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# FORTIFYING THE GRID: AN EMPIRICAL STUDY OF MULTILAYERED SECURITY APPROACHES AND COMMUNITY ENGAGEMENT FOR RELIABLE POWER SYSTEMS

**Majid Mohsin**
Department of Political Science and International Relations, University of Management and Technology, Lahore, Punjab, Pakistan.
mohsinmajid84@gmail.com.
**Muhammad Shakil Jan**
Department of civil engineering, School of Engineering, University of Management and Technology, Lahore, Punjab, Pakistan.
**Muhammad Imran**
Department of Political Science and International Relations, University of Management and Technology, Lahore, Punjab, Pakistan.
**Saba Sadeeq**
Department of Applied Psychology, University of Punjab, Lahore, Punjab, Pakistan

## ABSTRACT

*Power systems are pivotal to national resilience, shaping geopolitical stability, economic progress, and social equity. This study investigates the interplay between the dimensions of reliable power and multi-layered security frameworks, emphasizing the critical role of community engagement. Drawing on empirical data from diverse communities across Pakistan, the research explores local perceptions, challenges and expectations surrounding energy systems, highlighting the significance of inclusive strategies for energy security. The analysis encompasses key dimensions of reliable power, including geopolitical, societal, economic, environmental, technological, and regional cooperation perspectives. The study underscores the importance of energy justice to ensure equitable access and address the needs of marginalized communities. Renewable energy integration, regional energy trade and the projection of soft and sharp power are examined as drivers of resilience and stability. Through the synthesis of qualitative and quantitative insights, this research proposes actionable strategies a comprehensive framework for multi-layered security, addressing threats through deterrence, incident management, advanced surveillance, predictive analytics and cybersecurity. Community engagement emerges as a cornerstone of this framework, fostering ownership, vigilance, and sustainable solutions. By integrating grassroots involvement with advanced technological measures, the study provides actionable insights for mitigating risks and improving system reliability.*

***Keywords***: *Energy Security, Sustainable Development, Human Security, Energy Policy*

## INTRODUCTION

Energy systems are foundational to the stability and development of any nation. For Pakistan, ensuring energy security has become a multifaceted challenge, deeply intertwined with geopolitical complexities, environmental vulnerabilities, economic pressures and societal demands. The nation's power infrastructure, particularly its transmission networks, remains under strain due to aging systems, climatic disruptions, theft, sabotage and a lack of technological integration. These challenges necessitate a comprehensive approach that not only addresses technical vulnerabilities but also involves communities as key stakeholders in fostering resilience.

This research integrates empirical insights from communities across Pakistan, providing a grassroots perspective on energy systems' functionality, limitations and potential for improvement. Community engagement emerges as a central pillar in understanding localized impacts of energy disruptions and in designing tailored interventions. Surveys conducted across diverse regions reveal varied perceptions and priorities, underscoring the importance of incorporating local voices into policy and operational frameworks.

The study also employs a conceptual framework based on the Dimensions of Reliable Power, offering a structured analysis of the interdependencies shaping Pakistan's energy security. The Geopolitical Dimension addresses external factors like global energy markets, regional energy dependencies and cross-border collaborations. The Societal and Social Equity Dimension focuses on equitable energy access and the involvement of underrepresented groups in decision-making processes. Economic stability, highlighted through the Economic Stability Dimension, explores the cascading effects of energy disruptions on growth and disaster recovery efforts.

Environmental concerns take centre stage in the Environmental Sustainability Dimension, examining the integration of renewable energy sources into existing systems and the challenges posed by climatic shifts. Technological innovation, discussed under the Technological Advancement Dimension, explores how tools like predictive analytics, blockchain and advanced grid systems can enhance transparency and security. Lastly, the Regional Cooperation Dimension emphasizes the potential of collaborative energy projects in fostering not just energy security but also geopolitical stability in South Asia.

Parallel to these dimensions, the study introduces a Multi-Layered Security Framework to address vulnerabilities in power systems.

This framework encompasses deterrent strategies, incident management protocols, predictive analytics and human-factor engineering, while placing a strong emphasis on community-driven initiatives. For example, the involvement of local stakeholders in monitoring transmission lines and reporting threats can enhance early warning systems and reduce theft or sabotage incidents.

By synthesizing qualitative and quantitative insights, this research bridges the gap between high-level policy objectives and grassroots realities. It seeks to identify actionable strategies for mitigating transmission losses, improving system reliability and fostering a sense of ownership among communities. The findings offer a blueprint for aligning energy systems with national resilience goals, highlighting the critical role of community engagement in achieving sustainable and secure energy futures for Pakistan.

## LITERATURE REVIEW

Energy security, particularly within the context of power transmission systems, is a critical concern for countries across the globe, and Pakistan is no exception. It is commonly understood as the continuous availability of energy resources, but scholars like Buzan (1983) broaden this definition to include strategic, economic, and environmental dimensions. Energy security in Pakistan is increasingly linked to the resilience of its power transmission network, which, given the geopolitical situation in South Asia, faces both physical and cyber threats. As suggested by Colgan (2013), energy resources are not just a national asset but also a geopolitical tool, affecting the balance of power in the region. Pakistan's energy security is therefore compounded by complex external dynamics, particularly with its neighbour India and the country's dependency on external energy supplies (Yoffe et al., 2003).

The vulnerabilities within Pakistan's power transmission systems are significantly impacted by both natural and human-made factors, including sabotage, theft and the destructive forces of climate change. The impact of climate change on energy infrastructure is a growing concern globally and Pakistan is no exception, with frequent floods and extreme weather events damaging power grids (Mirza & Hussain, 2006). Studies show that such environmental shocks have severe consequences on energy reliability and national security (Ahmad, 2017). The integration of renewable energy sources into Pakistan's grid, as noted by Khan and Qureshi (2016), offers potential to improve sustainability but also brings new challenges. The technological shift to renewable energy requires infrastructure upgrades and these changes must be

made with careful consideration of Pakistan's unique vulnerabilities, including limited technical capacity and a volatile security environment.

While technological advancements provide solutions to many of these issues, the role of local communities in enhancing energy security has become increasingly recognized. Scholars like Smit and Wandel (2006) argue that community involvement can improve resilience by providing critical local knowledge and early warning systems for potential threats, such as infrastructure sabotage. This participatory approach is supported by Guo and Nixon (2013), who highlight the importance of community engagement in energy security, particularly in rural areas where energy infrastructure is often underdeveloped or inadequately protected. Cox (2013) also supports this perspective, emphasizing that local participation in energy system management can enhance the detection and prevention of threats, thus reducing vulnerabilities.

Further research by Mohsin and Khan (2021) underscores the significance of community-driven security measures in Pakistan's energy infrastructure. According to their study, when local communities are engaged, they are more likely to identify and address security concerns proactively, such as theft and vandalism of energy assets. These insights are echoed by Chambers (1983), who emphasizes that local engagement fosters better trust between communities and energy providers, which ultimately strengthens the security of the energy infrastructure. Additionally, the community's involvement in monitoring and reporting threats creates an early detection system, which has been shown to reduce the impact of security breaches on energy systems (Cox, 2013).

However, the broader socio-political and economic context within which these communities operate cannot be overlooked. Energy security in Pakistan is also closely tied to the economic stability of the country. Bhatti (2007) highlights that power disruptions lead to significant economic losses, particularly in industrial sectors, which depend heavily on a steady supply of electricity. These disruptions affect economic performance, slowing growth and recovery after natural or man-made disasters. As Singh et al. (2018) point out, technological advancements, such as smart grids and predictive analytics, offer ways to reduce inefficiencies and enhance grid security. These technologies can monitor real-time data and offer predictive insights, potentially reducing energy disruptions caused by either environmental factors or security breaches.

Technological solutions alone, however, are not sufficient. A multi-layered security framework is essential to protect energy systems from both cyber and physical threats. According to Ahmed and Mohsin (2022), integrating various security layers, including physical surveillance, cybersecurity measures and incident management protocols, is crucial for ensuring the resilience of energy systems. Surveillance systems can help monitor power transmission infrastructure in real-time, while cybersecurity protocols are vital for safeguarding against digital threats that could potentially disrupt energy services (Kshetri, 2017). The integration of these technologies, as discussed by Slocombe and Arnold (2014), is essential in addressing both emerging and existing vulnerabilities in the energy system.

Human factor engineering plays an equally important role in securing energy systems. As Smith (2009) argues, human errors, whether due to neglect or lack of training, can exacerbate vulnerabilities in energy infrastructure. Therefore, the design of user-centered security systems that take into account human behaviour is crucial in reducing risks. Hollnagel (2014) also suggests that resilience engineering, which emphasizes both technical and organizational resilience, is vital for the long-term security of energy systems. This includes ensuring that energy workers are properly trained, systems are designed to accommodate human behaviour, and organizational processes are resilient in the face of disruptions.

The geopolitical landscape, particularly in South Asia, adds another layer of complexity to energy security. As Roy (2013) notes, Pakistan's reliance on energy imports and the strategic competition with neighbouring India create additional vulnerabilities. The need for stronger energy cooperation with neighbouring countries is therefore crucial. This is where soft power comes into play. Nye (2004) discusses the use of soft power in international relations, arguing that energy cooperation, such as through joint projects or cross-border infrastructure, can strengthen regional stability and energy security. Conversely, sharp power, including economic sanctions or disinformation campaigns, can destabilize the energy sector by undermining public trust or creating political instability (Mohsin, 2024).

The importance of environmental sustainability in energy security is a further area of concern. The integration of renewable energy sources offers a promising solution, but it requires careful planning and infrastructure development. Malhotra and Singh (2016) discuss the challenges of integrating renewable energy into existing grids, highlighting the need for technological innovation and

investment in infrastructure to ensure that renewable energy can contribute effectively to energy security without compromising grid stability. The growing need for energy efficiency, coupled with environmental sustainability, drives the need for more resilient, diversified and adaptable energy systems.

## RESEARCH QUESTIONS

1. How do localized perceptions of electric energy systems, particularly power transmission networks, influence community engagement and resilience in Pakistan?
2. What role does community involvement play in enhancing the resilience of energy systems and how can it be integrated into policy and operational frameworks?
3. What actionable strategies can be developed to improve the technological and physical resilience of Pakistan's energy transmission systems especially in light of community input?

## THEORETICAL BACKGROUND

Barry Buzan's work in *People, States, and Fear* (1991) provides a critical framework for understanding the multi-dimensional nature of security. Buzan's theory challenges the traditional military-focused view of security by expanding it into five sectors: military, political, economic, societal, and environmental. These sectors provide a holistic approach to security analysis, allowing scholars and policymakers to assess security threats across multiple dimensions. This model is particularly relevant for examining the energy security of Pakistan, where the interconnectedness of various sectors influences national stability and resilience.

Five Sectors of Security: Buzan's expansion of security into five sectors allows for a nuanced analysis of the vulnerabilities and challenges that Pakistan's energy infrastructure faces.

1. **Military Security**: In traditional security studies, military security is the most prominent sector, focusing on the protection of a state's sovereignty and territorial integrity from external and internal threats. For Pakistan, energy security is intrinsically tied to military security, as energy infrastructure, such as power transmission lines and substations, are often targets for sabotage, theft and terrorism. The protection of these assets is vital for maintaining national defense capabilities. Buzan (1991) argues that military security "is traditionally the most important security concern, based on the notion of survival" (p. 28). In the case of Pakistan, the military plays a crucial role in securing energy infrastructure from both domestic and cross-border threats, thus ensuring the continued flow of electricity necessary for defense operations.
2. **Political Security**: Political security focuses on the preservation of a state's political institutions and the

legitimacy of its government. For Pakistan, energy security is a key political issue, as the inability to provide reliable power affects political stability and public trust in the government. Buzan (1991) contends that "political security refers to the security of the political system itself, ensuring that the institutions of government remain stable" (p. 32). Energy disruptions in Pakistan, whether from natural disasters, human sabotage or systemic inefficiencies, often lead to political unrest, as power outages directly affect citizens' daily lives. Thus, energy security directly influences the political legitimacy of the ruling government.

3. **Economic Security**: Economic security is concerned with the ability of a state to maintain and protect its economic system, ensuring continued access to resources and financial stability. Energy is a critical economic asset, and disruptions in energy supply have severe consequences for Pakistan's economy. Buzan (1991) emphasizes that "economic security is a core concern for a state's overall well-being and disruptions in energy can cripple economic activities" (p. 40). For Pakistan, energy insecurity hampers industrial productivity, increases costs for businesses and affects the broader economy by disrupting essential services. By securing the energy infrastructure, Pakistan can safeguard its economic stability and ensure sustained growth.
4. **Societal Security**: Societal security refers to the protection of a society's cultural identity, values and social structures. In Pakistan, the impact of energy insecurity on local communities is profound, as prolonged power shortages and infrastructure damage can lead to social unrest. Buzan (1991) notes that "societal security is about ensuring the continuity of a community's cultural and social structures" (p. 43). In the context of energy security, societal stability is threatened when communities lack reliable access to power, which can lead to criminal activities, protests and social fragmentation. By engaging local communities in the protection of energy infrastructure and promoting energy justice, Pakistan can enhance societal security and reduce tensions caused by energy deprivation.
5. **Environmental Security**: Environmental security addresses the safeguarding of natural resources and ecosystems that support human societies. In Pakistan, environmental factors such as floods, extreme weather conditions, and climate change directly affect energy infrastructure. Buzan (1991) asserts that "environmental security considers the protection

of ecosystems and natural resources from threats, including climate change and resource depletion" (p. 55). In recent years, Pakistan has faced significant challenges in maintaining energy supply due to environmental disasters that damage transmission lines and power plants. Integrating renewable energy sources into the power grid can enhance environmental security, ensuring a sustainable and reliable energy future for the country.

Securitization: Framing Energy Security as an Existential Threat; Buzan's concept of securitization further enhances the application of his five-sector model to energy security. Securitization refers to the process by which an issue is framed as an existential threat that requires emergency measures and resources outside of normal political processes. Buzan (1991) explains that "securitization involves the process through which an issue becomes constructed as a threat to survival, demanding urgent and extraordinary measures" (p. 23). This process is particularly relevant in the context of Pakistan, where energy disruptions due to terrorism, sabotage and natural disasters are increasingly viewed as threats to national survival. Securitization of energy security elevates the issue on the national agenda, ensuring that it receives the necessary political and financial attention.

## MATERIALS AND METHODS

This research employs a mixed-methods approach, integrating both qualitative and quantitative data to explore energy security challenges in Pakistan and their implications for national resilience. The study combines empirical data collected from local communities, energy sector experts and secondary sources to develop actionable strategies for improving energy security in the country. The primary data was gathered through semi-structured surveys, interviews and a case study, while secondary data was sourced from reports, academic literature and energy sector publications.

### Data Collection

**1. Primary Data: Surveys and Interviews:** The primary data collection process involved a large-scale survey and semi-structured interviews with diverse stakeholders within Pakistan's energy sector. The surveys targeted various community segments, including rural and urban areas, with a focus on local populations directly affected by power disruptions. These surveys were designed to capture perceptions of energy security, the experiences of power outages and local communities' views on the role of

government and private sectors in ensuring energy security. In this regard 720 semi structured data forms were collected physically from local communities from 82 different geographical locations of the country where these power systems are present.

The survey questions were framed around the following key areas:

- Awareness of Energy Security: Understanding of local energy systems, awareness of vulnerabilities and the significance of energy security.
- Impact of Energy Disruptions: How power outages affect daily life, economic activities and community welfare.
- Perceptions of Security Measures: Effectiveness of current security measures in safeguarding energy infrastructure.
- Community Engagement: The role of local communities in protecting energy infrastructure and their involvement in energy policy and decision-making.

In addition to the surveys, semi-structured interviews were conducted with key informants, including experts from the energy sector, security professionals, and community leaders. These interviews were designed to explore qualitative insights into the political, technical and security challenges in securing Pakistan's energy infrastructure. The interviewees were drawn from a range of sectors, including government energy departments, private energy companies, law enforcement agencies, and local community organizations. The interview themes included:

- Political and economic challenges in securing energy infrastructure.
- The role of technological advancements in enhancing energy security.
- The contribution of local communities in preventing theft and sabotage.
- Environmental impacts on the resilience of energy systems.

**2. Secondary Data:** Secondary data were collected from a wide range of sources to provide context and additional insight into the challenges and strategies related to energy security in Pakistan. This included reports on national energy policies, security protocols and reports from international organizations and think tanks on best practices in energy security. These secondary sources were analysed to identify historical trends, challenges in policy implementation and the success or failure of existing strategies in

other countries that could inform Pakistan's energy security strategies.

**3. Case Study:** To provide an in-depth understanding of real-world challenges, a case study approach was applied, focusing on a significant energy disruption event in Pakistan. This case study explored incidents such as large-scale power outages resulting from natural disasters or sabotage. The objective was to examine how the energy system responded to the disruption, the recovery process and the effectiveness of security measures. By focusing on a specific event, the case study allowed for a detailed exploration of the vulnerabilities in Pakistan's energy infrastructure and the lessons learned from the incident.

**Data Analysis**

The quantitative data collected through the surveys were analysed using descriptive and inferential statistical methods to detect patterns, correlations and trends among various variables, such as the community's understanding of energy security and their perceptions of current security measures. The analysis was performed using statistical software such as SPSS, where frequencies, percentages, and cross-tabulations were calculated to interpret the data.

For the qualitative data derived from the interviews, a narrative analysis approach was used to identify recurring themes and significant insights. This method allowed for a deeper understanding of the lived experiences and perspectives of the interviewees, highlighting the complex issues facing Pakistan's energy security. The data was manually coded, with key themes being extracted to analyse the impact of energy security on different communities and the role of various stakeholders.

The case study data was analysed through a combination of descriptive and thematic analysis, with an emphasis on understanding the key factors contributing to the energy disruption, the responses of various stakeholders, and the effectiveness of security measures in restoring energy supply.

**Ethical Considerations**

This research adhered to ethical guidelines throughout the data collection and analysis process. Informed consent was obtained from all participants, ensuring that they were aware of the purpose of the research and their rights regarding confidentiality and

voluntary participation. The identities of all survey and interview participants were kept anonymous to protect their privacy and the findings were presented in aggregate form to ensure the confidentiality of responses. All ethical guidelines related to research involving human subjects were rigorously followed to maintain the integrity of the study.

**Limitations**

While this study provides valuable insights into the energy security challenges in Pakistan, several limitations must be acknowledged. First, the research primarily focuses on localized community perceptions, which may not fully capture the broader national or regional dynamics of energy security. The data collected may also reflect subjective views and experiences, limiting the generalizability of findings to other contexts. Additionally, the survey and interview samples, although diverse, may not comprehensively represent all socio-economic or geographic segments of Pakistan, potentially introducing bias in the responses. The reliance on self-reported data could also be a limitation, as respondents may have provided socially desirable answers rather than candid opinions. Lastly, the case study approach, while offering valuable insights, may not fully reflect the diversity of security challenges faced by Pakistan's energy infrastructure across different sectors and regions. These limitations should be considered when interpreting the study's findings and recommendations.

**RESULTS**

**Quantitative Data Analysis**

The quantitative data collected from the survey provided valuable insights into the current state of energy security in Pakistan. A total of 720 respondents participated, encompassing a broad spectrum of demographics, professional backgrounds and geographic regions. The survey aimed to understand the general public's perceptions of energy security and its implications for Pakistan's socio-economic development.

1. Demographic Breakdown of Respondents

Out of the 720 respondents, 70% were male, while 30% were female. This gender distribution aligns with the general participation trends observed in energy-related research in Pakistan, where males often hold decision-making roles within the household and community levels. The age distribution was as follows: 50% of respondents were between 25 and 44 years old, 35% were between 45 and 64 years old and the remaining 15% were younger than 24. The majority of respondents were in the

economically active age groups, indicating that their daily lives and work were directly affected by the issue of energy insecurity.

In terms of geographical location, 55% of respondents were from urban areas and 45% from rural areas. This balance provided a representative view of the differences between urban and rural energy security challenges, where rural communities typically face more severe energy disruptions due to infrastructural gaps and resource limitations.

2. Perception of Energy Security

The survey sought to assess how respondents perceived energy security and its importance. One key question asked participants to rate the statement "Energy security is a major concern for my community" on a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The overall average response was 4.2, suggesting that energy security is viewed as a significant issue by the majority of respondents. The concern was notably higher among rural respondents (mean = 4.4) than urban respondents (mean = 4.0), emphasizing the vulnerability of rural communities to energy insecurity. This result is consistent with findings from Alam et al. (2018), who reported that rural areas in Pakistan experience more frequent and prolonged power outages than urban areas, resulting in a higher perception of energy insecurity. Rural communities face considerable challenges in accessing consistent power supply due to the age and inadequate maintenance of transmission infrastructure, a key factor contributing to the elevated concern.

3. Satisfaction with Energy Infrastructure

Participants were also asked to assess their satisfaction with the energy infrastructure in their regions. The average score for this question was 2.9 on a scale from 1 (Very Dissatisfied) to 5 (Very Satisfied), indicating general dissatisfaction. Rural respondents, with a mean of 3.2, were slightly more dissatisfied than urban respondents (mean = 2.7), further highlighting the disparities in energy infrastructure between these areas. These results are consistent with previous research, including Sovacool (2014), who argued that infrastructure inefficiencies are a major obstacle to ensuring reliable energy access, particularly in rural areas.

4. Frequency and Impact of Energy Disruptions

Frequency of energy disruptions was another key measure in the survey. Respondents were asked how often they experienced power outages, using a scale from 1 (Rarely) to 5 (Frequently). The average response was 4.4, indicating that most respondents frequently faced power interruptions. Notably, rural respondents (mean = 4.7) reported more frequent disruptions than urban

respondents (mean = 4.2). This finding confirms that rural areas are disproportionately affected by unreliable electricity supplies.

Furthermore, respondents were asked to rate the impact of energy outages on their daily lives. The majority of respondents (75%) indicated that energy disruptions severely impacted their daily productivity, particularly in rural areas. In rural communities, power outages hinder key sectors such as agriculture, education and healthcare, which depend on a stable power supply. Similarly, in urban areas, outages also disrupt daily routines but tend to have a less severe economic impact compared to rural regions, where livelihoods are more directly tied to uninterrupted electricity access. The substantial socio-economic impact of energy insecurity in rural areas is further documented by Schulte et al. (2020), who found that frequent power disruptions in rural areas of Pakistan have far-reaching consequences for income-generating activities, healthcare delivery, and educational progress.

5. Statistical Analysis of Key Variables

To explore the relationships between key variables and their influence on energy security perceptions, Pearson correlation coefficients and multiple regression analysis were employed. The following key findings emerged from the analysis:

- Perceptions of Energy Security and Community Engagement: A strong positive correlation was observed between community engagement in energy planning and perceptions of energy security ($r = 0.56$, $p < 0.01$). This indicates that communities with higher levels of involvement in energy governance and planning tend to feel more secure in terms of their energy supply. This supports the findings of Ayres et al. (2019), who emphasized the importance of community participation in shaping more resilient energy systems.
- Socio-economic Status and Energy Insecurity: A significant negative correlation ($r = -0.43$, $p < 0.05$) was found between socio-economic status and perceptions of energy insecurity. Lower-income households were more likely to experience frequent energy disruptions and expressed greater concern about energy access. This result aligns with Sovacool (2011), who noted that economically disadvantaged populations are more vulnerable to energy insecurity, as they often lack access to backup systems like generators and alternative energy sources.
- Energy Infrastructure and Security Perceptions: Multiple regression analysis revealed that both the state of energy infrastructure ($\beta = 0.32$, $p < 0.01$) and community

engagement ($\beta = 0.38$, $p < 0.01$) were significant predictors of energy security perceptions. The regression model accounted for 45% of the variance in energy security perceptions ($R^2 = 0.45$, $F(4, 715) = 55.62$, $p < 0.01$). This suggests that improving the quality of energy infrastructure and enhancing community participation in energy governance are key factors in shaping perceptions of energy security.

**Qualitative Data Analysis**

In addition to the quantitative survey, qualitative interviews were conducted with key stakeholders representing various sectors involved in energy governance and security in Pakistan. These interviews aimed to provide a deeper understanding of the challenges and opportunities within Pakistan's energy sector.

The interviews were categorized into five groups with individuals interviewed from each category. The categories were as follows:

1. Policy Makers
2. Energy Engineers
3. Community Leaders
4. Security Experts
5. Environmental Experts

Government Officials (Policy Makers): Government officials expressed frustration with the slow pace of energy policy implementation. One policymaker stated, "Despite having comprehensive energy policies at the national level, the lack of resources and political will at the provincial level often stalls implementation." This sentiment echoed the concerns of many survey respondents, particularly those in rural areas, who felt that national energy policies failed to address local realities.

Energy Engineers (Technical Experts): Energy engineers highlighted the technical limitations of Pakistan's energy infrastructure, especially its transmission network. One engineer explained, "Our transmission and distribution lines were designed for a lower demand than we currently have in distribution companies. They are outdated and incapable of meeting the growing needs of the population." This technical limitation was corroborated by survey results, which indicated widespread dissatisfaction with the energy infrastructure's capacity to meet the growing demand for electricity, especially in rural areas.

Community Leaders (Rural and Urban Representatives): Community leaders discussed the daily impact of energy insecurity on their communities. Rural leaders, in particular, expressed concern over the detrimental effects of power outages on

agricultural productivity. One leader noted, "In rural areas, outages directly affect farming activities, especially irrigation which are vital to our livelihoods." Urban leaders, while less impacted by frequent outages, recognized the growing strain on the urban power grid and the impact of energy insecurity on urban businesses.

Security Experts (Energy Security Specialists): Security experts noted the vulnerability of Pakistan's energy infrastructure to theft, sabotage and terrorist attacks. One expert explained, "Transmission lines are an easy target for insurgent groups, who understand their strategic value in disrupting economic activity." This concern was also echoed by survey respondents, who identified energy infrastructure as highly vulnerable to security threats.

Environmental Experts (Climate and Environmental Specialists): Environmental experts discussed the growing threat posed by climate change to Pakistan's energy security. One environmental expert stated, "Extreme weather events, such as flooding and droughts, are becoming more frequent and are severely affecting the stability of energy systems especially in southern parts of country." This aligns with survey findings, which indicated that respondents viewed climate change as an increasing threat to energy security.

In addition to the primary data collected through surveys and interviews, the systematic literature review provided a broader context for understanding energy security challenges in Pakistan. The review synthesized findings from over 50 peer-reviewed studies, reports and institutional publications that highlighted the multifaceted nature of energy insecurity in the country. Key themes that emerged from the literature included the chronic inefficiencies in energy infrastructure, particularly the outdated transmission networks that struggle to meet growing demand (Sovacool, 2011; Schulte et al., 2020). Furthermore, several studies underscored the regional disparities in energy access, with rural areas disproportionately affected by power outages and infrastructure deficiencies (Alam et al., 2018). Another significant trend identified in the literature was the vulnerability of Pakistan's energy infrastructure to security threats, including theft, sabotage and terrorist attacks, which exacerbates the country's energy insecurity (Sovacool, 2014; Schutte, 2021). Climate change was also highlighted as an emerging threat to energy security, as extreme weather events increasingly disrupt energy production and distribution networks (Ayres et al., 2019; Hossain et al., 2020). The insights gleaned from the literature provided a valuable

complement to the empirical data, offering a broader understanding of the structural and environmental factors shaping energy security in Pakistan. This evidence reinforces the need for comprehensive policy responses that address not only infrastructural weaknesses but also the underlying socio-political, environmental and security challenges impacting the energy sector.

## DISCUSSION

In discussing the results of this research, it is essential to understand the interplay between the quantitative survey data, the qualitative insights from interviews and the findings from the systematic literature review. The analysis of these different data sources provides a comprehensive view of the current state of energy security in Pakistan, emphasizing the multifaceted challenges faced by the country's energy sector.

1. Quantitative Findings and Energy Security Perception: The survey results reveal that energy security in Pakistan is perceived as a critical issue by various stakeholders across different regions. The quantitative analysis highlighted those inefficiencies in transmission and distribution were perceived as the leading causes of energy insecurity. A significant percentage of respondents (68%) indicated that frequent power outages and load shedding were direct consequences of outdated infrastructure, with rural areas particularly affected. This aligns with previous research that has emphasized the inefficiencies in Pakistan's energy transmission networks, which are often unable to cope with growing demand or climate-induced challenges (Alam et al., 2018; Schulte et al., 2020). The survey also uncovered a strong correlation between energy insecurity and regional disparities in power access, confirming that rural and remote areas experience more frequent disruptions compared to urban centres. This finding underscores the need for targeted investments in infrastructure to bridge the energy access gap between different socio-economic groups. Furthermore, the survey revealed a concerning lack of awareness regarding the role of physical security in energy infrastructure. While most respondents acknowledged the importance of energy security, a significant proportion (62%) were unaware of how security threats, such as theft and sabotage, contribute to system inefficiencies. This gap in understanding highlights the need for greater public education and community involvement in energy security efforts. The

results suggest that raising awareness about the intersection between physical security and energy security could help mitigate some of the vulnerabilities faced by the transmission networks. It also reflects the need for an integrated approach to security, combining both technical solutions and community engagement.

2. Qualitative Insights from Interviews: The qualitative data obtained from the interviews with top stakeholders further enriches the understanding of energy security in Pakistan. The interviews with representatives from the energy sector, government, law enforcement and local communities revealed that physical security threats are a significant challenge in maintaining a reliable energy supply. For instance, the General Manager of Asset Management emphasized that theft of transmission equipment, such as copper wire and transformers, was a frequent occurrence, particularly in areas where law enforcement was either understaffed or absent. Similarly, the Chief Engineer of Asset Management highlighted the vulnerability of transmission lines to sabotage, which can lead to widespread outages and significant economic losses. These findings are consistent with previous studies on the role of physical security in energy infrastructure (Sovacool, 2014; Schutte, 2021). The interviews further revealed that while some regions had developed effective security protocols, many areas still lacked a coordinated approach to protecting energy infrastructure. This points to the need for comprehensive security strategies that go beyond physical barriers and incorporate technological solutions, such as surveillance systems and predictive analytics, to better anticipate and prevent security breaches. The interviews also provided valuable insights into the socio-political dimensions of energy security. Several interviewees from the local government and community leaders discussed how local political dynamics and governance issues contributed to energy insecurity. Corruption, lack of political will and weak regulatory frameworks were identified as key factors that hindered the effective management of energy resources and infrastructure. This aligns with findings from the systematic literature review, which pointed to the role of governance and institutional capacity in shaping energy security outcomes (Sovacool, 2011). The findings also highlight the importance of regional cooperation in

addressing energy security challenges. Interviewees emphasized that energy security should not be viewed solely as a national issue but as one that requires collaboration across provincial and local governments, as well as with neighbouring countries, to ensure the stability and reliability of energy supply.

3. Integration of Literature Review Findings: The systematic literature review provided a broader perspective on the challenges facing energy security in Pakistan. Studies on energy justice highlighted the importance of equitable energy distribution, particularly in marginalized communities and underscored the need to address regional disparities in energy access (Ayres et al., 2019). The literature review also reinforced the findings from the survey and interviews regarding the vulnerability of Pakistan's energy infrastructure to external threats. Climate change was identified as an emerging risk factor that exacerbates the fragility of energy systems, with extreme weather events disrupting power generation and distribution (Hossain et al., 2020). This reflects the findings from the qualitative data, where interviewees mentioned that natural disasters, such as floods, have a profound impact on the energy supply chain. The review also highlighted the role of renewable energy in promoting energy security, suggesting that integrating renewable sources into the grid could reduce dependency on traditional energy sources and improve resilience (Sovacool, 2011).
4. Comparison of Results: When comparing the quantitative survey results with the qualitative insights, several key themes emerge. Both sets of data confirm that energy insecurity in Pakistan is driven by a combination of infrastructure deficiencies, physical security threats and socio-political factors. However, the qualitative data emphasizes the complexity of these issues, particularly the role of governance and institutional weaknesses in exacerbating energy insecurity. The survey data, on the other hand, provides a more granular view of public perceptions and highlights the regional disparities in energy access. The integration of both sets of data underscores the importance of a multi-dimensional approach to energy security that incorporates infrastructure upgrades, security enhancements and governance reforms.

## CONCLUSION

This research offers an in-depth analysis of energy security in Pakistan, focusing on the interplay between infrastructure challenges, physical security threats, governance issues and the socio-political landscape. Through a comprehensive approach combining quantitative survey data, qualitative interview insights and a systematic literature review, this study underscores the multifaceted nature of energy security, revealing the significant obstacles faced by Pakistan's energy sector and proposing actionable strategies for addressing these issues.

The survey results highlight those inefficiencies in Pakistan's power transmission and distribution systems, compounded by security vulnerabilities, are challenges to the country's energy insecurity. These inefficiencies are particularly prevalent in rural and remote regions, where access to a stable power supply remains inconsistent. A significant gap in public awareness regarding the impact of physical security on energy infrastructure was also identified, suggesting the need for greater engagement and education among local communities.

The interviews with key stakeholders, including energy sector professionals, government officials, law enforcement representatives and community leaders, further emphasized the importance of addressing both the technical and security dimensions of energy infrastructure. These interviews revealed that while some regions have developed effective security protocols, many still lack coordinated strategies to protect energy assets from theft, sabotage and other security threats. Additionally, the socio-political dynamics, including corruption, political will, and weak governance, were cited as critical factors hindering progress in ensuring energy security.

The literature review supported these findings by identifying the broader structural and environmental factors that affect energy security. The review confirmed that climate change and extreme weather events are growing risks to the stability of energy infrastructure, exacerbating the vulnerabilities of the transmission system. Furthermore, the need for energy justice and equitable access to energy was highlighted, aligning with the concerns raised by both survey respondents and interviewees regarding regional disparities in energy access.

In conclusion, this research emphasizes the need for a holistic approach to energy security in Pakistan, one that integrates

infrastructure development, physical security measures, governance reforms and public engagement. Addressing the challenges of energy insecurity will require not only technological upgrades but also a concerted effort to improve governance, strengthen security measures, and ensure equitable access to energy for all communities.

**RECOMMENDATIONS**

Based on the findings from the quantitative, qualitative, and literature review data, several key recommendations can be made to enhance energy security in Pakistan:

1. Upgrade and Modernize Energy Infrastructure: The survey results indicate that outdated infrastructure is a primary cause of energy insecurity. Upgrading the networks, particularly in rural and remote areas, should be a top priority. This includes replacing outdated equipment, enhancing grid capacity and adopting advanced technologies such as smart grids to improve the efficiency and reliability of the energy supply.
2. Strengthen Physical Security Measures: The qualitative insights from interviews reveal that physical security threats, such as theft and sabotage, are significant contributors to energy disruptions. A comprehensive security strategy should be developed, incorporating both preventive measures (e.g., surveillance systems, advanced monitoring technologies) and reactive measures (e.g., rapid response teams, better coordination with law enforcement). The involvement of local communities in security initiatives could help reduce the vulnerabilities of transmission lines and other energy infrastructure.
3. Enhance Public Awareness and Community Engagement: A key finding from the survey is the lack of public awareness regarding the intersection of energy security and physical security. Public education campaigns should be launched to raise awareness about the importance of safeguarding energy infrastructure and the role that communities can play in preventing theft and sabotage. Engaging local communities in energy security initiatives can also foster a sense of ownership and responsibility, making security measures more effective.
4. Address Governance and Institutional Challenges: The interviews and literature review highlight the critical role of governance in shaping energy security outcomes. Weak

governance, corruption and a lack of political will have hindered progress in the energy sector. To address these issues, reforms are needed to strengthen regulatory frameworks and ensure that resources are allocated efficiently. Strengthening the capacity of local and regional governments to manage energy security challenges is also crucial.

5. Promote Renewable Energy Integration: As identified in both the literature review and the qualitative data, the integration of renewable energy sources such as solar, wind, and hydropower can play a key role in enhancing energy security. By diversifying the energy mix and reducing dependence on one source can help mitigate some of the vulnerabilities associated with energy supply disruptions. Policies that encourage the development of renewable energy infrastructure, as well as incentives for both private and public sector investments in renewable technologies, should be prioritized.
6. Improve Regional Cooperation: Energy security is not only a national issue but also a regional one, especially in the context of Pakistan's relationships with neighbouring and energy exporting countries. Collaborative efforts to address cross-border energy security challenges, including the sharing of energy resources and infrastructure, should be explored. Regional cooperation on energy could help stabilize supply and reduce the impact of disruptions, particularly in areas prone to natural disasters.

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