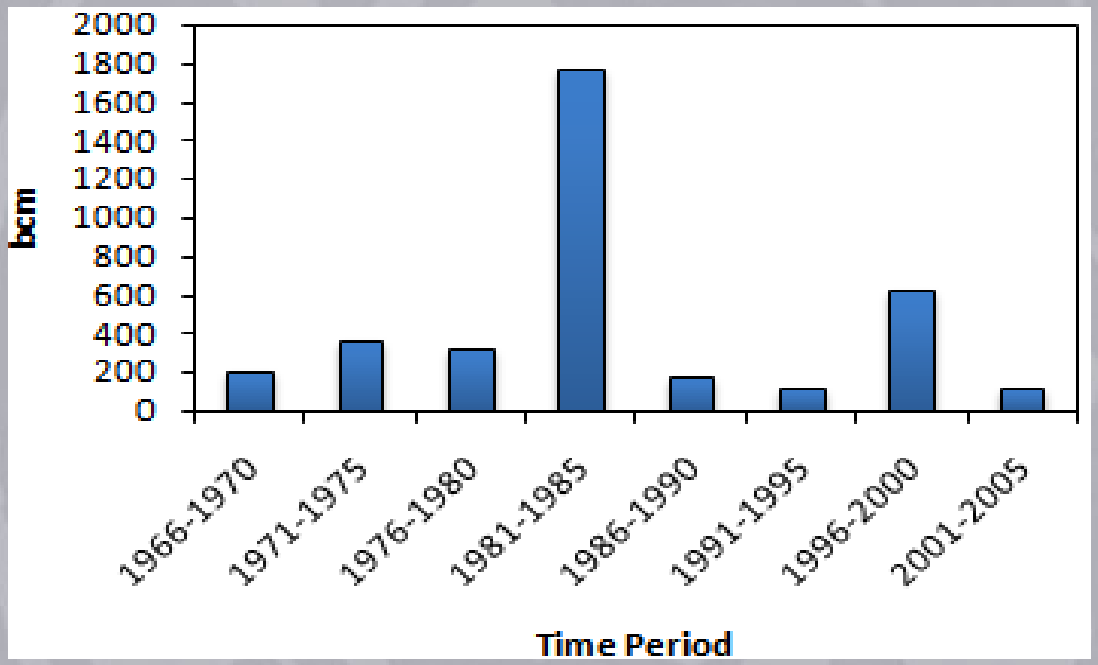
Norway is becoming a mature gas producer

- 80% of Norway's initial reserves are concentrated in only 10 giant gas fields.
- All Norwegian giant gas fields have been put in to production.
- With the exception of Ormen Lange and Snøhvit, all giant fields have already reached their planned production level.
- The production from current reserves in the Norwegian North Sea peaked in 2006 at 73 bcm/year .
- Estimated peak in production from Norway's current reserves in 2010 at 115bcm/year.

Source: Söderbergh, B., et al., European energy security: The future of Norwegian natural gas…. Energy Policy (2009)

Declining discovery trend

Norwegian Gas Discoveries 1966-2005



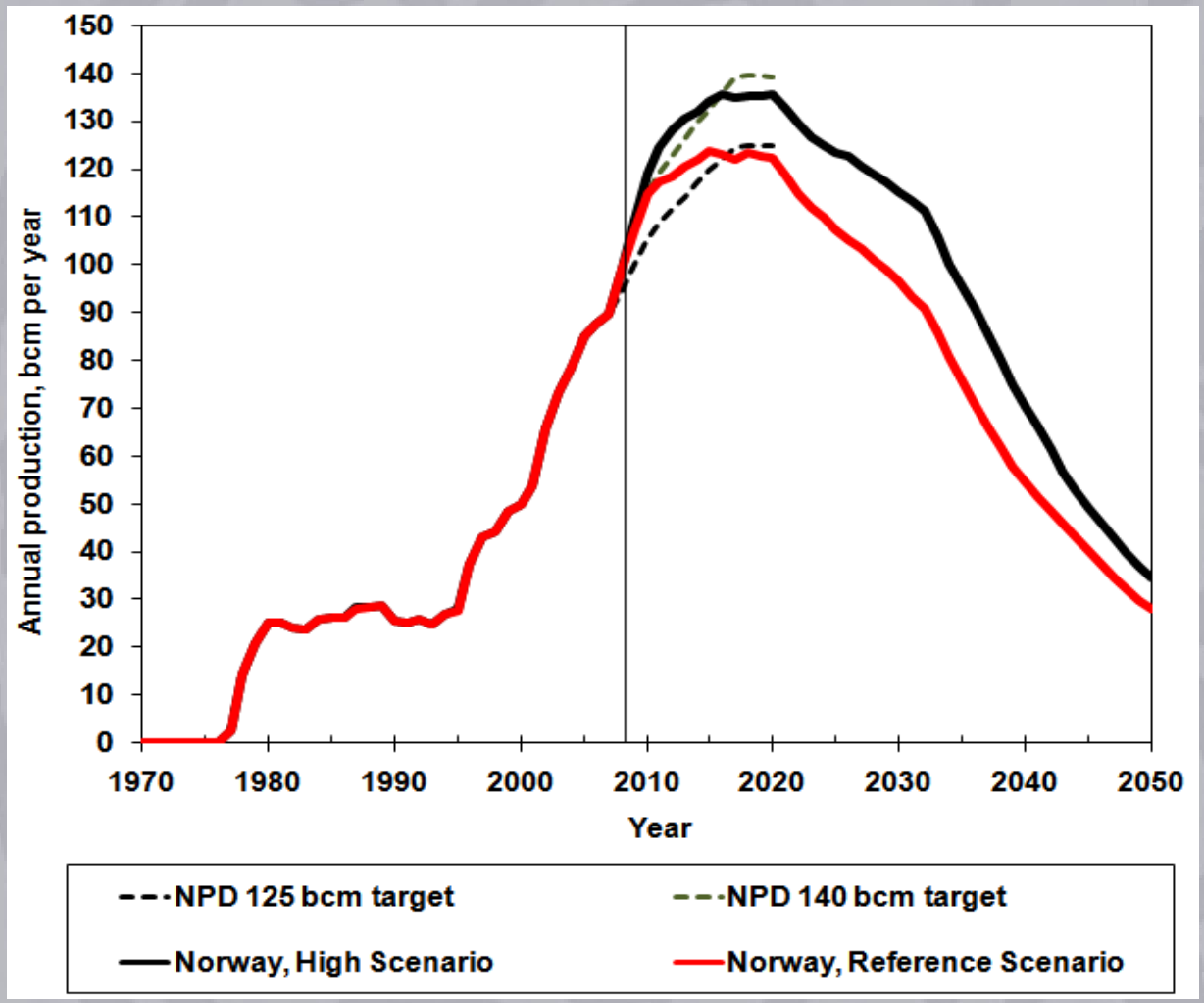
- No giant gas field discovered in Norway during the last 10 years.
- About 85 exploration wells drilled in the Barents Sea since 1980.
- Only the Snohvit and Goliat fields discovered in the Barents Sea.

Source: Söderbergh, B., et al., European energy security: The future of Norwegian natural gas…. Energy Policy (2009)

UPPSALA UNIVERSITET

Kjell Aleklett

Limited Norwegian Potential for Increase



- **Total Norwegian gas production peaks between 2015 and 2020.**
- **By 2030 Norwegian pipeline exports 80-95 bcm/year.**

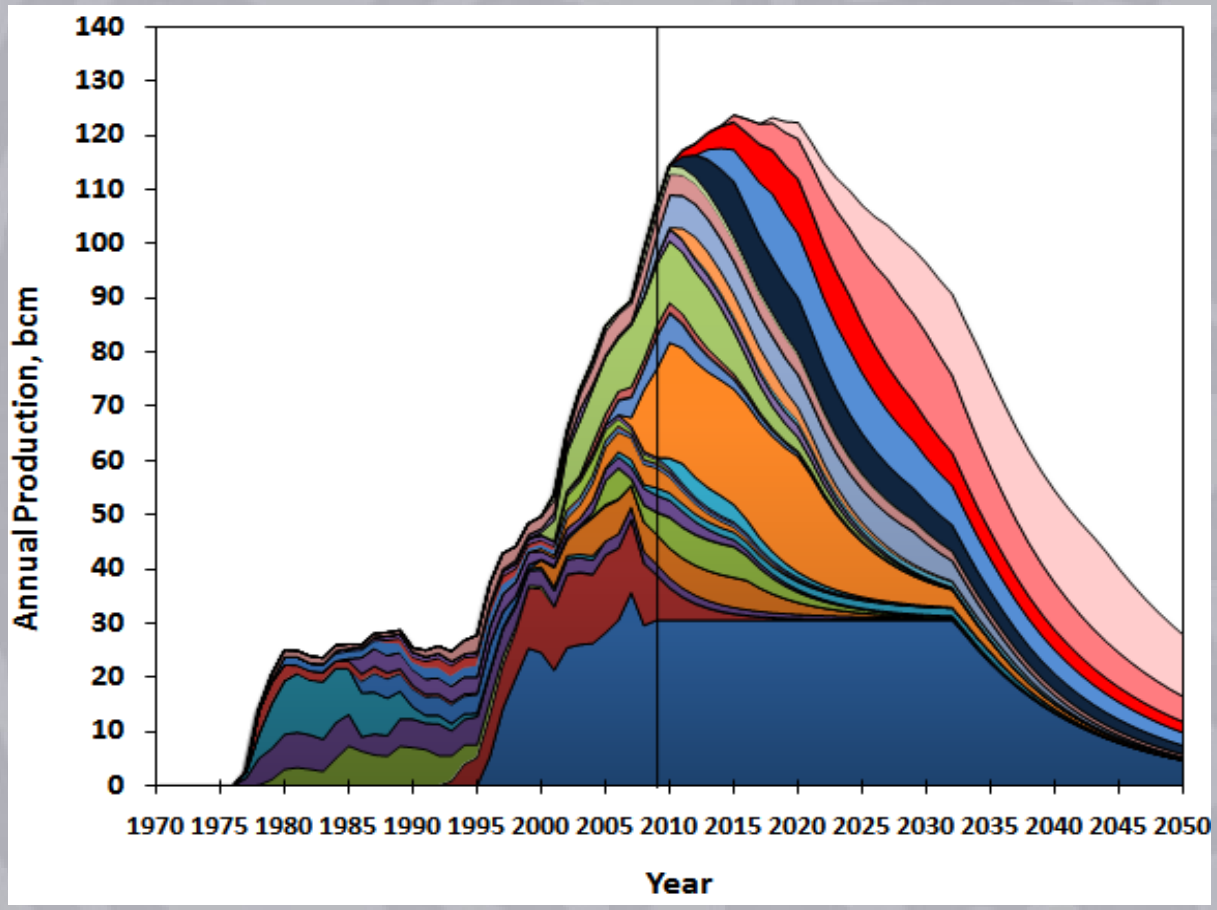
Source: Söderbergh, B., et al., European energy security: The future of Norwegian natural gas…. Energy Policy (2009)

UPPSALA UNIVERSITET

Kjell Aleklett

Norway - A Bottom-up Analysis

Norwegian Natural Gas Production Forecast – Reference Scenario



- **Field-by-field study of Norwegian gas production.**
- **Contingent and undiscovered resources included.**

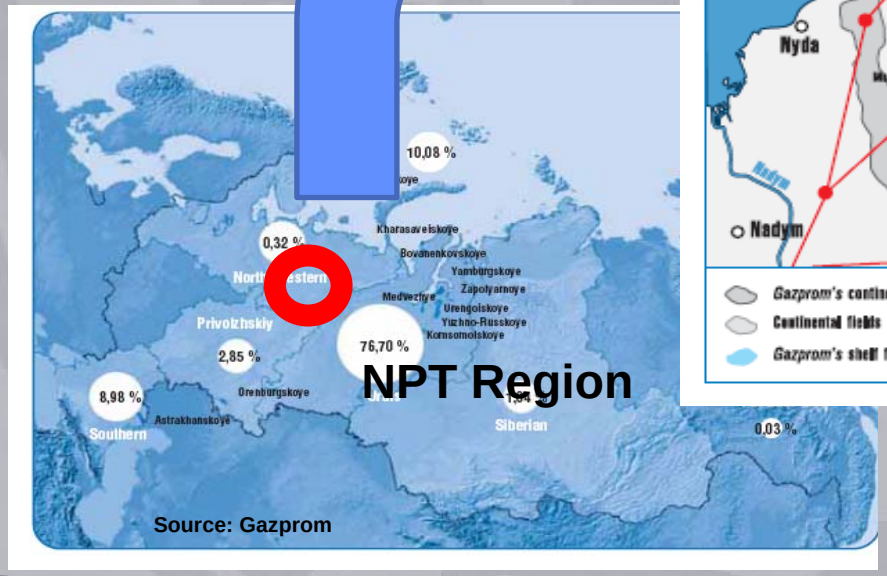
Source: Söderbergh, B., et al., European energy security: The future of Norwegian natural gas production, Energy Policy (2009)

UPPSALA UNIVERSITET

Bengt Söderbergh
Kjell Aleklett

Western Siberia, Europe's Energy Centre

- **Nadym Pur Taz (NPT) Region is the world's largest gas production center.**
- **Over 90% of Russian production (about 20% of global production).**



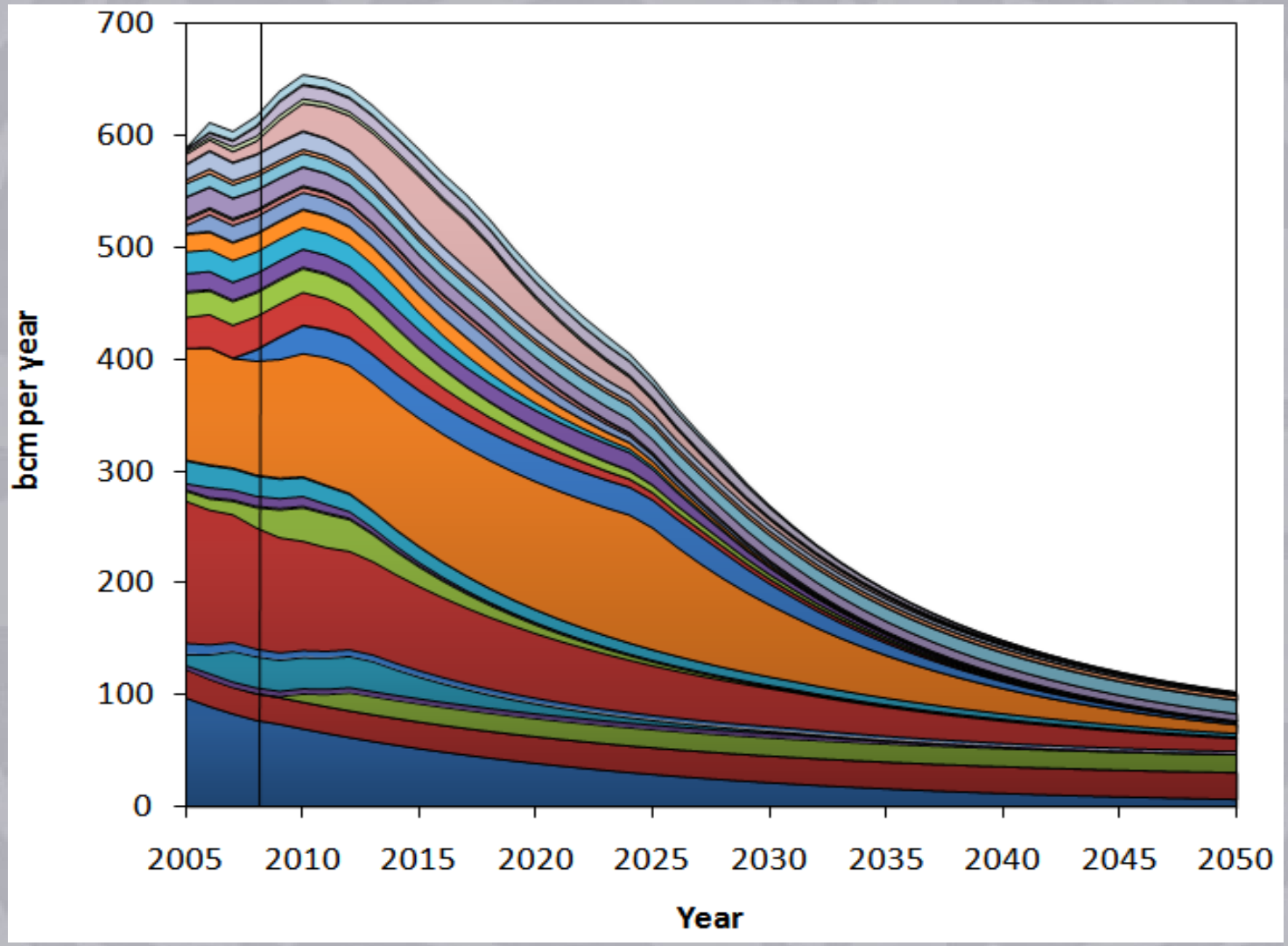
Source: Gazprom

Source: Gazprom

UPPSALA UNIVERSITET

Kjell Aleklett

The NPT Region is about to Peak



Source: Söderbergh, B., (2010). Production from Giant Gas Fields in Norway and Russia and Subsequent Implications for European Energy Security

UPPSALA UNIVERSITET

Kjell Aleklett

Development of New Areas – Tough Areas Left

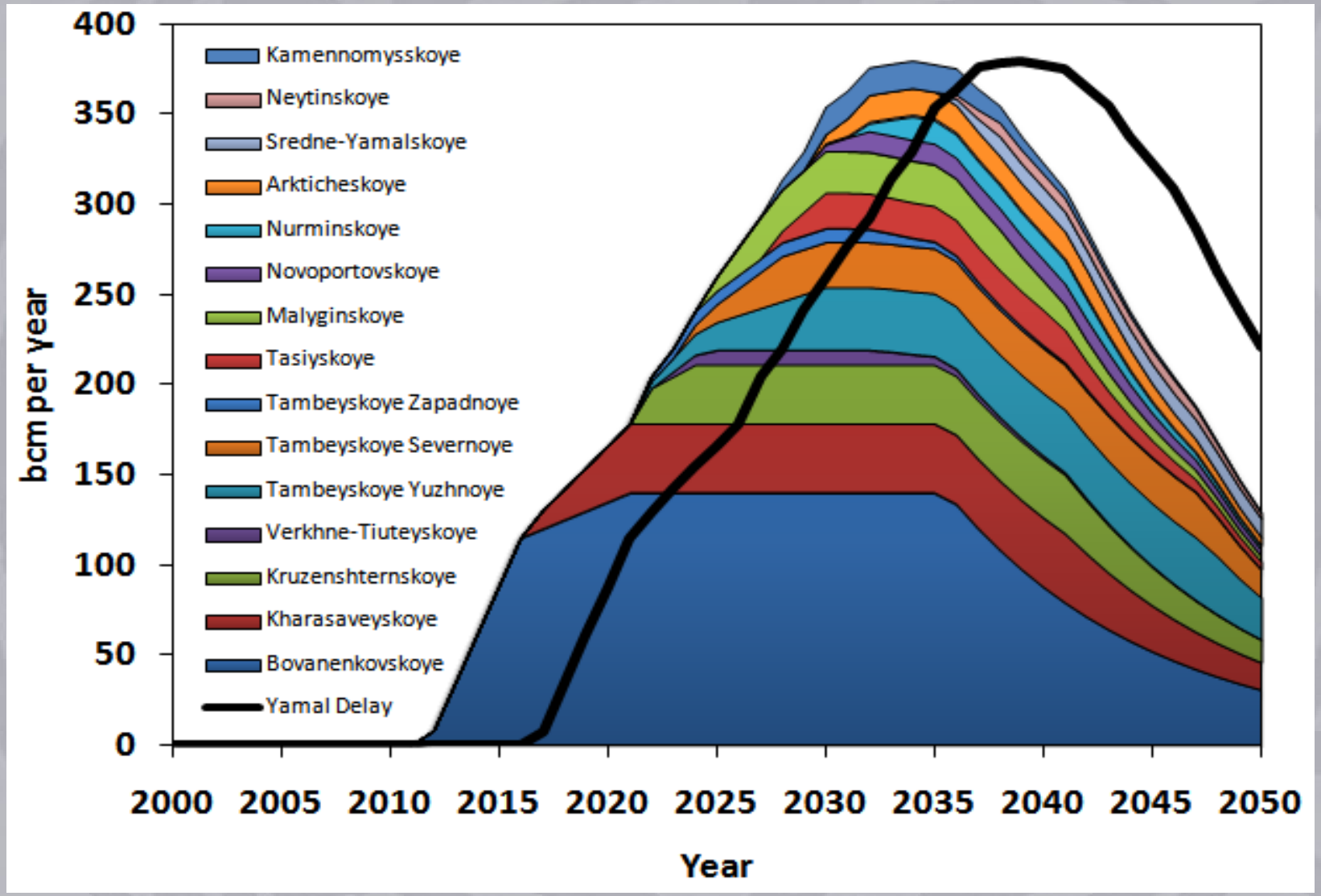
- The Shtokman field, arctic offshore.
- The Yamal Peninsula – harsh weather conditions.
- East Siberia and Sakhalin – remote areas.

UPPSALA UNIVERSITET

Kjell Aleklett

Yamal – The Future Russian Gas Centre

Yamal Peninsula Production Forecast

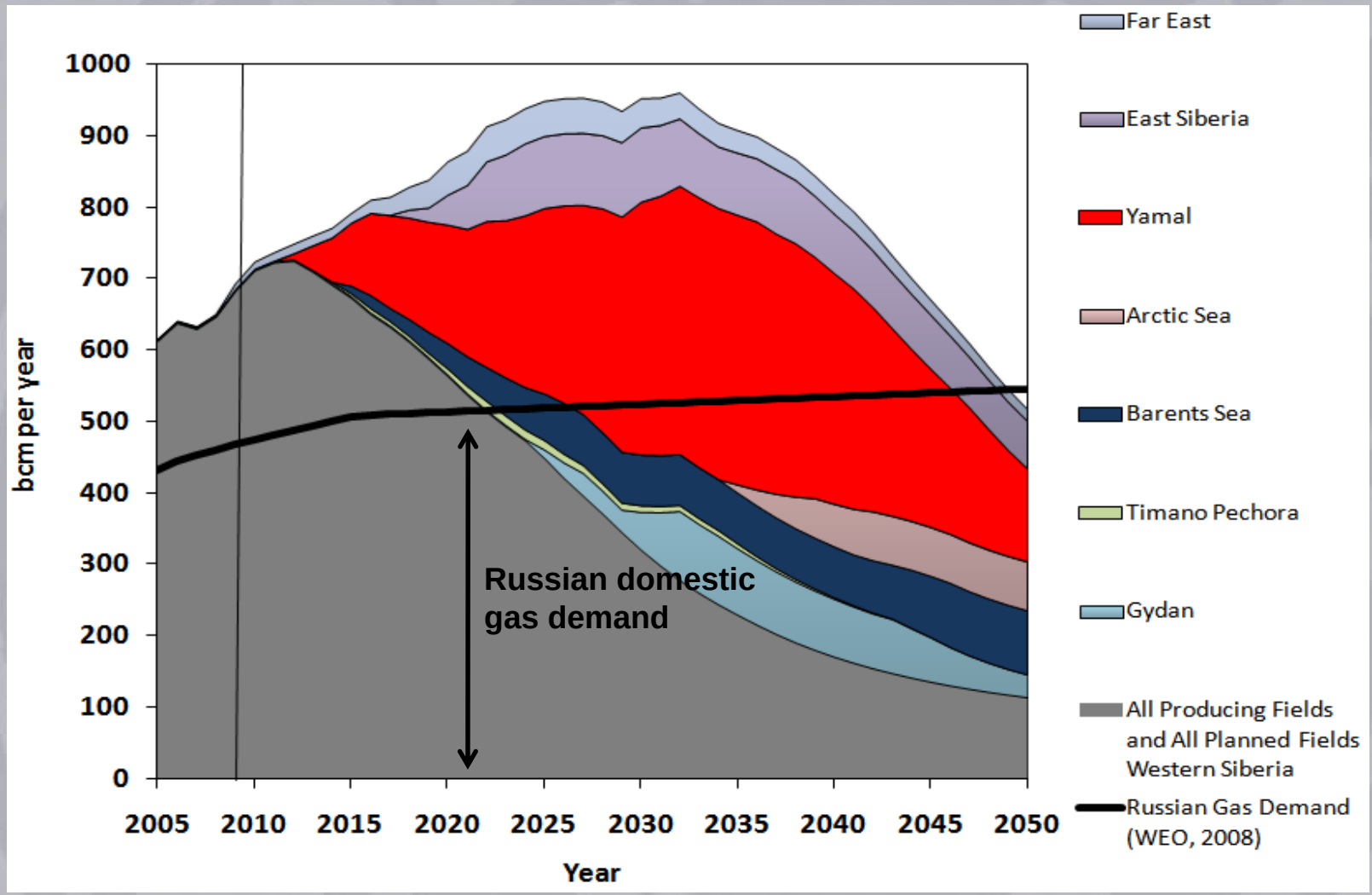


Source: Söderbergh, B., (2010). Production from Giant Gas Fields in Norway and Russia and Subsequent Implications for European Energy Security

UPPSALA UNIVERSITET

Kjell Aleklett

Future Russian Gas Production and Demand



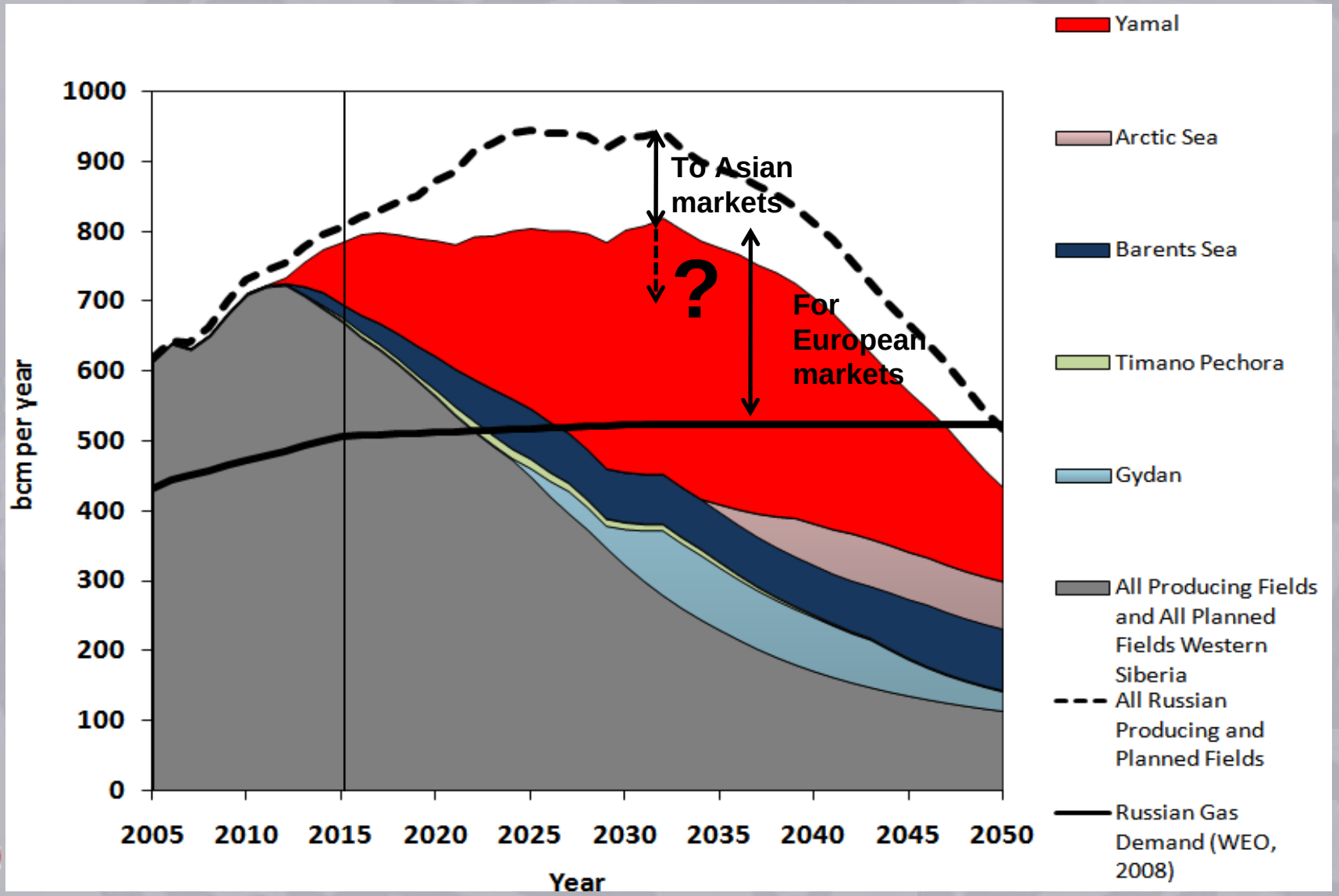
Limited increase of export potential due to increasing Russian domestic demand.

Source: Söderbergh, B., (2010). Production from Giant Gas Fields in Norway and Russia and Subsequent Implications for European Energy Security

UPPSALA UNIVERSITET

Kjell Aleklett

Limits to Available Gas Supplies for Europe

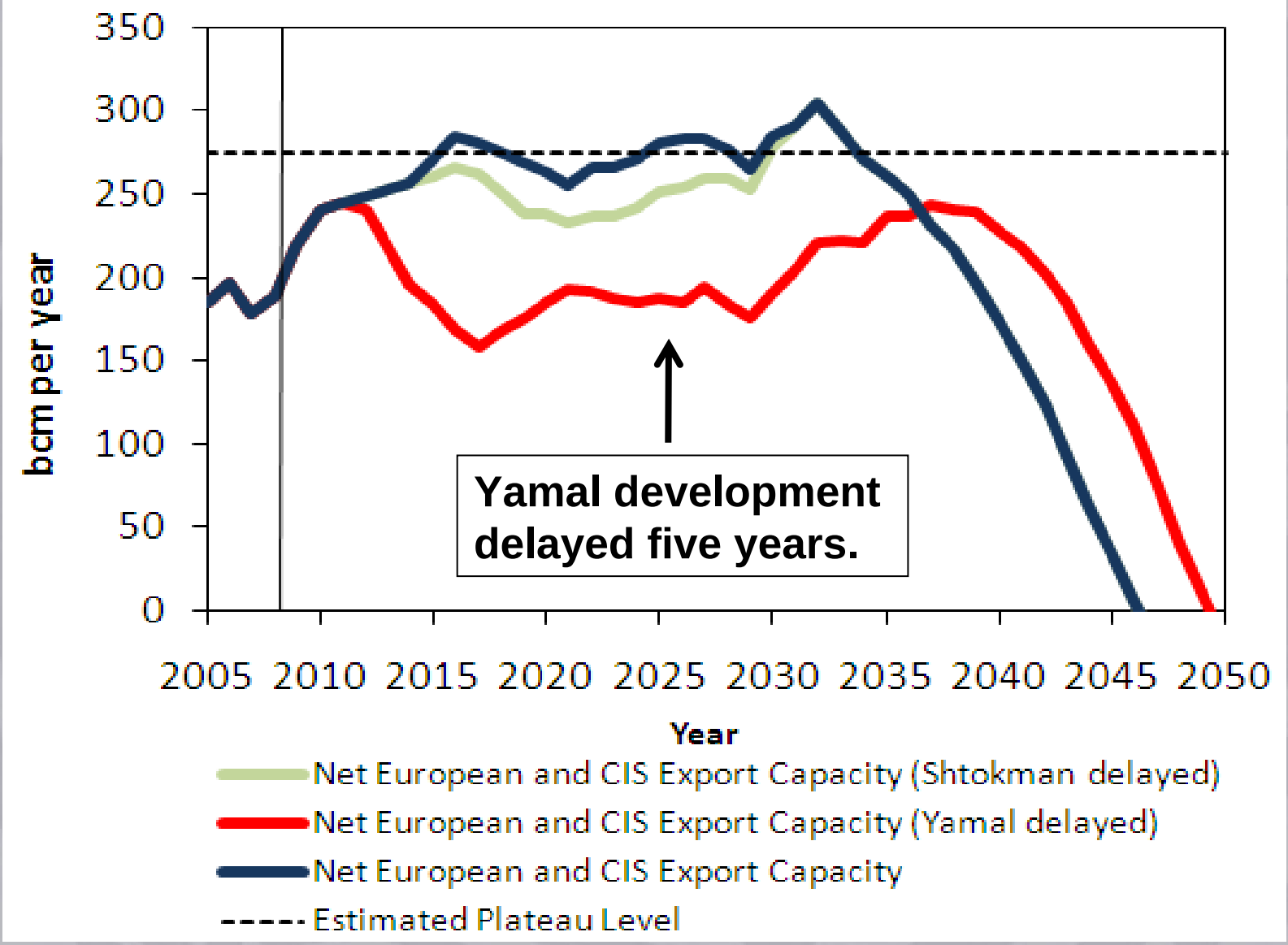


Source: Söderbergh, B., (2010). Production from Giant Gas Fields in Norway and Russia and Subsequent Implications for European Energy Security

UPPSALA UNIVERSITET

Kjell Aleklett

If Yamal Delayed - No European Export Increase

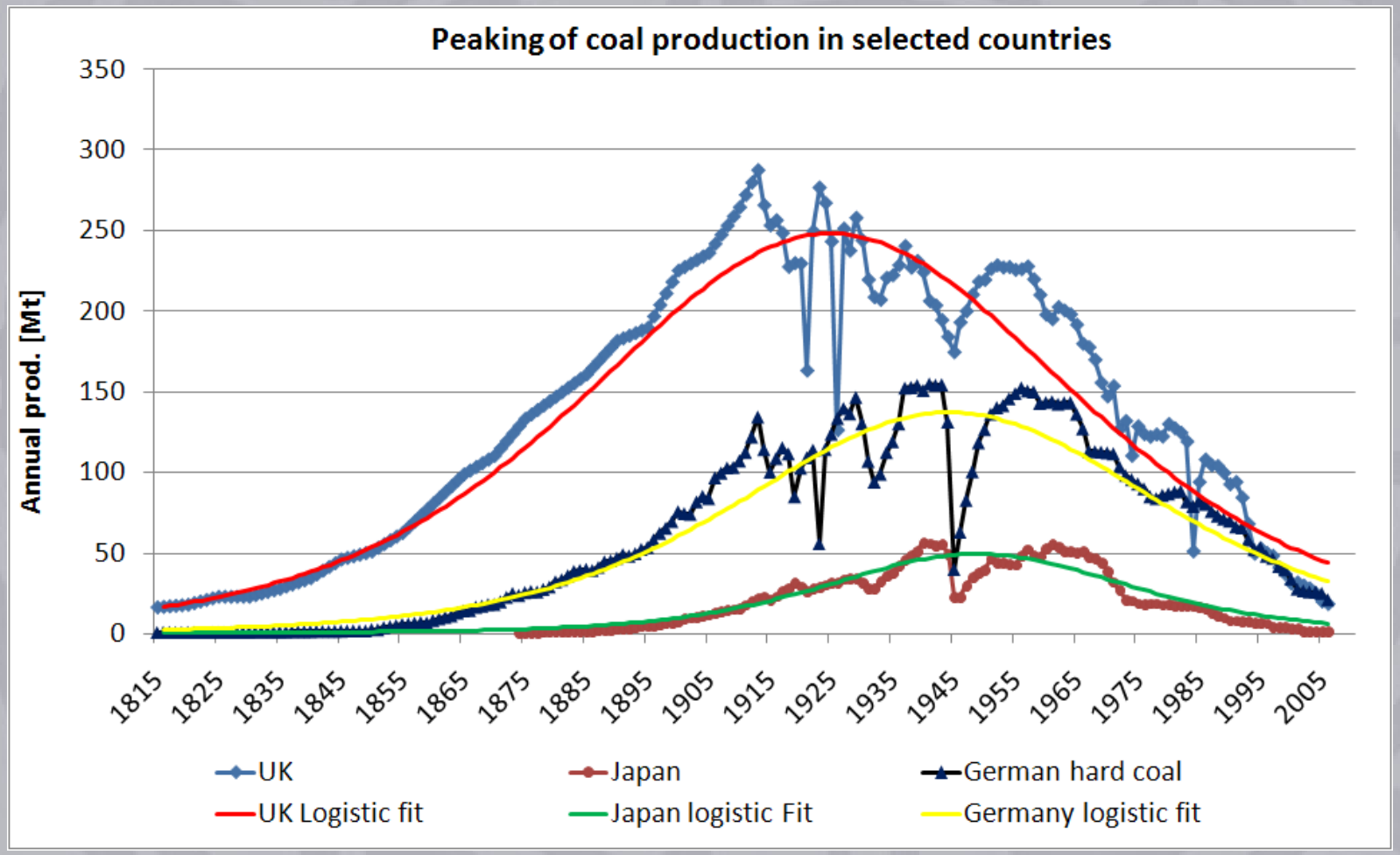


Source: Söderbergh, B., (2010). Production from Giant Gas Fields in Norway and Russia and Subsequent Implications for European Energy Security

UPPSALA UNIVERSITET

Kjell Aleklett

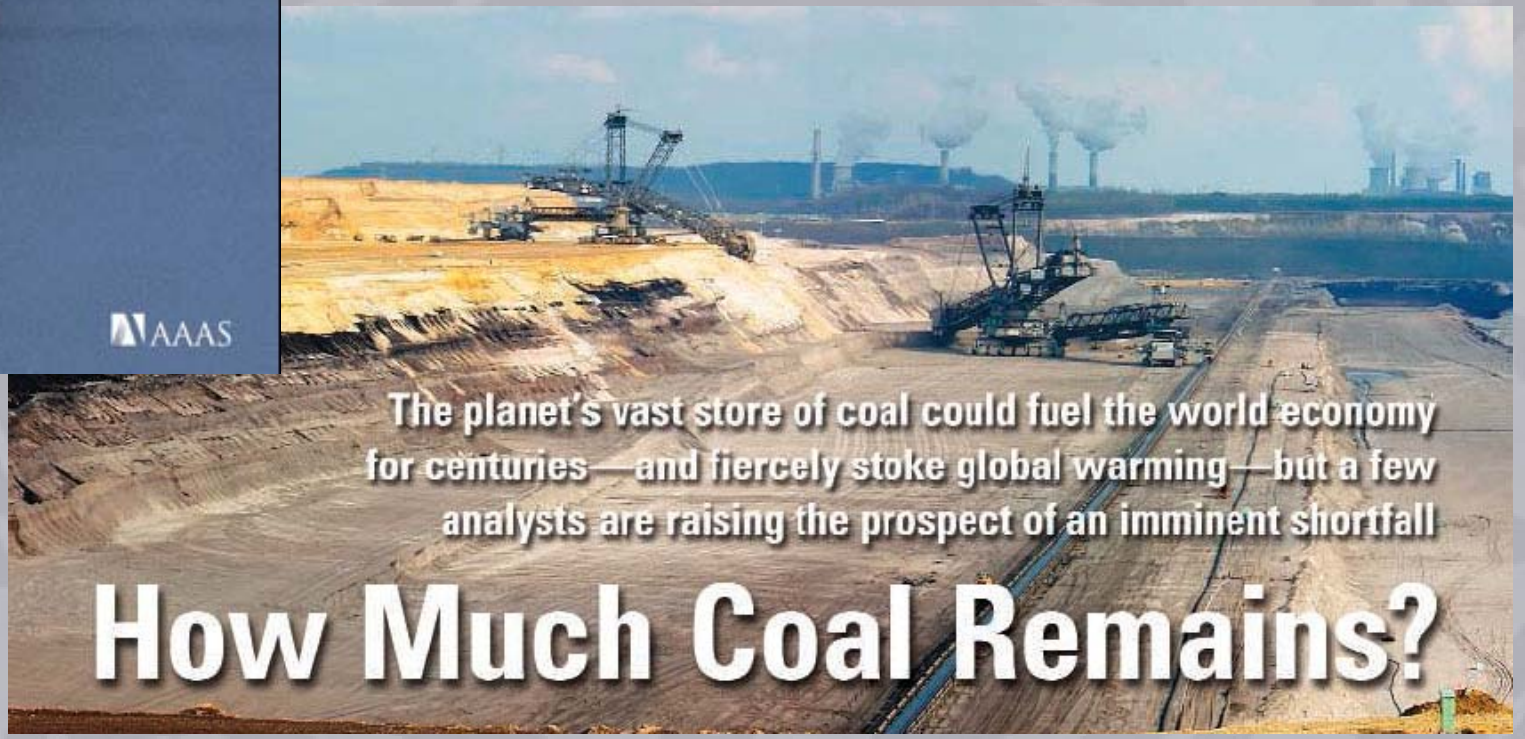
Peak Coal



UPPSALA UNIVERSITET

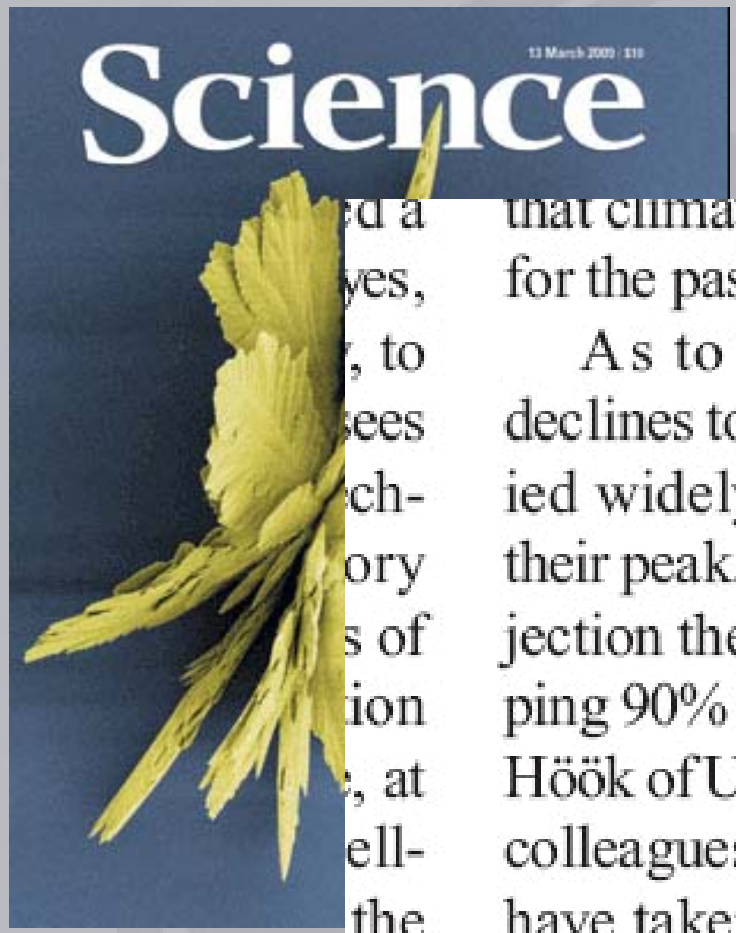
Kjell Aleklett

How Much Coal?
Science 13 March 2009



UPPSALA UNIVERSITET

Kjell Aleklett



How Much Coal?

009

that climate scientists have been working with for the past 10 years.

As to when coal will peak, Rutledge declines to say, citing the way peak timing varied widely among regions already well past their peak. He will say, however, that in his projection the world will have produced a whopping 90% of its coal by 2069. Physicist Mikael Höök of Uppsala University in Sweden and his colleagues are willing to point to a peak. They have taken a similar approach to Rutledge's but with some reliance on estimated reserves. Still, they see world coal production topping out by 2020, entering a 30-year-long plateau, and then declining.

UPPSALA UNIVERSITET

Kjell Aleklett

Coal Reserves

- **Top Seven Coal Reserves 2006 [Mt]**

	Country	Reserve	Share of world
1.	*USA*	*246 643*	*27.1 %*
2.	*Russia*	*157 010*	*17.3 %*
3.	*China*	*114 500*	*12.6 %*
4.	*India*	*92 445*	*10.2 %*
5.	*Australia*	*78 500*	*8.6 %*
6.	*South Africa*	*30 500*	*3.7 %*
7.	*Poland*	*7 500*	*0.9 %*

UPPSALA UNIVERSITET

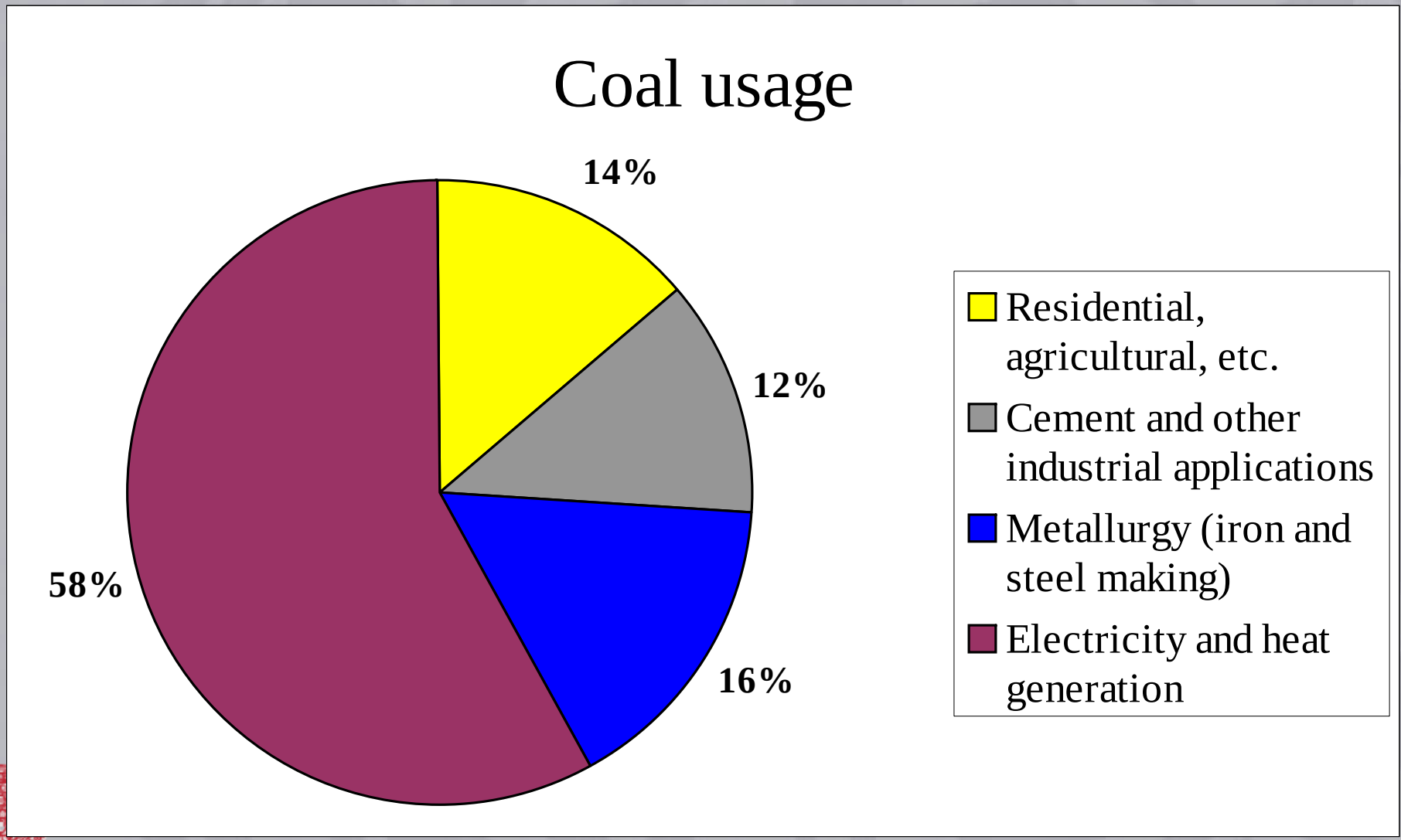
Coal Production

- **Top Six Coal Producers 2006 [Mt]**

	Country	Production	Share of world
1.	*China*	*2 380*	*38,4 %*
2.	*USA*	*1 054*	*17.0 %*
3.	*India*	*447*	*7,2 %*
4.	*Australia*	*374*	*6.0 %*
5.	*Russia*	*309*	*4.9 %*
6.	*South Africa*	*250*	*4.2 %*

UPPSALA UNIVERSITET

Coal Usage


Coal usage
14%
12%
16%
58%
Residential, agricultural, etc.
Cement and other industrial applications
Metallurgy (iron and steel making)
Electricity and heat generation

Coal reserves in USA

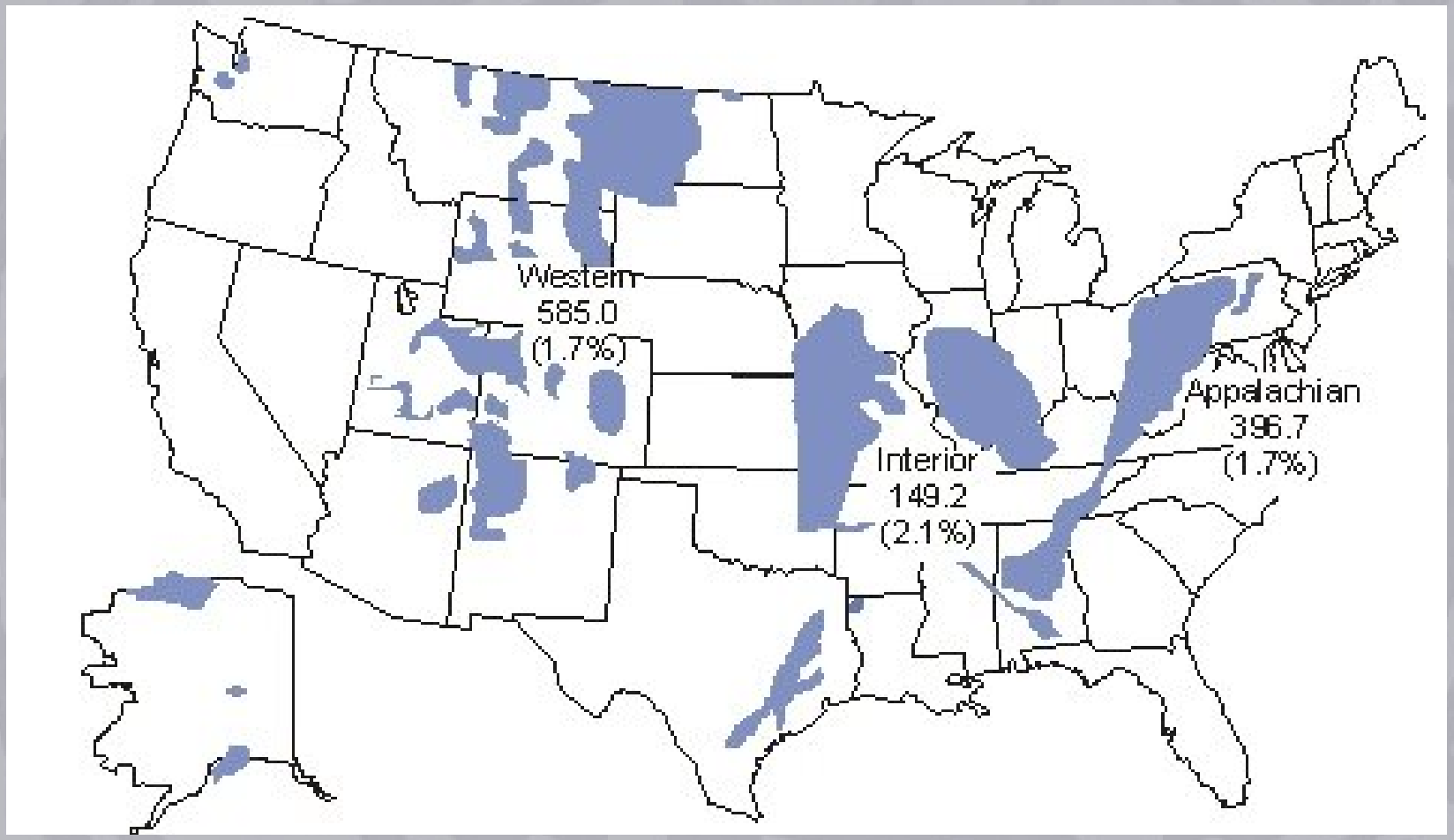
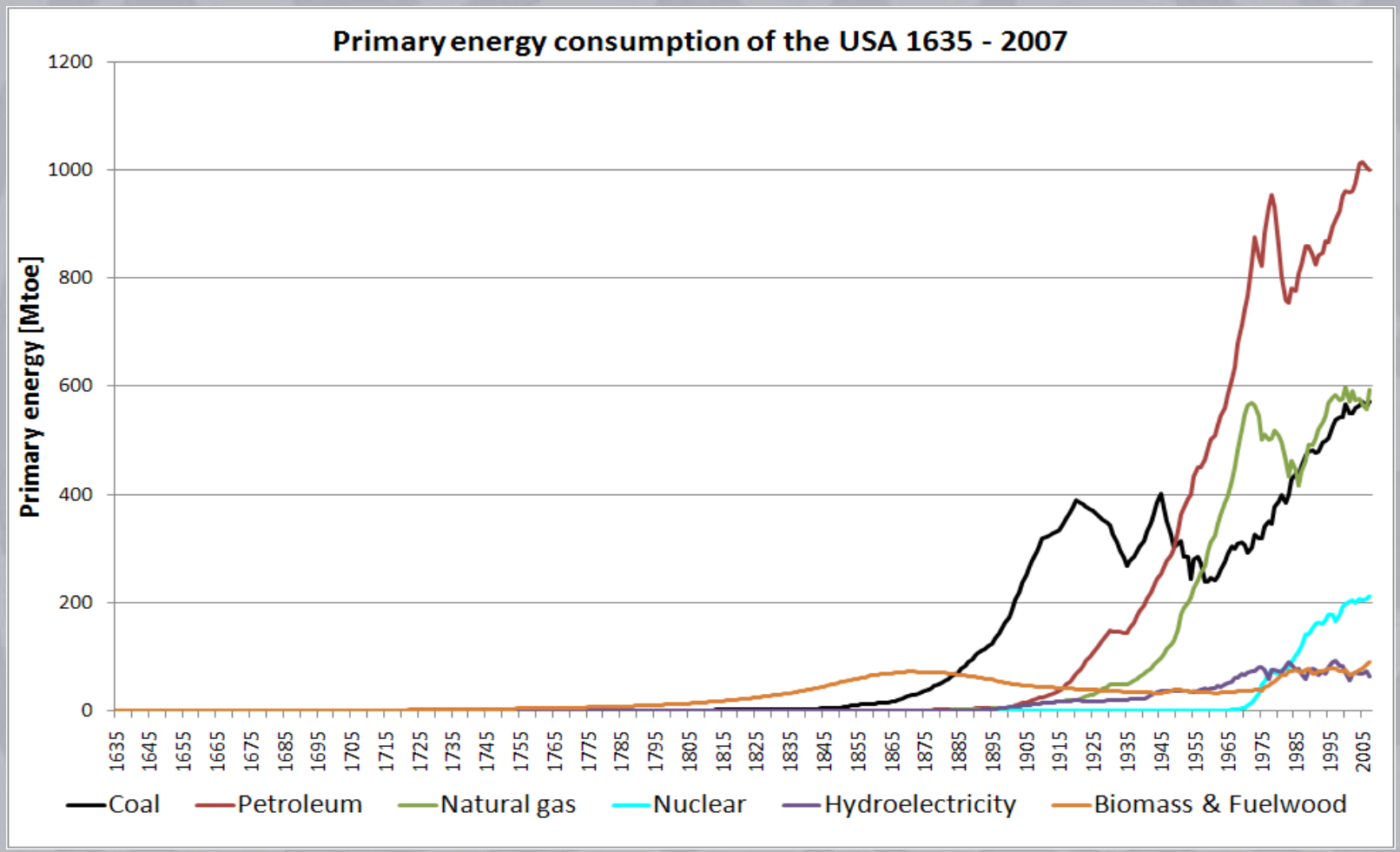


Figure 2: *Coal Production by Coal-Producing Region, 2005*
(Million Short Tons and Percent Change from 2004)
Source: *EIA, Annual Coal Report, 2005*

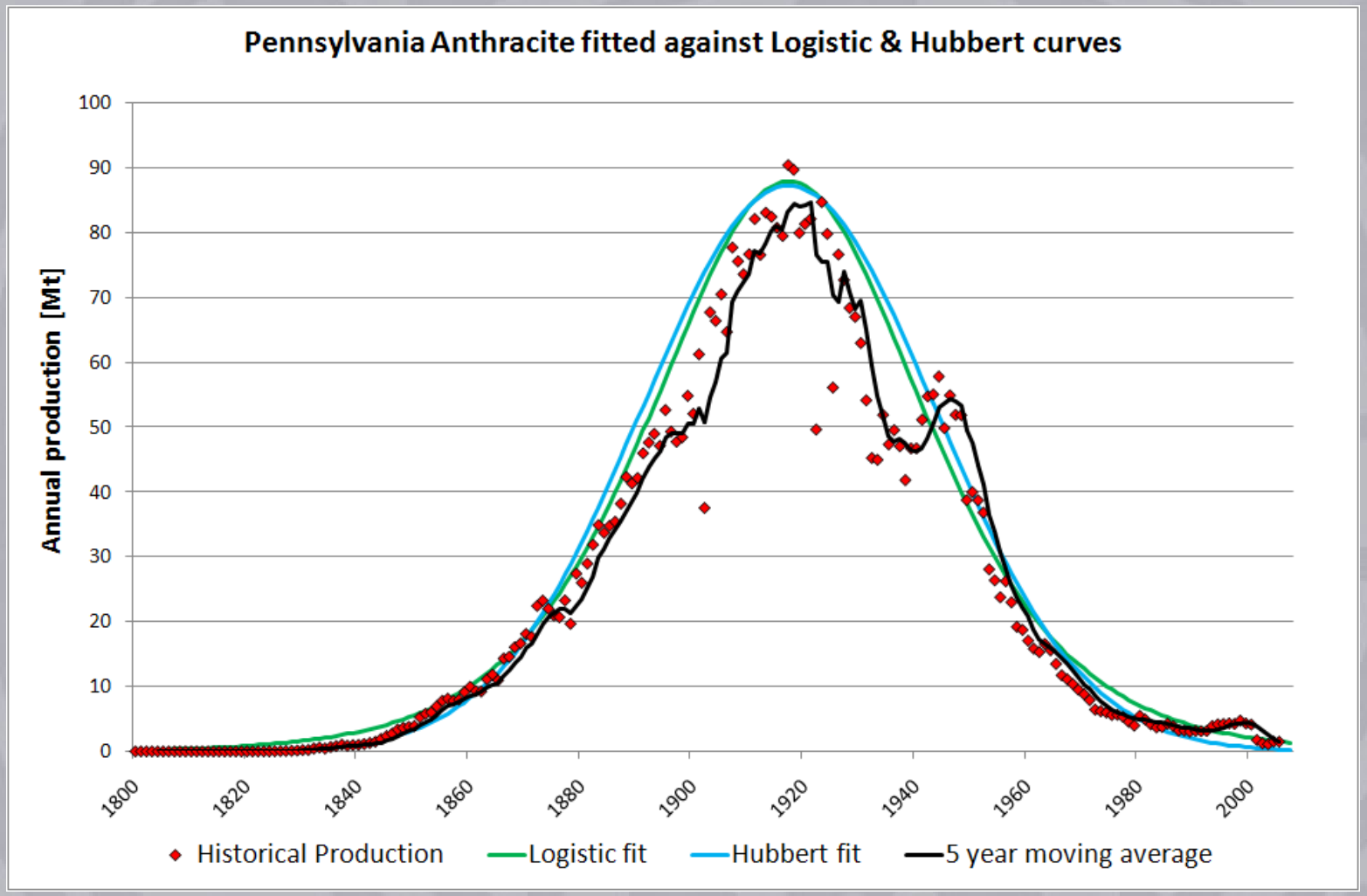
Energy consumption of coal in the USA



UPPSALA UNIVERSITET

Kjell Aleklett

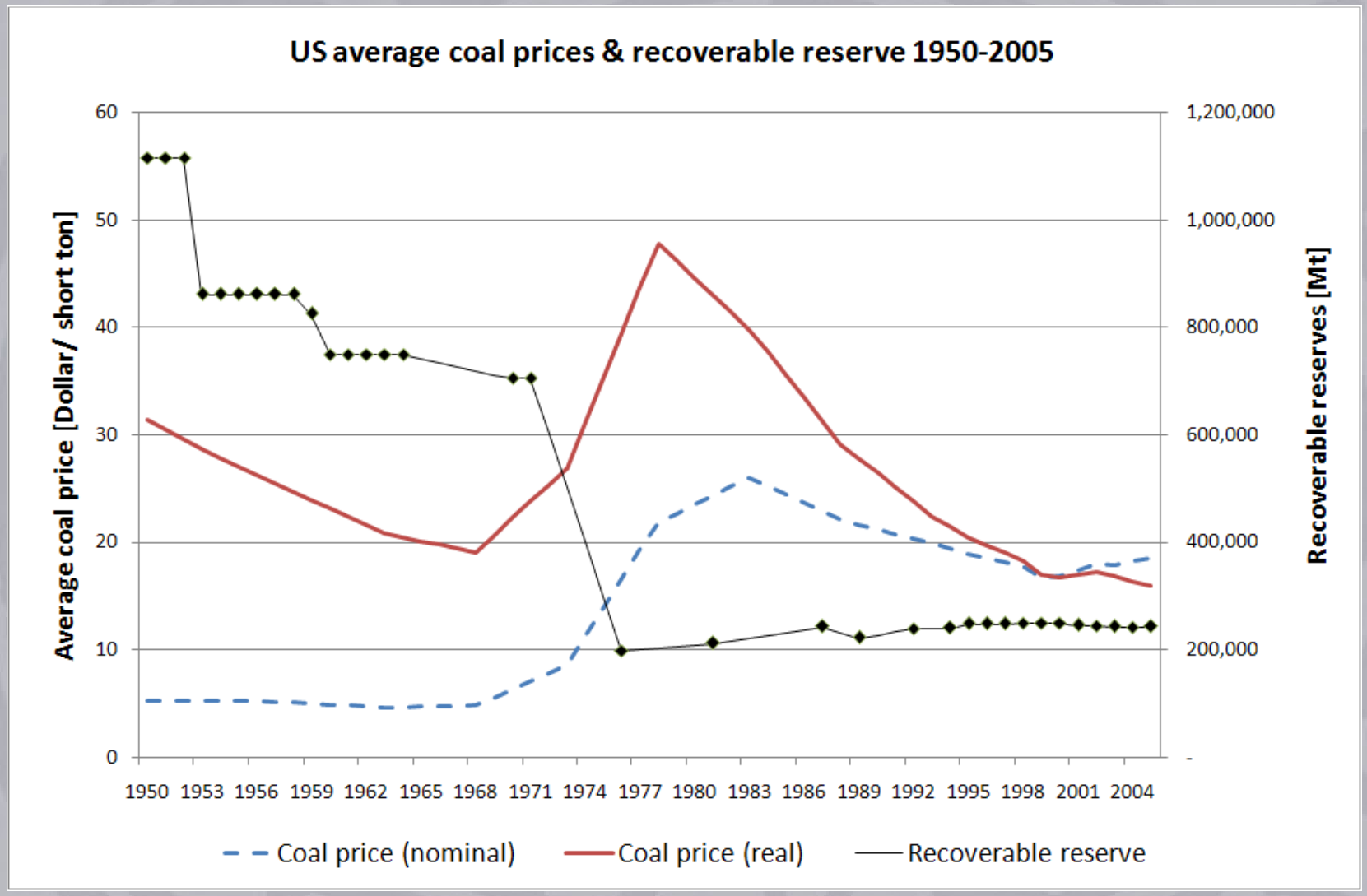
Peak Coal



UPPSALA UNIVERSITET

Kjell Aleklett

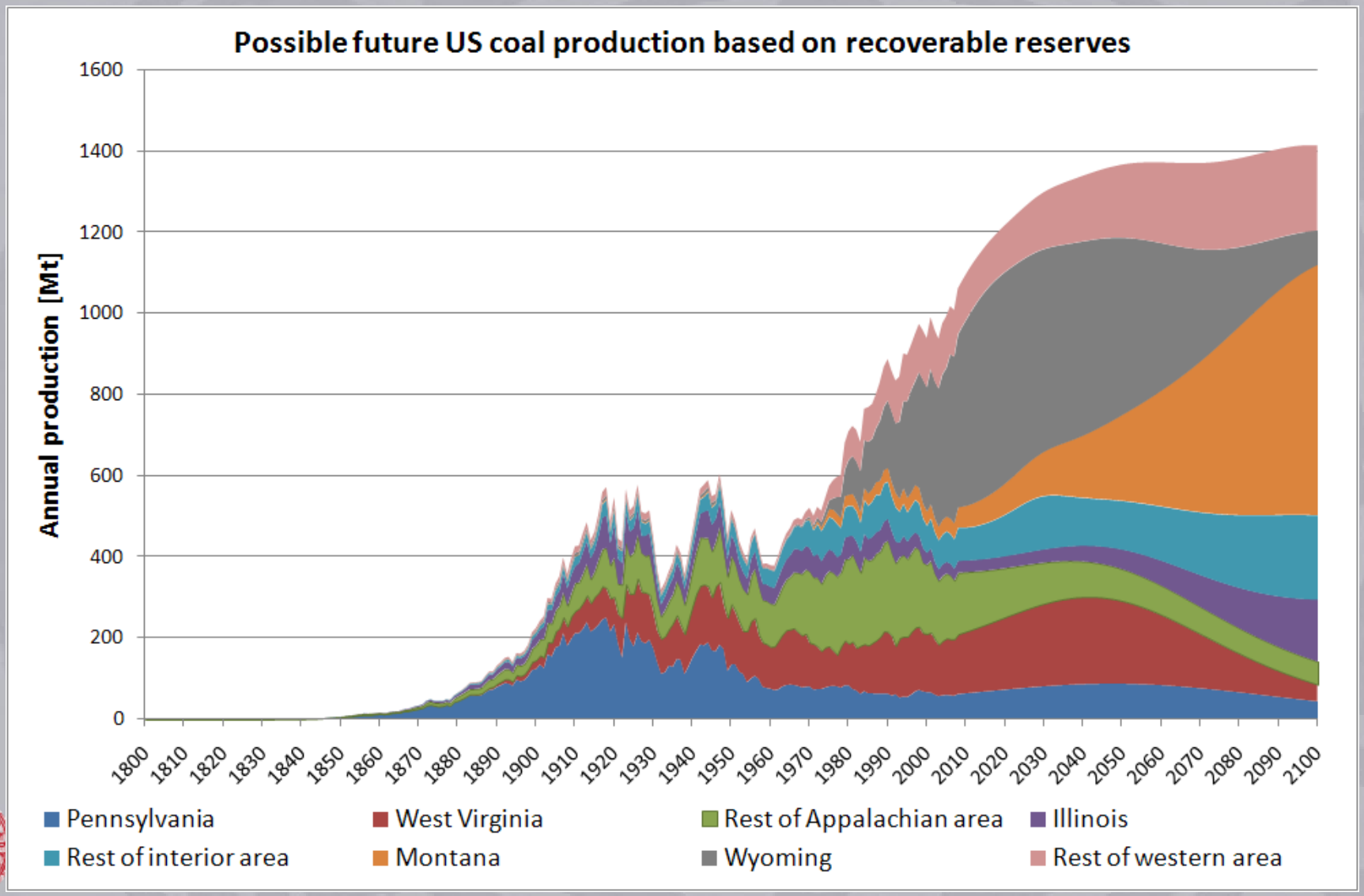
Coal statistics USA



UPPSALA UNIVERSITET

Kjell Aleklett

Future coal production in the USA



UPPSALA UNIVERSITET

Kjell Aleklett

Coal in Russia

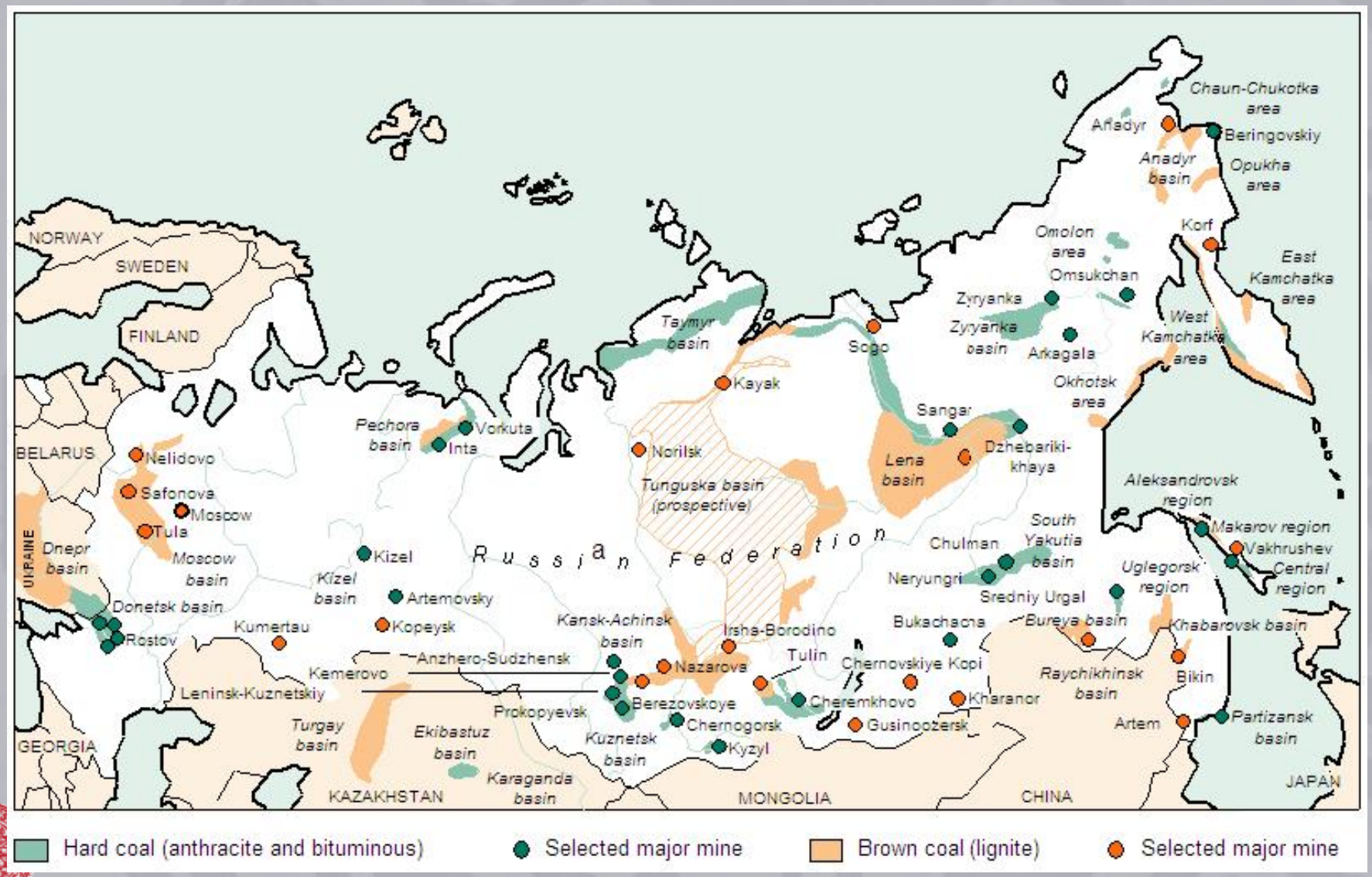
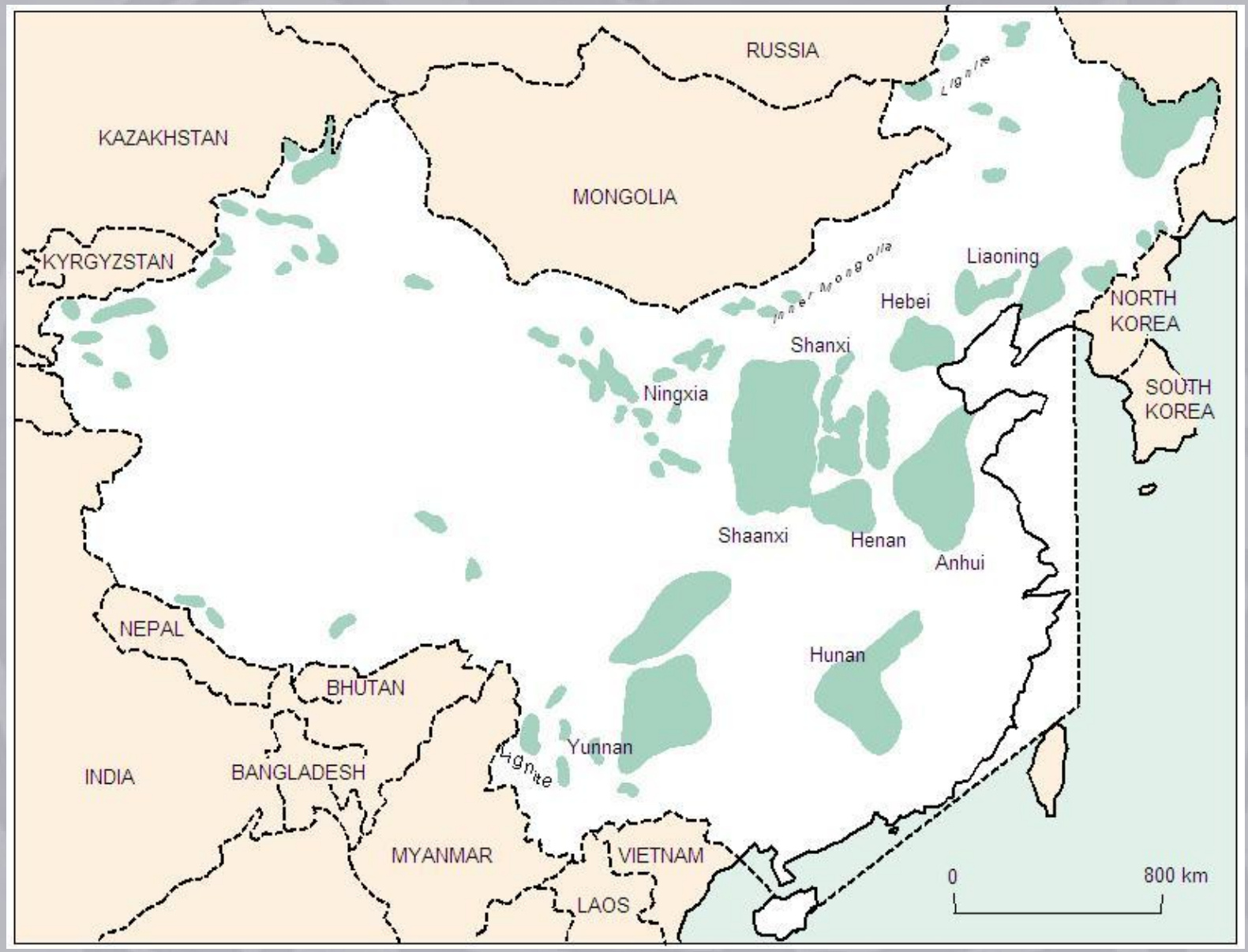


Figure 8: *Geographical distribution of the Russian coal basins*

UPPSALA UNIVERSITET

Kjell Aleklett

Coal Reserves in China



Distribution of coal deposits in China

UPPSALA UNIVERSITET

Kjell Aleklett

Coal to Liquids

Four million barrels per day:

60 % of Chinas coal production of today

60% more then USA coal production of today

UPPSALA UNIVERSITET

The Human Well Being (HWB) equation

HWB(E) =

Food&Water(E) + Economy(E) + Climate(E) + Security(E)

E = Energy

UPPSALA UNIVERSITET

Food and Fuel – can agriculture provide?

Agriculture as provider of both food and fuel

Kersti Johansson, Karin Liljequist, Lars Ohlander, and Kjell Aleklett

Accepted for publication in AMBIO
The Royal Swedish Academy of Sciences

UPPSALA UNIVERSITET

Food Energy on the Table

Nobel Dinner 2007

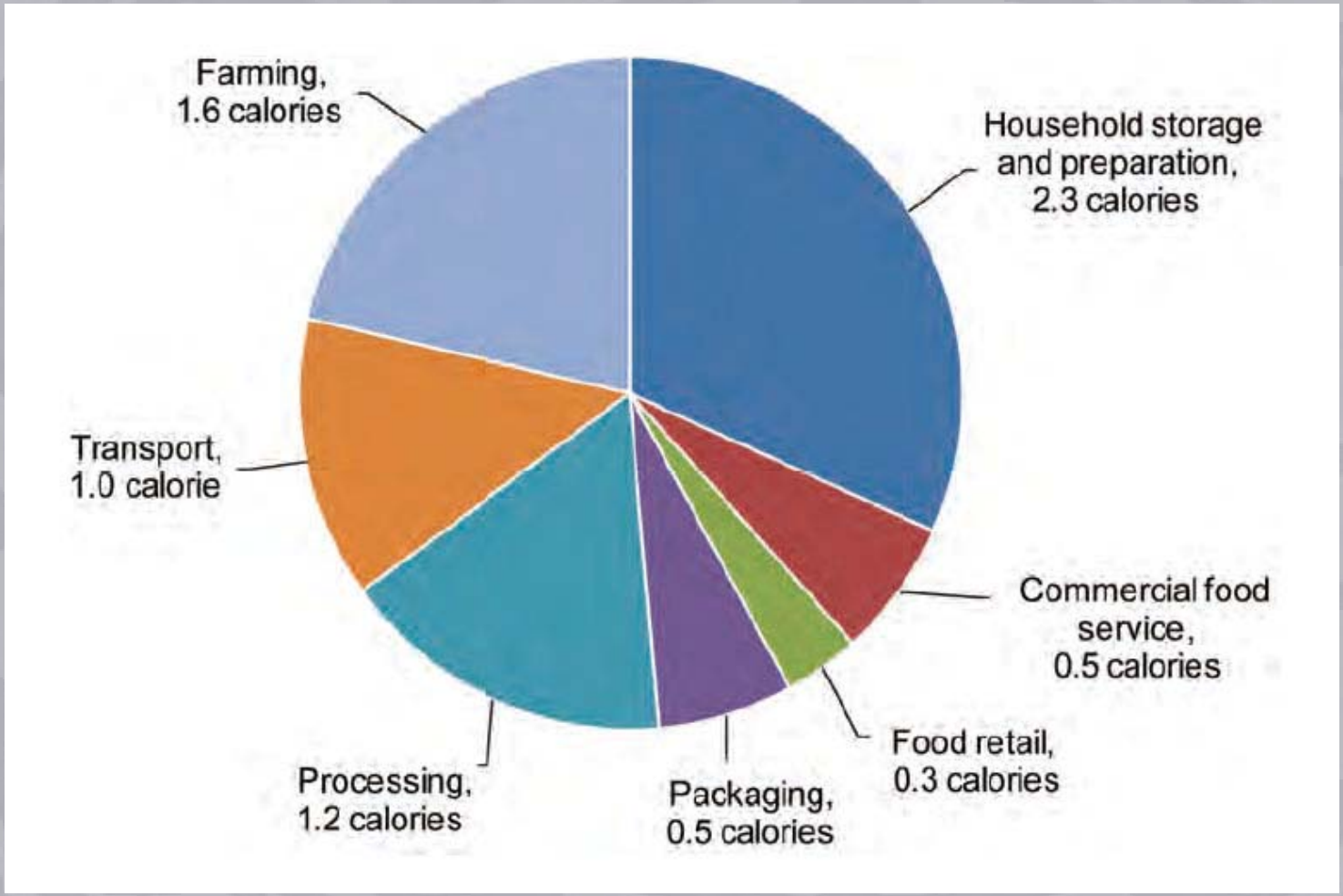
Recommended energy per person:
2500 kcal per day

Recommended energy for the global population, 6.7 billion persons:
7100 TWh per year

Or in oil equivalence:
12 million barrels per day

UPPSALA UNIVERSITET

Needed energy for food production

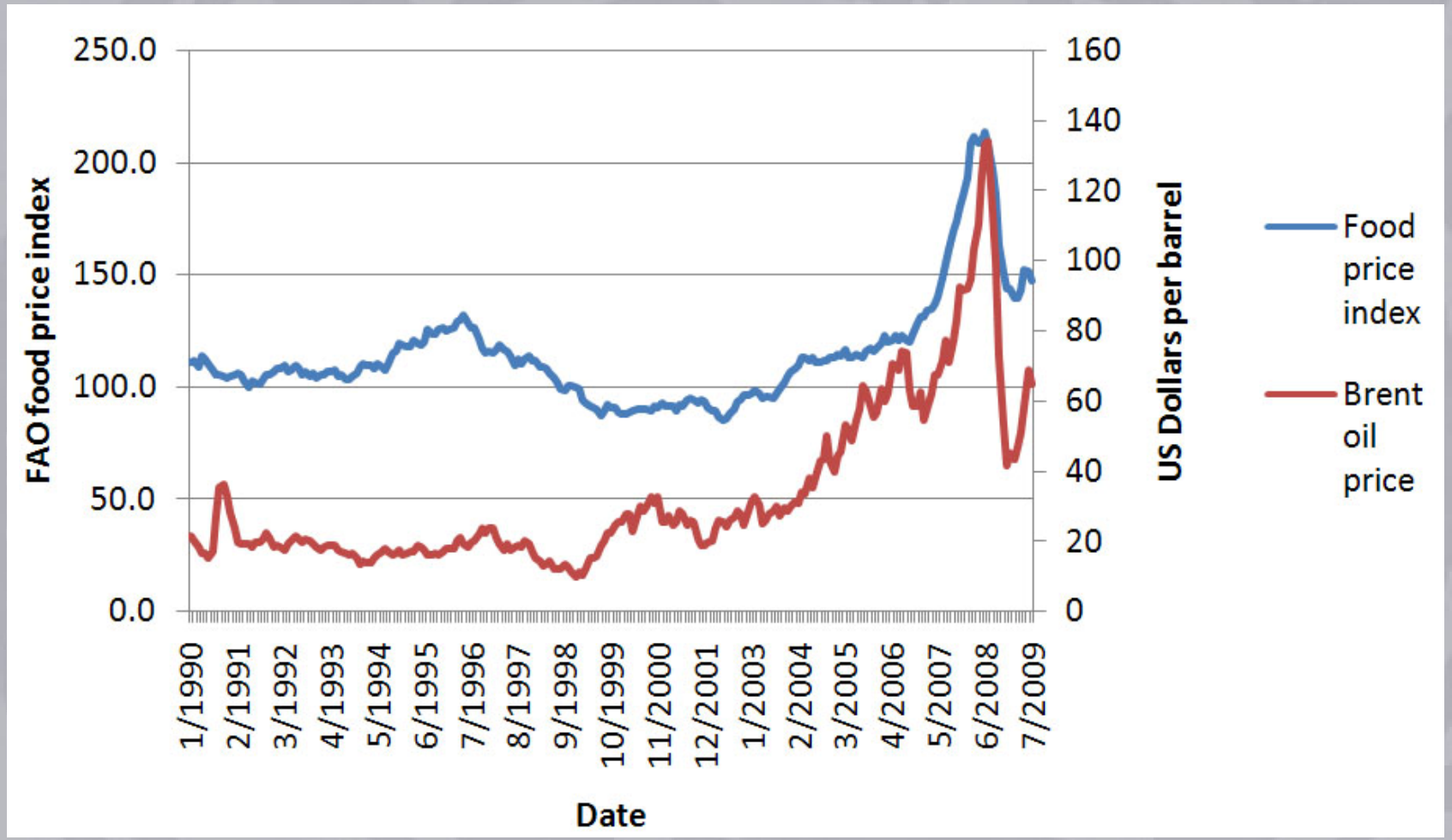


1 calorie on the table in USA needs 7.4 calories of energy.
With a global factor of 5 calories we get that 12 Mb/d food energy need around 60 Mb/d oil, gas and coal, and most of that is oil.

UPPSALA UNIVERSITET

Kjell Aleklett

Food and oil prices 1990 - 2009



UPPSALA UNIVERSITET

Kjell Aleklett

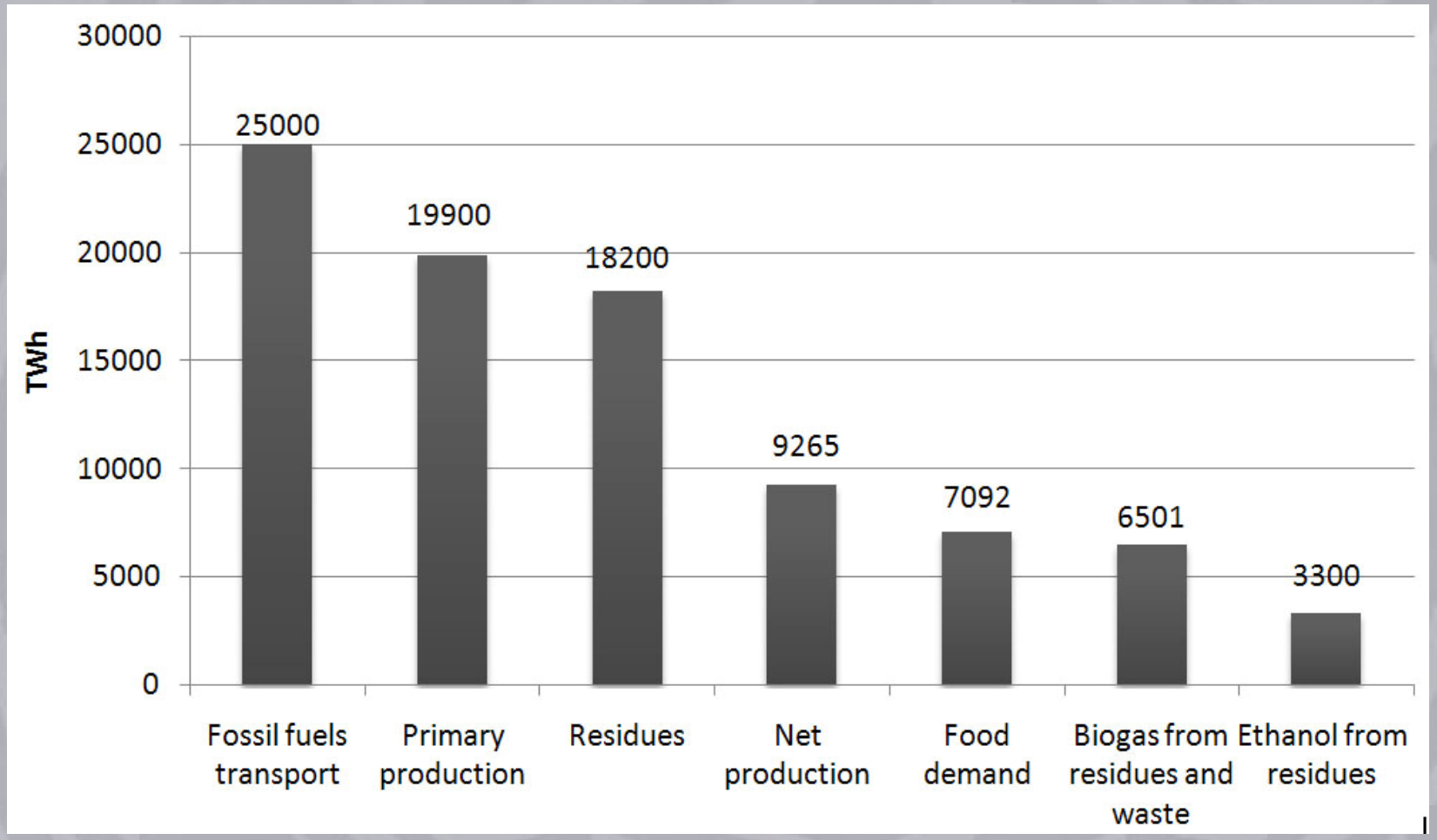
We are eating oil

Nobel Dinner 2007

UPPSALA UNIVERSITET

Kjell Aleklett

Food and Fuel

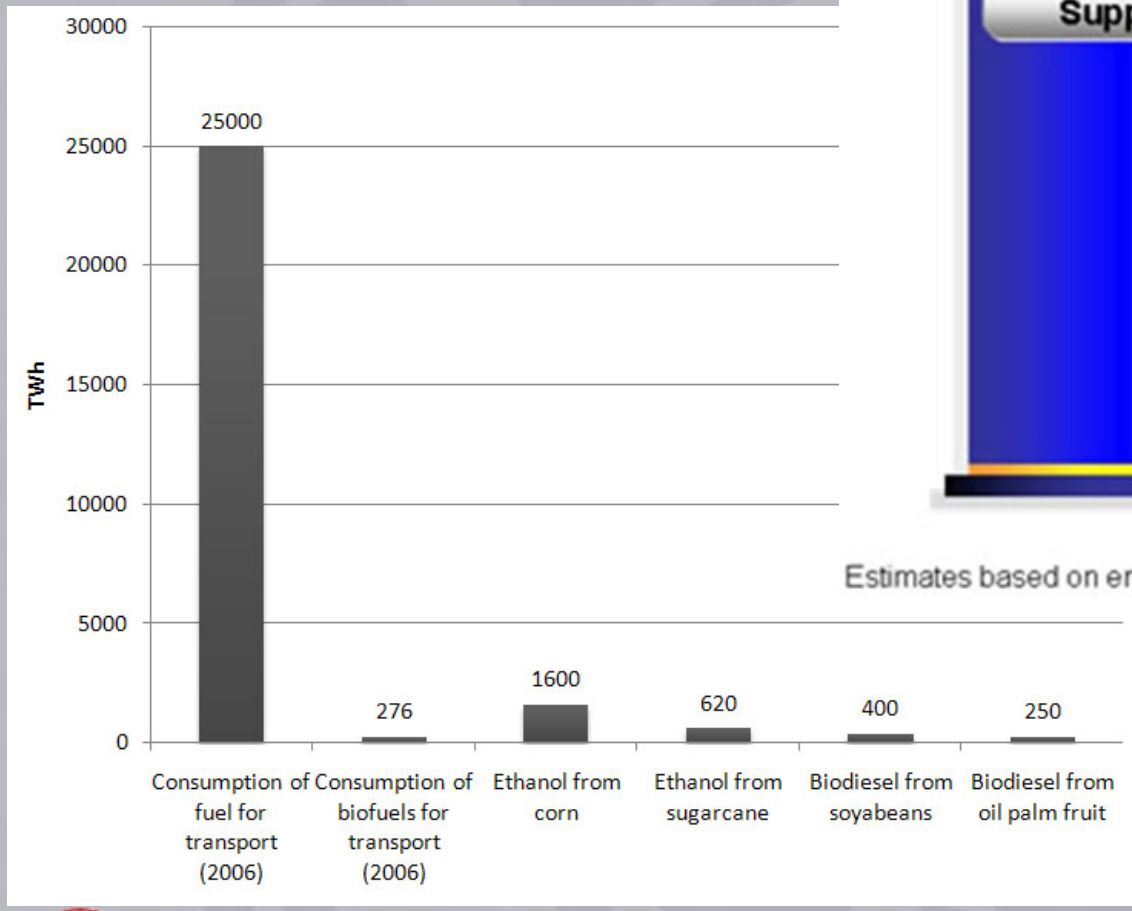


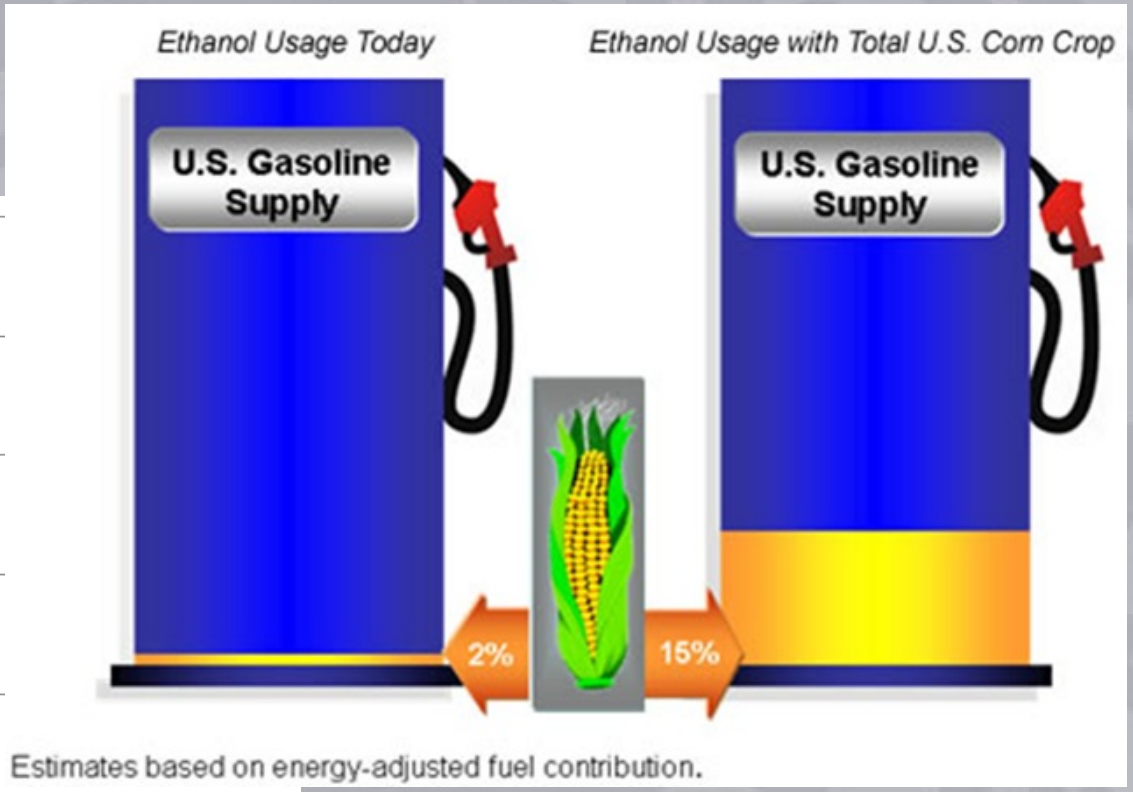
Global agricultural production and some scenarios for possible biogas and ethanol production compared to present consumption of fossil motor fuels and global food demand.

UPPSALA UNIVERSITET

Kjell Aleklett

Food or Fuel





Today's agricultural cannot provide us with food and fuel.

UPPSALA UNIVERSITET

Kjell Aleklett

The Human Well Being (HWB) equation

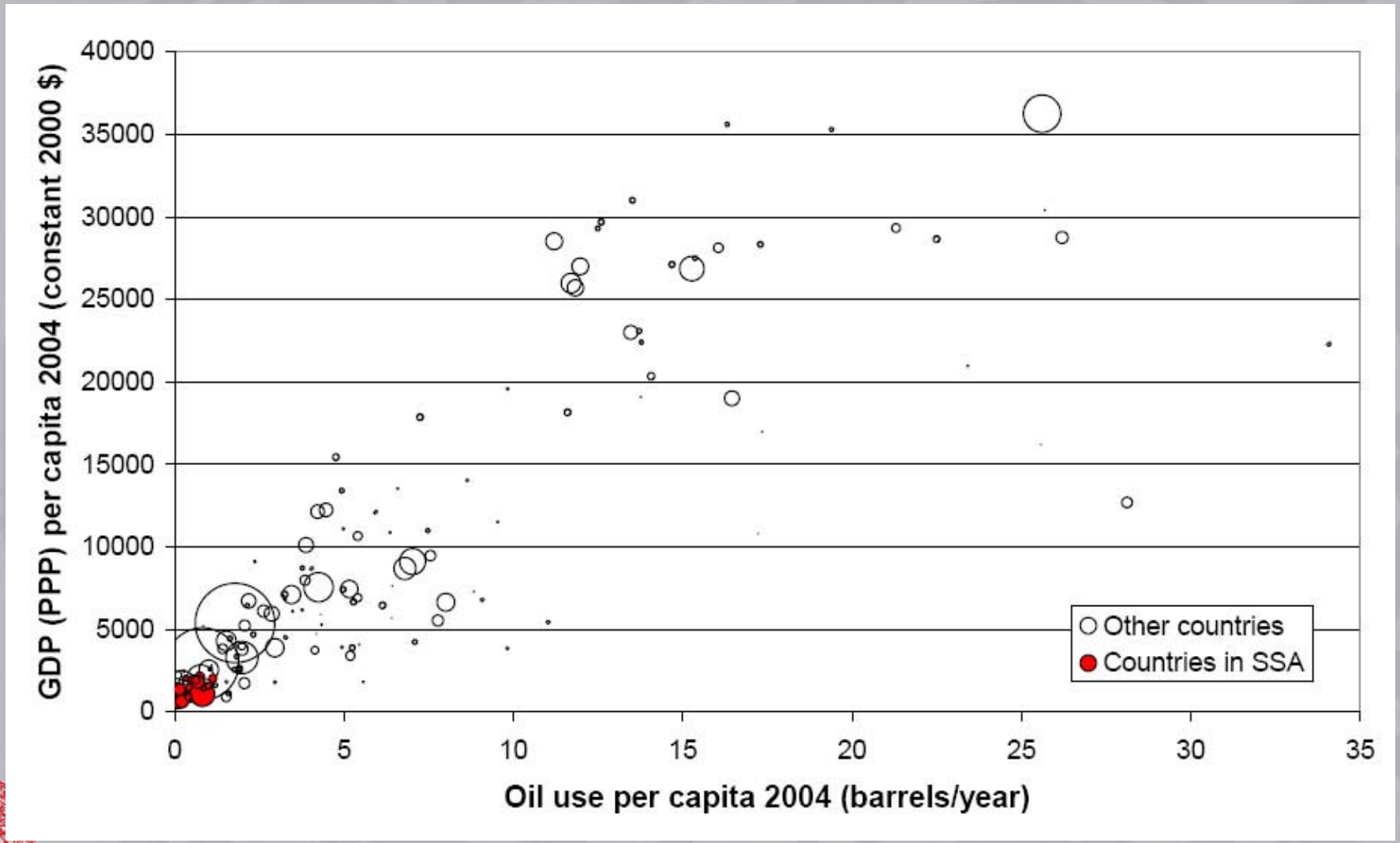
HWB(E) =

Food&Water(E) + Economy(E) + Climate(E) + Security(E)

E = Energy

UPPSALA UNIVERSITET

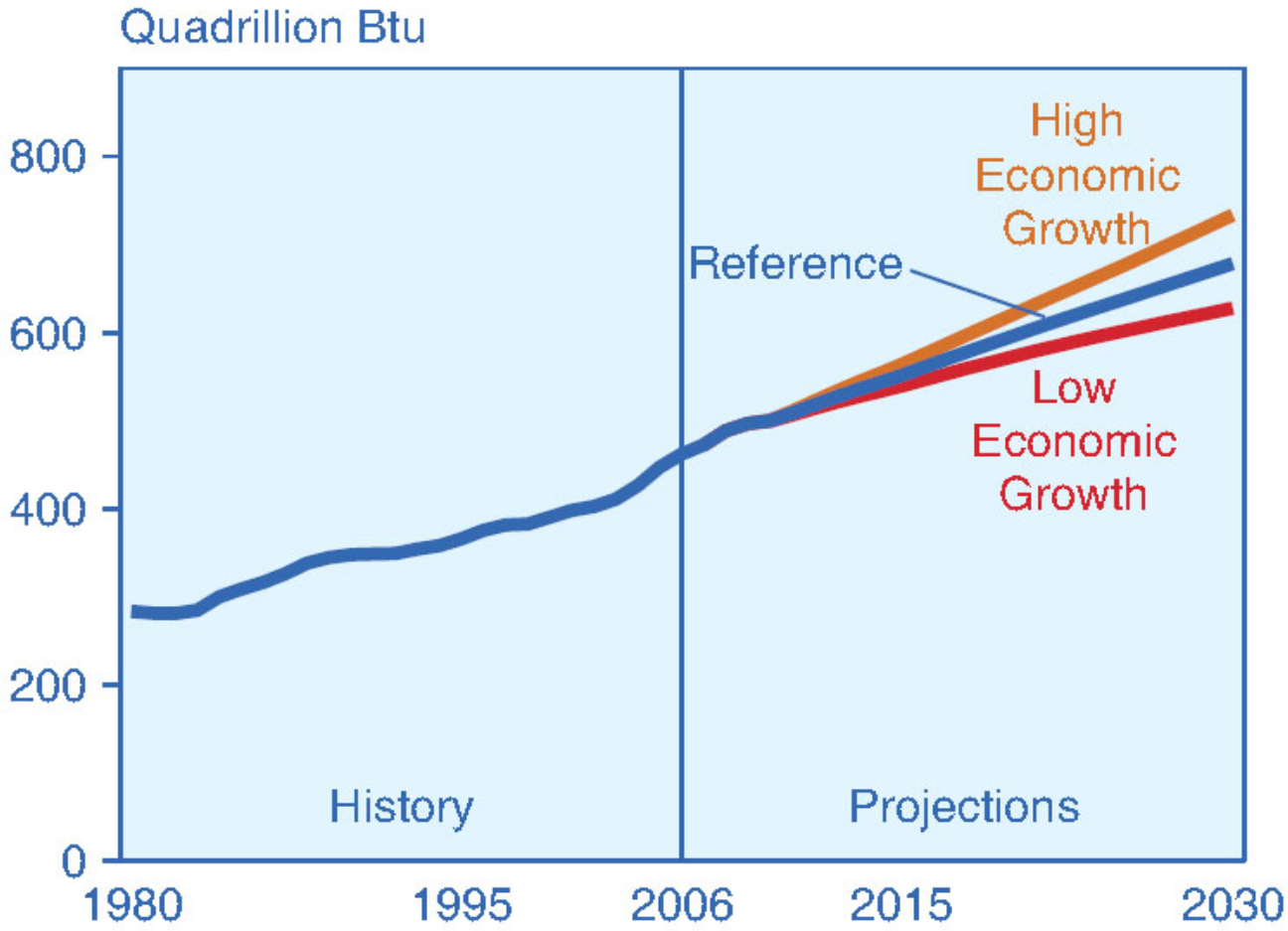
GDP and oil use per capita



UPPSALA UNIVERSITET

Kjell Aleklett

Energy and Economic Growth



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

UPPSALA UNIVERSITET

Kjell Aleklett

GDP Per Capita

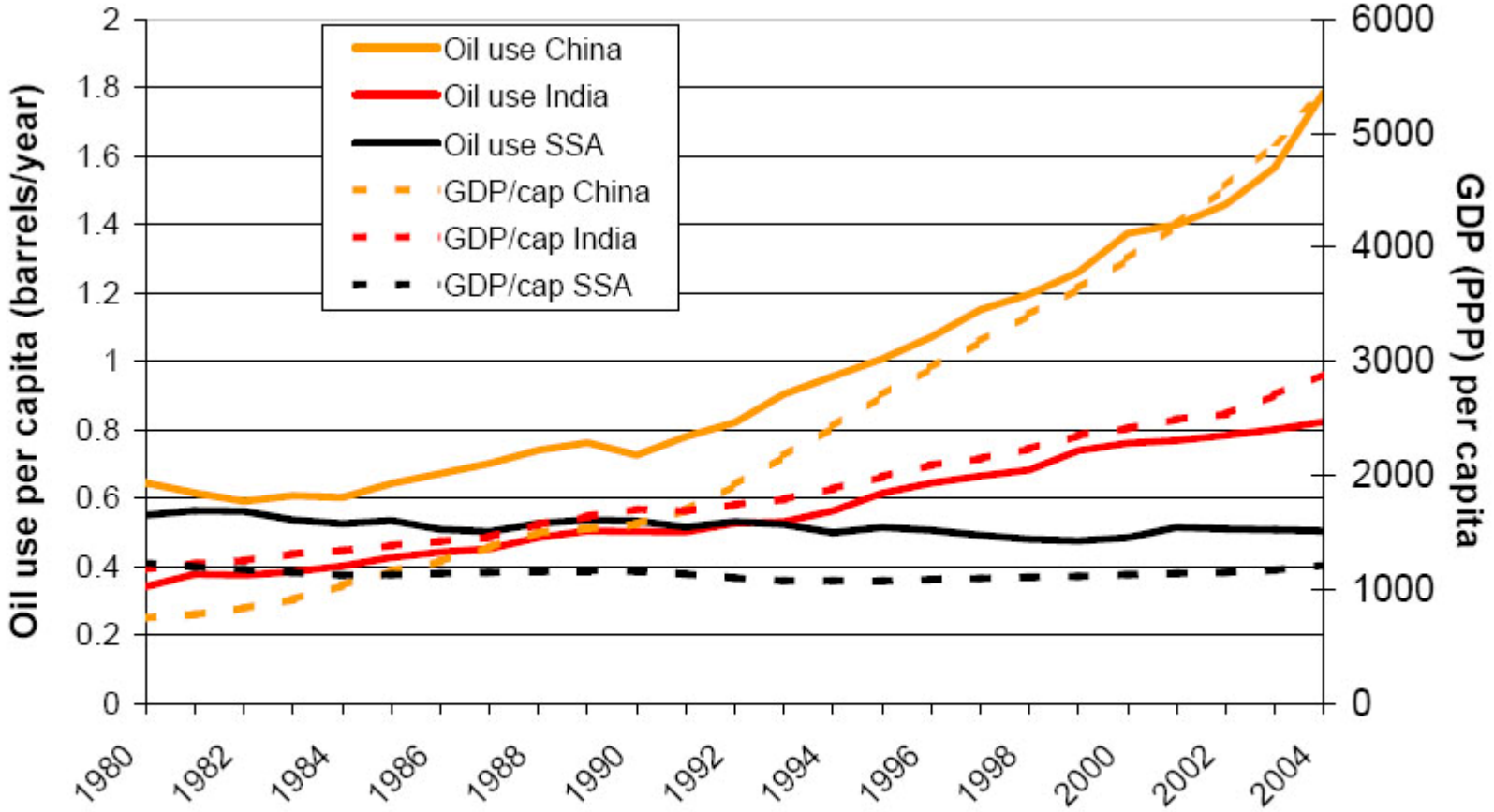
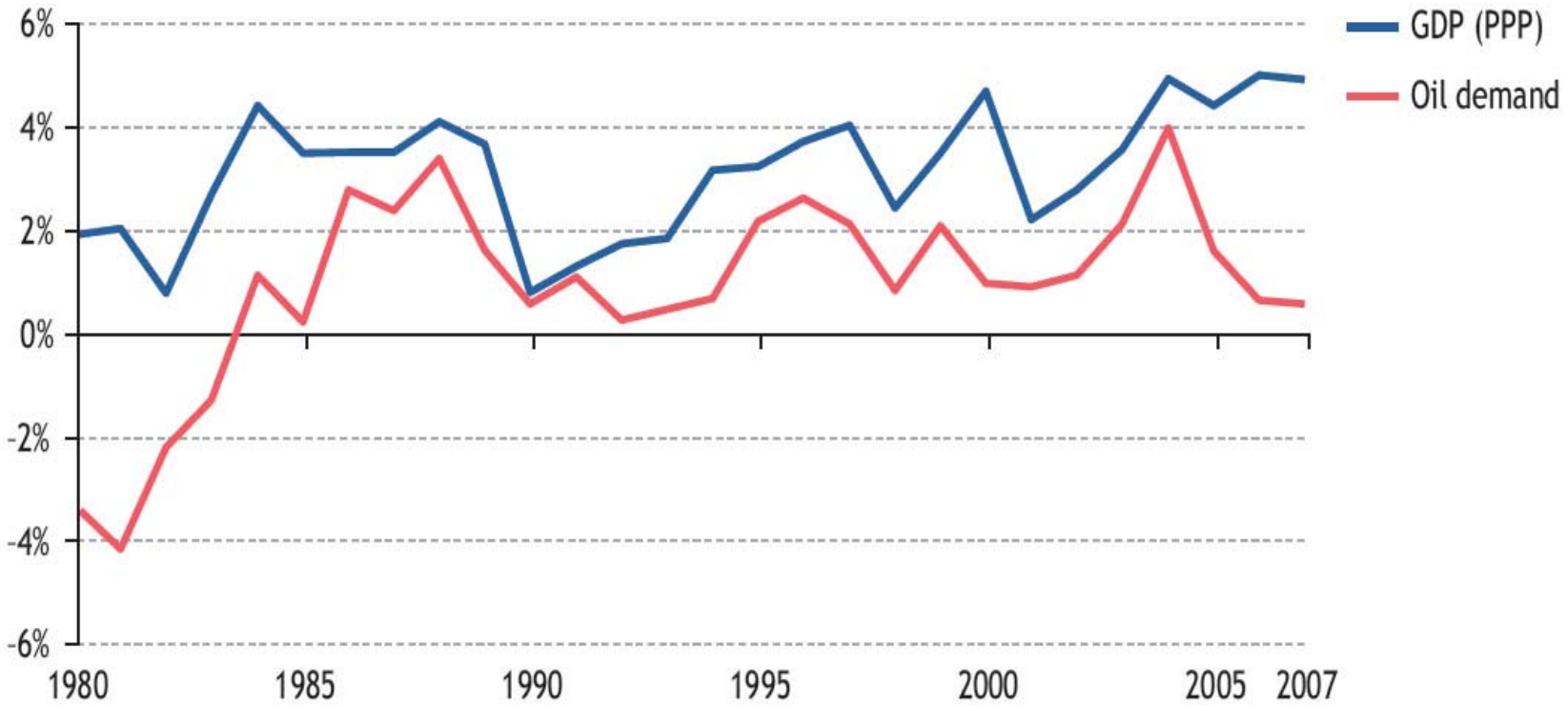


Figure 21. Development of GDP (PPP) and oil use per capita in SSA, China and India 1980-2004.

"Business as Usual" and Oil Demand

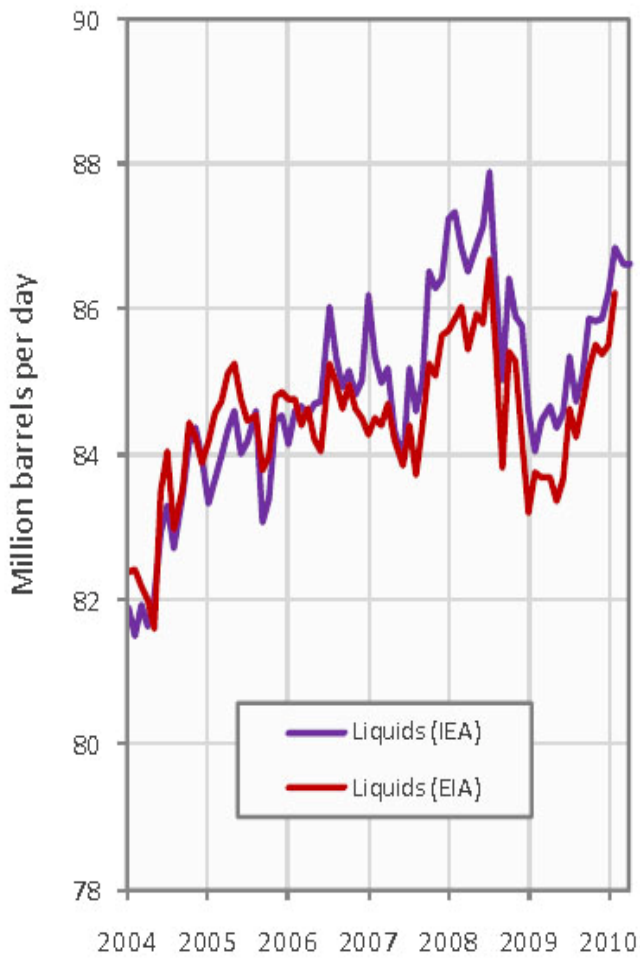
Figure 3.1 • Change in world primary oil demand and real GDP growth



World Energy Outlook 2008, International Energy Agency

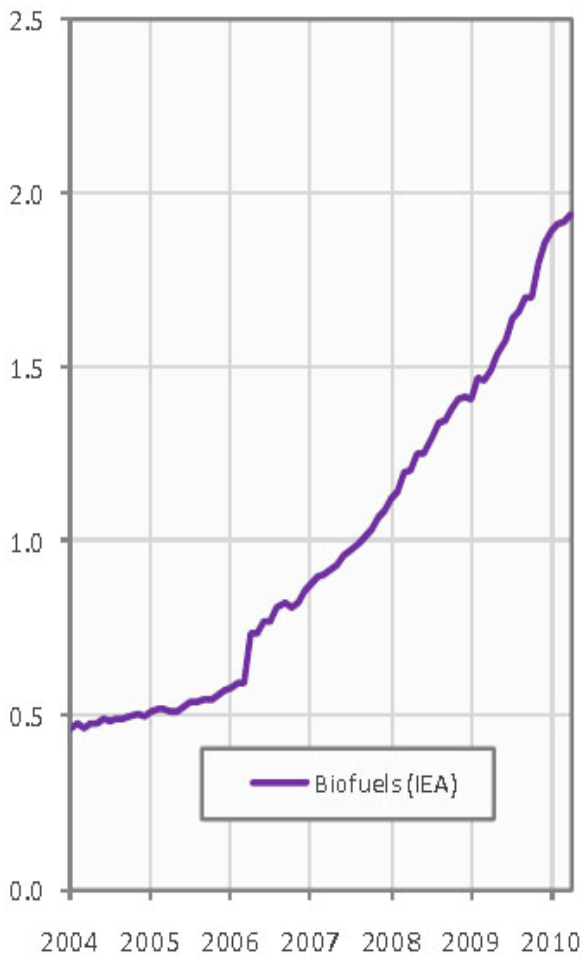
World Production of Liquids and biofuels

Chart 2: Liquids Production January 2004 - April 2010



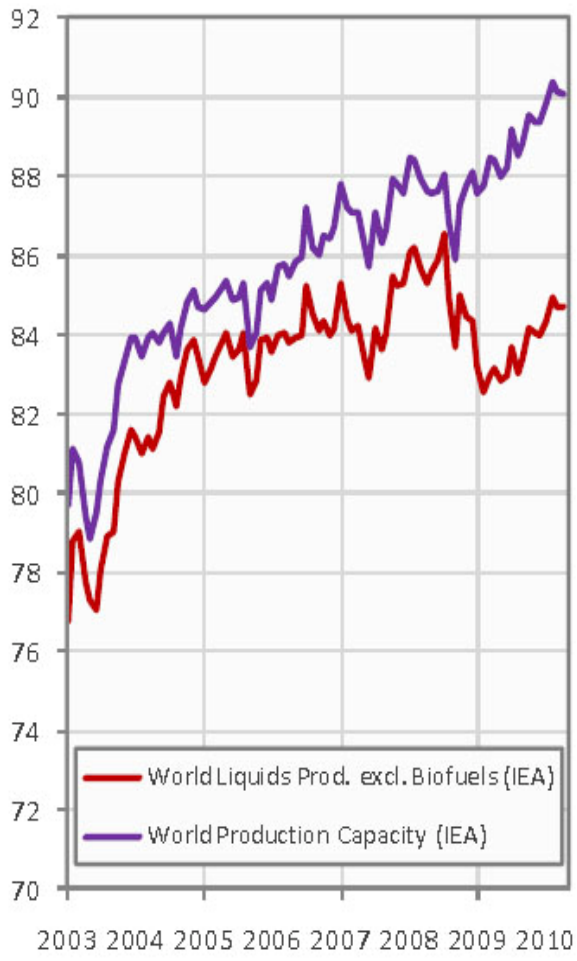
Source: International Energy Agency

Chart 3: World Biofuels Production Jan. 2004 - April 2010



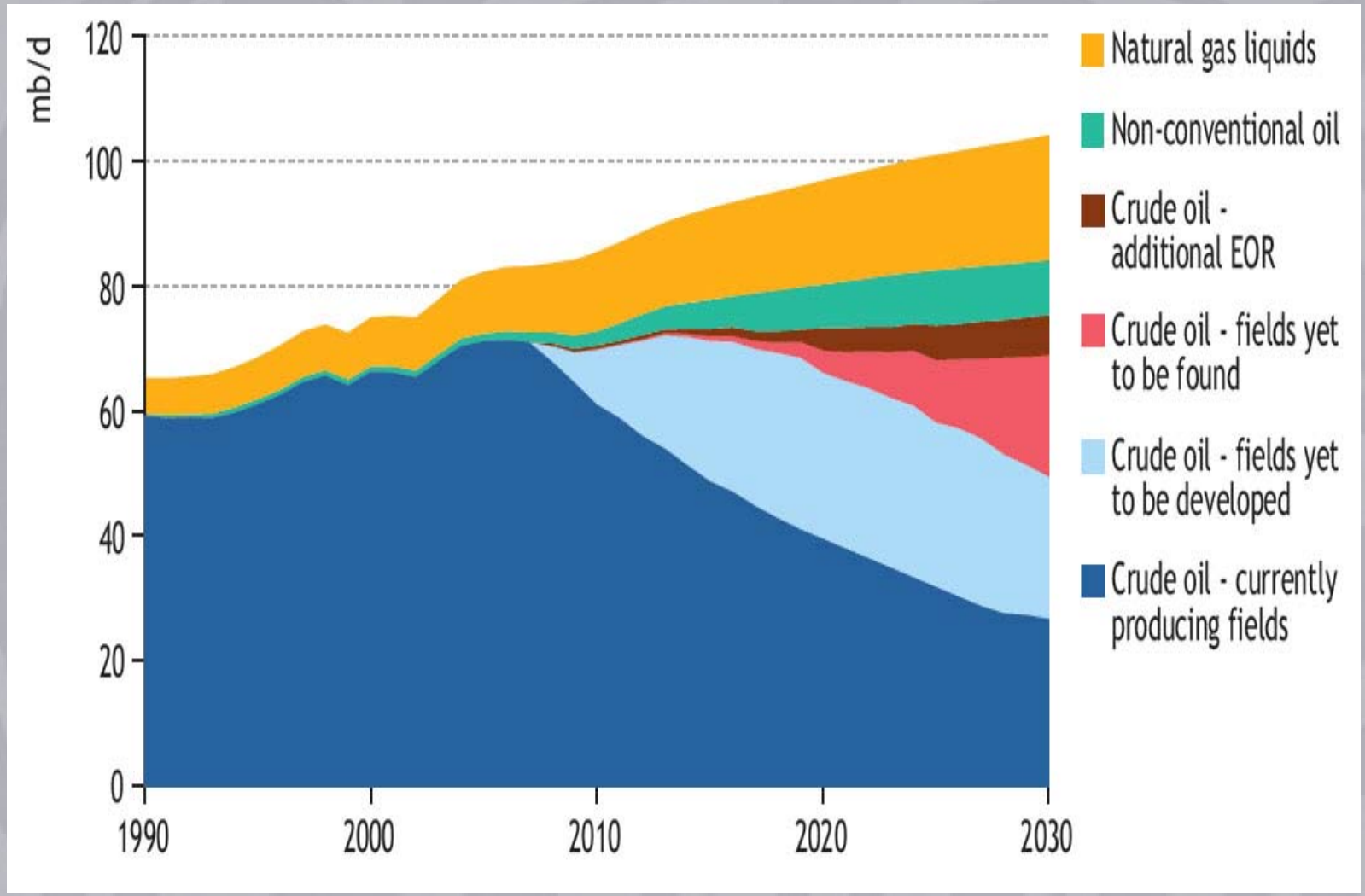
Source: IEA, EIA,

Chart 4: World Production Capacity Jan. 2003 - April 2010



Source: Energy Information Administration

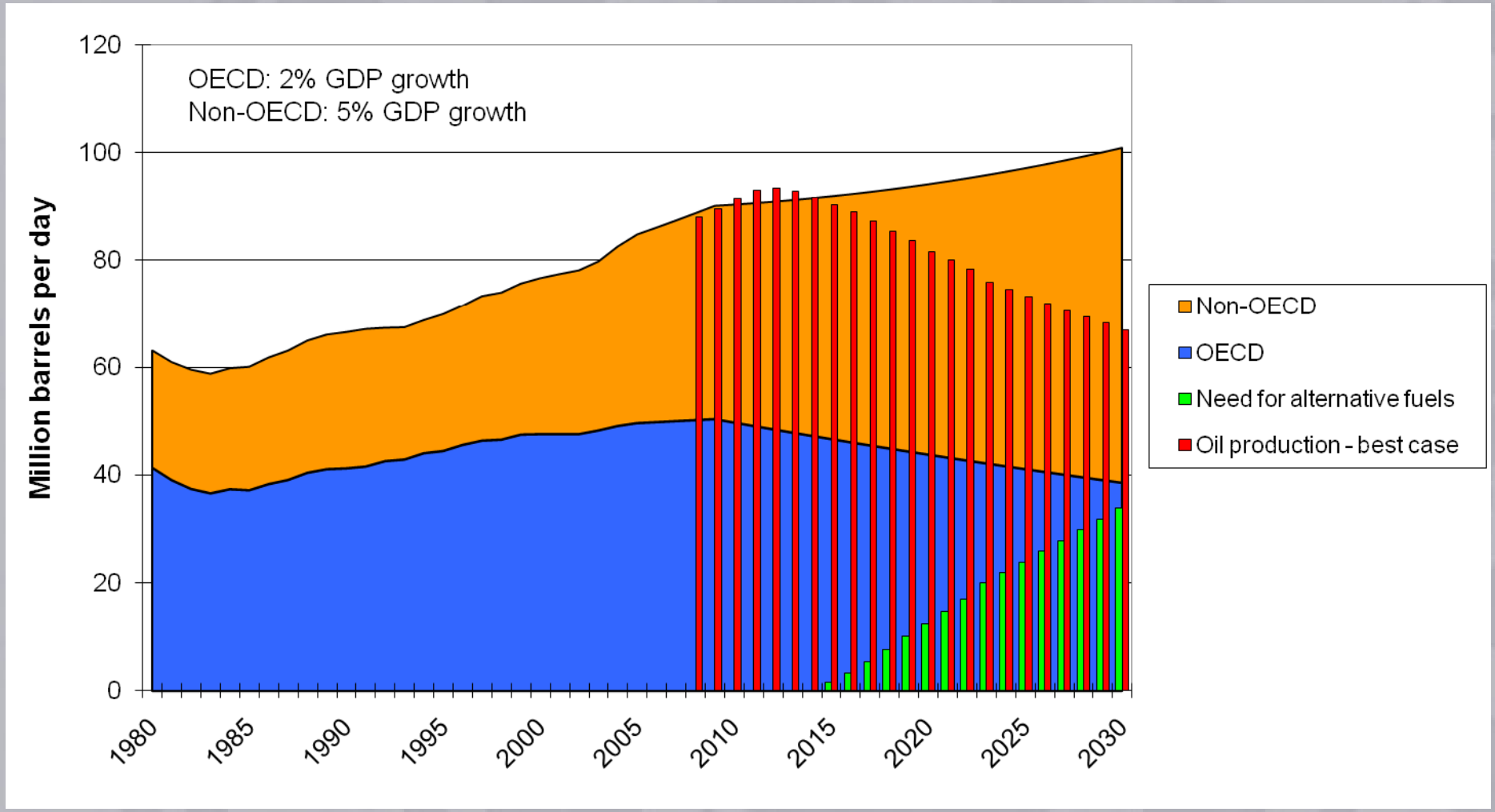
World Energy Outlook 2008



UPPSALA UNIVERSITET

Kjell Aleklett

A Sustainable World Scenario



UPPSALA UNIVERSITET

Kjell Aleklett

The Human Well Being (HWB) equation

HWB(E) =

Food&Water(E) + Economy(E) + Climate(E) + Security(E)

E = Energy

UPPSALA UNIVERSITET


热烈欢迎瑞典Uppsala大学代表团莅临高培中心
Daqing
ASIA

Daqing - China

”Petroleum has a compact relationship with a countries political, economical and military strength.”

UPPSALA UNIVERSITET

Kjell Aleklett

The Human Well Being (HWB) equation

HWB(E) =

Food&Water(E) + Economy(E) + Climate(E) + Security(E)

E = Energy

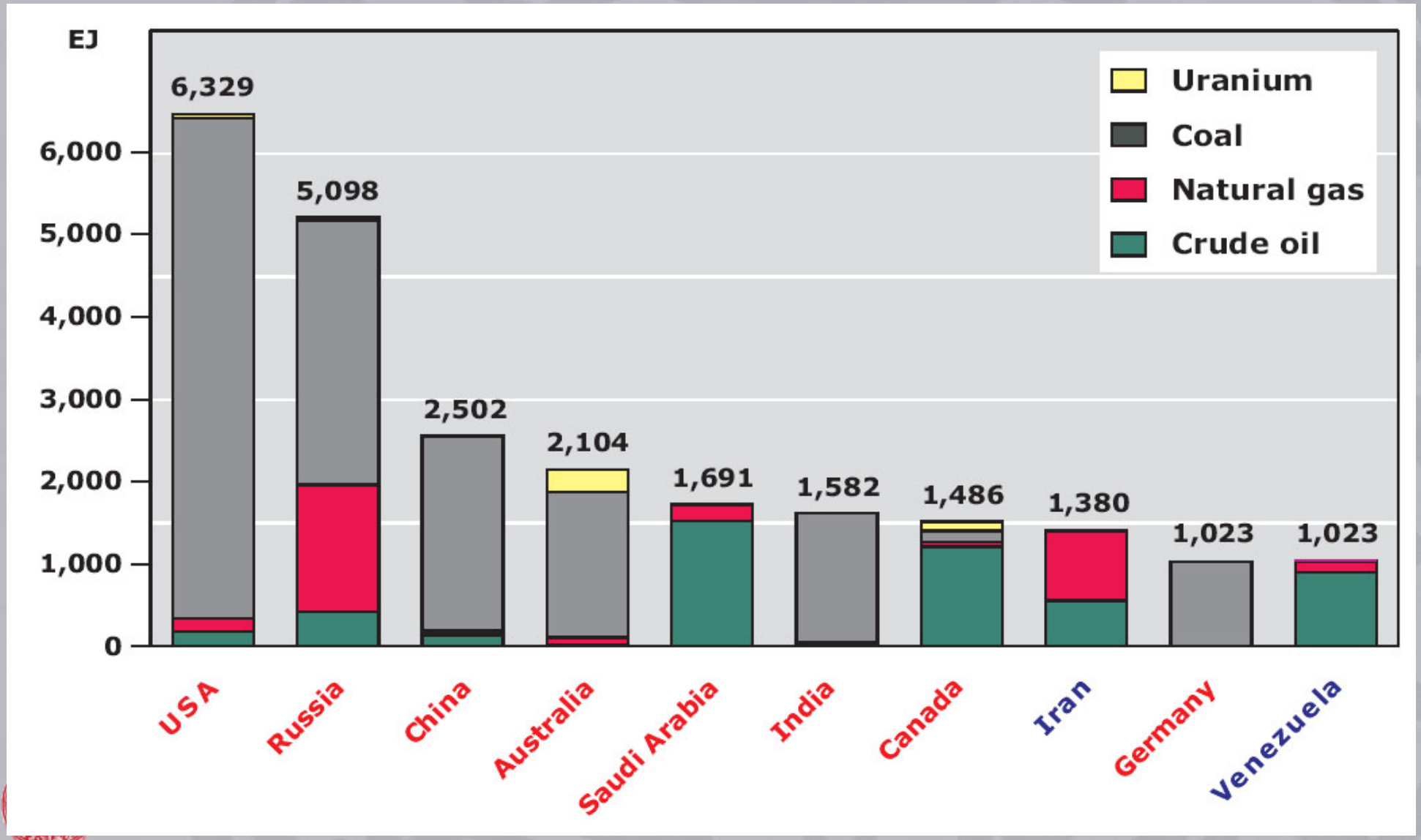
UPPSALA UNIVERSITET

We need to extinguish the fossil fire!

UPPSALA UNIVERSITET

Kjell Aleklett

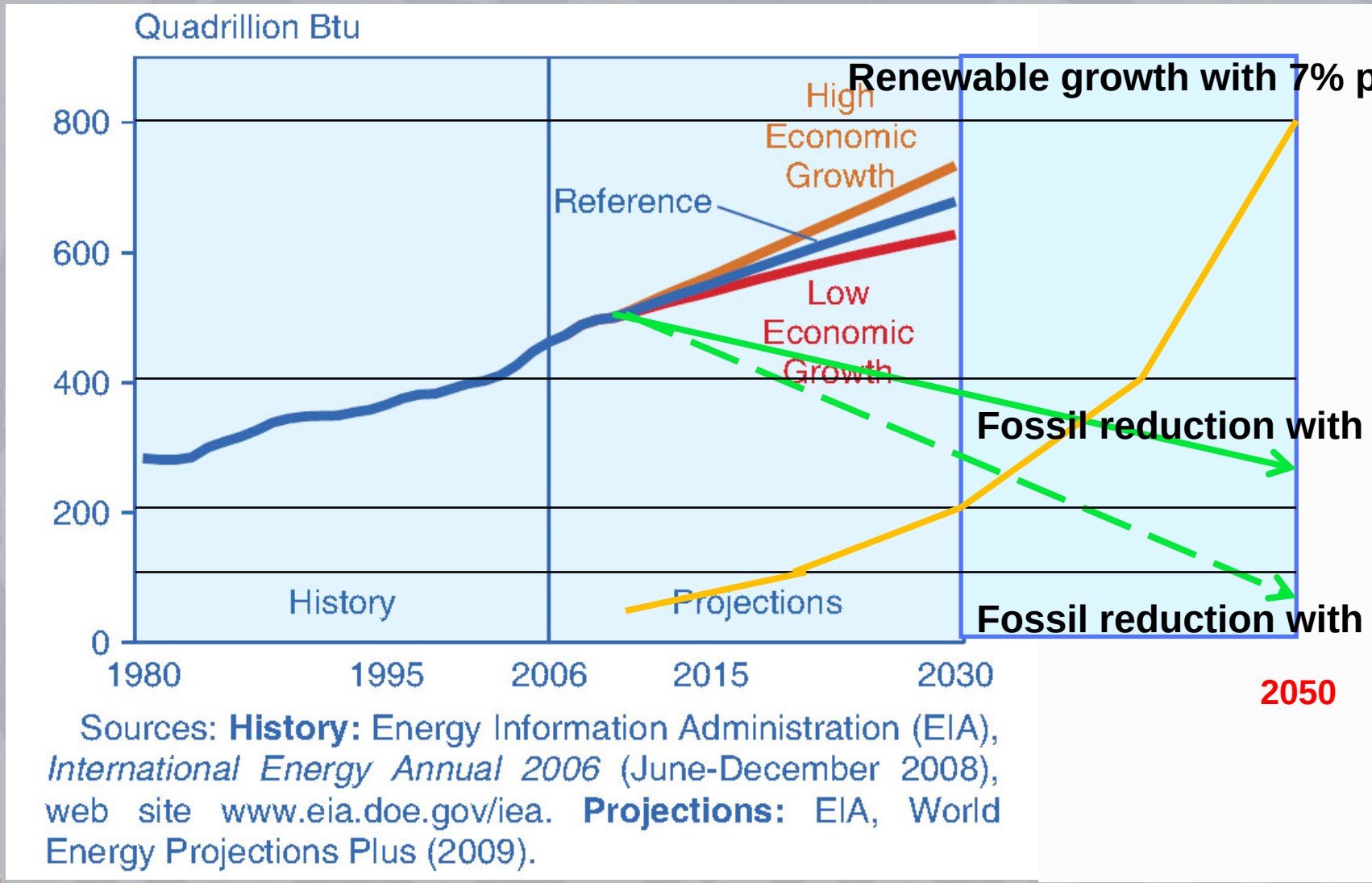
Where to find fossil fuel



UPPSALA UNIVERSITET

Kjell Aleklett

Emission reductions before Copenhagen

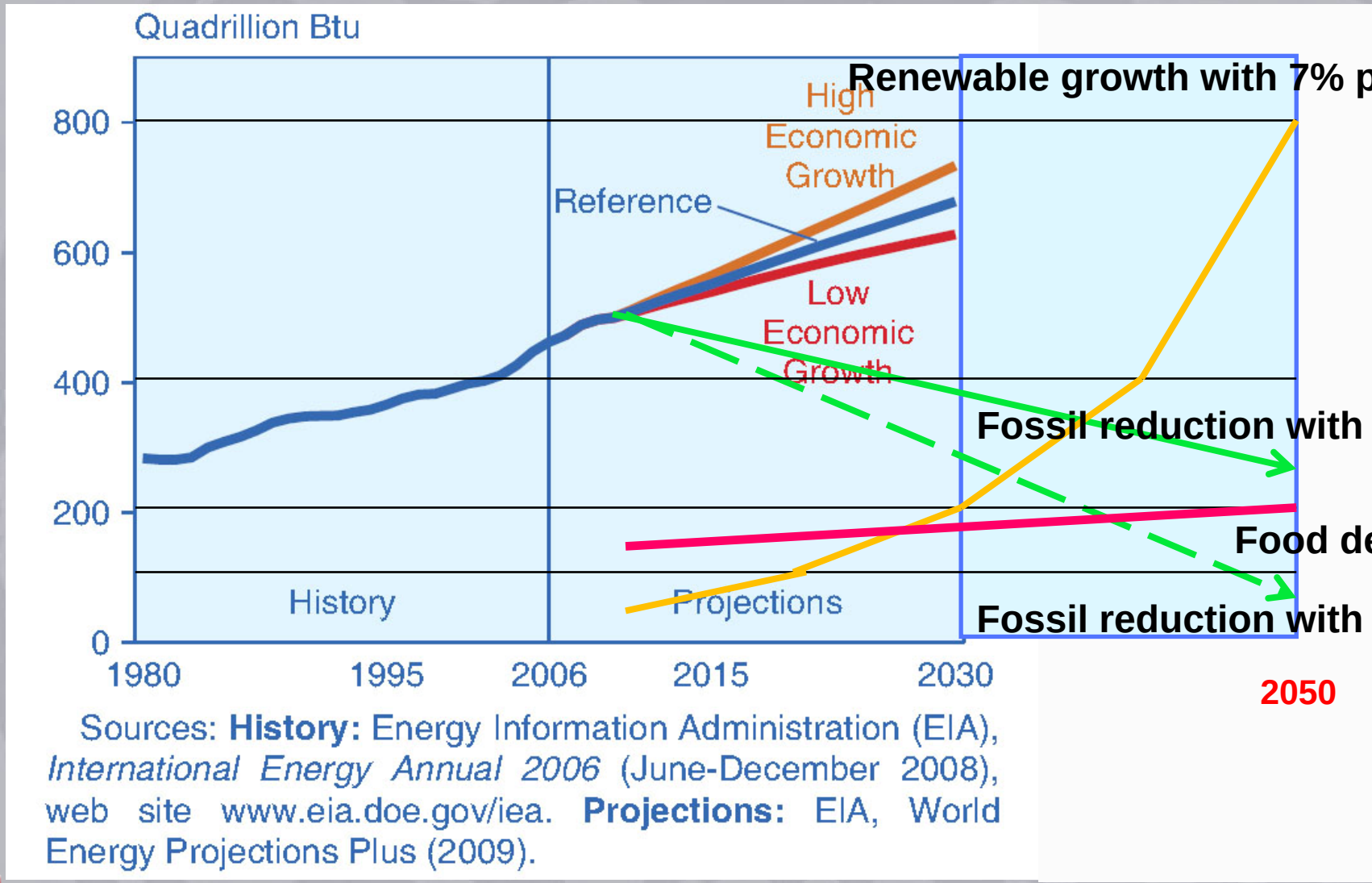


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

UPPSALA UNIVERSITET

Kjell Aleklett

Emission reductions before Copenhagen



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

UPPSALA UNIVERSITET

Kjell Aleklett

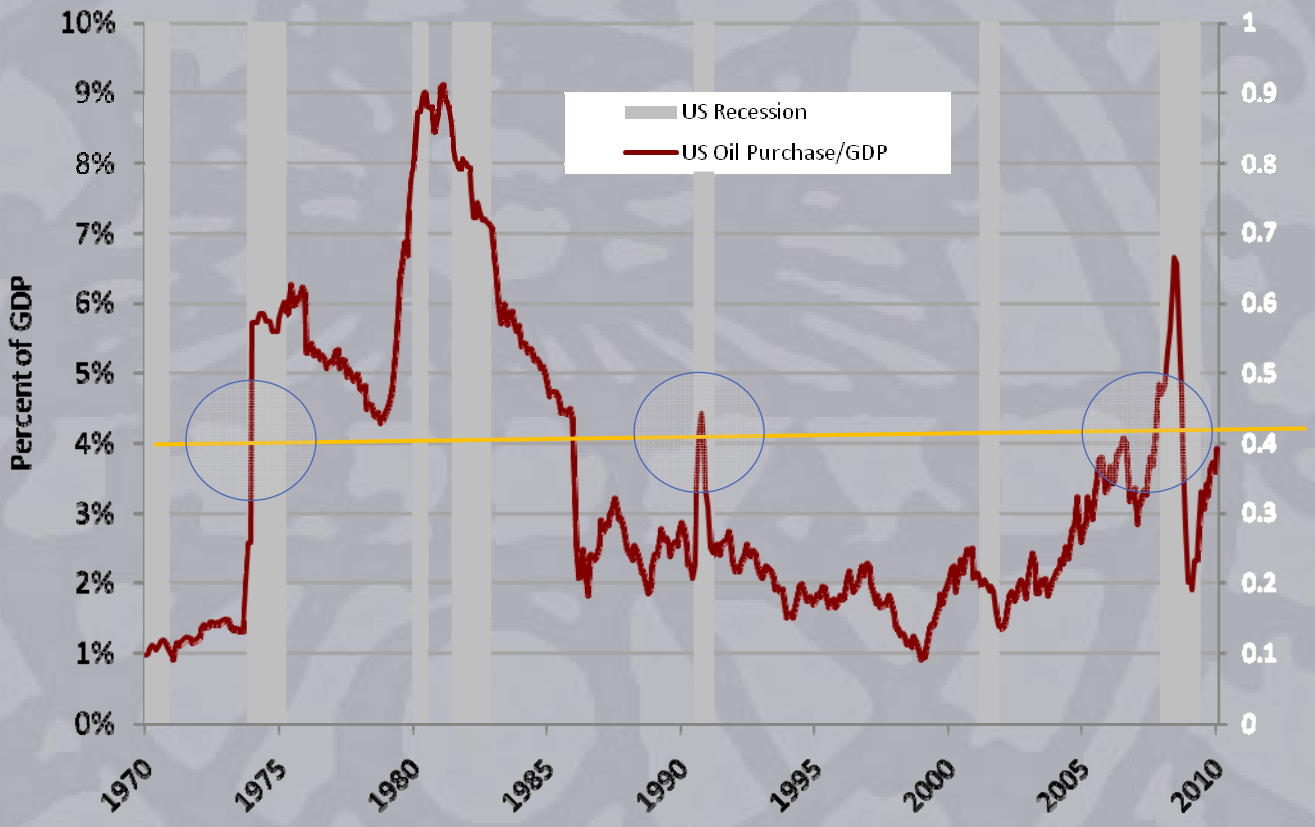
Future important trends for shipping

UPPSALA
UNIVERSITET

Kjell Aleklett

Historical Crude Oil Expenditures and Recession

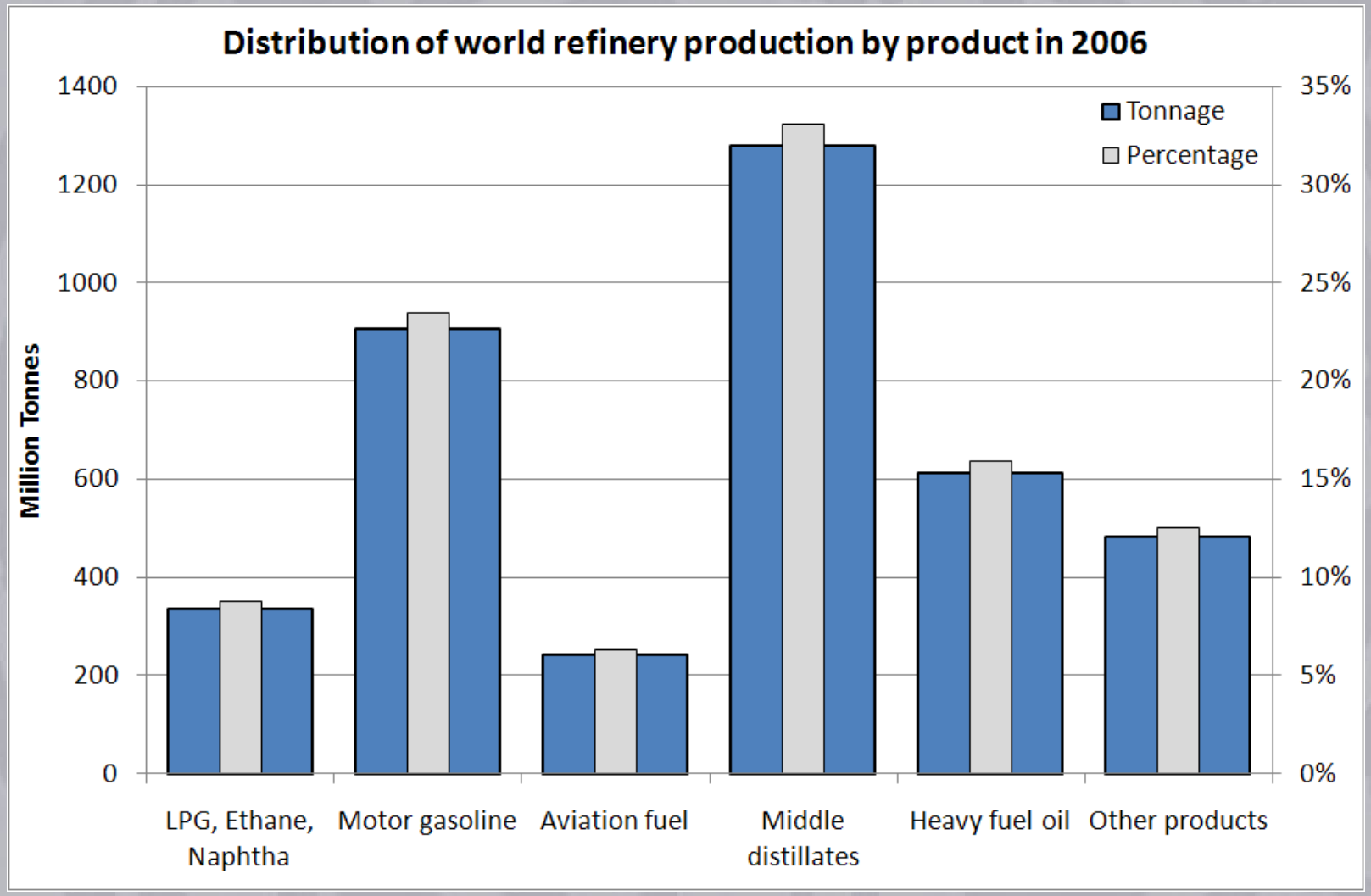
- By 2008, the supply-demand balance had become untenable
- When crude oil expenditure reached 4% of GDP, the US fell into recession
- As every other time since 1972
- Equals $80 oil
- WTI today: $75



UPPSALA UNIVERSITET

Kjell Aleklett

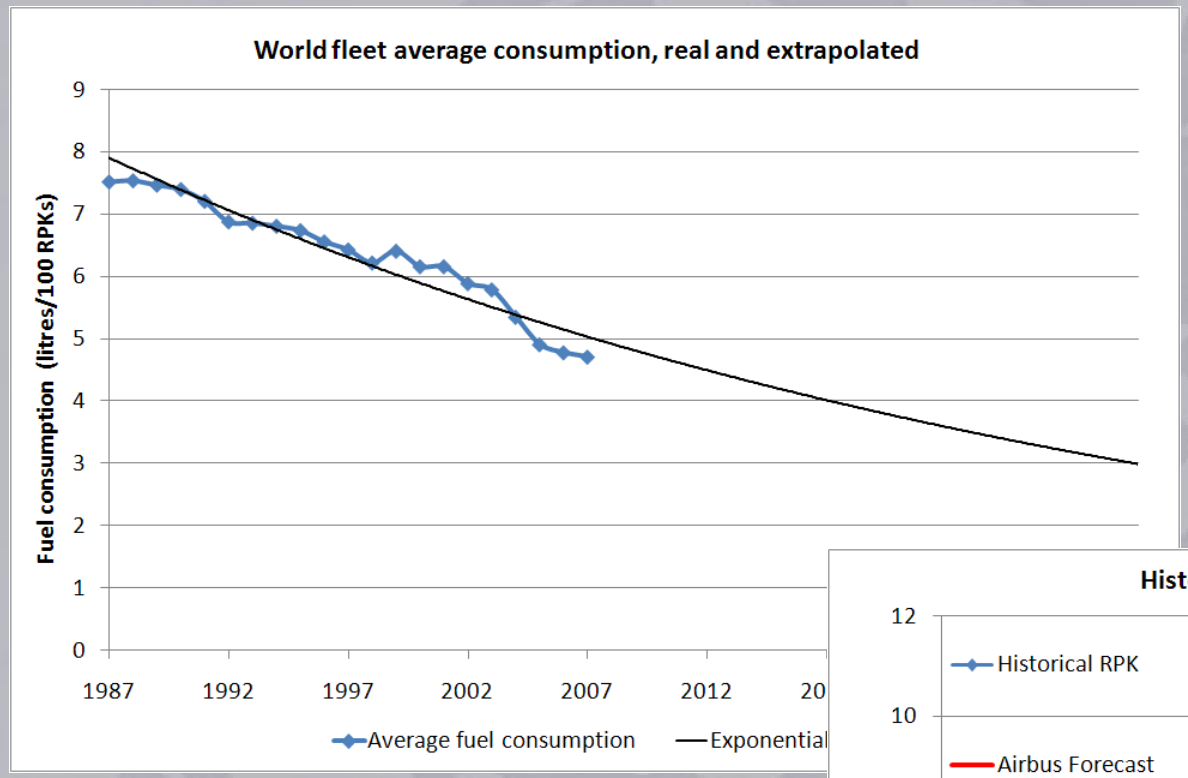
Transport Fuels in the Future

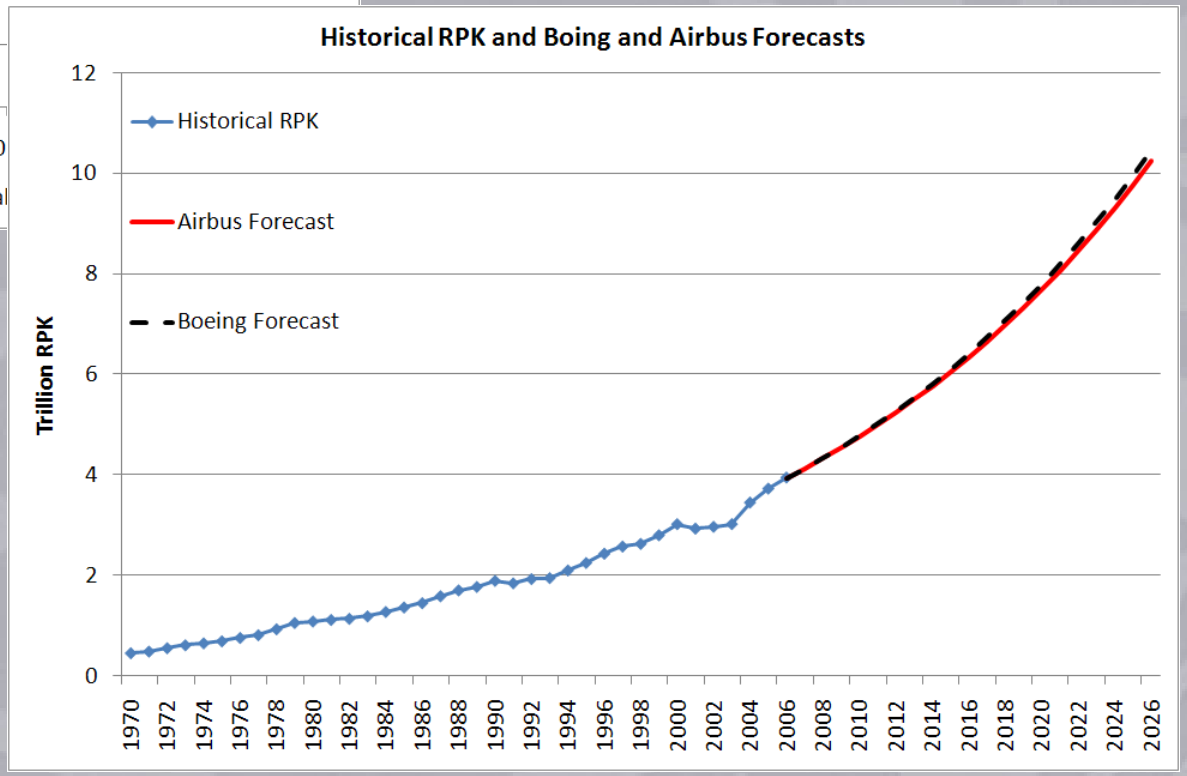


UPPSALA UNIVERSITET

Kjell Aleklett

"Business as Usual" for the Aviation Industry

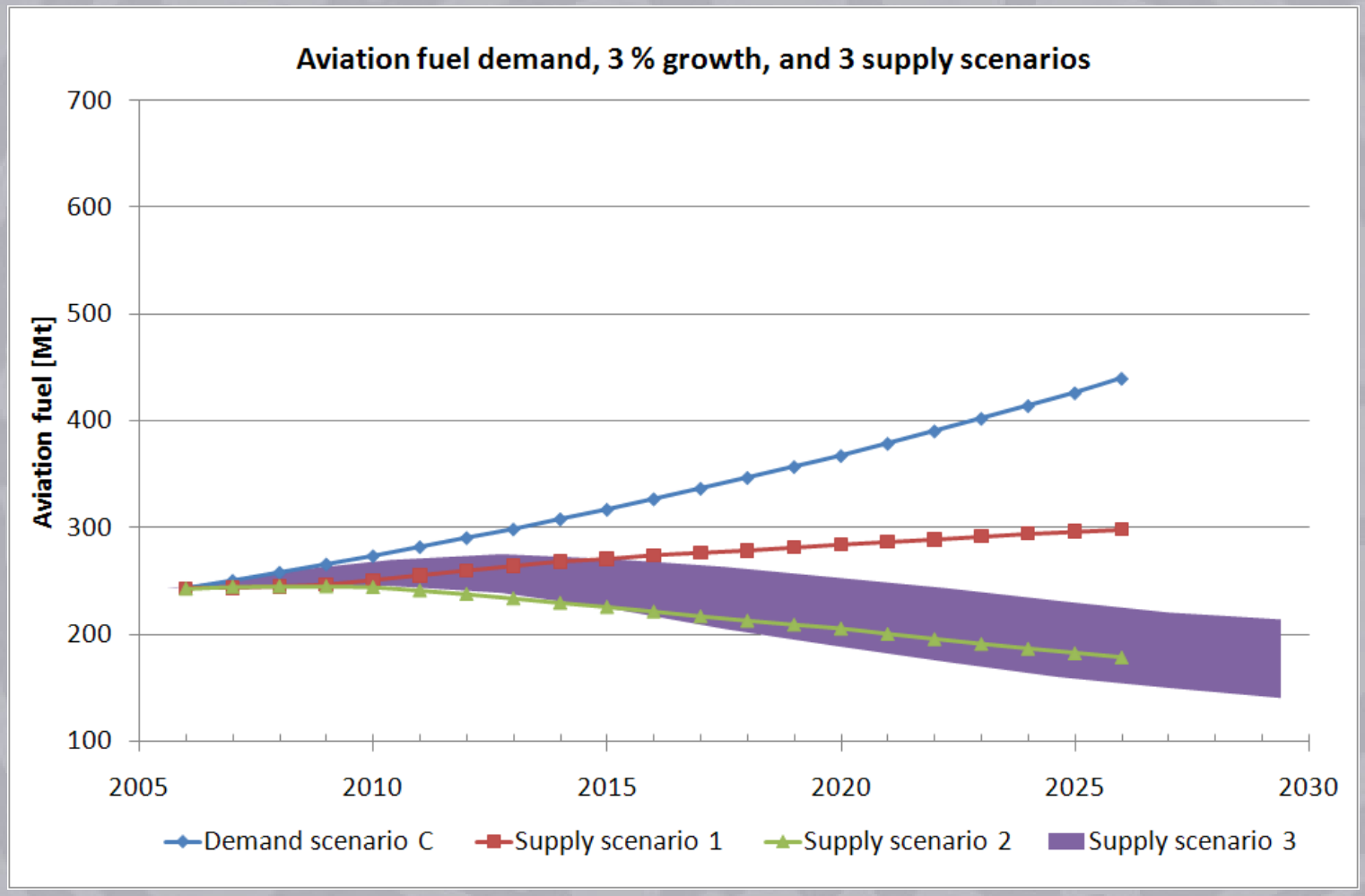




UPPSALA UNIVERSITET

Kjell Aleklett

Future Aviation Fuel Demand and Production

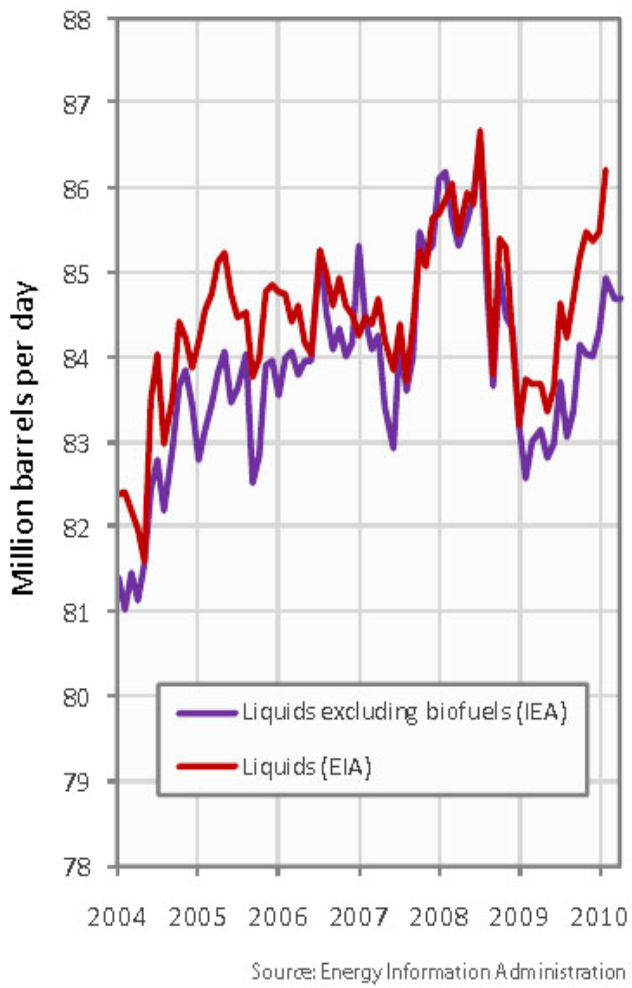


Aviation fuel and future oil production scenarios, Emma Nygren, Kjell Aleklett, Mikael Höök, Accepted by Energy Policy

UPPSALA UNIVERSITET

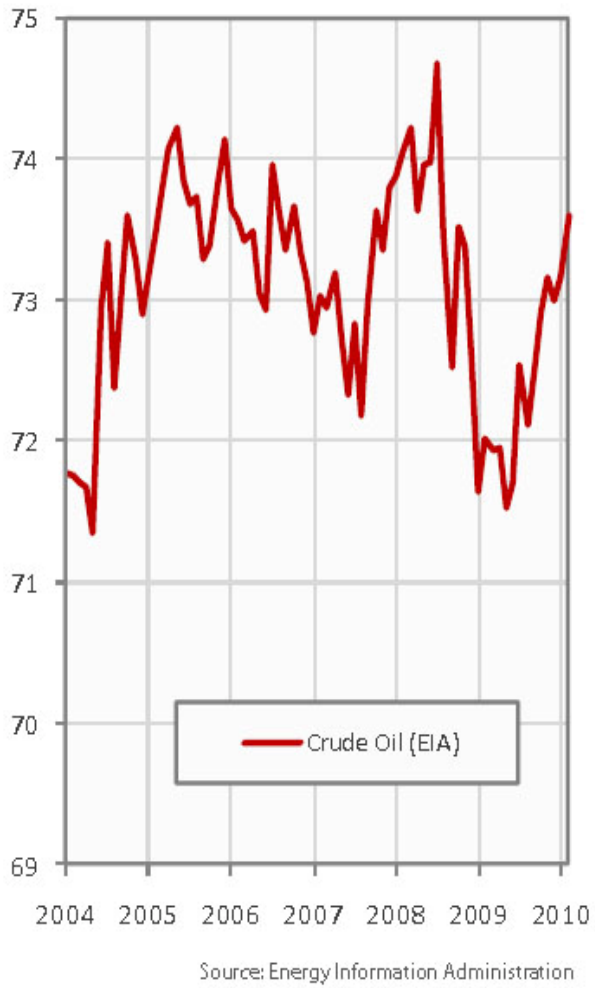
Crude Oil and NGL

Chart 5: EIA & EIA Liquids Comparison Jan. 2004 - April 2010



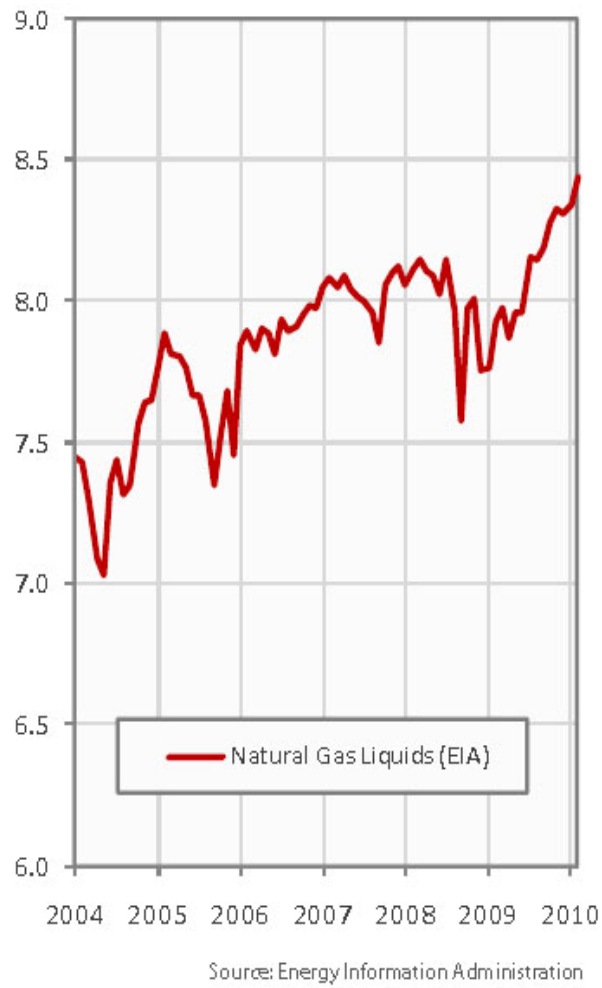
Source: Energy Information Administration

Chart 6: Crude Oil Production January 2004 - April 2010



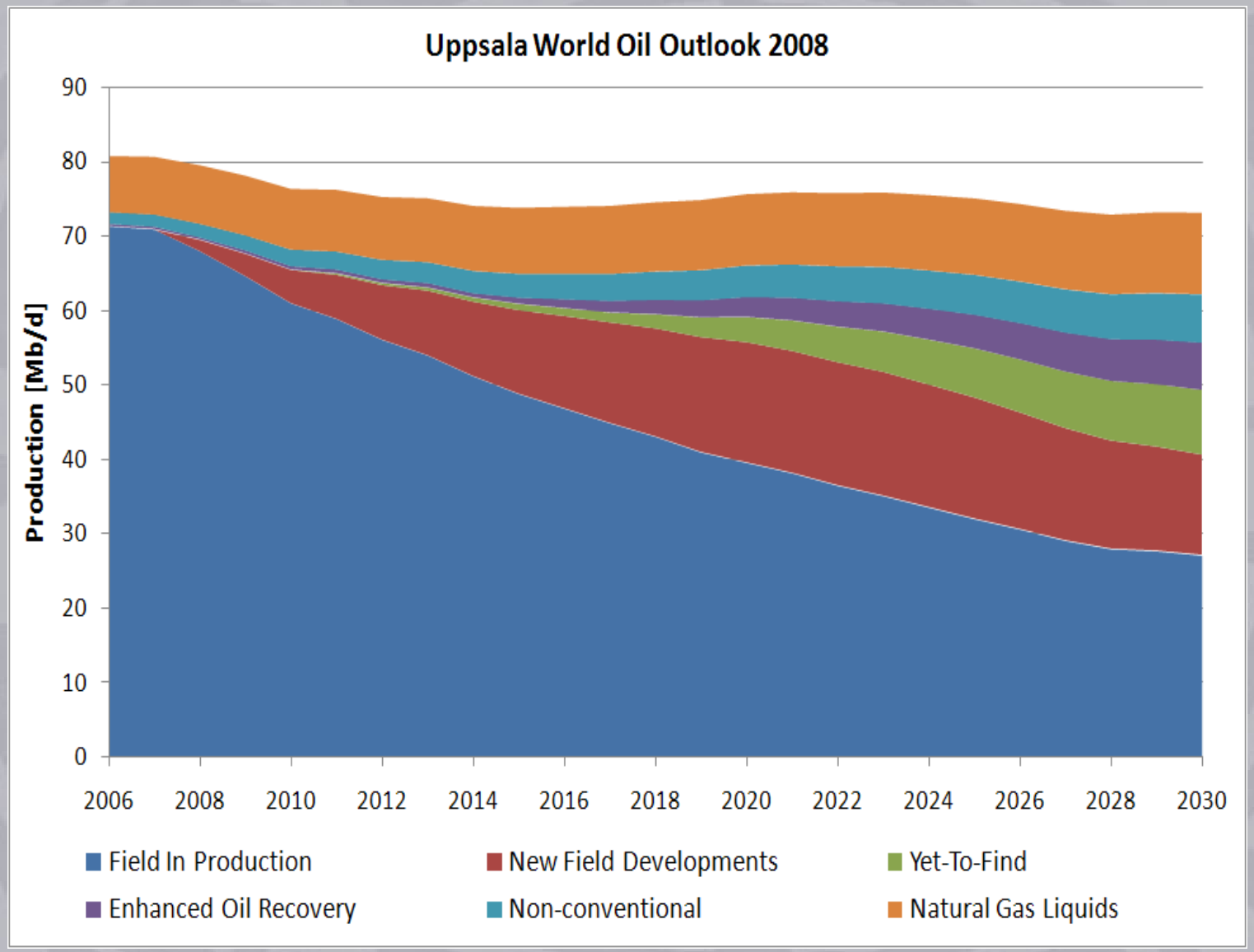
Source: Energy Information Administration

Chart 7: Nat. Gas Liquids Production Jan. 2004 - February 2010



Source: Energy Information Administration

Ideas about the future

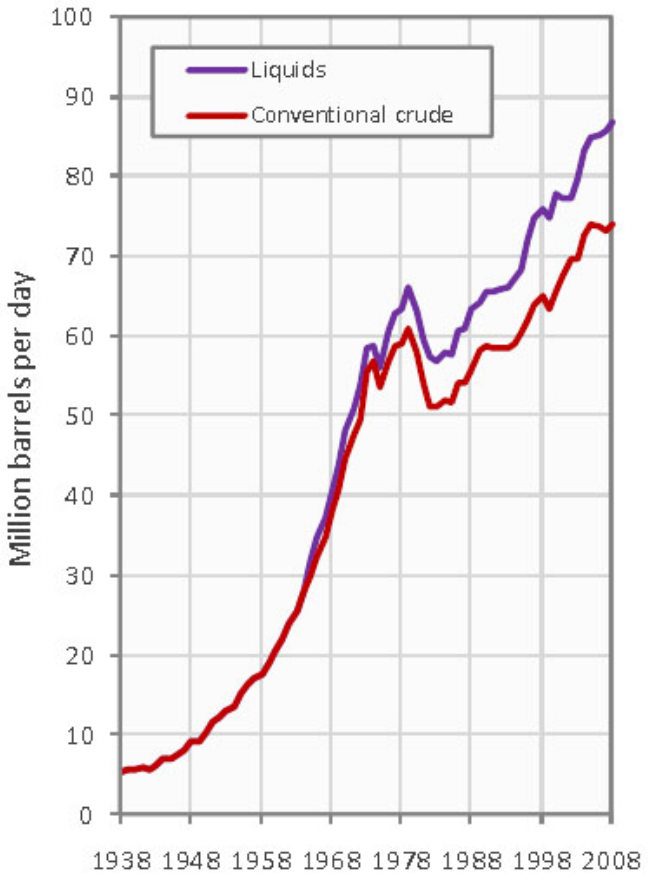


UPPSALA UNIVERSITET

Kjell Aleklett

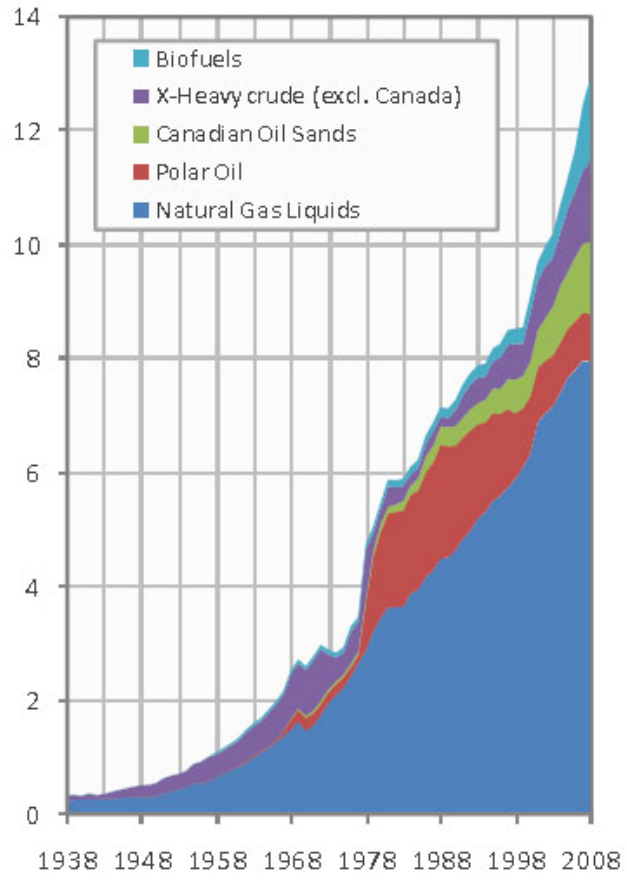
Conventional and Unconventional oil

Chart 8: World Crude and Liquids production 1938 - 2008



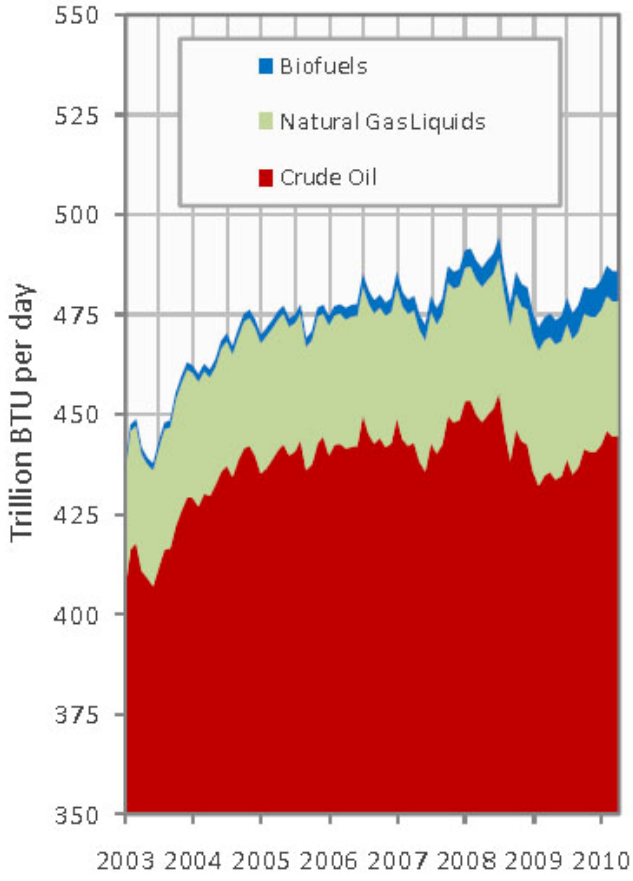
Source: International Energy Agency & Energy Information Administration

Chart 9: Unconventional Oil Production 1938 - 2008



Source: EIA, EIA & CAPP

Chart 10: World Production in BTU January 2003 - April 2010



Source: International Energy Agency

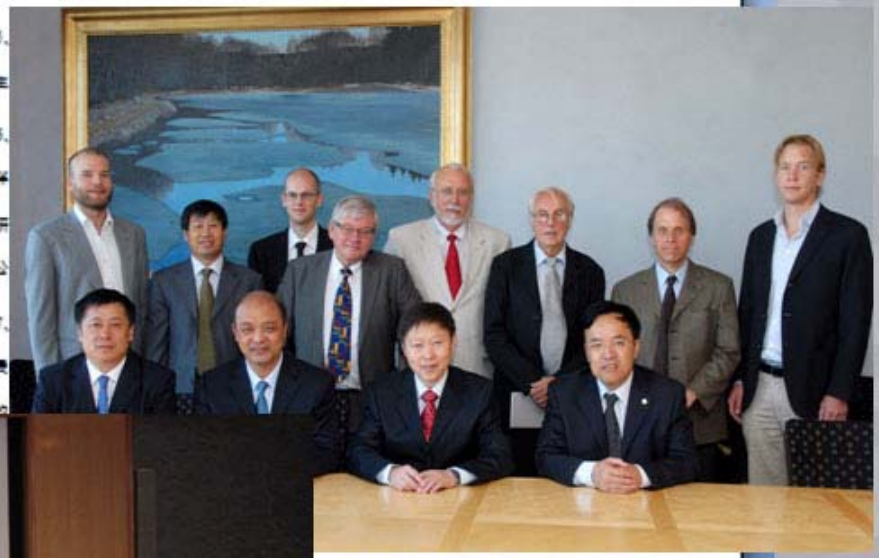
Collaboration: China University of Petroleum and Uppsala University, Sweden

中国石油大学（北京）和瑞典乌普萨拉大学

合作研究协议

中国石油大学（北京）和乌普萨拉大学的石油峰值研究小组的代表于 2007 年 10 月 25 日在北京就以下几个方面的问题进行讨论并取得了共识：石油、天然气和煤是能够枯竭的有限资源，其产量都会达到一个峰值；这些能源产品对中国和瑞典都非常重要；化石资源的生产和消耗正影响着未来全球的气候；石油、天然气和煤的消耗与一个国家的 GDP 密切相关；石油、天然气和煤受到有限供应的限制，其进出口会导致一些问题。

双方通过商议决定开展合作研究，形成协议如下：



北京）和瑞典乌普萨拉大学双方首

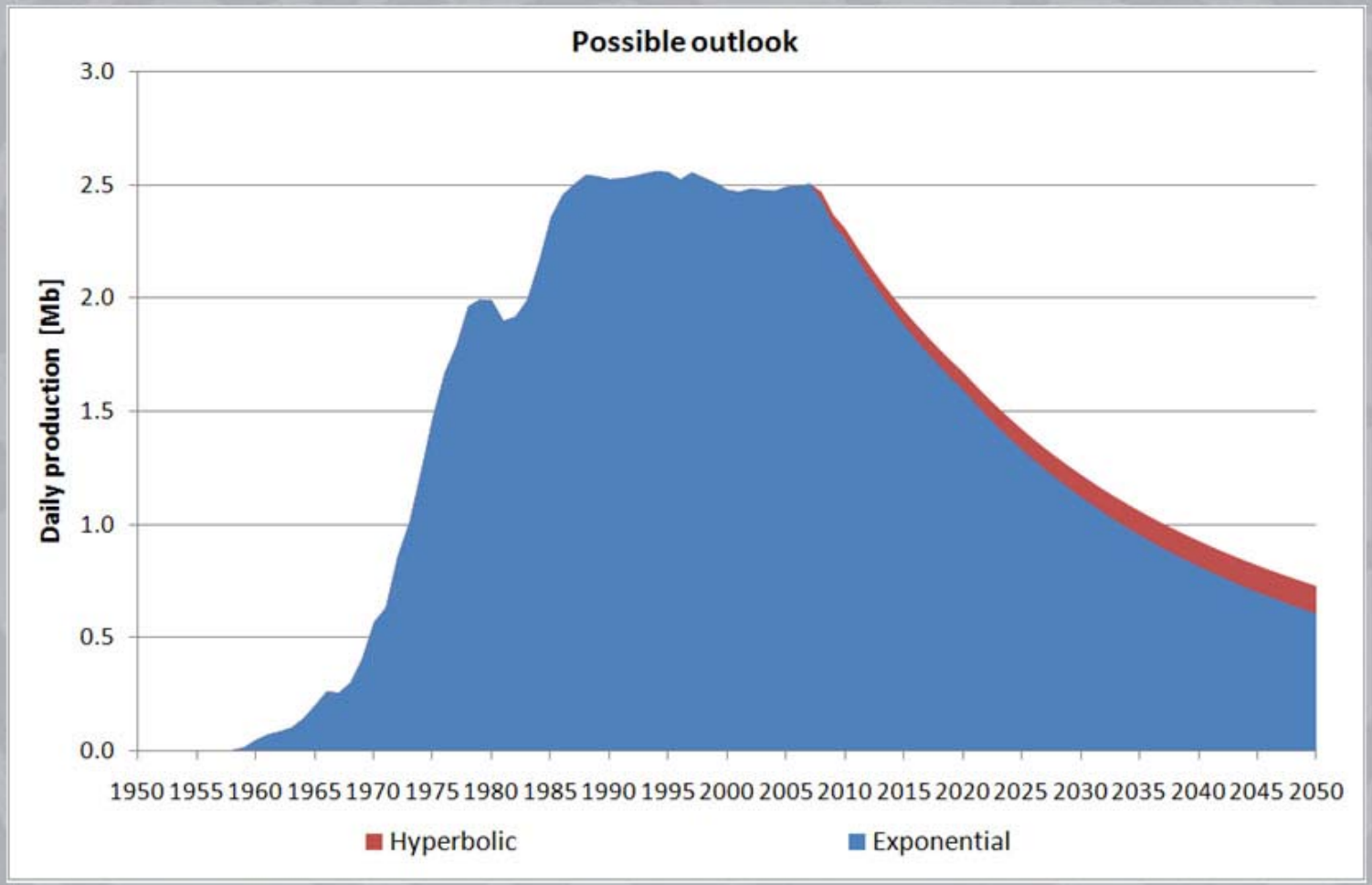
瑞典乌普萨拉大学教授

瑞典乌普萨拉大学

Aleklett

The Long March of the Chinese Giant Oil Fields

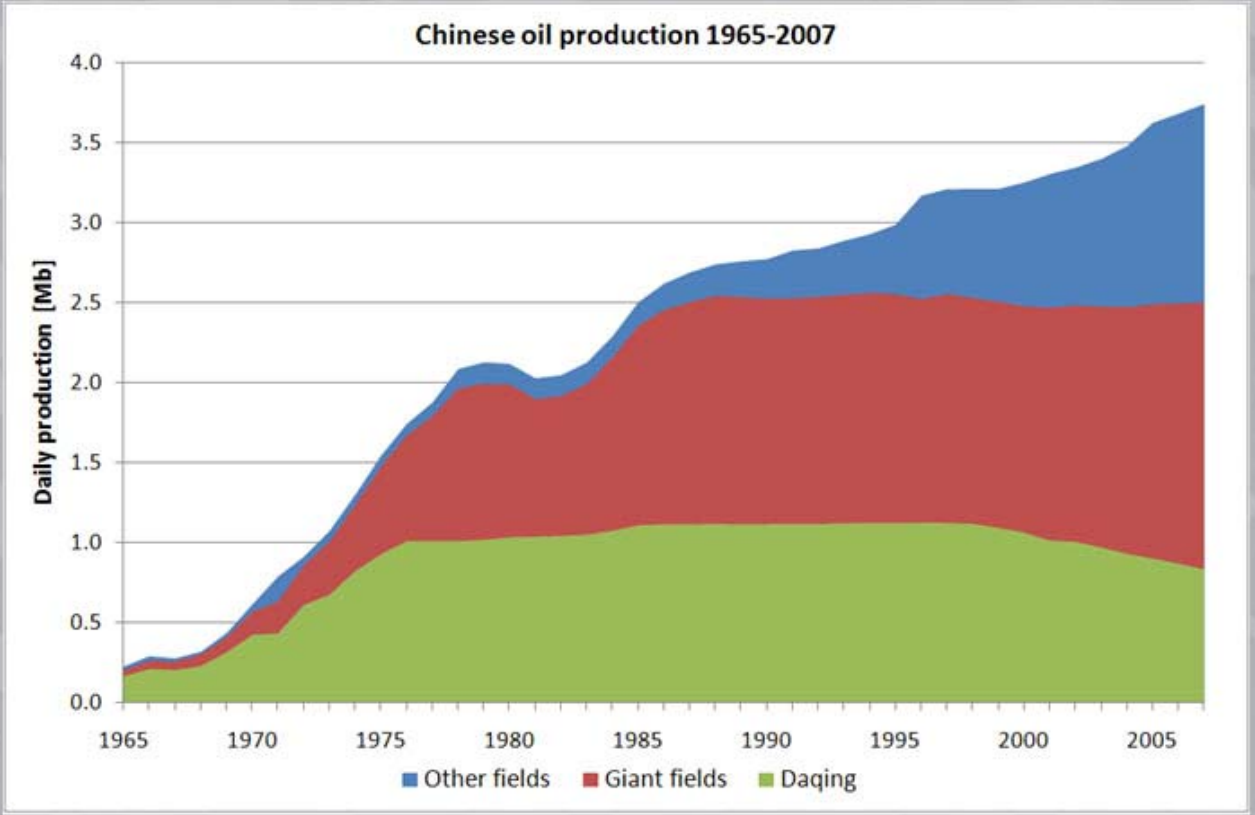
Mikael Höök*, Tang Xu+, Pang Xiongqi¤, Kjell Aleklett*



UPPSALA
UNIVERSITET

The Long March of the Chinese Giant Oil Fields

Mikael Höök*, Tang Xu+, Pang Xiongqi¤, Kjell Aleklett*



Field name	URR [Gb]	Discovery year	First oil	Peak year	Peak production [b/d]
Changqing	2.2	1971	1975	-	-
Dagang	1.5	1965	1965	-	-
Daqing	24.1	1959	1959	1999	1 100 000
Huabei	2.2	1975	1975	1979	350 000
Liaohe	5.0	1958	1970	1995	312 000
Shengli	15.8	1961	1961	1992	672 000
Tarim	1.1	1989	1989	-	-
Xinjiang	5.5	1951	1951	-	-
Zhongyuan	1.3	1975	1976	1988	145 000

UPPSALA UNIVERSITET

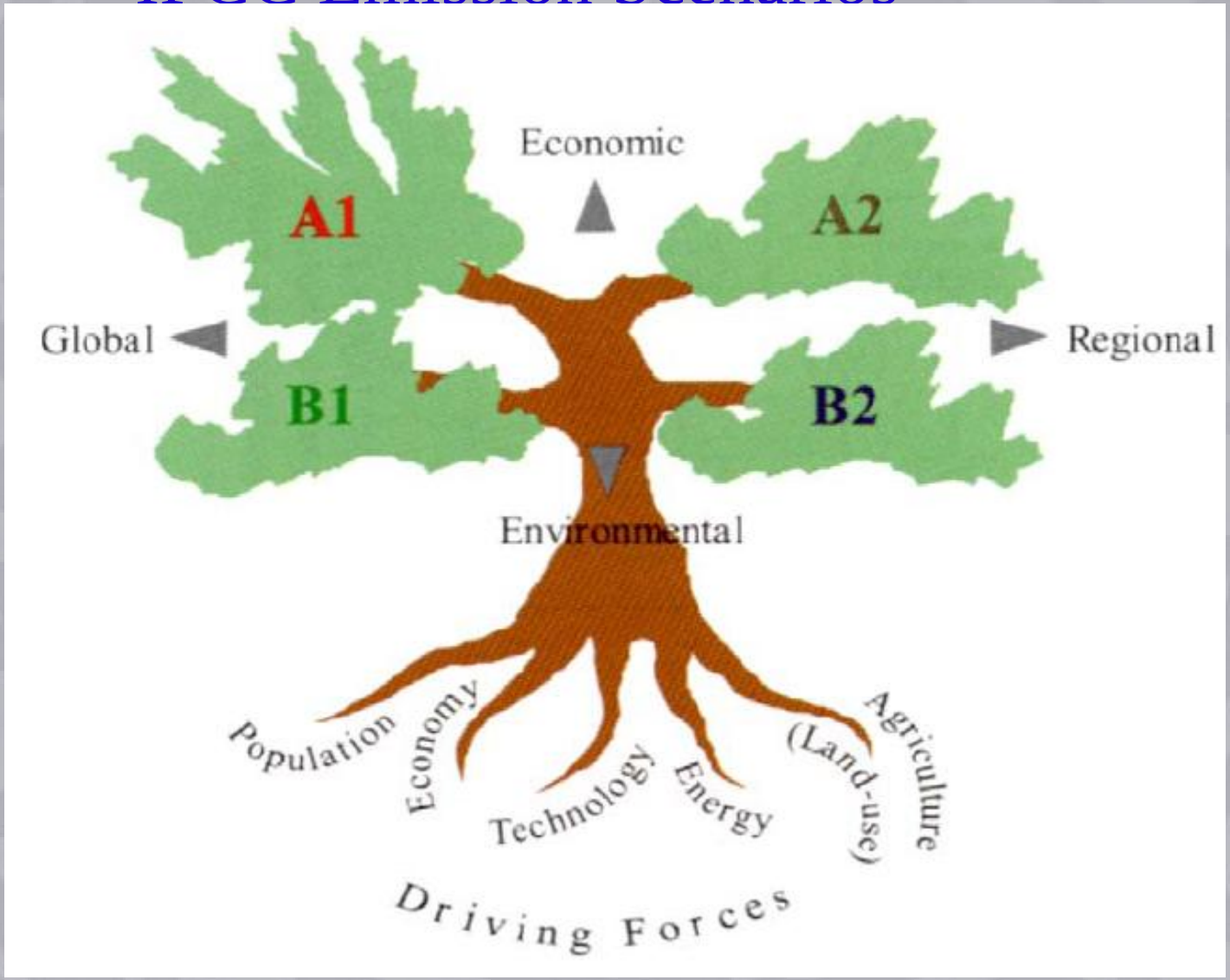
Kjell Aleklett

The Special Report on Emission Scenarios (SRES), IPCC

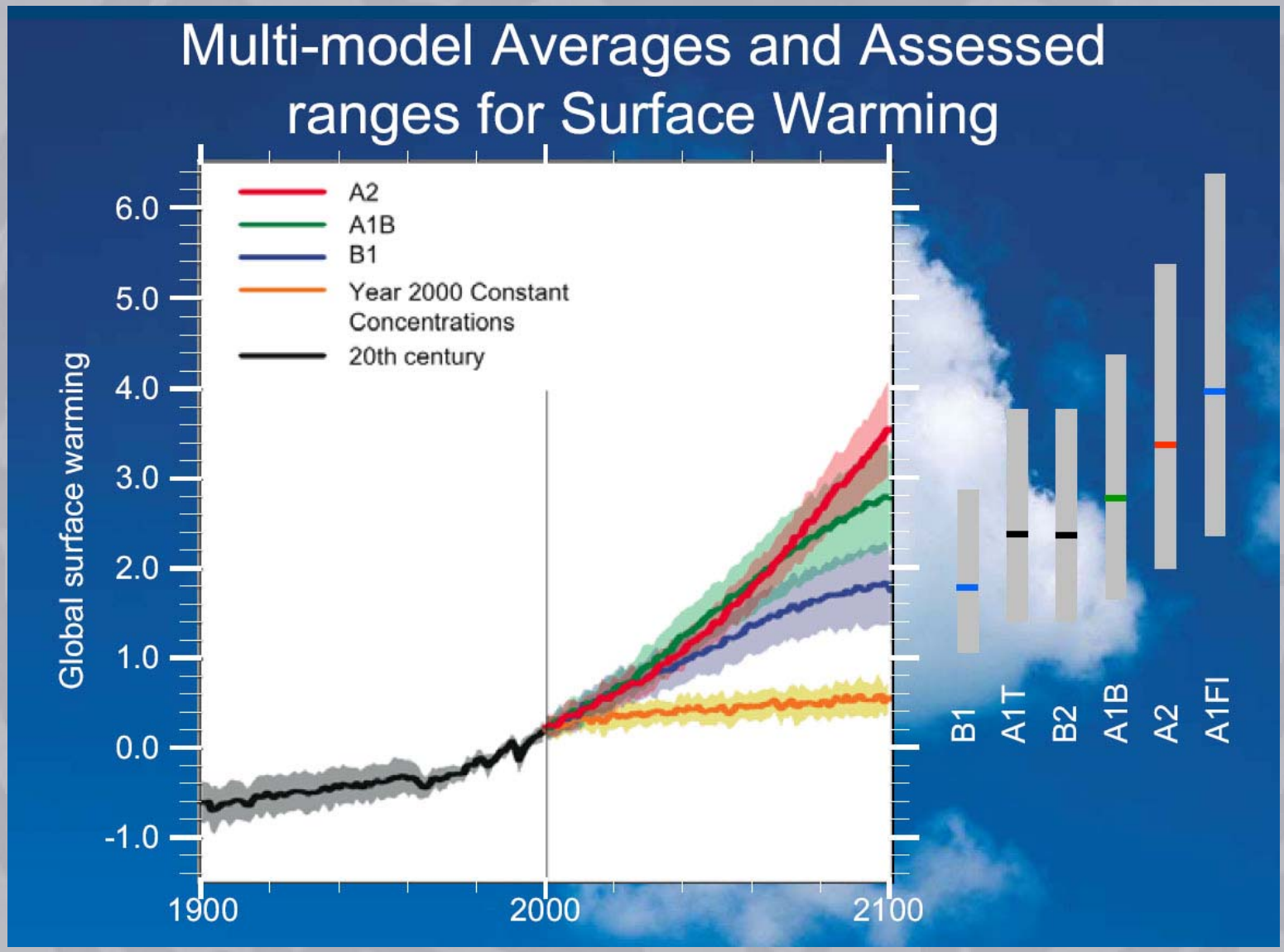
- **Validity of the fossil fuel production outlooks in the IPCC Emission Scenarios**
- **Mikael Höök, Anders Sivertsson, and Kjell Aleklett**
- **Publiched by Natural Resources Research (2010)**
- **http://www.springerlink.com/content/105547/**

UPPSALA UNIVERSITET

IPCC Emission Scenarios

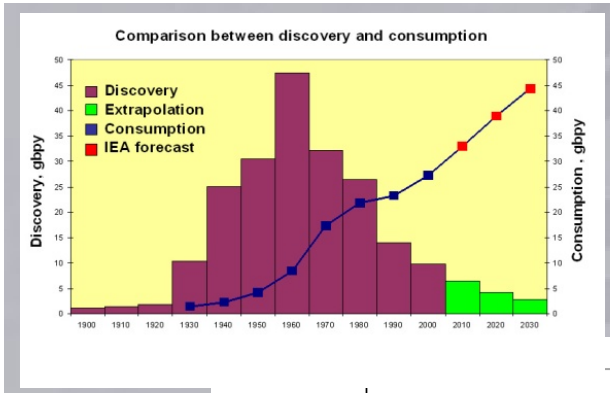


IPCC

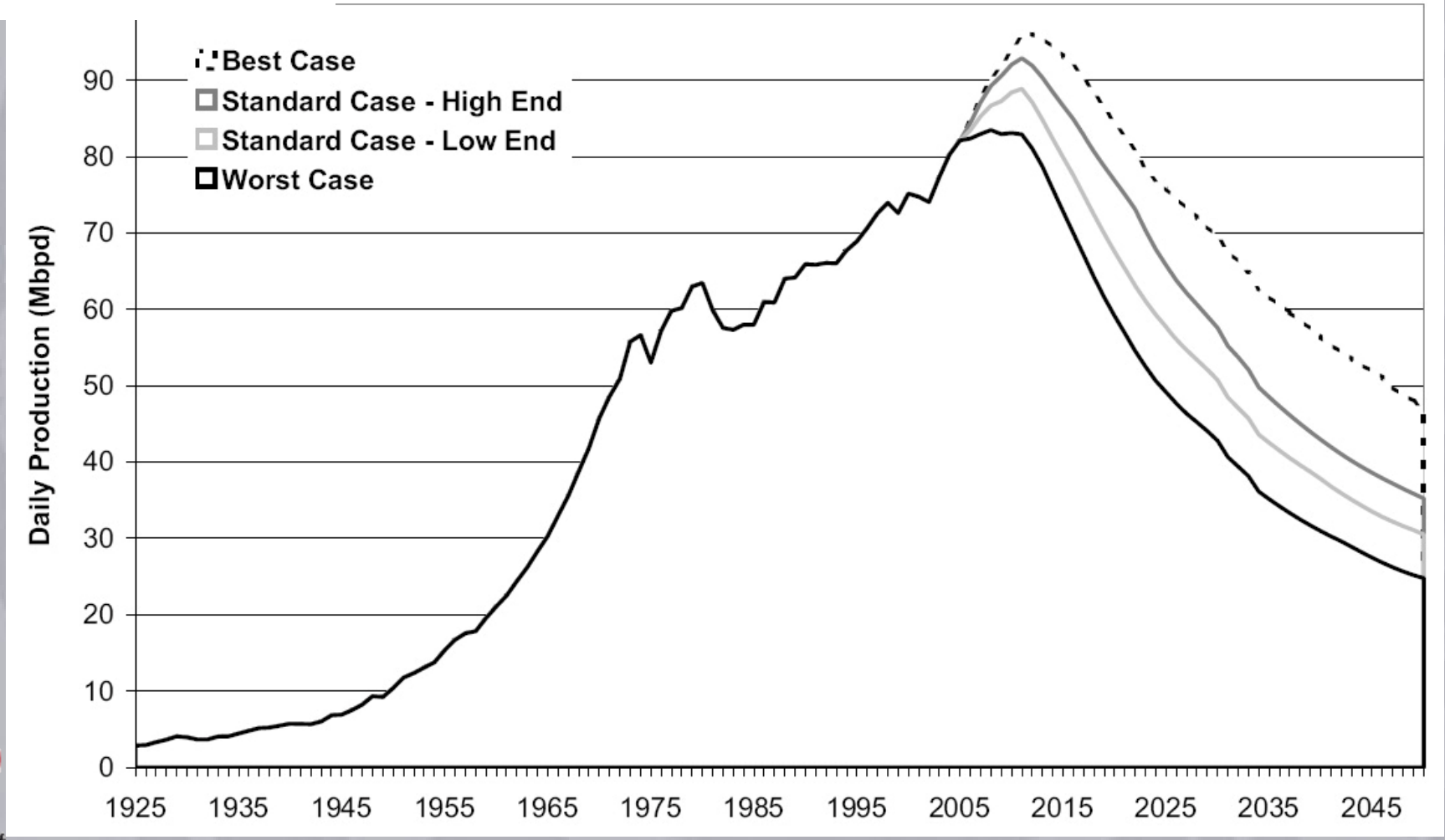


UPPSALA UNIVERSITET

Kjell Aleklett



Uppsala Giant Oilfield Model



UPPSALA UNIVERSITET

Kjell Aleklett

Comparison: Oil

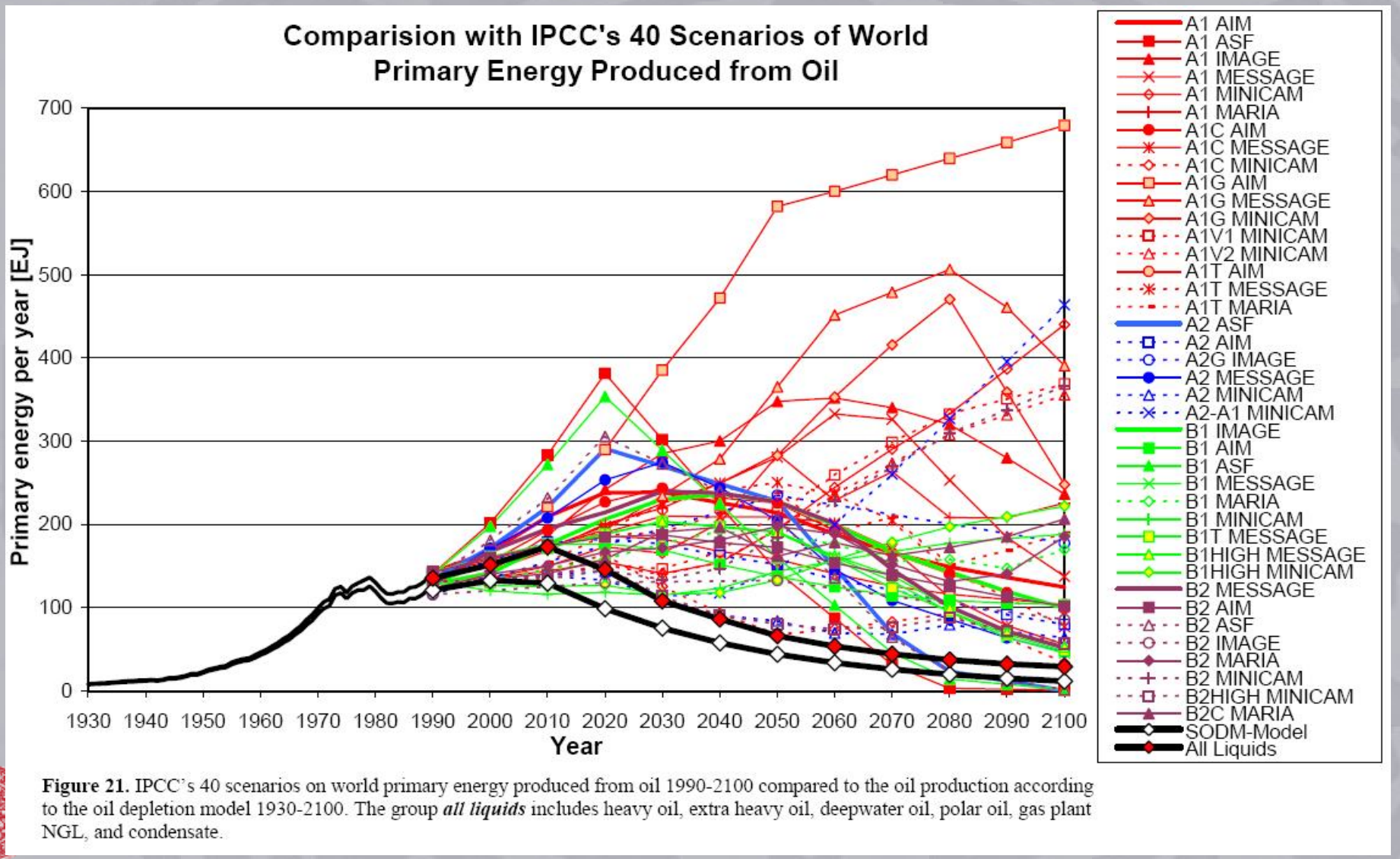
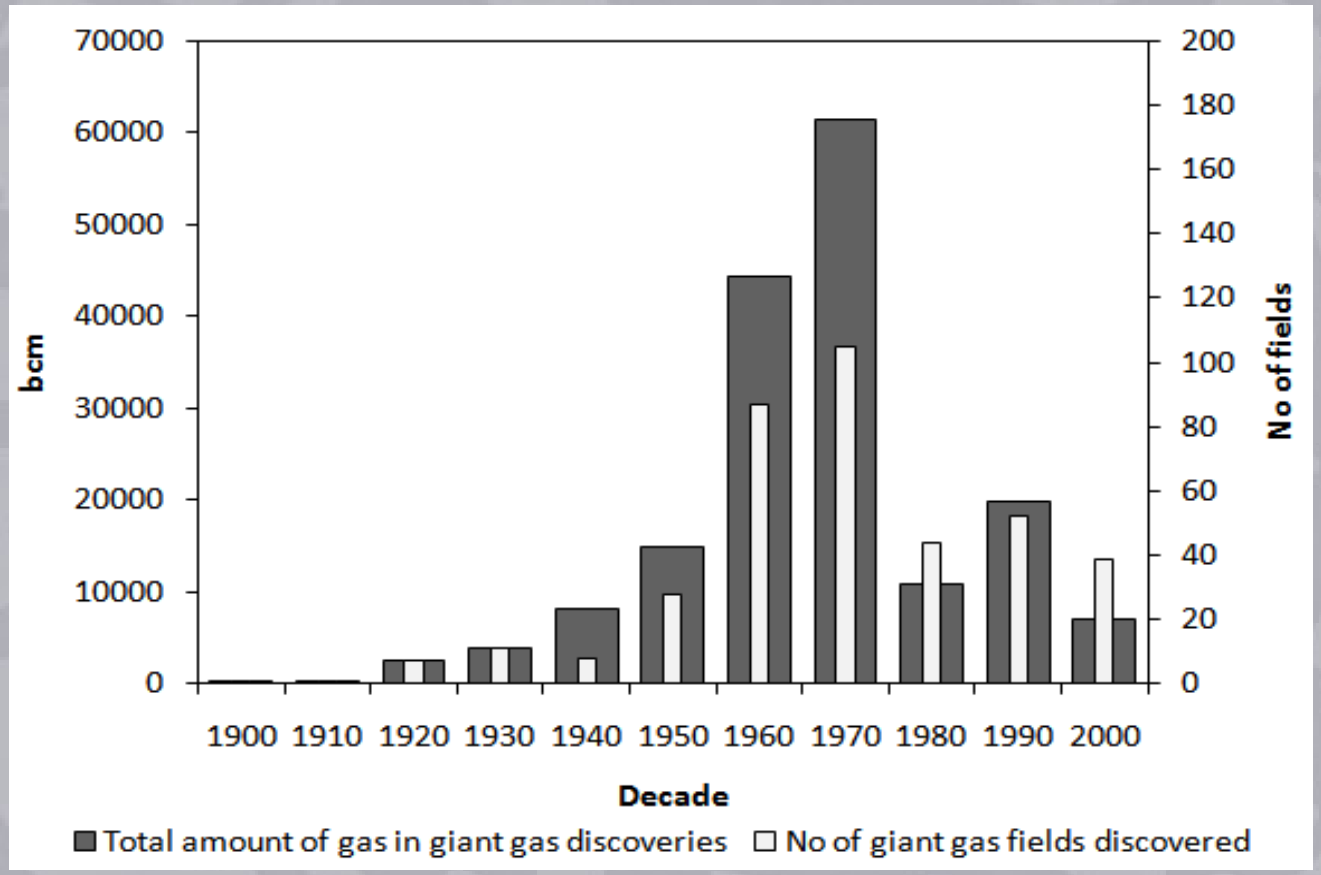


Figure 21. IPCC's 40 scenarios on world primary energy produced from oil 1990-2100 compared to the oil production according to the oil depletion model 1930-2100. The group ***all liquids*** includes heavy oil, extra heavy oil, deepwater oil, polar oil, gas plant NGL, and condensate.

Peak Gas



A peak in discoveries must give a peak in production!

UPPSALA UNIVERSITET

Kjell Aleklett

Comparison: Gas

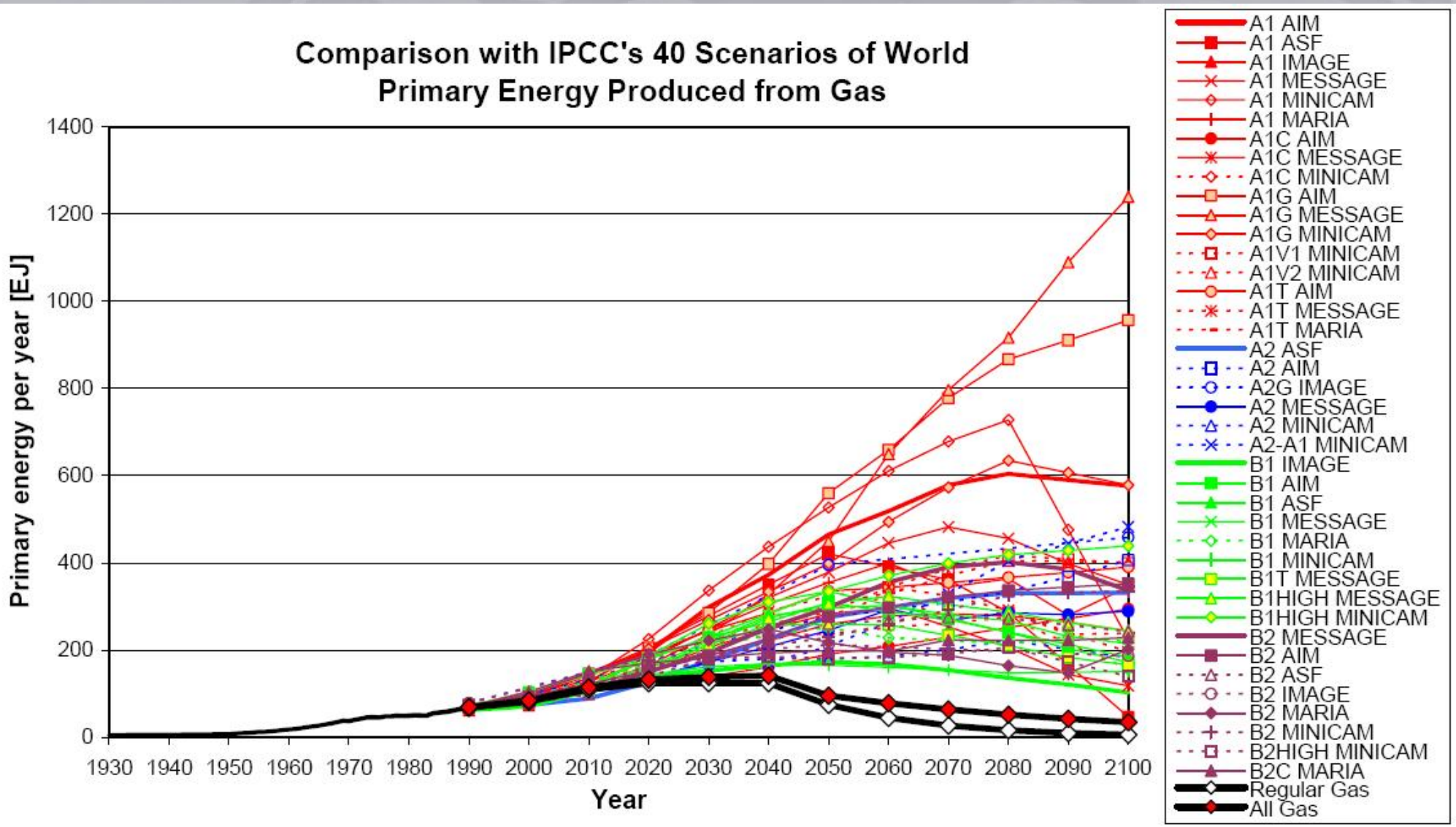
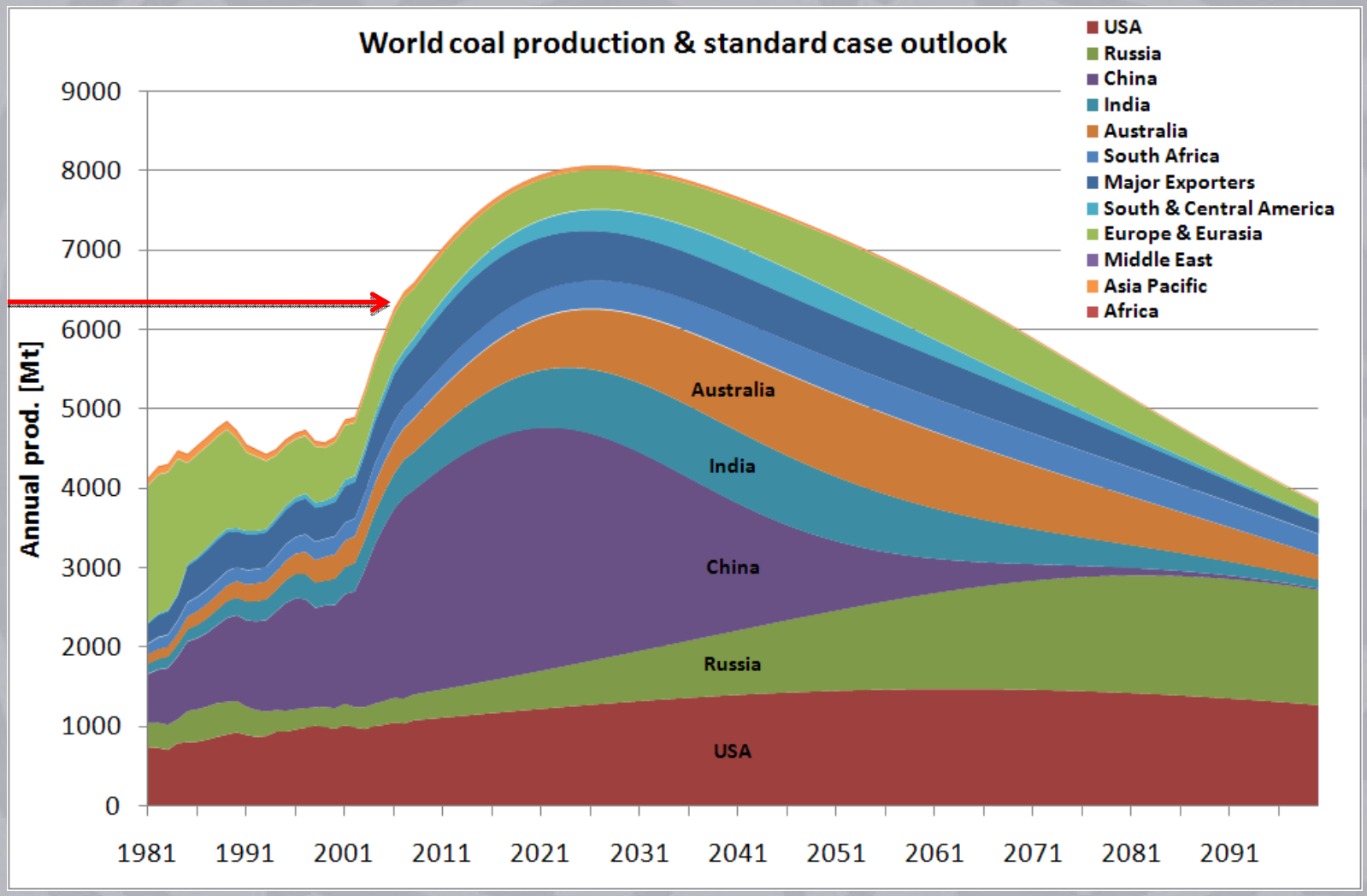


Figure 23. IPCC's 40 scenarios on world primary energy produced from gas 1990-2100 compared to the gas production according to the oil depletion model 1930-2100. The group ***all gas*** includes non-regular gas e.g. coal bed methane.

Coal production forecast

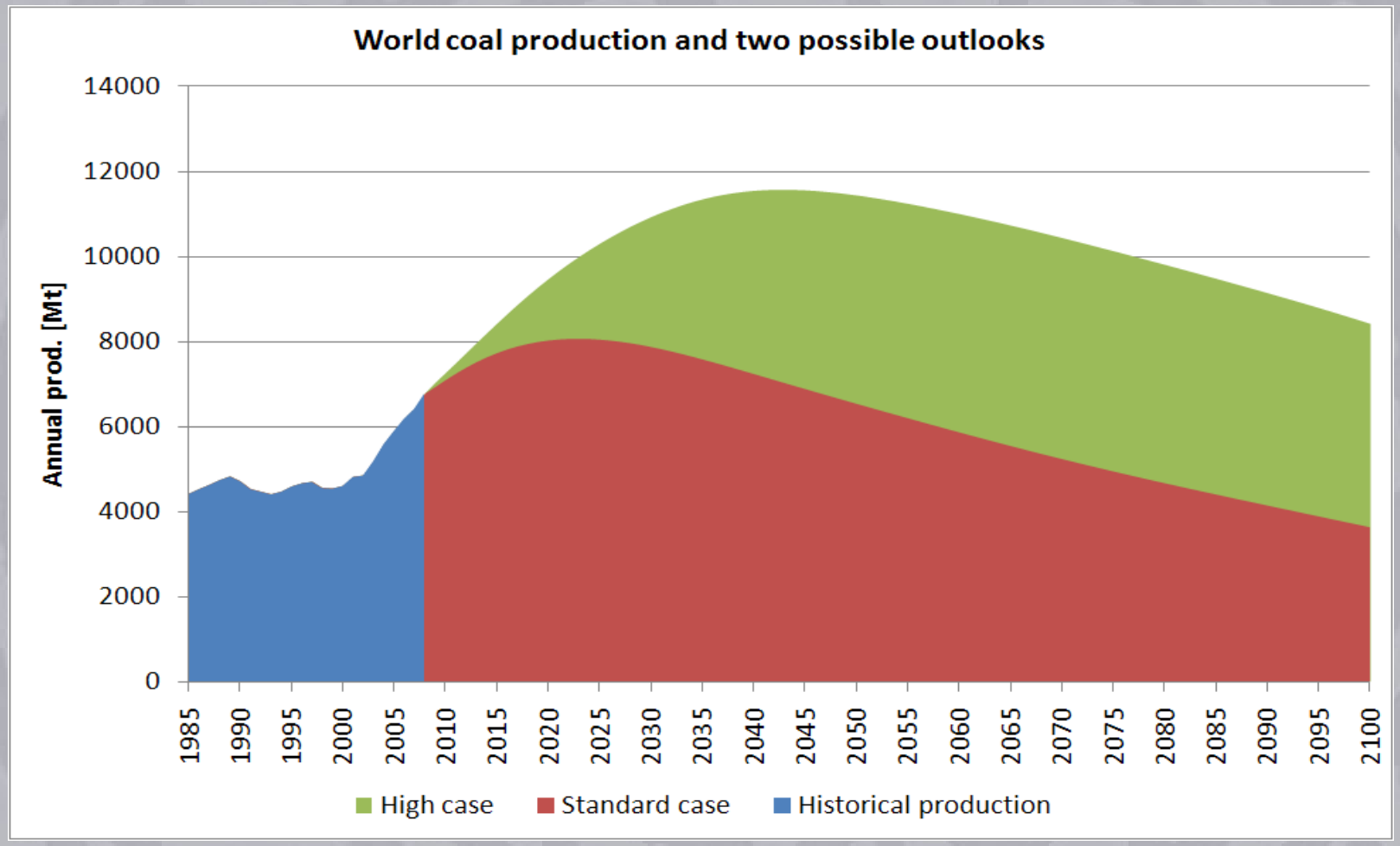
2006



UPPSALA UNIVERSITET

Kjell Aleklett

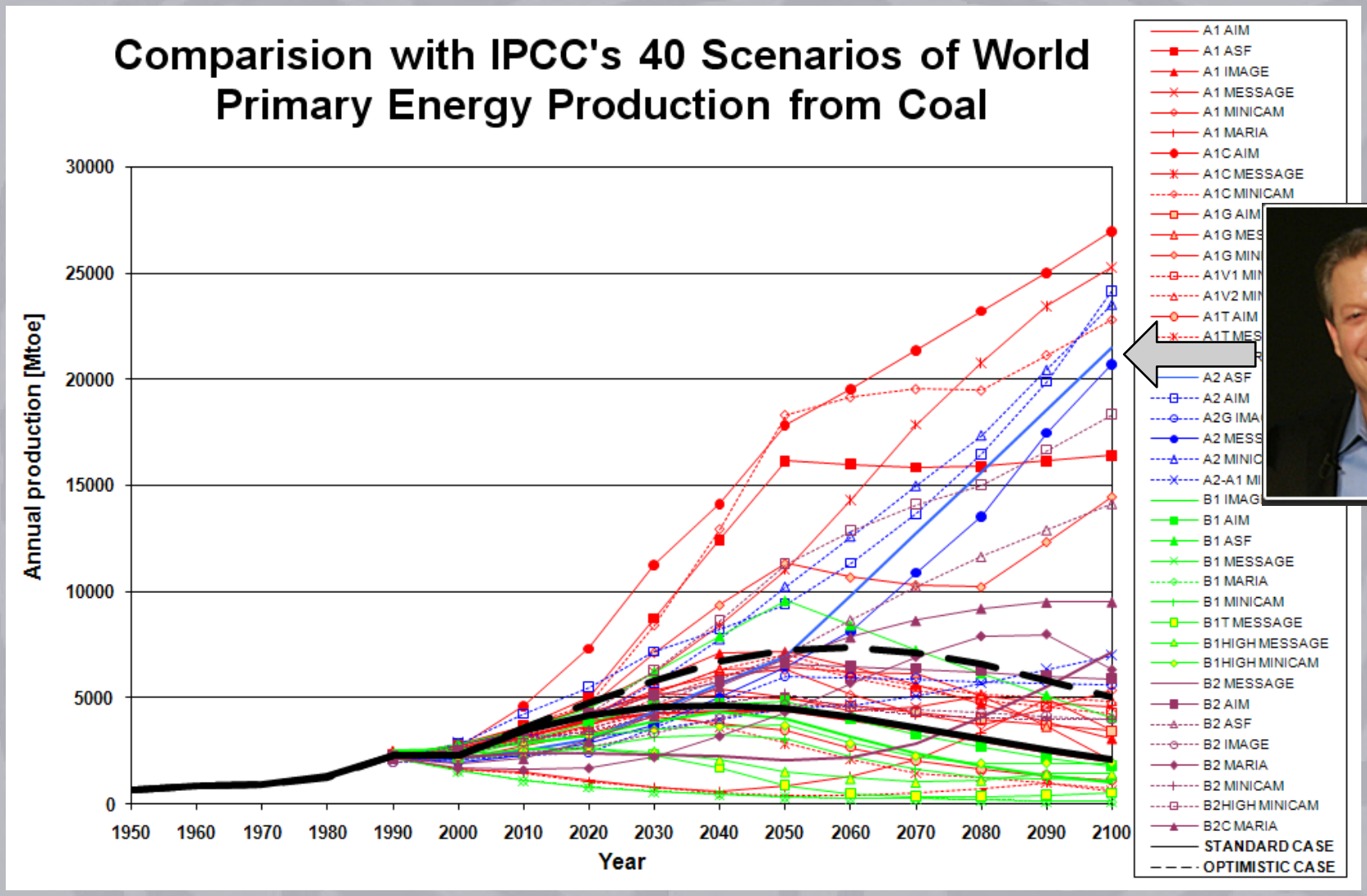
World outlook



Source: Hook et al (2010) *Global coal production outlooks based on a logistic model*, to be published

Kjell Aleklett

Comparison: Coal



UPPSALA UNIVERSITET

Kjell Aleklett

President Barack Obama

"No single issue is as fundamental to our future as energy"

2009 Jan 26

UPPSALA UNIVERSITET

UPPSALA UNIVERSITET

Global Energy Systems

UPPSALA HYDROCARBON DEPLETION STUDY GROUP

Web page: www.fysast.uu.se/ges

UPPSALA UNIVERSITET

Kjell Aleklett