Combustíveis fósseis

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Combustíveis e biocombustíveis

Universidade Federal do Paraná – UFPR
Pós Graduação em Bioenergia

Conteúdo

- Parte 1
  - Energia no mundo
  - Formação
  - Características gerais
  - Reservas no mundo e no Brasil
  - Modos de exploração
- Parte 2
  - Uso final
  - Impactos ambientais e desafios
  - Perspectivas

Conteúdo

- Parte 1
  - Energia no mundo
  - Formação
  - Características gerais
  - Reservas no mundo e no Brasil
  - Modos de exploração
- Parte 2
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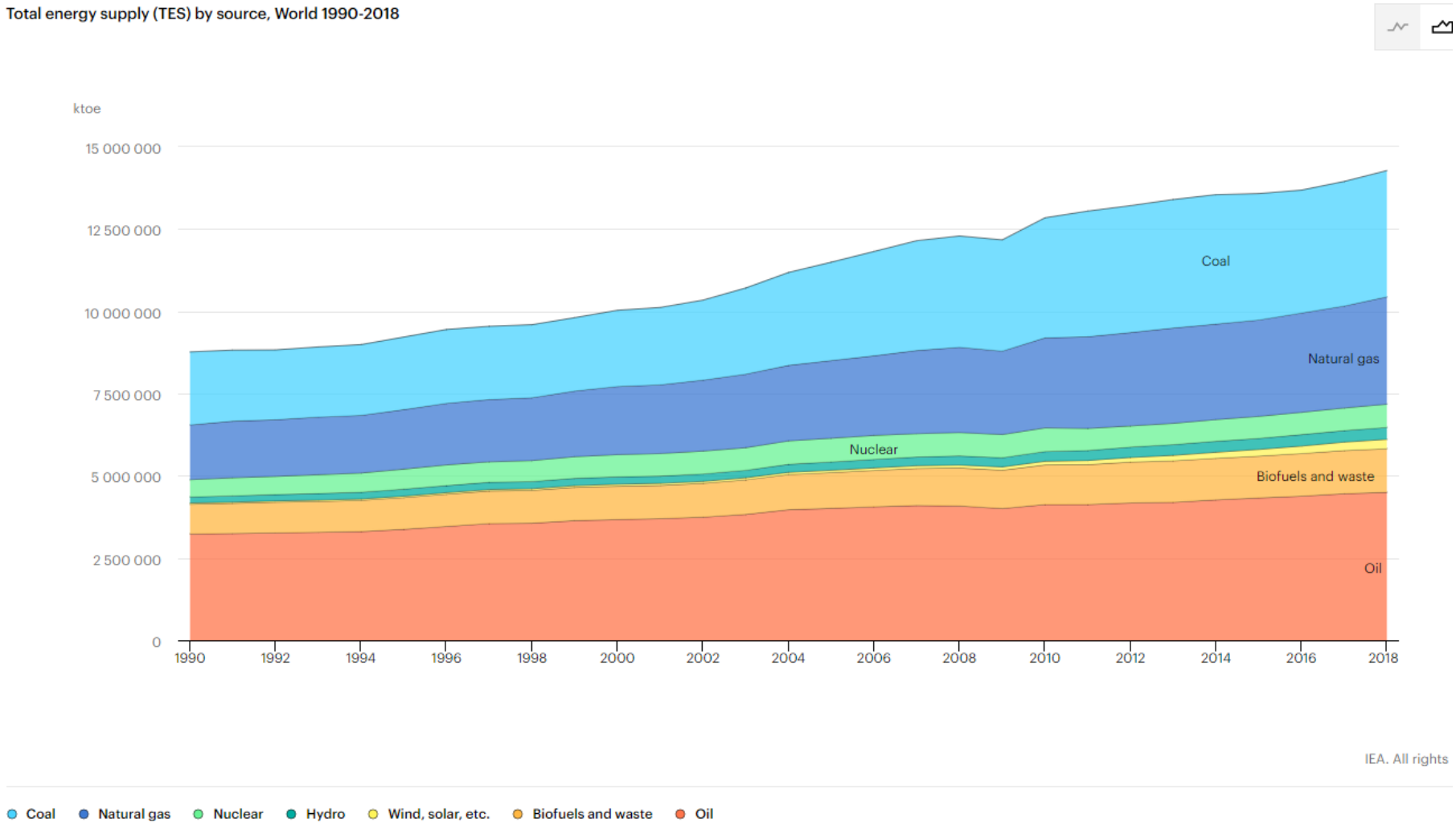
  - Impactos ambientais e desafios
  - Perspectivas

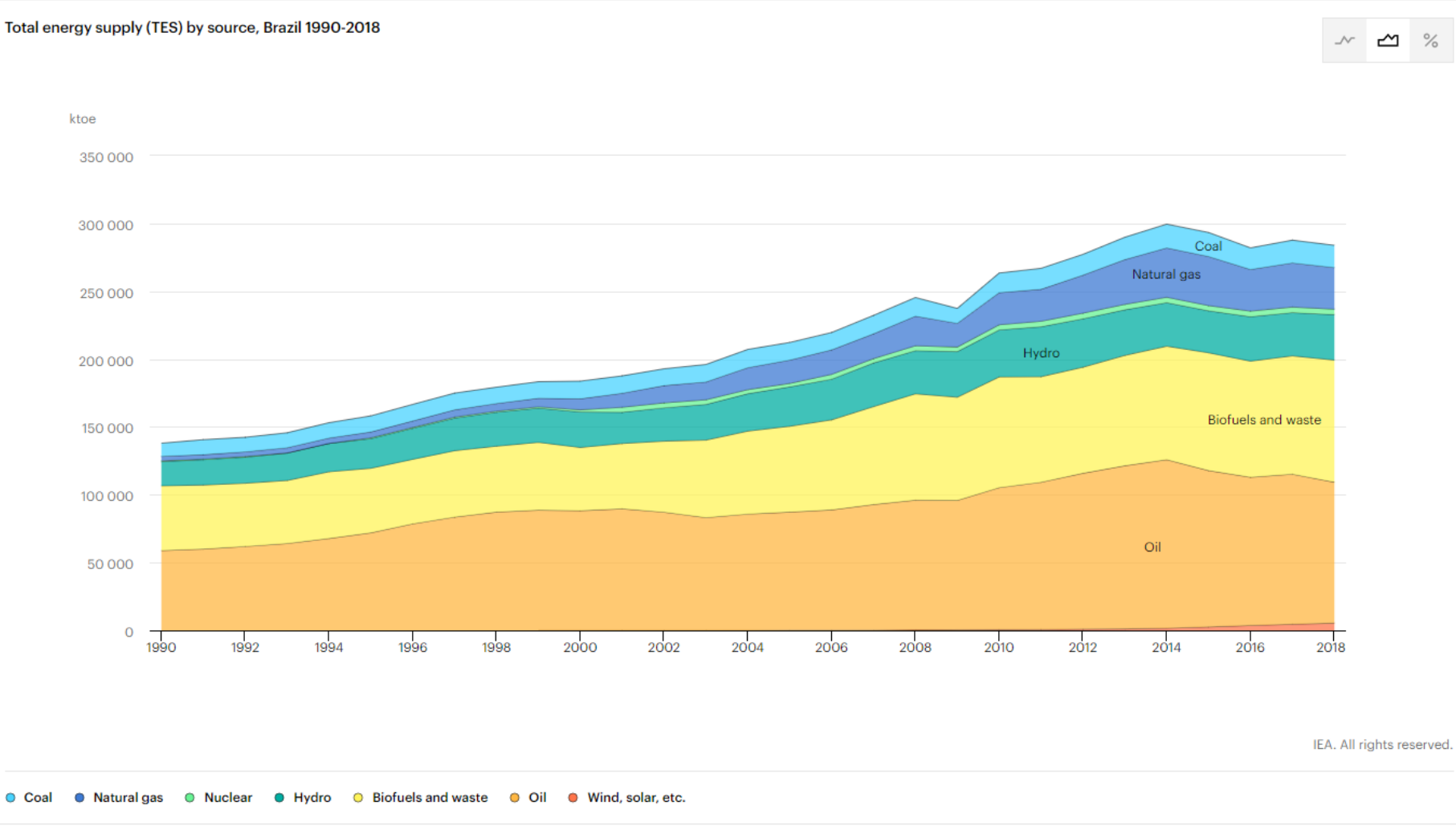
Energia no mundo

- Oferta de energia primária – mundo [ktoe]



Energia no mundo

- Oferta de energia primária – Brasil [ktoe]



Energia no mundo

- Energia elétrica – capacidade instalada no Brasil

B

Matriz Elétrica Brasileira

SCG - Superintendência de Concessões e Autorizações de Geração

Data de referência dos dados: 16/9/2020 01:00

Filtro por Fonte

CGH | CGU | EOL | PCH | UFV | UHE | UTE | UTN

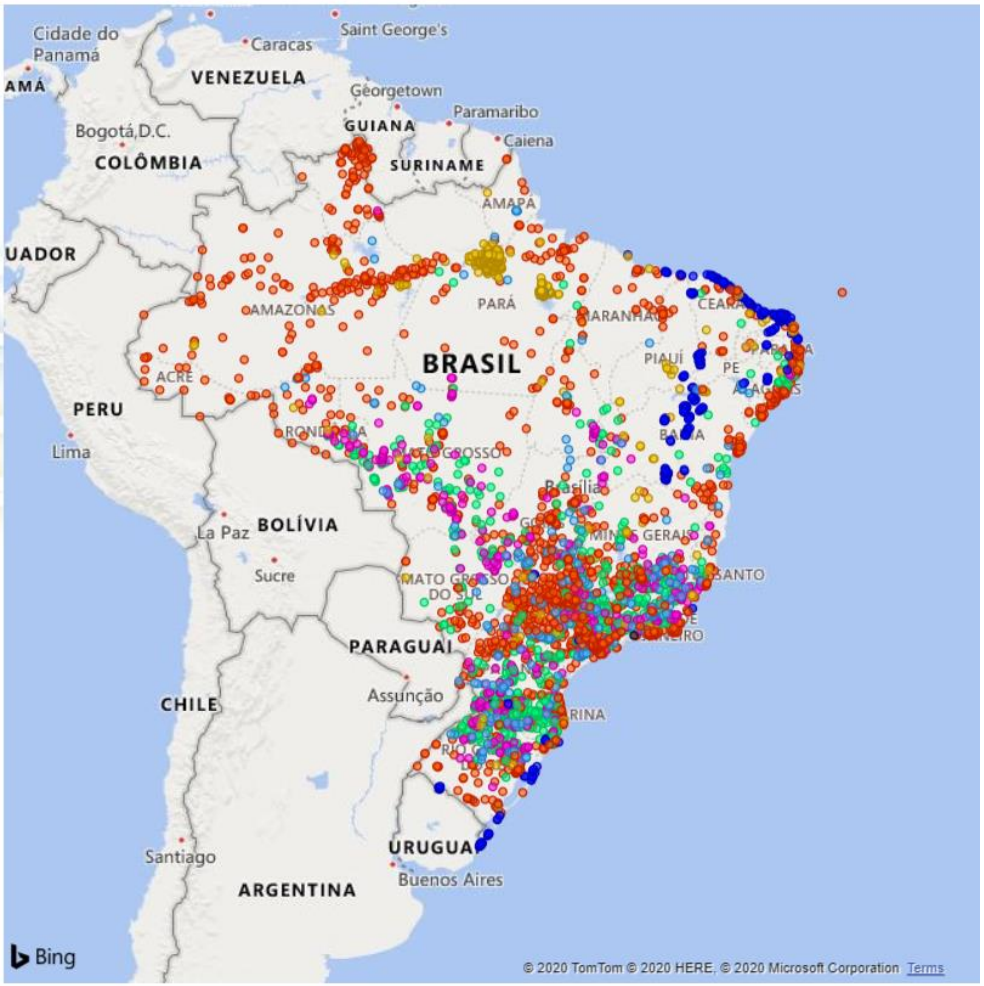
Filtro por Estado

AC | AL | AM | AP | BA | CE | DF | ES | GO
MA | MG | MS | MT | PA | PB | PE | PI | PR
RJ | RN | RO | RR | RS | SC | SE | SP | TO

Filtro por Fase

Construção não iniciada
Construção
Operação

CGH
CGU
EOL
PCH
UFV
UHE
UTE
UTN



Tipo	Potência Outorgada (kW)	Potência Fiscalizada (kW)	Quantidade	% (Pot. Outorgada)
CGH	813.644,77	811.129,77	736	0,46%
CGU	50,00	50,00	1	0,00%
EOL	16.146.003,86	16.092.522,86	653	9,22%
PCH	5.407.080,49	5.355.148,57	419	3,09%
UFV	3.025.726,25	3.017.726,25	3904	1,73%
UHE	102.999.428,00	103.026.876,00	219	58,81%
UTE	44.755.194,79	43.011.586,89	3062	25,55%
UTN	1.990.000,00	1.990.000,00	2	1,14%
Total	**175.137.128,16**	**173.305.040,34**	**8996**	**100,00%**

SIGA ANEEL (16/09/20)

Energia no mundo

- Energia elétrica – capacidade instalada no Brasil

Matriz Renováveis / Não Renováveis

SCG - Superintendência de Concessões e Autorizações de Geração

Data de referência dos dados: 16/9/2020 01:00

RENOVÁVEIS ▶ 82,79%

Biomassa

Quantidade	Potência (kW)	%
574	15.182.942,45	8,76%

Hídrica

Quantidade	Potência (kW)	%
1.374	109.193.154,34	63,01%

Solar

Quantidade	Potência (kW)	%
3.904	3.017.726,25	1,74%

Eólica

Quantidade	Potência (kW)	%
653	16.092.522,86	9,29%

Undi-elétrica

Quantidade	Potência (kW)	%
1	50,00	0,00003%

NÃO RENOVÁVEIS ▶ 17,21%

Petróleo e outros

Quantidade	Potência (kW)	%
2.300	9.300.875,65	5,37%

Gás natural

Quantidade	Potência (kW)	%
166	14.944.938,79	8,62%

Carvão mineral

Quantidade	Potência (kW)	%
22	3.582.830,00	2,07%

Nuclear

Quantidade	Potência (kW)	%
2	1.990.000,00	1,15%

- Empreendimentos em Operação
- % da Potência Fiscalizada

SIGA ANEEL (16/09/20)

Energia no mundo

- Energia elétrica – geração por tipo

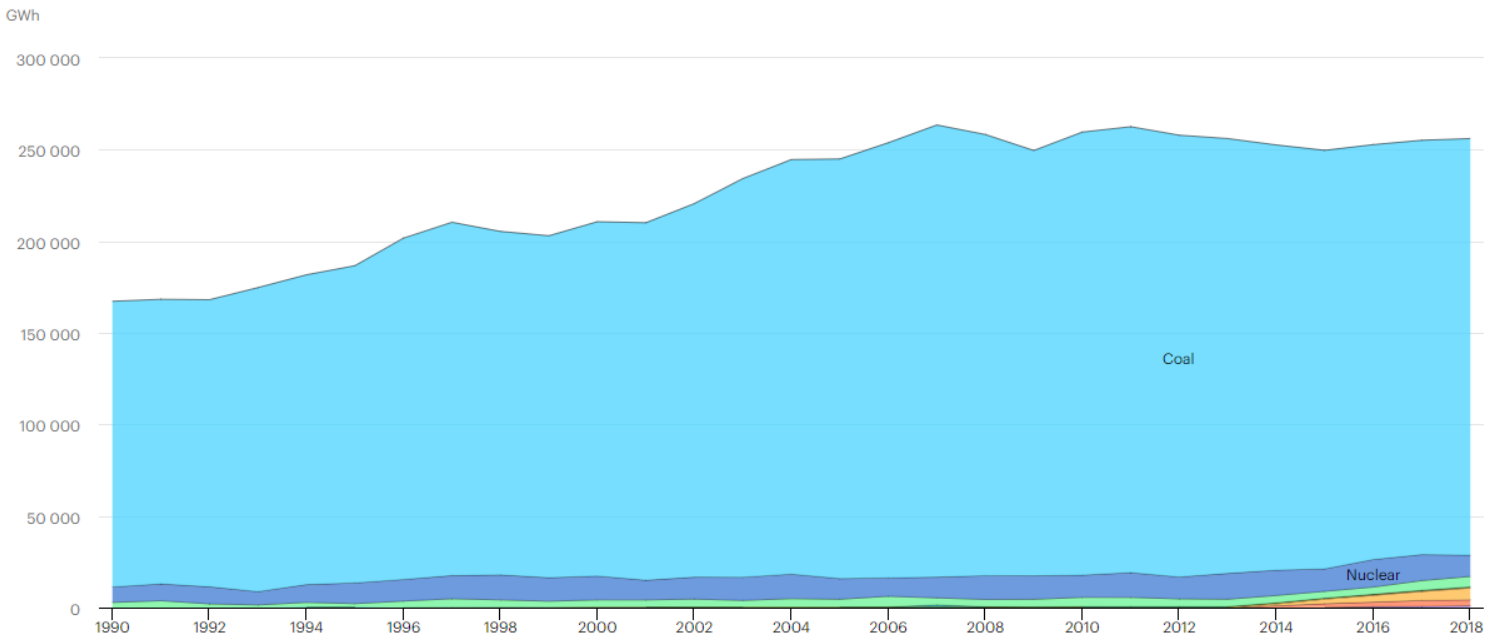
Electricity generation by source, Brazil 1990-2018

Electricity generation by source, Russian Federation 1990-2018

Electricity generation by source, India 1990-2018

Electricity generation by source, China (People's Republic of China and Hong Kong China) 1990-2018

Electricity generation by source, South Africa 1990-2018



IEA

Energia no mundo

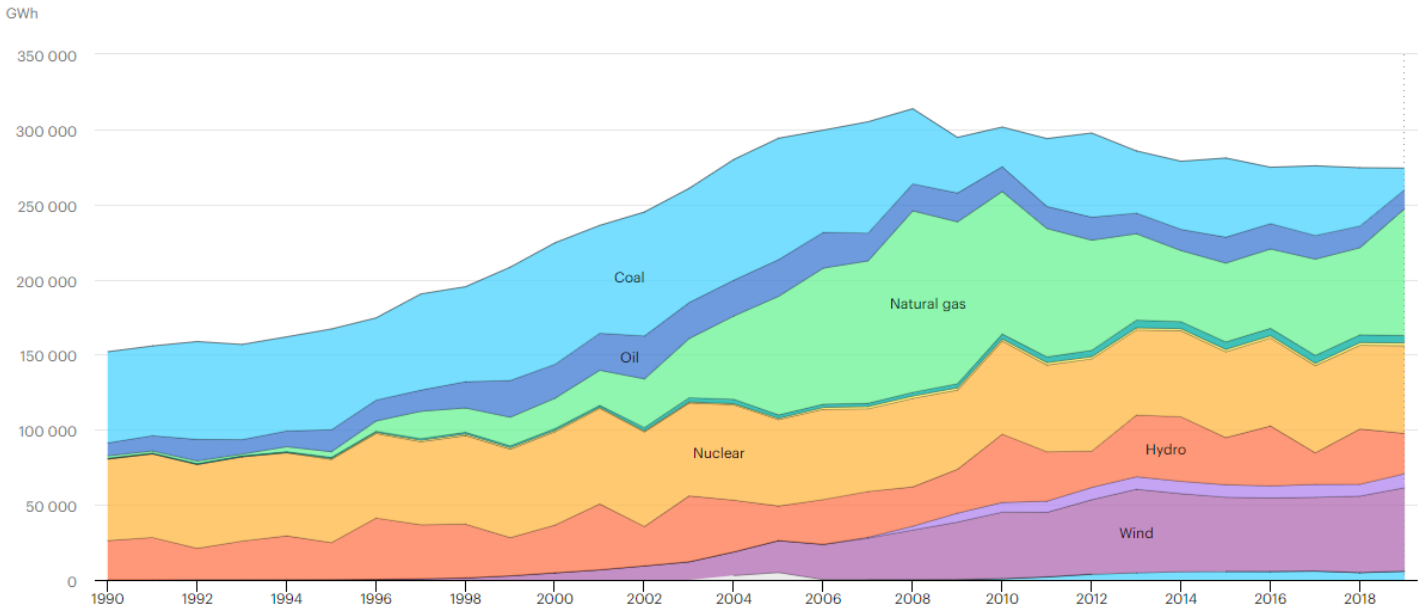
- Energia elétrica – geração por tipo

Electricity generation by source, United States 1990-2019

Electricity generation by source, Germany 1990-2019

Electricity generation by source, France 1990-2019

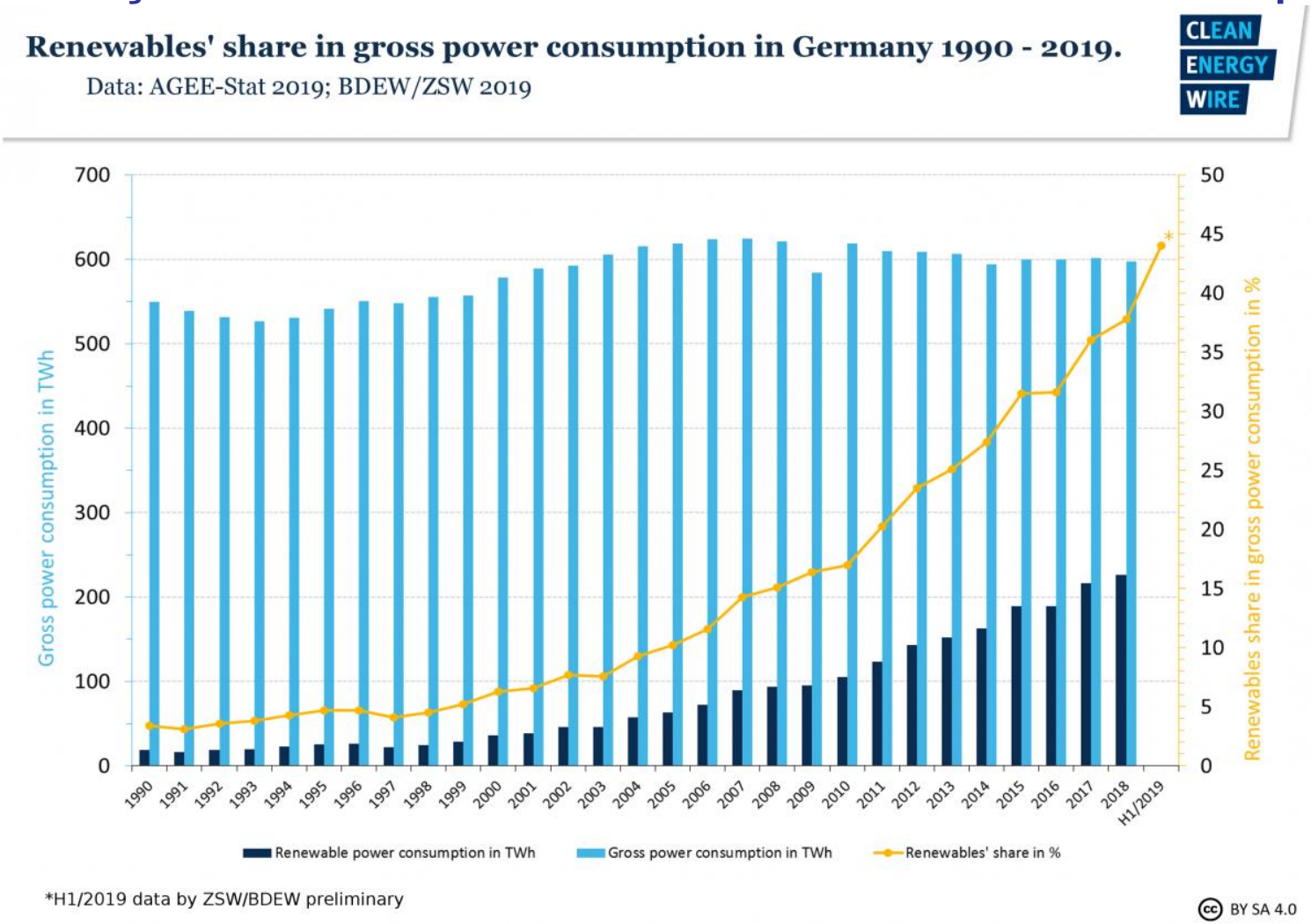
Electricity generation by source, Spain 1990-2019



IEA

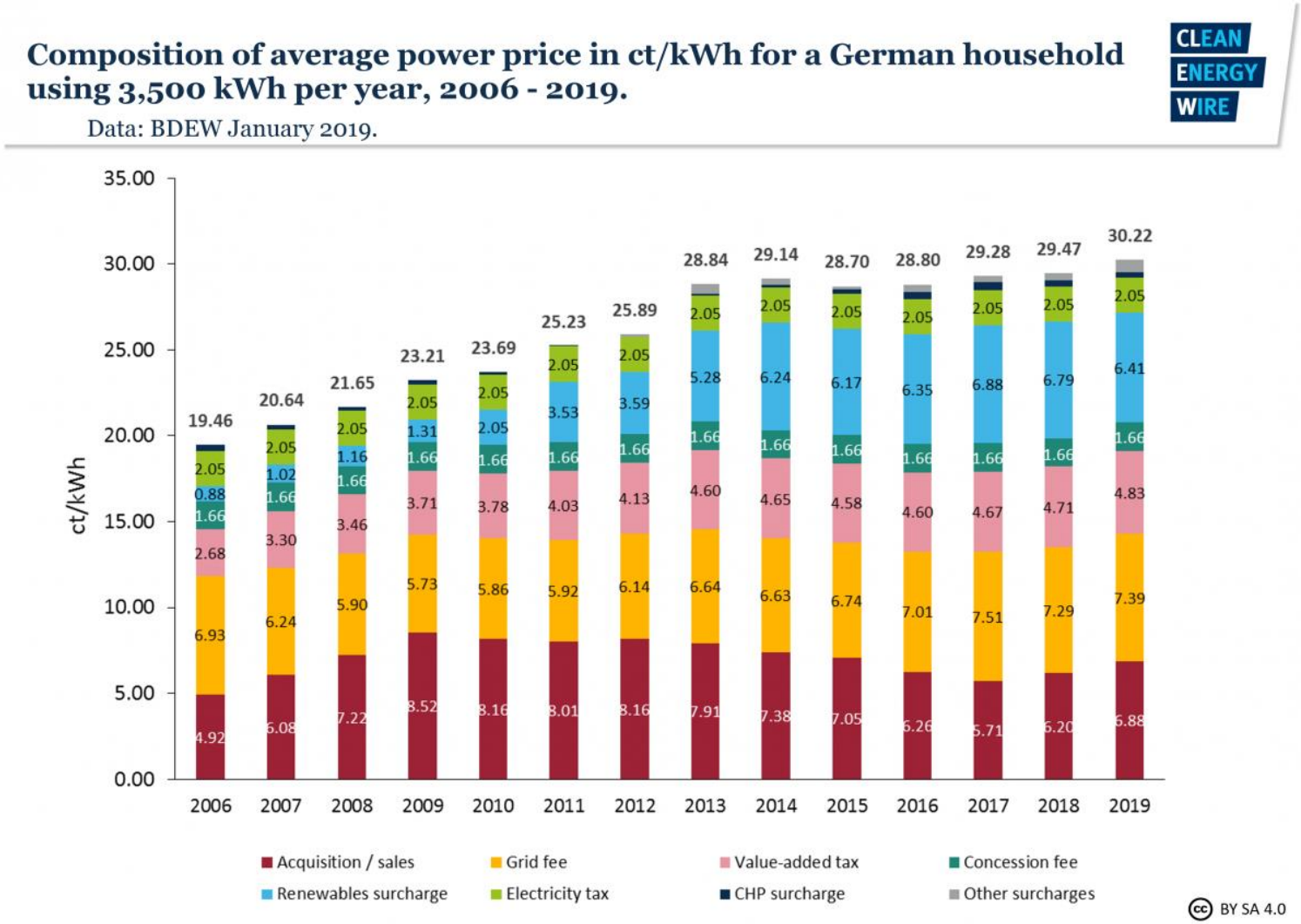
Energia no mundo

- Redução das emissões de CO2 – tarefa complicada



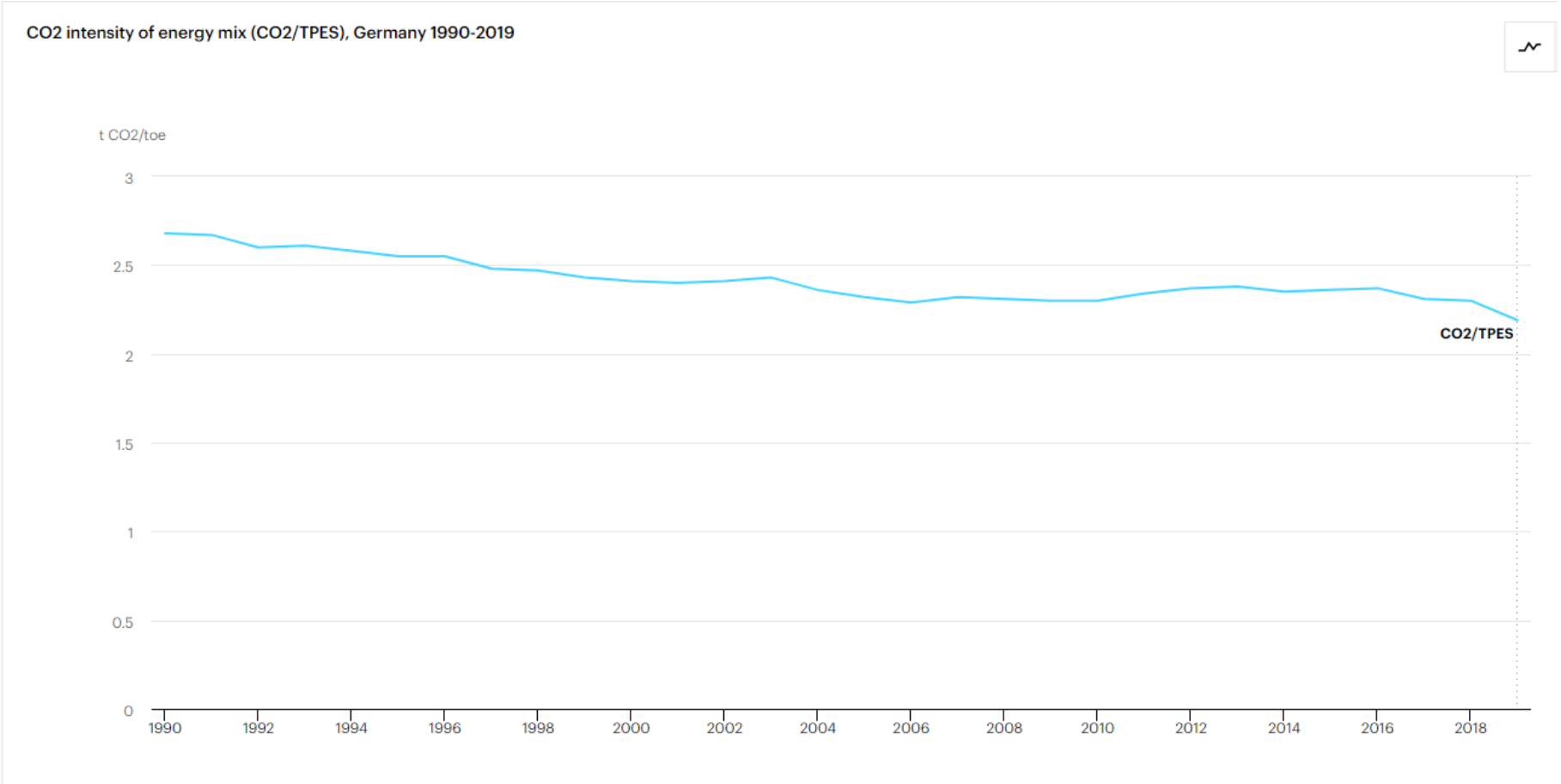
Energia no mundo

- Redução das emissões de CO2 – tarefa complicada



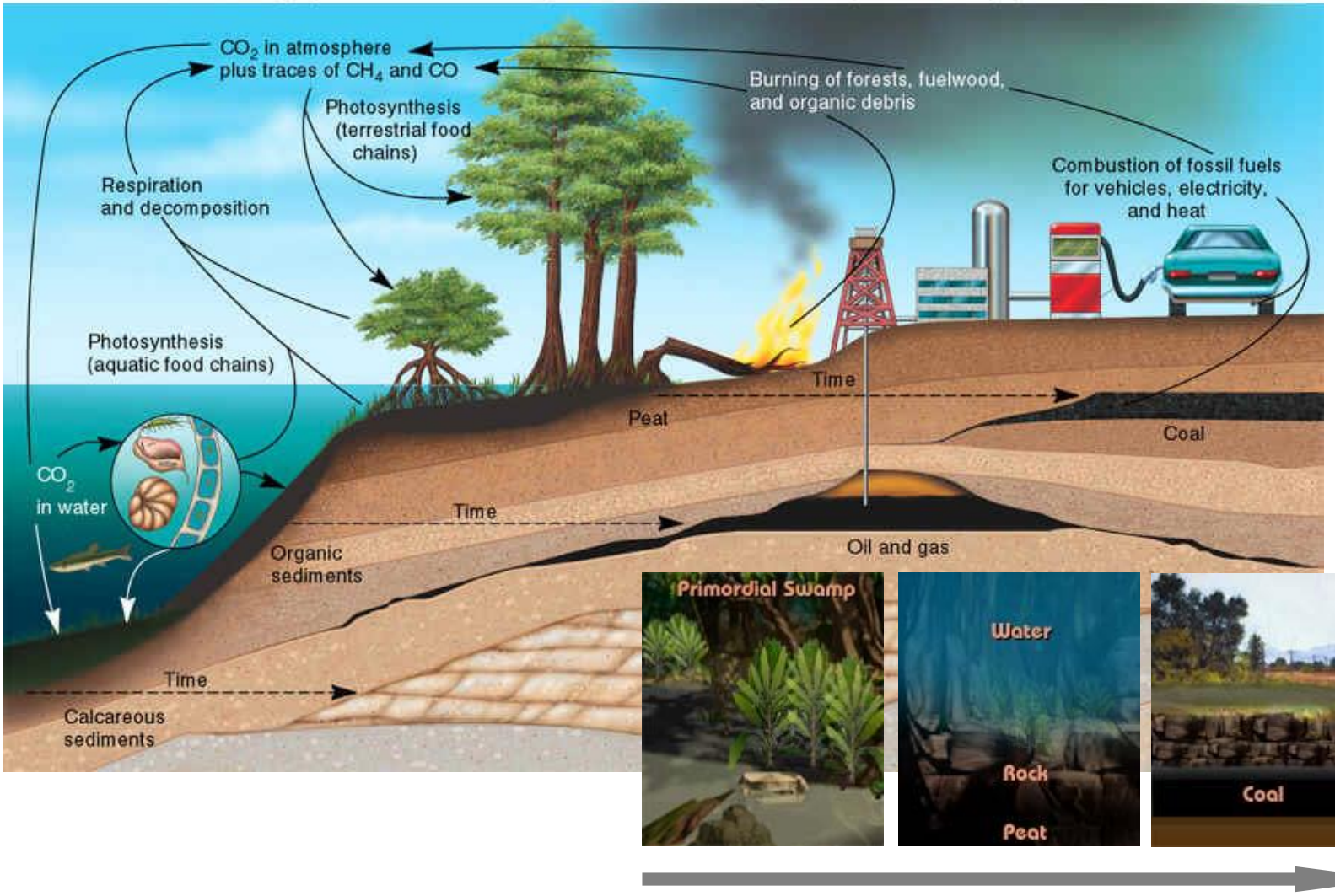
Energia no mundo

- Redução das emissões de CO2 – tarefa complicada



IEA

Formação



http://www.fe.doe.gov/education/energylessons/coal/gen_howformed.html

Formação

- Turfa

Campo de turfa[1]

Carvão linhito

[1]http://carlosrabello.org/geografia/biogeografia/flora/turfa/

Características gerais

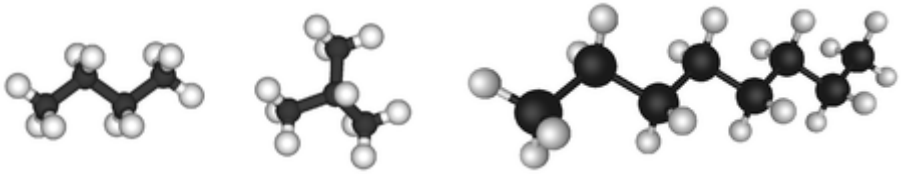
- Petróleo

Composição química [%(m/m)]

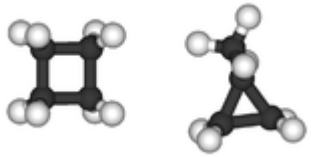
Componentes	Faixa
Carbono	83-87
Hidrogênio	10-14
Enxofre	0,05-6,0
Nitrogênio	0,1-2,0
Oxigênio	0,05-1,5
Metais	0,00-0,14

Hidrocarbonetos	Média	Faixa
Alcanos	30	15-60
Naftênicos	49	30-60
Aromáticos	15	3-30
Asfálticos	6	Complem.

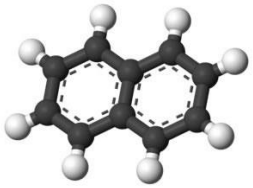
Alcanos:



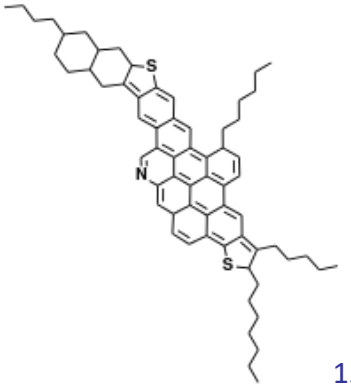
Naftênicos (cicloalcanos):



Aromáticos



Asfaltenos



Ramana, U.V. Crude oil characteristics and refinary products. Workshop on Refinary and Petrochemicals, 2010.

Características gerais

- Petróleo

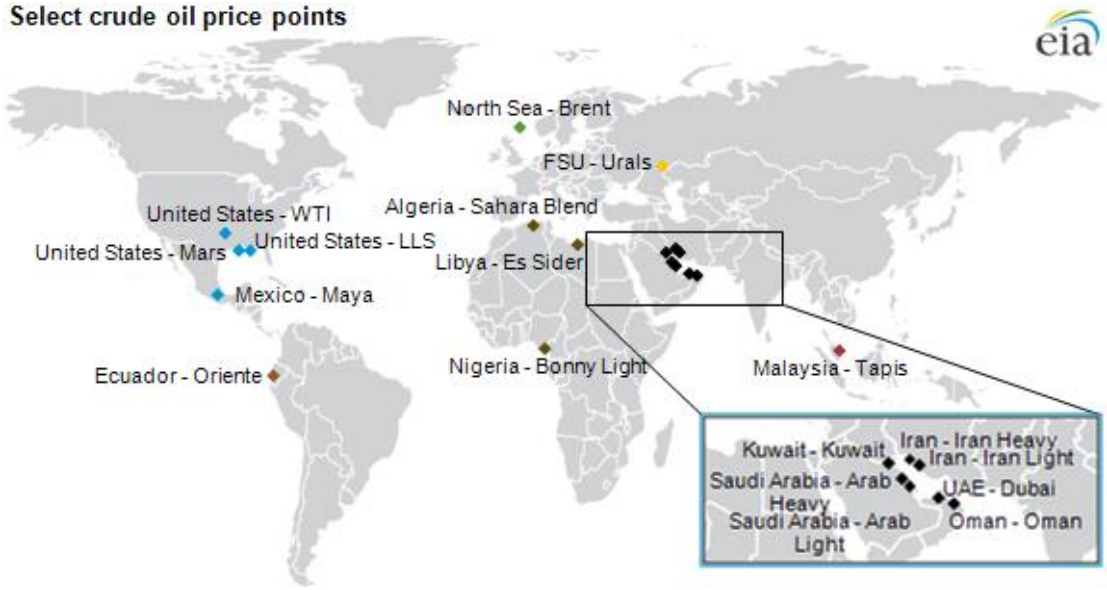
°API=141,5/ρ – 131,5

Classificação do Petróleo[1]

a) **Densidade:** Leves (acima de 30 °API); Médios (entre 21 e 30 °API) e Pesados (abaixo de 21 °API);

b) **Constituintes:** base naftênica; base aromática; base parafínica;

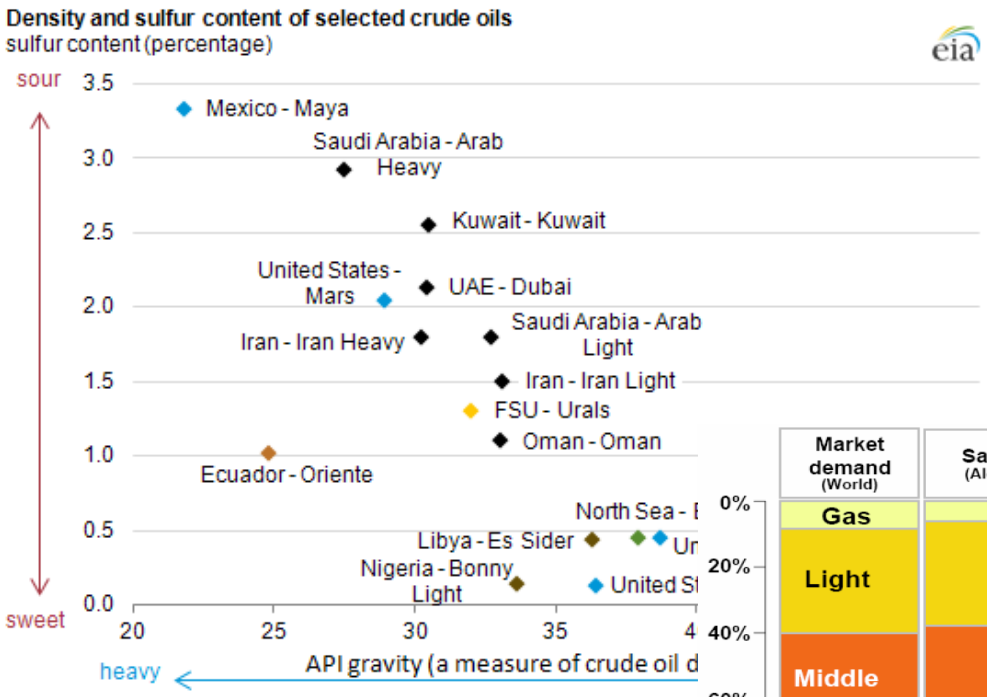
c) **Local de origem[2]:**

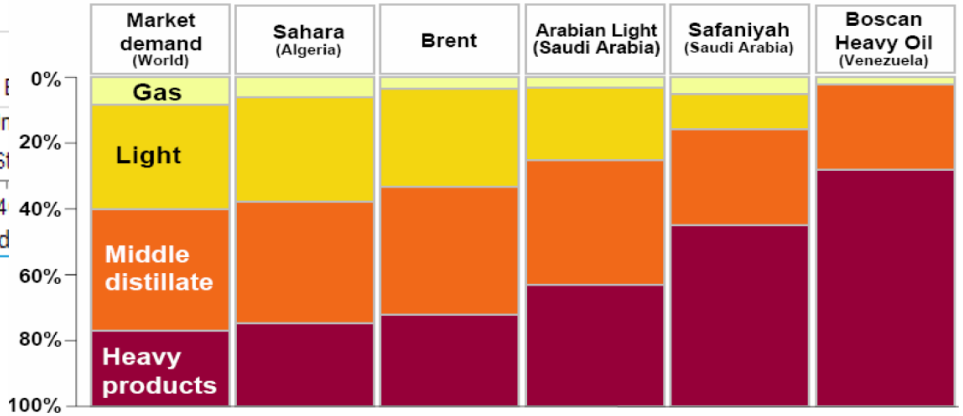


[1] http://www.ufrgs.br/lapol/materias_primas/ll_26.html
[2] http://www.eia.gov/todayinenergy/detail.cfm?id=7110

Características gerais

- Petróleo





	Market demand (World)	Sahara (Algeria)	Brent	Arabian Light (Saudi Arabia)	Safaniyah (Saudi Arabia)	Boscan Heavy Oil (Venezuela)
Density	0,806	0,837	0,855	0,893	0,995	
° API	44	37,5	34	27	10,7	
Sulfur content Wt %	0,2	0,3	1,7	2,8	5,3	

http://www.eia.gov/todayinenergy/detail.cfm?id=7110

Ramana, U.V. Crude oil characteristics and refinary products. Workshop on Refinary and Petrochemicals, 2010.

Características gerais

- Gás natural

Composição química [%(v/v)]

Component	Typical Analysis (mole %)	Range (mole %)
Methane	95.0	87.0 - 97.0
Ethane	3.2	1.5 - 7.0
Propane	0.2	0.1 - 1.5
iso - Butane	0.03	0.01 - 0.3
normal - Butane	0.03	0.01 - 0.3
iso - Pentane	0.01	trace - 0.04
normal - Pentane	0.01	trace - 0.04
Hexanes plus	0.01	trace - 0.06
Nitrogen	1.0	0.2 - 5.5
Carbon Dioxide	0.5	0.1 - 1.0
Oxygen	0.02	0.01 - 0.1
Hydrogen	trace	trace - 0.02
Specific Gravity	0.58	0.57 - 0.62
Gross Heating Value (MJ/m^3), dry basis *	38.0	36.0 - 40.2

[1]https://www.uniongas.com/about-us/about-natural-gas/Chemical-Composition-of-Natural-Gas

Características gerais

- Carvão mineral

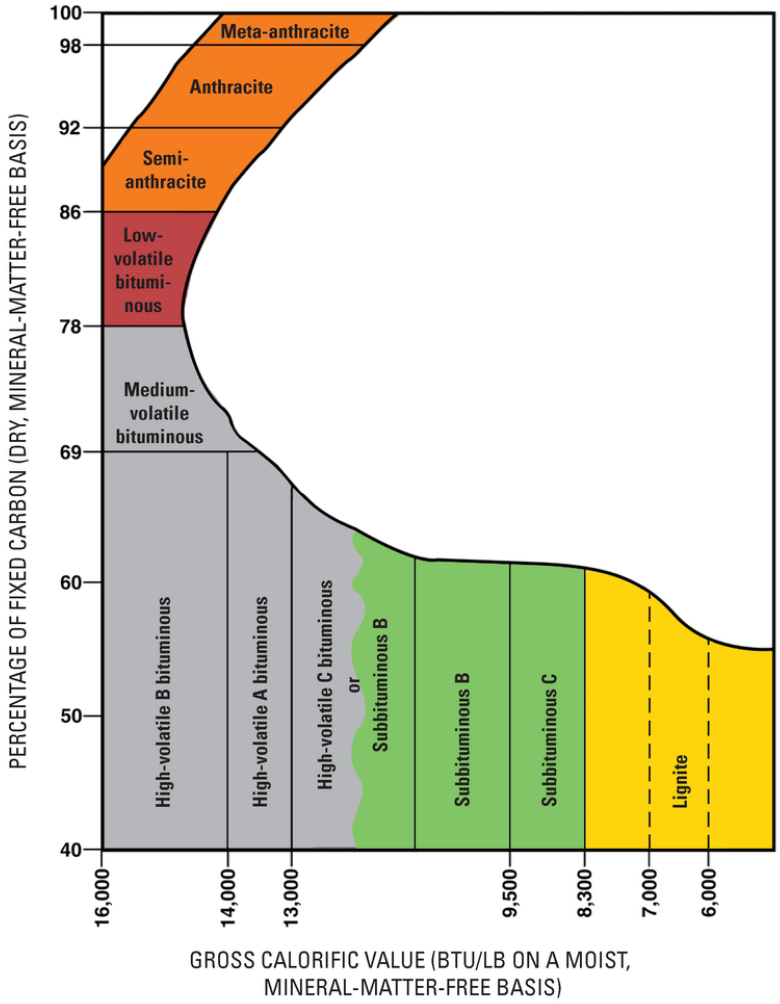
Class	Group	Fixed Carbon Dry%	Fixed Carbon Moist%	Volatile Matter Dry%	Volatile Matter Moist%	Energy Dry (BTUs/lb)	Energy Moist (Mj/kg)
Anthracite	Met anthracite	> 98	> 92	< 2	< 2	13,500	31.4
	Anthracite	92–98	89–95	2–8	2–8	15,300	35.5
	Semi anthracite	86–92	81–89	8–14	8–15	14,900	34.6
Bituminous	Low-volatile	78–86	73–81	14–22	13–21	15,400	35.8
	Medium-volatile	69–78	65–73	22–31	21–29	14,900	34.6
	High-volatile A	< 69	58–65	> 31	> 30	>14,000	>32.5
	High-volatile B	57	53	57	40	13,000–14,000	30.2–32.5
Sub-bituminous	High-volatile C	54	45	54	40	10,500–13-000	24.4–30.2
	A	55	45	55	38	10,500–11,500	24.4–26.7
	B	56	43	56	35	9,500–10,500	22.1–24.4
	C	53	37	53	36	8,300–9,500	19.3–22.1
Lignite (brown coal)	Lignite A	52	32	35	38	6,300–8,300	14.7–-19.3
	Lignite B	52	26	32	50	< 6,300	< 14.7

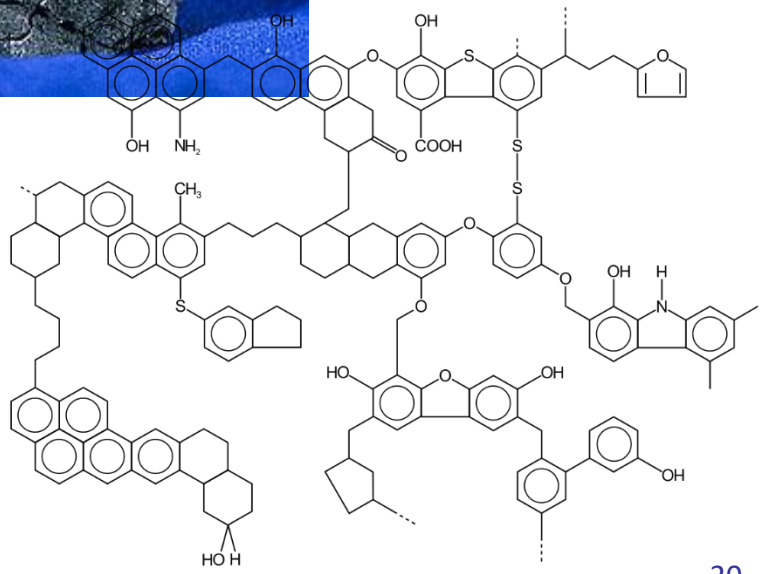
Source: American Society for Testing and Materials [37].

[1]Eberhard Lindner; Chemie für Ingenieure; Lindner Verlag Karlsruhe, S. 258
[2]Vissoto (2012)

Características gerais

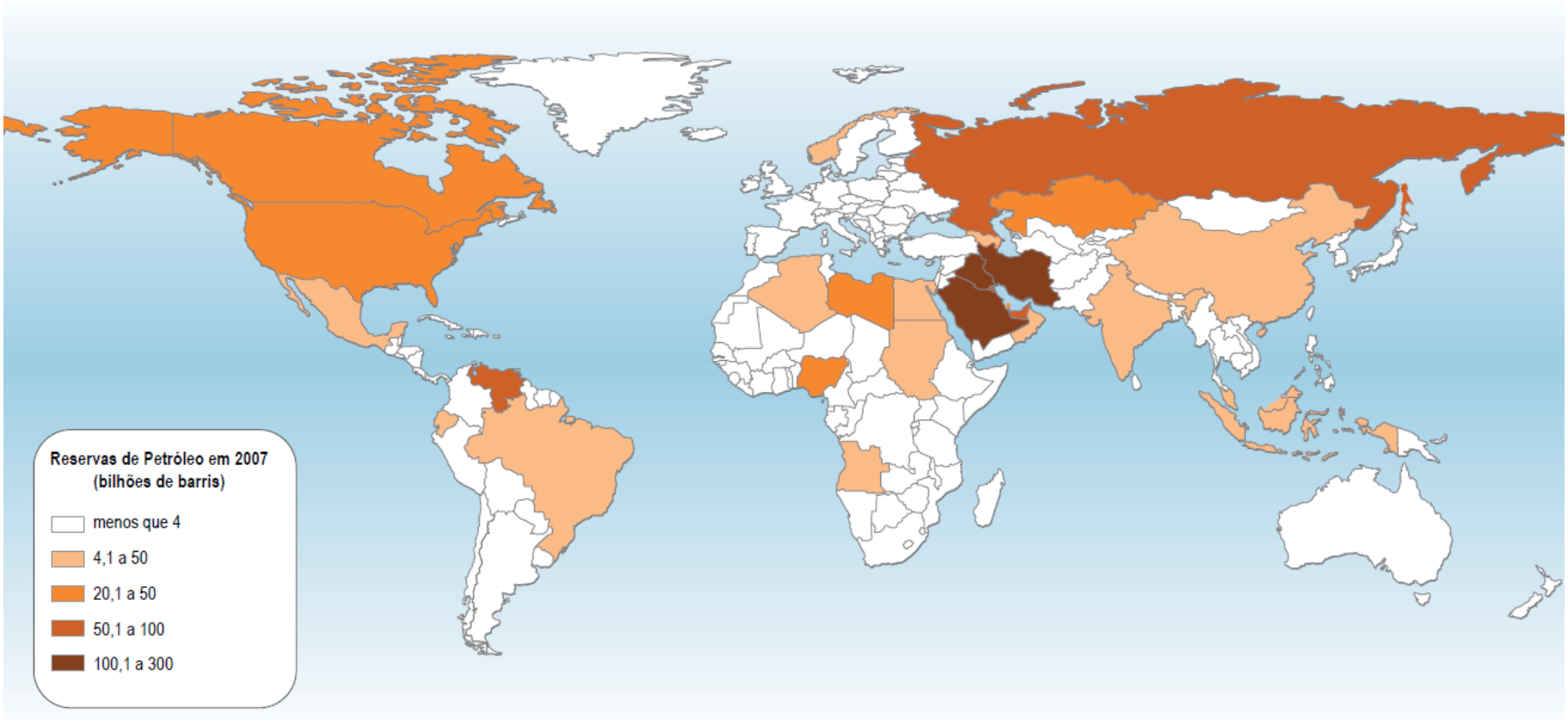
- Carvão mineral





Reservas no mundo e no Brasil

- Petróleo[1]



1730 bilhões de barris [2]

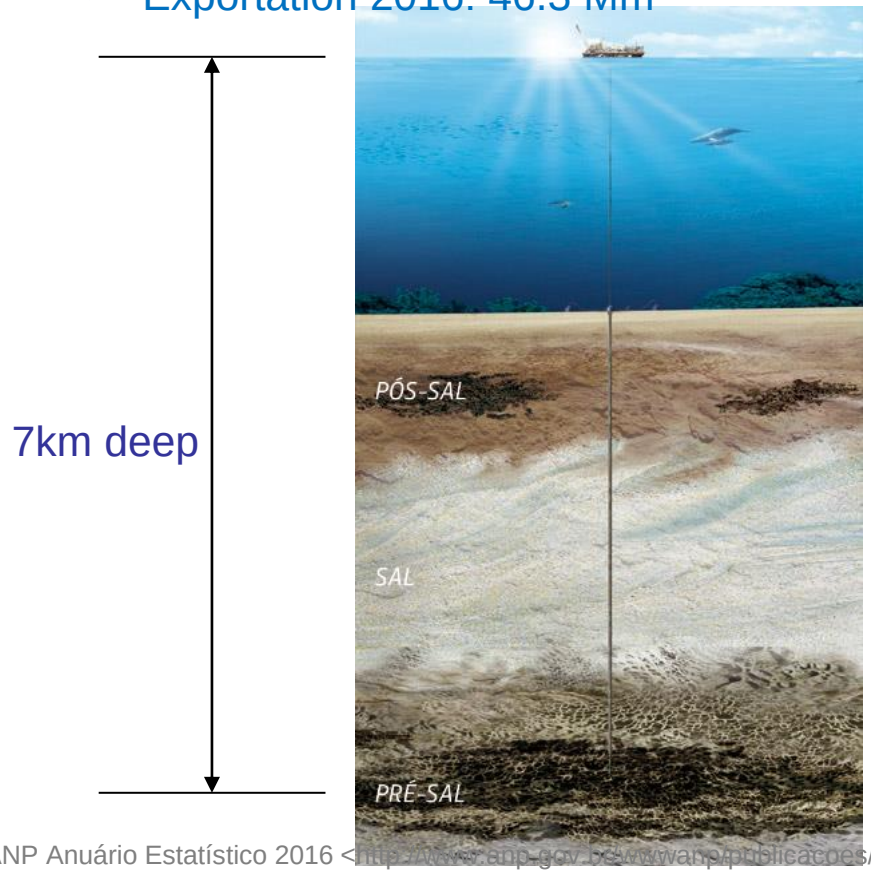
13.4 bilhões de barris (Brasil) [2]

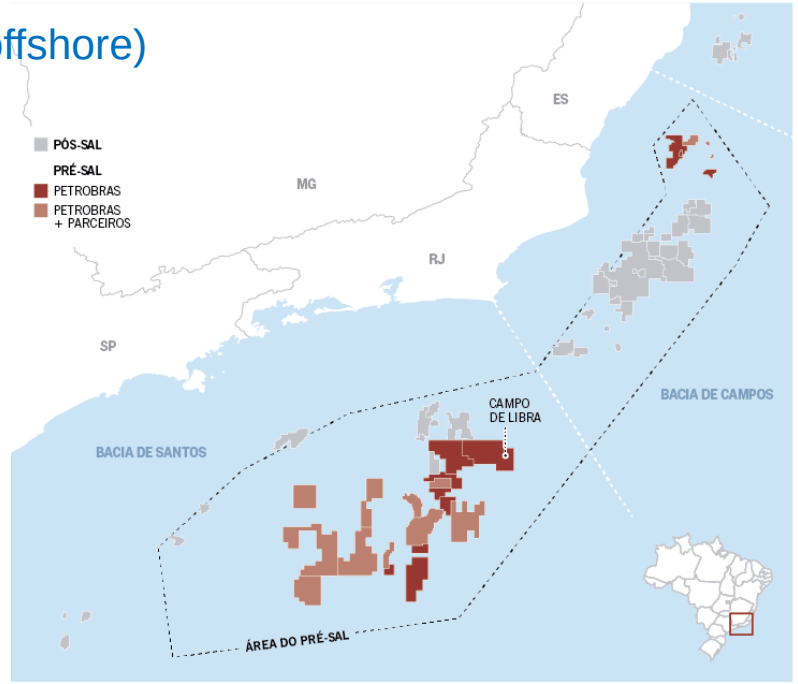
[1]BP Global – disponível em www.bp.com

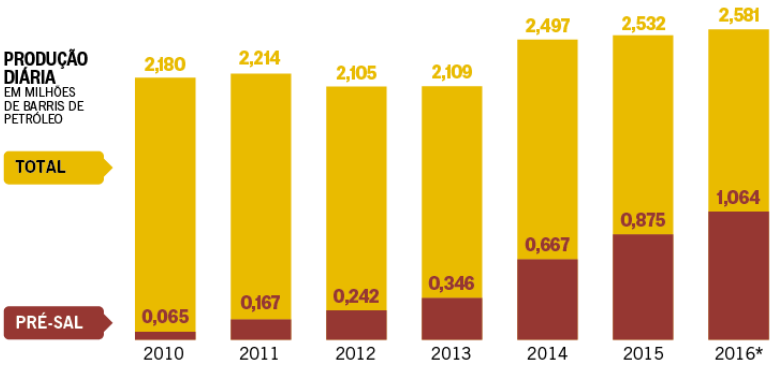
[2]ANP – Anuário estatístico 2019

Reservas no mundo e no Brasil

- Petróleo
  - Production 2016: 146.1 Mm³/year (>90% offshore)
  - Presal > 40%
  - Importation 2016: 10.4 Mm³
  - Exportation 2016: 46.3 Mm³



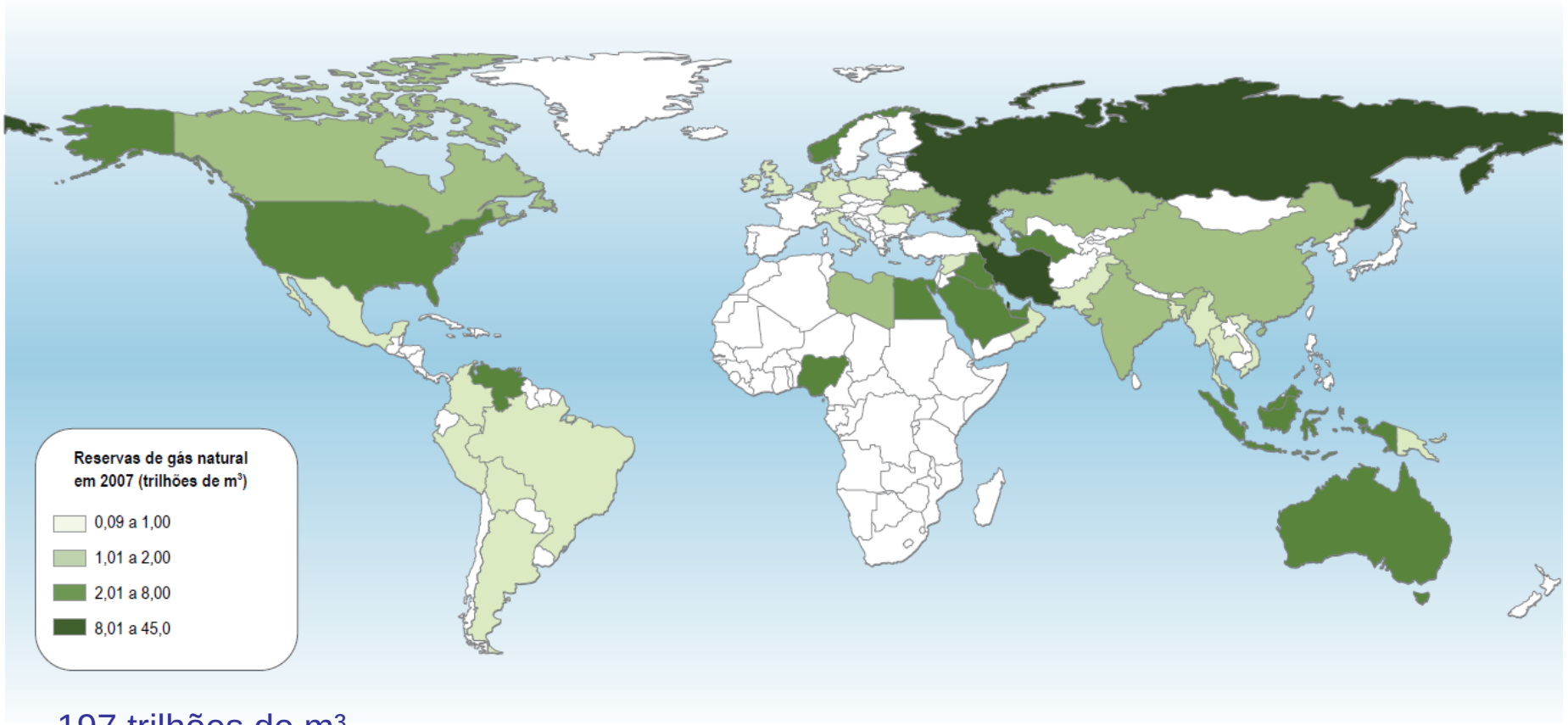




[1]ANP Anuário Estatístico 2016 <http://www.anp.gov.br/wwwanp/publicacoes/anuario-estatistico/3819-anuario-estatistico-201>

Reservas no mundo e no Brasil

- Gás natural (convencional)



197 trilhões de m³

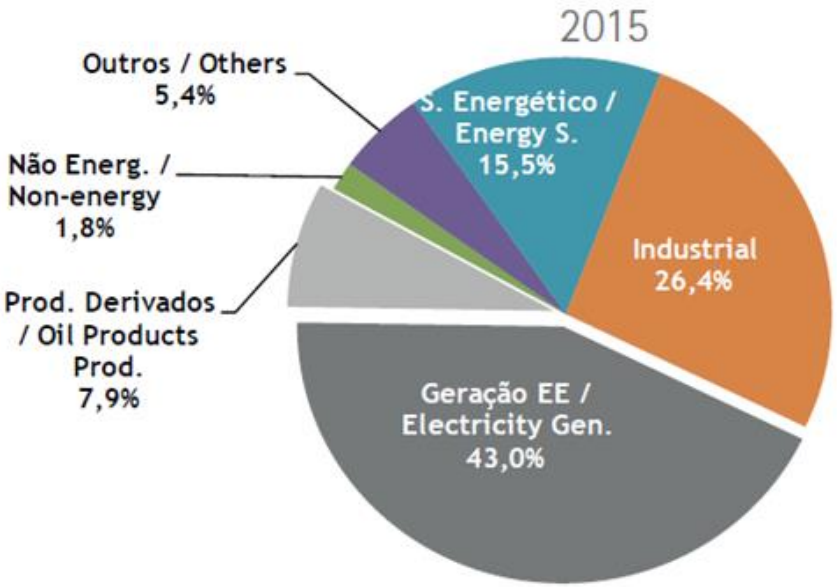
0,38 trilhões de m³ (Brasil)

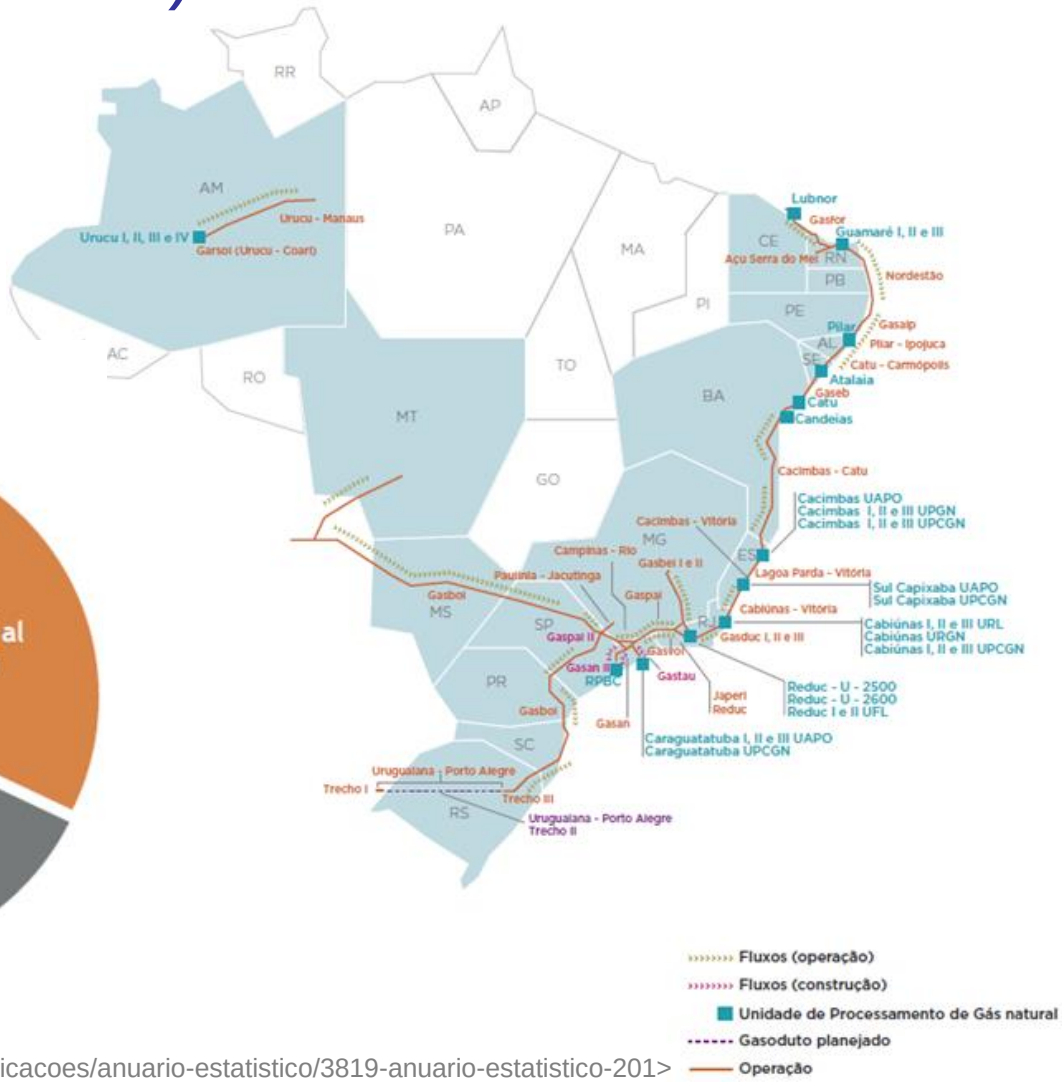
[1]BP Global – disponível em www.bp.com

[2]ANP – Anuário estatístico 2019

Reservas no mundo e no Brasil

- Gás natural (convencional)
  - Production 2016: 96.2 Mm^3/year
  - Importation 2016: 50.4 Mm^3
    - 62% from Bolivia

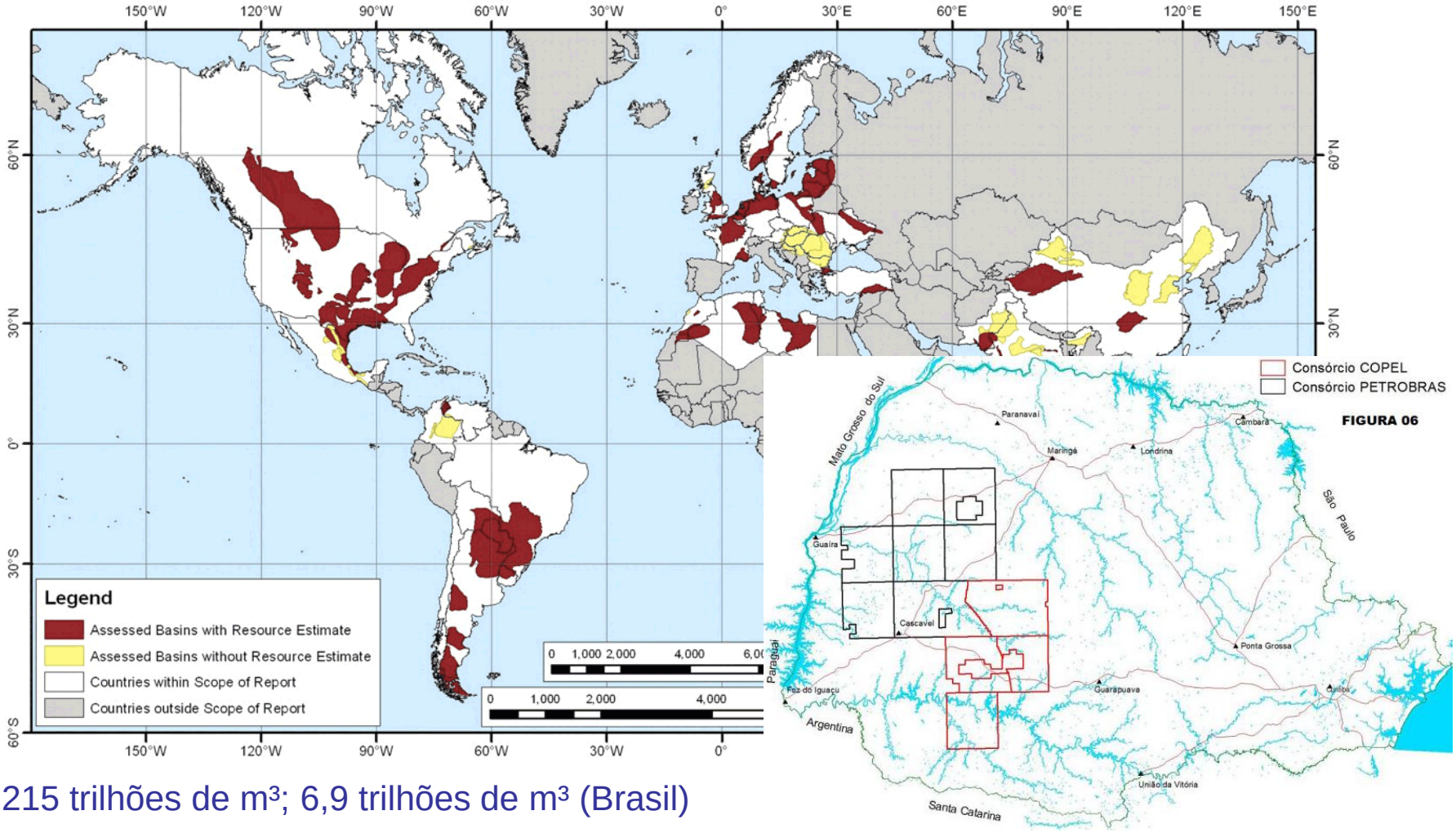




[1]ANP Anuário Estatístico 2016 <http://www.anp.gov.br/wwwanp/publicacoes/anuario-estatistico/3819-anuario-estatistico-201>

Reservas no mundo e no Brasil

- Gás natural (shale, gás de xisto)

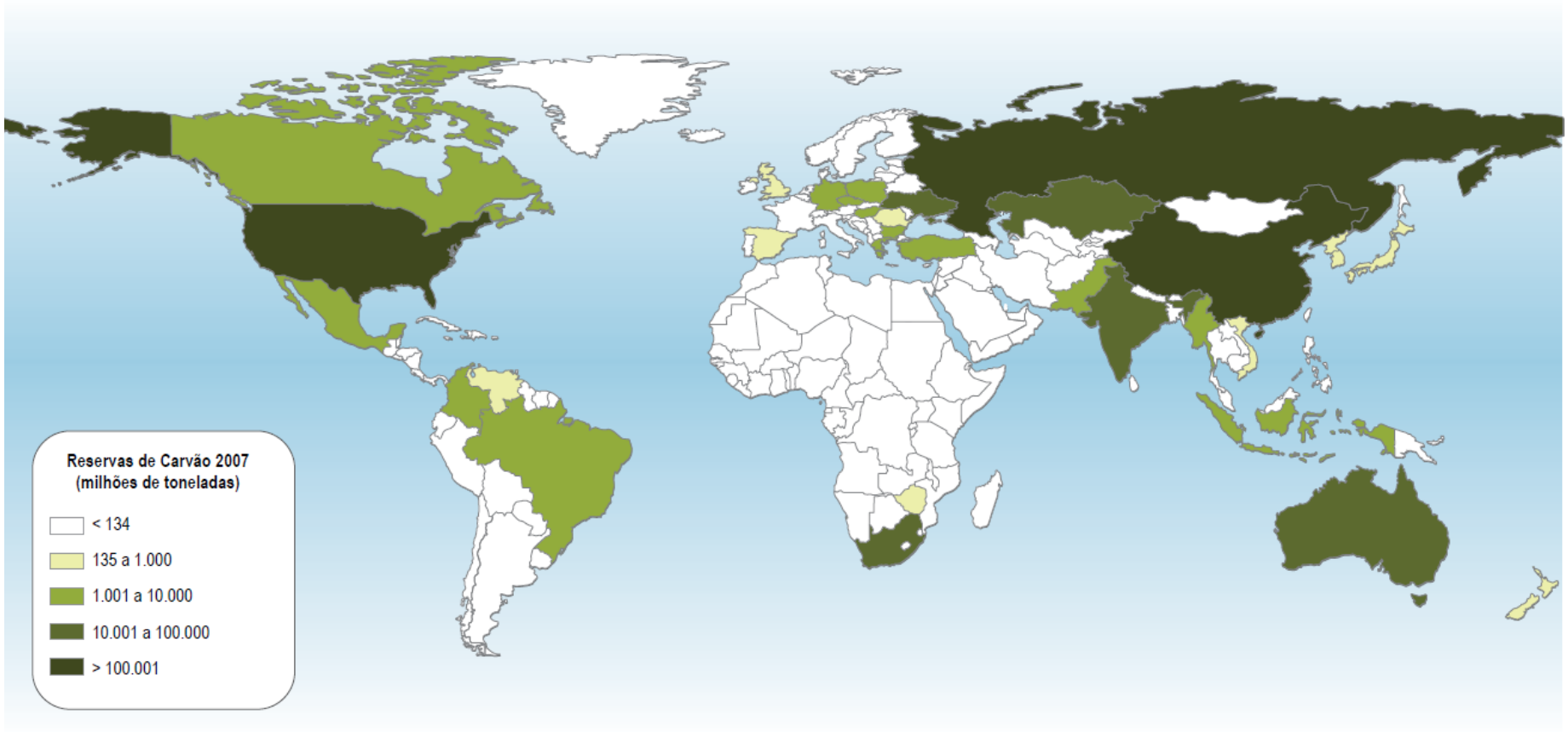


215 trilhões de m³; 6,9 trilhões de m³ (Brasil)

[1]EIA – disponível em https://www.eia.gov/analysis/studies/worldshalegas/

Reservas no mundo e no Brasil

- Carvão mineral



847 bilhões de toneladas

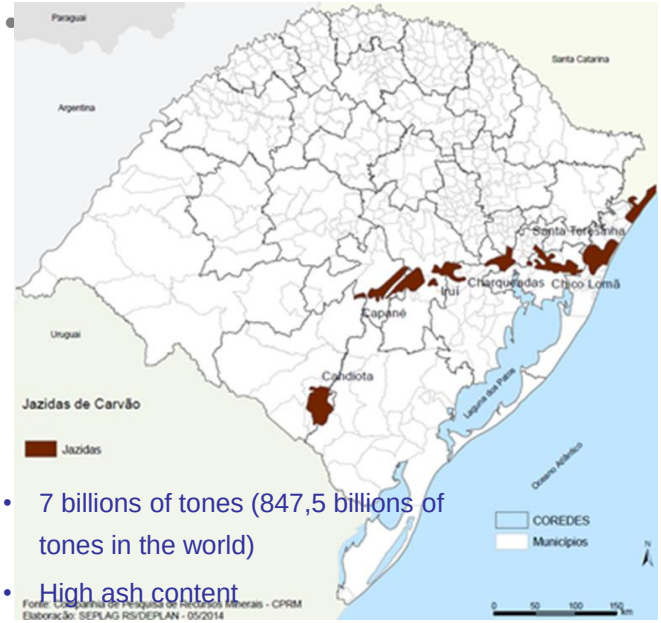
[1]BP Global – disponível em www.bp.com

Reservas no mundo e no Brasil

Carvão mineral

► Coal

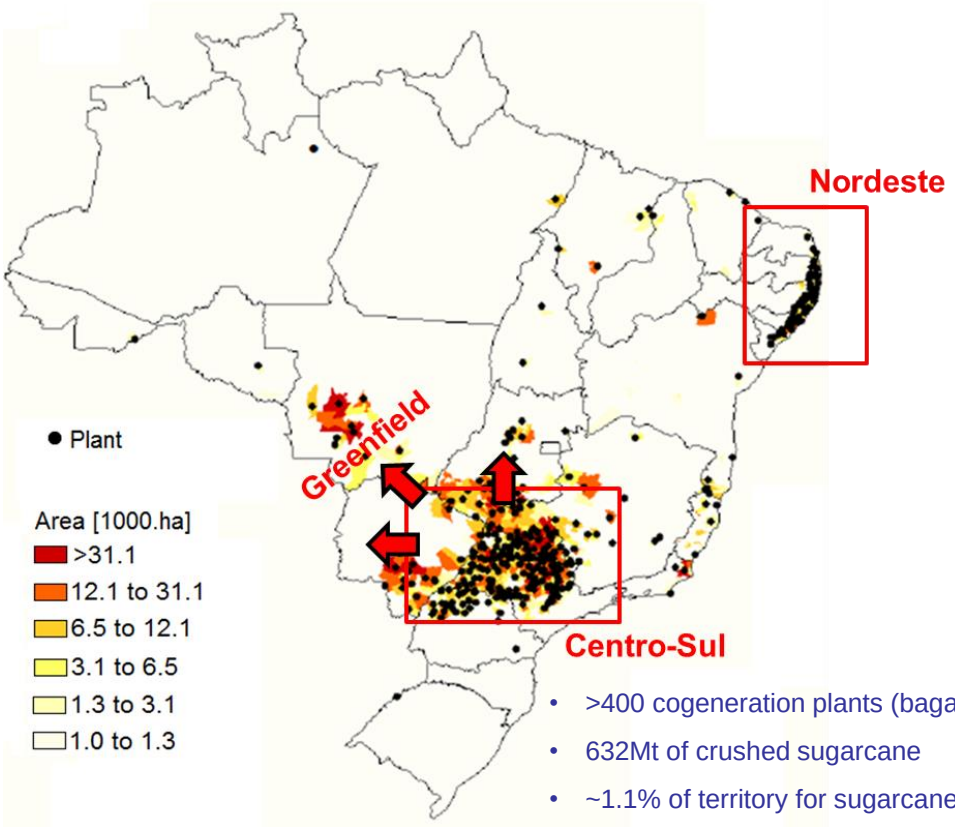
- 3.7 GW (2.3% of installed capacity)
- Steam coal:
  - Production 2015: 8Mt/year
  - Import 2015: 10Mt/year



- 7 billions of tones (847,5 billions of tones in the world)
- High ash content

► Biomass

- 14.1 GW (9% of installed capacity)
- 8% of total internal electricity supply



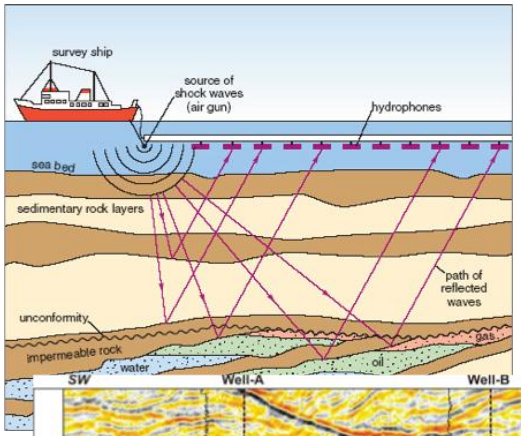
- >400 cogeneration plants (bagasse)
- 632Mt of crushed sugarcane
- ~1.1% of territory for sugarcane plantation

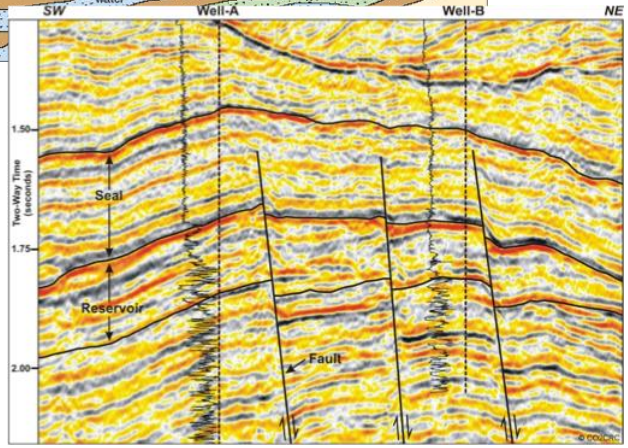
EPE BEN2016 <https://ben.epe.gov.br/>

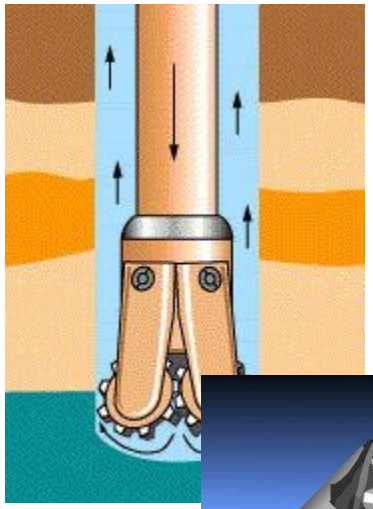
Modos de exploração

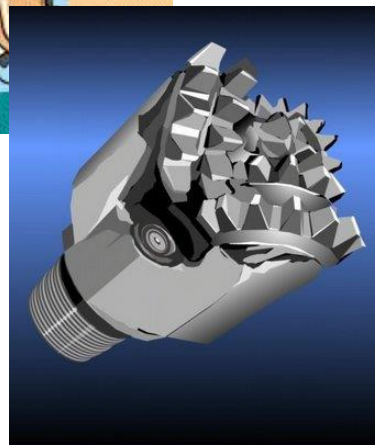
- Petróleo

Prospecção → Perfuração → Extração









Modos de exploração

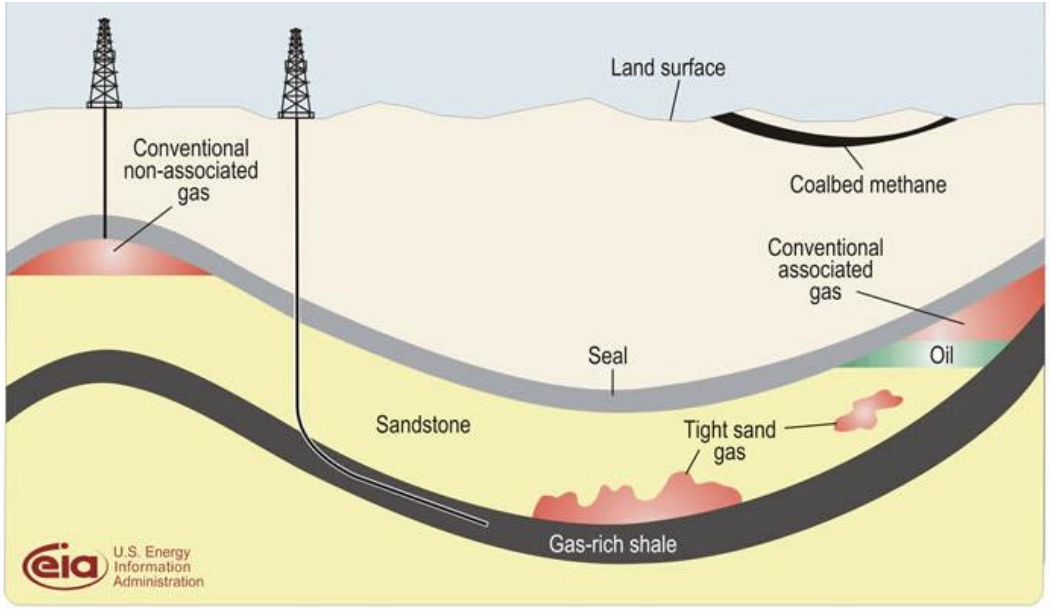
- Gás natural

Gás convencional

- Gás associado
- Gás não associado

Gás não convencional

- Fracking



Modos de exploração

- Carvão mineral

Lavra do carvão

- Céu aberto
- Subterrânea

Beneficiamento

- Extração de materiais inertes
- Secagem

Modos de exploração

- Carvão mineral

Conteúdo

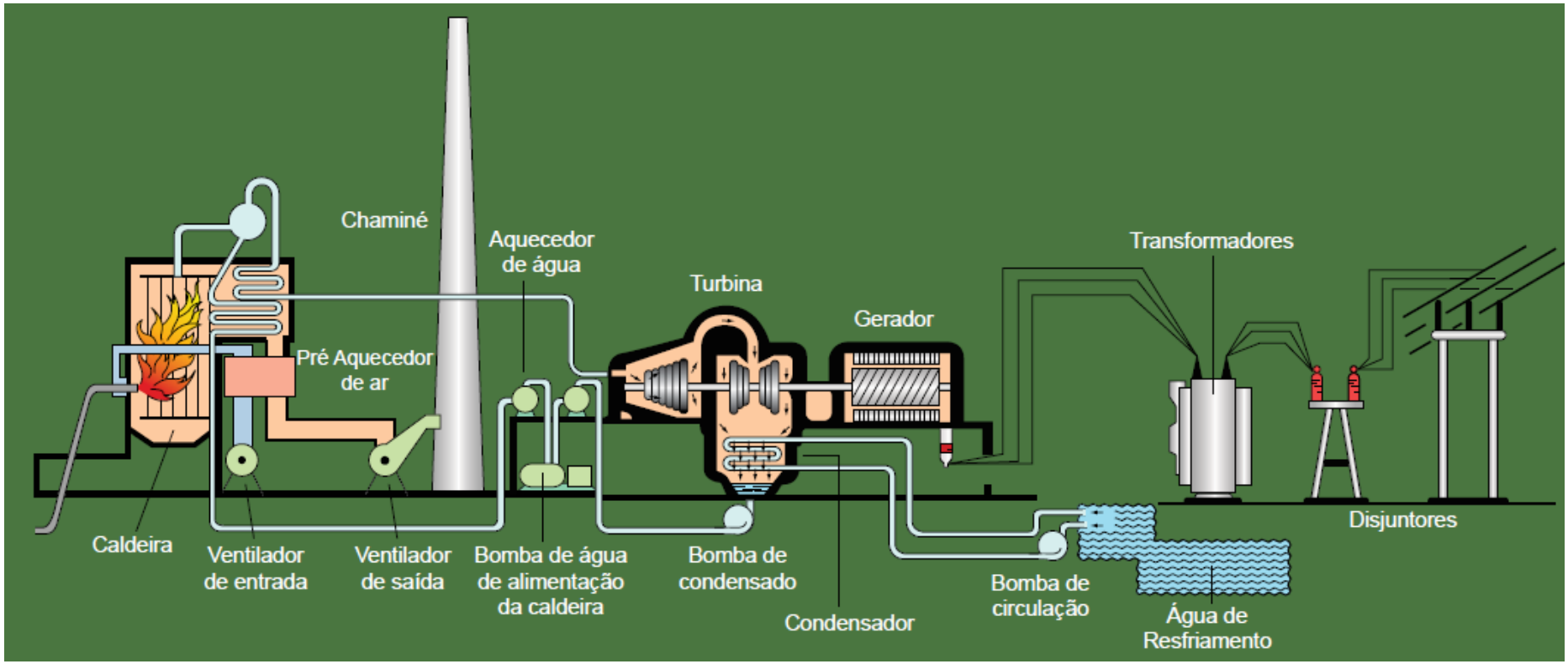
- Parte 1
  - Energia no mundo
  - Formação
  - Características gerais
  - Reservas no mundo e no Brasil
  - Modos de exploração
- Parte 2
  - Uso final
  - Impactos ambientais e desafios
  - Perspectivas

Uso final

- Diagrama de Sankey (International Energy Agency)
  - Avaliar consumo final (transporte, geração termelétrica, outros usos);

Uso final

- Petróleo



[1]ANEEL – Atlas de Energia Elétrica, 2008.

Uso final

- Petróleo

SUAPE: 381 MW; FC=0,70

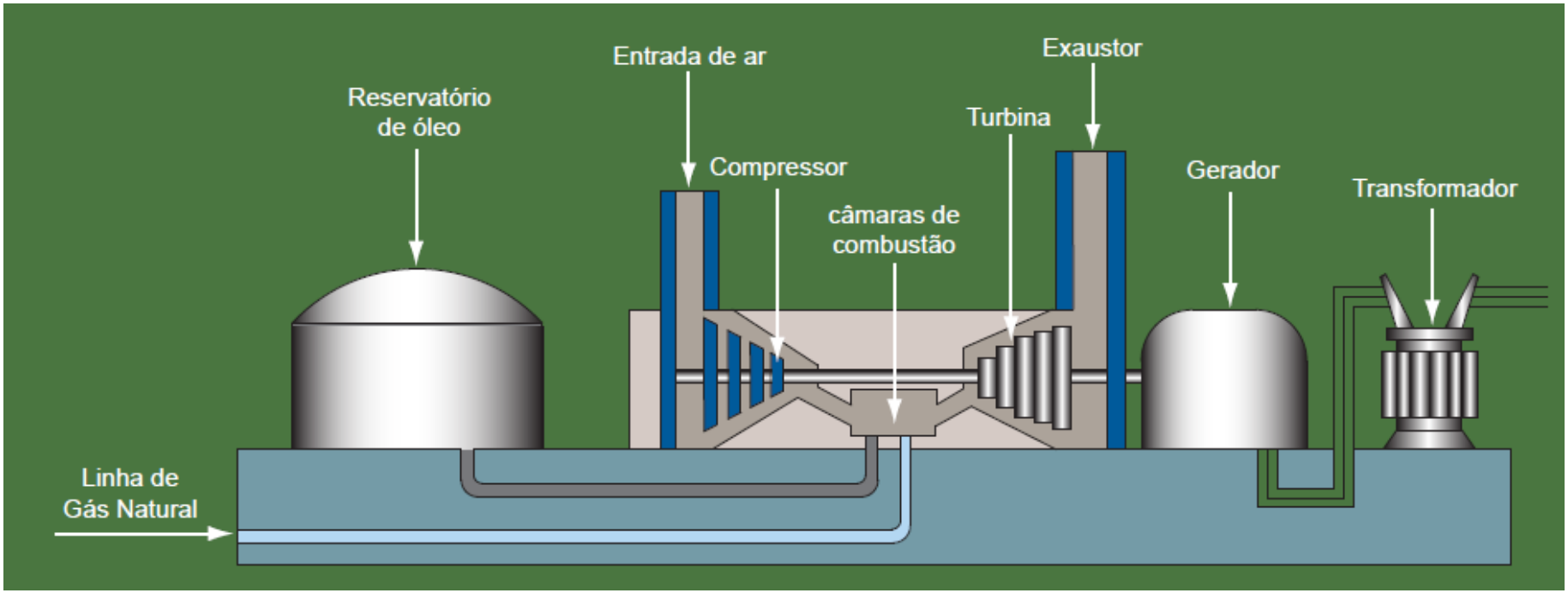
Borborema Energética: 169 MW; FC=0,76

Uso final

- Petróleo

Uso final

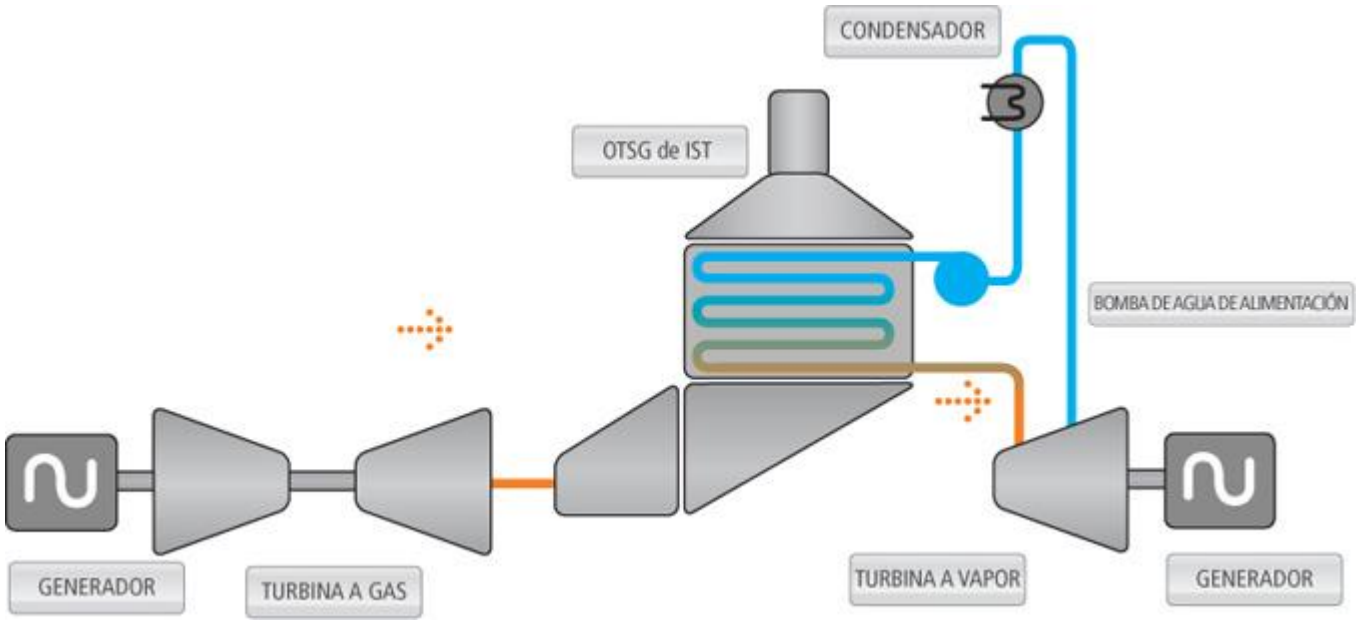
- Gás natural



[1]ANEEL – Atlas de Energia Elétrica, 2008.

Uso final

- Gás natural



Uso final

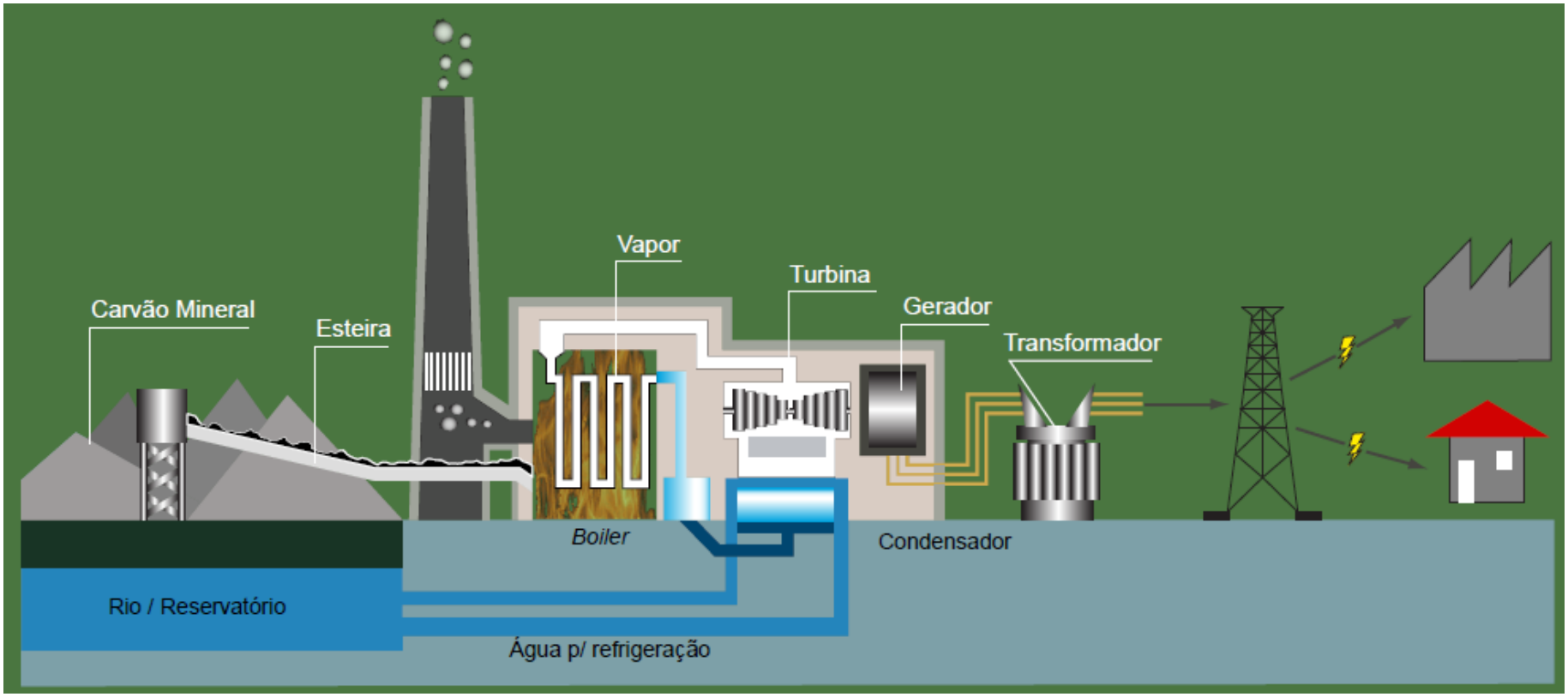
- Gás natural

TERMOPE: 530 MW; FC=0,81

[1]http://www.termope.com.br

Uso final

- Carvão mineral



[1]ANEEL – Atlas de Energia Elétrica, 2008.

Uso final

- Carvão mineral

Jorge Lacerda, Unidade C, Santa Catarina

363 MW

170 bar; 538 C

[1]www.tractebelenergia.com.br

Uso final

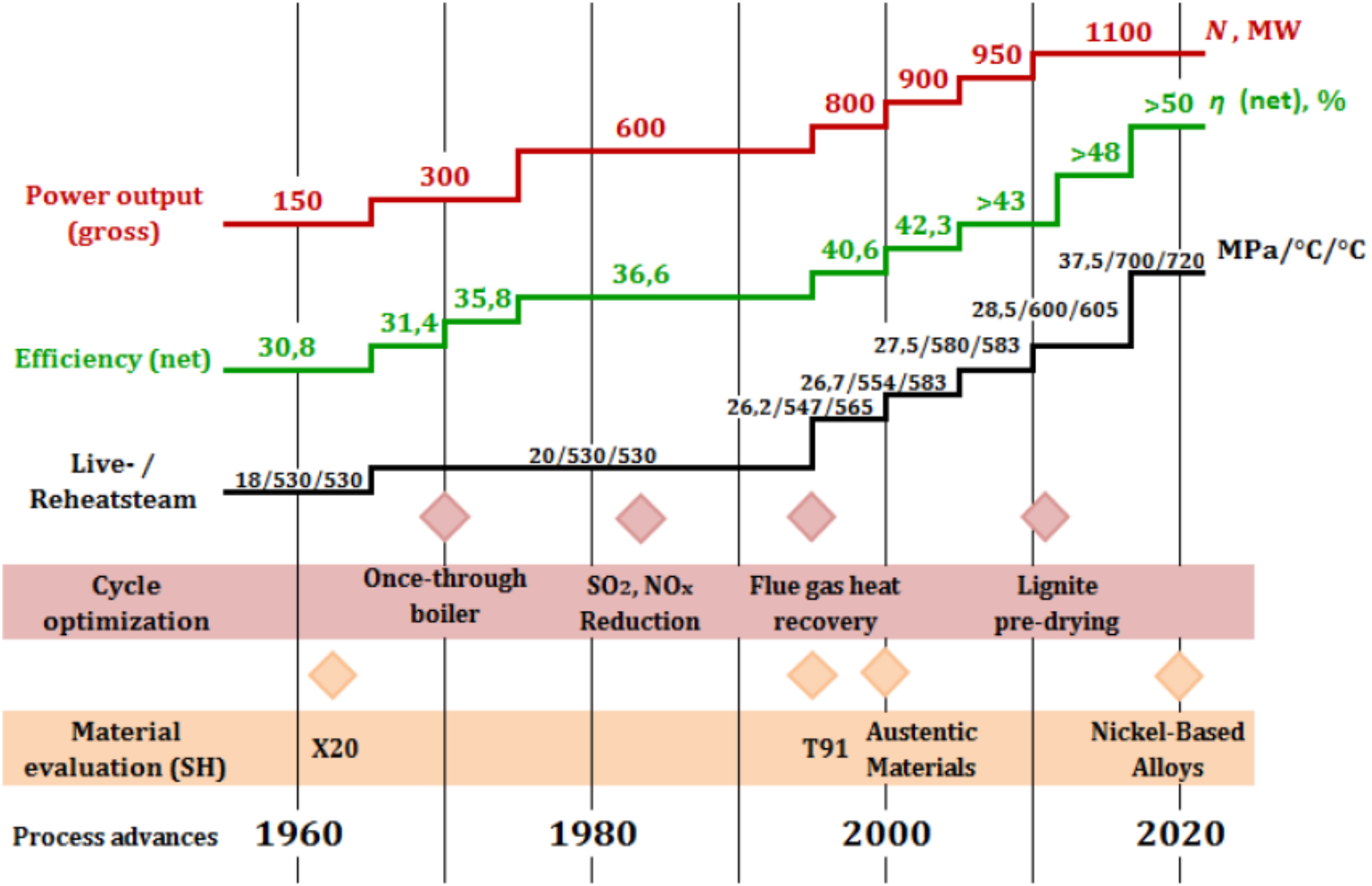
- Carvão mineral

Boa 2 e 3; Nordrhein-Westfalen, Alemanha

1.060 MW + 1.060 MW; 280 bar / 600 C

Uso final

- Carvão mineral

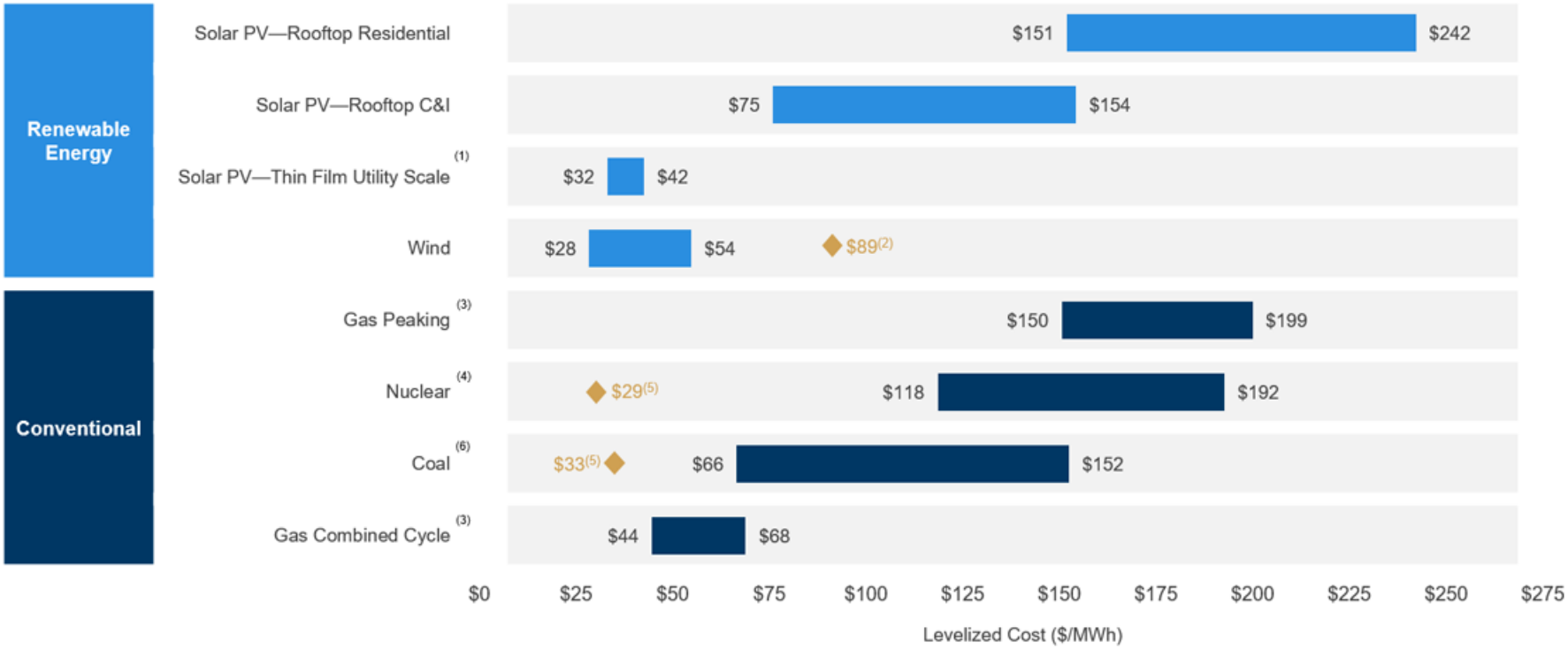


Ragolev, N; Golodnitskiy, A; Tumanovskiy, A; Rogalev, A.
A Survey of State-of-the-Art Development of Coal-Fired Steam Turbine Power Plant Based on Advanced Ultrasupercritical Steam Technology, Contemporary Engineering Sciences, 2014.

Uso final

Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



Source: *Lazard estimates.*

Note: Here and throughout this presentation, unless otherwise indicated, the analysis assumes 60% debt at 8% interest rate and 40% equity at 12% cost. Please see page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities. These results are not intended to represent any particular geography. Please see page titled "Solar PV versus Gas Peaking and Wind versus CCGT—Global Markets" for regional sensitives to selected technologies.

(1) Unless otherwise indicated herein, the low end represents a single-axis tracking system and the high end represents a fixed-tilt system.

(2) Represents the estimated implied midpoint of the LCOE of offshore wind, assuming a capital cost range of approximately $2.33 – $3.53 per watt.

(3) The fuel cost assumption for Lazard's global, unsubsidized analysis for gas-fired generation resources is $3.45/MMBTU.

(4) Unless otherwise indicated, the analysis herein does not reflect decommissioning costs, ongoing maintenance-related capital expenditures or the potential economic impacts of federal loan guarantees or other subsidies.

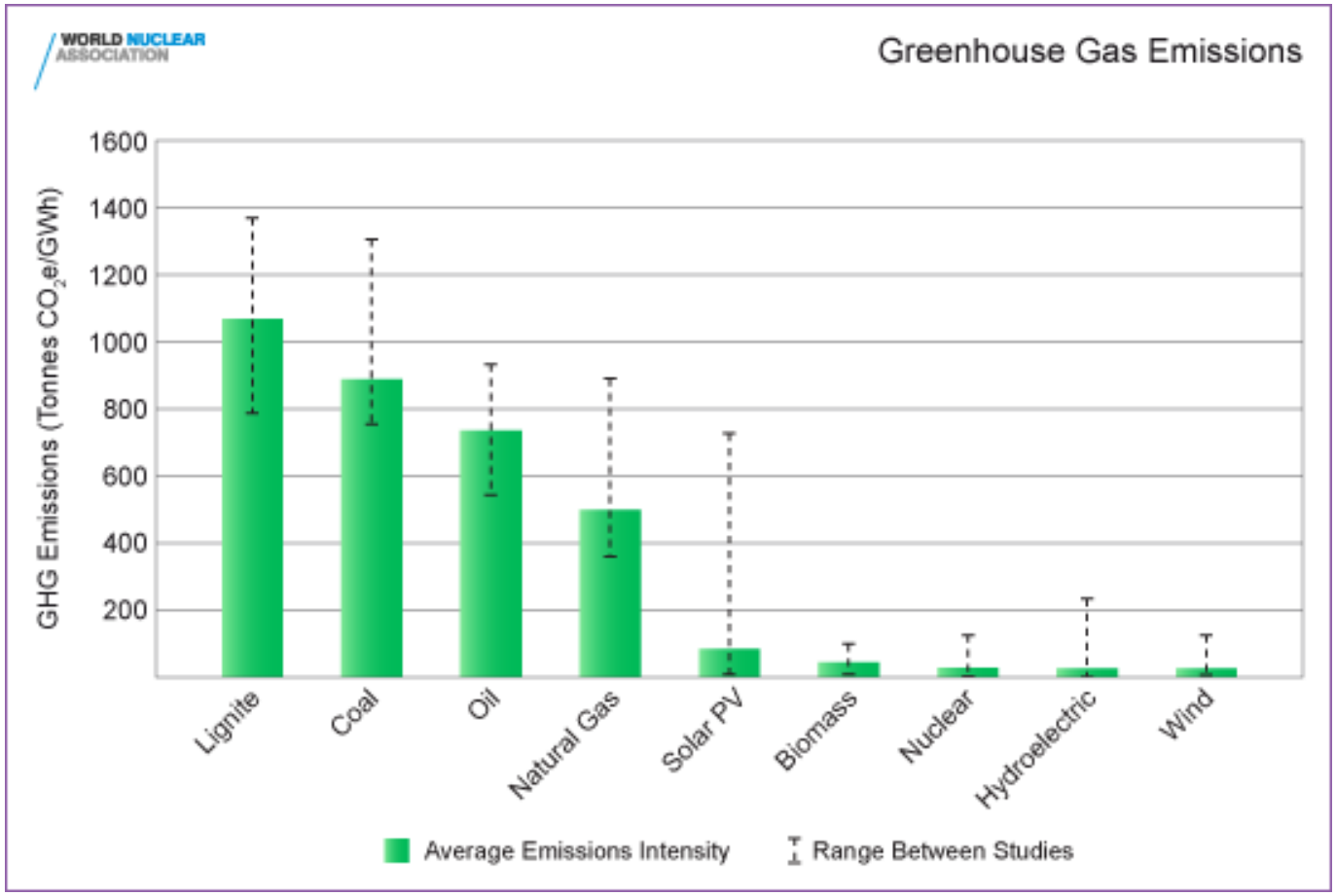
(5) Represents the midpoint of the marginal cost of operating coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned coal plant is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating coal and nuclear assets across the U.S. Capacity factors, fuel and variable and fixed operating expenses are based on upper and lower quartile estimates derived from Lazard's research. Please see page titled "Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation" for additional details.

(6) High end incorporates 90% carbon capture and compression. Does not include cost of transportation and storage.

https://www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf

Impactos ambientais e desafios

- Emissão de gases do efeito estufa



http://www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx

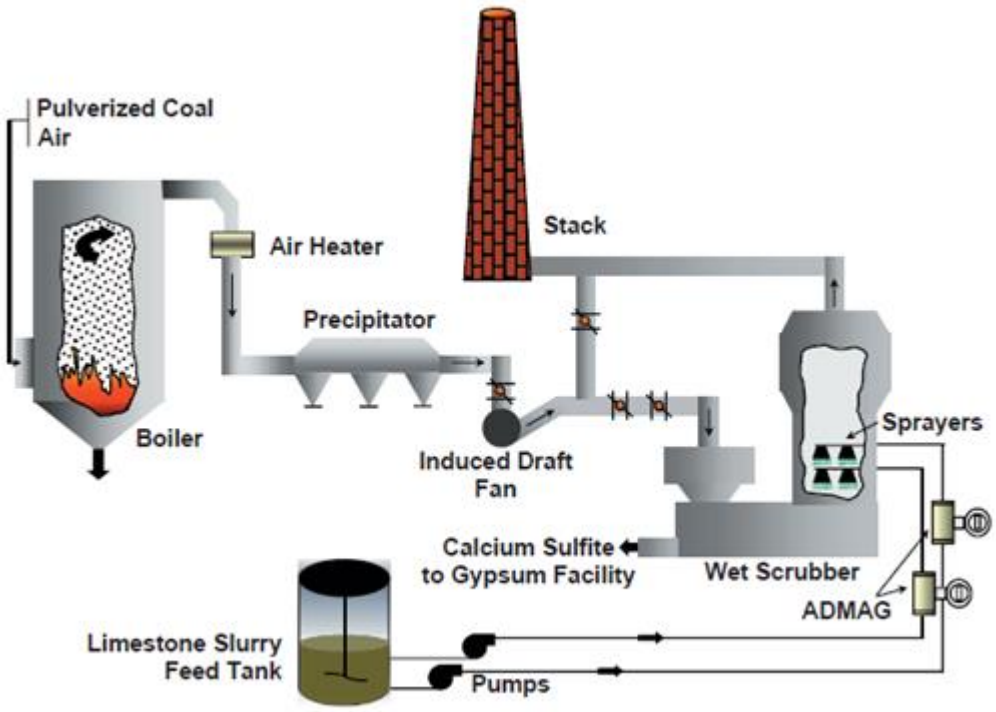
Impactos ambientais e desafios

- Emissões de SOx
  - Queimar combustíveis com menor teor de S;
  - Tratar gases de combustão

Formação de chuva ácida

$$SO_2(g) + H_2O(\ell) \longrightarrow H_2SO_3(aq)$$

$$H_2SO_3(aq) + \frac{1}{2}O_2(g) \longrightarrow H_2SO_4(aq)$$



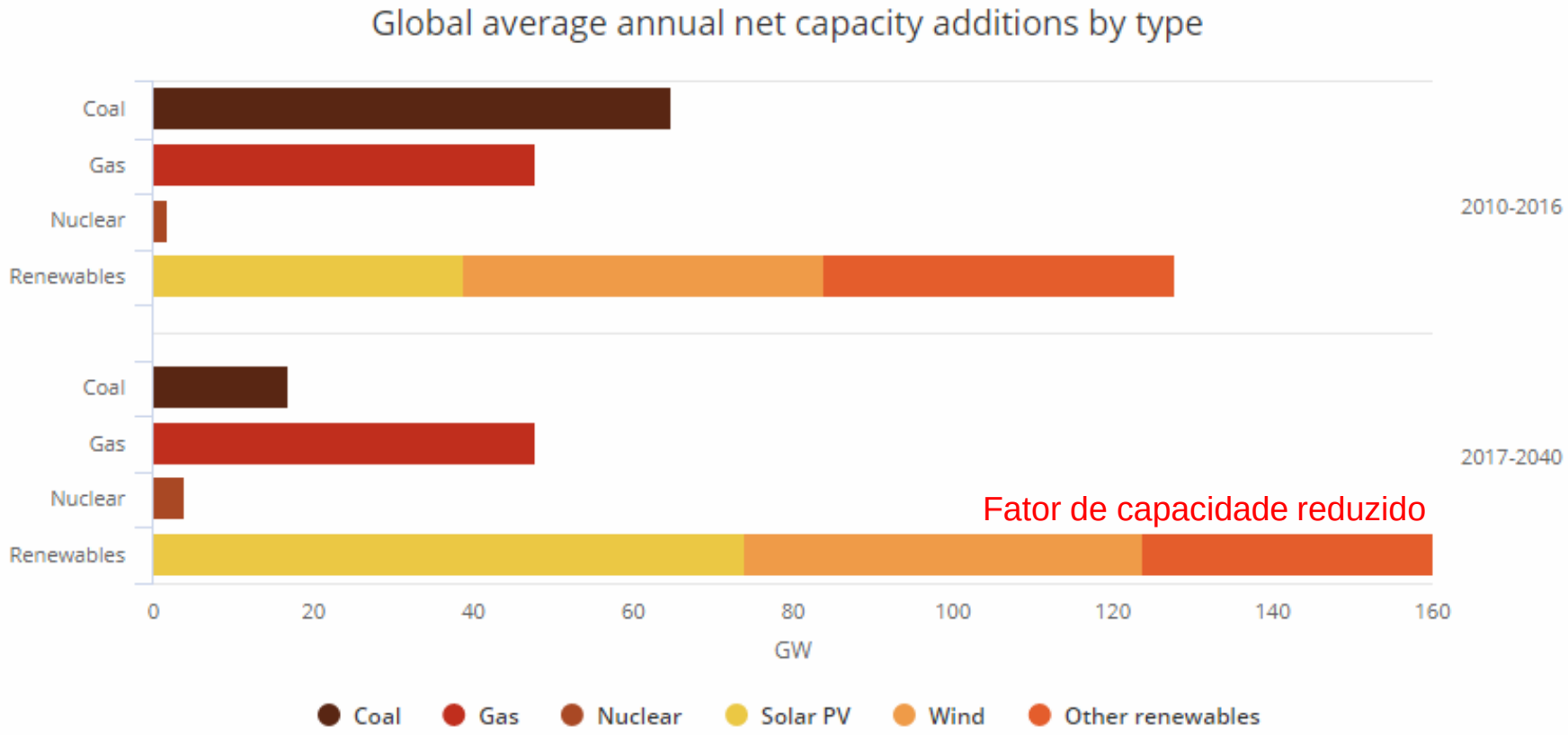
http://www.yokogawa.com.br/noticias/detalhe/saiba-como-reduzir-o-nivel-das-emissoes-de-enxofre-no-meio-ambiente.html

Impactos ambientais e desafios

- Emissões de NOx
  - NOx combustível
  - NOx térmico (>1400 C)
- Desafios
  - Aumentar a eficiência dos sistemas de geração termelétrica
  - Desenvolvimento de combustíveis com baixo teor de S
  - Encontrar substitutos para os fósseis

http://www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx

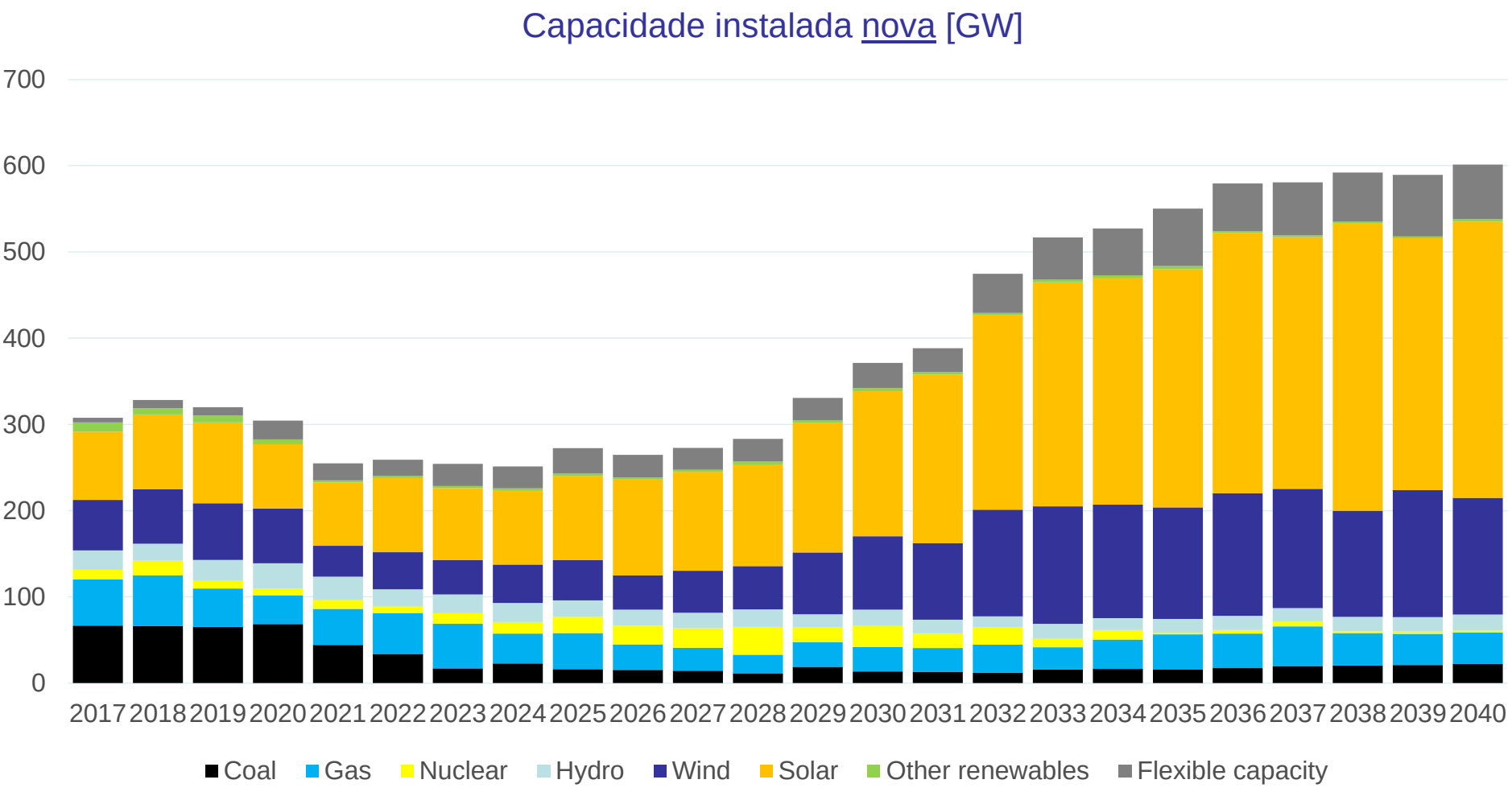
Perspectivas



[1] Bloomberg New Energy Outlook 2018 <https://about.bnef.com/new-energy-outlook/>

[2] https://www.iea.org/weo2017/

Perspectivas



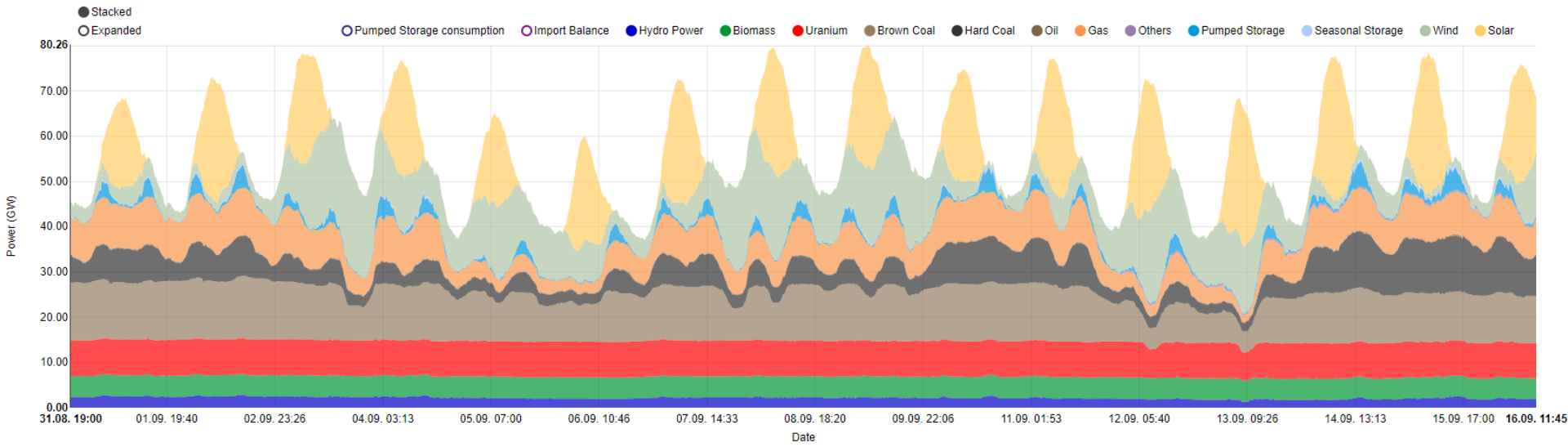
[1] Bloomberg New Energy Outlook 2018 <https://about.bnef.com/new-energy-outlook/>

[2] https://www.iea.org/weo2017/

[1] Bloomberg New Energy Outlook 2017

Perspectivas

Geração em setembro na Alemanha



[1] https://www.energy-charts.de/power.htm?source=all-sources&year=2020&month=9

Perspectivas

- O sistema elétrico precisará ser flexível
- Precisaremos das usinas térmicas
  - Balanço energético da geração hidráulica: sazonal
  - Balanço energético da geração solar e eólica: diário

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