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Curso de Engenharia Ambiental da Escola Politécnica da USP

IEE 0005 - Produção e Consumo de Combustíveis e o Meio Ambiente

2a. aula: Panorama internacional da produção de combustíveis

- evolução histórica; situação atual e previsões.

Principais unidades utilizadas para a quantificação de energia:

J: joule

Cal: caloria

Tep: tonelada equivalente de petróleo (tons of oil equivalent)

Bep: barris equivalentes de petróleo (barrels of oil equivalent)

Btu: unidade térmica britânica (British termal unit)

kWh: kilowatt-hora

1 J = 1 kg x m^2/s^2 - energia que acelera uma massa de 1 kg a 1 m/s^2 num espaço de 1 m

Nota: o Joule (j) é a unidade padrão de energia do Sistema Internacional de unidades (SI)

1 Cal - energia necessária para elevar em 1 grau Celsius a temperatura de 1 quilograma de água.

1 Tep - unidade de energia definida como o calor libertado na combustão de uma tonelada de petróleo cru

Nota: importância como unidade de energia decorrente da dinâmica econômico-política na atualidade

1 Btu - quantidade de energia necessária para se elevar a temperatura de uma massa de uma libra de água em 1ºF, sob pressão constante de 1 atm (utilizada nos EUA e Reino Unido). 1ºF = -17,22 ºC

1 kWh - unidade de energia elétrica - é a quantidade de energia necessária para alimentar uma carga com potência de 1 quilowatt durante 1 hora

Para grandes quantidades de qualquer unidade de energia, (ver exemplo com a unidade joule) utiliza-se:

1 kJ =	kilojoule	10^3 joules	1 TG =	terajoule	10^{12} joules
1 MJ =	megajoule	10^6 joules	1 PG =	petajoule	10^{15} joules
1 GJ =	gigajoule	10^9 joules	1 EJ =	exajoule	10^{18} joules

Tabela VIII.5 – Fatores de Conversão para Energia

Table VIII.5 – Energy Conversion Factors

Multiplicar por ↗ de	para	J	BTU	cal	kWh	tep (toe)	bep (boe)	to ↖ from	*Multiply by*
Joule	(J)	1	$947{,}8 \times 10^{-6}$	0,2388	$277{,}8 \times 10^{-9}$	$2{,}388 \times 10^{-11}$	$1{,}681 \times 10^{-10}$	(J)	*Joule*
Unidade Térmica Britânica	(BTU)	$1{,}055 \times 10^{3}$	1	252	$293{,}07 \times 10^{-6}$	$2{,}52 \times 10^{-8}$	$1{,}776 \times 10^{-7}$	(BTU)	*British Thermal Unit*
Caloria	(cal)	4,1868	$3{,}968 \times 10^{-3}$	1	$1{,}163 \times 10^{-6}$	10^{-10}	$7{,}042 \times 10^{-10}$	(cal)	*calorie*
Quilowatt-hora	(kWh)	$3{,}6 \times 10^{6}$	3412	860×10^{3}	1	$8{,}598 \times 10^{-5}$	$6{,}061 \times 10^{-4}$	(kWh)	*kilowatt-hour*
Tonelada equivalente de petróleo	(tep)	$41{,}868 \times 10^{9}$	$39{,}68 \times 10^{6}$	10^{10}	$11{,}63 \times 10^{3}$	1	7,0369	(toe)	*Tons of oil equivalent*
Barril equivalente de petróleo	(bep)	$5{,}95 \times 10^{9}$	$5{,}63 \times 10^{6}$	$1{,}42 \times 10^{9}$	$1{,}65 \times 10^{3}$	0,1421	1	(boe)	*barrels of oil equivalent*

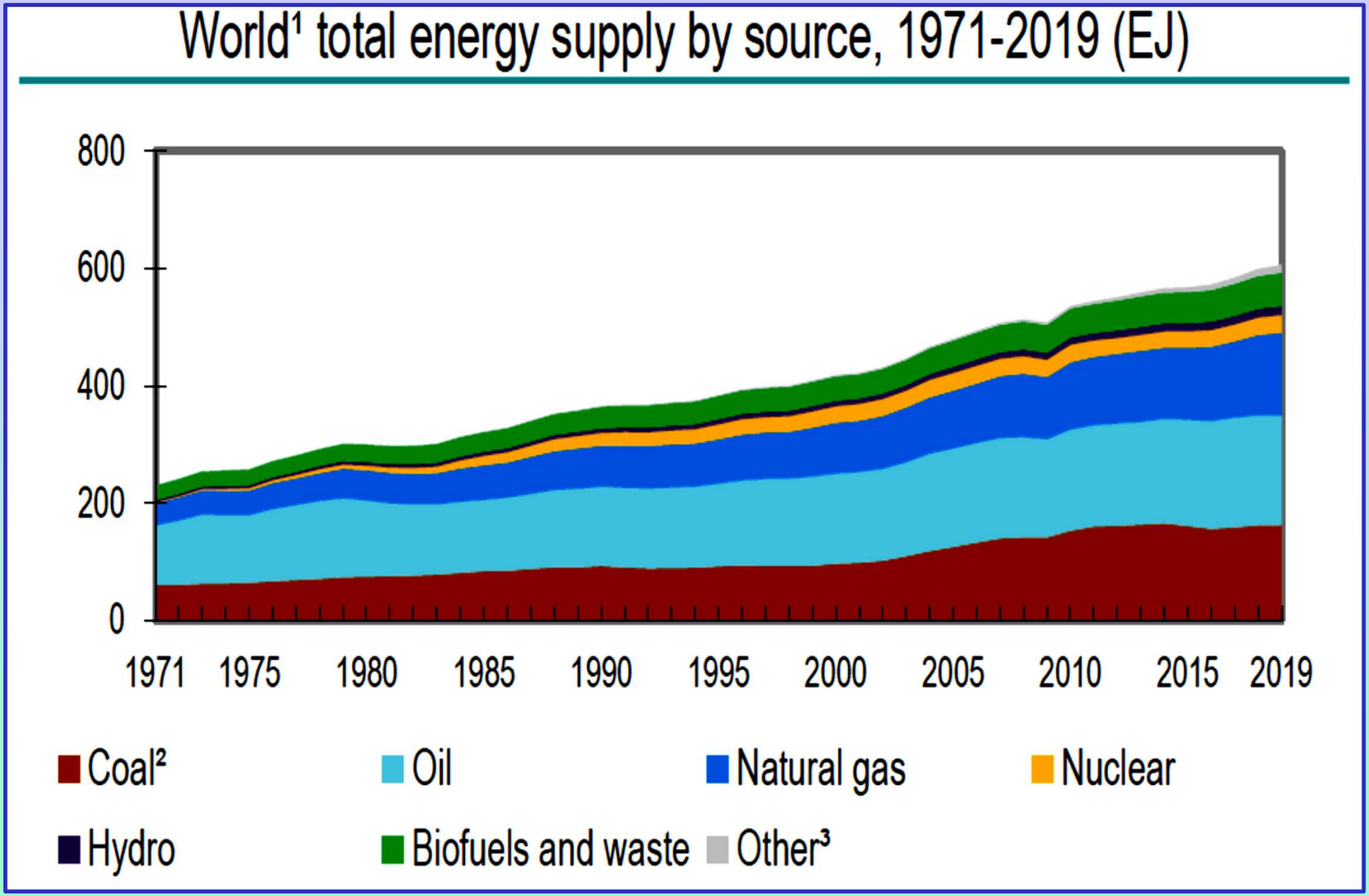
Fonte: MME/EPE. Balanço Energético Nacional - ano-base: 2020, 2021.

General conversion factors for energy

To:	PJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
PJ	1	2.388×10^{5}	2.388×10^{-2}	9.478×10^{5}	2.778×10^{2}
Gcal	4.187×10^{-6}	1	1.000×10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.187×10^{1}	1.000×10^{7}	1	3.968×10^{7}	1.163×10^{4}
MBtu	1.055×10^{-6}	2.520×10^{-1}	2.520×10^{-8}	1	2.931×10^{-4}
GWh	3.600×10^{-3}	8.598×10^{2}	8.598×10^{-5}	3.412×10^{3}	1

Fonte: IEA - Key World Energy Statistics, 2021.

Panorama Mundial

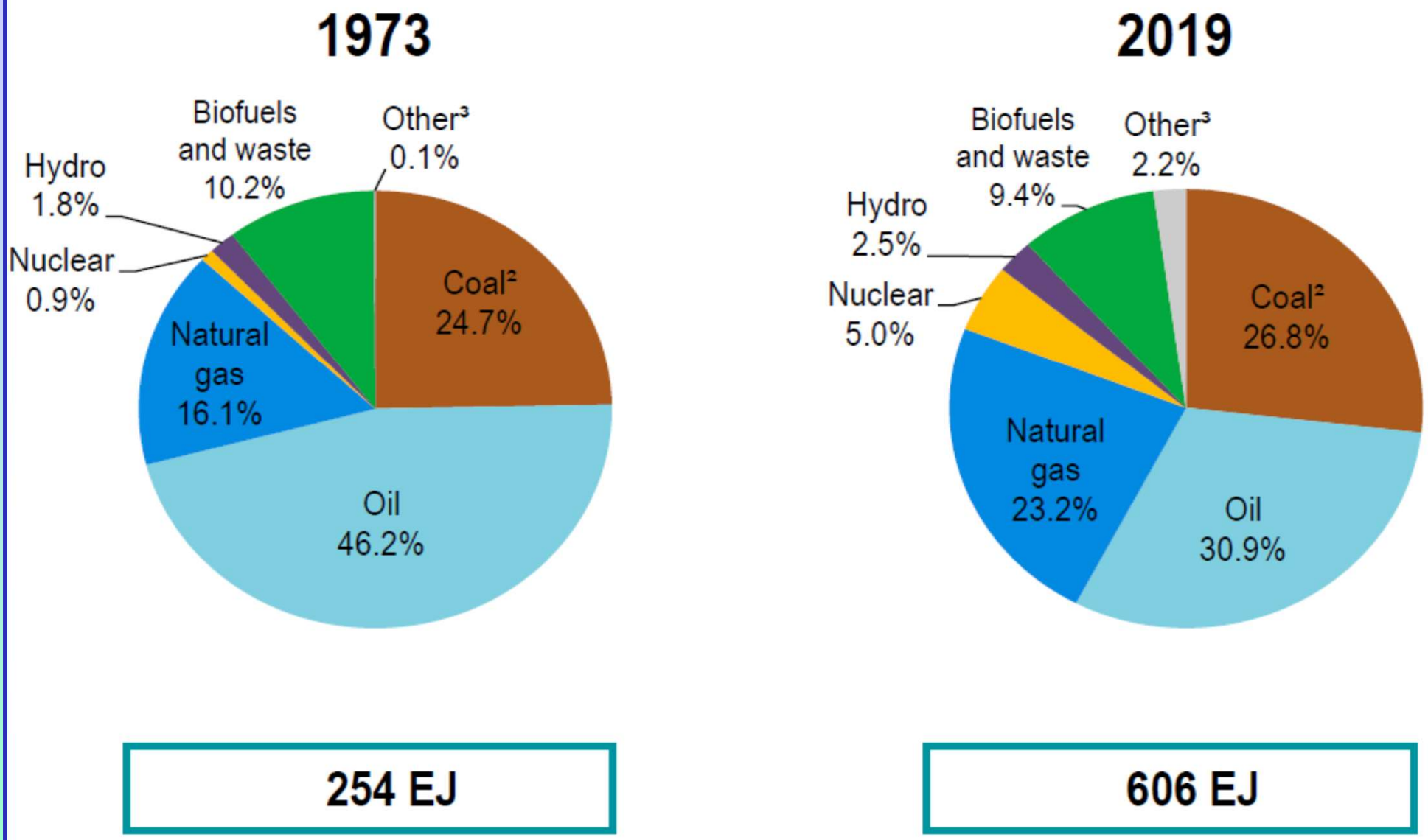


Total Energy Supply (Oferta Total de Energia) valores em EJ: Exajoules (unidade energética)

Obs.: [1] Inclui atividade internacional de navegação e aviação. [2] Inclui turfa e petróleo de folhelho (*peat and oil shale*). [3] Inclui energia geotérmica, solar, eólica (vento), maré/ondas, calor e outras fontes.

Fonte: IEA - Key World Energy Statistics, 2021.

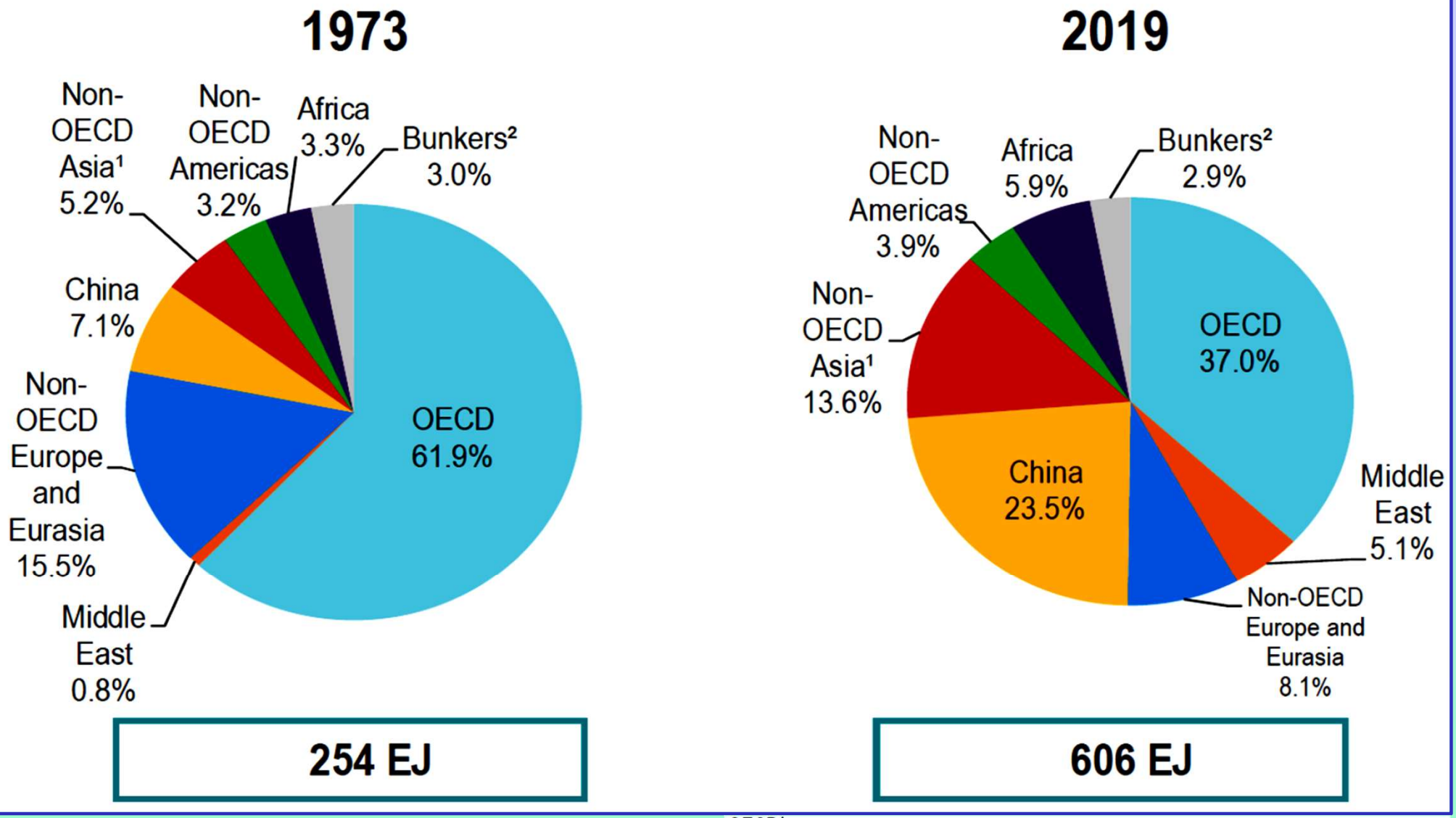
Share of world total energy supply by source, 1973 and 2019



* Outras inclui energia geotérmica, eólica (vento), solar.
TES: Total Energy Supply.
Fonte: IEA - Key World Energy Statistics, 2021.

- **não-renováveis: 85,9%**
- **renováveis: 14,1%**

Share of world total energy supply by region, 1973 and 2019



[1] Asia exclui China

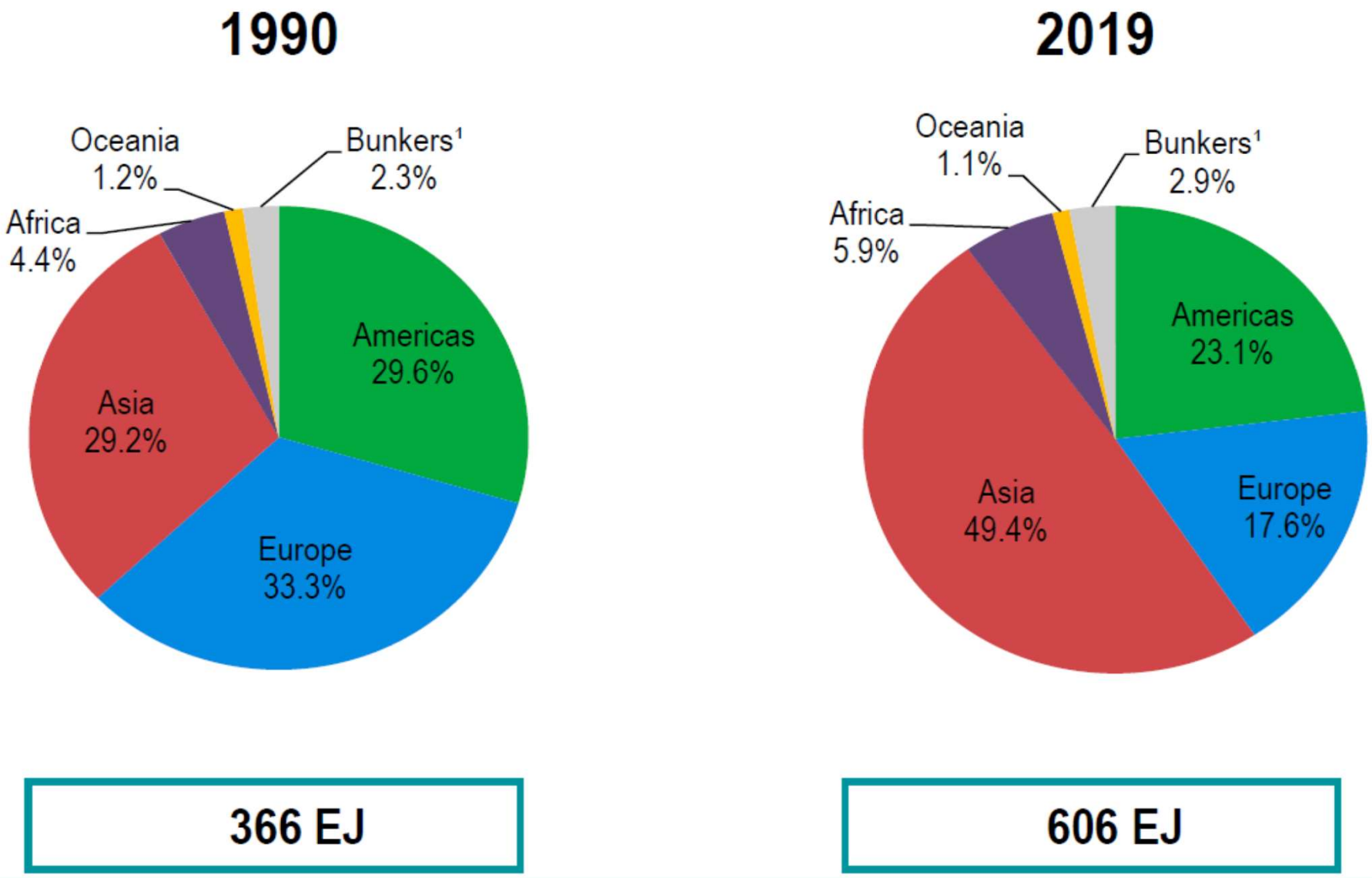
[2] ***Bunkers***: Consumo de combustíveis pela atividade internacional de navegação e aviação.

Fonte: IEA - Key World Energy Statistics, 2021.

OECD[1]

Australia, Austria, Belgium, Canada, Chile, Colombia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel[4], Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

Share of world total energy supply by geographical region, 1990 and 2019

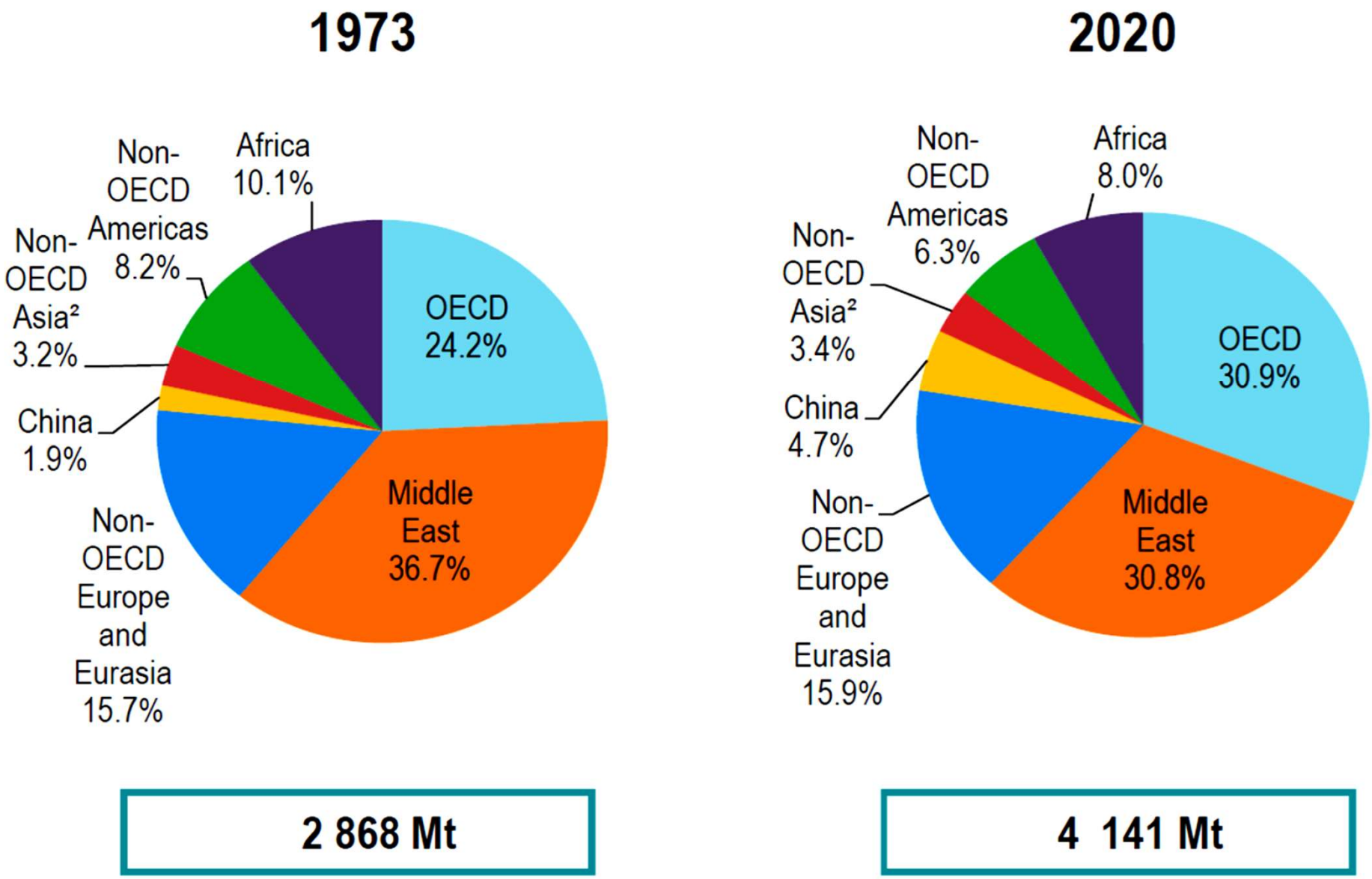


[1] ***Bunkers***: Consumo de combustíveis pela atividade internacional de navegação e aviação.

Fonte: IEA - Key World Energy Statistics, 2021.

Petróleo

Share of world crude oil[1] production by region, 1973 and 2020



2 868 Mt

4 141 Mt

[1] Inclui petróleo bruto, LGN (*NGL: natural gas liquids*), matérias-primas (*feedstocks*), aditivos e outros hidrocarbonetos líquidos

[2] Exclui a China e outros países da OECD asiáticos.

Fonte: IEA - Key World Energy Statistics, 2021.

Principais países produtores de petróleo bruto

Producers	Mt	% of World total
Saudi Arabia	507	12.9
Russia	477	12.1
United States	310	7.9
Islamic Rep. of Iran	216	5.5
People's Rep. of China	184	4.7
Mexico	183	4.6
Canada	151	3.8
Venezuela	151	3.8
Kuwait	139	3.5
United Arab Emirates	134	3.4
Rest of the World	1 484	37.8
World	**3 936**	**100.0**

2006 data

Producers	Mt	% of world total
Russian Federation	502	12.6
Saudi Arabia	471	11.9
United States	336	8.5
Islamic Rep. of Iran	227	5.7
People's Rep. of China	200	5.0
Canada	159	4.0
Venezuela	149	3.8
Mexico	144	3.6
Nigeria	130	3.3
United Arab Emirates	129	3.2
Rest of the world	1 526	38.4
World	**3 973**	**100.0**

2010 data

Producers	Mt	% of world total
United States	706	17.0
Russian Federation	512	12.4
Saudi Arabia	511	12.3
Canada	255	6.2
Iraq	201	4.9
People's Rep. of China	195	4.7
United Arab Emirates	174	4.2
Brazil	153	3.7
Kuwait	131	3.2
Islamic Rep. of Iran	130	3.1
Rest of the world	1 173	28.3
World	**4 141**	**100.0**

2020 provisional data

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

Produção de Petróleo Bruto
Tendência: 2006-2010-2020

Principais países exportadores de petróleo bruto

Exporters	Mt
Saudi Arabia	364
Russia	253
Islamic Rep. of Iran	132
Nigeria	119
Norway	115
Mexico	100
Venezuela	97
United Arab Emirates	97
Kuwait	84
Canada	84
Rest of the World	733
World	**2 178**

2005 data

Net exporters	Mt
Saudi Arabia	313
Russian Federation	247
Islamic Rep. of Iran	124
Nigeria	114
United Arab Emirates	100
Iraq	94
Angola	89
Norway	87
Venezuela	85
Kuwait	68
Others	574
Total	**1 895**

2009 data

Net exporters	Mt
Saudi Arabia	352
Russian Federation	269
Iraq	195
Canada	154
United Arab Emirates	148
Kuwait	102
Nigeria	99
Kazakhstan	70
Angola	63
Mexico	59
Others	531
Total	**2 042**

2019 data

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

Exportação de Petróleo Bruto
Tendência: 2005-2009-2019

Principais países importadores de petróleo bruto

Importers	Mt
United States	582
Japan	213
People's Rep. of China	127
Korea	115
Germany	112
India	99
Italy	95
France	84
Netherlands	62
Spain	60
Rest of the World	709
World	**2 258**

2005 data

Net importers	Mt
United States	510
People's Rep. of China	199
Japan	179
India	159
Korea	115
Germany	98
Italy	80
France	72
Netherlands	57
Spain	56
Others	477
Total	**2 002**

2009 data

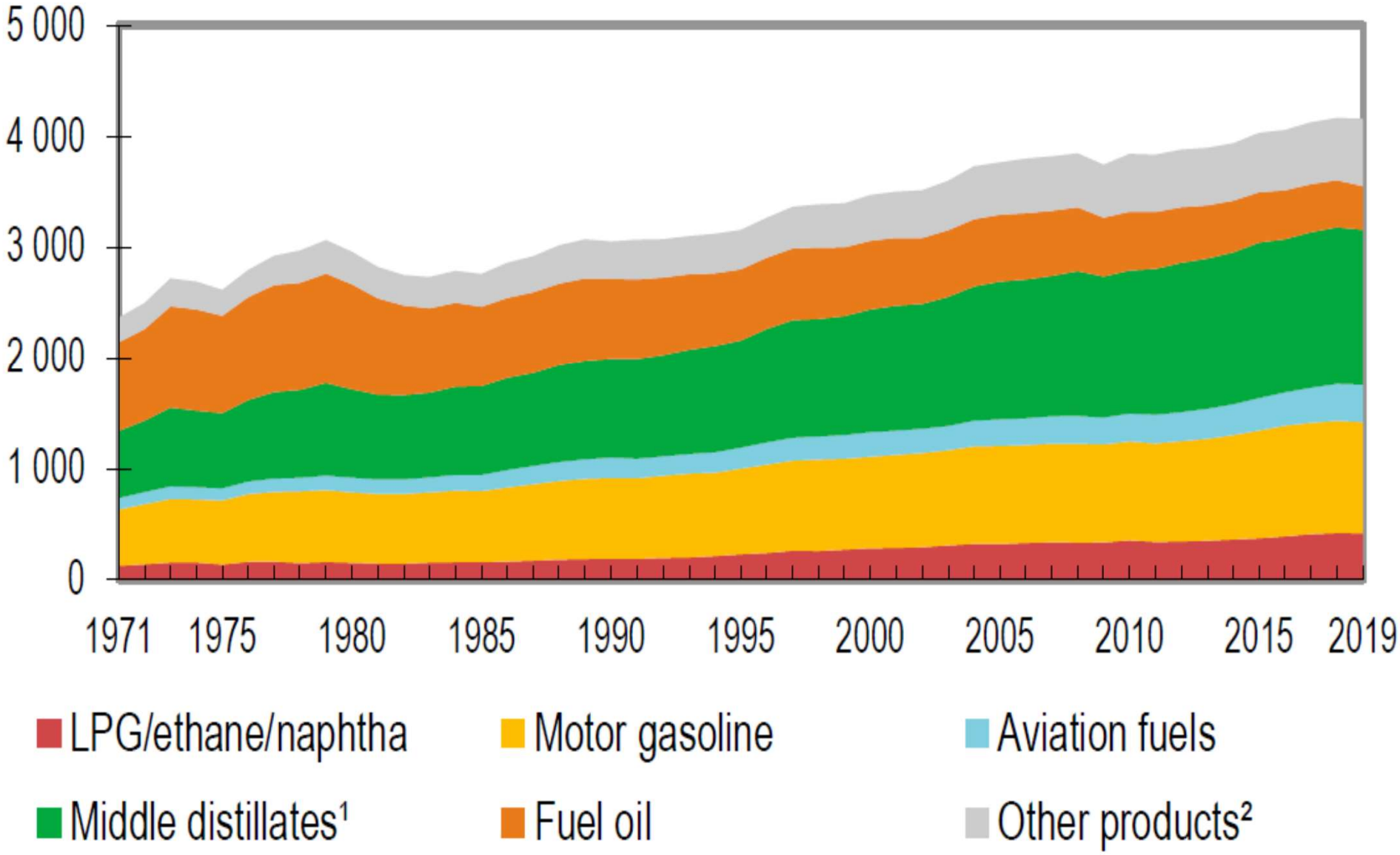
Net importers	Mt
People's Rep. of China	505
India	227
United States	202
Japan	149
Korea	145
Germany	86
Spain	66
Italy	65
Netherlands	62
Singapore	53
Others	509
Total	**2 069**

2019 data

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

Importação de Petróleo Bruto
Tendência: 2005-2009-2019

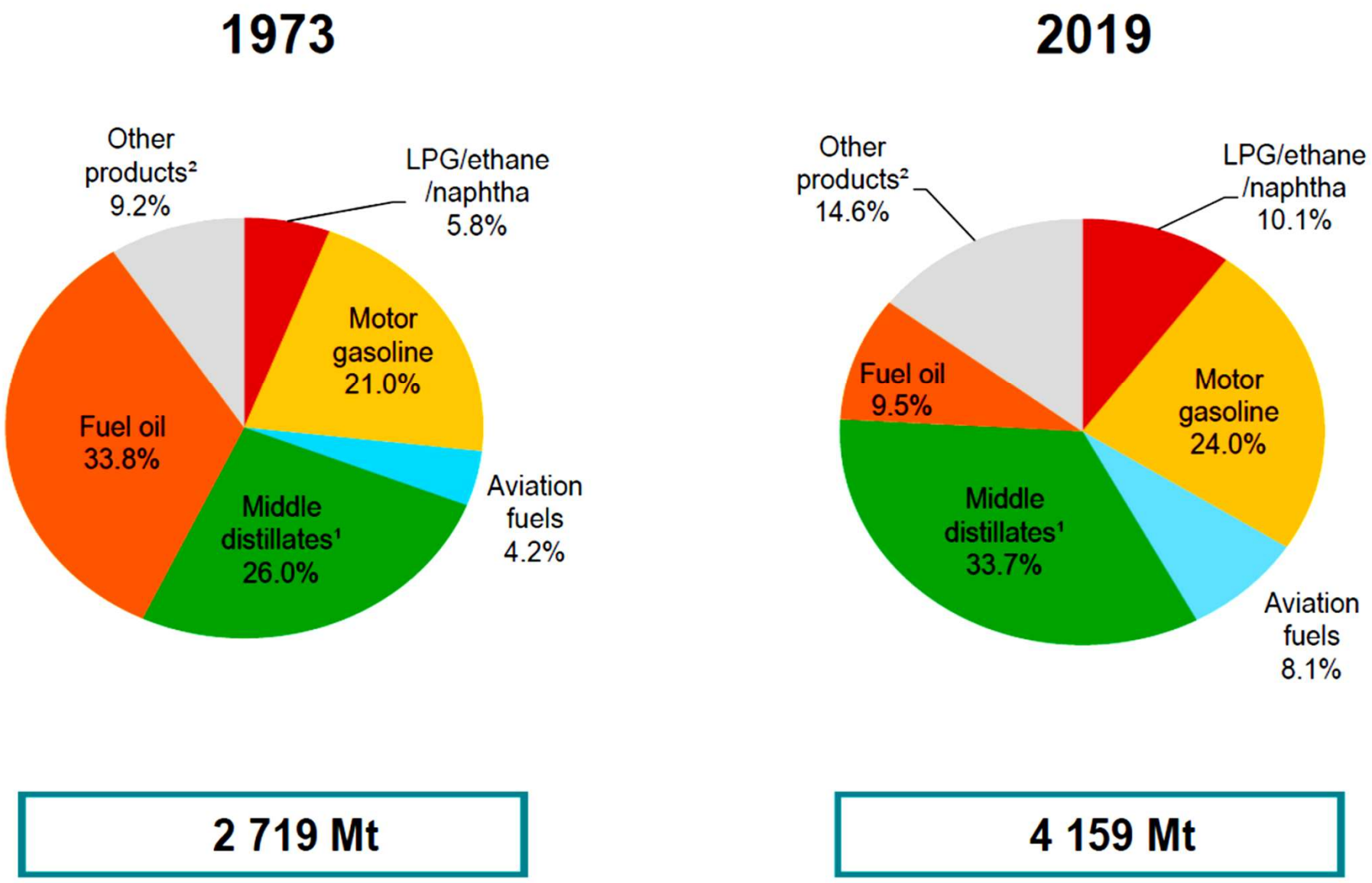
World refinery output by product, 1971-2019 (Mt)



Obs: Middle distillates: querosene (para aquecimento) e óleo diesel

Fonte: IEA - Key World Energy Statistics, 2021.

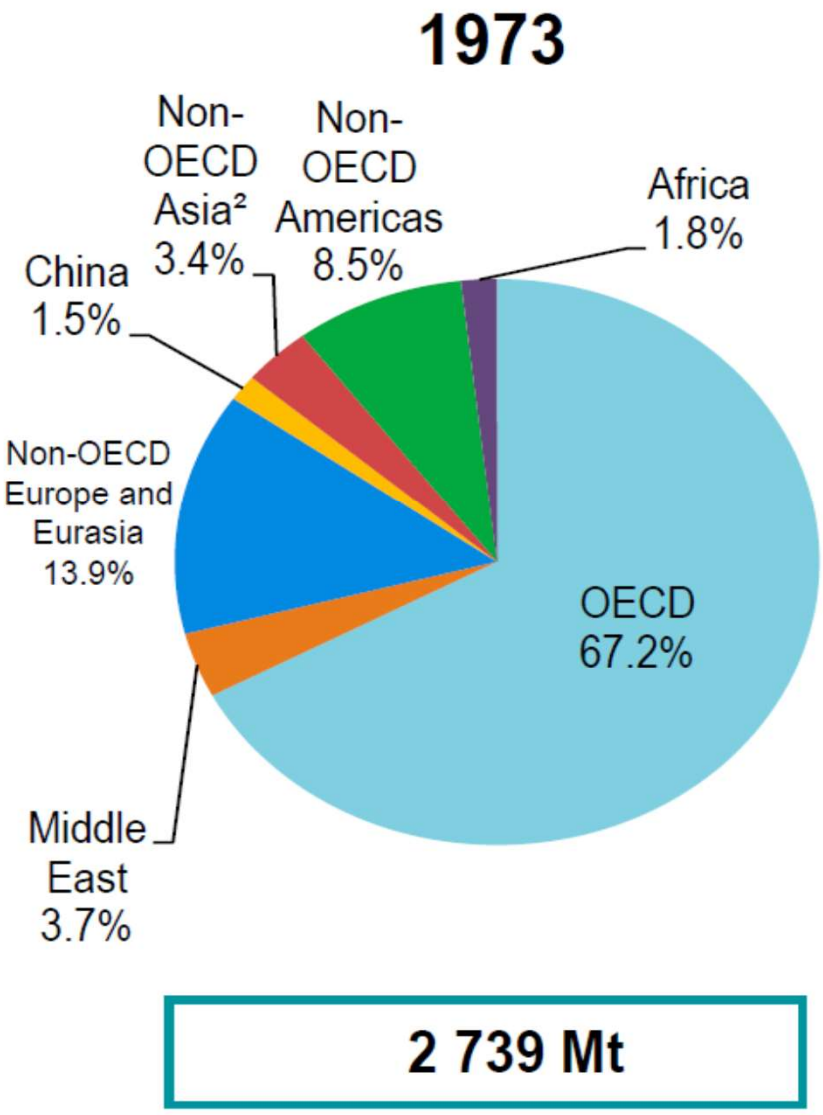
Share of world refinery output by product, 1973 and 2019

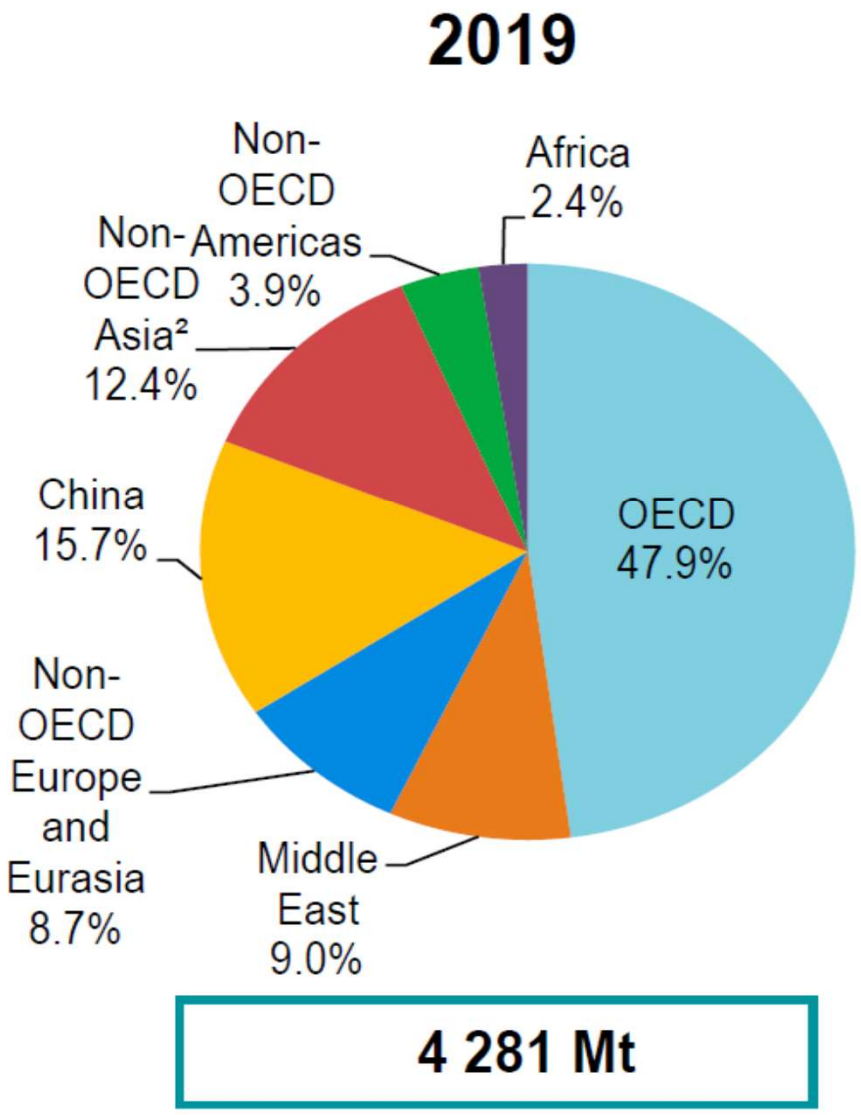


[1] Inclui petróleo bruto, LGN, matérias-primas (*feedstocks*), aditivos e outros hidrocarbonetos líquidos.
[2] Exclui a China e outros países da OECD asiáticos.

Fonte: IEA - Key World Energy Statistics, 2021.

Share of world refinery intake[1] by region, 1973 and 2019





[1] Inclui petróleo bruto, LGN, matérias-primas (*feedstocks*), aditivos e outros hidrocarbonetos líquidos.
[2] Exclui a China e outros países da OECD asiáticos.

Fonte: IEA - Key World Energy Statistics, 2021.

Principais países por capacidade de refino de petróleo

Crude Distillation Capacity	kb/cd	% of World total
United States	17 287	20.1
Former USSR	7 740	9.0
People's Rep. of China**	7 200	8.4
Japan	4 670	5.4
India	2 980	3.5
Korea	2 580	3.0
Germany	2 430	2.8
Italy	2 320	2.7
Saudi Arabia	2 100	2.4
Canada	2 020	2.3
Rest of the World	34 765	40.4
World	**86 092**	**100.0**

2006 data

Crude distillation capacity	kb/cd	% of world total
United States	17 515	18.8
People's Rep. of China**	9 890	10.6
Russian Federation	5 291	5.7
Japan	4 692	5.0
India	4 003	4.3
Korea	3 003	3.2
Germany	2 392	2.6
Italy	2 277	2.4
Saudi Arabia	2 098	2.3
Brazil	1 981	2.1
Rest of the world	39 938	42.9
World	**93 081**	**100.0**

2010 data

Crude distillation capacity	kb/cd	% of world total
United States	18 384	18.0
People's Rep. of China	17 045	16.7
Russian Federation	6 819	6.7
India	5 308	5.2
Korea	3 525	3.5
Japan	3 443	3.4
Saudi Arabia	3 249	3.2
Brazil	2 229	2.2
Islamic Rep. of Iran	2 193	2.1
Germany	2 022	2.0
Rest of the world	37 875	37.0
World	**102 092**	**100.0**

2020 data

kb/cd: thousand barrels per calendar day

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

Capacidade de Refino de Petróleo
Tendência: 2006-2010-2020

Principais países produtores de derivados de petróleo

Producers	Mt	% of World total
United States	837	22.2
People's Rep. of China	279	7.4
Japan	205	5.4
Russia	203	5.4
India	129	3.4
Germany	123	3.3
Korea	120	3.2
Canada	102	2.7
Italy	101	2.7
Saudi Arabia	99	2.6
Rest of the World	1 575	41.7
World	**3 773**	**100.0**

2005 data

Producers	Mt	% of world total
United States	807	21.4
People's Rep. of China	355	9.4
Russian Federation	232	6.1
India	186	4.9
Japan	179	4.7
Korea	116	3.1
Germany	108	2.9
Canada	96	2.5
Brazil	96	2.5
Saudi Arabia	94	2.5
Rest of the world	1 510	40.0
World	**3 779**	**100.0**

2009 data

Producers	Mt	% of world total
United States	833	20.0
People's Rep. of China	635	15.3
Russian Federation	280	6.7
India	263	6.3
Korea	158	3.8
Japan	147	3.5
Saudi Arabia	124	3.0
Canada	99	2.4
Germany	98	2.4
Brazil	91	2.2
Rest of the world	1 431	34.4
World	**4 159**	**100.0**

2019 data

Produção de Derivados de Petróleo
Tendência: 2005-2009-2018

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2020.

Principais países exportadores de derivados de petróleo

Exporters	Mt
Russia	84
Netherlands	76
Saudi Arabia	62
United States	58
Singapore	57
Korea	35
Venezuela	34
Kuwait	30
United Kingdom	30
Italy	28
Rest of the World	458
World	**952**

2005 data

Net exporters	Mt
Russian Federation	102
Saudi Arabia	50
India	36
Venezuela	33
Kuwait	28
United States	19
Algeria	16
Belarus	13
Korea	13
Italy	12
Others	139
Total*	**461**

2009 data

Net exporters	Mt
United States	139
Russian Federation	129
Saudi Arabia	63
Korea	28
India	25
Kuwait	24
Islamic Rep. of Iran	22
Netherlands	21
United Arab Emirates	20
Algeria	18
Others	149
Total[1]	**638**

2019 data

Exportação de derivados de Petróleo
Tendência: 2005-2009-2020

Fonte: IEA - Key World Energy Statistics, 2007; 2011, 2021.

Principais países importadores de derivados de petróleo

Importers	Mt
United States	116
Netherlands	64
Japan	49
Singapore	49
People's Rep. of China	41
France	37
Germany	35
Spain	28
United Kingdom	23
Indonesia	21
Rest of the World	414
World	**877**

2005 data

Net importers	Mt
Japan	23
People's Rep. of China	20
Hong Kong (China)	19
France	16
Spain	15
Australia	14
Mexico	13
Indonesia	13
Turkey	13
Vietnam	13
Others	196
Total*	**355**

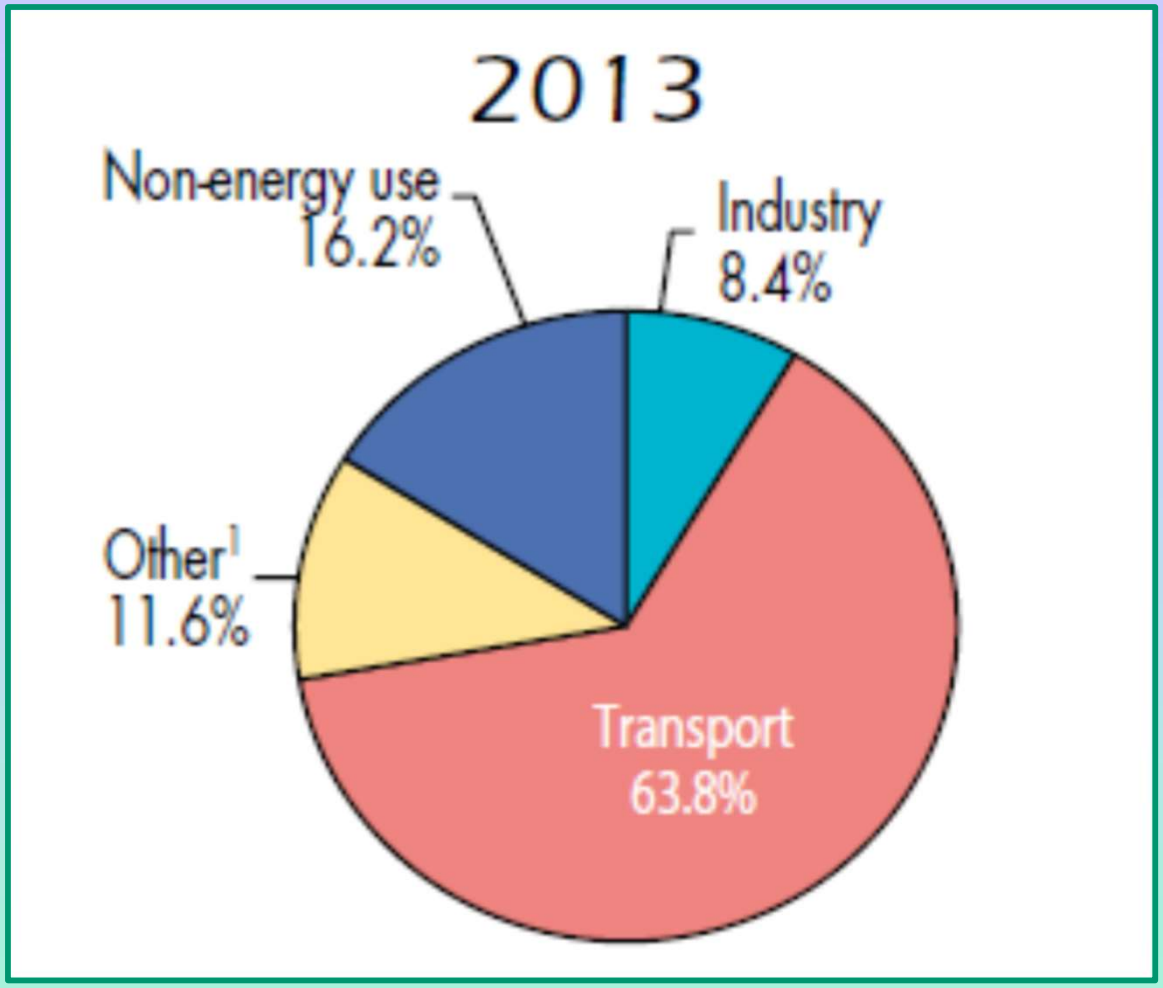
2009 data

Net importers	Mt
Mexico	47
France	28
Australia	27
Singapore	27
Nigeria	21
Japan	21
Germany	20
Hong Kong, China	20
Indonesia	20
Brazil	19
Others	306
Total[1]	**556**

2019 data

Importação de Derivados de Petróleo
Tendência: 2005-2009-2019

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

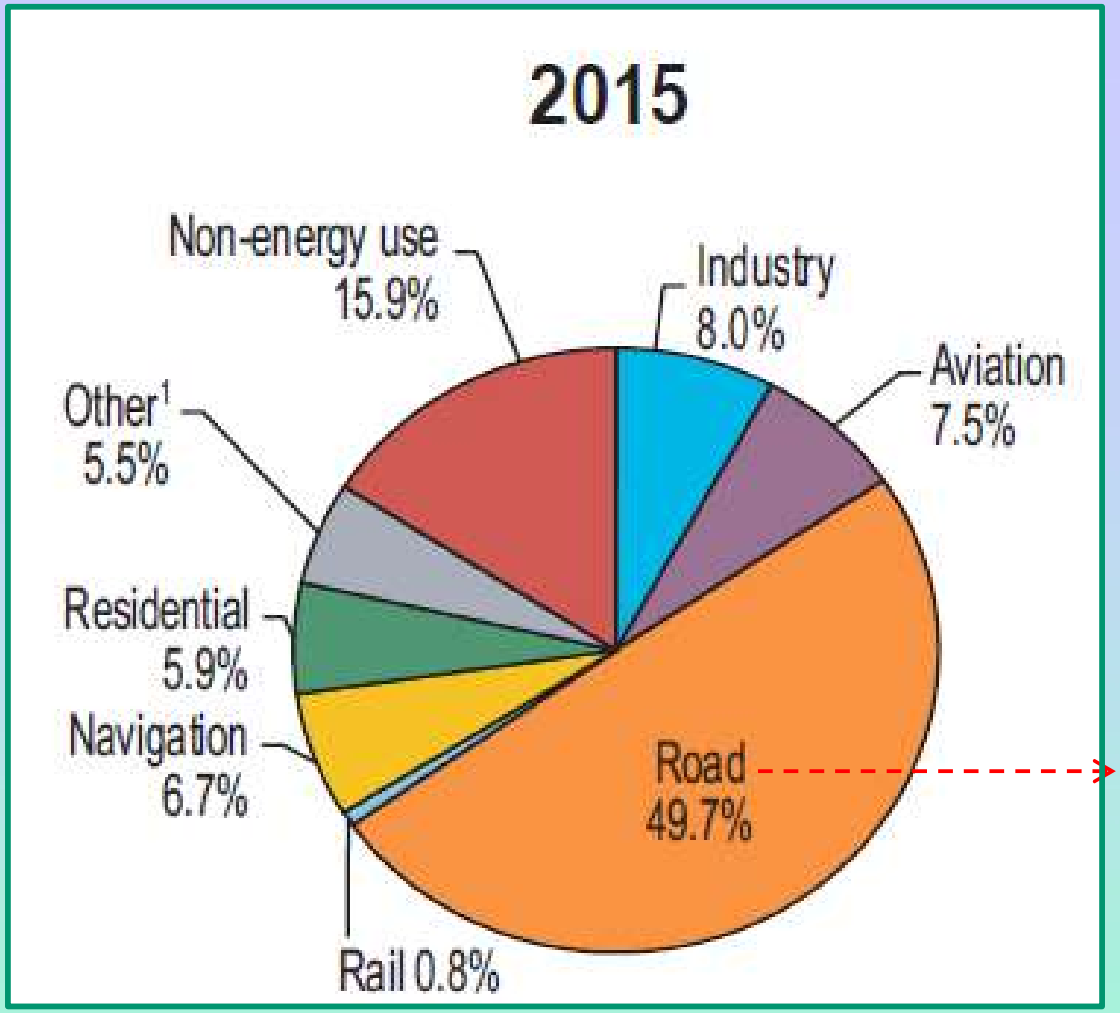


[1] Outros inclui agricultura, residencial, comércio e serviços públicos.

Distribuição do consumo de petróleo no mundo em 2013.
Fonte: IEA-Key World Energy Statistics, 2015.

Observa-se que a principal atividade de consumo de petróleo é o transporte, com 63,8%.
Este consumo se verifica basicamente em dois de seus derivados: **a gasolina e o óleo diesel**.

OBS: O mundo consumiu em 2013 91,2 milhões de barris por dia, ou cerca de 33,3 bilhões de barris/ano.

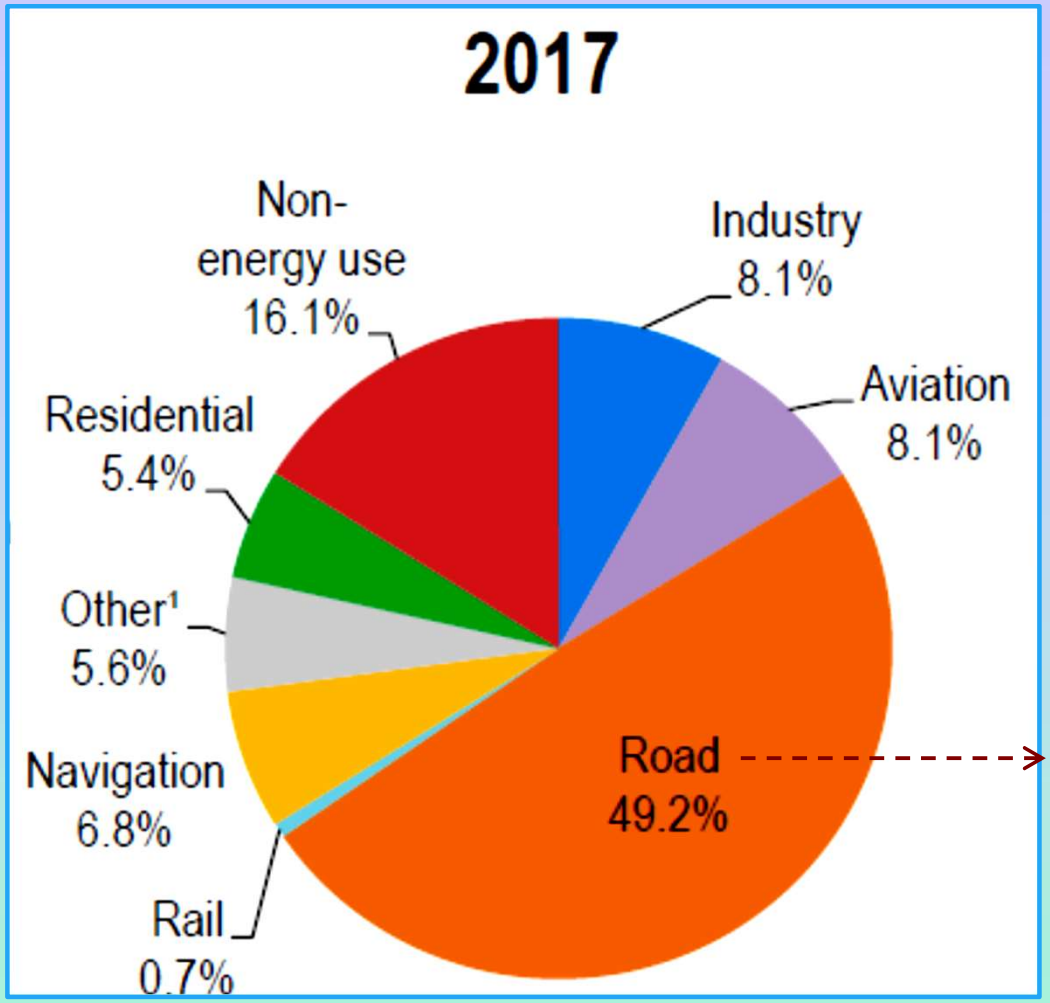


[1] Outros inclui agricultura, comércio e serviços públicos.

Distribuição do consumo de petróleo no mundo em 2015.
Fonte: IEA-Key World Energy Statistics, 2017.

Observa-se que a principal atividade de consumo de petróleo é o transporte, com 64,7%.

OBS: O mundo consumiu em 2016 96,5 milhões de barris por dia, ou cerca de 35,2 bilhões de barris/ano.

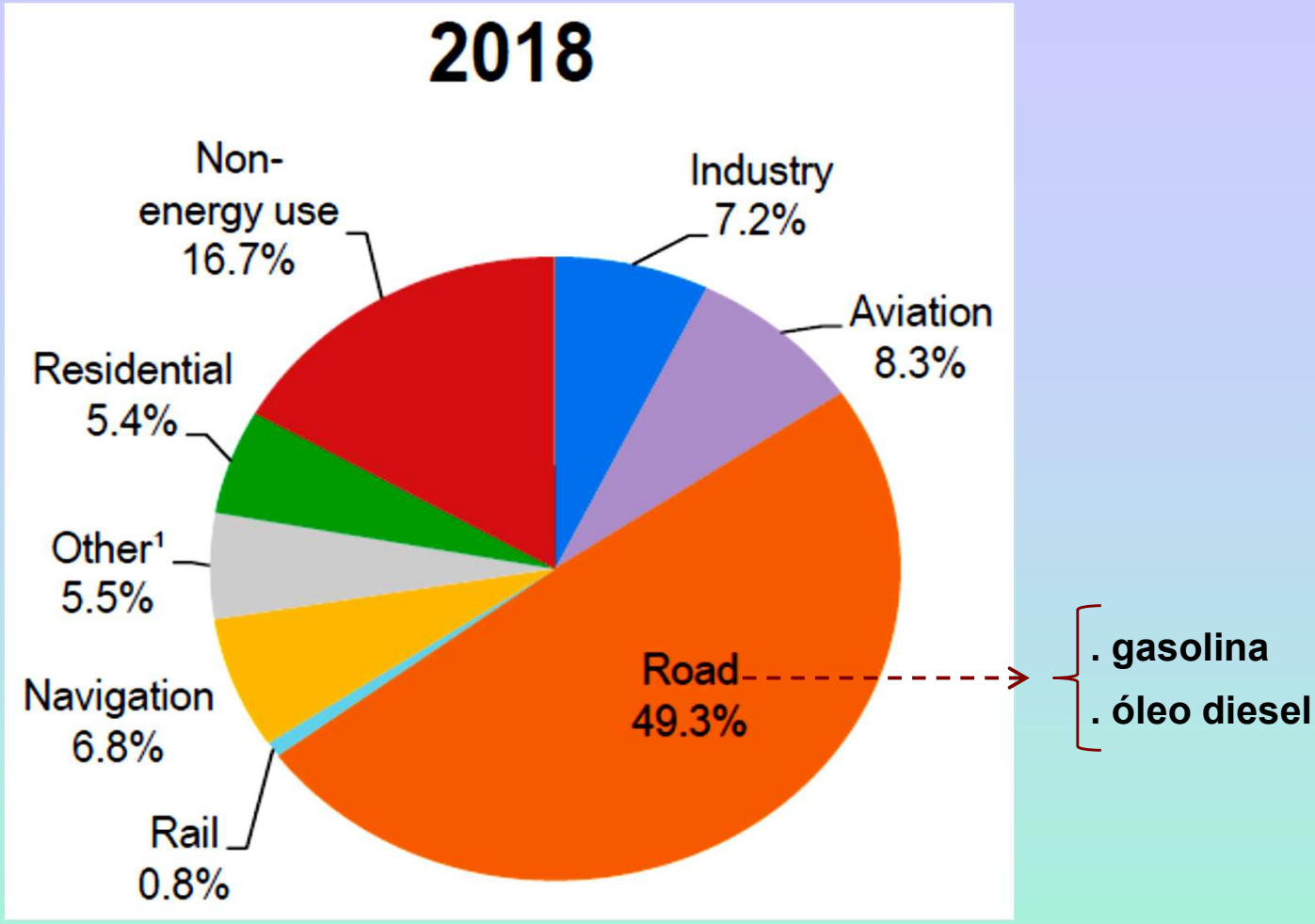


[1] Outros inclui agricultura, comércio e serviços públicos.

Distribuição do consumo de petróleo no mundo em 2017.
Fonte: IEA-Key World Energy Statistics, 2019.

Observa-se que a principal atividade de consumo de petróleo é o transporte, com 64,8%.

OBS: O mundo consumiu em 2017 98,2 milhões de barris por dia, ou cerca de 35,8 bilhões de barris/ano.

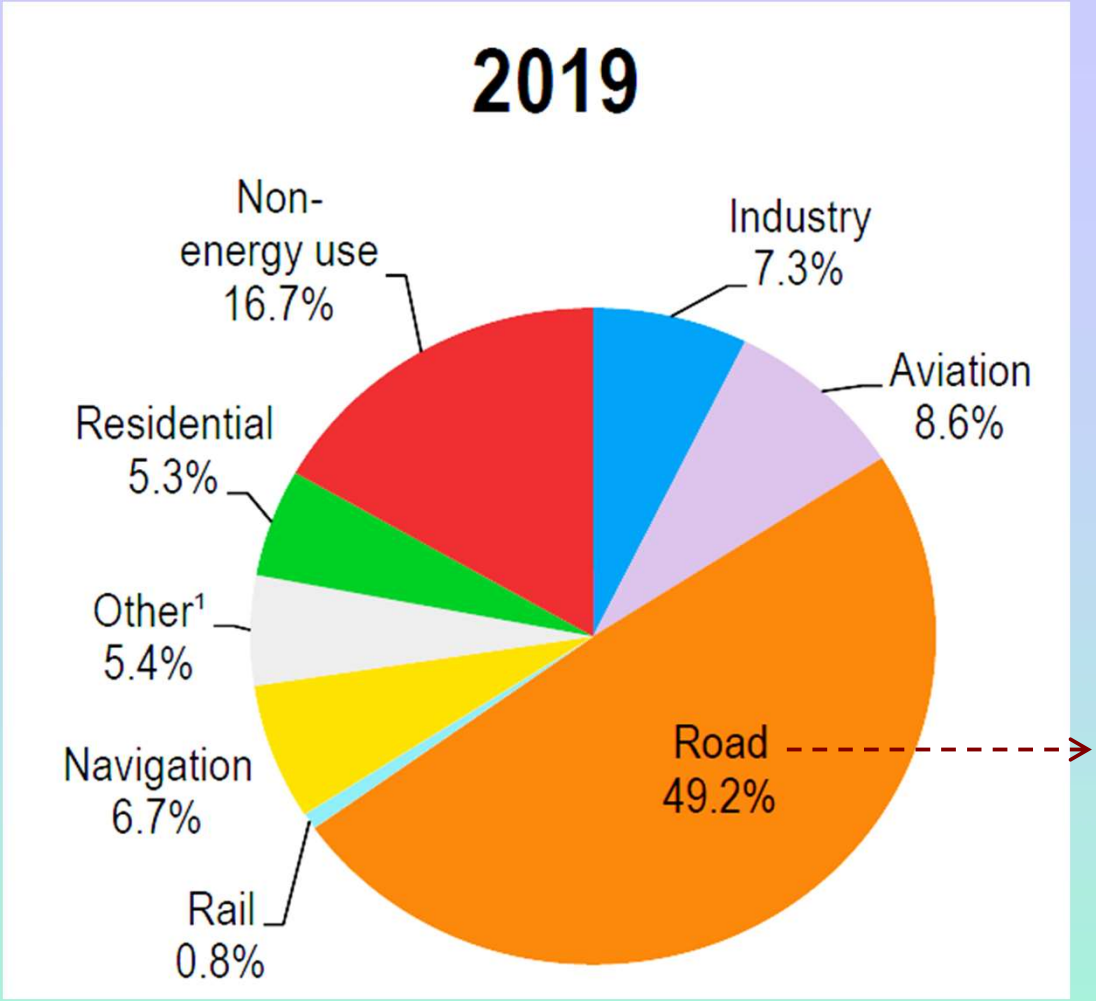


[1] Outros inclui agricultura, comércio e serviços públicos.

Distribuição do consumo de petróleo no mundo em 2018.
Fonte: IEA-Key World Energy Statistics, 2020.

Observa-se que a principal atividade de consumo de petróleo é o transporte, com 65,2%.

OBS: O mundo consumiu em 2018 99,8 milhões de barris por dia, ou cerca de 36,4 bilhões de barris/ano.



[1] Outros inclui agricultura, comércio e serviços públicos.

Distribuição do consumo de petróleo no mundo em 2019.
Fonte: IEA-Key World Energy Statistics, 2020.

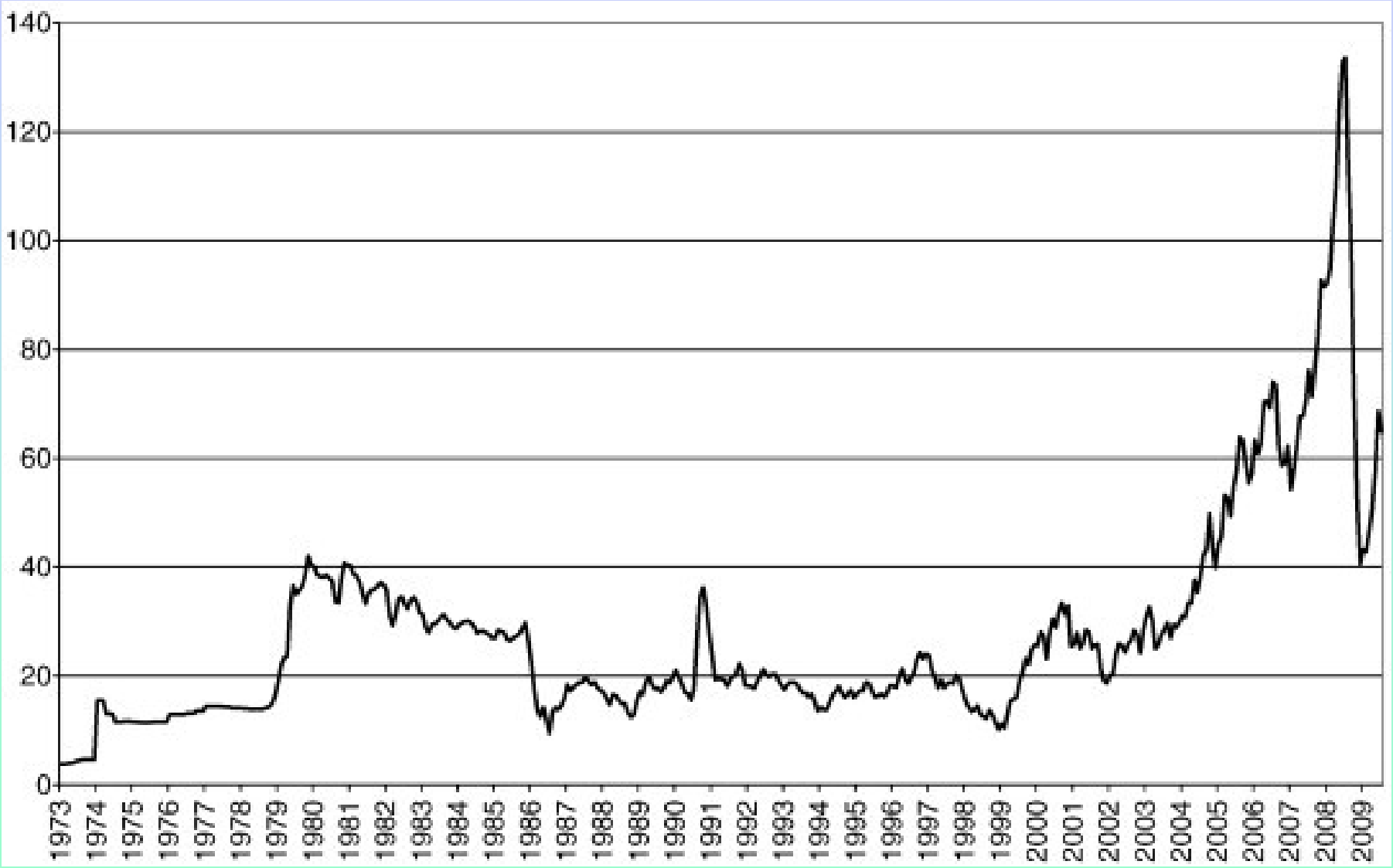
Observa-se que a principal atividade de consumo de petróleo é o transporte, com 65,2%.

OBS: O mundo consumiu em 2019 98,3 milhões de barris por dia, ou cerca de 35,9 bilhões de barris/ano.

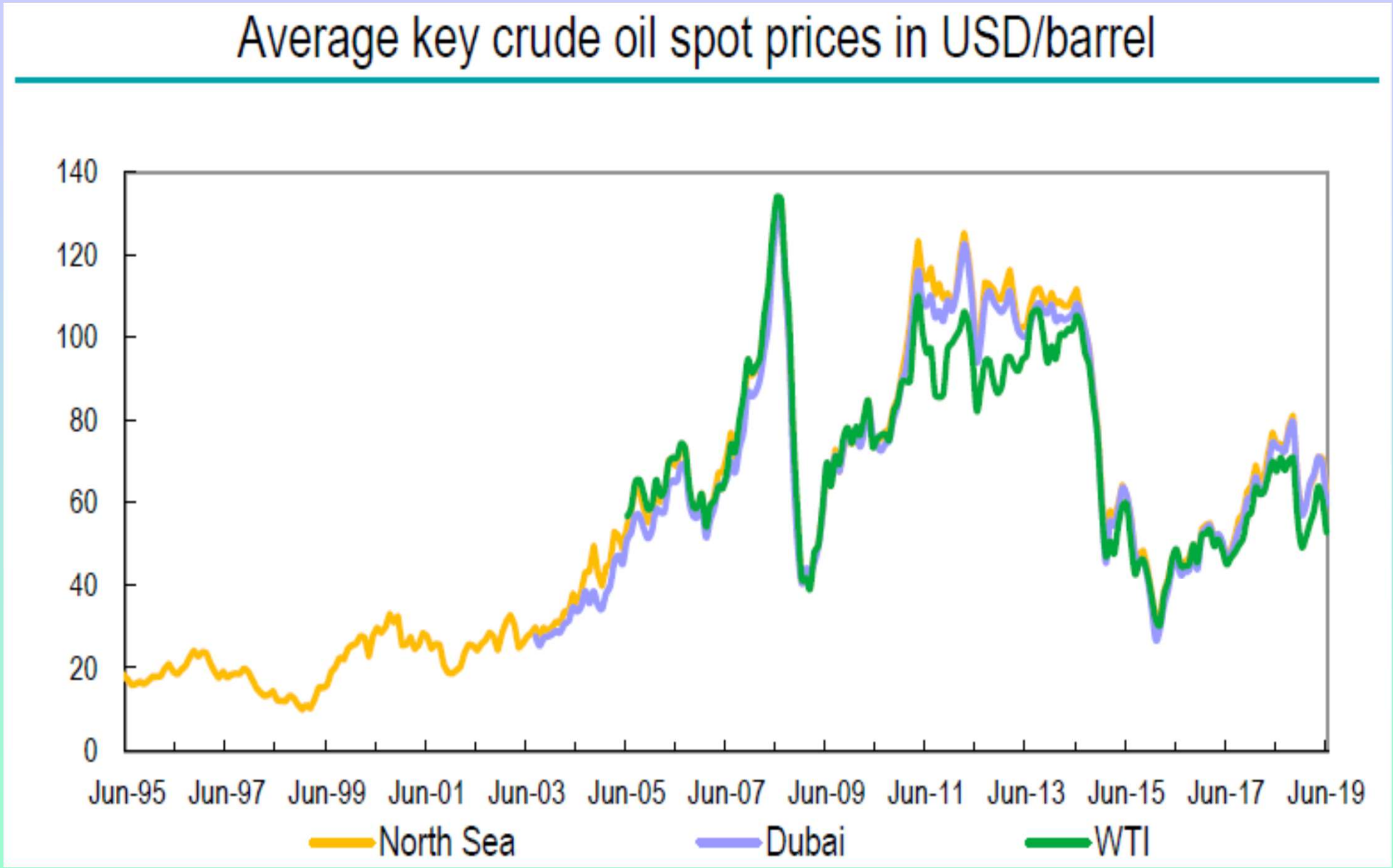
(2020: estimativa de redução de -9,3 milhões de b/d em relação a 2019: 98,3 mbd)

Evolução dos preços do petróleo (em dólares correntes)

(US dollars per barrel)



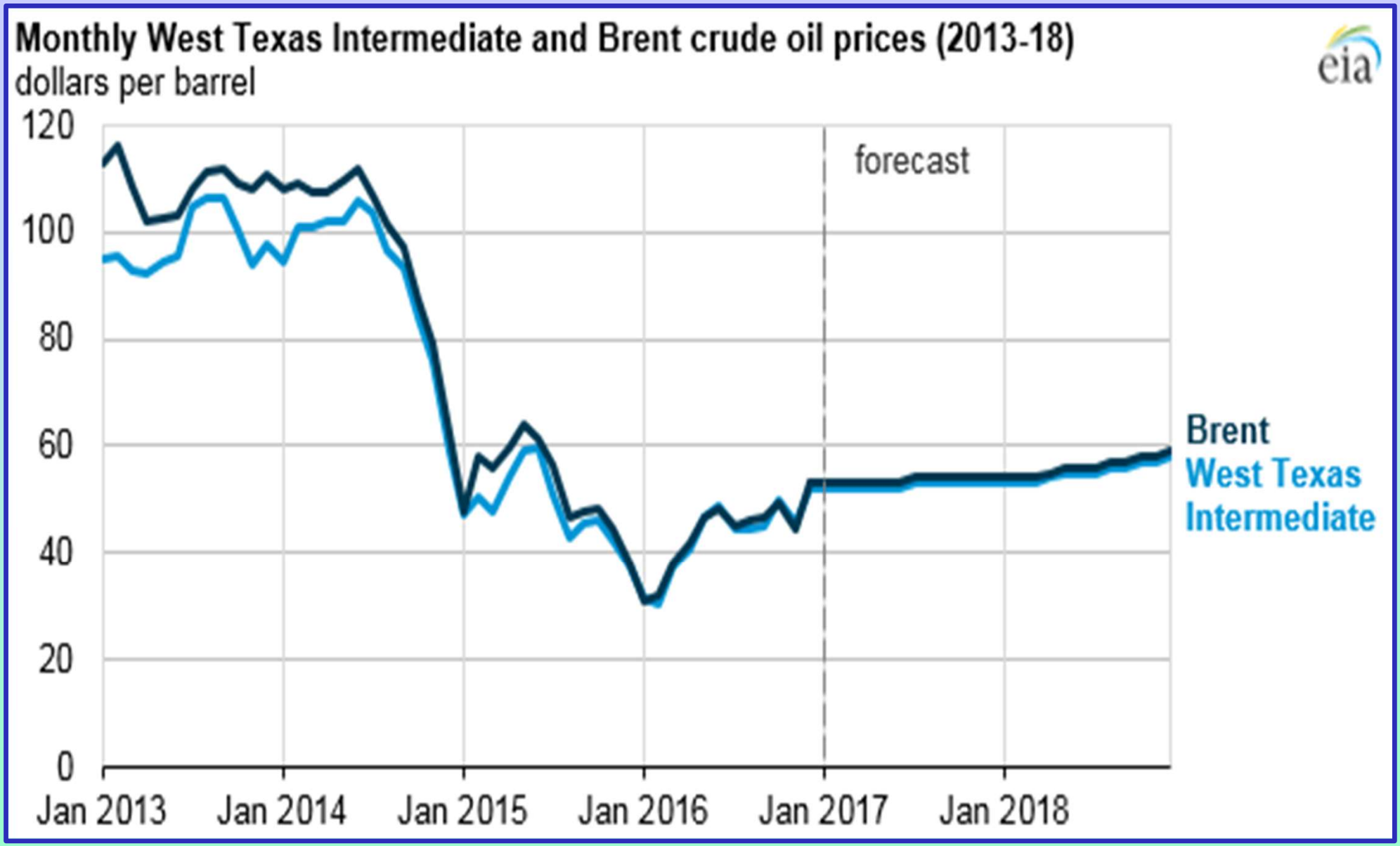
Fonte: Brémond, V.; Hache, E.; Mignon, V. “Does OPEC still exist as a cartel? An empirical investigation”. In: Energie Economics, vol.31, January 2012, pp.125-131



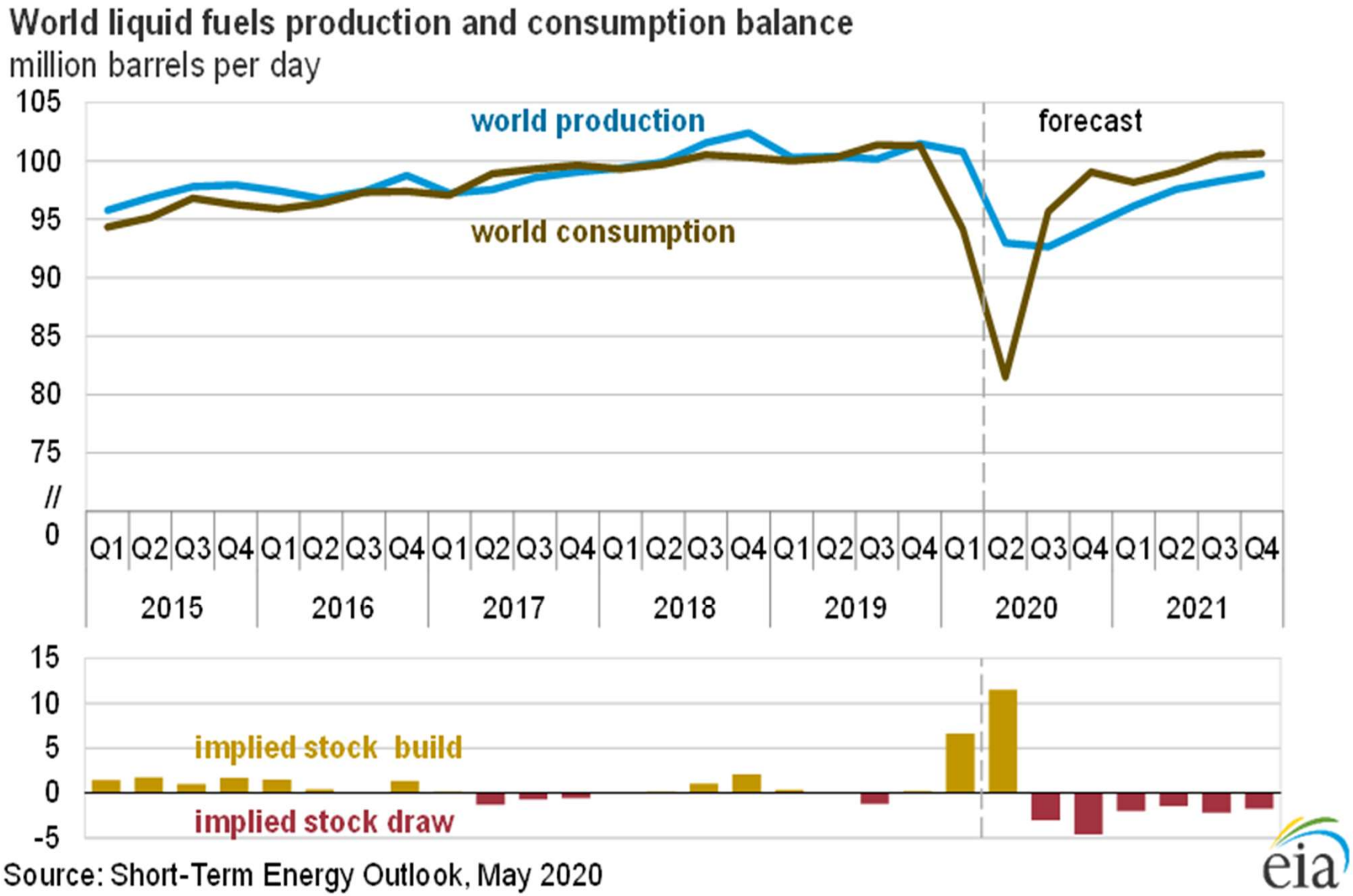
Fonte: IEA - Key World Energy Statistics, 2019.

West Texas Intermediate

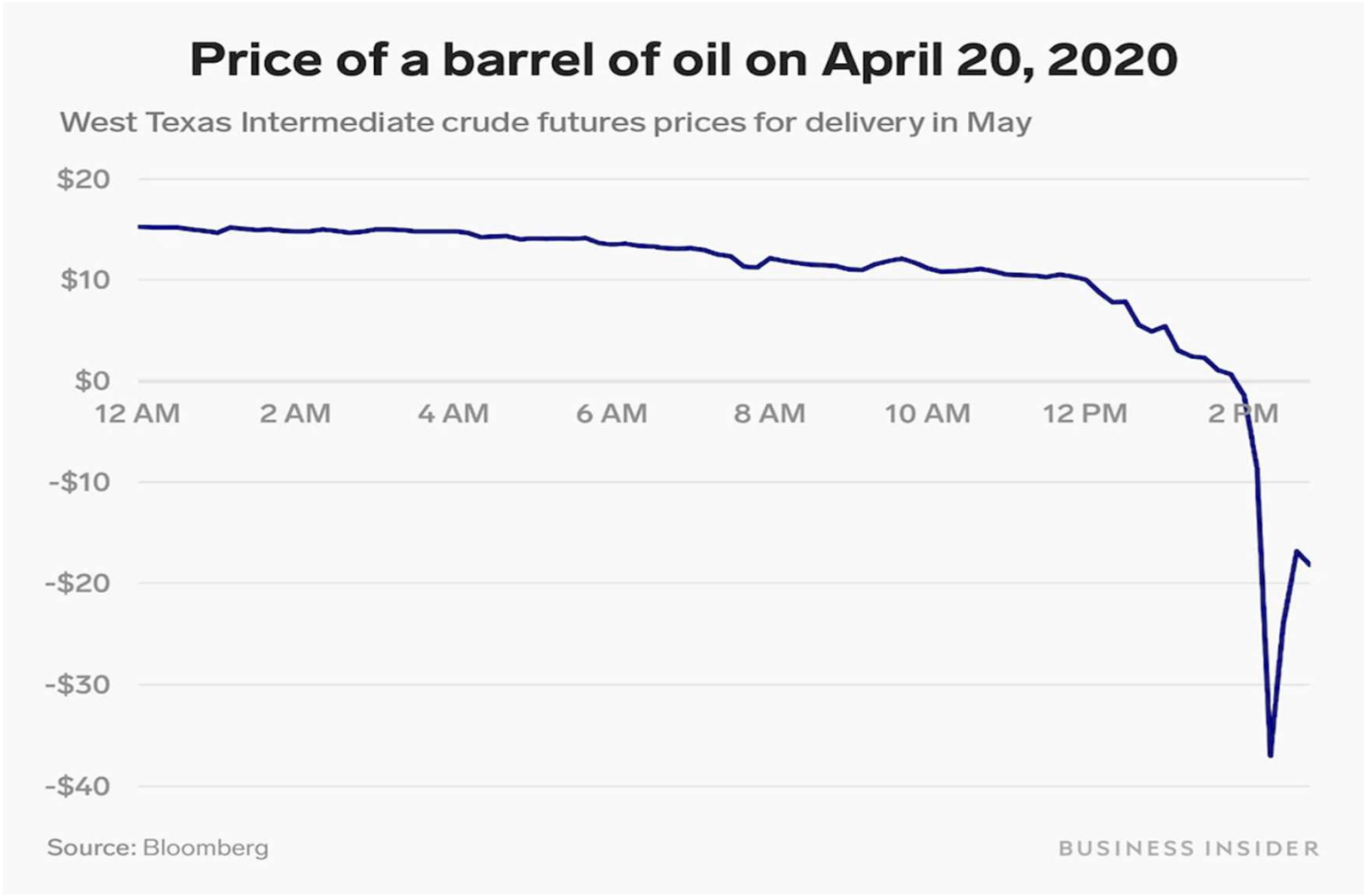
Monthly WTI and Brent crude prices (2013-18), from eia.gov.



Fonte: https://www.eia.gov/todayinenergy/detail.php?id=29532.

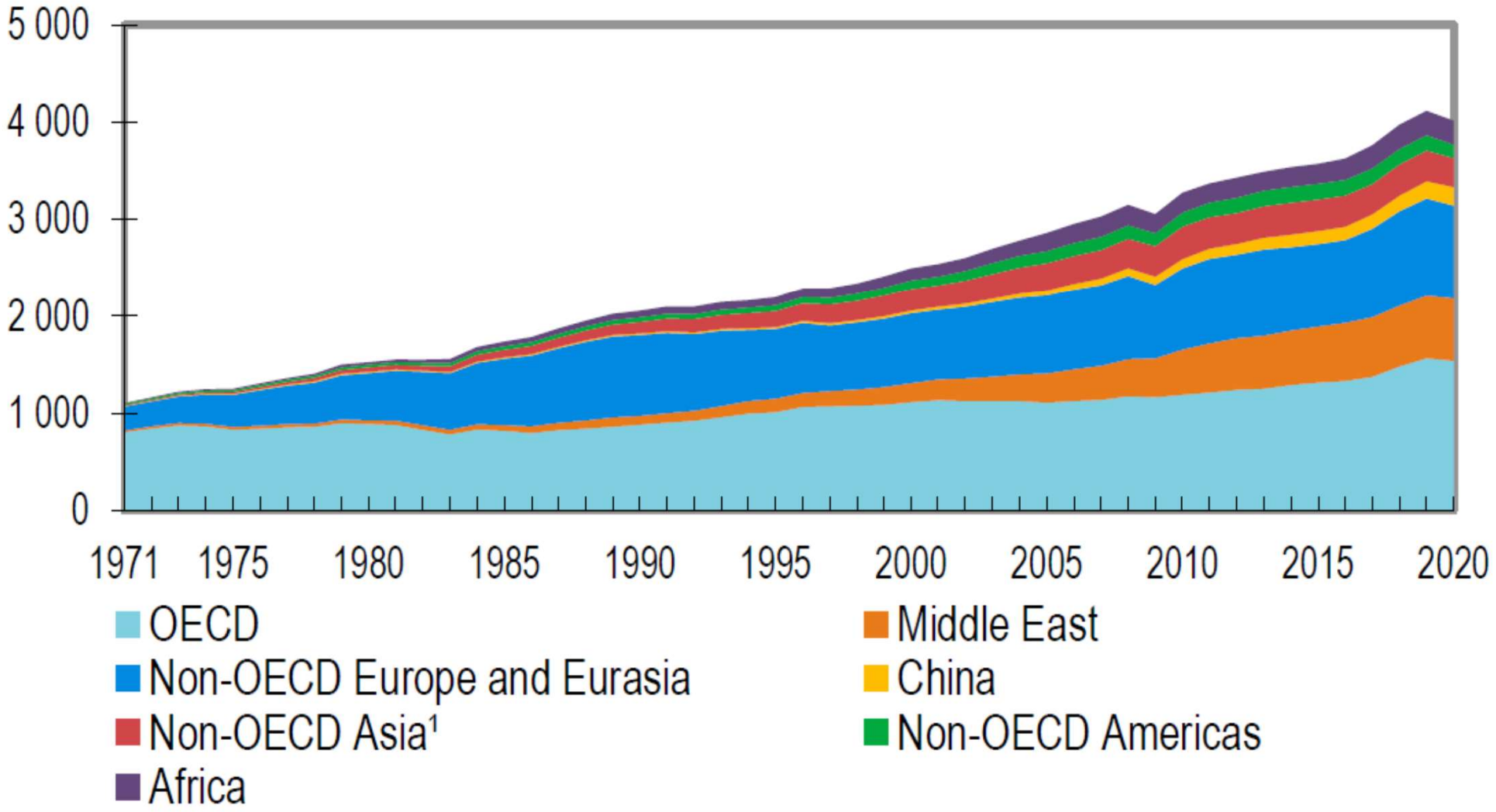

World liquid fuels production and consumption balance
million barrels per day
105
100
95
90
85
80
75
//
0
world production
world consumption
forecast
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
2015
2016
2017
2018
2019
2020
2021
15
10
5
0
-5
implied stock build
implied stock draw
Source: Short-Term Energy Outlook, May 2020
eia

Oil Black Monday



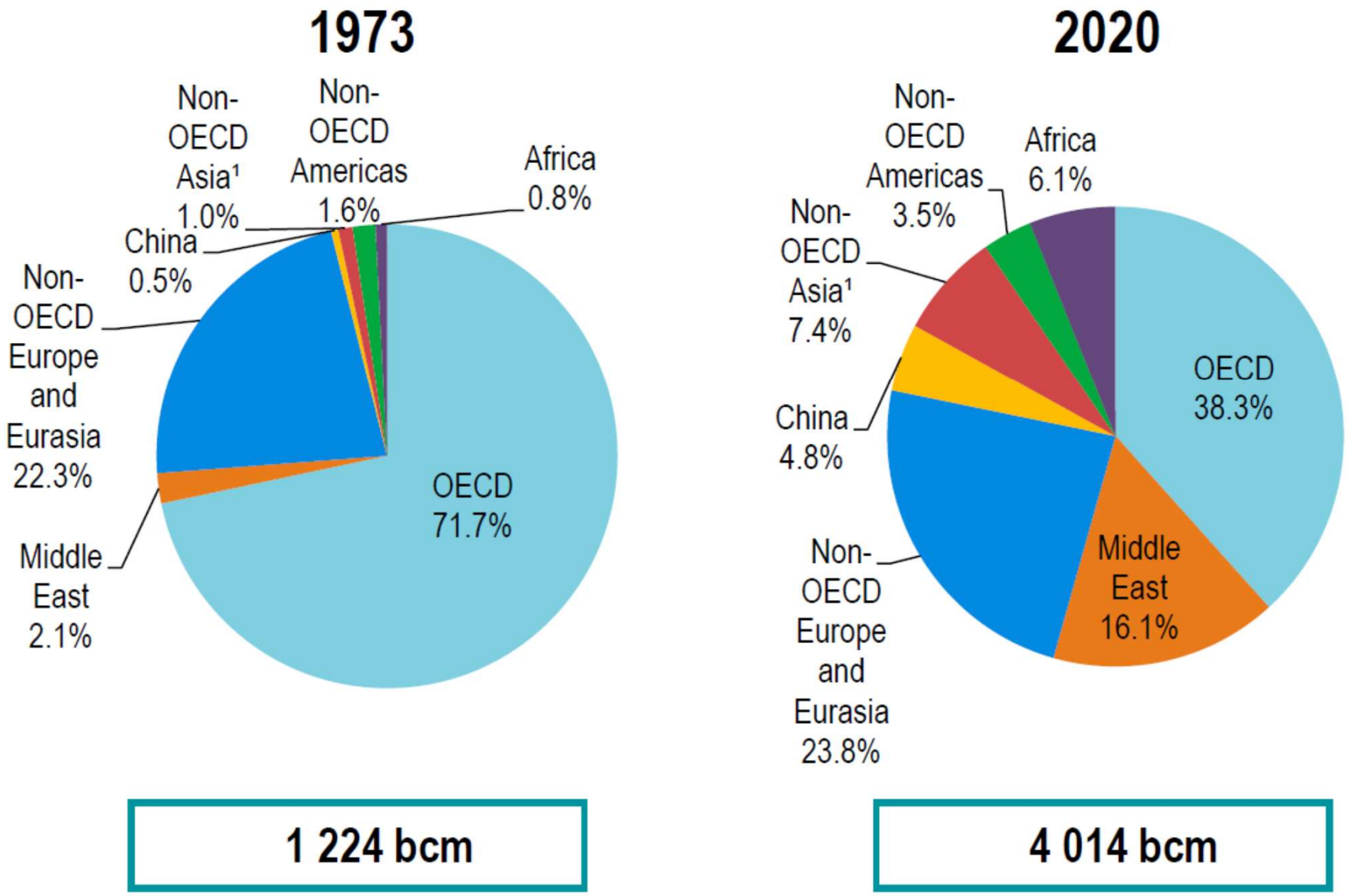
Gás Natural

World natural gas production by region, 1971-2020 (billion cubic metres, bcm)



Fonte: IEA - Key World Energy Statistics, 2021.

Share of world natural gas production by region, 1973 and 2020



Fonte: IEA - Key World Energy Statistics, 2020.

Principais países produtores de gás natural

Producers	Mm^3	% of World total
Russia	656 290	22.0
United States	524 368	17.6
Canada	189 179	6.4
Islamic Rep. of Iran	98 123	3.3
Norway	91 834	3.1
Algeria	88 785	3.0
United Kingdom	83 821	2.8
Netherlands	77 295	2.6
Indonesia	72 096	2.4
Turkmenistan	67 052	2.3
Rest of the World	1 027 709	34.5
World	**2 976 552**	**100.0**

2006 data

Producers	bcm	% of world total
Russian Federation	637	19.4
United States	613	18.7
Canada	160	4.9
Islamic Rep. of Iran	145	4.4
Qatar	121	3.7
Norway	107	3.3
People's Rep. of China	97	3.0
Netherlands	89	2.7
Indonesia	88	2.7
Saudi Arabia	82	2.5
Rest of the world	1 143	34.7
World	**3 282**	**100.0**

2010 data

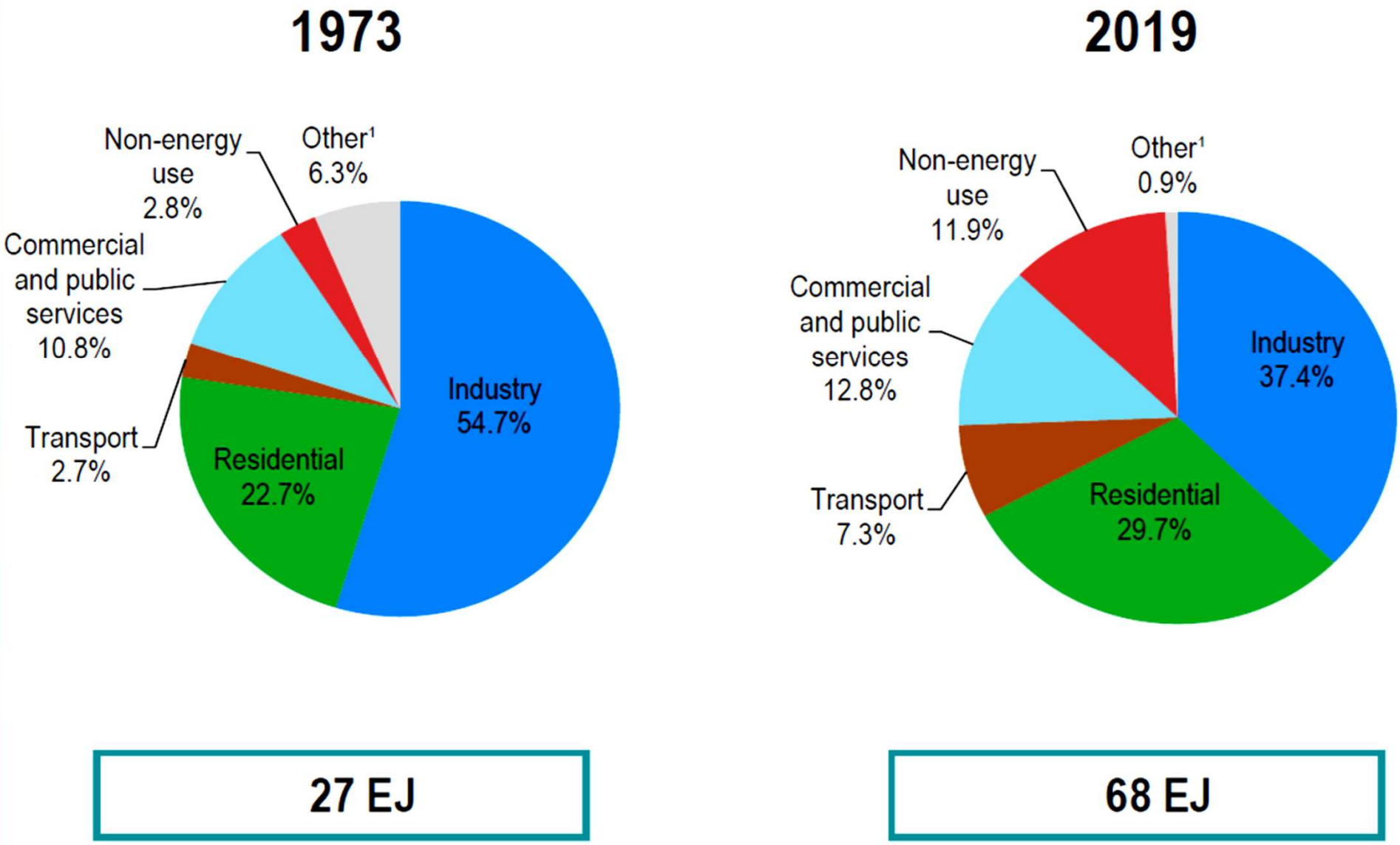
Producers	bcm	% of world total
United States	949	23.6
Russian Federation	722	18.0
Islamic Rep. of Iran	235	5.9
People's Rep. of China	191	4.8
Canada	184	4.6
Qatar	167	4.2
Australia	148	3.7
Norway	116	2.9
Saudi Arabia	99	2.5
Algeria	92	2.3
Rest of the world	1 111	27.5
World	**4 014**	**100.0**

2020 provisional data

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

Produção de Gás Natural
Tendência: 2006-2010-2020

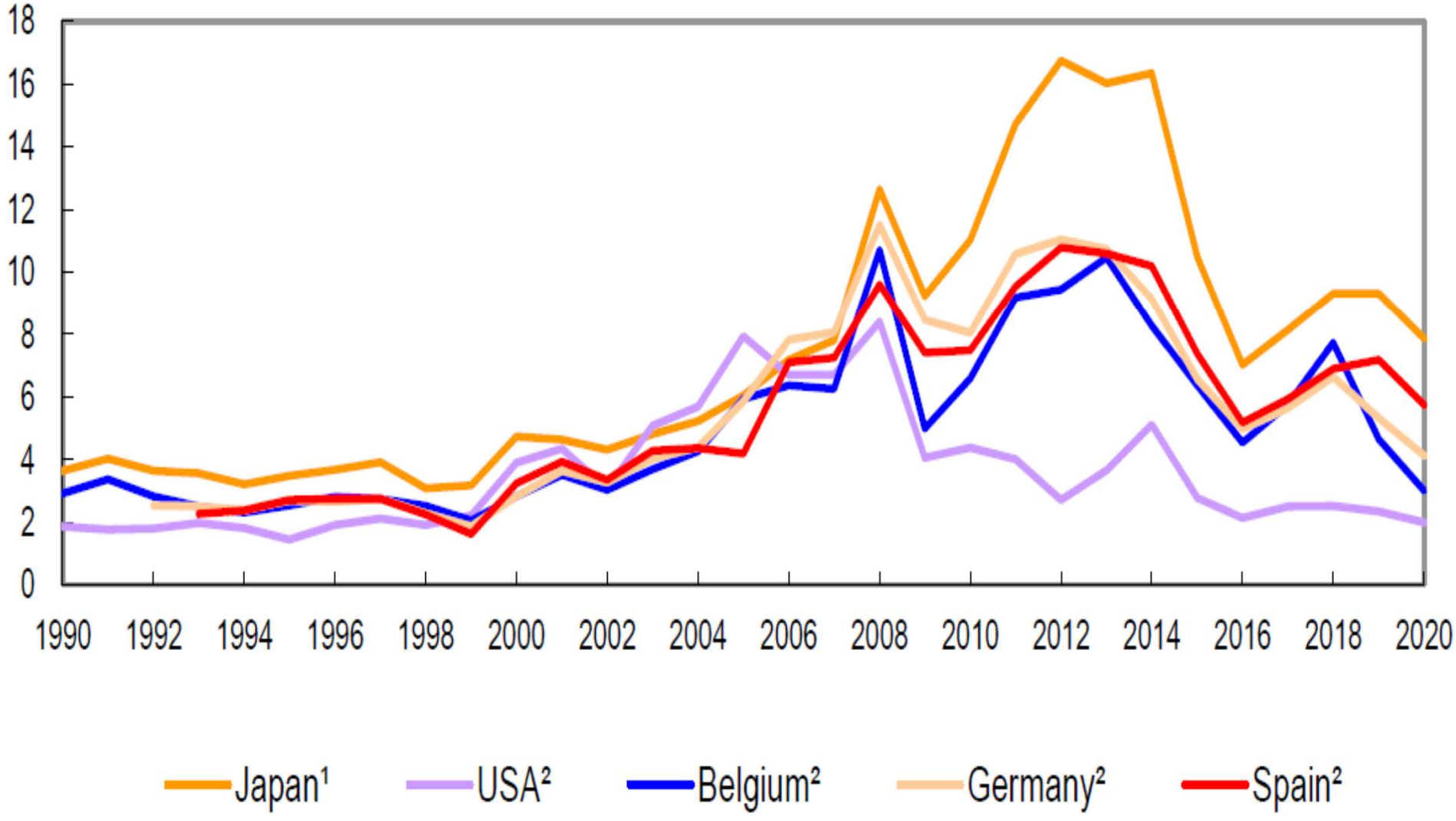
Share of natural gas final consumption by sector, 1973 and 2019



[1] Outros inclui agricultura, pesca e outros não especificados.

Fonte: IEA - Key World Energy Statistics, 2021

Average natural gas import prices in USD/MBtu, 1990-2020

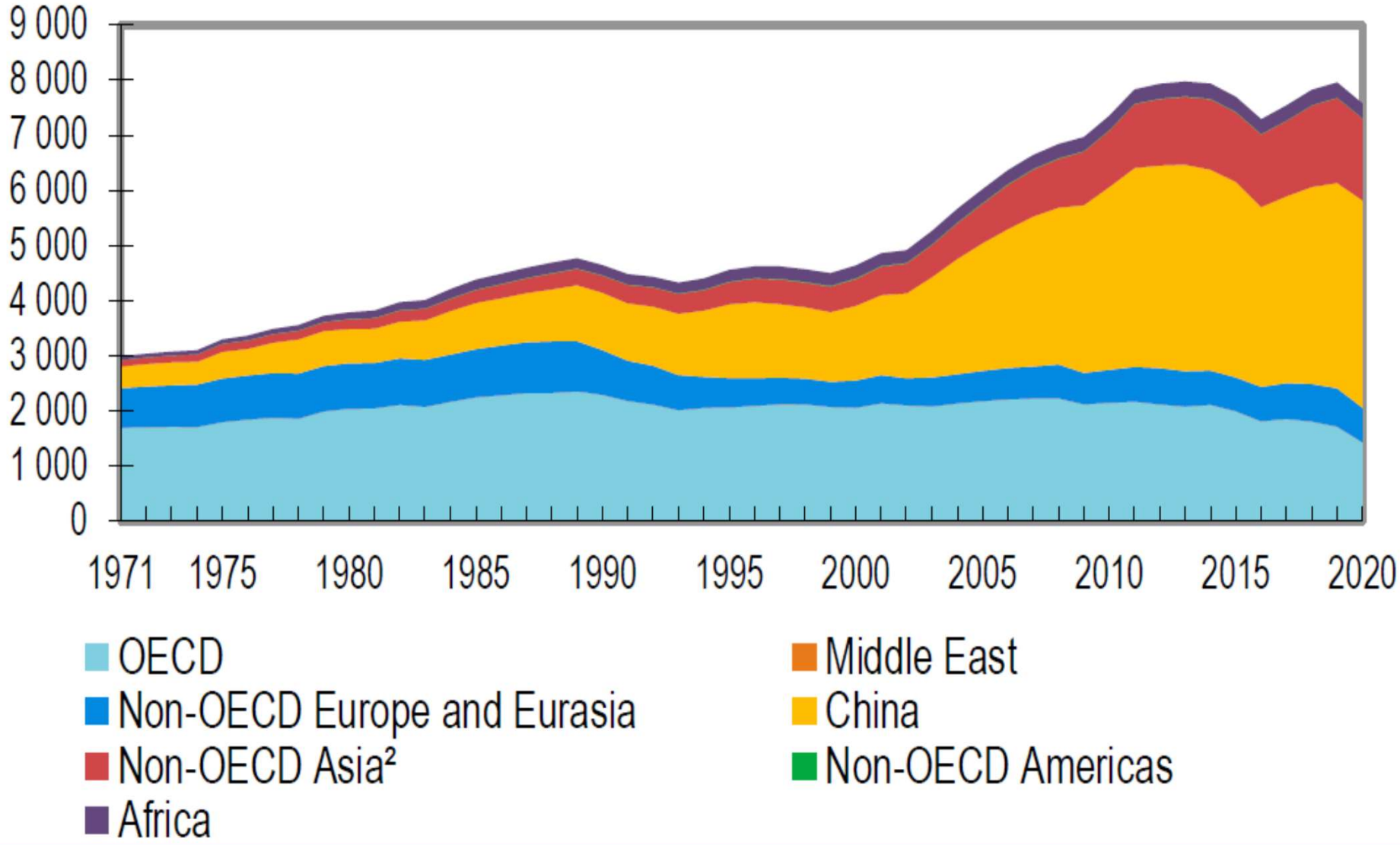


[1] GNL (Gás natural liquefeito)
[2] Gasoduto

Fonte: IEA - Key World Energy Statistics, 2021.

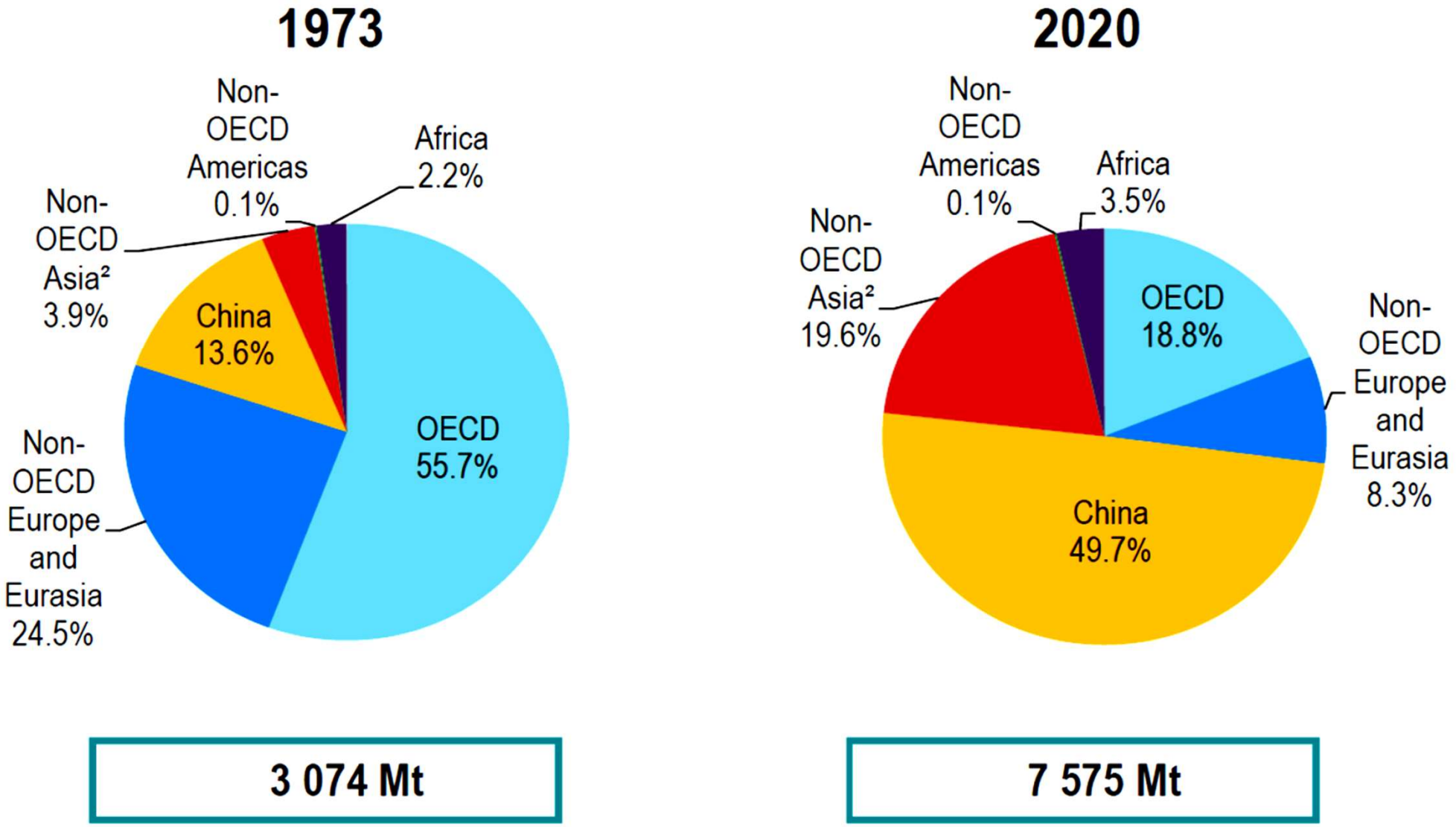
Carvão Mineral

World coal[1] production by region, 1971-2020 (Mt)



Fonte: IEA - Key World Energy Statistics, 2021.

Share of world coal[1] production by region, 1973 and 2020



[1] Inclui Carvão Antracito, Betuminoso e Sub-betuminoso (*steam coal*), carvão de coque (*coking coal*), Lignito (*lignite*) e resíduos recuperados de carvão (*recovered coal*).

[2] Ásia exclui a China e países OECD da região.

Fonte: IEA - Key World Energy Statistics, 2021.

Principais países produtores de carvão mineral

Producers	Hard Coal (Mt)	Brown Coal (Mt)
People's Rep. of China	2 481	*
United States	990	76
India	427	30
Australia	309	71
South Africa	244	0
Russia	233	76
Indonesia	169	0
Poland	95	61
Kazakhstan	92	5
Colombia	64	0
Rest of the World	266	595
World	**5 370**	**914**

2006 data

Producers	Hard coal* (Mt)	Brown coal (Mt)
People's Rep. of China	3 162	**
United States	932	65
India	538	33
Australia	353	67
South Africa	255	0
Russian Federation	248	76
Indonesia	173	163
Kazakhstan	105	6
Poland	77	57
Colombia	74	0
Rest of the world	269	576
World	**6 186**	**1 043**

2010 data

Producers	Mt	% of world total
People's Rep. of China	3 764	49.7
India	760	10.0
Indonesia	564	7.4
Australia	493	6.5
United States	485	6.4
Russian Federation	398	5.3
South Africa	247	3.3
Germany	107	1.4
Poland	101	1.3
Kazakhstan	100	1.3
Rest of the world	556	7.4
World	**7 575**	**100.0**

2020 provisional data

Hard coal: antracito; betuminoso

Brown coal: sub-betuminoso, lignito

Produção de Carvão Mineral
Tendência: 2006-2010-2020

Fonte: IEA - Key World Energy Statistics, 2007; 2011; 2021.

Principais Países produtores, exportadores e importadores de carvão mineral

Producers	Mt	% of world total
People's Rep. of China	3 764	49.7
India	760	10.0
Indonesia	564	7.4
Australia	493	6.5
United States	485	6.4
Russian Federation	398	5.3
South Africa	247	3.3
Germany	107	1.4
Poland	101	1.3
Kazakhstan	100	1.3
Rest of the world	556	7.4
World	**7 575**	**100.0**

2020 provisional data

Net exporters	Mt
Indonesia	396
Australia	390
Russian Federation	188
South Africa	62
United States	58
Colombia	30
Mongolia	29
Canada	26
Kazakhstan	24
Mozambique	7
Others	2
Total	**1 212**

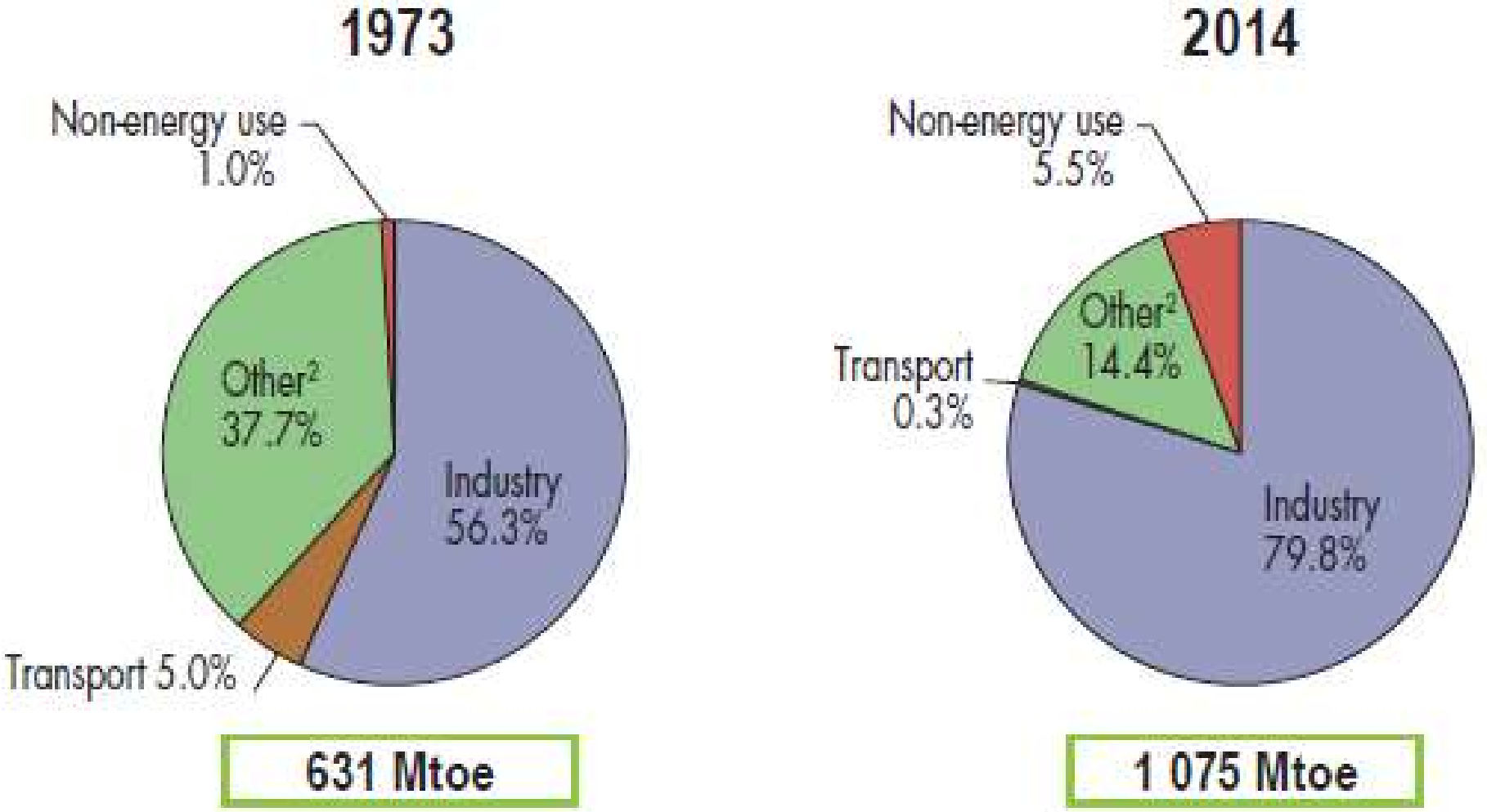
2020 provisional data

Net importers	Mt
People's Rep. of China	306
India	210
Japan	183
Korea	123
Chinese Taipei	63
Viet Nam	52
Turkey	40
Malaysia	31
Germany	29
Thailand	25
Others	202
Total	**1 264**

2020 provisional data

Fonte: IEA - Key World Energy Statistics, 2021.

1973 and 2014 shares of world coal[1] consumption

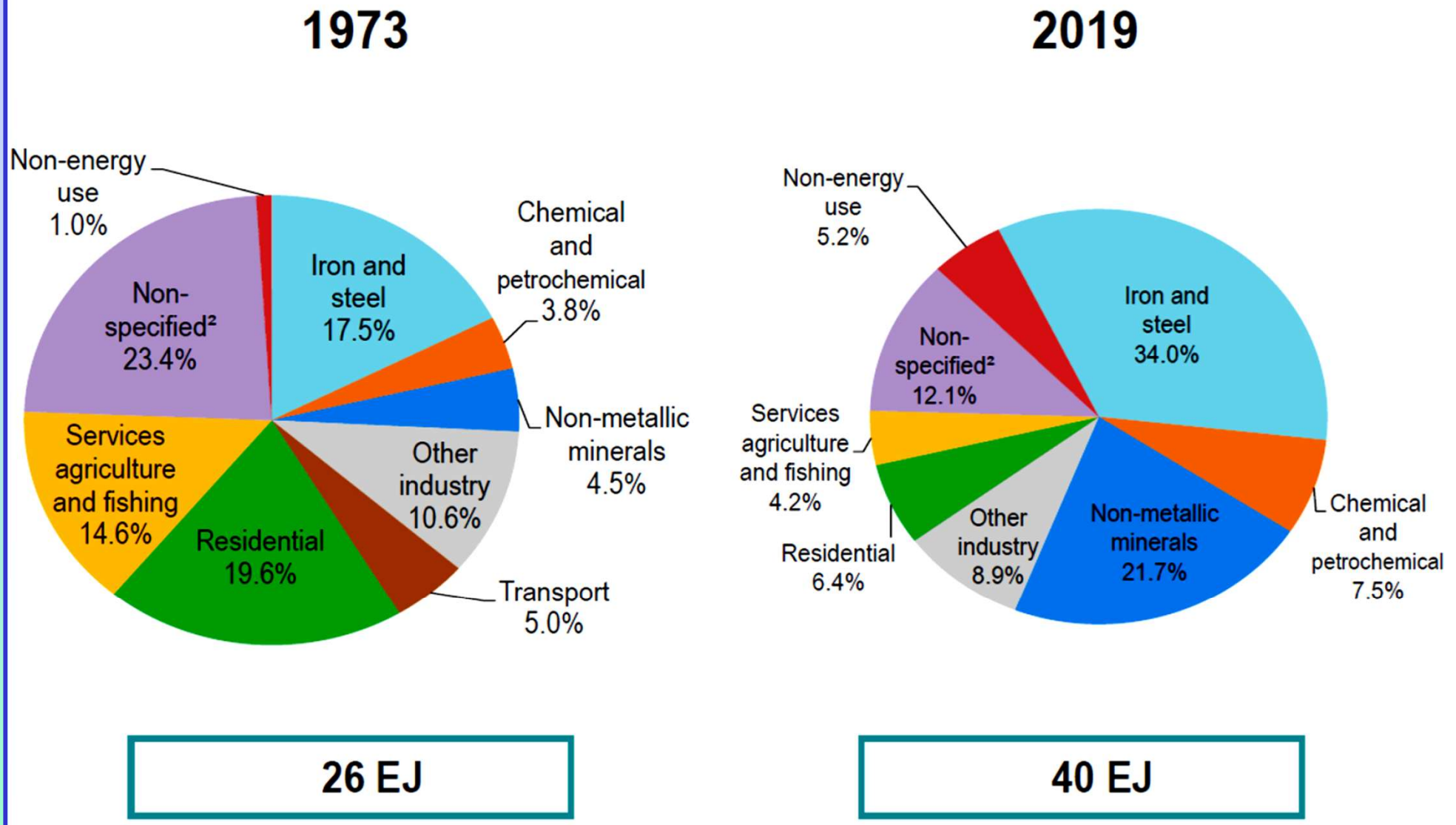


[1] Inclui turfa (peat) e óleo de folhelho (oil shale) agregados ao carvão no gráfico.

[2] Outros inclui agricultura, serviços públicos, os setor comercial, residencial e outros não especificados.

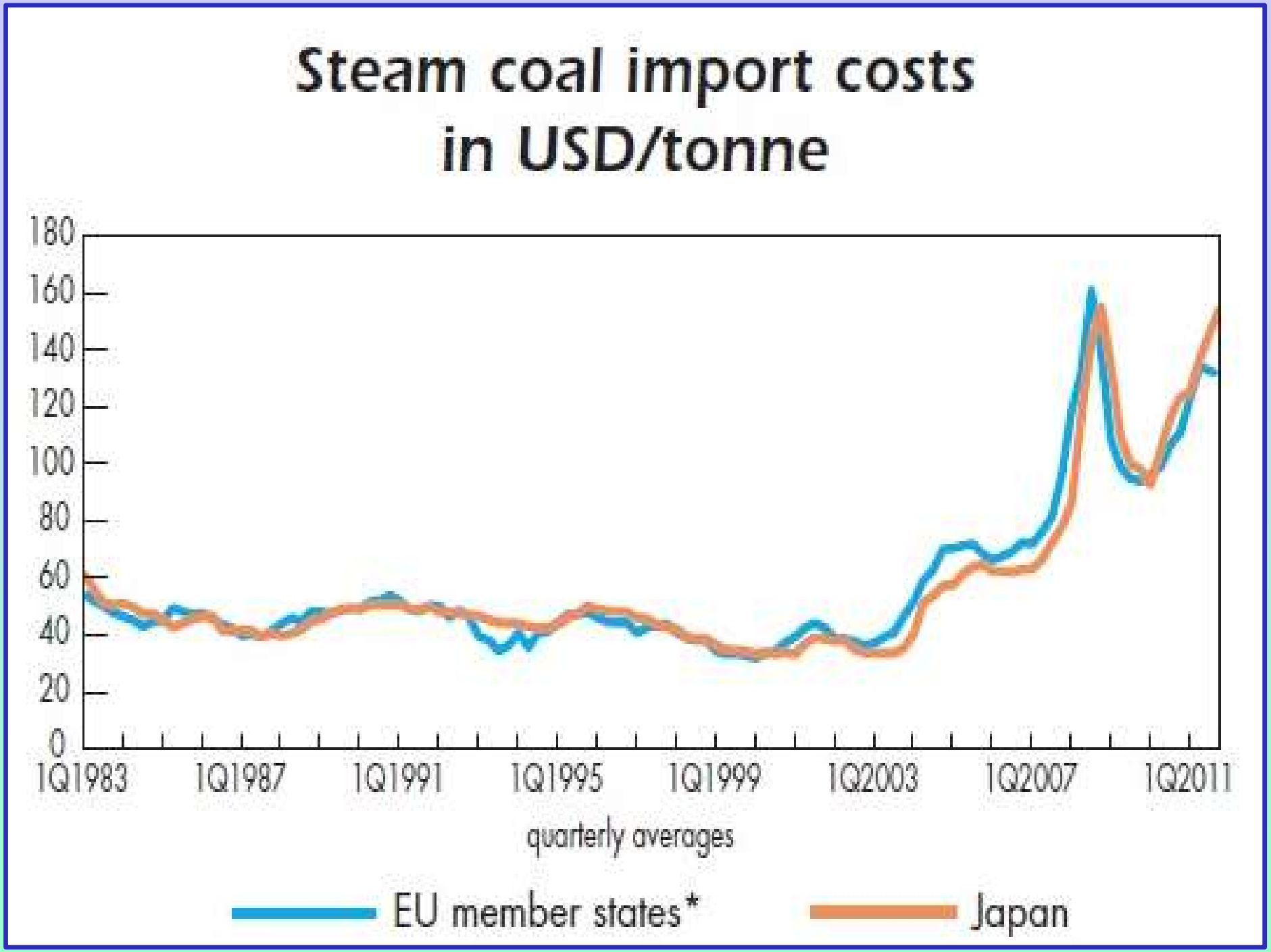
Fonte: IEA - Key World Energy Statistics, 2016.

Share of coal final consumption by sector, 1973 and 2019



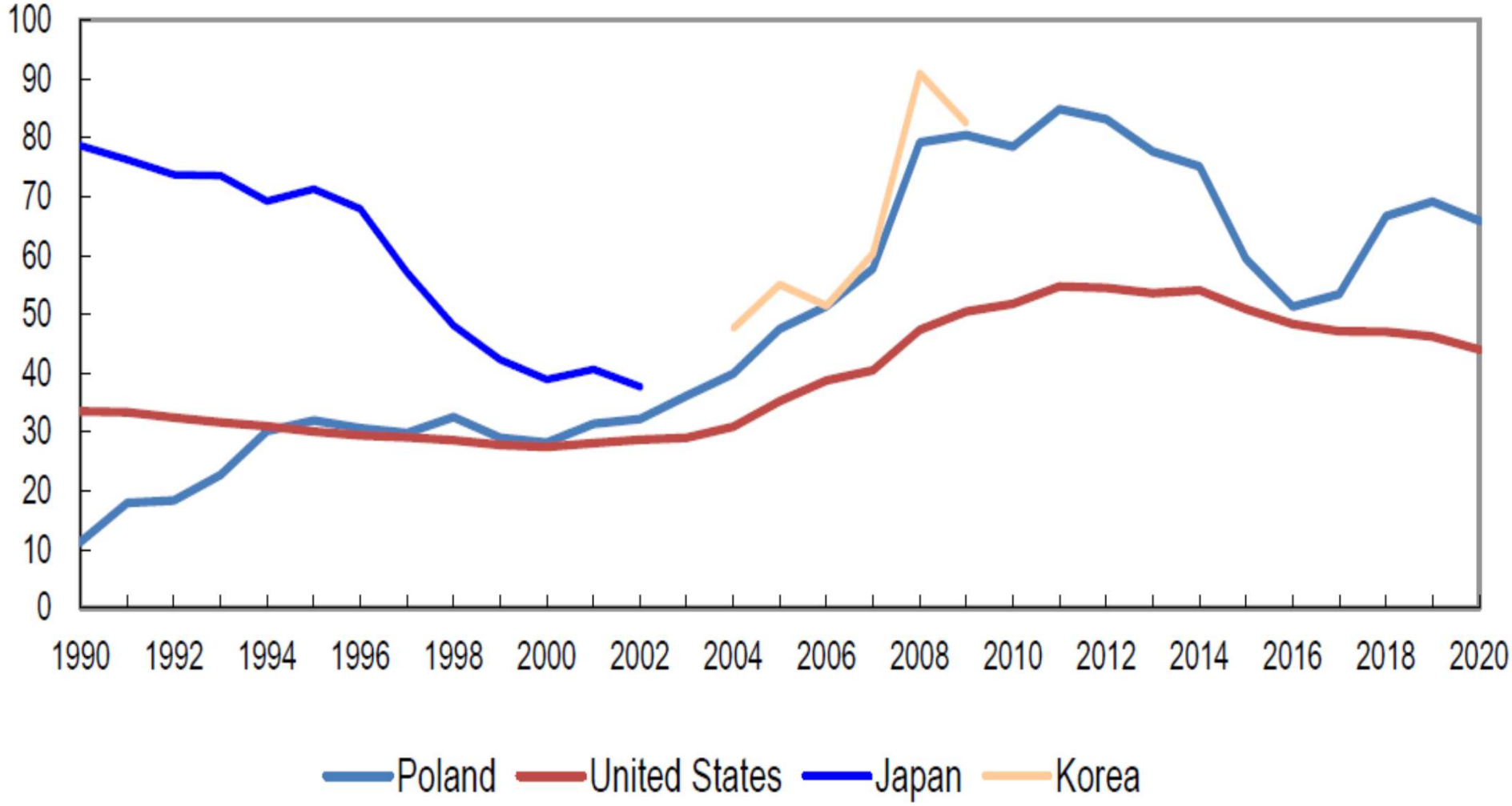
[1] Inclui turfa (peat) e óleo de folhelho (oil shale) agregados ao carvão no gráfico.
[2] Inclui indústria não especificada, transporte e outros.

Fonte: IEA - Key World Energy Statistics, 2020.



Fonte: IEA - Key World Energy Statistics, 2013.

Average steam coal prices for electricity generation in USD/tonne, 1990-2020



Fonte: IEA - Key World Energy Statistics, 2021.

Agrocombustíveis*

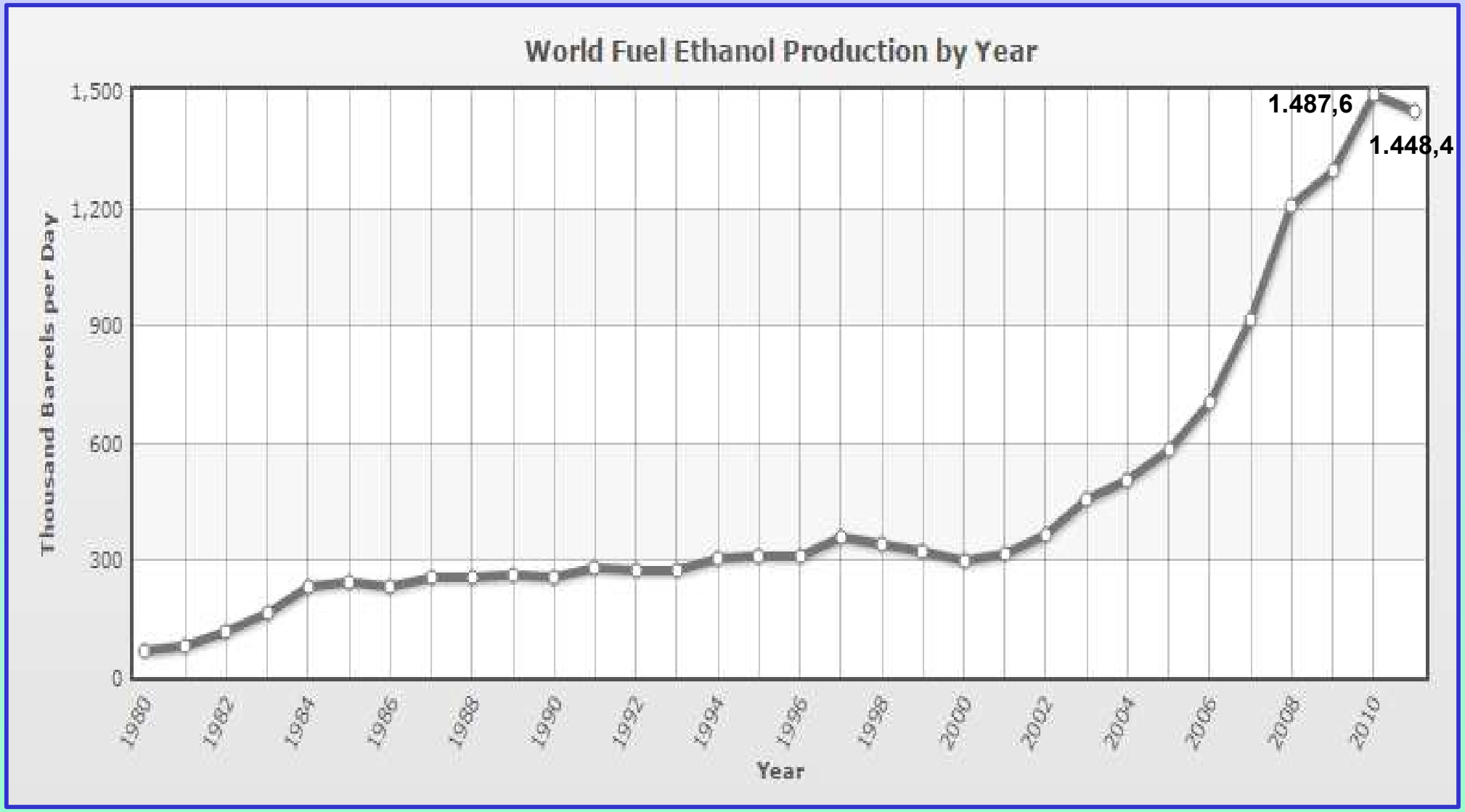
(*Biocombustíveis*)

(Biofuels)

* Emprega-se aqui o termo agrocombustíveis, em contraposição aos biocombustíveis.

Para Eric Holt-Giménez, diretor executivo da FoodFirst (Institute for Food and Development Policy), “o termo (biocombustíveis) invoca a imagem vital de renovação e abundância – uma garantia limpa, verde, sustentável em tecnologia e no poder do progresso. (...) Obscurece fundamentalmente as relações políticoeconômicas entre terra, povo, recursos e alimentos.” Cf. Holt-Giménez, E. “Biocombustíveis: os cinco mitos da transição dos agrocombustíveis”, 27.11.2006.

Disponível em:
http://www.inesc.org.br/noticias/noticias-gerais/2007/setembro-2007/biocombustiveis-os-cinco-mitos-datransicao-dos-agrocombustiveis/.



Fonte: http://www.indexmundi.com/energy.aspx?product=ethanol&graph=production
a partir dos dados de United States Energy Information Administration, 2012.

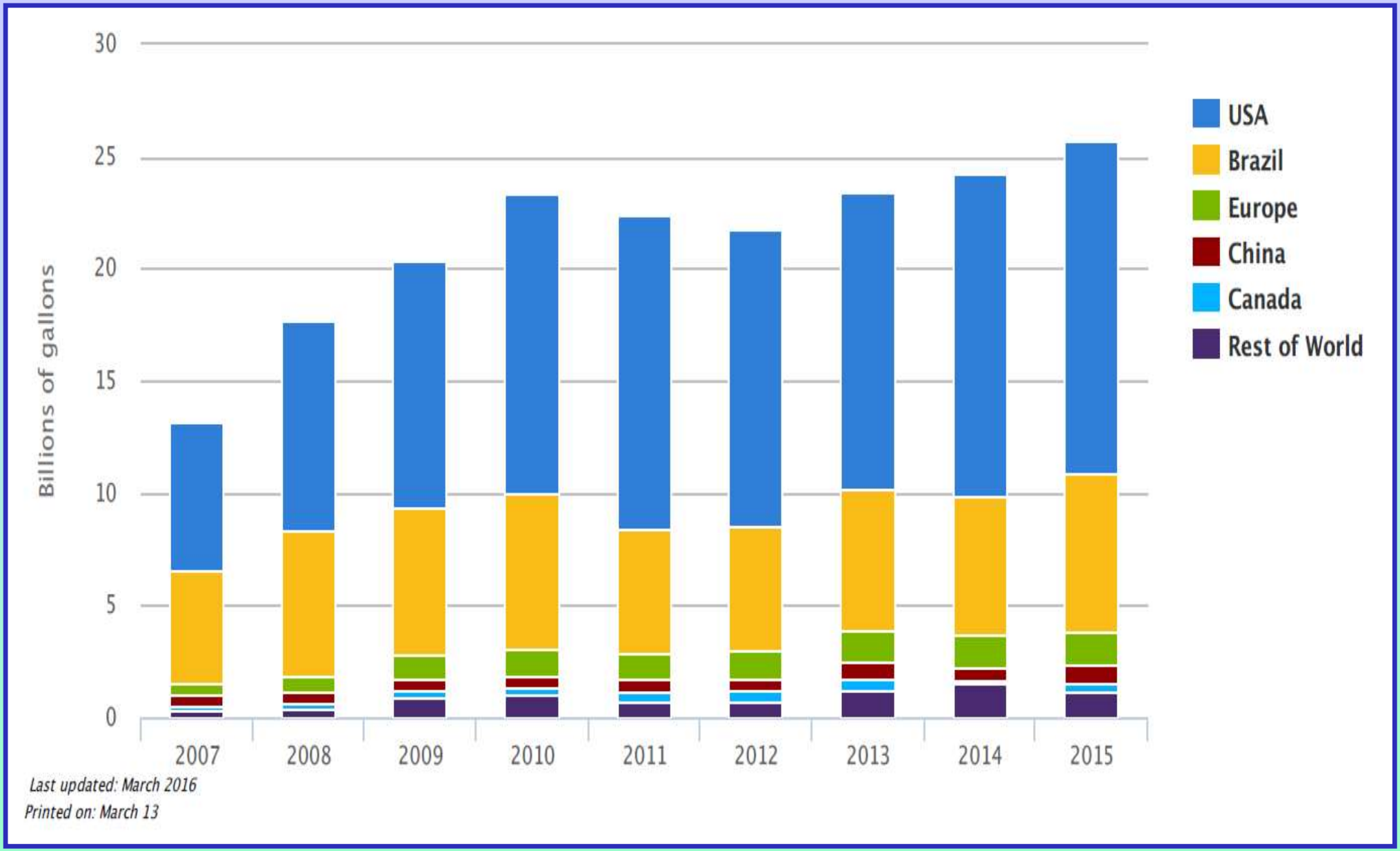
Obs.: Produção Mundial de gasolina automotiva: 22,3 Milhões de b/d (2010).

Fuel Ethanol Production (Thousand Barrels Per Day)

Region/Countries	2007	2008	2009	2010	2011
North América	439.178	620.566	733.493	891.744	938.919
United States	425.378	605.566	713.490	867.444	908.619
Central & South America	**414.638**	**497.845**	**476.545**	**502.912**	**415.903**
Brazil	388.709	466.291	449.818	486.011	392.000
Colombia	4.700	4.400	5.600	4.800	6.000
Guatemala	2.900	2.900	3.000	3.000	4.000
Jamaica	4.852	6.423	6.900	2.000	3.000
Europe	**31.410**	**47.360**	**59.310**	**72.101**	**72.801**
Austria	0.300	1.500	2.500	2.500	2.500
Belgium	0	0.400	2.500	5.000	6.500
France	9.300	16.000	17.000	18.000	17.400
Germany	6.800	10.000	13.000	13.000	13.300
Hungary	0.500	2.400	2.600	3.200	3.000
Netherlands	0.200	0.200	0	2.000	4.000
Poland	2.000	2.000	3.000	4.000	2.900
Sweden	1.500	1.700	3.000	3.500	3.400
United Kingdom	0.300	1.200	1.300	5.000	5.000
Eurasia	**0.650**	**0.700**	**1.300**	**1.220**	**0.420**
Asia & Oceania	**38.402**	**48.453**	**55.243**	**58.780**	**64.800**
Australia	1.400	2.500	3.500	6.500	7.500
China	28.700	34.400	37.000	37.000	39.000
India	4.500	5.000	6.000	5.000	6.000
Thailand	3.000	5.700	6.900	7.500	8.900
World	**924.478**	**1,215.224**	**1,326.341**	**1,527.607**	**1,493.463**

Source: U.S. Energy Information Administration – International Energy Statistics, 2013

Produção mundial de Etanol



Obs: 1 US galão = 3,79 litros

Fonte: Renewable Fuels Association, 2016.

Table 1: World Ethanol Production (2009 - 2016)

Country	Production (thousand barrels/day)	
	2009	2016
USA	710.71	977.28
Brazil	412.71	460.44
China	42.49	54.22
Canada	22.63	30.39
France	15.44	15.57
Germany	12.51	15.44
Thailand	7.22	21.98
India	1.72	19.13
Argentina	0.19	15.22
World Total	**1,289.96**	**1,720.48**

Source: DOE/USA. Energy Information Administration – EIA Beta - International Energy Statistics, 2019.
Available in: https://www.eia.gov/beta/international/data/browser/ (Accessed 25 November 2019)

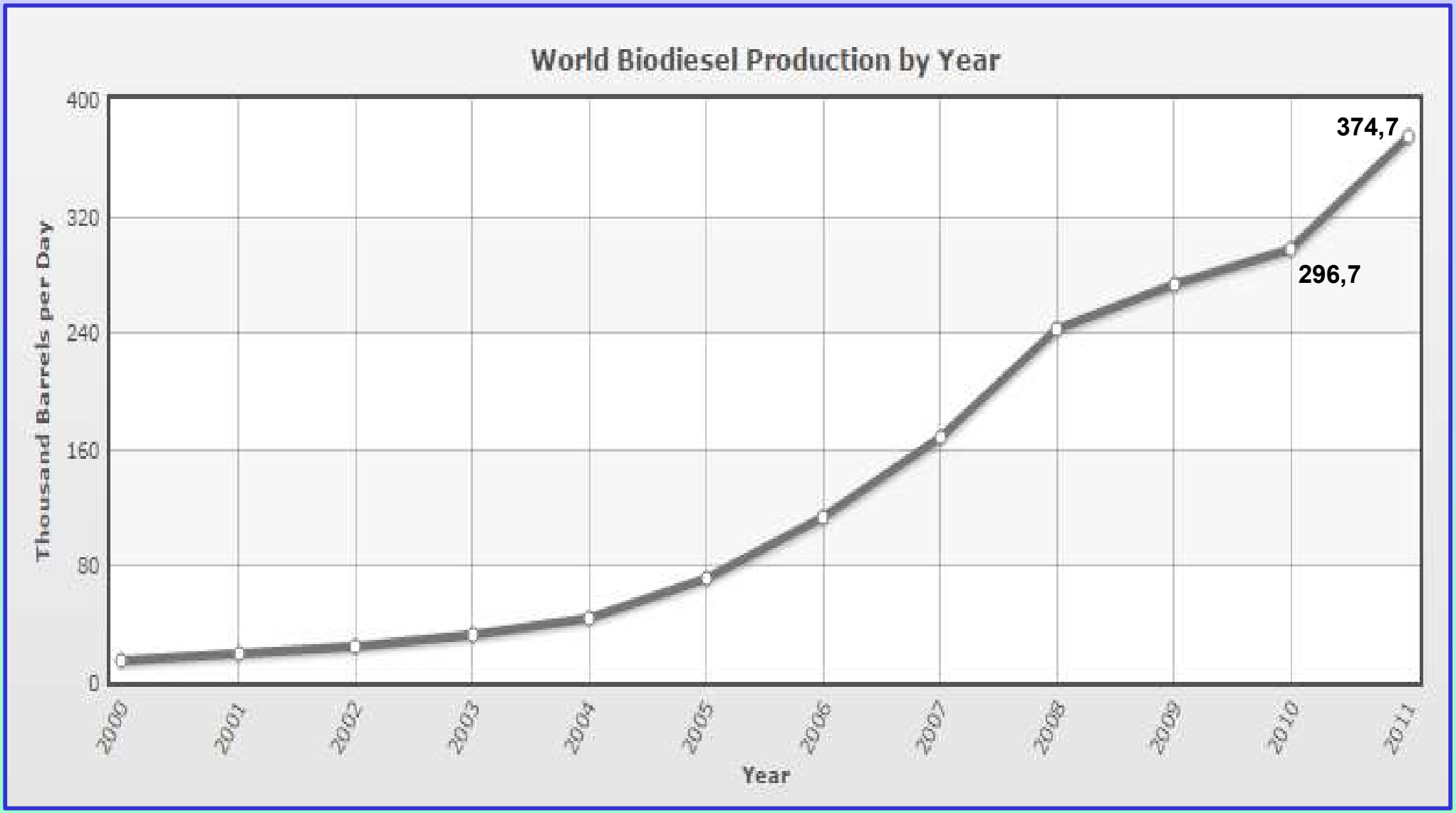
> Gasoline Replacement Rate by Ethanol:

2009: 3.8%

2016: 4.4%

Note: equivalence relation of 0.664 of ethanol compared to gasoline, in terms of its lower heat content.

Cf. ENERS (2010), ethanol has an average of 0.508toe/1,000 liters, while gasoline offers 0.765 toe/1,000 liters.



Fonte: http://www.indexmundi.com/energy.aspx?product=biodiesel&graph=production
a partir dos dados de United States Energy Information Administration, 2013.

Obs.: Produção Mundial de óleo diesel mineral: 25,4 Milhões de b/d (2010).

Biodiesel Production (Thousand Barrels Per Day)

Region/Countries	2007	2008	2009	2010	2011
North América	**33.652**	**45.913**	**35.847**	**24.903**	**65.910**
United States	31.952	44.113	33.647	22.403	63.110
Central & South America	**11.248**	**35.828**	**56.942**	**85.154**	**103.249**
Argentina	3.600	13.900	23.100	36.000	47.340
Brazil	6.968	20.057	27.711	41.123	46.058
Europe	**122.390**	**150.690**	**173.870**	**183.142**	**177.690**
Austria	5.200	4.200	6.100	5.700	6.200
Belgium	3.200	5.400	8.100	8.500	8.700
France	18.700	34.400	41.000	37.000	34.000
Germany	57.000	55.000	45.000	49.000	52.000
Italy	9.200	13.100	15.600	14.500	11.200
Netherlands	1.700	2.000	5.400	7.500	9.600
Poland	0.900	5.000	6.000	7.000	7.500
Portugal	3.500	3.300	4.900	6.000	5.500
Spain	3.500	4.300	14.000	16.000	12.000
Sweden	2.200	2.800	3.500	4.000	5.000
Eurasia	**0.720**	**2.500**	**3.800**	**3.260**	**3.250**
Asia & Oceania	**10.820**	**27.120**	**38.524**	**41.031**	**53.371**
China	2.000	5.000	6.000	6.000	7.800
South Korea	1.700	3.200	5.000	6.500	6.300
Thailand	1.200	7.700	10.500	11.000	10.200
World	**178.830**	**262.096**	**309.072**	**337.760**	**403.739**

Fonte: U.S. Energy Information Administration – International Energy Statistics, 2013

Table 2: Biodiesel World Production (2009 - 2016)

Country	Production (thousand barrels/day)	
	2009	2016
Germany	48.31	62.38
France	41.76	45.07
USA	33.65	101.99
Brazil	27.72	65.51
Argentina	23.00	48.30
Italy	15.72	10.96
Spain	14.59	26.82
Thailand	10,51	21.37
China	10.18	8.62
Poland	7.47	17.72
Indonesia	5.69	63.00
Netherlands	5.40	28.71
South Korea	4.61	9.53
Malaysia	4.24	7.22
Colombia	3.19	8.76
Canada	2.13	7.46
Singapore	1.00	18.00
World Total	**307.46**	**551.42**

> Diesel Oil Replacement Rate by Biodiesel:

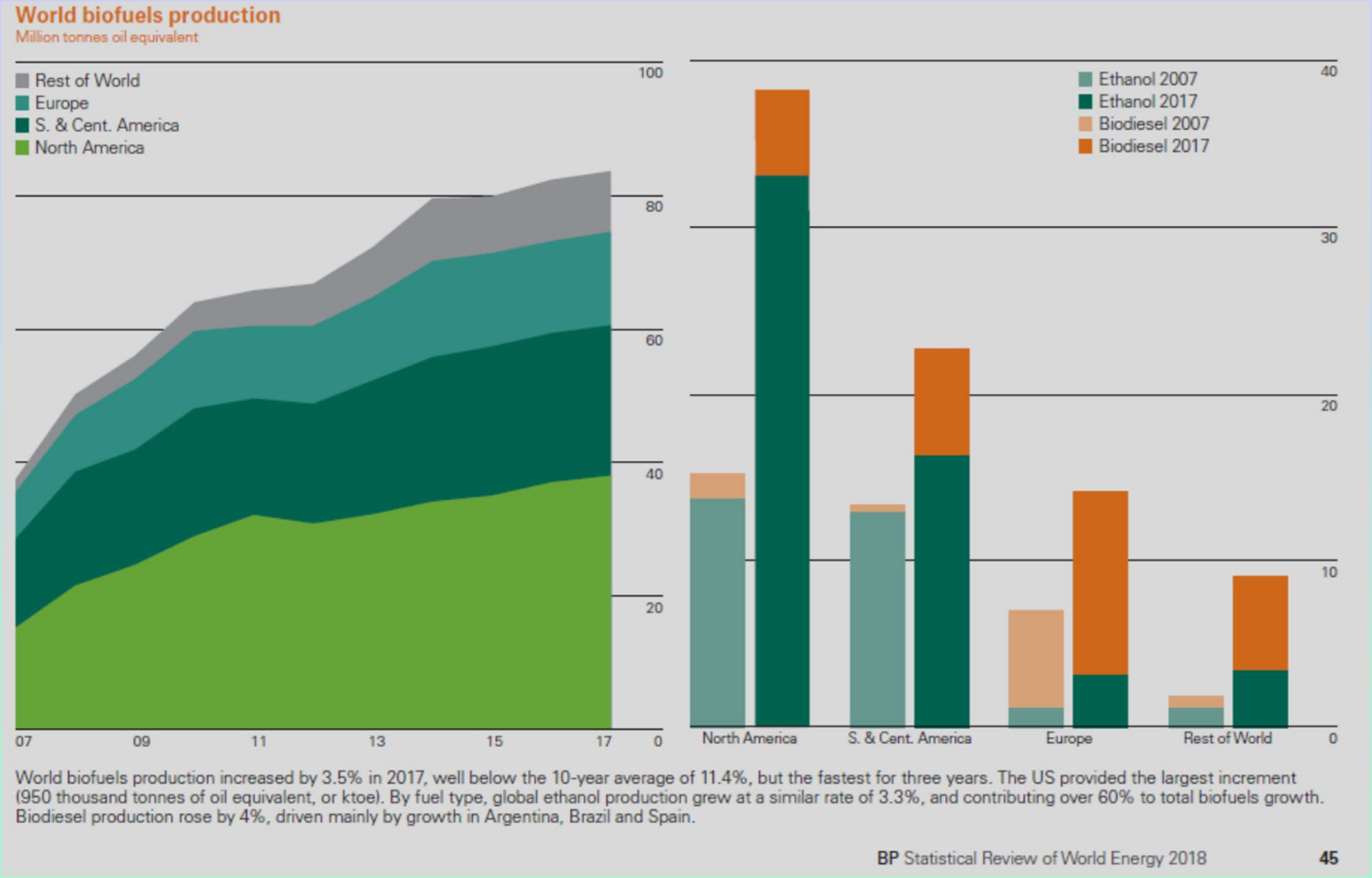
2009: 1.2%

2016: 1.8%

Note: equivalence relation of 0.919 of biodiesel compared to mineral diesel, in terms of its lower heat content.

Cf. ENERS (2010), biodiesel has an average of 0.792toe/1,000 liters, while mineral diesel presents an average of 0.862 toe/1,000 liters.

Source: DOE/USA. Energy Information Administration – EIA Beta - International Energy Statistics, 2019.
Available in: https://www.eia.gov/beta/international/data/browser/ (Accessed 10 February 2020)



Fonte: BP Statistical Review of World Energy, 2018.

Energia e o atual debate ambiental

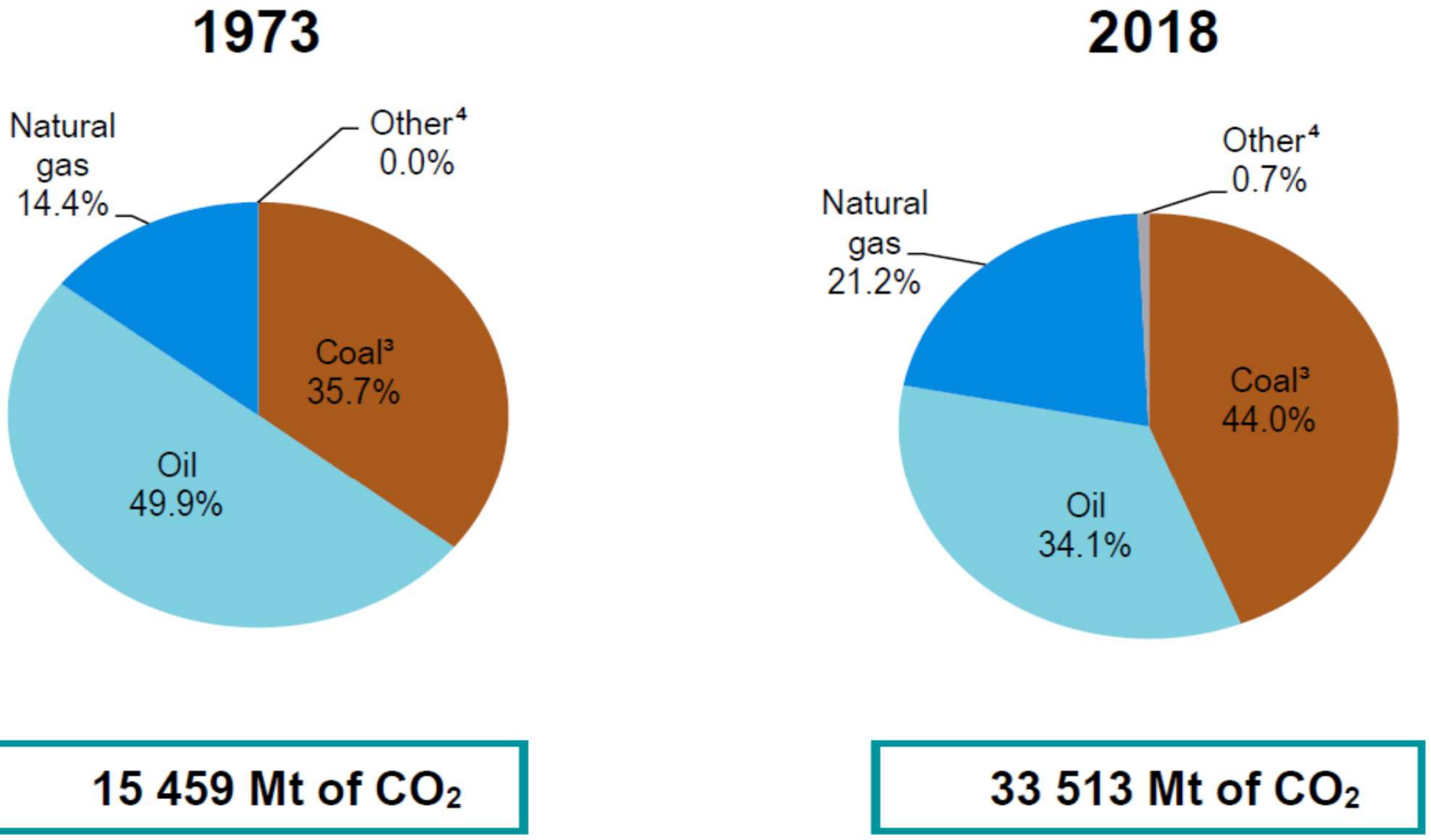
Para o cálculo das emissões de CO_2 para cada fonte:

Fatores de conversão:

óleo diesel: 3,15 t CO_2/tep
óleo combustível: 3,34 t CO_2/tep
querosene: 3,04 t CO_2/tep
gasolina: 2,93 t CO_2/tep
GLP: 2,65 t CO_2/tep
lenha e carvão vegetal: 4,27 t CO_2/tep
outros de petróleo: 3,04 t CO_2/tep
carvão mineral: 3,83 t CO_2/tep
coque de carvão mineral: 3,83 t CO_2/tep
gás de coqueria: 2,84 t CO_2/tep
gás natural: 2,12 t CO_2/tep

Fonte: IEA-International Energy Agency, 1994 (coeficientes expressos em t CO_2/TJ-terajoules ou 10^{12} joules convertidos para tep).

1973 and 2018 fuel shares of CO_2 emissions from fuel combustion[2]



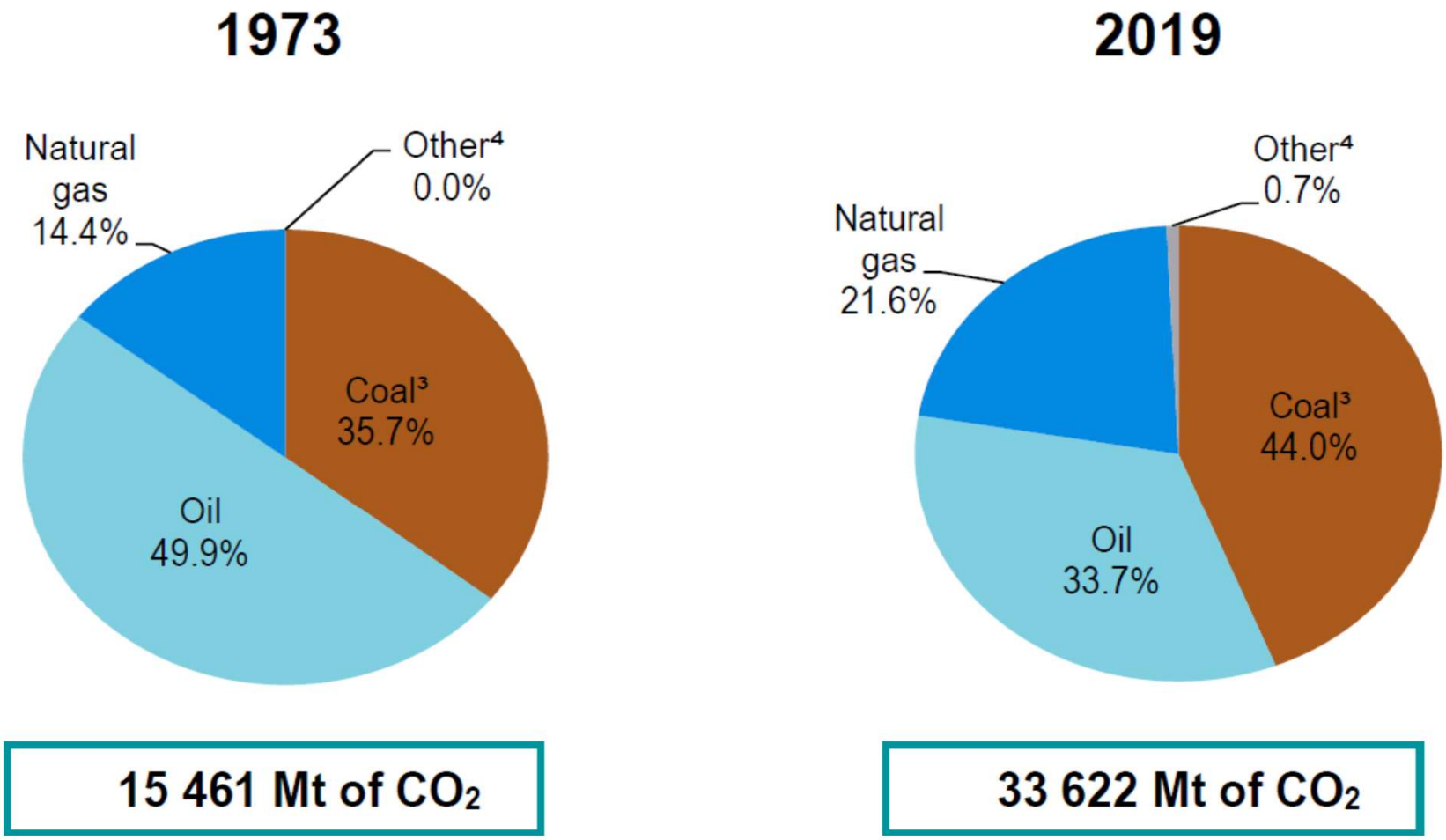
15 459 Mt of CO_2

33 513 Mt of CO_2

1. World includes international aviation and international marine bunkers.
2. CO_2 emissions from fuel combustion are based on the IEA World energy balances and the 2006 IPCC Guidelines for national greenhouse gas inventories, and exclude emissions from non-energy use. 3. In these graphs, peat and oil shale are aggregated with coal.
4. Includes industrial waste and non-renewable municipal waste.

Fonte: IEA - Key World Energy Statistics, 2020.

Fuel share of CO_2 emissions from fuel combustion[2], 1973 and 2019



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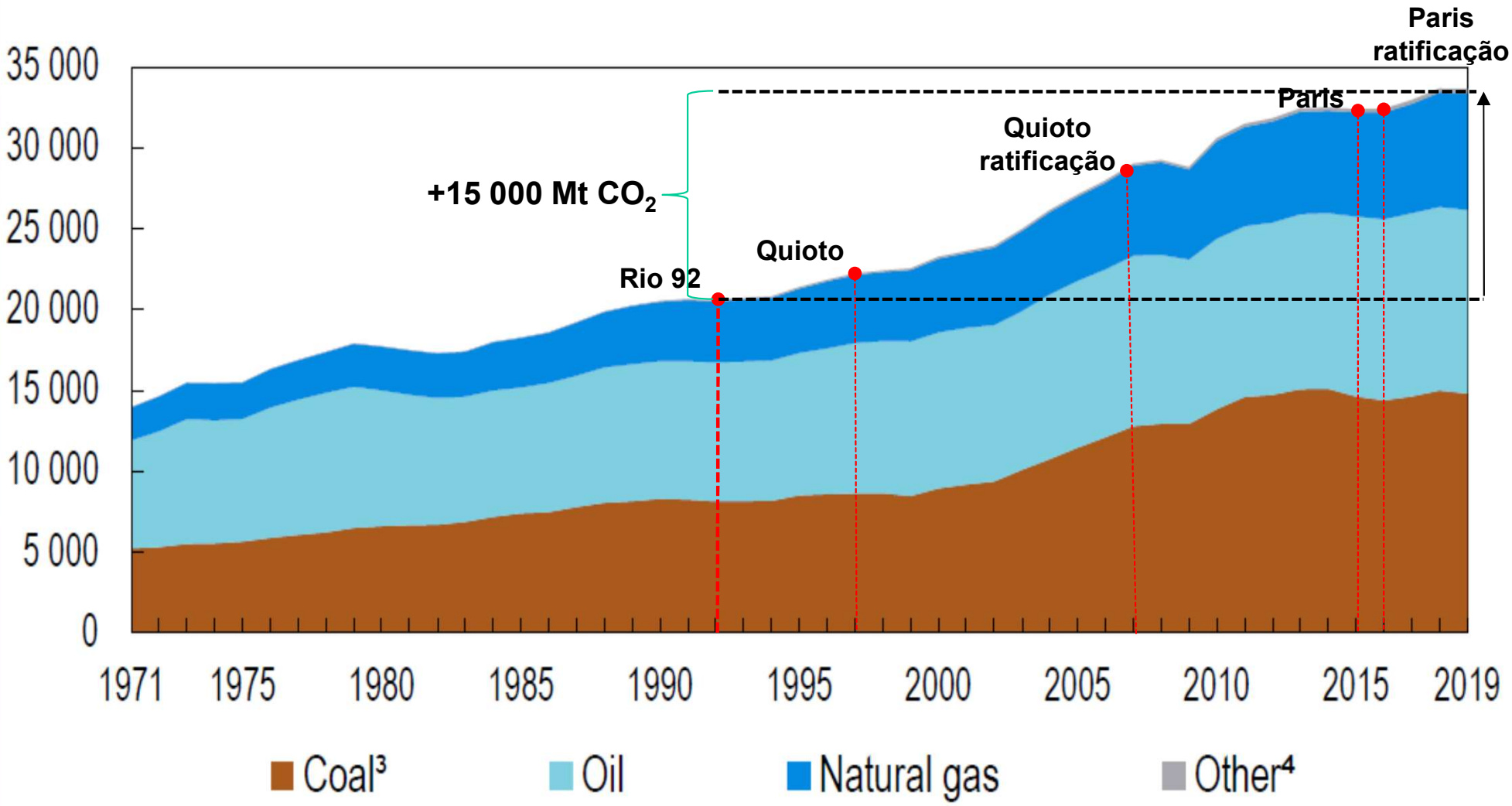
4. Includes industrial waste and non-renewable municipal waste.

Fonte: IEA - Key World Energy Statistics, 2021.

World[1] CO_2 emissions from fuel combustion[2] by fuel, 1971-2019 (Mt of CO_2)



1. World includes international aviation and international marine bunkers.
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Fonte: IEA - Key World Energy Statistics, 2020.