Strategies for Coal Transition in Korea

International Energy Agency

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Abstract

This report was commissioned by Korea's Ministry of Trade, Industry and Energy and carried out jointly by the International Energy Agency (IEA) and the Korea Energy Economics Institute. The objective of the study was to provide high-level policy recommendations on Korea's clean energy transition from coal in the power sector. The report covers a detailed review of policy and market developments around Korea's transition to net zero. The scope of the report includes all sectors of the economy, industry and all the regions across the world, where we extract the main recommendations that are applicable to the case of Korea.

Currently, the power sector is the largest CO_2-emitting sector and coal is the single biggest source of CO_2 emissions, as it is the backbone of many electricity systems. Thus, coal power plants have been a target for reaching net zero emissions by 2050 for long time. Korea has firm objectives to achieve carbon neutrality by 2050, aiming to accelerate the clean energy transition of coal power plants. Policy recommendations were formulated around two priorities: affordable and secure supply of electricity and people-centred transition.

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Executive summary

CO_2 emissions from coal are at the centre of the climate and energy debate

Coal is the largest energy source for electricity generation, steel making and cement production, three indispensable ingredients of modern life. At the same time, coal is the largest source of CO_2 emissions, responsible for around 40% of energy-related emissions. This puts coal at the centre of the energy and climate debate.

The fight against climate change entered a new phase in 2015 with the historic Paris Agreement, in which 195 countries and the European Union pledged to keep the temperature increases well below 2°C, preferably below 1.5°C above pre-industrial levels. Despite the strong signal given by the Paris Agreement, CO_2 emissions have not decreased since then, with the exception of 2020, in which the pandemic induced a temporary decline. In 2021, a strong rebound resulted in emissions surpassing 2019 levels to set a new record high. The same year, the International Energy Agency (IEA) published its first net zero roadmap, in which a narrow but possible pathway was identified to lead the global energy sector to carbon neutrality by 2050. In November 2022, the IEA published *Coal in Net Zero Transitions: Strategies for Rapid, Secure and People-Centred Change*; its analyses and conclusions will be one of the sources of this report. In particular, chapter 1 of this report draws mainly from *Coal in Net Zero Transitions* report.

The electricity sector of advanced economies must lead the race to net zero

Globally, two-thirds of coal – and therefore the associated emissions from it – are used for power generation, and the rest is mostly for industrial purposes, mainly steel, and to a lesser extent, cement. In addition, in the electricity sector there are a variety of low-carbon technologies that can replace coal, unlike in sectors such as steel, in which there are no commercially available technologies to replace coal at scale today. For these two reasons, the electricity sector should be the first sector to move to net zero emissions. Moreover, given that part of the strategy for the net zero transition is the increasing electrification of the transport and industrial sectors, such a strategy can be successful only if the electricity sector is net – or close to net – zero.

The energy transition requires important investments, which are more challenging – and more costly due to higher cost of capital – for emerging and developing economies than for mature economies. Therefore, the electricity sector of mature economies must

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lead the transition to net zero. Following that line, it is necessary to explore the opportunities and challenges of the transition to zero of coal power generation in Korea and which policies can help in this regard.

The challenges of transition of coal power in Korea

Korea's energy sector relies on coal up to some extent. The IEA has developed a Coal Transition Exposure Index, with which we assess the challenges faced by the countries when transitioning away from coal, which reflects that Korea is not highly dependent on coal. As Korean coal production is very limited, the country relies mostly on coal imports to meet its demand. At a national level, coal makes up 27% of total energy use. More than two-thirds of coal consumption is concentrated in the power sector followed by the iron and steel sector which account for most of the balance.

Driving down coal-related emissions in the power sector in Korea will be essential for wide energy-sector decarbonisation in the country, as they account for three-quarters of national power sector CO_2 emissions (and about a third of overall energy use). Presently, coal accounts for a third of the Korean power generation mix (closely followed by gas with 29% and nuclear with 27%). Renewables, on the other hand, make up about 7% of electricity generation in Korea. The 57 operational coal power plants (29 of them in Chungnam province) add up to 37 GW of coal-based generation capacity (among the top 10 in the world), and averaging 21 years of lifetime, it can be considered a moderately young coal-fired generation fleet. Moreover, the Korean coal-fired generation sector employs over 50 000 workers (considering both permanent and temporary jobs). Lock-in effects due to remaining uncovered capital of coal-fired plants, a relatively low share of renewable electricity in the power sector, and re-employment needs mark clear challenges for a quick transition away from unabated coal power in Korea.

Korea is already making some progress towards phasing down emissions from coal. Coal-fired generation declined from 240 TWh (42% of the power mix) in 2018 to 200 TWh in 2021 (34% of the mix), due to coal plant closures in 2017-2021 being offset by increases in nuclear, gas and, to a lesser extent, renewable output. Plans are already in place (for example, in Chungnam province) to address workers' relocation and tax revenue issues. More broadly, the Korean government has implemented relevant policies that impact coal-fired generation, such as the 3rd National Master Plan for Energy and the 9th Basic Plan for Long-Term Electricity Supply and Demand (BPLE), which aimed to ban construction of new coal power plants and retire (or convert) ageing inefficient units. Further, the Korean government unveiled 2050 carbon-neutral scenarios and aims to base its coal phase-down ambition on a legal framework and compensation arrangements. As per the Korean government, nuclear power expansion will be an essential driver of emissions reductions, as planned in the 10^{th} BPLE.

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An ad-hoc survey performed in Korea among 2 000 adults found that climate change is perceived by Koreans as the main challenge for the humankind, but only the third main challenge for Korea, after socio-economic disparity and ageing population. The government is the most important player in the transition, followed by business, public and municipalities. More than 90% of the participants were aware of the carbon neutrality pledge, but less than one-quarter knew the exact date to achieve it. Concerns about electricity security and price were identified as the main challenges. Around 70% of participants supported the coal transition despite the challenges. More than 90% think that the coal transition must go hand in hand with just transition policies.

Policy action in Korea can be a significant driver for a successful transition away from unabated coal use

To face the complexities entailed in a successful transition away from unabated coal use, policy makers in Korea must design and implement a well-studied set of policies. These measures should enable the country to unlock opportunities presented by the clean energy transition, while avoiding unintended consequences of phasing down unabated coal use, such as severe employment and economic impacts, particularly in labour-intensive regions with regard to coal. Many lessons can be obtained from experiences across the world as other countries progress in the transition and also, in particular regarding just transitions, from the past.

Promote a people-centred transition from coal power

A people-centred transition away from unabated coal should ensure fair treatment to workers and communities, opportunities for re-employment or alternative employment, compensation schemes, and sustainable production pathways. Korea should seek engagement and create governance schemes involving stakeholders directly affected by coal closures, but also other parties such as from academia and civil society. Social safety net expansions, retraining and job relocation programmes for coal power plant workers and their communities will be essential to ensure that nobody is left behind. Establishing clear long-term energy transition strategies would foster investment in promising technologies, such as electric mobility and renewable energy, resulting in stable job creation opportunities. Another crucial goal should be to carefully design the policy set to avoid regressive distributional impacts.

Ensure security and affordability of electricity supply

Electricity security and affordability are two essential components for a successful clean energy transition, and this is no exception in the case of Korea. Coal power plants not only provide electricity, but also contribute to system adequacy and flexibility and provide inertia to the grid. IEA analysis shows that those services can also be provided by low-emissions assets and storage technologies, which combined with other

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measures such as energy efficiency can support a transition to a more sustainable power grid without significant increases in electricity bills. Other tools such as demand response can enable the Korean power system in the future to avoid resorting to high-emissions generation to meet demand. Additionally, enhancements in electricity market design, for example on capacity and flexibility payments, can help to provide enough incentives for dispatchable assets to contribute to the system, particularly those that will see fewer operating hours per year than in the past. Finally, investments in enabling infrastructure such as transmission and distribution capacity will be crucial; this requires social engagement, especially when seeking to speed up the approval processes while still ensuring compliance with legal and social procedures.

Make the most out of existing coal assets

Repurposing existing coal power plant sites presents several potential benefits, such as longer asset utilisation, mitigation of impacts on jobs and tax revenues, enhanced security of supply, and making use of existing grid connections that may otherwise take a long time to be established for new plants. Coal-fired plants can be retrofitted to use carbon capture, utilisation and storage technologies, helping to decrease their emissions substantially while keeping some of their advantages such as flexibility and ability to provide ancillary services. Other low-emissions conversion possibilities include retrofitting coal power plants to co-fire coal with biomass or ammonia, for which there are already successful projects around the world. Additionally, coal plants could be repurposed to host a small modular reactor for nuclear electricity generation. As the upfront costs and technology readiness for these options vary, policy makers and industry will have to carefully decide which option is best for each plant intended to be repurposed. Early retirements could also be a feasible solution in some cases, to then potentially repurpose their sites for other ends.

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Chapter 1. Coal in clean energy transitions

Coal in the net zero transition in the global context

Introduction

For some time, climate change has been identified as one of the main challenges the world is facing. Despite decades of significant international efforts, it was not until 2015 when a legally binding international treaty was adopted by the practical totality of the countries of the world, as 195 countries plus the European Union signed the Paris Agreement, with the goal of limiting global warming to well below 2° C, preferably to 1.5° C, compared with pre-industrial levels. The Paris Agreement is a historical milestone in the climate negotiations process. However, the analyses of the International Energy Agency (IEA) showed that the pledges as expressed in the nationally determined contributions of the countries were far from what was needed to lead the trajectory that the agreement actually pursued. Climate ambitions have been gaining momentum since the Paris Agreement was signed, with a growing number of countries pledging to reach carbon neutrality or net zero emissions by mid-century or soon afterwards. However, with the exception of the decline driven by the Covid-19 outbreak and associated lockdowns and economic recession, global greenhouse gas (GHG) emissions have continued to increase. Actually, the rebound of over 2 Gt CO_2 emissions in 2021 is the biggest increase ever, making 2021 the all-time high at that time, with preliminary figures suggesting that 2022 would mark a new high.

Turning the trajectory around requires reductions in emissions from all fuels, including from oil and gas. However, a rapid decline in unabated coal use is inevitably a central feature of all pathways to a more sustainable energy system. Coal is the most carbon-intensive fossil fuel and is responsible for a larger share of global GHG emissions than any other source of energy – 15 Gt CO_2 in 2021.

However, global coal demand and its CO_2 emissions have been stagnant, at or close to its highest level for a decade. With over 95% of global coal consumption occurring in countries that have pledged to reach net zero, governments and other stakeholders need to move quickly to decrease emissions. Global coal use is heavily concentrated in a small number of countries, in which coal plays a crucial role in their energy sector – in particular, electricity, and also in the industry and the wider economy.

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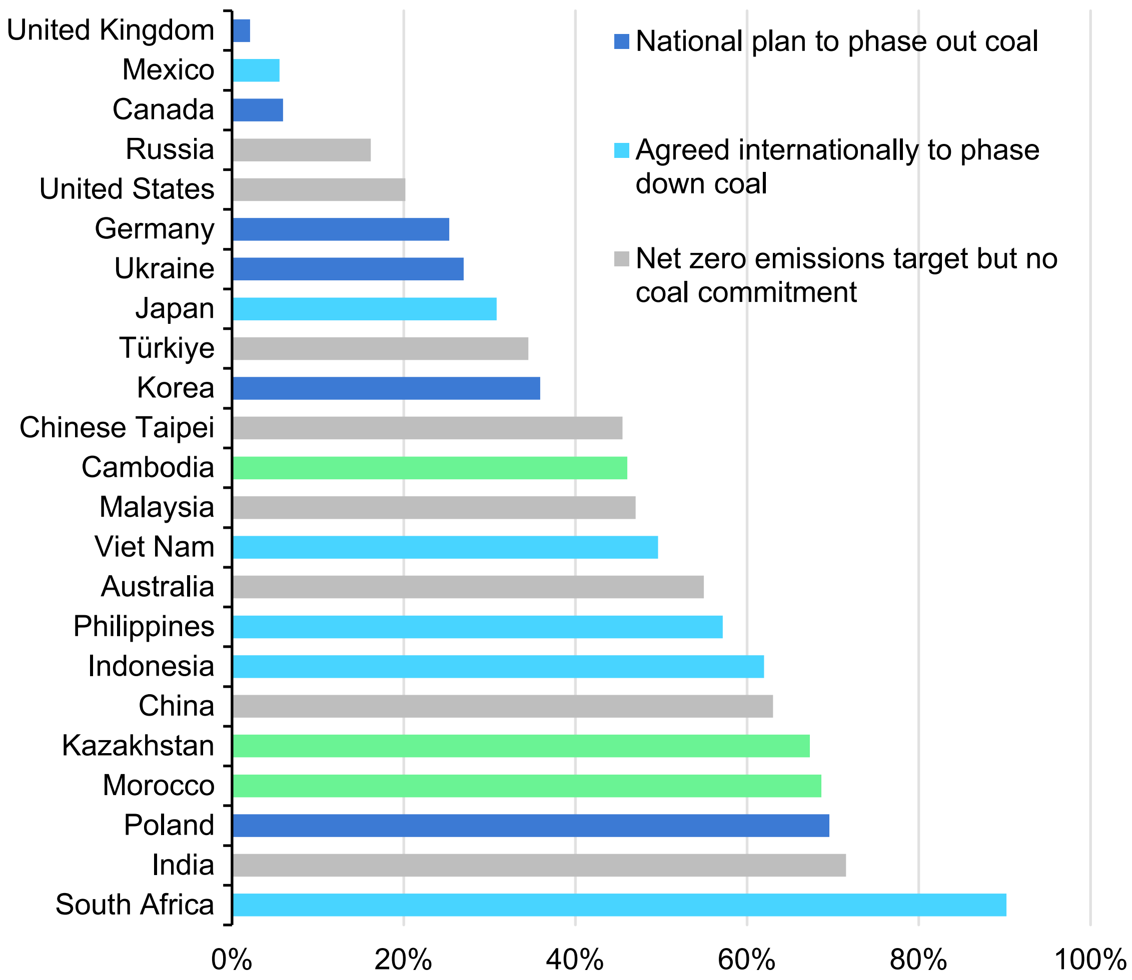
Specifically in the electricity system, the deployment of renewables and other clean alternatives is vital to replace coal power plants, although it should be accompanied by adequate infrastructure such as grids and energy storage in order to secure a reliable energy supply.

Share of coal in electricity generation and coal policies



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Impacts of the clean energy transition relative to coal are country-specific. It varies depending on the level of coal in the national energy mix, resource endowments, the structure of the labour market and the acceptance of local society. In order to assess the challenges the countries face in the transition process, the IEA developed the Coal Transition Exposure Index (CTEI), a typology of major coal-producing and -consuming countries' exposure to the global clean energy transition. The CTEI maps out which countries are dependent on coal and in what ways. It is structured with four key categories and two indicators for each category.

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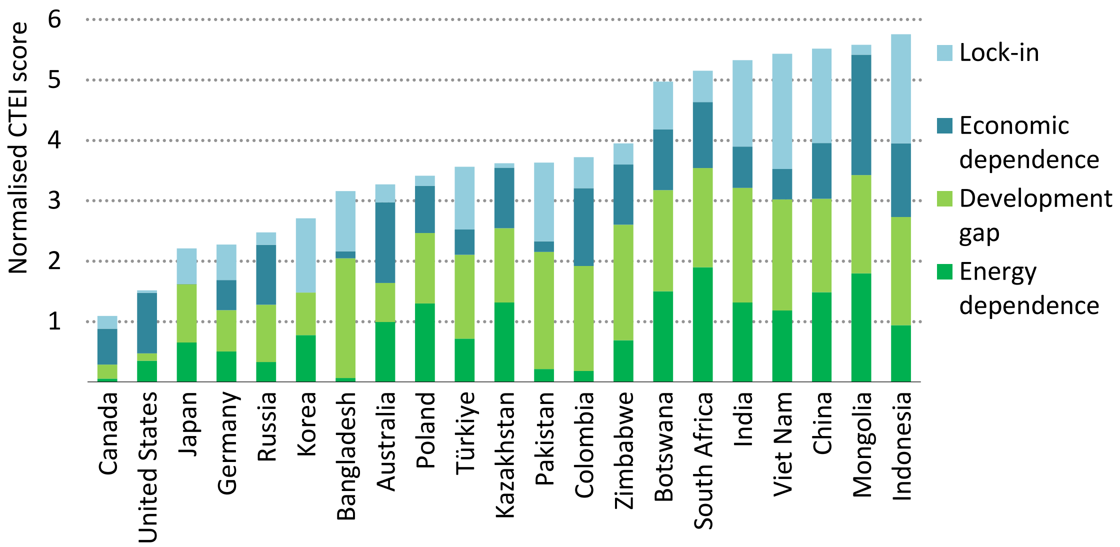
- **Energy dependence on coal** is its share in the energy mix and in electricity generation. This category gives a direction of what it will take for a country to reduce coal use.
- **Development gap** is quantified by GDP per capita measured at purchasing power parity and total final energy consumption per capita. It provides an approximate idea for a country's future rate of energy demand growth and its financial and technological capacities. A country with rapidly increasing energy demand will have to expand clean energy supply as fast as demand in order to avoid increased coal use.
- **Economic dependence** is the share of coal in total goods exports and the share of coal produced domestically compared with total coal consumption. Domestic production of a sizeable share of coal demand is likely to see coal playing a larger role in the economy than for a country that imports coal.
- **Lock-in** quantifies the challenge of potential early retirement of assets that have not been fully depreciated. Two indicators used are the capacity-weighted ages of a country's integrated steel mills and its coal-fired power plants.

The raw data of each indicator were normalised in order to assign a total score to generate the index. From least to most, Botswana, South Africa, India, Viet Nam, the People's Republic of China (hereafter "China"), Mongolia and Indonesia have a particularly heavy and multifaceted dependence on coal, the biggest among the world's countries. Scores have been calculated for a selection of countries that represent more than 90% of global coal production and consumption. The 15 largest coal producers and 15 largest coal consumers are included.

Coal Transition Exposure Index and its components



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Korea, despite its medium to high coal dependency in the power generation mix, is a developed economy without a significant domestic coal-mining sector, and therefore is

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not among the most impacted countries, but this does not mean that a coal transition for Korea is going to be a simple task.

Coal mining – a particularly labour-intensive sector – is usually concentrated in few regions even in large producing countries. Therefore, it is important to consider the regional aspect of transitions. Regions such as Shanxi in China, Mpumalanga in South Africa and East Kalimantan in Indonesia have a strong density of jobs, companies and tax revenues linked to coal mining, and this needs to be addressed in a very particular way. In the case of the coal power sector, the labour intensity is lower and might need less intervention, but the social aspects of the transition have to be properly addressed. The second chapter of this report analyses the regional distribution of plants and jobs in Korea.

In the Net Zero by 2050 report, the IEA clearly states that the clean energy transition is for and about people. Indeed, workers of the fossil fuel industry are the most recognisable vulnerable element in the transition to net zero. But this is not just about workers, and this is why the IEA has widened the concept of just transition, with a focus on workers, towards the people-centred transition, which incorporates all the principles of just transition, but tries to be more inclusive. It means that the citizens, not only those linked to coal or the fossil fuel industry, must be recognised as active participants of the transition for at least two very good reasons. First, because this is the fair way to do it. Second, because without people's engagement and support, the clean energy transition will derail.

After the publication of Net Zero by 2050 in May 2021, the World Energy Outlook (WEO), the IEA's flagship publication, included the Net Zero Emissions by 2050 (NZE) Scenario within its long-term scenarios, taking into account the latest information about energy markets and technologies. The NZE Scenario identifies four priorities in order to keep the door to 1.5° C open in the current decade. The priorities are clean electricity, energy efficiency, prevention of methane leaks and technology innovation. The acceleration in the first three areas can be done with existing technologies with adequate policy and financing support. However, almost half of emissions reductions in the NZE Scenario come from technologies which are not commercially available today, mainly linked to heavy industries and long-distance transportation, the sectors in which electrification is the most challenging. Technology innovation is therefore a key element in achieving global climate goals and ensuring a smooth transition in the electricity system.

In November 2021, the 26th Conference of the Parties (COP26) concluded the Glasgow Climate Pact, which included a call on the parties to "accelerate efforts towards the phase-down of unabated coal power".

In parallel to COP26, 46 countries and more than 30 subnational governments and organisations signed the Global Coal to Clean Power Transition Statement, in which signatories recognised the need to accelerate the transition from unabated coal power

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generation to clean energy. The statement comprises four points, of which point two is especially relevant, as it includes the commitment to achieve a transition away from unabated coal power generation in the 2030s or soon afterwards for major economies and in the 2040s or soon afterwards globally. The signatories of the statement include big consumers of coal, such as Germany, Indonesia, Kazakhstan, Korea, Poland and Viet Nam.

As coal is the single largest CO_2-emitting fuel and the backbone of many electricity systems, especially in emerging and developing economies, unabated coal was one of the main topics of discussion in Glasgow. From the discussions, it was evident that the world needs clear strategies and strong policies in order to rapidly reduce coal emissions. In the case of emerging and developing economies, international support is also needed to face the consequences throughout the economy of transitioning away from unabated coal. In Glasgow, it was also clear that the gap between pledges and targets versus reality and data was increasing. In order to help narrow the ambition gap, in the run-up to COP27, the IEA launched a report, Coal in Global Net Zero Transitions: Strategies for Rapid, Secure and People-Centred Change, with the purpose of giving clear guidance for countries to reduce coal-related emissions, focusing particularly on emerging economies, a people-centred transition and practical recommendations to make progress in this decade. The analyses and conclusions extracted from Coal in Global Net Zero Transitions, together with complementary research made on Korea, constitute the foundations of this report. The report mainly focuses on coal use in the electricity sector in Korea, and thus contains relatively limited discussions on the two important aspects identified in the Coal in Global Net Zero Transitions report.

a) **Coal transitions in industry:** While the power sector is the largest consumer of coal, rapidly reducing coal use in the energy system also requires actions in the industry sector, which consumes a large amount of coal. For some of those industries there are no current technologies at scale to replace coal use. Moreover, some of the industrial emissions come from the process itself, regardless of the fuel used in production. While carbon capture, utilisation and storage (CCUS) can provide some abatement of emissions, there is still a big technological gap to be covered by innovation.

b) **International financial support to aid coal transitions in emerging and developing economies (EMDEs):** One of the main barriers for the energy transition is the lack of investment in EMDEs. Financial and technological support for EMDEs needs to be an important pillar of the coal transition strategies in advanced economies, including Korea. Our analyses suggest that with strong international co-operation, the world can achieve the energy transition more smoothly than in a segmented world.

In many markets, coal has been seen as a relatively cheap fuel, and its position in the electricity sector is often shielded from market competition by long-term power purchase agreements or other instruments. However, the tight supply amid the current

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energy crisis as well as inflation in the input costs of coal production are driving up coal prices. The global fleet of coal power plants saw unprecedented growth in the last two decades driven by developments in Asia. A number of EMDEs have very young fleets, in which large amounts of capital remain unrecovered. For example, the average age of the coal fleet in China is only 13 years, 12 years in Indonesia, and 8 years in Viet Nam. The average age of Korea's coal power plants is 21 years. An estimated 8.4 million people are employed in coal production, processing, transport and power generation around the world. Many of these jobs, in particular those related to mining and processing, are very localised and the coal sector is deeply embedded in the local economies of producing regions. In the case of Korea, the majority of coal-related jobs are concentrated in import terminals, transportation and coal power plants.

The IEA adopts the concept of people-centred transitions, which is a broader concept than just transitions. In any case, the common element of both approaches is the support for workers and communities impacted by the transition. The closure of coal power plants may have a significant impact on communities, which needs to be carefully addressed. There are also many considerations around the closure of coal mines, given the high labour-intense nature of coal mining and some other peculiarities.

Global coal demand rebounded strongly in 2021 to 5 650 Mtce as economies recovered from the pandemic and coal-fired power generation reached a historic high in 2021. The global energy crisis in 2022 sharpened energy security concerns, and several countries have announced plans to extend the use of coal in the near term, although long-term strategies towards net zero have remained firm. Against this backdrop, it is essential to understand the factors underpinning today's high levels of coal consumption and what lessons can be drawn from countries that have successfully reduced reliance on coal, and to find ways to align near-term energy security imperatives with longer-term energy transition goals.

A new context for the net zero transition

Coal and energy security

Energy commodities in the global market rose to record prices in 2022 as a result of market imbalances and supply chain disruptions following the Covid-19 pandemic and that were exacerbated by the Russian Federation's (hereafter, "Russia") invasion of Ukraine. Prices of natural gas in Europe have been regularly above USD 40/MBtu for more than one year, which is more than double the oil price on an energy-equivalent basis. International coal has also seen unprecedented price levels, higher than USD 400/tonne, more than tripling the average price of the 2010s. In turn, high prices of natural gas and coal have led to high electricity prices in many markets. The global energy crisis is hurting entire economies – more severely in the EMDEs.

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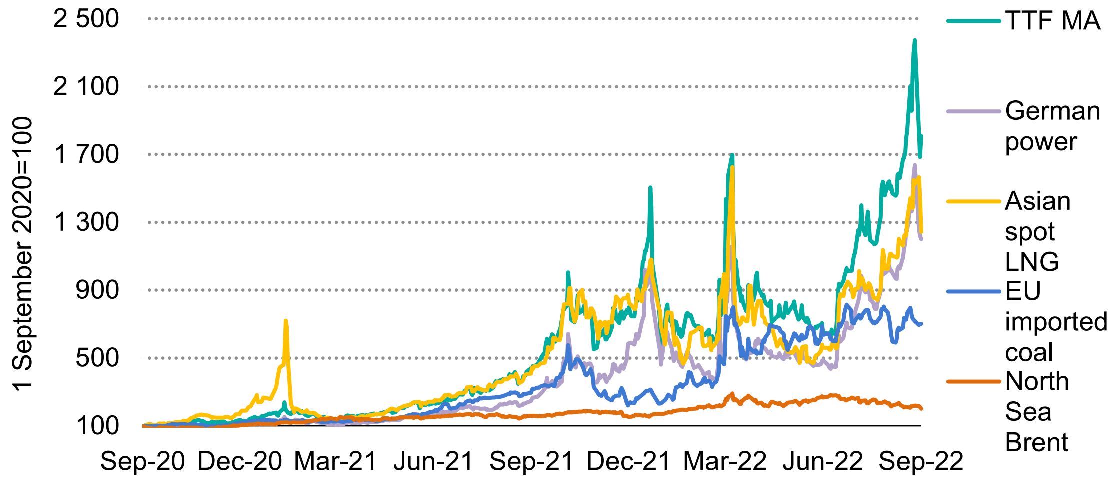
Energy prices in global markets, 2020-2022



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Note: TTF MA = Title Transfer Facility month-ahead; LNG = liquefied natural gas.

Coal is the most abundant fossil fuel and reserves would be enough to satisfy 100 years of global consumption with current levels. The United States is estimated to have the largest coal reserves with more than 200 Gt, followed by China, Russia, Australia and India. The low energy density of coal, less versatility than other fossil fuels and air pollution issues have driven the substitution of coal in transportation and residential heating, meaning that its direct use is overwhelmingly directed to the electricity and some industrial sectors.

In 2022, importing countries have faced extremely high prices, but the aggregate costs of coal to the energy system have not increased as much: in countries that use domestic coal, prices are often lower than in international markets. Price changes in international markets have a strong impact in countries that import almost all of their coal such as Korea and Japan.

Global coal demand has been stable for over a decade

Total coal accounts for around a quarter of the world's total energy supply, which is at its highest-ever level. Energy supply from coal has been between 5 200 Mtce (155 EJ) and 5 650 Mtce (165 EJ) each year since 2010, oscillating by 3% around a central value of 5 500 Mtce depending on annual changes in economic growth, weather and energy markets. Contrary to some accounts of the imminent end of coal or of a coal renaissance, coal demand has been surprisingly stable for more than a decade despite many changes in the global economy and energy sector.

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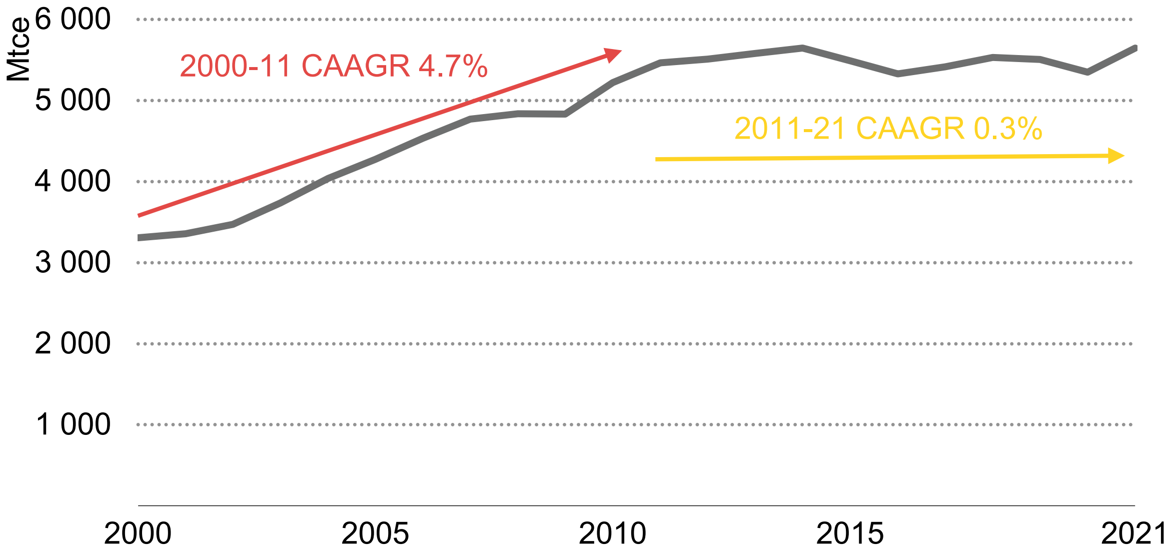
Global total energy supply from coal, 2000-2021



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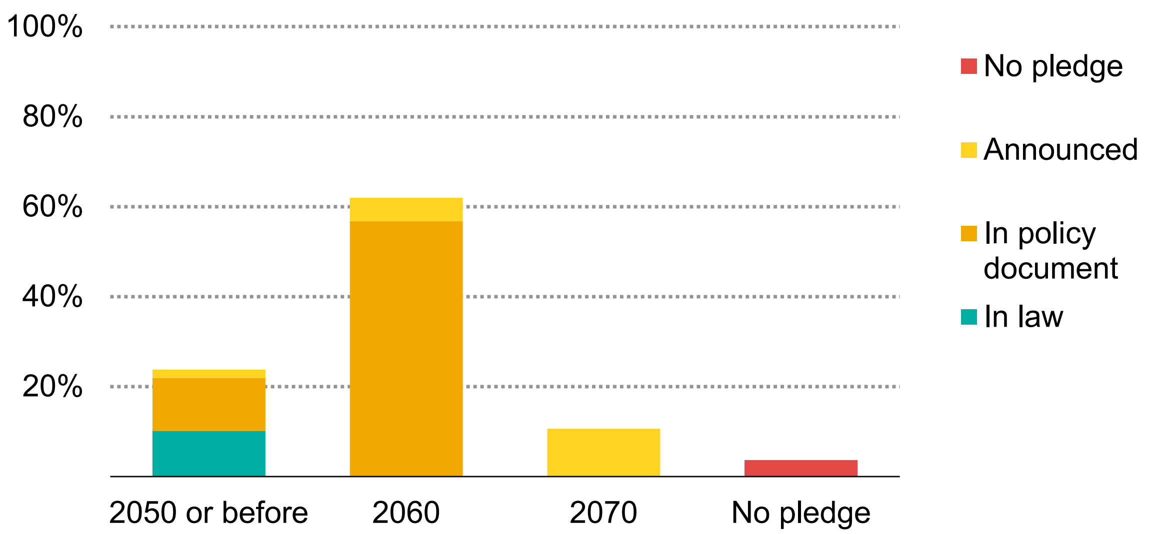
Note: CAAGR = compounded annual average growth rate.

Nonetheless, coal has been increasingly in the spotlight for policy makers, investors and activists. This is not surprising given that more than 95% of global coal consumption occurs in countries that have net zero emissions pledges, albeit on different timescales and varying levels of legal status. Despite all these commitments, unabated coal demand has not yet entered into a structural decline.

Share of global coal consumption covered by net zero emissions pledges, by target date and status



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Emerging market and developing economies increasingly dominate coal use

Coal is unique among fuels in the unparalleled dominance of a single country: China, which accounts for over 55% of global coal demand. China's power sector alone accounts for one-third of global coal demand. Indeed, China's coal-fired power generation is larger than total generation in any country. China is also the largest coal producer by far, mining roughly half of global output, and the largest coal importer. Despite China's impressive deployment of clean energy technologies, coal still accounts for more than half of China's energy supply and almost two-thirds of electricity generation.

The second-largest coal-consuming country is India, accounting for over 10% of global coal demand. Coal is also the cornerstone of India's electricity generation, accounting for around three-quarters of total generation. India has around 45% of the coal share in the total energy supply mix, which is lower than in China (around 60%), owing to India's lower level of coal-intensive industrial energy demand.

Together, China and India account for two-thirds of global coal demand. EMDEs as a whole accounted for over 80% in 2021, up from less than half in 2000. Coal demand in advanced economies has declined by about one-third over the last two decades. The United States now accounts for around 6% of global coal demand and the European Union for around 4%.

The picture is slightly different in per capita terms, due to the large population and lower energy demand per capita in EMDEs. In the early 2000s, the United States consumed nearly 2.5 tce, or 80 GJ, of coal per capita. As a result of a modest decline in total energy demand, and a substantial switch to natural gas and renewables, the United States' total coal demand per capita has more than halved over the last two decades, and is now well below China's. Despite the large size of India's total coal demand, in per capita terms it consumes only around 0.45 tce (13 GJ), still less than half the level of the United States. Nonetheless, the decline in the European Union's consumption of coal means that per capita coal demand in the European Union is close to that of India today (around 0.5 tce or 15 GJ).

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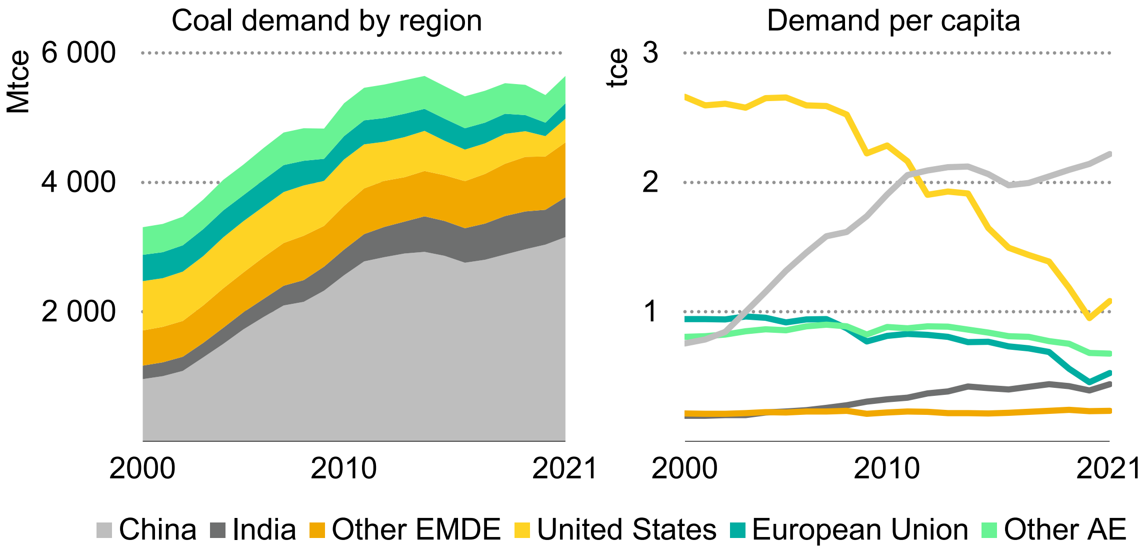
Regional share in global coal demand and regional coal demand per capita, 2000-2021



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Note: Other EMDEs = emerging market and developing economies excluding China and India; Other AEs = advanced economies excluding the United States and the European Union.

Coal use is deeply embedded in few sectors

Coal's stable position in the global energy mix has been driven by its role in power generation, which accounts for two-thirds of total coal demand. Although low-emissions sources of electricity generation, -i.e. renewables and nuclear- as a group have recently overtaken it, coal is still the single largest source of electricity generation, responsible for 36% of total electricity generation. The share of coal in the generation mix has been slowly decreasing as the share of electricity in total energy has been rising.

The industry sector accounts for almost one-third of global coal demand. In particular, coal is the dominant source of energy used to make two essential products for modern civilisation: steel and cement. The iron and steel sector accounts for around 16% of total coal demand. Coal is the largest source of energy for cement production with a share of over 50% due to its low cost and high availability.

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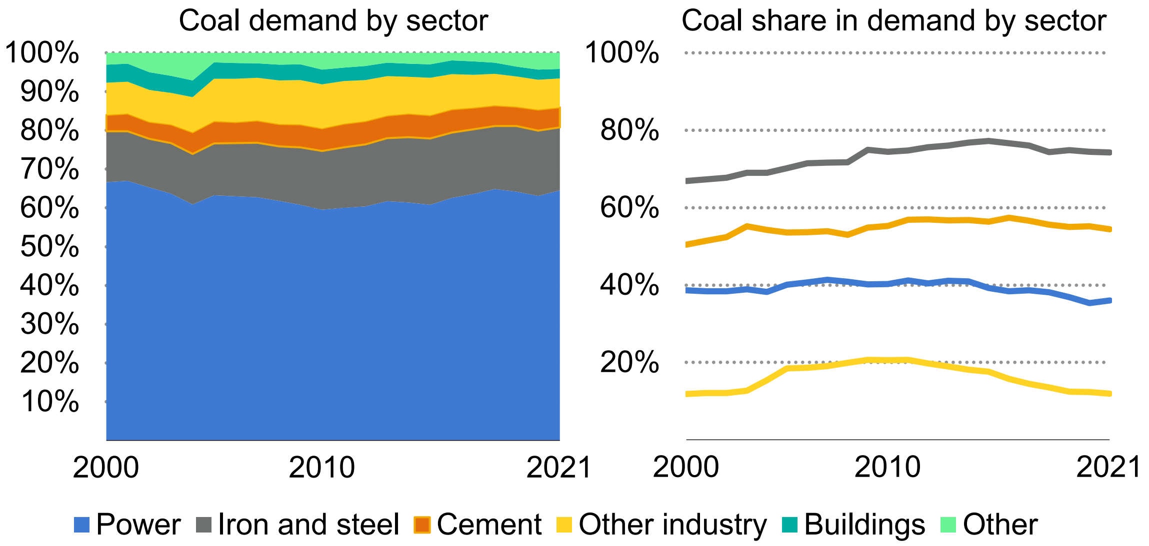
Global coal demand by sector and coal share in energy demand by sector, 2000-2021



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Notes: For end-use sectors the right panel shows the share of coal in the sector's total final consumption. For the power sector it shows the share of coal-fired electricity in total generation. Power generation accounts for two-thirds of total coal demand; coal is the dominant energy source for steel and cement manufacturing.

The surge in coal-fired capacity additions since 2000 was unprecedented. Between 2000 and 2021, the total installed capacity of coal-fired generation almost doubled, from about 1 100 GW to almost 2 200 GW. Even taking account of growing population, the expansion represents the fastest increase in the global installed capacity of coal-fired generation since the birth of this technology. The rapid growth in coal-fired generation capacity in the 2000s was largely driven by EMDEs, particularly in the Asia Pacific region and especially in China. The world now has a large stock of young coal-fired power plants, which must be made compatible with the pathway to net zero emissions.

Status of coal phase-down pledges

An increasing number of countries have made net zero emissions pledges or adopted policies to reduce coal use in the power sector. Since the Paris Agreement was signed, 21 countries have committed to fully phase down coal within a fixed time frame. EU climate policies were significant in reducing coal's share of power generation, which has accelerated the transition from coal in the region. Among Group of 20 (G20) countries, only 5 have a full coal phase-down target: Canada, France, Germany, Italy and the United Kingdom. Emissions from the coal-fired power sectors of these five countries take up less than 0.8% of global emissions. By August 2022, only four countries had completed their phase-downs, Austria in 2020, Belgium in 2016, Portugal in 2021 and Sweden in 2020. Though the current high gas prices and scarcity are obliging some countries to rely on coal more than previously expected, no major changes have been perceived so far regarding coal phase-down plans. The main

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changes are that in France and the United Kingdom, the full phase-down might be delayed one year or so, and in Austria the Mellach coal power plant could be connected again to the grid, delaying its coal phase-down for few years, if it ever works. However, the capacity of the plant is only 240 MW.

Seven large countries with a net zero emissions target remain without a coal phase-down plan: Brazil, China, India Japan, Korea, South Africa and the United States. In any case, Group of Seven (G7) countries committed to achieving carbon neutrality in the power sector by 2035 and an eventual phase-down of unabated coal power generation. In the United States, carbon neutrality in the power system by 2035 implies the end of unabated coal power generation by that date or earlier. Other countries from the G20, most notably Russia, do not have a net zero target yet. Several countries made announcements in 2021 to retire their coal power plant fleet ahead of time, which includes Chile, Hungary and the United Kingdom.

Share of coal in the power mix (%)

Countries	Target date	IEA Net Zero by 2050 target	Coal's share in the national power supply (2020)	Share of coal in national CO_2 emissions (2019)	Most power generation coal from domestic mines
Austria	2020	2050	3%	8.6%	No
Belgium	2017	No	3%	5.8%	No
Canada	2030	2050	5%	7.2%	Yes
Chile	2040	2050	31%	32.9%	No
Denmark	2028	2050	11%	11.2%	No
Finland	2029	2035	8%	27.6%	No
France	2022	2050	1%	3.6%	No
Germany	2038	2045	26%	28.0%	Yes
Greece	2028	No	13%	22.8%	Yes
Hungary	2025	2050	11%	11.9%	Yes
Ireland	2025	2050	5%	7.5%	No
Israel	2030	No	28%	32.2%	No
Italy	2025	2050	5%	7.1%	No
Netherlands	2029	2050	8%	13.4%	No
New Zealand	2030	2050	5%	8.9%	Yes
Portugal	2021	2050	5%	11.6%	No

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Countries	Target date	IEA Net Zero by 2050 target	Coal's share in the national power supply (2020)	Share of coal in national CO_2 emissions (2019)	Most power generation coal from domestic mines
Romania	2032	No	17%	25.3%	Yes
Slovak Republic	2030	2050	7%	11.5%	Yes
Spain	2030	2050	2%	6.2%	No
Sweden	2020	2045	1%	8.0%	No
United Kingdom	2024	2050	2%	3.3%	No

During COP23 in 2017, Canada and the United Kingdom launched the Powering Past Coal Alliance (PPCA), with the goal of accelerating the transition from unabated coal power generation. The PPCA shares memberships with national and subnational governments and business and international organisations. In addition to most of the countries listed in the table above, the following countries have joined the PPCA: Albania, Angola, Costa Rica, Croatia, El Salvador, Ethiopia, Fiji, Latvia, Liechtenstein, Lithuania, Luxembourg, Marshall Islands, Mexico, Niue, the Republic of North Macedonia (hereafter, "North Macedonia"), Peru, Senegal, Switzerland, Tuvalu, Uruguay and Vanuatu. Among them, only Croatia, Mexico, North Macedonia, Peru and Senegal generate some electricity from coal. During COP26 came the Global Coal to Clean Power Transition Statement, with the goal of accelerating the transition of unabated coal power generation. These international agreements also include provisions on just transitions, attraction of private finance, energy security, and utilities and grids.

The outlook for coal use and emissions

This report uses the latest scenarios from the IEA Global Energy and Climate Model, developed for the World Energy Outlook 2022 (WEO-2022). The WEO-2022 includes detailed analysis of the energy sector transformation of each of the scenarios listed below. The sections below focus on the implications for coal markets, emissions and the role of CCUS.

- **The Announced Pledges Scenario (APS)** assumes that all climate commitments made by governments around the world, including nationally determined contributions (NDCs) and longer-term net zero pledges, will be met in full and on time, regardless of whether these pledges are currently backed by detailed implementing laws, policies and regulations.
- The **Net Zero Emissions by 2050 (NZE) Scenario** sets out a narrow but achievable pathway for the global energy sector to achieve net zero

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CO_2 emissions by 2050. In this scenario, advanced economies take the lead, but all regions achieve very rapid reductions in energy sector CO_2 emissions in order to enable the global energy sector to reach net zero by 2050.

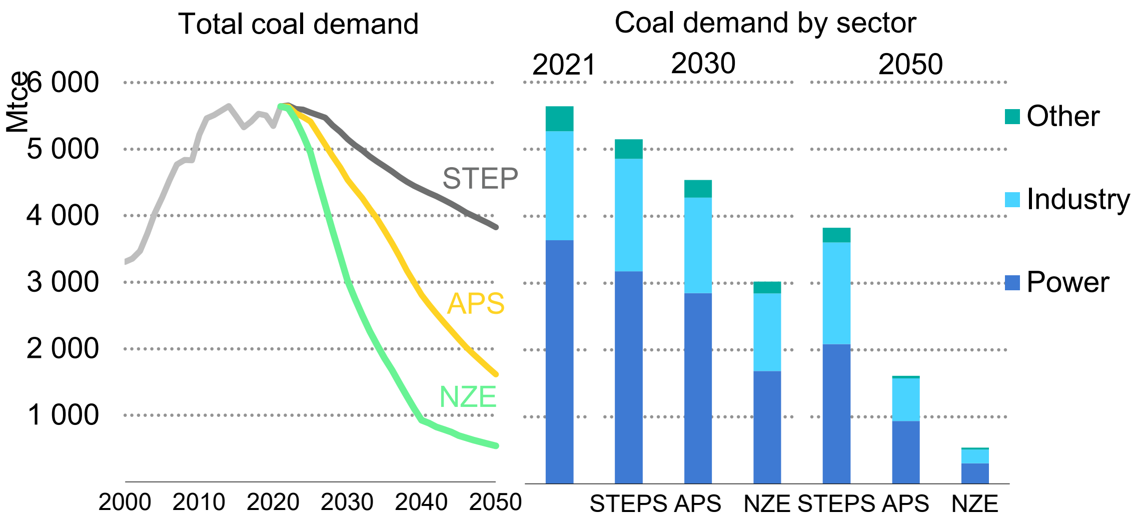
- The **Stated Policies Scenario (STEPS)** takes a more conservative and granular approach, integrating sector-by-sector analysis of the impacts of established and announced policies and regulations. It does not assume that net zero emissions pledges are met in full and on time unless they are backed up by specific policy measures.

Coal demand

The drop in coal demand in 2020 was more than offset by a strong rebound in 2021, taking it very close to its all-time high. In 2022, demand for coal was expected to increase marginally as nations attempted to fulfil rising energy demand while contending with slower economic development. Despite the energy crisis had a strong impact on many variables, expectations were confirmed and after a moderate growth, coal demand reached a new all-time high in 2022.

Demand for coal is projected to fall structurally in all of our scenarios starting in the current decade, but the speed of this decline is highly dependent on the stringency of climate legislations. In STEPS, the need for coal declines by just under 10% to 2030 and by 30% by 2050. While industry coal demand declines moderately, the majority of the drop takes place in the power sector, which is concentrated mostly in advanced economies.

Coal demand by scenario and sector, 2010-2050



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Note: Other includes the small amounts of coal consumed in the buildings and transport sectors, and in the other energy transformation sector. Power includes both electricity and heat production. ‘

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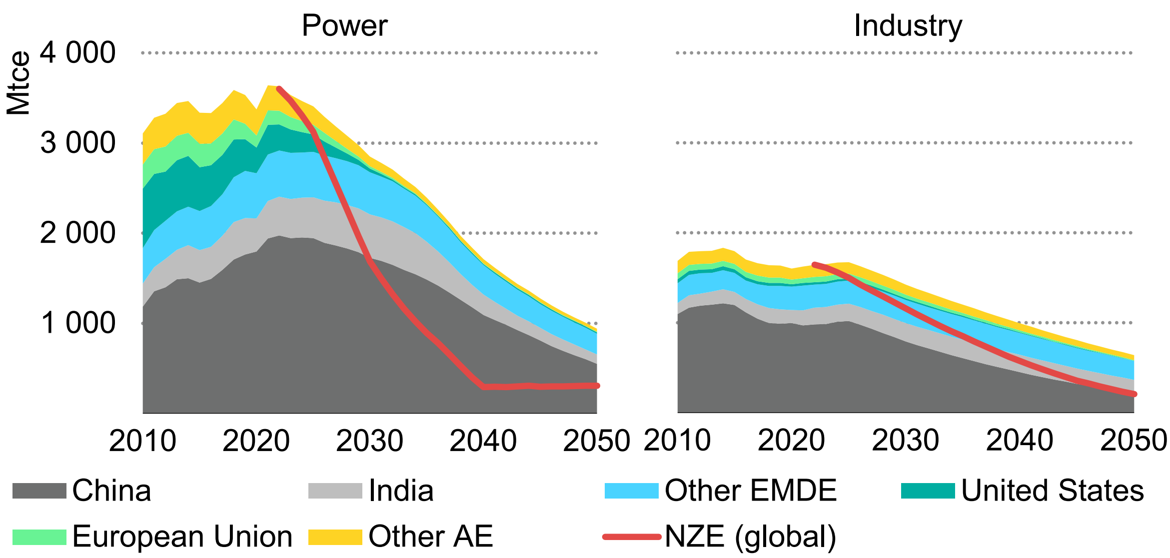
In the APS, total coal demand falls by around 20% to 2030 and by 75% to 2050. The electricity sector experiences the largest declines through 2030 as renewable energy and other low-emissions sources start to displace coal. Just slightly slower than the pace of increase in the world's coal demand between 2000 and 2010, total coal use declines by just over 2% annually from now until 2030. After 2030, global coal demand shrinks at an annual pace of more than 5%, which is quicker than the rate at which industrialised economies reduced their coal consumption over the previous decade.

Given net zero commitments for 2050 and a relatively slower pace of energy demand growth (electricity consumption increases by 2% per year to 2030), coal use in advanced economies falls by almost 75% to 2030. Electricity consumption grows faster in EMDEs (nearly 3.5% per year through to 2030), and many nations have committed to achieving net zero emissions at a later timing, by 2060 or 2070. As a result, between 2021 and 2030, coal use for power generation decreases by 10%, with China experiencing a 10% decline and India experiencing a 15% increase. These patterns are a result of the two countries' divergent rates of economic development, with China's mature economy experiencing slower increases in both GDP and energy demand than India. By 2050, coal use in the electricity sectors of EMDEs has been reduced by more than half.

Coal demand by region in power and industry, 2010-2050



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In industry, options to substitute coal are at a lower technological maturity than in the power sector. In the APS, coal use in advanced economies decreases by around 20% to 2030, largely due to energy and material efficiency measures. By 2030, China's demand for coal will have decreased by roughly 20% as the market for raw materials such as steel starts to become saturated. In other emerging market and developing

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nations, coal demand in the industry sector increases by roughly 5% to 2030 as demand for steel and cement production continues to grow. Global industry demand for coal falls by more than 60% by 2050.

Both the electricity and industry sectors see declines in coal demand in the APS, initially led by reductions in advanced economies. Declines in the NZE Scenario are much steeper. In the NZE Scenario, global coal demand falls by 45% to 2030 and by 90% to 2050 to 540 Mtce. Declines are led by the electricity sector, where coal use is reduced by nearly 55% between 2021 and 2030 as low-emissions sources of generation dramatically ramp up.

The use of coal with CCUS

Coal facilities equipped with CCUS can produce low-emissions power, industrial products (steel, cement) and hydrogen and hydrogen-based fuels. CCUS provides an opportunity for countries with large coal resources to continue to produce domestic energy resources, preserve existing strategic assets and cushion the impacts of transitions on coal-dependent communities, while reducing emissions.

The development of coal-related CCUS applications has been limited to date. There are five CCUS projects in operation globally that capture around 5 Mt CO_2 each year from coal-based applications. This amounts to around 13% of current global capture capacity. As seen in the table below, China has three operating projects in the coal-based chemicals, power and fertiliser sectors, although the largest single facility is in the United States.

Operating coal-related commercial-scale CCUS facilities and their applications

Country	Project	Project promoter	Application	Capacity (Mt/yr)
China	Nanjing Chemical Industries CCUS project	Sinopec	Chemicals	0.2
	Qilu Petrochemical Plant	Sinopec	Chemicals	1
	Guohua Power Jinjie	China Energy	Power	0.15
Canada	Boundary Dam CCS	Saskpower	Power	1
United States	Great Plains Synfuel Plant	Dakota Gas	Fuel supply	3

Notes: CCS = carbon capture and storage. Projects are considered commercial-scale if they have an annual capture capacity of 0.1 Mt CO_2 or greater. The Nanjing Chemical Industries CCUS project and Qilu Petrochemical Plant use coal as their primary feedstock.

Source: IEA Tracking, (Cai, Lin, & Ma, 2020) and corporate communications.

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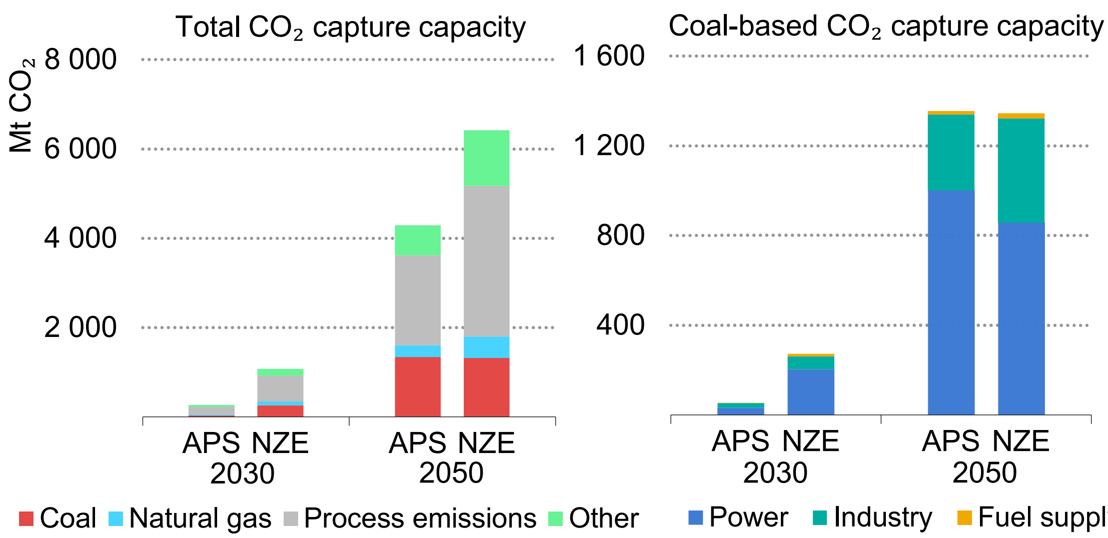
As of December 2022 there were 18 coal-related CCUS projects currently under development: 12 are in the power sector, 3 are in industry and 3 are for fuel supply. China is developing 7 projects, the United States is developing 5, and the remainder are in Australia, Japan, India, Indonesia and Russia. If all 18 projects were to be fully developed, they would capture around 30 Mt CO_2 each year by 2030.

In the APS, around 53 Mt CO_2 is captured from coal facilities in 2030 and 1 300 Mt CO_2 is captured in 2050. In the power sector, CCUS is retrofitted onto coal plants to support emissions reductions while allowing existing plants to continue to operate; this is especially important in developing economies in Asia which have a very large fleet of young coal-fired power plants. In industry, coal use with CCUS continues mainly in steel and cement production and is concentrated in EMDEs such as China, India and Russia. Around 30% of global coal in 2050 in the APS is equipped with CCUS.

In the NZE Scenario, there is a much faster ramp-up in coal CCUS to 2030 (when 260 Mt CO_2 is captured from coal plants) but volumes captured in 2050 are slightly lower than levels in the APS. This is because the NZE Scenario sees more fuel-switching away from coal, the faster retirement of coal-fired assets and a much greater role for renewable power generation. More than three-quarters of coal use in 2050 in the NZE Scenario is equipped with CCUS.

The current pipeline of under-construction and proposed projects would provide around 70% of the CO_2 captured from coal CCUS in 2030 in the APS and less than 15% in the NZE Scenario. Making up the difference will require strong policy support. Coal CCUS is important in the APS and NZE Scenario, especially in EMDEs. CCUS is used with 30% of coal in the APS in 2050 and 70% in the NZE Scenario.

CO_2 capture capacity by scenario, sector and fuel



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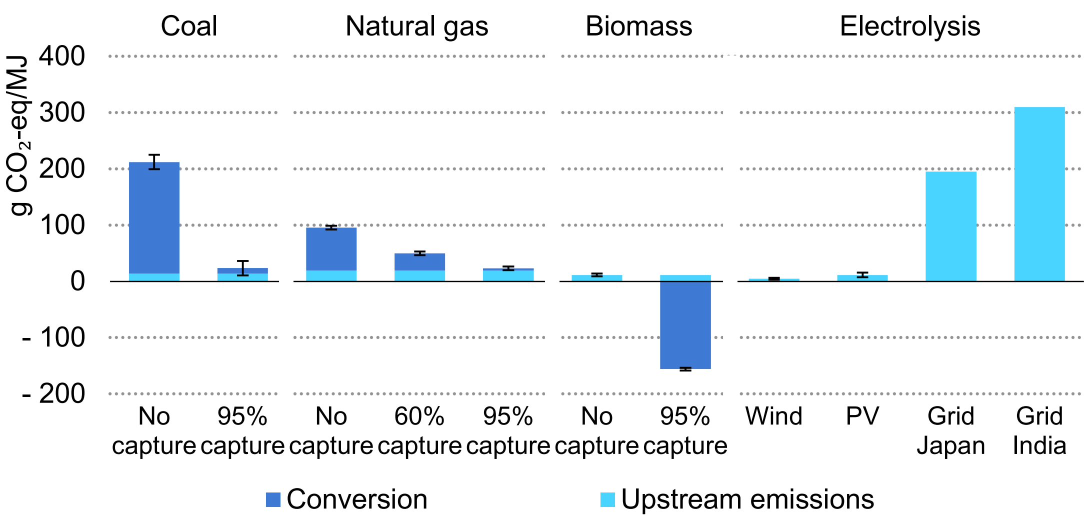
Accelerating the deployment of coal CCUS

In order for CCUS projects to successfully contribute to emissions reduction goals, governments and industry need to commit to long-term funding and investments to make CCUS technology more cost-effective and available. This includes investing in research and development and creating public-private partnerships to develop and deploy CCUS projects. In addition, policy incentives and regulations need to be implemented to encourage the uptake of CCUS technology and create a supportive environment for investment and deployment of these projects. In the NZE Scenario, projects need to capture more than 90% of the CO_2 emissions arising from coal combustion or conversion; GHG emissions associated with the extraction, processing and transport of coal need to be kept to a minimum; and the end product needs to have a lower emissions intensity than the product it is replacing. Coal-producing regions and countries can still employ CCUS to manufacture low-emissions hydrogen, hydrogen-based fuels and chemicals, as well as to reduce emissions from existing assets through retrofits.

In order to accelerate the deployment of CCUS, countries must make sure they have the proper legal and regulatory frameworks in place and support assessments of CO_2 storage potential. Increased economies of scale and affordable transport and storage costs can result from the development of shared CO_2 transport and storage infrastructure. In various nations and regions, including China, Europe and the United States, shared infrastructure is being built. In Canada, shared infrastructure has been operating since 2020 as a result of the Alberta Carbon Trunk Line Project. In turn, coal-based CCUS deployments can assist in the establishment of a common CO_2 transit and storage infrastructure. The deployment of coal CCUS installations can produce volumes of centralised CO_2 emissions and this in turn can act as an anchor for the development of wider CO_2 transport networks and storage hubs.

Emissions of different routes of hydrogen production



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Greenhouse gas emissions and air pollution

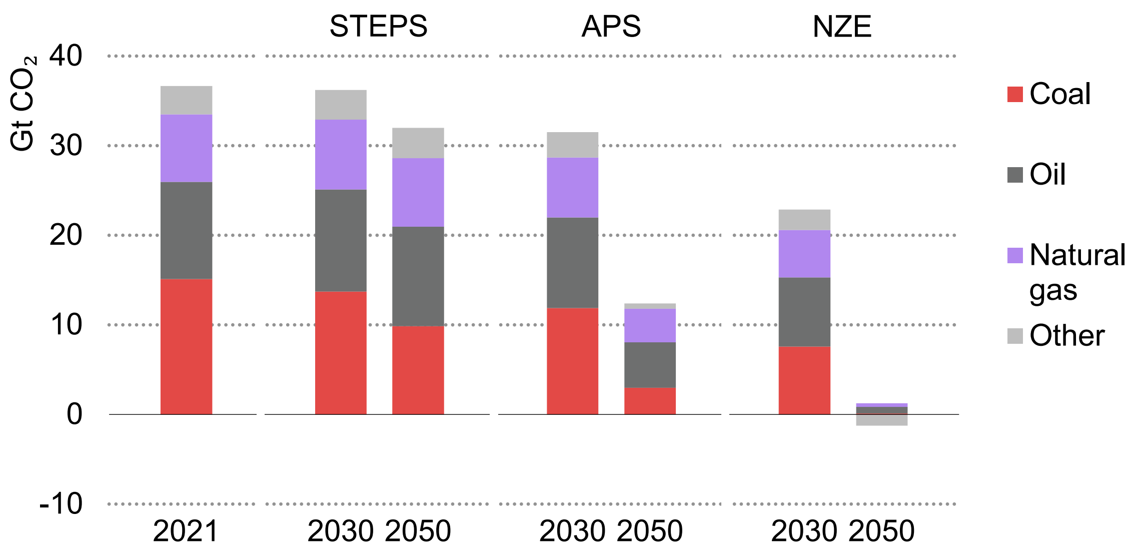
CO_2 emissions

In 2021, coal combustion accounted for around 40% (15 Gt CO_2) of all global energy-related CO_2 emissions. In 2021, China and India produced more than two thirds of the world's coal-related CO_2 emissions, followed by the United States, the European Union, Russia, Japan and South Africa.

In all scenarios, total energy sector emissions peak in the present decade, with coal playing a significant role in this pattern. According to the STEPS, emissions from coal fall by 1.5 Gt CO_2 by 2030, more than offsetting increases in combustion emissions from oil and gas and from industrial process emissions. After 2030, coal emissions continue to decline, falling by another 3.8 Gt CO_2 by 2050.

In the APS, all fuel emissions are expected to decrease by 2030 although coal leads the way with a 20% decrease from 2021 levels. By 2030, this drop is roughly half as large as the reductions in emissions from oil, natural gas and industrial processes combined. Coal emissions decrease between 2021 and 2030 at a 3% annual pace (as opposed to a 1% annual fall in the STEPS), and by 7% between 2030 and 2050. In contrast, coal emissions increased at a rate of 4.5% per year from 2000 to 2010 during the economic boom. Coal emissions are 80% lower in 2050 than 2021 levels.

CO_2 emissions by source and scenario



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Up to 2030, roughly two-thirds of the emissions reductions in the APS come from coal reductions. This highlights the need to reduce coal use if countries are to reach their net zero emissions targets and expanding the range of affordable alternatives to coal in the power sector, which makes up the majority of coal use. Due to the rapid transition

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to clean energy technologies, particularly solar PV and wind, advanced economies see the largest reductions in emissions over the period to 2030. Between 2021 and 2030, advanced economies cut annual coal emissions by about 2 Gt CO_2 (a reduction of nearly 70%).

In EMDEs, the near-term trend is tempered by rapid electricity demand growth and the additional space given by longer-term net zero pledges (e.g. 2060 for China and 2070 for India). Coal emissions in EMDEs decline by 1.3 Gt CO_2 between 2021 and 2030 (a 10% reduction). The rapid growth of low-emissions sources of generation to 2030 lays the foundation for a much stronger reduction in emissions from coal thereafter, and emissions from coal are reduced by more than 4 Gt CO_2 in the 2030s and around 3 Gt CO_2 in the 2040s.

In the NZE Scenario, emissions from all fossil fuels decline substantially by 2030. Coal leads the way, given its high emissions intensity and the competitiveness of low-emissions alternatives in the electricity sector. Emissions from coal drop by half from 2021 to 2030, driven by the rapid rise of low-emissions sources of electricity generation.

Coal mine methane emissions

Methane emissions are responsible for around 30% of the current rise in global average temperatures; rapid and sustained reductions are key to limiting near-term global warming. Coal mine operations released around 43 Mt of methane into the atmosphere in 2021, close to one-third of total energy-related methane emissions. This is equivalent to around 1.3 Gt CO_2-eq, more than all the CO_2 emissions from Europe's power sector.

Coal seams naturally contain methane (referred to as coal mine methane), which can be released during or after mining operations in a number of ways. Absent mitigation measures, methane emissions tend to be higher for underground mines than for surface mines. Underground mines, which accounted for about 60% of total coal production in 2021, were responsible for around 80% of total coal mine methane emissions.

We estimate that it is technically possible to avoid around half of global methane emissions from coal operations today, and more than 90% of abatement potential is associated with underground coal mines. For operating mines, ventilation air methane can be directed to processes such as blending or oxidation to make it usable as an energy source, for instance to heat mine facilities or to dry coal. Thermal or catalytic oxidation technologies can be used even with low methane concentrations (between 0.25% and 1.25%) and reduce over 50% of associated emissions.

Air pollution

Polluted air causes serious diseases, damages natural habitats, and reduces the health and yield of farmed crops. Around 3 million premature deaths were attributable

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to ambient air pollution in 2021, 85% of which occurred in EMDEs, primarily in Asia. Additionally, 2.4 million premature deaths were attributed in 2021 to household air pollution, primarily from the traditional use of biomass for cooking and concentrated mainly in Africa. Public healthcare systems are further burdened by air pollution, which also constrains economic growth. Different fuels are responsible for various air pollutant emissions. Over 60% of the sulphur dioxide emissions in 2021 came from burning coal, 80% of the nitrogen oxide emissions were from burning oil, and burning biomass caused around three-quarters of fine particulate matter ($PM_{2.5}$) emissions.

Risk of locked-in CO_2 emissions from existing coal plants

The current fleet of relatively young coal-fired power plants risks locking in CO_2 emissions for decades to come. To measure the risks, the IEA developed a plant-by-plant assessment of the remaining technical lifetime of coal-fired power plants in operation at the start of 2022 and analysed the potential associated emissions from these plants through to the year 2100. Total coal-fired power plant capacity today stands at a little under 2 185 GW and is made up of around 9 000 units with an average age of 20 years per unit. If existing plants continue to operate at current levels and without CCUS retrofits or co-firing with low-emissions fuels over the rest of their technical lifetime, 330 Gt CO_2 emissions could be emitted from 2022 to 2100, with the Asia Pacific region contributing almost 90%. The 330 Gt of emissions would account for two-thirds of the remaining cumulative emissions budget of 500 Gt consistent with a 50% chance of limiting average global temperature warming to below 1.5° C. Emissions for the period from 2022 to 2030 alone could be as high as 90 Gt, and, if unchecked, cumulative emissions to 2060 from the existing coal plant fleet could exceed all coal plant emissions to date.

Industrial facilities using coal are similarly long-lived: for coal-dependent heavy industries such as steel and cement, the year 2050 is just one investment cycle away. Average lifetimes for emissions-intensive industry sector assets such as blast furnaces and cement kilns are around 40 years, but plants often undergo a major refurbishment after about 25 years of operation. Around 60% of steel production facilities globally and half of cement kilns will undergo investment decisions this decade, which to a large degree will shape the outlook for coal use in heavy industry. Without any modification to their current mode of operation, these existing assets would generate 66 Gt CO_2 emissions through their remaining lifetime. Together with the existing coal-fired fleet, emissions from existing coal assets – on their own – would tip the world across the 1.5° C limit.

A variety of existing technologies offer options to reduce emissions from existing coal-fired power plants in ways that best fit the particular circumstances. They include: repurposing coal plants to focus on flexibility; retrofitting with CCUS technology; retrofitting to co-fire with low-emissions fuels such as ammonia or biomass; and retiring them early. Against a baseline of coal plants continuing to operate as they have in the

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recent past, the cumulative CO_2 emissions savings to 2050 in the APS is close to 100 Gt. Repurposing accounts for 60% of these reductions, with early retirements the second-largest contributor to cutting emissions (33% of the total), followed by CCUS retrofits and co-firing with other fuels.

Lessons from past transitions

A number of countries have already seen major transitions in their coal sectors over the past 60 years. While each country's coal transition must be assessed through the prism of its unique circumstances and historical context, a survey of past transitions provides some valuable lessons for the future. In this section, we focus on lessons from coal transition experiences in the power sector.

Transitions in coal demand have often happened relatively quickly

A number of countries have already seen a peak in unabated coal in their total energy supply with subsequent decline. Among them, we focus here on the countries that meet the following criteria:

- *sustained*: the peak in coal demand was sustained across at least ten years, and total unabated coal demand was at least 10% below the peak in the most recent annual data
- *substantial*: coal accounted for at least 10% of total energy supply in the peak year
- *growth-compatible*: GDP growth was positive in the ten years immediately following the peak.

These criteria leave a sample of 22 countries with coal peaks that were sustained, substantial and growth-compatible. A number of countries in the former Soviet Union are among those that do not meet these criteria: their coal transitions were driven by a collapse in their GDP after 1990, and they do not qualify as growth-compatible.

What were the patterns related to the peaks in unabated coal demand?

- The median peak occurred at a GDP per capita of around USD 21 000 in purchasing power parity (PPP) terms, and GDP grew at a robust 3.3% per year in the ten years following the peak in unabated coal. Today China and India are the biggest consumers of coal: the median peak in our historical sample compares with a GDP per capita in 2021 of USD 19 500 in China, and a little more than USD 7 000 in India (in PPP terms).
- For the median country, the coal peak occurred at a point when total energy demand was essentially saturated, growing only 0.2% per year in the ten years following the peak. This compares with 0.05% per year in China in the APS over the next decade and 2.3% per year in India.
- Within ten years of the peak of unabated coal demand, the median country saw coal demand fall by roughly one-third. Within 20 years, the median country saw a

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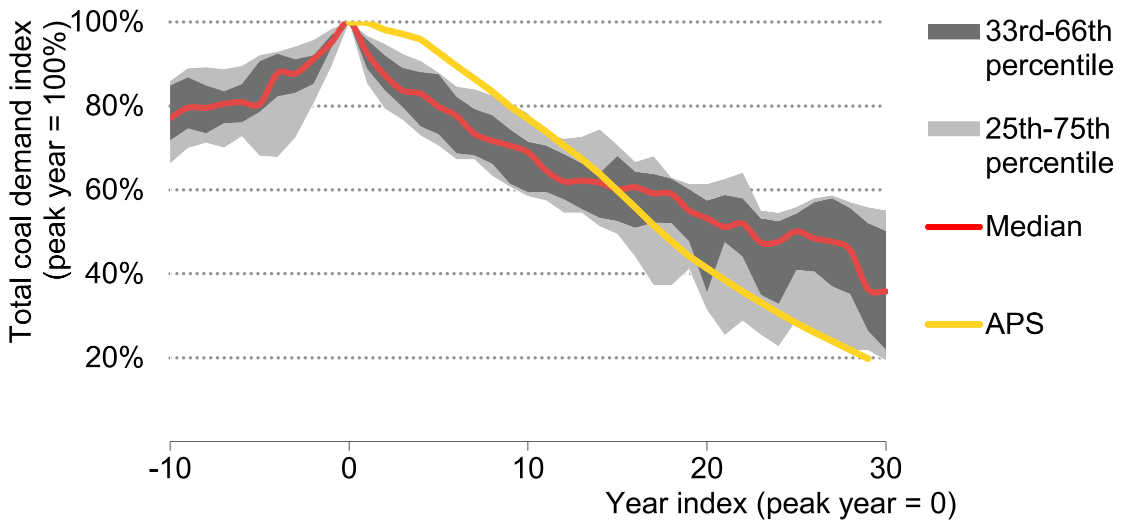
halving of unabated coal demand. These trends are roughly in line with the speed of the decline in global unabated coal demand after it peaks in the APS.

Historical trends in unabated coal demand, 1960-2020, compared with the Announced Pledges Scenario, 2020-2050



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Historical transitions away from coal have occurred roughly as fast as the global transition seen in the APS.

The figure below looks at historical examples in 33 countries of decade-long transitions away from unabated coal in the power sector. It shows the decline in coal generation, growth in the main alternative source and change in total electricity demand, all expressed as a percentage of total generation from all sources at the start of the ten-year transition period. Most coal transitions were driven by the growth of wind and solar PV or of natural gas, although a smaller number were driven by growth in hydropower or nuclear power.

- The largest number of observed coal transitions in the electricity sector were driven by the growth of wind and solar PV. These transitions typically took place in economies where the rate of total electricity generation growth was often modest or even negative: the median rate of demand growth during the ten years after the peak was 0.2% per year, and the median rate of solar PV and wind growth relative to total generation at the start of the period was 1% per year. This highlights the critical importance of scaling up renewables fast enough to substitute away from coal, particularly where there is rapid demand growth in EMDEs. It is also worth noting that although wind and solar replaced a larger share of the energy provided by coal than other fuels, they did not provide a substitute for the system services provided by coal.
- The median rate of electricity demand growth in natural gas-driven transitions was higher than in the transition to solar PV and wind (1.9% per year versus 0.2% per

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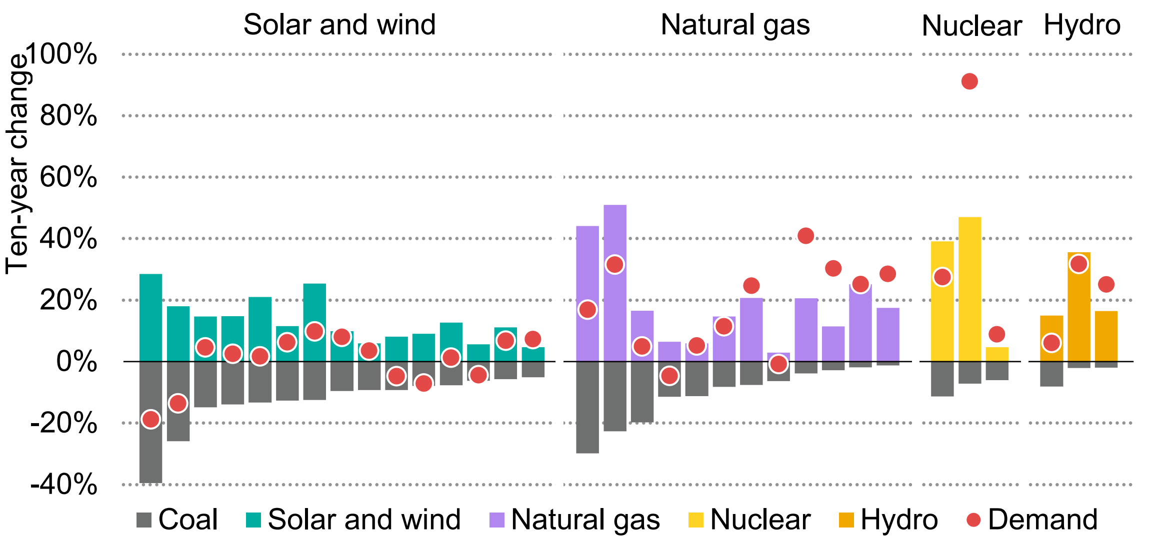
year), and the median rate of growth of the main substitute fuel source (natural gas) was also higher (1.6% per year).

Decadal episodes of coal transitions in electricity generation, as a percent of total generation in the start year, 1960-2019



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Historical transitions were largely unanticipated

Policies to manage socio-economic impacts came too late

Some countries have experienced large declines in coal production activities. Governments have often intervened to sustain domestic coal production, but these interventions have rarely been effective in the longer term. For example, Germany provided over EUR 280 billion in subsidies for coal production from 1958 to 2018, but domestic production remained uneconomic and continued to decline in the long run. Similarly, Poland provided subsidies for coal production of around USD 25 billion between 1990 and 2016 together with almost USD 1.5 billion per year for coal miners' pensions. As in Germany, these subsidies failed to halt a gradual decline in production. In some cases, governments gave companies one-time transfers to make needed upfront investments in mechanisation and productivity improvements, though many operations then slid back into deficit. In other cases, nationalisations and privatisations injected new capital but could not compensate in the long run for mines with geological conditions that led to high production costs.

When coal transitions have come, whether or not after attempts to sustain production, they have not always been anticipated by policy makers, and have often taken place without wide-ranging efforts to help those affected in coal mining regions. Governments have frequently provided some compensation to affected workers when coal mining jobs have been lost, but initial responses have sometimes proved relatively ineffective,

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and have only later been supplemented by additional measures to support broader community and economic development in response to emerging socio-economic challenges.

In the United Kingdom, for example, workers who lost their jobs when mines were closed in the 1980s were offered redundancy payments lasting up to a year, and were eligible for unemployment and incapacity benefits. But it was not until 1997 that the government established the Coalfields Task Force and enacted measures to redevelop coal communities. These included efforts to reclaim mine land at over 100 coal sites for productive use such as housing and industry, and to channel European Union funding towards support for local infrastructure, businesses and vocational training. The Welsh Development Agency sought from the outset to attract investment and create jobs, but new infrastructure projects were generally not located in the counties where unemployment was the highest.

To take another example, in the United States, many Appalachian coal mining counties took advantage of local grants and investments provided by the Appalachian Regional Commission to build their own transition strategies focused on education or economic diversification. For instance, Athens County in Ohio launched a cross-county retraining programme to help former coal miners and their families find well-paid jobs outside the mining industry after the closure of the last coal mine in 2002. Coal mining counties have also benefited from broader infrastructure development support from the Tennessee Valley Authority since the 1930s and later from the Appalachian Development Highway System. In 2015, President Barack Obama added to the help available by launching the Partnerships for Opportunity and Workforce and Economic Revitalization (POWER) Plus Plan to provide funding for economic diversification, job creation and employment in Appalachia. Funding was also allocated for the clean-up of abandoned mines and for schools, public health services and cultural amenities to attract investment and diversify local economies. However, this package was designed and implemented long after coal production and employment in Appalachia had begun to decline.

Coal regions were often left with profound and long-lasting socio-economic scars

The measures taken to support coal miners and communities in the face of closures and job losses have often not been able to compensate for the socio-economic challenges associated with coal transitions. Decades after the transitions began, coal mining communities still lag behind much of the rest of their respective countries.

Across the United Kingdom, for example, every former coal region still sees lower job density than the nationwide average. In many regions, the employment rate is 5-10% below the level in south-east England. In Wales in particular, where around 20% of Welsh working-age males lost their jobs during the 1980s, mine closures led to a rise

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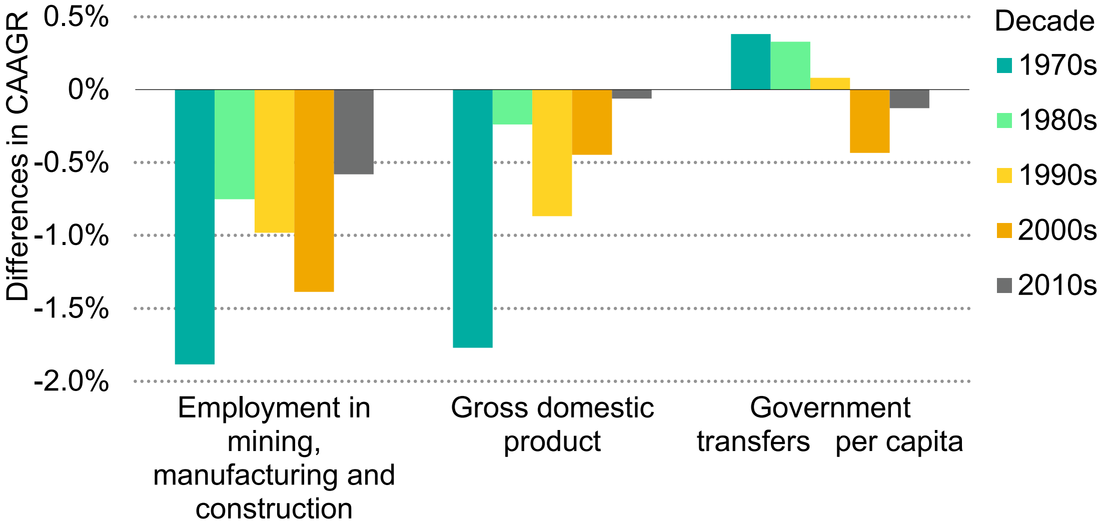
in poverty and to people moving away from the affected counties. The failure to attract new heavy industry with blue-collar jobs into former coalfields led to many miners being unable to find new jobs.

Differences in selected socio-economic indicators between Appalachian Basin counties and the rest of the United States, 1970-2020



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Note: Computations draw on county-level data except for GDP data for 2000 and before, which is available only by state.
Source: Bureau of Economic Analysis (2022).

In the United States, the loss of jobs in the coal mining industry has had broad socio-economic impacts. Appalachia, once the cornerstone of the country's energy supply, has seen coal mining jobs decline from over 500 000 to just 30 000 over the last century. It has struggled for decades with high levels of poverty and with public health crises, and its employment and GDP growth lag behind the rest of the country. As in other coal regions around the world, access to alternative opportunities was hampered by geographic isolation and lack of infrastructure. As a result, it proved difficult for a large mining workforce to find other blue-collar jobs, especially against the background of a nationwide decline in manufacturing jobs.

People-centred transitions

Employment

In 2019, almost 8.4 million people worked in coal value chains, including 6.3 million in supply (both production and transportation) and 2.1 million in power generation. These numbers include our best estimate of informal workers as well as those formally employed. Jobs in coal supply and in coal-fired power generation account for around 0.25% of total global employment, but they tend to be concentrated in areas around coal mines where entire communities may be dependent on income generated in the

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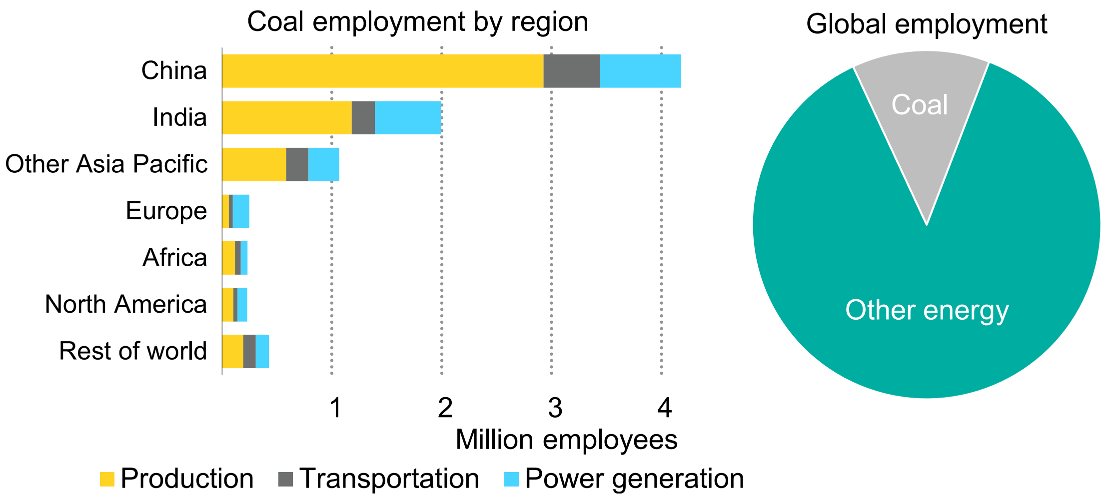
coal industry. In these regions, coal revenues are critically important for the operation of many other businesses and industries and hence for the jobs they provide.

Today coal supply jobs are concentrated in Asia, with 3.4 million coal workers in China, 1.4 million workers in India, and around 470 000 workers in Indonesia. In recent years, some key coal producers have seen declining employment as labour productivity has improved, in part because of increasing mechanisation. For example, China reduced coal mining employment by almost 2.5 million jobs between 2013 and 2019 while maintaining production volumes.

The largest number of coal supply jobs are in mining, the most labour-intensive part of the value chain, but the transportation, washing and processing of coal also provide many jobs. An estimated 740 000 workers were employed in coal-related power sector jobs in China in 2019. This compares with around 150 000 in Europe and over 80 000 in North America, where these jobs have been declining in recent years. Coal jobs in power generation involve tasks such as operating and maintaining existing plants, constructing new capacity, and manufacturing components such as boilers, turbines and generators.

Employment in the coal value chain by region and as a share of global employment, 2019



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Countries with net zero emissions targets currently account for more than 95% of coal consumption and employment along coal value chains. In the APS, total coal employment declines from 8.4 million in 2019 to 6.1 million in 2030. Some of this decline is due to a fall in coal production and consumption as countries make progress towards their net zero emissions targets. It also reflects improvements in productivity and increased mechanisation.

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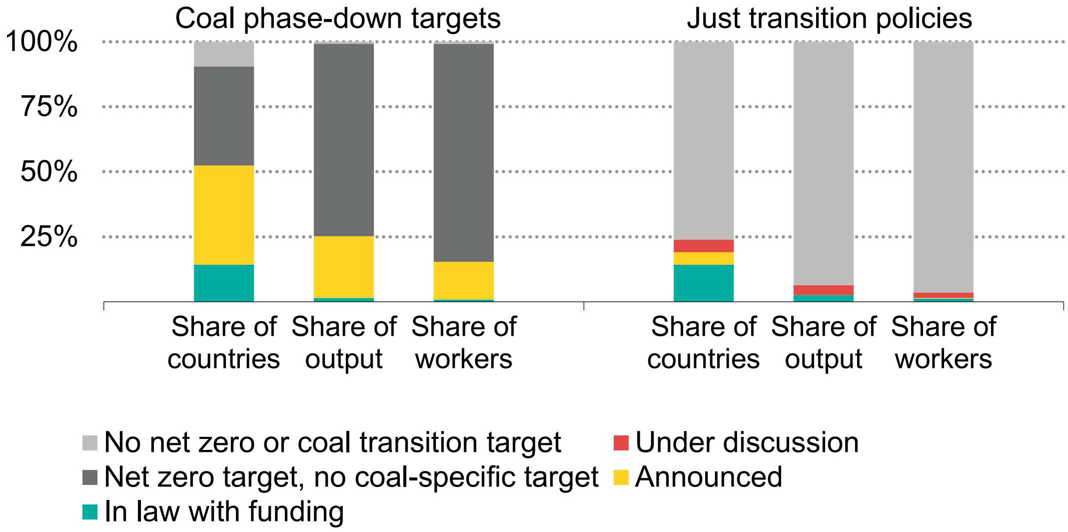
Despite an increase in employment at coal plants with CCUS, coal employment sees a sharper decline than either oil or natural gas employment, making it an area of particular concern in terms of just transitions policies. The decline in coal sector jobs forms part of a broader shift in energy sector employment to clean energy, which increases from around 32 million jobs in 2019 to 54 million jobs in 2030, thanks in particular to increasing numbers of jobs focused on delivering low-emissions power generation and improving end-use efficiency.

Of the 21 countries with the highest rankings on the IEA CTEI, 17 have made net zero commitments or incorporated net zero emissions objectives in law, and 11 have undertaken or executed plans to phase down or limit their usage of coal. It is notable that only five countries, which represent a mere 4% of the world's coal workers, have implemented, announced or initiated discussions on just transition policies for the coal workers and communities affected by transitions away from coal. This suggests that there is an urgent need for more countries to consider how best to help those individuals and communities that stand to lose coal-related jobs, especially in those regions that are most dependent on coal.

Coverage of coal phase-down targets and just transition policy in 21 selected coal-dependent countries



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A framework for best practice people-centred transition policies

An important first step before the transition starts is comprehensive stakeholder engagement with the goal of reaching broad consensus around the transition. Mapping existing human resources and infrastructure in affected communities can be useful in identifying alternative industries that could make the most of local comparative advantage. Several countries, including Canada, the Czech Republic, Germany, South Africa and Spain, have convened national task forces or commissions to

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estimate the financial implications of socio-economic challenges and provide policy recommendations.

After establishing a timeline for coal transition, the next step is to agree on a set of just transition policies. Such policies need to address three objectives, which in the end offer tailored support to the people, local communities and economies:

- supporting workers and companies directly affected by the energy transition, including through inclusive policy-making processes
- developing alternative industries and stimulating macroeconomic growth in the region to provide additional opportunities for local workers and companies
- promoting environmental rehabilitation in the affected region to enhance its attractiveness and growth potential, and fostering local culture and identity to strengthen social cohesion and improve quality of life.

Coverage of just transition policies designed in the context of coal phase-down in selected countries

	Canada	Germany	Korea	Poland	South Africa
Net zero or carbon neutrality target	2050	2045	2050	2050*	2050
National coal phase-out target	2030	2035	2050	2049**	
Support for workers					
Direct payments and compensation	●	●	○	○	○
Training, reskilling, career services	●	○	○	○	○
Support for industry development and economic diversification in coal communities					
Coal decommissioning or retrofits	●	●		○	○
Clean energy industries	●	●	○		○
Non-energy industries	●	●	○	○	○
Holistic support for coal communities					
Environmental rehabilitation		●			○
Community identity and cohesion					○

● Policy enacted with funding ○ Policy announced or recommended by just transition commission

* Reflects the EU objective of carbon neutrality by 2050.

**Applies only to hard coal mining.

Notes: Both national and subnational policies are included. Broader labour market policies are not included.

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In acknowledgement of the fact that expedited coal phase-downs typically occur over a short period of time and are concentrated in certain places, many governments have developed measures to supplement standard labour regulations for coal workers. These policies cover early retirement options, welfare payments, and short-term income support programmes such as severance packages. In Germany, the government permits tax-free income support and a subsidy for health insurance for workers laid off from the coal business. Several governments provide support with job searches, career counselling, and reskilling and training. For example, the Canadian Coal Transition Initiative, established in 2018, provides USD 27 million over five years for economic diversification and skills development, and has established transition centres in coal regions. It is complemented by a related Coal Transition Infrastructure Fund providing another USD 116 million for coal communities through 2025.

Some governments have also introduced measures to stimulate economic growth in coal-dependent regions. This is especially important in EMDEs where many coal mining regions have high dependence on the coal industry. In order to create realistic plans and initiatives, effective economic development strategies should carefully consider regional comparative advantage while also looking at the best ways to increase connectivity.

So far, fewer governments have introduced measures that aim to enhance the local quality of life and social cohesion including environmental restoration in a comprehensive manner. However, such measures can be helpful in boosting employment and attracting capital. Furthermore, people-centred transition policies also need to be tailored to affected communities and people in terms of age and gender. Coal miners tend to be older on average than the workforce as whole – the median age of coal miners is 44 in the United States, 42 in India and 37 in South Africa – but they span a wide range, so government spending should be divided strategically between enabling early retirements and providing career services and retraining.

Regarding the gender aspects of people-centred transition, coal miners are predominantly male, but job losses have repercussions for women, too. In the past, more women have joined the labour force during and following coal transitions to bolster household income, primarily by taking on low-paying employment in the services sector. Interviews also reveal that men who lose their employment in the coal industry are unwilling to take on housework and instead choose to stick with labour-intensive manual jobs. Given this, there is a justification for governments to offer more childcare services and to extend career services to all members of households with coal miners throughout the transitions.

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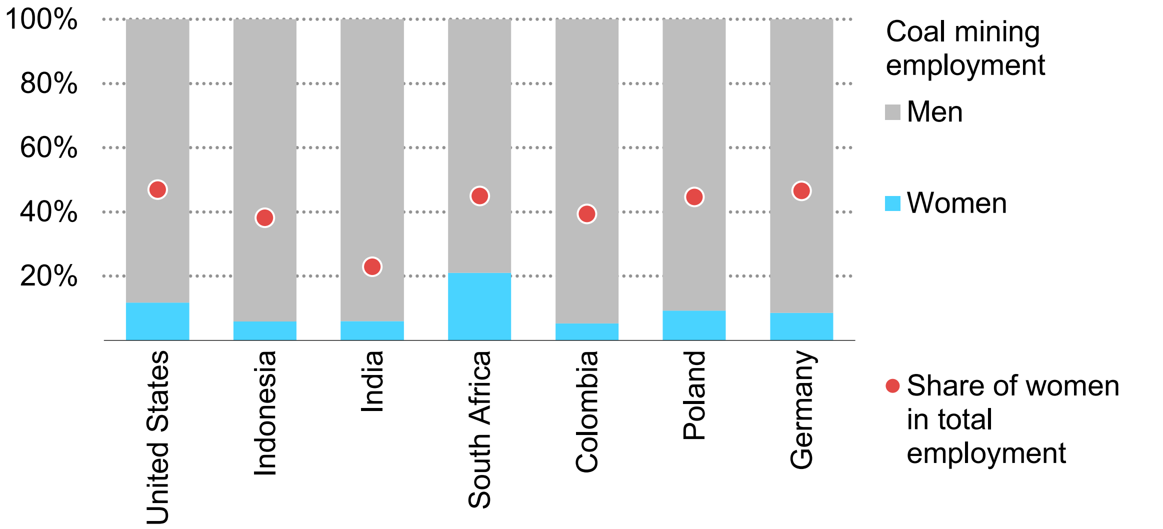
Employment in coal mining by country and by gender, 2019



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The age profile of coal workers is a critical variable in just transition policies

The age profile of coal workers is important when considering people-centred transitions since it provides information on the natural retirement rate of workers and the number of those in the workforce who are likely to be economically active until a specific retirement age. The IEA uses labour market surveys to build a model of the age profile of coal miners in India, South Africa, Indonesia and China, which together account for the majority of global coal mining employment. The IEA models a natural retirement timeline for these workers by using a range of retirement ages between 55 and 60 to take into account differences in retirement ages between countries and between formal and informal workers. We then compared this natural retirement rate to the level of employment required in the APS and the NZE Scenario.

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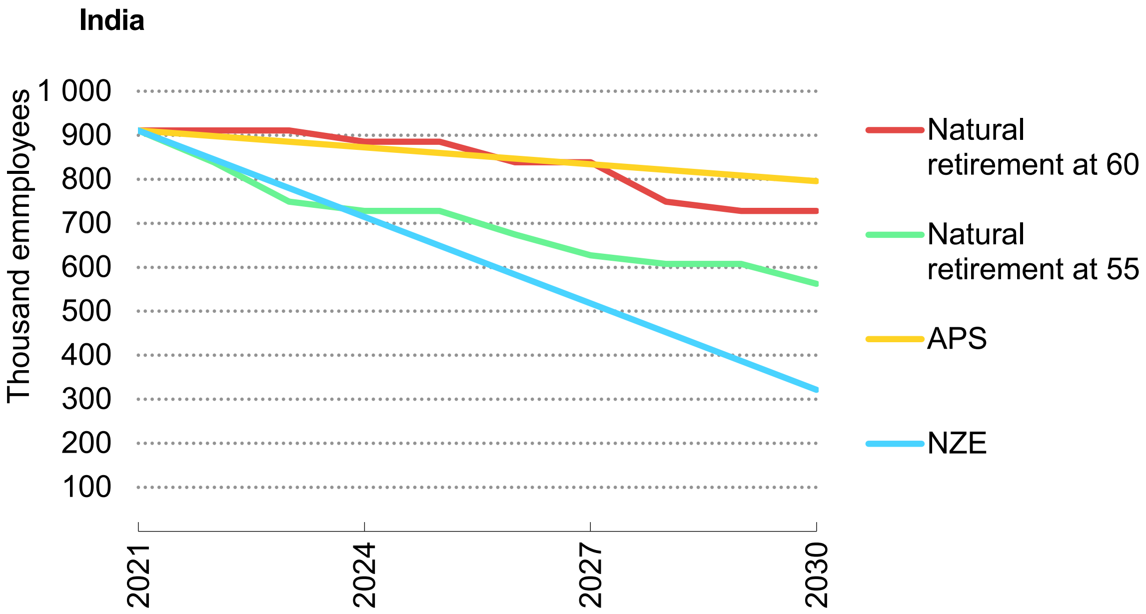
Natural retirement rates for coal mining workers in India, South Africa, Indonesia and China compared with coal mining employment levels in the Announced Pledges and Net Zero Emissions Scenarios



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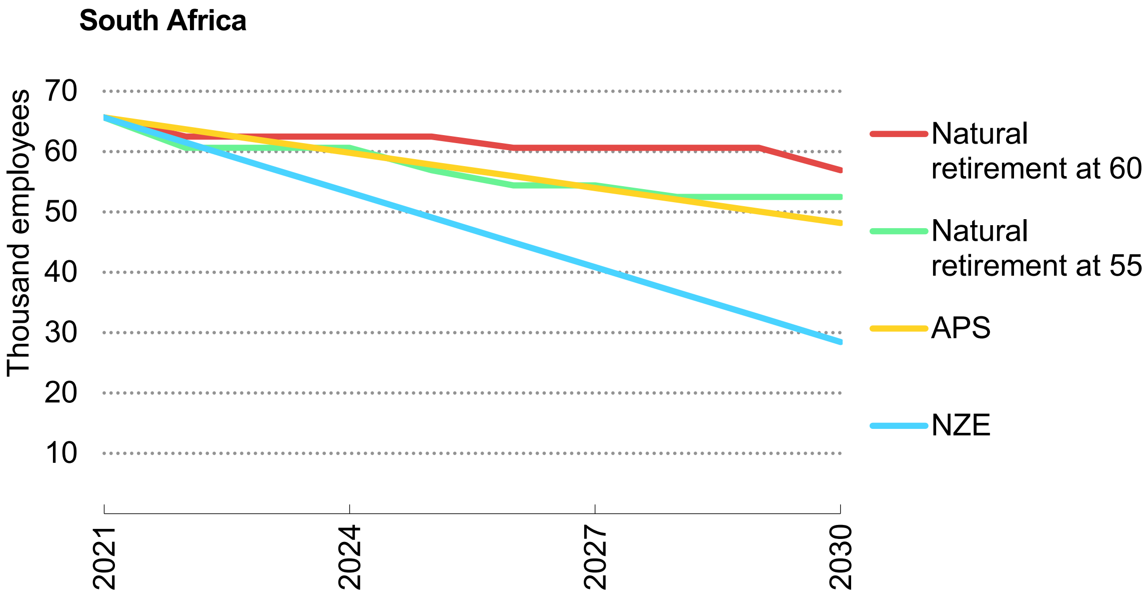

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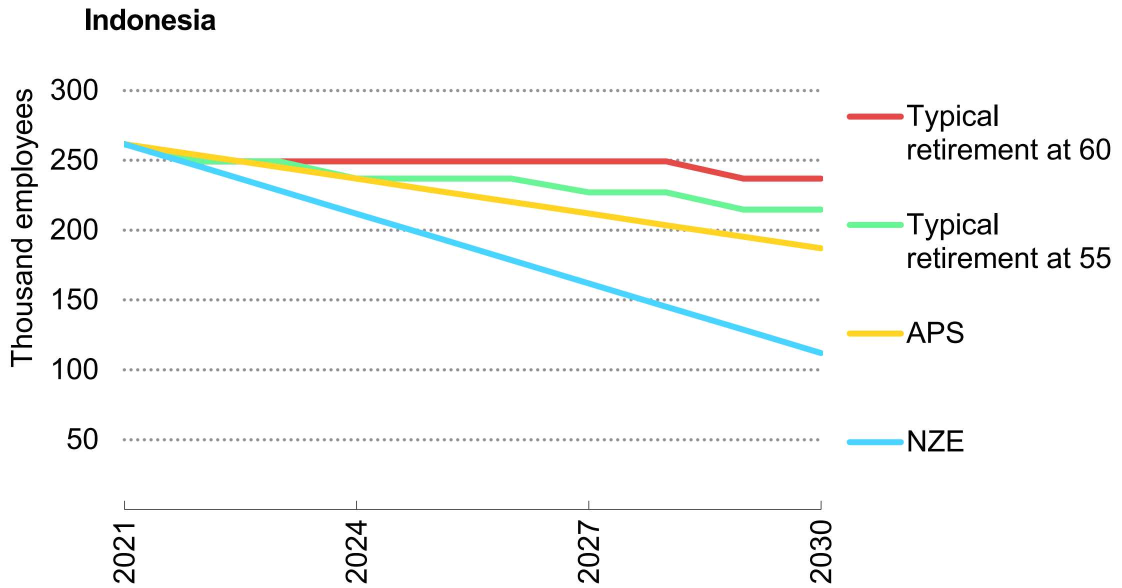

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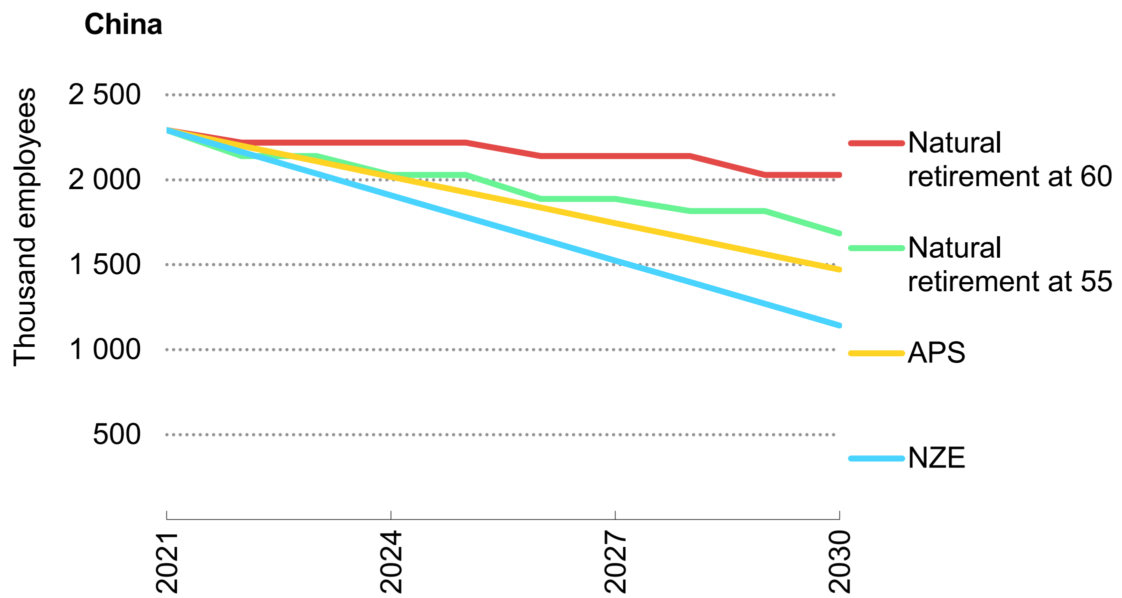

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The level of coal demand and employment seen in the APS implies that about 710 000 workers would need to retire early by 2030 in four major coal-producing countries.

Despite the fact that many coal regions in EMDEs have young, active populations that need jobs, this analysis of the natural retirement rate of coal workers leaves no room for new workers to enter the sector. This emphasises the necessity of creating alternate development pathways for regions dependent on coal in order to diversify local economies, while also focusing on the individuals currently working in the sector.

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Financing the coal transition

Financing the coal transition lies at the intersection of a number of energy and development challenges, making integrated approaches critical. Even though there is a number of cost-competitive clean technologies that can replace coal, a rapid transition away from the most polluting assets will not occur at the required pace without a strong policy effort and adequate financing. In that sense, public finance, public policy and international co-operation all play crucial roles in accelerating the change.

In many industrial applications, zero-emissions substitutes for coal are still in their infancy, thus innovation and demonstration projects must take a front seat in the near future in order to bring costs down. Compared with the power sector, these initial investments have a different risk profile and a considerably greater need for public funding and support. In the power sector, three-quarters of the USD 6 trillion investment to transition away from coal goes into renewables, grids and energy storage. The economic forces that underpin new generation investments encourage the use of private capital. By replacing coal assets with mature and affordable renewable technologies, emissions can be reduced while simultaneously bringing down overall system costs and costs to consumers.

There is more than USD 1 trillion of unrecovered capital in today's fleet of coal-fired power plants, meaning that their owners – often state-owned enterprises – have a strong stake in their continued operation. Emissions from the plants may be locked in by inflexible power purchase agreements, which remunerate plants regardless of their operation. In Viet Nam, for example, such contracts govern the operation of around half the fleet.

Since most coal plants are effectively protected from market competition, their exit needs to be secured by other means in order to support the expansion of low-emissions sources. The IEA evaluates a variety of options available to governments to end this impasse, such as direct regulation, market-based solutions and financial mechanisms. The common denominator is that they alter the incentives facing coal plant owners so that they operate more flexibly, retrofit with CCUS, co-fire with low-emissions fuels or retire.

Governments and financial institutions have made an increasing number of declarations in recent years to limit or forbid funding and investment in the coal industry. Nearly all of the multilateral development banks and export credit organisations have imposed tight lending requirements or outright bans on projects involving coal. The financial sector, where numerous institutional investors, pension funds, banks, insurance firms and others have pledged to cut or eliminate their engagement in coal, is providing additional momentum for restricting coal funding. Banks' pledges to lessen their ties to the coal industry mostly take the form of lending limits, larger initiatives to decarbonise their loan books and a rise in the proportion of loans given to "green" assets. Similarly, in bond markets, there has been a rapid growth in sustainable

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issuances by capital providers in key markets, particularly in Europe where sustainable finance regulations are most advanced, and investors seek to reduce fossil fuel lending unless it is associated with achieving sustainability targets.

Effective and fair coal transitions will require global co-operation, public financial support and integrated approaches that take into account the social components. Unintended consequences might result from poorly planned or fragmented interventions; for instance, retiring one coal plant without a holistic strategy may encourage others to operate more. There is also considerable scope for innovative financing to help bring down the total cost of the coal transition.

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Chapter 2. Current transition policy for the coal-fired power sector in Korea

Status of Korea's coal-fired power generation

In the first half of 2022, Korea's total installed capacity amounted to 134 237 MW, and power generation to 291 531 GWh. Gas takes the largest share of 30.7% (41 201 MW) in the installed capacity, followed by coal (27.6%; 37 088 MW), renewables (19.8%; 26 581 MW) and nuclear (17.3%; 23 250 MW). Gas has been the most dominant source of Korea's installed capacity over the last five years, followed by coal with a decreasing share. Nuclear has been the third-largest capacity until renewables took over its place in 2022.

Installed capacity by energy source (in MW, %)

	2018. H1	2019. H1	2020. H1	2021. H1	2022. H1
Total installed capacity	117 205	121 147	127 338	131 069	134 237
Nuclear	21 850	21 850	23 250	23 250	23 250
Share	18.6	18.0	18.3	17.7	17.3
Coal	36 877	37 063	37 053	36 798	37 088
Share	31.5	30.6	29.1	28.1	27.6
Gas	37 853	38 225	41 170	41 170	41 201
Share	32.3	31.6	32.3	31.4	30.7
Renewables	11 695	15 252	17 861	22 478	26 581
Share	10.0	12.6	14.0	17.1	19.8
Oil	4 230	4 057	2 101	2 159	960
Share	3.6	3.3	1.6	1.6	0.7
PSH	4 700	4 700	4 700	4 700	4 700
Share	4.0	3.9	3.7	3.6	3.5
Others			1 203	514	457
Share			0.9	0.4	0.3

Note: PSH = pumped storage hydropower.
Source: Monthly Electricity Statistics (476th, 488th, 500th, 512th, 524th), KEPCO

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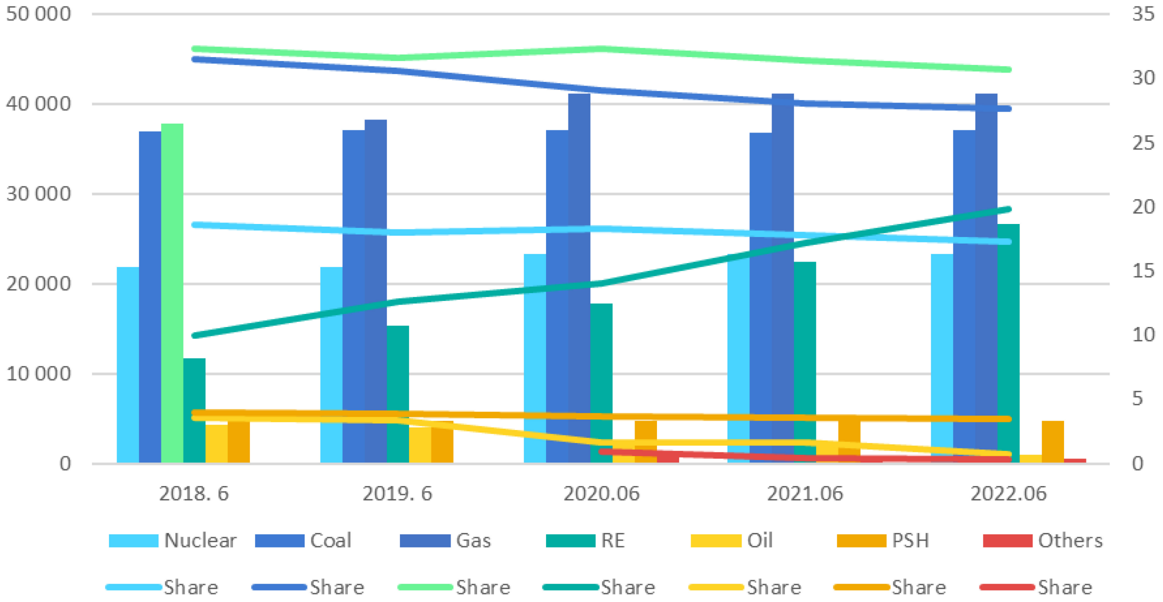
Installed capacity by energy source (in MW, %)



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Note: RE = renewable energy.
Source: Monthly Electricity Statistics (476th, 488th, 500th, 512th, 524th), KEPCO.

In the first half of 2022, coal accounted for the largest share of 31.1% (90 657 GWh) in the generation mix, followed by nuclear (29.7%; 86 681 GWh), gas (28.5%; 82 985 GWh) and renewables (9.2%; 26 800 GWh). Coal has been the dominant source of power generation in the last five years despite a decreasing share. The shares of nuclear and gas have been slightly increasing with fluctuations.

Power generation by energy source (in GWh, %)

	2018	2019	2020	2021	2022.H1
Total power generation	570 647	563 040	552 162	576 809	291 531
Nuclear	133 505	145 910	160 184	158 015	86 681
Share	23.4	25.9	29.0	27.4	29.7
Coal	238 967	227 384	196 333	197 966	90 657
Share	41.9	40.4	35.6	34.3	31.1
Gas	152 924	144 355	145 911	168 378	82 985
Share	26.8	25.6	26.4	29.2	28.5
Renewables	35 598	36 392	36 527	43 096	26 800
Share	6.2	6.5	6.6	7.5	9.2
Oil	5 740	3 292	2 255	2 354	1 196
Share	1.0	0.6	0.4	0.4	0.4
PSH	3 911	3 458	3 271	3 683	1 834
Share	0.7	0.6	0.6	0.6	0.6
Others		2 249	7 681	3 316	1 378
Share		0.4	1.4	0.6	0.5

Source: Monthly Electricity Statistics (524th), KEPCO

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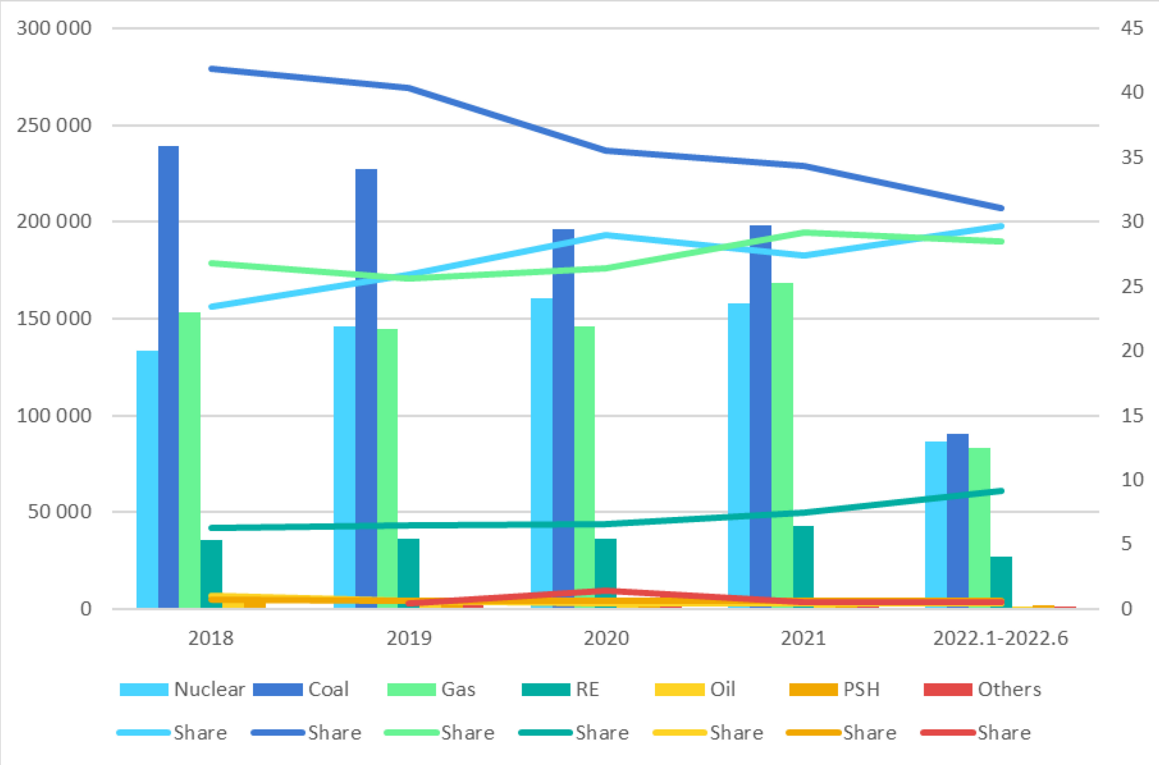
Power generation by energy source (in GWh, %)



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Source: Monthly Electricity Statistics (524th), KEPCO.

Korea has a relatively high share of power generation from coal. In 2021, coal-fired power generation accounted for 34.3% in Korea's energy mix, which was a larger share than that of France, Italy and the United Kingdom. Australia had a 52.84% share of coal-fired power generation followed by Korea, Germany (29.1%), Japan (28.55%) and the United States (22.75%). While Australia and Germany have been rapidly reducing the share of coal in recent years, Korea started to reduce the share of coal only since 2020 after a continued increase from 1992.

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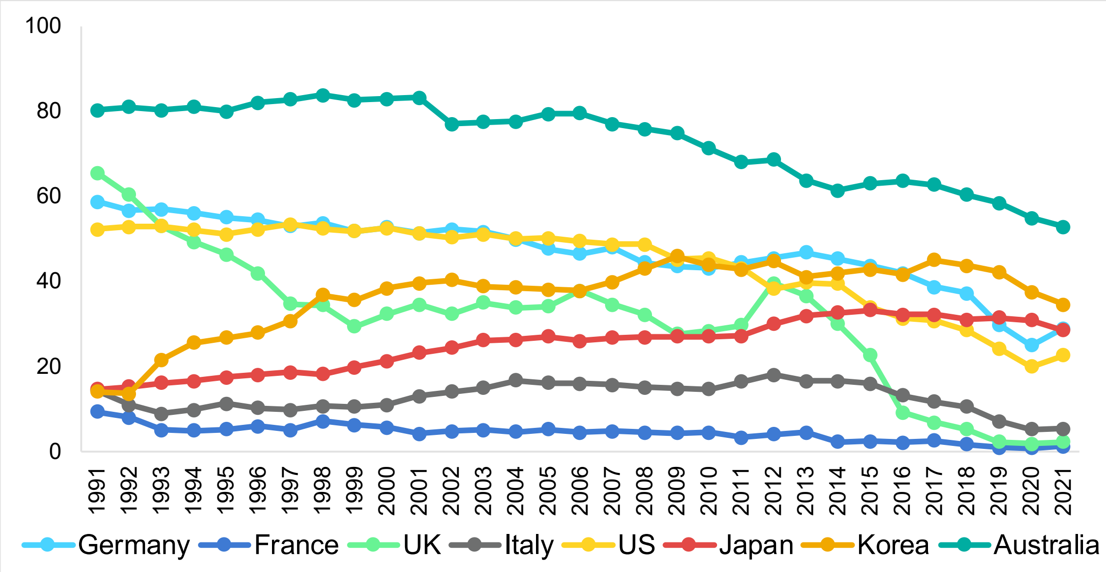
The share of power generation from coal in key OECD member countries (%)



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Note: OECD = Organisation for Economic Co-operation and Development.
Source: Enerdata, www.enerdata.net.

As of 2022, 57 domestic coal-fired power units are in operation and 4 units are under construction. Chungnam has the largest share with 29 units, followed by Gyeongnam (14), Gangwon (6), Incheon (6) and Jeonnam (2). In the first half of 2022, coal accounted for the largest share of 31.1% in the generation mix.

Coal-fired power units by province (2022)

Status	Province (no. of units)	Name of units	Installed capacity (MW)	Note
In operation	Chungnam (29)	Dangjin-1-10	6 040	
		Taean-1-10	6 100	
		Boryung-3-8	3 050	
		Shin Boryeong-1-2	2 038	
	Gyeongnam (14)	Samcheonpo-3-6	2 120	
		Hadong-1-8	4 000	
		Goseong High-1-2	2 080	
	Gangwon (6)	Bukpyung-1-2	1 190	
		Samcheok Green Power-1-2	2 044	
		Donghae-1-2	400	
	Incheon (6)	Yeongheung-1-6	5 080	

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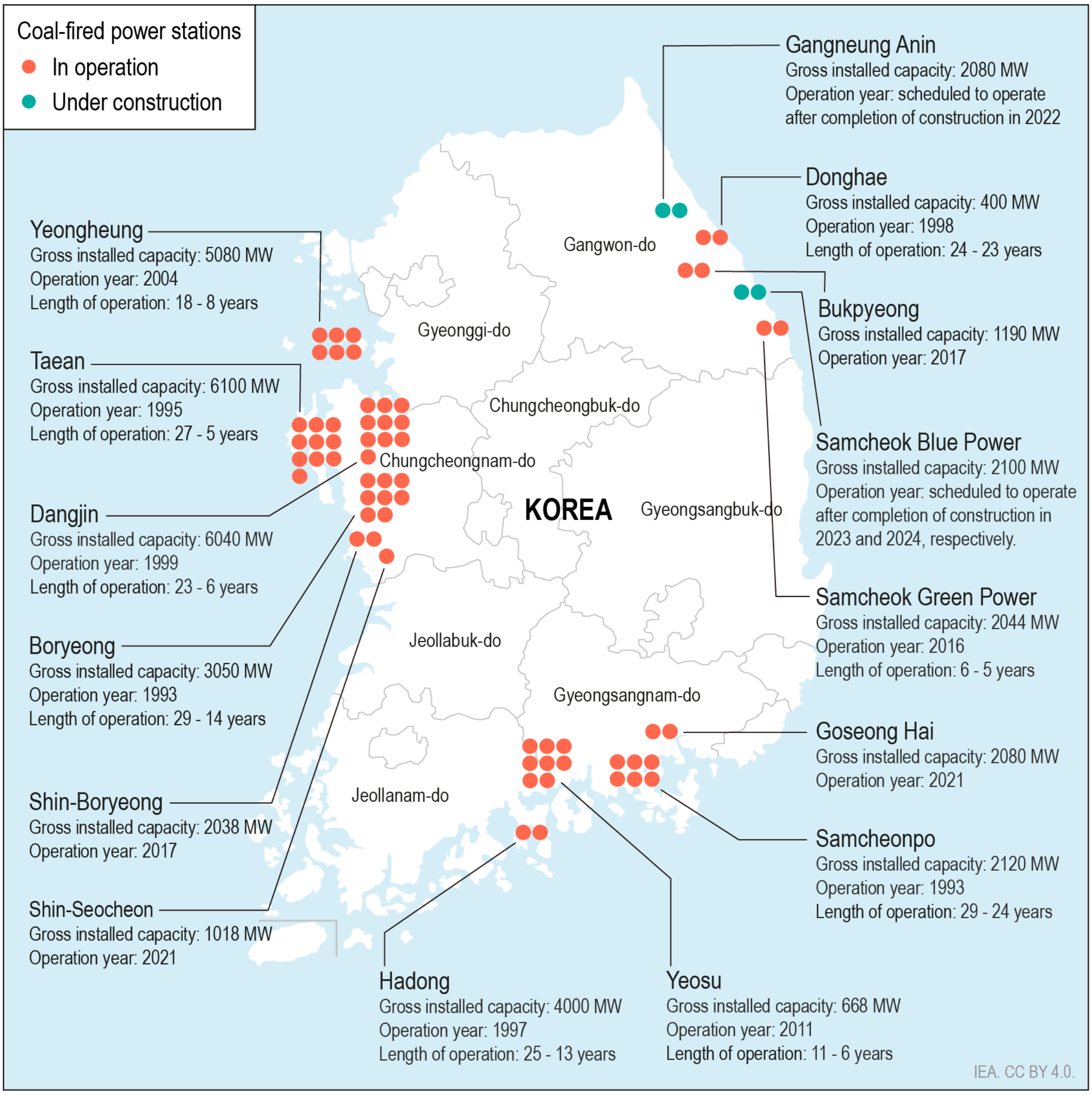
Status	Province (no. of units)	Name of units	Installed capacity (MW)	Note
	Jeonnam (2)	Yeosu-1-2	668	
Under construction	Gangwon (4)	Gangneung Anin Thermal-1-2	2 080	Construction period: May 2017 – Mar 2023 Operator: Gangneung Eco Power
		Samcheok Thermal-1-2	2 100	Construction period: Aug 2018 – Apr 2024 Operator: Samcheok Blue Power

Source: KFEM & Monthly Electricity Statistics (524th), KEPCO.

Current coal-fired power plants in Korea (2022)



Source: KFEM.

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As of 2022, the Southern Power Corporation has the largest installed capacity among the five largest power corporations, followed by Western Power Corporation, Midland Power Corporation, East-West Power Corporation and South-East Power Corporation.

Power generation market in Korea (2022)

Category	South -East Power	Midland Power	Western Power	Southern Power	East-West Power	Hydro & Nuclear Power	Others	Total
Installed capacity (MW)	9 279	10 757	11 456	11 476	9 564	28 621	53 084	134 237
Market share (%)	6.9	8.0	8.5	8.5	7.1	21.3	39.7	100.0
Power generation (GWh)	21 87 1	22 691	20 839	24 893	18 569	88 954	93 714	291 531
Market share (%)	7.5	7.8	7.1	8.5	6.4	30.5	32.3	100.0
Revenue (KRW hundred milli on)	32 49 8	35 400	30 696	40 603	29 615	49 049	156 087	373 947
Market share (%)	8.7	9.5	8.2	10.9	7.9	13.1	41.7	100.0

Notes: KRW = Korean won. Exchange rate: 1 Korean won (KRW) = USD 0.00076 (as of 08 March 2023).
Source: Half-year Report, Korea East-west Power, 2022. 8. 16.

Coal takes the largest share in the installed capacity of the five largest power corporations. In case of South-East Power, coal plays a dominant role with a capacity of 7 869 MW. The installed coal capacity of East-West Power has installed coal capacity of 6 400 MW, Midland Power of 6 106 MW, Western Power of 6 100 MW and Southern Power of 6 044 MW.

Power corporations' installed capacity and power generation by energy source

Energy source	South-East Power		Midland Power		Western Power		Southern Power		East-West Power	
	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)
Coal	7 869	19 414	6 106	14 758	6 100	14 626	6 044	15 697	6 440	13 472
Oil	-	-	-	-	-	-	-	-	-	352
Gas	-	-	-	-	1 400	508	-	-	-	-

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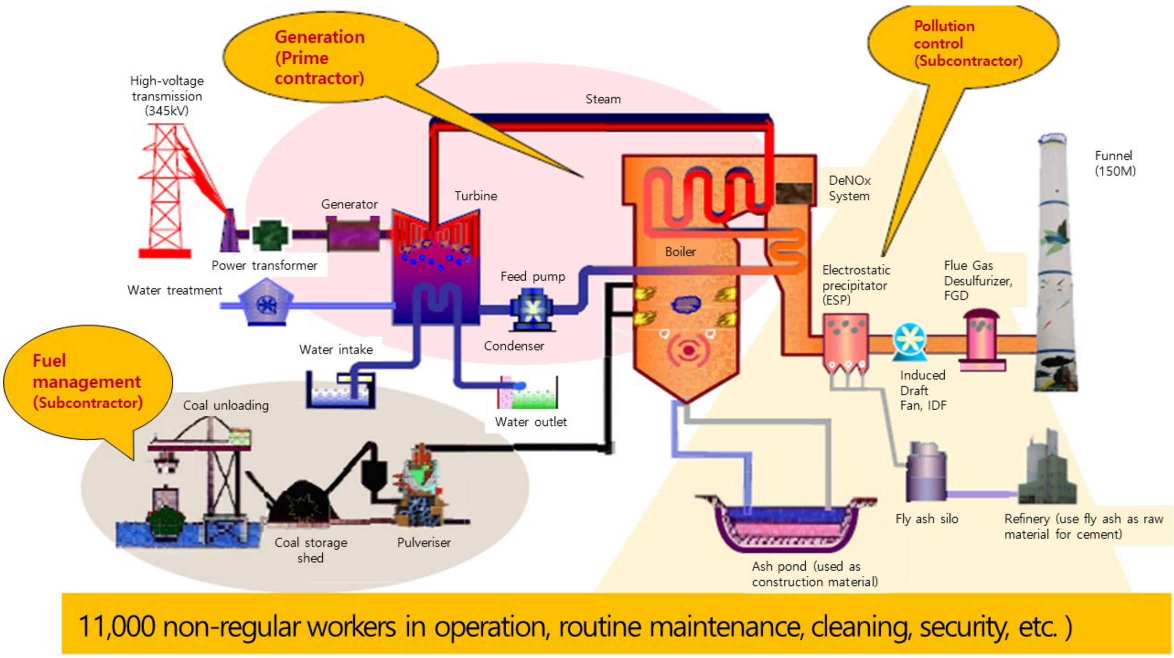
Energy source	South-East Power		Midland Power		Western Power		Southern Power		East-West Power	
	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)	Installed capacity (MW)	Power generation (GWh)
IGCC	922	1 565	4 310	7 262	3 387	4 220	5 061	8 342	2 972	4 413
Internal combustion	-	-	80	156	-		-	-	-	-
Renewables and others	488	892	261	515	569	1 486	371	854	152	332

Note: IGCC = integrated gasification combined cycle.
Source: Monthly Electricity Statistics (524th), KEPCO.

The number of workers in the sector excluding the plant workers amounts to 22 306 (including the primary contractors). In other words, each of the almost 60 units employs around 372 workers on average. While these units could potentially retain 57% their employees through converting coal to liquefied natural gas (LNG), the outcome may vary significantly by company and job responsibility.

Coal phase-down progress

Schematic diagram of a coal power plant



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Source: Policy Discussion on the implications of decarbonisation policies on employment and a just energy transition

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Employment in the coal-fired power generation sector

Category	Employment	Type of company	Features
Generation operation	12 090	5 power corporations	· Regular workers of power corporations operate main components such as the generator, turbine and boiler, and supervise partner companies and subsidiaries. · They work in rotation and can be relocated.
Fuel management and pollution control	2 283	Private companies	· KEPCO's KPS and KEPID have high levels of expertise with patented technologies and large-scale operations nationwide. In contrast, community-based companies have small-scale operations. · Workers could face job insecurity depending on the power corporations' planning. · Fuel management and pollution control jobs are likely to decrease in case of coal-to-LNG switching.
Routine maintenance	5 310	Corporations (45%) and private companies (55%)	· Routine maintenance workers are more likely to retain their jobs as LNG power plants require similar skills. · Workers of community-based small-sized companies and secondary partners could face a higher risk of job loss.
Subsidiaries	2 623	Subsidiaries of power corporations	· Subsidiaries are responsible for cleaning, facilities maintenance, security, fire protection and exhibition. · Subsidiaries have a higher level of job security than other partner companies in general, which, however, may differ by task, e.g. a partial retirement of power units could lead to a reduction in cleaning work. · Most of the cleaning workers are middle-aged female community residents with limited labour mobility.
Plant	30 000	Private companies	· These are temporary jobs for routine maintenance work. · While the retirement of coal power plants is highly likely to reduce the number of these jobs, it is difficult to obtain specific data. · If the retiring process takes place in sync with the construction of LNG power plants, there could be alternative jobs.
Total	52 306		

Note: KEPCO = Korea Electric Power Corporation; KPS = Korea Plant Service & Engineering; KEPID = Korea Electric Power Industrial Development Co Ltd.

Source: Nam Tae-sup, 2021 & Research on Climate Crisis and the Transition of Industry and Labour, 2022. 2. 22.

The former Moon administration (Ministry of Environment) shuttered ten coal power plants, which had been operating for at least 30 years, under its policy task of improving

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the air quality through pollution control. A total of 3 300 MW of coal power generation was closed while two units, Yeongdong-1 and 2, went through a fuel-switching transition. The Moon administration, at its inauguration, also banned the construction of new coal-fired power plants except those already in process.

Coal phase-down progress

Year	Coal power plant	Power corporation	Installed capacity (MW)	Coal-to-LNG switching	Total
2017	Seocheon-1, 2	Midland	400	-	400 (2 units)
	Yeongdong-1	South-East	125	-	525 (3 units)
2019	Yeongdong-2	South-East	200	-	725 (4 units)
2020	Boryeong-1, 2	Midland	1 000	-	1 725 (6 units)
2021	Samcheonpo-1, 2	South-East	1 120	-	2 845 (8 units)
	Honam-1, 2	East-West	500	-	3 345 (10 units)

Source: MOTIE, 2020. 12. 28.

On 29 December 2020, Chungnam province announced a comprehensive plan in response to the two-year early retirement of Boryeong-1 and 2, scheduled two days later. The plan aimed to resolve issues around employment and tax revenues. The provincial government signed an agreement with Midland Power Corporation for the job retention of the 326 workers of Boryeong-1 and 2, and set up a special account for the continued support for local communities which would have been financed by a KRW 1.7 billion[1] tax revenue from the power plant over the two years. The province also accommodated government-funded projects in areas impacted by coal power plant closures, changed the local industrial ecosystem and eased the concerns for an economic downturn. Boryeong city also won a government-led development project (a KRW 6 trillion project) for a 1 GW offshore wind farm in a 62.8 km^2 site off the west coast, near the islands of Oeyeon-do and Hwang-do, and received KRW 4.5 billion of national funding for basic planning, and wind and ecology surveys for three years until 2023.

[1] Exchange rate: 1 Korean won (KRW) = USD 0.00076 (as of 08 March 2023).

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Ninety-five percent of the workforce (or 1 207 of total 1 268 workers) in the eight power plants that were retired between 2017 and 2021 were relocated. Two more units, Honam-1 and 2, were closed as of 31 December 2021 and among the total 320 workers, 290 will either remain in position to complete the closure work or be relocated to other coal-fired or LNG-fired power plants. Among the rest, 20 will end their contracts and 10 will retire. After the closure of ten power plants, 90% (1,555) of the total 1 727 workers were relocated. Thirty-two (1.9%) retired and 59 (3.4%) were dismissed, but the trend differed by employment type. While all 740 regular workers were relocated, only 82.6% (815 of 987) of the workforce was relocated for partner companies, and all workers that retired or were dismissed were from either subsidiaries or partner companies; 81 remained in position.

Relocation of the workforce after the retirement of the 8 coal power plants

Power plant	Power corporations			Partners		
	Before retirement	After retirement	Retention rate	Before retirement	After retirement	Retention rate
Seocheon-1, 2	139	Complete relocation	100%	218	197 relocated, 8 retired, 13 dismissed	90.4%
Yeongdong-1, 2	213	Complete relocation	100%	158	148 relocated, 10 dismissed	93.7%
Boryung-1, 2	139	Complete relocation	100%	146	124 relocated, 6 retired, 16 dismissed	84.9%
Samcheonpo-1, 2	110	Complete relocation	100%	145	137 relocated, 8 retired	94.5%
Honam Thermal-1, 2	139	90 relocated, 40 remained	100%	320	209 relocated, 81 remained, 10 retired, 20 dismissed	90.6%
Total	740	Complete relocation or retention	100%	987	606 relocated, 22 retired, 39 dismissed	90.8%

Source: MOTIE, 2021. 12. 28.

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Relevant policies on coal-fired power generation

The following is the list of plans on coal-fired power generation in Korea's recent energy policies.

The 3rd National Master Plan for Energy

The plan aimed to address air pollution and greenhouse gas (GHG) emissions through an ambitious phase-down of coal. The plan banned the construction of new coal power plants and aimed to retire inefficient ageing units or convert them into cleaner facilities such as LNG power plants. The plan aimed to promote the complex-scale projects to reduce air pollution, and the details were to be reviewed and included in the 9th Basic Plan for Long-Term Electricity Supply and Demand (BPLE). The plan also aimed to further reduce the amount of power generation from coal by implementing environmental dispatch, which takes into account environmental costs such as emissions trading costs, expanding limits on plant operations and reducing coal power generation in the spring season.

The 9th Basic Plan for Long-Term Electricity Supply and Demand

The 8th BPLE retired six ageing units and made progress in converting two units under construction and four units subject to retirement to LNG power plants. The six ageing units were Boryeong-1 and 2, Samcheonpo-1 and 2, and Honam-1 and 2. The two units under construction were Dangjin Eco-1 and 2. The four units subject to retirement were Taean-1 and 2, and Samcheonpo-3 and 4. The 9th BPLE was set out to reduce the share of coal in power generation from 40% in 2019 to 29.9% in 2030.

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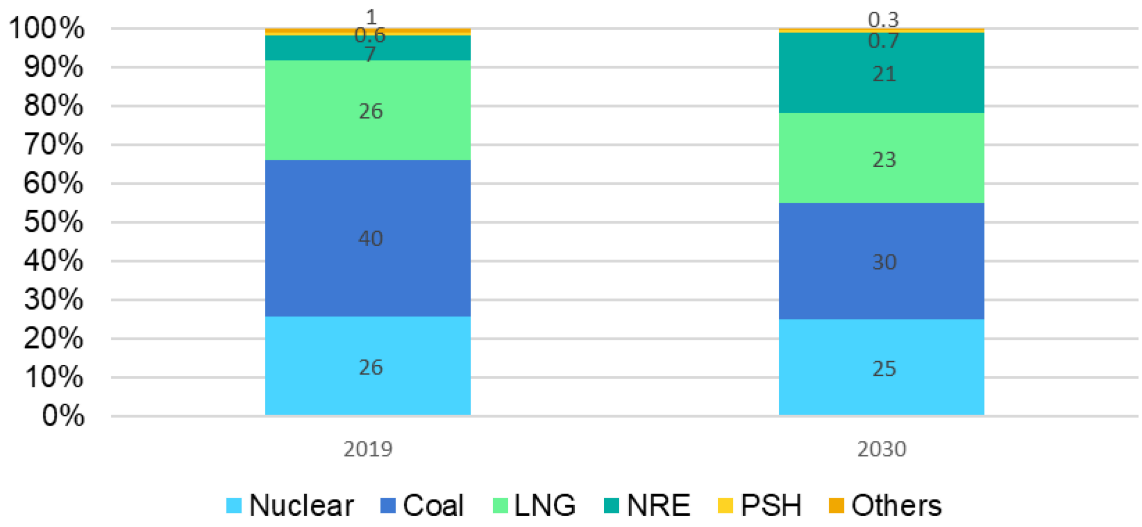
Generation mix in 2019 and 2030



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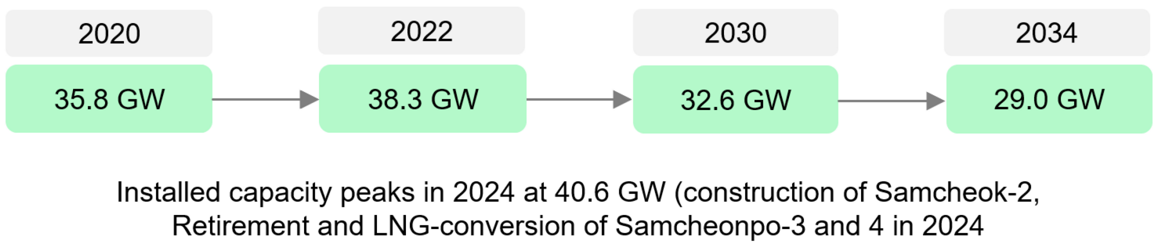
Note: NRE: New renewable energies (wind and solar).
Source: The 9th BPLE, MOTIE, 2020. 12. 28.

Coal power generation in the 9th BPLE



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Source: The 9th BPLE, MOTIE, 2020

Fuel shares in power generation in the 9th BPLE (%)

Year	Nuclear	Coal	LNG	Renewables	PSH	Others	Total
2019	25.9	40.4	25.6	6.5	0.6	1.0	100.0
2030	25.0	29.9	23.3	20.8	0.7	0.3	100.0

Source: The 9th BPLE, MOTIE, 2020.

The enhanced nationally determined contribution

The new goal is to restructure the generation mix by reducing oil and coal, expanding renewables and introducing co-firing of zero-emission fuels, such as ammonia. The government insisted that in order to facilitate the early retirement of coal power plants which are scheduled to operate until 2031-2034, the 10th BPLE needs to provide the legal basis, which will set the liability of plant operators and prevent the abuse of power

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by the government. The government also noted the need to take a clear stance on overseas GHG emissions, such as its funding for overseas coal power plants, and develop a relevant framework which allows for the possibility of emissions reduction through international carbon market purchases by enterprises.

Change in generation mix (in TWh)

2018	Nuclear	Coal	LNG	Renewables	Oil	PSH	Total
Power generation	133.5	239.0	152.9	35.6	5.7	3.9	570.7
Share	23.4%	41.9%	26.8%	6.2%	1.0%	0.7%	100.0%

↓

2030	Nuclear	Coal	LNG	Renewables	Ammonia	PSH	Total
Power generation	146.4	133.2	119.5	185.2	22.1	6.0	612.4
Share	23.9%	21.8%	19.5%	30.2%	3.6%	1.0%	100.0%

Source: Enhanced Update of Korea's First Nationally Determined Contribution, 2021. 10. 18.

2050 carbon-neutral scenarios

The government launched a presidential committee on carbon neutrality in May 2021, released draft 2050 carbon-neutral scenarios, announced the draft 2050 carbon neutrality plan in August and finalised two scenarios in October which target net zero emissions by 2050. The coal phase-down is set to be based on a legal framework and compensation arrangements. Market mechanisms such as environmental dispatch and emissions trading system will be employed to facilitate the transition.

- (Scenario A) Full decarbonisation of the transition sector by phasing down thermal power generation: LNG will still be used for heating industrial complexes, households and public facilities (emissions will be accounted for in the industry and buildings sector).
- (Scenario B) Partial decarbonisation of the transition sector by phasing down thermal power generation and through coal-to-LNG switching: Coal will be phased out and LNG will be used as baseload power generation.

In any case, the coal phase-down plan is linked to the 2050 carbon-neutral scenario. The phase-down of coal power generation requires expansion of renewables and also some form of flexibility, such as hydrogen-based generation. There are two options regarding this scenario. Both Scenario A and B will conclude with complete phase-down of coal by 2050, according to the 2050 carbon-neutral scenario.

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Power generation and GHG emissions from energy sources in the two scenarios (in TWh)

Category	Nuclear	Coal	LNG	Renewables	Fuel cell	NEA Grid	Zero-carbon gas turbines	By-product gas	Total	Projected emissions (million tonnes)
Scenario A	76.9 (6.1%)	0.0 (0.0%)	0.0 (0.0%)	889.8 (70.8%)	17.1 (1.4%)	0.0 (0.0%)	270.0 (21.5%)	3.9 (0.3%)	1 257.7 (100%)	0
Scenario B	86.9 (7.2%)	0.0 (0.0%)	61.0 (5.0%)	736.0 (60.9%)	121.4 (10.1%)	33.1 (2.7%)	166.5 (13.8%)	3.9 (0.3%)	1 208.8 (100%)	20.7

Source: 2050 Carbon Neutral Scenarios, 2021. 10. 18.

Work plan for the 10th BPLE

Energy security is emerging as a key task for national security. Major foreign countries are setting energy supply and demand stabilisation as a top priority policy to strengthen national security in response to the uncertainty in the global energy supply chain caused by Covid-19 and the Russia-Ukraine war. In this context, in the 10th BPLE announced by Korea, stable electricity supply and demand for strengthening energy security is considered as a top priority, as well as economic feasibility (cost efficiency), environmental effect (carbon neutrality) and safety. The 10th BPLE suggests a feasible and balanced power supply mix for stable electricity supply and demand, which can be summarised as active use of nuclear power plants, reasonable supply of renewable energy and inducing reduction of coal power generation.

First of all, the construction of new nuclear power plants and the continuous operation of nuclear power plants whose operation permits have expired are planned to be promoted to supply power cost-effectively on the promise of securing safety. As new nuclear power plants, the construction of Shin Hanul Units 3 and 4 are planned to be resumed through compliance with the licensing procedures and efficient processes. Nuclear power plants under construction such as Shin Hanul Unit 2 and Shin Kori Units 5 and 6 are planned to be completed and connected to the grid system in a timely manner. Continued operation of nuclear power plants whose operation permits have expired (total of ten units by 2030) will proceed after a thorough safety inspection through a review by the Nuclear Safety and Security Commission, collecting opinions from residents, and securing public acceptance. With the continued operation of nuclear power plants and the new nuclear power plants, the share of nuclear power generation is expected to increase to 34.6% in 2036.

Renewable energy is planned to be supplied at a reasonable level in consideration of feasibility and acceptance by residents. The proportion between solar and wind power generation is expected to be more balanced from 87:13 in 2021 to 60:40 in 2030 by faster deployment of wind power. In addition, it is planned to contribute to stabilising

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power supply and demand by expanding investment in the power grid, increasing residents' acceptance, and securing devices such as energy storage systems (ESS) to respond to variability in renewable energy. According to the renewable supply plan considering feasibility, the share of renewable power generation is expected to increase to 30.6% in 2036.

In order to reduce GHG emissions from coal and achieve carbon neutrality, the share of coal power generation is supposed to be reduced through the abolition of old coal facilities. The 10th BPLE reflects a plan to gradually abolish 28 coal-fired power plants by 2036 and switch fuel to LNG for carbon neutrality and GHG reduction. Meanwhile, in order to strengthen energy security and prevent the stranded assetisation of old coal facilities, the plan considers a policy to keep coal-fired power plants as a cold reserve. In addition, in order to minimise job security issues caused by the abolition of coal power generation, the plan reviews various measures with related ministries and local governments, such as relocating manpower to other power plants such as LNG power generation and renewable energy, and utilising existing coal power generation infrastructure. LNG power generation is expected to maintain a certain level as the replacement of old coal power generation with LNG is promoted. However, there is room for adjustment according to the amount of hydrogen co-fired power generation.

Power generation projections by energy source in 2030 (in TWh)

Year		Nuclear	Coal	LNG	RE	Hydrogen/ Ammonia	Others	Total
2030	Generation	201.7	122.5	142.4	134.1	13.0	8.1	621.8
	Share (%)	32.4	19.7	22.9	21.6	2.1	1.3	100
2036	Generation	230.7	95.9	62.3	204.4	47.4	26.6	667.3
	Share (%)	34.6	14.4	9.3	30.6	7.1	4.0	100

Note: RE = renewable energy.
Source: The 10th BPLE, MOTIE, 2023

In the 9th BPLE, the emissions target in the transformation sector in 2030 was 192.7 Mt, but in the new nationally determined contribution (NDC) revision, the emissions target was enhanced to 149.9 Mt, which is a challenging target of reducing 44.4% compared with the emissions in 2018. The 10th BPLE plans to achieve the target by expanding nuclear power plants and renewable energy, and reducing coal power generation. Moreover, it plans to contribute to reducing GHG emissions by utilising carbon-free sources such as hydrogen and ammonia. By facilitating co-firing 20% ammonia with coal and gradually expanding co-firing 50% hydrogen with LNG, ammonia power generation is expected to reach 20.9 TWh and hydrogen power generation is 26.5 TWh in 2036.

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Hydrogen and ammonia power generation projections (in TWh)

Year	2030	2036
Hydrogen	6.1	26.5
Ammonia	6.9	20.9

Source: The 10th BPLE, MOTIE, 2023

Policy response to coal phase-down

Clean energy transition

Korea aims to accelerate the phase-down and clean energy transition of coal power plants through laws and systems. First of all, the government plans to reduce GHG emissions through expansion of nuclear power plants, reasonable supply of renewable energy and reduction of coal power generation, with further reductions through short-term measures such as capping coal power generation. Korea aims to facilitate the transition of coal power plants by including LNG power generation in the Korean Green Taxonomy (also so-called K-taxonomy). Twenty-eight coal-fired power plants are planned to be closed by 2036 and switched to LNG in the 10th BPLE. Second, Korea aims to facilitate the technological development of and investments in low-carbon and zero-carbon energy sources. Korea plans to promote ammonia co-firing through technological development and demonstration with targets of 20% co-firing demonstration by 2027, 20% co-firing commercialisation by 2030 and 100% ammonia-fuelled firing by 2050. Korea also aims to promote a hydrogen economy by adopting the Clean Hydrogen Portfolio Standards under the Hydrogen Act Amendment Bill.

Support for worker relocation and local communities

The government plans to reassign coal power plant workers to the construction and maintenance of transmission and distribution systems, which are expected to be high in demand given the expansion of LNG, hydrogen and ammonia-fuelled power generation as well as renewables. The government also plans to repurpose coal power plant sites, based on community acceptance, in a way that contributes to the local economy and electricity supply. For examples, the electricity-related infrastructure of coal power plants can be reused for cleaner electricity generation. Some designated coal power plants may be mothballed and remain as backup power supply. The remaining sites can be redeveloped as industrial complexes or tourist/cultural sites.

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Prospects for the power generation sector after the coal phase-down and policy directions

Category	Present	Transition period	Future	Policy direction
Power generation transition	Coal	LNG Ammonia RE, CCUS, ESS	Hydrogen	Accelerated transition
Site (local economy)	Coal power plant	LNG power plant Ecological restoration Culture/tourist site	Hydrogen, ammonia, RE power plant	Engagement among companies, local authority and residents
Key employment change	Coal power generation equipment operation and maintenance	LNG power generation equipment operation and maintenance	Operation and maintenance of equipment for hydrogen/ammonia production, implementation and storage and Operation of cultural/tourist facilities	Transition training and restructuring
Law and institution	- Energy Transition Act as basis for early retirement/ transition of coal power plants and compensation arrangements - Electric Utility Act as basis for coal power generation operation limits - Energy Act Amendment as basis for local consultation systems			

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Source: MOTIE, 2021. 12. 28

Survey for coal phase-down policy

Overview

A national online survey of 2 000 adults (over the age of 20) was conducted to find public attitudes towards the transition policy of the coal-fired power generation sector. This table shows the content of the survey.

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Content of survey questions

Category	Content of questions
Demographics	Gender, age, place of residence, marital status, employment status, education level, economic status (average monthly income), average monthly electricity bill
Awareness of climate crisis	Biggest threat to humanity Biggest threat to Korea Recognition of climate change as a social challenge Shares of non-CO_2 GHG emissions Domestic GHG emissions share by sector Key player(s) in climate mitigation efforts Activities related to climate mitigation
Awareness of carbon neutrality policy	Level of awareness of carbon neutrality Level of awareness of the target year for carbon neutrality Level of awareness of the enhanced GHG emissions reduction target Opinions on the revision of the GHG emissions reduction target Awareness of coal-exit policy Opinions on coal-exit policy Reasons for approval Reasons for disapproval Opinions on new coal builds Opinions on coal phase-down in cases of higher electricity bills Opinions on (the pace of) the coal phase-down plan Awareness of Europe's return to coal Potential social conflicts due to the closure of coal-fired power plants
Awareness of compensation and support plans for coal phase-down	Opinions on policy development for just transition Efforts needed to minimise impact on the most vulnerable Who will be impacted most by the closure of coal-fired power plants Policy measures needed to minimise impact on local communities Policy measures needed to minimise impact on workers Key factors in developing just transition policy Stakeholder participation in development of just transition policy

Source : KEEI

Survey results

Awareness of climate change

While climate change was selected by the majority of respondents (60.3%) as the biggest threat facing humanity, followed by widening socio-economic disparity (18.0%)

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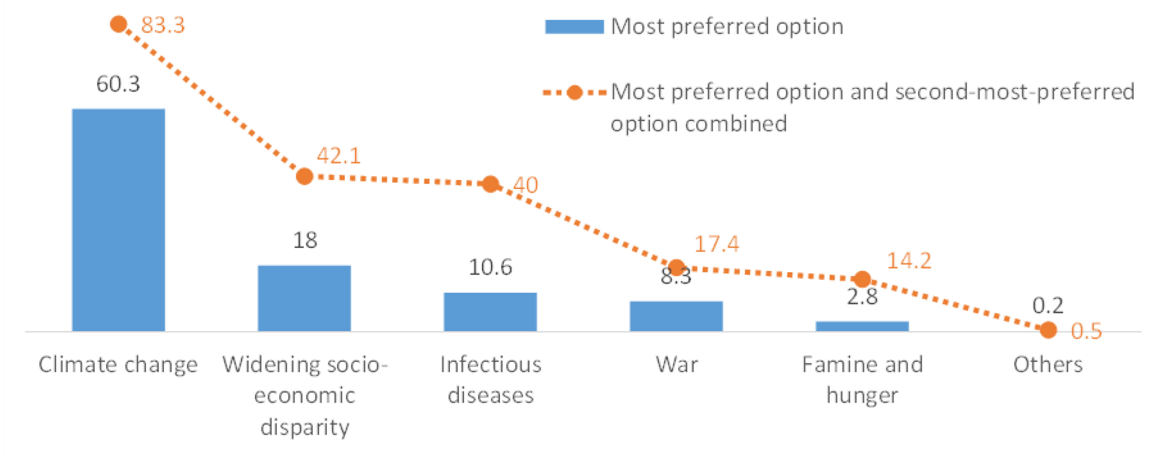
and infectious diseases (10.6), it was deemed the third-biggest threat (12.7%) to Korea after widening socio-economic disparity (39.9%), and low birth rate and population ageing (37.5%).

Biggest threat to humanity



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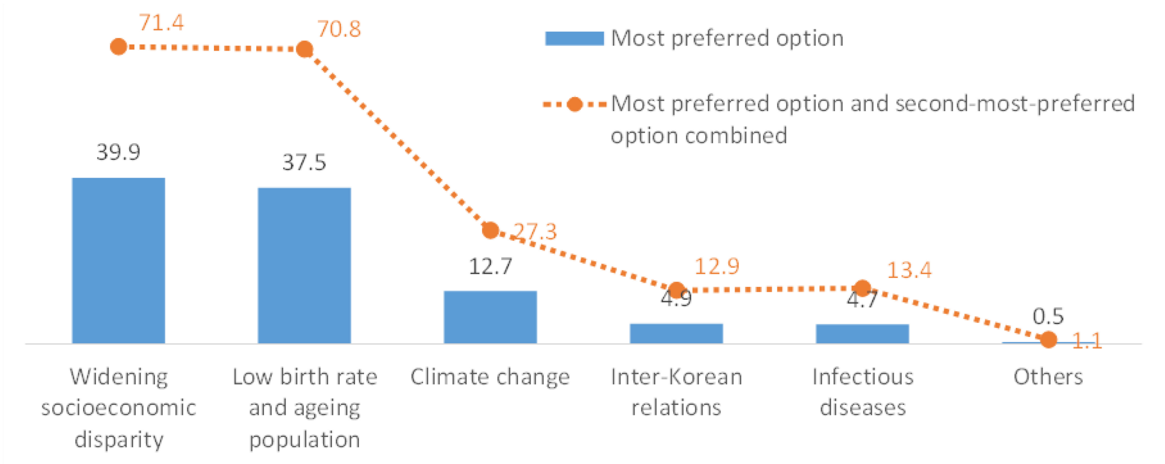
Source: KEEI.

Biggest threat to Korea



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Source: KEEI

Although climate change came third as a threat to the nation, it was confirmed that most of the respondents (94.7%) were aware of its seriousness. At the same time, it also indicates that more efforts are needed to improve public understanding of the climate crisis before the development of relevant policy including those for the just transition of the coal-fired power generation sector. The central government was chosen as the key player in climate mitigation efforts by 54.5% of respondents; 20.6% chose businesses, 20.3% chose the public and 3.7% chose municipalities.

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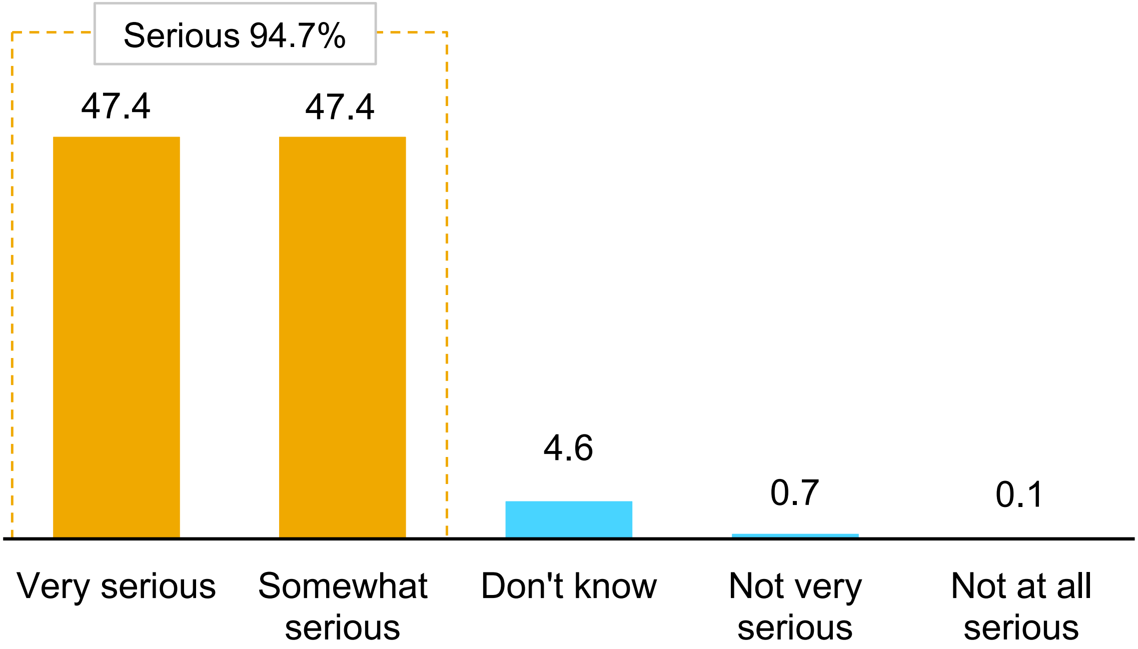
Seriousness of climate change



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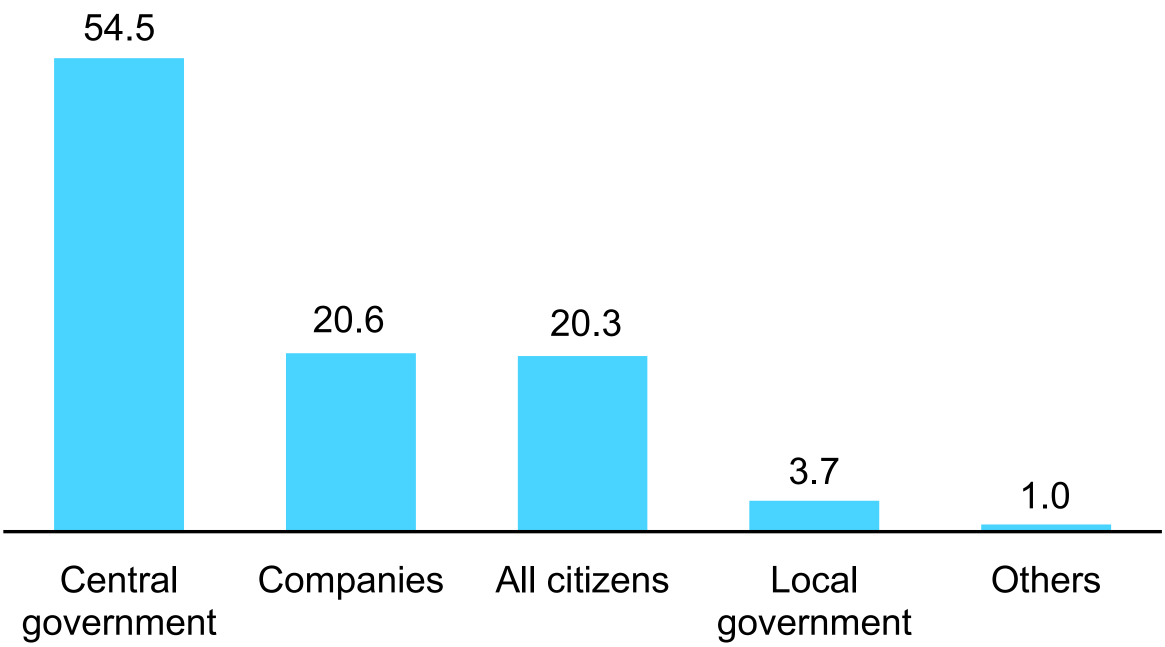
Source: KEEI.

Most responsible actors for climate change action



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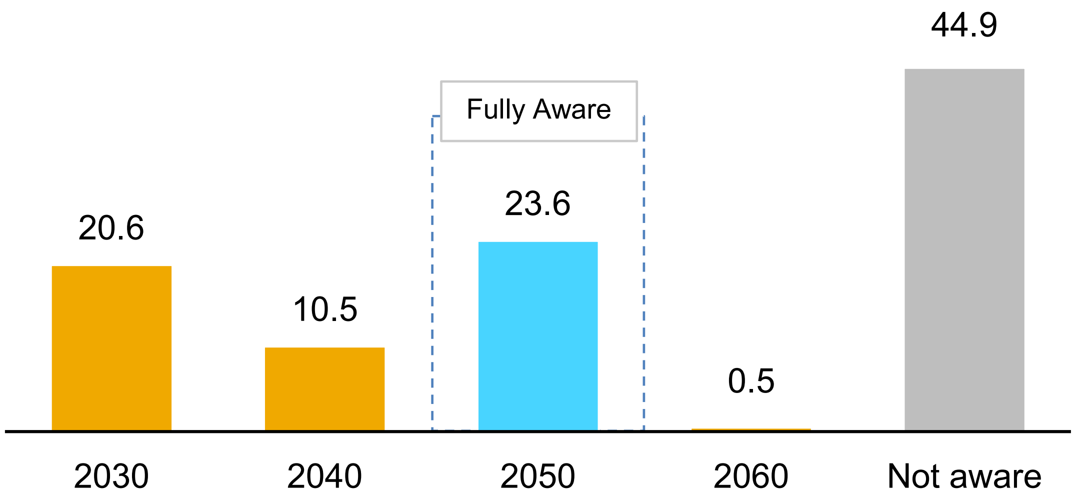
Awareness of carbon neutrality policy

While 94.0% of respondents were aware of carbon neutrality policy, only 23.6% knew about the exact target year for carbon neutrality (2050) and 10.1% knew about the enhanced emissions reduction target (40%).

Awareness of the target year for carbon neutrality



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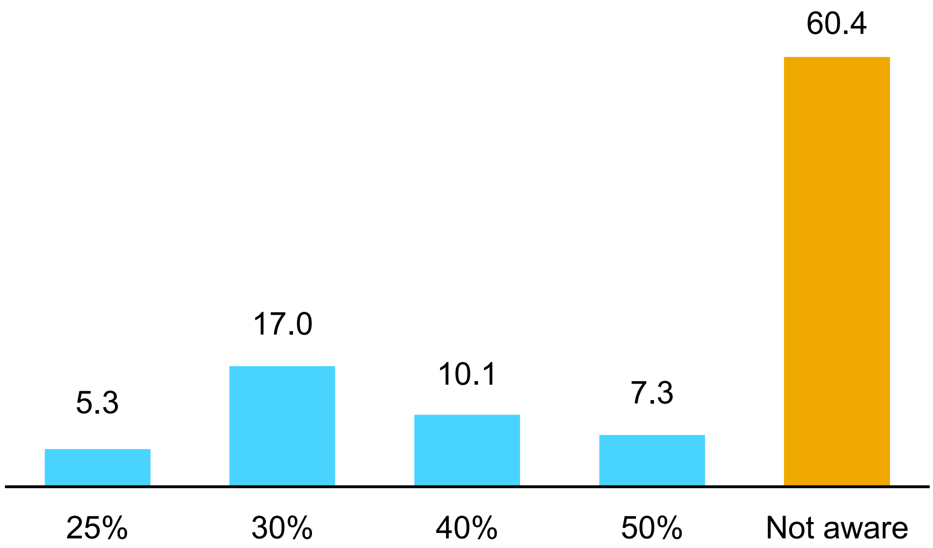
Note: Base: Total(N=2000) / unit: %.
Source: KEEI.

Awareness of the enhanced emissions reduction target



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Note: Base: Total(N=2000)/ unit: %.
Source: KEEI.

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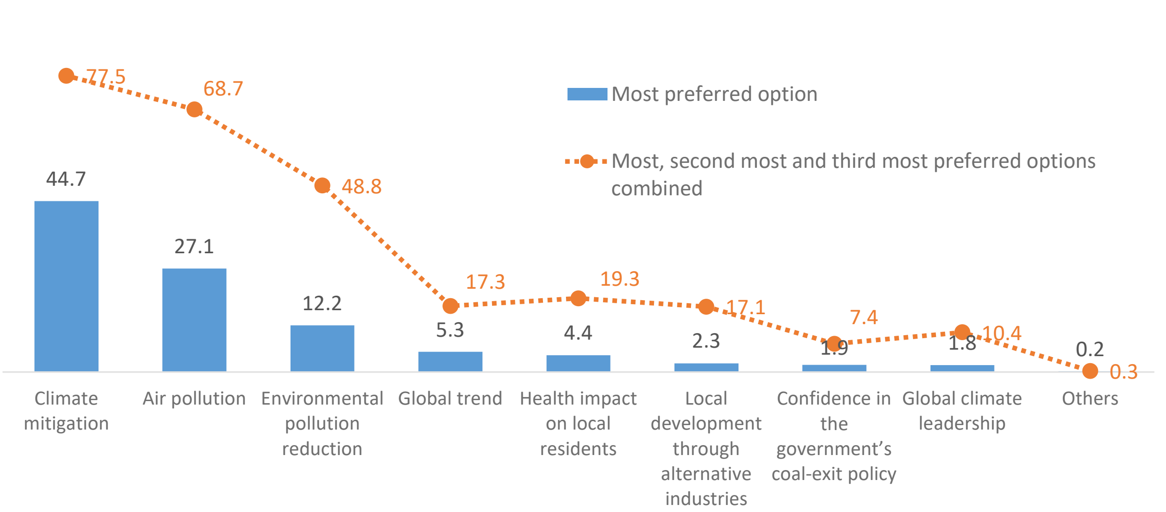
Respondents supported coal-exit policy mostly due to environmental factors such as climate change and air pollution while concerns about electricity supply and high electricity bills were the biggest reasons for disapproval. Concerns about electricity supply and energy security (40.2%), higher electricity bills (21.1%) and loss of industrial competitiveness (10.8%) were the main reasons against the policy while climate mitigation (44.7%), reduction in air pollution (27.1%) and reduction in environmental impact (12.2%) were the main reasons for the policy.

Reasons for coal-exit policy



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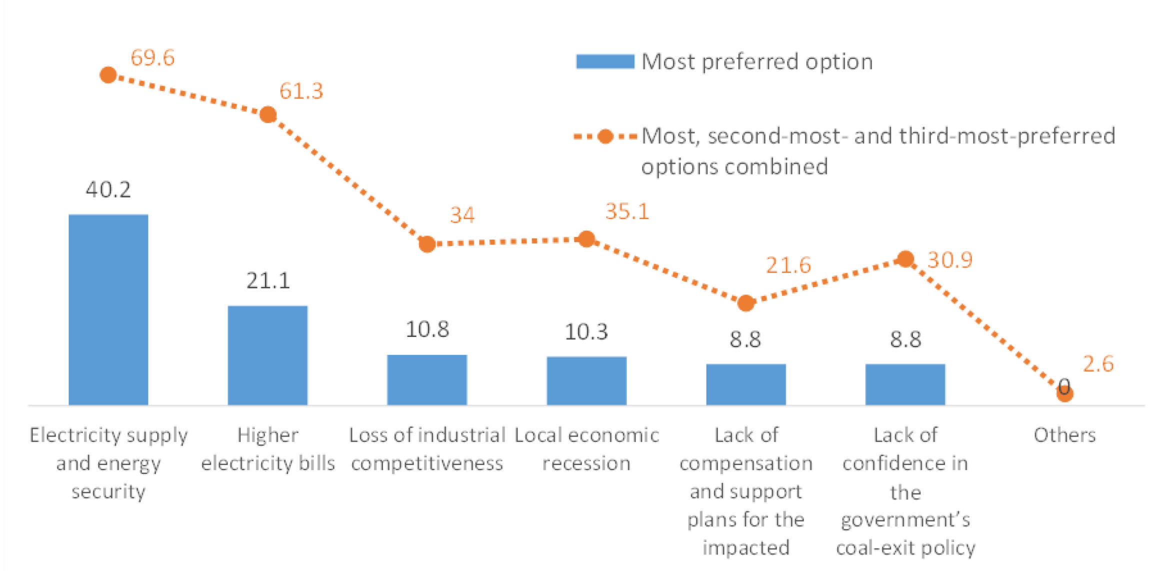
Source: KEEI.

Reasons against coal-exit policy



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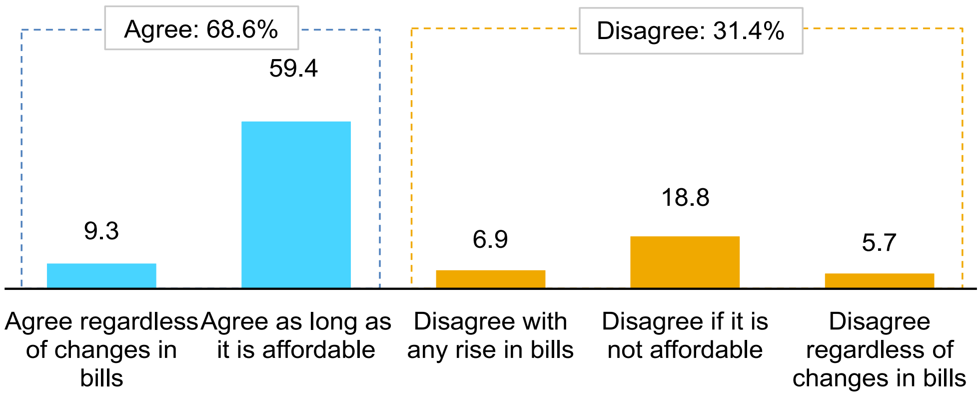
The coal-exit policy was supported by 68.6% despite a possible rise in electricity bills (9.3% said "regardless of changes"; 59.4% said "as long as it is affordable"), outnumbering the opposition (31.4%).

The current plan of phasing down all coal-fired power plants by 2050 was supported by 41.1% of respondents, 25.7% said a later coal phase-down with an increased share of nuclear power in the mix would be reasonable, and 19.0% called for a coal phase-down at the earliest opportunity due to climate change (an accelerated phase-down).

Opinions on higher electricity bills



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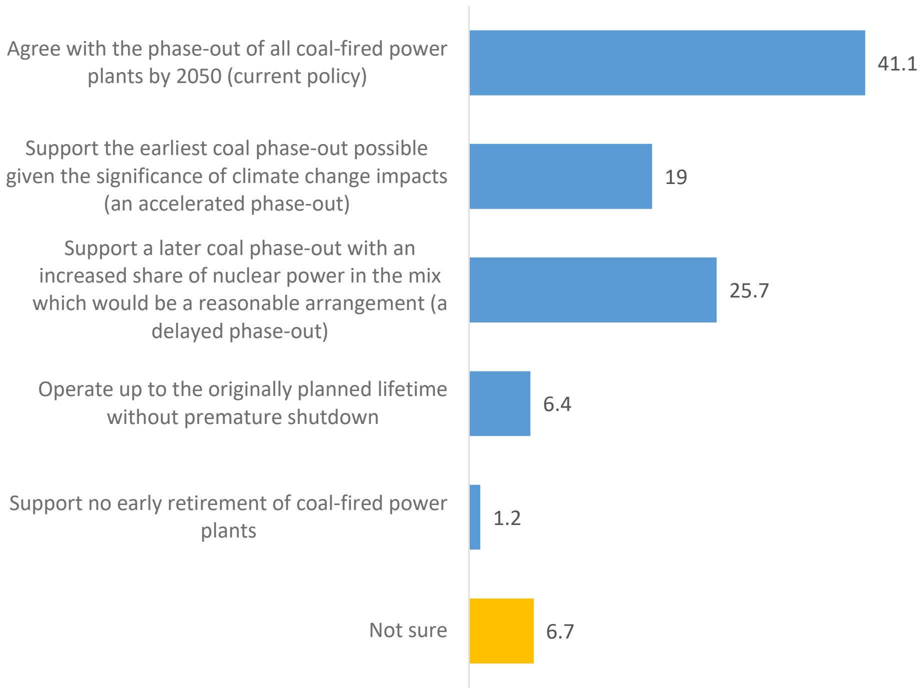
Opinions on (the pace of) the coal phase-down plan



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Source: KEEI

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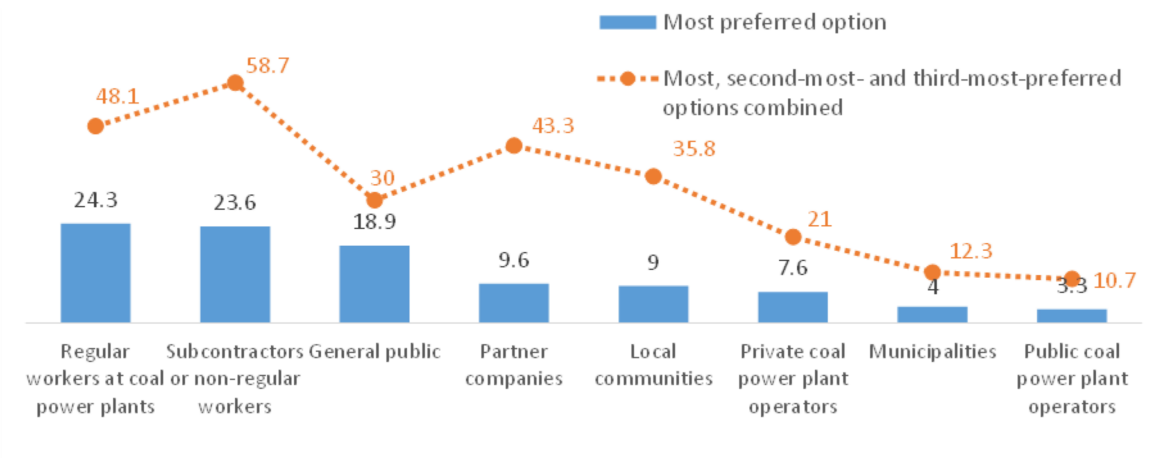
Awareness of compensation and support plans for coal-exit

Ninety-three percent of respondents agreed that the coal-exit policy must be developed hand in hand with a just transition policy to support the impacted, while only 39.9% believed that the government was taking sufficient action and 60.2% thought otherwise.

Among respondents, 24.3% thought regular workers at coal power plants would be most impacted in the event of a coal phase-down, 23.6% thought it would be subcontractors or non-regular workers, and 18.9% thought it would be the general public. However, when results for the most impacted group and the second-most-impacted group were combined, 58.7% chose subcontractors or non-regular workers, 48.1% chose regular workers and 43.3% chose partner companies. This shows that respondents failed to make a clear distinction between varying employment types at power plants.

Most impacted group in case of coal power plant closures



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Source: KEEI

As for necessary policy to minimise impact on local communities, 28.2% of respondents chose support for local energy enterprises, 19.7% chose creation of quality local jobs and 10.3% chose remediation of plant sites and local environmental recovery.

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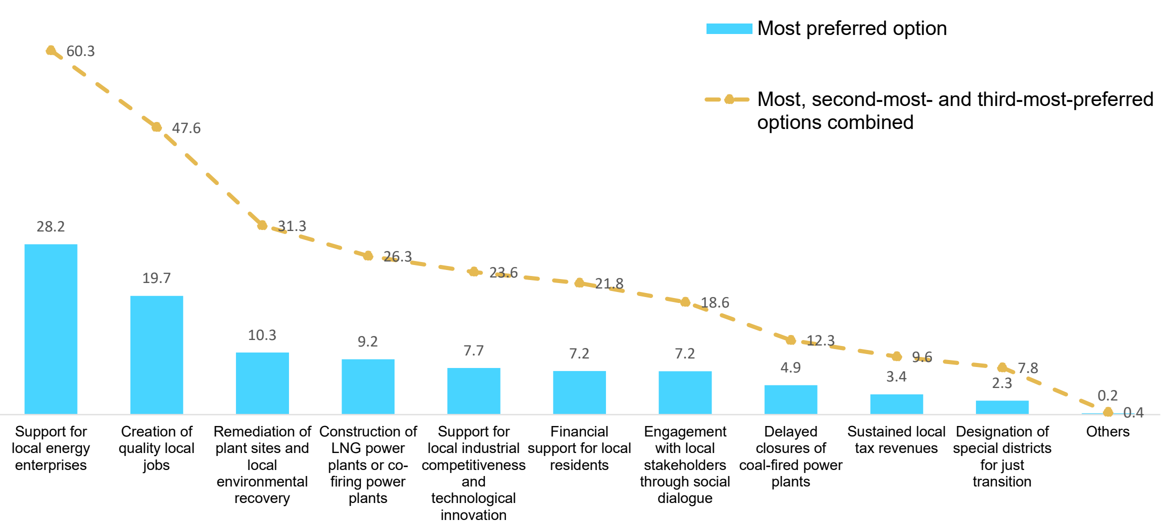
Necessary policy to minimise impact on local communities



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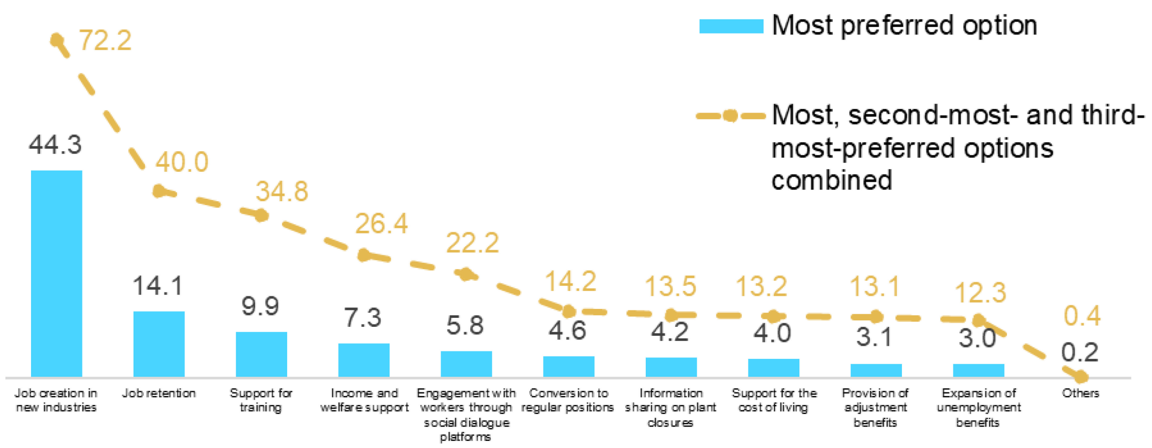
Source: KEEI

As for necessary policy to minimise impact on workers, 44.3% of respondents chose job creation in new industries, 14.1% chose job retention, and 9.9% chose support for training.

Necessary policy to minimise impact on workers



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Source: KEEI

When asked about key factors in developing just transition policy to minimise impact on stakeholders, 36.9% of respondents chose accurate impact analysis and transparent information sharing on government plans, 28.5% chose stakeholder

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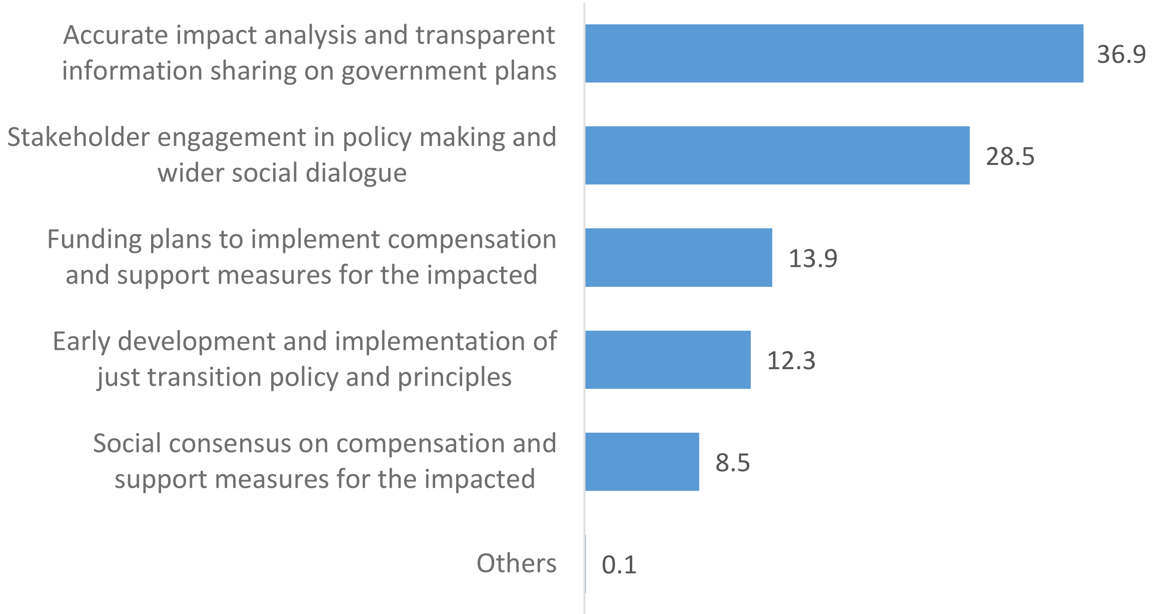
engagement in policy making and wider social dialogue, and 13.9% chose funding plans to implement compensation and support measures for the impacted.

Key factors in developing just transition policy



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Source: KEEI

Chapter 3. High-level policy recommendations for the coal transition in Korea

Coal transitions in the world

There are some countries and jurisdictions which have started the process of coal transition in the power sector. The Canadian province of Ontario was the first jurisdiction that established a strategy to close its coal power plants with a given deadline. The Australian state of South Australia is another one among the front runners. In Europe, Austria, Belgium, Portugal and Sweden are countries where coal power capacity has been fully decommissioned, while coal power generation has virtually disappeared in others such as France, Spain and the United Kingdom. Many other countries are in different phases of the transition process.

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Within the Glasgow Climate Pact, shared interests and collaborative actions from countries will keep alive the hope of limiting the rise of global temperature to 1.5° C. In the 26th Conference of the Parties (COP26), for the first time in the 26-year history of the United Nations Framework Convention on Climate Change (UNFCCC), after many discussions, the participants agreed on phasing down unabated use of coal in the power sector. This was a compromise among countries which wanted a stronger language and others which did not want to single out any specific fuel. Sixty-five countries have now committed to transition away from coal, with more than 20 new commitments made at COP26. In addition, 48 countries are members of the Powering Past Coal Alliance. Therefore, there are a number of countries in different phases of the unabated coal power transition process.

An important consideration refers to the different profiles of energy demand in advanced economies compared with those in emerging market and developing economies (EMDEs). In the case of advanced economies, energy demand, and thus also electricity demand, is growing only marginally or stagnating or even declining, whereas energy demand is rapidly increasing in EMDEs. This makes the abatement of coal emissions through reduction of energy demand more challenging in these regions, unless carbon capture, utilisation and storage (CCUS) is adopted. Amid the lack of energy supplies, it is difficult to consider capacity retirements as a way to reduce coal emissions. The financial capacity to support coal transitions in many EMDEs is not buoyant. The cost of capital they typically face is much higher than in advanced economies. Given the high capital intensity of most of the low-emissions alternatives, either wind, solar PV, nuclear or CCUS retrofit, a higher cost of capital translates into higher generation costs. Two percentage points of higher costs of capital can typically mean a levelised cost of electricity (LCOE) USD 20/MWh higher. In addition, financial requirements for the investment needed to replace coal plants and the additional growth in demand can be difficult to secure for some players in certain geographies. Moreover, quite often, coal power plants are shielded by long-term contracts in the form of power purchase agreements or the equivalent, whose modification can require a strong financial capacity. Several initiatives have recently been launched to address these challenges. One of the ambitious initiatives is the so-called Just Energy Transition Partnerships (JETPs). This is a programme launched during COP26 by France, Germany, the United Kingdom, the United States and the European Commission – often called the International Partners Group – in order to make available the financial resources necessary to accelerate energy transitions and meet the climate targets, while ensuring a just transition. This approach is more comprehensive than the former Energy Transition Partnerships as they include elements of just transition. During COP26, the JETP for South Africa, with an economic funding of USD 8.5 billion, was announced. On 15 November 2022, Japan, the United States and other partners announced a USD 20 billion package for Indonesia's JETP, which follows the South African model, but with increased ambition. In December 2022, the International Partners Group announced a USD 15.5 billion for

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Viet Nam's JETP. Other countries, such as India and the Philippines, are negotiating similar agreements within the JETP framework.

Related to the JETP arrangements, on 7 November, the International Partners Group announced the endorsement of South Africa's Just Energy Transition Investment Plan, prepared by the government of South Africa, which includes investment on clean energy – including hydrogen and EVs – and elements of just transition. It identifies USD 98 billion of financial requirements over five years, of which the coal transition features strongly in the investment plan. The difference between the USD 8.5 billion committed by the JETP and the USD 98 billion needed to start the transition can look staggering, but the purpose of the JETP is not to wholly finance the transition. It is rather to catalyse funds from both public and private origin in order to start the process. On 14 November, Indonesia, the Asian Development Bank and the owner of the 660 MW Cirebon 1 coal power plant signed an agreement to refinance the plant with the conditions to close down the plant 10 to 15 years before its useful lifetime. The deal involves an amount between USD 250 million and USD 300 million.

Applications to Korea

The Coal in Net Zero Transitions report outlines a series of high-level key recommendations for policy makers in jurisdictions where the transition from unabated coal is planned to take place. However, the scope of that report covers all the sectors of the economy, industry and all the regions across the world, while emerging economies and advanced economies present different cases in at least two important issues: the pace of energy demand growth and the availability of finance.

Chapter 1 highlighted that the electricity sector and the industry sector need different approaches regarding the transition to net zero, in particular coal's transition to net zero. First of all, two-thirds of global coal demand is concentrated in the power sector. This makes the abatement of coal emissions from electricity generation all the more urgent and paramount. There are also a variety of readily available low-emissions technologies to produce electricity, whereas for some industrial applications, there are limited, if any, commercial technologies available today at scale to replace coal. This highlights the important role of the power sector in taking the lead in coal transitions.

From various experiences and analyses, we did a screening to identify the main recommendations which are applicable to the coal power sector in Korea. In concrete, based on the global context presented in Chapter 1 and the comprehensive analysis of Korea's coal power sector presented in Chapter 2, this chapter aims to provide policy recommendations in order for Korea to transition from unabated coal power generation, addressing the following key issues:

- **Follow the principles of a people-centred transition:** What is needed to assist workers, companies and communities to move away from unabated coal-based electricity, while ensuring a just transition?

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- **Ensure security and affordability of the electricity system:** How can the transition away from unabated coal power be consistent with maintaining electricity security and affordability in Korea?
- **Consider conversion of coal-fired plants to low-emissions assets:** How can the existing coal generation assets be used during the transition in order to address the two issues mentioned above?

In the past there have been many energy transitions across the globe, but none compared with the scale of the current transition towards a net zero energy system. Moreover, transitions from one fuel to another usually imply addition rather than complete substitution. When coal use started ramping up, it did not replace wood, but added to wood-based energy. When nuclear power started, it generally added generation on top of the former technologies. With respect to coal transitions, there is a long experience of countries transitioning away from coal mining. The main driver was often the better competitiveness of imported coal. More recently, some countries or regions have transitioned from coal power generation, mostly driven by climate considerations, although air pollution has also played a role. The case of the United States in the 2010s requires special consideration, as it is the largest reduction of coal power generation that any country has ever experienced. On top of climate and air pollution considerations, the abundance of low-cost natural gas untapped by the shale revolution accelerated the replacement of coal in the electricity system. Whereas lessons can be extracted from all those historical experiences, the most relevant ones that can be applied to Korea are those coming from countries which decided to phase down unabated coal power generation.

Concerning the impact on communities, the closure of coal mines offers ample experience, but they are only partially applicable to coal power plants, requiring caution when using lessons from coal mining as a benchmark. Given the important role that coal power plants have been playing to keep lights on, questions regarding affordability and security of electricity supply are also relevant, and the experience of countries which have done or are undergoing the transition process could be very relevant.

In addition, a set of policy recommendations around the concept of repurposing or converting existing coal power plants were presented as, if left unchecked, the existing fleet of coal plants are set to incur a large amount of emissions in the coming decades. In particular, the conversion of coal assets to low-emissions assets means there is still some activity in the community and can reduce the impact on the electricity system from the coal closure. In this case, there is less experience from the past, as most of the conversions so far have been in the United States, where conversion to gas boilers or combined cycle was the preferred option due to the prevailing low gas prices since the shale gas revolution. While natural gas power plants emit less CO_2 than coal-fired plants, they are still carbon-intensive, unless retrofitted with CCUS. Despite the limited

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global experience, this requires countries such as Korea to explore ways to repurpose or convert existing coal assets to low-emissions compatible ones.

Follow the principles of a people-centred transition

Today, countries accounting for more than 95% of total coal consumption worldwide have made net zero emissions pledges. In the Announced Pledges Scenario (APS), the implementation of these pledges brings profound change in coal industry and its workers. As stated in other parts of this report, in accordance with the International Energy Agency (IEA) approach, energy transitions are for people and about people. This is not only a good motto, but the key principle which should inspire the whole energy transition and every part of it, and indeed, this should be also the case in Korea.

The IEA concept of a people-centred transition is broader than the just transition. The concept of a just transition emerged in the United States in the 1970s from the discussions to create a fund to compensate workers that lose their jobs. Traditionally, the trade unions have used the concept as a framework to cover a range of social interventions needed to secure workers' rights when economies are shifting to sustainable production. In order to ensure a just transition away from coal and fossil fuels, targeted policy measures and enabling conditions are needed. The IEA estimates that the number of new jobs created due to clean energy transitions outweighs the number of those lost in fossil fuel industries. However, the jobs that are created may not be in the same places as those that are lost, and the required skills in many cases will be different.

The climate crisis is a global concern, but its social and economic effects are discriminatory from person to person. Therefore, the principle of a "people-centred transition" should be prepared, in which the damage and burden of responding to the climate crisis and industrial transition are not passed on to those weaker socio-economically. The preface to the Paris Agreement, agreed in 2015, also refers to "climate justice" and "just transition." In fact, Chungcheongnam-do, where there are a number of thermal power plants in the region, enacted the Just Transition Fund and Operation Ordinance for the first time among local governments in February 2021. However, instead of narrowly focusing on the affected workers and local issues, just transition policies should broaden their horizons to "people-centred transition", encompassing various aspects such as reducing GHG emissions, creating quality green jobs and addressing inequality.

People-centred transition should include:

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- Fairness: Fair treatment to workers and the community that relies on the coal industry.
- Re-employment or alternative employment: Employment should continue without loss of wages, benefits or working period.
- Compensation: When sustainable employment cannot be met, alternative compensation could be considered.
- Sustainable production: Shift to more sustainable means of production and service sector.

Chungcheongnam-do's 5 strategies for a just transition

Strategy	Details
Industry diversification	Fostering new industries (energy, environment, etc.) Establishing industrial transformation capacity of the regional economy
Worker support	Support for workers in the existing industries Fostering workers in new industrial sector
Local community support	Measures for decline in affected areas Fostering local community's transformation capacity
Restoration	Monitoring on environmental and health impacts Clean and safe restoration of abandoned land and facilities for regional development
Construction of base system	Direct participation on planning through having social dialogues with various stakeholders Need for institutional foundation (law, budget) to effectively drive long-term transition process

Source: A study on the feasibility of phase-down of coal power plant in ChungCheongnam-do: A just transition Strategy and Task in Chungcheongnam-do (2021)

In 2017, the Korean government mentioned that it is necessary to comprehensively consider not only the economy but also the environment and safety issues when establishing the 8th Basic Plan for Long-Term Electricity; however, changes in the labour market were not addressed. The 9th plan included a plan to close 30 coal-fired power plants by 2034, but there was limited mention of workers' job security. Given the major impacts from the coal transition, it is desirable for future plans to have these issues discussed.

It is also necessary to revisit the Labour Relations Act, Employment Insurance Act and Labour Relations Development Act to support changes in the labour market after the transition. It is also imperative to reflect the labour stability issue in laws enacted for decarbonisation. In the case of Germany, the Coal Phase-Out Act was established to stop coal power generation by the 2030s and to support workers, businesses and local communities.

In Korea, more than 25 000 workers were employed at coal-fired power plants as of 2022. Among them, 13 000 are regular workers and 12 000 are non-regular workers, which covers cleaning, security, facility subsidiaries, current maintenance, fuel and

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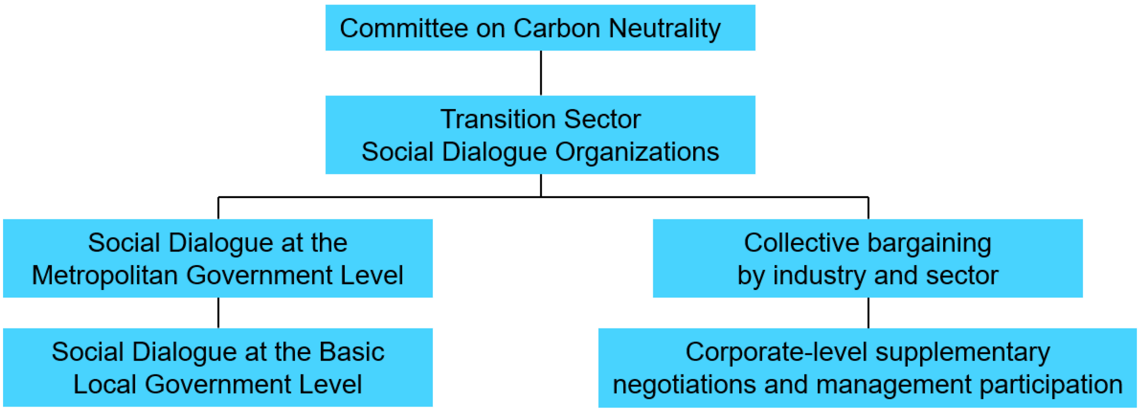
environmental facility operation. The coal supply chain in Korea consists of three processes. The first step is loading coal at the port through coal terminal and putting it into the generator. The next step is working with the generator at the power plant. More than 12 000 people are employed at the generation operation. Regular workers operate the main components including generator, turbine and boiler. The last step involves reducing environmental substances from the combustion process. Workers in fuel management and pollution control could face job insecurity depending on power corporations' planning. Furthermore, it might require fewer people in the job with a switch from coal to liquefied natural gas (LNG).

Consult with people affected by coal closures

The closure of a coal power plant has a direct impact on the company owning the plant, the workers working in the plant and auxiliary services, either as direct employees or subcontractors, and the public administrations which receive revenues through taxes. A more diffuse impact is felt on the community through indirect or induced jobs and through cultural and sentimental links. Apart from the job security issue, the changes will affect multiple aspects of people's lives from transport, heating and cooking to urban planning, which is why the transition should be for and about people.

It is therefore important to establish a dialogue in which all stakeholders are engaged: primarily workers' unions, employers and governments, but other stakeholders from academia, civil society and international organisations can also participate, in order to provide other experiences, different angles of analysis or innovative approaches to explore.

Example of multilayered governance for a people-centred transition



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Provide support for affected workers and communities

As mentioned above, the clean energy transition does not necessarily lead to a net job loss. However, this does not eliminate the need to support the workers and communities affected, as jobs will be created in different sectors and geographies from where the jobs will be destroyed. Moreover, most new jobs will require different skills than old jobs. Jobs created would not necessarily be in the same area where jobs were lost and the skill sets required would not be directly transferable. Even though the total number of direct jobs lost is small, the impact on the local economy may be significant. Government support would be needed to manage these transitions in people-centred way.

In the case of Korea, workers from the coal plants should be a matter of special concern. There has been experience across the globe with schemes to protect workers, mostly in areas of coal mining that can also be applied to workers in power plants. Early retirements have been used extensively, and retraining can be offered for those workers losing their jobs due to the closure. Given the impact on communities beyond the plant staff, the social safety net should also be expanded.

In Europe, as a part of the European Green Deal, a Just Transition Mechanism was established. It was included within the framework of cohesion policy, and therefore, this instrument is very much focused on reducing regional disparities and enhanced structural change in the less-favoured European regions while putting Europe on pace to reach climate neutrality. This idea of using the coal transition as an opportunity to narrow the economic development gap between the regions in which coal power plants are located and the richer regions can be adapted in Korea. The mechanism targets regions which suffer job losses and have to face an industrial transformation as a consequence of the energy transition. The Just Transition Mechanism has three pillars: the Just Transition Fund (JTF), a dedicated just transition scheme under InvestEU Programme and the public-sector loan facility.

The JTF management is shared with national, regional and local authorities and stakeholders. The member states must identify the regions which are expected to be most impacted by the clean energy transition and the JTF supports the economic reconversion of those regions. The main lines of support are investment in small and medium-sized enterprises, including the establishment of new companies. Areas of focus for the investment are R&D and innovation; environmental rehabilitation, preferentially to areas affected by closed infrastructure; and clean energy investment, including the conversion of the high-carbon infrastructure into low-emissions assets. There is a line for the workers impacted by the closure, through support to training and reskilling and assistance with job searches.

After the signing of the Paris Agreement, power generation companies began to reflect just transition considerations in their sustainable growth plans through having social dialogue with investors and labour unions. Enel, an Italian energy company, was one

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of the first power companies to actively embrace a just transition plan. Enel launched the Futur-e project in 2015 to promote an inclusive transformation of areas around the plant affected by its retirement. The purpose is to allow local stakeholders to change the use of existing infrastructure for regional economic growth and job creation. The project covered 23 power plants in Italy and 1 coal mine and 4 coal power plants in Spain. Since then, the scope has increased to 40 power plants around the world. The Futur-e project consists of the following four practical areas for workers:

- active job search for directly affected employees
- economic activities and employment in the region
- professional retraining of directly affected workers and maximising re-employment in Enel's new plants
- promoting the sustainability of the local society by minimising the financial impact on local community due to the retirement of the power plant.

A critical time has come for transforming the coal industry. It is important to strengthen the social and economic resilience of communities during the climate crisis. If left unchecked, they may leave behind harsh legacies: empty infrastructure, high unemployment rates and blighted mining lands. The key is to revive a local community with a wave of innovation in the manufacturing and energy sectors in a cleaner and more sustainable way. For example, the Marshall Plan for Middle America has been proposed in order to outline the vision for positioning the region as a powerhouse in the United States' transition to renewable energy and innovative technologies including EVs. Implementing the plan requires a significant amount of investment. It will need to modernise the electrical grids, promote regenerative agricultural practices and expand high-quality broadband networks, which will provide quality jobs while building the foundation for more prosperous economic development.

Nurture future-facing industries to offer decent jobs and worker protection

People-centred transition policies need to help coal-dependent regions pivot to a diversified, new clean energy economy where considerable job opportunities exist. Developing "future-facing industries" such as sustainable manufacturing, EV transportation, renewable energy and energy efficiency can offer high-quality jobs and work protection for the regions affected by the coal transition. Mining critical minerals from coal ash ponds for battery technology, turning fly ash from coal ash ponds into eco-bricks for green building materials, and creating paint primer from acid mine drainage can all be great examples. Redeveloping closed coal plants into low-emissions industrial parks provides another example. One of the biggest assets in coal communities are coal plants connected to significant transportation networks, extensive electricity grid networks and energy-generating assets which can be

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repurposed for cleaner energy. The highly skilled workforce who are already familiar with foundational technology, engineering and maintenance skills can also be a great asset in developing new businesses.

In order to nurture new industries and secure worker protection, collaborative actions by government, policy makers, workers and local communities is pivotal. Government should establish clear long-term energy transition strategies which will help stimulate investment in future-facing industries and reduce risks for private financing. They should align the direction of industrial and climate policies to promote innovation and job creation in new businesses such as smart technology and renewables. For instance, through RD&D efforts, Japan plans to make ammonia co-firing reach commercial scale by 2040, which can help retain existing workforces. Canada plans to use its existing assets in the oil and gas sector to develop its hydrogen sector, creating up to 350 000 quality jobs over the next 30 years.

When designing a transition, the focus should be given to the creation of decent jobs. The scheme can be assisted with tailored government support for communities and workers. For example, the European Green Deal is a comprehensive growth strategy covering all sectors of economy, designed to maximise the job potential of the transition. With EUR 55 billion over seven years, the Just Transition Mechanism in the European Union provides targeted support for the most affected regions by facilitating employment opportunities in new sectors and offering reskilling opportunities.

It is important to ensure that new jobs created by the transition are of good quality and accessible by people of all backgrounds. Policy makers need to analyse the volume and qualification of potential job opportunities in the pathway to net zero and plan reskilling schemes accordingly. For example, the United Kingdom has started a Green Jobs Taskforce to gather information on skills needed for the transition to a clean energy system. The education system, including flexible apprenticeships, skills boot camps and occupational traineeships, should place employers at the centre.

However, this should not be the responsibility of government alone. The coalition among businesses and private and public investors is also crucial. Business may come forward and invest in training a green workforce. The government and business sector can work closely to ensure their programmes meet workers' needs and reflect Korea's fast-changing labour market system.

Engage people as active participants

Gaining public support at the beginning of policy design is critical in accelerating the implementation of policy. Social engagement on sustainable goals and processes should be a goal, and social dialogue should be key to policy making and implementation at all levels. Consultations should be held continuously with information properly shared with all stakeholders. Workers and local communities should act as active participants, innovators, decision makers and beneficiaries of energy transition.

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In transitional governance, workers should be centred in social dialogue, industry-level collective bargaining and corporate-level joint decisions. Strong social consensus on the goal and implementation path can facilitate a smooth transition. Social dialogue which prioritises workers should be a part of the institutional framework for policy making and implementation at all stages. Properly informed and ongoing consultation should take place with the participation of all relevant stakeholders.

In addition to the traditional governance structure based on the three-party dialogue (labour, management and government), the role of people and local society should also be emphasised. It is also possible to consider forming an independent monitoring committee, which could have decision-making and implementation ability with deliberation and resolution procedures. It is also necessary to secure feedback between decarbonisation policies at industrial and regional levels and net zero transition strategies at a country level.

As trade unions are an important part of workers' participation, the role and capabilities of the unions are an important piece of the transition process. The key is to strengthen climate consciousness of union members and to assure their capacity of policy participation. In order to achieve this, it is important to represent the voice of "multiple levels", which can be obtained when transparent disclosure of information and relevant systems are combined. Transparent and straightforward communication can aid acceptance and build trust in the policy-making process. For example, the Swedish government identified groups that will be the most impacted and conducted targeted communication to understand their concerns before making any adjustments to its carbon pricing mechanism. Consistency of policies is also important to ensure that businesses, workers, investors and consumers can accept the changes.

Ensure equity, social inclusion and fairness

Some of the policies which are needed to accelerate the energy transitions are inherently regressive, as those receiving subsidies are more likely to be among the richer part of the society and the burdens in the form of taxes or higher costs bear a heavier toll on the poor segment of the society. In addition, the richer fraction of the society is better prepared to face extreme weather events than the most affected segment by the transition. People-centred transition should cut off the vicious cycle of inequality based on inclusion of various parties.

As all policies have distributional impacts, it requires a careful design to assure social inclusion and fairness. Public acceptability for the policy is likely to be higher with corresponding financial benefit to mitigate net impact on household. For example, the European Commission has proposed a social climate fund to help reduce the direct impact on vulnerable households by financing temporary direct income support. Furthermore, given that the coal-fired power sector is at the forefront in reducing emissions, a labour union's response to the closure of coal power plants can form a

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strategic model of their future response to whole climate crisis issue, which is why the union also needs an active stand in the transition.

From a global perspective, people in EMDEs are likely to be more affected by the coal transition than in advanced economies, and governments in these regions have less financial capacity to cushion the impacts on their people. This highlights the vital role of international support from advanced economies to ensure an equitable and fair transition at a global level. As discussed above, the JETP model that provides financing support for the transition in Indonesia, South Africa and Viet Nam provides an example of such efforts. An approach of this kind also needs to be part of Korea’s coal transition policy package.

Introduce incentives for deployment of clean alternatives

Although coal power plants provide a variety of system and flexibility services to the system, their main role lies in the provision of electricity. Replacing unabated coal-fired generation therefore requires clean sources of electricity to be scaled up rapidly. In all scenarios, solar PV and wind power dominate the replacement of unabated coal-fired electricity generation because of their low costs and widespread availability and because of the strong policy backing they enjoy.

Korea’s electricity demand growth slowed down substantially after 2012, following the pattern of mature economies. This means that additional clean energy sources will impact mostly on coal – and natural gas – power generation, as they are the marginal suppliers of electricity. This is an advantage for the coal transition in Korea. The second advantage is that costs of electricity from wind and solar PV have declined significantly in the last decade, making them generally more competitive than thermal fossil energy, at least in terms of the generated electricity.

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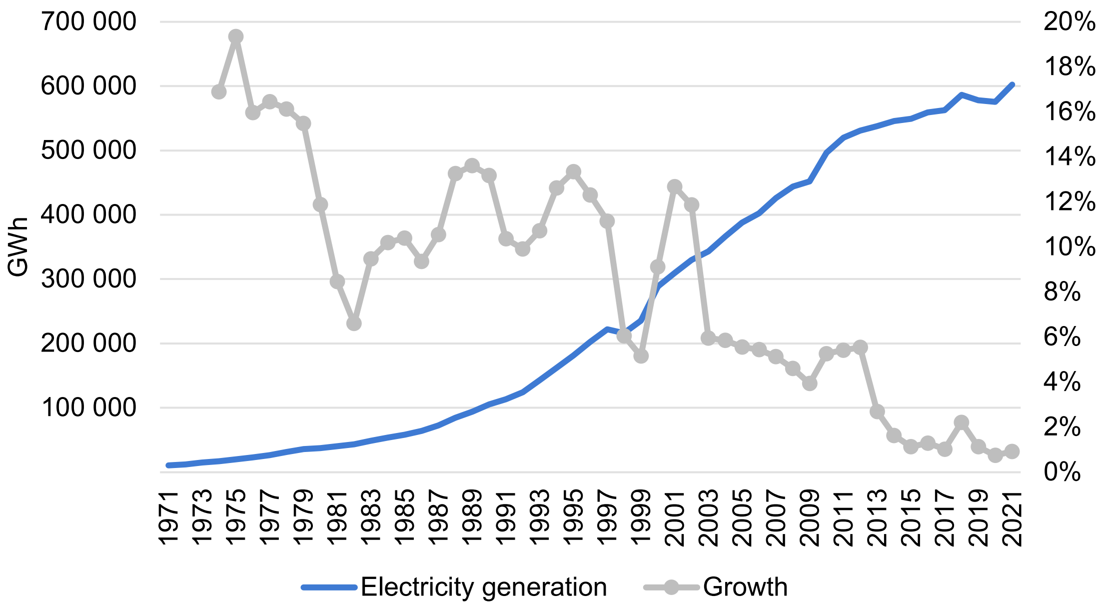
Total electricity generation and growth (right axis) in Korea



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Note: Figure displays in the right axis the average three-year growth in order to soften the weather-related or one-off circumstances.

The figure below plots wind and solar PV generation in Korea in this century. While the pace of growth was fast, variable renewables represented less than 5% of Korea's total electricity generation in 2021. This requires a significant scale-up in investment in clean sources of electricity. We estimate that the total investment required in the APS to transition away from unabated coal-fired power worldwide is about USD 6 trillion over the period to 2050, representing about half of the total investment needed to shift away from all unabated uses of coal.

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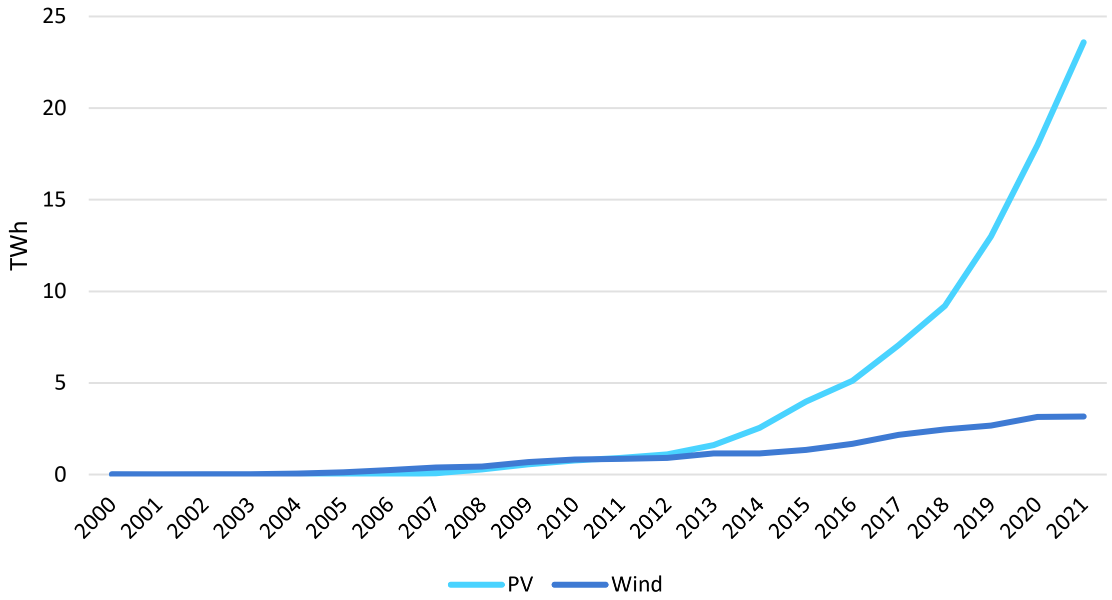
PV and wind power generation in Korea, 2000-2021



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The low costs of solar PV and wind mean that, while significant investment is needed in the APS to transition away from unabated coal, a significant portion of the necessary deployment can take place without adding to costs for electricity consumers. The average LCOE of utility-scale solar PV for projects commissioned in 2021 was below USD 50/MWh, which is seven times lower than in 2010. Regarding onshore wind, LCOE is around USD 33/MWh and off-shore wind is around USD 75/MWh, which is three or four times less than in 2010. The growing share of variable renewables requires a well-articulated strategy to integrate them into the power system. The figure below summarises the different phases in the integration of renewables into the grid based on the IEA's extensive analysis.

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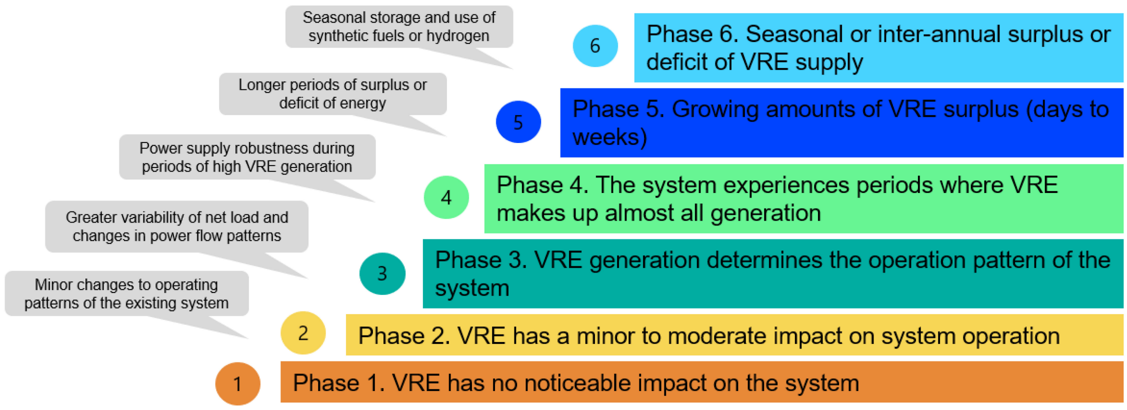
Characteristics and key transition challenges in different phases of integration of renewables



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Note: VRE = variable renewable energy.

Develop enabling infrastructure

Renewables generation capacity accounts for the main share of investment needed for the transition away from coal, with grids accounting for only a fraction of it. However, the proper consideration should be given to the development of transmission and distribution capacity, which has been – and continues to be – a major bottleneck in the energy transition. Grid planning needs to be considered at early stages of the transition. This requires taking care of economic provisions to make them happen, but also paying attention to the approval procedures. While the authorities need to guarantee strict compliance of the legal procedures and ensure the rights of citizens to participate in the approval process, they should also be mindful that grid constraints can slow down the transition significantly.

It is also important, although to a lesser extent, to provide economic incentives for ancillary service provision. Coal power plants – as well as nuclear, gas plants and others – have provided inertia of the rotating machines to provide frequency stability, reactive power injection to control voltage and the capacity of big synchronous machines to provide system strength against short-circuits as a by-product of their electricity generation. In a system dominated by variable sources connected to the grid, regulators need to guarantee that those services are provided.

Consider incentives to accelerate coal switching

The acceleration of renewable and/or other low-emissions sources of electricity is a non-negotiable condition for the transition. The competitiveness of wind and solar PV has increased notably in the last decade. But still coal power plants are generally a low-cost source of electricity generation in many places. Decisions in the markets are based

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on economic signals and economic incentives, and removing a low-cost source of generation is not an easy thing to implement. In many markets, a carbon price has supported the reduction of coal generation and a switch to lower-emissions sources.

The Asian Development Bank (ADB) launched a scheme called the Energy Transition Mechanism (ETM) to refinance coal plants in order to allow an earlier depreciation and give an incentive for retirement to the owner. The scheme has been recently tried in Indonesia, and targets the Philippines and possibly Viet Nam. The ETM has two funding vehicles. The first one focuses on early retirement or accelerating the transition of coal power plants, and the second vehicle is intended to facilitate investment in the electricity grid, clean energy and storage infrastructure. Whereas there are other economic incentives to accelerate coal switching, it is important that the framework is well thought out, avoiding loopholes and giving a predictable and stable signal for market players to make their decisions. While making the transition from coal to clean energy, it is also imperative to provide secure and affordable electricity.

Ensure security and affordability of the electricity system

To ensure electricity security throughout the transition away from unabated coal, it is critical to replace the system services as well as the electricity output. Coal-fired power plants contribute to the adequacy of power systems by supporting the ability of available electricity supply to meet demand in all hours of a year. They also contribute to system flexibility by adjusting output in many markets in minutes or hours to match supply and demand. In addition, they support grid stability by providing inertia continuously when operating their large spinning machines. The coal transition therefore raises an important question about ways to ensure the security of the electricity system, which should not be taken for granted. Korea’s latest energy policy direction also puts an emphasis on ensuring energy security while achieving net zero targets.

The coal transition also needs to take into consideration the affordability of electricity supply given that alternatives to coal require a significant upfront investment. However, the IEA analysis suggests that the transition away from unabated coal-fired power can be achieved without significant increases to costs for consumers. A huge amount of investment is indeed needed to replace coal-fired generation, the system services from coal and the grid construction needed to support the expansion of alternative sources. However, these are offset over time by lower overall system costs, because of large savings on fuel and electricity bills. A major effort to implement energy efficiency measures also helps to moderate system costs by making the most of existing and new power plants and grid infrastructure. In the APS, total electricity system costs per unit decline from 2021 to 2050 by a few percentage points in advanced economies and about 10% in EMDEs. Faster transitions in the Net Zero Emissions by 2050 (NZE)

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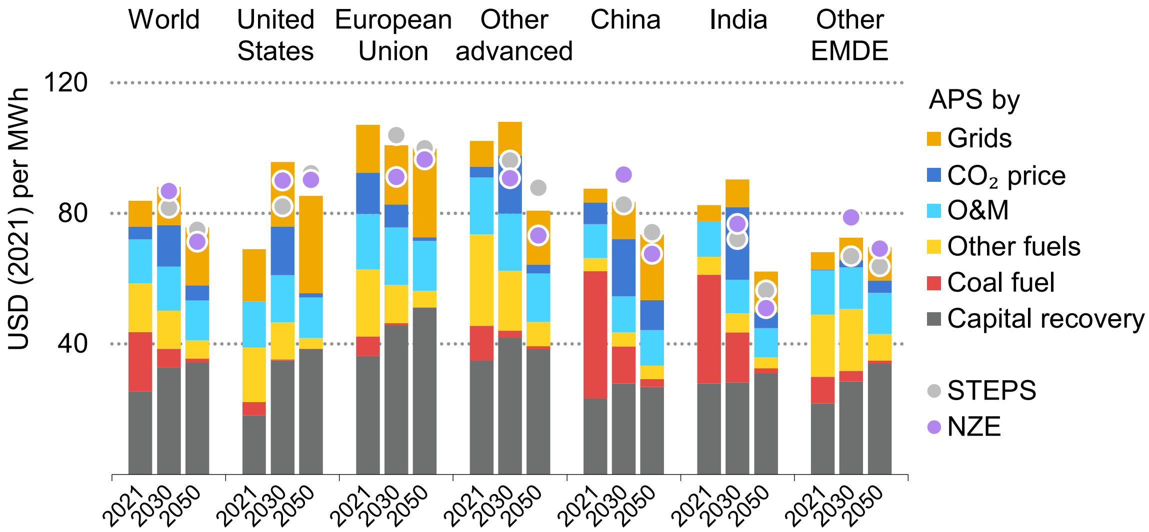
Scenario would cost USD 5/MWh more than the APS to 2030, but deliver the least expensive electricity in EMDEs by 2050.

Announced Pledges Scenario by countries



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Notes: O&M = operation and maintenance; STEPS = Stated Policies Scenario.

Ensure the security of power supply is guaranteed

The nature of electricity requires that supply and demand are continuously balanced throughout the power system. Any imbalance can give rise to the collapse of the grid, and the losses caused by blackouts can be on the order of billions of dollars. Ensuring the security of electricity supply is therefore a major issue when dealing with transitioning away from unabated coal power generation. In the case of oil and gas, storage can be built to give a buffer to deal with supply disruptions. In the case of coal, building storage is very cheap, making coal stored in the power plants among the lowest-cost form of energy storage.

As the global contribution of unabated coal-fired capacity to system adequacy declines, a broad suite of technologies will be required to provide flexibility and system services to the electricity system. Demand response becomes increasingly important in all scenarios to provide system flexibility and to reduce peak demands, thereby limiting system adequacy needs. Solar PV and wind, with variable output dependent on weather patterns, contribute less to replacing coal in terms of system adequacy (as well as other system services) than to replacing electricity output from coal. Battery storage, often paired with solar PV and wind, is able to make a significant contribution to all three of the main system services. Contributions from nuclear power to electricity security are another reason for its gaining momentum. Interconnected grid networks can also play a major role.

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The relative importance of other dispatchable technologies to replace coal varies between advanced economies and EMDEs. Advanced economies rely more on blending hydrogen in gas-fired power plants, particularly in Japan, the United States and the European Union, while EMDEs blend more ammonia in coal plants and develop more hydropower and other renewable sources.

The energy crisis provoked by Russia's invasion of Ukraine is a bitter reminder that the security of supply should not be taken for granted. A number of coal power plants in Europe which were scheduled to be closed continued their operation to guarantee reliable electricity supply. Some plants that were placed in strategic reserves have been returned to operation. Although the circumstances around the war in Ukraine are unique, it highlights the importance of mobilising capital to deploy alternative technologies that provide system services.

The province of Ontario, in Canada, was the first jurisdiction to move towards a coal phase-down. In 2003, the government of Ontario decided that coal plants in its territory would close by 2007. But two obstacles hampered the closure by that year: the inability to build the generation capacity to replace coal plants and the technical difficulties to upgrade the grid. Considering those hurdles, the phase-down was brought forward two years, to 2009. After a thorough consideration of the circumstances, a law was passed to be established in 2014 as the end of coal power generation. Ontario has a strong reliance on hydro and nuclear, two dispatchable sources.

On 2 November 2022, Germany's cabinet also approved a draft law to phase down coal-fired power plants in the western coal mining and heavy industry state North Rhine-Westphalia by 2030 instead of 2038, the previously agreed date in German coal-exit law. The use of lignite-fired power plants temporarily increased in Germany in order to secure the supply, and the German government has until 2026 to determine whether or not to keep RWE's final 3.6 GW of combined lignite-fired plants. RWE also plans to construct 3 GW of gas-fired power plant capacity that is prepared to run on hydrogen in order to lessen the impact on the area. In addition, the government plans to install 38 GW of solar capacity, 19 GW of onshore wind capacity, and 3.5 GW of offshore wind capacity between 2023 and 2025 in order to assure the supply.

Repurposing coal-fired power plants – reducing operations to focus on system adequacy or flexibility services – is also an option to cut emissions while ensuring system adequacy. It means that an unabated coal plant produces less electricity over a certain period, but remains available at times when the system needs are highest, contributing to the reliability of power systems, and is available to ramp up and down to meet flexibility needs. Repurposing coal plants for flexibility is widely adopted in the APS because it enables the existing coal fleet to support and facilitate the integration of increasing shares of variable renewables. In the NZE Scenario, unabated coal is repurposed more quickly, reducing the global average capacity factor to below 40% by 2030.

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Targeted investments can further enhance flexibility: for example, retrofitting alternative boilers can lower a coal plant's stable minimum load, while upgrades to control systems and plant components can increase ramping speeds and allow plants to be operated at levels higher than their rated capacity for brief periods of time. Other retrofit options, such as coupling the plant with battery energy storage, can further boost flexibility in terms of the grid. They can at the same time allow the plant to provide ancillary services such as fast frequency response or spinning reserves without burning additional fuel. Heat storage can be added to make coal co-generation plants more flexible.

Repurposing coal plants for flexibility has several appealing characteristics for coal plant owners, the surrounding communities, broader electricity consumers and policy makers. For coal plant owners, the financial impacts of repurposing for flexibility are modest in the short term, with limited investment requirements and progressive changes to operations as renewables scale up. For surrounding communities, employment remains broadly unchanged. For electricity consumers, repurposing coal plants helps maintain affordability throughout clean energy transitions by making good use of existing assets. For policy makers, repurposing coal plants for flexibility also reduces the potential need for other investments in fossil fuel power plants that could be inconsistent with clean energy transitions.

While existing dispatchable generators are among the least expensive ways of providing capacity and flexibility services, their owners may be reluctant to provide these services because they face significant uncertainties regarding their future operations. As a result, there are risks that a plant could be retired from the system before the need arises for system services that these plants could provide. Governments can help manage such risks with instruments that change the incentives of plant owners.

The principal way to do this is through a restructuring of the payments received for various services. Providing an adequate level of payment for services such as flexibility or capacity through the creation or improvement of remuneration schemes for capacity and ancillary services could incentivise a more flexible operating profile for many plants while also covering the additional capital costs they incur from reduced operating hours. The IEA's estimate of the investment needed to cover the increased capital recovery costs related to the reduced operating hours in the APS compared with the STEPS is around USD 8/MWh on average. The adoption of carbon pricing would further incentivise coal-fired generation plant operators to consider shifting to the provision of capacity and flexibility services.

In systems where markets are not the main method for recovering fixed costs for generators, different financing mechanisms might need to be devised. In this case, reverse auction mechanisms might prove an efficient way forward. Such auctions would in effect require different assets to compete for the level of support necessary for them to modify their operating pattern. In some cases, power purchase agreements

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and other contractual obligations may prove to be an impediment to coal-fired plants making a desired move to the provision of adequacy and flexibility services, and would need to be renegotiated. One option might be to buy them out with the support of climate financing.

Consider conversion of coal power plants to low-emissions assets

Coal power plants are complex facilities, including a variety of assets: coal storage, mills, conveyor belts to transport material, the boiler – the heart of the plant – and the balance of the plant, with the water/steam system as well as the turbine/generator system. An element of particular interest is the grid connection. As seen in the former section, the unavailability of grid connection can be a bottleneck that limits the expansion of low-emissions electricity sources, and therefore, delays the transition or puts the security of supply at risk. Conversion of coal plants into low-emissions assets can be a quadruple-win proposition. On the one hand, it allows the owner to retain part of the value of the assets. It also allows the community to retain jobs and tax revenues. In addition, the bottleneck represented by the grid connection can be avoided. Moreover, the approval process is usually more friendly and faster as the plant already has the ‘’social licence’’ to operate.

In addition, converting coal plants can support the security of the electricity system during the transition. For example, coal plants retrofitted to co-fire low-emissions fuels can also provide peak capacity and load balancing services.

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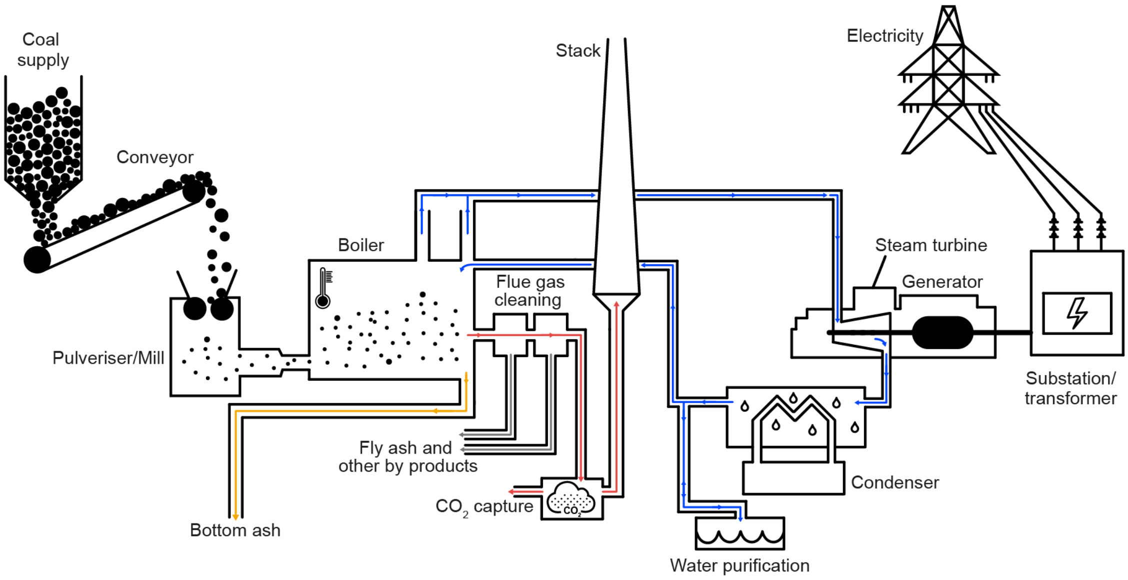
Consider retrofitting coal power plants with CCUS

Coal power plant retrofitted with post-combustion CCUS



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Coal plants retrofitted with CCUS can support power system transitions in several ways. As well as supplying low-emissions power from existing coal assets, they can provide stability services such as inertia, ramping flexibility and firm capacity at peak times. At the same time, they use transmission infrastructure that is already in place, and allow current plants to be operated so that investments can be recouped while reducing their carbon footprint. As Korea looks to get to net zero power generation by 2050, CCUS retrofits could provide an attractive path to do this.

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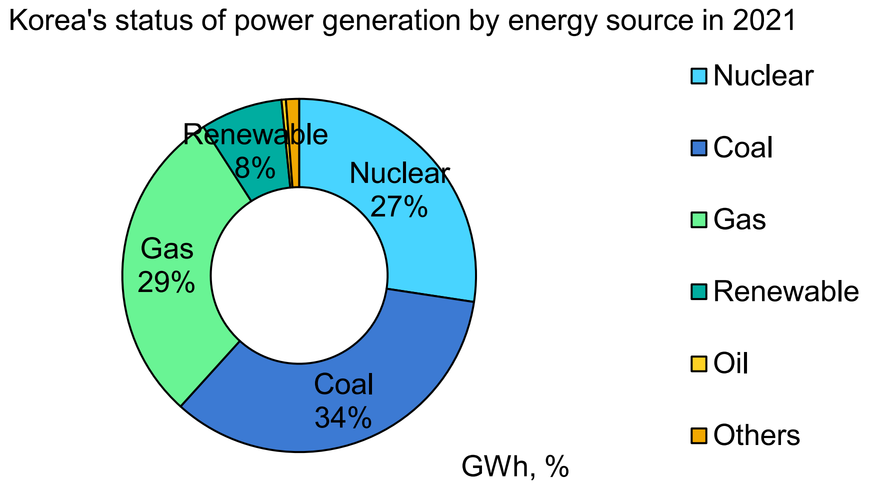
Power generation by energy source in Korea, 2021



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In 2021, the Korean government approved a country-level roadmap for 2050 carbon neutrality which included the phase-down of coal-fired power generation by 2050. In addition, Korea Electric Power Corporation (KEPCO) has committed to abandoning coal by 2050. In 2021, 34.3% of power generation in Korea came from coal. The option to retrofit with CCUS can enable these assets to operate in a way that is also consistent with climate goals. In addition to directly addressing emissions from existing and new fossil-based power assets, CCUS-equipped power plants can also enable the integration of growing shares of renewables as thermal plants are expected to be an important provider of flexibility (to manage both short-term and seasonal variations) to future power systems.

CCUS retrofits can be applied to the whole facility or to part of a plant. The simplest form of retrofit involves rerouting the flue gas from a unit boiler through a CO_2 capture facility. More extensive modifications include conversion of the boiler to oxy-fuel combustion or the construction of an external heat source, such as a natural gas-fired co-generation plant. The reduction in net electricity output of a coal-fired power plant unit retrofitted with CO_2 capture is around 20-30%.

CO_2 capture has been retrofitted onto coal-fired power plants at commercial scale in two places – the Petra Nova project in Texas, in the United States, and the Boundary Dam project in Saskatchewan, Canada. There is also an operating demonstration-scale project – Guohua Jinjie Power Plant in Shaanxi, China. The Boundary Dam CCUS project has been operating since 2014 and has a capture capacity of around 1 Mt CO_2 per year. The Petra Nova facility, which operated from December 2016 to May 2020, had the largest post-combustion carbon capture system (1.4 Mt CO_2 annually) installed on a coal-fired power plant. Captured CO_2 was used for enhanced oil recovery, but capture operations were suspended in May 2020 as a result of the low

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oil prices associated with the economic impact of the Covid-19 pandemic. The capture facility at the Guohua Jinjie Power Plant is demonstration scale (0.15 Mt CO_2 annually); construction was completed in January 2021.

In May 2013, Korea Midland Power installed a 10 MW CO_2 capture facility at the Boryeong power plant, which is the largest carbon capture and utilisation facility made with domestic technology. The capture plant is pilot scale and uses technology developed by the Korea Electric Power Company Research Institute (KEPRI). That power facility captures about 35 000 tonnes of CO_2, which is used in a greenhouse. Furthermore, KEPRI is currently conducting R&D to expand its capacity to 150 MW based on technical data obtained from pilot plant operation.

Despite limited progress in adding CCUS to coal-fired power plants, there are signs of growing interest with plans for around 15 new projects in development around the world. This momentum is driven by net zero emissions goals and an improved investment environment, particularly in the United States, where tax credits provide up to USD 85 per tonne of CO_2 stored. If all planned projects proceed, the potential CO_2 capture capacity from the coal power plant fleet would be around 28 Mt CO_2 in 2030. All but one of these projects are retrofits of existing coal-fired power plants, of which almost three-quarters are located in China and the United States.

In 2021, the Korean government announced that it intends to invest KRW 1.5 trillion (Korean won)[2] by 2030 to develop CCUS technologies. The bulk of these funds will be used to develop CO_2 storage technologies and to assess CO_2 storage resources. Developing CO_2 storage underpins the development and deployment of CO_2 capture facilities. Regarding capture technology, it will secure commercial-scale capture technology by 2024 with establishing test beds for major industries including steel, cement, hydrogen and LNG power generation. By using Donghae Gas Field, it will develop storage technology to store 12 Mt CO_2 for three years (400 000 tonnes per year). Furthermore, the utilisation technology will be developed for early commercialisation through intensive R&D investment. Korea aims to secure economical and safe storage of 100 Mt by exploring and drilling the continental shelf by 2023 and strives to secure additional storage by 2030.

Consider other conversions

As stated above, a consideration to repurpose coal plants to work fewer hours and provide services such as seasonal flexibility or ancillary services is a first approach. The retrofit with CCUS can be an interesting approach in certain circumstances. In case there is no suitable storage or for any other reasons CCUS retrofit is not feasible, there

[2] Exchange rate: 1 Korean won (KRW) = USD 0.00076 (as of 08 March 2023).

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are other possibilities of conversion to low-emissions assets, which allows the use of assets and retention of some jobs and economic activity in the community.

Carnot battery

A Carnot battery is a power storage technology consisting of a thermal power cycle that drives a heat pump to store power in a high-temperature thermal energy form and converts thermal energy into power. It can cover renewable energy's possible instability due to variable climate. In addition, following a series of fire accidents at battery energy storage sites, the need for non-toxic and non-explosive large-capacity energy storage devices has come to receive more recognition. With the large-scale addition of renewable energy, large-capacity energy storage system will also be needed.

Carnot batteries are both an economical and efficient option since they may have 50-70% round-trip efficiency, which is superior to power-to-grid technology; in terms of levelised cost of storage, compared with lithium-ion batteries costing EUR 0.25/kWh to EUR 0.34/kWh, Carnot batteries are EUR 0.1/kWh to EUR 0.15/kWh. They are considered an excellent choice for retrofits in that they can reuse coal-fired plant facilities including water treatment devices, cooling devices and power distribution network facilities. By having the infrastructure to store electricity in high-temperature thermal form, as a steam power generation, it can save additional construction costs.

Since Carnot battery technology converts and stores power into heat and drives a power generation cycle, it is likely to grow into a large-capacity energy storage technology. Its biggest advantage is that it can provide both electricity and heat at the same time. This is especially important in the industry because stored heat can be directly used in many industrial processes.

The key to the Carnot battery is storage temperature. Detailed research is needed for commercialisation, as a high-temperature heat pump used to raise heat temperature requires further development and has scope to improve efficiency, operating speed and energy density.

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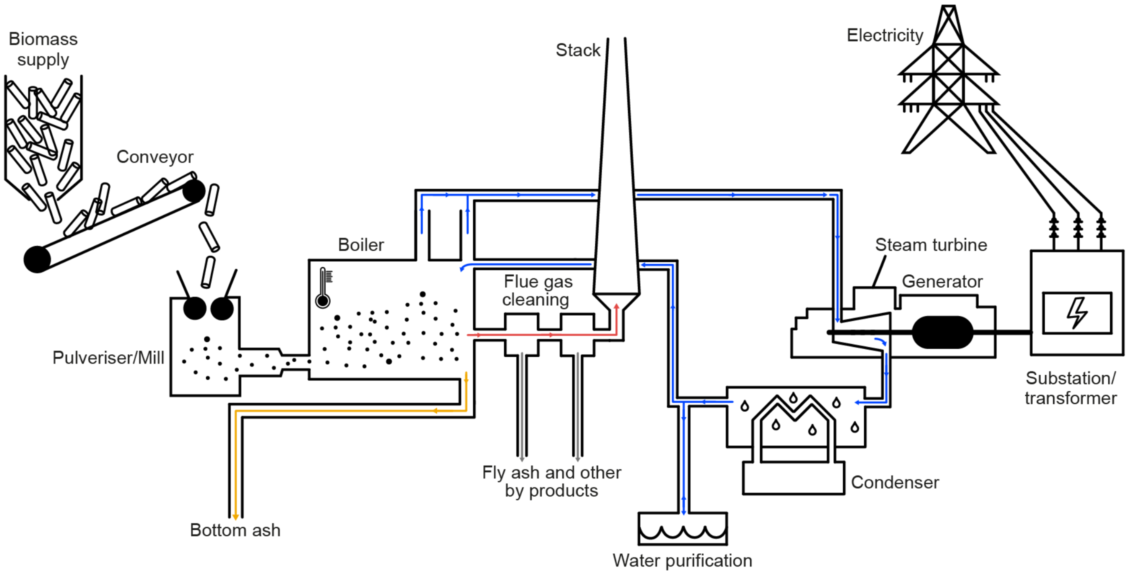
Convert to low-emissions fuels

Coal power plant converted into a biomass power plant



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Coal power plants can be converted to use other low-emissions fuels (biomass, ammonia and thermal). Since Korea introduced the Renewable Portfolio Standard (RPS) in 2012, a system that mandates power generation business operators (suppliers) of 500 MW_e or more to supply a certain percentage of total power generation as renewable energy, various biomass resources have been used to meet the RPS targets. For instance, SGC Energy made 100% conversion of a 60 MW_e coal power plant to a biomass power plant in October 2021. With this conversion, SGC Energy could reduce carbon emissions by 400 000 tonnes per year. A high share of biomass co-firing can reduce the use of fossil fuels at power plants. Furthermore, carbon-negative electricity can be produced by capturing by-product CO_2 from a biomass conversion plant if the biomass is sustainably produced.

Fully converting a coal power plant to use 100% biomass can be a solution for negative emissions when combined with CCUS. Since 2013, four out of six units of the Drax power plant (4 GW), which was the United Kingdom's biggest coal plant and the second-largest in Europe, have been converted to run on biomass. The two remaining units will be converted in the coming years. This process can be challenging as wood has a lower energy density than coal. The mass of biomass fuel needed is approximately double that of coal. If, as in the case of Drax, wood pellets are imported, the complex logistics of importing, transporting and storing the pellets need to be managed. Agricultural and forestry residues that otherwise would be burned without any benefit offer a pragmatic solution but given the size of a typical coal plant, the availability of biomass at the scale required may be a problem. Furthermore, emissions

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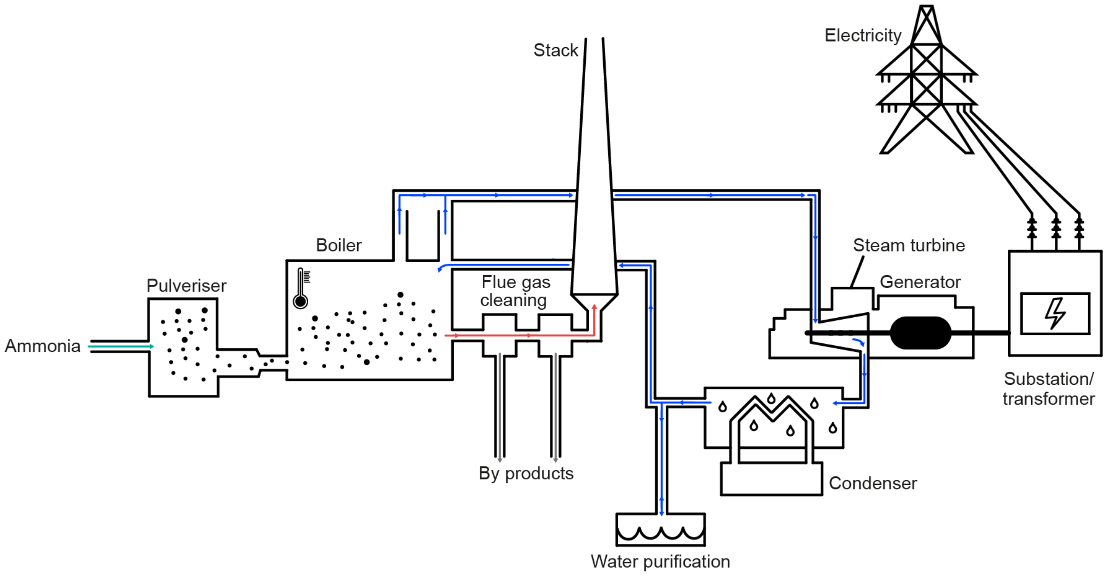
along the supply chain including collection, processing and transport and indirect land-use change need to be addressed.

Coal power plant modified to use ammonia as fuel



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Ammonia is also gaining interest as a low-emissions fuel for stable long-term storage. Japan has led efforts to co-fire coal with ammonia in existing plants, with demonstrations of less than 10% ammonia co-firing. There are now plans for 20% ammonia co-firing in Japan in 2023 and in Korea and India in the next couple of years. In parallel, China successfully demonstrated 35% ammonia co-firing in 2022. Technical development and demonstration of 50% or more co-firing in Japan is expected by 2028, with plans for single-fuel firing to start in the 2040s. In order to reduce emissions via ammonia co-firing, ammonia production needs to have low greenhouse gas emissions on a life-cycle basis.

The advantage of ammonia is that power companies can use existing plants without major modifications, and technology for production, transport and storage are already established.

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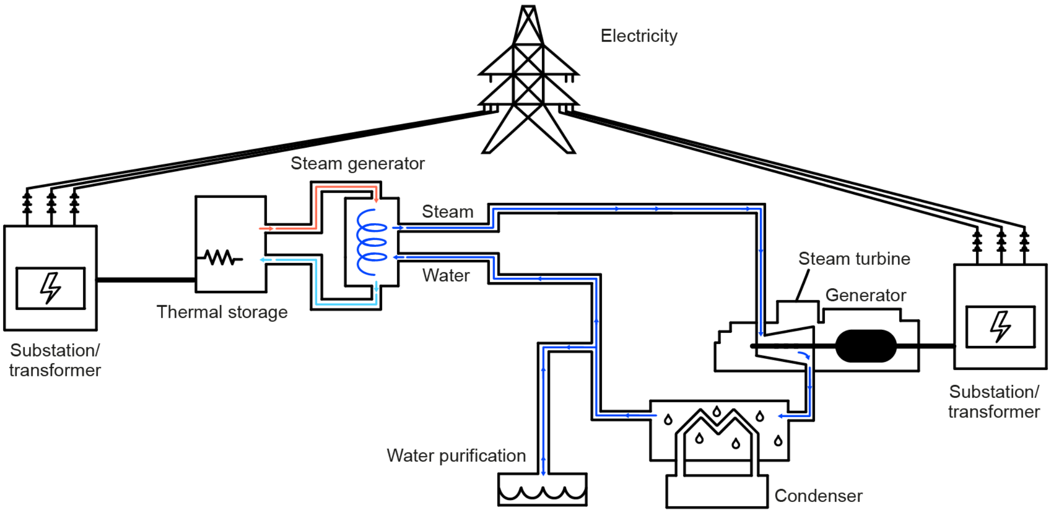
Coal power plant reutilised as thermal energy storage



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With the increasing share of renewable energy, the need for thermal energy storage may increase. When electricity produced from wind and solar PV is abundant, it can be stored in thermal storage. Those stored energy then can be transferred to water in the steam generator when there is a shortage in electricity generation. In that way, it can increase the overall efficiency of the energy system and ensure the security of energy supply, since it offers high energy density. Replacing coal plants with thermal energy storage can reduce the negative impact on the local community and reuse existing facilities. Such transformation is elementary and economically reasonable.

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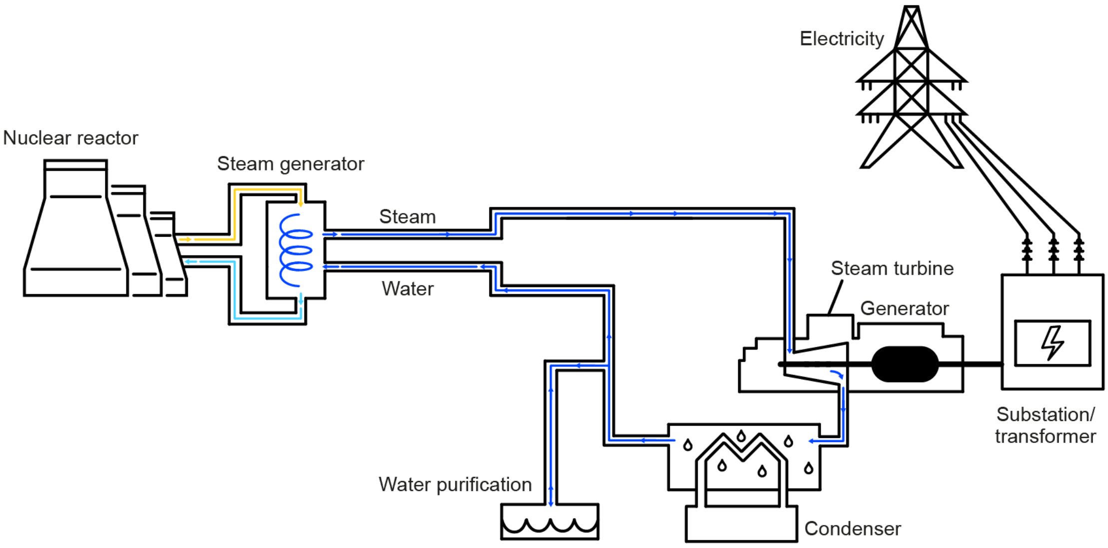
Small modular reactors

Coal power plant reutilised as a small modular reactor



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There is a possibility to convert coal-fired plants to nuclear power plants in countries where this is socially and politically acceptable. The most promising nuclear technology for converting coal plants is small modular reactors (SMRs). An SMR is an advanced nuclear reactor with power capacity typically up to 300 MW per unit, which takes about one-third of what traditional nuclear power reactors generate, and is able to produce low-carbon electricity.

An advantage of SMR technology is that they can be located in places not suitable for larger nuclear plants as they have smaller footprint. Modular means that they should be quicker to manufacture than the current plants design for a specific location. Modularity in principle would mean cost reduction. Additional advantages may come from simpler conceptual safety and less frequent refuelling. SMRs would also be large enough to serve a role to provide baseload, dispatchable power with a high-capacity factor, especially if coupled with thermal storage. And building an SMR would not require major changes to the electric grid.

Investment in coal power plants conversion

The nature of investment in CCUS retrofits and low-emissions co-firing is very different, especially from an investor perspective. The cost of capital and the level of upfront investment vary considerably from one technology to another. Their supply chains vary, as do their suitability in different circumstances.

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Investments in CCUS retrofits involve specific risks. The higher level of energy consumption required to capture and store CO_2 can increase fuel use per unit of output by around 20-30%, making fuel costs an important issue. The capital-intensive nature of CCUS technology also means that financial outcomes for investors largely depend on the level of capital expenditure required, cost of capital and future capacity utilisation rates. CO_2 prices are perhaps the most important tool for encouraging CCUS retrofits. Prices higher than USD 100/tonne of CO_2 would be required in the APS to incentivise CCUS retrofits in Japan, Korea, Russia, Europe and North America. Emissions reduction purchase agreements involving certificates of CO_2 reductions are another option.

Co-firing with low-emissions fuels requires less upfront capital than CCUS retrofits but involves much higher fuel costs than coal combustion alone, meaning that the availability of sustainable finance may depend to a large extent on price, volatility and contract terms for the fuel used for co-firing rather than on the capital structure of the project. A further factor is that the level of emissions reductions depends on co-firing levels: these can vary considerably depending on relative costs and market conditions, which complicates the case for financial interventions that are based on the monetisation of avoided emissions. Co-firing may be best suited to mid-merit or peaking operations in electricity systems, especially those with high shares of renewables, that have frameworks in place that value the contribution of plants delivering low-emissions electricity on demand.

Countries that support co-firing initiatives, such as Korea, do not generally produce low-emissions ammonia domestically and so would need to sign long-term procurement contracts with foreign suppliers. Their ability to do this depends on the development of low-emissions hydrogen and ammonia supply chains. Current ammonia production comes from fossil fuels, and only around 10% of the total demand is shipped. However, there is likely to be plenty of competition for low-emissions ammonia.

Early retirement of coal power plants

Another option to cut emissions from unabated coal-fired power plants is to retire them before they reach the end of their technical lifetimes, and potentially convert the site to another use. While the technical lifetime of a coal plant is generally 40-50 years, its economic lifetime is generally 20-30 years, and this is the timescale over which capital invested is usually recovered. As coal plants age, asset owners often face decisions about whether to invest in refurbishments, and these will invariably depend on the financial prospects for the plant. These decision-making points offer major opportunities for policy makers and financial institutions to exert influence and facilitate early retirements.

In many advanced economies, where coal plants tend to be older, early retirement is often likely to be the pragmatic solution for plants as they near the end of their economic

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or technical lifetimes. Since 2010, coal power plant retirements have averaged around 25 GW each year, largely as a result of the closure of ageing plants in Europe and the United States. Declining competitiveness, increased regulation in the form of pollution limits and carbon taxes, and increased competition from renewable energy sources and natural gas have all played a part in bringing about these early retirements.

There is no single blueprint for managing the retirement of coal-fired generation because a great deal inevitably depends on local circumstances and priorities. The possibility of converting coal-fired power plants to other uses should be assessed before any decision to close. But when it is required, a number of options may be available. The ADB is piloting a new market-based mechanism to accelerate the transition away from unabated coal in the Asia Pacific region. The ETM proposes to pool low-cost capital from various concessional and private sources to incentivise the early retirement or to repurpose coal-fired power plants. The ETM has a carbon reduction facility tasked with refinancing or purchasing coal assets. The potential monetisation of the CO_2 savings resulting from the accelerated closing of a plant through carbon credits may supplement the revenue stream.

Carbon pricing incentivises the retirement of coal assets by taxing or setting a cap on emissions, thus making coal-fired generation more expensive. One example is the European Union Emissions Trading System, which requires operators of emissions-intensive activities to purchase emission allowances for each tonne of CO_2 released. At the international level, several carbon crediting schemes allow the monetisation of emissions reductions that result from lower emitting technologies, thanks to dedicated fuel switching carbon crediting baselines methodologies in the UNFCCC Clean Development Mechanism, Verra or Gold Standard.

Some countries are studying and piloting the concept of using auction-based compensation mechanisms that allocate funding to plant owners in exchange for early retirement. The objective is to provide funding for the unrecovered capital remaining in the plant to the owner. The competitive nature of the auction mechanism aims to reveal the lowest amount of compensation that plant owners will accept in exchange for early retirement. For example, Germany established an auction mechanism where a shutdown premium would be awarded to plant operators that agree to take some capacity offline. To date five auctions have taken place between September 2020 and March 2022 and 34 coal units have been committed to retirement, accounting for almost 10 GW of capacity.

There are other mechanisms such as customer-backed securitisation, sustainability linked bonds, accelerated depreciation, and concessional debt or refinancing. It is important to be aware of these and to mitigate potential adverse outcomes.

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General annex

Abbreviations and acronyms

ADB	Asian Development Bank
APS	Announced Pledges Scenario
BPLE	Basic Plan for Long-Term Electricity Supply and Demand
CAAGR	compound average annual growth rate
CCUS	carbon capture, utilisation and storage
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
COP26	26th Conference of the Parties (UNFCCC)
CTEI	Coal Transition Exposure Index
EMDEs	emerging markets and developing economies
ESS	energy storage system
ETM	Energy Transition Mechanism
EU	European Union
EV	electric vehicle
G7	Group of Seven
G20	Group of 20
GDP	gross domestic product
GHG	greenhouse gas
IEA	International Energy Agency
JETP	Just Energy Transition Partnership
JTF	Just Transition Fund
KEPCO	Korea Electric Power Corporation
KRW	Korean won
LCOE	levelised cost of electricity
LNG	liqueified natural gas
NDC	nationally determined contribution
NZE	Net Zero Emissions by 2050 Scenario
OECD	Organisation for Economic Co-operation and Development
$PM_{2.5}$	fine particulate matter
PPCA	Powering Past Coal Alliance
PPP	purchasing power parity
PSH	pumped storage hydropower
PV	photovoltaics
R&D	research and development
RD&D	research, development and demonstration
RPS	Renewable Portfolio Standard
SMR	small modular reactor
STEPS	Stated Policies Scenario
UNFCCC	United Nations Framework Convention on Climate Change

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VRE	variable renewable energy
WEO	World Energy Outlook

Units of measurement

EJ	exajoule
g	gramme
GJ	gigajoule
Gt	gigatonnes
GW	gigawatt
GWh	gigawatt-hour
kV	kilovolt
MBtu	million British thermal units
Mt	million tonnes
Mtce	million tonnes of coal equivalent
MJ	megajoules
MW	megawatt
MW_e	megawatt electrical
MWh	megawatt-hour
Tce	tonne of coal equivalent
TWh	terawatt-hour

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