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Enlightening Bangladesh: Navigating power sector challenges through PPP excellence

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Abstract: As Bangladesh faces its current energy crisis, public-private partnerships (PPPs) emerge as a promising solution, bridging the strengths of both sectors toward a brighter, more electrified future. This research focuses on the challenges in Bangladesh's power sector: increasing electricity demand and the imperative for a consistent supply of renewable energy sources. The research employs content analysis, exploring various aspects, including policy documents, regulatory frameworks, stakeholder engagements, and resource assessments, with a specific focus on three key variables: regulatory framework, stakeholder engagement, and informed policymaking. Drawing on the 'resource-based view' theory, the study emphasizes the significance of 'mitigating resource risks' through 'resource assessment.' Empirical support is derived from an extensive review of literature in reputable journals and research articles, enhancing the research's credibility with real-world evidence. The study provides a practical roadmap for stakeholders navigating Bangladesh's power sector, addressing energy challenges, and promoting sustainability.

Keywords: power sector; public-private partnership; challenges; navigation; Bangladesh

1. Introduction

Amidst the evolving energy landscape in Bangladesh, a transformative force has emerged—public-private partnerships (PPPs). These innovative collaborations are forging a path towards a brighter and more sustainable energy future by harnessing the collective strengths, resources, and expertise of both the public and private sectors. Within the dynamic power sector, PPPs offer a distinct opportunity to bridge infrastructure gaps, elevate service standards, and attract private investments for vital areas like power generation, transmission, and distribution. In the ever-evolving energy landscape of Bangladesh, a dynamic force has emerged—public-private partnerships (PPPs). These collaborative endeavors represent a pivotal convergence of public and private sector capabilities, resources, and expertise, charting a course towards a more sustainable and electrified future. Within the realm of the power sector, PPPs present a unique opportunity to bridge infrastructure gaps, elevate service standards, and mobilize private investments in vital areas such as power generation, transmission, and distribution. This paper endeavors to provide a comprehensive analysis of the role and impact of PPPs in addressing the formidable energy challenges facing Bangladesh.

Case study of Sirajganj Combined Cycle Power Plant:

As we navigate the intricacies of this research, we place a particular spotlight on the Sirajganj Combined Cycle Power Plant. The landmark case study, Sirajganj Combined Cycle Power Plant case study (Islam, 2019; Salam et al., 2022) was a 670

MW (megawatt) dual fuel fired power project located in Barisal, Bangladesh, was successfully commissioned in November 2012. Developed and owned by Northwest Power Generation, this combined cycle gas turbine (CCGT) power plant primarily operates on natural gas but can seamlessly switch to high-speed diesel (HSD) in case of shortages. Under a power purchase agreement, it supplies electricity to the Bangladesh Power Development Board, contributing significantly to the nation's growing energy needs. The project was executed in phases with the involvement of reputable contractors, including China National Machinery Import and Export and Fujian Electric Power Survey and Design Institute. Each phase of the plant is equipped with specific components, such as Siemens and DEC (Dongfang Electric Corporation) Dongfang electric machinery turbines and generators. As of 20 July 2023, the Sirajganj Combined Cycle Power Plant continues to play a vital role in Bangladesh's power infrastructure, ensuring a reliable and diversified energy supply for the country's development.

This paper, driven by an unwavering commitment to unravel the intricate dynamics of PPPs in Bangladesh's power sector, as exemplified by the Sirajganj case study, unfolds through a structured framework. We aim to illuminate the multifaceted impact of PPPs, delve into the mechanisms that drive their success, and derive valuable insights that can guide our collective pursuit of a sustainable and electrifying future.

1.1. Problem statement

In Bangladesh, the power sector has numerous challenges to fulfill the growing electrical demand of the country and ensure a consistent supply of renewable energy. As the country's population has topped 173 million (Worldometer, 2023), its energy consumption has skyrocketed. The increased demand for electricity, however, makes it difficult for the current infrastructure to keep up, which frequently results in power outages and disruptions to daily operations in homes and businesses. To address these issues, the government has investigated the viability of public-private partnerships (PPPs) in the power sector. With the use of PPPs, it will be possible to increase the effectiveness and efficiency of power generation, transmission, and distribution by utilizing the private sector's knowledge, resources, and creativity. But overcoming the obstacles to their implementation and seizing the potential for sustainable and equitable growth are essential to the success of PPPs in the power industry. The deficits have a major negative economic impact on the nation's productivity and industrial progress. Furthermore, transmission and distribution inefficiencies in power provide serious difficulties. In addition to putting pressure on the industry's ability to continue operating profitably, these losses influence customers' access to reliable, affordable electricity. To resolve these problems and maximize the benefits of PPPs in the power sector, a thorough understanding of the opportunities and limitations is needed. By examining the regulatory frameworks, financial models, and stakeholder dynamics, this study aims to provide meaningful information to policymakers, investors, and practitioners in the Bangladeshi power sector. The creation of a more resilient and sustainable power industry in Bangladesh would ultimately benefit from these insights, which will help in formulating

strategies to address challenges and capitalize on PPP potential.

1.2. The objectives of this research

The primary objectives of this research are to comprehensively evaluate the impact of public-private partnership (PPP) models in the power sector of Bangladesh, considering both their successes and challenges. This study aims to assess their role in updating and enhancing the efficiency of the power sector, while also addressing valid concerns related to transparency and accountability within these partnerships. Additionally, we seek to examine the substantial investments made in expanding the nation's power generation capacity and their contribution to economic growth and development. To achieve these objectives, the research will navigate the complexities of data authenticity in online resources, establishing robust research development and explore strategies for striking the right balance between public and private interests in PPPs. Ultimately, the overarching goal is to understand how Bangladesh can harness the potential of PPPs to meet its growing energy demands and foster sustainable economic advancement.

1.3. Purpose of study

The study's main goal is to address the following fundamental issues, which will help policymakers, practitioners, and researchers get insightful information; the other uses are:

- Determining the main obstacles preventing Bangladesh's power sector from utilizing PPPs effectively.
- Examining the possibilities for improving the sustainability and effectiveness of PPPs in the power sector.
- Investigating potential plans for enhancing legal and regulatory frameworks to remove obstacles and promote the implementation of PPPs.
- Encouraging private participation and guarantee the financial feasibility of PPP projects, evaluate financial models and risk-sharing systems.
- Offering policymakers and practitioners evidence-based suggestions for creating and putting into place successful PPPs in the power industry.
- Making use of research findings to guide policy choices that can help Bangladesh's electricity sector operate and be governed better overall.
- Getting stakeholders involved in PPP project creation, management, and monitoring some applicable best practices and recommendations.

1.4. Significance of study

The significance of this study lies in its analysis of the challenges and opportunities posed by public-private partnerships (PPPs) in Bangladesh's power industry. By evaluating the significance, the research aims to show the importance of the study and any potential effects it may have on different stakeholders. The relevance of the study is explained in more detail by the following:

- Decision maker: The results of this study will offer them evidence-based perceptions of the difficulties and possibilities of PPPs in the power industry. Policymakers may promote sustainable power generation and reduce the

electricity shortage by creating informed policies and regulatory frameworks that create an environment that is favorable to the adoption of PPPs.

- Practitioners: This study will help practitioners in the electricity sector, like utility corporations and private investors, by giving them a better knowledge of the difficulties PPP projects may provide. They may develop efficient strategies, minimize risks, and maximize the potential advantages of PPPs in the electricity industry by identifying opportunities.
- Researchers: This study adds to the current body of knowledge on public-private partnerships in the power sector, notably in Bangladesh. The findings and approach can be used by researchers to better understand PPP dynamics, power sector governance, and infrastructure development. It opens possibilities for additional research and discovery in linked domains.

The Bangladesh Power Development Board (BPDB), for example, forecasts a continued demand-supply imbalance in electricity, with peak demand exceeding available supply (BPDB, 2022). Furthermore, the World Bank estimates that transmission and distribution losses in the electricity industry account for roughly 15% of total efficiency (World Bank, 2018). These findings underline the vital relevance of overcoming obstacles and capitalizing on the benefits provided by electricity sector PPPs.

2. Research design

2.1. Research questions

- 1) How can the government overcome the challenges associated with public-private partnerships?
- 2) How does Bangladesh's power industry, with an emphasis on public-private partnerships, contribute to the global electrical landscape in terms of sustainable development, renewable energy integration, and efficient service delivery?
- 3) What is the impact of private sector involvement in power generation on addressing electricity shortages in Bangladesh?
- 4) How can the financing of PPP projects in the power sector be improved to attract more private investment and achieve long-term progress?

Justifications of the research questions:

- (1) How can the government overcome the challenges associated with public-private partnerships?

The government of Bangladesh has taken significant steps to address issues related to public-private partnerships (PPPs) in the power industry, as reported in the Bangladesh Power System Master Plan 2016 and the Bangladesh Power System Development and Reform Program 2010–2021. These steps include strengthening policy and regulatory frameworks to encourage PPP investments by developing clear guidelines and laws. The aim is to foster an equitable distribution of duties and responsibilities through effective risk-sharing mechanisms, ensuring a balanced partnership between public and private partners. In addition, there has been a focus on improving cooperation and capacity by enhancing coordination among government agencies, regulatory groups, and private-sector entities. Capacity-building programs have improved project management and supervision capabilities.

Furthermore, transparency and accountability have been enhanced through the implementation of strong monitoring and evaluation mechanisms, as well as the adoption of best practices in procurement and contract administration. These measures collectively aim to create a favorable environment for PPP investments in the power industry and promote openness and accountability throughout the PPP process.

(2) How does Bangladesh's power industry, with an emphasis on public-private partnerships, contribute to the global electrical landscape in terms of sustainable development, renewable energy integration, and efficient service delivery?

Bangladesh's power industry contributes considerably to the worldwide electrical environment in terms of sustainable growth, renewable energy integration, and efficient service delivery, with a heavy emphasis on public-private partnerships (PPPs). Several national and international journals have emphasized Bangladesh's success in renewable energy integration, particularly through PPP solar and wind power projects. For example, Kirikkaleli (2022) stressed the country's successful adoption of PPPs in boosting its renewable energy potential. Furthermore, a study published in the *Journal of Governance and Innovation* by Islam and Rahman (2019) indicated that private sector involvement in the power industry resulted in improved service delivery, including increased grid dependability and decreased downtime. These findings suggest that Bangladesh's power industry, led by PPPs, actively contributes to sustainable development, renewable energy integration, and efficient service delivery on a worldwide scale.

(3) What is the impact of private sector involvement in power generation on addressing electricity shortages in Bangladesh?

This research question focuses on assessing the contribution of private sector involvement in power generation to alleviate electricity shortages in Bangladesh. By examining the performance and outcomes of independent power producer (IPP) projects, the study can provide insights into the effectiveness and impact of private sector participation. The findings will inform policymakers and stakeholders about the benefits, limitations, and potential improvements in engaging the private sector to address electricity shortages and ensure a consistent and reliable power supply.

(4) How can the financing of PPP projects in the power sector be improved to attract more private investment and achieve long-term progress?

This research question addresses the critical issue of financing PPP projects in the power sector. By exploring the availability of low-cost funding and interventions in the financing domain, the study can identify strategies to attract more private investment. Understanding the financial challenges and potential solutions will inform policymakers and investors about the necessary steps to create a favorable investment climate and enable sustainable and long-term progress in the power sector through PPPs.

2.2. Research methodology

This study aims to determine Bangladesh's electricity situation using time series energy data. The World Bank (WB), Bangladesh Power Development Board (BPDB), Power System Master Plan (PSMP), Bangladesh Perspective Plan, and

other organizations provide secondary data. Several indicators are included in this analysis, including energy demand, energy sources, GDP (Gross Domestic Product) and population, and power generation. A substantial amount of information has been gathered to aid in the creation of the literature review. The Power Development Board of Bangladesh's "Annual Report 2021–2022" has been included in the content analysis procedure, as has the government's ambition to achieve a total generation capacity of 24,000 MW by 2030 and 60,000 MW by 2041.

The analysis in this study incorporates several indicators to assess the electricity situation comprehensively. These indicators include energy demand, energy sources, GDP and population, and power generation. By examining these indicators over a specific period, the researchers aim to gain insights into the trends, patterns, and challenges in Bangladesh's electricity sector. To support the literature review, a substantial amount of information has been gathered. The researchers have accessed relevant reports, publications, and documents, including the Power Development Board of Bangladesh's "Annual Report 2021–2022" (BPDB, 2022). This report provides valuable insights into the current state of the power sector in Bangladesh, including the government's targets for future power generation capacity. In the research methodology, content analysis has been conducted on the collected data. This involves systematically analyzing the content of the literature, reports, and documents to identify key themes, trends, and information relevant to the study's objectives. By conducting a content analysis, the researcher can extract meaningful information and draw conclusions based on the data. It is important to note that this study relies on secondary data sources, which may have inherent limitations. The accuracy and reliability of the data depend on the quality of the sources and the methodology used by the organizations providing the data. The researchers acknowledge these limitations and have taken steps to ensure the use of reputable sources to enhance the validity of the study's findings. Overall, the research methodology used in this study combines the analysis of time series energy data, secondary data from reliable sources, and content analysis to determine the electricity situation in Bangladesh. By employing this methodology, the researchers aim to provide a comprehensive understanding of the country's power sector, its status, and the government's ambitions for future power generation capacity. The techniques and methodologies employed in this study offer several benefits for understanding Bangladesh's electricity situation comprehensively. First, the utilization of time series energy data allows for the identification of long-term trends and patterns in the country's power sector, enabling policymakers and stakeholders to make informed decisions for sustainable development. Second, the reliance on secondary data from reputable sources such as the World Bank, Bangladesh Power Development Board, and government plans enhances the reliability and validity of the study's findings, providing a robust foundation for analysis. Third, the inclusion of multiple indicators like energy demand, sources, GDP, population, and power generation enables a holistic assessment of the electricity situation, facilitating a nuanced understanding of the complex interplay between these factors. Additionally, the content analysis methodology aids in identifying key themes and extracting valuable insights from a vast array of reports and documents, streamlining the research process. Moreover, the study highlights significant achievements in

Bangladesh's power generation sector, including increased capacity, energy access, and diverse energy sources. The government's ambitious plans to further expand capacity reflect its commitment to meeting the country's growing energy needs, which is crucial for sustaining economic growth and reducing poverty rates. Overall, these techniques contribute to a comprehensive and data-driven analysis, offering valuable insights into Bangladesh's electricity landscape and its prospects.

In the fiscal year 2021–2022, the country added 669 MW of new generation capacity, bringing the total installed capacity in the public, private, joint venture, and import sectors to 22,512 MW. The private sector contributes 44% (9978 MW), joint ventures account for 6% (1244 MW), and imports contribute 5% (1160 MW) of the total installed capacity. Despite challenges in the public sector, Bangladesh has achieved 100% population electricity access with a per capita generation of 609 kWh. The government has ambitious plans to construct 34 power generation projects, aiming to add about 25,840 MW of additional capacity by 2027. The public sector contributes 10,130 MW, while joint ventures, independent power producers (IPPs) and small independent power producers (SIPPs), rental power plants, no electricity no payment (NENP) power plants, and power imports from India account for the remaining capacity. The power generation capacity in Bangladesh is diverse, with hydro, gas, furnace oil, diesel, coal, and solar contributing to the overall mix. Over the years, both the governmental and private sectors have significantly increased their capacity for electricity generation by utilizing a variety of fuels. The public sector's power generation capacity has grown by more than five times, from 255 MW in 2010 to 1349 MW in 2018. In 2011, the private sector began generating electricity and reached a peak capacity of 797 MW, surpassing the public sector in certain years. Currently, the public sector accounts for 45% of the installed generation capacity, while the private sector makes up 44%. This collaboration between the two sectors has been instrumental in meeting the rising demand for power in Bangladesh.

3. Literature review

3.1. Expansion of power capacity in Bangladesh

The Bangladesh Power Development Board (BPDB) initiated efforts to address this challenge. Starting in 1972 with an installed capacity of only 200 MW, BPDB embarked on a significant capacity expansion plan to increase power production. As of 29 May 2019, the installed capacity had grown to 20,000 MW. However, despite this capacity growth, Bangladesh was able to generate only 12,893 MW against the demand of 14,796 MW in 2019. Recently, Bangladesh's power generation capacity reached 23,436 MW, providing electricity coverage to over 97% of the population. Researchers like Bhuiyan et al. (2021) have emphasized the importance of renewable energy resources for sustainable development in Bangladesh. Solar energy has gained popularity in rural, hilly, and coastal areas. Bangladesh has also initiated micro and mini-hydropower projects and explored biomass energy sources, including animal manure, agricultural residues, and municipal solid waste. Various researchers have assessed different aspects of renewable and sustainable energy resources in Bangladesh, including their potential, technologies, and socio-economic impacts.

Continuous assessment and collaboration between private and governmental projects are crucial for successfully meeting the country's electricity demands.

3.2. Meeting future electricity demand

The demand for electricity in Bangladesh is projected to reach 50,000 megawatts (MW) by 2041, and the government aims to attract \$127 billion in investments in the power generation sector over the next two decades to support economic growth and meet the needs of a growing middle class. Despite significant increases in electricity generation capacity over the past decade, challenges such as poor transmission and distribution infrastructure, outdated power plants, and a mismatch between energy needs and available fuel sources persist. Approximately half of the installed capacity comes from private power production units.

3.3. Growth of electrical generation capacity

From 2009 to 2022, electrical generation capacity in Bangladesh has grown from about 5 gigawatts to roughly 25.5 gigawatts. The government claimed in March 2022 that 100 percent of the population now has access to electricity. However, the reliability and quality of electricity supply remain major concerns. Ensuring a reliable and affordable energy supply is crucial for supporting the growth of industry and commerce in the country.

The primary source of fuel for Bangladesh's power plants is natural gas. To reduce dependence on domestic natural gas, the government plans to increase the use of imported liquefied natural gas (LNG). There were previous considerations to shift towards coal-based power plants, aiming for coal to constitute up to 50 percent of total electricity generation by 2030. However, plans to build 10 coal-fired power plants were scrapped in June 2021. The government is now looking at reducing coal's priority in its Power System Master Plan (PSMP) (2016) in response to environmental concerns and pressure from development partners. Additionally, the country is exploring options to import more electricity from neighboring countries and expand the use of renewable energy sources like solar and wind power.

3.4. U.S. companies in Bangladesh's power sector

U.S. companies have a significant presence in Bangladesh's power and energy industry, supplying approximately 55 percent of the country's domestic natural gas production and being major investors in power projects. U.S. origin power turbines currently contribute 80 percent of Bangladesh's installed gas-fired power generation capacity (U.S. Department of State, 2021).

3.5. Opportunities in offshore gas exploration

Opportunities also exist for offshore gas exploration in the Bay of Bengal, with 26 offshore blocks, including both shallow and deep-sea blocks. Petrobangla, the state-owned oil and gas exploration company, awarded a contract to a U.S.-Norway joint venture for a seismic survey in these blocks (Rahman, 2022). In 2019, the government amended the terms of the model production sharing contract (PSC) to attract more international interest, including allowing offshore drilling companies to

export gas if Petrobangla declines to purchase it. In 2021, Bangladesh, in collaboration with ONGC (Oil and Natural Gas Corporation Ltd) Videsh Limited, an Indian company, began drilling in a new block in the Bay of Bengal under a PSC.

3.6. Success of public-private partnerships (PPPs)

To address its infrastructure challenges, Bangladesh has successfully executed projects using the public-private partnership (PPP) model, following in the footsteps of other developing nations. As of now, Bangladesh has completed a total of 41 PPP projects with a combined investment value of \$2.9339 billion, while an additional 40 projects are currently in the national PPP pipeline (Rashed et al., 2014). In the realm of legal and regulatory frameworks, transparent procurement processes, efficient off-take guarantees, and the establishment of specific entities like the PPP office and power cell, PPPs have been particularly successful in the power generation sector in Bangladesh. However, there is a pressing need to replicate this success in other sectors such as roads and social infrastructure.

It is noteworthy that PPP project development, especially in these sectors, has not kept pace with the increasing demand. Therefore, it is imperative to assess the effectiveness and challenges of PPP implementation in the country. Identifying these challenges is vital for policymakers to devise effective solutions. This paper aims to pinpoint existing gaps in the roles and procedures of various stakeholders involved in PPP project development and propose short-term, medium, and long strategies.

3.7. Abundance of natural resources in Bangladesh

The government of Bangladesh has recognized the necessity of transitioning from fossil fuels to cleaner energy sources, such as renewable and sustainable energy, to meet the country's growing electricity demands. However, the current development of these energy resources in Bangladesh is insufficient for electricity production, and their efficient utilization has not yet made a significant impact. Nonetheless, given the ongoing energy crisis and global demand for green energy, renewable and sustainable energy sources have become inevitable, and Bangladesh is no exception. The government's Vision 2021 aims to achieve a 10% share of renewable and sustainable energy generation capacity, equivalent to around 3700 MW. Various renewable energy sources, including solar energy, hydropower, wind power, biomass and biogas energy, geothermal energy, and tidal power, are being explored.

Bangladesh's strategic geographical location in South Asia provides an ideal environment for harnessing solar energy, with abundant solar irradiance. The Chittagong region shows great promise for solar energy utilization, offering affordable and reliable energy solutions through technologies like solar thermal energy and photovoltaic cells.

Hydropower is another clean energy source with significant potential, especially in hilly areas. Bangladesh's first hydropower plant was established at Kaptai, Rangamati. Small-scale hydropower projects can bring electricity to remote hill tracts. Wind energy is also gaining momentum, with favorable zones identified in places like Chandpur's Kachua, Khulna's Mongla, Patuakhali's Kuakata beach, and

Cox's Bazar Inani beach, primarily in coastal regions.

In Bangladesh, natural resources such as natural gas, petroleum, and coal is abundant. Natural gas serves as the primary source of power and energy in the country. The government has set ambitious goals to provide electricity to the entire nation by 2021, aiming to meet the growing demand of the middle-class population and boost the export-oriented economy. Sustainability in the power and energy sector is considered essential for achieving overall sustainable development.

3.8. Mitigating greenhouse gas emissions in India

Mitigating greenhouse gas emissions in India is a complex and pressing challenge that requires a multifaceted approach. The adoption of renewable energy sources, such as solar and wind power, has gained momentum in the country, driven by initiatives like the National Solar Mission (Ministry of New and Renewable Energy, Government of India). Real income levels play a pivotal role in shaping consumption patterns and environmental awareness (Narayan and Narayan, 2010). Additionally, investment in the energy sector is essential for the transition to cleaner technologies and infrastructure (Li, 2023). However, addressing emissions in India also entails addressing the unique challenges posed by a growing population, urbanization, and the need to balance emissions reduction with energy access (Gupta et al., 2019). To effectively mitigate emissions in India, policymakers must continue to implement comprehensive strategies that incorporate these factors and foster sustainable development.

3.9. Spatiotemporal factors affecting energy efficiency in Europe

The research paper titled "Spatiotemporal influencing factors of energy efficiency in 43 European countries: A spatial econometric analysis" (Quito et al., 2023) is likely to delve into the intricacies of energy efficiency within the European power sector. It investigates a wide range of factors, including the composition of the energy mix, investments in clean energy technologies, advancements in power generation and distribution, and the influence of energy policies and regulations specific to the power sector. Understanding the dynamics of energy efficiency within the power sector is vital for enhancing sustainability, reducing carbon emissions, and ensuring the reliability of electricity supply systems across Europe. The research findings can serve as a valuable resource for policymakers, energy industry stakeholders, and environmental advocates seeking to develop targeted strategies to optimize energy efficiency and promote sustainable power generation and distribution practices in the region.

3.10. Combined heat and power (CHP) systems in Bangladesh's power sector

The literature review explores the potential benefits and challenges of implementing combined heat and power (CHP) systems through public-private partnerships (PPPs) in Bangladesh's power sector. Islam et al. (2021) highlight the advantages of CHP systems, such as improved energy efficiency, reduced emissions, and increased energy security. Adopting CHP systems in PPP models can also

facilitate technology transfer, attract private-sector investment, and create new business opportunities. A modest cogeneration plant is given in Islam et al. (2018)'s report as a promising way to increase the production of alternative energy in Bangladesh. Bagasse, biogas, and coal are the energy sources used in the integrated combined heat and power (CHP) system presented in the model. With 2 MW set aside for internal use, the goal of the North Bengal Sugar Mills is to produce 6 MW of electricity. In addition to giving the sugar mills another source of income, the extra 4 MW will be smoothly incorporated into the national grid. The potential to improve sustainability and improve Bangladesh's energy landscape through the combination of varied energy sources is demonstrated by this creative model (Islam et al., 2018). However, the lack of a clear legal and regulatory framework, as well as effective risk-sharing mechanisms, hinders private sector participation in CHP projects (Mahmud and Saleh, 2019). To fully utilize the potential of CHP systems, a comprehensive legal and regulatory framework, along with mechanisms for risk-sharing and financing, needs to be established.

3.11. Implementation of solar power plants through PPP models in Bangladesh's power sector

The review also focuses on the implementation of solar power plants through PPP models in Bangladesh's power sector. Solar power, which includes converting solar energy into thermal or electrical forms, is a flexible and sustainable option that may be used for a variety of reasons, from heating water to producing electricity. Bangladesh's advantageous solar climate has made it possible to successfully install more than four million solar home systems (SHS), or off-grid rooftop solar power installations. Even though these SHS installations have greatly enhanced the quality of life in isolated villages and helped the government achieve its targets for renewable energy, their overall influence on the nation's power consumption—less than 2% of total capacity—remains small. Notable is the 73 MW solar power plant in Mymensingh, which has been in operation since October 2020 and contributes to the government's goals for generating renewable energy by 2021 (Rahman and Begum, 2021). According to Gheewala (2019), solar power plants in PPP models can offer benefits such as increased access to clean energy, reduced dependence on fossil fuels, and improved energy security. Additionally, PPP models can facilitate technology transfer and attract private-sector investment. A holistic approach to sustainable energy is demonstrated by solar irrigation programs and solar-diesel hybrid solutions for telecom BTS (Base Transceiver Station), which satisfy crucial needs (Hossain and Rahman 2021). On the other hand, obstacles consist of difficulties obtaining funding, the impression of exorbitant interest rates, and protracted loan distribution procedures. Stakeholders are still ignorant of the good improvements made to the Bangladesh Bank's green refinancing strategy. The industry's expansion is further hampered by the absence of thorough implementation instructions, higher import taxes on inverters, and worries about the caliber of renewable energy technology. Meeting these obstacles is essential to meeting Bangladesh's goals for renewable energy and building a climate-resilient, low-carbon future (Alam, 2021). However, challenges exist, including the lack of a

comprehensive regulatory framework, ineffective risk-sharing mechanisms, and limited access to affordable financing (Hassan, 2012). Overcoming these challenges requires the establishment of a supportive legal and regulatory framework, effective risk-sharing mechanisms, and improved access to affordable financing.

3.12. Biomass boilers in Bangladesh's power sector

The literature review examines the implementation of biomass boilers through PPP models in Bangladesh's power sector. Biomass boilers offer benefits such as increased access to clean energy, reduced dependence on fossil fuels, and improved energy security (Islam et al., 2014). PPP models can facilitate technology transfer and attract private sector investment. However, challenges exist, including high upfront costs, the need for reliable biomass feedstocks, the lack of a comprehensive regulatory framework, and ineffective risk-sharing mechanisms (Huda et al., 2014). Two options, biogas and biomass, are important in Bangladesh. One study highlights biomass's varied and significant contribution, especially that of biogas, to the country's energy landscape (Uddin et al., 2019). To fully utilize the potential of biomass boilers in PPP models, a comprehensive legal and regulatory framework, along with mechanisms for risk-sharing and financing, needs to be established. Greater awareness and understanding of biomass energy and the development of policies to promote its adoption are also necessary.

3.13. Limited private sector participation in PPP projects

One of the key issues identified in the literature was the limited private sector participation in PPP projects in Bangladesh's power sector just a decade ago. The involvement of the private sector is essential for the effective integration of renewable technologies in decentralized electricity, especially in isolated and rural areas that are off the grid. Significant progress in decentralized electrification as a substitute for grid extension has not been made in Bangladesh, despite efforts to promote private investment through incentives and subsidies in the renewable hybrid mini-grid sector. To explore the possibility of private sector participation in public-private partnership (PPP) projects in Bangladesh's power sector, Alam and Bhattacharyya (2017) focuses on examining rural communities' willingness to pay (WTP) for decentralized electricity provision. The efforts to attract private investment have had a fruitful result with the private sector now sharing about half of the total installed generation capacity (Sarower, 2021). The literature highlights the need for improved governance, transparency, accountability, and stakeholder engagement to overcome these challenges and increase private sector participation (Abdulrazak and Hossain, 2021).

3.14. Governance challenges of PPPs in developing countries

The review analyzes the governance challenges of PPPs in developing countries, using Bangladesh as a case study. Governments realize the substantial value of PPP contracts, yet the governance problems associated with PPPs in developing nations exist widely. A clear dispute resolution process is essential to maximizing the benefits of PPP involvement. Certain governments adopted provisions for resolving

disputes in PPP laws, guaranteeing a uniform process that may require turning to courts, chambers of commerce arbitrators, regulators, and foreign arbitrators. To promote successful PPP outcomes in developing nations and prevent service delivery interruptions, it is imperative that certain governance issues to be addressed effectively (Almarri and Abuhijleh, 2017). Challenges identified include corruption, political interference, and a lack of capacity (Khan et al., 2012). These challenges can lead to delays, inefficiencies, and erosion of public trust in PPP projects (Reyes-Tagle, 2018). To address these issues, transparency, accountability, and stakeholder engagement are crucial.

3.15. High project costs and cost overruns

The literature highlights the significant cost overruns. High project costs and cost overruns pose significant challenges in public-private partnerships (PPPs) within Bangladesh's power sector, as highlighted in various reports and journals. The Bangladesh Power Development Board's (BPDB) Power Sector Master Plan 2016 identified cost escalation as a major concern in power projects. The plan emphasized the need for effective project management and risk assessment to control project costs and prevent cost overruns. Additionally, a study by Islam et al. (2019) examined the factors influencing cost overruns in power sector PPPs in Bangladesh. The research found that inadequate project planning, inaccurate cost estimation, delays in obtaining necessary permits, and changes in project scope were key contributors to high project costs and cost overruns. Similarly, a study by the Sarower (2021) acknowledged the challenge of cost escalation in power sector PPPs and recommended strengthening project appraisal, improving contract management, and enhancing coordination among stakeholders to mitigate these issues.

3.16. Political interference in PPP projects

The interferences often lead to delays in decision-making processes, as projects may be subjected to constant changes in priorities, objectives, or even outright cancellation based on political motivations. These delays not only hinder project timelines but also result in increased costs, jeopardizing the financial viability of PPP initiatives. It can also contribute to inefficiencies in the power sector because the projects based on the PPP factors are likely to be awarded to less qualified or inexperienced private partners based on political affiliations rather than merit and competence. As seen throughout the examples, a negative correlation exists between efficiency deterioration and political interference can cause major delays during the purposeful application of PPP projects, so as a result, the private sector's knowledge, expertise, and innovative solutions may not be fully leveraged, impeding the sector's progress, and hindering the implementation of effective and sustainable power generation, transmission, and distribution systems, and an example was the huge accusation of Sheikh Hasina, the former prime minister of Bangladesh and the leader of Awami league who was told to be taking kickbacks in a power plant deal for the betterment of the power sector of Bangladesh (Taniguchi and Kaneko, 2009). As a result, the private sector's knowledge, expertise, and innovative solutions may not be fully leveraged, impeding the sector's progress, and hindering the implementation of

effective and sustainable power generation, transmission, and distribution systems.

3.17. Limited institutional capacity on PPP projects

Due to the lack of expertise and resources, institutions may struggle to conduct thorough and comprehensive assessments, including feasibility studies, financial analyses, and risk evaluations. This can result in poorly designed project structures, unrealistic financial projections, and inadequate risk management strategies, which ultimately undermine the success and sustainability of PPP initiatives. Insufficient capacity hampers the ability of institutions to develop and negotiate robust and equitable contracts with private partners which can lead to imbalanced risk allocation, ambiguous terms and conditions, and inadequate performance monitoring mechanisms. Consequently, the power sector may face challenges in ensuring adherence to contract provisions, addressing disputes, and achieving the desired project outcomes. Inadequate capacity can impede effective monitoring and evaluation of PPP projects, making it difficult to detect and address instances of corruption, mismanagement, or non-compliance with contractual obligations, and this lack of transparency erodes public trust, undermines investor confidence, and hinders the realization of the intended benefits of PPPs in the power sector. With the recent growth of the industrialization sectors in Bangladesh, there may or may not be proper space for inputting architectural projects of PPP projects in Bangladesh, and stakeholders and other collaborators may even go to further lengths to execute their projects (Azad and Jin, 2021).

3.18. Suggestions and recommendations for the effectiveness of PPPs in the power sector

To ensure the success of PPPs in the power sector, it is crucial to strengthen the legal and regulatory framework. This can be achieved through the development of clear and comprehensive laws, regulations, and guidelines that govern the implementation and operation of PPP projects and the promoted framework should instill a sense of transparency, fairness, and competition, while also providing a supportive environment for private sector participation and investment. Effective risk-sharing mechanisms and financial arrangements are essential to attract private sector investment and ensure the sustainability of PPP projects and also to establish mechanisms that appropriately allocate risks between the public and private sectors, taking into account factors such as project complexity, financial viability, and long-term sustainability because including the use of public funds, private equity, and debt instruments, should be explored to diversify funding sources and reduce reliance on limited resources. In conclusion, the recommendations put forward in this study aim to overcome challenges and improve the effectiveness of PPPs in the power sector of Bangladesh. By strengthening the legal and regulatory framework, implementing effective risk-sharing mechanisms, enhancing stakeholder engagement, focusing on rural electrification and renewable energy integration, and strengthening governance and institutional capacity, evaluating assessments and managements of fiscal risks and contingent liabilities, extended pipeline of bankable projects that can be identified through clear processes prioritize screen projects for PPP suitability, solid

project preparation and structuring capacity, strong transaction support and contract management capacity etc. (Batjargal and Zhang, 2021, 2022). The power sector can harness the full potential of PPPs with properly conducted research to ensure the practicality and impact of these recommendations in driving sustainable and efficient power infrastructure development in Bangladesh.

3.19. Background of public-private partnership in Bangladesh: Present sectors wise PPP policy in Bangladesh

As indicated in the 2014 report by Rashed et al. (2014), the government of Bangladesh launched public-private partnership (PPP) in 1996, following the approval of the private sector power generation strategy. This project aims to promote the development of public infrastructure and services in the country. In accordance with Vision 2021 objectives and the Global Agenda 2030 (Giménez et al., 2014; Carpentier and Braun, 2020), the present government has improved the PPP framework by introducing policy guidelines. Since its inception in 2009, various private entities have worked with public authorities to improve water supply, sanitation, health, the environment, energy, and physical infrastructure. These collective efforts are critical in increasing Bangladesh's progress toward reaching the sustainable development goals (SDGs). The public-private partnership (PPP) concept has been critical in mobilizing resources.

4. Data collection

4.1. Bangladesh's remarkable power sector progress

Over the past decade, Bangladesh's power sector has undergone a remarkable transformation, resulting in substantial growth in energy production. In the fiscal year 2009–2010, the country's total electricity production stood at 4606 MW (Bangladesh Power Development Board, 2022). By FY (Fiscal Year) 2018–2019, this figure had surged to an impressive 12,893 MW, marking a three-fold increase within a span of just nine years (Bangladesh Power Development Board, 2022). This extraordinary growth extended beyond mere numbers; it symbolized Bangladesh's unwavering commitment to providing a reliable and ample energy supply as a cornerstone for economic growth.

Development goals and achievements:

Bangladesh, with a population of approximately 170 million, has set ambitious development goals. It aspires to attain middle-income status by 2021 and transition into a fully developed nation by 2041 (Sadeque et al., 2014). In 2014, the World Bank classified Bangladesh as a lower middle-income country, considering factors such as per capita income, electricity consumption, literacy rates, unemployment, poverty levels, and healthcare indices (World Bank, 2014; Badiuzzaman et al., 2018). To reach these objectives, the nation aims to elevate per capita income to \$4645, maintain energy consumption within a range of 600 to 1000 kWh, and reduce poverty to less than 14% (World Bank, 2014).

Electricity access and generation:

Bangladesh has made significant strides in ensuring universal access to

electricity. By the fiscal year 2021–2022, the country had achieved 100% population access to electricity (Bangladesh Power Development Board, 2022). On a per capita basis, electricity generation reached 609 kWh, encompassing both captive and renewable energy sources. This increased access to electricity has not only improved the quality of life for its citizens but has also been a catalyst for higher economic growth.

Diverse energy sources:

Bangladesh’s electricity generation is diversified, drawing from various sources. These include hydroelectric power, natural gas, furnace oil, diesel, coal, solar energy, and power imports (Bangladesh Power Development Board, 2022). This diverse mix of energy sources ensures a stable and diverse energy supply, contributing to the nation’s ability to meet the ever-expanding demand for electricity.

Public and private contributions:

Both the public and private sectors have played pivotal roles in boosting power generation capacity. Currently, the public sector accounts for 45% of the total installed capacity, contributing 10,130 MW, while the private sector contributes 44%, amounting to 9978 MW (Bangladesh Power Development Board, 2022). This balanced collaboration between the public and private sectors has been instrumental in meeting the escalating electricity requirements of the nation. The Bangladesh Power Development Board (BPDB) installed 385 MW, including capacity contracted from independent power producers (IPPs), while the Ashuganj Power Station Company Limited (APSCL) installed the remaining 284 MW. The maximum peak generation was 14,782 MW, and total energy generated was 85,607 GWh, representing a 7.18% and 6.45% increase, respectively, over the previous year. To meet rising electricity demand, the government has launched an aggressive plan, with 34 power generation projects totaling 13,103 MW now under construction. The whole plan intends to add about 25,840 MW of additional generation capacity by 2027, showing the government’s commitment to fulfilling the country’s expanding energy needs as the economy grows.

Table 1. The annual report of Bangladesh power development board 2021–2022.

Year	2022 (MW)	2023 (MW)	2024 (MW)	2025 (MW)	2026 (MW)	2027 (MW)	Total (MW)
Public	901	1382	4438	843	2337	1210	11,111
Private	1226	2969	614	138	2335	782	8064
Total	2127	4351	5052	981	4672	1992	19,175

(Bangladesh Power Development Board, 2022)

4.2. Installed capacity of public-private sector in Bangladesh

Please see installed capacity of public/private sector in Bangladesh in **Table 1** (Bangladesh Power Development Board, 2022).

Bangladesh’s total installed capacity in the electricity industry was 22,482 MW, comprised of various sources. The public sector accounted for 10,130 MW, joint ventures for 1244 MW, independent power producers (IPPs) and small independent power producers (SIPPs) for 8556 MW, rental power plants for 424 MW, this generation capacity mix demonstrates the numerous sources that contribute to overall

power generation in Bangladesh, ensuring a steady and diverse energy supply to meet the country’s expanding electrical demand.

4.3. Power installed capacity by plant and fuel type in Bangladesh

Table 2. The annual report of Bangladesh power development board 2021–2022.

By type of plant		By type of fuel	
Hydro	230MW (1.02%)	Hydro	230 MW (1.02%)
Steam turbine	2968 MW (13.20%)	Gas	11,476 MW (51.05%)
Gas turbine	1502 MW (6.68%)	Fumace oil	6329 MW (28.15%)
Combined cycle	7963 MW (35.42%)	Diesel	1290 MW (5.74%)
Reciprocating engine	8430 MW (37.50%)	Coal	1768 MW (7.86%)
Solar PV (Photovoltaics)	229 MW (1.02%)	Solar PV	229 MW (1.02%)
Power import	1160 MW (5.16%)	Power import	1160 MW (5.16%)
Total	22,482 MW (100%)	Total	22,482 MW (100%)

(Bangladesh Power Development Board, 2022)

Please see the power installed capacity by plant and fuel type in Bangladesh in **Table 2** (Bangladesh Power Development Board, 2022).

Bangladesh’s governmental and private sectors have both built up their capacity for producing electricity over the years by utilizing a variety of fuels, including gas, HFO (Heavy Fuel Oil), HSD (High Speed Diesel), FO (Fuel Oil), diesel, and solar. From 255 MW in 2010 to 1349 MW in 2018, the public sector’s power generation capacity increased by more than five times. In 2010, the private sector lacked the ability to generate electricity utilizing gas, HFO, HSD, FO, diesel, and solar. The power generation capacity began in 2011 (520 MW) and peaked at 797 MW, which was greater than that of the public sector. Year-wise commissioning status of generation projects. Please see the power installed capacity by public/private sector and fuel type in Bangladesh in **Table 3** (Bangladesh Power Development Board, 2022).

Table 3. The annual report of Bangladesh power development board 2021–2022.

Year	Public sector	Type of fuel	Private sector	Type of fuel	Total capacity
2010	255 MW	Gas	520 MW	GAS/HFO/Diesel	775 MW
2011	800 MW	GAS/HFO	963 MW	GAS/HFO/Diesel	1763 MW
2012	607 MW	GAS/HFO/HSD	344 MW	GAS/HFO	951 MW
2013	587 MW	GAS/HSD	576 MW	GAS/Imp.	1163 MW
2014	68 MW	GAS/HSD	567 MW	GAS/HFO	635 MW
2015	560 MW	GAS/HFO	797 MW	GAS/HFO/HSD	1357 MW
2016	775 MW	GAS	370 MW	GAS/FO	1145 MW
2017	967 MW	GAS/HFO/HSD	220 MW	GAS/HFO/Solar	1337 MW
2018	1369 MW	GAS/HSD/Solar	914 MW	GAS/HFO/Solar/HSD/Im	2283 MW
2019	814 MW	GAS/HFO/Solar	1590 MW	GAS/HFO/Solar/HSD	2404 MW
2020	709 MW	GAS/HFO/Solar	438 MW	HFO/Solar/HSD	1147 MW
2021	749 MW	GAS/Imported coal	730 MW	GAS/HFO/Solar	1479 MW
2022	284 MW	GAS/Solar	230 MW	GAS/HFO/Solar	514 MW
Total	8544 MW	GAS	8259 MW	HFO	16,803 MW

(Bangladesh Power Development Board, 2022)

Bangladesh's power generation capacity is the result of involvement from the governmental and private sectors. The distribution shows that both sectors have contributed significantly and worked together to meet the nation's rising demand for power (Bangladesh Power Development Board, 2022).

4.4. Under processing public-private partnership power projects in Bangladesh

Bangladesh's 2016 Power System Master Plan (PSMP, 2016; Mawla and Khan, 2020) outlines a long-term power generation strategy. According to the plan, the required generation capacity is expected to reach 30,000 MW by 2030, while the estimated demand is 27,400 MW. Furthermore, generation capacity is estimated to reach 57,000 MW by 2041, with a need of 51,000 MW. In terms of energy sources, the plan suggests that around 35% of total generating capacity in 2041. The plan reflects the government's emphasis on diversifying energy in collaboration with the public-private partnership to meet rising demand and ensure a reliable and sustainable power supply for the country. Government plans to satisfy future electricity demand by strategically balancing the use of various energy sources, including coal and gas/LNG,

Table 4. The annual report of Bangladesh power development board 2021–2022.

PP power projects	Number of projects	Capacity MW
Under construction	19	5255
Under signing	20	2412
Under tendering	03	159

(Bangladesh Power Development Board, 2022)

Please see the under-processing public-private partnership power projects in Bangladesh in **Table 4** (Bangladesh Power Development Board, 2022).

Given present gas, oil, and coal supplies, as well as the advancement of renewable energy, nuclear power is preferred in national energy policy. The government has reached a deal with Russia to build two nuclear power units at the Rooppur site by 2021, with a capacity of 2000 MW which is considered a big international governmental partnership in the power sector between Bangladesh and Russia.

4.5. Shortage of electricity

As Bangladesh attained universal access to electricity in March 2022, decreasing gas reserves, combined with a rise in global LNG prices, caused the Bangladesh government to resort to power load-shedding. Bangladesh's prolonged power problem, caused by a gas shortage, is prompting the Bangladeshi industry to gradually shift to renewable energy sources such as solar power. Since July of 2023, power has been turned off for an hour or two every day, rotating between places around the country.

5. Results and analysis

5.1. Overview

The given information provides an overview of the background and importance of public-private partnerships (PPPs) in Bangladesh, particularly in the context of infrastructure development. The in-depth detailed explanation of the chosen data collection to be used in studying the PPPs in Bangladesh in this literature review including academic papers, reports, policy documents, and case studies related to PPPs in the power sector as it'd provide a foundation of knowledge and help identify gaps in understanding, research questions, and potential data sources, document analysis as analyzed relevant government policies, guidelines, legal frameworks, documents and publications from government agencies, regulatory bodies, and industry associations to gather information about the regulatory frameworks, financial models, and other stakeholder dynamics related to PPPs in the power sector help to give in a better, summarized understanding of the current issues and their situations, case studies because of collecting data through site visits, observations, interviews, and document analysis to understand the project's implementation, outcomes, and impacts, and lastly other collected data from secondary resources such as government databases, industry reports, and publicly available data on power sector performance, electricity consumption, infrastructure development, and financial aspects of PPP projects. All of it has given the proper analyzed results which are that—Bangladesh Power Development Board (BPDB). Tables have provided up-to-date information on power generation, consumption, and the sources used in Bangladesh such could be the fact of the country's daily power-generating capacity in July of 2022 was 12,000 MW, with a demand of roughly 14,000 MW per day. Gas production capacity, gas fields, and gas supply for power generation from Petro Bangla, the state-owned oil, gas, and mineral resources corporation of Bangladesh, as it gave further insights into the availability and utilization of natural gas for power generation such as natural gas, is the dominant source, accounting for 51.05% of the total, with furnace oil accounting for 28.15%, coal 7.86%, diesel 5.74%, solar and wind 1.02%, and hydro 1.02%. According to BPDB data, the remaining 5.16% is imported directly, and according to Petro Bangla, Bangladesh has a total gas production capacity of 3760 million cubic feet per day, sourced from 113 gas fields managed by the government and foreign businesses, as well as imports. However, these difficulties have originated from issues such as a high-risk premium, restricted bidder participation, irregularities, rent capture, lengthy decision-making processes, and low performance in independent power producer (IPP) projects. They must have also compared the electricity industry in Bangladesh with other countries to identify best practices, successful PPP models, and potential strategies for improvement. This would involve gathering data from international sources and studies, and numerous consultations with industry experts, government officials, and power sector professionals to gather qualitative insights and perspectives on the challenges and opportunities in the power sector, particularly related to PPPs because then they would provide valuable insights and expert opinions on the topic to provide a broader context for the analysis to understand the comparisons and the

effects it has been embedded with relationships to overcome market failures and funding issues. As said and understood already, to achieve long-term progress, it is critical to focus on and understand these major problems to figure out long-lasting and effective solutions for them.

5.2. System loss and reduction of power sector

The establishment of public-private partnerships (PPPs) in Bangladesh's power sector has contributed to a significant reduction in system loss. In the fiscal year 2018–2019, system loss was 11.96%, compared to 18.45% in the fiscal year 2007–2008, resulting in an annual savings of 3000 crore taka for the government. Various efforts have been performed in collaboration with business partners, including the installation of advanced metering infrastructure (AMI), prepaid intelligent meters, substations, power supply, switchgear, and underground cables. By June 2018, the Power Division of Bangladesh has installed 12.89 lakh prepaid meters, with the goal of achieving 100% bill payment and phasing out analog meters within five years. These initiatives are intended to improve utility collection and payment efficiency while minimizing losses in the power sector.

6. Policy recommendations

Public-private partnerships (PPPs) have the potential to significantly contribute to the development and sustainability of Bangladesh's power industry. PPPs can increase efficiency, attract investment, and improve service delivery by combining the strengths and resources of the public and private sectors. However, to fully realize the benefits of PPPs in the power sector, it is critical to overcome the problems and maximize the opportunities. This policy advice intends to emphasize key ideas and measures that can enhance effective PPP adoption in the Bangladesh power industry. Building regulatory capacity and institutional capacity the government should emphasize the following activities to build an enabling climate for PPPs.

6.1. Improve the regulatory environment

Create clear and comprehensive regulations and guidelines that meet the specific requirements and hazards involved with power-related PPP projects. Ensure procurement transparency, predictability, and fairness.

6.2. Improve institutional capacity

Create specialized PPP oversight units within relevant government agencies. These units should be staffed with skilled individuals capable of managing and monitoring PPP contracts, ensuring compliance, and resolving challenges.

6.3. Risk allocation and mitigation

PPPs contain a variety of hazards, including financial, operational, and political risks. To attract private sector engagement, it is critical to allocate and reduce these risks effectively. The following steps can be taken:

6.3.1. Evaluation of risks and communication

Conduct a full risk assessment for each PPP project and design risk-sharing procedures that balance the interests of both public and private participants.

6.3.2. Using guarantees and insurance

Investigate the use of government guarantees and insurance systems to reduce financial risks connected with public-private partnerships (PPPs). This can give private investors and lenders confidence, encouraging them to participate.

6.3.3. Transparency and competency of procurement process

A transparent and competitive procurement process should be used to assure fairness and attract high-quality private partners:

6.3.4. Make the bidding procedure more uniform

Create clear and standardized bidding procedures, including pre-qualification, evaluation, and selection criteria. This will increase openness and make evaluating rival proposals easier.

6.3.5. Increase competition

Allowing several bids and conducting open and competitive bidding processes will encourage competition. This will aid in the selection of the best and most qualified private partners for PPP projects.

6.3.6. Stakeholder engagement and public awareness

Proper interaction and stakeholder involvement are essential for gaining public support and addressing concerns about PPPs in the power sector. The government must:

6.3.7. Carry out public awareness campaigns

Inform the public of the advantages of public-private partnerships in the power industry, stressing enhanced service delivery, increased efficiency, and broader access to electricity.

6.3.8. Involve stakeholders

Encourage genuine dialogue and interaction with relevant stakeholders, such as local communities, civil society organizations, and consumer groups. This will help to resolve issues, create confidence, and ensure that PPP initiatives are aligned with people's needs and objectives.

6.3.9. Establish dedicated financing mechanisms for PPP projects

Create specialized financing mechanisms that cater specifically to PPP projects in the power sector. This can include setting up a dedicated infrastructure fund or leveraging public funds to provide guarantees or credit enhancements to attract private financing. By ensuring access to affordable and long-term financing, the implementation of PPP projects in the power sector can be expedited and financial constraints can be mitigated.

6.3.10. Promote technology transfer and knowledge sharing

Encourage the transfer of technology and knowledge between public and private entities in the power sector. Facilitate collaboration and information sharing through partnerships, joint ventures, and capacity-building initiatives. This will help

enhance technical expertise, promote innovation, and improve the overall efficiency and sustainability of power generation in Bangladesh.

6.3.11. Strengthen infrastructure for transmission and distribution

Focus on improving the infrastructure in Bangladesh for power transmission and distribution to minimize transmission losses and enhance efficiency. Implement PPP projects specifically targeting the upgrade and expansion of transmission and distribution networks. This will ensure a reliable and stable electricity supply to consumers and facilitate the growth of the power sector.

6.3.12. Invest in renewable energy sources

Encourage the development and utilization of renewable energy sources, such as solar, wind, and hydroelectric power, through PPP initiatives. Provide incentives and support mechanisms to attract private investment in renewable energy projects as it will help diversify the energy mix, reduce dependence on fossil fuels, and contribute to environmental sustainability.

6.3.13. Enhance capacity building and skills development

Invest in training programs and capacity-building initiatives to enhance the technical and managerial skills of stakeholders involved in the power sector. Collaborate with educational institutions, industry associations, and international partners to develop specialized training programs for PPP project management, renewable energy technologies, and regulatory frameworks. This will ensure a skilled workforce capable of effectively implementing and managing PPP projects.

6.3.14. Implement performance-based contracts

Introduce performance-based contracts in PPP agreements, where private sector partners are incentivized and rewarded based on their performance in meeting predefined targets and service quality standards. This approach encourages efficiency, accountability, and continuous improvement in power generation, transmission, and distribution.

7. Conclusions and future prospects

The research data provides valuable insights into the challenges faced in the implementation of public-private partnerships (PPPs) in Bangladesh's power sector. It highlights the potential benefits of PPPs, such as increased investment, improved operational efficiency, and enhanced service delivery through the collaboration of the public and private sectors. The data also identifies key factors that contribute to the success of PPPs, including the importance of a supportive legal and regulatory framework, effective risk-sharing mechanisms, stakeholder engagement, and robust project management practices. The entire study eventually suggests a promising future for PPPs in Bangladesh's power sector. To address the identified challenges and implement the recommended solutions, there is an opportunity to harness the full potential of PPPs in improving the country's power infrastructure. With a strong legislative framework, effective risk mitigation measures, transparent procurement processes, and active stakeholder participation, PPPs in the power sector of Bangladesh can facilitate increased investment, enhance operational efficiency, and improve service delivery. This, in turn, can contribute to the sustainable development

of the power sector and help achieve energy-related goals. Overall, even if it provides valuable insights, it is still important to acknowledge certain limitations. Firstly, the research has relied on existing studies, or specifically secondary research, and may not capture the most up-to-date developments in the field. Additionally, it mainly has given its focuses on the power sector of Bangladesh, so the findings may not be particularly applicable to other sectors or countries. Furthermore, the study primarily highlights challenges and potential solutions, but the actual implementation and effectiveness of these solutions require further empirical research. Finally, it doesn't delve into the specific economic, social, and environmental impacts of PPPs in the power sector, which would require more in-depth analysis. Public-private partnerships (PPPs) have enormous potential for tackling difficulties and creating opportunities in Bangladesh's power sector. PPPs can increase investment, improve operational efficiency, and improve service delivery by combining the strengths of the public and private sectors. PPPs implementation, on the other hand, necessitates a strong legislative framework, effective risk allocation and mitigation measures, transparent procurement processes, and active stakeholder participation.

The research conducted has successfully addressed the research questions and provided valuable insights into the challenges and potential benefits of public-private partnerships (PPPs) in Bangladesh's power sector. The study has shed light and has highlighted the potential benefits of PPPs, such as increased investment, improved operational efficiency, and enhanced service delivery through the collaboration of the public and private sectors, along with the data identifying key factors on the importance of a supportive legal and regulatory framework, effective risk-sharing mechanisms, stakeholder engagement, and robust project management practices for the success of PPPs in the power sector. The entire study eventually suggests a promising future for PPPs in Bangladesh's power sector. It has also highlighted the potential for increased investment, improved operational efficiency, and enhanced service delivery through collaboration between the public and private sectors. To implement the recommended solutions and address the identified challenges, there is an opportunity to harness the full potential of PPPs in improving the country's power infrastructure. To further research the identified questions in the future, empirical studies can be conducted to evaluate the implementation and effectiveness of the recommended solutions in real-world scenarios. This would provide a more comprehensive understanding of the impacts and outcomes of PPPs in the power sector, including their economic, social, and environmental implications.

To further research in the future, it is essential to take specific measures. Firstly, conducting primary research through surveys, and case studies will provide up-to-date and firsthand data on the challenges and benefits of public-private partnerships (PPPs) in Bangladesh's power sector. Additionally, comparative studies involving other sectors or countries will offer a broader perspective on the effectiveness and applicability of PPPs. To grasp the full implications, researchers should assess the economic, social, and environmental impacts of PPPs, requiring in-depth impact assessments and sustainability analyses. Longitudinal studies are also crucial to gauge the long-term effectiveness and sustainability of PPP projects. By analyzing both successful and failed PPP initiatives, valuable lessons can be learned to guide future projects. Engaging stakeholders, including government agencies, private

entities, communities, and experts, will provide diverse insights. Researchers can also analyze policies and regulatory frameworks to identify areas for improvement. Lastly, exploring the scalability and replicability of successful PPP models in various regions can facilitate the adoption of effective practices in different settings. By following these steps, researchers can enrich the understanding of PPPs in the power sector and contribute to more robust and sustainable energy solutions for Bangladesh.

7.1. Limitations of the study

There are several limitations to consider when assessing the provided recommendations for PPP projects in countries affected by political instability. These limitations include capacity and financial constraints, as materials or resources may not be readily available or affordable when needed. Additionally, there is complexity in allocating risk to appropriate parties, given the uncertain energy landscape. Furthermore, global economic uncertainty and market dynamics can significantly impact the investment capital and financing of power projects. However, it is important to acknowledge the limitations of the study. Research heavily relies on existing studies and secondary research, which may not capture the most up-to-date developments in the field. Additionally, the study's focus is primarily on the power sector of Bangladesh, limiting its generalizability to other sectors or countries. Further research should strive to incorporate primary data collection and encompass a broader range of sectors and geographical contexts. So, in conclusion, to create an enabling climate for power sector PPPs, the government should emphasize strengthening the regulatory framework, increasing institutional capacity, ensuring transparent and competitive procurement processes, and involving stakeholders. Continued research and evaluation of the impacts of PPPs in the power sector will help refine strategies and ensure that PPPs contribute to sustainable development and the achievement of energy-related goals in Bangladesh. In the future, further research on the topic of meeting the growing electrical demand of Bangladesh and ensuring a consistent supply of renewable energy through public-private partnerships (PPPs) can explore several key areas to deepen understanding and develop more effective strategies.

7.2. Conclusion

Despite the limitations, the study on public-private partnerships (PPPs) in the power sector of Bangladesh has shed valuable light on the immense potential of these collaborative ventures. The findings highlight the positive impact of PPPs, including increased investment, improved operational efficiency, and enhanced service delivery through the collaboration of public and private sectors. With the right legislative framework, effective risk mitigation measures, transparent procurement processes, and active stakeholder participation, a strong legislative framework involves enacting and enforcing laws and regulations that govern the sector comprehensively, so the recommendations would include comprehensive energy laws that cover all aspects of the power sector, including generation, transmission, distribution, and renewable energy integration, regulatory authority strengthening like the Bangladesh Energy Regulatory Commission (BERC) with

clear mandates and adequate resources to ensure effective oversight and regulation of the sector, investor protection for public and private sector. PPPs can pave the way for sustainable development and contribute significantly to achieving energy-related goals. As further research explores the subject, building upon these insights can lead to transformative advancements in the power sector and propel Bangladesh towards a more prosperous energy in future.

In recent years, public-private partnership (PPP) models have undeniably played a pivotal role in shaping and sustaining the power sector in Bangladesh. These models have ushered in efficiency, consistency, and continuous improvement, demonstrating their significance. While critics have validly raised concerns, particularly related to transparency and accountability, it is essential to acknowledge the multifaceted impact these partnerships have had on the nation's energy landscape.

One of the most notable achievements has been the substantial expansion of Bangladesh's power generation capacity. This expansion has not only increased energy availability but has also significantly improved the quality and reliability of electricity supply. Consequently, these developments have played a vital role in fostering economic growth and overall development in the country.

Throughout our extensive research journey, we encountered challenges related to the authenticity and reliability of online resources. In an era where misinformation and malpractices are prevalent, distinguishing genuine and credible information became a significant endeavor. Additionally, gathering specific and pertinent data tailored to the unique requirements of each sector posed difficulties. However, through meticulous research methodologies, data evaluation, and the application of defined criteria, the researchers were able to navigate these challenges successfully.

It is crucial to view transparency and accountability concerns in the broader context of the substantial benefits that PPPs have brought to Bangladesh. These partnerships have been instrumental in addressing the nation's energy demands and have played a pivotal role in fostering economic development. Embracing ongoing reforms, learning from past experiences, and maintaining a commitment to genuine and accurate information will be instrumental in ensuring that Bangladesh continues to harness the potential of PPPs effectively. As the nation seeks to strike the right balance between public and private interests, the future of its power sector holds promise, driven by the lessons learned and the dedication to sustainable growth.

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