COUNCIL OF ENGINEERS FOR THE ENERGY TRANSITION
An independent advisory council to the United Nations Secretary-General

Navigating the Coal Transition in Asia: Challenges, Lessons, Pathways

Key Messages

The primary challenge for the Asian region in reaching net-zero carbon emissions by 2050 is phasing out almost 1,700 GW of coal-fired power plants. Asia accounts for 78% of the world's coal electricity production, with China and India alone accounting for a combined coal capacity of 1,373 GW.

Halting global financing for coal investments has been key to reducing coal projects across Asia. Financial measures shift economic and cost structures, thus reducing the value of coal-fired power plants while enhancing the value of low-carbon assets. These measures have contributed to the cancellation of over 1,300 GW of coal projects since 2010 across Asia.

To phase out coal in Asia, renewable energy must be scaled rapidly in tandem. Tripling renewable energy and doubling energy efficiency by 2030, supported by bankable projects and private sector funding, is critical to meet rising energy demand and significantly reduce coal reliance in the region.

The effective implementation of coal phase-out in Asia requires strong support from a mix of policy and financial mechanisms. Key measures and incentives being deployed include stricter emissions and efficiency standards, caps on coal electricity production, the elimination of fossil fuel subsidies, and carbon pricing.

Countries can retrofit and refurbish coal-fired power plants to incorporate cleaner energy sources. This includes repurposing coal assets with either biomass or ammonia, repowering facilities with nuclear, or retrofitting plants for renewables and energy storage. The estimated cost of decommissioning a 1 GW coal-fired plant and replacing it with clean energy can exceed USD 1.9 billion, depending on the plant's age.

The phase-out of coal in Asia represents a significant financial challenge and could result in negative economic impacts, as well as backlash from workers and companies in coal-dependent regions. Whole-of-economy approaches, just transition policies, and financial strategies are essential for countries to succeed in phasing out coal.

Purpose and Objectives of the Report

The purpose of the report, *Navigating the Coal Transition in Asia: Challenges, Lessons, Pathways*, is to inform stakeholders about the best practices and possible pathways to reduce coal use in Asia. This report aims to accomplish the following:

1. Provide a comprehensive overview of the key challenges and gaps in the phase-out of coal in Asia.
2. Identify key levers and determinants for reducing the use of coal in electricity generation.

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3. Facilitate best practices and knowledge sharing in technology, financing, policy, and market mechanisms using country case studies.
4. Recommend possible pathways for phasing out coal-fired power generation in Asia.

While phasing out coal remains a critical priority in line with global climate goals, the report recognizes that for countries facing significant energy security and economic challenges, phasing down coal can serve as a practical, immediate step. The challenges and solutions discussed in this report apply to both phase-down and phase-out strategies, ensuring a pathway that supports countries in transitioning while addressing their unique circumstances.

This report is intended to garner support for a coal phase-out from key regional stakeholders. It aims to spur coordinated action, foster investment, and guide strategic decision-making among governments, financial institutions, and private sectors across the region.

Executive Summary

A delayed phase-out of approximately 1,700 GW of coal-fired power plants presents the biggest challenge for the Asian region in reaching net zero by mid-century. Encouragingly, halting coal financing has been one of the most significant factors in preventing the construction of new coal-fired power plants, helping the region substantially reduce its pipeline of coal projects over the past decade.

Given the urgency and complexity of the coal transition, which involves a combination of technical, financial, and social factors, this brief aims to provide an overview of the key challenges and gaps in phasing out coal-fired generation in the region and to discuss strategies, solutions, and best practices for reducing coal use in the energy system. Figure 1 provides indicative implementation timelines for key solutions to reduce coal use in ASEAN.

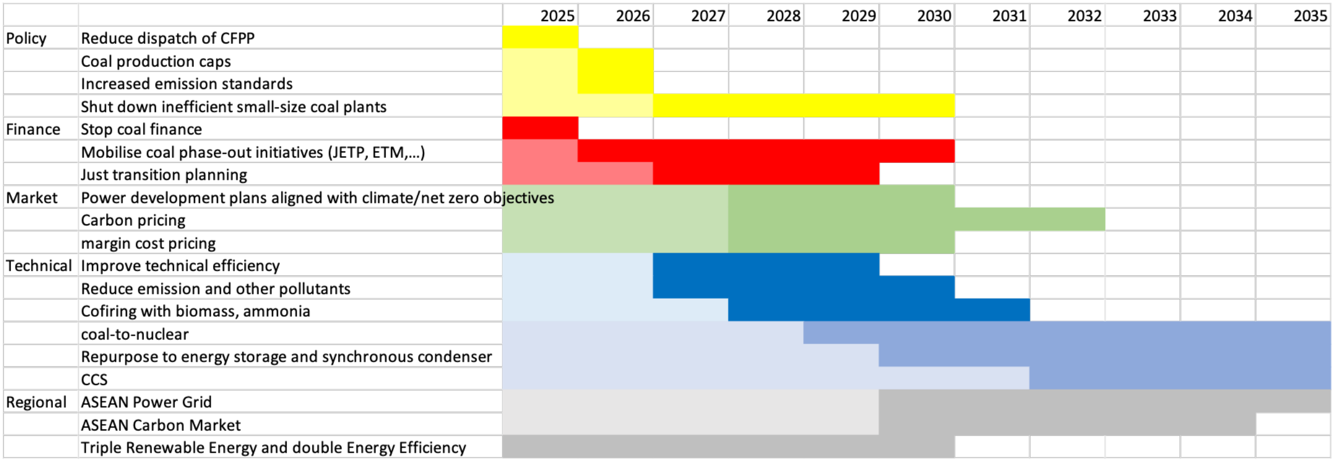
Policy measures can be implemented in a relatively shorter timeframe. These may include more stringent emission and efficiency standards, phasing out coal subsidies, capping coal-generated electricity, and intentionally reducing coal generation dispatch. Market measures can also be considered in countries with advanced electricity markets, such as carbon pricing and marginal cost pricing, to promote renewable electricity and encourage investment, thereby reducing coal generation.

Technical solutions generally involve investments in physical equipment and assets to increase plant efficiency and reduce emissions and pollutants. This can be achieved through upgrading and modifying plants and equipment; for example, by retrofitting and replacing low-efficiency subcritical plants, transitioning from coal to nuclear, using biomass or ammonia cofiring, or repurposing sites for energy storage or synchronous condensers to enhance grid capacity.

At the system level, **more rapid development of clean and renewable energy** will weaken the economic case for coal plants and accelerate the coal phase-out in the region.

Focusing on country case studies, this brief aims to enhance understanding of strategies and solutions for phasing out coal-fired power plants in the region and to serve as part of a toolkit for policymakers and utilities in energy system planning toward carbon neutrality. Additionally, we hope this brief can serve as a reference for collective action among regional efforts and initiatives in the phase-out of coal-fired power generation in Asia.

Figure 1. Indicative implementation timelines for key solutions for reducing the use of coal. Light colors signal the length of planning stage; dark colors signals the length of implementation stage; dashed lines signals the ongoing implementation and effectiveness; small red triangle signals the discontinued actions due to complete shut down inefficient small-size coal plants in Asia. Figure was created by the author for this Issue Brief.



1. Introduction

As of April 2024, 78% of the global capacity of coal-fired power plants (CFPPs) is located in Asia (excluding Australia), totalling 1,667 GW.[1] All six countries with the most coal-fired power capacity added since 2015 are in Asia: China (+260 GW), India (+48 GW), Indonesia (+26 GW), Vietnam (+14 GW), Japan (+13 GW), and South Korea (+10 GW).

China and India have the world's largest coal fleets, with a combined capacity of 1,373 GW, and both would need to phase out coal by 2040 to meet Paris Agreement goals. China has pledged to slow coal expansion and "start phasing down coal use from 2026," while India has not set a coal phase-out date. However, their coal fleets continue expanding to meet the demands of their growing economies, with more than 200 GW and 80 GW of new coal capacity in the pipeline in China and India, respectively. Much of this new capacity will be supercritical[2] or ultra-supercritical with higher efficiencies. As the share of renewable energy in both countries increases significantly, coal-fired generation load factors are expected to gradually decline over the next two decades. For example, India is projected to see a sharp decline in coal-fired generation share from over 70% in 2025 to 34% by 2040, while solar power's share will increase to 31%.[3] In the near term, however, the overall capacity of coal-fired generation continues to grow.

In Southeast Asia, there is approximately 106 GW of active coal-fired power capacity, with Indonesia and Vietnam having the largest fleets at over 45 GW and 25.8 GW, respectively. The region's coal power fleet is relatively young, with an average plant age of about 13 years as of 2023.[4] Currently, 17.9 GW of new coal-fired power plants are planned in Indonesia, Lao PDR, the Philippines, Thailand, and Vietnam. Since 2010, another 135 GW of coal-fired power plants were planned in Southeast Asia but were ultimately canceled.

Several Asian countries, listed in Table 1, have pledged either to withdraw coal financing or to phase out their coal-fired power plants to align with the Paris Agreement goals.

Amid tighter international financing restrictions for coal-related investments, many proposed coal-fired power plant projects in the region have been canceled over the past 15 years, totaling 1,197 GW between 2010 and 2024. However, the region still has 125 GW of new coal-fired power plants in the pipeline, excluding China. This figure, nonetheless, represents a significant decline compared to 476 GW as of July 2022.[5]

Despite this progress and trend, it is well known that "To meet the Paris Climate Agreement goals, all existing coal plants must be retired by 2030 in the world's richest countries and **by 2040 everywhere**."[6]

Table 1. List of selected Asian countries that have pledged to reduce coal use

China	In 2021, President Xi Jinping announced that Chinese public banks will stop supporting new coal-fired power plants abroad.
Indonesia	In 2022, a presidential decree was issued to create a plan to eliminate coal generation by 2050. There have been over 8 GW captive coal generators constructed.
Japan	In 2020, Japan announced to withdraw their financing for coal projects. In 2024, G7 members commit to phase out existing unabated coal power generation in their energy systems during the first half of 2030s or in a timeline consistent with keeping a limit of 1.5°C temperature rise within reach, in line with countries' net-zero pathways.
The Philippines	In 2020, the Philippines imposed a moratorium on building new coal-fired power plants and is contemplating a strategy to phase out coal power by 2050.
Republic of Korea	In 2020, the Republic of Korea announced to withdraw their financing for coal projects.
Vietnam	In 2021, Vietnam committed to phase out unabated coal power by the 2040s, or as early as possible thereafter. Liu Caiyu, "Industrial Report Calls for Optimizing China's Nuclear Power Layout," Global Times, April 15, 2024.

Progress in moving away from coal has been slow in Asia, even with strong support from global initiatives and partnerships in recent years, including the Asian Development Bank's Energy Transition

Mechanism (ETM), the launch of Just Energy Transition Partnerships (JETP), and the 2021 Global Coal to Clean Power Transition Statement at COP26.

Working closely with key stakeholders in the region, this report aims to address the following questions:

- What technical and technological options are there to reduce coal usage in electricity generation?
- What are the key determinants of coal investments in the region?
- What instruments and measures are being employed? What lessons can be learned from other countries, both within the region and across the globe?
- What are possible pathways in phasing out coal-fired power plants in the region?

Section 2 explores critical challenges and gaps in phasing out coal-fired power plants (CFPPs), including technical and financial challenges, just transition, renewable energy implementation challenges, as well as whole-of-economy considerations in CFPP investment decision-making. Section 3 delves into solutions and best practices for reducing coal use in the Asian region and beyond. Section 4 outlines a range of financial, policy, and economic mechanisms to facilitate the coal phase-out. In Section 5, we conclude with recommendations and possible pathways for coal transition in Asia.

2. Opportunities and Challenges in Phasing-out Coal-fired Power Plants

Challenges and considerations in phasing out coal-fired power plants to meet the Paris Agreement goals include potential negative economic impacts, socio-political feasibility, technical feasibility, financial feasibility, and securing a just and socially equitable transition. These factors may relate to energy security, regional development, use of domestic resources, international trade and relationships, rent extraction by vested interests, environmental conditions and regulations, energy economic conditions, available technologies, institutions, stakeholders, and political considerations.[7,8]

Technical Challenges

The types and extent of technical challenges are specific to each country and its electric power grid. However, they can be broadly categorized as follows:

A. **Grid Stability, Reliability, and Resilience**: Grid operators are concerned about the stability, reliability, and resilience of power system operations without adequate baseload generation from traditional resources, which provide inertia and dispatchable capacity. The growth and large-scale deployment of alternative resources, such as battery energy storage systems (BESS) and synchronous condensers from converted thermal units, will help alleviate these concerns but will take time to become cost-effective and scalable. In short, for system operators, ensuring grid stability and reliability requires sufficient baseload capacity. Maintaining grid stability with renewable resources alone is challenging in the near term, creating a need to keep part of the thermal generation in operation.

B. **Carbon Reduction and Decarbonization of Residual Thermal Generation**: Carbon reduction can be achieved through several technologies, including: (i) increasing the efficiency of power generation, optimizing dispatch, and reducing spinning reserves; (ii) converting coal-fired generation to gas-fired generation where technically and commercially feasible; (iii) co-firing with ammonia or biomass; (iv) adding carbon capture, utilization, and storage (CCUS) to select plants with strong technical or commercial drivers to support the required investment; and (v) using carbon-free fuels such as green hydrogen. Elements (i) and (ii) are based on well-proven technologies, while (iii) to (v) are in various stages of pilot testing and demonstration.

C. **Increasing Electricity Demand**: In several Asian countries, there is a significant rise in electricity demand driven by industrialization, urbanization, and increasing standards of living. Consequently, although much of the new demand is being met by renewables, the need for existing thermal generation remains high—as does the need to ensure dispatchability and flexibility. These challenges will diminish over time; however, until thermal generation is decommissioned, repurposed, or decarbonized, solutions must be quickly adopted to improve the efficiency of the existing coal fleets.

Financial Challenges

The phase-out of coal-fired power plants requires substantial financing to transition to cleaner generation resources. This financing must cover the costs of modernizing existing infrastructure, the opportunity costs and economic losses associated with shutting down existing coal-fired generation capacity, and facilitating a just and equitable transition for communities reliant on coal for their livelihoods.

The financial costs are largely correlated with the age of the coal-fired power plants (CFPPs). Younger plants entail higher write-off values, particularly where outstanding debt remains and Power Purchase Agreements (PPAs) are yet to be fulfilled. For example, legacy PPAs for coal-fired power plants with “take-or-pay” conditions in India, Indonesia, and Vietnam are likely to incur substantial economic losses as these assets’ value is often guaranteed by contractual terms.

Conversely, newer plants are more suited for retrofitting with biomass or ammonia combustion and fuel blending, or for repurposing as synchronous condensers.

The estimated cost of decommissioning a 1 GW coal-fired power plant and replacing it with clean energy resources is substantial, at around USD 1.9 billion or more.[9] For example, Indonesia and Vietnam would need at least USD 114 billion and USD 57 billion, respectively, to retire their current and under-construction coal power fleets. Average compensation per GW of installed coal capacity across all countries is USD 800 million, which currently exceeds the cost to build a new coal-fired power plant in Indonesia and Vietnam. The coal transition for China and India will require 20 and 10 times, respectively, the combined financing needed for Indonesia and Vietnam, totaling between USD 3-5 trillion.[10]

The investment challenge for the region's transition from coal is substantial. Financial and budget constraints in many countries lead to a high reliance on international finance to phase out existing coal assets. Significant private investment is essential for implementing solutions, and risks must be minimized to catalyze financial commitments.

Just Coal Transition

Coal mining and related industries in some countries employ a large workforce, contributing significantly to local economies and creating strong community ties. An unplanned coal phase-out could lead to socio-economic hardship for coal-dependent regions and electoral losses for politicians. Potential shifts in economic and social structures necessitate firm policies to encourage a smooth transition

Studies indicate that only six percent of coal phase-out compensation policies across countries with coal phase-out pledges (excluding JETP funding) provide direct support for unemployment benefits and worker retraining.[11] Beneficiaries of coal phase-out compensation are mostly coal-dependent countries, regions, and energy companies, rather than workers. To ensure a just and equitable coal transition, key questions must be addressed, including: how the transition can align with principles of distributional, gender, and social justice; how to ensure good governance of compensation policies; and to what extent compensation covers the real costs for different stakeholders.

These questions highlight the importance of forming a coalition among community-based organizations, higher education institutions, government, and industry to develop a portfolio of coal-to-clean-energy technologies. This coalition could also advocate for substantial federal and state-level support for pension and re-employment guarantees, along with income, retraining, and relocation support for fossil-fuel-dependent communities.[12,13]

There are also concerns over potential electricity tariff increases for consumers, as coal-generated electricity prices have been kept artificially low in several countries, including China, India, and Indonesia. Lessons from successful coal transition stories in other parts of the world should be carefully considered in Asia's coal phase-out planning.

Gaps Between Renewable Energy (RE) Ambition and Implementation

Given the scale of the coal phase-out challenge in Asia, a critical step to aid this effort is the rapid scaling up of renewable energy development. There have been successful efforts in many countries over the past two decades, including China, India, the Philippines, and Vietnam, among others.

However, the pace of this transition varies across the region as countries pursue different strategies to address energy security, affordability, and sustainable development goals. For example, rapidly expanding renewables are expected to meet all the additional electricity demand growth from 2024 to 2026 in China. In India, renewables are set to meet nearly half of its demand growth, with one-third expected to come from increased coal-fired generation. In Southeast Asia, renewables are projected to meet around 40% of the demand growth, while coal is expected to account for about 35% and gas for around 25%.[14]

The speed and scale of renewable energy development are impeded by several factors, including challenges in attracting sustainable finance, a lack of bankable projects, weak local financial markets, and limited climate-related standards and disclosures.

The shortage of bankable projects may stem from weak regulatory frameworks for renewable energy, inconsistent procurement processes, inadequate tariff levels, and, at times, high local content requirements, which can hinder renewable energy investments. There is also a high perceived risk in financing low-carbon and green projects due to uncertain returns, high initial costs, and the long investment horizons for green projects. These challenges are compounded by significant upfront capital expenditures and extended project development timelines, which can be difficult to align with the cash flows needed over commercial project life cycles.

Additionally, private sector equity funding is limited, and domestic banks often charge high interest rates for green investments due to perceived risks, further increasing the cost of capital and reducing the economic attractiveness of low-carbon projects. For instance, typical lending interest rates for renewable energy (RE) projects in high-risk countries (e.g., Indonesia, the Philippines, and Vietnam) range between 5-8% for U.S. dollar-denominated loans from local or foreign banks, compared to below 5% in countries with lower perceived risks.[15] To overcome these barriers requires appropriate incentive mechanisms and adequate policy support from governments to de-risk RE and energy efficiency (EE) investments.

Whole-of-Economy Considerations

The economics of coal-fired power plants are relatively sensitive to wholesale electricity tariffs, higher coal prices, and lower load factors.[16] There is therefore a distinct divide between coal-producing and coal-importing regions, as well as between fixed electricity systems and spot market electricity systems. Both physical and market conditions may be stable in the short term; however, strategies can be developed to create favorable conditions that incentivize reduced coal use.

On the other hand, new coal power investments, from the government's perspective, may require a broader and more comprehensive assessment at the national level, weighing the relative economic costs and benefits of coal power (e.g., job losses, upstream environmental impacts, investment multiplier effects) against alternative power sector investment options.[17] Potential negative economic impacts, such as escalating electricity prices and power shortages, could impede rapid industrial growth and economic development. Furthermore, expectations of financial losses, early retirement, and stranded asset risks do not necessarily render new coal plant construction economically unjustifiable, especially when considering energy security or potential electricity tariff increases. This is reflected in the decisions of several Asian countries—such as China, India, Indonesia, Japan, and Vietnam—to continue developing coal-fired power generation despite their net-zero pledges.

3. Solutions and Best Practices for Reducing and Eliminating the Use of Coal

A mix of strategies and technical solutions for reducing coal use has been successfully implemented in Asia and around the world. Effective strategies include targeted policy measures to reduce coal use, phasing out coal subsidies, reducing the dispatch and output of coal-fired power plants, and leveraging international coal phase-out initiatives. Technical and technological solutions may involve strengthening emission standards, improving the technical efficiency of coal-fired power plants, and repurposing existing plants for nuclear energy, energy storage, or synchronous condensers.

Strengthen Emission Standards and Technical Efficiency

For conventional coal units, it is not feasible to convert a subcritical unit into a more efficient supercritical or ultra-supercritical unit. However, old, inefficient, smaller subcritical units (e.g., those with a capacity of up to 350 MW) can be decommissioned and replaced with fewer, more efficient, large ultra-supercritical units. These new units can be built for co-firing to further reduce carbon emissions, made "carbon capture ready," and equipped with boilers capable of co-firing ammonia, biomass, or even full conversion.

The most economical and climate-friendly pathway for old subcritical units is early retirement. However, before retirement, the operational and environmental performance of older subcritical units can be improved through various technologies, such as:

a. the use of variable frequency driven on large pumps and fans;

b. the use of very low sulfur fuel, enabling reduction in flue gas temperature and losses with more heat recovery within the boiler;

c. the maximization of a condenser vacuum within the technical limits of the turbines;

d. the replacement of motor-driven boiler feed pumps with steam-driven boiler feed pumps;

e. the optimization of dispatch for high efficiency load points;

f. the minimization of leaks and air ingress;

g. the change of fuel or co-firing where feasible;

h. conversion to combined cycle plants where feasible; and

i. partial addition of heat such as feedwater heating with solar thermal to improve cycle efficiency. In addition, co-firing with green fuels such as green ammonia or biomass should be incorporated to significantly reduce carbon dioxide emissions for the remaining operational lifespan of these plants

Current environmental emissions guidelines, such as the 2008 IFC Environmental, Health, and Safety Guidelines for Thermal Power Plants, focus on reducing particulate matter, NOx, SOx, and noise. The new revision of such guidelines needs to be strengthened for setting much stricter thresholds on carbon emissions.

Repurposing and Co-Firing Coal Assets with Biomass and Ammonia

Coal-fired units can be successfully converted to use biomass as fuel, either through co-firing or full conversion. However, scaling up biomass firing for the existing coal generation capacity in Asia can be extremely challenging and controversial. There may be strong opposition against such conversions due to its close intersection with land and food.

Several large-scale conversions of coal units to biomass have been implemented, including Drax Power in the UK, Asnaes Power Plant in Denmark, and Polaniec Power Plant in Poland. Several large units are also exploring biomass conversion potential.

Green-ammonia is another alternative to biomass co-firing. While it has the potential to reduce emissions from existing coal-fired power plants, if ammonia production is powered by clean energy, it could also extend the lifespan of these coal assets. Recent developments in the region include:

- China is already producing in excess of 180 billion kWh of electricity with biomass. The target is to reduce CO2 emissions in coal plants by blending between 20% and 60% of green ammonia by calorific value, resulting in a corresponding reduction in CO2 emissions, with a long-term goal of 100% green ammonia combustion in large coal-fired boilers.
- Trials have been conducted on ammonia combustion in gas turbines, achieving 100% ammonia use in a small 2 MW unit. Large-scale pilots are underway in Japan (JERA's Hekinan Power Plant and Kyushu Electric's Reihoku Power Plant), Indonesia (Nusantara Power Plant), and are in advanced stages in the Republic of Korea and India (Mundra Power Plant).

- Memoranda of Understanding for studies and trials have been signed between local companies and major technology providers in Malaysia, the Philippines, Thailand, and Singapore (focused on gas turbines). Additionally, an agreement was signed between companies from the Republic of Korea and Indonesia to prepare two units (Jawa #9 and #10) for 60% ammonia co-firing when the fuel becomes available.

Case Study on Repowering Coal Facilities with Nuclear

Since nuclear and coal-fired plants share similarities—they are both thermal power plants relying on similar components and supply chains—nuclear power is a viable replacement for coal in electricity and heat production on the path to net-zero emissions. The high-temperature gas-cooled reactor (HTR-PM),[18] with a thermal capacity of 500 MW and an electric capacity of 210 MW, is a promising candidate for retrofitting existing coal-fired power plants. This process would involve replacing coal-fired boilers with nuclear-based high-temperature heat sources.

For example, a 2022 study shows that more than two-thirds of the nearly 3,000 coal-fired power units in China, totaling 906 GW of capacity, are suitable for nuclear power retrofit decarbonization. Once implemented, this HTR-PM retrofitting project could accelerate the coal-to-nuclear replacement rate in China and potentially save up to USD 1,200 billion in China's energy transition.[19]

China has introduced coal-to-nuclear policies to reduce coal use. The State Council published the Energy Development Strategy Action Plan, 2014–2020 in November 2014, aiming to reduce China's reliance on coal and promote clean energy, reaffirming the 2012 target of 58 GWe (gigawatts electrical) nuclear capacity by 2020, with 30 GWe more under construction. In 2016, the Chinese government specified that by 2050, nuclear-based clean heating would become the country's primary source for district heating. Since 2022, a gradual coal-to-nuclear replacement policy, following the "build first, destroy later" principle, has been implemented.[20]

Coal-to-Nuclear Electricity: Following President Xi Jinping's announcement to make China carbon-neutral by 2060, the Chinese government in 2021 highlighted nuclear energy as the only energy source with specific goals in the 14th Five-Year Plan (2021–2025), aiming for a generation capacity of 70 GWe by 2025 to partially reduce coal dependency.[21] Afterwards, a longer-term target for nuclear energy in China to substitute coal-fired generation was set at 200 GWe by 2035, especially in the central inland region, which lacks the necessary conditions for large-scale deployment of wind and solar power.[22,23] Recently, HTR-PM entered commercial operation in late 2023 to kickstart the replacement of coal-fired power plants in inland China. As a high-temperature gas reactor, HTR-PM can also produce high-temperature steam (up to 500°C) for petrochemical processes, though other reactor types can also provide heat.

Coal-to-Nuclear Heat: In 2021, the Haiyang Nuclear Power Plant (NPP) in Shandong became the first NPP in China to provide municipal (district) heating at commercial scale to the entire nearby city of Haiyang. By diverting steam from the secondary circuits of its two large Light Water Reactors (AP1000 design) to an on-site heat exchange station, the plant operator supplies heat to an off-site heat exchange station managed by Fengyuan Gas Thermal Power, which then distributes it to local consumers as heated water. Following the success of this project, Shandong's energy bureau announced plans to build an additional 10 GWe of nuclear energy capacity to provide district heating to millions of households.[24]

In December 2022, China's first nuclear-based industrial heating project was launched at the Qinshan NPP in Zhejiang, supplying about 288,000 gigajoules of industrial heat annually. Most recently, the Heqi No. 1 project at the Tianwan NPP in Jiangsu was announced to provide around 4.8 million tons of steam to petrochemical operations in the nearby city of Lianyungang.[25] The benefits from a number of nuclear-based projects in terms of coal use and emission reduction are presented in Table 2.

TABLE 2. Selected nuclear-based projects and their benefits in terms of coal use and emission reduction.

Project	Annual Standard Coal Use Reduction	Annual CO2 Emission Reduction	Other Annual Emissions
Haiyang NPP district heating[26]	23,200 tons	60,000 tons	382 tons SO2, 362 tons NOX
Table Hongyanhe NPP district heating [27]	5,726 tons	14,100 tons	No data available
Qinshan NPP industrial heating[28]	10,000 tons	24,000 tons	No data available
Tianwan NPP steam generating [29]	400,000 tons	1.07 million tons	184 tons SO2, and 263 tons NOX

Repurposing Sites to Support Renewables and Energy Storage

Several jurisdictions, including the U.S. and Australia, are deploying renewables and energy storage assets on decommissioned coal-fired power plant sites.

- AES has received regulatory approval from the Indiana Utility Regulatory Commission (IURC) for a stand-alone battery energy storage system at the company's Petersburg Generating Station in Pike County, Indiana, USA. The 200 MW/800 MWh BESS will utilize existing infrastructure and is expected to be operational by December 2024.
- DTE Energy is building a 220 MW/880 MWh BESS system at the retired Trenton Channel coal-fired power plant in Trenton, Michigan, USA. This stand-alone BESS project is expected to be commissioned in 2026.
- One of the most significant transitions from fossil fuel generation to BESS is the Moss Landing Generating Station in Monterey, California. Using existing grid infrastructure at two units of the now-retired natural gas power plants, Vistra Energy brought the Moss Landing Energy Storage Facility online, with a total capacity of 750 MW/3,000 MWh. This facility became operational in 2023.
- Another similar project is Calpine Corporation's Menifee Power Bank, a 680 MW BESS, at the site of the former Inland Empire Energy Center natural gas-fired power plant in Riverside, California, which is expected to become operational in 2025.
- A coal-fired unit was successfully converted into a synchronous condenser in the Midwest in the US.
- Australia has installed four new synchronous condensers in South Australia. Various agencies, such as ARENA (Australian Renewable Energy Agency), the Australian Energy Council, as well as academics and research institutions across the world, including in India and China, are highlighting this potential.

In the U.S., over 200 GW of coal-fired generation capacity, with an average plant life of 52 years, is planned for retirement over the next 15 years. Additionally, 22 GW of coal-fired generation capacity was retired in the last two years.

While many combined cycle natural gas power plants are being built, capitalizing on abundant gas resources in the U.S., numerous sites are being repurposed for the deployment of renewables and energy storage assets due to their increasing cost competitiveness.

Several proposals have also been made to repurpose aging coal-fired power plants for hydrogen-based generation or as sites for small modular reactors. Most of these projects are in the early stages, with many going through regulatory and other necessary approvals. Initial projects are primarily stand-alone battery storage installations. Additionally, repurposing coal-fired units as synchronous condensers to provide grid stability (inertia) is a cheaper, larger-scale, and faster option than building new synchronous condensers.

Targeted Policy Measures in China to Reduce the Use of Coal

Despite the continued build-out of coal-fired power plants in China in recent years, a reduction in coal use for electricity generation is anticipated, with emissions targeted to peak by 2026.

Over the years, China has implemented the following policy measures and action plans to reduce the use of coal, as listed in Table 3.

TABLE 3. Policy measures and action plans taken by China to reduce coal use

Project	Project	Project
2007	"Opinions on Accelerating the Closure of Small Thermal Power Units"[30]	Forced the closure of six types of small thermal power units, targeting the shutdown of small (<200 MW) and outdated units that either did not meet emission standards or had 10-15% lower efficiency than the provincial or national average.[31] This has resulted in a continuous decline in coal consumption per unit of electricity generated.
2011	"Emission Standards for Air Pollution from Thermal Power Plants"	Approved in 2011 and implemented in 2012, "Emission Standards for Air Pollution from Thermal Power Plants" establishes more stringent standards for CFPPs, upgrading their energy efficiency.
2013	Coal-to-Gas Project	The Coal-to-Gas Project was a key strategy to reduce air pollution in China by switching residential heating energy from bulk coal to natural gas. From 2017 to 2019, there was a total reduction of 176 million tons of bulk coal, and a total of 16.43 million households were converted from coal to gas use by October 2020.[32]

Project	Project	Project
2014	"Opinions on Promoting the Clean Development and Efficient Use of Coals"	By 2015, 100% of the power plants, out of approximately 1,000 GW thermal capacity, were equipped with fabric filters, electrostatic precipitators, and other dust-extraction systems, while 92.9% were equipped with desulfurization systems and Wet Flue Gas Desulfurization (WFGD) technology. Approximately 95% had NOx control systems, and 95.79% of the generation capacity with NOx control equipment chose Selective Catalytic Reduction (SCR) systems.
2015	"Implementation Work Plan of Retrofits for Ultra-Low Emissions and Energy Savings of CFPPs"	Formulated in 2015, this plan included the closure of small unit CFPPs under 300 MW, installation of efficient air pollution control devices (for PM2.5, SO2, and NOx), and improved power generation efficiency via upgraded boilers and generation technologies to mitigate highly toxic mercury (Hg).[33]
2020	Specific cleaning requests on CFPPs from the national level	Specific national cleaning requests for CFPPs were made to guide the development, renovation, and retirement of all CFPP units until 2025. These include controlling the introduction of new units, phasing out old units, and implementing clean transformations of existing units. This aims to reduce the national average CFPP heat rate to 300 grams of coal equivalent per kilowatt-hour (gce/kWh), which could improve the average cleaning efficiencies of CFPP units in Mainland China by 25 t/GWh and reduce 0.64 gigatons of carbon emissions cumulatively during the 14th Five-Year Plan period.[34]
2024	Coal Power Low Carbon Transformation Construction Action Plan (2024—2027)	The action plan promotes the low-carbon transformation of existing coal power units, aiming to reduce carbon emissions per kilowatt-hour of related projects by around 50% compared to the average emissions of similar coal-fired units in 2023, approaching the emissions level of natural gas-fired units. The plan also proposes biomass co-firing at 10%, green ammonia co-firing at 10%, and CCUS and other decarbonization transformations.[35]

Removal of Fossil Fuel Subsidies and CFPPs as Standby Plants in Malaysia to Reduce Outputs

Malaysia has announced that it will not build any new coal plants and is now considering early retirement, mothballing, co-firing, or brown-to-green swaps for its seven existing coal-fired power plants, which have a total capacity of 7 GW. Several recent measures have been implemented to reduce coal use, including the following:

- Policy to shift from blanket to targeted subsidies for fossil fuel-powered electricity. If complemented with renewable energy generation subsidies, this plan will likely enhance social welfare and support the net zero target.
- Merit order for electricity generated from less efficient coal plants to low dispatch priority, helping to reduce the output and economic value of these coal generators.
- Expiration of power purchase agreements for more than 7 GW of coal power plants by 2033, creating conditions for re-evaluating the coal generation assets in Malaysia.
- Exploration of the JETP initiative to phase out coal and reduce reliance on fossil fuels.

This set of measures benefits countries reliant on fossil energy and coal imports. Reducing government support for fossil fuels also allows the private sector to step in for faster renewable energy development. The addition of more near-zero marginal cost renewable energy to the grid will further push CFPPs into quicker retirement, creating a virtuous cycle for the deployment of clean energy.

Balancing Energy Security, Economics, and Environment in India

India faces the complex challenge of balancing energy security, economic growth, and environmental sustainability. A premature or abrupt shift away from coal could jeopardize energy security and potentially hinder economic progress, while an overly gradual transition could compromise India's climate commitments and worsen environmental issues.

A pragmatic approach involves a carefully calibrated strategy that combines the following elements:

- **Continued Investment in Coal Efficiency**: Improving the efficiency of existing coal-fired power plants through technological upgrades and operational optimizations to reduce emissions while maintaining energy security.
- **Accelerated Deployment of Renewable Energy**: Leveraging India's abundant solar and wind resources to increase the share of renewable energy in the energy mix.
- **Development of Energy Storage Technologies**: Prioritizing research and development in energy storage solutions to address the intermittency challenges of renewable energy.
- **Strategic Coal Phase-Out**: Developing a plan for coal phase-out, considering factors such as regional energy demands, grid stability, and the availability of alternative energy sources.
- **International Cooperation**: Seeking financial and technological support from developed countries to facilitate India's energy transition.
- **Policy and Regulatory Framework**: Creating a conducive policy environment that encourages investment in clean energy technologies and incentivizes energy efficiency.
- **Involvement of Coal Mining Companies**: As the largest coal mining company in India, Coal India Limited (CIL) plays a pivotal role in the country's energy landscape. CIL's participation in the energy transition will be crucial. Potential strategies include diversification, R&D in advanced coal mining technologies and CCS, adopting sustainable mining practices, and offering training and retraining programs for employees to support a smooth transition.

Leverage international finance and the Coal Phase-out Initiatives to Retire CFPPs

These initiatives aim to enhance the socio-economic and political feasibility of coal phase-outs for long-term sustainability through concessional and blended finance. For example, the JETP mechanism has been adopted by several Southeast Asian countries, such as Indonesia, Malaysia, the Philippines, and Vietnam.

A number of aspects are important in creating suitable conditions for the early retirement of CFPPs. First, the candidate is a middle-aged plant with an interested owner and a financial structure suitable for refinancing. Second, the project company is engaged with its community and has interest in establishing an active corporate social responsibility program. These factors help improve the financial and economic viability of the coal plant's retirement while ensuring strong just-transition considerations.

One example is the South Luzon Thermal Energy Corporation (SLTEC), a 246 MW coal plant in Batangas, Philippines. The plant is slated for early retirement, 25 years ahead of schedule, by ACEN, leveraging the ADB's Energy Transition Mechanisms (ETM). The scheme could save up to 50 million metric tons of carbon emissions. The process involved USD 245 million debt financing and USD 66 million in equity investments, as well as USD 312 million coming from a newly established Special Purpose Vehicle. Key enabling factors included alignment with the strategic priorities of the plant's home entity, commitment from private lenders, financial infrastructure maturity, local insurance support, equity investors, a secure offtake agreement, and an operations and maintenance agreement.

Loans and grants provided can help improve the economics of phasing out coal plants, accelerate the development of renewable energy, and compensate affected stakeholders, such as coal communities, coal regions, coal-fired power plants, and workers.

4. Mechanisms to Facilitate Coal-fired Power Plant Phase-out

External factors, such as the cessation of finance flows for coal investments and high, fluctuating international coal prices, can significantly influence countries' energy planning and decision-making. It is therefore paramount for the international community to guide and direct financial resources and assistance away from fossil fuels and toward low-carbon development and clean energy transitions.

Policy measures, such as removing coal subsidies or implementing subsidies for renewable energy, along with economic measures like carbon pricing or reflective electricity pricing, have been implemented in various countries to facilitate the phase-out of coal-fired power plants in the region.

The aim of these policy, economic, and financial measures is to shift economic and cost structures to reduce the value of CFPP assets and increase the value of lower-carbon assets, thus incentivizing the supply and development of alternative clean energy assets. This further decreases the value of CFPP assets and gradually pushes them to retire from the market.

Key mechanisms to facilitate the phase-out of coal-fired power plants are listed below:

No Coal Finances: This has been a key determining factor for the reduction of coal generation projects in Asia (excluding China, India, and Japan), as most developing countries rely on foreign financing to fund their coal power plants. The number of CFPP projects in the pipeline has decreased by 75% since 2022 due to a coal phase-down or phase-out pledge made by several governments, including China, Indonesia, Japan, the Philippines, the Republic of Korea, and Vietnam.

High and Fluctuating Coal Prices: Studies on the impact of COVID-19 and the war in Ukraine have highlighted the reduced incentives to build domestic coal and gas power plants due to high export prices for these commodities. This is especially relevant for countries that rely on coal imports for their power plants, such as Bangladesh, Lao PDR, and Vietnam. Conversely, coal-exporting countries like Indonesia may incur economic losses to keep domestic coal prices artificially low.

Coal Assets Policy and Regulations: Strong environmental policies governing the power sector, such as pollution emission standards, can significantly influence the efficiency of the technologies deployed, such as subcritical coal power plants. For example, studies of Chinese-backed coal-fired power plant investments in Bangladesh, India, Indonesia, and Vietnam indicated that there are preferential domestic policies for coal in these countries. In at least one case, renewables are disallowed by regulation from competing on a level playing field with coal. None of these countries have environmental policies that would require cleaner or more efficient plants to be constructed and operated.[36]

Regulations need to be strengthened in areas such as detailed plans for unabated coal power phase-outs, the management of coal power assets, job transitions, and compensation for early closures. The lack of well-developed regulations to facilitate the advancement of renewable energy is exemplified by grid transmission bottlenecks and energy storage development.[37]

National and Regional Planning: Energy sector plans in each country provide guidance on the future increased capacity of various energy sources, including CFPPs. For example, based on Vietnam's National Power Development Plan 8, from 2021 to 2030, Vietnam plans to further increase its capacities in thermal, LNG thermal, and coal-fired thermal power plants to 14,930 MW, 22,400 MW, and 30,127 MW, respectively. The large pipelines of CFPPs being planned in capacities and numbers in countries such as Bangladesh, China, India, Indonesia, and Vietnam will pose significant challenges in developing a viable pathway for each country to reach net-zero by 2050.

Carbon Pricing and Coal Production Caps: Key policy instruments such as carbon pricing and production caps can serve as strong deterrents to new plant construction for financiers and developers by reducing the financial returns on investments in coal assets. For example, studies on China's coal power plant investments found that a shadow carbon price rising linearly from USD 15 to USD 30 per ton of CO2 from 2026 through 2041 is sufficient to prevent the project from ever generating a positive economic return. A more ambitious shadow carbon pricing trajectory, increasing to USD 60 per ton of CO2 in 2041, would lead to an economic loss of USD 355 million for the plant.

Reflective Market Pricing: High shares of renewable energy can frequently push market prices into negative territory. For coal-fired power plants, negative prices can lead to large losses, thinning profit margins and reducing asset value. This has been evident in many countries with dynamic electricity prices determined by demand and supply in electricity spot markets.

In light of these lessons learned, regional coal phase-out initiatives, such as the Just Energy Transition Partnership (JETP) or the Energy Transition Mechanism (ETM), can focus on strengthening or creating these instruments or conditions for a more effective phase-out of coal.

5. Recommendations and Possible Pathways

Given the large capacity of coal-fired power plants in the region set to be gradually shut down, a staged phase-out plan should be developed for individual countries to meet the technical and market requirements of their energy systems and socio-economic objectives for sustainable development. Figure 1 provides indicative implementation timelines for key solutions to reduce coal use in Asia.

All measures, solutions, and technologies must be considered to tackle this enormous challenge. Policy and administrative measures, such as reducing the dispatch of coal plants, implementing coal production caps, and establishing more stringent emission standards, can be implemented relatively quickly for an immediate reduction of coal use. Longer-term solutions will involve investments in the decarbonization and modernization of coal assets and the large-scale development of clean energy alternatives, where a range of technological and technical solutions can be employed.

The effective implementation of these solutions and technologies will require a supportive mix of policy and incentive mechanisms, as well as national and regional power development plans that are well-aligned with climate and net-zero objectives. This will help create the right incentives for clean energy investment to flourish and further suppress coal investment in the region.

In addition to addressing the challenges surrounding existing coal assets, stopping international coal finance has proven to be an effective way to prevent the construction of coal-fired power plants in many countries.

It is encouraging that there have been many success stories and strategies in the region and around the globe regarding the phase-down or reduction of coal use that can be learned from across countries. We hope that this brief serves as a reference for a collective vision and action to expedite the phase-out of coal-fired generation in Asia.

ENDNOTES

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