

ME265: Thermal Engineering & Heat Transfer

Chapters
1. Energy Scenario
2. Thermodynamics
3. Mechanical Devices & Systems
4. Heat Transfer

1.1	Global Energy Scenario
1.2	Energy Scenario of Bangladesh

ME265: Energy Scenario

1.1 Global Energy Scenario¹

➤ Primary Energy Supply

Coal, NG, Oil, Nuclear, Hydro, Wind, Solar

➤ Primary Energy Consumption

Coal, NG, Oil, Nuclear, Hydro, Wind, Solar

➤ Electricity Consumption

Electricity

^[1] <https://www.iea.org/newsroom/news/2018/june/weo-2018.html>

1.1 Global Energy Scenario

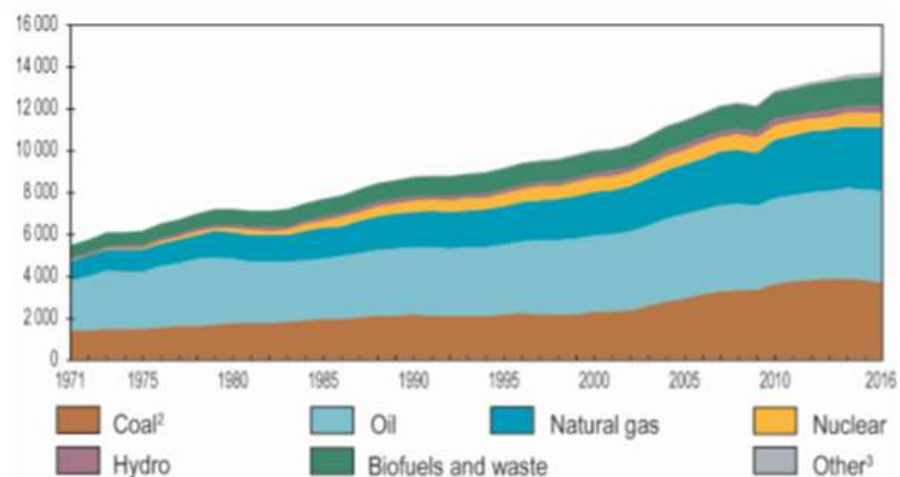
□ World Energy Reserve²

Fuel Type	Example	Energy, Q*
Fossil	Coal	32
	Oil & Gas	6
Fissile	Uranium & Thorium	600
Fusile	Deuterium	10^{10}

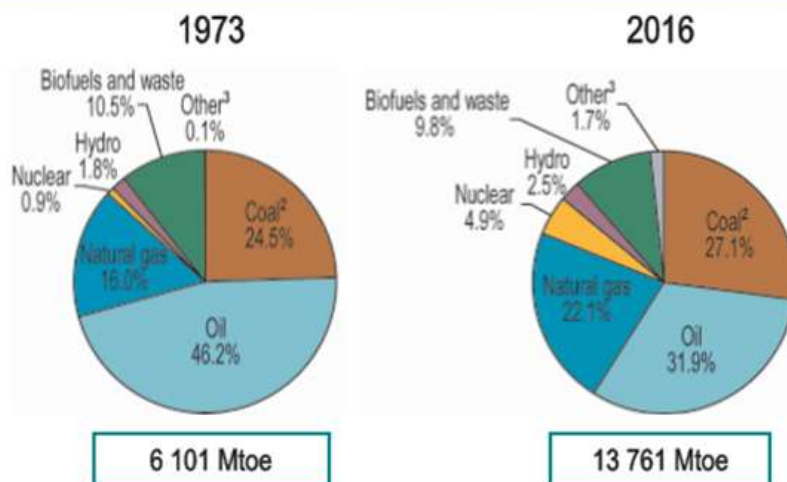
*1 Q = 10^{18} Btu = 10^{21} J, Ref: [2] El Wakil p.123

1.1 Global Energy Scenario

World¹ TPES from 1971 to 2016 by fuel (Mtoe)



1973 and 2016 fuel shares of TPES



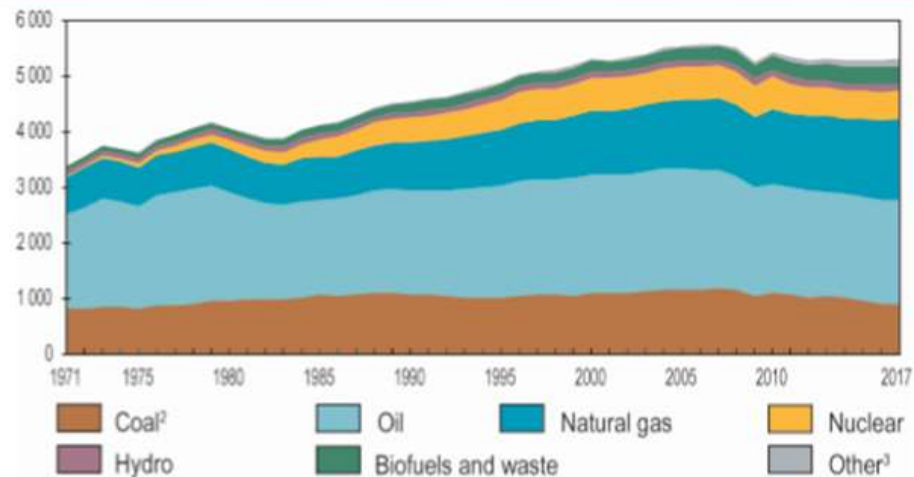
1. World includes international aviation and international marine bunkers.
2. In these graphs, peat and oil shale are aggregated with coal.
3. Includes geothermal, solar, wind, tide/wave/ocean, heat and other.

28 October 2018

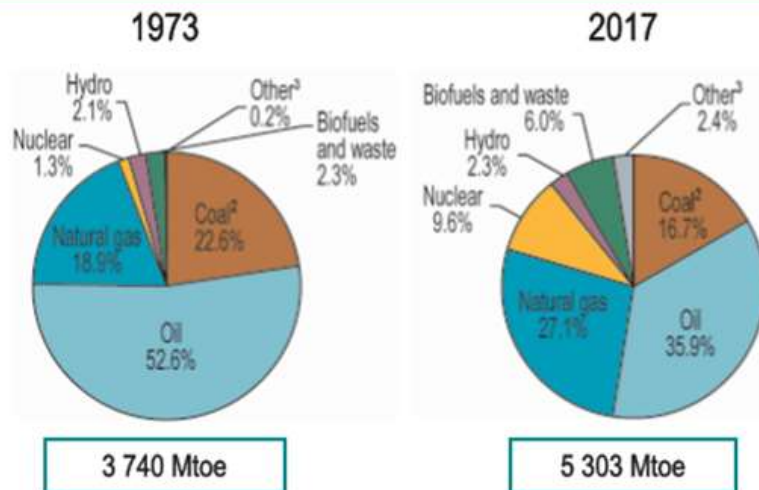
[1] <https://www.iea.org/newsroom/news/2018/june/weo-2018.html>

1.1 Global Energy Scenario

OECD TPES¹ from 1971 to 2017 by fuel (Mtoe)



1973 and 2017 fuel shares of TPES¹



[1] <https://www.iea.org/newsroom/news/2018/june/weo-2018.html>

1. Excludes electricity trade.
 2. In these graphs, peat and oil shale are aggregated with coal.
 3. Includes geothermal, solar, wind, tide/wave/ocean, heat and other.

Geographical coverage

World

OECD¹ Total, Africa, Non-OECD Americas, Non-OECD Asia (excluding China), China (People's Republic of China and Hong Kong, China), Non-OECD Europe and Eurasia, Middle East, World aviation bunkers and World marine bunkers. It is also the sum of Africa, Americas, Asia, Europe, Oceania, World aviation bunkers and World marine bunkers.

Africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, the Republic of the Congo (Congo), Côte d'Ivoire, the Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Sao Tome and Principe, Senegal, the Seychelles, Sierra Leone, Somalia, South Africa, South Sudan (from 2012), Sudan, Swaziland, the United Republic of Tanzania (Tanzania), Togo, Tunisia, Uganda, Zambia, Zimbabwe.

Americas

Antigua and Barbuda, Argentina, Aruba, the Bahamas, Barbados, Belize, Bermuda, the Plurinational State of Bolivia (Bolivia), Bonaire (from 2012), the British Virgin Islands, Brazil, Canada, the Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Curaçao², Dominica, the Dominican Republic, Ecuador, El Salvador, the Falkland Islands (Malvinas), Guatemala, French Guiana, Grenada, Guadeloupe, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saba (from 2012), Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and the Grenadines, Sint Eustatius (from 2012), Sint Maarten (from 2012), Suriname, Trinidad and Tobago, the Turks and Caicos Islands, the United States, Uruguay, the Bolivarian Republic of Venezuela (Venezuela).

Asia (from 1990)

Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, the People's Republic of China, Cyprus³, Georgia, Hong Kong, China, India, Indonesia, the Islamic Republic of Iran, Iraq, Israel⁴, Japan, Jordan, the Democratic People's Republic of Korea, Korea, Kazakhstan, Kuwait, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Macau, China, Malaysia, the Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, the Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, the Syrian Arab Republic, Tajikistan, Chinese Taipei, Thailand, Timor-Leste, Turkey, Turkmenistan, the United Arab Emirates, Uzbekistan, Viet Nam, and Yemen.

Europe (from 1990)

Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, the Former Yugoslav Republic of Macedonia, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Kosovo⁵, Latvia⁶, Lithuania, Luxembourg, Malta, the Republic of Moldova (Moldova), Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, Serbia⁷, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, the United Kingdom.

Oceania

Australia, New Zealand, Cook Islands, Fiji, French Polynesia, Kiribati, New Caledonia, Palau, Papua New Guinea, Samoa, the Solomon Islands, Tonga, Vanuatu.

OECD¹

Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel⁴, Italy, Japan, Korea, Latvia⁶, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

OECD Americas

Canada, Chile, Mexico, the United States.

OECD Asia Oceania

Australia, Israel⁴, Japan, Korea, New Zealand.

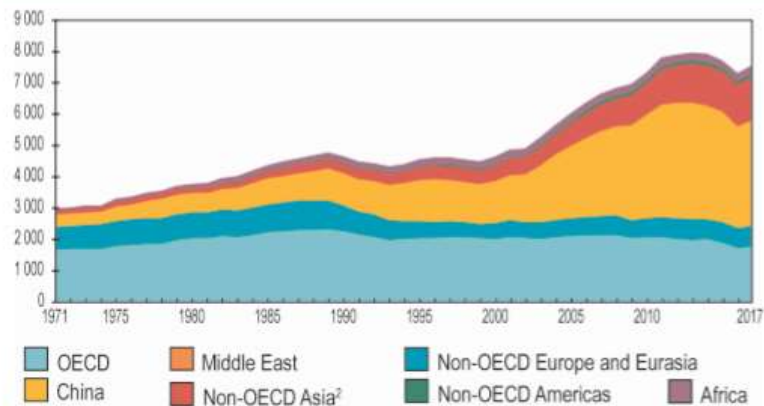
OECD Europe

Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia⁶, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom.

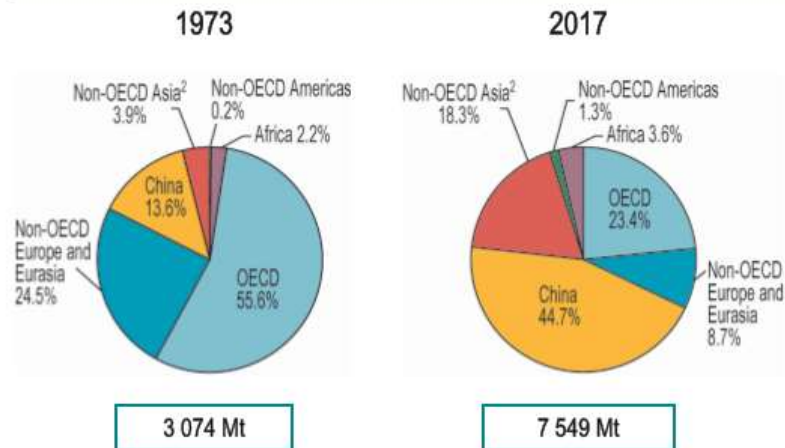
1.1 Global Energy Scenario

Coal production

World coal¹ production from 1971 to 2017 by region (Mt)



1973 and 2017 regional shares of coal¹ production



1. Includes steam coal, coking coal, lignite and recovered coal.
2. Non-OECD Asia excludes China.

Producers, net exporters and net importers of coal¹



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Producers	Mt	% of world total
People's Rep. of China	3 376	44.7
India	730	9.7
United States	702	9.3
Australia	501	6.6
Indonesia	488	6.5
Russian Federation	387	5.1
South Africa	257	3.4
Germany	175	2.3
Poland	127	1.7
Kazakhstan	106	1.4
Rest of the world	700	9.3
World	7 549	100.0

2017 provisional data

Net exporters	Mt
Indonesia	387
Australia	379
Russian Federation	161
Colombia	86
United States	81
South Africa	71
Mongolia	33
Kazakhstan	27
Canada	24
Mozambique	12
Others	2
Total	1 263

2017 provisional data

Net importers	Mt
People's Rep. of China	263
India	207
Japan	188
Korea	148
Chinese Taipei	68
Germany	48
Turkey	38
Malaysia	31
Thailand	24
Brazil	21
Others	244
Total	1 280

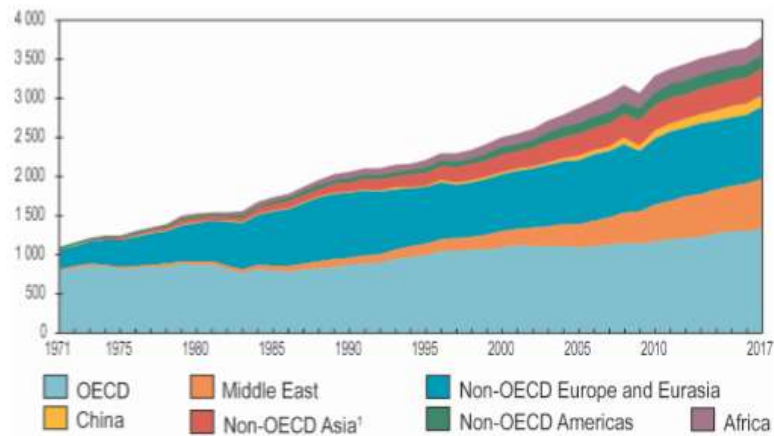
2017 provisional data

1. Includes steam coal, coking coal, lignite and recovered coal.

1.1 Global Energy Scenario

Natural gas production

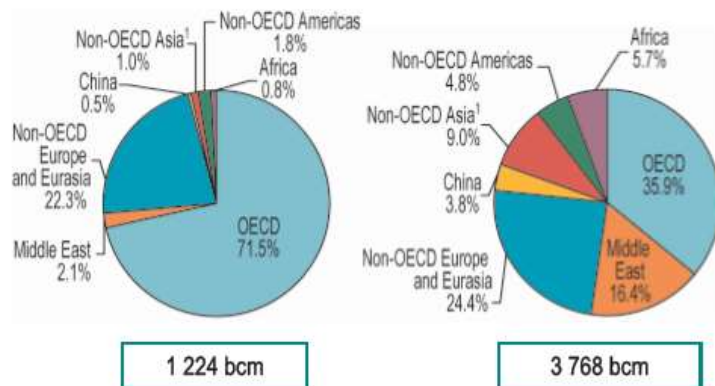
World natural gas production from 1971 to 2017 by region
(billion cubic metres, bcm)



1973 and 2017 regional shares of natural gas production

1973

2017



1. Non-OECD Asia excludes China.

Producers, net exporters and net importers¹ of natural gas



Producers	bcm	% of world total
United States	760	20.2
Russian Federation	694	18.4
Islamic Rep. of Iran	214	5.7
Canada	184	4.9
Qatar	169	4.5
People's Rep. of China	142	3.8
Norway	128	3.4
Australia	105	2.8
Algeria	94	2.5
Saudi Arabia	94	2.5
Rest of the world	1 184	31.3
World	3 768	100.0

2017 provisional data

Net exporters	bcm
Russian Federation	217
Norway	123
Qatar	121
Australia	62
Canada	61
Turkmenistan	55
Algeria	54
Indonesia	29
Malaysia	28
Nigeria	27
Others	151
Total	928

2017 provisional data

Net importers	bcm
Japan	115
People's Rep. of China	86
Germany	85
Italy	69
Turkey	54
Mexico	50
Korea	49
France	43
United Kingdom	37
Spain	32
Others	296
Total	916

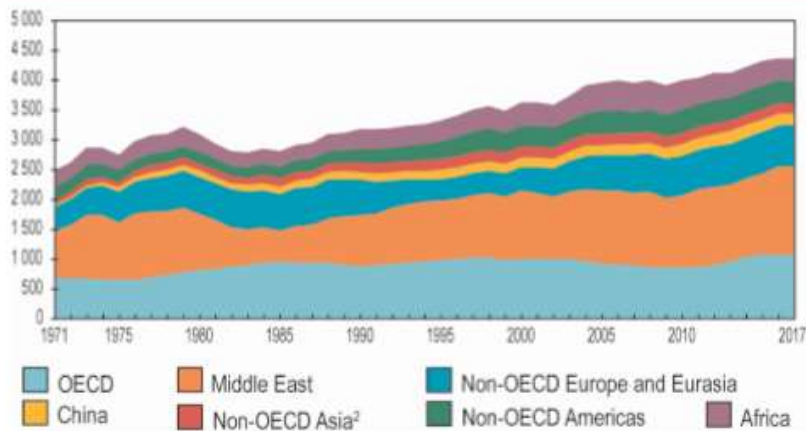
2017 provisional data

1. Net exports and net imports include pipeline gas and LNG.

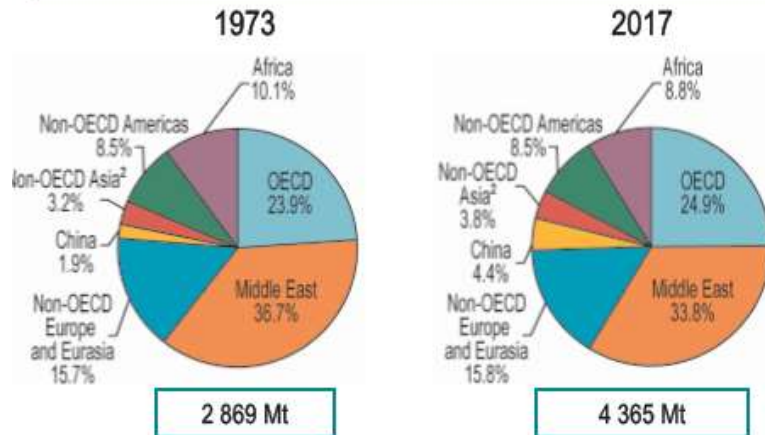
1.1 Global Energy Scenario

Crude oil production

World crude oil¹ production from 1971 to 2017 by region (Mt)



1973 and 2017 regional shares of crude oil¹ production



1. Includes crude oil, NGL, feedstocks, additives and other hydrocarbons.

2. Non-OECD Asia excludes China.

Producers, net exporters and net importers of crude oil¹



Producers	Mt	% of world total
United States	563	12.9
Saudi Arabia	560	12.8
Russian Federation	548	12.6
Canada	237	5.4
Islamic Rep. of Iran	229	5.2
Iraq	225	5.2
People's Rep. of China	192	4.4
United Arab Emirates	178	4.1
Kuwait	149	3.4
Brazil	137	3.1
Rest of the world	1 347	30.9
World	4 365	100.0

2017 provisional data

Net exporters	Mt
Saudi Arabia	373
Russian Federation	254
Iraq	187
United Arab Emirates	120
Islam Rep. of Iran	119
Canada	113
Kuwait	108
Venezuela	90
Nigeria	87
Angola	82
Others	548
Total	2 081

2016 data

Net importers	Mt
People's Rep. of China	378
United States	371
India	214
Japan	162
Korea	146
Germany	91
Italy	65
Spain	64
Netherlands	61
France	55
Others	506
Total	2 113

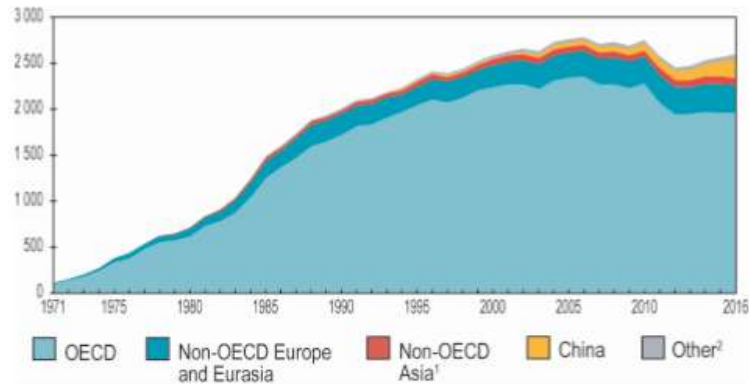
2016 data

1. Includes production of crude oil, NGL, feedstocks, additives and other hydrocarbons.
Excludes liquids from other fuel sources (renewable, coal and natural gas).

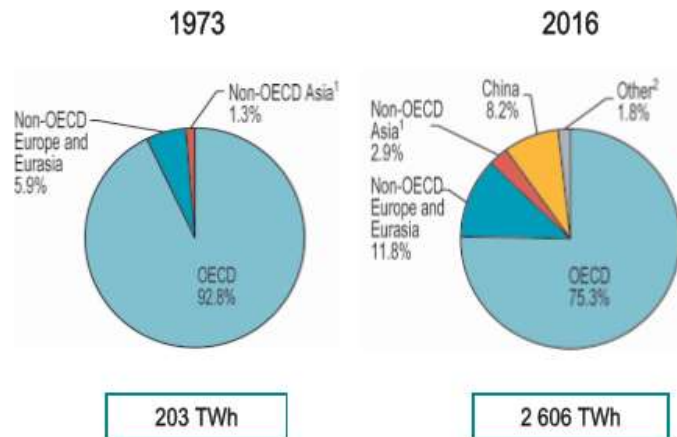
1.1 Global Energy Scenario

Nuclear electricity production

World nuclear electricity production from 1971 to 2016 by region (TWh)



1973 and 2016 regional shares of nuclear electricity production



1. Non-OECD Asia excludes China.

2. Other includes Africa, Non-OECD Americas and the Middle East.

Producers of nuclear electricity



Producers	TWh	% of world total
United States	840	32.2
France	403	15.5
People's Rep. of China	213	8.2
Russian Federation	197	7.6
Korea	162	6.2
Canada	101	3.9
Germany	85	3.3
Ukraine	81	3.1
United Kingdom	72	2.8
Sweden	63	2.4
Rest of the world	389	14.8
World	2 606	100.0

2016 data

Net installed capacity	GW
United States	100
France	63
Japan	40
People's Rep. of China	31
Russian Federation	26
Korea	23
Canada	14
Ukraine	13
Germany	11
Sweden	10
Rest of the world	60
World	391

2016 data

Sources:
International Energy Agency,
International Atomic
Energy Agency

Country (top ten producers)	% of nuclear in total domestic electricity generation
France	73.1
Ukraine	49.7
Sweden	40.5
Korea	29.0
United Kingdom	21.3
United States	19.5
Russian Federation	18.1
Canada	15.2
Germany	13.2
People's Rep. of China	3.5
Rest of the world ¹	7.3
World	10.4

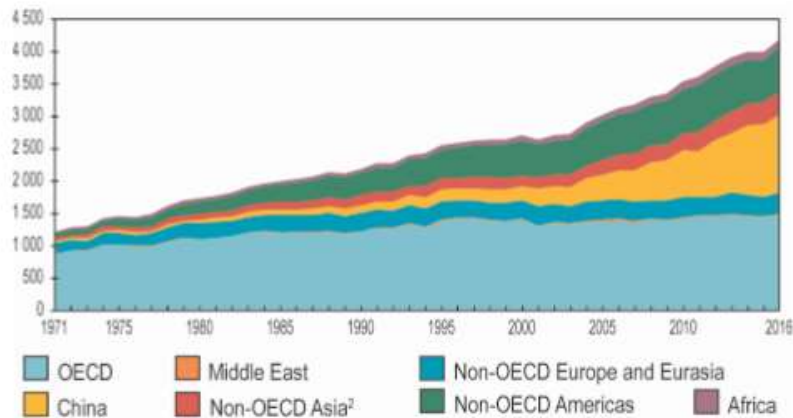
2016 data

1. Excludes countries with no nuclear production.

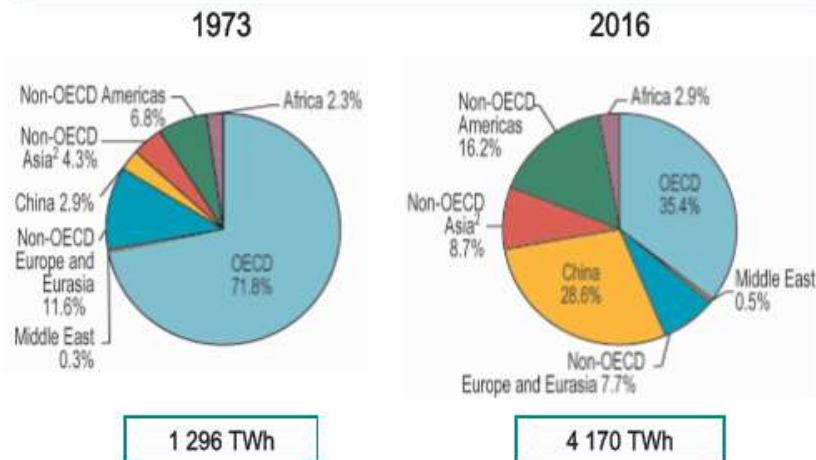
1.1 Global Energy Scenario

Hydro electricity production

World hydro electricity production¹ from 1971 to 2016 by region (TWh)



1973 and 2016 regional shares of hydro electricity production¹



1. Includes electricity production from pumped storage.
2. Non-OECD Asia excludes China.

Producers of hydro electricity¹



Producers	TWh	% of world total
People's Rep. of China	1 193	28.6
Canada	387	9.3
Brazil	381	9.1
United States	292	7.0
Russian Federation	187	4.5
Norway	144	3.5
India	138	3.3
Japan	85	2.0
Venezuela	68	1.6
Turkey	67	1.6
Rest of the world	1 228	29.5
World	4 170	100.0

2016 data

Net installed capacity	GW
People's Rep. of China	344
United States	103
Brazil	97
Canada	80
Russian Federation	51
Japan	50
India	45
Norway	32
Turkey	27
France	26
Rest of the world	302
World	1 157

2016 data

Sources:
International Energy Agency,
United Nations

Country (top ten producers)	% of hydro in total domestic electricity generation
Norway	96.2
Brazil	65.8
Venezuela	60.1
Canada	58.0
Turkey	24.5
People's Rep. of China	19.2
Russian Federation	17.1
India	9.3
Japan	8.0
United States	6.8
Rest of the world ²	14.9
World	16.6

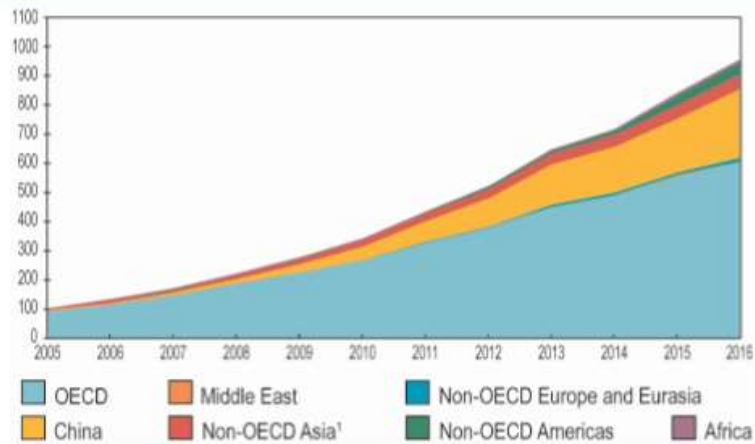
2016 data

1. Includes electricity production from pumped storage.
2. Excludes countries with no hydro production.

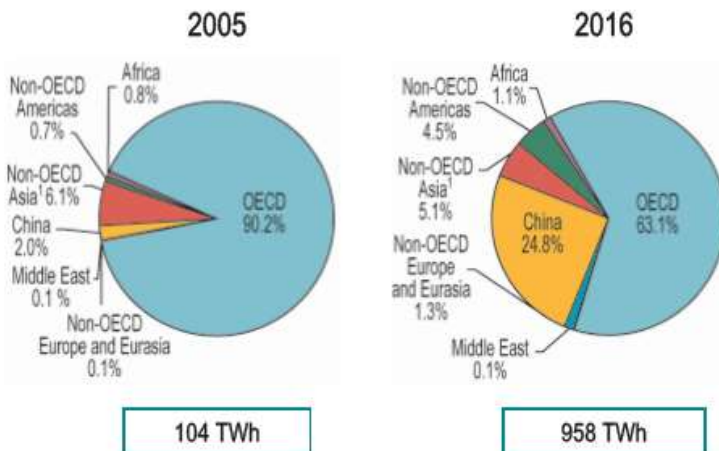
1.1 Global Energy Scenario

Wind electricity production

World wind electricity production from 2005 to 2016 by region (TWh)



2005 and 2016 regional shares of wind electricity production



1. Non-OECD Asia excludes China.

Producers of wind electricity

Producers	TWh	% of world total
People's Rep. of China	237	24.8
United States	229	24.0
Germany	79	8.2
Spain	49	5.1
India	45	4.7
United Kingdom	37	3.9
Brazil	33	3.5
Canada	31	3.2
France	21	2.2
Italy	18	1.8
Rest of the world	178	18.6
World	958	100.0

2016 data

Net installed capacity	GW
People's Rep. of China	148.6
United States	81.4
Germany	49.6
India	28.7
Spain	23.0
United Kingdom	16.2
Canada	12.0
France	11.5
Brazil	10.1
Italy	9.4
Rest of the world	76.9
World	467.4

2016 data



Country (top ten producers)	% of wind in total domestic electricity generation
Spain	17.8
Germany	12.1
United Kingdom	11.0
Italy	6.1
Brazil	5.8
United States	5.3
Canada	4.6
France	3.9
People's Rep. of China	3.8
India	3.0
Rest of the world¹	2.2
World	3.8

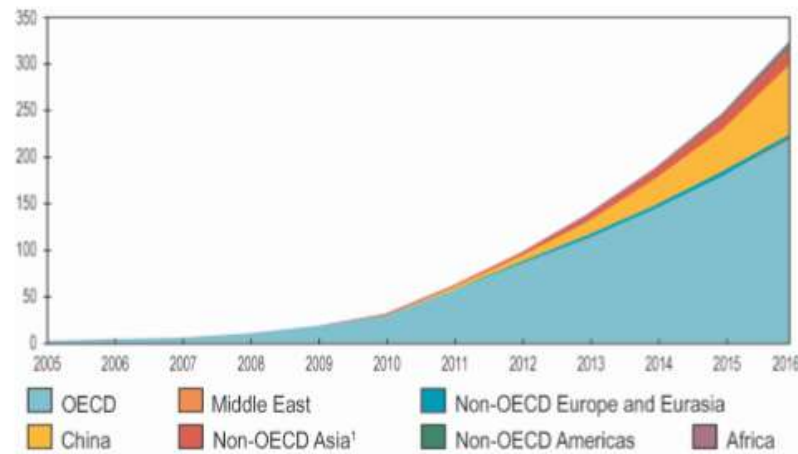
2016 data

1. Excludes countries with no wind production.

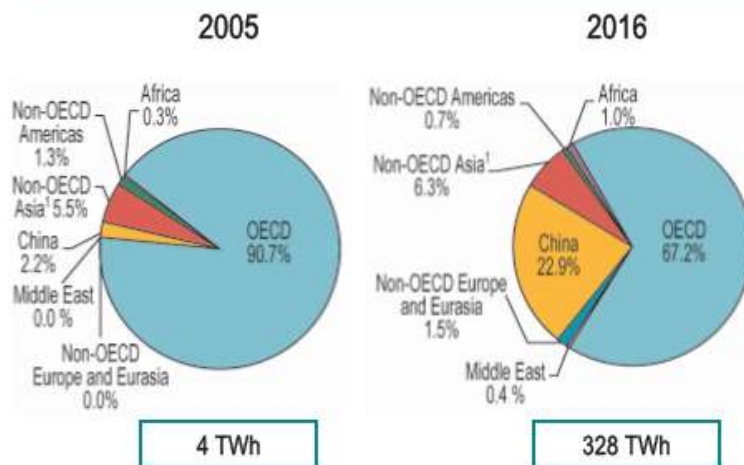
1.1 Global Energy Scenario

Solar photovoltaic electricity production

World solar PV electricity production from 2005 to 2016 by region (TWh)



2005 and 2016 regional shares of solar PV electricity production



1. Non-OECD Asia excludes China.

Producers of solar PV electricity

Producers	TWh	% of world total
People's Rep. of China	75	22.9
Japan	51	15.5
United States	47	14.2
Germany	38	11.6
Italy	22	6.7
India	14	4.3
United Kingdom	10	3.2
France	8	2.5
Spain	8	2.5
Australia	6	1.9
Rest of the world	49	14.7
World	328	100.0

2016 data



Net installed capacity	GW
People's Rep. of China	77.5
Japan	42.0
United States	41.4
Germany	40.7
Italy	19.3
United Kingdom	11.9
India	9.4
France	7.3
Australia	5.6
Spain	5.0
Rest of the world	40.0
World	300.1

2016 data

Country (top ten producers)	% of solar PV in total domestic electricity generation
Italy	7.6
Germany	5.9
Japan	4.8
United Kingdom	3.1
Spain	2.9
Australia	2.4
France	1.5
People's Rep. of China	1.2
United States	1.1
India	1.0
Rest of the world¹	0.6
World	1.3

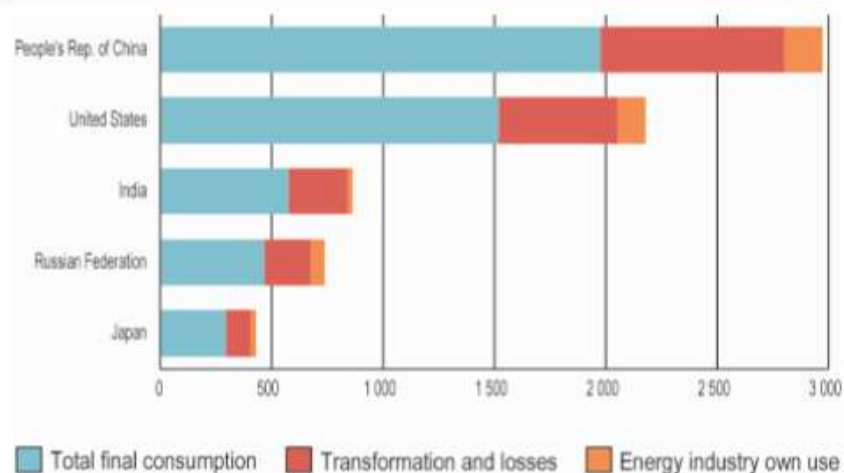
2016 data

1. Excludes countries with no solar PV production.

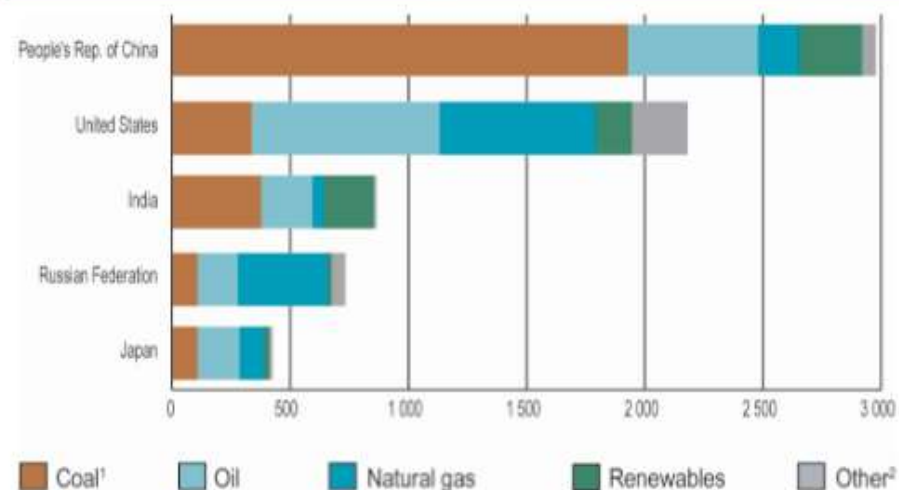
1.1 Global Energy Scenario

Top five countries by total primary energy supply (TPES)

TPES by sector (Mtoe)



TPES by energy source (Mtoe)



1. In this graph peat and oil shale are aggregated with coal.
 2. Other includes nuclear, electricity trade, heat, non-renewable waste.

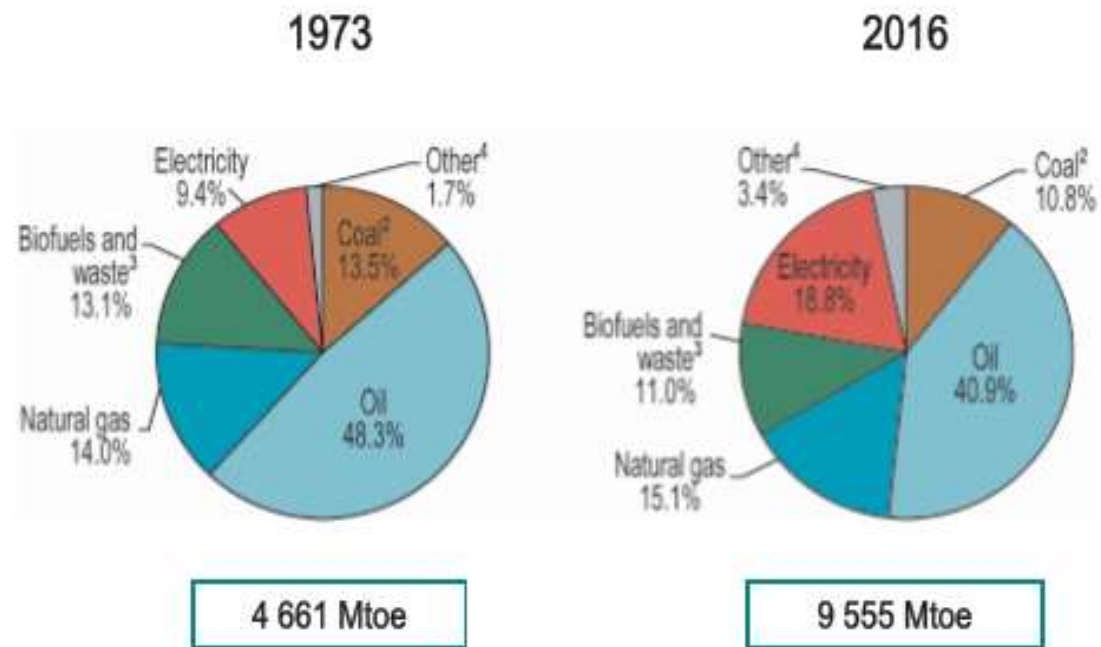
1.1 Global Energy Scenario

- **Primary Energy Consumption**
Coal, NG, Oil, Nuclear, Hydro, Wind, Solar
- **Electricity Consumption**
Electricity

1.1 Global Energy Scenario

Primary Energy Consumption

1973 and 2016 fuel shares of TFC

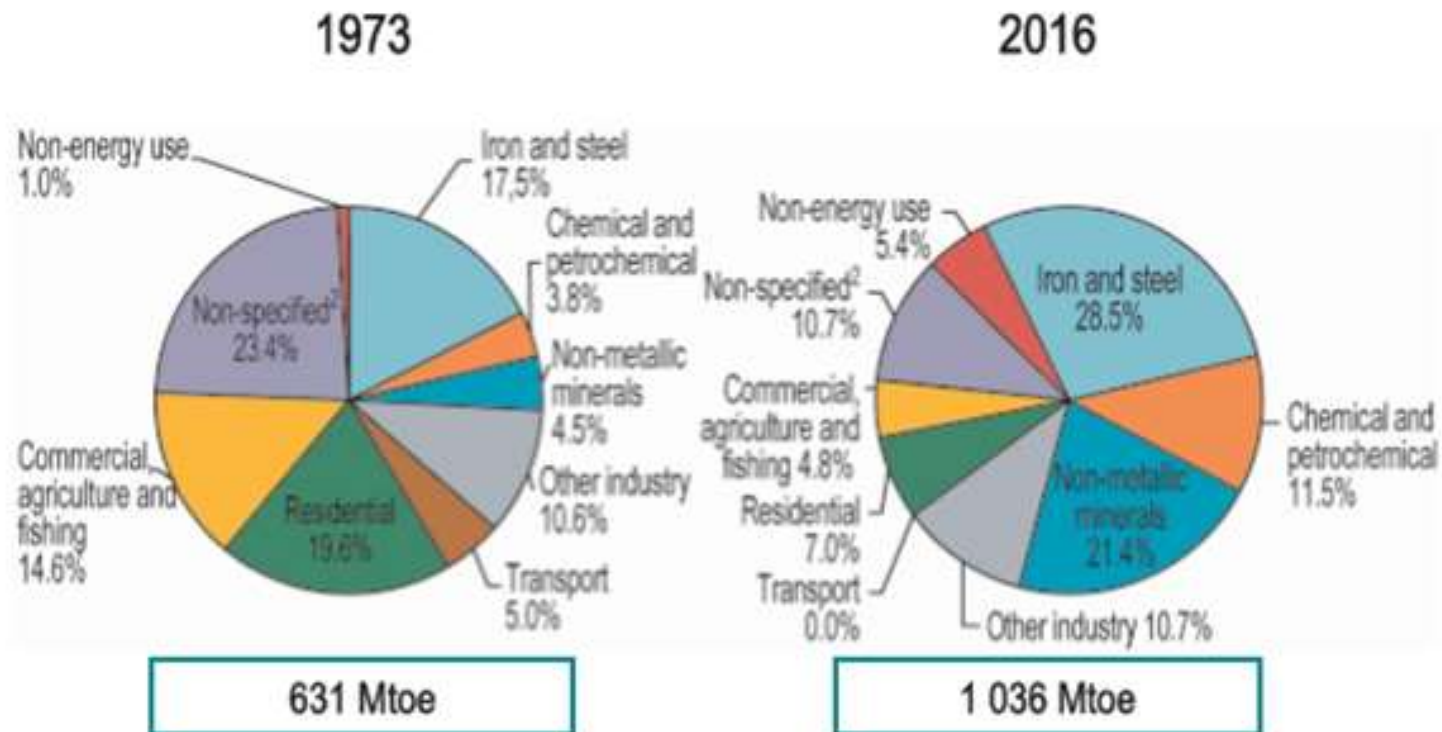


1. World includes international aviation and international marine bunkers.
2. In these graphs, peat and oil shale are aggregated with coal.
3. Data for biofuels and waste final consumption have been estimated for a number of countries.
4. Includes heat, solar thermal and geothermal.

1.1 Global Energy Scenario

Primary Energy Consumption

1973 and 2016 shares of world coal¹ consumption



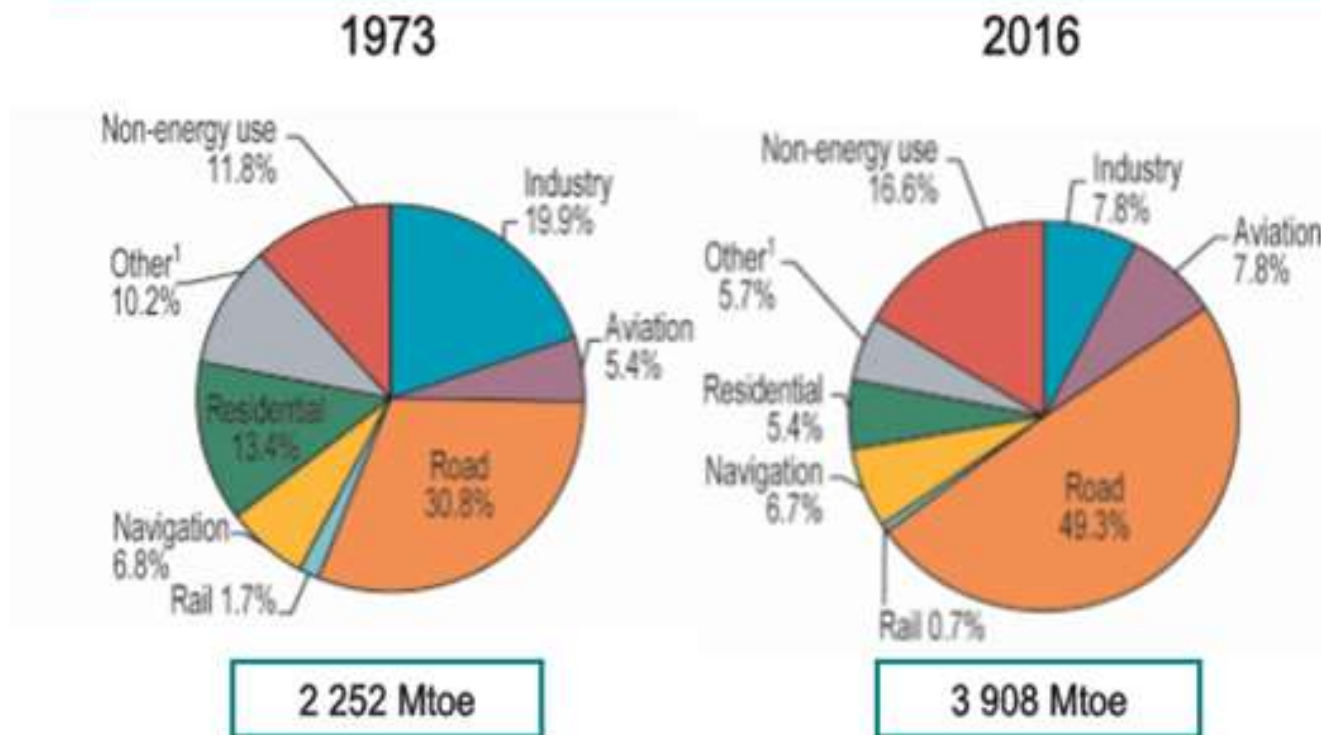
1. In these graphs, peat and oil shale are aggregated with coal.

2. Includes non-specified industry, transport and other.

1.1 Global Energy Scenario

Primary Energy Consumption

1973 and 2016 shares of world oil consumption

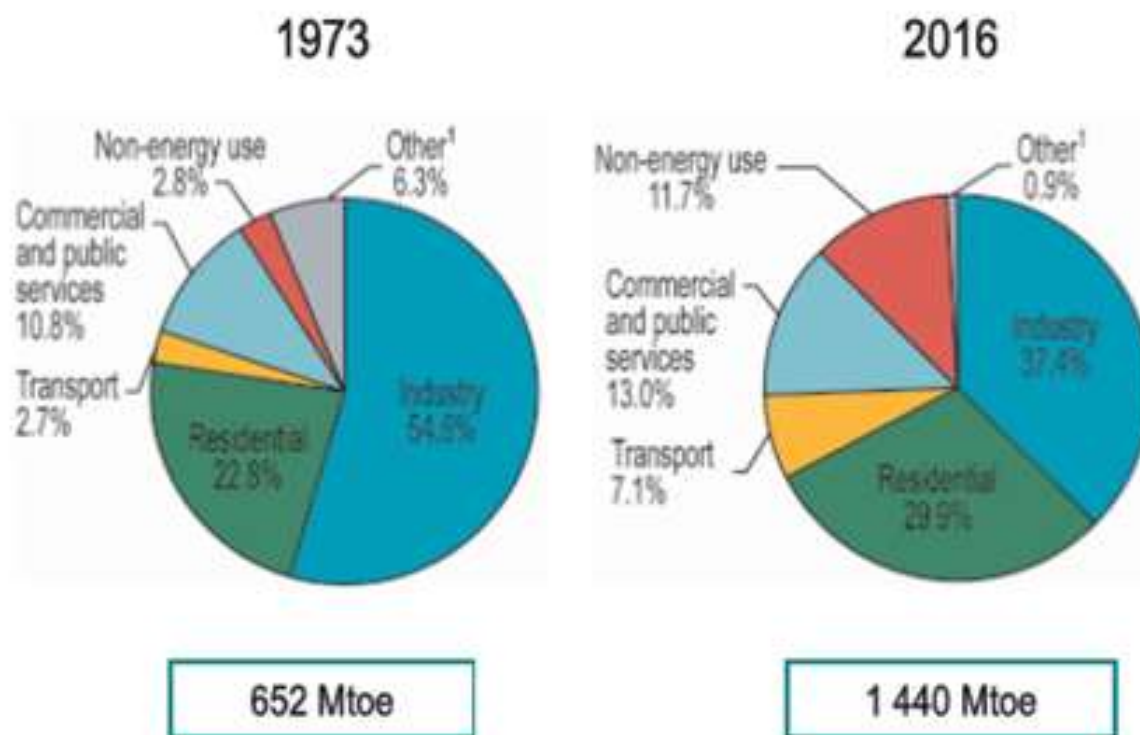


1. Includes agriculture, commercial and public services, non-specified other, pipeline and non-specified transport.

1.1 Global Energy Scenario

Primary Energy Consumption

1973 and 2016 shares of world natural gas consumption

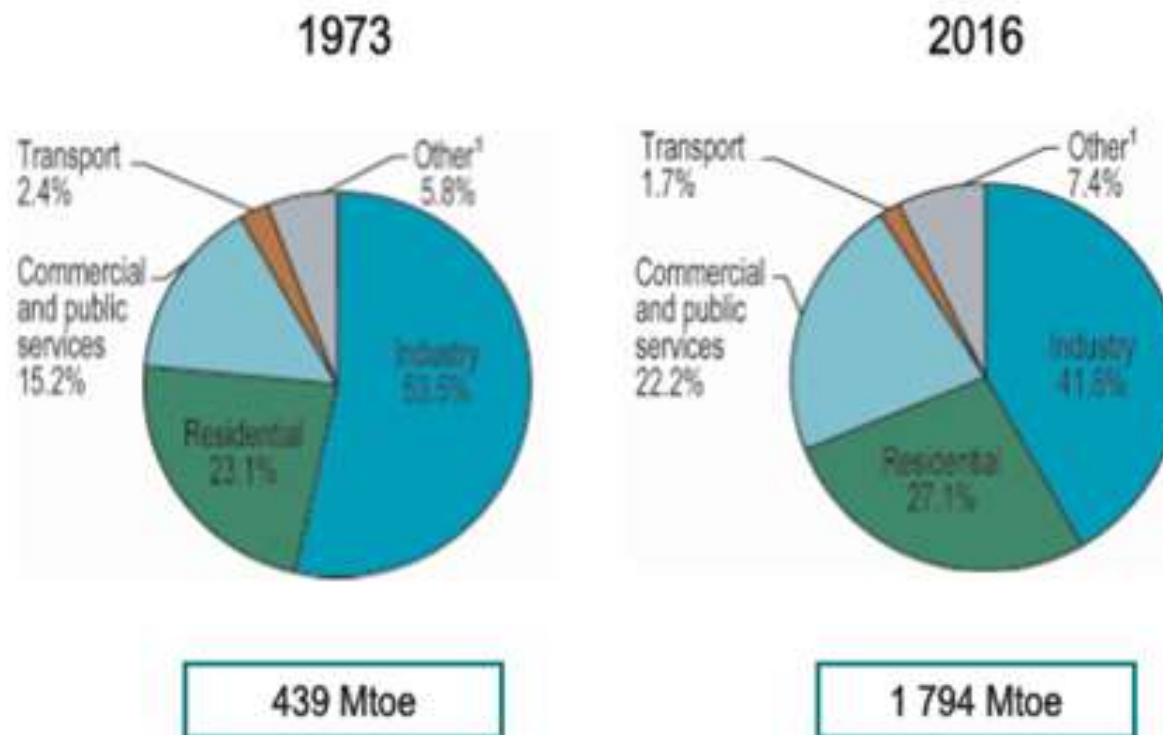


1. Includes agriculture, fishing and non-specified other.

1.1 Global Energy Scenario

World Electricity Consumption

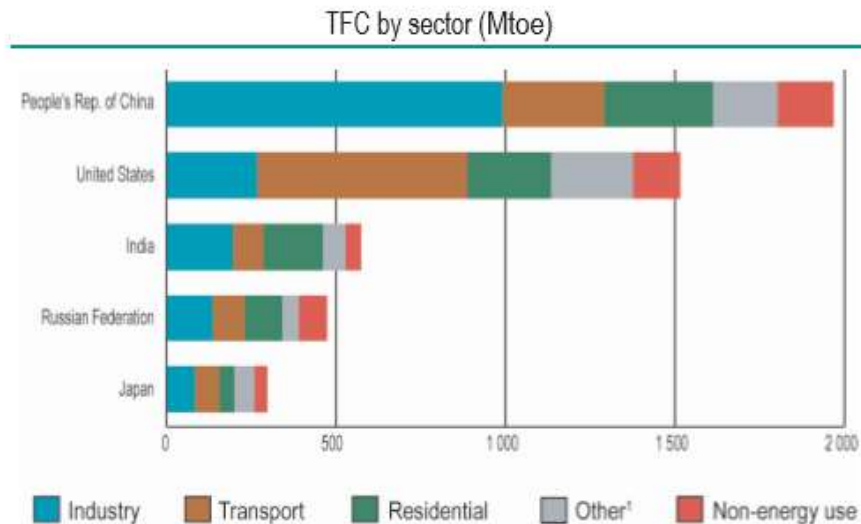
1973 and 2016 shares of world electricity consumption



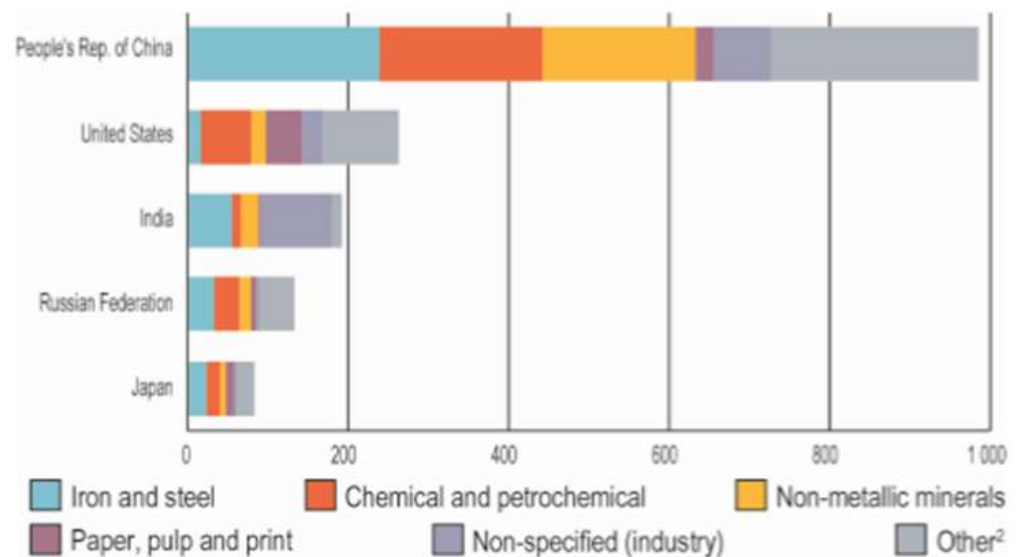
1. Includes agriculture, fishing and non-specified other.

1.1 Global Energy Scenario

Top five countries by total final consumption (TFC)



Industry consumption by sub-sector (Mtoe)

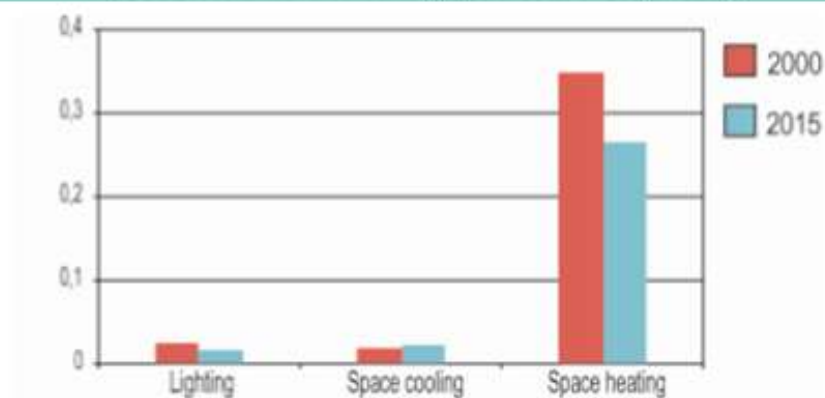


1. Other consumption includes commercial and public services, agriculture/forestry, fishing and non-specified.
 2. Other includes non-ferrous metals, transport equipment, machinery, mining and quarrying, food and tobacco, wood and wood products, construction, textile and leather.

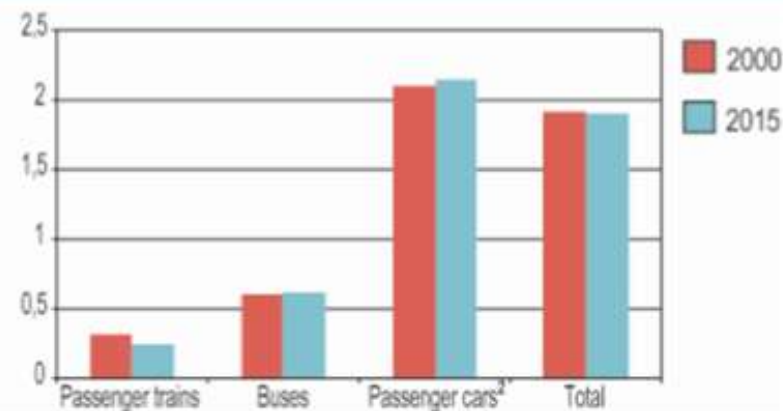
1.1 Global Energy Scenario

Energy Efficiency Indicators

Residential in IEA¹: energy per floor area (GJ/m²)



Passenger transport in IEA¹: energy per passenger-kilometre (MJ/pkm)



1. Refers to the 19 IEA countries for which data are available for most end-uses: Australia, Austria, Canada, Czech Republic, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, New Zealand, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom and the United States.

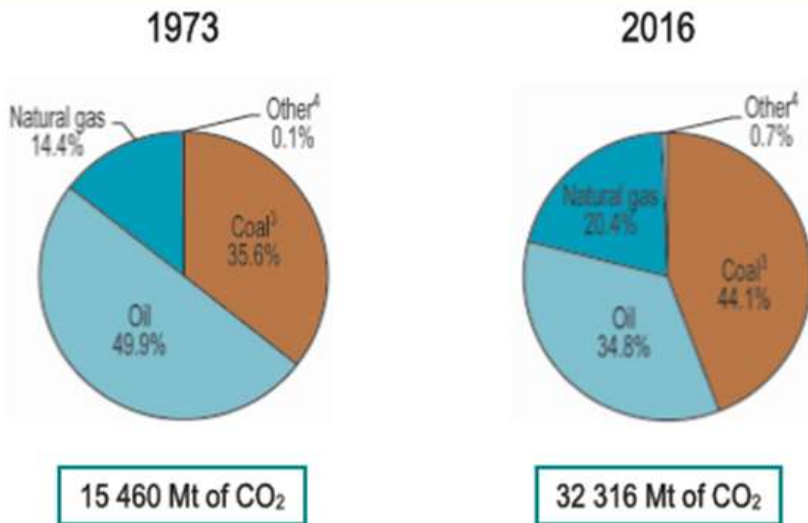
2. Passenger cars include cars, sport utility vehicles and personal trucks.

Source: IEA Energy Efficiency Indicators (database). 2018.

1.1 Global Energy Scenario

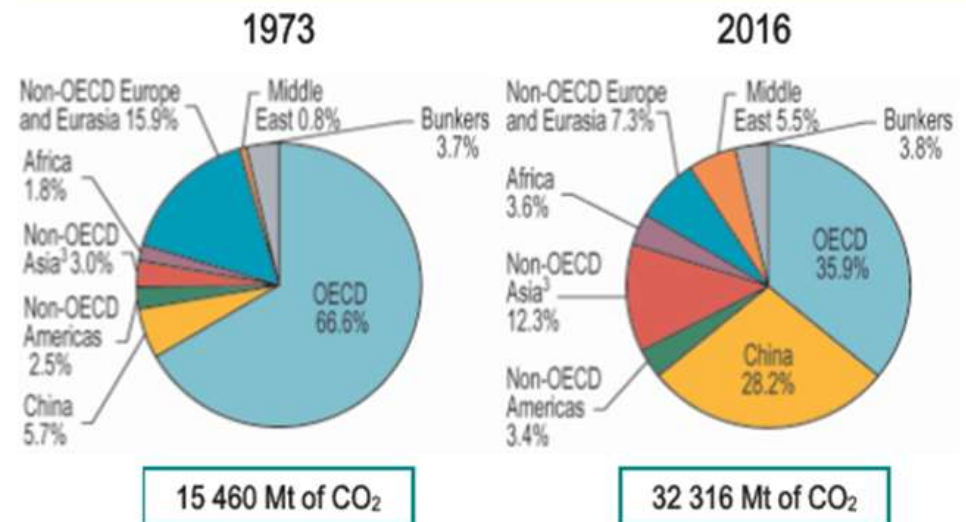
Emissions of CO₂

1973 and 2016 fuel shares of CO₂ emissions from fuel combustion²



1. World includes international aviation and international marine bunkers.
2. CO₂ emissions from fuel combustion are based on the IEA Energy Balances and on the 2006 IPCC Guidelines, and exclude emissions from non-energy.
3. In these graphs, peat and oil shale are aggregated with coal.
4. Includes industrial waste and non-renewable municipal waste.

1973 and 2016 regional shares of CO₂ emissions from fuel combustion²



1. World includes international aviation and marine bunkers, which are shown together as Bunkers.
2. CO₂ emissions from fuel combustion are based on the IEA Energy Balances and on the 2006 IPCC Guidelines, and exclude emissions from non-energy.
3. Non-OECD Asia excludes China.

1.2 Energy Scenario of Bangladesh

Next Class