



ENVIRONMENTAL ENERGETICS

Fossil energy sources

Energy source: a source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. solid fuels, liquid fuels, solar energy, biomass, etc.)

There are two forms of energy sources:

1. non-renewable energy sources
2. renewable energy sources

- non-renewable energy sources are energy sources that cannot be replaced and will eventually run out
- renewable energy sources are natural energy sources which do not get used up



Energy sources	Primary energy sources	External sources	Solar and cosmic rays
			Gravitational effects (eg. Moon effect)
		Internal sources	Earth's internal heat (eg. inner core heat)
			Earth's rotational and gravitational energies
	Secondary energy sources	Non-renewable energy sources	Coal
			Oil
			Natural gas
			Nuclear energy
		Biomass	Photosynthesis
			Animal energy
			Wind
		Renewable energy sources	Water and marine technologies
			Geothermal energy

- primary e.s.: can supply energy independently without any other source of power
- secondary e.s.: formed by the transformation of primary energy sources

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- a., non-renewable: fossil fuels
- b., energy bound during photosynthesis
- c., renewable: that can be replenished in a short period of time - continuously generated

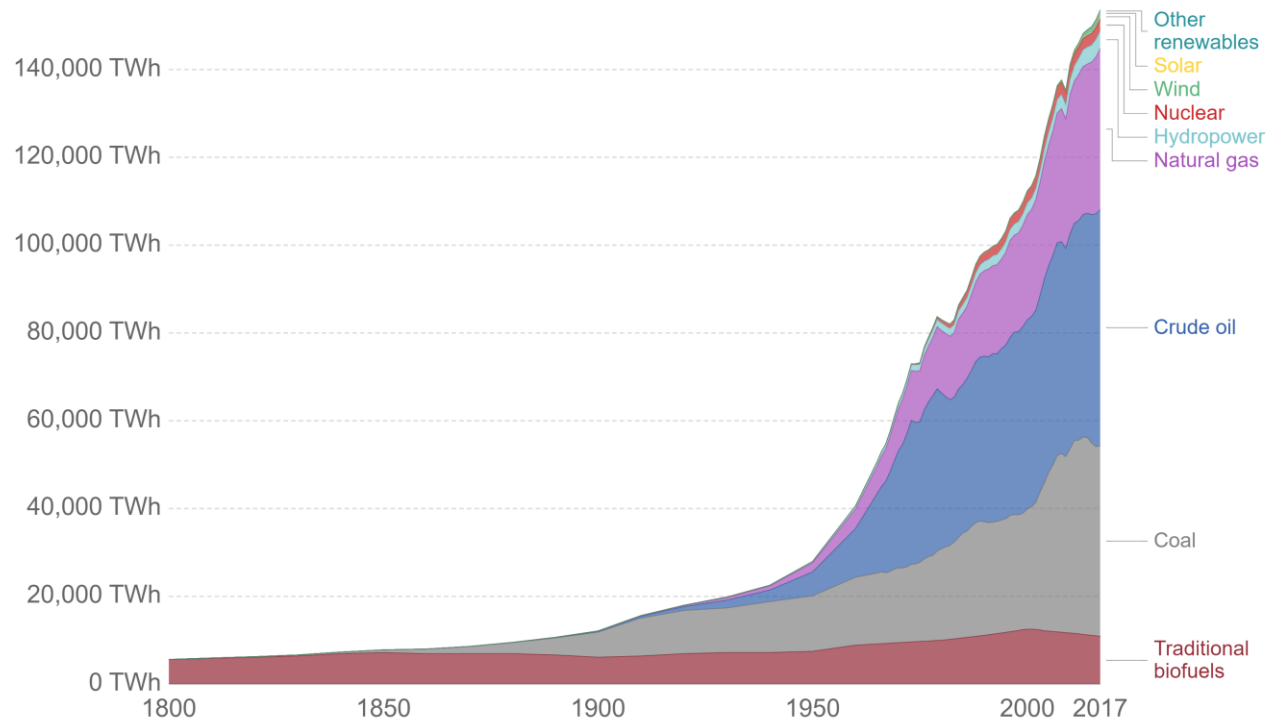


- fossil energy sources, including **oil, coal and natural gas**, are **non-renewable resources** that formed when prehistoric plants and animals died and were gradually buried by layers of rock. Over millions of years, different types of fossil fuels formed -- depending on what combination of organic matter was present, how long it was buried and what temperature and pressure conditions existed as time passed
- today, fossil fuel industries drill or mine for these energy sources, burn them to produce electricity, or refine them for use as fuel for heating or transportation
- **over the past 20 years, nearly three-fourths of human-caused emissions came from the burning of fossil fuels**

Global primary energy consumption

Global primary energy consumption, measured in terawatt-hours (TWh) per year. Here 'other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.

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Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

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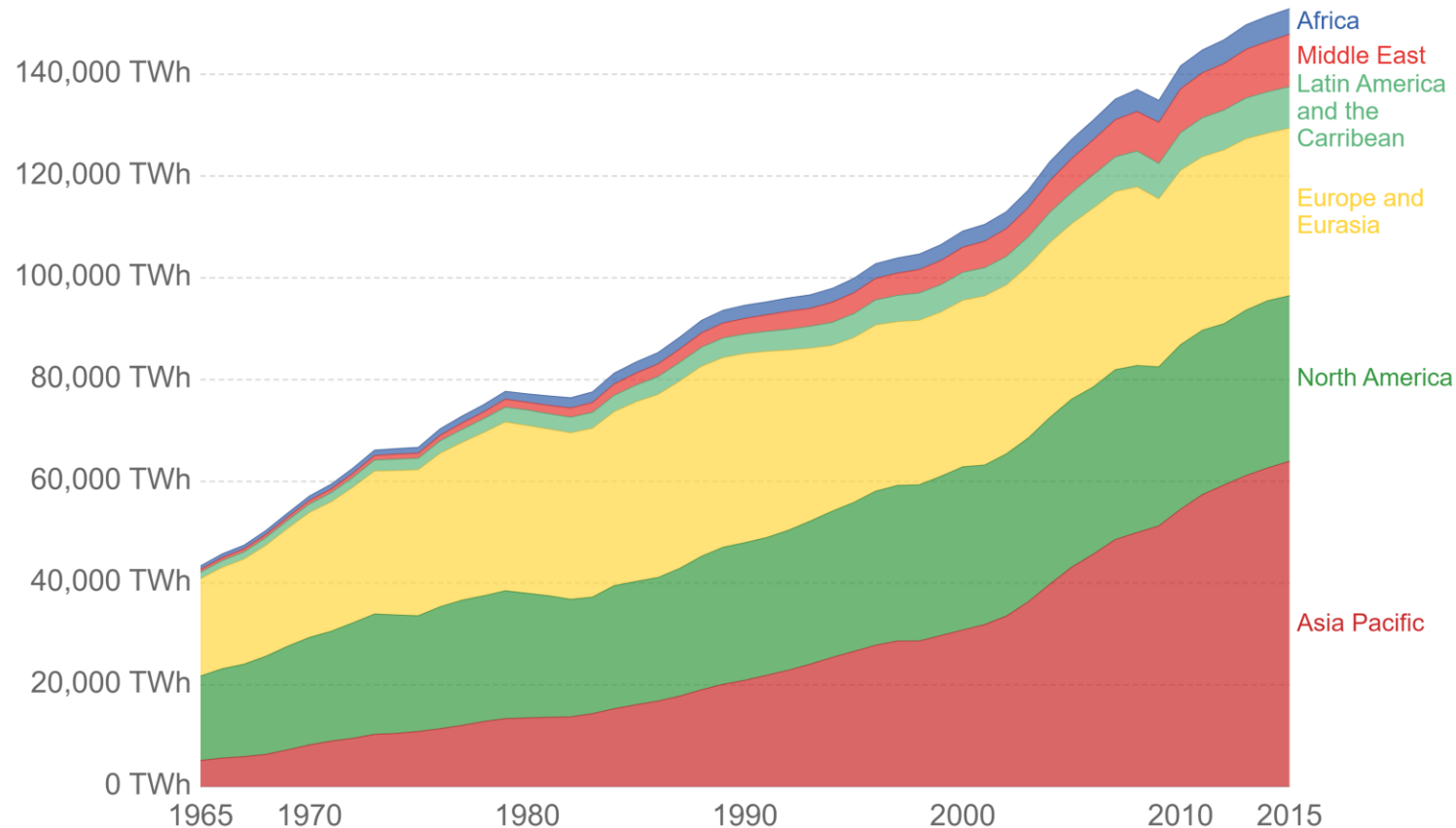
Global energy use

- in 1800s nearly all of the world's energy was produced from traditional biomass (essentially burning wood and other organic matter)
- by 1900s, coal consumption had increased significantly, accounting for almost half of global energy (the other half remaining biomass, since oil, gas and hydroelectricity remained small)
- by 1960 the world had moved into nuclear electricity production
- in 2017, the world consumed 146,000 terawatt-hours of primary energy - more than 25 times more than in 1800

Primary energy consumption by world region

Global energy consumption by region, measured in terawatt-hours (TWh). Note that this data includes only commercially-traded fuels (coal, oil, gas), nuclear and modern renewables used in electricity production. As such, it does not include traditional biomass sources.

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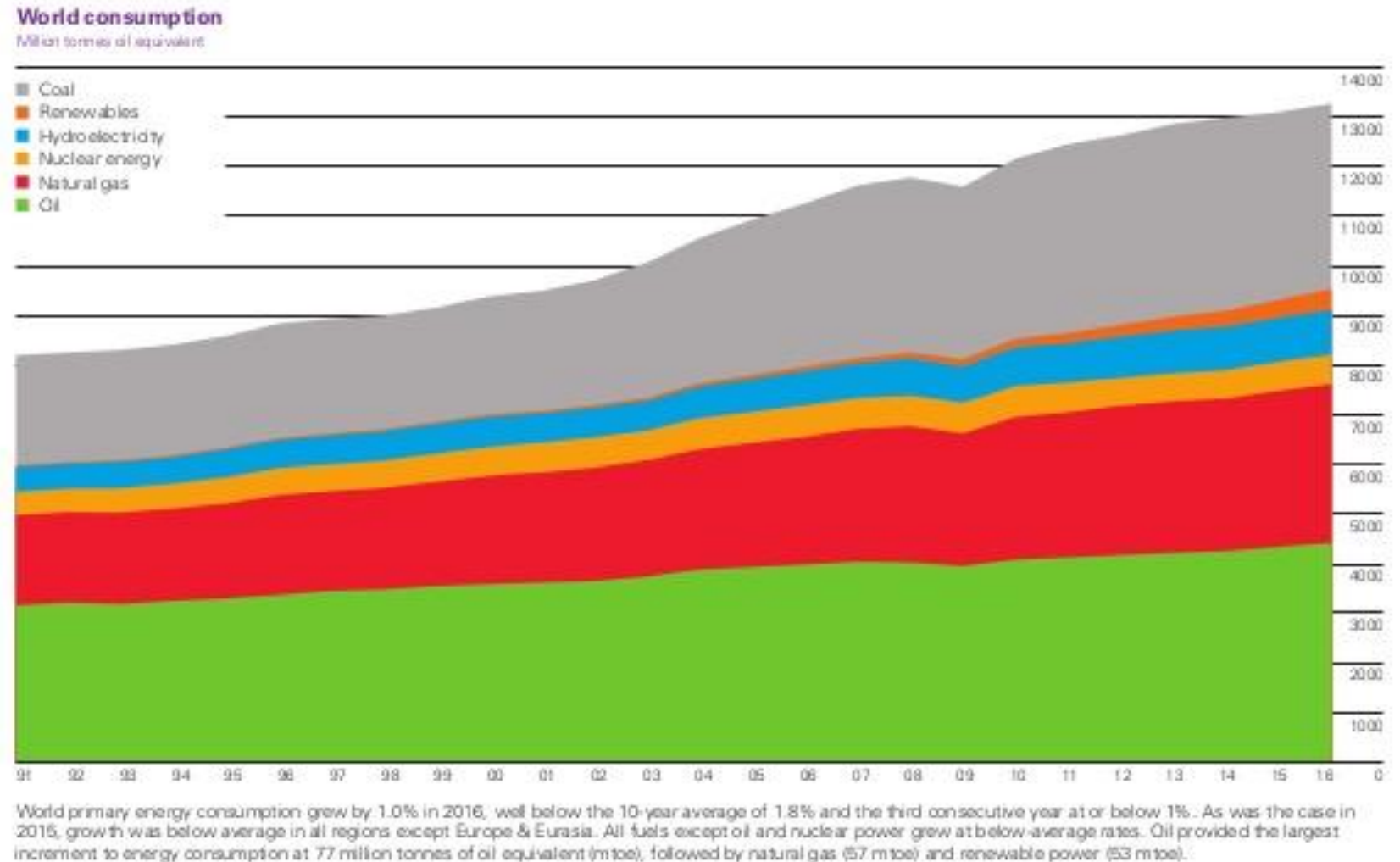
Source: BP Statistical Review 2016

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- in 1965 the bulk of total energy was consumed North America, Europe and Eurasia - collectively, they accounted for more than 80% of global energy consumption
- in 2015 Asia Pacific was by far the largest regional consumer with 42%

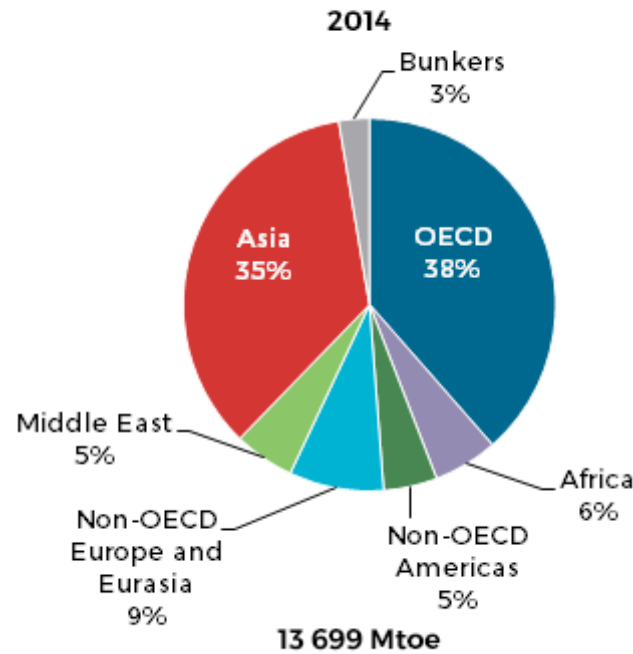
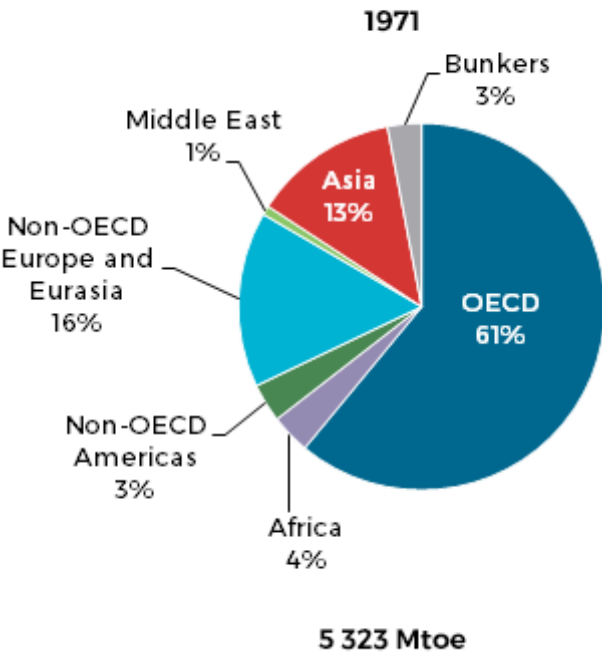
Human energy needs are influenced by 3 factors:

- change in world population
- degree and structure of the social and economic development of the world
- the development of technology based on sustainable development and the widespread dissemination of environmentally friendly technologies

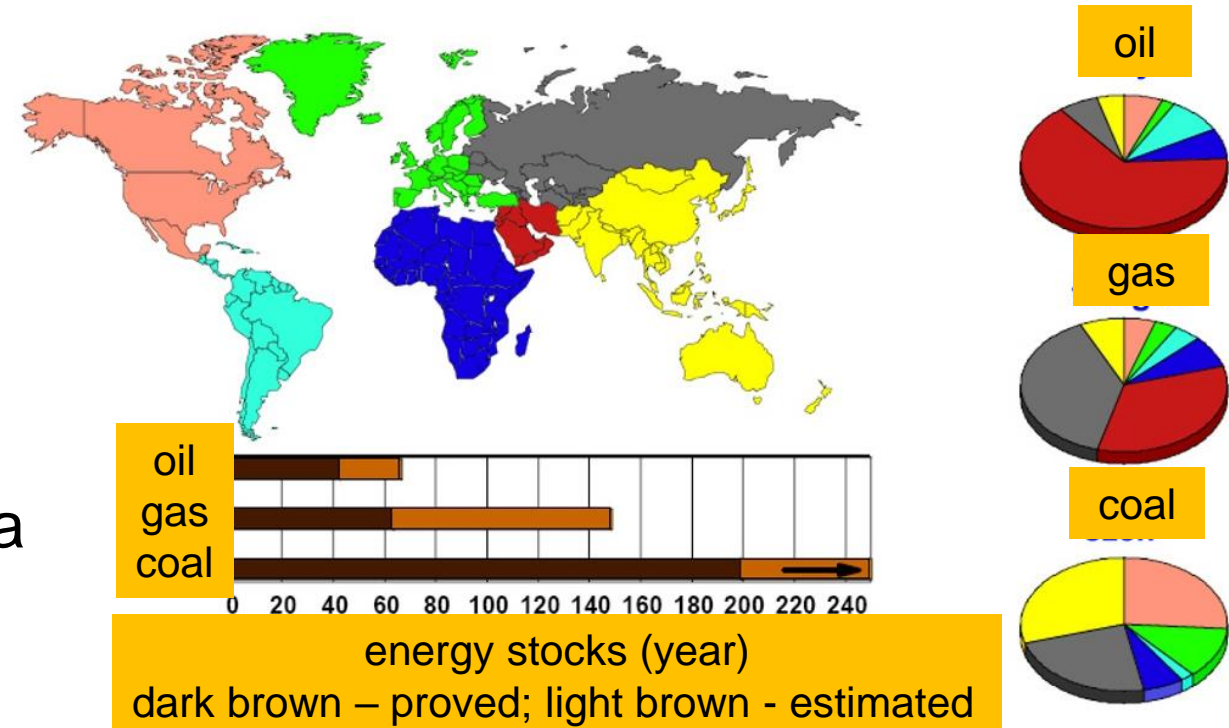


Evolution of world energy supply (BP Statistical Review of World Energy June 2017)

Total primary energy supply (TPES) by region

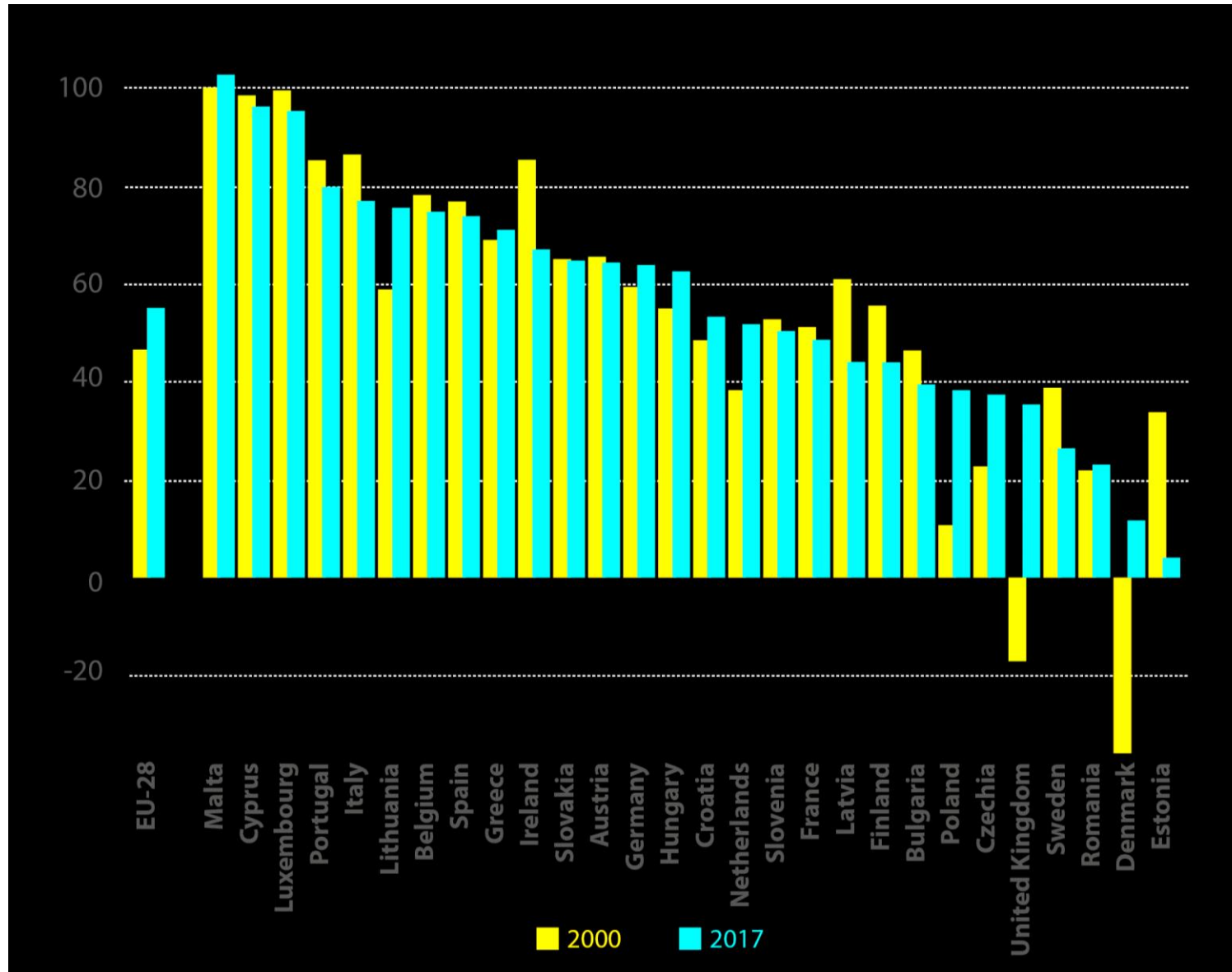


Reserves of fossil energy sources in the world



- coal: Asia (China+India), USA and Russia
- gas: Middle East and Russia
- oil: Middle East

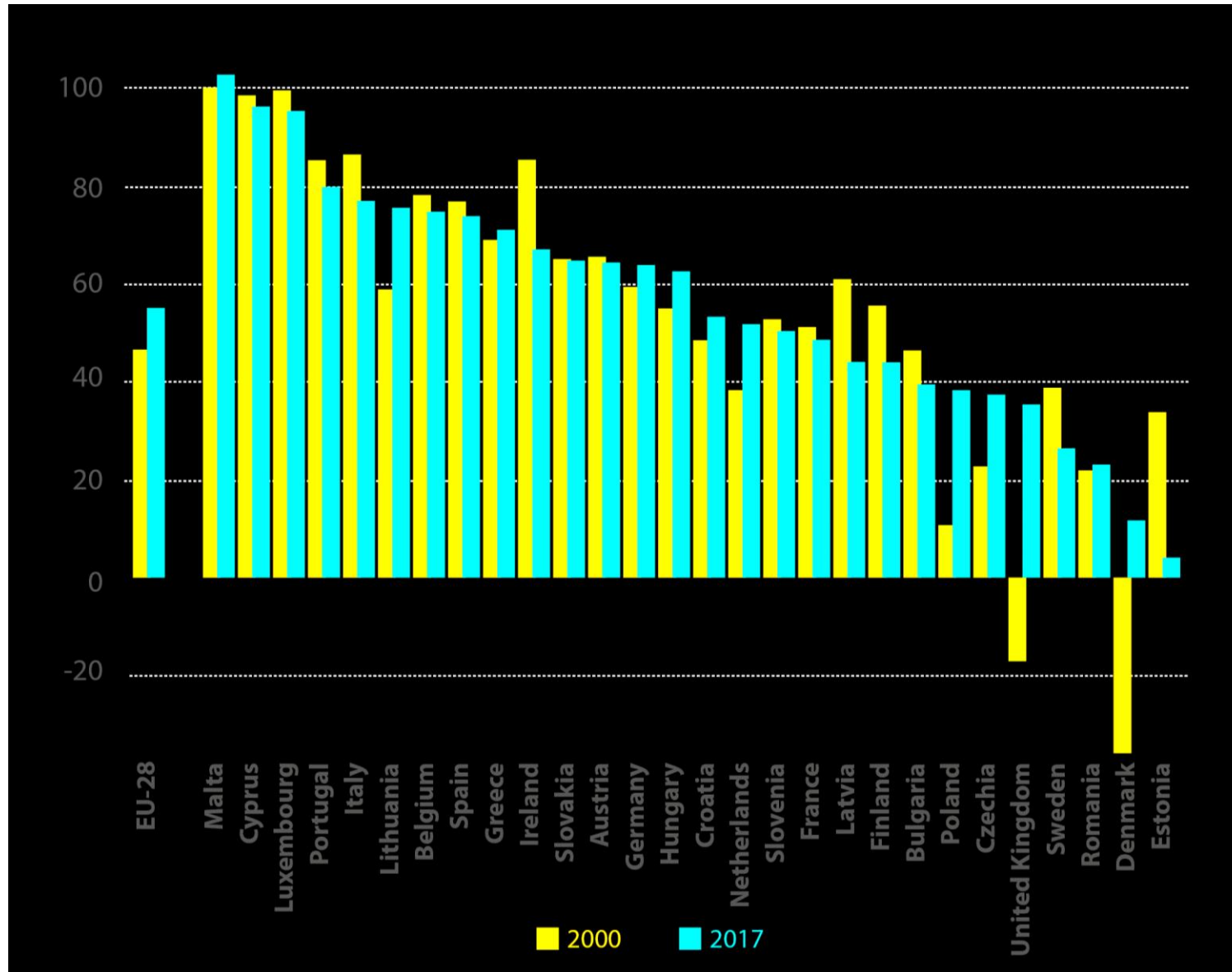
Energy dependency rate (%)



Source: Eurostat

- **the dependency rate** shows the extent to which an economy relies upon imports in order to meet its energy needs
- in the EU in 2017, the dependency rate was equal to 55 %, which means that more than half of the EU's energy needs were met by net imports
- the EU mainly depends on Russia for imports of crude oil, natural gas and solid fuels, followed by Norway for crude oil and natural gas

Energy dependency rate (%)



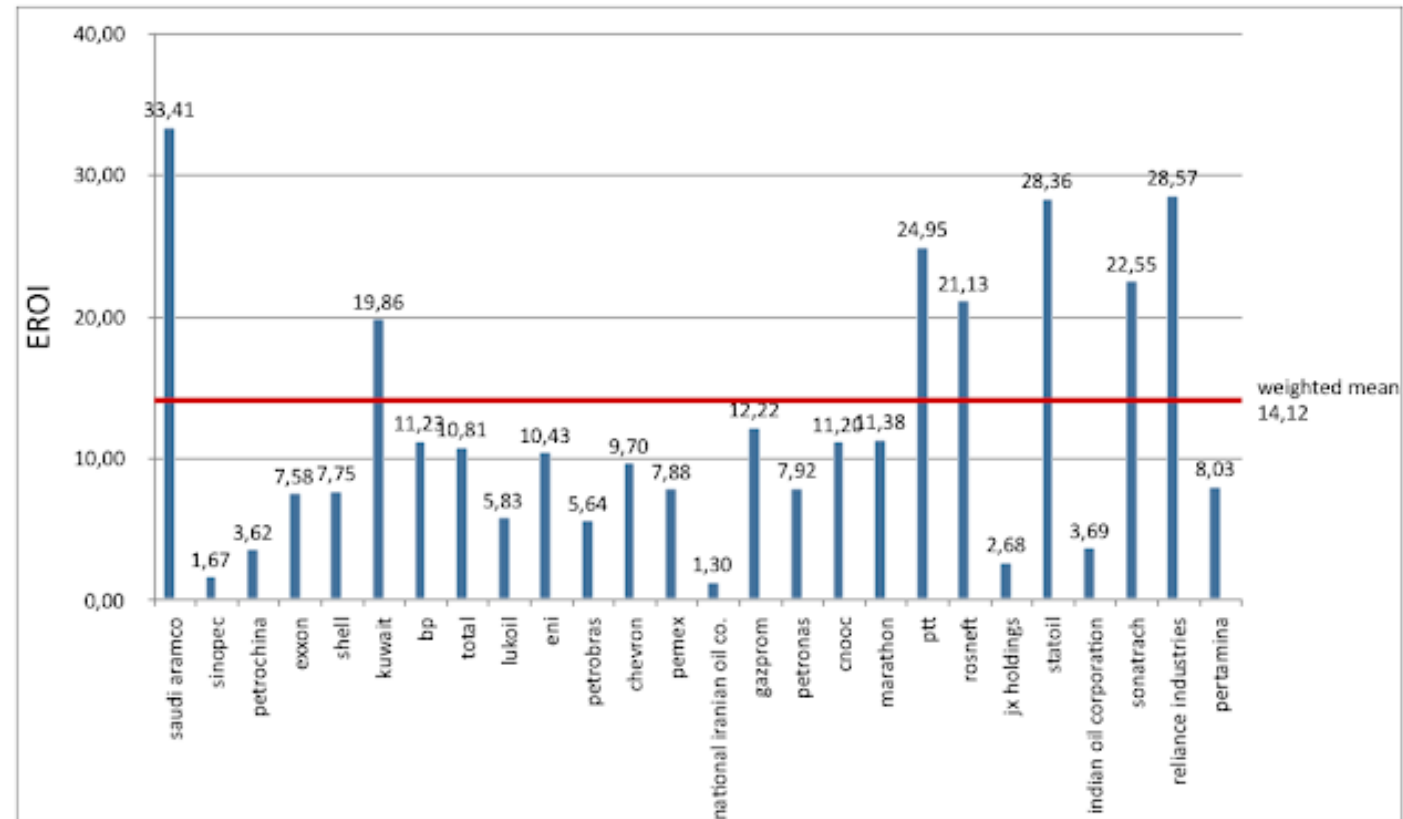
Source: Eurostat

- in 2017, almost two thirds of the extra-EU's **crude oil imports** came from Russia (30%), Norway (11%), Iraq (8%), Kazakhstan and Saudi Arabia (both 7%)
- more than three quarters of the EU's imports of **natural gas** came from Russia (40 %), Norway (26 %) and Algeria (11 %), while
- almost three quarters of **solid fuel** (mostly coal) imports originated from Russia (39 %), Colombia and United States (17 % each)

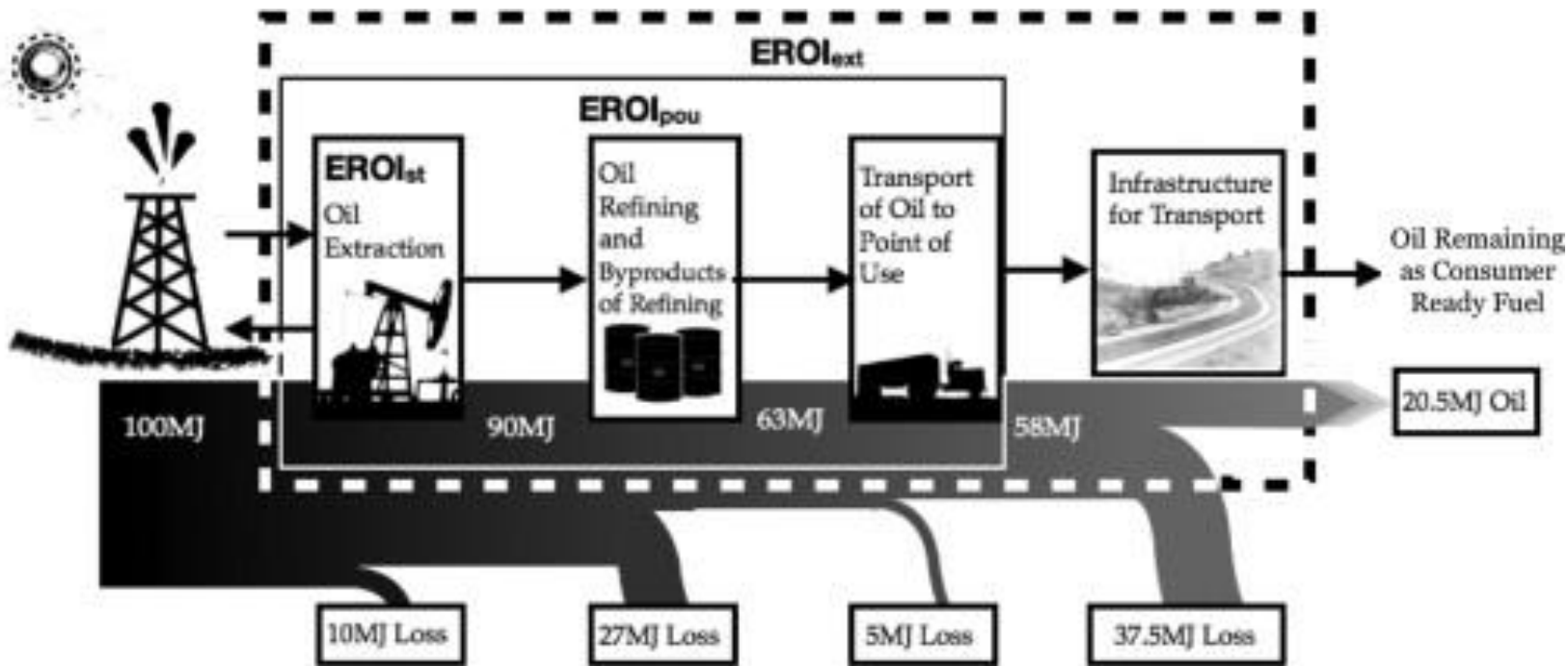
Energy Return On Investment - EROI

- is a means of measuring the quality of various fuels by calculating the ratio between the energy delivered by a particular fuel to society and the energy invested in the capture and delivery of this energy
- the theoretical limit of EROI is 1:1, below this value, energy production is no longer worth it

The companies with the highest revenues in the world



(the estimated values of EROI are represented in the figure)



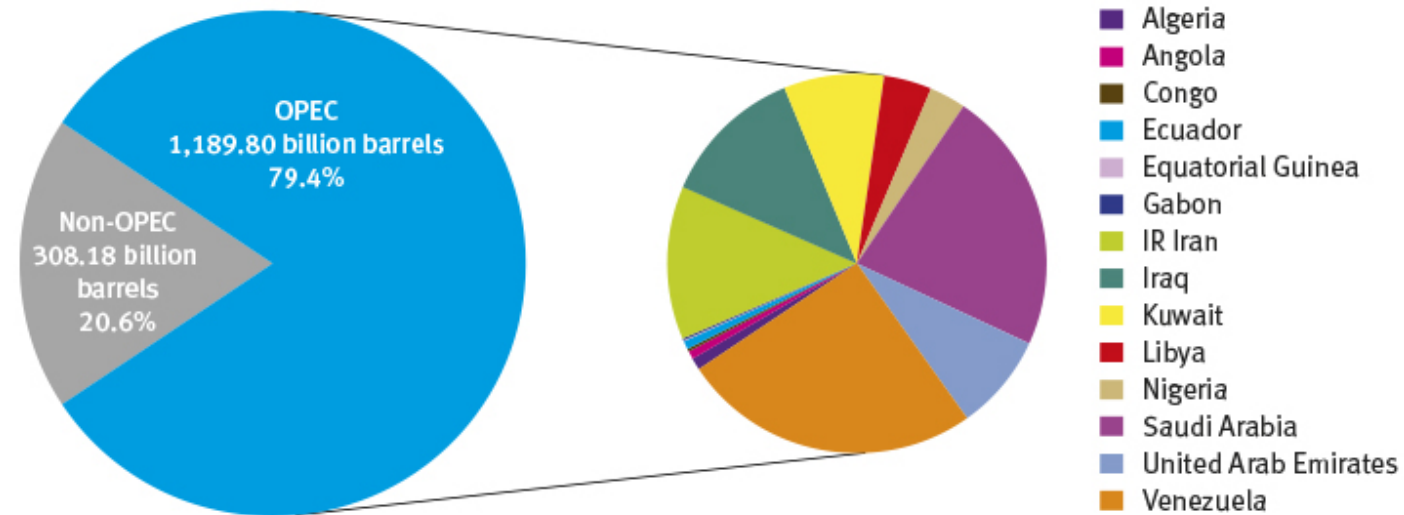
Boundaries of various types of EROI analyses and energy loss associated with the processing of oil as it is transformed from “oil at the well-head” to consumer ready fuels (figure from Charles A.S. Hall et.al. 2014)

- in calculating EROI, not only production but also the energy requirements of all related activities are included
- influencing factors eg.:
 - size of the source of the energy source
 - type of mine (open-pit or underground)
 - technological development

1. Oil

- it is also important as an energy source and as a raw material (eg. transport, electricity generation, chemical industry, agriculture)

OPEC share of world crude oil reserves, 2018



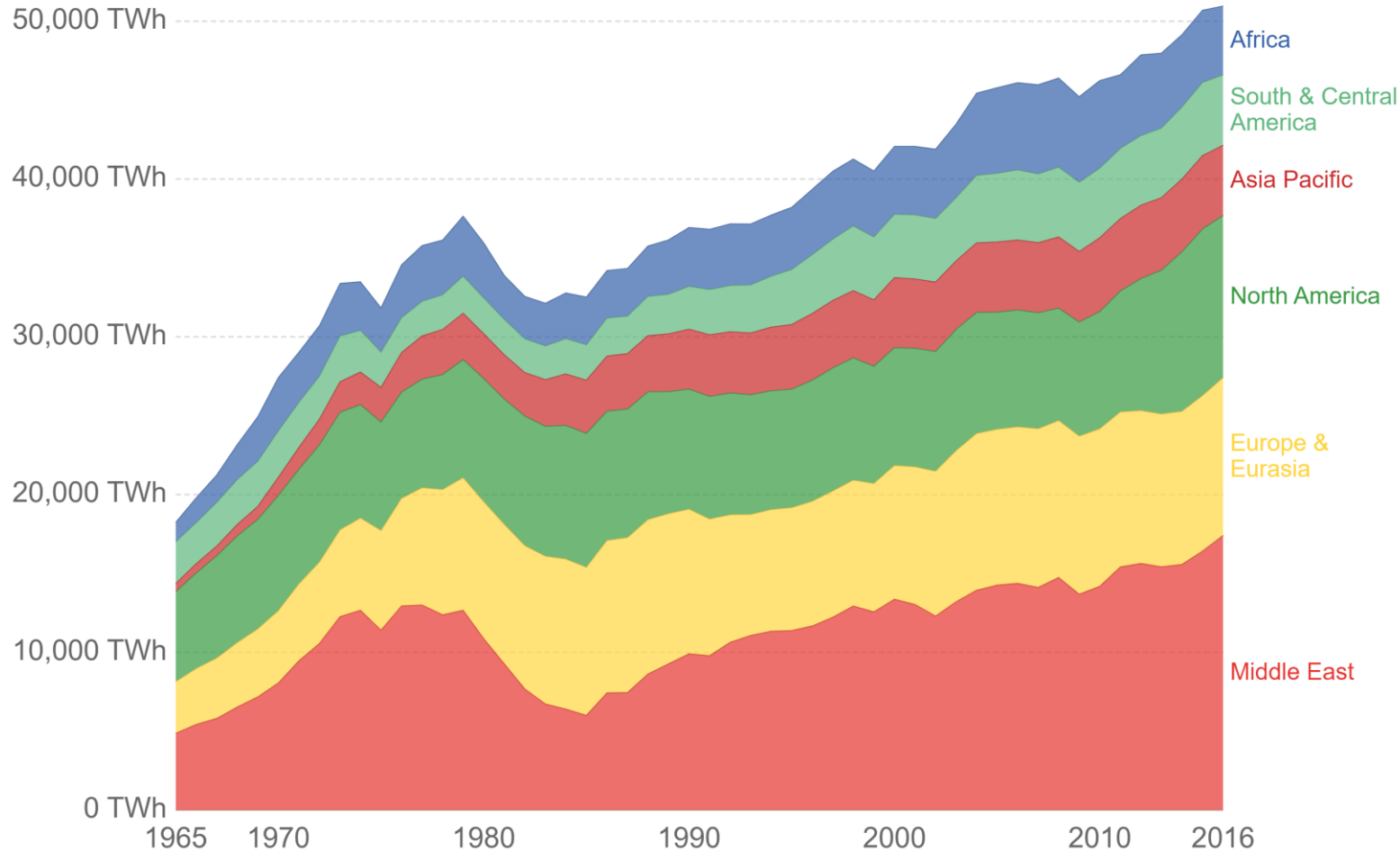
OPEC proven crude oil reserves, at end 2018 (billion barrels, OPEC share)

Venezuela	302.81	25.5%	Kuwait	101.50	8.5%	Algeria	12.20	1.0%	Gabon	2.00	0.2%
Saudi Arabia	267.03	22.4%	UAE	97.80	8.2%	Ecuador	8.27	0.7%	Equatorial Guinea	1.10	0.1%
IR Iran	155.60	13.1%	Libya	48.36	4.1%	Angola	8.16	0.7%			
Iraq	145.02	12.2%	Nigeria	36.97	3.1%	Congo	2.98	0.3%			

Source: OPEC Annual Statistical Bulletin 2019.

Oil production by region

Annual oil production, measured in terawatt-hour (TWh) equivalents.



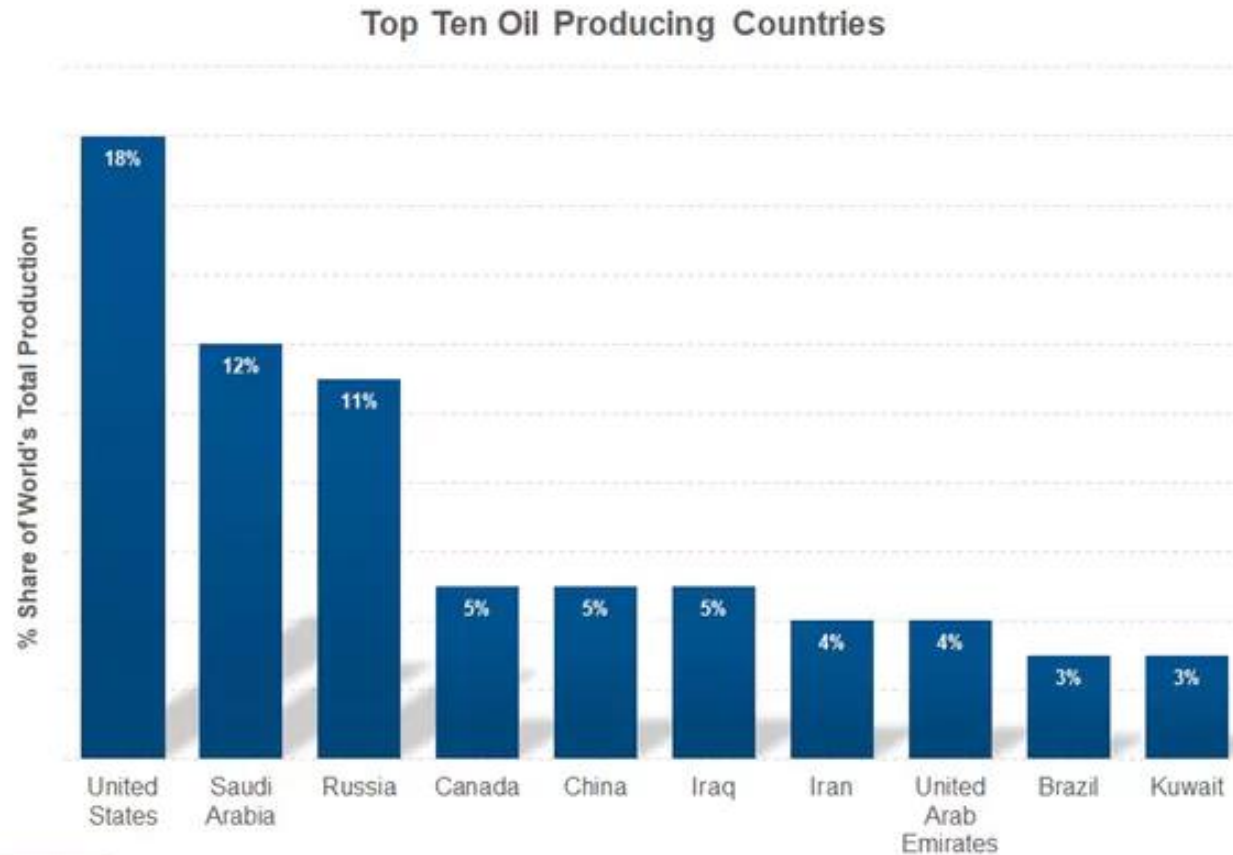
Source: BP Statistical Review of Global Energy

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- the Middle East is the world's largest oil producer, accounting for nearly 35%
- global oil production has increased more than 2.5-fold over the last 50 years

- expected „running out” 40 years

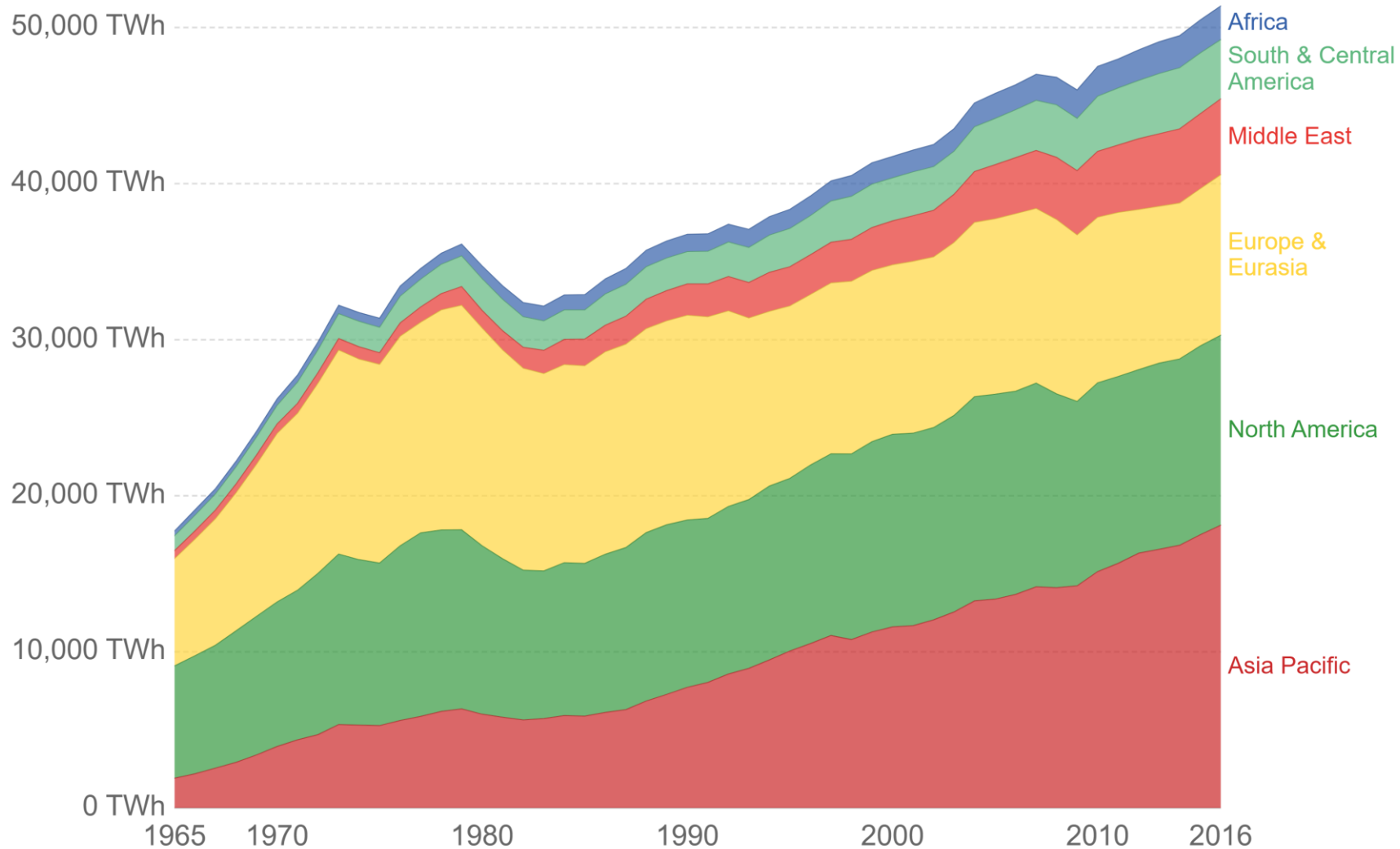
- **the United States, Saudi Arabia, and Russia are the world’s top three crude oil producers**



- the United States accounted for 18% of global oil production in 2018, next came
- Saudi Arabia, which produced 12%, and Russia, which accounted for 11% of global oil production
- Canada and China were, respectively, the fourth- and fifth-largest crude oil producers

Oil consumption by region

Annual oil consumption, measured in terawatt-hour (TWh) equivalents.



Source: BP Statistical Review of Global Energy

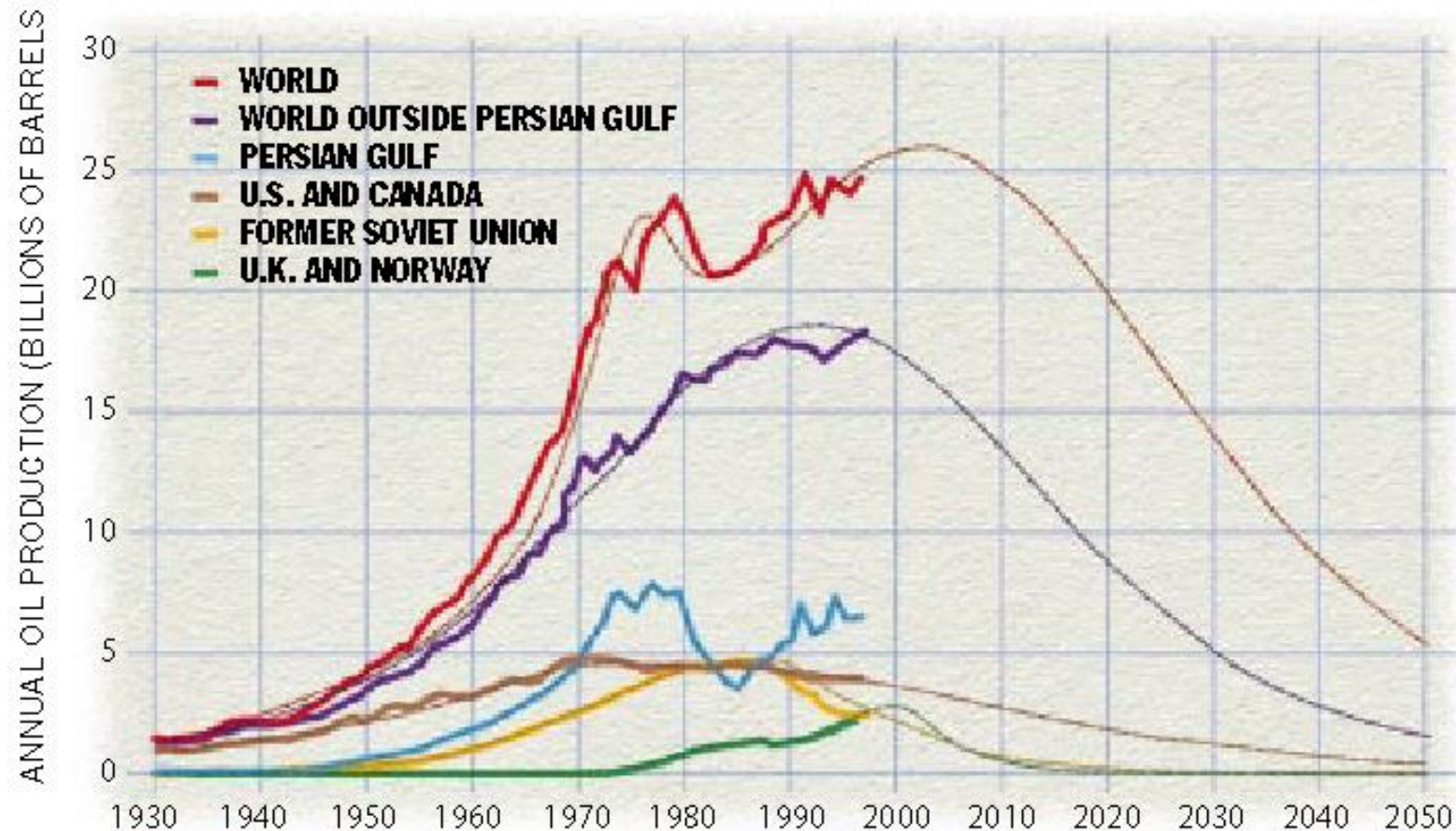
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the Middle East is a much smaller consumer than producer of oil (it produces more than 30%, and consumes around 10%), meaning it is a large net exporter; in contrast

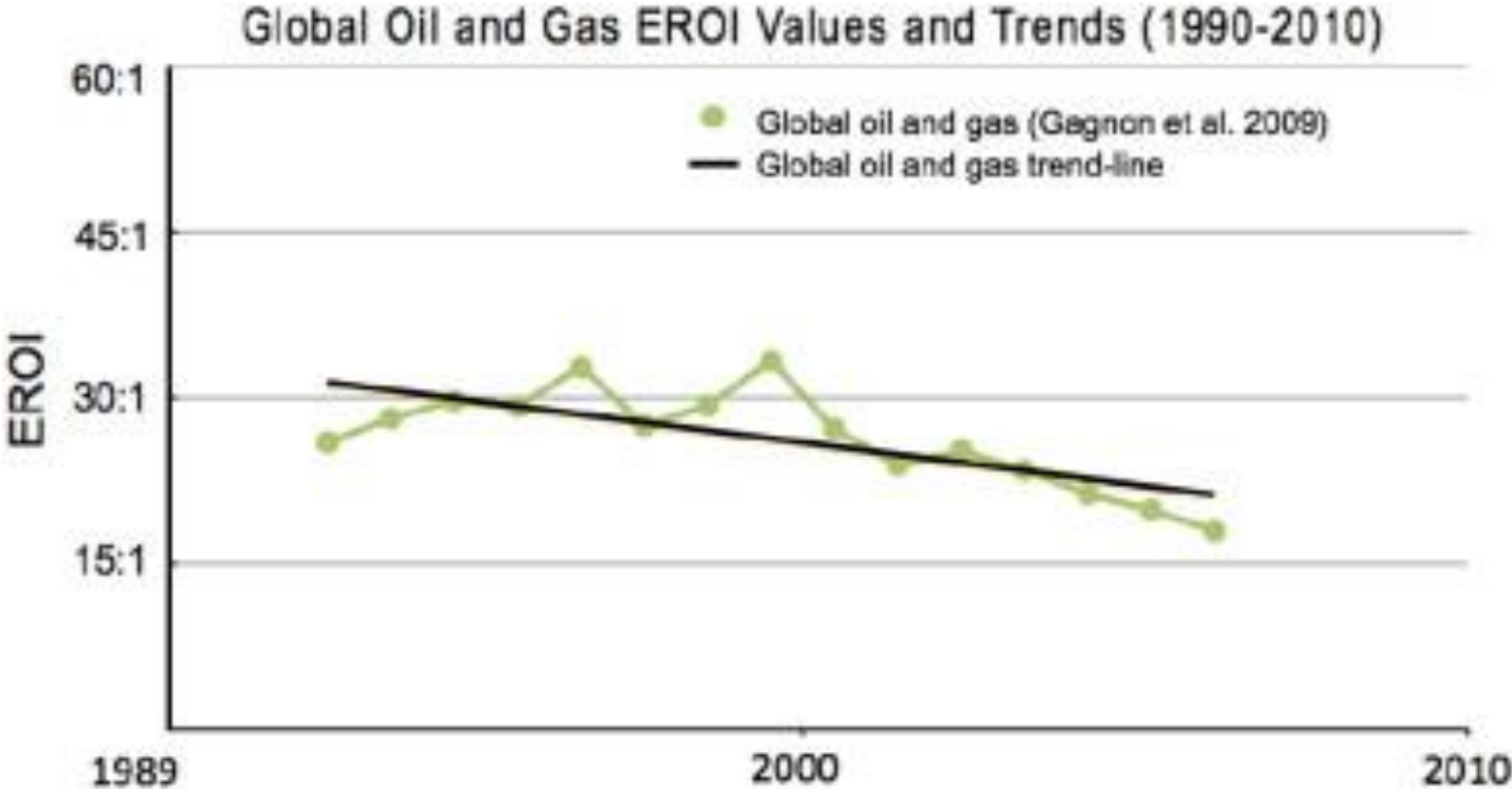
- the Asia Pacific region consumes significantly more oil than it produces (only 8-9% production versus 32% consumption), meaning it is a net importer

When will we run out of oil?

- most important question is maybe: *when will production begin to decline?* (ie, “when will peak oil production occur?”)
- in March 1998, two retired petroleum geologists (Campbell and Laherre) claimed that oil would peak in the first decade of the 21st century

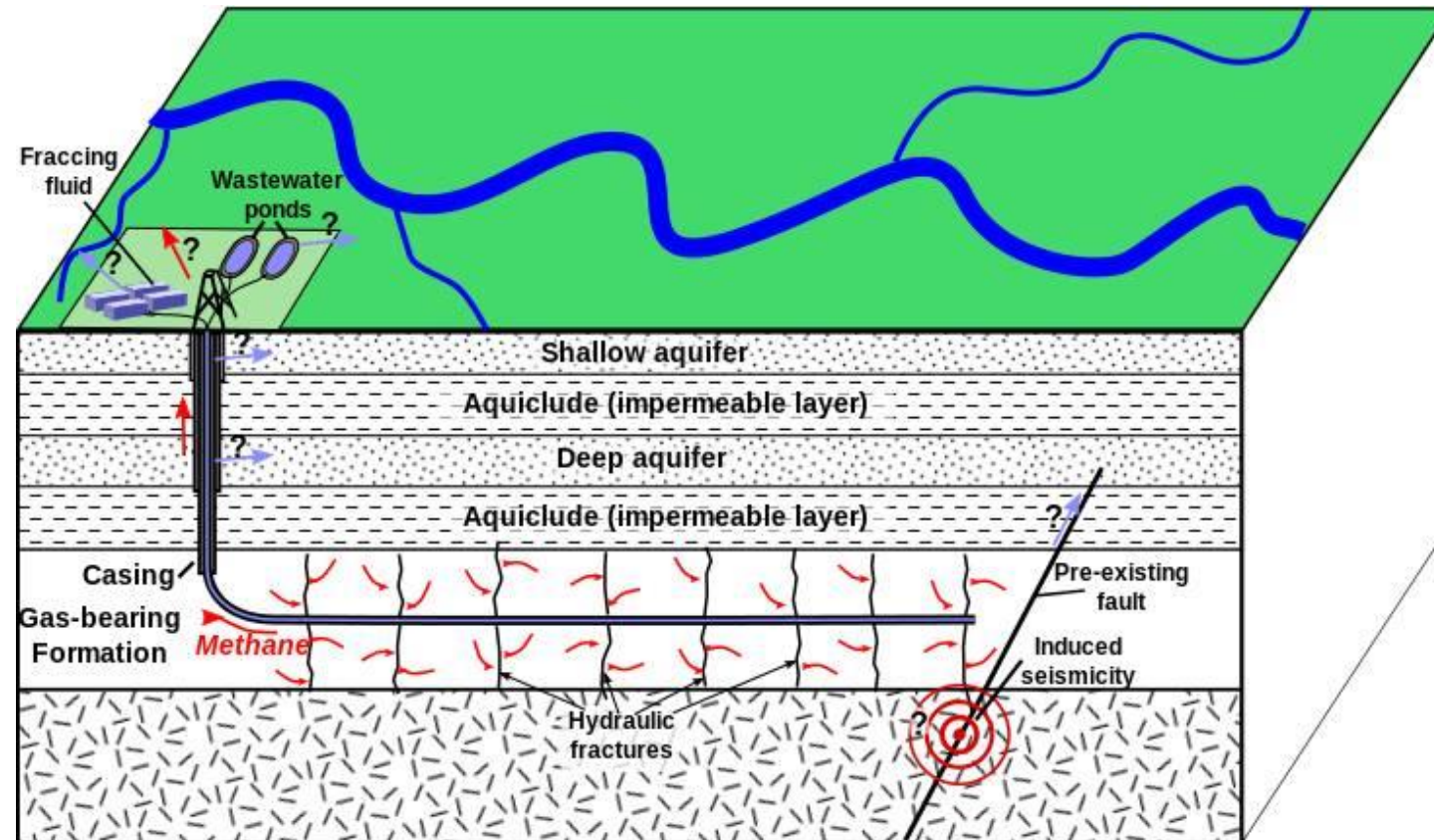


- the value of EROI was 100:1 (100 barrels of oil could be extracted from the energy of 1 barrel of oil), nowadays this number 7-10:1



Hydraulic fracturing:

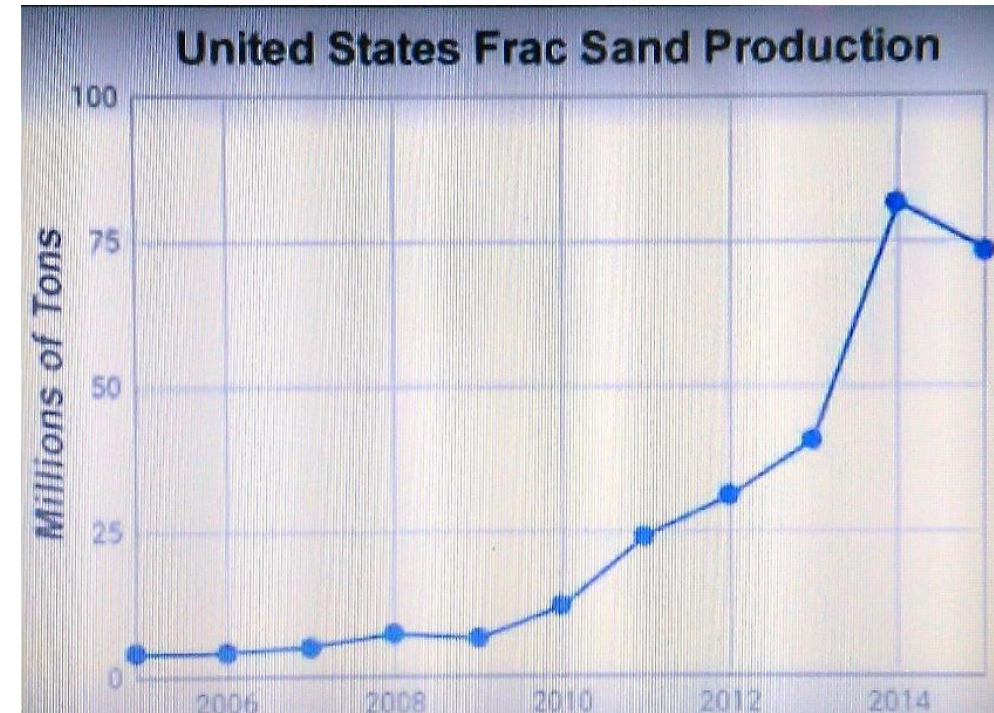
- new, secondary extraction process
- water is injected into the rock under high pressure, it will cause artificial earthquakes, as a result, oil-containing cracks open and crude oil/gas can be easily extracted
- the process has serious environmental problems



- it is important to preserve the rift through which the oil is extracted, for this they use proppant/flexible material: sand
- thousands of tons of sand are needed to operate one oil well
- as a result of this, the rate of special sand mining has increased suddenly and drastically: Iowa, Michigan, Minnesota and Wisconsin states – paleozoic sandstone

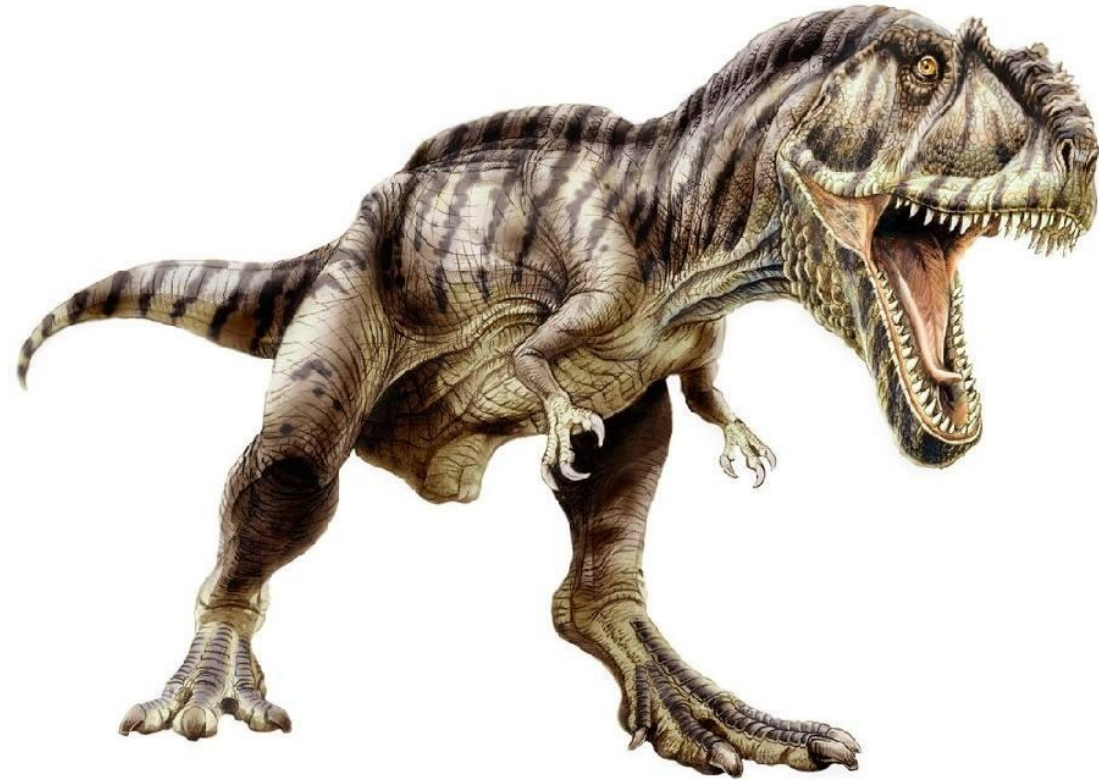
„common sand”: sand containing several minerals

clean homogenized quartz sand





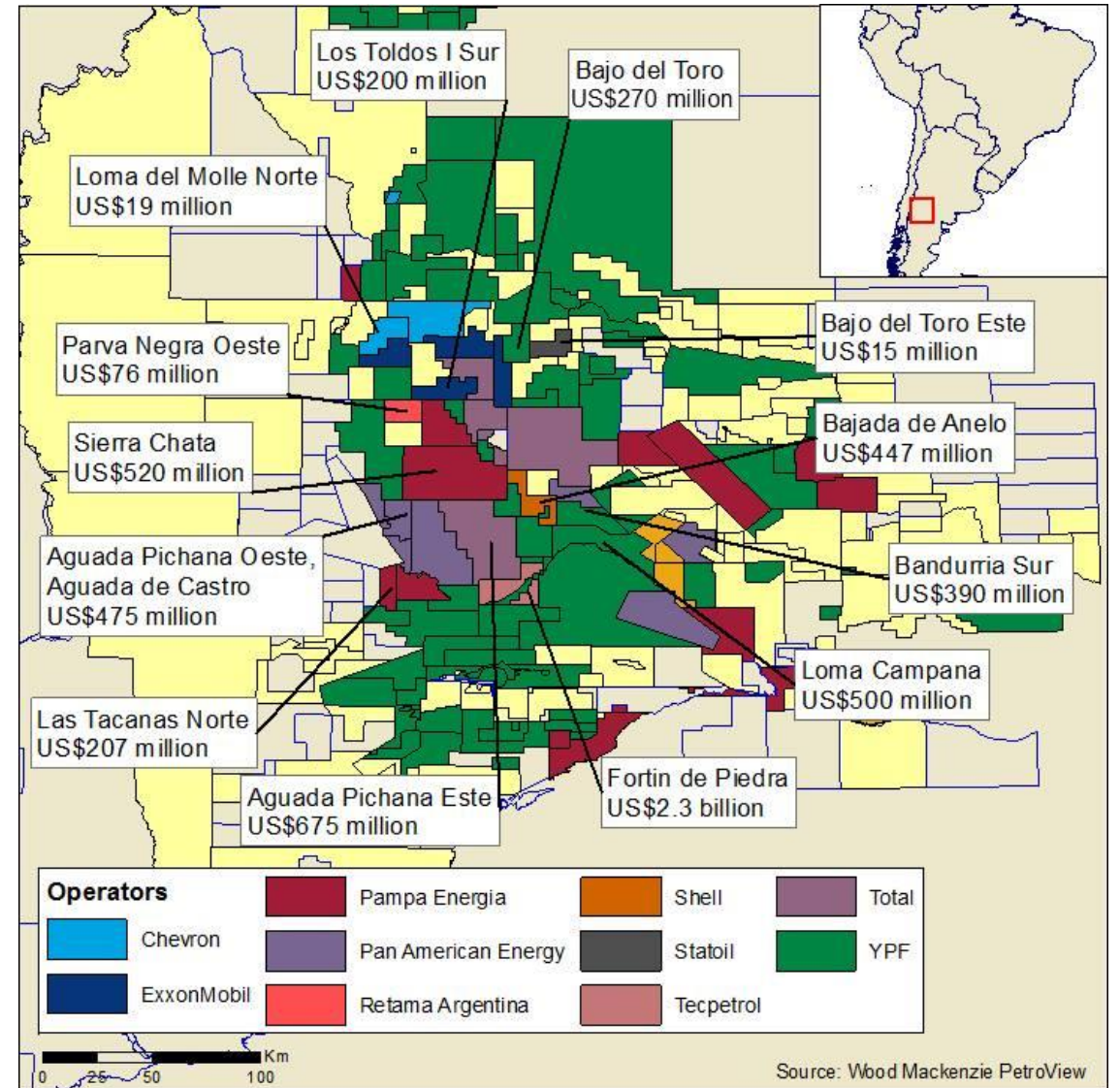
The Neuquén river in the Eastern half of the Andes



Giganotosaurus carolinii



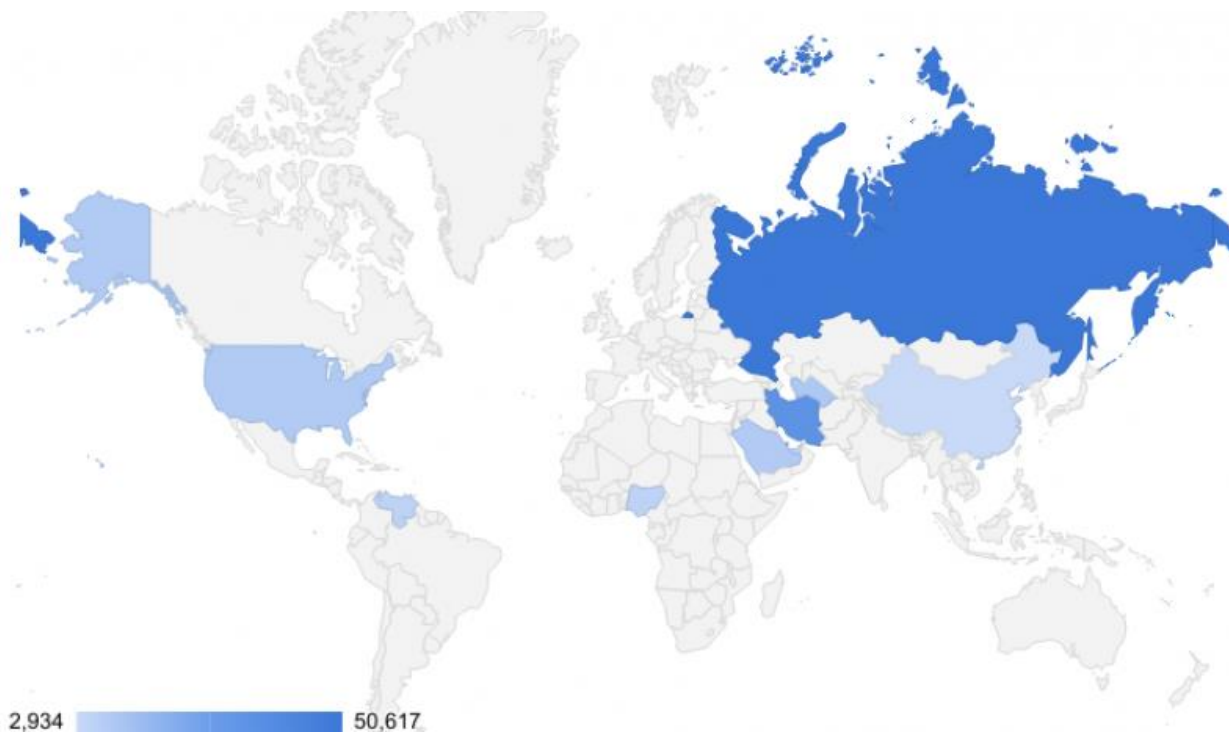
388 boreholes in the area of formation of Vaca Muerta



Investments by individual oil companies

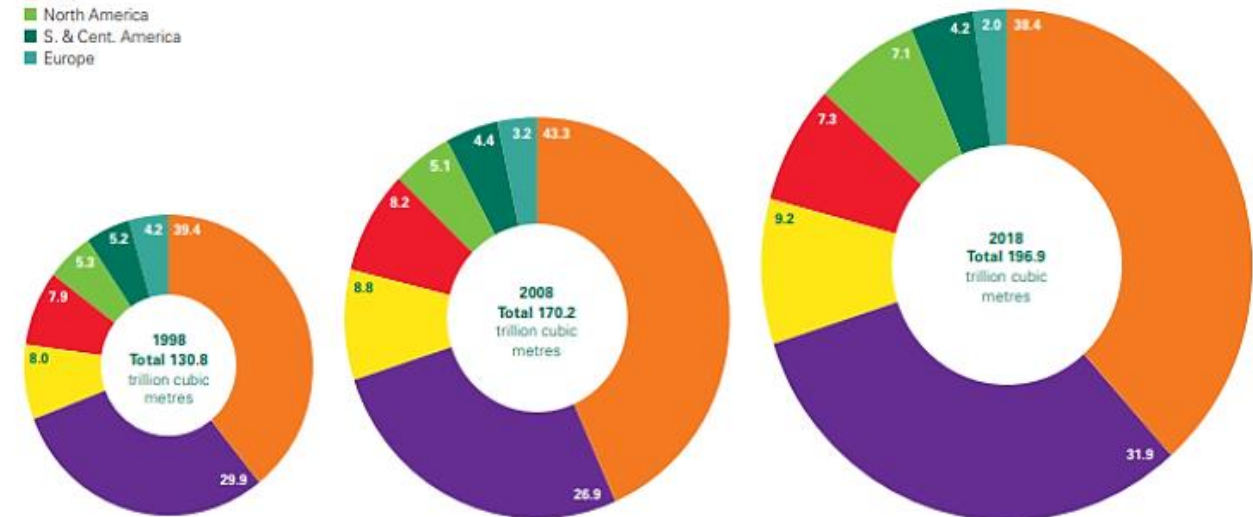
2. Gas

- easy to handle, significant in the production of heating energy
- its importance is increasing among residential consumers
- natural gas is seen as "**lower carbon**" relative to other fossil fuels



Distribution of proved reserves in 1998, 2008 and 2018

Percentage



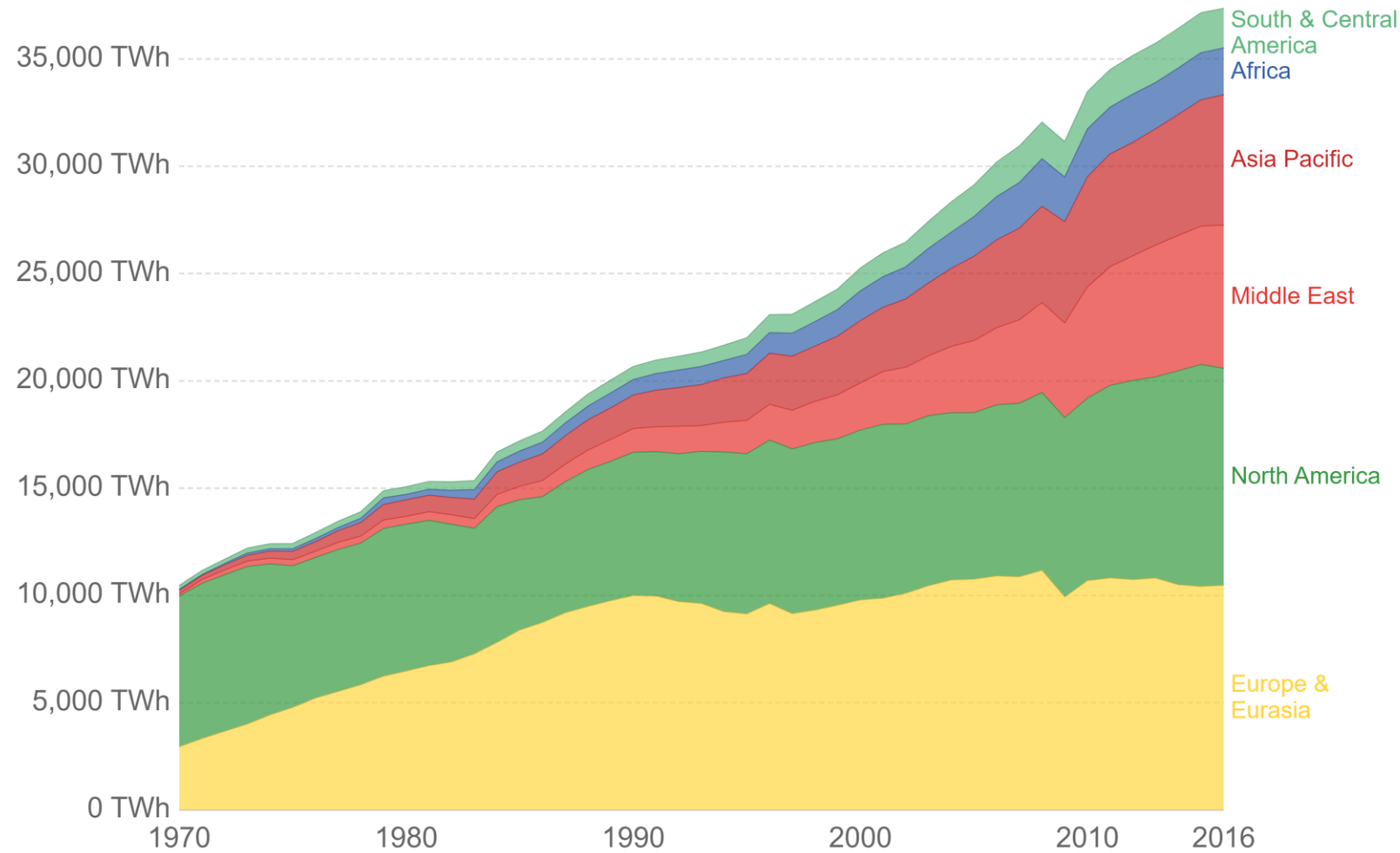
Map with TOP 10 countries with the largest reserves of Natural Gas

Source: *BP Statistical Review of World Energy 2019*
| 68th edition

Natural gas production by region

Annual natural gas production, measured in terawatt-hour (TWh) equivalents.

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in Data



Source: BP Statistical Review of Global Energy

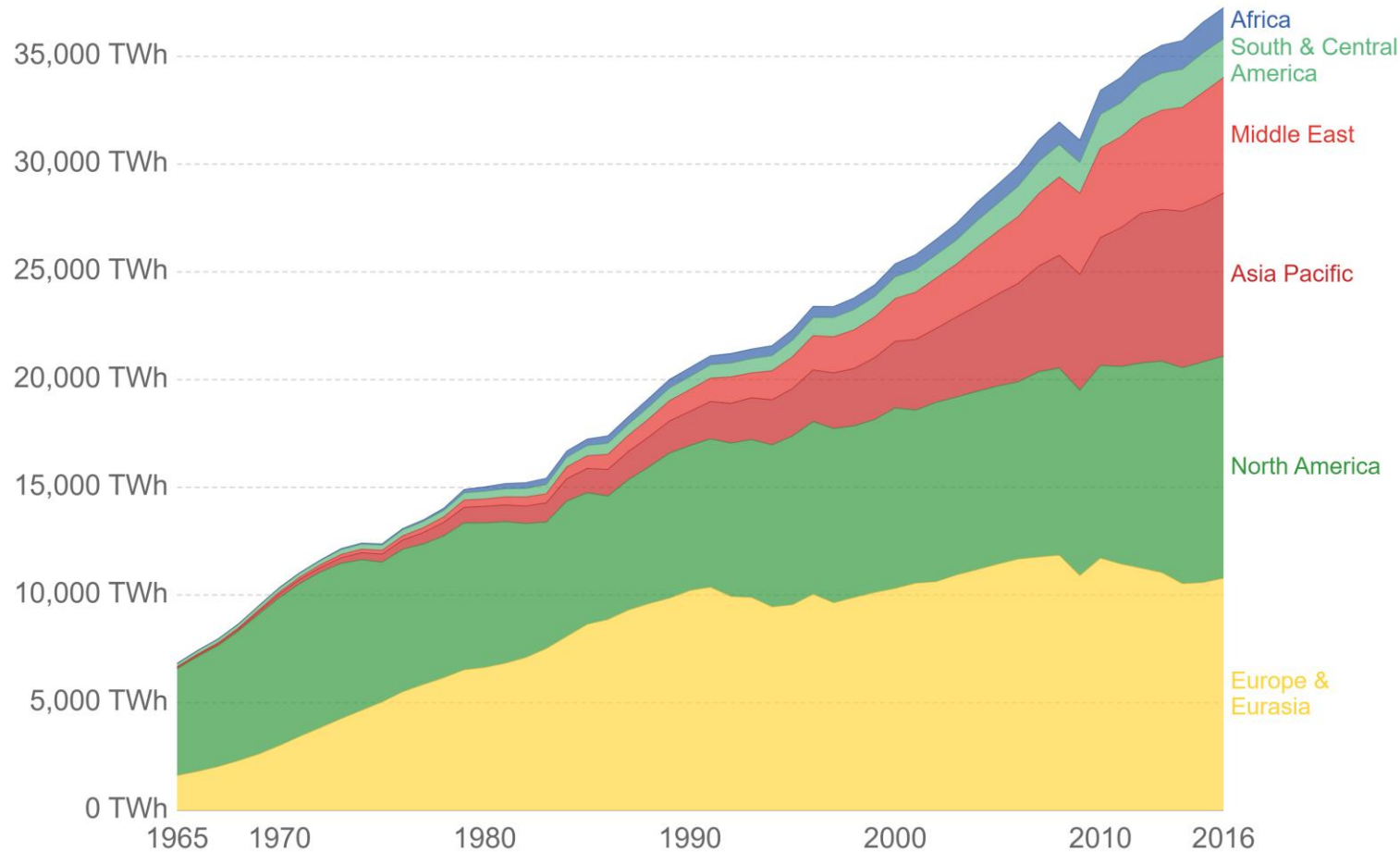
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- natural gas production has nearly quadrupled over the last 40-50 years
- the USA is the world's largest single producer of natural gas producer, accounting for approx. one-fifth of global production
- followed by Russia, Iran, Canada, China and Saudi Arabia which all produce more than 1000 TWh/year

Natural gas consumption by region

Annual natural gas consumption, measured in terawatt-hour (TWh) equivalents.

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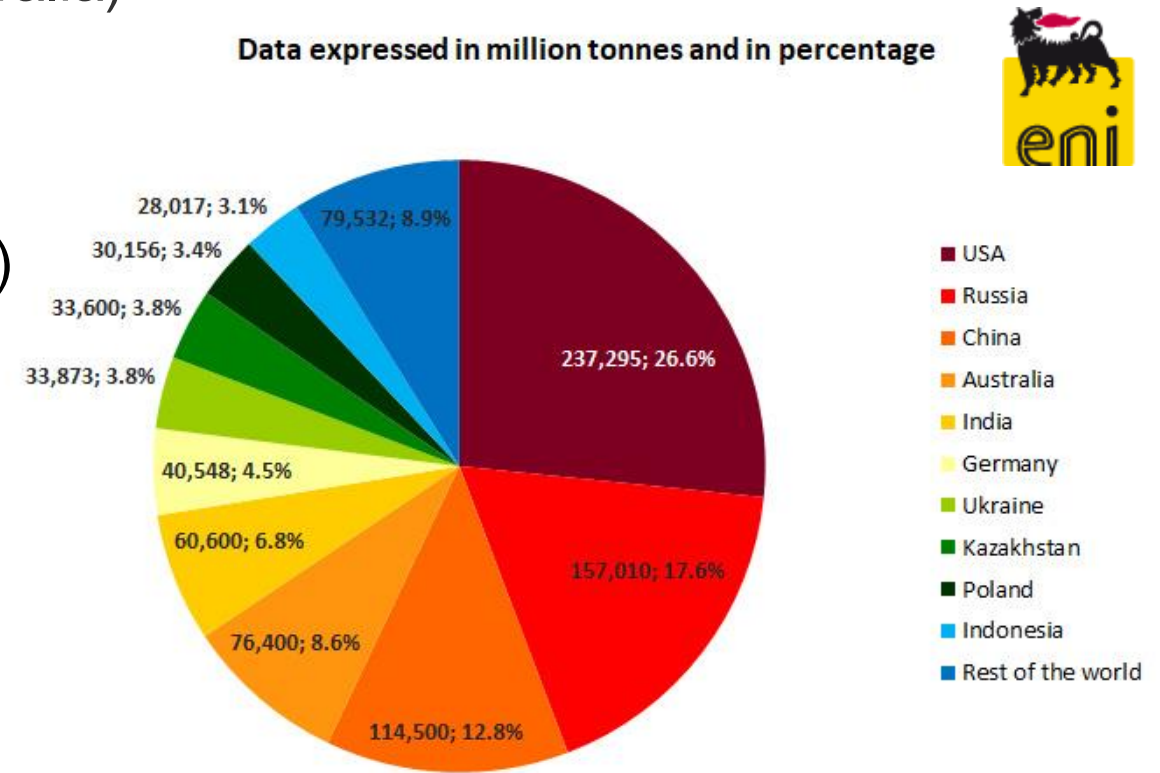
Source: BP Statistical Review of Global Energy

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- the Middle East is a net gas exporter, whilst the Asia Pacific is a net importer
- the United States is the world's largest consumer, followed by Russia, Iran, Canada, China and Saudi Arabia
- natural gas consumption has seen significant growth across all regions over the last few decades - this is true of both high and lower-income nations as nations seek to improve domestic energy security, and economies attempt to shift from coal consumption

3. Coal

- the first 3 countries (USA, Russia and Australia) have 53.7% of global coal reserves
(global coal reserves= 1,035 billion tonnes)
- consumption growth was led by India (36 mtoe) and China (16 mtoe)
- coal's share in primary energy fell to 27.2%, its lowest in 15 years



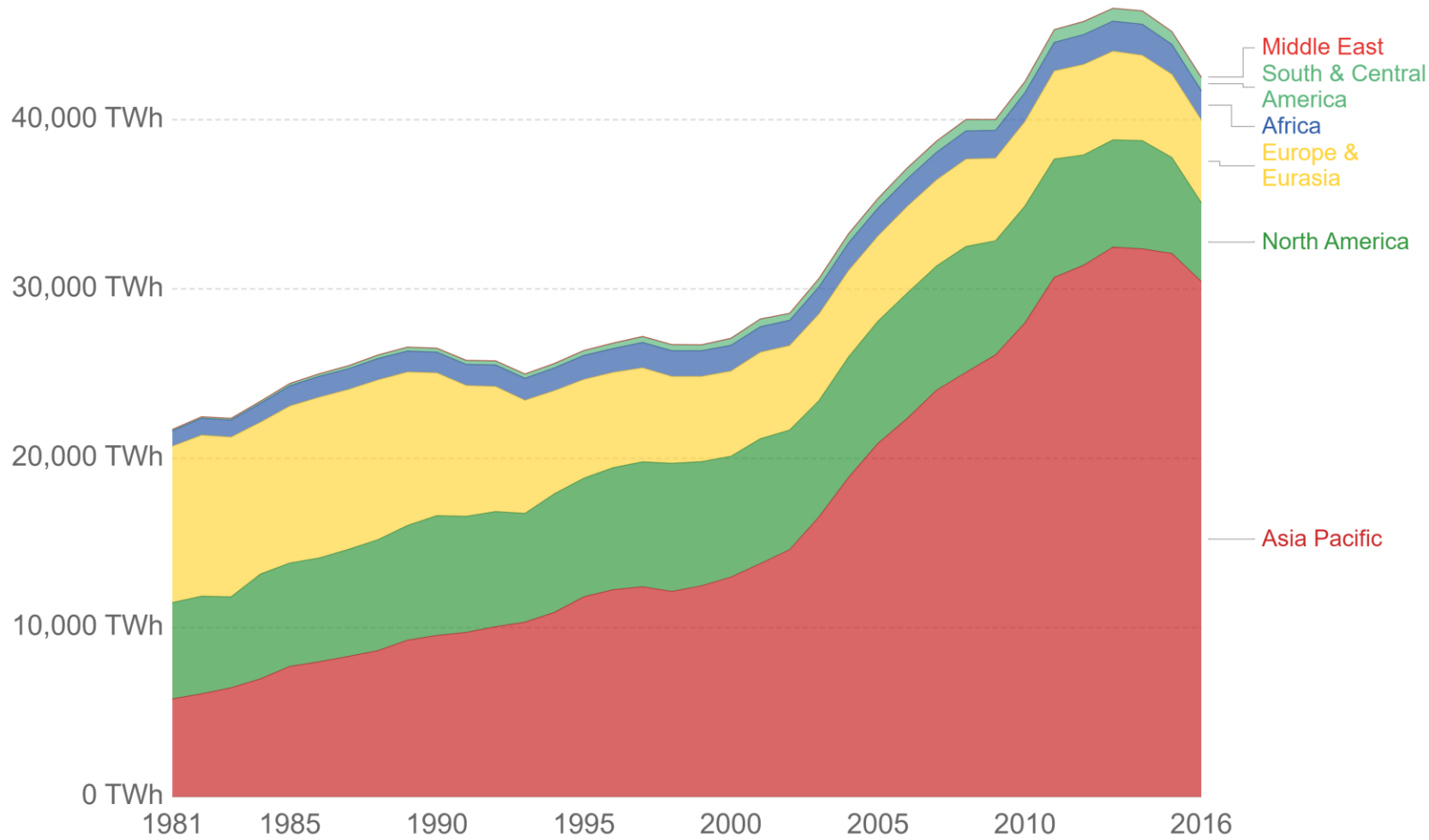
World coal reserves in 2017

Source: *BP Statistical Review of World Energy 2018*

Coal production by region

Annual coal production, measured in terawatt-hour (TWh) equivalents.

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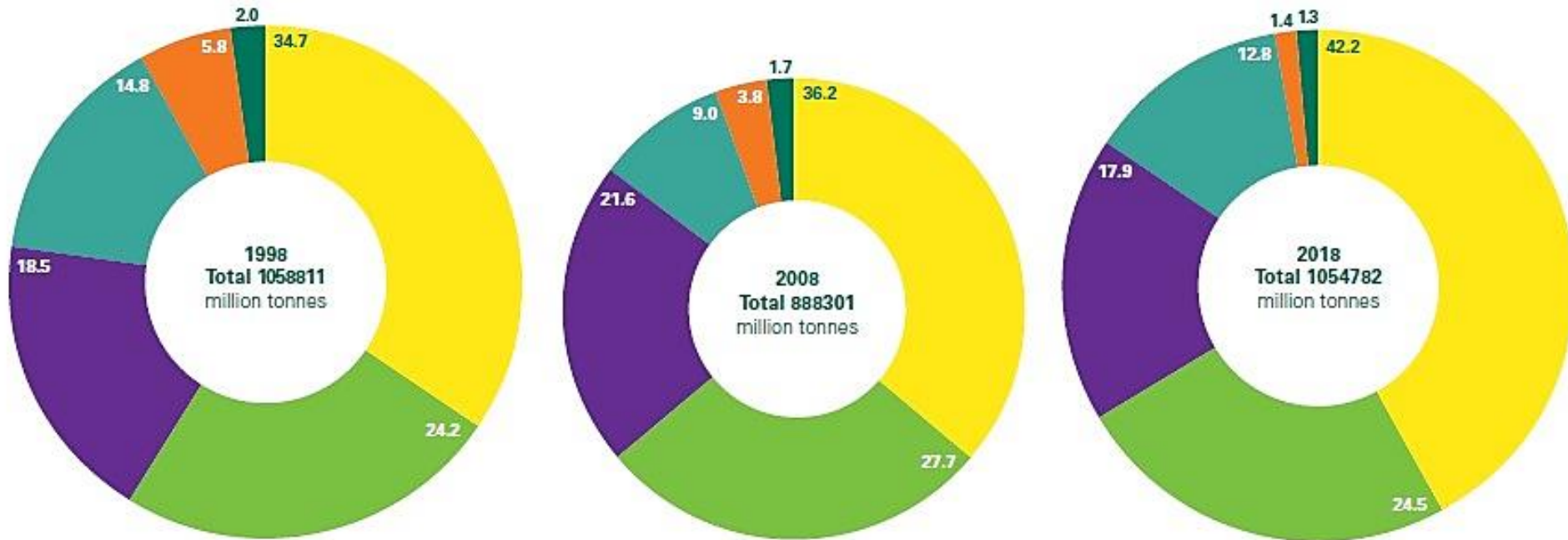


- China dominates global coal production, accounting for nearly half of total output

- **the growth in coal consumption** was more than accounted for by **increasing** use in the power sector
- even if renewables are growing at truly exceptional rates, **the pace of growth of power demand**, particularly in developing Asia, **limits the pace at which the power sector can decarbonize**

Distribution of proved reserves in 1998, 2008 and 2018
Percentage

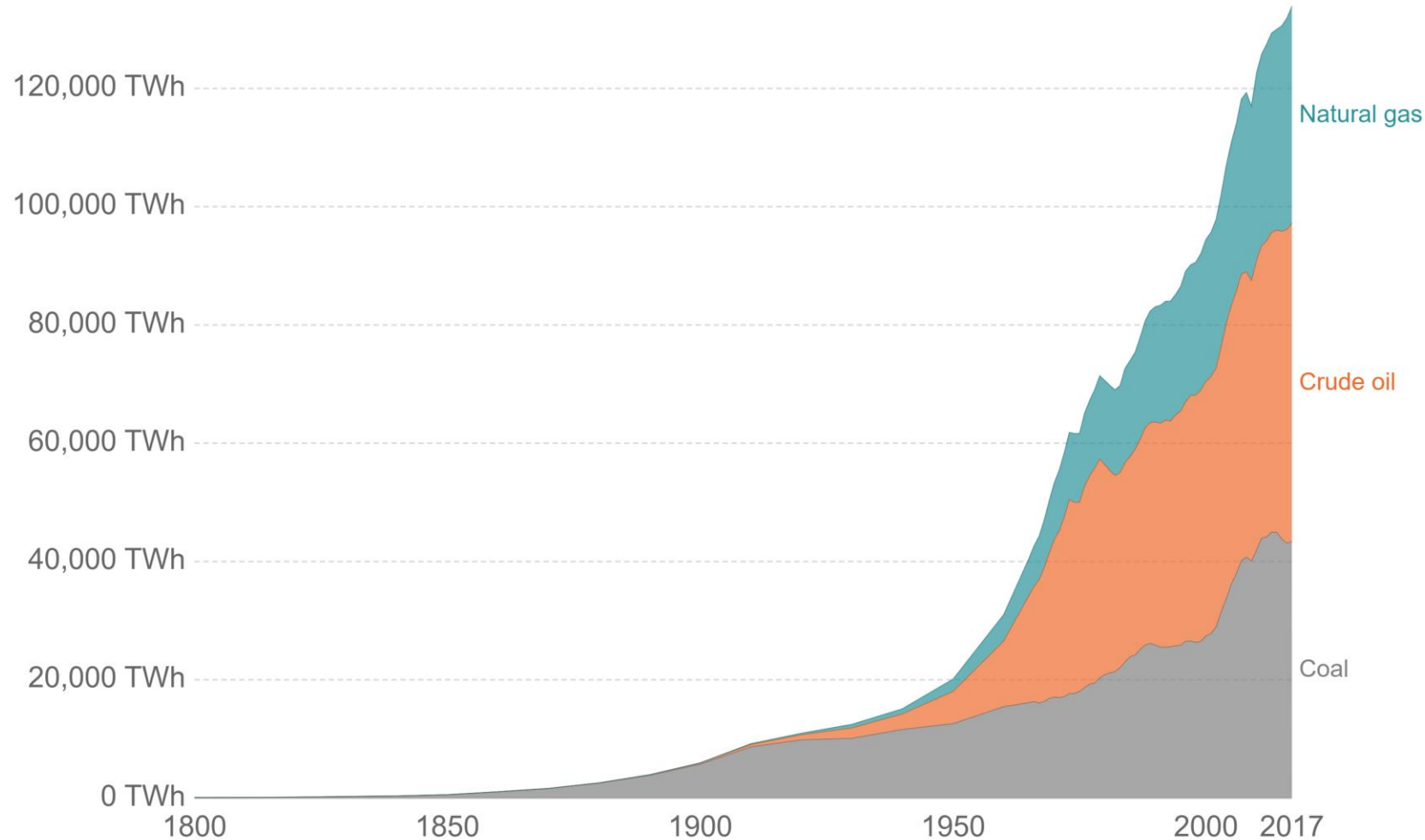
■ Asia Pacific
 ■ North America
 ■ CIS
 ■ Europe
 ■ Middle East & Africa
 ■ S. & Cent. America



Source: BP Statistical Review of World Energy 2019 | 68th edition

Global fossil fuel consumption

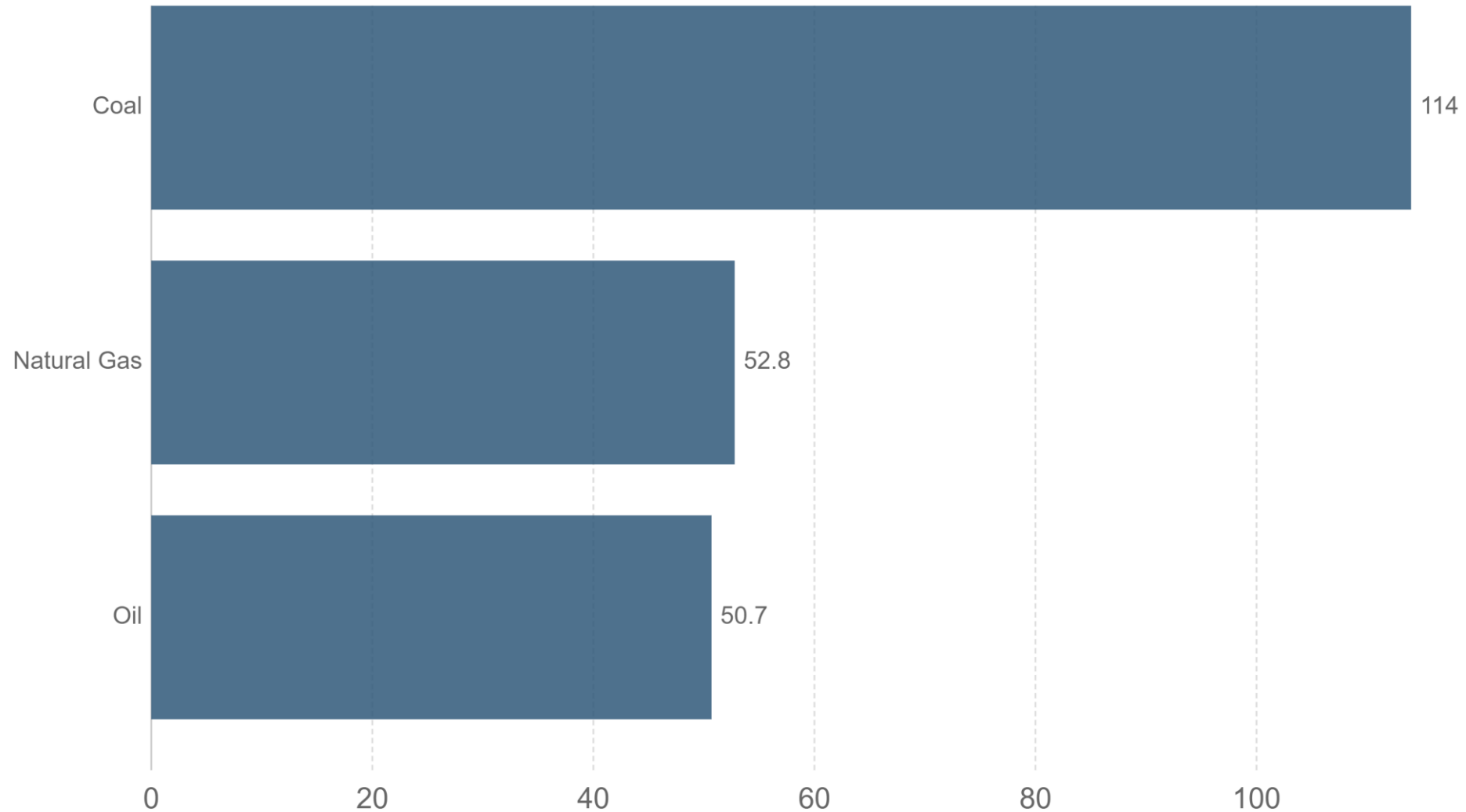
Global primary energy consumption by fossil fuel source, measured in terawatt-hours (TWh).



- global consumption of fossil energy has increased more than 1300-fold
- today, crude oil is the largest energy source, accounting for around 39% of fossil energy, followed by coal and natural gas at 33% and 28%, respectively

Years of fossil fuel reserves left

Years of global coal, oil and natural gas left, reported as the reserves-to-product (R/P) ratio which measures the number of years of production left based on known reserves and annual production levels in 2015. Note that these values can change with time based on the discovery of new reserves, and changes in annual production

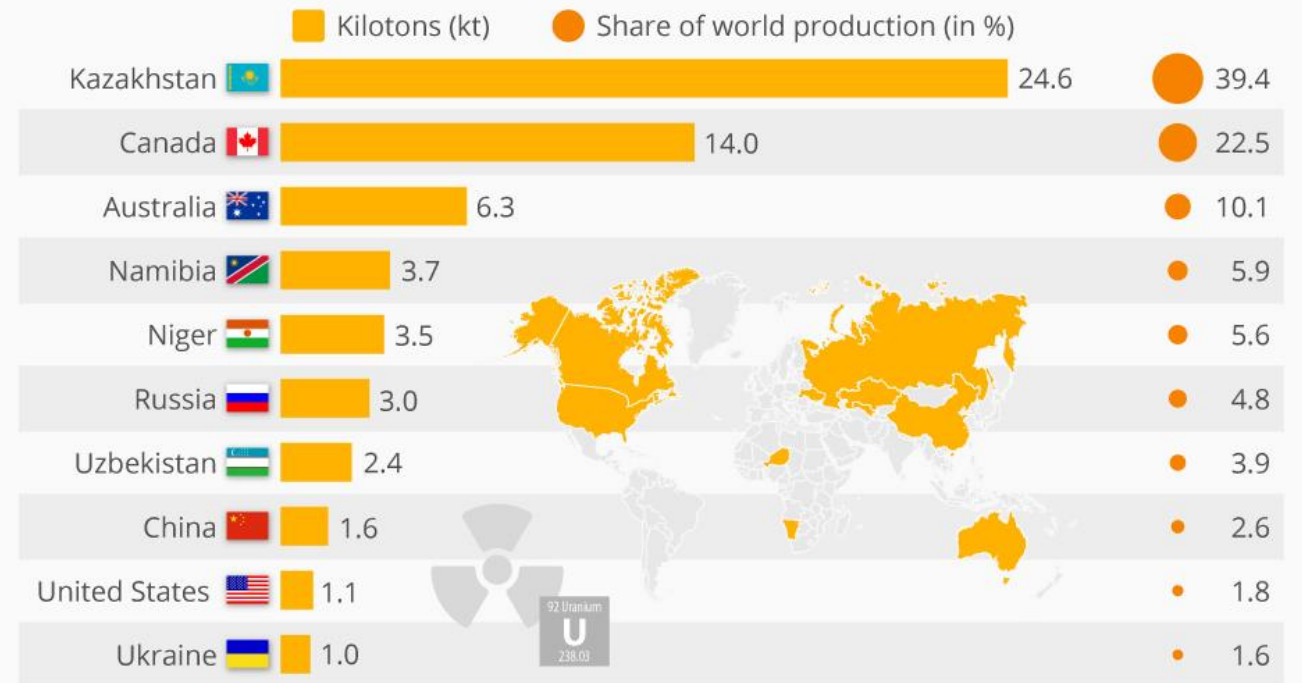


4. Nuclear energy

- uranium reserves are declining
- **Kazakhstan is the biggest producer of the radioactive metal.** The central Asian country produced around 24,600 metric tons of the substance in 2016. This is a share of close to 40 percent of the worldwide production
- until now, **the United States is still the biggest consumer of uranium**

Where the Uranium comes from

Ranking of countries with the largest production volume of uranium in 2016 (in kilotons)

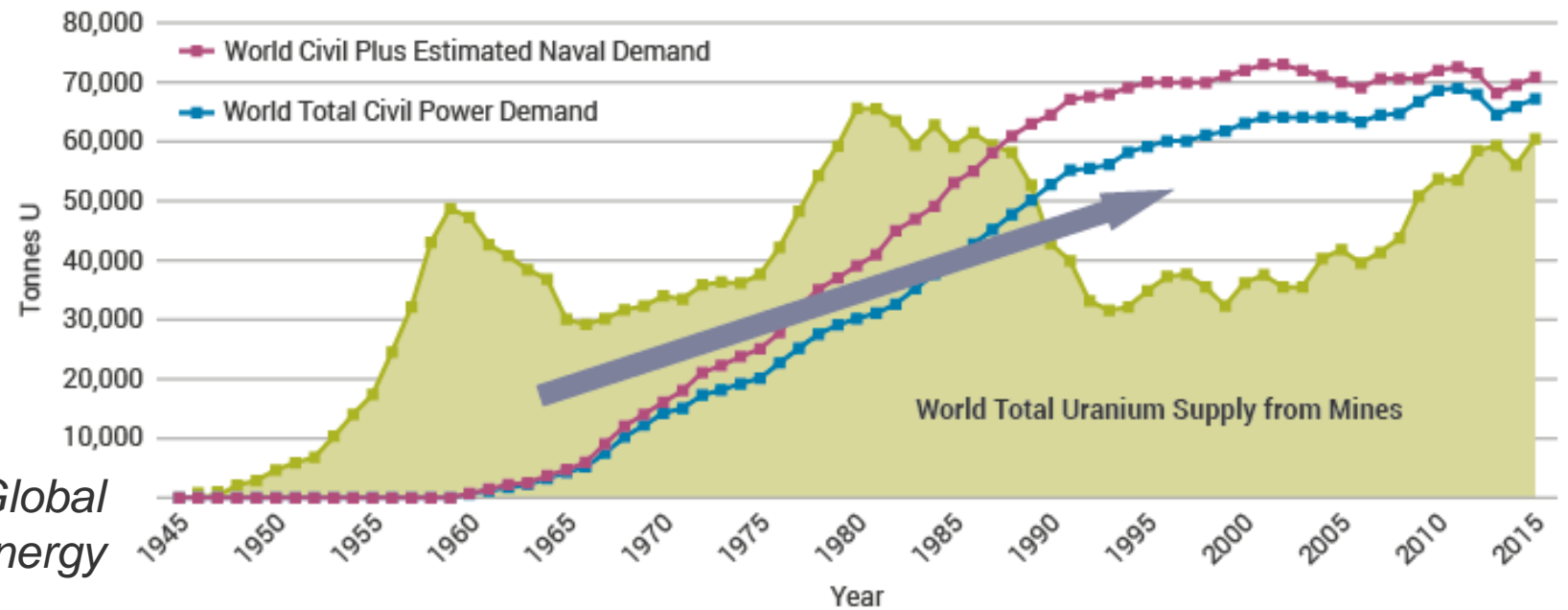


@StatistaCharts Source: BGR

statista

- it doesn't emit CO₂ into the atmosphere but can be very dangerous due to radioactivity
- environmental problem:
 - thermal pollution in water
 - disposal and treatment of reactor waste

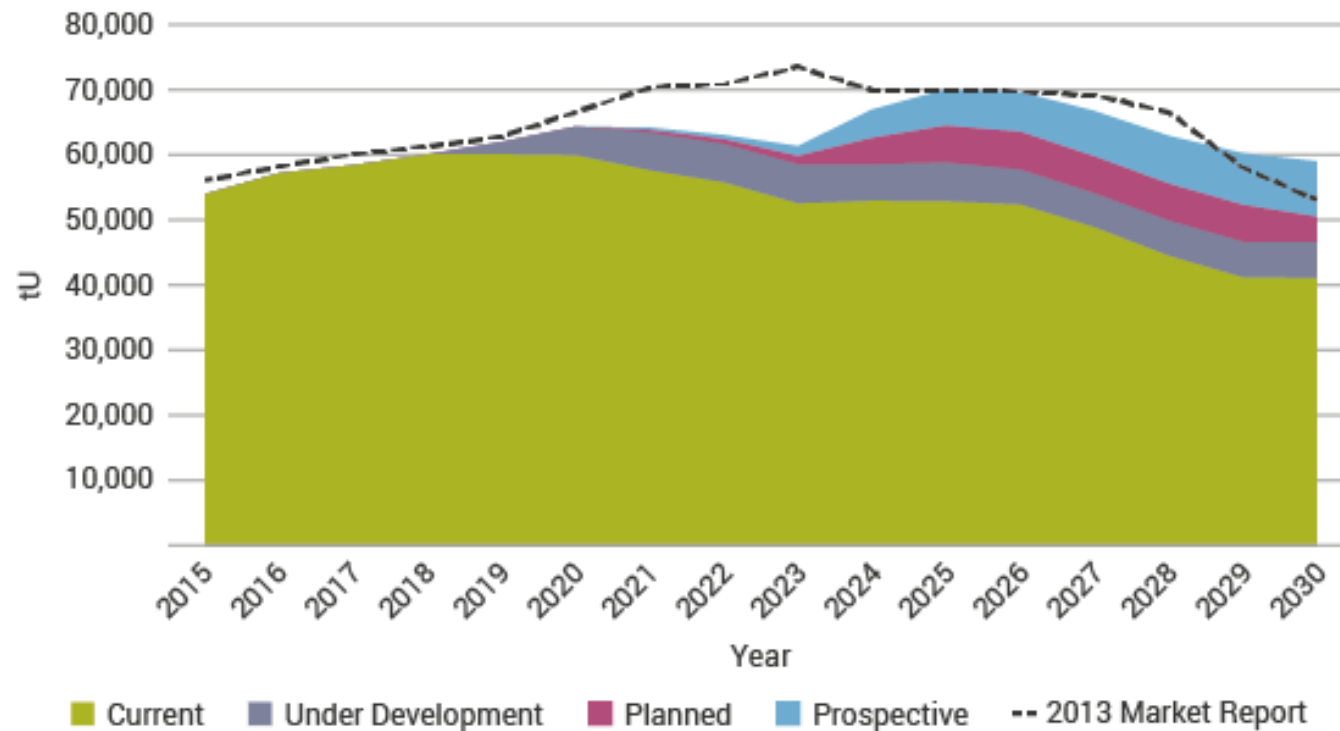
World Uranium Production and Demand



Sources: World Nuclear Association Global Nuclear Fuel Report; International Energy Agency World Energy Outlook

- nuclear energy is energy in the nucleus (core) of an atom
- can be used to make electricity, but first the energy must be released. It can be released from atoms in two ways: nuclear fusion and nuclear fission.
- nuclear energy plants are very expensive to built

Reference Scenario Prospective Production, tU



- in 2016, there were 447 nuclear reactor in operation, add in 12% of the world's energy production
- 117 nuclear reactors are planned to be operational by 2025
- about 372 reactors are planned to be built in different countries

Sources: World Nuclear Association *Global Nuclear Fuel Report*, International Energy Agency *World Energy Outlook*



Nuclear fission uses uranium to create energy, but



nuclear energy is a nonrenewable resource because once the uranium is used, it is gone!

- <http://www.thoriumenergyworld.com/energy.html> - world energy in 4 minutes
- www.theguardian.com/environment/video/2019/oct/08/who-are-the-worlds-biggest-climate-polluters-video

Learning:

http://www.sze.hu/~radicsa/Dr_Kozma_Katalin/Environmental_protection/

presentations and a book to learn from:

Michael Allaby: Basics of Environmental Science, pp.1-135.