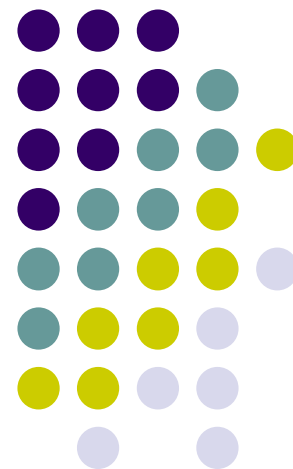


# **Caminhos do Setor Energético Mundial Pós-Pandemia da COVID-19 e Pós-Guerra Rússia/Ucrânia**

**Semana Nacional de Engenharia Nuclear e da Energia e  
Ciência das Radiações – SENCIR  
Universidade Federal de Minas Gerais - UFMG**

Gustavo Nikolaus Pinto de Moura  
Planejamento Energético  
Universidade Federal de Ouro Preto - UFOP

**Novembro de 2022**

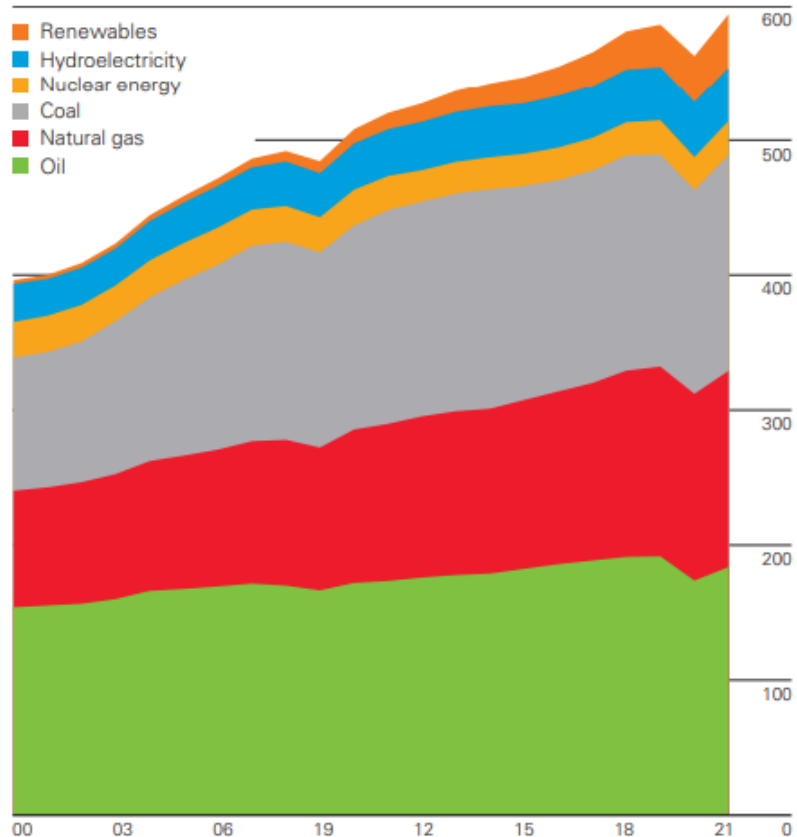


# Introdução – “Transições energéticas”



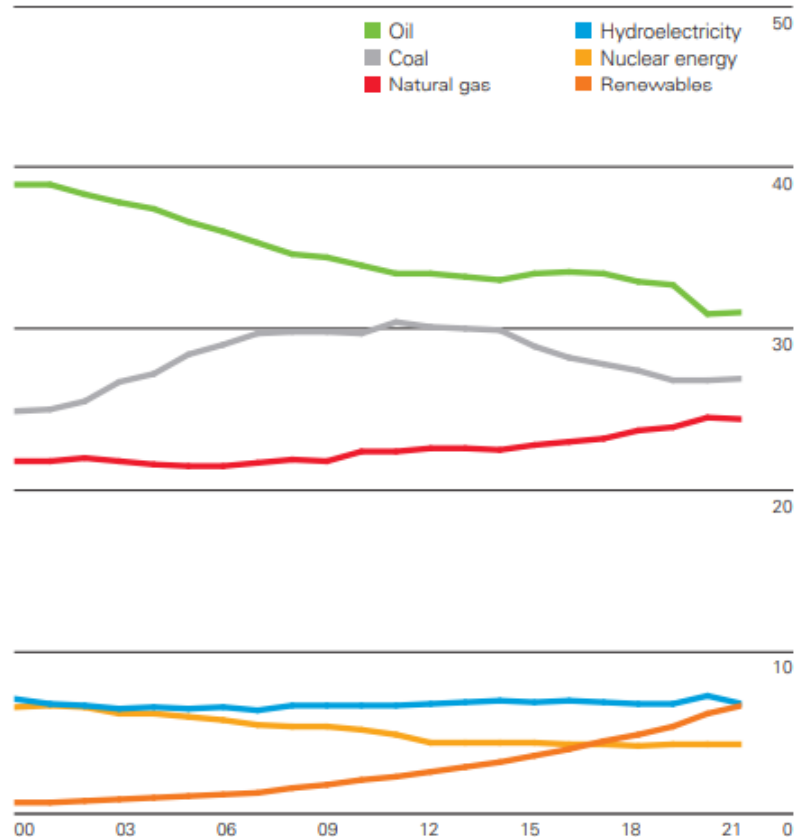
**World consumption**

Exajoules



**Shares of global primary energy**

Percentage

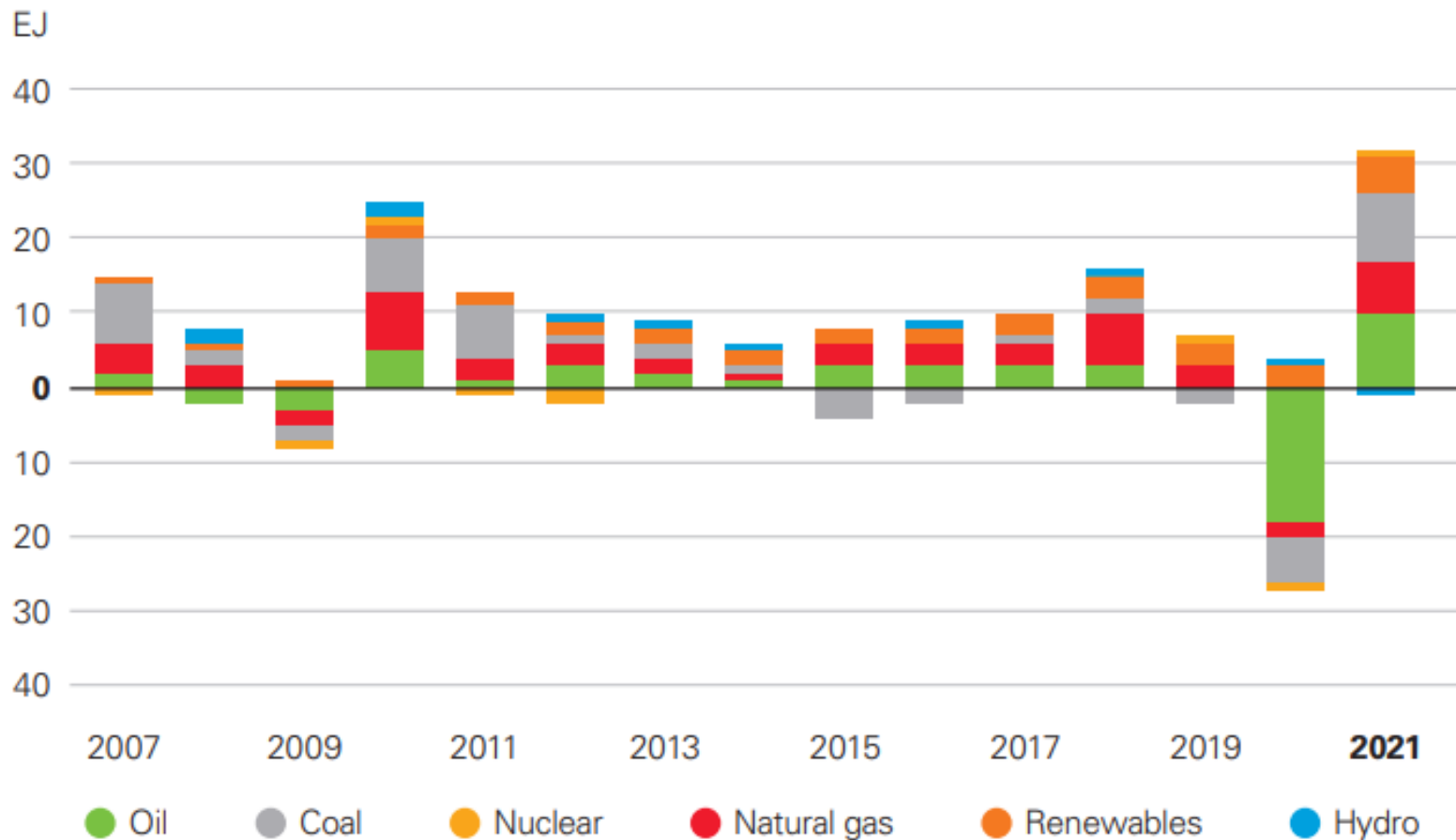


# Introdução



## ✓ Alterações na oferta de energia

Change in primary energy by fuel



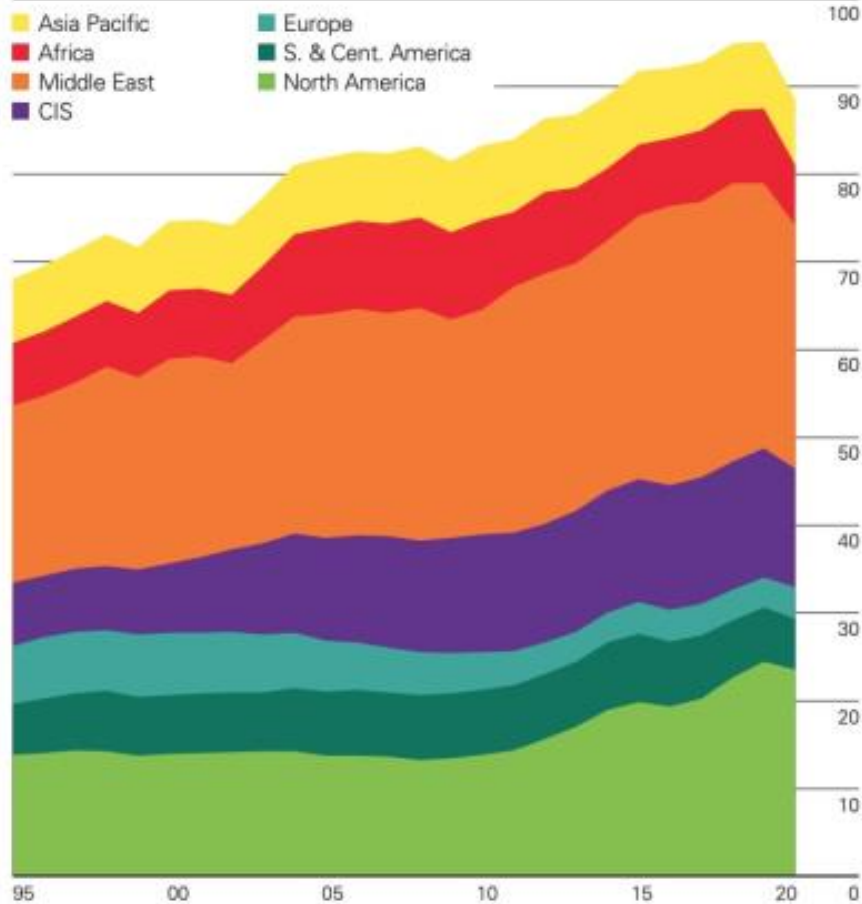
# Introdução



## ✓ Produção e Consumo de petróleo

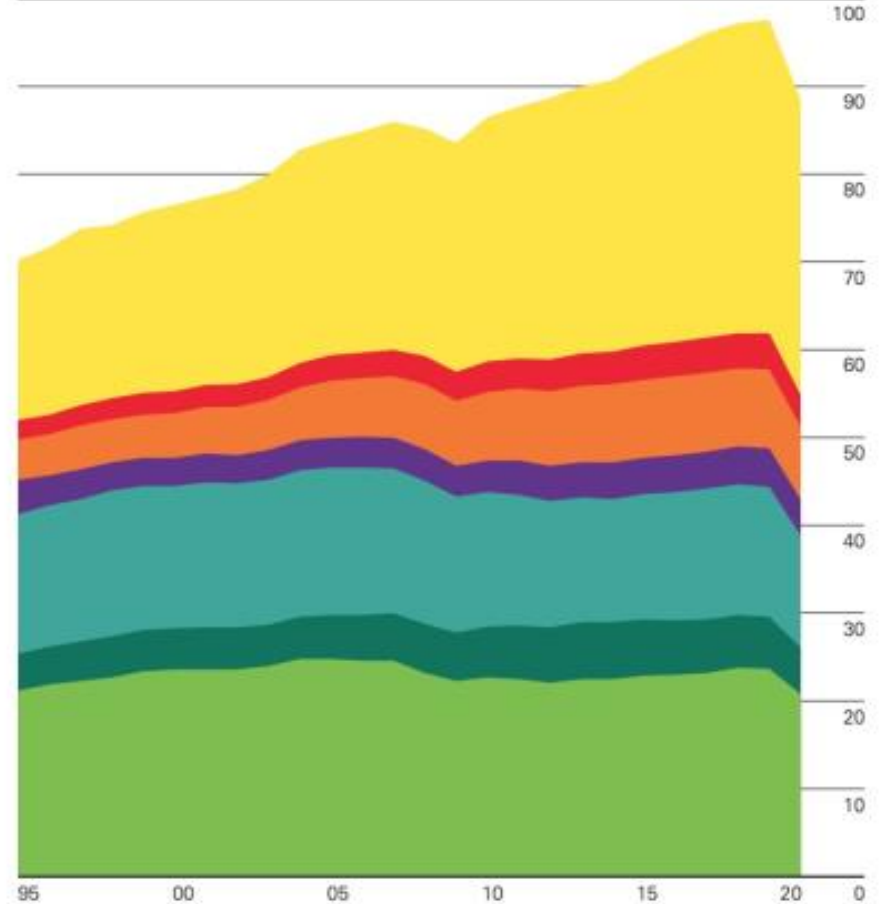
**Oil: Production by region**

Million barrels daily



**Oil: Consumption by region**

Million barrels daily



# Estados Unidos



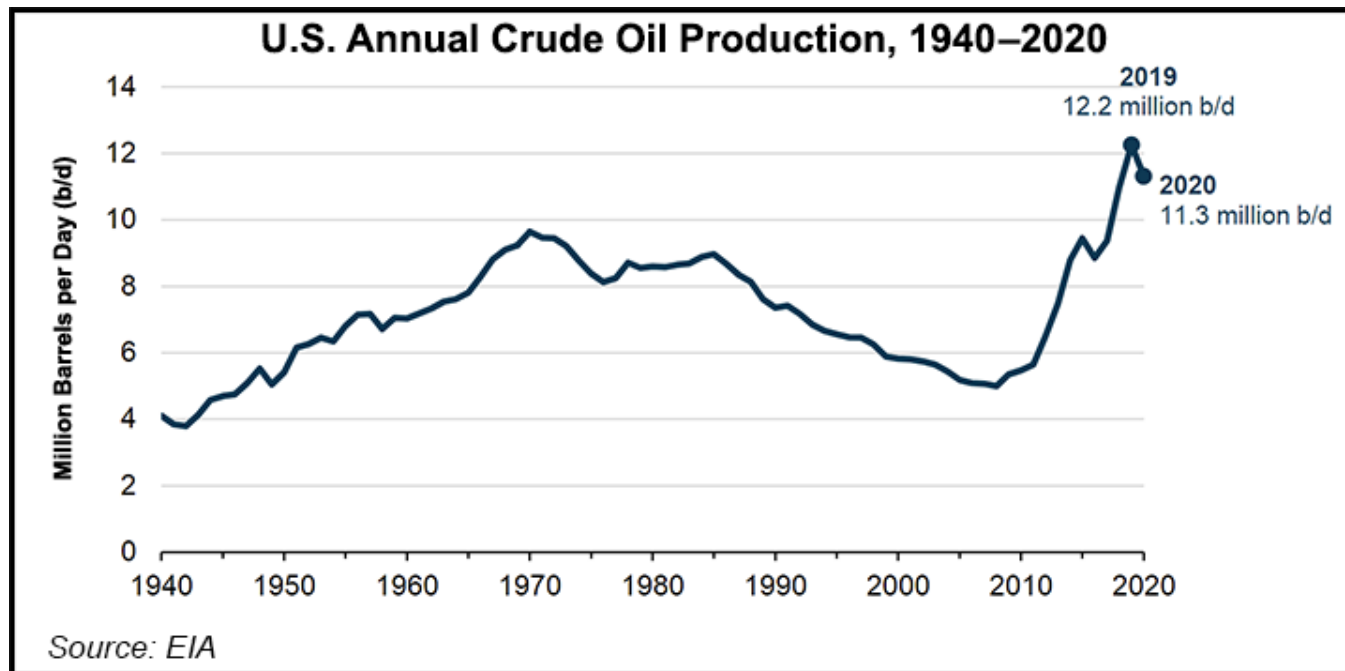
- ✓ Origem da indústria do petróleo e automobilística;
- ✓ Produção Fordista – Linha de montagem;
- ✓ Modelo T;



# Estados Unidos



- ✓ Indústria do petróleo - Segurança energética;
- ✓ Curva de Hubbert >>> Pico do Petróleo (Quando?);

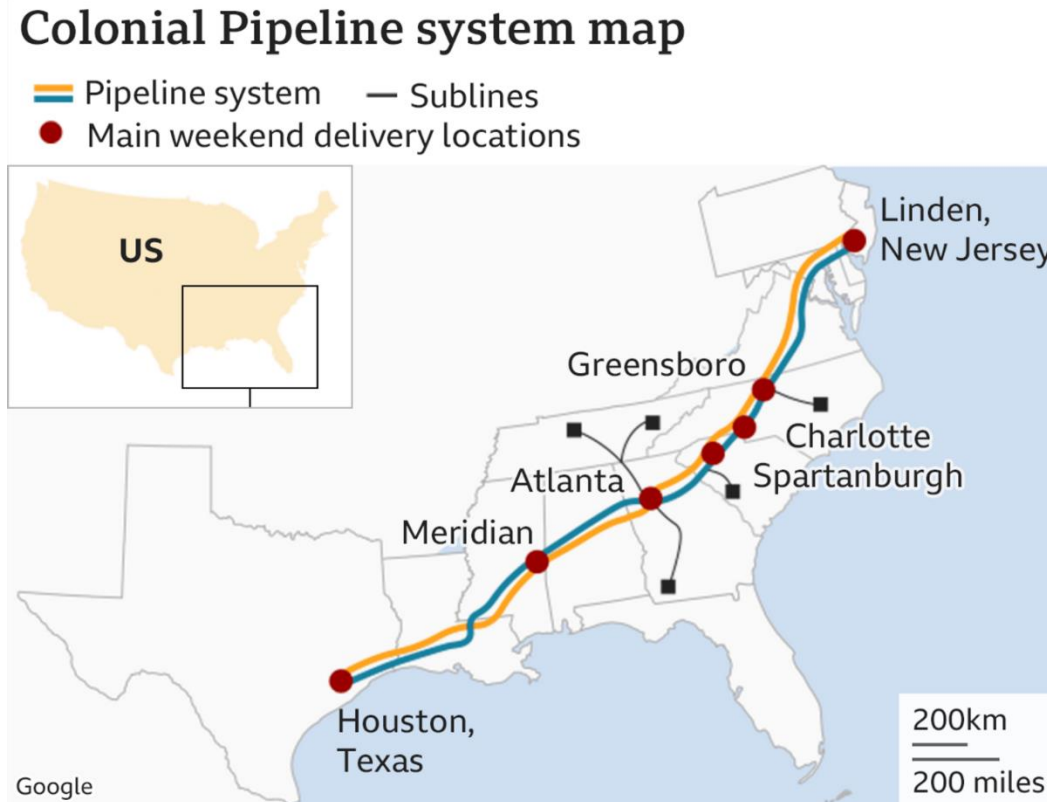


- ✓ Óleo e Gás do Xisto – Governo Obama;
- ✓ Dependência do petróleo do Oriente Médio?

# Estados Unidos



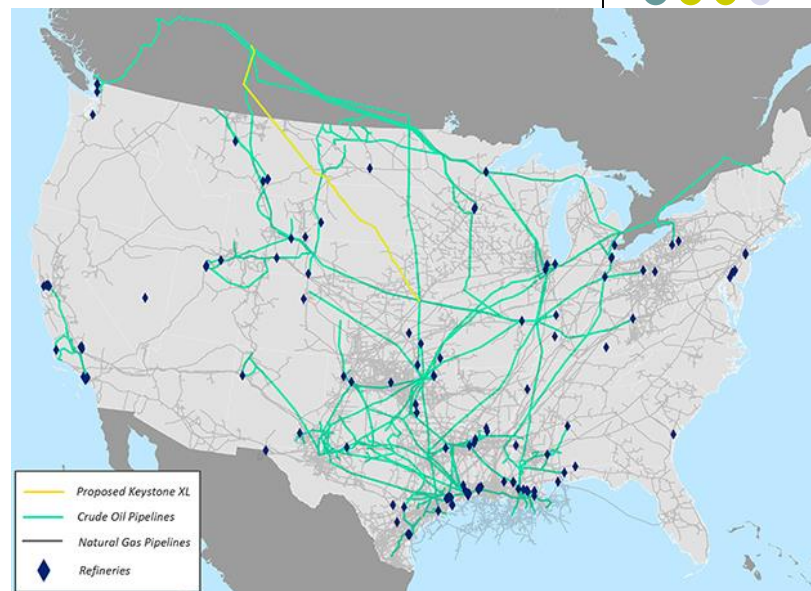
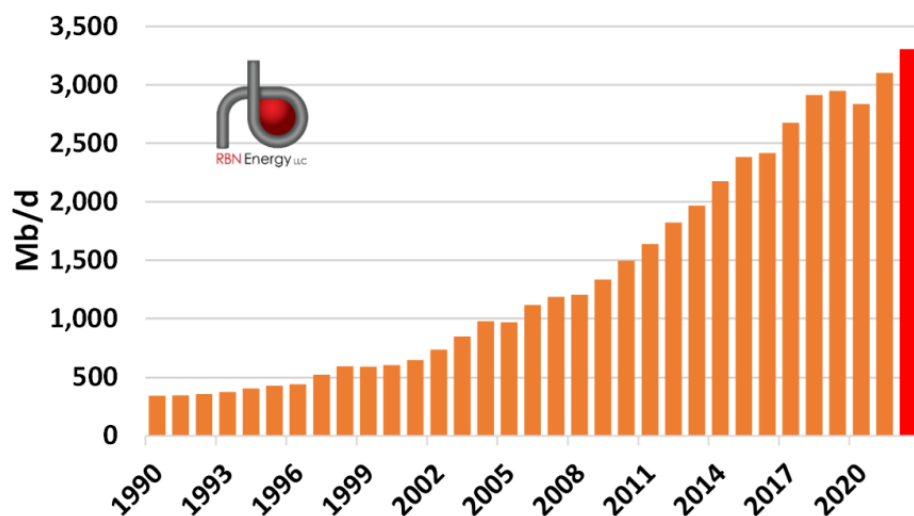
- ✓ Indústria do petróleo - Insegurança energética;
- ✓ **Ataque cibernético** >>> *Colonial Pipeline* (3 Mbpd - Maio de 2021 – Pagamento de 75 bitcoins ou US\$ 4,4 milhões);



# Canadá

- ✓ Indústria do petróleo - Segurança energética;
- ✓ Areias Betuminosas;
- ✓ Exportação média (2016/2021) de 3,5 Mi bpd para Estados Unidos;

Oil Sands Production: 1990-2022





# China



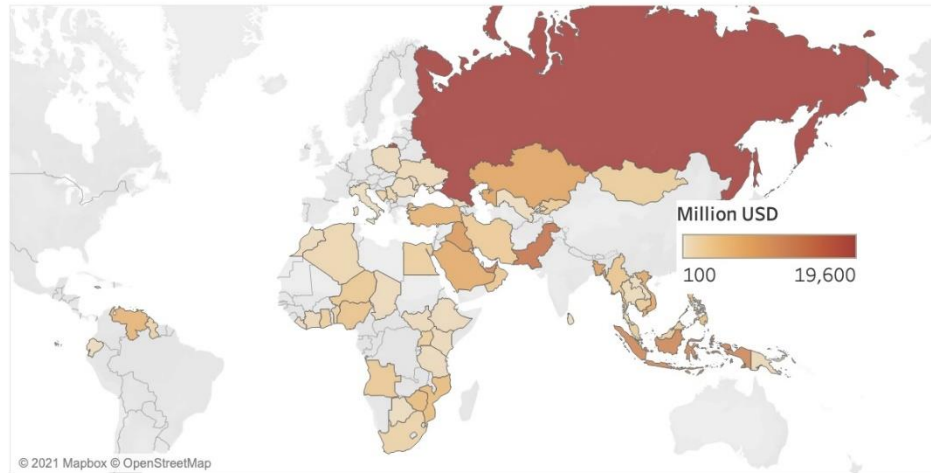
- ✓ *Belt and Road Initiative – “Nova Rota da Seda”*
- ✓ Investimentos em energia de **US\$ 35 bilhões por ano**;
- ✓ *In 2021, the Chinese government announced that it would **end the financing of coal-fired power plants overseas.***
- ✓ *China has provided a lot of loans to Africa, approximately \$150 billion.*
- ✓ Paquistão – Carvão Mineral e Hidroelétricas;
- ✓ Rússia – Gás Natural - “Power of Siberia 1 e 2”;

# China

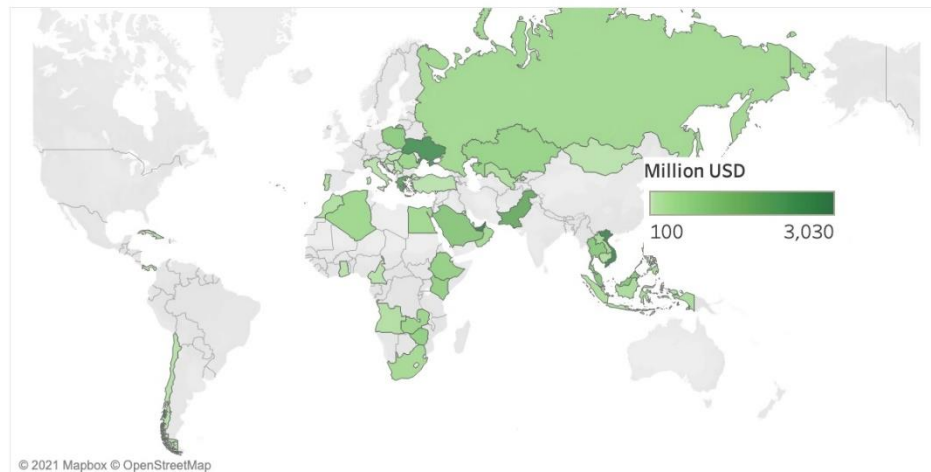


## Chinese energy investments in the Belt and Road Initiative (BRI) 2013-2020

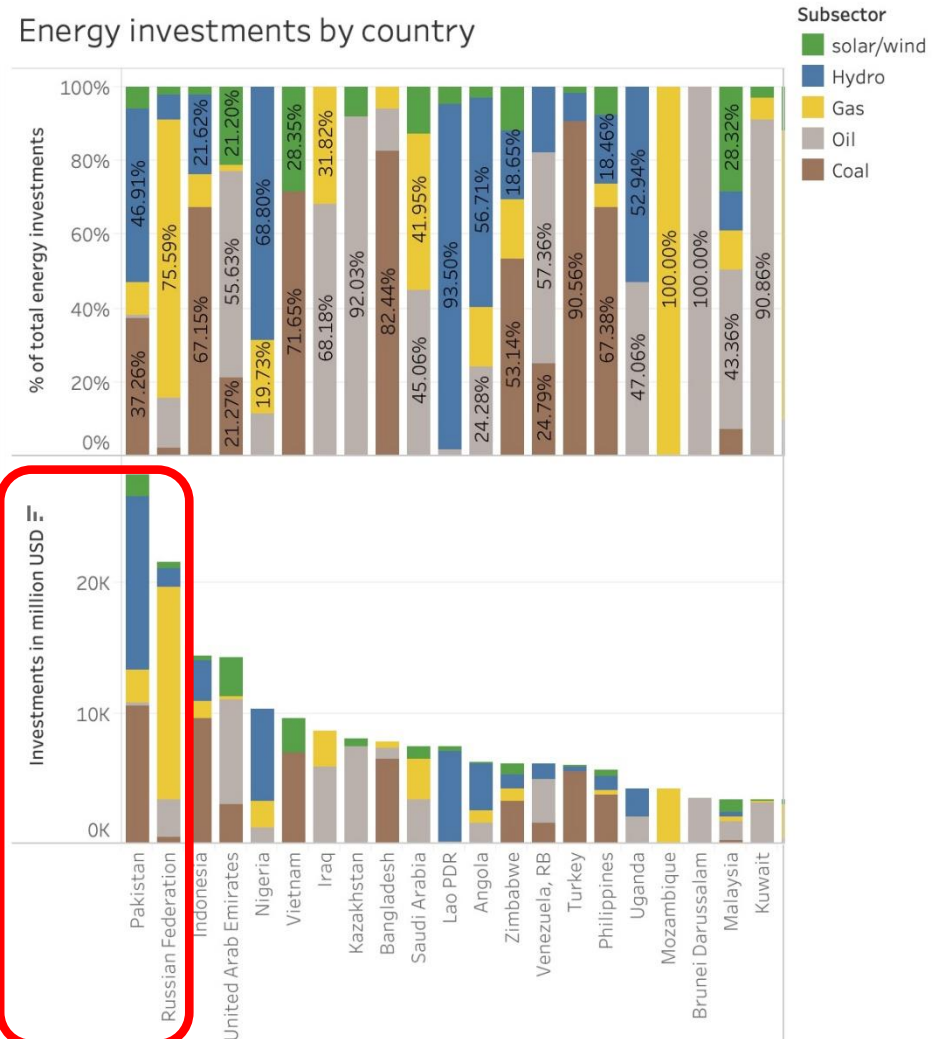
### Fossil-fuel energy investments



### Green energy investments



### Energy investments by country



(c) 2021 IIGF Green BRI Center (Data: AEI and others)

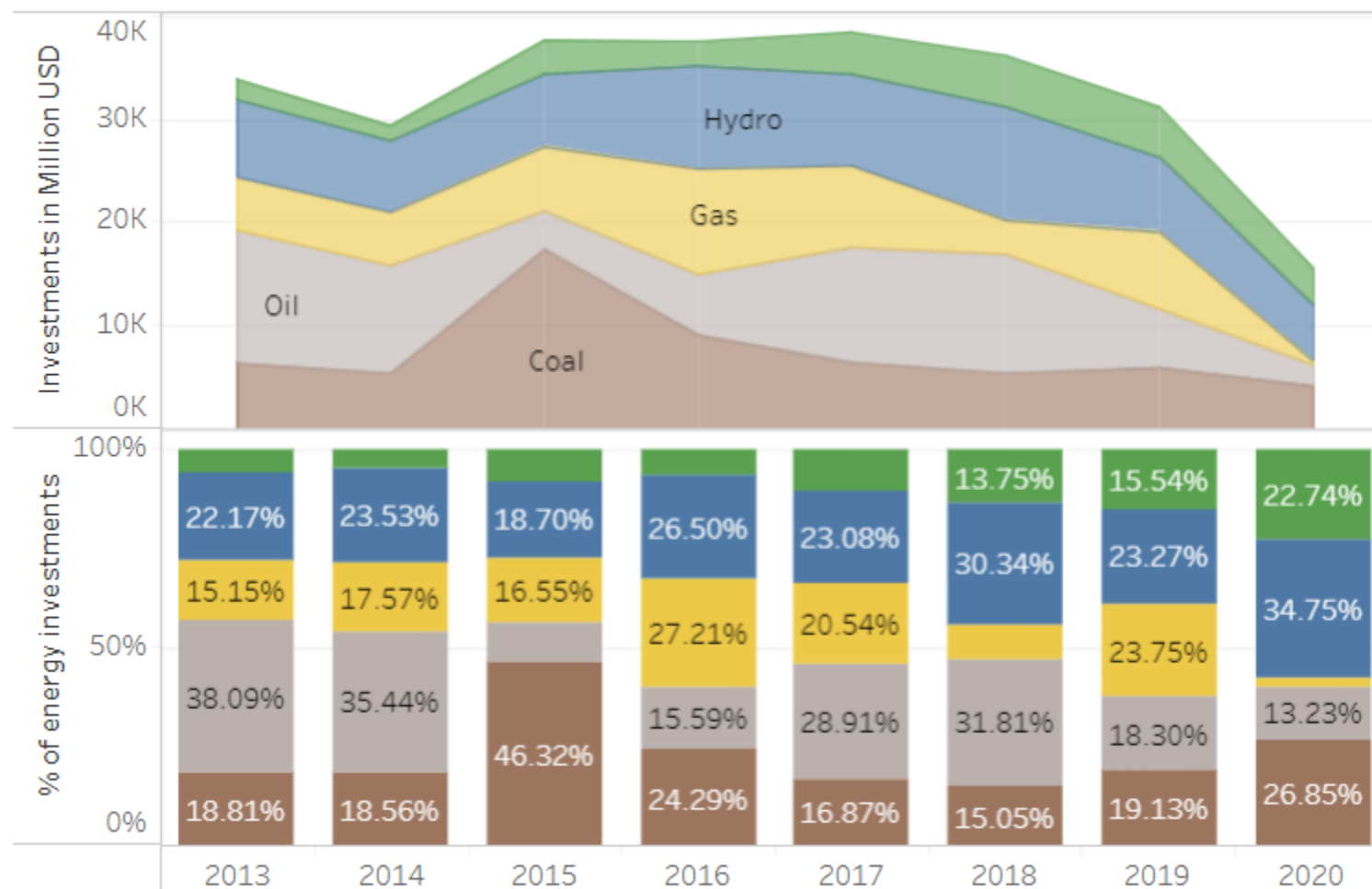
# China



Subsector

- solar/wind
- Hydro
- Gas
- Oil
- Coal

## Chinese energy investments in the Belt and Road Initiative (BRI) 2013-2020



# Europa – União Europeia



## Diretrizes

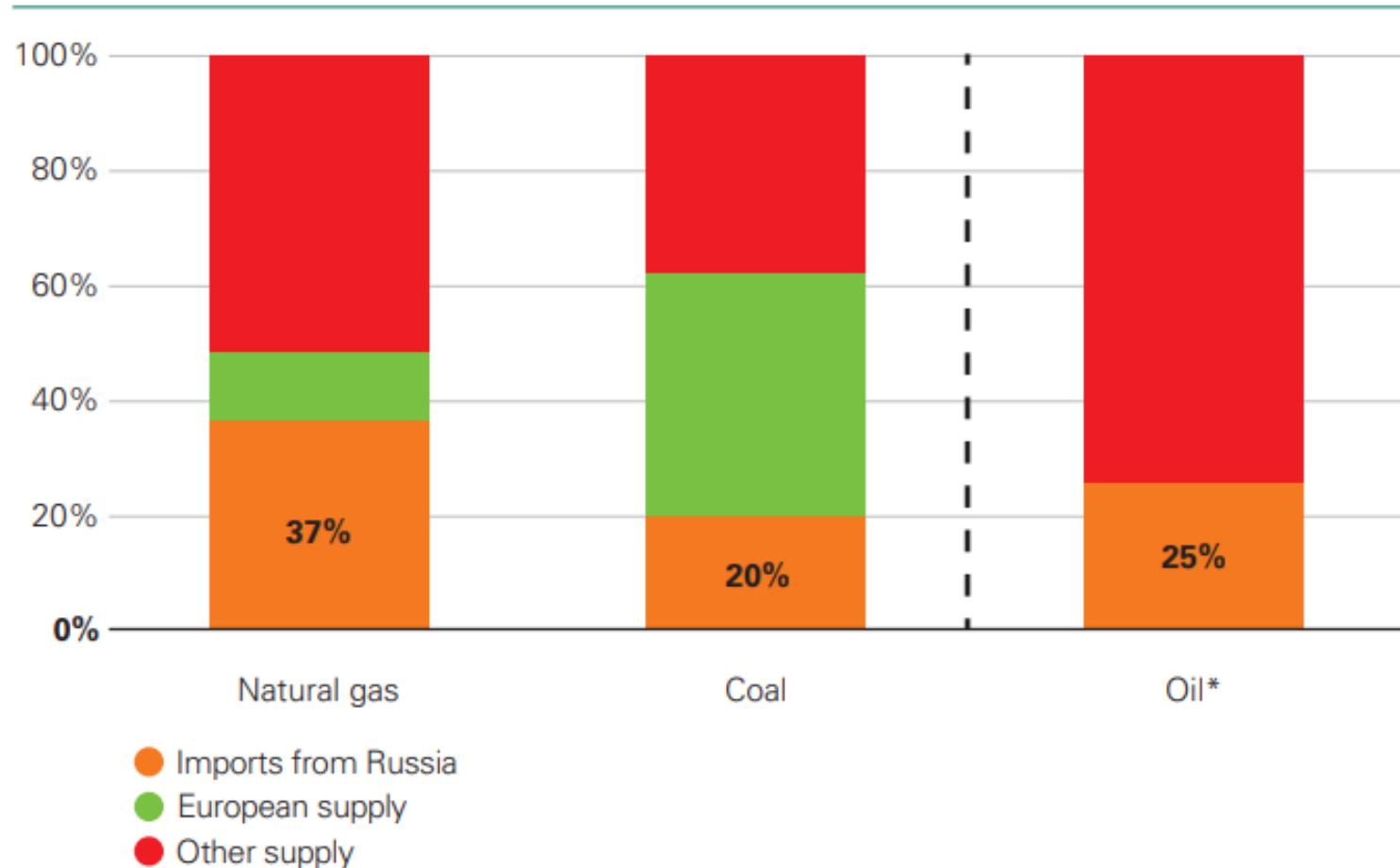
- ✓ Energia Renovável (2009/28/EC);
- ✓ Eficiência Energética (2012/27/EU);
- ✓ Parlamento Europeu (Junho de 2022) – Banimento veículos combustão interna (ICE) até 2035;



# Europa – União Europeia



## Russian share of EU-27 Natural gas and Coal consumption and Oil imports



\*Crude and products. May include re-exports of product and oil that is stored but not processed.

BP, 2022.

# Europa - França



✓ Segurança Energética >>> Energia Nuclear;

✓ Outubro de 2022:



- ✓ *The French government unveiled its **biggest energy conservation measures since the 1970s oil crisis**;*
- ✓ *Part of a Europe-wide effort to save power this winter as Russia shuts off natural gas supplies to countries that support Ukraine.*
- ✓ ***Reduce France's energy consumption by 10% in two years, and ultimately by 40% by 2050;***

# Europa - Alemanha



- ✓ **Insegurança energética** > Cortes no fornecimento de gás russo;
- ✓ Gás natural: Dependência de 40% do fornecimento russo;
- ✓ Gasodutos Nord Stream I e II;
- ✓ Boas relações Merkel / Putin;
- ✓ Realismo X Idealismo;
- ✓ Guerra Rússia/Ucrânia;
- ✓ Julho de 2022 - Nacionalização UNIPER >>> 15 bilhões de euros;



# Europa – Reino Unido



- ✓ Segurança Energética >>> Produção de Gás Natural no Mar do Norte / Noruega;

Mas...

- ✓ Outubro de 2022: *Energy Prices Bill* >>> *Price cap*;
- ✓ *The Energy Price Guarantee will ensure that a typical household in the United Kingdom pays around £2,500 a year on their energy bill, depending on their use, for the next 2 years, from 1 October 2022.*
- ✓ *It is expected to cost £100 billion-plus.*



# Rússia

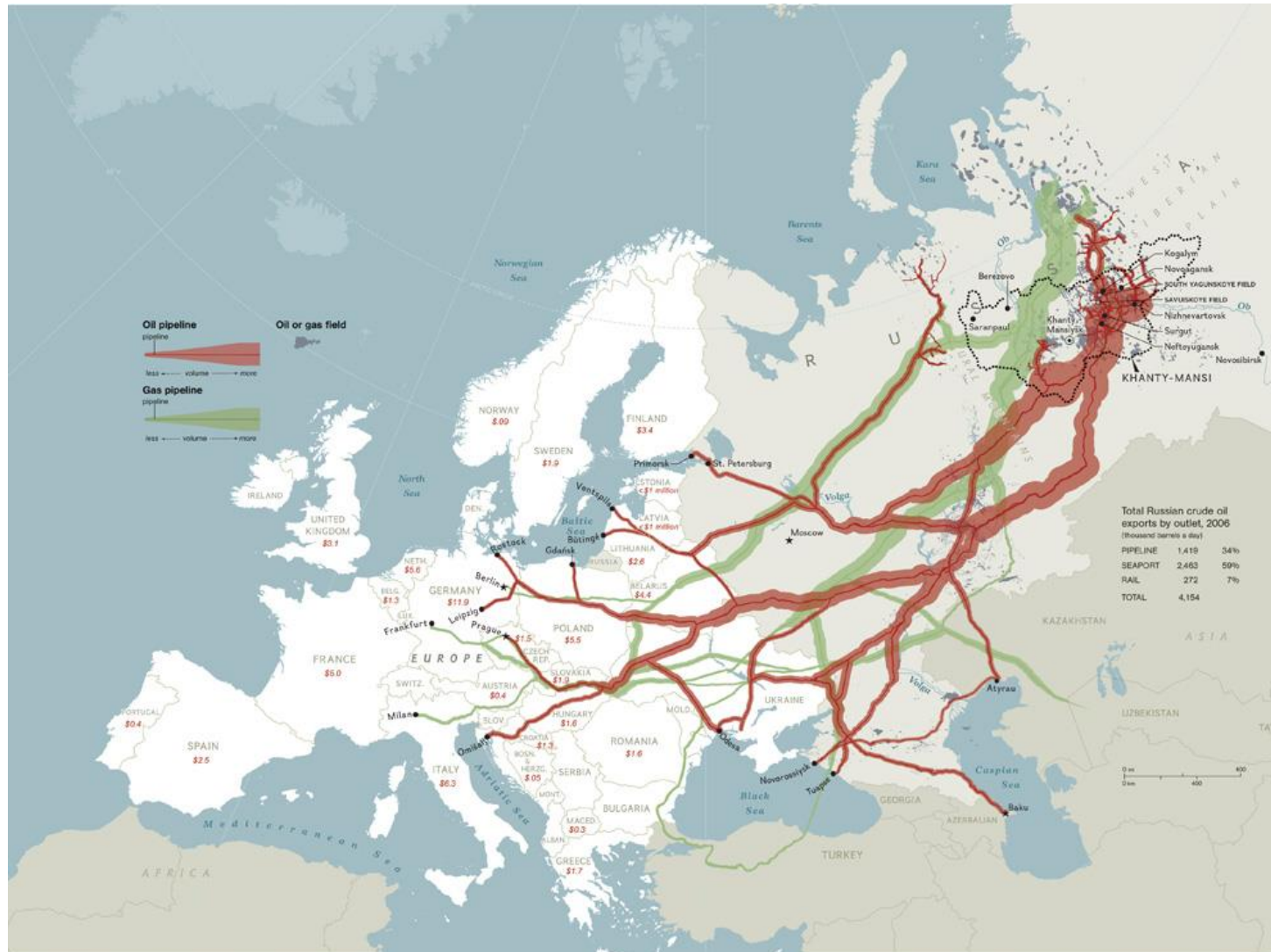


- ✓ **Mackinder e a teoria do “*Heartland*”** – ferrovias séc. XIX;
- ✓ **Rússia como “Superpotência Energética”** – Carvão Mineral, Petróleo e Gás Natural;
- ✓ Gasodutos ao Oeste >>> Europa - Gasodutos na Ucrânia;
- ✓ Gasodutos ao Leste >>> China - Gasodutos “*Power of Siberia*”;
- ✓ Guerra Rússia/Ucrânia >>> crescente influência da União Europeia e OTAN;
- ✓ Realismo X Idealismo;

# Rússia



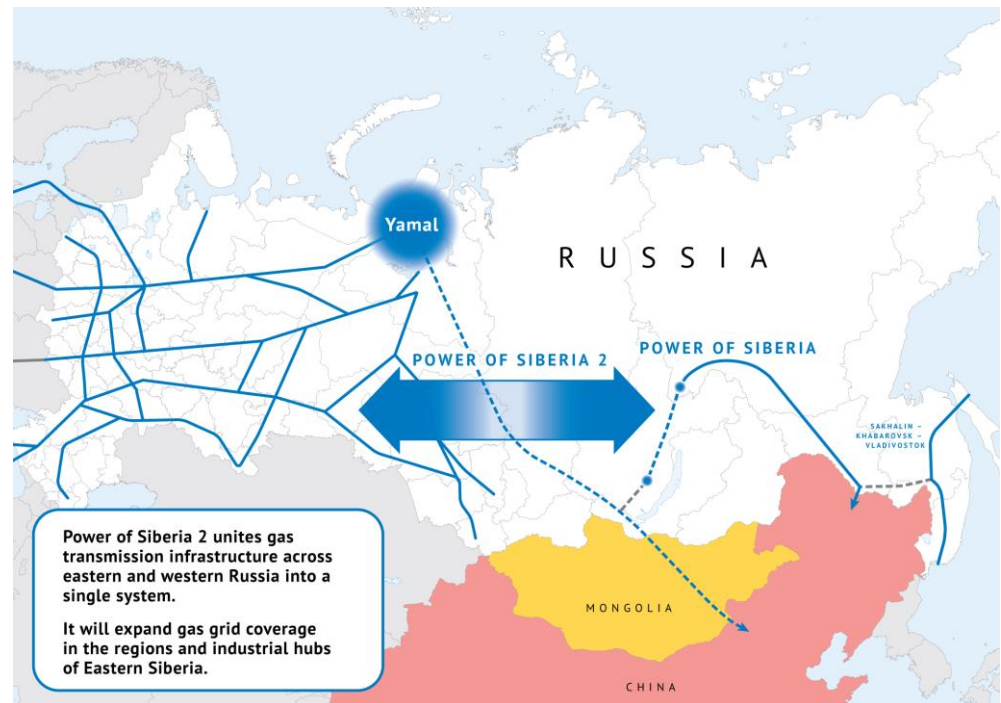
✓ Rede de dutos (gás natural e petróleo) Rússia >>> Europa;



# Rússia



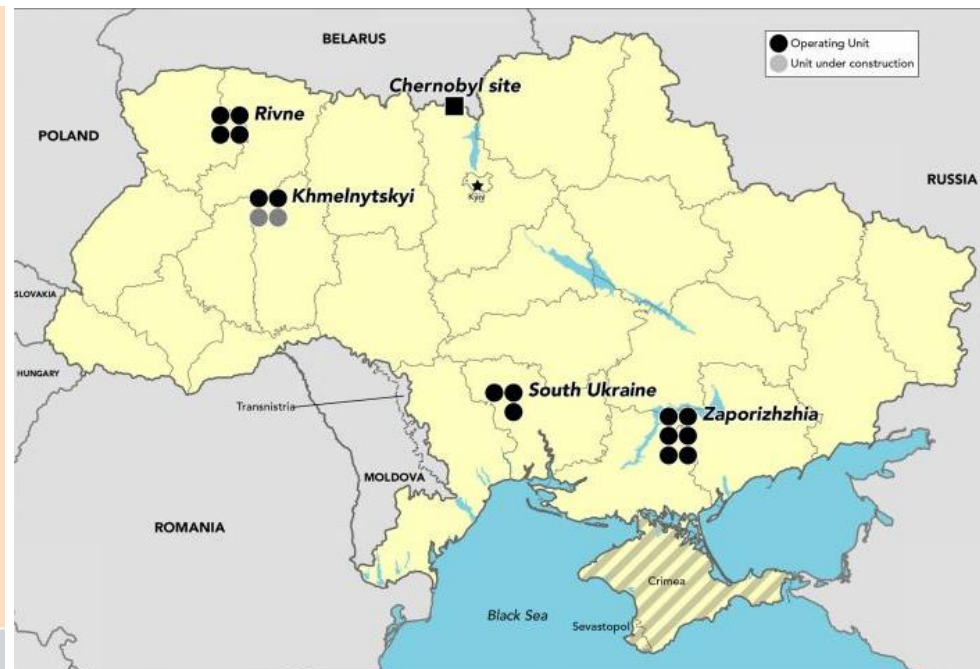
- ✓ Gasodutos ao Leste >>> **Power of Siberia 1**: 4 mil km - 2019 - US\$ 55 Bilhões; **Power of Siberia 2**: 1,5 mil km – 2024 – US\$ 14 bilhões; **Mercado chinês**;
- ✓ *Russia's Gazprom already supplies gas to China through the first Power of Siberia pipeline under a 30-year, \$400 billion deal, which was launched at the end of 2019.*



# Ucrânia



- ✓ Rota de gasodutos russos para Europa;
- ✓ Produção de eletricidade – Nuclear e Carvão Mineral;

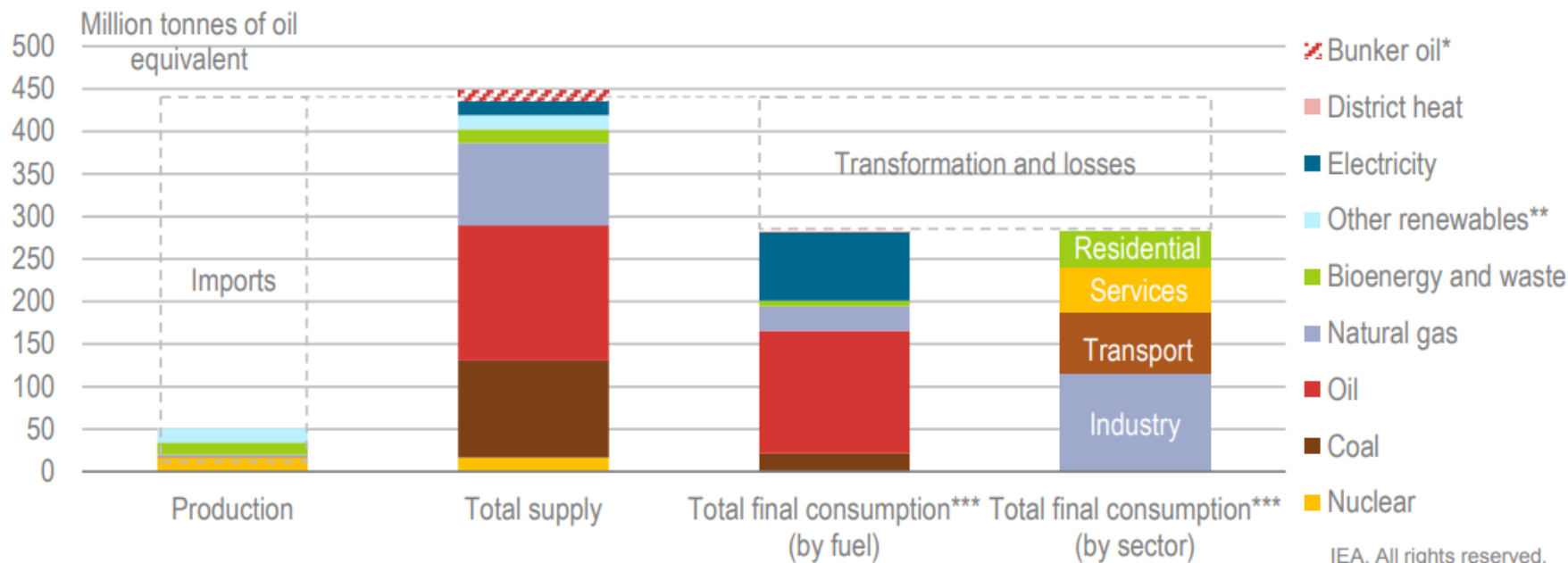


# Japão



- ✓ Pós-Fukushima – Energia Nuclear;
- ✓ Retomada gradual da geração nuclear;
- ✓ Neutralidade de carbono até 2050;

## Overview of Japan's energy system by fuel and sector, 2019



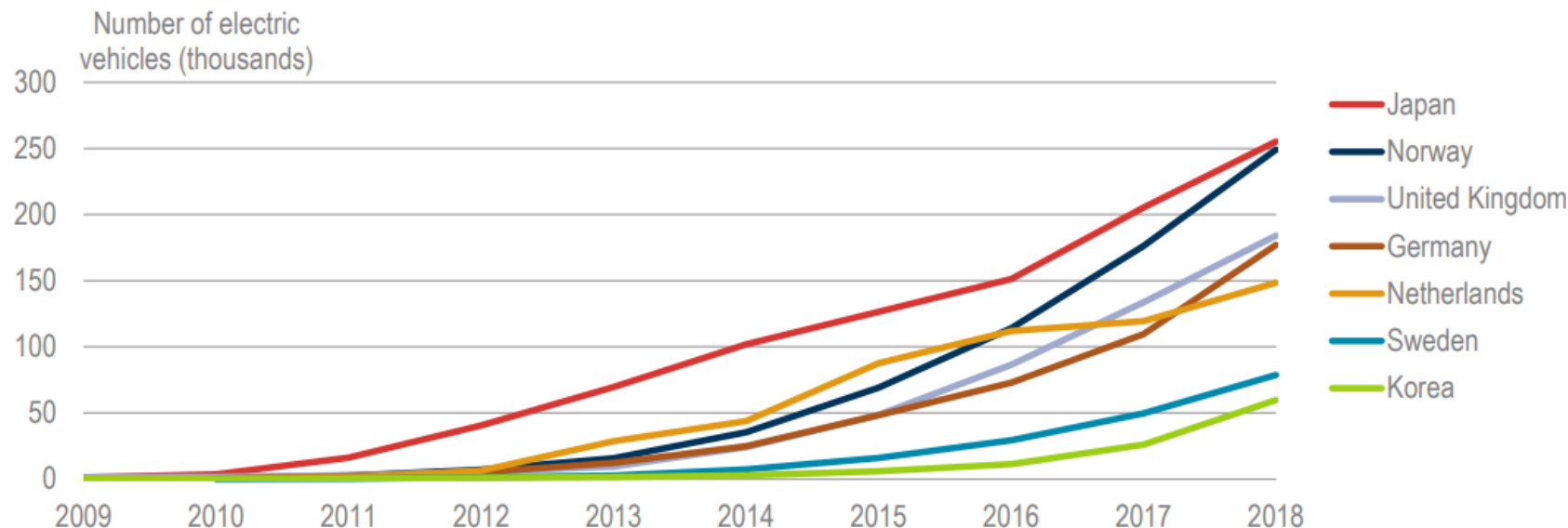


# Japão



- ✓ *“Next-generation vehicles” – which include HEVs (Hybrid), BEVs (Battery), PHEVs (Plug-in Hybrid), FCEVs (Fuel Cells) and “clean” diesel vehicles – are expected to grow from just 1% to at least 20% by 2030.*

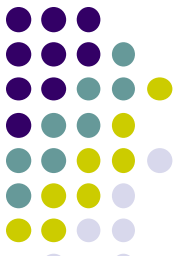
## Electric vehicle fleets in Japan and a selection of IEA member countries, 2009-18



Note: Excludes hybrid electric vehicles.

Source: IEA (2019a)

# Indústria de transportes



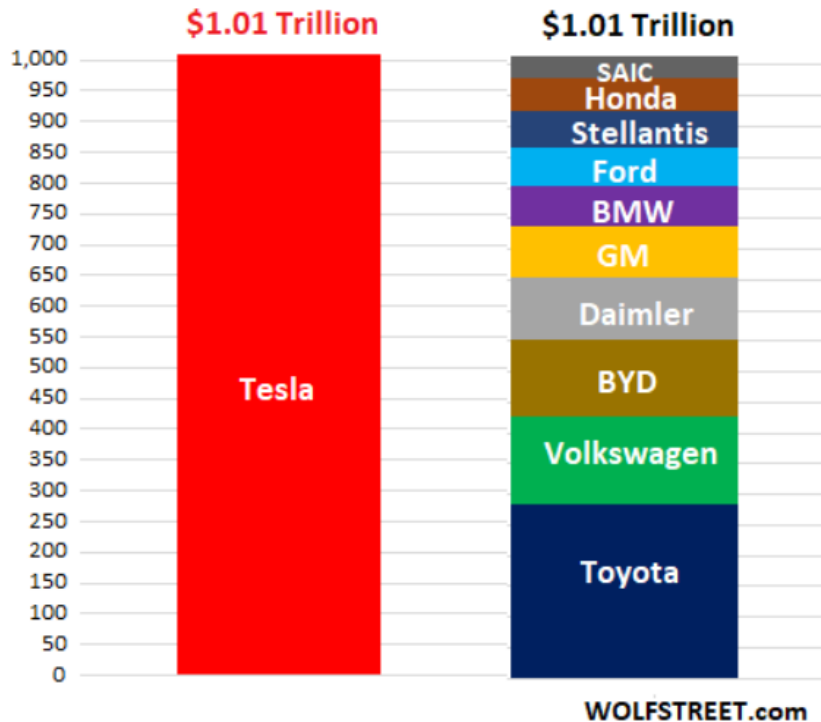
- ✓ Veículos elétricos;
- ✓ **Eficiência** >>> *EVs convert over 77% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12%–30% of the energy stored in gasoline to power at the wheels.*
- ✓ Veículos autônomos;
- ✓ *Smart Grids; V2G;*
- ✓ Redes 5G;
- ✓ Fim da era do petróleo? E o uso não energético?

# Indústria de transportes



✓ Veículos elétricos >>> Valor de mercado Tesla: US\$ 1 trilhão;

Market Capitalization, USD, Oct 25, 2021  
Tesla v. Next 10 Automakers



Kwid



Model 3





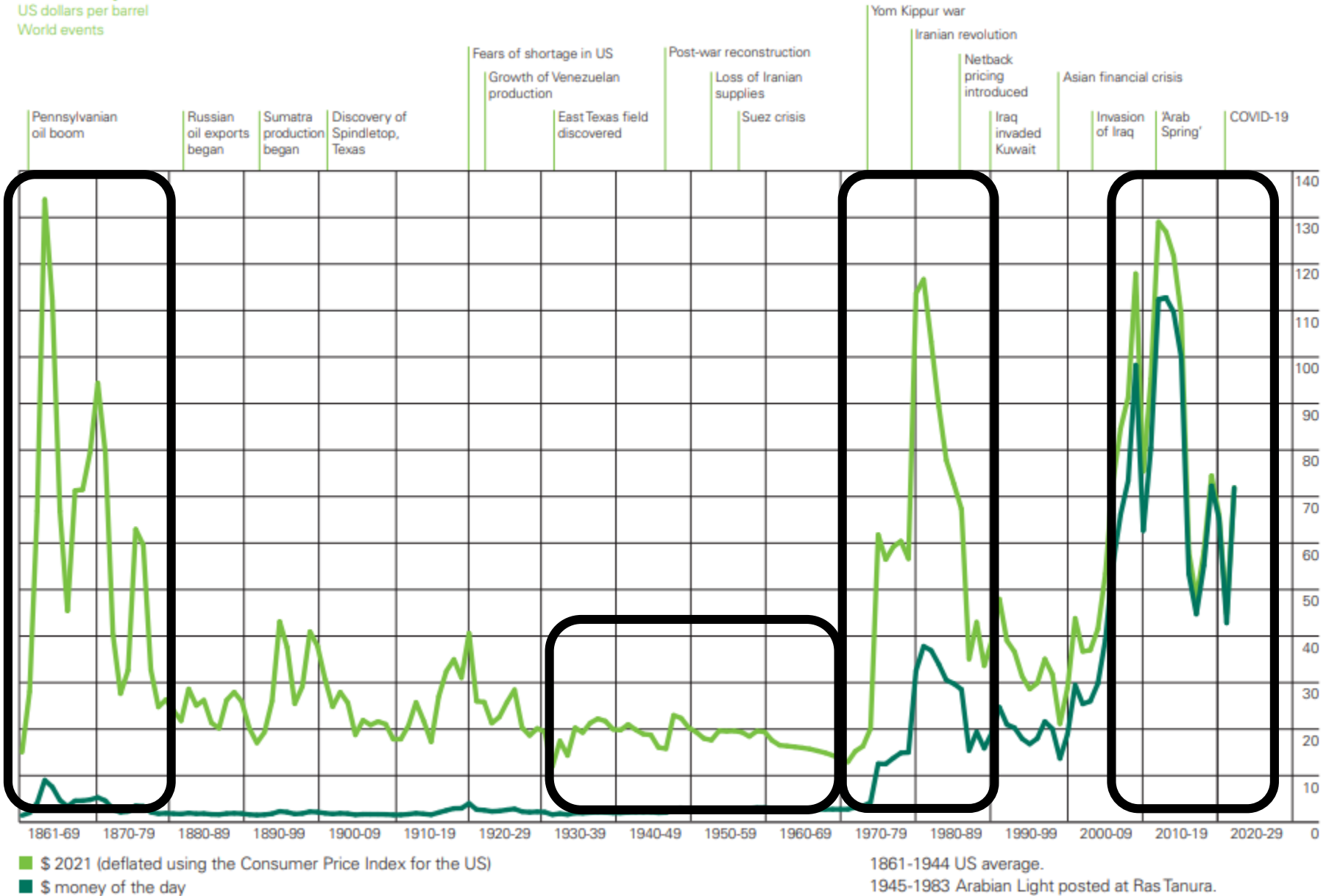
# Preço do Petróleo - Volatilidade



## Crude oil prices 1861-2021

US dollars per barrel

World events



■ \$ 2021 (deflated using the Consumer Price Index for the US)

■ \$ money of the day

1861-1944 US average.

1945-1983 Arabian Light posted at Ras Tanura.

1984-2021 Brent dated.

\$2021 (deflated using the Consumer Price Index for the US).

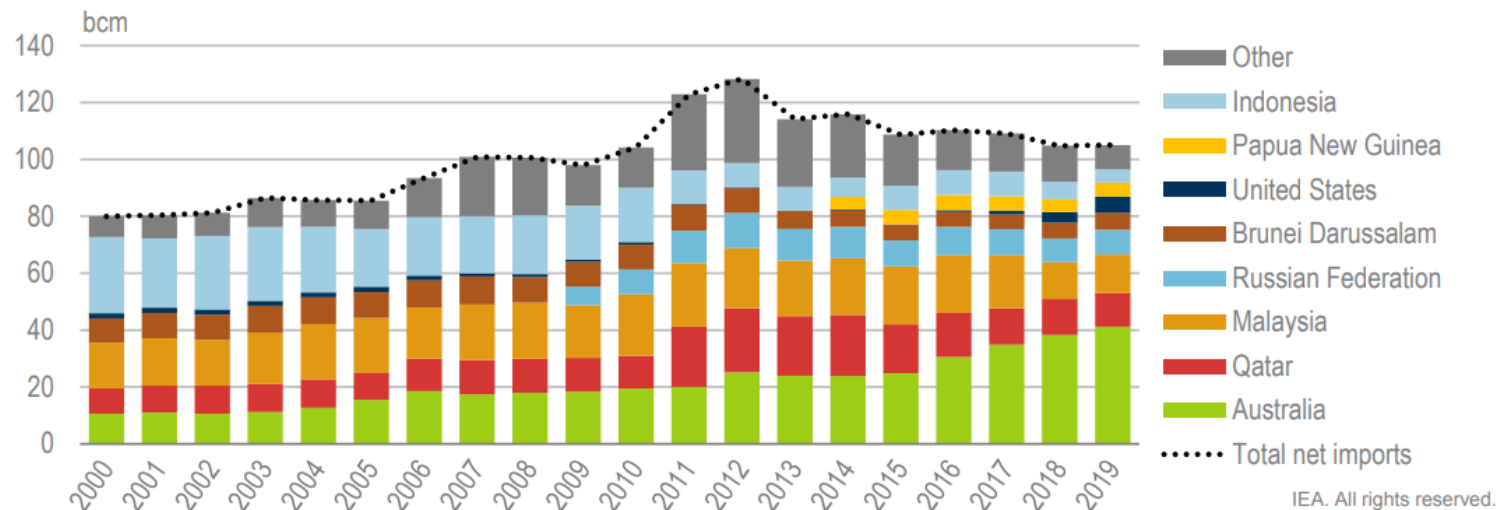
BP, 2022.

# Japão



- ✓ IEA 2021: *Japan Energy Policy Review*;
- ✓ Mercado de Gás Natural Liquefeito – GNL >>> Austrália;

**Natural gas imports to Japan by country, 2000-19**



Japan imported 105 bcm of LNG in 2019, over a third of which came from Australia, followed by Malaysia, Qatar and the Russian Federation, and recently increasingly also from the United States.

Note: bcm = billion cubic metre.

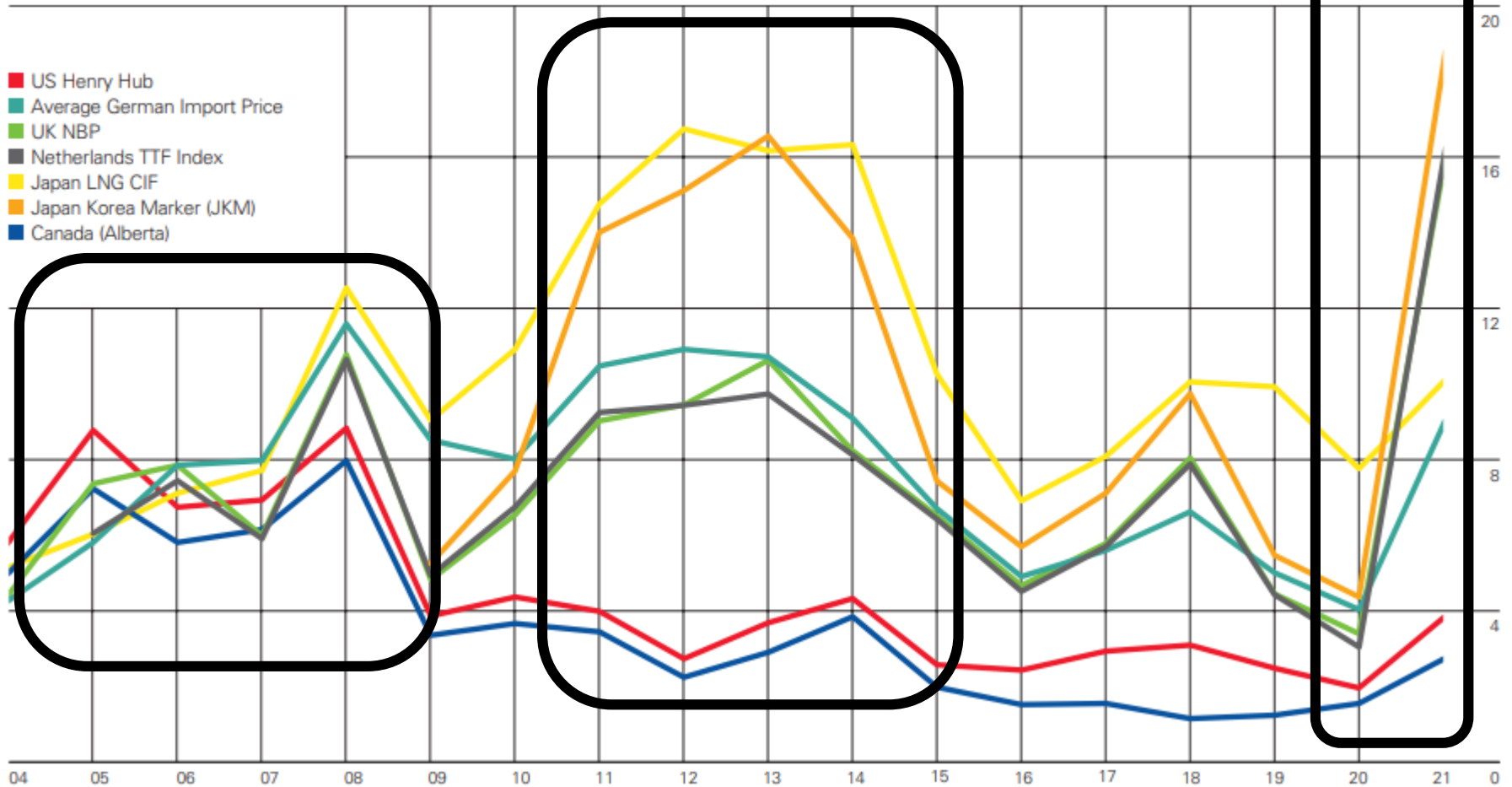
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), [www.iea.org/statistics](http://www.iea.org/statistics).

# Preço do Gás Natural - Volatilidade



## Prices

\$/mmBtu




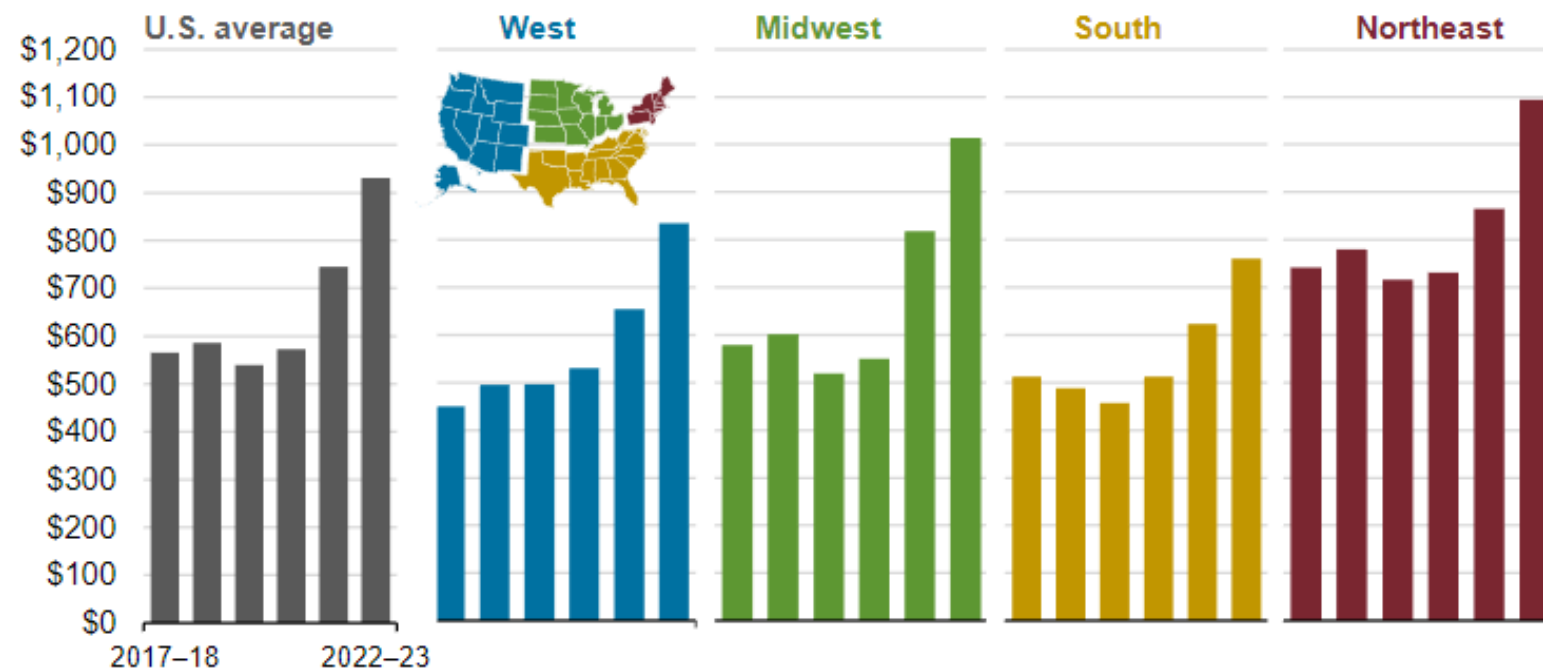
# Mercado de Gas Natural - EUA

OCTOBER 17, 2022



## U.S. natural gas bills will increase in all regions this winter

**Average U.S. residential winter natural gas expenditures (winter = Oct–Mar, 2017–2023)**  dollars



Data source: U.S. Energy Information Administration, *Winter Fuels Outlook*

# Mercado de Gas Natural - Europa



Europe (EU-27 and the UK) liquefied natural gas imports by source country (2010–2021)  
billion cubic feet per day



# Mercado de Gas Natural - Europa



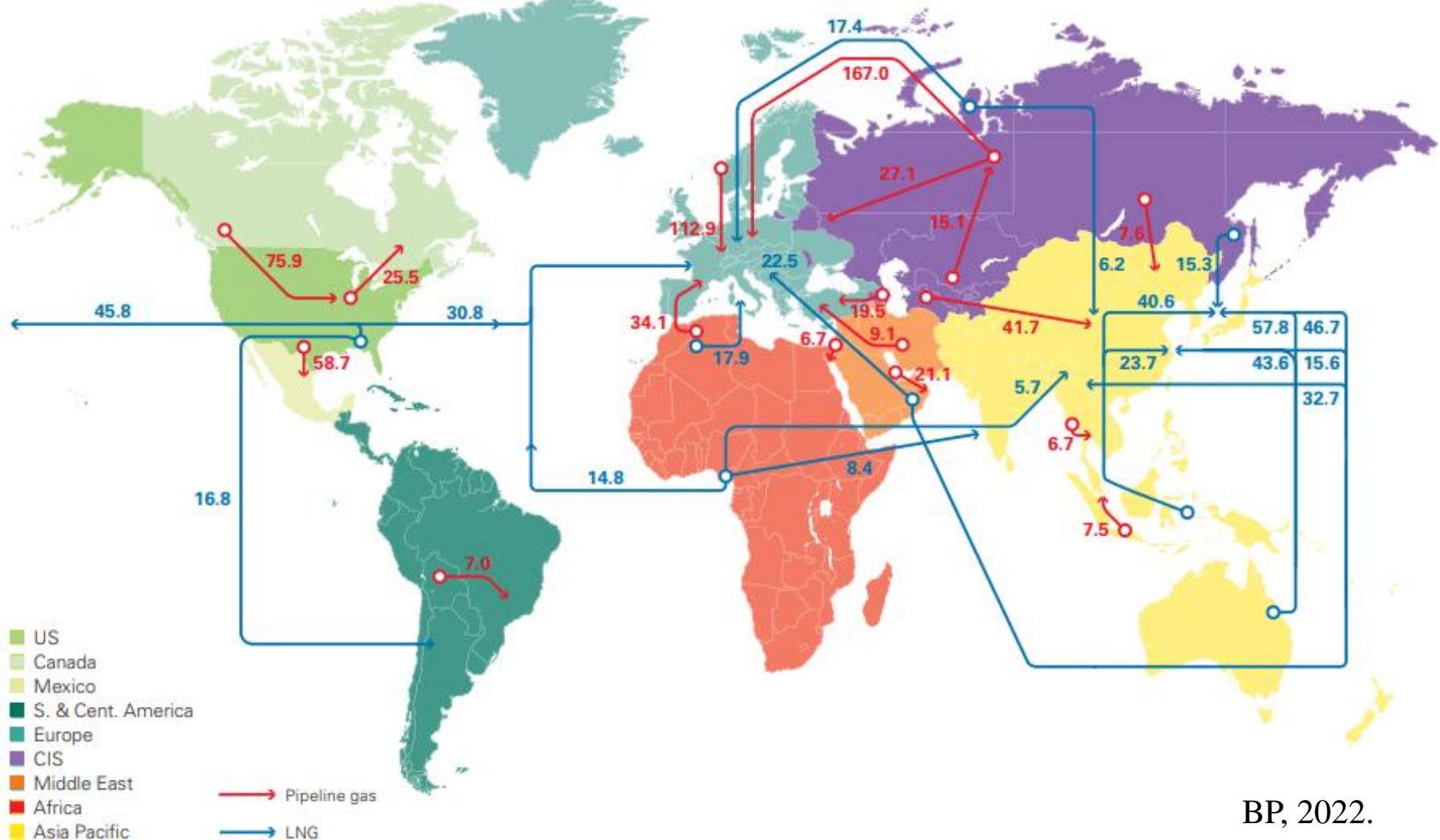
- ✓ *Natural gas futures linked Europe's wholesale gas price were trading around the €130 per megawatt-hour mark as abundant supplies of **LNG**, particularly from the US, helped countries fill storage sites ahead of the winter session.*
- ✓ *Europe's gas storage sites are more than **91%** full, above the five-year average, while Germany's stockpile rate reached 95%.*
- ✓ *Forecasts for a milder winter, with above-normal temperatures during the peak heating season between December and February, could suggest lower heating demand.*
- ✓ *The **European Union** is due to propose new energy measures to tackle the ongoing energy crisis, including a range of options for **natural gas price caps**.*
- ✓ *Natural gas futures were **more than four times higher than average** for this time of the year, with risk remaining on the upside amid concerns about further supply disruptions, particularly those from **Russia**.*

# Mercado de Gas Natural



## Major trade movements 2021

Trade flows worldwide (billion cubic metres)



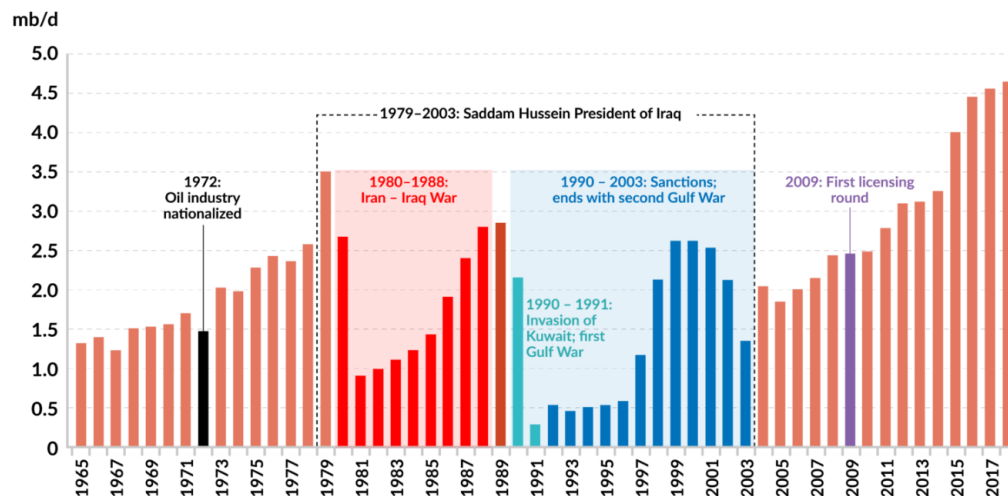
BP, 2022.



# Oriente Médio



- ✓ OPEP;
- ✓ Arábia Saudita X Irã;
- ✓ Irã – Programa Nuclear / JCPOA; Influência russa;
- ✓ Síria – rota alternativa para gasodutos; Influência russa;
- ✓ Qatar - Exportação de GNL (Gás Natural Liquefeito);
- ✓ Iraque – risco iminente de guerra civil;

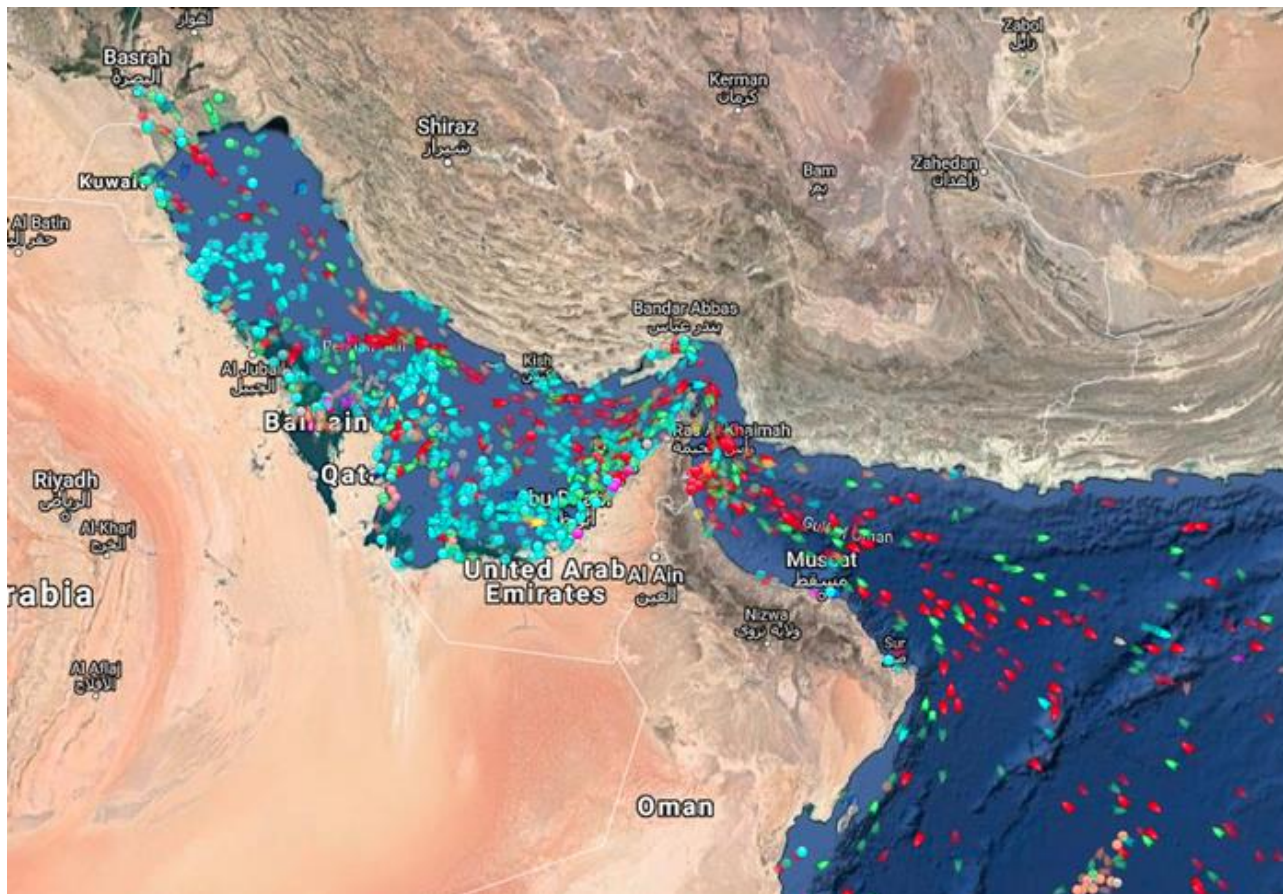




# Oriente Médio



- ✓ “*Heartland energético*” do mundo;
- ✓ Estreito de Ormuz: 70 km de largura no trecho navegável;

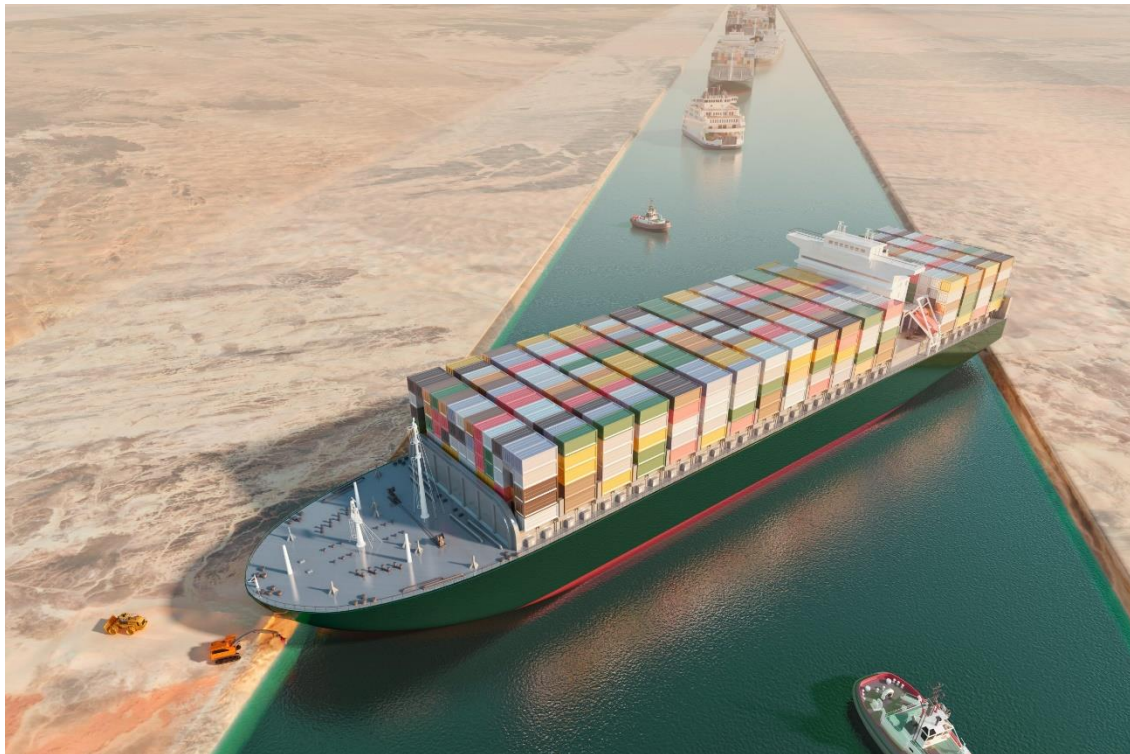


# Estreitos



## Canal de Suez

- ✓ Acesso a mercado europeu;
- ✓ Março de 2021: Navio Ever Given encalha no canal por seis dias;

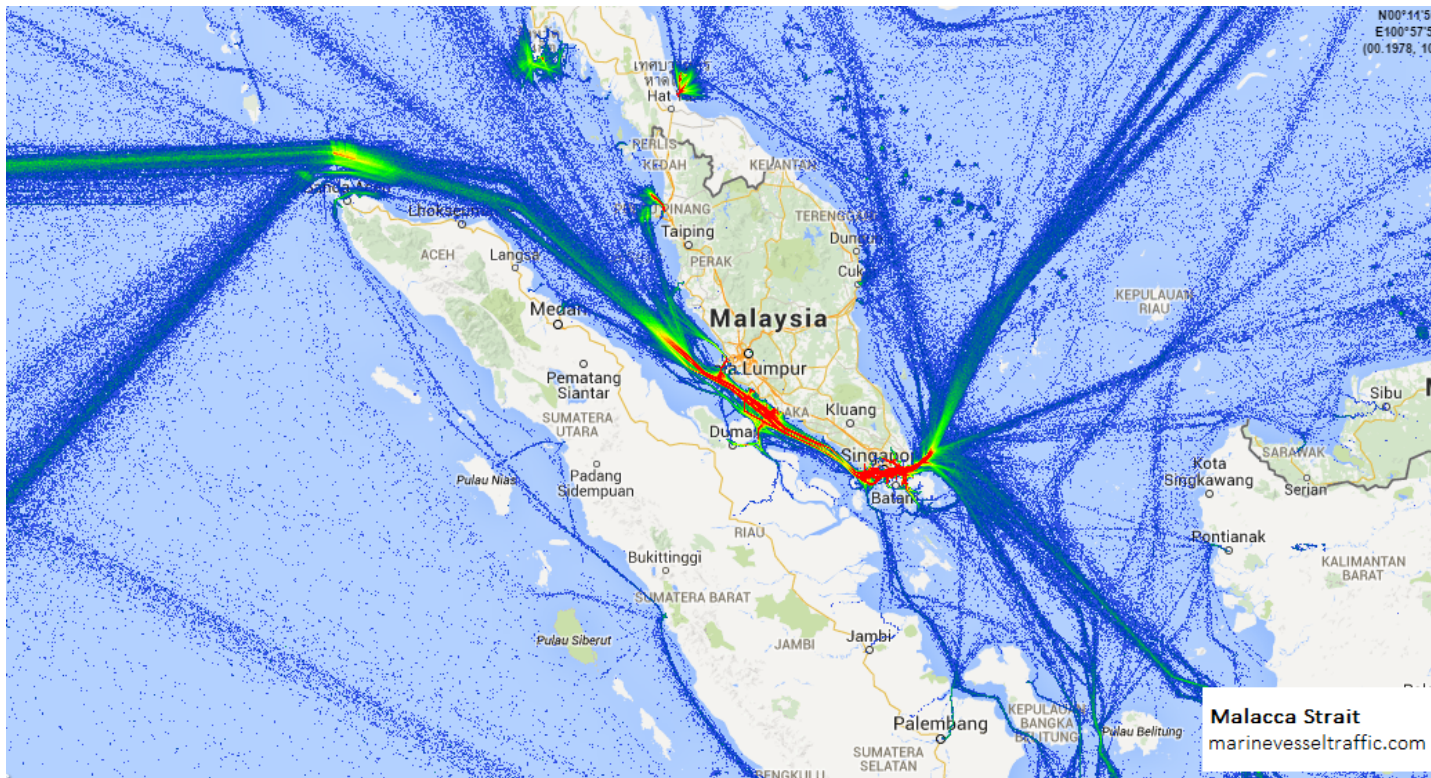




# Estreitos

## Málaca

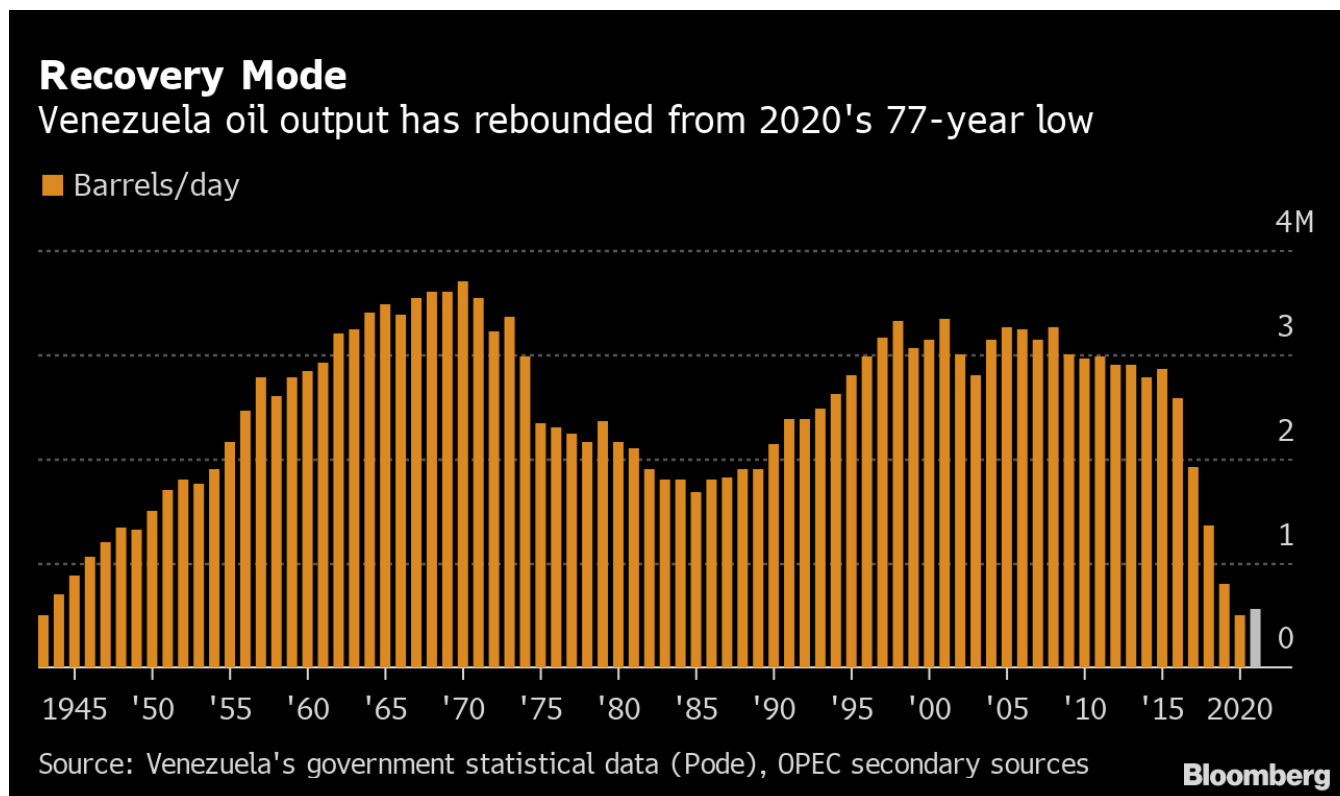
- ✓ Acesso a mercado chinês – Petróleo / PV inclusive;
- ✓ Comércio GNL Oriente Médio;



# Venezuela



- ✓ Governo Maduro
- ✓ Queda na produção de petróleo – 3,0 Mi bpd >>> 0,5 Mi bpd;
- ✓ Maior reserva do mundo – 300 bilhões de barris;

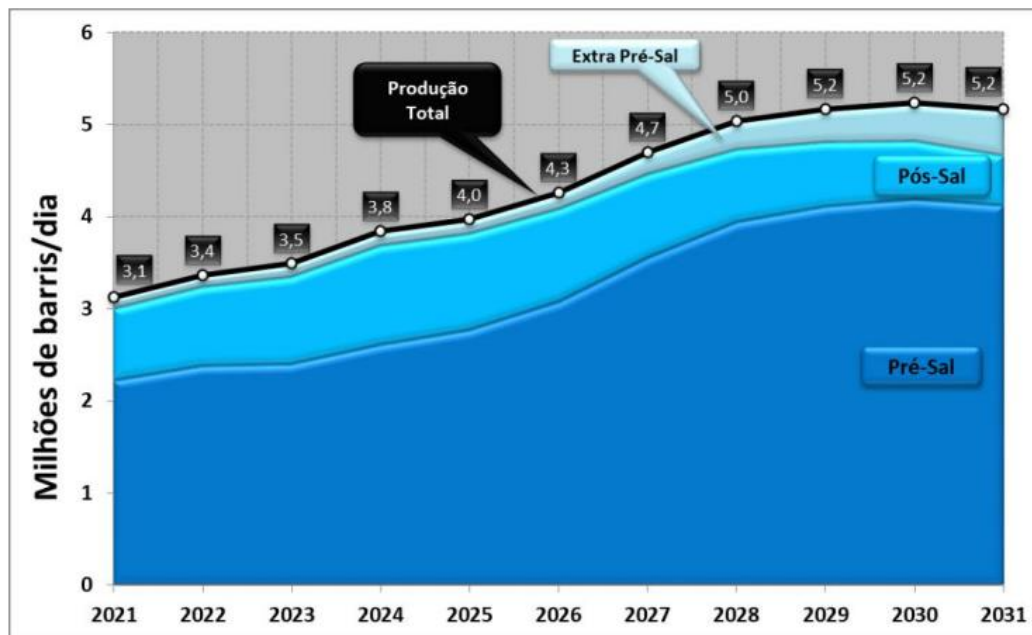


# Brasil



- ✓ Autossuficiência em petróleo (2006); Pré-Sal (2007);

Previsão da produção de petróleo nacional para o pré-sal, pós-sal e extra pré-sal



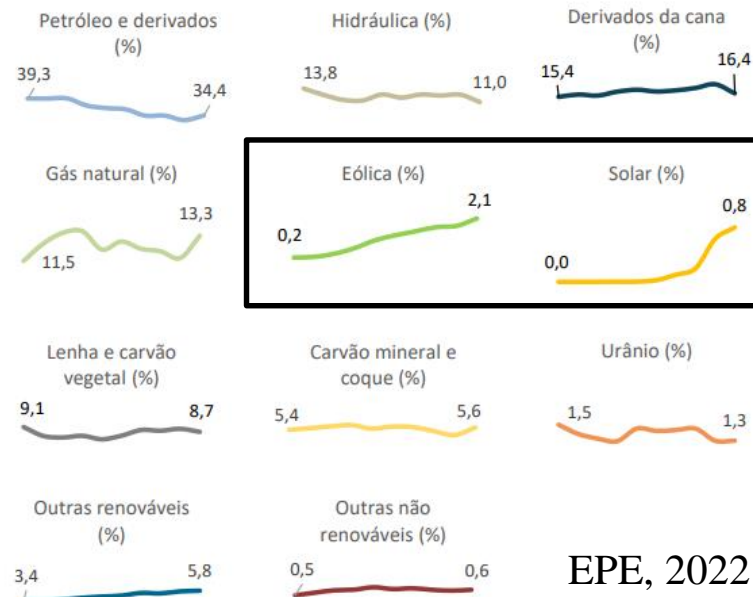
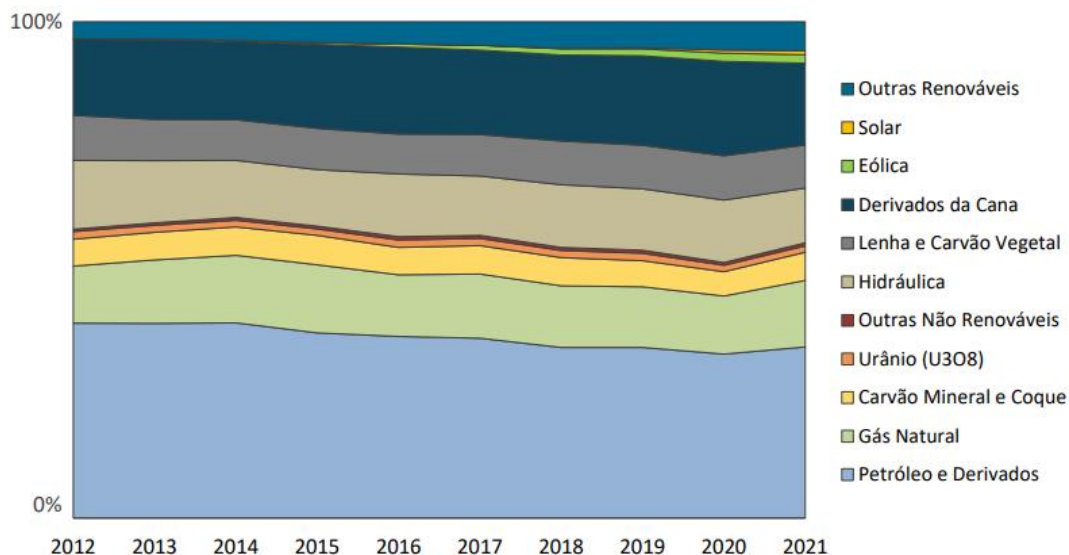
- ✓ Dependência em derivados (2021) - diesel (33%) e gasolina (10%);
- ✓ Impacto Guerra Ucrânia/Rússia – Redução do ICMS sobre gasolina (de 30% para 17%);

# Brasil



- ✓ NDC – 2016; Revisão 2020;
- ✓ Veículos Flex (Biocombustíveis) X Veículos elétricos;
- ✓ 2021: Expansão da Solar PV (16 TWh) e Eólica (72 TWh);
- ✓ Amazônia “*Heartland ambiental*” do mundo – Bertha Becker;

Oferta Interna de Energia 2012-2021



EPE, 2022.

# Mudanças Climáticas



- ✓ *Intergovernmental Panel on Climate Change* IPCC (1988);
- ✓ Rio 1992 (CNUMAD) – *Conference of Parties* (COP);
- ✓ Protocolo de Kyoto (1997); metas específicas: *top-down*;
- ✓ Emenda de Doha (2012);
- ✓ **Acordo de Paris (2015)** – limitar até 2°C; NDC: *bottom-up*;
- ✓ *Nationally Determined Contributions* (NDC); Revisão periódica;
- ✓ Compromisso de financiamento de US\$100 bilhões por ano;
- ✓ Guerra Rússia/Ucrânia >>> Impacto nas NDCs, sobretudo de países europeus;

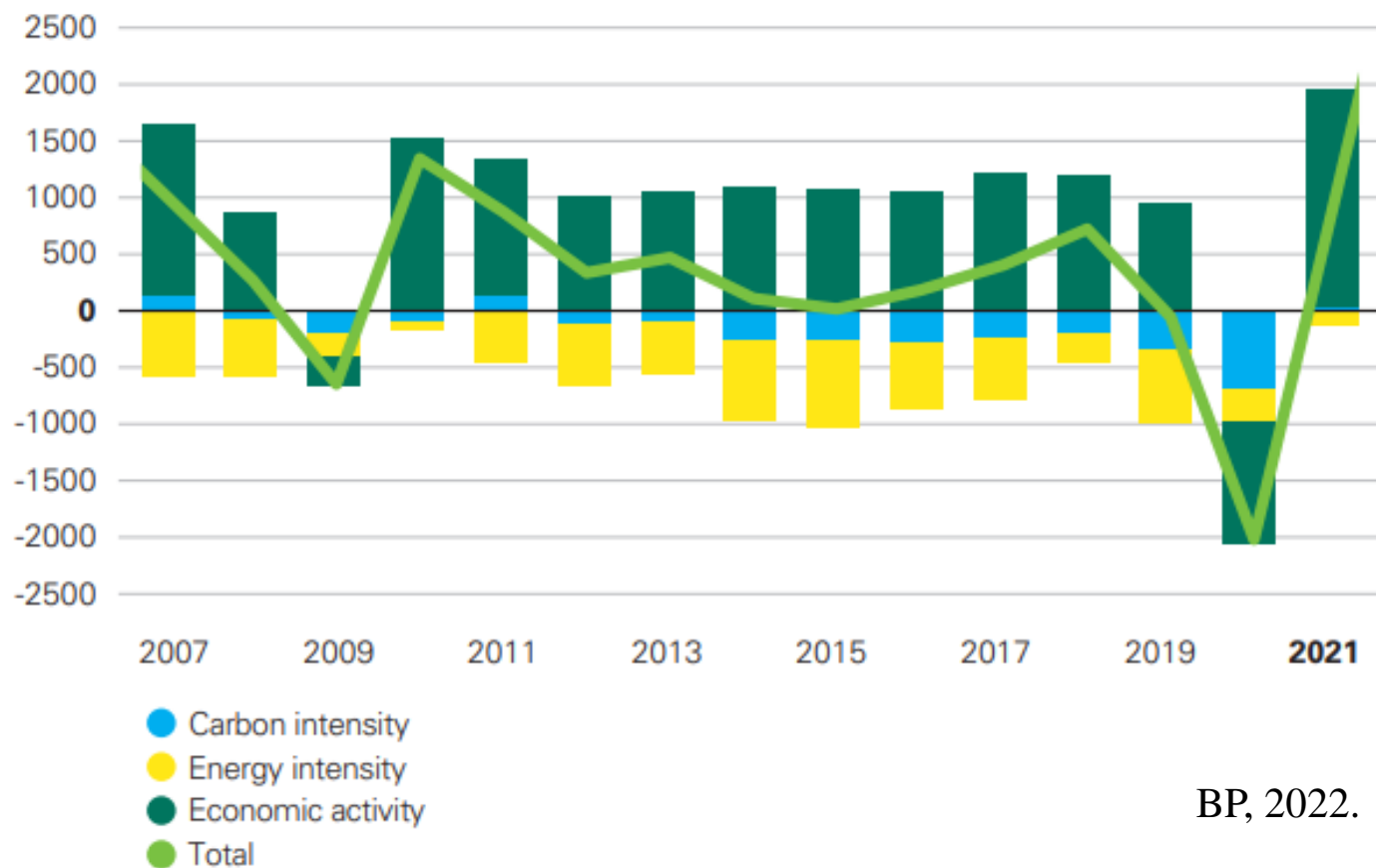
# Mudanças Climáticas



## ✓ Emissões de carbono – BP Statistical Review

**The increase in carbon emissions in 2021 was driven by the rebound in economic growth**

Annual change MtCO<sub>2</sub>e



BP, 2022.



# Mudanças Climáticas

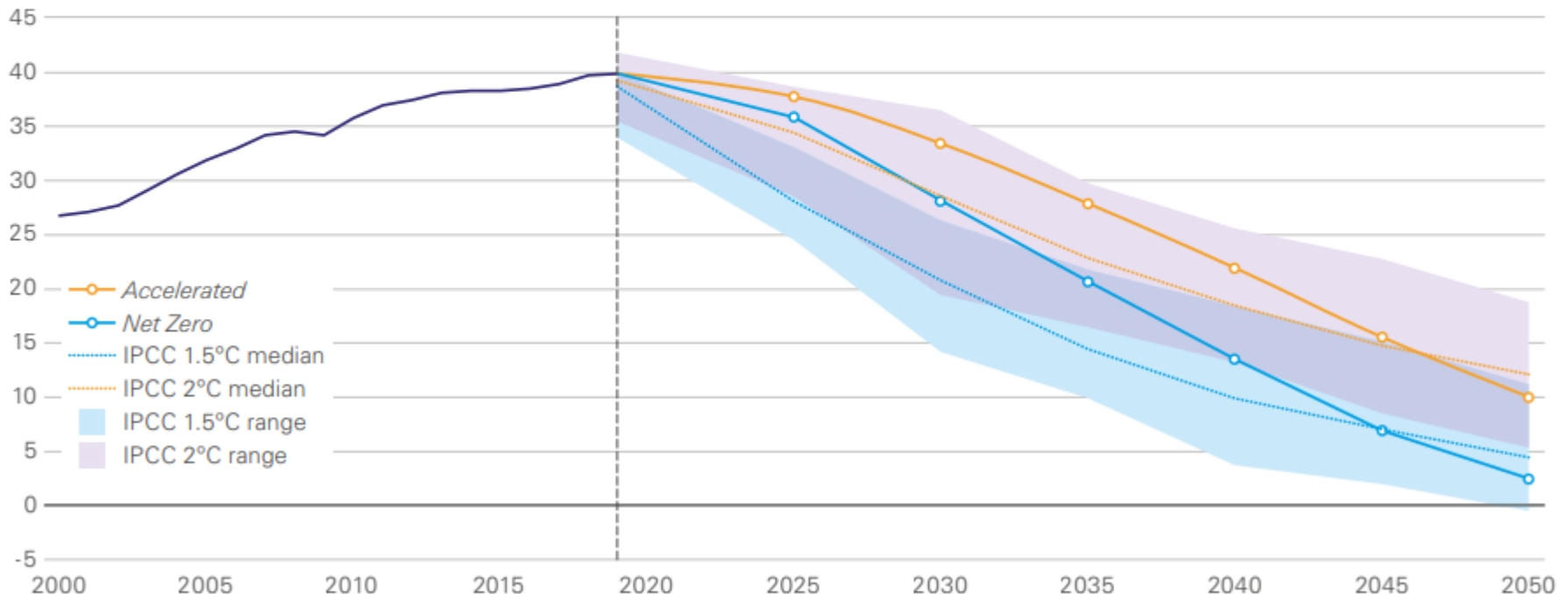


## ✓ Emissões de carbono – BP Energy Outlook 2022

*Accelerated* and *Net Zero* are broadly in line with 'Paris consistent' IPCC scenarios

### Carbon emissions

Gt of CO<sub>2</sub>e



Carbon emissions include CO<sub>2</sub> emissions from energy use, industrial processes, natural gas flaring, and methane emissions from energy production. Ranges show 10th and 90th percentiles of the IPCC scenarios.

# Mudanças Climáticas



✓ **Geração Elétrica Renovável >>> Solar PV e Eólica;**

## **Desafios:**

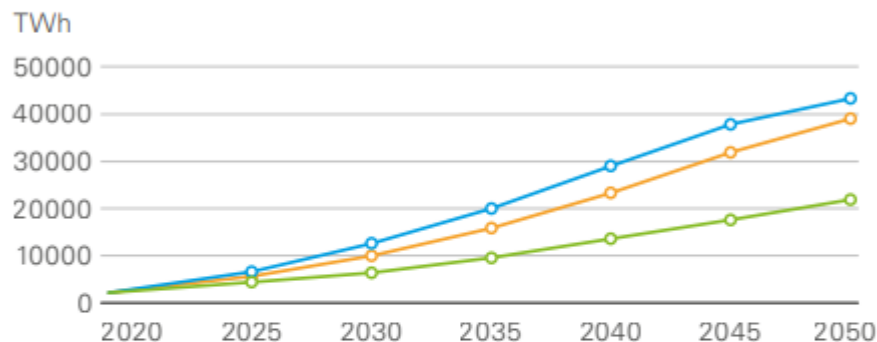
- ✓ Baixa densidade energética;
- ✓ Intermitência no suprimento;
- ✓ Risco de apagões;
- ✓ Novas rotinas de operação de sistemas elétricos com grande capacidade instalada de fontes intermitentes;
- ✓ Desenvolvimento de baterias de grande porte >>> flexibilidade;

# Mudanças Climáticas

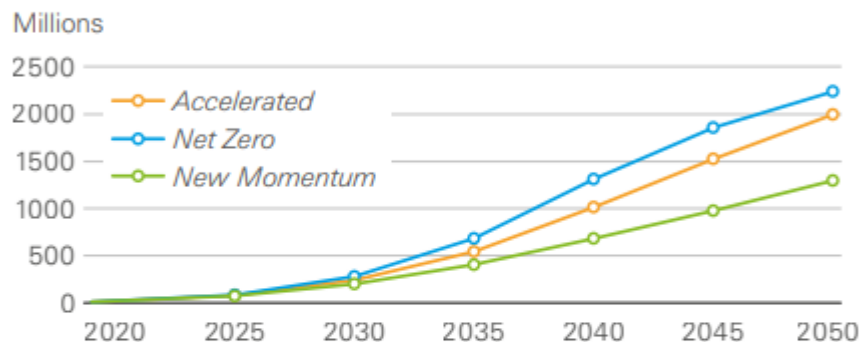


Energy transition underpinned by a range of low-carbon energy sources and technologies

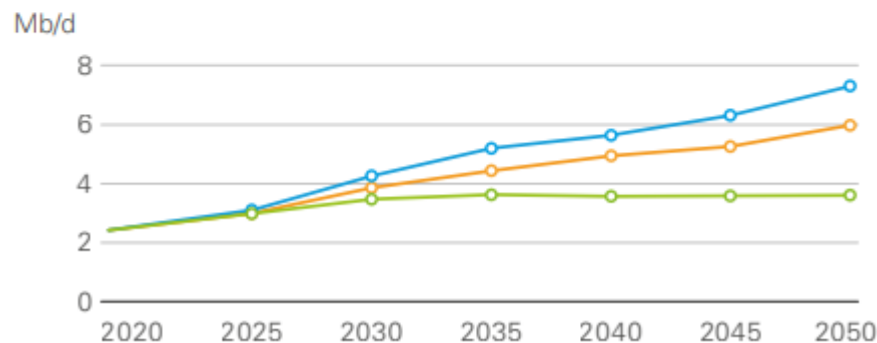
## Wind and solar power generation



## Electric vehicles

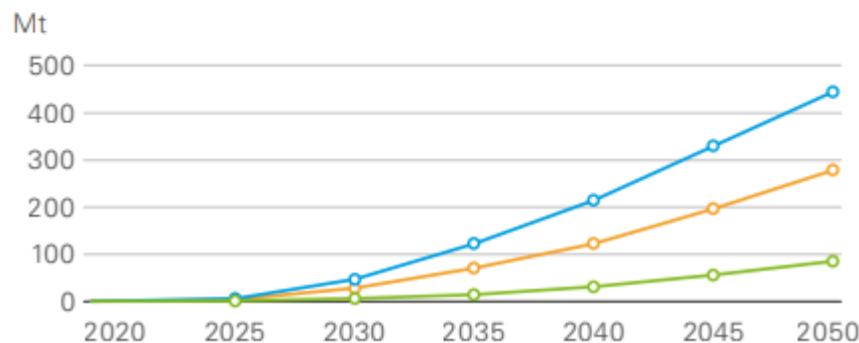


## Biofuels



Biofuels includes liquids biofuels and gaseous biofuels (biomethane, expressed in biodiesel equivalent terms)

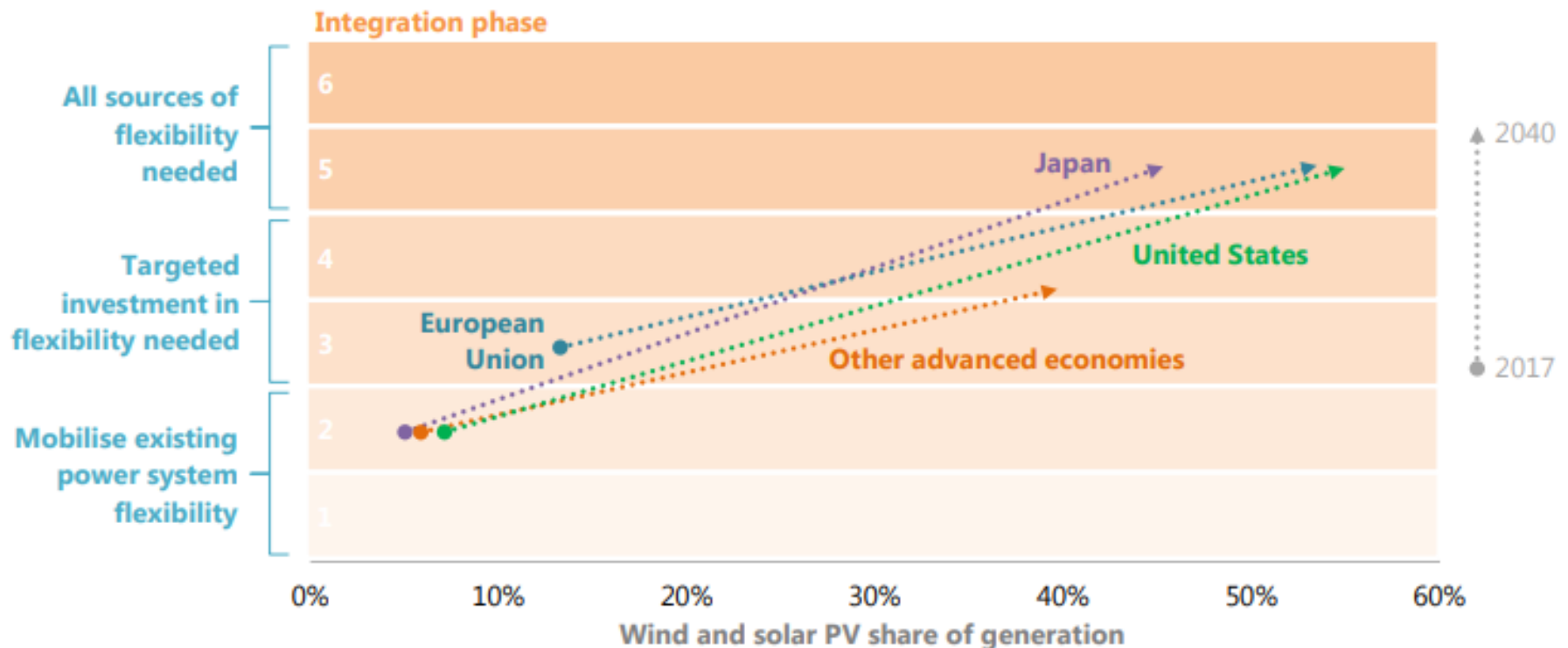
## Low-carbon hydrogen



# Mudanças Climáticas



## Phases of VRE integration in the Nuclear Fade Case of the Sustainable Development Scenario in selected advanced economy regions/countries



IEA (2019). All rights reserved.

Rising VRE output needs to be accompanied by increased investment in various sources of flexibility, such as batteries, interconnections, electrolysis for hydrogen storage and demand-side management.

# Indústria de painéis fotovoltaicos



## China

- ✓ *China has invested over **USD 50 billion** in new **PV supply capacity** – ten times more than Europe – and created more than 300.000 manufacturing jobs across the solar PV value chain since 2011.*
- ✓ *The country is home to the **world's 10 top suppliers of solar PV manufacturing equipment**.*
- ✓ *The level of **geographical concentration in global supply chains** also creates potential challenges that governments need to address.*

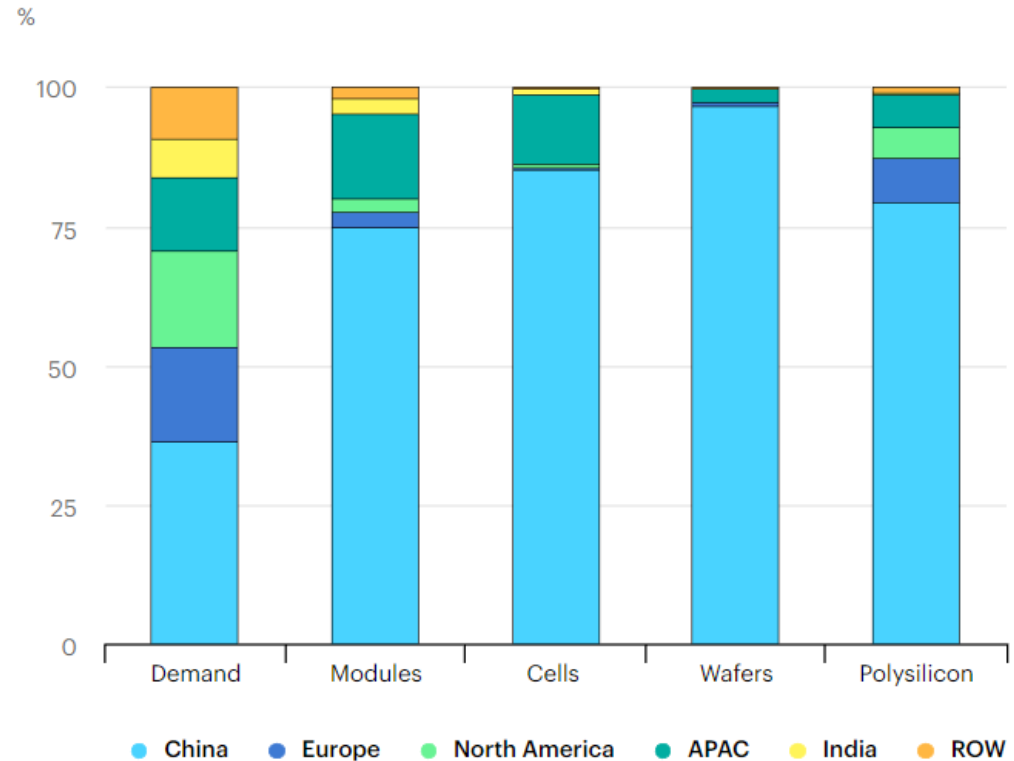
# Indústria de painéis fotovoltaicos



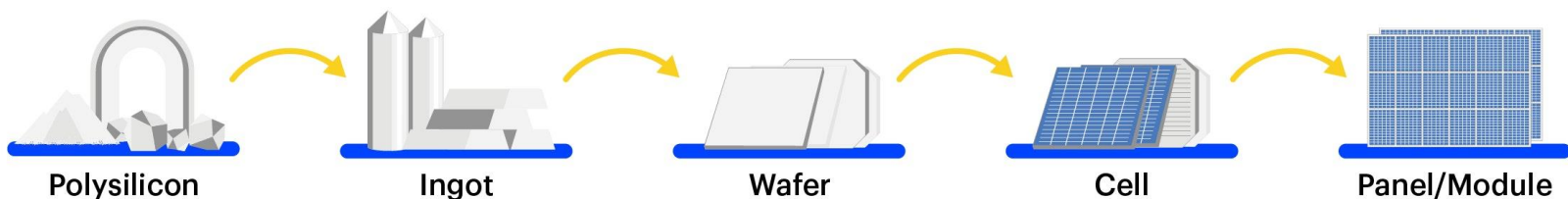
## China

✓ 75% da produção;

Solar PV manufacturing capacity by country and region, 2021



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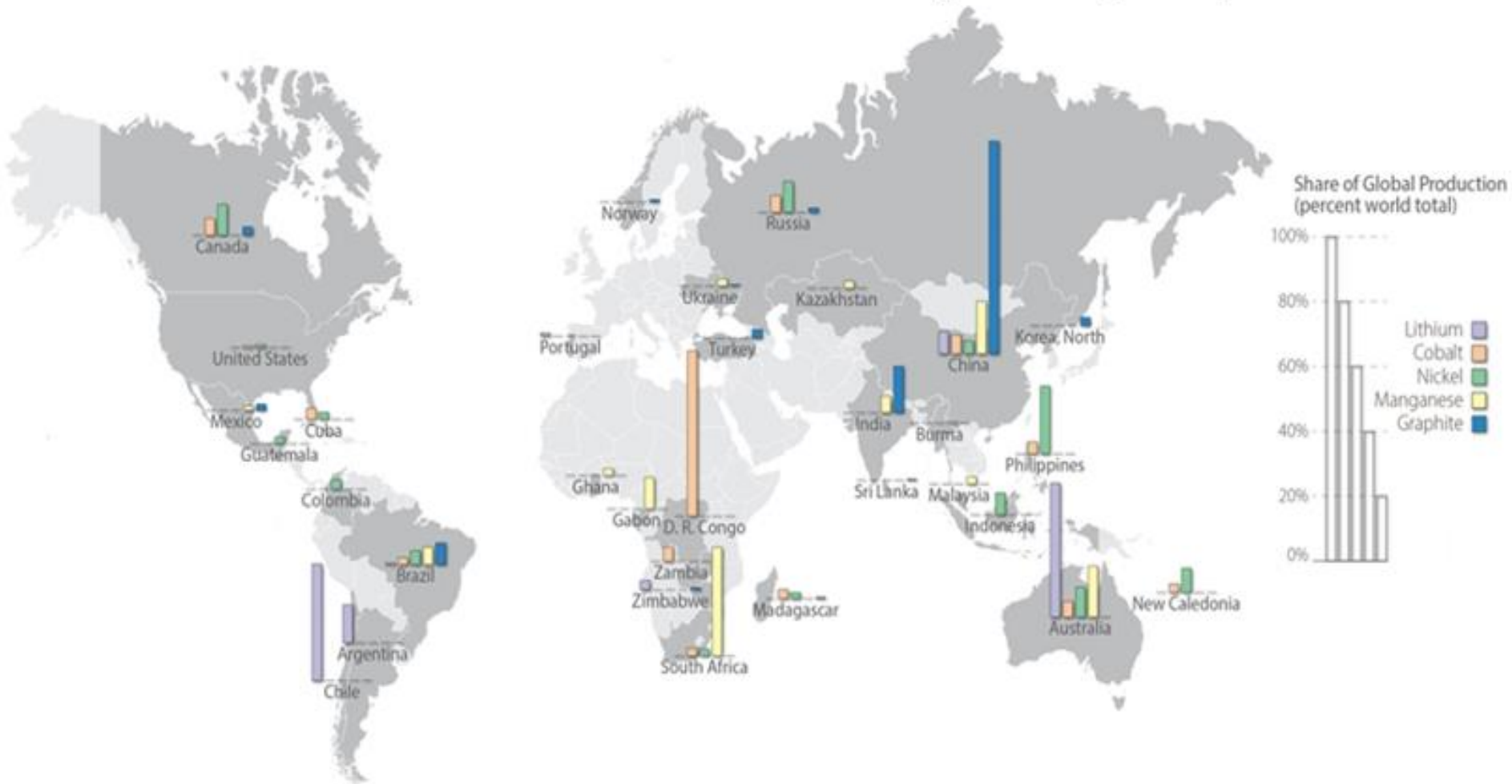


# Baterias Íon-Lítio



✓ Lítio: Austrália (44%), Chile (34%) e Argentina (13%);

**Global Production Shares of Selected Lithium-ion Battery Materials by Country, 2017**



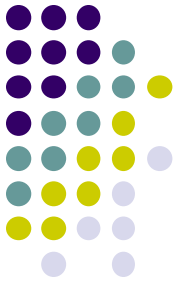


# Novos Reatores Nucleares



- ✓ **Geração nuclear >>> Estabilidade e flexibilidade;**
- ✓ Experiência francesa em geração nuclear flexível;
- ✓ *IEA Report (2019): Nuclear Power in a Clean Energy System;*
- ✓ *Encouraging investment in Small Modular Reactors (SMR);*
- ✓ *Support innovative new reactor designs - Accelerate innovation in new reactor designs with lower capital costs and shorter lead times and technologies that improve the operating flexibility of nuclear power plants to facilitate the integration of growing wind and solar capacity into the electricity system.*

# Obrigado!



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`gustavo.moura@ufop.edu.br`

**Dúvidas?**