PRIED
Policy Research Institute
for Equitable Development

Case Studies

THE NEED FOR CHANGING GEARS

Exploring opportunities for Chinese investment in Pakistan's energy transition

Authors

Rimsha Rehan, Manzoor Ahmed Alizai & Amina Shahab

Reviewers

Shaheera Tahir and Ammara Aslam

Designer

Usman Tariq

Acknowledgement

We extend our sincere appreciation to an esteemed constellation of contributors who have helped us illuminate our report with their expertise. We extend our heartfelt gratitude to the organizations and acknowledge their inputs for our study.

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

CPEC	China - Pakistan Economic Corridor
RE	Renewable Energy
NDC	National Determined Contributions
G-G	Government to Government
B-B	Business to Business
MW	Megawatt
AJK	Azad Jammu & Kashmir
LOI	Letter of Intent
BRI	Belt & Road Initiative
ML-1	Main line 1
KCR	Karachi Circular Railway
ICT	Information and Communication Technology
SECP	Securities Exchange Commission of Pakistan
CoPHC	China Overseas Ports Holding Company Pakistan (Private) Limited
MoU	Memorandum of understanding
BOI	Board of Investment
KAPCO	Kot Addu Power Company
WAPDA	Water & Power Development Authority
NPKAL	National Power Kot Addu Power Limited
UK	United Kingdom
GWh	Gigawatt Hour
KWh	Kilowatt Hour
GENCO	Generation Company
HFO	Heavy Furnace Oil
TPS	Thermal Power Station
NEPRA	National Electric Power Regulatory Authority
RLNG	Re-gassified Natural Gas
SynCoN	Synchronous Condenser
GW	Gigawatt
PPA	Power Purchase Agreement
KV	Kilovolt
KE	K-Electric
VSS	Voluntary Separation Scheme
CTBCM	Competitive Trading Bilateral Contract Market
HSD	High Speed Diesel
FY	Financial Year
PV	Photovoltaic
NPV	Net Present Value
NTDC	National Transmission and Dispatch Company

CPPA-G	Central Power Purchasing Agency- Government
LCOE	Levelized of Cost of Energy
NGLE	Nigbo Green Light Energy
CMEC	China Machinery Engineering Corporation
O&M	Operation & Maintenance
FDI	Foreign Direct Investment
IGCEP	Integrated Generation Capacity Expansion Plan
IMF	International Monetary Fund
KPK	Khyber Pakhtunkhwa
GHG	Green House Gas
ETM	Energy Transition Mechanism
ADB	Asian Development Bank
NUST	National University of Sciences and Technology
CBA	Cost Benefit Analysis
DFI	Development Finance Institutions
PPP	Private Partnerships
VFM	Value for Money
IPPs	Independent Power Producers
SOEs	State Owned Enterprises
BESS	Battery Storage Energy System
CAPEX	Capital Expenditure
CFPPs	Coal Fired Power Plants
BAU	Business As Usual
EPS	Earning Per Share
RFO	Residual Furnace Oil

Executive Summary

This report evaluates the financial viability of repurposing aging thermal power plants in Pakistan intoPakistaninto renewable energy facilities. As the China-Pakistan Economic Corridor (CPEC) enters its second phase (CPEC 2.0), the investment focus is shifting from large-scale infrastructure to sustainable energy, presenting a strategic opportunity for Chinese investors to support Pakistan's clean energy transition.

Redirecting investments from inefficient thermal power plants into renewable energy facilities aligns with global trends, where several countries have successfully converted coal and gas plants to solar and wind power. We also analyse the global process of decommissioning and repurposing an asset including a guideline for phases of decommissioning including benefits of repurposing decommissioned assets. For this, we extensively study the cases of decommissiondecommision process of thermal plants in India, Florida and Pakistan. Finally, we study two prime candidates for such a transition in Pakistan– Kot Addu Power Company (KAPCO) and Muzaffargarh Thermal Power Station (TPS, Muzaffargarh)– both of which have reached the end of their project life and suffer from critically low efficiency. The study employs a mixed-methods approach, integrating qualitative and quantitative analysis to assess feasibility. A cost-benefit analysis (CBA) highlights the inefficiencies of these plants, with critically low utilization factors and high operational costs. Repurposing them to solar energy offers significant financial and environmental advantages, with the potential for substantial savings in generation costs. As per our comparative analysis on generation cost, we estimate that::

For KAPCO, a comparison of the 210 MW Unit 3 with a 210 MW solar PV plant shows that solar PV significantly outperforms the gas turbine combined cycle in cost-effectiveness, with lower initial costs, zero fuel cost savings expenses, and accelerated much shorter payback period of 1 year. The analysis also shows that repurposing KAPCO to a 1350 MW solar facility would result in 74.4 million dollars per annum in savings from generation costs alone.

For TPS Muzaffargarh, the analysis reveals that a 300 MW solar PV plant is projected to generate 464 GWh per year with a payback period of 2.4 years, compared to the existing 320 MW steam turbine's 31 GWh annually. Solar PV also has lower initial and O&M costs. Repurposing TPS Muzaffargarh to a 1600 MW solar facility would result in 2.79 million dollars per annum in savings from generation costs alone.

This Retscreen Analysis also indicates positive net returns and a higher export revenue for repurposed Solar plantsplant as compared to thermal plants in both cases. Findings indicate that decommissioning these plants would be relatively straightforward, as both do not have any outstanding international debt obligations. However, targeted financing—whether through debt or equity—will be essential to support decommissioning and repurposing efforts.

Despite these advantages, several bottlenecks were identified including interviews with Chinese stakeholders hindering implementation, including sovereign risk, institutional uncertainty, financial constraints, and a volatile foreign exchange market. Addressing these challenges requires a clear policy mandate to extend the plants' use through repurposing, alongside a cost-effective strategy leveraging Chinese investments under CPEC 2.0. Establishing a dedicated financing mechanism could enhance investor confidence and accelerate the transition.

In conclusion, retiring and repurposing thermal plants (including coal power plants) such as KAPCO and TPS Muzaffargarh into hybrid renewable energy facilities presents a bankable opportunity for Chinese investors while ensuring Pakistan's long-term energy security and sustainability. Aligning with global trends, this transition offers both economic viability and environmental benefits, making it a compelling strategy for Pakistan's clean energy future.

Chapter: 1

Introduction

1.1. Overview

The global average surface temperatures are rising exponentially, giving rise to extreme weather events and climate-induced disasters[1]. These temperatures are exacerbated by anthropogenic activities such as burning of fossil fuels, industrial processes, and agricultural activities, causing increased greenhouse gas (GHG) emissions. Pakistan's agriculture and energy sectors contribute to the majority share of GHG emissions of the country, owing to its outdated practices, technology, and its heavy reliance on dirty fossil fuels. A sustainable alternative to these are renewable energy technologies such as solar and wind, offering sustainable solutions to curbing GHG emissions, improving energy security, promoting economic growth, and reducing environmental degradation[2].

Since 2006, Pakistan has introduced multiple policies to support Renewable Energy (RE) and decarbonization, aiming to create a more diverse and sustainable electricity mix. The Alternative and Renewable Energy Policy 2019 aimed to increase the share of RE from 5% to at least 20% by 2025 and 30% by 2030. Additionally, Pakistan joined the Asian Development Bank's (ADB) Energy Transition Mechanism (ETM) to explore the early retirement of coal-fired power plants. However, these RE goals contrast with ongoing policies that emphasize coal as a key solution for energy security, with plans to quadruple domestic coal capacity to reduce dependence on natural gas[3]. Pakistan's Indicative Generation Capacity Expansion Plan (IGCEP) 2022–2031 shows that an additional 1,290 megawatt (MW) of coal-based capacity (300 MW from imported coal and 990 MW from local sources) is planned before 2031[4].

Despite Pakistan's RE targets, a clear roadmap or commercial incentives (such as Feed-in Tariffs or auctions) to drive RE investments remain absent. Moreover, significant investments in grid infrastructure are required to integrate variable renewable energy sources effectively. These bulk investments and financing is not possible to be procured only from public sector investments, and requires significant private financing. A major opportunity comes in the form of The China-Pakistan Economic Corridor (CPEC), which has seen heavy investments from Chinese businesses and private sector developers. CPEC consists of key components that have shaped Pakistan's economic landscape, including Gwadar development, energy projects, transport infrastructure, investments, and industrial cooperation. These projects offer diverse opportunities for investors, fostering holistic economic development across Pakistan. Major projects under the CPEC initiative can be visualized through Figure 1.

1 *Global Surface Temperature: A New Insight*

2 *Carbon neutrality in the Finnish energy sector: prospects for a fossil‐fuel phase out - Proskurina - 2024 - Biofuels, Bioproducts and Biorefining - Wiley Online Library*

3 *Exclusive: Pakistan plans to quadruple domestic coal-fired power, move away from gas | Reuters*

4 *IGCEP 2024-34 Report.pdf*

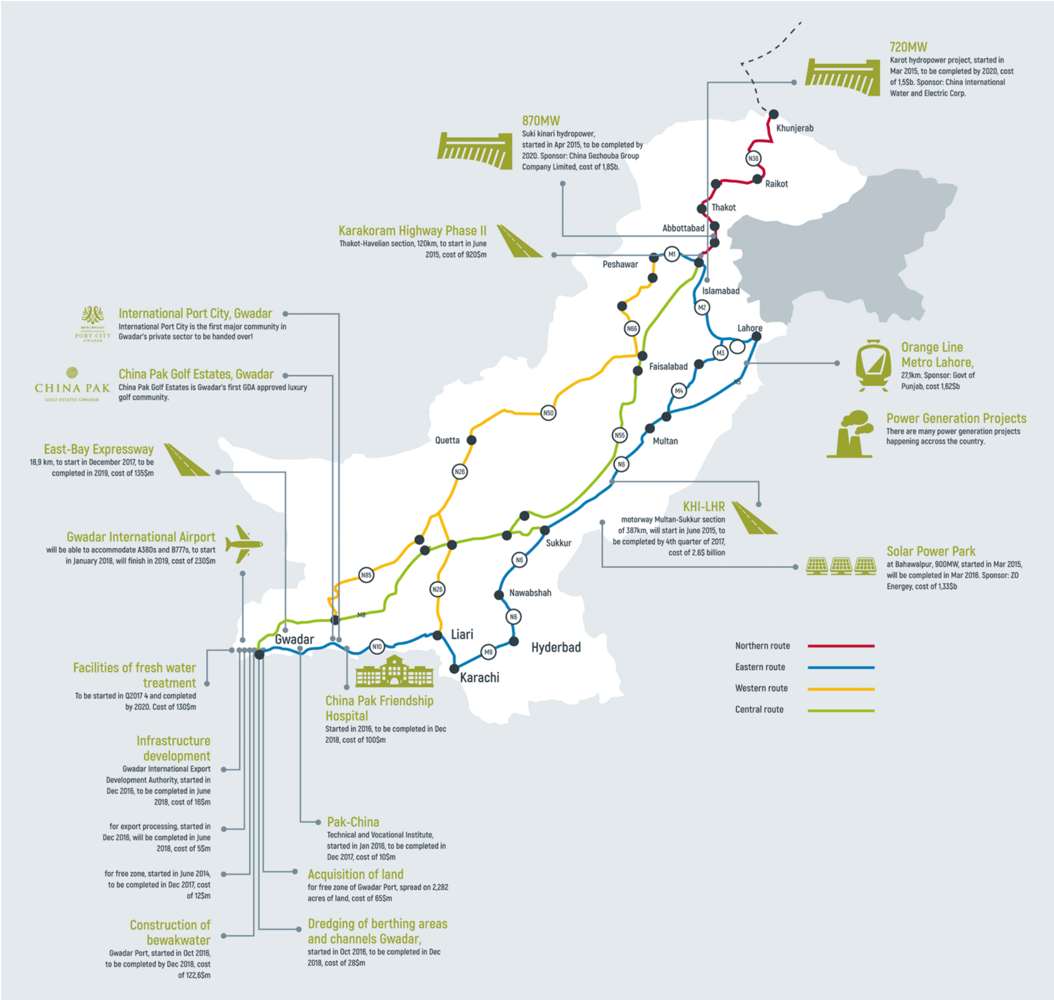


Figure 1: CPEC route and major projects under CPEC[5]

The CPEC initiative has drawn significant Chinese investments, with the total projected investment reaching 60 billion dollars. Of this, 57 billion dollars is earmarked for infrastructure development, including highways, railways, pipelines, and power generation projects, which will drastically improve connectivity in the region. The infrastructure upgrades will complement the development of key sectors such as education, communication, and economic zones, particularly focusing on the growth of Gwadar, a port city located on the Arabian Sea. Ultimately, through CPEC, China is not only investing in infrastructure but also fostering a deeper socio-economic partnership with Pakistan, reinforcing both nations' strategic objectives and regional stability.

1.2. Objectives

The primary objective of this study is to conduct a comprehensive analysis, particularly for Chinese investors, to redirect investments from fossil fuel projects to renewable energy (RE) projects. Given China's significant involvement in Pakistan's energy sector, Pakistan faces the dilemma of growing energy demand-supply gap alongside the need to shift toward an affordable, sustainable, and reliable energy mix. This study aims to highlight the current opportunities and co-benefits of energy transition for Chinese investors, who can capitalize on business opportunities that yield both financial returns and contribute to Pakistan's commitment to reducing its carbon footprint.

5 https://www.cpicglobal.com/pakistan-overview/cpec/

To illustrate this case, our study focuses on the following:

- To map out existing and in-pipeline energy projects under CPEC 1.0
- To explain the current state of play for investors under CPEC 2.0 (the shift from G2G towards B2B)
- Provide global examples of decommissioning and repurposing of thermal plants towards RE.
- Carry out a detailed cost-benefit analysis of two case studies in Pakistan as opportunities for redirecting investments from thermal to RE.
- Identifying major bottlenecks for investors in Pakistan and possible recommendations to overcome these.

1.3. Methodology

This study employs a mixed-methods approach, combining qualitative and quantitative analyses to achieve its objectives. The methodology is designed to map existing and pipeline energy projects under CPEC, assess the current investment landscape, and evaluate the potential benefits and challenges of transitioning from thermal to renewable energy (RE). The steps are outlined below:

1. Qualitative Analysis

a. Literature Review

A extensive review of secondary sources was conducted by the PRIED team to build a foundational understanding of the energy landscape in Pakistan. The literature review included:

I. Research papers and policy documents on CPEC Phase 1.0 and 2.0.

II. Case Studies on decommissioning and repurposing thermal plants to renewable energy globally, focusing on examples such as India and Florida.

III. News articles and reports providing recent developments in Pakistan's energy sector and Chinese investments.

b. Stakeholder Interviews

One-on-one semi-structured interviews were carried out by PRIED team, with key Chinese stakeholders involved in CPEC and renewable energy projects. These included representatives from:

I. China Study Centre, NUST

II. Ningbo Private Limited

III. China Three Gorges Corporation

2. Quantitative Analysis

Cost-Benefit Analysis (CBA)

A detailed cost-benefit analysis was performed by PRIED's team for two case studies in Pakistan: KAPCO (Kot Addu Power Company) and TPS Muzaffargarh (Thermal Power Station Muzaffargarh).

1. State-of-Industry Reports Analysis

Using data from industry reports, the cost of electricity generation was evaluated if the plants were decommissioned and repurposed for renewable energy.

2. RETScreen Software Analysis

RETScreen Expert software was utilized for advanced financial and technical modeling:

I. For TPS Muzaffargarh, the cost-benefit analysis was conducted for a solar-based repurposing of one thermal unit.

II. For KAPCO, a similar analysis was carried out to assess the potential financial and environmental benefits of transitioning to renewable energy.

The RETScreen analysis provided detailed insights into: Energy generation costs, cost-benefit ratio of repurposing and financial returns on investment to solar based generation.

3. Synthesis of Findings

By integrating the results of the qualitative and quantitative analyses, the study identifies:

I. The key bottlenecks for investors in transitioning to renewable energy projects under CPEC Phase 2.0.

II. Specific recommendations to overcome these barriers and leverage opportunities for renewable energy development in Pakistan, aligned with international commitments and sustainable energy goals.

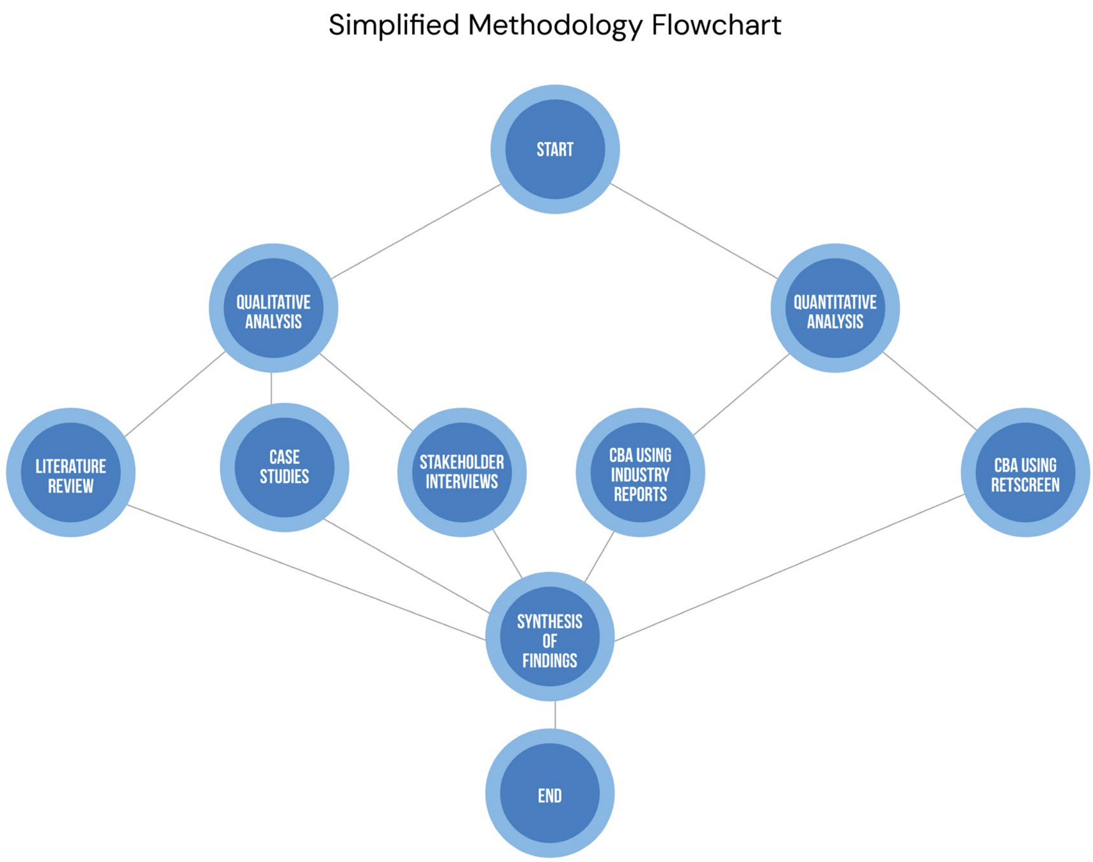


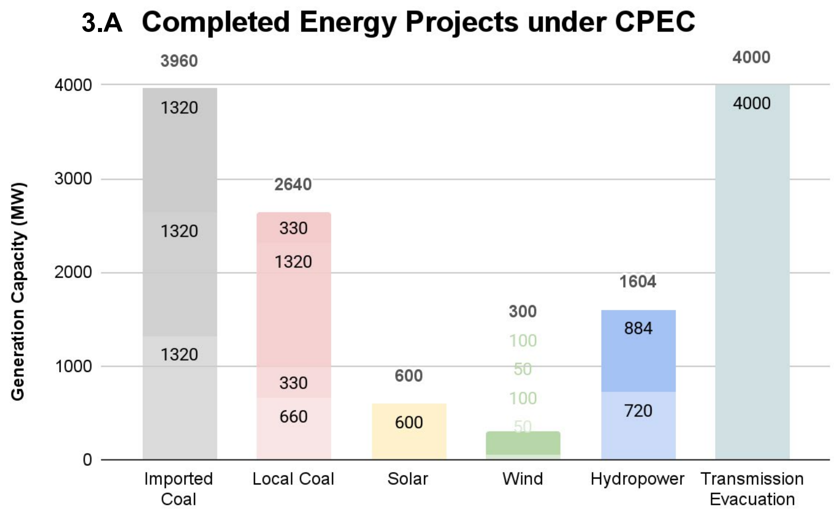
Figure 2: Methodology Flowchart

Chapter: 2

Energy Sector Investments under CPEC

2.1. CPEC 1.0: Government-to-Government Projects

As seen from the figure 1 above, various infrastructure, socio-economic and development projects are operational and have been planned under the CPEC. However, in particular, the energy sector has a substantive role in the first phase of CPEC projects. The details of these projects are shown below in Figure 3:



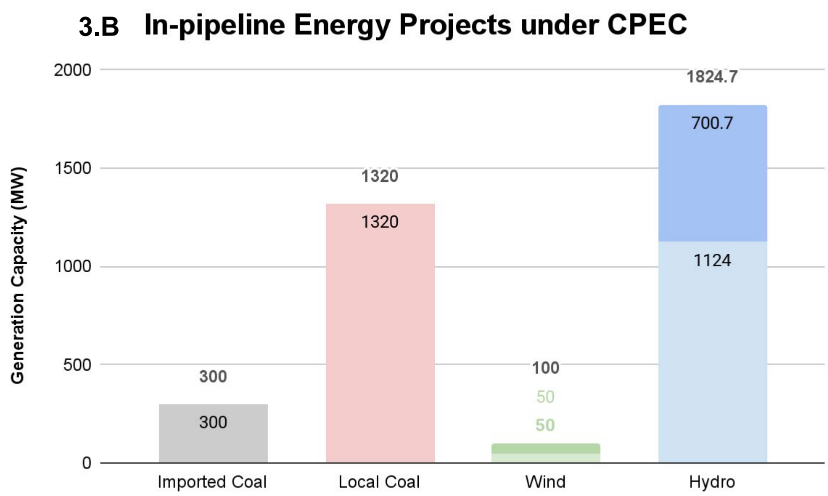


Figure 3A and 3B: Completed versus Pipeline Energy Projects under CPEC[6]

As seen from the figure 3 above, 15 energy projects (including transmission) were completed and currently operational under CPEC phase 1.0. However, most of these completed energy projects were based on thermal energy including 3960 MW of Imported Coal projects and 2460MW of local coal project, with an aggregate of 6600 MW coal based generation (that constitutes to 72 percent of their total energy portfolio) out of the total 9104 MW (excluding transmission project). As compared to this, variable renewable energy based projects (solar and wind) only constituted 1904 MW which is approximately 20 percent of the energy mix.

6 https://cpec.gov.pk/energy

In comparison to the completed projects, the in-pipeline energy projects show a significant decline in coal based power generation as its share has been drastically reduced to 1620 MW (imported and local both), whereas om-pleted projects. The 100MW in-pipeline wind energy project and 1824MW hydro project indicate a window of opportunity for a shift towards renewable energy.

Overall, 21 G-G power projects are underway, with varying stages of completion and operational readiness: 15 projects are already commissioned as shown above and are commercially operational, contributing significantly to Pakistan's energy supply. From the total 6 in-pipeline projects, 3 projects are in the final stages of financial closing

I. 300MW Coal-Fired Power Project at Gwadar

II. 1124MW Kohala Hydropower Project, AJK

III. 700.7MW Azad Pattan Hydropower Project, AJK/Punjab)

The remaining 3 projects have received the Letter of Intent (LOI) indicating their progression toward formal approval and subsequent development.

IV. 1320 MW Thar Mine Mouth Oracle Power Plant & surface mine

V. 50MW Cacho Wind Power Project

VI. 50MW Western Energy (Pvt.) Ltd. Wind Power Project)

2.2. CPEC 2.0: A shift from G2G towards B2B

The CPEC 1.0 phase primarily focused on coal and fossil fuel-based energy projects, with an emphasis on government-to-government (G2G) collaboration. This initial phase was aimed at addressing Pakistan's severe energy shortfalls by rapidly deploying power generation infrastructure. However, the limited attention to renewable energy in this phase has drawn criticism, particularly given the global shift towards cleaner energy solutions and concerns about the environmental impact of fossil fuels.

From the energy security perspective, CPEC 1.0 was focused on enhancing the overall capacity and energy infrastructure. This approach catered to the immediate electricity needs of the country, prioritizing quick fixes over long-term sustainability. Contrary to that, there is now a notable shift of focus towards cleaner energy investments. These changes are reflected in policy adjustments and financial commitments within China's Belt and Road Initiatives (BRI) projects such as CPEC.

In Phase 2, renewable energy projects under CPEC are intended to balance out the fossil fuel-heavy portfolio of Phase 1. This phase includes ambitious initiatives like the development of solar and wind farms and exploring green and digital corridors that support low-carbon, technologically advanced economic zones. The establishment of these zones and sustainable infrastructure will not only address Pakistan's energy demands in an eco-friendly manner but also create a competitive business environment, attracting investment in technology, innovation, and high-value industries.

For transport infrastructure, projects like Main Line-1 (ML-1) and Karachi Circular Railway (KCR) are other crucial components that are geared to enhance sustainable connectivity, thereby contributing to CPEC's green corridor vision. There is also a focused push to develop Gwadar Port as a regional logistics and trade hub, enhancing its commercial viability. In addition to these, sectors such as agriculture, science, information and technology, and digital commerce have also been included in the phase 2. While these developments are essential for economic diversification, their long term success depends on reliable and sustainable energy infrastructure.

This shift in China's approach, with a commitment to investing 100 billion dollars in green initiatives, opens significant opportunities for private sector involvement in Pakistan's energy transition. Within the CPEC framework, this evolving focus aligns with Pakistan's urgent need for renewable energy solutions to address its growing demand and while ensuring affordability. The scale of this transition requires massive financial investment, with estimates indicating that approximately 115.7 billion dollars will be needed for renewable energy development alone, presenting a promising avenue for private sector participation and collaboration[7].

2.3 Facilitating Chinese Business Operations in Pakistan: A Guide to Registration and Expansion

The Government of Pakistan has signed an MOU with the Chinese government to simplify the process for Chinese companies to establish subsidiaries or branch offices in Pakistan. Through this MOU, Chinese companies that are already registered can apply to register and operate subsidiary or branch companies in Pakistan by applying to the Securities and Exchange Commission of Pakistan (SECP).

To streamline operations, the China Overseas Ports Holding Company Pakistan (Private) Limited (COPHC) has established a facilitation center within the Gwadar Free Zone. This center, created in collaboration with SECP, acts as a bridge between SECP's registration offices and foreign investors, assisting with registration and post-incorporation activities, as well as addressing other business needs in Pakistan.

Registration Process and Requirements for Foreign Companies

1. Initial Permission from BOI: Foreign companies need to secure a permission letter from the Board of Investment (BOI), which has a specified validity period for business operations in Pakistan.

2. Document Submission and Ministry Approvals: Following BOI approval, requisite documents must be submitted for registration with SECP. Depending on the nature of the business, specific ministry approvals may also be required before incorporation.

3. Categories of Foreign Company Incorporation:

   I. Fresh Company (New): A newly incorporated company with independent business operations.

   II. Branch Office: Established to fulfill specific contractual obligations in Pakistan, limited to the scope of the contract, and restricted from engaging in commercial trading activities.

   III. Liaison Office: Set up to promote products, provide technical advice, explore joint collaborations, and promote exports. Liaison offices are similarly restricted from engaging in commercial or trading activities.

This strategic framework and facilitation center support cross-border investment and collaboration, ensuring Chinese businesses can effectively navigate local regulatory requirements while strengthening bilateral economic ties.[8]

Building on CPEC's evolving focus on green initiatives and private sector participation, the repurposing or decommissioning of aging fossil fuel plants like Muzaffargarh and KAPCO emerges as an opportunity within Pakistan's energy transition. These plants, once central to meeting the country's energy needs, are now hindered by declining performance and rising operational costs, making their traditional operation increasingly unsustainable.

7 *https://www.thenews.com.pk/magazine/money-matters/1232789-cpecs-road-to-renewables*

8 *https://hamzaandhamza.com/how-to-incorporate-registered-foreign-chinese-companies-in-pakistan/*

Chapter: 3

Repurposing Thermal Power Plants to RE

As Pakistan navigates its energy transition, aligning its domestic policy actions with broader regional initiatives like CPEC green shift is crucial. In this context, repurposing of aging thermal power plants, KAPCO and TPS Muzaffargarh to renewable (solar) based power plants presents a significant opportunity.Repurposing aging power plants can help Pakistan reduce operational costs, cut fossil fuel imports, and accelerate its energy transition while serving as a model for similar projects.

Before conducting the cost-benefit analysis, it is essential to examine global experiences, such as India and USA, which provide insights into both plant-specific and broader societal benefits. These case studies highlight decommissioning costs—covering labor, environmental remediation, and site cleanup—as well as the economic potential of converting fossil fuel plants into solar facilities, offering valuable lessons for Pakistan's transition.

3.1. Global Process of Decommissioning & Repurposing an Asset

Decommissioning is not just about shutting down an outdated asset but it is about strategically assessing whether to dismantle, repurpose, or integrate them into a new energy framework. The cost of decommissioning plants varies according to multiple factors such as fuel type, plant size, location etc. One such example is that the decommissioning of a 500-MW coal-fired power plant, on average, can range from **5 million to 15 million dollars**, after accounting for the value of scrap materials. The process usually takes **18 to 30 months** to complete.[9] Successful global examples demonstrate that a well-planned transition can minimize economic disruptions, optimize infrastructure reuse, and accelerate the deployment of renewable energy solutions.

This section explores the structured process of decommissioning and repurposing fossil fuels based power plants, focusing on key phases, decision-making frameworks, and pathways for asset transition.

3.1.1. Phases of Decommissioning[10]

Phase 1: Scope Identification and Allocation

Figure 4 illustrates the flowchart of the decision-making process for managing the transition of energy assets, focusing on the decommissioning, repurposing, and equitable transition of existing infrastructure. It outlines three main pathways based on the condition and future use of the asset, with associated responsibilities.

Decision-Making Framework: The transition of energy assets follows three main pathways—decommissioning, repurposing, and equitable transition, with responsibilities assigned based on asset condition and future use.

1. **Decommissioning of Existing Assets:** Two approaches: Location Reuse (new facility at the same site) or Process Integration (reconfiguring for a new function). If decommissioning is required, responsibilities are split between power and non-power sector entities, depending on the asset's alternative use. Structural changes vary significantly for non-power-based transitions, though this framework focuses on power-to-power transitions.
2. **Repurposing and Operation:** If decommissioning is unnecessary, responsibility merges with constructing and operating the new asset, optimizing infrastructure utilization.
3. **Just and Equitable Transition:** Ensures social and environmental impacts are addressed fairly, with Government and Development Finance Institutions (DFIs) supporting inclusive, sustainable transitions.

9 *https://www.powermag.com/coal-power-plant-post-retirement-options/*

10 *https://www.cif.org/knowledge-documents/react-simplified-guide-repurpose-coal-assets*

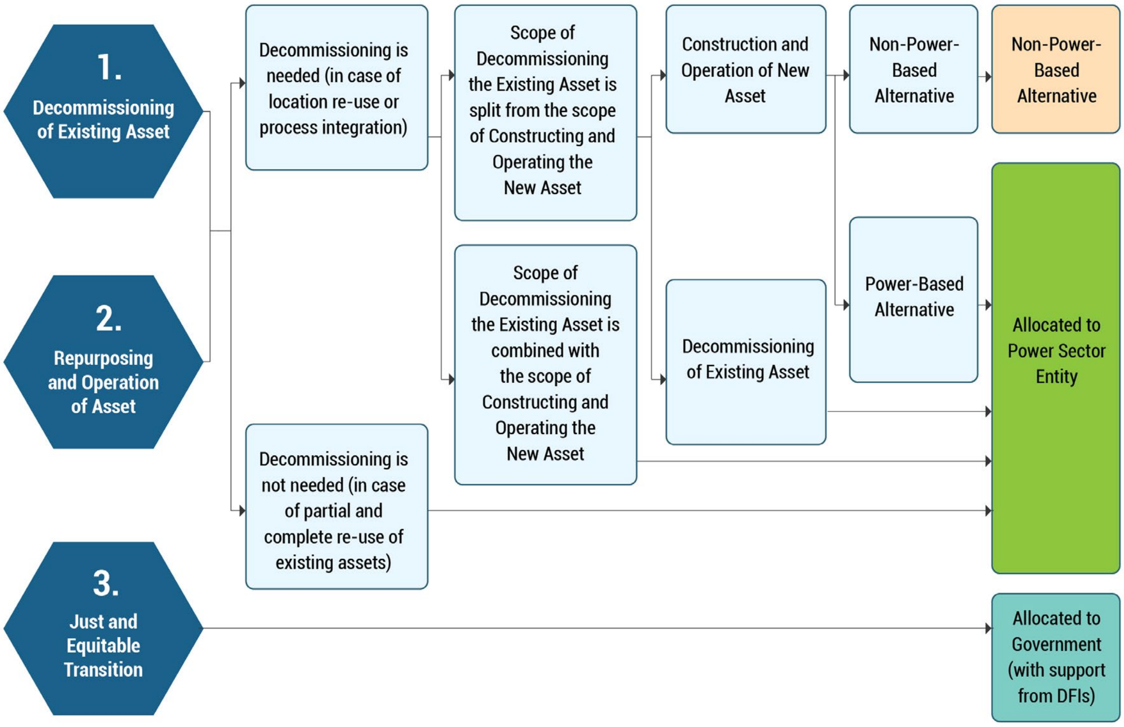


Figure 4: Scope Identification & Allocation of Decommissioning[11]

Phase 2: Selection of a Procurement Model

Once the scope of repurposing is defined, the next step is choosing a procurement model—either a traditional public sector model or a public-private partnership (PPP) model. The decision depends on two key factors:

1. Criticality of the Asset: Most power plants can be repurposed through the PPP model. However, if a plant is strategically important—such as the primary power source for a region—the government or state-owned enterprises (SOEs) may handle repurposing directly.
2. Value-for-Money (VFM) Analysis: For non-critical assets, the choice between traditional procurement and PPP depends on cost-effectiveness. The PPP model often provides advantages, such as:
   I. Better financial flexibility, reducing upfront costs by spreading payments over the asset's lifetime.
   II. Improved efficiency and innovation, leveraging private sector expertise.
   III. Optimal risk allocation, ensuring smoother project execution.

A VFM analysis helps compare the long-term costs of repurposing under both models.

Phase 3: Establishment of a Detailed Transaction Structure

This step involves a detailed commercial and risk assessment to establish a viable framework for repurposing. The key areas covered include:

11 https://www.cif.org/knowledge-documents/react-simplified-guide-repurpose-coal-assets

I. Assessing the Existing Capital Structure	Repurposing energy assets requires managing financial obligations for **IPPs and State Owned Enterprises (SOEs)**, each with unique challenges. **IPPs** face complications from outstanding debt, potential **prepayment penalties**, and financial hedge unwinding. **SOEs**, funded through corporate or sovereign debt, must navigate broader **fiscal constraints**. If **decommissioning** is involved, asset write-offs and financing restrictions must align with **government debt regulations**.
II. Contractual Structure & Risk Allocation	Repurposing follows either a **traditional procurement** or a **PPP model**. The **traditional model** is simpler, with **government/SOE oversight**, but must ensure **financial viability**. The **PPP model** is more complex, requiring **risk allocation** and careful structuring, especially for **unconventional projects**. Clear **contractual terms** for decommissioning and a **market assessment** are crucial to align **financial, regulatory, and operational factors** for a smooth transition.
III. Evaluating Financial Viability; Who will pay?	A financial assessment ensures the **repurposing model** is self-sustaining by analyzing **cash flow, subsidies, and consumer affordability**. **Cash flow analysis** confirms if projected revenues cover costs, while **subsidies or DFI support** (e.g., tax breaks, grants, concessional financing) may be needed if viability is uncertain. **DFIs** also offer **risk mitigation tools** to attract investment. The model must balance **cost-competitiveness for consumers** with **long-term sustainability** for investors and the government.
Phase IV. Assessment of Implementation Capacity	The **off-taker** must assess its expertise in structuring and implementing **repurposing finance mechanisms**. If internal capacity is insufficient, especially for **pilot projects**, **DFIs** can offer **technical assistance**. With experience in **coal transitions across Asia and Africa**, DFIs are well-equipped to support successful implementation.

3.1.2. Benefits of Repurposing Decommissioned Assets

As illustrated in **Figure 5**, repurposing decommissioned fossil fuel plants into renewable energy facilities offers **direct plant-specific benefits**, **indirect system benefits**, and **indirect societal benefits**. Direct benefits include cost savings from avoided demolition, reuse of existing grid infrastructure, and faster project deployment. Indirect system benefits enhance grid stability, improve energy security, and optimize capacity planning. Indirect societal benefits include job creation, reduced environmental pollution, and long-term energy affordability.

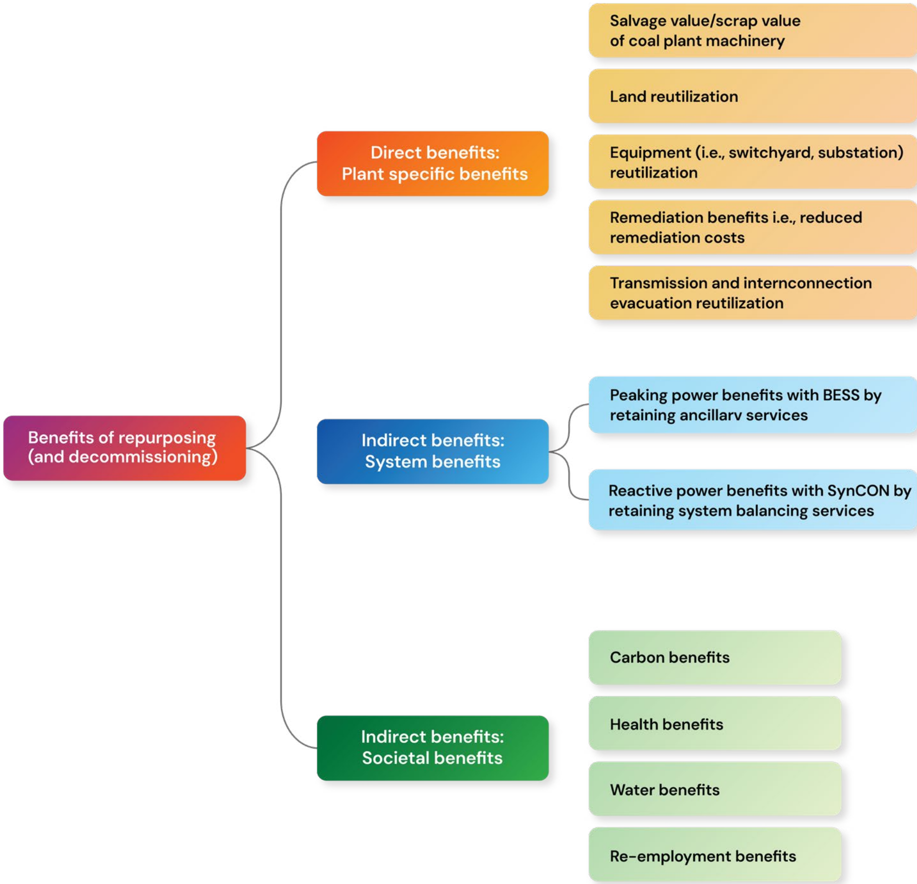


Figure 5: Benefits of Repurposing & Decommissioning[12]

Building on the basic process of decommissioning and repurposing and its detailed phases, some examples of the decommissioning processes globally such as those of India and Florida need to be explored. There have been a few studies that analyse the potential of retirement of coal plants in Pakistan and Vietnam[13] as well. The case studies will also help develop an understanding of the feasibility of repurposing thermal-based plants to renewable based power plants as a bankable opportunity in Pakistan.

3.2. Cost of Decommissioning in India[14]

A 2022 study conducted in India provides a detailed breakdown of decommissioning costs for a 1000 MW coal-fired power plant, highlighting both direct plant-specific costs and indirect system costs. As shown in Table 1, the total decommissioning cost amounts to 117.4 million dollars, with key cost components including employee expenses, station overheads, operation and maintenance (O&M), environmental compliance, demolition, and coal site remediation. Notably, system balancing costs, which account for grid stability measures post-decommissioning, contribute significantly to the overall financial burden.

12 https://www.sciencedirect.com/science/article/abs/pii/S0301421522001367

13 https://www.sciencedirect.com/science/article/pii/S0301421524003112

14 https://www.sciencedirect.com/science/article/abs/pii/S0301421522001367

Table 1: Costs of decommissioning a representative coal plant (million dollars/1000 MW)

S. No.	Item	Plant specific costs (million US dollar)	Lifetime costs*
A.1	Employee, Station overheads and O&M expenses	35.15	
(i)	Employee costs	7.11	
(ii)	Station overheads	24.14	
(iii)	Operation and Maintenance (O & M) expenses	3.90	
A.2	Pre-demolition costs: Environmental regulation	0.09	
A.3	Demolition costs	4.05	
A.4	Coal combustion residuals	15.72	
A.5	Coal storage area cleanup	3.10	
	Direct costs: Plant specific costs (A.1-A.5)	58.11	
B.3	System balancing costs		59.31
	Indirect costs (B.3)		59.31
	Total costs (A.1-B.3)	117.42	

For a representative coal plant of 1000 MW, Table 2 presents the gross benefits of repurposing the coal plant with a combination of solar, battery energy storage systems (BESS), and synchronous condensers (SynCON). Among the direct benefits, the scrap value is the most significant contributor at 65.65 million dollars, fully covering the direct decommissioning costs of 58.11 million dollars. This includes the salvage value of coal plant equipment after deducting repurposing costs. Land reutilization adds 9.07 million dollars, while retained equipment such as switchyards and substations contributes 16.40 million dollars. Additionally, avoided ash pond cleanup costs provide 15.72 million dollars in remediation benefits. In total, direct benefits amount to 122.79 million dollars, which remain consistent across all three repurposing scenarios.

Table 2: Gross benefits of repurposing options (million dollars /1000 MW)

S. No.	Item	Plant Specific Benefits	Lifetime benefits*
A.1	Scrap value	65.65	
A.2	Land utilization	9.07	
A.3	Equipment (Switchyard, substation)	16.40	
A.4	Remediation benefits	15.72	
A.5	Transmission & interconnection evacuation	15.96	
	Direct benefits: Plant specific benefits (A.1-A.5)	122.79	
B.1	Peaking power benefits: BESS		29.6
B.2	Reactive power benefits (Net): SynCON		54.32
	Indirect benefits: System (B.1-B.2)		83.92
B.3	Carbon benefits		515.09
B.4	Water benefits		3.4
B.5	Re-employment benefits	3.6	
	Indirect benefits: Societal (B.3-B.5)		522.02
Total benefits:			
	Solar only (A.1-A.5+B.3-B.5)	644.81	
	Solar and BESS (A.1-A.5+B.1+B.3-B.5)	674.41	
	Solar, BESS and SynCON (A.1-A.5+B.1-B.2+B.3-B.5)	728.73	

The Figure 6 illustrates the benefits of three repurposing options i.,e if a coal plant is replaced by solar plant only, solar plant with battery and solar plant + battery + SynCON[15]. The analysis shows that the benefits of repurposing the coal plant with solar far exceed the decommissioning costs across all scenarios. The maximum potential benefits from repurposing—considering different combinations of solar, BESS, and SynCON—reach 122.79 million dollars, 468.03 million dollars and 590.82 million dollars in total respectively. Figure 6 illustrates the net present benefits of each repurposing option, both in absolute financial terms and as a percentage of the combined capital expenditure (CAPEX) for decommissioning and repurposing. This comparison highlights the strong economic case for transitioning from coal to renewable energy.

15 *SynCON is used for reactive power management*

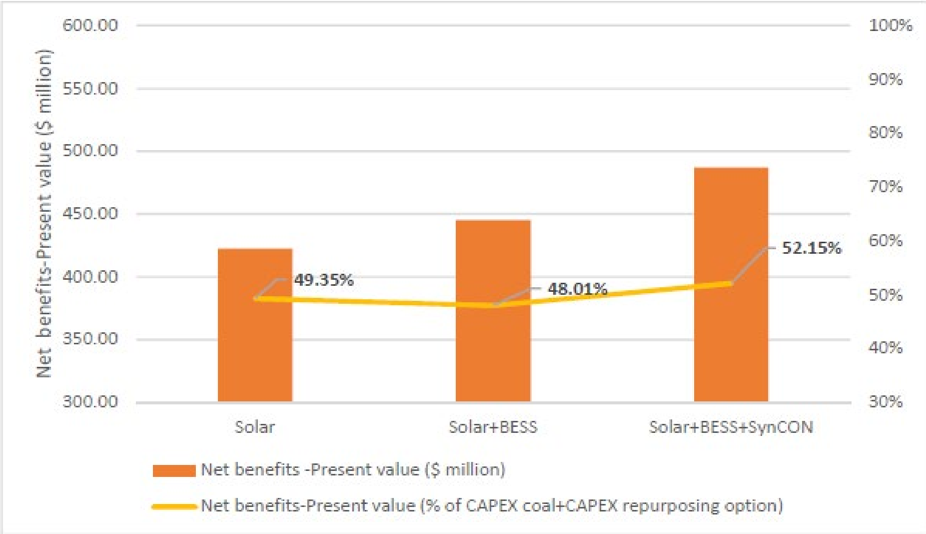


Figure 6: Net benefits - Present value (million US dollar and percentage).[16]

3.3. Cost of Decommissioning in Florida

For gas plants, dismantling turbines is a major expense, while for petroleum plants, the removal of boilers represents a significant cost. Figure 7 highlights the primary cost factors for decommissioning petroleum and gas plants in Florida. The salvage value of scrap steel from larger plants can exceed 20 million dollars, offering some financial offset. Additionally, substantial costs are incurred in cleaning and removing fuel storage infrastructure, including tanks and pipelines. Contractors also include fees and contingency budgets to account for unexpected costs during the decommissioning process.[17]

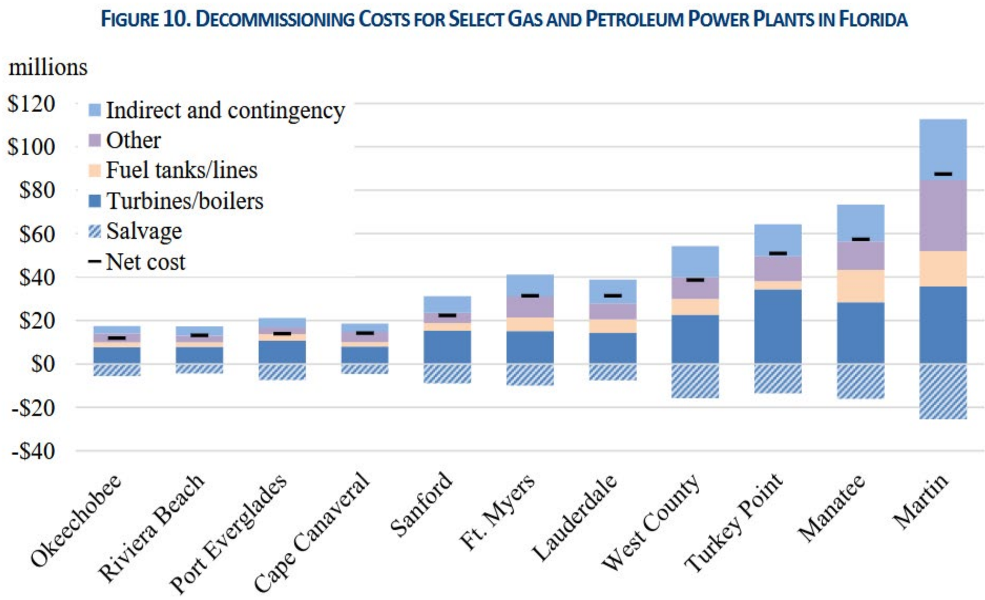


Figure 7: Decommissioning Costs for Select Gas and Petroleum Power Plants in Florida

16 https://www.sciencedirect.com/science/article/abs/pii/S0301421522001367

17 https://media.rff.org/documents/RFF20Rpt20Decommissioning20Power20Plants.pdf

Figure 8 illustrates the variation in decommissioning costs for plants of different sizes. There is no significant difference in decommissioning costs between gas-fired and petroleum-fueled plants.[18]

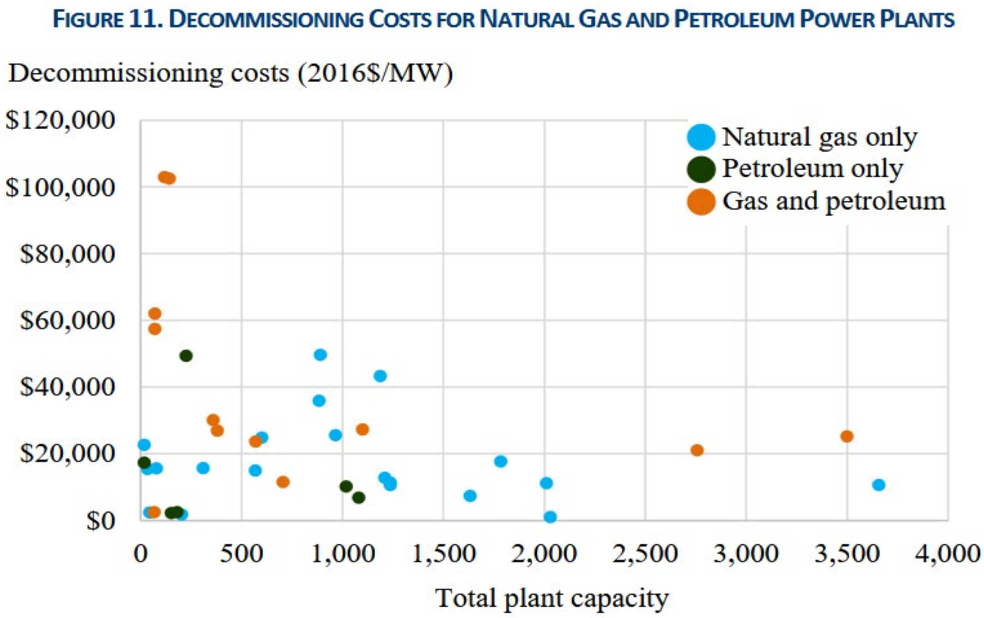


Figure 8: Decommissioning Costs for Natural Gas & Petroleum Power Plants

Considering figure 8, we can infer that for decommissioning of a 1350MW[19] gas and thermal fired power plant, it will approximately cost 33.7 million dollars[20] (in 2016 dollar terms).

3.4. Cost Comparison of Decommissioning in Pakistan's context

Available estimates for the United States (US) suggest that decommissioning costs range from 21 to 466 million dollars per GW, with an average of 117 million dollars per GW [21]. In comparison, the estimated direct decommissioning costs for power plants in India are significantly lower at approximately 58 million dollars per GW[22]. Several factors may explain these differences. Firstly, while the US estimates are based on actual costs incurred after decommissioning, the Indian estimates are made in advance, which can vary depending on market conditions such as scrap value and labor costs. Secondly, the Indian estimates account for only a limited set of costs and exclude components such as contingency costs for unexpected environmental remediation and broader social costs. Finally, decommissioning in the US typically involves higher expenses due to stricter environmental regulations, severance pay for employees, and obligations under pre-existing contracts, all of which are less prominent cost drivers in India.

Can investors benefit from the early retirement of coal plants: A plant-level analysis of Chinese-sponsored coal stations in Vietnam and Pakistan

A recent study[23] carried out by Griffith Asia Institute, Climate Smart Ventures, and Fudan University examined the financial impact of early retirement of six Chinese-sponsored coal-fired power plants (CFPPs) in Vietnam and

18 https://media.rff.org/documents/RFF20Rpt20Decommissioning20Power20Plants.pdf
19 Reference to TPS Muzaffargarh
20 25000$ x 1350 = 33750000
21 https://www.ourenergypolicy.org/wp-content/uploads/2017/10/RFF-Rpt-Decommissioning-Power-Plants.pdf
22 https://www.sciencedirect.com/science/article/abs/pii/S0301421522001367
23 https://www.sciencedirect.com/science/article/pii/S0301421524003112

Pakistan under various financing models and future economic scenarios. Using financial and operational data from three CFPPs in each country, they calculated the enterprise values—which represent the total financial worth of each plant as a standalone entity—and equity values, which are particularly relevant for investors. For Pakistan, Engro Thar, Sino Sindh Resources Limited (SSRL) Thar, and Sahiwal CFFP were selected for analysis. The enterprise value assessments rely on discounted cash flow analysis, recognizing that investors assign a higher value to money today than to the same amount in the future due to increasing risks. Instead of relying on speculative financial models based on avoided carbon emissions, the study used actual cash flows to evaluate retirement options.

To compare financial outcomes, it modeled asset refinancing as an alternative to the conventional business-as-usual (BAU) scenario, where plants operate for the full 25-year duration of their power purchase agreements (PPA). It also analyzed a retirement-plus-renewable substitution model, assuming a 2:1 renewable capacity replacement ratio.

The findings reveal that:[24]

I. Early retirement, when combined with refinancing, increases enterprise value for all plants.

II. Bundling refinancing with renewable energy investments more than triples enterprise value compared to the original PPA-based approach.

III. Contrary to previous assumptions, younger CFPPs can be retired earlier due to their higher relative debt burden and financing costs in the early years of operation.

IV. Equity values also increase in most cases, strengthening the financial case for proactive refinancing. For example, refinancing the three youngest CFPPs in Pakistan would enable their early retirement 7 to 9 years ahead of schedule while ensuring full enterprise value recovery compared to the BAU scenario.

Based on these insights, this study recommended that Chinese companies, financial institutions, and investors reduce their exposure to coal-fired power by shifting towards renewable energy investments. The financial viability of early CFPP retirement—particularly when bundled with renewable energy—can be further enhanced through concessional loans, credit enhancement mechanisms, and innovative financing tools such as debt-for-climate swaps involving Chinese CFPP sponsors.[25]

This study concludes (as well as previous cases of India and Florida) that retiring expensive and inefficient thermal plants using unclean fuel technology including coal are both economically feasible and environmentally sustainable. Pakistan presents specific opportunities where retrofitting existing thermal plants into renewable energy facilities can provide high economic returns. In the next section two prime candidates have been analyzed for repurposing:

KAPCO: A thermal power plant that can be converted into a hybrid renewable energy facility, reducing costs and emissions while increasing energy output.

TPS Muzaffargarh: A large thermal station that can be redeveloped into a solar or wind energy hub, leveraging existing transmission infrastructure for a cost-effective transition.

Investors—particularly Chinese companies under CPEC 2.0—can maximize returns, reduce risks, and gain access to international green financing while contributing to Pakistan's energy security and sustainability.

24 *https://www.sciencedirect.com/science/article/pii/S0301421524003112*

25 *https://www.sciencedirect.com/science/article/pii/S0301421524003112#bib40*

Chapter: 4

Case Studies

KAPCO and TPS Muzaffargarh, A Cost Benefit Analysis

KAPCO and Muzaffargarh power plants have long been integral to Pakistan's power generation. However, aging infrastructure, declining efficiency, and shifting energy priorities have prompted discussions on their decommissioning and repurposing.

Here we have examined the historical performance of both plants, analyzing their capacity utilization trends, financial parameters, and overall viability in the evolving power sector. Since the plan is under consideration by the government to repurpose these power plants, therefore, building upon the global decommissioning and repurposing frameworks discussed in the previous chapter, we are applying them to these two power plants. The cost-benefit analysis explores whether repurposing these assets—such as transitioning to solar power with storage solutions—presents a more sustainable and economically viable alternative compared to outright retirement.

4.1. Case 1: Kot Addu Power Plant (KAPCO)

4.1.1. KAPCO's Current State of Play[26]

The Kot Addu Power Plant, located in Muzaffargarh, is a multi-fuel gas-turbine facility with a nameplate capacity of 1,600 MW[27]. It can generate electricity using gas, furnace oil, or diesel. The plant was constructed by the Pakistan's Water and Power Development Authority (WAPDA) in five phases, completed between 1985 and 1996. In 1996, the plant was incorporated a public limited company, marking the beginning of its privatization journey.[28] Later that year, WAPDA sold 36 percent of its shares to a strategic investor, transforming the plant into a private entity[29]. In 1996, the initial investment in KAPCOwas valued at 1,583 million dollars when National Power Kot Addu Limited (NPKAL), a subsidiary of National Power of the UK acquired a 26 percent stake[30]. By 2005, the plant was listed on the Pakistan Stock Exchange, allowing greater public participation and investment. In August 2013, the strategic investor sold its entire shareholding in the company to local corporate entities and individuals.[31] The other majority shareholder in KAPCO is Wapda with a shareholding of 46 percent, while the general public holds 18 percent shares of the company[32].

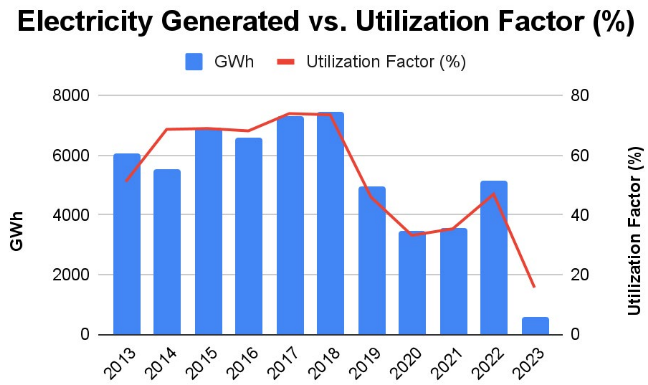


Figure 9: Energy Generation and Utilization Trend of KAPCO

26 https://tradechronicle.com/kapco-has-applied-for-a-seven-year-extension-for-its-generation-license/#google_vignette
27 https://www.brecorder.com/news/4692210
28 https://www.kapco.com.pk/
29 https://www.brecorder.com/news/4692210
30 https://www.meed.com/pakistan-national-power-bids-high-for-kot-addu-power-plant/#:~:text=Bidding%20took%20place%20on%2027%20March%20for,Power%20valued%20the%20plant%20at%20$1%2C583%20million.
31 https://www.kapco.com.pk/
32 https://www.brecorder.com/news/3435441

The figure 9 shows electricity generation from KAPCO against its utilization factor. Over the last decade, the quantum of electricity generation from KAPCO has remained inconsistent and has peaked around 5000 GWh in 2019 and 2022. Whereas, the utilization factor of KAPCO has consistently remained below 50 percent during 2019 and 2022, making the plant increasingly uncompetitive in Pakistan's energy mix.

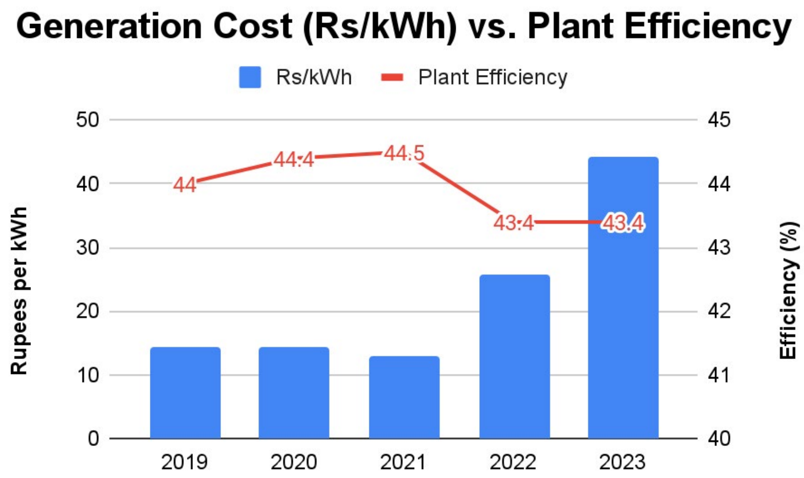


Figure 10: Generation Cost (Rs/kWh) and Efficiency Comparison of KAPCO

Figure 10 illustrates a clear correlation between the rising cost per unit of electricity (Rs/kWh) and the decline in the plant's efficiency (percent). From 2022 to 2023, as the efficiency of the KAPCO power plant dropped, the cost per unit surged. This indicates that the plant's operational inefficiency contributed to higher generation costs, highlighting its economic inviability.

In terms of financial performance, in 2023, the plant generated revenue of Rs. 25.43 billion (around 88 million dollars) and an operating income of Rs. 13.07 billion (approximately 45 million dollars), with a net income of Rs. 3.95 billion (around 14 million dollars). As of 2023, its total assets were valued at Rs. 98.9 billion rupees (approximately 350 million dollars), and equity stood at Rs. 66.08 billion (about 230 million dollars) as shown in Figure 11.

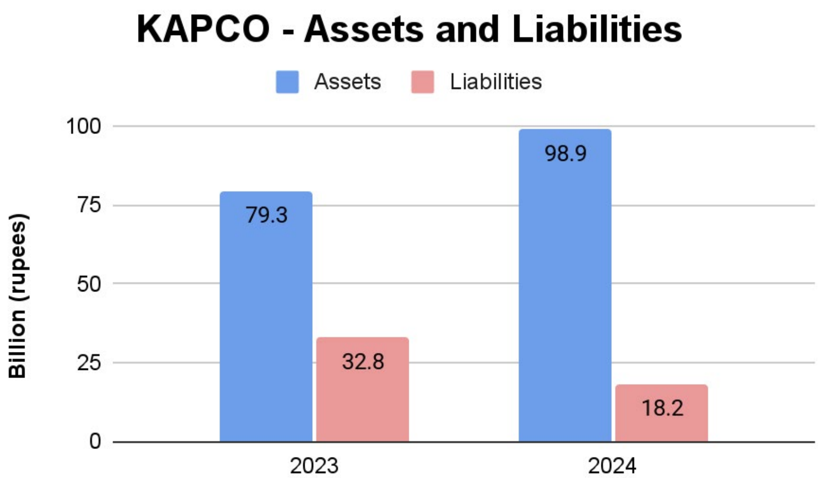


Figure 11: KAPCOs Liabilities vs. Assets

Table 3: KAPCO's Financial Performance: 2024 vs. 2023

Rs in Million	2023-24	2022-23
Generation (GWh)	-	588
Revenue (Rs in Million)	-	25,435
Cost of Sales	-	-23,373
Gross Profit	-	2,062
Plant maintenance and preservation costs	-4,161	-2,617
Administrative Expenses	-711	-843
Other Expenses	-439	-1,360
Other Income	14,630	15,830
Operating Profit	9,319	13,072
Finance Cost	-3,780	-6,253
Profit before levy and income tax	5,539	6,819
Levy - final tax	-2,178	-
Profit before income tax	3,361	6,819
Income tax	952	-2,860
Profit for the year	4,313	3,959
EPS (Rs / Share)	4.9	4.5

Tariff Update and License Extension

Due to expiration of its power purchase agreement (PPA) which was scheduled for 2024, KAPCO generated no electricity during the financial year 2024 and has applied for a seven-year extension of its PPA for 500 MW under a take-or-pay basis.

KAPCO's generation license has been extended until September 21, 2024. If Competitive Trading Bilateral Contract Market (CTBCM) is implemented, no further extension will be required; otherwise, an extension will be applied before its expiry. As per IGCEP (2022-31), approved by NEPRA in February 2023, a minimum 500MW capacity from KAPCO will remain operational until 2026 due to system constraints.Additionally, KAPCO plans to apply separately for the tariff of its switchyard facility (220KV to 132KV line), which is critical for ensuring the continuity of power supply from KAPCO to MEPCO.

An independent study by M/S Ramboll UK (2023) assessed KAPCO's major equipment, estimating a remaining useful life of over 10 years—extending viability until 2033. Even with the 7-year extension from 2024, the generation license would be valid until at least 2031.[33] With the CTBCM expected to become operational within the next 1 to 1.5 years, KAPCO plans to capitalize on this opportunity under the take-and-pay model, leveraging its 47 percent efficiency compared to the next closest PakGen power plant, which has 38 percent efficiency.

33 https://www.kapco.com.pk/entry/wp-content/uploads/2023/10/KAPCO-Corporate-Briefing-Oct2023-Final.pdf

4.1.2 AES PakGen being replaced with 500MW from KAPCO[34]

Recently, NTDC has recommended AES PakGen to be replaced with KAPCO's 500 MW capacity (with Units 13,14,15 and Units 1,2,9,10). This presents a viable opportunity for the repurposing of KAPCO's 500 MW capacity to solar (as it is currently RFO+HSD based) as it is both economically and environmentally compelling. AES PakGen's current RFO (Residual Fuel Oil) reliance makes it an expensive and environmentally detrimental option for power generation. Similarly, while KAPCO offers technical advantages in grid compatibility and transmission support, its existing RFO-based generation incurs significantly higher costs and inefficiencies (with less than 15 percent utilization rate as last recorded in FY22-2023) as compared to renewable alternatives such as solar energy.

4.1.3. Cost-Benefit Analysis: RETScreen Evaluation of KAPCO vs. Solar PV

To assess the cost-benefit of transitioning from a Combined Cycle Gas Turbine (CCGT) power plant to solar PV, we compared the 210 MW Unit 3 at KAPCO with a 210 MW generic solar PV plant. Using RETScreen Expert, we evaluated key financial and operational metrics to determine the feasibility of this shift.

For this analysis, we used data from KAPCO's NEPRA generation license and the 2022-2023 NEPRA State of Industry Report. Annexure A-1 provides a detailed overview of the input parameters. Operational since 1996, KAPCO relied on RLNG, RFO, and HSD and exceeded its 25-year lifespan, consuming 617,772 tonnes of fuel in FY 2021-22. In June 2024, its 1,336 MW capacity was removed from the grid following the expiration of its power purchase agreement. RETScreen results show that the 210 MW solar PV plant significantly outperforms the 210 MW gas turbine combined cycle in cost-effectiveness, with lower initial costs and zero fuel expenses. We considered a fuel mix of 70 percent natural gas and 30 percent RFO, with a total fuel consumption of 37.5 million m^3 of gas and 582,862 MMBTU of oil, based on the 2022-2023 NEPRA State of Industry Report.

Table 4: Comparison of KAPCO and Solar PV Performance & Financial Metrics

Parameter	Gas Turbine - Combined Cycle	Photovoltaic
Capacity	210 MW	210 MW
Electricity	275,633 MWh	404,712 MWh
Initial Costs	$207,668,368	$21,000,000
Electricity Export Revenue	$16,951,402	$20,235,600
Fuel Cost	$4,781,992	$0
O&M Costs	$8,390,641	$126,000
Simple Payback	55.0 Years	1.0 Years

The comparative analysis in table 4 shows that solar PV is the feasible energy generation option. GT-CC incurs a total fuel cost of 4.78 million dollars, with a fuel rate of 8.398 dollars per MWh, making it a cost-heavy option. In contrast, solar PV generates 404,712 MWh annually, significantly more than GT-CC's 275,632 MWh. Financially, solar PV's initial cost is just 21 million dollars, with O&M expenses of 126,000 dollars per year, while GT-CC requires a 207 million dollars investment and incurs 8.39 million dollars in annual operational costs. Additionally, solar PV's

34 *https://profit.pakistantoday.com.pk/2024/11/06/ntdc-recommends-kapco-as-replacement-for-aes-pakgen-amid-grid-stability-concerns/*

NPV stands at 196.02 million dollars, with a fast 1-year payback period, whereas GT-CC faces negative returns and growing losses over 50 years.

Despite GT-CC earning 16.95 million dollars in export revenue, solar PV surpasses it at 20.24 million dollars, reinforcing its role in cost reduction and energy transition. This analysis confirms that solar PV is the preferred investment, offering higher electricity generation, lower costs, and a more strategic alternative to KAPCO's high-cost, loss-incurring Combined Cycle Gas Turbine (Unit 3).

4.1.4. Comparitive Analysis on Generation Cost - KAPCO

This analysis compares the cost implications of extending KAPCO's existing operations versus repurposing it to a solar-based alternative. It also examines the decommissioning costs associated with transitioning from a thermal power plant. The cost of decommissioning was evaluated based on case studies from **India and Florida**, presented in **Section 3**, which provide insights into decommissioning trends and cost variations. The detailed analysis is provided in **Annexure A3**.

Table 5 KAPCO Generation Cost Comparison

Scenario	Generation (GWh)	Cost per kWh (Rs.)	Annual Cost (Billion Rs.)	7-Year Cost (Billion Rs.)
KAPCO (Existing – Thermal)	587.84	44.24	25.97	181.79
KAPCO (Repurposed – Solar)	587.84	8.97	5.235	36.6
Savings (based on seven years extension)			20.73 billion Rs./year 74.4 million USD/year	145.2 billion Rs. 522.72 million USD

Table 5 presents a cost comparison between extending KAPCO's existing thermal operations and repurposing it to a solar-based alternative. While both scenarios assume the same 587.84 GWh annual generation, the cost per unit for thermal power is significantly higher at Rs. 44.24/kWh, leading to an annual cost of Rs. 25.97 billion. As KAPCO has applied for a 7-year extension of its license[35], and we assume that if approved, the seven-year cost will be Rs. 181.79 billion. In contrast, repurposing solar would assume the per-unit cost as per recent bid received by KE for its 220 MW hybrid solar-wind plant i.e. 3.0899 US cents. This translates to an average tariff of Rs. 8.97/kWh, and Rs. 5.235 billion annually and Rs. 36.6 billion for 7 years. This highlights the substantial cost savings associated with transitioning to solar.

Table 6 provides a comparative analysis of decommissioning costs for different power plant types. A 1350 MW coal-fired plant is estimated to have a decommissioning cost of 158.22 million dollars based on India's case study as shown earlier in Table 3, while as per literature, a RFO/Gas plant is expected to have a lower decommissioning cost than coal plant. For instance, decommissioning costs for gas and petroleum-fired plants in the US are significantly lower, estimated at 33.7 million dollars based on historical cost data of 25,000 dollars per MW in 2016. This suggests that international benchmarks could provide a more cost-effective approach to decommissioning thermal plants in Pakistan.

35 https://tradechronicle.com/kapco-has-applied-for-a-seven-year-extension-for-its-generation-license/

Table 6: Decommissioning Cost Comparison

Power Plant Type	Capacity (MW)	Decommissioning Cost per MW ($)	Total Cost ($ Million)
Coal-Fired Plant (India)	1350	117.2M / 1000 × 1350	158.22
US-Based Gas/Petroleum Plant	1350	25,000 × 1350	33.7
RFO/Gas Plant (KAPCO)	1350	33.7< KAPCO <158.22	

So, we can assume that a 1350 thermal power plant (RFO/Gas plant) would incur REPURPOSING COST < 158.22 million dollars but greater than 33.7 million dollars. As per this information, we assume that the average repurposing cost for KAPCO's 1350 MW would be **95.96 million dollars.**

Table 7: Gross benefits of repurposing options (million dollars /1000 MW)

Solar only /1000 MW	644.81
For a 1350MW Solar plant	644.81 /1000 *1350 = 870.4 Gross benefits < 870.4

As per India's case study, as noted earlier in Table 4, the gross benefits of repurposing the coal plant to solar facility generated 644.81 million dollars/1000MW including direct and indirect benefits. If we assume the same parameters for a 1350 MW facility to be repurposed, it will result in 870.4 million dollars in gross benefits. However, as we are considering to repurposing KAPCO which is a RFO/RLNG based plant, we assume the gross benefits to be less than 870.4 million dollars.

We can deduce that:

KAPCO 1350 MW	
Average Decommissioning cost	95.96 million dollars
Gross benefits	870.4 million dollars.
Cost-benefit ratio	9.09

As Gross benefits > decommissioning costs and a positive cost benefit ratio indicates the financial viability of repurposing KAPCO to a solar facility with an estimate of 74.4 million dollars per annum in savings from generation cost alone.

4.1.5. Cost Competitiveness of 220MW Solar Plant vs. Thermal based KAPCO plant

Compared to thermal (tri-fuel: RFO, HSD, RLNG)-based generation solar energy offers drastically lower Levelized Cost of Electricity (LCOE) due to falling solar panel prices, zero fuel costs, and minimal operational expenditures. A 500 MW solar power plant, if established in place of KAPCO's tri-fuel based units, would not only reduce per-unit generation costs but also stabilize long-term energy pricing, shielding consumers from volatile global fuel prices. KE's recent bid for a 220 MW solar plant serves as a benchmark, reflecting solar energy's growing affordability and feasibility in Pakistan's energy landscape. In this regard, KAPCO has submitted a bid of Rs9.8319 per kilowatt-hour (kWh), equivalent to 3.4061 cents/kWh at a reference exchange rate of USD/PKR 288.65, for the proposed solar project to be established in Deh Halkani, District West, Karachi.[36] However, as KAPCO's PPA has expired already, NTDC has requested CPPA-G for utilizing its 500MW capacity as per NEPRA's approval. Under these circumstances, there is a viable opportunity for investors to convert (at least 500 MW thermal plant to solar

The NTDC has underscored KAPCO's importance for voltage stability and transformer load relief in Muzaffargarh and Multan. These functions can be maintained by deploying solar plants equipped with modern grid-support technologies, such as inverters providing reactive power and grid stability services. Furthermore, KAPCO's existing infrastructure and grid connectivity can be repurposed to integrate solar generation, ensuring minimal disruption during the transition. A repurposed 500 MW solar plant at KAPCO's site would seamlessly supply clean, affordable power to critical substations while alleviating overloading during peak demand periods.

4.2. Case 2: Muzaffargarh Thermal Power Station (TPS)

4.2.1. Current State of Play

TPS Muzaffargarh is one of the power plants under GENCO-III officially known as the Northern Power Generation Company Limited (NPGCL) — a public limited company in Pakistan established on October 15, 1998. It has been a key contributor to the country's thermal power generation for nearly five decades, and primarily relied on steam turbines powered by heavy fuel oil (HFO) or natural gas. Most units of TPS Muzaffargarh by the 2010s had an aging infrastructure that led to frequent breakdowns, low thermal efficiency, and high operational costs. Many units exceeded their designed operational life of 30–40 years, with deterioration of critical components causing reduced reliability and frequent outages. These challenges underscored the need to retire TPS Muzaffargarh and modernize the national energy infrastructure.

Table 8: TPS Muzaffargarh Overview and Unit Details [37]

Power Station	Unit Details	Total Capacity (MW)	Status
Thermal Power Station (TPS) Muzaffargarh	Units 1, 2, 3: Russian-made steam turbines (210 MW each)	630 MW	Operational at only 1.15 percent Utilization Factor (NEPRA State of Industry Reports 2023-2024)
	Units 4, 5, 6: Chinese-made steam turbines (320 MW, 200 MW, 200 MW)	720 MW	

36 https://profit.pakistantoday.com.pk/2024/11/27/kot-addu-power-company-submits-lowest-tariff-bid-for-kes-120mw-solar-project/#:~:text=KAPCO%20reported%20that%20it%20submitted,Halkani%2C%20District%20West%2C%20Karachi.

37 https://npgcl.com.pk/company-profile/

TPS Muzaffargarh has a total capacity of 1350 MW spread across six units, comprising Russian-made steam turbines (210 MW each) and Chinese-made turbines (320 MW, 200 MW, and 200 MW). However, by 2024 its dependable capacity dropped to 450 MW according to the NEPRA State of Industry Reports 2023-2024, with its utilization rate falling to mere 1.15 percent. As per the generation license, the units of this thermal power station were made operational between 1993 to 1997 having an expected lifetime of 30 years only, which makes them either retired or close to their retirement and decommissioning phase.[38] This also suggests that the plant might be facing issues such as technical inefficiencies, plant reliability, and over consumption of fuel because of old technology.

The variation in unit capacities and different operational tenure also points to a mixed infrastructure that may require tailored upgrades or optimization. According to the NEPRA State of Industry 2022-2023 report, Units 2, 5, and 6 of TPS Muzaffargarh are currently in standby mode, while Unit 4 is damaged. Similarly, Units 1 and 3 are operating at very low utilization levels. This declining performance, as also highlighted in the annual report of NPGCL, reflects the aging and obsolescence of assets of TPS Muzaffargarh, reinforcing the necessity for an overhaul of Pakistan's energy systems. Therefore, we further analyzed the technical parameters of TPS Muzaffargarh in figure 12, comparing its performance in the form of net electrical output (GWh) and utilization factor (percent) within its operational years, using data from the annual report of NPGCL 2022.

The performance of Muzaffargarh TPS, as shown in the figure 12, has significantly declined in both the net electrical output and the utilization factor. From approximately 50 percent utilization factor in 2016-17, it has sharply declined to less than 5 percent in 2021-22 and as of 2024 it was only 1.15 percent.

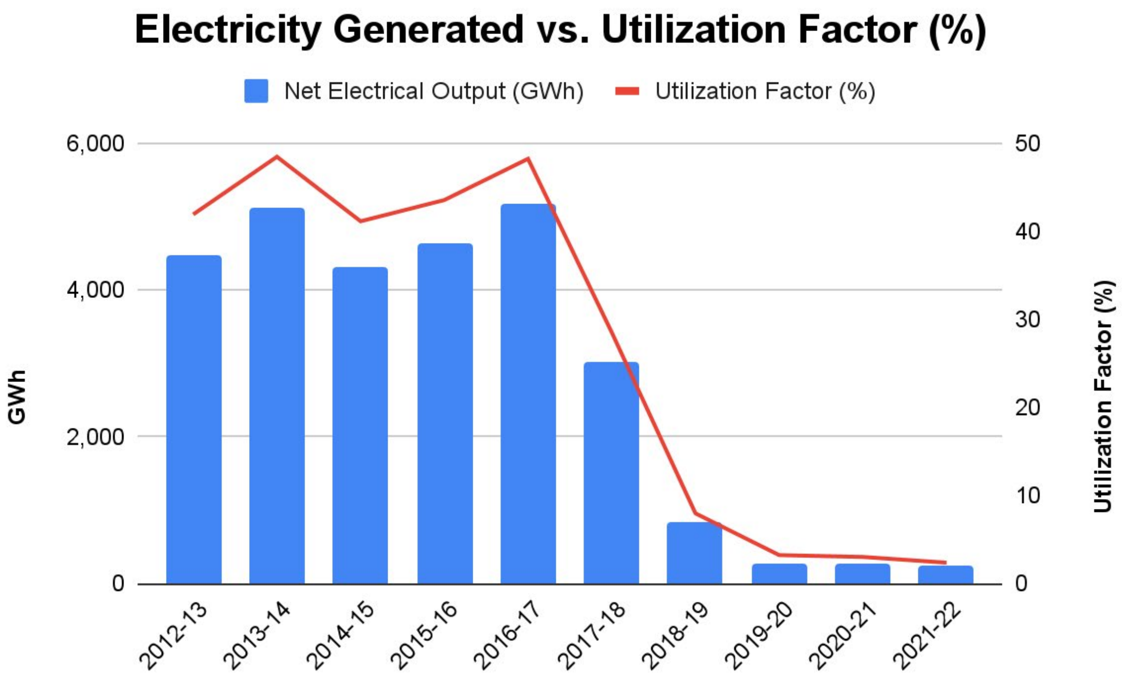


Figure 12: Energy Generation and Utilization Trend of TPS Muzaffargarh

38 https://npgcl.com.pk/?s=annual+report

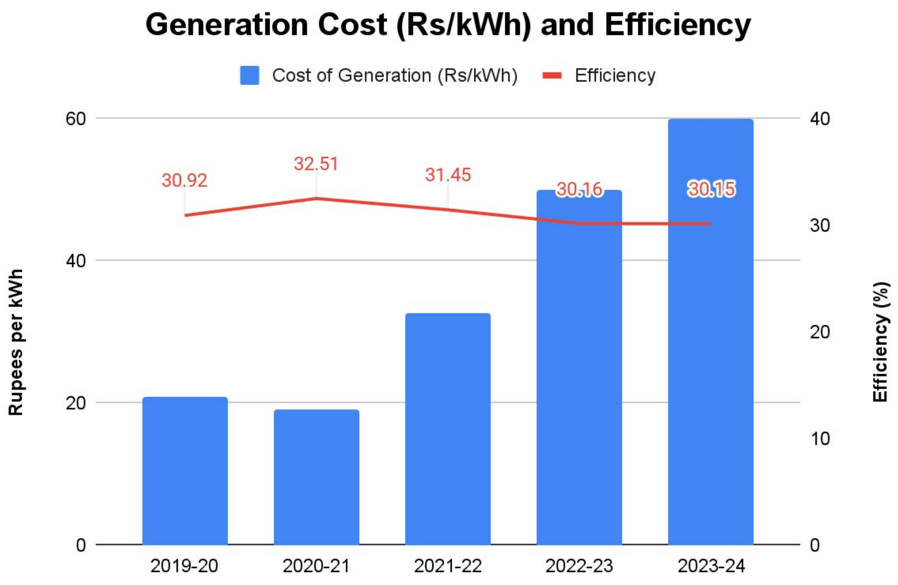


Figure 13: Generation Cost (Rupees per kWh) and Efficiency Comparison of TPS Muzaffargarh

Figures 12 and 13 illustrate the decline of the Thermal Power Station (TPS) Muzaffargarh, as evident from the rising trend in the cost of generation (Rs/kWh) over five years, while efficiency (percentage) has remained relatively stable, with a slight decline after 2020-21. The drop in net electrical output (GWh) and utilization factor (percentage) over the past decade reflects a combination of factors, including operational inefficiencies, high generation costs, and the government's commitment to phasing out aging thermal power plants.

4.2.2. TPS Muzaffargarh's financial performance

As of December 2015, the total assets of TPS Muzaffargarh were valued at Rs 85 billion, while the liabilities amounted to Rs 113.4 billion. As per 2022 annual report of the company, the company faced 3752,240 million rupees of loss during the FY 2021-22[39]. By the time the cumulative loss of the company has reached 38,585.755 million rupees, and the main contributors of this state that company reports are the change in tariff regime by NEPRA along with other factors contributing to this loss. For system stability mid-country in-feed 600-900 MW power through TPS Muzaffargarh is important.

4.2.3. Transition of TPS Muzaffargarh to Solar Power through Ningbo Green Light Energy (NGLE) Pvt Ltd, China[40]

The government is conducting a comprehensive review of power sector assets, including GENCO-III, to determine the economic viability of its remaining functional units. A significant element of the government's transition plan for GENCO-III involves converting the Muzaffargarh facility into a 300 MW solar power plant. NPGCL (GENCO-III) and NGLE Pte Ltd have signed a Memorandum of Understanding (MoU) for this project, facilitated by the Special Investment Facilitation Council (SIFC) with 200 million dollars in Foreign Direct Investment (FDI). This transformative initiative aims to generate 400 million units of affordable electricity annually, reducing production costs from Rs. 45 to Rs. 14 per unit. By repurposing barren land and utilizing existing GENCO-III assets, the project underscores the country's commitment to sustainable energy and is projected to save 44 million dollars annually in import bills by eliminating the need for heavy fuel oil (HFO).

39 https://npgcl.com.pk/annual-report-2022/

40 https://www.sifc.gov.pk/news/178

This marks a shift towards cleaner energy while offering significant economic benefits and opportunity for Chinese financing institutes to invest in Pakistan. It is also pertinent to note that Pakistan is currently undergoing a solar boom with with 17 gigawatts (GW) of imported modules in the first half of the year and forecasts reaching 22 GW by year-end[41]. The rapid expansion of solar panel production in China has led to a significant decrease in prices, making solar technology more accessible to a wider range of consumers. As a result, Pakistan has emerged as the third-largest destination for Chinese solar exports. With growing consumer interest in solar energy, coupled with a substantial increase in solar-based electricity generation and the pressing need to retire thermal power plants, we have conducted a comprehensive cost-benefit analysis for two case studies: GENCO III TPS Muzaffargarh and KAPCO, exploring their potential repurposing into renewable energy plants as under consideration. This analysis will provide a strategic framework for investors, particularly Chinese investors, to shift their focus from thermal power generation to renewable energy projects.

4.2.4 Cost-Benefit Analysis: RETScreen Evaluation of TPS Muzaffargarh vs. Solar PV

To assess the cost benefit analysis, we compared the 320 MW Unit 4 at the Muzaffargarh Thermal Power Station (MTPS) with a 300 MW solar PV plant. Using RETScreen, we evaluated key financial and operational metrics to examine the economic and energy generation feasibility. The parameters used for analysis are given in the Annexure A-2. The shift to solar PV is projected by SIFC to reduce costs and save 44 million dollars annually in fuel imports, strengthening the economic case for renewables.

For this analysis, we used data from MTPS's NEPRA generation license and the NEPRA State of Industry Report (2022-2023). Solar PV parameters were sourced from the SIFC agreement with Ningbo Green Light Energy (NGLE) for repurposing MTPS. Unit 4, commissioned in December 1997, operates on HFO and RLNG, consuming approximately 1,800 metric tons of fuel daily. The table below presents the input parameters used in RETScreen for analyzing the financial and operational feasibility of transitioning from TPS Muzaffargarh Unit 4 to the proposed solar PV plant, highlighting their cost, efficiency, and operational differences.

Our RETScreen results highlight a stark contrast in energy output between the two technologies. The table 9 shows that the 300 MW solar PV plant demonstrates clear superiority over the 320 MW MTPS steam turbine in energy generation, financial viability, and cost-effectiveness.

Table 9: Comparison of MTPS and Solar PV Performance & Financial Metrics

Parameter	Steam Turbine	Photovoltaic
Capacity (MW)	320	300
Electricity (GWh)	31	464
Initial Costs (Million $)	124 (1997)	199
Electricity Export Revenue (Million $)	5	83
Fuel Cost ($)	611	0
O&M Costs ($)	25,520,604	18,000
Simple Payback (yr)	None	2.4

41 *https://www.weforum.org/stories/2024/11/pakistan-solar-power-energy-transition/*

The RETScreen results in Table 9 reveal a significant difference in energy output and financial performance. The existing 320 MW steam turbine at TPS Muzaffargarh operates at a low utilization factor of 2.79 percent, generating approximately 31 GWh annually. In contrast, the 300 MW solar PV plant is projected to generate 464 GWh per year. Financially, solar PV has a lower initial cost of 200 million dollars and minimal O&M expenses of 18,000 dollars per year, compared to the steam turbine's 124 million dollars installation cost (1997) and high annual operational costs of 25.52 million dollars. The cost-benefit analysis confirms Solar PV as the preferred option for RE investments, with an NPV of 860.99 million dollars, and a 2.4-year payback.

In contrast, the MTPS steam turbine faces negative returns and increasing financial losses. Solar PV cuts production costs, saves 44 million dollars annually on fuel imports, as it aligns with the aims of NGLE, and eliminates fossil fuel reliance, making Solar PV a clear economic and strategic investment.

4.2.5. Comparative Analysis on Generation Cost - TPS Muzaffargarh

This analysis evaluates the cost implications of continuing TPS Muzaffargarh's existing thermal operations versus replacing it with a solar-based alternative. As of June 2024, the dependable capacity of TPS Muzaffargarh is 450 MW, with net generation of 15.23 GWh (15,230,000 kWh) in FY 2023-2024. The cost of generation per kWh for the existing thermal plant stands at 59.9 rupees, leading to a total annual generation cost of Rs. 912.28 million.

In contrast, if TPS Muzaffargarh is replaced with a solar-based alternative, using a reference cost of Rs. 8.97/kWh (based on a 220 MW hybrid project), the total annual generation cost would be significantly lower at Rs. 136.6 million. This indicates that replacing the existing thermal generation with solar could yield substantial cost savings.

Table 10: Generation Cost Comparison

Scenario	Net Generation (GWh)	Cost per kWh (Rs.)	Total Annual Cost (Billion Rs.)
TPS Muzaffargarh (Existing – Thermal)	15.23	59.9	0.912
TPS Muzaffargarh (Repurposed – Solar)	15.23	8.97	0.137
Savings		**50.93**	**0.775** **2.79 million dollars/ year**

This comparison underscores the **financial advantage** of transitioning to solar energy, offering a **cost reduction of nearly 85** percent compared to thermal generation.

Table 11: Decommissioning Costs Comparison

Power Plant Type	Capacity (MW)	Decommissioning Cost per MW ($)	Total Cost ($ Million)
Coal-Fired Plant (India)	1600	117.2M / 1000 × 1600	187.52
US-Based Gas/Petroleum Plant	1600	25,000 × 1600	40
RFO/Gas Plant (TPS M.garh) 1600		40< TPS M.garh <187.52	

So, we can assume that a 1600 thermal power plant (RFO/Gas plant) would incur REPURPOSING COST < 187.52 million dollars but greater than 40 million dollars. As per this information, we assume that the average repurposing cost for KAPCO's 1350 MW would be **113.76 million dollars.**

Table 12: Gross benefits of repurposing options (million dollars /1000 MW)

Solar only /1000 MW	644.81
For a 1600MW Solar plant	644.81 /1000 *1600 = >1031.6

If we apply the same parameters to a 1,600 MW facility for repurposing, the estimated gross benefits would be 1031.6 million dollars and the expected gross benefits are likely to be lower than 1031.6 million dollars.

We can deduce that:

TPS Muzaffargrah 1600 MW	
Average Decommissioning cost	113.76 million dollars
Gross benefits	1031.6 million dollars.
Benefit-Cost ratio	9.06

As Gross benefits > Decommissioning costs and a positive cost benefit ratio indicates the financial viability of repurposing TPS Muzaffargarh to a solar facility with an estimate of 2.79 million dollars per annum in savings from generation cost alone.

Chapter: 5

Bottlenecks in RE Investment

As noted in the previous chapter, repurposing thermal plants in the case of Pakistan is financially viable as the net positive returns through the cost-benefit analysis presents a profitable opportunity for investors as well as financing institutions of China. However, it is imperative to note that this repurposing involves limitations and bottlenecks when seen from an investors point of view. Particularly, for Chinese financing institutions there is an inherent sludge and procedural impediments regarding RE investment in Pakistan. Challenges include policy uncertainty, limited incentives and inconsistent priorities and economic outlook of the country. As per Pakistan Institute of Development Economics, over 50 percent of federal decisions are delayed due to excessive bureaucracy. Extreme centralization and outdated manual systems contribute to these delays, creating inefficiencies among different state institutions.[42]

From a global perspective, the hesitation to invest in Pakistan centered around the high cost of borrowing, lack of long term commitment for debt, underdeveloped local financial markets, weak regulatory frameworks, underdeveloped credit facilities, and a lack of mechanisms to de-risk investments. The following table summarizes some of the most prominent challenges in this regard:

Sovereign Risk	Credit ratings evaluate a country's outlook, political and economic stability, FDI inflows, government debt, and banking sector performance, providing investors with a measure of risk and confidence. In Pakistan, frequent fluctuations in ratings by S&P, Moody's, and Fitch, driven by political and economic instability, have undermined investor confidence. This instability has stalled initiatives like the government's repeated efforts to attract bids for a 600 MW solar project in Muzaffargarh.
Institutional Uncertainties	The lack of coordination among decision-making authorities, coupled with an inconsistent policy environment, creates market uncertainty that undermines investor confidence and restricts financial flows. In Pakistan, such uncertainty has repeatedly shaken investor trust. For instance, in early 2023, customs duties and taxes were reinstated on solar and wind technologies but later reversed following resistance. Similarly, on-grid renewable energy (RE) targets fluctuated significantly, dropping to 10 percent in the 2021 IGCEP, rising to 29 percent in 2022, and falling again to 13 percent in the 2024 IGCEP, deviating from the ARE Policy 2019.
Financing Constraints	Financing options for renewable energy (RE) projects vary by size. Small-scale projects often struggle due to high transaction costs relative to investment size, limited financing instruments, and inadequate long-term debt options. In Pakistan, the State Bank's concessional financing scheme for utility-scale solar and wind projects was offered to scale up RE adoption. However, this financing scheme has also been terminated due to the conditionalities imposed by the IMF. The government also plans to not extend any other concessional scheme for RE projects
Volatile Foreign Exchange Market	Foreign exchange market volatility poses another significant challenge for attracting international investment in Pakistan. Exchange rate fluctuations create foreign exchange risk, increasing the cost of capital and heightening concerns among foreign investors. Between 2013 and 2024, rupee exchange rate with dollar have shown exponential growth.

42 https://www.thenews.com.pk/print/1230938-over-50pc-of-federal-decisions-delayed-due-to-excessive-bureaucracy-pide

In Pakistan, the RE projects have been significantly hampered by political and regulatory barriers, as well as prolonged delays in administrative processes. These challenges have created a sluggish and inconsistent trajectory for the expansion of solar and wind power projects, reflecting the systemic issues within the country's energy sector. Over 100 renewable energy projects, including wind and solar power, have faced major delays, as shown in Figure 14. These projects have now been referred to the Special Investment Facilitation Council (SIFC) Secretariat because the Power Division has been reluctant to approve many renewable energy initiatives.

In Punjab, wind projects with a total capacity of 100 MW and solar projects of 1,010 MW are underway, with one wind and seven solar projects receiving Letters of Intent (LoI) and land allocation. Sindh has 490 MW of wind projects and 590 MW of solar projects, with 21 wind and four solar LoIs granted. In Khyber Pakhtunkhwa (KPK), solar projects totaling 250 MW have four LoIs issued. Meanwhile, Balochistan has 1,190 MW of wind projects and 2,500 MW of solar projects[43]

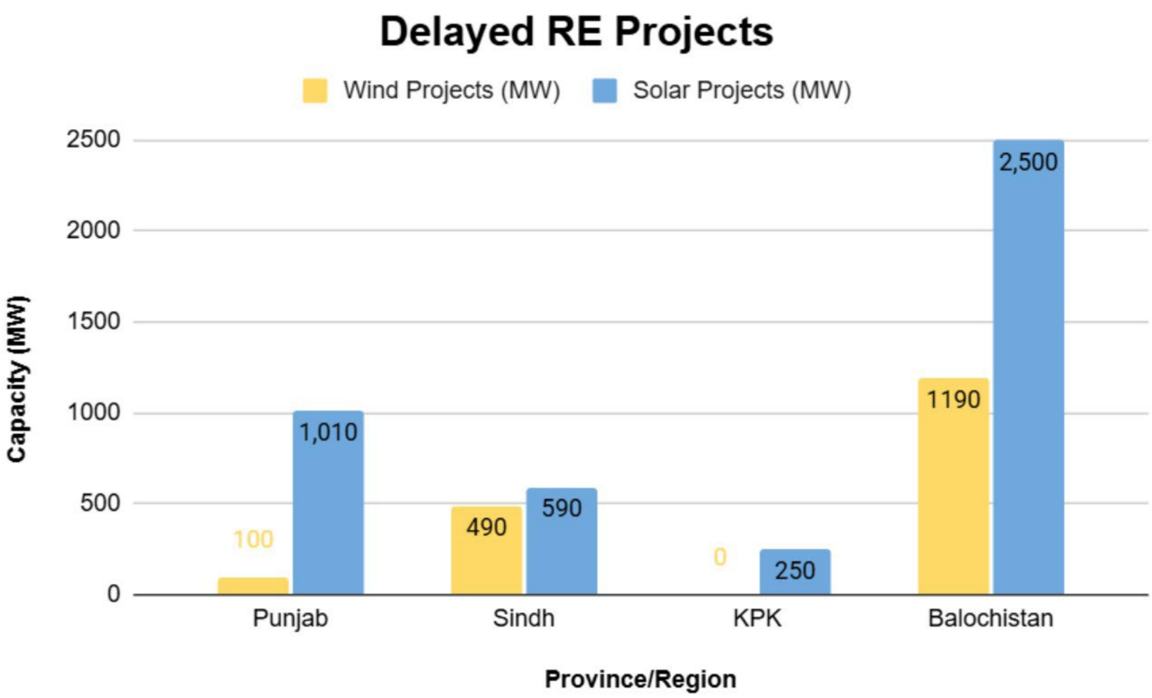


Figure 14: Delayed RE Projects in Pakistan

43 https://profit.pakistantoday.com.pk/2023/10/07/sifc-seeks-information-on-projects-facing-delays-or-stuck-in-arbitration/

Chapter: 6

Recommendations

Our analysis based on decommissioning costs versus gross benefits clearly indicates the positive benefit-cost ratio of repurposing the entire facility (ideal scenario) of both– KAPCO and Muzaffargarh– to solar facilities. Similarly, RetScreen Analysis compares existing fossil fuel-based generation with renewable energy alternatives at KAPCO and TPS Muzaffargarh. By evaluating one unit from each plant against an equivalent solar PV capacity, the analysis shows positive net revenue and a favorable cost-benefit ratio for solar PV in both cases. This demonstrates the economic and environmental viability of solar PV, making it a strong investment opportunity.

Based on this analysis, we recommend the following policy measures to facilitate a sustainable transition from fossil fuels to renewable energy:

- Mandate the retirement of thermal plants beyond their life, i.e. 25–30 years, transitioning them to renewable energy (RE) instead of costly refurbishments by developing a phase-out strategy for all coal power plants.
- Limit operation beyond a defined utilization factor threshold and establish a structured timeline for decommissioning approval before the end of the operational phase.
- Develop a strategy and assess each coal/thermal power plant unit for the most feasible and cost-effective renewable energy conversion, ensuring an optimal transition to RE while maintaining grid stability.
- Convert decommissioned thermal plant sites into large-scale solar, wind, or hybrid renewable energy hubs to minimize stranded assets, while fast-tracking regulatory approvals to expedite their development and deployment.
- The government should incentivize renewable energy producers to install reactive power components at generation sources before transmission, reducing losses, improving grid stability, and ensuring the seamless integration of renewable energy.
- Set competitive tariffs for renewables to enhance their financial viability within the Competitive Trading Bilateral Contract Market (CTBCM), encouraging private-sector investment.
- Promote Build-Operate-Transfer (BOT) distributed generation and microgrids to accelerate investment in decentralized renewable energy systems, ensuring reliable energy access for remote communities currently dependent on aging coal plants.
- Conduct feasibility assessments, including Poverty and Social Impact Analysis (PSIA), Environmental Impact Assessment (EIA) prior to bidding, renewable energy potential analysis, and generation profile evaluation, to attract private sector investment in solar and other renewable energy projects, ensuring transparency by making the findings publicly available.
- Most importantly, Chinese financial institutions should prioritize renewable energy investments in Pakistan under CPEC to enhance sustainability and long-term returns. CDB, CHEXIM, ICBC, CCB, and the Bank of Communications can support solar, wind, and hydro projects through preferential financing, green loans, and infrastructure funding. This shift will reduce investment risks, boost profitability, and strengthen Pakistan's energy security while aligning with global clean energy trends.
- Enhance RE Financing for coal-to-RE conversion, restructure debts into green bonds or RE funds, and introduce Feed-in Tariffs (FiTs) to ensure financial viability.

Conclusion

Pakistan's transition to renewable energy presents a financially viable and strategically beneficial opportunity for investors, particularly under CPEC 2.0. The Muzaffargarh and KAPCO case studies highlight how repurposing inefficient thermal plants into solar and wind energy hubs can enhance enterprise value, reduce investment risks, and improve energy security. However, addressing financial and regulatory challenges is crucial to unlocking further investments.

Key measures include currency hedging strategies, streamlined regulatory approvals, stable investment guarantees, and joint financing mechanisms. Strengthening government-to-government (G2G) negotiations, securing investment protection agreements, and leveraging risk insurance will further bolster investor confidence. By implementing these strategies, Pakistan can accelerate its clean energy transition while ensuring economic stability, long-term profitability, and sustainable growth.

Annexure

A-1 : Input Parameters for RETScreen Analysis

KAPCO Vs Solar PV		
Parameter	**CCGT System**	**Solar PV System**
Capacity (MW)	210	210
Initial Cost ($)	207,668,368	21,000,000
Utilization Factor (percentage)	15	22
Heat Recovery Efficiency (percentage)	33.3	0
Efficiency (percentage)	35	18
O&M Cost ($/year)	8,390,641	126,000
Fuel Cost ($/year)	4,781,992	None
Electricity Export Rate ($/kWh)	0.062	0.05

A-2: Input Parameters for RETScreen Analysis

Parameter	MTPS Unit 4 (320 MW Steam Turbine)	300 MW Solar PV Plant
Capacity	320 MW	300 MW
Fuel Consumption	1,800 MT per day (HFO/Natural Gas)	0
Utilization Factor	2.79 percent	22 percent
Fuel Cost	22.68 rupees per MWh ($0.00179/MWh)	0
Energy Export Rate	50 rupees per kWh ($0.1786/kWh)	14 rupees per kWh ($0.05/kWh)
Initial Cost	$124 million (1997)	$200 million
O&M Cost	$25.52 million annually	$18,000 per year

A-3: Manual Analysis

Scenario 1: KAPCO's Current Generation Costs

- In **2022-23**, KAPCO generated **587.84 GWh** at an overall generation cost of **44.24 Rs/kWh**.
- This resulted in a **total cost of generation of Rs. 25.97 billion** for the year.
- If KAPCO's operations were extended for **seven more years**, the total cost of generation would be: 25.97 billion×7=181.79 billion Rs

Scenario 2: Repurposing KAPCO to a Solar-Based Alternative

- A referenced **8.97 Rs/kWh** was used for solar-based generation.
- Assuming the same **587.84 GWh** generation capacity, the annual generation cost would be: 587,000,000×8.97=5.235 billion Rs
- Over **seven years**, this results in a total generation cost of **Rs. 36.6 billion**, significantly lower than extending KAPCO's existing operations.

Decommissioning and Repurposing Costs

- Based on India case study **representative 1350 MW coal-fired power plant** would incur a decommissioning cost of: 117.21000×1350=158.22 million dollars
- Since **thermal (RFO/Gas) plants generally have lower decommissioning costs than coal plants**, the decommissioning cost for a **1350 MW RFO/Gas plant** would be **< $158.22 million**.
- Comparing to **US-based petroleum and natural gas plant decommissioning**, using a cost estimate of **$25,000 per MW**, the total cost would be: 25,000×1350=33.7 million dollars
- This suggests that if the **same plant were decommissioned in the US**, it would incur a cost of **$33.7 million** instead of **$158.22 mill**ion estimated for a coal plant.

PRIED

Policy Research Institute
for Equitable Development

www.priedpk.org

+92 51 8440512

Second Floor, Plot No. 5-N. Sitara Market, G-7/2 Islamabad