MASTER MANAGEMENT MARCHÉS DE L'ENERGIE - SÉMINAIRE CHARBON

Fondamentaux, passé et perspectives

Hugo DUTERNE – Economiste, membre d'ASPO France

hduterne@outlook.fr

21 janvier 2026

Plan du cours

1- Le charbon dans l’histoire : moteur de la révolution industrielle

2- Géologie du charbon

3- Économie du charbon

4- Perspectives

I. Le charbon dans l'histoire

« Nous devons choisir entre une grandeur brève et une médiocrité continuée plus longtemps. »

William Stanley Jevons, La question charbonnière, 1865

Prolégomènes

Le siècle d’or néerlandais (1600-1700)

Essor économique des pays bas dans un contexte européen récessif, forte urbanisation (>60% de la pop), essor du commerce (1ere flotte mondiale), de la science et des arts

mappemonde de Frederik de Wit, 1662

La Leçon d'anatomie, Rembrandt

Departure of the fleet of Jacob van Neck, 1598 by Hendrick Cornelisz Vroom, 1599

Prolégomènes

Un siècle propulsé par la tourbe

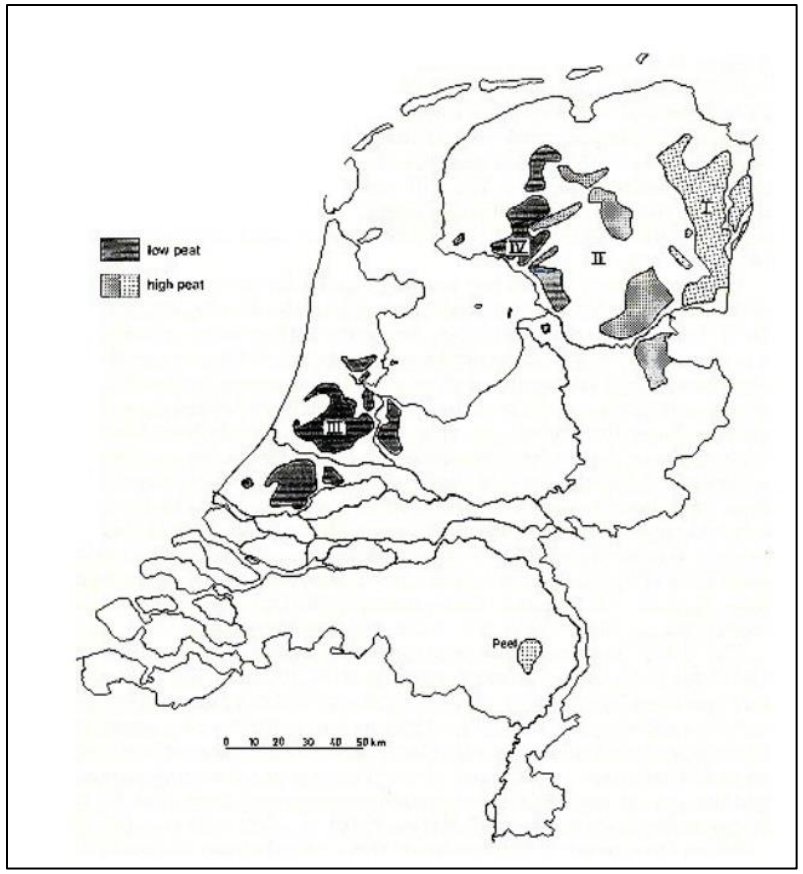


TABLE I. Summary of total estimated rated[1] volumes of peat extracted in the Netherlands.

I	High peat region of Groningen and Eastern Drente	$2.5 \times 10^9 m^3$
II	High peat region ofWestern-Drente, Friesland and Overijssel	$1.0 \times 10^9 m^3$
III	Low peat region of Holland and Utrecht	$2.0 \times 10^9 m^3$
IV	Low peat region of Friesland and Overijssel	$0.7 \times 10^9 m^3$
	The Netherlands	$6.2 \times 10^9 m^3$

Source : J. W. DE ZEEUW,PEAT AND THE DUTCH GOLDEN AGE

Exploitation de la tourbe 1500-1950 dont 2/3 extrait avant 1850

Consommation de 16,5 GJ de tourbe per capita au XVIIe siècle

Prolégomènes

Essor et déclin de la tourbe

Premières techniques d'extraction en surface (1100-1530)

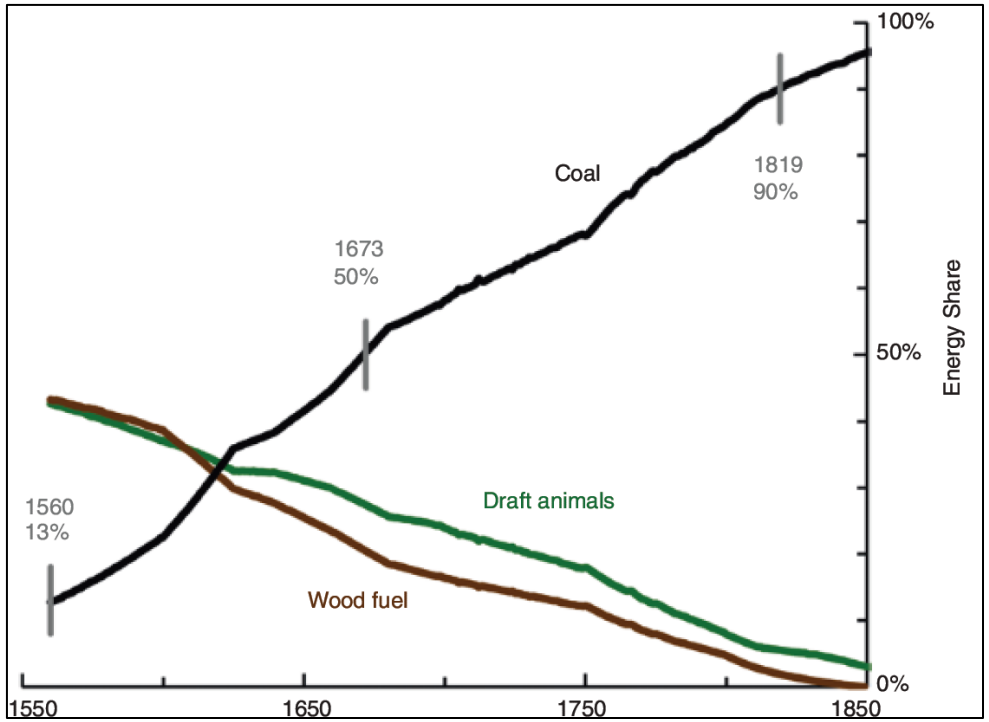
Extraction sous le niveau de la mer avec le « baggerbeugel » 1530-1800

Valorisation des high peat du nord (capital intensif) : 1600-1950

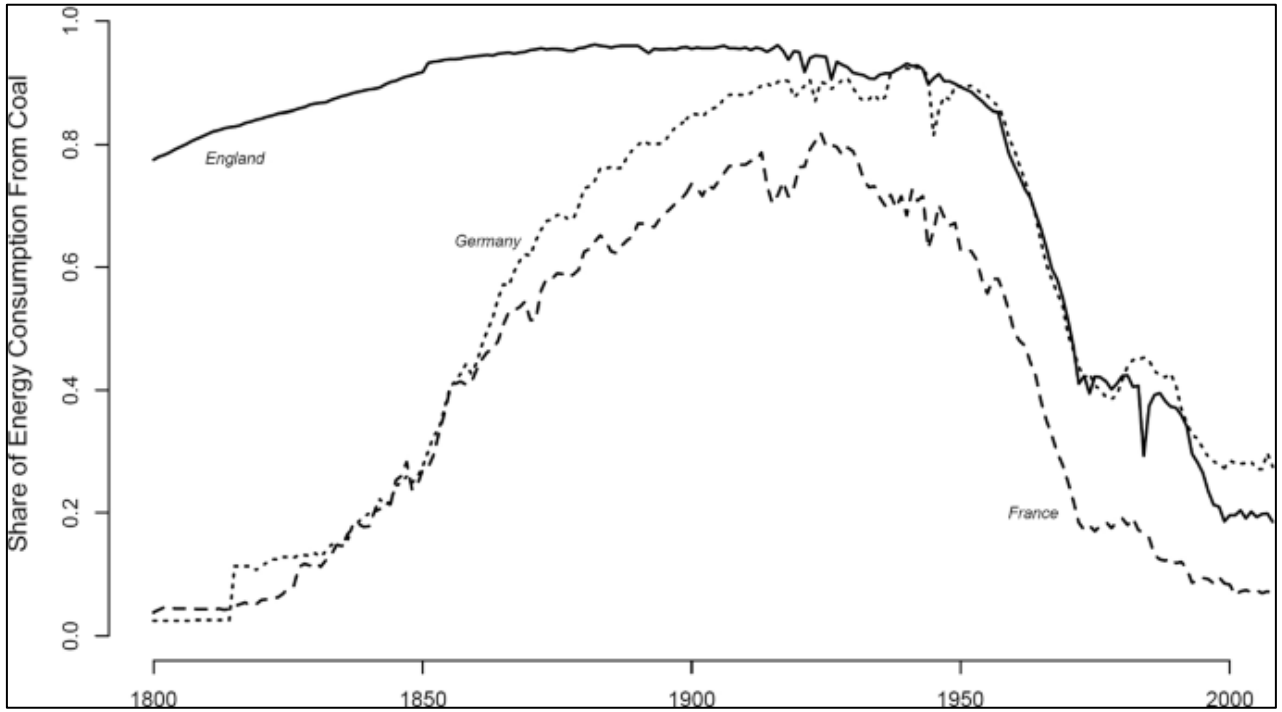
Un schéma se dégage → augmentation de la complexité d'extraction et du coût

Le charbon dans l'histoire

Les débuts de la révolution industrielle en Angleterre

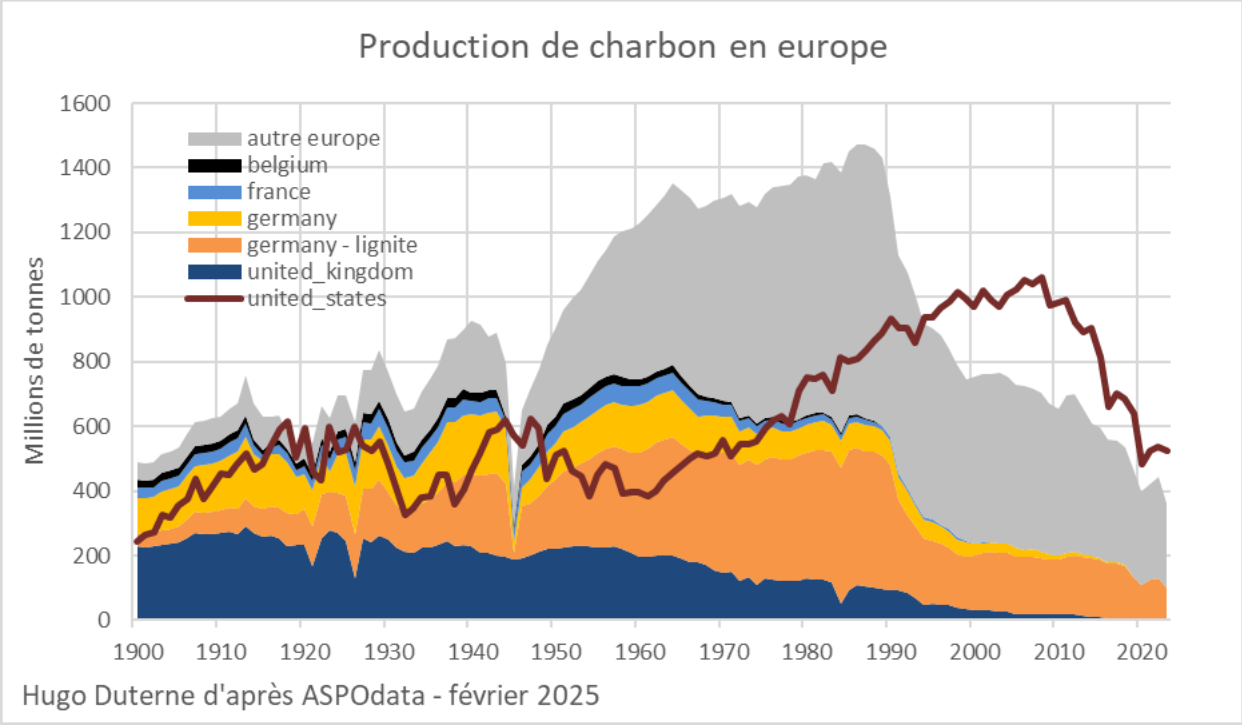


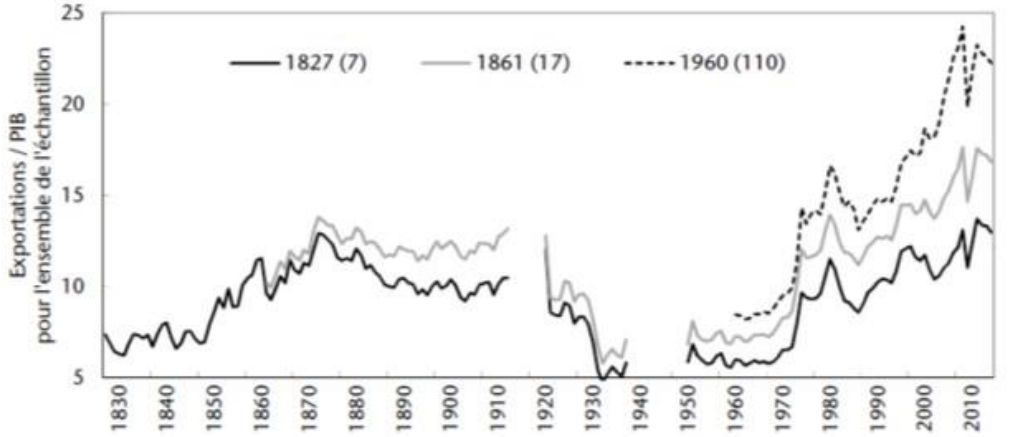
Mix énergétique de l'Angleterre et du pays de galles, (Paul Warde, 2007)



Share of total energy consumption from coal. Coal Consumption in England & Wales, France, and Germany data (Kander et al. 2014)

Extension de l’industrialisation





Lecture : la légende indique l’année initiale de l’échantillon. Le nombre de pays inclus dans chaque échantillon figure entre parenthèses.

Source : Fouquin et Hugot [2016].

Fouquin M. et Hugot J. [2016], « Back to the future : trade costs and the two globalizations, 1827-2014 », CEPII Working Paper, n° 2016-13.

Déclin de la puissance britannique

Moteur de la révolution industrielle

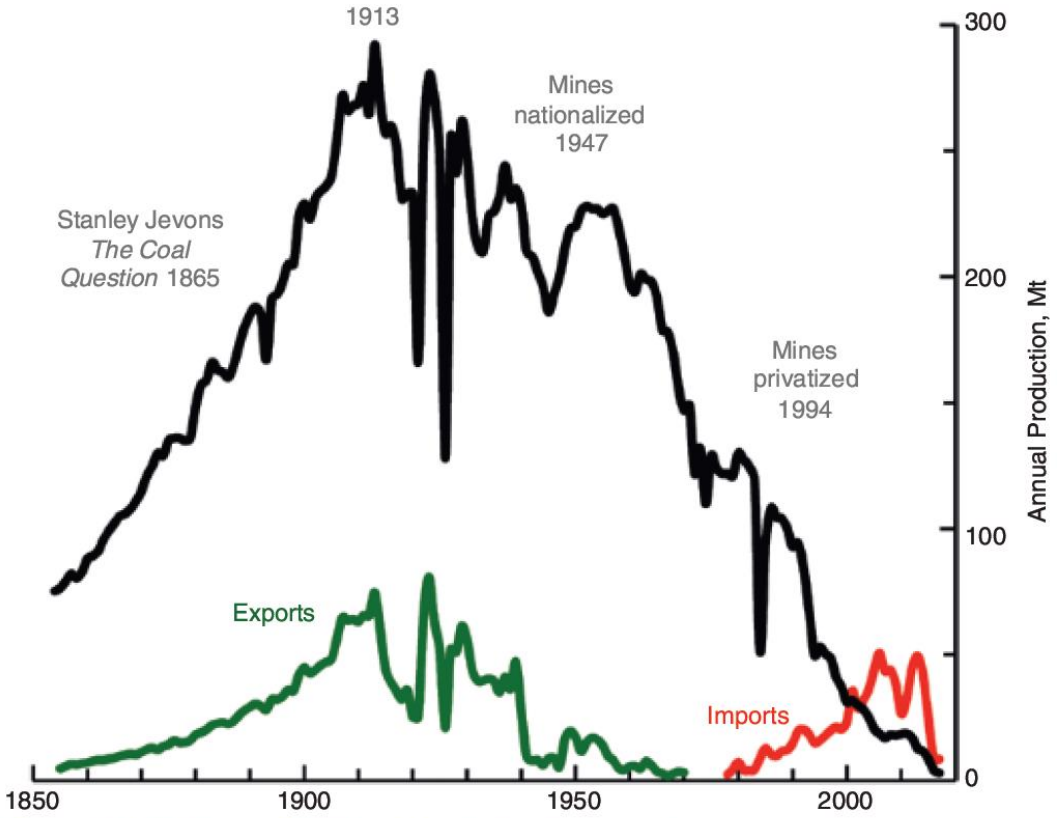
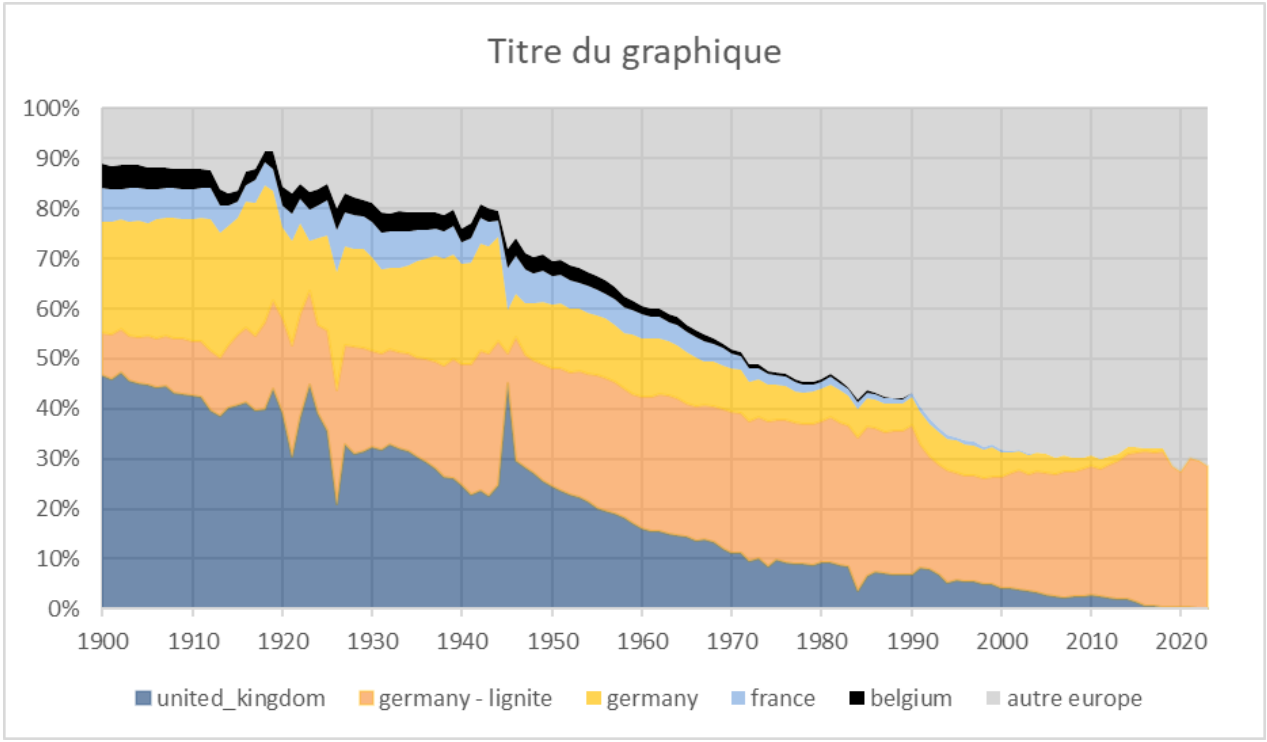
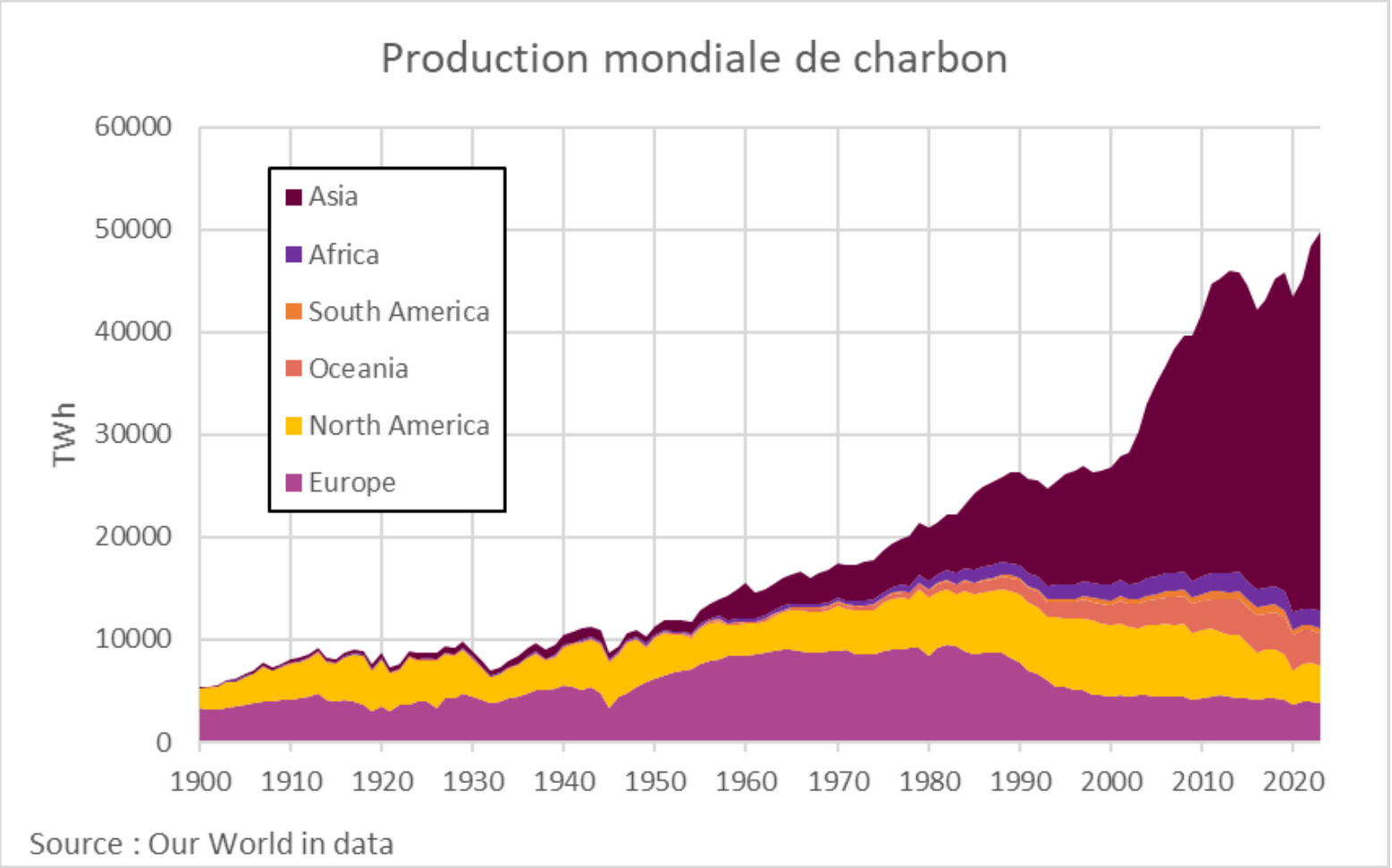


Figure 4.26 The history of British coal production, imports, and exports.



Production mondiale depuis 1900



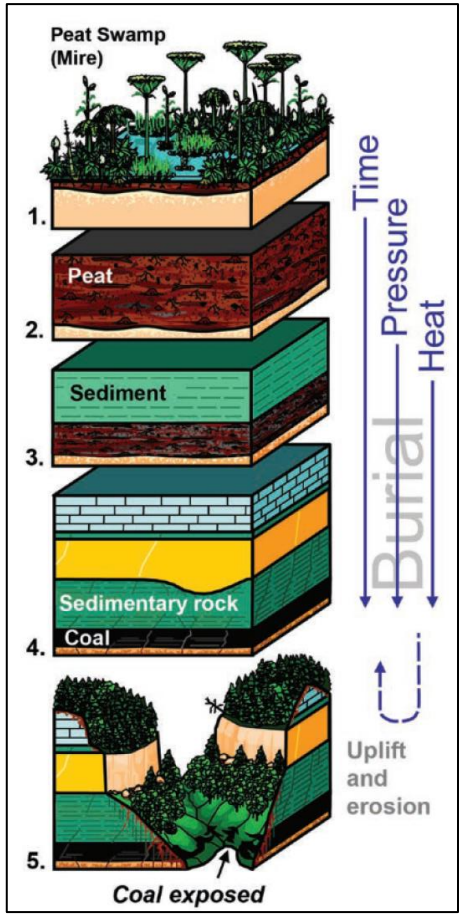
CentraleSupélec

II. Géologie du charbon

« Le simple est toujours faux. Ce qui ne l'est pas est inutilisable. »

Paul Valéry, Œuvres II, 1942

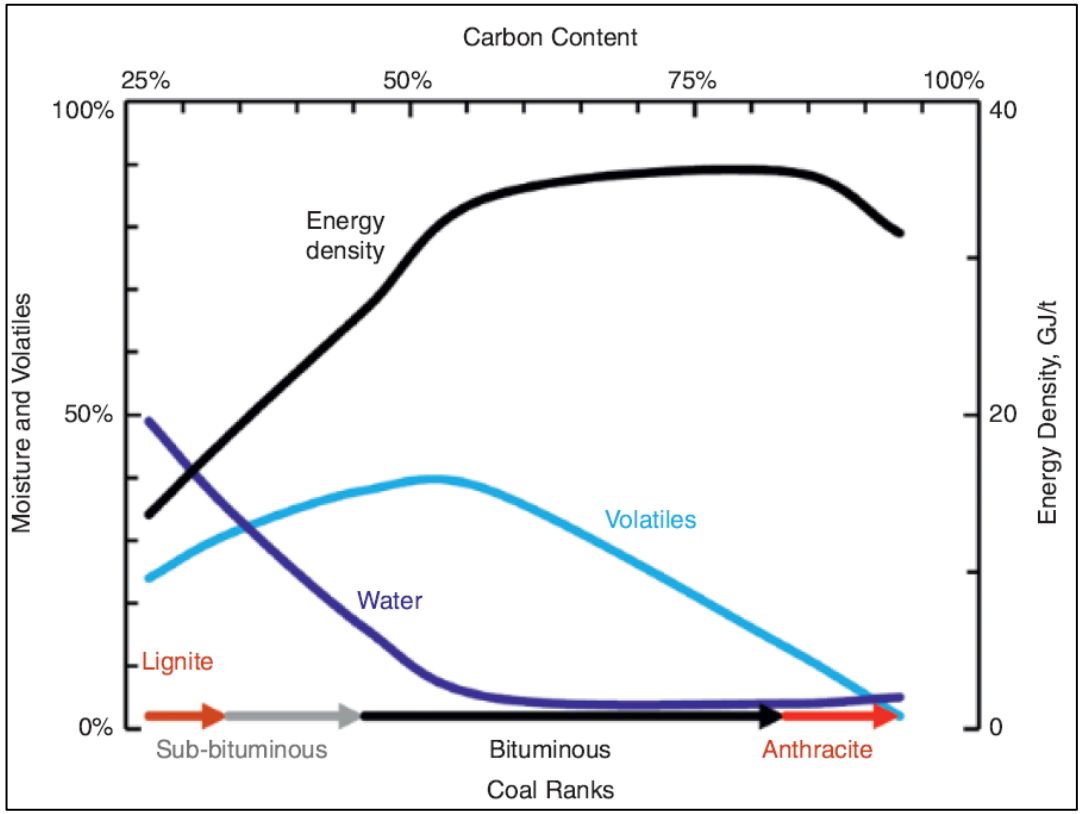
Formation du charbon



Formation géologique

Structure moléculaire du charbon

Classification du charbon



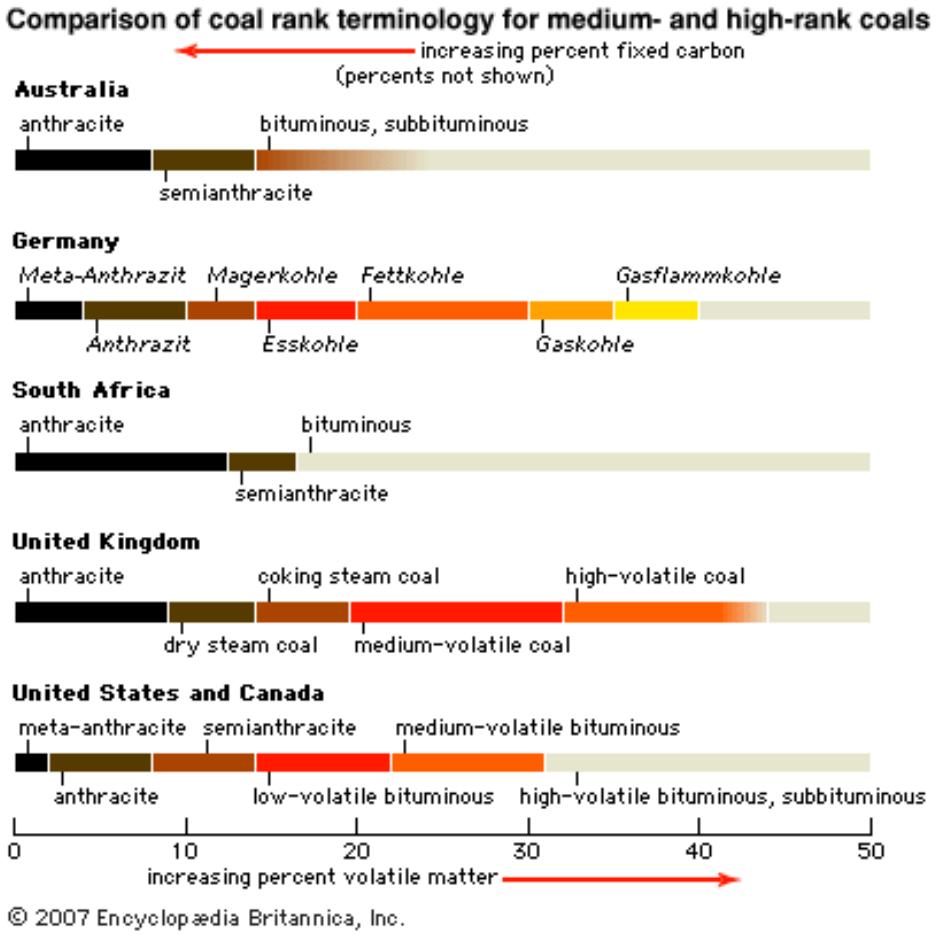
Fonction des classifications

	Anthracite	Bitumineux à coke	Bitumineux vapeur	Sous bitumineux	Lignite
Teneur en carbone	90 à 98%	75 à 90%	70 à 90%	70 à 80%	50 à 60%
Pouvoir calorifique inférieur	>= 29,3 MJ/kg	< 29,3 MJ/kg >= 20,9 MJ/kg	< 29,3 MJ/kg >= 20,9 MJ/kg	< 20,9 MJ/kg >= 14,7 MJ/kg	< 14,7 MJ/kg
Teneur en matières volatiles	< 10%	15 à 25%	30 à 40%	25 à 50%	50%
Humidité	1 à 6%	5 à 10%	5 à 10%	15 à 25%	25 à 50%
Teneur en cendres	0 à 10%	10 à 20%	10 à 20%	20 à 30%	30 à 50%
Pouvoir agglutinant		Oui	Non		

« hard coal »/ Houille

«brown coal »

Une classification peu harmonisée mondialement



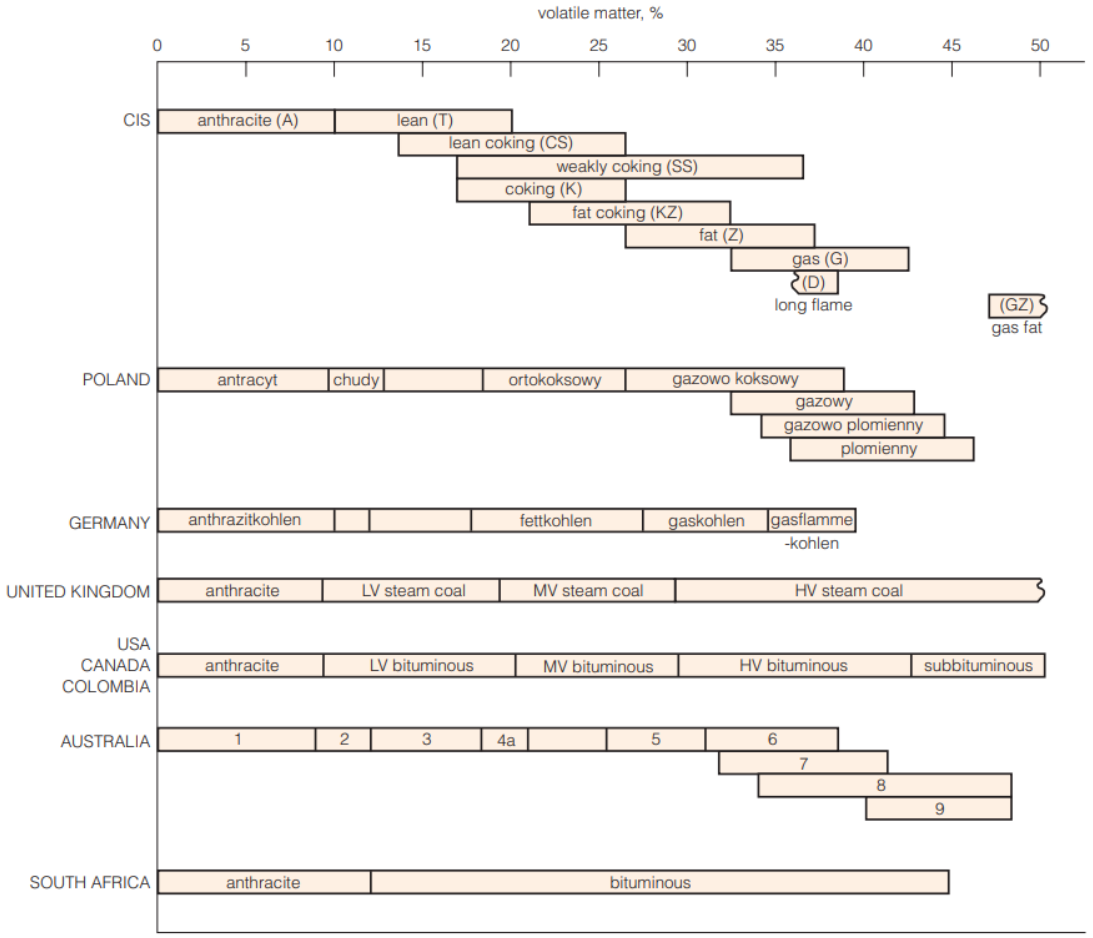


Figure A1 Comparison of national classification systems for rank based on volatile matter

Extraction du charbon

Extraction souterraine:

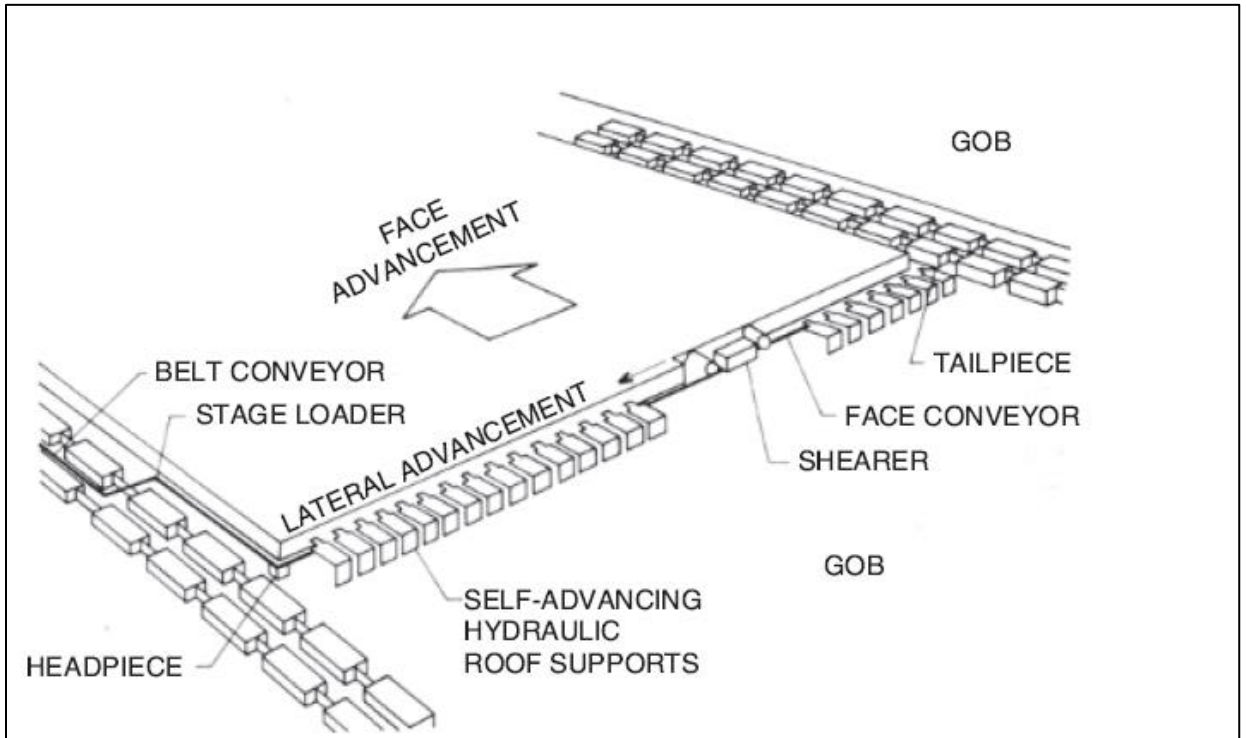
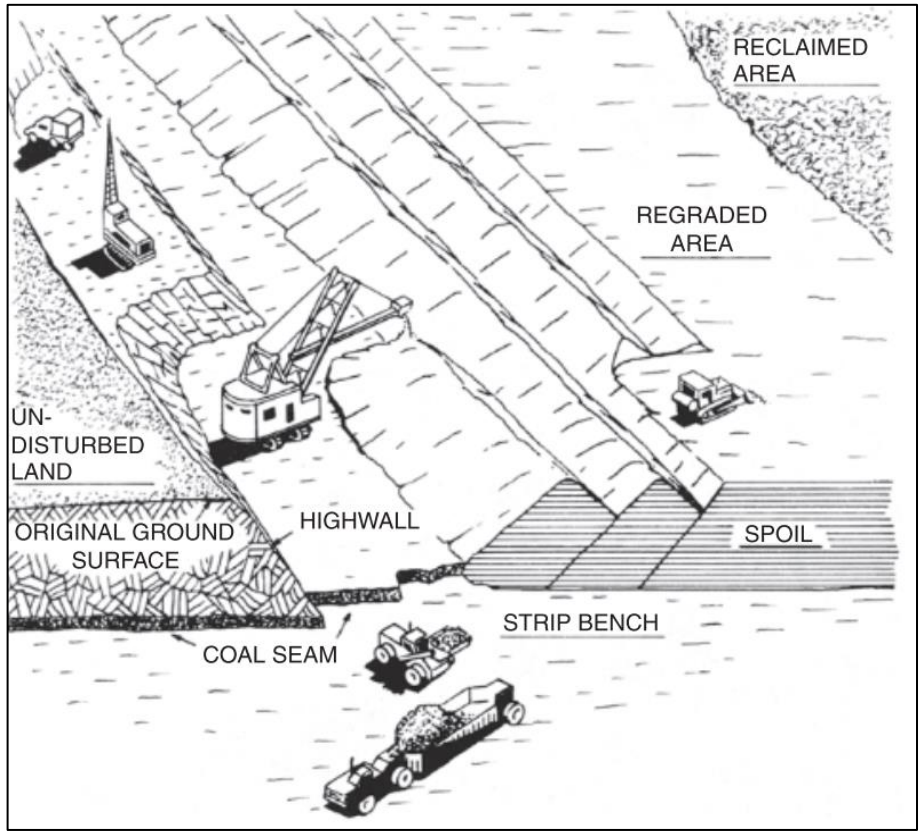


Figure 4.14 Layout of a longwall mine. From Robert Stefanko, *Coal Mining Technology*, the Society of Mining Engineers, 1983.

Extraction à ciel ouvert :

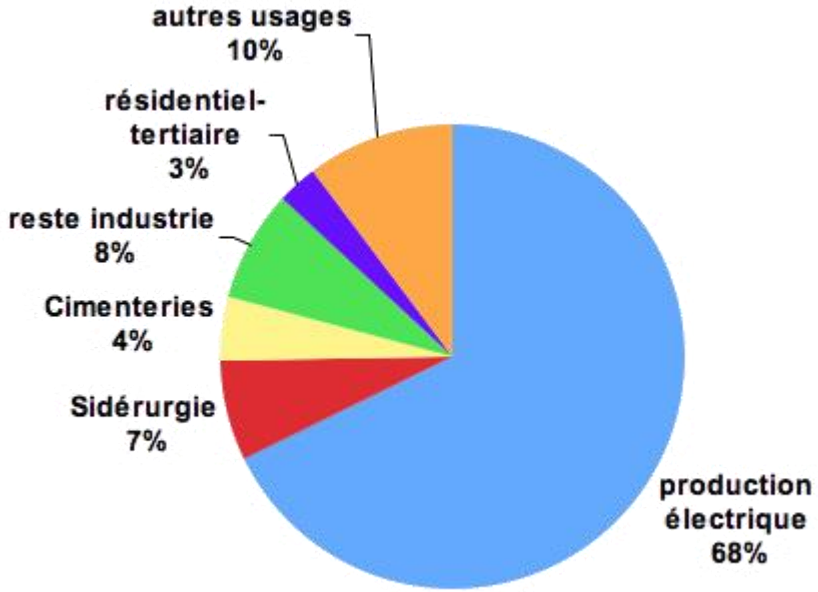


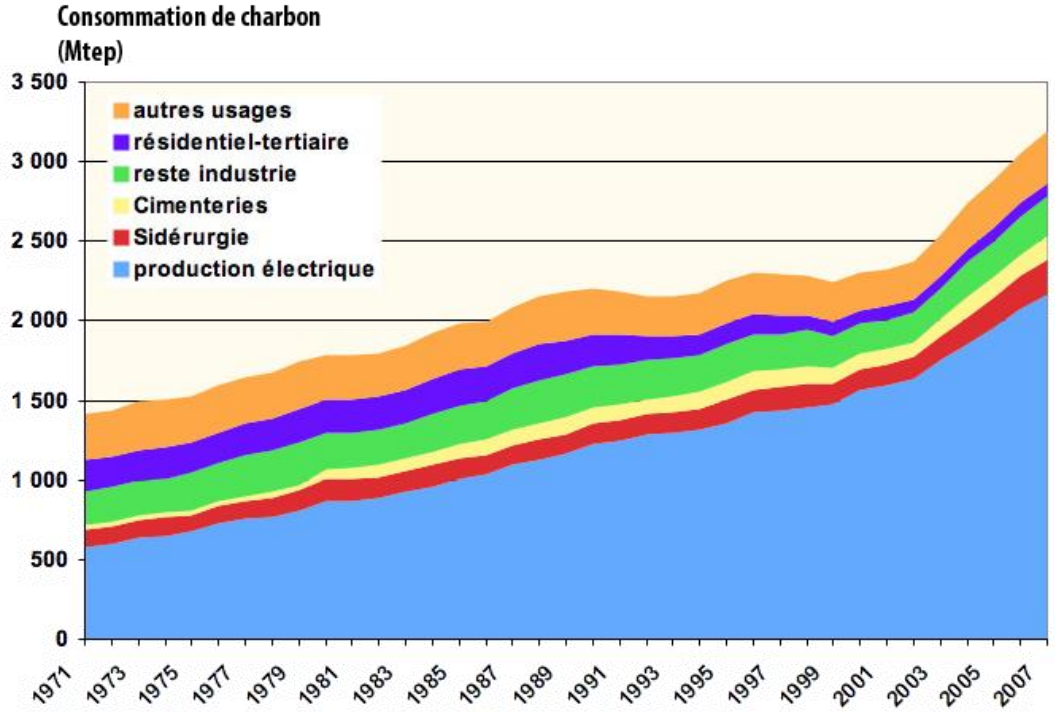
Extraction du charbon

Haveuse à charbon opérant à 800 mètres de profondeur dans la mine de Daw Mill en Angleterre

Mines de lignite de Welsow et Nochten en Allemagne

Les usages du charbon

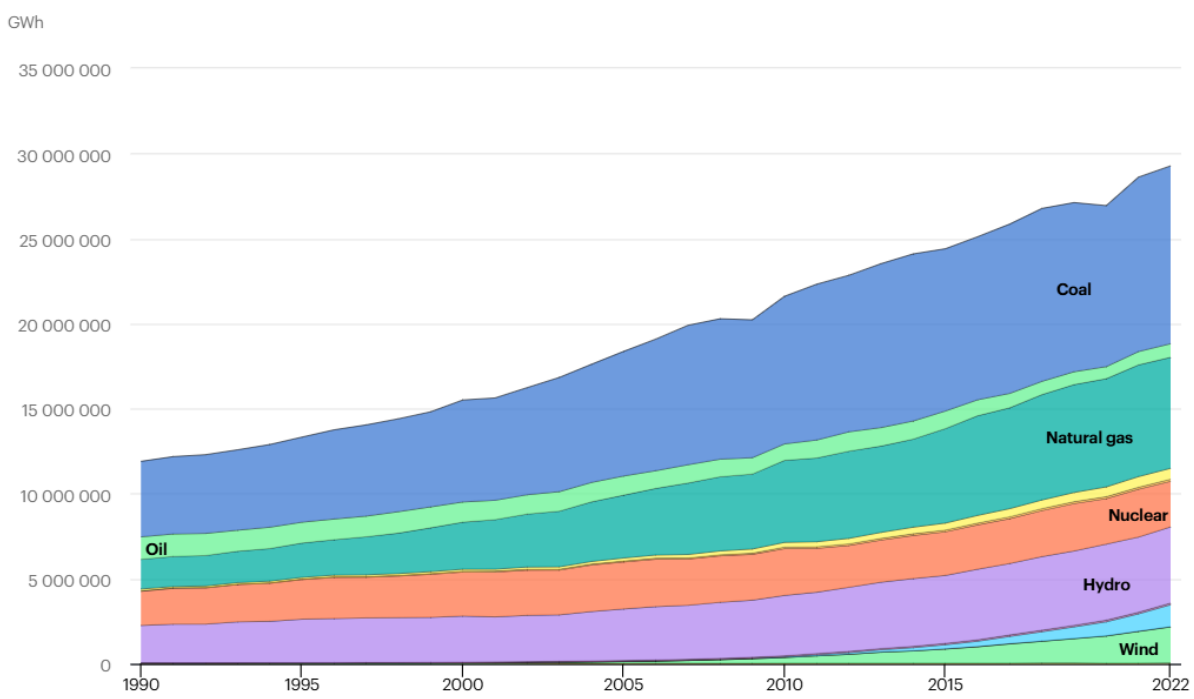




Source : Jancovici d'après AIE

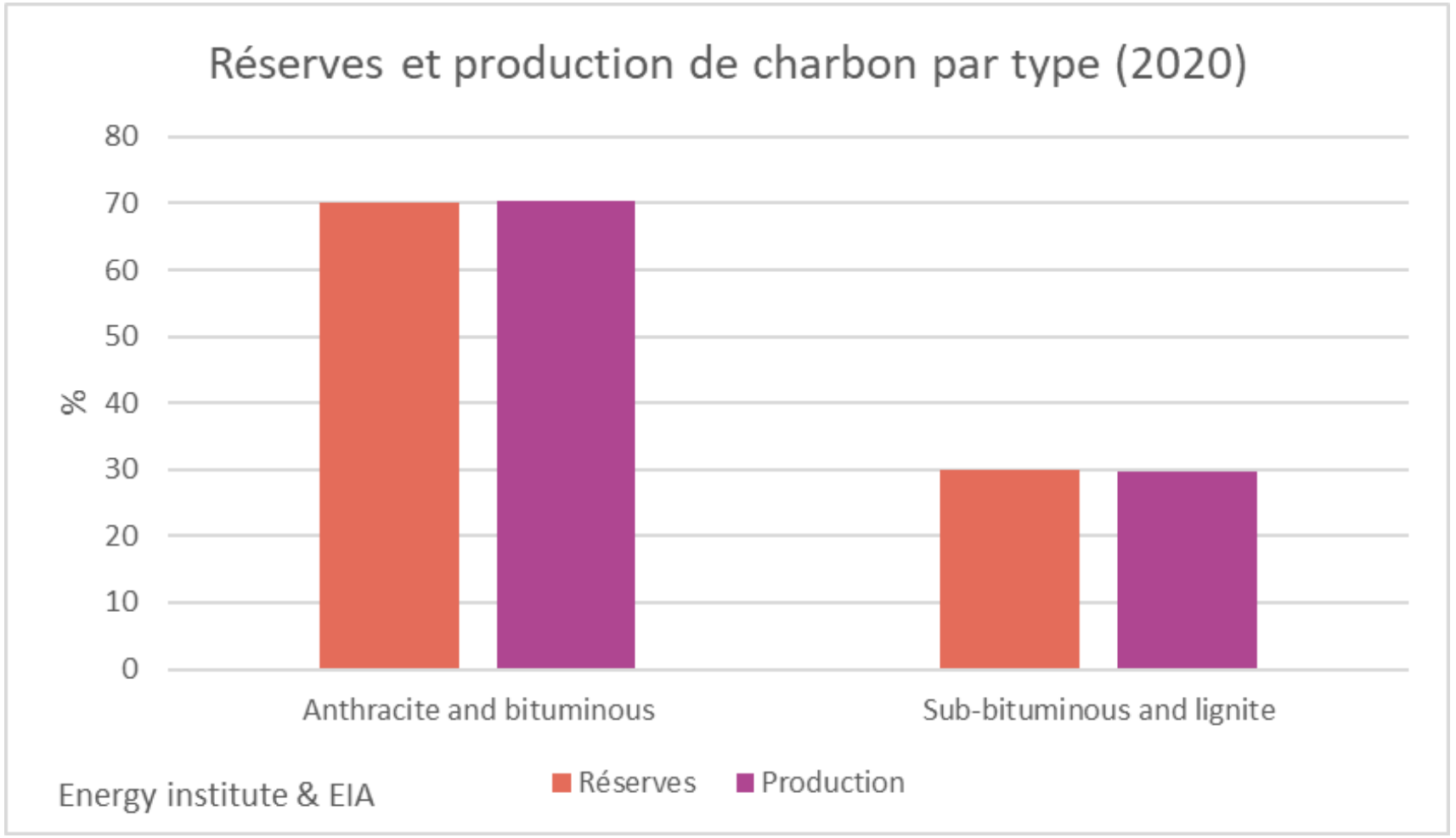
Les usages du charbon

Electricity generation by source, World, 1990-2022

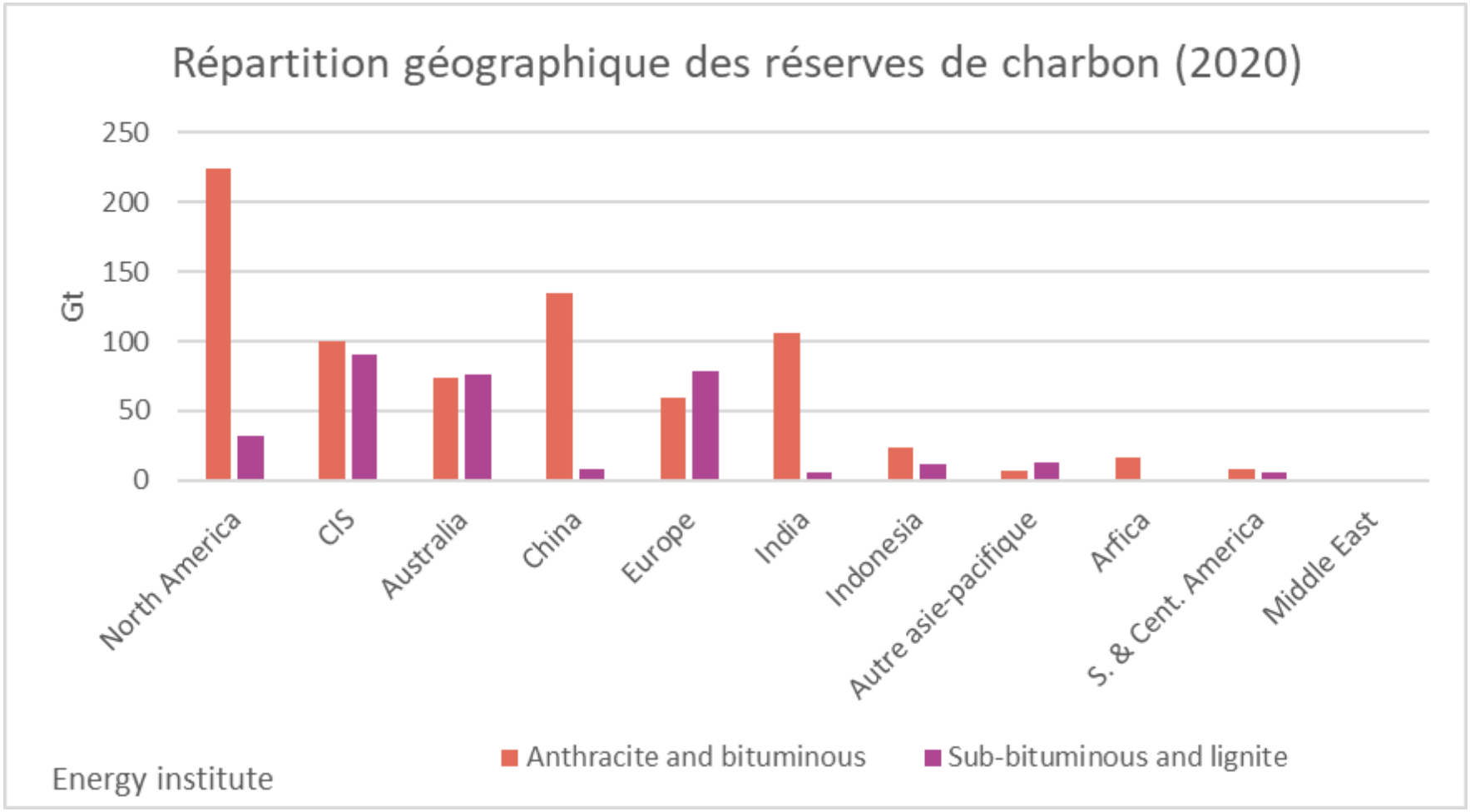


Coal · Oil · Natural gas · Biofuels · Waste · Nuclear · Hydro · Geothermal · Solar PV · Solar thermal · Wind · Tide · Other sources

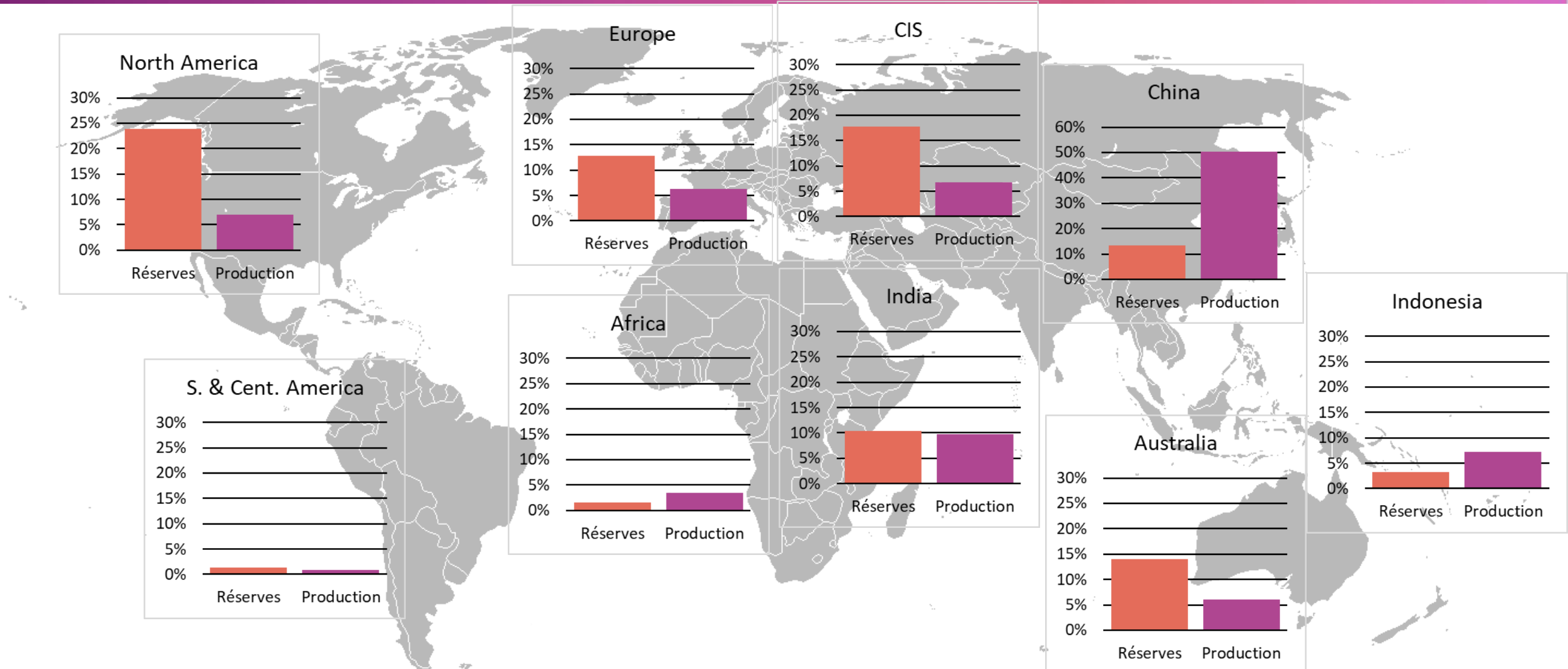
Réserves par type



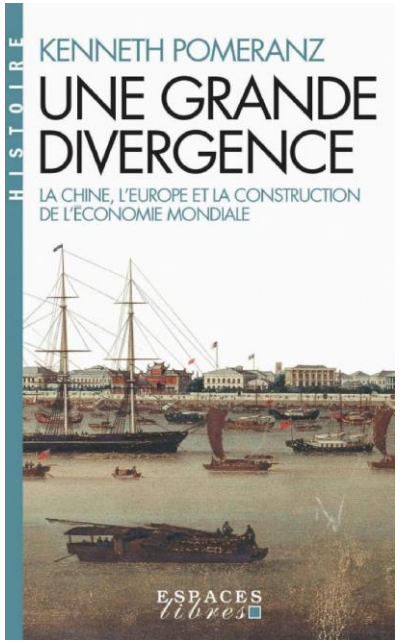
Réserves par géographies

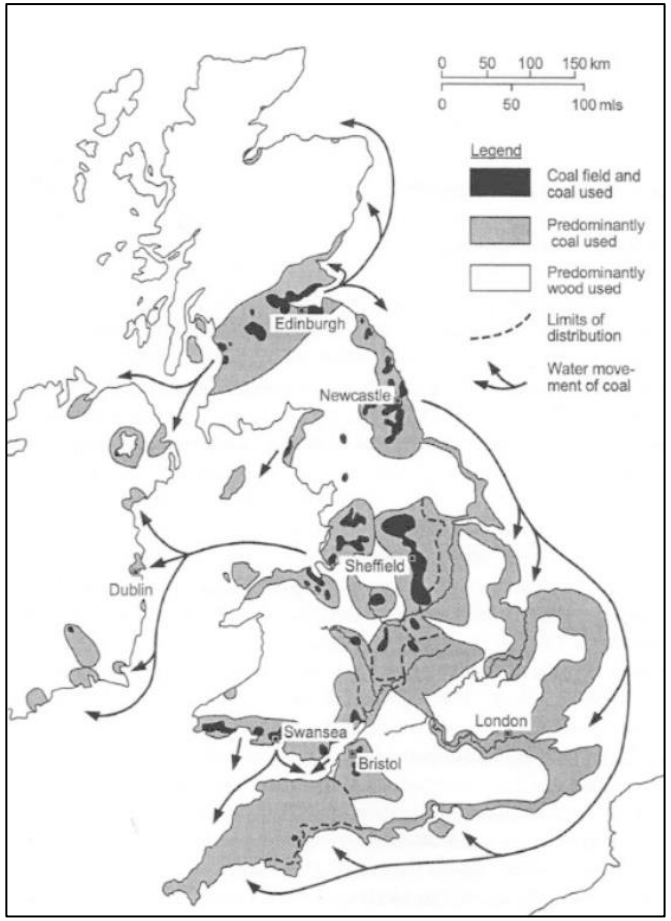


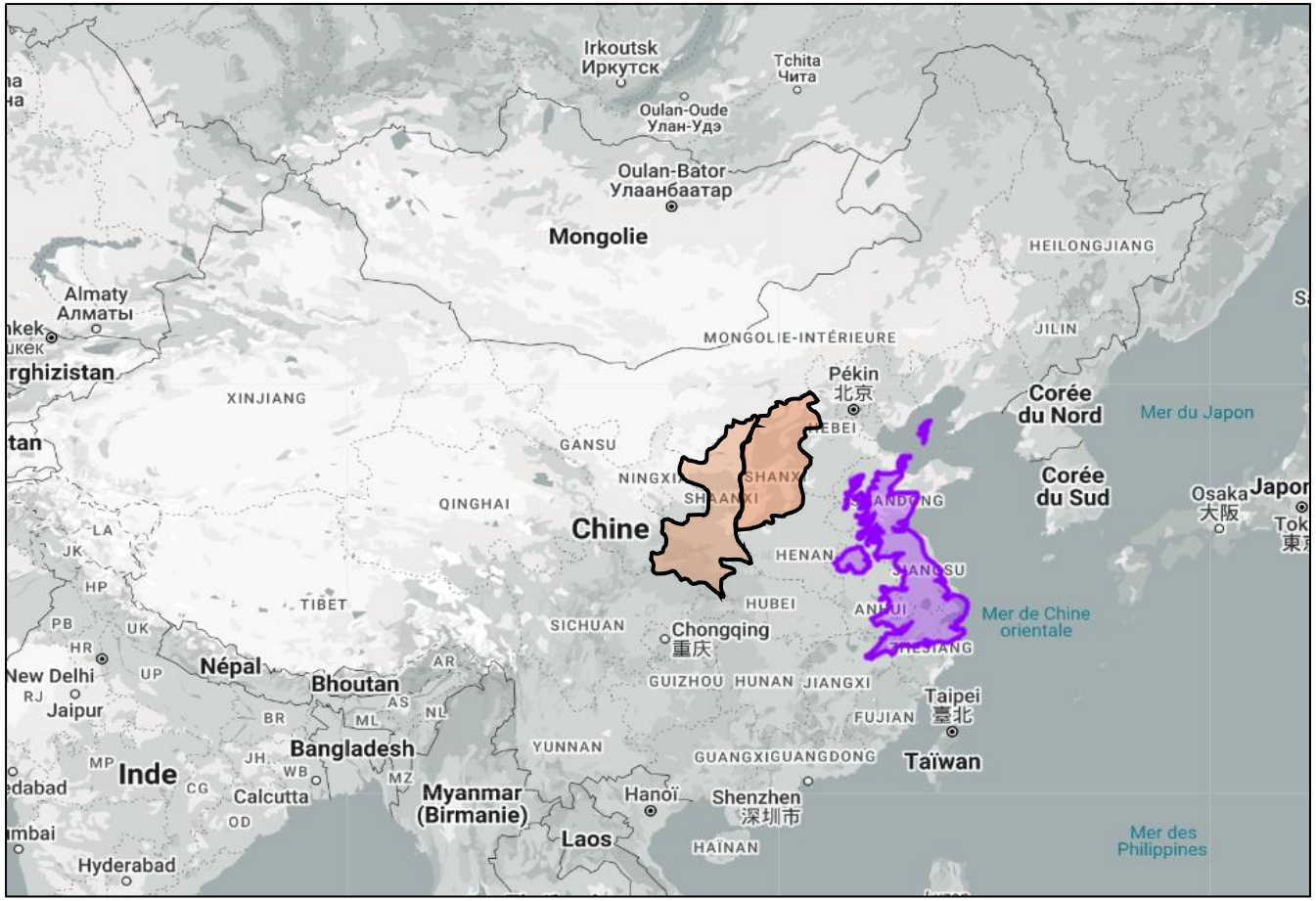
Réserves et production



Focus : comprendre le retard chinois







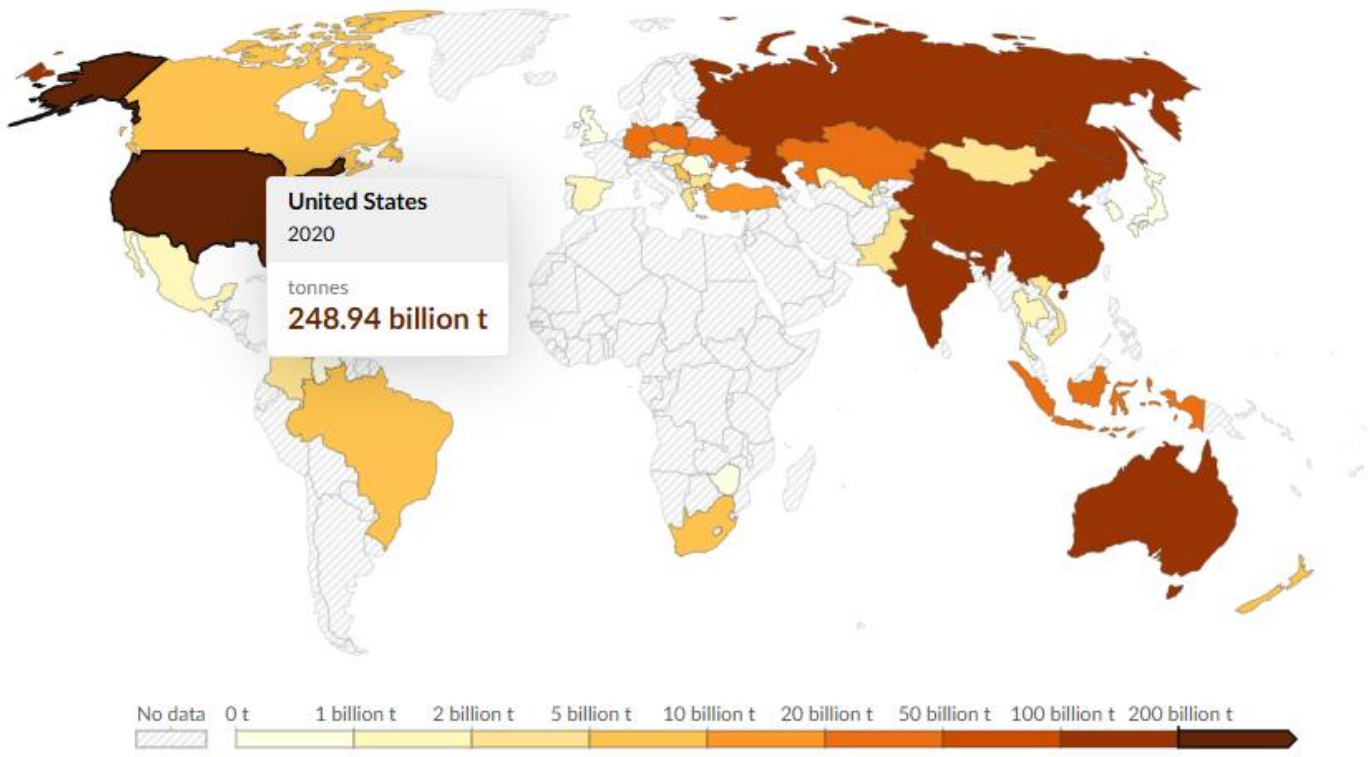
CentraleSupélec

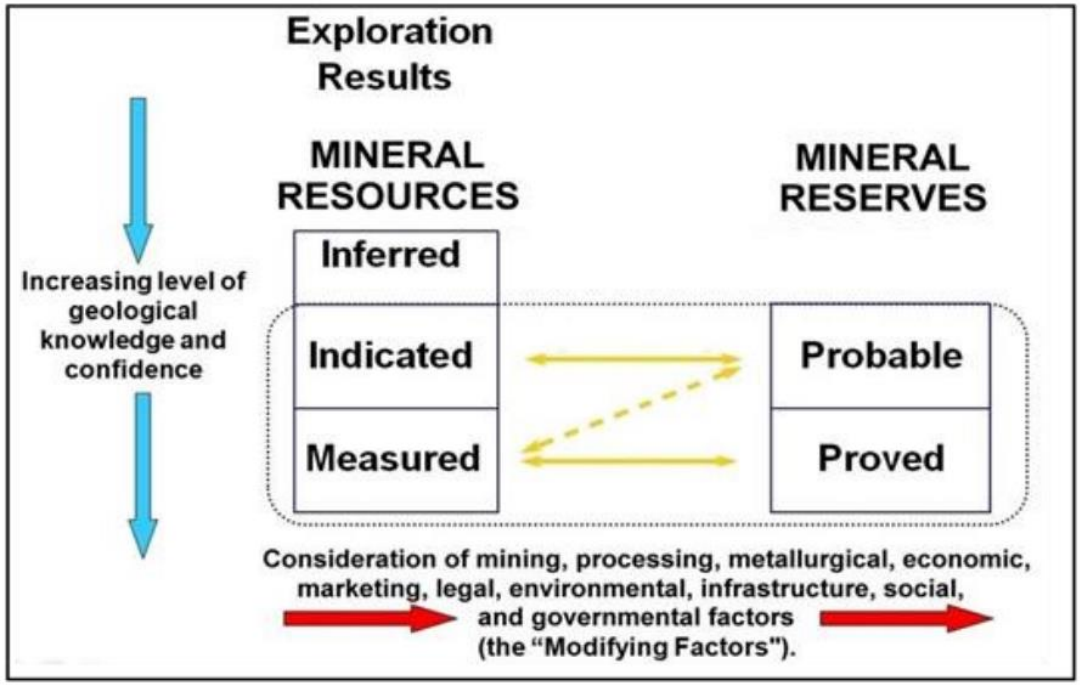
III. Économie du charbon

« There's No Such Thing as a Free Lunch »

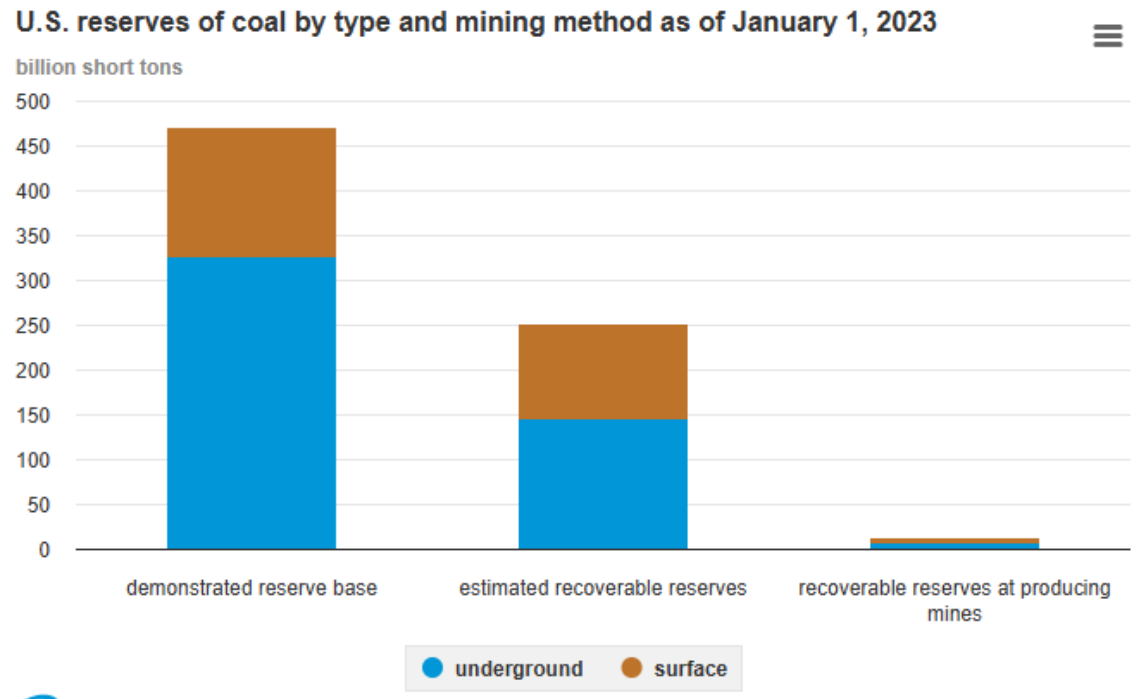
Milton Friedman, 1975

Qu’est-ce qu’une réserve de charbon ?





Qu’est-ce qu’une réserve de charbon ?

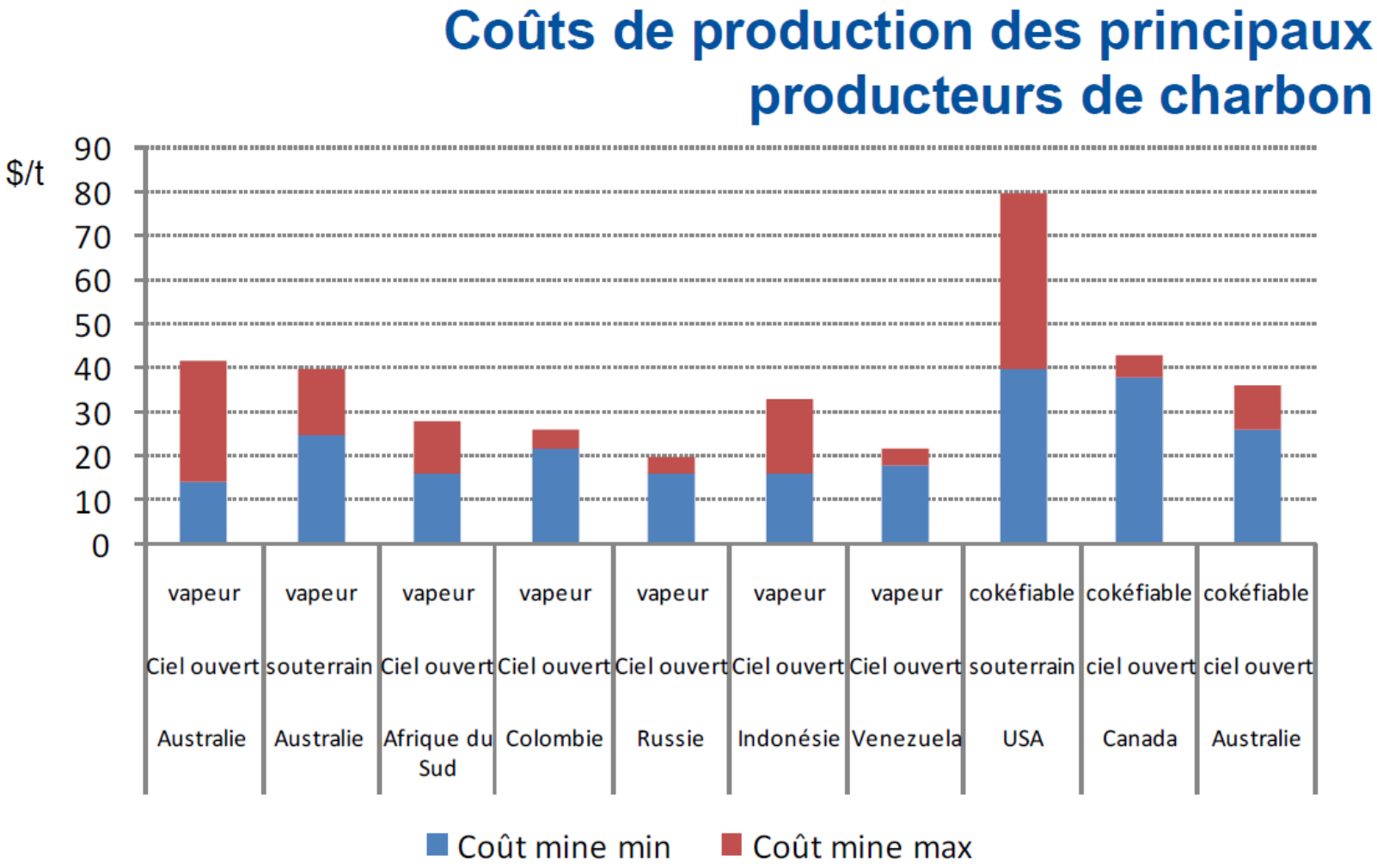


eia Data source: U.S. Energy Information Administration, *U.S. Coal Reserves*, Table 15, October 2023

EIA’s estimates for the amount of coal reserves as of January 1, 2023, by type of reserve are:[1]

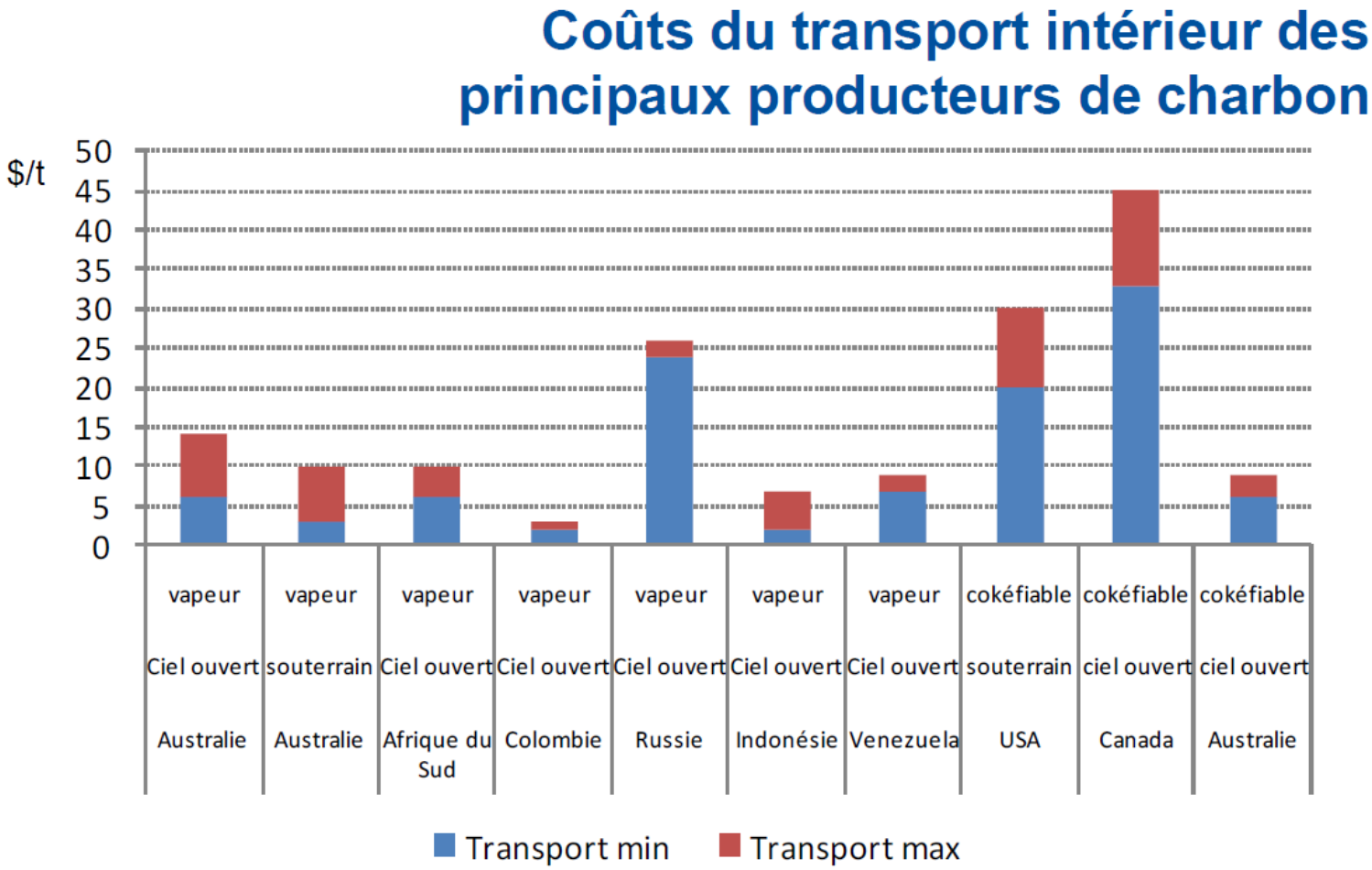
- **Demonstrated Reserve Base** (DRB) is the sum of coal in both measured and indicated resource categories of reliability. The DRB represents 100% of the in-place coal that could be mined commercially at a given time. EIA estimates the DRB at about 470 billion short tons, of which about 69% is underground mineable coal.
- **Estimated recoverable reserves** include only the coal that can be mined with today’s mining technology after considering accessibility constraints and recovery factors. EIA estimates U.S. recoverable coal reserves at about 250 billion short tons, of which about 58% is underground mineable coal.
- **Recoverable reserves at producing mines** are the amount of recoverable reserves that coal mining companies report to EIA for their U.S. coal mines that produced more than 25,000 short tons of coal in a year. EIA estimates these reserves at about 12 billion short tons of recoverable reserves, of which 53% is surface mineable coal.

Coût d'extraction du charbon



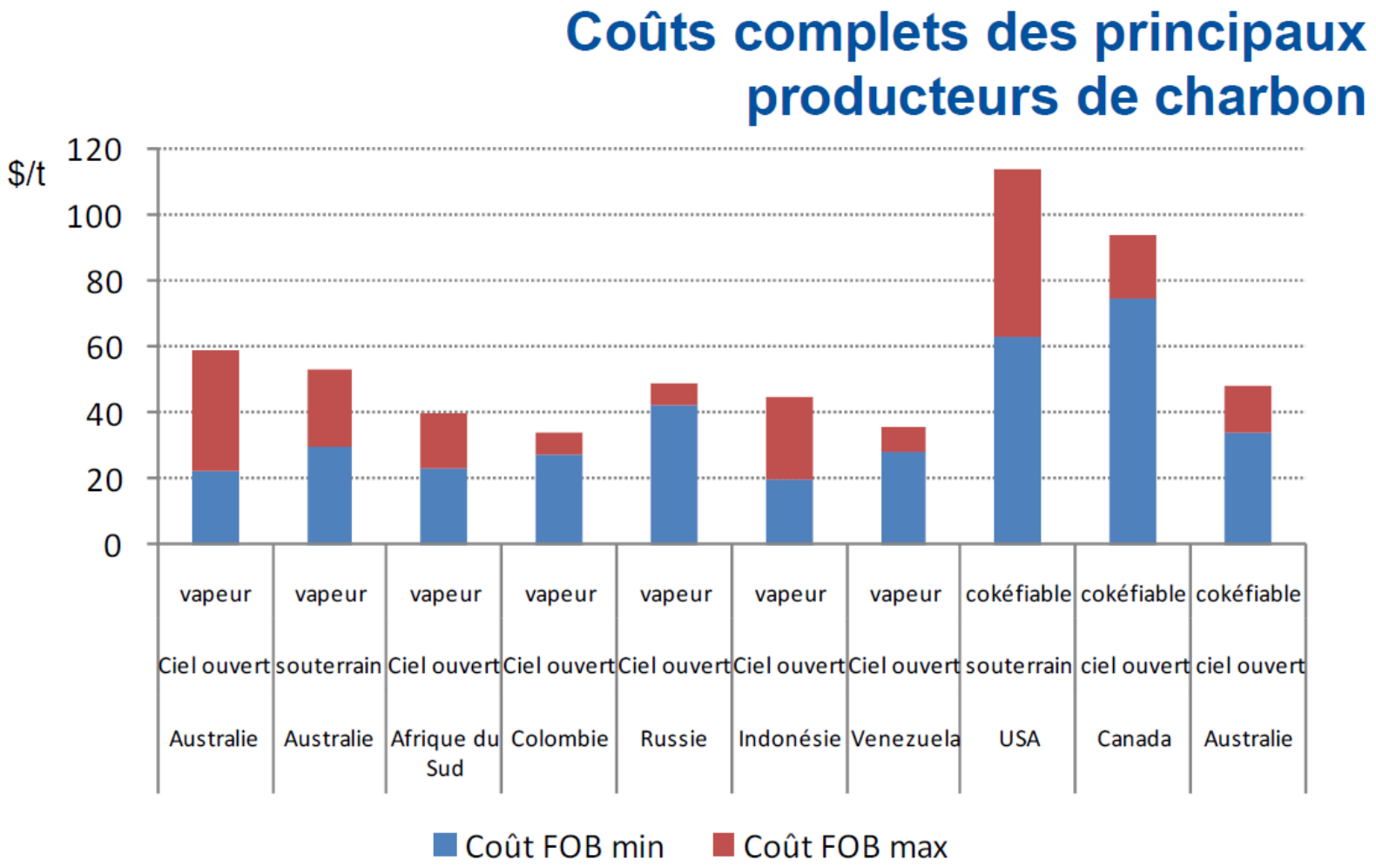
Source: Jean-Marie Marin-Amouroux, 2008.

Coût d'extraction du charbon



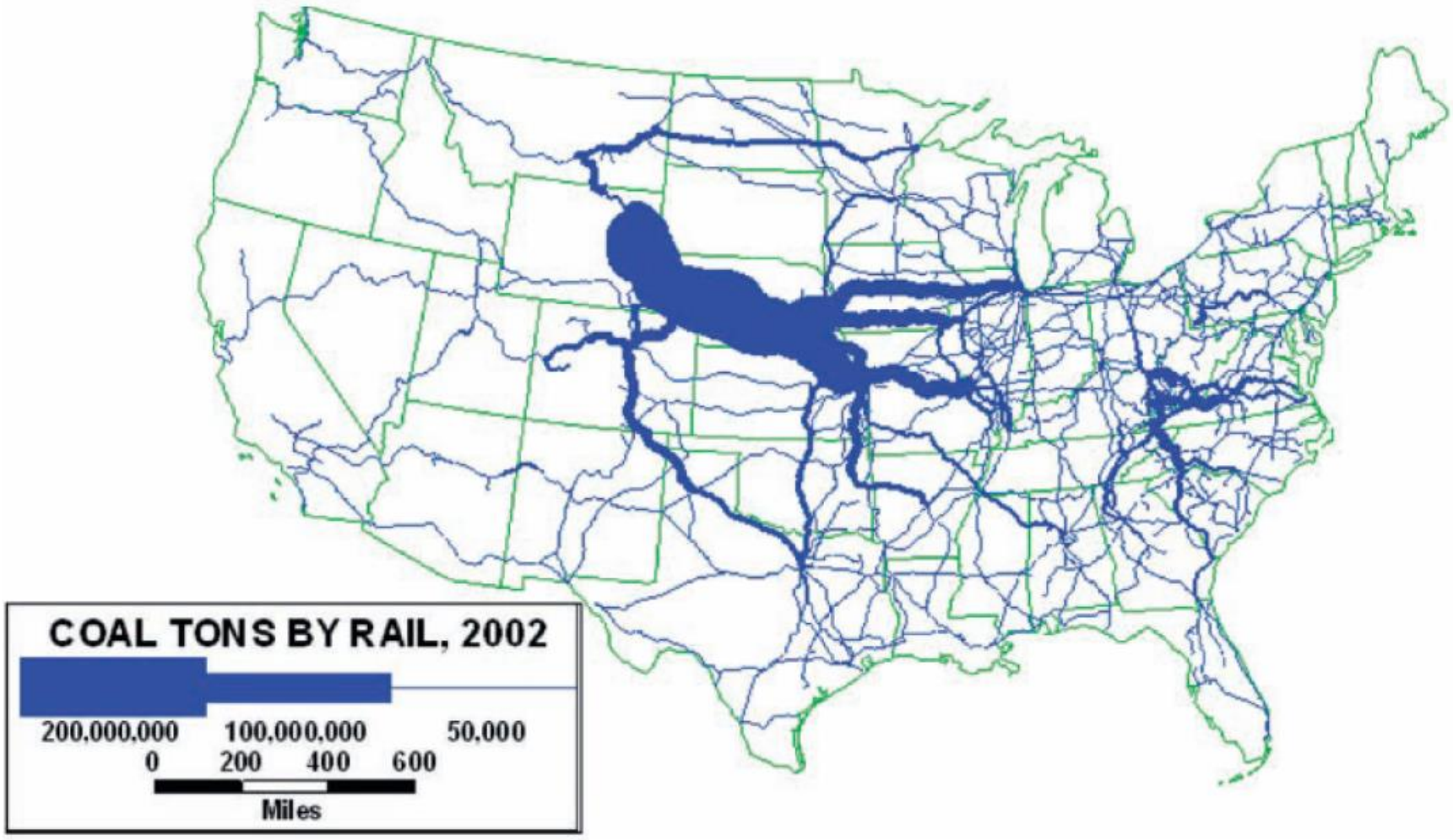
Source: Jean-Marie Marin-Amouroux, 2008.

Coût d'extraction du charbon

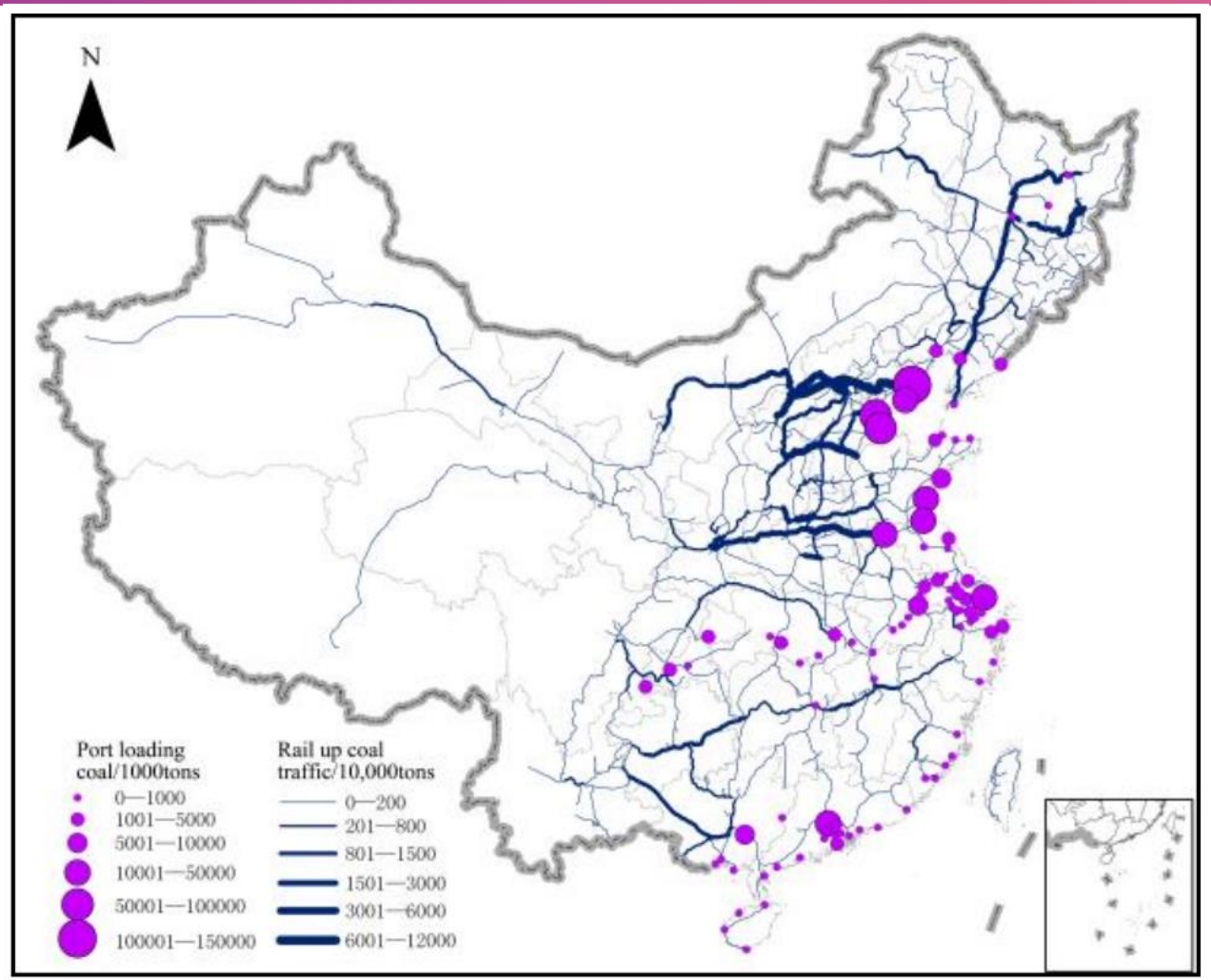


Source: Jean-Marie Marin-Amouroux, 2008.

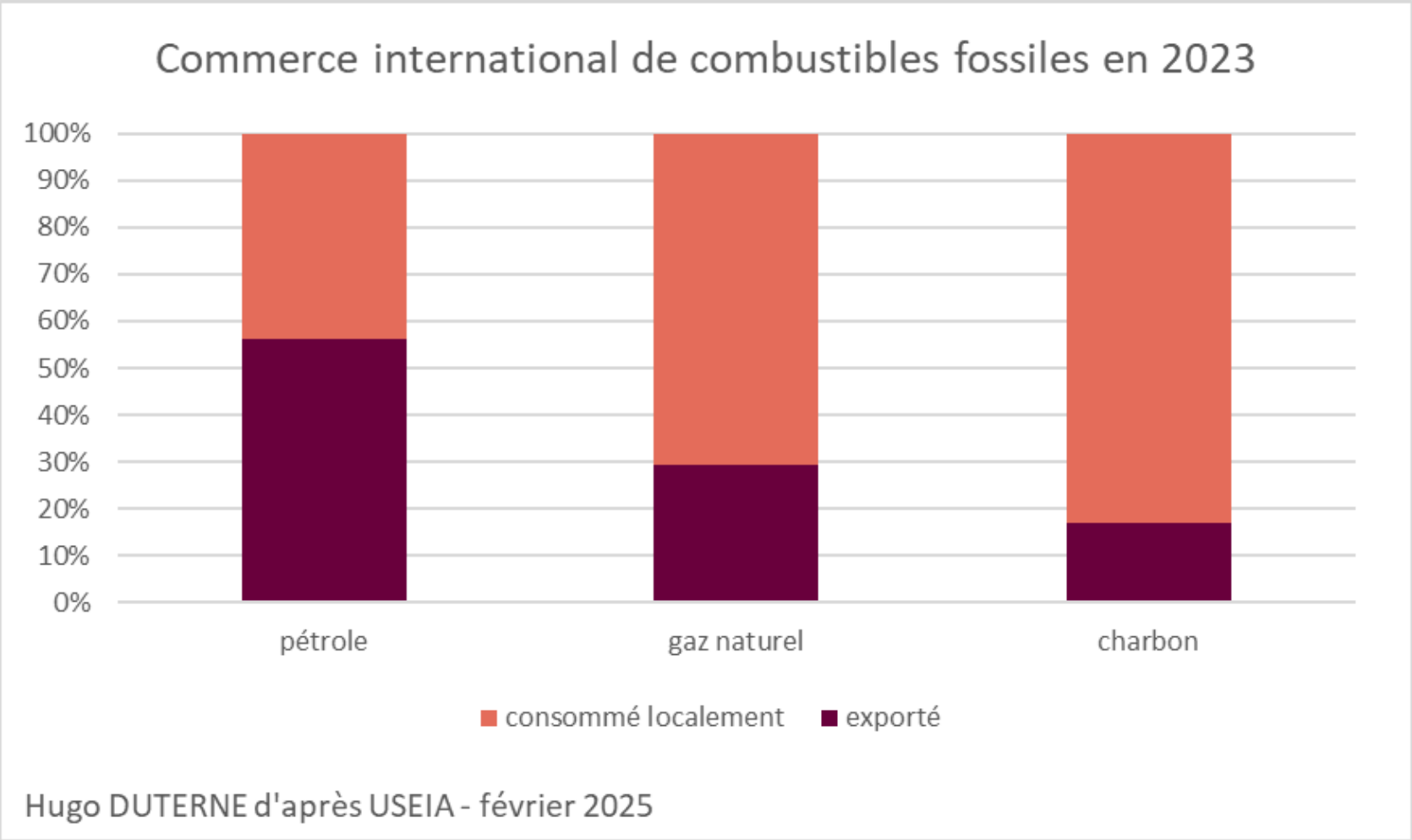
Le transport intérieur US



Le transport intérieur chinois



Le marché international



Domination du transport maritime

Table 3.1: World and seaborne coal trade

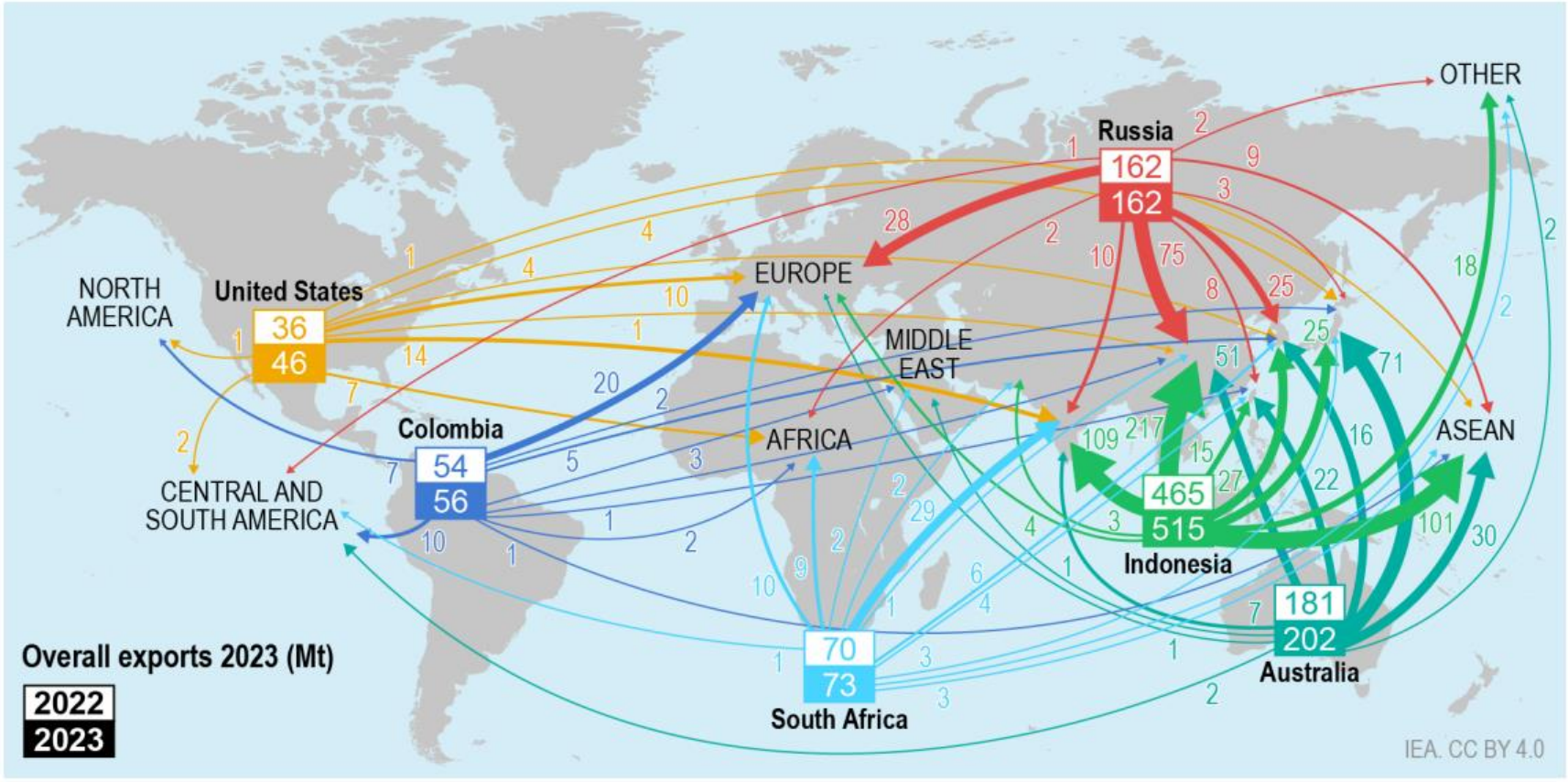
(million tonnes)

	Steam coal		Coking coal		Total coal[1]	
	Total	Seaborne	Total	Seaborne	Total	Seaborne
1995	296.2	240.3	195.1	173.2	500.8	420.9
1996	319.8	268.0	193.5	173.4	521.9	446.7
1997	343.6	283.7	197.0	178.1	546.7	466.7
1998	359.1	287.0	184.4	169.6	549.4	460.4
1999	362.4	303.4	179.0	166.8	546.6	474.1
2000	423.9	355.4	186.0	170.2	614.8	528.3
2001	462.8	387.4	193.7	176.4	661.6	567.2
2002	473.0	411.7	181.7	167.0	658.3	581.9
2003	528.1	454.5	186.2	172.2	717.6	630.6
2004	560.3	488.4	190.4	173.6	753.3	664.3
2005	602.8	529.7	206.2	186.6	812.2	717.2
2006	679.2	592.7	200.2	183.7	882.8	778.9
2007	697.6	617.0	215.1	196.5	916.6	816.4
2008	688.3	599.4	234.7	212.1	927.3	813.8
2009	713.3	638.5	210.3	190.5	927.1	829.9
2010	785.7	700.3	275.6	242.2	1066.2	943.9
2011	894.5	809.2	269.9	232.4	1168.1	1043.0
2012	969.1	879.4	283.9	247.9	1260.6	1131.9
2013	1031.7	926.9	294.8	261.3	1332.9	1190.1
2014	1022.4	912.7	314.6	286.1	1345.9	1202.0
2015	953.2	865.3	305.2	288.6	1267.8	1162.3
2016	969.5	898.1	313.2	283.0	1292.7	1185.9
2017	1025.2	929.3	324.5	287.0	1363.4	1223.8
2018	1067.4	905.6	336.8	304.0	1420.1	1233.6

Échanges de charbon vapeur

Total mondial = 1054 Mt

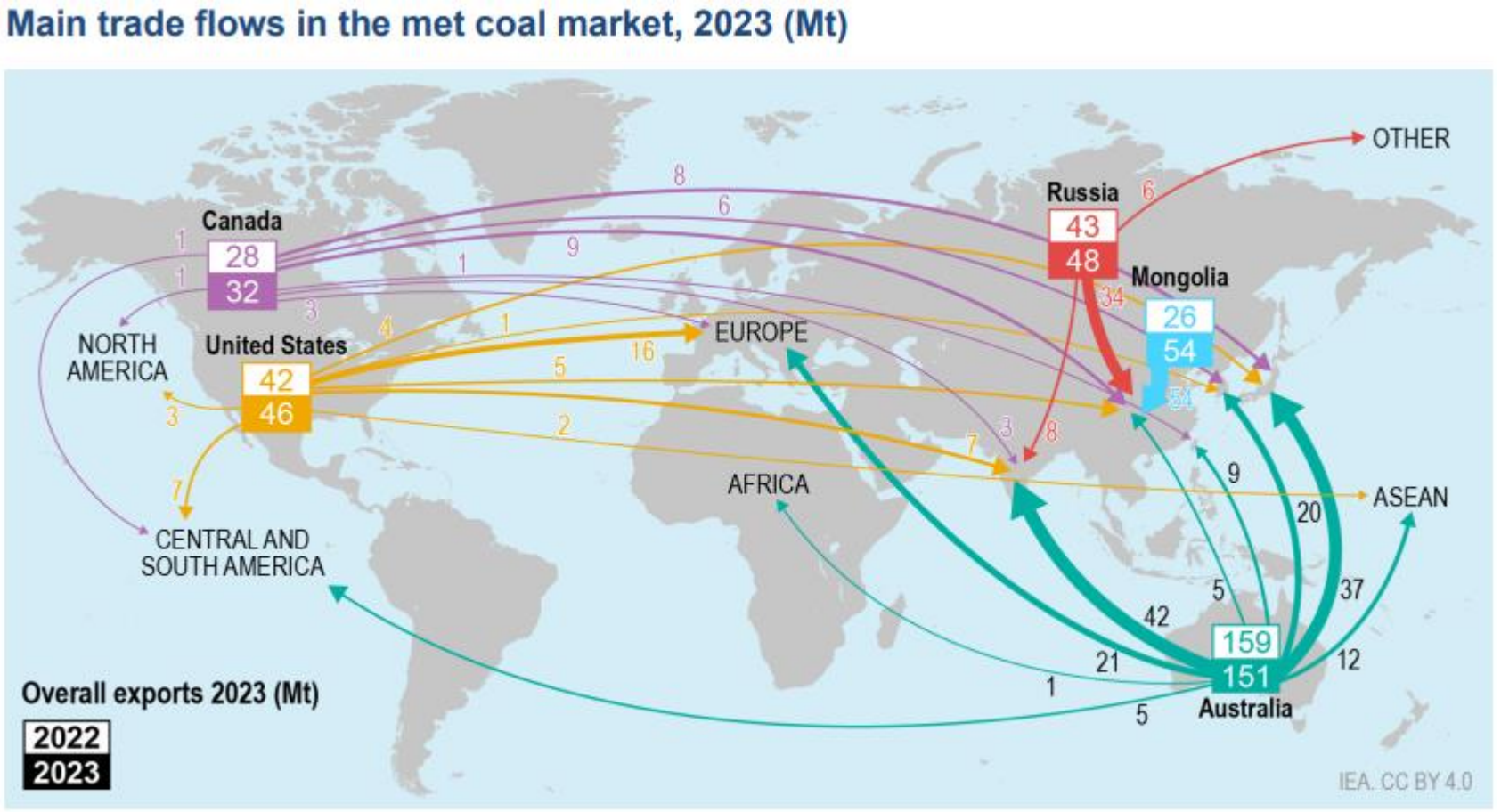
Main trade flows in the thermal coal market, 2023 (Mt)



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

Échanges de charbon à coke

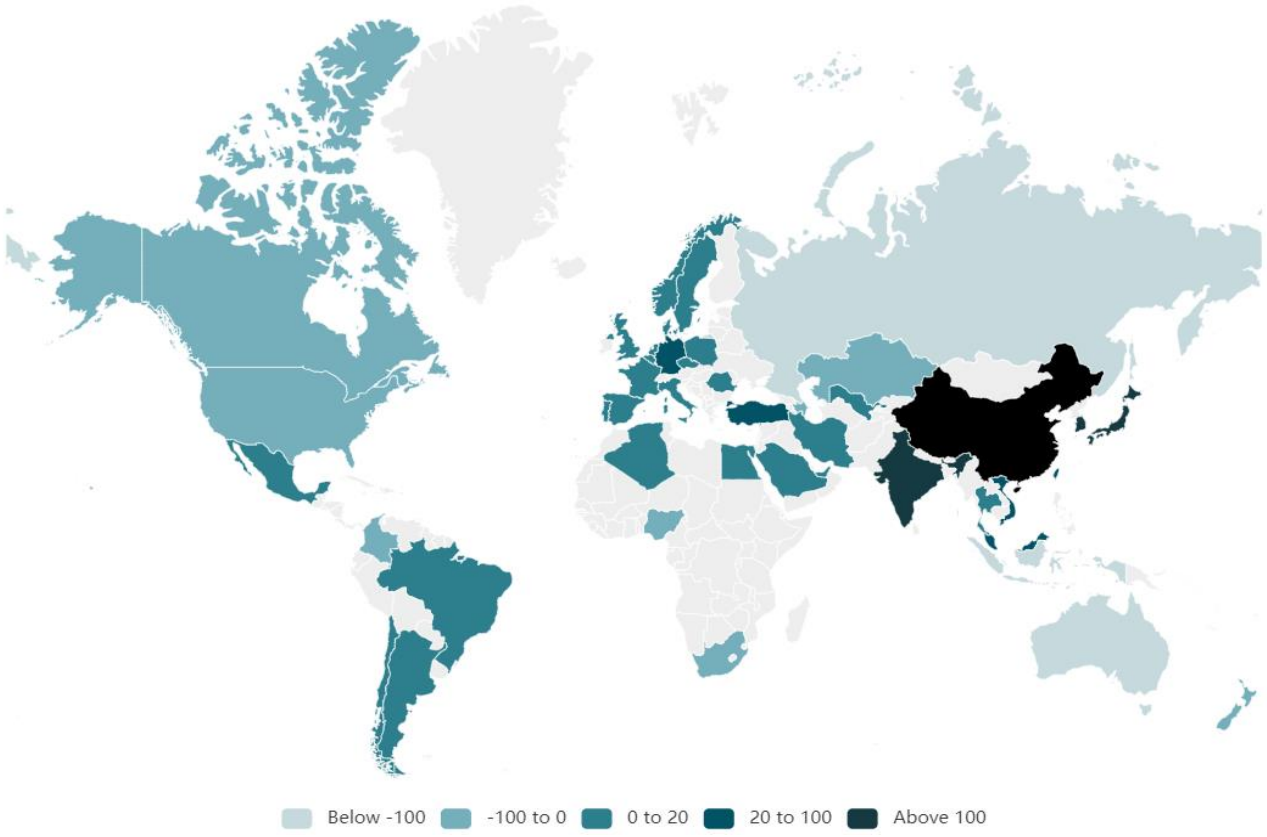
Total mondial = 331 Mt



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

Etat du marché mondial

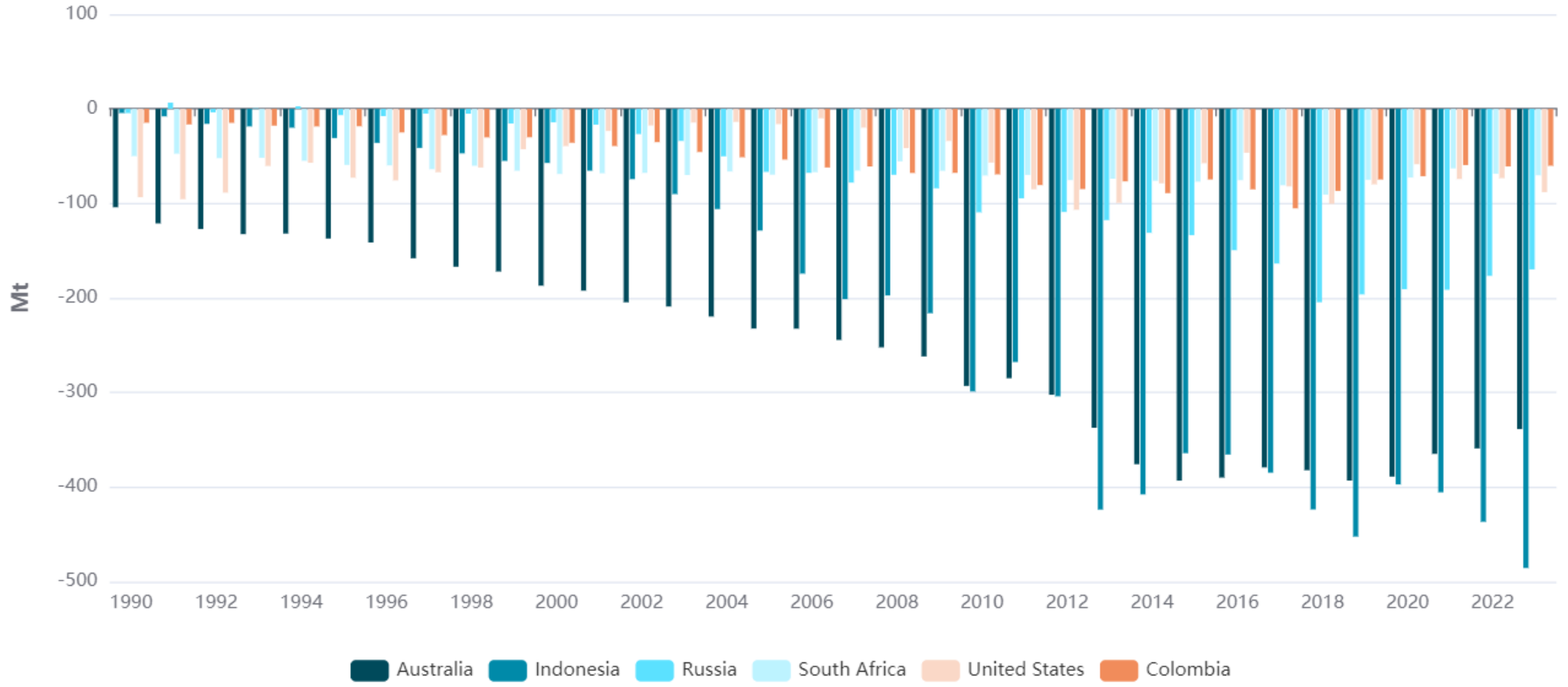
Year : 2023 ◀◀ ▶ Play ▶▶ Picture Unit: Mt Highest



China	463.2
India	222.8
Japan	164.8
South Korea	120.6
Taiwan	58
Vietnam	52.4
Turkiye	41
Malaysia	35.1
Germany	30.9
Thailand	18.1
Brazil	16.8
Mexico	13.2

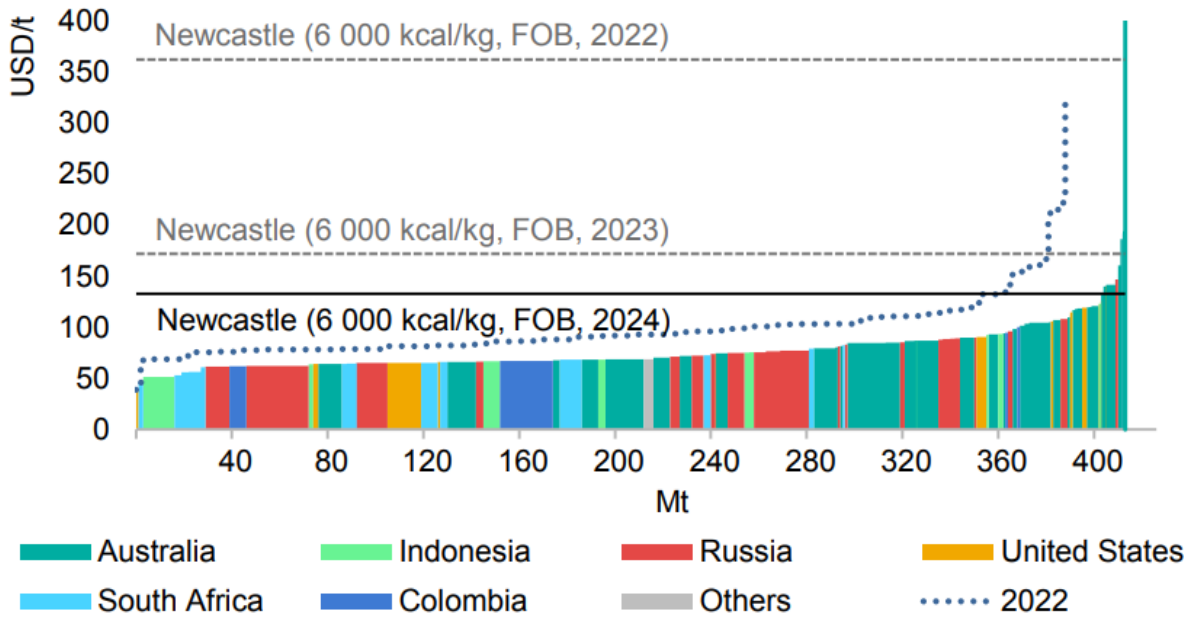
Indonesia	-485.4
Australia	-338.5
Russia	-169.7
United States	-88.1
South Africa	-70.2
Colombia	-60.1
Canada	-32.8
Kazakhstan	-30.8
New Zealand	-1
Azerbaijan	0
Nigeria	0
Portugal	0

Principaux exportateurs

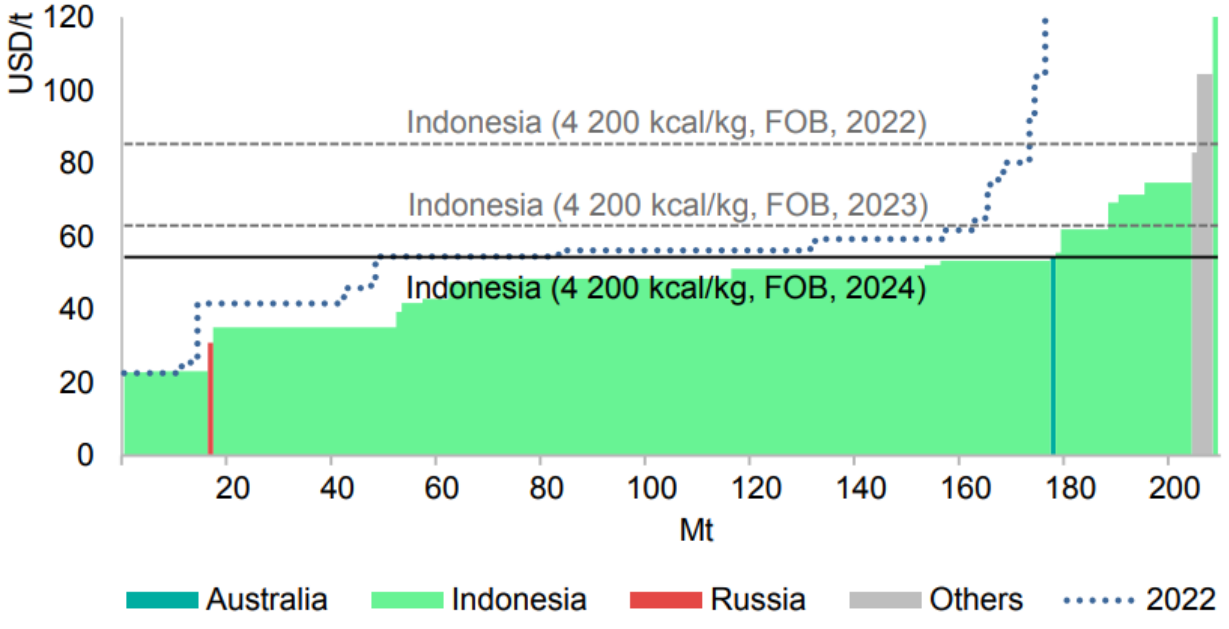


Courbes d’offre

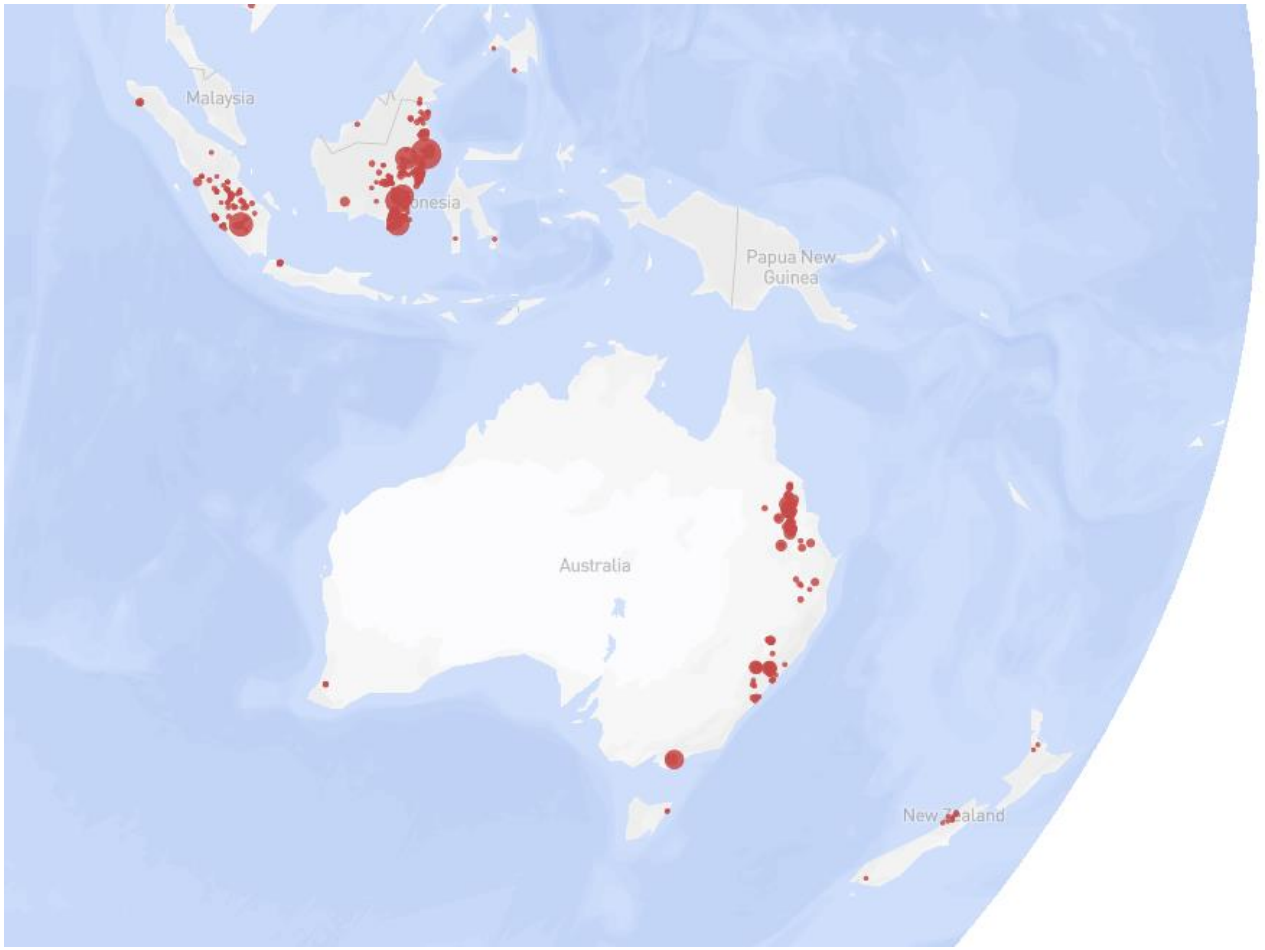
Indicative high-CV (> 5 700 kcal/kg) thermal coal FOB supply curve, 2023, and average FOB price markers, 2022-2024



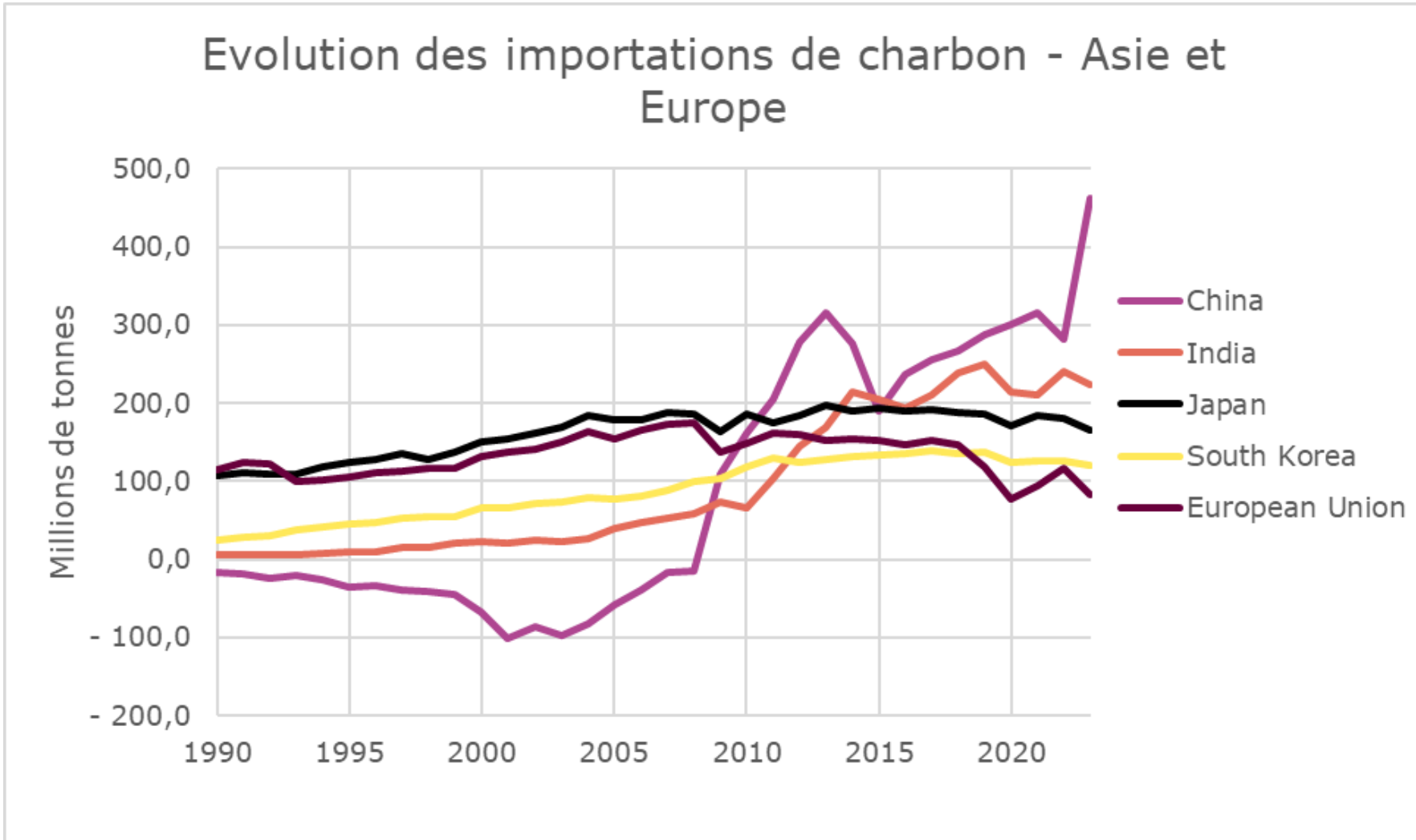
Indicative low-CV (< 4 500 kcal/kg) thermal coal FOB supply curve, 2023, and average FOB price markers, 2022-2024



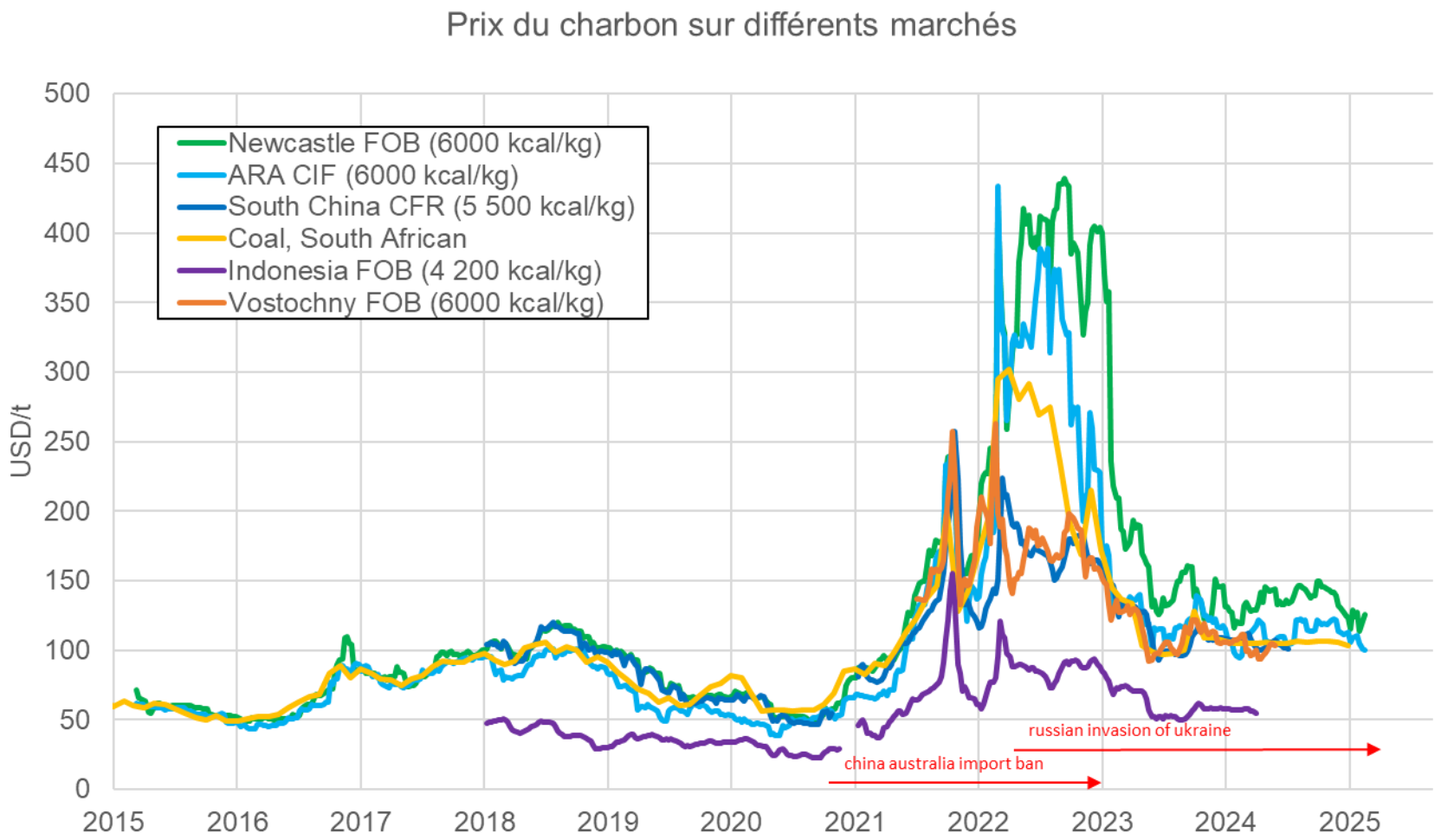
Localisation des mines



Principaux importateurs



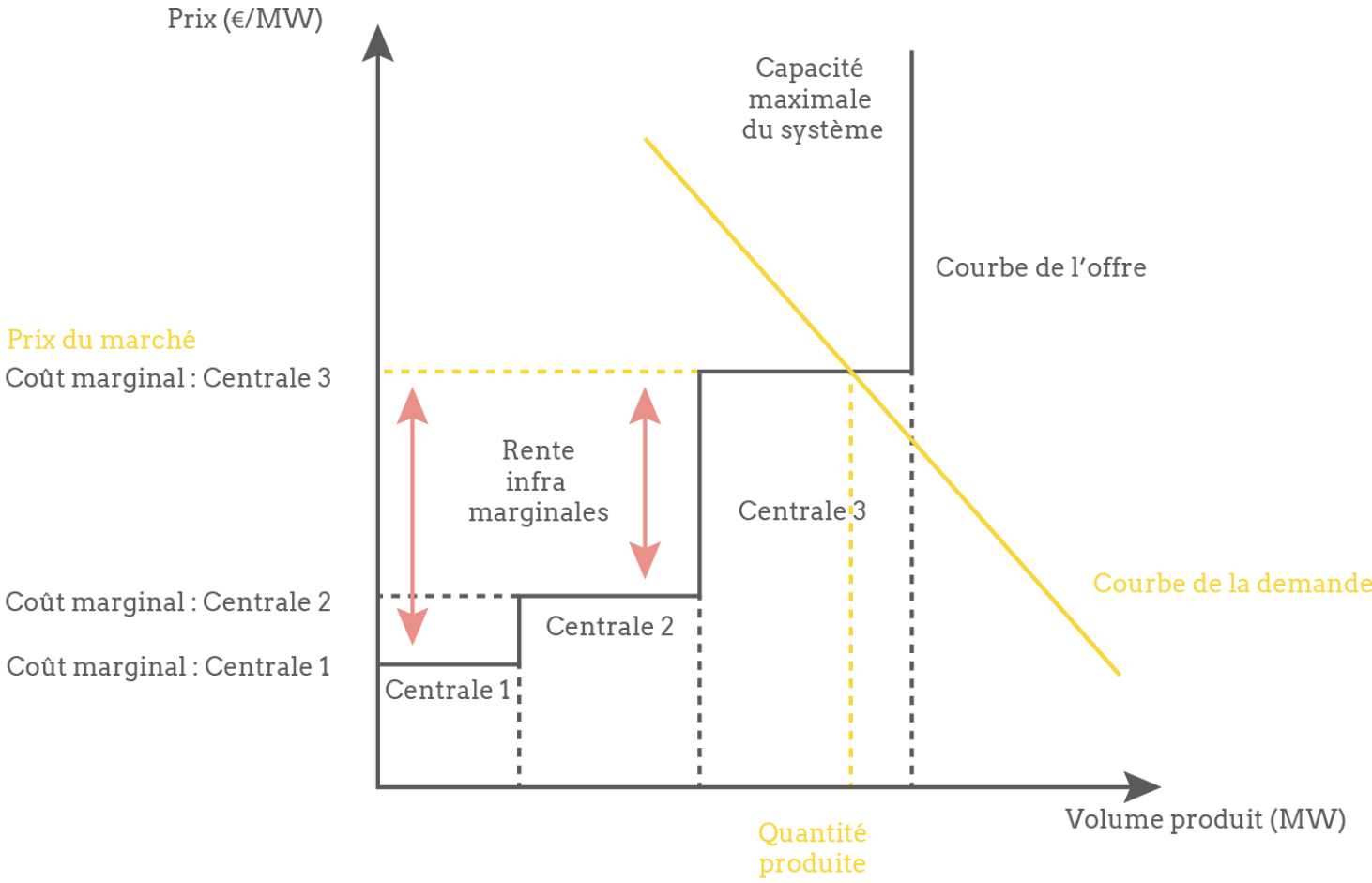
Facteurs coûts conjoncturels



Hugo DUTERNE d'après AIE et Banque mondiale

Tarification au coût marginal

Fixation des prix selon le « merit order »



Facteurs coûts structurels

Table 15 - Coal trade transport costs ($/GJ) between world regions, 2005 [7]

	Africa	Australia-NZ	Canada	China	Central & South America	Eastern Europe	Former Soviet Union	India	Japan	Middle East	Mexico	Other Developing Asia	South Korea	USA	Western Europe
Africa										0.2		0.3			0.3
Australia-NZ				0.2	0.6	0.9		0.3	0.2	0.4		0.1	0.2		0.8
Canada									0.2	0.6		0.3	0.2	0.5	
China									0.1	0.3		0.1	0.0		
Central & South America											0.1			0.1	0.2
Eastern Europe															0.1
Former Sovier Union						0.6			0.7	0.8			0.7		0.7
India															
Japan															
Middle East															
Mexico															
Other Developing Asia				0.1					0.1						0.5
South Korea															
USA			0.5	0.73					0.6	0.5	0.1	0.7	0.7		0.2
Western Europe															

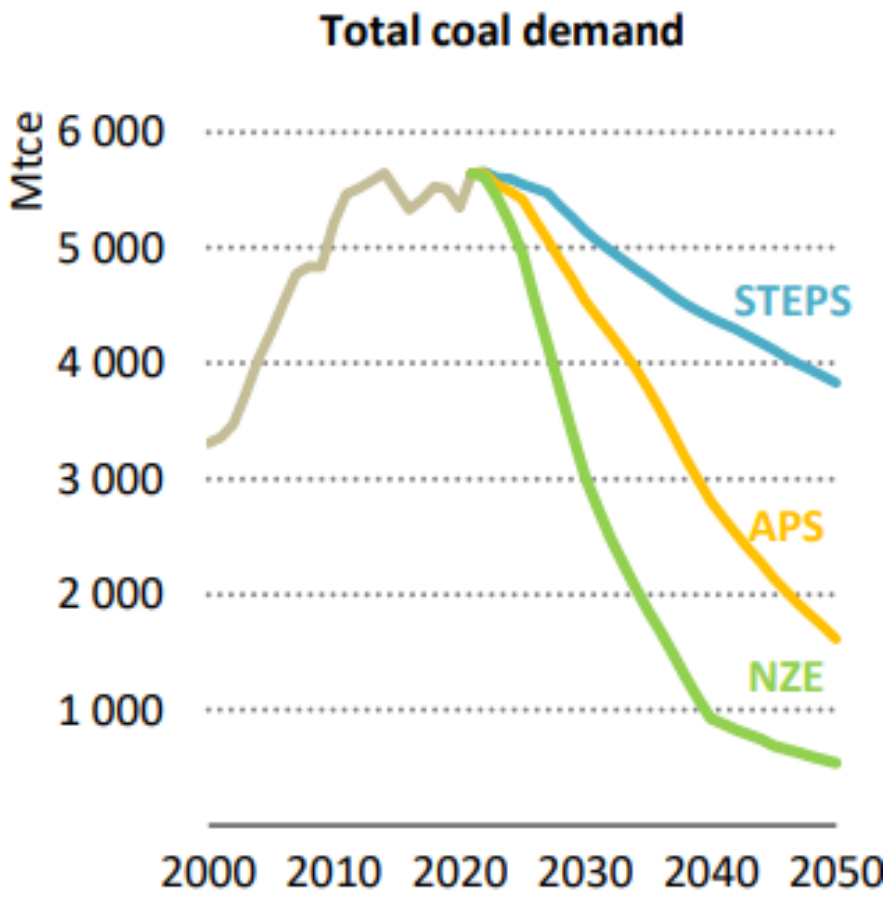
CentraleSupélec

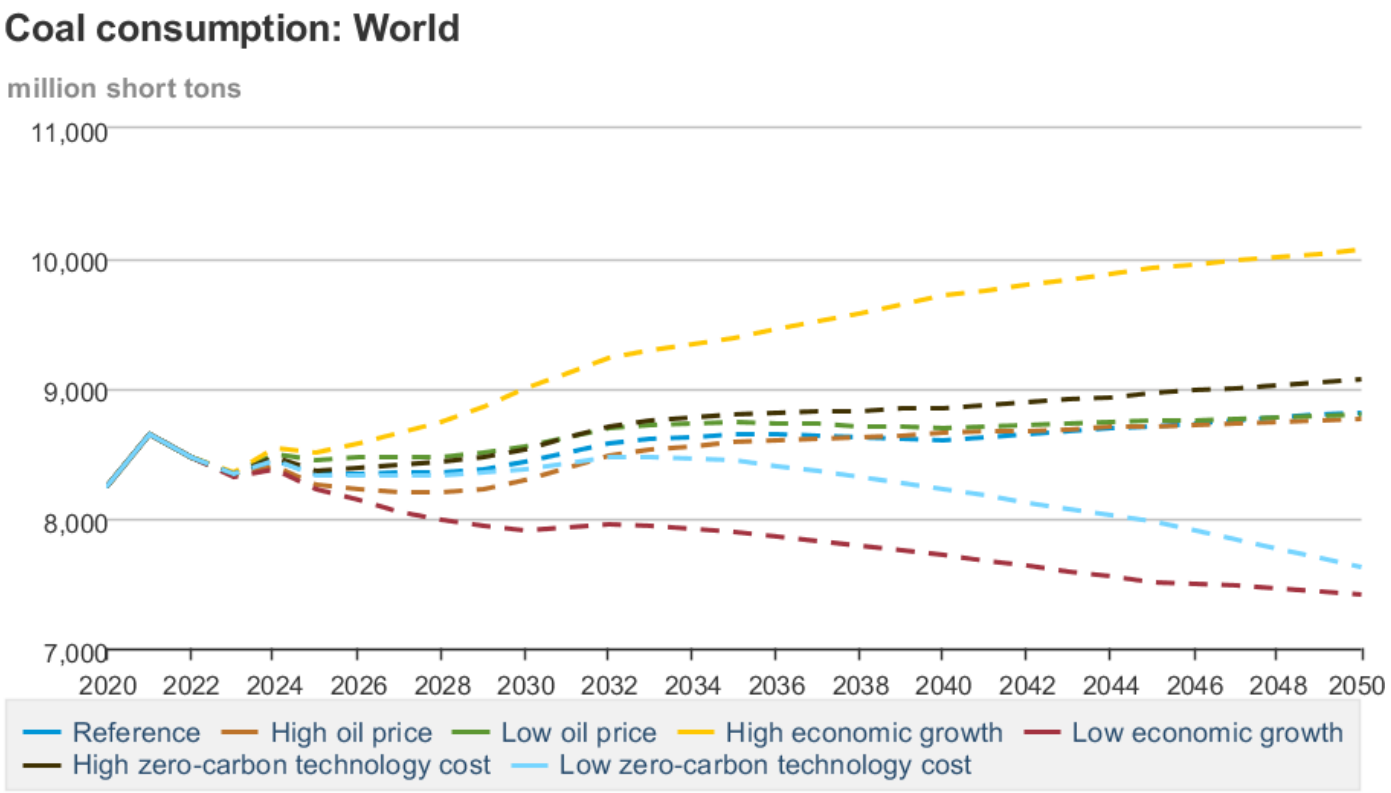
IV. Perspectives

« Celui qui croit qu'une croissance exponentielle peut continuer indéfiniment dans un monde fini est soit un fou, soit un économiste. »

Kenneth E. Boulding, 2008

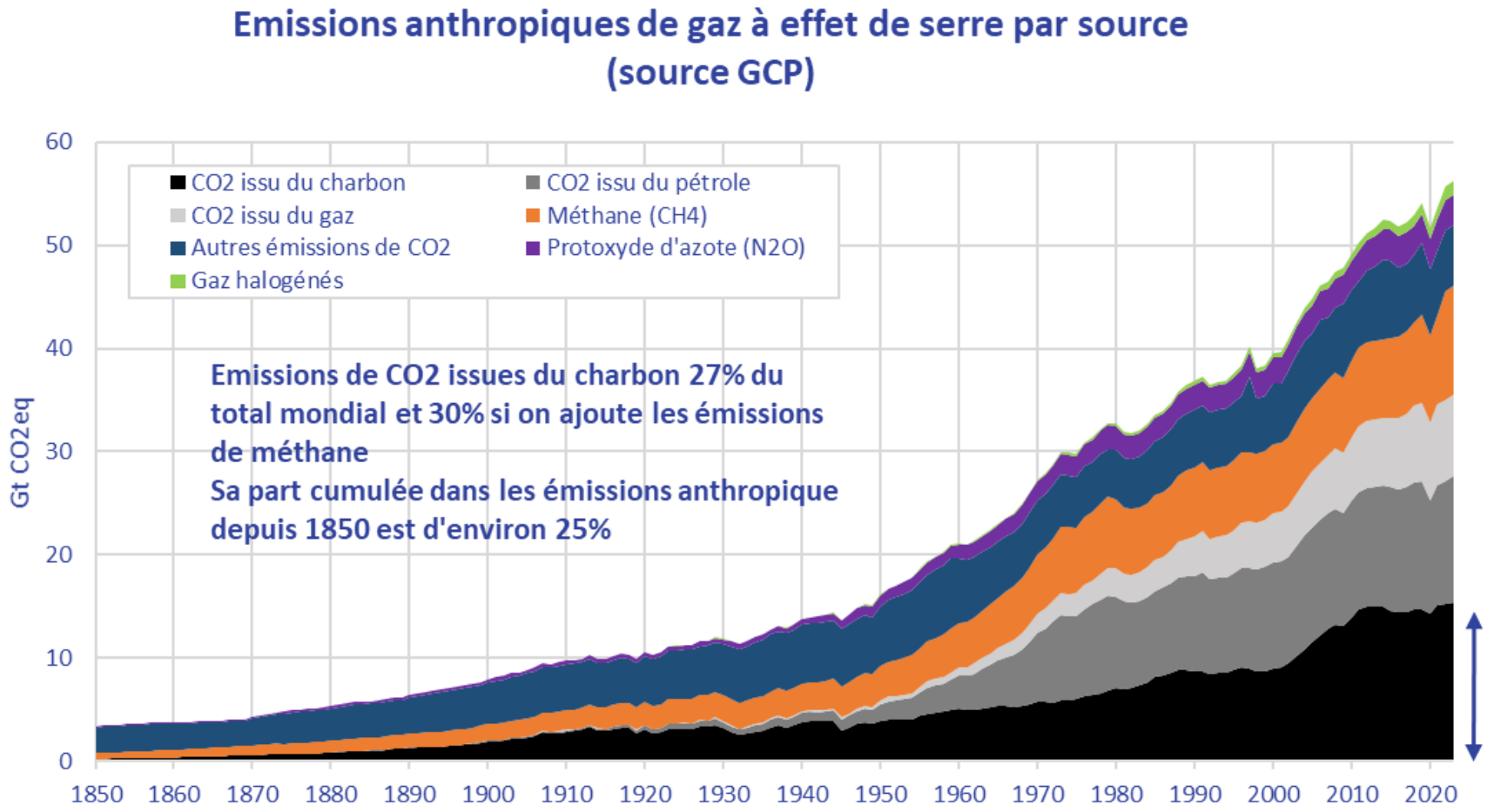
Les scénarios de transition





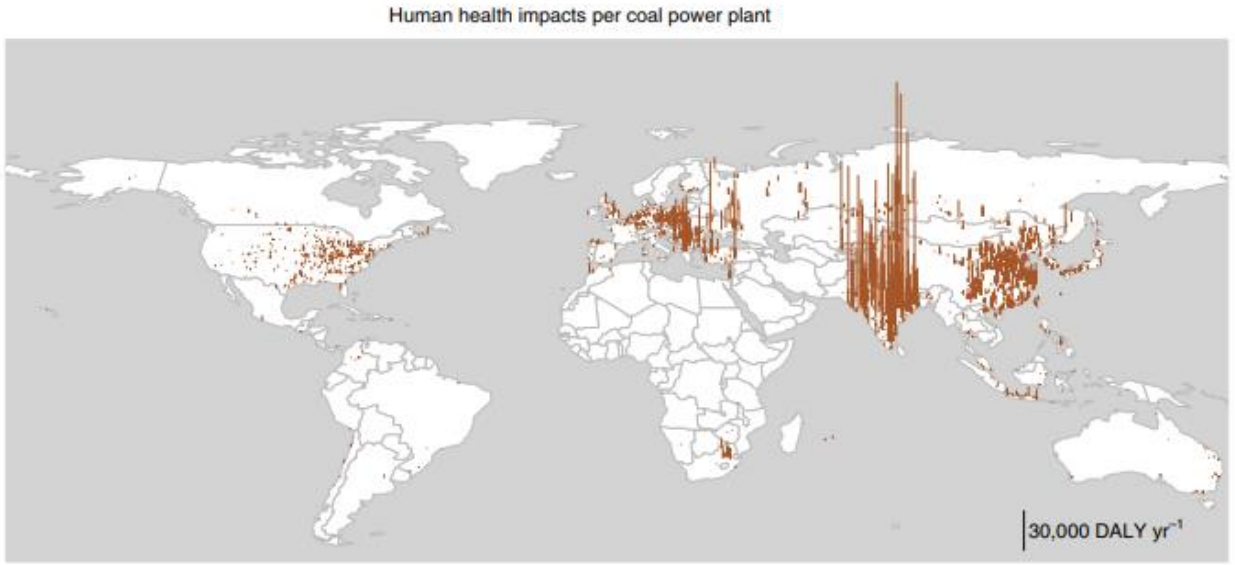
eia Data source: U.S. Energy Information Administration

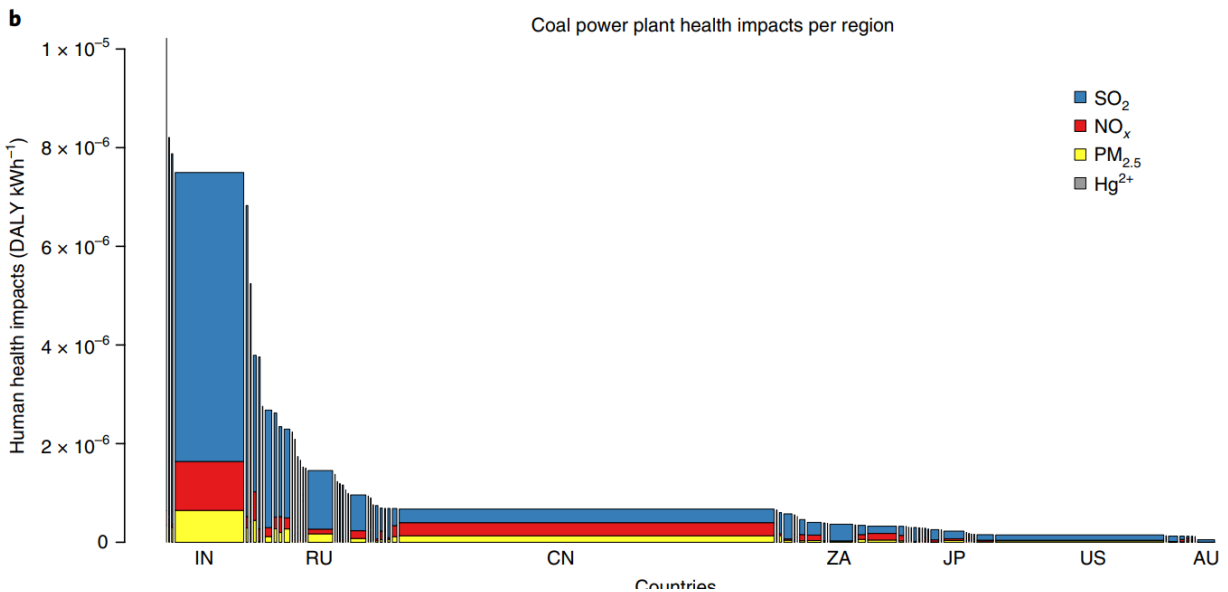
Impact climatique



Hugo DUTERNE

Impact sur la santé publique



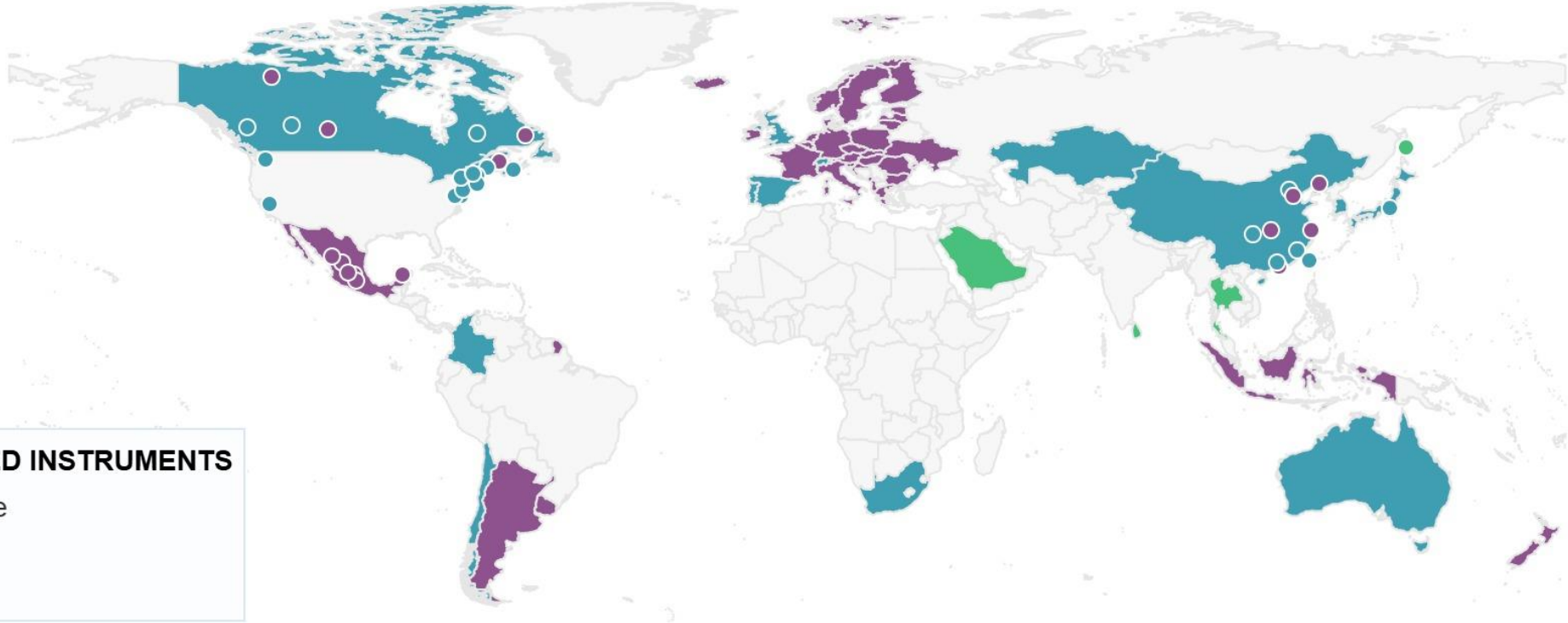


Source :Oberschelp, C., Pfister, S., Raptis, C. E., & Hellweg, S. (2019). Global emission hotspots of coal power generation. Nature Sustainability,

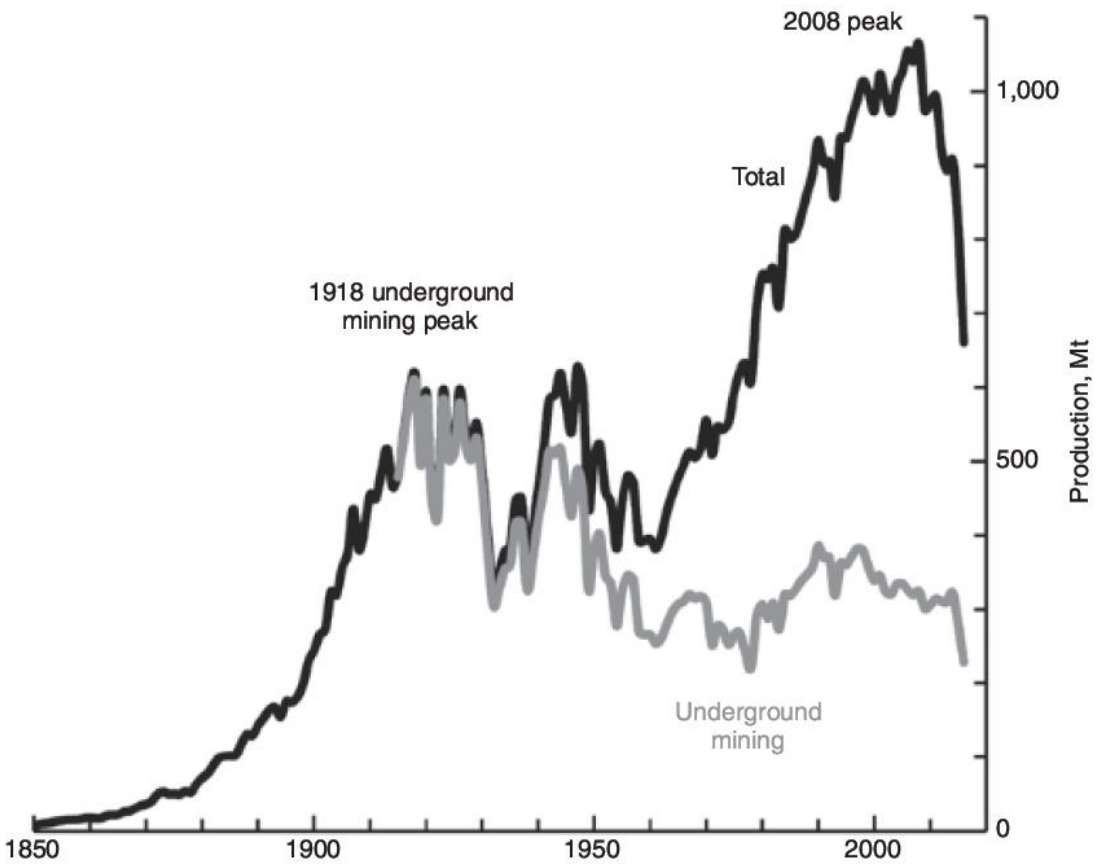
Tarification carbone

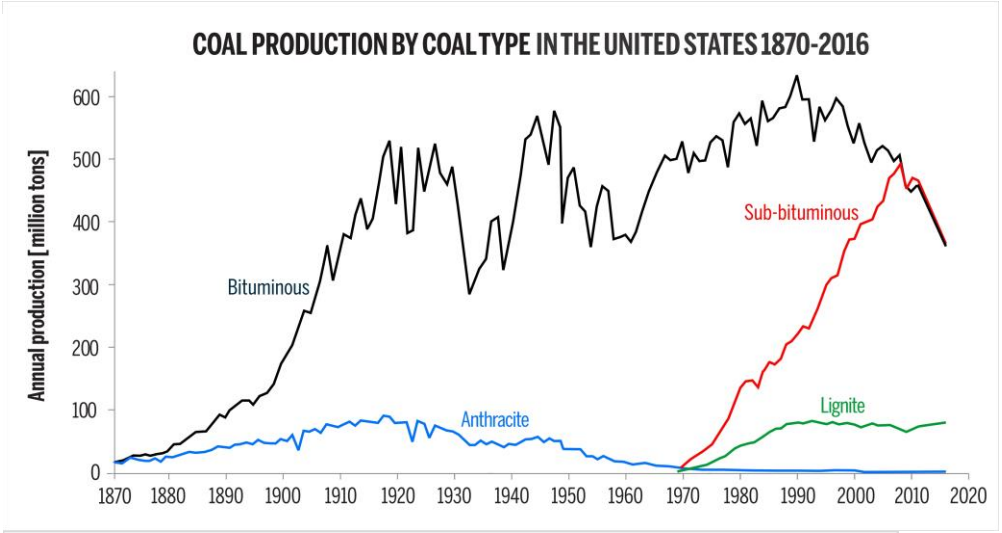
Carbon pricing instruments around the world, 2024

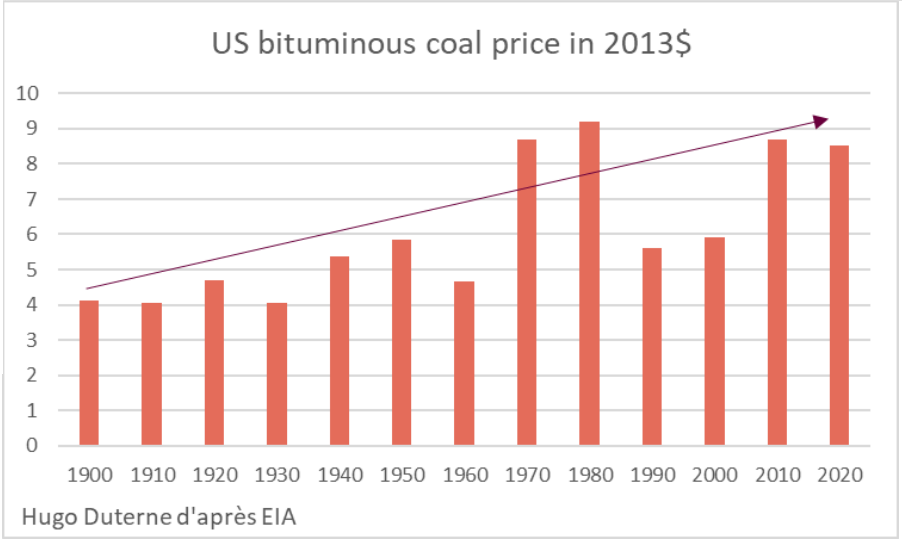
Map shows jurisdictions that have implemented Direct Carbon Pricing Instruments - Compliance instruments (Emissions Trading Systems (ETS) and Carbon taxes) and/or domestic carbon crediting mechanisms, subject to any filters applied. The year can be adjusted using the slider below the map.



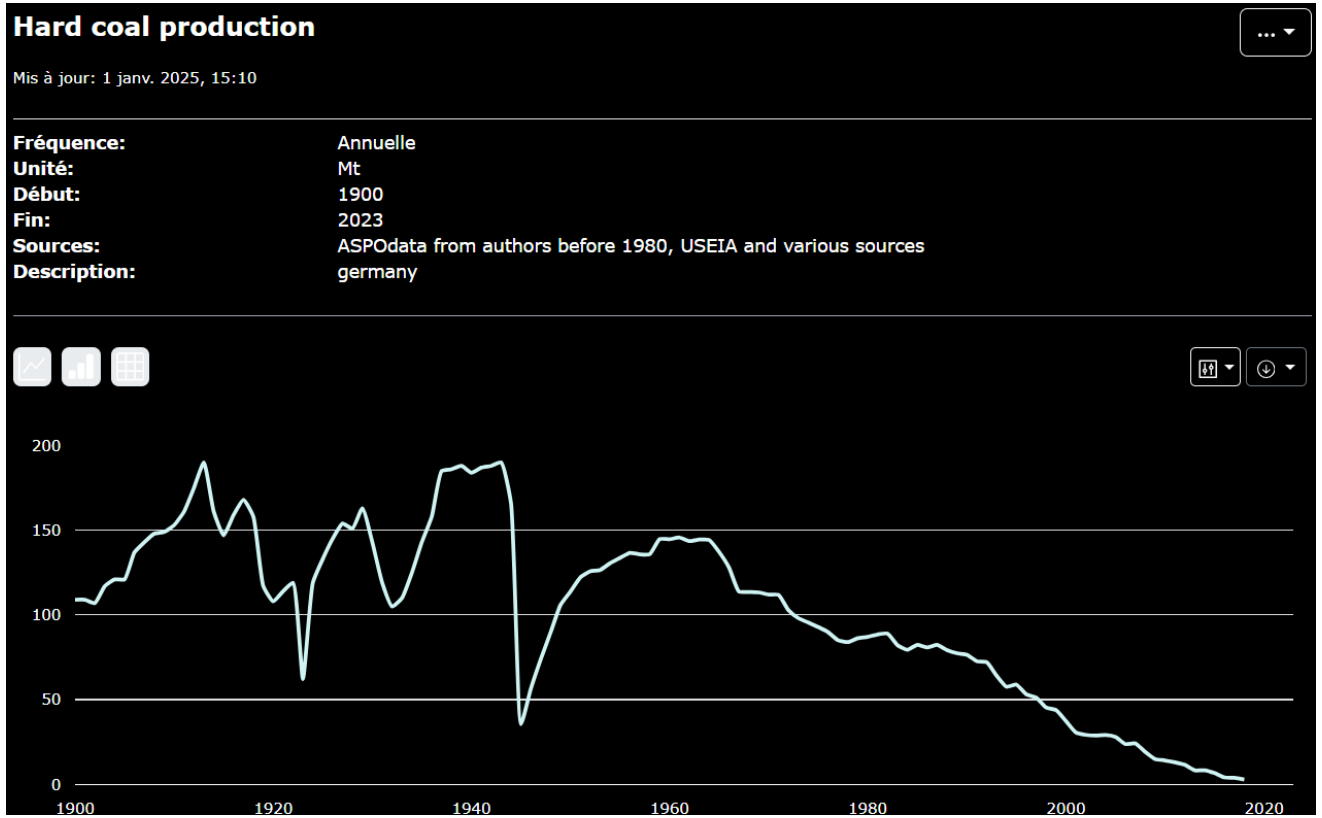
Hausse des coûts dans les zones matures

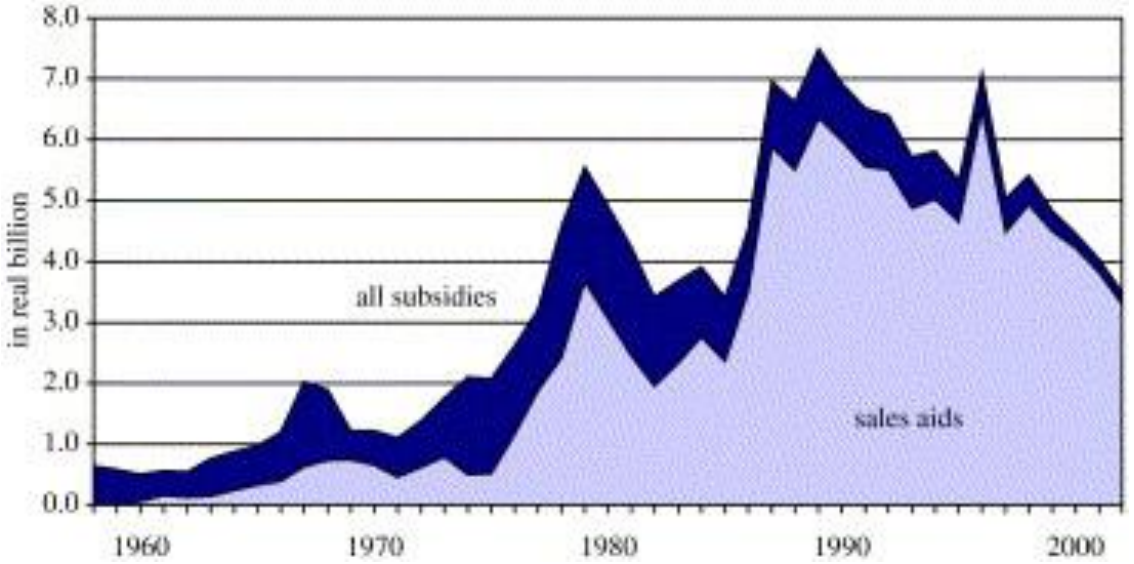






Hausse des coûts dans les zones matures





Hard coal subsidies in Germany 1958–2002

Hausse des coûts dans les zones matures

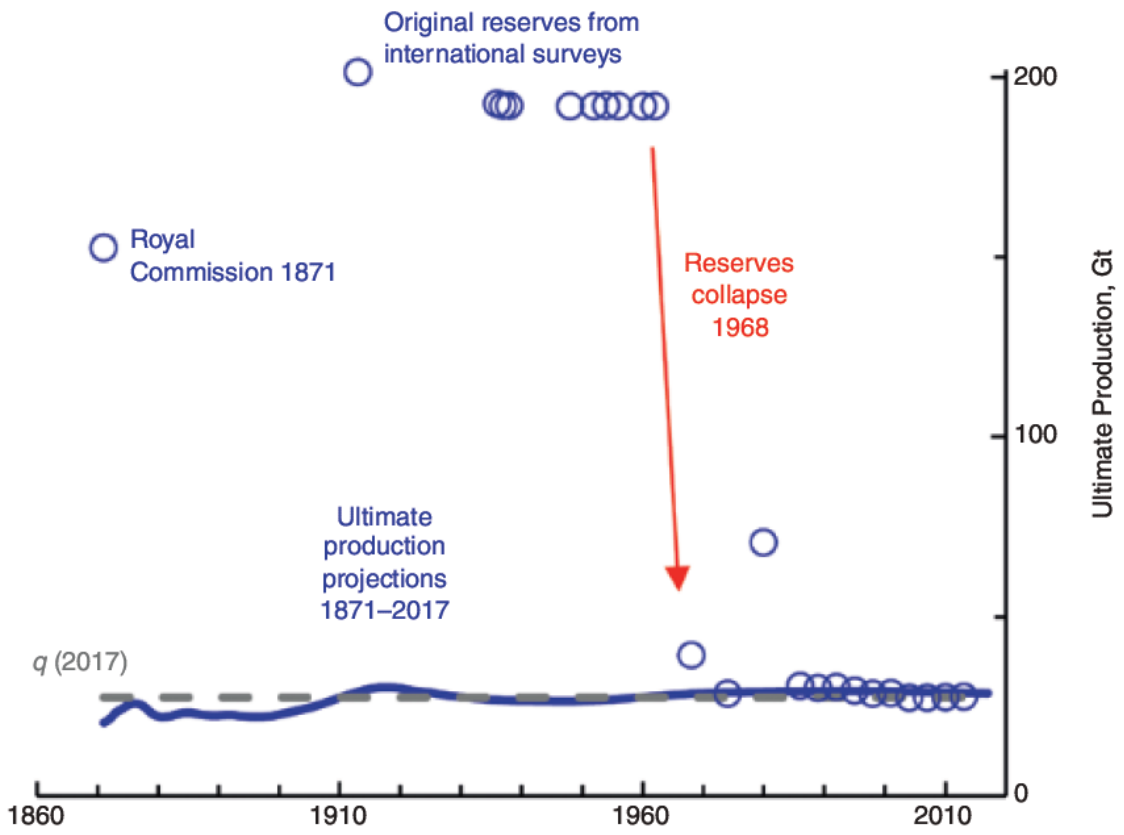


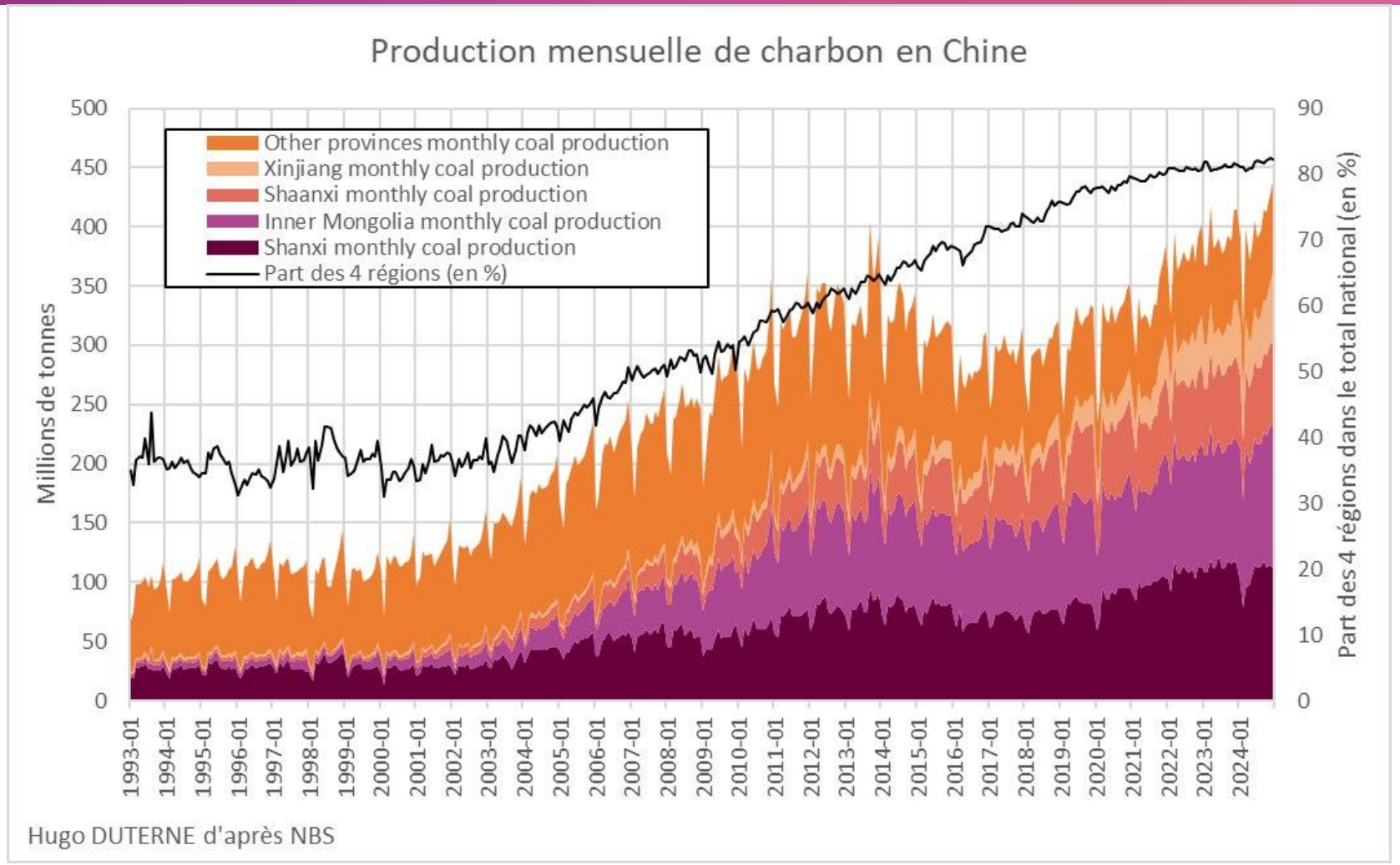
Figure 4.28 Comparing the ultimate production projections with original reserves and the current cumulative production. Reserves from the 12th International Geological Congress, the World Power Conference *Statistical Yearbooks*, and the World Energy Council *Surveys of Energy Resources*.

Table 4.2 Summary of the results for the mature coal regions.

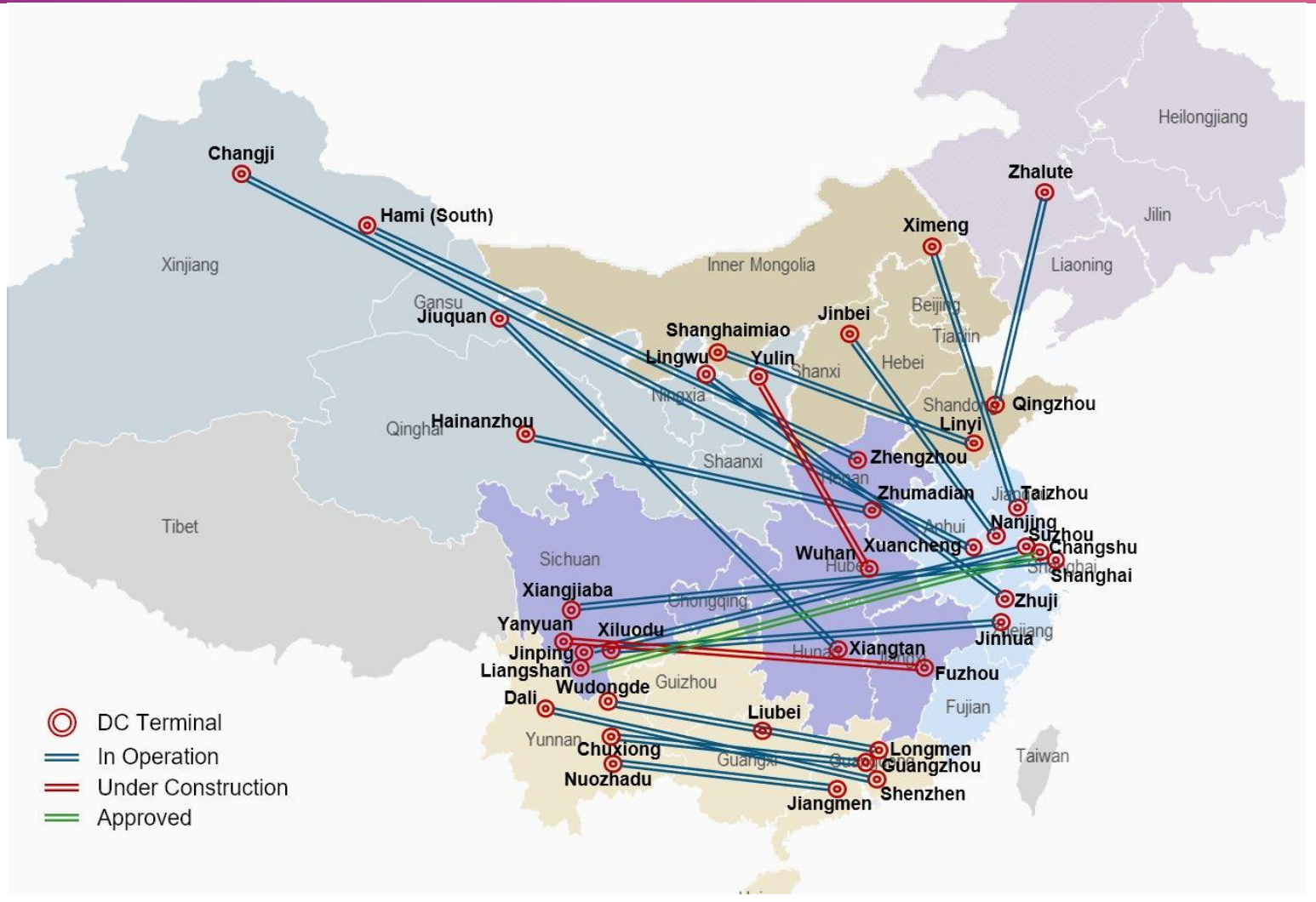
	Ultimate production U, Gt	Ultimate production fraction of original reserves U/R_o (reserves year)	Ultimate production projection range ΔU, Gt (starting year)	% of peak production at t_{90} (t_{90})
United Kingdom	27.5	18% (1871)	20.5–30.3 ±19% (1871)	45% (1973)
German hard coal	12.1	5% (1913)	8.4–12.5 ±20% (1946)	53% (1985)
France and Belgium	7.2	23% (1913)	4.3–8.5 ±33% (1900)	58% (1970)
Pennsylvania anthracite	5.0	42% (1921)	3.1–5.1 ±24% (1900)	41% (1952)
Japan and South Korea	3.6	21% (1936)	2.6–4.0 ±20% (1946)	63% (1986)
Median percentages	na	21%	±20%	53%

Fin du cycle ou nouveau cycle ?

Modernisation de l’extraction



Réseau UHVDC en Chine



CentraleSupélec

MASTER MANAGEMENT MARCHÉS DE L'ENERGIE - SÉMINAIRE CHARBON

Fondamentaux, passé et perspectives

21 janvier 2026