Petroleum Geology

Introduction

Prof. Dr. Stefan M. Luthi

Course Data

Course Code: AES3820

Target Group:

1st Year MSc students Petroleum Engineering and Geosciences and Applied Geophysics, also Minor Geosciences

Course Credits: 3 ECTS

Course Material: *PPT Presentation on Blackboard;* books on reference list

Content

- Why it matters: Some basics
- History of petroleum
- The carbon cycle, organic matter and maturation
- Composition of oil and gas
- Migration from source to reservoir
- Reservoir rock properties
- Trapping
- Basin types and their exploration and development
- Reserves and resources

Course Description

This course aims at introducing the students to the basics of petroleum geology, a vast field that includes geochemistry, structural geology, sedimentology, mineralogy, fluid mechanics, mapping, volumetric calculations, risk and uncertainty analysis, and a vast array of industrial technologies.

Course Description

The course goal is to obtain a basic knowledge of the origins of petroleum and gas, of the accumulation conditions, and of the techniques to find and exploit hydrocarbons.

This should give the students a sufficient basis for further M.Sc. courses in the field, either here at the TU Delft or elsewhere, or to join a company where in-house training is provided.

It is your course

Make the best of it!

Reference Textbooks

Gluyas J. & Swarbrick R. (2004): Petroleum Geoscience. Blackwell Publishing, 359 p.

Furthermore:

North, F.K. (1985): Petroleum Geology. Allen & Unwin, 607 p.

Selley R.C. (1997) Elements of Petroleum Geology, 2nd edition. Academic Press, 490 p.

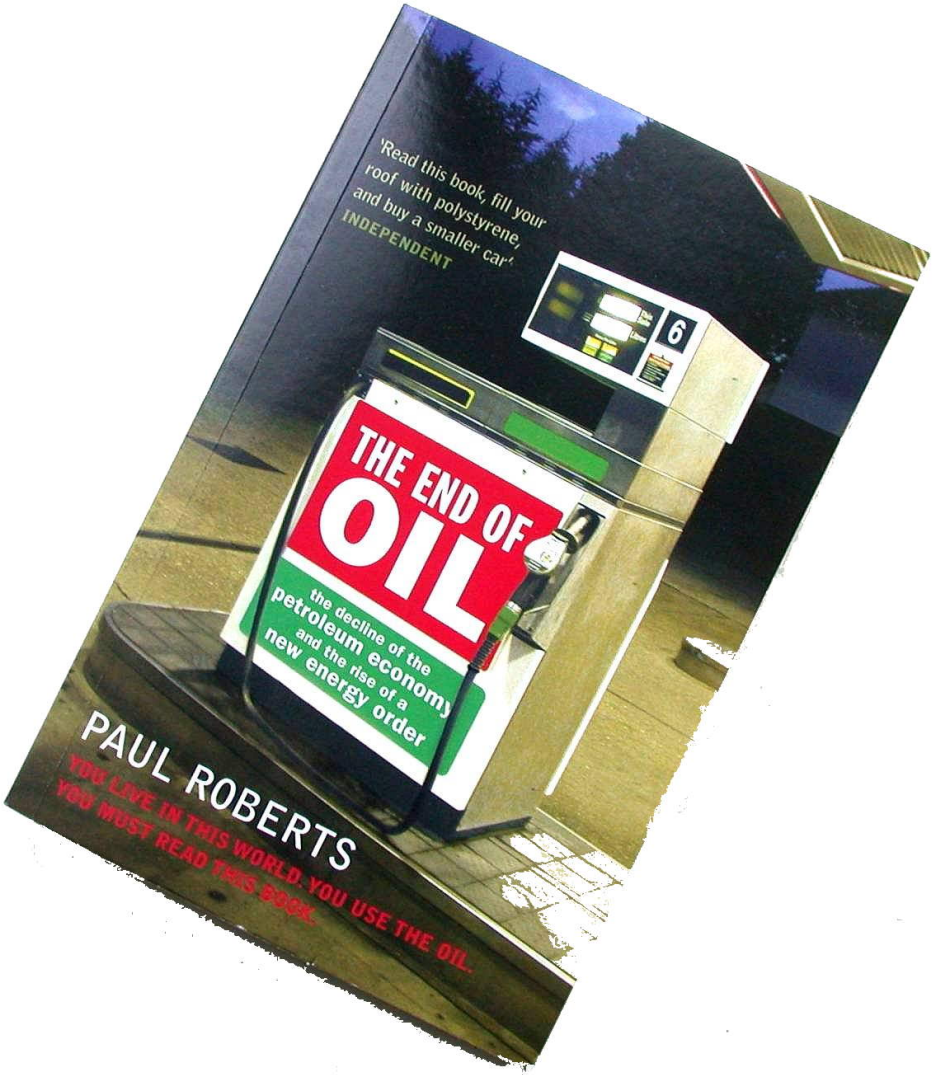
Lint P.K. (1990) Basic Petroleum Geology. OGCI, 480 p.

Levorsen, A.I. (1967): Geology of Petroleum. W.H. Freeman and Co, 724 p.

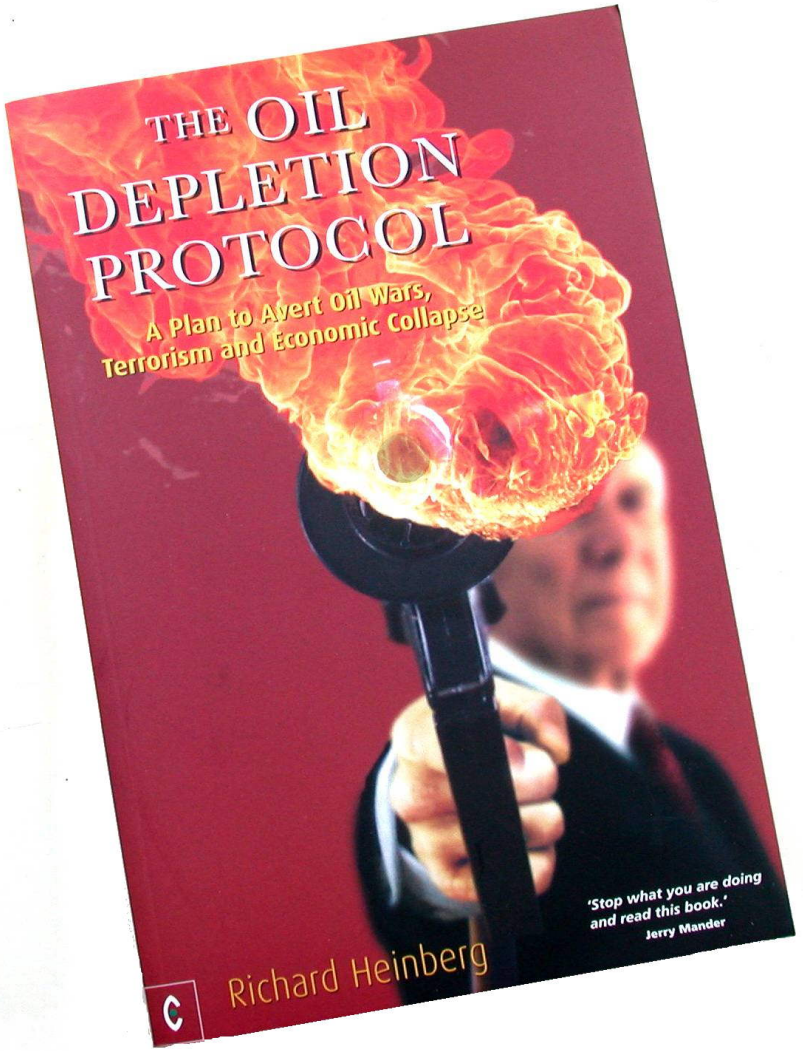
Hunt, J.M. (1995): Petroleum Geochemistry and Geology, 2nd edition. W.H. Freeman & Co, 743 p.

Tissot, B.P. & Welte, D.H. (1978): Petroleum Formation and Occurrence. Springer, 538p.

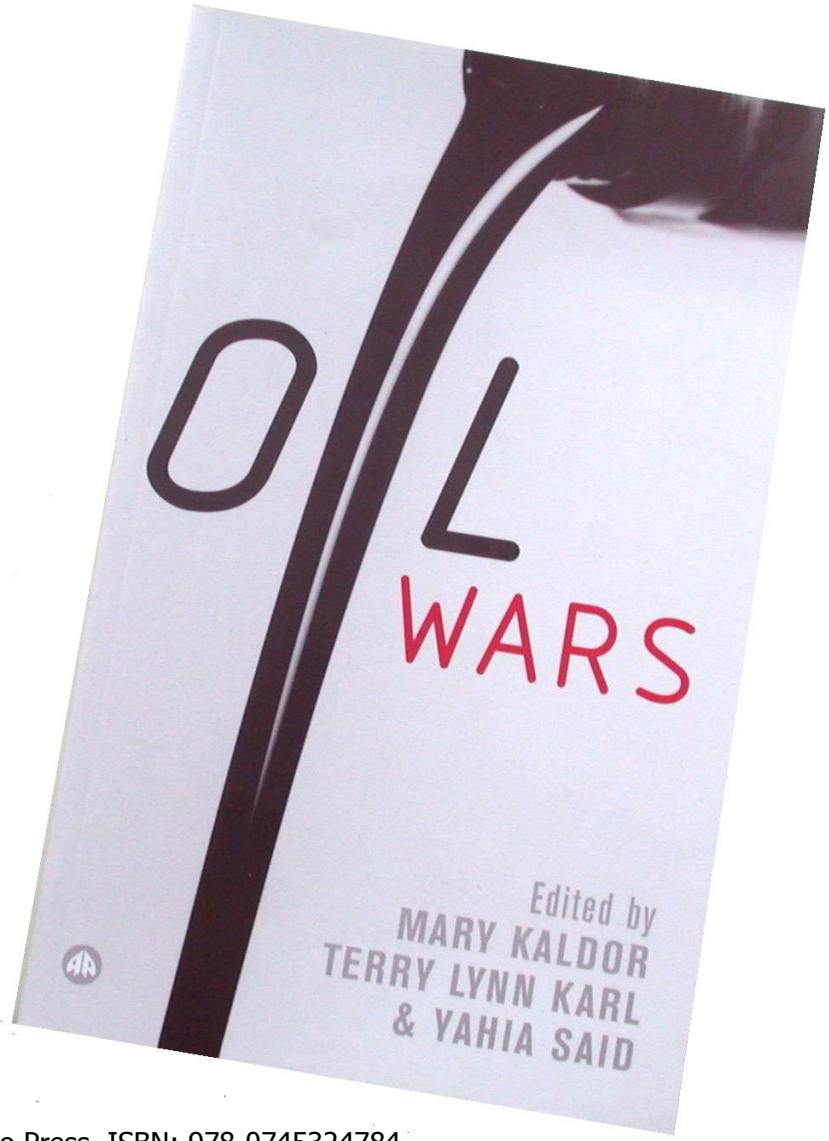
Why it matters



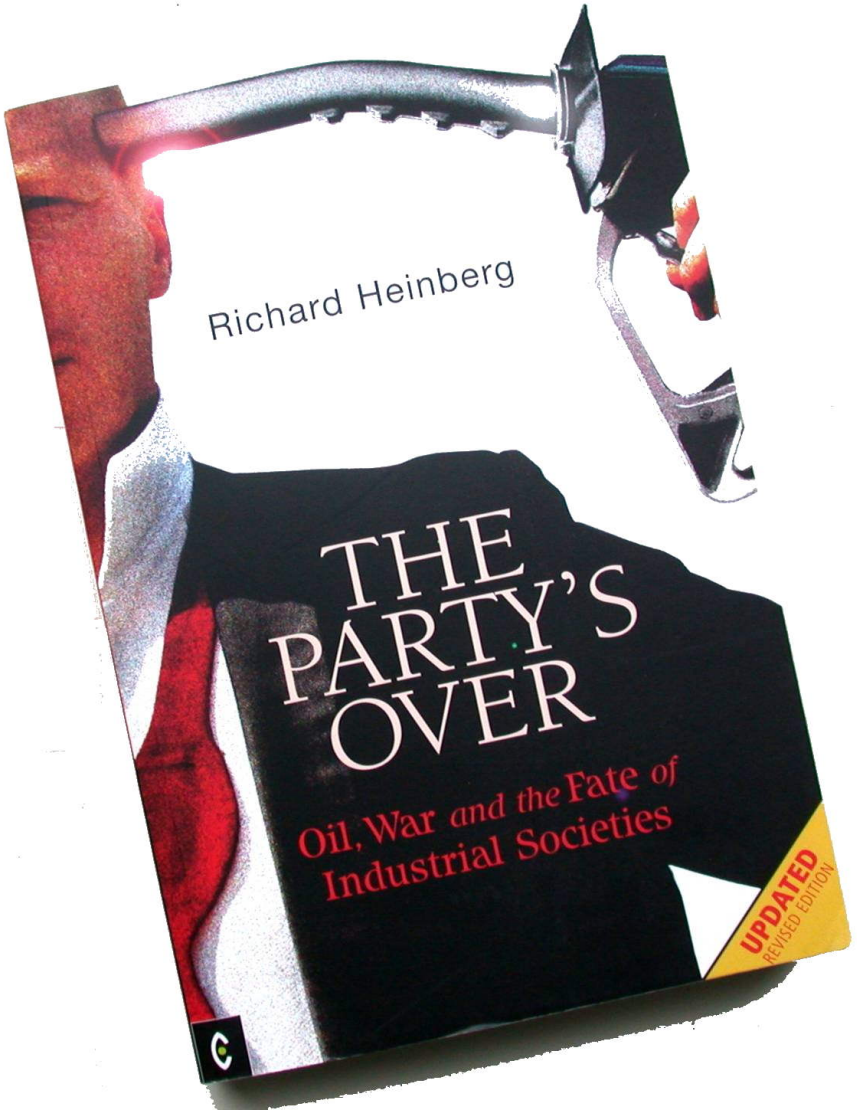
Roberts, P. (2005) *The end of oil: the decline of the petroleum economy and the rise of the new energy order*, Bloomsbury Publishing PLC, ISBN: 978-0747570813



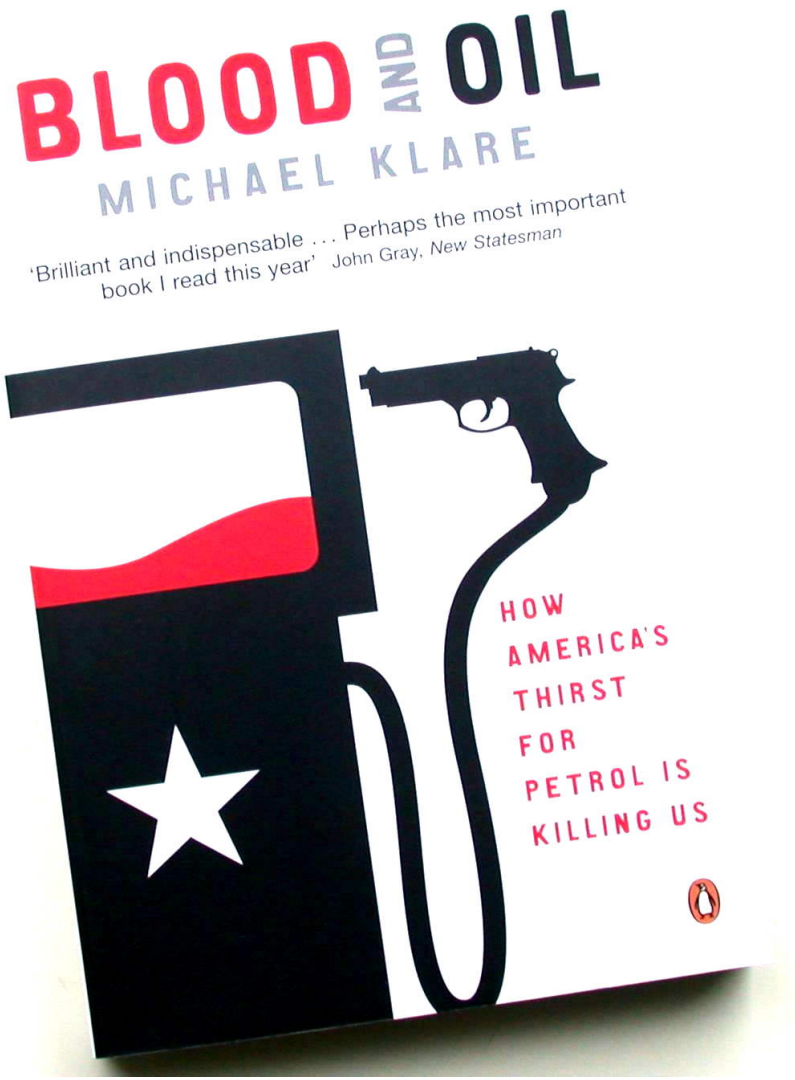
Heinberg, R. (2006) *The oil depletion protocol: A plan to alert oil wars, terrorism and economic collapse*, Clairview books, Canada, ISBN: 978 1 905570 04 1. Available online via books.google.com



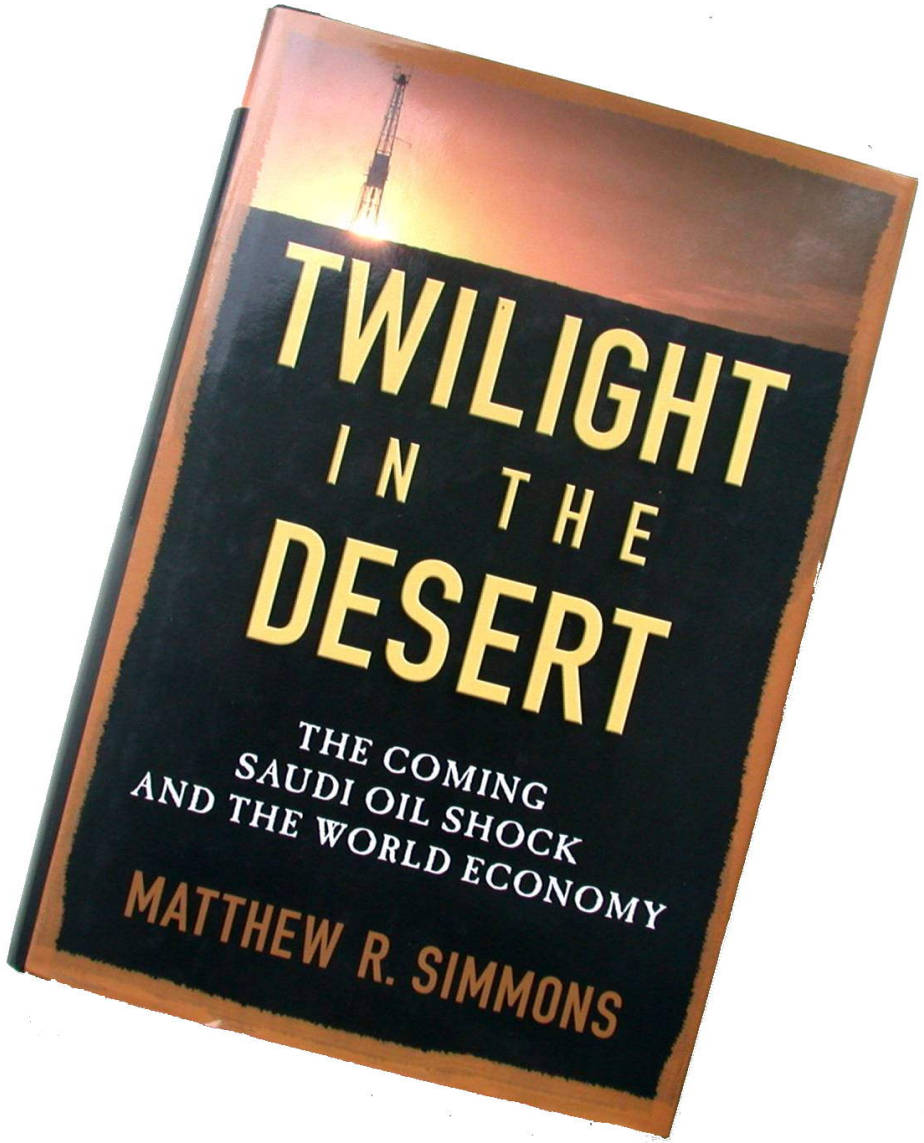
Kaldor, M.; Karl, T. L.; Said, Y. (2007) *Oil Wars*, Pluto Press, ISBN: 978-0745324784



Heinberg, R. (2003) *The party's over: oil, war and the fate of industrial societies*, updated edition, New society publishers, ISBN: 9780865715295



Klare, M. (2005) *Blood and oil: how America's thirst for oil is killing us*, Hamish Hamilton, ISBN: 0 241 14306 3



Simmons, M. R. (2005) *Twilight in the dessert: the coming Saudi oil shock and the world economy*, Wiley, ISBN: 978- 0471738763

Measurement Units

Quantities of oil are expressed in barrels:

1 barrel = 159 liters
1 cubic meter = 6.37 barrels

1 metric ton = 6.8 to 7.6 barrels (dep. on gravity)

Gas is expressed in millions of cubic feet:

1 MMcf ≈ $3 \cdot 10^4$ m^3

Energy-wise, gas can be expressed in oil equivalents:

1 boe ≈ 6000 to 6500 cf

1 barrel = 159 liters

Some Numbers

Number of oil and gas wells drilled to date: ~ 7 million
Percentage of wells in the USA: ~50%
Producing wells worldwide: ~ 1 million
Average production of oil wells in USA: 20 bbls/day
Average production of oil wells in Middle East: 7,000 bbls/day

Total number of producing fields: ~40,000

Total number of petroleum geologists: ~ 100,000 (exc. China)
Total number of drill rigs worldwide: ~ 5,000

More Large Numbers

32.4 Gbo	Annual World Oil Consumption 2012 (proj)
4-8 Gbo	Annual Oil Discovery Rates in 1990s-2000s
1175 Gbo	Total World Oil Consumption 1860-2012
850 Gbo	Conventional World Oil Reserves (P50)[1]
1372 Gbo	Conventional World Oil Reserves (P50)[2]
2311 Gbo	Conventional World Oil Reserves (P50)[3]
1900 Gbo	World Reserves (OIP) of Heavy Oil, Tar Sands, and Oil Shales

1 Campbell & Laherrère, 1998
2 BP Statistical Review 2007, includes 164 Gbo of oil sands in Canada
3 USGS, 2000, includes 688 Gbo reserve growth and 732 Gbo undiscovered reserves

1 Gbo = 1 billion barrels of oil

Oil Companies (International) 2011

Company	Prod	Res*	R/P	Revenues	Net	Staff
Exxon/Mobil	3.9 Mboe/d	24.9 Gboe	17.5 y	$486 b	$41.1 b	83,600
BP	3.4 Mboe/d	17.8 Gboe	14.3 y	$386 b	$25.7 b	79,700
RD/Shell	3.1 Mboe/d	11.9 Gboe	10.5 y	$470 b	$31.2 b	90,000
Chevron	2.8 Mboe/d	10.5 Gboe	10.3 y	$254 b	$26.9 b	62,000
Total	2.4 Mboe/d	10.4 Gboe	11.9 y	$217 b	$12.3 b	96,100

* Proved

Sources: Annual Reports, Press Releases, Newspaper Reports

Oil Companies (National + Seminational)

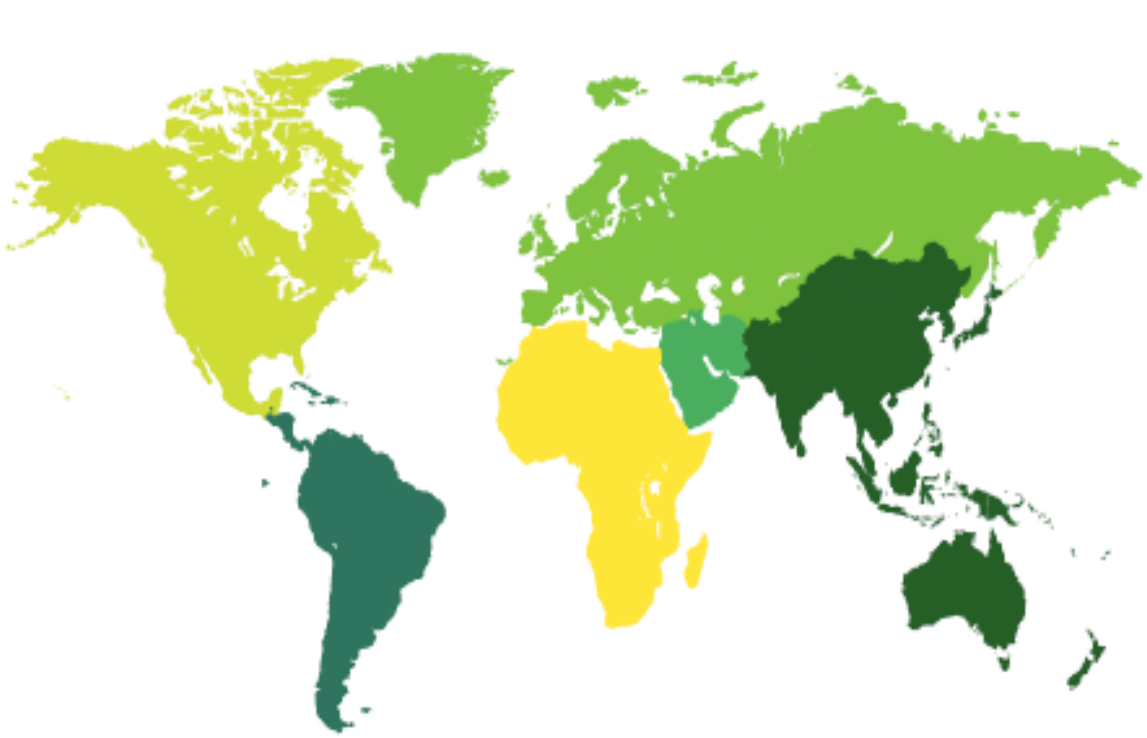
Company	Production	Reserves	R/P
Saudi Arabian Oil Co,	11.0 Mboe/d	303.0 Gboe	75.5 y
China Nat. Petrol. Co.	4.1 Mbo/d	14.7 Gbo	9.8 y
Petroleos Mexicanos	2.5 Mboe/d	12.9 Gboe**	14.1 y
National Iranian Oil Co.	4.0 Mboe/d	300.0 Gboe	205.5 y
Iraq National Oil Co.	2.7 Mboe/d	134.0 Gboe	136.0 y
Petroleos de Venezuela	2.6 Mboe/d	129.0 Gboe*	135.9 y
Kuwait Petroleum Co.	3.7 Mboe/d	111.0 Gboe	82.2 y
Libya National Oil Co.	2.1 Mboe/d	50.0 Gboe	65.2 y
Abu Dhabi Nat. Oil Co.	2.6 Mboe/d	126.0 Gboe	132.8 y
Nigerian Nat. Petrol. Co.	2.3 Mboe/d	68.0 Gboe	81.0 y
Sonatrach	1.3 Mboe/d	39.0 Gboe	82.2 y
Petrobras	2.2 Mbo/d	15.1 Gbo	18.8 y
6 largest Russian Oil Co.	9.8 Mbo/d	79.5 Gbo	22.3 y

* Plus 267 Gbo of heavy oil reserves
** Other sources cite >100 Gbo

Claimed reserves
BP Statistical Review 2011 and other sources

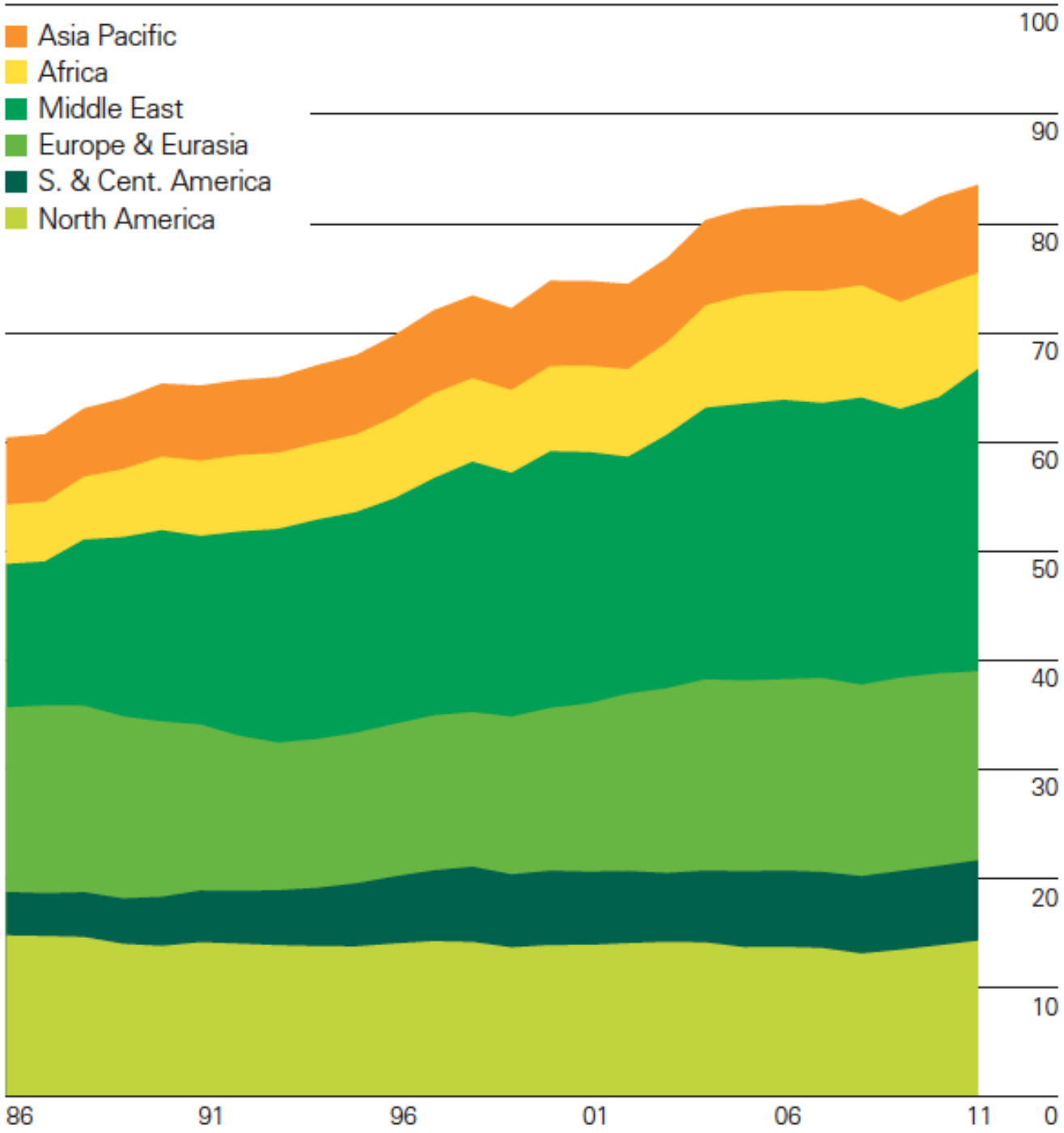
Source: BP Statistical Review 2007

Proved reserves at end 2006
Thousand million barrels



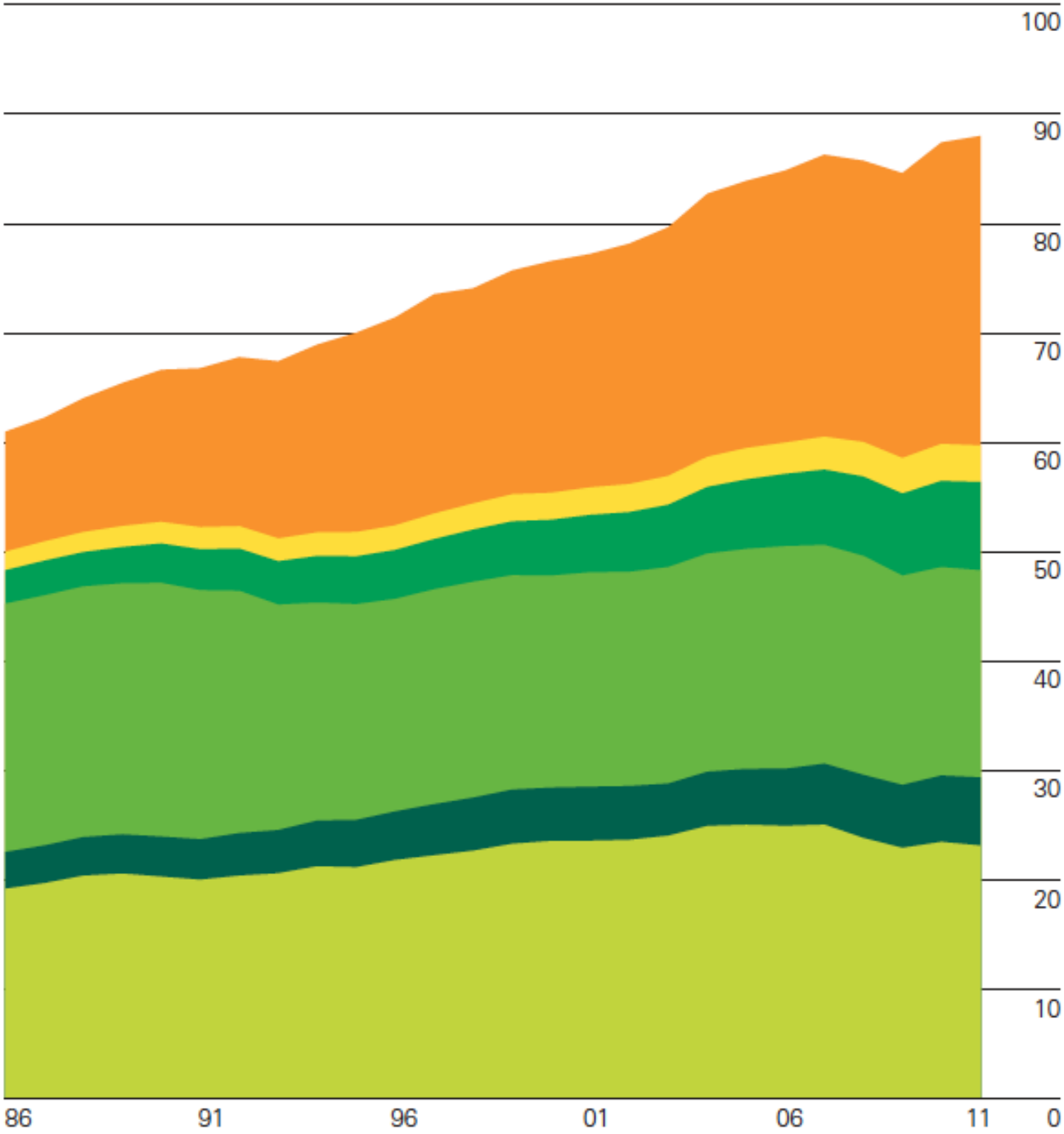
Source: BP Statistical Review 2007

Oil Production by Region 2011



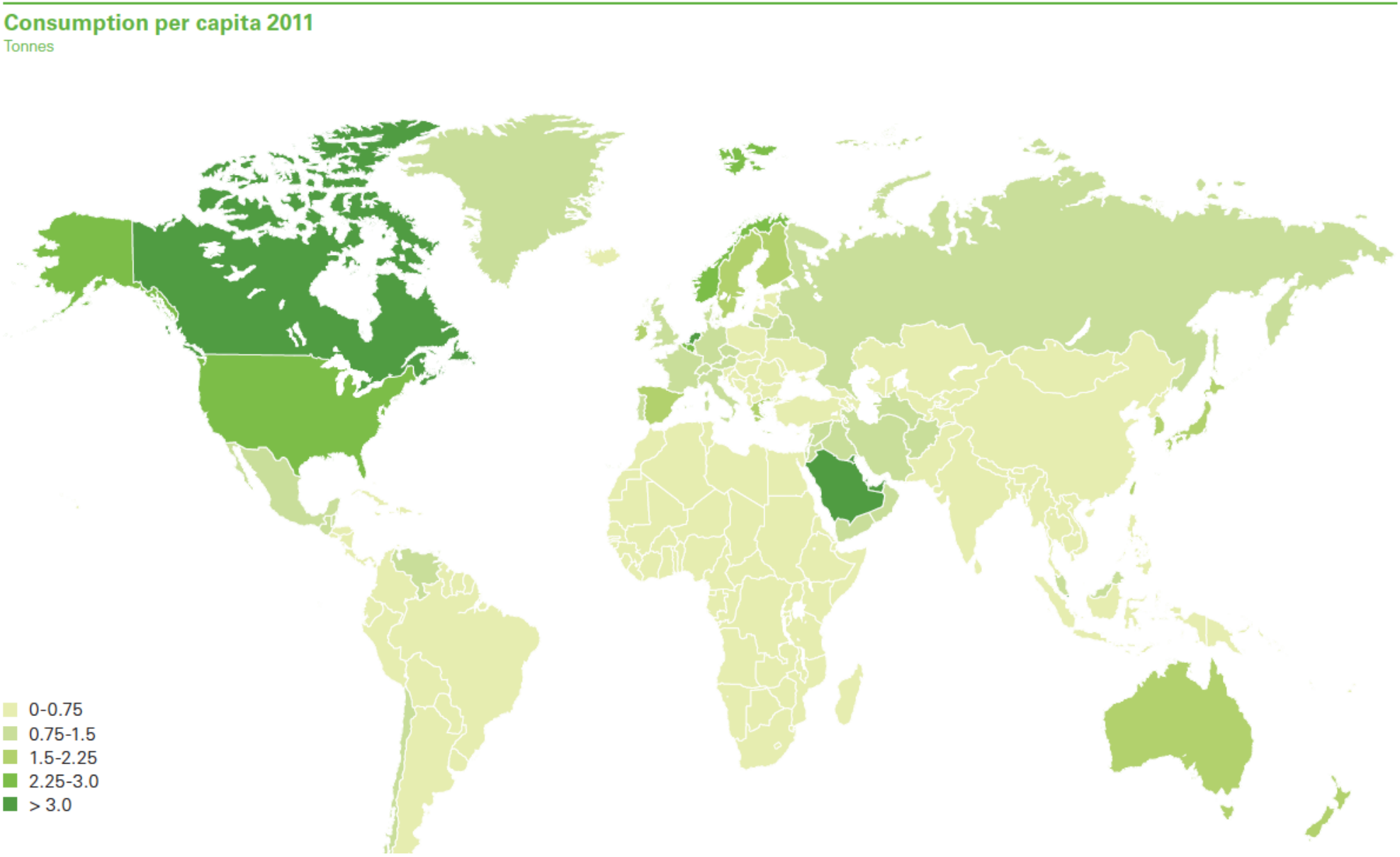
Source: BP Statistical Review 2012

Oil Consumption by Region 2011



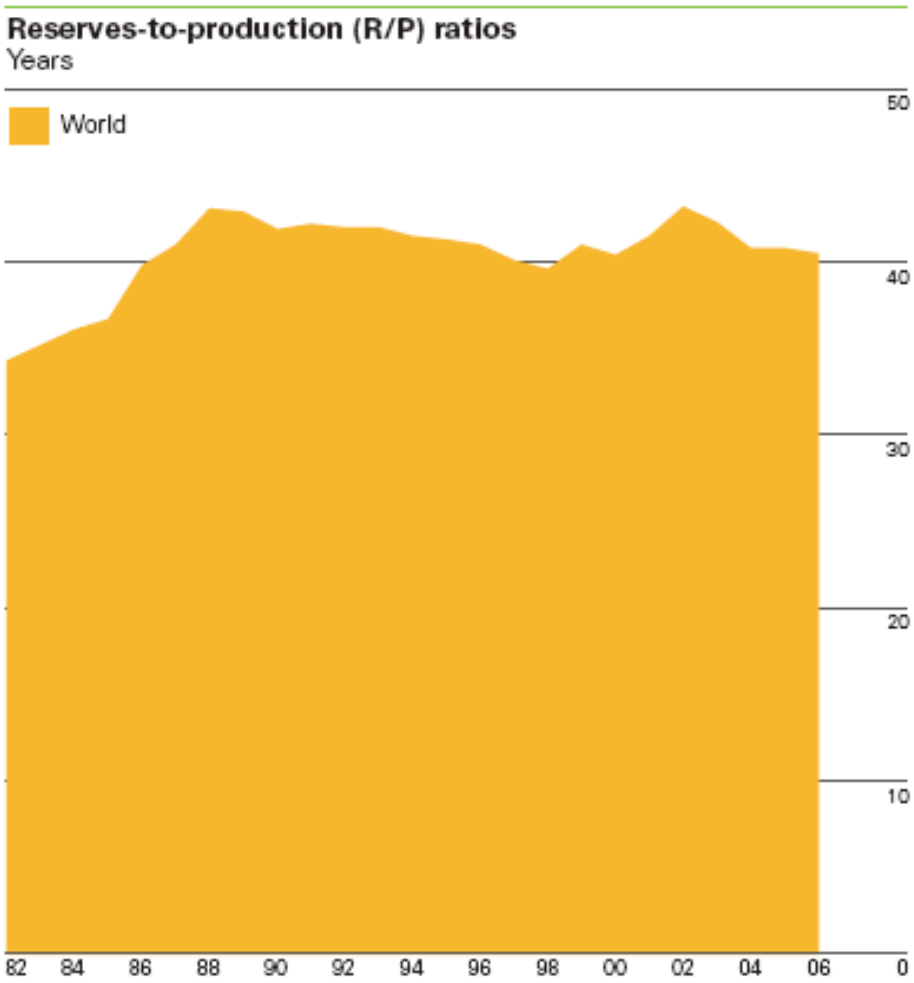
Source: BP Statistical Review 2012

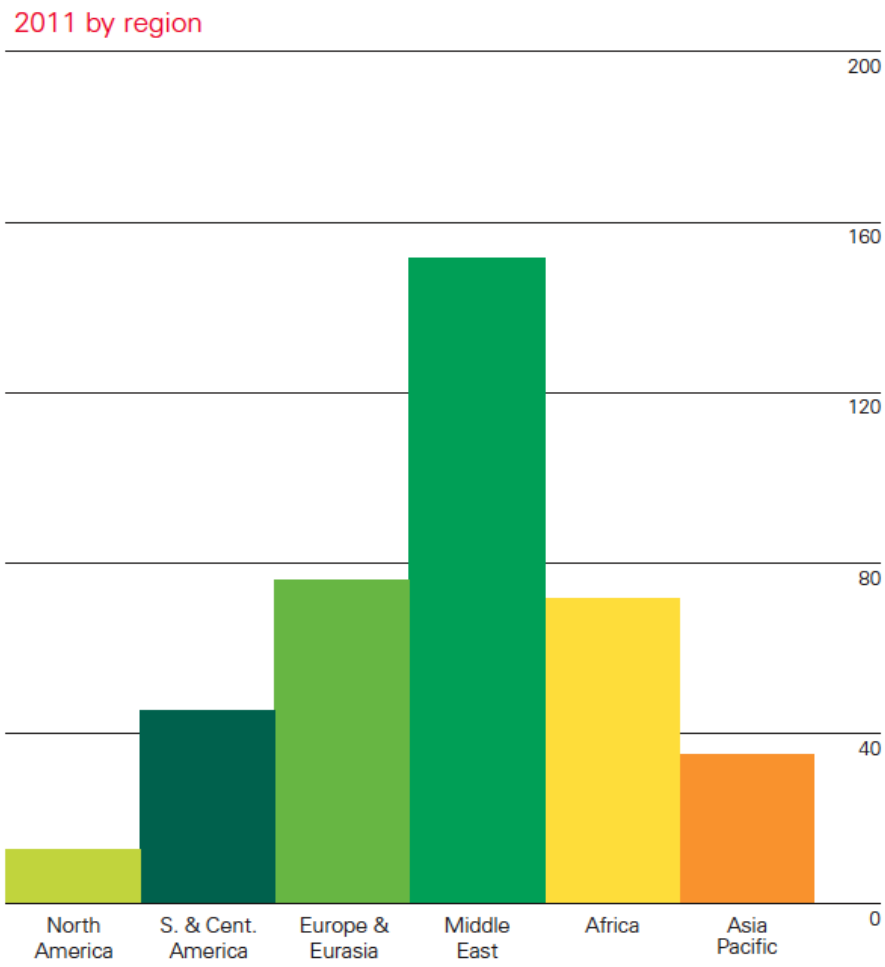
Oil Consumption per Capita



Source: BP Statistical Review 2012

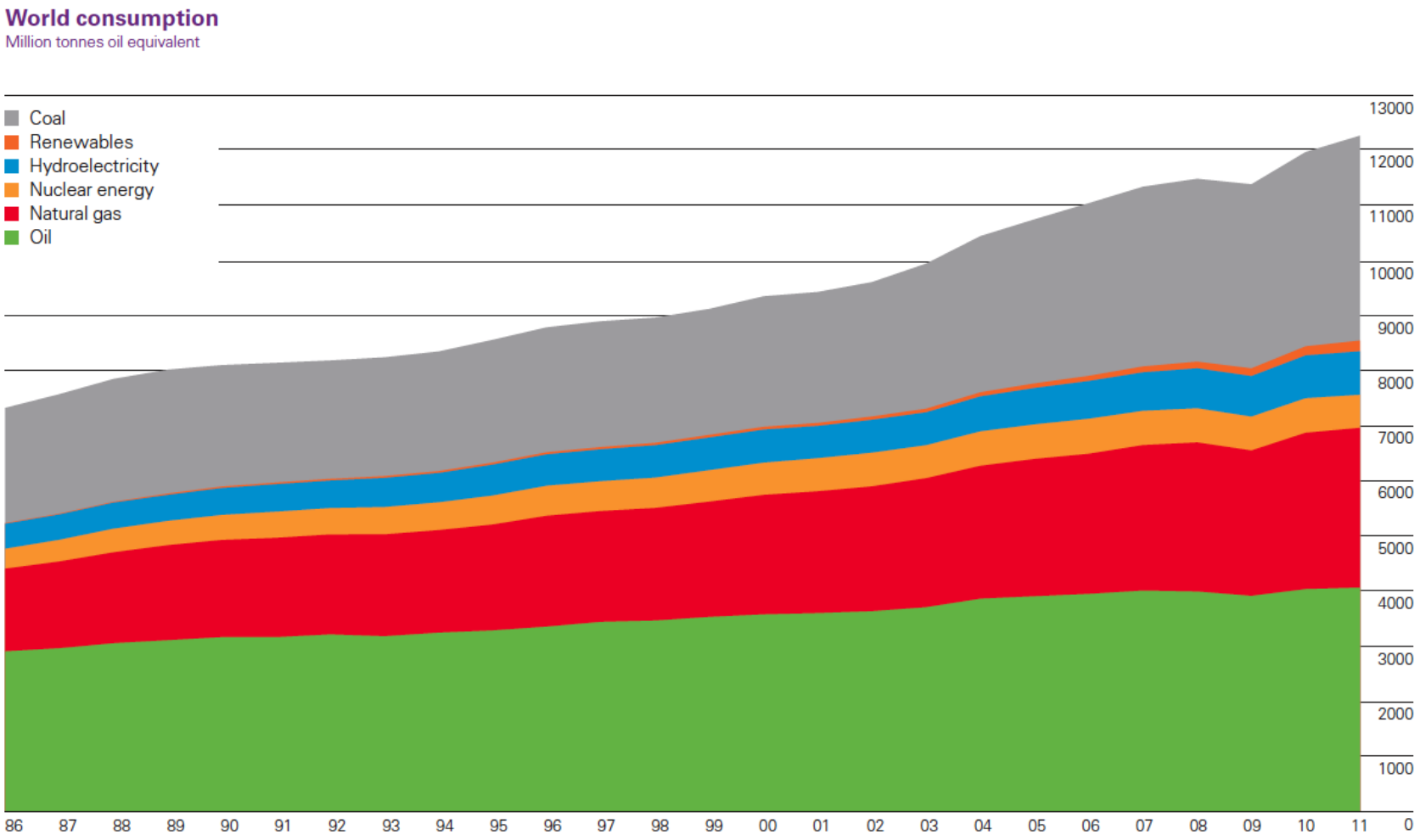
R/P by Area and for World





The world's oil R/P ratio edged lower in 2006, reaching 40.5 years, compared with 41 years in 1996 and 39.8 years in 1986. The level of reserves fell by 1 billion barrels, or 0.1%. Declines in Norway and Mexico were partially offset by increases in Russia and Brazil.

Total World Energy Consumption



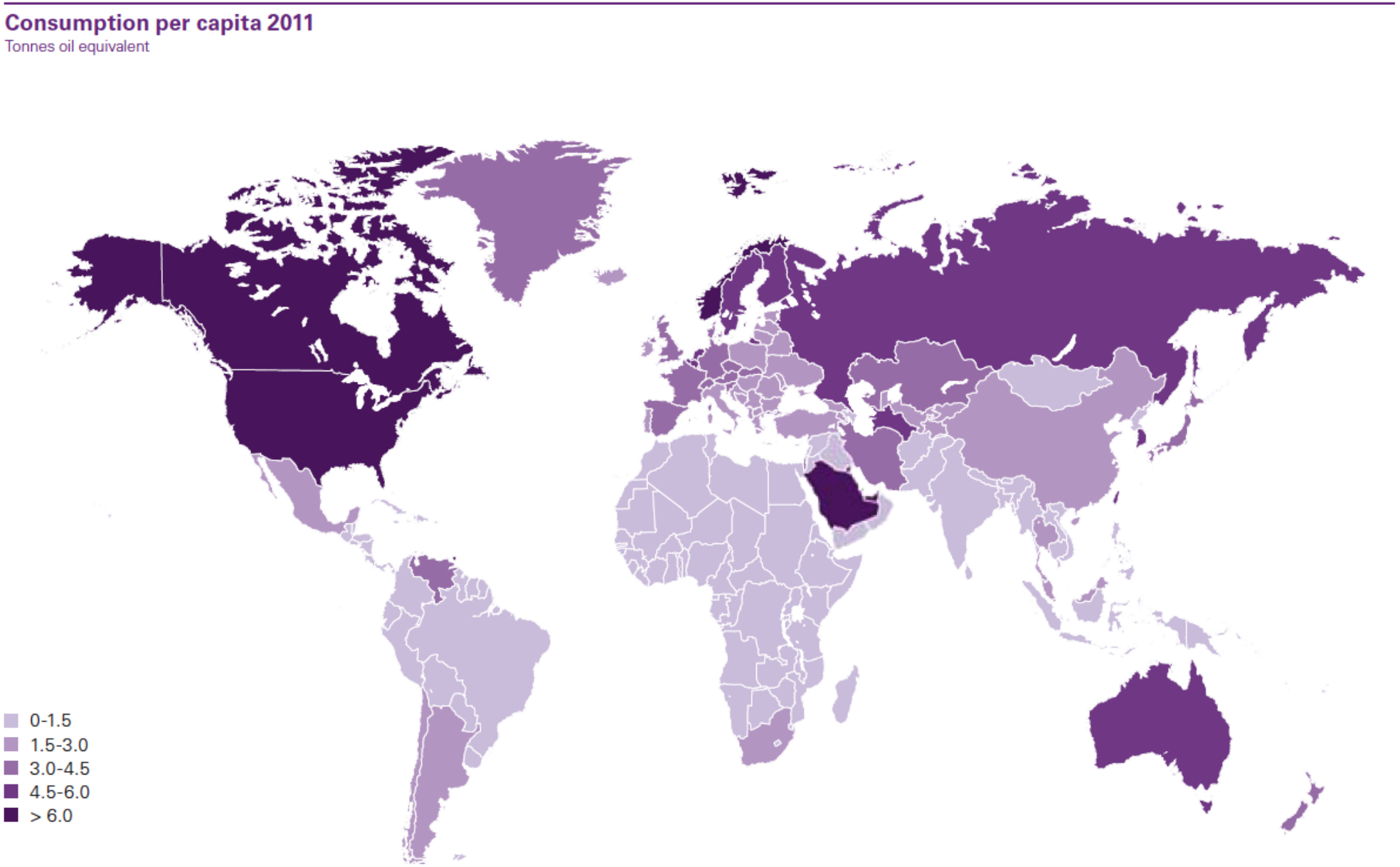
In Mtoe = Million tons of oil equivalent.

Source: International Energy Agency (IEA)

TU Delft

Source: BP Statistical Review 2012

Total Energy Consumption per Capita



Reserves/Production

Oil

Saudi Arabia	262.3 Gbo
Canada	179.2 Gbo
Iran	136.3 Gbo
Iraq	115.0 Gbo
Kuwait	101.5 Gbo
United Arab Emirates	97.8 Gbo
Venezuela	80.0 Gbo
Russia	60.0 Gbo
All others	< 42 Gbo
Total	1317.4 Gbo

R/P = 45.4 y

Gas

Russia	1680 Tcf
Iran	974 Tcf
Qatar	911 Tcf
Saudi Arabia	240 Tcf
United Arab Emirates	214 Tcf
USA	204 Tcf
Nigeria	182 Tcf
Venezuela	152 Tcf
All others	<100 Tcf
Total	6183 Tcf

R/P = 74.5 y

Coal

USA	270.7 billion tons
Russia	173.1 billion tons
China	126.2 billion tons
India	101.9 billion tons
Australia	87.2 billion tons
All others	<40.0 billion tons
Total	1000.9 billion tons

R/P = 185.4 y

R/P is a static measure with little predictive value,
but it is a simple metric with a message

Historical Development

Prior to 1900

No “petroleum geology”; all oil discovered through seepages (Appalachian, California, Baku, Ploesti, Peru, Egypt, Borneo...)

“Anticlinal theory” known but not used in practice

Many fields located in so-called “geomorphic traps” (where the reservoir rock is truncated by a recent erosion surface)

Drake well in 1859 first to discover oil (Pennsylvania)

Historical Development ctd.

1901-1924

"Anticlinal theory" put in practice with Spindeltop well in Texas

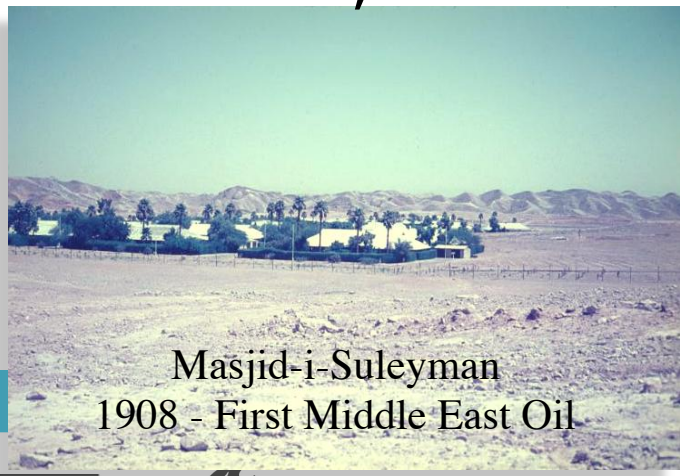
Important discoveries in Lake Maracaibo (Venezuela), Masjid-y-Suleiman (Iran), Trinidad, Borneo, Mexico, Oklahoma, San Joaquin Valley, California (all USA)

Petroleum geology is "American"; foundation of AAPG

Bolivar Coastal field: First in homoclinal trap, first offshore, first large field with heavy oil, launches

SOC becomes first major oil company

Automobiles! Gas stoves!


Masjid-i-Suleyman
1908 - First Middle East Oil

Historical Development ctd.

1925 - 1945

Important discoveries in La Paz (Venezuela), Kirkuk (Iraq; carbonate reservoir!), numerous fields in Middle East (most also carbonates)

Oil is organic, not inorganic; micropaleontology and organic geochemistry developed as important tools

Technological breakthroughs: Rotary drilling, torsion balance, gravimeter, reflection seismology, electrical well logs, perforations; wells to 3000 meters depth (before: to 1000 m)

World Petroleum Congress founded

Historical Developments ctd.

1945 - 1960

Drilling boom, discovery of major oil fields in Middle East, USA, Western Canada, Russian platform

Drilling depths reach 6000 meters; gas became important

Important insights into hydrocarbon migration and accumulation (e.g. by King Hubbert; Levorsen)

Sedimentology becomes important to understand reservoirs

“Log-normal distribution” of oil fields

Historical Developments ctd.

1960 - 1980

Offshore drilling technology developed

Discovery of North Sea, Libya, Nigeria, Siberia, eastern Mexico oil provinces

“Subtle traps” (e.g. North Dome in Qatar)

Vast improvement of seismic acquisition and processing; becomes vital exploration tool. Further technological improvements in drilling, construction, and logging

Historical Developments ctd.

Since 1980

Passive margins plays discovered (Gulf of Mexico, West Africa, Brazil). Deep to ultra-deep drilling technology developed

Huge carbonate fields in intra-cratonic setting discovered (Peri-Caspian oil province)

3-D and 4-D seismics provide volumetric and dynamic picture of reservoirs; leads to seismic stratigraphy

Integration of petroleum disciplines; computerized workflows

Half of the “easy oil” is produced

Summary: Why it matters

- We depend on energy: In the industrial world every person uses the energy corresponding to about *200 human powers 24 hours per day*
- Fossil energy constitutes *±85% of our energy consumption*
- Fossil fuels have a high caloric value per volume
- Fossil fuels are finite
- The burning of fossil fuels has undesirable climatic consequences
- But: Energy companies are important for the economy