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Simulating a Managed Phaseout of Coal-Fired Power Plants in the Asia-Pacific Region

MSCI Sustainability Institute

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Authors

Manish Shakdwipee
Executive Director, MSCI Research
Institute Research Fellow, Energy Transition

Elchin Mammadov
Vice President, MSCI Research
Institute Research Fellow, Energy Transition

Guido Giese
Managing Director, MSCI Research

MSCI Sustainability Institute

Executive Summary

Transitioning to an economy that adds no net greenhouse gases (GHGs) to the atmosphere will demand that countries gradually discontinue the use of coal to generate power.[1] Yet, because coal-fired power plants and mines tie tightly to energy security and jobs in the countries and regions that rely on them, phasing out the use of coal, the most-carbon-intensive fossil fuel, and replacing it with cleaner sources of energy presents a series of challenges.[2]

In this report, we simulate potential pathways for a managed phase-out (MPO) of coal power in 15 markets in the Asia-Pacific (APAC).[3] The APAC region accounts for more than three-quarters (78%) of current global coal-power generation and virtually all (96%) of the planned expansion of coal-fired power plants globally.[4] These plants in APAC, if not decommissioned before the end of their useful lives, would add roughly 215 gigatons (Gt) of carbon emissions to the atmosphere between now and 2050 and consume more than 40% of the remaining global carbon budget for limiting global warming to 1.5°C.[5]

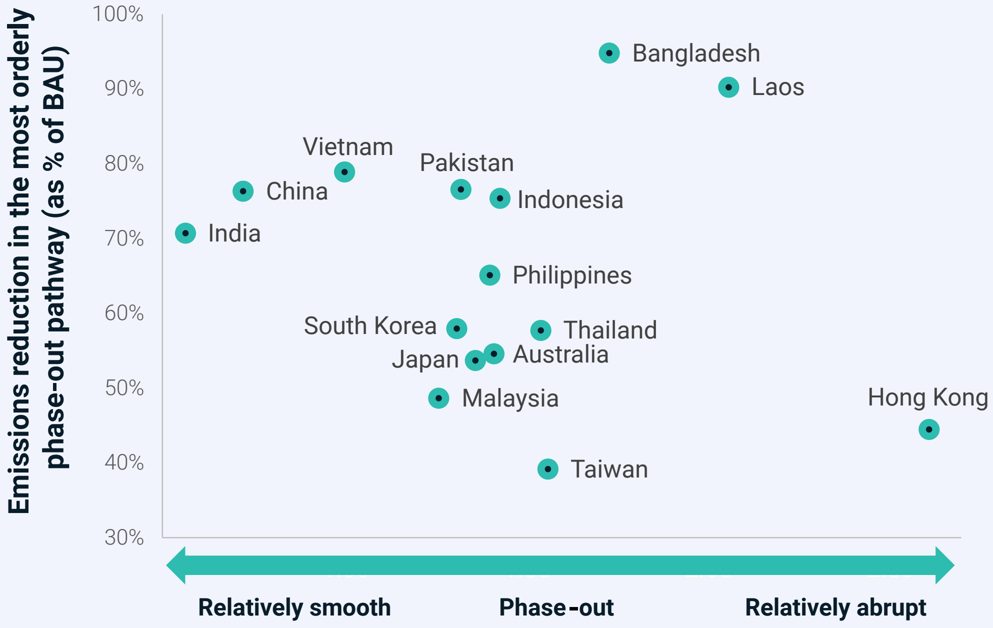
We have prepared this report at the request of the Glasgow Financial Alliance for Net Zero (GFANZ), which through its Asia working group is exploring feasibility for an MPO of coal power assets in the APAC region.[6] The working group has asked the MSCI Sustainability Institute to simulate approaches for an orderly phasing out of coal power in the region and to quantify how an MPO may help to reduce global warming.[7]

We find that the 15 markets analyzed can potentially reduce their coal-power-generation-related carbon emissions by 39% to 95% in an orderly MPO scenario between now and 2050 compared with business-as-usual (BAU). Taken together, an orderly MPO across all 15 markets in APAC could reduce their aggregate carbon emissions by roughly 160 Gt — three-quarters (74%) less than business-as-usual — with mainland China (116 Gt), India (23.2 Gt) and Indonesia (5.9 Gt) the biggest beneficiaries.

The most orderly MPO pathway varies by market (Exhibit 1). For major emitters such as mainland China, India and Indonesia, for example, the most orderly MPO scenario would restrict the life of existing coal-fired power plants to 20 years with the aim of winding down operations at all of them by 2040. (The average life of a coal-fired power plant in the APAC region is assumed to be about 40 years if not disclosed.) Orderly MPO scenarios for Japan and Taiwan, where existing plants are older, would limit the life of coal-fired power plants to 30 years. Even the most orderly MPOs for Laos and Hong Kong would be relatively abrupt, our analysis shows.

Orderly scenarios for an MPO of coal-fired power in individual markets also reveal differences in the amount of emissions that can be reduced. Mainland China and Indonesia, for example, may be able to lower their emissions between 75% and 80% compared with BAU in a relatively orderly manner through MPO. In Australia and Japan, by contrast, no MPO scenario we evaluated, no matter how orderly or disorderly, could reduce cumulative emissions by more than 75% from BAU.

Exhibit 1: Emissions reductions achieved by APAC markets in their most orderly phaseout path



Source: MSCI Sustainability Institute

MPOs may help countries meet their climate pledges. The 15 markets analyzed here could eliminate as much as 83% of the cumulative reductions in coal-power generation needed to stay within their remaining 1.5°C-aligned budget were they to each pursue their most orderly MPO.

The framework discussed here could help policymakers across the APAC region evaluate the trade-offs of various MPOs for their countries and map out suitable time scales. The findings may also be useful for companies and investors. Companies that own or operate coal-fired power plants may reduce their exposure to policy shifts and improve their access to capital by aligning their strategy with an orderly MPO pathway. Investors with exposure to emissions-intensive industries such as coal-fired power can apply this evaluation framework to understand scenarios of MPO pathways that may help them navigate between avoiding an abrupt transition of energy systems and maximizing reductions in emissions.

Introduction

The COP28 climate conference will gather delegates from nearly 200 countries in Dubai, where they will aim to accelerate action by countries to stop climate change. Discussion will focus on achieving the goals of the Paris Agreement, which aims to constrain the rise in average global temperatures to well below 2°C above preindustrial levels, and preferably to no more than 1.5°C.[8] Some countries will need to support "the early retirement of unabated coal power plants," Sultan Ahmed Al Jaber, president-designate of COP28, wrote to delegates in October.[9]

To achieve this objective, countries agreed to set climate-related targets and timetables for their share of the global contribution to climate action. The collective carbon emissions of countries, including the companies and industries that operate within them, can be tracked against an emissions budget; that is, the total amount of carbon or other GHGs that can be released into the atmosphere while still limiting warming to globally agreed thresholds.

GFANZ, a coalition of eight financial industry alliances, coordinates efforts to promote climate finance and investing in line with a net-zero global economy. GFANZ has proposed four key strategies for investors who aim to drive the decarbonization of the real economy.[10] They comprise:

- Financing or enabling entities and activities that develop and scale climate solutions;
- Financing or enabling entities that are already aligned to a 1.5°C pathway;
- Financing or enabling entities committed to transitioning in line with 1.5°C-aligned aligned pathways; and
- Financing or enabling the accelerated, MPO of high-emitting physical assets

The phasing out of thermal coal is a precondition for achieving global climate goals. A MPO of coal may include decommissioning coal-fired power plants, substituting their output with sustainably produced energy such as power generated from renewables, or converting the plants themselves to run on clean energy.[11] However achieved, phasing out reliance on coal-fired power plants holds particular significance for the APAC region, which accounts for roughly 80% of coal emissions globally and where countries are currently planning to expand production of coal-fired power.[12]

Managing the phasing out of coal in APAC countries has become a focus of research to support investment decision-making. A recent study by researchers at the University of Maryland found that an early phasing out of coal and replacement with renewable energy sources in Indonesia would contribute significantly to that country's aligning with a 1.5°C pathway and benefit it financially in the long run.[13] Indonesia, however, would need international support in financing the transition in the near term.[14] An MPO of coal-fired power in mainland China between now and 2050 is essential to align the country's emissions with a 1.5°C pathway, a similar study finds.[15]

Our analysis assesses the feasibility of pathways for phasing out coal based on each market's ability to replace coal with renewable sources of power generation in a timely manner and trade-offs that policymakers and investors may need to consider. When evaluating the feasibility of a hypothetical MPO pathway, markets confront a trade-off between phasing-out coal quickly — which can maximize reduction of emissions but may require a sudden ramp-up in alternative energy and risk disruption in the energy supply — and phasing out coal slowly, which would mean delaying the transition at the cost of more emissions.

Hence, we've defined and examined the "smoothness" of the switchover of energy sources in hypothetical MPO pathways. We explore how markets might navigate this trade-off between reducing emissions and switching away from coal-fired power abruptly to identify an MPO that strikes a balance between the two extremes.

The results of our analysis estimate the quantity of emissions that each of the 15 markets can reduce, relative to a BAU scenario, by pursuing a smooth pathway in comparison with other pathways analyzed. We also evaluate which markets have a current stock of coal assets that may be more conducive to pursuing an orderly MPO compared with markets for which pursuing an orderly MPO would present more trade-offs.

Need for orderly transition from coal in the APAC region

By design, an MPO aims to minimize disruption to economies and livelihoods and maintain societal support for national climate action. MPOs for coal-power assets typically involve stopping construction of new coal-based power plants and gradually reducing the operating capacity of existing plants with the goal of closing them before the end of their operating life.

Though more than 40 countries agreed at the COP26 climate conference in 2021 to phase out coal-fired electricity generation, coal consumption globally hit a new high in 2022.[16] Consumption is expected to grow as demand from the APAC region, especially in mainland China and India, would more than offsets decline in the U.S. and EU.[17]

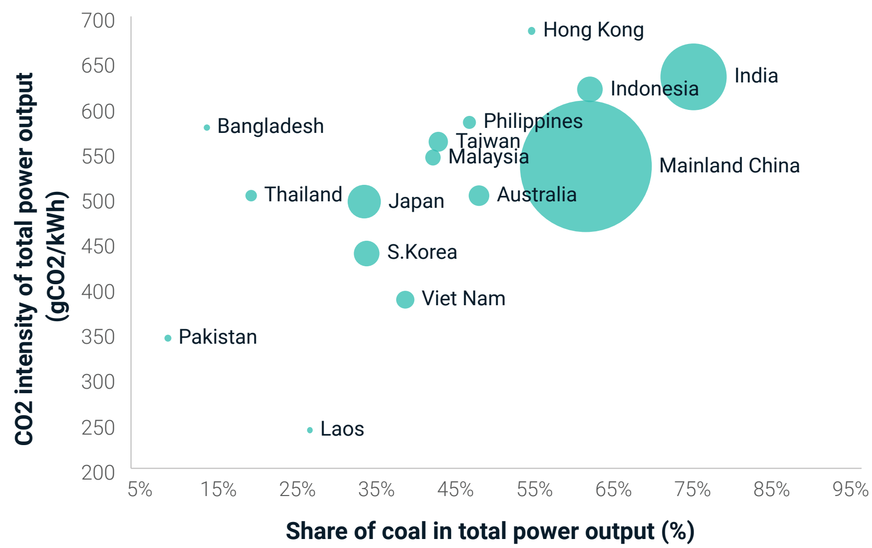
In the APAC region, several countries are still planning to build new coal-fired power plants. As of January 2023, the region accounted for 78% of operational and 96% of planned coal-fired electricity generation capacity globally.[18] Many governments in the region see coal as playing a key role in ensuring the security and affordability of energy (Exhibit 2). Mainland China, India, Indonesia, Australia and Vietnam in particular favor locally produced coal to minimize reliance on imports of natural gas and oil that both tend to be more expensive and subject to unpredictable changes in price. If not phased out, coal-fired power plants in use and planned for the APAC region would add roughly 215 Gt of carbon emissions to the atmosphere between now and 2050.[19] That's more than 40% of the global carbon budget that remains if society is to limit warming to 1.5°C above preindustrial levels.[20]

Still, phasing out coal more rapidly presents practical challenges for countries that depend on it. Several APAC countries and utilities that operate in them rely heavily on coal-generated electricity (Exhibits 2 and 3a). Since 2017, these companies have added coal-power generation capacity to meet growing demand for electricity in their respective markets (Exhibit 3b).

The faster the phase-out, the greater the likelihood of stranding coal assets, disrupting power supplies and triggering a sudden need for massive investment in renewables.[21] Decommissioning coal-fired plants may also bring with it a need to retrain workers and strengthen the safety net for communities.[22] The slower the phase-out, the less likely countries may be to uphold climate commitments that avoid the costliest warming. In this context, countries may prefer an orderly transition away from coal designed both to minimize the risk of energy disruption and help to achieve national climate plans designed to stave off the worst warming.

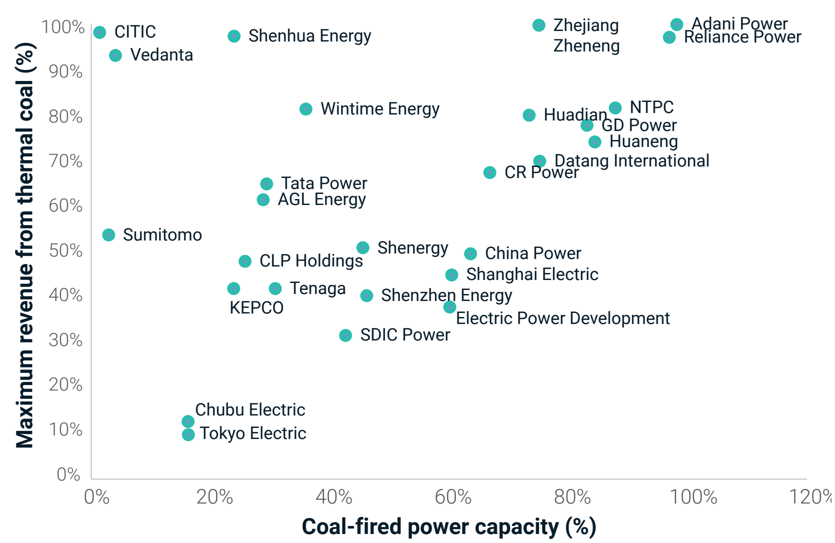
Countries that rely on coal, meanwhile, face global calls for a hard stop to its use. The International Energy Agency, for example, envisions that all unabated coal generation end by 2030 in countries that are members of the Organization for Economic Cooperation and Development and by 2040 everywhere else.[23]

Exhibit 2: Coal remains central to energy production and emissions in the APAC region



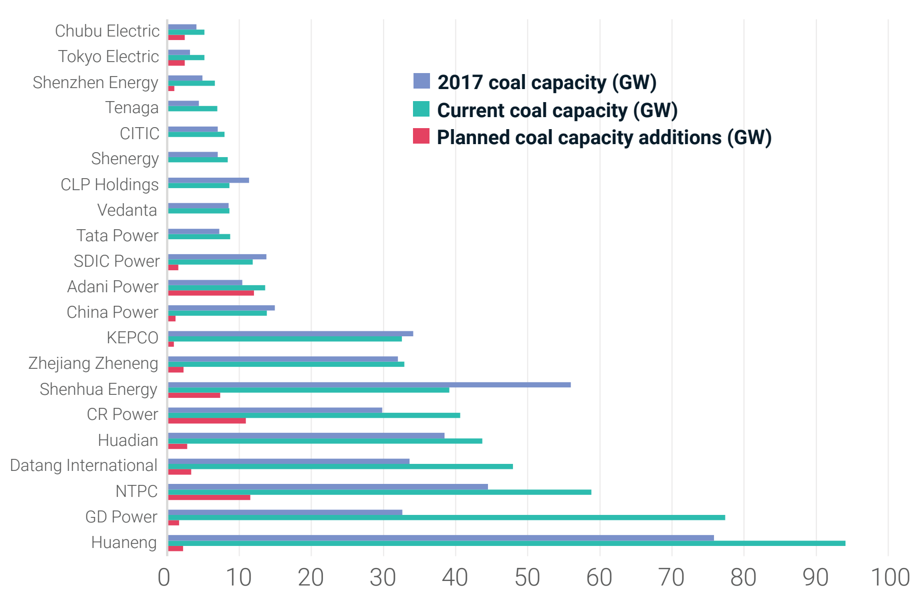
Source: MSCI Sustainability Institute calculations based on Ember Climate data as of Sept. 4, 2023. The chart shows data for 15 countries in APAC identified in the 'Scope of the analysis' section below. All values are for year 2022, except Laos and Hong Kong (2021). The size of the bubbles corresponds to the volume of coal-fired power generated.

Exhibit 3a: Largest coal-fired power generators in the APAC region



Source: MSCI Sustainability Institute estimates based on the latest company disclosures. Constituents of the MSCI ACWI Investable Market Index (MSCI ACWI IMI) as of Sept. 4, 2023 incorporated in APAC with at least 5 gigawatts of installed coal-fired power generation capacity.

Exhibit 3b: Evolution of coal-fired power capacity in the APAC region by company



Source: MSCI Sustainability Institute estimates based on the latest company disclosures. Constituents of the MSCI ACWI IMI, as of Sept. 4, 2023 incorporated in APAC with at least 5 gigawatts of installed coal-fired power generation capacity and installed coal-power capacity data available from 2017 onward.

MPO analysis for the APAC region

Below we evaluate scenarios for mapping the most orderly pathway for phasing out coal in each of the 15 markets examined and the reductions in GHG emissions that could result. We also estimate both the emissions that phasing out coal-fired power pursuant to an MPO would avoid and the increase in renewable energy capacity that would be required to substitute for the power phased out. The analysis may help policymakers in each market map policies for phasing out coal with an MPO as a possible approach.

Scenario description

To analyze the impact of MPO measures for coal-based power plants in a given market, we first defined both BAU and MPO scenarios based on the following assumptions:

BAU Scenario

- Existing coal plants continue to operate at the current utilization rate, also known as a plant-load or capacity factor.[24]
- Existing coal plants are retired in their retirement year, which is the disclosed year, if available. The scenario otherwise assumes that plants are retired at the end of 40 years of a plant's useful life. Mothballed plants are retired immediately.
- Pre-construction plants or those under construction are built and operated as planned.

MPO Scenario

- Existing coal plants continue to operate at their current rate of use. Mothballed plants are retired immediately.
- Pre-construction plants or those under construction are halted immediately and replaced with renewable energy power plants that provide a comparable amount of power.[25]
- Phasing out of existing coal plants starts in 2024. The life of such plants is reduced to between 10 and 40 years, depending on the MPO scenarios considered (Exhibit 4).
- We also consider two scenarios for the backstop year, which refers to the year by which all coal-based power plants are phased out.
- We assume that shortfall in power generation that results from an MPO compared with a BAU scenario would be addressed by the installation of renewable-energy power plants (via a combination of large-scale photovoltaic plants and wind energy) that produce a comparable amount of power.

We further assume in both the BAU and MPO scenarios that measures designed to reduce overall power demand, such as energy-efficiency programs in the respective markets, for example, have no impact on either the use of coal- and renewable-energy power plants in particular.

Varied MPO scenarios can be developed depending on the life of coal power plants and backstop year assumed. For this analysis, we have defined the MPO scenarios shown in Exhibit 4, where the name of each scenario reflects its parameters. An MPO scenario, for example, that envisions the average age of retirement for coal plants to be 20 years and 2040 as the backstop year is labeled a 20/2040 scenario.

Exhibit 4: MPO parameters and scenarios

Plant age at retirement (years)	2030	2040
40	40/2030	40/2040
35	35/2030	35/2040
30	30/2030	30/2040
25	25/2030	25/2040
20	20/2030	20/2040
15	15/2030	15/2040
10	10/2030	10/2040

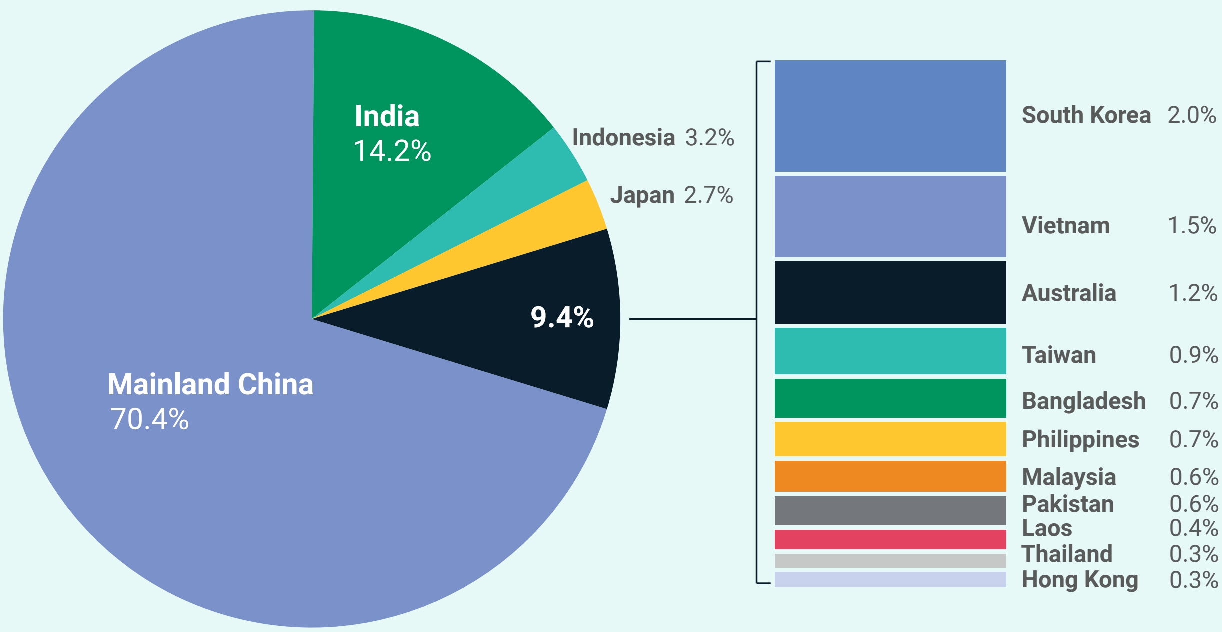
Backstop year

Source: MSCI Sustainability Institute

Scope of the analysis

We focus here on 15 markets in the APAC region (Exhibit 5).[26] Mainland China accounts for close to 70% of the region's roughly 2,100 gigawatts (GW) of coal-based power-generation capacity (both current and planned), with India and Indonesia accounting for 14.2% and 3.2% apiece, respectively.

Exhibit 5: Geographical distribution of coal power capacity (MW) in the APAC region



Source: Global Coal Plant Tracker, Global Energy Monitor, January 2023 release

Exhibit 6: Overview of coal-based power generation plants in the APAC region

	TOTAL		Operating	Construction	Permitted	Pre-permit	Announced	Average age of currently operating plants
Country/Region	**#**	**MW**	**MW %**	**MW %**	**MW %**	**MW %**	**MW %**	**Years**
Australia	58	24,977	96	0	0	4	0	36
Bangladesh	23	15,279	19	37	0	5	39	5
Mainland China	3,703	1,458,430	75	8	6	5	6	14
Hong Kong	14	6,110	100	0	0	0	0	35
India	933	294,759	79	11	4	3	3	18
Indonesia	321	66,976	61	28	1	6	4	10
Japan	157	55,928	95	4	0	1	0	22
Laos	15	8,914	21	0	22	11	45	8
Malaysia	25	13,280	100	0	0	0	0	15
Pakistan	31	12,380	62	6	10	22	0	4
Philippines	72	14,248	83	5	2	9	0	11
South Korea	83	42,294	93	7	0	0	0	17
Taiwan	55	19,244	100	0	0	0	0	23
Thailand	22	6,738	91	0	9	0	0	22
Vietnam	89	31,967	77	19	0	4	0	11
TOTAL	**5,601**	**2,071,523**	**76.2**	**8.9**	**5.1**	**4.8**	**5.0**	**15**

Source: MSCI Sustainability Institute

Calculation methodology

Our analysis used the methodology detailed below (Exhibit 7).

Exhibit 7: Assessment methodology

Analysis conducted and input data

Analysis

1. Project future coal power generation (MWh) and emission (tons CO2) trajectory for BAU scenario for all plants in a given market.
2. Project future coal power generation (MWh) and emission (tons CO2) trajectory for each MPO scenario for all plants in a given market.

Input data

- **Plant data:** plant capacity (MW), utilization rate, carbon emission factor, projected retirement year.
- **MPO scenario specific data**: plant's maximum life and backstop year.
- For a given market, coal power generation volume (MWh) trajectory aligned with NGFS' net-zero 2050 scenario.

Analysis conducted and input data

For each MPO scenario:

1. Incremental annual and cumulative **coal power capacity retirement (MW and MWh)** and **renewable energy capacity needed (MW and MWh).**
2. **MPO orderliness** – measures how orderly a given phase-out path is. A more orderly phaseout path will have even and/or distributed renewable energy additions during the phase-out. It is measured as the standard deviation of annual renewable capacity addition schedule normalized by the average of annual capacity additions.
3. **Avoided emissions** – computed as the difference between projected cumulative emissions in BAU scenario and MPO scenario.
4. **Coal power reduction achieved vs. required (%):** measured as the ratio of coal power reduction achieved in the MPO scenario and the coal power reduction required in net-zero 2050 scenario.

Source: MSCI Sustainability Institute

Key performance metrics

We explain key performance metrics below. Key input data and sources are explained in the Appendix.

1. Coal power capacity retirement and renewable power capacity additions

a. Incremental annual and cumulative coal power capacity retirement (in MW)

i. Incremental annual coal power capacity retirement is computed as the difference between coal power capacity retirement in the MPO and BAU scenarios.

ii. Cumulative coal power capacity retirement in the MPO scenario is computed as the sum of annual coal power capacity retirement from 2024 to the respective backstop year.

b. Annual and cumulative renewable capacity addition (MW)

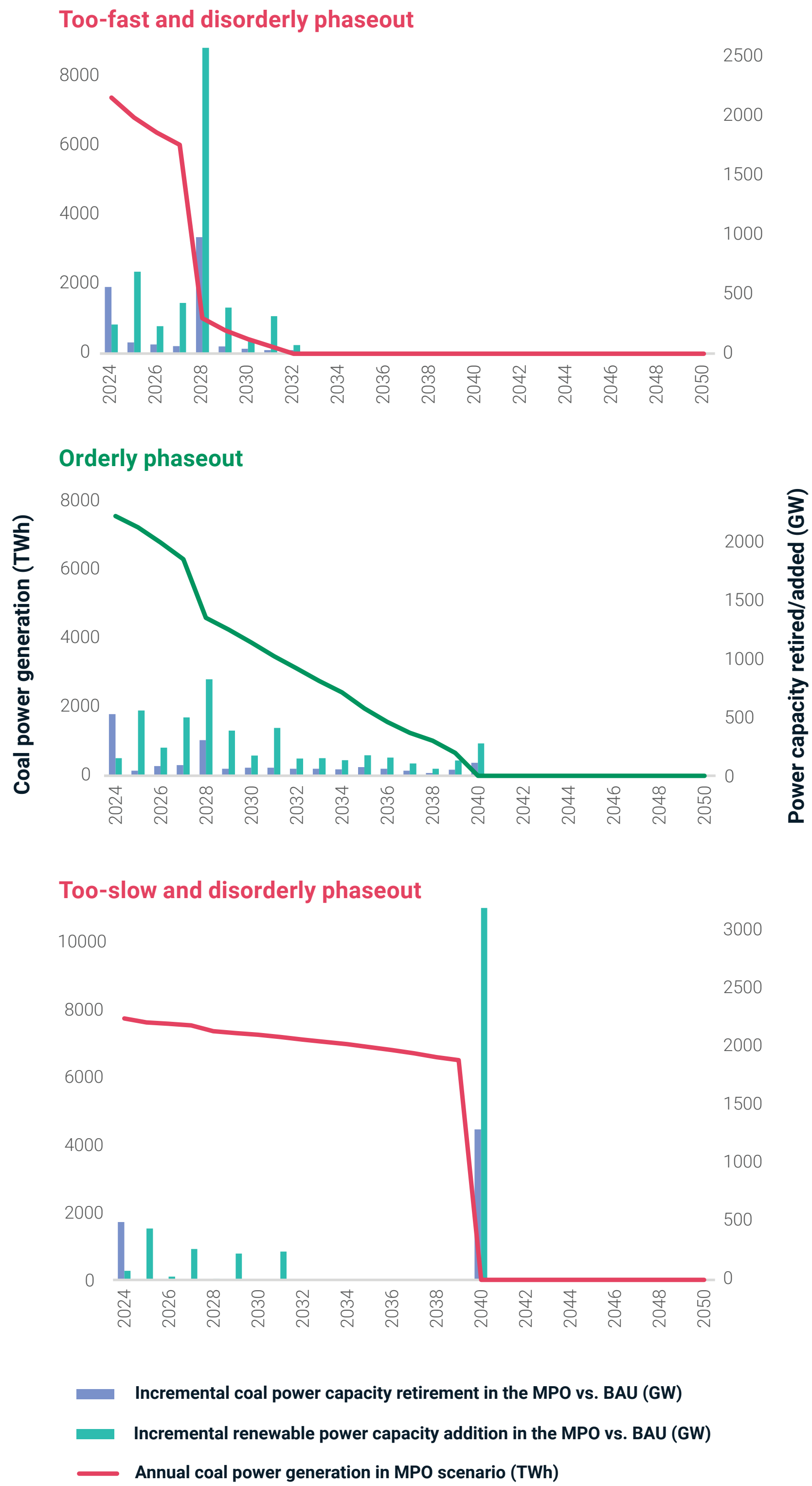
i. Annual renewable capacity addition is computed as the renewable power capacity needed to address the power generation volume (MWh) shortfall created due to incremental retirement of coal power capacity in the MPO scenario.

ii. Cumulative renewable capacity (MW) addition in the MPO scenario is computed as the sum of annual renewable capacity addition from 2024 to the respective backstop year.

2. MPO orderliness

We assess the orderliness of a given MPO scenario by assessing the evenness of renewable energy capacity additions anticipated for a given market. We compute orderliness as the standard deviation of annual renewable capacity additions normalized by the average annual capacity addition; that is, coefficient of variance of annual renewable capacity addition schedule. The lower the value of this metric is, the more orderly the MPO is assumed to be (Exhibit 8).

Exhibit 8: MPO orderliness explained

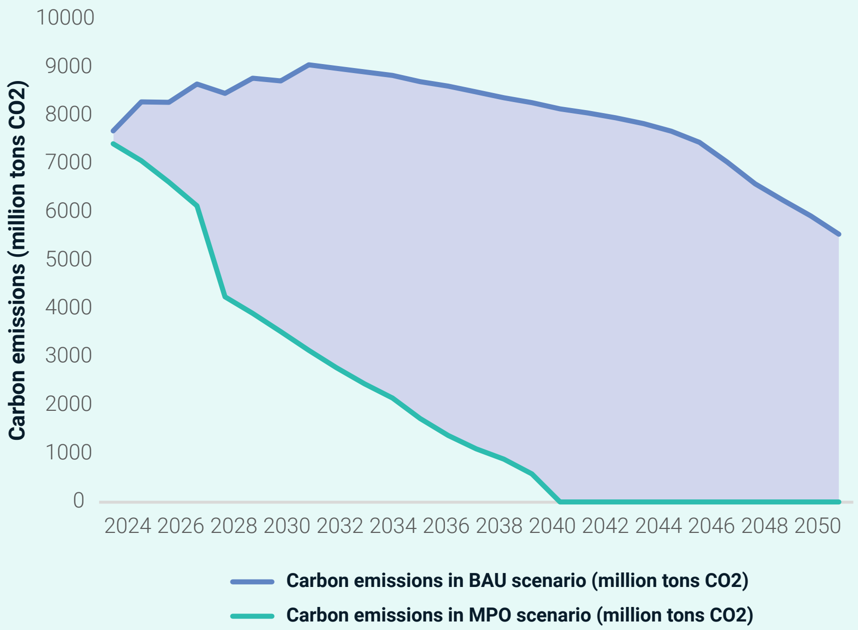


Source: MSCI Sustainability Institute. Results are for the APAC region comprising 15 markets.

3. Avoided emissions (Gt CO2)

We compute avoided emissions as the difference between cumulative carbon emissions in the BAU MPO scenarios (Exhibit 9). By quantifying the potential carbon emissions reductions due to MPO measures, this metric is designed to highlight the potential contribution of implementing an MPO to reducing warming.

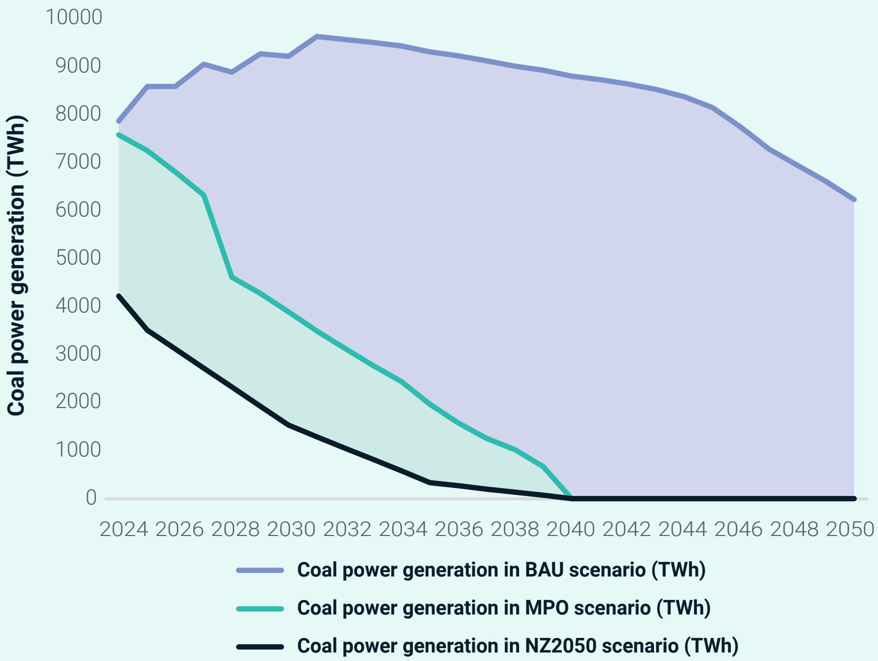
Exhibit 9: Avoided emissions in most orderly scenario for the APAC region



Source: MSCI Sustainability Institute

To see the extent to which a given MPO scenario may help markets in achieving their net-zero 2050 targets, we compute a ratio of avoided coal-power-generation through MPO measures (vs. BAU scenario) and the required reduction in coal power in a net-zero 2050 scenario (vs. BAU) in the respective markets. The calculation appears as the ratio of area highlighted in green to total highlighted area in Exhibit 10.

Exhibit 10: Coal power reduction achieved vs. required for the APAC region



Source: MSCI Sustainability Institute

Results

Below we discuss the results of the analysis, which seeks the most orderly path from among the scenarios for phasing out coal-fired power generation and replacing it with power produced from renewable energy in each of 15 markets in the APAC.

Identifying an orderly MPO

An orderly MPO would proceed along a timeline that's anticipated and come with commensurate additions of clean-electricity generation. We measure orderliness of a phase-out as the standard deviation of the annual renewable capacity addition schedule normalized by the average of annual capacity additions. The lower the value of this ratio is, the more orderly the MPO is assumed to be. We term this ration as MPO orderliness.

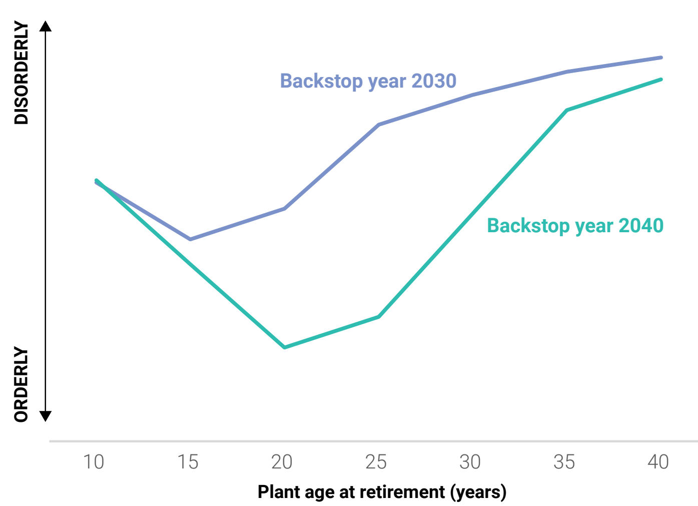
MPO orderliness varies with the speed of the phase-out. Orderliness tends to be low in a phase-out that proceeds too fast or too slowly, as in those scenarios, a sudden ramp-up and abrupt switchover to renewable capacity is required. Our hypothesis is that a path characterized by relatively higher orderliness exists somewhere between those two extremes (Exhibit 8). At either extreme, markets face the prospect of cutting coal-power without a commensurate and timely ramping up of investment and delivery of sustainably generated power, increasing the risk of power disruptions.

Exhibit 11 highlights the impact of both MPO parameters — plant age and backstop year — on the orderliness of MPO scenarios. Note that for a given plant age, scenarios with an early backstop year (such as 2030) generally tend to be disorderly compared with scenarios that set 2040 as the backstop. The phenomenon reflects a concentration of plant retirements over the remaining six years of this decade and the sudden ramp-up of sustainably produced power (and commensurate investment) that would be required to meet the shortfall created due to phase-out of coal power plants.

Note too that when the backstop year remains constant, MPO scenarios marked by either very young or very old plant age demonstrate higher disorderliness. Scenarios that restrict the limit on plant age to a lower value mean the market confronts a phase-out that unfolds over less time, leading to the need to add renewable capacity all at once.

Scenarios that allow for older plants, by contrast, incentivize the market to slow its phase-out. Without plant closures over the near- to medium term, the market has less need to generate electricity from renewables. As the backstop approaches however, the market faces the need to add sustainably produced power suddenly, creating disruption and cost. Between these two extremes should logically lie an MPO scenario marked by relatively higher orderliness (Exhibit 11).

Exhibit 11: Impact of MPO parameters on the MPO orderliness for the APAC region



Source: MSCI Sustainability Institute

The most orderly MPO scenario differs by market (Exhibit 12). 2040 appears to be the backstop year associated with the most orderly scenario for each of them, the analysis finds. The most orderly MPO scenario for most APAC markets is associated with coal-fired power plants that have operated for about 20 years, meaning they are about halfway through their useful life. An MPO in such markets, which include mainland China, India and Indonesia, would aim to retire those plants before 2040.

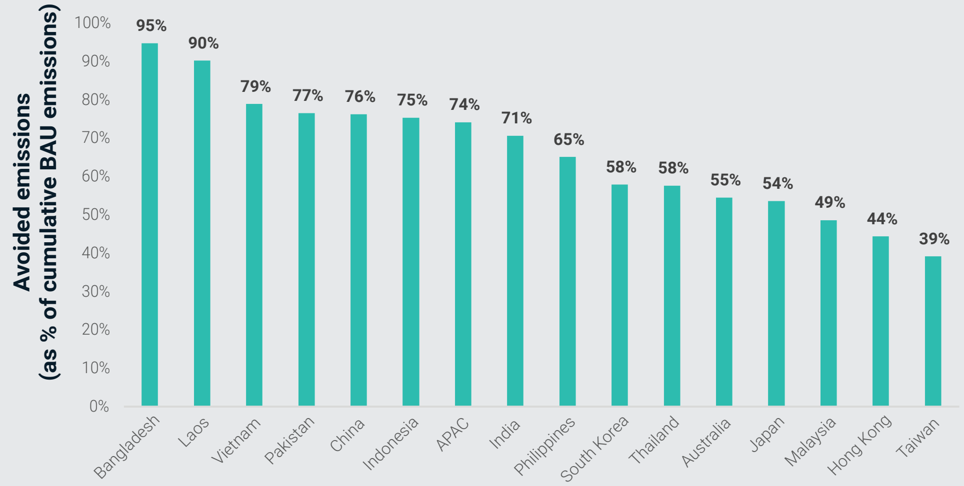
Exhibit 12: Most orderly MPO scenario for markets in the APAC region

Source: MSCI Sustainability Institute. Based on the simulation, the analysis finds the backstop year associated with most orderly scenario for all markets to be 2040.

Avoided emissions and coal power in the most orderly scenarios

The 15 markets examined could cut their carbon emissions nearly three-quarters (74%) on average between now and 2050 were they to follow their most orderly MPO compared with business-as-usual (Exhibit 13). The reductions range from a low of 39% in Taiwan to a high of 95% in Bangladesh. On an absolute basis, the most orderly MPO translates to 160 Gt of emissions reduced cumulatively across the region, including reductions of 116 Gt in mainland China, 23.2 Gt in India and 5.9 Gt in Indonesia.

Exhibit 13: Avoided emissions (% of BAU carbon emissions)

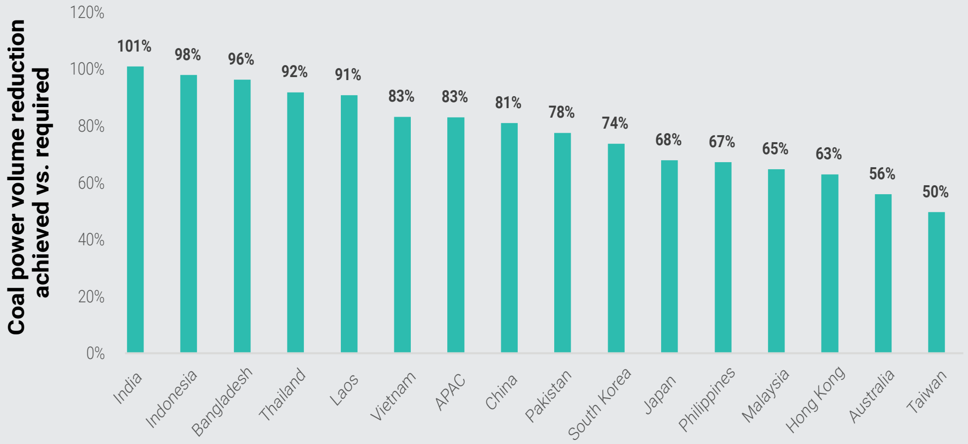


Source: MSCI Sustainability Institute

To assess the extent to which MPOs would help the 15 markets achieve their net-zero targets, we computed a ratio (%) of coal power reduced through the cutback in coal-fired power via MPOs (vs. BAU) and the reduction in coal-fired power required in a scenario that aims to reach net-zero by 2050 while limiting the rise in average global temperatures to 1.5°C.[27]

The analysis indicates that by following their respective MPO pathway markets can reduce coal power generation by between 50% to 101% of the quantity each would need to remain within its share of the global budget for the coal power sector (Exhibit 14). At the aggregate level for the APAC region, this translates to approximately 83% of the coal power reduction that would be required to reach net-zero by 2050 for the coal power sector.

Exhibit 14: Coal power reduction achieved vs. required as per NGFS scenario

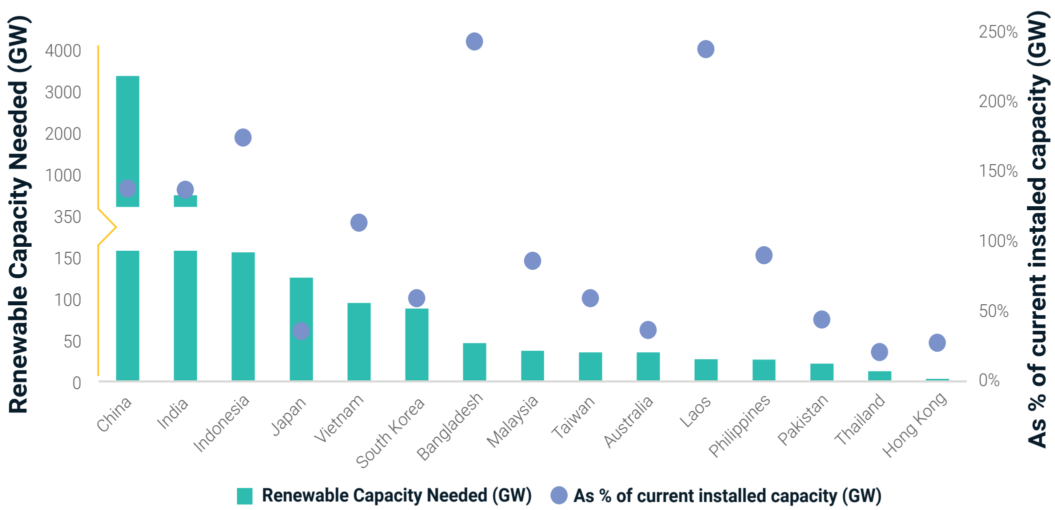


Source: MSCI Sustainability Institute

Renewable energy capacity needed in the most orderly MPO scenarios

The additional amount of renewable energy capacity the 15 markets would need to substitute for coal-fired power in their respective most orderly MPO scenario would range from 3,350 GW in mainland China to roughly 3.2 GW in Hong Kong (Exhibit 15). While major markets such as mainland China and India would have substantial demand for renewable energy capacity on an absolute basis, on a relative basis markets such as Bangladesh and Laos could see demand for renewable energy of more than double their current total installed capacity.

Exhibit 15: Renewable energy capacity (GW) needed in the most orderly MPO scenarios



Source: MSCI Sustainability Institute

Conclusion

Our study simulated scenarios for an MPO of coal-fired power plants in 15 markets in the APAC region with the aim of identifying the most orderly way of winding these plants down and replacing with clean energy. We further assessed the relevance of an MPO of coal-fired power plants for aligning their respective countries with global climate goals.

Our analysis shows that the most orderly MPO scenarios will differ by market, a finding that may help policymakers in each of those examined fine-tune the phasing out of coal-fired power. It also shows the important contribution that MPOs can have as part of a broader energy-sector transition plan.

MPOs may help markets achieve their climate commitments, with an orderly MPO helping some markets completely avoid consuming more than their share of the global carbon budget for the use of coal-fired power. Other markets would need to find additional ways to reduce emissions from burning coal to reach net-zero even were they to implement the most-orderly MPO.

The report offers information that may be of use for companies and investors. Financing of companies based on their plans for phasing out their carbon-intensive assets may offer an opportunity for investors who want to promote an orderly transition by investing in whole-economy decarbonization. Such investors could measure avoided emissions to quantify the potential contributions to mitigating warming from their investments.

Aligning their business with an MPO may also help companies that aim to reconfigure their operations around renewable energy. These companies can often struggle to raise capital because of their ownership of coal-fired power plants, but such an alignment may improve their access to capital and lower its cost. Finally, MPOs may help countries that rely on imported coal for energy improve energy security by boosting production from locally available sources of renewable energy such as solar and wind.

Appendix

Data assumptions

1. When there is no information regarding the start year of an operating plant, the start year is estimated as the average of start years of other plants in the same market.

2. When there is no information regarding the start year of a plant under construction or pre-construction stage, it is assumed that under construction plants will start their operations in two years from now (in 2025). Similarly, plants in permitted, pre-permit and announced stages will start their operations respectively in four, six and eight years from now.

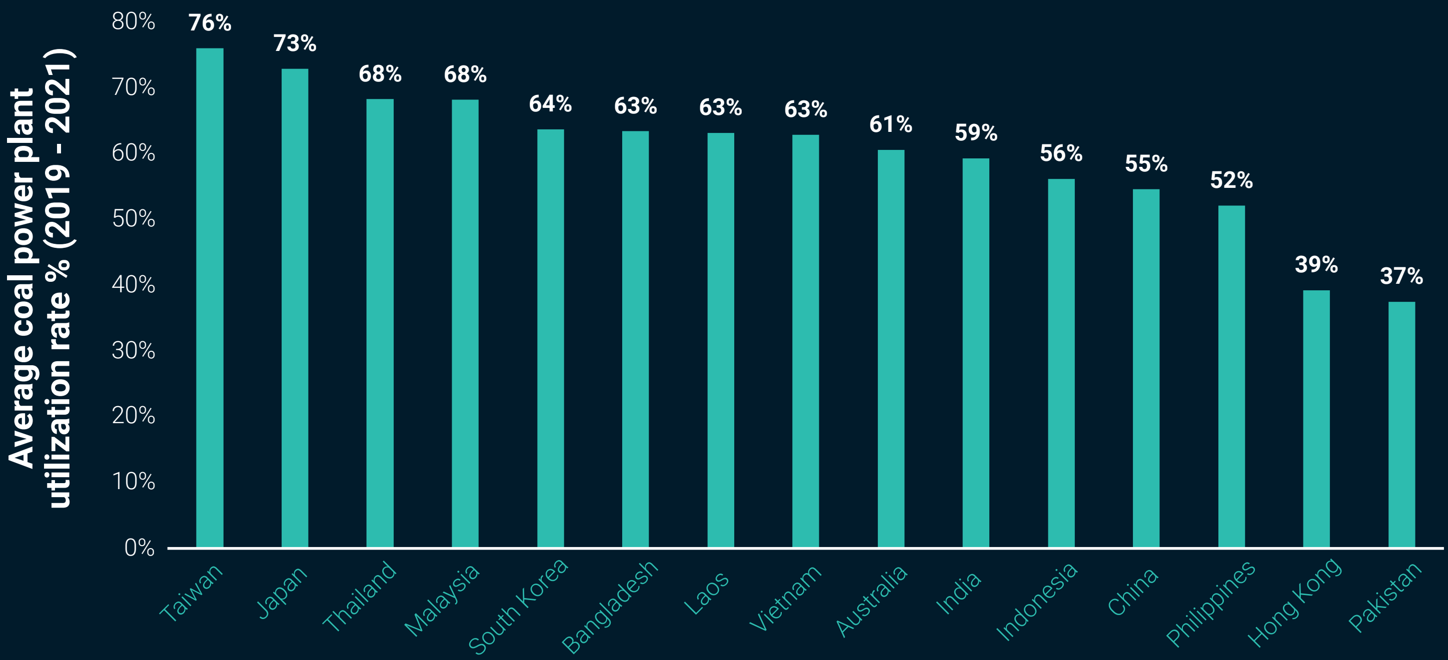
3. A plant's age is computed as the difference between its retirement year and start year. In case this information is unavailable, it is assumed to be 40 years in the BAU scenario.

4. Plant utilization rate for future years for all plants in a given market is estimated based on coal-power-generation volume and coal capacity data during 2019-2021.

Data sources

Data	Source
Plant data: capacity, location, emission factor, plant status, start year, retirement year.	Global Coal Plant Tracker, Global Energy Monitor, January 2023 release
Average coal-power-plant utilization rate (Exhibit 16)	Ember Climate. Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/
Plant utilization rate for renewable energy	World Energy Outlook 2022, International Energy Agency (IEA)
1.5°C-aligned coal power generation trajectory for given markets	NGFS' net-zero 2050 scenario (REMIND-MAgPIE 3.0-4.4)

Exhibit 16: Average coal-power-plant utilization rate by market



Source: MSCI Sustainability Institute

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1. Coal accounts for roughly 40% of global carbon dioxide emissions. See, Anthony Burke and Stefanie Fishel, "A coal elimination treaty 2030: Fast tracking climate change mitigation, global health and security," Earth System Governance, Volume 3, March 2020.
2. See generally, "Coal in Net-Zero Transitions," International Energy Agency, November 2022
3. We use markets here to refer to a set of governments that includes both mainland China and Taiwan.
4. "Global Coal Plant Tracker," Global Energy Monitor, January 2023.
5. Assumes a remaining 1.5°C carbon budget of +/- 500 Gt. See IPCC's Sixth Assessment Report, Working Group 1, Chapter 5, FAQ 5.4. The term plants in this analysis refers both to coal-fired power plants that currently exist and those that are planned.
6. GFANZ's request for this work does not signify endorsement of the entire report and its recommendations.
7. Orderliness of the phase-out refers to its gradualness over the phasing out period for coal-fired power and its replacement with sustainably-produced power in a specific country or region. Disorderliness refers to suddenness that would come, for example, with phasing out a large chunk of coal-power capacity all at once in a specific country or region.
8. "The Paris Agreement," UN Framework Convention on Climate Change, 2015.
9. "COP28 UAE, United, Act, Deliver," Letter from Dr. Sultan Ahmed Al Jaber, Oct. 18, 2023.
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11. Cui, R. Y. et. al., "Quantifying operational lifetimes for coal power plants under the Paris goals," Nat Commun 10, 4759 (2019).
12. "Coal in Net Zero Transitions," International Energy Agency, November 2022
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15. In November 2022, Indonesia's government and members of the Group of 20 nations, co-led by the U.S. and Japan, launched a partnership for ambitious new targets for Indonesia's energy-sector transition backed by an initial USD 20 billion in public and private financing to support the country achieving its objectives. See, "Indonesia and International Partners Secure Groundbreaking Climate Targets and Associated Financing," The White House, Nov. 15, 2022.
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18. "Coal Market Update," International Energy Agency, July 2023.
19. "Global Coal Plant Tracker," Global Energy Monitor, January 2023.
20. The APAC region is acutely vulnerable to the effects of climate change. See, "Most Prevalent Climate Hazards Found in Asia-Pacific," MSCI Sustainability Institute, May 10, 2023.
21. Assumes a carbon budget of less than 500 Gt. "Climate Change 2021: The Physical Science Basis, Sixth Assessment Report," Intergovernmental Panel on Climate Change, Aug. 9, 2021.
22. Listed-company owners of stranded coal plants could face stranded assets up to 78% of their share price. See, Angelika Van Dulong, "Concentration of asset owners exposed to power sector stranded assets may trigger climate policy resistance," Nature Communications, Oct. 13, 2023.
23. "UN Agencies Support the Just Energy Transition in Asia," UN Framework Convention on Climate Change, June 21, 2022.
24. "Phasing Out Unbated Coal, Current status and three case studies," International Energy Agency, October 2021.
25. Source: Glossary - U.S. Energy Information Administration. Capacity factor is defined as the ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period. Please refer to Appendix for more information on sources of utilization-rate data.
26. An equal combination of large-scale solar photovoltaic and onshore wind power.
27. We excluded countries from the former Soviet Union and those with less than 10 terawatt hours of annual coal-power output (according to data provided by Global Coal Plant Tracker) to arrive at a list of 15 markets in the APAC region.
28. As per NGFS' Net-Zero 2050 scenario (REMIND-MAgPIE 3.0-4.4)