



Lomonosov Moscow State University
Business School

Global Limits of Economic Growth

*Lomonosov Moscow State University,
Inter-Departmental Course, 2023-2024, Spring Fall*

Course Reader:

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Requirements to Pass the Course

- 1) At least 50% of sessions are attended (6 sessions)
- 2) At least 60% points for the final course test
- 3) Individual Project (Presentation) is done properly and delivered in time



Pre-Reading and Food-for-Thought Assignment before and after Session 5 (March, 5)

Files for pre-reading are available in corresponding folders of the course in Microsoft Teams and Moodle

ENERGY STATISTICS and INDICATORS


- Familiarize yourself with the latest BP Statistical Review of World Energy ([bp.com](https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html)):
<https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html>

Think about:

What kind of data is presented in this report?

What energy indicators are used there?

What other websites do you know with similar statistics?



General Scheme for Resource Limitations Analysis



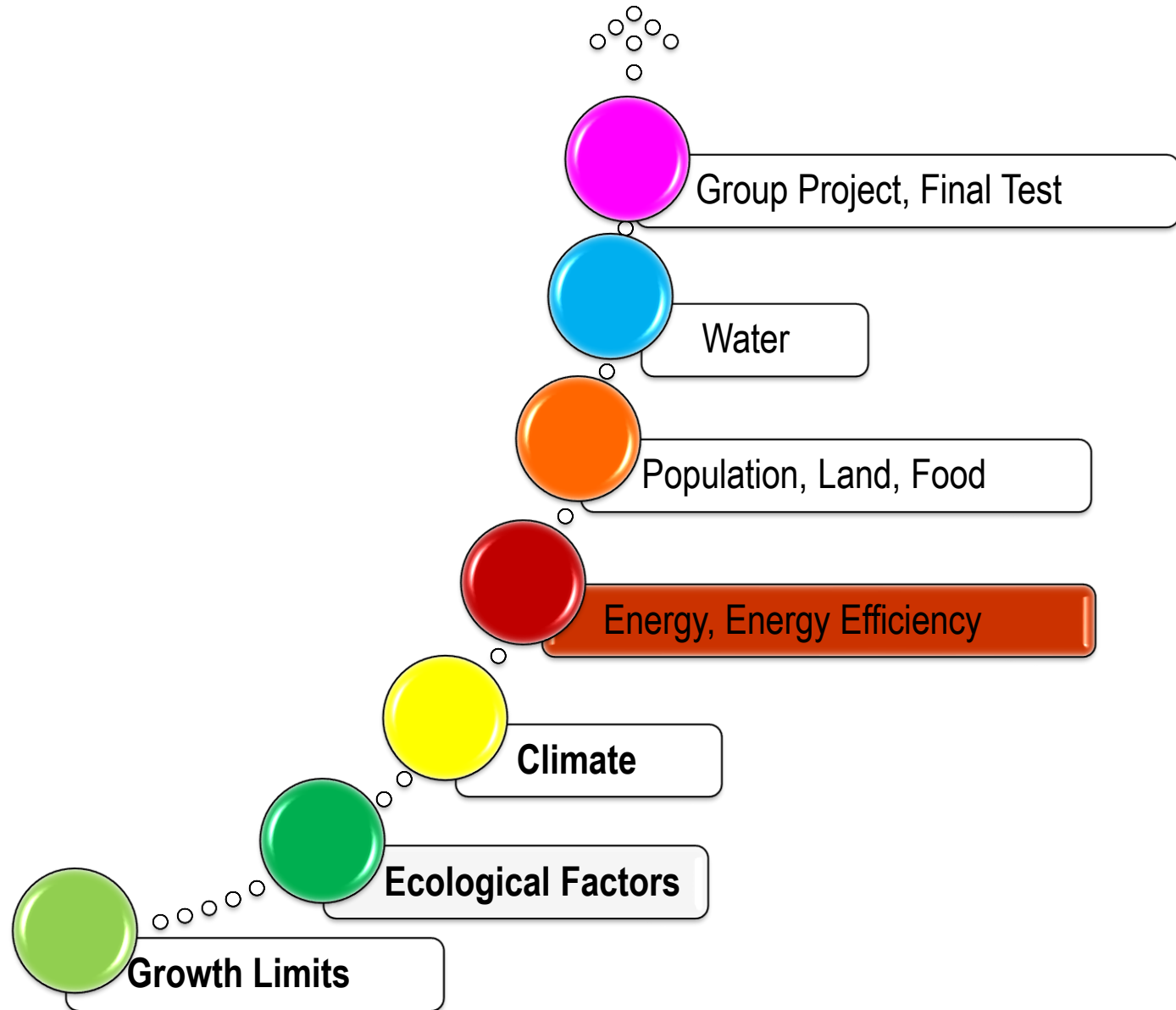
Scheme for the Individual Project (1-2 students per 1 project)

Resources	Steps of Analysis					
	Step 1	Step 2			Step 3	Step 4
	Role/ Importance	Limitations produced for			Ways used to overcome existing limitations	Suggestions how to improve these ways of coping with limitations
	World economy	National economy	Industries/ Business			
Unique Resource or Problem selected by you Scale: world or a country or an industry

Learning Schedule

- Our classes will take place on Wednesdays at 15:00 for 3 months (12 weeks)
- Communication with the course reader:
 - During classes
 - Via e-mail
 - All administrative issues should be addressed via **your Personal Account in the MSU Learning Management System**
- Before each session you will receive **Pre-Reading and Food-for-Thought Assignment** through your Personal Account

Course Route



PLAN of the Session 5

1. World Market of Energy Resources and Energy Balance
 - *Experiential Exercise on Energy Balances*
2. Energy Intensity of Different Economies and Industries

Session 5

Energy Resources and Energy Demand-Supply

2024

The Aims of the Session 5

1. To understand the idea of energy balances, to be able to give a description of the country's economy according to it
2. To know peculiarities of different energy indicators and be able to interpret them correctly

World Market of Energy Resources

- Primary energy sources

- Oil, natural gas, coal, nuclear, **hydro** and **geothermal** power, **biomass**



- Secondary energy sources

- Electricity, such renewables as **wind** and **solar** power, different derivatives from oil like fuel oil, kerosene etc.



Energy Mix VS Electricity Mix

- Mix = Structure
- Energy Mix refers *mainly* to the final energy consumption by primary energy source



- Example of a Primary Energy Balance Structure

	Oil	Gas	Coal	Nuclear	Hydro	Geothermal and others	Total	Total (%)
Production								
Consumption								
Export (-)/ Import (+)								
Total								

- Scheme to analysis of any energy source:
 - Reserves (R), Production (P), Consumption, Reserves/Production, Import/Export
- Reserves/Production: method “to the last drop”
- Method of “Peak Oil” ($\text{Reserves}/2 \approx \text{time of shortage begins}$)

Simplified Energy Balance: World (2014)

(Mtoe)

SUPPLY AND CONSUMPTION	Coal ¹	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Biofuels and waste ²	Other ³	Total
Production	3976.14	4308.45	-	2928.32	661.35	334.94	1413.06	183.17	13805.44
Imports	842.15	2213.37	1193.32	844.32	-	-	20.22	61.73	5175.12
Exports	-863.14	-2159.50	-1242.64	-863.25	-	-	-18.97	-59.35	-5206.85
Stock changes	-36.66	-12.46	-15.23	-8.81	-	-	-1.41	-	-74.58
TPES	3918.49	4349.86	-64.56	2900.58	661.35	334.94	1412.91	185.55	13699.13

Simplified Energy Balance: World (2014)

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Stock changes	-36.66	-12.46	-15.23	-8.81	-	-	-1.41	-	-74.58
Total Primary Energy Supply = TPES	3918.49	4349.86	-64.56	2900.58	661.35	334.94	1412.91	185.55	13699.13
Transfers	-0.47	-204.86	231.24	-	-	-	-	-	25.92
Statistical diff.	-21.91	0.12	4.51	14.68	-	-	0.16	-0.94	-3.38
Electricity plants	-2112.98	-40.62	-201.89	-771.07	-653.73	-334.94	-95.03	1726.81	-2483.47
CHP plants	-164.61	-0.01	-17.07	-307.53	-7.62	-	-57.43	325.45	-228.81
Heat plants	-130.32	-0.68	-13.19	-78.82	-	-	-11.45	178.30	-56.17
Blast furnaces	-209.84	-	-0.38	-0.16	-	-	-0.05	-	-210.43
Gas works	-10.92	-	-2.73	5.08	-	-	-0.09	-	-8.67
Coke ovens ⁴	-76.25	-	-2.80	-0.01	-	-	-0.12	-	-79.19
Oil refineries	-	-4123.03	4049.60	-	-	-	-	-	-73.43
Petchem. plants	-	33.00	-32.62	-	-	-	-	-	0.38
Liquefaction plants	-9.67	14.03	-	-17.42	-	-	-	-	-13.07
Other transf.	-0.43	10.07	-0.52	-11.88	-	-	-82.90	-0.73	-86.40
Energy ind. own use	-101.76	-11.42	-205.29	-291.69	-	-	-13.94	-209.33	-833.44
Losses	-3.89	-8.90	-0.65	-21.77	-	-	-0.19	-188.89	-224.29
Total Final Consumption = TFC	1075.42	17.57	3743.64	1419.98	-	-	1151.86	2016.21	9424.69
Industry	858.49	6.80	294.67	548.54	-	-	193.52	849.15	2751.17
Transport ⁵	2.86	-	2426.33	97.90	-	-	73.89	26.04	2627.02
Other	155.39	0.18	424.53	613.41	-	-	884.45	1141.03	3218.98
Non-energy use	58.68	10.60	598.11	160.13	-	-	-	-	827.52

Total Primary Energy Supply = TPES

Total Final Consumption = TFC

Source: IEA, 2016

(Key world energy statistics)

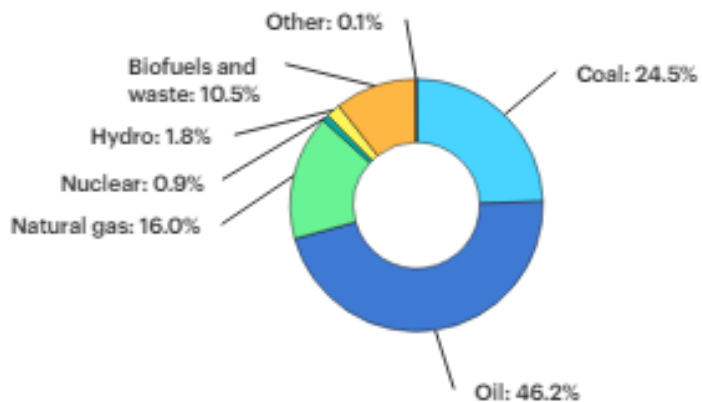
World Fuel Shares of Total Primary Energy Supply

Global share of total energy supply by source, 1973

Open ↗

Mtoe

World total energy supply: 6 098 Mtoe

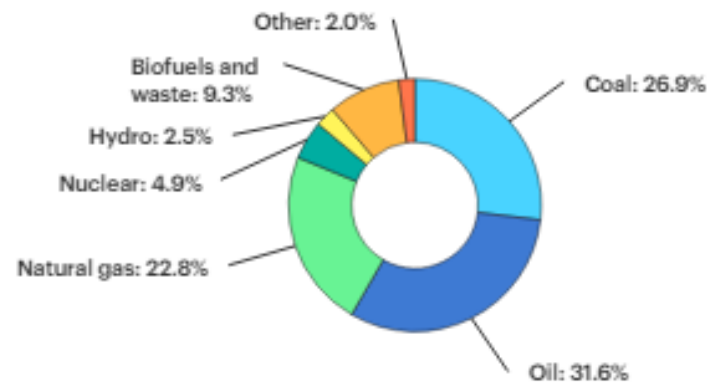


Global share of total energy supply by source, 2018

Open ↗

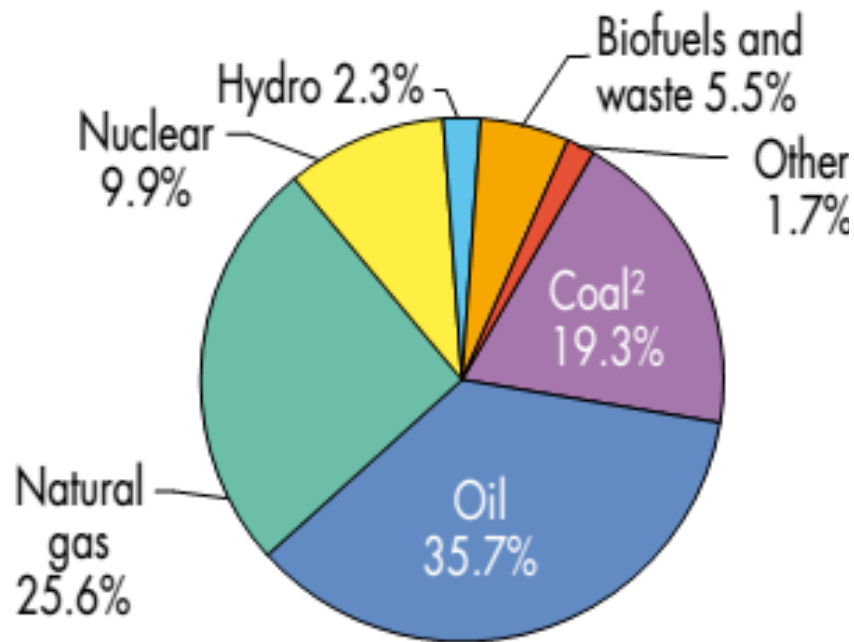
Mtoe

World total energy supply: 14 282 Mtoe



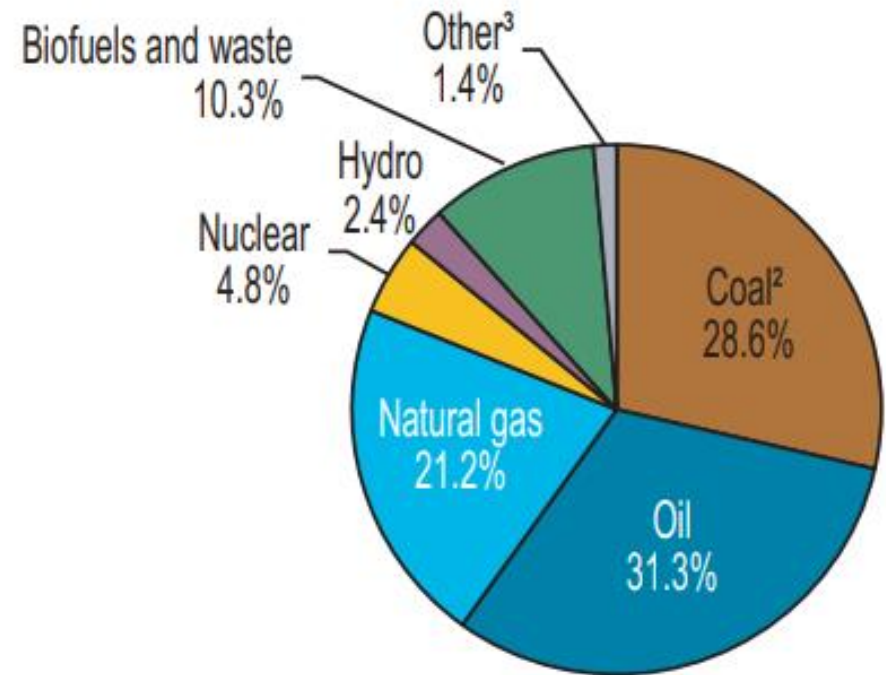
World Fuel Shares of Total Primary Energy Supply (TPES)

2014



Source: OECD/IEA, 2015

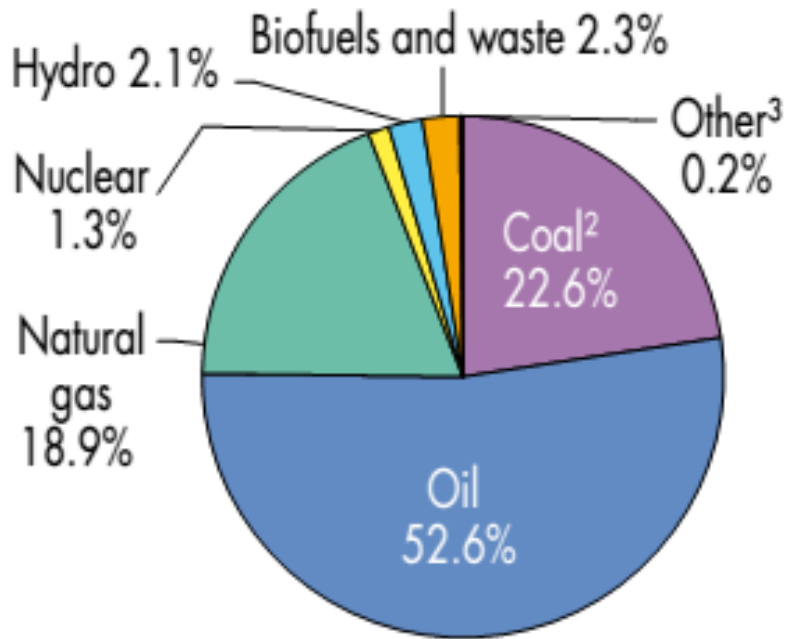
2014



Source: IEA, 2016
(*Key world energy statistics*)

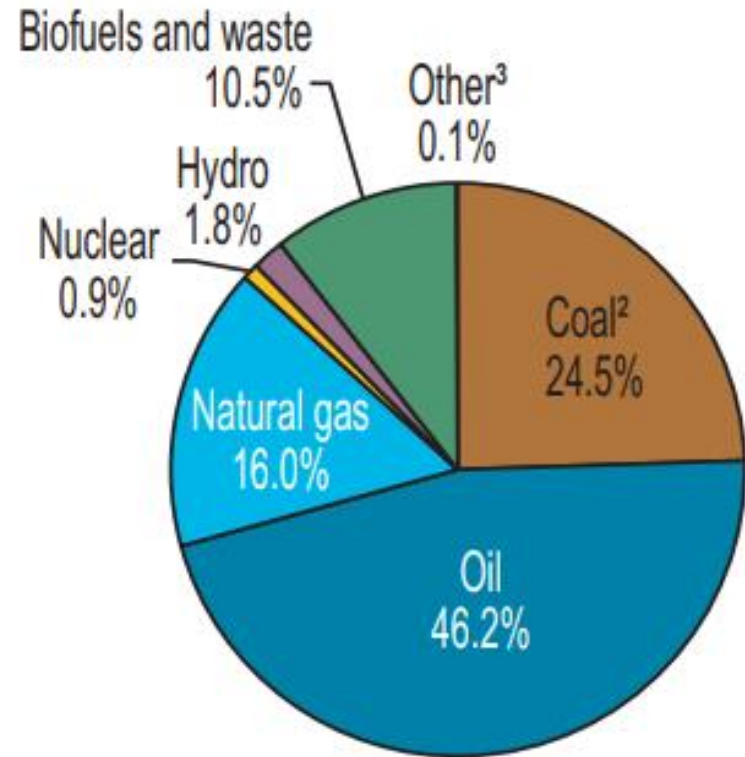
World Fuel Shares of Total Primary Energy Supply

1973



Source: OECD/IEA, 2015

1973



Source: IEA, 2016
(Key world energy statistics)

What fossil fuel out of the traditional fossil fuels:

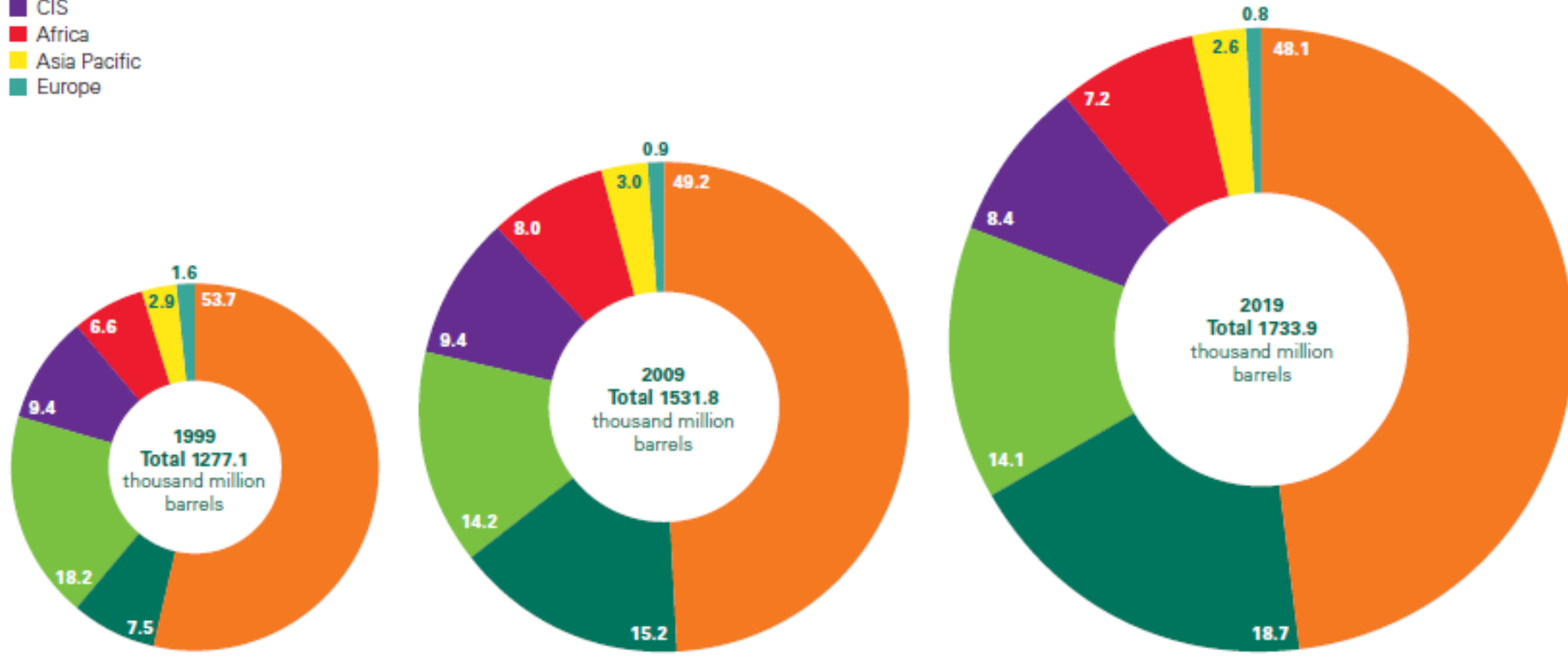
1. Is the most abundant?
2. Has the most energy per carbon (carbon unit)?
3. Is the cleanest-burning?
4. Is the most expensive?
5. Is most likely to be in a short supply soon?

Oil



Oil: Proved Reserves in 1999, 2009 and 2019 (%)

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



Producers, net exporters and net importers of crude oil

- 2006 – the peak of oil production (IEA)
- Principle: "grab what's best and what's closer"

- Economic profitability of oil production in the USA:
 - 100:1 in 1930
 - 30:1 in 1970
 - 12:1 on 2005

Producers	Mt	% of world total
United States	742	16.7
Russian Federation	560	12.6
Saudi Arabia	546	12.3
Canada	265	6.0
Iraq	234	5.3
People's Rep. of China	192	4.3
United Arab Emirates	189	4.3
Islamic Rep. of Iran	146	3.3
Brazil	145	3.3
Kuwait	144	3.2
Rest of the world	1 276	28.7
World	4 439	100.0

Notes: 2019 provisional data. Sources: IEA, World Energy Statistics, 2020.

Net exporters	Mt
Saudi Arabia	368
Russian Federation	260
Iraq	
Canada	
United Arab Emirates	
Islamic Rep. of Iran	
Kuwait	
Nigeria	
Kazakhstan	
Angola	
Others	
Total	

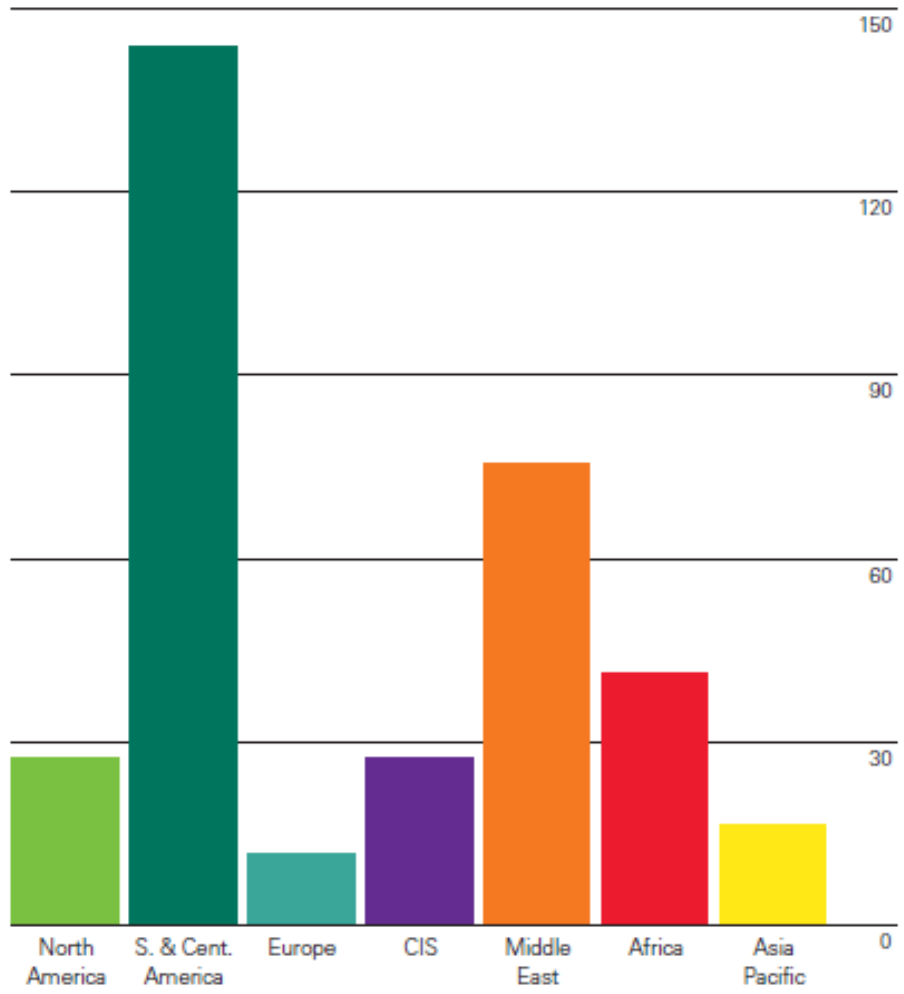
Net importers	Mt
People's Rep. of China	459
United States	292
India	226
Korea	151
Japan	151
Germany	85
Spain	67
Italy	63
Netherlands	61
Singapore	55
Others	525
Total	2 135

Source: IEA, 2020
(Key world energy statistics)

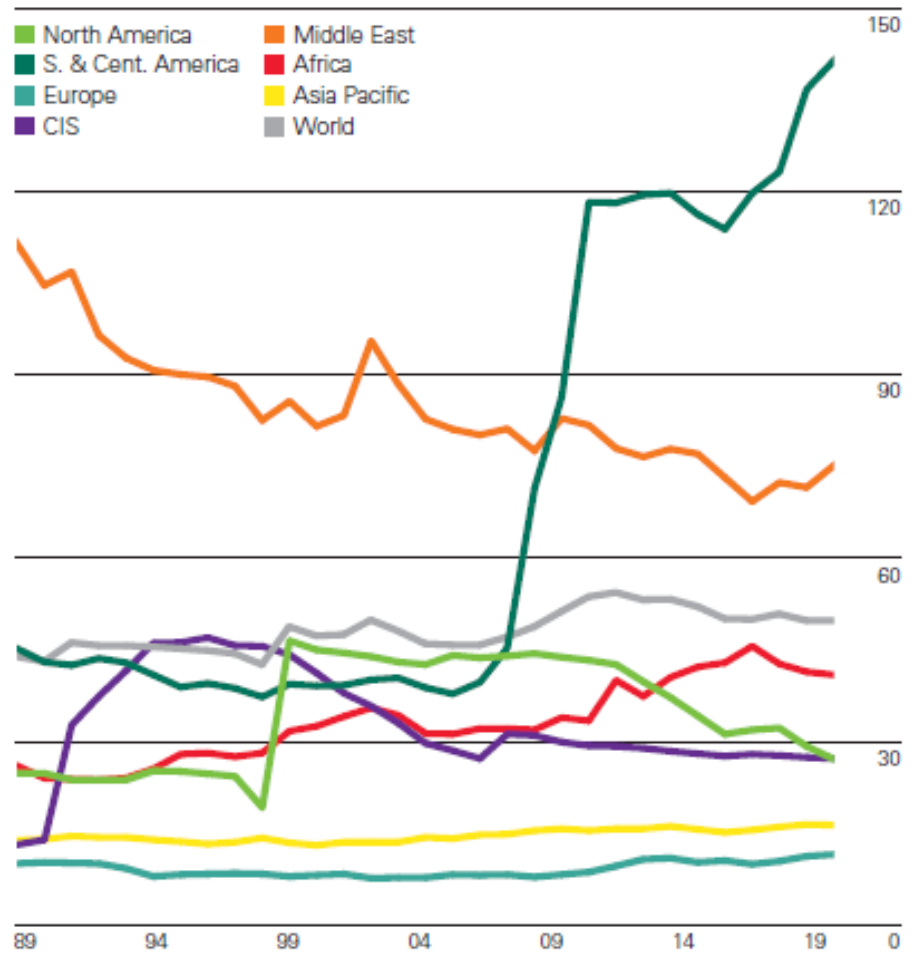
Oil: Reserves-to-Production (R/P) Ratios, 2019 (years)

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

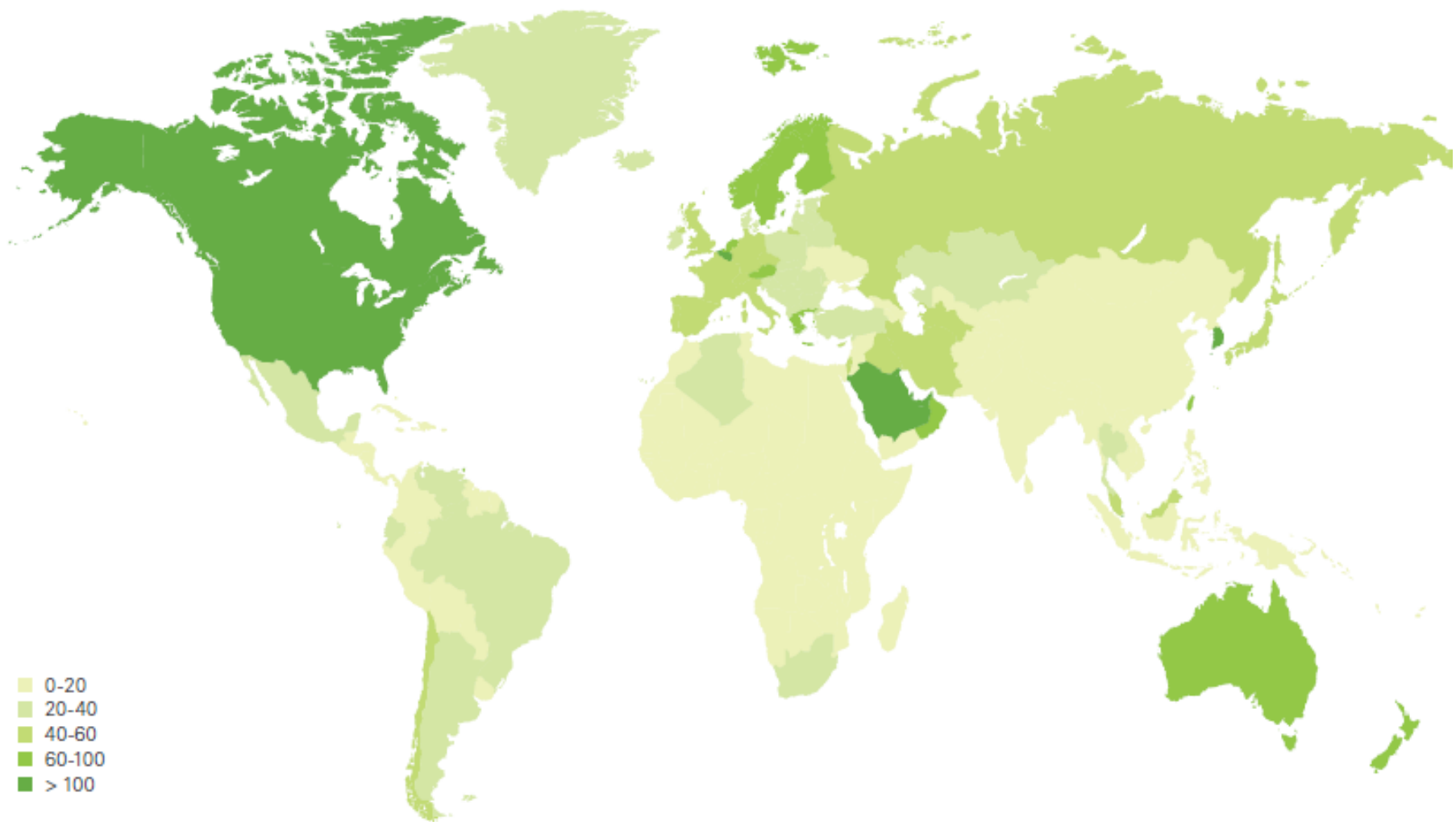
2019 by region



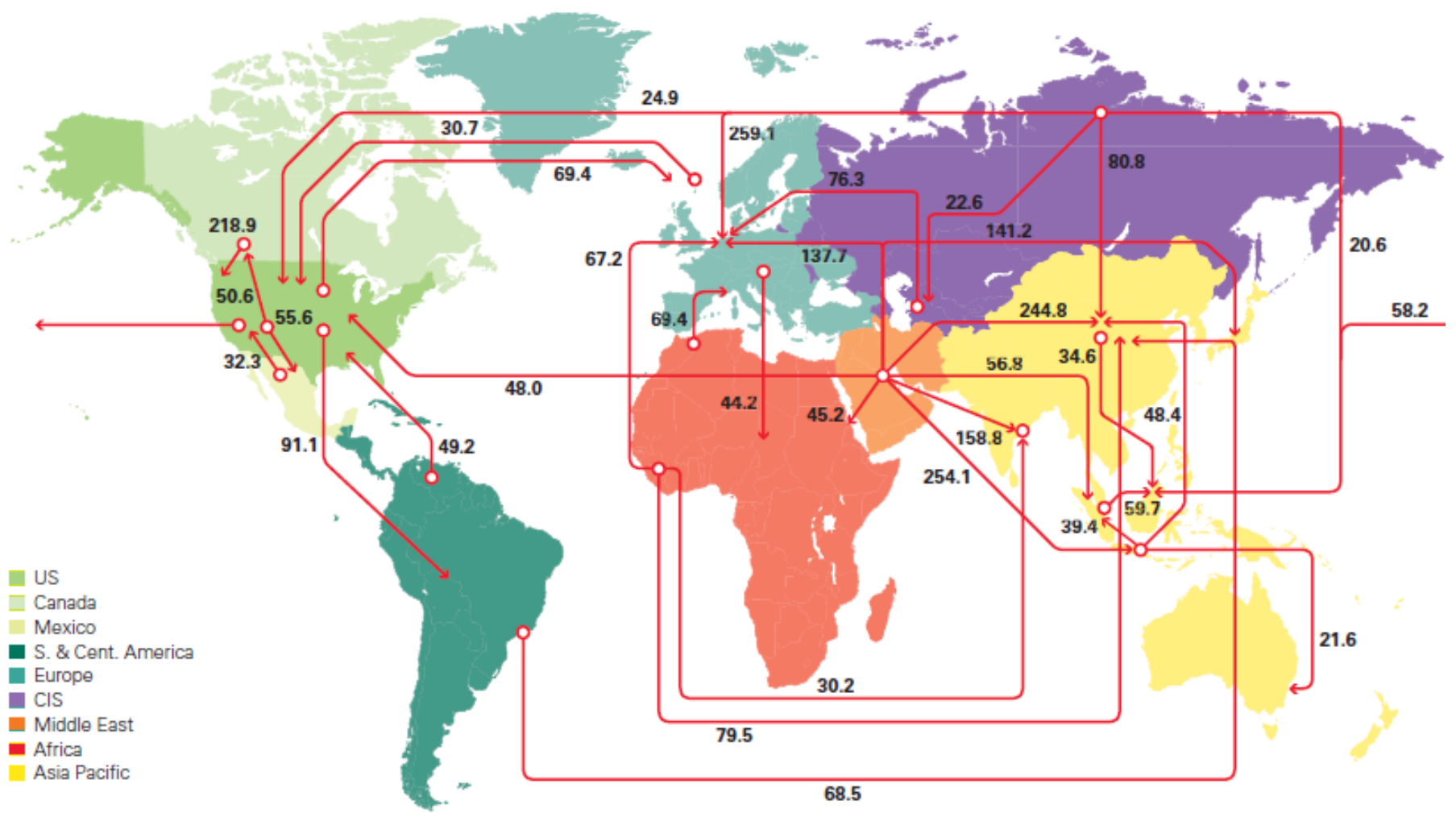
History



Oil: Consumption per Capita, 2019 (GJ per capita)

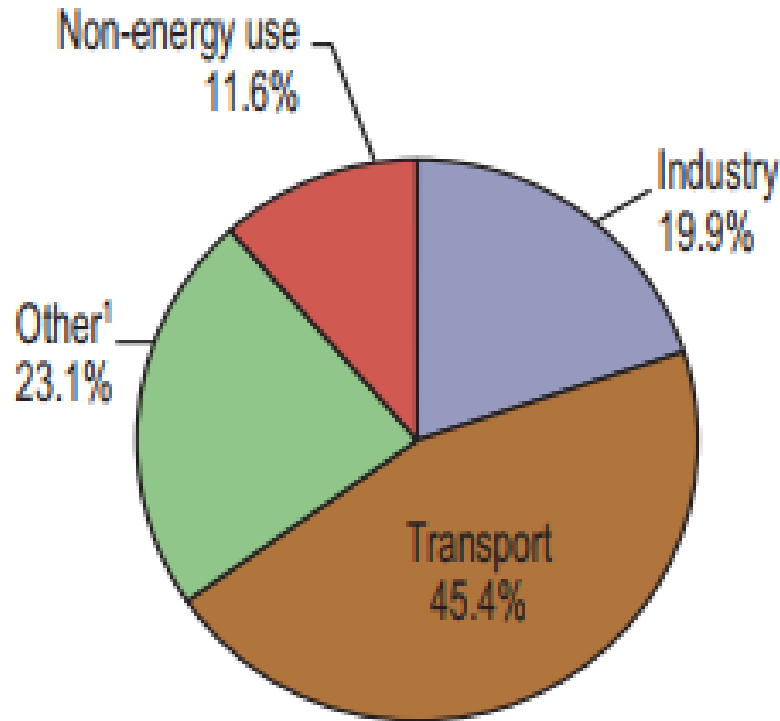


Major Trade Movements 2019 (trade flows worldwide, mln tonnes)



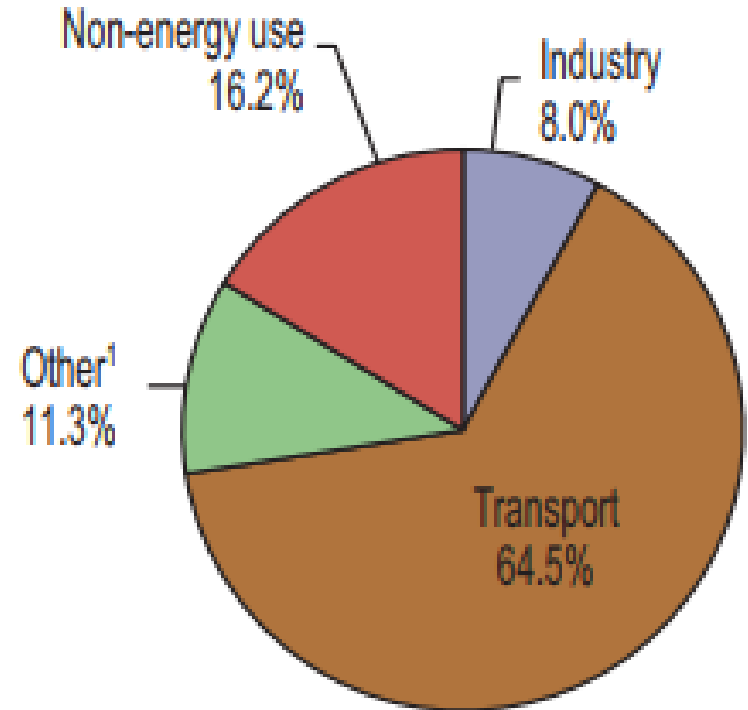
Shares of World Oil Consumption by Sector

1973



2 252 Mtoe

2014



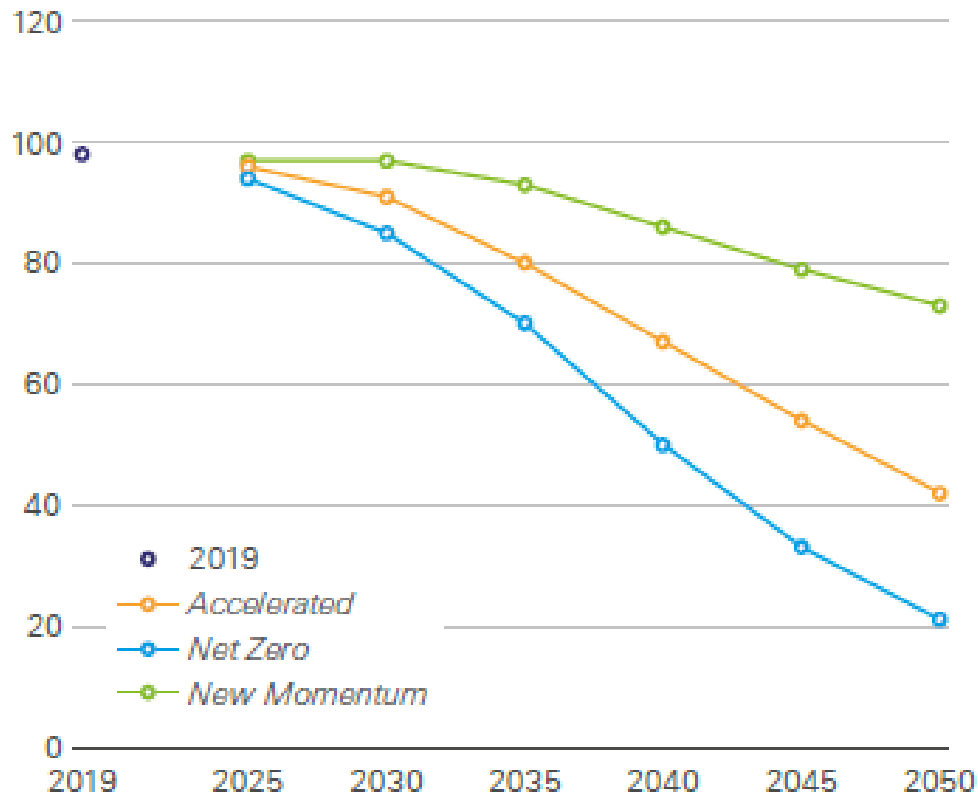
3 761 Mtoe

1. Includes agriculture, commercial and public services, residential, and non-specified other.

Oil demand falls over the outlook as use in road transportation declines

Oil demand

Mb/d



The role of oil in transport declines as the world switches to lower-carbon alternatives

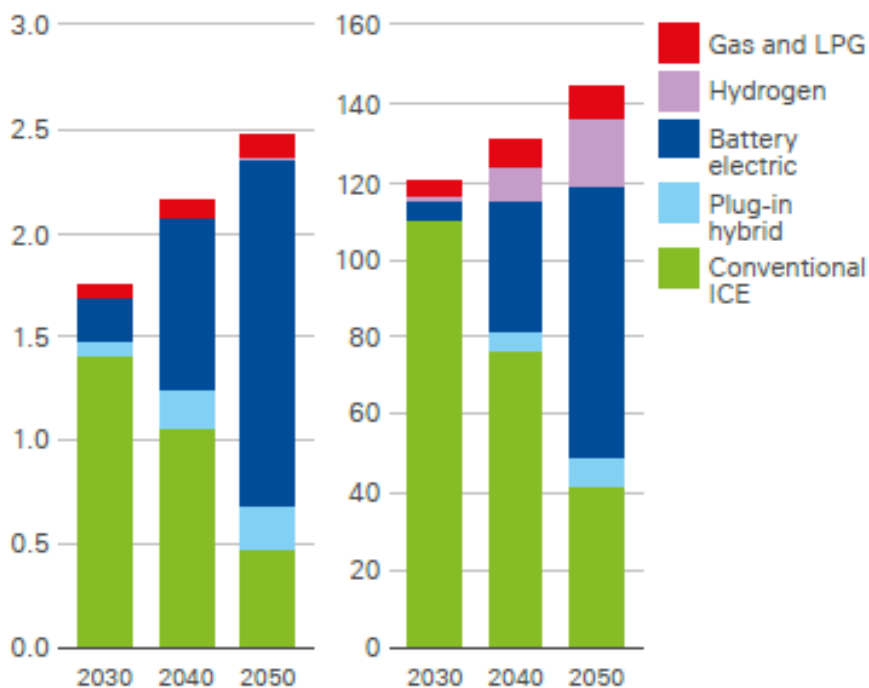
Global vehicle parc in *Accelerated*:

Light vehicles

Heavy vehicles

Billion vehicles

Million vehicles



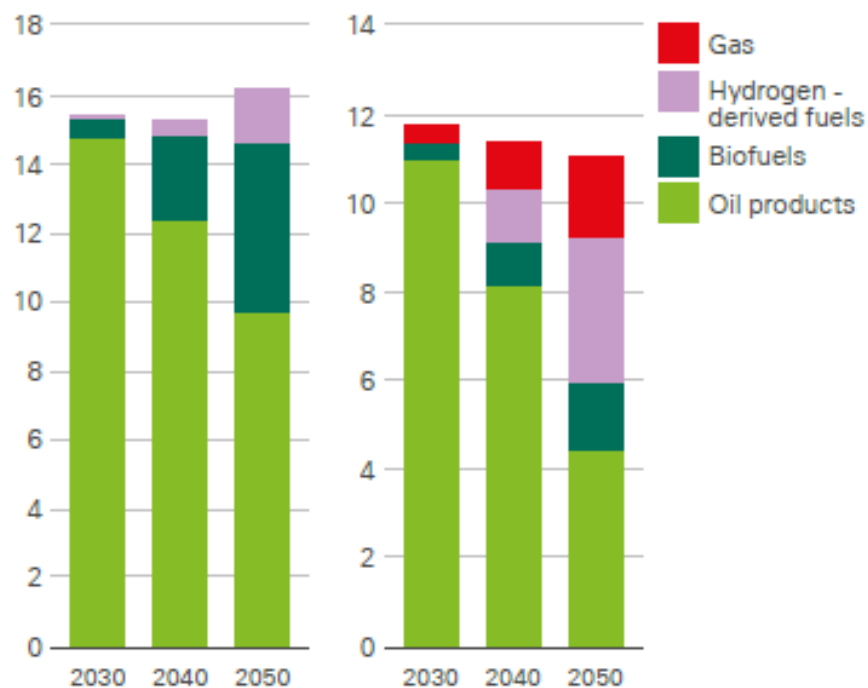
Total energy usage by fuel in *Accelerated*:

Aviation

Marine

EJ

EJ



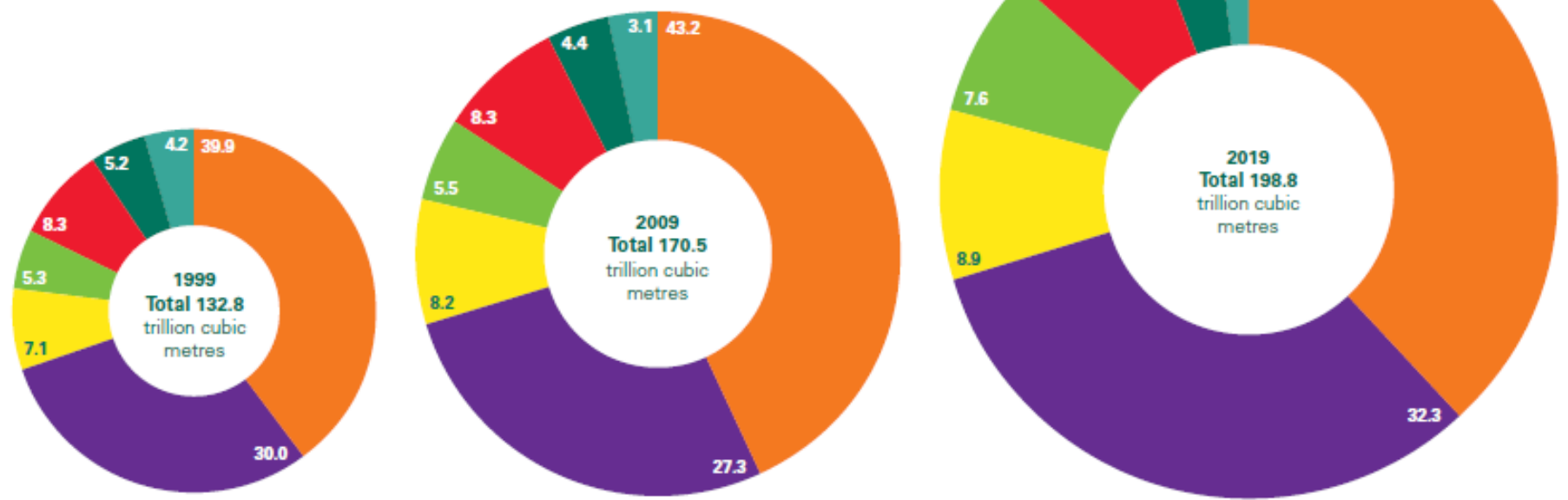
Gas includes biomethane

Natural Gas



Natural Gas: Proved Reserves in 1999, 2009 and 2019 (%)

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



Producers, Importers, Exporters

Producers	bcm	% of world total
United States	955	23.4
Russian Federation	750	18.3
Islamic Rep. of Iran	232	5.7
People's Rep. of China	178	4.4
Canada	177	4.3

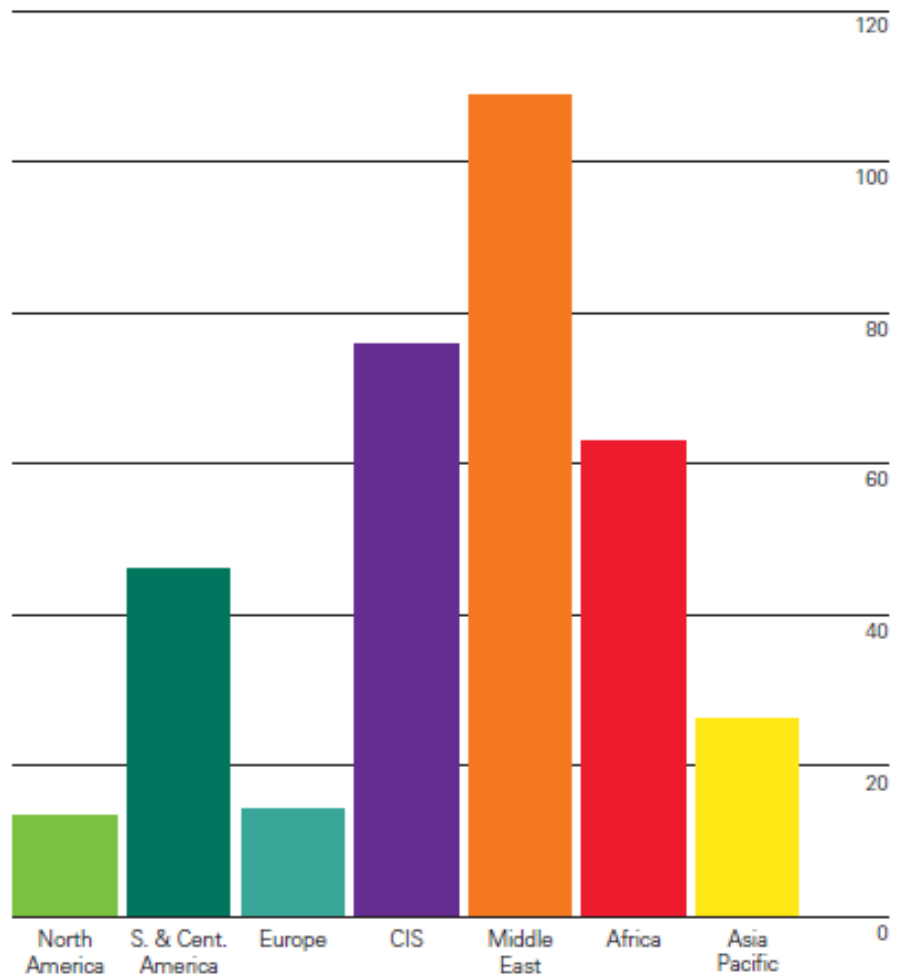
	Net exporters	bcm
Qatar	168	4.1
Australia		
Norway		
Saudi Arabia		
Algeria		
Rest of the world		
World		
	Russian Federation	265
	Qatar	124
	Norway	113
	Australia	95
	United States	54
	Turkmenistan	52
	Canada	51
	Algeria	43
	Nigeria	29
	Malaysia	24
	Others	203
	Total	1 053

Net importers	bcm
People's Rep. of China	122
Japan	105
Germany	103
Italy	71
Mexico	57
Korea	54
Turkey	44
France	44
United Kingdom	39
Spain	36
Others	324
Total	999

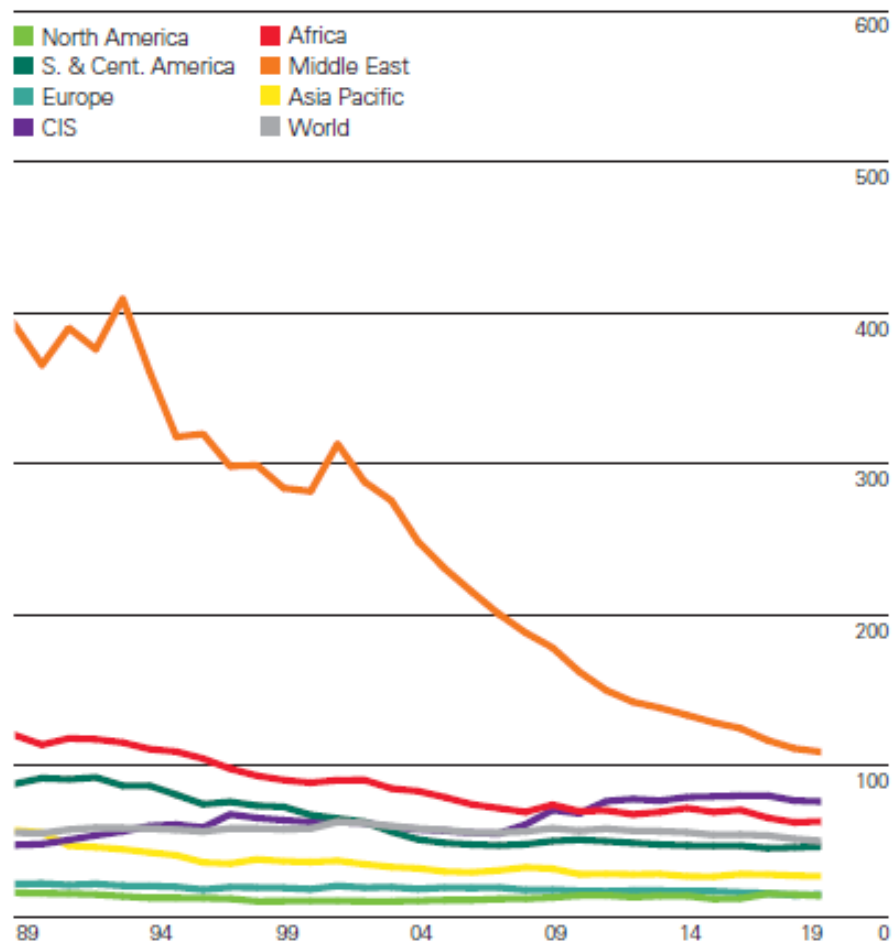
Notes: 2019 provisional data. Sources: IEA, Natural Gas Information

Natural Gas: Reserves-to-Production (R/P) Ratios, 2019 (%)

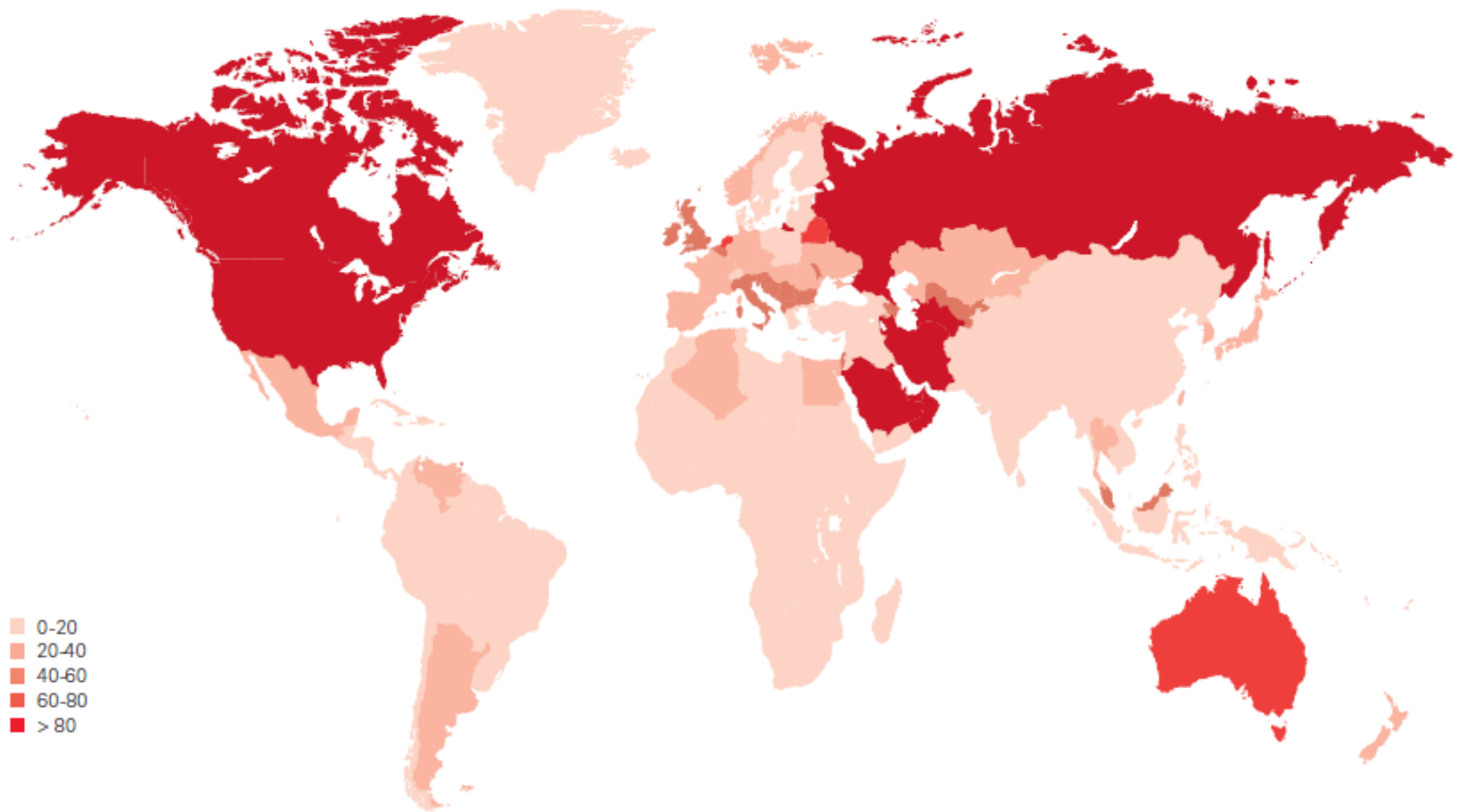
2019 by region



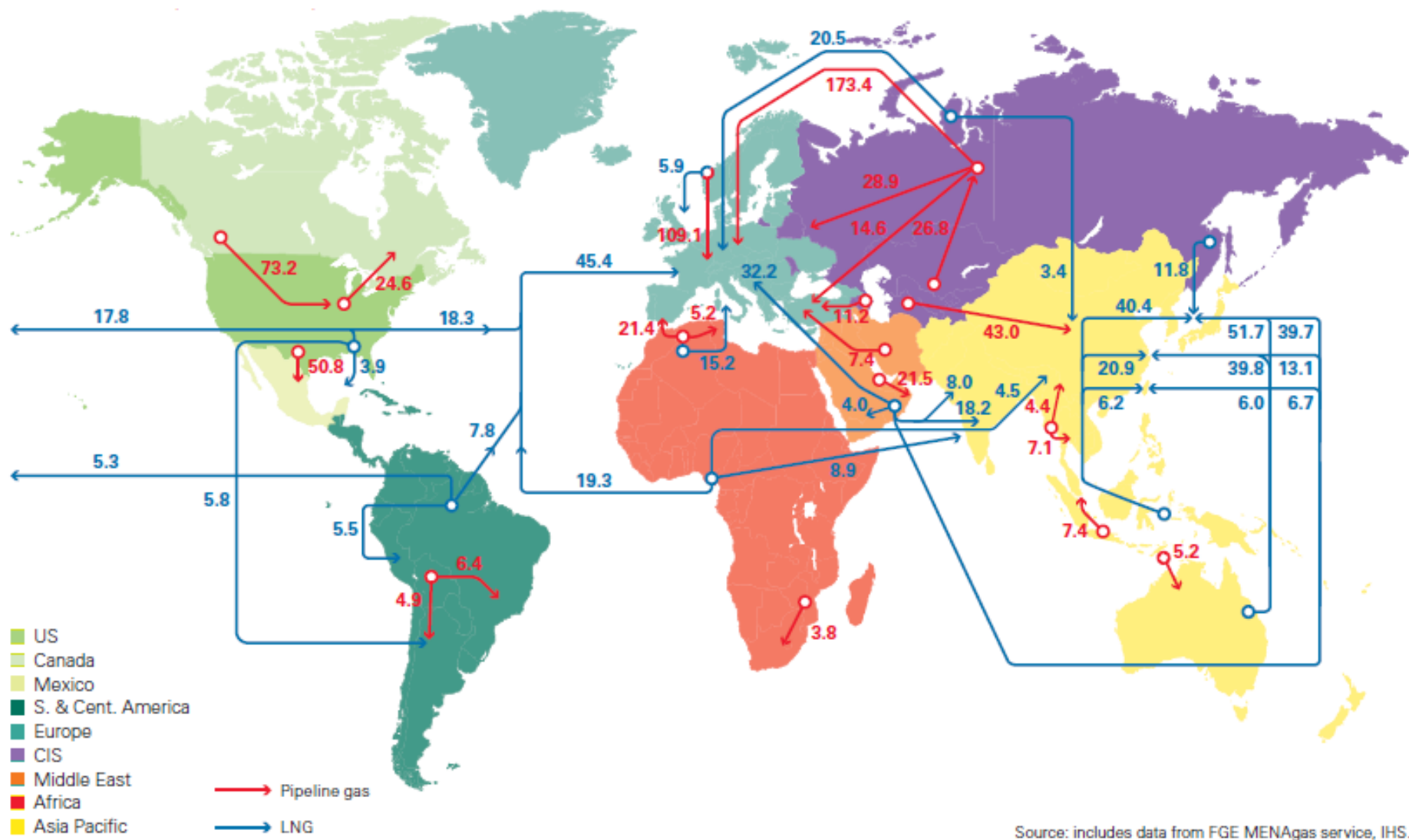
History



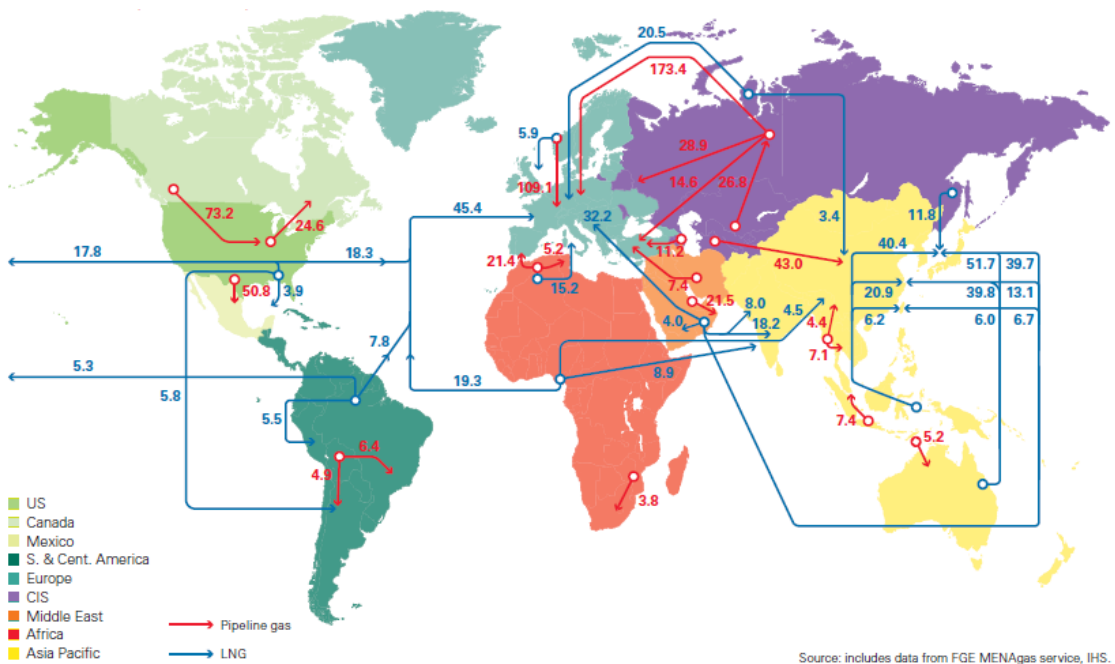
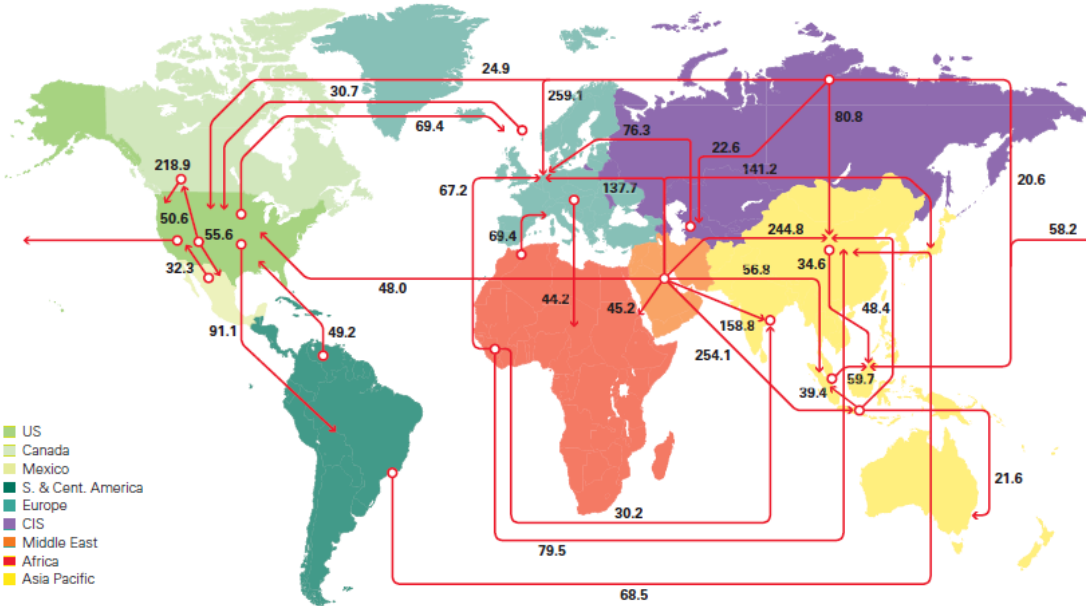
Natural Gas: Consumption per Capita, 2019 (GJ per capita)



Natural Gas: Major Trade Movements, 2019 (bln cubic m)



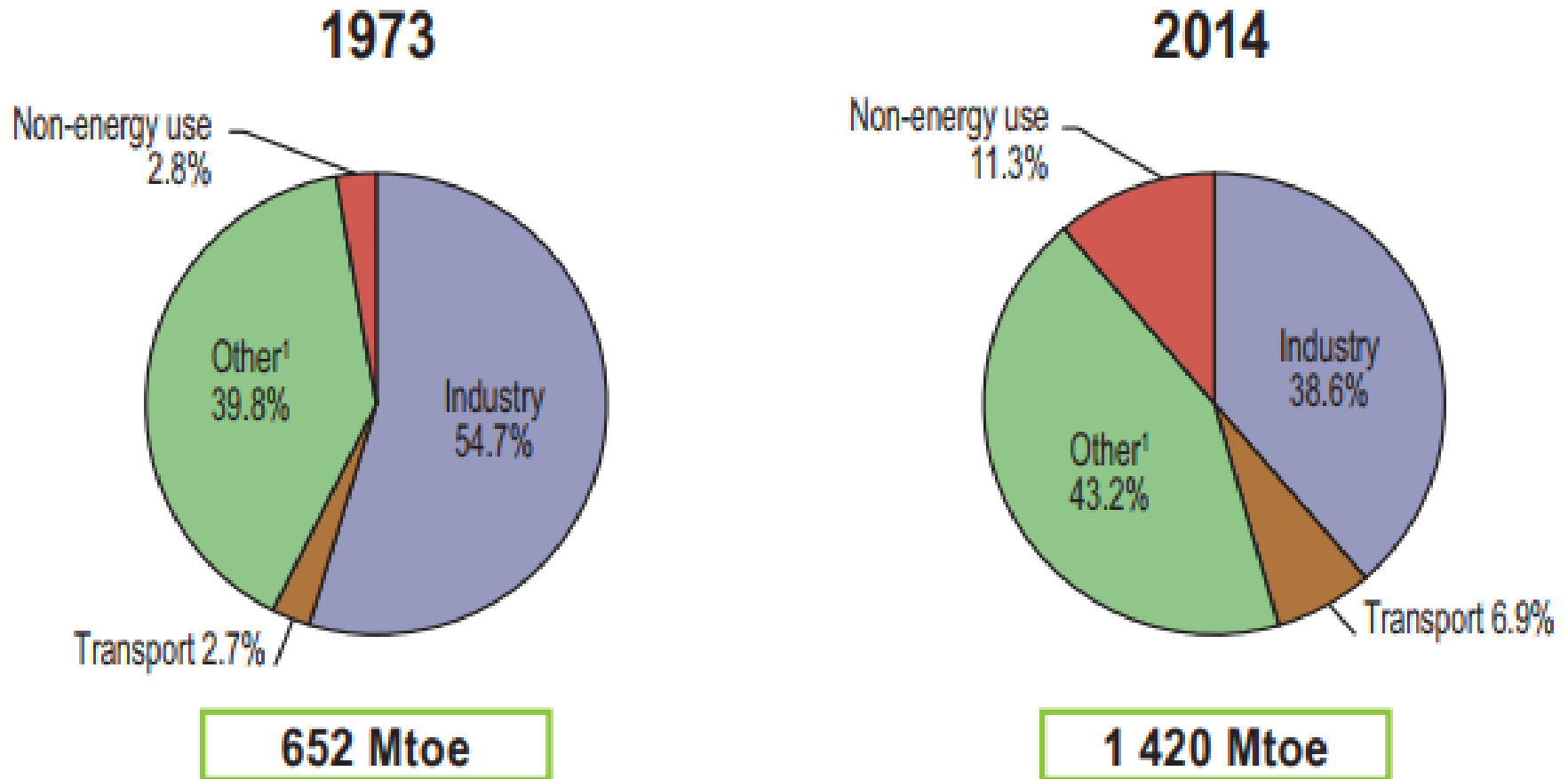
Source: includes data from FGE MENAgas service, IHS.



Compare international natural gas trade and international oil trade in terms of intensity

Source: includes data from FGE MENAgas service, IHS.

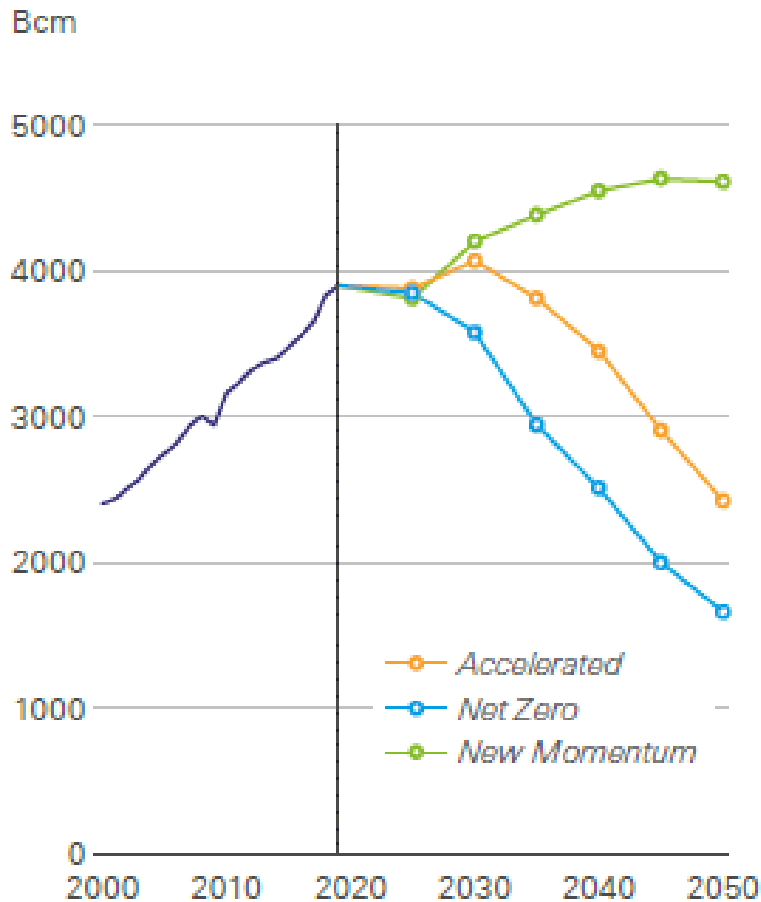
Shares of World Natural Gas Consumption by Sector



1. Includes agriculture, commercial and public services, residential, and non-specified other.

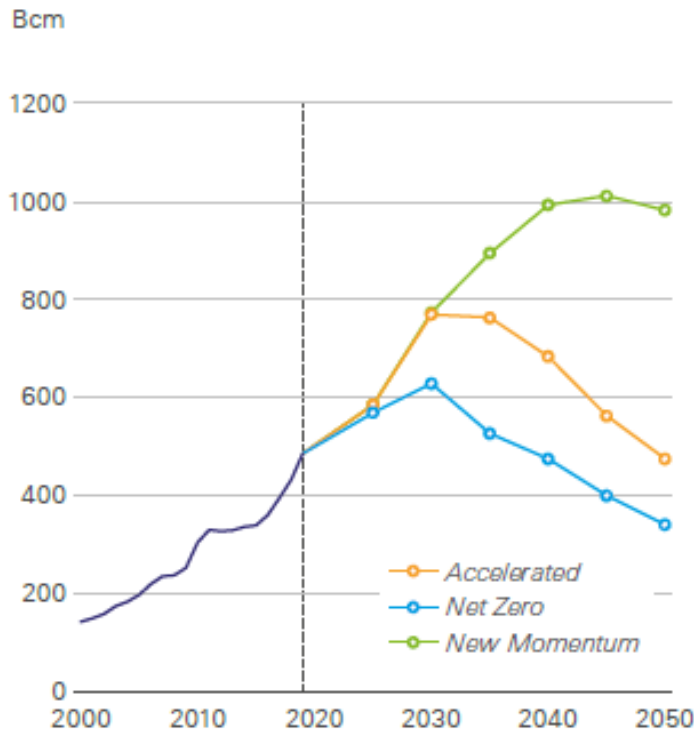
Prospects for natural gas depend on the speed of the energy transition

Natural gas demand

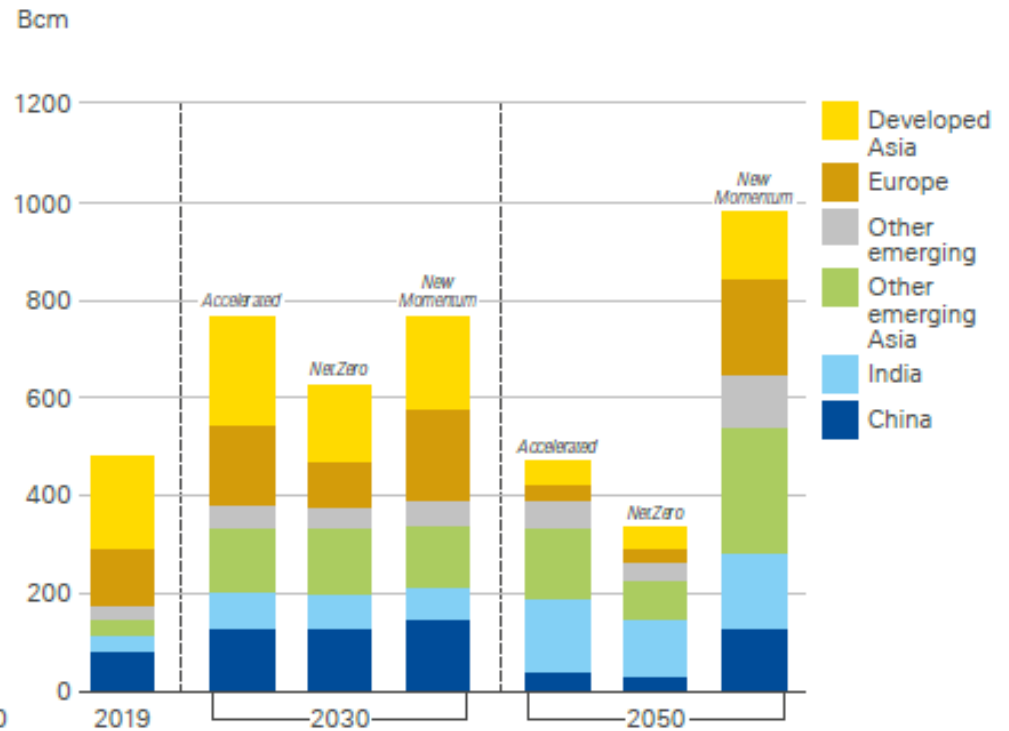


LNG trade increases in the near term, with the outlook becoming more uncertain post 2030

LNG trade



LNG imports by region

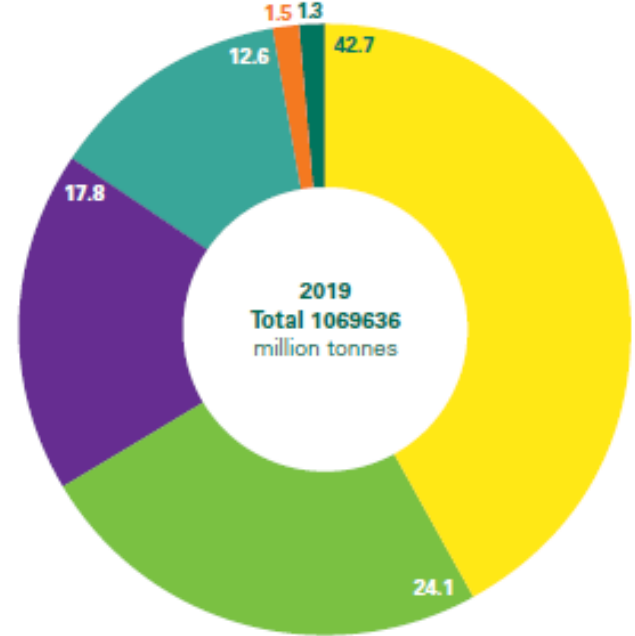
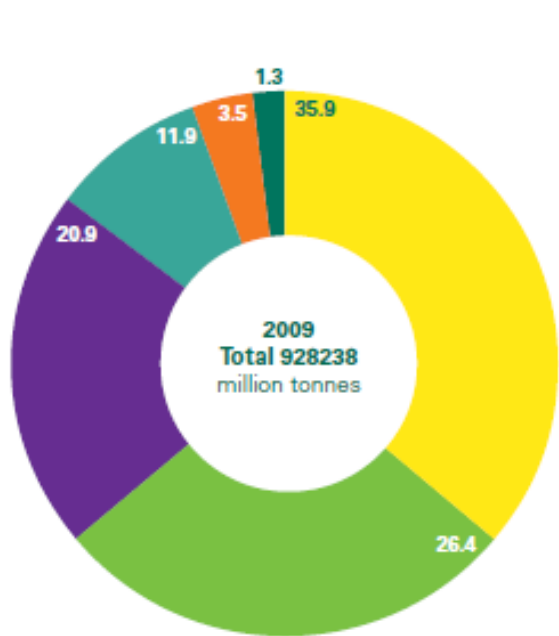
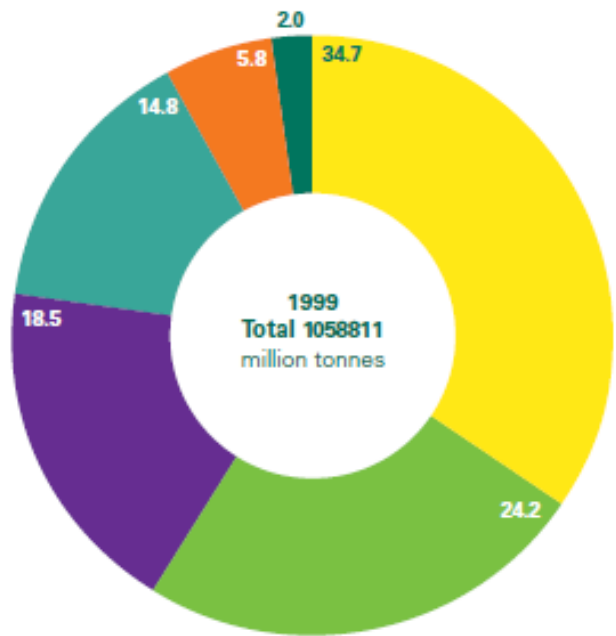


Coal



Coal: Proved Reserves at End 1999, 2009 and 2019 (%)

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



Producers, net exporters and net importers of coal

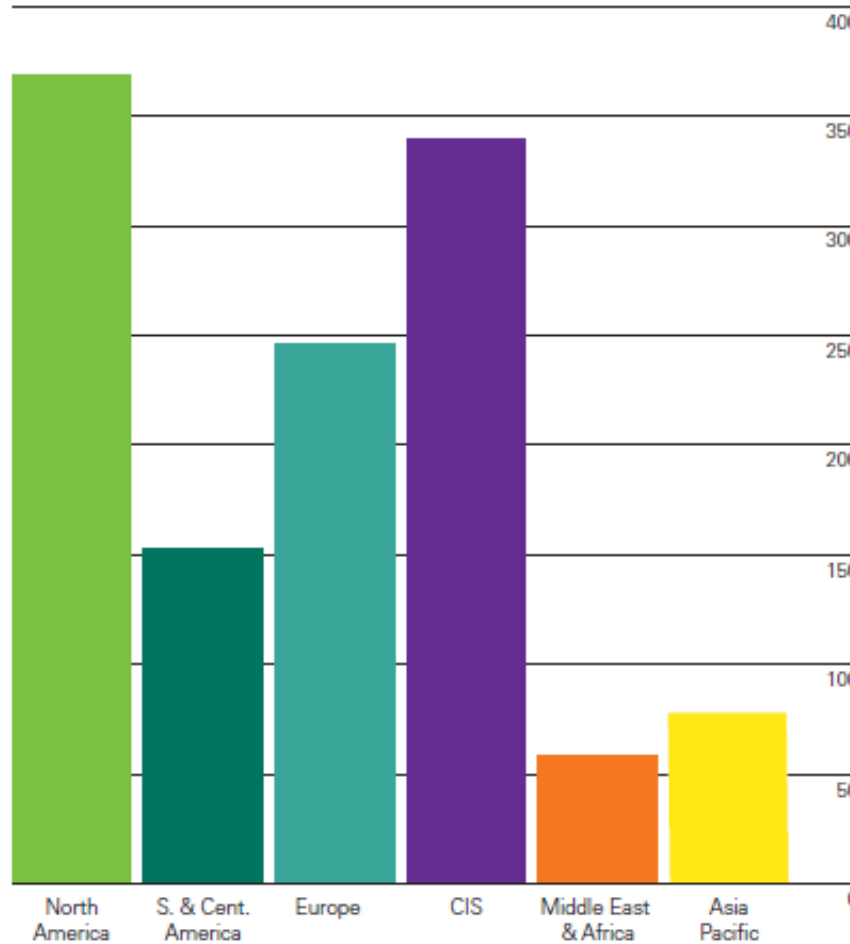
Producers	Mt	% of world total
People's Rep. of China	3 693	46.6
India	769	9.7
United States	640	8.1
Indonesia	616	7.8
Australia	503	6.4
Russian Federation	418	5.3

	Net exporters	Mt	Net importers	Mt
South Africa	Indonesia	448	People's Rep. of China	296
Germany	Australia	393	India	246
Poland	Russian Federation	189	Japan	185
Kazakhstan	South Africa	78	Korea	130
Rest of the world	United States	78	Chinese Taipei	67
World	Colombia	71	Viet Nam	43
	Mongolia	28	Germany	41
	Canada	28	Turkey	38
	Kazakhstan	25	Malaysia	35
	Mozambique	10	Thailand	23
	Others	4	Others	235
	Total	1 352	Total	1 339

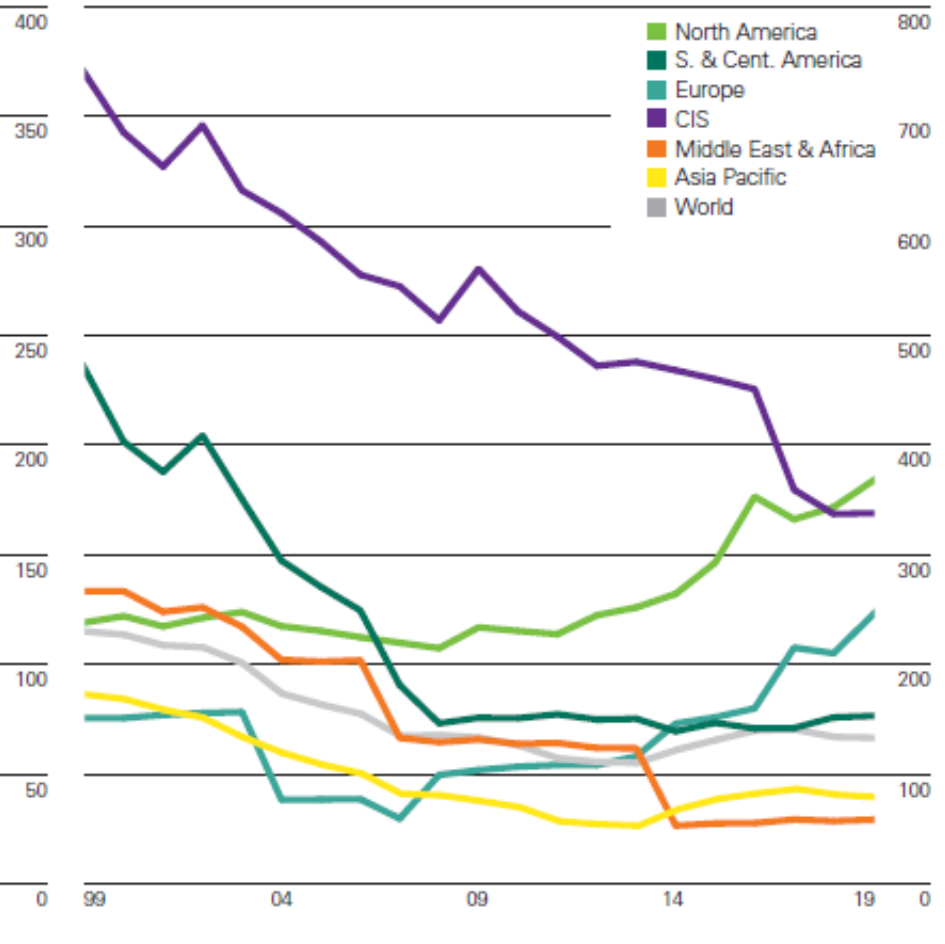
Notes: 2019 provisional data. Sources: IEA, World Energy S

Reserves-to-Production (R/P) ratios (years), 2019

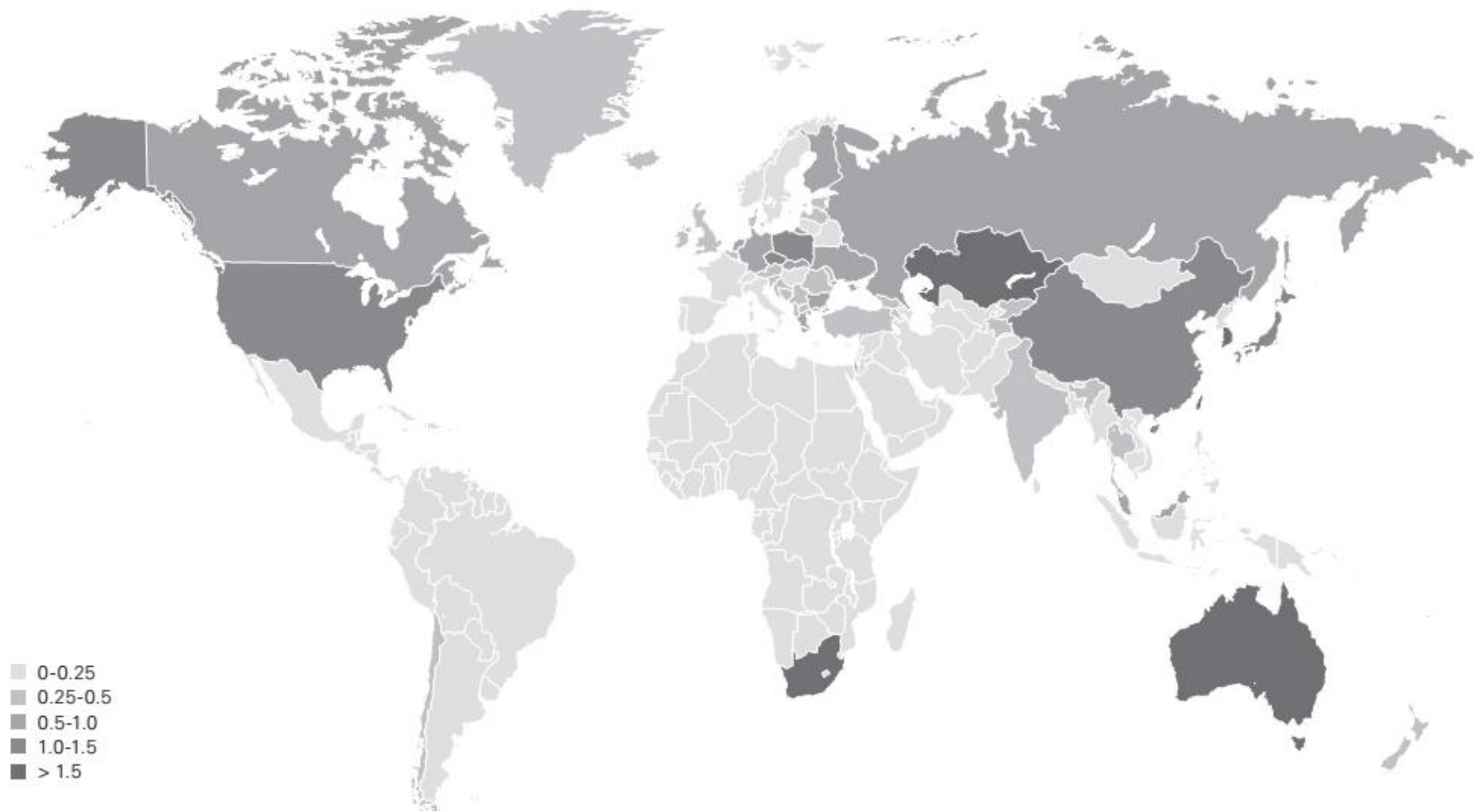
2019 by region



History

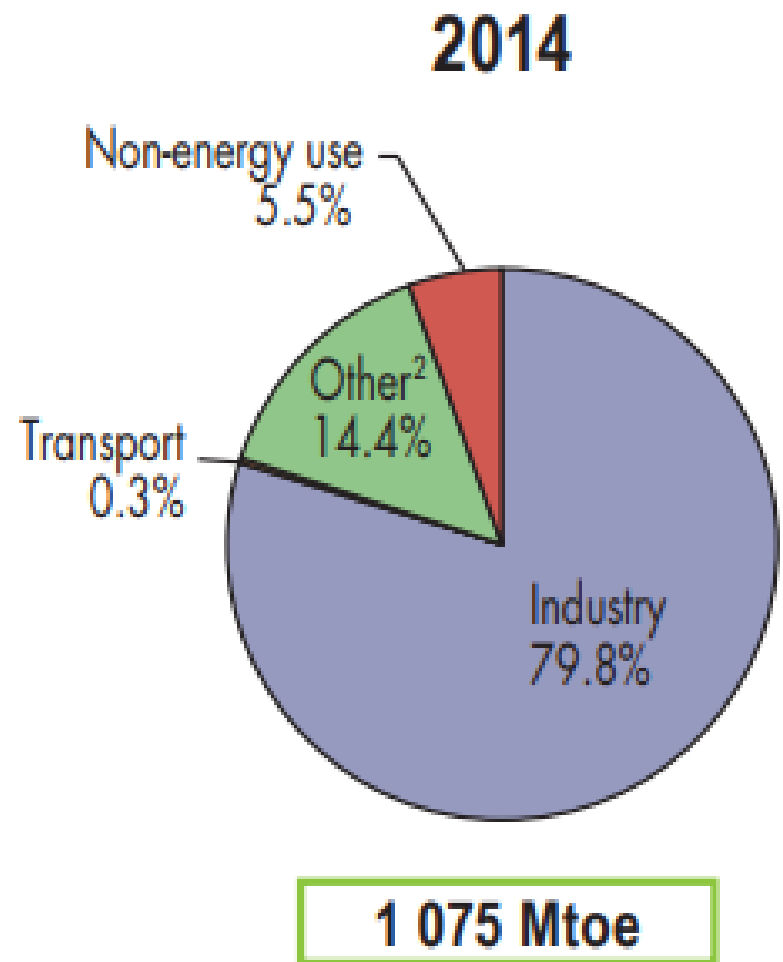
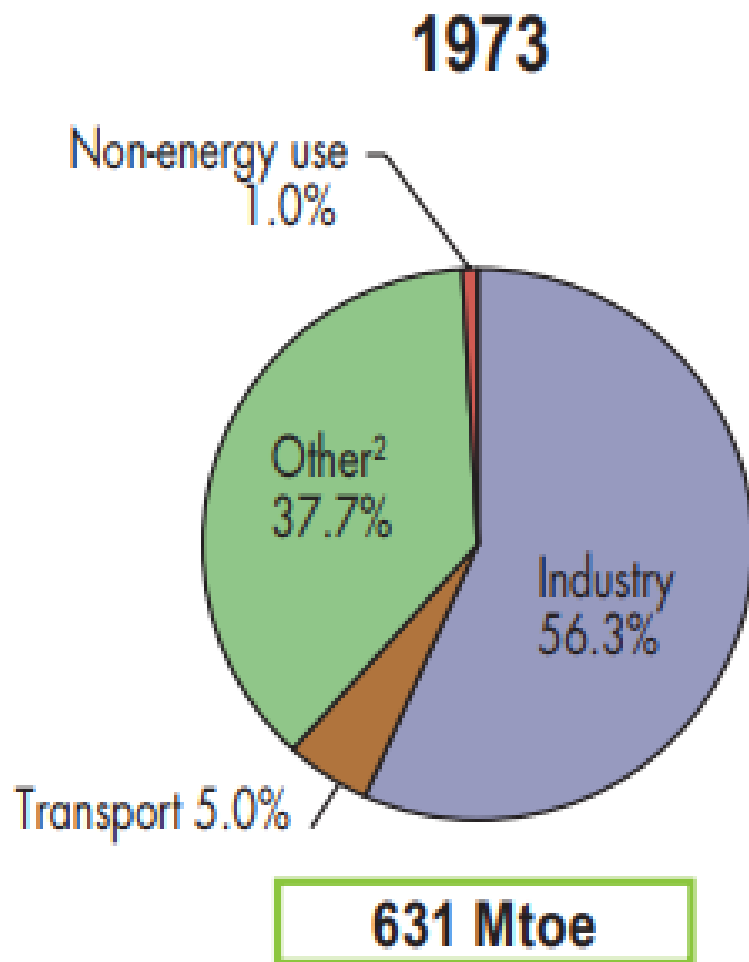


Coal: Consumption per Capita, 2019 (TOE)



- 0-0.25
- 0.25-0.5
- 0.5-1.0
- 1.0-1.5
- > 1.5

Shares of World Coal Consumption by Sector

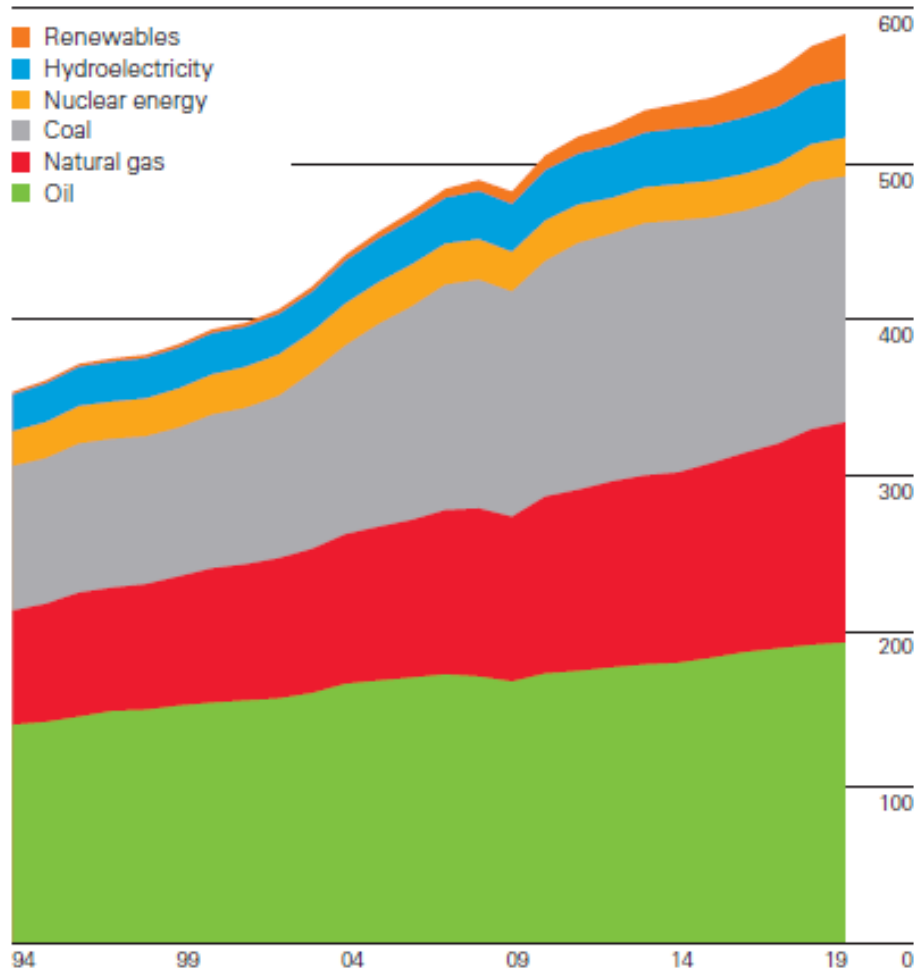


1. In these graphs, peat and oil shale are aggregated with coal.
2. Includes agriculture, commercial and public services, residential, and non-specified other.

World Primary Energy Sources

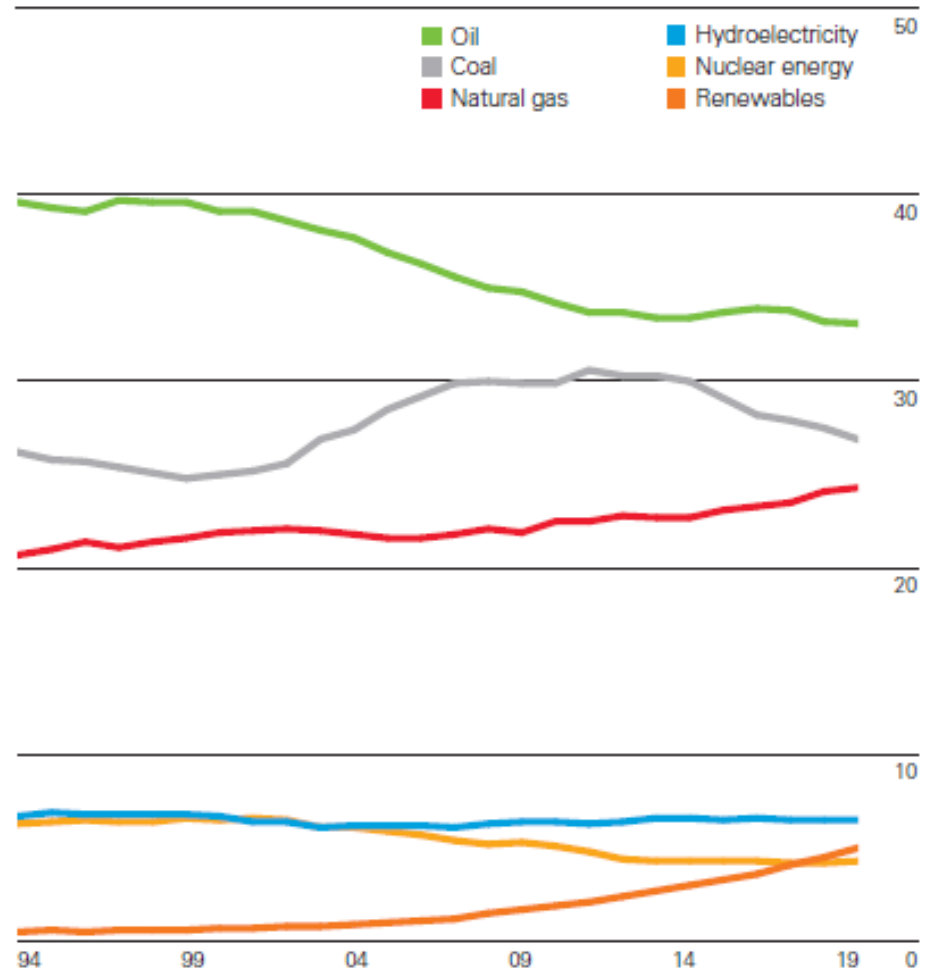
World consumption

Exajoules



Shares of global primary energy

Percentage



Energy charting tool

The screenshot shows the interface of an energy charting tool. On the left is a sidebar menu with 'Series types (10)' and 'Data types (14)'. The main area features a world map with a globe icon, and a grid of featured reports at the bottom. Annotations with arrows point to various elements: the information icon, the globe icon, the main menu, the globe icon again, the view options (gear, download, fullscreen), the map, and the featured reports. A 'Don't show this again' dialog box is overlaid on the featured reports.

Select a Series type, a Featured report or region from the map

Featured reports >

Series types (10) **The information icon provides useful tips as you navigate through the tool**

Oil

Natural gas

Coal

Nuclear

Hydroelectricity **The main menu allows you to select a vast range of data types**

Biofuels

Other renewables

Primary energy

Refining

Electricity

Data types (14) >

Energy prices (3) >

Energy indicators (3) >

Calculations (6) >

Clear

The globe icon allows you to filter menu results by region or political grouping

View options

Download a chart to Excel

View in fullscreen

The map allows you to do a basic search by continent and country

Featured reports are quick links to predefined charts

0.9% ↑
Growth in world primary energy consumption.

57.5%
The non-OECD's share of global energy consumption

6.0%
Share of global power generation met by renewables.

Don't show this again

OK

Oil
Production by region in KBD

Natural gas
Consumption by region in BCM

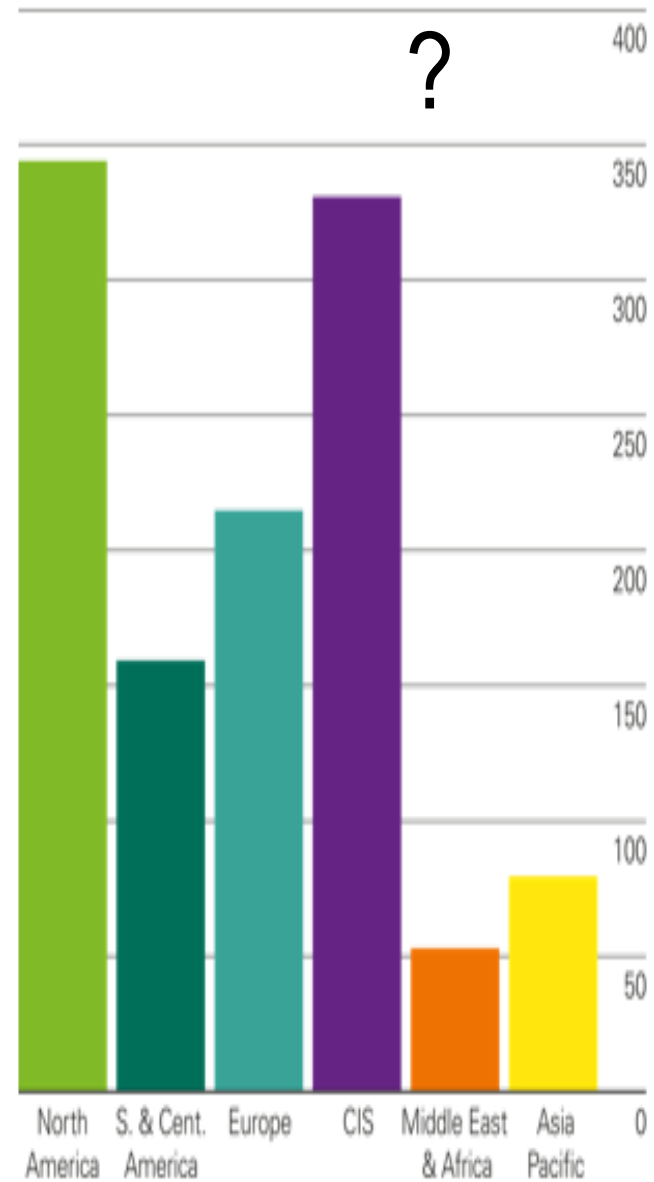
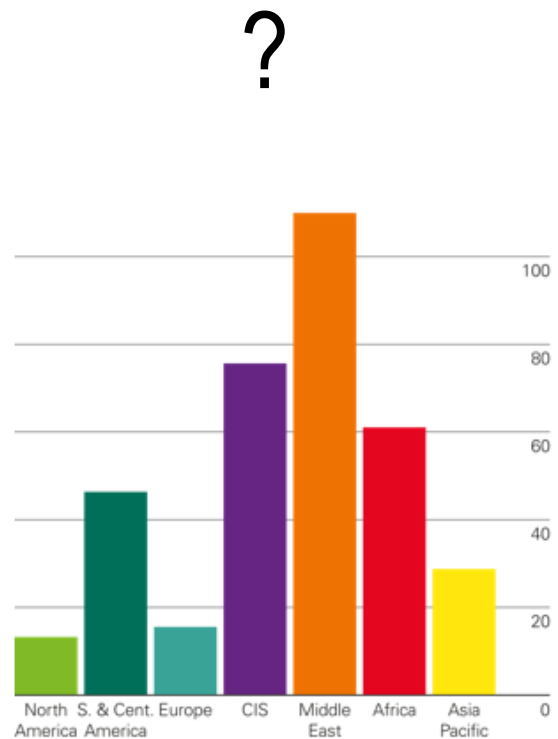
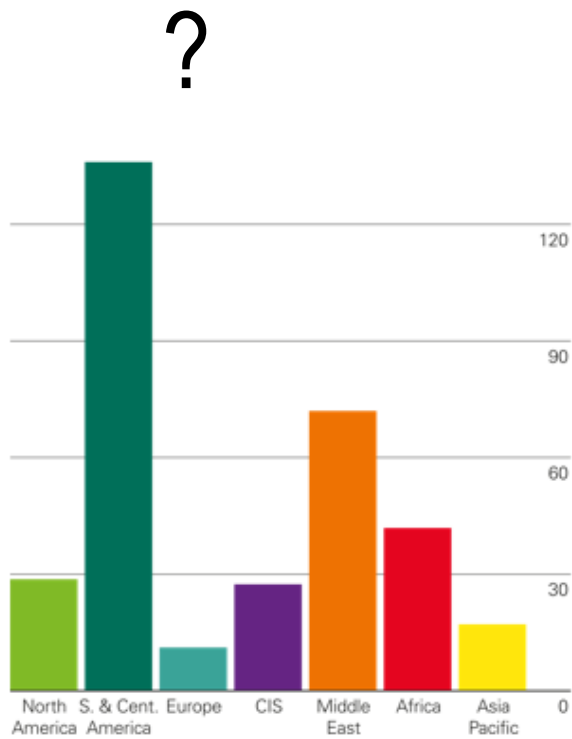
Coal
Consumption in MTOE

Biofuels
Production by region in KTOE

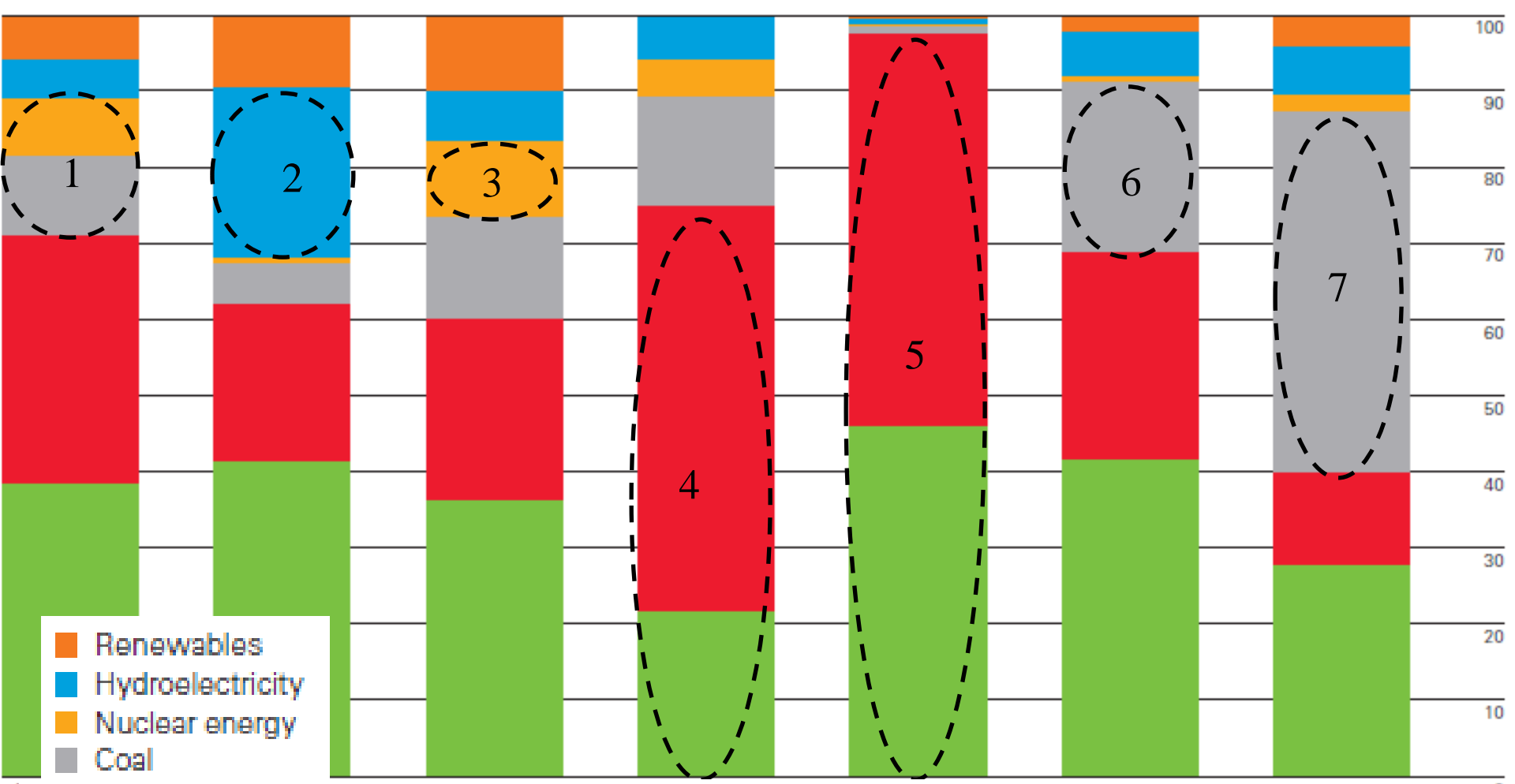
Other renewables
Consumption by region in TWH

Primary energy
Consumption by region in MTOE

R/P ratio of ... Coal, Oil, Gas



Regional Consumption by Fuel (2019), %

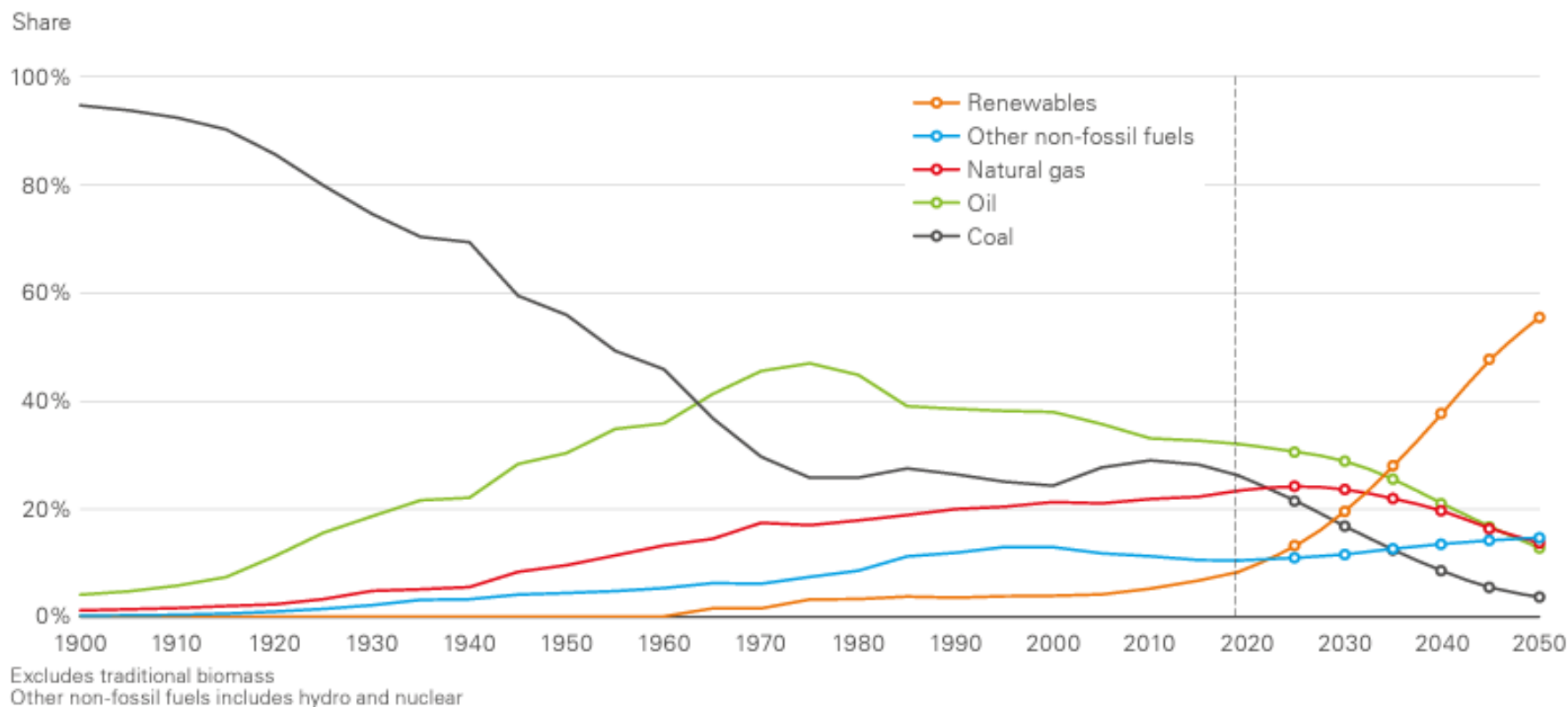


- Renewables
- Hydroelectricity
- Nuclear energy
- Coal
- Natural gas
- Oil

- North America
- Asia Pacific
- Africa
- CIS
- Europe
- C.& S.America
- Europe

Changing nature of global energy markets: more diverse energy mix, increased competition and greater customer choice

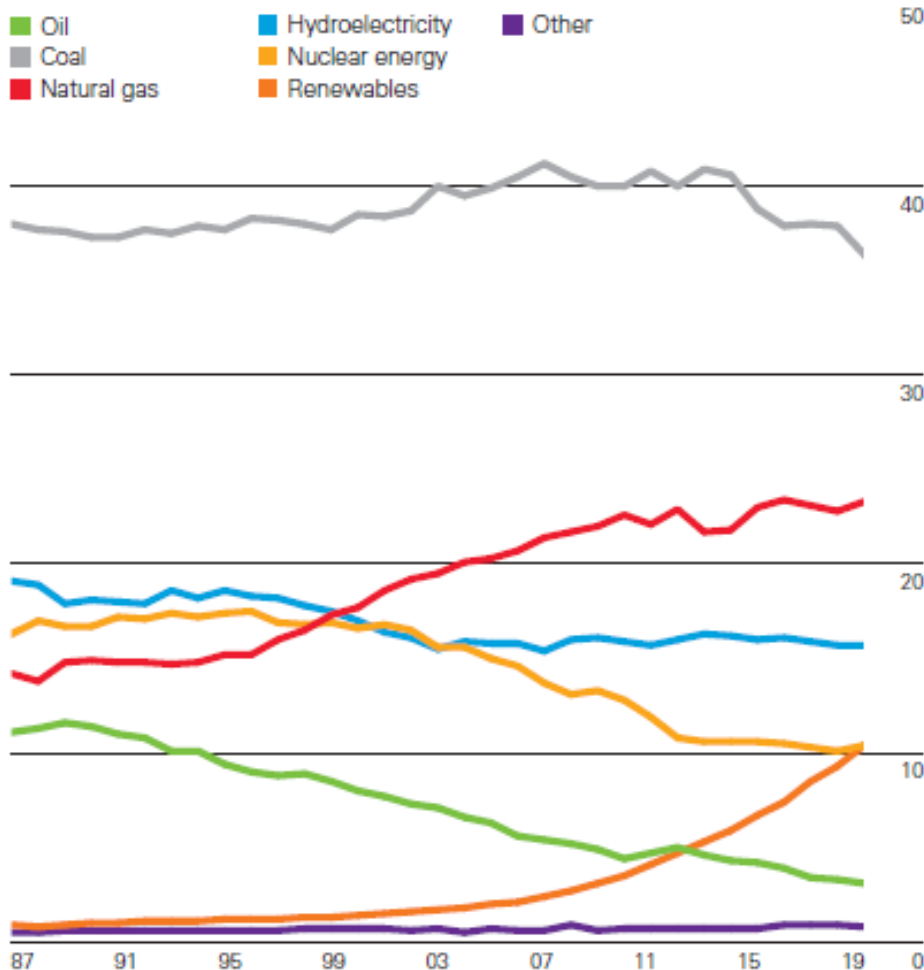
Share of primary energy in *Accelerated*



Fuel Shares of Electricity Generation

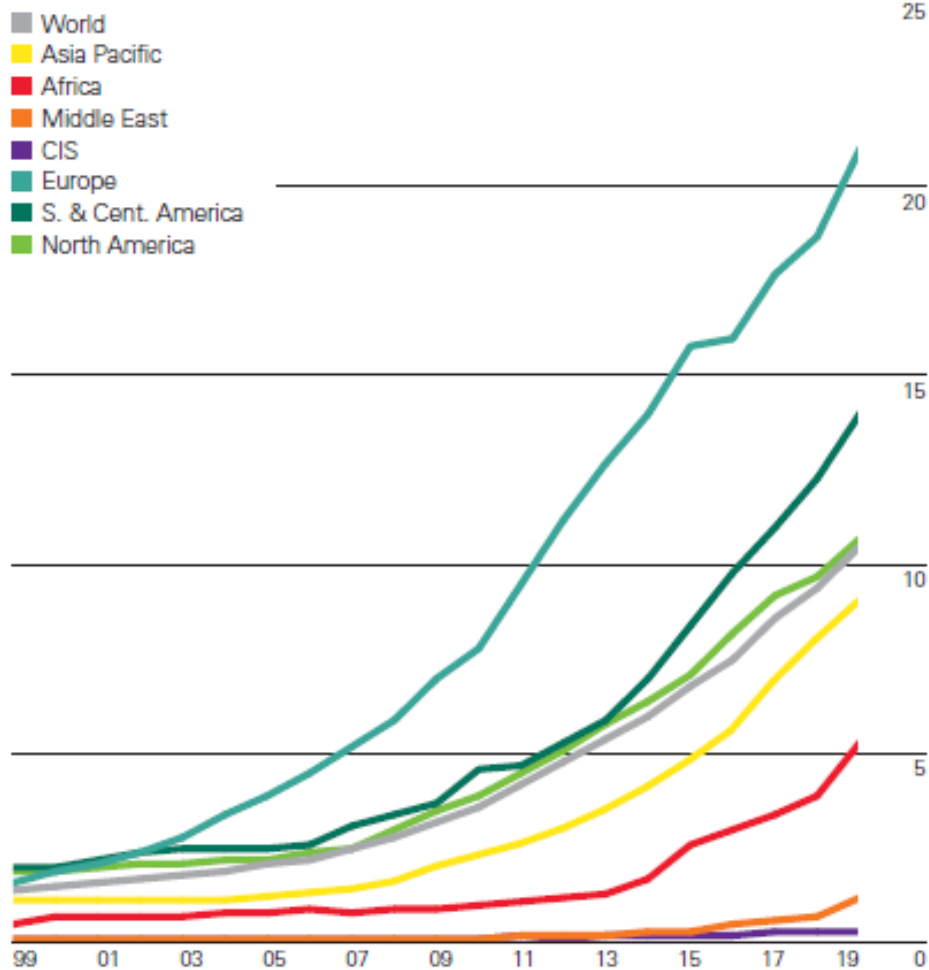
Share of global electricity generation by fuel

Percentage



Renewables share of power generation by region

Percentage



World's Largest Electricity Producers

Producers ¹	TWh	% of world total
People's Rep. of China	5 666	23.8
United States	4 319	18.1
India	1 287	5.4
Russian Federation	1 062	4.5
Japan	1 036	4.4
Canada	656	2.8
Germany	622	2.6
Brazil	591	2.5
France	557	2.3
Korea	546	2.3
Rest of the world	7 474	31.3
World	23 816	100.0

➤ **56.2% of the world's electricity (IEA, 2016)**



Net exporters	TWh
France	67
Canada	46
Paraguay	41
Germany	34
Czech Republic	16
Sweden	16
Norway	16
People's Rep. of China	11
Bulgaria	9
Ukraine	8
Others	64
Total	328

2014 data

Net importers	TWh
United States	53
Italy	44
Brazil	34
United Kingdom	21
Finland	18
Belgium	18
Netherlands	15
Hungary	13
Iraq	12
Thailand	11
Others	117
Total	356

2014 data

Electricity Production from Fossil Fuels

Coal ¹	TWh
People's Rep. of China	4 115
United States	1 713
India	967
Japan	349
Germany	285
South Africa	232
Korea	232
Russian Federation	158
Australia	152
Poland	132
Rest of the world	1 372
World	9 707

2014 data

Natural gas	TWh
United States	1 161
Russian Federation	533
Japan	421
Islamic Rep. of Iran	196
Mexico	172
Saudi Arabia	160
Egypt	135
Korea	130
Turkey	121
Thailand	119
Rest of the world	2 007
World	5 155

2014 data

Oil	TWh
Saudi Arabia	152
Japan	116
Islamic Rep. of Iran	59
Iraq	50
Kuwait	43
Pakistan	42
United States	40
Brazil	35
Mexico	33
Indonesia	26
Rest of the world	427
World	1 023

2014 data

Producers of Nuclear Electricity

Producers	TWh	% of world total
United States	831	32.8
France	436	17.2
Russian Federation	181	7.1
Korea	156	6.2
People's Rep. of China	133	5.2
Canada	108	4.3
Germany	97	3.8
Ukraine	88	3.5
Sweden	65	2.6
United Kingdom	64	2.5
Rest of the world	376	14.8
World	2 535	100.0

2014 data

Net installed capacity	GW
United States	99
France	63
Japan	42
Russian Federation	25
People's Rep. of China	24
Korea	21
Germany	14
Canada	14
Ukraine	13
Sweden	9
Rest of the world	60
World	384

2014 data

Country (top-ten producers)	% of nuclear in total domestic electricity generation
France	78.4
Ukraine	48.6
Sweden	42.3
Korea	28.7
United States	19.2
United Kingdom	19.0
Russian Federation	17.0
Canada	16.4
Germany	15.6
People's Rep. of China	2.3
Rest of the world ¹	9.4
World	10.7

2014 data

Sources: IEA, International Atomic Energy Agency.

Producers of Hydro Electricity

Producers	TWh	% of world total
People's Rep. of China	1 064	26.7
Canada	383	9.6
Brazil	373	9.4
United States	282	7.1
Russian Federation	177	4.4
Norway	137	3.4
India	132	3.3
Venezuela	87	2.2
Japan	87	2.2
France	69	1.7
Rest of the world	1 192	30.0
World	3 983	100.0

2014 data

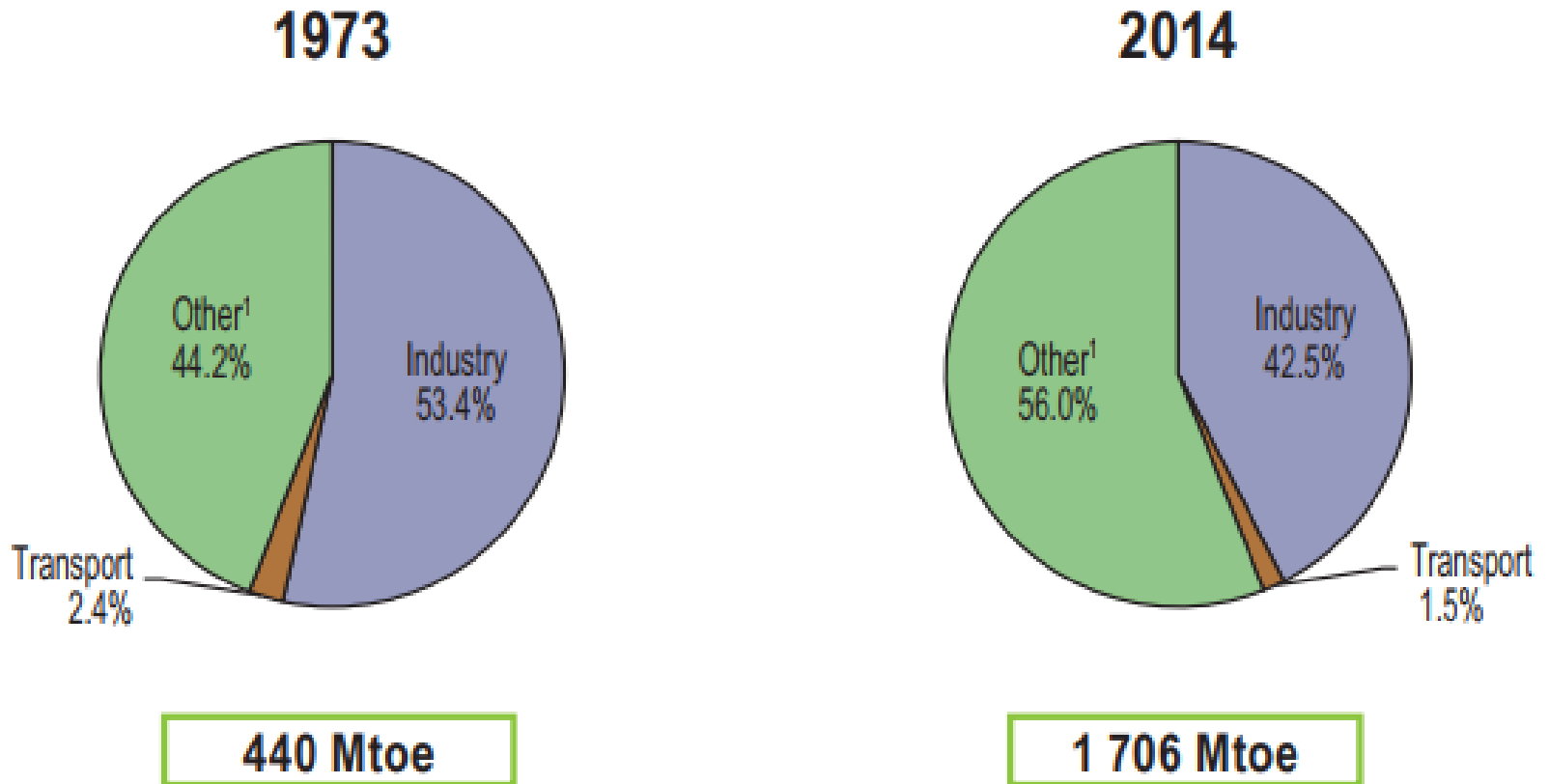
Net installed capacity	GW
People's Rep. of China	311
United States	102
Brazil	89
Canada	76
Russian Federation	51
Japan	50
India	40
Norway	31
France	25
Turkey	24
Rest of the world	372
World	1 171

2014 data

Country (top-ten producers)	% of hydro in total domestic electricity generation
Norway	96.0
Venezuela	68.3
Brazil	63.2
Canada	58.3
People's Rep. of China	18.7
Russian Federation	16.7
France	12.2
India	10.2
Japan	8.4
United States	6.5
Rest of the world ²	15.6
World	16.7

2014 data

Shares of World Electricity Consumption

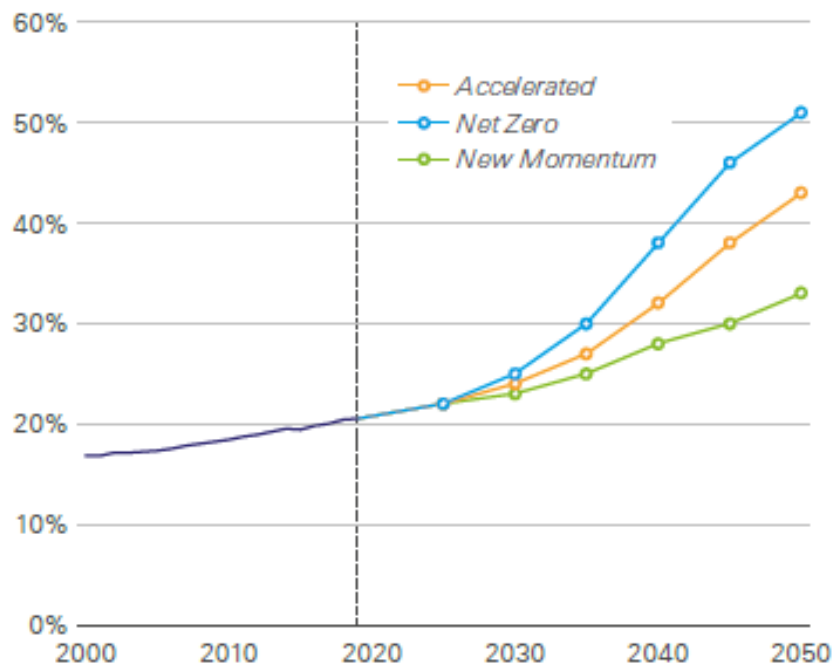


1. Includes agriculture, commercial and public services, residential, and non-specified other.

Electricity demand expands significantly as prosperity in emerging economies grows and the world increasingly electrifies

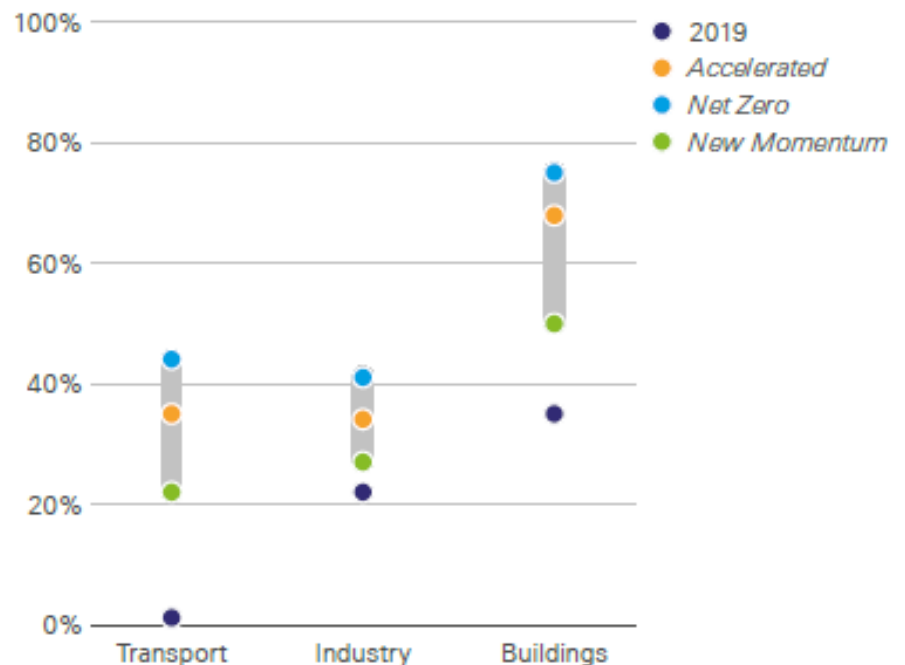
Electricity as a share of total final consumption

Share



Range of electrification across end-use sectors in 2050

Share of total final consumption



Main impacts:

- 1) Direct impact(s)
- 2) Indirect impact(s)

2020 at a glance

The COVID-19 pandemic had a dramatic impact on energy markets, with both primary energy and carbon emissions falling at their fastest rates since the Second World War. Nevertheless, renewable energy continued to grow, with solar power recording its largest ever increase.

1. Primary energy consumption fell by 4.5% in 2020 with oil demand accounting for 72% of the decrease
2. Renewables power grew by a record 358 TWh and increased its share of total generation to 12%
3. Carbon emissions fell by 6.2% and the carbon intensity of the energy mix (the average carbon emitted per unit of energy used) declined by 1.8%

Units in EJ unless otherwise stated	Level			Growth rate per annum				Share		
	2009	2019	2020	(%)		(EJ)		(%)		
	2009	2019	2020	2009-19	2020	2009-19	2020	2009	2019	2020
Consumption										
Primary energy	482	582	557	1.9	-4.5	10	-24	100	100	100
Oil	167	192	174	1.4	-9.5	2.5	-18	35	33	31
Natural gas	106	141	138	2.9	-2.3	3.5	-2.9	22	24	25
Coal	145	158	151	0.9	-4.2	1.3	-6.2	30	27	27
Nuclear	25	25	24	-0.2	-4.1	-0.1	-0.9	5.3	4.3	4.3
Hydro	31	38	38	2.1	1.0	0.7	0.5	6.4	6.5	6.9
Renewables	8.2	29	32	13	9.7	2.1	2.9	1.7	5.0	5.7
Wind	2.6	13	14	17	11	1.0	1.5	0.5	2.2	2.5
Solar	0.2	6.3	7.6	41	20	0.6	1.3	0.0	1.1	1.4
Other renewables*	5.4	9.9	10	6.3	0.8	0.5	0.1	1.1	1.7	1.8

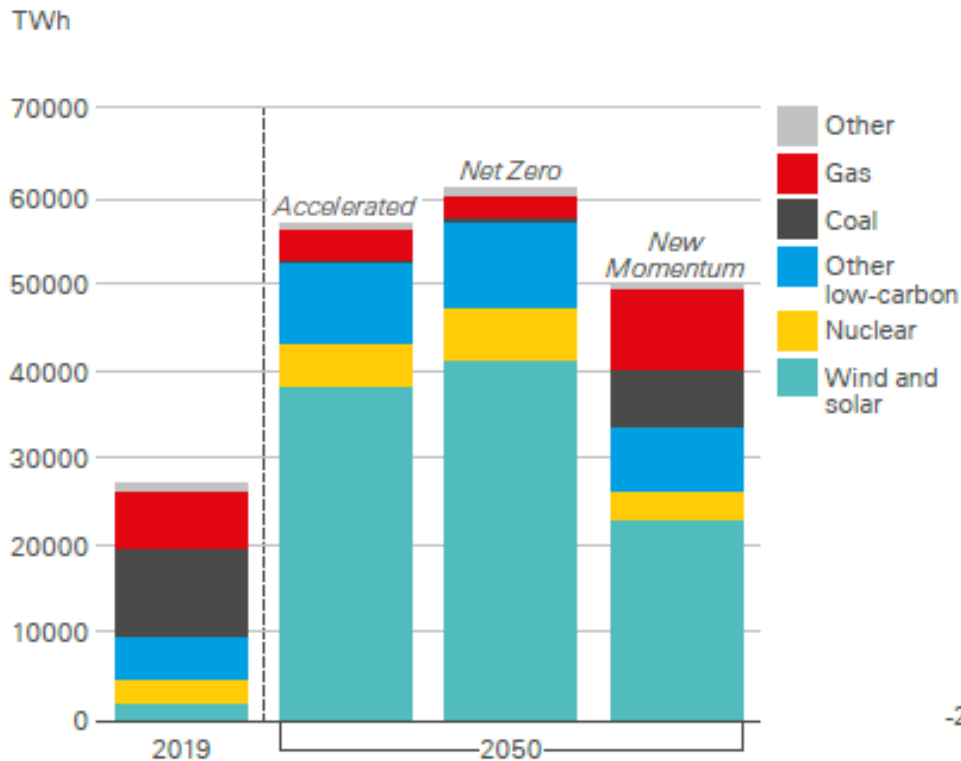
Main impacts:

- 1) the direct impact of coronavirus on employees of energy companies and on the stability of enterprises
- 2) the consequences of various kinds of restrictive measures for the fight against coronavirus, leading on the one hand to *disruptions in the supply chain*, and on the other - to *a sharp decline economic activity and reduced demand for energy*
- 3) a tough price triggered by a drop in demand competition and, as a result, a sharp drop in prices

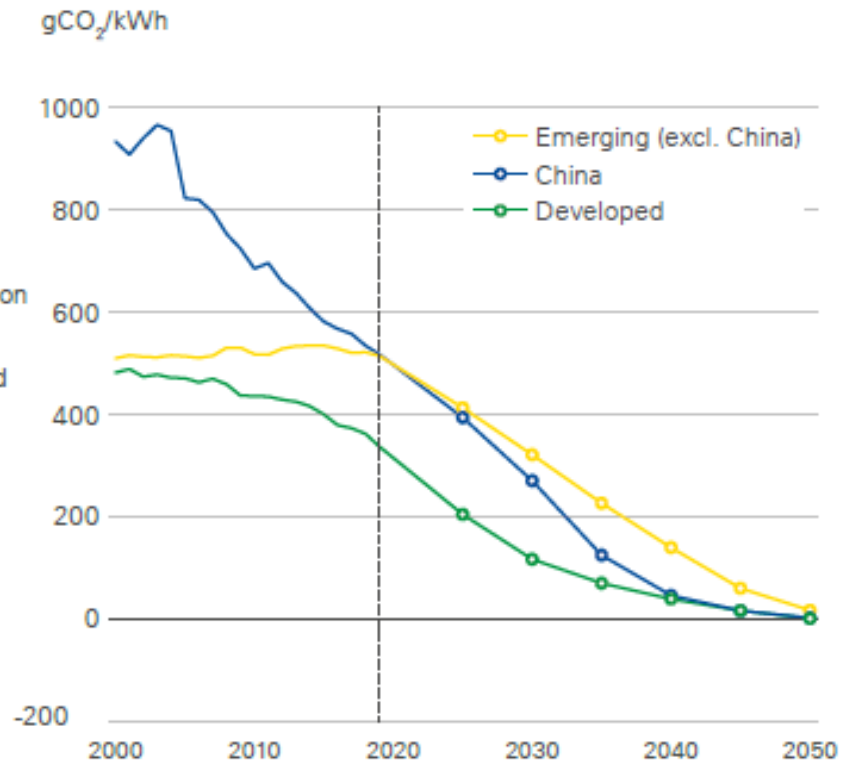
What's next? Decarbonization.

The global power system decarbonizes, led by the increasing dominance of wind and solar power

Electricity generation by fuel



Carbon intensity of power generation in *Accelerated*



Definitions of some energy terms & indicators

Energy	Electricity, fuels, steam, heat, compressed air, and other similar media.
Energy use	The manner or type of application of energy.
Energy consumption	The quantity of energy used.
Energy efficiency	Formally the ratio between energy input and energy output but usually used to mean energy performance.
Energy performance	The ratio between delivery of an output e.g. production output and energy input.
Energy conservation	Reducing energy use by reducing or stopping an energy using activity e.g. switching off a light or a machine.
Energy management	The set of processes and tools to manage energy demand within enterprises i.e. managing the process of improving energy efficiency, managing energy costs and managing energy risks.
Energy intensity	Energy use per unit of Gross Domestic Product e.g. toe/USD 1000 of GDP.
Energy productivity	Gross Domestic Product per unit of energy input - the inverse of energy intensity.

- Energy intensity is the ratio of energy use to output.

$$\text{Energy intensity} = \frac{\text{Energy use} \quad [\text{MJ, Kcal, t, etc. }]}{\text{Output} \quad [\text{\$ of GDP, \$ of Gross Output, \$ of Industry Production; tonnes, cubic metres, etc.}]}$$

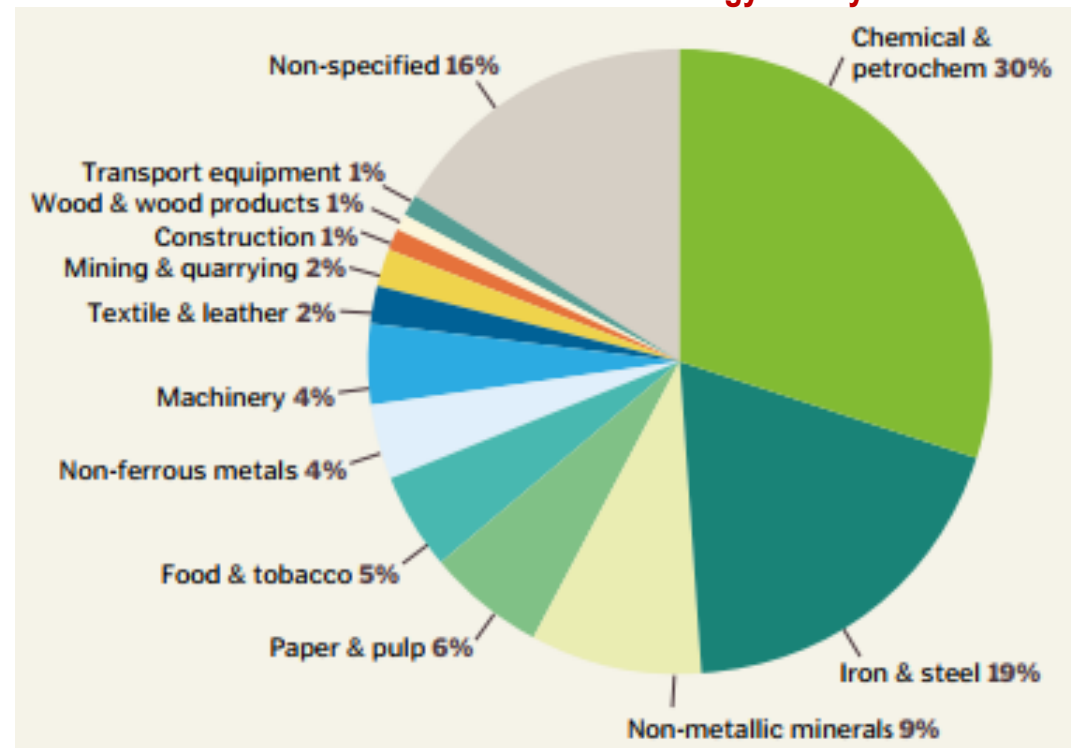
What factors influence the energy intensity of a country?

Energy Intensity of Industries

Nearly two-thirds of industrial energy use is accounted for by 4 industries:

1. *Chemical and petrochemical*
2. *Iron and steel*
3. *Non-metallic minerals*
4. *Paper and pulp*

Breakdown of industrial energy use by sector 2004.



Sources:

- IEA, 2007
- Fawkes S., Oung K., Thorpe D., (2016) Best Practices and Case Studies for Industrial Energy Efficiency Improvement – An Introduction for Policy Makers. Copenhagen Centre on Energy Efficiency.