

BOOK 9

Coal Industry Fundamentals

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TPA

Sharing Experience

Building bridges between the oil industry and academic circles by delivering technical or business-related presentations by professors or experts.



OIL & GAS and ENERGY GLOBAL ISSUES

A Toolbox to understand the World of Energy in the Global Economy

The Toolbox is updated twice a year and benefits from the contributions of TPA Professors:

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Coal



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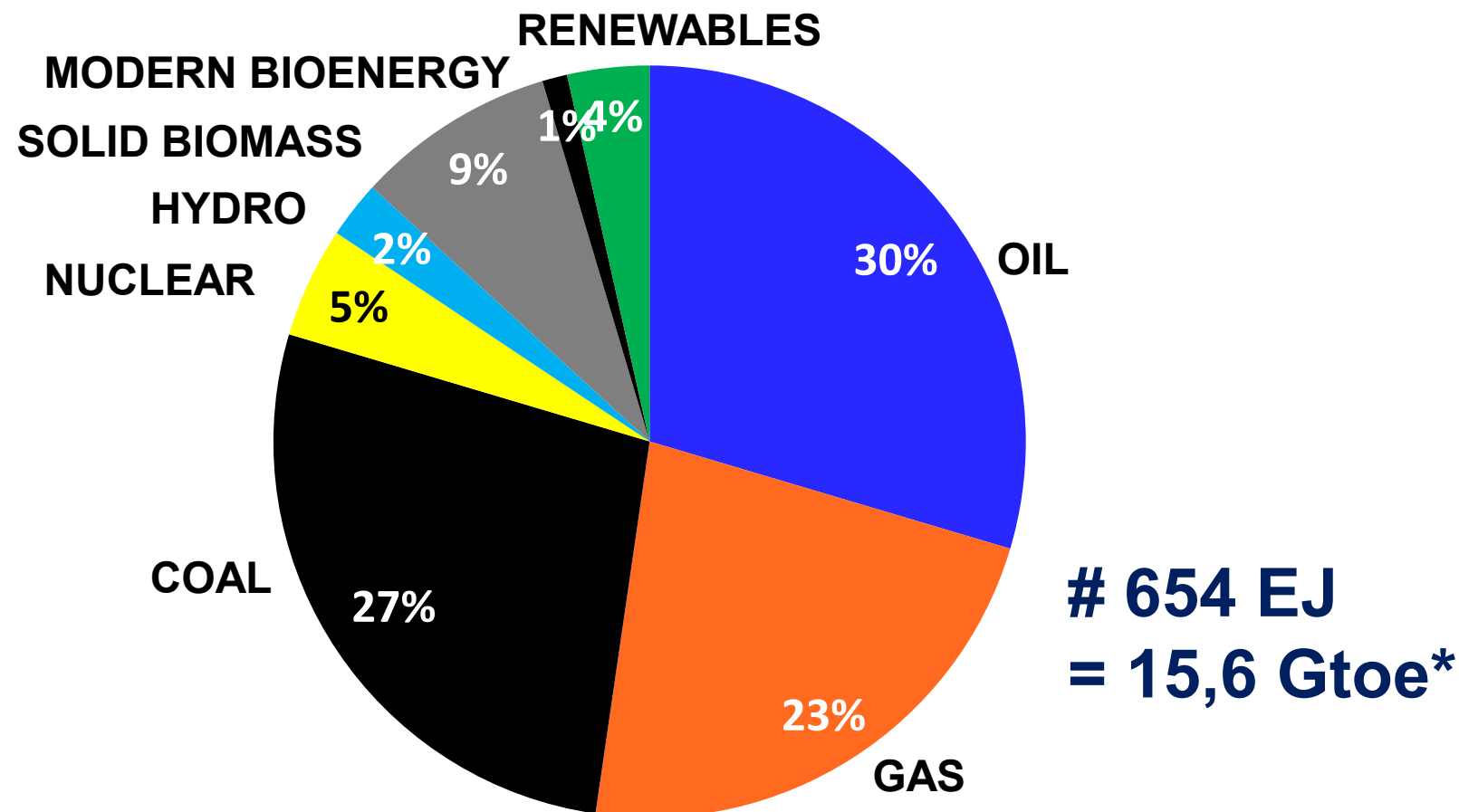
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Coal fundamentals



World Primary Energy Demand – 2024

+ 2,0% vs 2023



* out of which electricity generation # 6,2 Gtoe # 29 700TWh (eq. Primary Energy)

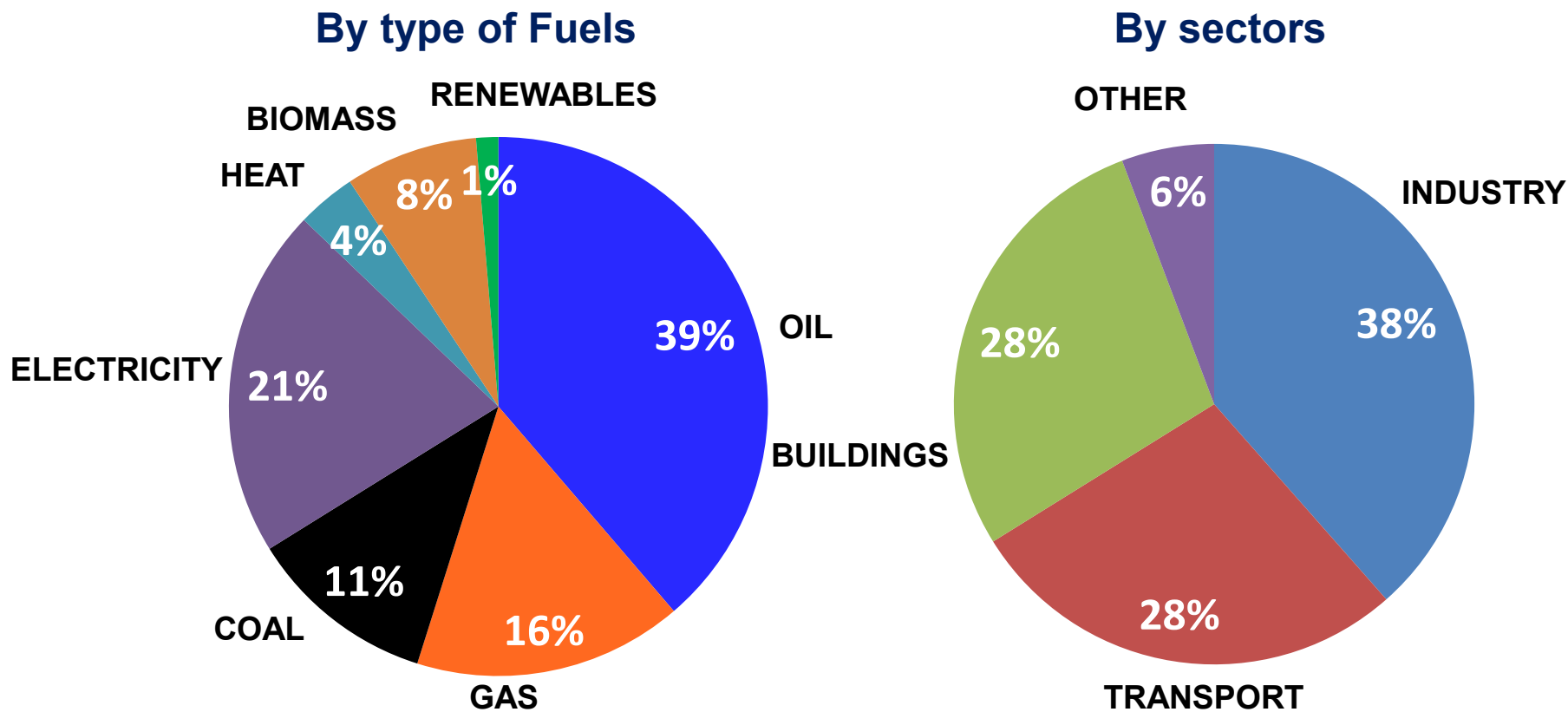
Source: Data from IEA WEO 2025. Nota: Sums might not be equal to 100% due to rounding

Solid Biomass: tradit. wood & charcoal & solid residues. Modern Bioenergy: liquid & gaseous bioenergy (biofuels & biogases) Renewables: Solar, Wind, Geothermal, Marine Energy,...

TPA Toolbox Energy Book 9 – Coal



Total Final Consumption – 2024 + 2,0% vs 2023



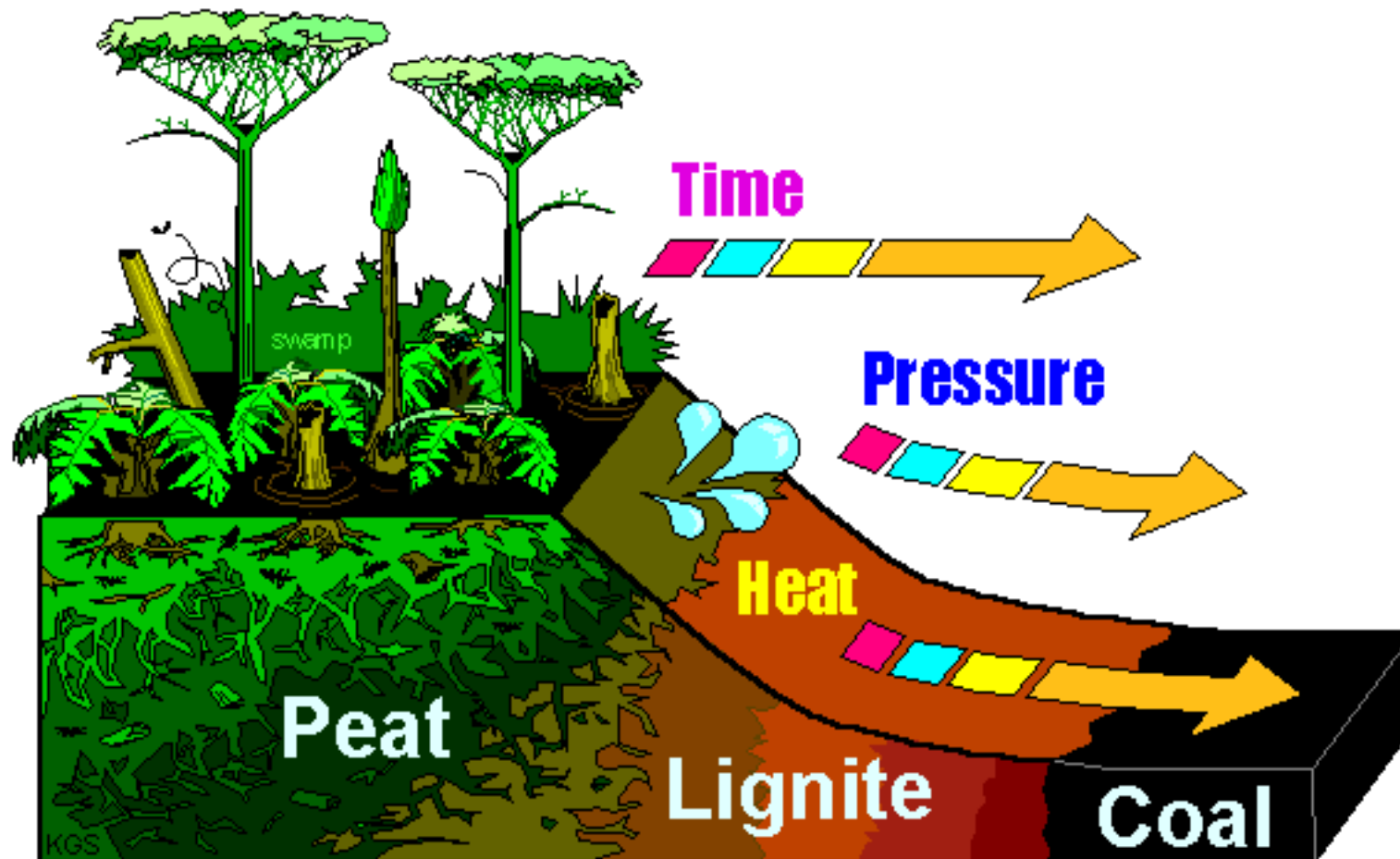
453 EJ = 10,8 Gtoe

Nota: Sums might not be equal to 100% due to rounding
OTHER relates to agricultural sector & other non-energy use
Source: Data from IEA WEO 2025

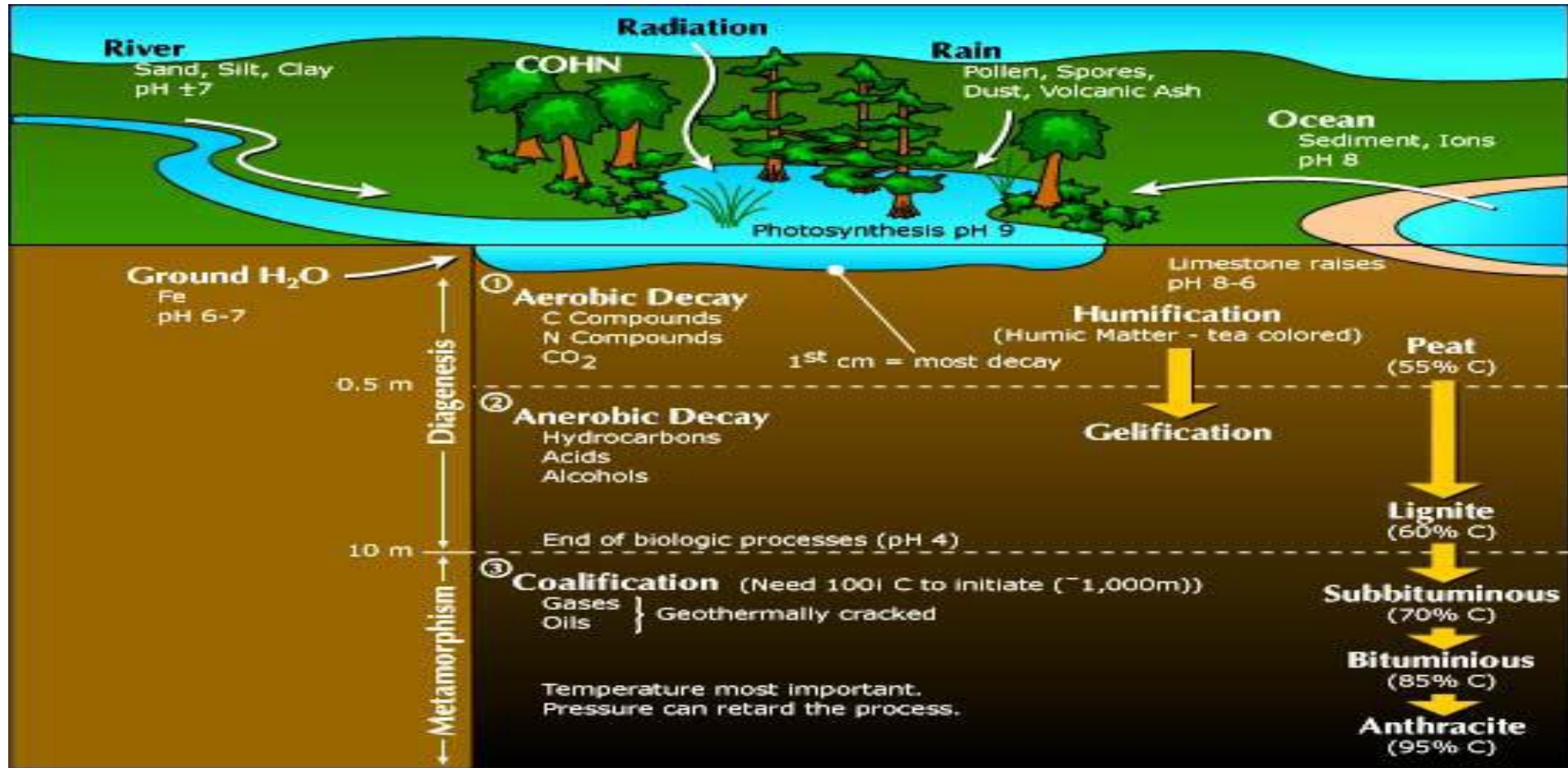


Coal Origin & Formation

Coalification Process



The Coal ranks



Oxygen & H₂O release



Various categories of Coal

Coal is an organic sedimentary rock formed from vegetable matter, particularly during the Carboniferous period, and consolidated in seams between strata of non-organic rock. The IEA classifies coal as hard coal and brown coal, and also includes peat.

Hard coal: coal with a gross calorific value greater than 5 700 kilocalorie per kilogramme (kcal/kg) (23.9 gigajoules per tonne [GJ/tonne]) on an ash-free but moist basis and with a mean random reflectance of vitrinite of at least 0.6. It includes anthracite and bituminous coal. Hard coal is calculated as the sum of coking and steam coal:

- Coking coal: Hard coal with a quality that allows the production of coke suitable to support a blast furnace charge (see footnote for the term metallurgical coal¹).
- Steam coal: All other hard coal not classified as coking coal. Also included are recovered slurries, middlings and other low-grade coal products. Coal of this quality is sometimes referred to as thermal coal.

Brown coal: non-agglomerating coal with a gross calorific value less than 5 700 kcal/kg (23.9 GJ/tonne) containing more than 31% volatile matter on a dry mineral matter free basis. Brown coal is the sum of sub-bituminous coal² and lignite:

- Sub-bituminous coal: Non-agglomerating coal with a gross calorific value between 4 165 kcal/kg and 5 700 kcal/kg.
- Lignite: defined as non-agglomerating coal with a gross calorific value less than 4 165 kcal/kg.

Peat: a solid formed from the partial decomposition of dead vegetation under conditions of high humidity and limited air access. It is available in two forms for use as a fuel, sod peat and milled peat. Milled peat is also made into briquettes for fuel use.

Source: IEA 2011. Gross Calorific Value or Higher Heating Value (HHV) is the Calorific Value (CV) under laboratory conditions



Coal

Brown Coal



- ◆ Open cast + underground mining
- ◆ Energy content < 4500 kcal/kg LCV
- ◆ Water content > 35%, hence only regional transport
- ◆ Utilization on regional energy markets only
- ◆ Subdivided into sub-bituminous coal and lignite

LCV: Low Calorific Value. Difference with HCV is the latent heat of the water vapor produced
1 cal. = 4,18 J.

Hard Coal



- ◆ Open cast + underground mining
- ◆ Energy content > 4500 kcal/kg LCV
- ◆ Water content < 35%
- ◆ Worldwide traded commodity
- ◆ Subdivided into anthracite and bituminous coal, or thermal (or steam) coal and coking coal for final use



The 4 Commercial Ranks



Peat



Lignite/Brown Coal



Sub. & Bituminous



Anthracite

Classification Coal Types & Peat

Coal Types and Peat				Total Water Content (%)	Energy Content af* (kJ/kg)	Volatiles maf** (%)	Vitrinite Reflection in oil (%)
UN-ECE	USA (ASTM)	Germany (DIN)					
Peat	Peat	Torf					
Ortho-Lignite	Lignite	WEICHBRAUNKOEHLE		75	6,700		
Meta-Lignite		Sub-bituminous Coal	Mattbraunkohle		35	16,500	
Subbitum. Coal	Glanzbraunkohle		25		19,000		0.45
Bituminous Coal	High Volatile Bituminous Coal		Flammkohle		Steinkohle	10	25,000
		Gasflammkohle	40	0.75			
		Gaskohle	Kokskohle	35			
	Medium Vol. Bitumin. Coal	Fettkohle		36,000		28	1.2
	Low Vol. Bitumin. Coal	Eßkohle		19		1.6	
				14		1.9	
	Anthracite	Semi-Anthracite	Magerkohle	3		36,000	10
Anthracite		Anthrazit					

af* = ash-free maf** =moisture ash-free

(UN-ECE) Ortho-Lignite up to 15,000 kJ/kg; Meta-Lignite up to 25,000 kJ/kg; Subbituminous Coal up to 35,000 kJ/kg; Bituminous Coal up to 47,000 kJ/kg; Vitrinite Reflection: (DIN) Lignite up to 0.35; Bituminous up to 2.2.

Source: DIN

Main uses:

Steam Coal

**Boilers
Power Generation
Cements**

Metallurgical

Domestic



H/C/O Ratios Biomass & Coal

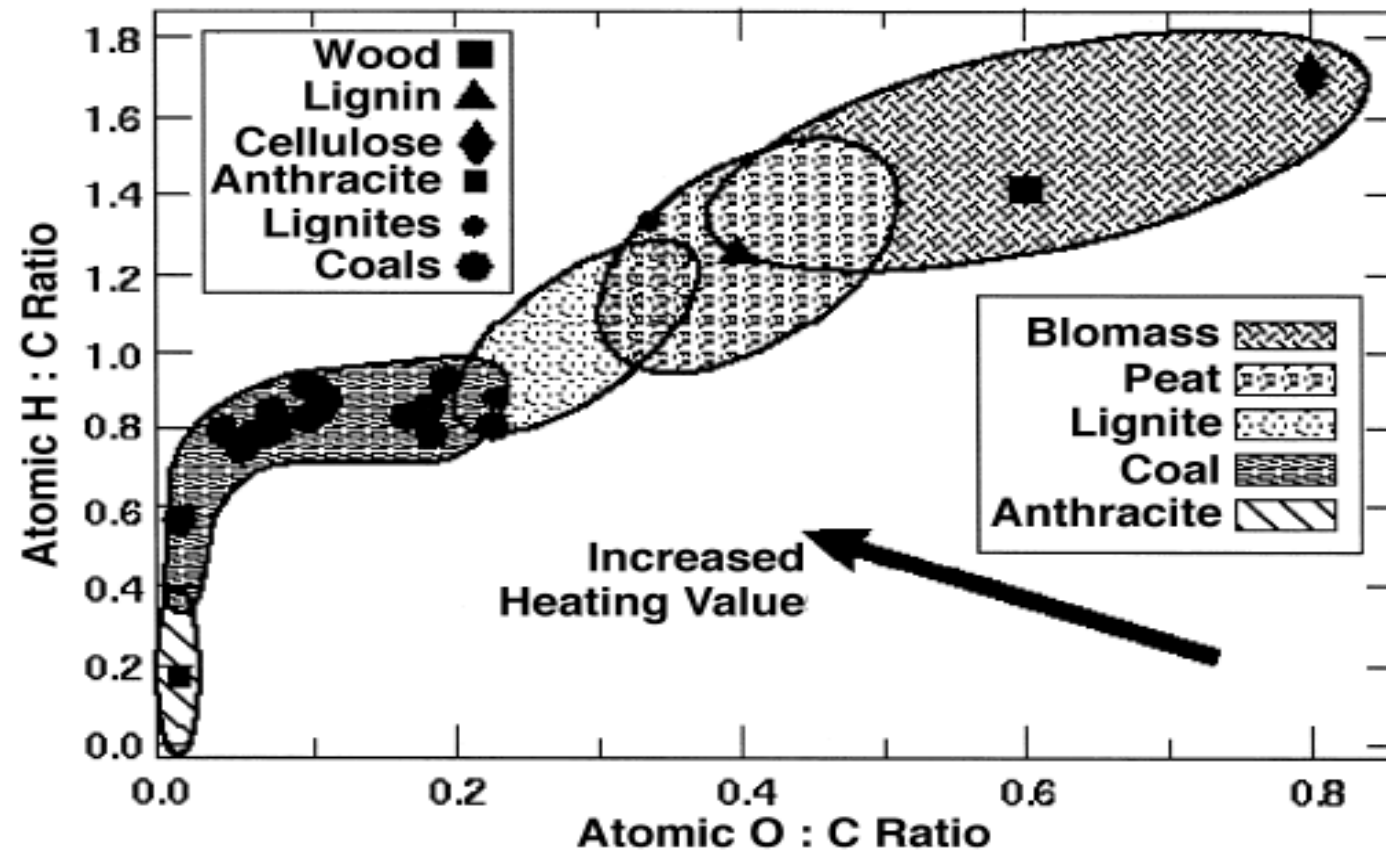


Fig. 2. Coalification diagram showing compositional differences among coals and biomass [14].

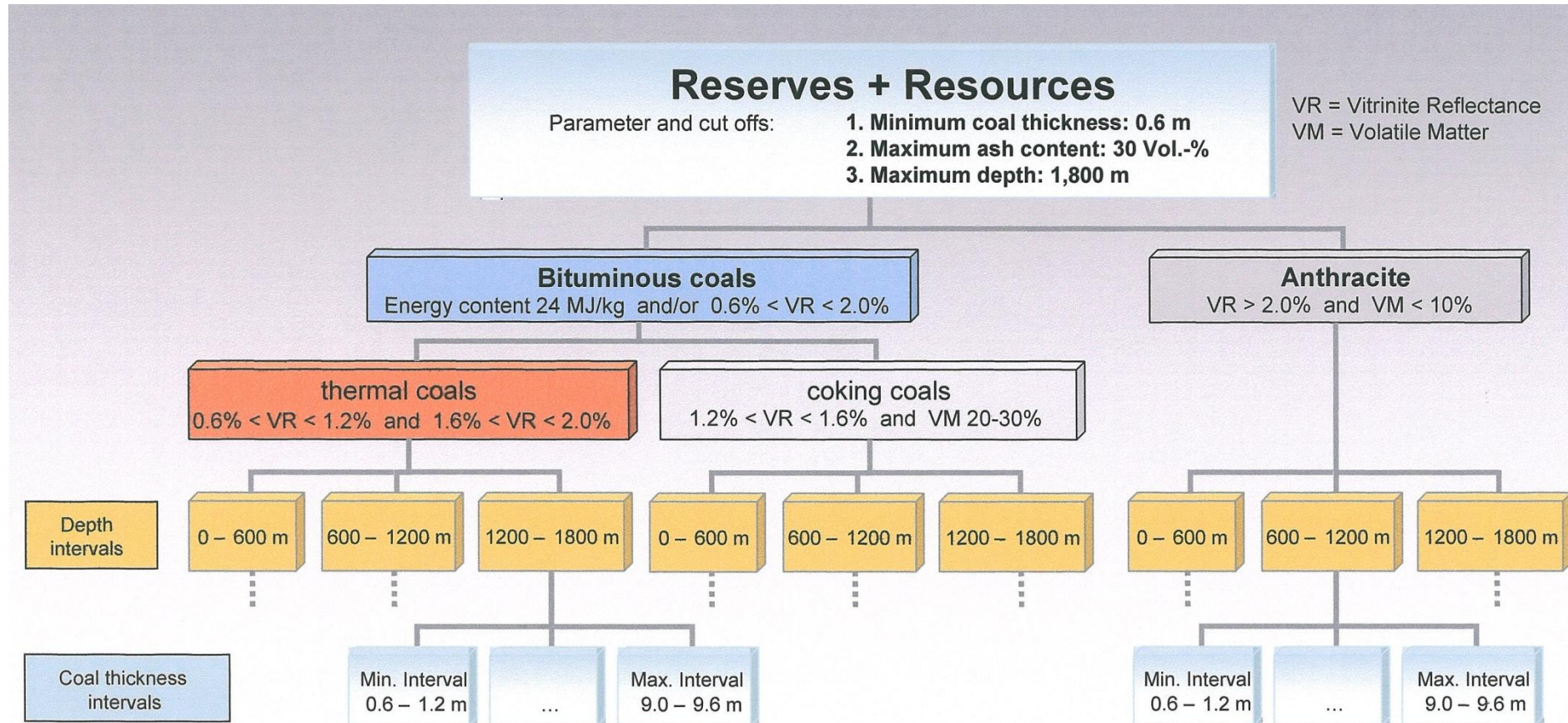


Van Krevelen diagram

B.M. Jenkins et al. / Fuel Processing Technology 54 (1998)



Classification of Hard Coal Reserves and Resources



Various qualities of Coal

- Coal qualities vary substantially
- When not defined in t, quantities are defined in tonnes of coal equivalent (tce)
- 1 tce represents 7 Million kcal (7 000 kcal/kg)
- 1t # 0,70 tce
- 1tce # 0,70 toe 
- 1 t # 0,70 tce # 0,49 toe (World average, based on world production split*)
- 1 short ton = 0,907 t
- 1 Exajoule (EJ) # 40 Mt Hard Coal, # 95 Mt Lignite & sub-bituminous Coal

* On the basis of BP Stat. Review 2018



Various qualities of Coal

REMINDER - WARNING

Coal quantities can be expressed in tonne (t), tonne coal equivalent (tce), or tonne oil equivalent (toe)

These quantities are substantially different:

1 t # 0,7 tce

1 tce # 0,7 toe

1t # 0,49 toe



Definition of Reserves: various sources

- **Proven reserves are defined as those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.**
- **Two internationally recognised methods for assessing coal reserves exist.**
- **The first one is produced by the German Federal Institute for Geosciences and Natural Resources (BGR) and is used by International Energy Agency (IEA)**
- **The second one is produced by the World Energy Council (WEC) and was used by the BP Statistical Review of World Energy till 2016.**
- **Reminder: Coal reserves at end 2015 reported by WEC/BP (891 Gt) were lower by 8% than those reported by BGR (985 Gt).**
- **BP Statistical Review of World Energy has been replaced by Energy Institute (EI) Statistical Review of World Energy in 2023.**
- **Qualities of coal varies substantially. Coal reserves can be expressed in t (metric tonnes) or tce (tonnes coal equivalent). The conversion factors can be different depending upon the producing country.**



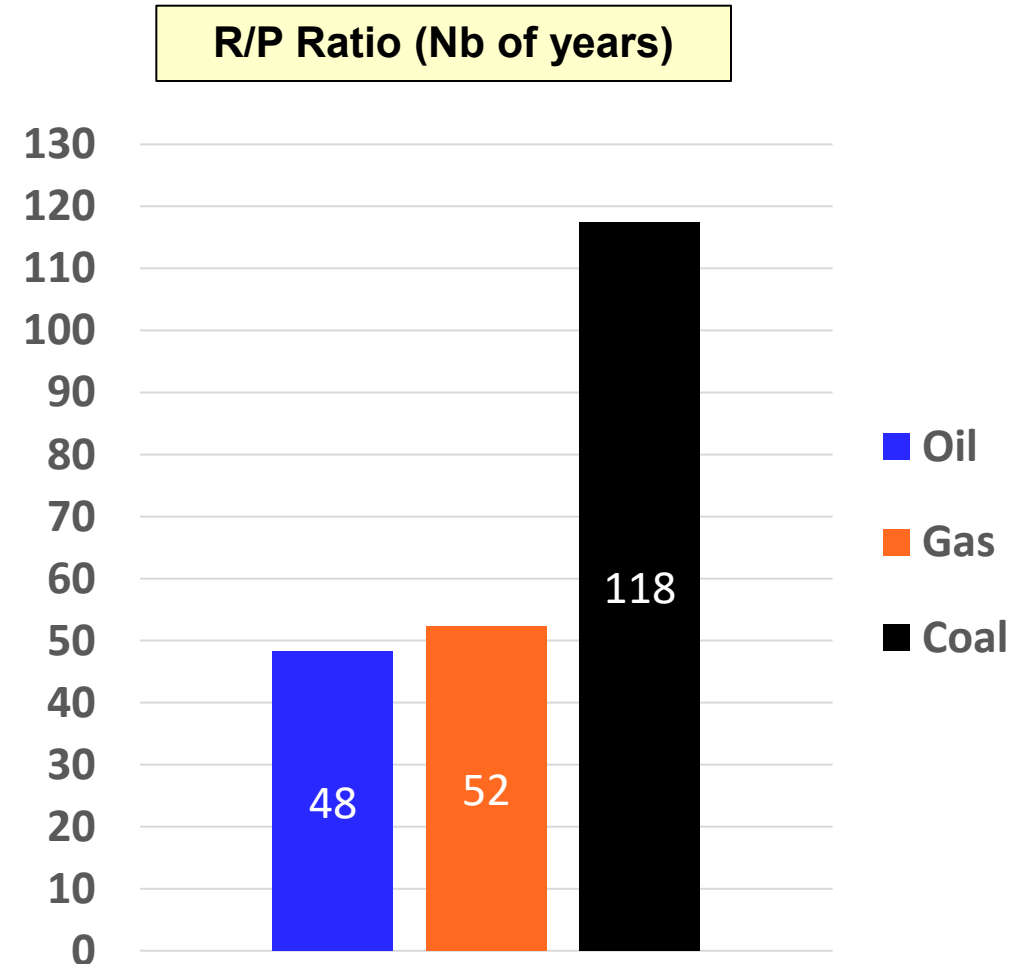
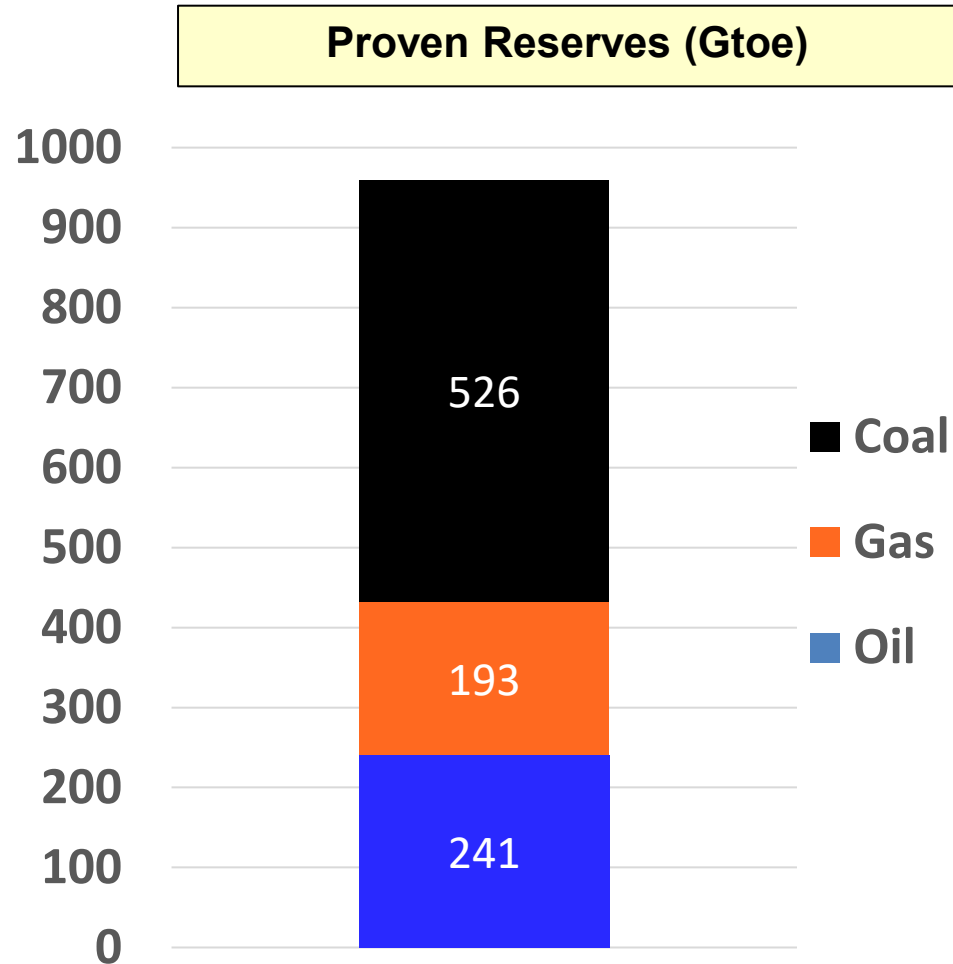
Definition of Reserves: various sources

- For the 2017 edition of the BP Statistical Review of World Energy and later, BP changed sources. They switched the **Chinese coal reserve data** previously sourced from World Energy Council – (WEC) to national data from **Ministry of Land and Resources from 2007 onwards**. Other countries coal reserves are now sourced from German Federal Institute for Geosciences and Natural Resources (BGR) Energy Study 2016.
- Reserves figures in BP Statistical Review of World Energy are therefore substantially different for 2017 and later than those of previous years.
- BP Statistical Review of World Energy has been replaced by Energy Institute (EI) Statistical Review of World Energy in 2023.
- Coal Reserves are no longer published by these organizations.



Fossil Fuels – « Proven Reserves » end 2024

960 Gtoe # 7,0 Tboe (Drastic decrease in China Coal Reserves vs end 2016)



Source;: Data from IEA 2025
toe: tonne oil equivalent*
boe: barrel oil equivalent



Coal Reserves and Resources at end 2024 (Gt)

Coal (billion tonnes)	Proven reserves	Resources	Coking coal	Steam coal	Lignite
North America	257	8 387	1 032	5 837	1 519
Central and South America	14	60	3	32	25
Europe	137	980	164	415	402
Africa	15	343	43	299	-
Middle East	1	41	36	5	-
Eurasia	191	2 015	391	992	632
Asia Pacific	460	8 950	1 712	5 824	1 413
World	1 074	20 776	3 380	13 405	3 991

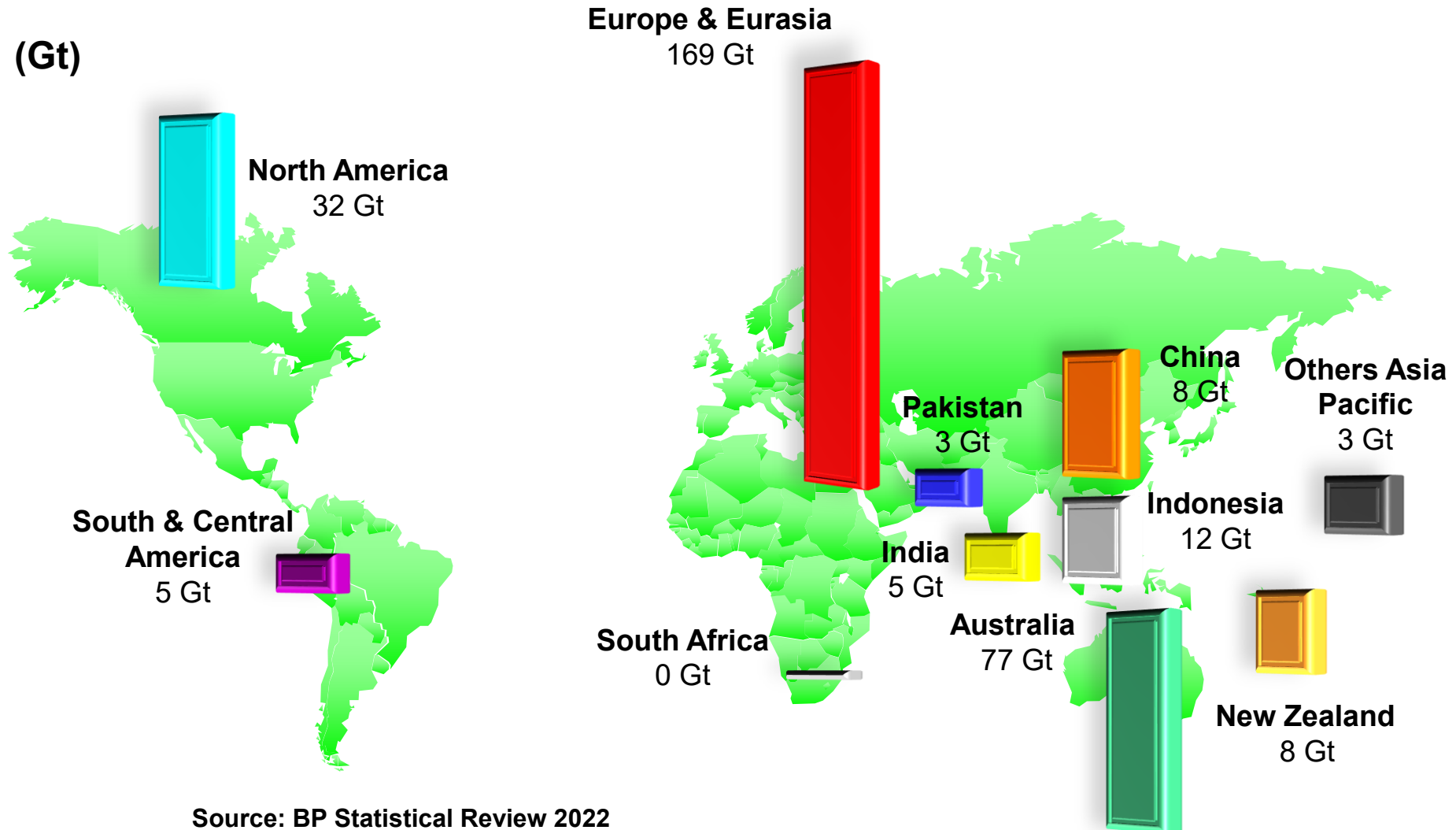
Notes: NGLs = natural gas liquids; EHOB = extra-heavy oil and bitumen. The breakdown of coal resources by type is an IEA estimate. Coal world resources exclude Antarctica.

Sources: BGR (2024); CEDIGAZ (2025); Energy Institute (2024); OGI (2024); US EIA (2025); USGS (2012a and 2012b); IEA databases and analysis.

Source: IEA WEO 2025



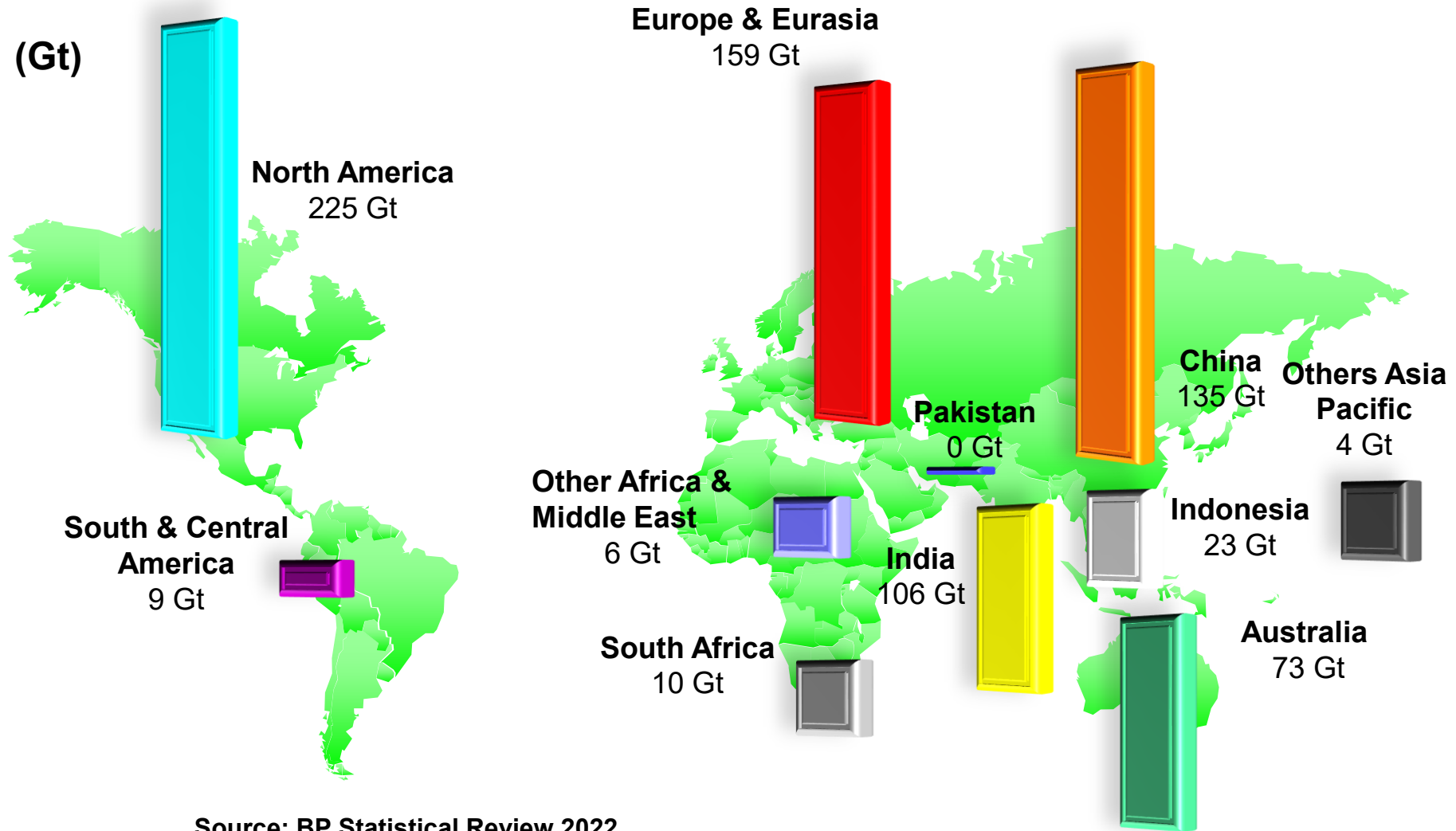
Worldwide Sub-bituminous and Lignite (Brown Coal) Proven Reserves at end 2020 = 320 Gt



Source: BP Statistical Review 2022
Nota: Bars not at scale



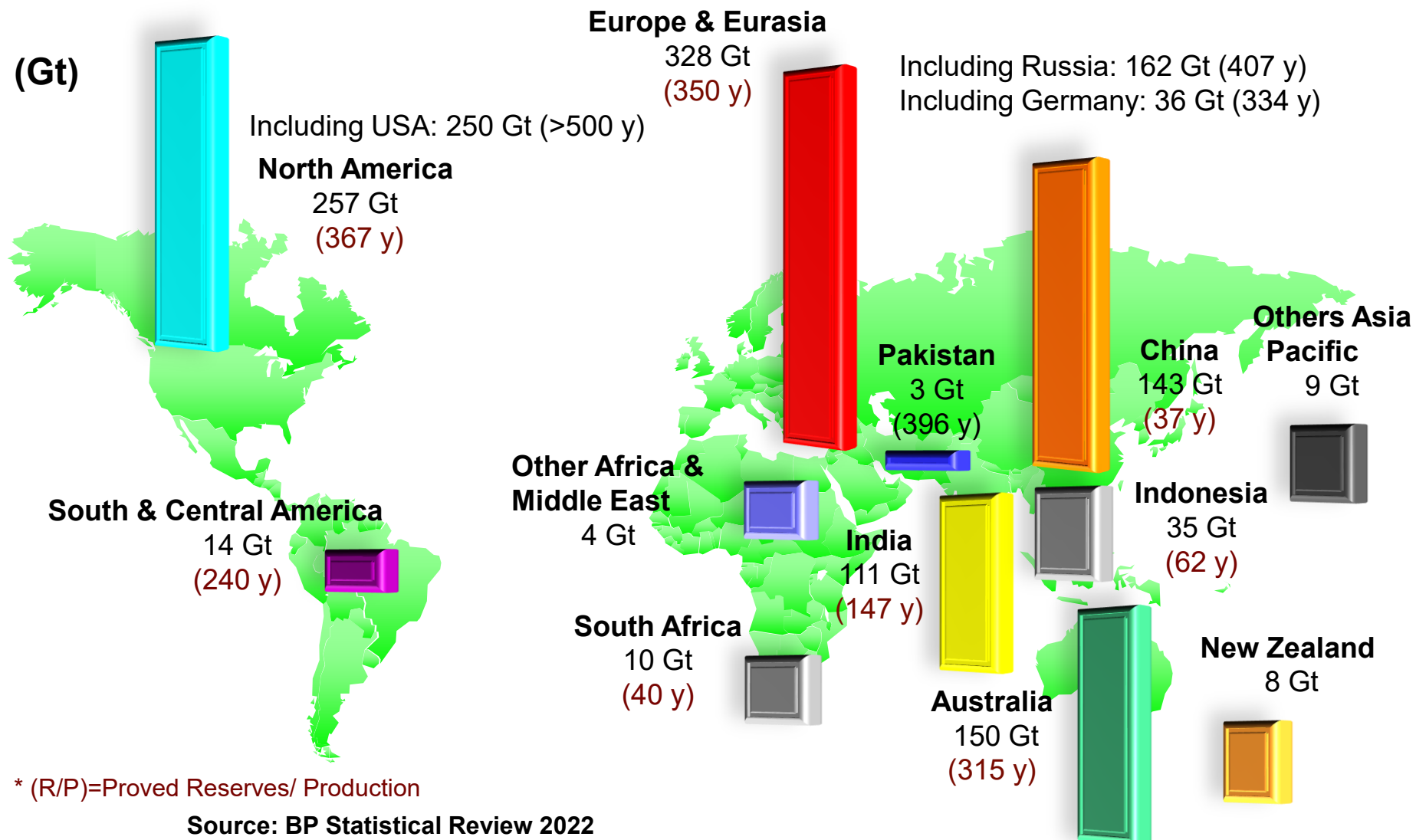
Worldwide Anthracite and Bituminous (Hard Coal) Proven Reserves at end 2020 = 754 Gt



Source: BP Statistical Review 2022
Nota: Bars not at scale



Worldwide Coal Proven Reserves at end 2020: 1074 Gt (# 526 Gtoe) and and 136 years*



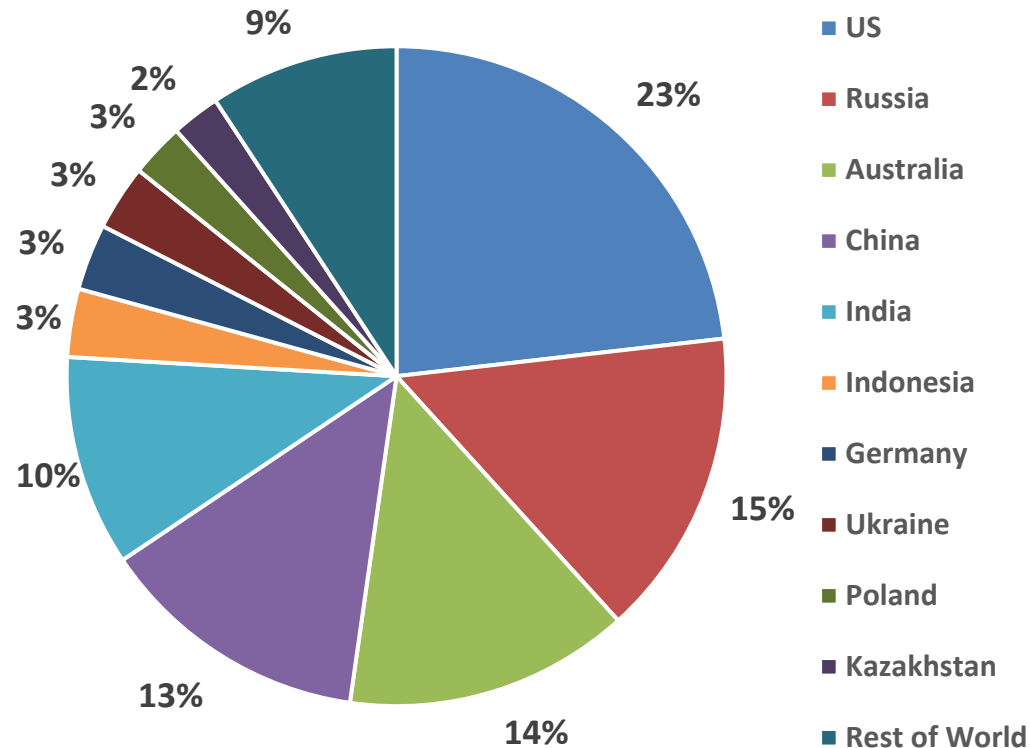
Source: BP Statistical Review 2022
Nota: Bars not at scale



Coal Reserves (Hard Coal + Brown Coal)

N°1 USA, N°2 Russia

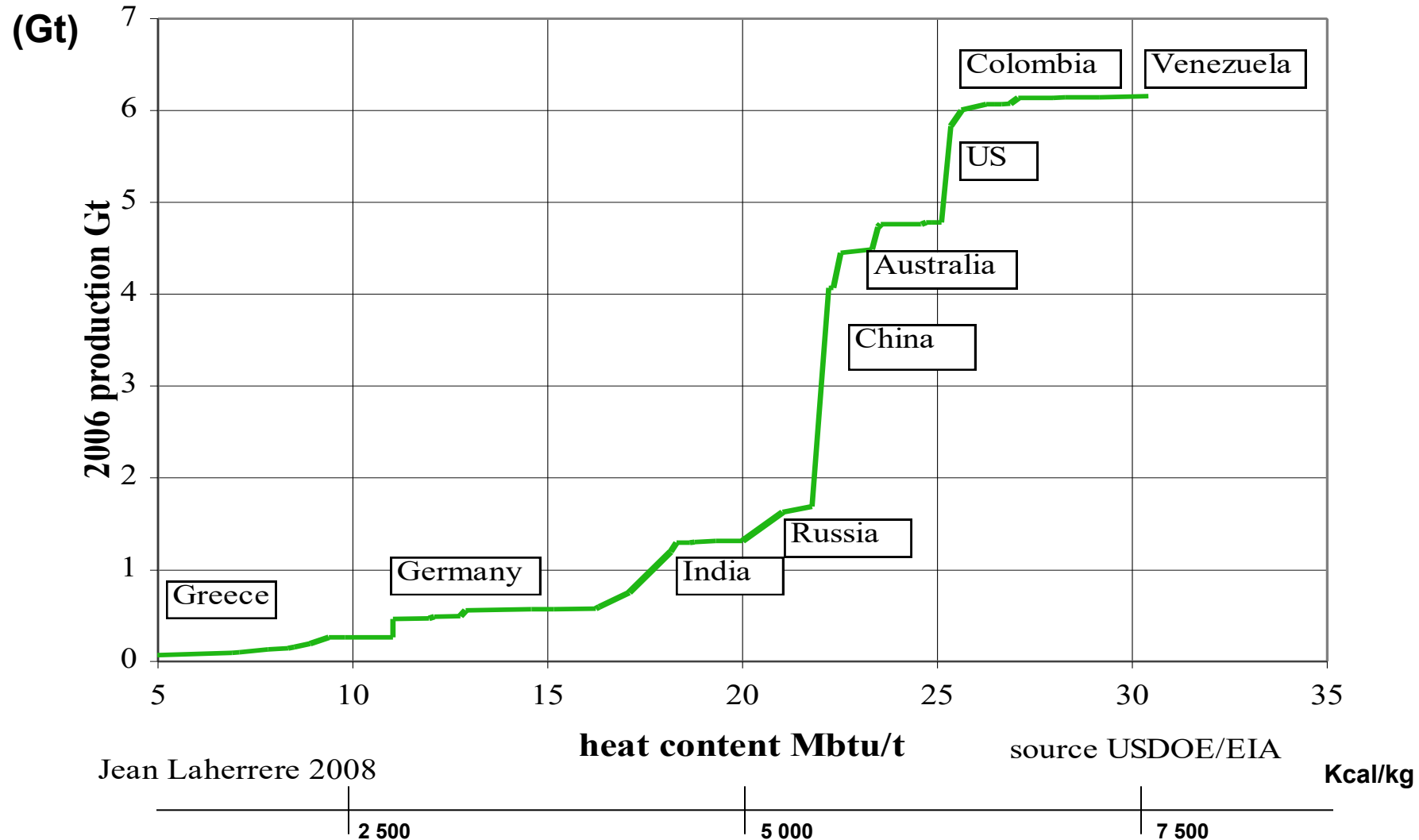
Coal: Proven Reserves end 2020 Total: 1074 Gt



- ◆ US, Russia, Australia and China Coal reserves represent 65% of the world reserves.
- ◆ Russia and Australia have the reserves to increase power generation from coal-firing plant, in order to release oil and gas for the international market.
- ◆ Great uncertainties on reserves of China. Compared to previous years estimates, China reserves have been decreased by # 40%!
- ◆ CO2 emissions constraints represent a bottleneck for coal production.



Coal heat content per country versus 2006 production. A great variety of Quality



Hard Coal (Reserves+Resources) with cut-offs at 0.6m coal seam thickness and down to 1800m depth

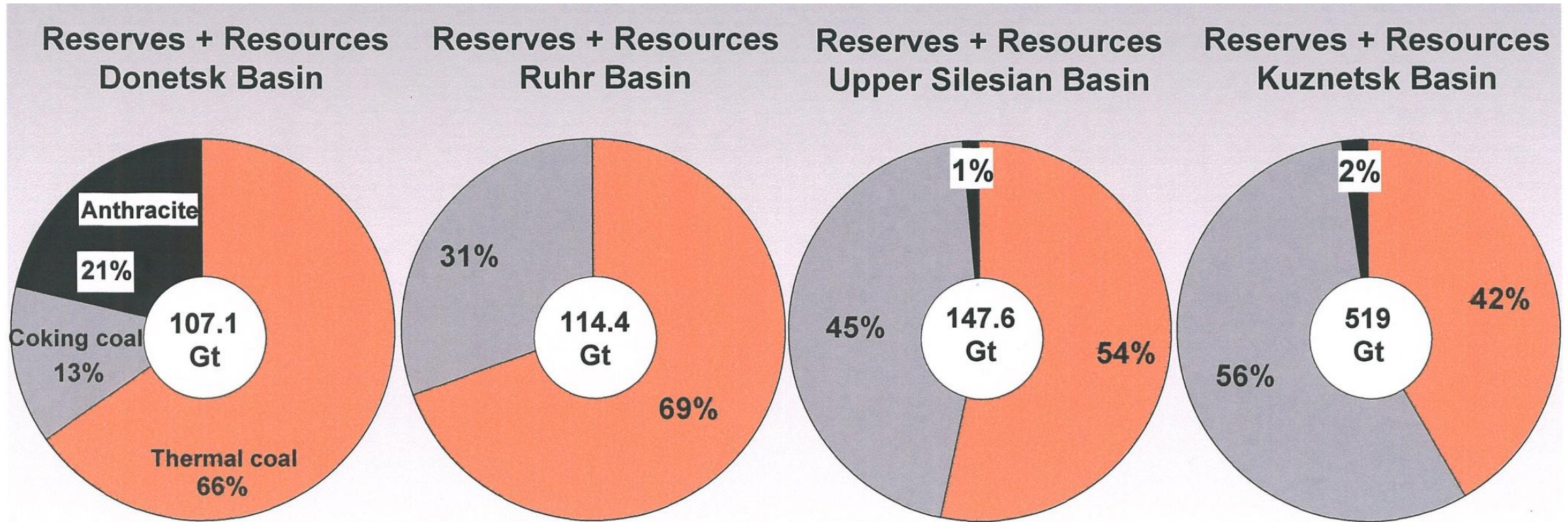


Illustration: at end 2010

Hard Coal (Reserves+Resources) with cut-offs at 1.2m coal seam thickness and down to 1200m depth

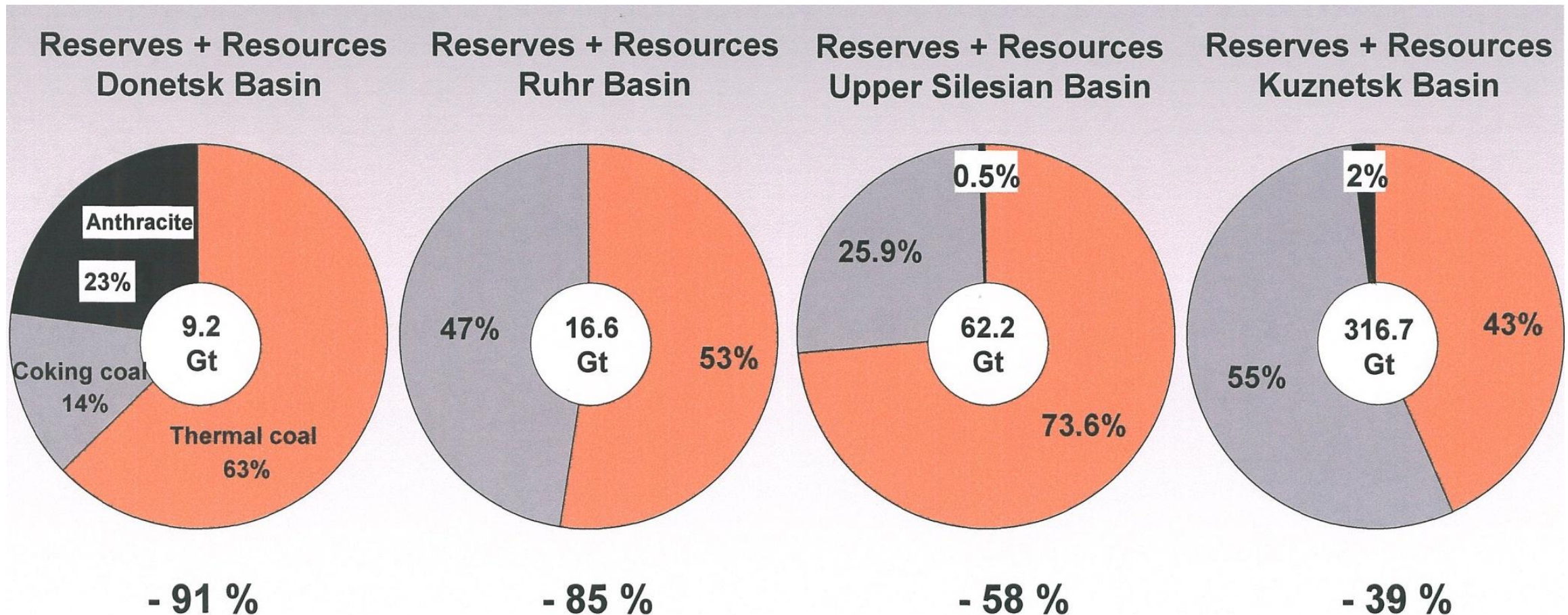
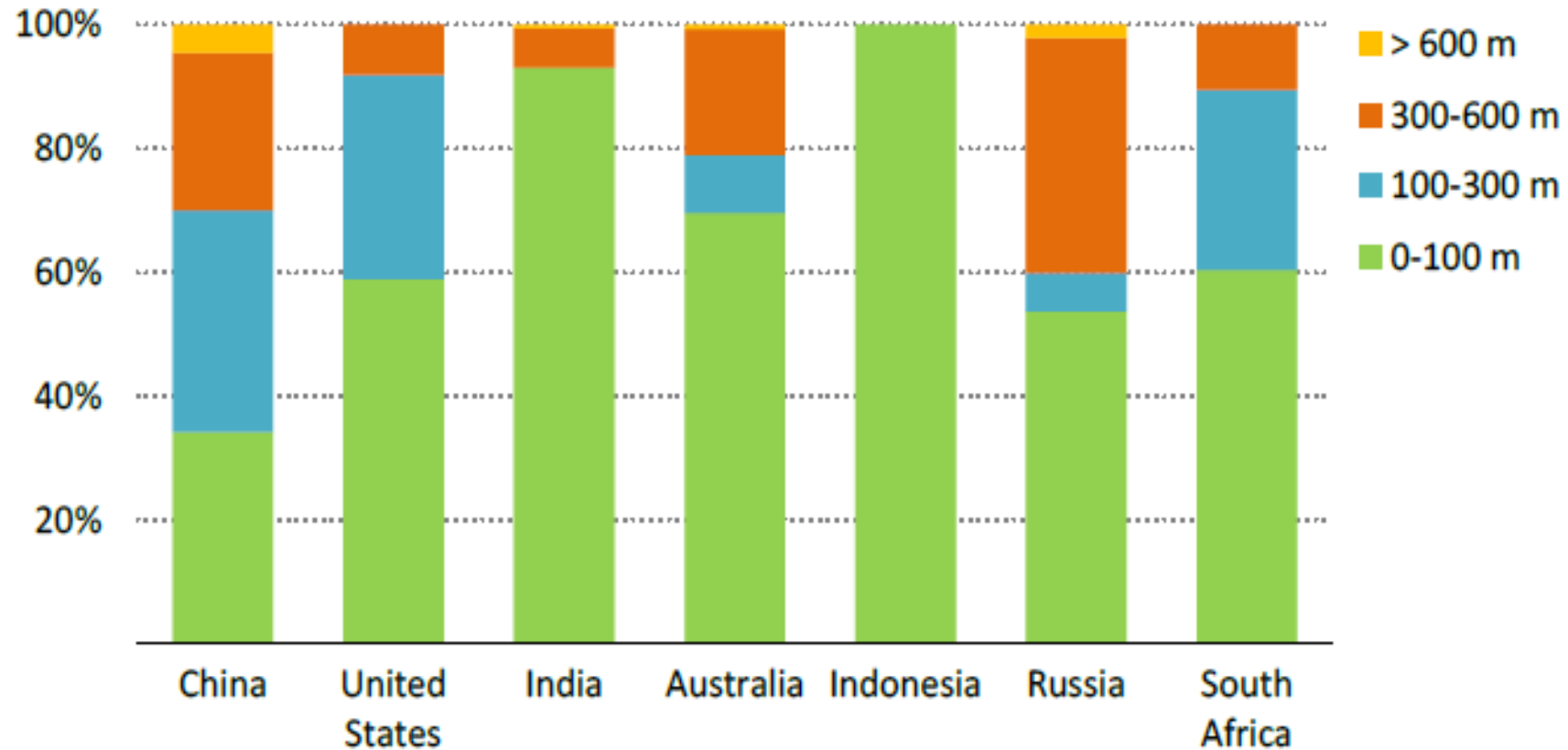


Illustration: at end 2010



Classification of Coal Mines by depth and countries



*There is wide variation in the depths of coal mines across countries;
deeper mines tend to have higher methane concentrations*



Coal Reserves « elasticity »

- There are huge differences between Coal reserves and also between Coal and Oil/Gas reserves.
- While Oil and Gas reserves have a rather low « price elasticity », Coal reserves have a very high « price elasticity » as they vary greatly when the technical basis used to differentiate between resources and reserves are modified.
- Oil shales should have « price elasticity » characteristics similar to Coal.
- Oil sands have « in between » price elasticities.
- The same characteristics, for different reasons, can be observed with Uranium resources.



The Coal Chain



The Coal Chain



From the Mine to the User

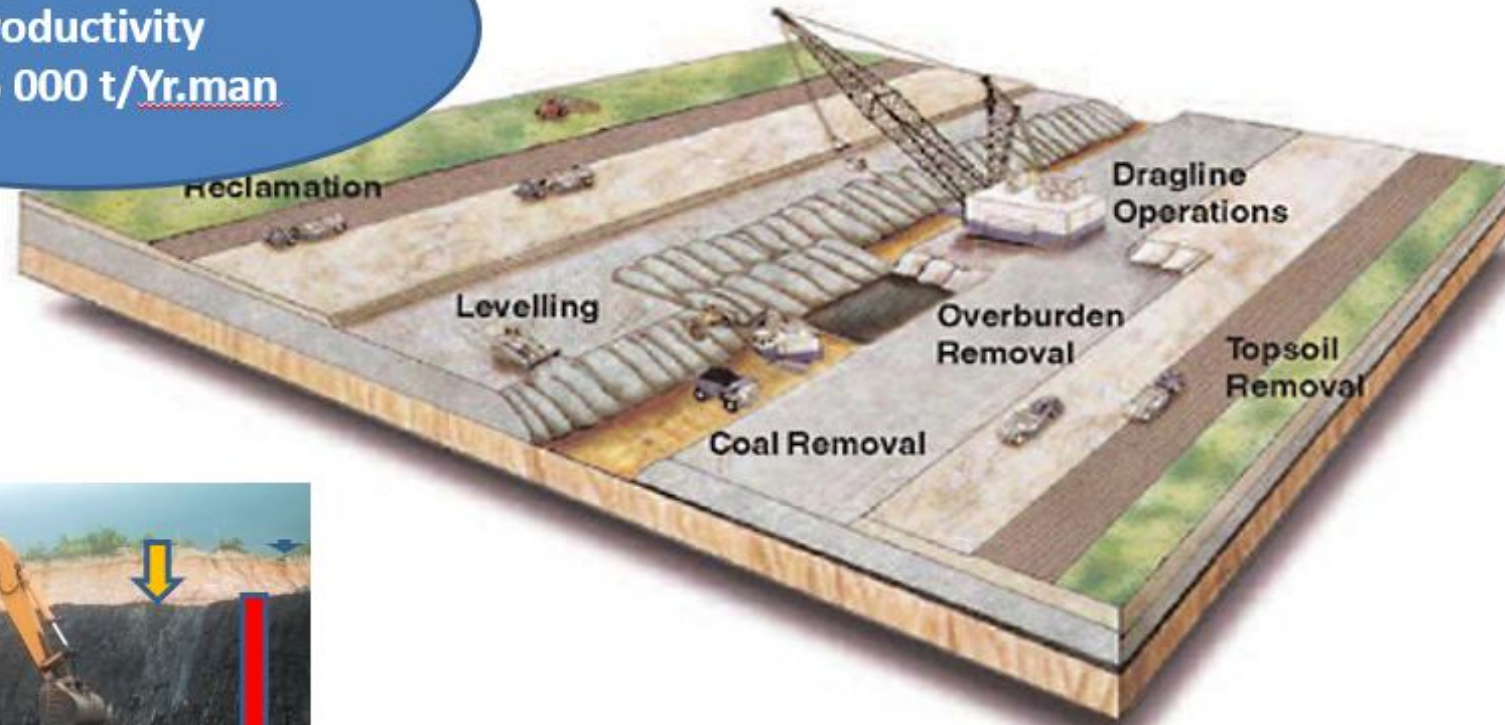
The coal chain



Mining Technique – Open Cast/Surface

Variable costs
High Productivity
10-25 000 t/Yr.man

60% world production



THE NATIONAL ACADEMIES PRESS

The Stripping Ratio:
Sterile /Coal Seam Thickness

20



Modern and massive Bulk Industry – Civil Works



- Drag line to uncover coal seam

- Truck and shovel to remove coal



Leigh Creek Australia



Pingshuo mine China

21



Lignite mine RWE - Garzweiler - Germany



Reserves: 1.25 Gt – Production: 35-40 Mt/Year

High productivity: 240 000 m³/day capacity each ...)

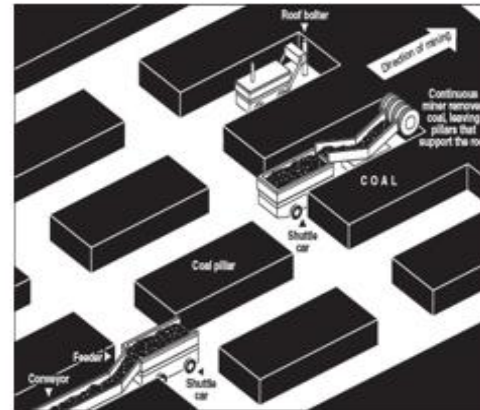
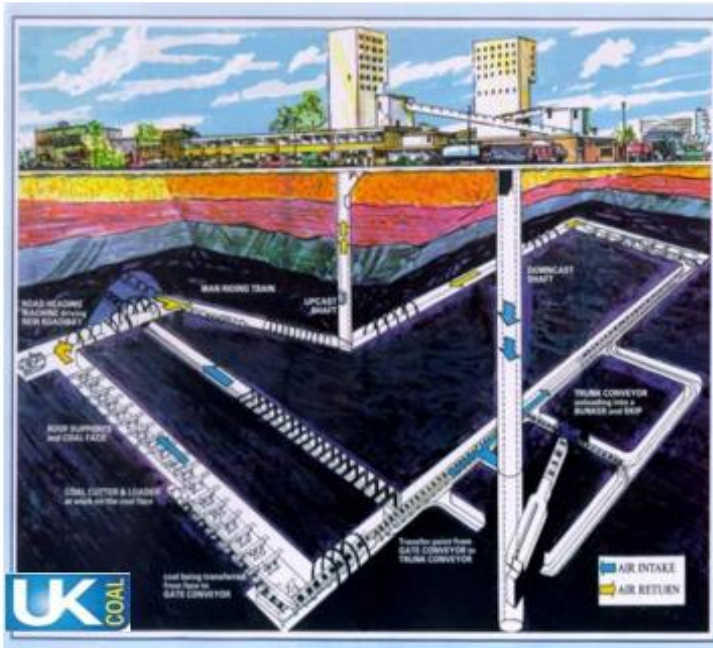
Stripping ration 4.4 - 3 seams : 40m thick on average

Courtesy RWE Power AG

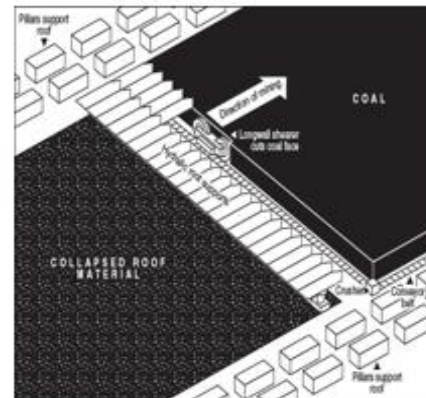


Underground Mining

High Capex
Productivity 1- 8kt/Yr.man
Hazardous



- ROOM & PILLAR: Continuous Miner CM



-LONGWALL: Remote monitoring process..



HEALTH, SAFETY & ENVIRONMENT - HSE

Coal Mining: *Hazardous and Harmful Operations...*



1 - Mining project qualifications

Project Agreement from
Mine Authority

- [Mine Project: Definition/Mining Plan](#)
- [Mining process](#)
- [Staff qualification](#)
- [Health & Safety rules and qualifications](#)
- [Environmental legislation](#)
- [Water, Waste dump...](#)
- [Closure and land return plan...](#)

2 - Mining Operations

Regular controls
Mine Authority & Management:

- [Mining plan & Operations control :](#)
- [Health and Safety : Dust –Ventilations- Gas atmosphere - Roof resistance-Geology-](#)
- [Safety /Emergency Rules and equipmen](#)
- [Regulations enforcement](#)
- [Regular inspections, monitoring and compulsory reporting of any Incident/Accident](#)



Massive Bulk Storage & Transportation...



200 trucks

17/20 000 t

Australia: Queensland Rail - Dawson mine



**RBCT - RSA
80Mt /year
Ship loader 8-16kt/hr**

Richard's Bay Coal Terminal - RSA

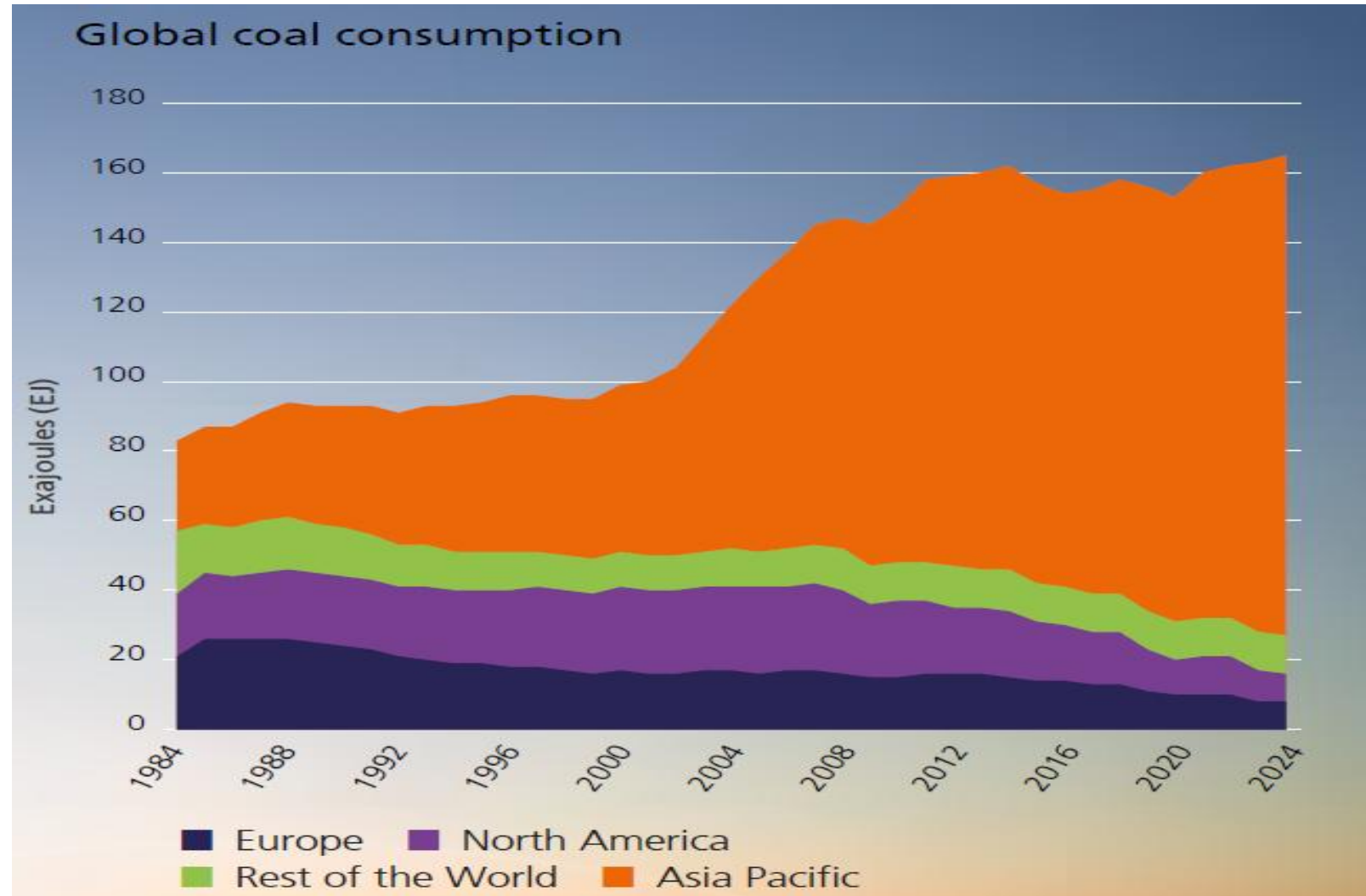


Coal Consumption and Production



Global Coal Consumption 1965 – 2024 (EJ)

Important growth from 2002 to 2014, then a stabilization from 2015 to 2024



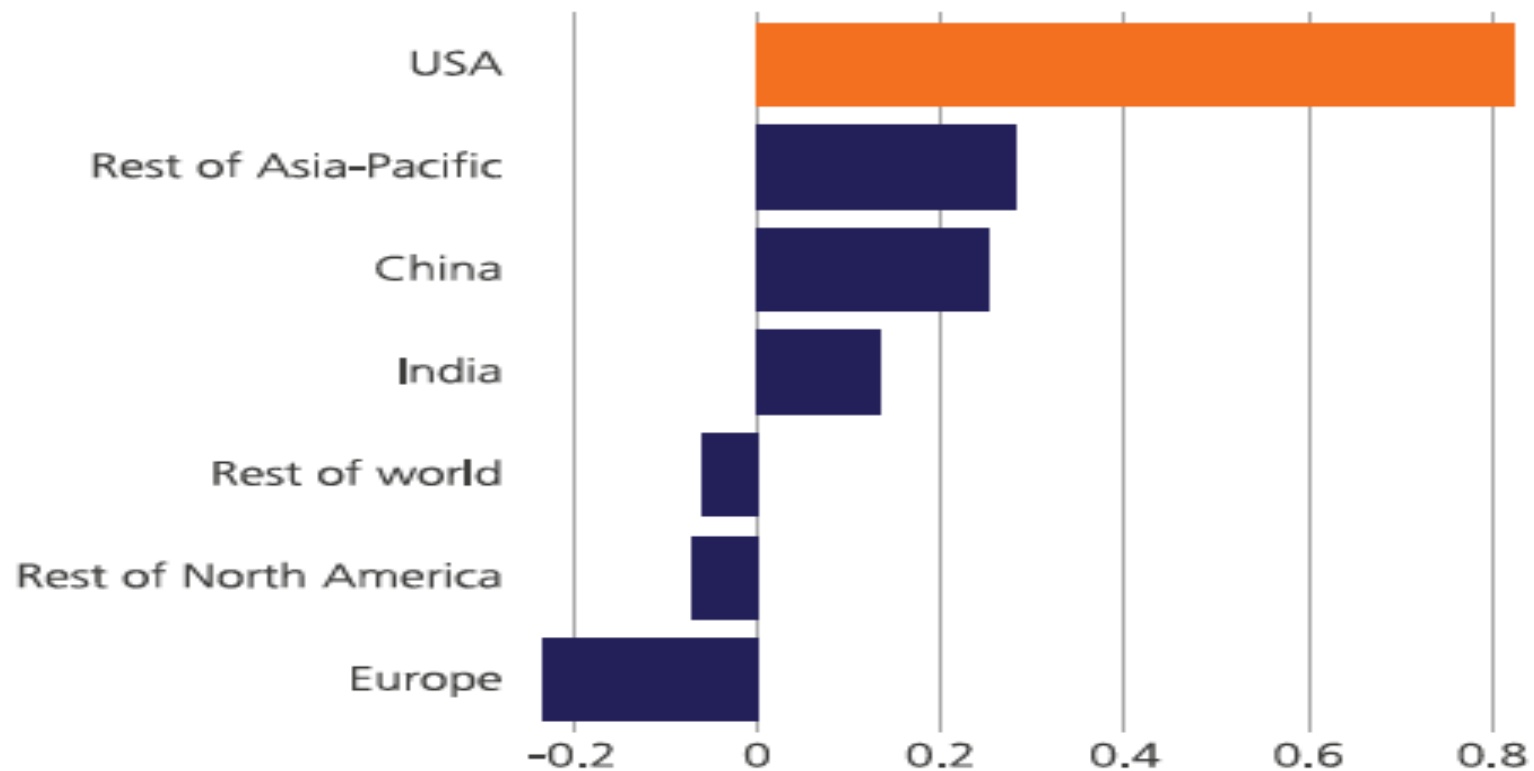
US coal production
reached its lowest level
for over 44 years



Additional Coal Consumption 2025 (EJ)

The US accounted for the vast majority of additional global coal consumption in 2025

Year-on-year change in coal consumption (EJ)



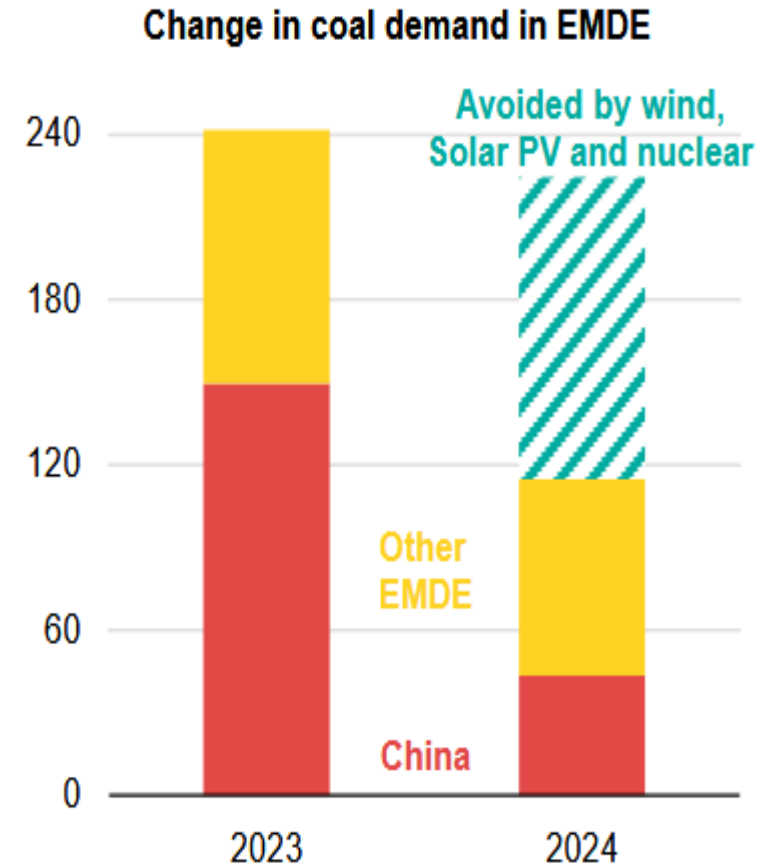
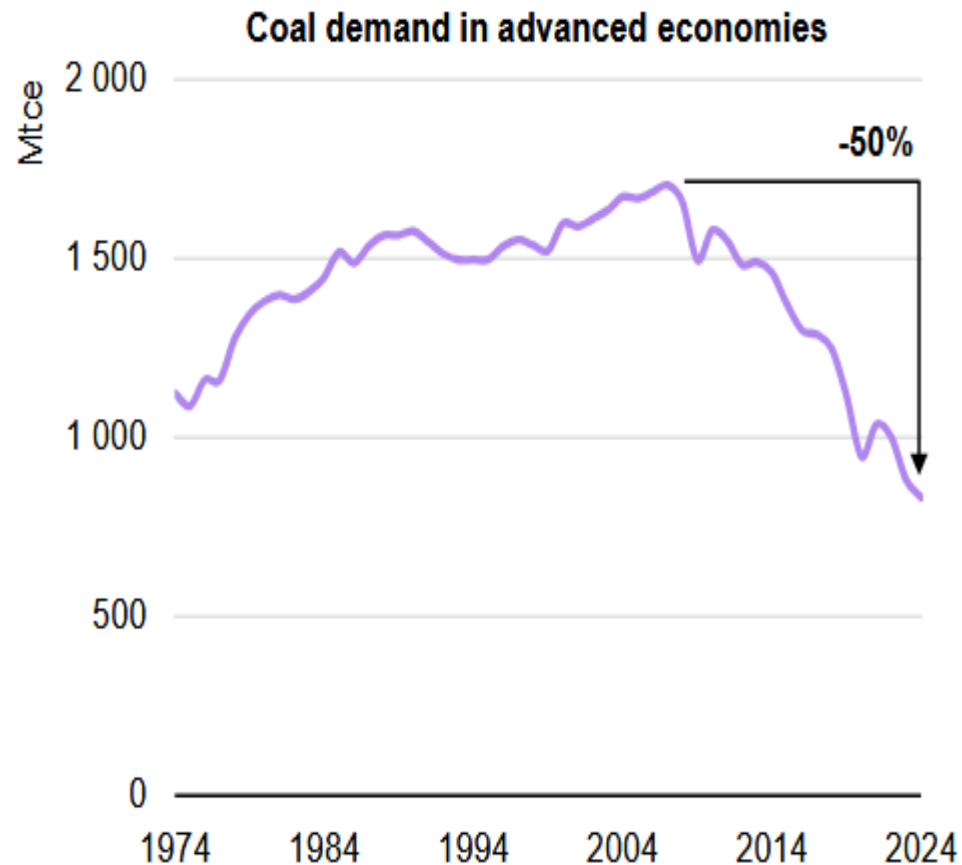
Note: Absolute changes are adjusted for leap years



Coal Consumption 1974 – 2024 (Mtce)

In advanced economies, growth from 1973 to 2024, then a 50% decrease up to 2024

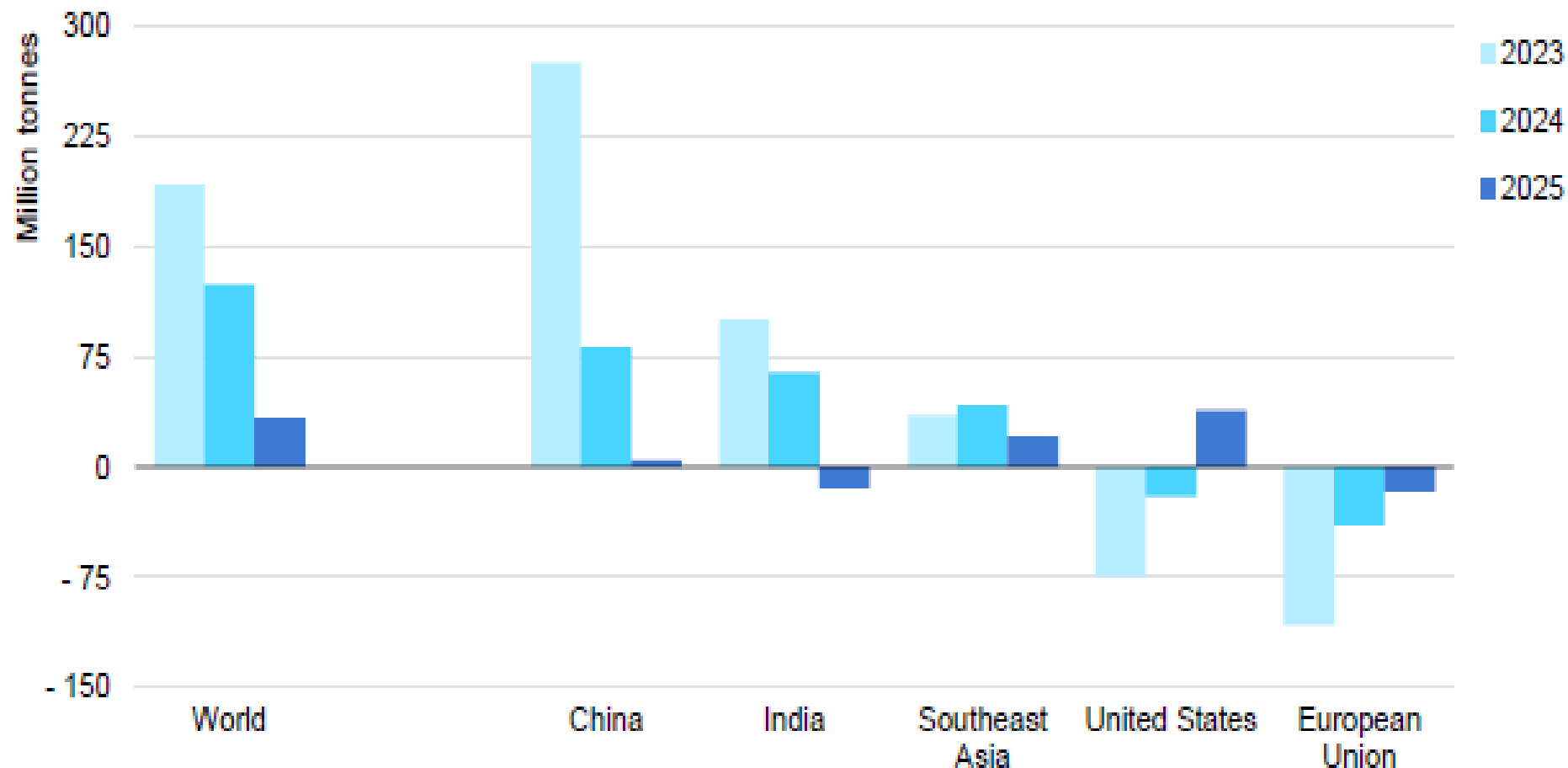
Coal demand in advanced economies, 1974-2024, and change in coal demand in emerging market and developing economies in 2023 and 2024



Change in Coal Consumption 2023 – 2025 (Mt)

In advanced economies, growth from 1973 to 2024, then a 50% decrease up to 2024

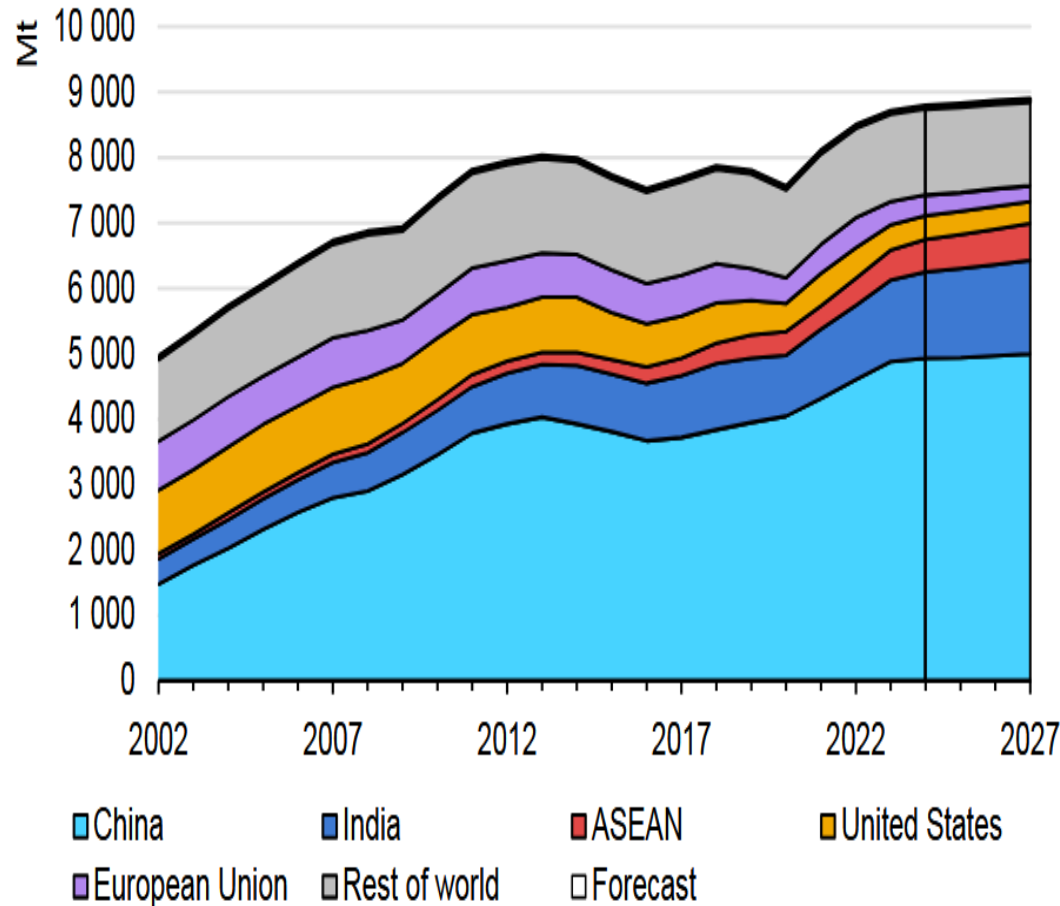
Annual change in coal demand by region, 2023-2025



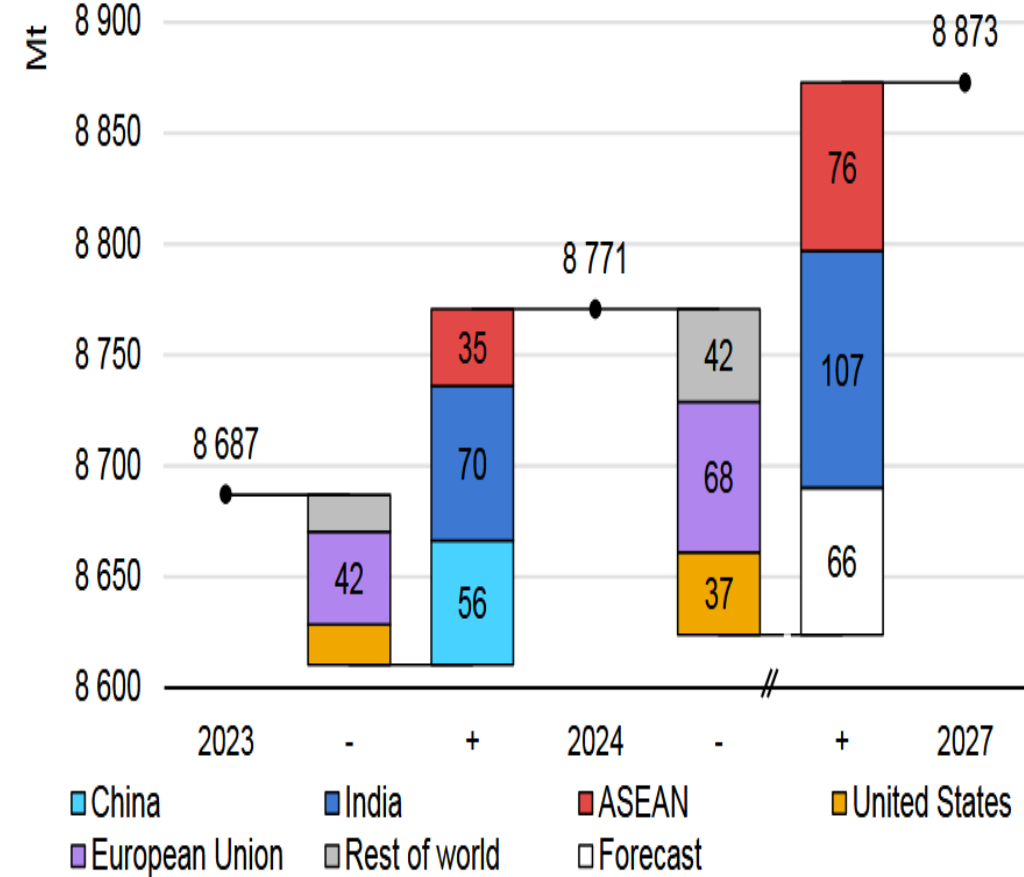
Coal Consumption 2002 – 2027 (Mt)

Important growth from 2002 to 2014, then a Consumption in the range 8,5/9,0 Gt from 2022 to 2027

Global coal consumption, 2002-2027



Change in global coal consumption, 2023-2027



Source: IEA Coal 2024

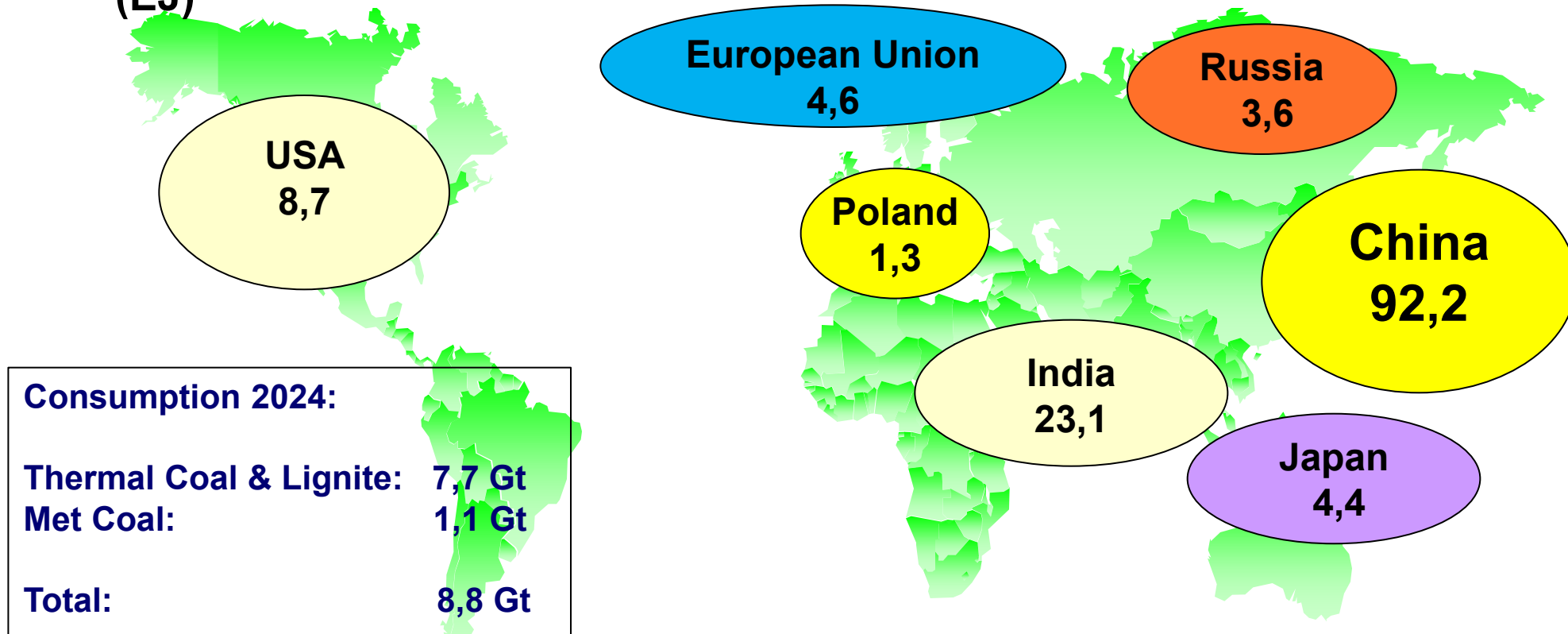


Worldwide Coal Consumption 2025 by EJ # 166 EJ # 8,8 Gt

Total Coal accounts for around 30% of world primary commercial energy supplies, 40% of Electricity generation and 70% of the world steel

China N°1, India N°2 – Decline in USA & EU in 2024 vs 2023

More than 70% of the World Coal is consumed by China & India, 56% by China (EJ)



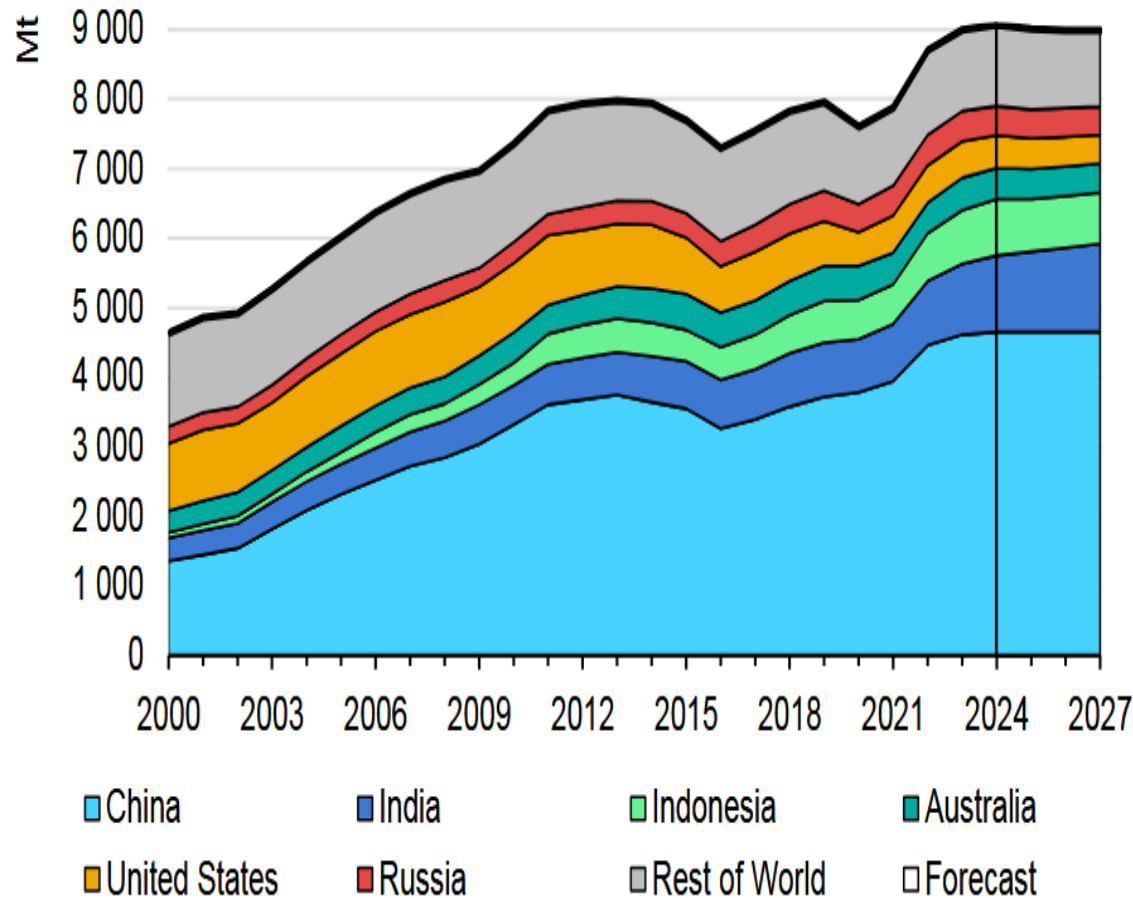
Source: Data from IEA Coal 2024 & EI Stat. Review 2026
Nota: t and not tce. IEA & EI figures are slightly different.
1EJ # 53 Mt. For Poland & Russia, 1EJ # 70 Mt Coal



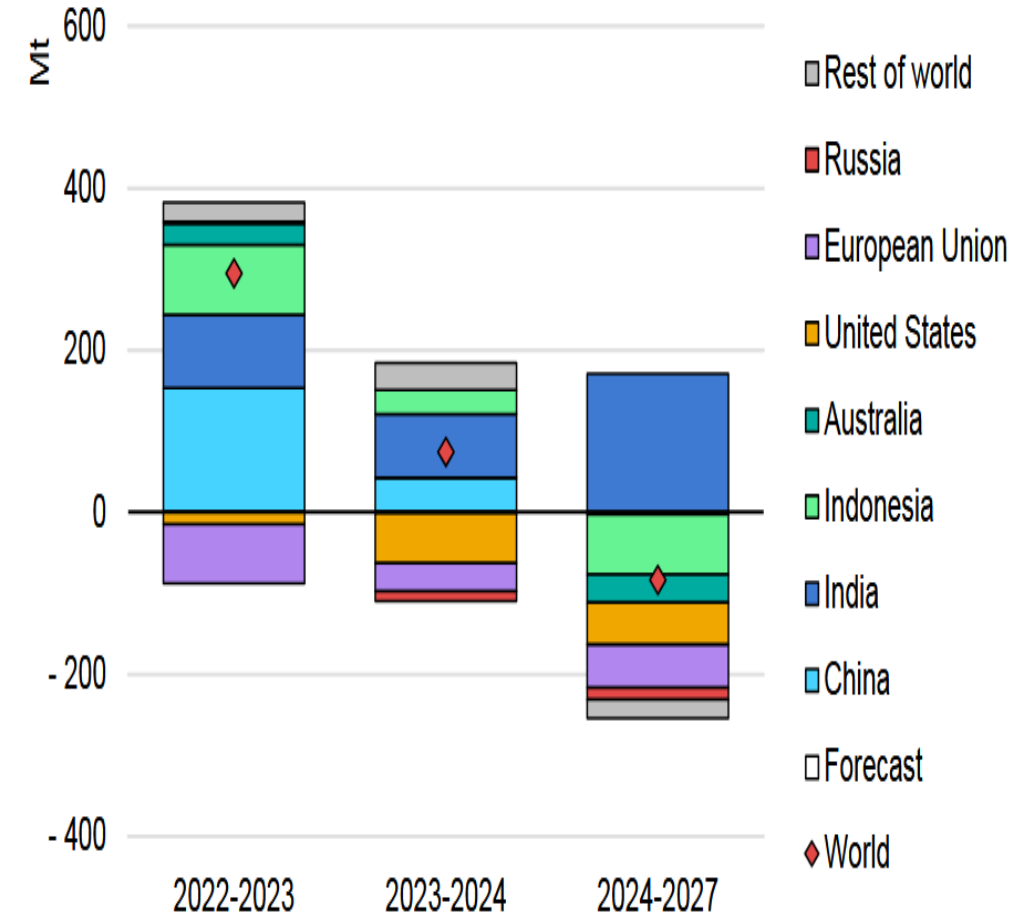
Coal Production 2000 – 2027 (Mt)

Important growth from 2002 to 2014, then a Production in the range 8,5/9,0 Gt from 2022 to 2027

Global coal production, 2000-2027



Change in global coal production, 2022-2027

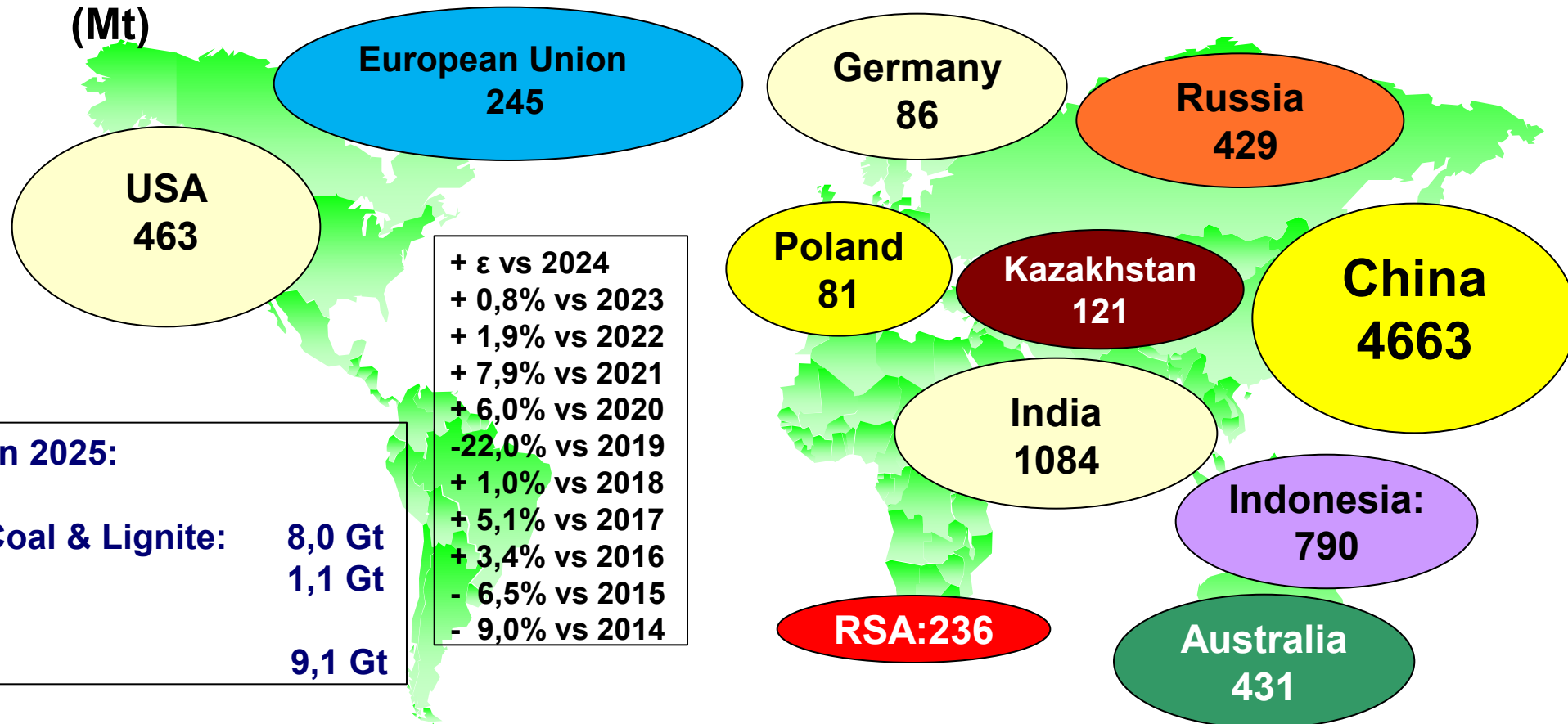


Worldwide Coal Production 2025 by EI # 9,1 Gt

Total Coal accounts for around 30% of world primary commercial energy supplies, 40% of Electricity generation and 70% of the world steel

China N°1, India N°2

More than 80% is produced by China, USA, India, Australia, Indonesia and Russia



Source: Data from EI Statistical Review 2025

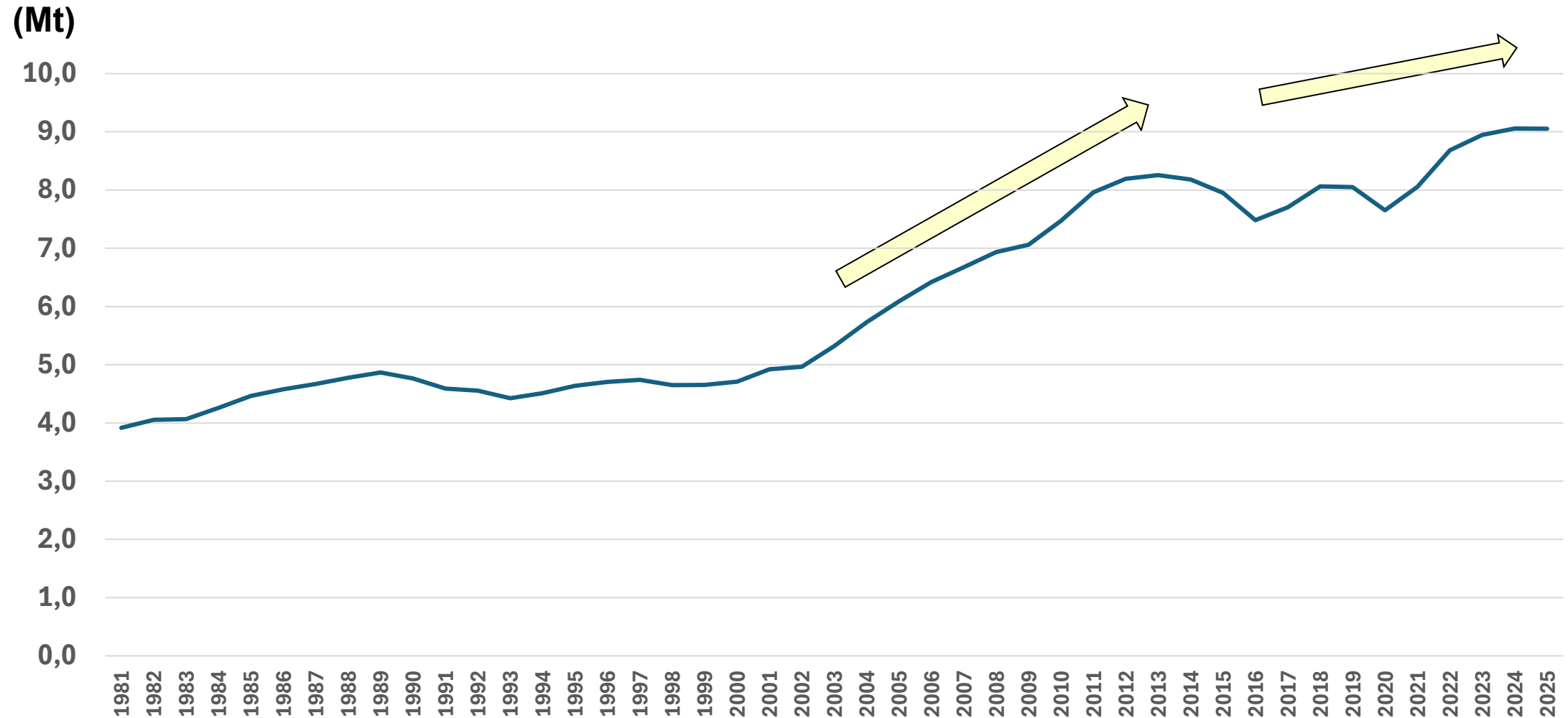
Nota: t and not tce

IEA & EI figures are slightly different



History of Coal Production 1981 – 2025 (Mt) by EI

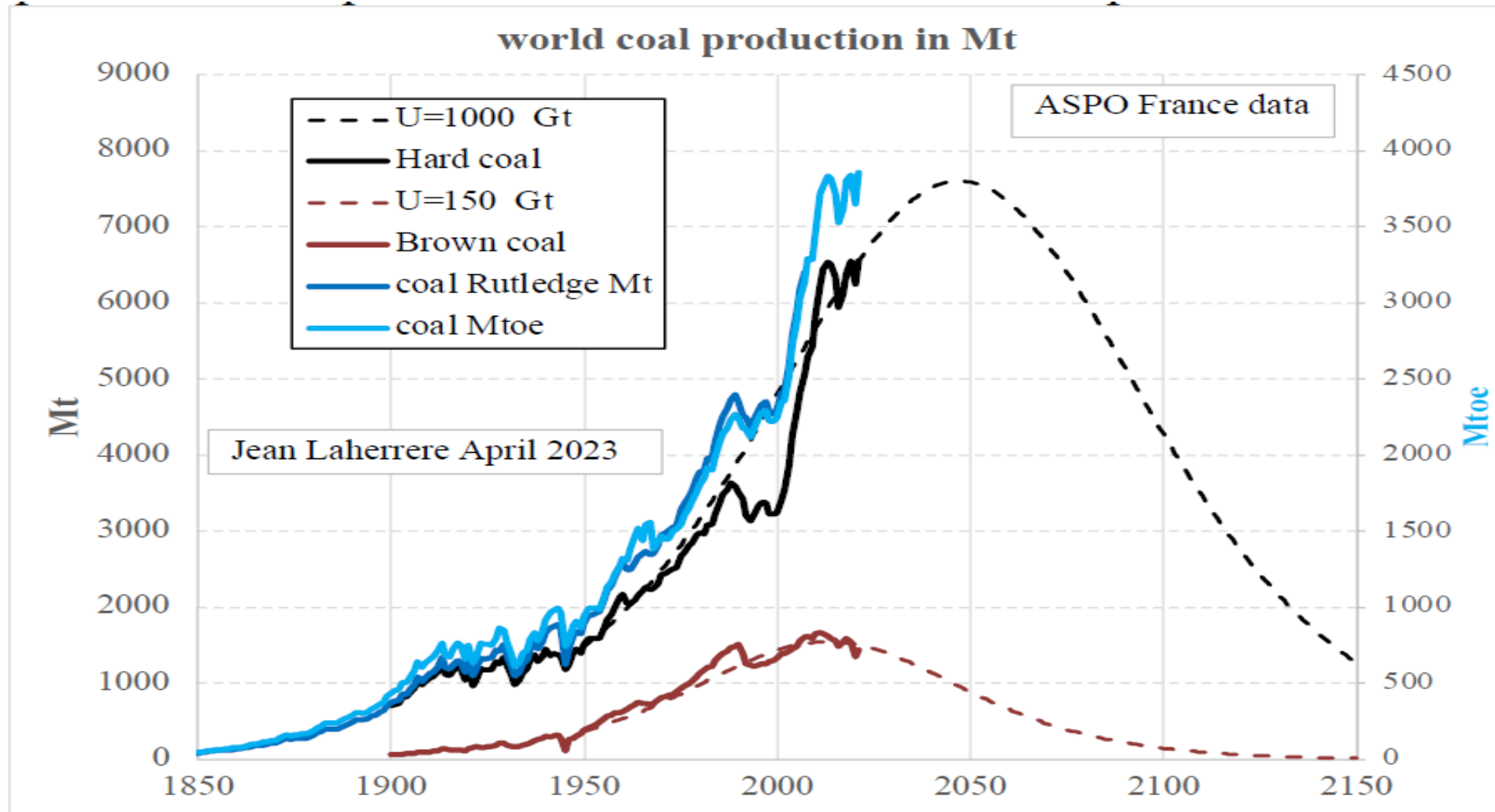
After a relative stability, important growth from 2002 to 2012, then a Production in the range 7,5 – 9,0+ Gt from 2012 to 2025 with a sharp increase in 2022



Coal – What Perspectives?



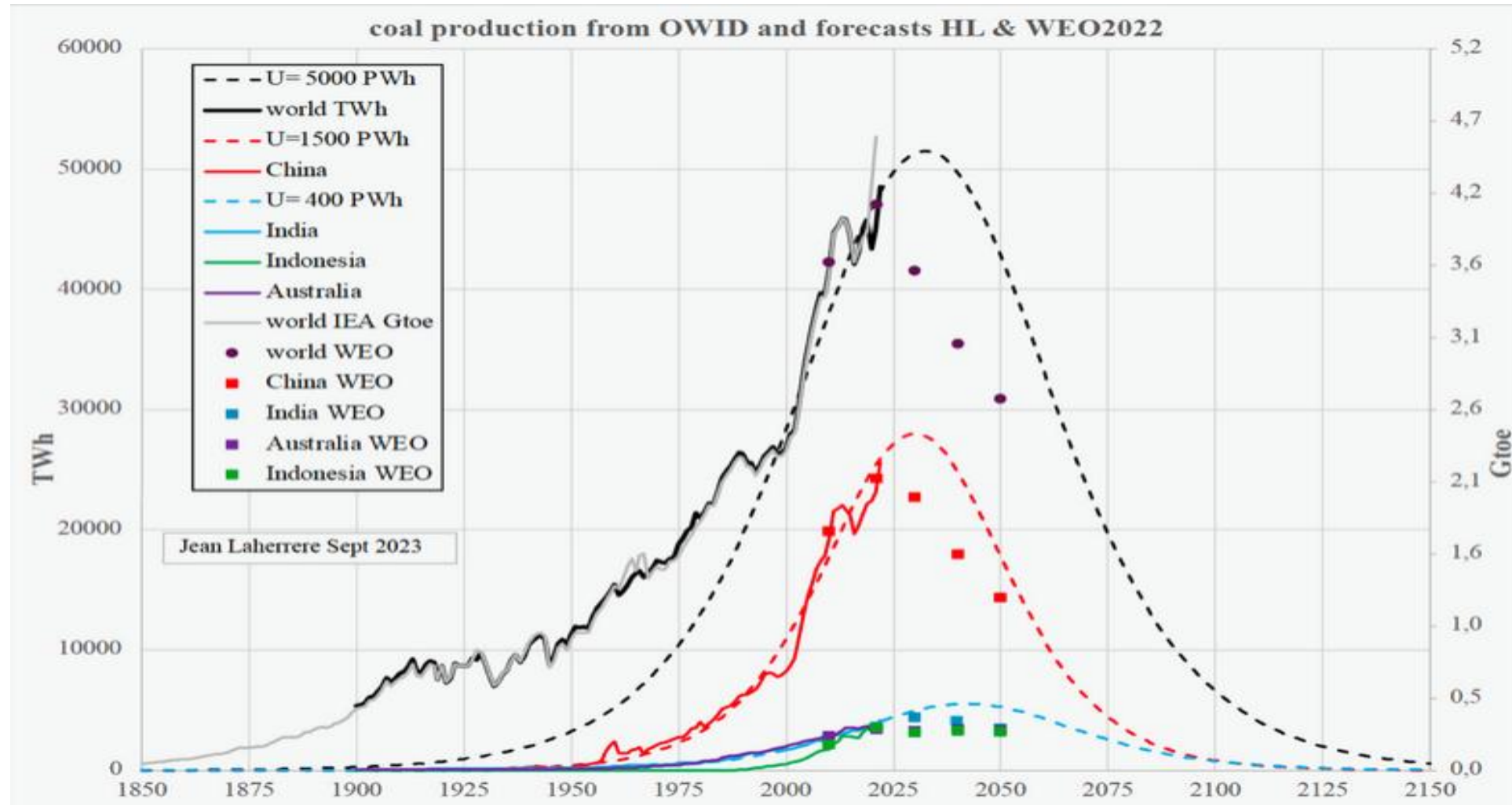
Coal Production Perspectives by ASPO



Source: Jean Laherrere April 2023
ASPO: Association for the Peak Oil



Coal Production Perspectives by ASPO



Source: Jean Laherrere September 2023
ASPO: Association for the Peak Oil

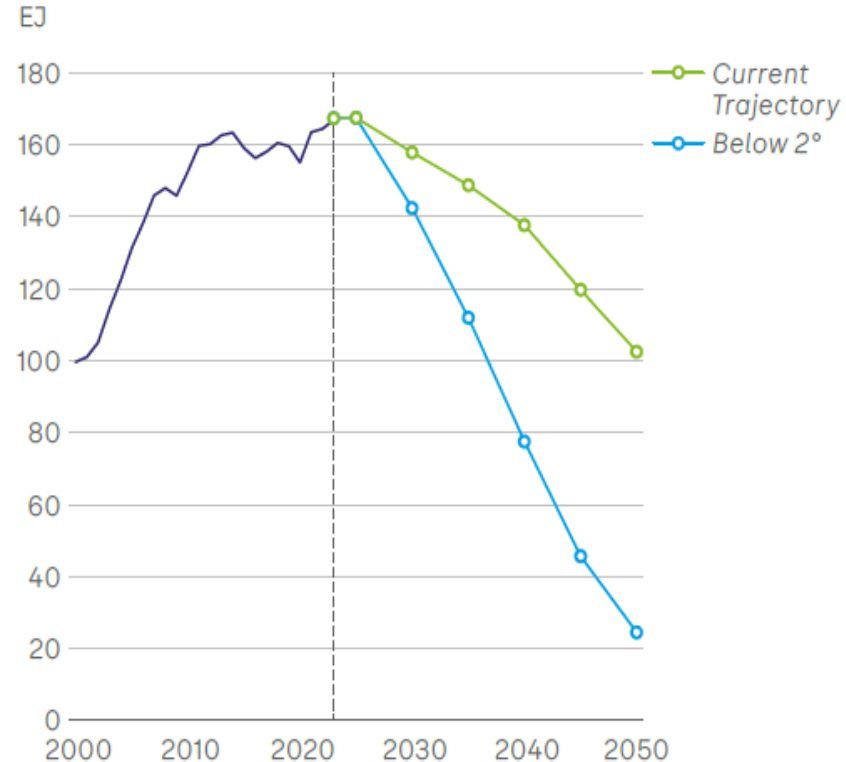
Coal – BP Perspectives



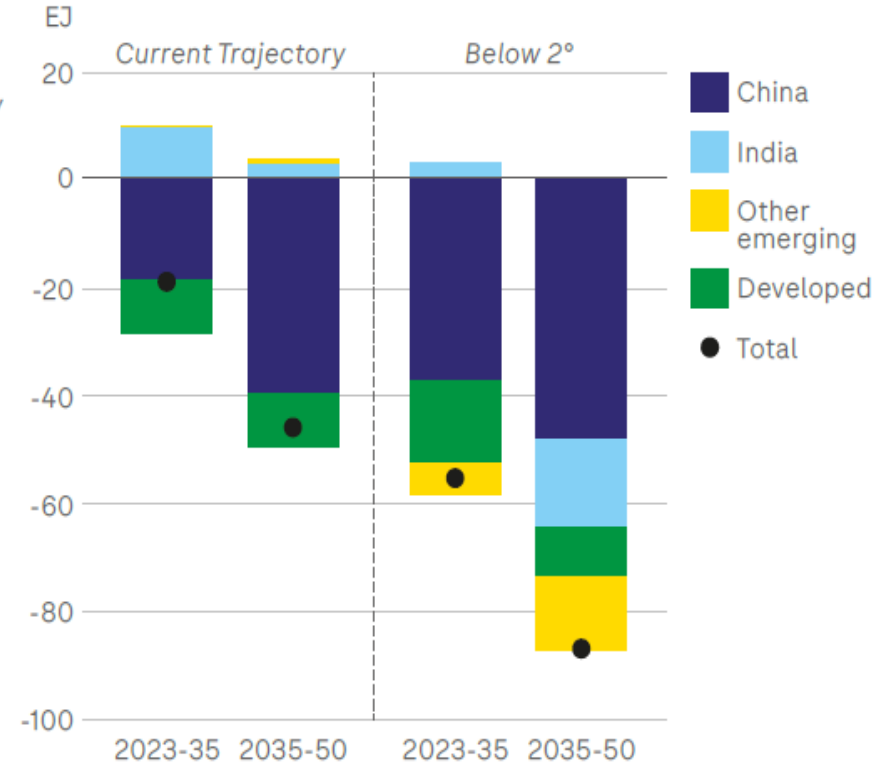
Coal – BP Perspectives

The role of coal in the global energy system declines, led by China

Coal demand



Change in coal demand by region



Coal – TotalEnergies Perspectives



TotalEnergies Scenarios November 2025

Drastic decline of Coal in the Rupture Scenario

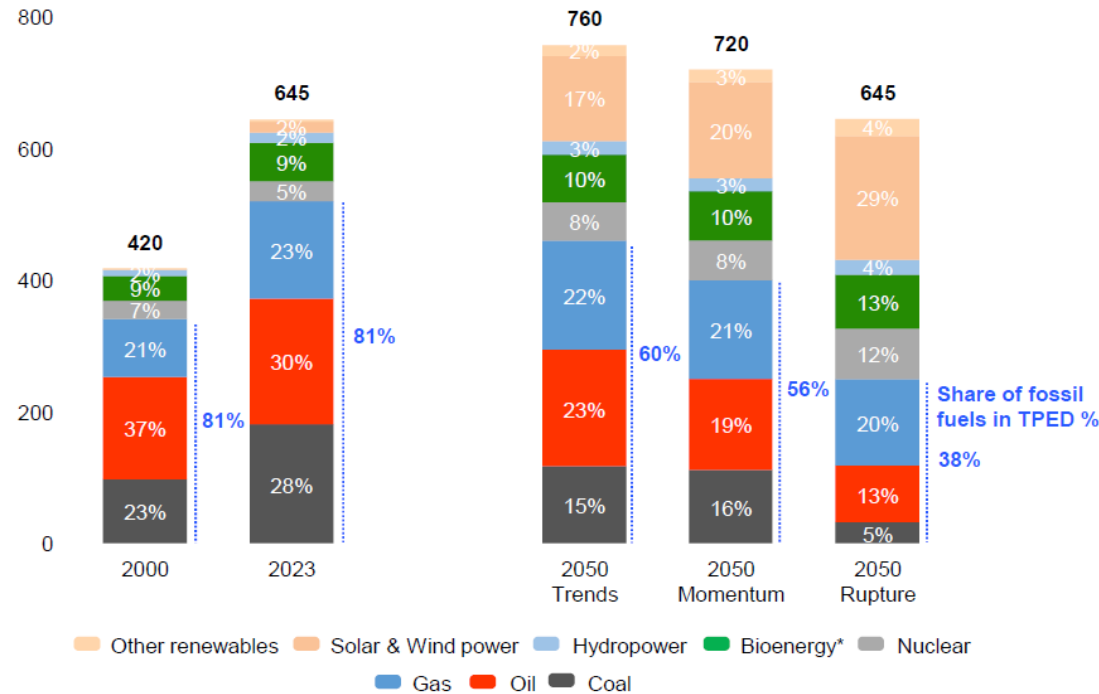
THREE SCENARIOS

Primary Energy Demand in 2050

From sustained transition to global transformation

World Total Primary Energy Demand (TPED)

EJ



The *Trends* scenario assumes that Coal demand gradually declines, particularly in China's power sector. Governments policies supporting electric vehicle adoption remain in place (e.g., ICE 2035 ban in the EU).

The *Momentum* scenario assumes the 2050 targets set by the OECD countries and the 2060 targets set by China are met.

The *Rupture* scenario assumes significantly enhanced multilateral cooperation towards global decarbonization. Geopolitical fragmentation and tensions make this scenario out of reach.

Variable renewables expected to play a central role in electricity generation, which requires:

- a profound transformation of the operations of electricity systems
- massive investment in electricity grids

Gas maintains a stable share in the TPED, notably as an energy source in industry.

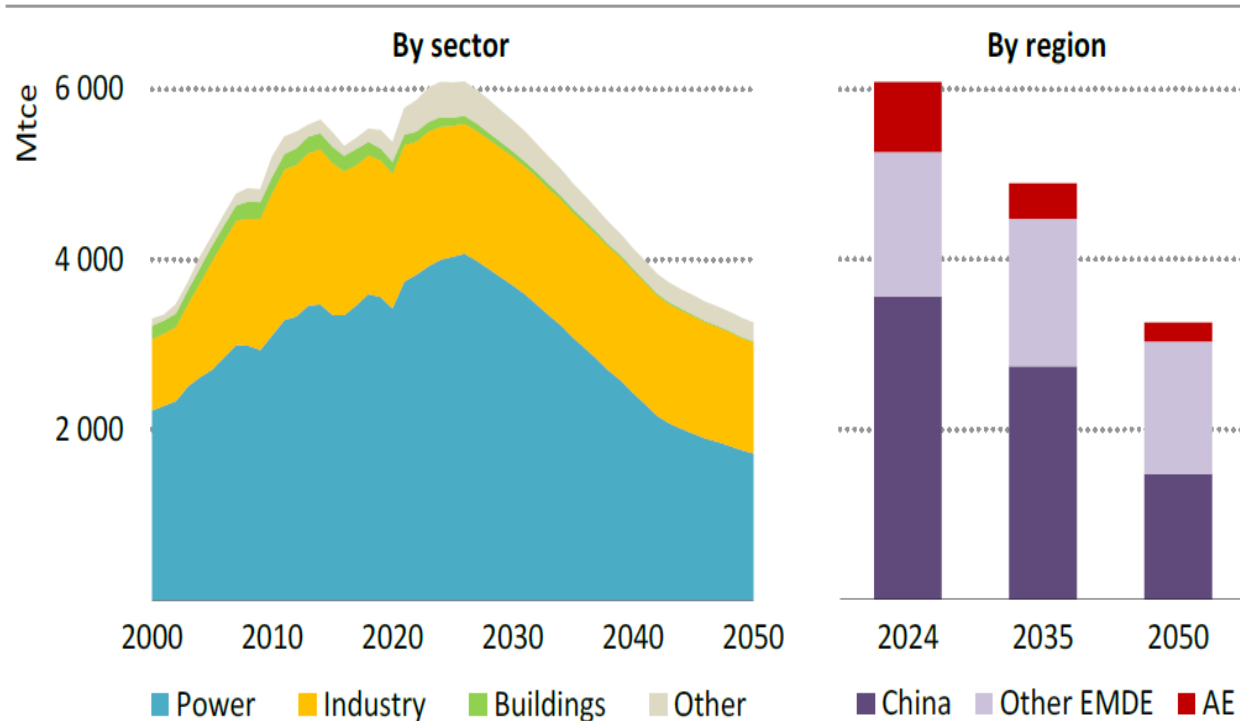


Coal – IEA Perspectives



Coal Demand & Production by IEA 2025 STEPS Scenario (Mtce)

Demand



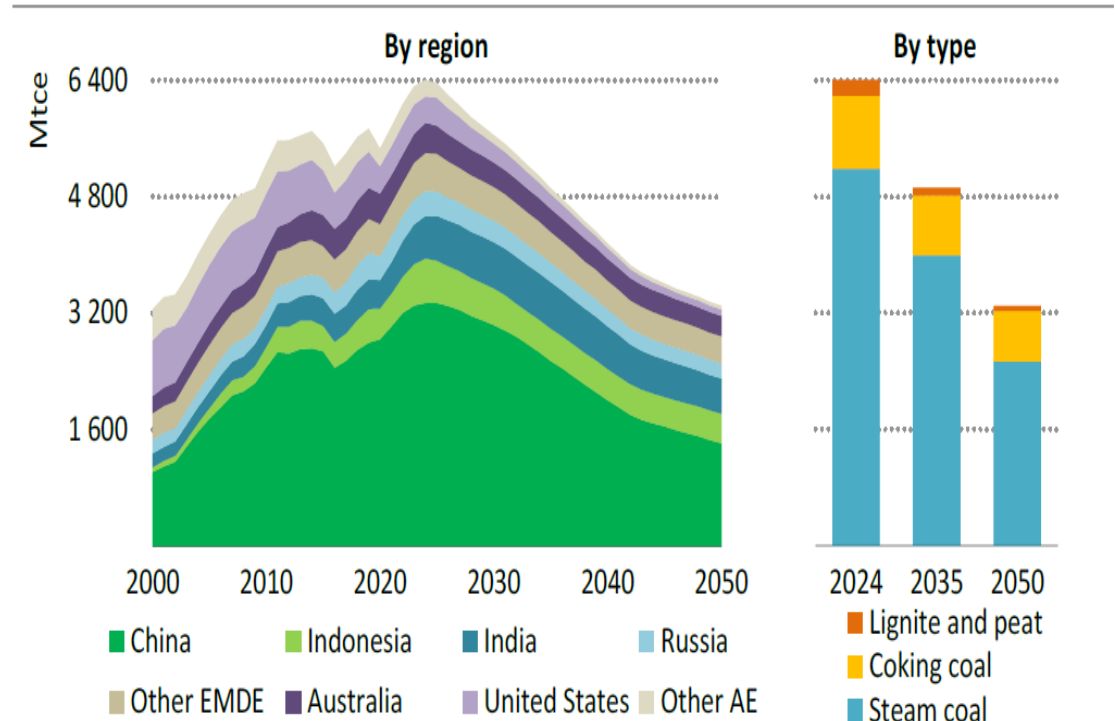
IEA. CC BY 4.0.

Coal demand falls by 20% to 2035 and 45% to 2050, mainly from declines in power; coal demand in industry is more resilient as there are few alternatives for steel production

Note: Mtce = million tonnes of coal equivalent. EMDE = emerging market and developing economies; AE = advanced economies.

Source: IEA WEO 2025

Production



IEA. CC BY 4.0.

China cuts its coal output by nearly 800 Mtce between 2024 and 2035, almost as much as total coal production from all advanced economies in 2024

Note: Mtce = million tonnes of coal equivalent; EMDE = emerging market and developing economies; AE = advanced economies.



Coal Demand by IEA 2025 by Countries/Regions vs Scenarios (Mtce)

	2010	2023	2024	Current Policies		Stated Policies	
				2035	2050	2035	2050
World	5 208	6 018	6 089	5 617	4 724	4 894	3 258
North America	769	316	305	226	170	151	42
United States	717	289	280	217	161	143	35
Central and South America	38	40	41	41	47	39	41
Brazil	21	20	21	24	28	22	25
Europe	539	291	268	171	148	138	109
European Union	361	185	168	78	57	56	34
Africa	156	148	153	128	115	119	93
Middle East	3	7	7	9	9	8	8
Eurasia	203	265	266	228	202	212	181
Russia	151	204	203	166	138	153	120
Asia Pacific	3 501	4 952	5 050	4 813	4 032	4 226	2 784
China	2 565	3 515	3 562	3 200	2 276	2 745	1 476
India	392	728	765	901	977	840	706
Japan	165	142	137	76	54	63	47
Southeast Asia	112	312	336	456	562	417	427

Source: IEA WEO 2025



Coal Production by IEA 2025 vs Scenarios (Mtce)

	2010	2023	2024	Current Policies		Stated Policies	
				2035	2050	2035	2050
World	5 250	6 314	6 404	5 617	4 725	4 920	3 297
Steam coal	4 082	5 084	5 184	4 619	3 805	3 991	2 531
Coking coal	867	1 004	1 002	874	813	825	692
Lignite and peat	300	226	218	125	107	104	74
North America	818	447	402	316	250	230	111
Central and South America	81	67	62	32	27	20	11
Europe	331	167	155	71	43	50	19
European Union	220	113	101	35	18	21	7
Africa	210	214	217	199	181	177	144
Middle East	1	3	2	3	3	3	2
Eurasia	309	419	421	356	313	333	272
Asia Pacific	3 500	4 997	5 145	4 640	3 907	4 107	2 738
Southeast Asia	325	628	671	568	564	506	465

Source: IEA WEO 2025



Coal – US EIA Perspectives (No update since 2023)

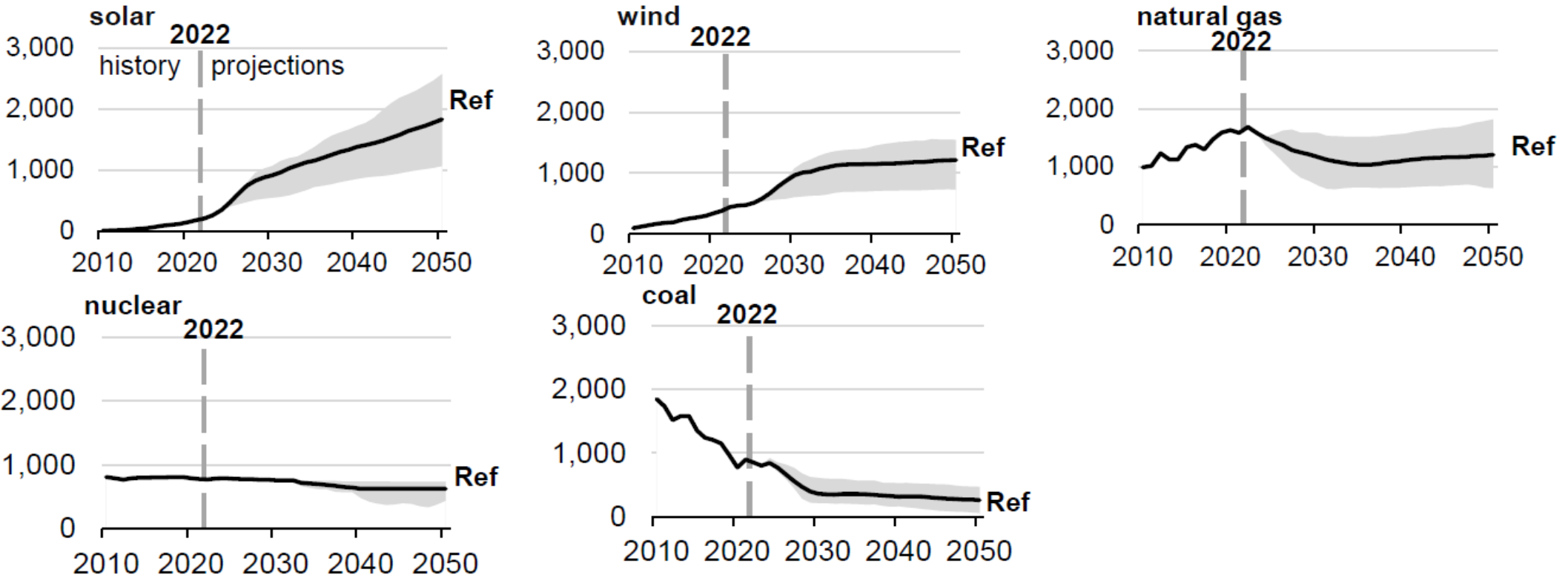


EIA AEO 2023 Highlights – Coal declines drastically

Power demand is increasingly met by renewables

U.S. electricity generation by select technologies for all cases

billion kilowatthours



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases.

Ref=Reference case

Source: EIA AEO 2023 – March 2023
1 quad = 1 quadrillion Btu # 25 Mtoe



Coal - Electricity Generation

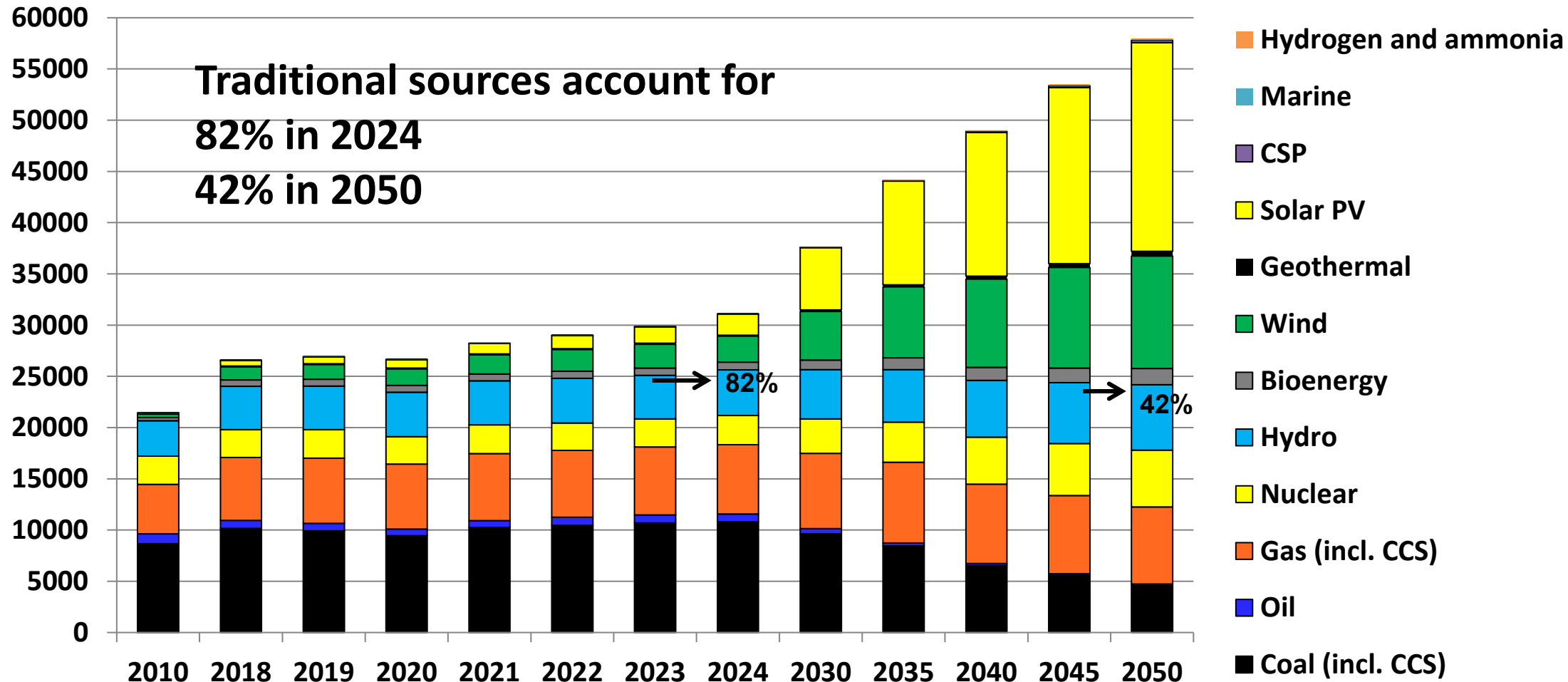


World Electricity Generation by Source

IEA WEO 2025 STEPS

Electricity Generation grows substantially, « traditional » Energy sources are drastically reduced. Wind and Solar PV take the lead

(TWh)



Source: Data from IEA WEO 2025

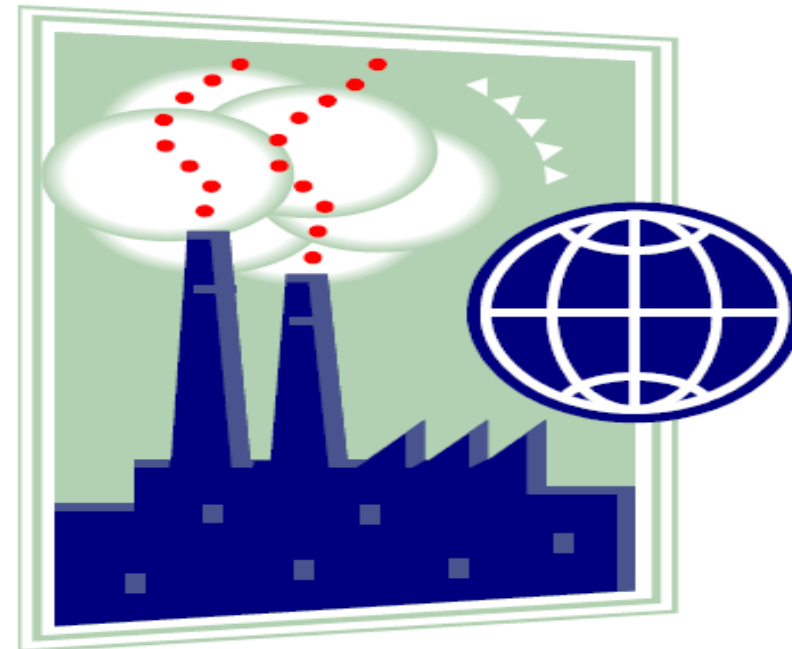


Coal Share in Electricity Generation by Countries 2013 and 2024

> 50%: S.Africa, Poland, China, Kazakhstan, India, Morocco

Coal fuel share in Electricity Generation (%)

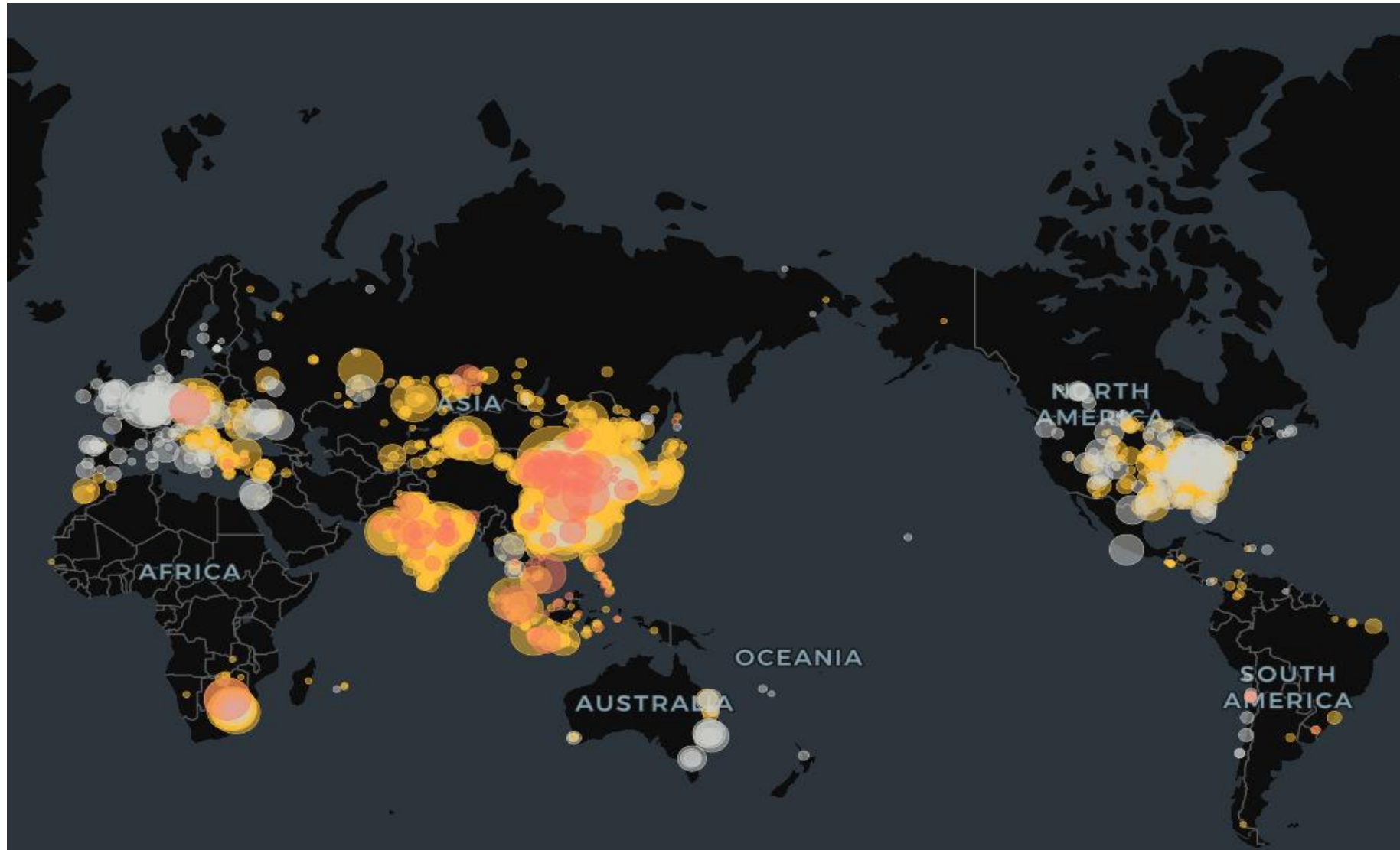
	2013	2024
S. AFRICA	93	82
POLAND	90	54
PR CHINA	79	58
AUSTRALIA	76	46
ISRAEL	63	18
KAZAKSTAN	70	55
INDIA	69	75
CZECH Rep	56	37
MOROCCO	55	59
GREECE	55	6
USA	45	15
GERMANY	44	22
JAPAN	25	32
FRANCE	3.5	<1



2013 WCA

Source: WCA & Ember/EI 2024

Coal fired Electricity Generation Plants in the World 2024



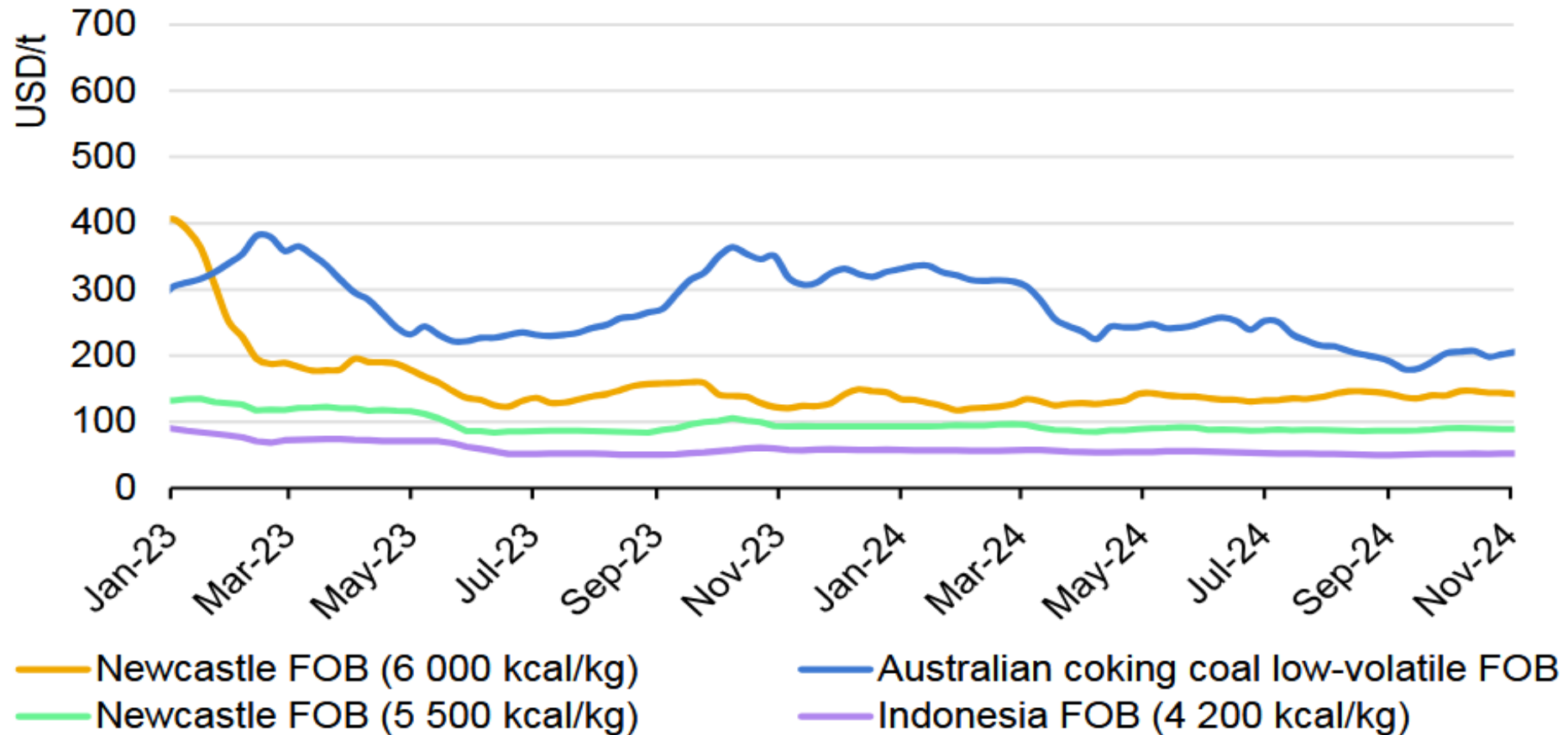
Source: Carbon Brief

Coal Prices and Supply Costs



Coal Price markers for different qualities 2023 – 2024

Price markers for different qualities of coal, 2023-2024



IEA. CC BY 4.0.

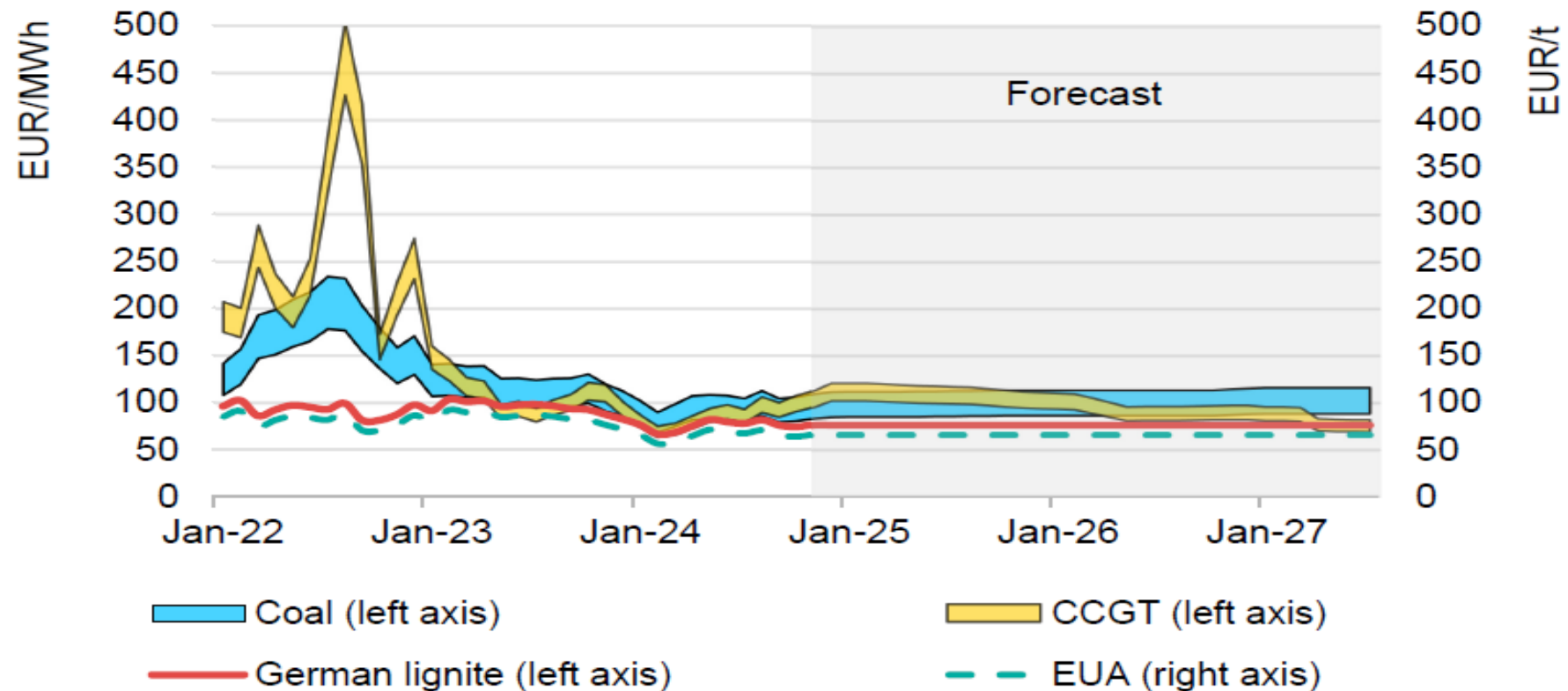
Note: FOB = free on board.

Source: IEA analysis based on data from Argus Media group (all rights reserved).



Electricity Generation costs from Coal and Natural Gas 2021 – 2027 in EU – Impact of Ukraine invasion by Russia

Electricity generation costs in the European Union, 2022-2027



IEA. CC BY 4.0.

Notes: EUA = European Union Allowance. CCGT = combined-cycle gas turbine. CCGT net efficiency = 49-58%. Coal net efficiency = 35-46%. Lignite net efficiency = 39%.

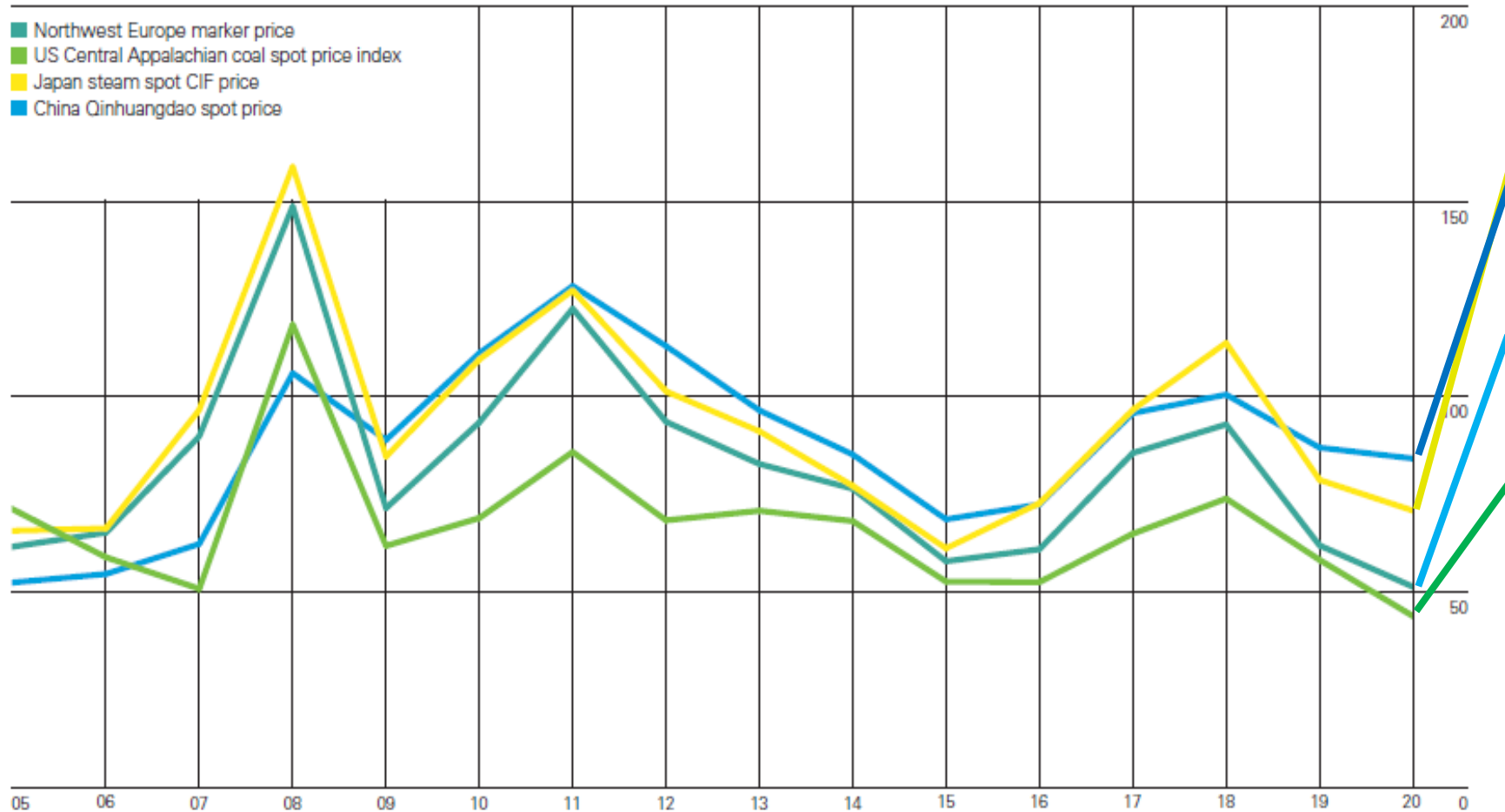
Sources: IEA analysis based on Argus Media group (all rights reserved) and IEA estimates.



Coal Prices Evolution

40 – 80 \$/t in 2020 → 75 – 160 \$/t in 2021

Coal prices
US dollars per tonne



Source: BP Statistical Review 2022



Average Coal Prices evolution by destinations – A peak in 2022

73 – 97 \$/tce in 2025

	Coal US dollars per tonne								Uranium \$/lb
	United States ¹	Colombia ²	Northwest Europe ³	South Africa ⁴	Indonesia ⁵	South China ⁶	Japan ⁷	Australia ⁸	Canada ⁹
1987	—	—	31.30		—	—	—	—	—
1988	—	—	39.94		—	—	—	—	—
1989	—	—	42.08		—	—	—	—	—
1990	31.59	—	43.48		—	—	—	—	—
1991	29.01	—	42.80		—	—	—	—	—
1992	28.53	—	38.53		—	—	—	—	—
1993	29.85	—	33.68		—	—	—	—	—
1994	31.72	—	37.18		—	—	—	—	—
1995	27.01	—	44.50		—	—	—	—	—
1996	29.86	—	41.25		—	—	—	—	—
1997	29.76	—	38.92		—	—	—	—	—
1998	31.00	—	32.00		—	—	—	—	—
1999	31.29	—	28.79		—	—	—	—	—
2000	29.90	—	35.99			27.52	—	—	—
2001	50.15	—	39.03		—	31.78	37.69	—	—
2002	33.20	—	31.65		—	33.19	31.47	—	—
2003	38.52	—	43.60		—	31.74	39.61	—	—
2004	64.90	—	72.13		—	42.76	74.22	—	—
2005	70.12	—	60.54		—	51.34	64.62	—	—
2006	57.82	—	64.11		—	53.53	65.22	—	—
2007	49.73	—	88.79		—	61.23	95.59	—	—
2008	117.42	—	147.67		—	104.97	157.88	—	—
2009	60.73	—	70.39		—	87.86	83.59	—	—
2010	67.87	59.21	92.50		—	110.08	108.47	—	—
2011	84.75	79.73	121.48		—	127.27	126.13	—	—
2012	67.28	65.02	92.50		—	111.89	100.30	—	—
2013	69.72	54.18	81.69		—	95.42	90.07	—	—
2014	67.08	50.25	75.38	62.80	—	84.12	76.13	—	—
2015	51.57	47.31	56.79	47.48	—	67.53	60.10	—	—
2016	51.45	52.62	60.09	53.04	—	71.35	71.66	—	—
2017	63.83	68.75	84.51	71.59	—	94.72	96.02	—	—
2018	72.84	72.76	91.83	78.03	—	99.45	112.73	71.13	—
2019	57.16	51.26	60.17	55.67	50.53	35.20	73.57	54.24	—
2020	58.63	51.57	50.13	48.30	43.35	54.62	61.05	44.75	30.46
2021	96.96	116.17	124.20	96.49	96.07	124.41	115.14	83.26	35.16
2022	216.64	258.06	293.63	212.99	127.72	177.16	215.88	174.49	49.78
2023	98.77	108.44	129.34	99.66	84.33	119.69	129.86	103.59	60.37
2024	77.67	82.99	112.08	88.41	73.51	101.90	115.40	89.41	86.24
2025	74.70	75.86	97.96	72.59	61.31	87.89	95.67	72.95	72.40

¹ Source: S&P Global Energy ©2025 by S&P Global Inc. Prices are for CAPP 12,500Btu, 1.25O₂ coal, FOB to 2019. From 2020, S&P Global Energy ©2026 by S&P Global Inc.

Thermal Coal FOB Baltimore 6,900 kcal/kg NAR 3% S.

² Source: S&P Global Energy ©2026 by S&P Global Inc. Thermal Coal FOB Colombia 6,000kcal/kg NAR 90 Day.

³ Source: IHS Northwest Europe prices for 1990-2000 average monthly marker prices, 2001-2018 average weekly prices. 2019 monthly average of S&P Global Energy ©2025 by S&P Global Inc Thermal Coal CIF ARA 6,000kcal/kg NAR. From 2020 S&P Global Energy ©2026 by S&P Global Inc Thermal Coal CIF ARA 6,000kcal/kg NAR 15-60 Day.

⁴ Source: S&P Global Energy ©2026 by S&P Global Inc FOB Richards Bay 5,500kcal/kg NAR 7-45 Day.

⁵ Source: S&P Global Energy ©2026 by S&P Global Inc FOB Kalimantan 5,000kcal/kg GAR 15-60 Day.

⁶ Source: South China prices are the average monthly price for 2000-2005, weekly prices 2006-2018, 2019 monthly average of S&P Global Energy ©2026 by S&P Global Inc CFR South China 5,500kcal/kg NAR. From 2020, S&P Global Energy ©2026 by S&P Global Inc. Thermal Coal Platts PCC 8 CFR South China 5,500kcal/kg NAR 15-60 day. Yearly average currency exchange rates applied.

⁷ Source: 2001-2018 IHS Japan prices basis = 6,000kcal/kg NAR CIF. 2019 monthly average of S&P Global Energy ©2026 by S&P Global Inc NEAT 5,750kcal/kg NAR. From 2020 Platts NEAT 15-60 day CFR Kinuura 5,750kcal/kg NAR.

⁸ Source: S&P Global Energy ©2026 by S&P Global Inc. Thermal Coal FOB Newcastle High Ash 5,500kcal/kg NAR 7-45 Day.

⁹ Source: S&P Global Energy ©2026 by S&P Global Inc Uranium U3O8 Spot Canada Mo01.

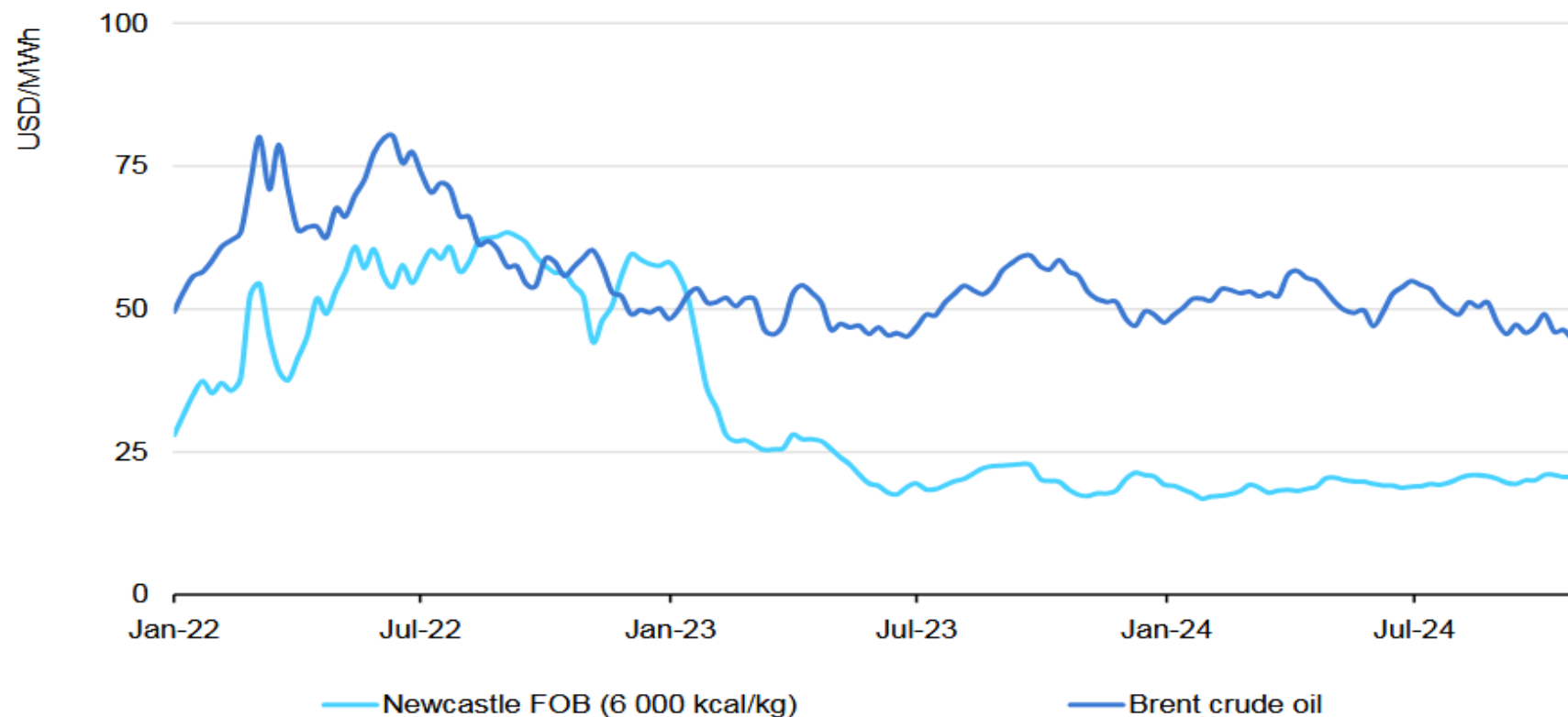
Note: NAPP = north appalachian, CIF = cost+insurance+freight (average prices); FOB = free on board, NAR = net as received, CFR = cost+freight.



Price markers for Coal & Crude Oil

After the 2022 crisis, Coal remains twice less expensive than Oil

Price markers for Australian high-CV coal and Brent crude oil, 2022-2024



IEA. CC BY 4.0.

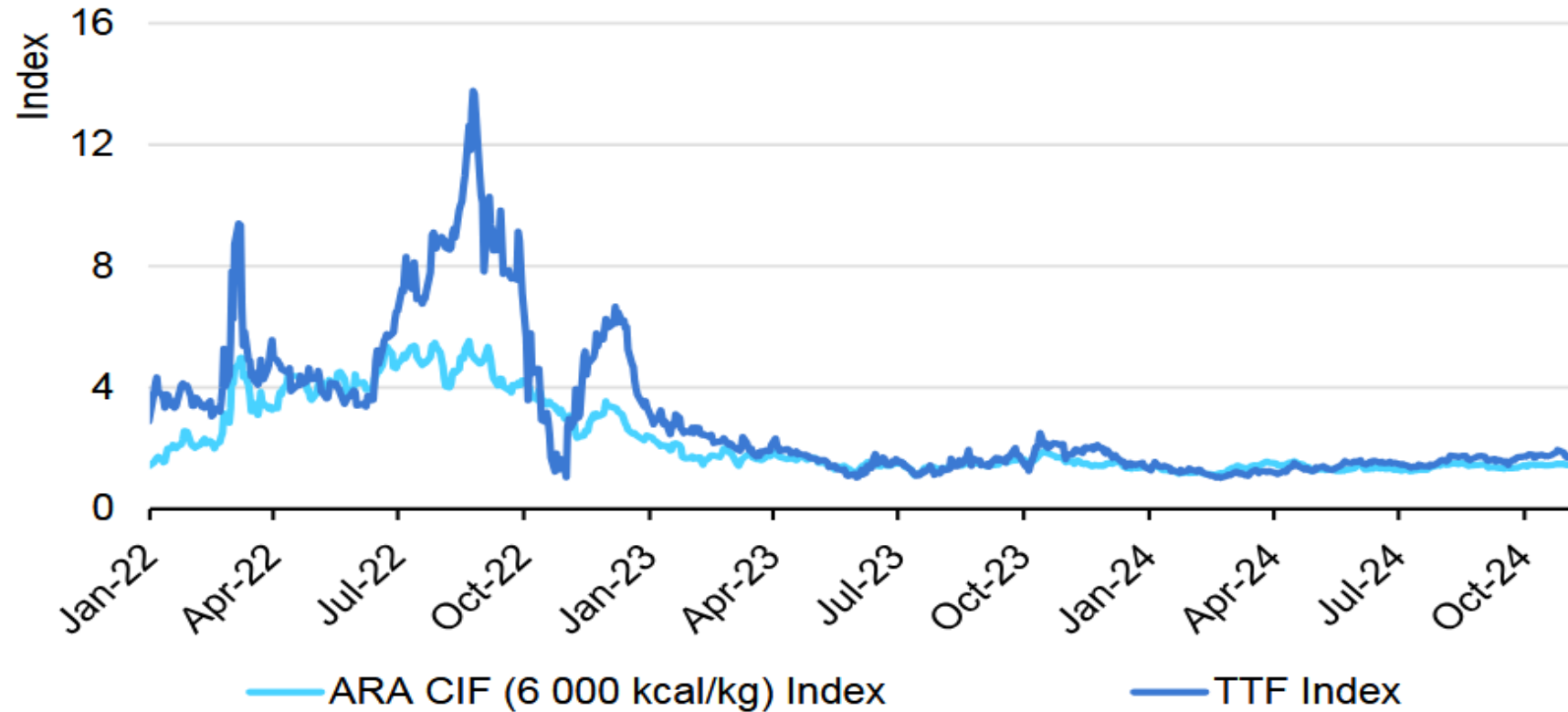
Note: FOB = free on board.

Source: IEA analysis based on Argus Media Group (all rights reserved).



Coal & Gas Prices – Evolution 2022 - 2024

Trajectories of ARA CIF coal and TTF gas prices, 2022-2024



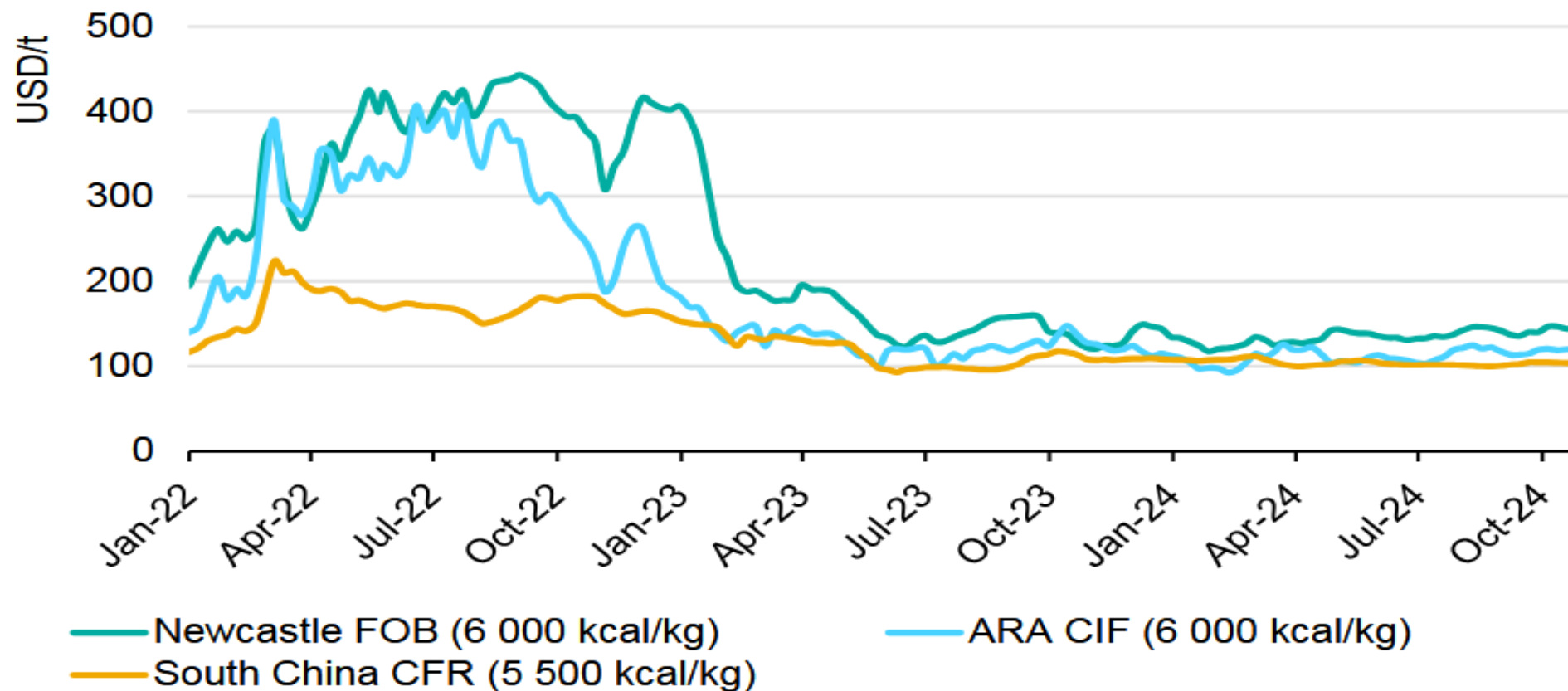
IEA. CC BY 4.0.

Notes: ARA = Amsterdam Rotterdam Antwerp; CIF = cost, insurance and freight; TTF = Title Transfer Facility.

Source: IEA analysis based on Argus Media Group (all rights reserved).

Thermal Coal Prices evolution by destinations

Thermal coal price markers, 2022-2024



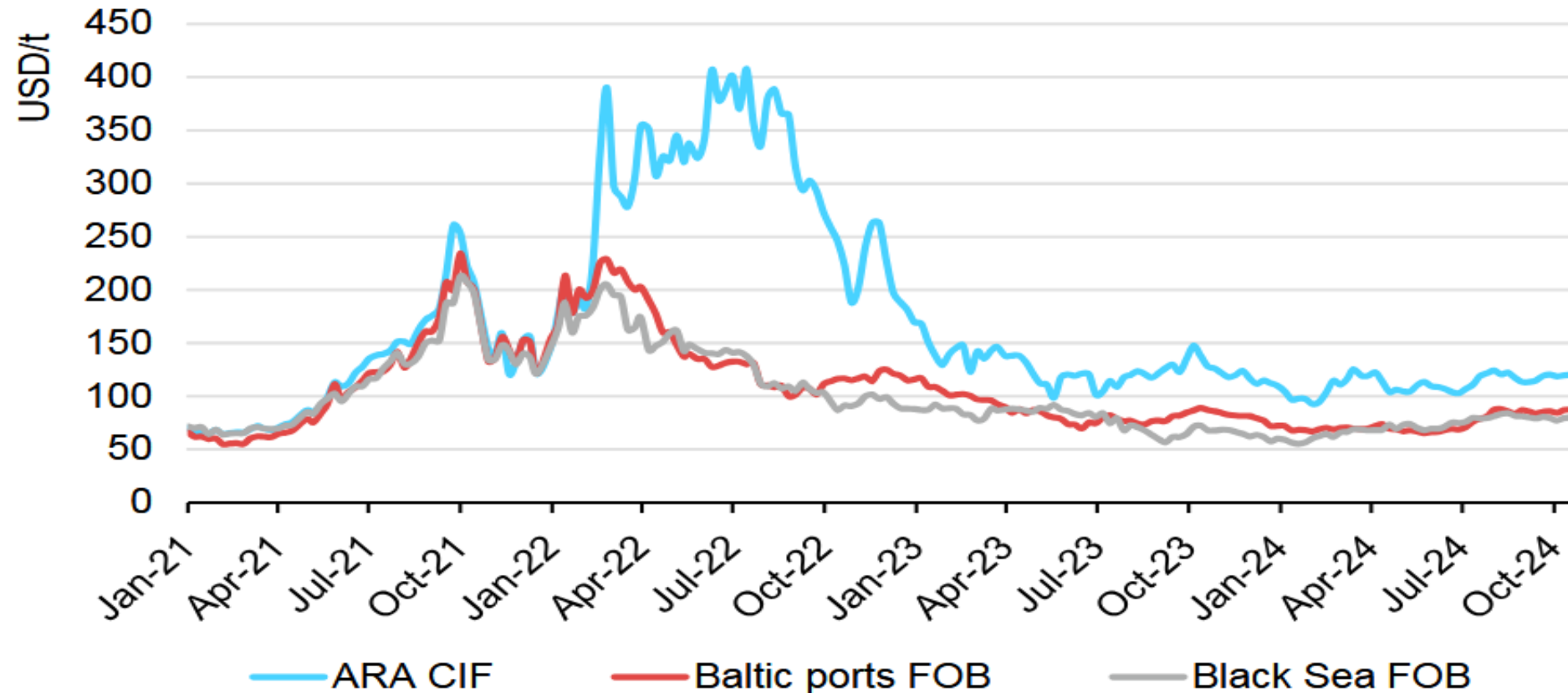
IEA. CC BY 4.0.

Note: FOB = free on board; ARA = Amsterdam Rotterdam Antwerp; CIF = cost, insurance and freight; CFR = cost and freight.

Source: IEA analysis based on data from Argus Media group (all rights reserved).

Coal Prices evolution – European & Russian Thermal Coal

European and Russian high-CV (6 000 kcal/kg) price markers, 2021-2024



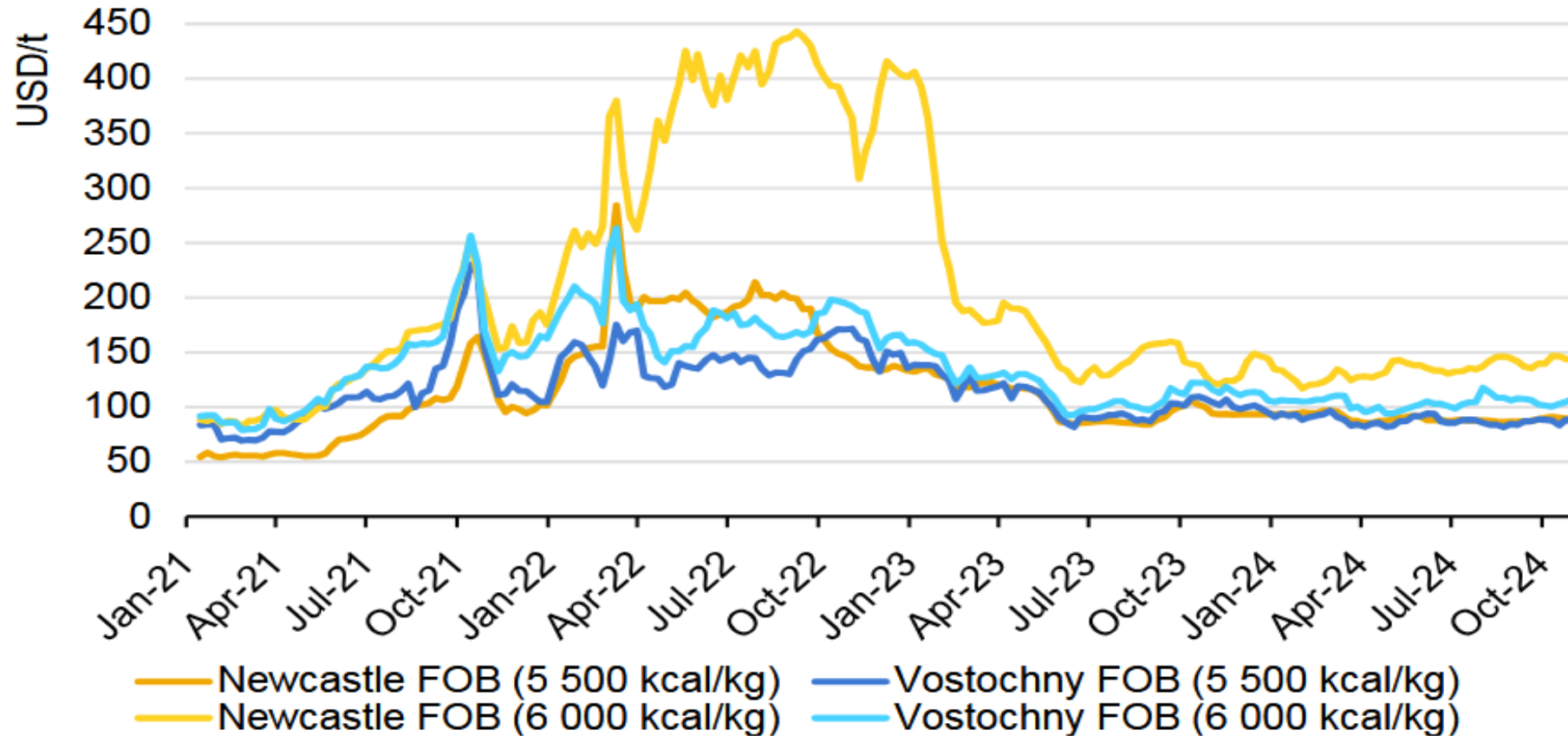
IEA. CC BY 4.0.

Notes: ARA = Amsterdam Rotterdam Antwerp. FOB = free on board. CIF = cost, insurance and freight.

Source: IEA analysis based on Argus Media Group (all rights reserved).

Coal Prices evolution – Australian & Russian Thermal Coal

Australian and Russian thermal coal price markers, 2021-2024



IEA. CC BY 4.0.

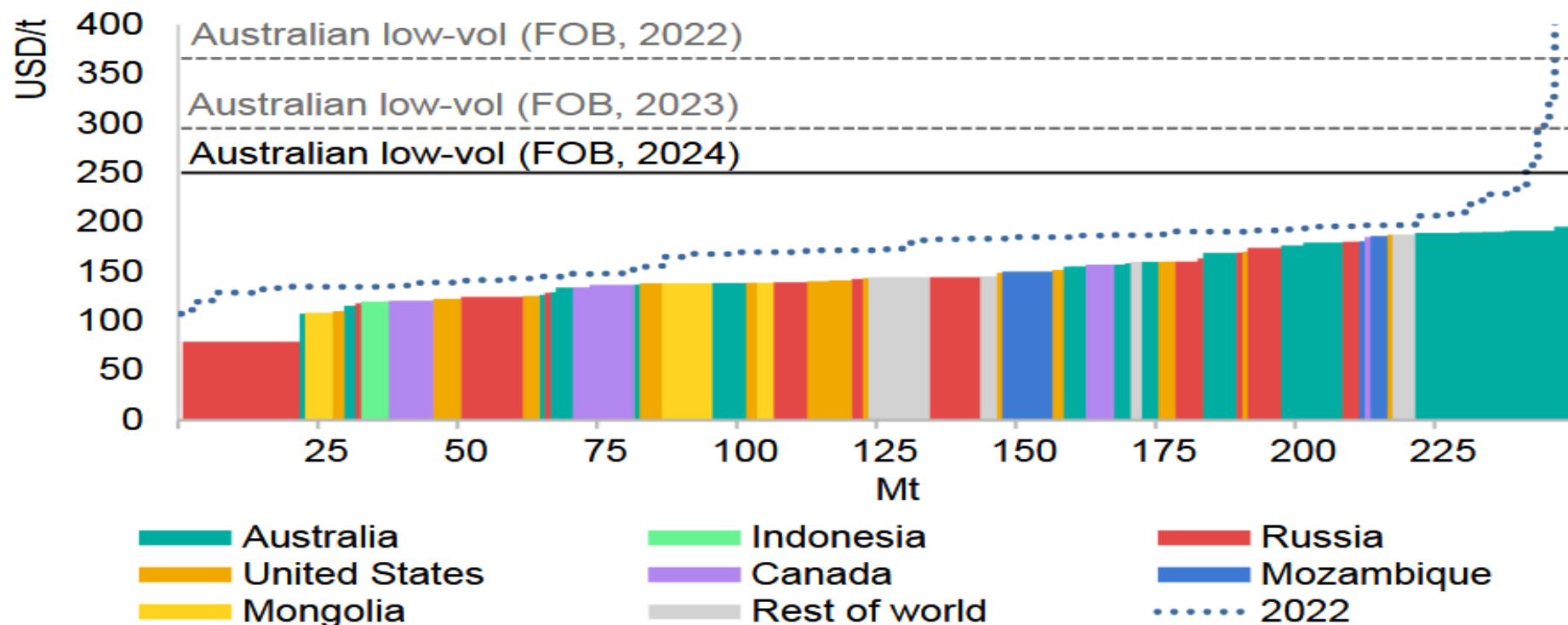
Notes: FOB = free on board. Vostochny = port in the Russian Far East.

Source: IEA analysis based on Argus Media Group (all rights reserved).

Supply Costs of Hard Coking Coal in 2024

Some mines are no longer competitive, but global profitability is persistent

Indicative hard coking coal FOB supply curve, 2023, and average FOB price markers, 2022-2024



IEA. CC BY 4.0.

Notes: low-vol = low-volatile. FOB = free on board. Cost curves account for variable production costs, overburden removal, royalties, inland transport, and port usage fees. The annual average FOB price marker is based on the monthly average index for Australian prime hard coking coal. The 2024 price is based on the average from January to September.

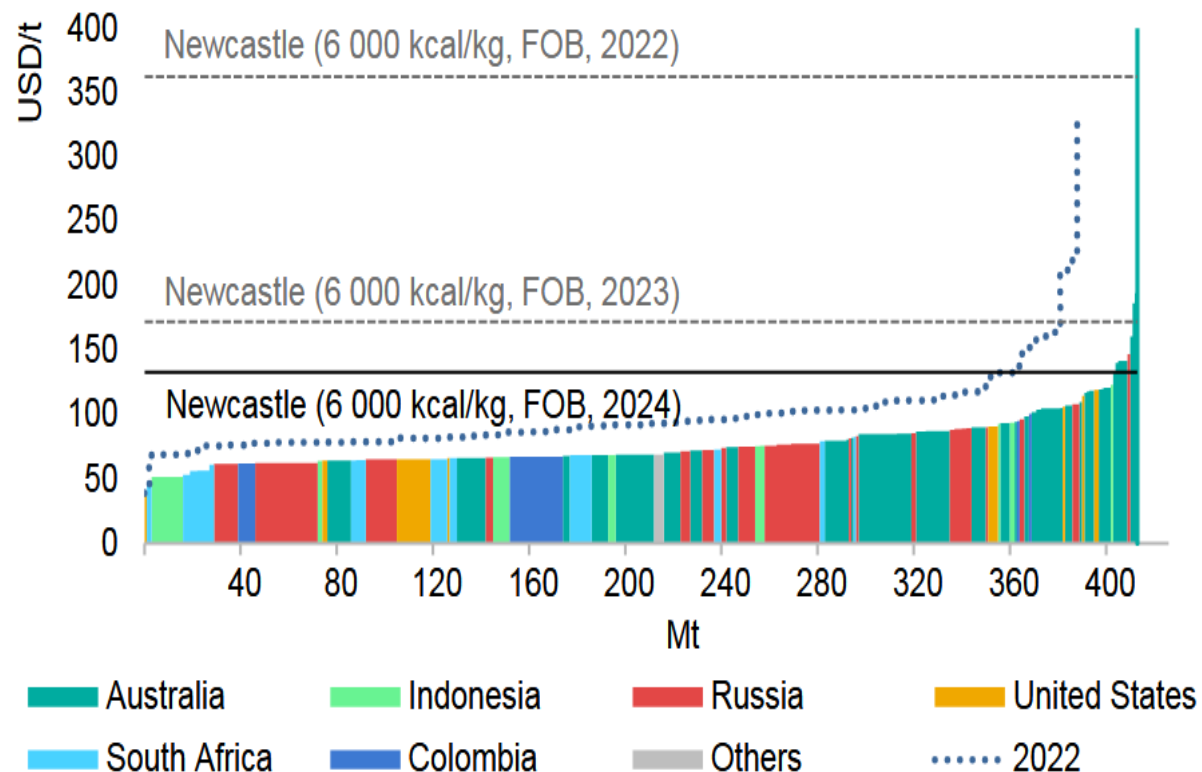
Sources: IEA analysis based on Argus Media Group (all rights reserved) and adapted from CRU (2024), Metallurgical Cost Model (database).



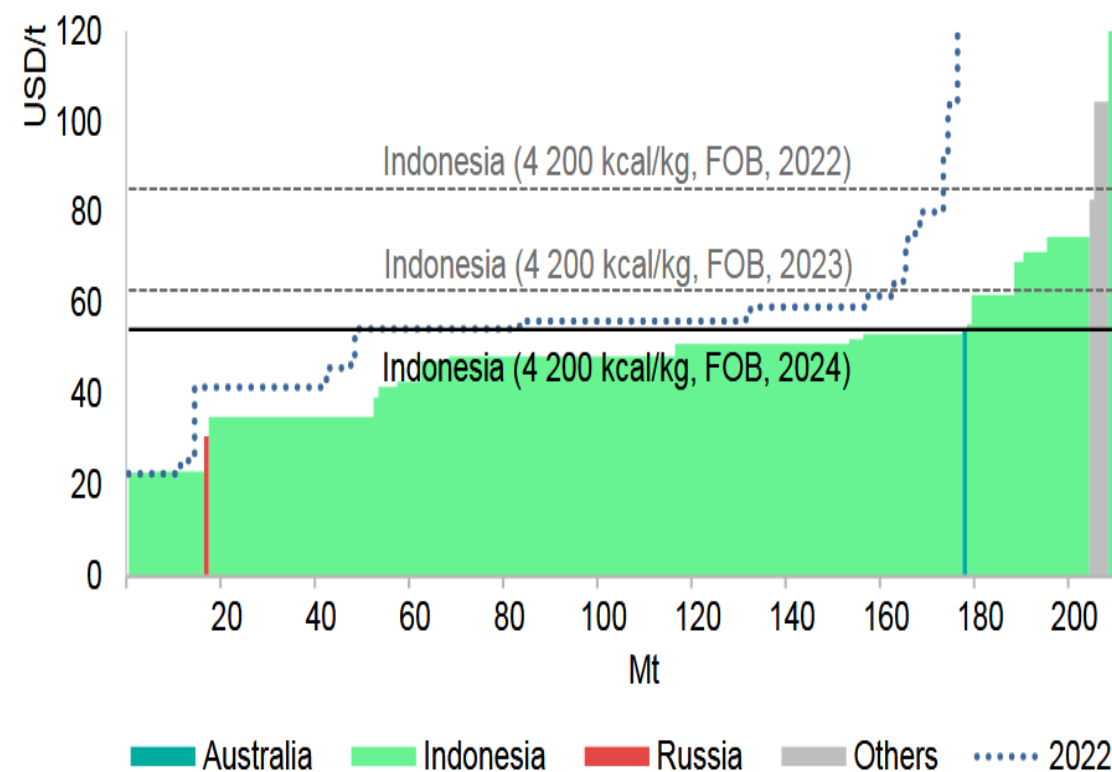
Supply Costs of High Cal. & Low Cal. Thermal Coal in 2024

Despite a slight decrease in Supply Costs, profitability has decreased vs 2022

Indicative high-CV (> 5 700 kcal/kg) thermal coal FOB supply curve, 2023, and average FOB price markers, 2022-2024



Indicative low-CV (< 4 500 kcal/kg) thermal coal FOB supply curve, 2023, and average FOB price markers, 2022-2024



Notes: The cost curves account for variable production costs, overburden removal, royalties, inland transport, and port usage fees. The cost curve is not adjusted for different qualities of coal. The transport costs given are to the closest port, so the FOB costs of Russian producers in Asia can be somewhat higher than shown in the figure. The 2024 prices are based on the monthly average from January to September.

Sources: IEA analysis based on Argus Media Group (all rights reserved) and adapted from CRU (2024), Thermal Cost Model (database).



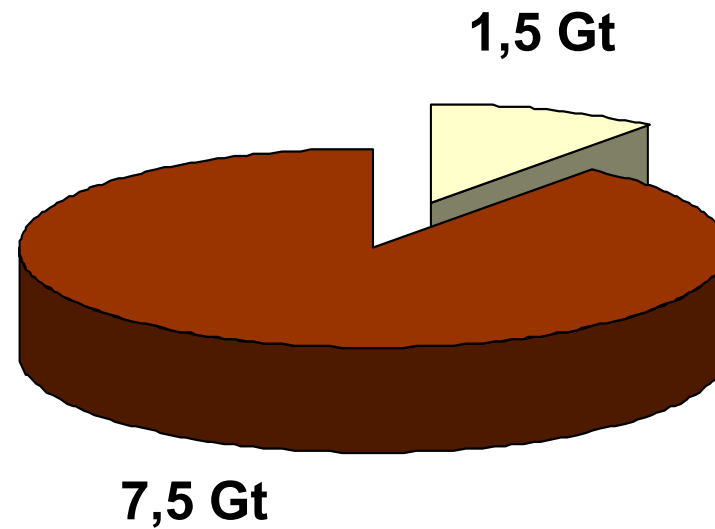
Coal international trade

◆ The coal trade characteristics:

- A limited share of coal is internationally traded
- However with oil price evolution and lack of production capacity, international coal trade is dynamic
- Coal sea transport is cheap
- Coal ground transport is expensive
- Australia and Indonesia are major coal exporters
- Coal consumption is now affected by a negative image due to the high degree of carbon emissions



**International Traded Coal represents 16% of Coal
World Production # 9,0 Gt – Year 2024
Seaborne trade in 2024 # 1,5 Gt**

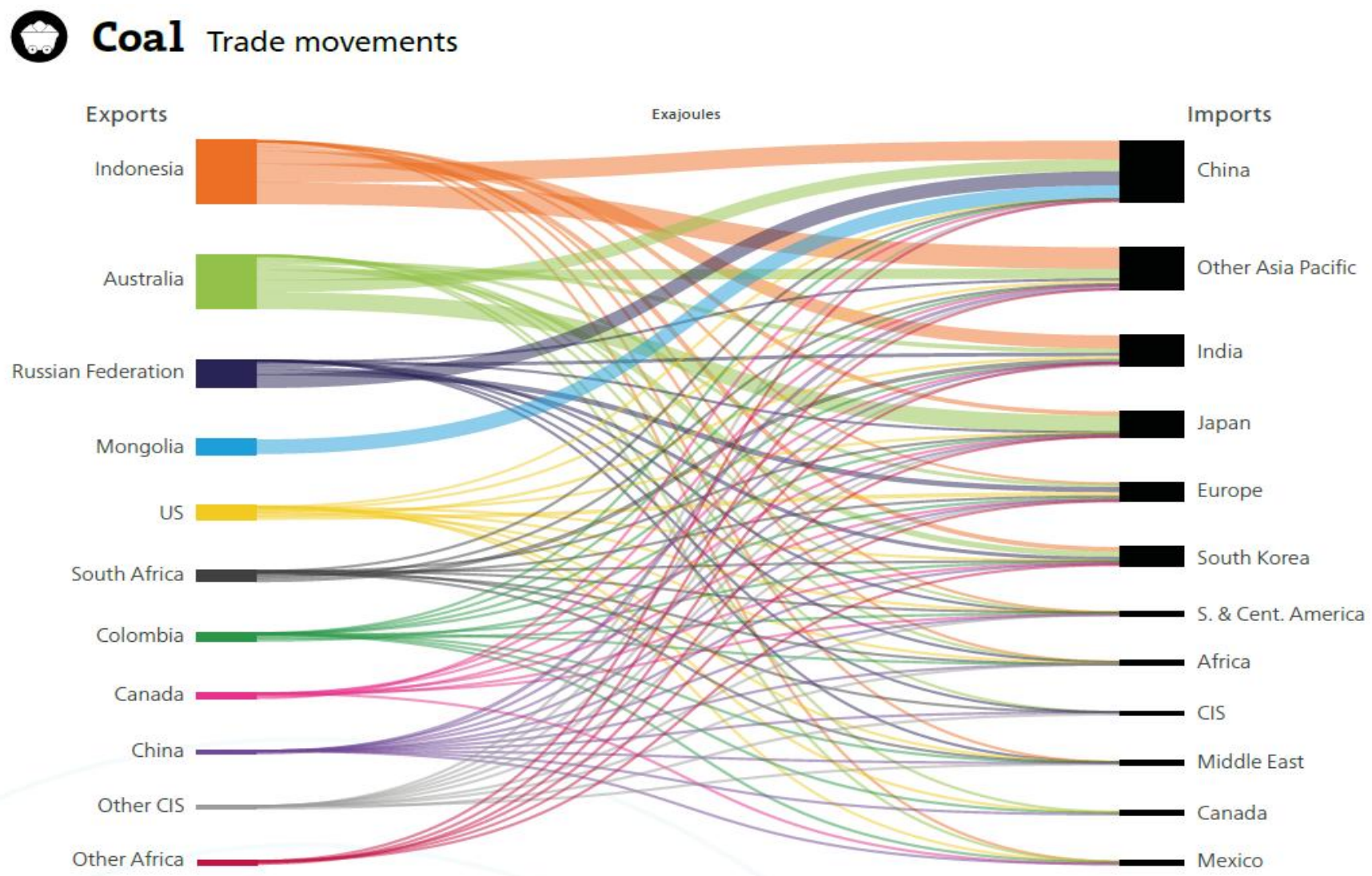


■ Seaborne ■ Domestic

Note: Quantities in t and not tce



Coal Trade around the World - 2025



Source: EI Stat. Review 2026



Coal Trade around the World - 2025



Coal Trade movements

Exajoules	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Growth rate per annum		Share
												2025	2015–25	2025
Imports														
Canada	0.22	0.19	0.22	0.23	0.21	0.17	0.19	0.18	0.19	0.18	0.18	1.1%	-1.7%	0.5%
Mexico	0.23	0.21	0.32	0.32	0.25	0.13	0.05	0.05	0.13	0.11	0.11	0.8%	-7.0%	0.3%
US	0.28	0.25	0.19	0.15	0.17	0.65	0.14	0.16	0.11	0.06	0.09	50.6%	-10.7%	0.3%
S. & Cent. America	1.00	1.06	1.20	1.18	1.12	1.04	1.25	1.05	0.96	0.87	0.83	-4.4%	-1.9%	2.3%
Europe	6.03	5.40	5.83	6.34	5.08	3.93	4.44	4.95	3.60	3.00	3.01	0.8%	-6.7%	8.5%
CIS	0.53	0.48	0.60	0.65	0.70	0.66	0.64	0.49	0.49	0.47	0.47	2.0%	-1.2%	1.3%
Middle East	0.38	0.34	0.36	0.37	0.34	0.38	0.34	0.25	0.26	0.25	0.21	-15.3%	-5.6%	0.6%
Africa	0.44	0.50	0.63	0.82	0.92	0.52	0.68	0.73	0.76	0.67	0.66	-0.3%	4.1%	1.9%
China	4.69	5.65	5.87	6.00	6.40	6.61	6.68	5.83	10.16	11.62	10.41	-10.1%	8.3%	29.5%
India	4.92	6.46	5.25	5.68	4.70	4.74	4.67	4.99	5.35	5.30	5.28	†	0.7%	14.9%
Japan	5.05	5.01	5.06	5.00	4.90	4.56	4.84	4.82	4.39	4.35	4.24	-2.2%	-1.7%	12.0%
South Korea	3.54	3.53	3.89	3.90	3.73	3.28	3.35	3.36	3.19	3.07	2.94	-4.0%	-1.8%	8.3%
Other Asia Pacific	3.96	4.60	4.25	4.83	4.79	6.11	5.95	5.49	5.97	6.62	6.87	4.1%	5.7%	19.5%
Total World	31.27	33.69	33.67	35.48	33.29	32.78	33.23	32.35	35.56	36.55	35.32	-3.1%	1.2%	100.0%
Exports														
Canada	0.86	0.78	0.92	1.00	0.99	0.92	0.94	0.95	0.97	0.91	0.93	2.5%	0.9%	2.6%
US	1.89	1.52	2.41	2.90	2.21	1.74	2.18	2.25	2.48	2.65	2.34	-11.5%	2.2%	6.6%
Colombia	2.19	2.33	2.46	2.41	2.07	1.81	1.66	1.60	1.61	1.63	1.28	-21.3%	-5.2%	3.6%
Europe	0.10	0.13	0.19	0.25	0.24	0.21	0.22	0.15	0.20	0.12	0.10	-12.9%	0.8%	0.3%
Russian Federation	4.11	4.47	4.88	5.54	5.60	5.42	5.80	5.18	5.31	4.69	4.78	2.3%	1.5%	13.5%
Other CIS	0.48	0.45	0.50	0.49	0.55	0.63	0.65	0.69	0.66	0.61	0.66	7.9%	3.2%	1.9%
South Africa	2.30	2.16	2.70	2.96	1.42	1.75	1.61	1.68	1.64	1.58	1.68	6.7%	-3.1%	4.8%
Other Africa	0.26	2.02	0.66	0.24	0.28	0.74	0.37	0.47	0.57	0.54	0.49	-9.0%	6.3%	1.4%
Australia	9.95	9.87	9.17	9.30	9.05	8.98	8.98	7.67	8.37	8.97	8.90	-0.5%	-1.1%	25.2%
China	0.45	0.51	0.55	0.63	0.77	0.61	0.88	0.98	0.95	0.70	0.67	-3.5%	4.0%	1.9%
Indonesia	7.48	7.73	7.91	8.42	8.39	8.72	8.99	9.23	10.27	11.31	10.45	-7.4%	3.4%	29.6%
Mongolia	0.41	0.73	0.95	0.99	1.04	0.83	0.49	0.90	1.93	2.27	2.42	7.1%	19.5%	6.9%
Other Asia Pacific	0.65	0.77	0.32	0.29	0.60	0.34	0.36	0.44	0.45	0.44	0.44	-0.3%	-3.9%	1.2%
Rest of World	0.14	0.22	0.06	0.08	0.09	0.08	0.08	0.15	0.13	0.13	0.17	30.6%	2.4%	0.5%
Total World	31.27	33.69	33.67	35.48	33.29	32.78	33.23	32.35	35.56	36.55	35.32	-3.1%	1.2%	100.0%

† Less than 0.05%.

Notes: Commercial solid fuels only, i.e. bituminous coal and anthracite (hard coal), and lignite and brown (sub-bituminous) coal, and other commercial solid fuels.

Intra-area movements (for example between countries in Europe) are excluded.

Annual changes and shares of total are calculated using exajoules figures. Growth rates are adjusted for leap years.

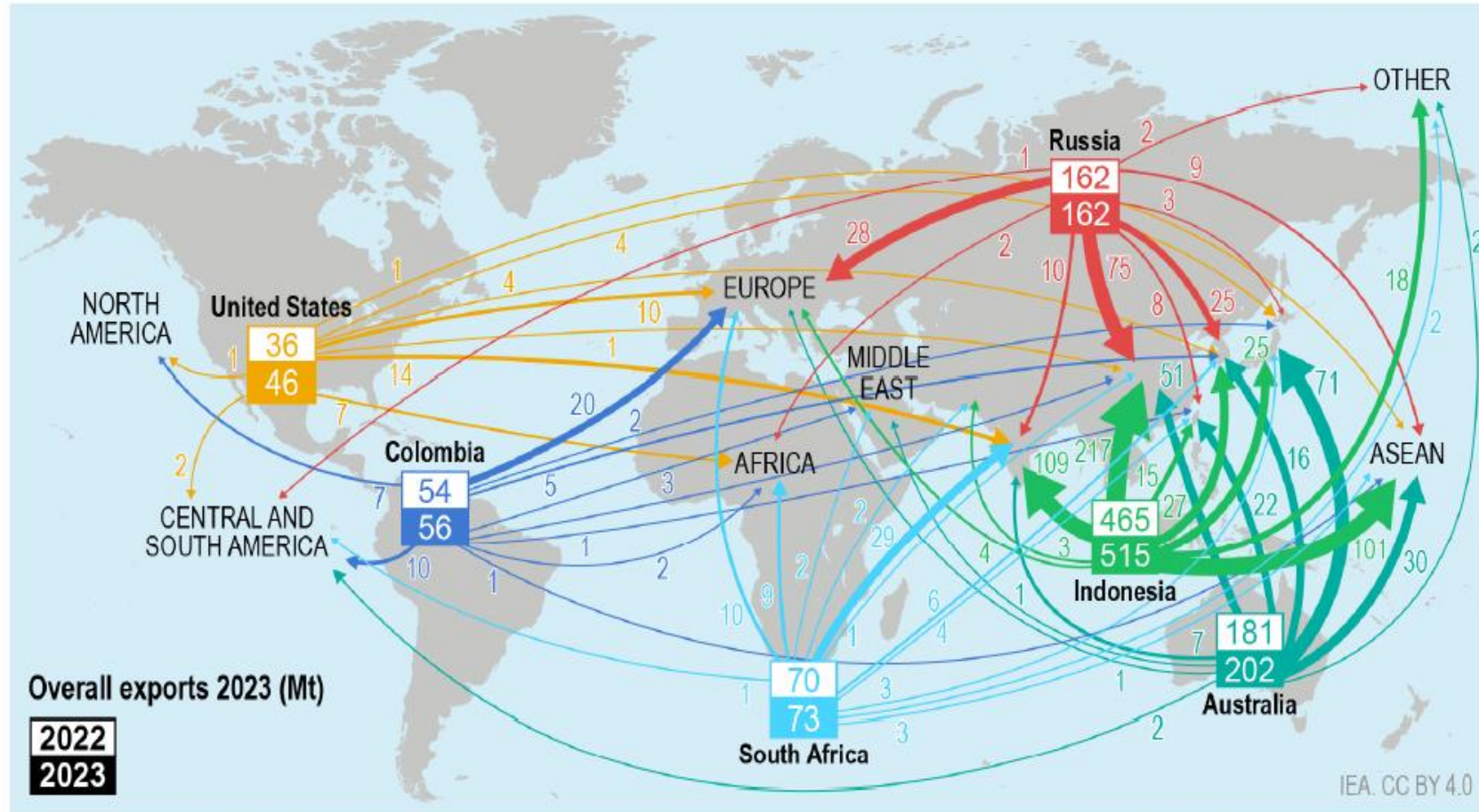
Source: EI Stat. Review 2026



Thermal Coal Trade around the World 2023 (Mt)

Thermal Coal Trade remains concentrated in the Asia Pacific basin

Main trade flows in the thermal coal market, 2023 (Mt)



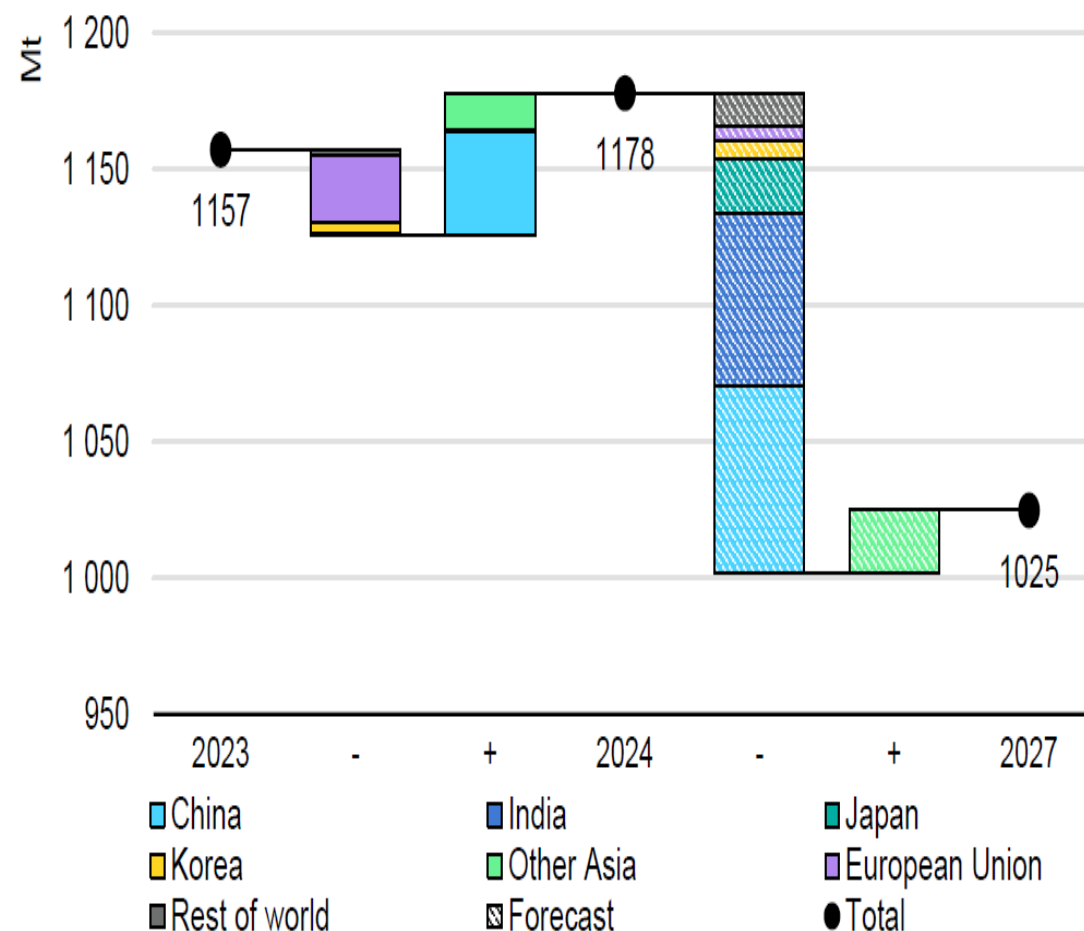
Note: Map values are based on available export data and do not necessarily match import numbers due to reporting times.

Source: IEA Coal 2024

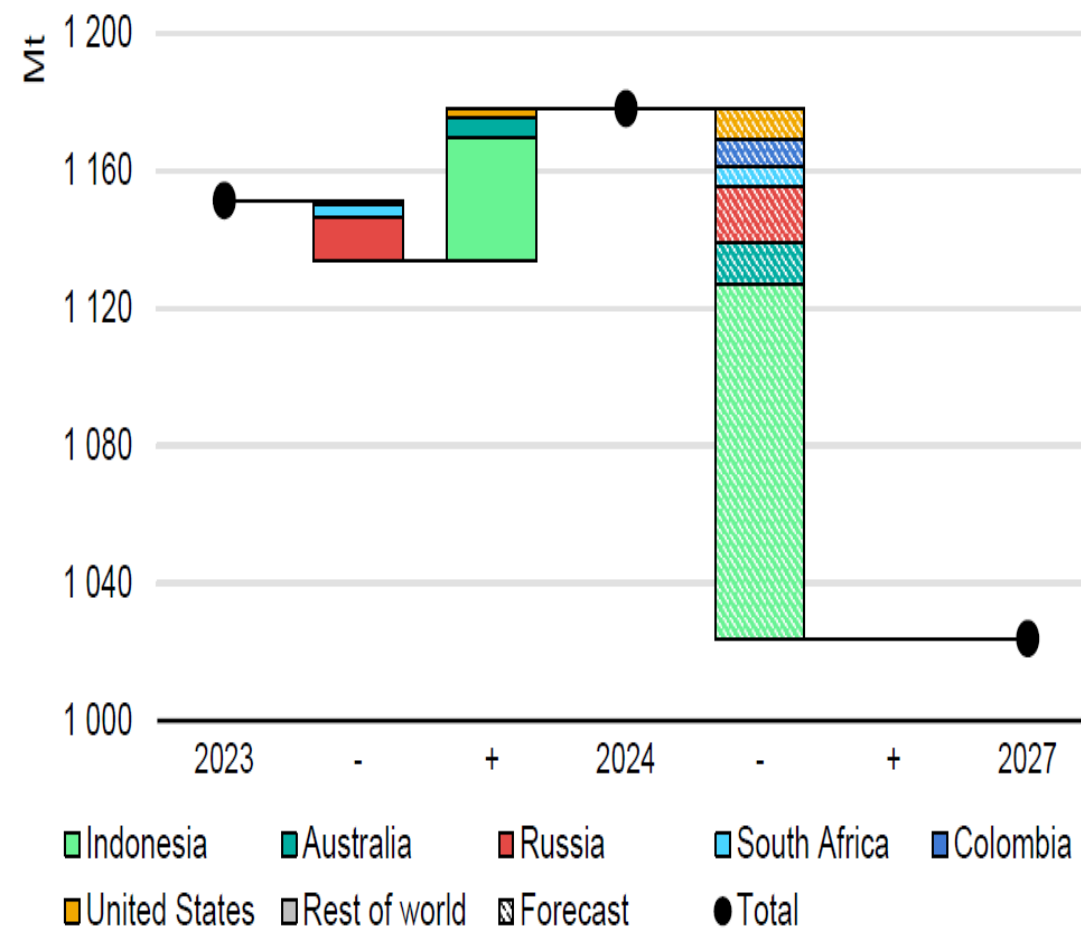
Nota: Thermal Coal is a part of Hard Coal

Thermal Coal Trade around the World 2023 - 2027 (Mt)

Forecast global thermal coal import changes, 2023-2027



Change in global thermal coal exports, 2023-2027



Source: IEA Coal 2024

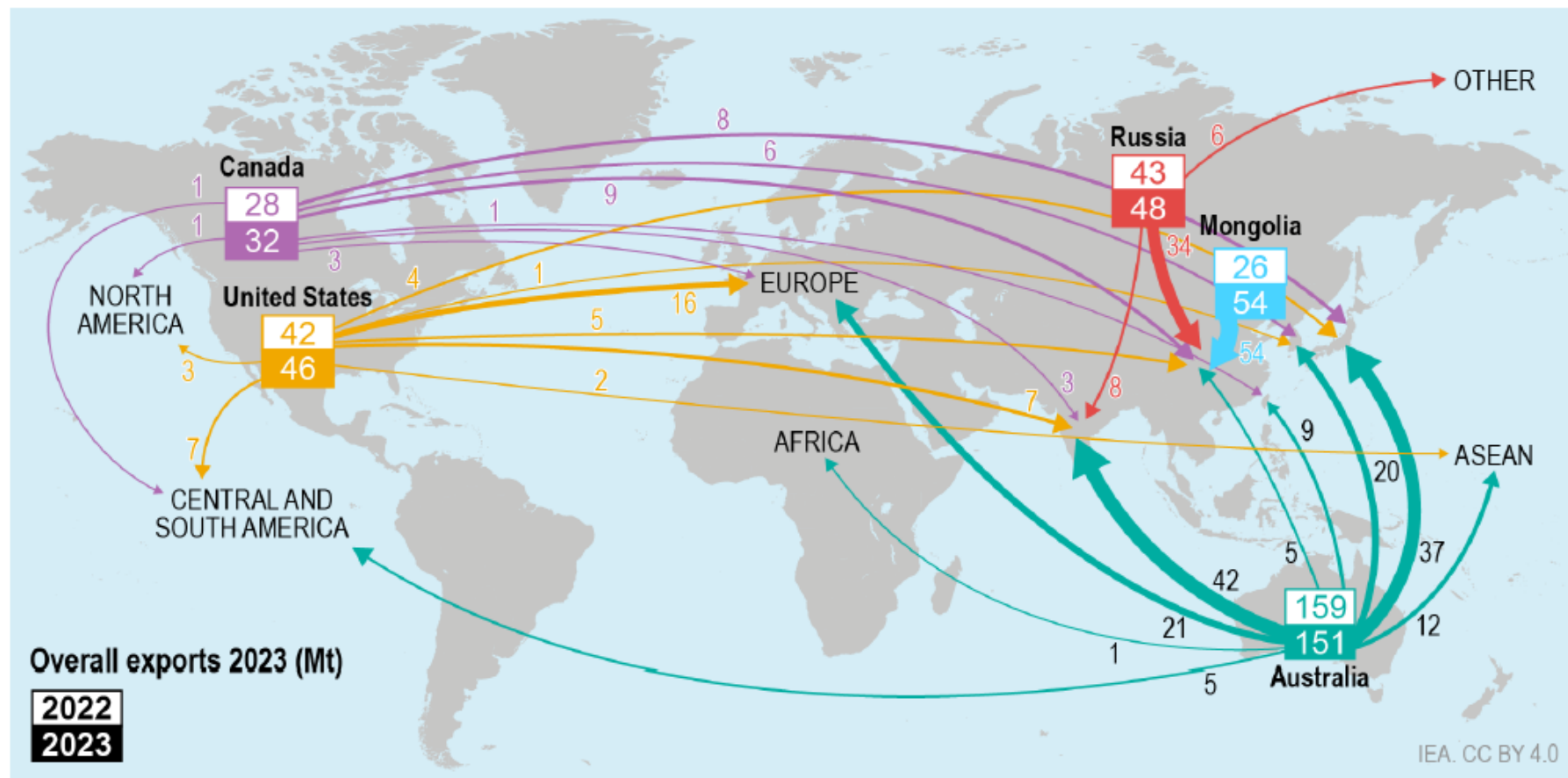
Nota: Thermal Coal is a part of Hard Coal



Met Coal Trade around the World 2023 (Mt)

Australia dominates Met Coal Trade

Main trade flows in the met coal market, 2023 (Mt)



Note: Map values are based on available export data and do not necessarily match import numbers due to reporting times.

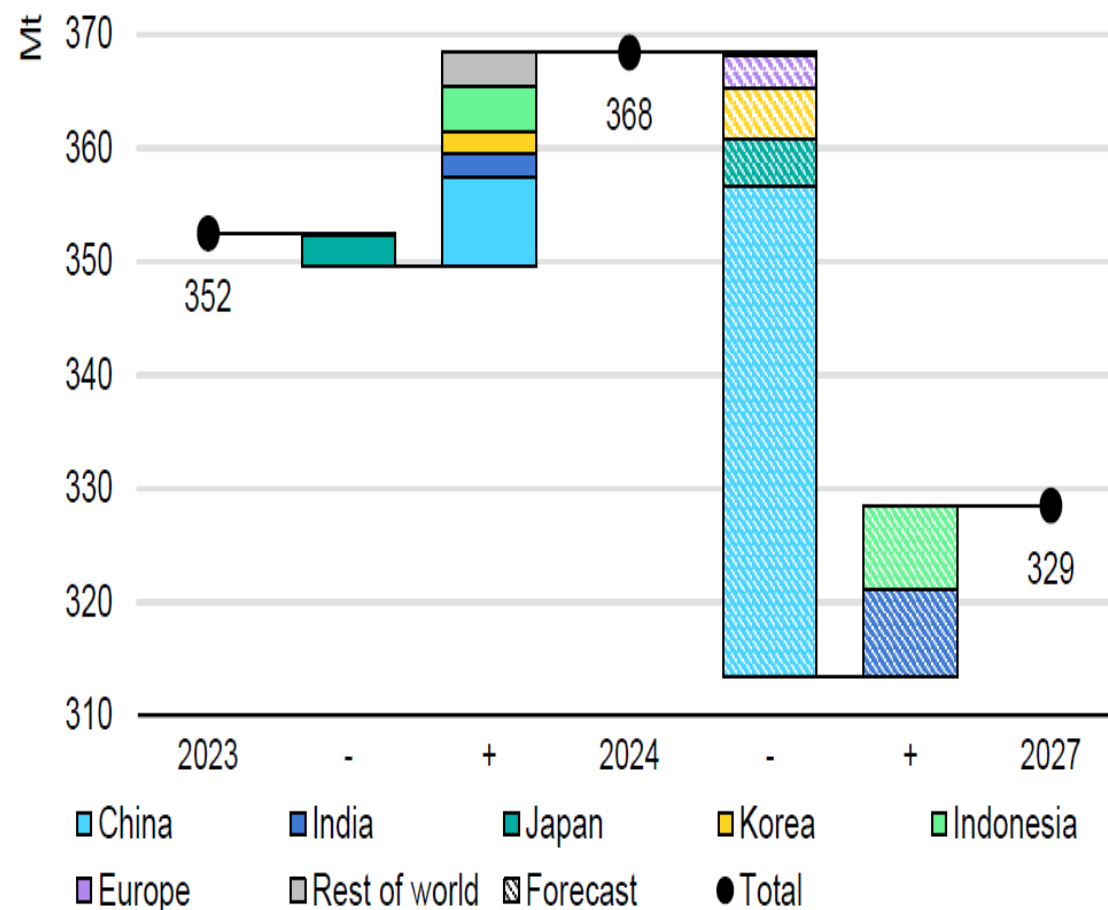
Source: IEA Coal 2024

Nota: Metallurgical Coal (or Coking Coal) is a part of Hard Coal 87

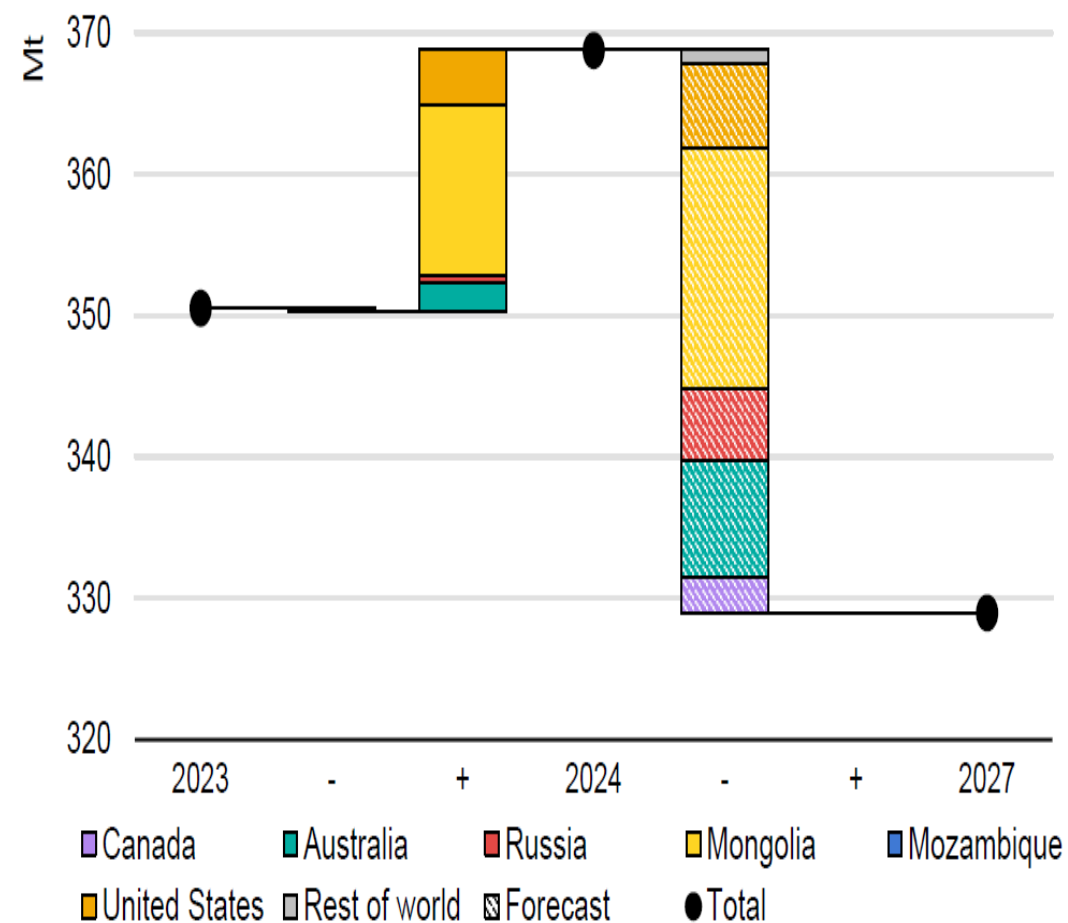
TPA Toolbox Energy Book 9 – Coal

Met Coal Trade around the World 2023 - 2027 (Mt)

Change in met coal imports, 2023-2027



Change in met coal exports, 2023-2027



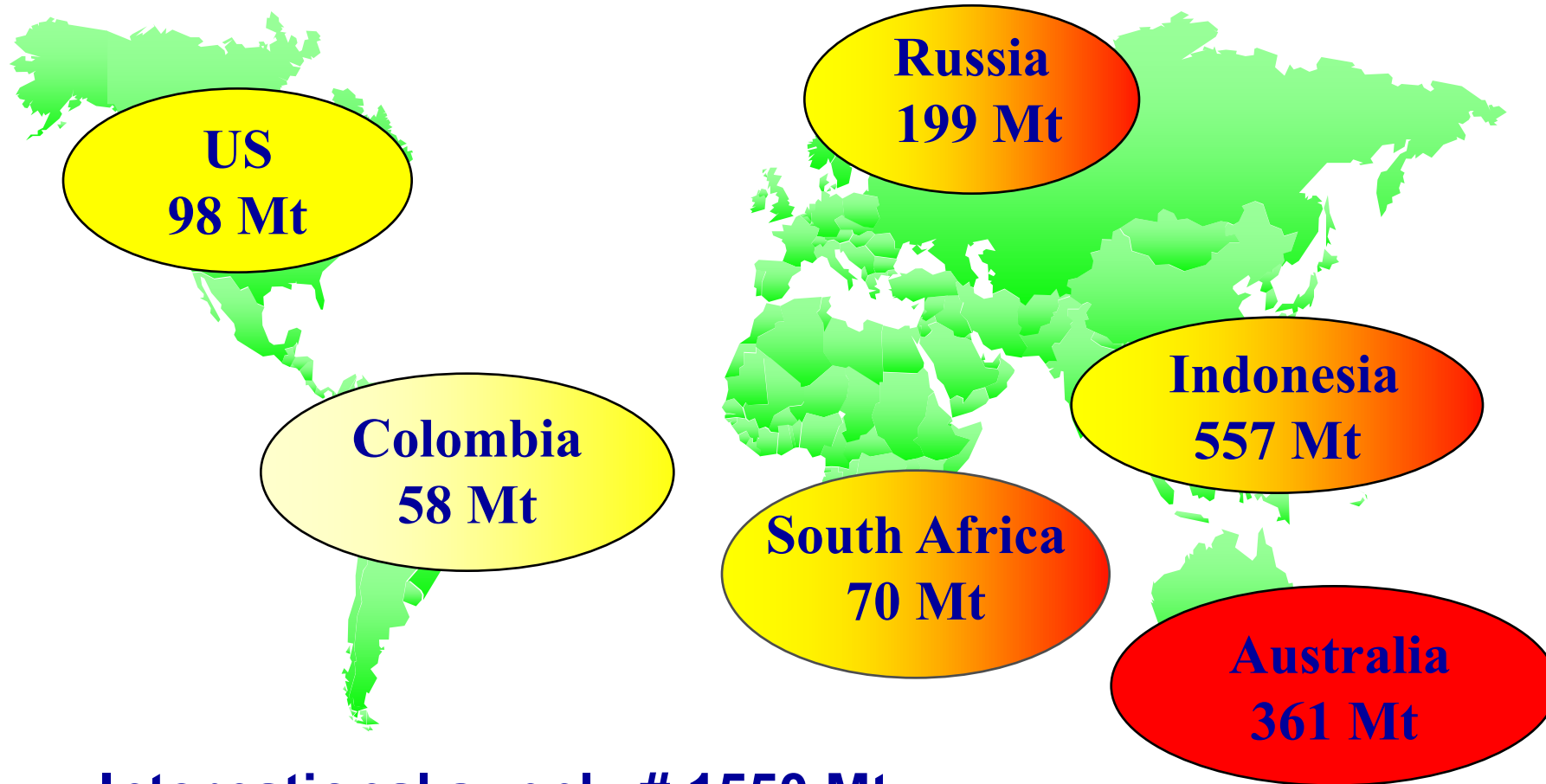
Source: IEA Coal 2024

Nota: Thermal Coal is a part of Hard Coal



International Hard Coal net exports 2024

Hard Coal includes Steam & Coking Coal

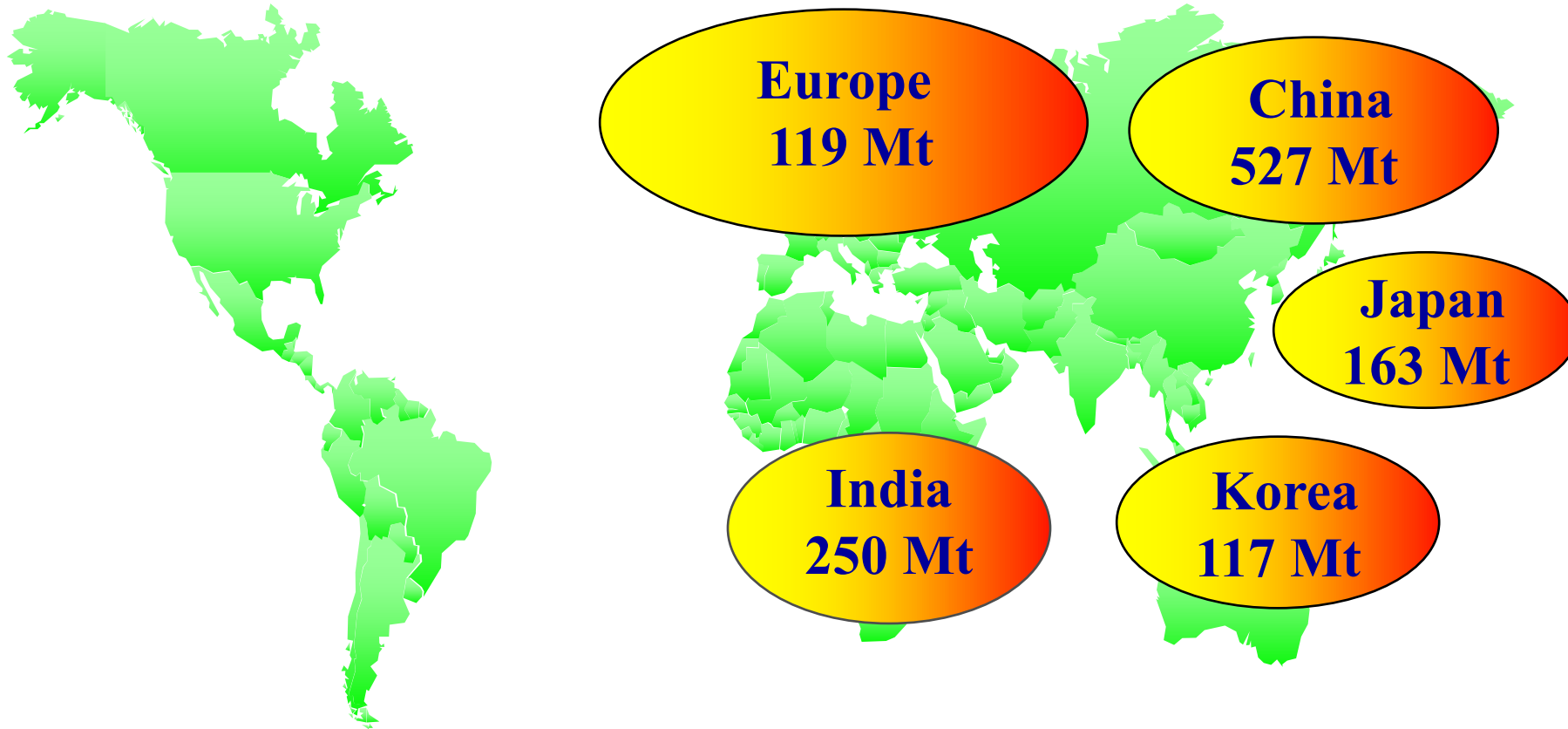


International supply # 1550 Mt

Not including intra-regional trade

International Hard Coal net imports 2024

Hard Coal includes Steam & Coking Coal



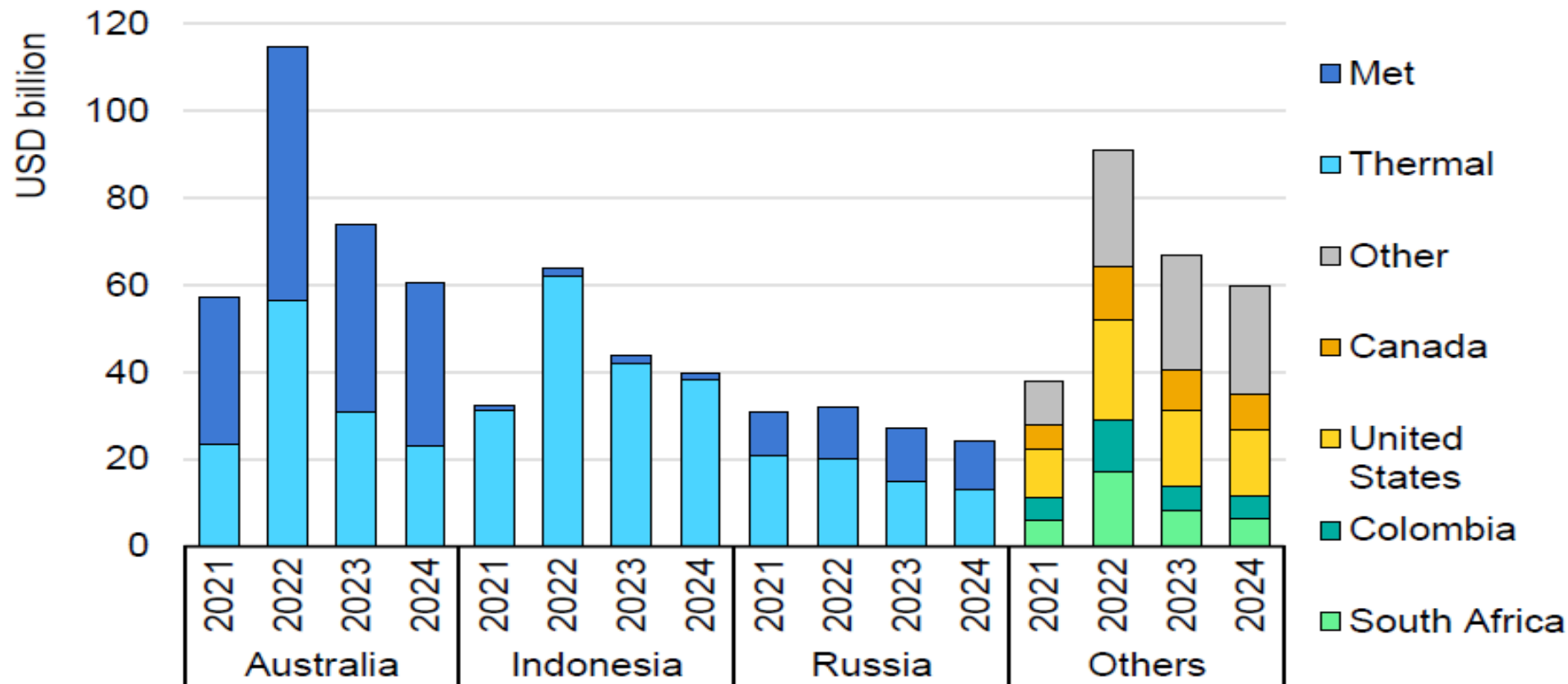
International supply # 1550 Mt

Not including intra-regional trade



Coal Export Revenues – Evolution from 2021 to 2024

Coal export revenue, select countries, 2021-2024



IEA. CC BY 4.0.

Notes: Revenue for Australia, Indonesia and Russia calculated using weighted average realised prices (FOB). Realised prices for 2024 are based on data to June 2024. Canadian realised prices based on US realised prices. Revenues include land-based trade assuming the same realised prices as FOB.

Source: IEA analysis based on CRU (2024).



What will be the main drivers of the imports growth in the future?

Coal Demand evolution greatly depends on Countries strategies

Impact of Climate issues: a drastic limitation of Coal Use is foreseen

◆ In the Atlantic zone :

- ❑ Replacement of ongoing decline of European production of coal. German coal still important in connection with the decline of nuclear production.
- ❑ An evolving US market on coastal area due to environment constraints (low sulfur) and improved ports capacity for imports. The new US administration favors coal industry....US is a net exporter of Coal. Although the US is producing most of that it consumes, it imports Coal to meet some domestic demand (optimization of supply costs)
- ❑ The growth of Shale gas production in the US leads to overcapacity of coal production, coal exports at low prices will continue.

◆ In the Pacific zone :

- ❑ a growth forecasted in electricity coal fired generating capacity located mainly in emerging countries such as :
 - ❑ China : has become a net importer . Imports will stabilize and decline.
 - ❑ India : huge potential for imports (340 Mtce in 2040? + 88% vs 2014)
 - ❑ Malaysia : policy in favour of coal imports and more gas exports
 - ❑ Australia: coal for domestic market, increase of coal exports and LNG exports.
- ❑ Continuous imports in mature countries such as Japan and South Korea



Markets & Freight



Coal Seller/Buyer Agreements – Main clauses

Main Contractual Terms:

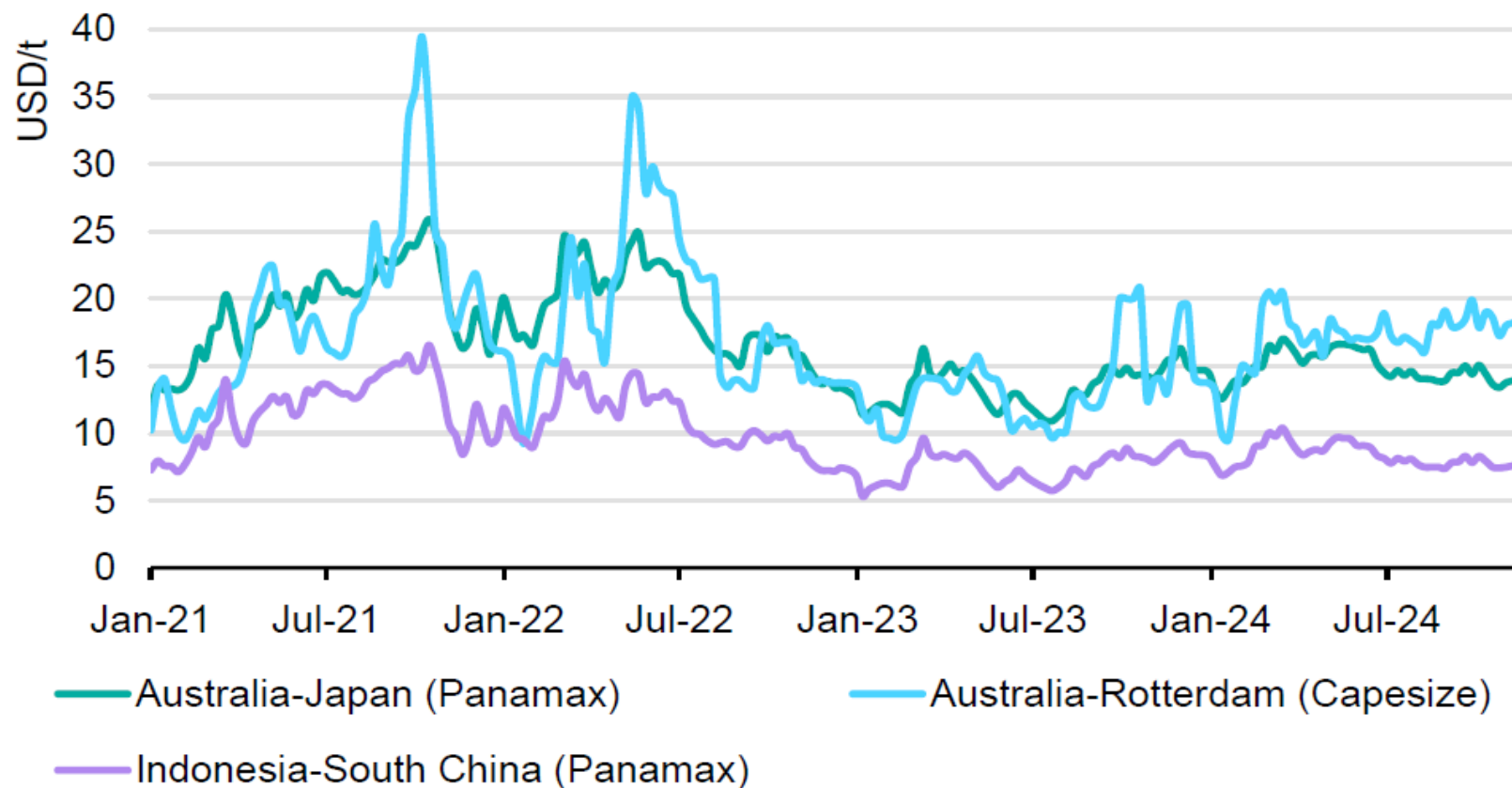
- **Price:** US\$/t - FOB / CIF (Freight & Insurance Inclusive)
- **Mine Origin:**
- **Coal Specifications**

CV: Net or Gross	23 MJ- 5500 kcal/kg
Humidity: AD/AR	Max 3-5%
Sulfur	Max %
Ash	Max %
VM	Min-Max %
Ash Fusion/AFT	Mini 1150 DC
- **Price Adjustment:** pro rata CV – Humidity...
- **Penalty:** Over limit: sulfur-ashes...%
- **Rejection:** Sulfur- above threshold ...
- **Litigation:** Experts- International court
- **Analysis:** Independent laboratory / Loading Port.....



Coal Market & Freight Rates on selected routes 2021 - 2024

Freight rates on select routes, 2021-2024



IEA. CC BY 4.0.

Source: IEA analysis based on Argus Media Group (all rights reserved).

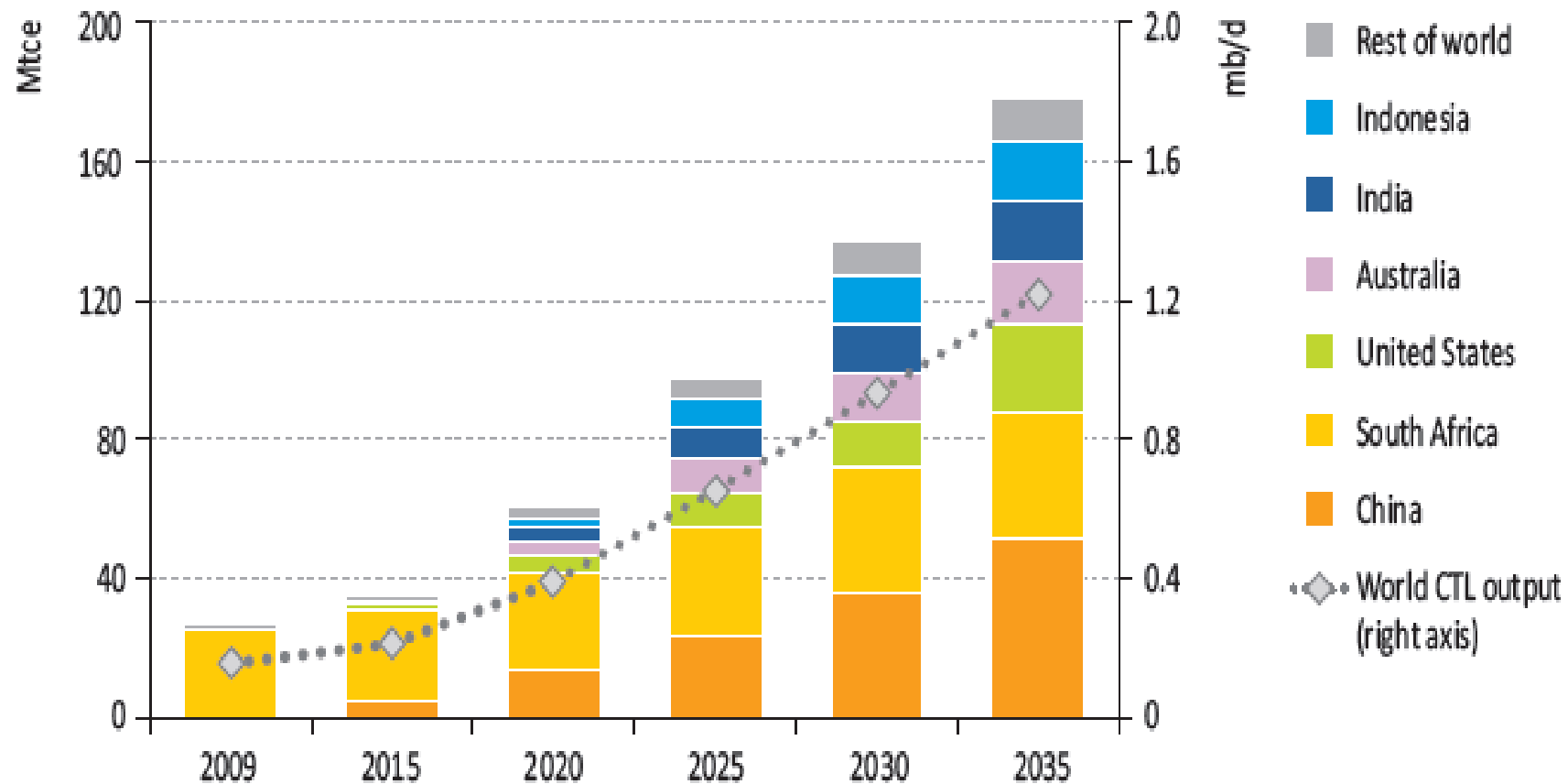
Source: IEA Coal 2024



Coal to Liquids (CtL)



p.m. Coal to Liquids (CTL) inputs and outputs (IEA Central Scenario Vision 2011)



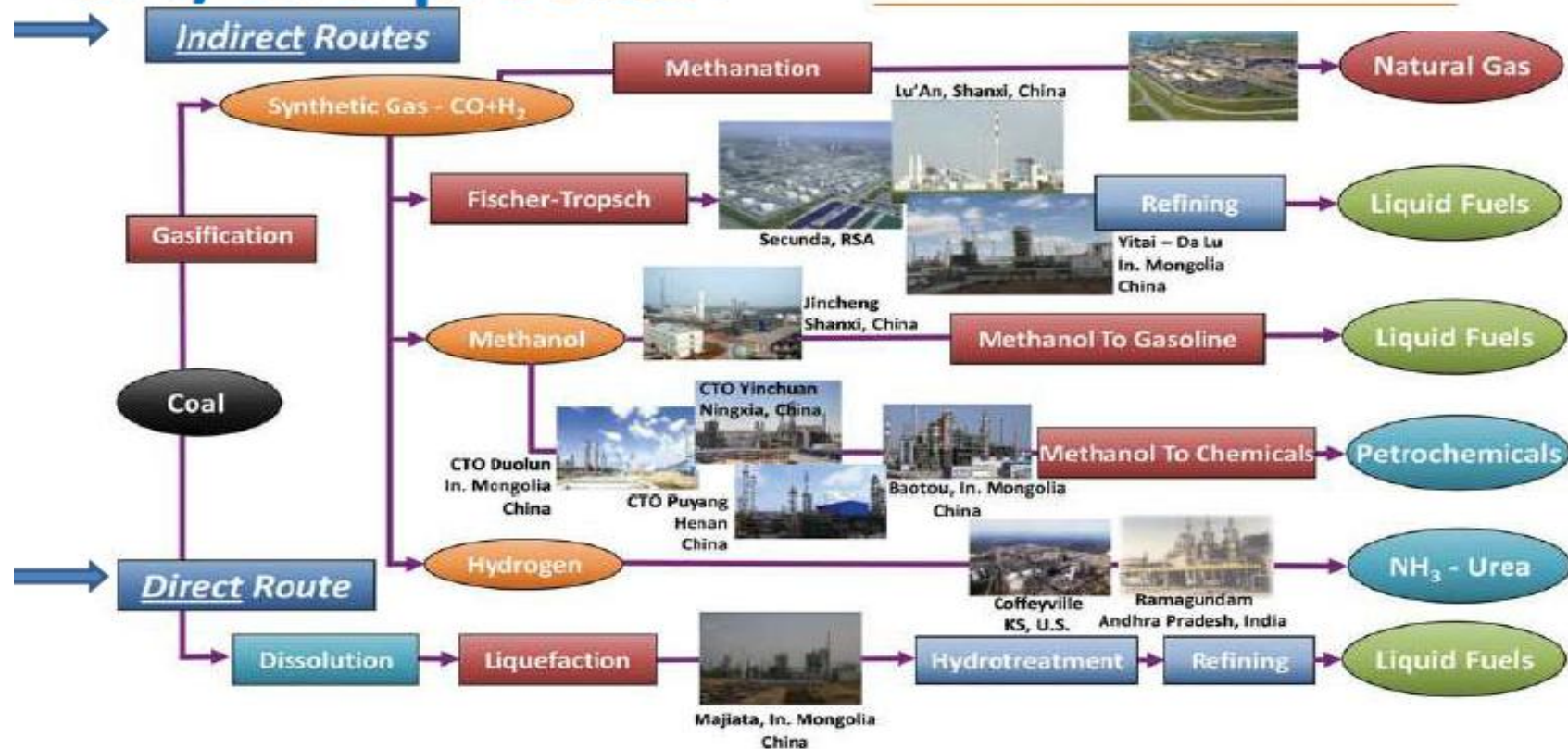
Source: IEA 2011 World Energy Outlook



Coal to Liquids Processes

Coal to liquid CTL/CTO process:

"The increase in the price of crude oil at the beginning of the 21st century generated new interest in CTL, particularly in China and the U.S."



Coal to Liquids Processes

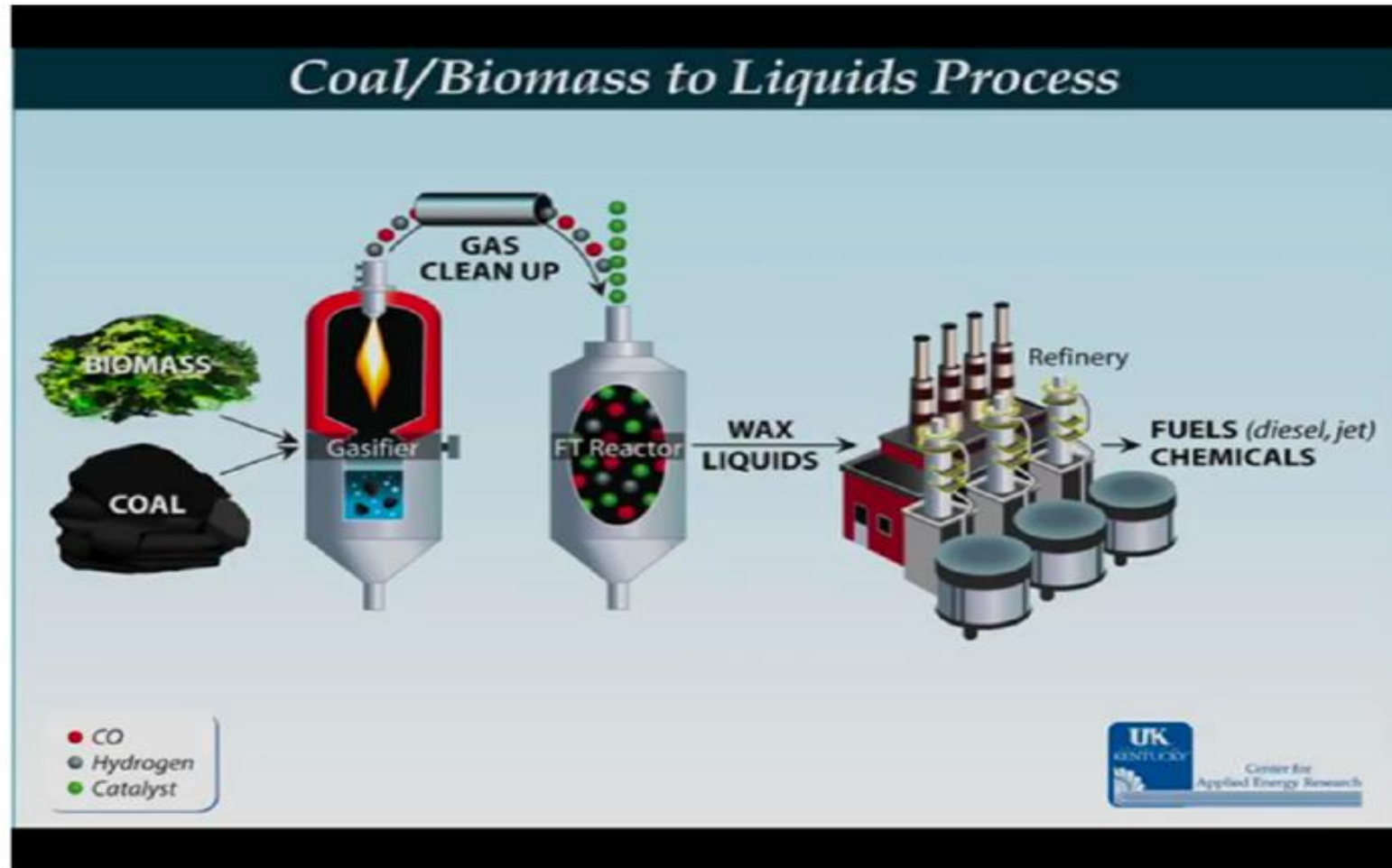


Photo courtesy of the University of Kentucky Center for Applied Energy Research



Coal to Liquids Pathway Many Challenges

Barriers to Coal-To-Liquids

- Technical
 - Integrated operations of advanced CTL technologies have never been demonstrated
- Economic
 - Uncertainties about future world oil production
 - High capital and operations costs
 - Investment risks
 - Energy price volatility
- Environmental
 - CO₂ and criteria pollutant emissions
 - Expansion of coal production and requisite infrastructure (railroads, railcars, etc.)
 - Water use
- Commercial Deployment
 - Competition for critical process equipment, engineering, and skilled labor
 - Who would take the lead in commercial deployment? Part power part liquid fuels
- Social
 - NIMBY and public resistance to coal use



A zoom on China



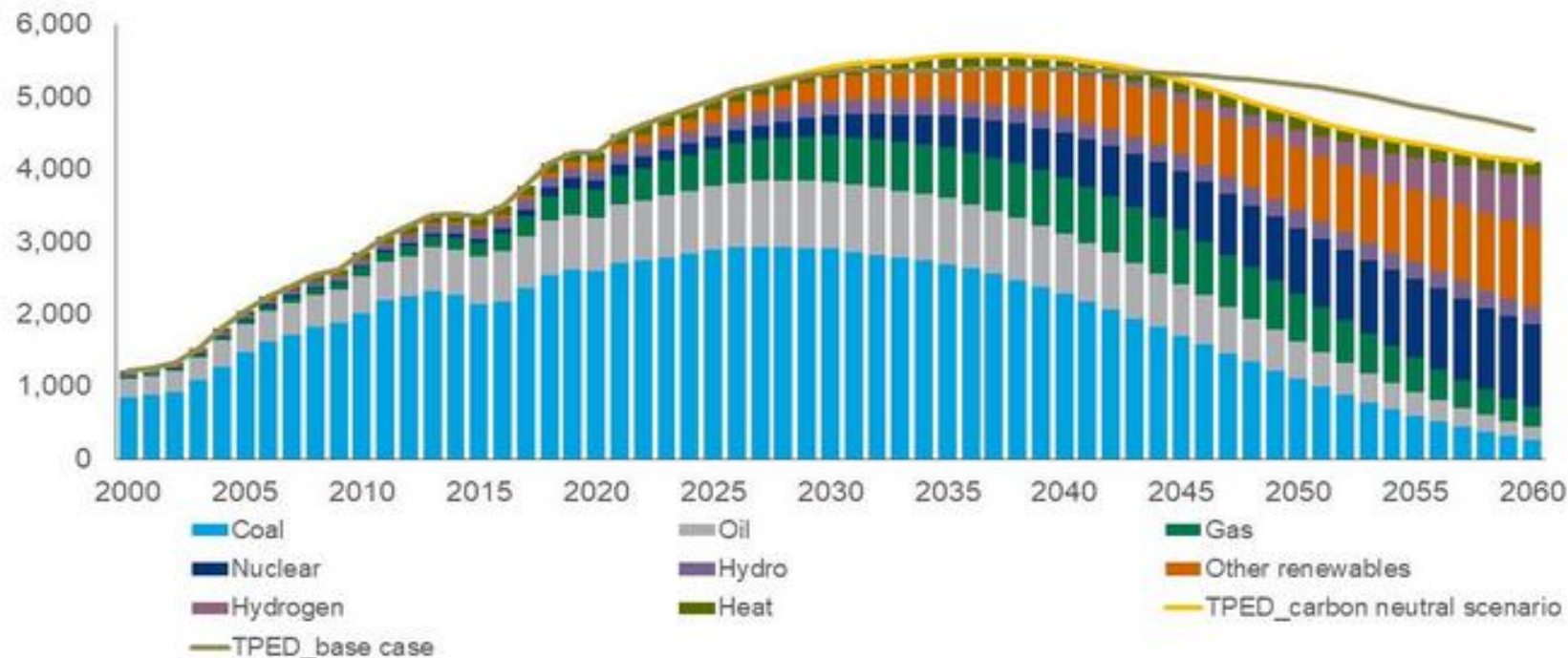
Primary Energy Demand in China – A view by Woodmac

Coal will grow till 2030 – Increase of Nuclear and Renewables

woodmac.com



China total primary energy demand (Mtce*) – a growing role for nuclear



Source: Wood Mackenzie. *Mtce = million tonnes of coal equivalent

1

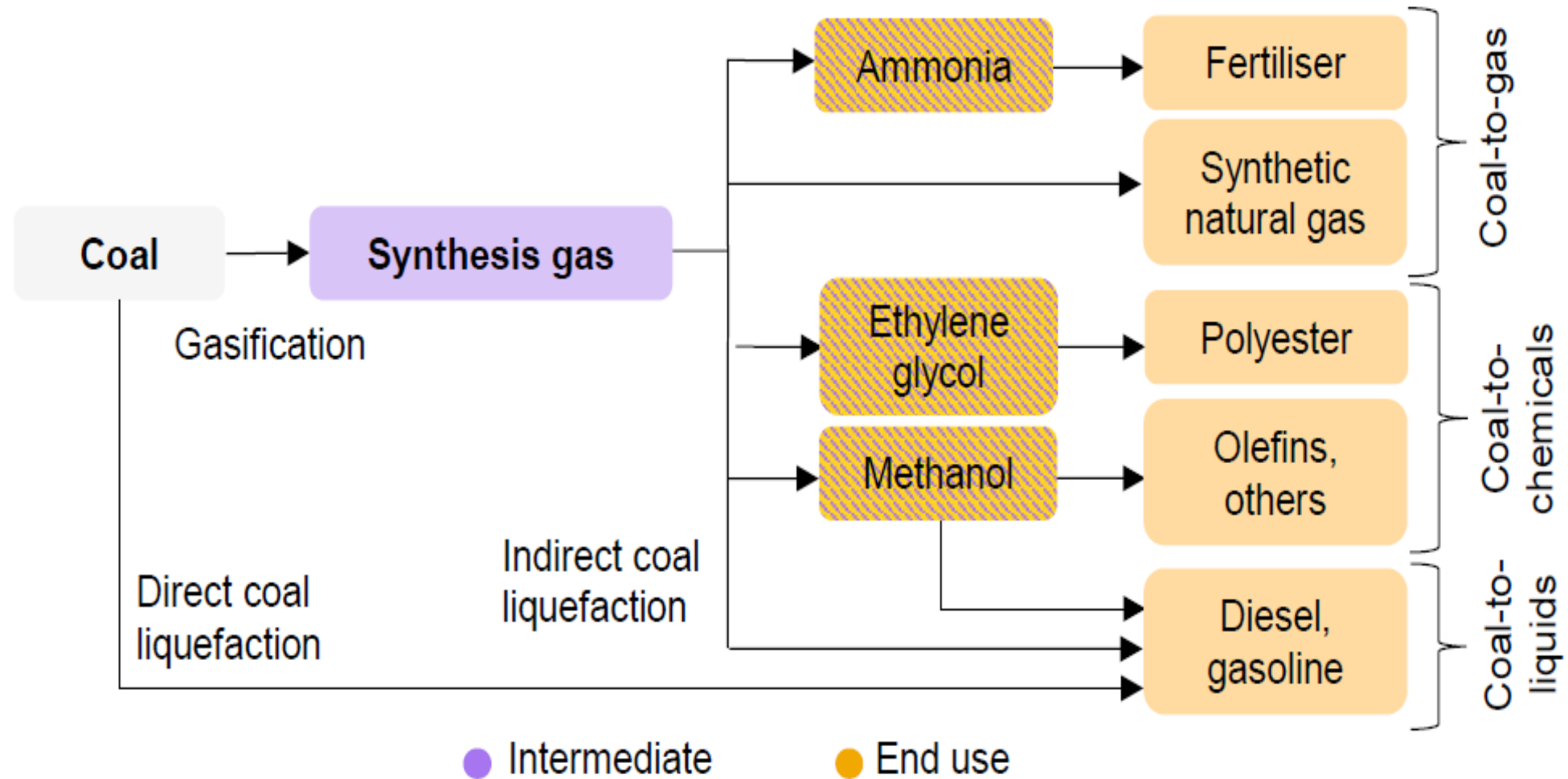
China's nuclear buildout (dark blue) grows exponentially between now and 2060. Pic: Wood Mac

Source: Woodmac

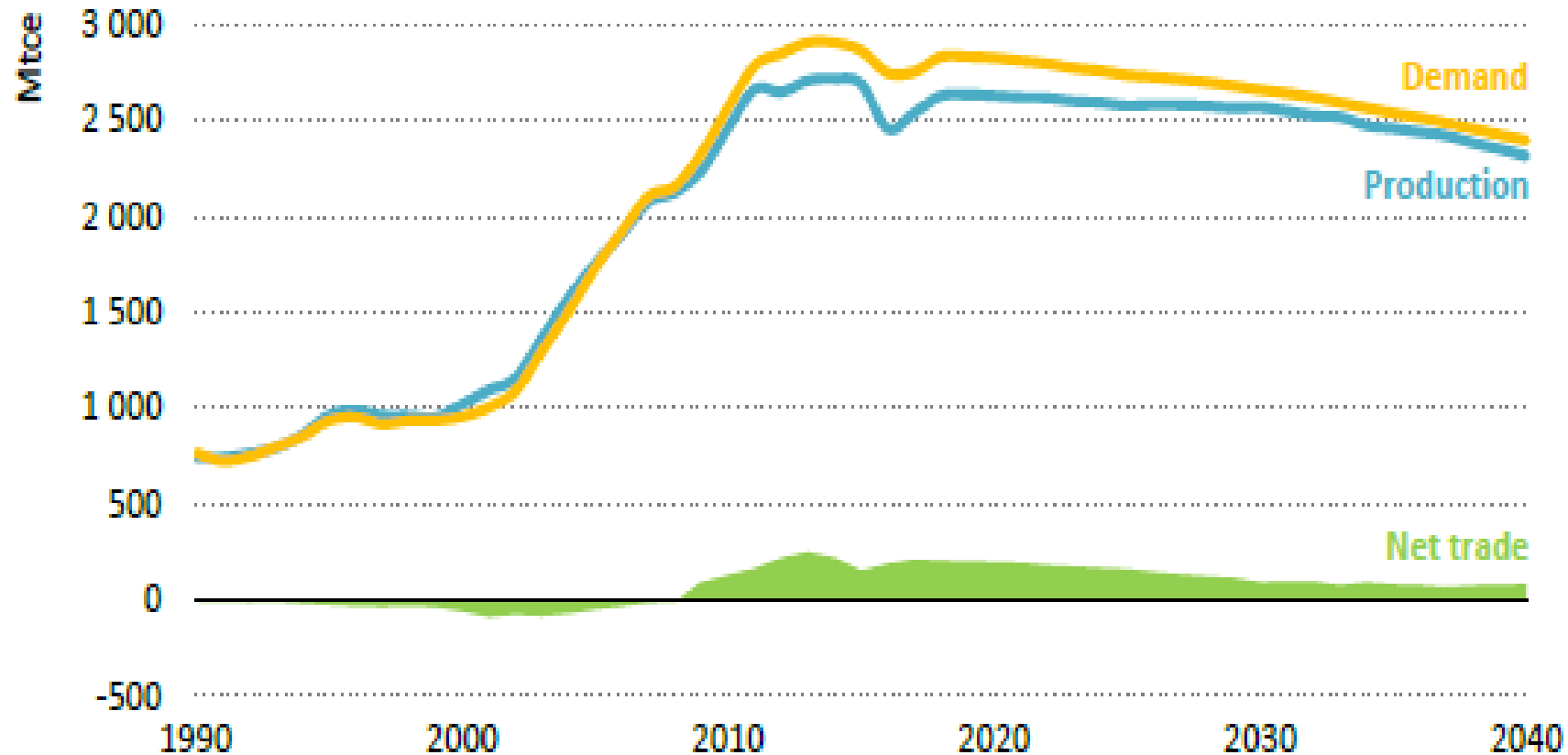


Coal conversion processes in China

Key process routes of the coal conversion sector in China



Reminder: Chinese Coal Demand Perspectives (Mtce) IEA 2018 Central Scenario



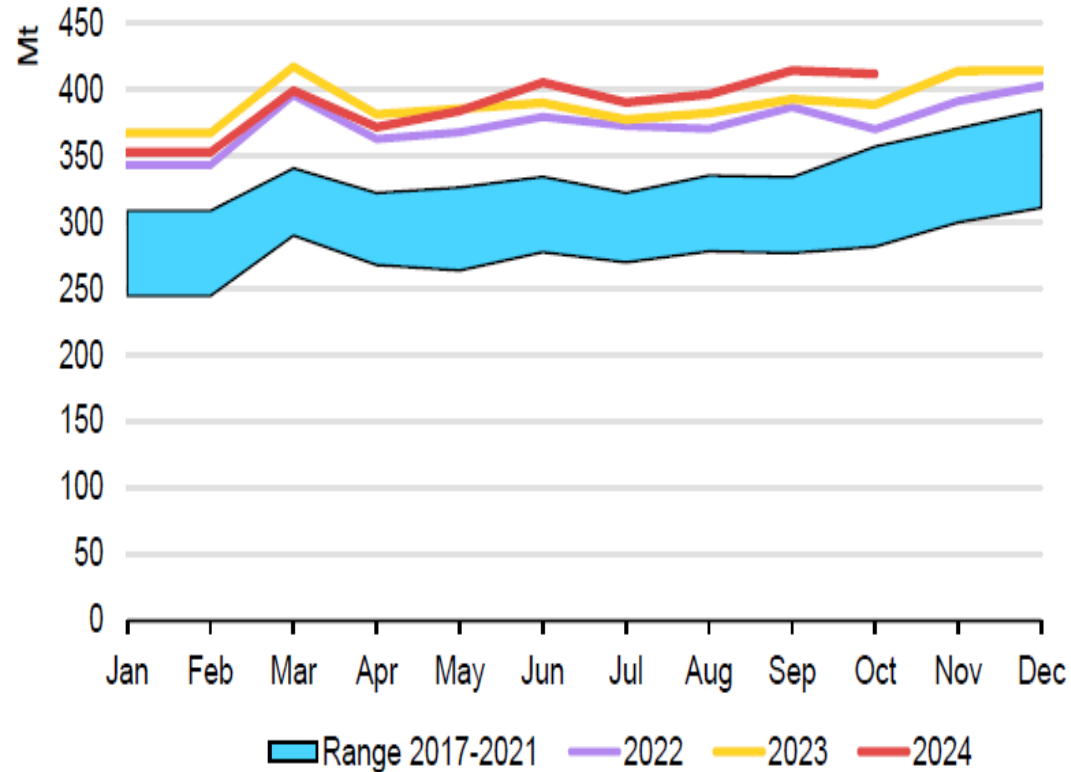
China's trade position is the balance between two very large numbers for production and demand: a relatively small shift in either could have large implications for trade



Chinese monthly Coal Production 2017 – 2024

350 – 400 Mt per month in 2024 # 4,5 Gt for the year

Coal production by month in China, 2017-2024



IEA. CC BY 4.0

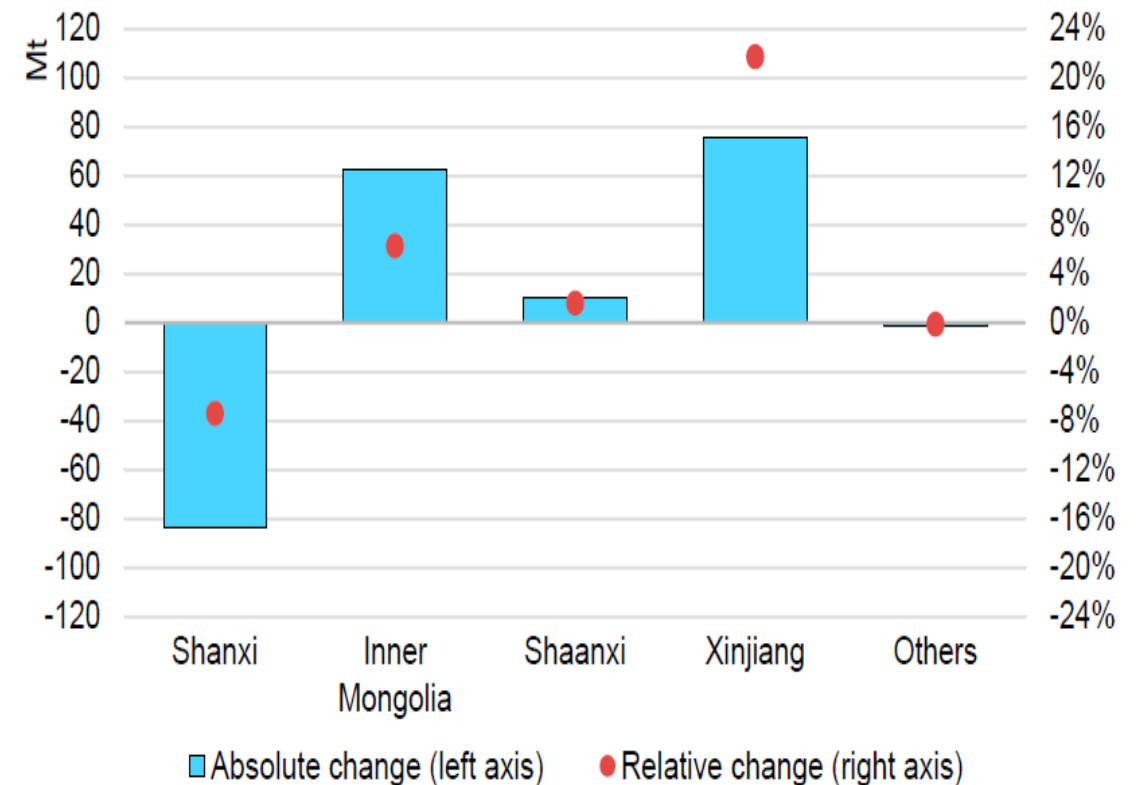
Note: January and February based on cumulated data from February.

Source: IEA analysis based on National Bureau of Statistics of China (2024), [Statistical Database](#).

Source: IEA Coal 2024

105

Year-on-year change in coal production by region of China, January to October, 2023-2024

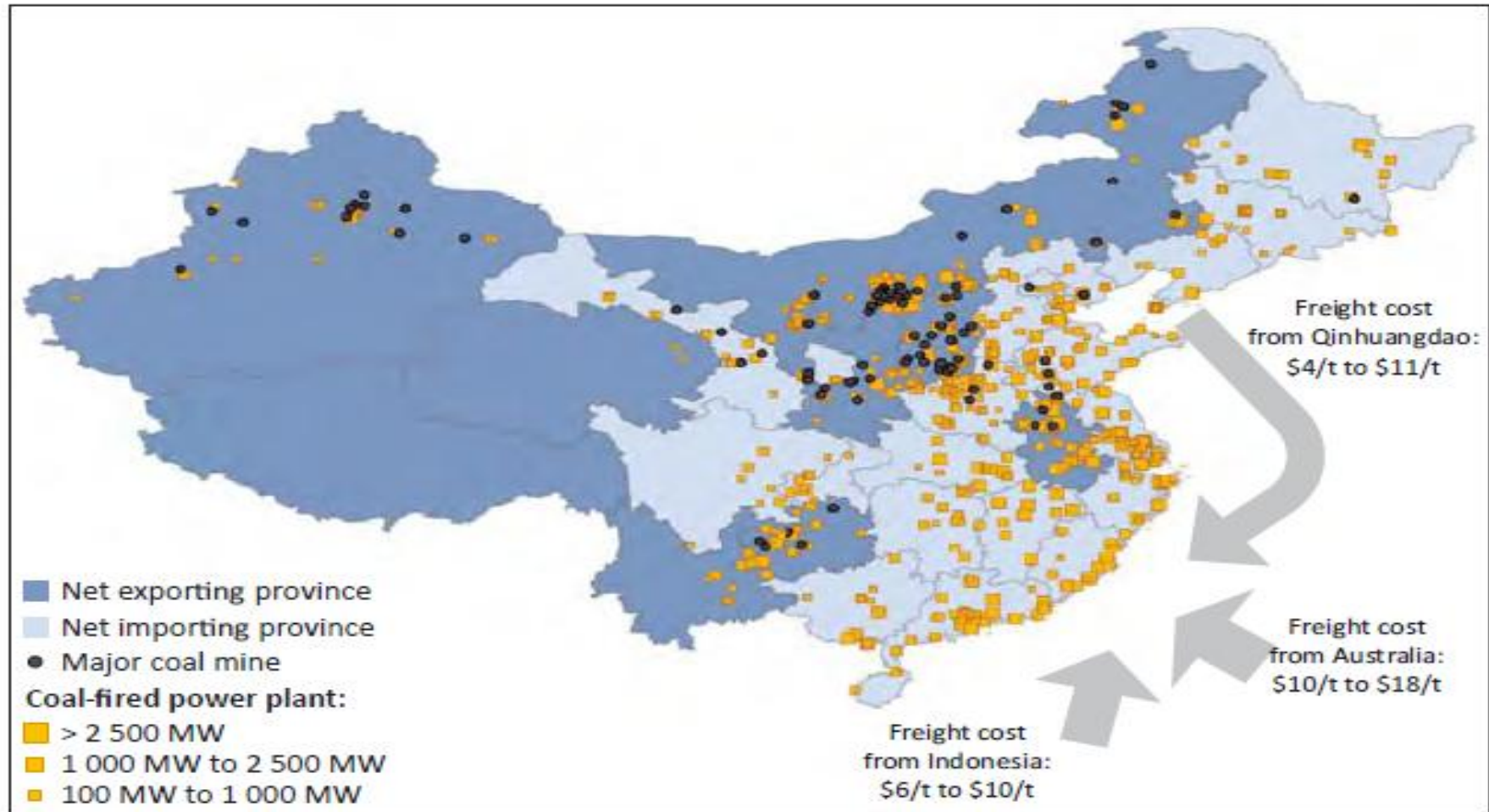


IEA. CC BY 4.0.

Source: IEA analysis based on National Bureau of Statistics of China (2024), [Statistical Database](#).



Major Coal Production centers and Coal-fired power plants in China



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Sources: IEA analysis and Wood Mackenzie databases.

Mongolia is the first Coal supplier of China

Flow of trucks from an extraction mine in the Gobi desert to the Chinese border (130 kms)



Au XXI^e siècle, le charbon étend encore sa suprématie mondiale

Source: Figaro/Rentsendorj
Bazarsukh/Reuters 2019



Daqin Railway to Qinhuangdao Port

Shanxi, Shaanxi, Inner Mongolia... mines
Qinhuangdao port export to **China South
East Coast**

1000 km electrified double track line
Train capacity +/- 20 000 t
Up to 1,5Mt/day

Port throughput
up to 400 Mt ?

1st World Coal port

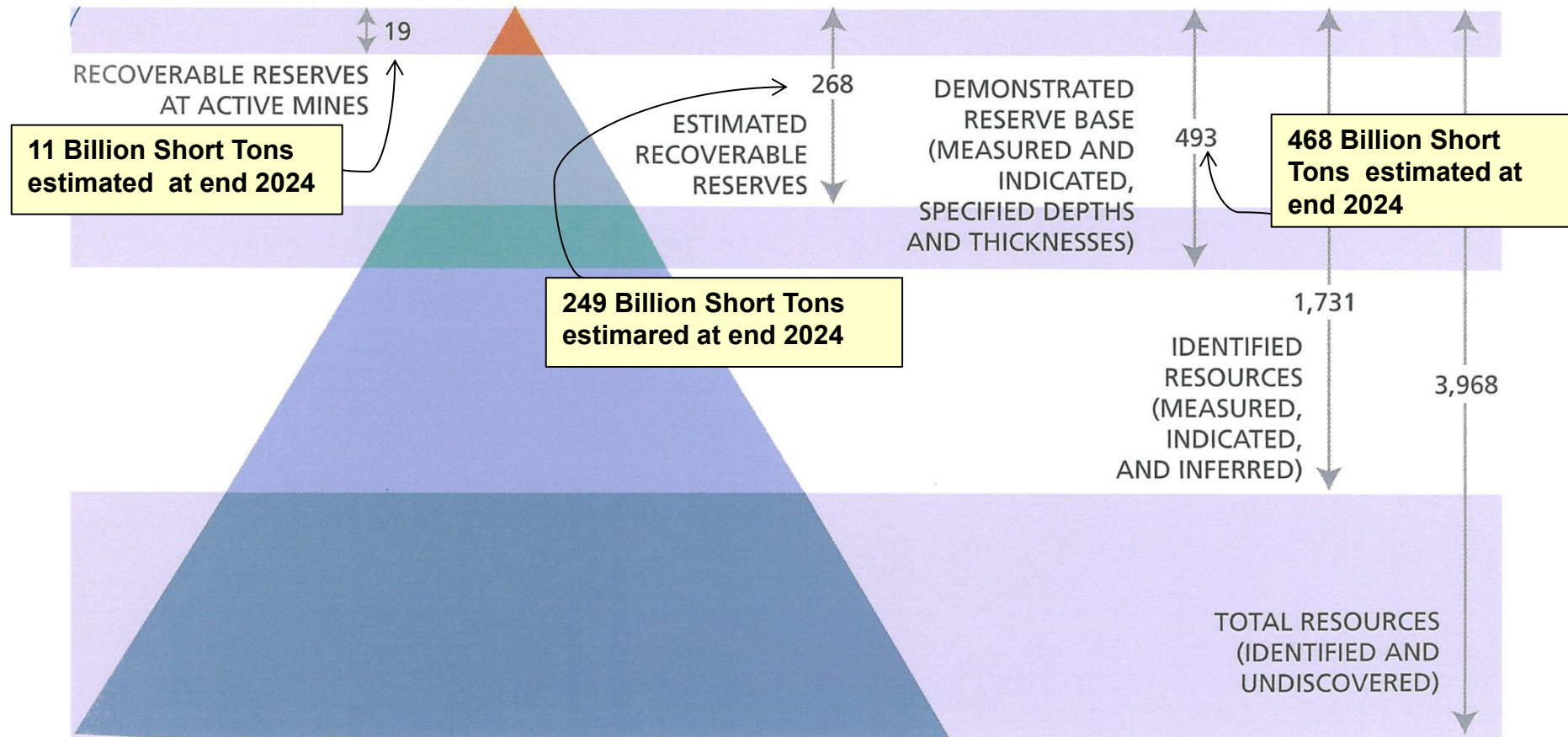


3

Coal and the U.S.



U.S. Coal Resources and Reserves Pyramid (Billion Short Tons) updated at end 2024

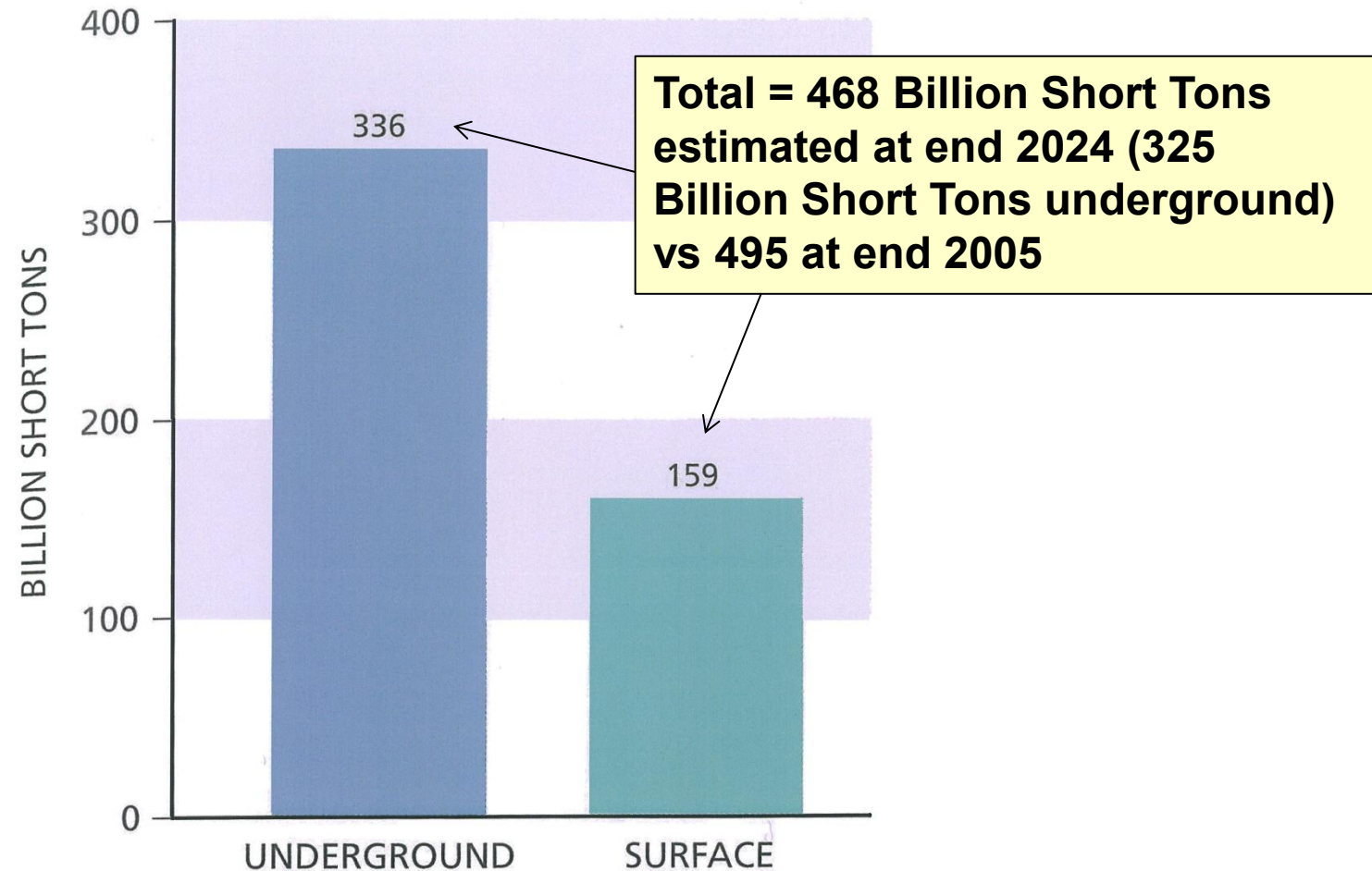


Sources: Energy Information Administration 2004; and United States Geological Survey 1974.

Nota: 1 short ton = 0,907 ton



U.S. Coal Demonstrated Reserves Base (DRB) by Mining Method

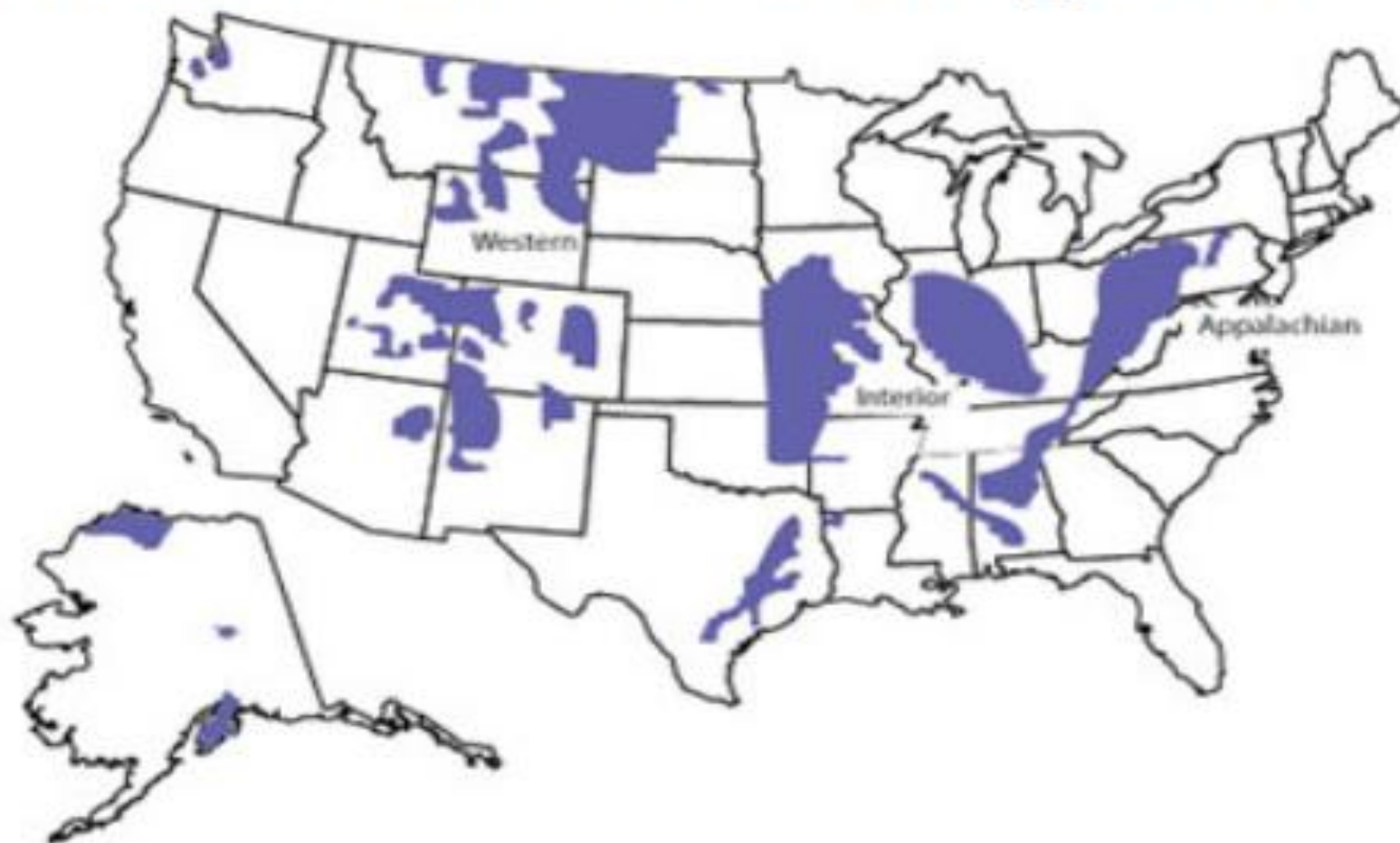


Source: Energy Information Administration,
Annual Energy Review 2005.



US Coal Resource Regions

U.S. Coal Resource Regions



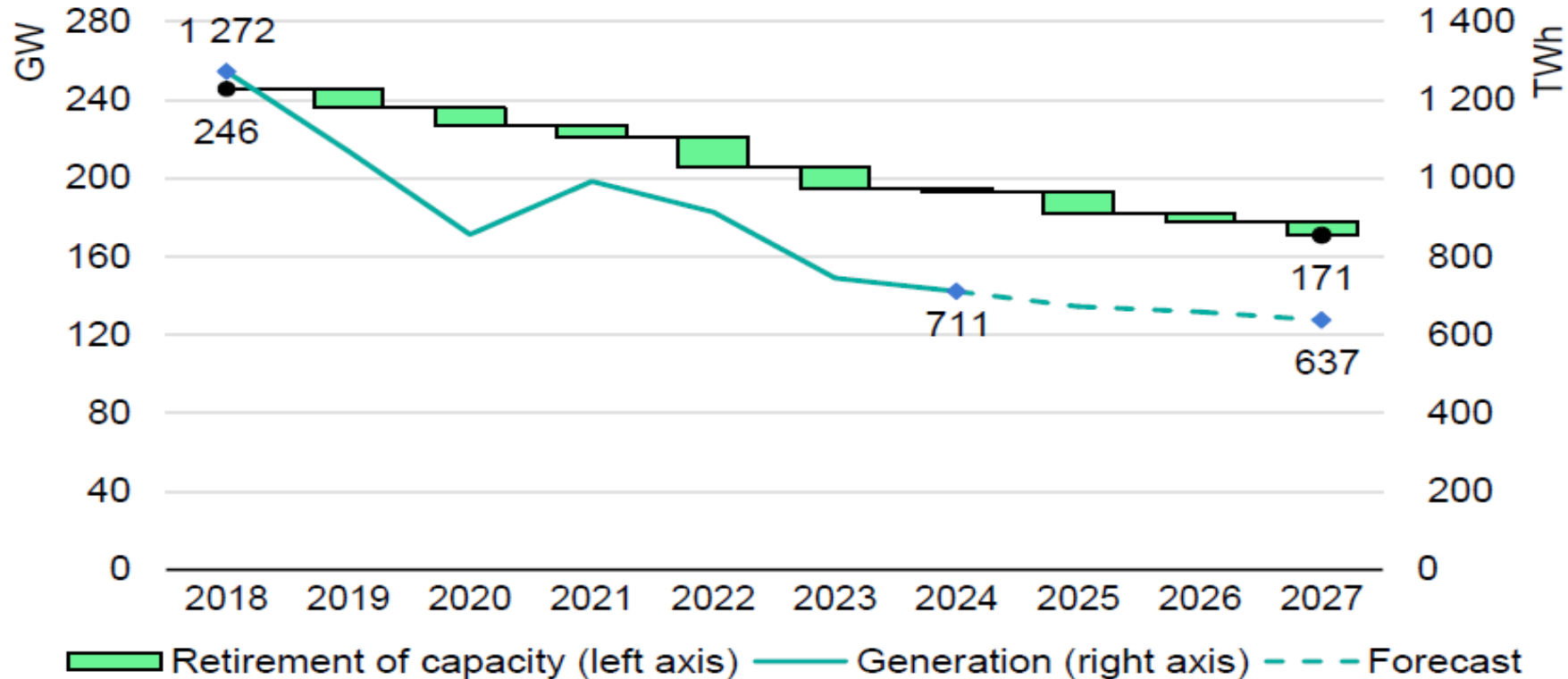
Source: EIA 2025



US Coal-fired Capacity & Generation 2018 – 2027

A regular decrease

Coal-fired capacity and generation, United States, 2018-2027



IEA. CC BY 4.0.

Notes: Capacity values for 2024 to 2027 are based on announced retirements. 2018 aggregated capacity is based on operational capacity in 2023 and retirements and commissions between 2018 and 2023. Retirements after 2023 are planned retirements.

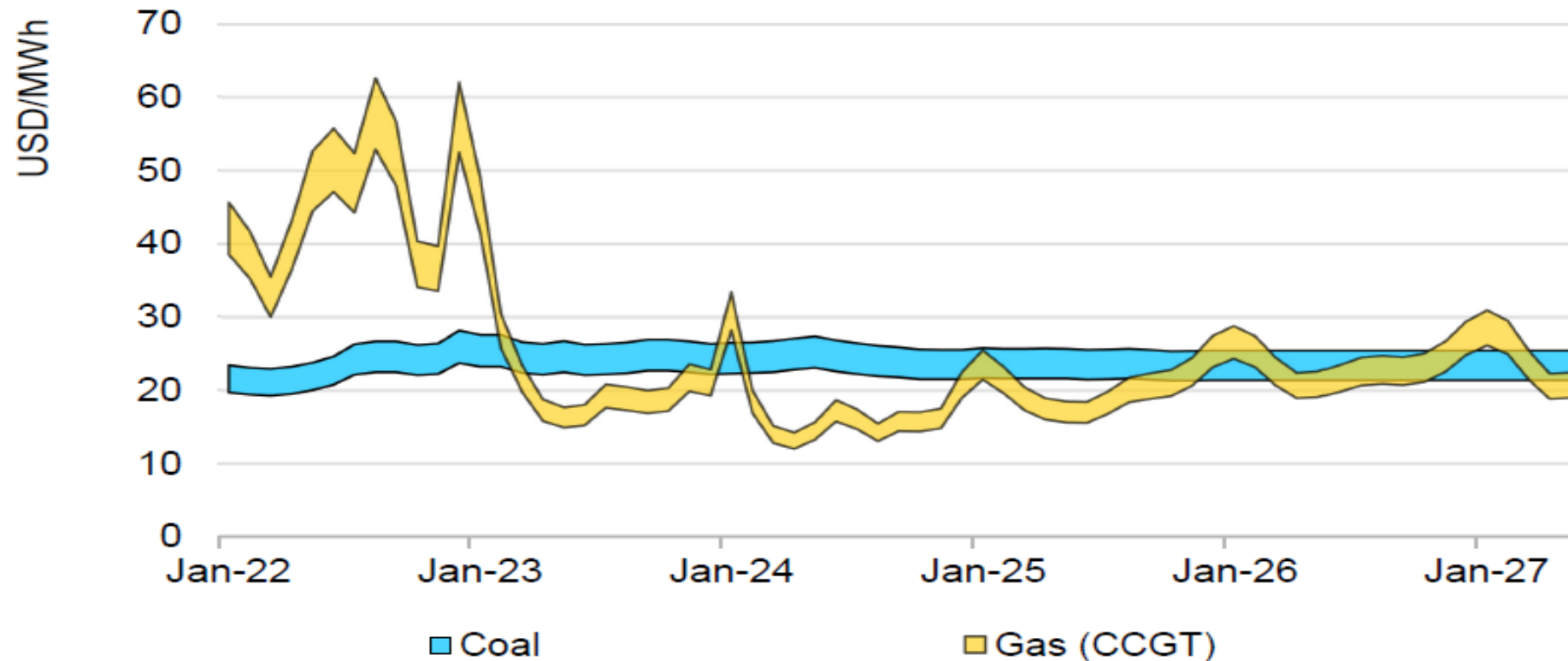
Sources: IEA analysis based on EIA (2024), [Electric Power Monthly](#), EIA (2024), [Coal Data](#) and IEA estimates.



Electricity Generation Costs 2022 – 2027

Coal Costs remain stabilized upon time vs Gas

Electricity generation costs in the United States, 2022-2027



IEA. CC BY 4.0.

Notes: CCGT = combined-cycle gas turbine. CCGT net efficiency = 49-58%. Coal net efficiency = 35-46%.

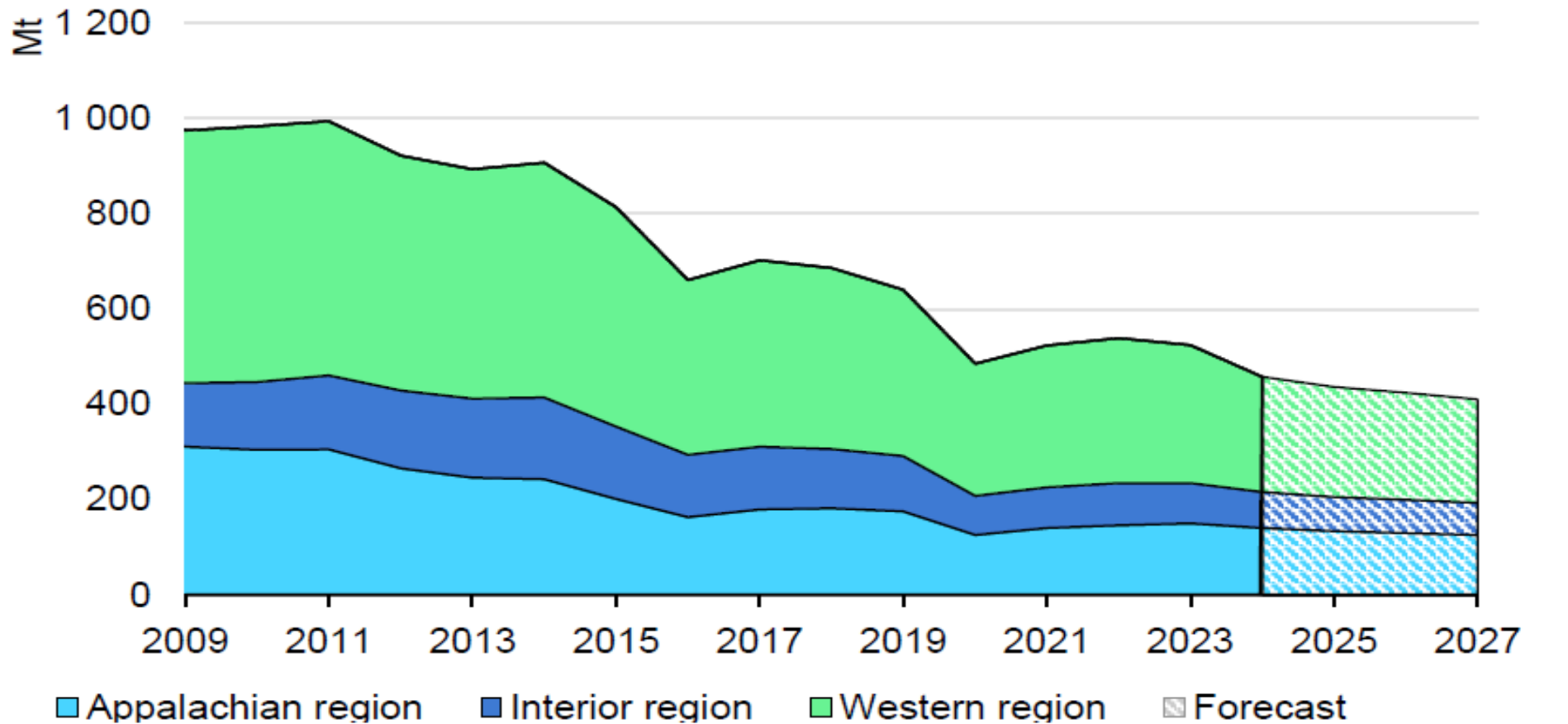
Sources: IEA analysis based on Argus Media group (all rights reserved) and IEA estimates.



US Coal Production by Regions 2009 – 2027

A regular Decrease

Coal production by region, United States, 2009-2027



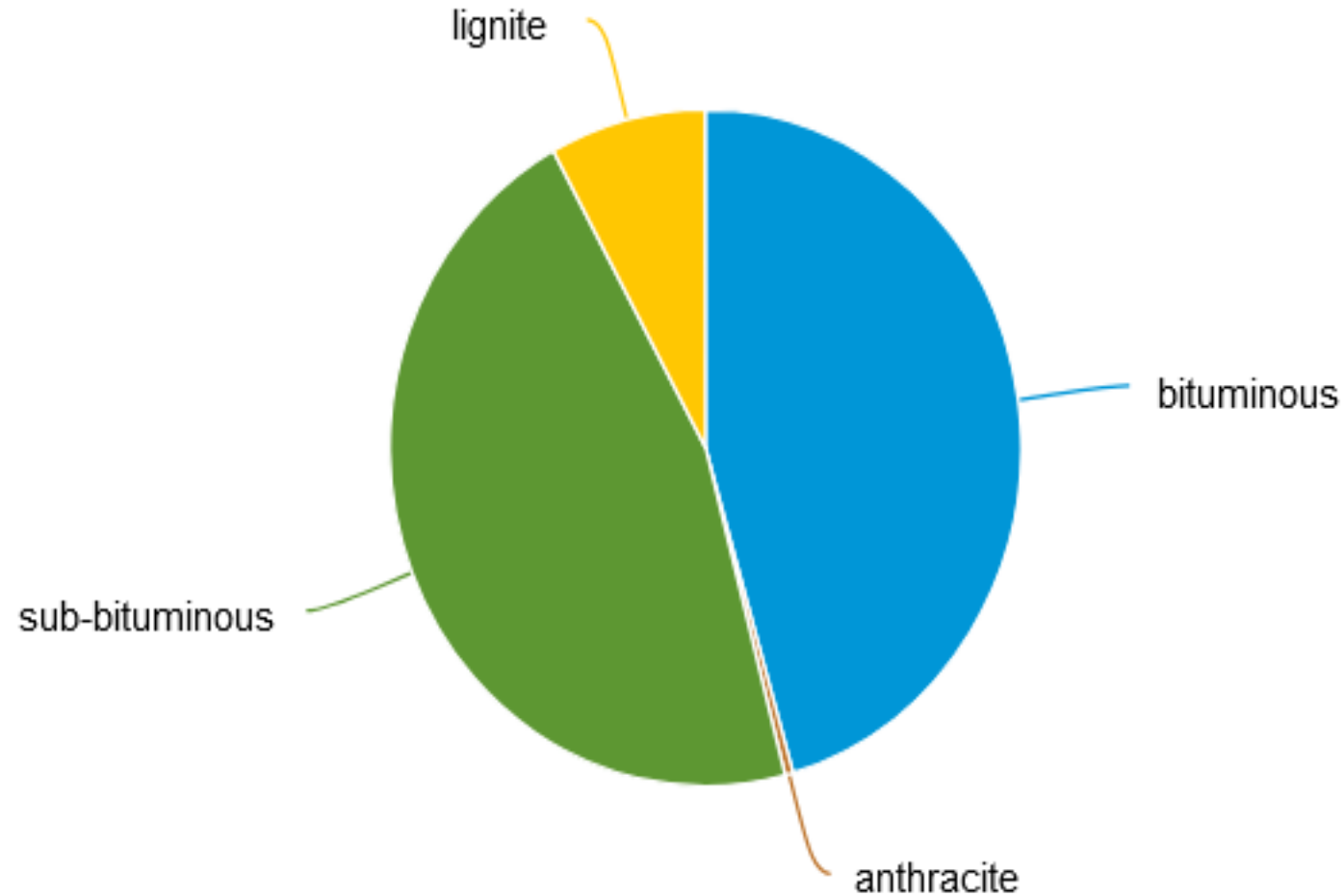
IEA. CC BY 4.0.

Source: Estimates based on US EIA (2024). [Coal data](#).



US Coal Production by quality

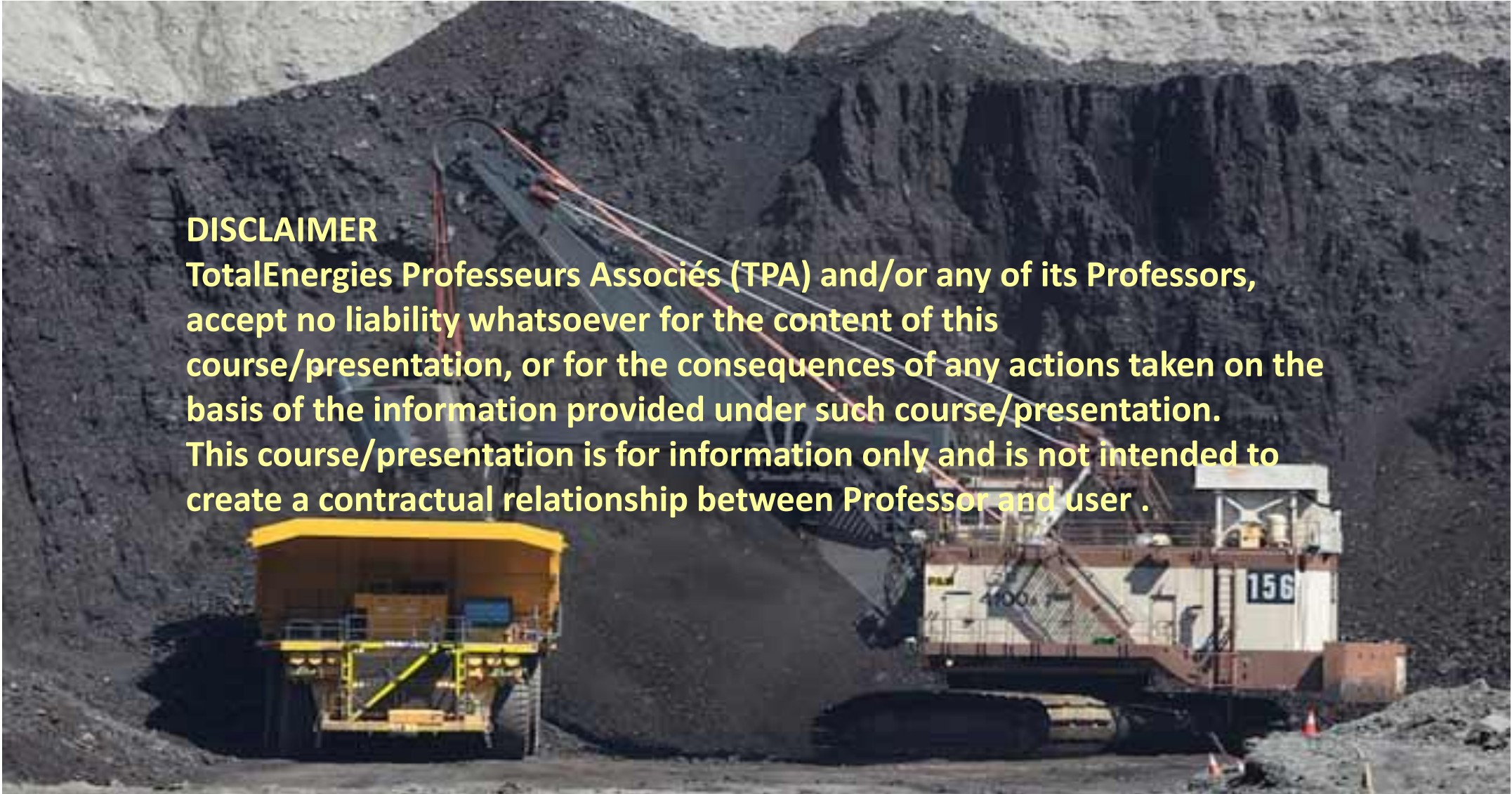
Year 2022 = 594 Millions short tons



Nota: 1 short ton = 0,907 ton

Source: US EIA Annual Coal Report 2023





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