# ENERGY and its RESOURCES

## GENERAL

| Primer mover | **Date** | Output in horsepower (HP) |
|---|---|---|
| Man pushing a lever | 3000 BC | 0.05 |
| Ox pulling a load | 3000 BC | 0.5 |
| Water turbine | 1000 BC | 0.4 |
| Vertical waterwheel | 350 BC | 3 |
| Turret windmill | 1600 AD | 14 |
| Savery's steam pump | 1697 AD | 1 |
| Newcommen's steam engine | 1712 AD | 5.5 |
| Watt's steam engine (land) | 1800 AD | 40 |
| Steam engine (marine) | 1837 AD | 750 |
| Steam engine (marine) | 1843 AD | 1,500 |
| Water turbine | 1854 AD | 800 |
| Steam engine (marine) | 1900 AD | 8,000 |
| Steam engine (land) | 1900 AD | 12,000 |
| Steam turbine | 1906 AD | 17,500 |
| Steam turbine | 1921 AD | 40,000 |
| Steam turbine | 1943 AD | 288,0001, |
| Coal-fired steam power plant | 1973 AD | 1,465,000 |
| Nuclear power plant | 1974 AD | 1,520,000 |
| Source: Cook, E, Man, **Energy**, Society, WH Freeman and Co, San Francisco, US (1976). | | |

FROM MIT ENERGY COURSE

# Energy rate scaling

- food - ---------- 250 kcal/candy bar
- average daily requirement --------- 2000-3000 kcal/day = 100 W
- human heart ---------- 2 W
- running ---------- 500 W
- 1 horsepower ---------- 750 W
- 757 jet plane ---------- 1 – 10 MW
- automobile ---------- 100 -160kW
- space shuttle ---------- 1 GW
- Typical electric generating plant --------- 1000 MW
- 1 wind turbine ---------- 1-3 MW
- laptop computer ---------- 10 W
- cell phone ---------- 2 W

**US energy consumption per year ----------**

**100 quads or Q=100,000,000,000,000,000,000 J or 3.5 TW**

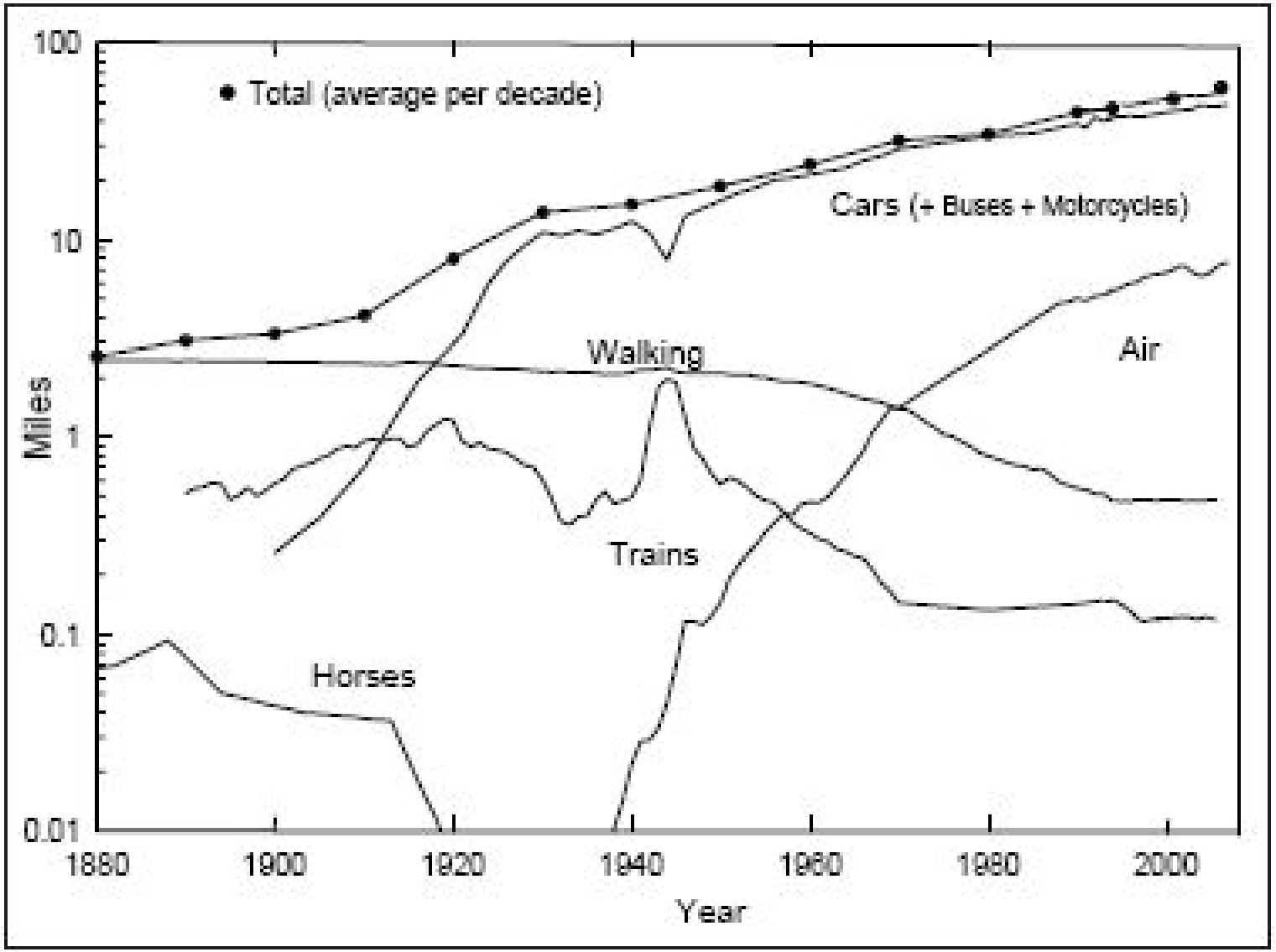



**Figure 9.** US passenger travel per capita per day (range).
Sources: US Historical Abstracts; US Statistical Abstracts; A. Gruebler 1989; US Bureau of Transportation Statistics, 2006.

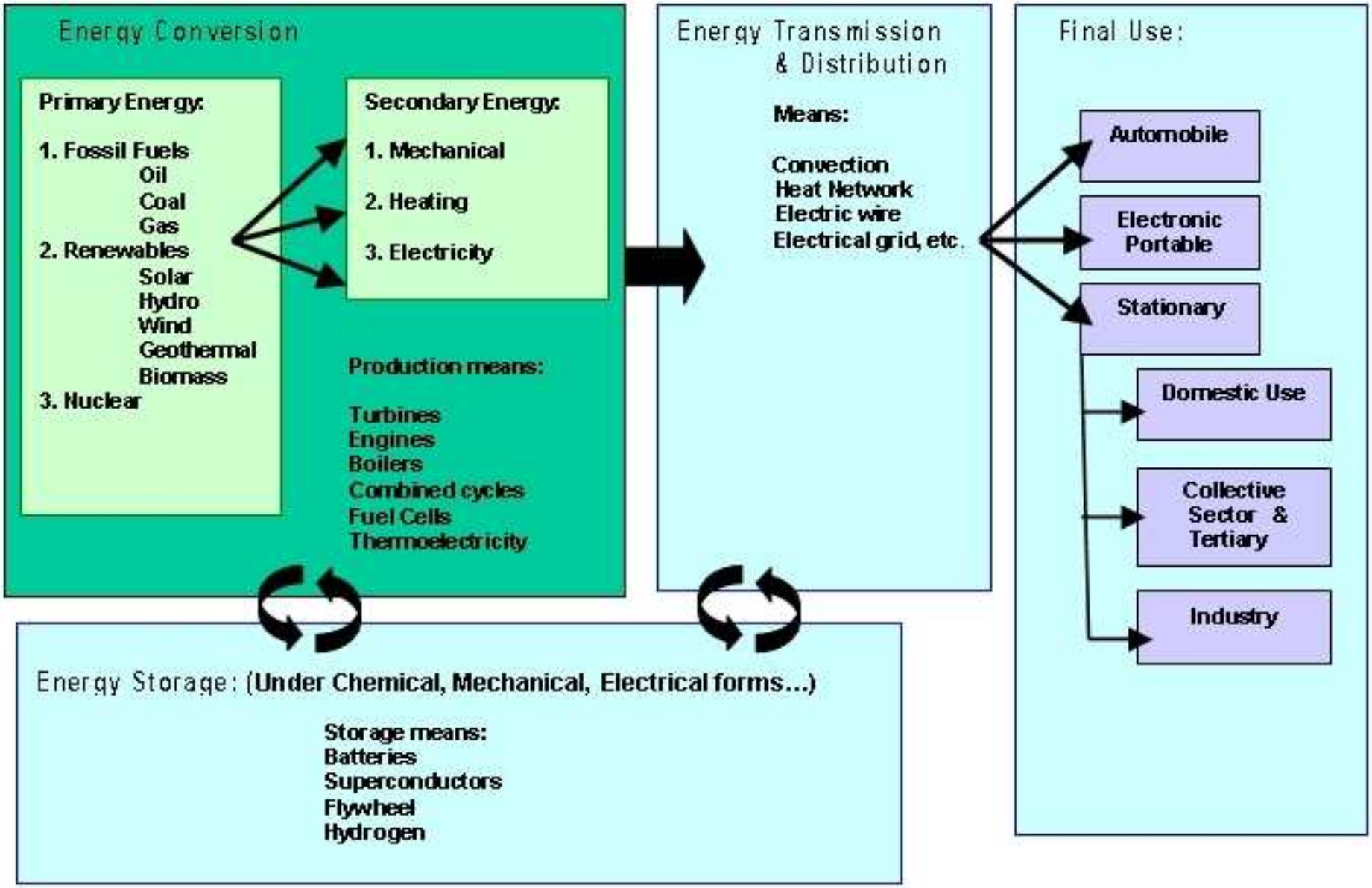
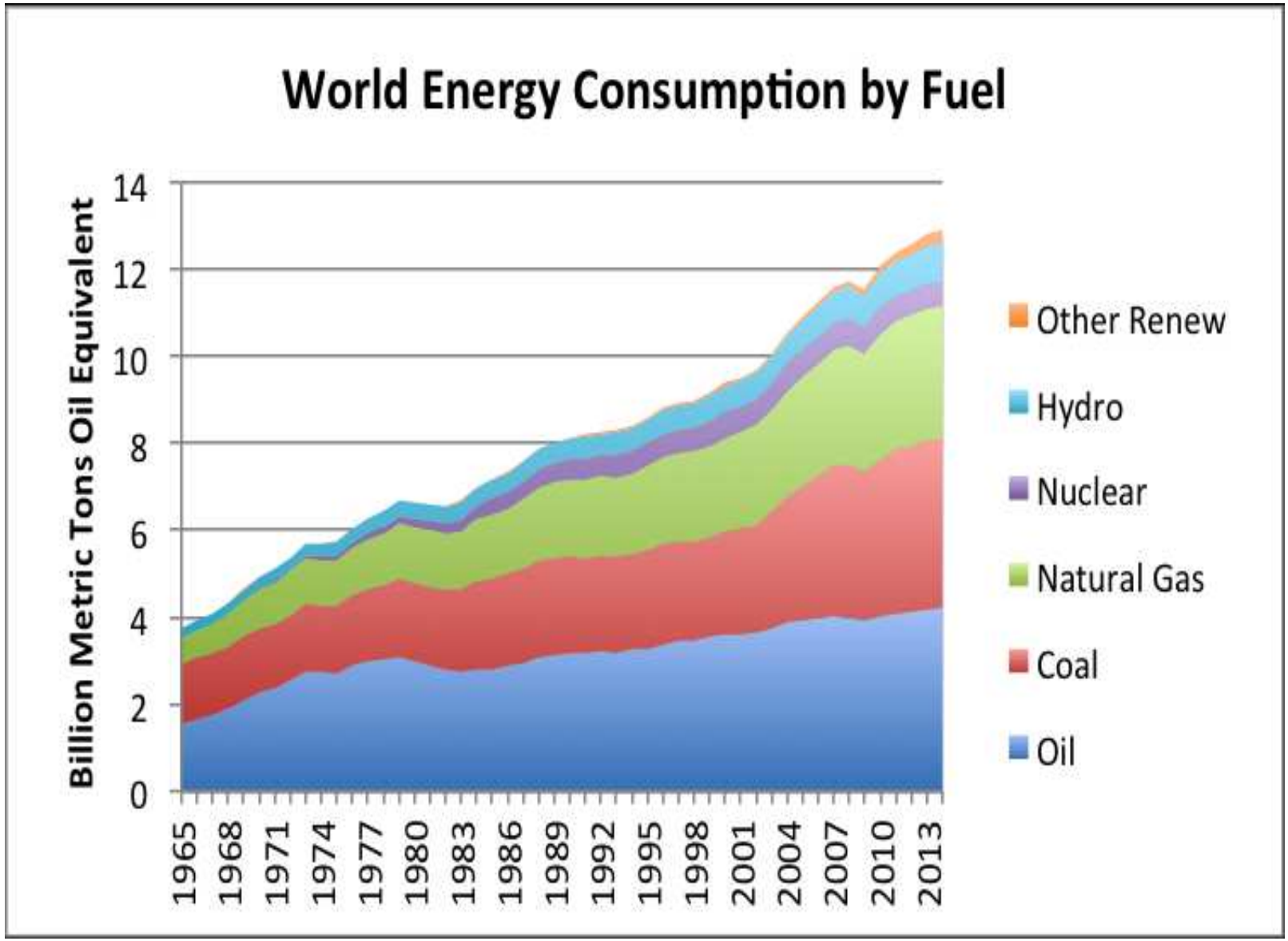
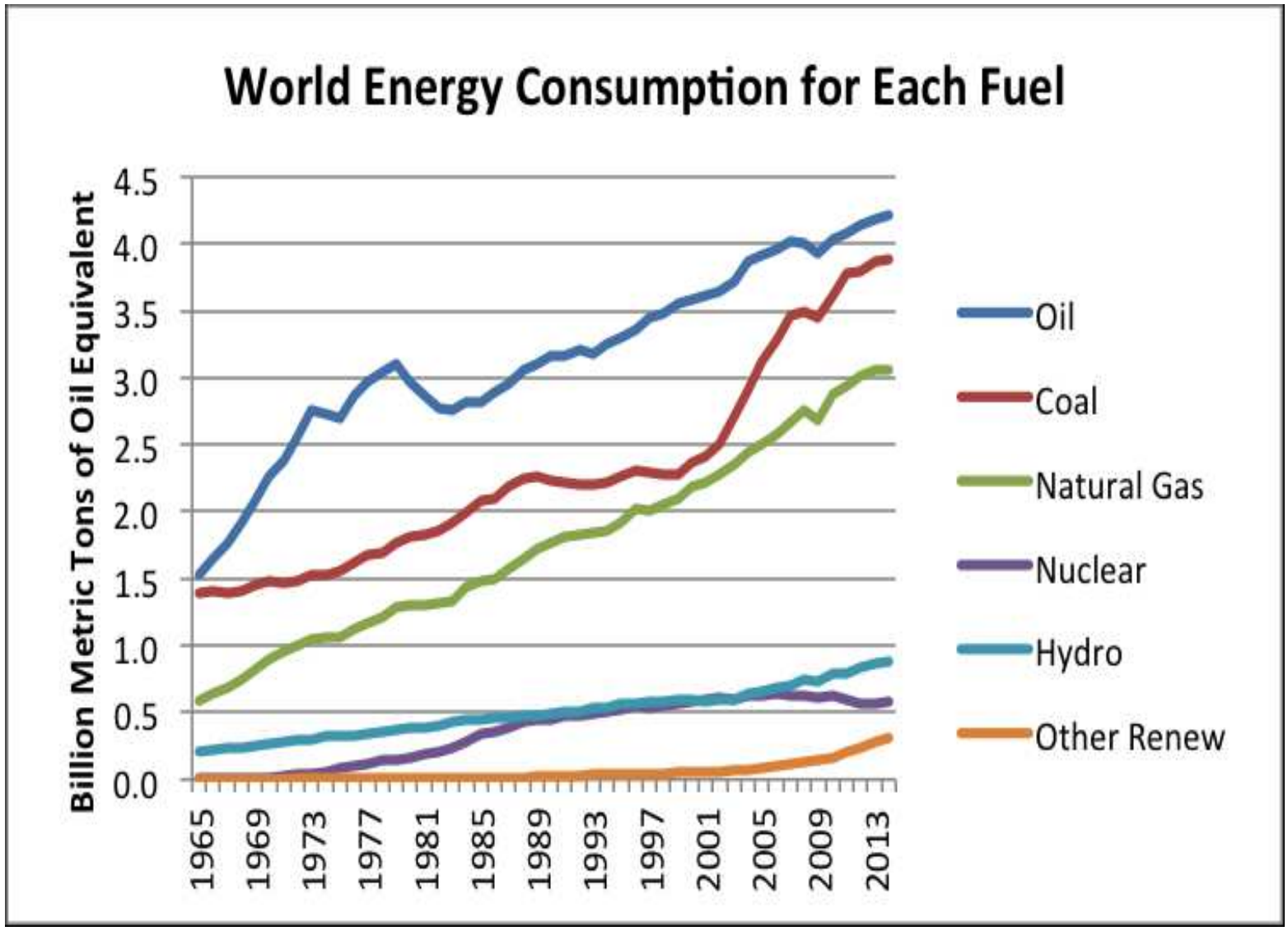
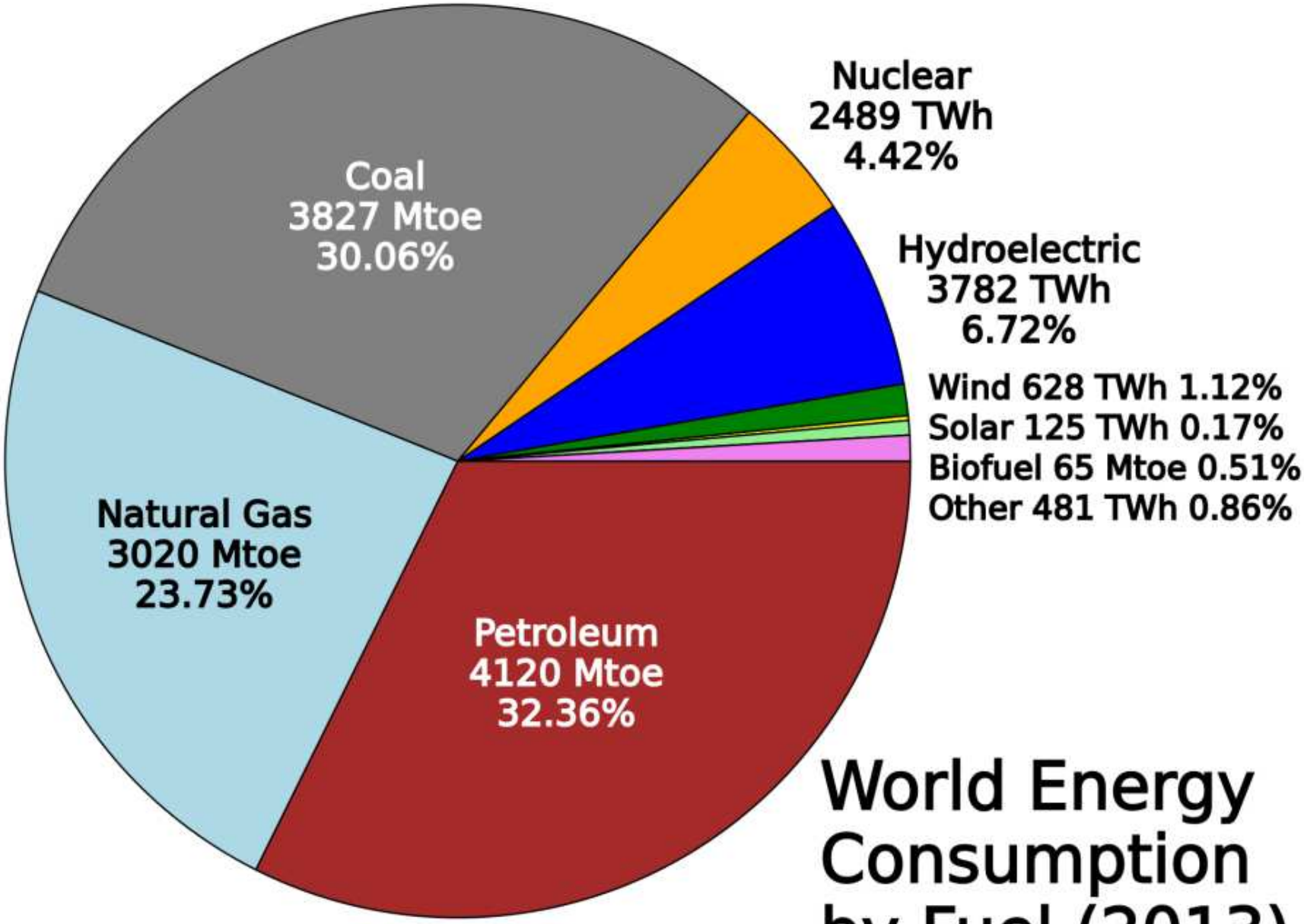



*Figure 1.2.8: Dependencies of different energy systems (Source: CEA/LETI)*

# Energy consumption

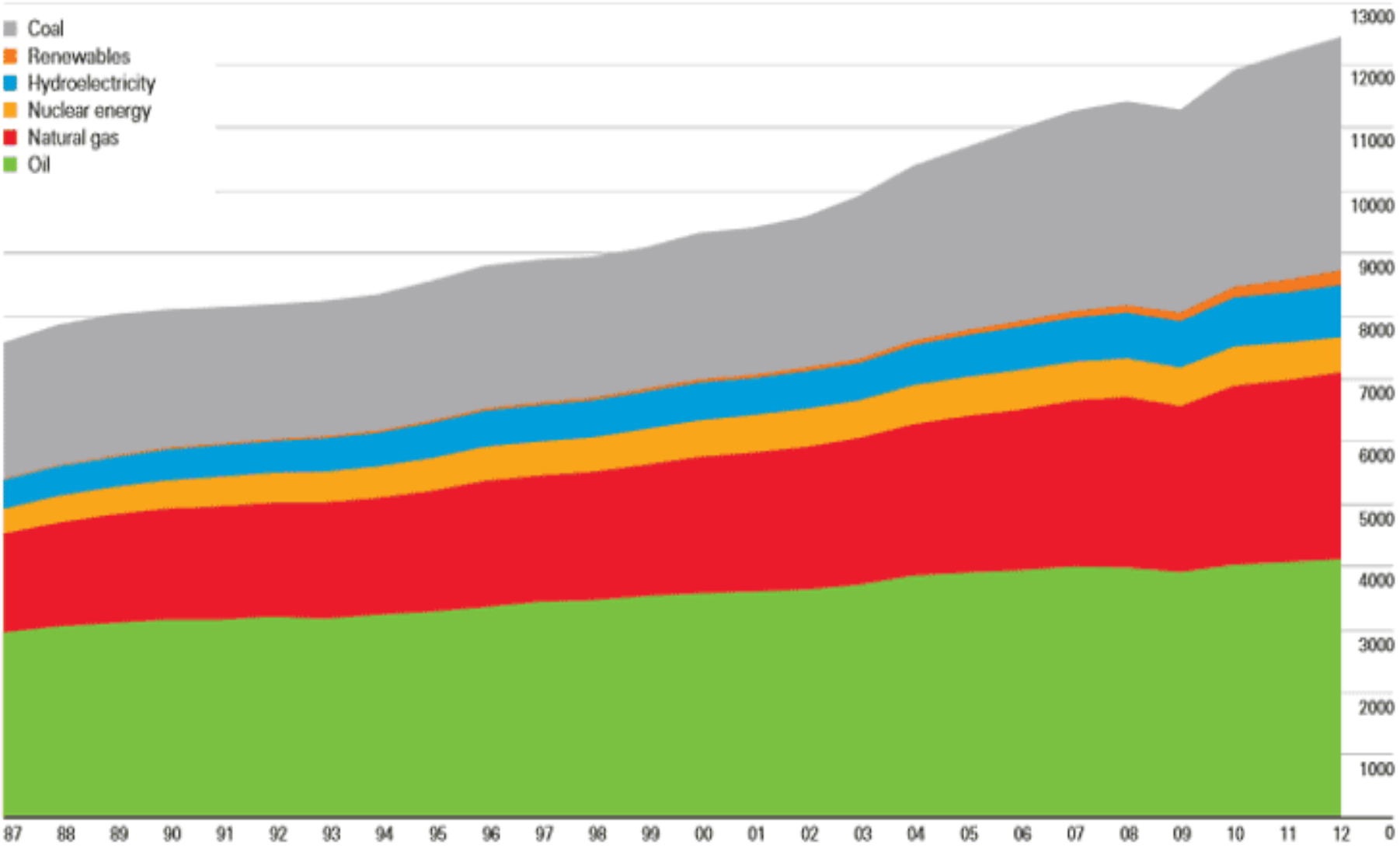

World Energy Consumption by Fuel
Billion Metric Tons Oil Equivalent
0
2
4
6
8
10
12
14
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Other Renew
Hydro
Nuclear
Natural Gas
Coal
Oil


World Energy Consumption for Each Fuel
Billion Metric Tons of Oil Equivalent
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013
Oil
Coal
Natural Gas
Nuclear
Hydro
Other Renew

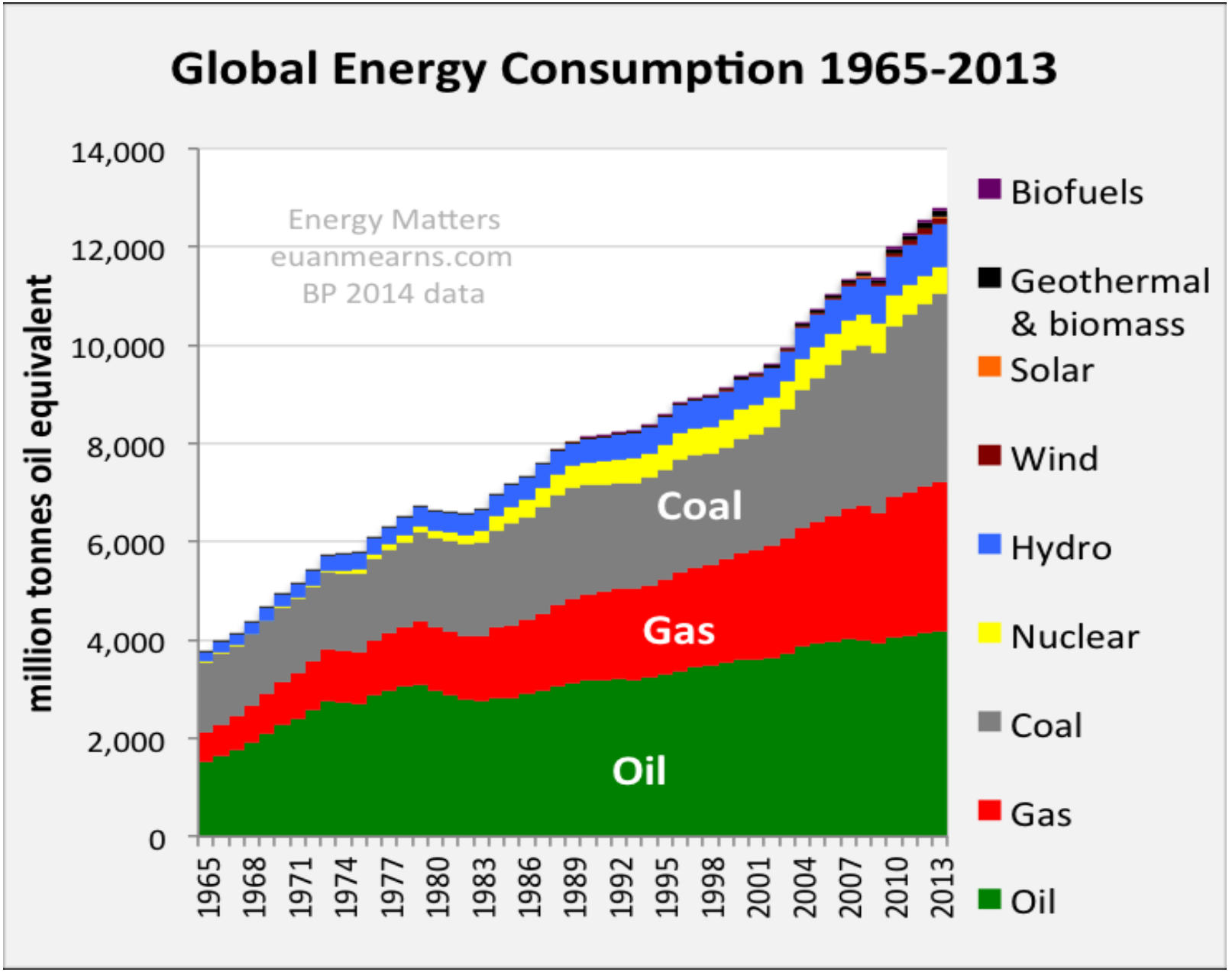

Coal
3827 Mtoe
30.06%
Nuclear
2489 TWh
4.42%
Hydroelectric
3782 TWh
6.72%
Wind 628 TWh 1.12%
Solar 125 TWh 0.17%
Biofuel 65 Mtoe 0.51%
Other 481 TWh 0.86%
Natural Gas
3020 Mtoe
23.73%
Petroleum
4120 Mtoe
32.36%
World Energy Consumption by Fuel (2013)
Fossil Fuel 86% Renewable 9.4%

## World consumption

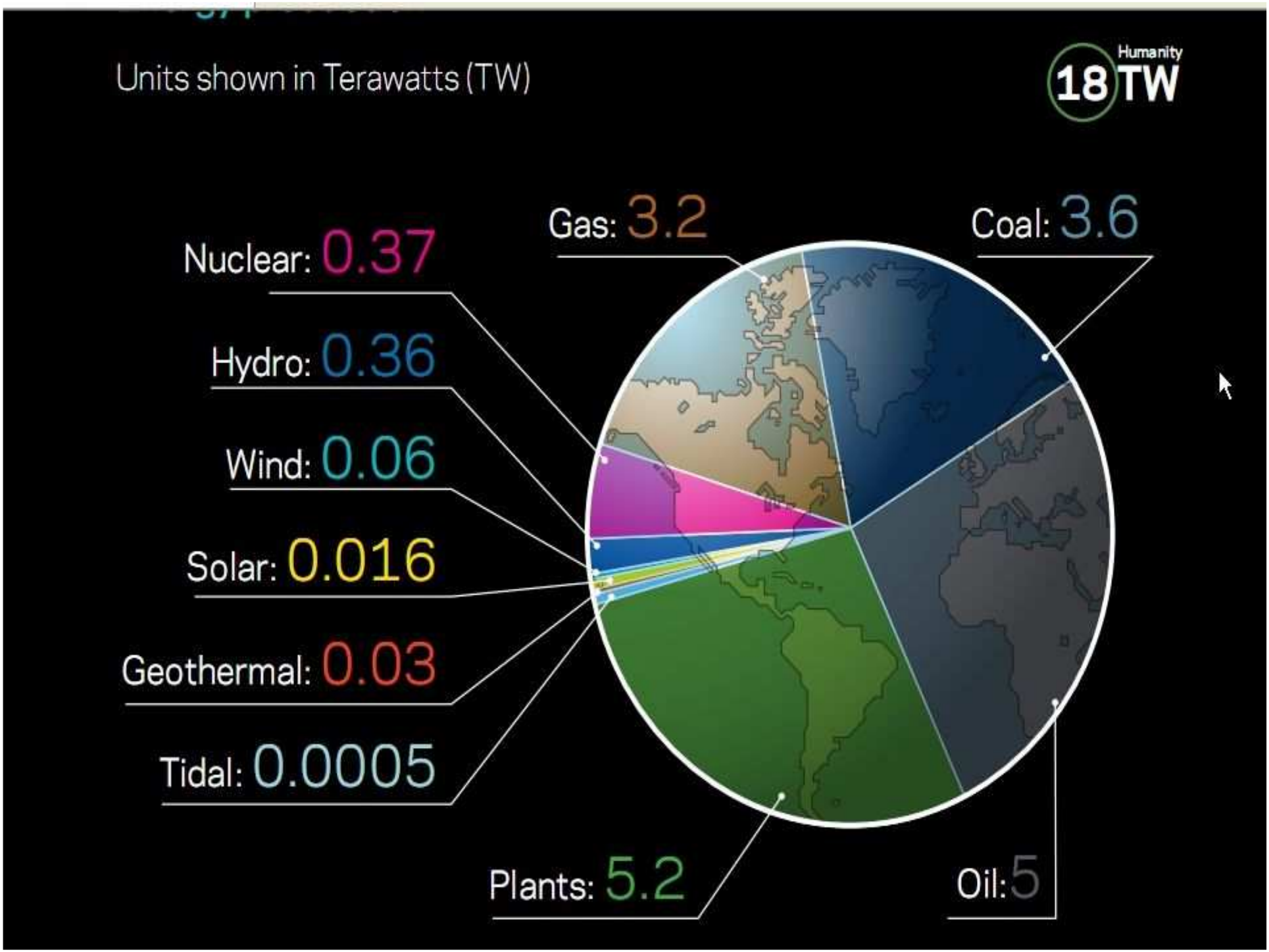
Million tonnes oil equivalent




World primary energy consumption grew by a below-average 1.8% in 2012. Growth was below average in all regions except Africa. Oil remains the world's leading fuel, accounting for 33.1% of global energy consumption, but this figure is the lowest share on record and oil has lost market share for 13 years in a row. Hydroelectric output and other renewables in power generation both reached record shares of global primary energy consumption (6.7% and 1.9%, respectively).

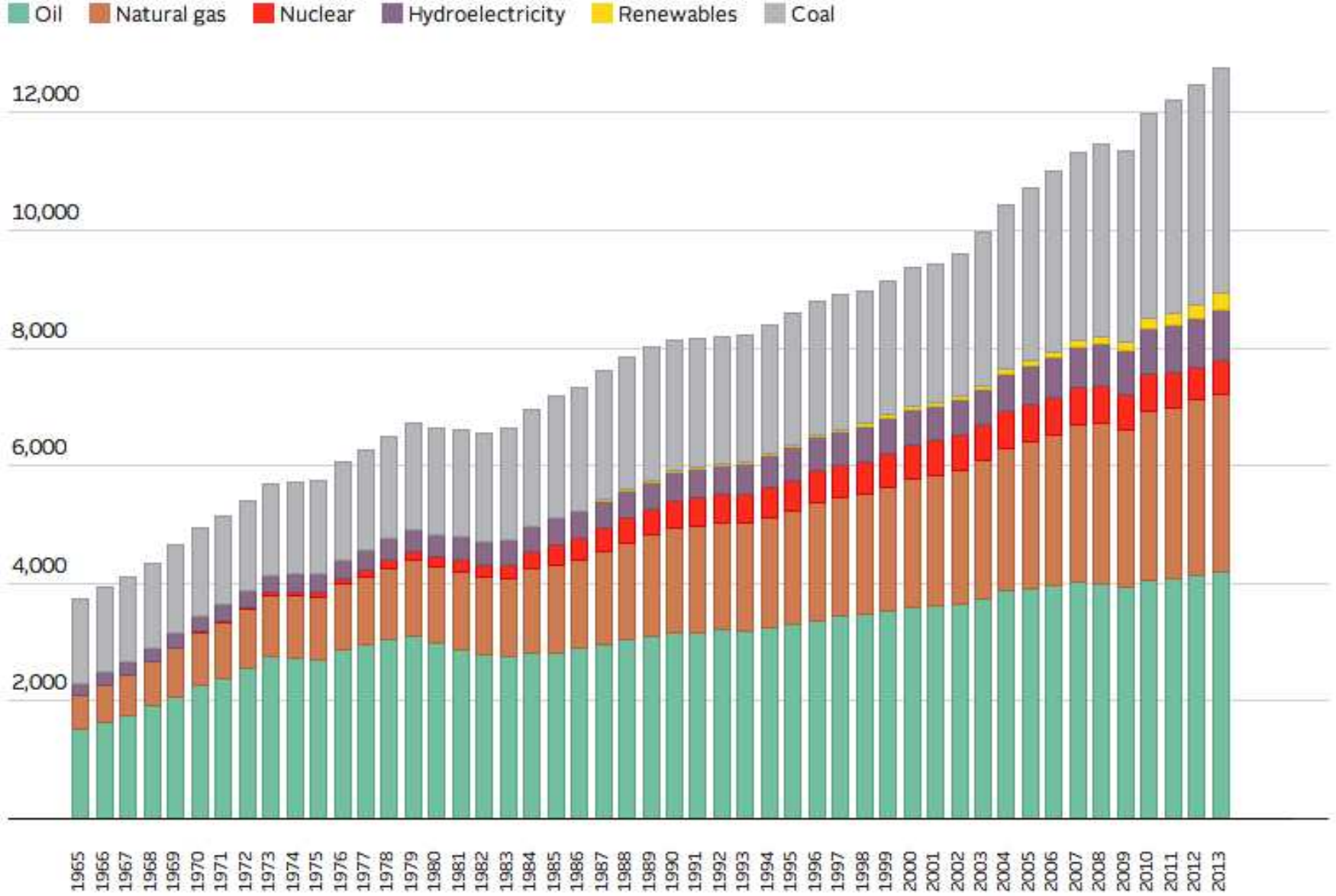

Global Energy Consumption 1965-2013
million tonnes oil equivalent
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Energy Matters
euanmearns.com
BP 2014 data
Coal
Gas
Oil
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Biofuels
Geothermal & biomass
Solar
Wind
Hydro
Nuclear
Coal
Gas
Oil

# Renewable energy

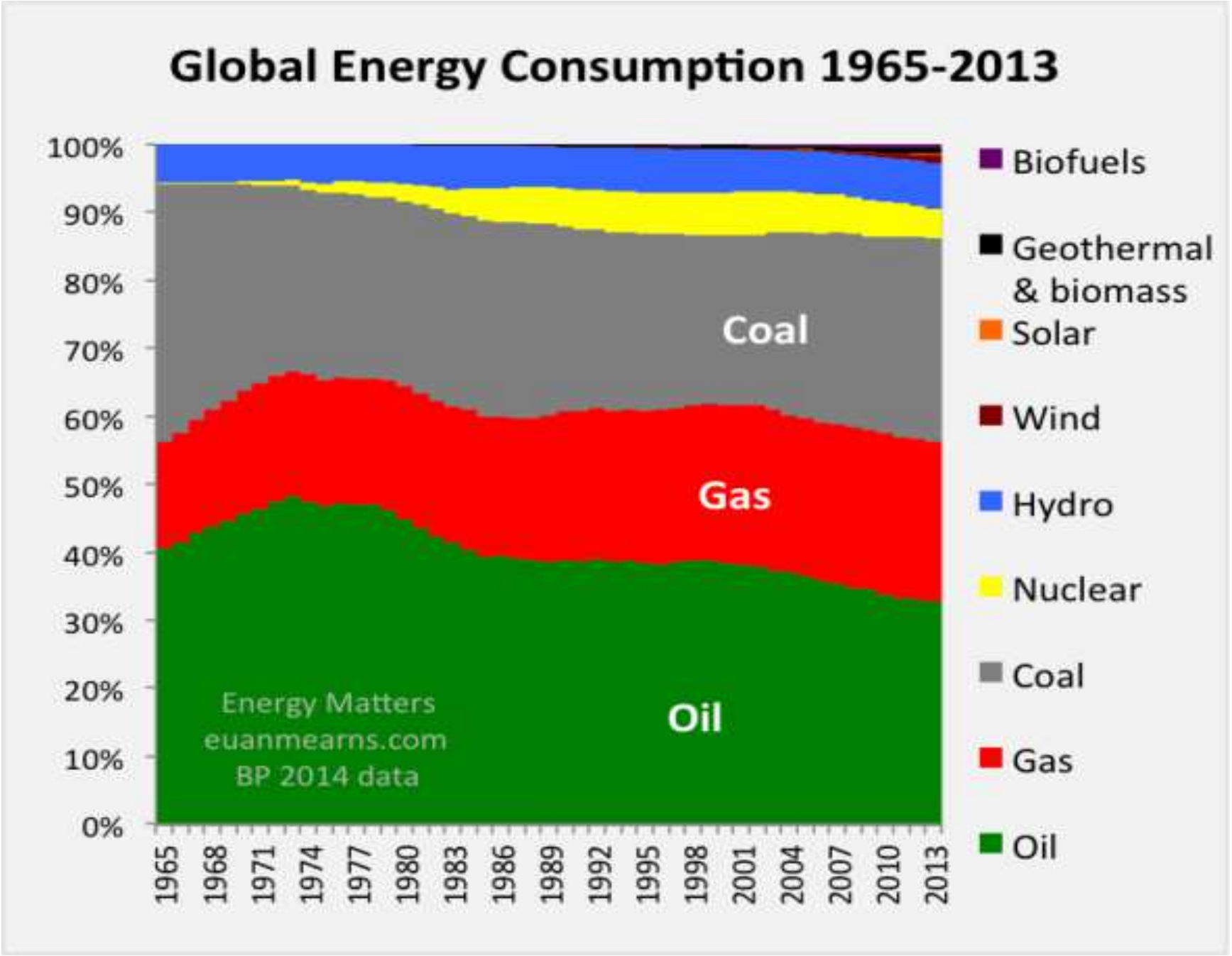

Units shown in Terawatts (TW)
Humanity
18 TW
Nuclear: 0.37
Hydro: 0.36
Wind: 0.06
Solar: 0.016
Geothermal: 0.03
Tidal: 0.0005
Gas: 3.2
Coal: 3.6
Plants: 5.2
Oil: 5

# Global energy use by source

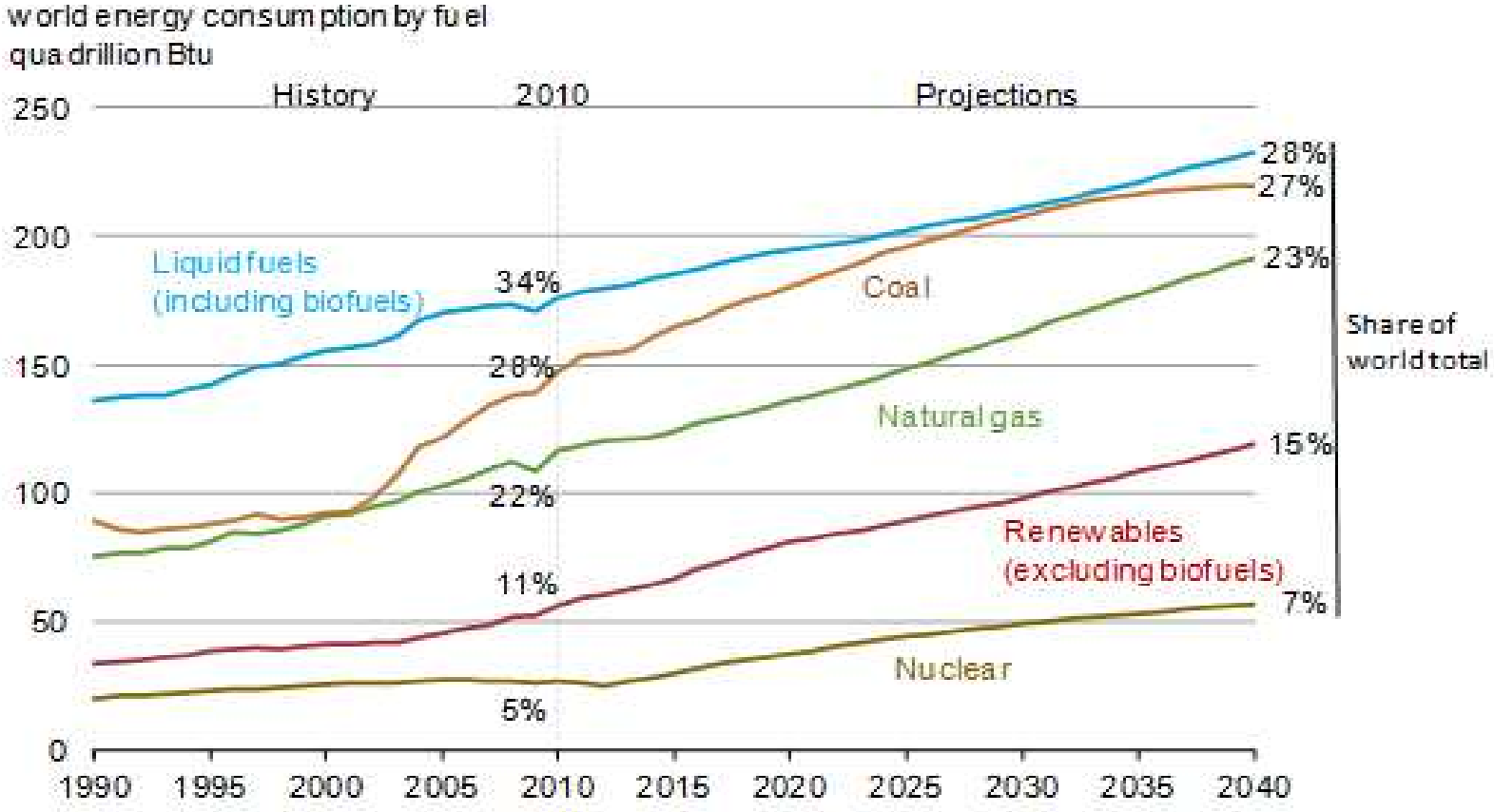
In million tons of oil equivalent



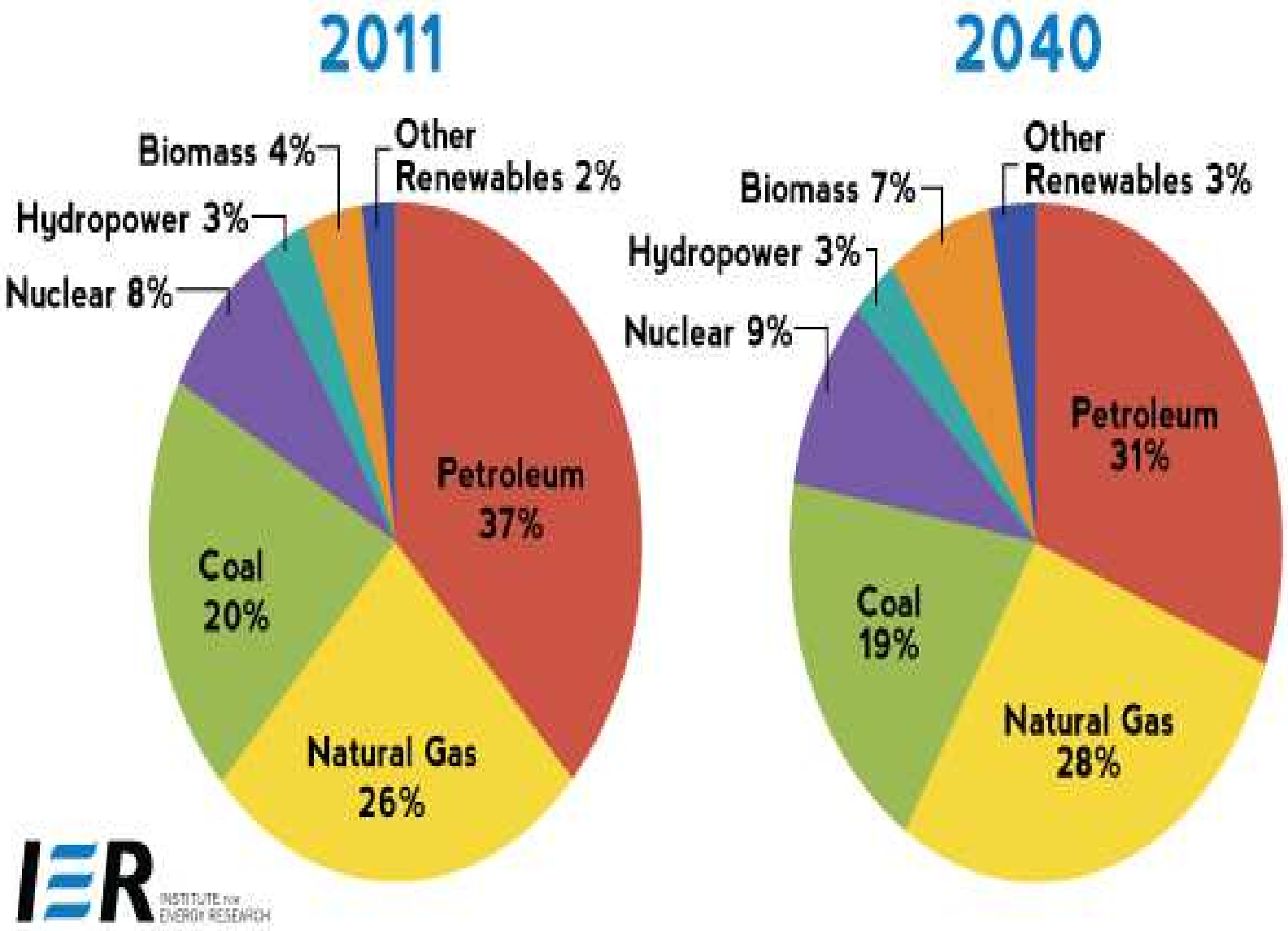

Source: BP Statistical Review of Energy 2014


Global Energy Consumption 1965-2013
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Coal
Gas
Oil
Energy Matters
euanmearns.com
BP 2014 data
Biofuels
Geothermal & biomass
Solar
Wind
Hydro
Nuclear
Coal
Gas
Oil

# Figure 2. Renewable energy and nuclear power are the fastest growing sources of energy consumption



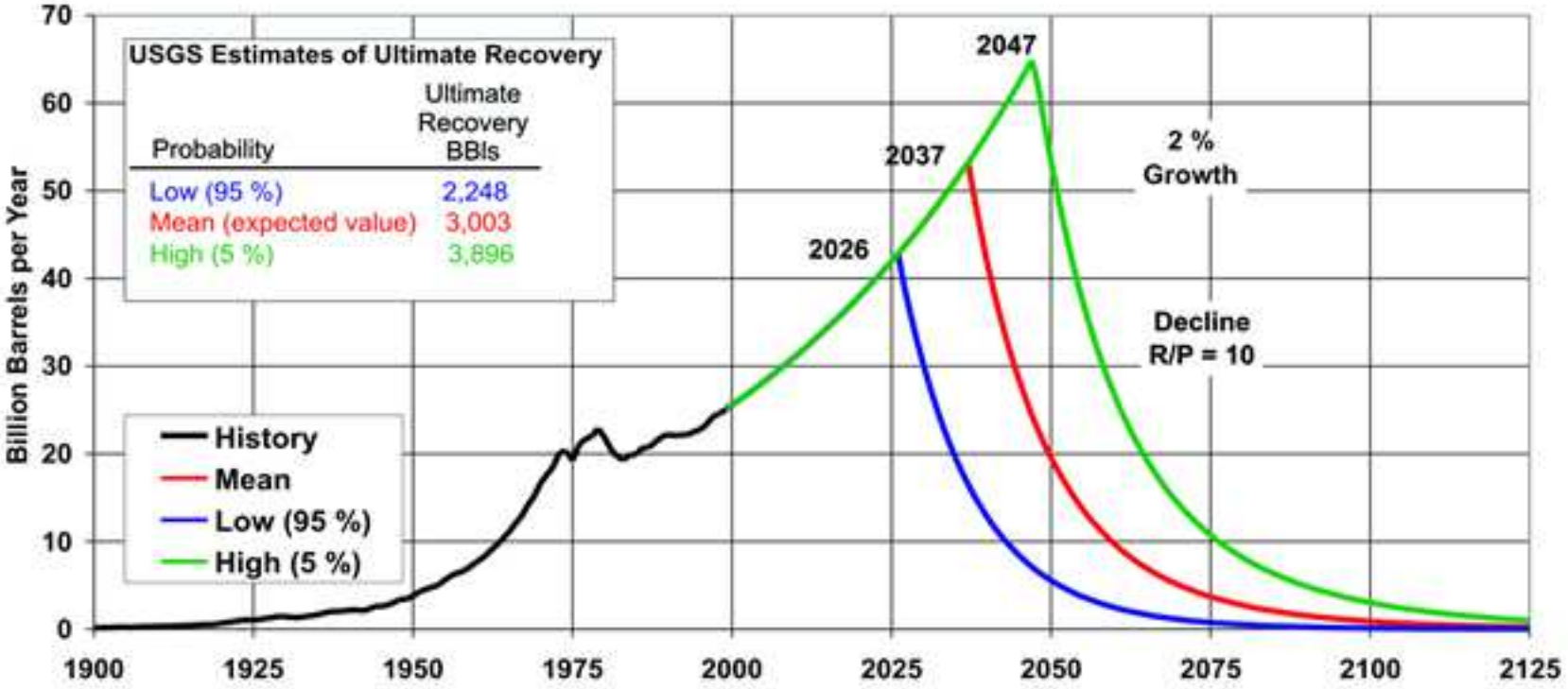

Source: EIA, International Energy Outlook 2013


2011
Biomass 4%
Other Renewables 2%
Hydropower 3%
Nuclear 8%
Petroleum 37%
Coal 20%
Natural Gas 26%
2040
Biomass 7%
Other Renewables 3%
Hydropower 3%
Nuclear 9%
Petroleum 31%
Coal 19%
Natural Gas 28%
IER
INSTITUTE for ENERGY RESEARCH

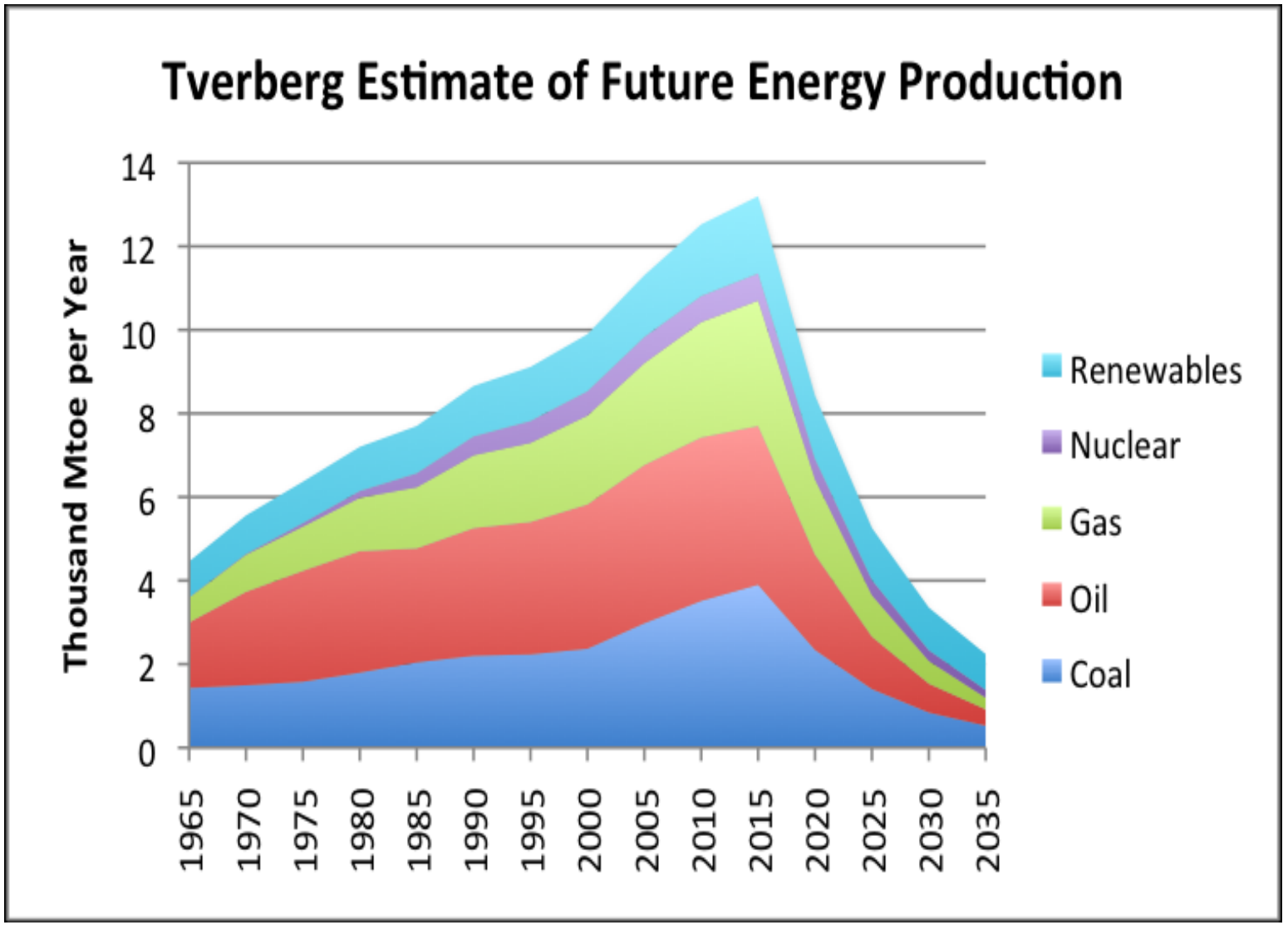
# Future predictions

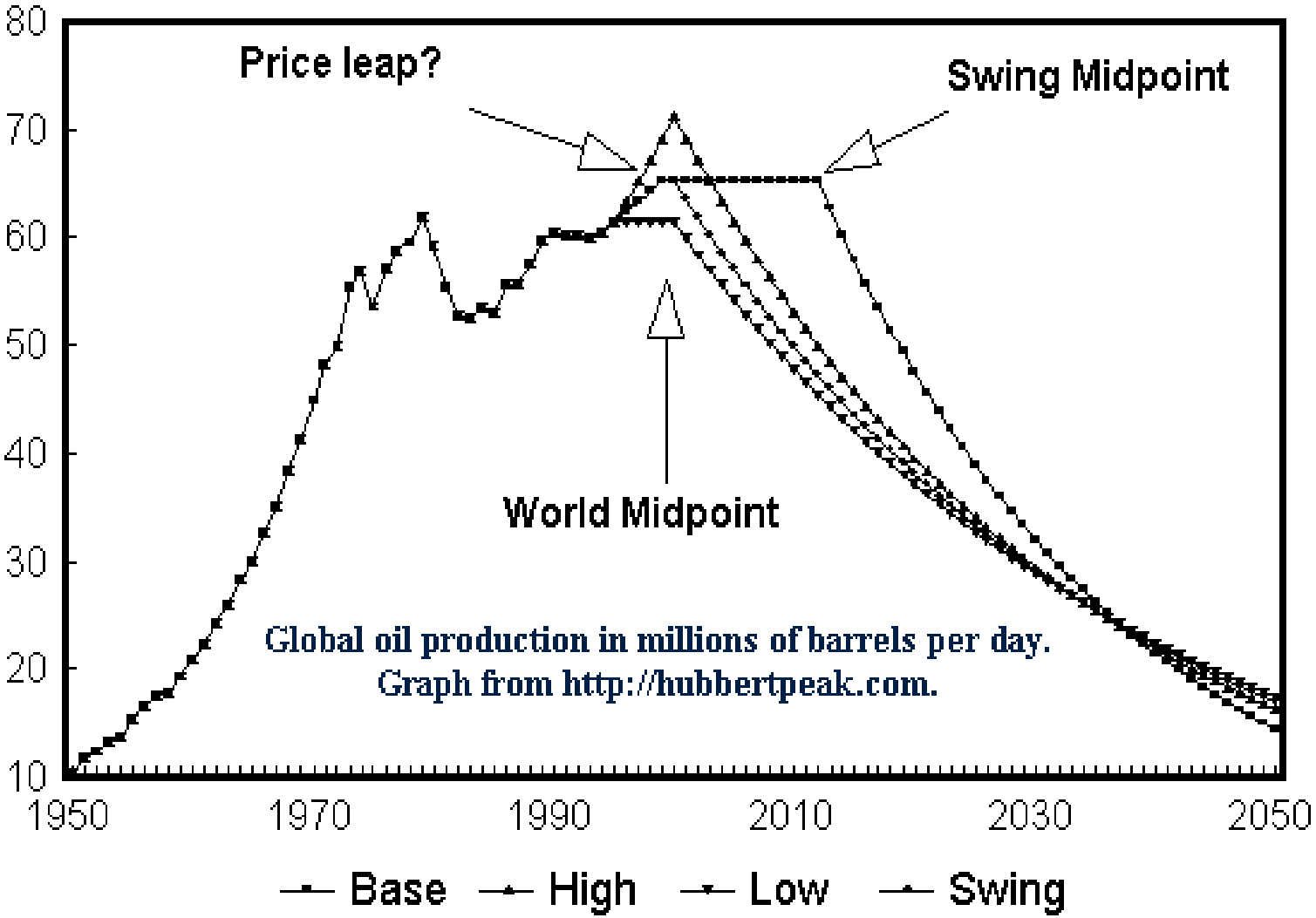
**Change often**

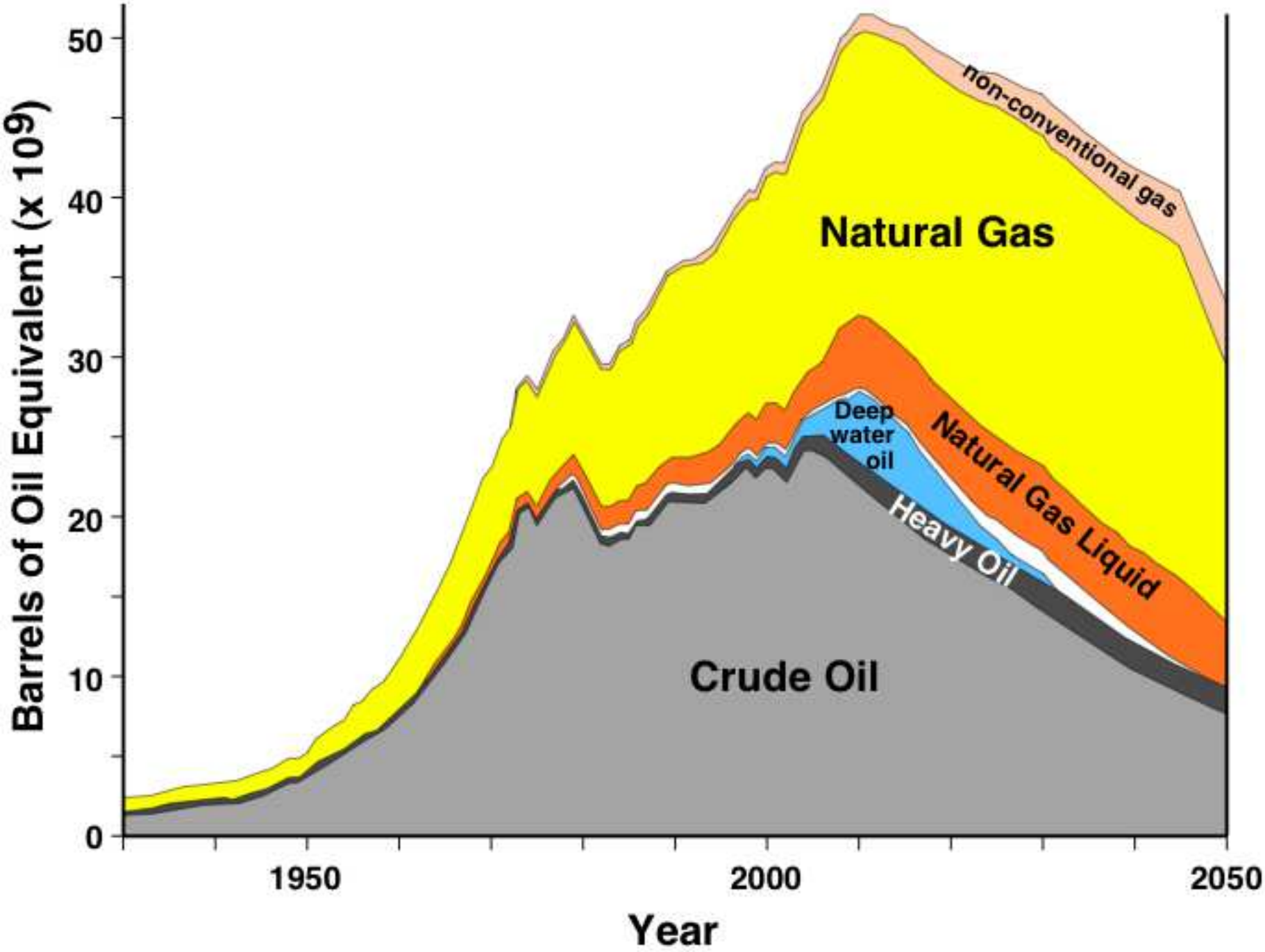
**Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)**



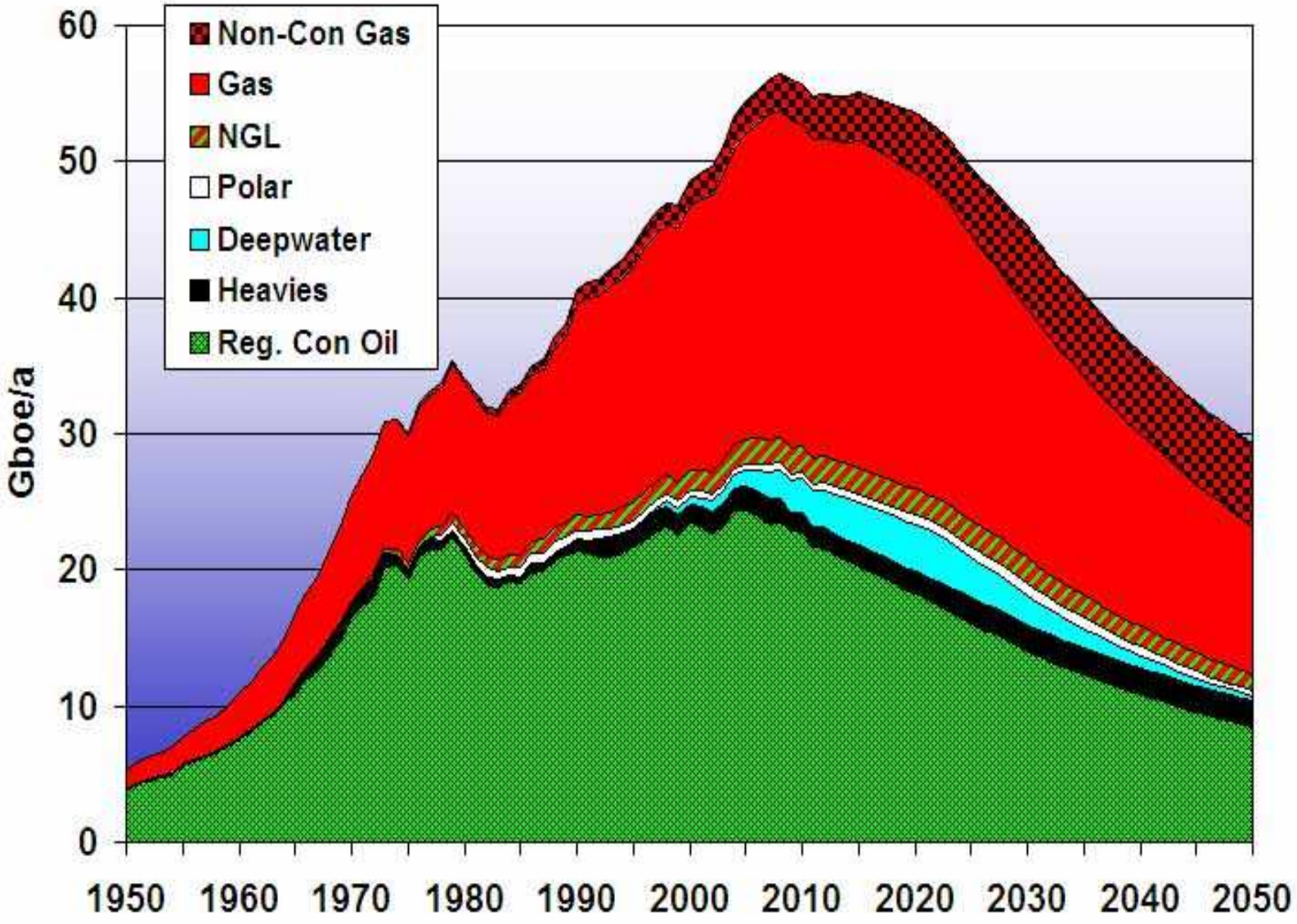

Source: Energy Information Administration
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.


Tverberg Estimate of Future Energy Production
Thousand Mtoe per Year
0
2
4
6
8
10
12
14
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Renewables
Nuclear
Gas
Oil
Coal

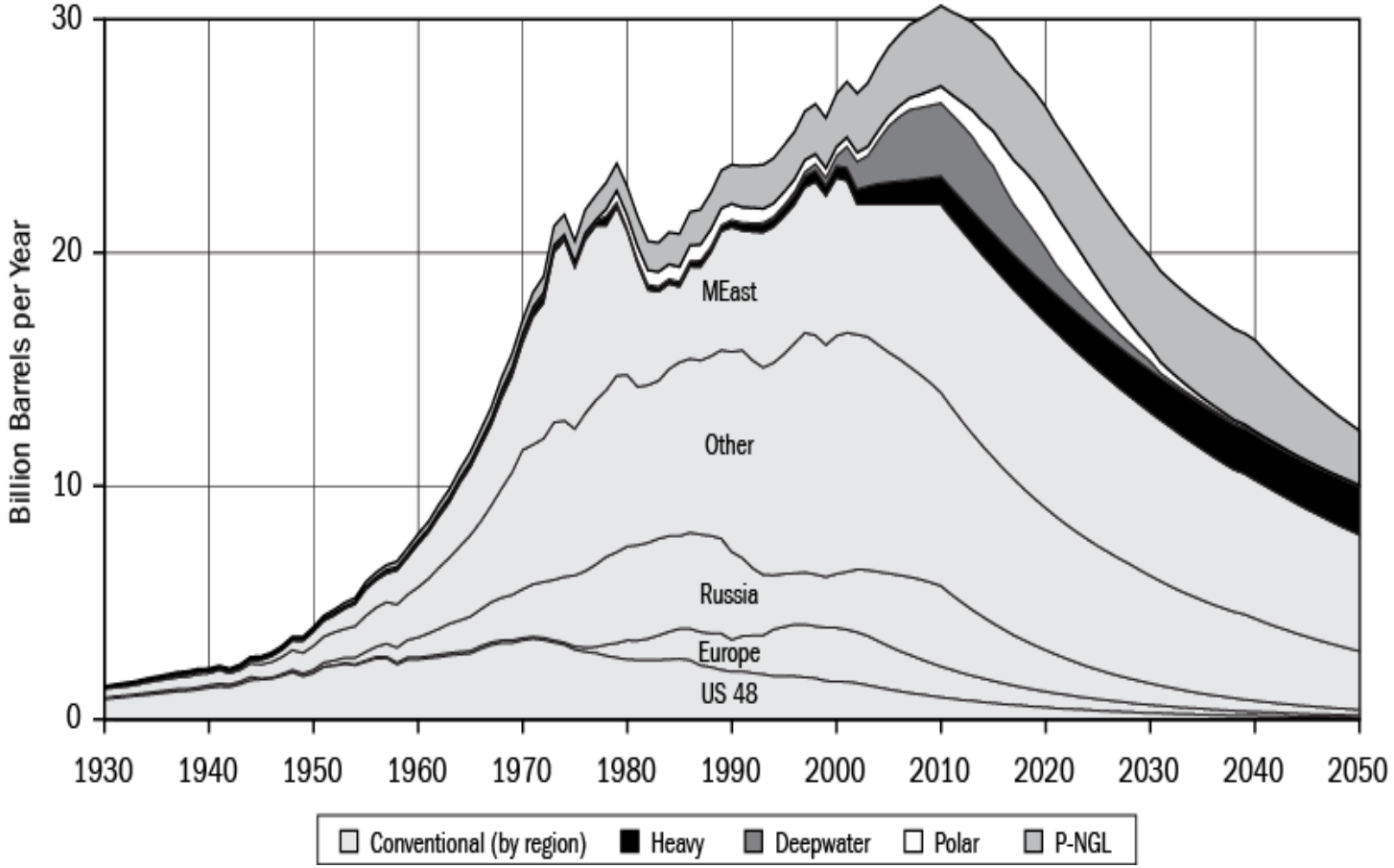

80
70
60
50
40
30
20
10
1950
1970
1990
2010
2030
2050
Price leap?
Swing Midpoint
World Midpoint
Global oil production in millions of barrels per day.
Graph from http://hubbertpeak.com.
Base
High
Low
Swing

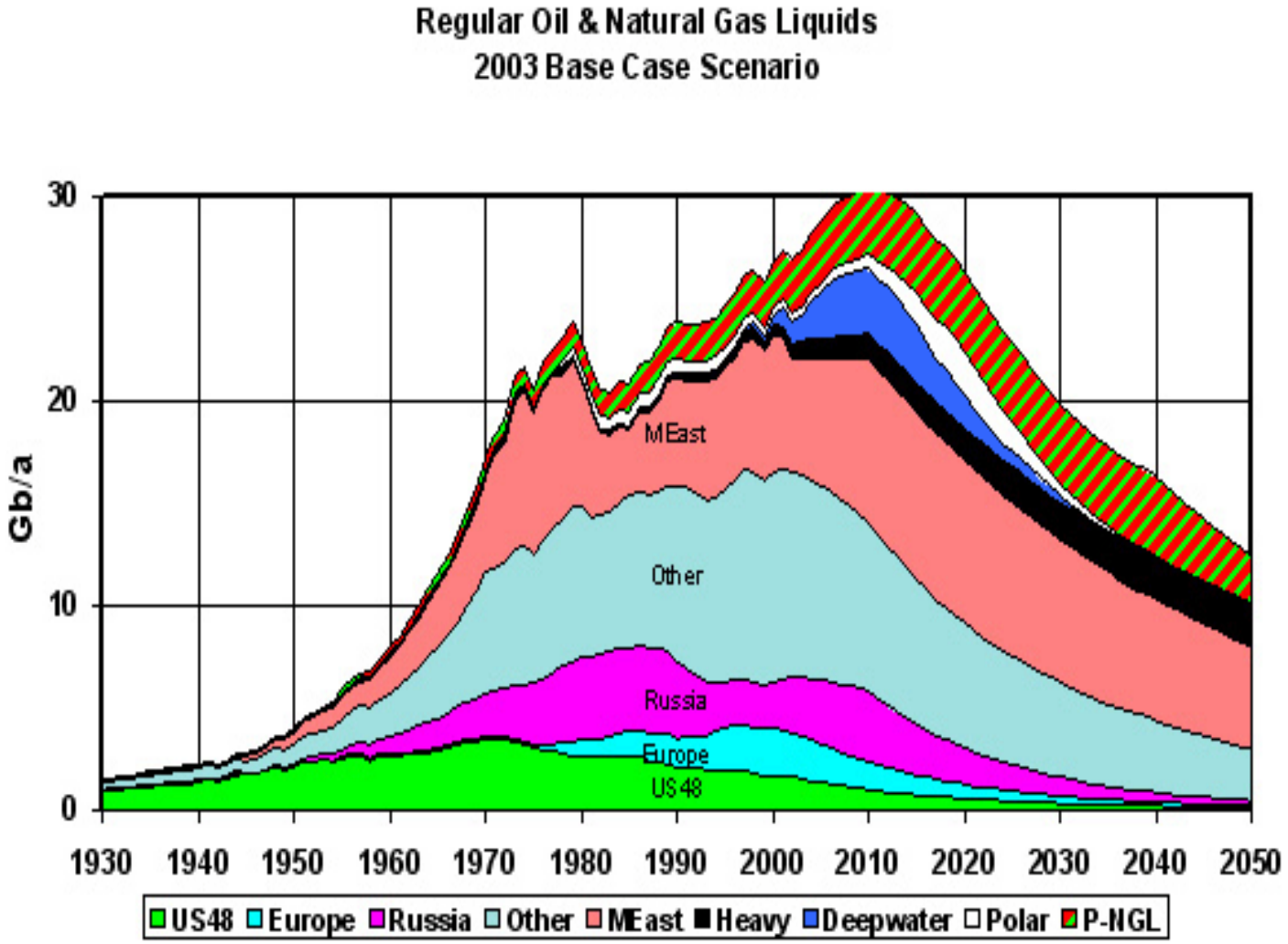

Barrels of Oil Equivalent (x 10^9)
50
40
30
20
10
0
1950
2000
2050
Year
non-conventional gas
Natural Gas
Natural Gas Liquid
Deep water oil
Heavy Oil
Crude Oil

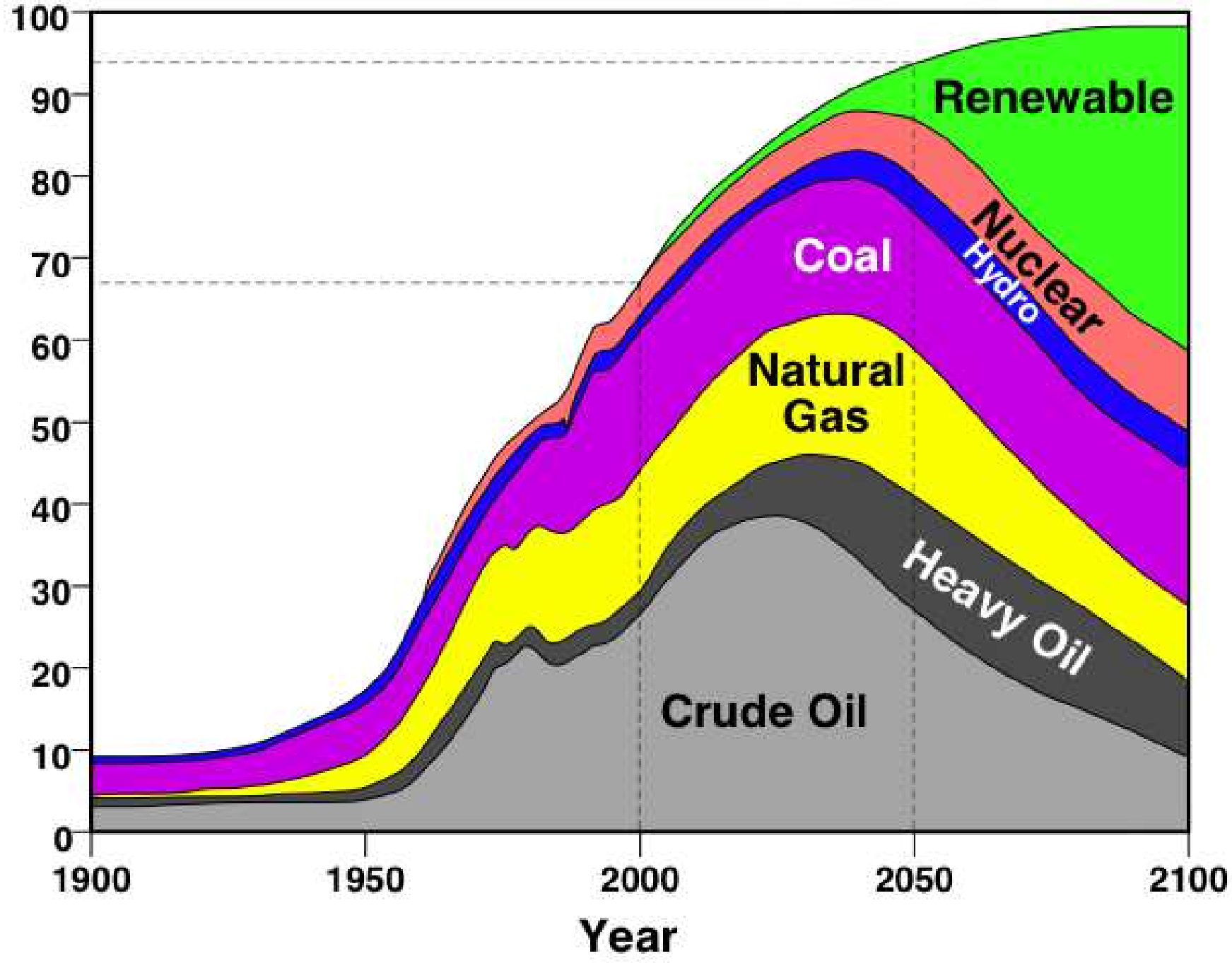
# Oil & Gas Production 1950-2050




Source: Association for the Study of Peak Oil (ASPO) / Campbell 2011


Billion Barrels per Year
30
20
10
0
MEast
Other
Russia
Europe
US 48
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Conventional (by region)
Heavy
Deepwater
Polar
P-NGL


Regular Oil & Natural Gas Liquids
2003 Base Case Scenario
Gb/a
30
20
10
0
MEast
Other
Russia
Europe
US48
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
US48
Europe
Russia
Other
MEast
Heavy
Deepwater
Polar
P-NGL

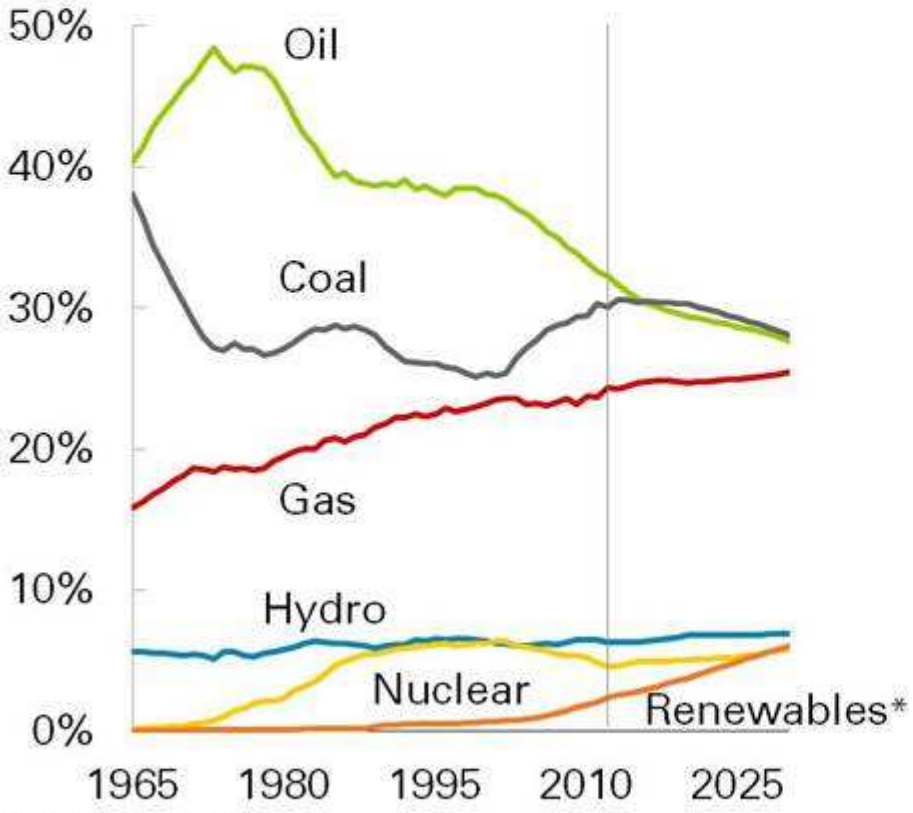

100
90
80
70
60
50
40
30
20
10
0
1900
1950
2000
2050
2100
Year
Renewable
Nuclear
Hydro
Coal
Natural
Gas
Heavy Oil
Crude Oil

economic


WORLD ENERGY PRODUCTION 2012
Billion BTU's
CRUDE OIL 34,425,681
COAL 32,791,081
NATURAL GAS 25,320,704
HYDROELECTRIC 6,811,409
NUCLEAR 5,501,789
WIND 1,308,927
BIOFUELS 520,384
SOLAR 260,538
GEOTHERMAL 71,371
TOTAL PRODUCTION 105,484,688
TOTAL CONSUMPTION 105,549,688
OilPrice.com
GET WIDGET
WORLD ENERGY CONSUMPTION 2012
Billion BTU's
CHINA 21,371,745
UNITED STATES 20,088,623
RUSSIA 6,071,275
INDIA 4,604,552
JAPAN 4,481,229
GERMANY 2,803,192
CANADA 2,776,865
FRANCE 2,214,287
WORLD TOTAL 105,535,988
OilPrice.com
GET WIDGET

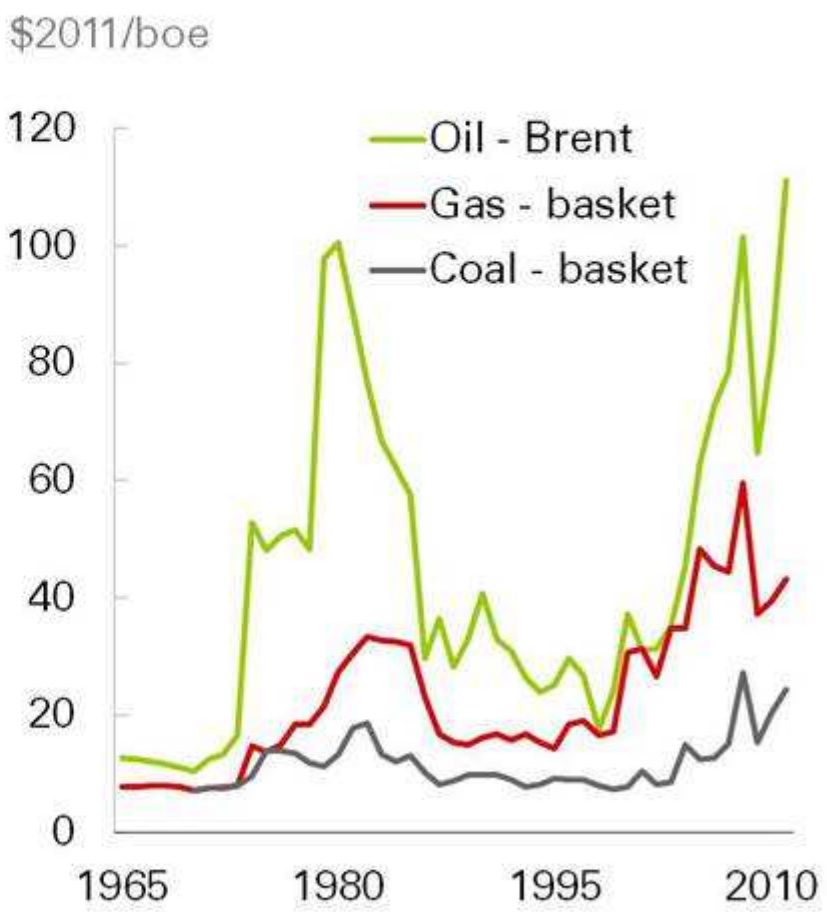
# Energy prices play a key role...

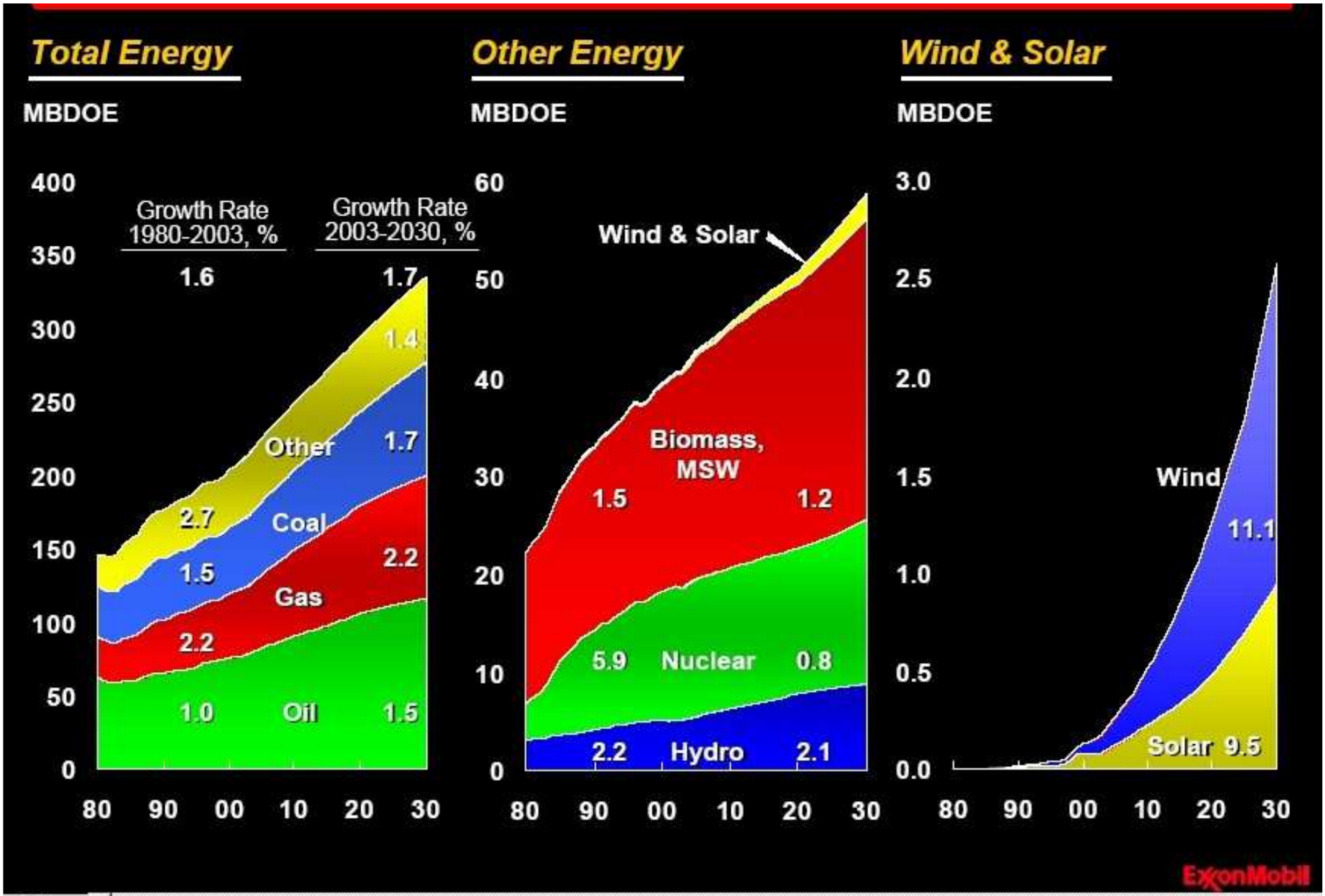
## Shares of world primary energy




*Includes biofuels

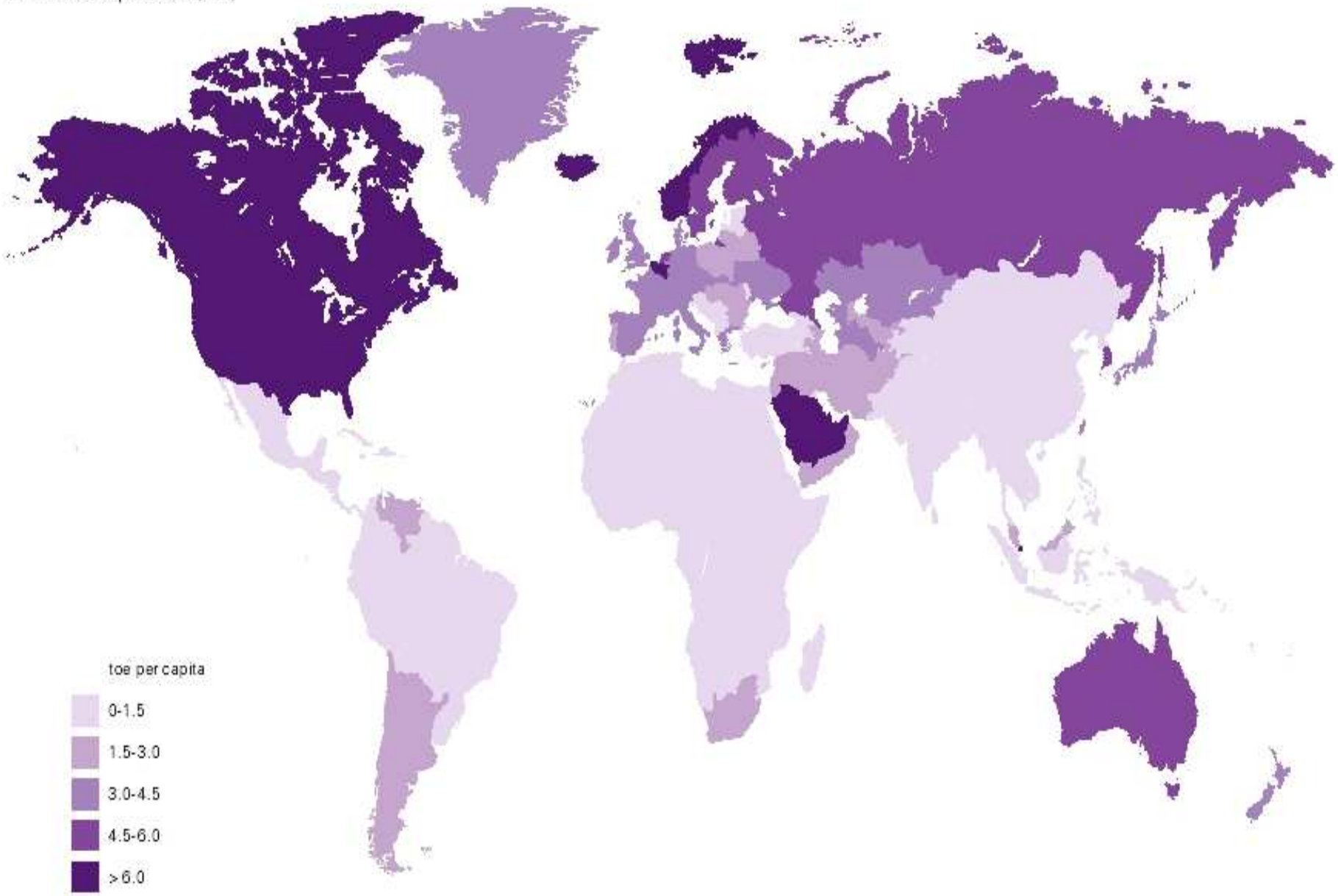
## Energy prices




Total Energy
MBDOE
400
350
300
250
200
150
100
50
0
Growth Rate 1980-2003, %
1.6
Growth Rate 2003-2030, %
1.7
Other
2.7
1.4
Coal
1.5
1.7
Gas
2.2
2.2
Oil
1.0
1.5
80 90 00 10 20 30
Other Energy
MBDOE
60
50
40
30
20
10
0
Wind & Solar
Biomass, MSW
1.5
1.2
Nuclear
5.9
0.8
Hydro
2.2
2.1
80 90 00 10 20 30
Wind & Solar
MBDOE
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Wind
11.1
Solar 9.5
80 90 00 10 20 30
ExxonMobil

**Consumption per capita**

Tonnes oil equivalent (toe)



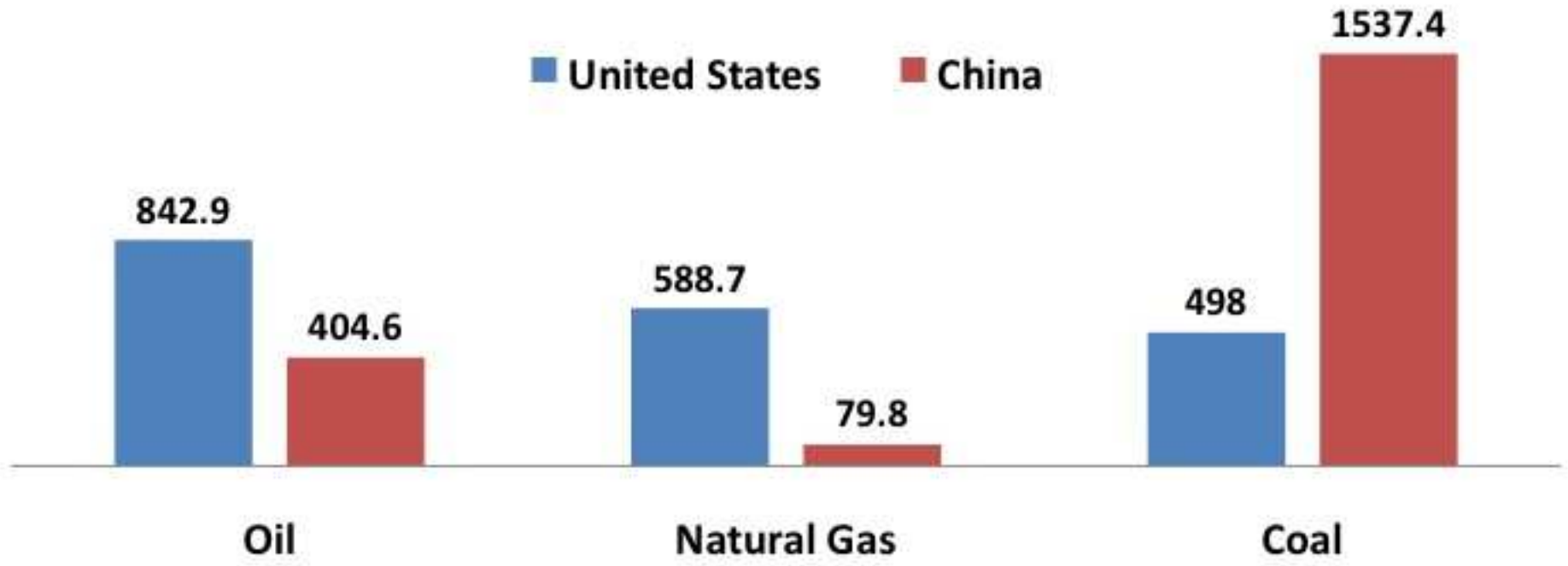
# Annual energy consumption per capita


toe : ton of oil equivalent

FROM MIT ENERGY COURSE

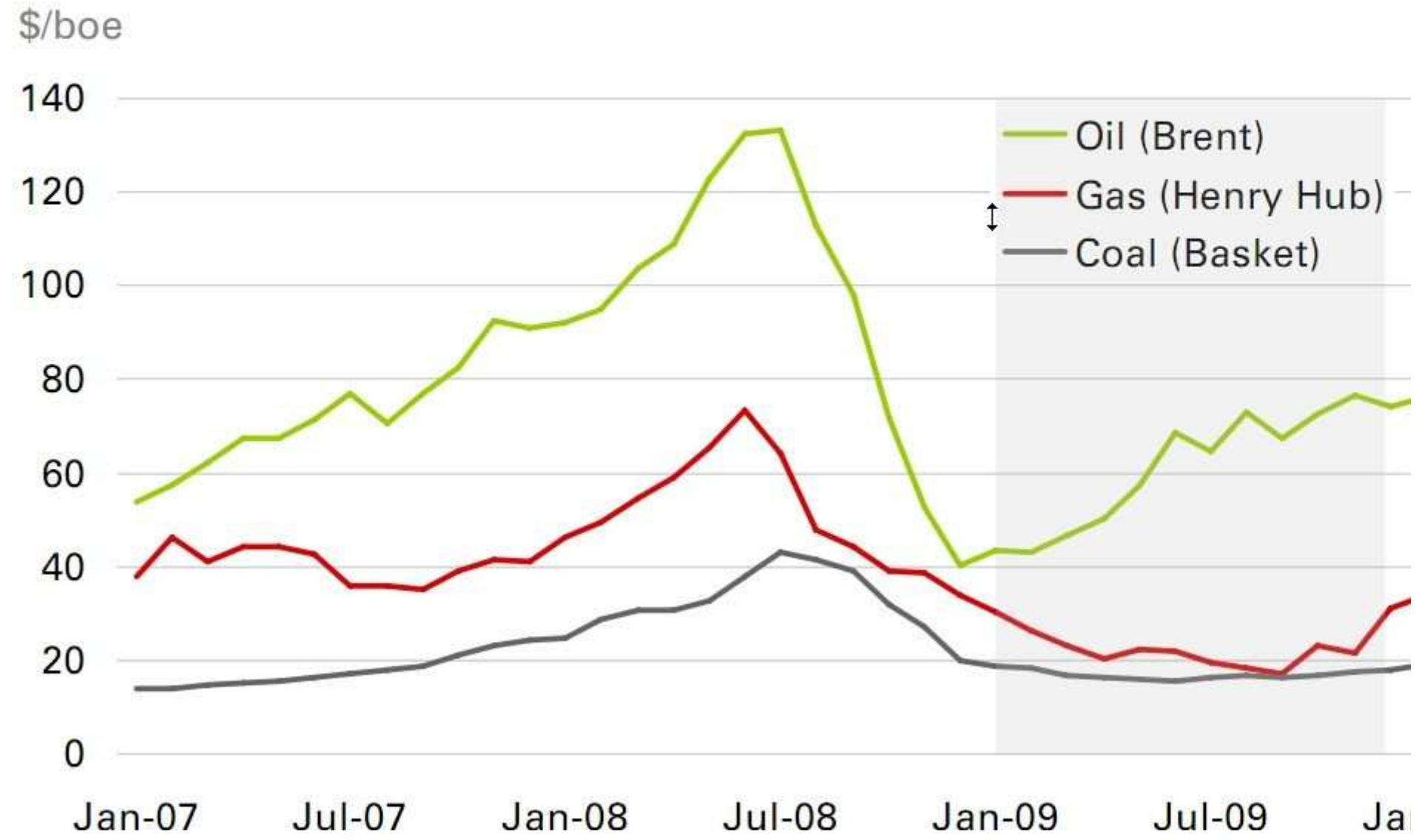
| Country | % of World Population 2001 | % of World GDP 2002 | % of World Energy Consumption 2002 |
|---|---|---|---|
| United States | 4.6% | 32% | 24% |
| Japan | 2.0% | 12% | 5% |
| France | 0.9% | 4% | 3% |
| Germany | 1.4% | 6% | 4% |
| United Kingdom | 1.0% | 5% | 2% |
| | | | |
| China | 20% | 4% | 11% |
| Indi | 17% | 2% | 4% |

# Comparison of Fossil Fuel Consumption, 2009: United States and China
## (million tons oil equivalent)




Source: BP Statistical Review of World Energy, June 2010

# Energy Prices



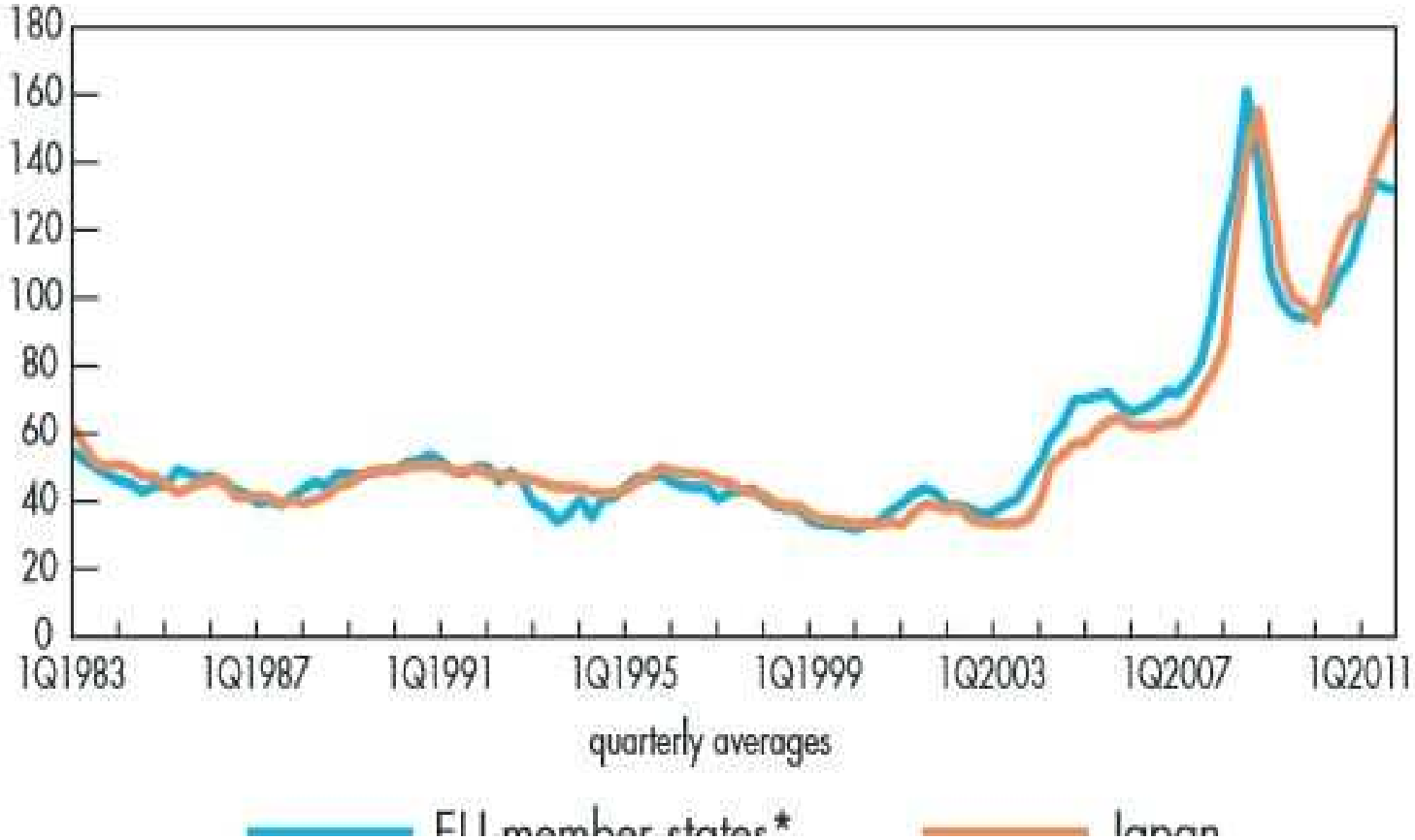
# Cost Comparison Summary

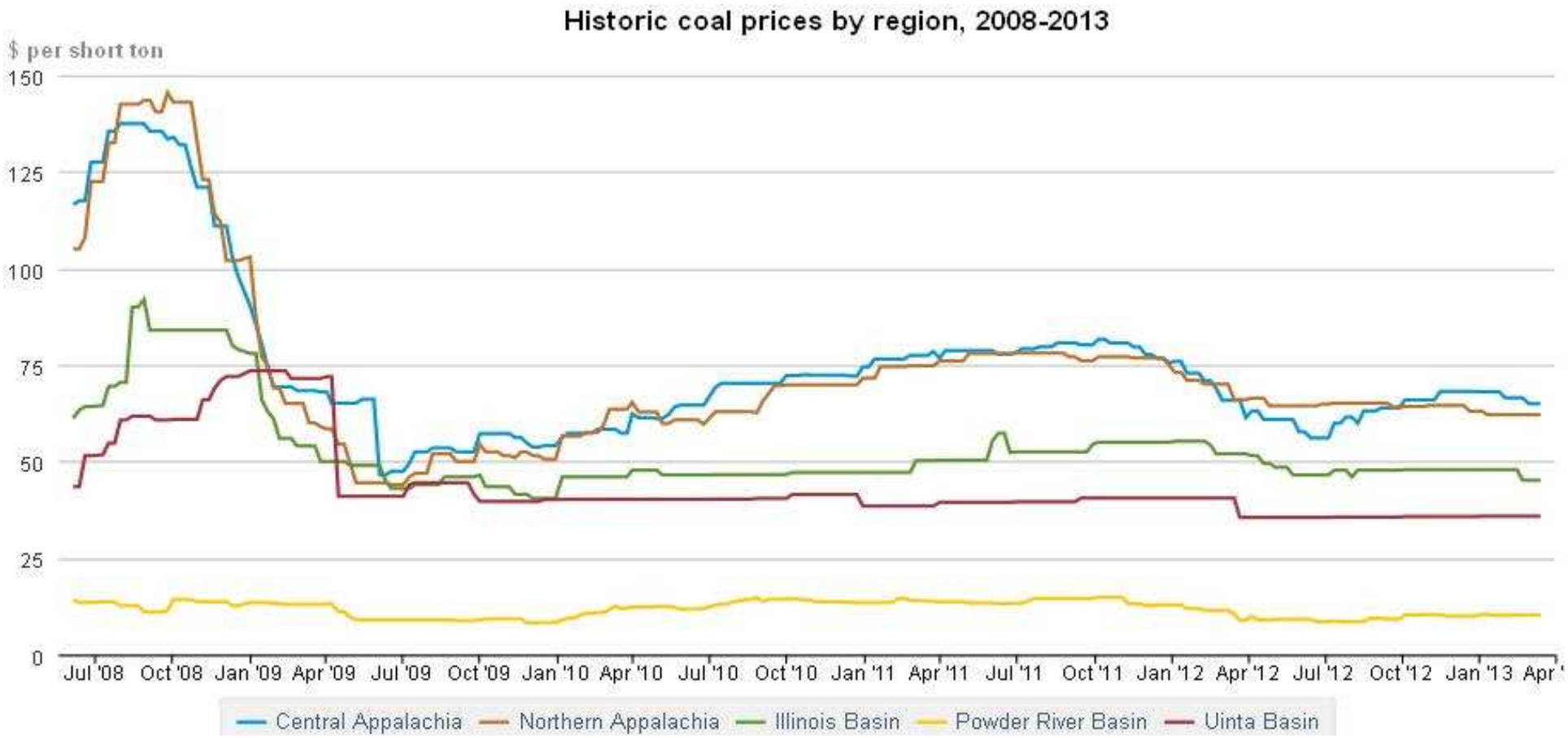
| | Costs in cents per delivered Killowatt Hour | | | | Estimates shown with question mark? | | |
|---|---|---|---|---|---|---|---|
| **Technology** | **Capital Cost** | **Capacity Factor** | **O&M Cost** | **Fuel Cost** | **Direct Costs** | **Indirect Social Costs** | **Total Costs** |
| Coal | 0.72 | 95% | 1 | 2.14 | 3.14 | 6.43 | 10.29 |
| Nuclear | 0.9 | 95% | 1.4 | 0.76 | 2.16 | 0.25 | 3.31 |
| | | | | | | + other not quantified | |
| Natural Gas | 0.42 | 95% | 0.5 | 4.9 | 4.95 | 2.27 | 8.09 |
| Solar | 17.12 | 15 - 20% | 1 | none | 18.12 | not quantified | 18.12 |
| Wind | 2.45 | 25 - 35% | 1 | none | 3.14 | not quantified | 3.45 |
| | | | | | | New England | 6 - 7 |
| Tidal | | | | | | | |
| Barrage / Low Dam | 7 - 10? | 12 - 18%? | 1? | none | 8 - 11? | not quantified | 8 - 11? |
| Free-Flow Current | 5 - 8? | 30 - 50% | 2? | none | 7 - 10 | not quantified | 7 - 10 |
| Tidal Fence | 6 - 9? | 35 - 40% | 2? | none | 8 - 11? | not quantified | 8 - 11? |
| Submerged Array | 5 - 7? | 40 - 60%? | 1.5? | none | 6.5 - 8.5? | not quantified | 6.5 - 8.5? |

# COAL

# Coal

## Steam coal import costs in USD/tonne

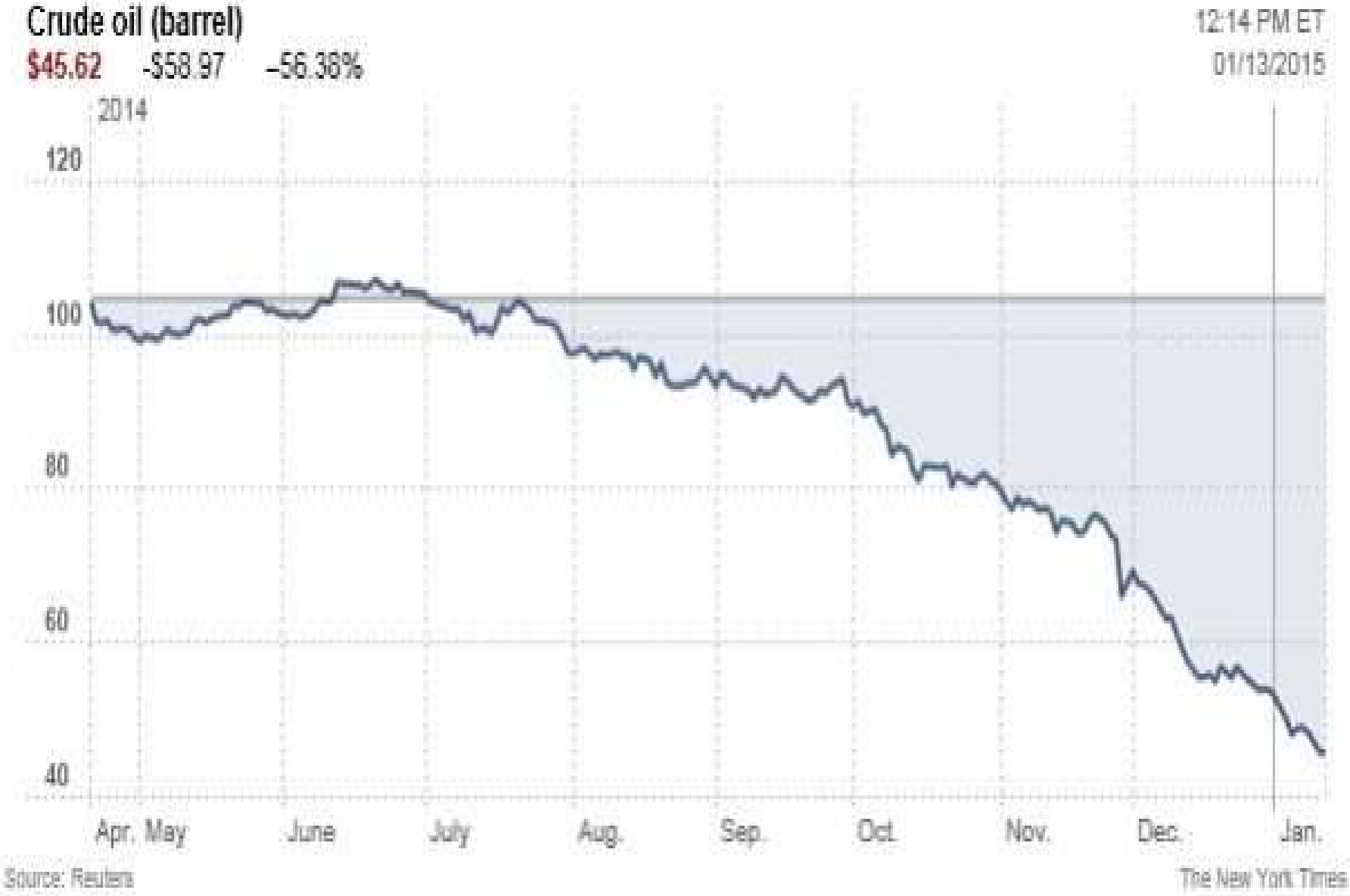



Historic coal prices by region, 2008-2013
$ per short ton
150
125
100
75
50
25
0
Jul '08
Oct '08
Jan '09
Apr '09
Jul '09
Oct '09
Jan '10
Apr '10
Jul '10
Oct '10
Jan '11
Apr '11
Jul '11
Oct '11
Jan '12
Apr '12
Jul '12
Oct '12
Jan '13
Central Appalachia
Northern Appalachia
Illinois Basin
Powder River Basin
Uinta Basin

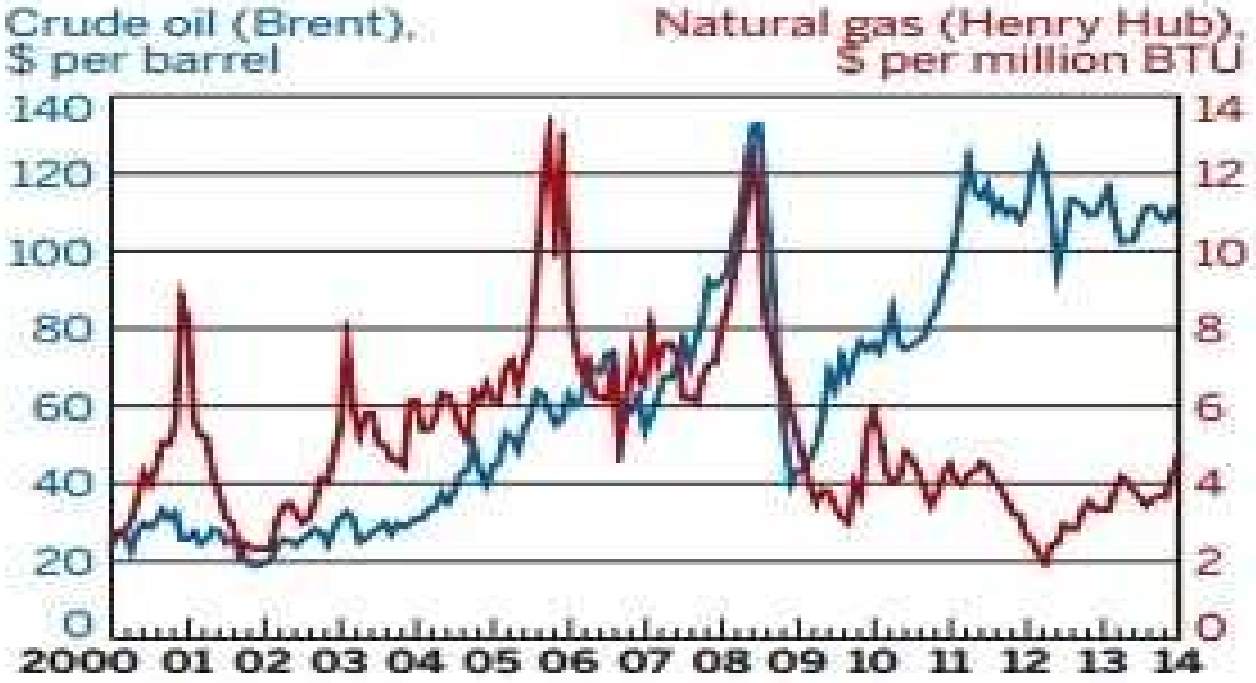
# OIL

# Crude Oil

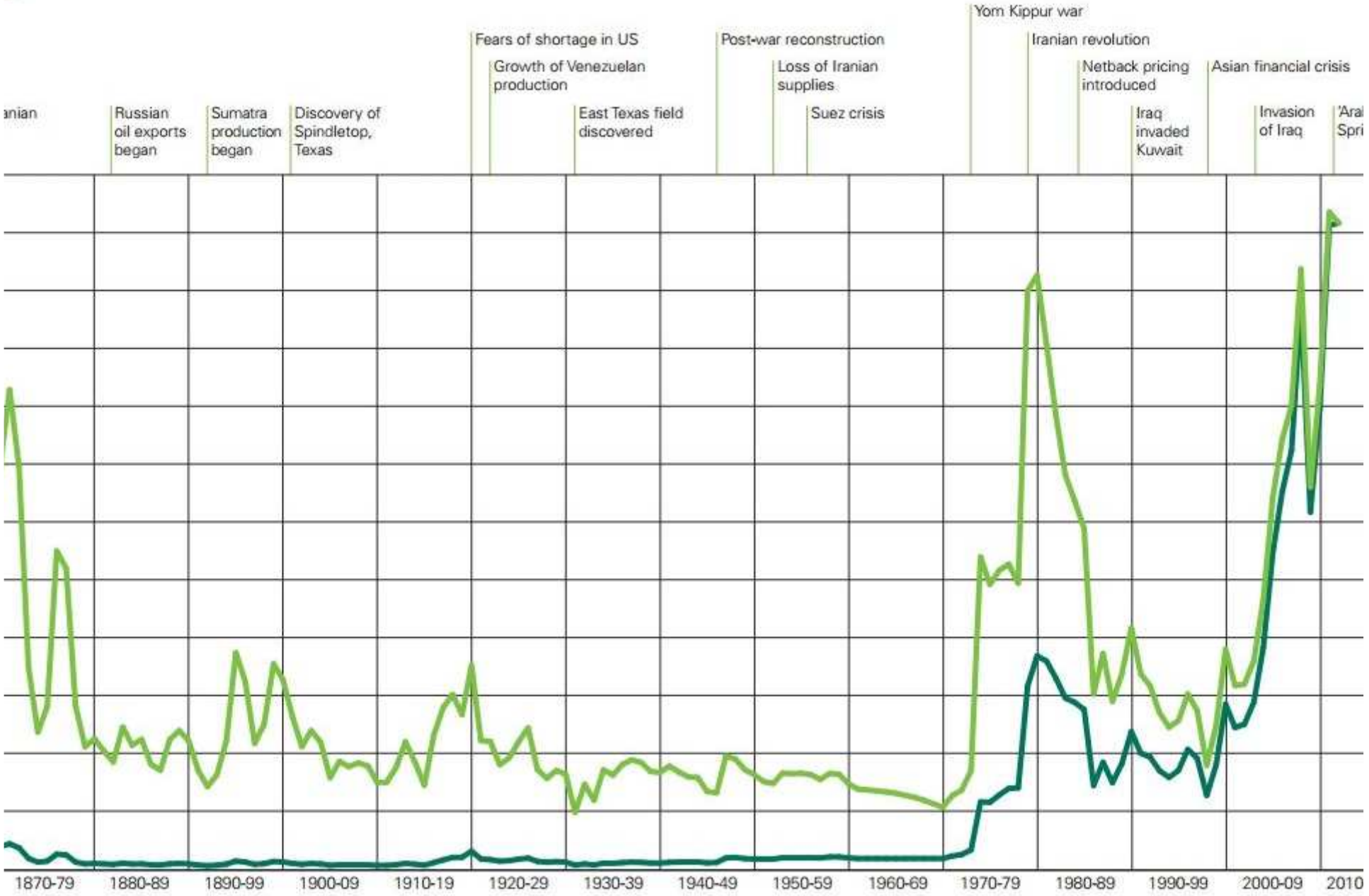
## Key crude oil spot prices in USD/barrel


Crude oil (barrel)
$45.62 -$58.97 –56.36%
12:14 PM ET
01/13/2015
2014
120
100
80
60
40
Apr. May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Source: Reuters
The New York Times

**WIDE GULF** The price of natural gas—the feedstock of choice in the U.S.—has plummeted relative to that of oil.




**SOURCE:** U.S. Energy Information Administration

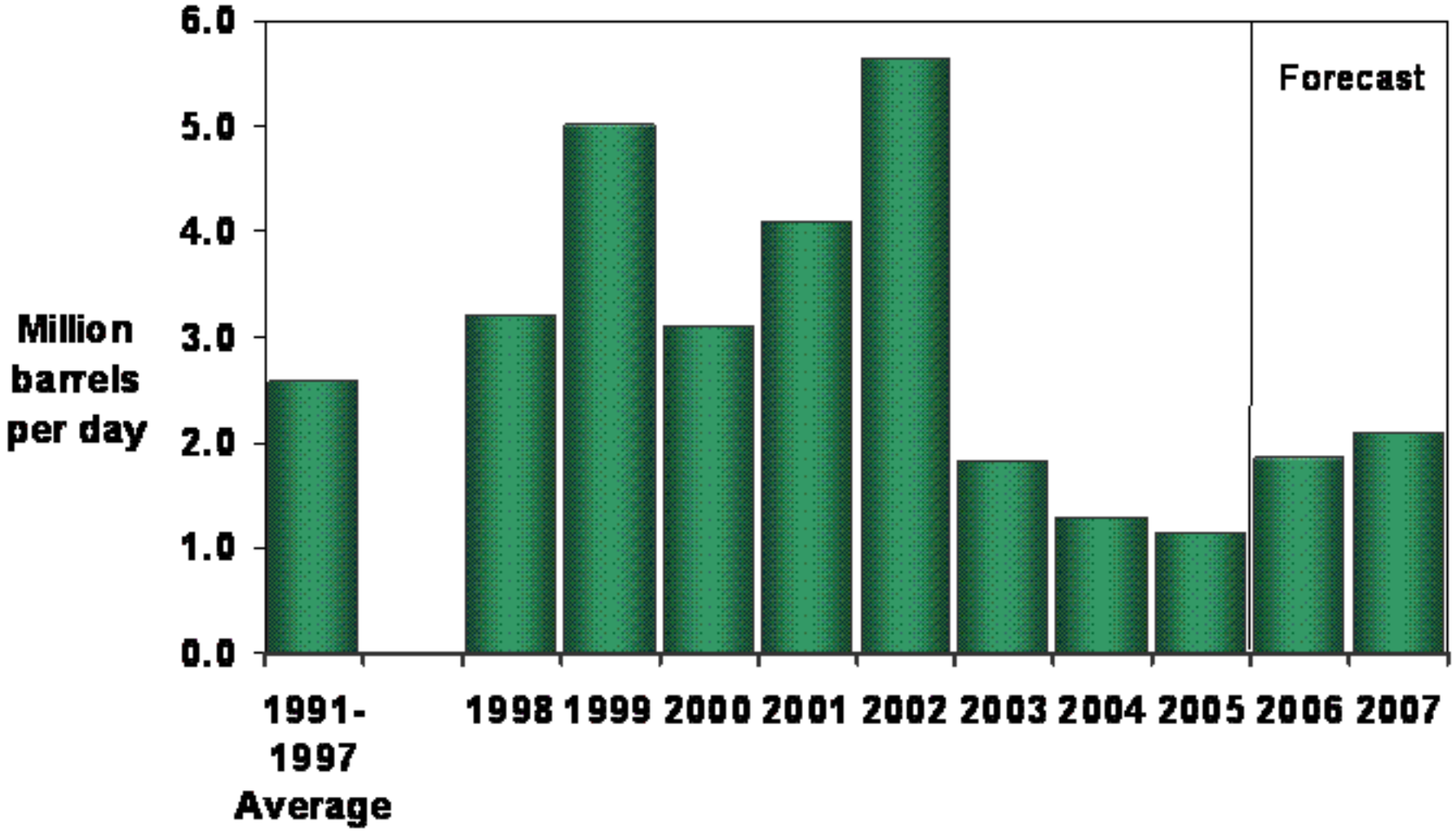



er barrel

y of the day

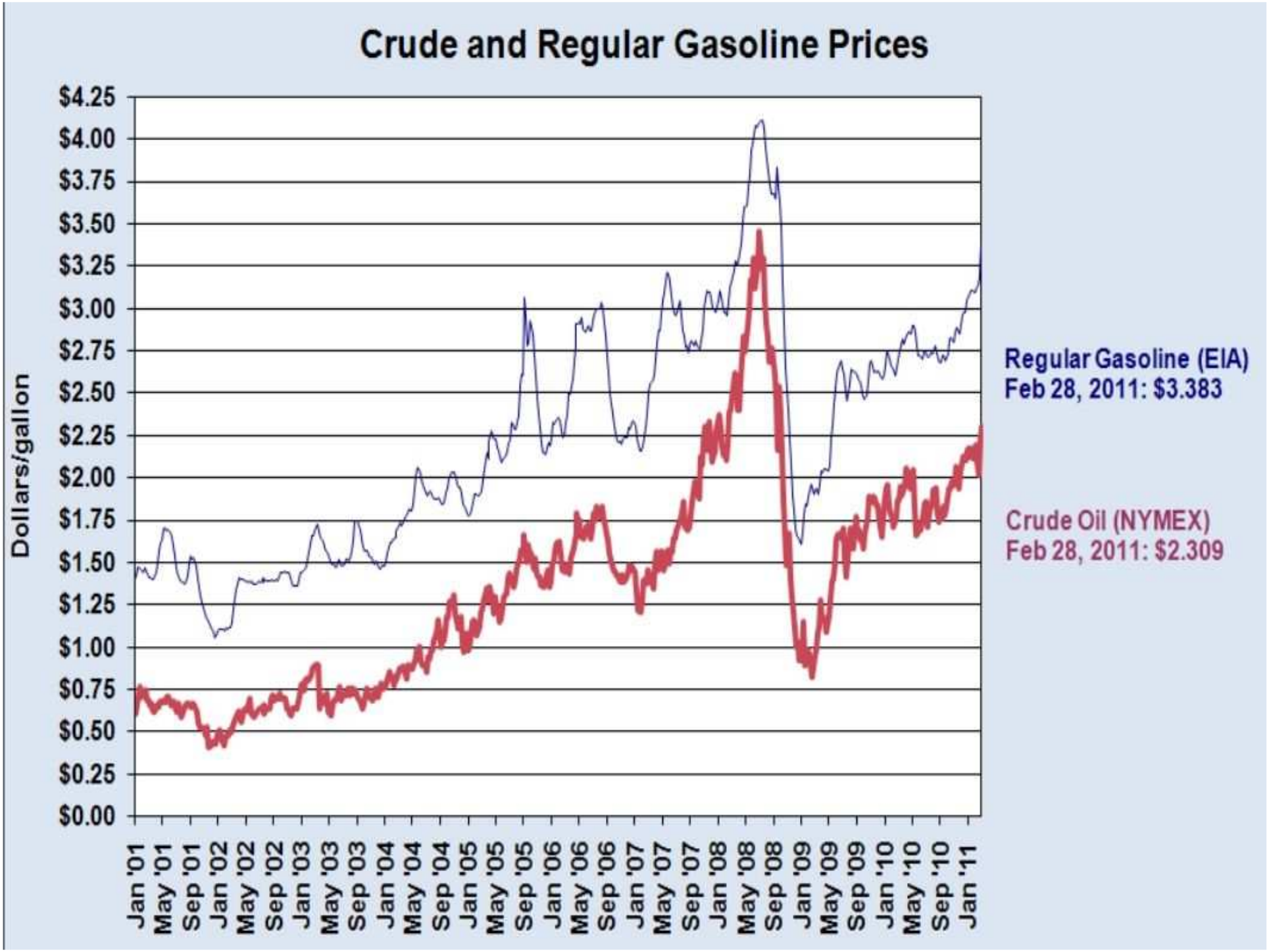
1861-1944 US average.
1945-1983 Arabian Light posted at Ras T

# Figure 9. World Oil Spare Production Capacity

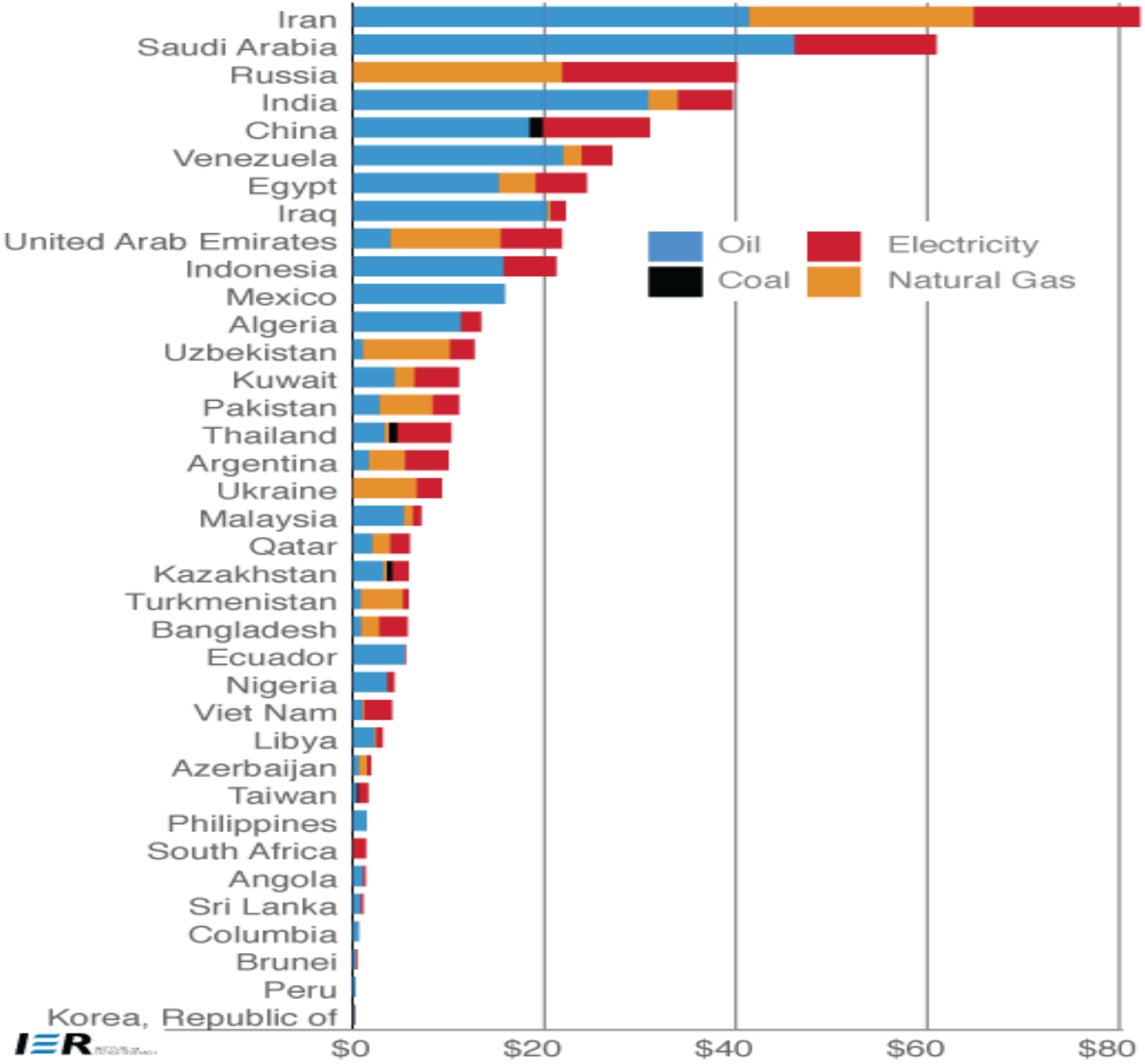



Short-Term Energy Outlook, January 2006

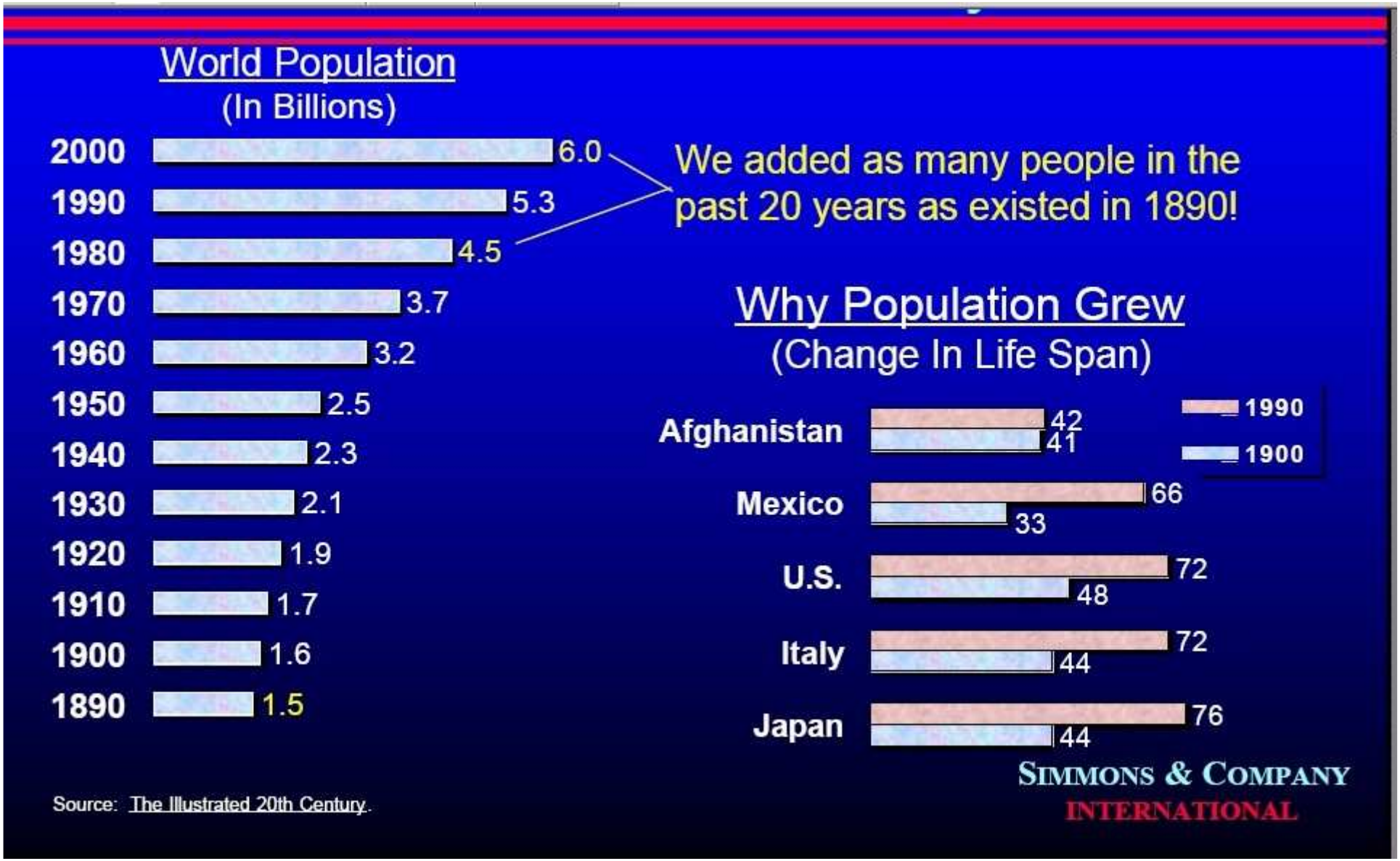
www.eia.doe.gov


Crude and Regular Gasoline Prices
Dollars/gallon
$4.25
$4.00
$3.75
$3.50
$3.25
$3.00
$2.75
$2.50
$2.25
$2.00
$1.75
$1.50
$1.25
$1.00
$0.75
$0.50
$0.25
$0.00
Jan '01
May '01
Sep '01
Jan '02
May '02
Sep '02
Jan '03
May '03
Sep '03
Jan '04
May '04
Sep '04
Jan '05
May '05
Sep '05
Jan '06
May '06
Sep '06
Jan '07
May '07
Sep '07
Jan '08
May '08
Sep '08
Jan '09
May '09
Sep '09
Jan '10
May '10
Sep '10
Jan '11
Regular Gasoline (EIA)
Feb 28, 2011: $3.383
Crude Oil (NYMEX)
Feb 28, 2011: $2.309

# Fossil-Fuel Consumption Subsidies, by Country, 2011 (billion dollars)



# Causes for rise in energy use


World Population
(In Billions)
2000
6.0
1990
5.3
1980
4.5
1970
3.7
1960
3.2
1950
2.5
1940
2.3
1930
2.1
1920
1.9
1910
1.7
1900
1.6
1890
1.5
We added as many people in the past 20 years as existed in 1890!
Why Population Grew
(Change In Life Span)
1990
1900
Afghanistan
42
41
Mexico
66
33
U.S.
72
48
Italy
72
44
Japan
76
44
Source: The Illustrated 20th Century.
SIMMONS & COMPANY
INTERNATIONAL

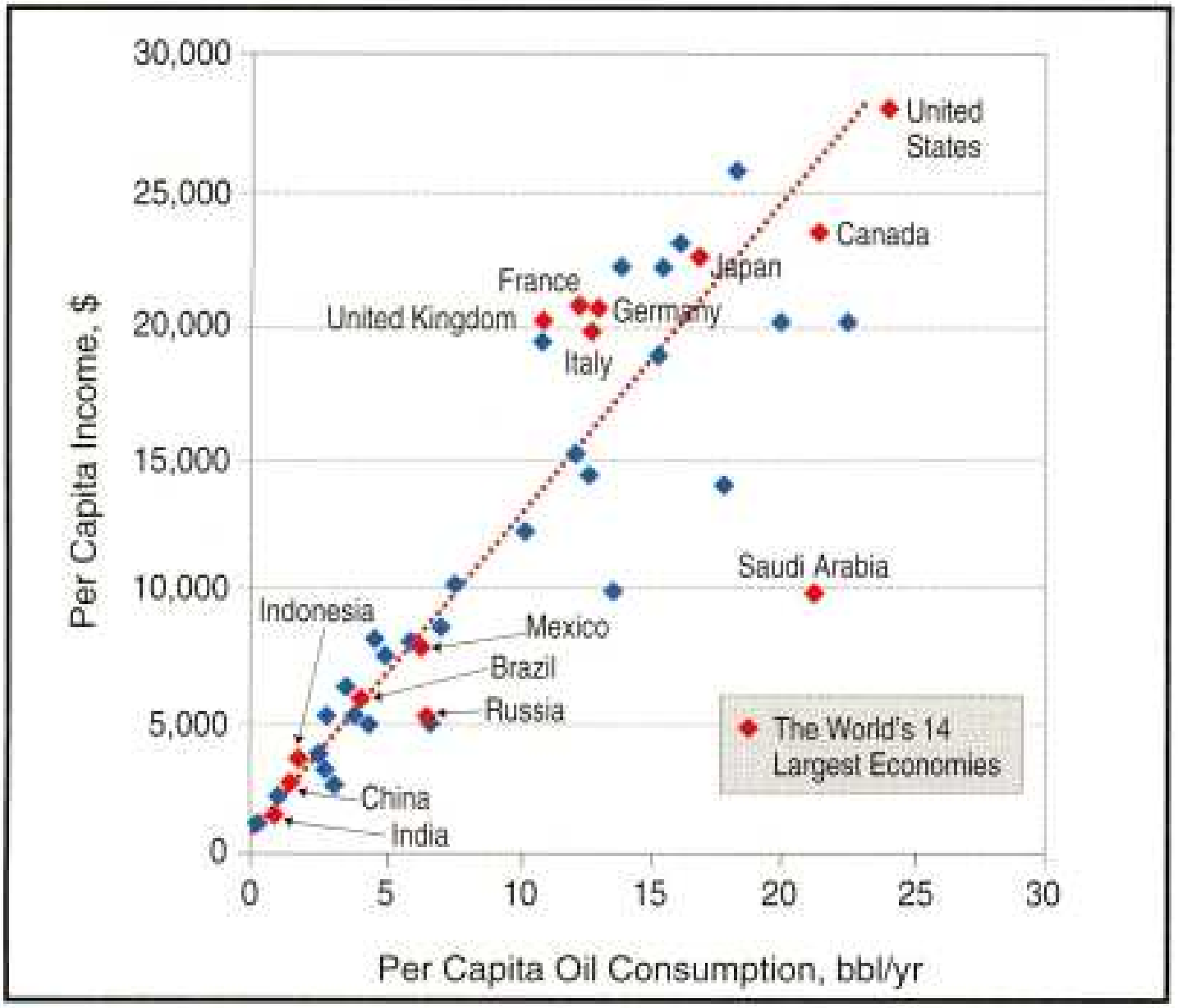
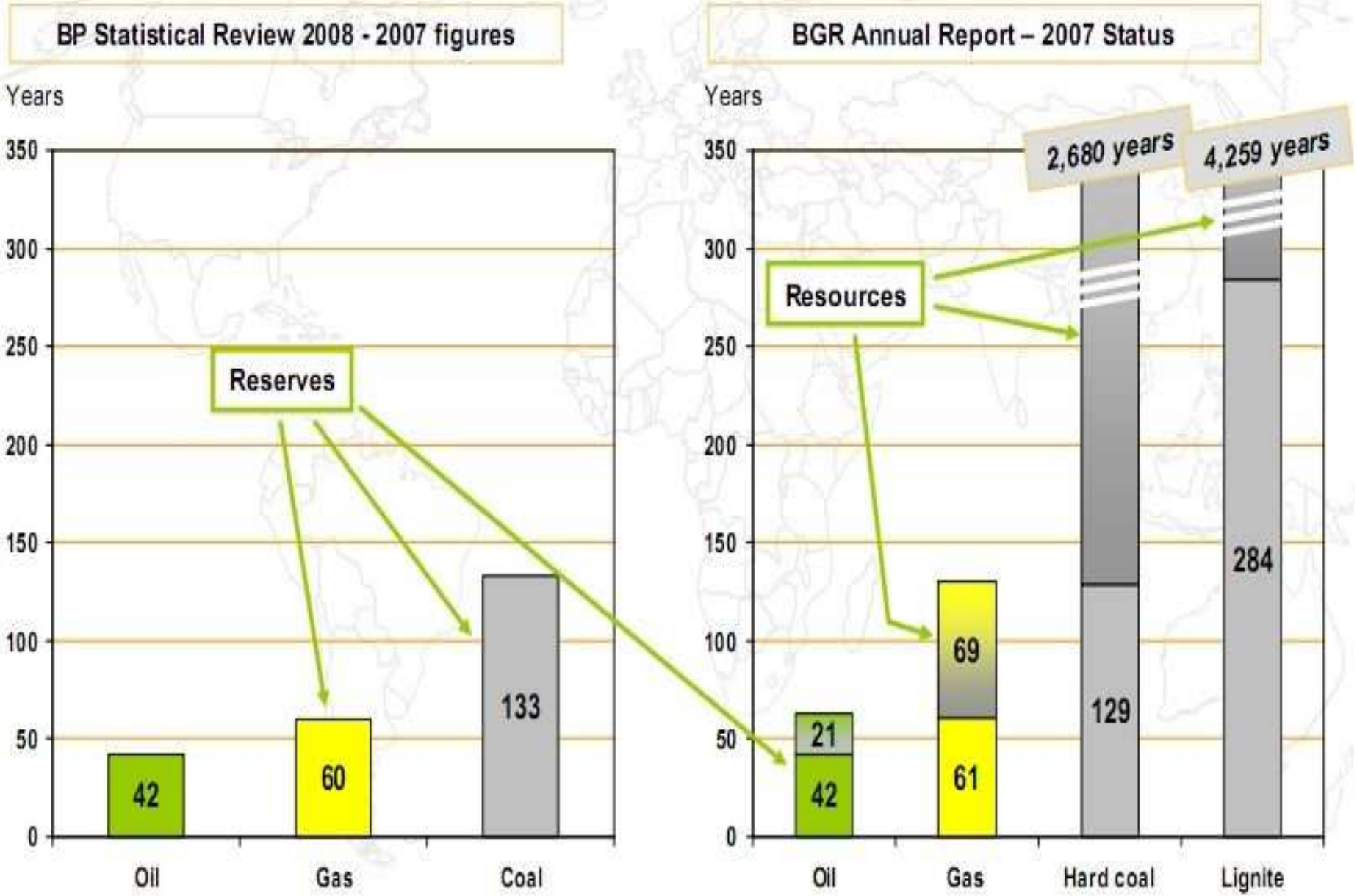



Figure 3. Correlation between per capita income and energy consumption (*6*).

# Energy Reserves

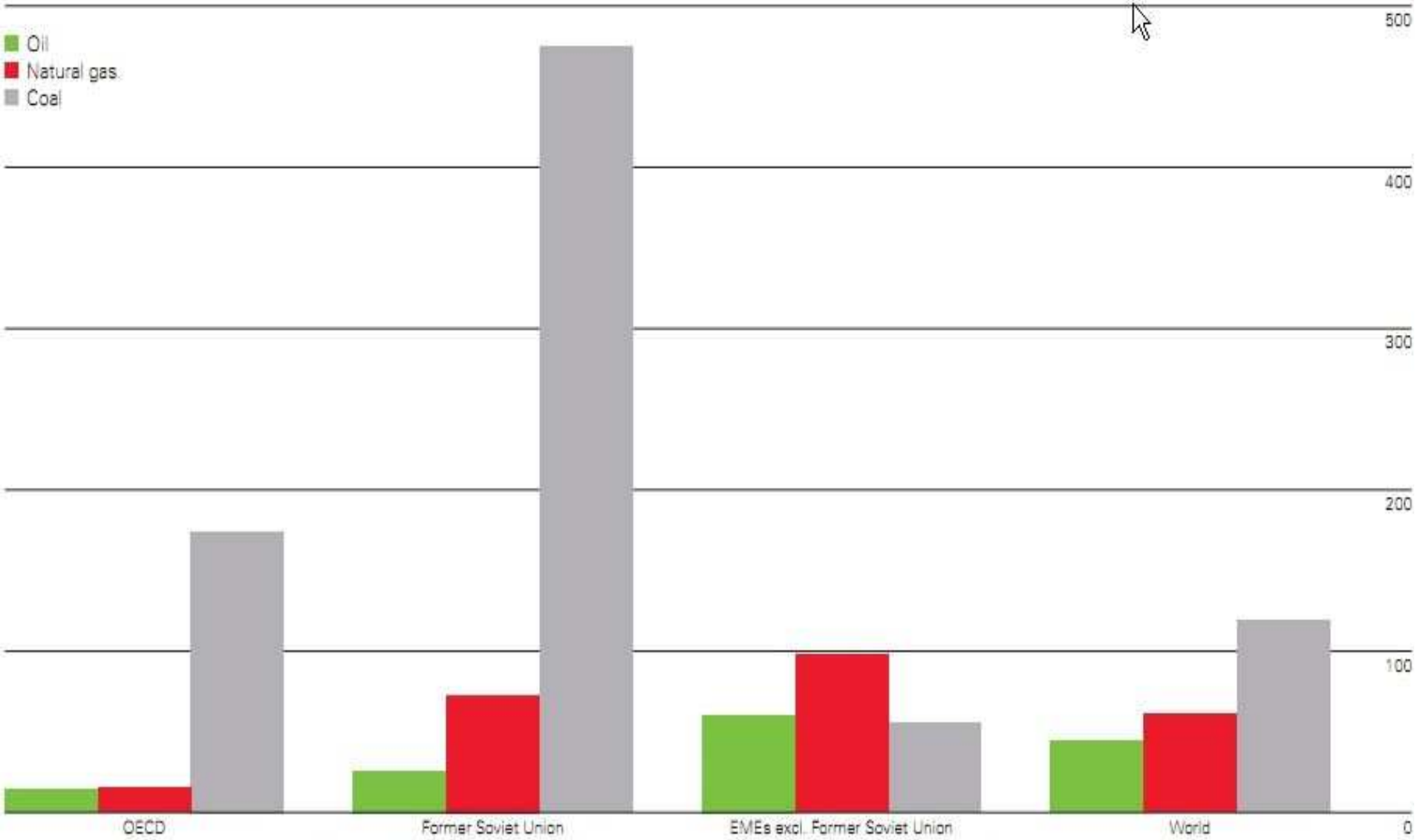
Change over the years

# Fossil energy reserves and resources



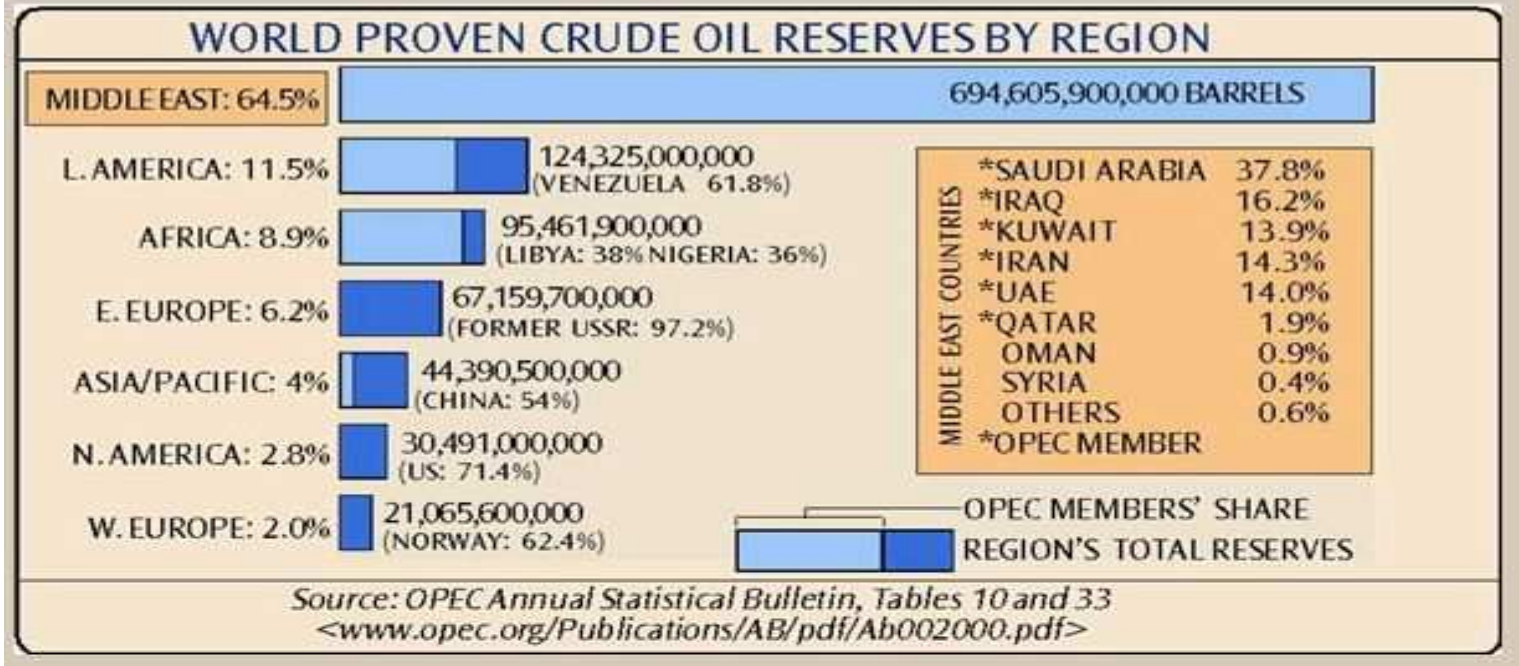
## Fossil fuel reserves-to-production (R/P) ratios at end 2009

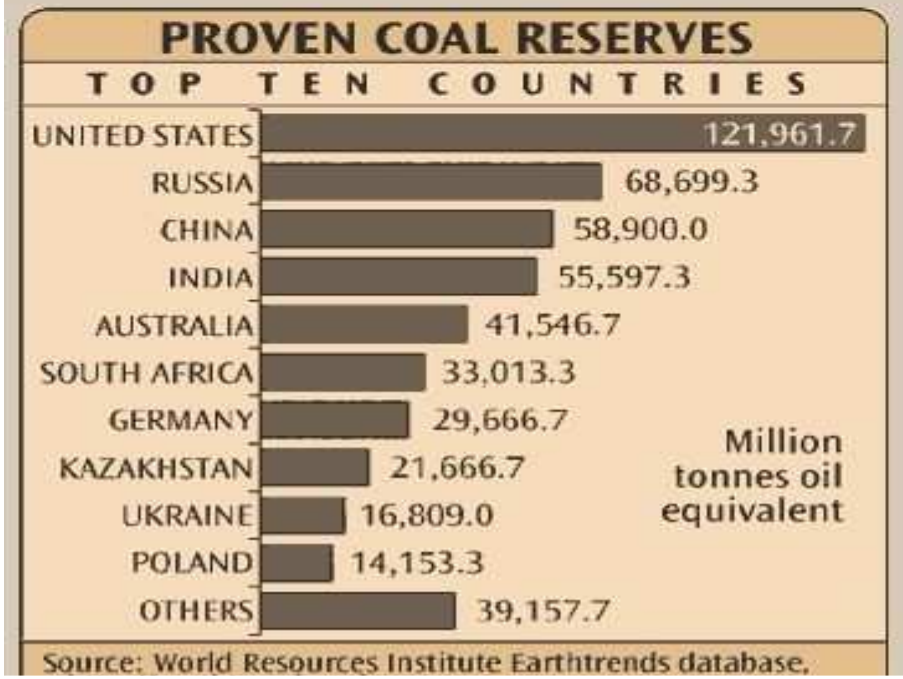
Years

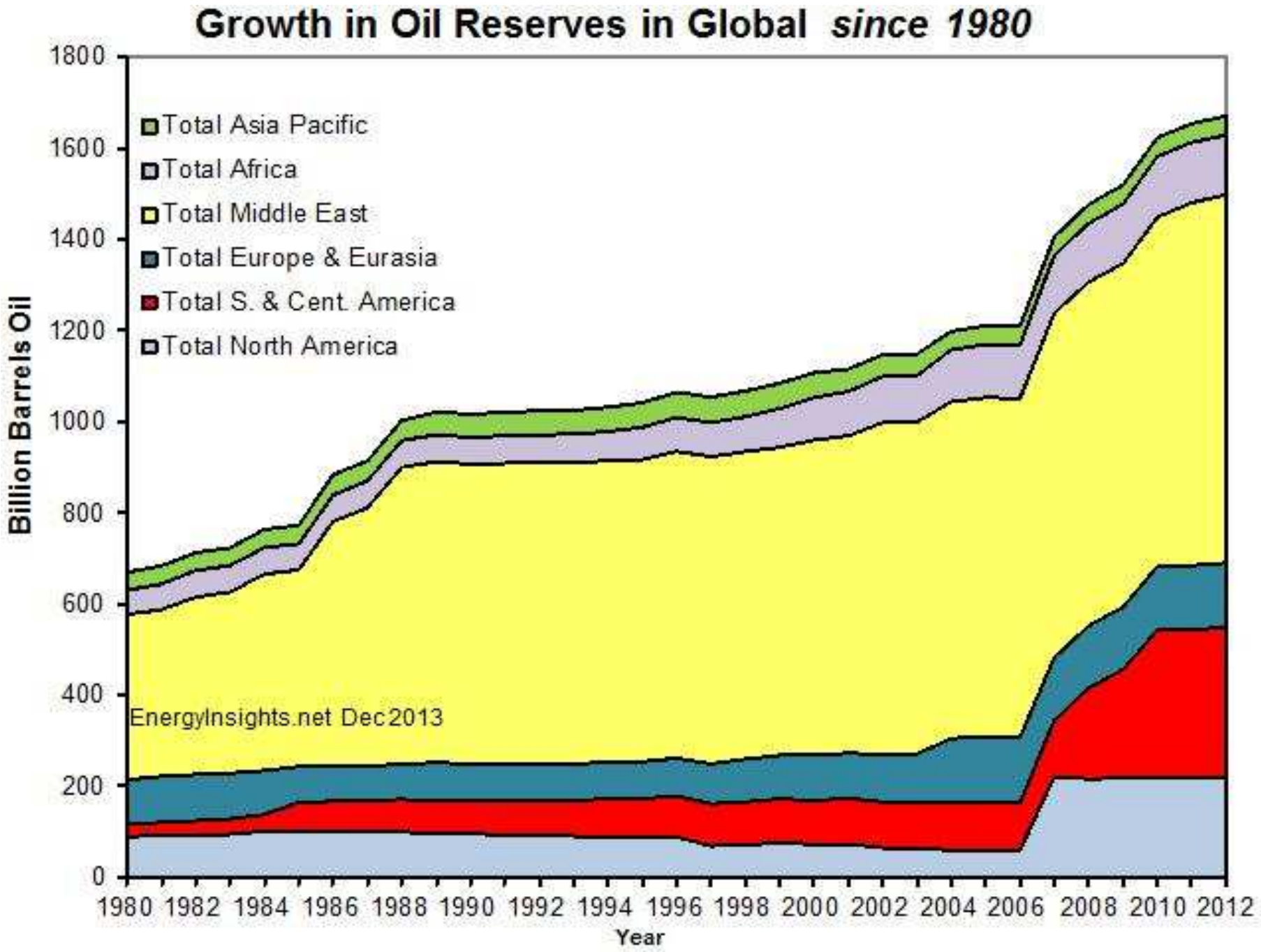



While coal remains the world's most abundant fossil fuel, with an R/P ratio of 119 years, proved reserves of oil and natural gas increased in 2009 and have tended to rise over time. OECD countries account for less than 10% of global proved reserves for oil and natural gas, but 42.6% of proved coal reserves.

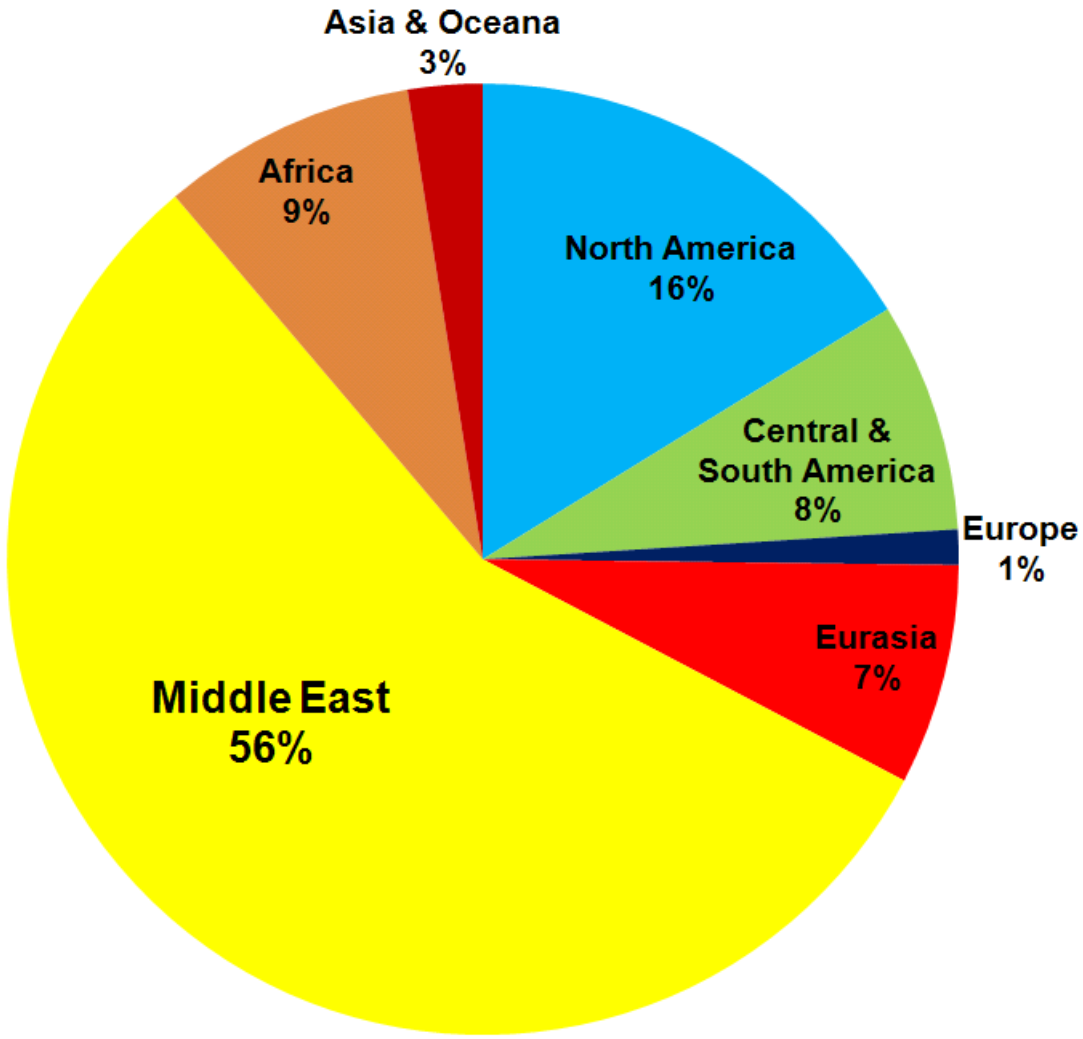
## World Reserves of Oil, Coal, and Natural Gas



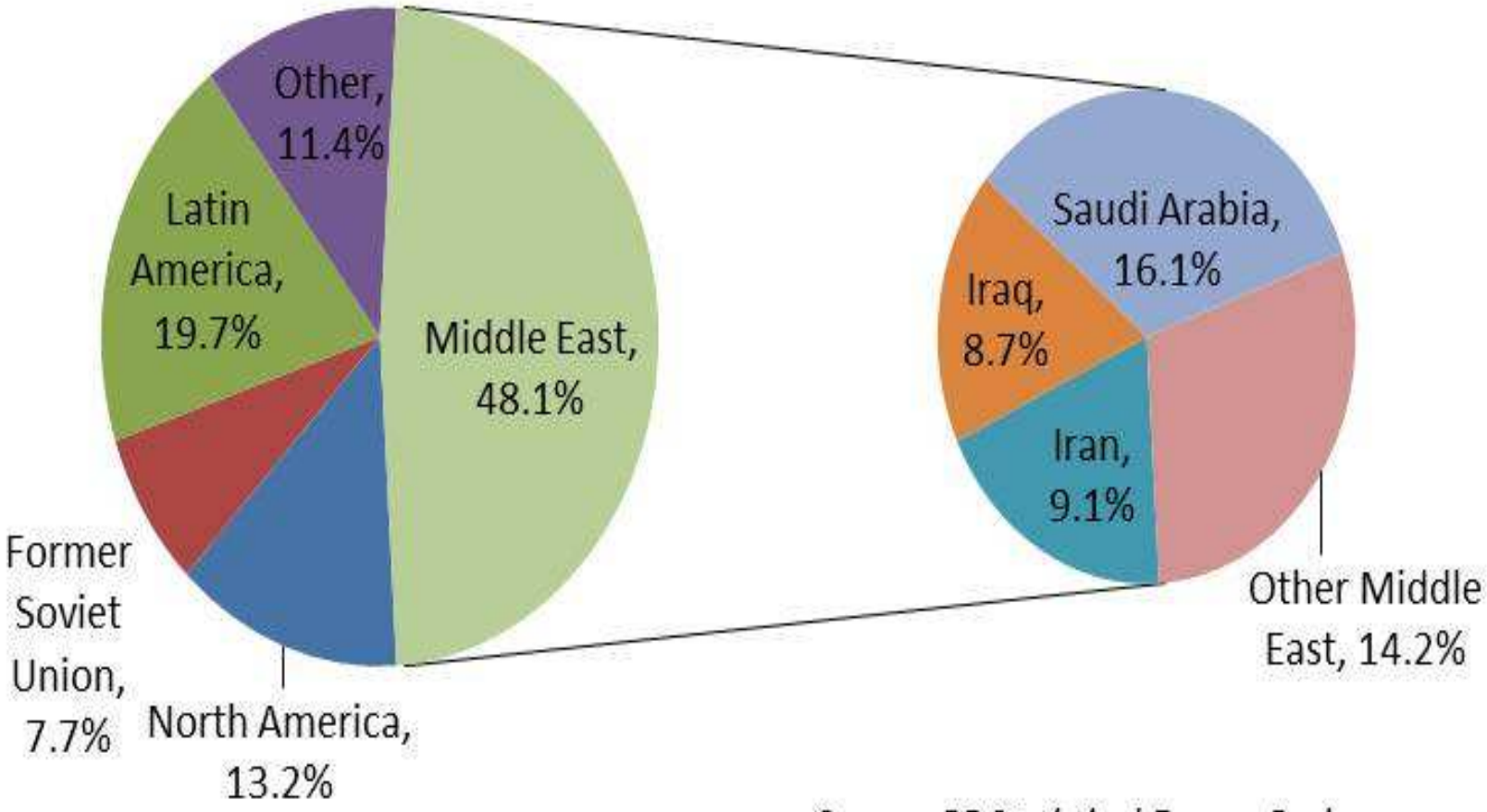


Growth in Oil Reserves in Global since 1980
Billion Barrels Oil
1800
1600
1400
1200
1000
800
600
400
200
0
Total Asia Pacific
Total Africa
Total Middle East
Total Europe & Eurasia
Total S. & Cent. America
Total North America
EnergyInsights.net Dec 2013
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year

# World Oil Reserves by Region

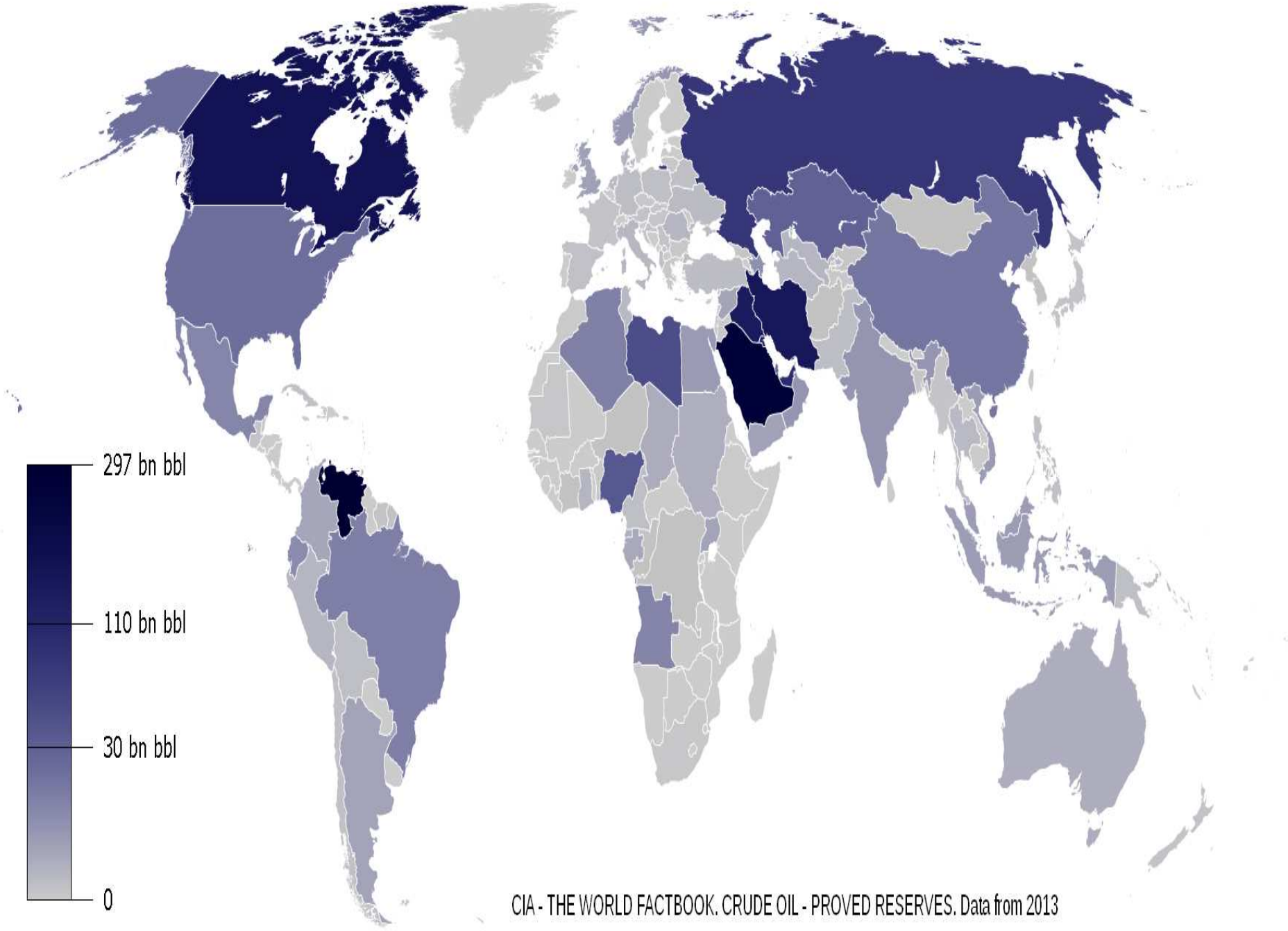


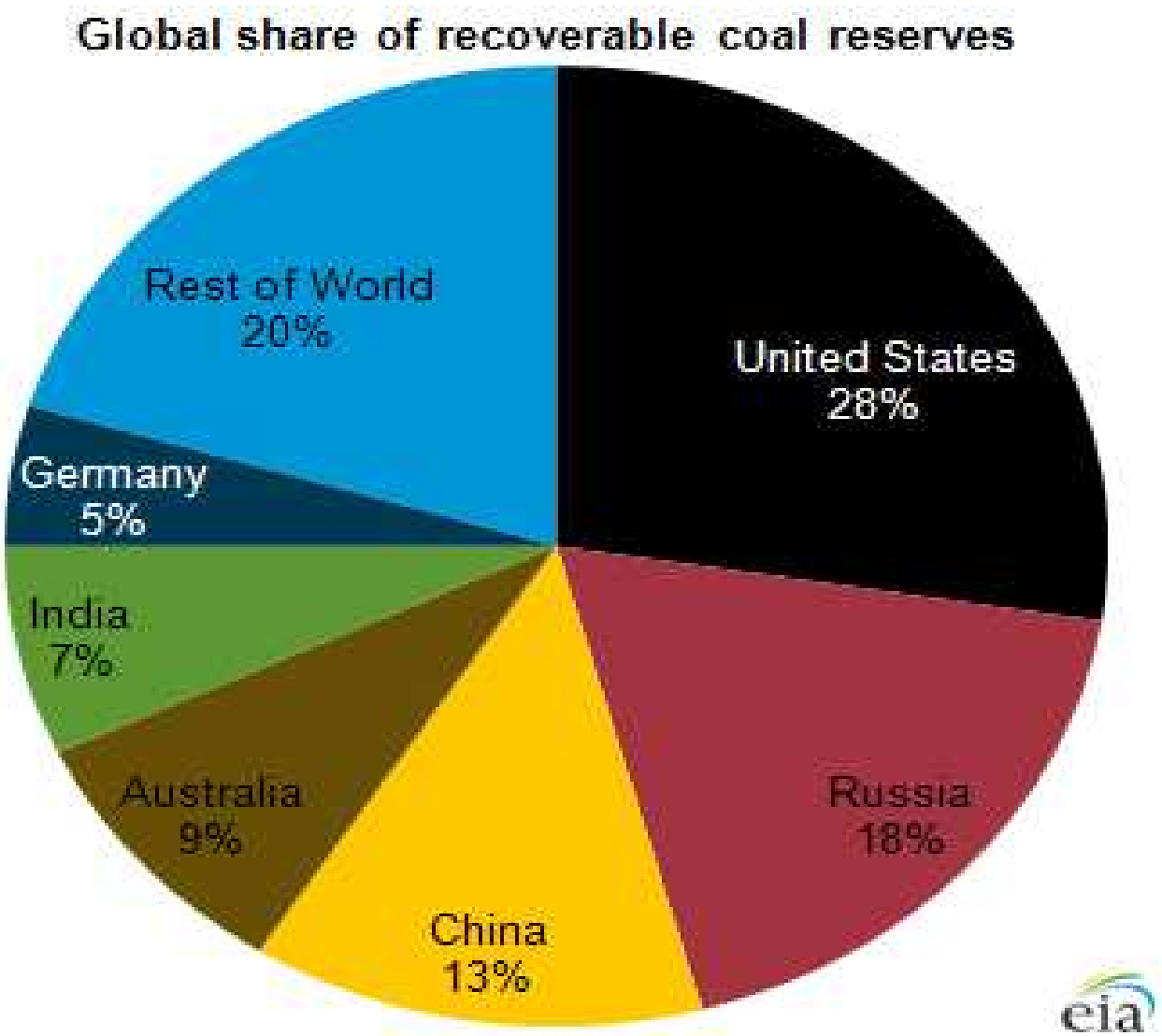

Data source: US Energy Information Adminstration from Oil and Gas Journal (2007)
Oil includes crude oil and condensate

# Share of Global Proven Crude Reserves (2011)



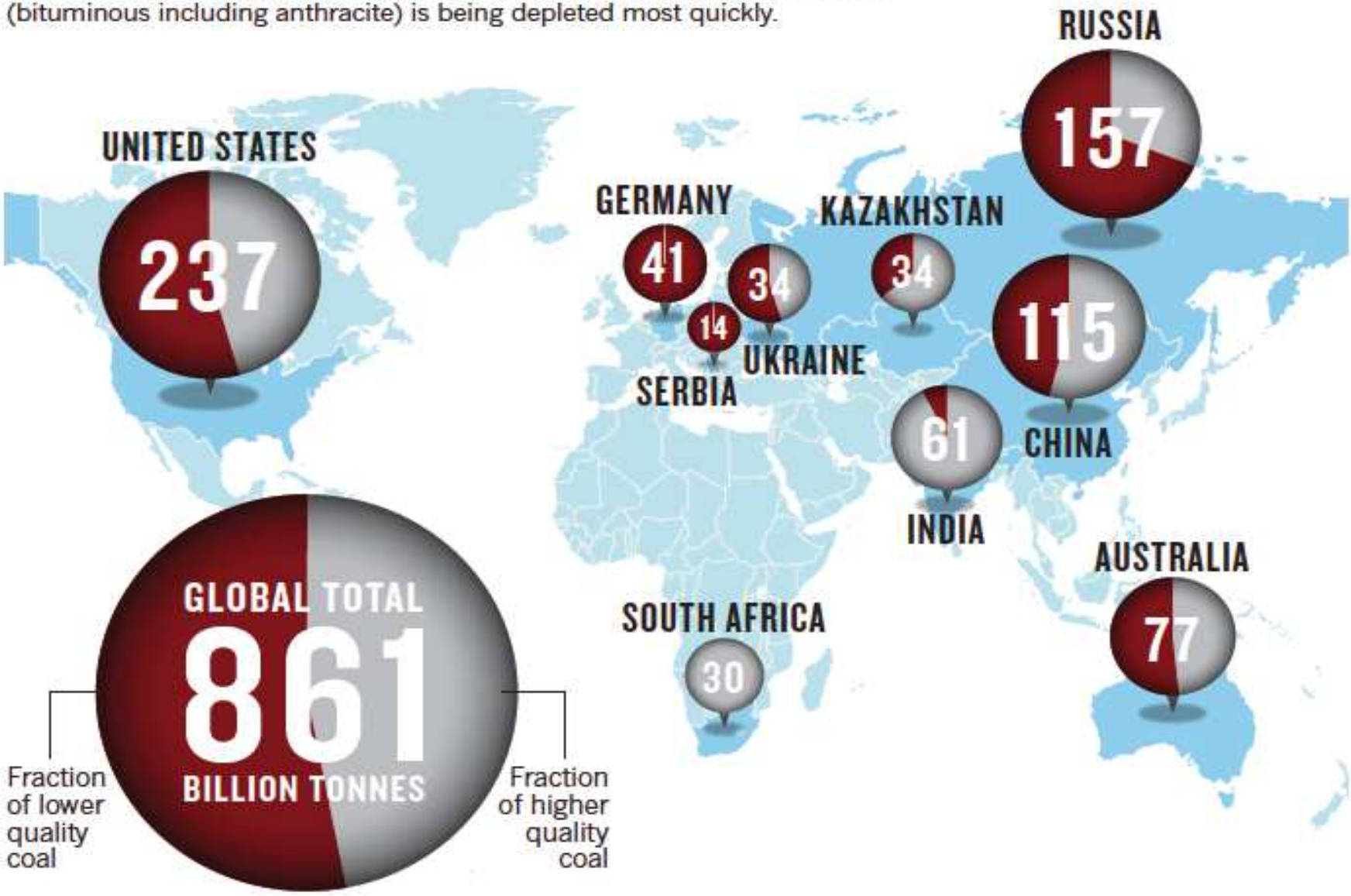

*Source: BP Statistical Energy Review*

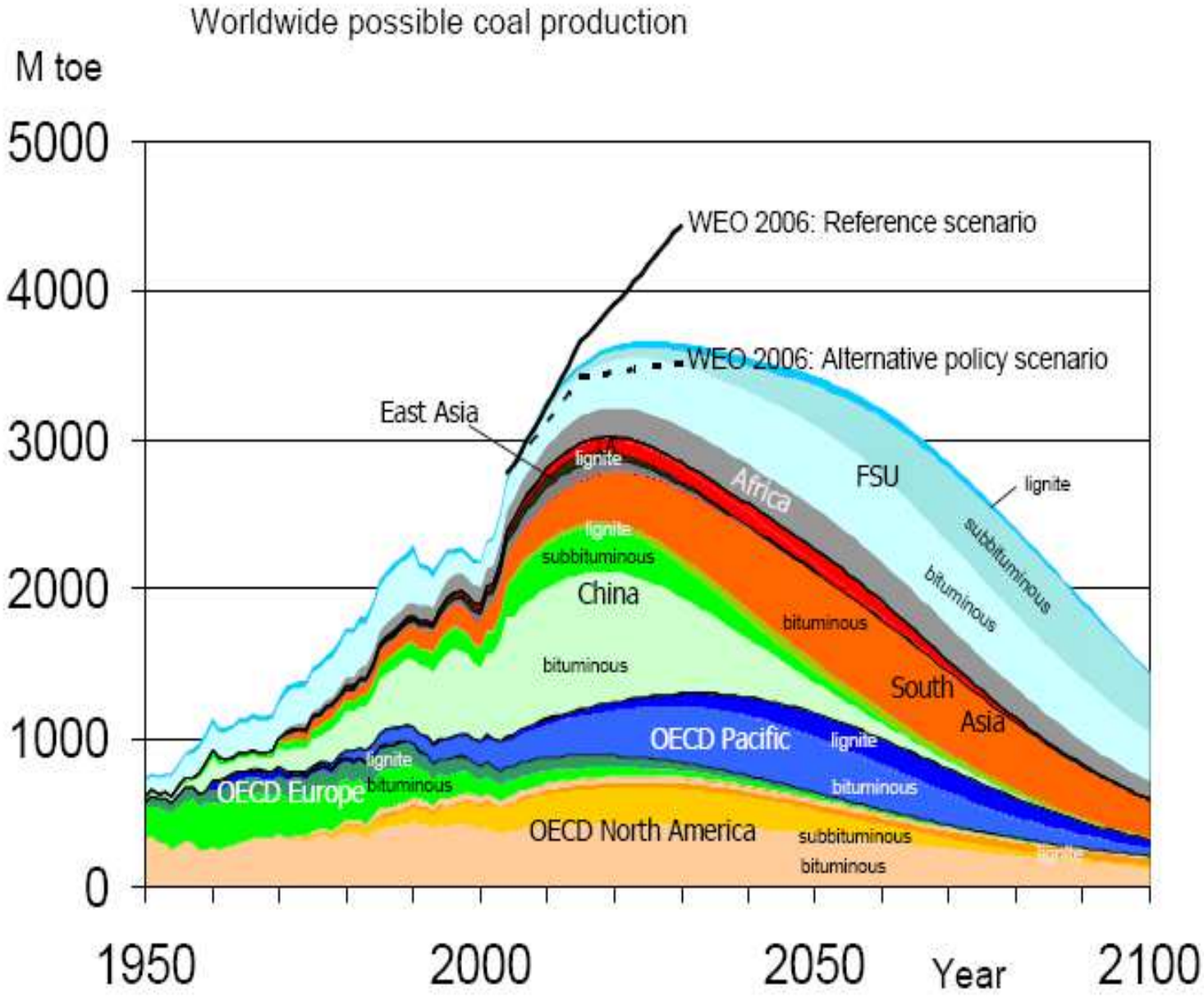

297 bn bbl
110 bn bbl
30 bn bbl
0
CIA - THE WORLD FACTBOOK. CRUDE OIL - PROVED RESERVES. Data from 2013


Global share of recoverable coal reserves
Rest of World
20%
United States
28%
Germany
5%
India
7%
Australia
9%
China
13%
Russia
18%
eia

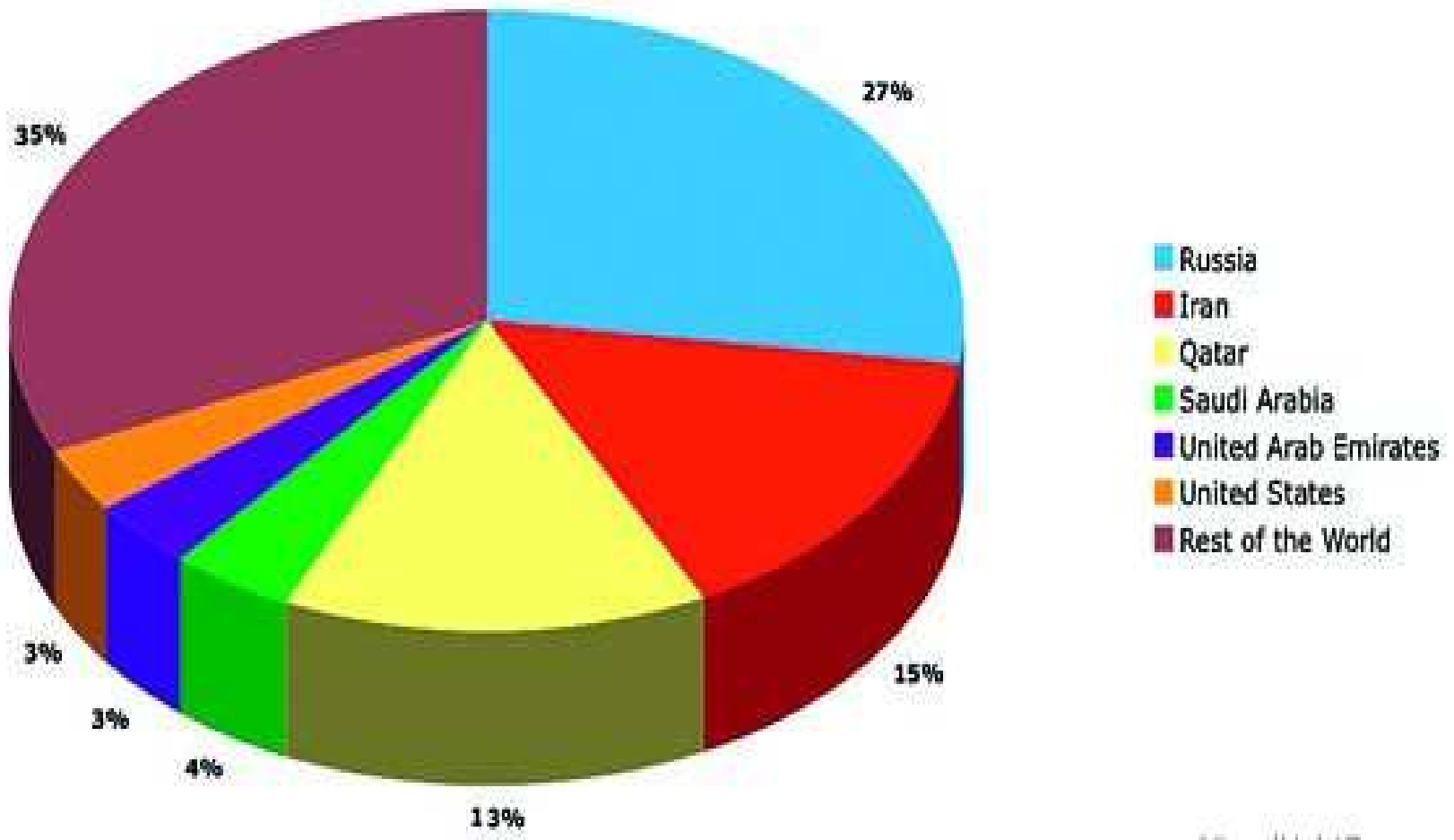
# WORLD COAL RESERVES

Proven recoverable coal reserves reported to the World Energy Council by the top-ten coal-producing countries at the end of 2008. Coal of higher quality (bituminous including anthracite) is being depleted most quickly.



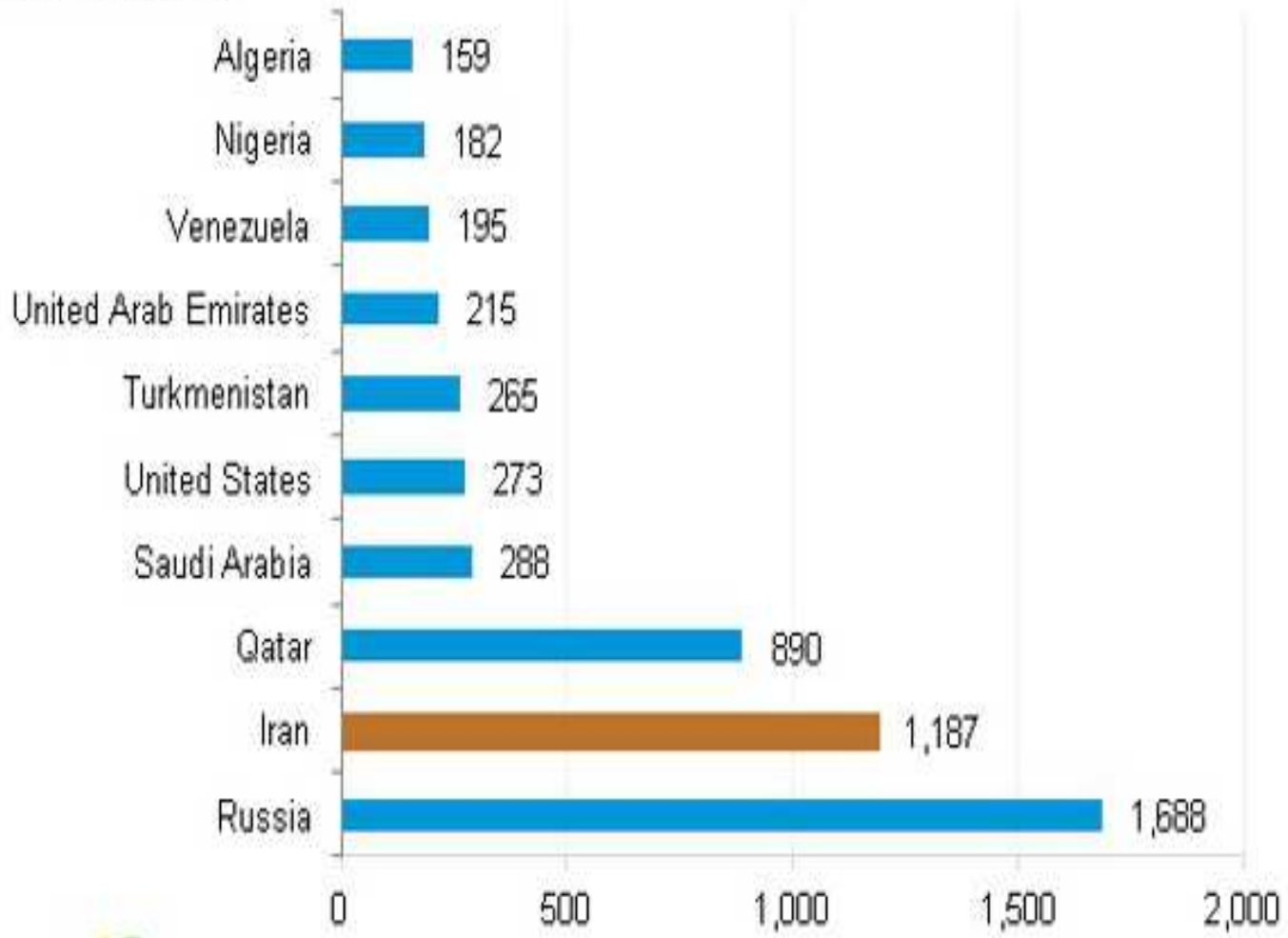

Worldwide possible coal production
M toe
5000
4000
3000
2000
1000
0
1950
2000
2050
Year
2100
WEO 2006: Reference scenario
WEO 2006: Alternative policy scenario
East Asia
lignite
subbituminous
China
bituminous
Africa
bituminous
FSU
lignite
subbituminous
bituminous
South Asia
bituminous
OECD Pacific
lignite
bituminous
OECD Europe
lignite
bituminous
OECD North America
subbituminous
bituminous

# Global Distribution of Proven Natural Gas Reserves

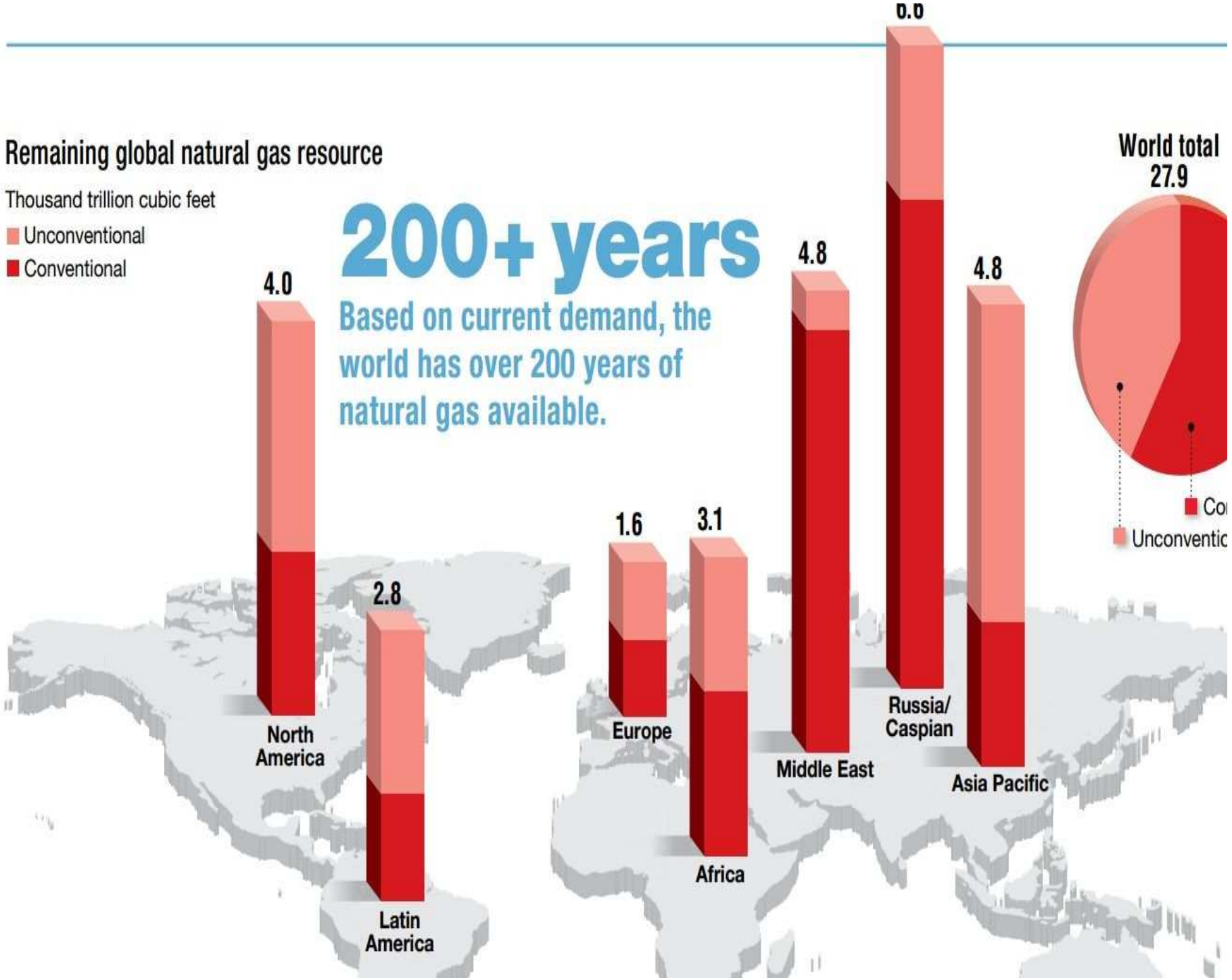


# Largest proven reserve holders of natural gas, January 2013

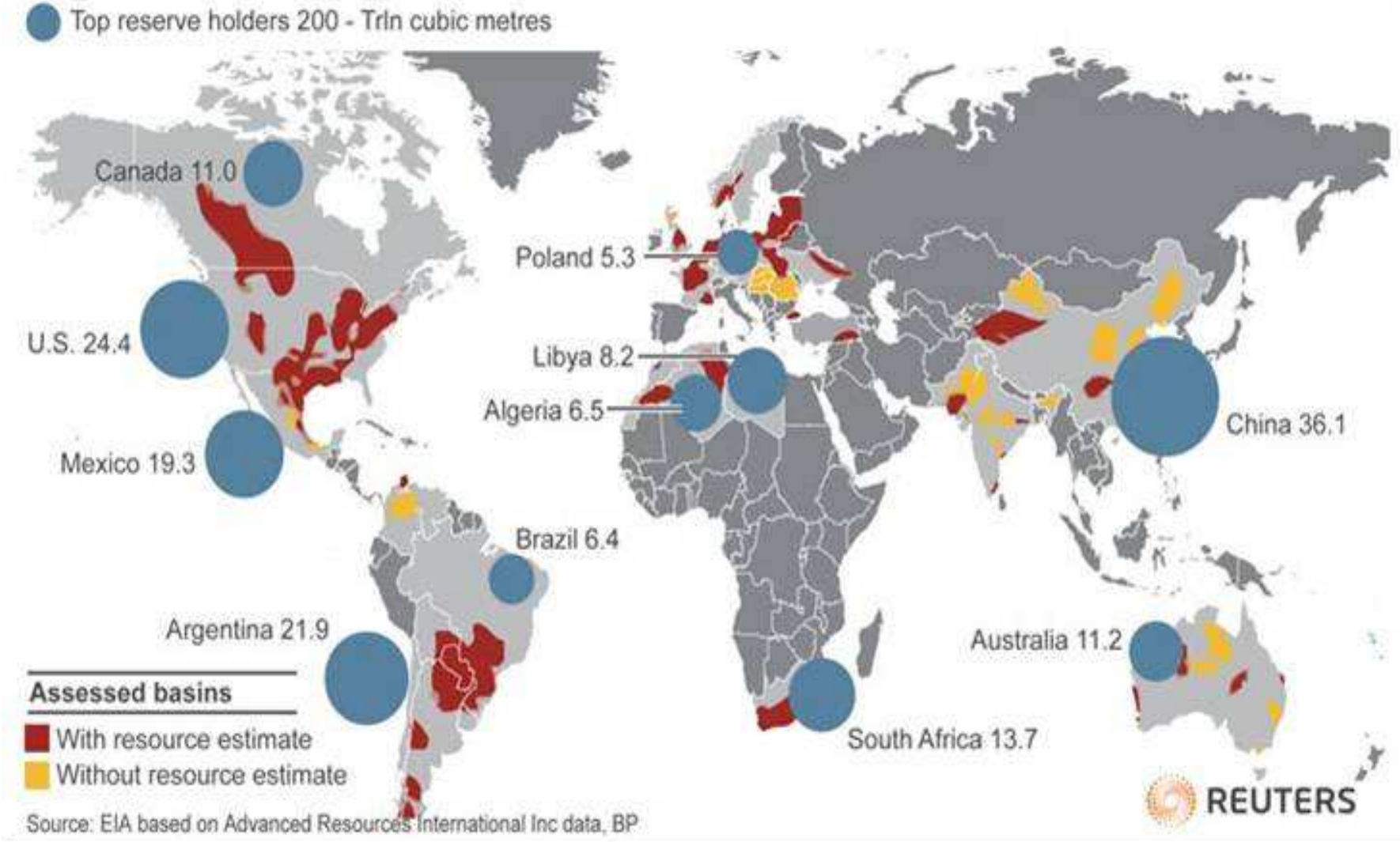
trillion cubic feet




eia Source: Oil and Gas Journal


Remaining global natural gas resource
Thousand trillion cubic feet
Unconventional
Conventional
200+ years
Based on current demand, the world has over 200 years of natural gas available.
4.0
North America
2.8
Latin America
1.6
Europe
3.1
Africa
4.8
Middle East
8.0
Russia/ Caspian
4.8
Asia Pacific
World total
27.9
Unconventic

# Global shale gas basins, top reserve holders

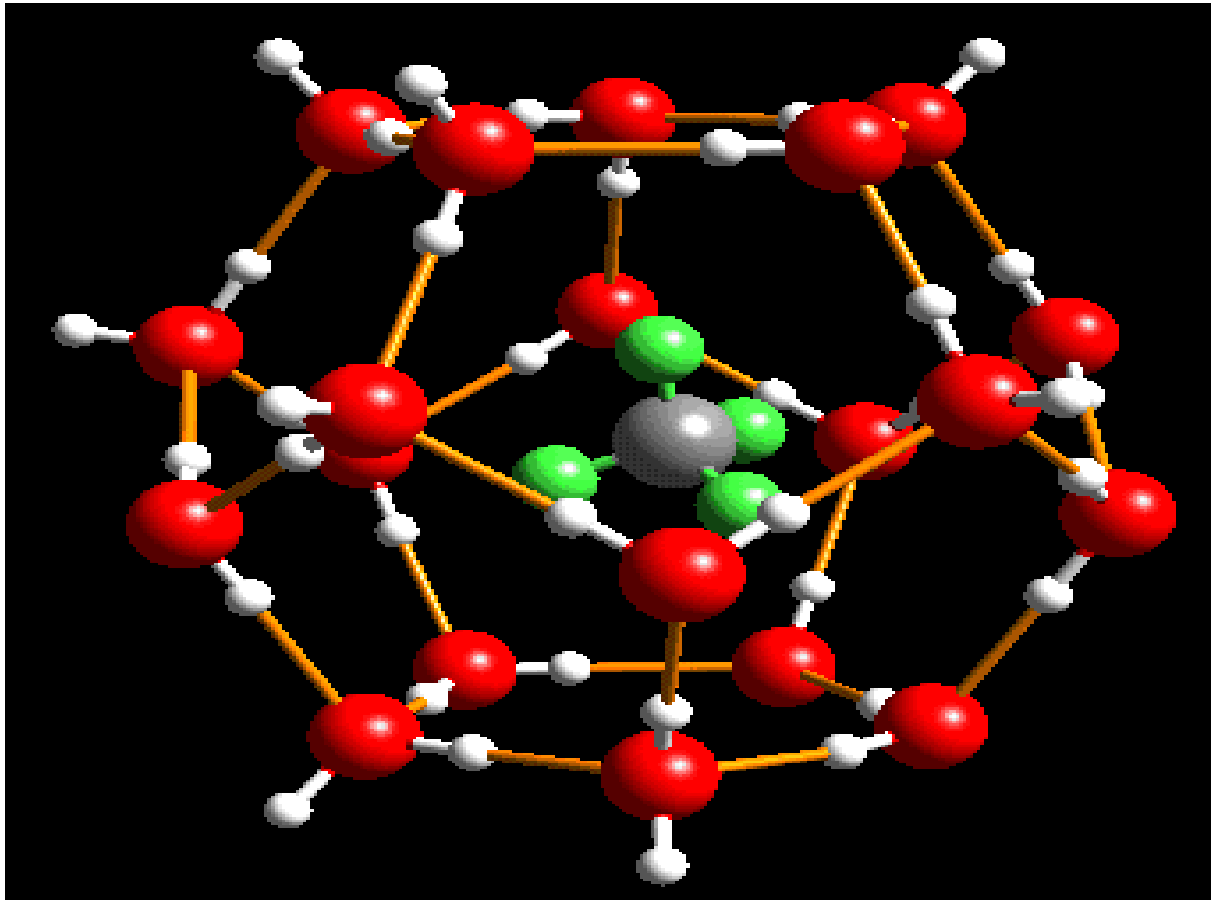


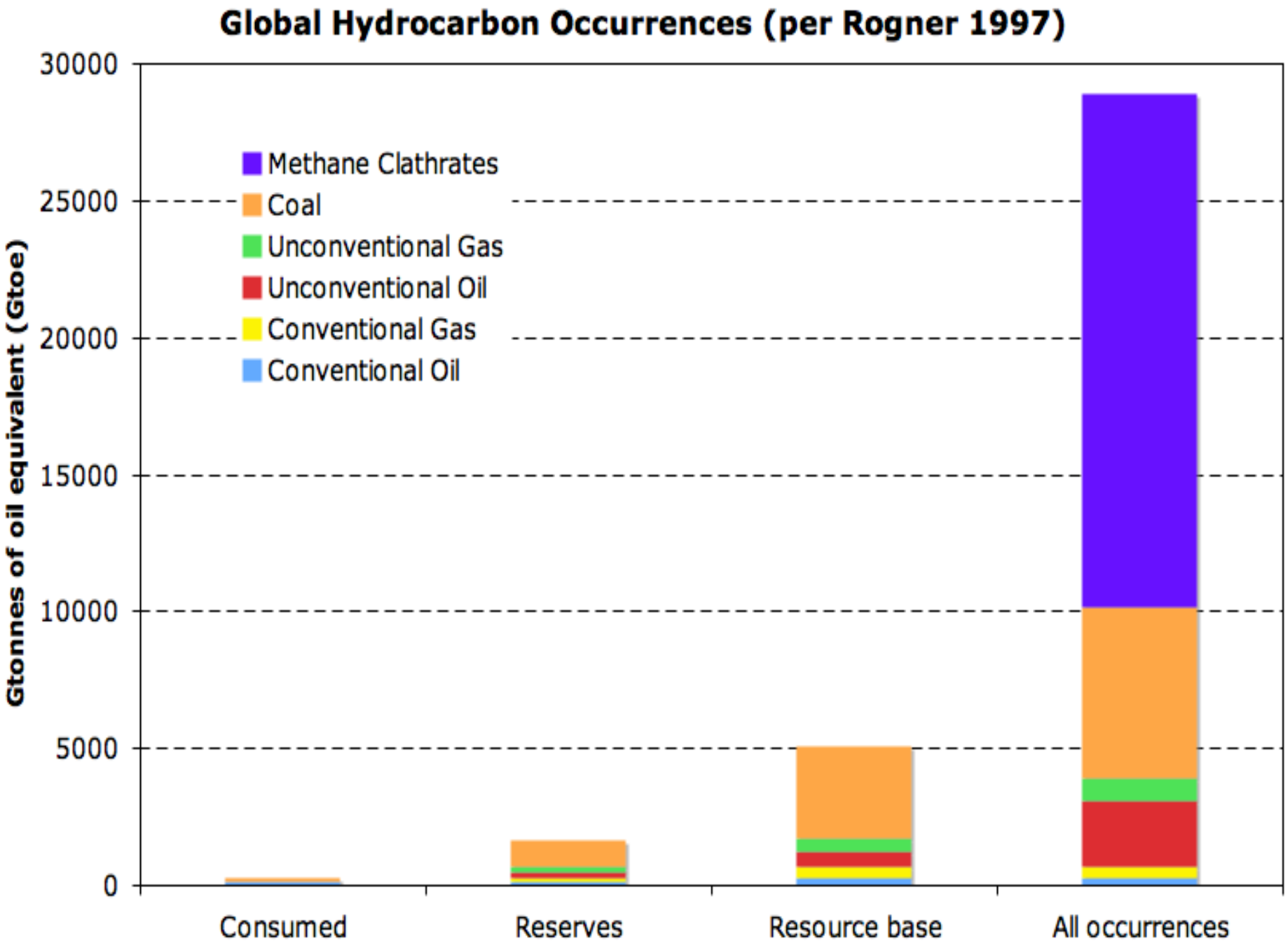

Reuters graphic/Catherine Trevethan

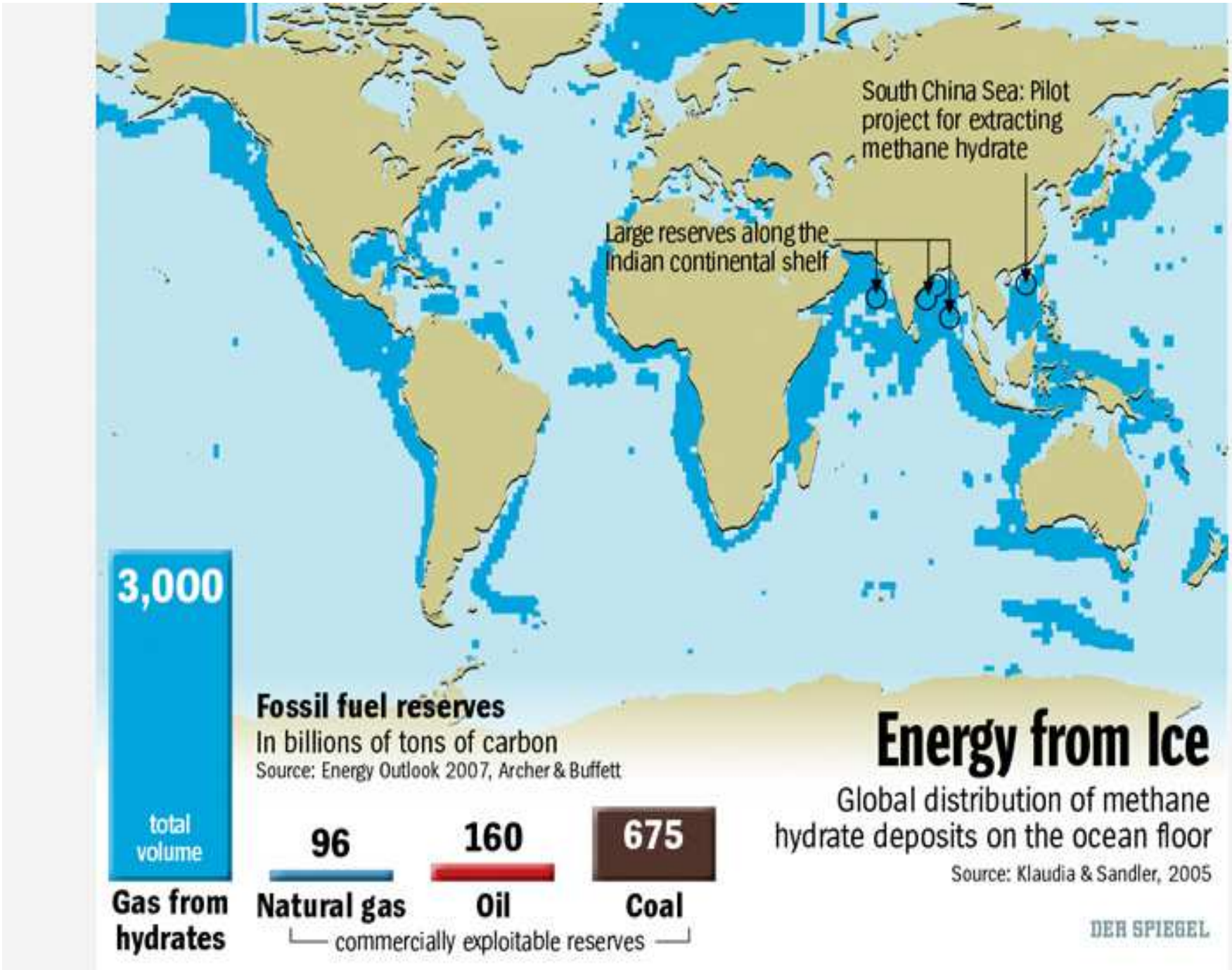
# BLESSING

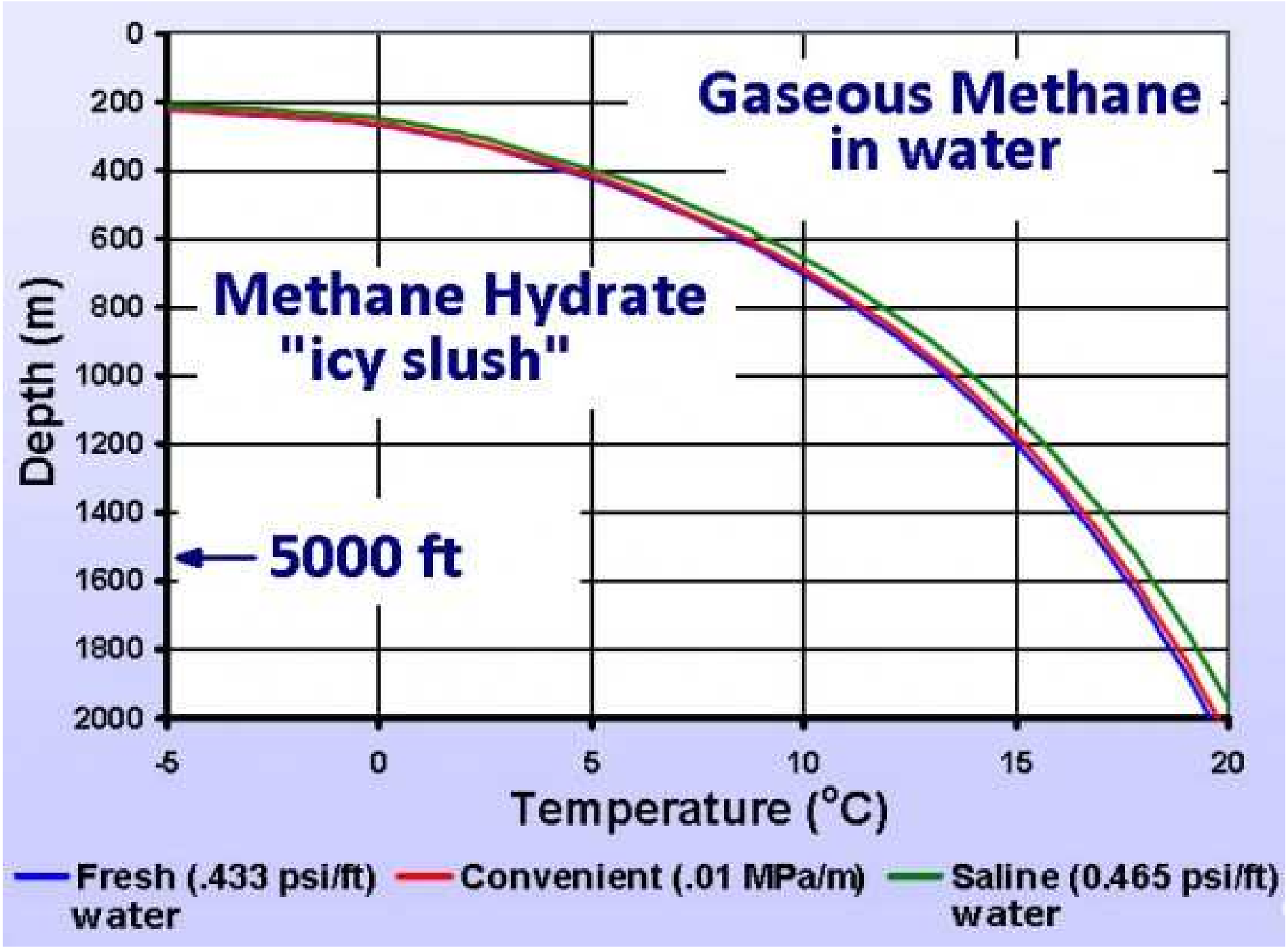
OR CURSE

# Methane hydrates



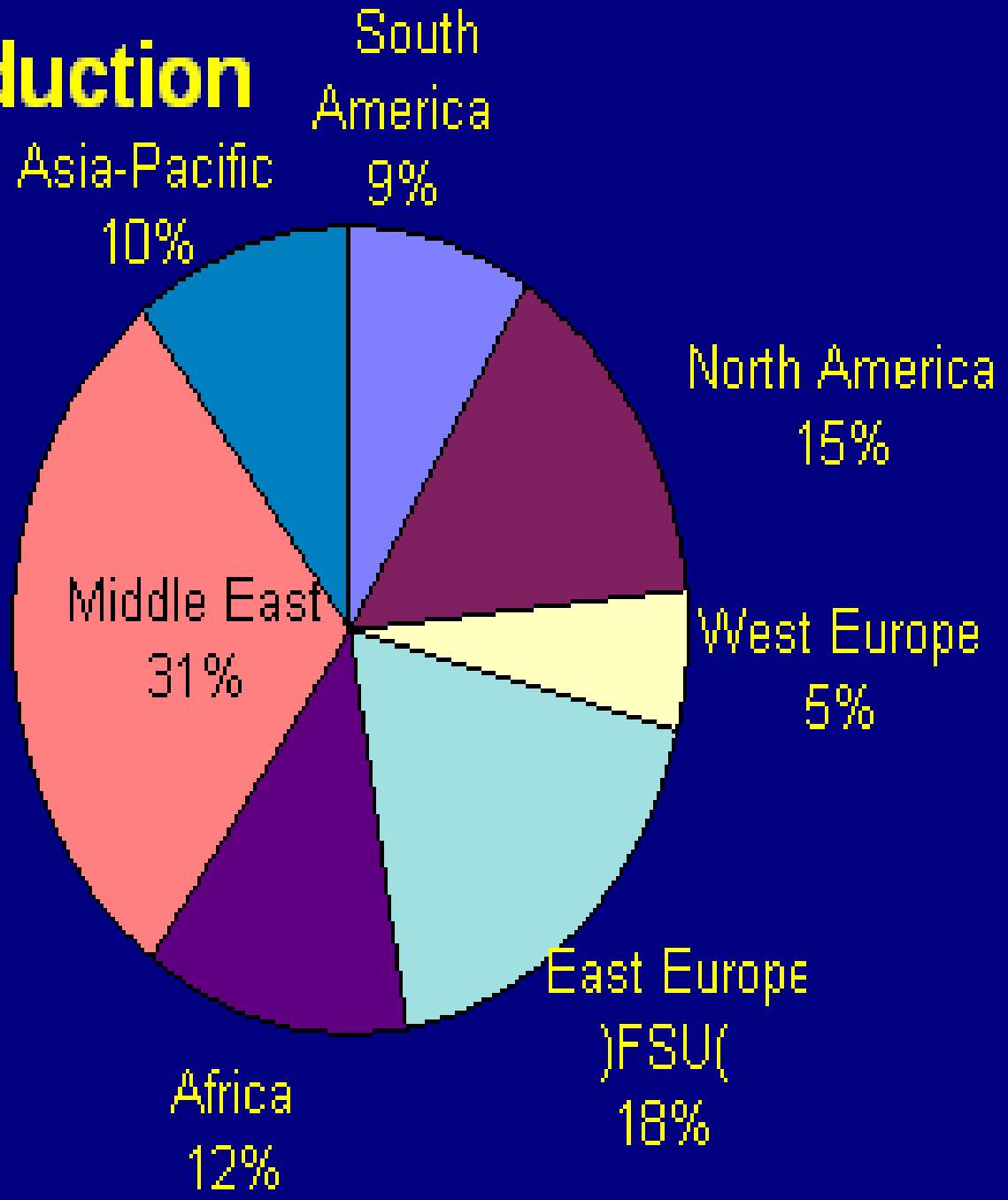

Global Hydrocarbon Occurrences (per Rogner 1997)
Gtonnes of oil equivalent (Gtoe)
30000
25000
20000
15000
10000
5000
0
Methane Clathrates
Coal
Unconventional Gas
Unconventional Oil
Conventional Gas
Conventional Oil
Consumed
Reserves
Resource base
All occurrences

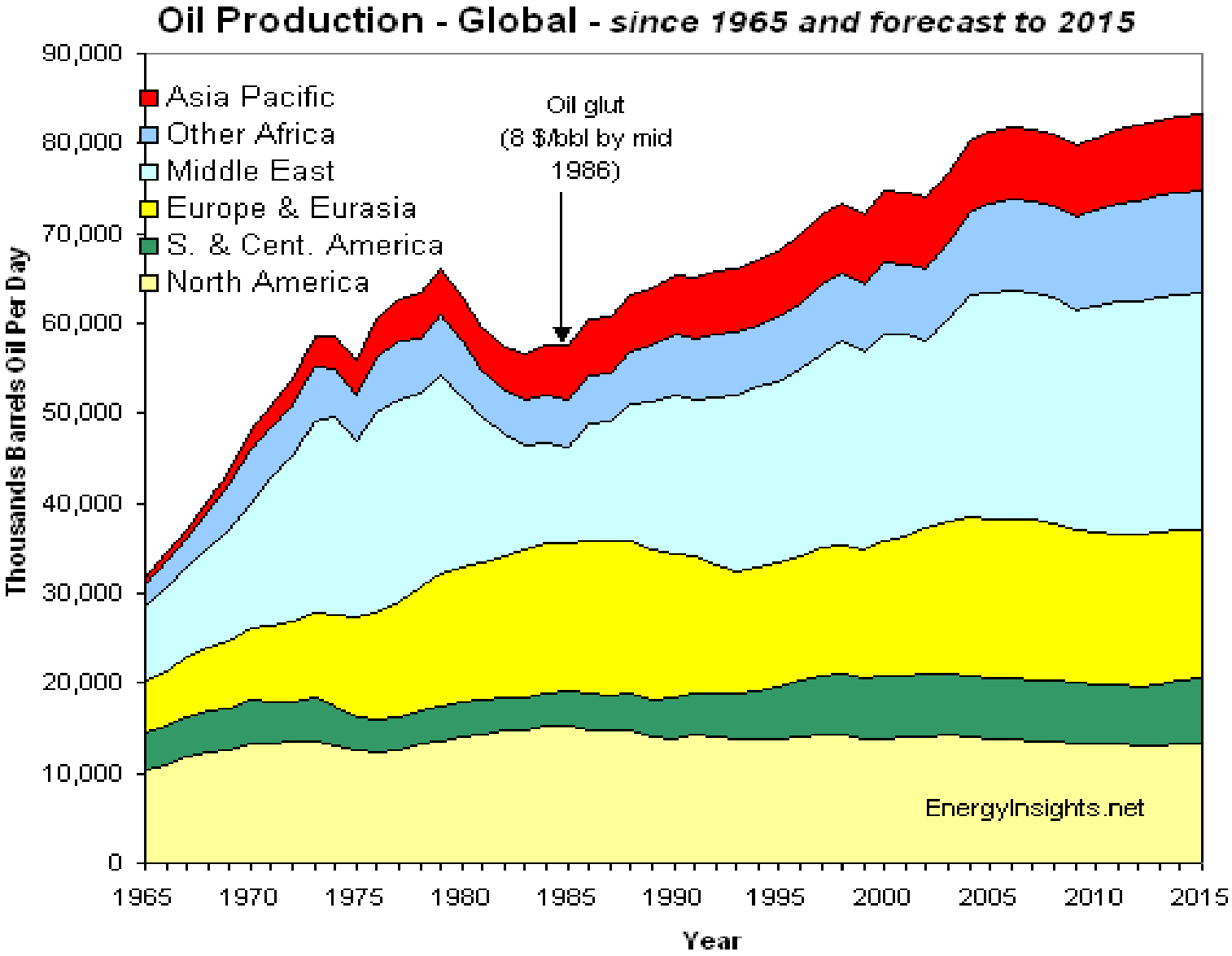

South China Sea: Pilot project for extracting methane hydrate
Large reserves along the Indian continental shelf
3,000
total volume
Gas from hydrates
Fossil fuel reserves
In billions of tons of carbon
Source: Energy Outlook 2007, Archer & Buffett
96
Natural gas
160
Oil
675
Coal
commercially exploitable reserves
Energy from Ice
Global distribution of methane hydrate deposits on the ocean floor
Source: Klaudia & Sandler, 2005
DER SPIEGEL

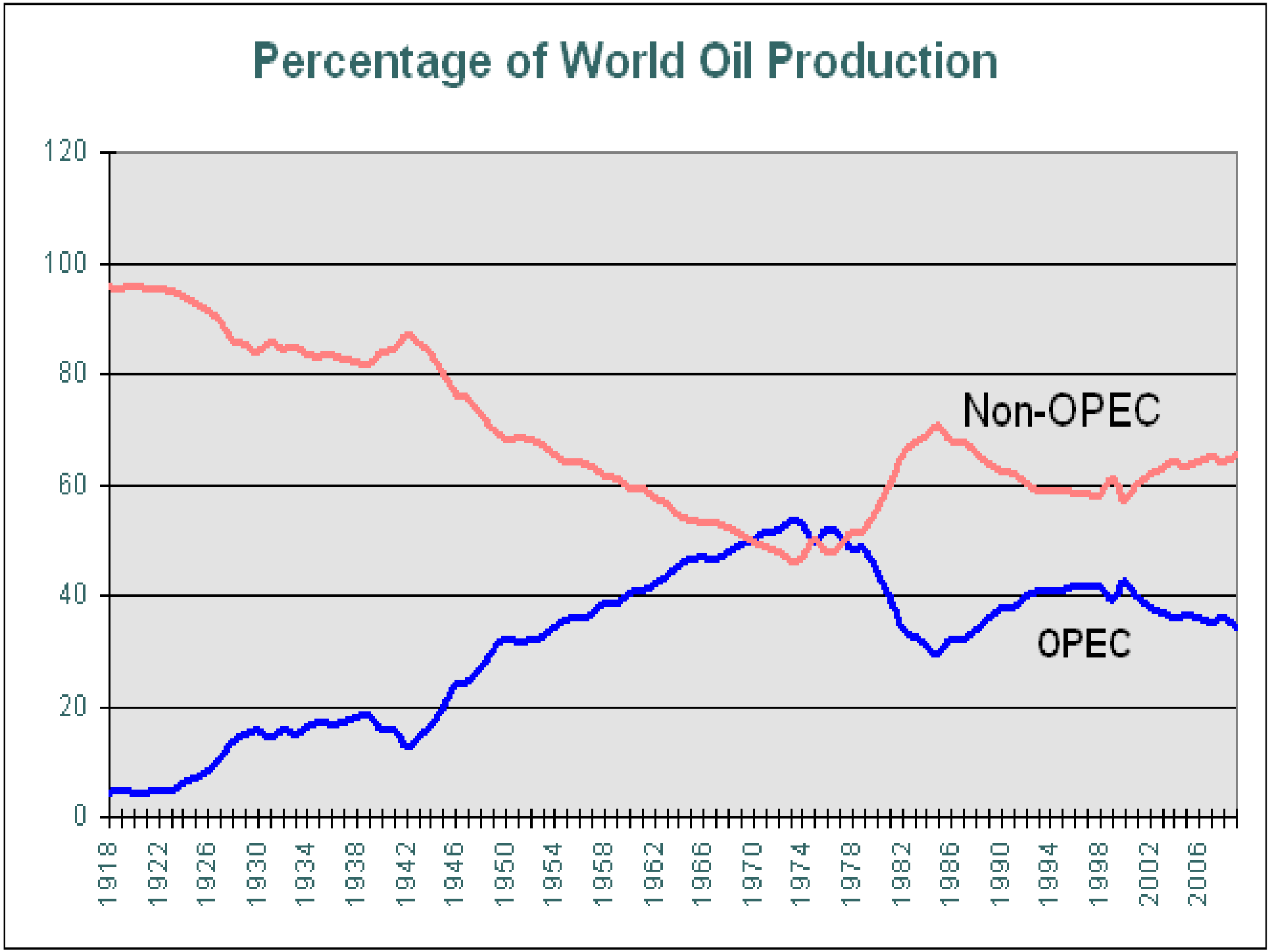

Gaseous Methane in water
Methane Hydrate "icy slush"
5000 ft
Depth (m)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
-5
0
5
10
15
20
Temperature (°C)
Fresh (.433 psi/ft) water
Convenient (.01 MPa/m)
Saline (0.465 psi/ft) water

# Crude Oil Production

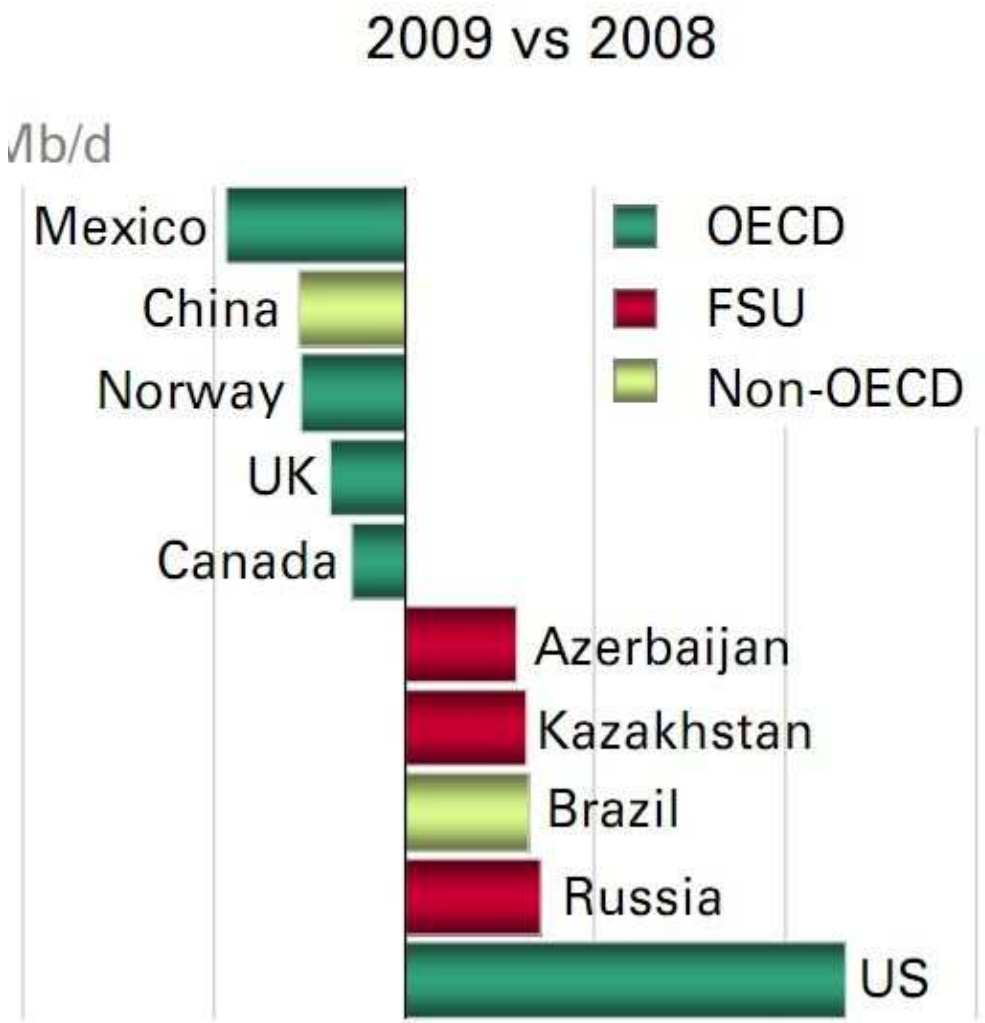
# World Oil Production



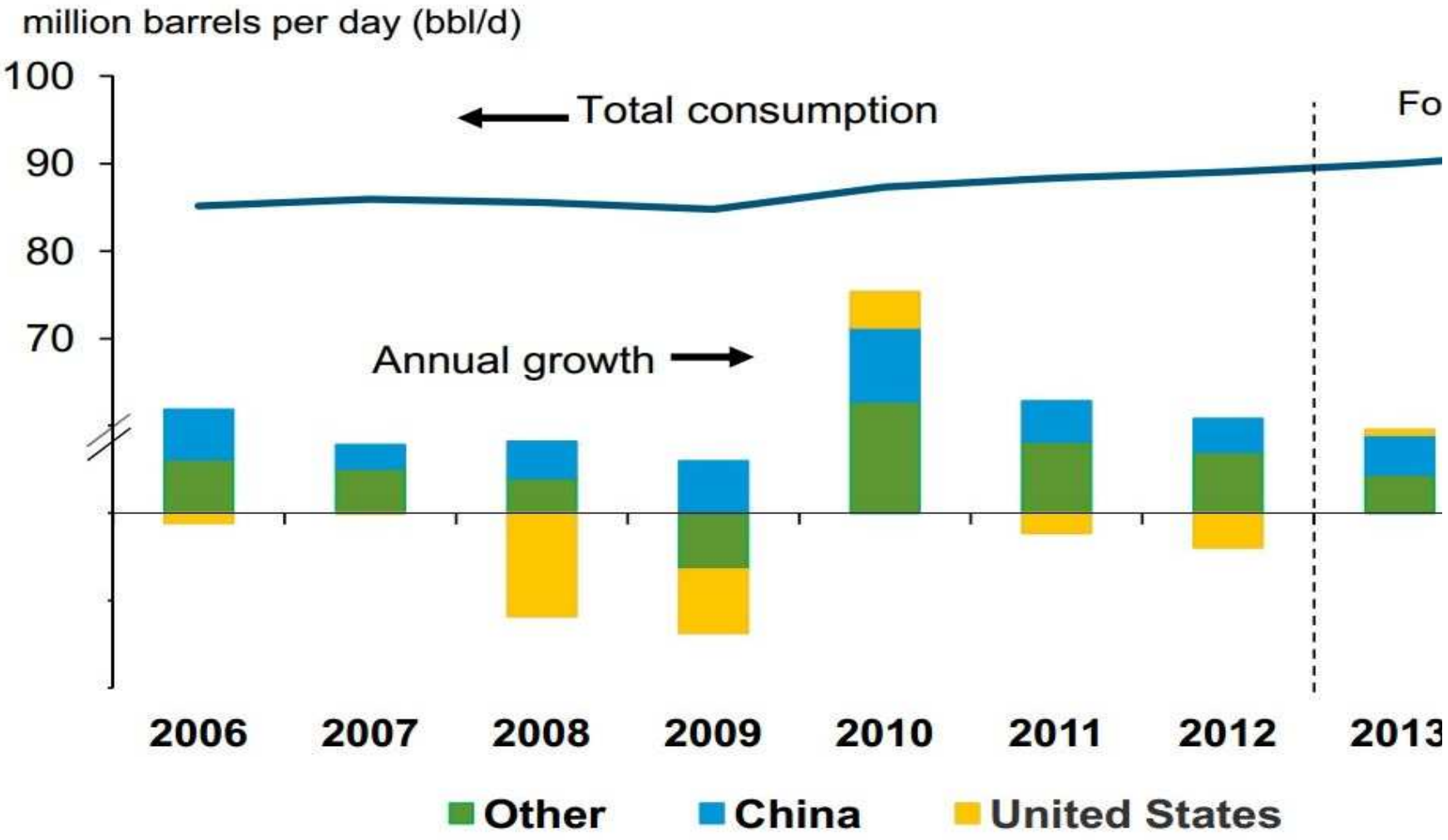

Oil Production - Global - since 1965 and forecast to 2015
Asia Pacific
Other Africa
Middle East
Europe & Eurasia
S. & Cent. America
North America
Oil glut
(8 $/bbl by mid
1986)
Thousands Barrels Oil Per Day
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
EnergyInsights.net


Percentage of World Oil Production
120
100
80
60
40
20
0
Non-OPEC
OPEC
1918
1922
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
2006

# Non-OPEC Production

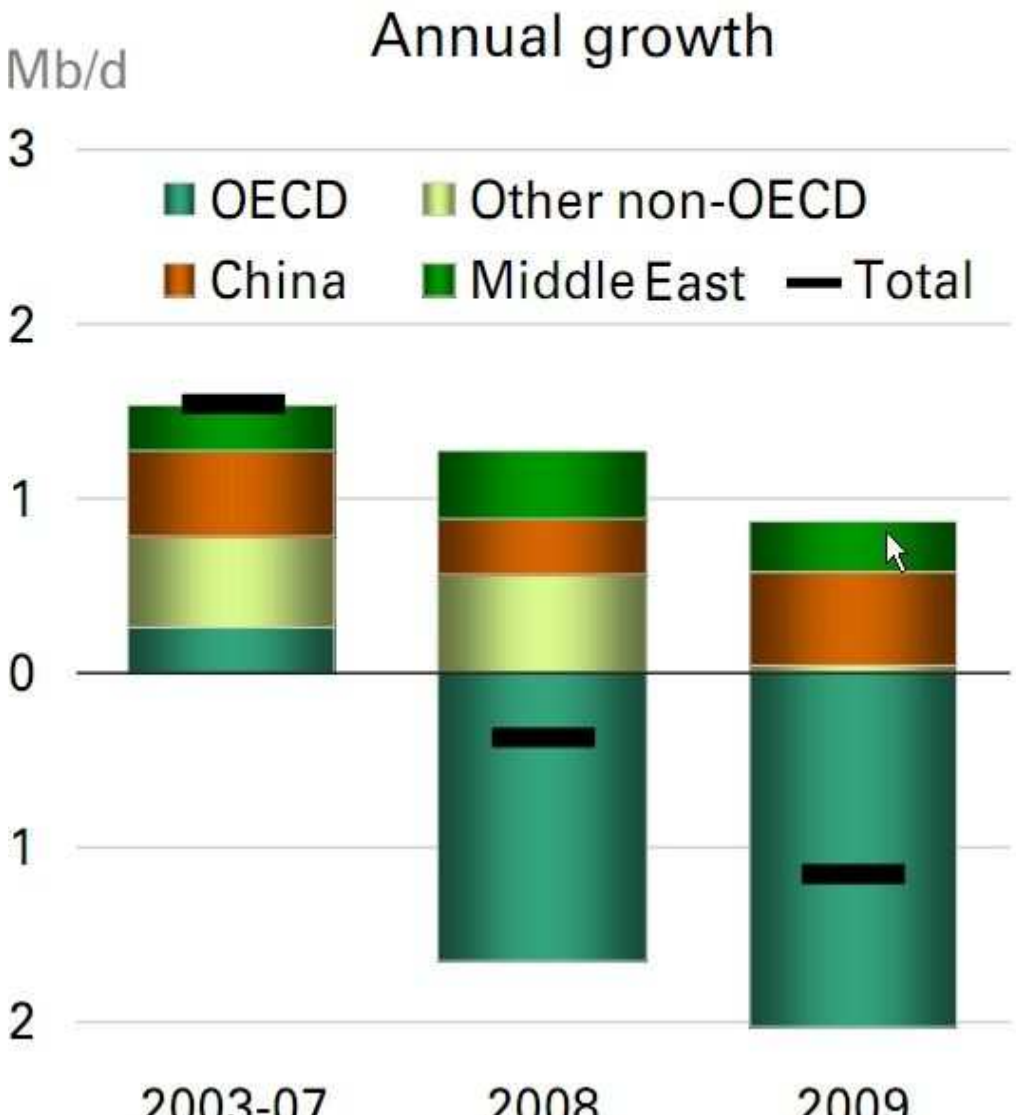


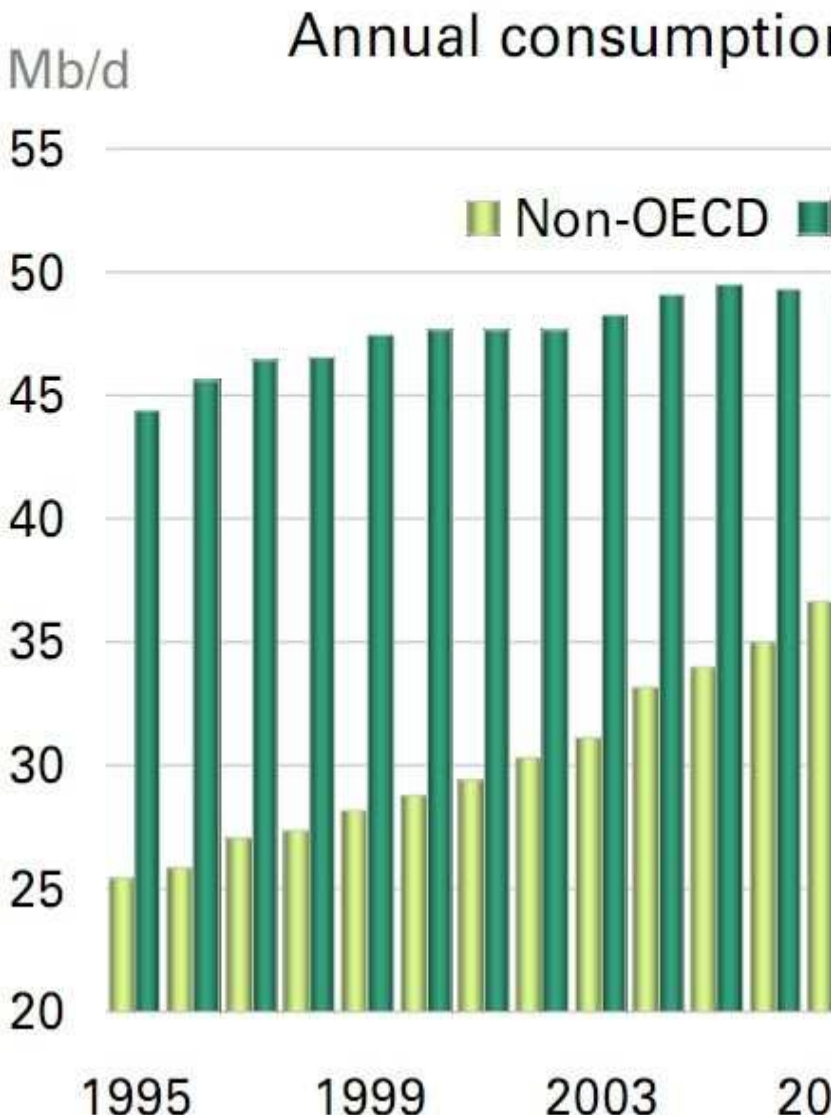

# World liquid fuels consumption is projected to increas million bbl/d in 2013 and 1.3 million bbl/d in 2014

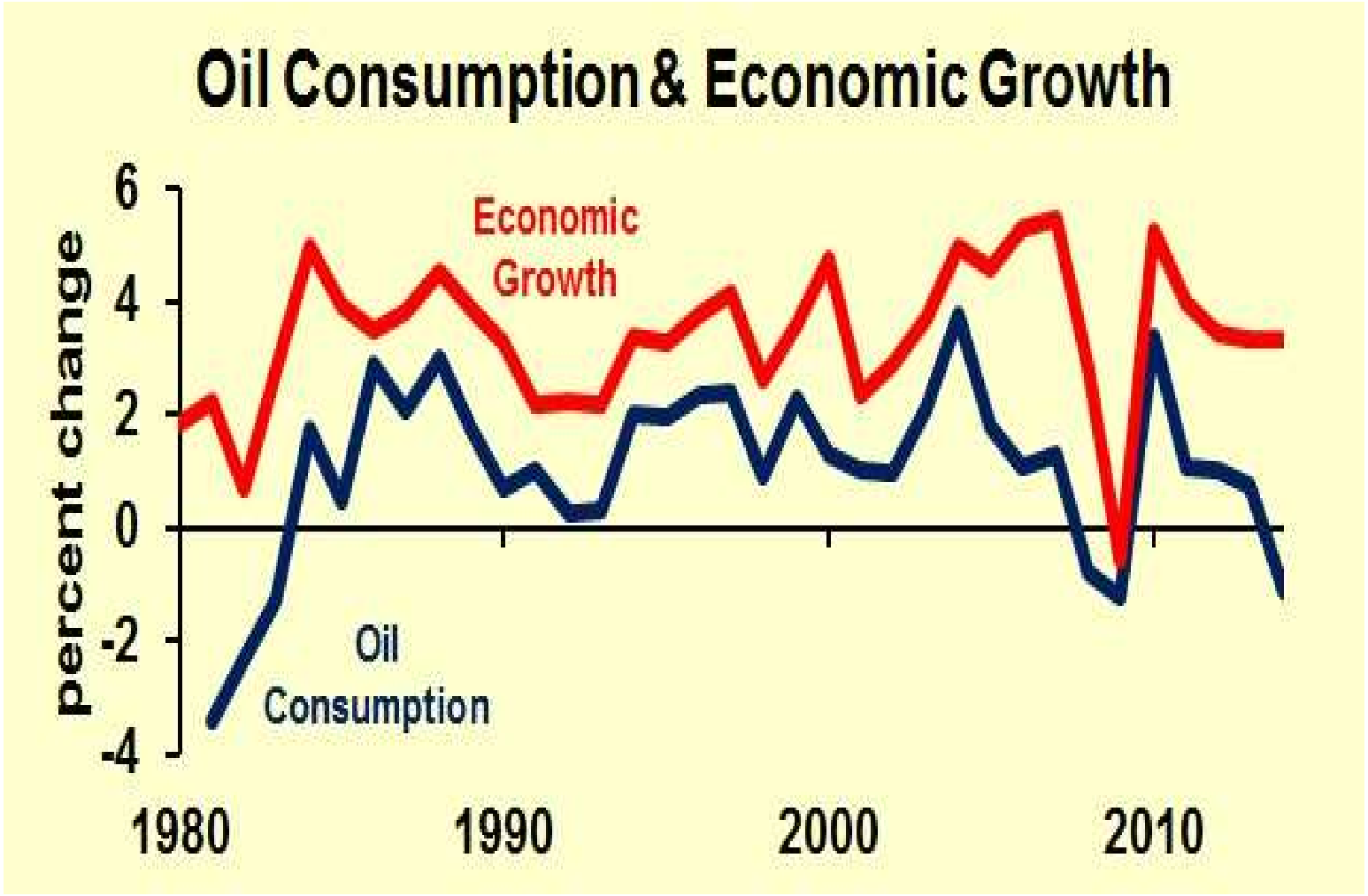



Source: Short-Term Energy Outlook, April 2013

# Oil Consumption



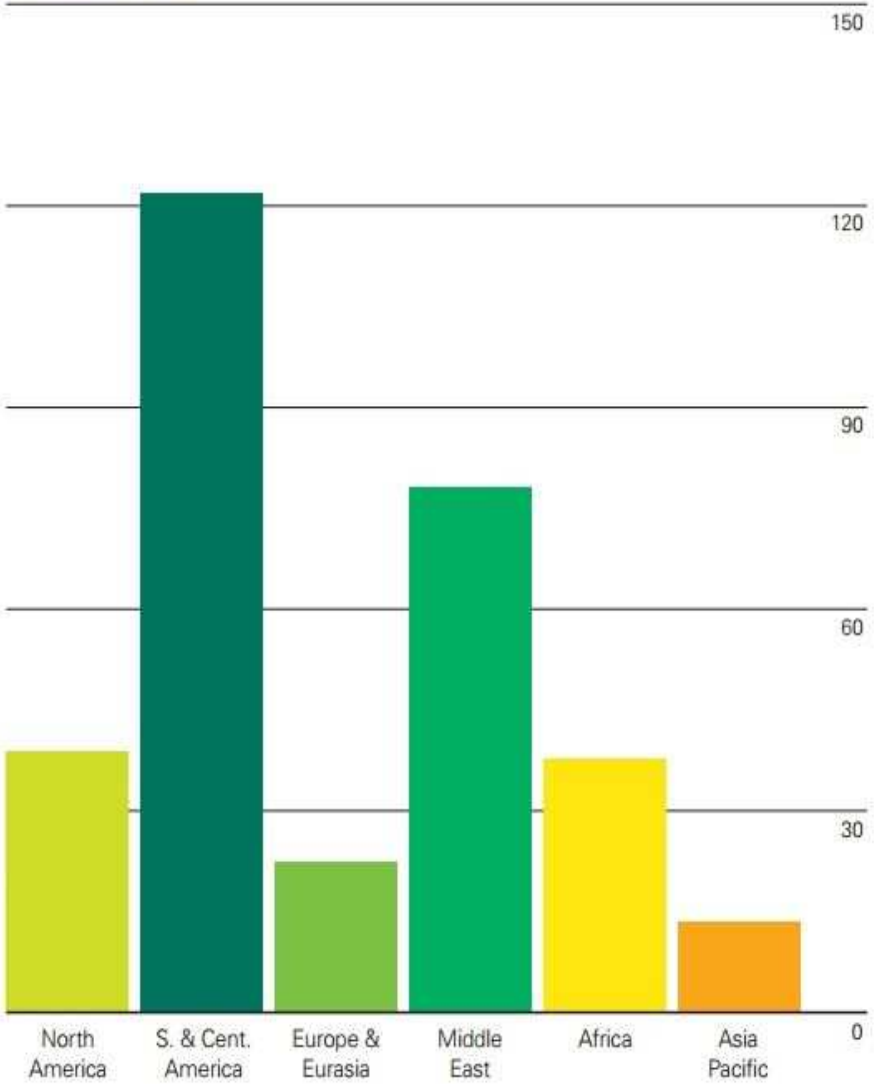

Oil Consumption & Economic Growth
percent change
6
4
2
0
-2
-4
Economic Growth
Oil Consumption
1980
1990
2000
2010

# Oil reserves

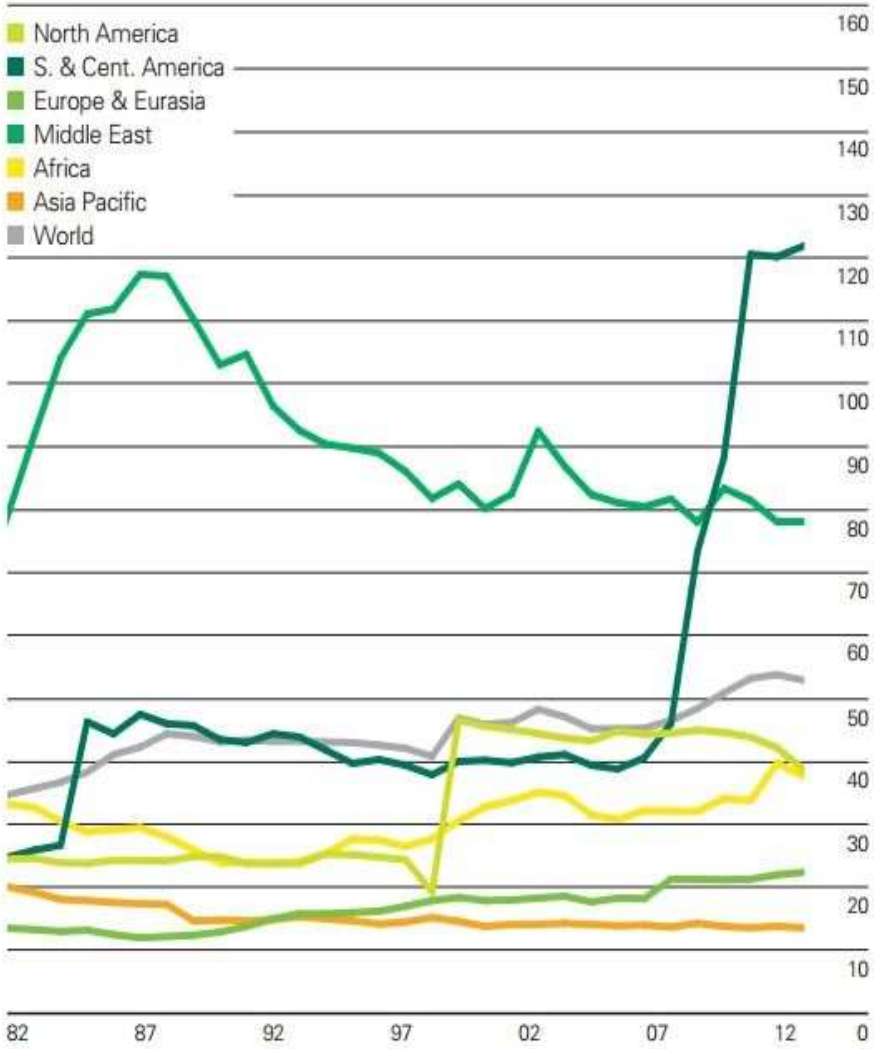
## Reserves-to-production (R/P) ratios

Years

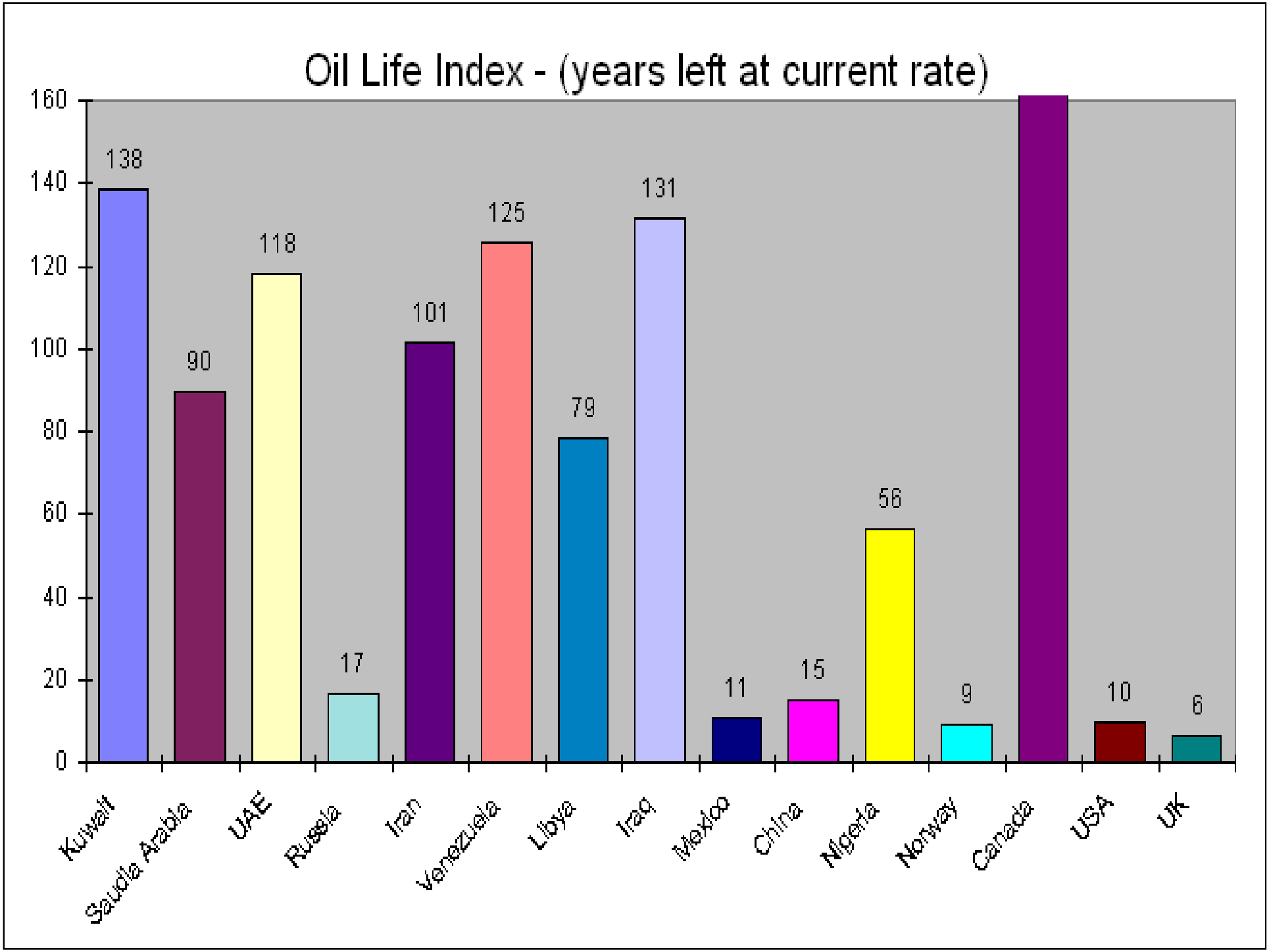
### 2012 by region

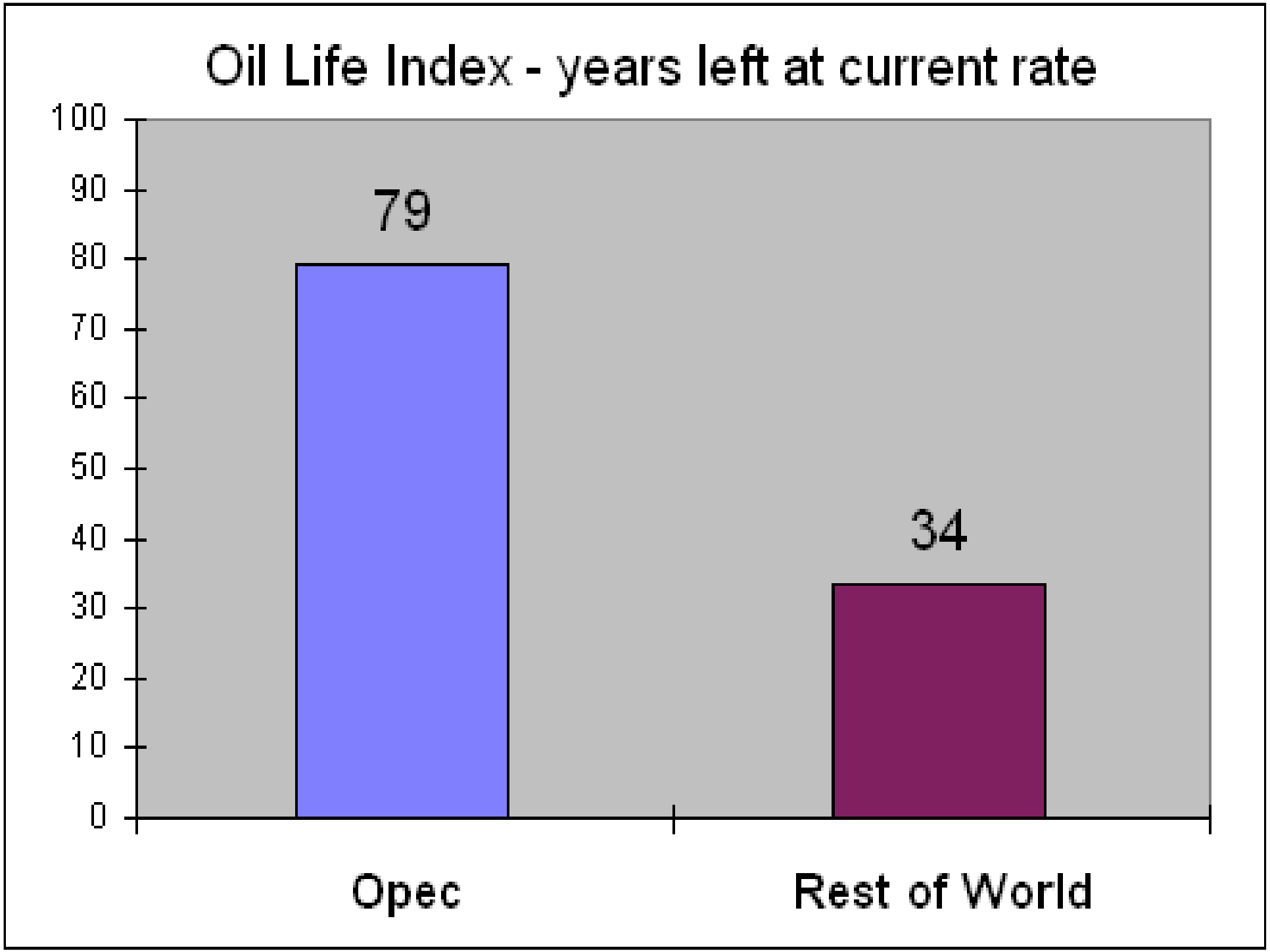



### History



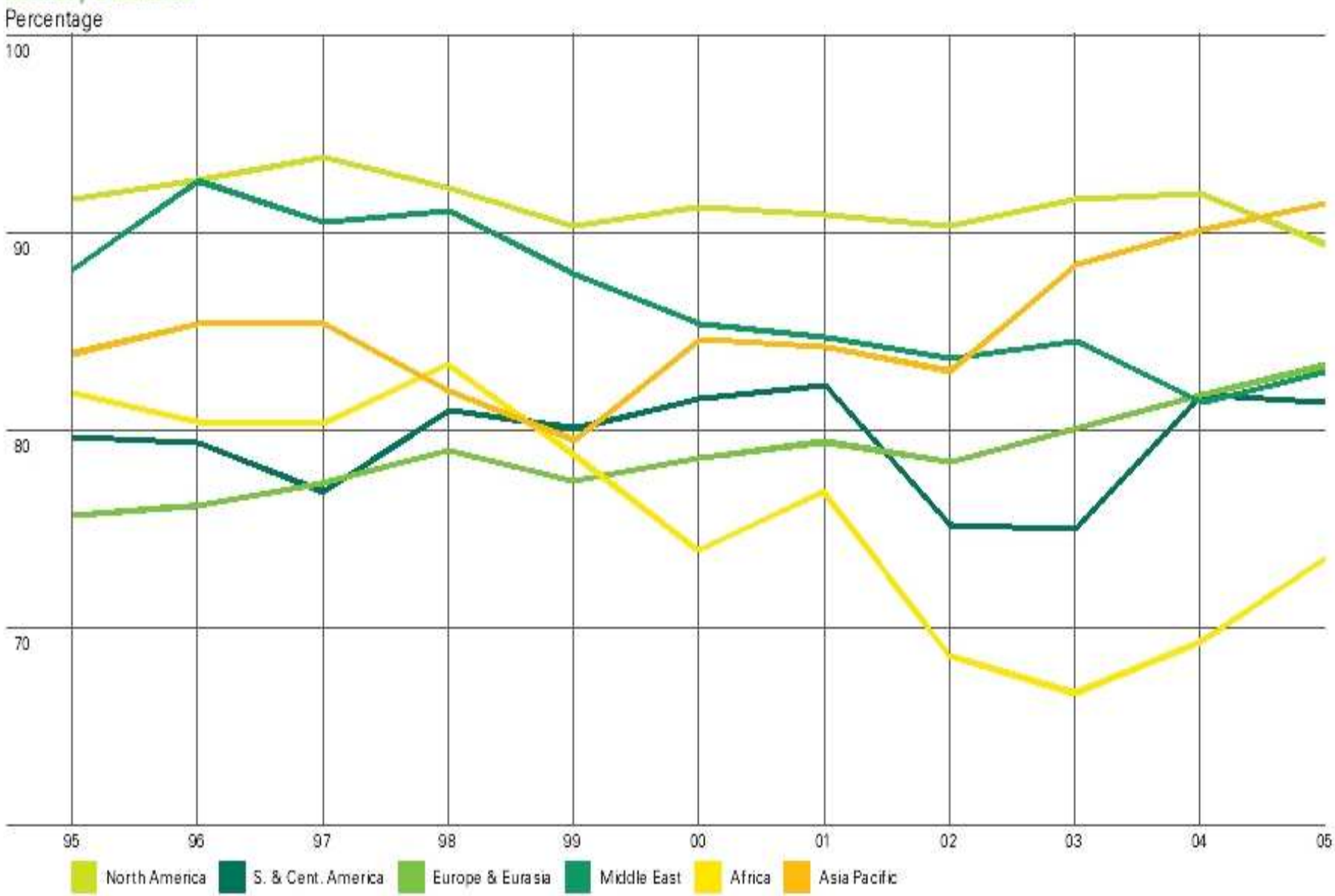

World proved oil reserves at the end of 2012 reached 1668.9 billion barrels, sufficient to meet 52.9 years of global production. An increase in official Iraqi reserves was the single largest addition, adding 6.9 billion barrels. OPEC members continue to dominate, holding 72.6% of the global total. South & Central America continues to


Oil Life Index - (years left at current rate)
160
140
120
100
80
60
40
20
0
138
90
118
17
101
125
79
131
11
15
56
9
10
6
Kuwait
Saudia Arabia
UAE
Russia
Iran
Venezuela
Libya
Iraq
Mexico
China
Nigeria
Norway
Canada
USA
UK


Oil Life Index - years left at current rate
100
90
80
70
60
50
40
30
20
10
0
79
34
Opec
Rest of World

# Crude Refining

## Refinery utilization




Demand growth slowed in 2005 but was still in excess of global refining capacity additions. As a result, global average refinery utilization increased to 86.3% versus a revised 85.9% for 2004. Crude runs in North America were lower than in 2004 because of the disruption caused by Hurricanes Katrina and Rita. Utilization increased in most other regions, partly to compensate for the reduction in US refinery operations.

# Refining Margins and Spare Capacity