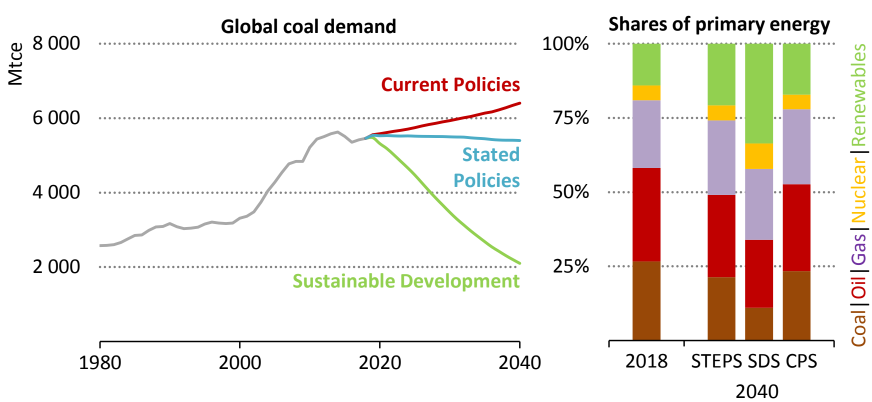
Outlook for coal

It is not just about power

SUMMARY

- Global coal demand increased for the second straight year in 2018, driven by strong electricity demand in developing Asian countries. This gradually rising trajectory is maintained in the Current Policies Scenario, but in the Stated Policies Scenario, demand is essentially flat, ending up in 2040 at around 5 400 million tonnes of coal equivalent (Mtce). Declines in China (-9%), United States (-40%) and European Union (-73%) are offset by rising demand in India (+97%) and Southeast Asia (+90%). Overall, coal use in power generation decreases and its industrial use expands.
- In the Sustainable Development Scenario, coal consumption falls steeply as a result of much more stringent environmental policies across the board. By 2040, unabated coal use comes under intense pressure, and global coal use is 60% lower than in the Stated Policies Scenario. As a result, coal's share in the primary energy mix falls towards 10% (Figure 5.1).

Figure 5.1 ▷ Global coal demand by scenario



Coal's future is heavily dependent on the breadth and stringency of environmental policies across the world

Note: Mtce = million tonnes of coal equivalent; STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario; CPS = Current Policies Scenario.

- In many advanced economies, coal demand for power in the Stated Policies Scenario is in deep structural decline, hastened by specific phase-out commitments in some countries, the continued rise of renewables, competition from natural gas in the United States and higher carbon dioxide (CO_2) prices in the European Union. Coal demand drops too in China – by far the world's largest coal consumer – due in large part to a strong policy push to improve air quality. However, in other parts of developing Asia countries look to increase their use of coal to satisfy fast-rising demand for electricity and for industrial development.

- The main source of coal production growth in the Stated Policies Scenario is India, which doubles its production by 2040 on the strength of government production targets and efforts to reduce supply chain bottlenecks. The additional supply, however, is not enough to meet growing domestic demand, and India overtakes China by the mid-2020s to become the world's largest coal importer.
- Industrial coal use which today accounts for around one-third of consumption, increases by some 225 Mtce over the period in the Stated Policies Scenario: coal remains the backbone of the iron and steel, and cement sub-sectors and its use in the chemicals sub-sector keeps rising, particularly in China. In the Sustainable Development Scenario, overall use drops significantly, but coal remains important to several industrial processes, reflecting the difficulty and expense of finding substitutes for coal in these processes.
- A crucial variable in the Sustainable Development Scenario, and for the future of coal, is the extent to which carbon capture, utilisation and storage (CCUS) technologies are deployed in power generation and industry. In the industry sector, CCUS can provide a cost-competitive decarbonisation option for key industrial processes. The current pipeline of projects however is far short of what is required under this scenario to abate emissions from key industrial sectors of the economy.
- Global investment in coal supply today stands at about $80 billion per year, half the level reached at the 2012 peak. In the Stated Policies Scenario, nearly $1 135 billion is spent over the projection period, although investment sees a gradual, broad-based decline, resulting in an annual average of $50 billion to 2040.
- Financing restrictions from an increasing number of lenders add to the headwinds facing coal supply projects. This is not yet an issue affecting projects in China and India, which are the main countries investing in coal in the Stated Policies Scenario. But projects elsewhere that cannot be financed from the balance sheets of larger companies could struggle to move ahead. Among exporters this could provide an opening for Russian producers to increase market share.
- Discussions of energy-related methane emissions have focused on oil and natural gas operations, but coal mining also releases methane. We estimate that global emissions of coal mine methane (CMM), the methane naturally contained in coal seams, were around 40 million tonnes in 2018, equal to around 1 200 million tonnes of CO_2-equivalent (Mt CO_2-eq). The concentration of CMM is often low and can fluctuate in quality and quantity, making it technically and economically difficult to abate. More active regulatory regimes are needed to incentivise operators to install CMM abatement technologies where technically possible.

Introduction

Global coal use in 2018 rose for the second straight year, although it remained some 160 million tonnes of coal equivalent (Mtce) below the level of the peak in 2014. A shift in consumption towards Asia was again visible, as coal use rose in China, India, Indonesia and some other countries in South and Southeast Asia. Demand for electricity in Asia has continued to grow and coal remains by some distance the largest source of electricity generated in Asia, and among the cheapest.

Meanwhile coal is being steadily squeezed out of the energy mix in many advanced economies by a mixture of environmental policies and competitive pressures from increasingly cost-competitive renewables and, in some markets, also from natural gas. The United Kingdom, whose industrial revolution was built on coal, now goes for extended periods without any coal-fired power. Germany, a stronghold of coal demand in Europe, plans to phase out coal by 2038, and the latest data show coal-fired power generation falling sharply in 2019.

In our projections, there is a stark variation in the coal outlook between the Stated Policies Scenario, in which coal demand is essentially flat, and the Sustainable Development Scenario, in which it falls rapidly. A major consideration in this *Outlook* is that coal plays a central role in much of Asia, given a large coal supply industry and the young average age of the coal-fired fleet (see Chapter 6). Large-scale deployment of CCUS technologies could yet allow for a distinction to be made between coal use and the emissions from its combustion, and this is an important feature of the Sustainable Development Scenario, alongside a significant reduction in overall coal demand.

This chapter delves into three aspects of this complex picture in more detail:

- The future of coal is often seen as synonymous with the future of power generation, but around one-third of coal is used outside the power sector, mostly in industry. We explore the dynamics of industrial coal use, the scope for finding substitutes for coal across the main industrial sub-sectors, the outlook for industrial coal use in China, and the role of CCUS in reducing coal-related industrial emissions.
- Access to finance for new coal investment is becoming constrained, as an increasing number of banks and other financial institutions announce that they will no longer support any coal-related investment. We take stock of this move away from coal financing and ask what impact it might have on coal supply.
- The issue of methane emissions from oil and natural gas operations has received more attention so far than the extent and nature of methane emissions in coal supply. We provide new estimates of methane released during mining operations, describe the abatement possibilities and examine the implications for lifecycle emissions comparisons of coal versus natural gas.

Figures and tables from this chapter may be downloaded from www.iea.org/weo2019/secure/.

Scenarios

5.1 Overview

Coal demand is essentially flat in the **Stated Policies Scenario**, ending up in 2040 at around 5 400 Mtce, some 60 Mtce below where it is today (Table 5.1). This represents a slight downward revision compared with the *World Energy Outlook (WEO)-2018* (IEA, 2018). Flat demand in an expanding energy system means that the share of coal in the global energy mix declines from 27% in 2018 to 21% in 2040, falling behind natural gas in the process.

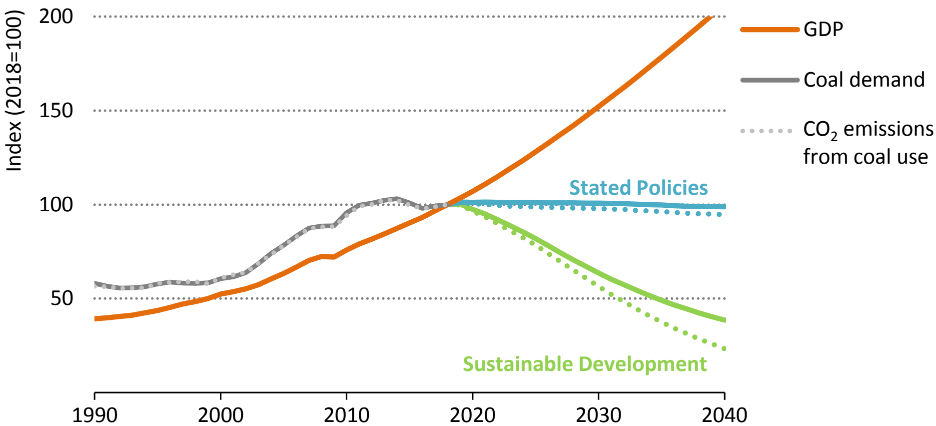
The strength of the economic and policy headwinds facing coal vary widely by scenario and, within each scenario, across different countries and sectors. The net effect in the Stated Policies Scenario is that global coal use in power generation decreases slightly, while its industrial use grows modestly. The **Current Policies Scenario**, in which energy demand is stronger and policy pressure on coal is weaker, sees coal use rise in both areas.

Table 5.1 ▷ Global coal demand, production and trade by scenario (Mtce)

			Stated Policies		Sustainable Development		Current Policies	
	2000	2018	2030	2040	2030	2040	2030	2040
Power	2 233	3 500	3 470	3 395	1 872	858	3 789	4 156
Industrial use	869	1 680	1 852	1 903	1 461	1 206	1 926	2 075
Other sectors	207	279	175	100	137	36	220	168
World coal demand	**3 309**	**5 458**	**5 498**	**5 398**	**3 471**	**2 101**	**5 934**	**6 399**
Asia Pacific share	*47%*	*75%*	*81%*	*83%*	*86%*	*84%*	*79%*	*81%*
Steam coal	2 504	4 342	4 393	4 394	2 672	1 515	4 753	5 266
Coking coal	449	955	857	790	676	497	885	854
Lignite and peat	302	270	247	214	123	89	297	280
World coal production	**3 255**	**5 566**	**5 498**	**5 398**	**3 471**	**2 101**	**5 934**	**6 399**
Asia Pacific share	*48%*	*73%*	*78%*	*79%*	*80%*	*83%*	*77%*	*78%*
Steam coal	310	859	733	726	381	197	888	964
Coking coal	175	319	314	371	258	247	332	404
World coal trade	**471**	**1 169**	**1 039**	**1 087**	**633**	**413**	**1 206**	**1 355**
Trade as share of production	*14%*	*21%*	*19%*	*20%*	*18%*	*20%*	*20%*	*21%*
Coastal China steam coal price ($2018/tonne adjusted to 6 000 kcal/kg)	**34**	**106**	**89**	**92**	**74**	**76**	**98**	**105**

Notes: Mtce = million tonnes of coal equivalent; kcal/kg = kilocalories per kilogramme. Unless otherwise stated, industrial use in this chapter reflects volumes also consumed in own use and transformation in blast furnaces and coke ovens, petrochemical feedstocks, coal-to-liquids and coal-to-gas plants. Historical supply and demand volumes differ due to changes in stocks. World trade reflects volumes traded between regions modelled in the *WEO* and therefore does not include intra-regional trade. See Annex C for definitions.

Figure 5.2 ▷ Growth in global GDP, coal demand and related CO_2 emissions by scenario



Coal demand has now decoupled from global GDP, largely due to changes in China; the relationship between future demand and emissions depends mainly on CCUS

Notes: GDP = gross domestic product. The divergence in decline rates for coal demand and CO_2 emissions from coal use over the period stems from efficiency gains and the uptake of CCUS.

The outlook for coal is very different in the **Sustainable Development Scenario**. With a much more stringent focus on reducing emissions, coal use decreases steeply at an annual rate of 4.2%. By 2040, world coal use is 60% lower than in the Stated Policies Scenario and coal's share in the primary energy mix falls towards 10%.

Until the early 2010s, coal demand was aligned with economic growth. That is not the case in the future in either the Stated Policies or Sustainable Development scenarios (Figure 5.2). In advanced economies, e.g. European Union, United States and Japan, the trend in coal demand becomes detached from the overall economic outlook. By contrast, strong growth in incomes and energy needs in parts of developing Asia continues to go hand-in-hand with higher coal demand. China's position moves progressively closer to that of the advanced economy group, exerting a strong influence on the global decoupling of coal demand from economic growth.

With coal demand growth levelling off, CO_2 emissions from coal combustion flatten in the Stated Policies Scenario, but they do not reduce significantly. In the Sustainable Development Scenario, the deployment of CCUS and improvements in plant efficiencies result in coal-related CO_2 emissions falling faster than coal demand. By 2040, almost 160 gigawatts (GW) of coal-fired plants are equipped with CCUS, accounting for 40% of the electricity generated from coal, although today's policies fall far short of those which could stimulate needed investment in CCUS.

5.2 *Coal demand by region and sector*

The flat outlook worldwide for coal demand in the Stated Policies Scenario masks significant contrasts between regions (Table 5.2).

In the United States, coal demand reached a 39-year low in 2018 and continues to fall over the outlook period, as coal-to-gas switching continues in the power sector.

In a growing number of other **advanced economies**, such as Canada, Germany and United Kingdom, demand has decreased and continues to do so over the period to 2040, reflecting the policy drive to reduce CO_2 emissions.

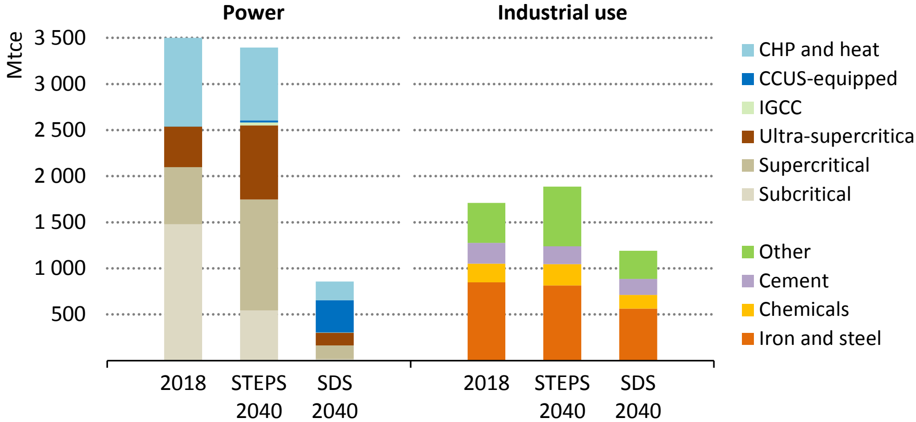
China sees a modest reduction in consumption of 0.4% per year on average from 2018 to 2040, while remaining, by some way, the largest consumer of coal worldwide. The outlook for coal use in China from year to year remains contingent on prevailing policy preferences and economic conditions. Final investment decisions for new coal-fired plants fell from 60 GW in 2015 to less than 6 GW in 2018 when, for the first time, more gas-fired power was approved than coal. However, China has a stock of more than 1 000 GW of coal-fired capacity, much of it recently commissioned and highly efficient (see Chapter 6).

Table 5.2 ▹ Coal demand by region and scenario (Mtce)

			Stated Policies				Sustainable Development	
	2000	2018	2025	2030	2035	2040	2030	2040
North America	818	492	369	328	304	285	81	50
United States	763	451	350	314	291	272	71	41
Central and South America	29	46	48	47	47	49	30	23
Brazil	19	24	23	23	23	23	14	12
Europe	578	447	314	263	219	203	129	84
European Union	459	319	204	157	113	87	84	59
Africa	129	159	165	160	160	161	113	92
South Africa	117	142	133	117	107	97	92	56
Middle East	2	6	9	10	12	14	7	6
Eurasia	202	229	225	212	203	199	136	74
Russia	171	166	160	144	136	129	88	50
Asia Pacific	1 551	4 079	4 385	4 476	4 502	4 487	2 976	1 771
China	955	2 834	2 934	2 845	2 710	2 568	2 065	1 154
India	208	586	771	938	1 063	1 157	546	395
Indonesia	17	72	97	114	130	148	67	39
Japan	139	165	141	124	115	107	70	43
Rest of Southeast Asia	28	132	172	194	219	241	91	38
World	**3 309**	**5 458**	**5 515**	**5 498**	**5 446**	**5 398**	**3 471**	**2 101**

Note: See Annex C for definitions.

Figure 5.3 ▷ Global coal demand by key sector and scenario



In the Sustainable Development Scenario, coal demand for unabated coal-fired power in 2040 is 90% lower than today. Industrial demand decreases across the sectors.

Notes: CCUS = carbon capture, utilisation and storage; IGCC = integrated gasification combined-cycle; CHP = combined heat and power; STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario.

Coal demand remains strong across much of **developing Asia**. India sees the largest increase, although the 3.5% annual rate of growth observed over the past five years is dampened by a large-scale expansion of renewables and the use of supercritical and ultra-supercritical technologies in new plants. Consumption also increases in Southeast Asia, notably in Indonesia: 40% of the projected rise in the region's electricity demand is met by coal.

Almost 65% of global coal demand today comes from the **power sector** (Figure 5.3). In the Stated Policies Scenario, slightly less coal is used in the power sector in 2040 than today (down 105 Mtce), but this generates slightly more electricity (up 305 terawatt-hours [TWh]) because more efficient technologies are deployed while old plants are retired: the average efficiency of coal-fired generation improves from 42% today to 43% in 2040.

Industrial coal use is a growth area for demand in some regions. The 225 Mtce growth in this sector in the Stated Policies Scenario is underpinned by the less energy-intensive industrial sub-sectors, and by the use of coal as a feedstock for coal-to-gas and coal-to-liquids projects, particularly in China (see section 5.6).

In the Sustainable Development Scenario, coal demand decreases across the majority of sectors. Coal-fired power drops to 6% of total generation, but industrial demand is more resilient because the substitution possibilities are more limited for some industrial processes than for power (see Chapter 6). The availability of CCUS at scale becomes a crucial variable in this scenario. CCUS and hydrogen are important tools to address emission abatement in industry (Box 5.1).

5.3 Coal production by region

Table 5.3 ▷ Coal production by region in the Stated Policies Scenario (Mtce)

							2018-2040	
	2000	2018	2025	2030	2035	2040	Change	CAAGR
North America	824	576	432	385	358	329	-247	-2.5%
United States	767	526	399	358	333	302	-223	-2.5%
Central and South America	48	82	75	75	62	62	-20	-1.3%
Colombia	36	77	70	70	58	58	-19	-1.3%
Europe	397	230	174	131	105	80	-150	-4.7%
European Union	307	163	117	79	57	30	-134	-7.5%
Africa	187	225	217	199	210	221	-4	-0.1%
South Africa	181	209	198	174	176	173	-37	-0.9%
Middle East	1	1	2	2	2	2	0	0.7%
Eurasia	234	414	408	409	415	424	10	0.1%
Russia	184	338	330	330	341	350	11	0.2%
Asia Pacific	1 564	4 039	4 208	4 297	4 295	4 282	243	0.3%
Australia	235	411	386	402	426	453	42	0.5%
China	1 019	2 668	2 751	2 710	2 589	2 481	-188	-0.3%
India	187	415	558	681	773	844	429	3.3%
Indonesia	65	416	380	367	368	359	-57	-0.7%
World	**3 255**	**5 566**	**5 515**	**5 498**	**5 446**	**5 398**	**-168**	**-0.1%**
Sustainable Development			4 473	3 471	2 682	2 101	-3 466	-4.3%

Notes: CAAGR = compound average annual growth rate. See Annex C for definitions.

China continues to be the largest coal producer over the projection period but, after a slight increase in the 2020s, the Stated Policies Scenario sees a gradual decline in output (Table 5.3). Authorities in China have been actively engaged in a programme of restructuring that has seen the closure of small, less efficient mines, but the expansion of capacity in the west of China has more than offset these closures.

India's production grows by 3.3% per year, reflecting the ambitious output targets set by the authorities (mainly for Coal India Limited, which accounts for around 80% of the country's output), together with efforts to reduce bottlenecks in the rail transportation network and overhaul the coal allocation system to increase the reliability of deliveries to consumers. Steam coal accounts for 90% of output and almost all the output growth. India's share in global production increases from 7% today to 16% in 2040 (Figure 5.4).

Russia has some of the lowest mining costs in the world, but output has to be transported over long distances from coal mining regions to ports. Transport costs are diluted by subsidies, but the share of transport in delivered costs is still higher than for most other producers. Russia has been investing in new mining capacity and infrastructure with a view to expanding exports to Asia. In our projections, coal production increases slightly from 338 Mtce in 2018 to 350 Mtce in 2040, while exports rise from 166 Mtce to around 220 Mtce.

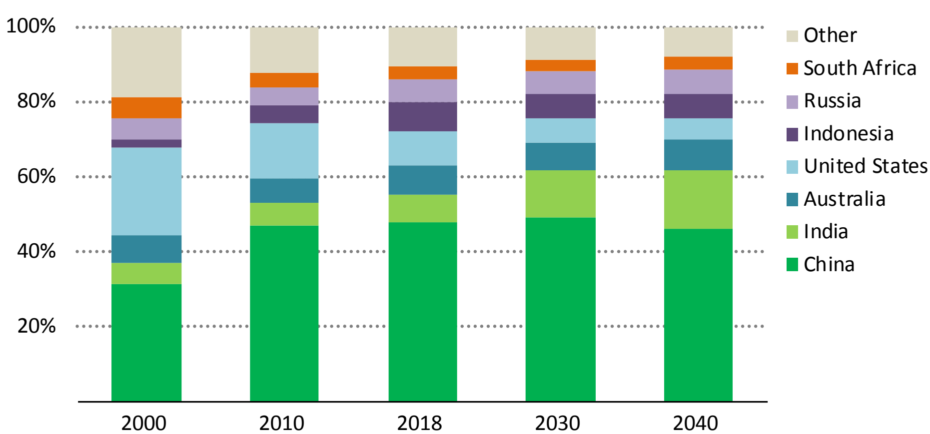
After an uptick in 2017, coal production in the **United States** declined slightly in 2018 as higher exports were offset by falling domestic demand. In our projections, the decline in output continues through the period. Coal production of 305 Mtce in 2040 is less than 40% of the peak level reached in 2008. Weakening demand in the power sector and shrinking export markets, especially for steam coal in Europe, lead to additional falls in US output.

In the **European Union**, near-term hard coal production remains steady in Poland and lignite production continues in Germany, Czech Republic and other Eastern European countries. Over time, however, coal production is reduced in line with plans to reduce domestic consumption, and coal output is down 80% in 2040 compared with today.

Even as domestic demand falls, **Australia** is one of the few major producers projected to increase coal production to 2040 in the Stated Policies Scenario. Our projections are consistent with the development of some new mines, although there are large uncertainties over the extent of import demand in Asia and the financing environment for greenfield projects (see section 5.7).

Indonesia's coal production reduces over the period to 2040. The share of output serving domestic markets rises steadily, from less than 20% today to 40% in 2040, and coal exports fall significantly. Indonesia serves as something of a swing producer in Asia, as companies wishing to export can increase production quickly in response to price signals from international markets.

Figure 5.4 ▷ Share of coal production by key country in the Stated Policies Scenario



While overall world coal production remains flat to 2040, India increases its share by more than doubling its level of production, offsetting declines in China and the United States

5.4 Trade[1]

In the Stated Policies Scenario, traded coal volumes remain broadly flat through to 2040 at around 1 100 Mtce, equivalent to about 20% of global coal production (Table 5.4). Import demand for coal slows in China and advanced economies in Europe and Asia, but it is partially offset by increasing imports of coal in India and in some other developing Asian economies.

Table 5.4 ▷ Coal trade by region in the Stated Policies Scenario

Net importer in 2040	Net imports (Mtce)				As a share of demand			
	2000	2018	2030	2040	2000	2018	2030	2040
India	20	187	256	313	10%	32%	27%	27%
Other Asia Pacific	52	122	181	257	56%	53%	60%	66%
Japan and Korea	192	280	219	178	97%	99%	100%	100%
China	-58	228	135	87	n.a.	8%	5%	3%
European Union	139	158	78	58	30%	50%	50%	66%
Rest of world	24	81	92	111	12%	33%	39%	40%
Net exporter in 2040	**Net exports (Mtce)**				**As a share of production**			
	2000	**2018**	**2030**	**2040**	**2000**	**2018**	**2030**	**2040**
Australia	173	353	359	418	74%	86%	89%	92%
Russia	14	166	186	221	7%	49%	56%	63%
Indonesia	48	341	253	211	74%	82%	69%	59%
South Africa	66	66	57	76	36%	32%	33%	44%
Colombia	33	76	62	48	93%	99%	88%	82%
United States	40	95	44	30	5%	18%	12%	10%
World	**Trade (Mtce)**				**As a share of production**			
	2000	**2018**	**2030**	**2040**	**2000**	**2018**	**2030**	**2040**
Steam coal	310	859	733	726	12%	20%	17%	17%
Coking coal	175	319	314	371	39%	33%	37%	47%
Stated Policies	**471**	**1 169**	**1 039**	**1 087**	**14%**	**21%**	**19%**	**20%**
Sustainable Development			633	413			18%	20%

Notes: n.a. = not applicable. World trade is the sum of net exports for all *WEO* regions and may not match the sum of steam and coking coal as a region could be a net exporter of one coal type but a net importer of another. See Annex C for definitions.

China's net import of coal is projected to peak in the next few years and then to decline substantially. By the mid-2020s, China is overtaken by India as the world's largest coal importer. However, there are uncertainties over how the supply-demand balance in Asia plays out. Among exporters, Australia and Russia could take advantage of any new export opportunities, as Indonesian exports decline.

[1] Unless otherwise stated, trade figures in this chapter reflect volumes of coking and steam coal traded between regions modelled in the *WEO* and therefore do not include intra-regional trade.

5.5 Investment

Investment in coal supply (mining and transport infrastructure) today stands at about $80 billion per year, half the level of the historical investment peak in 2012. Some 40% of this is spent on maintaining output at existing mines. Falling investment in China accounted for some three-quarters of this decline, but investment in China still accounts for more than half the global total, largely as a result of a continuing process of industrial restructuring involving the closure of smaller, inefficient mines and their replacement with more modern facilities, often in the west of the country. A westward shift in the location of mining areas in China increases the distance to the main demand hubs, implying higher transport costs and investment plans to reduce them.

In the Stated Policies Scenario, total global investment falls to an annual average of $50 billion between today and 2040, as suppliers calibrate their investment in line with demand trends (Table 5.5). Once China's restructuring process is complete, investment there in new facilities falls substantially, as existing mines are sufficient to meet the bulk of the country's needs at least until they start to reach the end of their operational lifetimes from the late 2020s.

Over the period to 2040, India is a key country investing in both existing mines and in new capacity, reflecting its goal of meeting a higher share of its rising demand from domestic sources and limiting reliance on imported coal. In North America and Europe, demand decreases, and public opposition and an unfavourable financing environment weigh on investment in new coal supply (see section 5.7).

Table 5.5 ⊳ Cumulative coal supply investment by region in the Stated Policies Scenario, 2019-2040 ($2018 billion)

	Total	Mining			Ports and rail	Total annual average
		Capacity additions	Maintenance	Total		
North America	44	17	24	41	3	2
Central and South America	16	8	6	14	1	1
Europe	16	4	6	10	6	1
Africa	43	17	18	35	8	2
Middle East	1	0	0	0	1	0
Eurasia	68	27	28	55	12	3
Asia Pacific	898	379	424	803	94	41
Shipping	47	n.a.	n.a.	n.a.	47	2
World	**1 133**	**453**	**506**	**959**	**174**	**51**
Sustainable Development	461	149	242	391	70	21

Note: See Annex C for definitions.

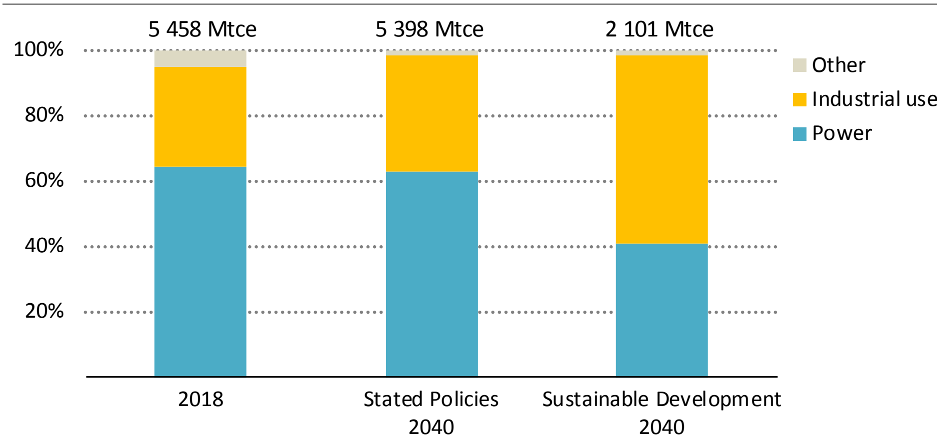
Key themes

5.6 A view beyond power: industrial coal use

The future of coal is often seen as synonymous with the future of power generation. However, around one-third of coal is used in industry, mostly in the iron and steel, cement and chemicals sub-sectors. The relative importance of industrial coal use increases in the Stated Policies Scenario as coal continues to power these sectors and as more of it is used as a feedstock for coal-to-gas and coal-to-liquids projects (Figure 5.5).

Overall coal use drops sharply in the Sustainable Development Scenario, but coal still remains an important part of the energy mix because of the difficulty in finding substitutes for it in some industrial processes. The share of industrial use in total coal demand almost doubles to 2040 as coal use in power generation declines, and innovative technologies like CCUS or the use of hydrogen become important levers for deep decarbonisation of industry over the outlook period and beyond.

Figure 5.5 ▷ Share of global coal demand by sector and scenario



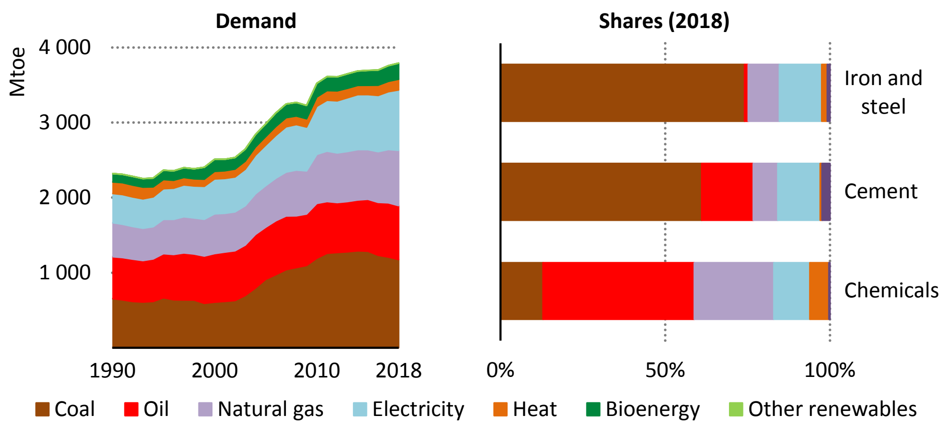
Industrial coal use accounts for an increasing share of coal demand in both scenarios

A series of technical and economic challenges differentiate the industry sector from other parts of the energy system, and they largely determine emission abatement opportunities and the scope for finding substitutes for coal. Current and planned industrial assets are important in this context because they have the potential to lock in production pathways for the future.

Current status

Coal is the largest fuel source in industry, ahead of electricity, natural gas and oil. It is the dominant fuel in the iron and steel (74%), and cement (61%) sub-sectors, and has a substantial share of 13% in the chemicals sub-sector (Figure 5.6). Coal's share in industrial energy use increased from 24% in 2000 to around 31% in 2018 due to the growth in coal consumption of nearly 93% over this period. This increase was in large part due to growth in industrial production in China. Increasing demand for cement, steel and chemicals has historically coincided with economic and population growth. However, as economies develop, urbanise, consume more goods and build up infrastructure, material demand per capita tends to increase significantly. Once industrialised, material demand per capita may level off and even begin to decline. At that stage, materials like steel and cement tend to be used primarily for replenishing and renovating rather than building the capital stock.

Figure 5.6 ▷ Global industrial energy use by fuel (left) **and energy mix for selected sub-sectors** (right)



Coal is the largest source of industrial energy use, dominating demand in the cement and iron and steel sub-sectors

In the iron and steel sub-sector, 70% of global crude steel is produced through the blast furnace-basic oxygen furnace (BF-BOF) route which is heavily dependent on coking coal for the production of coke. Scrap-based electric arc furnaces (EAF) account for most of the remaining production. The scope to shift away from coal by making greater use of scrap-based or direct reduction of iron (DRI)-based EAFs is limited by the availability and cost of scrap, as well as the cost competitiveness of electricity.

Coke serves three functions in the BF-BOF route: first, as a fuel (providing heat); second, as a chemical-reducing agent (reducing iron oxides); and third, as a permeable support. While coke is essential as a permeable support for the blast furnace charge, its two other functions can be substituted by oil, natural gas, coal or alternative fuels. Due to the scarcity and relatively high price of good quality coking coal, the ratio of coke to hot metal has increasingly been reduced in recent decades by the pulverised coal injection (PCI) method which injects pulverised coal into the furnace together with hot air.

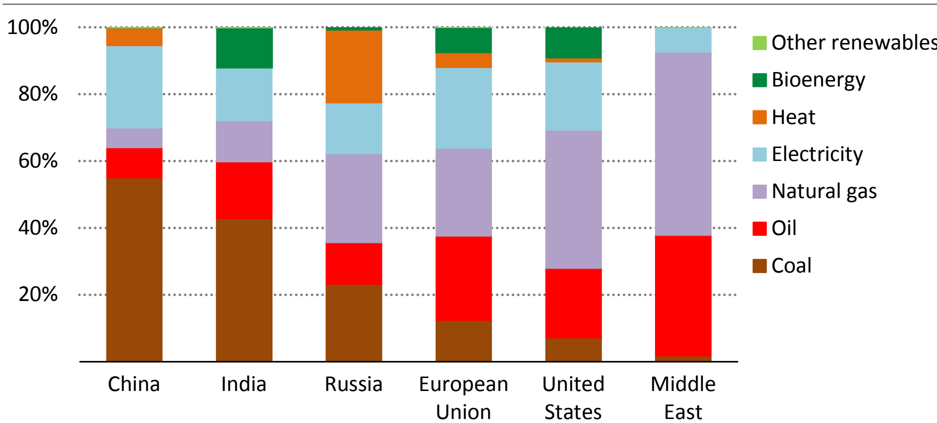
Coal is the most widely used fuel in cement production, although used tyres, mineral oil and industrial waste are also increasingly used as fuel. Kilns, predominantly fuelled by coal, heat raw materials to about 1 450 degrees Celsius (°C) to create clinker, the main ingredient in cement. While kilns could in principle also be fuelled by oil or natural gas, this is not economically viable in most regions. In any case, around two-thirds of CO_2 emissions from making cement come from the chemical reactions that take place when clinker is created through the calcination of limestone rather than from the coal that is used to provide heat.

Coal also plays an important role in the chemicals sub-sector, in particular in China where coal is the dominant feedstock in methanol and ammonia production. China has the largest coal conversion sector in the world, in which coal is converted into other fuels or chemical products. The majority of these are coal-to-liquids and coal-to-chemicals conversions. There are also some coal-to-gas projects, reflecting the push for natural gas in China's "Winning the battle for blue skies" policy, though poor economics and technical problems have plagued many of these projects.

Coal conversion operations in China, which can bring benefits in terms of air pollution, tend to be seen by their proponents as a way to increase energy security and to promote economic development in certain regions by monetising coal reserves that might otherwise be hard to commercialise. However, coal conversion projects require high upfront capital expenditure and substantial water consumption, and they produce significant CO_2 emissions.

While coal is the largest fuel in industry globally, there are marked regional differences (Figure 5.7). Coal is by far the main fuel used in industry in China and India. Outside Asia, natural gas tends to take larger shares in the industrial energy mix, in particular outside the iron and steel sector.

Figure 5.7 ⊳ Energy mix in industrial use for selected regions, 2018

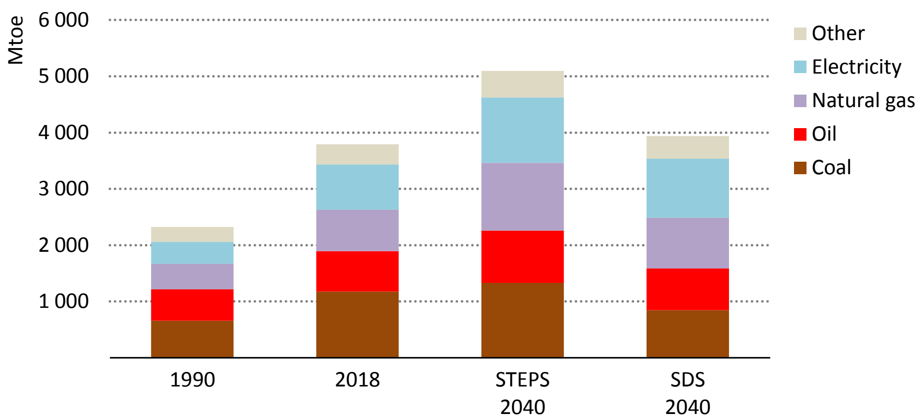


Coal is the dominant fuel in industrial energy use in China and India, while other fuels tend to account for larger shares elsewhere

Outlook and key uncertainties

In the Stated Policies Scenario, industrial coal use increases by some 225 Mtce over the period to 2040 (Figure 5.8). In the context of a rise of almost one-third in overall industrial energy consumption, this means that the share of coal in energy used for industrial processes declines from 31% today to 26% in 2040. The share of electricity in final energy use in this sector rises from 21% in 2018 to 23% in 2040. Pronounced regional differences in industrial production underlie these global trends. Most notably, while iron and steel and cement production in China declines over the outlook period, production in India and other developing Asian economies picks up strongly.

Figure 5.8 ▷ Global industrial use of energy by fuel and scenario



The challenge to find cost-effective substitutes for coal in industrial energy use means coal remains relatively strong even in the Sustainable Development Scenario

Coal use in the iron and steel industry declines in the Stated Policies Scenario by around 30 Mtce by 2040, reflecting efficiency gains and the gradual rise in the use of electricity-based routes for steel production. Coal use in cement production decreases by a similar amount, due to process improvements (a reduction in the clinker-to-cement ratio), energy efficiency improvements and a switch in some cases to alternative fuels such as waste or biomass. Together, these measures result in a reduction of around 13% in the CO_2 intensity of global cement production. There is, however, an increase of more than 180 Mtce in the use of coal as a feedstock for coal-to-gas and coal-to-liquids projects as well as in chemicals production, largely due to projected project start-ups in China.

In the Sustainable Development Scenario, coal demand decreases in all sectors, but coal remains an important fuel in industry, accounting for 21% of energy use in this sector in 2040. CCUS and hydrogen become important tools to address some of the most difficult to abate emissions in the energy sector. Together with cleaner production routes (via fuel switching), energy efficiency improvements and process improvements (via a reduction in the clinker-to-cement ratio) they reduce the CO_2 intensities of the iron and steel, and cement sub-sectors by an average 3% per year. The vigorous application of material efficiency strategies contributes by reducing the amount of iron and steel and cement produced from what it would otherwise have been (see Chapter 7). As a result, there are notable decreases in coal demand, especially in iron and steel (-285 Mtce) and in cement production (-50 Mtce). The scenario's trajectory is critically dependent on the implementation of policies to reduce the carbon footprint of industry, and to promote the deployment of technology innovations and the creation of markets for premium lower-carbon materials.

Box 5.1 ⊳ What role can CCUS play in mitigating emissions from industry?

Industrial CO_2 emissions are among the hardest to abate, one-quarter of these are non-combustion process emissions that result from chemical or physical reactions, and therefore cannot be avoided by a switch to alternative fuels. This presents a particular challenge for the cement sub-sector, where 65% of emissions result from the calcination of limestone, a chemical process underlying cement production. Furthermore, one-third of industrial energy demand is used to provide high-temperature heat. Switching from fossil to low-carbon fuels or electricity to generate this heat would require facility modifications and substantially increase electricity requirements (see *World Energy Outlook 2018*, Box 5.1 [IEA, 2018]). Plus, industrial facilities are long-lived assets of up to 50 years, and so have the potential to "lock in" emissions for decades. Exposure to highly competitive, low-margin international commodity markets accentuates the challenges faced by firms and policy makers.

A portfolio of technologies and approaches will be needed to address the decarbonisation challenge while supporting industry sustainability and competitiveness. CCUS technologies can play a critical role in reducing industry sector CO_2 emissions. CCUS is one of the most cost-effective solutions available to reduce emissions for some industrial and fuel transformation processes, especially those that inherently produce a relatively pure stream of CO_2, such as natural gas and coal-to-liquids processing, hydrogen production from fossil fuels and ammonia production. CCUS can be applied to these facilities in some cases for as little as $15-25 per tonne of CO_2.

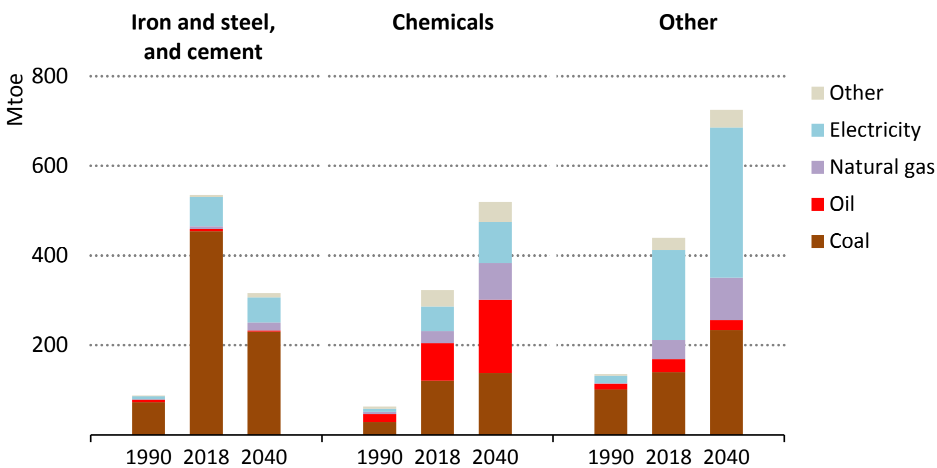
In the Sustainable Development Scenario, around 10 gigatonnes of carbon dioxide (Gt CO_2) is captured from industrial processes and fuel transformation in the period to 2040, the vast majority of it from the cement, iron and steel, and chemical sub-sectors. Around half of this comes from coal-based facilities. CCUS makes significant inroads in the late 2020s, capturing around 450 million tonnes (Mt) CO_2 in 2030, and expands rapidly thereafter.

Focus: industrial coal use in China

China is the world's largest producer of steel and cement, accounting for around 50% of iron and steel and 55% of cement production. In addition, a significant share of global chemicals production takes place in China. As a result of this dominance in global materials manufacturing, China also accounts for the world's largest shares of global industrial energy use (35%) and industrial CO_2 emissions (nearly 45%).

Industrial production in China has been based largely on domestic coal, but its reliance on coal gradually decreases over the outlook period in the Stated Policies Scenario. The share of coal in its industrial energy mix decreases from 55% today to 40% in 2040. Overall coal demand in industry decreases by some 0.8% per year, mainly due to lower coal demand in the iron and steel, and cement sub-sectors (Figure 5.9). Recent policies, often aimed at improving air quality, have already resulted in production cuts at inefficient steel plants and in plant closures. Electrification of steel-making, increased use of scrap steel, process improvements and general efficiency improvements are important drivers behind coal demand reductions.

Figure 5.9 ▷ Industrial use of energy by fuel and key sub-sector in China in the Stated Policies Scenario

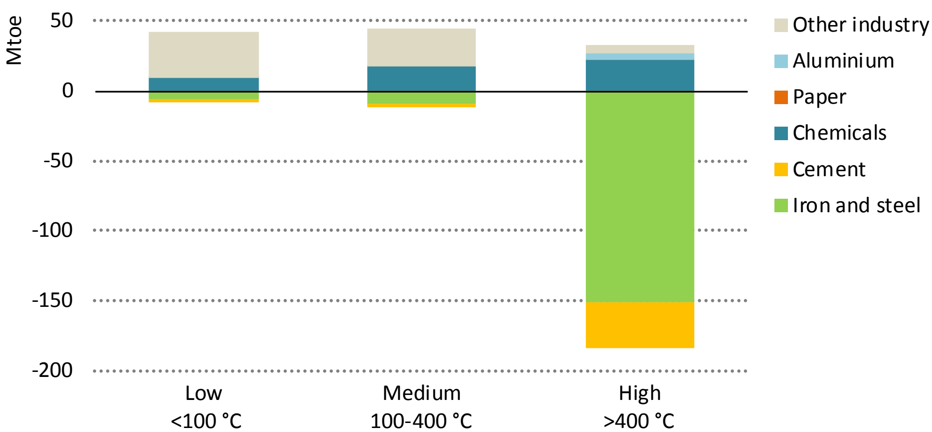


A deep rebalancing across industrial activities is underway in China, with large effects on the industrial energy mix

The anticipated rebalancing of the Chinese economy towards lighter and less energy-intensive manufacturing leads to a reduction in high-temperature heat demand over the projection period (Figure 5.10). This reduces the need for coal in industry and opens the possibility of other fuels to provide lower temperature heat. There has been some substitution in recent years of small industrial coal-based distributed boilers by gas or electric boilers, or combined heat and power (CHP) systems, especially for industries close to urban areas. This has resulted in improved air quality and a reduction in coal demand.

The main drivers of industrial coal demand in China in the Stated Policies Scenario are chemicals production and the use of coal as a feedstock for coal-to-gas and coal-to-liquids projects (+165 Mtce to 2040). Around 100 Mt of coal are used for dedicated hydrogen production using coal gasification in China today, with the resultant hydrogen used mainly to make ammonia – a key primary chemical and the chemical base of all nitrogen fertilisers – and methanol (see Chapter 11). The development of methanol-to-olefins and methanol-to-aromatics technology has opened an indirect route from methanol to high-value chemicals (HVCs), and thus to plastics. Methanol-to-olefins technology is currently deployed at commercial scale in China, accounting for 9 million tonnes per year or 18% of domestic HVC production in 2018. Methanol-to-aromatics, which is used to produce more complex HVC molecules, is currently in the demonstration phase.

Figure 5.10 ⊳ Change in heat demand by temperature in China in the Stated Policies Scenario, 2018-2040



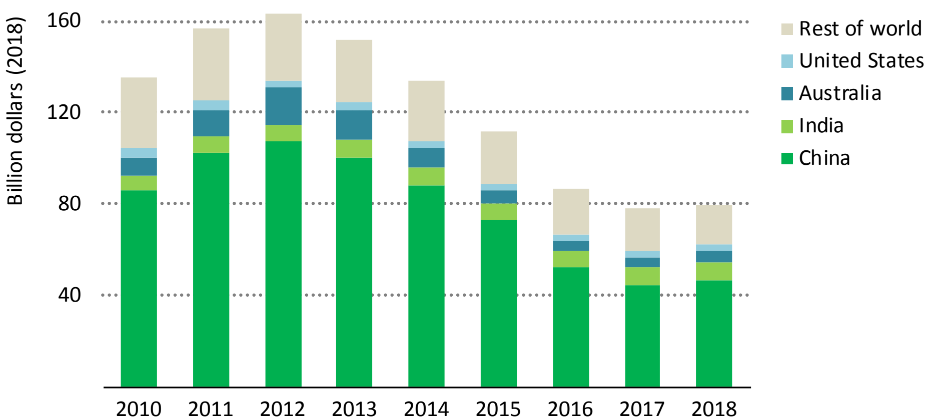
High-temperature heat demand in China is falling due to lower demand in the iron and steel, and cement sub-sectors

5.7 Who will invest in coal supply?

In 2018, for the first time since 2012, investment in coal supply increased slightly at 2% pushing the global estimate to $80 billion: growth was due to increased spending on existing mines, rather than capacity expansion, aided by the uptick in prices and revenues (Figure 5.11). The overall figure includes investment in mining and related infrastructure to bring coal to market, but excludes spending on coal-fired power plants, and represented 4% of overall capital spending on energy supply in 2018. The share of coal supply investment in total investment has been steadily decreasing in recent years; in 2012, coal supply investment of $163 billion was double the 2018 figure and made up more than 8% of the global total. In this section, we analyse the dynamics of coal supply investment, look at the increasingly restrictive conditions for access to finance for many coal supply projects and consider the implications for the scenarios.

The headwinds facing new coal supply projects start with uncertainties over future demand. Climate policies are hitting coal hard in many advanced economies. Air pollution policies, often overlooked, have been effective at reducing coal use, both in Europe and United States in the power sector, and in China in the industrial and residential sectors. In addition, an increasing number of countries are adopting phase-out policies and setting deadlines for the end of unabated coal power generation. This threefold policy action, alongside the fall in costs of renewables, and lower natural gas prices in some markets, is raising questions about the long-term profitability of coal assets. In addition, an increasing number of banks, insurance companies, institutional and private investors, utilities and mining companies are restricting, reducing or giving up investment in coal. The risk of reputational damage is becoming an increasingly important consideration, especially among companies for whom coal is not their core business. Last but not least, public opposition to coal, including through legal litigation, is an impediment for new coal developments across most of the world, from the developed world to emerging countries in Asia and Africa.

Figure 5.11 ▷ Coal supply investment



Investment in coal supply rose slightly in 2018, although the global total remains at around half the level seen at the start of the decade

The allocation of coal investment along the value chain is very different to that of oil or gas. The power sector, the largest user of coal, accounts for the bulk of the investment in the coal supply chain. Although the figure varies from country to country and from plant to plant, a 1 000 megawatt (MW) plant typically involves investment of somewhere between $700 million and $2.5 billion, whereas the mine to fuel the plant typically involves investment one order of magnitude lower. This is a very different allocation from the gas supply chain for electricity, in which the upstream (exploration and extraction) and midstream (transportation) typically account for the bulk of investment. In case of seaborne traded coal involving rail and ports, additional investment is needed for transport, but transportation costs for coal are still much cheaper than natural gas per unit of energy.[2]

Given that coal-fired power plants are the most capital-intensive part of the value chain, analysis of the implications of restricted access to finance for coal has typically focused on power. However, with the increasing constraints on coal finance and the long lifetime of coal consuming assets, the question also arises whether securing coal supply might become more difficult or expensive in the future.

The policy and financing setting is only part of the story. Coal is a commodity, and hence subject to standard commodity cycles, and affected by the broader economic and financial environment. The experience of the commodity price downturn in 2015-16 has made mining companies cautious about investing in capacity expansion. At present mining companies are generally avoiding big capital expenditures. Capital efficiency has overtaken growth as the key management principle.

The position of coal in different parts of today's energy sector is an important part of the context, including the significance of coal use outside the power sector, notably in industry (see section 5.6). Moving away from coal is not easy anywhere, but it is easier in some circumstances and countries than others, especially when existing assets are older and substitutes are readily available. In the power sector, around 70% of today's global coal power capacity and coal-based electricity generation is in Asia, where electricity demand is rising fast and coal plants are around 12 years old on average, more than two decades younger than those in North America or Europe. Reducing emissions from this stock of coal-fired assets poses difficult social and economic questions for policy makers (see Chapter 6); this helps to explain why global coal use in the Stated Policies Scenario in 2040 is only just below today's level.

Changing landscape for coal investment and financing

Opposition to coal is not new, but in recent years there has been an increasing number of announcements by various players, whether governments or business organisations, of restrictions or prohibitions on coal financing and/or investment. Even if some have come from countries or investors with limited interests in coal, these announcements create momentum, open dialogue and can point a direction to others. Within the coal industry, companies leaving coal mining or power generation typically sell their assets to other companies, so there may not be any reduction in overall capacity. However, the new owners may have different strategies or possibilities: for example, when a big mining company sells coal assets to a small player, the expansion potential decreases significantly, owing to weaker balance sheets, higher capital cost and less favourable access to finance,

[2] In significant cases like China, Russia and India, coal transport tariffs are not necessarily cost-reflective. This can cut both ways: in Russia, the railways subsidise coal exports, whereas in India, coal transport cross-subsidises passenger rail.

in particular when complex infrastructure is needed to develop a project. The cumulative impact of multiple decisions can also be very significant: one bank moving away from coal has little impact, but when one hundred banks decide not to finance coal, it is far from irrelevant.

One of the more consequential moves away from coal has come from multilateral development banks. In 2013, the World Bank Group (WBG) decided to stop financing coal power plants except in very exceptional circumstances. Other banks followed suit, including the European Investment Bank (EIB) and the European Bank for Reconstruction and Development. Institutions such as the Asian Development Bank or the Asian Infrastructure Investment Bank, although they have not excluded coal as explicitly as WBG or EIB, are not in practice financing coal projects. The African Development Bank has recently financed the Sendou coal power plant in Senegal, but it has not been involved in coal production for more than a decade. This strategy shift among the main multilateral lending institutions has constrained available financing for coal projects in developing countries and made private finance for projects more expensive, and many other banks and institutions are mirroring their stance. Export credit agencies (ECAs) represent a similar case. In November 2015, Organisation for Economic Co-operation and Development (OECD) countries agreed to strengthen the rules for ECAs and most have announced that they will not finance any new coal projects.

Among the country-led initiatives, the most prominent has been the Powering Past Coal Alliance (PPCA), launched by United Kingdom and Canada in November 2017 during the Conference of the Parties[3] (COP) 23 in Bonn, Germany. By joining the PPCA, governments commit to phase out unabated existing coal power generation and not to build any new capacity. Non-government members commit to powering their operations without coal. As of September 2019, the Alliance had 91 members: 32 country governments, 25 sub-national governments and 34 companies (PPCA, 2019). Among the country signatories, Germany is the largest coal power generator, followed by Canada, Mexico and Italy. South Chungcheong Province in Korea, home to half of the country's coal capacity and power generation, also joined the Alliance.

Overall, the coal used for power generation in the national and sub-national members of PPCA accounts for about 4% of global consumption, although in some of the countries concerned, such as Germany, Israel, Netherlands and Portugal, coal accounts for a significant share of their overall electricity generation. But the indirect effect on coal investment decisions nonetheless may be powerful, particularly since the members, both governments and businesses, commit to restricting financing for unabated coal power generation.

Another important trend is in the financial community. Many institutional investors and pension funds, banks, insurance companies and others have committed to reduce or end their involvement in coal in one way or another (Table 5.6). The early commitments came

[3] COP of the United Nations Framework Convention on Climate Change.

from Europe and North America, but recent announcements from China, Australia, Japan and Singapore underline the scale of this movement both in terms of the volumes involved and in geographical spread.

Table 5.6 ▷ Selected financial and investment institutions committed to reduce or end involvement in coal supply and coal-fired power

Country	Institutions
Australia	QBE
China	State Development & Investment Corporation
France	AXA, Société Générale, Crédit Agricole, BNP Paribas, CNP
Germany	Allianz, Deutsche Bank
Italy	Generali
Japan	Marubeni, Mitsui, Itochu, Sojitz, MUFG
Korea	Teachers Pension System, Government Employees Pension System
Norway	Wealth Pension Fund
Singapore	Oversea Chinese Banking Corp, United Overseas Bank
South Africa	Standard Bank, Nedbank
Spain	Mapfre, BBVA, Banco Santander
Switzerland	Zurich, Swiss Re
United Kingdom	Lloyds, Aviva, Barclays
United States	Chubb Ltd.

Others prefer engagement rather than divestment, as is the case of Japan's Government Pension Investment Fund, the world's largest pension fund by volume. The principle is that this gives investors more opportunities to have an impact. When Glencore, the world's largest coal exporter, pledged in February 2019 to cap coal production and look for growth in other commodities necessary for energy transitions, this came in part as a result of engagement with investor signatories of the Climate Action 100+ initiative. The commitment may not seem very stringent, but it establishes a principle and could be further tightened in the future.

Last but not least, any coal project has to deal with opposition from local communities and international civil society groups. This public opposition typically includes legal litigation, which can make projects more difficult and more costly, and can lead to cost overruns, delays and, in some cases, cancellation of projects.

Focus: the main global coal producers

A review of the main global producing companies shows how their composition has changed over time (Table 5.7).

The shift in recent years to Asia and, in particular, to China is striking. Coal India Limited, a state-owned company, remains as the top producer in the world by tonnes. China now accounts for six of the top-ten largest producers. In 2009, only two Chinese companies, Shenhua Group and China National Coal Group, both owned by the central government, were among the world's top-ten. China Energy Investment Corporation, its new name after

Shenhua merged with Guodian Group, remained in second place in 2017 (although if measured in terms of the value or energy content of production, rather than tonnes of output, it would be the largest producer), and China National Coal Group moved up to fourth. In addition, four companies owned by Chinese provinces joined the list of the top ten producers: Shandong Energy and Yankuang Group, both owned by Shandong Province; Shaanxi Coal and Chemical Industry Group, owned by Shaanxi Province; and Datong Coal Mining Group, owned by Shanxi Province. The share of China in global coal production was stable over this period: 46% in 2009 and 47% in 2017, and the changes to the top-ten list reflect the recent process of consolidation in the coal industry in China rather than a rise in its share of global coal production. The only new non-Chinese company in the list is SUEK, a Russian private company, which is also the world's fourth-largest coal exporter.

Table 5.7 ▻ Top-ten global coal producing companies

Main countries of operation	Company	Output (Mt)
2009		
India	Coal India	431
China	Shenhua Group	328
United States	Peabody Energy	221
United States / Australia	Rio Tinto	140
China	China National Coal Group	125
United States	Arch Coal	114
Colombia / South Africa / Australia	BHP Billiton	105
Germany	RWE	100
Colombia / South Africa / Australia	Anglo American	96
Colombia / South Africa / Australia	Xstrata	95
2017		
India	Coal India	561
China	China Energy Investment Corporation	513
United States / Australia	Peabody Energy	172
China	China National Coal Group	164
China	Shandong Energy	141
China	Shaanxi Coal and Chemical Industry Group	140
China	Yankuang Group	135
China	Datong Coal Mining Group	127
Colombia / South Africa / Australia	Glencore	121
Russia	SUEK	108

Among the big diversified global mining companies, Rio Tinto left the coal business definitively in 2018, after a divestment process which started with its US assets almost a decade ago and finished with the sale of its last coal assets in Australia. BHP, which spun off part of its coal assets to South32, and Anglo American, which also reduced its coal exposure, are still the world's second- and third-largest exporters. Glencore, which merged with Xstrata in 2013, remains in the top-ten, the only big diversified global mining company in this ranking. Meanwhile US companies, facing declining demand on the domestic market, are now more streamlined, with more focus on financial discipline and less on international expansion. Peabody, still the largest private producer and the only US company on the 2017 top-ten list, announced a joint venture with Arch Coal to share assets producing 185 Mt in 2018 in order to maximise value and compete in a difficult environment.

A related question is who owns the coal mining companies. In China, state-owned companies produce most of the coal. The same is true in India, where Coal India accounts for 80% of domestic production and other public companies produce a further 10%. Analysis of recent trends in the ownership of listed companies shows that large institutional investors have maintained their positions in the big diversified mining companies, and there are no new large investors, apart from Anil Agarwal's Conclave, which bought 20% of Anglo American. The main shift in terms of ownership has occurred in US coal companies, following the bankruptcy and recovery process that almost all of the big US companies have followed. The large institutional investors have reduced their positions, with some hedge funds and other asset managers stepping in. In the case of pure coal export-oriented companies, the story is quite different: these companies are much smaller than the big diversified miners and the participation of international institutional investors is rather limited. Individuals or families are the main owners of some of them, with increasing participation from Chinese state-owned enterprises. These two types of companies, big global diversified mining groups and pure coal export-oriented players, face very different financing constraints (Box 5.2).

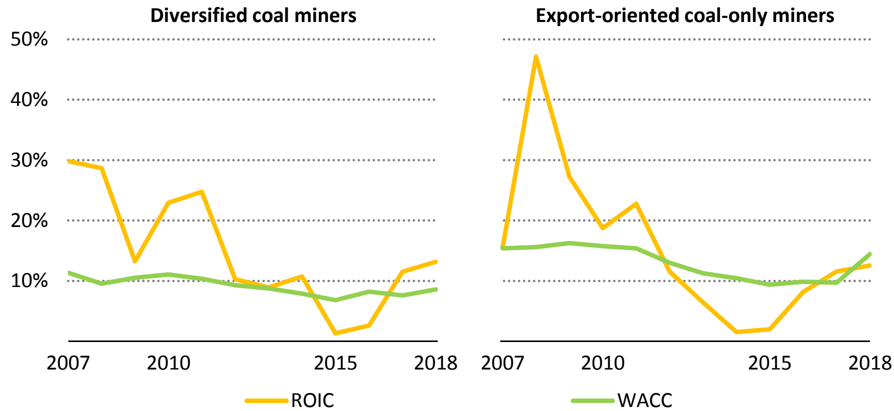
Box 5.2 ▻ Increasing cost of capital for coal producers

Access to capital is becoming more difficult for coal producers. An increasing number of financial institutions and investors are turning away from coal, and this is contributing to higher financing costs.

Historically, coal mining has been characterised by high volatile returns and a higher cost of capital than other extractive energy industries, such as upstream oil and gas. Figure 5.12 shows the weighted average cost of capital (WACC) and return on invested capital (ROIC) for big global diversified mining groups and for a group of selected export-oriented coal companies. The ROIC trend closely follows the commodity price cycle for the diversified companies and the coal price for the coal-only companies.

In addition, coal-only companies have historically seen higher financing costs than diversified companies. This continues to be the case. From 2015, the cost of capital has increased for both diversified miners and coal-only companies, but the increase has been bigger for the coal-only companies, reflecting investor perceptions that the risks associated with coal supply businesses have increased for the reasons described. Coal-only companies have had considerable difficulty in creating value for shareholders over the past decade, and this may constitute another hurdle for investment in the sector in the current environment of rising pressure against coal, although coal proved to be a profitable commodity in 2017.

Figure 5.12 ▷ Return on invested capital and after-tax weighted average cost of capital for selected coal companies



Coal-only companies have seen more upswing in financing costs than diversified players, which combined with trailing returns, signals a challenging investment environment

Notes: Diversified coal miners include Glencore, BHP Billiton, Rio Tinto and Anglo American. Export-oriented coal-only miners include Adaro Energy, Bumi Resources, Exxaro Resources and Whitehaven Coal. ROIC measures the ability of a company's core business investments to generate profits, expressed as operating income adjusted for taxes divided by invested capital. The WACC is expressed in nominal terms and measures the company's required return on equity and the after-tax cost of debt issuance, weighted according to its capital structure. The tax rate is assumed at 35% for all companies.

Sources: IEA analysis based on data from Thomson Reuters Eikon (2019) and Bloomberg (2019).

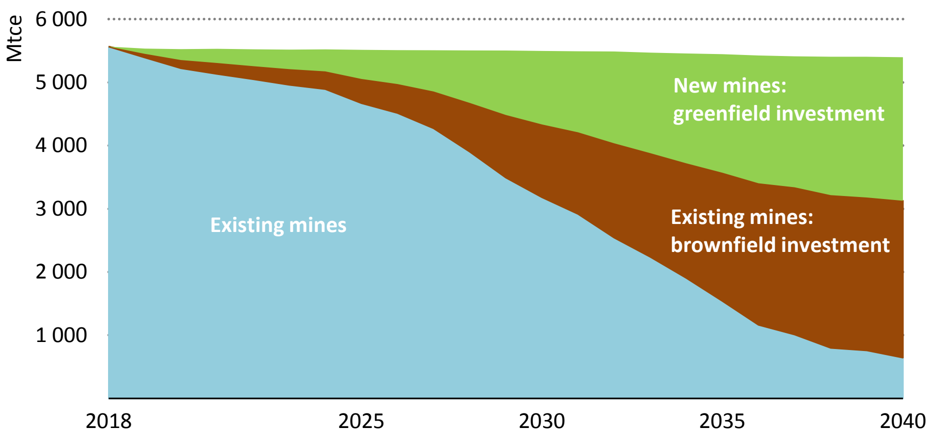
Outlook and key uncertainties

The decline in coal supply investment since the high point in 2012 – notwithstanding the slight uptick in 2018 – is set to continue in our projections in both scenarios. From $80 billion in 2018, average annual investment declines to around $60 billion in the Stated Policies Scenario by the 2020s (averaged for the decade as a whole) and to around a third of this in the Sustainable Development Scenario. These sums also represent a smaller share of the overall amount of capital expenditure in the energy sector, which edges higher towards $2.5 trillion per year from about $1.8 trillion today. Investment in coal supply increasingly bifurcates into two worlds – one in which financing constraints start to bite and the other in which financing does not yet appear to be such a hard constraint. Most of the projected coal supply investment is concentrated in the latter.

China and India account for a large portion of projected expenditure on coal supply. Cumulative investment in coal supply in China to 2040 is $585 billion in the Stated Policies Scenario (50% of the global total and $27 billion per year on average), and $220 billion in the Sustainable Development Scenario (just under half of the global total). The comparable figures for India are $170 billion in the Stated Policies Scenario and $50 billion in the

Sustainable Development Scenario. National policies are set to play a defining role in determining investment outlooks in both cases, and the predominance of state-owned companies in production means that external financial constraints may not loom large in these decisions.

Figure 5.13 ▷ Global coal production by type in the Stated Policies Scenario



As production from existing mines declines, so demand in the Stated Policies Scenario requires investment either to expand existing mines or to open new ones

In China, a pivotal moment for coal supply investment arrives in the mid-2020s, when the wave of mines that were opened in the early 2000s start to reach the end of their operational lifetimes. In the Stated Policies Scenario, we assume a decision to reinvest in new coal production capacity, in line with future projected domestic needs. But this could also be a point at which there is a significant move away from coal, if alternative technologies and fuels are deemed to provide adequate substitutes and the implications for employment appear manageable. Much will depend on the timing of the retirement of existing coal-fired power plants and the extent to which any move away from coal is slowed by widespread deployment of CCUS technologies (see Chapter 6).

India too faces crucial decisions in the 2020s, once the current over-capacity in the power sector is absorbed by rising demand for electricity. In the Stated Policies Scenario, the next wave of investments in generation capacity involves a balance of renewables, battery storage and coal, the latter stimulating new investment in domestic coal supply in turn. However, India could decide at this point to opt for a more dramatic transformation of the power mix. Much is likely to depend on developments between now and then in renewables and storage technologies (see sensitivity analysis on battery storage in Chapter 6). Financing considerations could also play into these power sector choices.

Outside China and India, there is a distinction to be made between sustaining capital expenditure to maintain production from existing mines and funding new mines (Figure 5.13). In the Stated Policies Scenario, half of the $275 billion in coal mining investment outside China and India goes to sustaining capital expenditure; this share is higher in the Sustainable Development Scenario (60%). The distinction is important because the expansion of existing mines is likely to be financed by the incumbent, whereas greenfield projects are likely to require external financing, which could be challenging to obtain.

Russian producers are likely to be least affected by constraints on investment finance. Big producers have access to finance from Russian and Asian banks, and expansion plans are backed by the government strategy of developing infrastructure to increase market share. In part for this reason, our projections in the Stated Policies Scenario show Russia continuing to expand exports and to increase its share in the seaborne traded coal market.

A visible trend in recent years has been for companies to downsize big supply projects. Carmichael, in Australia, was first planned as a 60 million tonnes per annum (Mtpa) mine with external project finance and has been downscaled to 10 Mtpa to be self-financed by Adani, the owner. Boikarabelo mine in South Africa, initially planned for about 20 Mtpa, has been downscaled to 6 Mtpa and is still working on a lending syndicate. Market conditions may partially explain this downsizing trend, but the increasing restrictions on external finance for major projects have also played an important role.

The apparent market oversupply in 2019 following the high prices in 2017-18 suggests that restrictions affecting external financing have not so far had much impact on curtailing coal production, but increased restrictions imply a higher cost of capital in the future, pushing up the long-term supply cost curve and making the profitability of projects more uncertain. It is difficult to know how this will play out. Producers in countries such as the United States and Indonesia may be ready to step in if the market starts to signal a shortfall in supply. Conversely, the tougher environment for investment and difficult conditions for market entry may reduce the possibility of oversupply, one of the biggest risks in the commodity business.

5.8 Coal mine methane

The energy sector is responsible for around 40% of anthropogenic methane emissions. This is a major cause for concern because methane is a potent greenhouse gas: over a 100-year timeframe, one tonne of methane absorbs around 30-times more energy than a tonne of CO_2 (the 100-year global warming potential [GWP]); over a 20-year timeframe, one tonne absorbs as much as 85-times more energy.

Previous *WEO* analysis looked in detail at the levels of methane emissions from oil and gas operations, and the costs and opportunities of avoiding the emissions (IEA, 2017). This analysis found that around 45% of the current 80 Mt of methane that is emitted by the oil and gas sector could be avoided at no net cost, since the value of the captured methane is greater than the cost of installing the abatement measures.

Methane emissions play a critical role both in the lifecycle emissions intensity of different sources of oil and gas and in the emissions savings that would result from switching from one fuel to another (see Chapter 4). Methane emissions also occur during coal mining operations: coal seams naturally contain methane, referred to as coal mine methane (CMM) and this can be released during or after mining operations (Box 5.3). The extent of these emissions is relevant to coal-to-gas switching. Coal combustion results in around 75% more CO_2 emissions than gas per unit of energy, but a more complete comparison between coal and gas must also look at the methane emissions from getting the coal or gas from the ground to the end-user.

Box 5.3 ▹ What is the difference between CMM and CBM?

Coal mine methane is trapped in coal seams that are suitable for mining. CMM is a hazard to mining activities and must therefore be dealt with carefully. It can be released in various ways during coal mining operations, including:

- Seepage of methane from coal seams exposed in surface or open pit mines.
- Degasification and ventilation systems that are used to extract and dilute methane found in underground coal mines to create safe working conditions and avoid explosions.
- Post-mining activities such as processing, storage and transport when quantities of methane still trapped in the matrix of the coal seeps out.
- Abandoned mines, since there may still be large volumes of coal remaining in a mine even after operations have ended; methane contained in this coal may continue to escape to the atmosphere.[4]

Coalbed methane (CBM)[5] is natural gas, predominantly methane, which is deliberately extracted from underground coal seams that generally are not suitable for normal mining. However in some countries – most notably in China – CBM can also include CMM emissions that are captured and subsequently marketed. CBM is considered an "unconventional" source of natural gas with nearly 90 billion cubic metres produced globally in 2018.

If coal is used in conjunction with CCUS, this would reduce the associated combustion emissions and open longer term possibilities for coal. But it would still be important to minimise the methane emissions that occur before combustion.

As with oil and gas, there is a high degree of uncertainty in estimating the level of CMM emissions that occur today. Few direct measurements of methane emissions occur at coal mines: baseline or background levels of emissions were often not established prior to the start of operations and the emissions levels that do exist are based on sparse and sometimes conflicting data.

[4] This analysis focuses on CMM emissions from active coal mines since we aim to estimate the full emissions intensity of current sources of coal production. Abandoned mines are therefore not included.

[5] CBM is also sometimes called coal-seam gas.

This section describes our new approach to estimating methane emissions from coal operations, provides an overview of some of these estimates and examines how the full lifecycle emissions of coal compare with gas.

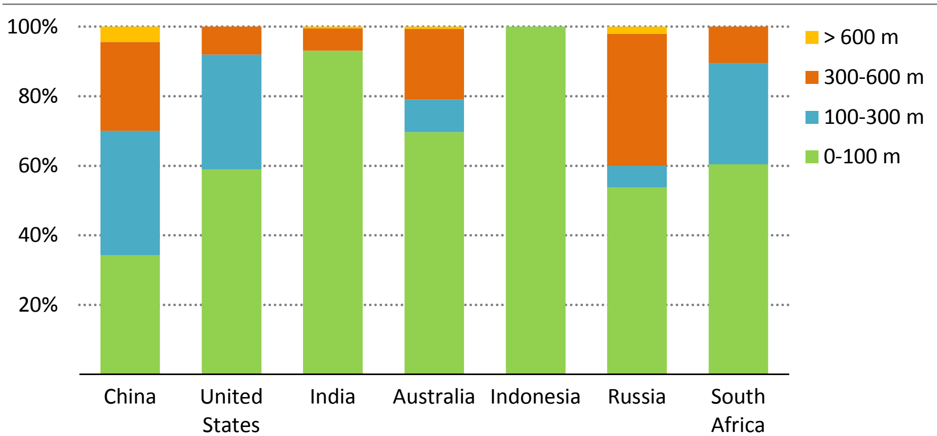
Method for estimating methane emissions from coal supply

Our new estimate of CMM is based on deriving mine-specific methane emissions intensities for all major coal producing countries.[6] The starting point was to generate emission intensities for coal mines in the United States using the US Environmental Protection Agency's Greenhouse Gas Reporting Program and 2018 US Greenhouse Gas Inventory (US EPA, 2018). This was supplemented by data sources that provided disaggregated CMM data for China (Wang et al, 2018; Zhu et al, 2017) and India (Singh and Sahu, 2018; India Ministry of Coal, 2018). The mine-level CMM estimates generated in this way were then aggregated and verified against the country-level estimates for China and India taken from satellite-based measurements (Miller et al., 2019). Based on these data, coal quality (e.g. the ash content or fixed carbon content of coal produced by individual mines), mine depth and regulatory oversight[7] were used as key factors to estimate CMM emission intensities for mines in other countries for which there are no reliable direct estimates.

5

An important factor in estimating CMM emissions is the depth in metres (m) and age of various mines in operation today (Figure 5.14). Deeper coal seams tend to contain more methane than shallower seams, while older seams have higher methane content than younger seams. In the absence of any mitigation measures, methane emissions to the atmosphere will therefore tend to be higher for underground mines than for surface mines.

Figure 5.14 ▷ Depth of coal production in selected countries, 2018



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

[6] Mine-level data is provided in the coal mine database produced by the CRU Group (CRU, 2019).

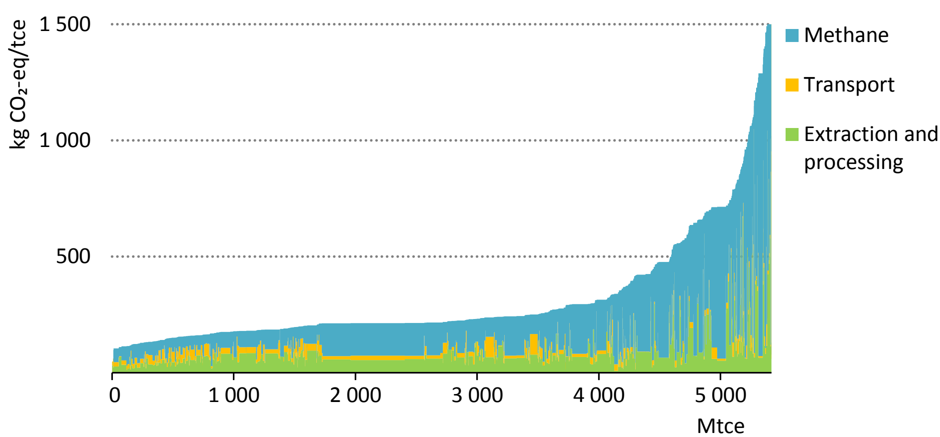
[7] This incorporates government effectiveness, regulatory quality and the rule of law as given by the Worldwide Governance Indicators compiled by the World Bank (World Bank, 2019).

Methane emissions from coal supply

We estimate that global CMM emissions in 2018 were just under 40 Mt. Assuming that one tonne of methane is equal to 30 tonnes of CO_2, this is equivalent to around 1 200 Mt CO_2-eq, which is broadly similar to the current level of total annual emissions from international aviation and shipping combined. On average, the production of coal results in just over 0.3 tonnes of CO_2-eq indirect emissions for every tonne of coal equivalent (tce) produced. CMM emissions are responsible for two-thirds of these emissions. Coal combustion emissions average around 2.9 tonne CO_2-eq/tce globally, which means that indirect emissions account for around 10% of the lifecycle emissions of a tonne of coal.

The level of CMM emitted to the atmosphere is the main determinant of how the indirect emissions intensities of different mines compare (Figure 5.15). The lowest 10% production has a total average emissions intensity of 80 kilogrammes (kg) of CO_2-eq/tce, while the highest 10% has an emissions intensity of 1 000 kg CO_2-eq/tce. In other words, the most emissions intensive coal produces more than ten-times more indirect emissions than the least emissions intensive.

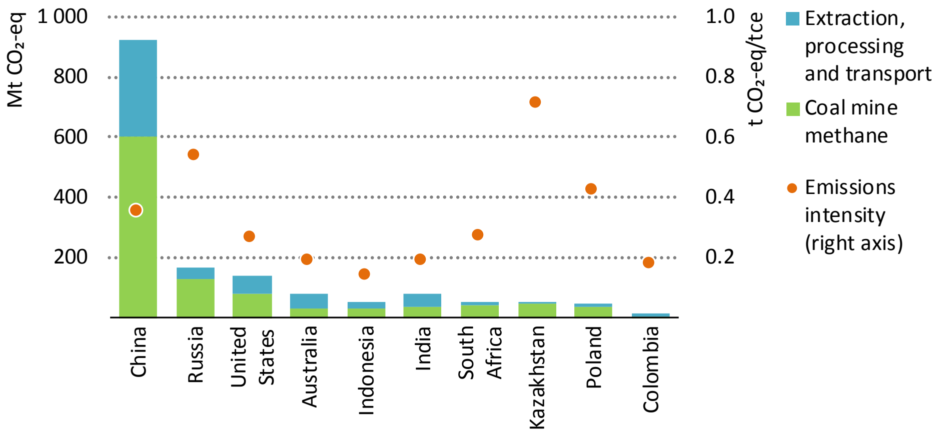
Figure 5.15 ▷ Indirect CO_2 and methane emissions intensity from global coal supply, 2018



There is wide distribution in the emissions associated with different coal mines; CMM is the main determinant of where coal sits in the indirect emissions spectrum

It is no surprise that the geographic distribution of total indirect emissions is clearly weighted towards overall levels of production (Figure 5.16). Coal operations in China alone result in over 900 Mt CO_2-eq today. The indirect emissions intensity of coal production in China is marginally higher than the global average, largely because of the number of deep underground mines in operation in China, despite the use of a number of mitigation technologies to reduce or make productive use of these methane emissions (Box 5.4).

Figure 5.16 ▷ Indirect CO_2 and methane emissions, and emissions intensities for the ten-largest coal producing countries, 2018



Countries with deeper coal mines and less regulatory oversight have higher indirect emissions intensities, but China dominates the absolute level of emissions

Box 5.4 ▷ Other indirect emissions from coal mining

The indirect emissions intensity of coal includes all sources of greenhouse gas (GHG) emissions from the point where coal is extracted to, but not including, where and how it is consumed. Indirect emissions come from CMM, but they also from the energy required to extract, process and transport the coal. The level of CO_2 emissions produced depends on the method of extraction, coal quality, and transport methods and distances. In surface mines, for example, diesel is usually used to power the earth-moving equipment such as draglines, shovels and trucks. Underground mining tends to rely on more mechanised processes powered by electricity, which is also required to power belt conveyors, crushers and other auxiliary equipment at or near production sites. Data for the energy use across mines is available from the CRU database, which we convert into emissions based on the emissions intensity of diesel and electricity within each country.

Depending on its quality, coal also often undergoes some processing prior to use. Coal "washing", for example, aims to reduce or remove ash, impurities and contaminants, and requires the use of electric-powered systems and large quantities of water. Plus, the coal needs to be transported from where it is produced to consumers; this is usually done by rail or ship. Our estimates of transportation energy use and emissions take into account the two modes of transport and corresponding trade routes.

In the Stated Policies Scenario, there are very few policies in place globally that aim to reduce the emissions intensity of coal production and so CMM emissions remain broadly constant at around 40 Mt to 2040. In the Sustainable Development Scenario, the 60%

decline in coal demand to 2040 is the primary factor in reducing CMM, but there are also some broader efforts to reduce emissions from mines, and total methane emissions fall to less than 15 Mt in 2040.

Reducing CMM

A key problem with mitigating CMM is that the methane concentration of emissions is often very low and can fluctuate in quality and quantity. The lower the concentration of methane, the more technically and economically difficult it is to abate. The same applies to methane emitted during the mining process. For example, air from the ventilation and degasification systems of underground mines (called ventilation air methane) contains less than 1% methane.

Processes such as blending or oxidation are required to make the recovered methane usable as an energy source (e.g. for heating mine facilities or drying coal). These can be expensive, are not always fully effective and can also pose considerable safety risks. However, there may be opportunities to produce higher concentration sources of methane if these are carefully planned prior to the start-up of mining operations either in a new mine or a new area. Degasification wells and drainage boreholes can produce methane and this can be used for small-scale power generation or, if concentrations exceed 95%, injected into a local gas grid.

A lack of gas infrastructure or nearby consumers can preclude the business case for onward sale of recovered methane. In the absence of a viable recovery project, methane can either be destroyed by thermal oxidisation or flared. However there are relatively few projects globally that have installed the equipment necessary to do this, with safety concerns and a lack of regulatory incentives cited as reasons for the lack of progress.

Much more active policies and regulatory regimes are clearly needed to incentivise or require mine operators to install CMM abatement technologies. This would need to involve requiring any new mines to develop plans to handle methane emissions before operations commence (or expand to a new area) and to make the necessary capital investments in drainage technologies, pipelines networks, and auxiliary and monitoring equipment.

S P O T L I G H T

How does the environmental performance of coal and gas compare?

The supply and use of coal and natural gas has a number of environmental impacts. Coal is responsible for over 40% of global emissions of energy-related sulfur dioxide (SO_2) emissions – a cause of respiratory illness and a precursor of acid rain – and nearly 15% of particulate emissions. In contrast, SO_2 and particulate emissions from the use of natural gas are close to zero. Combustion of natural gas does produce nitrogen oxides (NO_X), which can trigger respiratory problems and the formation of other hazardous particles and pollutants, but it accounts for less than 10% of global energy-related NO_X emissions compared with around 15% for coal.

With our new estimates for indirect emissions of coal, it is possible to provide a full comparison of the relative GHG emissions performance of coal and gas. Processing and transport are generally more energy intensive for gas than for coal, but gas extraction is generally less energy intensive than coal production. While there is a wide range in emissions from different sources of both coal and gas, on average the indirect emissions intensity of gas is around 50% higher than coal (0.67 tonne CO_2-eq per tonne of oil equivalent (toe) and 0.45 tonne CO_2-eq/toe respectively).

Indirect emissions intensity is only one element in this comparison. The emissions associated with the use of gas and coal also need to be factored in. There is some variation in the combustion emissions of coal depending on its quality (lignite has a higher emissions intensity than steam coal for example), but on average emissions are around 75% higher than gas. Gas-fired power plants are also generally more efficient in producing electricity than coal plants (the global average efficiency of gas-fired plants today is 52% while for coal-fired plants it is 42%).

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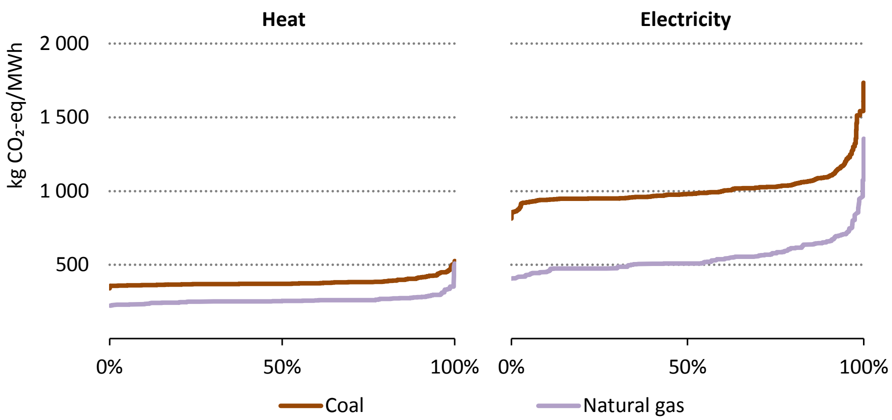
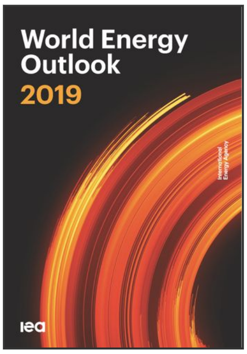
Figure 5.17 ▷ Lifecycle emission intensities of coal and natural gas used for heat and electricity generation, 2018



Over 98% of heat and electricity generation from natural gas today has a lower lifecycle emissions intensity than from coal

Notes: MWh = megawatt-hour. For heat, includes 1 300 Mtoe natural gas and 1 000 Mtoe coal used in the residential and industrial sectors in 2018. For electricity, includes 1 280 Mtoe natural gas and 2 400 Mtoe coal converted to electricity using region-specific electric plant efficiencies.

Overall we find that around 98% of heat generated in the residential and industrial sectors using gas has lower lifecycle emissions intensity than the heat provided from coal; similarly, 98% of electricity generated from gas has lower lifecycle emissions intensity than coal. Therefore, it is clear that the vast majority of gas use results in fewer emissions than coal (Figure 5.17). This finding highlights the importance both of minimising methane emissions from coal operations and reducing combustion emissions through the use of CCUS.



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