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Bridging the Electricity Demand-Supply Gap in Pakistan: The Role of Circular Debt and Transmission Losses

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Abstract
The study examines the energy situation in the country and identifies the primary issues contributing to the ongoing energy crisis. The analysis reveals two critical factors responsible for the crisis: circular debt and transmission and distribution losses. Addressing these two problems could significantly reduce the gap between electricity demand and supply. It is estimated that resolving these issues could add approximately 3,885 MW of electricity to the national grid, thereby reducing load shedding, which currently ranges from 6 to 8 hours in urban areas and 10 to 12 hours in rural areas. Circular debt, a major impediment in the energy sector, arises from the inability of power producers to pay their debts to fuel suppliers and other stakeholders, leading to a financial bottleneck that hampers electricity generation. The study suggests that eliminating circular debt through financial restructuring and improved payment mechanisms can restore the financial health of the power sector, ensuring a steady flow of resources necessary for uninterrupted electricity production. Transmission and distribution losses, the second critical issue, involve the loss of electrical energy during transmission from power plants to consumers due to outdated infrastructure, technical inefficiencies, and theft. The study highlights the need for substantial investments in modernizing the grid infrastructure, implementing advanced metering systems, and enforcing stricter regulations to curb energy theft. By addressing these losses, the efficiency of the electricity supply chain can be greatly enhanced, ensuring more reliable power delivery to end-users. In addition to resolving these issues, the study advocates for the utilization of alternative energy resources, such as coal, to meet the country's electricity needs. The integration of coal into the energy mix could provide a stable and abundant source of power, capable of supporting both household and industrial sectors. This diversification not only enhances energy security but also moves the country towards self-sufficiency in electricity production. The study further explores the potential for generating surplus electricity, which can be exported to neighboring countries, thereby earning valuable foreign reserves. By expanding the energy export market, the country can boost its economic stability and strengthen its position in the regional energy market. Overall, the findings of this study underscore the urgent need for comprehensive reforms in the energy sector. Policymakers must prioritize the resolution of circular debt and transmission and distribution losses to bridge the electricity demand-supply gap. Simultaneously, investing in alternative energy sources and improving grid infrastructure are essential steps towards achieving energy self-sufficiency and economic growth.
Keywords: Energy Crisis, Circular Debt, Transmission Losses, Alternative Energy
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1. INTRODUCTION

Pakistan has been grappling with an acute energy crisis for many years. The unreliable supply of electricity, characterized by frequent and often unpredictable load shedding, severely disrupts both civil and economic life. This persistent energy shortage has far-reaching implications for households, businesses, and industries across the country. For households, the erratic electricity supply affects daily activities, leading to a decline in the quality of life. Basic necessities such as lighting, heating, cooling, and the operation of household appliances are compromised. Additionally, students find it challenging to study, and families face difficulties in maintaining a comfortable living environment. The economic impact is equally profound. Industries and businesses experience significant disruptions due to power outages, leading to reduced productivity and increased operational costs. Manufacturing processes are interrupted, causing delays in production schedules and resulting in financial losses. Small businesses, particularly those that cannot afford backup power solutions, are especially vulnerable. The energy crisis also hampers investment, as potential investors perceive the unstable power supply as a risk to business continuity and profitability. Moreover, the energy crisis has broader implications for the country's development. It affects the performance of critical infrastructure such as hospitals, schools, and public services, exacerbating the challenges faced by an already strained system. The unreliable electricity supply also impacts agricultural activities, as irrigation and other farming operations depend on a stable power supply.

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Addressing Pakistan's energy crisis requires a multifaceted approach. Investment in energy infrastructure, diversification of energy sources, and the adoption of energy-efficient technologies are crucial steps. Renewable energy sources such as solar, wind, and hydropower offer sustainable solutions that can alleviate the pressure on the national grid. Additionally, policy reforms and effective management of energy resources are essential to ensure a reliable and consistent power supply. Several factors contribute to the persistent energy crisis and the widening gap between demand and supply in Pakistan. Among these, transmission and distribution losses are particularly significant, exacerbating the problem. It is estimated that 20-24% of the electricity generated is not paid for, due to various inefficiencies and issues within the system. Transmission and distribution (T&D) losses occur when electricity is lost as it travels from power plants to consumers. These losses can be technical, resulting from the inherent inefficiencies in the power lines and equipment, or non-technical, arising from theft, faulty meters, and billing errors. The high T&D losses in Pakistan are a major drain on the energy sector, reducing the amount of electricity available to consumers and increasing the cost of power. Technical losses are often due to outdated and poorly maintained infrastructure. Much of the transmission network is old and unable to handle the current load efficiently. Upgrading this infrastructure requires significant investment, which has been lacking. As a result, electricity is lost during transmission, and the system struggles to meet the growing demand. Non-technical losses, on the other hand, include electricity theft and meter tampering, which are rampant in many areas. Illegal connections and meter bypassing reduce the amount of electricity that is accounted for and paid by consumers. This not only causes financial losses for the power companies but also leads to increased load shedding as the supply falls short of the demand. In addition to T&D losses, several other factors contribute to the energy crisis. The existing power plants are insufficient to meet the increasing demand for electricity. Investment in new power generation projects has been slow, and many plants are operating below capacity due to fuel shortages and technical issues. The power sector relies heavily on imported fuels, which are subject to price fluctuations and supply disruptions. Domestic fuel sources, such as natural gas and coal, are also inadequately exploited, leading to frequent fuel shortages.

There is a lack of energy-efficient practices and technologies in both residential and industrial sectors. This results in higher consumption and wastage of electricity, further straining the supply. The energy sector faces numerous regulatory and policy hurdles. Inconsistent policies, lack of long-term planning, and bureaucratic delays hinder the development and implementation of effective solutions. Power companies often face financial difficulties due to the high levels of unpaid bills and circular debt. This limits their ability to invest in infrastructure upgrades, maintenance, and new projects. Addressing the energy crisis requires a comprehensive approach that includes upgrading the transmission and distribution infrastructure, reducing technical and non-technical losses, increasing generation capacity, and promoting energy-efficient practices. Additionally, policy reforms and improved governance are essential to ensure a stable and reliable energy supply in the long term. However, the cost of these losses is ultimately recovered from the consumers who do pay, leading to higher electricity bills and greater financial strain on households and businesses. Reducing these high transmission and distribution losses is crucial and achievable through targeted investments in infrastructure and technology. In addition to transmission and distribution losses, the issue of circular debt significantly exacerbates the energy crisis. Circular debt arises when there is a delay or non-payment in the supply chain of the energy sector. For instance, power producers do not receive payments from distribution companies, which in turn do not receive payments from consumers, including government entities. This creates a financial shortfall that disrupts the entire energy supply chain.

Although the current government has attempted to address this issue by paying Rs. 480 billion to clear the circular debt, which resulted in the addition of 1752 MW to the national grid, the problem persists and continues to re-emerge. This suggests that temporary fixes are insufficient and a permanent resolution is necessary. Sustainable solutions might include restructuring the payment mechanisms, improving the efficiency and accountability of power companies, and ensuring timely payments across the board. The power sector in Pakistan has been grappling with significant challenges for several years. These issues were particularly noticeable when the country's GDP growth rate reached 9%, buoyed by healthier socio-economic conditions. Despite various corrective measures being implemented, the desired results have yet to materialize. Consequently, the power sector is now on the brink of a crisis that affects the entire country. One of the most pressing problems is the substantial gap between electricity demand and supply. During the summer months, this gap typically ranges from 4500 MW to 5500 MW, while on an annual basis, it is around 4000 MW to 4500 MW. This shortfall has severe implications for both the economy and the daily lives of citizens. The frequent and unpredictable load shedding disrupts industrial activities, hampers economic growth, and affects the quality of life.

The persistent demand-supply imbalance underscores the need for a comprehensive and effective strategy to address the underlying issues in the power sector. This includes improving the efficiency of power generation, reducing transmission and distribution losses, and ensuring timely payments within the energy supply chain to prevent the re-emergence of circular debt. Additionally, investments in renewable energy sources and modernization of the grid infrastructure could help alleviate some of the pressure on the power sector and contribute to a more stable and reliable electricity supply. The main purpose of this policy is to not only overcome the energy problem and address the key challenges in this sector but also to set Pakistan on a path of rapid growth and social development. It aims to create a culture of energy conservation and responsibility while ensuring the generation of inexpensive and affordable electricity for domestic, commercial, and industrial use by utilizing indigenous resources such as coal (Thar coal) and hydel power. The policy also seeks to minimize

inefficiencies in the distribution system and financial losses across the system. Additionally, it emphasizes the elimination of the demand-supply gap during the tenure of the present government.

To achieve these goals, the policy outlines several strategic initiatives. First, it promotes the use of Thar coal and hydropower resources to reduce reliance on imported fuels and lower generation costs. By tapping into these indigenous resources, the government aims to produce more affordable electricity, thereby easing the financial burden on consumers and businesses. Second, the policy addresses inefficiencies in the distribution system. By investing in modern infrastructure and reducing technical and non-technical losses, the government hopes to improve the overall efficiency of the electricity supply chain. Another critical component of the policy is the elimination of the demand-supply gap. This involves not only increasing the generation capacity but also implementing measures to manage and reduce demand. Energy conservation campaigns and the promotion of energy-efficient technologies are key strategies in this regard. The government aims to foster a culture of responsible energy use among consumers, encouraging behaviors that help reduce overall demand. The five-year forecast of demand and supply is presented in Table 1, illustrating the projected trends and expected improvements in the energy sector. This forecast is crucial for planning and ensuring that the initiatives are aligned with the anticipated growth in demand, thereby preventing future shortages and ensuring a stable and reliable electricity supply.

Table 1: Demand Supply GAP in Pakistan

Energy Projection for Five Years				
Year	Installed Capacity	Supply	Demand	Gap
2013	18167.0	14402.0	16316.0	-1914.0
2014	23996.0	16202.3	17947.6	-1745.4
2015	27995.0	18308.5	19742.4	-1433.8
2016	31445.0	20688.7	21716.6	-1027.9
2017	36260.0	23378.2	23888.3	-510.1
2018	42275.0	26417.3	26277.1	140.3

The table 1 outlines Pakistan's energy demand and supply dynamics from 2013 to 2018, highlighting a progressive narrowing of the gap between supply and demand. In 2013, the installed capacity was 18,167 MW, while supply lagged at 14,402 MW against a demand of 16,316 MW, resulting in a shortfall of 1,914 MW. Over the subsequent years, installed capacity steadily increased, reaching 42,275 MW in 2018. Similarly, supply improved to 26,417.3 MW, closely matching the demand of 26,277.1 MW, ultimately yielding a surplus of 140.3 MW. This shift from a deficit to a surplus indicates significant strides in balancing energy supply with demand, showcasing an effective response to the energy needs of the country. The data, provided by the Water and Power Development Authority (WAPDA), reflects the country's ongoing efforts to enhance energy infrastructure and capacity. Table 1 presents the projections of supply, demand and installed capacity using 2013 as benchmark year. The data of installed capacity is obtained from Water and Power Development Authority (WAPDA). It is estimated that demand for electricity would be 26277.1 MW in 2018 from 16316.0 current years under the assumption that the demand will increase 10% annually. It is estimated that to meet the demand for electricity and overcome the energy crisis problem till 2018, government has to increase its supply of electricity at an annual rate of 13% as shown in above table that in 2018, government has 140.3 MW surplus of electricity. Electricity is the key factor to boost the economic development process. It is the fact that per gross national product is directly related to per capita energy production. During the last seven years, the GDP growth is less than 4% for the country due to power outages while the country need to grow an average of 8-10% to accommodate the massive youth population adding in the labour force.

2. KEY ISSUES RISING ENERGY CRISES

2.1. PAKISTAN'S ENERGY MIX OF ELECTRICITY PRODUCTION

The energy mix of the country indicates that the main sources of energy production are hydro, oil, and gas, which together hold a 93.3% share in total electricity production. It is imperative to seek alternative resources to generate electricity to fulfill the existing demand rather than relying on expensive sources such as oil and gas. The country has sufficient coal reserves that can potentially produce 10,000 MW of electricity. Inam and Abbasi (2014) critically reviewed the energy mix situation in Pakistan, comparing it with regional and OECD countries, and found that coal and peat are the main sources used to generate electricity and meet the countries' requirements. Their investigation revealed that in regional countries, coal and peat contribute 40% to total electricity generation, while in OECD countries, coal and peat have a dominant share, holding 34% in total generation. On the other hand, Pakistan continues to depend on expensive sources such as oil and gas for electricity production. This reliance on costly energy sources not only strains the economy but also limits the potential for more sustainable and cost-effective energy solutions. Shifting towards coal and other indigenous resources could significantly reduce the cost of electricity production and provide a more stable and affordable energy supply. The utilization of local coal reserves, particularly those in Thar, could help alleviate the energy crisis by providing a reliable and cheaper alternative to oil and gas. Moreover, investing in renewable energy sources such as wind, solar, and biomass could diversify the energy mix, enhance energy security, and promote environmental sustainability.

The transition to a more balanced and diversified energy mix requires strategic planning and investment in infrastructure, technology, and human resources. Policymakers need to create favorable conditions for investment in alternative energy projects, including regulatory support, financial incentives, and public-private partnerships. Additionally, raising awareness about the benefits of alternative energy sources and promoting energy efficiency practices can help drive the shift towards a more sustainable energy future for Pakistan. The country needs to utilize its coal reserves because the high cost of electricity production increases the cost of production for industries, reducing their competitive advantage in the international market. Additionally, this reliance on expensive energy sources raises the import bill, as Pakistan is an oil-importing country. High electricity costs directly impact the people of Pakistan through increased electricity bills, exacerbating economic challenges for many households. The high unit cost of electricity can create significant socio-economic issues in a country where a substantial portion of the population lives in poverty. Increased energy expenses reduce disposable income for other essential needs such as food, education, and healthcare. This can lead to a lower standard of living and increased financial stress for many families. Moreover, the high cost of electricity can hinder economic growth by reducing industrial output and making Pakistani products less competitive in the global market. Utilizing the country's coal reserves, particularly those in Thar, offers a viable solution to these challenges. By tapping into these indigenous resources, Pakistan can produce cheaper electricity, reducing the overall cost of energy production. This would lower electricity bills for consumers and production costs for industries, enhancing their competitiveness.

In addition to leveraging coal reserves, Pakistan should also focus on developing renewable energy sources such as wind, solar, and biomass. Diversifying the energy mix with renewable sources can enhance energy security, reduce dependence on imported fuels, and promote environmental sustainability. Investments in renewable energy infrastructure and technology can create new job opportunities, stimulate economic growth, and improve the overall quality of life for the population. To achieve these goals, the government needs to implement policies that encourage the development of alternative energy projects. This includes providing financial incentives, regulatory support, and fostering public-private partnerships. Raising public awareness about the benefits of alternative energy and promoting energy efficiency practices are also crucial steps in transitioning to a more sustainable and affordable energy future for Pakistan. The electricity generation potential in Pakistan, based on the consumption of 536 million tonnes of coal per year, is estimated to be around 100,000 MW. This significant fuel resource could be a critical component in supplementing gas-based capacity with coal-based load capacity. Utilizing these coal reserves not only fulfills domestic electricity demands but also has the potential to make Pakistan self-sufficient and capable of exporting surplus energy to regional countries.

To achieve this, the present government must prioritize the utilization of the country's 175 billion tonnes of coal resources. This strategic move could be instrumental in eradicating the ongoing energy crisis by 2018. By tapping into these extensive coal reserves, Pakistan can significantly reduce its reliance on imported fuels, lower electricity production costs, and enhance its energy security. Utilizing coal reserves effectively requires substantial investment in mining infrastructure, modern power plants, and environmentally sustainable technologies. The government should encourage public-private partnerships and provide incentives for investments in coal mining and coal-based power generation. Additionally, adopting cleaner coal technologies and implementing stringent environmental regulations will help mitigate the environmental impact of coal usage. The development of coal resources can also stimulate economic growth by creating jobs in the mining and energy sectors, increasing industrial productivity, and reducing the overall energy costs for consumers and businesses. Furthermore, by exporting surplus electricity to neighboring countries, Pakistan can generate additional revenue, improve regional energy cooperation, and strengthen its economic position in South Asia. Overall, the strategic utilization of Pakistan's coal reserves presents a viable solution to the energy crisis, with the potential to transform the country's energy landscape, bolster economic growth, and improve the quality of life for its citizens.

2.2. CIRCULAR DEBT

Circular debt is a critical issue in Pakistan's energy sector, requiring special attention to resolve it permanently. Unless this issue is settled, the power crisis will continue to hamper the process of economic development. A study by the Planning Commission in 2013 identified several factors contributing to circular debt. These include non-collection from government and private consumers, tariff differential subsidies (TDS), and fuel price adjustments. Additionally, delays in tariff determination and notification, along with discrepancies between actual and estimated transmission and distribution losses, also contribute to the rising circular debt. Addressing these issues necessitates a multifaceted approach. Improving the collection mechanism from both government and private consumers is essential. Implementing stricter enforcement measures and providing incentives for timely payments can help mitigate non-collection issues. Tariff differential subsidies need to be managed more efficiently, with a focus on reducing the gap between the cost of power generation and the tariffs charged to consumers. Fuel price adjustments should be handled transparently, ensuring that fluctuations in global oil prices are reflected accurately and promptly in the domestic market. This requires close coordination between regulatory bodies and energy providers. Furthermore, delays in tariff determination and notification should be minimized by streamlining the regulatory process and enhancing communication between stakeholders.

Addressing transmission and distribution losses is also crucial. Investing in modern infrastructure, upgrading outdated systems, and implementing advanced monitoring technologies can help reduce these losses. Regular maintenance and timely repairs of the transmission and distribution networks are necessary to ensure their efficiency. To tackle circular debt effectively, a comprehensive policy framework is needed, focusing on financial discipline, transparency, and accountability

within the energy sector. Government and private sector collaboration, along with international support, can play a significant role in overcoming this challenge. By addressing the root causes of circular debt, Pakistan can create a more sustainable and reliable energy sector, which is essential for the country's economic growth and development.

2.3. TRANSMISSION & DISTRIBUTION LOSSES

Transmission and distribution losses pose a significant challenge to Pakistan's energy sector, contributing to the ongoing energy crisis faced by the country. These losses occur during the process of delivering electricity from power plants to end-users through the national grid and distribution networks. High transmission and distribution losses not only strain the capacity of the grid but also exacerbate the energy shortfall experienced by consumers and industries nationwide. Efforts to address these losses are crucial for enhancing the reliability and availability of electricity. Improving the efficiency of transmission and distribution systems involves several strategic approaches. First, upgrading and modernizing infrastructure is essential, including replacing outdated equipment and integrating advanced technologies such as smart grids and automated metering systems. These technologies enable real-time monitoring and control, optimizing electricity flow and minimizing losses. Implementing effective loss reduction programs is another key strategy. This includes regular maintenance of transmission lines, transformers, and other equipment to prevent inefficiencies that contribute to higher losses. Capacity building among personnel involved in managing and operating these systems is also essential, ensuring they have the skills and knowledge to implement best practices in energy management.

Policy and regulatory reforms play a critical role in incentivizing efficiency improvements across the sector. Introducing tariffs and regulations that encourage conservation and penalize wasteful practices can drive utilities and consumers alike to adopt energy-saving measures. Moreover, fostering a culture of energy conservation through public awareness campaigns and educational initiatives can further support efforts to reduce transmission and distribution losses. By focusing on these initiatives, Pakistan can mitigate transmission and distribution losses, enhance energy security, and improve the overall sustainability of its energy infrastructure. These efforts are vital for meeting the growing energy demands of the country's population and economy, paving the way for long-term economic development and prosperity.

3. CONCLUSIONS

The energy crisis in Pakistan has had profound impacts on both economic growth and the daily lives of its citizens. Recognizing the urgency of the situation, the government introduced the National Energy Policy 2013 to address the issues and outline strategic measures for bridging the gap between energy demand and supply. The policy's primary objective is to eliminate the shortfall in electricity generation, which fluctuates between 4500 MW to 5500 MW during peak summer months, ultimately aiming for a balanced supply scenario. One of the critical targets of the policy is to reduce transmission and distribution losses, which currently contribute significantly to the energy deficit. By improving the efficiency of these systems and minimizing losses, the policy aims to enhance the reliability and availability of electricity across the country. Additionally, efforts are underway to increase the collection efficiency of electricity bills, aiming to raise it from the current 85% to 95% by 2017. This improvement is crucial for ensuring sustainable revenue streams to support ongoing investments in the energy sector infrastructure. Another key focus area of the policy is to reduce the per unit cost of electricity from the current 12/unit to 10/unit. Lowering the cost of electricity is not only beneficial for consumers but also enhances the competitiveness of industries, promoting economic growth and job creation. Achieving this target involves various strategies, including optimizing the use of indigenous energy resources like coal and hydropower, which can help mitigate dependence on expensive imported fuels. Overall, the National Energy Policy 2013 underscores the government's commitment to resolving the energy crisis comprehensively. By implementing these measures effectively, Pakistan aims to stabilize its energy sector, ensure sustainable development, and improve the quality of life for its citizens through reliable and affordable access to electricity.

The current study identifies several critical factors contributing to Pakistan's energy crisis. Despite having significant coal reserves capable of generating up to 100,000 MW of electricity, the country heavily relies on hydro, oil, and gas for 93.3% of its electricity production. This heavy dependence on more expensive fuel sources significantly impacts the economy, leading to high import bills and increased production costs for industries. Coal-based electricity generation offers a more cost-effective alternative compared to oil and gas. By harnessing its coal reserves, Pakistan can potentially reduce its reliance on expensive imported fuels. This shift could not only stabilize electricity prices domestically but also enhance the competitiveness of Pakistani industries in international markets where energy costs play a crucial role in production expenses. Furthermore, integrating coal into the energy mix aligns with global trends where many countries leverage coal for its affordability and abundance. It also provides a reliable base load capacity, ensuring a more stable and consistent supply of electricity across the country. This strategic move not only addresses immediate energy shortages but also lays the foundation for long-term energy security and economic sustainability.

In conclusion, diversifying Pakistan's energy sources to include more coal-based electricity production holds the promise of mitigating the energy crisis, reducing costs, and supporting industrial growth. It represents a vital step towards achieving energy independence and fostering economic development in the country. The critical issues of circular debt and transmission losses significantly exacerbate Pakistan's energy crisis. Transmission and distribution losses currently account for a substantial portion of electricity loss, estimated at 4266 MW. Reducing these losses to 10% would not only optimize the efficiency of electricity distribution but also potentially add around 2133 MW to the national grid, effectively narrowing

the gap between demand and supply. Circular debt, on the other hand, poses a persistent challenge, with recent efforts to clear Rs. 480 billion in debt resulting in increased utilization of Independent Power Producers (IPPs) to 66% from 55%. This initiative added 1752 MW to the national grid. Resolving the circular debt issue permanently would further enhance electricity production capacity. Combined, resolving both circular debt and transmission losses could potentially add up to 3885 MW of electricity to the national grid, significantly bridging the demand-supply gap. Addressing these critical issues is crucial for Pakistan to achieve energy security, stabilize electricity prices, and support economic growth. By improving efficiency in electricity distribution and resolving financial bottlenecks, the government can pave the way for a more reliable and sustainable energy sector that meets the needs of industry, commerce, and households across the country.

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