STATE OF GLOBAL COAL POWER 2023

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Summary

2023 is the year of the first Global Stocktake, a mechanism to review and track global progress towards the Paris Agreement goals and identify opportunities to enhance ambition. In addition to assessing the overall emissions outcomes and reduction potential embedded in current pledges and policies, the stocktaking of specific sectors is also critical, especially to identify concrete actions for the next steps. This brief focuses on the stocktaking of the global coal power sector. Progress toward a 1.5°C-aligned coal transition in the power sector is insufficient globally and uneven across regions. With recent conflicting trends in rapid renewable deployment and continued coal builds, our analysis finds that many countries are struggling with various near-term challenges and competing priorities at the early- to mid-stage of the transition. In this critical decade, we need to reduce global unabated coal power generation by a quarter in 2025 and by 60% in 2030, where joint efforts are needed to address key technical, financial, and institutional challenges hindering the transition.

An accelerated coal-to-clean power transition is one of the most important near-term mitigation strategies to deliver large emissions reductions quickly (IPCC, 2022). Recent years have observed positive progress regarding coal retirements and cancellations, new commitments to no new coal and coal phaseout, new financing mechanisms to support a just transition, and accelerated renewable deployment. However, other national or local priorities, including energy security and economic recovery from the global pandemic, have added tremendous near-term challenges and uncertainties to the transition. A key question remains: as of 2023, are we on track to achieve a rapid and just coal transition in the power sector that is in line with limiting global temperature change to 1.5°C?

Ultimately, answering this question—and establishing a basis for accelerating action in different national circumstances—depends on understanding the diverse driving factors leading to total unabated coal power generation. Total coal power capacity (both in operation and under development) is one of the most important metrics to assess progress made in the sector. In addition, the overall level of generation from this capacity—which can vary—can be critical as emerging regional and national factors may shift the focus as the expected role of coal plants in the power system starts to change to grid stabilization, rather than maximum generation, in key countries. Conflicting trends in simultaneous coal and renewables deployment have also emerged recently, illustrating the complexity of power system transitions when new technologies like wind and solar have become substantial contributors—yet the entire system, including its design, infrastructure, operation, and institutions, has not advanced accordingly to support an increasing share of intermittent renewable generation with dispatchable technologies like coal are still seen as necessary.

This report summarizes the state of global coal power in 2023 with an assessment of its driving factors. Specifically, we conduct a comprehensive data and policy review, track changes in coal power capacity and generation since the Paris Agreement, estimate the emissions impact of operating and new coal plants based on the latest pipeline data, and then quantify the gap to 1.5°C- and 2°C-aligned pathways by combining bottom-up data and a global integrated assessment model (GCAM).

Several key findings emerge from the analysis:

- Operating coal power capacity has reached 2,095 GW globally in 2023, growing by 9% since the Paris Agreement in 2015. Overall, 280 GW of old coal plants retired but 458 GW of new plants added, for a net addition of 178 GW.
- Compared to 2015, the expected growth of coal capacity has been dramatically reduced due to a large number of cancellations: projects under development have declined by 937 GW during this period.
- Nevertheless, new coal plants are still being built (204 GW) and planned (353 GW) across 38 countries today, which may further increase total coal capacity in the next few years.
- The share of total electricity generation globally that is produced by coal continues to decrease. Although global electricity demand has increased by 21% since 2015, coal power generation has only grown by 11%. In many key regions, coal plants are utilized at lower capacity and are expected to have a different role in the evolving power system.

- Since 2016, important policy progress has been made regarding setting goals for coal phaseout and finance. 30 national and 48 subnational governments committed to a coal phaseout. The G7 and China announced a stop to financing overseas coal projects, and several new international financial mechanisms were launched to support clean energy transitions. 14 countries removed all new projects in the pipeline compared to 2016, and 6 countries have made no new coal commitments to reduce current projects in the pipeline.
- Since 2016, the expected 2030 emissions from coal power generation have decreased by 2.9 $GtCO_2$ due to project retirements and cancellations; however, coal power emissions are still growing globally, albeit at a slower rate. Coal power emissions in 2030 should decrease by roughly 3.9 $GtCO_2$ to stay in line with a 2°C pathway and by 5.8 $GtCO_2$ with a 1.5°C pathway.
- To close the emissions gap and stay on a 1.5°C-aligned pathway, global coal power generation needs to decline from today by roughly a quarter in 2025 and by nearly 60% in 2030. This can be achieved through a combination of canceling new coal projects under development, closing down older and inefficient coal plants, and/or lowering the utilization of remaining coal fleets, alongside tripling the total installed renewable capacity and substantially adding new storage capacity by 2030, which needs to increase by more than twenty times current capacity levels to reach net-zero emissions.
- The global coal transition has been delayed, especially since 2021 across most countries. While new coal capacity is still being added in Asia, progress in closing existing old coal plants in the OECD regions is also insufficient.
- Key reasons for the delayed transition include energy security and grid stability concerns, economic recovery from the global pandemic, financing challenges for renewables and other alternatives, and the political economy of coal with powerful stakeholders. The near-term challenges need to be resolved during this critical decade to break through the power system transition bottleneck, which has a continued preference for coal over other solutions.
- Successful project-level transition cases in different countries demonstrate the feasibility and benefits of a rapid, just coal phaseout carried out with important policy support, finance, stakeholder engagement, and reliable energy infrastructure. They provide important lessons for scaling up these efforts.

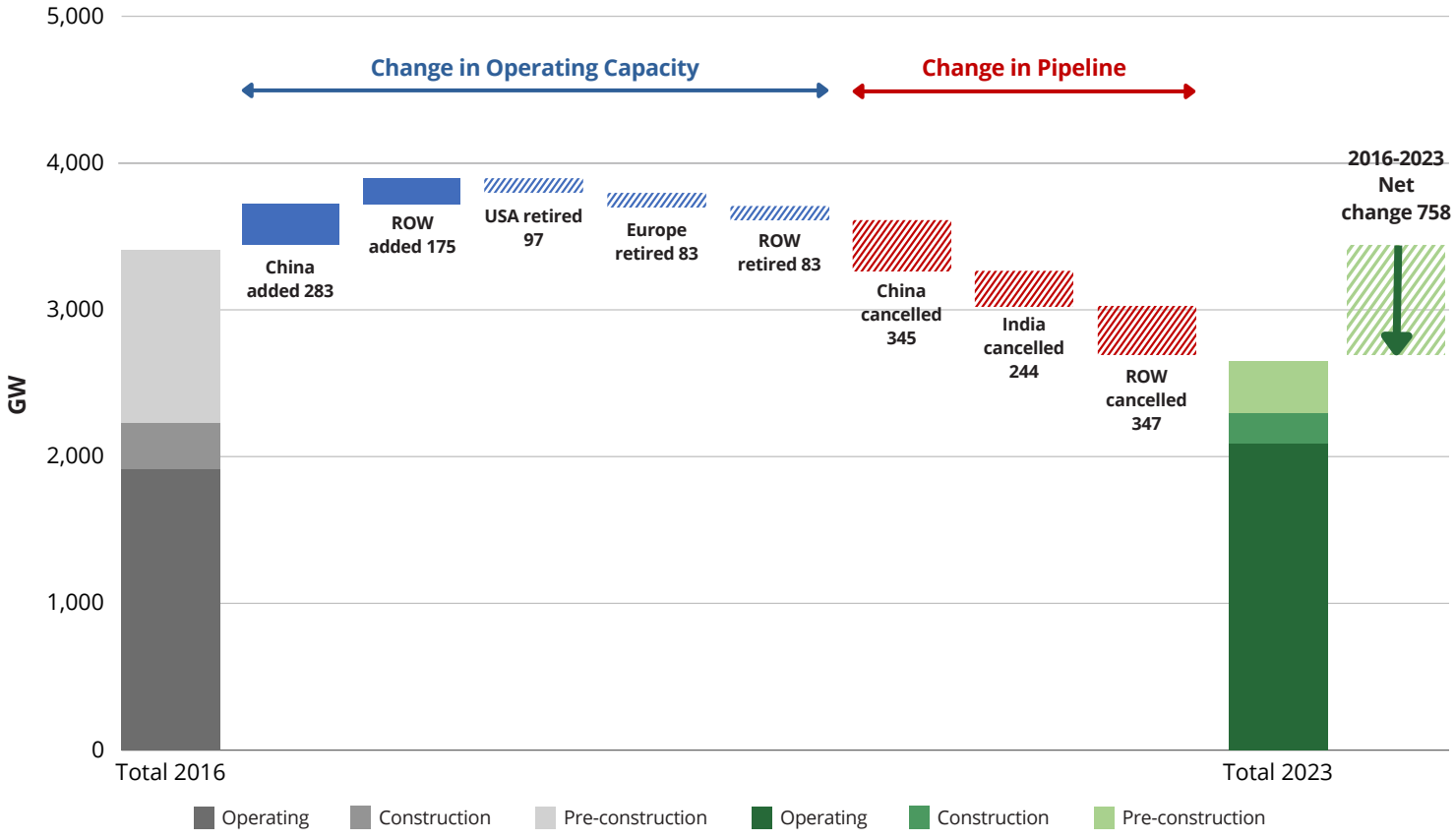

Figure 1. Change in global coal power capacity in operation and under development between January 2016 and July 2023.

Coal power capacity in operation

Globally, total installed coal power capacity has continued to grow since Paris, where new builds in Asia offset retirements of old plants in the United States and the European Union. Between January 2016 and July 2023, a total of 458 GW of coal-fired power plants started operation, dominated by China (283 GW) and other countries in Asia (India, Indonesia, Japan, and South Korea) (Global Energy Monitor, 2023). During the same period, a total of 280 GW of coal-fired power plants retired globally, dominated by retirements in the U.S. (97 GW), Europe (83 GW) (mainly in the United Kingdom, Ukraine, and Germany), and China (54 GW) (Global Energy Monitor, 2023). As a result, total operating coal power capacity has increased by 9% (178 GW) globally, from 1,917 GW to 2,095 GW (Figure 1).

Out of the total of 2,407 coal-fired power plants (2,095 GW) in operation today, 9% have been running for over 50 years, the majority (63%) have started operation within the last 20 years, and 38% started operation within the last 10 years, resulting in an average age of 22 years (Global Energy Monitor, 2023). While the operational lifetime of closed coal plants was on average 46 years in the past, meeting the Paris climate goals requires the remaining coal fleets to retire at a much earlier age (Cui et al., 2019).

Coal power capacity in the pipeline[1]

The global coal projects pipeline (projects under construction and at pre-construction stages) has shrunk by 63%, from 1,494 GW in January 2016 to 557 GW in July 2023 (Global Energy Monitor, 2023). The number of countries building or developing new coal projects has declined from 72 to 38 during the same period, and all countries have a smaller pipeline, where major reductions happened in China by 345 GW and India by 244 GW through project cancellations (Global Energy Monitor, 2023).

Out of the total of 499 coal-fired power projects (557 GW) under development globally, 206 projects (204 GW or 37%) have already started construction, and the other 322 projects (353 GW or 63%) are at various pre-construction stages and can be targeted for cancellation. Outside China, pre-construction projects are mostly being developed in India, Turkey, Bangladesh, Indonesia, Vietnam, and Pakistan (Global Energy Monitor, 2023).

Coal power generation

Total coal power generation has also grown, by 11% from 2015 (9,195 TWh) to 2022 (10,199 TWh). However, as total electricity demand grew faster, coal contributed to a smaller share of total electricity generation, from 39% in 2015 to 36% in 2022 globally (Figure 2). Meanwhile, renewable power generation has grown by 54%, and its contribution to total electricity has increased from 23% to 30% during the same period (Ember, 2022). This growth is dominated by solar and wind, which account for 12% of total electricity generation in 2022, up from 5% in 2015, whereas hydropower amounts to 15% of total electricity generation in 2022 (Ember, 2022).

Across regions, trends vary in terms of how fast total electricity demand has grown and how fast alternative technologies are deployed to meet the demand. Between 2015 and 2022, large reductions in coal power generation occurred in Europe (by 42%), the United States (by 39%), and Australia (by 20%), where coal also contributes to a declining share of total electricity (Figure 2). With a relatively stable demand (8% increase in Australia, 5% increase in the United States, and 15% decrease in Europe) alternative fuels – mostly gas and renewables – have been able to replace coal in these regions (Ember, 2022).

By contrast, for countries with large increases in coal power generation, including China (by 33%), India (by 37%), and Indonesia (by 65%), electricity demand has been growing much more rapidly (52% increase in China, 41% increase in India, and 37% increase in Indonesia) between 2015 and 2022 (Ember, 2022). However, with different progress in renewable deployment, the trend of coal share in total electricity varies. In China, the share of electricity generation from coal has been declining from 70% in 2015 to 61% in 2022, where it stays almost constant in India from 76% in 2015 to 74% in 2022, and has been increasing in Indonesia from 51% to 62% during the same period (Ember, 2022). Overall, growing demand is met more by renewables and less by new coal in China, more equally between coal and renewables

[1] Coal power projects under construction and at pre-construction stages

in India, and primarily by coal in Indonesia due to its slow renewable deployment (Ember, 2022). Both China and India have seen strong growth in solar and wind power. The share of renewables in electricity generation has grown from 24% to 30% in China and from 15% to 21% in India, between 2015 and 2022.

South Korea and Japan both experienced a small decrease in coal power generation but ended up with either a declining or constant contribution to total electricity. In South Korea, the decrease in coal power generation (by 8%) between 2015 and 2022 is associated with a 16% increase in total demand, a 49% increase in gas power generation, an 8% increase in nuclear power generation, and a substantial expansion of solar power (Ember, 2022). In Japan, total electricity demand, coal generation, as well as coal share remain fairly constant (Ember, 2022). At the same time, the restart of nuclear power and a rapid expansion in solar mostly replaced other fossil power generation.

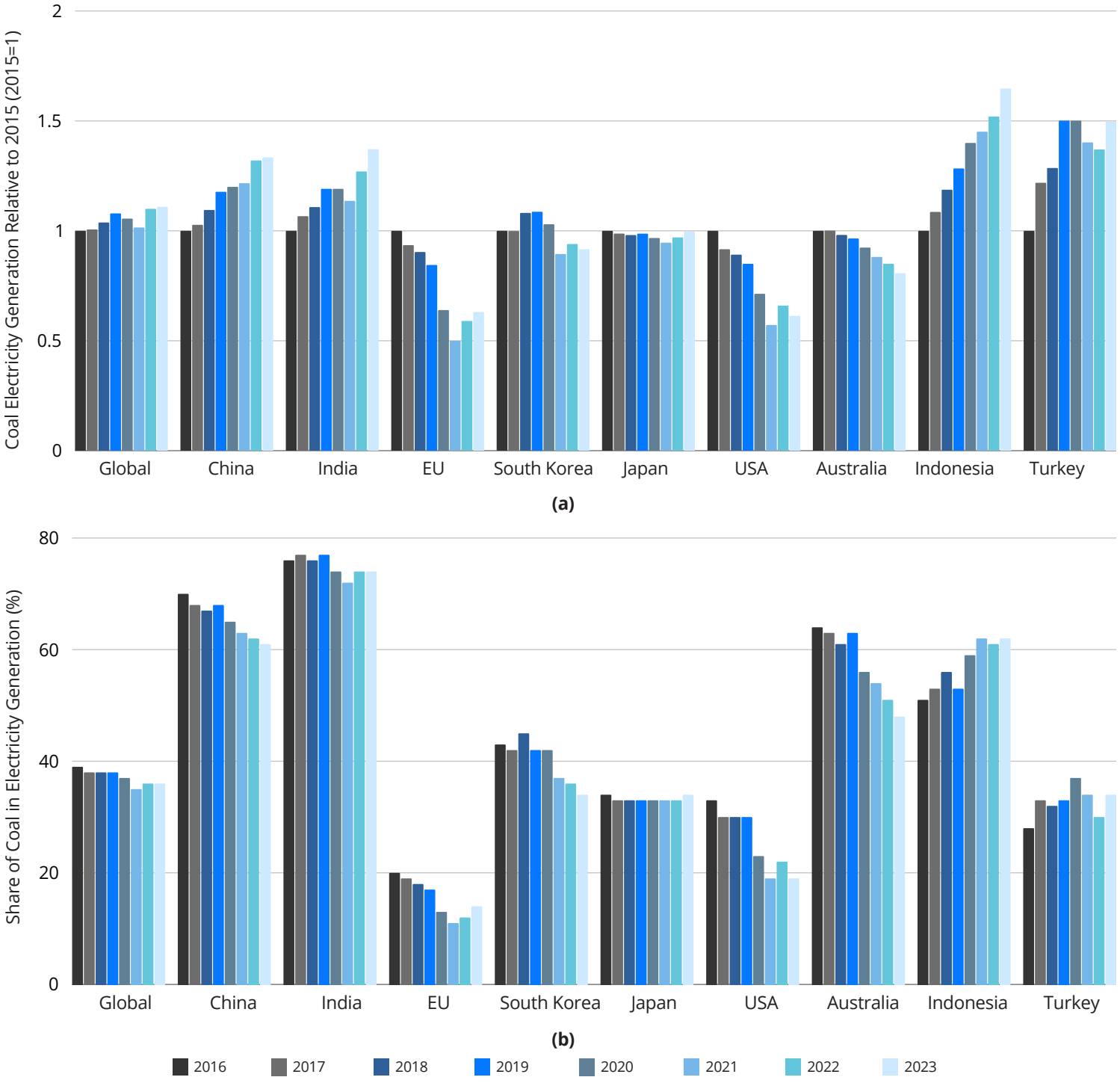

Figure 2. Coal Electricity Generation by Region and Globally, 2015-2022: (a) Relative to 2015 (b) Share in Total Electricity Generation.

In many countries, the slower growth rate of coal power generation compared to capacity indicates a declining utilization of existing coal plants. For example, coal plants in China have been running at an average of 4,300 to 4,600 hours in recent years (or about half of the full capacity), much lower than the designed 5,500 hours for making a profit. Similar trends are visible in other countries, like South Korea, South Africa, and Japan, where the average utilization, estimated by total coal power capacity and generation (Ember, 2022), has declined substantially (by 36%, 25%, and 14%, respectively) between 2015 and 2022.

Policy progress

Coal phaseout policy progress has predominantly come in four different forms: coal phaseout commitments (ending the use of coal for electricity generation), no new coal commitments (committing to not allowing any new coal-fired electricity generation projects), commitments to stop financing overseas coal projects, and finance mechanisms to help close coal plants before the end of their lifetime while addressing potential social and economic impacts.

Since Paris, 30 countries have committed to phasing out coal by 2040, covering 19% of global coal-fired electricity capacity and 15% of global coal-fired electricity generation in 2022. Of those countries, 18 plan to phase out coal in electricity generation before 2030, and three countries (Austria, Portugal, and Sweden) achieved phaseouts in 2020 and 2021. In addition, five countries are either discussing explicit coal phaseout plans or implementing policies to enable a phaseout, including Colombia, Mexico, Poland, Senegal, South Korea, and the United States. If enacted, these plans would phase out an additional 12% of global coal electricity generation, and 14% of global coal power capacity. 38% (73) of all global countries have committed to phasing out coal by 2040 (or already are coal-free) at the latest. In the United States, the Inflation Reduction Act (IRA) has also provided funding to transition away from coal, with $5 billion to back $250 billion of funding in low-cost loans for utility companies to reduce coal debt and reinvest their finances in clean energy technologies like wind and solar, and an additional $9.7 billion in financial assistance for rural-based electric companies and co-ops to move toward clean sources of electricity (Solomon, 2022; White House, 2022). Beyond the national level, 14 countries have at least one subnational actor that has made a coal phaseout commitment since 2017 and eight countries have multiple subnational commitments. In total, 48 subnational governments have joined the Powering Past Coal Alliance (PPCA), including those in Australia, Japan, Poland, South Korea, and the United States, where national phaseout timelines are still missing.

In addition to coal phaseout commitments, progress has been achieved through no new coal commitments. At the 2021 UN High-level Dialogue on Energy, Sri Lanka, Chile, Montenegro, Denmark, the United Kingdom, France, and Germany signed the No New Coal Energy Compact, which works in conjunction with the PPCA to help countries phase out the use of coal in power plants. The No New Coal Energy Compact is a precursor to signing onto the PPCA by signifying a commitment to stop building new coal power projects. Thus, governments may continue to use coal to generate electricity in the interim; however, they can not expand their coal plant capacity, an essential first step to phasing out coal in electricity generation. The compact continues to grow with 6 new countries — Panama, Azerbaijan, Canada, New Zealand, Grenada, and Vanuatu — joining since 2021. Vietnam, the Philippines, and Indonesia have also made strides in stopping the advancement of new coal plants, by not developing any new coal plants after 2030 (Vietnam), not accepting new coal plant proposals as of 2020 (the Philippines), and not building new coal plants after 2023 (Indonesia).

Another critical policy step is the commitment to stopping international coal finance, as many coal projects rely on overseas investments and international developers. At COP26, 39 countries and entities, including six G20 countries, banks, and development agencies, signed a commitment to stop financing overseas coal projects (United Kingdom, 2023). China and South Korea continued this momentum and banned overseas coal projects in 2021. Furthermore in 2022, all G7 countries' environment and energy ministers committed to stopping overseas coal financing projects at a meeting in Berlin in 2022 (Germany, 2022). These commitments cover all major international coal investors and contribute substantially to reducing global coal investments. For example, between 2019 and 2021, G20 countries, along with multilateral development banks (MDBs), publicly financed $55 billion per year in fossil fuel projects, almost twice the financial support provided for clean energy which averaged only $29 billion per year (O'Manique et al., 2022). If all G20 countries and MDBs shift their financial support from fossil fuel energy to clean energy, renewable energy investments would almost triple to $85 billion (O'Manique et al., 2022).

Lastly, financial policies regarding limiting the use of coal include both banning the financing of coal projects and financial mechanisms such as the Just Energy Transition Partnerships (or JETPs), the African Development Bank's (ADB's) energy transition mechanism (ETM), and more local financial mechanisms such as the Green Climate Fund's (GCF's) Shandong Green Development Fund. JETPs aim to bridge the gap between developed and developing nations fighting climate change by funding the movement towards clean renewable energy. JETPs signed between public and private sector investors (typically G7 governments, development banks, and financial institutions) and the governments of South Africa, Indonesia, Vietnam, and most recently Senegal are focused on providing blended financing towards clean energy and movement away from coal. Similarly, the ADB's ETM, launched in 2021, aims to help confront climate change, ensure energy security, and mitigate emissions in Asia and the Pacific, by seeking to retire existing coal-fired power plants by providing funding to help countries transition to renewable energy (Asian Development Bank, 2021). The ETM began with a focus on three pilot countries, Indonesia, the Philippines, and Vietnam, with recent extensions to Pakistan and Kazakhstan. The largest contribution to date has been to Indonesia, which received $500 million of concessional capital for its transition away from coal (Asian Development Bank, 2021).

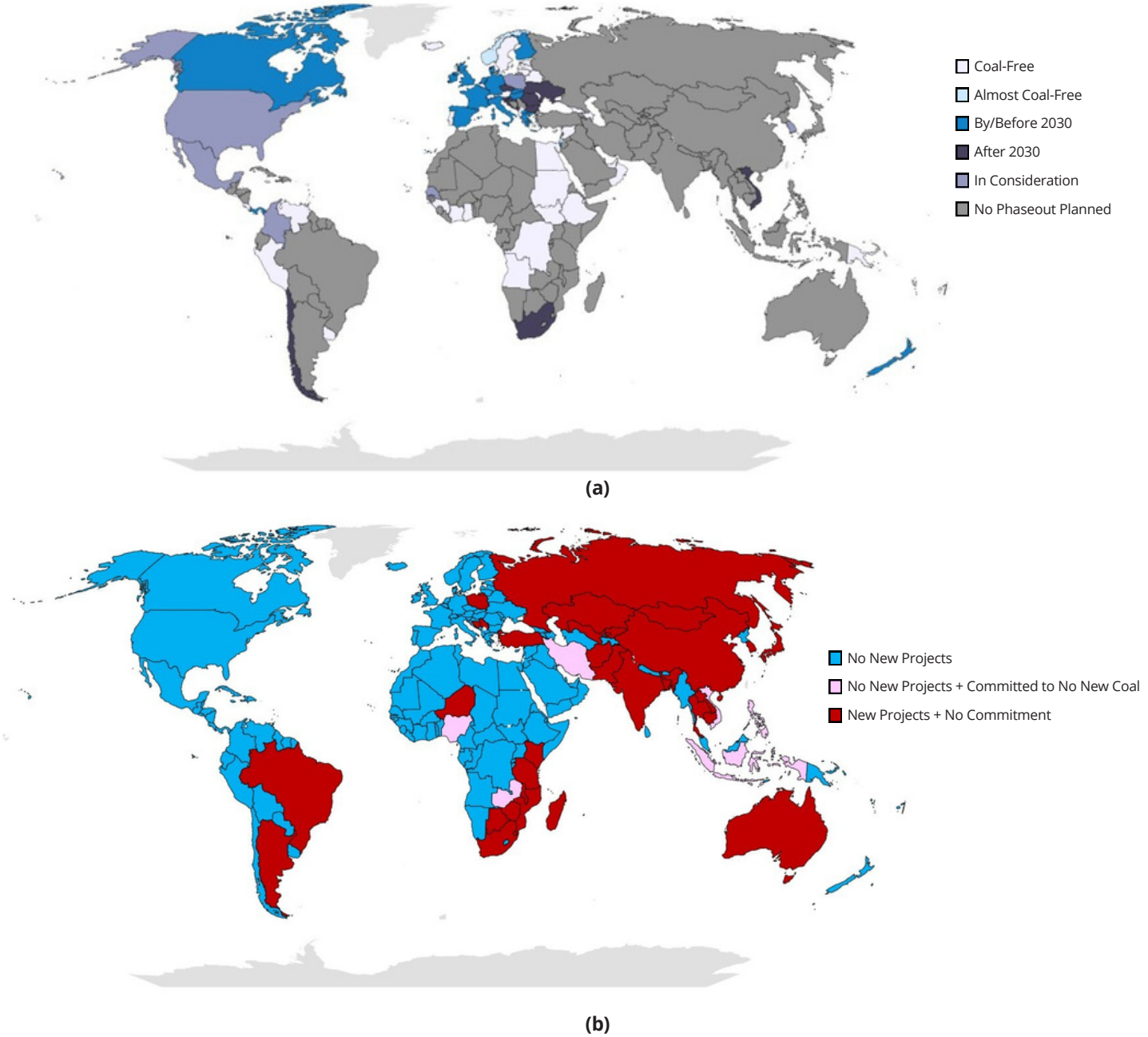

Figure 3. Policy Progress by Country: (a) Coal Phaseout and (b) No New Coal

Emissions outcomes and the gap to 1.5°C

Coal power plants are long-lived infrastructure and can continue to pollute for decades once they are built. Without actions, the operating and new (under- and pre-construction) coal power projects as of 2016 may have increased the coal power emissions by 38% to 13.2 $GtCO_2$ in 2030. Progress made till 2023 has lowered the 2030 emissions to 10.3 $GtCO_2$, a 22% reduction from business as usual. However, continuing the current trend still leads to a 7% increase from 2016 and leaves an emissions gap of 3.9 $GtCO_2$ to be in line with a 2°C pathway in 2030, and of 5.8 $GtCO_2$ for a 1.5°C pathway, based on our analysis using a global integrated assessment model, the Global Change Analysis Model (GCAM, see Technical Appendix for method).

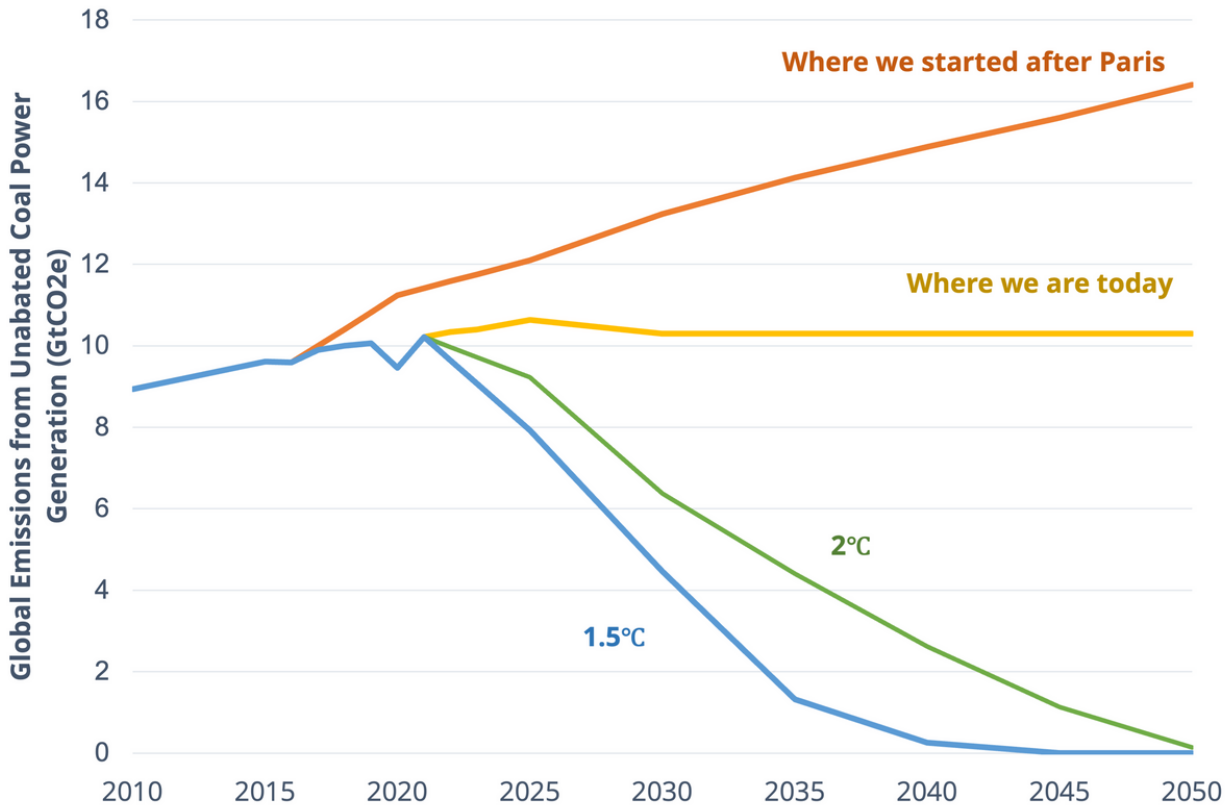

Figure 4. Global GHG emissions from coal power generation under different scenarios.

To close the emissions gap and stay on a 1.5°C-aligned pathway, global coal power generation needs to decline by roughly a quarter in 2025 and nearly 60% in 2030 from today's level. This can be achieved by employing a combination of strategies: canceling new coal projects under development, closing down older and inefficient coal plants, and/or reducing the utilization of the remaining coal fleets. To illustrate, the three different scenarios below can achieve the emissions reduction needed globally by 2030, and individual countries and regions may choose between the different strategies based on specific contexts.

- Scenario 1: by 2025, cancel all the 557 GW of new projects currently in the pipeline and retire 434 GW of operating plants; by 2030, retire an additional 780 GW of operating plants; both assume remaining coal plants operate at today's utilization levels;
- Scenario 2: by 2025, cancel all 353 GW of pre-construction projects and retire 638 GW of operating plants; by 2030, retire an additional 780 GW of operating plants; both assume remaining coal plants operate at today's utilization levels;
- Scenario 3: by 2025, cancel all 353 GW of pre-construction projects and retire 342 GW of operating plants older than 40 years, while lowering the utilization of remaining plants by 15% from today's levels; by 2030, retire an additional 296 GW of operating plants older than 30 years, while lowering the utilization of remaining plants by 47% from today's levels.

Across countries, the retirement of existing capacity can be prioritized in regions with old coal fleets, such as the U.S. and E.U., while regions with newer capacity can take a combined strategy of targeted retirement and lowered plant utilization. However, the progress of coal power capacity retirement and cancellation in the OECD countries is insufficient. As of July 2023, the majority of the OECD countries are not on track to achieve the midpoint (50%) of the 1.5C-aligned reductions needed between 2021 and 2025. Based on our analysis, Australia and the U.S. have achieved 31% and 25% of the capacity reductions needed, respectively, while Japan and South Korea only achieved 7%. Europe collectively has achieved 58% of the capacity reductions, passing the midpoint and on track to meet the 1.5C-aligned target in 2025. In general, enhanced actions are needed in the OECD regions.

Furthermore, for newer coal plants, a broader range of technological options could be explored at the individual asset level to capitalize on specific opportunities while addressing local challenges. For example, biomass co-firing can provide near-term emissions reductions at existing plants that are close to abundant biomass resources, which can also generate long-term emissions reductions with eventually a full conversion to biomass plants and even negative emissions if equipped with carbon capture and storage (BECCS). These options can be useful to help existing plants transition. However, as they must demonstrate real emission reductions and will require additional investments, assessments should be made carefully across multiple options and over a longer timeframe to avoid increased stranded assets.

To meet the increasing demand and to replace coal and other fossil power generation under the 1.5°C-aligned pathway, the global total installed renewable capacity will almost triple from about 3,500 GW in 2022 (BNEF, 2023) to over 10,300 GW by 2030 (Cui et al., 2023). Solar and wind power contribute to almost all of the capacity growth, with a threefold increase from 2,160 GW (BNEF, 2023) to 8,900 GW (Cui et al., 2023). As a result, renewable energy accounts for 62% of total electricity generation in 2030 under the 1.5°C-aligned pathway. In addition, to support higher solar and wind penetration, backup storage capacity, with nearly 45 GW installed in 2022, needs to increase to over 1,000 GW, or nearly 23 times the current level by 2030 to be in line with a net-zero transition pathway (IEA, 2023).

Key challenges for accelerating the coal power transition

Coal transition in the power sector has been delayed in most countries, especially since Glasgow, with emerging obstacles in energy security and global pandemic recovery as well as long-standing issues in terms of political economy and finance. These challenges need to be addressed to deliver meaningful emissions reductions from the coal power sector in the 2020s.

First, energy security has become a top priority in many countries. The 2021-2023 energy crisis, spurred on by the COVID-19 pandemic and Russia's invasion of Ukraine, resulted in shortages and surging energy prices, even for countries not reliant on Russian oil or gas ("World Energy," 2022). The crisis placed energy security high on many countries' policy agendas and renewed concerns over how an energy transition would impact an already volatile energy market. During the energy crisis, many countries, even ones leading the energy transition, turned back to coal to provide critical energy needs.

Second, grid stability concern rises with higher intermittent renewable penetration, combined with extreme weather events exacerbated by climate change. With rapid wind and solar deployment, intermittent renewable energy starts to have a considerable impact on the electrical grid, which may require adding backup capacity to ensure stability. While coal plants have technical disadvantages as backup, coal becomes attractive in countries like China where alternatives (such as gas plants and battery storage) are expensive. However, this potential lock-in of the coal-RE package may preclude or delay the development and deployment of various solutions, including cross-region grid balancing, demand-side management, and investment in battery and other storage technologies. To successfully transform the power sector into a clean, efficient, flexible, and resilient system, countries must invest in grid infrastructure, advance the design, operation, and management of the system through new technologies and improved institutions, and reshape the role of consumers to prosumers.

Box. Power shortages and blackout events in China and India

Two key coal countries, China and India, are undergoing periods of energy instability, as they face higher energy prices, global supply chain disruptions, and soaring energy demand. Higher energy demand can be partially attributed to extreme weather events, e.g. heat waves and droughts, affecting both countries. Currently, demand is outpacing electricity generation, including renewable energy. Droughts in China (the first major drought in the last nine years) and India (the driest August in a century) in 2022 and 2023 caused a reduction in the amount of hydroelectric power supply (Varadhan and Chew, 2022; Kemp, 2023). With a lowered supply of hydroelectric power and renewable deployment unable to keep pace with demand, both countries began to rely more on coal to meet energy needs. In India, coal's share of electricity output grew to 67% in August 2023 due to these droughts, and hydroelectric power supply shrunk to 15% compared to a share of 18% in August the year before (Varadhan and Chew, 2022). Despite this reliance, instability in the coal power supply chain has exacerbated power shortages, especially in 2021 and 2022 during the global energy crisis, which could push both countries toward renewable energy. In addition to increased coal reliance, China and India have also resorted to rolling blackouts to reserve a diminished energy supply in times of need (Sharples, 2023). Blackouts frequently occur during extreme heat when greater demand is placed on the grid. As climate change worsens, both countries face more extreme heat and natural disasters that will exacerbate an already strained energy supply, making action on coal even more critical.

Third, while many parts of the world are accelerating renewable deployment, certain regions have made limited progress, due to a lack of finance and policy support as well as poor grid infrastructure. For example, as an island nation, grid connectivity and infrastructure is one of the most significant barriers to Indonesia's coal transition (Burke et. al, 2019). There must be significant financial and political support to build out Indonesia's electrical grid and generate reliable power across all islands. Globally, renewable energy continues to rapidly expand and all main regions increased their share of renewable energy in electricity generation between 2015 and 2022 except for the region of Africa, which had a 30% decrease (Ember, 2022). While renewable energy is increasingly cost-effective and cheaper than coal power in many countries, the upfront capital costs of renewable technologies and associated grid improvements can make it difficult for countries to afford the transition or make the necessary investments ("The cost of capital," 2021). Many coal-dependent developing countries are reliant on international transition financing to deliver on their own climate goals and renewable energy targets. As stated in the Paris Agreement, developed countries shall provide financial assistance to developing countries to assist in their clean energy transition (Paris Agreement, 2015). Funds have been slow to deploy, but financing pledges continue to grow through strategic partnerships with banks, governments, foundations, etc.

Fourth, due to the pandemic, there is a need for economic recovery. Coal construction projects are expected to boost the local economy and job growth in the near term, and thus the pandemic provided an opportunity to sustain the use of coal for local economic gains. In fact, in 2021, the International Energy Agency (IEA) projected that coal power generation could reach an all-time high in 2022 due to post-pandemic economic recovery. Although an all-time high of coal power generation did not occur, in contrast to 2020, where coal power generation dropped by 4% during the pandemic, coal power generation increased by 9% in 2021, with the reason cited as a surge in fossil fuels to aid economic recovery from the pandemic.

Finally, unlike the above challenges that have recently emerged or are temporary, the political economy of coal is a long-standing issue, which continues to play a strong role in key countries, often due to the influence of powerful stakeholders (Steckel and Jakob, 2021). Energy plays a vital role in society and as such, energy producers have immense resources and lobbying power they can wield to prevent governments from taking stronger action against coal power and protect their interests. Globally, the politically well-connected coal industry spends hundreds of billions of dollars to prevent policy progress (IEA, 2023b). Beyond lobbying, many individuals and communities are still heavily reliant on coal power for their livelihoods. Phasing out coal power requires addressing the communities that rely on coal for economic purposes and overall quality of life. Policy progress is often hindered by individuals and groups that will be adversely affected by a transition, often making action politically unpopular. A successful coal transition protects jobs and ensures that no one is left behind, which is integral for garnering support from affected communities.

Box. COVID-19 Impact

COVID-19 had an interesting impact on global and regional coal-fired electricity generation. Globally, coal-fired electricity generation decreased by 4% between 2019 and 2020, from 9,707 TWh to 9,335 TWh. However, global coal-fired electricity generation quickly rebounded between 2020 and 2021, increasing by 8% from 9,335 TWh to 10,085 TWh.

In our analysis, there were decreases in coal-fired electricity generation during the COVID-19 pandemic for most key countries and regions, with the most significant reductions occurring in Europe + Turkey, India, and the United States. In the United States, coal-fired electricity generation during COVID-19 first decreased by 20% between 2019 and 2020 (965 TWh to 773 TWh) and then increased by 16% between 2020 and 2021 (773 TWh to 898 TWh). A similar trend occurred in India, where coal-fired electricity generation during COVID-19 first decreased by 5% between 2019 and 2020 (1,199 TWh to 1,144 TWh) and increased by 11% between 2020 and 2021 (1,144 TWh to 1,274 TWh).

As a region, Europe (including Turkey) also experienced a similar trend, where coal-fired electricity generation decreased by 17% between 2019 and 2020 (658 TWh to 545 TWh) and increased by 11% between 2020 and 2021 (545 TWh to 604 TWh). All European countries except Finland decreased their coal-fired electricity generation between 2019 and 2020. The most significant reductions, ranging from 5% to 8% of total coal-fired electricity generation, occurred in Belgium, Bulgaria, Czechia, France, Germany, and Italy. Between 2020 and 2021, all European countries except the UK experienced a rebound in coal-fired electricity generation. The most significant coal-fired electricity generation rebounds occurred in Bulgaria (18% increase), Poland (14% increase), and Belgium (13% increase).

China had an individual trend, experiencing not only a 1.4% increase in coal-fired generation between 2019 and 2020 from 4,855 TWh to 4,923 TWh but also an 8% increase in coal-fired electricity generation between 2020 and 2021 from 4,923 TWh to 5,329 TWh.

Transition cases around the world

Successful transition cases have occurred at the project level across different regions. Three cases from Europe, America, and Asia are discussed below. Learning from these successful projects provides the first step for scaling up efforts.

The Belchatow Power Station, Lodz, Poland

The Belchatow Power Station, located in the Lodz region of Poland, has operated since 1988 and is Europe's largest and the world's 6th largest coal plant. It has a current capacity of 5,102 MW, mainly combusting lignite. In 2009, the Belchatow Power Station emitted the 4th most CO_2 emissions globally (29.5 million tons of CO_2) and became the largest CO_2-emitting coal-fired power station globally in 2019 (37.6 million tons of CO_2) (Don Grant et al., 2021).

Although recent demand for coal in Europe was boosted by war and an energy crisis, the longer-term outlook for coal and lignite power plants remains bleak. Poland's total lignite generation is expected to drop 75% over 2021-2030. Local lignite sources in Belchatow are also a concern, as they are expected to run out by 2036, forcing the plant to shut down in the next 13 years. Due to these outlooks, and despite Poland not having a coal phaseout commitment at the national level, the Lodz region in 2021 announced the closure of the Belchatow power plant by 2036. However, the plan was incomplete, lacking a post-lignite strategy for capacity replacement and incentives for investments, with additional hesitation stemming from transitioning the power plant's workforce of 7,500 residents. Due to a lack of ambition and a concrete data-driven plan, the region was at risk of missing EU funds to support the plants' transition. However, a BNEF report assessed the feasibility of replacing most of its generation with renewables paired with batteries and clean energy technologies, which helped gather funding for the project. BNEF found that 11 GW of wind and solar in the region can replace 80% of Belchatow's coal generation, with other significant opportunities for renewable investment in the Lodz region. The report helped to inform the European Commission's decision on the allocation of just transition funding and enabled the Lodz region to become eligible for €370 million of EU just transition funding.

Still, Belchatow is not a done deal despite the announcement of just transition funding. The region must present bankable and credible transition projects and ensure adequate transition support for workers. As a next step, policymakers should have a robust plan, including a method for training the local workforce and transitioning them to new clean energy jobs.

ACEN Corporation's South Luzon Thermal Energy Corp. (SLTEC) Coal Power Plant, Calaca, Batangas, Philippines
ACEN Corporation's South Luzon Thermal Energy Corp. (SLTEC) coal power plant is located in the Batangas province of the Philippines in the city of Calaca. The plant has two units, with the first becoming operational in April 2015 and the second unit becoming operational in early 2016 after construction finished in the second half of 2015. The total capacity of both units is 246 MW.

In November 2022, ACEN Corporation committed to retiring its SLTEC coal power plant in Calaca by 2040 (ACEN, 2022). ACEN is doing so using funds delivered by the Asian Development Bank's new energy transition mechanism (ETM), becoming the first deal of its kind. The announcement of the plant's retirement comes early, as it would halve its original proposed operational lifetime from 50 years to 25 years. With its early retirement, transitioning the plant to use renewable energy could avoid 50 million metric tons of Carbon emissions.

The ETM aims to leverage low-cost transitions away from coal by providing long-term funds for coal phaseouts and funds to reinvest in clean energy. To successfully transition the SLTEC plant away from coal, the ETM provided $250,000,000 for debt financing (mainly from the Bank of the Philippine Islands and Rizal Commercial Banking Corporation) and $66,000,000 in equity investments (mainly from the Government Service Insurance System (GSIS), InLife, and ETM Philippines holdings), for a total deal of $316,000,000. In addition, ACEN received $130,000,000 from the transaction to reinvest in clean energy sources for SLTEC use. ACEN seeks to be one of the climate-leading energy generation companies in the world, with commitments to 100% renewable energy generation in its entire portfolio (including plants in the Philippines, Vietnam, Indonesia, India, and Australia) and wants to be a pioneer in Southeast Asia, committing to a goal of reaching 20 GW in renewable energy capacity by 2030 (ACEN, 2022).

Chile's Coal to Clean Energy PPA Renegotiations
Chile boasted a host of energy power purchasing agreements (PPAs) between both coal mining companies and utility providers. Utility providers that originally had coal-based PPAs included AES Andes, Colbun SA, Engie, and Enel, all of which renegotiated or terminated their coal-centered PPAs. Enel, Chile's main electricity distributor, has particularly had success in renegotiating its PPAs, which resulted in numerous coal power plant closures.

Enel had a long history of supporting coal power plants, one of its largest being the Bocamina power plant. The Bocamina power plant began operation in 1970 and was a key driver of Chile's economic development through the 1990s, as it provided stability to the electrical system and the coal industry in Coronel and nearby Lota. The Bocamina power plant became even more important during Chile's water crisis in the 1990s, and in 2006, when Argentina cut its natural gas supply to Chile (Enel, 2022).

Enel's coal plant closures began following the announcement of Chile's new national decarbonization plan in June 2019, with the disconnection of the coal unit of the Tarapaca power plant and the disconnection of Bocamina I in December 2019. As of May 2020, Enel announced the closure of its last coal power plant, Bocamina II, eighteen years ahead of its expected end of operation. To become carbon neutral by 2040, Enel intends to increase renewable electricity generation through solar, wind, and geothermal deployment. Additionally, with the announcement of the closure of Bocamina II, Enel became the first Chilean electricity company to cease using coal in its generation operations (Enel, 2022).

Conclusions

There is no question that unabated coal power must be phased out rapidly for the world to achieve climate goals. Yet the picture of trends since the Paris Agreement is mixed—with some reasons for optimism that acceleration is possible with certain strategies, and with other reasons to be concerned that the transition is not happening as quickly as needed. Since the Paris Agreement, over 900 GW of planned coal plants have been canceled—nearly 50% of today's current total global capacity. That in itself is a remarkable reduction in the overall trajectory which has been made possible by expanded policy emphasis on electrification with low-cost renewable energy. At the same time, that is not nearly enough. Globally, progress made in the coal power transition has been insufficient to achieve the Paris climate goals. The required accelerated rates of phase-down have not yet been achieved due to enduring and emerging political and stakeholder challenges within various country contexts. These include concerns over energy security and grid stability, economic recovery from the global pandemic, financial obstacles for renewables and other alternatives, as well as the complex political dynamics surrounding coal, involving influential stakeholders. The near-term challenges need to be resolved during this critical decade to break through the power system transition bottleneck, which has a continued preference for coal over other solutions.

A strategy to accelerate the rate of coal phase-down can build on the recent success in renewable deployment in key countries and can be expanded further to more regions. Yet even with a new global goal of tripling the global total installed capacity of renewables by 2030, delivering meaningful emissions reductions from coal power generation will require a combination of multiple strategies that focus on canceling new projects as many as possible, targeting older, dirtier, and inefficient plants for rapid closure, and lowering the utilization of the remaining fleet that may also help support increasing intermittent renewable penetration in certain countries during the early- to mid-stage of the power system transition. Successful project-level coal transitions have happened all around the world, in different countries and development contexts. Experience shows it is possible—and scaling up more broadly will require strong policy, finance, and stakeholder support. Investment and financial resources are needed to manage a just transition at both the asset and community levels, to invest in additional or alternative technologies and infrastructures, and eventually to transform the power sector into a clean, efficient, flexible, and resilient system.

Appendix

Table A. Electricity generation by fuel type in the G20 countries in 2022 (Ember)

Country or Region	Coal		Other Fossil Fuels	Nuclear	Renewables
	Generation (TWh)	% of Total Generation	% of Total Generation	% of Total Generation	% of Total Generation
China	5,398	61	4	5	30
India	1,380	74	3	2	21
USA	829	19	40	18	23
EU	445	16	23	22	39
Japan	348	34	39	5	22
South Korea	207	34	29	28	9
Indonesia	205	62	18	0	20
South Africa	181	85	1	5	9
Germany	180	31	20	6	43
Russia	180	16	46	20	18
Australia	131	48	19	0	33
Turkey	111	34	24	0	42
Canada	37	6	11	13	70
Mexico	22	6	68	3	23
Italy	21	8	56	0	36
Brazil	16	2	9	2	87
UK	6	2	42	15	41
France	4	1	11	63	25
Argentina	2	1	62	5	32
Saudi Arabia	0	0	100	0	0

Current Coal Power Analysis using Global Coal Plant Tracker (GCPT) and EMBER

We used the newly released Global Coal Plant Tracker (GCPT) July 2023 Status Changes (2014-2023) dataset to calculate all three pipelines (Global Energy Monitor, 2023). The GCPT 2023 dataset release includes coal-fired electricity capacity information across 107 countries and 4,664 plants and is collected by the Global Energy Monitor (GEM). The dataset catalogs every operating coal-generating unit, every new unit proposed since 2010, and every unit retired since 2000 globally at the individual plant level. The status changes dataset includes detailed plant-level capacity data from 2014 - July 2023 (first half of 2023), with each year broken into half-year segments (H1 is the first six months of the year, and H2 is the second six months of the year). Therefore, the latest released data only provides data through July 2023. In our analysis using the GCPT data, we analyzed proposed plants (announced, pre-permit, permitted, and under construction), operating coal-fired power plants, and whether a power plant status has changed from proposed to canceled/shelved or operating to retired/mothballed, by country.

For the coal electricity generation analysis, we used Ember's 2022 electricity dataset for their electricity generation values (Ember, 2022). Ember provides electricity generation information by subcategory (fuel) and provides both raw generation values and the percentage of total electricity generated by each fuel type. Ember's data includes electricity generation information for 82 countries but does not include their data at the plant level, as it only provides data at the country level.

Global Change Analysis Model (GCAM)

We used the Global Change Analysis (GCAM) version 6.0 to run scenarios of future coal power from 2020 to 2100. GCAM is a global model that represents the behavior of, and interactions between five systems: the energy system, water, agriculture and land use, the economy, and the climate (Edmonds, J. and Reilly, J., 1982a; Edmonds, J. and Reilly, J., 1982b). The energy-economy system in GCAM operates at the scale of 32 regions. GCAM has been used widely to produce scenarios for international and national assessments, including the Intergovernmental Panel on Climate Change (IPCC) reports, the Representative Concentration Pathways (RCPs), and the Shared Socioeconomic Pathways (SSPs).

Coal Power Generation Pathways under Alternative Scenarios

Our scenario, *Current Pipeline 2023*, is based on detailed plant-level data from the Global Coal Plant Tracker for 2023 (Global Energy Monitor, 2023). The dataset includes 4,664 plants and their status (in operation, under construction, permit or pre-permit stage, and announced) across 107 countries. We assumed that all plants under construction become operational by 2025, those in the permit or pre-permit stage would be online by 2030, and those announced would become operational by 2035. A continued growth rate is assumed for post-2035. We used the planned shutdown date, and if this is not specified, we assumed plants would have been in operation for 50 years. We derived GCAM region-specific coal electricity capacity factors from coal electricity generation and installed capacity data from Ember for 2022 (Ember, 2022). We assumed the capacity factors remained constant over the model simulation. We used the observed region-specific coal electricity generation values from Ember for 2020. Using the region-specific coal capacities, we then projected future coal power and associated CO_2 emissions in GCAM to 2050.

The 1.5°C is from the All-of-Society 1.5 pathway developed with 11 key policy levers to keep global 1.5°C within reach (Cui et al. 2023). Under this scenario, global greenhouse gas emissions peak immediately and achieve rapid reductions through 2030, followed by continued emissions reduction reaching net-zero CO_2 by 2050. The modeled emissions pathway is aligned with the 1.5°C scenarios in the IPCC AR6 database. The 2°C scenarios (both with a 67% chance) are from Phase IV of climate scenario development for the Network for Greening the Financial System (NGFS), a group of 66 central banks and supervisors and 13 observers committed to sharing best practices, contributing to the development of climate and environment-related risk management in the financial sector and mobilizing mainstream finance to support the transition towards a sustainable economy.

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