Oil & Gas






History of Petroleum

- Asphalt used in the construction of Babylon
- Oil exploited by the Romans in Dacia (Romania) when it was known as *picula*
- Earliest oil wells in China 347CE
  - 240m deep – drilled with bits attached to bamboo poles
- China & Japan used natural gas for light and heat
- Petroleum was known as “burning water” in 7thCentury Japan

Babylon


Early Chinese drilling equipment

History of Petroleum

- Oils fields around Baku were first exploited in the 9th Century
  - 1860s Baku produced 90% of World's oil
  - First modern Russian oil refinery 1861
- Petroleum first distilled to kerosene for lamps by Persian alchemist Rhazes in the 9th Century
- First commercial oil well in Romania drilled in 1857
  - First country to record crude oil output
  - First large oil refinery at Ploesti, Romania on 1856-57
- First oil sands mined 1745 in Alsace, France – active until 1970
- First "rock oil" mine built in Bobrka (Poland/Ukraine) in 1853

First Romanian oil well

Baku

Ploiesti, Romania 1916

Pechelbronn

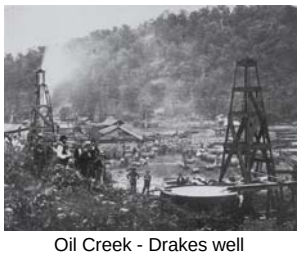
Bobrka oil field, Poland/Ukraine

History of Petroleum

- First record – Sir Walter Raleigh – Trinidad Pitch lake (1595)
- First North American oil well – 1858 at Oil Springs, Ontario, Canada
- First US oil well – 1859 at Oil Creek, Titusville Pennsylvania
  - 21 m deep
  - Start production 25 bpd – after 12 months down to 15bpd

Trinidad Pitch Lake

Oil Springs, Canada



Oil Creek - Drakes well

History of Petroleum

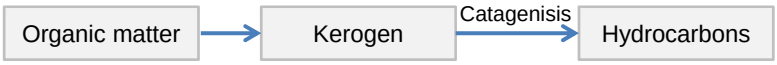
- Industry grew with demand for kerosene and oil lamps
- And then came the ICE..... But coal still dominated until mid 1950s

Year	US Oil Production (bpd)		US Oil Production (bpd)
1860	1	1940	4107
1870	14	1950	5407
1880	72	1960	7035
1890	126	1970	9637
1900	174	1980	8597
1910	574	1990	7355
1920	1210	2000	5822
1930	2460	2010	5479

Origins of Oil & Gas

Dominant view

- Products of complex, gradual transformation of ancient accumulations of dead organic matter (zooplankton & algae) in anaerobic conditions



Russian-Ukrainian view

- Abiogenic products formed under high temperatures and pressures deep in the earth's mantle from which they rise to be trapped in porous structures near the earth's surface

Composition

Complex mixture of hydrocarbons

- Ultimate elemental analysis
- C = 85% (83-87)
- H = 13% (1 – 15)
- H/C ratio 1.8 *cf* 0.8 for bituminous coal, 4 for methane

Contains three main series of hydrocarbons

- Alkanes (pentane, hexane) – *aka paraffin*
- Cycloalkanes (cyclopentane, cyclohexane) – *aka cycloparaffins*
- Arenes (benzene, toluene) – *aka aromatics*
- Sulphur most common undesirable contaminant
  - "sour" oils have >2% S
  - "sweet" oils have < 0.5% S

API

American Petroleum Institute gravity based on arbitrary assignment of 10 ^{o}API to water

Conversion for specific density

^{o}API = (141.5/specific density g/ml) – 131.5

Oil	Specific density (g/ml)	^{o}API
Very heavy crude oil	0.95	17.5
Light oil	0.82	41

API

Oil	°API
Most Saudi crude oils	28 - 33
Kuwait	23
Iraqui (Basra)	25
Alaska North Slope	29
North Sea Brent	38
Libyan, Algerian, Nigerian	37 - 44
Australian Northwestern Shelf	60

Price *versus* density

The lighter the oil (the higher the °API) the higher the price

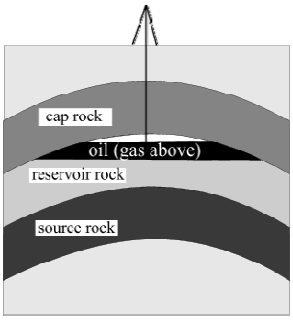
Barrel of oil

- 42 US Gallons/35 Imperial Gallons/159 litres
- Adopted by US Bureau of the Census in 1872
- bbl – blue barrel
- Most oils 7.0 – 7.5 barrels/tonne

Oil & Gas Deposits

Commercially viable oil deposits have:

- Rich source rocks
- Permeable & porous reservoir rock
- Tight trap to hold liquid/gas in place

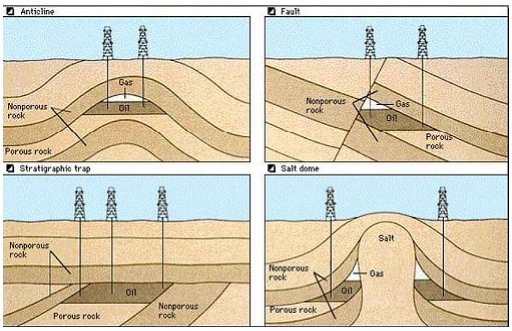


Two types of reservoir rock:

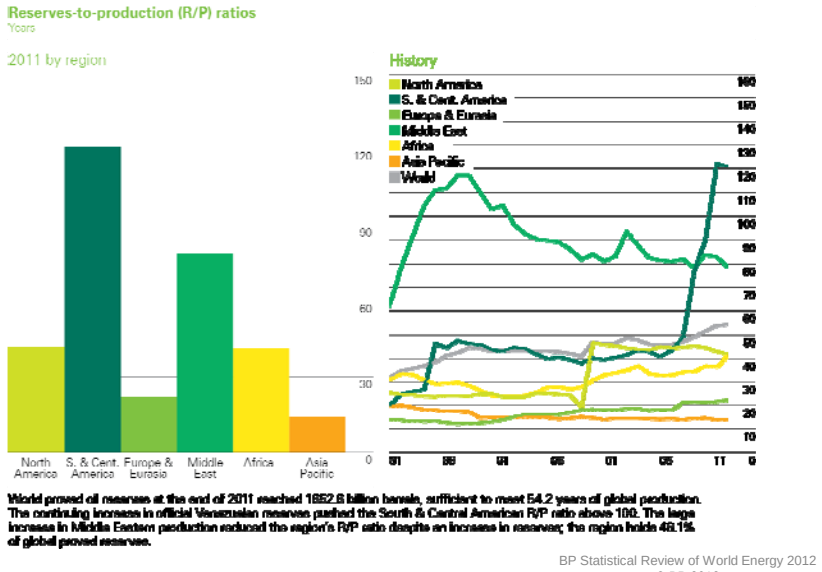
- Clastic
- Carbonate

Traps

- Anticline – 4/5 of world's largest reservoirs
- Fault
- Salt dome – world's 2nd largest oil field is of this type
- Stratigraphic – contains elongated sandstone structures



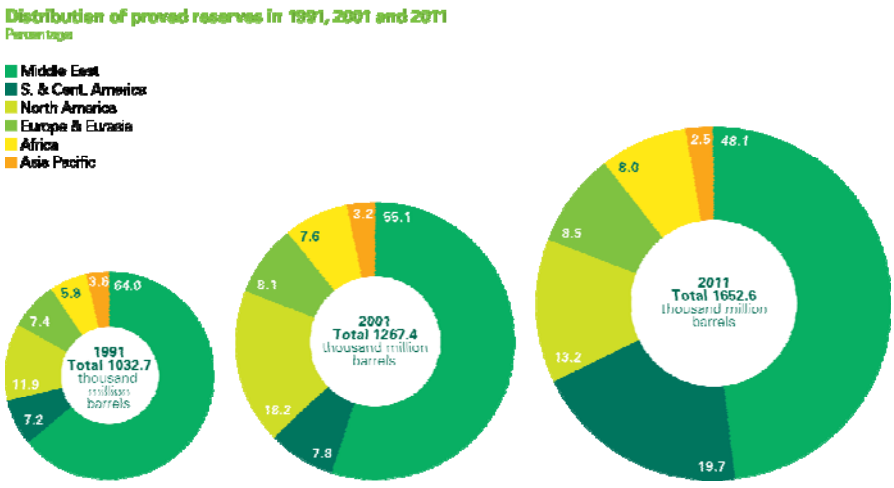
Oil reserves-to-production (R/P) ratios



World proved oil reserves at the end of 2011 reached 1652.6 billion barrels, sufficient to meet 54.2 years of global production. The continuing increase in official Venezuelan reserves pushed the South & Central American R/P ratio above 100. The large increase in Middle Eastern production reduced the region's R/P ratio despite an increase in reserves; the region holds 48.1% of global proved reserves.

BP Statistical Review of World Energy 2012

Distribution of proved oil reserves



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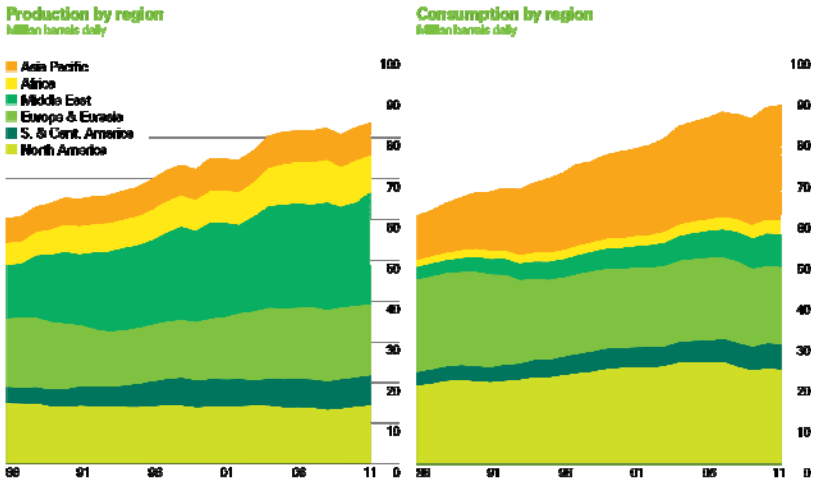
Oil production/consumption by region 2011



World oil production increased by 1.1 million b/d in 2011, with OPEC accounting for nearly all of the increase despite a 1.2 million b/d reduction in Libyan production. The US had the largest growth in non-OPEC supply for a third consecutive year. World oil consumption increased by roughly 600,000 b/d. All of the net growth came from emerging economies in Asia, South & Central America, and the Middle East, offsetting declines in Europe and North America.

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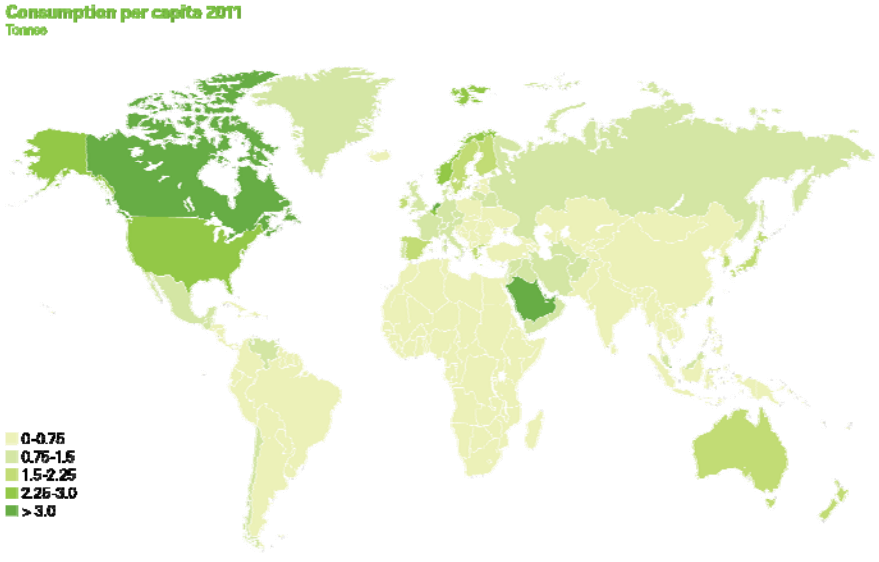
Oil consumption per capita 2011



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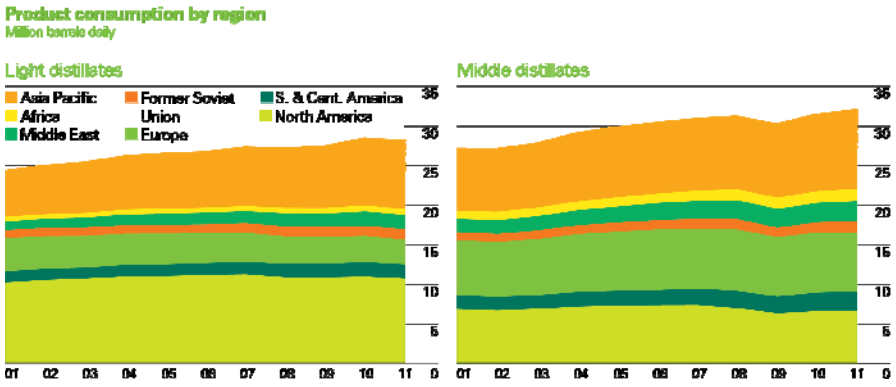
Oil product consumption by region



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Oil product consumption by region

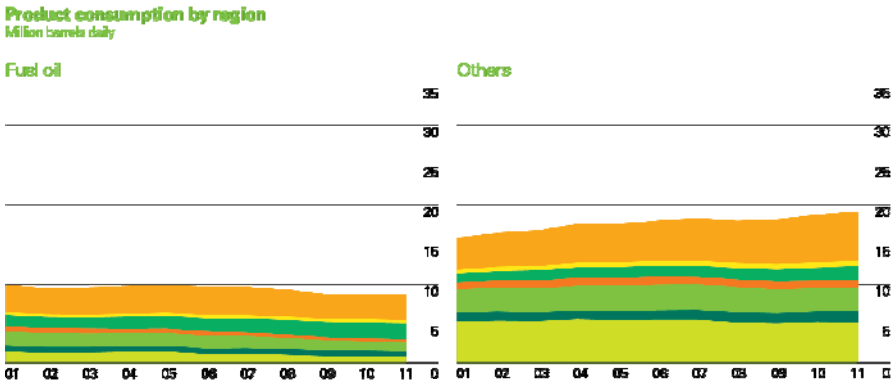

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Chart of Rotterdam & Gulf Coast product prices

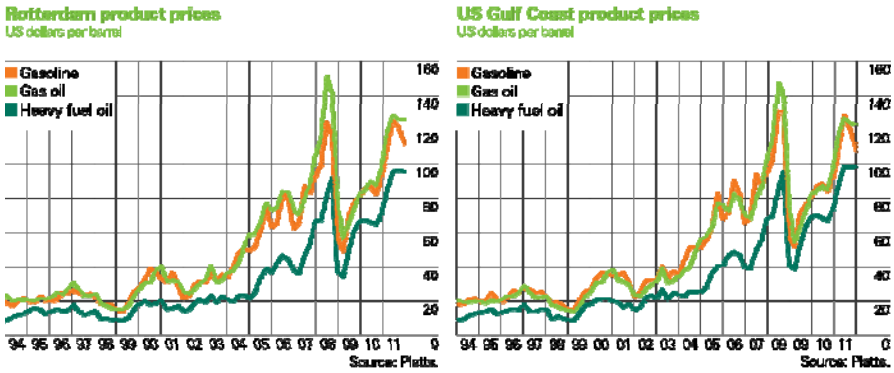

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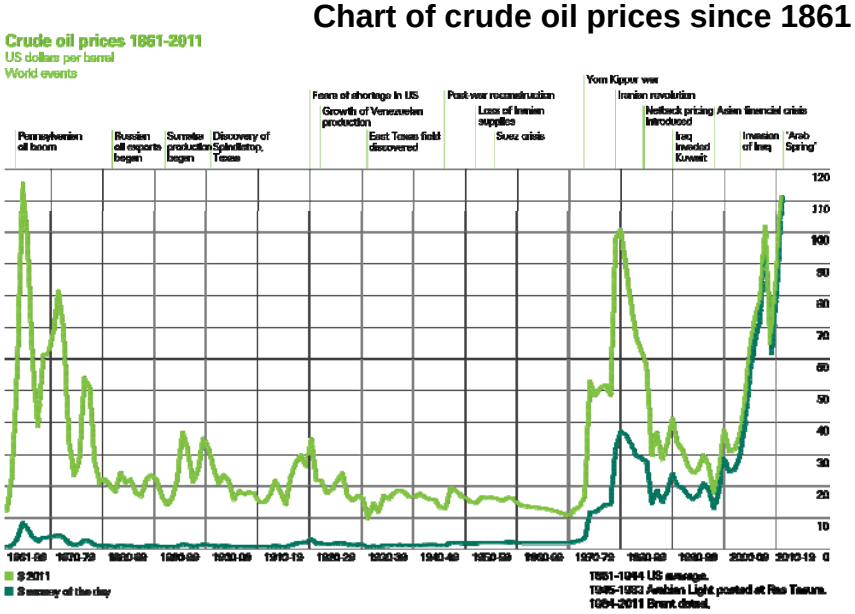
Chart of crude oil prices since 1861



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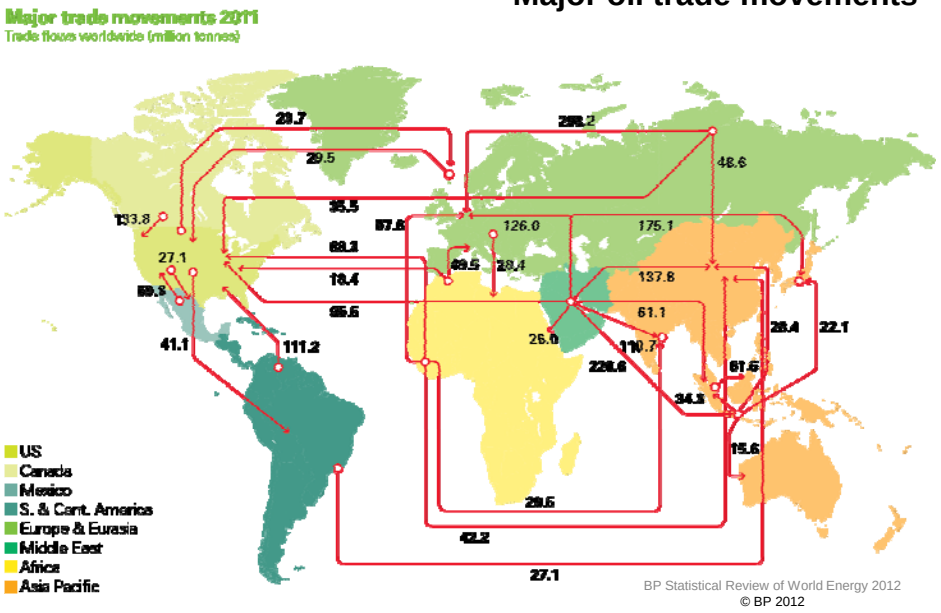
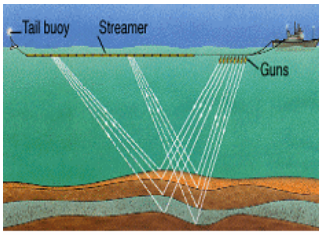
Major oil trade movements

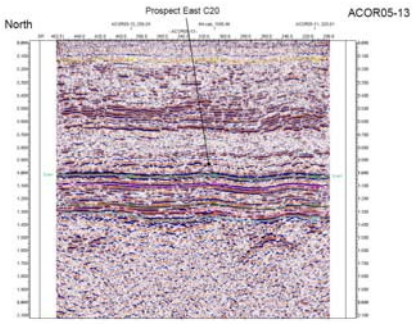


Finding oil - Exploration

- Remote sensing
- Surface geology
- Magnetic survey
- Gravity survey
- Seismic Survey



Seismic survey: sound wave propagation



Drilling

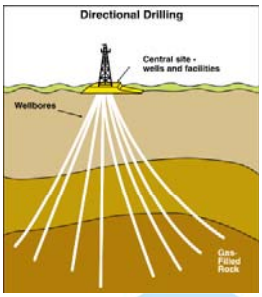
- Percussive drilling used in Han Dynasty to extract natural gas in Sichuan
- Rotary drilling – first use in Texas in 1895, but not dominant until 1950s
- Roller-cone drill bits – patent in 1909

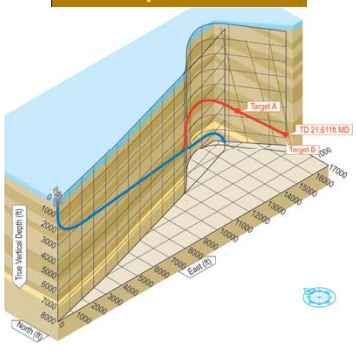
"consisted of 2 frusto-conical shaped rollers having longitudinally extending chisel teeth that disintegrate or pulverise the material with which they come in contact and thus form a round hole in said material when the head of the drill revolves"

- Major step was development of directional drilling in 1920s

Directional Drilling

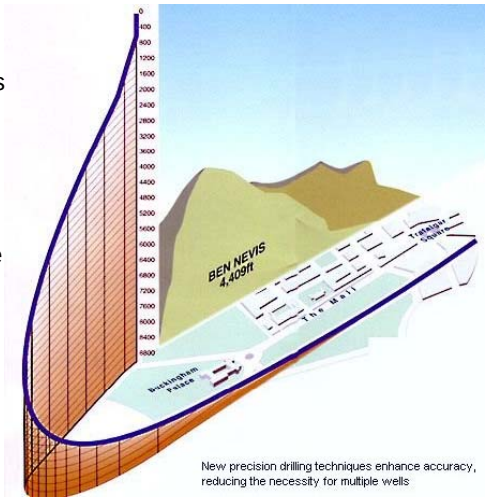
- Early wells drilled down vertically but started to deviate
- 10º deviation at 3km depth is 500m off vertical – could be into someone else's reservoir!
- Developed directional drilling
- First horizontal drilling in 1920 in Texas – but not commercial success until the 1980s
- 2-3 times more expensive than vertical wells but can enhance production by 15 – 20 times
- Horizontal wells open new production prospects in sandy reservoirs and in formations with water or gas problems or low permeability





Directional drilling

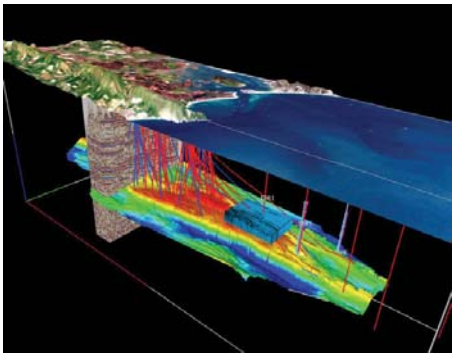
- Multiple wells from artificial sources
- Inaccessible locations
- Complicated reservoirs
- Problem formations (e.g. salt dome drilling)
- Sidetracking
- Relief wells



EG5066 Energy Technologies: current issues & future directions

Extended drilling

- Extended reach drilling is where the horizontal component is >2x vertical
- BP Wytch Farm in Dorset in 1999
  - Vertical well – 1638m
  - Horizontal – 10,728m
  - Goes from land out to reservoir under Poole Bay

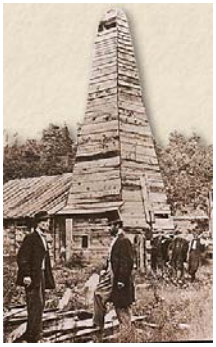


EG5066 Energy Technologies: current issues & future directions

Developments in Drilling Rigs

First oil well in USA -Drake Oil well, Titusville, Pennsylvania 1859

First offshore well in USA off Southern California in 1897



Spindle top gusher 1907

First Submersible rig Breton Rig 20 1949

Mr Charlie Drilling Rig 1953

First semi-submersible Bluewater 1 in Gulf of Mexico 1961

Developments in Drilling Rigs

Discovery class drill ships

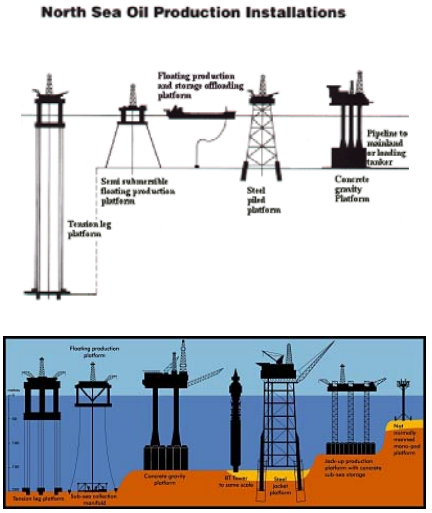
- Allow drilling in water
- Developed in 1970s
- By 2006 there were 650 worldwide
- Discovery deep seas – 5th generation
- Works in ultra-deep waters (>1.5 km (5000 ft)

Jack 2 test well in Gulf of Mexico

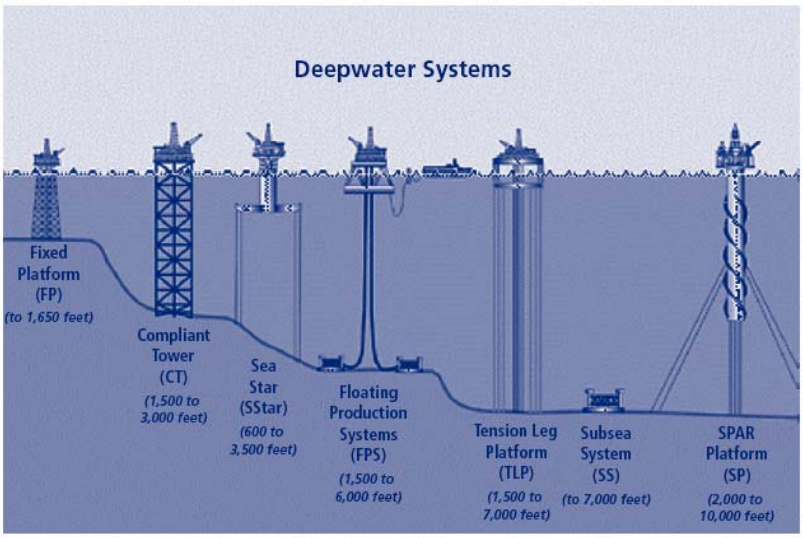
- 282 km offshore
- Water 2.1 km deep
- Well depth 6 km
- Total drilling depth 8.59km
- Field estimated at 3 – 15 billion – 50% of US oil reserves!

Production Platforms – Offshore Operations

Oil production platform technology developed as operations went into deeper waters. As water depths became greater then move from fixed to floating platforms and now the technology is moving to operations run on the sea floor (subsea) with connection via risers to surface floating vessels. Autonomous systems are the future.

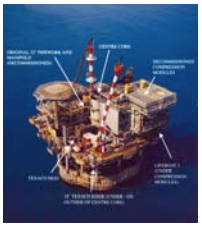


Source: Oil and Gas UK



Developments in Drilling Rigs – Offshore Operations


Jack-up rig


Concrete gravity platform


Steel jacket platform


Semi-submersible


modu


Floating Production & Storage

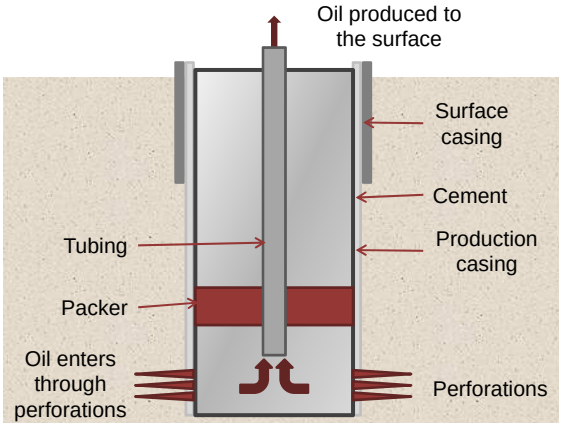

Drill ship

Developments in Drilling Rigs – Offshore Operations

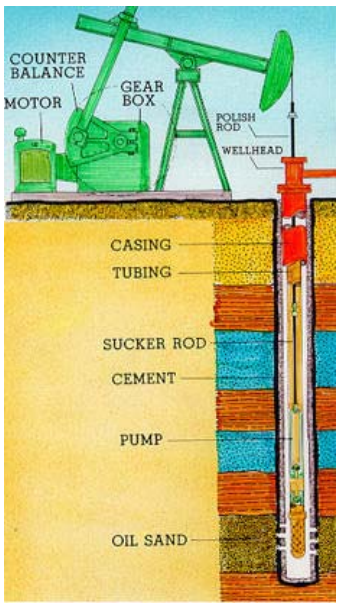

Mars tension-leg platform
Before

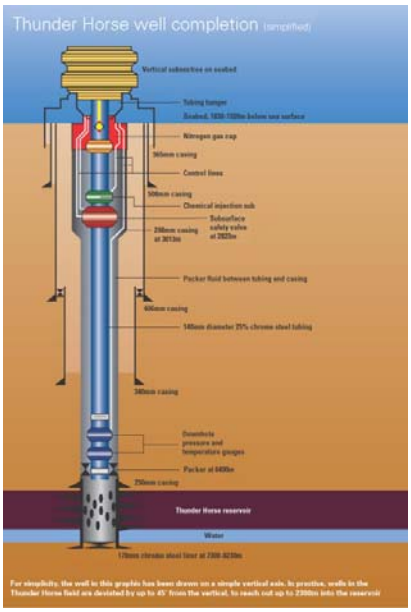

After Katrina (2005)

The Oil Well



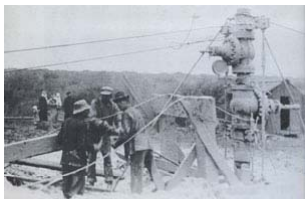
Oil Wells

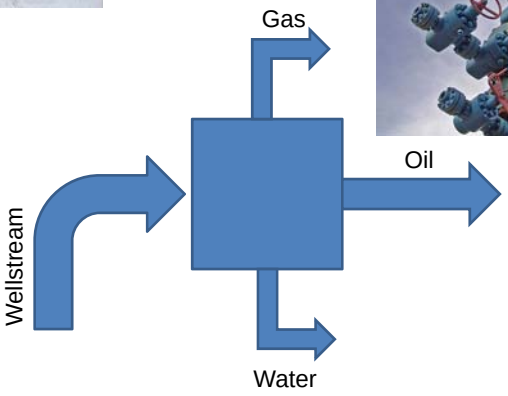




Source: BP

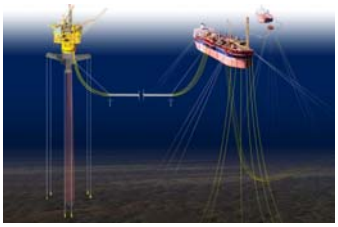
Processing





Topside Operations

- Offshore production platforms/FPSO collect the hydrocarbons produced under the seabed by means of specially designed flow-lines and risers.
- The platform also contains the necessary monitoring & control equipment, and gear for furnishing electric and/or hydraulic power to the subsea equipment installed at the various field wells.

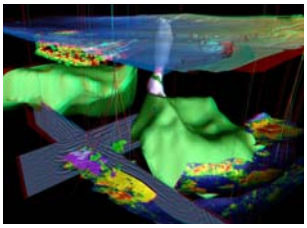


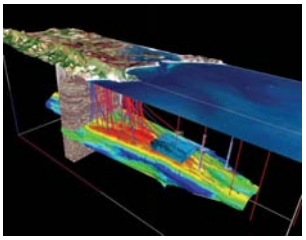
Operations

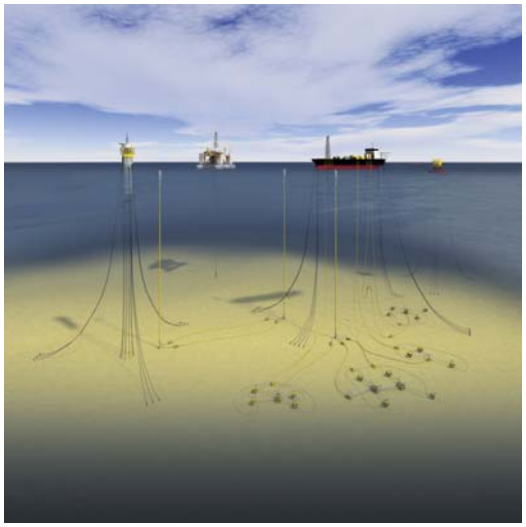
- Well control
- Support for well work-over equipment
- Separation of gas, oil, water, paraffin's/waxes, sand
- Support for pumps/compressors required to transport product to shore or re-injection of associated gas back into the well to enhance production
- Power generation
- Crew accommodation

Technological advances

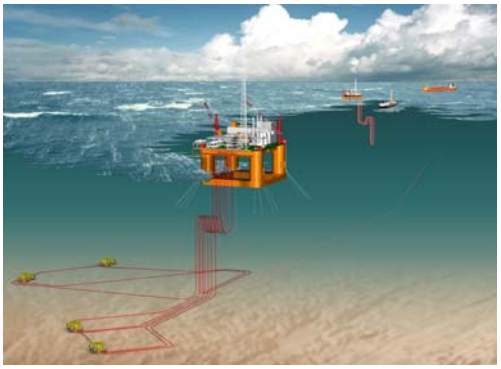
- 4D seismic
- Directional drilling
- Sub-sea facilities

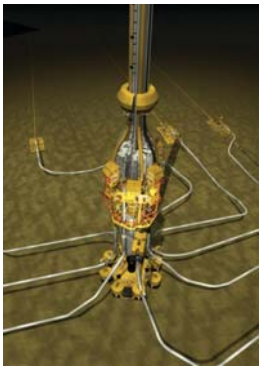


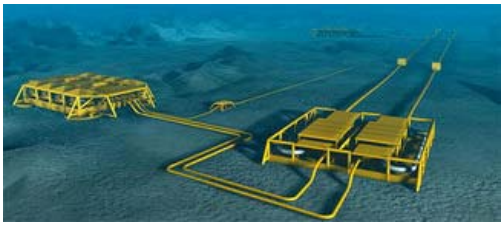


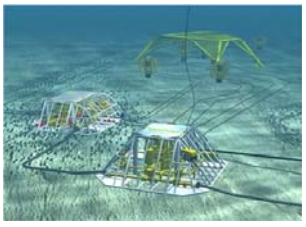


Subsea Operations









Enhanced Oil Recovery

- Generic term for techniques for increasing the amount of crude oil that can be extracted from an oil field
  - Primary & Secondary recovery – 20 – 40%
  - EOR – 30 – 60%
- AKA tertiary oil recovery

- Different techniques:
- Gas injection – miscible displacement*
- Chemical injection – chemical flooding*
- Ultrasonic stimulation
- Microbial injection
- Thermal recovery (cyclic steam, steam flooding, fireflooding)*

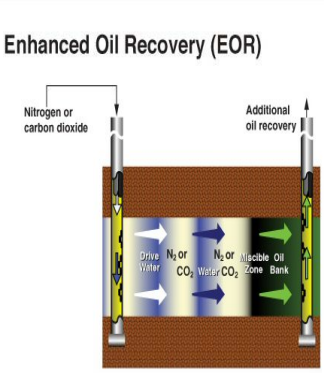
Enhanced Oil Recovery

Optimal application depends on:

- Reservoir temperature
- Pressure
- Depth
- Permeability
- Residual oil and gas saturation
- Porosity
- Oil API gravity
- Oil viscosity

Enhanced Oil Recovery – Gas injection

- Most common method
- A gas injected into the oil-bearing stratum under high pressure
- Pressure pushes the oil into the pipe and to the surface
- Method sometimes aids recovery by reducing the viscosity of the crude oil as the gas mixed with it
- Gases used – CO_2, natural gas, nitrogen
- With CO_2 50 – 66% of gas returns to surface with oil, then separated and re-injected



Enhanced Oil Recovery – Chemical Injection

- Several methods proposed:
- Injection of polymers
  - Either to reduce the crude oil's viscosity
  - Or increase the viscosity of water injected to force oil out
- Surfactants (such as petroleum sulphonates or biosurfactants such as rhamnolipds) to lower the interfacial pressure or capillary pressure impeding oil droplets moving through the reservoir
- Application limited by cost of chemicals and their loss by adsorption onto rock formation

Enhanced Oil Recovery

Ultrasonic stimulation

- Use high-powered ultasonic vibrations from a piezoelectric vibration unit lowered into the drillhead to shake the oil droplets from the rock matrix

Microbial injection

- Strains of microbes discovered & developed (GM) which:
  - Partially digest long hydrocarbon molecules
  - Generate biosurfactants
  - Emit carbon dioxide and then act like gas injection technique
- Not much used as rather expensive
- Used in Beverly Hills Oil Field, California

Enhanced Oil Recovery

Thermal Recovery

- Crude oil heated to reduce its viscosity and increase the flow – different techniques used to improve seep efficiency & displacement efficiency:
- Cyclic steam injection
- Steam drive
- In situ combustion

Solar thermal EOR

- Uses concentrated solar power to produce steam
- Used during day, natural gas at night
- Replaces 20% of natural gas used for EOR in California.
- Example plants:
  - McKittric, California
  - Coalinga, California (29MW solar to steam)
  - Oman

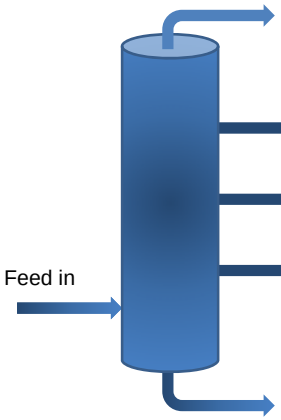
Enhanced Oil Recovery

Encana run Weyburn Oil Field in southern Skatchewan, Canada

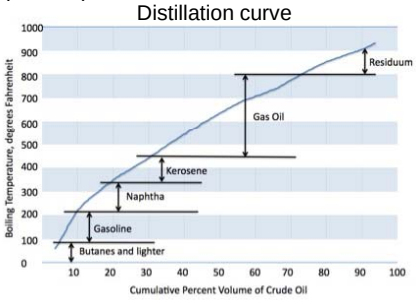
- A CO_2-EOR project
- Projected to inject net 18 million tonnes of CO_2
- Recover an additional 130 million barrels of oil
- Extending life of field by 25 years

Oil refining

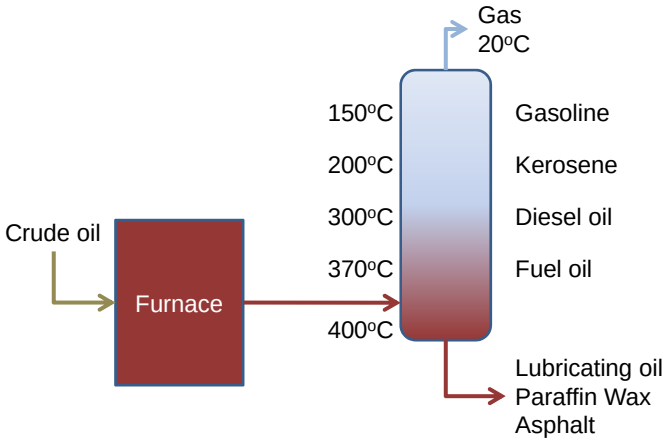
Oil Distillation



Distillation curve



Oil Distillation



Oil Refining

Major products – three main categories:

- Light distillates (LPG, gasoline, naphtha)
- Middle distillates (kerosene, diesel)
- Heavy distillates and residuum (heavy fuel oil, lubricating oils, wax, tar)

Main products

- Liquid petroleum gas (LPG)
- Gasoline (petrol)
- Naphtha
- Kerosene and related jet aircraft fuels
- Diesel fuel
- Lubricating oils
- Paraffin wax
- Asphalt & tar
- Petroleum coke

Oil Distillation

Fraction	Temperature	Fuel type
Light	7- 200^{o}C	Petrol Jet fuel Kerosene Feedstock for petrochemicals
Middle	200 – 350^{o}C	Diesel fuel Gas oil
Heavy	>350^{o}C	Marine diesel Fuel oil
Residuals		Paraffin waxes Lubricating oils Bitumen for road making Petroleum coke

Refinery Operations

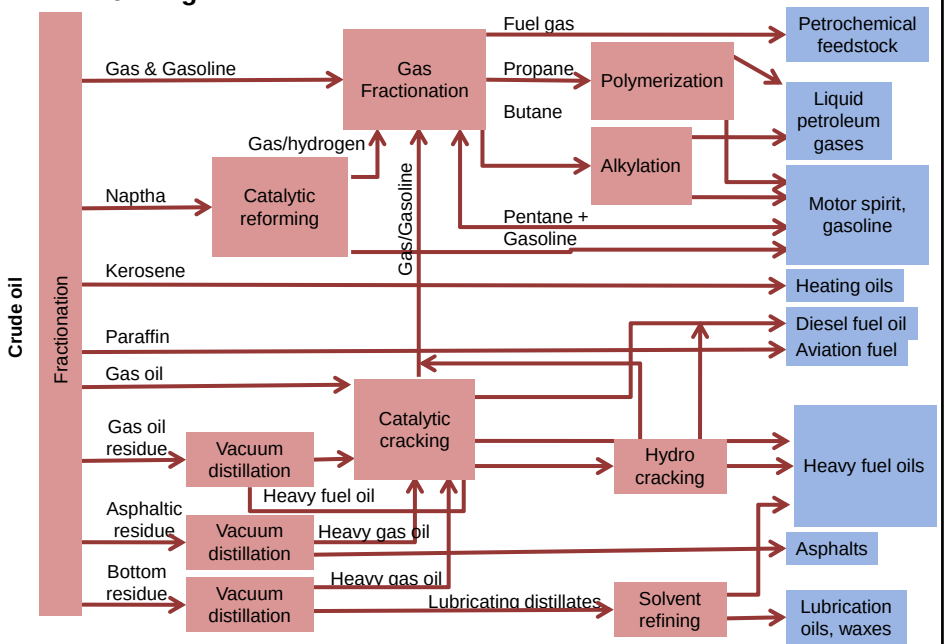
Fractionation (distillation)
Separation of crude oil in atmospheric and vacuum distillation towers into groups of hydrocarbon compounds or differing boiling-point ranges – “fractions” or “cuts”

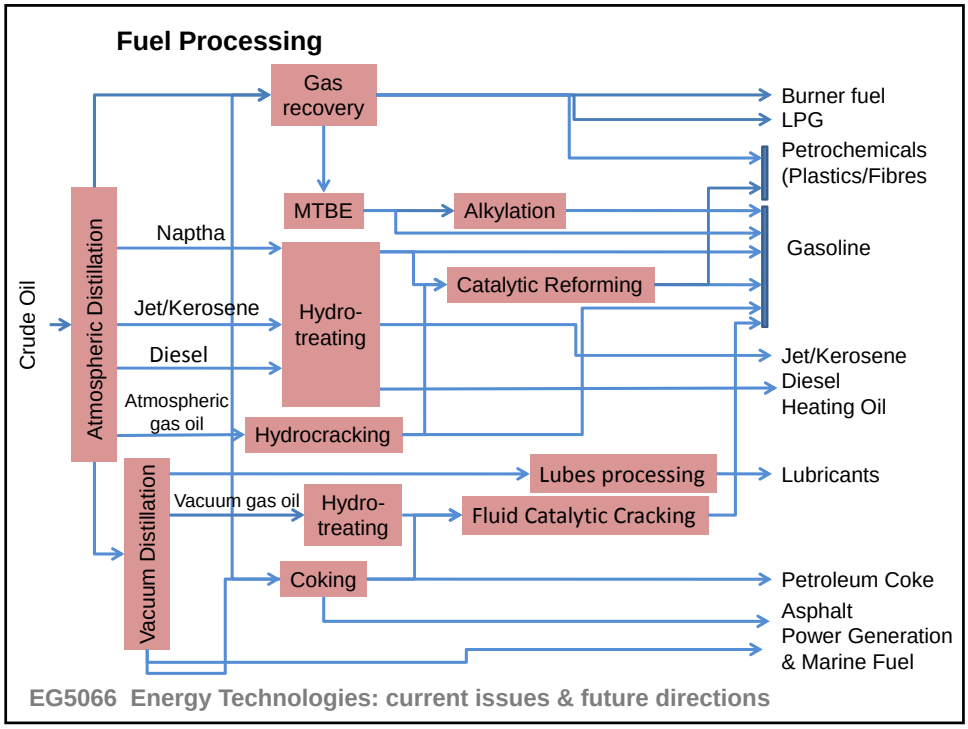
Light oil processing
Prepares light distillates through rearrangement of molecules using isomerization and catalytic reforming or combination processes such as alkylation and polymerization

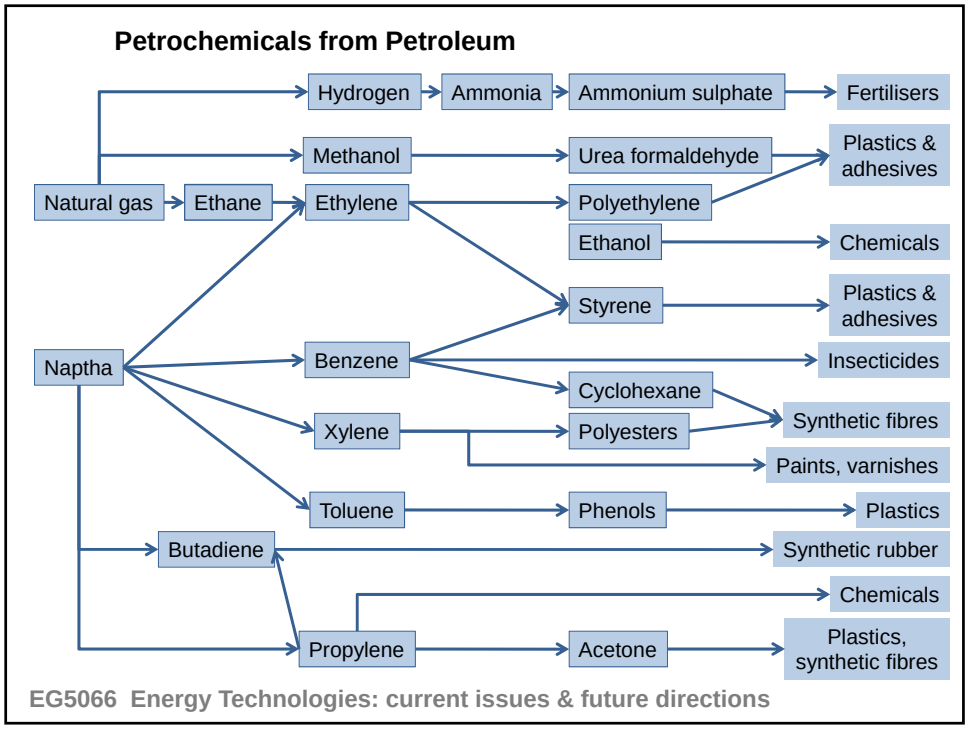
Heavy oil processing
Changes the size and/or structure of hydrocarbon molecules through thermal or catalytic cracking processes

Treatment and environmental protection processes
Chemical or physical separation such as dissolving, absorption or precipitation

Refining




Fuel Processing
Crude Oil
Atmospheric Distillation
Vacuum Distillation
Gas recovery
MTBE
Alkylation
Naptha
Jet/Kerosene
Diesel
Atmospheric gas oil
Hydro-treating
Catalytic Reforming
Hydrocracking
Vacuum gas oil
Hydro-treating
Fluid Catalytic Cracking
Lubes processing
Coking
Burner fuel
LPG
Petrochemicals (Plastics/Fibres
Gasoline
Jet/Kerosene
Diesel
Heating Oil
Lubricants
Petroleum Coke
Asphalt
Power Generation & Marine Fuel
EG5066 Energy Technologies: current issues & future directions


Petrochemicals from Petroleum
Natural gas
Naptha
Ethane
Hydrogen
Ammonia
Ammonium sulphate
Fertilisers
Methanol
Urea formaldehyde
Plastics & adhesives
Ethylene
Polyethylene
Ethanol
Chemicals
Styrene
Plastics & adhesives
Benzene
Insecticides
Cyclohexane
Xylene
Polyesters
Synthetic fibres
Paints, varnishes
Toluene
Phenols
Plastics
Butadiene
Synthetic rubber
Chemicals
Propylene
Acetone
Plastics, synthetic fibres
EG5066 Energy Technologies: current issues & future directions

Typical Yield from a Barrel of Oil

Product	USA	Europe/Asia
Propane/butane	10%	10%
Gasoline	50%	25%
Jet fuel	10%	10%
Diesel/heating oil	25%	40%
Heavy fuel oil	5%	15%

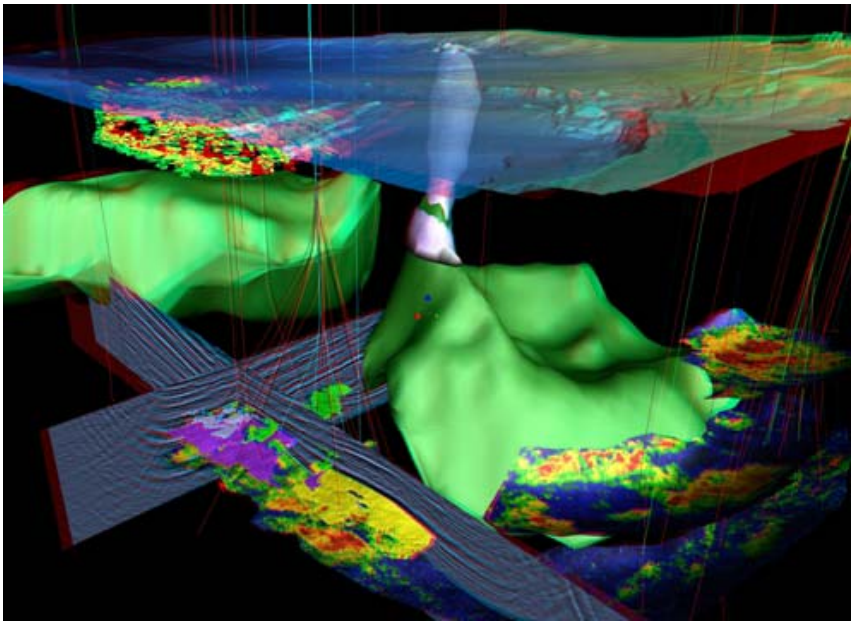
Source: Exxonmobil

Oil Refinery Capacity (Thousands of barrels per day)

Region	1980	1990	2000	2010
N America	21982	19195	19937	21008
S & Central America	7251	6009	6271	6653
Europe & Eurasia	32136	27808	25278	24435
Middle East	3528	5260	6491	7923
Africa	2102	2804	2897	3192
Asia Pacific	12364	13470	21468	28405
World	**79363**	**74546**	**82352**	**91616**
China	*1805*	*2892*	*5407*	*10302*
India	*557*	*1122*	*2219*	*3703*

Oil Refineries throughput
(Thousands of barrels per day)

Region	1980	1990	2000	2010
North America	16503	16483	18195	17740
S & Central America	5249	4301	5324	4615
Europe & Eurasia	24398	22689	19202	19624
Middle East	2427	4470	5430	6484
Africa	1439	2171	2188	2457
Asia Pacific	9227	11184	18083	24263
World	**59243**	**61297**	**68424**	**75188**
China	*1510*	*2153*	*4218*	*8571*
India	*502*	*1038*	*2039*	*3899*



EG5066 Energy Technologies: current issues & future directions

Natural Gas

Natural Gas

History

1000 BC Mount Parnassus, Greece

500 BC China – first to discover and use natural gas. Bamboo shoot pipeline to transport gas which was burnt to desalinate water

100 AD Persia – first recorded use of natural gas in the home

1785 UK – first commercial use to light houses

1803 UK – gas lighting system patented

1812 UK – first gas company founded in London

1821 USA – first well for natural gas in Fredonia, NY – used for house lighting

1826 UK – first gas cooker devised

Natural Gas

Consists primarily of methane (CH_4) but sometimes contains significant quantities of:

- Ethane
- Propane
- Butane
- Pentane
- And CO_2, nitrogen, helium and H_2S

- Found associated with crude oil
- Isolated natural gas reservoirs
- In coal beds – coal bed methane
- As methane clathrates
- Created by methanogenic organisms in marshes, bogs and landfills

Natural Gas

- Produced commercially from oil fields & natural gas fields
- At lower temperatures (shallower depths) more oil than gas
- At higher temperatures (deeper) more gas than oil
- Deeper you go the purer the natural gas
- Sour gas, tight gas, shale gas and coal bed methane

- An important fuel source
- Major feedstock for fertilisers
- A potent greenhouse gas

Components of Natural Gas

- Methane (CH_4)
- Ethane (C_2H_6)
- Propane (C_3H_8)
- Normal butane (n-C_4H_{10})
- Isobutane (i-C_4H_{10})
- Pentanes
- Acid gases – CO_2, H_2S, mercaptans – methanethiol (CH_3SH) and ethanethiol (C_2H_5SH)
- Other gases – Nitrogen (N_2) and Helium (He)
- Water – water vapour and liquid water
- Some natural gas condensate (aka casinghead gasoline or natural gasoline)
- Crude oil
- Mercury

Types of Raw Natural Gas Wells

Three types of gas wells:

Crude oil wells – known as *associated gas* either:

- Separate
- Dissolved in crude oil

Natural gas from gas wells with little or no oil – known as *non-associated gas*

Condensate wells produce raw natural gas & very low density liquid hydrocarbon – natural gas condensate

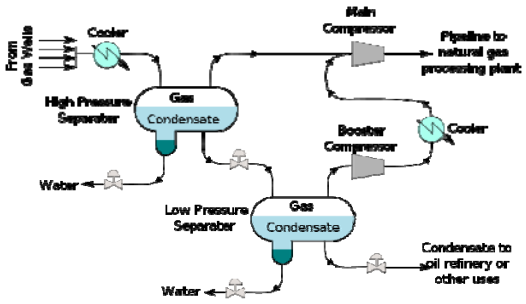
Natural Gas Condensates

- A low density mixture or hydrocarbon liquids present as gaseous components in raw natural gas
- Condense out if temperature reduced below hydrocarbon dewpoint temperature of raw gas
- Each wet gas field has its own unique gas condensate composition:
  - H_2S
  - Mercaptans
  - CO_2
  - Straight chain alkanes (C_2 – C_{12})
  - Cyclohexanes
  - Aromatics (benzene, toluene, xylenes, ethylbenzene)

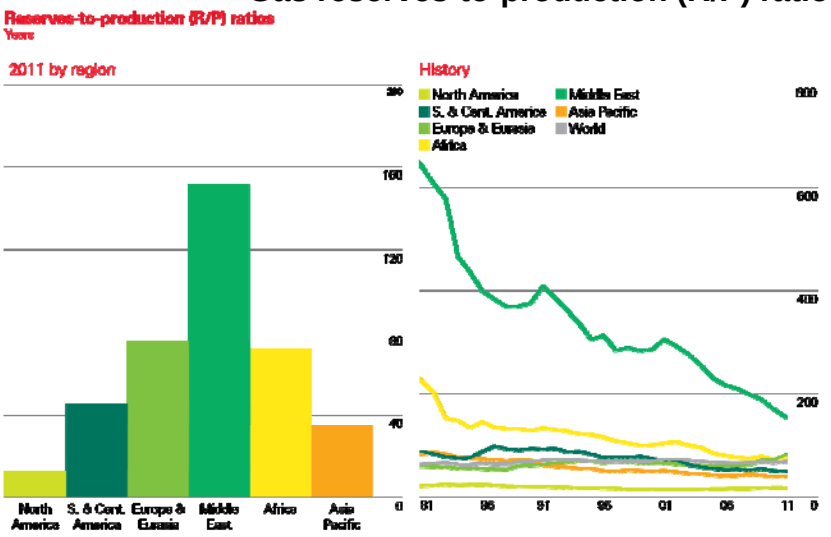
Natural Gas Condensates

Separation technique

- Raw gas cooled below hydrocarbon dewpoint
- Gas condensates condense out
- The condensates passed through high pressure separator where water and raw natural gas separated
- Condensates passed to lower pressure vessel and flash vaporised



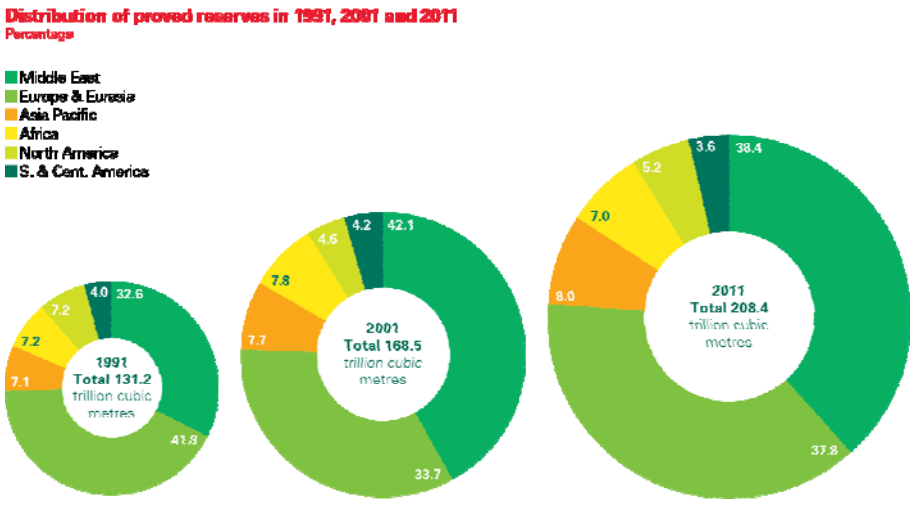
Gas reserves-to-production (R/P) ratios



World proved natural gas reserves at end-2011 were sufficient to meet 63.6 years of production. A large increase in Turkmen reserves pushed the R/P ratio for Europe & Eurasia to 76.9 years. The Middle East still holds the largest reserves (38.4% of the world total, compared with 37.8% for Europe & Eurasia) and has an R/P ratio of over 150 years.

BP Statistical Review of World Energy 2012

Distribution of proved gas reserves



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Natural Gas - reserves

Country	Gas Reserves 2011 (trillion m^3)	Share of world total (%)
Russia	44.6	21.4
Iran	33.1	15.9
Quatar	25.0	12.0
Turkmenistan	24.3	11.7
USA	8.5	4.1
Saudi Arabia	8.2	3.9
UAE	6.1	2.9
World	208.4	

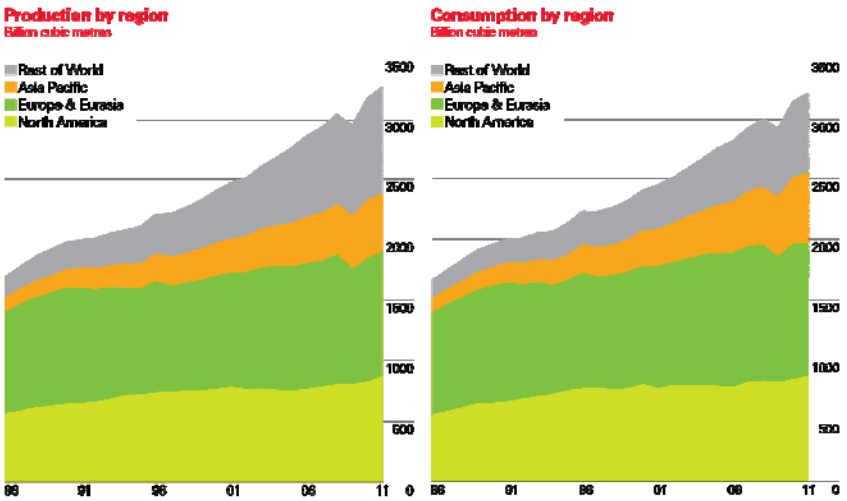
World's largest gas field

- North Field – offshore Qatar - 25 trillion m^3 gas in place

2nd largest

- South Pars Gas Field, Iran - 8 – 14 trillion m^3 in place

Gas production/consumption by region



World natural gas production increased by 3.1% in 2011. While the US saw the largest national increase, the Middle East recorded the largest regional increment to production. Production growth in Russia and Turkmenistan was partly offset by a large decline in European production. Natural gas consumption increased by 2.2%, with below-average growth in all regions but North America. The European Union experienced the sharpest decline in natural gas consumption (–9.9%) on record.

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Gas consumption per capita

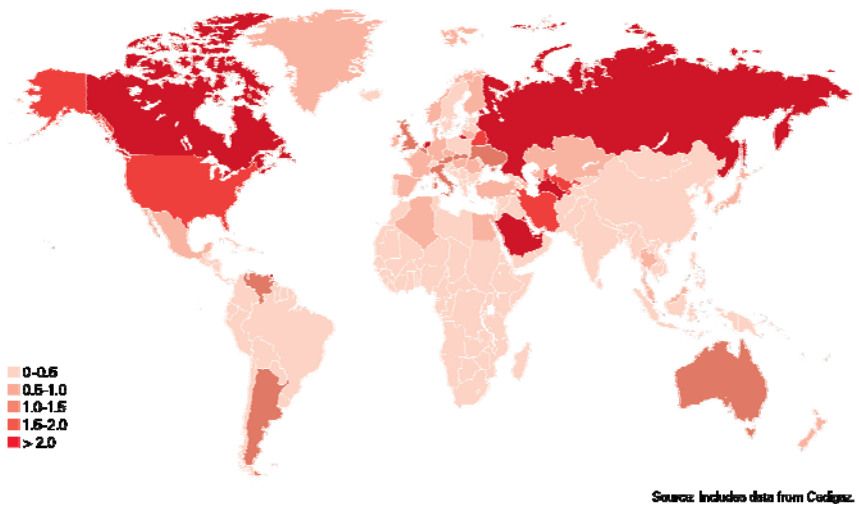

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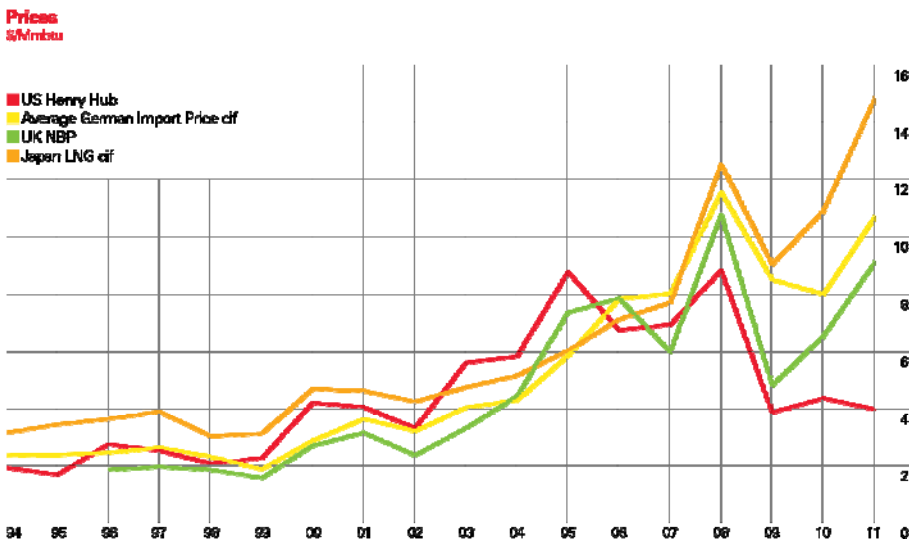
Chart of gas prices



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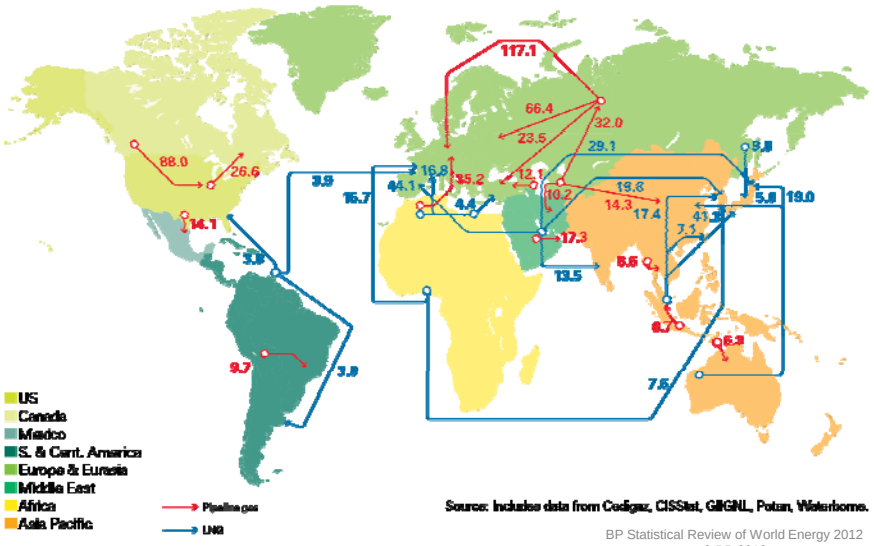
Major gas trade movements



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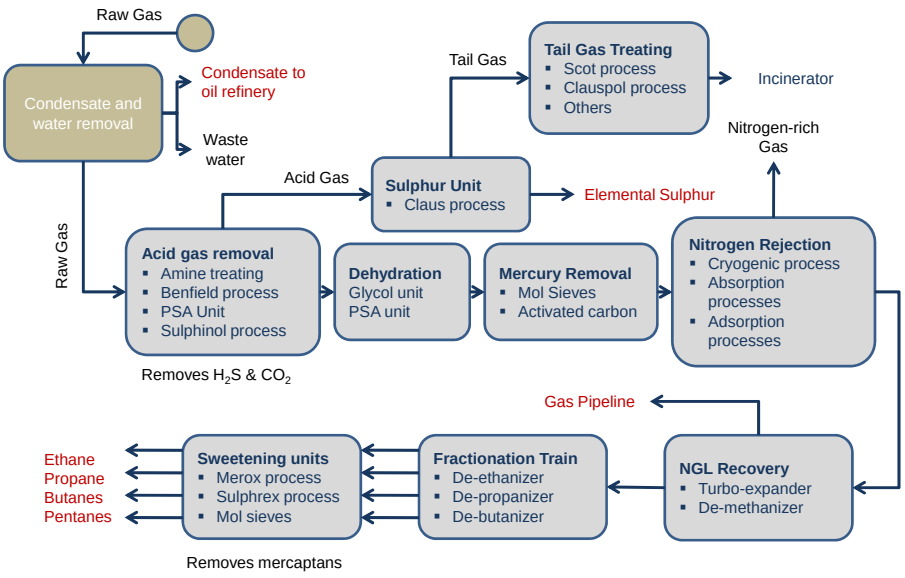
Flow Diagram - Natural Gas Processing Plant



Natural Gas