

History of the oil & gas industry and review of the natural gas markets



Constantinos Hadjistassou, PhD

Associate professor

Programme in Oil & Gas Engineering

University of Nicosia

Marine & Carbon Lab: www.carbonlab.eu

Sept., 2020



UNIVERSITY *of* NICOSIA

Course Outline

2

- OGEE-522 LNG Systems objectives, learning outcomes, expectations, syllabus and assessment
- History of the Oil & Gas (O&G) industry
- What is oil?
- What is natural gas?
- The O&G industry
- The (liquefied) natural gas markets

OGEE-522 LNG Systems objectives

3

- Historical perspective of O&G industry. NG & LNG markets. Focus on major producers, importers, & companies;
- Elaborate on the natural gas purification process;
- Thermodynamics of natural gas compression;
- Present main NG liquefaction technologies: a) Classical cascade, b) Mixed-refrigerant, c) Pre-cooled mixed refrigerant;
- Present LNG storage facilities: above ground metal tanks, above/below surface concrete tanks, inground frozen earth tanks & mined caverns;
- Detail export & import facilities, p/lines, & floating storage;
- Explain LNG tanker designs, containment stms, gas boil-off issues;
- Safety considerations for LNG plants, floating storage & LNG transport

OGEE-522 LNG Systems syllabus

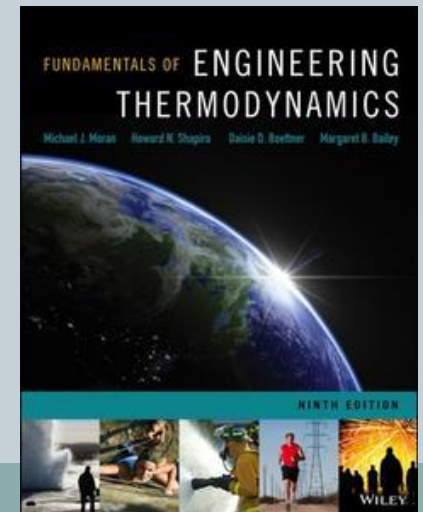
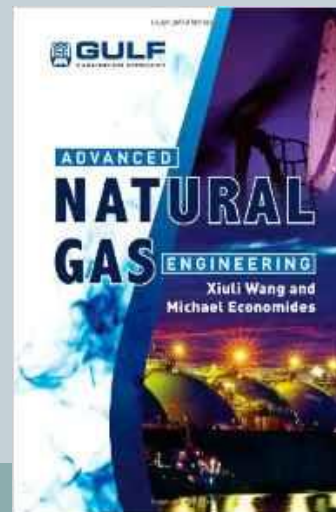
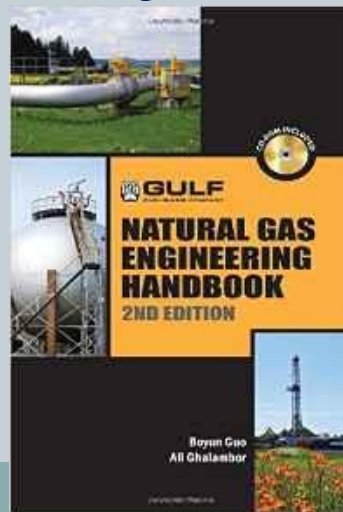
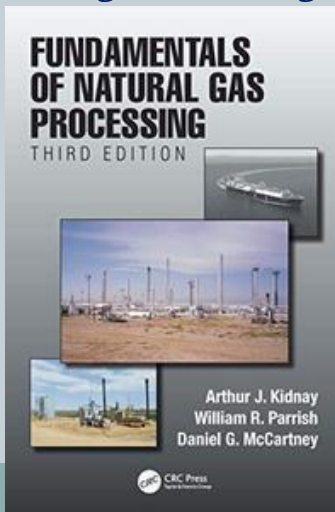
4

- Historical review of O&G industry, US, EU & Asian LNG markets;
- **Major LNG export players** (Qatar, Australia, USA) & **import countries** (Japan, South Korea, India, China);
- **NG processing** including **liquids** removal, **H₂O** & **gaseous** components;
- Liquefaction refrigeration cycles: a) **Classical cascade**, b) **Mixed-refrigerant**, c) **pre-cooled mixed refrigerant**;
- Characteristics of **above ground metal tanks**, **above or underground concrete tanks**, **inground frozen earth tanks** and **mined caverns**;
- **Export & import LNG facilities**, **floating storage** and **regas vessels**, **pipeline insulation**, **LNG carrier loading arms**, etc.;
- Particulars of **LNG tanker designs**, **containment stms**, **gas boil-off**;
- **Layout of LNG plants**, **LNG storage**, **particulars of LNG ships**;
- **Safety** matters confronting LNG infrastructure & LNG transport.

OGEE-522 LNG Systems– Textbooks

5

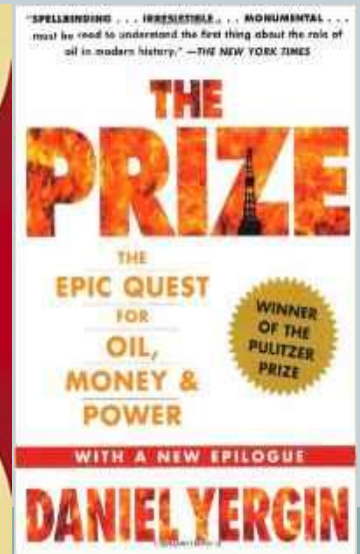
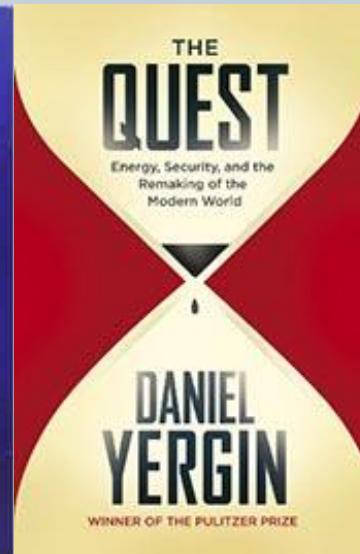
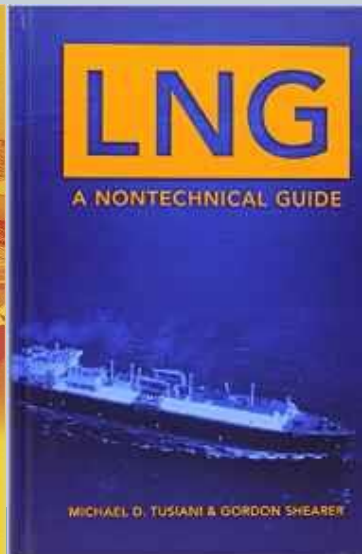
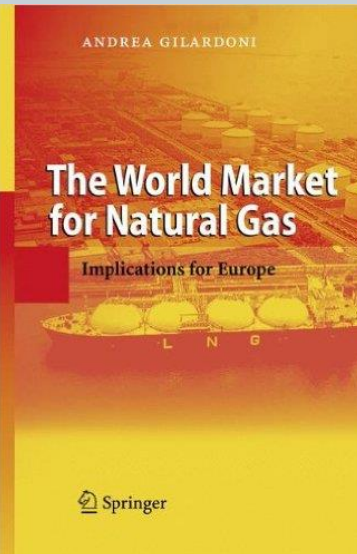
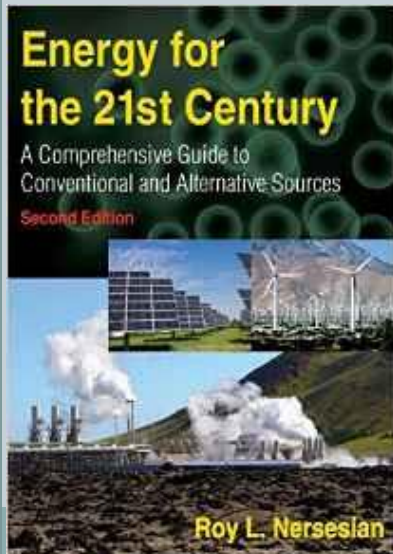
- Kidnay JA & Parrish RW “*Fundamentals of Natural Gas Processing*” 2020. ISBN13: 9781420085211, Taylor & Francis (Amazon UK: ≈€105)
- Guo B & Ghalambor A “*Natural Gas Engineering Handbook*” 2005 ISBN: 0976511339, Gulf Publishing Company
- Wang X & Economides JM “*Advanced Natural Gas Engineering*” 2009 ISBN: 9781933762388 , GPC
- Moran J., Shapiro N.M., Boettner D.D. & Bailey M.B. “*Fundamentals of Engineering Thermodynamics*,” 9th Ed., 2018, Wiley; 9781118412930



OGEE-522 LNG Systems– Textbooks (2)

6

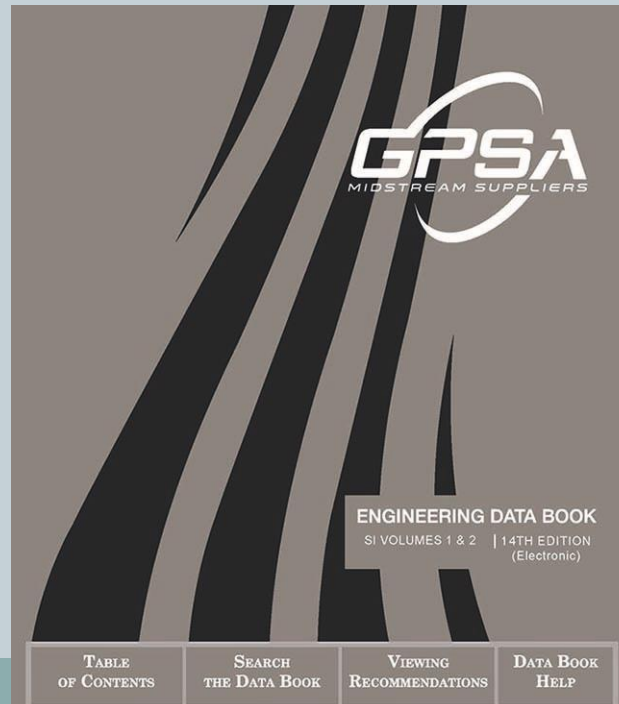
- Nersesian RL “*Energy for the 21st Century: A Comprehensive Guide to Conventional & Alternative Sources*,” 2nd Ed, 2010. #: 9780765624123
- Gilardoni A “*The World Market for Natural Gas: Implications for Europe*” 2008 ISBN: 9783540682004, Springer-Verlag
- Tusiani D. M. & Shearer G. “*LNG: A Nontechnical Guide*” 2007, 9780878148851
- Yergin D “*The Prize*” 2008, ISBN: 1439110123, Free Press



More (re)sources

7

- Gas Processors & Suppliers Association (GPSA), “*Engineering data book*”, 14th ed., 2017



OGEE-522 Assessment

8

- **Problem-sheet:** 15%
- **Assignment:** 5%
- **Final Exam** (comprehensive): 50%
- **Mid-Term Exam:** 25%
- **Class Participation:** 5%

Grading Policy

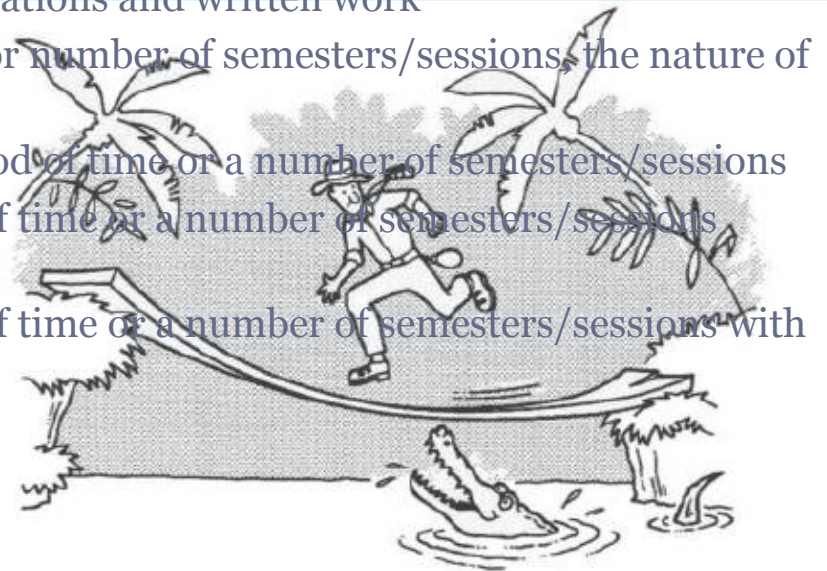
<i>Letter Grade</i>	<i>Meaning</i>	<i>Numerical Grade</i>	<i>Grade Points</i>
<i>A</i>	Excellent	93-100	4.0
<i>A-</i>		90-92	3.7
<i>B+</i>	Very Good	87-89	3.3
<i>B</i>		83-86	3.0
<i>B-</i>		80-82	2.7
<i>C+</i>	Good	77-79	2.3
<i>C</i>		73-76	2.0
<i>C-</i>		70-72	1.7
<i>D+</i>	Poor but Acceptable	67-69	1.3
<i>D</i>		63-66	1.0
<i>D-</i>		60-62	0.7
<i>F</i>	Failure	0-59	0.0

- **Pass mark:** >60%
- **Actual pass:** >73%

Plagiarism and cheating

9

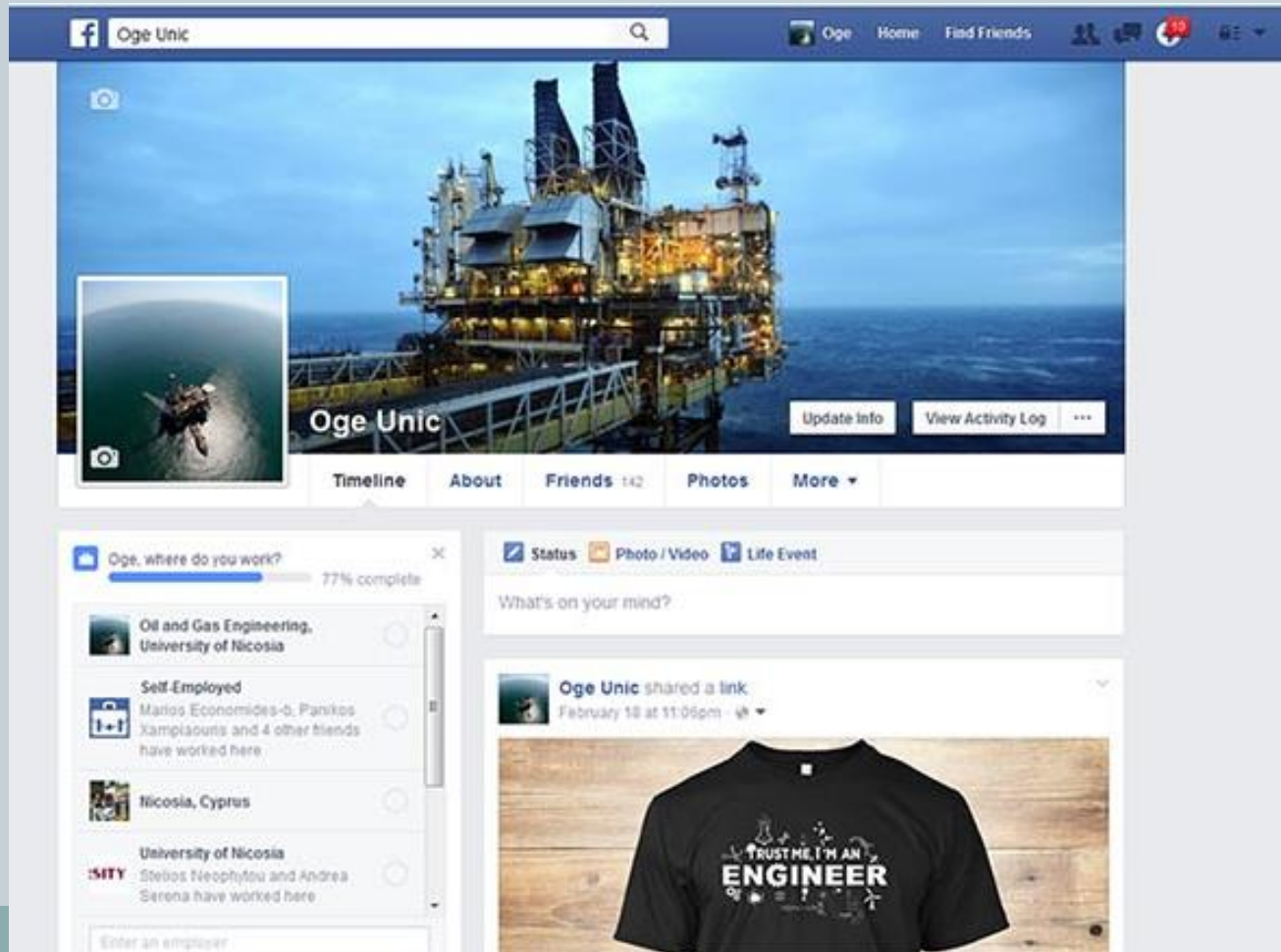
- Academic plagiarism and cheating related to examinations or written work is a *major offence*.
- Lecturer can decide to: **A**: To impose a penalty of up to 100% of mark deduction for the specific assessment or **B**: To refer the disciplinary offence to the Department Council
- **Penalties for Major Offences (including Cheating and Plagiarism)**
- These are as follows:
 - Oral reprimand
 - Written reprimand
 - Grade penalties for offences related to examinations and written work
 - Withdrawal of privileges for a period of time or number of semesters/sessions, the nature of which does not affect the students' education
 - Withdrawal of all student privileges for a period of time or a number of semesters/sessions
 - Suspension from the University for a period of time or a number of semesters/sessions without withdrawal of all student privileges
 - Suspension from the University for a period of time or a number of semesters/sessions with withdrawal of all student privileges
 - Dismissal from the University



Join us on Facebook

10

- <https://www.facebook.com/ogeunic>



Prelude FLNG

11

- Video

Petroleum (oil & gas) formation

12

- Natural occurring H/C Petroleum = πέτρα (rock, *Gr*) + oil (oleum, *Ltn*)
- Accumulation of organic matter (plankton, algae, marine life) with mud in sediments of river beds/lakes
- Immersing and decomposition of organic matter
- High pressure & temperature, bacterial action
- Million of years oil (&/or natural gas) forms
- Heating value of natural gas varies with inorganic compounds (N_2 , CO_2 , H_2S):
26.08MJ/m³ to 59.61MJ/m³



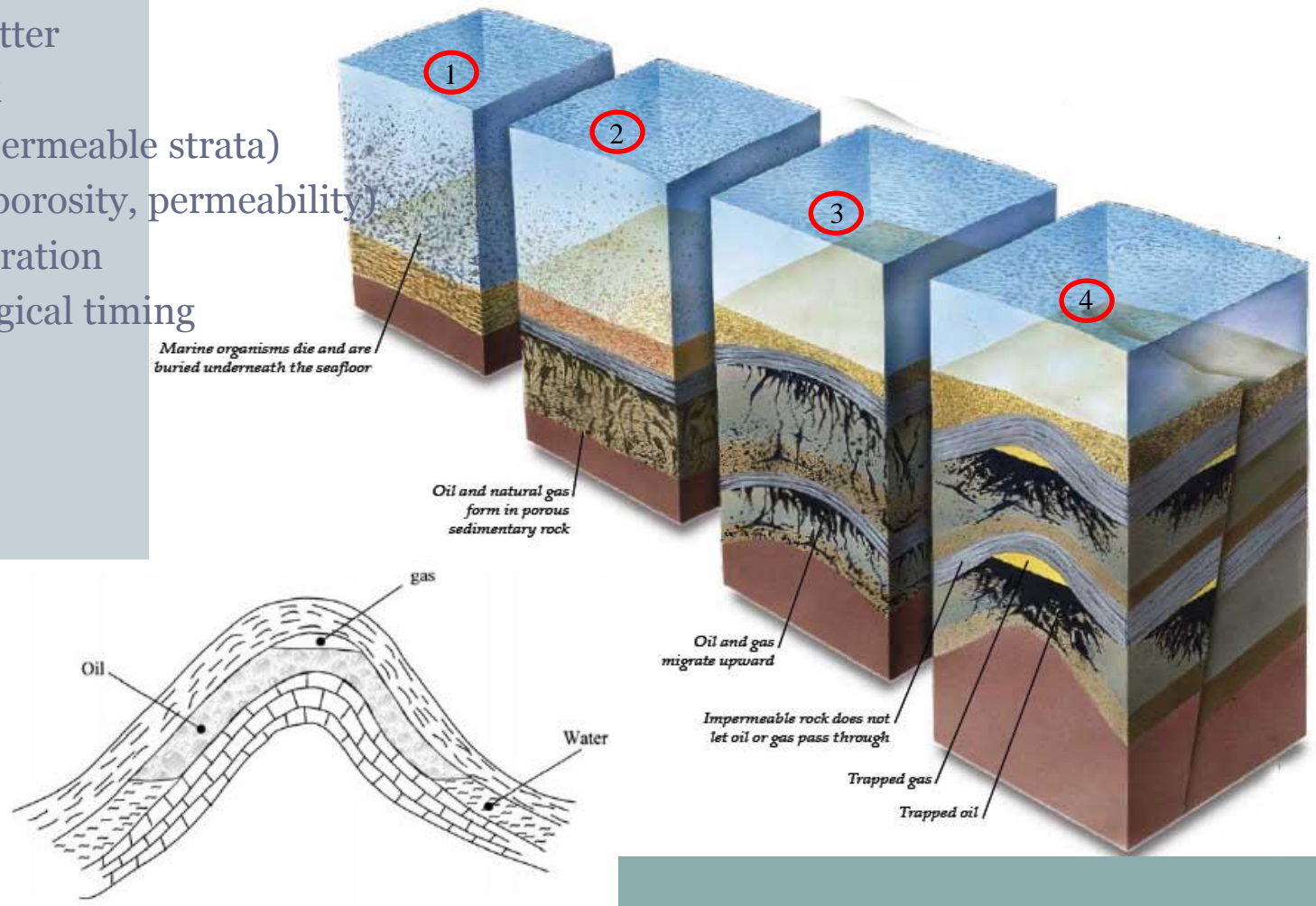
Bay of Biscay, France-Spain

Oil and natural gas systems

13

- Necessary prerequisites:

- Organic matter
- Source rock
- Rock cap (permeable strata)
- Reservoir (porosity, permeability)
- Oil/gas migration
- Right geological timing



Natural gas accumulations

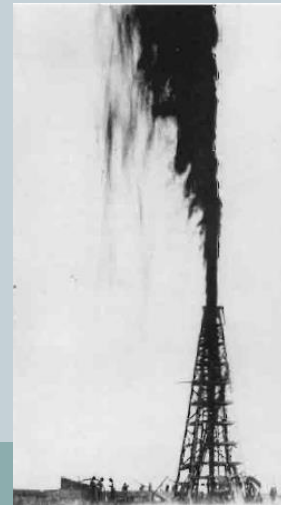
14

- Geological traps:
 - **Reservoirs**: a porous & permeable underground formation with individual bank of H/Cs confined by impermeable rock or water characterised by single pressure system;
 - **Fields**: area which consists of one or more reservoirs related to same structural feature
 - **Pools**: contain one or more reservoirs in isolated structures.
- 3 types of natural gases:
 - **Associated gas**: gas dissolved in oil
 - **Non-associated gas**: dry gas
 - **Gas condensates**: high content of liquid H/Cs
- Natural gas was once a by-product of oil wells (termed as nuisance)
- Natural gas are classified as:
 - **Conventional natural gas**: associated with oil or non-associated
 - **Gas in tight sands** with formations having porosities: 0.001 to 1 mdarcy (md)
 - **Gas in tight shales**. Shale is fissile, predominantly black, brown or greenish-gray
 - **Coal-bed methane** is found in minable coal beds at <1000m depth
 - **Geopressurised reservoirs**: due to collapsing strata reservoir pressure > expected pres.
 - **Gas hydrates**: snow-like solids which trap natural gas

History of the oil & gas industry

15

- **1859**: “Colonel” Drake, drills the first oil well in Pennsylvania, USA
- **1870**: John Rockefeller forms Standard Oil
- **1892**: Edison invents electricity
- **1896**: Ford builds the first automobile
- **1901**: Spindletop “gusher” is discovered in Texas
- **1908**: Anglo-Persian discovers oil in Iran
- **1911**: Standard Oil Trust is dissolved by supreme court



History of the oil & gas industry (2)

16

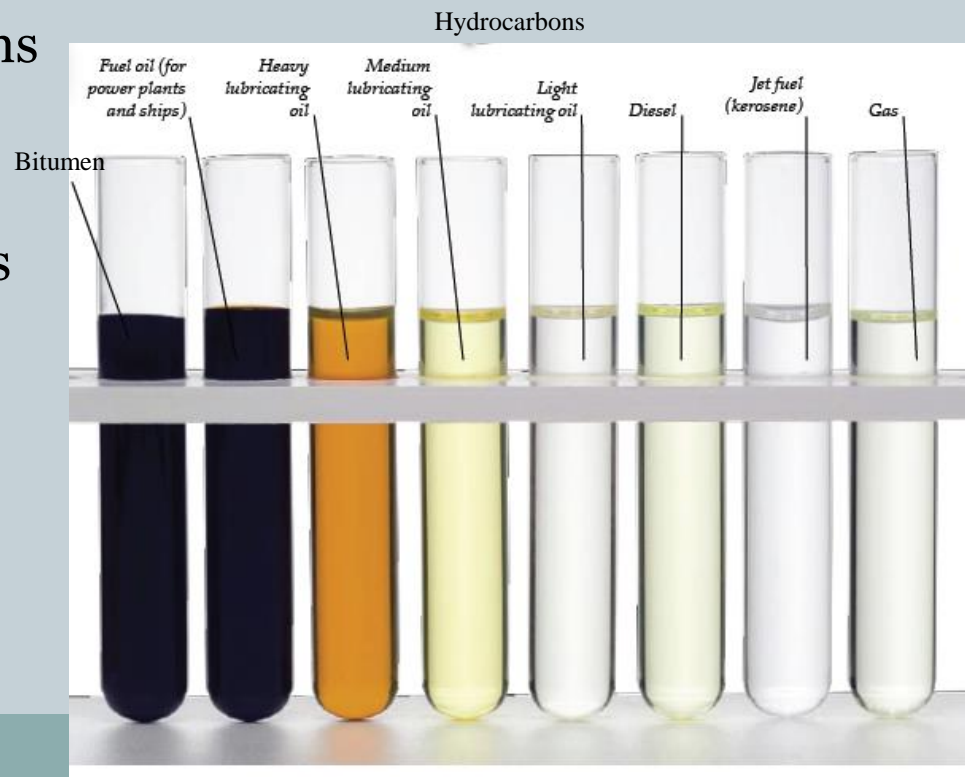
- **1938**: Oil is discovered in Kuwait & Saudi Arabia
- **1956**: Suez crisis— halts ship transits thru canal
- **1969**: Oil is found in North Sea (Ekofisk)
- **1972-3**: Arab-OPEC oil embargo
- **1979-81**: Khomeini ousts the Shah: oil price panic
- **1985**: oil glut sends oil prices tumbling
- **1990**: Iraq invades Kuwait
- **2002**: Oil found in Campos pre-salt



What is oil?

17

- Naturally occurring organic substance of H & C
- Petroleum = natural gas (Φ A) & (crude) oil
- Usually in liquid form. Exists in solid & gaseous states
- Could contain N, S, O
- Found in subterranean formations
- Combustible
- When burned it releases thermal energy & heat trapping emissions
- Raw material



Benefits from the use of O&G

18

- World economy depends on O&G
- Development tied to energy use
- 80% of oil used in transportation
- Ease of transport (liquid/gas)
- High energy density (Diesel: 38 MJ/L)
- Relatively safe – practical
- Petrochemicals
 - Plastics
 - Nylon
 - Cosmetics
 - Aspirin



Materials made from oil

19



Oil reserves

20

- Estimates: 6-8 trillion bbls (conventional), 6-8 trl. (non-conventional)
- 1 trillion barrels consumed since 1859
- World consumption: 31 bln bbls/year (2009)
- 19th century coal, 20th cent. oil, 21st cent. Natural gas & hydrogen
- 20th century O&G, and coal → 85% world energy mix
- Oil represents 40% of world energy mix (Rae, 2010)
- Boost in production from non-conventional sources



Non-conventional hydrocarbons

21

- Tar sands, Canada

- Area: 141,000 km² (15× Cyprus)
- Estimates: 178 bn of oil equivalent (boe)
- Production: 1.8 mbbl/d

- Shale oil & gas

- Hydraulic fracturing
- US Energy revolution

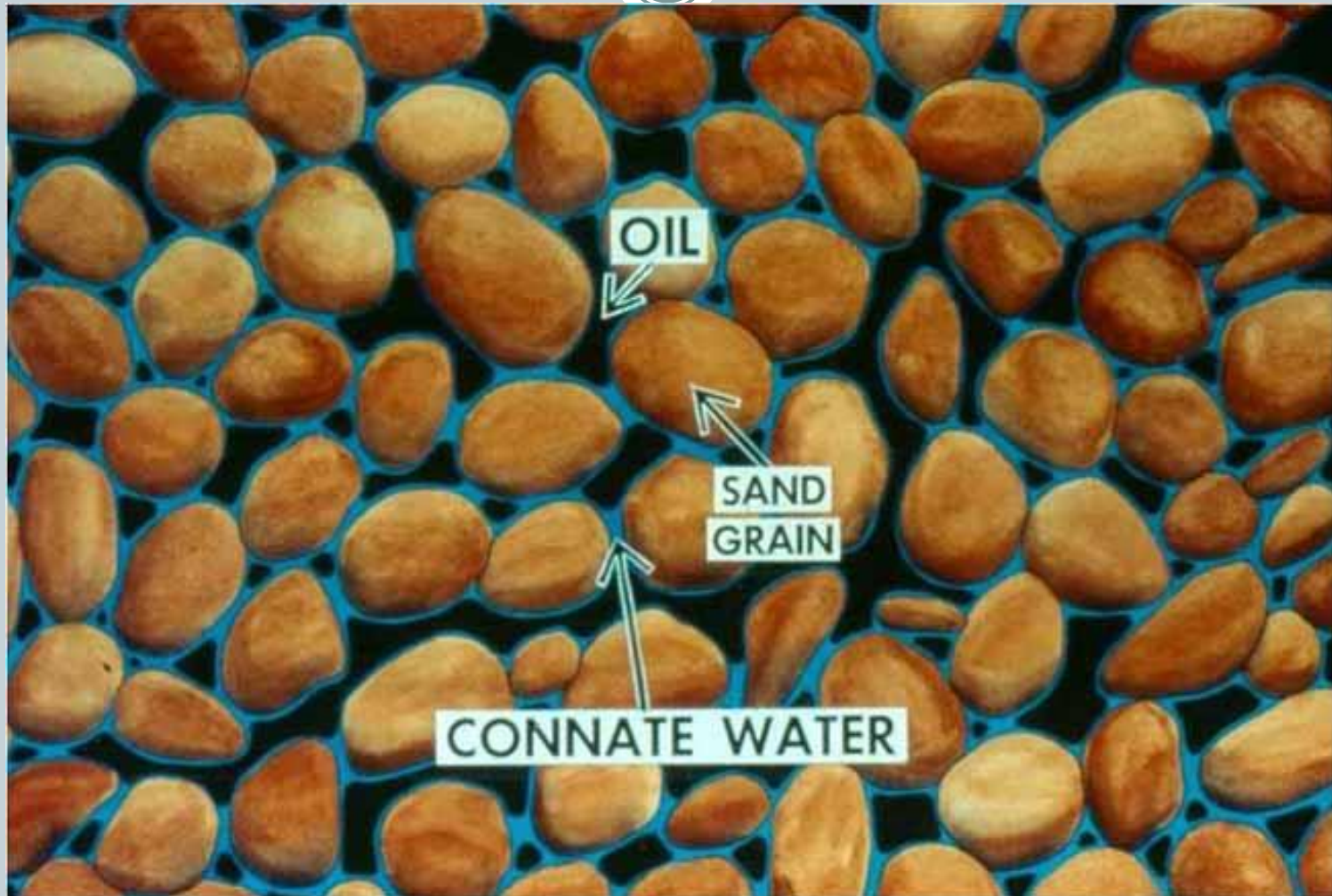
- Offshore developments

- Gulf of Mexico (US)
- Brazil
- West Africa
- East Africa
- N. West Australia
- North Sea



Reservoir characteristics

22



Oil price: 1861-2019

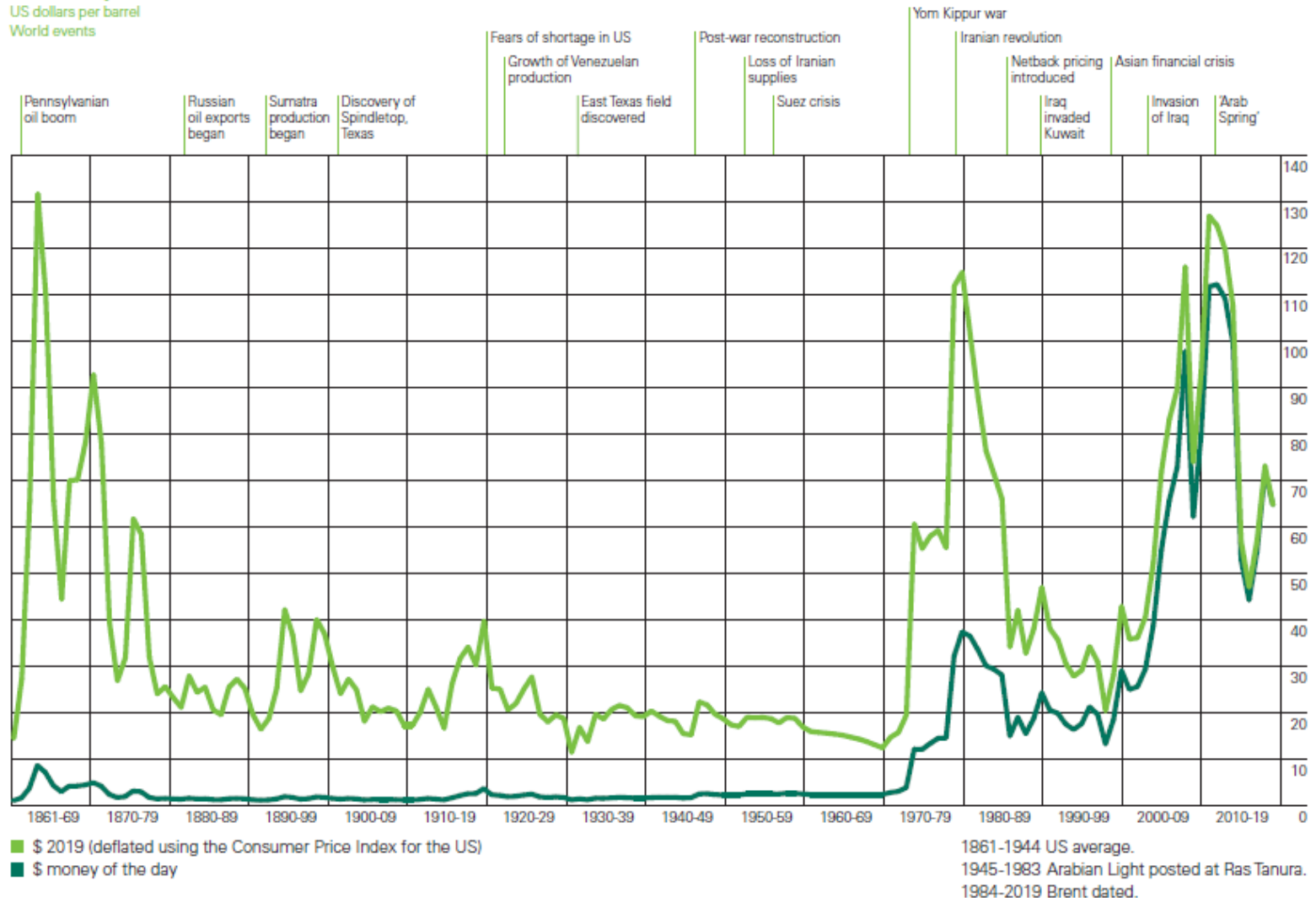
23

Source: BP Stat Review (2020)

Crude oil prices 1861-2019

US dollars per barrel

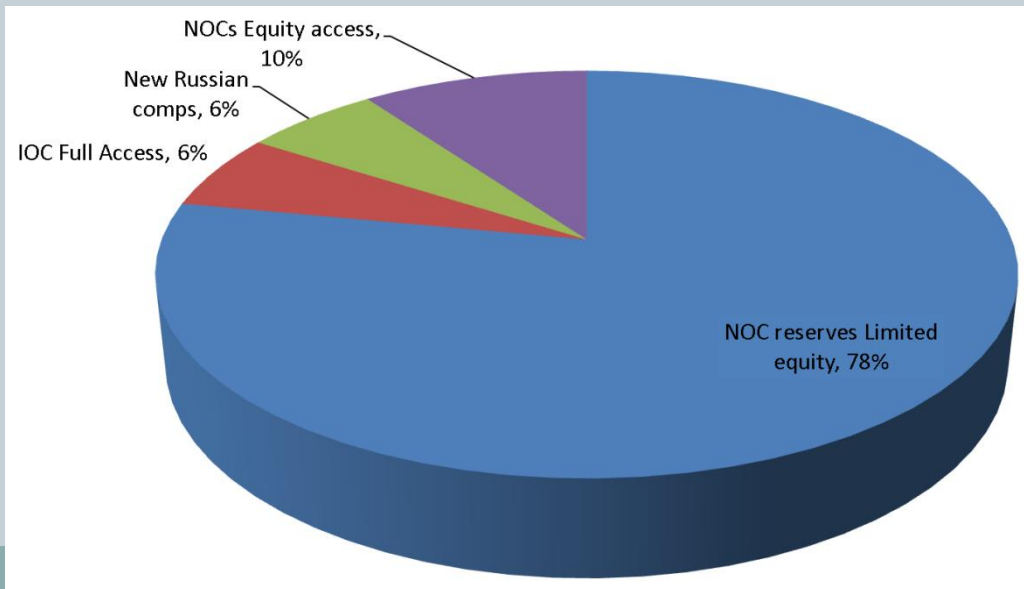
World events



Structure of O&G industry

24

- 1. National oil companies (NOCs): Petrobras, Socar, Pemex, ...
- 2. International NOCs (INOCs): CNOOC, CNPC, Kogas, ...
- 3. Majors: BP, Total, Exxon-Mobil, Shell, ...
- 4. Independent oil companies (IOCs): BG, Tullow oil, Noble
- 5. Oilfield service companies (OFS): Halliburton, Schlumberger, Baker Hughes



The 7 sisters (1950s)

25

- 1. Standard of New York (Exxon)
- 2. Standard of New Jersey (Mobil)
- 3. Standard of California (Chevron)
- 4. Anglo-Persian Oil Company (BP)
- 5. Royal Dutch/Shell (Shell)
- 6. Gulf Oil (Chevron)
- 7. Texaco (Chevron)



“Big oil” or “supermajors” (2000)

26

- 1. ExxonMobil corp. (USA)
- 2. BP plc (UK)
- 3. Total SA (France)
- 4. Royal Dutch Shell plc (Netherlands)
- 5. Chevron corp. (USA)
- 6. Conoco-Phillips (USA)

ExxonMobil

bp



TOTAL



ConocoPhillips

New “Seven Sisters” (today)

27

- 1. CNPC (China)
- 2. Gazprom (Russia); Rosneft (R.)
- 3. Petrobras (Brazil)
- 4. National Iranian Oil Company
- 5. PDVSA (Venezuela)
- 6. Petronas (Malaysia)
- 7. Saudi Aramco (SA)



Are we running out of oil?

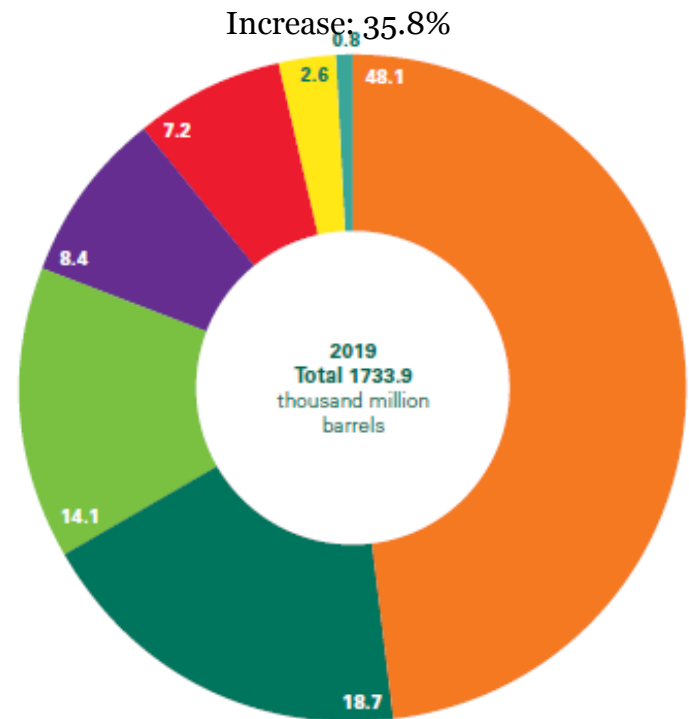
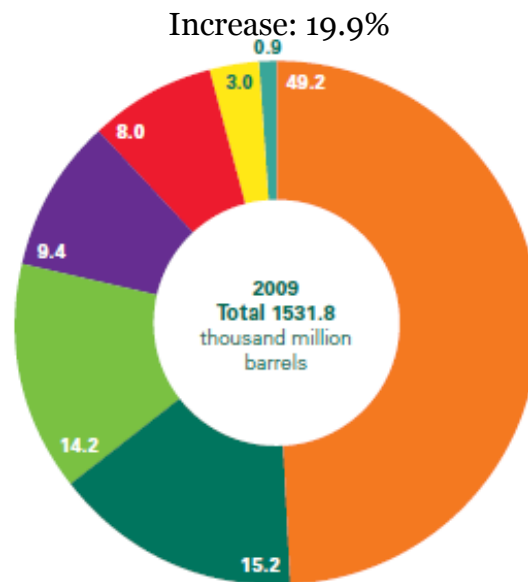
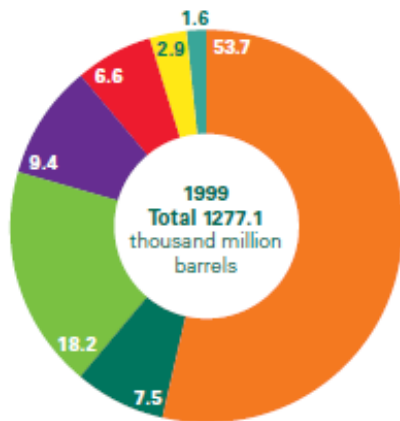
28

- World's O&G reserves change with technological progress

Source: BP Statistical Review 2020

Distribution of proved reserves in 1999, 2009 and 2019

Percentage



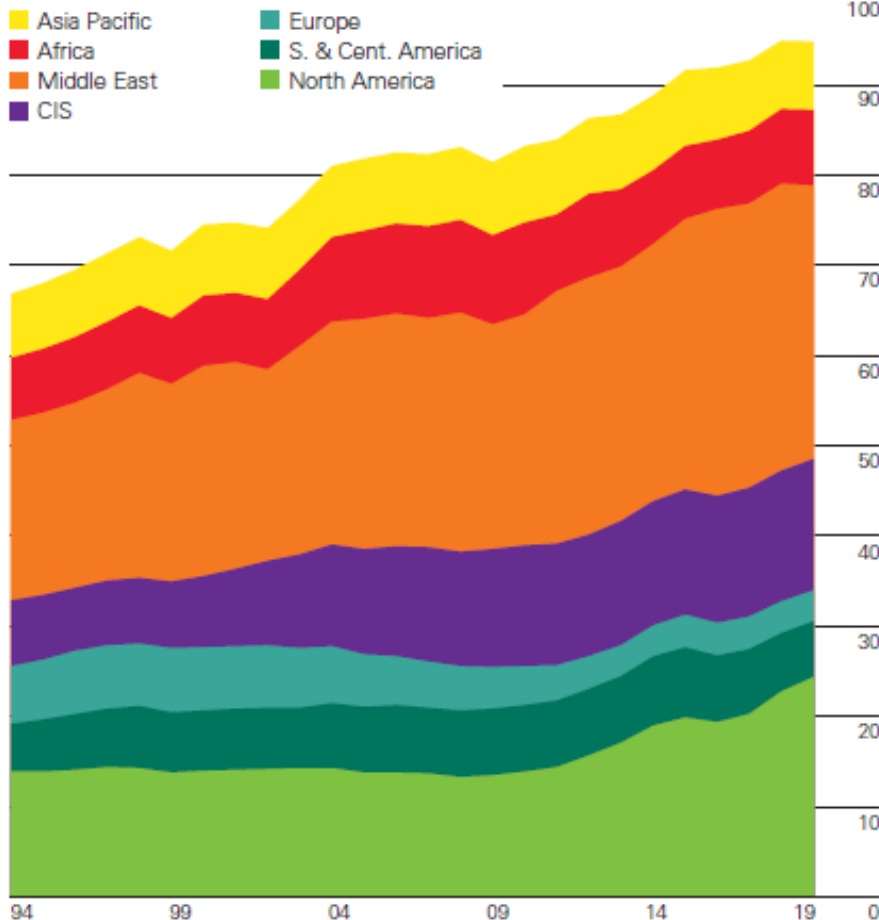
Oil production and consumption

29

Source: BP Statistical Review 2020

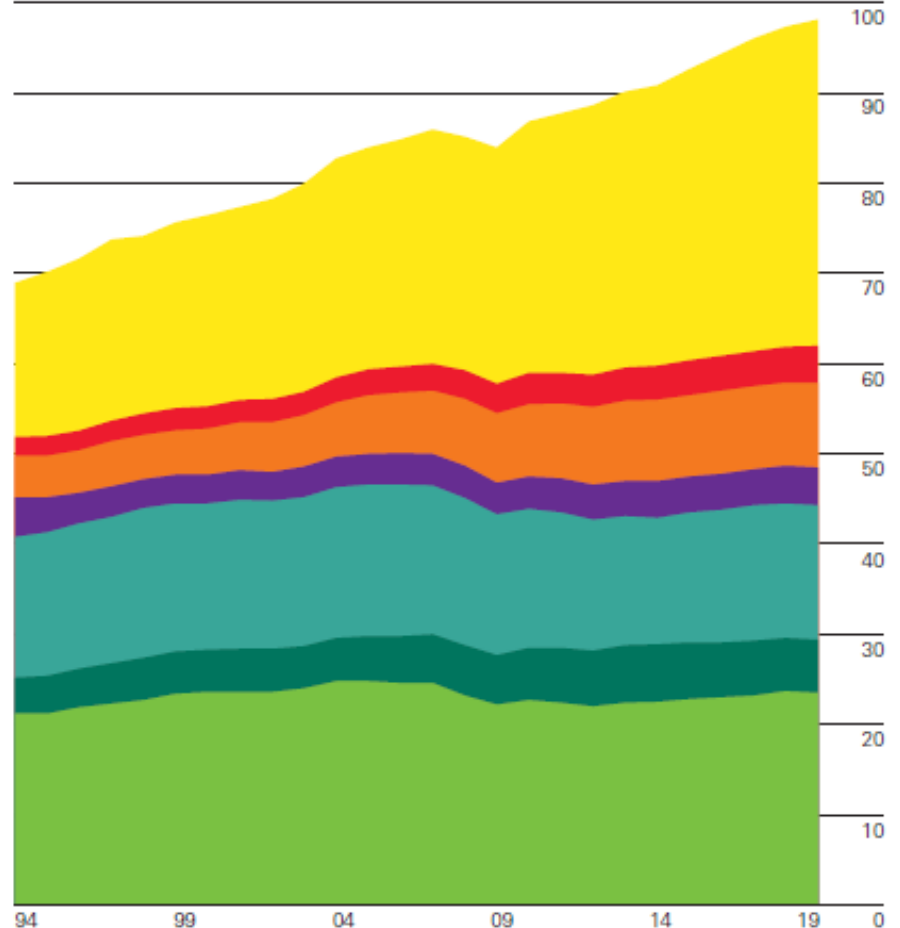
Oil: Production by region

Million barrels daily



Oil: Consumption by region

Million barrels daily

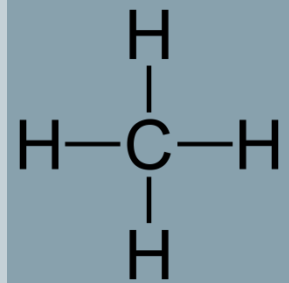


Natural Gas

What is natural gas?

31

- NG: methane (CH_4): 70-90% w%, Ethane (C_2H_6): 5-15%
- Methane: odourless, colourless, non-toxic, non-corrosive
- Condenses at -161°C
 - Occupies 1/610 volume in relation to its gaseous state rendering its transport with LNG carriers economically viable
- Flammable or explosive only in concentration 5-15% in air
- NG discovery in early oil wells considered failure (dry well)
- Owes its smell to “methanethiol”
- Natural gas is **not** LPG (LPG: C_3H_8 , C_4H_{10})



Natural Gas

32

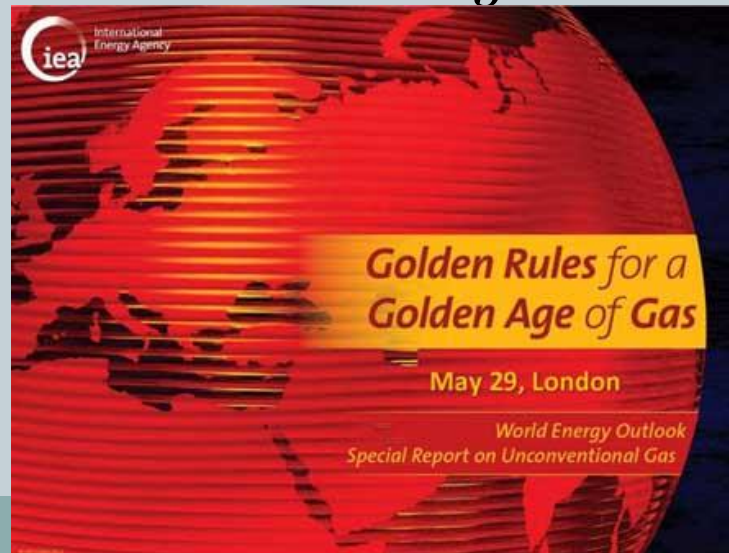
- **P:** Maybe one day “oil” industry will be renamed “natural gas” industry
- **P:** Cleanest H/C: $\text{CH}_4 + \text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O} + \text{thermal en. } 142\text{kJ/kg}$
- **P:** Extractability of NG: 70-80% (Oil: 30-40%)
- **P:** Restricted processing before use (vs. oil)
- **P:** LNG can be used in transportation
- **P:** NG can be converted into diesel
- **P:** Pipelines predominant transport mode over short distances
- **N:** Not easily “fungible” (difficulty of reaching market)
- **N:** Could cause asphyxia
- **N:** Costly export facilities; on a par to nuclear plants
- **N:** Flaring or vented into atmosphere
- **N:** Powerful heat trapping gas



Overview of natural gas (NG) industry

33

- **Delphi Greece**: “eternal flames”
- **~400 BCE**: Chinese first to use natural gas for salt distillation
- **Late 17th & early 18th**: NG originally used for house & street lighting
- **1821**: W. Hart drilled 9m deep NG well in NY. NG for commercial use
- **Post WWII**: Major boon in NG use due to emergence of steel pipelines
- NG mainly used for power generation, petrochemical feedstock & sul.
- IEA: 21st century “Golden Era of NG”: 25% world mix (by 2035)



Natural gas is an environmentally friendly fuel

34

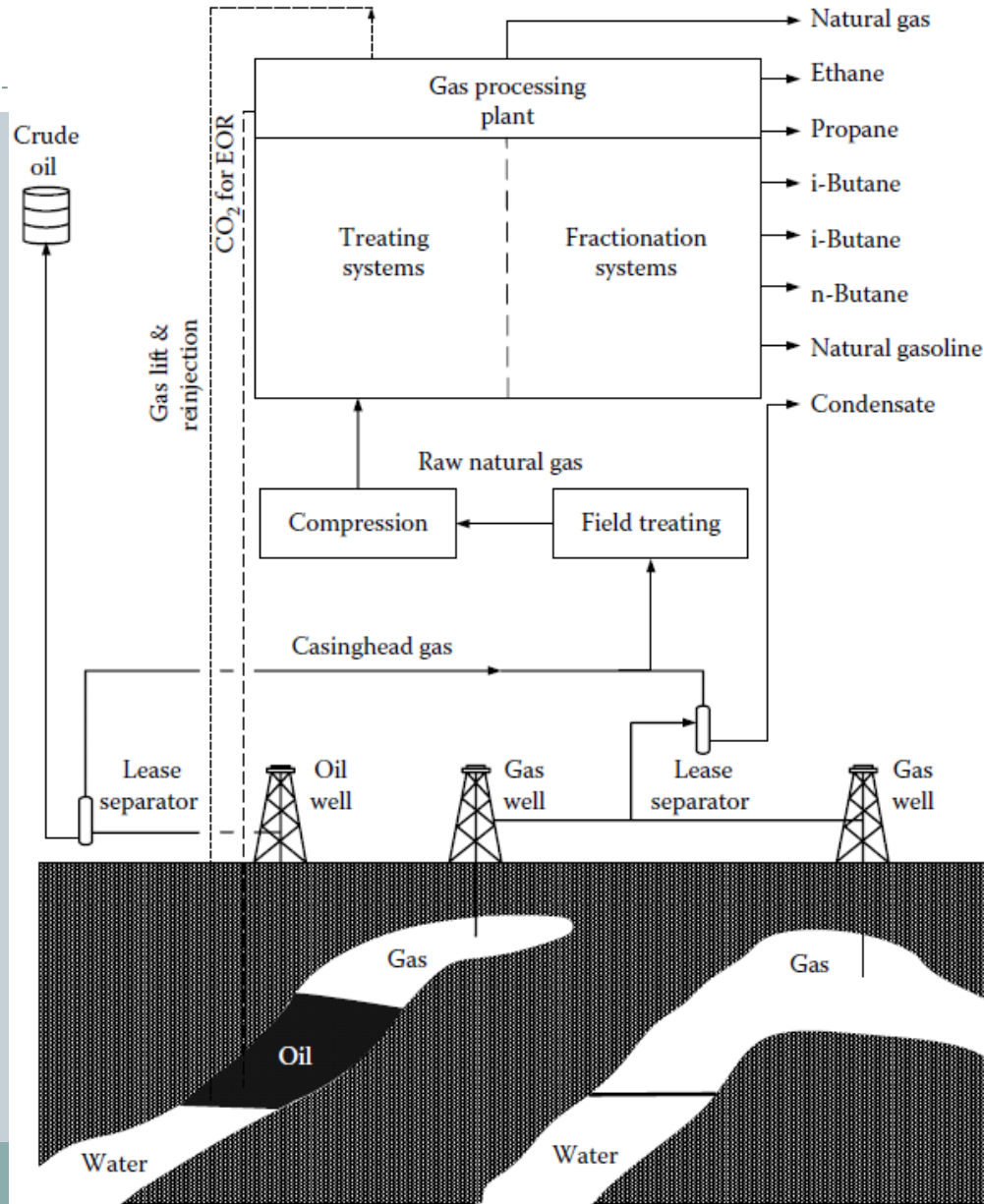
- Air pollutants produced/MMBTU
- Oil & coal: 1.4x & 1.75x more CO₂ than NG
- 20% less NO_x
- Less particulates

Pollutant	Natural Gas (kg)	Oil (kg)	Coal (kg)
CO ₂	53,070	74,389	94,347
CO	18	~15	34.3
NO _x	41	203	207.3
SO ₂	0.27	509	1,175
Particulates	3.18	38.1	1,244
Formaldehyde	0.34	0.1	0.1
Mercury	-	0.0032	0.0073



Source: EIA (1998)

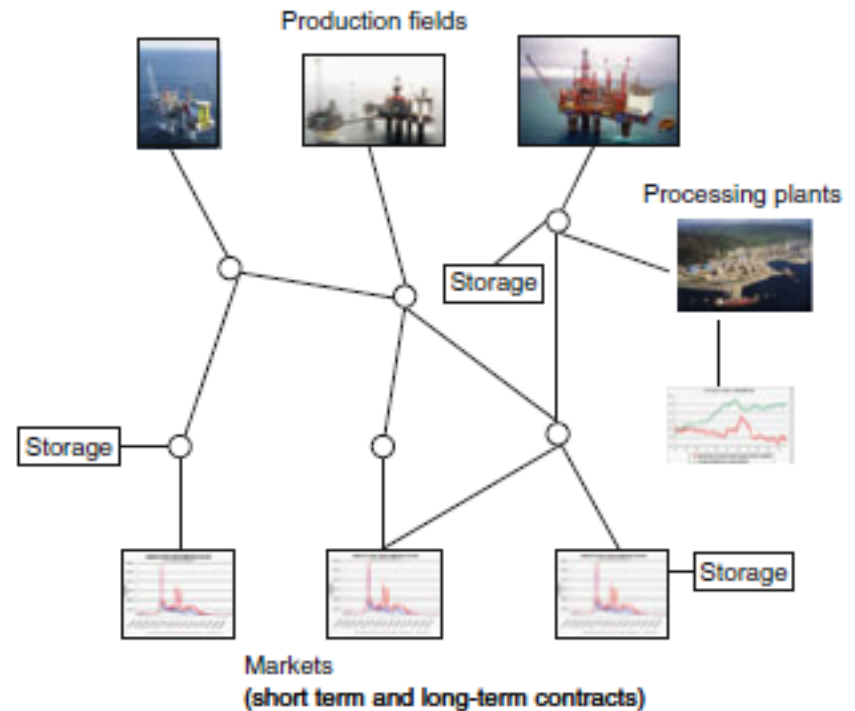
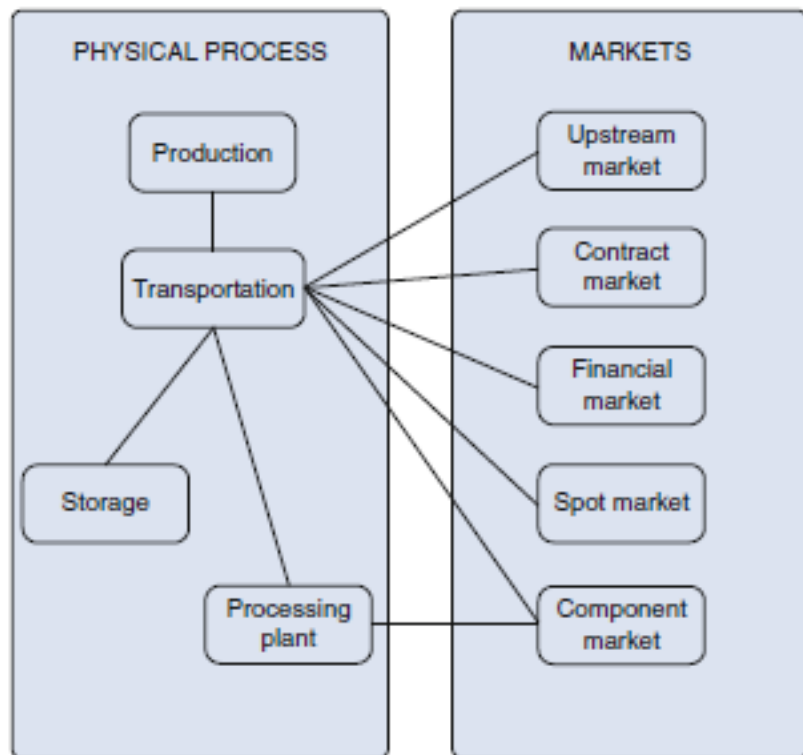
NG from reservoir to finished product



Natural gas value chain

36

- Natural gas demand subject to seasonal patterns & short-term volatility



Liquefied Natural Gas (LNG) history

37

- **1934**: first attempt to export LNG in Hungary
- **1951**: Louisiana to Chicago via Mississippi River
- **1959**: “Methane Pioneer” 1st large scale LNG exports from Libya to UK
- Early 1980s: NG given impetus
- LNG vessels operate on 15 to 20 year long selling contracts
- LNG fleet capacity. 5MMm³ (2008) → 35MMm³ (‘07) → 55MMm³ (‘10)
- LNG will meet 14 to 16% of global gas demand by 2015 (NGR, ‘07)
- Typical LNG shipload cost \$20–35 m, daily time charter rate of LNG ship ~\$70,000



World natural gas reserves

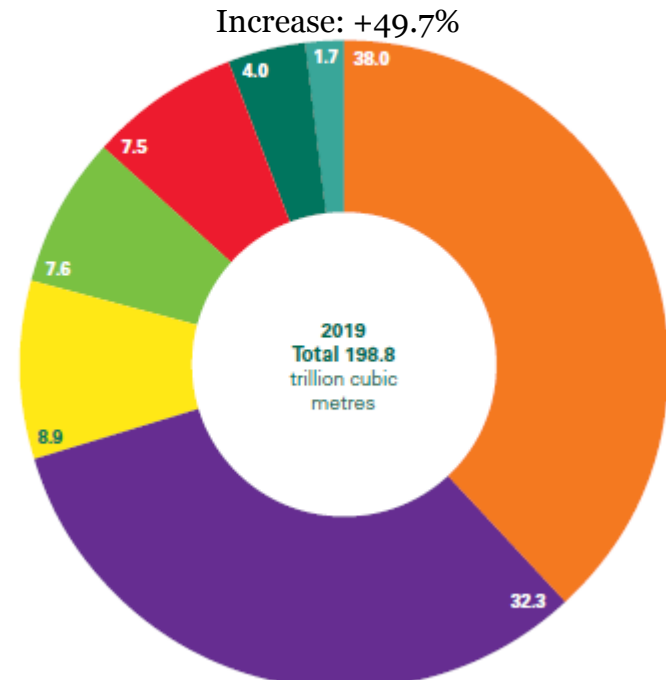
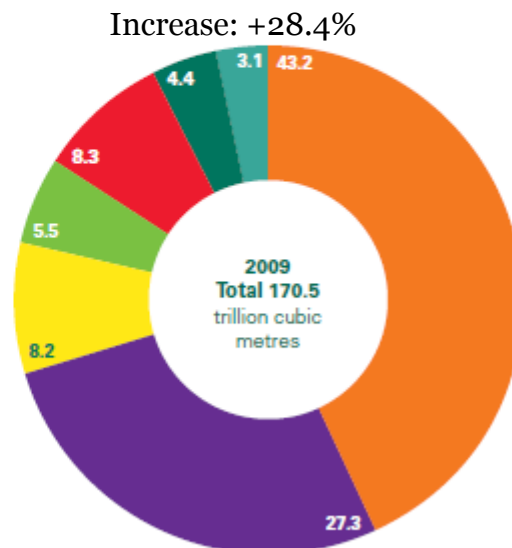
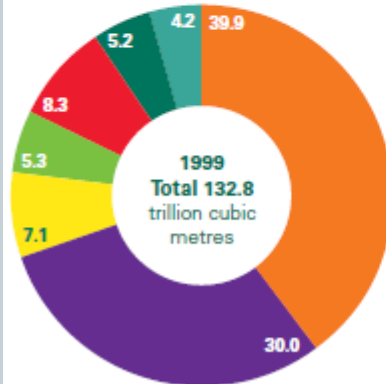
38

- There is enough gas to power the world for the next 300 years (IEA)!

Source: BP Statistical Review 2020

Distribution of proved reserves in 1999, 2009 and 2019

Percentage



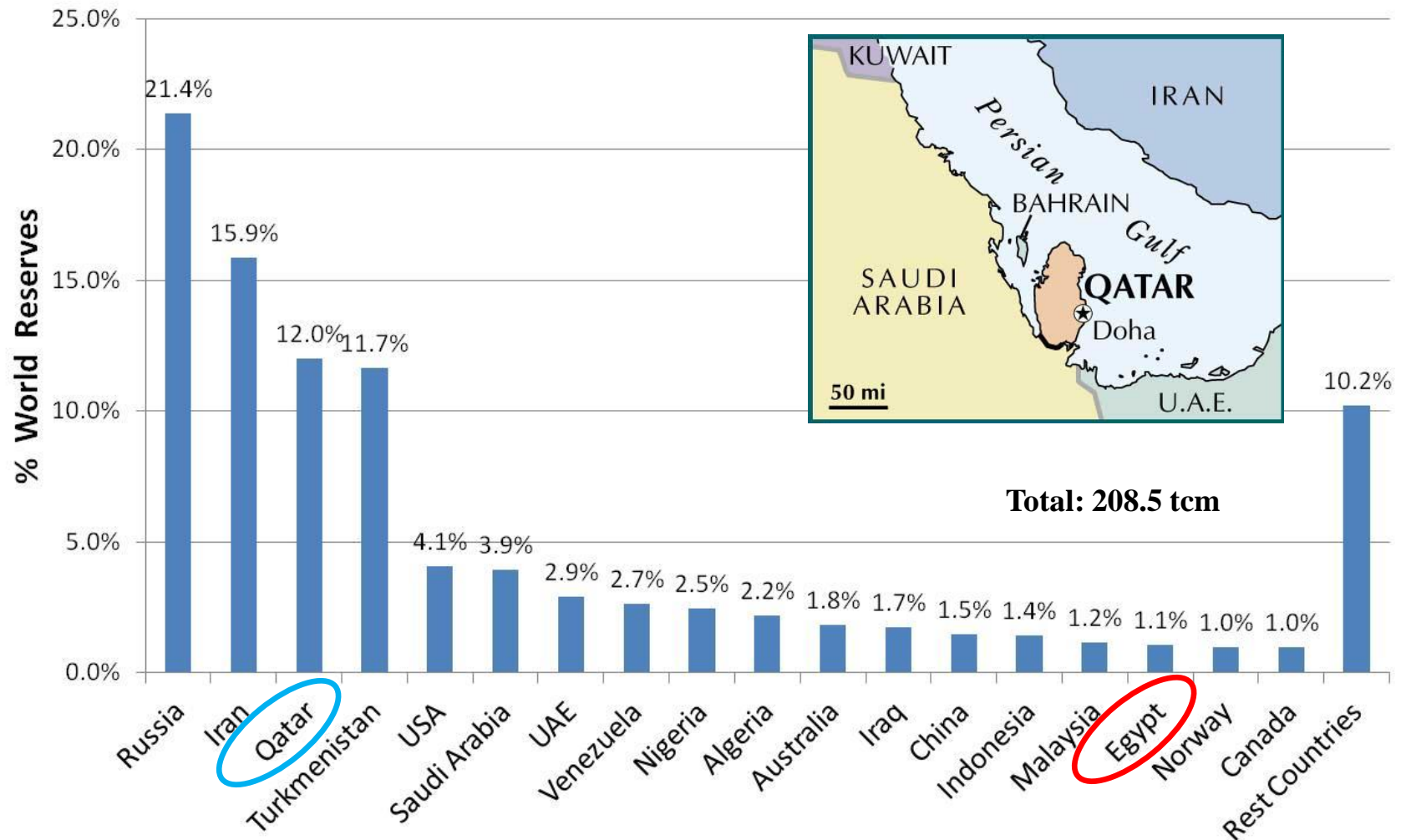
Units: Trillion cubic meters (tcm)

World proven natural gas reserves (1)

(39)

World Proven Natural Gas Reserves

Source: BP (2012)



Production & Consumption of NG

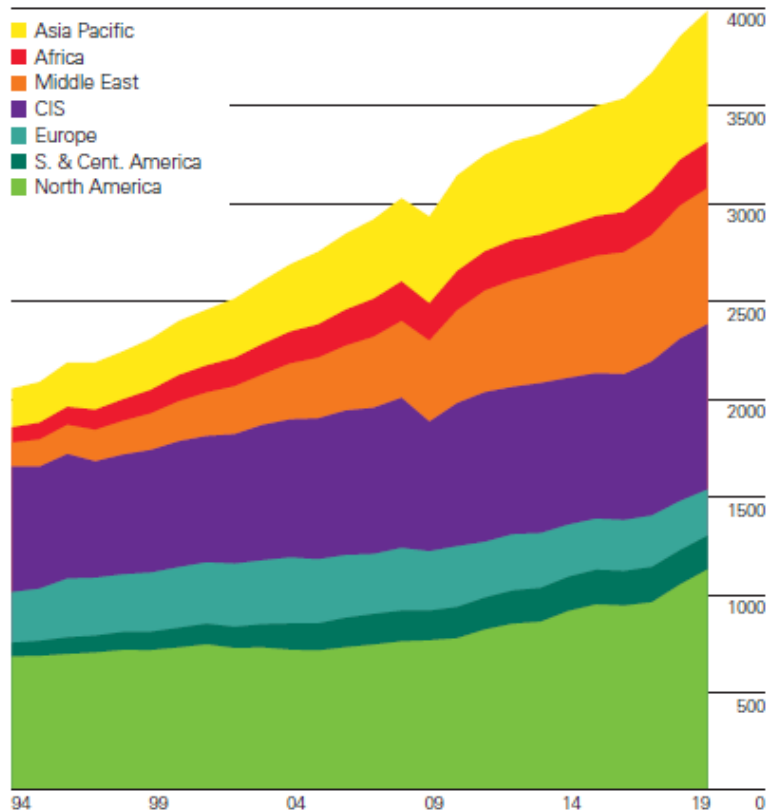
40

Global production = 3,325.8 mtoe

Natural gas: Production by region

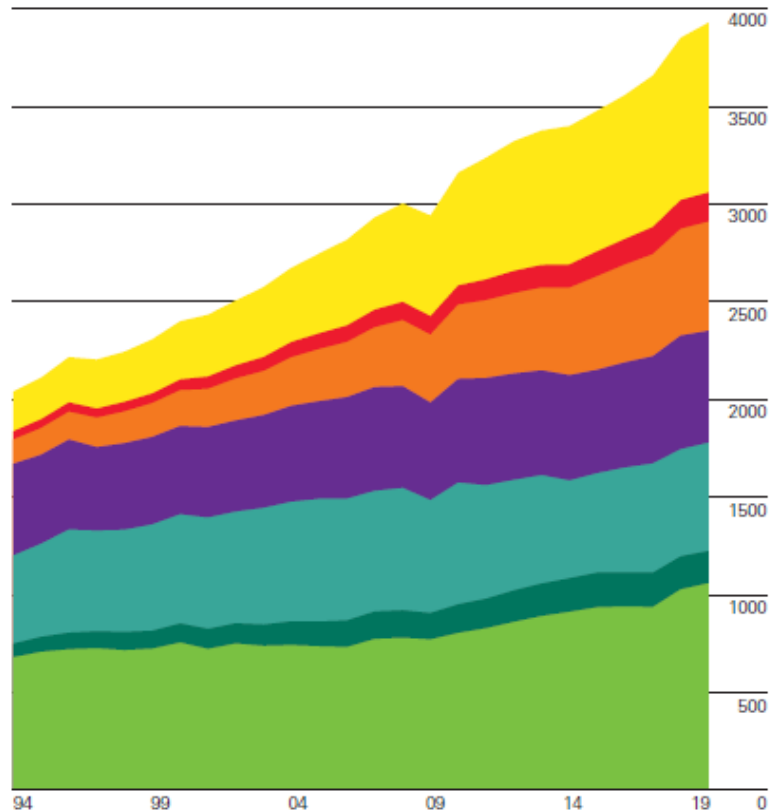
Billion cubic metres

- Asia Pacific
- Africa
- Middle East
- CIS
- Europe
- S. & Cent. America
- North America



Natural gas: Consumption by region

Billion cubic metres

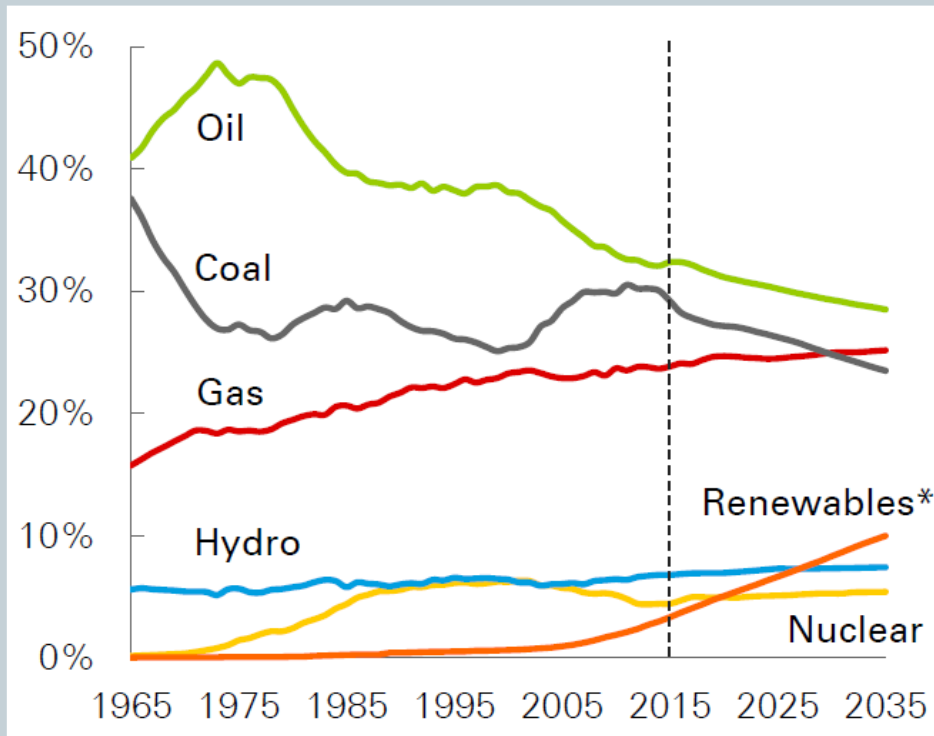


Natural gas consumption increased by 78 billion cubic metres (bcm), or 2%, well below the strong growth seen in 2018 (5.3%). Growth was driven by the US (27 bcm) and China (24 bcm), while Russia and Japan saw the largest declines (10 and 8 bcm respectively). Gas production grew by 132 bcm (3.4%), with the US accounting for almost two-thirds of this increase (85 bcm). Australia (23 bcm) and China (16 bcm) were also key contributors to growth.

Future energy projections

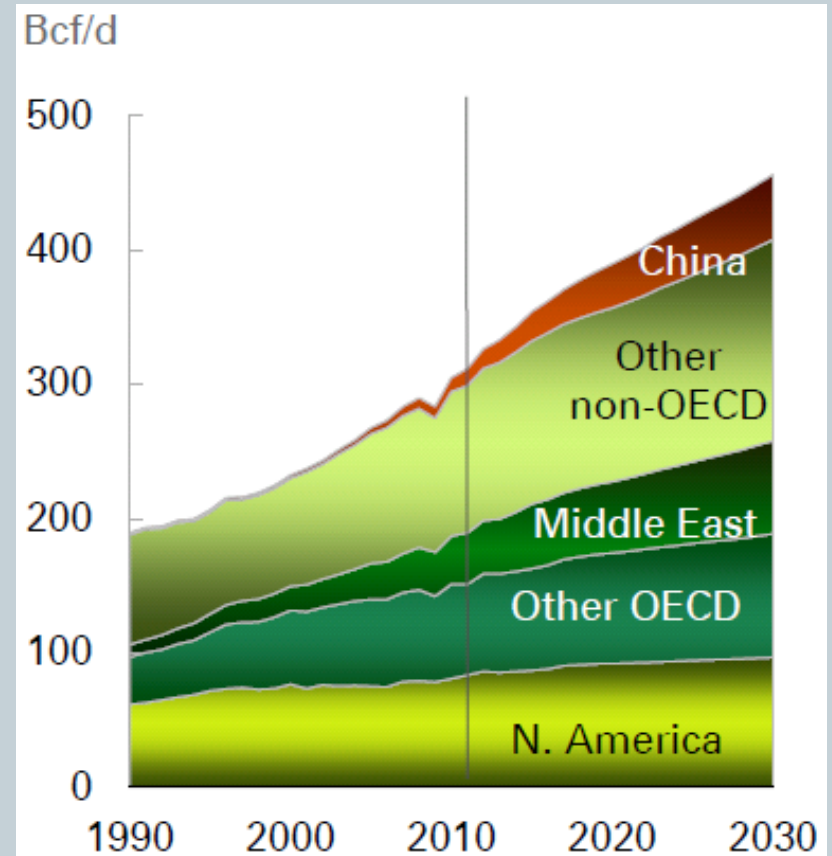
41

Primary energy



Source: BP Energy Outlook 2030 (2013)

Natural Gas



2010: 10 tcf/yr

2030: 15 tcf/yr

1 cubic metre = 35.3 cubic feet

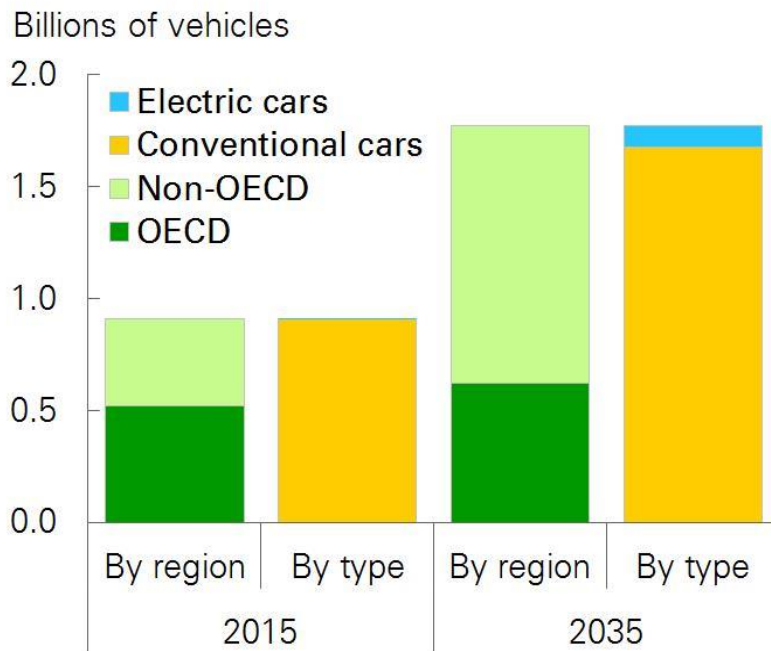
Electric cars

42

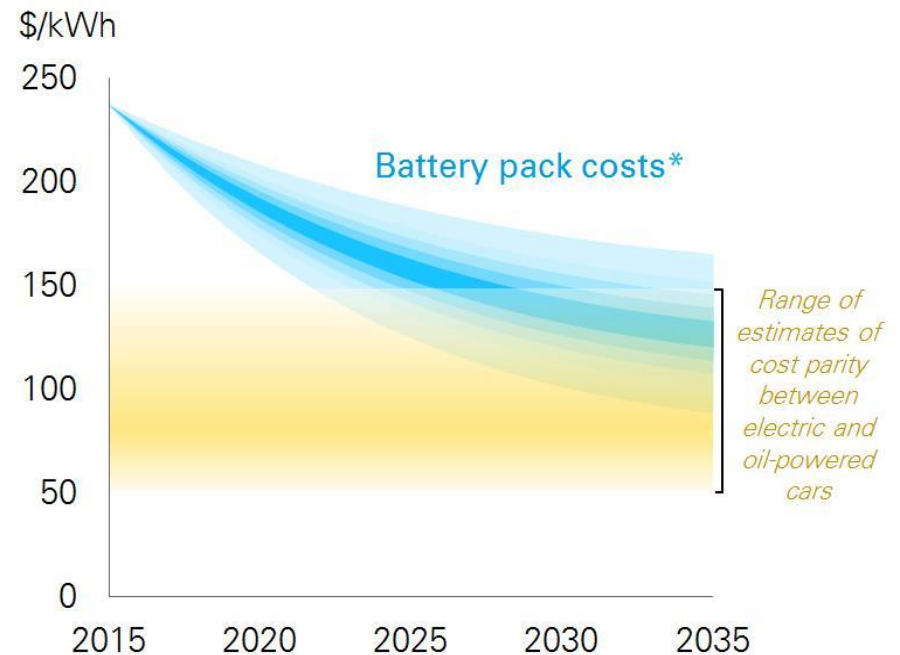


Growth of electric cars

The global car fleet: 2015-2035



Illustrative path for battery pack costs



*For a Battery Electric Vehicle with a 60 kWh pack. Cost projections depend heavily on the degree of EV uptake, which is uncertain, so ranges should be treated as illustrative only. Current estimates of battery costs also vary widely, but this uncertainty is not shown

EU Pipeline network

43



Source: IEA (2011)

US pipeline network

44



Thanks for your attention!