SUMMARY
OF CONTENTS
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01. EXECUTIVE SUMMARY
This short paper seeks to raise awareness of the potential to eliminate emissions from existing coal fired power plants (CFPPs), while supporting a just transition for communities, by investing in clean energy resources on the same sites.

In some Organization for Economic Cooperation and Development (OECD) member countries, policies supporting extensive investment in cleaner electricity generation, alongside the pricing of greenhouse gas emissions, have enabled CFPPs to be successfully retired or replaced and emissions to decline. The situation in developing countries is often more challenging, not least because of the young age of the coal assets, the energy market structure and rules, the growing overall demand for electricity, and the relative weakness of grid infrastructure or the absence of interconnectors between markets.

Repowering, defined as the sustainable reuse of all or part of an existing power plant, offers a solution. Repowering delivers as close to like-for-like (or even expanded) services as possible, minus coal burning. This offers increased energy security, lower overall system costs, and environmental, socio-economic, and political benefits. Examples include the reuse of valuable infrastructure, retention of jobs and firmed¹ electricity generating capacity, and associated community benefits. Reusing existing grid connections, environmental permissions, and permits also offer cost and time savings. Repurposing existing power plant land can circumvent the regulatory and social challenges often faced when securing new land in emerging markets and developing economies. Utilising existing power purchase agreements (PPAs) can streamline the transition process, avoiding the need for new negotiations. Overall, repowering can be a hugely powerful element of a just transition, and yet it is not currently receiving the attention it deserves.

Repowering is not a new concept; it is in its early stages and is yet to achieve large-scale adoption. We provide details of previous examples of repowering in Appendix IV: ‘Summary of Ongoing Coal Repowering Projects’. Existing and newly emerging classes of clean technologies, which can be used to repower coal and other fossil-fired power generation sites, have huge potential to speed the just transition to a clean global economy.

The range of sustainable technological options for repowering include reusing CFPP electricity infrastructure as the interconnection point(s) for new variable renewable energy (VRE) to the power grid, heat batteries², full conversion of the heat source to (or acting as the host site for) advanced geothermal or next-generation nuclear reactors, and the repurposing of certain types of existing generators as synchronous condensers (SCs)³.

The majority of CFPP retrofit projects to date have followed the coal to natural gas pathway. Natural gas burns more cleanly than coal but still emits unacceptable levels of CO₂ emissions⁴ when combusted. Methane can leak from wells, pipelines, and other infrastructure associated with gas production, transportation, and combustion. Therefore, assuming that the natural gas is unabated, this cannot be considered clean “repowering” by our definition, since it will not be considered sustainable in the long term. Although retirement of the CFPPs, ammonia co-firing, coal/gas and carbon capture storage (CCS) are not ruled out, their overall viability may be compromised by factors such as low full-cycle efficiencies for ammonia, limited local availability of sustainable fuels, and significant unabated upstream gas emissions (from wells, pipelines, and other sources). These challenges render these options less competitive than recommended technologies such as next-generation geothermal, concentrated solar power, or advanced nuclear reactors.

¹ Firmed in this context means reliable, dispatchable power generating capacity. Intermittent generating capacity, by contrast, has an output which is dependent on weather conditions.

² “Heat batteries” commonly go by other names, including thermo-electric energy storage, thermal energy storage (TES), thermal batteries, or thermal storage.

³ Synchronous condensers (SCs) are spinning generators that maintain grid stability.

⁴ Calculated over a 20-year period (20y Global Warming Potential), methane is 85 times more potent as a greenhouse gas than carbon dioxide. Over the conventionally used 100-year period, it is 28 times more potent. As a result, reductions in carbon dioxide emissions by a transition from coal to gas can be negatively offset by the increase in methane emissions.
What to Expect From This Whitepaper

This whitepaper explores the range of approaches used by the international finance community to facilitate a reduction in committed emissions from CFPPs following the repower pathway.

The paper concludes with a series of recommendations for how to include repowering considerations in policy development and investment negotiations.
Summary of Recommendations

1. Embrace Emerging Landscape of Clean Technologies

When considering refinancing or future of CFPP assets, it is important to be aware that the landscape of options is changing. It is imperative to fully understand the emerging landscape of clean technologies and avoid either lock-in to suboptimal solutions available now (unabated gas) or over-reliance on long-term solutions which are unlikely to be efficient or sustainable at a systems level (ammonia co-firing).

2. Integrate Repowering in CFPP Refinancing Programmes

Refinancing of existing plants to facilitate early closure of CFPPs is emerging, but the inclusion of repowering and repurposing should also be on the table, as investments in new clean capacity will further improve the long-term economic viability of the transaction. A number of financial initiatives to support early CFPP phase-down currently exist, and repowering and repurposing could be incorporated into these programmes.

3. Prioritise Investments in Clean Capacity and Redirect Subsidies Supporting CFPPs

Prioritising new capital investments that deliver equivalent clean capacity in addition to supporting early closure and/or repurposing of existing CFPPs will ensure both emissions reductions and economic development. The redirection of current policies and financial measures—including direct and indirect subsidies that support CFPPs—towards clean energy at those same sites will help reduce costs to consumers and taxpayers and facilitate a transition with numerous additional health and social benefits, including long term retention of jobs and community benefits.

4. Mapping all CFPP Sites and Evaluating Repowering Options

To accelerate towards repowering, the ambition must be to begin the process of mapping all existing CFPP sites to consider all the available options for repowering at each site, including the benefits of maintaining existing transmission infrastructure. This will be a priority for the Repower Initiative.
02. PROBLEM STATEMENT & SOLUTION
Problem Statement

Fossil-fuelled thermal power plants are still the mainstay of the global electricity sector, despite the greenhouse gas emissions and associated particulate air pollution. Of these, CFPPs are by far the most polluting source of electricity. Today, they have a total capacity of 2,000 gigawatts (GW). Almost 80% of that global coal-fired power generation is in Asia, making this the critical area of focus for repowering. [1]

Some OECD countries are rapidly achieving the retirement of CFPPs. In Europe, twelve countries have already moved away from coal power entirely, and another eleven have committed to a complete phase-out before 2030 [2]. The UK will phase-out coal power completely during 2024, and the US targets coal phase-out before 2035. [3] The old age of the plants, flat or even declining power demand, tighter environmental regulations (including carbon pricing), and investments in alternatives, including gas-fired power stations and renewable power sources have helped to retire CFPPs.

Outside the OECD, however, the picture looks different. While the topic of coal power is receiving plenty of attention, the actual transition away from using it is more challenging for a range of reasons. These include growth in demand for electricity and heat, availability of cheap local coal, and policies that seek to maintain and grow its role. Other reasons include, a relative lack of availability of gas, a lack of interconnected electricity grids and electricity storage capacity, and limited supply chains for new clean energy. The general investment environment is perceived as riskier by finance institutions. Some highly populated developing countries also lack the geographic conditions and available land necessary for a massive expansion of the cheapest, mature technologies, i.e. wind and solar⁵.

CFPP retirement in emerging economies can also be difficult due to the plants’ relatively young age, making the economic case for early retirement more complex. The average age of CFPPs in Vietnam is 6.7 years, in Indonesia it is 10.8 years. Compare this to the US, where the average age of CFPPs is more than 40 years. [5]

SOLUTION

The repowering of existing CFPPs with new clean electricity capacity can cost-effectively match, replace and even enhance the multiple roles these CFPPs fulfil. These include providing reliable power on demand, high-grade heat, vital grid services, and supporting livelihoods for the local communities. Repowering the plants with clean energy maintains local economic activity and the numerous additional services the plant provides, compared to retiring the plant and seeking replacement for the energy capacity elsewhere.

⁵ “Significant areas are excluded in this study due to lower-quality wind resources (capacity factors less than 15% for wind) that would not be typically appealing for commercial development. This significantly limits the potential wind capacity available at lower generation costs in countries such as Indonesia, Malaysia, and Brunei.” [4]
03. WHAT IS REPOWERING?
What is Repowering?

Rather than simply closing the plant, repowering offers an alternative that matches many or all of the services and reuses parts of the existing plant, minus the burning of coal. This may include reusing the grid connection, generator turbine, auxiliary buildings, port/logistics infrastructure, and local workforce. Depending on the repowering pathway and the age and condition, the majority of the plant infrastructure and equipment can remain in use.

At a minimum, grid connections may be reused to transmit power from grid-scale wind and solar projects if there is nearby available land (or suitable offshore conditions) and a viable wind and solar resource.

CFPPs’ existing steam turbines can be repowered with new, clean technologies that produce high-grade heat, such as advanced geothermal and nuclear. A third solution is to convert existing fossil-fuelled generators into synchronous condensers (SCs). SCs provide valuable grid balancing services and allow for more variable renewables to be integrated into islanded grids.

In most cases, repowering projects are more cost-effective than equivalent greenfield projects. Adding supplementary energy storage facilities to the site (e.g., stored heat) can also reuse existing infrastructure and add resilience to the grid.

FROM

CFPP site is decommissioned

Grid capacity is lost

Local employment is lost

Flexible power must be sourced from elsewhere, or imported

Greenfield developments drive land use changes

Greenfield developments drive costs associated with new grid infrastructure elsewhere

TO

CFPP site is repowered

Grid remains stable

Jobs are kept, new employment opportunities may be generated

Energy security is maintained or strengthened

Land use impact remains the same or less

Land use is at a lower cost compared to greenfield elsewhere
04. WHY REPOWER?
Reuse of Existing Infrastructure Reduces Costs

There is a strong economic rationale for repowering, which reduces decommissioning costs and is often more cost-effective than commissioning greenfield electricity generation capacity. In India, for example, a World Bank report found that the direct benefits of repurposing a typical CFPP vastly outweighed the direct decommissioning costs (US $122.97 million compared to US $58.11 million). [6]

The existing electricity grid connection at a CFPP is typically significant (hundreds of megawatts to several gigawatts). Developing, permitting, and constructing new transmission or distribution lines to connect new assets elsewhere can be slow. This adds uncertainty, increases costs and delays targeted emissions reductions. Reusing the grid connections can avoid these delays and costs.

The first in-depth techno-economic study published in peer-reviewed scientific literature on coal repowering found that repowering can lower upfront capital costs by 28–35% and levelised cost of electricity by 9–28% compared to a greenfield clean energy installation. [7] A report prepared for the US Department of Energy independently verified these findings. [8] It showed that repurposing the CFPP’s electrical equipment, turbine components, transmission/distribution grid connections, and administrative buildings, could cut construction costs by as much as 17–35%. The existing facilities of younger plants can be reused for longer, making these benefits more pronounced.

Social and Local Benefits

There is much focus on how to ensure a just transition to clean energy, sensitive to potential negative impacts. Repowering can result in the retention of local jobs, enhanced local economic activity and associated community gains. Reduced local particulate air pollution and health improvements decreases the likelihood of switchback to coal-fired generation in the future.

Considering extant workers’ re-skilling and upskilling needs will be critical to job retention. It will be important to work closely with local communities to retain the area’s identity, history, and legacy of industry. The US DOE report concluded that reusing the existing infrastructure of a 1,200 MWe coal plant with nuclear generation could increase local economic activity by US $275 million and create 650 new, permanent jobs. For reference, before the CFPP closure, the employment at the site was estimated at 150 jobs. This analysis excluded transitory roles (e.g., construction jobs), which would create additional short to medium-term employment opportunities. [8]

From an environmental perspective, even the best-executed greenfield developments can still significantly impact the local environment. Reusing an existing site and grid infrastructure may further reduce local environmental damage from not having to develop new land. In locations with coal mines, a shift away from mining will also bring local environmental and health benefits. However, these come with associated social impacts (e.g., lost jobs) that are not addressed here and will require specific additional policies. For example, Just Energy Transition Partnerships (JETPs), which were launched at the United Nations Framework Convention on Climate Change COP26 Summit in 2021, seek to ensure a just transition for workers and communities. Their intention is to aid those directly affected by the move away from fossil fuels, and to contribute to the sustainable development of a clean alternative economy.

Maintaining a Similar Generation Profile

Since electricity demand is rising in most places, closing coal is only feasible if replacement capacity can be added. Adding variable renewables alone often reduces grid stability, especially if electricity grids are islanded and lack transmission connections to other markets. Including dispatchable power and/or thermal storage at repurposed CFPPs can address many of these issues and may increase electricity generation from the site.
05. REPOWERING OPTIONS
Repowering Options

Repowering works by recapitalising plants and installing new, clean power technologies instead of the continued use of fossil fuels. The range of available generating options to replace the reliance on fossil fuels is expanding, and the choice for replacement depends on a range of factors including the type of original plant and its location, including the available renewable resources. Figure 1 shows an original coal power plant layout (top left), with a stylised diagram of nine technical options for repowering, and a combined repowering approach at the bottom (larger plot size). Note that the different technologies provide very different outputs and services, and a full cost-benefit analysis should be undertaken on a site-by-site basis to determine the best option(s) for each location.

Figure 1: Coal Power Plants Options for Repowering.
REUSE OF GRID INFRASTRUCTURE FOR VARIABLE RENEWABLE ENERGY (VRE)

Where available land and resources are close to existing fossil power plants (including offshore), sites could be repurposed to connect adjacent solar and/or wind power. This option utilises the CFPP’s connection to the larger grid infrastructure. Concentrated solar power (CSP) is an attractive option where conditions allow it, since it provides high-temperature heat and thermal storage.

Variable renewables can be combined with storage and other grid-balancing technologies at the CFPP site (see ‘Energy Storage and Grid Management’).

TRADITIONAL AND NEXT-GENERATION GEOTHERMAL

Traditional geothermal is tried and tested, with over 15 GW of installed geothermal power capacity globally. Much of this in Southeast Asia (Indonesia has 2.4 GW, and the Philippines 2 GW). Traditional geothermal is spatially restricted to specific hydrothermal sites, which greatly limits its ability to help repower existing assets. [9] Next-generation geothermal technologies, such as Enhanced Geothermal Systems (EGS) and Advanced Geothermal Systems (AGS) can drill deeper and access heat further down. These technologies unlock access to geothermal energy at a broader range of locations, including at existing power plants. These systems are now transitioning from prototypes to the first full-scale commercial installations. The industries bringing forth the technology operate under slogans like “Geothermal anywhere” or even “Geothermal everywhere”.

Natural gas, biomass, ammonia, etc.

Other options for fuel switching and emissions abatement include co-firing and conversion to biomass, waste to energy, ammonia/hydrogen, or conversion to natural gas. The benefits, sustainability or commercial availability of these options are limited at this point, and therefore do not meet our criteria for like-for-like repowering at scale, other than in cases where very specific sustainability criteria can be met. Refer to Appendix III: ‘Retrofit Options Not Recommended’ for further details.

Next-generation geothermal can be made to work almost anywhere. Particularly suitable sites for this technology can be readily found in Southeast Asian countries in areas which show less promise for specific renewables. For example, Indonesia and Malaysia have limited wind resource availability, but very high underground temperatures. [4] Where plants provide Combined Heat and Power (CHP), repowering with geothermal offers a like-for-like replacement.
ENERGY STORAGE AND GRID MANAGEMENT

Though not an energy source, technologies such as heat batteries, also referred to as Thermal Energy Storage (converting electricity into stored heat to provide steam later), can complement the increased use of VRE on the grid. If sited at the CFPP, heat batteries can provide additional income to the plant, help avoid curtailment of renewable power, relieve grid congestion, and take advantage of negative prices at times of overproduction. These services are particularly important in weak grids. Unlike chemical batteries, pumped hydro or compressed air storage, heat batteries offer a way of displacing coal burn directly by delivering turbine-grade steam, thus enabling the reuse of plant infrastructure. Heat battery technologies are at varying maturity levels. Offerings include using molten salts, liquid metal, bricks, and sand as storage media.

Heat batteries can be installed quickly and may serve as the first step in a comprehensive repowering strategy. When integrated with geothermal and nuclear sources, they enhance the flexibility, and increase the value of the energy output.

As the VRE levels increase, synchronous condensers (SCs) can offer additional grid stability and inertia services. Repowered SCs (using the original CFPP generator) have larger scales, and lower costs than new greenfield SCs. They also have faster implementation times. Repurposing can be achieved in 12-24 months at some sites, whereas new investments take more than 30 months. [10]

All the technologies mentioned in this section complement renewable forms of generation and nuclear power, and hence they can be combined when repurposing a site.

NUCLEAR

Nuclear power offers a source of low-emissions dispatchable power and heat, complementing variable resources such as wind and solar. Nuclear is the second largest source of low-emissions power globally, and in 2022, nuclear plants supplied 2,545 Terawatt hours of electricity to the world (around one-quarter of the world’s clean electricity). [11] There are an array of technical options for integrating advanced nuclear energy systems into equipment at an existing CFPP. Nuclear reactors capable of generating steam at high temperatures can directly replace coal boilers. This enables the reuse of nearly all existing power plant infrastructure (such as the steam turbines, generators, grid connection, and full cooling water supply system) in what is known as “full repowering”. [7] Many other technical options for partial repowering of CFPPs using nuclear are being explored. These range from re-configuring the existing steam turbine and reusing the rest of the plant as it stands, to reusing only the cooling water supply systems, permits, and the transmission grid interconnection. This is commonly referred to as “partial” (rather than “full”) repowering. [12]
Current Implementation Status

While coal-to-gas conversions are an established concept, repowering with zero-emissions technologies is a relatively new concept and has yet to become part of mainstream conversations. Repowering is rapidly gaining attention and momentum, through the Repower Initiative and programs that have followed, such as Powering Past Coal Alliance.

The US and Poland are the first to pursue coal to nuclear repowering projects, in the US with TerraPower Sodium project in Kemmerer, Wyoming, and in Poland with the ZE PAK project at Pątnów. Serious feasibility studies are ongoing in countries across Eastern Europe, as well as in Canada and China. There is growing interest in next-generation geothermal projects that can offer like-for-like repowering on CFPP sites, and a range of companies are emerging with offerings at a commercial scale, following successful demonstration projects.

At least one advanced geothermal coal repowering project is currently in development in Texas, USA [13]. Coal-to-solar and coal generator conversion to synchronous condenser operation projects have been carried out in Canada and the US, respectively [14, 15]. For further details on case studies, please refer to Appendix IV: ‘Summary of Ongoing Coal Repowering Projects’
Financing the Clean Repowering of Coal Power
06.
THE FINANCE LANDSCAPE
Due to the significant benefits of repowering, there is a case for deploying finance to kickstart some early projects and incentivise productive decommissioning and repowering of CFPPs, before the end of their economic lives.

Ownership Models

In recent decades, the aged fleets of CFPPs in OECD countries have begun to be replaced with gas-fired power plants and variable renewables, often built on greenfield sites in different locations to the original CFPP. However, CFPPs are anticipated to increase across the Asia-Pacific (APAC) region.

Ownership of these assets varies: particularly in China and Indonesia, most CFPPs providing power to the grid are owned by state-owned enterprises (SOEs), although partial debt and equity may be held by third parties, including by other countries. In some instances, several independent power producers (IPPs) have had the possibility to enter the market. For example, about 35% of coal capacity in India is owned and operated by IPPs.

Contractually, the plants across Asia typically work with a long-term PPA, which often lasts around 25 years or more. These can include:

- Regulated tariff with assured cost-plus return to the owners
- Tariffs based on competitive bidding

Contracts often include a take-or-pay clause, meaning that even underutilised CFPPs deliver a guaranteed return for investors. CFPP owners usually aim to structure a contract to cover any fuel price volatility, or, in the case of Indonesia, government policy caps the price of domestically used coal. In 2023, Indonesia had 14.4 GW of captive coal plants proposed/under construction to support its growing smelting industry. The economics of these plants can differ, particularly when fuel prices are capped, as is the case in Indonesia.

[17] Despite challenges, effective decarbonization policies in parts of China have driven growth in energy-intensive industries like smelting, and promoted their relocation to regions rich in renewable resources. [18]
Financing Mechanisms

As ownership of coal-fired power plants varies across Asian economies, financing structures for these assets also vary. Typically, private owners either finance an asset through their own balance sheets or project financing through special purpose vehicles (SPV). In either case, the equity share of plants between the start of construction and the start of operation is about 20-25%, with the rest of the financing made available through bank credit. [19] Bonds can be used to support both balance sheet and SPV-driven financing, at least when the SPV is anchored by well-established institutions, creating trust among bond investors.

Governments likewise finance CFPPs either through state-owned enterprise balance sheets, or through establishing fully state-owned/state-financed SPVs or public-private partnerships. In these cases, a typical debt to equity ratio at time of construction would be around 75/25, while the time for paydown of the debt portion can last for up to 20 years (depending on the specific financing structure and the length of the PPA). Refinancing can often become necessary if the tenure of the original debt instruments is short (e.g., due to finance institutions’ restrictions on tenure), and additional debt might be taken on for upgrading of the plant.

To support the financing of coal assets, governments across Asia have engaged in a variety of financial support mechanisms. These include:

- **Direct subsidies** (e.g., China for financing of construction)
- **Fuel subsidies** (e.g., China, Indonesia)
- **Indirect subsidies** (e.g., preferential distribution network access, lack of pricing of externalities such as air pollution and climate emissions, smoother planning and permitting, regular government transfers to SOEs)
- **Capacity Payment schemes** (e.g., Indonesia, Pakistan)
- **Credit Enhancement programs** (e.g., CFPP electricity generators in Indonesia can apply for a government loan guarantee and feasibility assurance)
- **Concessional Infrastructure Finance** (e.g., China supporting overseas development of CFPP infrastructure through syndicated loans, export buyers’ credit and insurance, commercial loans, and equity investments)
- **Captive Coal Mining & Power Production Licenses** (e.g., governments can grant CFPP operators captive coal mining licenses, giving them preferential access to coal resources at lower prices)
Supported by these support mechanisms, investment in coal has been the backbone of economic development and stimulus policy in many countries, but the real cost is masked. The International Monetary Fund estimates that China’s and Indonesia’s retail price of coal is about 25% of its actual supply cost, combined with the implied costs from climate change and local pollution. The corresponding value is about 50% of retail price for India, and 80% for Germany or France. [20]

Figure 3 below illustrates the various mechanisms that are prevalent in the region for financing coal assets:

Financing Coal Repowering in the Asia-Pacific Region

In emerging economies, primarily in the APAC region, where most of the new additions of CFPPs have occurred over the past 15 years, several new initiatives have been launched to support early CFPP phase-down (described in Table 1). Additional support mechanisms also exist in the region, including national energy policies to internalise environmental costs or to support supply security, but these are not listed.
## Table 1: Existing Financial Initiatives to Support Early CFPP Phase-Down.

<table>
<thead>
<tr>
<th>Name</th>
<th>Year of Launch</th>
<th>Description</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belt and Road Initiative International Green Development Coalition (BRIGC)</td>
<td>2019</td>
<td>Promotes international consensus, understanding, cooperation, and concerted actions to achieve the green development of BRI countries through joint efforts, and encourages adoption of sustainable development goals (SDGs) across BRI countries.</td>
<td>China-led, working in over 115 countries</td>
</tr>
<tr>
<td>Southeast Asia Energy Transition Partnership (ETP)</td>
<td>2020</td>
<td>Launched by the United Nations as a multi-donor partnership by governmental and philanthropic partners to accelerate sustainable energy transition.</td>
<td>Indonesia, Vietnam, Philippines</td>
</tr>
<tr>
<td>South Korea’s Green New Deal</td>
<td>2020</td>
<td>A government plan to invest in green and digital technologies, with an emphasis on greening industrial sectors and transitioning to smart grids and low-carbon energy technologies.</td>
<td>South Korea</td>
</tr>
<tr>
<td>Energy Transition Mechanism (ETM)</td>
<td>2021</td>
<td>Launched by the Asian Development Bank (ADB) as a public-private finance vehicle to expedite the retirement or repurposing of fossil fuel plants within 15 years or less.</td>
<td>APAC region</td>
</tr>
<tr>
<td>Just Energy Transition Partnerships (JETP)</td>
<td>2021</td>
<td>Their goal is to expand public and private financing for equitable energy transitions in emerging economies. JETP is mainly financially supported by the International Partners Group (IPG) comprising the European Union, UK, US, Japan, France, Germany, Italy, Canada, Denmark, Norway, and private financial institutions</td>
<td>South Africa, Indonesia, Vietnam, Senegal</td>
</tr>
<tr>
<td>Coal Asset Transition Accelerator (CATA)</td>
<td>2021</td>
<td>Platform intended to empower coal asset owners, government financiers, and local stakeholders, to leverage finance to support the global transition from coal. CATA was initiated by Climate Smart Ventures, Carbon Trust, and the Rocky Mountain Institute, with support from the European Climate Foundation (ECF), Growald Climate Fund, and IKEA Foundation.</td>
<td>Global</td>
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<tr>
<td>Name</td>
<td>Year of Launch</td>
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<tr>
<td>Accelerating Coal Transition (ACT)</td>
<td>2021</td>
<td>A comprehensive program designed to assist countries in transitioning away from coal. ACT operates as a multilateral development bank (MDB) financing platform under the Climate Investment Funds (CIF). The program has received substantial financial backing from the G7, who pledged up to US $2 billion.</td>
<td>Dominican Republic, India, Indonesia, North Macedonia, Philippines, South Africa, Scotland</td>
</tr>
<tr>
<td>Glasgow Financial Alliance for Net Zero (GFANZ)</td>
<td>2021</td>
<td>GFANZ is a global coalition of eight financial sector net-zero alliances, uniting over 675 financial institutions spanning 50 countries and representing 40% of global private financial assets. GFANZ regularly publishes guidance on net zero, including a report on the managed phase-out of coal in the APAC region.</td>
<td>675 financial institutions from a diverse range of 50 countries</td>
</tr>
<tr>
<td>ASEAN Taxonomy for Sustainable Finance</td>
<td>2023</td>
<td>Includes coal phase-out activities in the Plus Standards framework. It categorises coal phase-out into “Green” if the CFPPs achieve phase-out by 2040 and “Amber” if the CFPPs achieve phase-out by 2050.</td>
<td>Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam</td>
</tr>
<tr>
<td>ASEAN Japan Economic Co-Creation Vision</td>
<td>2023</td>
<td>Aims to promote decarbonisation technologies such as hydrogen, ammonia, carbon capture, utilisation, and storage technologies.</td>
<td>Japan</td>
</tr>
<tr>
<td>Monetary Authority of Singapore (MAS)</td>
<td>2023</td>
<td>Transition Credit Coalition (TRACTION): MAS’s TRACTION initiative develops transition credits to expedite the phase-out of coal power in Asia by financially supporting shifts to cleaner energy sources. Singapore-Asia Taxonomy: The Singapore-Asia Taxonomy, introduced by MAS, is a pioneering multi-sector framework that classifies and promotes investments in climate mitigation and adaptation across the region.</td>
<td>APAC region</td>
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</table>
07. RECOMMENDATIONS
Where initiatives embrace the concept of clean repowering, they will increase the pace of coal phase-outs, especially in Asia. There are a range of technologies especially suited to economies that are highly dependent on coal for both power and heat. As these technologies mature, it will be possible to envision a rapid, clean and just transition, combining the quick-to-deploy greenfield renewable solutions with the repurposing of existing centralised thermal assets.

To reach this outcome, stakeholders may observe the following recommendations:

For Finance Providers (Debt and Equity)

Refinancing existing plants to facilitate early closure of CFPPs has been shown to be financially possible, but the inclusion of repowering and repurposing should also be considered. Investments in new clean capacity will further improve the bankability of the overall investment, and ensure emissions reductions occur and are not eroded, thanks to other thermal plants increasing their running hours.

When considering the refinancing of CFPP assets, it is important to be aware that the landscape of options is changing. While gas has historically often been the most commercially viable option, it cannot be considered “clean” due to carbon dioxide gas emissions and high methane gas leakage from wells, pipelines, and other infrastructure. Some clean, renewable technologies are now mature, while others are at earlier stages of development. First-of-a-kind demonstrators will help to bring genuinely clean technologies to market faster and make good candidates for blended finance solutions in some regions.

To improve the business case, finance institutions should work with institutions providing credit enhancement, such as governments, facilitation funds (e.g., ADB ETM), and development finance institutions, to improve the economics for refinancing and like-for-like repowering investments.

On the technological side, financial institutions should work with in-house/external experts to fully understand the emerging option landscape. These include co-locating existing and emerging technologies at CFPPs to avoid either lock-in to suboptimal solutions now (gas), or over-reliance on long-term solutions which are unlikely to be efficient or sustainable at a systems level (ammonia co-firing).

For new technology solutions with higher technological risks, public finance, philanthropic investments, and concessional capital can be sought, potentially alongside equity investors to help achieve lower financing risks.
For Policy Makers

International Policymakers

Policymakers should start by assessing the capacity for existing thermal assets to be repowered cleanly, as this will help to produce a more efficient overall solution at a systems level. Policymakers should be aware of the different technological solutions mentioned in this paper. Advice should be provided in a technology-neutral way, best suited for specific circumstances, and inclusive of all technologies which offer clean, like-for-like replacements for CFPPs at a systems level.

Working closely with emerging economy governments and providing advice and funding where necessary is critical to facilitate a faster transition away from fossil fuels. International partners (including those from OECD countries) can support the build-out of the supply chain and share experiences, particularly where they involve novel approaches (e.g., for nuclear, next-generation geothermal and large-scale heat batteries). Prioritising new capital investments that deliver equivalent clean capacity, and support the early closure and/or repurposing of existing CFPPs, will ensure both emissions reductions and economic development. For CFPPs tied to specific industrial units and not on the grid, policies could focus on creating a green premium for the industrial product. This could be financed, for example, through the levying of a small tax on emissions from these sites that are recycled to support auctions for clean supply contracts on the same sites. Removing the distorting impact of fossil fuel subsidies, at national and international levels, is one way in which clean repowering can be incentivised. Different solutions will be applicable in different geographies. International policy makers should seek to avoid excluding clean technologies capable of repowering coal assets or overly focusing on a subset of solutions. A tool such as RepowerScore can be used to carry out both top-down rankings and bottom-up assessments of sites suitable for repowering with different solutions.

National Policymakers

Collaboration with governments to develop supporting policies, such as those exemplified by JETP agreements, is crucial to align international support effectively. To accelerate towards repowering, national policymakers should commission a study, and consider all the available options for repowering at each CFPP site, including the benefits of maintaining existing transmission infrastructure. They should then consider creating a policy mechanism that various coal asset owners could access to support repowering, which may include easier access to international funding.

The redirection of current policies and financial measures to provide greater certainty of long-term revenue streams towards clean energy at those same sites (including direct and indirect CFPP subsidies), will help reduce costs to consumers and taxpayers. It will help facilitate a transition with numerous additional health, social and community benefits, including long-term retention of jobs.

Policies that deliver investor confidence for repowering projects can include auctions for long-term, stable contracts (including grid balancing services, power generation, and for example, clean capacity market contracts), clean electricity standards, tradable mandatory quotas for repowered clean supply (or clean demand from big consumers), tax credits, and feed-in tariffs. Ensuring value for the consumer (e.g., addressing expensive take-or-pay contracts and supporting ‘prosumers’) can ensure these policies receive popular support.

Figure 3 on page 23 shows a range of ways in which CFPPs are economically supported through policies. These can be adapted to explicitly support investment at the same site to transition to clean energy services.
For Utilities/Asset Owners

Ambitious and achievable plans that can attract government support and private finance are possible if:

- familiarity with the full range of clean repowering technologies is increased
- a suitability assessment for deployment on existing plant sites is undertaken
- the range of financing options is understood

Utilities should conduct a techno-economic assessment of each site to consider detailed options. They should choose and design a plan that can access the policy support, carbon finance and repowering mechanisms, such as JETP and others mentioned in Table 1 above. This will enable companies owning these assets to plan for a net-zero transition, helping to secure finance from a wider pool of investors and banks, and maintain or enhance revenues while meeting sustainability goals. For owners of CFPPs that are “captured”, i.e., serving specific industries rather than contributing to grid power systems, onsite repowering with clean sources of heat represents an important route to net zero. Without grid stability or storage benefits, these sites will initially require incentives based on environmental performance. Meeting environmental standards is likely to become increasingly important to gain or maintain access to export markets. Over time, as more cost-effective options for clean heat production come to market, such sites should have less need for policy support to transition.

For Technology and Project Developers

Clean power and grid stability service vendors can add repowering of existing power generating sites to their business plans, and partner with local firms to develop investible projects that deliver climate and economic development benefits. Such partnerships could take the form of Joint Ventures and SPVs, and could take advantage of the range of the available financial support measures.

It is in technology vendors’ and project developers’ interests to take part in proactive information-sharing efforts about the use of their technologies for this purpose, focusing on increasing awareness among other stakeholders, including asset owners, local utilities, policymakers and financiers.
I. About this Report

We are grateful to Dr Christoph Nedopil Wang and Climate Smart Ventures for their expert contribution to this document, and to Ashur Nissan (Kaya Partners) and Alex Clark (Oxford Smith School) for reviewing it and providing invaluable feedback. A philanthropic grant from HSBC to the Clean Air Task Force supported the research for this document. The views and opinions expressed in this report are only those of authors and contributors and do not reflect the views and opinions of HSBC or the Clean Air Task Force.

II. About the Repower Initiative

The Repower Initiative is a not-for-profit international programme, philanthropically funded via The Clean Air Task Force, with work carried out under contract by Quantified Carbon Ltd.

Since work on this topic began in 2019, the following outcomes have been achieved →
Established the Repower Concept in Poland and Won Government Support

The Repower work started with a case study for Poland, which was carried out with partners from leading Polish universities. The main study articles were exceptionally well received, scoring in the top 2% of all research outputs ever tracked by Altmetric. [7]

Rafał Kasprow, CEO of OSGE (Orlen Synthos Green Energy), commented that, "From a business and industrial perspective, they are the most important and best scientific papers ever written for Poland."

The work on repowering in Poland and across central and eastern Europe, inspired great interest from government, academia, and industry. Following the publication and dissemination of the Repower case studies, the national centre for R&D selected repowering as one of five key national strategic R&D programmes under the DESIRE project, led by Professor Łukasz Bartela from the Silesian University of Technology, who was the first collaboration partner identified and employed by the Repower Initiative. The US Department of State has accelerated the process, which recently provided feasibility studies to Eastern European countries interested in repowering via Project Phoenix. The US national laboratory work on this topic has cited our studies.

Expansion Across Asian partners

The Repower Initiative has more impact the younger the age of the power station fleet, which is why we focus significant efforts on Asia, home to the largest number of newer CFPPs. Since receiving funding from Founders Pledge for this work, we have secured two additional high-profile academic partners in Korea (KAIST) and Indonesia (ITB), are in talks with a leading academic institution in India, and are continuing to expand our network in China (in addition to our existing partners XMU and ISETS). China is the most critical country for addressing emissions from the power sector, given it is home to over 1000 GW of CFPPs. Our reach in China has been significantly improved thanks to partnering with key organisations responsible for strategy related to nuclear energy siting (and focused on enabling inland siting).
Established the Techno-Economic Basis, Ranking and Strategy for Repowering Concept

The Repower Initiative has produced eight full-length, open-access, peer-reviewed scientific articles on the topic, establishing the bulk of the scientific basis of clean repowering potential, technology pathways and economics.

As an amalgam of this knowledge and understanding to date, we recently launched the beta version of an interactive ranking and analysis tool called RepowerScore, which has established an enthusiastic global userbase.

Added the Finance Community to Our Stakeholder Engagement

Our work started with a focus on the technical and socio-economic aspects of repowering, but we quickly realised the importance of bringing the finance community on board. We subsequently secured financial philanthropic and in-kind support from HSBC, one of the world’s leading financial institutions with relevant networks and expertise in Asia.

Together, we are helping to broaden the range of options considered for early replacement of CFPPs.
Replacement of Coal with Natural Gas

Even though natural gas plants produce relatively little local air pollution compared to CFPPs, they cannot be considered “clean” due to carbon dioxide gas emissions and high methane gas leakage from wells, pipelines, and other infrastructure. Methane is 28 times more potent at trapping heat than carbon dioxide. A recent report by Global Energy Monitor shows that coal-to-gas conversions, which represent 13% of global gas-fired capacity in development, represent an enormous potential stranded asset risk. [21]

Because of this, from a sustainability perspective, gas is often no better than coal, and in some cases may be worse.

Partial or Full Replacement of Coal with Biofuels

Local availability of sufficient quantities of sustainable biomass is a major limiting factor. In the worst cases, biomass co-firing can lead to local air pollution, increased deforestation and a net greenhouse gases (GHG) emissions surge from the change in land use. However, if sustainably sourced from waste products, there may be a limited role for biomass/biofuel.
Co-firing of Coal with Ammonia

Trials are underway to co-fire coal stations with ammonia to reduce coal burning. However, the full cycle efficiency of using green ammonia for power generation is very low (~14%). Burning it presents human health risks and increases NOx emissions (or requires expensive abatement equipment). [22]

Carbon Capture and Storage

We would not rule out CCS as an option to bring down emissions at CFPPs since both pre- and post-combustion options exist theoretically. However, while CCS has seen application in the global oil industry and some demonstration in the power sector, it has yet to achieve substantial commercial scale. The need for geographically available carbon storage and transport makes the analysis more challenging. CCS on a plant adds costs, decreases efficiency, and does not address upstream methane emissions from the fossil fuel supply chain.
IV. Summary of Ongoing Coal Repowering Project

The US DOE recently supported a nuclear reactor demonstration project on a CFPP in Kemmerer, Wyoming. In addition, DOE has published a detailed assessment of the potential for repowering existing CFPPs and has agreed to fund technical assessments in Eastern Europe through its recent Project Phoenix. Project Phoenix focuses on replacing retired and soon-to-be-retired coal plants with nuclear energy capacity from SMRs, consistent with the highest nuclear security and non-proliferation standards.

Meanwhile, the US Inflation Reduction Act (IRA) set aside US $5 billion for direct loans specifically for the repowering, modifying, or constructing of generation and transmission facilities, making repowering a nascent but increasingly attractive option for investors. [23]

An early CFPP repowering project occurred in 2013-14, when General Electric Company (GE) repowered Units 3 and 4 of the Eastlake plant in Ohio, US, into SCs. The two turbine-generators, built in 1957 and 1972, are now retired from generating real power and instead provide voltage support in the form of reactive power to the grid. [24]

The Nanticoke power plant in Ontario, Canada, was repurposed to solar and came online in 2019. Nanticoke once provided 3,964 MW of power to the southern Ontario power grid and was the largest power station in North America. In 2013, it was decommissioned in line with Ontario’s commitment to eliminate coal-fired electricity. A partnership between Ontario Power Generation (OPG), Six Nations Development Corporation and Mississaugas of the Credit First Nation combined to repurpose the CFPP into a 44MW solar plant. 192,431 solar panels were installed on the coal storage area and neighbouring land. Infrastructure such as the existing transmission switchyard was reused, along with several existing towers and equipment (busbars, capacitors, electrical protections, etc.). [25]
<table>
<thead>
<tr>
<th><strong>Poland</strong></th>
<th><strong>Chile</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland has the highest reliance on fossil fuels for energy in the EU, producing 79% of its electricity from fossil fuels and 69% from coal [26]. Recent assessments [7, 14, 27, 28, 29] of the different options for phasing out the coal in Poland’s CFPP fleet, including adding carbon capture, fuel conversion, and the replacement of coal boilers with low carbon energy sources, found that the replacement of coal boilers with high-temperature small modular reactors (SMRs) was the most financially attractive. This option lowered upfront capital costs by ~9–28% and levelised cost of electricity (LCOE) by 9–28% compared to a greenfield development of the same specification. Nuclear investments involving the use of the locations of currently operating coal-fired power plants are being considered by power companies. Analyses for such projects are being conducted with the participation of the Polish government. SMR reactors appear to be particularly attractive in this regard. Activities aimed at implementing SMRs in Poland are being carried out by Orlen Synthos Green Energy in cooperation with GE-Hitachi, ŚGP Industria in cooperation with Rolls-Royce SMR, and Respect Energy in cooperation with Nuward.</td>
<td>AES Andes, a Chilean subsidiary of AES Corporation, won approval in November 2023 to transform its 560 MW Angamos CFPP into a molten salt-based energy storage system. Located in Mejillones, in the Antofagasta region of Chile, the project seeks to replace Units 1 and 2 of the Angamos Thermoelectric Power Plant with a solar molten salt system. The project is a first-of-its-kind example of repowering a CFPP to meet the original coal capacity fully with a renewable and storage solution. When both units are up and running, the molten salts will generate the steam necessary to reach a capacity of 560 MW—matching the power of the original coal units. The project involves retraining current Angamos coal workers in the new technology, thus preserving their source of employment. The developers intend to use most of the infrastructure and the same power line as Central Angamos to minimise land use changes, and no additional water is required above what is currently being used by the CFPP. The US $450m project is supported by the German Cooperation Agency (GIZ) and Siemens Energy.</td>
</tr>
</tbody>
</table>
V. Further Examples

Repowering and the reuse of infrastructure for renewables, storage and grid balancing has been studied, and Table 2 below summarises a list of identified projects to date.

Table 2. Existing and Proposed Repowered Coal Plant Sites

<table>
<thead>
<tr>
<th>Link</th>
<th>Plant name</th>
<th>Owner</th>
<th>Location</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2</td>
<td>Drax</td>
<td>Drax Group, TRIG</td>
<td>North Yorkshire</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>3</td>
<td>Nanticoke</td>
<td>Nanticoke Solar LP</td>
<td>Ontario</td>
<td>Canada</td>
</tr>
<tr>
<td>4</td>
<td>Beckjord</td>
<td>Duke Energy</td>
<td>Ohio</td>
<td>United States</td>
</tr>
<tr>
<td>5</td>
<td>Eastlake</td>
<td>FirstEnergy</td>
<td>Ohio</td>
<td>United States</td>
</tr>
<tr>
<td>6</td>
<td>Widows Creek</td>
<td>Google</td>
<td>Alabama</td>
<td>United States</td>
</tr>
<tr>
<td>7</td>
<td>Mount Tom</td>
<td>ENGIE</td>
<td>Massachusetts</td>
<td>United States</td>
</tr>
<tr>
<td>8</td>
<td>Patnow Coal Plant</td>
<td>PGE, ZEPAK &amp; KHNP</td>
<td>Patnow</td>
<td>Poland</td>
</tr>
<tr>
<td>9</td>
<td>Liddell</td>
<td>AGL Energy</td>
<td>New South Wales</td>
<td>Australia</td>
</tr>
<tr>
<td>10</td>
<td>Angamos</td>
<td>AES Andes, support from German Cooperation Agency (GIZ) and Siemens Energy</td>
<td>Antofagast</td>
<td>Chile</td>
</tr>
<tr>
<td>11</td>
<td>Brayton Point</td>
<td>Dynegy</td>
<td>New England</td>
<td>United States</td>
</tr>
<tr>
<td>12</td>
<td>Prosper Haniel</td>
<td>RAG AG</td>
<td>North Rhine-Westphalia</td>
<td>Germany</td>
</tr>
<tr>
<td>13</td>
<td>Redbank</td>
<td>Verdant Technologies Australia</td>
<td>New South Wales</td>
<td>Australia</td>
</tr>
<tr>
<td>14</td>
<td>Guru Nanak Dev</td>
<td>Punjab State Power Corporation</td>
<td>Punjab</td>
<td>India</td>
</tr>
</tbody>
</table>

Source: Coal Plant Repurposing for Aging Coal Fleets in Developing Countries [6], with additions from public sources.
<table>
<thead>
<tr>
<th>End use</th>
<th>Status</th>
<th>Coal capacity / MW</th>
<th>Repowered capacity / MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass, battery storage</td>
<td>Completed</td>
<td>3,945</td>
<td>2,616, 100</td>
</tr>
<tr>
<td>Solar</td>
<td>Completed</td>
<td>3,964</td>
<td>44</td>
</tr>
<tr>
<td>Battery storage</td>
<td>Completed</td>
<td>1,433</td>
<td>4</td>
</tr>
<tr>
<td>Synchronous condenser</td>
<td>Completed</td>
<td>1,620</td>
<td>N/A</td>
</tr>
<tr>
<td>Data centre</td>
<td>Completed</td>
<td>1,969</td>
<td>N/A</td>
</tr>
<tr>
<td>Solar, battery storage</td>
<td>Completed</td>
<td>137</td>
<td>5.37, 3</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Proposed</td>
<td>1100</td>
<td>2800</td>
</tr>
<tr>
<td>Gas, Renewable Energy, battery storage, demand response</td>
<td>Proposed</td>
<td>2,000</td>
<td>1600, 250, 500, 150</td>
</tr>
<tr>
<td>Molten salt energy storage</td>
<td>Proposed</td>
<td>560</td>
<td>560</td>
</tr>
<tr>
<td>Offshore wind</td>
<td>Proposed</td>
<td>1,600</td>
<td>400</td>
</tr>
<tr>
<td>Pumped storage</td>
<td>Proposed</td>
<td>N/A</td>
<td>200</td>
</tr>
<tr>
<td>Biomass, solar, battery storage</td>
<td>Proposed</td>
<td>151</td>
<td>151, 40, 50</td>
</tr>
<tr>
<td>Solar</td>
<td>Proposed</td>
<td>460</td>
<td>100</td>
</tr>
</tbody>
</table>
References


